Jorge Perez Peraza
Lev Dorman
Igor Libin

Space Sources of Earth's Climate:

Natural science and economic aspects of global warming

Euromedia
Moscow 2011

Все пустыни друг другу от века родны,
Но Аравия, Сирия, Гоби, —
Это лишь затиханье сахарской волны,
В сатанинской воспрянувшей злобе.

Плещет Красное море, Персидский залив,
И глубоки снега на Памире,
Но ее океана песчаный разлив
До зеленой доходит Сибири.

...

И, быть может, немного осталось веков,
Как на мир наш, зеленый и старый,
Дико ринутся хищные стаи песков
Из пылающей юной Сахары.

Средиземное море засыпят они,
И Париж, и Москву, и Афины,
И мы будем в небесные верить огни,
На верблюдах своих бедуины.

И когда, наконец, корабли марсиан
У земного окажутся шара,
То увидят сплошной золотой океан
И дадут ему имя: Сахара.

Nikolay Gumilev

INTERNATIONAL ACADEMY
OF APPRAISAL AND CONSULTING (IAAC)

МЕЖДУНАРОДНАЯ АКАДЕМИЯ ОЦЕНКИ
И КОНСАЛТИНГА (МАОК)

UNIVERSIDAD NACIONAL AUTÓNOMA DE MÉXICO

НАЦИОНАЛЬНЫЙ АВТОНОМНЫЙ
УНИВЕРСИТЕТ МЕКСИКИ

ISRAEL COSMIC RAY CENTER (TEL AVIV UNIVERSITY,
TECHNION AND ISRAEL SPACE AGENCY)

ИЗРАИЛЬСКИЙ ЦЕНТР ИССЛЕДОВАНИЯ
КОСМИЧЕСКИХ ЛУЧЕЙ

Jorge Perez Peraza
Lev Dorman
Igor Libin

Space Sources of Earth's Climate:

Natural science and economic aspects of global warming

Publishing House "Euro-Media"
MOSCOW 2011

Хорхе Перес-Пераса
Лев Дорман
Игорь Либин

Космические источники климата Земли:

Естественнонаучные и экономические аспекты глобального потепления

Издательский дом "Евро-Медиа"

МОСКВА 2011

Translation from Russian ***Elizaveta Tokaeva***

Perez-Peraza J.A., Dorman L.I., Libin I.Ya. Space Sources of Earth's Climate. Research and economic aspects of global warming. Moscow, International Academy of Evaluation and Consulting, 2011. – 368 pages.

A.L. Chijzhevsky, an outstanding Russian scientist wrote, «In what way do roughness and storms occurring on the Sun influence the planet? Is our spacecraft «Earth» still sailing calmly and quietly or it is being rocked on the waves of solar cycles so much that time to time one can hear clatter of glasses in the cabin?».

In this book we have tried not only to generate the results of influence of solar activity on the Earth's climate (including our own ones) got with a lot of research but also to estimate what hazard do global climatic variations bring the humanity.

ISBN 978-5-905114-03-8

To the memory of Svetlana Chelyadina

Oh, Holy Face, omnipotent on high!
Out of abyss, while nights' approach,
The dreams, the cherished dreams His striking eye
Impenetrates with over astral knowledge.
The Face does not bewail people's loss.
Time, rivers slip away under its stare...
Be conscious of yourself is hard to bear
In callous coldness of the Universe.
But on the page which number secrets hides
The sense is flaming like amazing lights.

A.L. Chijzevsky "Cosmos"

(Translation Elizaveta Tokaeva)

Preface

During tens of years the majority of mass media in the whole world are making gloomy oracles. We know from them that the humanity has very few years left to live. Greenhouse effect together with ozone holes and global warming will annihilate the humanity and the Earth as well. And it is the man or, it is better to say, his technological activity which is guilty in the future tragedy.

All these nightmares have led to formation of very authoritative and aggressive political powers in many countries. They are various ecological and green movements which have already become parties, in some places even dominant ones, or, at least, included to the dominant coalition.

But damages caused to the world economy by extreme weather phenomena – floods, hurricanes, earthquakes, etc. – have risen from 10 to 150 billions of dollars a year for the last fifty years (but in absolute expression). Natural disasters become more and more scaled, and scientists connect the growth of a number of them with climatic variations. And it is another question if they are man-made ones or not.

In addition, about thirty years ago ideas about the dominant influence of human activity on the climate appeared, and it brought to formation of the main international phenomenon called Kyoto Protocol.

Not only scientists have understood that the problem of changing climate is really important for the humanity to survive. In 1992 representatives of the world community decided to begin practical actions during the famous meeting in Rio-de-Janeiro. The UN Framework Convention on climate change became an outcome of this meeting.

The Convention came into force in 1994, and 186 countries set their hand on it. In 1997 the Kyoto Protocol to the Convention where numerical obligations to reduce emissions were prescribed was signed in Kyoto (Japan).

The Kyoto Protocol is the first stage of global ecological agreement on prevention disastrous climatic fluctuations. The main thing in the protocol is quantitative obligations of developed countries and countries with economy in transition including Russia to limit and reduce emission of greenhouse gases to atmosphere in 2008 – 2012.

That time ten years ago a decision to form a many-mullioned fond for fighting with global warming – or with industrial and everyday emission of carbon dioxide – was taken in the OPEC conference in Riyadh (Saudi Arabia).

Moreover, the former vice-president of the USA Albert Gore got the Nobel Prize of 2007 for contribution to fight against emission of carbon dioxide. And the International organization studying climatic variations got the Nobel Prize together with him. Journalist Peter Obraztsov writes in the magazine Itogi, «The Nobel prize given to Gore is probably the last surge of activity of fighters with emission of carbon dioxide.

But who remembers now about the ozone hole above the Antarctica which absorbed so much money, because production of ideal coolant-freons was stopped? And which existed, but then disappeared?»

John Coleman, an American scientist, a founder of The Weather Channel, says that the global warming on the planet connected with human anthropogenic activity is a fiction invented by politicians, scientists and businessmen exploiting it pro domo sua.

John Coleman expressed his opinion that a legal action should be brought to the former vice-president Albert Gore, a famous fighter for environmental protection. As John Coleman says, it would help to disclose «artificially invented panic before global warming».

In Coleman's opinion, if this claim is noted, organizations selling greenhouse gases emission quotas can also be sued at law. (In some scientific clubs a phenomenon of global warming is considered to be a theory which could have been falsified. After signing the Kyoto Protocol limiting emissions to atmosphere states or separate companies can sell or buy carbon emission quotas.)

But it is quite another story connected with big state budgets which should be divided correctly, if possible.

It is important to emphasize that now we are talking only about years 2008 – 2012, since 2013 new obligations, new ratification, etc. will appear. By the way, an allowed level of emissions of greenhouse gases for years 2008 – 2012 in Russia is 100 per cent to the level of 1990 (92 per cent is in EU countries, 94 per cent is in Japan, 93 per cent is suggested in the USA, but the USA did not sign the proceedings.)

I.Ya. Libin, an author of the book, writes in one of his works, «It means that in case of sighing the Kyoto Protocol we have no possibilities for a free of charge growth of our economy (for those who does not know that the year 1990 was a failed one in the Russian economy).

All said above does not mean that it is necessary to refuse from the Kyoto Protocol sharply, like the USA. As one of the politicians said, «War is a very serious thing to trust it to military men».

Not separate representatives of meteorology incorporated to the power and not officials should decide about the future participation of Russia in the Kyoto Protocol, but a wide scientific society. The decision to be or not to be in the Kyoto Protocol for Russia should be taken after wide open discussions by specialists in climatic sphere and economists.

Global change of the climate is a problem of a planetary scale, and the whole world will have to settle it. Making a coordinated decision is as necessary and unavoidable as a common fight with terrorism. And the earlier politicians begin real actions, the less damage will be».

But we would like to understand if the man is really such a self-killer, that he tries to kill himself and every living thing on the planet so passionately? Since the first minute of it's comparatively intelligent existence the humanity has always made damage to the planet to survive. And it (the humanity) has not had any other way to continue its existence on the Earth. All natural forces and other types of animals have always been stronger then a Homo sapiens.

Skeptics say that technologies harmful for nature have been developed especially quickly during last decades after an industrial revolution. But nature-conservative measures have gained up momentum as well. A common sense prompts, that the existence of the humanity is connected directly with development of modern technologies. Or it will not support itself. But what about invocations of a future disaster in mass media?

We often listen to a forecast of helio (solar) and geomagnetic activity for the nearest days on the radio and television and read it in newspapers and nobody thinks about that great work (of many research teams) which stands for these forecasts.

All of us have become consumers of forecasts, got used to their existence and do not think about their importance for our life.

But except common people lending their ear to all these forecasts and planning their behavior for the nearest days, EMERCOM specialists, operators, cosmonauts and military men, meteorologists and biologists, doctors and hydrologists in our country and abroad are also consumers of these forecasts.

Galina Mashnich, a wonderful scientist, writes, «For successful forecast of the Earth's future climate it is necessary to come from a deadlock conception of geocentricism to a conception of heliocentricism in studying climate of our planet. It is necessary to understand that the Earth's climate is a natural component, prolongation of cosmic climate…»

But all forecasts are impossible without a fundamental science where the whole building of applied research is built on.

We can say the same about the science. It seems to me that today it has become a part of the world economy, because it makes it possible to value and make approximate forecasts of expected non-anthropogenic disasters, such as earthquakes, droughts, epidemics, weather cataclysms, frequency of hurricanes. It explains influence of solar activity variations on processes occurring on the Earth and in the closest cosmic space.

Nobody has abolished competition in the scientific society, but the price which the scientists are standing before today is very high – normal existence of the humanity in the nearest future.

That is why, scientists` practicalness and a wish to get the results as soon as possible overpowers normal individual ambitions.

Worldwide globalization which is widely discussed in the world but not always with respect unites not only finances and observation data today; it unites different researchers` creative multinational power. And as a result, multiethnic groups have made much more during the last years then during two decades of previous research.

That is why I would like to introduce not only this book to the readers, but also the authors, scientists from Russia (Igor Libin, International Academy of Evaluation and Consulting), Israel (Lev Dorman, Israel Cosmic Ray Center) and Mexico (Jorge Perez-Peraza, Institute of Geophysics of Mexican National Autonomous University). These scientists do not only try to explain the essence of solar influence on the Earth, but they are ones of the first scientists who have used the name of science about solar influence on the climate of our planet – Helioclimatology.

Evgeny Treyger,
Rector MAOK

HELIOCLIMATOLOGÍA: INFLUENCIA DE LAS VARIACIONES DE LA ACTIVIDAD SOLAR EN LOS PROCESOS CLIMATOLÓGICOS, HIDROLÓGICOS, GEOFÍSICOS Y BIOLÓGICOS TERRESTRES

El primero en la historia de la ciencia que puso atención en la sincronía de la actividad solar y de los procesos que transcurren sobre la Tierra fue A.L. Chijzhevskiy. "… ¿Cómo la agitación y las tormentas en el Sol influyen en el planeta? – escribía -. ¿Continúa nuestra nave cósmica, la Tierra, tranquila y plácidamente su curso o se balancea en las ondas de los ciclos solares de tal forma que de tiempo en tiempo se escucha el sonido de vasos en los camarotes?

Antes ya había sido establecido que los fenómenos y procesos climáticos – glaciares, calentamientos, la recurrencia de tifones y sismos – se encuentran ligados con el Sol. Con el Ciclo de 11, 22-30 y 80-90 años, así como los ciclos seculares está relacionada la temperatura del Ártico y de la Antártida, la fluctuación del nivel y el régimen térmico de los océanos, y las pulsaciones de la corriene del Golfo. Los valores máximos de energía de los sismos corresponden a años de máxima actividad solar.

El Ciclo de 11 años se observa en el movimiento de polos terrestres, así como en el aumento y descenso de la velocidad de rotación de la Tierra. En concordancia con el Sol varía la intensidad del geomagnetismo, la frecuencia de las auroras polares, la radioactividad del aire, la concentración del ozono y el espesor de la capa de esta componente atmosférica, se observan cambios en la ciclicidad de sequías e inundaciones, del nivel de lagos y pulsaciones de la corteza terrestre.

En la época reciente se ha demostrado que, en los períodos de explosiones en el Sol, la composición sanguínea sufre cambios bruscos: en estos momentos la sangre recuerda aquella, característica de gentes sometidas a emisiones radioactivas. La influencia solar en la sangre se ejerce no sólo por parte de los ciclos de largo período (como y sobre toda la naturaleza), sino también la ejercen los ciclos interanuales, anuales, estacionales, diarios, e inclusive con períodos del orden de segundos. La sangre varía constantemente: en nosotros como el vino fermenta el Sol. Sin embargo, desafortunadamente, a diferencia de los representantes de las ciencias exactas, biólogos y médicos no pueden acostumbrarse a esta realidad, aunque ya se conoce de manera cierta que los brotes de epidemia y las plagas de langosta se rigen por el Sol.

El historiador griego Fukidid escribió: "... las epidemias se acompañan frecuentemente por inundaciones, erupciones, malas cosechas, invasiones de langosta ...", y ya que las variaciones de la actividad solar se acompañan también de variaciones atmosféricas, los sistemas de signos celestes fueron prácticamente iguales para todos los pueblos. "... la coloración singular de cielo, nubes en forma de flechas, las columnas de las auroras polares, las manchas del Sol, notables en ocasiones a simple vista, todo esto precedía a la desgracia ...".

El ciclo solar más "pupular" es el de 11 años. Pero hay una gran cantidad de ellos: el de 27 días, el de 1.5 años, el cuasibianual, el de 7 años, el de 22 años, el de 36 años, de 80 – 90 años, de 320-480 años. Existen también los de superlargos períodos: de 600 y de 1800 años.

El economista soviético N.D. Kondratyev, fusilado en 1938 en la prisión de Súzdal, descubrió oscilaciones con períodos entre 58 y 64 años en la actividad económica, las cuales son ahora conocidas con su nombre. K. Enseniy un ciclo fractal de 17 años: los barcos holandeses aproximaron con este ciclo el límite de su utilidad.

En 1964, en una conferencia leningradense, el Profesor Packard hizo una declaración asombrosa, después de la cual químicos de diferentes países, a un mismo tiempo realizaron un sencillo experimento escolar: observaron la reacción de oxidación en una coloidal de cloruro de bismuto. Estos científicos no investigaban el resultado de la reacción, el cual era conocido, sino la velocidad de precipitación de los productos, que resultó diferente para diferentes experimentos, pero cada vez igual en todos los puntos sobre la Tierra.

Es decir, existe un factor para toda el planeta que influye de igual manera en la reacción. Este descubrimiento, brillantemente comprobado por S.E. Shnol, biofísico de Púshino, fue la gota que derramó el vaso. Con nuevos métodos instrumentales y matemáticos, se comenzó la investigación de la periodicidad, la influencia de relaciones, estadísticamente significativas, entre diferenes procesos en la Tierra y en el espacio interplanetario. La relación con el Sol, con las oscilaciones de la actividad solar y magnética de nuestra estrella se hacían evidentes, no sólo especulativamente, sino numéricamente.

¿Cómo pueden, concretamente, pueden estas oscilaciones solares transformarse en las variaciones que observamos en la Tierra? ¿Cuál es el mecanismo de la influencia Sol – Tierra? En la literatura constantemente se plantea la pregunta acerca de la realidad de la influencia de la actividad solar en los procesos hidrológicos y climáticos [Mendoza-Ortega 1992 – 1997, Arie 1986, Dorman 1987, Libin 1989, Dorman 1991, Pérez-Peraza 1994, Perez-Peraza 2008, Libin 2009, Kondratiev 2007, y otros].

Igor Ya. Libin,
Jorge A. Perez-Peraza

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And yet again Spots on the Sun arise
And sober minds have grown dark
And kingdoms fall, but that does not suffice
On Earth come hunger, misery and plague.
The ocean inner depths exploded with a shake
Tornadoes danced, the sky with storm was torn,
And in this contest of a global quake
Fanatics, heroes, torturers were born.
On the Life's wrap appeared a ripple
The compass hunted, rampaged the folk
Over the planet and the mass of people
The sun continued its eternal walk.

A.L. Chijzevsky, 1921

INTRODUCTION

Alexander L. Chijzhevsky was the first in the history of science who paid attention to synchronism of the solar activity and processes occurring on the Earth in the beginning of twenties of the last century.

An outstanding Russian scientist, philosopher, he was also a talented artist, refined poet and musician.

Participants of the 1st International Congress on Biophysics and Cosmology which took place in September, 1939, in New-York called Chijzhevsky Leonardo da Vinci of the twentieth century.

It is fully connected with the personality of Chijzhevsky himself, a person of encyclopedic learning, one of the founders of cosmic natural science (together with one more of our great compatriots V.I. Vernadsky), a founder of cosmic biology, heliobiology, aeroionofication and electric hemodynamic, historian, poet and artist, whose humanitarian culture lets him to state phenomena under study clearly.

It was noted in a special memorandum passed on that 1st International Congress on Biophysics and Cosmology in 1939, in New-York that «the proceedings genius in idea novelty, breadth, braveness of synthesis and depth of analysis have put professor A.L. Chijzhevsky at the head of the world and made him the real Citizen of the world, because his proceedings are global commons of the humanity».

Chijzhevsky was elected an honorary member of the Congress which nominated him to the Nobel Prize. By the way, Chijzhevsky`s bar-relief is among bas-reliefs of other great scientists of the world in the Sorbonne.

But world glory did not save the scientist from repression, he was repressed in 1942. It is clear that Stalin who preferred to think all cataclysms in the society to be a result of class struggle did not like Chijzhevsky`s opinion about connection of wars, revolutions and other cataclysms in the society with number of sunspots.

In prison Chijzhevsky formed a small laboratory in the camp hospital and went on working there after formal discharge to finish the next stage of testing of his curious health-improving device which is called now Chijzhevsky`s luster.

D.I. Blokhintsev, a famous physicist, wrote about him and his pictures, «…maybe the main thing these pictures and poems are talking about is the following – they reveal the image of a Great Russian person in a sense it has always been understood in Russia. A necessary and integral, obligatory characteristic of this image was not only success in this or that science but a formation of a world view. Science, poetry, art should have been only a part of the great humanist and his activity».

Chijzhevsky together with such leading figures in the science as V.I. Vernadsky, K.E. Tsiolkovsky initiated a new cosmic view.

One of his most important contributions to the modern scientific ideation is founding out the influence of cosmic factors on biological, scientific and social processes.

Chijzhevsky defined the life as a living thing's capability to let through a flood of cosmic energy, and considered that the biosphere is the place of transformation of cosmic energy emphasizing by it that life is a more cosmic phenomenon, then an Earth's one.

He wrote in his work An Earth's Echo of Solar Hurricanes, «Eruptive activity on the Sun and biological phenomena on the Earth are co-effects of one common reason – the great electromagnetic life of the Universe. This life has a pulse, its periods and its rhythms…

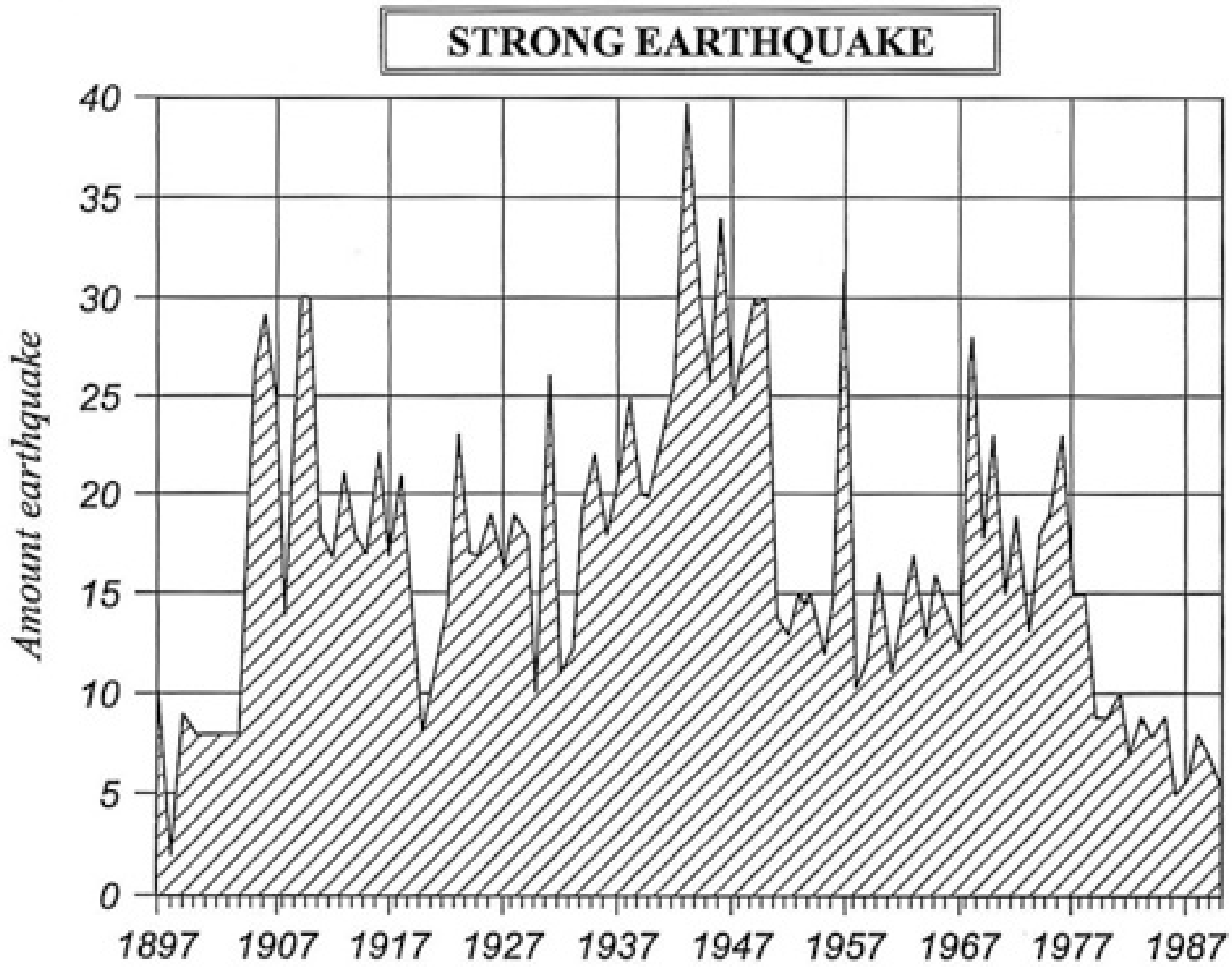
Life is not a result of a chance game of only the Earth's powers. It is created by influence of the Cosmos creative dynamics on the Earth's inert material. It lives with dynamics of these powers, and each organic pulsation conforms to cosmic the heartbeat, this enormous complex system of the Universe material objects.

For a very large period of time of cosmic powers influence on the Earth definite cycles of phenomena which are correctly and periodically repeated in space and time have strengthened. On the Earth we everywhere find cyclic processes that are a result of the cosmic power influence.

In this endless number of cyclic processes one can hear world's pulsation, a great dynamics of nature, different parts of which resound one with another consonantly and harmoniously».

It was found out later that climatic processes – glaciers, warming, recurrence of typhoons and earthquakes, precipitation – are connected with the Sun. Degree of the Arctic and Antarctic ice coverage, variations of ocean levels, the Gulfstream pulsation, the sea thermal regime are connected with 11-year, 22-, 30-year and 50-year cycles.

Peak values of earthquake energy fall on time of solar activity maximums. 11-year cyclicity is observed in the movement of the Earth poles, in increasing and decreasing of the Earth's rate of rotation [National Report, 2006].



A role of the Sun for the life on the Earth. Different types of solar radiation determine thermal balance of the land, ocean and atmosphere. Outside the Earth's atmosphere there is a bit more than 1.3 kilowatt of energy in each square meter of place perpendicular to solar rays.

The land and waters of the Earth absorb about half of that energy, and about one fifth of it is absorbed by the atmosphere. About 30 per cent of solar energy is reflected back to the interplanetary space, mainly by the Earth's atmosphere.

Edward Kononovich wrote, «It is very difficult to imagine what will happen if something blocks up the way of these rays to the Earth for some time. Arctic cold will begin to envelope quickly our planet. In a week the tropics will be covered with snow. Rivers will be frozen, winds will come down, and the ocean will be frozen through. Winter will come unexpectedly and everywhere. It will rain heavily but not with water but with liquid air (mainly by liquid nitrogen and oxygen). The rain will freeze quickly and cover the whole planet with a seven-meter layer. No life will be able to survive in such conditions. Fortunately, it is impossible, at least, unexpectedly and in the nearest future. But the picture described above shows very vividly the meaning of the Sun for the Earth».

Sunlight and warmth were the most important factors of appearance and development of biological living forms on our planet. Energy of wind, waterfalls, river and ocean flowing is an accumulated energy of the Sun. We can say the same about fossil fuel – coal, oil, gas.

Under the influence of electromagnetic and corpuscular radiation of the Sun air molecules break up into separate atoms which are in their turn ionized.

Charged upper layers of the Earth's atmosphere – ionosphere and ozonosphere – are formed. They draw aside or absorb ionizing and penetrating solar radiation making way to the Earth's surface for only that part of solar energy which is useful for a living world, and which plants and living beings have been accommodated to.

The hypothesis about the influence of the solar radiation on seismicity of the Earth is discussed in scientific literature and is mainly added up to studying appropriateness in time between active processes on the Sun and earthquakes on the Earth. In the work [Odintsov, 2004] a connection of global seismicity of the Earth with 11-year cyclicity of sunspots, with velocity leaps of the solar wind in the circumterrestrial space, coronal emission of solar mass is studied.

It is showed that maximum of earthquake full energy (of magnitude more than 5 Richter scale) in an 11-year cycle of sunspots falls on decrease of the cycle and is 2 years late from maximum of solar cycle. It is stated that maximum of earthquakes has a direct correlation with velocity leaps of the solar wind. Possible physical mechanisms of influence of solar activity on global seismicity of the Earth are also analyzed.

In time with the Sun tensity of the Earth's magnetism, frequency of auroras, radioactivity of the air, quantity of ozone in the ozone layer, draught and flood cyclicity, water level in lakes, pulsation of Earth crust are changed.

It was proved lately that during the periods of flares on the Sun blood structure is changed sharply, in such moments blood looks as if people have survived radioactive radiation. Not only long-period cycles influence the blood (as everything in the nature as well), but also year, seasonal, 24 hour and even second ones. Blood is changed constantly – the Sun is living inside us. But unfortunately unlike representatives of exact science biologists and doctors cannot get used to it, although it is already clear that flashes of epidemics, locusts invasion follow the Sun.

Fukidid, a Greek historian, wrote that epidemics are often accompanied by floods, eruptions, crop failures, and locusts' invasion. And as solar activity variations are accompanied by atmospheric variations as well all nations had the same systems of heaven signs.

«An unusual colour of the sky, cirrus clouds, aurora borealis, sunspots which one could see sometimes even with a naked eye – all these preceded to the disaster»[Nikonov, 1996].

The most popular and famous solar cycle is 11-year one. But there are a great number of other cycles – 22-year, 7-year, quasitwo-year, 1/5-year, 36-year, 80-90-year, 169-180-year, and 27-day ones. There are super long cycles – 600-year and 1800-year ones.

Nicolay Kondratiev, a Soviet economist, shot in 1938 in a Suzdal prison discovered 58 – 64-year variations of economic activity which are called after him now. K. Ensen discovered 17-year freight cycle – Holland shipbuilders adjusted life time of their ships to it.

In 1964 professor Pakkardi made a sensational report on the Leningrad conference. After it chemists of different countries made the simplest school test in the same time (GMT) – they watched a reaction of deposition bismuth oxychloride in colloidal solution. Scientists were worried not about the result of the test – it was clear – but speed of transmission of the reaction. It was because every time it was different for different tests but the same all over the world. It means that some factor common for the whole planet influencing the reaction transmission existed [Shnol, 1998; 2000; 2001; 2009].

This discovery proved wonderfully by famous Russian biophysics from Pushchino S.E. Shnol was the last drop in collecting data about curious cyclicities.

Periodicities were taken into consideration seriously – new instrumental and mathematic methods appeared, exposure of statistically significant correlations between different processes on the Earth and in the interplanetary space began.

Connection with the Sun, with solar and magnetic activity variations was becoming clear not only speculatively but rated.

But in what way can all these solar variations transform into changes on the Earth watched by us?

Where is the mechanism of this influence?

"Climate is the weather averaged for several decades".

1. CLIMATE AND GLOBAL WARMING

1.1. Climatic model elements

Climate like weather subjects to measuring. That is why thousands of watchers measure atmospheric pressure and temperature, air moisture, wind direction and velocity, cloudiness and visibility, precipitation (quantity and type), fog and snowstorms, thunderstorms and time of sunshine, soil temperature, snow cover height, solar radiation, etc. in the whole world every day and every hour.

The Earth climate is defined by global elements of environment; they are atmosphere, hydrosphere (ocean and land waters), land (continents), cryosphere (snow, ice and permafrost regions), and biosphere.

In the beginning of the twentieth century A.L. Chijzhevsky, an outstanding Russian scientist, paid attention that the weather and climate on the Earth are tightly connected with solar activity variations. In 1915 A. Chijzhevsky entered the Moscow archeological Institute where in the same year he made a report about solar-biosphere connections.

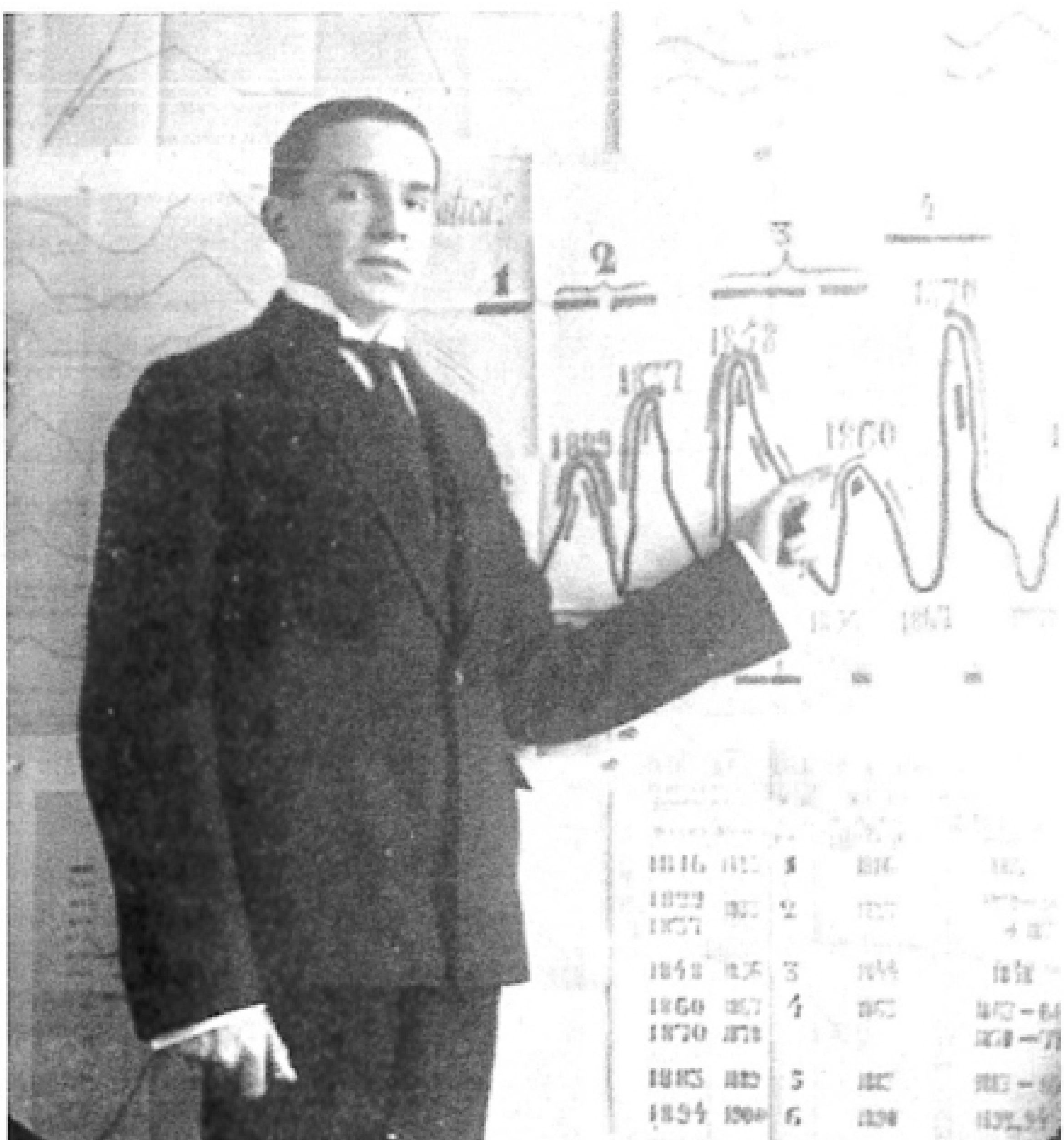
In 1918 when he finished the Institute he defended a dissertation Research of World-wide Historical Process Periodicity in the Moscow University and got a degree of the Doctor of Historical Sciences. Six years later he published his main work which made a young professor world-wide famous.

It was called Physical Factors of Historical Processes. This very book laid a foundation to studying solar influence on the Earth events.

It is obvious today that rising and falling of the temperature on the Earth are of a cyclic character and have happened lots of times without any human participation. In the past the Earth's climate changed not once, and more essentially and radically then it does now.

For example, about 35 million years ago average annual temperature was 5 – 6 degrees higher than now, palms and oaks grew and snakes and alligators lived on the Spitsbergen, and one could observe real tangle of tropic jungle on Taimyr.

A.L. Chijzhevsky (left) with his parents



A.L. Chijzhevsky reports to work «Echo of space storms»

When did we begin to discover the Arctic? In the thirties. Why so? Some of people think that it was a political will of the Soviet Power. It is not true. All achievements of the 30s were connected with enough warming in the Arctic. Then the ices stepped back hundreds of kilometers to the North. It was very easy to achieve, and ships achieved very high latitudes.

But before that in 10 – 20s of the 20th century it was very cold in the Arctic. In 60 – 70s the next fall of temperature happened. Glaciers stopped stepping back. Now warming has come again. Vladimir Kotlyakov, a director of the Geographical Institute RAS, an academician writes, «If we have compared today's climate with former epochs, we would think that we are living in Holocene, or in the interglacial period which was observed 100 thousand years ago when temperature on the Earth was about 1.5 degree higher then now. But 100 thousand years ago there were no men, heat stations, cars, other filth and dirt».

Yes, in the last decades in a result of economical activity of a man the content of carbon dioxide and methane has been increased by one third. Tons of greenhouse gases appeared.

But it has not impacted on the temperature. Not long ago scientists asserted that climate warming was caused by human activity, his influence on the environment. But the facts tell us about another thing, temperature is raised firstly, then the content of carbon dioxide. Gradual and inevitable variation of the climate is first of all explained by natural reasons. These changes are surely influenced by a human factor, but it is not a determinant, global one.

Scientists admit that a mechanism of global warming is very complex and is not understood by the science yet.

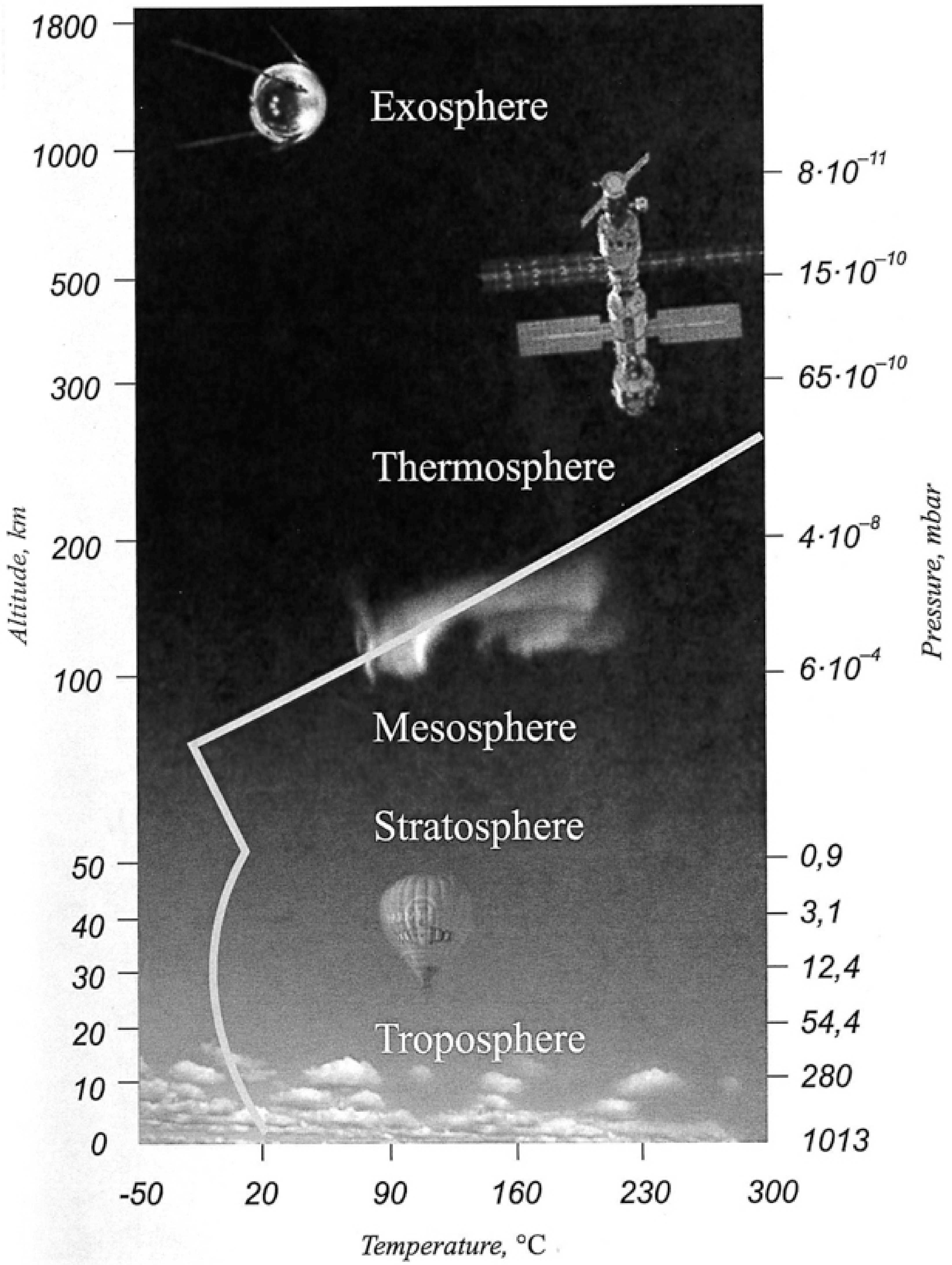
In many researchers` and authors` works a factual connection of the climate with emission of charged particles of different energies from the Sun, with an interplanetary magnetic field direction, a solar wind was proved. And first of all, the connection of solar activity with atmosphere processes was proved.

Atmosphere is a central element of a climatic system. A human being takes in changes of other elements through it.

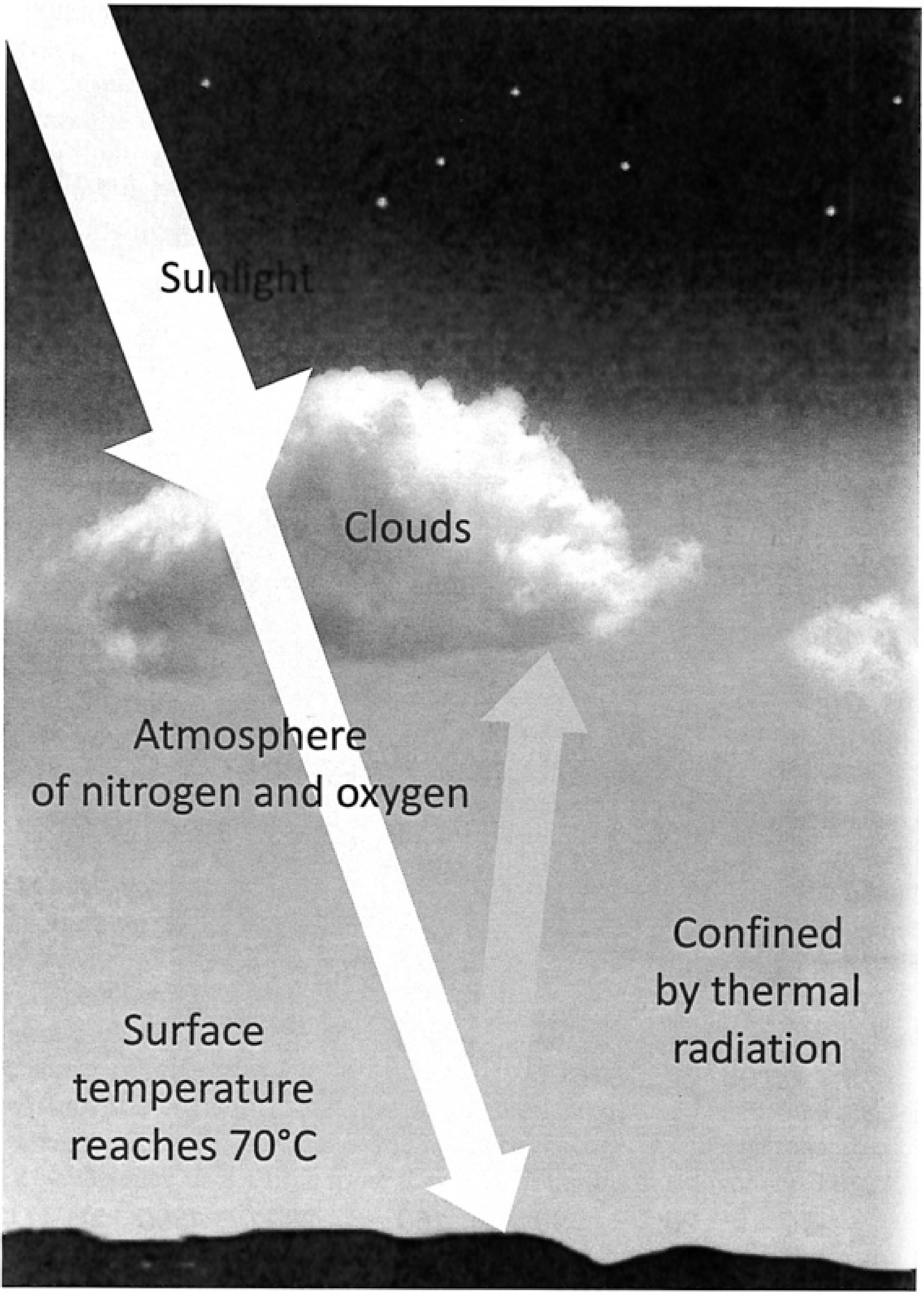
Atmosphere is in any Earth point, it is global. Other elements are local.

Ocean takes 70.8 per cent of the Earth's cover, accordingly, land takes 29.2 %. Glaciers take a little more than 3 % of the Earth's cover and 11 % if to add sea ices and snow cover.

Biosphere. In a modern natural science life problems on the Earth are united by a common term - biosphere (it was coined by Austrian geologist E. Seuss in 1875), firstly denoting the unity of all living organisms on our planet.



The structure of the Earth's atmosphere



Greenhouse effect

The biosphere is extended globally, but irregularly on the Earth's surface, its upper border is 25 – 30 km, the lower one (in the Earth's crust) is about 2 – 3 km, and from 3 to 10 km is in the water.

The biosphere is a unity of objects of wildlife and inanimate nature involved in the life sphere. Two basic components of the biosphere – living organisms and their environment – constantly interact ant influence each other.

The Sun is the basic source of energy for the life on Earth and a great majority of processes occurring on our planet are connected with its radiation. The whole biosphere is opened for Cosmos and, metaphorically speaking, it takes a bath in flows of cosmic energy. While processing this energy, a living substance transforms the whole planet. In this sense we can think that the origin, formation, and functioning of the biosphere is a result of cosmic powers` activity.

It was discovered recently that during the periods of flares on the Sun blood structure is changed sharply, in such moments blood look as if people have survived radioactive radiation.

Cosmic factors which influence biogeochemical processes and the Earth's climate are defined by its spatial location concerning the Sun (the tilt of the Earth axis to the Earth orbit plane), the distance from the Earth to the Sun, conditions of solar rays transmission and, mainly, by the processes occurring on the Sun. That is why study and defining of the nature of solar-terrestrial (especially solar-biospheric) relationships have a great meaning literally for all the processes on Earth.

An atmospheric gas is pervasive. It is constantly exchanging with other elements of the climatic system. Constituent parts of the atmospheric gas resolve in the hydrosphere. From the hydrosphere they come to the air, penetrate into pores and lithosphere clefts. In its turn the atmosphere is filled with volcanic gases` emissions and their weak flows from the lithosphere.

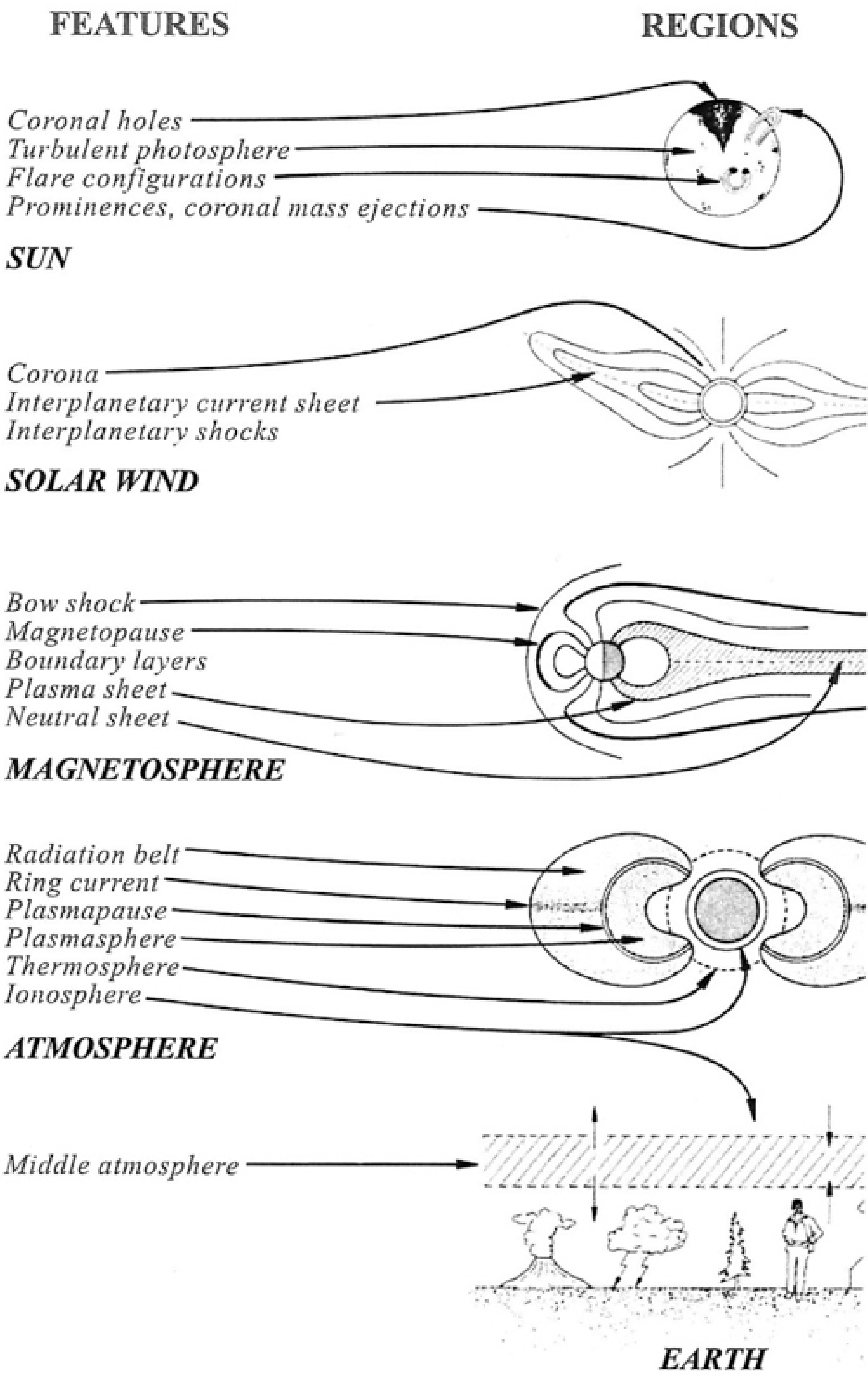
In ice caps atmospheric gases are also kept. When glaciers are melting, they become free in the form of bubbles and come back to the atmosphere. The atmosphere is exchanging gases with the biosphere in the process of breathing.

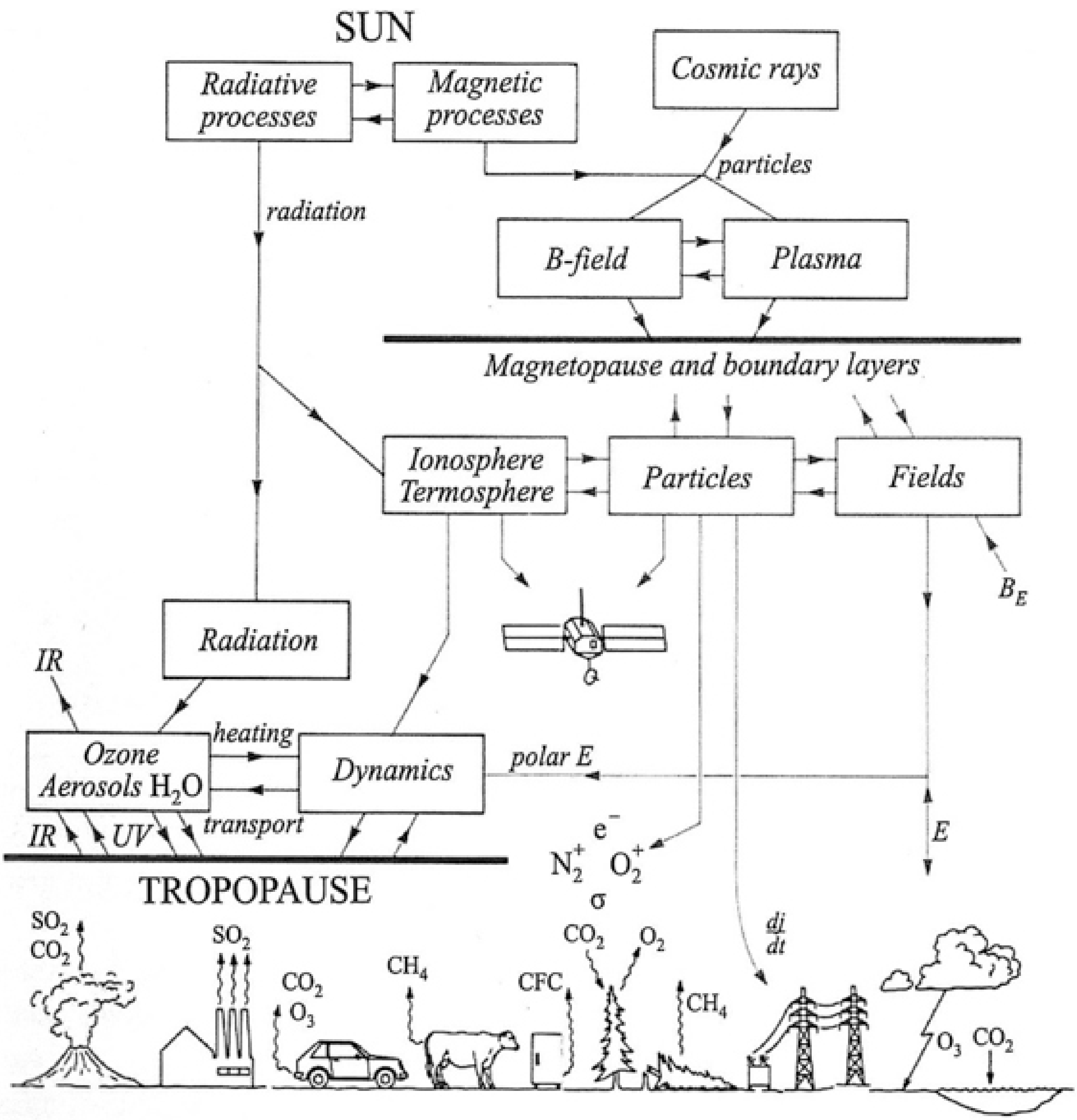
It is the biosphere which has created oxygen in the atmosphere.

The atmosphere as an element of the climatic system is the most movable among all the other elements.

The hydrosphere of the Earth and, first of all, the World ocean (as well as seas, lakes and rivers) are important components of formation the climate. Warmth, mass and movement energy are given from the atmosphere to waters of the World Ocean and back. They touch each other on two third parts of the ground surface.

THE SOLAR-TERRESTRIAL SYSTEM





Basic interaction channels between the principal domains of the STR system: Sun and solar wind, magnetosphere and ionosphere, middle atmosphere, troposohere and Earth [A.Programm, STEP, 2006]

Surface flows in the ocean are formed by atmospheric winds which carry a great deal of warmth.

The ocean is an enormous warmth accumulator. Mass of ocean water is 258 times more than mass of the atmospheric gas. For raising the temperature of the atmospheric gas 1 °C higher the ocean water should give the same quantity of heat energy. As a result, water temperature will fall 1/1000 °C. Such temperature changes are even difficult to measure.

In the last decades very important features of ocean water circulation have been revealed – together with famous ocean flows scientists found underwater ocean whirlwinds like cyclones and anticyclones in the atmosphere. A diameter of these whirlwind-like ring structures reaches hundreds of kilometers. And water features inside these whirlwinds are unlike water features outside them.

Underwater and surface ocean water movements have been also revealed (e.g. El-Niño in the Pacific Ocean near South America).

The hydrosphere is a moving sphere, although in comparison with the atmospheric gas its speed is tens and hundreds times less, a medium speed of ocean movement is several centimeters per a second, while the wind speed can be several hundred meters per a second.

The cryosphere (snow and ice) also participate in formation of the climate. Covering the ground they increase a reflective capability of the Earth. As a result about 90 per cent of solar warming energy is reflected back to the cosmos. The basic mass of ice is concentrated in the Antarctica. There is 90 per cent of the whole ice there.

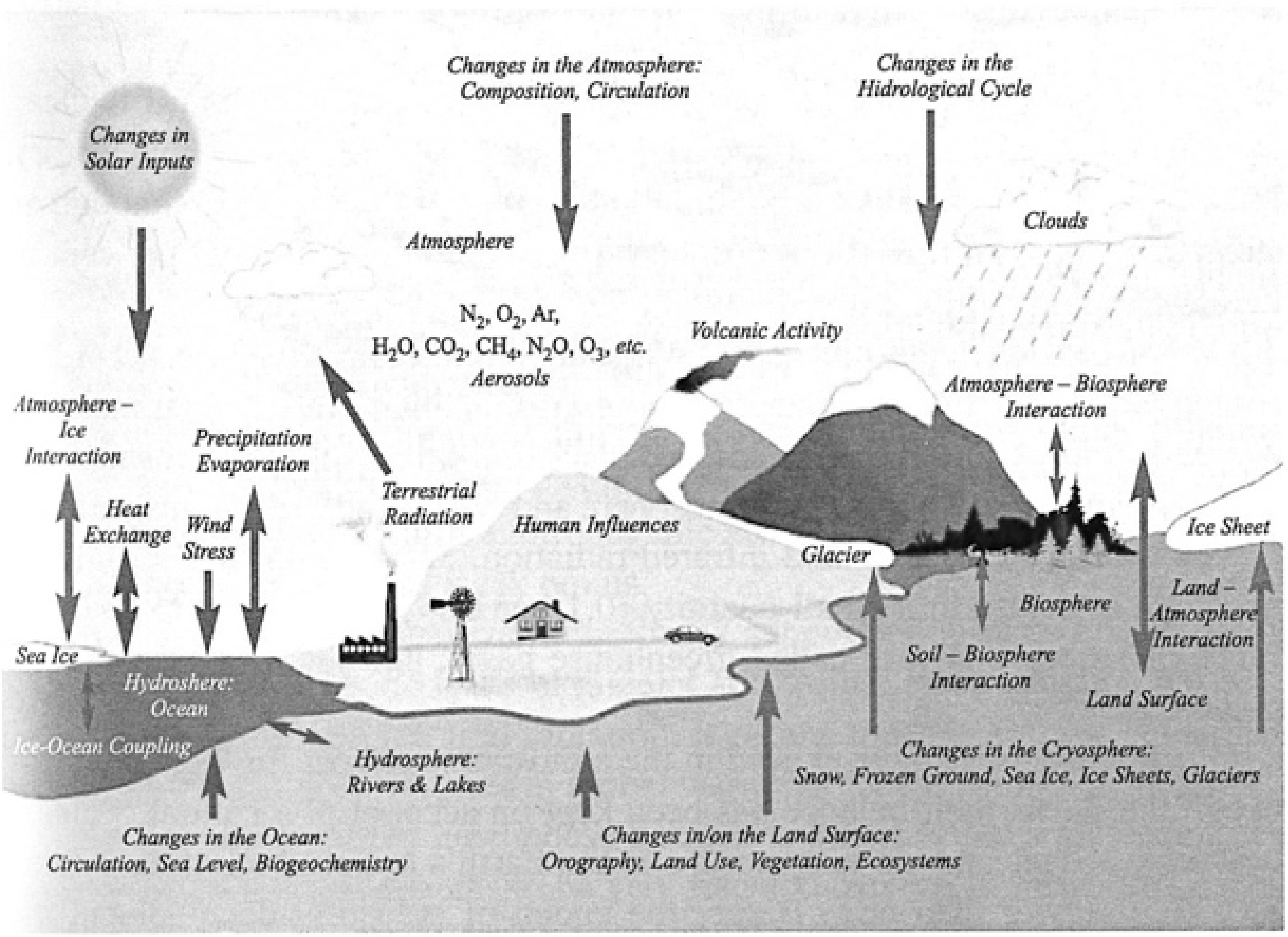
But in our case not mass of ice but square of the Earth's surface which it covers plays the main role. And the largest square on the Earth is occupied by sea ice and snow cover – in summer sea ice of the Arctic Ocean is kept on the square of about 8 million of sq. km., in winter this square grows twice as much. Snow covers on the average about 60 million of sq. km. of the ground for a year.

Land can be considered as the most inertial and passive element of the climatic system. It changes little for short periods of time. It is changed under the processes of soil formation, airing, erosion and desertification.

For millions of years continent drift happens which fully changes the Earth image.

The biosphere is a very active component of the climatic system. During the periods of growth vegetation, changes of plant communities, widening and shortening of squares occupied with plants, increasing or decreasing biomass of its influence on the climate variations are displayed in different ways, in different time scales.

If we compare the climatic system with a living organism, we can say that the role of blood in it is played by the water in different states (steam, liquid, snow, ice). Water is a carrier of mass and energy in the climatic system. On specialists` opinion, the climatic system is a basically self-regulating system. It means that a lot of inner and outer changes (disturbances) are put out.



IPCC Climate System

1.2. Basic theories of climate variations

Why does climate change? Nobody can answer this question exactly. There are a lot of hypotheses which examine possible reasons of such change.

All the hypotheses about reasons of glaciation and global warming epochs can be divided into two basic groups [Perez-Peraza 1996].

1.2.1. Carbon dioxide and greenhouse effect

One group of hypotheses is in the following that the reason of climate variations is in absorbing of a solar energy flow by the Earth. The idea is based on measuring data which show that from time to time some conditions appear in the Earth's atmosphere in which solar energy is absorbed much worse than usually and the temperature is falling much.

According to scientists` opinion, it is necessary to look for the reason of such a change of absorbing energy only in the atmosphere, a part of energy is reflected back to the cosmos, a part is let in to the Earth's surface, and a part is used to warm up the atmosphere.

This capability of the atmosphere depends on its structure, but it is clear, that the Earth atmosphere structure has changed radically for its whole history. Carbon dioxide CO_2 plays the most important role in this process, although an absolute quantity of it in the atmosphere is very small – only 0.03 per cent of the volume.

Carbon dioxide in the atmosphere works as a film on a greenhouse, according to the principle – to let in, but not let out. As a result, 30 per cent of solar radiation coming is reflected from the upper atmosphere and goes back to the cosmos, but its larger part comes through the atmosphere and warms the Earth's surface.

The warming surface emits infrared radiation. Some gases entering the atmosphere structure in a small quantity (0.1 per cent) are capable to keep infrared radiation. They are called greenhouse gases, and the phenomenon is a greenhouse effect.

Greenhouse gases have existed in the atmosphere almost for the whole history of the Earth, their balance has been kept on account of a natural cycle. If they were absent, the air temperature at the Earth's surface would have been 30 – 33 °C lower then now. Before the epoch of industrial development the concentration of carbon dioxide in the atmosphere was 280 ppm (particles per million), and now it has become 30 per cent higher and reached 368 ppm.

If a natural greenhouse effect kept the Earth's atmosphere in a state of a heat balance productive for animals and plants, anthropogenic increasing of greenhouse gases concentration in the atmosphere disturbs the natural heat balance of the planet at the expense of strengthening a warming effect, and results in global warming, followers of the theory of anthropology influence on the climate think.

This model adherents` common idea consists in the following.

Solar rays coming to the Earth's surface move through the atmosphere free. Certainly, part of radiation disperses because of the atmosphere relative opacity.

The light energy is partly absorbed and warms the Earth. A part of a solar energy is reflected on the Earth's surface (land or water surface) back to the atmosphere and then to the cosmos. The hot Earth like any hot thing begins to radiate.

But getting a light energy it radiates a warming one. It is infrared or ultraviolet radiation. This radiation going away from the Earth is kept by carbon dioxide CO_2.

If there were no CO_2 in the atmosphere, the average temperature on the Earth's surface would have fallen down substantially. And condition of the glaciation epoch would have appeared.

If the quantity of CO_2 in the atmosphere were increased, it would lead to the global warming epoch.

Supporters of global warming think that some very fragile balance had appeared on the Earth between all the sources of carbon dioxide practically before the industrial revolution of the 20th century.

It is clear that if such balance is disturbed the quantity of CO_2 in the atmosphere changed, and the climate changes should happen – today's global warming is connected with human anthropogenic activity.

This theory has several weak points.

The logics of the global warming theory supporters consisted in the following – as carbon dioxide leaks ultraviolet and visible solar radiation but does not leak warming and infrared radiation, it means that the surface is warmed more than cooled, and it results in global warming.

This effect was called greenhouse because it behaves like a glass roof of a greenhouse. Everything seems to be very fine and correct, it means it is necessary to decrease CO_2 emissions to a minimum and shorten industry.

But many years ago an American scientist Robert Wood doubted in validity of greenhouse effect explanation. It is necessary to add that he became famous for simplicity of his experiments and witty solution of the most complex physical problems [Sibruck, 1946].

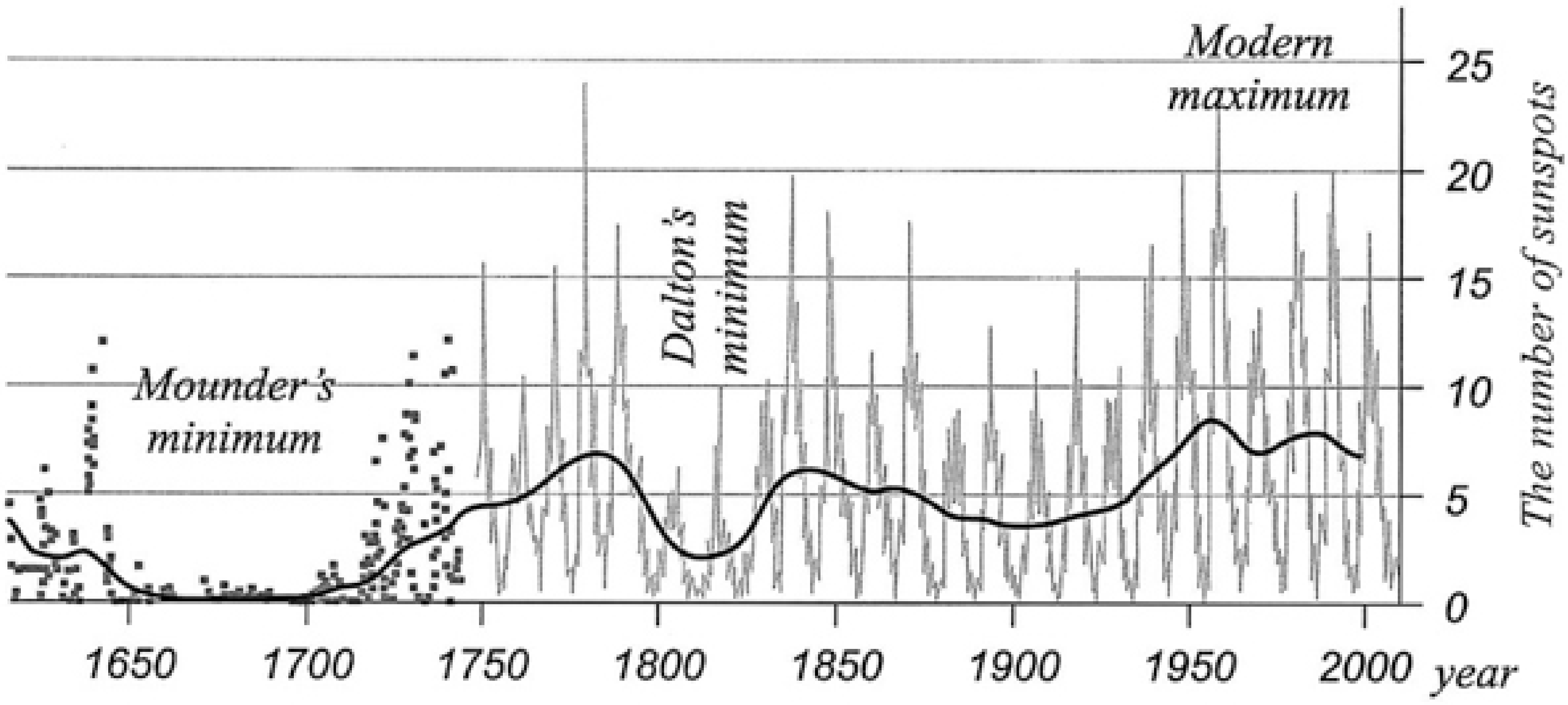
Wood built a table greenhouse with a roof from a transparent crystal of common salt (salt transmits infrared and ultraviolet rays).

It means, there should not have been a greenhouse effect there.

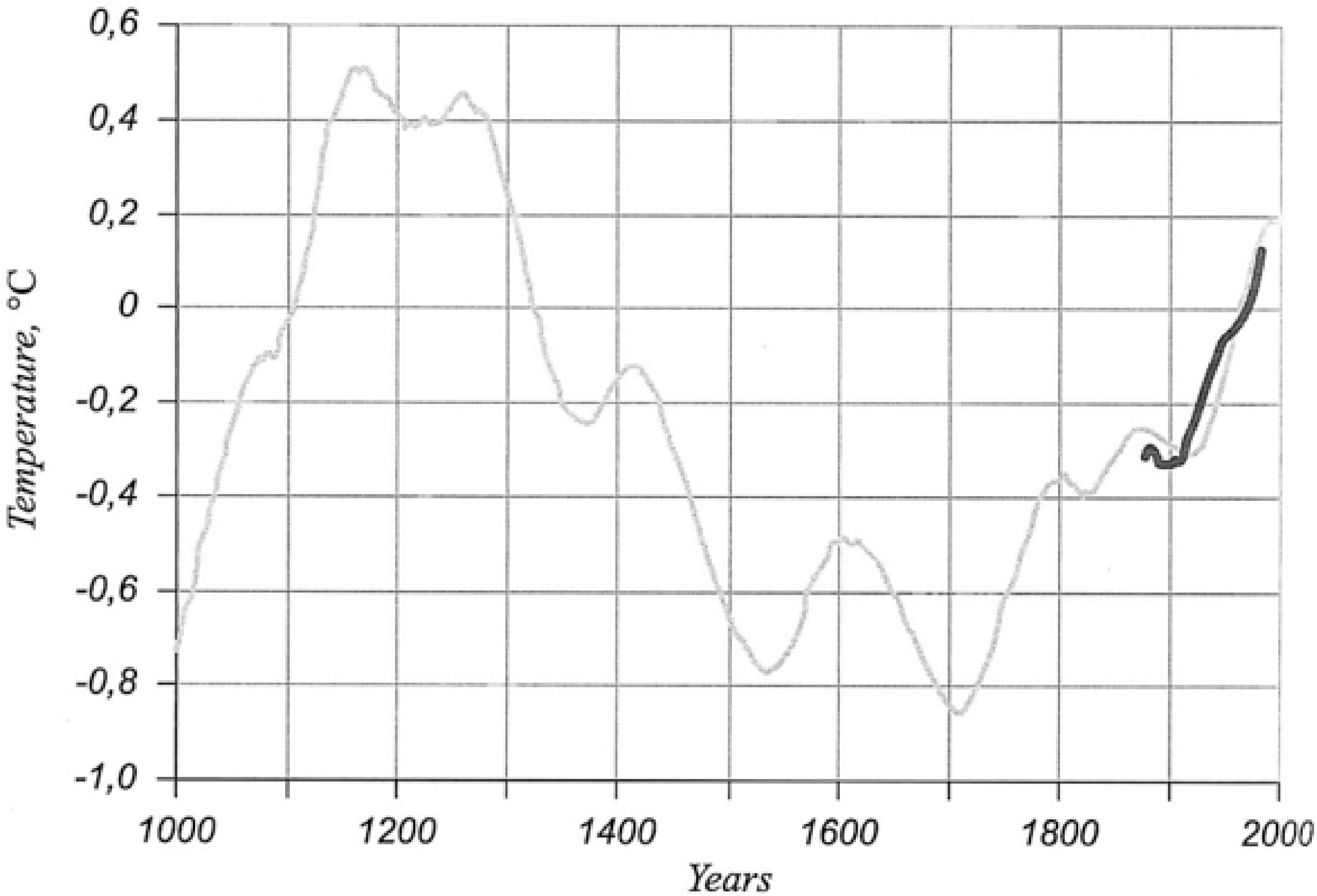
But it was! The greenhouse worked wonderfully, the temperature inside was raised up to the moment when a small door was opened…

So, Wood established (and all gardeners should take it into consideration) that it is warm in the greenhouse not because of some radiations and surface features but because the door is closed and there is no air exchange with the atmosphere. Open the door and the greenhouse effect will disappear.

Certainly, this conclusion is correct for the greenhouse effect on the Earth which, as they say, is caused by carbon dioxide. It means that CO_2 is neither here nor there, and industrial production is not the reason of the really rising temperature of the Earth atmosphere.



The behavior of solar activity in the last 500 years [Khorozov et. al., 2006]



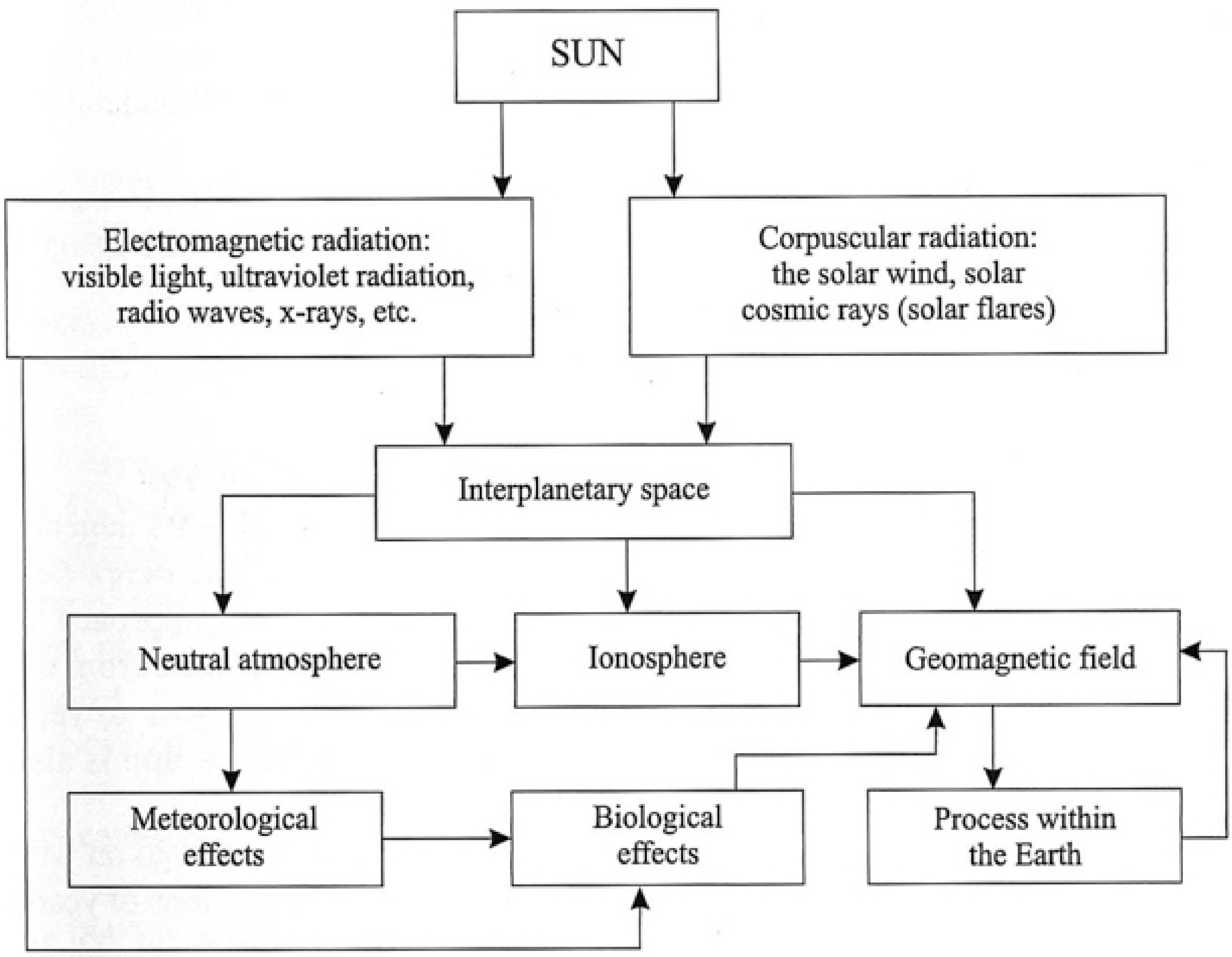
The behavior of temperature in the last 1000 years [Khorozov et. al., 2006]

In the seventies of the last century new data about warming of the climate on the whole territory of the planet appeared. It does not mean that scientists did not know about constantly average temperature change on the Earth.

No, they knew about glacial periods (including small ones), let us recall Bragel's pictures with skaters on Holland frozen canals. They also knew about just evident cooling and warming in different centuries of the human history.

Just remember the name Greenland given by Vikings little more than one thousand years ago! The Vikings discovering Greenland were shocked by the climate there where oaks, ash trees and grapes grew and a lot of birds lived. But it was not millions of years ago, but recently.

Roger Ravel, a Professor of the Harvard University, on comparing diagrams of temperature behavior and content of carbon dioxide in the atmosphere found a very well expressed correlation – raise of temperature was proportional to rise of CO_2 quantity.



The general scheme of the influence of the Sun to the Earth (IKI)

Yes, during the last years an evident raise of temperature under observing and CO_2 was really discovered.

Authors of discovery thought in such a way - carbon dioxide is formed first of all on burning of any organic material, for example, fuel. It means that the more carbon dioxide appear the more power plants exist in the country, the better industry is developed.

That is why if we do not want ice in the Arctic and Antarctica melt and St-Petersburg, Amsterdam, New-York go down under water, it is necessary to shorten industrial production or to use such ways of burning fuel not to emit CO_2 to the atmosphere.

It was the way how a global warming theory appeared mapping out basic methods of fighting it.

Many scientists think that not an atmosphere temperature is raised because of CO_2 emission, but visa versa CO_2 quantity in the atmosphere is raised because of warming.

There is a sense in it – sea and ocean water contains CO_2, and gas solubility, as we know, is lowered when the temperature is raised, and carbon dioxide is emitted to the atmosphere (try to make an experiment like Robert Wood did and warm a glass of gas water – a lot of bubbles will appear).

Moreover, and it is the main thing, correlation of two processes can be aroused by some common reason because of which those first two are changed like each other.

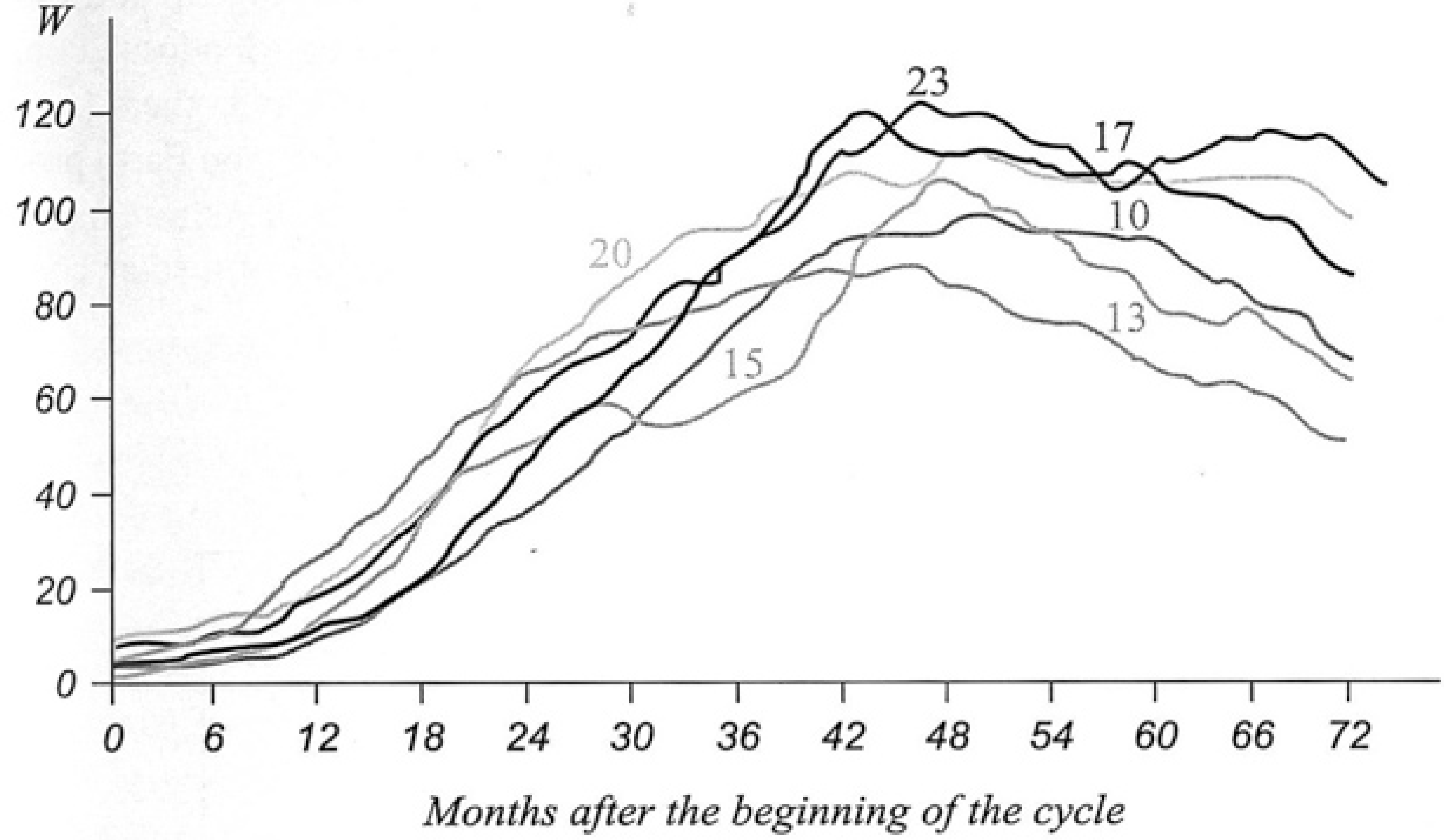
But what reason of the climate fluctuation can be?

Maybe this common reason is our Sun?

1.2.2. Solar activity is a source of the climate fluctuations

The Sun is a basic source of energy, warmth which the climate depends on [Andreasen 1993, Denkmayr 1995, Friis-Christensen 1991, Perez-Peraza 1996, 1997, Libin 2007]. All hypotheses of the second approach to the explanation of the climate fluctuations under observing come from the fact that the solar energy flux is considerably changing from year to year. That is why quantity of warmth which the Earth gets from the Sun is also changing.

Why can the Sun change energy? We know that solar processes go on with a certain periodicity, and duration of such periods is hundred millions of years. Solar activity is changed periodically with periods of approximately 11, 22, 35, 90, 200, 600, 2000 years.



23 solar activity cycle [Ishkov, 2007]

Quantity of energy which the Sun transports as solar charged particles into the circumsolar space depends on a solar activity level.

It was established earlier [Perez-Peraza 1995, 1999] that climatic processes, such as glaciers, warming, typhoons and earthquakes, precipitation, are also changed periodically with periods of 11, 22-35, 80-90, 200-280 years.

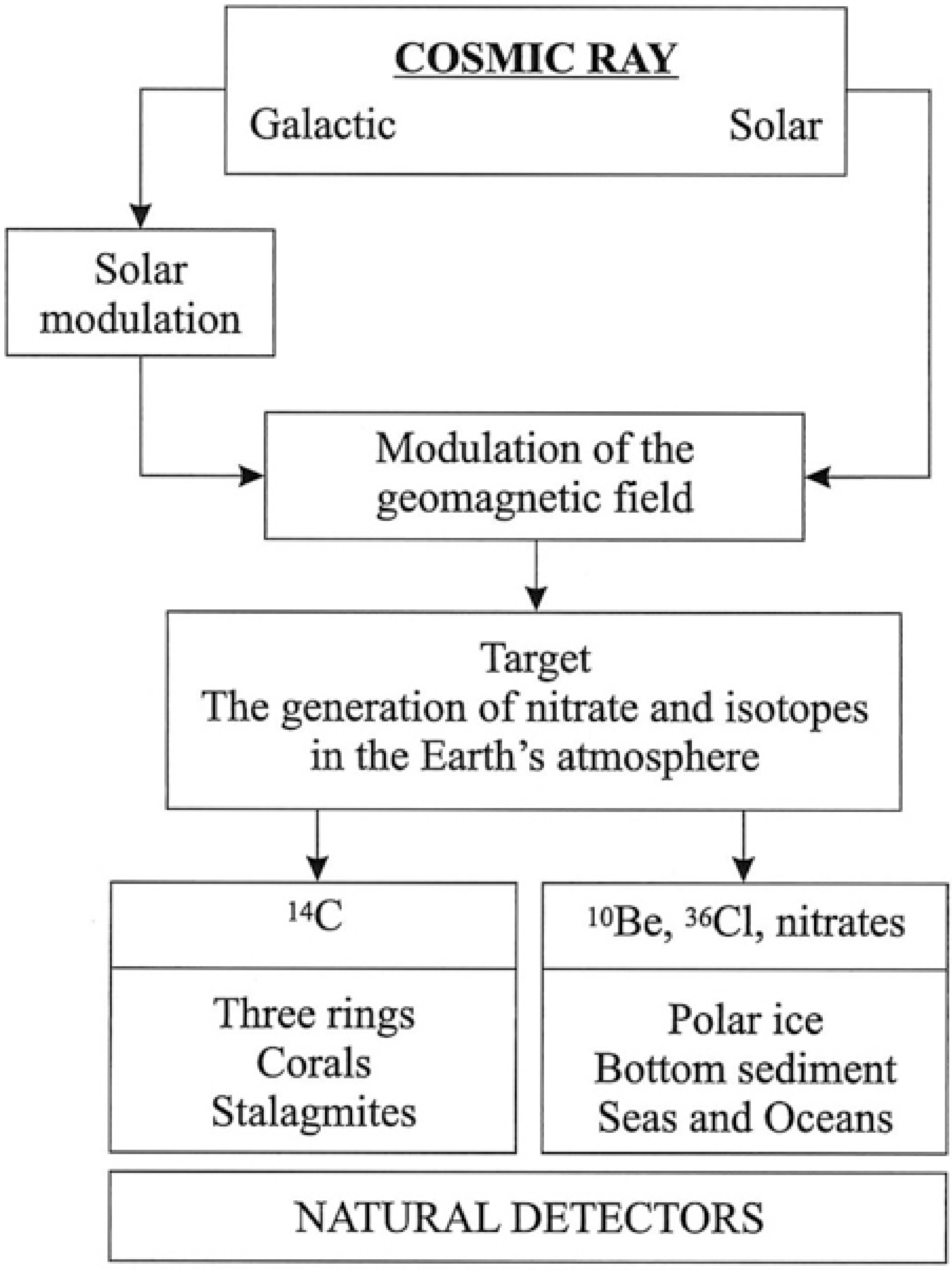
Degree of the Arctic and Antarctic ice coverage, variations of ocean levels, the Gulfstream pulsation, a sea thermal regime are connected with 11-year, 22-30-year and 150-year cycles. Peak values of earthquake energy fall on time of solar activity maximums. 11-year cyclicity is observed in the movement of the Earth poles, in increasing and decreasing of the Earth's rate of rotation.

Not long ago canals for filling the Caspian Sea which became shallow about our ears on a catastrophic level were going to be built. But now we can observe a threatening rise of the Caspian Sea level and flood of coastal cities without any canals.

In time with the Sun tensity of the Earth's magnetism, frequency of auroras, radioactivity of the air, quantity of ozone in an ozone layer, draught and flood cyclicity, water level in lakes, pulsation of Earth crust are changed.

A question about exact influence of solar activity on hydrological and climatological processes was raised in literature not once [Blanka-Mendosa 2006, Dorman 1987, Libin 1989, Dorman 1991, J.Peres-Perasa 1994 and others.].

An interesting theory about concrete influence of solar activity on Earth processes was suggested by G.A. Nikolsky in his work Variations of Astronomical and Meteorological Constant. According to him, changeability of a solar constant is several tenth per cent.



Cosmic rays in the Sun-Climate

At the same time the solar radiation coming to the troposphere can be changed in connection with solar activity variations with several per cent amplitude which is the result of influence of a stratosphere modulation mechanism.

Nikolsky was the first who showed the role of galactic cosmic radiation for change of the atmosphere state and contribution of solar constant changes in changes of the Earth atmosphere, biosphere observed on the Earth.

Lately after research in the Danish national cosmic center it was discovered that cosmic rays influence the Earth's climate fluctuation much more then specialists thought earlier [Swensmark 2007].

In November, 2008, Swensmark published the first experimental results which he had got during five years of research of cosmic rays influence on cloud cover. They were published in the magazine Works of the Royal Society – Mathematics, Physics and Engineering Sciences. A full report on his work will be published in the book Cold Stars – A New Theory of the Climate Fluctuations.

Change of cosmic rays quantity which is found in the atmosphere directly influences the increase of cloud cover of our planet. If there are a lot of clouds the Earth reflects solar radiation back to the cosmos. The planet gets cooler due to that.

Henric Swensmark is sure that the Earth is surviving a period today when cloud cover has been decreased because of the lack of cosmic rays. He says that it is the basic reason of today`s global warming.

Swensmark thinks that carbon dioxide emissions connected with anthropogenic activity influence the climate much less then the scientists say. These results were published a week later after the report of the Intergovernmental expert group UNO about climate fluctuations which informs that carbon dioxide emissions connected with anthropogenic activity will lead to making temperature 4.5 degrees C higher by the end of the century.

Swensmark thinks, «For the long time we have thought that climate fluctuation influence cloud appearance, but now we see it is clouds which are a dominant factor of the climate. It was not taken into consideration when creating models which help to determine the effect aroused by carbon dioxide.

It can happen that CO_2 arouses warming less than we have thought. These results demonstrate that on coming to the atmosphere cosmic rays form charged particles which attract molecules of water from the atmosphere and form the clouds».

In the result of research of ice samples it was discovered that temperature and CO_2 changes had happened earlier in the past.

In the nearest future a group consisting of 60 scientists from all over the world is going to make a large experiment with the use of the Geneva particle accelerator to reproduce an effect of coming of cosmic rays into the atmosphere.

They hope that it will show if cosmic radiation really influences cloud cover change. If it is so, climatologists will possibly have to revise their conceptions of global warming mechanisms.

Danish scientists` results are fully confirmed by research of temperature and solar activity having made by Russian scientists during about 150 years.

Regular measures of temperature of the upper atmosphere have begun to be held since1860. That is why they had no problems in studying this period of time.

But to understand and reveal the real reasons of warming and possible connections of them with the Sun it is necessary to have data of a longer period of time.

It is possible to do this successfully today studying annual rings of trees. It is considered that in the process of growing a tree fixes constantly a lot of changes in physical and chemical state of environment.

Width of rings is a sensitive indicator reacting on environmental changes and depending directly on temperature and moisture. By cross dating of two separate oak chronologies Russian scientists formed the European chronological scale for North Ireland and Germany the duration of which is 7272 years.

Ring chronologies made from European oak and pine-tree carbofossils cover the latest 11 thousand years practically without any breaks. But researchers thought this period short for making a serious conclusion.

Besides tree rings scientists used corals and stalagmites in their research. These natural formations contain isotope oxygen-18 which helps to make a conclusion about the quantity of precipitation during this or that period.

Glaciers can also give a lot of useful information – their age in Greenland and the Antarctica reaches sometimes hundreds thousands of years. With a help of ice chemical structure scientists can define climate fluctuation cyclicity since the moment when icy crystals appear.

Moreover science is capable to make out cosmogeneous isotope in ice mass – beryllium-10, a component which is a good indicator of a number of cosmic rays coming on the Earth in different epochs. For the beryllium-10half-value period is 1.5 million years.

It took years of hard work to gather and analyze data got from different sources. But the time to make first conclusions has come. An oxygen-18 curve which tells us about precipitation quantity coincides with curves got with a help of beryllium-10! And if it is so, there is a certain connection between cosmogeneous isotope and the climate state.

It became only clear after such research that cosmic rays coming to the atmosphere formed cosmogeneous isotopes mentioned above which ionized particles weighed in the atmosphere and formed core of condensation on which drops forming thick low clouds appear.

On the basis of that Russian scientists could prove that there is direct connection between a cosmic ray flux and a square covered with clouds. In their turn these clouds prevent warming the planet surface by the Sun. Maybe because of such constant atmospheric state the Earth gets cold up to the degree of global cooling.

This new theory was approved in scientific societies. For example, Yury Stozhkov, a Doctor of physics and mathematics, professor, head of Dolgoprudnenskaya scientific station after academician S.N.Vernov of Physical Institute after P.N. Lebedev RAS, is sure that «cosmic rays are responsible for the process of global warming.

Although energy of a cosmic rays flux falling on our atmosphere is approximately 108 less than a solar magnetic radiation flux which warms the Earth, cosmic rays is the main source of ionizing the air.

They provide work of a global electric chain, formation of thunderstorm electricity, strikes a lightning. Weakening of thunderstorm activity is a good indicator that a flux of galactic cosmic rays coming on the Ground from an interstellar sphere is decreasing».

On Russian physics` opinion, a quantity of cosmic rays depends on changes of the Earth's magnetic field which serves as a basic defense from cosmos influence. We know that the Earth's magnetic field is changeable. There is an effect which makes magnetic poles on a time line of two thousand years bend aside by 10 degrees of latitude and longitude.

And a full overturn of a magnetic field can occur on a scale of approximately million years, and then poles change their places. And tensity of the Earth's magnetic field in this period (thousands of years) becomes several times less.

As a result a screening action of the field for cosmic rays disappears and their flux comes from the interplanetary space to the Earth's atmosphere.

Anatoly Pavlov, a Candidate of physics and mathematics, research officer of the Institute of Physics and Techniques after A.I. Ioffe, says, «Now in laboratory conditions we model the situation when a cosmic ray flux in orbit round the Earth becomes several times higher. Preliminary results show that global disasters which have already shocked the Earth are connected only with activity of cosmic rays».

First of all cosmic rays arouse ionizing the atmosphere and influence the formation of such active molecules as nitric oxides (which fully confirms Danish physics` conclusion).

It is reflected in the stratosphere first of all where the basic ozone layer is found. Nitric oxides destroy ozone (but they themselves are not consumed) and it results in different unpleasant effects, for example, in slowing down a process of photosynthesis which gives energy to all living organisms.

Solar flashes play an important role on the Earth in a long-term (tens and hundreds of years) and short-term perspective outlook. So, in 1989 in Canada a powerful solar flash disabled an electro system of the whole region, and Quebec was left without electricity for 10 hours. On specialists` opinion that solar prank cost billions of dollars.

«Just imagine that Moscow will be without energy even for 24 hours. A solar flash breaks connections on short distances, short radio waves, leads to failure of radiolocation systems», Vladimir Obridko, a Doctor of physics and Mathematics, a famous physicist from the Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation RAS (IZMIRAN), a largest specialist in the sphere of solar-terrestrial relations writes in one of his articles.

This is the prognosis given by scientists from IZMIRAN. A minimum of solar activity was fixed approximately in 2007, but not for long.

After a short break (2008 and maybe partially 2009) a new rising will follow, and we should expect a new flash of solar activity by 2010, approximately up to the same level which was in 2000 (death of the Kursk, fire on the Ostankino TV tower), and before that in 1990-1991 (putsch, breakdown of the USSR, appearance of hotspots).

And let us remember the remote past. So, notorious 1917 and 1937 years were years of maximal solar activity.

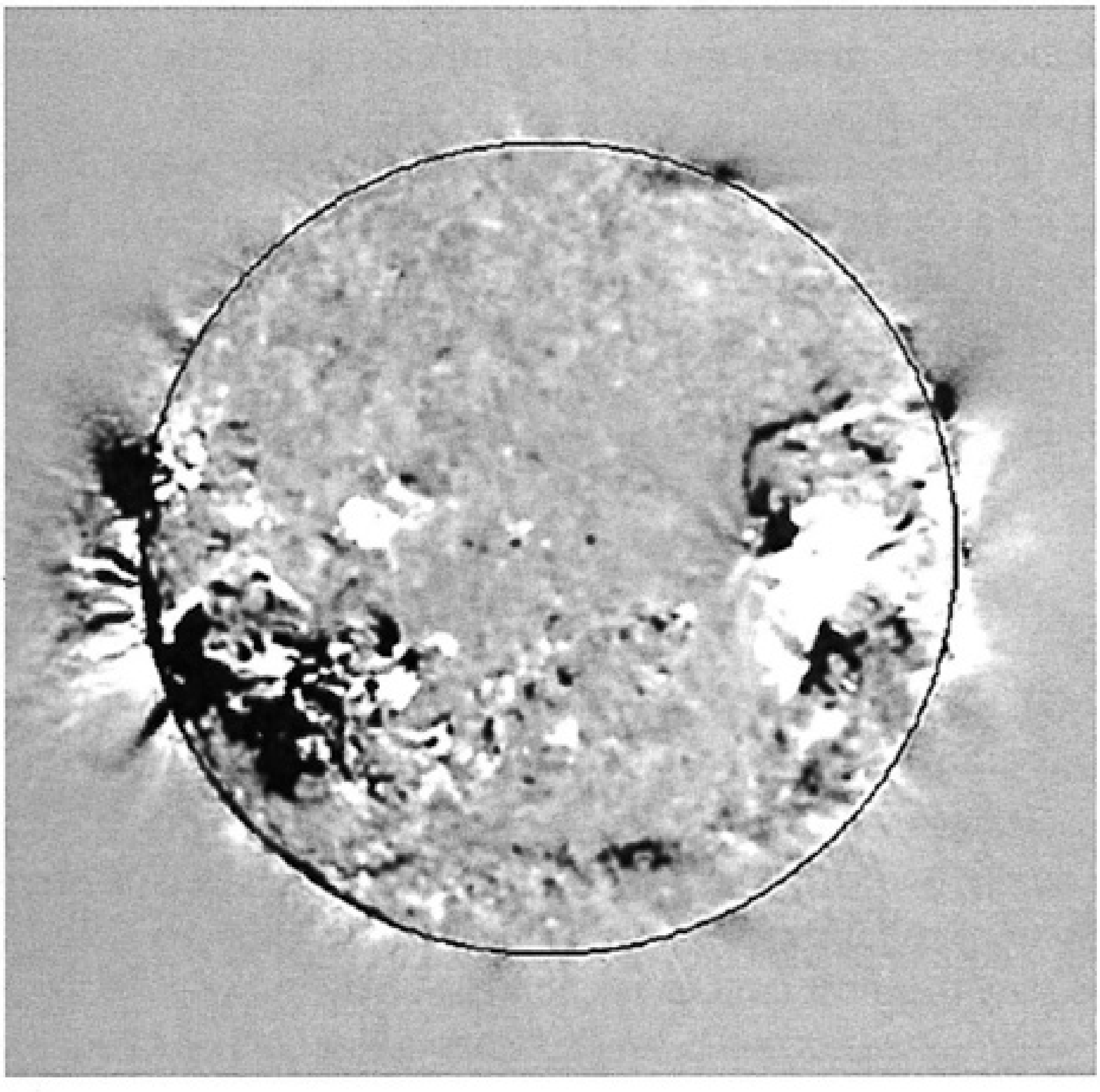
After 2010 solar activity will be very high during minimum several years. It means that we should expect any consequences on the Earth from climatic surprises, mass hysteria to increasing of death rate and a number of accidents and disasters.

A question of a possible connection of seasonal and many-year changes of the Earth atmosphere state with heliophysical and cosmophysical phenomena has often been discussed in scientific literature. Nowadays the fact that the Sun is the reason of different atmosphere indignations is beyond dispute [Libin, 2009; Bashkirtsev, 2004; Mashnich, 2004].

The atmosphere circulation is subject to cyclicity influence of changing solar activity which controls the state of geomagnetic activity[Levitin, 2006; Kovalenko, 1983; Ptitsina, 1998] and timely variations of galactic and solar cosmic rays [Dorman, 1982].

We may expect complex interaction between all phenomena mentioned above. Parameters of each of them have their own spectrum of seasonal and many-year vibrations [Libin, 2008; Chertkov 1985], because in spite of common possible mechanisms a part of variations under observing will be characterized by cause-and-effect relations.

The fact that such connections exist follows from a simple qualitative comparison of timely variations of average monthly and average yearly Wolf number values (W), solar sunspot squares (S), geomagnetic activity (Kp - index), cosmic ray intensity (Icr) and storm level index (P) describing frequency of



Sunspots and solar flares

dangerous winds (with the speed ≥ 12 м/s) in the North Sea [Mikalaunas, 1985; Vitinsky, 1973; Glokova, 1952].

The atmosphere variations as well as modulation of a flux of cosmic rays observed on the Earth seem to be connected by the same processes in the interplanetary space – powerful interplanetary waves, solar flashes, high-speed solar wind streams, and a sector structure of the interplanetary magnetic field (IMF).

One of the most remarkable peculiarities of the Sun is practically periodical regular configurations of different displaying of solar activity, or the sum total of observed changed (fast or slowly) phenomena on the Sun.

These are sunspots – areas with a powerful magnetic field and, as a result of it, with a lowered temperature, solar flares – more massive and quickly-developed explosive processes touching the whole solar atmosphere over an active zone, solar filaments – plasmic formations in solar atmosphere magnetic field looking like drawn (up to hundreds thousands of kilometers) fibre-like structures.

When filaments come to the visible border (limb) of the Sun it is possible to see protuberances, much larger active and calm formations of various forms and a complex structure.

It is also necessary to note coronal holes – areas in the solar atmosphere with a magnetic field opened to the interplanetary space. These are certain windows which a high-speed brunch of solar charged particles is thrown from.

High-speed corpuscular plasmic fluxes change the structure of a solar corona. When the Earth gets in such a flux the magnetosphere of it deforms and a magnetic storm appears. Ionizing radiance influences much the upper atmosphere conditions and creates indignations in the ionosphere. Influence on many other physical phenomena is also possible.

An active zone on the Sun (AZ) is a totality of changing structural formations in some limited area of the solar atmosphere connected with intensification of a magnetic field in it from 10 – 20 to several (4 – 5) thousand oerstred.

The most remarkable structural formation of an active zone in a visible light is dark chiseled sunspots which often form groups. Among a lot of small spots there are usually two large ones which form a bipolar group of spots with opposite polarity of a magnetic field in them.

Sunspots are the most famous phenomena on the Sun.

It follows from the written resources, that it was Galileo Galilee who firstly noticed through a telescope and described sunspots in 1610.

Calendar Aztec

Mayan Calendar

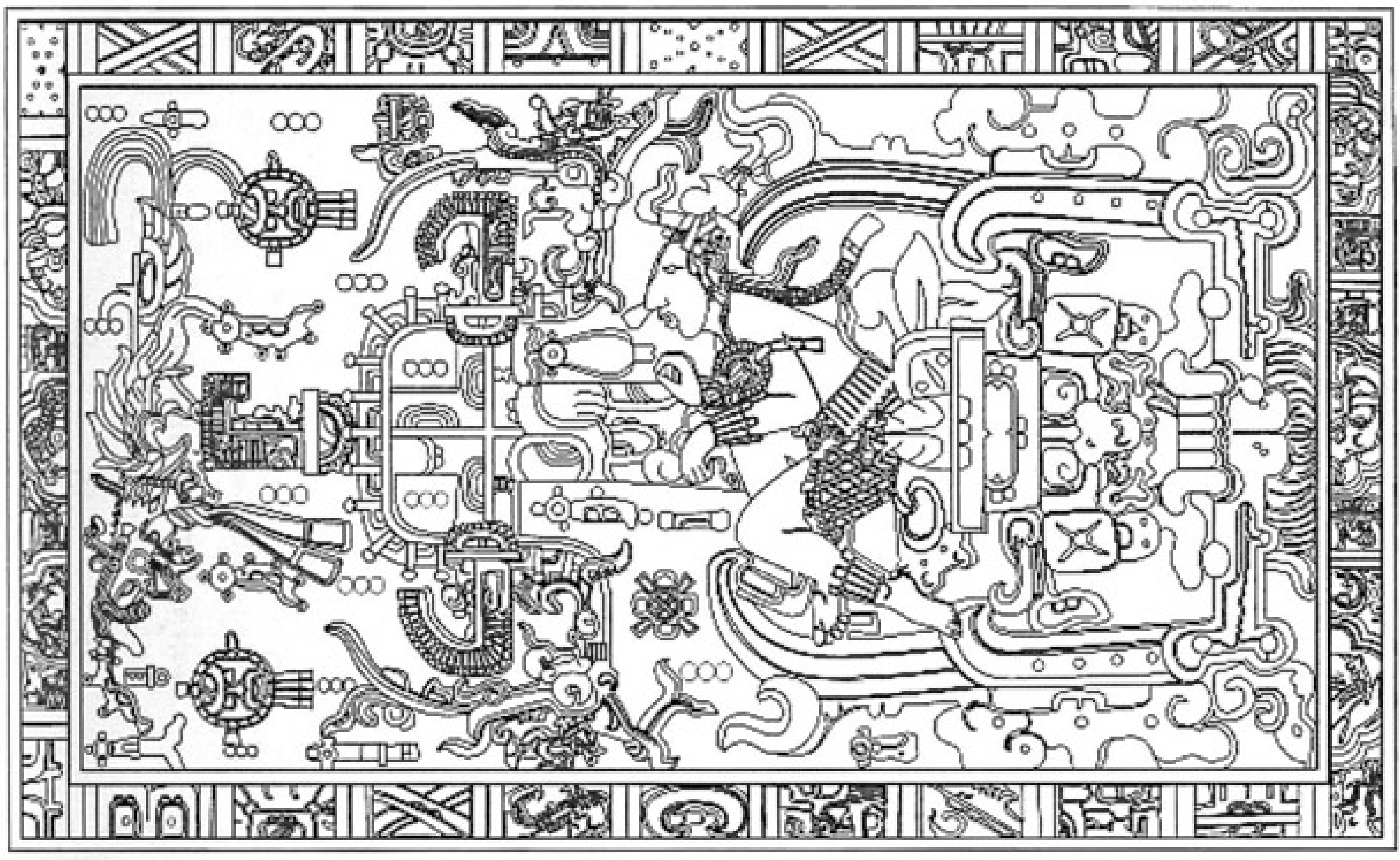


Image of "astronaut" on the cover burial Pakal, Palenque

We do not know when and how he learned to weaken a bright sunlight, but beautiful engravings representing sunspots and published in his famous letters about sunspots in 1613 became the first systematic rows of observations.

But we have to say that Maya and Aztecs were the first who paid attention to sunspots.

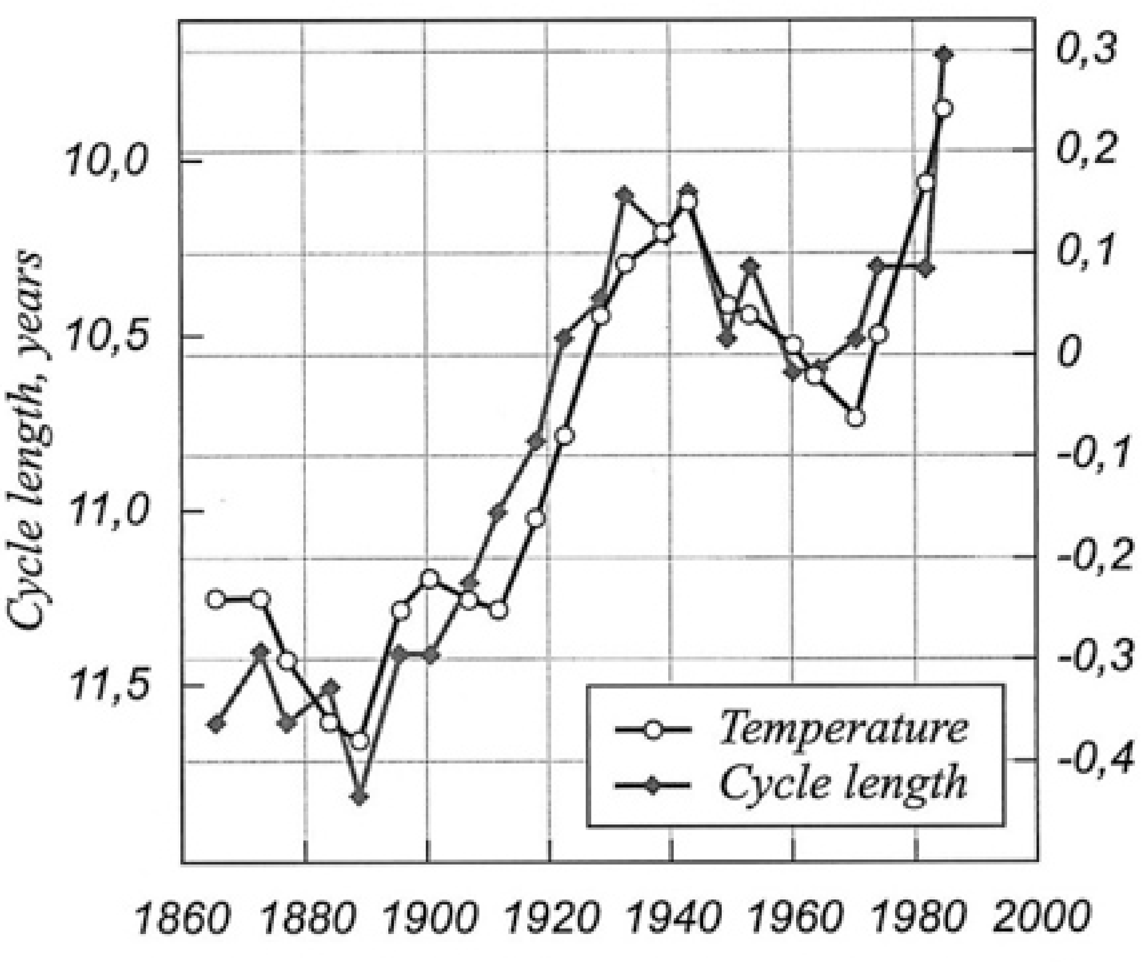
Deciphering symbols on a roof of a sarcophagus from Palenke and developing the theory of these symbols M. Cotterell [Gilbert, 2000] found out the connection between Maya and Aztecs` calendars and formation of sunspots.

(This representation is the most famous in the World because of the name Astronaut and similarity of the Maya tsar Pacal rising from the dead to the cosmonaut in the spacecraft.

Tsar Pacal himself is represented in the centre, there is a tree symbolizing the Milky Way and a mysterious bird pointing to the way to the other world of the Cosmos near him. The tsar's headwear looks like a cosmonaut's spacesuit and surrounding things are like a control console of a spacecraft [Libin, 2009]).

Since that time sunspots have registered, then stopped to be registered, then registered again. In the end of nineteenth century two observers – G. Sperer in

SUNSPOT CYCLE LENGTH AND TEMPERATURE



[Friis-Christensen and Lassen, 1991]

Germany and E. Maunder in England – pointed to the fact that during 70-year period up to 1716.

It seems that there are not enough spots on the solar disk. Nowadays D. Eddy having analyzed all the data has come to the conclusion that there was a solar activity decay in that period called Maunder`s minimum.

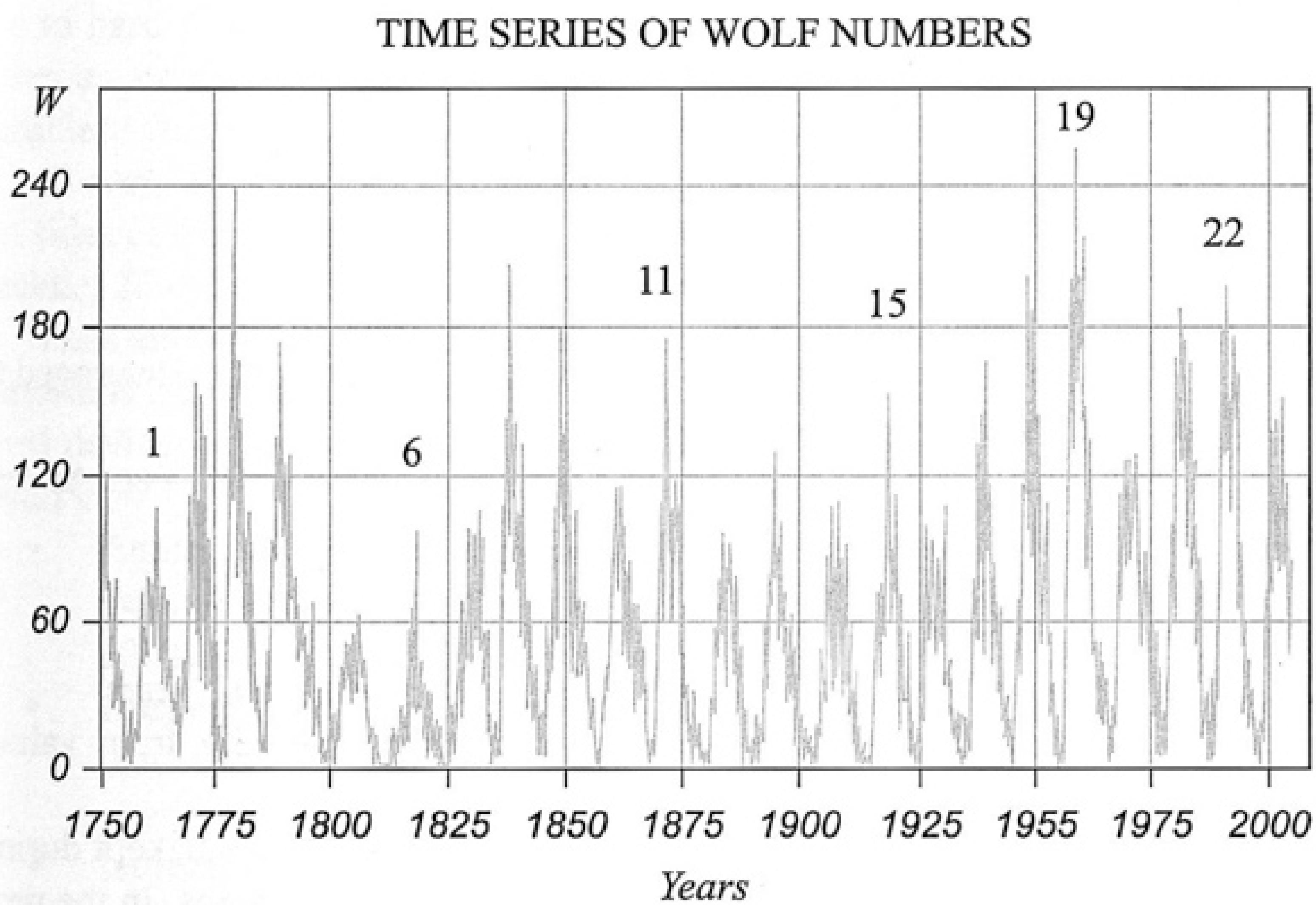
By the way, Wolf numbers were coined by R. Wolf, a manager of the Zurich observatory, who studied in detail early data of observing sunspots and organized systematic registration of them.

He coined a special index to characterize the solar spot formation activity $W = k(f + 10g)$, proportional to the sum $f + 10g$ where f – a number of all separate sports noticed on the disk of the Sun, g – a number of groups formed by them.

Later this index began to be called Wolf relative figures.

The Zurich system organized by Wolf himself was generally accepted. It appeared that maximum and minimum interchange of the Wolf figure row is not strictly periodical but cyclic in timely intervals varying from 8 to 15 years.

Cyclicity of solar activity (SA) was firstly discovered by Henrich Schwabe, a chemist from Dessau (Germany), who had regularly observed the Sun in re-



Cyclicity of solar activity for cycles 1-23 search of an unknown planet and noted the number of sunspots noticed by him since 1826 during 43 years.

Having been persuaded that this number was changed periodically he made the first announcement in 1843. In 1851 Humboldt published his data in Cosmos and drew scientists` attention to Schwabe`s discovery. There are everyday data since 1749, but before that are only separate observations made by chance.

But nowadays besides Schwabe-Wolf's 11-year cycle of solar activity discovered in the middle of the nineteenth century, Gansky`s 72-year cycle (two 36-year ones) discovered in the end of the nineteenth century and Rubashev`s more then 600-year cycle discovered in the middle of the twentieth century are famous.

In the sixties of the twentieth century Gnevyshev-Ol`s 22-year pair cycle connected with changing of sunspot polarity was also discovered in the Kislovodsk observatory. In its solar activity of the 11-year cycle, the second in the pair, is 1.4 times higher than in the previous one.

Almost all indexes of solar activity discover changes which repeat every 11 years on the average and because of that they are called the 11-year solar cyclicity. A lot of processes occurring on the Earth are connected with them in this or that degree.Indexes of helio- and geophysical activity

- Wolf relative figures *W*
- Sunspot squares *S*
- Square of calcium flocculi *K*
- Radio radiation flux 10.7 sm (2800 MHz) F10.7
- Index of flares 1,2 m…
- Irradiance (solar constant) *Q*
- *K*-index (the observatory geomagnetic field vector variation averaged to the thee directions and three-hour intervals) K
- K_p planetary *K*-index, averaged to 12 observatories. Variants ap, Ap and etc are used.

Basic peculiarities of 11-year cyclicity

1. Cycle duration from7 to 17 years
2. Growth phase from 2 to 5 years, decay phase from5 to 12 years
3. Amplitudes of successive cycles are changed gradually from values $W \approx 50$ (low) to $W \approx 200$ (high cycles).
4. Succession of magnetic polarity of basic spots in groups is kept during the cycle. But the polarity is opposite in both hemispheres. In the next cycle the polarity is changed to opposite.

5. Spot formation zone during the cycle moves from middle latitudes (30-35°) to 5° in the end of the cycle (Sperer`s law)

The main peculiarity of a solar activity cycle is the law of spot magnetic polarity changing.

During each 11-year cycle all leader sunspots of bipolar groups have the same polarity in the North hemisphere and opposite in the South one.

The same is correct for trailer sunspots the polarity of which is always opposite to the leader sunspot polarity. In the next cycle polarity of leader and trailer sunspots is changed to the opposite.

Together with it polarity of a general magnetic field of the Sun the poles of which are located near rotation poles is changed. That is why it is more correct to say about 22-year solar activity cycle, but not 11-year one (Hale`s cycle, 1919).

1.3. Operative center of the geophysical prognosis in IZMIRAN

Sun is the source of the life at the Earth, and at the same time it exposes this life to hard tests. Prodigious energy about 1023 kW partly reaches the Earth either as a radiation within the widest frequency range or as fluxes of charged particles. The whole complex of the solar phenomena and their manifestation at and near the Earth, the so-called "Space Weather", essentially effects different sides of the human vital activity [Feynman and Gabriel, 2000; Baker, 2004; Brekke, 2004; Watermann and references there, 2004].

It has already been mentioned in many references that strong space weather variations can influence various technical systems of the spacecraft and ground level devices [Belov et al., 2004; Oraevsky et al., 2003a]. In particular, it may result in:

- Anomalies and catastrophic failures in the operating of ground level, avionic and space technique [Allen and Wilkinson, 1993; Belov et al., 2004; Iucci et al., 2005];
- Breaks in the long distance communication and in the navigation systems working both on the short waves and on significantly higher frequencies [Lanzerotti, 2001];
- Increase of the radiation hazard for the cosmonauts and passengers of civil aviation;
- Changes in the satellite static charge;

- Heating of the upper atmosphere and consequent strong changes in the atmospheric density profile that cause the loss of orientation of the spacecraft and involuntary departure from the orbit;
- Inducing strong telluric currents resulting in the failure of the long electric lines and the breakdown of gas and oil pipelines due to increasing corrosion and anomalies in the system of anodic defense [Campbell, 1980; Boteler, 2000; 2003; Pirjola et al., 2000; Watermann, 2004];
- False functioning of the automatic and light-line systems on the railways [Oraevsky et al., 2003a].

Space weather also exerts influence directly on people's health:

- It deteriorates the total feeling of healthy people and enhances pathology of the chronic clients, in conjunction with vascular disease [Dmitrieva et al., 2000; Gurfinkel et al., 2003];
- Increase in a number of psychology disorders, as well as changes in the reaction speed and probability of inadequate solutions, suggestive of an effect of the weak magnetic field on biological systems [Aksyonov et al., 2001; Bingi and Savin, 2003].

Until now, the space weather influence on the climate variability and its potentially catastrophic manifestation has not been sufficiently studied yet. It is difficult to estimate this influence quantitatively. In any case it seems more reasonable to try to somehow prevent the effects of space weather than to struggle with its consequences.

It turns out that in Russia the easy-access sources of space weather information have been absent for a long time. Due to scientific passivity, the mass media were filled with pseudoscientific information and geomagnetic prognoses, at best of astrological origin that led to the faked psychological – "space weather" effect on the population.

Thus, the true and timely information on heliophysical conditions became of keen necessity for the society.

Considering the above-mentioned requirements, an operative Center of Forecasting of geophysical conditions was created at IZMIRAN. This allowed for the special possibilities and advantages of IZMIRAN as a scientific institute with more than 60 years of experience to be realized and utilized [Belov et al., 2004; Oraevsky et al., 2003a] .

A problem of solar-terrestrial relations is being studied at IZMIRAN comprehensively and from all possible aspects, due to the specialized theoretical scientific content and essential experimental base. The staff of the Center consists of the experts from various fields: solar physics, interplanetary physics, magnetosphere, ionosphere and cosmic ray physics. Such a group is able to comprehend most of the space weather data, to estimate operatively the situation at hand and to substantiate a tendency of the space weather evolution [Belov et al., 2004; Panasuyk et al., 2004].

The Center poses the following problem to be solved:

- Monitoring of the processes occurring at the Sun, in the interplanetary and near-Earth space by means of all available data sources and measurements;
- Continuous analysis of the helio-geophysical situation with account of the current information, pre-history and potential tendency for further evolution;
- Producing the different warning geomagnetic prognoses (nowcasting, short-time, mean time and long-term prognosis) and documents. Delivering them to users;
- Communication and collaboration with partners;
- Improving the forecasting methods with modern scientific approach.

1.3.1. Data and methods

There are two key statements in the basis of the geomagnetic prognosis:

1. Geomagnetic storms are created at the Sun;
2. Two main sources of the geomagnetic storms are coronal holes and coronal mass ejections (CME).

The prognoses of the IZMIRAN Center are mainly based upon the same sets of observations and operative data, which are used in all other space weather centers, in particular:

- Pictures and movies of the Sun within the optical, ultraviolet and X-ray ranges inform us about a position and evolution of the coronal holes, about evolution of the active regions and appearance of the new one, about filament activity, and eruptive and post eruptive phenomena;
- Changes in the photosphere magnetic fields provide the information on the development of the active complexes at the Sun and allow for the magnetic field distribution to be calculated on the solar wind source surface and in the interplanetary space;
- Solar radio burst measurements provide information about active processes at the Sun (coronal mass ejections-CME, shocks, acceleration of the charged particles);

- Data on the X-ray, gamma-ray, solar cosmic ray measurements (satellite and ground level observations) give the first evidences of the powerful energy release at the Sun;
- Pictures and movies from the satellite coronographs give the most direct information on the solar ejections. Unfortunately, ejecta, coming directly towards the Earth, are seen in these pictures much worse than ejects passing by the Earth.
- Data of helio-seismology allow for an indirect estimation of the stage and speed of the evolution of the active regions at the invisible portion of the solar disk;
- Variations of the interplanetary plasma velocity, density and temperature reflect dynamic features of the near-Earth solar wind, which directly influences the magnetosphere;
- Variations of the interplanetary magnetic field (IMF) intensity B and its three components, A_p, B_y, B_z, are used for the shortest time prognosis. The space apparatus located between the Sun and Earth near the libration's point, record disturbances originating from the Sun 20 – 60 min prior to when they start to impact the Earth's magnetosphere. On this basis it is possible to provide a rather reliable short time prognosis, or a well substantiated alert, just before the geomagnetic storm commencement;
- Cosmic ray variations of the solar, interplanetary and galactic origin measured on-board satellites and by the ground level neutron monitor network are used to define the onset of proton events, and Forbush effects usually associated with the geomagnetic storm. At present, data from about 25 ground level cosmic ray stations are accessible in a real-time regime;
- Variations of the geomagnetic field are available in real time from the measurements at more than 30 ground level stations distributed over the Earth. One of them is the IZMIRAN magnetic observatory;
- Variations of the geomagnetic field by the spacecraft measurements and associated changes in the electron fluxes inside the magnetosphere.
- Ionosphere data.

Despite that the prognoses in our Center are guided by the same data as those in the other centers, substantial peculiarities exist in the IZMIRAN approach and methods, due to the long experience in the study of the solar-terrestrial relations.

1.3.2. The production and users

The activity of the IZMIRAN Forecasting Center is intended to elaborate on the following kinds of prognoses:

- Short-term (1 – 6 days) forecasting of geomagnetic activity;
- Daily mean A_p-index for the next 1 – 6 days;
- Long-term prognosis (4 – 45 days and more);
- Probability of the maximum K_p-index for the next 1 – 6 days;
- Prognosis for the fixed days by special request;
- Detailed information and analytical overview of the solar and geomagnetic activity for the past month and preliminary prognosis for the next one.

Short-term prognoses are formed several times per day; every day throughout a week they are given out and delivered by various types of contact with the interested organizations.

Reliable contacts are formed with the Russian Space Agency (the Exploitation Center of the objects of ground space infrastructure, the Mission Control Center – MCC, Baykanur and Plesetsk Kosmodroms) and with the Russian Ministry of Civil Defense, Emergencies and Disaster Relief.

In order to sustain this collaboration, our Center launched the program of forming detailed databases on various extreme situations of natural and technogenic origin. Now, the Center provides information for the Russian spacecraft launches and further exploitation of the space objects by operative prognoses. Due to this information on large geomagnetic storms, often it turned out to be possible to retain space objects in orbit, for example, as in the case of the "OCEAN-O" satellite.

Apart from this, our prognoses are delivered to the Russian Academy of Sciences, the Institute of Medical-Biological problems, was well as to a number of various medical centers and hospitals [Oraevsky et al., 2002; 2003b]. Every day, the information on space weather is forwarded to different mass media (radio, TV, newspapers). For the first time in the world, an automatic system with a round-the-clock prognosis of the geophysical conditions is run in the from of a telephone answering machine. In addition to the standard prognosis, the current data on the geomagnetic disturbance and meteorological parameters are reported to these telephone callers, too.

There are several prognosis centers operating around the world, but unfortunately the accuracy of these prognoses is not so high yet. In the IZMIRAN Forecasting Center analyzed data from different centers: SEC – Space Environment

Center (NOAA, USA) (http://sec.noaa.gov/today.html), IPS – Australian Space Weather Agency (http://www.ips.gov.au/), SIDC–Solar Influence Data Analysis Center- RWC Belgium (http://sidc.oma.be/index.php3), and IZMIRAN Forecasting Center of Geophysical Conditions, Russia (http://forecast.izmiran.rssi.ru) – abbreviations these centers are seen in [Belov et al., 2004; Oraevsky et al., 2003a].

1.3.3. Some applications

1. Overcoming of the extreme situation in the orbit. One of the space weather hazards for the low orbital satellites is the strong variation in the upper atmosphere density profile during the magnetic storm, leading to the abrupt braking of the spacecraft and to the loss of orientation.

In particular, this problem arise from the first days after the launch of the spacecraft "OCEAN-O", which was developed for the purposes of remote scanning of the Earth and world ocean in optical, infrared and microwave spectral ranges.

The standard way of remote control of the on-board apparatus became unreliable during the extreme atmospheric variations throughout the magnetic storms. To improve the situation the solar battery configuration was reformed. This was severely, checked during the large magnetic storm on 15 – 16 July 2000, the greatest one in the last 10 years. The operative group of the Mission Control Center received in time the IZMIRAN Center warning and after the storm onset began to cope with its consequences.

During the time of each connection (which lasted not longer than 12 min), the necessary angle and program of the battery panel turning were defined, a sequence of the corresponding commands was elaborated and transferred onboard; their correct transmission and response to the on-board system was checked. In particular, in the hours of maximal geomagnetic activity the solar battery panel was turned in parallel to the spacecraft' movement.

With all necessity this work required the prognosis of geomagnetic disturbances to be carried out in a roundthe-clock regime, and, as a result, allowed the "OCEAN-O" to be saved during this severe magnetic storm.

This method was also used to retain this spacecraft' orbit during the next strong magnetic storms, which occurred very often throughout 2000 – 2001. Unfortunately, the Japanese satellite ASCA, during the same magnetic storm in July 2000, lost its orientation.

Its on-board control system automatically attempted to turn on the safety mode, but it was not possible to return back to normal functioning from this mode; the spacecraft solar battery lost the Sun and stopped producing the current. On the 2 March 2001 the uncontrolled ASCA satellite entered dense atmospheric layers and sank in the Pacific Ocean.

2. Mission on the space complex "MIR" leading off the orbit. The need continue monitoring of the geomagnetic situation was considered when a decision was required on the complex "MIR" landing in 2001. The IZMIRAN Forecasting Center provided daily mean Ap-indices and values of solar radio flux F10.7, as well, since both of these parameters were required for the atmosphere model and trajectory calculations.

In addition, the special method of long-term prognosis (up to 45 days) of the A_p and F10.7 indices was elaborated on, to provide long-term forecasting for the orbital complex landing. An optimal operation assumed the fall of the orbital complex down to 180 km, followed by a set of braking impulses after that.

There was a danger that the orbit complex would fall lower than this level and freely leave the orbit when themagnetic storm arose. For example, in the quiet and unsettled geomagnetic conditions the daily decrease in the orbit was about 500 m, whereas during the magnetic storm on 19 – 20 March, the fall was as much as 8.1 km.

Every day during 3 months the ballistics experts from the Mission Control Center calculated the parameters of the orbit on the basis of the IZMIRAN prognosis, which were compared with the trajectory measurements. During the winter months, the conditions were very quiet, whereas a new burst of solar activity had been expected by the end of March, thus, the operation needed to be finished without a delay. On the closing step the Space Agency and IZMIRAN were working in a roundthe-clock regime. The operation was finished on 23 March and all ensuing events on the Sun and in the magnetosphere could be considered as an evidence of the timeliness of the "MIR" sinking.

3. Failures of the railway automatics during the geomagnetic storm. The significant currents in the ionosphere during the geomagnetic storms may induce the so-called telluric currents in the long conductors, for example, in the electro-transmission lines, gas and oil pipelines, and railways, leading to anomalies in the operating of the mentioned systems [Boteler, 2003].

During 2000 – 2001 and then in 2003 – 2004, IZMIRAN was receiving a lot of reports from the Nyandoma part (63 – 640 N) of the Northern railway regarding the cases of failure of the railway, devices (signalization, centralization and block system) for a number of railway stations Shozhma, Lelma, Shalakusha, Lepsha, Ivaksha, Plesetskaya, Sheleksa, Puksa, Emtsa, Letneozersky, Shestiozersky. Some similar reports from the Gorky railway were also received during the last few years.

They reported about false signals at the duty tables regarding blockage on the tracks along the main railway [Oraevsky et al., 2003a]. It caused a delay in the train moving. The time and anomaly characteristics where compared to protocols.

It is characteristic that the checking of the apparatus after these anomaly signals indicated whether they were functioning properly or not. Comparison of the received reports with the data on the geomagnetic field variations revealed a well pronounced correlation between the anomalies in the railway automatics and big disturbances in the geomagnetic field during the greatest magnetic storms in these years.

In the work [Belov et al., 2004] shows the dates of the anomalies on the Northern railway, the 3-h K_p-index maximum, daily A_p-index, and the minimum hourly D_{st} index. It is clearly seen that almost all malfunctions fall during the time of severe geomagnetic storms (maximum K_p is 8+ and more) and only in one case was there a strong storm (K_p-index is 7). A more detailed analysis indicates a coincidence between the time of the anomalies and the most active geomagnetic periods with an accuracy up to hours. It is noteworthy to emphasize that these periods were selected by the information on the railway anomalies, and not by the geophysical situation. We did not receive any information on a similar problem in the quiescent periods. Although it may be assumed that analogous malfunctions (probably less in number) could occur during the weaker geomagnetic disturbances and not only at the Northern railway, the railway experts tried to explain them by simple technical anomalies or by the operator's mistakes.

However, the reason for these phenomena may really be the currents induced in the extended system of the railway automatics. They seem to have occurred often enough at all high latitudinal railways. The reports on similar anomalies have also been received from Sweden in 1982 and Norway in January 2000, and another Russian high latitude (Gorky) railway. To reduce the risk of possible extreme events at the high latitudinal railways the information for railway stations should be provided by a well-timed prognosis of geomagnetic activity and by the information about the current geomagnetic situation.

1.3.4. Basis for the long-term prognosis

A long-term prognosis for Ap-indices is presented in [Belov et al., 2004, Fig. 5]. It was calculated on the basis of some scientific results on the study of long-term solar-terrestrial dependences. To obtain this long-term curve the behavior of the solar activity index (or, more accurately, the sunspot number) in the 24th cycle was supposed to be the same as the averaged index behavior, averaged over the last 7 cycles.

It was also taken into account that the base indices of geomagnetic activity vary regularly within the solar cycle, therefore the averaged behavior of the A_p-index over the 17 – 23 cycles was defined for the different phases of the solar cycle separately. This averaged behavior of the Ap-index, in combination with its seasonal tendency, obtained from the multi- year data, directly forms the basis for the long-term prognosis thus offered. In [Belov et al., 2004], a fraction of the days with the magnetic storms ($K_p \geq 5$) for different months during the year is presented, together with its autocorrelation function (see Fig. 6).

These data have also been used for the long-term prognosis. Of course, we can calculate only a smoothed variation of geomagnetic activity, and the real behavior will be less regular. The new, unexpected bursts of solar activity will inevitably occur and cause numerous storms, exceeding the predicted numbers in some cases.

1.3.5. Possibilities of further improvement

The numerous works are carried out in IZMIRAN, which may be directed towards refining the geomagnetic prognosis. In particular, the efforts are concentrated on the following models:

- Model of the magnetic field at the solar wind source surface for the current moment;
- Model of the relation between characteristics of the magnetic field on the source surface and of the solar wind near the Earth.

  This plasma, incoming to the Earth, crosses the surface of the solar wind source several days prior. Thus, the solar wind behavior near the Earth, and the consequent variations of geomagnetic activity appear to be predicted if plasma properties on the source surface are known.

  The essential prerequisites [Wang and Sheley, 1992] exist for the prognosis of different components of the IMF and solar wind velocity. It requires regular observations and measurements of the magnetic field at the photosphere and a reliable method allowing the field at the source surface to be calculated on the basis of photosphere observations;

- Model of the geomagnetic cloud structure from observations of the solar filaments and solar magnetic field;
- Model of the solar wind fast stream from the coronal hole;
- Model of the coronal holes – interrelation of active regions.

Some new improvements, used as a tool to analyze the current conditions and for the short-term forecasting, are discussed now, such as a stacked plot of data in real time to show the key parameters, combining solar X-rays (GOES), solar wind and interplanetary magnetic field (ACE), solar protons (GOES), high-energy electrons (GOES), K_p and D_{st} geomagnetic indices.

1.4. Solar-terrestrial physics and fundamental cosmic research

The Sun and solar-terrestrial relations are studied with a help of terrestrial and cosmic watch facilities [V.N. Oraevsky, V.D. Kuznetsov, 2007].

But the most important results have been achieved within the last years due to cosmic research. Most types of observations are possible only from the cosmos, and this explains an indispensable role of cosmic research in solar-terrestrial physics.

Arising understanding the influence of cosmic weather factors on the climate, the Earth environment, and different spheres of human activity determines practical value of research in this sphere. As before, discussion of many fundamental scientific problems of solar and stellar physics and plasmic astrophysics with a help of observing the Sun is only in store for us.

Solar resources of cosmic weather are basic. They often disturb calmness on the Earth and in the circumterrestrial cosmic space. It is enough to say that about 37 000 flares happen during 11-year cycle of solar activity (according to data for 22-year cycle of solar activity – 1986 – 1996). In the maximum of a solar cycle at the average 1 flare happens per 1 – 2 hours, in the minimum 1 – 2 flares per a day. Other powerful manifestations of solar activity – coronal substance emissions at the average happen 5 – 10 times per day in the maximum of a cycle, and only a small part of them spreads to the direction of the Earth and arouses geomagnetic storms.

Moreover, about 500 magnetic storms which can influence people's health, lead to dangerous, sometimes disastrous influence on different technical systems happen for a solar cycle on the Earth under different solar resources.

In the IZMIRAN there is a Geophysical situation forecasting center which observes solar activity state based on terrestrial and cosmic data and provides interested organizations and offices with information about the Earth's magnetic field state and magnetic storms.

Observations made in the IZMIRAN in cooperation with medical institutions showed that during magnetic storms in a human organism adrenalin rate is increased and bloodstream character is changed in microcapillaries – bloodstream becomes interrupted and arouses changes in pulsation and blood pressure.

As adrenalin discharge happens also during the stress, magnetic storms can be regarded as a stress influence on the human organism the consequences of which are well-known, and they are especially noticeable and essential for people with cardiovascular diseases.

In these periods (of indignations) a number of hospitalizations of people with cardiovascular diseases are also raised, and just this indication has a high degree of correlation with magnetic storms.

Moreover, observing the Sun from the cosmos has a great value for fundamental astrophysics and practical purposes as they let us answer the questions

- about the origin of mass coronal emissions and solar flares,
- about warming a solar corona and fastening of the solar wind,
- about mechanisms of a solar cycle
- about global structure of the heliosphere and indignations coming from the Sun
- about forecasting of solar phenomena geoeffectiveness.

The active and workable cosmic projects of the Russian Federal cosmic program are directed to solve these and many other problems [V.N. Oraevsky, V.D. Kuznetsov, 2007].

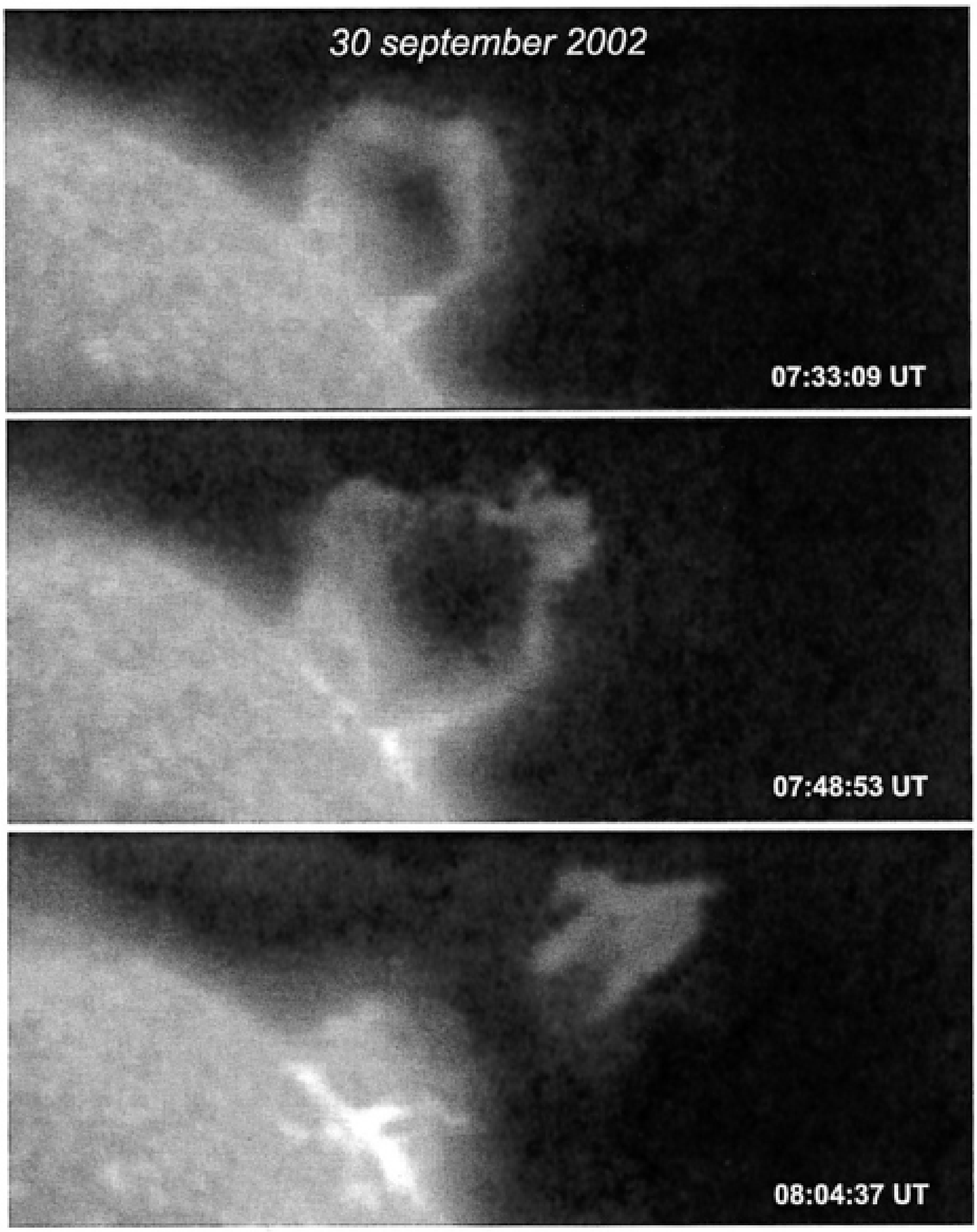
Program CORONAS and CORONAS-F project

For researching the Sun and solar-terrestrial relations on different phases of the 11-year solar cycle the IZMIRAN worked out and put into practice an international program CORONAS (COCOSA – Complex Orbital Circumterrestrial Observations of Solar Activity) [V.N. Oraevsky, V.D. Kuznetsov, 2007].

Within this program the first satellite CORONAS -I (launched in 1994) observed the Sun near the minimum of its activity.

The second satellite CORONAS-F, launched in July, 31, 2001 researches solar activity in the current 23d cycle. Maximum of the current 23d solar activity cycle was achieved in April, 2000, and a high level of activity was kept during 2 – 3 years. Maximum of the next 24th solar cycle is expected in 2013.

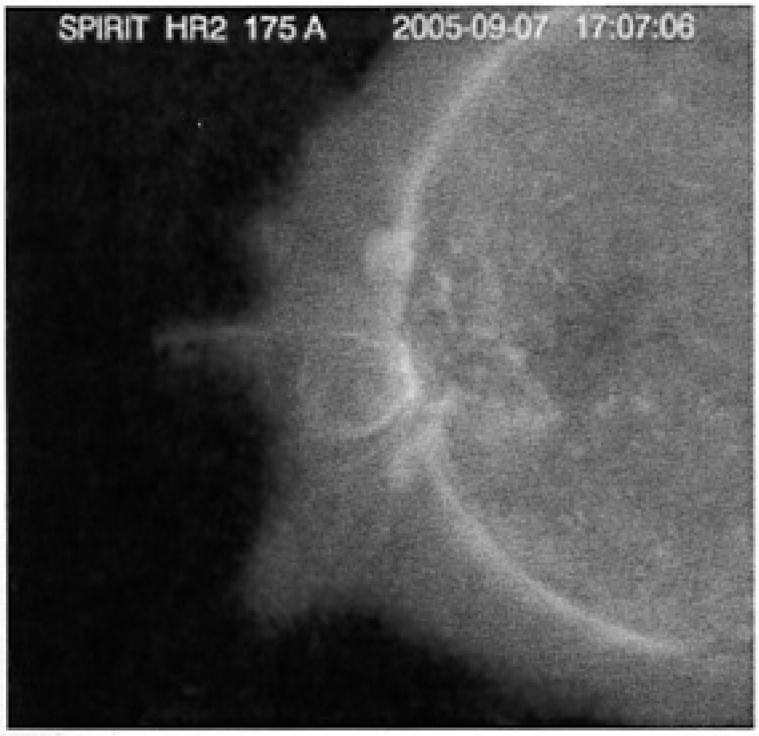
The orbit of the satellite CORONAS-F (orbit inclination is 82.49°, minimal removal from the Earth's surface is 500.9 km, maximal removal from the Earth's surface is 548.5 km, period of satellite is 94.859 min.) provides periodically changing periods of continuous observations of the Sun with duration of about 20 days that is very important for patrolling solar phenomena and flares, for registration of solar global variations.



The coronal mass ejection in the solar atmosphere. Experiment Sprint / Coronas [Kuznetsov, 2008]

The basic scientific problems of the project CORONAS-F are observations of solar global variations and on the basis of them studying the depth and inner structure of the Sun.

Questions of complex researches of active zones, flares, plasma emissions in a wide range of wavelength, studying solar cosmic rays fastened during active phenomena on the Sun, conditions of their doing out, spreading in the interplanetary magnetic field and influence on the Earth magnetosphere are also solved.

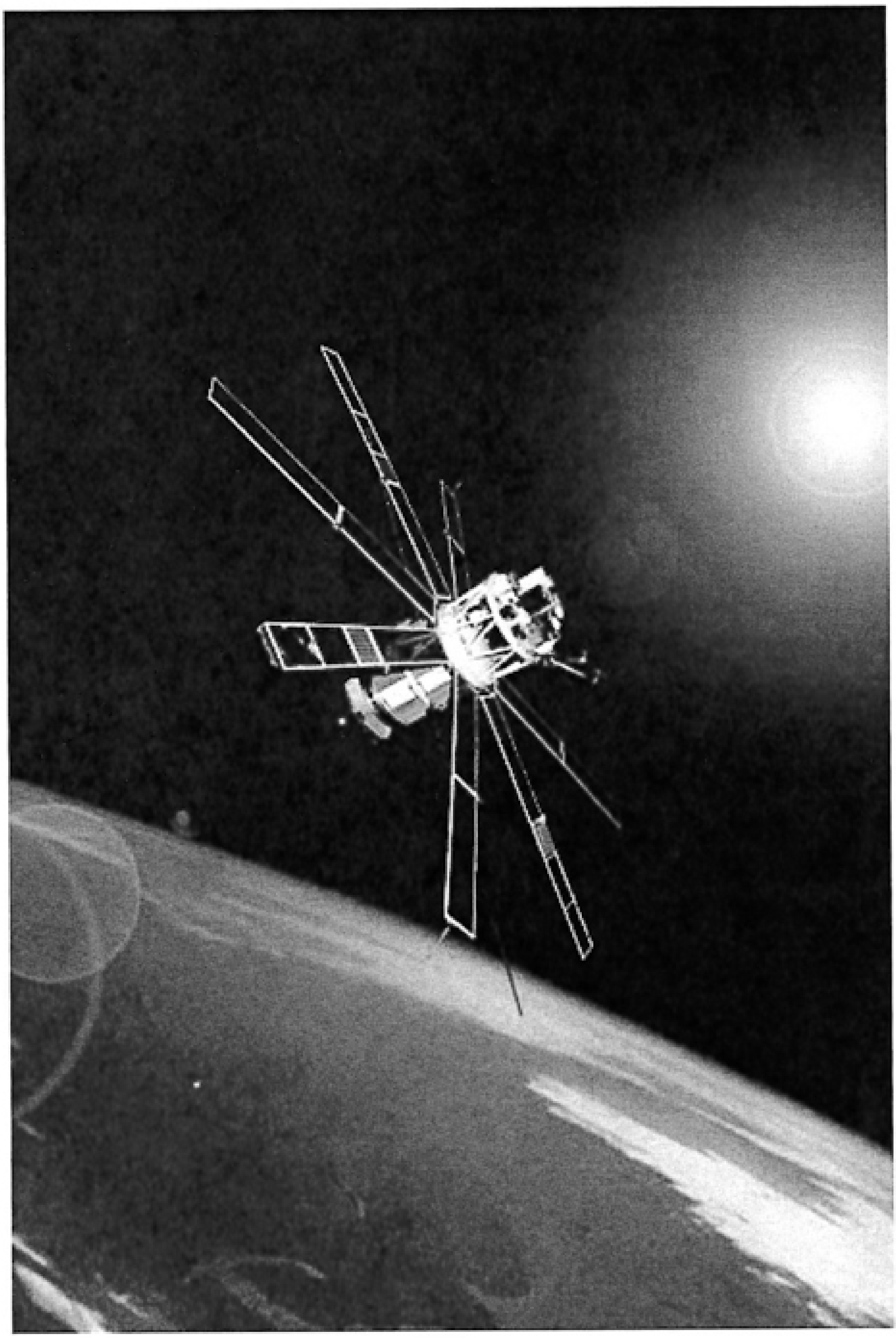


Restructuring of the magnetic field in the solar corona during a flare September 7, 2005.
Experiment Sprint / Coronas [Kuznetsov, 2008]

A large stuff of scientists, engineers and specialists of a wide cooperation of Russian, Ukrainian and foreign organizations and agencies under the IZMIRAN participate in realization of the project CORONAS-F. PIAS (Physical Institute of AS), PTI (Physical and Technical Institute), IAG (Institute of Applied Geophysics), RINP MSU (Research Institute of Nuclear Physics of the Moscow State University), ISR PAS (Institute of Space Research of the RAS), MEPI (Moscow Engineering and Physical Institute) participate in scientific experiments of the project CORONAS-F.

Global variations of the Sun and the inner structure of it

Observed solar activity is a reflection of processes occurring in its depth. Thermonuclear reactions occur in the Sun core, a discharged energy of them are brought to the outer layers giving birth to the complex structure and dynamics of these layers – a convective zone, photosphere, chromospheres, corona and solar wind.So, studying the inner structure of the Sun is the basic moment for understanding the solar activity nature. Such characteristics of the inner layers of the Sun as density, temperature and depth distribution, dependence of angular velocity on a radius and width, depth of a convective zone, etc. are important.



CORONAS-F satellite in orbit [Kuznetsov, 2000]

Helioseismology is a science about the inner structure of the Sun. One of the most workable modern methods of studying the inner structure of the Sun is helioseismology studying natural oscillations of the Sun. Helioseismology as a new part of physics of the Sun was born in sixties when 5-minute oscillations covering the whole surface of the Sun were discovered (in the period of 3 – 10 of minutes).

With a help of helioseismology it is possible to make a research of the solar structure from a convective zone up to the core. In the spectrum of natural oscillations there is information about temperature, pressure, magnetic fields, rotational velocity depending on the depth.

Cosmic (extra-atmospheric) helioseismology. Terrestrial observations of global oscillations meet a row of difficulties. A wish to achieve maximally possible special and partial resolution of global oscillation spectrum demands to provide observation regularity during at least two weeks because frequency resolution is inversely to time of observation.

On observing from the Earth's surface it is possible only if there are several points of observation distributed along the longitude and which have the same equipments or if to observe from polar spheres. But in these cases getting long rows of data depends on good weather. Besides, instability of the Earth atmosphere and presence of natural oscillations lower the signal-noise correlation, and observations in some parts of the spectrum, in ultraviolet, for example, get impossible because of strong absorption of solar radiation by the atmosphere.

That is why it is better to observe global oscillations of the Sun from the cosmos. And solar-synchronic orbit of the satellite CORONAS-F providing observations without any breaks for 20 days allows to watch solidly dynamics of different modes of global oscillations – growth, saturation and amplitude decreasing phases which have characteristic time from several hours to several days.

Data of solar radiation intensity in a wide range of spectrum got on the spacecraft allow to find out the variation nature of a solar constant and pick out contribution of sunspots, faculae, chromospheric network and other expressions of solar activity to these variations and to study dependence of parameters of global oscillations under study on 11-year cycle of solar activity.

Solar flares

Solar flares are the most powerful expression of solar activity. When flare rays, accelerated particles and indignation of the solar wind reach the Earth, they influence the magnetosphere and atmosphere, raise radiation hazard in the circumterrestrial cosmic space and lead to many effects which have become the subject of cosmic weather research. A complex of the scientific equipment (SCR) consisting of three devices makes complex research of solar cosmic rays and their manifestations in the circumterrestrial cosmic space.

Representing X-ray spectroscopy of the Sun

To get images of the Sun representing the most characteristic traits of its face has become a visit card of any modern solar cosmic project. A new direction in solar astrophysics has been realized on the CORONAS-F satellite in the network of the experiment SPIRIT (FIAN). It is representing X-ray spectroscopy of the Sun which permits reestablish three-dimensional structure basing on monochromatic pictures of the Sun and research dynamics of plasmic formations of solar atmosphere in a wide range of temperatures existing on the Sun – from 50 thousand to 50 million degrees Kelvin. More than 200 sun images are registered every day.

The project CORONAS-F is a constituent part of a perspective program of solar research worked out by the IZMIRAN under the aegis of Rosaviacosmos and RAS in cooperation with other Russian and foreign organizations.

This program includes the project Interhelioprobe for researching the Sun from close distances and the project Polar-Ecliptic Patrol for global vision of the Sun and controlling the cosmic weather.

Project RESONANCE

The aim of the RESONANCE project is to study plasma dynamics and wave-particle interactions in the Earth's inner magnetosphere from an orbit, co-rotating with the magnetic flux tubes on L-shells around 5, which are rarely visited by scientific spacecraft [Mogilevsky, 2002; Demekhov, 2003]. It is a joint project of Space Research Institute (IKI Moscow) and Institute of Applied Physics (IPF N.Novgorod) with participation of many other scientific institutions from Russia, France, Finland, Germany, USA, and Ukraine. The scientific program of the project consists of two parts. The first, "passive", part, is aimed at the investigation of natural magnetospheric phenomena. Main goals of this part are as follows:

- Magnetospheric cyclotron maser and its long-term evolution;
- Role of small-scale phenomena in the global dynamics of magnetospheric plasma;

- Ring current and outer radiation belt formation and evolution, MeV electron dynamics;
- Plasmasphere dynamics and refilling, sub-auroral zone physics;
- Plasma injection development, magnetic field reconfigurations;
- Mid-altitude auroral zone, polar cap and cusp physics.

Investigations in the frame of the second, "active", part, will focus on the joint experiments of the RESONANCE atellite(s) with ground-based HF heating facilities (HAARP and/or MURMANSK). We expect that parameters of the natural magnetospheric oscillatory system will change, if powerful HF electromagnetic emissions heat the ionosphere and thus modulate the ionospheric mirrors. Phase and amplitude of magnetospheric oscillations, measured onboard the RESONANCE satellite, will be transmitted to the heating facility and used to modulate the HF radiation. In the case of in-phase modification, the amplitude of the natural oscillations should increase, whereas inverse anti-phase modification should decrease the oscillation. Such a unique experiment will help to investigate important underlying principles in cyclotron maser theory and clarify the role of ionospheric mirrors in wave generation.

The onboard instruments will include:

- DC and AC magnetometers;
- Electric field instrument;
- DC/ULF fields analyzer (0 – 35 Hz, dynamic range: DC – 120 dB, ULF – 80 dB);
- ELF/VLF fields analyzer (3 electric and 3 magnetic components, 0.01 – 30 kHz, dynamic range: 70 dB);
- HF fields analyzer (3 electric and 3 magnetic components, 0.01 – 30 MHz, dynamic range: 70 dB);
- Mutual impedance probe for plasma density and temperature measurements;
- Thermal plasma spectrometer (electrons and 3 sorts of ions (hydrogen, helium, oxygen) 1 – 100 eV, time resolution: 1 – 5 sec);
- Hot plasma spectrometer (electrons and 3 sorts of ions, 10 – 104 eV, time resolution: 1 sec);
- Fast electron spectrometer (5 – 50 keV, energy resolution 100 eV, time resolution 10 ms);
- Energetic particle instrument.

The novel type of a magneto-synchronous orbit proposed and designed for this project will allow the satellite to conduct measurements within (approximately) the same magnetic flux tube for sufficiently long time intervals (See next Figures). Duration of the spacecraft and magnetic tube co-rotation near the equatorial plane might reach a couple of hours, if the transverse size of the flux tube at the ionospheric level is taken as 50 – 100 km (significantly longer than the maser characteristic time scales).

An important constraint is the magnetic latitude of the orbit apogee, which must be in the inner magnetosphere not far from the plasmapause; otherwise reliable co-rotation is impossible. For active experiments the flux tube should map to the heating facility. Possibility of launching a pair of identical RESONANCE satellites is under investigation now and will provide additional opportunities to monitor dynamics of large-scale natural oscillating processes.

Satellite locations will be determined with the onboard GPS/GLONASS navigation receivers. Preliminary orbital parameters are as follows: apogee: 28 000 km, perigee: 500 km, inclination: ±63.4 (for two satellites [web site is http://www.resonance.romance.iki.rssi.ru].

Project PLASMA-F/SPECTR-R

SPECTR-R is an international space VLBI project of Russian Space Agency, led by the Astro Space Center of Lebedev Physics Institute (http://www.asc.rssi.ru/radioastron). A 10 meter radio telescope will be launched in late 2007 to an orbit with apogee about 350,000 km, perigee 5,000 km and inclination of 54°. At this 9-day orbit, the spacecraft will spend 90 % of time in the near-Earth interplanetary medium and thus it is a convenient platform for a solar wind experiment. PLASMA-F primary scientific goal is to resolve smallscale solar wind structures down to 10 – 100 km, to track energy and momentum transformations below the scales of ion inertial length and gyro-radius and to understand role of small-scale processes in formation of solar wind discontinuities, boundaries and dissipation. Specially designed instruments will perform synchronized measurements of magnetic field, solar wind ions and energetic particles with temporal resolution up to 32 samples per second.

The secondary scientific goal is interplanetary medium monitoring in the interests of space weather research and forecast, participation in multi-spacecraft campaigns. The experiment will contribute to ILWS and International Heliophysical Year programs. Scientific Leader of the experiment is Prof. L.M. Zelenyi and PLASMA-F Project scientist is G.N. Zastenker (Space Research Institute). Experiment is managed by Space Research Institute.

PLASMA-F experiment consists of four instruments: Fast solar wind flow monitor BMSW includes 6 Faraday cups with different looking directions and retarding potentials, providing 32 solar wind flow measurements per sec. Combination of simultaneous data from all sensors allows to instantaneously determine direction, speed, density, temperature of solar wind ion flow in the Maxwellian approximation. Instrument PI is G.N. Zastenker (Space Research Institute).

Data collection and processing unit SSNI-2 performs data collection from PLASMA-F instruments, on-board data storage and transmission to spacecraft telemetry along with some other tasks. SSNI-2 has 200 GB of onboard memory to perform intelligent onboard data treatment with possibility of data selection, averaging and compression. Instrument PI is L.S.Chesalin (Space Research Institute). Expected data rate in case of permanent 32-Hz measurements is about 1 GByte per week. Browse and scientific data will be available for the broad scientific community within short time interval.

Project Interhelioprobe

In the project Interhelioprobe a spacecraft located on the heliocentric orbit will perform many gravity-assist maneuvers near the Venice and come close to the Sun at the account of attraction of the Venice along a torsile trajectory. In a result a spacecraft will hover above a certain area of the Sun's surface during a week, and it will allow establishing important for solar-terrestrial relations direct correlations of phenomena on the Sun and in the interplanetary sphere.

Making a circle around the Sun approximately for 1/3 of the year the Interhelioprobe will take different positions relative to a Sun-Earth line locating and observing the Sun from the side of that line and a reverse side invisible from the Earth.

The project will permit to answer the questions basic for solar-terrestrial physics and astrophysics about a solar corona warming mechanisms, origin and acceleration of the solar wind, origin of the most powerful expressions of solar activity – solar flares and coronal substance emissions.

Project Polar-Ecliptic Patrol

In the framework of the project Polar-Ecliptic Patrol worked out by the IZMIRAN it is planned to provide a continuous monitoring of the solar activity and the solar wind, solar emissions and heliospheric indignations moving to the direction of the Earth and observing polar areas and the back side of the Sun.

Two small spacecrafts are located on polar (or tilted at 45 degree angle to the plane of the ecliptic) heliocentric orbits at the distance 0.5 a.u. so that their orbit planes are mutually transverse to each other, and on the orbits the equipments are allocated for the ¼ of the period (about 130 days).

Within such an orbital scheme the control for a Sun-Earth line is constantly provided from one of the spacecrafts and from both spacecrafts during a long time. When one of the spacecrafts is located in the plane of the ecliptic, the other one is located above one of the solar poles, and when one of the spacecrafts moves away from the plane of the ecliptic, the other one moves closer to it. So, simultaneous monitoring is carried out in ecliptic and in polar areas.

It gives a possibility to study regularly low- and high-speed solar wind, 3-D image of a solar corona and solar emissions.

In separate periods one of the spacecrafts will be located in the other hemisphere then the Earth relative to a Sun-Earth line, and, so, this spacecraft will observe the reverse side of the Sun invisible from the Earth.

S.P. Korolyov, a general constructor of soviet cosmos, wrote in the article Steps to the Future in 1966, «There is no other branch in Soviet science which is developing so quickly as cosmic research. A little more than 8 years have passed since a man-made cosmic body – the first Soviet artificial Earth satellite - firstly appeared in the Universe. The history of astronautics is only about three thousand days, but it is so rich in events the most important for the humanity, that it is possible to separate out whole epochs in it».

Nowadays continuous cosmic research of the Sun, solar wind, interplanetary space at the distance of tens a.u. from the Earth and solar-terrestrial relations have become a common thing. Spacecrafts «Voyager-1» and «Pioneer-10», «Cassini» and «Galileo», «Genesis» and «Soho», «Coronas» and «Interheliaprobe», «SOHO», MKC and others work in the cosmos.

By the way, the first direct results of measuring the solar wind were sent to the Earth from the Moon by spacecrafts Apollo. (The Moon which neither has atmosphere no magnetic field has appeared to be a good place for gathering such information.)

On the 20 of July, 1969, at 20.17 (GMT) an American spacecraft Apollo-11lended on the Moon's surface. For the first time the man realized his dream and set his foot on another celestial body. Setting his foot on the Moon's surface American cosmonaut Neil Armstrong said, «This small step of a human is a gigantic step of the humanity».

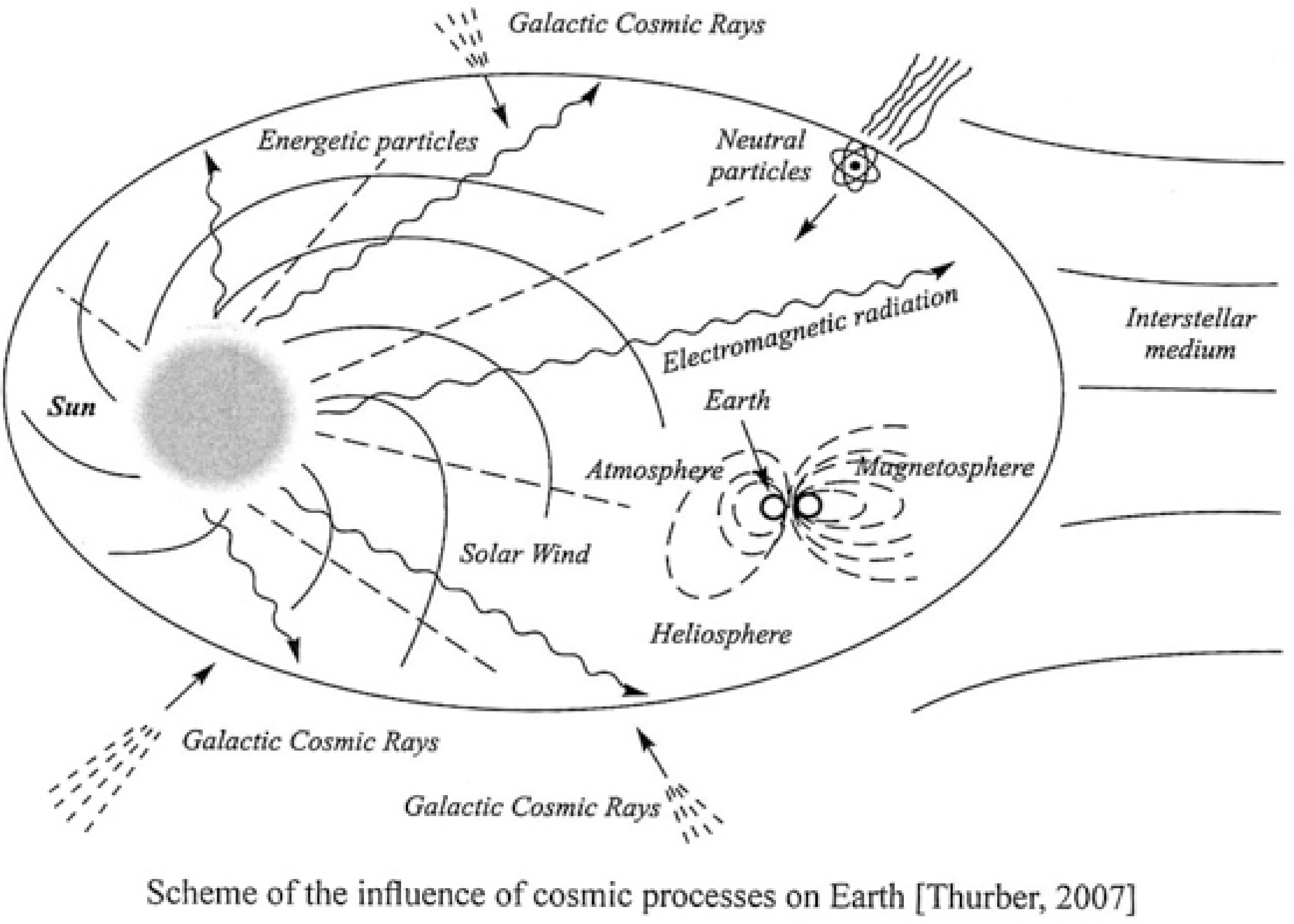
Neil Armstrong at a meeting of COSPAR.
Leningrad, 1971

The Earth loves the Sun for being
That the Sun burns and laughs.
And the Sun for like the Earth,
That the cries and freeze it.
Do not get close to them ever
They are far and near;
Until cool star,
Lives and suffering Earth.

Igor Severianin, 1911

2. SOLAR ACTIVITY INFLUENCE ON COSMOPHYSICAL AND GEOPHYSICAL PROCESSES

B.M. Kuzhevsky writes in his work A Research Object is the Sun, «Everything that happens with the Earth as a planet – geological and climatic processes in it, conception of life, evolution of it from a primitive level to Homo sapiens, spiritual and psychical life of a separate human being and the whole nations – is connected with the life of the Sun.



Scheme of the influence of cosmic processes on Earth [Thurber, 2007]

In some sense it is possible to assert that we live in the Sun's atmosphere. That is why wide research of our heavenly body is very important, especially study of processes in its atmosphere.

Being connected with the most powerful, although spatially-local, relatively short-time energy release they are attended by generation of neutral and charged particles and the most powerful electromagnetic radiation which pierce through an interplanetary space, influence its objects including the Earth effectively. That is why physical processes in it are very important for us» [Kuzhevsky, 2002].

2.1. Active processes on the Sun

From the ancient times people noticed dark spots of different square and forms on the surface of the Sun which appeared and disappeared.

Today we know that sunspots are external manifestation of subsurface active processes on the Sun. Observing them has permitted to show different cyclicities in solar activity which become apparent in periodical change of different parameters which characterize sunspots and in solar electromagnetic radiation.

One more impressive phenomenon which was discovered about 100 years ago is a chromospheric flare – sporadic release of a great deal of energy equal to a synchronic explosion of 100 million 1 kiloton nuclear bombs in the part of solar atmosphere (the chromosphere).

A chromospheric (solar) flare spreads far outside the chromosphere covering lower (solar photosphere) and higher (solar corona) regions.

A solar flare is usually characterized by fast rising (up to ten minutes) and slow decay (20-100 min.). During a flare radiation in practically all ranges of electromagnetic spectrum is raised.

About a half of common flare energy is removed by powerful emissions of plasma which comes through the solar corona and reaches the orbit of the Earth as corpuscular fluxes interacting with the Earth's magnetosphere, and sometimes it leads to auroras.

Powerful energy is released in flares in different ways – as gas-dynamic movement of solar atmosphere plasma and as electromagnetic radiation in a widest range of solar cosmic ray (SCR) particles with energy up to tens of billions of electron-volts (SCR energy spectrum).

Flare origin. Sometimes an unexpected explosion of a small volume of solar plasma can be observed in a well-developed active region. This most powerful manifestation of solar activity is called a solar flare. It appears in the area of the magnetic field polarity change where powerful opposite magnetic poles collide in a small region, and, in a result, their structure is essentially changed.

A solar flare is usually characterized by fast increasing of brightness and square (for several minutes if the phenomenon is fast and for an hour if it is slow) and slower decays (20–100 min.).

Observation of flares. Carrington and Hodgson were the first, who observed a flare in a white light independently in England on the 1st of September, 1859.

The easiest way to observe solar flares is in hydrogen red line radiated by the chromosphere. In the radio-frequency range increase of radio brightness in active areas can be so large that a full radio-wave energy flux moving from the Sun becomes tens or even thousand times larger. These phenomena are called solar radio bursts.

A role of a magnetic field. When a magnetic field (MF) density is increased in some area of the chromosphere or a corona (for example, on account of emersion of a new magnetic flux from a convective zone) a picture of magnetic field lines distribution is changed (field topology).

It is possible to suggest, when an old and new magnetic fields approach to each other in approach areas where field lines of opposite direction and the same size meet each other neutral points and lines appear where a MF becomes a zero. In the vicinity of them MF fluxes should be reallocated and their common structure should be changed.

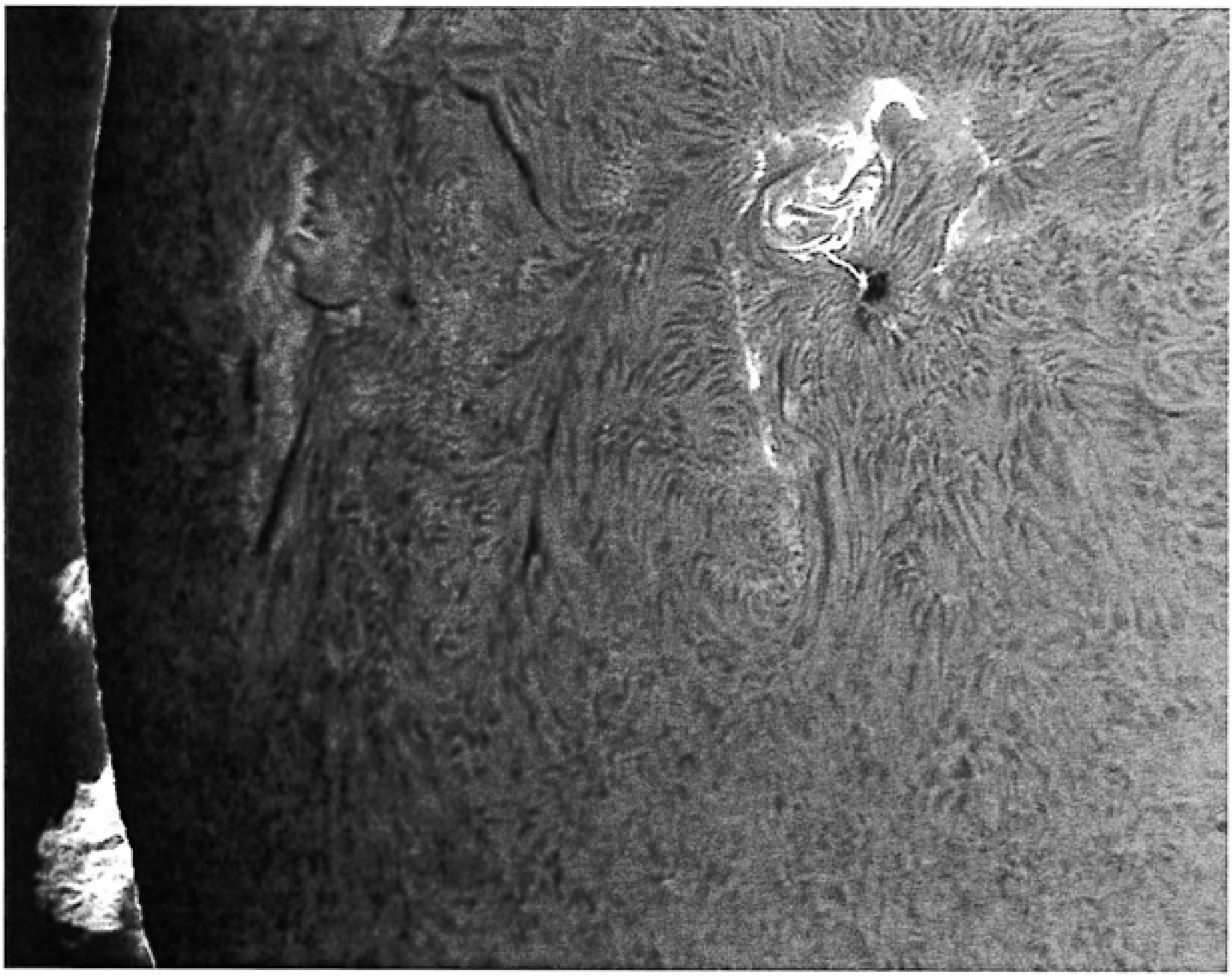
In some cases of collecting MF considerable energies this change can lead to an instability state, indexing of large electric currents and fast thermal energy release.

As a whole the process is similar to a powerful explosion accompanied by plasma particle acceleration up to high energies and plasma cloud emissions into an interplanetary space with a velocity of thousands km/s.

Electromagnetic and corpuscular flare radiation. During a flare radiation in almost all spectrum ranges is raised. In a visible sphere this increasing is relatively not large – not more then 1.5–2 times during the most powerful flares observed even in a white light on the background of bright photosphere.

But in distant ultraviolet and X-ray spectrum regions and especially in a radio-region on meter waves this increasing is very substantial. Sometimes one can observe gamma ray bursts.

About a half of common flare energy is removed by powerful emissions of plasma which comes through a solar corona and reaches the orbit of the Earth as corpuscular fluxes interacting with the Earth's magnetosphere, and it leads to auroras and magnetic storms.



Flash on Sun May 2, 2006

Proton flares. Powerful flares attended by high-energy charged particles – protons with tens and hundreds mega electron-volt energies are called proton ones. They are accompanied by electron fluxes with more than 40 kilo electron-volt energies, and sometimes even relativistic electron fluxes with more than ten mega electron-volt energies.

Particle energy fluxes from proton flares are dangerous for cosmonauts` life and health in the space. They can arouse failures and degradation of on-board computers and other devices. One can see powerful flares even in a white light on the background of bright photosphere but it is very rare.

Flare index

CLASS	Average duration (min)	Square in solar hemisphere fractions	New classification (Square in 1/1mln solar hemisphere square fractions)
1–(S)	Subflare	$< 10^{-4}$	< 100
1 (1)	20	$(1\text{-}3)\cdot 10^{-4}$	100 – 250
2 (2)	33	$(3\text{-}8)\cdot 10^{-4}$	250 – 600
3 (3)	62	$(8\text{-}15)\cdot 10^{-4}$	600 – 1200
3+ (4)	–	$>15\cdot 10^{-4}$	> 1200

It is clear that an absolute energy particle flux and a SCR energetic spectrum range are connected with flare power. It was discovered that particles of relatively low energies are registered before a SCR flare at the average during 24 hours. Later this phenomenon began to be called preflare increasing.

It is possible to use observation of low-energy preflare increasing to raise reliability of radiation environment forecasting in the interplanetary space. The first works in this direction gave essential improvement of the forecast; probability of exact forecasting has become 85 – 90 % higher.

Finding out low-energy particle preflare increasing phenomenon has confirmed many researchers` opinion that one can observe processes of particle acceleration in the Sun's atmosphere continuously. Only power of an active process is changed. That is why the terms calm or active Sun are relative and do not reflect the real life of the Sun.

Instrumental observations in cosmic condition have permitted to understand what solar activity and what solar cosmic rays are.

Solar cosmic rays are a flux of high-energy charged particles accelerated in the upper solar atmosphere which appear during solar flares. They are registered on the Earth's surface as sudden and sharp increase of cosmic ray density on the background of more high-energy galactic cosmic rays.

A conditionally accepted lower limit of solar cosmic ray energy is $10^5 – 10^6$ eV. If energies are lower a particle flux possesses qualities of plasma which cannot neglect electromagnetic interaction of particles with each other and an interplanetary magnetic field.

Energy and charge distribution of solar cosmic rays on the Earth is determined by a particle acceleration mechanism in the source (a solar flare), peculiarities of particle yield from the acceleration area and the conditions of their spreading in the interplanetary space. Particle acceleration is tightly connected with solar flare origin and a development mechanism.

Leaving acceleration area solar cosmic ray particles walk about in the interplanetary magnetic field for many hours scattering on its non-uniformities and step-by-step go away to the periphery of the solar system.

A part of them penetrate into the Earth's atmosphere arousing additional ionization of atmospheric gases (mostly in the sphere of polar caps).

If it was possible to register and study particles with energy of hundreds of thousands of electron-volt and higher basing on observations from the Earth's surface it has become possible to register particles of low energies from the Sun up to units and tens of thousands of electron-volt with scientific equipment brought to the interplanetary space by spacecrafts and satellites.

Fluxes of such particles from the Sun were registered much more often than high-energy particle fluxes.

2.2. Modern conceptions about the solar corona structure

A solar corona is a key to understand processes occurring on the Sun from one side and an important precursor and indicator of future events in the heliosphere, from the other.

Experimental corona research methods are observation of separate corona line radiation or parts of its radiation spectrum.

For the first time such observations took place on the 20th of May, 1947, in Brazil with a help of equipment fixed on board of the Griboedov ship (observations were held on 1.5 meter wave with a help of a synphased antenna fixed on ship board). Vitaly L. Ginsburg, a future Nobel prize-winner, and other astronomers and physicists such as I.S. Shklovsky (State Astronomical Institute after P. Sternberg – SAIS), Y.L. Alpert (IZMIRAN) took part in the expedition.

After the Second World War (1941-1945) academician N.D. Papalexi asked V.L. Ginsburg to estimate conditions of reflection of meter and decimeter range radio waves from the Sun. This problem appeared in connection with N.D. Papalexi`s ideas about the possibility to locate not only the Moon and planets, but the Sun.

A group of participants of the Soviet expedition ship "Griboyedov. The first right in the 1st row – S. Khaikin, 4th – G. Ushakov, 4th from left in the second row Vitaly Ginzburg, 9th – B. Chihachev, 2nd right in the 3rd row – I. Shklovsky

But as that time V.L. Ginsburg had a developed theory of radio wave transmission in plasma he came quickly to an uncommon conclusion that radio waves would be absorbed in the corona and chromosphere.

An interesting conclusion followed that the resource of solar radio-frequency radiation is not the photosphere, like in the optics, but the upper chromosphere and a solar corona the temperature of which is about a million degrees C for longer waves of a meter range.

In a result V.L. Ginsburg wrote two radio astronomical reviews in the magazine Success in Physical Science (in 1947 and 1948). In these works he discussed a question about radio-wave diffraction on the lunar limb as well which permits to increase angular discrimination of details on the Sun during the solar eclipse.

Moreover, it gave a stimulus to work out a theory of synchrotron cosmic radio-frequency radiation and its connection with a cosmic ray origin problem and high-energy astrophysics.

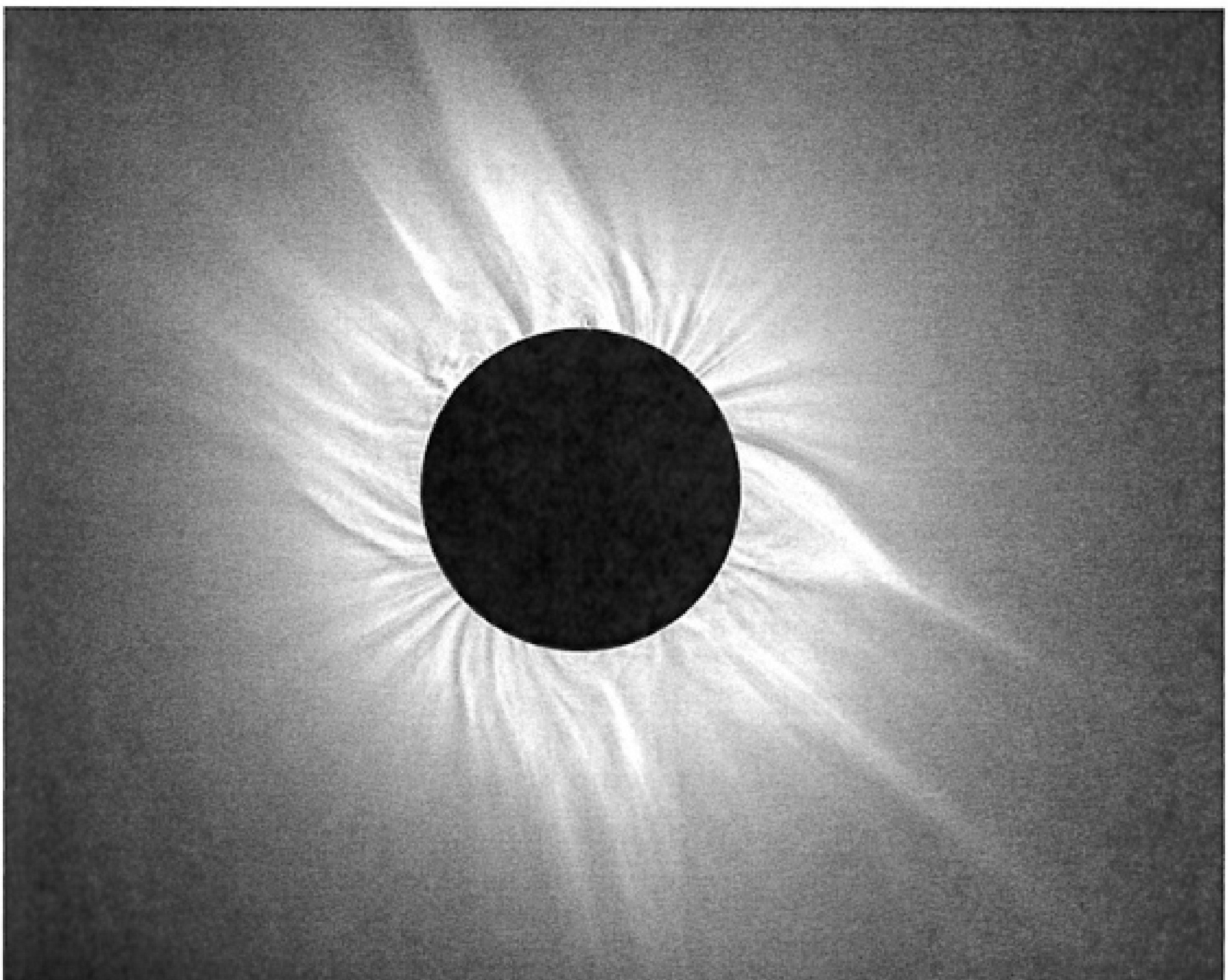
(By the way, on V.L. Ginsburg's opinion, startup of link between radio astronomy and cosmic rays led to formation of a new direction in astronomy – cosmic ray astrophysics and high-energy astrophysics or gamma- and X-ray astronomy).

The basic method of research of a corona fine structure and corona dynamics are observations of so called white corona which make it possible to research coronal processes.

Processes in the corona are conditionally called quasi-stationary ones (for the time > 24 hours) and sporadic ones (for the time < 24 hours). In the absence of sporadic processes (or if they are weak) the corona is quasi-stationary.

Research of a quasi-stationary corona in a white light «is first of all studying the brightest constituent part of it – a belt of corona streamers» [Eselevich, 2002].

A cross section of streamers on corona representations is regarded as a highlight of the helmet turning into a pencil beam as it goes away from the Sun.



Solar Corona

All preceding research of this theme can be divided into two large periods – before launching the spacecraft SOHO (Solar and Heliospheric Observatory) with an instrument LASCO (Large Angle Spectrometric Coronagraph) on board in the end of 1995 and after launching it up to nowadays. LASCO is three parallel coronagraphs with concentric and overlapping fields of view.

When observed in a white light streamers in the corona are regarded as ray-like structures of highlight reflecting distribution peculiarities of the magnetic field forming them.

Because of its global characteristics the unity of them in the space forms a streamer belt several degrees thick covering the Sun (surface) inside of which a slow solar wind is flowing with a high density of plasma which is several times higher than surrounding plasma density.

A streamer belt in the corona divides regions with opposite polarity of the Sun's radial magnetic field (or magnetic tubes of open field lines with opposite polarity coming from neighbor coronal holes).

It means that a neutral line of a radial magnetic field goes along the belt, the position of which comes from estimation of the magnetic field in the corona in potential approximation.

2.3. Physical basis of disturbance forecasting

2.3.1. Solar wind

Because of a solar wind the Sun looses about one million tons of substance every second. In general a solar wind consists of electrons, protons and helium cores (alpha-particles), cores of other elements and non-ionized particles (electrically neutral) contain in a very small quantity.

Although the solar wind comes from an outer layer of the sun it does not reflect real element composition in this layer, as in the result of differentiation processes contents of some elements is increased, and some is decreased (FIP-effect).

Intensity of the solar wind depends on solar activity fluctuations and its sources. Depending on velocity solar wind fluxes are divided into two classes – slow (about 300 – 400 km/s about the Earth orbit) and fast (about 600 – 700 km/s about the Earth orbit). There are also sporadic high-speed (up to 1200 km/s) short-time fluxes.

A slow solar wind is born by a calm part of a solar corona in its gas-dynamic expansion – when the temperature is about $2 \cdot 10^6$ K, the corona cannot be in hydrostatic balance conditions and this expansion should lead to coronal substance acceleration up to supersonic speed in boundary conditions.

Warming of a solar corona up to such temperature is the result of convective nature of heat transport in the photosphere of the Sun – development of convective turbulence in plasma is attended by intensive magneto sonic wave generation, in their turn sonic waves are transformed to shock ones when distributing to a direction of decreasing density of solar atmosphere, shock waves are absorbed effectively by corona substance and warm it to the temperature $1-3 \cdot 10^6$ K.

Parameters of solar wind

Parameter	Average	Slow solar wind	Rapid solar wind
Density n, sm^{-3}	8,7	11,9	3,9
Velocity V, km/s	468	327	702
nV, $sm^{-2} \cdot s^{-1}$	$3{,}8 \cdot 10^8$	$3{,}9 \cdot 10^8$	$2{,}7 \cdot 10^8$
The proton temperature T_p, K	$7 \cdot 10^4$	$3{,}4 \cdot 10^4$	$2{,}3 \cdot 10^5$
The electron temperature T_e, K	$1{,}4 \cdot 10^5$	$1{,}3 \cdot 10^5$	$1{,}0 \cdot 10^5$
T_e / T_p	1,9	4,4	0,45

Fluxes of a recurrent fast solar wind are emitted by the Sun during several months and have a frequency period of 27 days if to observe from the Earth (the Sun rotation period).

These fluxes are associated with coronal holes - corona areas with relatively low temperature (about 0,8 × 106 K), low plasma density (one forth density of corona calm spheres) and radial magnetic field relative to the Sun.

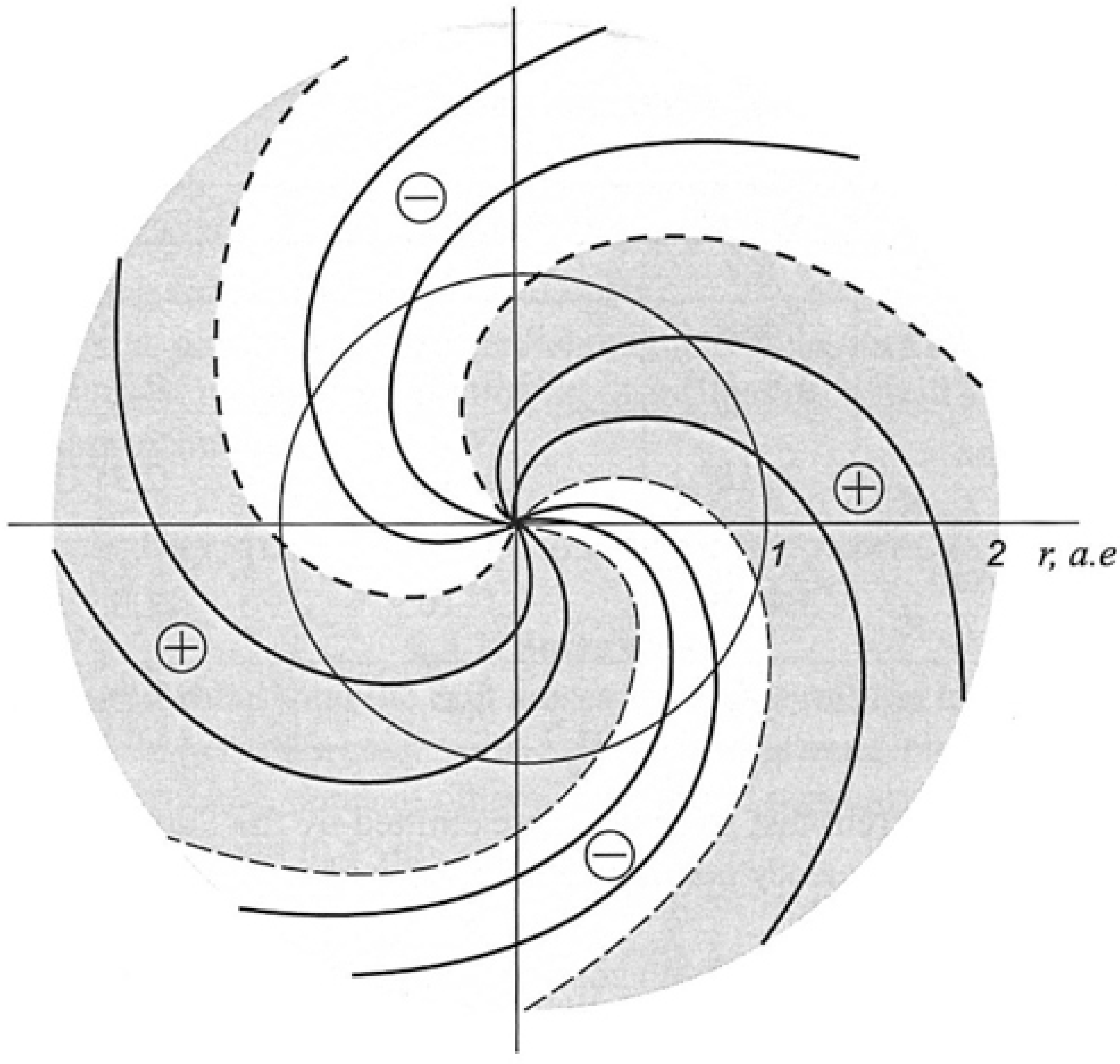
Moving in space full of plasma of a slow solar wind sporadic fluxes compact plasma before its front forming a shock wave moving together with it.

It was suggested earlier that such fluxes were aroused by solar flares, but nowadays (2005) it is regarded that sporadic high-speed fluxes in the solar wind are conditioned by coronal emissions. It is also necessary to note that solar flares and coronal emissions are connected with the same active areas on the Sun and there is statistic dependence between them.

The solar wind forms heliosphere, and due to that it prevents an interstellar gas penetrating into the solar system. The solar wind gives birth to such phenomena as auroras and planet radiation belts on the planets of the solar system possessing the magnetic field.

The solar wind stream non-uniformity (far from planets) gives birth to the interplanetary magnetic field.

A Scheme Picture of Magnetic Force Lines in a Solar Wind Representing a Possible Four-Sector Structure.



Schematic picture of magnetic field lines in the solar wind, showing a possible structure of a four-sectors

2.3.2. Disturbance forecasting in a circumterrestrial environment

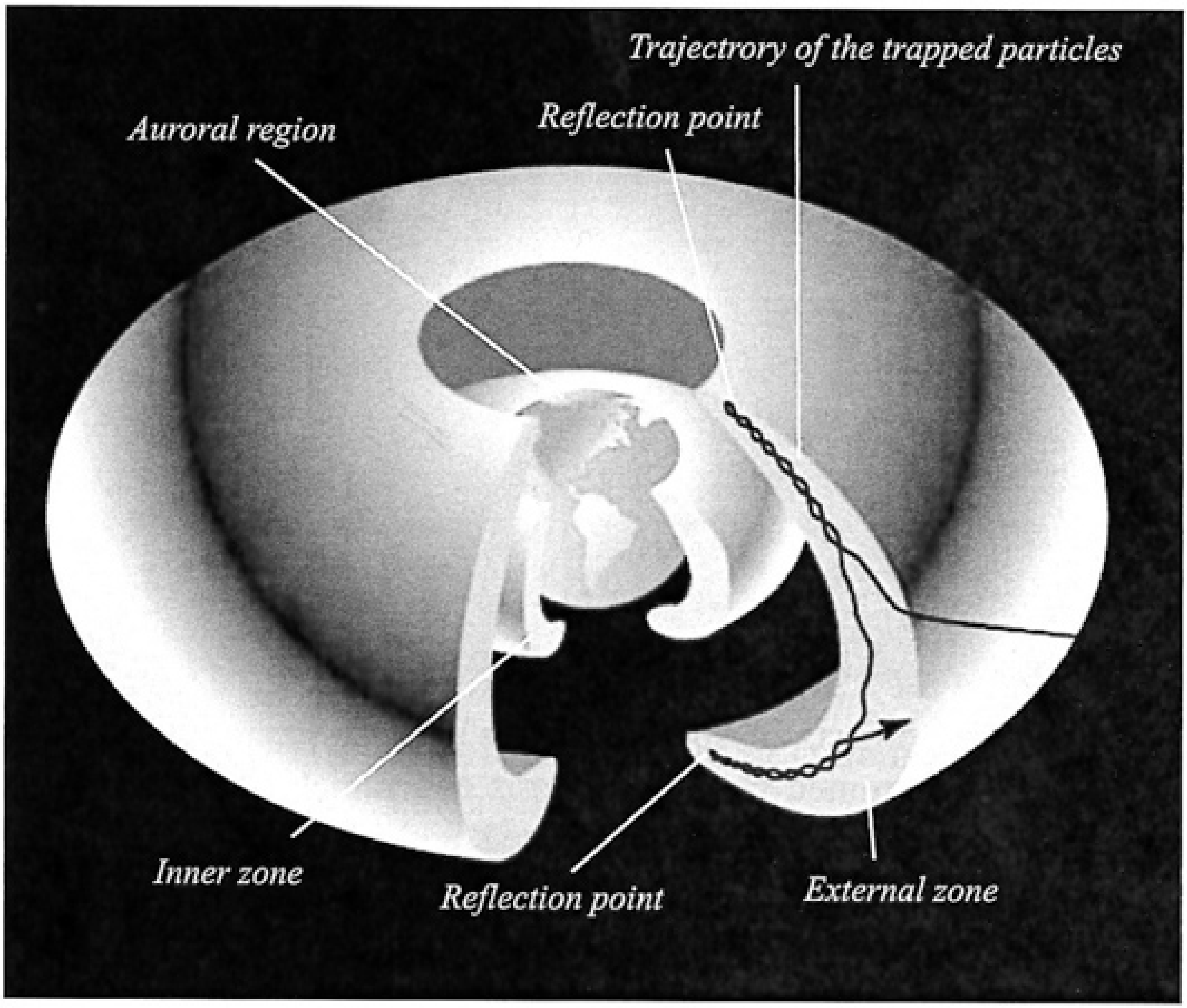
The main types of energetic fluxes (particles and radiation) from the Sun the influence of which leads to some disturbance in a circumterrestrial environment (magnetosphere, ionosphere and atmosphere of the Earth) are:

a. fluxes of comparatively dense ($n \approx 1 - 70$ sm^{-3} on the Earth orbit) quasi-neutral and low-energy ($E < 10$ kiloelectronvolt) solar wind plasma which arouse magnetospheric and ionospheric storms lasting 24 hours and more;

b. fluxes of energetic ($E \approx 10 - 100$ Megaelectronvolt) flare protons of a low density ($n \approx 10^{-10} - 10^{-7}$ sm^{-3}) lasting several hours and arousing a phenomenon called Polar Cap Absorption (PCA);

c. outbursts of ultraviolet radiation fluxes from solar flares which arouse concentration change in different spheres of the ionosphere, characteristic time is about 1 hour;

d. outbursts of soft and hard X-ray radiation fluxes from flares which arouse sudden ionospheric disturbance in *D*-area of the ionosphere, characteristic time is several minutes.



Van Allen Belts

(A) – fluxes arouse an inconsiderable rebuilding of the magnetosphere and ionosphere. That is why basic attention is paid to their study. It has been established by today that (*a*) – fluxes can be divided into two big classes – quasi-stationary solar wind (SW) fluxes, life time of their resources is more than 24 hours, and SW sporadic fluxes, life time of their resources is less than 24 hours.

In its turn the quasi-stationary solar wind is divided into two types – fast SW which flows from the area of coronal holes and reaches the Earth on the orbit $V \approx 400 - 800$ km/sec. and a slow SW which flows in the streamer belt or streamer chains $V \approx 250 - 400$ km/sec.

Knowledge about researches of SW fluxes and their characteristics on the Sun permits to estimate meaning forecast SW parameters at the distance 1 a.u. and geomagnetic activity indexes connected with them subject to time.

In its turn, knowledge of $K_p(t)$ и $A_p(t)$ gives a possibility to define positions of the most important spatial structures using the models of disturbed magnetosphere and ionosphere – plasma sheet boundary, plasma sphere boundary, place and time of substorm beginning and position of the main ionospheric trough.

2.4. Precursors of cosmic storms

In 1896 Olaf Birkelund, a Norwegian physicist, supposed that besides light the Sun also emits corpuscular radiation, and its speed is almost one thousand times less than a light speed.

On reaching the Earth this radiation arouses magnetic storms and auroras. Birkelund supposed also that auroras can be created by electrical charged particles (corpuscular rays) which are released from the Sun and taken in by the Earth magnetic field near poles.

Cosmic rays in the Earth's atmosphere [Y.I. Stozhkov]. Cosmic rays (CR) is one of important objects of space weather because namely CR of galactic and solar origin determined radiation storms and radiation hazard for people and technology, computer and memory upsets and failures, solar cell damage, radio wave propagation disturbances, failures in communication and navigation systems. Beside this CR can be used as effective instrument for space weather monitoring and forecasting dangerous phenomena. In Figure (see below) are shown space weather effects on satellites, communication, navigation systems and others.

The main resource of CR inside galaxy is explosions of supernova stars. Cosmic rays are accelerated on shock waves which are formed in these explosions.

Maximal energy which particles can possess in such processes is $E_{\text{max}} \approx 10^{16}$ eV. Cosmic rays of higher energies are formed in methagalaxy.

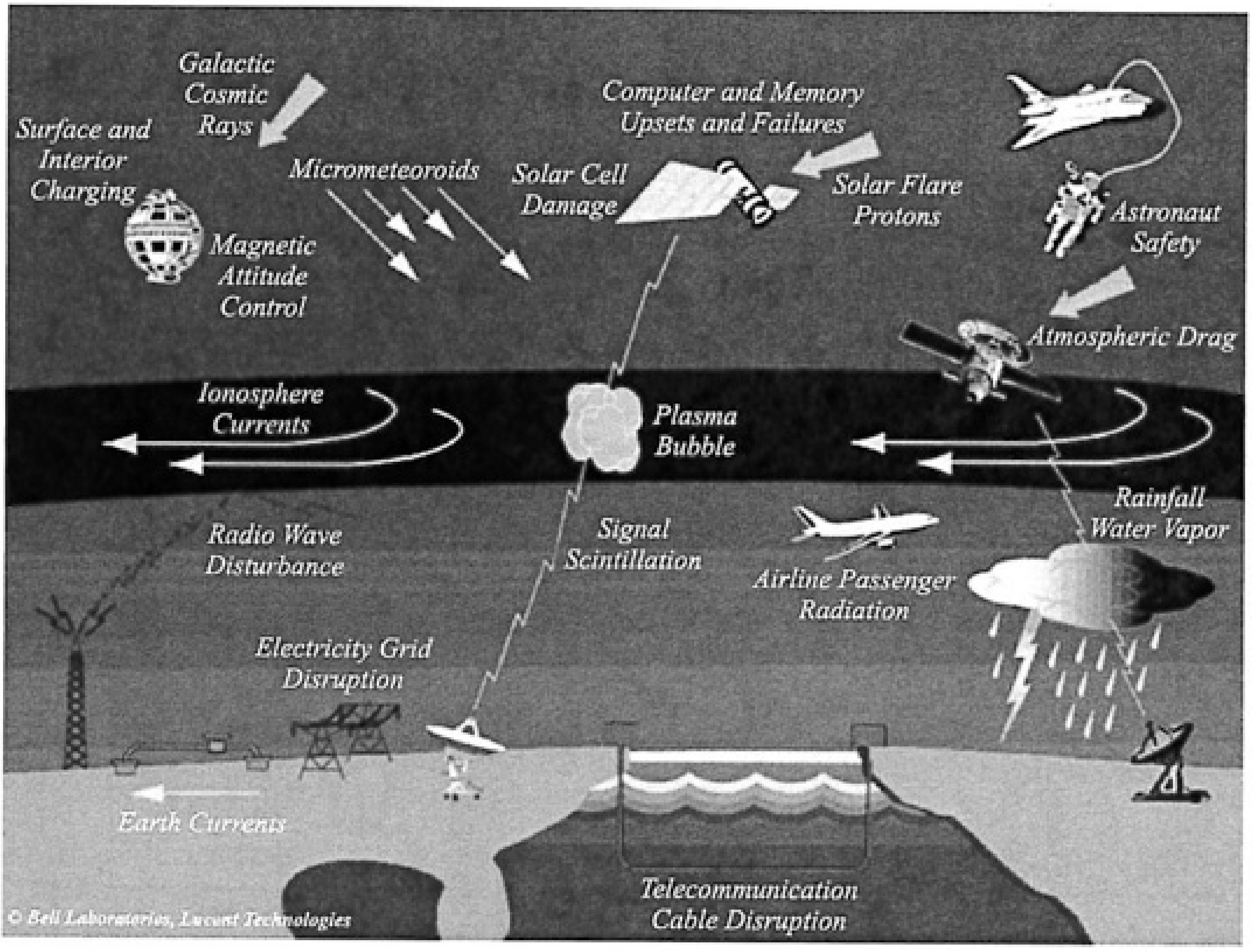
According to their origin CR can be divided into several groups

– CR of galactic origin (GCR)

– CR of methagalactic origin (with energies from $E > 10^{16}$ eV to $E \approx 10^{21}$ eV)

– Solar CR (SCR) generated on the Sun during solar flares.

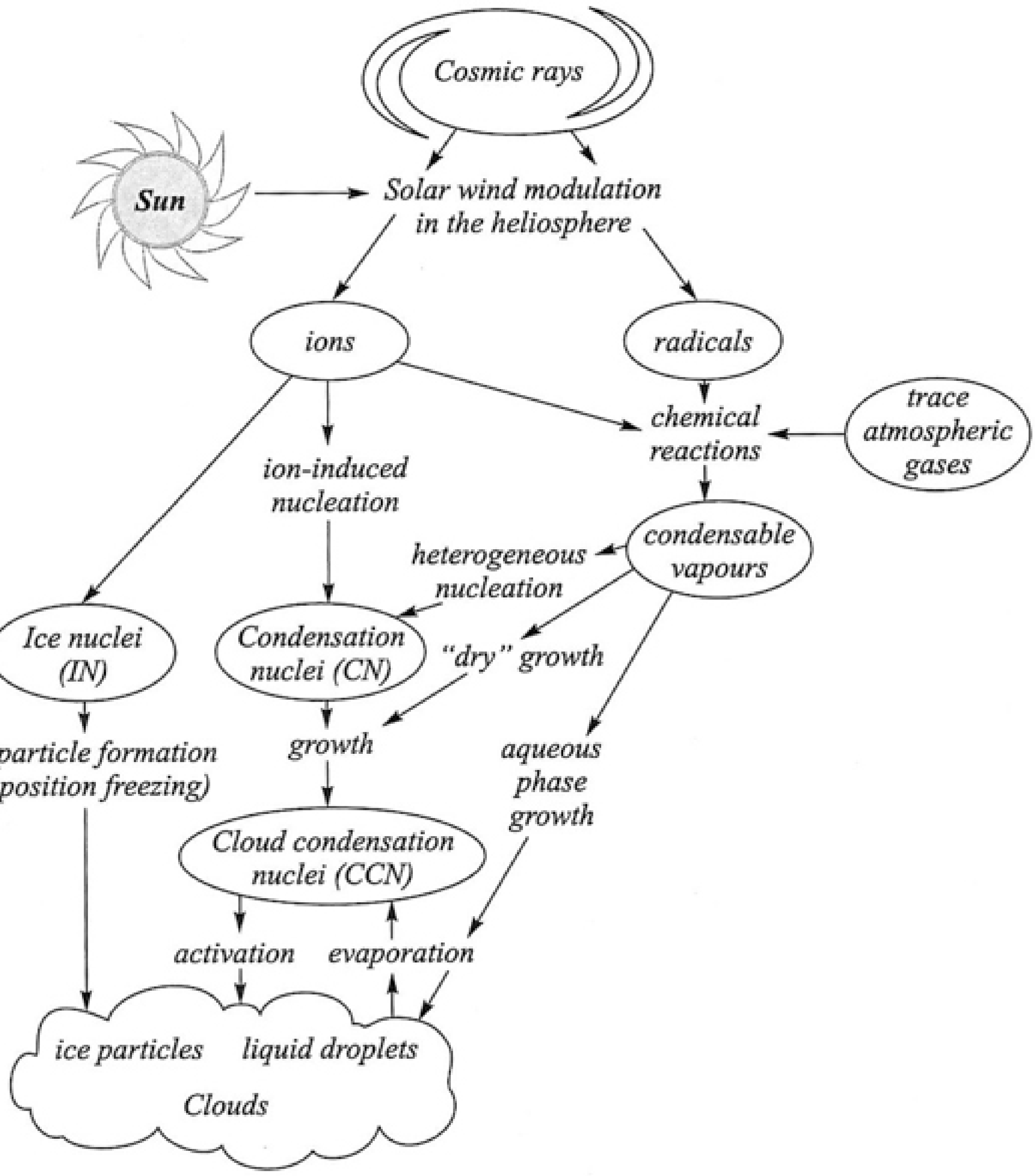
Constant observation of CR was organized to study peculiarities of their long-time behavior.



Space weather effects (from Bell Laboratories web-site in Internet) [Dorman, 2009]

By the beginning of the International Geophysical year (1957) a network of CR stations had been formed in the World. In our country academician S.N. Vernov organized continuous terrestrial observations of CR. Under his direction in the middle of fifties in the USSR unique observations of CR in the Earth's atmosphere began.

Long-time measuring CR fluxes led to discovery of the whole row of new phenomena. First of all, in CR one can observe 11-year cycle conditioned by 11-year cycle of solar activity.



Possible paths of solar modulated CR influence on different processes in the atmosphere leading to the formation of clouds and their influence on climate. [Dorman, 2009]

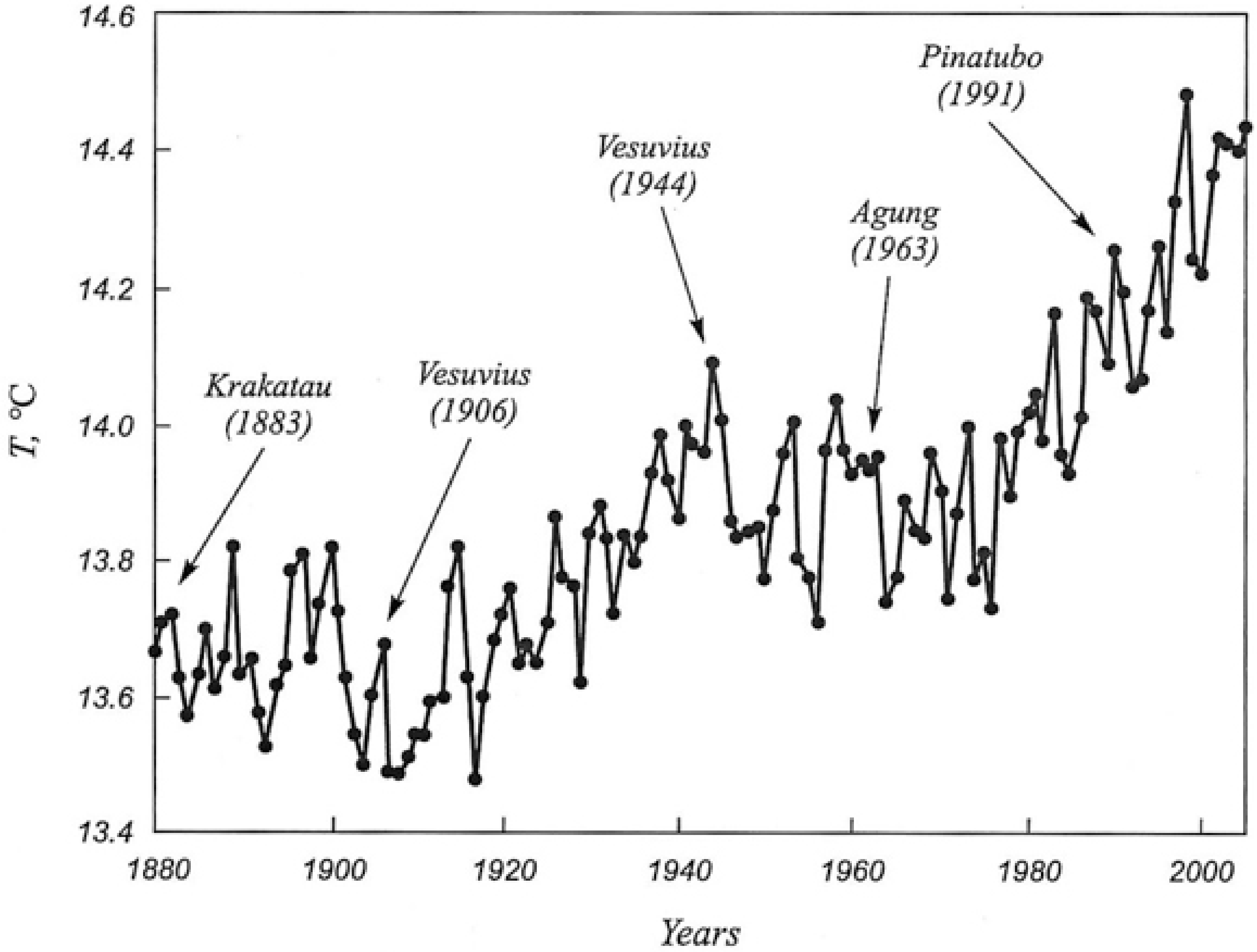
When the Sun is calm and solar activity is minimal a CR flux in the heliosphere and on the Earth orbit reaches maximal values. If the Sun is active a CR flux is minimal.

In CR one can observe sporadic changes of their intensity called Forbush decrease the meaning of which consists in the following. Suddenly during several hours or less a CR flux in the Earth's atmosphere or on satellites registered by terrestrial stations begins to decrease sharply.

In some cases amplitude of this decreasing is 10 per cent. Such events happen after powerful explosions on the Sun.

As solar flares occur more often during the years of high solar activity Forbush decrease is also often observed during the years of active Sun.

CR looses the majority of energy (more than 95 per cent) in the Earth's atmosphere. Although this energy is not large and much less then solar energy falling on our Earth a role of CR is the main in many processes observed in the Earth's atmosphere.



Yearly average values of the global air temperature, *t*, near the Earth's surface for the period from 1880 to 2005. Arrows show the dates of the volcano eruptions with the dust emission to the stratosphere and short times cooling after eruptions. [Dorman, 2009]

Cosmic rays discovery history. In 1912 Victor Franz Hess, another famous physician from Austria , made a flight by a balloon with equipment for cosmic rays registration to study cosmic rays nature and he proved by visual demonstration that a cosmic radiation flux is increased together with height of the balloon.

Next proof of solar corpuscular radiation appeared when studying one more phenomenon – magnetic storms which, as it was discovered, are connected with the Earth magnetic field fluctuations. As they usually appear two days after a solar flare the explanation of English physician Sidney Chapman about solar corpuscular radiation has become reasonable.

Finally, in the forties an American researcher Scott Forbush discovered that intensity of cosmic radiation reaching the Earth in the period of high solar activity was low and was decreased sharply during magnetic storms.

So, in other words, the higher solar activity was, the less cosmic radiation particles reached the Earth surface. «It seems that something in solar radiation must hinder penetrating of cosmic rays into the solar system, and this hindrance is increased when the Sun becomes very active», Forbush wrote.

E. Parker, an American astrophysicist, suggested to call this radiation (which hinders cosmic rays to reach the Earth) a solar wind. The solar wind blows constantly in the solar system. Appearing on the Sun it flies past the Earth at speed 300 – 500 km/sec. and determines the weather in cosmic space near the Earth.

Victor Franz Hess after a flight on August 7, 1912 [Dorman, 1985]

Parker wrote, «A powerful hydrogen wind is constantly blowing in the solar system. Appearing on the Sun it flies past the Earth at speed 400 km/sec, reaches remote planets and goes away into an interstellar space. Like a broom it sweeps out gases flowing from planets and comets, small particles of meteoritic dust and even cosmic rays. This wind is responsible for outer regions of the Earth radiation belts, for auroras in the Earth's atmosphere and for geomagnetic storms. It can even participate in formation of a general weather picture on the Earth».

The solar wind is the main reason of such events as geomagnetic storms and their influence on life of the Humanity and the World economy. In this connection systematic observation of a solar wind is necessary for understanding regularities of geo- and astrophysics and estimating perspectives of human activity in the nearest future as well.

One of the agents of the solar wind which feels its inspirer's state is cosmic rays – research of turbulence in the solar wind in connection with shock wave transmission there is one of the central problems of modern astrophysics. Shock wave transmission in turbulent cosmic medium conditions many physical processes, for example, acceleration of cosmic rays.

The most convenient object to study the solar wind is an interplanetary medium accessible today to modern experimental methods.

CR fluctuations are precursors of cosmic disturbances. A wide-spread method of study the turbulence of an interplanetary medium is studying fluctuations – short-period changes of an interplanetary magnetic field and fluctuations of cosmic rays connected with them and appearing on account of cosmic ray charged particle scattering on random non-uniformities of an interplanetary magnetic field.

The first fluctuations were discovered in the end of sixties of the last century by Danjy and Sarabay with a help of gigantic (that time) 60 square meter plant on stations Chacaltaya in Bolivia.

For the last years there are such plants in almost all cosmic laboratories on the Earth.

And although research fluctuations in the cosmic rays takes its place today among basic instruments of modern cosmophysics the fact of fluctuation existence as an effect of displaying influence of an interplanetary medium on cosmic rays is in some cases disputable.

What is more in such cases – defects of mathematical methods of revealing fluctuations, equipment shortcomings or researchers` bad luck – is difficult to say, but even negative results in some cases have permitted to make conclusions about fluctuation nature.

So, absence of meaningful fluctuations during observations on the equator and their simultaneous presence during observations in high latitudes are persuasive evidence that the Earth magnetic field changes can not be a resource of fluctuations under study, because such changes on the equator are minimal.

It is necessary to note that fluctuation revealing is a very delicate, difficult and hard thing.

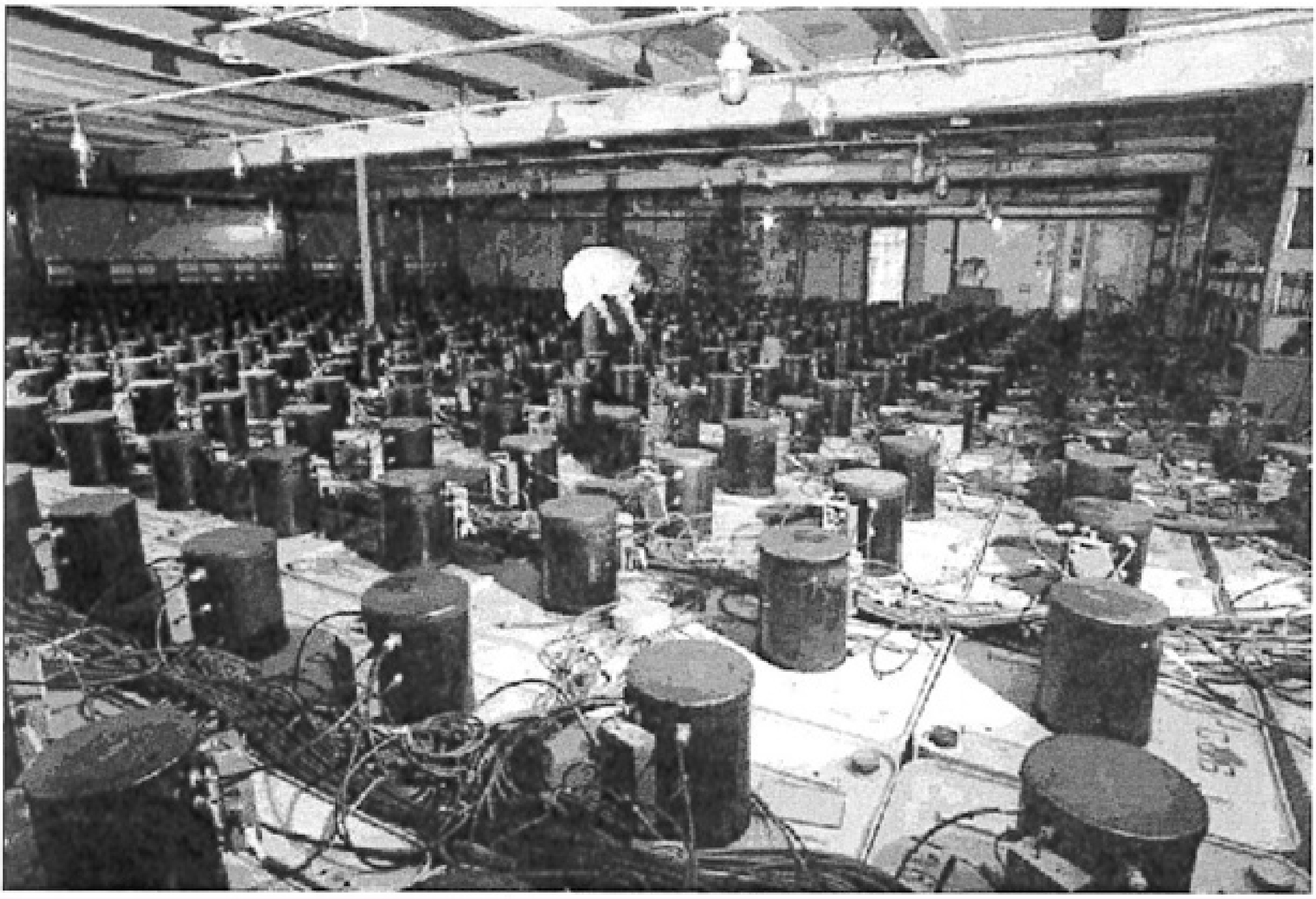
Methods of research of spatial-temporal flux changes, cosmic rays spectrum and composition which have existed till today have met serious difficulties while studying fluctuation, because to reveal these fluctuations, clear up nature of them one had to operate nonstationary processes with constantly changing amplitude, phase, frequency, from one side, and to study a lot of correlation connections between fluctuations themselves and with heliophysical and geophysical processes, from the other side.

Usual correlation spectral methods appeared to be uninformative because data array were used little. Scientists had to use special spectral methods based on autoregressive analysis.

Advantages of the autoregressive spectral analysis consists in controlling comparison of different notes, as functions of the same parameter – frequency – are compared, and no serious limitations are imposed on this process. Applying autoregressive spectral analysis has permitted to estimate not only presence of fluctuations with different periods in observing data but verification of them as well.

Studying fluctuation behavior dynamics, their origin and development in complex with different heliophysical processes has permitted to reveal some curious regularities – sharp increase in fluctuation amplitude is connected with solar flares, shock waves in the interplanetary medium near the Earth, and such increase is observed on the Earth minimum 10 – 12 hours before beginning of the Earth disturbance, and it is weakened 12 – 20 hours after maximal disturbance. So, fluctuation increase is some indicator of expected disturbance on the Earth.

The effect of fluctuation advance of expected disturbance can be easily explained – disturbance transmission velocity in the interplanetary medium is 300 – 500 km/sec, and cosmic ray charged particles velocity is a bit less than a light velocity, in this case the distance L at which cosmic rays feels approaching disturbance is $L = R / 300 B$, where B is intensity of the interplanetary magnetic field, R – particle rigidity, L – sensitivity distance or Larmor particle radius.



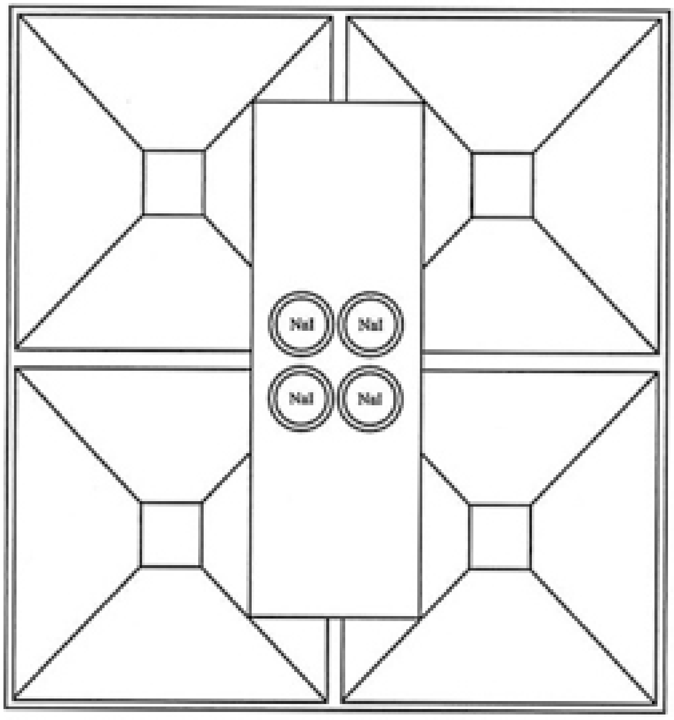
Scintillation telescope FIAN, Baksan [Berkova, 2010]

Consequently, it is very easy to take into consideration difference in time when cosmic rays having felt disturbances (and their fluctuations) and disturbances themselves reach the Earth. As this distance is determined only by particle energy (field density for each concrete case is constant) it is possible to probe a cosmic space at different distances from the Earth registering fluctuations of cosmic particles of different energies on the Earth.

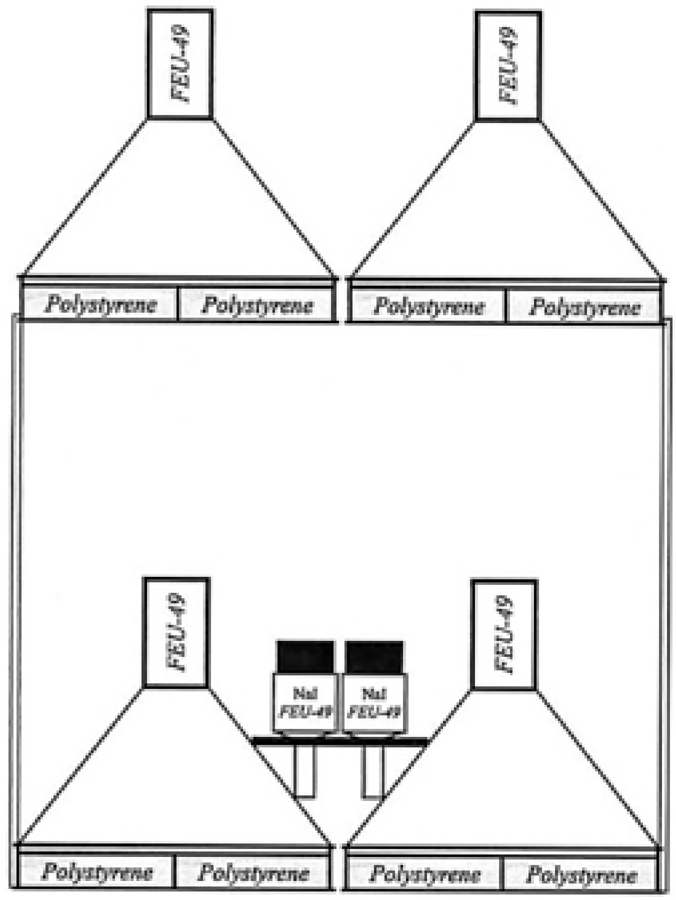
In a result of many experiments and calculations methods of shock wave short-period forecasting and diagnostics with a help of observing terrestrial fluctuations of cosmic rays with periods from 12 – 15 to 420 min. which feel effectively a shock wave approaching to the Earth were worked out.

As it is said above, the effect of cosmic rays advance of magnetic field disturbance can be easily explained – cosmic rays feel nonuniformities at the distance of transfer range particle scattering which neutron supermonitors and scintillation telescopes register on the Earth surface.

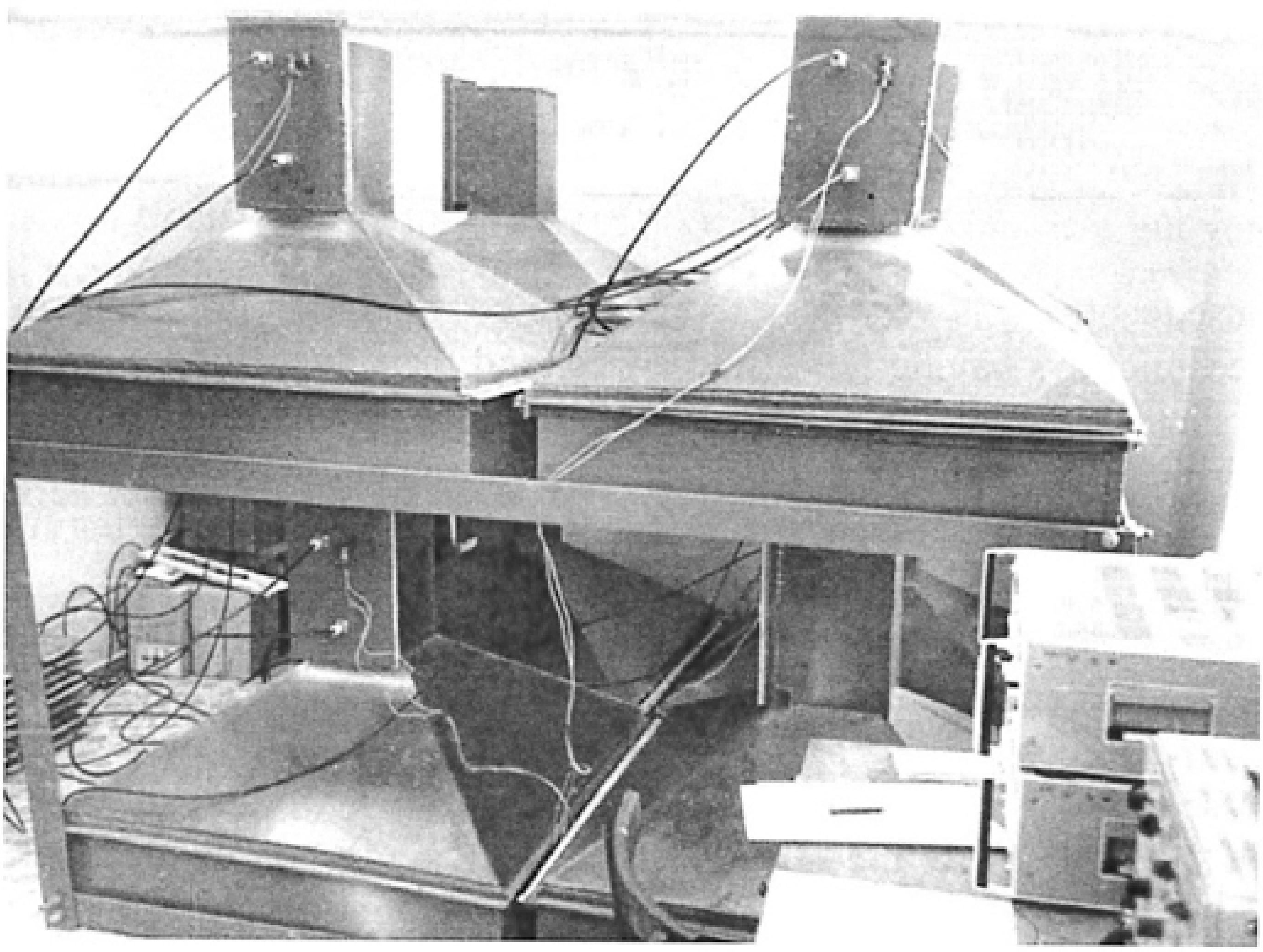
Top view of the installation SSTIS



Side view of the installation SSTIS



Scintillation telescope IZMIRAN



One of the sections supertelescopes IZMIRAN

But it is necessary to take it into consideration that cosmic ray velocity is almost one thousand times higher than velocity of disturbance moving to the Earth, it means that cosmic rays will bring the information about approaching disturbance in a flash, but disturbance will travel to the Earth for several long hours.

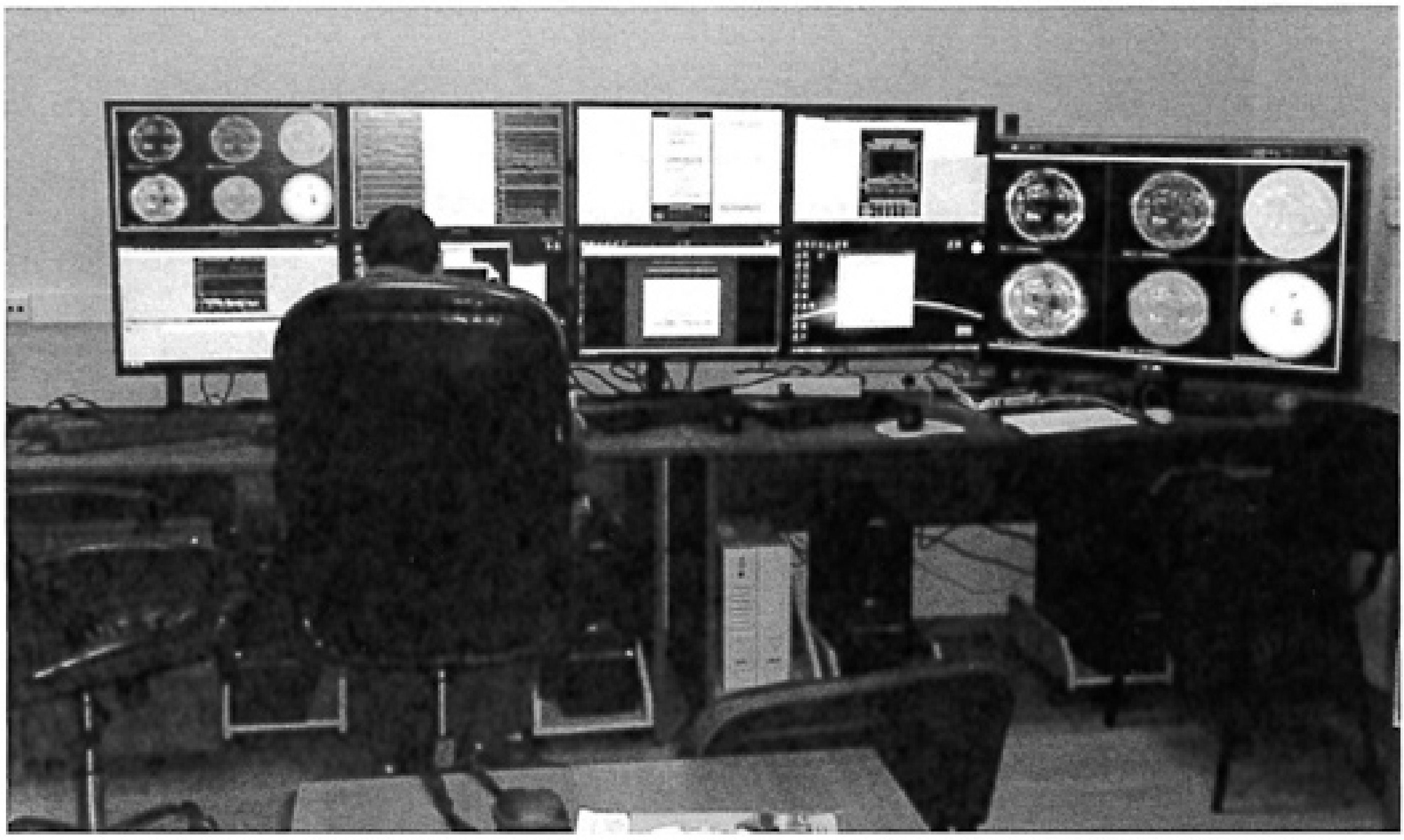
As energies of cosmic rays registered on the Earth are in a wide range, distances at which cosmic rays will feel disturbances approaching to the Earth can be essentially different – registering particles of different energies one can find out nonuniformities up to several a.u.

It is necessary to note that possibilities to study fluctuations are not limited by that – researching power spectrum of cosmic ray fluctuation has shown connection with a level of storminess of the interplanetary medium of not only fluctuations of different frequencies but the whole spectrum – inclination of cosmic ray fluctuation spectrum increases step by step to maximal value several hours before approaching of interplanetary medium disturbance to the Earth, stays minimal during disturbance and decreases after it passes by the Earth.

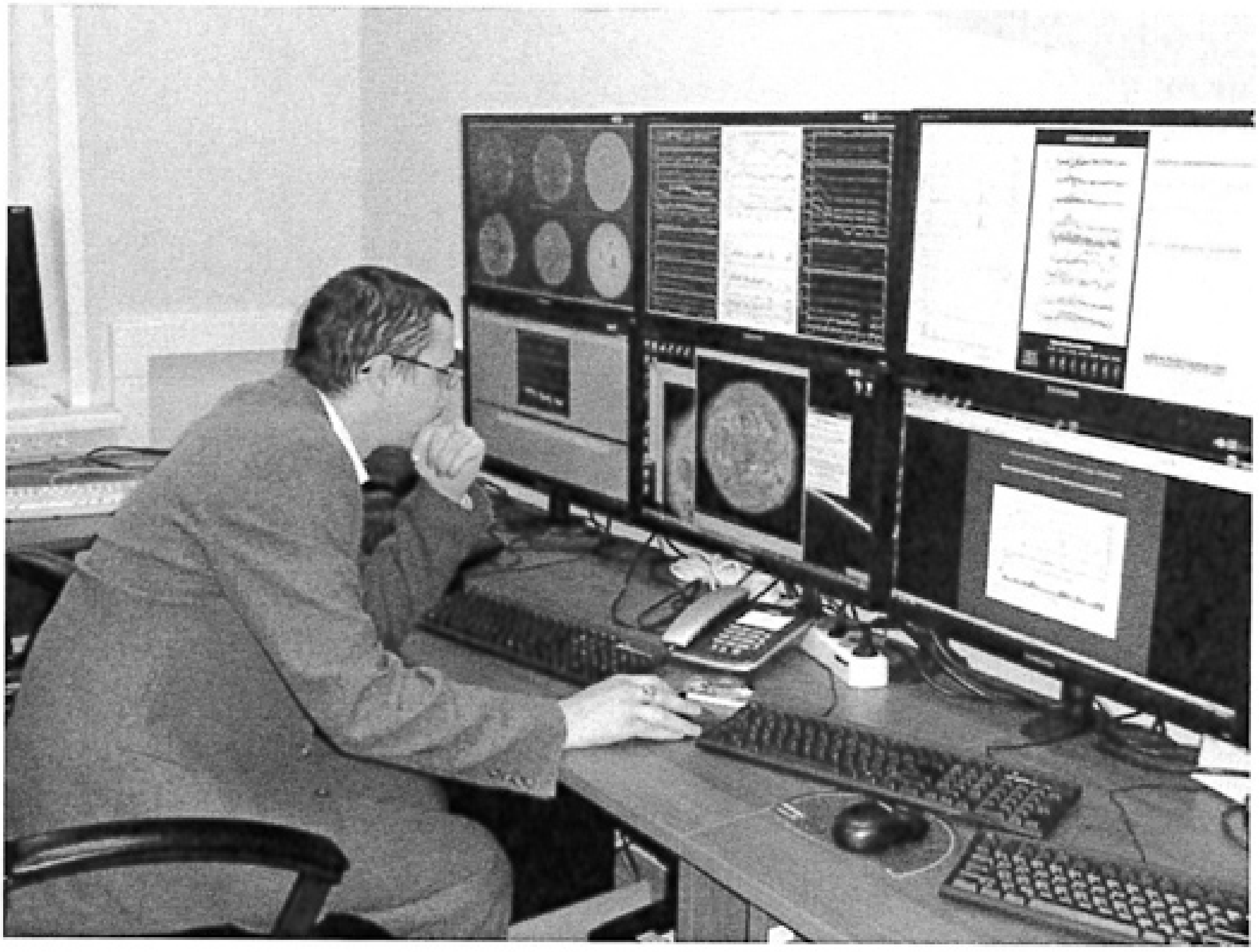
IZMIRAN

The authors discovered the fact of spectrum power increase on different frequencies when interplanetary magnetic field spectrum boundary pass by the Earth, or it seems that a high-speed flux boundary also should be noticed during observing cosmic rays fluctuations.

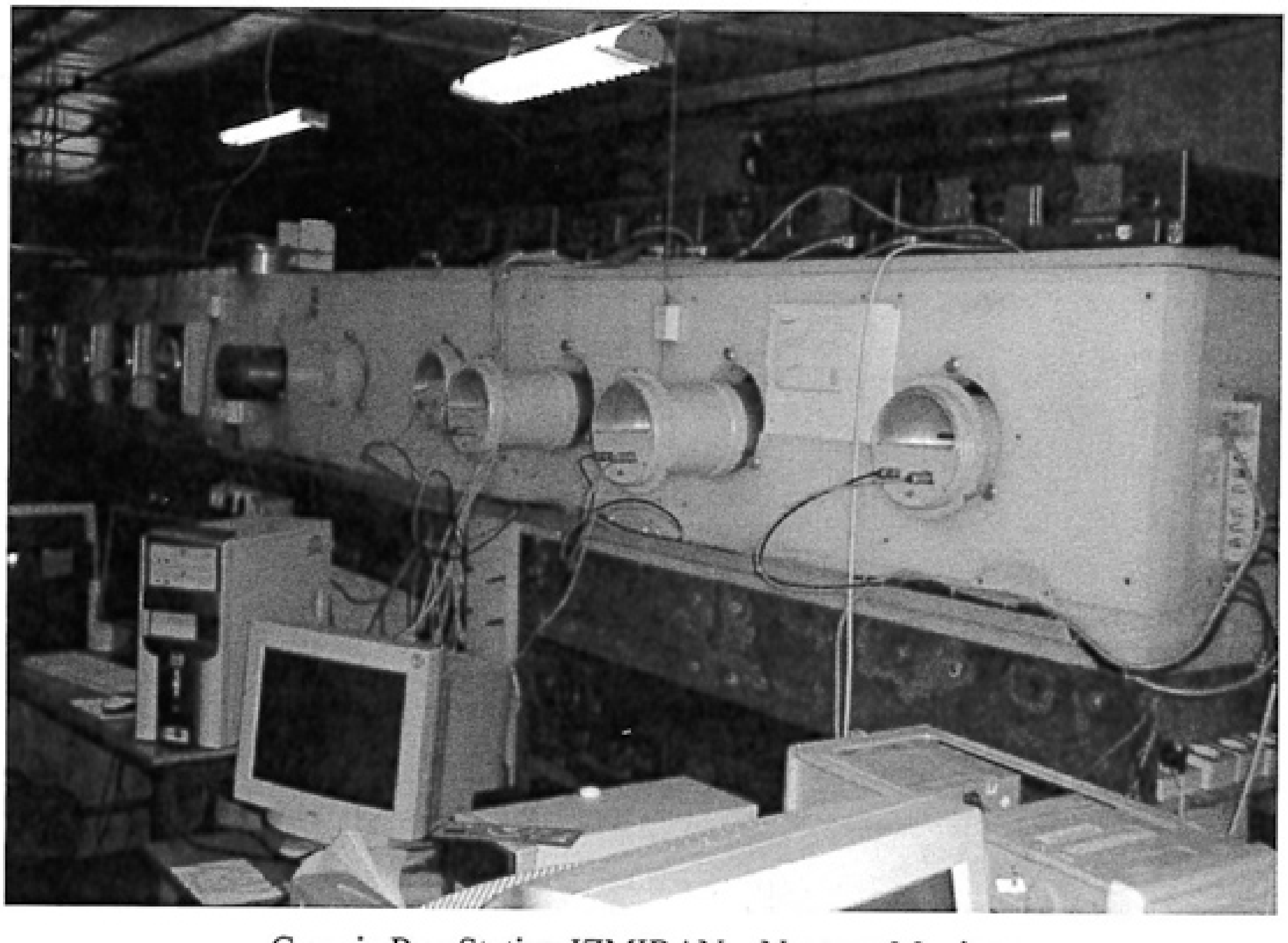
Cosmic Ray Station IZMIRAN



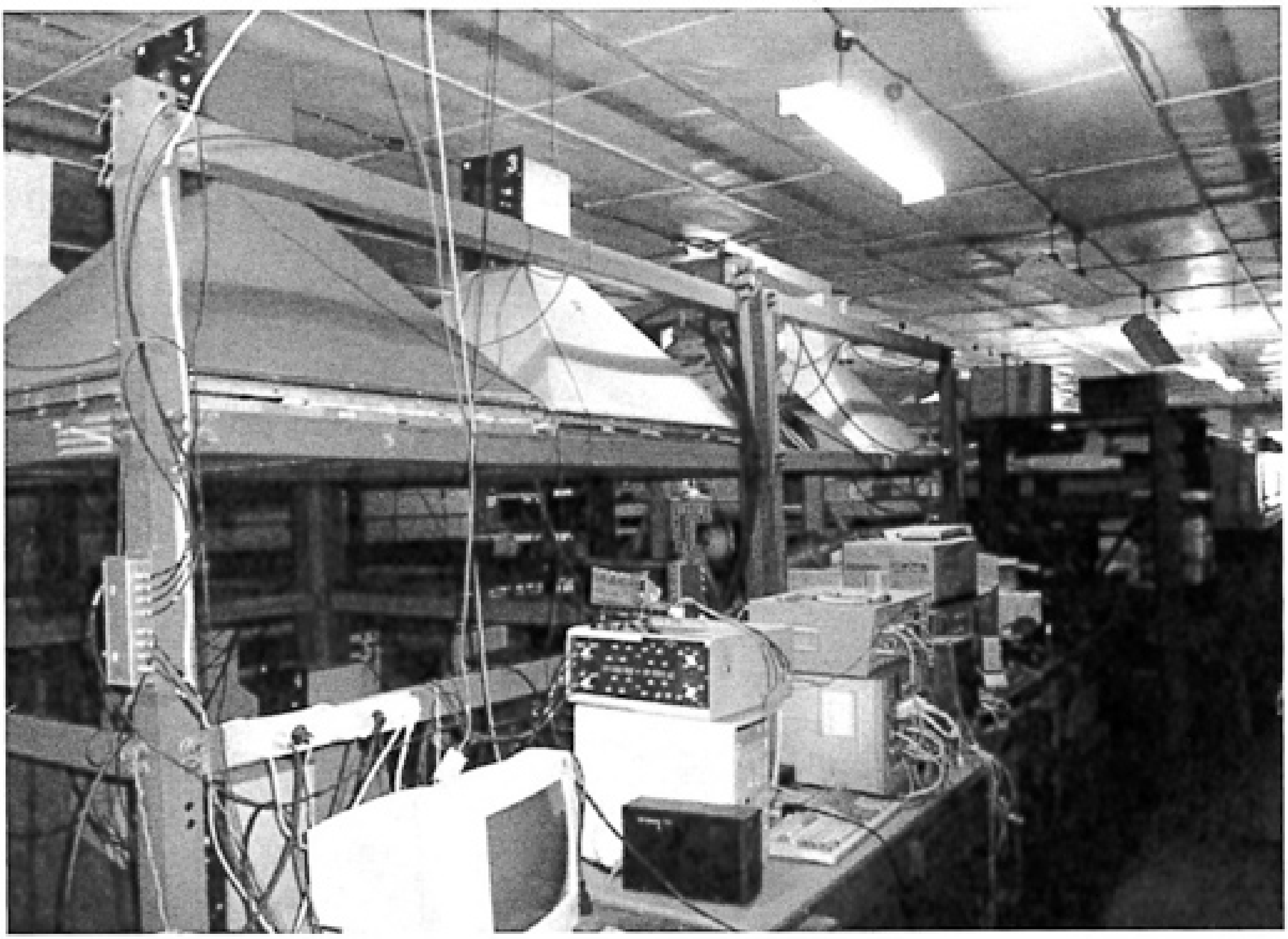
Center forecasts of space weather IZMIRAN



Here's a prediction of space weather



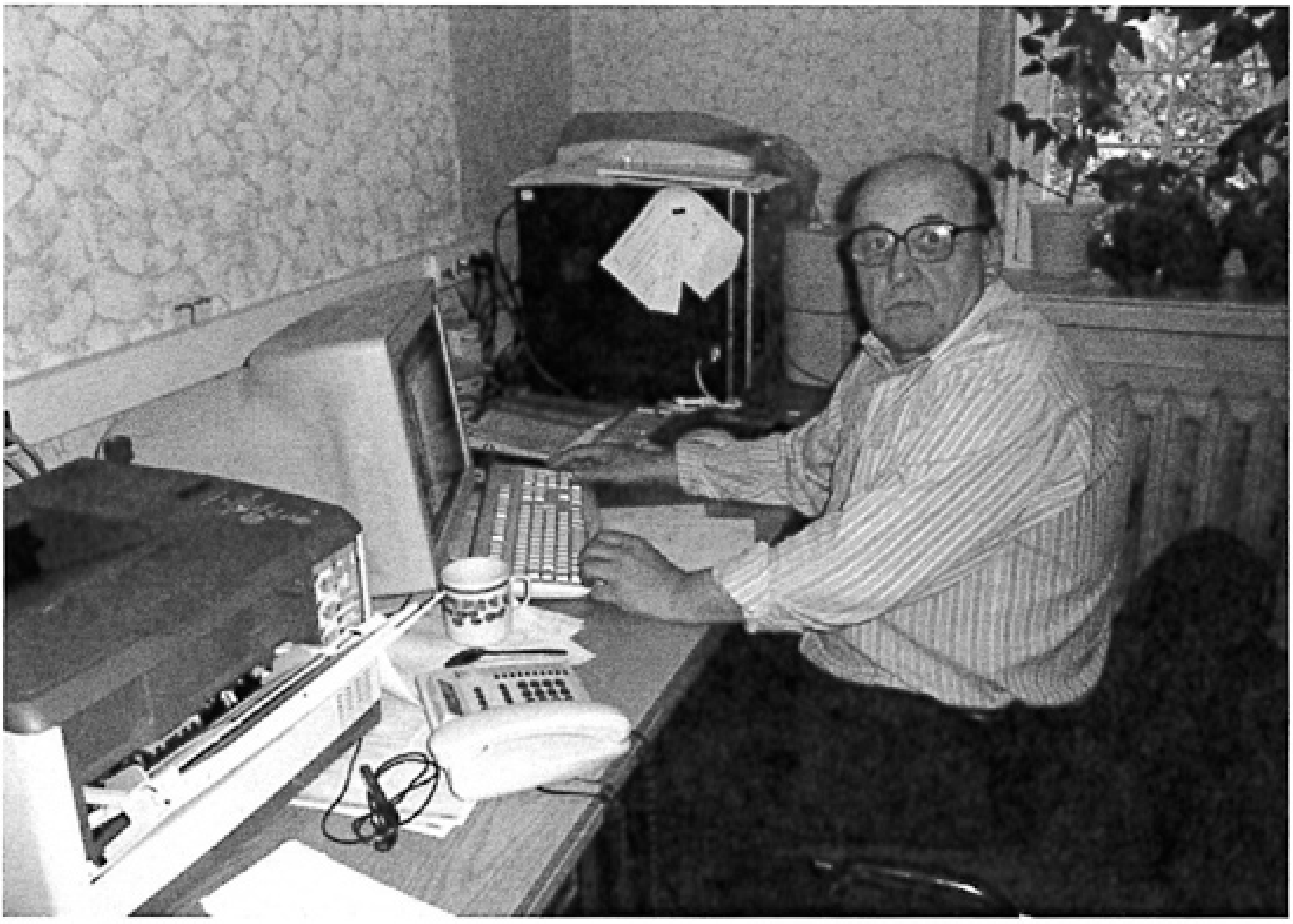
Cosmic Ray Station IZMIRAN – Neutron Monitor



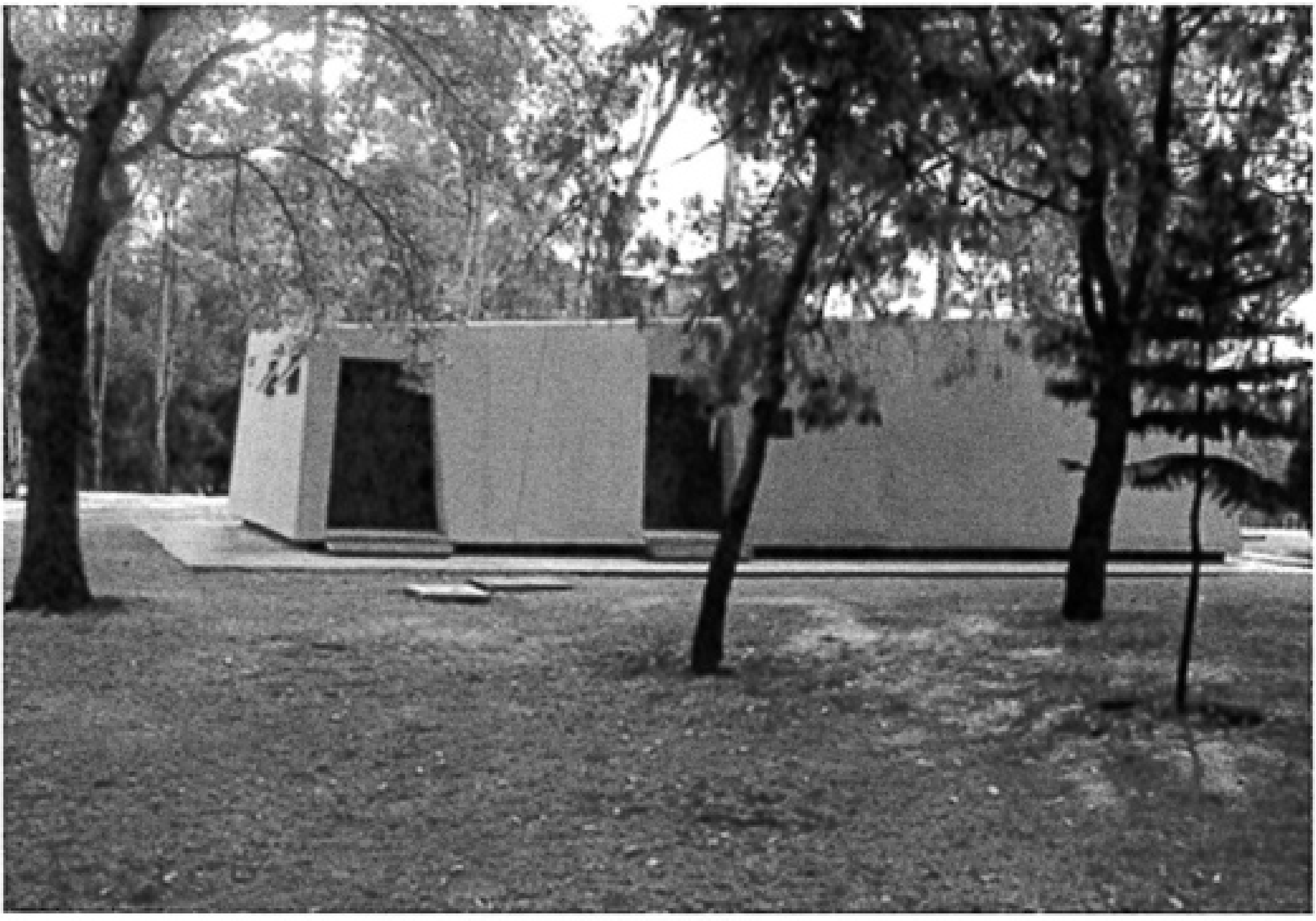
Cosmic Ray Station IZMIRAN – Scintillation Supertelescope

Researchers IZMIRAN near scintillation telescope
(Vladimir Zirakashvili, Konstantin Yudakhin and Evgeny Klepach)

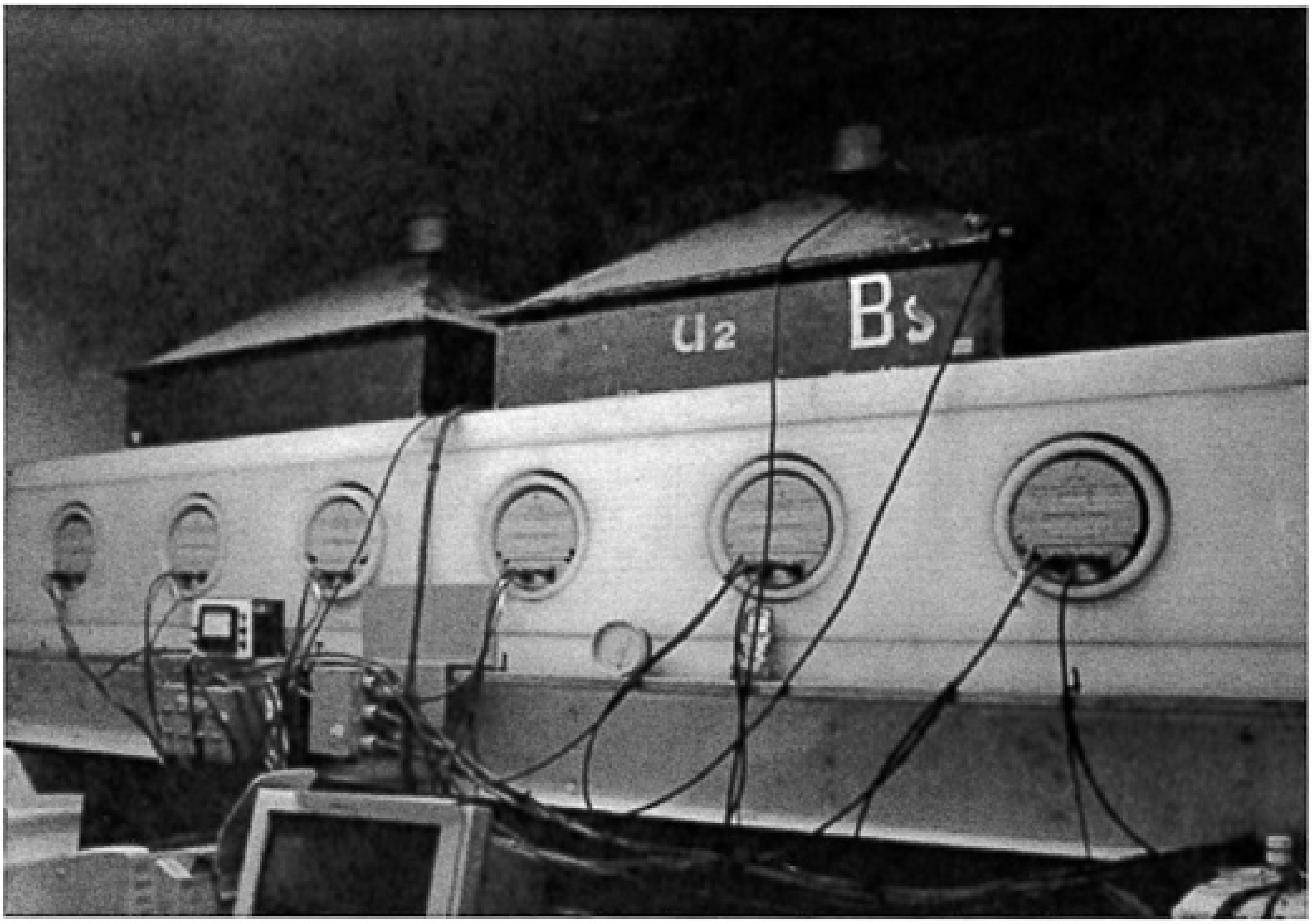
Cosmic Ray Station IZMIRAN – Counters Telescope



Head of Cosmic Ray Station IZMIRAN (Viktor Yanke)



Neutron Monitor Station (NMS) of the Instituto de Geofísica (IG) at the Universidad Nacional Autónoma de México (UNAM)



Neutron Monitor Detector (NMD) of the (IG) at UNAM

We connect further perspectives of studying cosmic rays fluctuations and using them for diagnostics and forecasting with, first of all, further development of theoretical research (kinetic theory of fluctuation, approaching in the framework of isotropic and anisotropic diffusion models, theory of fluctuation of atmospheric and geomagnetic origin, theory of fluctuation appearance in a generation process of solar cosmic rays and their propagation in the corona, in the interplanetary space and in the Earth's magnetosphere).

Widening of experimental works will be of great value in forecasting IMF disturbance (registration of cosmic rays fluctuations with a help of precision instruments on the Earth surface from different asymptotic directions, using a world network neutron monitors – as a united planetary multiway super device, registration of cosmic rays fluctuations with a help of multi-directional super telescopes on different levels of depth under the Earth, wider use of observing cosmic rays fluctuations from balloons, satellites and spacecrafts).

And it will become possible to solve some important problems of quantitative diagnostics and forecasting such events important for cosmic research and its terrestrial applications as powerful solar flashes, interplanetary shock waves, disturbances, propagating in the interplanetary space.

Very soon we will get estimations of near space state on the Earth as regularly as cosmic rays are registered. The first steps have been already made.

Cosmic rays will meet 100-year anniversary that will be celebrated in 2012 on the proscenium of science.

Could Victor Franz Hess imagine beginning his famous flight by a balloon on the 7th of August,1912, which opened the door to modern cosmophysics, that rays which he had discovered would be precursors of cosmic storms?

2.5. Solar activity and cosmic rays

2.5.1. Long-period variations of solar activity and cosmic rays

Changes in magnetic field structure occurring in deep layers of the Sun and reaching its surface determine configuration of coronal magnetic fields. In their turn these fields (their form is changed periodically which one can see well in a white light during solar eclipses) form conditions of flowing out of the solar wind which influences intensity of cosmic rays in a modulating way.

Such changes of solar magnetism occurring every 11 years are expressed in various solar activity manifestations.

That is why different characteristics depending on the problem can be used as indexes of solar activity.

To solve problems of solar-atmospheric cosmophysical connections indications of a slowly changing solar activity component (number and square of sunspots, coronal indexes, density of a solar radio-frequency radiation flux, total squares of photospheric and chromospheric faculae and calm protuberance) and indications of quickly changing solar activity component (solar flares, radio-frequency radiation outbursts, active protuberance) can be used.

All parameters of slowly changing solar activity components are interconnected and characterized by 11-year cyclicity.

Among all solar activity characteristics mentioned above sunspot figures (*W*) are a classical and the most frequently used index when studying solar-atmospheric and solar-cosmophysical connections. Just analysis of Wolf figure temporal changes and cosmic ray intensity has helped researchers to reveal 11-year and 22-year variations of cosmic rays [Dorman, 1989].

However, as it is noted in [Dorman, 1989], sunspot square (*S*) is a more objective index (in comparison with *W*), as in this characteristic definition there are no mistakes connected with an observer's individual peculiarities and the method of observation. Sunspot square and Wolf figures are connected with each other, however, a coefficient connecting these characteristics is changed when a solar cycle is developed. It says about some independence of both parameters.

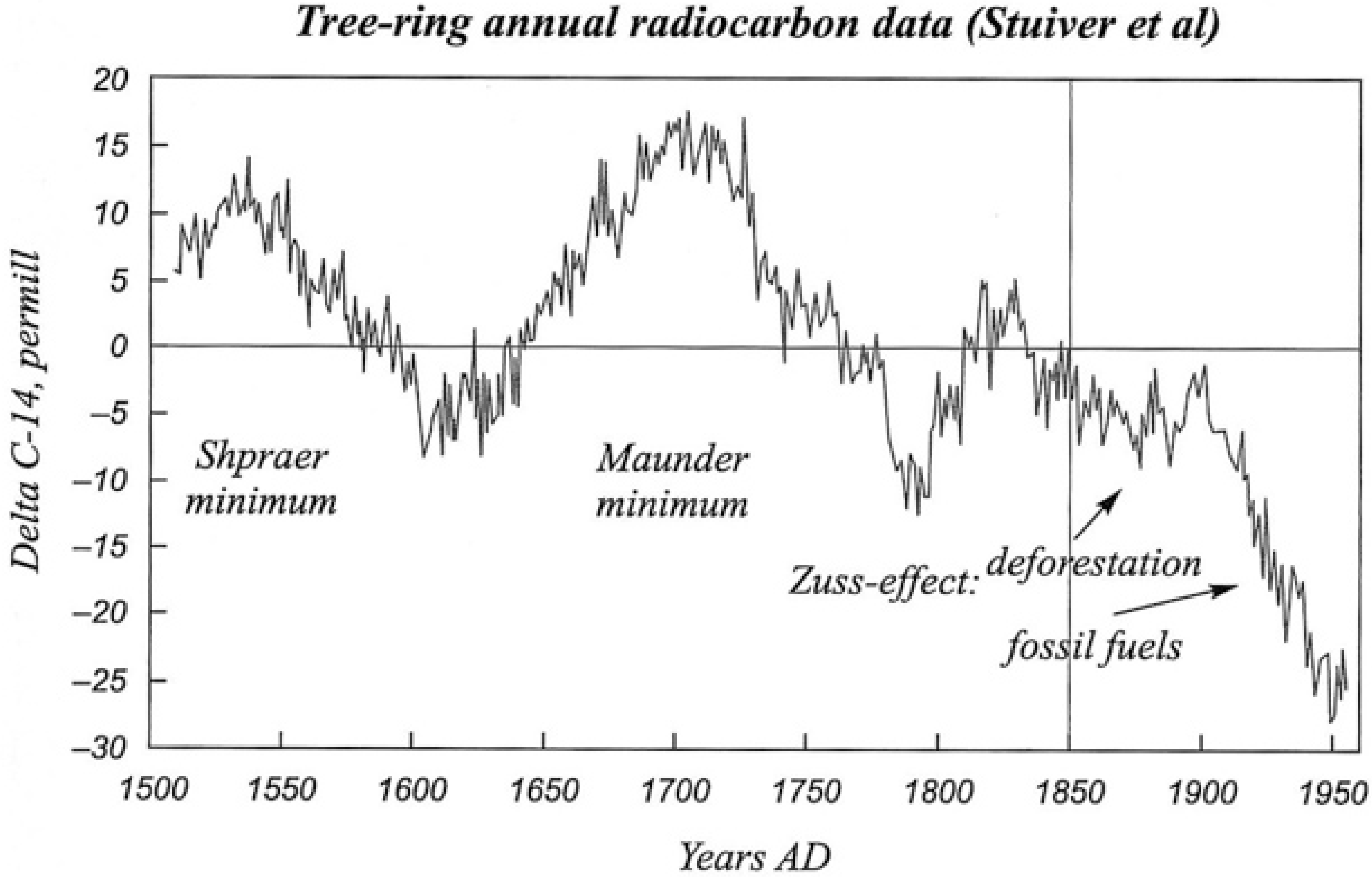
During researching long-period variations of cosmic rays a change of sunspot square as a solar activity index is preferable, because it reflects dependence of transfer distance for particle scattering on density of magnetic nonuniformities brought by a solar wind and reflecting sunspot square [Cosmos Model, 2007; Belov, 2004; Gushina, 1968].

On making a diagram Cosmic ray intensity – sunspot square for an 11-year period one observes a characteristic hysteresis loop. It is possible to explain that such loop is a result of delay of electromagnetic condition change in the interplanetary medium relative to processes which give birth to them on the Sun. Retardation time estimated from hysteresis, $\tau_{ret} \approx 1$ year, and, consequently, the modulating heliosphere size is very large ($\approx 80 - 100$ a.u.) if to suppose that the solar wind velocity is constant ($U \approx 400$ km/sec.).

It was showed later that to reveal long-period variations in cosmic rays it is necessary to use data which have been got with a help of a 6 or 12 month moving average, but in smoothing data in general one reveals comparatively short-period variations for one month.

Retardation value is different in different periods of solar cycle. The largest one is in solar activity decay period. Let us note that in the same period a year variations of cosmic rays are most clearly defined. Moreover, τ_{ret} depends on cosmic radiation particle energy and decreases while energy is raised.

In connection with the fact that in the first works absence of high correlation of cosmic ray temporal changes and sunspot number in some periods was discovered [Libin, 1989] in comparison of these characteristics [Dorman, 1967; Simpson, 1963] on the whole solar disk, it was regarded as a result of an unsuccessful choice of a solar activity parameter. And it was suggested to use intensity of coronal radiation (with a wave length λ 5303 Å) as a measure of effluent plasma. Intensity of this coronal line is a good indicator of solar cyclic activity [Gushina, 1968], changing essentially from solar maximum to minimum.



The content of C-14 from 1500 to 1950

Some peculiarities of an 11-yeatr cycle of the Sun, important for studying solar activity and long-period variations of solar rays, were firstly noted during analyzing data of green coronal line intensity.

So, M.N. Gnevyshev [Gnevyshev, 1963] researched temporal changes of this index and established the presence of this index of the second maximum which did not yield to the first one energetically in the 11-year cycle. And later it was revealed for other characteristics of solar activity.

A choice of intensity of a coronal index as a solar activity index was made in terms of Parker's [Parker, 1982] correlation between a solar wind velocity and temperature of the inner corona which in its turn is connected with intensity of a green coronal line (I_λ) by correlation dependence.

Further research of coronal radiation permitted to reveal large-scaled emissive structures in a corona [Parker, 1965] conditioned by a sector structure of the solar magnetic field. This interconnection of I_λ and structure peculiarities of the solar magnetic field and, consequently, an effluent solar wind confirmed choice validity of coronal activity as a solar activity index.

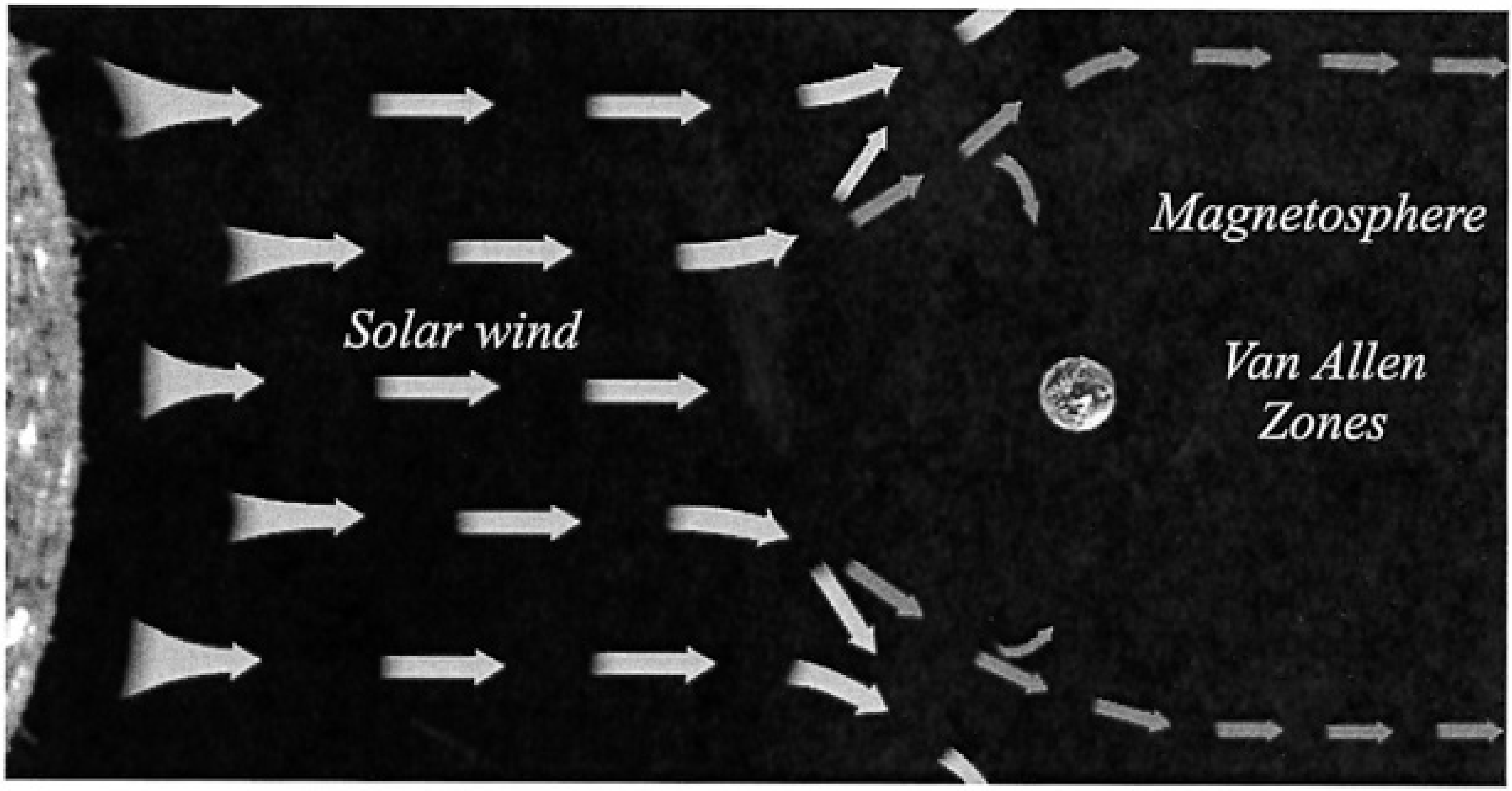
Time dependence of cosmic and coronal radiation intensity for 11 years reveals the same cosmic ray retardation effect relative to solar activity manifestations as an index which characterizes sunspot square. Scientists tried to explain an abnormal behavior of cosmic rays in solar maximum periods noted in [Stozhkov, 2008] in a following way – heliolatitude distribution on solar active regions is changed as an 11-year cycle is developed. However, on taking this factor into consideration this anomaly is left in cosmic ray behavior. The answer can appear only if to take into consideration change of a sign of the solar global field which is going on in solar maximum [Kraynev, 2005].

On using the results (indexes) characterizing different manifestations of changing solar activity (SA) cyclicity, such as coronal radiation intensity, radio-frequency radiation, total sunspot square, scientists noted breach in correlation of cosmic ray intensity (CRI) with SA in inversion periods of large-scaled solar magnetic fields.

There is a question – what is the connection between different values characterizing solar activity with a solar magnetic field, a resource, which arouses this activity? Babcock [Babcock, 1959] gave and Leighton [Leighton, 1964] developed a persuasive model which could explain SA cyclicity. In the basis of this model there is an idea that all irregular activity manifestations on the Sun surface and above it are aroused by changes of poloidal and toroidal components of the magnetic field during differential rotation of the Sun.

In general the solar wind wafts away just a poloidal magnetic field of the Sun into the interplanetary space. It is possible to observe a magnetic cycle of a poloidal component on the basis of coronal activity changes [Parker, 1982].

Particularly, according to [Dorman, 2005], brightness of the green coronal line is a measure of magnetic activity and corona warming. Fields of active areas existing on the Sun surface are areas of a toroidal azimuth field emersion of which form the famous latitudinally elongated biopolar magnetic regions. Herewith, poloidal and toroidal solar magnetic fields and their changes during an 11-year cycle are connected with each other and generated by the same dynamo-process.



The emergence of shock waves in the collision of solar wind and interstellar medium

Polarity of sunspot magnetic fields as well as magnetic fields of polar regions are characterized by a 22-year cycle [Vasilieva, 1984], and polarity of preceding and following spots in biopolar groups in both hemispheres of the Sun changes while transmitting from one 11-year cycle to another, or in solar minimum (and this time one observes maximum of a poloidal field).

A magnetic field sign in polar regions changes near maximum of an 11-year cycle, and process of inversion of these fields is rather long. Latitude change of the sign of common solar magnetic field is also revealed during development of a SA cycle in latitude distribution of its active regions [Vitinsky, 1983].

All this confirm validity of a choice of total sunspot square and coronal radiation intensity as basic SA indexes for helioclimatological problems.

Since the beginning of fifties when 11 year modulation of cosmic ray intensity by solar activity was revealed scientists have suggested a lot of different modulation models to explain this fact.

However, nowadays Parker`s model [Parker, 1982] is the fullest and generally-accepted. In the basis of it there is an idea that cosmic ray modulation and propagation in the interplanetary space is determined by features of a plasma flux flowing out from the Sun and «carrying a frozen magnetic field» and nonuniformities characterizing it, density spectrum of them is changed together with 11-year cycle [Libin, 2008]. (Later Parker's idea was successfully confirmed with many experiments in the interplanetary space including that on the International Cosmic Station – ICS in the beginning of the century).

In Parker's differential equation for cosmic ray density cosmic ray diffusion process and simultaneous convective particle transmission for a spherically symmetrical case with a glance of particle energy changes in interaction of them with the solar wind is reflected. During solving equations of cosmic ray anisotropic diffusion the use of joint data of observing coronal radiation and sunspot square for definition transfer distance for particle scattering permitted to take into consideration peculiarities of solar wind modulating influence in different epochs of a 22-year solar magnetic cycle.

Finding out peculiarities of long-period cosmic ray variations during periods of solar maximum or periods when a solar magnetic field sign in polar zones is changed resulted in finding out 22-year variations of intensity of cosmic rays themselves. It demanded a more detailed approach to solving the problems of distribution of opposite particles in large-scaled interplanetary magnetic fields (IMF) which change direction with a particular regularity.

In theoretical description of a 22-year cycle in cosmic rays a model of occurrence of drift flows changing direction subject to solar common field sign is generally accepted. (Direct changes of cosmic ray intensity in the cosmos during the last 25 years confirm appraisals of modulating heliosphere size (which were got earlier empirically from comparison CRI and SA) (50-100a.u.).

Today common characteristics of solar cycles and their energy have been described in the work [Ishkov, 2004]. An average duration of solar cycles is 10.81 years, and there is a tendency of its decreasing – duration of last 8 cycles has been 10.44 years each.

An estimation of average energy released during a cycle is determined by a full kinetic energy of rotation and a full energy of electromagnetic radiation for a cycle. Other phenomena let much less energy be released, although they can determine separate processes during solar cycle development.

Mathematical images of even and uneven cycles give a possibility of forming a closed structure of a solar physical magnetic field. A low statistic of solar cycles (14) and a lack of a physical model of SA cycle development do not permit to make a true cycle forecast before a cycles begins.

But the situation changes with a beginning of a new cycle, in 18-24 months it is possible to reveal its height, an epoch of maximum and a possible duration of a current SA cycle.

Besides above mentioned long-period 11-year and 22-year cosmic ray variations connected with solar activity, variations and fluctuations with periods of 4-5 years, 2 years, 1 year [Libin, 1989; Libin, 1998] and several months are observed in intensity of a cosmic ray flux.

Nature of extra-atmospheric short-period cosmic ray variations discovered more than 40 years ago [Tai, 1963] when measures of a cosmic ray muonic component were analyzed is generally explained by changing of the Earth position in the space relative to the helioequator.

It is necessary to note that studying short-period variations and fluctuations of cosmic rays and solar activity is of a separate interest, as comparison of periodicity in both processes can give information about their interaction. So, making calculations of power spectrums in the interval of 50 – 1000 days (10 day averaged data of CR registration with a neutral monitor Deep-River, sunspot numbers, data about a radio-frequency radiation on a frequency 2800 MHz, data about measuring parameters of the Sun acceleration relative to a common solar system mass centre were used) scientists established oscillations with periods 650 – 680, 350, 238, 170 and 75 days [Stozhkov, 1969] modulated by an 11-year wave that confirms a solar origin of some of them (2 years, 1 year, 1 – 2 months).

Model research of 11-year solar activity changes and cosmic ray intensity made by the authors have showed that a great part (exert 2-year, a year and 1 – 2 month ones) of variations [Libin, 1989; Libin, 2008] are harmonic components of 11-year and 22-year cycles.

In connection with that, a research of two-year (or to say exactly, quasi-biennial) cosmic ray variation is of great interest for research of solar-terrestrial connections [Charakhchyan, 1973].

In her works T.N. Charakhchyan showed that the energetic spectrum of two-year cosmic ray variations is close to the spectrum of 11-year variations, and relations of their amplitudes is of a steady character and at the average equal to $A_{11}/A_2 = 5.3$ that is much higher than if 2-year variations were harmonic components of 11-year ones.

Moreover, a two-year variation is observed in solar and magnetic activity and also in climatological processes. Being found two-year variations have an extraterrestrial origin and are connected with physical conditions in the region of an interplanetary space, the closest to the Sun [Libin, 1995].

Quasi-biennial variations of cosmic rays are manifested in alteration of solar-daily anisotropy phases subject to the position of the Earth relative to the helioequator – while the poles of the common solar magnetic field are altered an alteration order of anisotropy phases is changed to the opposite correlating with behavior of quasi-biennial variations (QBV) of North-South asymmetry of a solar wind.

The reasons for quasi-biennial variations of cosmic ray intensity are cyclic changes of solar wind characteristics in the whole heliosphere and appropriate variations of behavior of different atmospheric processes.

Quasi-biennial variations (QBV) are found in many solar and terrestrial processes including a low-latitude stratospheric wind (LSW), the solar magnetic field on the surface of *Br* recourse and the Earth rotation speed *V*. QBV behave differently on the Sun and on Earth – in LSW they dominate, but in many processes on the Sun QBV are found only after observation filtration.

A statistic analysis of 36-year rows of filtered values U^*, Ba^* and V^* was made to reveal solar-stratospheric connections [Ivanov-Kholodny, 2004] where U is an averaged velocity of LSW, Ba is a module Br average in all solar latitudes and symbol * means filtration according to the scheme used in [Ivanov-Kholodny, 1992]. An important correlation between values U^* and Ba^* ($r = -0.58 \pm 0.08$) and a line connection U^* with Ba^* and V^* characterized by a coefficient of multiple correlation $R = 0.68$ are found. So, it is proved that there is connection between stratospheric and solar QBV.

As for all the other short-periodic variations mentioned above, revealing and analyzing them (as manifestation of solar activity) demands a certain care because of difficult behavior of them from cycle to cycle and a lack of reliable correlation connections with solar activity [Libin, 1979], although many research made by the authors in each case show a rather stationary character of them during short periods of time (3 – 4 years).

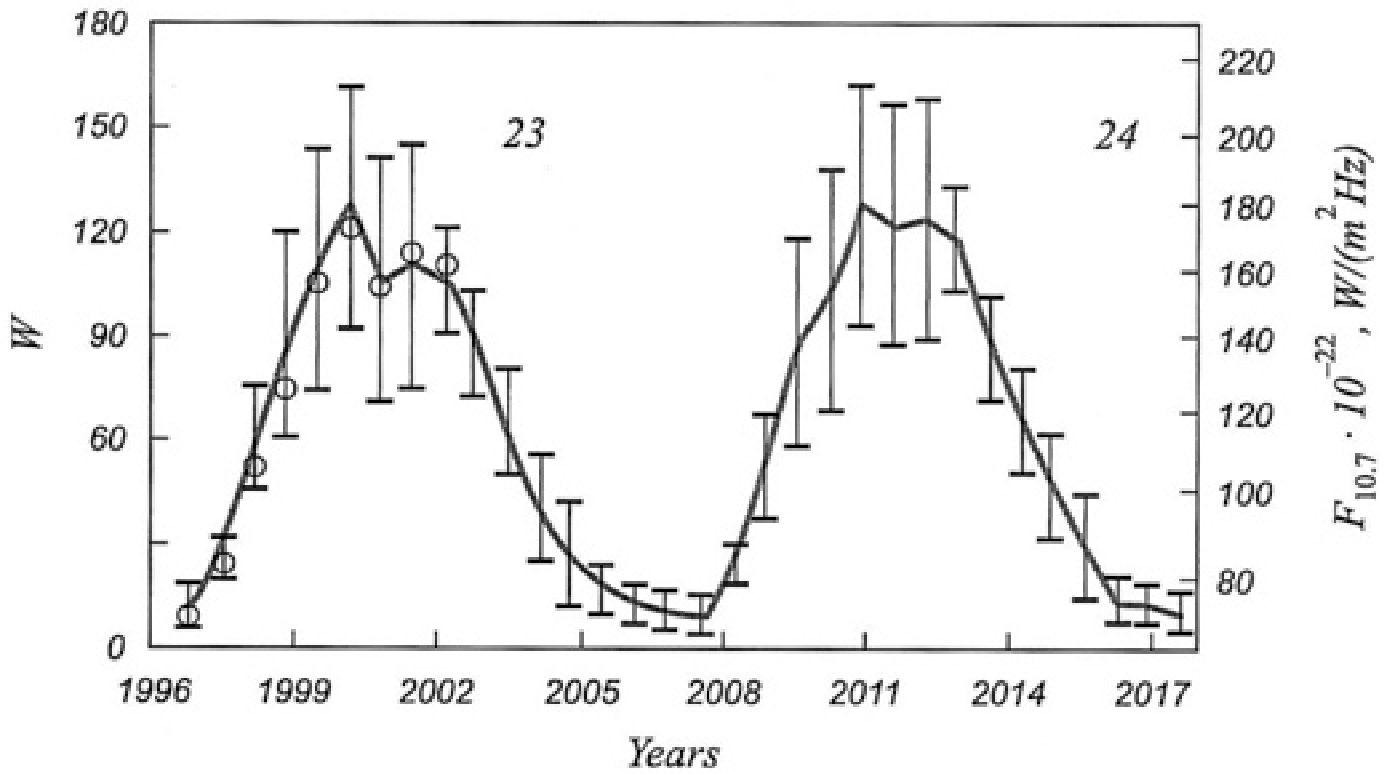
Periodical cosmic rays variations in the time interval from 1953 to 2004 have been researched with a help of a modified method of spectral analysis. An initial row of monthly data of a cosmic ray flux has been synthesized from measures made in different periods of time of this long period with 100 terrestrial neutron monitors distributed about the whole surface of the Earth.

These measuring station data corrected with barometers are on the server http://spidr.noaa.gov in format 4096. The method of formation of a joint synthesized data row is based on principles of processing unequal temporal rows with a prescribed balance or mean-square measure errors.

It is found out that weak quasi-periodic components appear in periods of 0.75, 1.0, 2.0 years and more powerful ones appear in periods of 1.5, 1.75, 2.6, 3.0, 4.1, 9.0 and 23.0 years in a spectral periodogram of synthesized data. On the basis of synthesized data values a cosmic ray activity index has been coined and interaction of it with solar activity indexes in X-rays, radio and optic ranges has been studied [Dergachev, 2004].

One of the mechanisms of variation appearance in cosmic rays in periods which are not connected with cyclic solar activity are heliosphere self oscillations which are of a clear quasi-stationary character, a period of such oscillations which appear because of disturbing action of large-scaled [Otaola, 1983; Attolini, 1983] nonuniformities of the interplanetary medium and a solar wind can be from 2 to 8 – 9 years [Libin, 2007].

What is practical appliance of such regularities? The IZMIRAN made a forecast of a cosmic ray flux for the next solar cycle and reestablished CR behavior in 17 – 20 centuries on the basis of the model connecting cosmic ray (CR) modulation with solar activity indexes [Belov, 2004].



Forecast of solar activity before 2017 [Khramova at. al., 2002]

A forecast of a cosmic ray (CR) flux was made on the basis of the forecast of the main solar magnetic field characteristics. To reestablish CR behavior in the past sunspot numbers and geomagnetic activity indexes were used.

For forecasting scientists needed reliable data about CR variations in the network of CR stations and data about changing solar global magnetic field characteristics (inclination of a heliosphere current sheet, average intensity of the solar magnetic field on the surface of the resource of a solar wind and field polarity). A worked multiparametric model of CR modulation in the heliosphere permits to estimate CR variations under study exactly and gives a possibility to make a long-time forecast.

Such forecast before 2017 was made in the MGU (RINP and SAIS) with a method of phase mean-values for Wolf figures and a radio-frequency radiation flux F10.7 based on the information for the first 22 cycles (from 1 to 22, see the picture above).The circles are observed data, the sections are confidence intervals corresponding to 99 per cent of probability.

Solar activity forecasting [Lychack, 2002]. Solar activity is a reflection of solar dynamic processes as a non-linear dynamic system. Connection between all the processes occurring on the Sun is complex and indirect, that is why on observing and fixing values of some black box (the Sun as we see nowadays) outputs it is possible to expect that only certain regularities like cyclicity will be revealed.

In his work Lychack suggested to use a set-theoretical approach to building up a mathematical model of signals on outputs of a dynamic system which is characterized by chaotic oscillations. He said about chaotic events and processes on consideration of quality difference from a probable approach.

New methods of presentation of a mathematic uncertainty model lead to new approaches to solution of famous problems of manipulating measure (observation) results received with some mistakes. Particularly, necessity to know some interval characteristics of uncontrolled mistakes or to work out methods of experimental determination of them and also to get not only close values of finite data, but interval estimations of possible mistakes follows from them.

Lychack worked out methods of statistic processing solar activity indicators (Wolf figures, solar radio-frequency flux values), received interval estimations of periods of its manifestation cyclicity and showed a cycle synchronism based on both solar activity factors. On the basis of concepts about solar processes as chaotic oscillations a forecast of solar activity till the end of the last cycle which has been not finished yet based on the both indicators was made.

For statistical data manipulation he used data about daily values of a Wolf number from January of 1818 to May of 2003 and also monthly average values of it from January, 1700 (in fact, from 1700 to 1748 there were yearly average values) to December 1984 [14]. Averaging out monthly every day values of a Wolf number after December of 1984 resulted in monthly average values of it from January, 1700 to May, 2003.

An average Wolf number for the whole period 1700-2003 is 49.96. Monthly average values of a Wolf number were smoothed out with a 13-monthly rectangular window, and beginnings and ends of standard (11-year) solar activity cycles are determined basing on these smoothing values. Dates of beginnings and ends and, correspondently, duration of these cycles have been received. A number of full cycles for the period mentioned above is 26, and the last – 27th cycle – has been not finished yet (the date of the beginning is September of 1996).

An average value of the cycle duration is 131.19 months (10.9 years). A maximal duration was observed in the 8th cycle (from September of 1784 to April of 1798) – 163 months (13.6 years), then in the 9th cycle there were 152 months (12.7 years). A minimal duration was observed in the 6th cycle (from June of 1766 to June of 1775) – 108 months (9 years), then in the 7th cycle there were 111 months (9.25 years), then in the 12th cycle there were 113 months (9.4 years).

As an alternative estimation of the cycle average duration an average distance between absolute maximums of Wolf number values on the neighboring cycles were used on the basis of the data. It is equal to 131.08 months (10.9 years) or almost the same when estimating with a standard method. It is interesting to note that in general duration of cycles with larger values of a maximal Wolf number on the cycle is shorter.

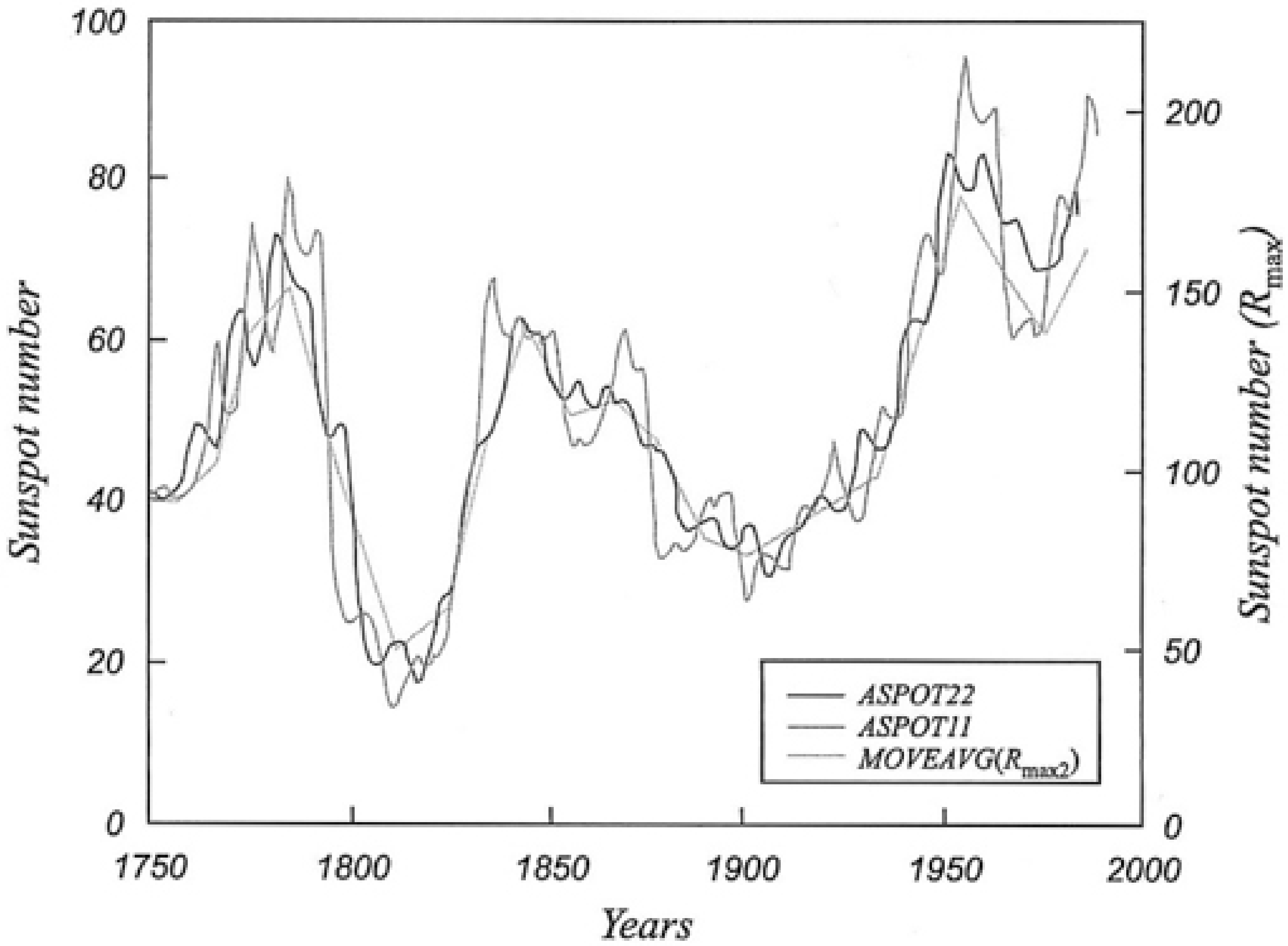
On manipulating data of an average Wolf number with a wider 396-month (33-year) sliding window three so-called century cycles were established among which the third one is not finished yet.

There are three cycle groups (with duration of about 100 years) – 1 – 9 (with duration of 1182 months – 98.5 years), 10 – 17 (with duration of 1088 months – 90.7 years), 18 – 26 (with duration of 1141 months – 95 years).

The solar-terrestrial physics data from the archives of the World data centre in Russia, particularly, about absolute changes of monthly average values of a solar radio-frequency radiation flux on wave 10.7 sm for the period from February, 1947 to May, 2003 were used. Its average value for the whole period equal to 119.63 has been found.

For the period mentioned above one can observe 4 full cycles of solar radio-frequency radiation flux variations on a fixed wave 10.7 sm.

The cycle duration in months is max = 144; min = 116; mid = 127. A timely interval between cycle absolute maximums in months is max = 148; min = 109; mid = 132.

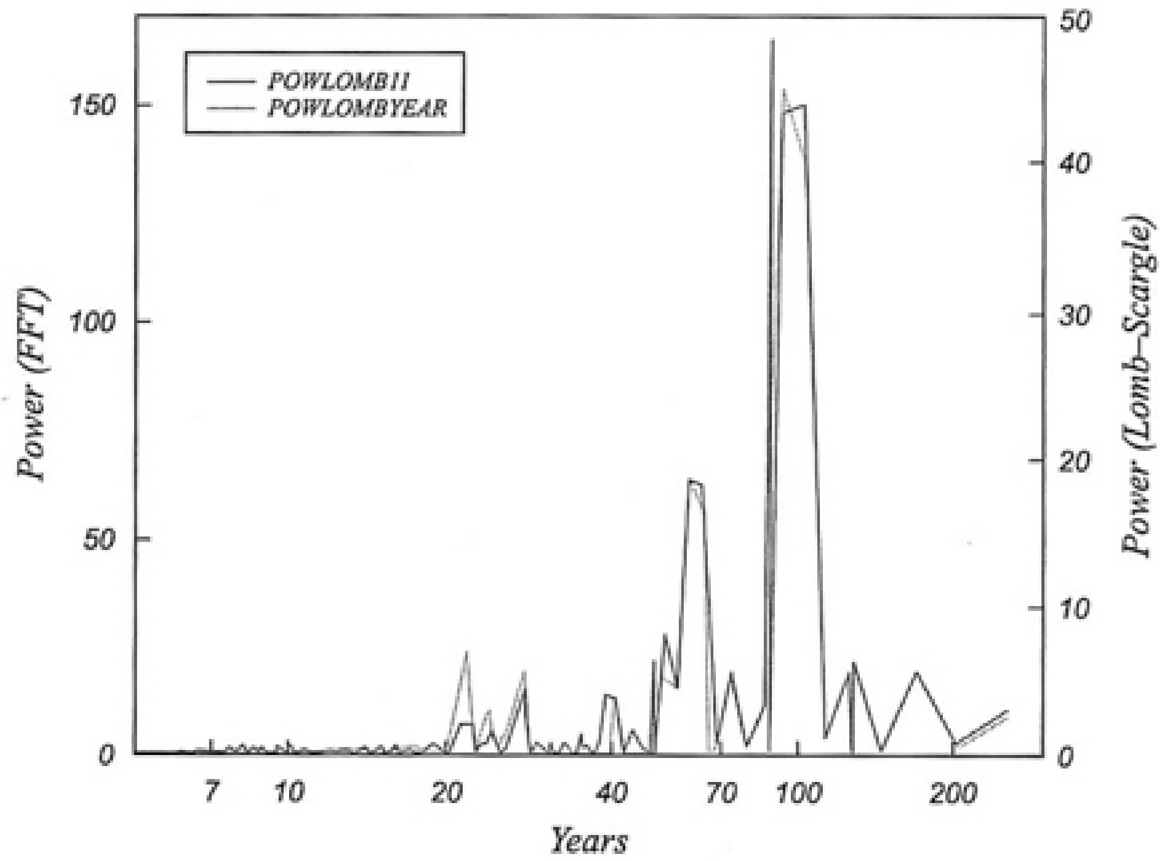


Centennial variations in solar activity [Friis-Christensen and Svensmark, 2003]

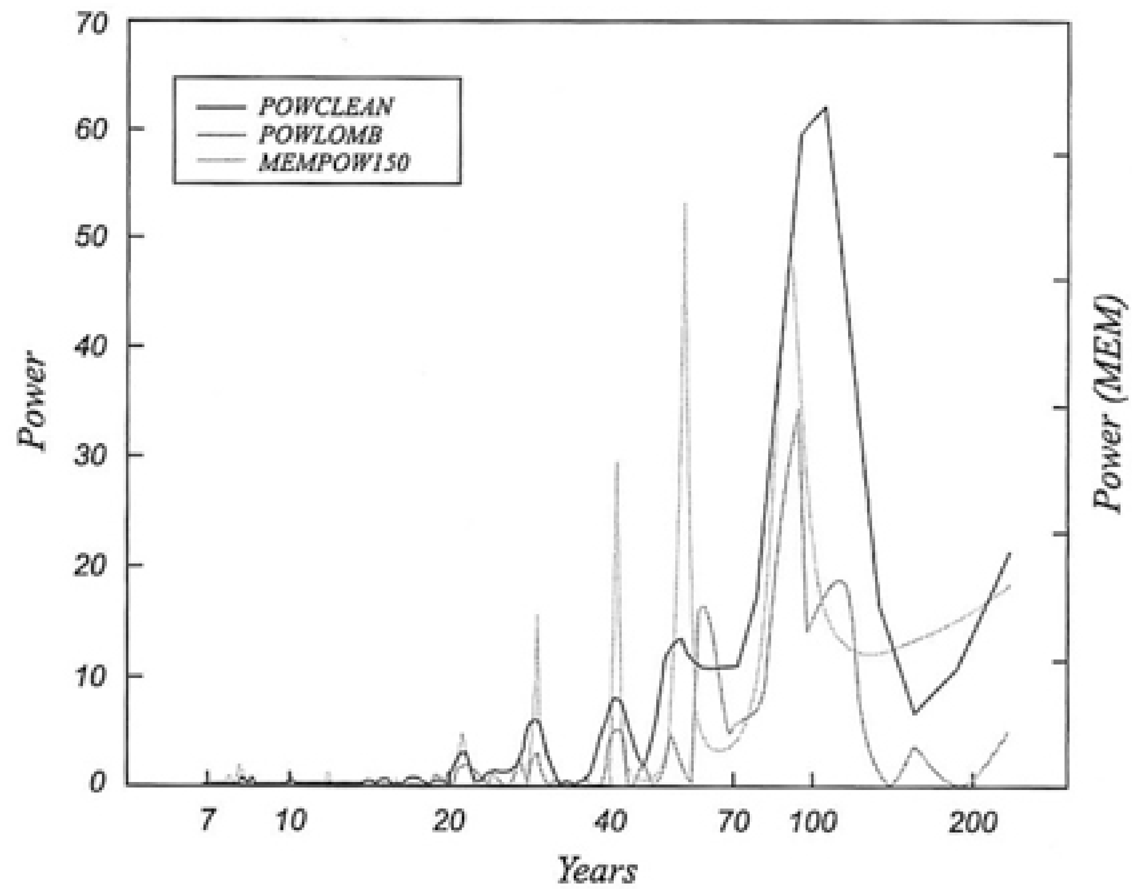
An average value of the cycle duration (average on 4 full cycles) is 126.75 months (10.6 years). An average Wolf number of 4 last full cycles gives the same value, it means that average Wolf numbers in solar activity cycle duration and values of a radio-frequency radiation flux coincide during the synchronic measuring of both factors.

Comparison of values (see the picture above) of a radio-frequency radiation flux (an upper line) with relevant monthly average Wolf numbers for the same period (a lower line) shows a synchronism of cycles with regard to both solar activity factors.

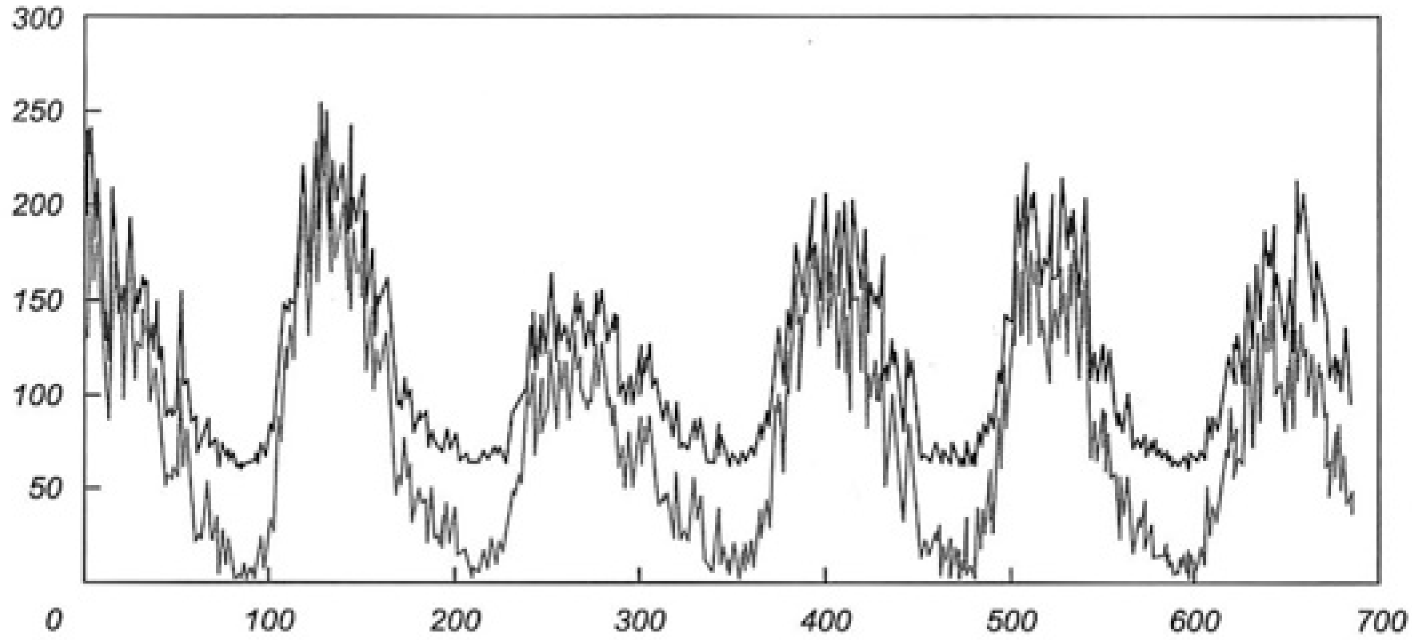
Lychack made a forecast of solar activity relative to monthly average Wolf numbers till the end of 27th cycle. For that he compared its observed part with relevant parts of preceding 26 cycles normalized with multiplication by a coefficient equal to relation of an average Wolf number of 27-cycle observed part to an average value of the cycle.



FTT power spectra for different window functions are calculated for 11-year running of mean sunspots numbers spanning from 1732 to 1987 ($N = 256$). The columns in the frequencies $V_k = k / N$ ($k = 0, 1, 2, \ldots N/2$) on the logarithmic abscissa scale are slightly shifted: left – Parzen window, right – Welch window. The curves are Lomb-Scargle periodograms for the same data set as the FTT spectra (Fully drawn) and for annual R values from 1732 to 1987 (dash, only drawn for period > 20 years), respectively.
[Friis-Christensen and Svensmark, 2003]



Comparison of power spectra for different methods: Spectral analysis of the centenary of solar activity variations [Friis-Christensen and Svensmark, 2003]



The values of radio flux and the Wolf numbers [Lichak, 2002]

Such cycle (according to mean-square deviation minimum) is 24th cycle. The forecast was made with joining a relevant part of 24th cycle to such part of the 27th cycle that corresponds to a solar activity recession phase. Satisfied results of the forecast conformation were received for both solar activity factors during the first seven months.

In a result of a lot of research technique of estimating solar activity factors – Wolf numbers and a level radio-frequency radiation flux on wave 10.7 sm – were worked out. (A new mathematic model of time changes of these factors as a chaotic process with some interval characteristics was used).

On the basis of presentation of solar activity manifestations as a result of some oscillations of solar dynamics a forecast of the last solar activity cycle for Wolf's numbers, particularly of duration of it and averaged Wolf numbers on the whole cycle was made.

An analogical forecast was made relative to the other solar activity factor – a level of radio-frequency radiation flux on wave 10.7 sm.

Comparison of forecasted values with real ones (the forecast was made beginning from May of 2003) showed a rather good coincidence of oscillation form of monthly average values during the first six forecasting months. (After that period difference of forecasted and real values is increased sharply).

Though the majority of forecasts of the 24th solar activity cycle were made in supposition that minimum would not last for long and it was possible to expect that some active regions forming a new solar activity cycle would appear on the Sun in 2008. However, although rebuilding of the main magnetic field was noted as an indication of a new cycle beginning solar activity is still very low. Moreover, calmness of the last year is record. There has been no such a long solar pause in preceding activity cycles.

Forecasters do not know what to think and have to review not only minimum duration, but the beginning moment of the whole active part of the cycle. It is possible to expect that telescopes TESIS fixed on board of the CORONAS-FOTON spacecraft will be able to watch formation of new activity zones, although there are no sunspots on the solar surface now, and the Sun seems calm from the Earth.

It is just the configuration which two active areas registered with telescopes in the solar corona on 27 of March, 2009, and observed for 4 days without a break form. Both areas are rather far from the equator, and this fact says much to astrophysicists. Just here, on high heliocentric latitudes powerful magnetic fields of a new cycle which have been formed in the depth of the Sun for several years should come to the top. Now this zone will come closer to the equator during several years increasing activity and forming something that is called solar cycle.

A new high-latitude activity zone is usually formed together with destruction of an old equatorial zone which is left from the preceding cycle. Thereby activity cycles collide. Besides, as a rule two symmetrical activity zones - in the North and South hemispheres – are formed on the Sun.

Nowadays besides a lack of the equatorial zone there is a lack of the South hemisphere zone. Time will show how long such asymmetry will stay and if it will be a peculiarity of a new solar cycle.

Does the 24th solar activity cycle begin?

2.5.2. About a year component in the solar activity cycle

In research of cosmic ray effects connected with peculiarities of solar activity heliolatitude distribution [Dorman, 1998] and a slope of an ecliptics plane to the helioequator plane, a question about a year component in the solar activity cycle, its peculiarities, appearance and disappearance dynamics becomes important.

To find oscillations in SA close to 1 year sunspot squares for 1 solar turnover for the Sun as a whole and for the North and South hemispheres separately were used in the works [Libin, 1995]. Oscillations with periods 1.2 years were found with methods of a sliding average and epoch syncopation. This periodicity does not depend on an 11-year cycle number and forms a continuous series during 1878 – 2007.

A similar research for cosmic rays was made with a use of HL-index of solar activity [Gushina, 1970], because as there is heliolatitude dependence of SA and a solar wind velocity a year cosmic ray variation has to be observed because of misalignment of a solar equator and the Earth orbit planes.

Such variation (with amplitude 0.34 per cent and maximum in January) was found according to monthly average values of cosmic ray neutral component intensity (cosmic ray stations Inuvik and McMurdo, adjustments for a temperature effect and non-cyclic variations were inserted).

A character of a year cosmic ray variation supposed a presence of a transverse gradient of cosmic ray density 8 per cent per 1 a.u. (relative to solar equator plane) which was later confirmed in satellite experiments.

Long-term changes of year (and half-year) cosmic ray variations revealed a large changeability, but year variation amplitude was always 2 – 3 times higher than a half-year one.

A lack of anomalies in a year (and half-year) wave in solar activity and in cosmic rays shows that their amplitude and phase changeability is conditioned by broadband noise.

Intensity spectrums of cosmic ray and solar activity variation (in a range from $3 \cdot 10^{-8}$ to $3 \cdot 10^{-7}$ Hz) calculated by the authors for each 11 years for the period 1960 – 2008 are well approximated by the function $P(f) \approx A f^{-2.4}$. Herewith a half-year wave exceeds only a 90 per cent confidence interval, when a year one exceeds 95 per cent one.

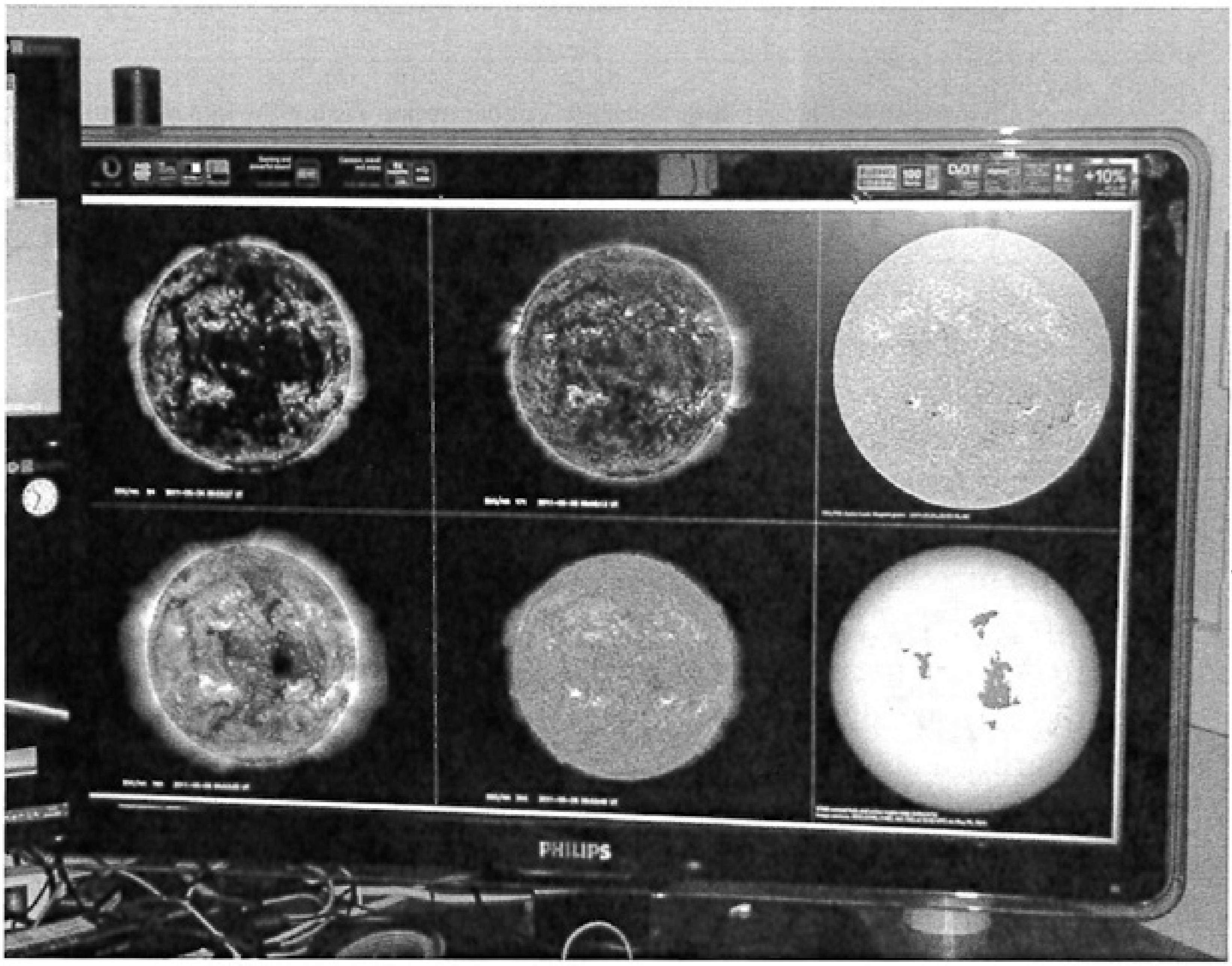
A more complex correlation connection (changing from cycle to cycle and depending on a solar activity phase) is observed between cosmic ray intensity and geomagnetic activity and atmospheric processes.

According to calculation data for the period 1960-2008, the authors showed a good correspondence between short-periodic variations of CRI, solar radiation and closed water system levels for, at least, a half of observed periods.

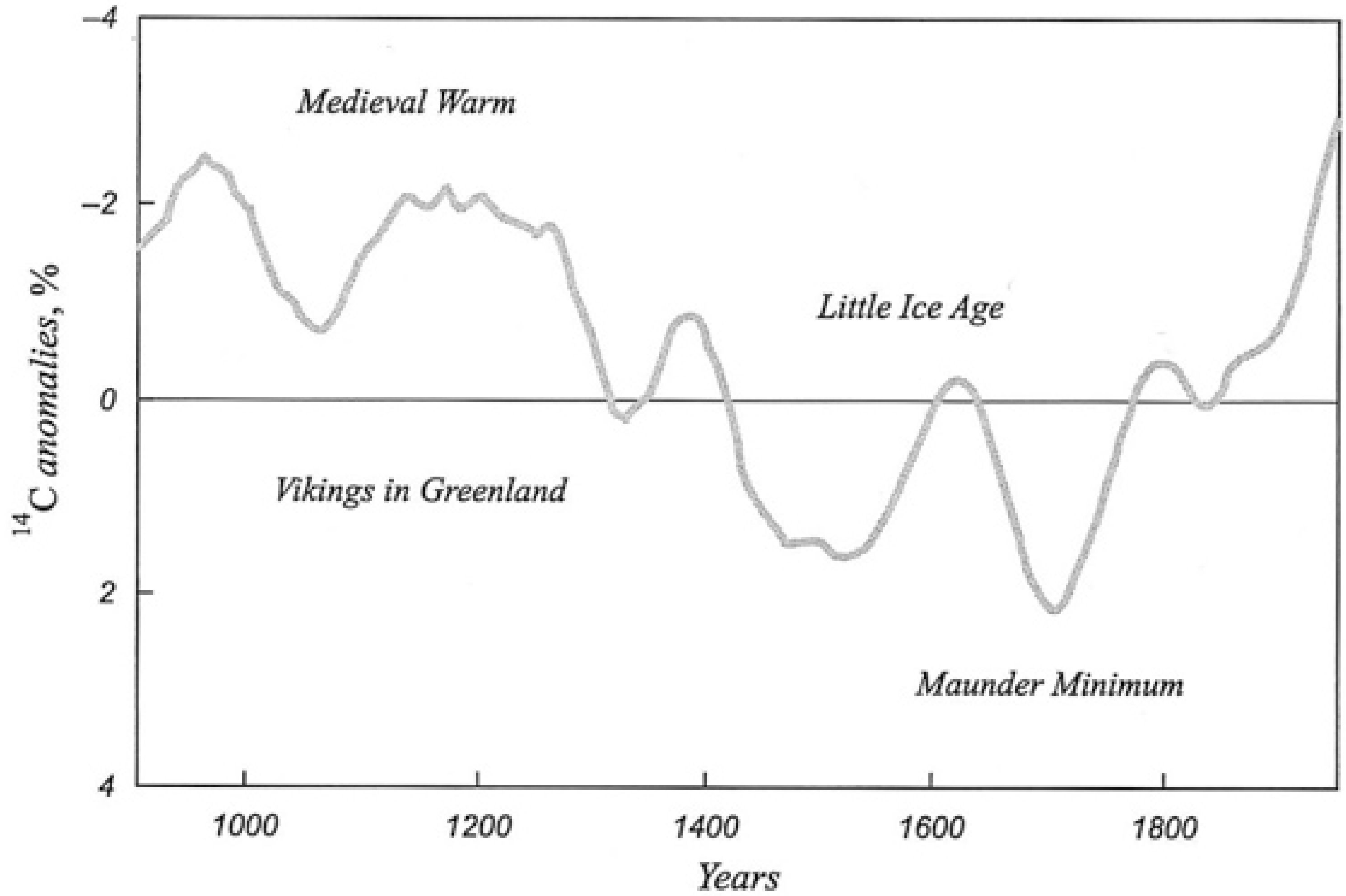
2.5.3. Solar Activity and Cosmic Ray Variations as Possible Causes of Climate Change

About two hundred years ago the famous astronomer William Herschel (1801) suggested that the price of wheat in England was directly related to the number of sunspots with periodicity about 11 years. He noticed that less rain fell when the number of sunspots was big (Joseph in the Bible, recognised a similar periodicity in food production in Egypt, about 4,000 years ago). The solar activity level is known from direct observations over the past 450 years, and from data of cosmogenic nuclides (through CR intensity variations) for more than 10,000 years (see details in Chapters 10 and 17 in [Dorman, 2004]). Over this period there is a striking qualitative correlation between cold and warm climate periods and high and low levels of galactic CR intensity, correspondingly (low and high solar activity). As an example, Figure shows the change in the concentration of radiocarbon ^{14}C during the last millennium (a higher concentration of radiocarbon corresponds to a higher intensity of galactic CR and to lower solar activity).

It can be seen from Fig. 1 that during 1000 – 1300 the CR intensity was low and solar activity high, which coincided with the warm medieval period (during this period Vikings settled in Greenland). After 1300 solar activity decreased and CR intensity increased, and a long cold period followed (the so called Little Ice Age, which included the Maunder minimum 1645 – 1715 and lasted until the middle of 19th century).



Observations of the Sun being constantly (IZMIRAN)



The change of CR intensity reflected in radiocarbon concentration during the last millennium [Swensmark, 2000]

2.5.4. The Possible Role of Solar Activity and Solar Irradiance in Climate Change

Friis-Christiansen and Lassen [Friis-Christiansen, 1991], Lassen and Friis-Christiansen [Lassen, 1995] found, from four hundred years of data, that the filtered solar activity cycle length is closely connected to variations of the average surface temperature in the northern hemisphere. Labitzke and Van Loon [Labitzke, 1993] showed, from solar cycle data, that the air temperature increases with increasing levels of solar activity. [Swensmark, 2000] also discussed the problem of the possible influence of solar activity on the Earth's climate through changes in solar irradiance. But the direct satellite measurements of the solar irradiance during the last two solar cycles showed that the variations during a solar cycle was only about 0.1%, corresponding to about 0.3 W/m2. This value is too small to explain the observed climate changes during solar cycles. Much bigger changes during a solar cycle occur in UV radiation (about 10%, which is important in the formation of the ozone layer). Haigh [Haigh, 1996], and Shindell et al. [Shindell, 1999] suggested that the heating of the stratosphere by UV radiation can be dynamically transported into the troposphere. This effect might be responsible for small contributions towards 11 and 22 years cycle modulation of climate but not to the 100 years or more of climate changes that were observed in the past and during the last hundred years.

2.5.5. The Connection between Galactic CR Solar Cycles and the Earth's Cloud Coverage

Recent research has shown that the Earth's cloud coverage (observed by satellites) is strongly influenced by CR intensity [Swensmark, 2000; Marsh and Swensmark, 2000a,b]. Clouds influence the irradiative properties of the atmosphere by both cooling through reflection of incoming short wave solar radiation, and heating through trapping of outgoing long wave radiation (the greenhouse effect). The overall result depends largely on the height of the clouds. According to Hartmann (1993), high optically thin clouds tend to heat while low optically thick clouds tend to cool (see Table).

Parameter	High clouds		Middle clouds		Low clouds	Total
	Thin	Thick	Thin	Thick	All	
Global fraction /(%)	10.1	8.6	10.7	7.3	26.6	63.3
Forcing (relative to clear sky):						
Albedo (SW radiation)/($W \cdot m^{-2}$)	–4.1	–15.6	–3.7	–9.9	–20.2	–53.5
Outgoing LW radiation/($W \cdot m^{-2}$)	6.5	8.6	4.8	2.4	3.5	
Net forcing / ($W \cdot m^{-2}$)	2.4	–7.0	1.1	–7.5	–16.7	–27.7

Table. Global annual mean forcing due to various types of clouds, from the Earth Radiation Budget Experiment (ERBE), according to Hartmann (1993). The positive forcing increases the net radiation budget of the Earth and leads to a warming; negative forcing decreases the net radiation and causes a cooling. (Note that the global fraction implies that 36.7% of the Earth is cloud free.)

2.5.6. Connection of solar activity with geomagnetic processes

Solar activity influence on the Earth's magnetosphere is manifested by two basic types of magnetic storms – storms with a sudden and gradual beginning.

(As a rule magnetic disturbances with a sudden beginning are connected with chromospheric flares and change in an 11-year cycle in the phase with solar activity)

A reason of a sudden beginning is that a front of a shock hydrodynamic wave appearing on the Sun during a sudden particle emission from a chromospheric flare and arousing a sharp compression of the Earth's magnetosphere comes to the Earth.

27-day repetition and the most powerful development to solar minimum for 1 – 3 years are characteristics of the second type of storms. This type appears when the Earth crosses sector boundaries of the interplanetary magnetic field (IMF) which rotates together with the Sun. According to [Vasilieva, 1984],the common solar magnetic field is maximal 1 – 2 years before solar minimum, that is why magnetic fields in sectors are the largest just in this period.

Geoeffective boundaries are those boundaries between sectors when a vertical component of the interplanetary magnetic field is changed from a north direction to a south one (in the ecliptic coordinate system). IMF influences the geomagnetic one because an IMF component directed to the South gives a possibility to interplanetary field lines to reconnect with geomagnetic lines of force on a magnetosphere daily side which leads to forced transmission of these field lines to the magnetospheric tail. And it promotes field line reconnections in the tail or beginning of magnetospheric disturbances.

Long-term changes of geomagnetic disturbances reflect 11-year, 22-year and century (80 – 90 year) solar activity cycles [Ryvin, 1983]. In some works [Ryvin, 1985; Libin, 1995] it is shown that flare magnetic storms typical for 11-year cycle maximum are better developed in uneven cycles, and recurrent disturbances developed on a cycle recession curve are much stronger in even cycles.

That is why it is more correct to connect geomagnetic disturbances with a 22-year cycle of solar magnetic activity.

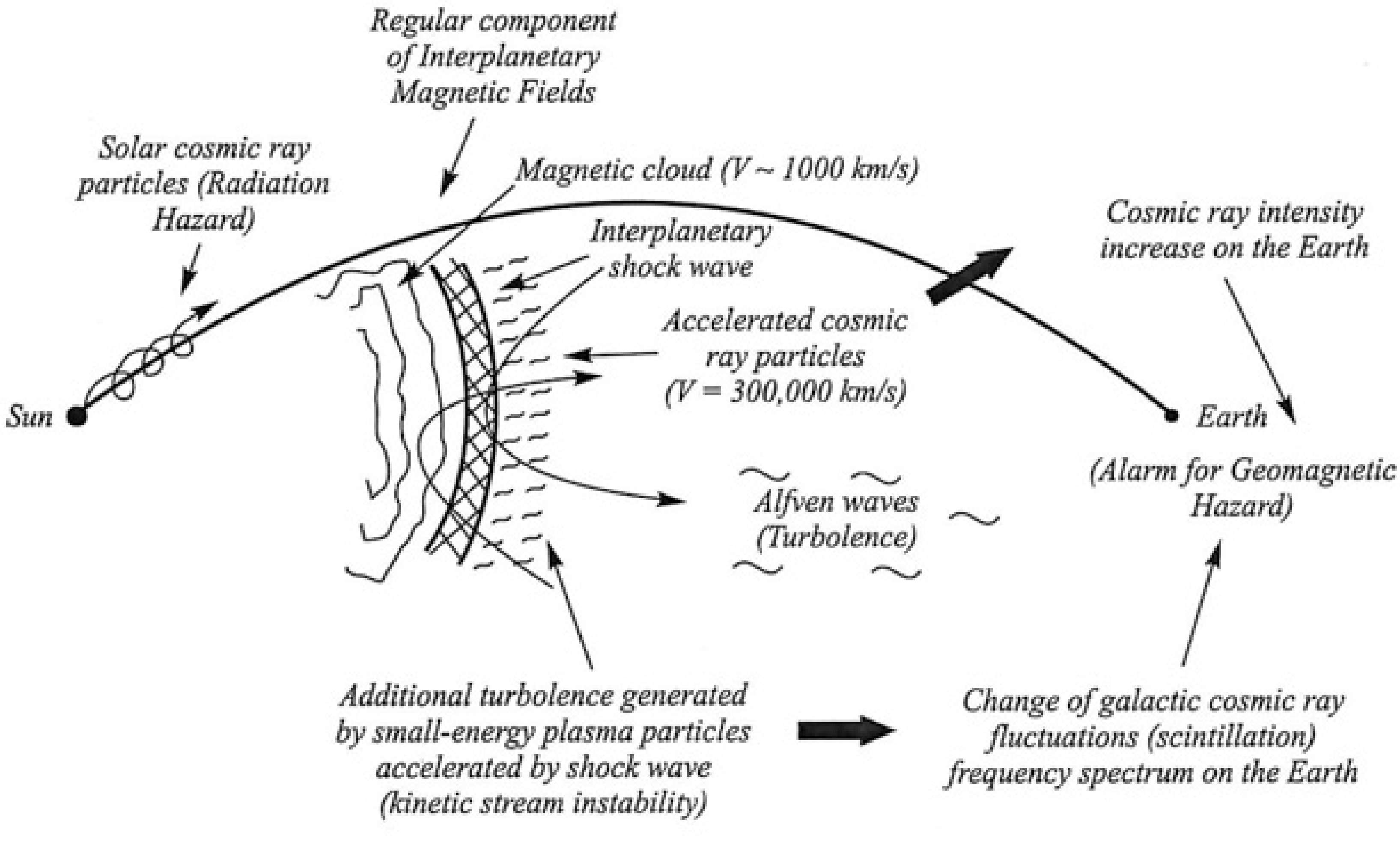
The Earth climate oscillations are also of a polycyclic character, as it was mentioned before. These are cycles which last 2 – 3 years (quasi-biennial), 4 – 7, 10 – 12, 20 – 23, 80 – 90 and 380 – 450 years.

For the first time a spectral analysis of 1000-year row of a correlation index of deuterium content to hydrogen content was made in the work [Aall, 1973] (in tree rings this index changes are proportional to changes of the atmospheric temperature).

In a result of the analysis a 22.26-year period close to a 22-year solar activity cycle was determined.

2.5.7. Cosmic ray on-line one-hour data using for forecasting of dangerous geomagnetic storms accompanied with Forbush-decreases

Thus, FD events can be used as reliable indicators of health- and safety-related harmful geomagnetic storms. For a practical realization of forecasting hazardous geomagnetic storms by means of FD indicators, it will be necessary to get data from most CR stations in real-time. (now main part of data are available only after about one month). Therefore, it is necessary to found a special Real-Time Cosmic Ray World Data Center to transform the cosmic ray station network in a real-time International Cosmic Ray Service (ICRS) [Dorman, 1993]. We present here basic ideas of the organization of such real-time data collection and processing, for providing a reliable forecast-service of FD and related dangerous disturbances of geomagnetic field. The main features observed in CR intensity before the beginning of FD that can be used for FD forecasting are the following (see Figure below):



Scheme of mechanisms of possible precursory effects in CR

a. CR pre-increase. The discovery of this effect in 1959 [Blokh, 1959] stimulated to develop the mechanism of galactic CR interactions with interplanetary shock waves [Dorman, 1959; Dorman and Freidman, 1959] and further analyses [Dorman 1995, Belov et al. 1995] showing that this effect is related to particle interaction and acceleration by interplanetary shock waves;

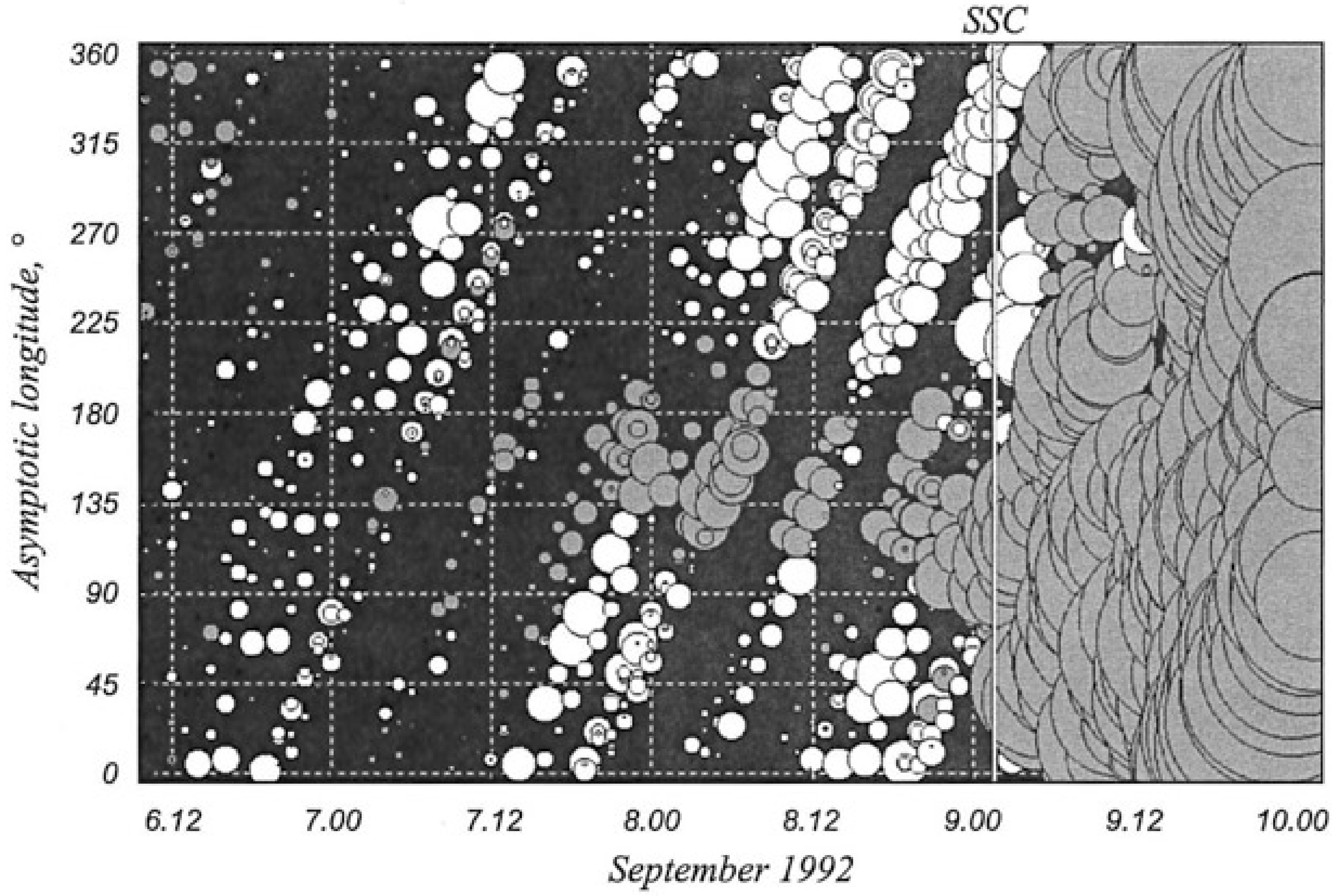
b. CR pre-decrease [McCracken and Parsons, 1958]. This effect was analyzed recently both theoretically and experimentally on the basis of the network of CR stations [Belov et al. 1995]. The pre-decrease effect can be due to a magnetic connection of the Earth with regions (moving from the Sun) with reduced CR density; this lower density can be observed at the Earth along the actual direction of IMF lines [Nagashima, 1990];

c. CR fluctuations. Many authors found some peculiarities in behavior of CR fluctuations before FD: changes in frequency spectrum; appearance of peaks in spectrum at some frequencies; variations in some special parameter introduced for characterizing the variability of fluctuations. Though the obtained results are often contradictory, sometimes CR fluctuations appear as reliable phenomena for FD prediction, as expected from additional Alfven turbulence produced by kinetic stream instability of low-energy particles accelerated by shock waves [Libin, 1995];

d. Change in 3-D anisotropy. The CR longitudinal dependence changes abruptly in directions close to usual directions of interplanetary magnetic field and depends on the character and source of the disturbance. These effects, appearing much before Forbush decreases (up to 1 day) may be considered as predictors of FD. Estimation of CR anisotropy vector may be done by the global survey method described in [Belov, 1997].

In Figure (Galactic cosmic ray, see below) we show an example of such estimation done for the 9.09.1992 event represented as a longitude-time distribution. The grey circles mark the CR intensity decrease and white circles mark the CR intensity increase (in both cases bigger diameter of circle means bigger amplitude of intensity variation). The vertical line marks the time of Sudden Storm Commencement (SSC).

One can see that the pre-increase, as well as the pre-decrease, occurs some hours (at least, 15-20 hours) before the SSC. As it was shown recently by [Munakata, 2000], the CR pre-increase and pre-decrease effects can be observed very clear also by multidirectional muon telescope world network. They investigated 14 "major" geomagnetic storms characterized by $K_p \geq 8$ – and 25 large storms characterized by $K_p \geq 7$ – observed in 1992 – 1998. It was shown that 89 % of "major" geomagnetic storms have clear precursor effects what can be used for forecasting (the probability of exact forecasting increased with increasing of the value of storm).



Galactic cosmic ray pre-increase (white circles) and pre-decrease (grey circles) effects before the Sudden Storm Commencement (SSC) of great magnetic storm in September 1992, accompanied with Forbush-decrease

We suppose that this type of analysis on the basis of on-line one-hour neutron monitor and muon telescope data from the world network CR Observatories can be made in near future automatically with forecasting of great geomagnetic storms. This important problem can be solved, for example by the ICRS, what will be based on real-time collection and exchange through Internet or FTP of the data from about all cosmic-ray stations of the network.

Then, computerized data analysis and interpretation will be done on the basis of modern theories listed in (1 – 4). It will be necessary to use also related spacecraft data in real time: cosmic ray variations in small and very small energy regions, interplanetary magnetic field and solar wind data. For this purpose neutron monitor stations of the network should have a data collection time of 1 minute and 1 hour. The organization of ICRS and continue automatically forecast will provide necessary information to space agencies, health authorities, road police and other organizations to apply the appropriate preventive procedures.

2.6. Space factors and Global Warming

It is now commonly thought of that the current trend of the global warming is causally related to the accelerating consumption of fossil fuels by the industrial nations. However, it has been suggested that this warming is a result of a gradual increase of solar and magnetic activity over the last 100 a. According to Pulkkinen et al. [Pulkkinen, 2009], as shown the solar and magnetic activity has been increasing since the year 1900 with decreases in 1970 and post 1980. Pulkkinen et al. show that that the aa index of geomagnetic activity, (a measure of the variability of the interplanetary magnetic field, IMF), varies, almost in parallel, with the sunspot activity and with the global temperature anomaly.

It has been well established that the brightness of the Sun varies in proportion to solar activity. The brightness changes are very small and cannot explain all of the present global warming. However, the gradual increase of solar activity over the last hundred years has been accompanied by a gradual decrease of CR intensity in interplanetary space [Dorman, 2009]. The direct measurements of CR intensity on the ground by the global network of NM as well as regular CR intensity measurements from balloons in the troposphere and stratosphere over a period of more than 40 a, show that there is a small negative trend of galactic CR intensity [Dorman, 2009]) of about 0.08 % per year. Extrapolating this trend to a 100 a, gives a CR intensity decrease on 8 %. According to Dickinson [Dickinson, 2006], decreasing cloud coverage by 2 % corresponds to increasing the solar radiation falling on the Earth by about 0.5 %. Using this information, Stozhkov et al. [Stozhkov] concluded that the observed increase of average planetary ground temperature of 0.4 – 0.8 °C over the last 100 a, may be a result of this negative trend of CR intensity. Sakurai [Sakurai] came to the same conclusion on the basis of analyzing data of solar activity and CR intensity.

2.6.1. A role of the interplanetary magnetic field in atmospheric processes

In Aall`s work [Aall, 1973] it is shown that in the same time an 11-year cycle is expressed in meteorological processes much weaker than a 22-year one, although an 11-year cycle (which is the basic one in sunspot formation activity) has a larger amplitude then a 22-year one.

In the work Aall also confirmed the existence of variations with periods 7, 11 – 12, 17 and 30 months in meteorological processes and also nonstationary (or quasi-stationary) variations with periods 27, 9 – 14, and 6 – 7 days which are observed synchronically in almost all meteorological indications and in disturbance characteristics of the Earth geomagnetic field [Hamilton, 1983].

He supposed in his work that 6 and 9-day rhythms in the Earth`s atmosphere are connected with an interplanetary magnetic field structure, and a 9-day one corresponds to the existence of 6 sectors with three geoactive boundary in the IMF, and a 6-day one corresponds to eight sectors with four geoactive boundaries.

So, existence of common solar rhythms in atmospheric processes and geomagnetic disturbance tells us about a common solar recourse connected with a sector structure of IPF.

In many works a connection of the lower atmosphere with the interplanetary magnetic field and a solar wind was discovered. Herewith a correlation sign between atmospheric processes and a solar wind and IMF was changed to the opposite, when the Earth moved from one sector of IMF to another.

The IMF sector structure arouses changes of a vorticity index (determined as a region in km^2 where the atmosphere circulation per a square unit reaches the value $20 \cdot 10^{-5}\ c^{-1}$), corresponding to a well-formed cyclone on isobaric surface of 300 and 500 MB in the North hemisphere.

Square of hollow low pressure regions in the North hemisphere in winter can become minimal 24 hours later after the Earth crosses the IMF sector boundary, and a vorticity minimum value is more percentagewise for regions in the troposphere characterized with more intensive circulation.

Processing of observing results made by Wilcox's group [Wilcox, 1979] in the eighties of the last century showed that a process of passing sector boundaries is accompanied with a proton flux with energy equal to tens of MeV, and a vorticity index minimum connected with sector boundaries which were followed by proton fluxes is almost twice deeper then minimum connected with usual boundaries.

Wilcox's conclusions that boundaries with proton fluxes were accompanied with a large increasing of IMF density and a vorticity index have been out of doubt till nowadays.

According to observing data of cosmic ray intensity, IMF and data about vorticity squares in the troposphere (index VAI) with a epoch syncopation method (a day when the Earth crosses a sector boundaries is considered to be a zero day) the following was found out:

1. crossing a IMF sector boundary arouses a stable effect in VAI (about 20 %, while the effect is unstable in cosmic rays);

2. when there are 21 crossings of IMF boundaries one can observe 0.5 % increase for a cosmic ray flux three days before crossing with further 1.0 – 1.5 % decrease in the same period of time;
3. when there are 28 crossings of sector boundaries effects in cosmic rays have not been observed;
4. when there are 17 crossings effects in cosmic rays have been observed but they have had an opposite character in comparison with the first case.

So, after research of sector boundary influence on a troposphere vorticity index it was proved that the effect cannot be observed directly through cosmic rays.

In a result of studying high-speed solar wind flux influence on the atmosphere circulation, geomagnetic activity and galactic cosmic ray intensity it was proven that sudden recession of galactic cosmic ray intensity begins 1 – 2 days before velocity maximum in a solar plasma flux, reaches minimum in the first day and is rebuilt to the initial value on the 4 – 5th day.

In time dependence of a geomagnetic activity index K_p a clear peak is developed in a day of plasma flux velocity maximum. In the middle and upper troposphere of the North hemisphere in middle latitudes in the moment when the Earth falls in a solar plasma high-speed flux a sudden decrease of squares occupied by deep cyclones is found out.

Received results are fully confirmed by Loginov`s works [Loginov, 1980], where he showed that increasing of a solar wind velocity leads to decreasing of cyclical activity in the troposphere. Decreasing of cyclical activity in the troposphere seems to be connected with intensity decreasing of galactic cosmic rays which play a certain role in disturbances of tropospheric circulation [Swensmark, 2008].

This effect is also well observed in studying influence of solar flares on the Earth's atmosphere. These flares lead to changes in atmosphere circulations in middle and high latitudes in 12 hours after observing flares in an optical range.

During the last years there were some attempts to check connection between cyclonic disturbance development and atmospheric vorticity, on one side, and the Earth's crossing the interplanetary magnetic field sector boundary, solar wind high-speed fluxes and solar flares, on the other. Researches that have been made during the last 20 years let us to make following conclusions:

1. The Earth moves through sector boundaries and high-speed fluxes of a solar wind and it arouses decrease of vorticity which happens in the same time with geomagnetic and electromagnetic [Artekha, 2005] disturbances and rebuilding of cosmic ray fluctuation spectrum [Libin, 2009].

It is true that a role of all electromagnetic phenomena in cyclone formation and other crisis atmospheric processes can clear up all facts mentioned above. Herewith a low (4,8 km) negative area exerts the largest influence on cyclonic rotation of whirl storm, and anticyclone movement is determined by a high (10.16 km) positive area.

If appearing charged areas really play a big role in formation, support and movement of rotating atmospheric units, a row of other factors become clearer. For example, cyclones appear more often than anticyclones, because it is easier for a denser (as it is located lower) negative area to support rotation in the whole atmospheric region in a cyclone system then for a positive area which is not so dense (as it is located higher) to rotate anticyclone system, and to organize a system of a smaller size is always easier.

For the same reason average sizes of an anticyclone are larger than average sizes of a cyclone, because the charged subsystem size threshold for supporting rotation is different.

In the work [Artekha, 2005] a plasma model of a large-scaled whirl storm to describe formation and further quasi-stationary phase of vorticity was suggested.

A process of organization of a powerful cloudy structure which accompanies powerful vorticities (where a large number of charges concentrate) is also of a great interest. Here a big role can be given to forces of electromagnetic nature (e.g. dielectrophores), when a particle is influenced by the force $F = 0,5(\varepsilon_1 - \varepsilon_2)E/r$ transmitting the particle with dielectric penetrability ε_1 in the environment with penetrability ε_2 to the region of higher density of the electric field.

As dielectric penetrability ε_1 of water steam, a fortiori, water and ice is different from dielectric penetrability of air, the mentioned force should play a big role in process of increasing of local moisture, cloud crowding to a charged zone and keeping clouds in the united system.

In a result of action of all these mechanisms for vorticities a height structure of charged regions between the positive Earth surface and a negative layer of the tropopause nearby is formed.

2. Vorticity amplification comes after powerful solar flares in the interval of heliografical longitudes 0 – 44° E.

3. Substantial amplification of vorticities can be connected with flares which are accompanied with powerful geomagnetic disturbances. As a rule, these flares are located in the eastern part of the solar disk and appear serially.

So, we can observe complex interconnection between solar activity, geomagnetic disturbance, cosmic ray intensity and atmospheric processes, and a character of this connection between all mentioned phenomena is changed from time to time and also can be different for different regions, and it makes a process of studying mechanisms of solar activity influence on the climate very difficult.

It is true, in some regions, especially, in Northern Atlantics, after geomagnetic disturbance dispersion of surface pressure variability increases. It reflects a level of conversion of a potential energy to a kinetic one that inevitably has to appear in a wind field. As a result of a statistic analysis of 90-year observation of surface pressure it was discovered that the atmosphere instability increase in middle latitudes in the northern hemisphere was observed after powerful geomagnetic disturbance [Mustel, 1981; Veretenenko, 2005].

Just because of it, research of possible connections between solar activity, the atmosphere vorticity, wind velocity, precipitation, temperature, pressure, cosmic radiation fluxes, geomagnetic and electromagnetic activity is becoming the most important problem to understand a mechanism of solar-terrestrial connections, to form helioclimatology basis.

Meanwhile, it is clear now that modulation of a cosmic ray flux and changes of climatological parameters are connected with the same processes – powerful shock waves in the interplanetary space, geomagnetic disturbances, solar flares, etc.

That is why during working out any prognostic and climatological models it is important and even necessary (as Danish and Russian scientists` latest results show) to take into consideration changes of cosmic ray intensity besides solar, geomagnetic and electromagnetic activity [Libin, 2009].

2.6.2. Data from the Past and Classification of Space Weather Dangerous Phenomena (NOAA Classification and its Modernization)

NOAA Space Weather Scale establishes 5 gradations of FEP events, what are called Solar Radiation Storms: from S5 (the highest level of radiation, corresponded to the flux of solar protons with energy > 10 MeV about 10^5 proton · $sm^{-2} \cdot sec^{-1}$) up to S1 (the lowest level, the flux about 10 proton · $sm^{-2} \cdot sec^{-1}$ for protons with energy > 10 MeV).

From our opinion, by ground level CR neutron monitors and muon telescopes it is possible monitoring and forecast (by using much higher energy particles than smaller energy particles caused the main radiation hazard) FEP events of levels S5, S4 and S3. With increasing of FEP event level of radiation will increase the accuracy of forecasting. Let us note that from our opinion, for satellite damage and influence on people health and technology, on communications by HF radio-waves more important is the total fluence of FEP during the event than the protons flux what is used now in NOAA Space Weather Scale.

The second note is, that the level S5 (corresponds to the flux 10^5 proton $\cdot$ sm$^{-2}\cdot$ sec^{-1}, or fluency $F \approx 10^9$ proton $\cdot$ sm^{-2} for protons with $E_k \geq 10$ MeV) is not maximal (as it is supposed by NOAA Solar Radiation Storms Scale), but can be much higher and with much smaller probability than S5 [Dorman et al., 1993; Dorman and Venkatesan, 1993; Dorman and Pustil'nik, 1995, 1999]. As it was shown recently by McCracken et al. (2001), the dependence of event probability from fluency can be prolonged at least up to $F = 2\cdot 10^{10}$ proton $\cdot$ sm^{-2} for protons with $E_k \geq 30$ MeV, what was observed in FEP of September 1869 according to data of nitrate contents in polar ice. This type of great dangerous events is very rarely (about one in few hundred years). According to [McCracken et al., 2001] it is not excluded that in principle can occurred very great FEP events with fluency in 10 and even in 100 times bigger (correspondingly one in few thousand and one in several ten thousand years). So, we suppose to correct the very important classification, developed by NOAA, in two directions: to use fluency F of FEP during all event (in units proton $\cdot$ sm^{-2}) instead of flux I, and to extend levels of radiation hazard. As result, the modernized classification of FEP events is shown in Table (see below).

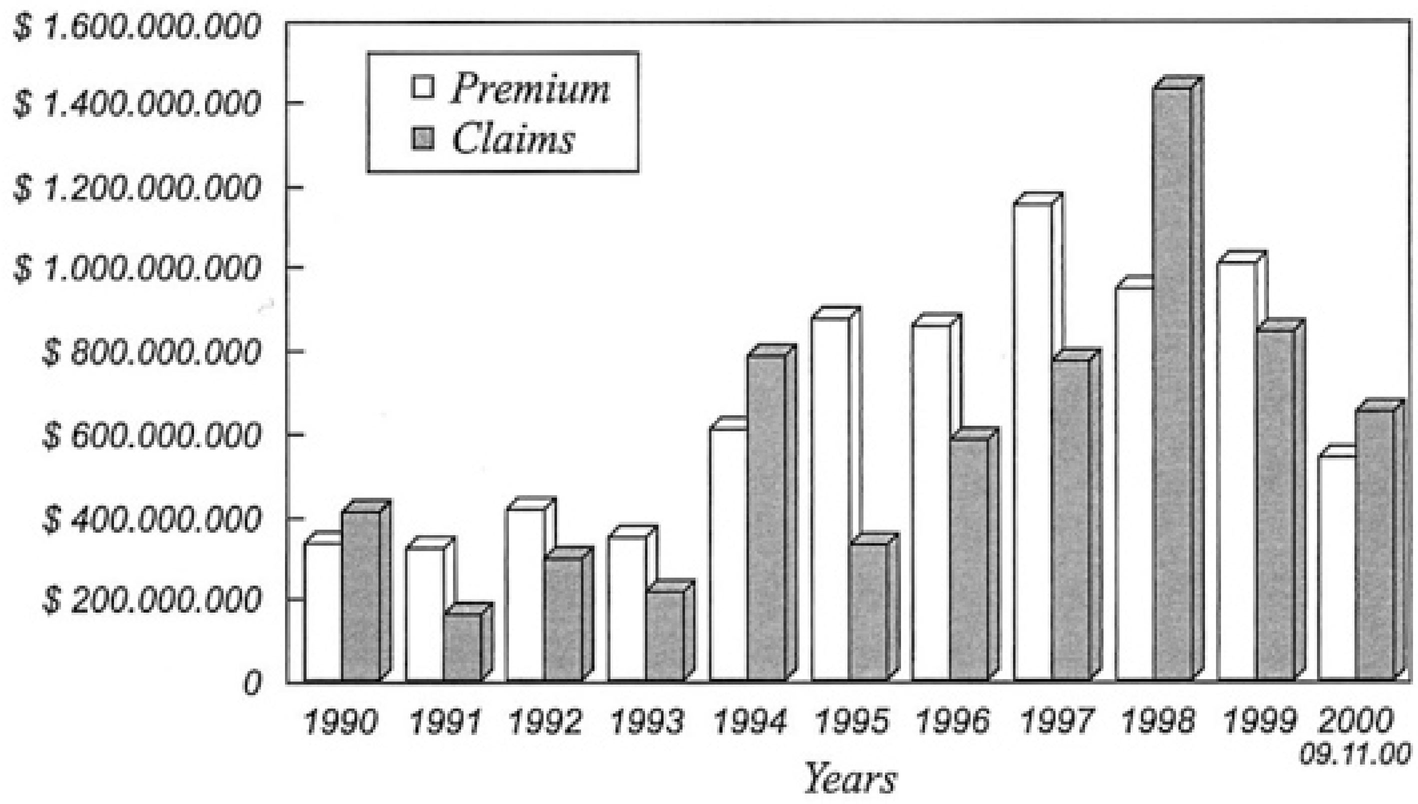
FEP events radiation hazard			Fluence level ≥ 30 MeV protons	Number of events per one year
S7	***Especially extreme***	**Biological:** Lethal doze for astronauts, for passengers and crew on commercial jets; great influence on people health and gene mutations on the ground **Satellite operations:** very big damages of satellites electronics and computers memory, damage to solar panels, loosing of many satellites **Other systems:** complete blackout of HF (high frequency) communications through polar and middle-latitude regions, big position errors make navigation operations extremely difficult.	$10^{(11-12)}$	**One in few thousand years**
S6	***Very extreme***	**Biological:** About lethal doze for astronauts, serious influence on passengers and crew health on commercial jets; possible influence on people health and genes mutations on the ground **Satellite operations:** a big damages of satellites electronics and computers memory, damage to solar panels, loosing of several satellites **Other systems:** complete blackout of HF communications through polar regions, some position errors make navigation operations very difficult.	$10^{(10-11)}$	**One in few hundred years**

FEP events radiation hazard			Fluence level ≥ 30 MeV protons	Number of events per one year
S5	***Extreme***	**Biological:** unavoidable high radiation hazard to astronauts on EVA (extra-vehicular activity); high radiation exposure to passengers and crew in commercial jets at high latitudes (approximately 100 chest x-rays) is possible. **Satellite operations:** satellites may be rendered useless, memory impacts can cause loss of control, may cause serious noise in image data, star-trackers may be unable to locate sources; permanent damage to solar panels possible. **Other systems:** complete blackout of HF (high frequency) communications possible through the polar regions, and position errors make navigation operations extremely difficult.	10^9	**One in 20 – 50 years**
S4	***Severe***	**Biological:** unavoidable radiation hazard to astronauts on EVA; elevated radiation exposure to passengers and crew in commercial jets at high latitudes (approximately 10 chest x-rays) is possible. **Satellite operations:** may experience memory device problems and noise on imaging systems; star-tracker problems may cause orientation problems, and solar panel efficiency can be degraded. **Other systems:** blackout of HF radio communications through the polar regions and increased navigation errors over several days are likely.	10^8	**One in 3 – 4 years**

FEP events radiation hazard			Fluence level ≥ 30 MeV protons	Number of events per one year
S3	***Strong***	**Biological:** radiation hazard avoidance recommended for astronauts on EVA; passengers and crew in commercial jets at high latitudes may receive low-level radiation exposure (approximately 1 chest X-ray). **Satellite operations:** single-event upsets, noise in imaging systems, and slight reduction of efficiency in solar panel are likely. **Other systems:** degraded HF radio propagation through the polar regions and navigation position errors likely.	10^7	**One per year**

2.6.3. Cosmic rays and space weather: effects on global climate change

Cosmic rays (CR) is one of important objects of space weather because namely CR of galactic and solar origin determined radiation storms and radiation hazard for people and technology, computer and memory upsets and failures, solar cell damage, radio wave propagation disturbances, failures in communication and navigation systems. Beside this CR can be used as effective instrument for space weather monitoring and forecasting dangerous phenomena.



Market premiums of insurance companies for satellite losses and failures in 1990 – 2000 [Dorman, 2009]

From Figure can be seen that the annual premiums are many hundred millions dollars. Let us note that there are not excluded very rarely, but very dangerous space phenomena (as ,for example, it was solar event at February 23, 1956), when can be destroyed about all satellites in 1 – 2 hours, the price of this will be more than 10 – 20 Billion dollars, total destroying satellite communications and a lot of other problems).

Why we need to use solar high energetic particles for FEP forecasting and determine the time of their arriving? It is well known that in periods of great flare energetic particle (FEP) ground events, fluxes of energetic particles can be so big that memory of computers and other electronics in space may be damaged, and satellite and spacecraft operations can be seriously degraded.

In these periods it is necessary to switch off some part of electronics for a few hours to protect computer memories. The problem is how to forecast exactly these dangerous phenomena. We show that exact forecasts can be made by using high-energy particles (few *GeV/nucleon* and higher) whose transportation from the Sun is characterized by much bigger diffusion coefficients than lower energy particles. High-energy particles arrive from the Sun much earlier (8 – 20 minutes after acceleration and escaping into solar wind) than the lower energy particles that damage electronics (about 30 – 60 minutes later). We describe here the principles and operation of automated programs "FEP-Search-1 min", "FEP-Search-2 min", and "FEP-Search-5 min", developed and checked in the Emilio Segre' Observatory (ESO) of the Israel Cosmic Ray Center (2025 m above sea level, R_c =10.8 GV).

The determination of increasing flux is made by comparison with the intensity, averaged from 120 to 61 minutes, prior to the current one-minute data. For each minute of data the program "FEP-Search-1 min" is run. If the result is negative (no simultaneous increase in both channels of total intensity $\geq 2.5\ \sigma_1$, where σ_1 is the standard deviation for one minute of observation in one channel [for ESO σ_1 =1.4 %]), start the program "FEP-Search-2 min", using two minute averages with $\sigma_2 = \sigma_1 / \sqrt{2}$, and so on. If any positive result is obtained, the "FEP-Search" programs check the next minute of data. If the result is again positive, automatically run the on-line the programs "FEP-Collect" and "FEP-Research" that determine the expected flux and spectrum and generate automatic alerts. These programs are described in Dorman and Zukerman (2001).

Short description of Israel Cosmic Ray Center and Emilio Segre' Observatory. The Israel Cosmic Ray Center (ICRC) and Emilio Segre' Observatory (ESO) were established in 1998, with affiliation to Tel Aviv University, to the Technion (Israel Institute of Technology, Haifa) and to the Israel Space Agency (under the aegis of the Ministry of Science). The Mobile Cosmic Ray Neutron Monitor of the Emilio Segre' Observatory, was prepared in collaboration with scientists of the Italian group in Rome, and transferred in June 1998 to the site selected for the Emilio Segre' Observatory (33°18′N, 35°47.2′E, 2025 m above sea level, vertical cut-off rigidity R_c = 10.8 GV).

The results of measurements (data taken at one-minute intervals of cosmic ray neutron total intensities at two separate 3NM-64, as well as similar one-minute data about the intensities relating to neutron multiplicities $m \geq 1, 2, 3, 4, 5, 6, 7$ and ≥ 8) have been computer-stored. Similar one-minute data relating to the atmospheric electric field, wind speed, air temperature outside, and humidity and temperature inside the Cosmic Ray Observatory have also been recorded and archived. Each month one-hour data of the Emilio Segre' Observatory (short title ESO) are sending to the World Data Center in Boulder (USA, Colorado), to the WDC C-2 for cosmic rays (Japan) and to many Cosmic Ray Observatories in the world as well as are putting to our website. We established the automatic system of electric power supply using a diesel generator for providing continuous power for the Emilio Segre' Observatory. We finished the foundation of direct radio-connection in real time scale of the Emilio Segre' Observatory with our Laboratory in Qazrin, and with the Internet. In Figure 4.1 we show a block-scheme of the main components of the Emilio Segre' Observatory (ESO) and their connection with the Central Laboratory of Israel Cosmic Ray Center in Qazrin and with the Internet.

Short description of the method of automatically search of the start of ground FEP events. Let us consider the problem of automatically searching for the start of ground FEP events. Of course, the patrol of the Sun and forecast of great solar flares are very important, but not enough: only very small part of great solar flares produce dangerous FEP events. In principal this exact forecast can be made by using high-energy particles (few *GeV/nucleon* and higher) whose transportation from the Sun is characterized by much bigger diffusion coefficient than for small and middle energy particles. Therefore high-energy particles arrive from the Sun much earlier (8 – 20 minutes after acceleration and escaping into solar wind) than the lower energy particles that cause a dangerous situation for electronics (at least about 30 – 60 minutes later). The flux of high-energy particles is very small and cannot be dangerous for people and electronics.

The problem is that this very small flux cannot be measured with enough accuracy on satellites to use for forecast (it needs very large effective surfaces of detectors and thus large weight). High-energy particles of galactic or solar origin are measured continuously by ground-based neutron monitors, ionization chambers and muon telescopes with very large effective surface areas (many square meters) that provide very small statistical errors. It was shown on the basis of data in periods of great historical FEP events (as the greatest of February 23, 1956 and many tens of others), that one-minute on-line data of high energy particles could be used for forecasting of incoming dangerous fluxes of particles with much smaller energy. The method of coupling (response) functions [Dorman, 1957; Dorman et al., 2000; Clem and Dorman, 2000] allows us to calculate the expected flux above the atmosphere, and out of the Earth's magnetosphere from ground based data. Let us describe the principles and on-line operation of programs “FEP-Search-1 min”, “FEP-Search-2 min”,”FEP-Search-5 min”, developed and checked in the Emilio Segre’ Observatory of ICRC.

On-line determination of flare energetic particle spectrum by the method of coupling functions. . Principles of FEP radiation hazard forecasting.

The problem is that the time-profiles of solar cosmic ray increases are very different for different great FEP events. It depends on the situation in the interplanetary space. If the mean free path of high-energy particles is large enough, the initial increase will be sharp, very short, only a few minutes, and in this case one or two-minute data will be useful. Conversely when the mean free path of high energy particles is much smaller, the increase will be gradual, possibly prolonged for 30 – 60 minutes, and in this case 2-, 3- or 5-minute data will be useful. Moreover, for some very anisotropic events (as February 23, 1956) the character of increase on different stations can be very different (sharp or gradual depending on the station location and anisotropy). Dorman et al. (2001) described the operation of programs “FEP Search-*K* min” (where *K* = l, 2, 3, and 5). If any of the “FEP Search-*K* min” programs gives a positive result for any Cosmic Ray Observatory the on-line program “FEP Collect” is started and collects all available data on the FEP event from Cosmic Ray Observatories and satellites. The many “FEP Research” programs then analyze these data. The real-time research method consists of:

1. Determination of the energy spectrum above the atmosphere from the start of the FEP-event (programs “FEP Research-Spectrum”);
2. Determination of the anisotropy and its energy dependence (program “FEP Research-Anisotropy”);
3. Determination of the propagation parameters, time of FEP injection into the solar wind and total source flux of FEP as a function of energy (programs “FEP Research-Propagation”, “FEP Research-Time Ejection”, “FEP Research-Source”);
4. Forecasting the expected fluxes and the spectrum in space, in the magnetosphere and in the atmosphere (based on the results obtained from steps 1 – 3 above) using programs “FEP Research-Forecast in Space”, “FEP Research-Forecast in Magnetosphere”, and “FEP Research-Forecast in Atmosphere”;
5. Issuing of preliminary alerts if the forecast fluxes are at dangerous levels (space radiation storms **S5**, **S4** or **S3** according to the classification of NOAA. These preliminary alerts are from the programs “FEP Re-

search-Alert 1 for Space", "FEP Research-Alert 1 for Magnetosphere", and "FEP Research-Alert 1 for Atmosphere".

Then, based on further on-line data collection, more accurate Alert 2, Alert 3 and so on are sent. Here we will consider three modes of the research method:

1. A single station with continuous measurements and at least two or three cosmic ray components with different coupling functions for magnetically quiet and disturbed periods;
2. Two stations with continuous measurements at each station and at least two cosmic ray components with different coupling functions; and
3. an International Cosmic Ray Service (ICRS), as described in Dorman et al. (1993), that could be organized in the near future based on the already existing world-wide network of cosmic ray observatories (especially important for anisotropic FEP events).

These programs can be used with real-time data from a single observatory (very roughly), with real-time data from two observatories (roughly), with real-time data from several observatories (more exactly), and with an International Cosmic Ray Service (much more exactly). Here we consider how to determine the spectrum of FEP and with a simple model of FEP propagation in the interplanetary space, and how to determine the time of injection, diffusion coefficient, and flux in the source. Using this simple model we can calculate expected fluxes in space at 1/2, 1, 3/2, 2 and more hours after injection. The accuracy of the programs can be checked and developed through comparison with data from the historical large ground FEP events described in detail in numerous publications (see for example: Elliot (1952), Dorman (1957), Carmichael (1962), Dorman and Miroshnichenko (1968), Duggal (1979), Dorman and Venkatesan (1993), Stoker (1995)).

Cosmic ray using for forecasting of major geomagnetic storms accompanied by Forbush-effects.

On the influence of geomagnetic storms accompanied with CR Forbush-decreases on people health and technology. There are numerous indications that natural, solar variability-driven time variations of the Earth's magnetic field can be hazardous in relation to health and safety. There are two lines of their possible influence: effects on physical systems and on human beings as biological systems. High frequency radio communications are disrupted, electric power distribution grids are blacked out when geomagnetically induced currents cause safety devices to trip, and atmospheric warming causes increased drag on satellites. An example of a major disruption on high technology operations by magnetic variations of large extent occurred in March 1989, when an intense geomagnetic storm upset communication systems, orbiting satellites, and electric power systems around the world. Several large power transformers also failed in Canada and United States, and there were hundreds of misoperations of relays and protective systems [Kappenman and Albertson, 1990; Hruska and Shea, 1993]. Some evidence has been also reported on the association between geomagnetic disturbances and increases in work and traffic accidents [Ptitsyna et al. 1998].

These studies were based on the hypothesis that a significant part of traffic accidents could be caused by the incorrect or retarded reaction of drivers to the traffic circumstances, the capability to react correctly being influenced by the environmental magnetic and electric fields. The analysis of accidents caused by human factors in the biggest atomic station of former USSR, "Kurskaya", during 1985 – 1989, showed that ~70 % of these accidents happened in the days of geomagnetic storms. In Reiter (1954, 1955) it was found that work and traffic accidents in Germany were associated with disturbances in atmospheric electricity and in geomagnetic field (defined by sudden perturbations in radio wave propagation).

On the basis of 25 reaction tests, it was found also that the human reaction time, during these disturbed periods, was considerably retarded. Retarded reaction in connection with naturally occurred magnetic field disturbances was observed also by Koenig and Ankermueller (1982). Moreover, a number of investigations showed significant correlation between the incidence of clinically important pathologies and strong geomagnetic field variations. The most significant results have been those on cardiovascular and nervous system diseases, showing some association with geomagnetic activity; a number of laboratory results on correlation between human blood system and solar and geomagnetic activity supported these findings [Ptitsyna et al. 1998].

Recently, the monitoring of cardiovascular function among cosmonauts of "MIR" space station revealed a reduction of heart rate variability during geomagnetic storms [Baevsky et al. 1996]; the reduction in heart rate variability has been associated with 550 % increase in the risk of coronary artery diseases [Baevsky et al. 1997]. On the basis of great statistical data on several millions medical events in Moscow and in St. Petersburg were found an sufficient influence of geomagnetic storms accompanied with CR Forbush-decreases on the frequency of myocardial infarcts, brain strokes and car accident road traumas [Villoresi et al., 1994, 1995]. Earlier we found that among all characteristics of geomagnetic activity, Forbush decreases are better related to hazardous effects of solar variability-driven disturbances of the geomagnetic field [Ptitsyna et al. 1998].

Next Figure shows the correlation between cardiovascular diseases, car accidents and different characteristics of geomagnetic activity (planetary index AA, major geomagnetic storms MGS, sudden commencement of geomagnetic storm SSC, occurrence of downward vertical component of the interplanetary magnetic field B_z and also decreasing phase of Forbush decreases (FD)). The most remarkable and statistically significant effects have been observed during days of geomagnetic perturbations defined by the days of the declining phase of Forbush decreases in CR intensity.

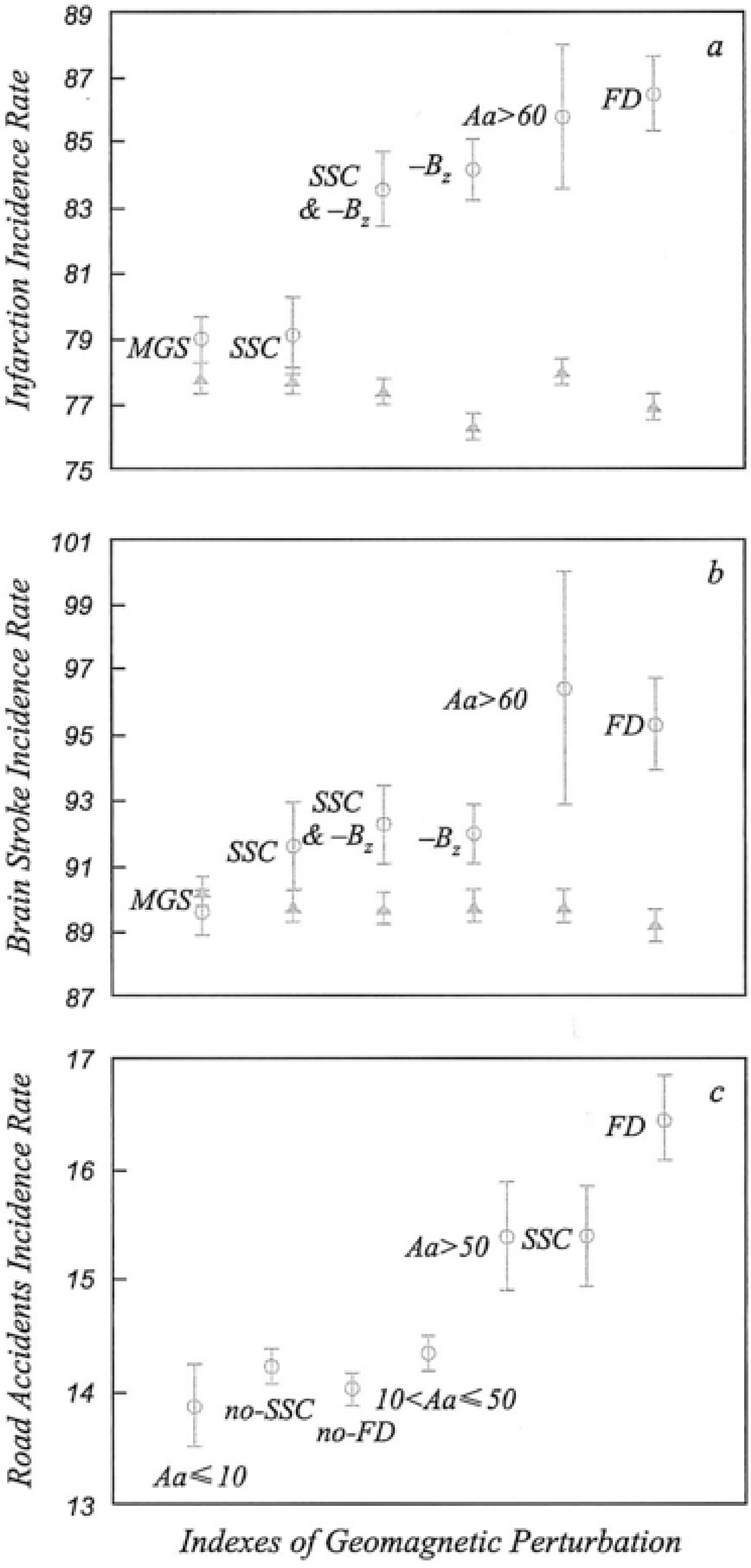
During these days the average numbers of traffic accidents, infarctions, and brain strokes increase by (17.4 ± 3.1) %, (10.5 ± 1.2) % and (7.0 ± 1.7) % respectively.

In Table (see Chapter 2) we added some preliminary information on possible biological effects according to our results discussed above.

The extended NOAA scale of geomagnetic storms influence on people health, power systems, on spacecraft operations, and on other systems (greatest three types, mostly accompanied with Forbush-decreases). In the original NOAA scale are included biological effects according to results discussed above.

Cosmic ray on-line one-hour data using for forecasting of dangerous geomagnetic storms accompanied with Forbush-decreases. Thus, FD events can be used as reliable indicators of health- and safety-related harmful geomagnetic storms. For a practical realization of forecasting hazardous geomagnetic storms by means of FD indicators, it will be necessary to get data from most CR stations in real-time. (now main part of data are available only after about one month). Therefore, it is necessary to found a special Real-Time Cosmic Ray World Data Center to transform the cosmic ray station network in a real-time International Cosmic Ray Service (ICRS) [Dorman et al. 1993]. We present here basic ideas of the organization of such real-time data collection and processing, for providing a reliable forecast-service of FD and related dangerous disturbances of geomagnetic field. The main features observed in CR intensity before the beginning of FD that can be used for FD forecasting are the following:

1. **CR pre-increase** [Blokh et al., 1959; Dorman, 1959; see review in Dorman, 1963a,b]. The discovery of this effect in 1959 [Blokh et al., 1959] stimulated to develop the mechanism of galactic CR interactions with interplanetary shock waves (Dorman, 1959; Dorman and Freidman, 1959) and further analyses [Dorman 1995, Belov et al. 1995] showing that this effect is related to particle interaction and acceleration by interplanetary shock waves;



Myocardial infarction (*a*), brain stroke (*b*) and road accident (*c*) incidence rates per day during geomagnetic quiet and perturbed days according to different indexes of activity.

2. **CR pre-decrease** [McCracken and Parsons, 1958; Fenton et al 1959; see review in Dorman, 1963a,b]. This effect was analyzed recently both theoretically [Dorman et al., 1995] and experimentally on the basis of the network of CR stations [Belov et al. 1995]. The pre-decrease effect can be due to a magnetic connection of the Earth with regions (moving from the Sun) with reduced CR density; this lower density can be observed at the Earth along the actual direction of IMF lines [Nagashima et al. 1990, Bavassano et al. 1994];
3. **CR fluctuations.** Many authors found some peculiarities in behavior of CR fluctuations before FD: changes in frequency spectrum; appearance of peaks in spectrum at some frequencies; variations in some special parameter introduced for characterizing the variability of fluctuations. Though the obtained results are often contradictory [Dorman et al. 1995], sometimes CR fluctuations appear as reliable phenomena for FD prediction, as expected from additional Alfven turbulence produced by kinetic stream instability of low-energy particles accelerated by shock waves [Berezhko et al. 1997];
4. **Change in 3-D anisotropy.** The CR longitudinal dependence changes abruptly in directions close to usual directions of interplanetary magnetic field and depends on the character and source of the disturbance. These effects, appearing much before Forbush decreases (up to 1 day) may be considered as predictors of FD. Estimation of CR anisotropy vector may be done by the global survey method described in Belov et al. (1997).

   The described above International Program for continue CR on-line one-minute and one-hour data exchange in real time scale, continue monitoring by using on-line CR data of space weather phenomena and forecasting of dangerous situations for people and technology in space, in the magnetosphere, and in atmosphere, need at least several years for realization, but, from my opinion, we need to start to go step by step along this way what is very interesting from science view, and very important from practice view. In more details this research will be reflected in monographs Dorman (2003a, b).

It is now obvious, according to past data on large variations in planetary surface temperature over timescales of many thousands (even millions) of years, that the Earth's global climate change is determined not only by internal factors but also by factors originating in space. These include the moving of the solar system around the center of our galaxy, thus crossing galactic arms, clouds of molecular dust, nearby supernovae and supernova remnants. Another important space factor is the cyclic variations of solar activity and the solar wind (mostly on the scales of decades and hundreds of years). The space factors which influence Earth's climate most, however, are cosmic rays (CR) and space dust, which influence the formation of clouds and therefore control the total energy transferred from the Sun to the Earth's atmosphere.

The propagation and modulation of galactic CR (generated mostly during supernova explosions and in supernova remnants in our galaxy) is determined within the heliosphere by their interaction with magnetic fields frozen in the solar wind and in coronal mass ejections (CME) with accompanying interplanetary shock waves (that produce big magnetic storms during their interactions with the Earth's magnetosphere). The most difficult problem of monitoring and forecasting the modulation of galactic CR in the heliosphere is that the CR intensity at some 4D point in space-time is determined not only by the level of solar activity at the time of the observations or the electromagnetic conditions at this point, but rather, by the electromagnetic conditions in the total Heliosphere.

These conditions in the total heliosphere are determined by the development of solar activity during many months leading up to the time-point of observations. This is the cause of the so-called hysteresis phenomenon in connecting galactic CR and solar activity. On the other hand, detailed investigations of this phenomenon yield the important possibility to estimate conditions in and the dimensions of the heliosphere. To solve the problem described above of CR modulation in the heliosphere, we considered as the first step the behavior of high energy particles (more than several GeV, for which the diffusion time of propagation in the heliosphere is very small in comparison with the characteristic time of modulation) on the basis of neutron monitor data in the frame of convection diffusion theory. We then take into account drift effects. For low energy galactic CR detected on satellites and space probes, we also need to take into account the additional time lag caused by diffusion in the heliosphere. Then, we consider the problem of CR modulation forecasting for several months and years ahead, which gives the possibility to forecast some part of the global climate change caused by CR.

Solar activity and CR variations as possible causes of climate change. About two hundred years ago, the famous astronomer William Herschel (1801) suggested that the price of wheat in England was directly related to the number of sunspots with periodicity about 11 years. He noticed that less rain fell when the number of sunspots was big (Joseph in the Bible, recognised a similar periodicity in food production in Egypt, about 4,000 years ago). The solar activity level is known from direct observations over the past 450 years and from data of cosmogenic nuclides (through CR intensity variations) for more than 10,000 years (see details in Chapters 10 and 17 in Dorman, M2004). Over this period there is a striking qualitative correlation between cold and warm climate periods and high and low levels of galactic CR intensity, correspondingly (low and high solar activity). As an example, Figure (see page 115) shows the change in the concentration of radiocarbon ^{14}C during the last millennium (a higher concentration of radiocarbon corresponds to a higher intensity of galactic CR and to lower solar activity). It can be seen from Figure (page 115) that during 1000 – 1300 the CR intensity was low and solar activity high, which coincided with the warm medieval period (during this period Vikings settled in Greenland). After 1300 solar activity decreased and CR intensity increased, and a long cold period followed (the so called Little Ice Age, which included the Maunder minimum 1645 – 1715 and lasted until the middle of 19th century).

The possible role of solar activity and solar irradiance in climate change. Friis-Christensen and Lassen (1991), Lassen and Friis-Christensen (1995) found, from four hundred years of data, that the filtered solar activity cycle length is closely connected to variations of the average surface temperature in the northern hemisphere. Labitzke and Van Loon (1993) showed, from solar cycle data, that the air temperature increases with increasing levels of solar activity. Svensmark (2000) and Shapiro et al. (2011) also discussed the problem of the possible influence of solar activity on the Earth's climate through changes in solar irradiance. But the direct satellite measurements of the solar irradiance during the last two solar cycles showed that the variations during a solar cycle was only about 0.1 %, corresponding to about 0.3 W/m^2. This value is too small to explain the observed climate changes during solar cycles (Lean et al., 1995).

The reconstruction of solar irradiance from 7000 BC up to 500 AD shows variations from 1358 up to 1370 W/m^2, i.e. not more than 1 % (Shapiro et al., 2011). Much bigger changes during a solar cycle occur in UV radiation: according to Shapiro et al. (2011), the flux of solar irradiation during 1600-2000 in interval 500 – 600 nm varied in limits of 0.4 %, in 370 – 400 nm (CN violet system) ~3.2 %, in 200 – 242 nm (Herzberg continuum) ~10.9 %, and in 175 – 200 nm (Schumann-Runge bands) ~26.6 % (these changes are important for variations in formation of the ozone layer). Haigh (1996), and Shindell et al. (1999) suggested that the heating of the stratosphere by UV radiation can be dynamically transported into the troposphere. This effect might be responsible for small contributions towards 11 and 22 years cycle modulation of climate but not to the 100 years or more of climate changes that were observed in the past and during the last hundred years (Dobrica et al., 2009). Hong et al. (2011) examined the effect of the 11-year solar cycle and quasi-biennial oscillation on the 27-day solar rotational period detected in tropical convective cloud activity (it was analyzed data of outgoing long wave radiation for 1979 – 2004).

Cosmic rays as an important link between solar activity and climate change. Many authors have considered the influence of galactic and solar CR on the Earth's climate. Cosmic radiation is the main source of air ionization below 40 – 35 km (only near the ground level, lower than 1 km, are radioactive gases from the soil also important in air ionization – see review in Dorman, M2004). The first who suggest a possible influence of air ionization by CR on the climate was Ney (1959). Svensmark (2000) noted that the variation in air ionization caused by CR could potentially influence the optical transparency of the atmosphere, by either a change in aerosol formation or influence the transition between the different phases of water. Many authors considered these possibilities (Dickinson, 1975; Pudovkin and Raspopov, 1992, Pudovkin and Veretenenko, 1995, 1996; Belov et al., 2005; Dorman, 2005a, b, 2006, 2007). The possible statistical connections between the solar activity cycle and the corresponding long term CR intensity variations with characteristics of climate change were considered in Dorman et al. (1987, 1988a, b). Dorman et al. (1997) reconstructed CR intensity variations over the last four hundred years on the basis of solar activity data, and compared the results with radiocarbon data.

Cosmic rays play a key role in the formation of thunder-storms and lightnings (see extended review in Dorman, M2004, Chapter 11). Many authors [Markson, 1978; Price, 2000; Tinsley, 2000; Schlegel et al., 2001; Dorman and Dorman, 2005; Dorman et al., 2003] have considered atmospheric electric field phenomena as a possible link between solar activity and the Earth's climate. Barnard et al. (2011) used data on cosmogenic nucleus in ice for about 9300 years for investigation of great solar energetic particle events and long-time galactic cosmic ray variations for research of space climate in the past and possible predictions for some time ahead.

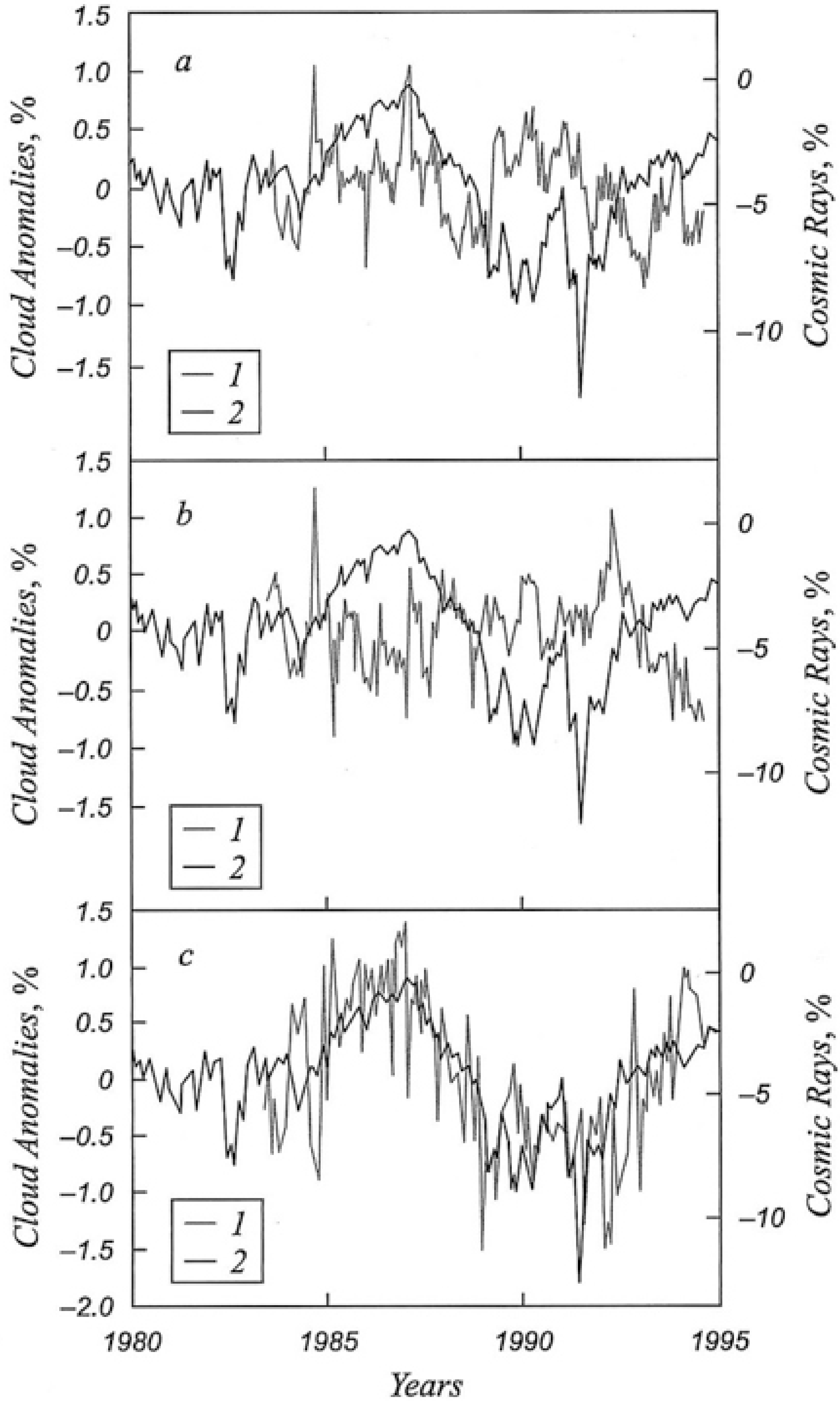
The obtained important information can be used for investigation of the link between cosmic ray intensity and the Earth's climate change. Also important in the relationship between CR and climate, is the influence of long term changes in the geomagnetic field on CR intensity through the changes of cutoff rigidity (see review in Dorman, M2009). It can be considering the general hierarchical relationship: (solar activity cycles + long-term changes in the geomagnetic field) → (CR long term modulation in the Heliosphere + long term variation of cutoff rigidity) → (long term variation of clouds covering and aerosols + atmospheric electric field effects) → climate change.

The Connection between galactic CR solar cycles and the Earth's cloud coverage. Recent research has shown that the Earth's cloud coverage (observed by satellites) is strongly influenced by CR intensity [Svensmark, 2000; Marsh and Svensmark, 2000 a,b]. Clouds influence the irradiative properties of the atmosphere by both cooling through reflection of incoming short wave solar radiation, and heating through trapping of outgoing long wave radiation (the greenhouse effect). The overall result depends largely on the height of the clouds. According to Hartmann (1993), high optically thin clouds tend to heat while low optically thick clouds tend to cool (see Table 1). According to Smith at al. (2011), the Clouds and Earth Radiant Energy System (CERES) project's objectives are to measure the reflected solar radiance (shortwave) and Earth-emitted (longwave) radiances and from these measurements to compute the shortwave and longwave radiation fluxes at the top of the atmosphere and the surface and radiation divergence within the atmosphere.

From other hand, we can see that the total cloudiness gives input of solar energy – 27.7 W/m^2, so 3% decreasing of cloudiness will give about + 1 W/m^2.

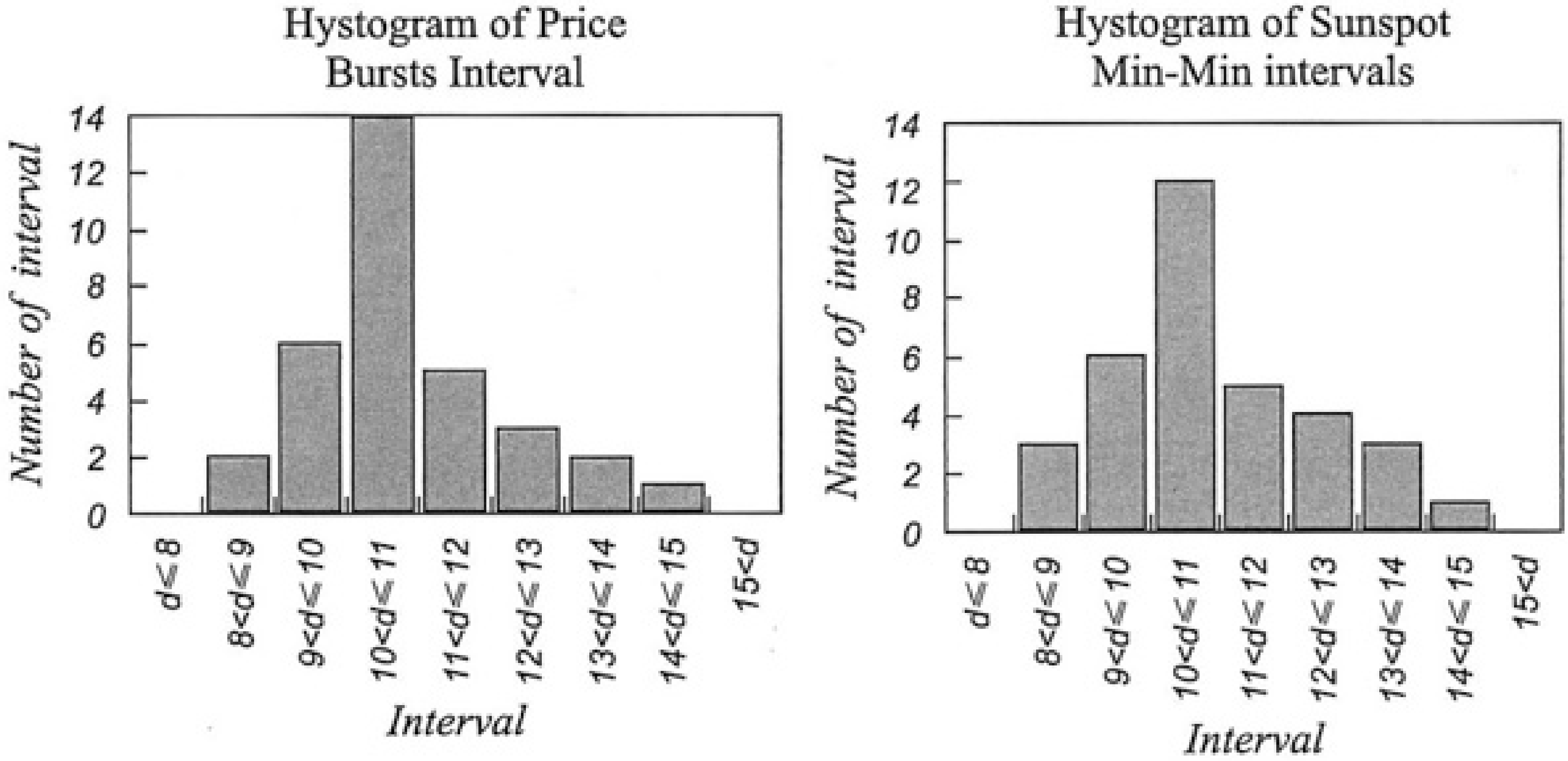
From next Figure it can be seen that practically is no connection between CR intensity variations and changes in cloudiness for high and middle altitude clouds (panels *a* and *b*), but is a high positive correlation for low altitude clouds (panel *c*).

Solar irradiance and cosmic ray fluxes during Maunder minimum: influence on climate change. During the Maunder minimum the CR intensity was very high, so the planetary surface temperature is expected to be lower than in years with high level of solar activity. As was shown above, exactly this was observed by using ^{14}C data.



CR intensity obtained at the Huancayo/Haleakala neutron monitor (normalized to October 1965, curve *2*) in comparison with global average monthly cloud coverage anomalies (curves *1*) at heights, *H*, for: *a* – high clouds, $H > 6.5$ km, *b* – middle clouds, 6.5 km $> H >$ 3.2 km, and *c* – low clouds, $H < 3.2$ km. According to Marsh and Svensmark (2000)

Variations of CR Intensity and wheat prices in the medieval England. As it was noted in Section 2, Herschel's observations (1801) were based on the published wheat prices (Smith, M1776), and showed that five prolonged periods of sunspot numbers correlated with costly wheat. This idea was taken up by the English economist William Jevons (1875, 1982). He directed his attention to the wheat prices from 1259 to 1400 and showed that the time intervals between high prices were close to 10 – 11 years. The coincidence of these intervals with the period of the eleven year cycle of solar activity led him to suggesting that the solar activity cycle was a 'synchronization' factor in the fluctuations of wheat prices. As a next step, he extrapolated his theory to stock markets of the 19th Century in England and was impressed by a close coincidence of five stock exchange panics with five minima in solar spot numbers that preceded these panics. The Rogers (M1887) database on wheat prices in medieval England was used by Pustil'nik, Dorman, and Yom Din (2003) to search for possible influences of solar activity and CR intensity variations on wheat prices. Obtained results are demonstrated in Figsure (see below).



Distributions of intervals d (in years) between wheat price bursts during 1249 – 1702 (left), and of intervals between minimums of sunspot numbers during 1700 – 2000 (right). According to Pustil'nik, Dorman, and Yom Din (2003)

On the Influence of galactic CR Forbush decreases and solar CR increases on rainfall and air temperature. A decrease of atmospheric ionization leads to a decrease in the concentration of charge condensation centres. In these periods, a decrease of total cloudiness and atmosphere turbulence together with an increase in isobaric levels is observed (Veretenenko and Pudovkin, 1994). As a result, a decrease of rainfall is also expected. Stozhkov et al. (1995a, b, 1996), and Stozhkov (2002) analyzed 70 events of Forbush decreases (defined as a rapid decrease in observed galactic CR intensity, and caused by big geomagnetic storms) observed in 1956 – 1993 and compared these events with rainfall data over the former USSR. It was found that during the main phase of the Forbush decrease, the daily rainfall levels decreases by about 17%. Similarly, Todd and Kniveton (2001, 2004) investigating 32 Forbush decreases over the period 1983 – 2000, found reduced cloud cover on 12 – 18 %. Laken and Kniveton (2011) investigate 47 Forbush decreases over the period 1985-2006 and confirmed this result of Todd and Kniveton (2001, 2004).

Artamonova and Veretenenko (2011), using the Apatity neutron monitor data, analyzed daily averaged values of geo-potential heights (GPH) of the main isobaric levels 1000, 850, 700, 500, 300 and 200 mb (NCEP/NCAR data) and found effects of Forbush decreases on the variations of pressure in the lower atmosphere during 48 events in October – March for the period 1980 – 2006. Mansilla (2011) found that big magnetic storms (produced Forbush decreases) lead to increasing of air temperature and wind's velocity.

During big solar CR events, when CR intensity and ionization in the atmosphere significantly increases, an inverse situation is expected and the increase in cloudiness leads to an increase in rainfall. Studies of Stozhkov et al. (1995a, b, 1996), and Stozhkov (2002) involving 53 events of solar CR enhancements, between 1942 – 1993, showed a positive increase of about 13 % in the total rainfall over the former USSR.

Convection-diffusion and drift mechanisms for long-term galactic CR variation: possible forecasting of some part of climate change caused by cosmic rays. From above consideration follows that CR may be considered as sufficient link determined some part of solar wind as element of space weather influence on the climate change. From this point of view it is important to understand mechanisms of galactic CR long-term variations and on this basis to forecast expected CR intensity in near future. In Dorman (2005a, b, 2006) it was made on basis of monthly sunspot numbers W with taking into account time-lag between processes on the Sun and situation in the interplanetary space as well as the sign of general magnetic field. From obtained results it follows that in the frame of convection-diffusion and drift models can be determined with very good accuracy expected galactic CR intensity in the past (when W are known) as well as behaviour of CR intensity in future (if sunspot numbers W can be well forecast).

Influence of main geomagnetic field on global climate change through CR cutoff rigidity variation. When we consider galactic CR variations $\Delta I/I_0$ as a factor influencing global climate change, we need to take into account not only the effects of the solar wind and Heliosphere, but also cutoff rigidity RC changes on C_R intensity variation: $\Delta I/I_0 = \Delta R_C \cdot W(R_C, R_C)$, where ΔRC is the change of cutoff rigidity and $W(R_C, R_C)$ is the coupling function $W(R_C, R)$ at $R = R_C$ (see in details in Dorman, M2004). Expected changes of cutoff rigidities were found in many papers [Bhattacharyya and Mitra, 1997; Shea and Smart, 2003; Kudela and Bobik, 2004; see review in Dorman, M2009]. It can be seen a big changes of cutoff rigidities in some places. We suppose to investigate this problem in near future in more details in possible connection with historically known places on the World where local climate changes pressed people to move to other places with better climate. It is not excluded that observed 22-year hurricane cycle connection with geomagnetic and solar activity cycles ([Mendoza and Pazos, 2009]) may be caused also by the link of these cycles with cosmic rays and their influence on on meteorological processes.

Analysis of Kristjánsson and Kristiansen (2000) contradicts the simple relationship between cloud cover and radiation assumed in the cosmic-ray-cloud-climate hypothesis, because this relationship really is much more complicated and is not the main climate-causal relationship. I agree with this result and with result of Erlykin et al. (2009a, b) and Erlykin and Wolfendale (2011) that there is no simple causal connection between CR and low cloud coverage (LCC), that there is no correlation between CR and LCC for short-term variations, and that while there is correlation between CR and LCC for long-term variations, that this connection can explain not more than about 20 % of observed climate change.

But the supposition of Erlykin et al. (2009a, b) that the observed long-term correlation between cosmic ray intensity and cloudiness may be caused by parallel separate correlations between CR, cloudiness and solar activity contradicts the existence of the hysteresis effect in cosmic rays caused by the big dimensions of the Heliosphere [Dorman and Dorman, 1967a, b; Dorman et al., 1997; Dorman, 2005a, b, 2006]. This effect, which formed a time-lag of cosmic rays relative to solar activity of more than one year (different in consequent solar cycles and increasing inverse to particle energy), gives the possibility of distinguishing phenomena caused by cosmic rays from phenomena caused directly by solar activity (i.e. activity without time lag). The importance of cosmic ray influence on climate compared with the influence of solar irradiation can be seen clearly during the Maunder minimum. Cosmic ray influence on climate over a very long timescale of many hundreds of years can be seen from Fig. 1 (through variation of ^{14}C).

It is necessary to take into account that the main factors influencing climate are meteorological processes: cyclones and anticyclones; air mass moving in vertical and horizontal directions; precipitation of ice and snow (which changes the planetary radiation balance, see Waliser et al., 2011); and so on. Only after averaging for long periods (from one-ten years up to 100 – 1000 years and even million of years) did it become possible to determine much smaller factors that influence the climate, such as cosmic rays, dust, solar irradiation, and so on. For example, Zecca and Chiari (2009) show that the dust from comet 1P/Halley, according to data of about the last 2000 years, produces periodic variations in planetary surface temperature (an average cooling of about 0.08 °C) with a period 72 ± 5 years.

Cosmic dust of interplanetary and interstellar origin, as well as galactic cosmic rays entering the Earth's atmosphere, have an impact on the Earth's climate (Ermakov et al., 2006, 2007, 2009; Kasatkina et al., 2007a, b). Ermakov et al. (2006, 2009) hypothesized that the particles of extraterrestrial origin residing in the atmosphere may serve as condensation nuclei and, thereby, may affect the cloud cover. Kasatkina et al. (2007a, b) conjectured that interstellar dust particles may serve as atmospheric condensation nuclei, change atmospheric transparency and, as a consequence, affect the radiation balance. Ogurtsov and Raspopov (2011) show that the meteoric dust in the Earth's atmosphere is potentially one of the important climate forming agents in two ways:

1. Particles of meteoric haze may serve as condensation nuclei in the troposphere and stratosphere;
2. Charged meteor particles residing in the mesosphere may markedly change (by a few percent) the total atmospheric resistance and thereby, affect the global current circuit.

Changes in the global electric circuit, in turn, may influence cloud formation processes.

Let us underline that there is also one additional mechanism by which cosmic rays influence lower cloud formation, precipitation, and climate change: the nucleation by cosmic energetic particles of aerosol and dust, and through aerosol and dust – increasing of cloudiness. It was shown by Enghoff et al. (2011) in the frame of the CLOUD experiment at CERN that the irradiation by energetic particles (about 580 MeV) of the air at normal conditions in the closed chamber led to aerosol nucleation (induced by high energy particles), and simultaneously to an increase in ionization [Kirkby et al., 2011].

Let me note that in our paper, we considered cosmic rays and dust aerosols separately, but acting in the same direction. Increasing cosmic ray intensity and increasing of aerosols and dust leads to increasing of cloudiness and a corresponding decrease of planetary surface temperature. Now, consistant with the experimental results of Enghoff et al. (2011) on aerosol nucleation in the frame of the CLOUD Project on the accelerator at CERN (see short description of this Project in Dorman, M2004), it was found that with increasing intensity of energetic particles, the rate of formation of aerosol nucleation in the air at normal conditions increased sufficiently. This result can be considered as some physical evidence of the cosmic ray – cloud connection hypothesis.

When considering CR variations as one of the possible causes of long-term global climate change, we need to take into account not only CR modulation by the solar wind but also the changing of geomagnetic cutoff rigidities. This is especially important when we consider climate change on a scale of between 10^3 and 10^6 years. Paleomagnetic investigations show that during the last 3.6×10^6 years, the magnetic field of the Earth has changed polarity nine times. The Earth's magnetic moment has changed as well, sometimes having a value of only one-fifth of its present value (Cox et al., 1967). This corresponds to a decreasing of the cutoff rigidity, which in turn leads to an increasing of CR intensity and a decreasing of the surface temperature. When we consider the situation in the frame of timescales of many thousands and millions of years, we need to take into account also possible changes of galactic CR intensity out of the Heliosphere. It is furthermore not excluded that the gradual increasing of planetary surface temperature observed in the last hundred years is caused not by anthropogenic factors, but by space factors (mainly by CR intensity variation).

It is necessary to continue investigations on the connection between CR intensity and climate factors like cloudiness, raining, and surface temperature, not only by statistical investigations in the frame of different timescales, but also by special experiments on accelerators and through the development of physical models. As we mentioned in Section 11, it will also be important to investigate the possible connection between big changes in cosmic ray cutoff rigidity and historically known places in the world where local climate change pressed people to move to other places with better climates.

"My tongue was truthful like a spectral analysis,
And words dragged under my feet".

Arseny Tarkovsky

"Everybody knows a curious capability of a spectral autoregressive analysis to make the difficult simple and to find out logic harmonious mutual correspondence in a seeming disorder".

M. Batt "Spectral Analysis in Geophysics".

3. ABOUT POSSIBLE ANALYSIS OF SOLAR ACTIVITY INFLUENCE ON CLIMATIC PROCESSES

3.1. Methods of joint analysis of cosmophysical and climatological processes

3.1.1. Spectral analysis of researched processes

The analysis of parameters of solar activity (Wolf numbers W, sunspot square S, HL-index, solar radiation level on the Earth), geomagnetic disturbances (K_p-index) and atmospheric processes (pressure, temperature, precipitation, level of closed water system, ice square) was made in general with methods of correlation and spectral analysis.

Practical technique of spectrum estimation always consists of several stages – preliminary analysis, calculation of sample covariance and correlation functions and spectral estimations, calculation of mutual correlation functions and mutual spectral estimations, interpretation of receive results.

Preliminary analysis consists in research of temporal series to reveal stationarity and leading them, if it is necessary, to a stationary or quasi-stationary look, finding out apparent trends and periodicities in the data set under research (it is important for solving a problem about data filtration in a test analysis PILOT ANALYSIS).

If it becomes clear in a result of a preliminary analysis that a larger part of estimated spectrum power concentrates on one or several dedicated frequencies, data filtration or conversion of each of initial rows x_t and y_t to a certain data set x'_t and y'_t with a help of various linear and quasi-linear correlations is necessary.

To solve a problem about the use of initial or filtered rows for the analysis, to choose a width of the window with a help of which the series under research are seen during the analysis sample correlation functions are calculated:

$$C_{xx}(\tau)=\left(\frac{1}{N-1}\right)\sum_{t=1}^{N-k}(x_t-\hat{x})(x_{t+\tau}-\hat{x}) \tag{1}$$

for values $\tau = 0, 1, 2, \ldots\ldots, L_{max}$. (A cut-off point quantity L_{max} is chosen from the criterion of sample correlation minimum. A cut-off point L_{max} is reached when sample correlations $C_{xx}(\tau)$ become equal to 0.05 – 0.1. A problem about the use of initial or filtered rows is solved on the basis of the condition that correlation functions of them are reduced to zero).

After solving of a problem about the use of initial or filtered rows and choosing a cut-off point sample spectral densities $S_{xx}(f)$ are calculated. (To avoid terminological confusion – spectral density of the process under research is Fourier transform of its correlation or covariance functions):

$$S_{xx}(f)=2\Delta\left[C_{xx}(0)+2\sum_{\tau=1}^{L_{max}-1}C(\tau)W(\tau)\cos 2\pi f\tau\Delta\right]$$

where Δ is the series sampling interval, $W(\tau)$ is a lag window with a cut-off M chosen from the correlation $M = L_{max}\tau$ (there are a great deal of lag windows each of which has its own advantages and disadvantages relative to exact problems).

To find out correlation connections between different processes a mutual spectral analysis is used. It consists in calculation of mutual correlation functions which permit to find out delay time of one of the processes under study relative to another on the basis of maximal coefficient of mutual correlation or shift quantity r between maximum position of a mutual correlation function and zero value r.

(Delay time estimation is of a great importance especially during analysis of connections between solar and magnetic activities and processes occurring on the Earth and can be used by scientists in their attempts to forecast processes occurring on the Earth basing on changes of solar and interplanetary activity).

Formulas for discreet estimation of mutual spectrums (when two or more data series are estimated simultaneously) are analogical to formulas for estimation of spectral densities of univariate processes (when only one data series is analyzed), but mutual analysis gives a possibility to get information about phase difference between analyzed processes on each frequency (a phase spectrum) and degree of correlatedness of processes between each other on different frequencies (a coherence spectrum).

As it is showed in many works about spectral analysis, if two series in some frequency interval are moved in relation to one another to some timely interval or they can be presented as:

$$x_{2t} = z_{2t} + \beta_1 z_{1t-d}, x_{1t} = z_{1t},$$

$$x_{2t} = z_{2t} + \beta_1 x_{1t-d}$$

a phase spectrum in this frequency range is regarded as a linear function of frequency.

It means that a cosine wave of frequency *f* Hz makes *fd* oscillations for delay time *d* and, consequently, phase delay is 2*nfd* rad.

So, on the basis of a phase spectrum showing phase differences between processes it is possible to find delay time of one series relative to another for each frequency, and it can be of a great importance during making forecasts of different duration (short-term and long-term).

Analysis of parameters of solar activity, geomagnetic disturbances, solar radiation, global and local atmospheric processes and cosmic ray intensity was made with a help of methods of a univariate and mutual spectral analysis, two-dimensional spectral analysis Hissa, multiple correlation conversion, methods of periodically correlated sudden process theory.

The analysis was made on the basis of data of monthly average and yearly average solar activity values (Wolf numbers *W*, sunspot square *S*, *HL*-index for 1880 – 2008), cosmic ray intensity (registration data of cosmic ray stations Kiel, Troitsk, Appatity, Mac-Merdo, etc. for 1963 – 2008), geomagnetic activity (K_p and A_p-indexes for 1945 – 2001), the atmosphere circulation (storm degree index *P* for 1950 – 2000), temperature *T* °C, pressure and precipitation (registration data of meteorological stations of Russia, Estonia, Mexico, Sweden, Lithuania, Canada for 1920 – 2008), levels of closed water systems (Lake Patscuaro in Mexico, Lake Chudskoye and Lake Baikal in Russia, the Caspian Sea for 1880 – 2007), solar radiation (registration data of meteorological stations of Russia, Mexico, Cuba, Denmark and Canada for 1960 – 2008), ice square in the Baltic and White Seas (registration data of meteorological stations of Russia, Estonia, Denmark and Sweden for 1920 – 2008).

Spectral estimations were calculated on the basis of all intervals as a whole and 72-month (or 144-month) realizations with 12-month sliding shift (to receive a time-detailed picture of behavior of correlation and spectral estimations during 18 – 24 solar activity cycles).

Truthfulness of received results was controlled with simultaneous appliance of different special methods and procedures (data filtration, closing spectral windows, etc.) as well as constant use of test programs.

It is possible to find out detailed information about spectral estimation calculations in many works, but it is necessary to take into consideration that a preliminary stage of any mutual spectrum calculations estimations of displacement between processes should be with a help of calculation of maximal value of mutual shift correlation:

$$K_{xy}(\tau) = \sum_{t=1}^{N-\tau} \frac{(x_t - \hat{x})(y_{t+\tau} - \hat{y})}{\sigma_x^2 \sigma_y^2}$$

or on the basis of a shift τ value between mutual correlations function maximum and a zero.

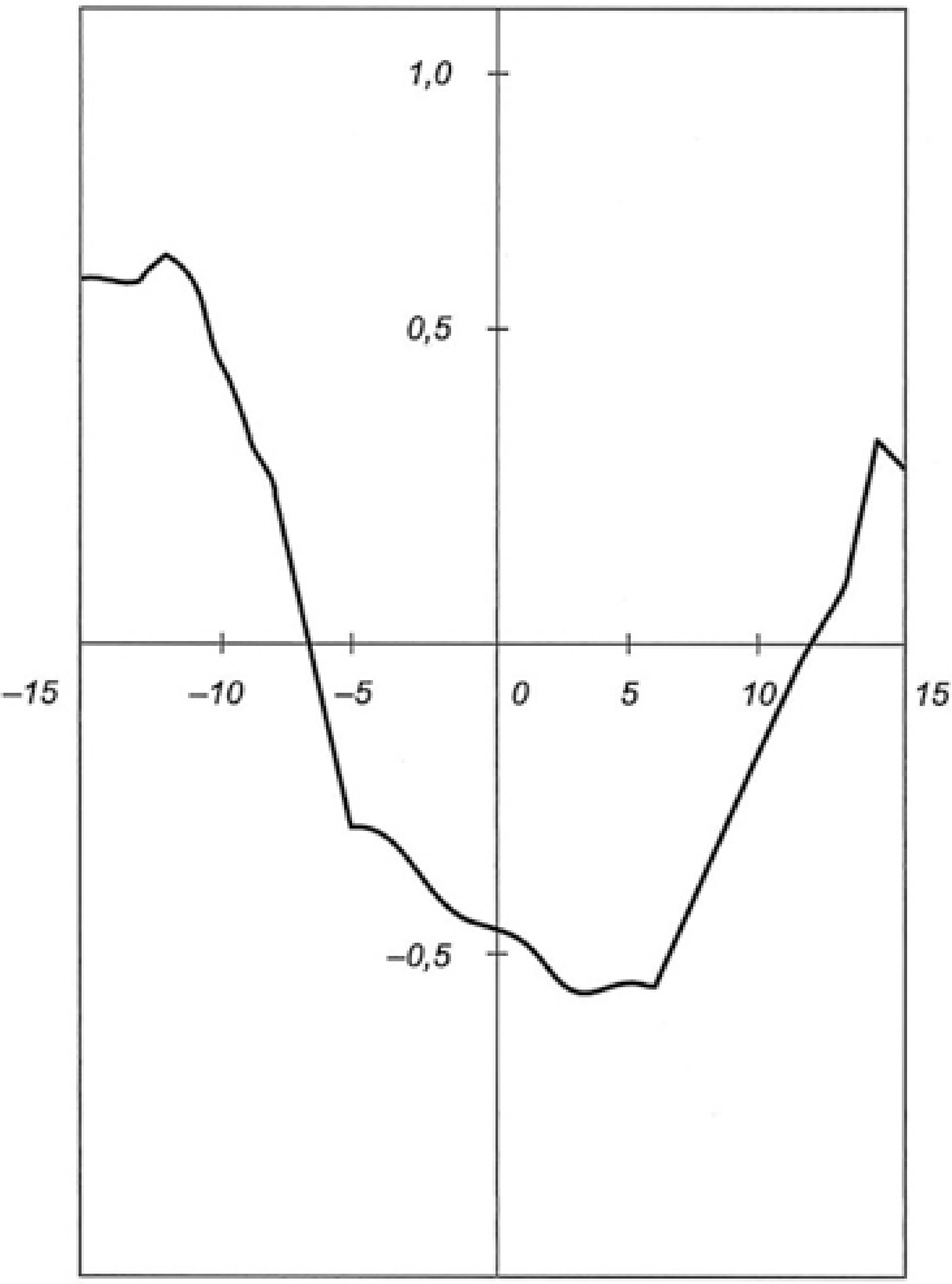
An example of these calculations are shown in the figure. Here is a cross-correlation between solar activity and temperature. Magnitude of the shift is 36 months.

All tests of spectral analysis programs permitted to precise the use of different methods in different conditions for concrete events and data series. If to test all used programs of dynamic spectral analysis with a help of the function

$$S(f) = \sin(f_0 + \Delta f) + \sin(f_1) + \sin(f_2)$$

it is possible to be sure that if position of density spectrum peaks is not changed on fixed frequencies, on frequency $f_0 + \Delta f$ a peak is transformed slowly to the region of higher frequencies tracing the change Δf_i.

It is necessary to note that practically all spectral methods are useful for stationary processes when all analyzed processes are not stationary. That is why analyzed data filtration precedes calculation of spectrums, especially dynamic ones.



Cross-correlation function between SA and T °C [Libin and Perez Peraza, 2009]

3.1.2. Autoregressive analysis methods for estimation of connections between cosmophysical and meteorological parameters

Together with the use of spectral methods the use of independent periodicity methods with properties different from the others is reasonable. (The latter is important for mutual control of received results).

Besides, in a series of analyzed processes statistic characteristics of them are rebuilt, or processes are becoming non-stationary. In this case a concept of spectrum is not defined, but classical data rebuilding based on the fast Fourier and Blackman-Tukey transform methods often give incorrect results.

A usual way in such situation is separation of quasi-stationary parts meets some difficulties. Such parts (if they exist) can be short, and the Fourier method based on a small quantity of data gives bad results and does not permit to separate close frequencies.

In the same time a frequency separation problem is one of the main points of the problem under study, as each of these frequencies can be connected with different physical mechanisms of interaction of cosmophysical and meteorological parameters.

To separate frequencies on short data sections autoregressive methods have been used lately. The essence of them consists in entering additional supposition that each researched processes can be described with an autoregressive model of an unknown order p (for $t = 0, 1, 2, \ldots$).

$$x_{t+1} = \sum_{i=0}^{p} a_{i+1} x_{t+1} \tag{2}$$

In this supposition autoregression coefficients are estimated with this or that method and the best order is searched, and the spectrum is calculated on the basis of these coefficients.

This approach with the use of different algorithms (as Berg, Levinson-Derbin, Pisarenko, Prony methods and their modifications) was realized by O.V. Gulinsky and K.F. Yudakhin and gave good results in some cases.

To get over the difficulties the authors (together with O.V. Gulinsky and K.F. Yudakhin) suggested the following approach – it was supposed that the process could be described with an autoregressive model in which coefficients themselves were changed in time

$$x_{t+1} = \sum_{i=0}^{p} a_{i+1}(t)\, x_{t+1},\ t = 0, 1, 2, \ldots \tag{3}$$

It is clear that such process is not stationary. Each coefficient is presented as some given full function system series $\{\varphi_k\}$

$$a_i(t) = \sum_{k=1}^{N} C_{ik} \varphi_k(t) \tag{4}$$

with unknown coefficients $\{C_k\}$. A power series $\{1, x, x^2, \ldots\}$ particularly can be chosen as a function system.

Then coefficients C_k are calculated with a least square technique for the elected decomposition number N (4) and the model order p (3). The model order p and term number N in decomposition can be chosen optimally in some sense. Such approach permits to enter the term ***instantaneous spectrum*** for the non-stationary process.

In each given moment t^* the parameters $\{C_k\}$ are corresponded with an autoregressive model with known constant coefficients.

$$a_i(t^*) = \sum_{k=1}^{N} C_{ik} \varphi_k(t^*) \tag{5}$$

Such process is called stopped in the moment t^* (it can be continued to the eternity). This process is stationary and some ***t^*-instantaneous*** spectrum which is calculated analytically based on coefficients C_k corresponds to it.

Building an instantaneous spectrum succession in time we can study going dynamics (rebuilding) of the process.

Together with classical spectral methods of analysis other modern methods of time series non-linear analysis and non-linear forecast were used to control the results.

Reconstruction of universe dynamic system model in the Euclidean space of convenience dimension can be the basis of modern approaches to predict time series. It is supposed for that [Makarenko, 2005]

1. System trajectories fill an attracting set of a small dimension d – an attractor – in the phase space;
2. The first coordinate trajectory protections are continuous non-linear functions of phase coordinates;
3. Protection values in discreet time is an observed time series;
4. There is an ergodic invariant measure which can be estimated as a dwelling time of a point in the elementary phase volume.

In these suppositions it is possible to build up a time series enclosing $\{x_i\}$, $i = 1, N$ in R^m, $m > 2\Delta$ which will be a topological copy of the real attractor.

A copy dynamics is specified by a non-linear regression equation $x_i + \tau = \Phi(x_i)$, $x_i = (x_i, x_{i-\tau}, \ldots, x_{i-(m+1)\tau})$ which is just a predictor model. Function $\Phi \in C^1$ is even differentiable but specified by a finite pair set $\{x_{i+\tau}, \Phi(x_i)\}$ on the series history. That is why, any approximation problem in L_2-metrics is not correct.

Possible approaches to the solution on the level of technical rigor are divided into local and global methods. The first are based on the Lorenz analog method and add up to approximation Φ in local vicinity of each reconstruction point.

Polynomials of a small degree are usually used for that. Global methods approximate Φ in all points at once.

Radial basis functions (RBF) and artificial neuron networks (ANN) serve as instruments for that. The latter permit to represent the m variable function as superposition of functions only from one variable using one non-linear standard function of a formal neuron.

There are two important problems. The first is connected with estimation of a series predictability horizon which is determined by a maximal Luapunov exponent of a universal model. The existence of such exponent is connected with recession of close trajectories of chaotic dynamics and leads to exponential growth of a prediction mistake on practice.

The situation can be improved with a help of a vector prediction scheme. The second problem is connected with a model mistake. Such mistake is aroused with noise in data and unknown latent parameters which Φ can depend on.

Changing of parameters lead to rebuilding the dynamic regimes which are observed as non-stationarity of a time series.

In his work [Makarenko, 2005] Makarenko discusses two approaches to decrease a model mistake. The first is based on the idea of nonuniform enclosing and meant for time series which have several correlation lengths.

Using the principle of Minimal Description Length it is possible to find RBF parameters to improve the model. The second approach leads to corrector of the first prediction made with a help of ANN.

Anyway, incorrectness of an approximation problem leads to a large number of possible variants of the future.

3.1.3. Modeling a mechanism of interaction of heliophysical and geophysical processes

Modeling with a help of autoregressive models is based on supposition that a predicted value is a weighted sum p of previous reading (one-parameter representation) or weighted sums $p, q, \ldots$ of previous reading of different time series (multi-parameter representation). Researches made for different meteorological, geophysical processes have shown that any meteorological parameters $P(t)$ measured in some periods of time in the framework of the autoregression model can be represented as:

$$P(t)=\sum_{i=1}^{q} a_i P(t-i)+\sum_{i=1}^{s} b_i W(t-i-w)+\sum_{i=1}^{r} c_i K_p(t-i-k)+\sum_{i=1}^{m} d_i I(t-i-i)+\xi_t$$

where a, b, c, d are coefficients calculated with known values P, W, K_p and I. In expression (1) W means Wolf numbers; K_p is geomagnetic activity index value; I – means cosmic ray intensity for periods preceding the time t; q, r, s and m are an order of multi-parameter autoregression used for building up a prediction model; ξ_t – is a succession of independent random vectors; w, k, i are delays between W, K_p and I and the researched (predicted) process P.

On the basis of accumulated sets of atmospheric data, solar activity, geomagnetic activity and cosmic ray intensity data with dimension N_0 one creates a matrix for a system of linear equations (1) the solutions of which determine vectors $\{a\},\{b\},\{c\},\{d\}$.

It is necessary to take it into consideration in this case that sets of autoregression coefficients can be determined almost for each period of time. So, using monthly average data for the period 1950 – 2000 we will be able to get about 600 equations. Consequently, if we take yearly averaged values equation number is decreased up to 50-k where k is maximal value of any values q, s, r, m, so, equation number about 40.

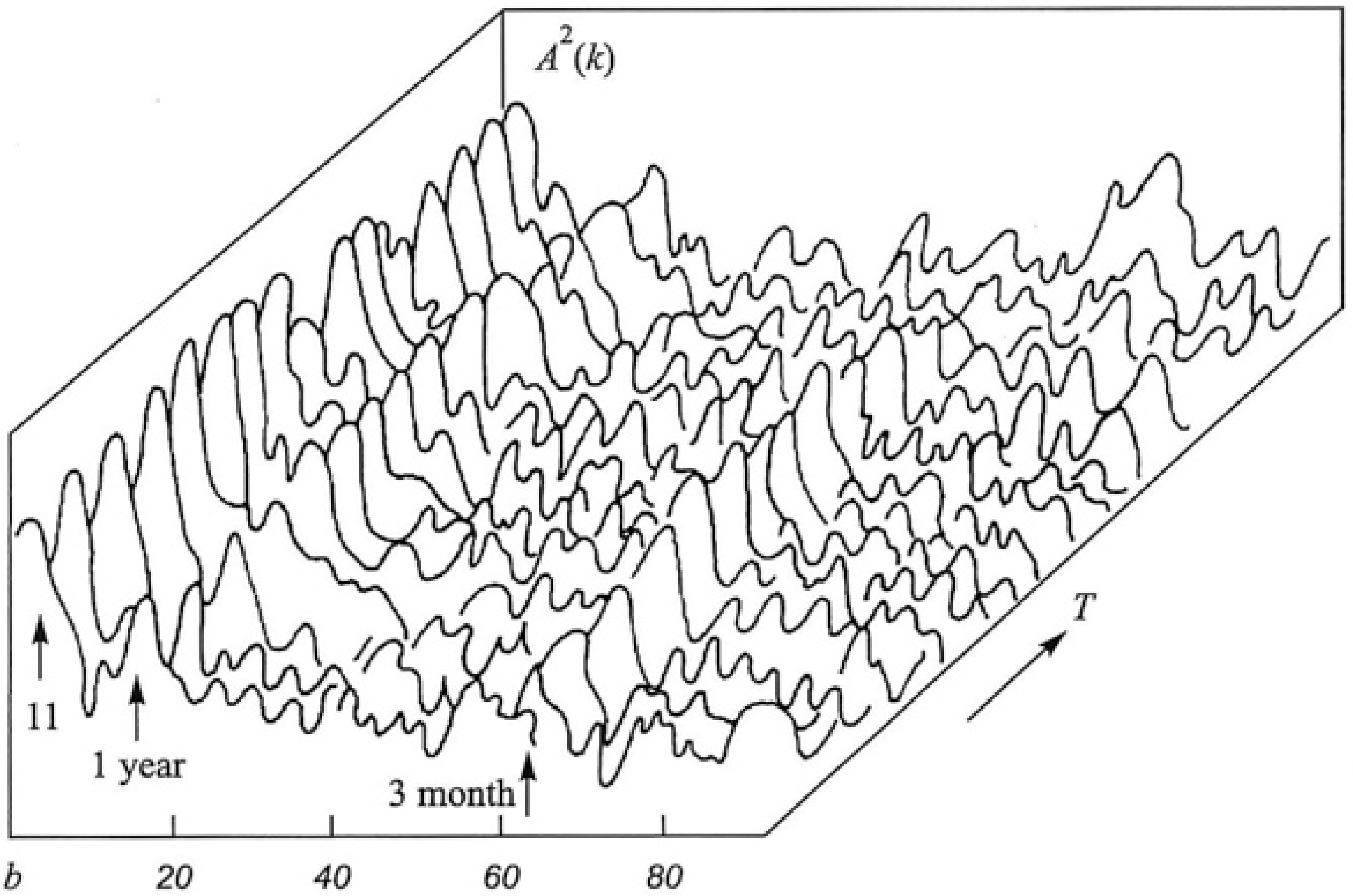
The aim of autoregression parameter estimation is to solve the system of linear equations like Yule-Worker one [Key, 1981].

Using model orders for atmospheric processes, solar activity, geomagnetic activity and cosmic ray (influencing the atmosphere transparence [Pudovkin, 1995]) it is possible to predict average values (or any other characteristics of the Earth) of the atmosphere ONE STEP FORWARD, and the distance of this step will be determined only by data discretisation level.

It is necessary to note that calculation of autoregression coefficients can help to appraise a contribution of this or that process to the predicted process. So, during analysis of atmospheric processes autoregression coefficients for geomagnetic activity were very small (it means that contribution of it into atmospheric circulation is small), but coefficients for cosmic rays observed on the Earth are rather big [Libin, 1996a], which later was explained in Pudovkin-Raspopov's model of solar activity influence on atmospheric processes.

So, using standard autoregressive models to work out methods of forecasting cosmo- and geophysical processes of the atmosphere changeability will give good results.

A result of the first steps in this direction was a yearly forecast of a level of closed water systems in Mexico (Lake Patscuaro) and Russia (Lake Chudskoye) based on solar activity, cosmic ray intensity and preceding values of lake levels. Veracity of such forecast for 2003 was 9 % that for 2004 was 8 %, 8 % for 2005, 12 % for 2006, 11 % for 2007. Years 2008 – 2009 will show justification of our ambitions.



Results of dynamic spectral analysis of variations in solar activity and temperature

3.2. Study of spectral characteristics of solar activity and climatological processes

3.2.1. Study of correlation and spectral characteristics of cosmophysical processes and stormicity

Several years ago the authors made spectral and autoregressive circulation research in North Atlantics in regions of northen-atlantic oscillation NAO (stormicity in the Northern Sea) for 1950 – 2002.

Existing continual sets of monthly averaged data for 52 years (624 points) permitted to study oscillations with cyclicities from several months to 22 years rather confidently. (Stormicity is an index of regularity of powerful storms with a wind velocity more than 17 m/s).

In a result of joint correlation, spectral and autoregressive (with studying dynamic spectrums) analysis of stormicity, solar activity, geomagnetic activity and cosmic ray intensity the existence of the whole set of stormicity oscillations tightly connected with oscillations of helio- and geomagnetic activity especially in a frequency range from $2 \cdot 10^{-9}$ to $8 \cdot 10^{-8}$ Hz was found.

(Model research of a spectrum show that peak amplitude on frequency $3 \cdot 10^{-9}$ Hz does not provide peak amplitudes on other frequencies, and modeling slow trends on frequencies more then $5 - 6 \cdot 10^{-9}$ Hz does not influence spectrums. Sudden emissions intensify only a low-frequency part of the spectrum which tells on quantity B in an essential degree and does not tell on quantity γ, if to specify the spectrum as $P(f) \sim Bf^{-\gamma}$).

The authors created a data processing system in which some secondary procedures were realized – high and low frequency filtration, elimination of regular changes, estimation of process imbalance or appearance of non-stationarity, calculation of basic statistic characteristic of the process.

Besides, the analysis showed that processes of stormicity and solar activity are, firstly, opposite in phase and are, secondly, shifted by 3.5 – 4.0 years relative to each other. (Update of this estimation based on less data intervals leads to close estimations – stormicity P retardation relative to solar activity W for periods, for example, 1950 – 1963 gives 4-year value, for 1961 – 1976 3-year value, for 1977 – 1994 3-year value and for 1993 – 2002 4-year value. For the whole period of researched data the total retardation is about 45 month).

Analogical calculations of mutual correlation functions between solar activity (W and S) and geomagnetic activity (K_p) parameters lead to 1.5 year K_p-index retardation relative to solar activity, and both processes are in phase almost in the whole 52-year period.

Together with it, joint correlation analysis between geomagnetic activity (K_p) and stormicity (P) leads to1.9 – 2.5 year stormicity retardation relative to geomagnetic activity (the processes are opposite in phase) which corresponds well with the results mentioned above.

Received results correspond well with analysis of a cosmic ray intensity retardation effect relative to a helio-latitude index of solar activity HL where retardation quantity is changed from 6 to 20 months depending on a solar activity cycle [Gulinsky, 2002].

Calculations of mutual correlation functions between cosmic ray intensity I (stations Apatite and Moscow) and stormicity P show that cosmic rays pass ahead of stormicity by 3 years which coincides with the results of calculation of P retardation relative to W if to take pairs $W - I$ and $HL - I$ analysis into consideration.

Let us note that dependence of atmospheric phenomena on solar activity factors does not add up to only adequate image of processes, growth or decay of their parameter quantities in branches of solar activity cycles (during analysis it is enough time to watch dynamics of spectral estimation behavior), but appears to be a process of set amplitude and phase rebuilding relative to small-scale oscillations with periods 3 – 4.6 and 12 months and large-scale ones with periods 2, 9 – 15, 20 – 28 and even 80 – 90 years. In this case relatively constant retardation between stormicity and solar activity becomes essential. It permits to get a mode of approximate estimation of an average level of stormicity 1 – 2 years before.

Research showed that one can separate 4 cycles in time series of stormicity in the Northern Sea (and in a less degree in the Baltic Sea):

1. 24-hour one connected with differences in heat capacity of an underlying surface;
2. Synoptical one appearing in a result of cyclone and anticyclone activity;
3. Yearly one connected with season intensity pulsation of energoactive zones of Northern Atlantics;
4. Climatological (many year) one conditioned by different geophysical, heliophysical and tropospheric factors.

Similar conclusions can be made for a climatological cycle (on the basis of joint analysis of all four processes in the framework of a multiparametrical model) – W, P, I and K_p for the whole 52-year period contain not only clearly separated (with more than 95 % of veracity) 11-year and quasi-biennial variations of all processes but a precise structure in the region of higher frequencies (22-year and century variations).

Received spectral estimations agree with results of spectral analysis of energy exchange ocean-atmosphere in Northern Atlantics [Ariel, 1986] which demonstrate temporal scales of climatological and within-year variability which coincide with spectral estimations of stormicity, solar activity and cosmic ray intensity.

3.2.2. Tendency of changes of the Baltic Sea ice square (glaciation) with climate change estimation

– Study of glaciations with method Track.

It is interesting to compare the basic oscillation periods revealed by many researchers in many year periods of a yearly average level of Lake Chudsko-

Prudskoye (see chapter 3.2.4.) and in series of total afflux to lakes Pesvo and Udomlya with oscillation periods in a series which has the nature different from the first two but connected with them indirectly.

In the capacity of such a series a series of glaciations or maximal square of the Baltic Sea ice can be used [Libin, 1996]. Waters of Lake Chudsko-Prudskoye and lakes Pesvo and Udomlya flow into this sea, and one can expect any oscillations revealed in these lakes in oscillations of its glaciation. There is a reason to suppose that the leading 28.5 years period which is in oscillations of the first two series will become apparent in the glaciation series as well.

Jaani [Solntsev, 1997] researched 273-year series of observations characterizing maximal square of the Baltic Sea ice since 1720 to 1992. It is clear that there is no single standard solution of a problem of separating a trend from long time series. The choice of a solution method depends on a priori information about a model of the process under study and on behavior of the real statistic data describing this process.

The peculiarity of data is their distribution, very far from normal. So, when the average value of ice squares is 218 thousand km^2, the minimal one is 52 thousand km^2 and the maximal one is 420 thousand km^2 a standard deviation of them is rather big – 114 thousand km^2.

A sample histogram shows that a distribution of it has almost no tails; it looks like a little deformed even one (there is a noticeable positive asymmetry). A lack of tails is determined by the fact that maximal value of ice square is limited from above by the Baltic Sea square (420 thousand km^2) and from below by ice square of shallow gulfs which are frozen even in the warmest winters.

In this case it is difficult to expect that traditional procedures like a sliding average will directly give clear information about presence or absence of some searched slow trend. But there was an attempt to apply such a procedure – polynomial approximation – with a least square method. The best approximation was received for a 3d degree polynomial. However, a confidence belt for a regression line is too wide to talk about veracity of this solution. A result of polynomials of higher degrees is even worse.

In connection with inadequacy of received results an initiate series of ice square was researched with the method Track, $M = 40$ were taken as a parameter. Studying the basic components shows that high-frequency constituents dominate in a high degree. Among them the largest part of dispersion falls on oscillation with a period 5.4 years (it becomes apparent in the first three basic components and explains 14 % of dispersion), with a period 7.8 years (4 and 5 components, 7,8 % of dispersion) and with a period of about 3 years (7 and 7 components, 7.5 % of dispersion). A slow trend is weakly presented in the 1st and the 3d components.

To suppress high-frequency components of the process different procedures carrying out a researched series filtration were used. A sliding average is the simplest linear filter of this kind. However, now when the character of a signal hindering components is known it is possible to manage width of an averaging interval, find a filter characteristic to suppress these harmonic components as much as possible.

We know that a sliding average suppresses wonderfully the harmonic components the period of which coincides with an average interval width or keeps within this interval integrally (it appears to be a common multiple for these periods).

In our case 15 point summing up was to suppress components with periods of about 3, 5 and 7.5 years, or three most powerful components. After 15 point smoothing the first seven and the last seven points were excepted from the received series (as they are calculated on the basis of shorter series segments and can arouse distortions in the further analysis), and an analysis of the smoothing series with the program Track was made. The track length was 30 which give a more precise reproduction of a slow trend. In this case the first main component containing more than 60 % variations and picking out a slow trend is sharply distinguished.

To control the results the analogical analysis of the series received with smoothing the initiate data with a sliding average method on the basis of 7 points with further exception of the first three and the last three ones was made. Herewith the weight of the first main component corresponding to a slow trend became twice as less.

This fact confirms doubts that the use of the initiate time series linear smoothing procedures is optimal which is connected with above mentioned difference in distribution of researched ice square values from normal.

For such data G. Tukey suggested to apply so-called resistant (steady) smoothing using not an arithmetical mean, but a median average or weight averaging and special procedures of flat segment exception.

The authors made five different procedure smoothing (the procedures were realized in the statistic packet STATGRAPHICS). Each procedure uses not more than five series points coming one by one. Received results appeared to be rather close to each other and much different from linear smoothing results. For the further analysis a series was taken got with averaging of five mentioned smoothing variants and worked up with the Track method. In this case a slow trend becomes apparent in the first main component, explaining 26.5 % of dispersion, the 2nd and the 3d components (28 % of dispersion) release oscillations with a period of about 19 years.

The most important result of this stage of research may be the following – the three smoothing procedures gave almost coinciding curves of a slow trend looking like a sinusoid segment with a period of about 300 years or a cubical polynomial with a curve bend part.

So, it is proved that the hypothesis about the climate warming in Northern Europe is not confirmed by the researched material. The opposite supposition about a cooling period which began in the 50s of the 20 century because of slow periodical climate oscillations can be expressed.

Moreover, it is necessary to note periods when a kind of failures happen in the process dynamics. Such periods are well seen on diagrams reestablished on the basis of separate components of the process values. Such periods correspond to time intervals 1790 – 1800 and 1910 – 1920. These intervals on the diagram of a slow trend reestablished on the basis of the first main component correspond to the points of minimal and maximal ice squares.

In the process of data analysis with the Track method a great number of periodic components with periods from 2 to 40 years were found out. So, in main components with big numbers oscillations with periods 5.9 years and about 20 years are also found out.

To control these periodic components a periodogram of the initiate series was also calculated. Although exactness of process component period definition is small it is possible to say that the basic components received with the Track method on the previous analysis stages are found out in this case as well. So, the following components were found out in a descending order – ***about 300 years, 90 – 100 years, about 46 years, 27 – 30 years, about 20 years, 14 – 15 years, 10 – 13 years 8 – 9 years and some others.***

– Study of glaciation with method of multivariate spectral analysis.

The works by A. Vald (a consecutive analysis and a general statistical decision theory), G. Tukey (methods of jack knife and multiple comparisons), Efroimson (step-by-step procedures), P. Hubert (robust procedures), B. Efron (bootstrap method), S.P. Rao (common multivariate linear models) and many others led to a step-by-step review of a statistic analysis common technique which was applied 20 – 30 years ago.

That is why together with the research with the Track method based on the 282nd series of observations characterizing maximal ice squares of the Baltic Sea since 1720 to 2002, G. Tukey's methods (methods of jack knife and multiple comparisons) a spectral and autoregressive analysis was made, and the analysis was made separately for even and uneven solar activity cycles.

The results of the autoregressive analysis showed the existence of the Baltic Sea square ice oscillations with periods 80 – 90 years, 20 – 22 years, 9 – 13 years and 4 – 7 years.

It is necessary to note that mutual autoregressive analysis for the whole data set and separately for even and uneven solar activity cycles shows an interesting picture – in uneven cycles one can observe well-expressed 4 – 7 year, 10 – 12 year, and 80 – 90 year square ice variations (on the background of weakly-expressed 300-year variations), in even cycles 20 – 30 year, 89 – 90 year and 300-year variations prevail.

It is natural to suppose that the existence of 11-year square ice variation in uneven cycles and the absence of it in even cycles only intensify 22-year variation.

There is one more important thing that received results correlate well with any solar activity indexes.

We think it possible to give one more conclusion made by the authors from mentioned calculations – during filtration of the initiate series with a sliding average with periods 50, 75, 100 and 150 years and further joint ARMA-analysis with analogical solar activity data a secular trend with a period much prevailing found variations (>700 – 1000 years) was discovered.

This trend behavior says about total (very large) common warming of the climate in the northern hemisphere especially in the last 100 – 200 years.

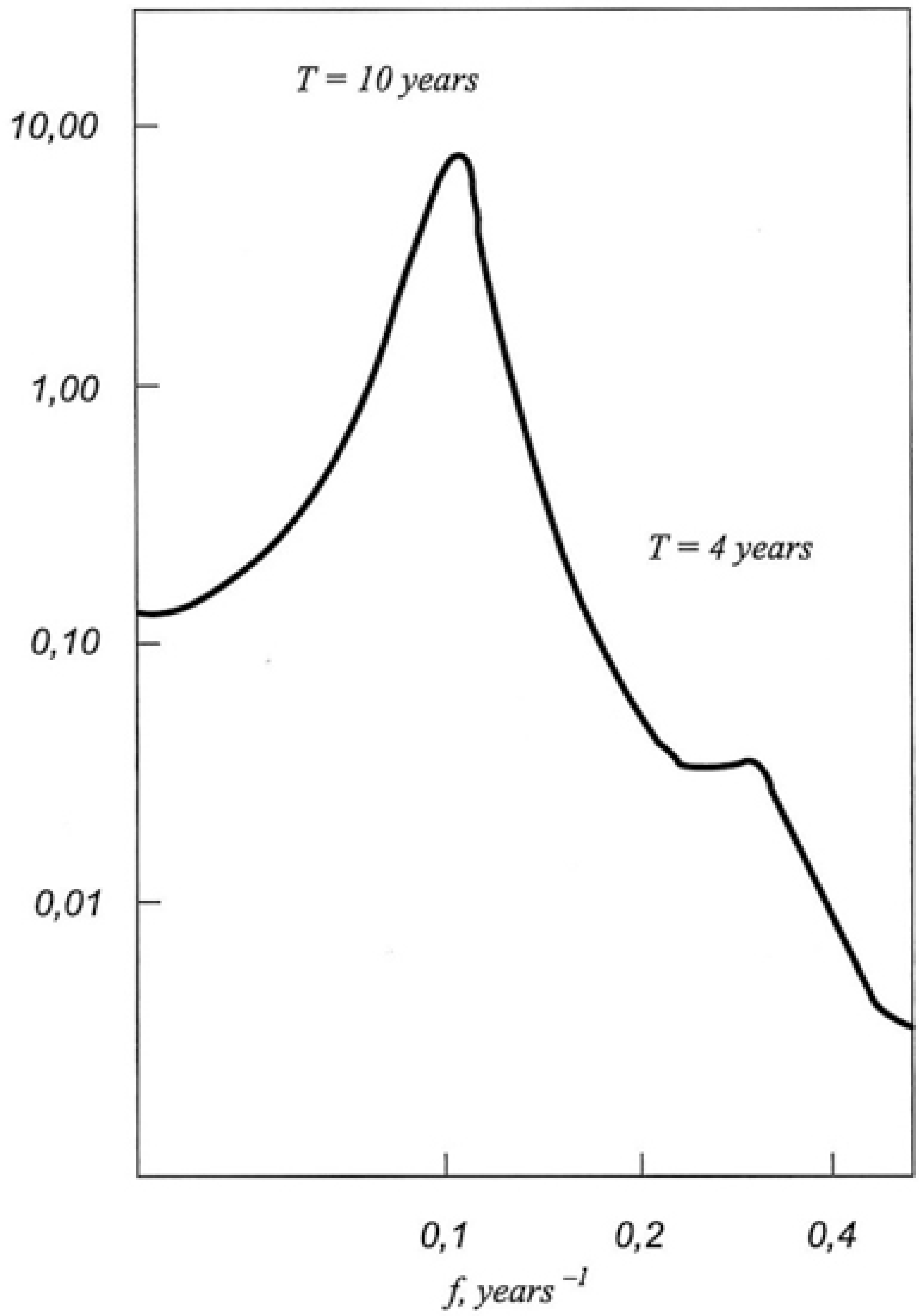
Receive results fully coincide with the results of many year research made by V.V. Betin, Y.V. Preobrazhensky, who researched glaciation of the Baltic and winter severity in Europe for the period since 1770 to1950.

Their aim was to make a forecast of these measures for coming thirty years, it means to 1980.

The predicted change of the Baltic glaciation justified itself – the Baltic maximal glaciation predicted for 1959 – 1960 really took place, and later, after 1960, as it had been predicted, the Baltic Sea glaciation began to decrease.

Research showed that the Baltic Sea glaciation changes with different periods, such as 80 – 90, 28, 22 – 20, 15 – 11, 6 – 5 years and even 3 – 2 years.

Air temperature and river flows are changed almost in the same way (researchers used temperature data measured in Helsinki and river flow measuring results). (In the work [Babkin, 2008] results of researching the Volga flow oscillations in the late Pleistocene were described. It is shown that the Volga flow in separate periods of the late Pleistocene was changed in the range 600 – 120 km^3 per a year. Structures of many year flow oscillations of the upper Volga, Oka, Don, Dnepr for the period of hydrological research lasting 4 – 5, 10 – 12, 20 – 24 and 80 – 90 years were found out).



Mutual power spectra of the ice cover NAO and solar activity for the years 1950 – 2005

3.2.3. Modulation of solar radiation observed on the Earth and a possible connection of it with solar activity changes

A solar radiation spectrum is close to spectrum of a black body heated to the temperature 5770 K with radiated energy deficit in the range of close ultraviolet radiation. Solar radiation intensity in far ultraviolet radiation and in the X-ray range is several orders more than corresponding radiation of an absolutely black body.

The difference in solar and blackbody spectrums is explained by the following – short-wave radiation in different ranges of wave lengths are generated in different regions of the Sun's atmosphere.

Particularly radiation with a wave length $\lambda < 1500$ Å is generated in the chromosphere and a solar corona, or in the regions the temperature of which is much higher than the temperature of the photosphere.

In the same time we know that the chromosphere and corona parameters are very changeable and depend much on a solar radiation level that is why it is not surprising that short-wave solar radiation intensity also changes together with solar activity level from day to day.

A relative value of solar radiation intensity cyclical variations reaches 10 if $\lambda = 300 - 500$ Å and decreases sharply if $\lambda > 2000$ Å. In a result a solar constant does not subject to variations more than 0.1 %.

Lately a lot of publications have appeared which say about the fact that solar radiation variations are not an energetic resource of the observed atmospheric disturbance. In connection with that the results received by Russian scientists K.Y. Kondratiev and G.A. Nikolsky saying about noticeable (to 6 %) change in an 11-year solar cycle of the atmosphere transparency are of a great interest.

The atmosphere transparency variations. Relatively dense atmosphere protects the Earth 's surface from fatal short-wave radiation with $\lambda < 3000$ Å. A wide window in the atmospheric screen is observed on wave lengths $\lambda = 3000 - 10\,000$ Å or in the intensity maximum region in a solar radiation spectrum, which provides penetration of a larger part of solar energy to the lower atmosphere and the Earth's surface.

The existence of the second window on wave lengths $\lambda = 7000 - 15\,000$ Å is also very important. This wave length corresponds to maximum radiation of a blackbody heated to the temperature $T \approx 300$ K which is close to an average temperature of the Earth's surface.

However, optical characteristics of the atmosphere are not given quantities forever and ever. Absorption of solar radiation in the atmosphere depends on contents ozone, water vapor, carbon monoxide and other small components in it concentration of which can be changed.

In a result of it the thermodynamic balance in the atmosphere is very fragile and may be broken easily. A constantly increasing inflow of carbon dioxide formed as a result of a human technical activity to the atmosphere leads to decrease of velocity of warmth withdrawal from the atmosphere (a greenhouse effect) and, consequently, to the rising of the Earth temperature. A noticeable change of chemical composition and contents of small components, as well as the atmosphere transparency is aroused, in particular, with ionized radiation flux variations in the atmosphere during magnetospheric disturbances.

But if decrease of an energy cosmic particle flux arouses increase of the atmosphere transparency, increase of such particle flux should arouse decrease of the atmosphere transparency. Basic calculations show that a total solar energy flux on a latitude zone 55 – 80 ° increases or decreases by $\sim 3 \cdot 10^{26}$ erg/a day which is commensurable with power of observed atmospheric processes.

Detailed research of possible changes of the atmosphere chemical composition, optical characteristics of it and a high-altitude profile of air temperature in the lower atmosphere was made by D. Huglustine and G. Gerald in 1990.

According to the model suggested by them penetration of energy particles to the atmosphere arouses ionization and molecule dissociation N_2 and O_2.

Ions appearing here participate in a complex of photochemical reactions; one of the products of these reactions is nitric oxide NO which interacts actively with ozone molecules:

$$NO + O_3 \rightarrow NO_2 + O_2$$

Ozone is destroyed in interaction with atomic oxygen:

$$O_3 + O \rightarrow 2O_2$$

So, penetrating of energy particles to the atmosphere arouses ozone destruction O_3 and formation of nitrogen dioxide NO_2. In its turn it arouses significant changes in a radiation balance in the atmosphere.

In the lower atmosphere and on the Earth's surface a solar ultraviolet radiation flux with c $\lambda < 3250$ Å increases as a result of decrease of absorbing it by ozone.

In the framework of ecological programs connected with atmospheric pollution a long-term experiment was made (data for 50 years from 1958 to 2008 were used) on the basis of solar radiation measures in different points of the Earth which caused serious anxiety – Mexico, Moscow, St-Petersburg and Vilnius.

Together with estimations of contribution of human industrial activity (emissions of dust, combustion products and exhaust gases to the atmosphere, aerosols, etc.) an attempt to estimate a possible modulation of solar radiation observed on the Earth with solar activity was made.

Analysis of connection of 11-year cosmic ray intensity variation with different solar activity indexes (Wolf numbers, intensity of a green coronal line with a wave length 5303 Å, number of sunspot groups, solar radio-frequency radiation, sunspot square) has shown that changes of solar activity characteristics under study are connected with changes of a cosmic ray flux.

The existence of well-expressed correlation dependence between long-period changes of cosmic ray intensity and indexes mentioned above is not casual, as each of them reflects common characteristics of solar activity cyclicity.

However, direct use of solar activity indexes is possible only with analysis of atmospheric processes (but not always).

Such use of indexes for cosmic rays is not correct, as solar wind plasma fluxes from different heliolatitudes possess different effectiveness of modulating influence [Gushina 1992].

It is also possible to make an analogical conclusion for solar radiation observed on the Earth, because one of the possible mechanisms of solar activity influence on solar radiation is modulation of galactic cosmic rays by a solar wind.

Moreover, for observations on the Earth modulating characteristics of any active region on the Sun are determined not only by its activity, heliocoordinates, but an angular width of a solar wind flux.

In the work [Gushina, 1970] an index accounting heliolatitude of the Earth in the moment of cosmic ray intensity registration, non-similar activity of the northern and southern hemispheres of the Sun, changing of sunspot heliolatitude during a solar activity cycle was suggested:

$$HL\left(\Theta_e, \Theta_0, t\right) = \alpha \int_{-\pi/2}^{\pi/2} K_i\left(\Theta, t\right) \exp\left(-\frac{\Theta - \Theta_e}{\Theta_0}\right)$$

where K_t is a parameter characterizing solar activity in the moment t on the heliolatitude, Θ, Θ_0 is a parameter characterizing angular half-width of solar wind fluxes, Θ_e is heliolatitude of the Earth entering which lets cosmic rays and solar radiation except effects appearing because of the Earth orbit inclination to the equator plane, α is a standardized multiplier defined from the condition:

$$\alpha \int_{-\pi/2}^{\pi/2} \exp\left(-\frac{\Theta - \Theta_e}{\Theta_0}\right) d\Theta = 1 \tag{7}$$

Where

$$\alpha = \left\{ 2\Theta_0 \left[1 - \cosh\left(\frac{\Theta_e}{\Theta_0}\right) \exp\left(-\frac{\pi}{2\Theta_0}\right) \right] \right\}^{-1} \tag{8}$$

In the work [Dorman, 1978] *HL*-indexes were calculated for 18 – 20 solar activity cycles, a parameter of activity was sunspot number and square.

Continuous series of monthly average values of a heliolatitude index for more than two solar activity cycles give a possibility to make correlation and ARMA-analysis between total sunspot square, solar radiation, cosmic rays and heliolatitude index values.

In spite of the fact that all mentioned processes are not stationary, quasi-stationarity does not add significant distortions to spectral estimations received with a help of ARMA-analysis and significant changes to observed retardation of analyzed processes relative to solar activity [Libin, 1996].

The authors made joint two-dimensional autoregressive spectral analysis of total sunspot square, *HL*-index, solar radiation and cosmic rays on the basis of monthly average observation data for 1952 – 2000 in Mexico, Russia, and Lithuania.

It was found out that in a wide frequency range in solar radiation observation data on the Earth one can observe oscillations with periods 3 – 4 months, 2, 4, 11 years tightly connected with solar activity.

Comparison of received results with analogical research of solar activity influence on stormicity shows not only good qualified, but quantitative (within retardation) correlation.

The result of behavior of coherence coefficient and residual dispersion of analyzed processes and solar activity when using a *HL*-index or total sunspot squares is of a great importance.

(Calculations of coherence coefficients between solar activity and solar radiation for quasi-biennial and 11-year variations show that when using sunspot square S coherence coefficients are 0.7 (for Russia) and 0.8 (for Mexico), then using a HL-index coherence coefficients are 0.85 (for Russia) and 0.92 (for Mexico). In this case calculations of solar radiation residual dispersion make up a quantity not more then 10 – 20 % when describing it with an ARMA-model).

In a result of calculations it is shown that during researches of connections between solar radiation on the Earth and solar activity and building up prediction models on the basis of these researches it becomes very important to choose a solar activity index and to take contribution of cosmic ray intensity into account.

3.2.4. Solar activity and levels of closed water systems

– Heterochronism of closed water system level variations.

The conclusion about the existence of connection of solar activity and lake level variation is not new. In 1917 on processing the observations for 1815 – 1910 Fridtjof Nansen and B. Helland-Hansen showed an inverse relation between air temperature in a tropical zone and a number of sunspots. They found out that the larger a sunspot number was the lower the temperature was and vice versa.

Nowadays trade-antitrade atmosphere circulation is well-known according to Brook's works. Air ascending motions are increased in the equatorial zone during years with a great deal of precipitation. In connection with it quantity of the air which an antitrade wind carries away from the equatorial zone is also increased during a year.

The extra-tropical barometrical maximum which appears everywhere in winter and only over the ocean in summer feeds substantially on the account of air carried by an antitrade wind. That is why the years with increased air transmission by an antitrade wind have above normal pressure in subtropics.

In 1929 Brooks came to the conclusion that quantity of precipitation in the tropical zone and levels of African lakes are changed parallel to a sunspot number – the highest level of lakes corresponds to sunspot maximum and vice versa. V.Y. Vize showed that there is correlation connection between degree of Arctic glaciation and water level in Lake Victoria located at the equator.

So, we can consider that connection of lake levels and solar activity is proved. But the mechanism of atmosphere circulation which makes this remote connection real is not quite clear. It seems that it is impossible to explain it with any process, but we can find an explanation in a series of basic air-mass transport processes looking at the Earth's atmosphere as at a whole unity.

L.S. Berg noted heterochronism of water level variations in the Aral Sea and Lake Sevan (Gokhcha), on one side, and the Caspian Sea, on the other. A.V. Shnitnikov noticed synchronism of level oscillations in the Aral Sea, Lakes Balkhash, Alakul and other closed lakes of semiarid and arid zones.

So, the level of the Caspian Sea which feeds in general only on account of precipitation in the Volga basin in a damp zone changes heterochronically with levels of arid zone lakes.

In his report Heterochronism of Increased Moistening Periods of Damp and Arid Zones V.N. Abrosov described the results which showed that analysis of meteorological elements (precipitation, pressure, temperature, etc.) pointed to the existence of direct connection between solar activity and frequency and intensity of air mass changing over any territory.

We know that mutual antagonistic West-East transfer and meridional circulation are the main mechanism of the Earth's atmosphere circulation. Frequency and intensity of air mass changing rises together with solar activity increase and it falls down with SA decrease. In conformity with it the basic transfers are increased or decreased too.

In his report B.N. Abrosov described the results of observation of Lake Balkhash level since 1900 to 1954, and there are hydrometric station observation data since 1934.

Analysis of their work shows that rise of level was of an oscillating character on the general background of level lowering. Rise of yearly average levels (years 1935, 1937, 1942, 1943, 1947, 1949, 1950) alternated more than once with lowering of them (years 1936, 1938, 1939, 1940, 1944, 1945, 1946 and 1951). In 1952 – 1954 rise of Lake Balkhash level was observed. By 1931 observations had been only visually descriptive (see the table).

1900 – 1910	rise of level
1911 – 1920	lowering of level
1921	V.S. Titov notes rise of level
1922 – 1930	lowering of level
1931	P.F. Domrachev notes rise of level

Basing on data described above we can make the following conclusions:

1. When solar activity in the first cycle was weak, rise of Lake Balkhash level was observed;
2. During the next years rise of Lake Balkhash level was observed only for a short time when solar activity observed only when one cycle was changed by another was weak (1926, 1931, 1942 – 1943, 1952 – 1954);
3. Since 1911 Lake Balkhash level is lowered which correlates well with general increase of solar activity with each new 11-year cycle. All three conclusions can be united into one general conclusion – rise of Lake Balkhash level is observed during the years when solar activity is relatively weak.

In connection with it we should note that a maximal level of the Aral Sea was in 1911, Lake Sevan in 1912. The Balkhash level had been raised till 1911, and the most sudden rise was observed in 1908 – 1909.

The lowering of the Caspian Sea level had begun since 1930, and by 1946 it had become 2 meters lower. Such sudden level lowering had not been observed for 100 – 125 years. The largest timely rises of the Caspian Sea level were in 1931 – 1932, 1942 and 1944, and they corresponded to the moments of solar activity when one 11-year cycle was changed by another.

So, we can make a conclusion that oscillations of the Caspian Sea and Lake Balkhash levels change according to the same regularity, but changes of their levels usually happen heterochronically and only sometimes synchronically.

According to B.Y. Vise, in a result of it periods with low solar activity and slow atmosphere circulation are years with relatively high atmospheric pressure in the northern and southern polar regions and high glaciation of them.

In periods of high solar activity in warm seasons over the Atlantic Ocean an axis of a barometrical hollow situated from Iceland to Eurasian coast moves to the north. In a result cyclones move about Eurasia more to the north then latitudes of Lake Sevan, the Aral Sea, Lake Balkhash in a damp zone.

Solar activity lowering moves an axis of a barometrical hollow over the Atlantic Ocean to the south in summer which results in some movement of cyclone route to the south, and it seems that in this case their movement along the Iranian branch of a polar front becomes more frequent.

During the years when the atmosphere circulation is intensive, and an eastern front of an Atlantic-Arctic barometric hollow moves far to the east through the utmost north of Eurasia, there may be little precipitation not only in closed basins of an arid zone, but in basins of the rivers Don, Volga, situated in the north, and rivers of Ural and Western Siberia.

– *Spectral analysis of lake level.* To reveal retardations, find out values of them and study general cyclicities in given water content of closed ecosystems (lakes) and solar activity we have used traditional methods of spectral analysis (developed in supposition about quasi-stationarity of the processes under study) and methods of autoregressive spectral analysis (useful for nonstationary processes) – analysis of solar activity parameters (Wolf numbers, sunspot squares, intensity of a coronal line with a wave length 5303 Å, *HL*-index, solar radio-frequency radiation on 10.7 sm frequency) and levels of lakes was made with a help of Tukey's correlation and spectral analysis and methods of autoregressive spectral analysis.

Analysis of solar activity parameters (Wolf numbers, sunspot squares, intensity of a coronal line with a wave length 5303 Å, *HL*-index, solar radio-frequency radiation on 10.7 sm frequency) and levels of lakes was made with a help of Tukey's correlation and spectral analysis [Andersen 1976, Bendat 1983, Key 1981] and methods of autoregressive spectral analysis [Dorman 1987, Dorman 1992, Libin 1992, Libin 2005, Prilutsky 1988].

The analysis was based on monthly average measuring values of solar activity (sunspot squares, *HL*-index, radio-frequency radiation on 10.7 sm frequency), cosmic rays and surface temperature [Friis 1992] and levels of isolated lakes in Mexico (Lake Patscuaro), Estonia-Russia (Lake Chudskoye), Russia (the Caspian Sea and Lake Baikal) for 1880 – 2008.

After choosing relevant intervals for the analysis (we took solar activity cycles and then went through the whole data set moving each time 5 years further, so only two neighboring results appeared to be partially dependant) we began calculation based on a standard procedure described in the work [Libin 1994].

In spite of the variety of applied methods it is necessary to understand that mutual power spectrums give rather reliable *quantitative estimations* of connections between observed processes and permitted to estimate drifts between them, but veracity of the whole series of received correlations is on the verge of confidence to these results.

It is also necessary to understand that veracity of received results of mutual power spectrum calculations is in a high degree determined by *a researcher's capability* (choice of methods of analysis and approach to estimation of result validity).

That is why the autoregressive spectral analysis (ARMA) firstly described in works [Prilutsky 1991, Judakhin 1991, Libin 1992] was used additionally as a criterion of validity.

The autoregressive analysis differs from standard methods, as it gives a possibility to estimate correlations between analyzed data series with 100 % veracity in the frequency region, and, which is the main thing, it is workable for *quasi-stationary (and sometimes even nonstationary) processes*, which analyzed data of water content and solar activity appear to be.

On the other side it is always necessary to remember that all amplitude estimations received during the autoregressive analysis are relative and cannot be absolutely correlated to the initial series, although *behavior of amplitude estimations in time* is quite comparable.

It means, although we cannot attach results of amplitude spectrum calculations to the initiate data exactly, meanwhile, their dynamics in time is observed.

Description of the researching objects.

1. ***Lake Chudskoye*** is one of the largest lakes in Russia and Estonia (and Europe as well).The water-surface area of it (3.6 thousand km^3) takes the 5th place in Europe. The common *water-collecting area* (including the square of the lake itself) is 47 800 km^3.

The catchment area is elongated 370 km in a meridional direction from 56°10′ to 59°30′ degrees of latitude north and has an average width 160 km (Lake Pskovsko-Chudskoye based on the data of 1983). The lake itself is also elongated almost 140 km in a meridional direction and situated between 57°51′ – 59°01′ degrees of latitude north and 26°57′ – 28°10′ degrees of longitude east. It consists of three parts differing from each other in morphometric and regime characteristics, but make up the whole water body [Jaani 1987].

If an average many-year level is 30 meters (taken by us) the volume of water mass is 25.07 km^3. The lake is shallow, the average depth of it is 7 meters. About 240 rivers and streams fall into Lake Chudskoye. Among them the largest rivers are Velikaya (catchment square is 25 200 km^3), Amaiygi (9960 km^3), Vykhandu (1410 km^3) and Zhelcha (1220 km^3).

The beginning of regular researches of Lake Chudskoye is connected with a lot of floods causing a big damage (1840, 1844, 1867) and decrease of fish catch. Academician K. Barr who worked as the head of the committee in 1851 – 1852 came to the conclusion about step-by-step rise of the lake level.

However in 1864 academician G. Helmersen noted the beginning of the lake level lowering. Analyzing possibilities for building Chudsko-Baltiysky road, I.B. Spindler did not find confirmation to a generally accepted opinion about lowering of the lake level, as it was found out for the first time that the level of the lake changed from year to year.

The latest discovery led to the decision to open the first hydrological stations on Lake Chudskoye in 1902, one of which in the village Vasknarva has been working till nowadays.

In 1921 a lake hydrological station was built in Mustvee which is the main nowadays and has a continuous and qualified series of observations. So, using data from all the stations we have managed to get today a reliable 102-year series of observations of monthly and yearly average levels of Lake Chudskoye. The series consists of three parts.

- every day natural observations in Mustvee since March, 1921 (separate breaks in 1937 and in 1941 – 1944 are exactly restored on the basis of observations from the other stations),
- monthly average observations in Mustvee for separate periods during 1903 – 1917 are restored on the basis of correlation with the levels from the station Vasknarva,
- yearly average levels in Mustvee for separate years in the period 1885 – 1902 and 1918 – 1920 are restored on the basis of correlation with data of water level in the river Amaiygi (correlation coefficient is 0.92).

As it was mentioned above, years 1840 – 1844 in the 19 century were flood ones; a high level was also observed in 1867 (almost 22 years later) and in 1879 – 1884, as it seemed to be. In the period of instrumental observations the highest levels were observed in 1924 – 1928, 1957 and 1987.

In 1940 A. Wollner and in 1971 T. Apere noted the existence of cyclicity in observations of the lake level. Ago Jaani showed in 1973 that maximal levels were observed during solar minimums.

Jaani discovered intercentury cycles of water content with duration 19 – 34 years (close to so- called Brickner cycle) and short-time cycles with duration 4 – 5 years.

In 1981 A. Reap [Reap 1981] separated cycles with duration 6.1 – 6.4, 10 – 11 and 80 – 90 years. He supposed that in the flow of north-western rivers minimum of 11-year cycle is observed 1 – 3 years after solar maximum, and maximum of the flow is observed 2 – 4 years before solar minimum.

2. ***Lake Baikal*** is one of the most ancient lakes of the planet, according to scientists, it is about 25 million years old. The majority of lakes, especially of glacier origin, live 10 – 15 years, then they are filled with precipitation and disappear. Different from many lakes in the World, Lake Baikal does not have any signs of aging. On the contrary, researches of the last years let geophysicists express a hypothesis that Lake Baikal is an incipient ocean.

When someone mentions Lake Baikal everybody recalls the fact known from the childhood that the lake contains 1/5 of available drinking water of our planet. It is true, if the water surface area of Lake Baikal is less than that of such great American lakes as Lakes Superior and Huron and great African lakes (Lakes Victoria and Tanganyika), the volume and depth of the lake make it the champion among lakes.

The sizes of the lake really make a great impression. The water-surface area is 31.5 thousand km^3 that is more than the territory of such countries as, for example, Belgium or Israel, and the square of the largest from twenty two islands of Lake Baikal – Olkhon – is more than squares of such European countries as Andorra, Liechtenstein, San-Marino, Monaco and Vatican taken together.

Lake Baikal is situated in a mountain kettle, its length is one and a half thousand kilometers, its width is five hundred kilometers, the lake contains 23 thousand km^3 of the purest water.

The enormous water volume of the lake serves a stabilizer of the climate in the suburbs. It is colder in Lake Baikal region in summer and warmer in winter then in other Western Siberia.

The square of a catchment basin of the lake (the territory from which water flow down to Lake Baikal) is more than half of a million square kilometers. Water coming to the lake with the rivers Selenga, Bargusin, Upper Angara spends there more than four hundred years, and then leaves it through a head of the Angara. It explains the unique purity of the lake water.

The important peculiarity which makes Lake Baikal different from other deep lakes is high concentration of oxygen in the water spreading to depth. Maybe, that is why, Lake Baikal is covered with ice late enough (in January) and gets free from the ice only in June – July.

The first reliable (from scientific point of view) information about Lake Baikal refers to the 18th century. In the middle of the seventeenth century the first scheme of Lake Baikal was made. In the second half of nineteenth century regular scientific study of Lake Baikal was connected, first of all, with the names Benedict Dybovsky and Victor Godlevsky (exile participants of the Polish up-rising of 1863 – 1864) who laid the basis of studying bottom topography of the lake, bottom precipitation, temperature and ice regime and Baikal winds.

Unfortunately, scientists of Irkutsk State University started regular reliable observations of water level in Lake Baikal only in twenties of the last century that is why for our purposes data series since 1921 are used. And herewith there is a possibility to restore (but not with a high veracity) data of Lake Baikal level up to 1880.

Such data are very important not only because the lake is the largest source of drinking water, but because a substantial sudden lowering (or rising) of water level put at hazard the unique ecology in this region.

Lake Baikal is the unique system and regulates itself when there should be more or less water, and we must not interfere in this process.

After building Irkutsk hydropower station an average level of Lake Baikal became 1 meter higher. But amplitude of level oscillations and the highest notes of the level are kept in the former range. For the last decade marks of the water level in Lake Baikal has become much lower, and its minimal values have come back to values which had been before the building a dam.

The state of Lake Baikal, the largest drink-water object of our planet, which contains ten-year inflow of the Volga, Ob, Yenisei, Lena and Amur, taken together, has not undergone any changes since 2000, although during some years there were several unusual situations.

The first situation in the middle of 2003 was connected with a level of Lake Baikal. The reason was a low water content of basic inflows of it since 1996. For seven years only 382 km^3 of water had come to the Baikal that was 90 % of the norm. The side inflow to the Bratskoye reservoir in the first half of 2003 was 1.5 times below normal. In 2002 and 2003 the level of Lake Baikal was close to a minimal mark 456.0 m. On the 8th and 9th of May a minimal daily average value of a level in 2003 was marked (456.02). However by August, 2003, the water level had arisen and reached 456.71 m in October, 2003. The situation was normalized, but it could be repeated again.

That is why the problem of regulating the water level in Lake Baikal became the subject of discussion in Irkutsk at the Chairman of Government of the Russian Federation's meeting in June, 25, 2003. The meeting was devoted to the question About Measures to Protect the Unique Ecological System of Lake Baikal.

Meanwhile, because of water evacuation by workers of the Angara cascade of the hydropower station which lasted from October, 2007, to 29th of January, 2008, the level of the Baikal was lowered to 456 meters again. On scientists' opinion, in April of the current year in a result the lake level could fall down to the mark comparable to the most water-short dry years.

Fortunately, the level had restored again by October, 2008. That is why it is important to understand where natural processes and where anthropogenic influence work.

3. ***Lake Patscuaro*** (coordinates are 19°35′ latitude north and 101°35′ longitude west) is one of the most highland in the world (altitude above sea level is 2220 meters).

The size of the lake is not large, 20×14 km, an average depth is 50 meters. The main wealth of the lake is the purest fresh water which is one of the basic resources of drinking water in state Michoacán.

In summer one can feel a sweet melancholy on the background of constant low clouds around the lake. It is usually cool in Patscuaro (in comparison with weather in Mexico) – a maximal temperature is +24 °C in the day-time, +11 °C at night.

The first mentions about Lake Patscuaro covers 1526, after conquest the lake region by the Spanish and building city Patscuaro. This historical city on the southern shore of the lake was a large and religious centre of the Indian tribe Tarasque. During the colonial period the city turned to an administrative, religious, cultural and scientific centre of the state for some time due to Vasco de Kiroga, the first bishop and scientist.

Among well-known cities on the shore of the lake there is an ancient Tarasque capital Tzintzuntsan. Tzintzuntsan is famous for its unusual Tarasque pyramids – yakatas – one of which was devoted to a pre Spanish hummingbird-idol, due to its rhythmical flapping this city got such a ringing name.

For a short time Tzintzuntsan, the capital of colonial Michoacán, was a refuge of the first Franciscan mission in this region and the first mission studying culture of the Tarasque and Lake Patscuaro [Perry, 2008].

Regular observations of the lake level began in 1921 on the hydrological station situated on the shore of the lake three kilometers from city Patscuaro and on the hydrological station on Janitsio island.

The second and the third hydrological stations were organized on the western shore of the lake and on Jaracuaro island.

On the western shore of Lake Patscuaro there are villages, each of them has its own colonial monument to draw visitors' attention. A thin cross made of stone is situated in front of St Pedro Pareo colonial church, the façade of which is decorated with various animals and figures made of stone, such as the sun and the moon.

In the ancient times the top of Jaracuaro island unprotected from wind was a temple for Ksaratanga, a Tarasque goddess of the Moon. Nowadays there is St. Pedro church and a hydrological station here.

It is rather easy to reach hydrological stations situated on islands – from piers San Pedrito (to Haracuaro) and General (to Janitsio). You cross the lake by ship of a certain color depending on the pier from which you start and come back by any ship of the same color in any convenient time (till 6 p.m.). By the way, traveling by ship to Janitsio island (like any other trips about the lake) costs about 30 peso (3 US dollars), but you can start only when there are enough people on the ship.

Since the end of the thirties of the last century the Mexican government assumed some measures to increase monitoring and controlling the lake, made some capital investments to observing a network of water monitoring and complex monitoring of surface and underground waters in the region of Lake Patscuaro. Since that moment observation data of water level of the lake have been quite reliable.

Spectral and autoregressive analysis of the state of water resources (lake levels).

In the work [Libin 1989] results of preliminary calculations of spectral water content (level) characteristics of Lake Chudskoye and solar activity were given – the existence of statistically important water content variations with periods 4 – 5, 11, 22, 80 – 90 years were shown.

The authors discovered that retardation of water content relative to solar activity oscillates from 1.5 to 3 – 4 years and depends on a solar activity cycle. (A water content maximum is 2 years late relative to solar minimum for uneven cycles and about 3 years for even ones).

Herewith a structure of water content histogram for even and uneven cycles is different, which tells us that 22-year cyclicity prevails in hydrological processes [Libin 2005].

Comparison of results of water content spectral analysis received by the authors and analogical spectrums of galactic and solar cosmic rays shows very good frequency and phase correlation. [See the works Attolini 1985, Venkatesan 1990].

Based on data of cosmic ray measuring in 1952 – 2006 scientists observed variations of 5 – 6 year, 1 year and 11 year periodicity well-correlated with solar activity and surface temperature which coincided with variations of solar activity and temperature for the same period.

Calculation of spectral characteristics of Lake Chudskoye level oscillations with a help of the 7th ARMA-model for the period 1921 – 2006 discovered noticeable oscillations of water content (level) with periods 1.0 – 1.2, 9.0 – 11.0, 21.5 – 22.8 and 80 – 90 (as it seems) years connected with solar activity.

Similar calculation results for water content spectrums for Lake Patscuaro in 1932 – 2004 and for Lake Baikal in 1927 – 2006 show similar pictures – periodicities of 1 – 2, 9 – 11, 22 and 90 years.

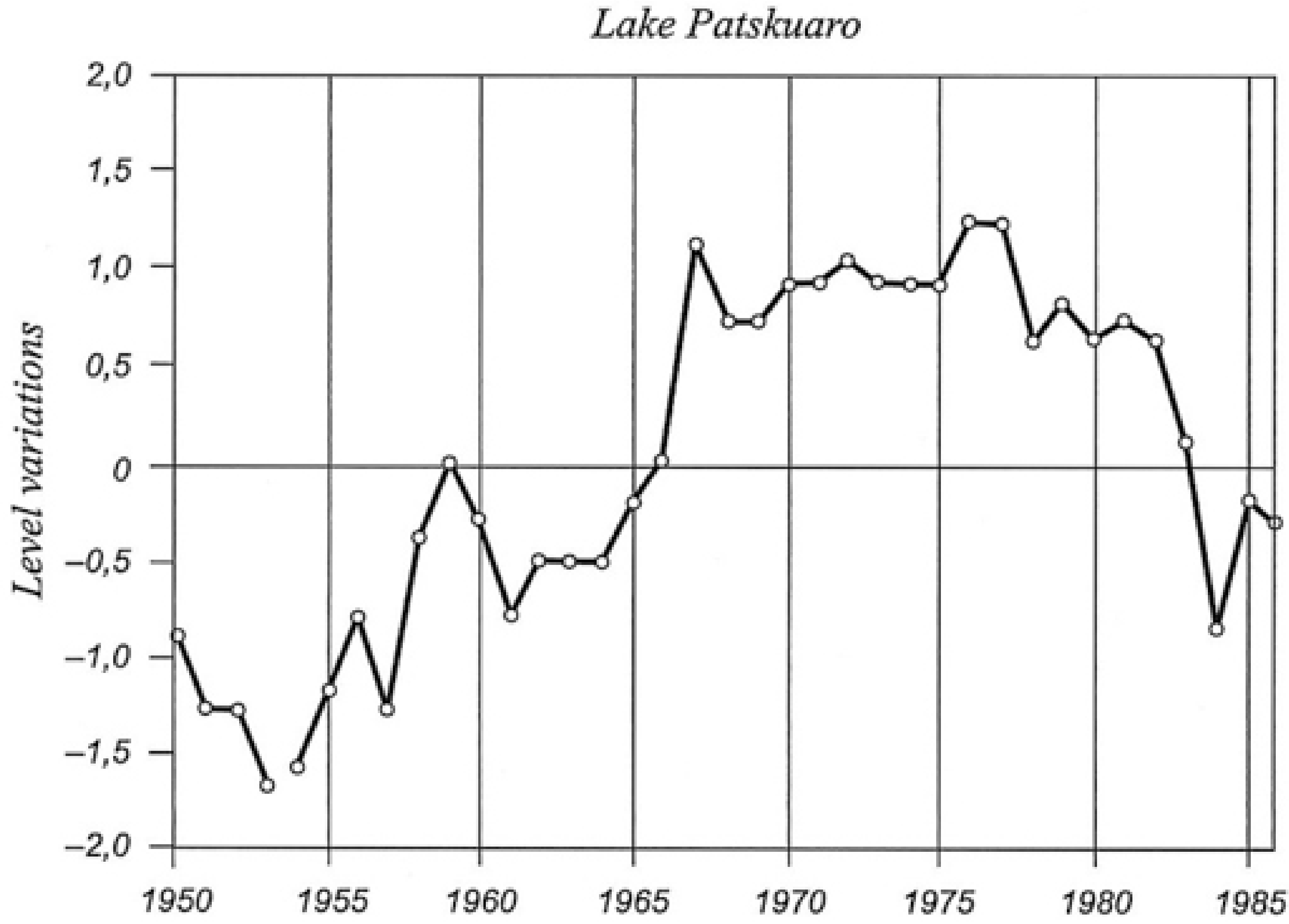
It is absolutely clear that all discovered periodicities are connected with solar activity and *have single-type retardations of water content in relation to solar activity for even and uneven cycles*.

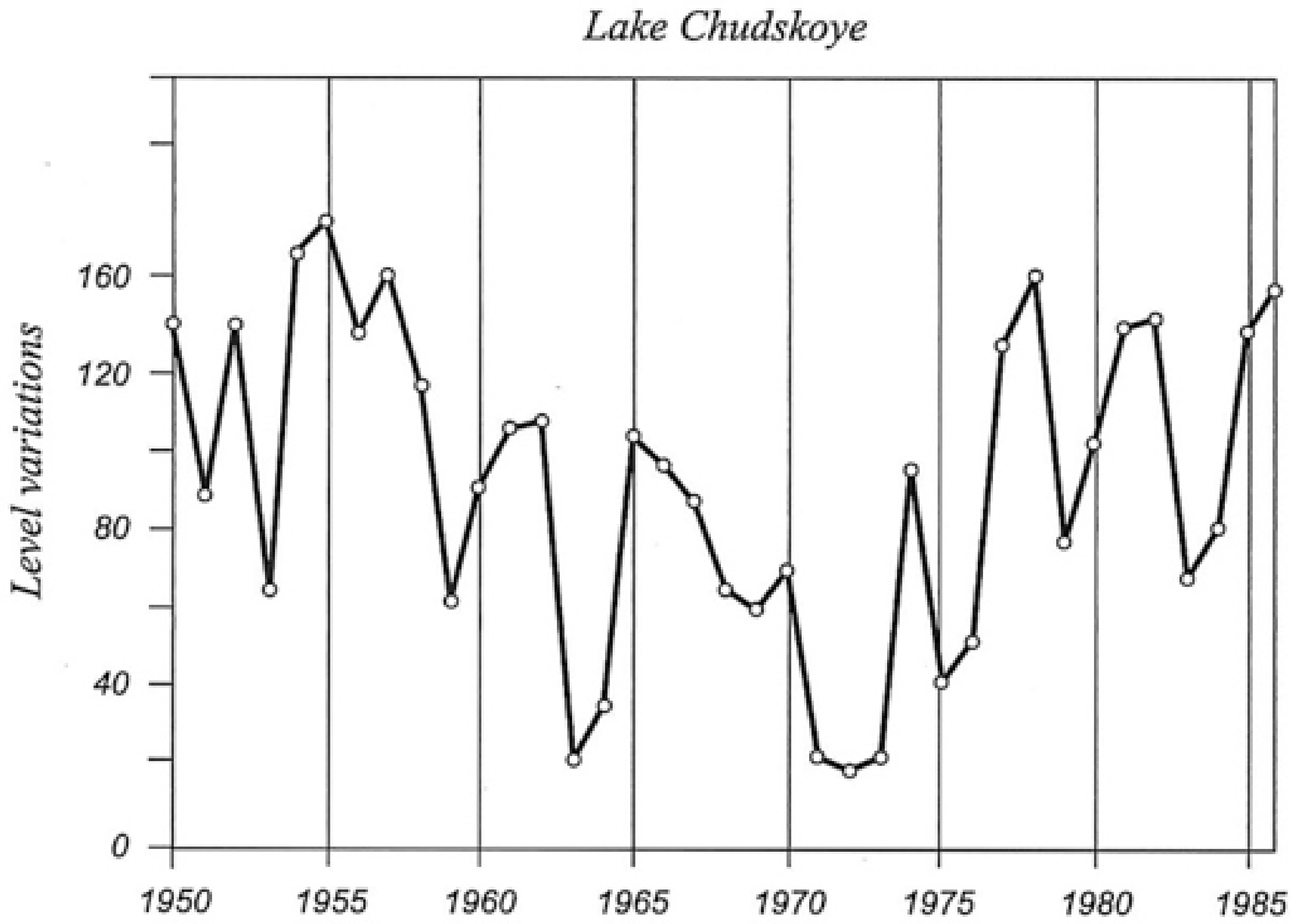
Besides, we can see from the calculations that like for all the other meteohydrological parameters, on the background of relatively stable yearly, 11-year, 22-year and 90-year variations of water content an unstable character of variations with other periods is noticed. (Oscillations with periods from several months to 4 years are observed in not all solar activity cycles although repeat solar rhythms well).

To be sure in veracity (truthfulness) of received estimations scientists decided to make a full autoregressive analysis of water content oscillations of all three lakes and solar activity in the following succession:

1. ARMA-analysis of water content oscillations (levels) of Lakes Patscuaro, Baikal and Chudskoye separately for 1932 – 2006;
2. ARMA-analysis of level oscillations of Lake Chudskoye and solar activity for the same period (based on existed data);
3. ARMA-analysis of level oscillations of Lake Patscuaro and solar activity (based on existed data);
4. ARMA-analysis of level oscillations of Lake Baikal and solar activity (based on existed data);
5. Joint multivariate ARMA-analysis of level oscillations of three lakes and other meteorological and hydrological parameters and also variations of galactic cosmic ray intensity on Earth (based on existed data for 1951 – 2006).

The level behavior of Lakes Patscuaro, Baikal and Chudskoye during 1921 – 2006 showed, at least, two curious peculiarities – 22-year variations are well-observed and, which is the main thing, oscillations of Lakes Patscuaro and Baikal are out of phase with oscillations of Lake Chudskoye.





Behavior of the levels of lakes Peipsi and Patskuaro

Calculations of mutual correlation function Patscuaro-Chudskoye give 0.6 anticorrelation with 1 – 2 year retardation.

Analysis of Lakes Chudskoye and Baikal behavior does not give such a beautiful picture (anticorrelation is about 0.4), although 22-year wave is observed in water content behavior for Lake Baikal as well.

Received results correspond well with other researchers results for Lake Chudskoye (see the table above).

Periods of water level oscillations (Lake Chudskoye)

Author	Periods (number of years)					
Jaani		5,1 – 8,0		19 – 34	80 – 90	
Reap		5,1 – 6,4	10 – 11		80 – 90	
Doganovsky				26, 33		
Libin, Jaani	2,6		11.2	22	80 – 90	
Libin, Prilutsky	2 – 4		9 – 11	22		
Current work on three lakes	2,6	5,4 – 7,0	11,0 – 12,8	22,1 – 23,0 28,0 – 35,0	84 – 91	300 – 380

It is rather difficult to identify received results of analysis in all researched data sets with results in literature data. It is necessary to know a level of truthfulness of estimations got by other authors.

As for our results, we can be sure in coincidence of estimations of separated periods including 28-year period which were got with independent methods (the Track method [Rozhkov 1988, 1989]) and methods of autoregressive analysis.

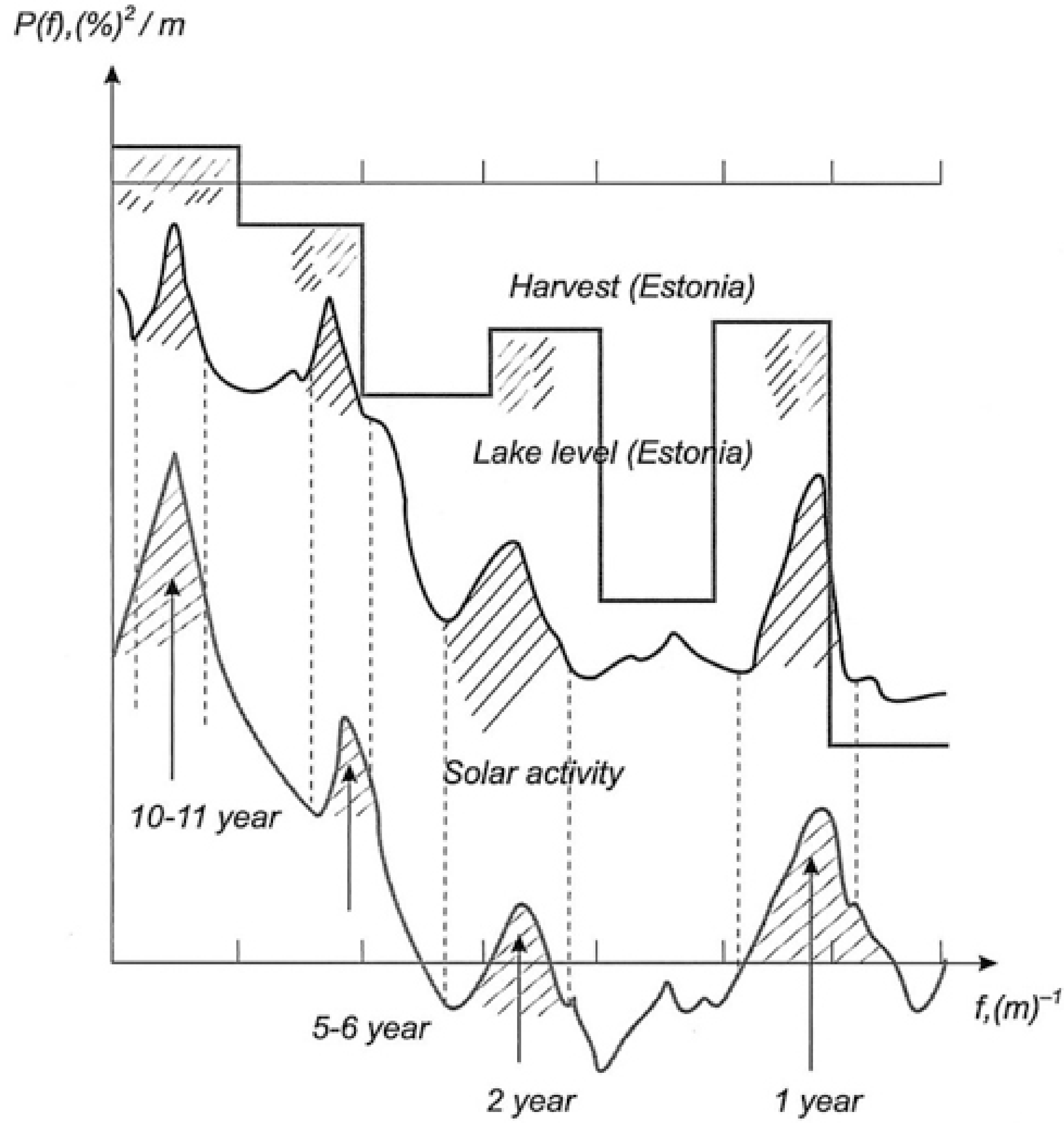
Autoregressive analysis between oscillations of the given lakes (*based on yearly average data*) has confirmed the existence of well expressed oscillations with periods 11, 22, 35, 90 and 380 years (and even 720 years with not a high truthfulness 90 %).

In this case, in general, coherence of both processes is very high, and for 22-year and 90-year oscillations a coefficient of coherence (square coefficient of process correlation on the given frequency) is 0.75 – 0.85 (0.6 for 11-year and 35-year oscillations and, unfortunately, only 0.4 for 380-year ones).

Comparison of process amplitude show some relative exceeding of oscillations of Lake Chudskoye level (that is connected with solar activity) in comparison with the Caspian Sea by 40 – 60 %, by 80 – 90 % with Lake Baikal and by 100 – 120 % with Lake Patscuaro.

ARMA-analysis of oscillations of the lake level and solar activity has permitted to come to some conclusions, important for future forecast of water content:

- *behavior of water content (level) oscillations of isolated lakes reflects dynamics of solar oscillations,*
- *retardations of water content oscillations relative to solar activity coincide with retardations of other hydrometeorological processes and reflect a joint mechanism of solar activity influence on the Earth climate.*



Spectral estimates of solar activity, the level of Lake Peipsi and productivity in Estonia in 1950 – 2000 years

Estimation of water resources in Russia, Mexico and Estonia and the forecast of them for the nearest decade.

So, the use of the whole existing spectral apparatus and comparison of results of different spectral calculations show that *solar cyclical activity and its influence on the Earth's atmosphere is a resource of mechanism of influence on closed lake water content changing* [Libin 2005].

Results received in a whole series of works permit to use an autoregressive prognostic model [Libin 2005] applied by the authors for forecasting water content of closed lakes with a purpose to raise exactness of the model on précising a series of used predictors (today's estimations give quantitative forecasts with an 35 – 40 % error).

In a result of calculations based on a large volume of measuring data a probable interconnection of processes on the Sun and in the Earth's atmosphere is shown. In this case analysis of behavior of retardation between atmospheric processes and solar activity shows the existence of stable drifts from 12 to 42 months between processes, and it correlates well with the results of calculations based on other technique [Reap 1986, Rozhkov 1988].

Moreover, it is found out, during joint analysis of water content in different points of the Earth and solar activity (and analysis of temperature behavior as well) *a choice of solar activity indexes does not play a decisive role* – so, the sunspot square in the near-equatorial zone of the Sun, as it was used by the authors earlier [Libin 1994], is the most admissible index for calculations.

That is why when solving problems of revealing large-scale processes in the atmosphere or trying to create prognostic models of climatological or hydrological processes it is necessary to take solar activity variations, processes in the interplanetary medium and cosmic radiation variations observed on Earth into account.

In a result of application of an autoregressive prognostic model the authors predict insignificant rise of water content of all three lakes connected with solar activity by 2020.

Calculations show 1.0 % increase of water content for Lake Baikal, 2.5 % increase for Lake Chudskoye, 3.0 % increase for Lake Patscuaro (only if no anthropologic disasters leading to extreme water consumption from lakes occur like it happened with Lake Baikal in the end of 2007).

Analogical researches were made in the work [Golyandina, 1997] where the author studied behavior of three series of yearly average hydrological characteristics.

1. The level of water of Lake Chudsko-Pskovskoye since 1885 to 1993. The leading period in a series of observations is a period approximately equal to 23 – 28 years.
2. Water inflow to Lakes Pesvo and Udomlya, lakes-coolers of the Kalininskaya nuclear power plant (NPP) since 1882 to 1992. The leading period in a series of observations is a period approximately equal to 24 – 28 years.
3. Maximal ice squares of the Baltic Sea since 1720 to 1992. The leading period in a series of observations is a period approximately equal to 23 – 28 years.

Received results are of a special interest for authors in connection with the fact that researchers apply [Golyandina, 1997] independent methods of analysis (multivariate statistics) – the Track method and methods of statistic modeling for researching temperature regimes of water objects, a possibility to rule a water balance of lakes-coolers, ecological consequences of hydroeconomic activity.

Multivariate statistics. Multivariate statistics works [Solntsev, 1997] were directed to the research of connections between different methods (analysis) of multivariate statistics and to development of a single approach to the system of methods of multivariate statistics which does not rest on traditional use of nondegenerate multivariate normal distribution.

The works are directed to studying the hydrological and ecological conditions of water objects of North-West including Lakes Chudskoye and Pskovskoye, Pesvo and Udomlya, used nowadays as basin-coolers of the Kalininskaya NPP, the Baltic Sea and others.

Using methods of multivariate statistics and the Track method scientists try to make long-term (to 15 years) hydrological prognoses with the aim to estimate possibilities of development of economic objects, in particular, extension of NPP.

Analysis of time series. Works on analysis of time series gave special consideration to working out theory, development, program realization and practicing technique of applying the method Track-SSA, the idea of which was firstly formulated by O.M. Kalinin in 1971. Modes of time series forecast, finding out disorder moments, analysis of multivariate time series and point images were suggested on the basis of the main algorithm of the method [Solntsev, 1997].

A.V. Shnitnikov who researched level changes of steppe lakes between Ural and the Ob for more than last 200 years got the same results. It appeared that the water level in the lakes oscillated constantly – the lakes were full of water or dried up.

V.V. Zverinsky wrote in the last century, «Grass grew up on the bottoms of many lakes, and the lakes turned to grasslands which people used to cock hay and cultivated to sow wheat and flax. Since 1854 all dried lakes began to fill with water and in 1859 they became real lakes.

As for large lakes, such as Lake Baikal, the water level in them can change by 5 meters. These changes of shallow lakes are less (about 3 meters)».

Cyclic changes a in range of a century cycle of solar activity can be in various natural processes, for example, in precipitation level, but not only in droughts, changes of water content in the rivers and water level in the lakes.

And it is necessary to take into account that lakes, especially isolated ones, are very sensible to precipitation amount and air temperature changes. The more precipitation is, the higher the water level in the lake should be.

On the other hand, rise of air temperature leads to faster expulsion of water from the lake surface. In a result, the water level lowers.

So, both factors work simultaneously.

It is clear that the water level changes while precipitation amount changes, but not quickly, not at once. There is certain retardation.

Observations show that after 2 – 4 years of the most active precipitation; the water level in the lake reached maximal value. It is clear, as the lake is not a reservoir with impermeable walls. A part of water goes to soil, and it becomes sated not at once.

Solar activity change arouses atmospheric circulation change, in a result of which precipitation amount changes too.

Changes of precipitation amount and air temperature lead to oscillations of a water level in the lakes relative to the rate. Years of low water (very low, low and middle) change with years of high water (middle, high, very high).

3.2.5. Solar activity influence on cyclic changes of precipitations

In a result of temperature and hydrological parameter research a prognostic model was built which gave a 10 – 30 % error in forecasting levels of Lakes Chudskoye and Baikal for the following year.

Analysis of possible mechanisms of lake level oscillations results in a necessity to use different meteorological parameters for a prognostic model, in particular, data of precipitation amount measures in the region of Lakes Chudskoye and Patscuaro, and, consequently, a question about a character of these changes has appeared.

Observation data of precipitation in Mexico, Estonia, Lithuania and Russia for 1910 – 2008 and solar activity (sunspot square *S*) were used for the analysis. Correlation and mutual correlation functions demonstrate good coincidence of process behavior.

The analysis was made with a help of autoregressive spectral methods [Libin, 2007], and together with it connections between solar activity and oscillations of precipitation amount in each region and connections between precipitation oscillations in all given regions were studied.

Calculations of spectral characteristics were based on monthly and yearly average values of the analyzed series which permitted to estimate precipitation amount and interconnection in a large frequency range. Correlation and mutual correlation functions of both processes (precipitations) demonstrate good coincidence of behavior of these processes.

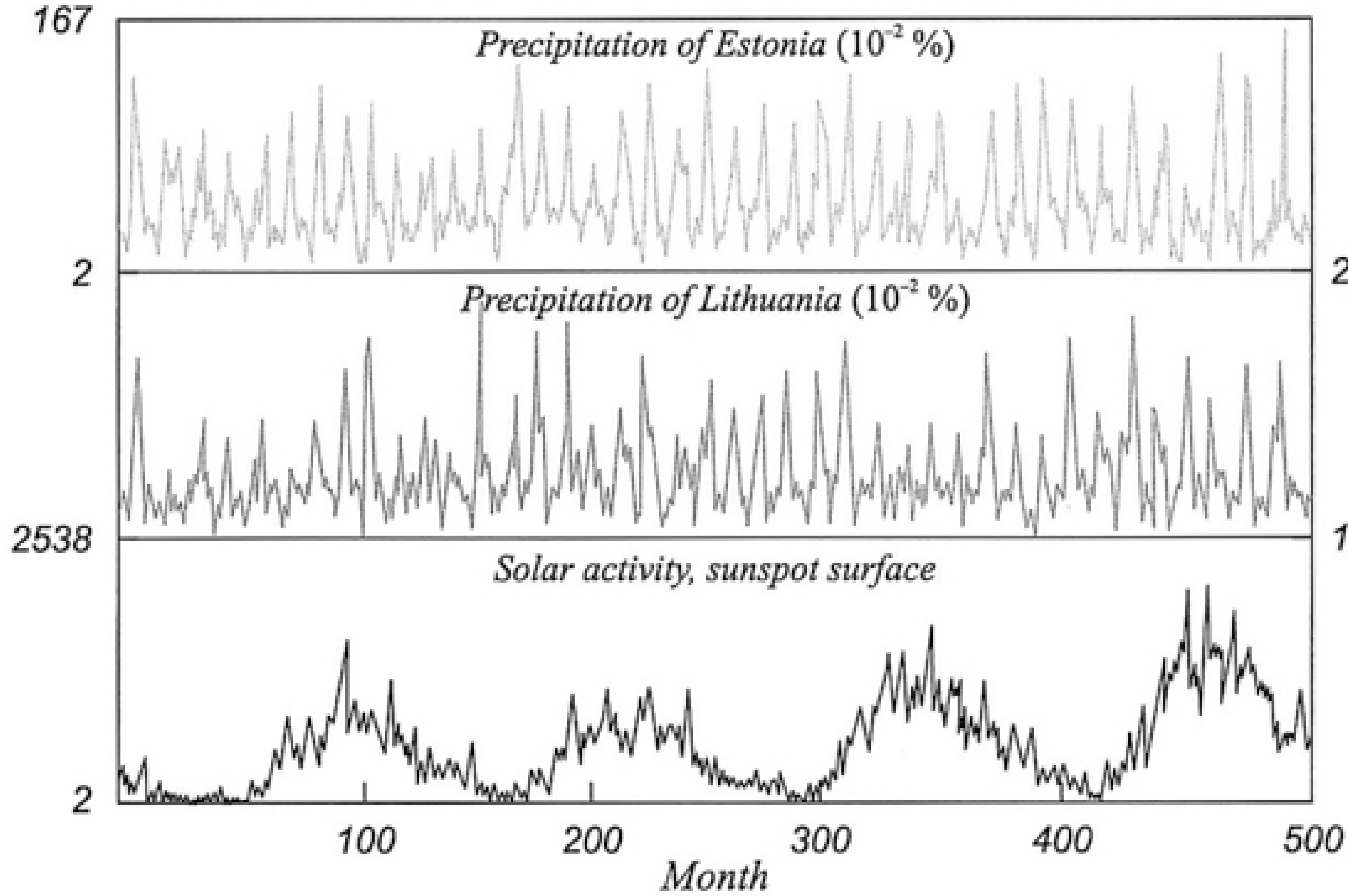
Spectrums for each analyzed series and mutual spectrums are also alike; they show the existence of the same separated peaks and confirm assumptions about identity of both processes.

In this case 2 year and, maybe, yearly periodicities in all data are connected with solar activity which is proved with results of ARMA-spectral analysis of monthly average values of solar activity and oscillations of precipitation amount in Mexico, Russia and Lithuania.

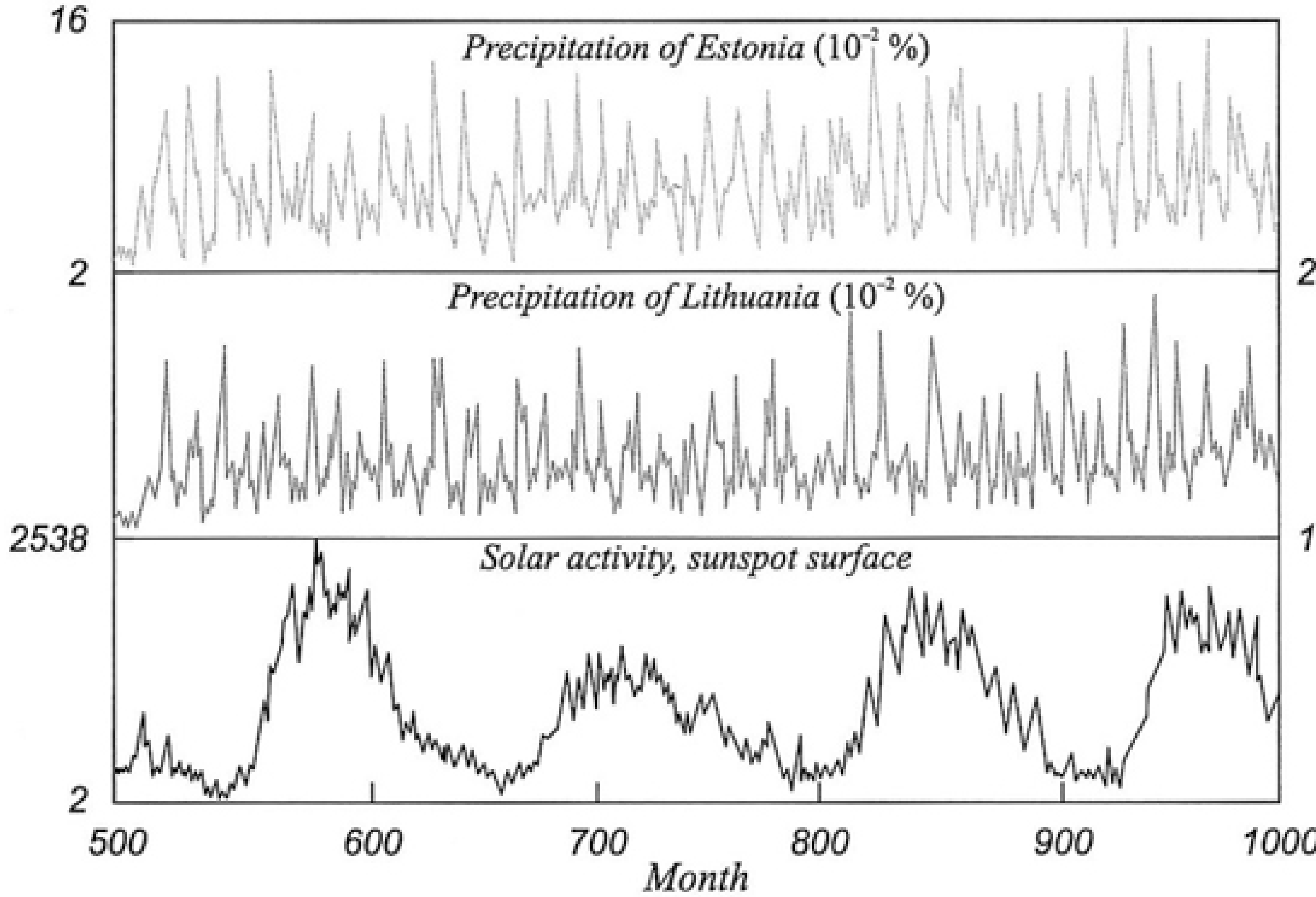
Autoregressive analysis for yearly average values of precipitation amount oscillations was made analogically. Calculations of amplitude spectrums and spectrums of coherence showed the existence of analyzed data of an 11-years component and a quasi-biennial wave.

Received results correlate well with the data of analogical calculations for temperature [Libin, 2007] and lake levels [Libin, 2008]. Besides, received results correlate well with results of analysis of average wind velocity in energoactive zones [Dorman, 1987] and, consequently, fit themselves well in the common picture of connections of atmospheric processes with solar activity.

Calculations based on yearly average data of solar activity and temperature in the same regions during the same periods show the similar results – temperature oscillations with periods 2 – 4, 9 – 11 years connected with analogical solar activity oscillations are found out.

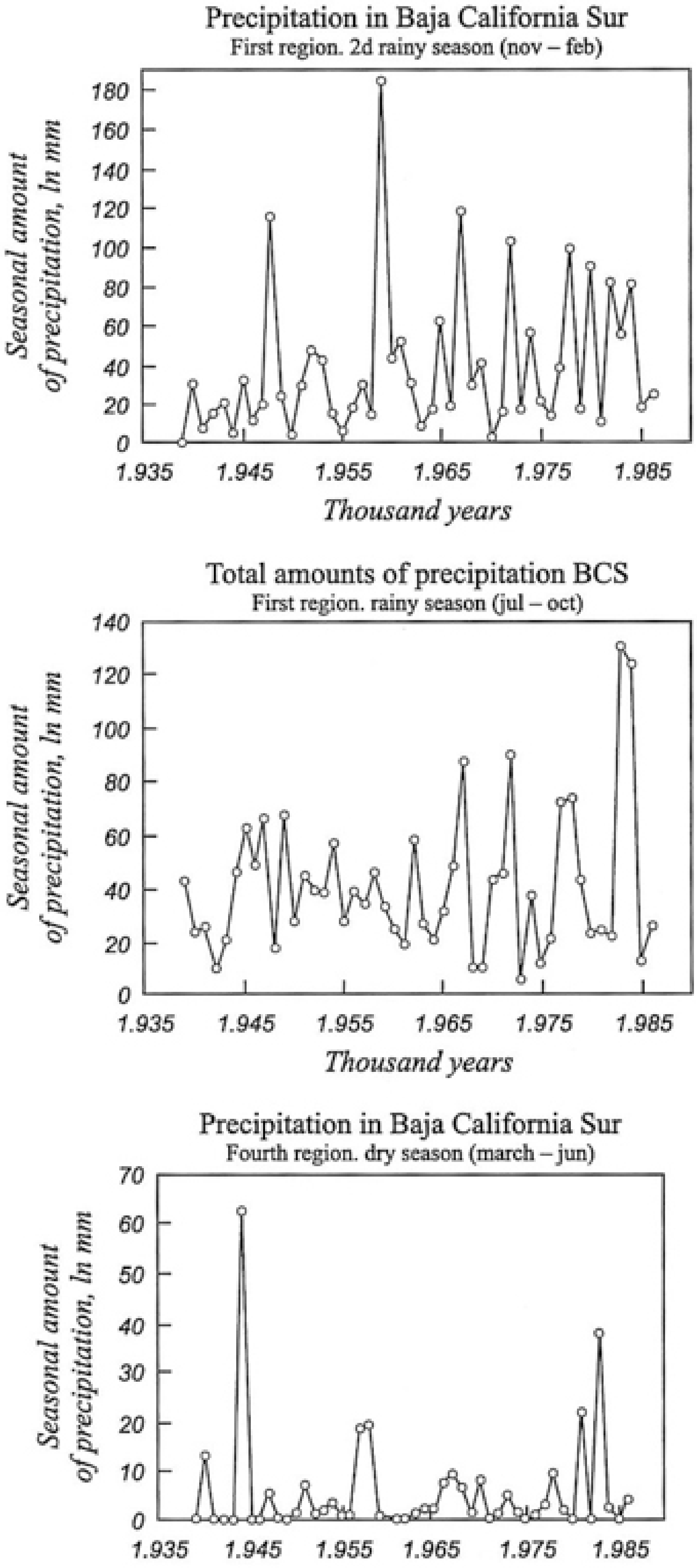


a

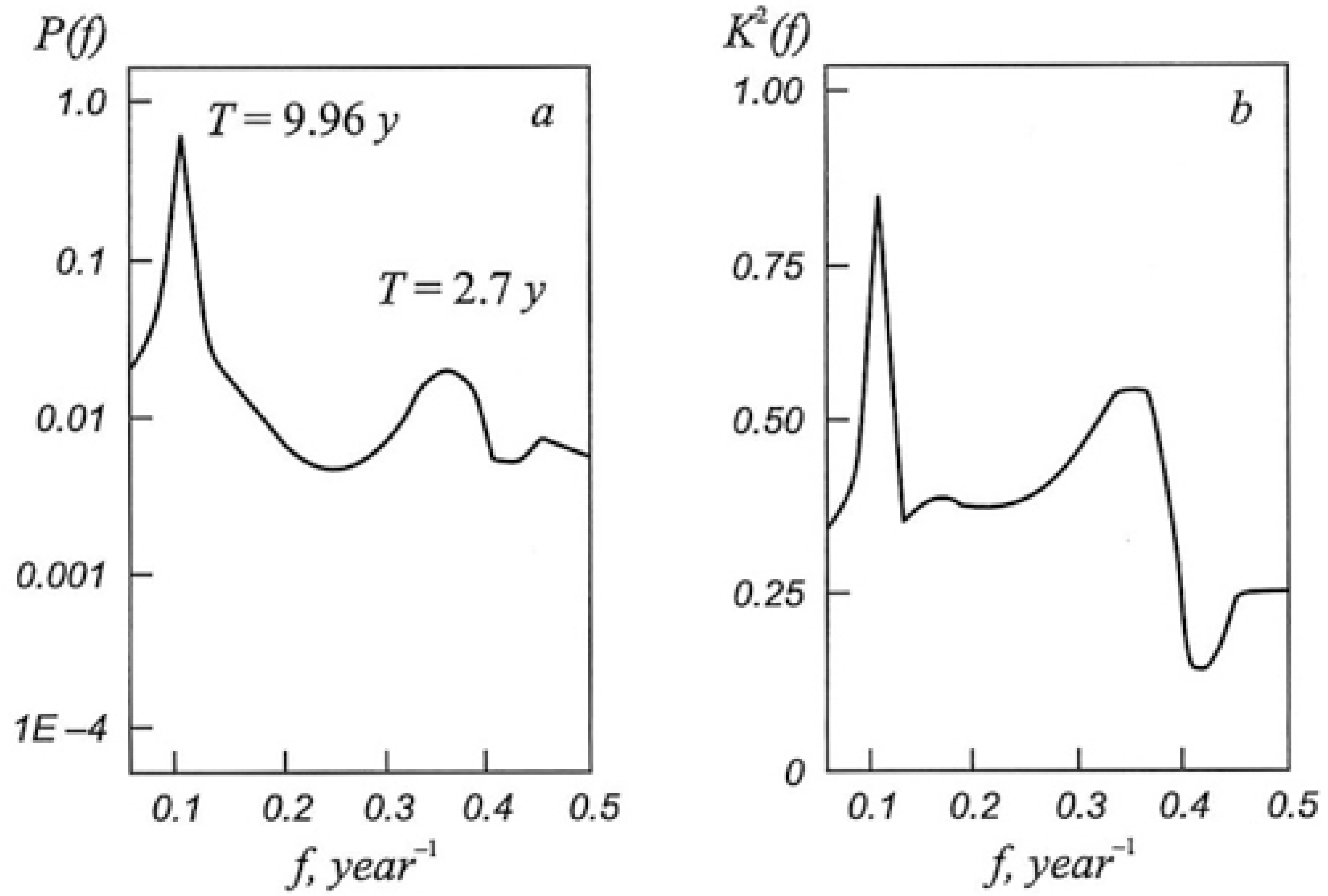


b

Monthly data of Estonian and Lithuanian precipitation series and solar activity index *S* series: *a* – for Jan.1910 to Aug.1950, *b* – for Sept.1950 to April 1993.



Annual precipitation values are averaged for different seasons (for the region of Baja California, Mexico)



Amplitude and (*b*) coherence co-spectra of Estonian precipitation and *S* annual series for 1915 – 1934. AR (1,5) and AR (2,5), respectively.

Dynamics of oscillation behavior coincides too – if 9 – 11 year oscillations exist always, 2 – 4-year oscillations are more casual that also correlates well with behavior of analogical solar activity oscillations.

In this case phase spectrums show retardations of temperature changes which correlate with results of works devoted to studying solar activity influence [Pudovkin, 1992] on geographical and hydrological processes.

Comparison of spectral characteristics of atmospheric parameters with analogical spectrums of galactic and solar cosmic rays shows a good frequency and phase correlation (in 1952 – 2000 in cosmic rays one could observe 3 – 5 month, 1 year, 2 – 4 year and 11-year variations well correlated with solar activity and temperature which coincided with variations of solar activity and precipitation for the same period).

Based on received regularities an autoregressive model was built:

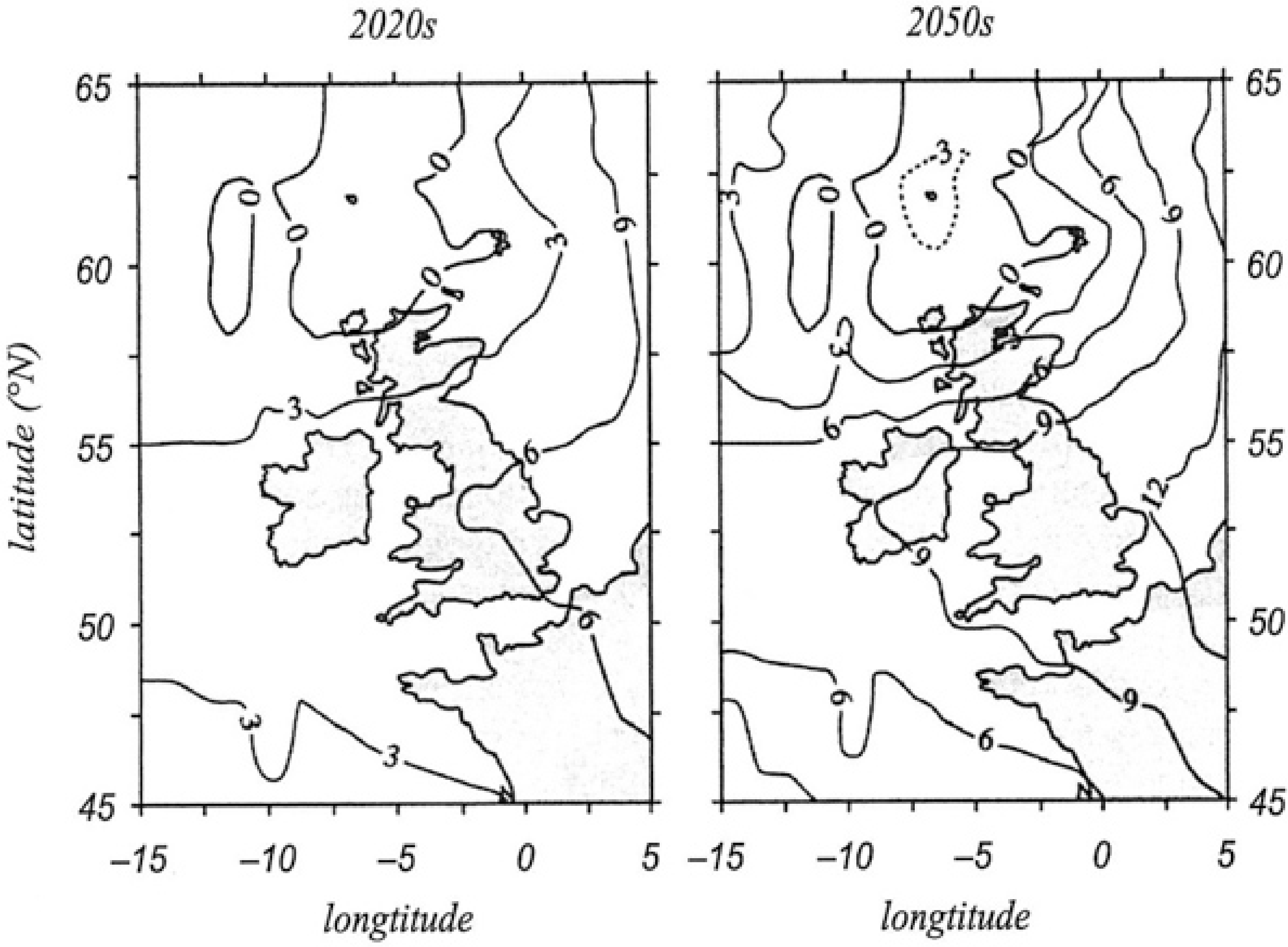
$$\Pr(t)=\sum_{i=1}^{q} a_i \Pr(t-i)+\sum_{i=1}^{s} b_i W(t-i-w)+\sum_{i=1}^{r} c_i I(t-i-i)+\xi_t \qquad (9)$$

where $\Pr(t-i)$ is current data of registration of precipitation amount, $W(t-i-w)$ is solar activity and $I(t-i-i)$ cosmic ray intensity; $\Pr(t)$ is a predicted parameter; a_i, b_i, c_i are autoregressive coefficients; ξ_t is a residential noise value minimized during calculations.

Involvement of registration data of cosmic ray intensity (parameter) improves exactness of the model much – application of CRI decreases a definition error from 40 to 20 %.

Received results correlate well with analogical calculation data of temperature and lake levels as well as results received by Australian scientists [Robert Baker, University of New England, 2008] and English scientist Mark Saunders [Saunders, 1999].

Besides, received results correlate well with results of analysis of average wind velocity in energoactive zones and, consequently, fit themselves in the common picture of connection of atmospheric processes with solar activity.



Precipitation trends over the UK expected in a warmer world.
The figure shows the percentage change in mean winter precipitation for the 2020s (left) and 2050s (right) decades with respect to the average of 1961 – 1990. (Figure reproduced courtesy of Climate Change Impacts UK (1996); Crown copyright is reproduced with the permission of the Controller of Her Majesty's Stationery Office). [Saunders, 2009]

Mark Saunders studied the problems Earth's future climate [Saunders, 1999]. Enhanced evaporation will intensify the global hydrological cycle, leading to a global precipitation increase of between 3 and 15 % by 2100. Although trends at local levels are less certain, some areas such as southern Europe in summer and Australia are expected to see a decrease in precipitation. Models agree in predicting an annual precipitation increase of 15 ± 10% over many northern high-latitude regions, this increase being mainly during winter.

A high spatial resolution model prediction for the UK and northwest France is shown in figure (see bellow). Mean winter precipitation is shown for the 2020s and 2050s expressed as a percentage change from the 1961 – 1990 average. Winters are significantly wetter throughout the UK, and by up to 10 % in southeast England by the 2050s.

Robert Baker from University of New England (Australia) put forward a theory about interconnection of the Earth's climatic system and cycles of the solar magnetic field which change poles each 11 years. In his work the researcher based on data about a precipitation level in Australia.

According to scientists' estimation, in the end of 2007 and in 2008 there will be highly intensive precipitation in Western Australia as, for example, it used to be in the dampest 1924 and 1925. In general, there is a tendency of increasing precipitation amount on the whole territory of the smallest continent.

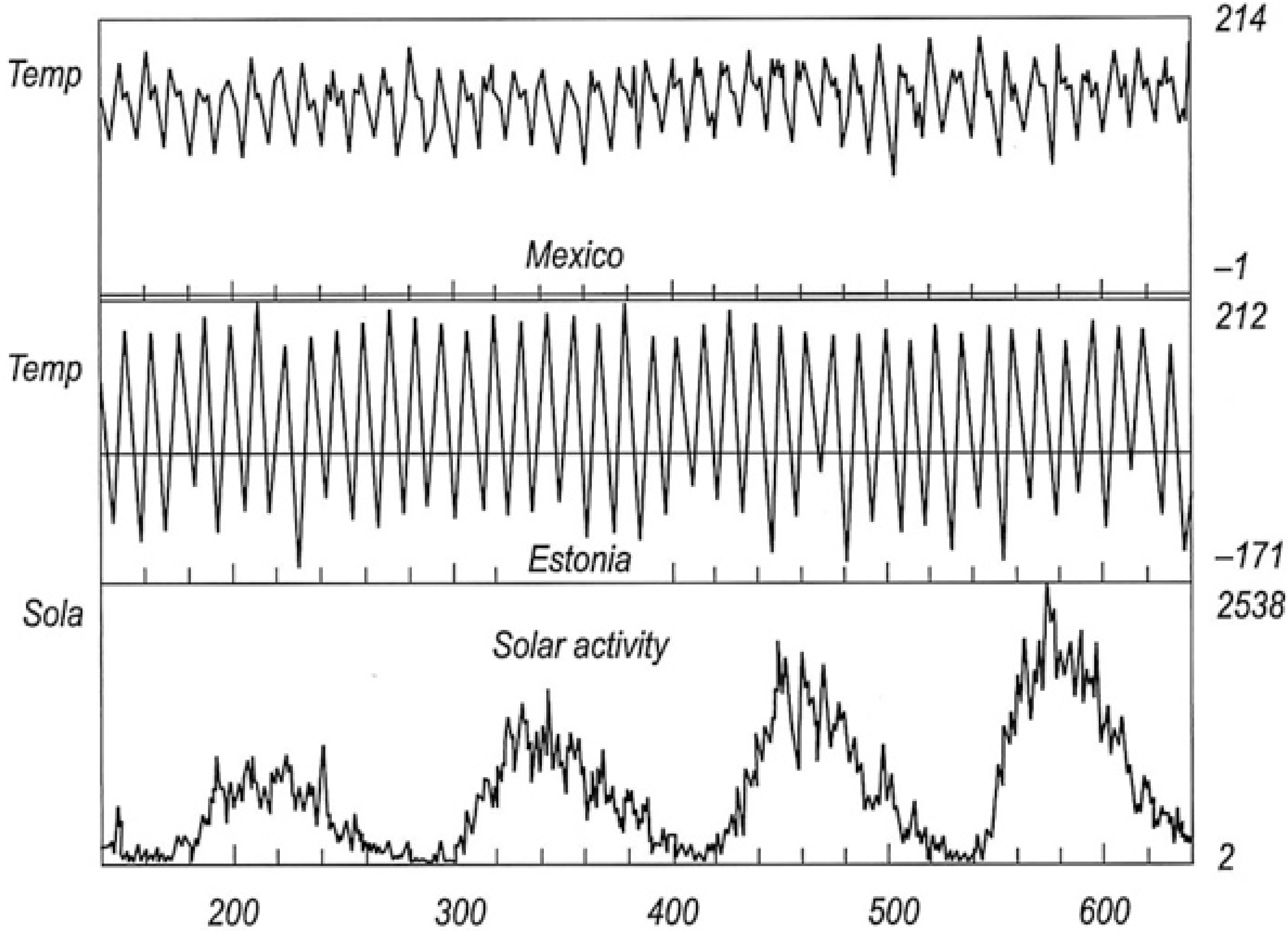
Baker bases his theory on a physical sunspot model made by him. In a result of working on it Baker found out convergence between sunspot minimum and droughts in Eastern Australia during last 100 years. If Baker's model is correct, the next drought is in store for the continent after 2009.

The Earth's weather changes depending on solar activity as a result of influence of the latest factor on the atmosphere of our planet that leads to intensification of cloud formation.

3.2.6. Solar activity changes and possible influence of them on long-period variations of surface temperature

The analysis was based on monthly average values of surface temperature measuring in Mexico (Tacubaya, Sonora, Sinaloa and Baja-California, see a list of meteostations in the end if the chapter), Estonia (Tartu), Sweden (Stockholm), Lithuania (Kaunas) and Moscow for 1910 – 2008.

Calculation results of solar activity (SA) spectrums and analogical results of mutual SA and temperature spectrums demonstrate precise coincidence of separated frequencies (correlating to 2 – 4 year and 9 – 11 year periodicities) and good coincidence of 2 – 3 year retardations between processes. In this case, dynamics of oscillation behavior also coincides – if 9 – 11 year oscillations exist always, 2 – 4-year oscillations are more casual that also correlates well with behavior of analogical solar activity oscillations.



Temperature behavior in Mexico and Estonia against the background of solar activity based on measurements in the years 1950 – 2000

Comparison of spectral characteristics of atmospheric parameters with analogical spectrums of galactic and solar cosmic rays shows a good frequency and phase correlation

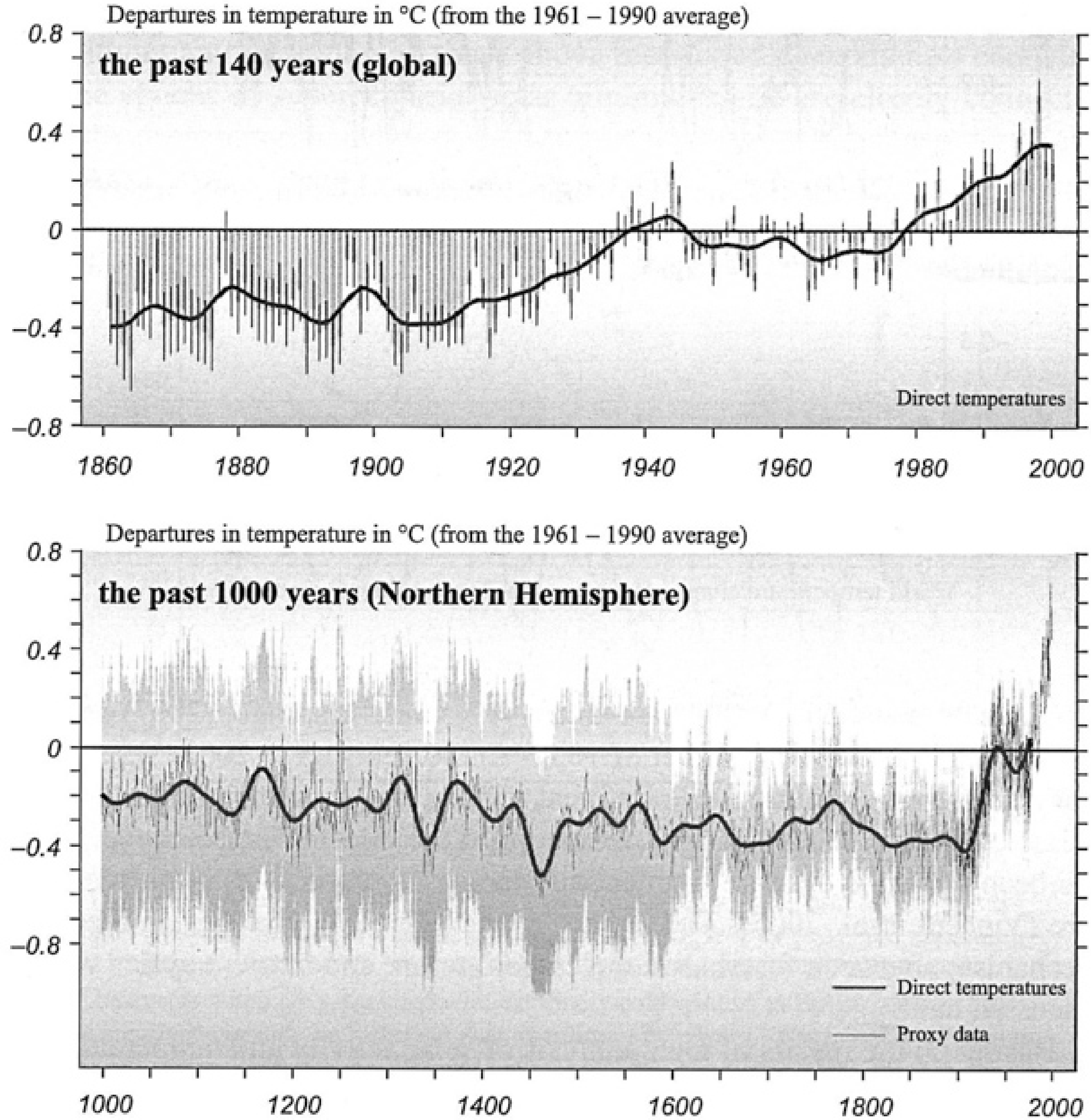
Comparison of calculation data of amplitude and phase temperature spectrums for 1937 – 2004 in Estonia and Sweden, cosmic rays for the same solar activity period gave the most impressive result.

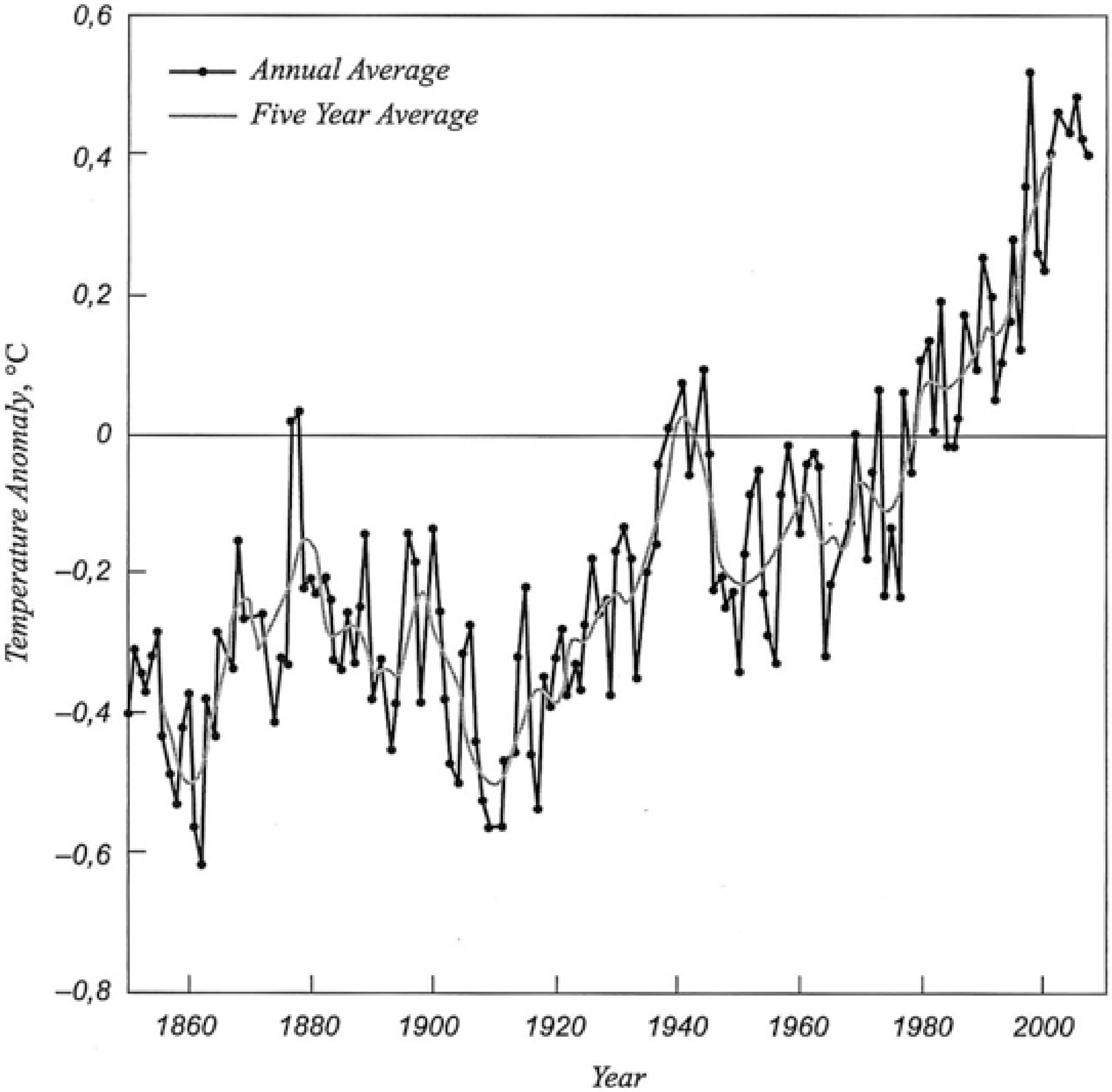
Not only 10.5, 2 – 3.7 and 1.3 – 1.7 year oscillations common for all data sets, but simultaneous phase change of all given oscillations in 1958 – 2002 were found out.

On the other hand, if to take away all separated within-year and climatic variations from temperature observation data of all researched regions and to analyze the data clean from variations it is possible to reveal that 700 – 800 year temperature trend which is called global warming.

It is clear that veracity of the spectral analysis of the given temperature data set is not high (practically we have a series which is a bit larger than a half period of the studied phenomenon), nevertheless, the existence of global warming is out of doubt [Libin, 2007, 2009], as it was written in the 1st chapter.

Variations of the Earth's surface temperature





World temperature change [Instrumental Temperature Record (NASA)]

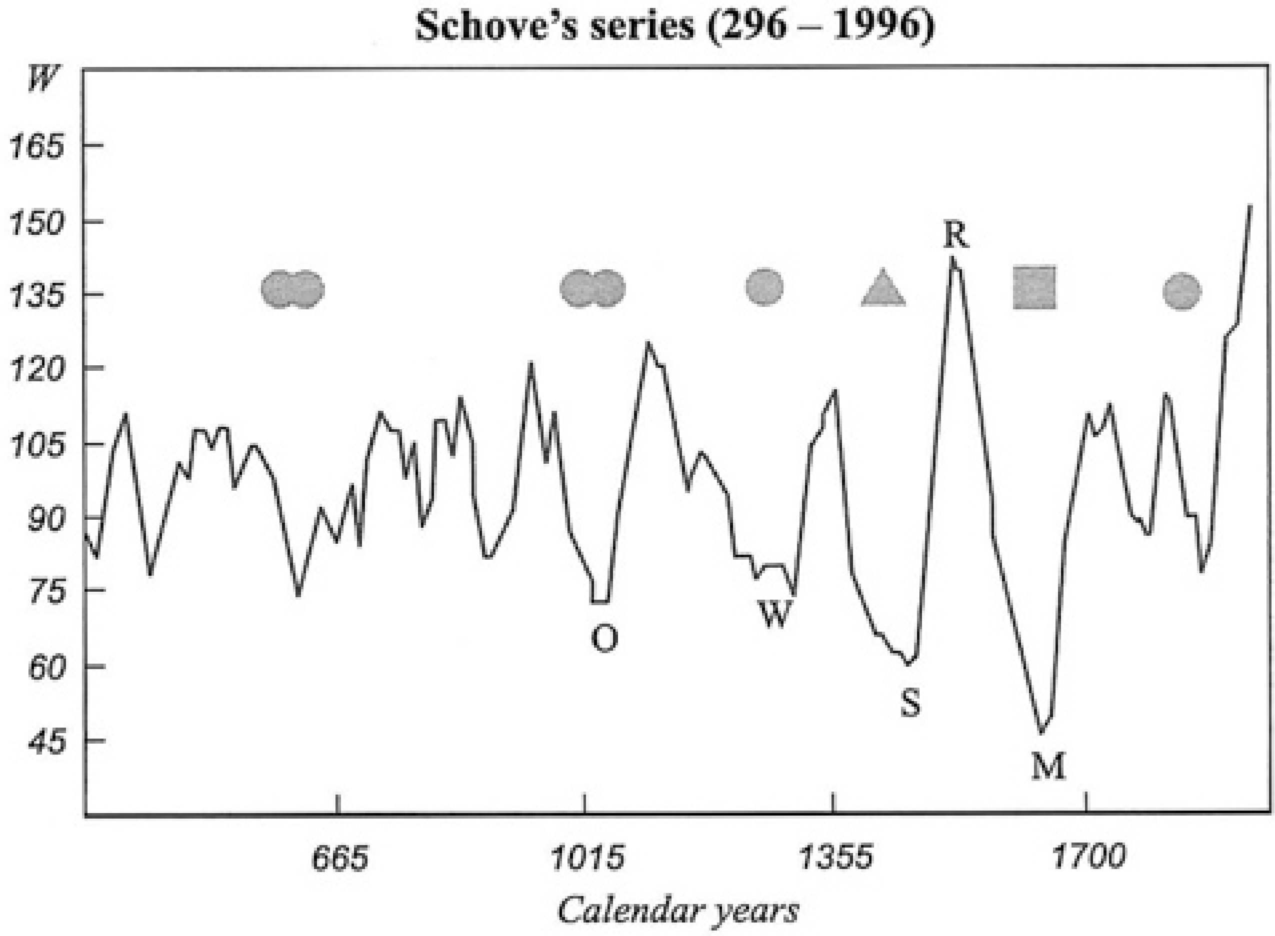
At a regional level, [Victoria et al., 1998] found a temperature increase in the Amazon of +0.56°C/100 years until 1997, while Marengo, (2007) showed an even stronger warming effect of +0.85°C/100 years up to 2002. Yet another study investigating all tropical rainforest regions found a mean temperature increase of 0.26 °C ± 0.05 °C per decade since the mid-1970s. Moreover, there has been evidence of more frequent and increased extremities in air temperature [Vincent et al. 2005]. The impact of these specific changes on feedback mechanisms between forests and the carbon, water, and nutrient cycles will be discussed next.

Basing on the results of joint analysis of solar activity and temperature we think that a tendency of temperature rise on the Earth will continue, at least, till 2050 (we should take into account that exactness of our estimation is, at least, ± 15 years), and then a process of global cooling will begin.

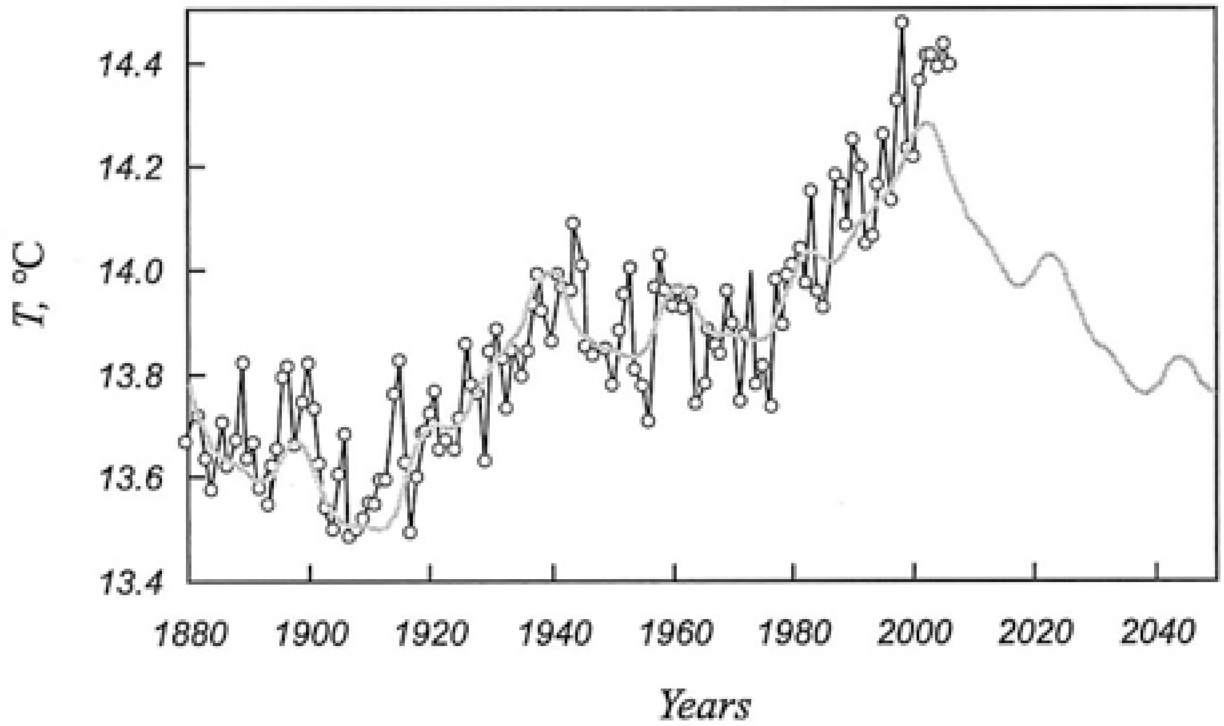
These conclusions are supported by research some extremely cold winters on Bulgarian territories in 6-th – 19th Centuries.

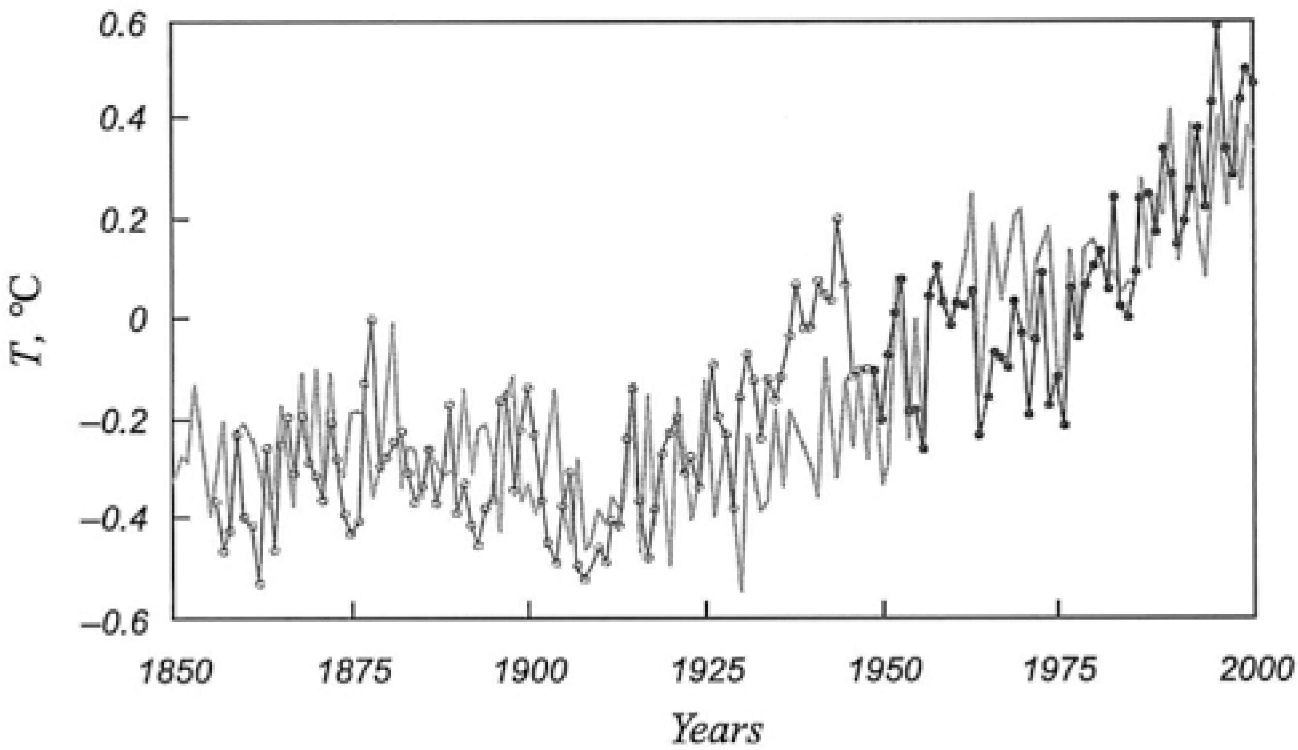
There are data from different historical sources concerning the extremely cold winters on the territory of Bulgaria in the epoch before the instrumental meteorological measurements [Zlatarski, 1972]. These are messages for natural phenomena's, which could be associated direct or indirect to the extremely low winter temperatures like full surface freezing of Danube river, waterside freezing of Black Sea or direct messages for very cold winters. All these data ones are in context with different historical events.

Without any exception all these above mentioned phenomena's come under the epochs of supercenturial solar minimums and are closely connected with the decreasing branches or near-minimal phases of the bicenturial solar cycles.



The supercenturial behavior of solar activity on the basis of the data for the powers of 11-yr cycles in Schove's series. By the letters "O", "W", "S", "M" the minimums of Oort – "O", Wolf – "W", Spoerer – "S" and Maunder – "M" are shown. The events witch are associated with extremely cold winters in Bulgarian Territories are mentioned trough the historical data as follows: by circles – the freezing of Danube; by squares – waterside freezing of Black Sea; by triangle – Vladislav III Yagello (king of Poland and Lietuania) stops the war against Turkey because of the very cold winter





Measurements, model calculations and forecast the behavior of temperature [Klimenko, 2009]

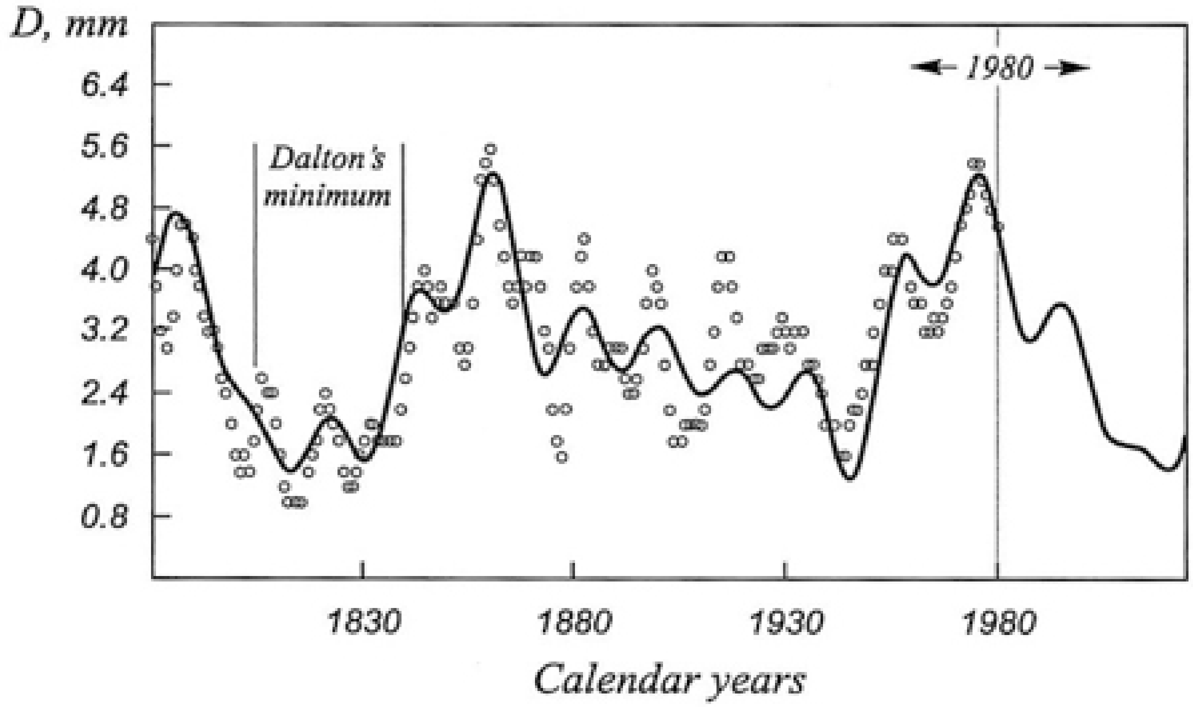
K. Willet, a famous American meteorologist, on the basis of studying a sunspot cycle predicts that the Earth temperature will begin to fall in the nearest 25 years, and in a result, it will fall much more then it has arisen for the last decades.

He confirms that there will be less long-term droughts in the middle latitudes and longer periods of insufficient precipitation amount in northern latitudes.

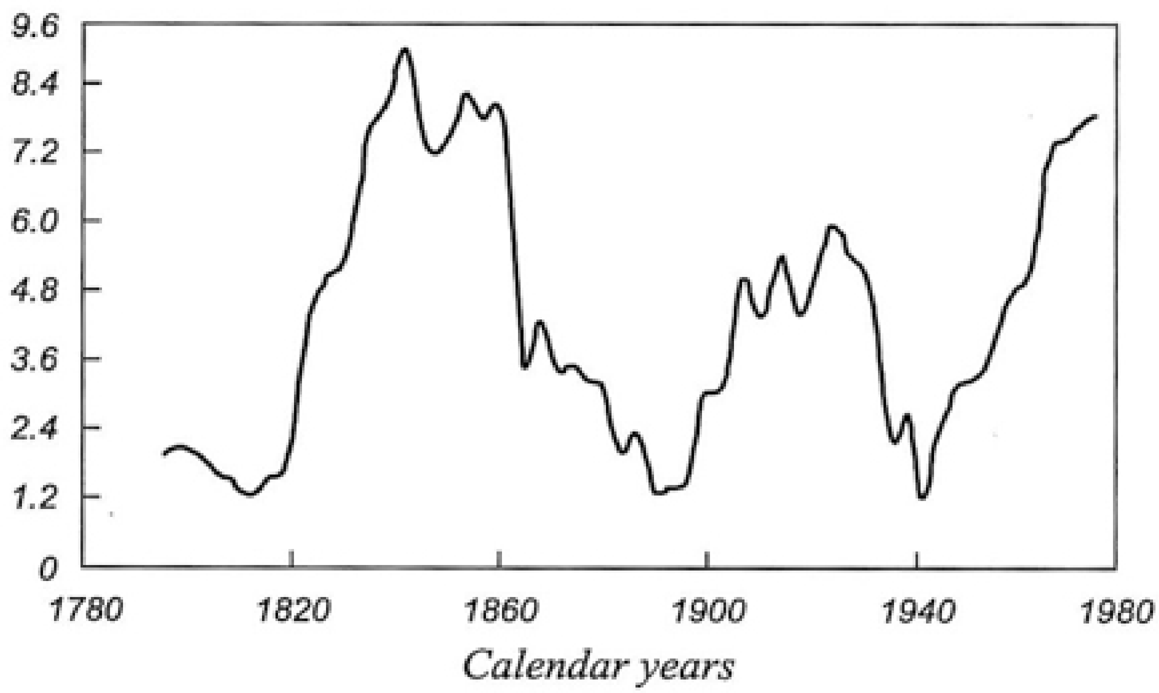
First of all, it concerns Canada and Northern Europe. In Africa and Asia there will be a ten-year period of dry weather. According to Willet's hypothesis, today's temperature is rising on Earth (from 2000 to 2030). In the next years temperature will fall substantially, and in 2140 (during the peak of 720-year solar activity cycle) a short glacier period will come.

Indirectly, these conclusions are confirmed by studies of Bulgarian scientists. Based on dendrohronology data (tree rings age 209, 147 and 125 years) with «TR periodogramanaliz» [Komitov, 1986; Komitov, 2000; Mitchel, 2001] studied the effect of SA on the climate in central Bulgaria.

The behavior of the results of dendrochronological measurements shown in the figure (see below). These results show good agreement with the behavior of solar activity is observed as a coincidence with the "minimum Dalton" and good enough sovpalenie with "secular" cycle of SA.

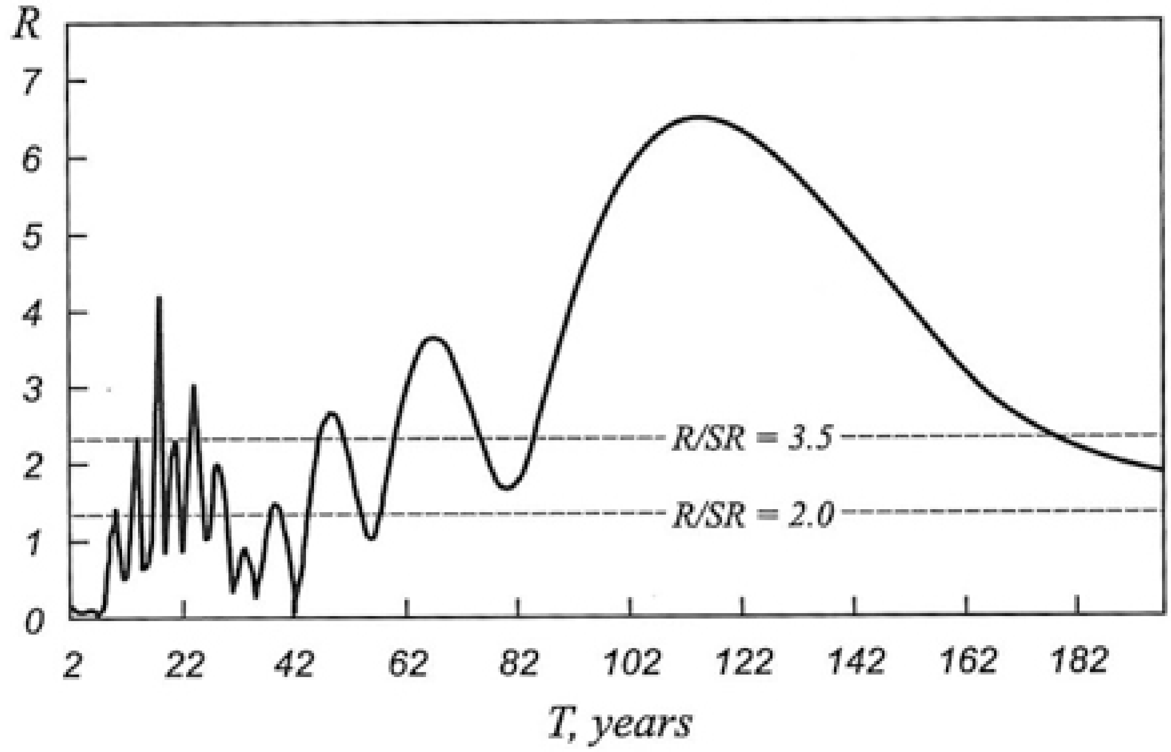


Time series of annual data for 1983 – 2015 dendrochronological measurements [Komitov, 2000]

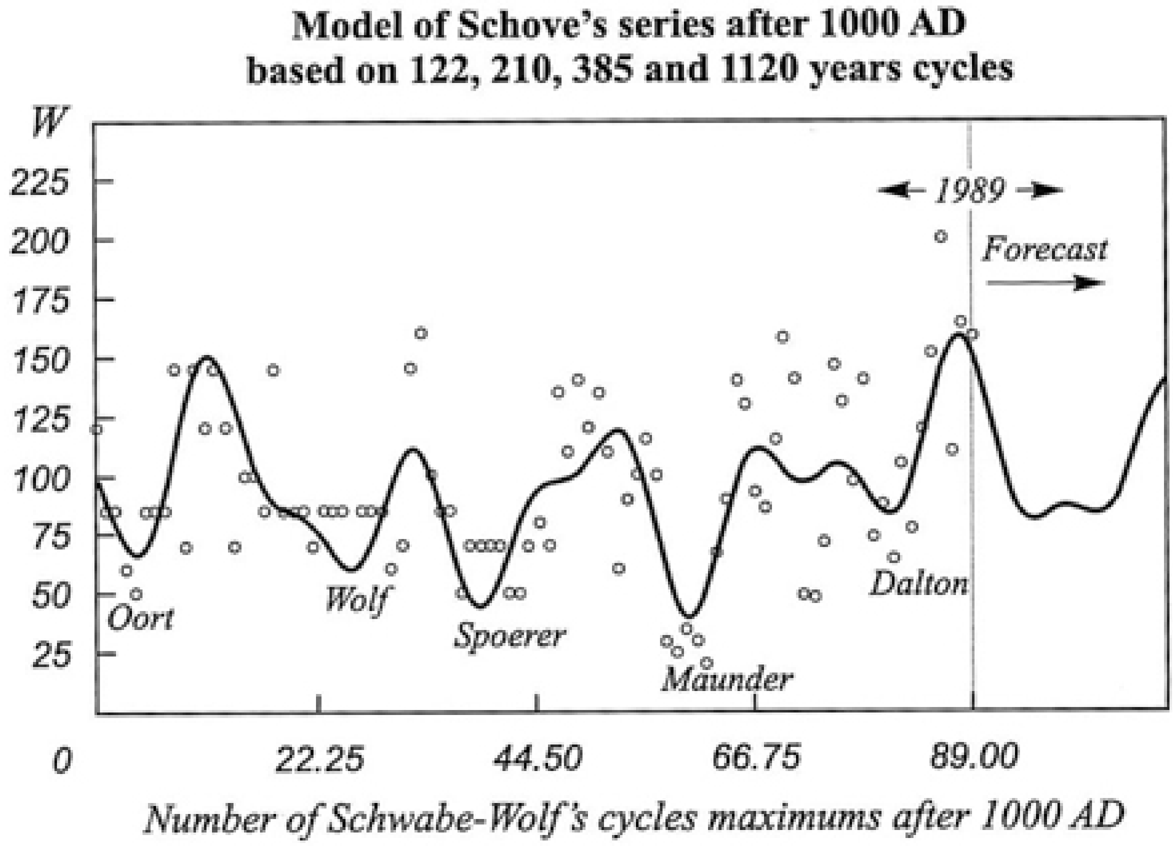


Variations dendrohronologichesih data for 1780 – 1980 years [Komitov, 2000]

A detailed analysis of annual data allows us to allocate dendrohronological 22-year variations are well correlated with similar fluctuations in solar activity with a delay of 1 year, which agrees well with the results obtained by the authors of [Libin, 2009].

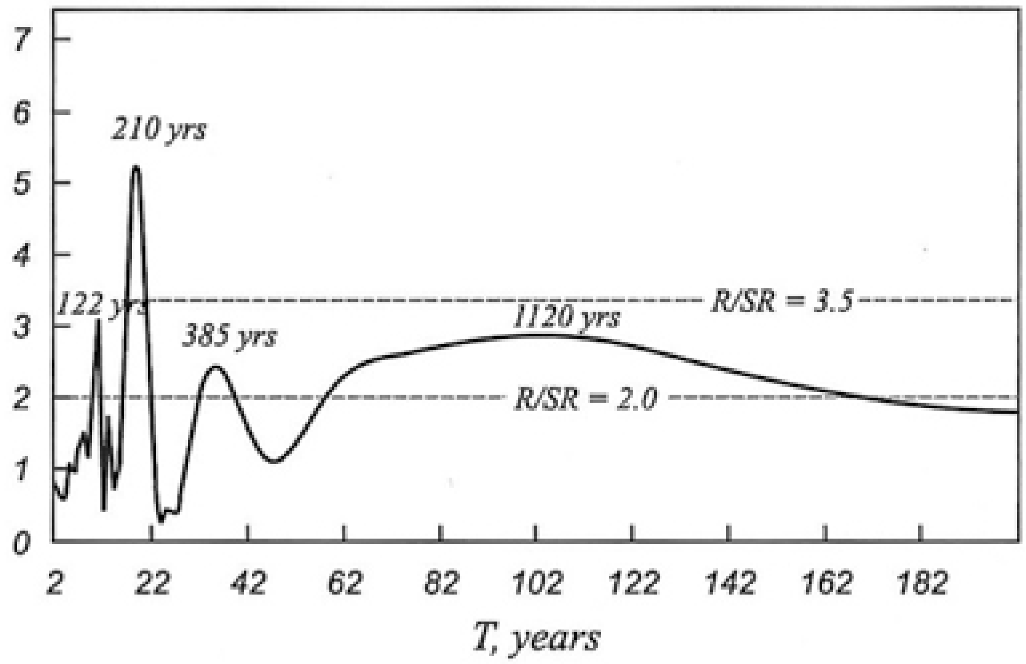


TR korelogramma dendrochronological data for 1780 – 1983 [Komitov, 2000]



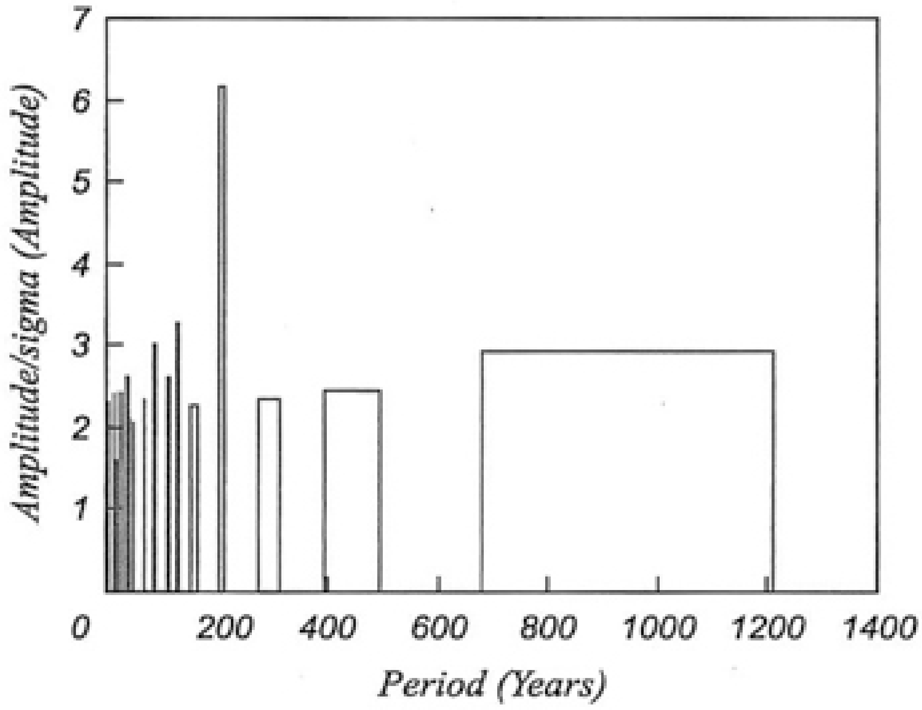
The plots bellow show the tendency of the solar activity in the future nearest decades. A new supercenturial solar minimum is clear shown. It is determined from Schove's series by using of the both abovementioned methods [Komitov and Kaftan, 2003]

«TR-periodogramanaliz» data for the past 200 years shows that there is a dendrochronological data 17 – 24-year-old (which is quite natural, since the same 22-year solar cycle and magnetic cycle Hale) 50 – 67-year-old and well-defined 90 – 120-year waves.



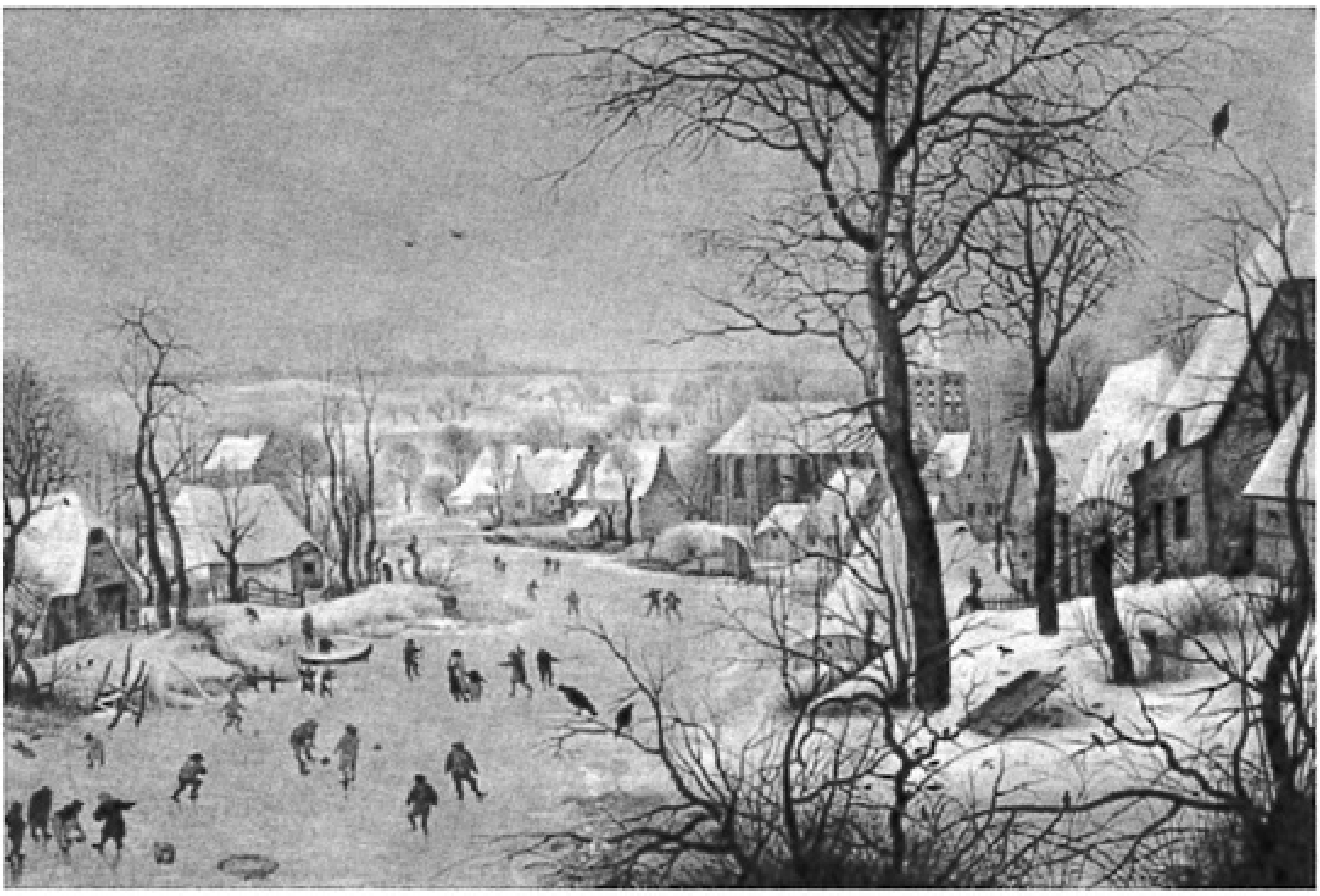
The T – R correlogramm of Schove's series (1000 – 1996 AD). The main cycle is at $T = 210$ years [Komitov and Kaftan, 2003]

Correlative-regresional factor-analysis between the dendrochronological data and SA (+0.7 %) shows good agreement between them. Similar results were obtained for the joint analysis of dendrochronological data and temperature, but the correlation is negative (–0.75 %).



The Schove's series: Spectra of variations by using the method of V. Kaftan [Komitov and Kaftan, 2003]

A similar analysis of solar activity for the years 1000 – 1996 confirmed the presence of long-term changes in climate and SA: 90 – 130, 210, 360 – 400 and 1000 – 1200 years.



Winter Landscape, painted in 1601 by Pieter Brueghel the Younger showing skaters on the frozen canals of Holland. The cold winters necessary for the canals to freeze were regular features of this time (the Little Ice Age). Skating on these canals has now become a rare event due to rising global temperatures. [Saunder, 2009]

Another method of analysis of the long-therm variations of solar activity (the Schove's series), which is used by V. Kaftan, shown a some results.

And what then? We do not have to wait long till 2040.

3.2.7. Solar activity changes and possible influence of them on processes in the World Ocean

Weather in Europe is much influenced by so-called North Atlantic Oscillation NAO which describes changes of atmosphere pressure on sea level measured over Iceland and the Azores, where, as we know, centers of atmospheric action are situated – Iceland minimum and Azor maximum pressure.

During last 50 years in winter months we could observe a tendency of atmospheric pressure fall over Iceland and rise over the Azores. But during last years this trend has increased a bit, however, influence of this climatic system spreads from the upper troposphere to the ocean floor.

Scientists discovered that for the last 50 years this tendency has led to frequent droughts in Southern Europe in winter and more precipitation on the North of the continent.

As for other seasons, this effect does not look so clearly as in winter, although today's summer heat in Southern Europe and a great deal of rain in its Northern regions illustrate well influence of this climatic system on European weather. And we do not think that anthropogenic influence on the environment is the reason of changes in North Atlantic oscillation.

There are probably some mechanisms unknown to scientists, but to establish them a long series of meteorological observations is necessary.

In the same time the models show that today's tendencies in North Atlantic oscillation will be kept in future that will make the climate in Southern Europe drier, when Northern Europe will subject to heavy storms.

In this case the Earth climate will become warmer and warmer which will lead to decrease of pure water stocks on the planet.

On the basis of difference of North Atlantic oscillation index (NAOI) from its rate value it is possible to estimate what kind of winter will be next year in Europe – cold and frosty or warm and damp. But as nowadays such calculation models have not been worked out yet, it is very difficult to make reliable forecasts.

Large researching work is in store for scientists; they already understand the most important components of this weather mix in the Atlantic Ocean and can understand some consequences of it.

Gulfstream plays one of the decisive roles in the game between the Ocean and atmosphere. Today it is responsible for warm, mild weather in Europe, without it climate in Europe would be more severe then now.

If a warm flow of Gulfstream is strong its influence increases atmospheric pressure difference between the Azores and Iceland. In this situation a high pressure zone near the Azores and a low pressure zone near Iceland arouse leeway of a western wind. A result of it is a mild and damp winter in Europe.

If Gulfstream is cool there is an opposite situation – pressure difference between the Azores and Iceland is much lower, or NAOI has a negative value. A result is a weak western wind, and a cool air from Siberia can penetrate unobstructed on the territory of Europe. In this case, a frosty winter comes.

NAO which point pressure difference value between the Azores and Iceland let us understand what kind of winter will be. If it is possible to predict summer weather in Europe on the basis of this method is not clear yet.

Some scientists among which Doctor Mojib Latif, a meteorologist from Hamburg, and Mikolas Mikalayunas, a meteorologist from Lithuania, predict high probability of heavy storms and precipitations in Europe.

In future if a high pressure zone near the Azores becomes weaker usual storms in Atlantics will reach South-Western Europe, Doctor Latif says. He also supposes that in the given phenomenon, like in El Niño, circulation of warm and cold ocean flow during uneven periods of time plays a big role. There is still much unstudied in this phenomenon.

Two years ago James Hurrell, an American climatologist, from the National Center for Atmospheric Research in Boulder/Colorado compared NAOI indicators with the real temperature in Europe during many years. The result was satisfactory – undoubted interconnection was revealed. So, for example, a severe winter during the Second World War, a short warm period in the beginning of the 50s and a cold period in the 60s correlate with NAOI indicators and solar activity cycles. The authors researched stormicity in NAO during many years. The results of solar activity influence on NAO are given in this chapter.

Simultaneously with researches of atmosphere circulation processes in the Atlantic Ocean (study of stormicity in the region of North Atlantic energoactive zone – North Atlantic oscillation) the phenomenon El Niño (ENSO) attracted researchers' attention [Bucha, 1988; Philander, 1990; Anderson, 1992; Mendoza, 1991; Libin, 1995; Perez-Enriquez, 1993; Friis-Christensen, 1993].

South oscillation or El Niño is a global ocean-atmospheric phenomenon. This is the name of abnormal warming of surface water of the Pacific Ocean near Ecuador and Peru which happens once per several years. This tender name reflects only the fact that the beginning of El Niño often falls on Christmas, and fishermen of western coast of South America connected it with the name of baby Jesus.

Being a characteristic feature of the Pacific Ocean El Niño and La Niña are temperature fluctuations of surface water in tropics of an eastern part of the Pacific Ocean. The names of these phenomena taken from local people's Spanish language and firstly introduced for scientific use in 1923 by Gilbert Thomas Walker means baby-boy and baby-girl.

Circulation is a substantial aspect of Pacific phenomenon ENSO (El Niño Southern Oscillation). ENSO is many interacting parts of one global system of ocean-atmospheric climatic fluctuations which is succession of ocean and atmospheric circulations. ENSO is the most famous resource of interannual variability of weather and climate in the World (from 3 to 8 years).

During normal years temperature of the ocean surface oscillates in a narrow seasonal range from 15 °C to 19 °C along the whole Pacific coast of South America because of coastal rise of depth water aroused by a Peruvian cold flow.

During El Niño period temperature of the ocean surface in a coastal zone rises by 6 – 10 °C. According to geological and paleoclimatic research, the phenomenon has been existed not less than 100 thousand years. Temperature oscillations of the ocean surface from extremely warm to neutral or cold happen once per a period from 2 to 10 years.

T.D. Michalenco and E.Y. Leonova, the leading weather forecasters of the Forecast Department of the Far Eastern Scientific Research Hydrometeorologic Institute (FESRHMI) write in their report, «There is a constant warm flow springing from the Peruvian coast and spreading to the archipelago which is situated to south east from the Asian continent. It looks like an elongated tongue of heated water and its square is equal to the territory of the USA. Heated water evaporates intensively and fills the atmosphere with energy.

During El Niño in the equatorial region this flow warms up more than usually, that is why trade winds become weaker or stop blowing. Heated water spreads over, flows back to the American coast. An abnormal convection zone appears. Rains and tornados fall upon Central and South America».

The La Niña phenomenon is opposite to El Niño and manifests itself as a fall of surface water temperature lower then a climatic rate in the east of a tropical zone of the Pacific Ocean. During La Niña formation trade (eastern) winds from the western coast of both Americas become stronger and move the warm water zone, and a cold water tongue 5000 km elongates just in the same place where during El Niño a warm water zone must be. In this case Caribbean countries and the USA suffer from storms and draughts.

La Niña like El Niño appears more often since December to March. The difference between them is the following – El Niño appears at the average once per 3-4 years, and La Niña once per 6 – 7 years. Both phenomena bring a larger quantity of storms, but during La Niña they can be 3 – 4 times more than during El Niño.

In the Pacific Ocean during substantial warm events El Niño warming becomes wider by a large part of the Pacific tropics and finds itself in a direct connection with intensity SOI (South oscillation index). When ENSO events are mainly between the Pacific and Indian Oceans, ENSO events in the Atlantic Ocean is 12 – 18 months later from the first.

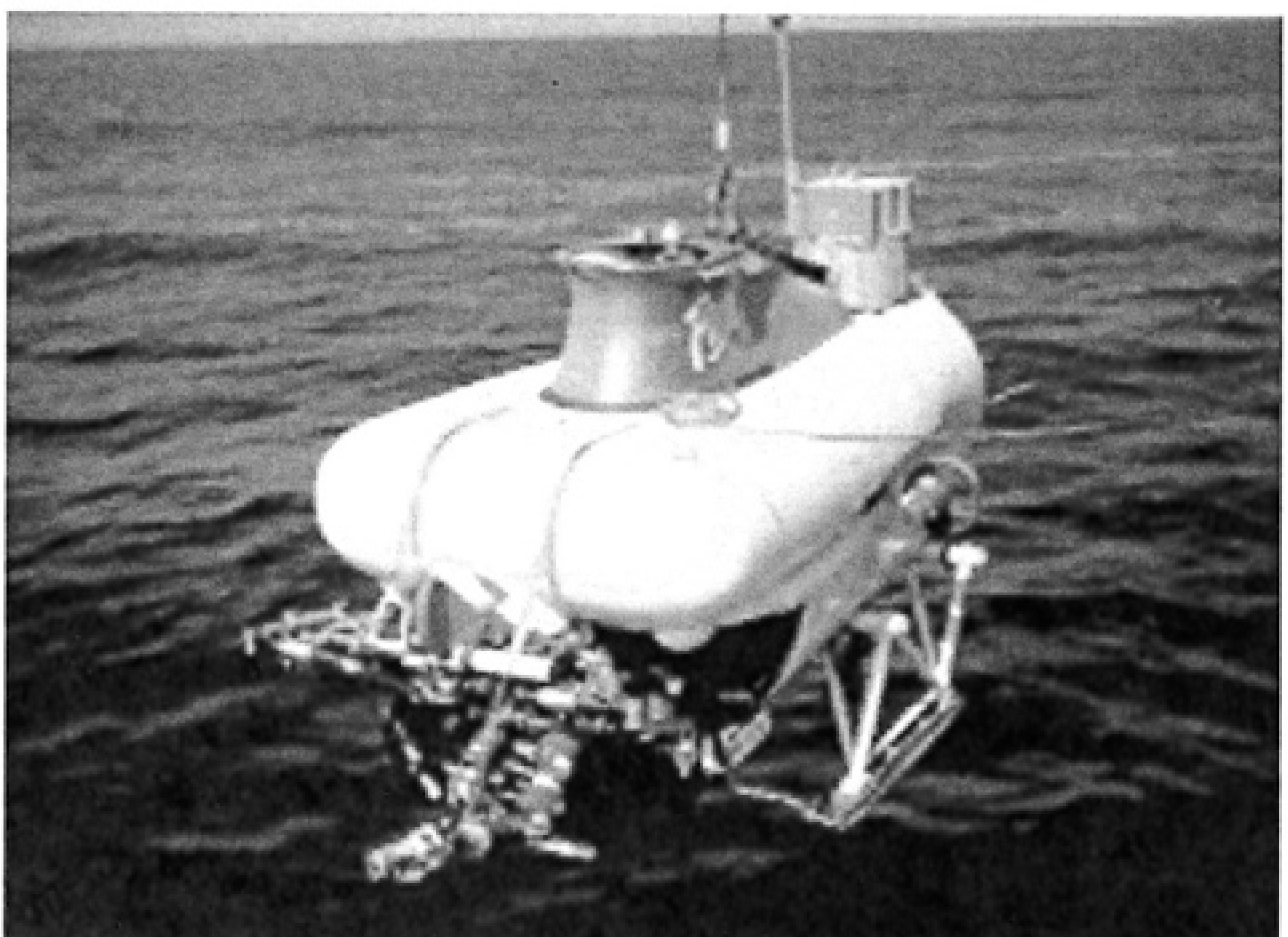
As ENSO is a global and natural part of the Earth climate it is important to find out if intensity and frequency change can be a result of global warming.

Low-frequency changes were found in the work [Bucha, 1988], where using autoregressive spectral method 22-year and 400-year oscillations were also found in addition to 90-year oscillations of El Niño appearance discovered by [Libin & Mikalayunas, 1987].

Invert correlation between ENSO number and quantity W and sunspot squares S was also discovered. We can observe well expressed correlation of ENSO with atmospheric quasi-biennial oscillations (AQBO) [Perez-Peraza, 1994; Anderson, 1992].

Researches of the last 50 years has permitted to find out that El Niño means something more than just correlated oscillations of surface pressure and temperature of ocean water.

El Niño and La Niña are the most brightly expressed manifestations of within-year climate change in a global scale. These phenomena are large-scale changes of ocean temperature, precipitation, atmospheric circulation, vertical air movements over a tropical part of the Pacific Ocean.



Underwater Vehicle "Paysis" explores the Pacific Ocean (Institute of Oceanology)

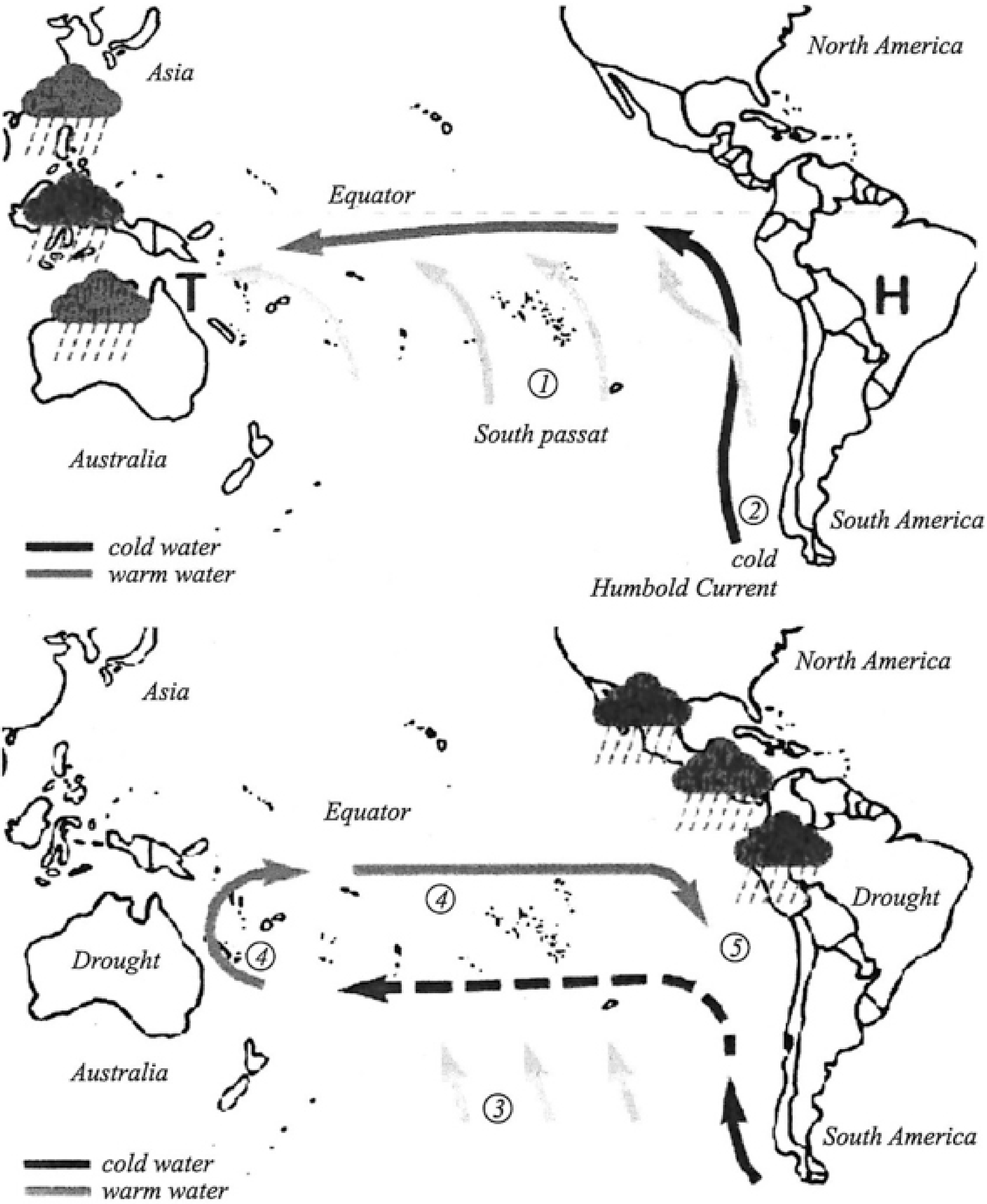
El Niño phenomena are also responsible for large-scale abnormalities of air temperature in the whole World. There can be outstanding rises of temperature. The conditions warmer than normal ones in January-February were over south-western Asia, Far East, Japan, the Japan Sea, south-western Africa and Brazil, south-western Australia.

Temperatures warmer than normal ones are noted in June-August along the western coast of South America and over south-eastern Brazil. Colder winters (December-January) can be along the south-western coast of the USA.

Underwater vehicle "Mir" explores the CAO (Institute of Oceanology)

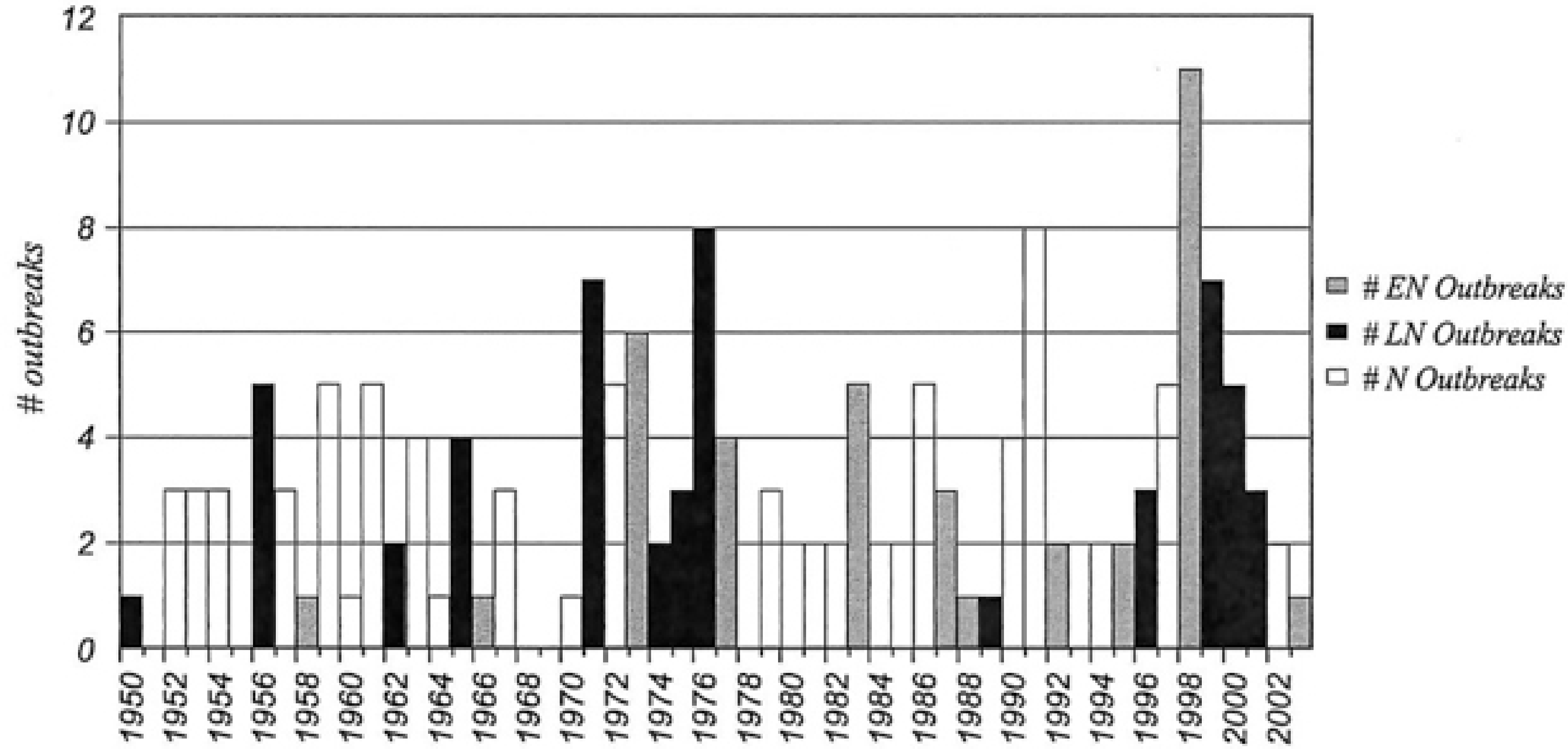
During La Niña periods the conditions drier than normal ones are observed over Ecuador coast, north-western Peru and an equatorial part of eastern Africa during December-February and over south Brazil and central Argentina during June-August. All over the World scientists note large-scale abnormalities with the largest quantity of regions suffering from abnormal cold conditions – cold winters in Japan and Far East, in southern Alaska and western and central Canada; cool summers in south-western Africa, India and south-eastern Asia. Warmer winters can be observed in South-West of the USA.

During El Niño more energy is carried to the troposphere of tropical and middle latitudes. It is manifested in increase of thermal contrasts between tropical and polar latitudes, activation of cyclonic and anticyclone activity in the middle latitudes.

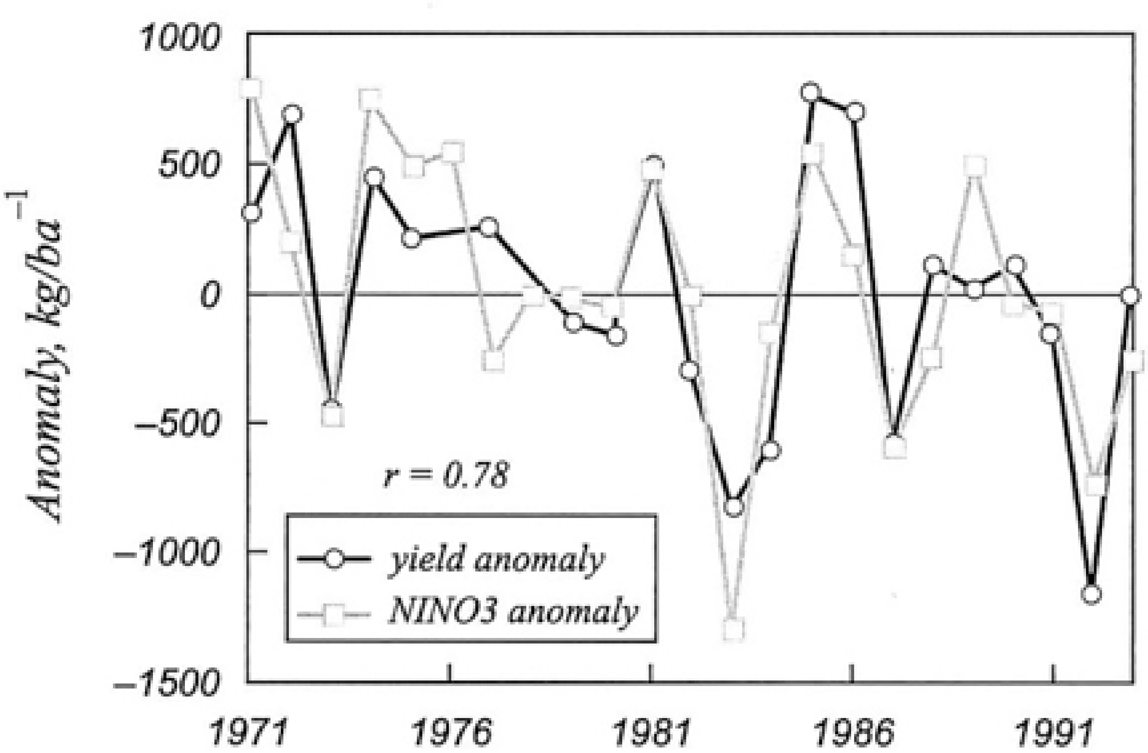


El Niño

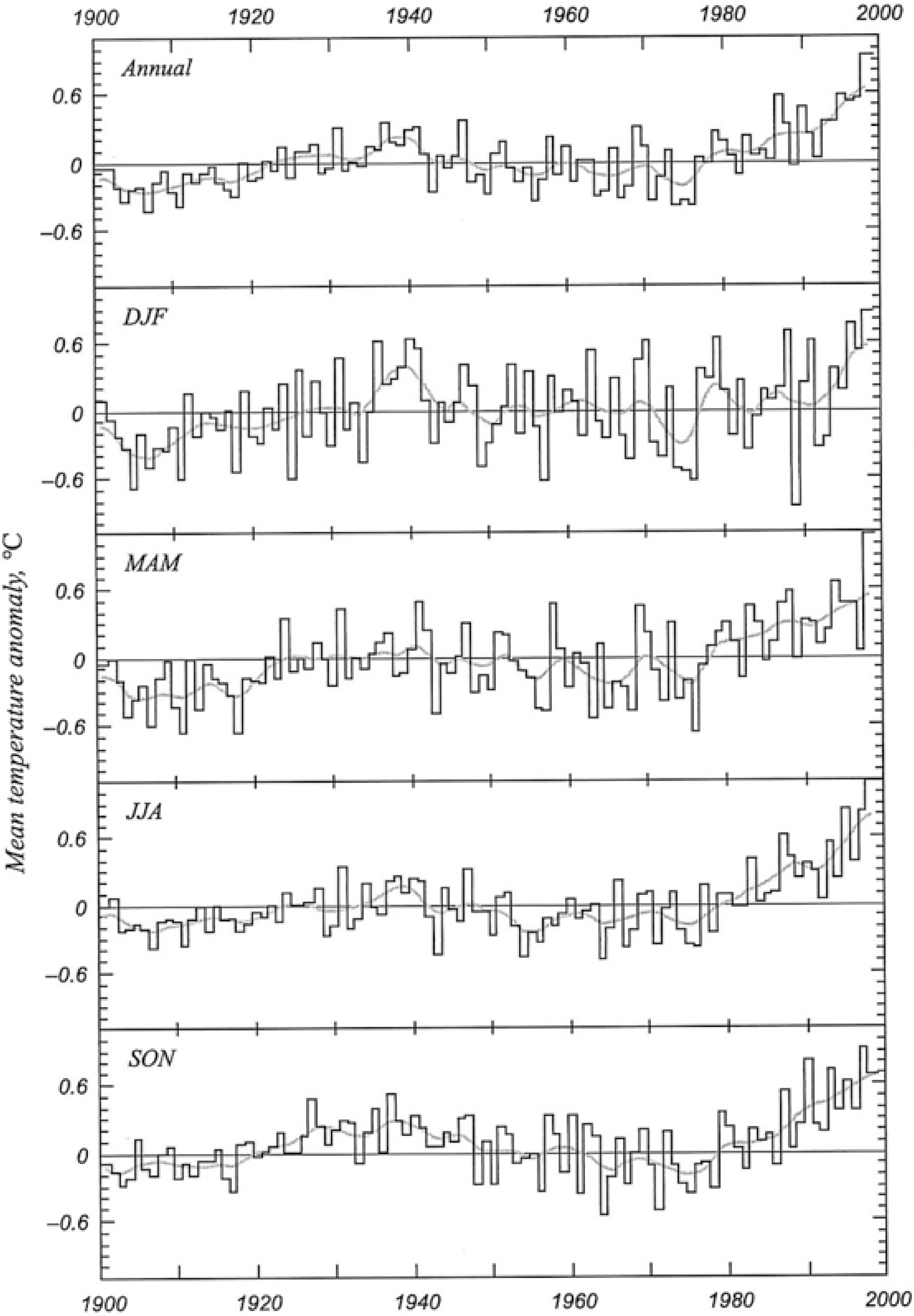
(In the Far Eastern Scientific Research Hydrometeorologic Institute calculations of cyclone and anticyclone repetition along a northern part of the Pacific Ocean from 120° longitude east to 120° longitude west were made. It appeared that more cyclones in the 40° – 60° latitude north zone and anticyclones in the 25° – 40° latitude north zone appear in winters following after El Niño then in preceding ones. So, processes in winter months after El Niño are more active than before the period).



Number of winter tornado days per year (CPC ENSO classifications).
Shading indicates ENSO phase [Cook, 2008]

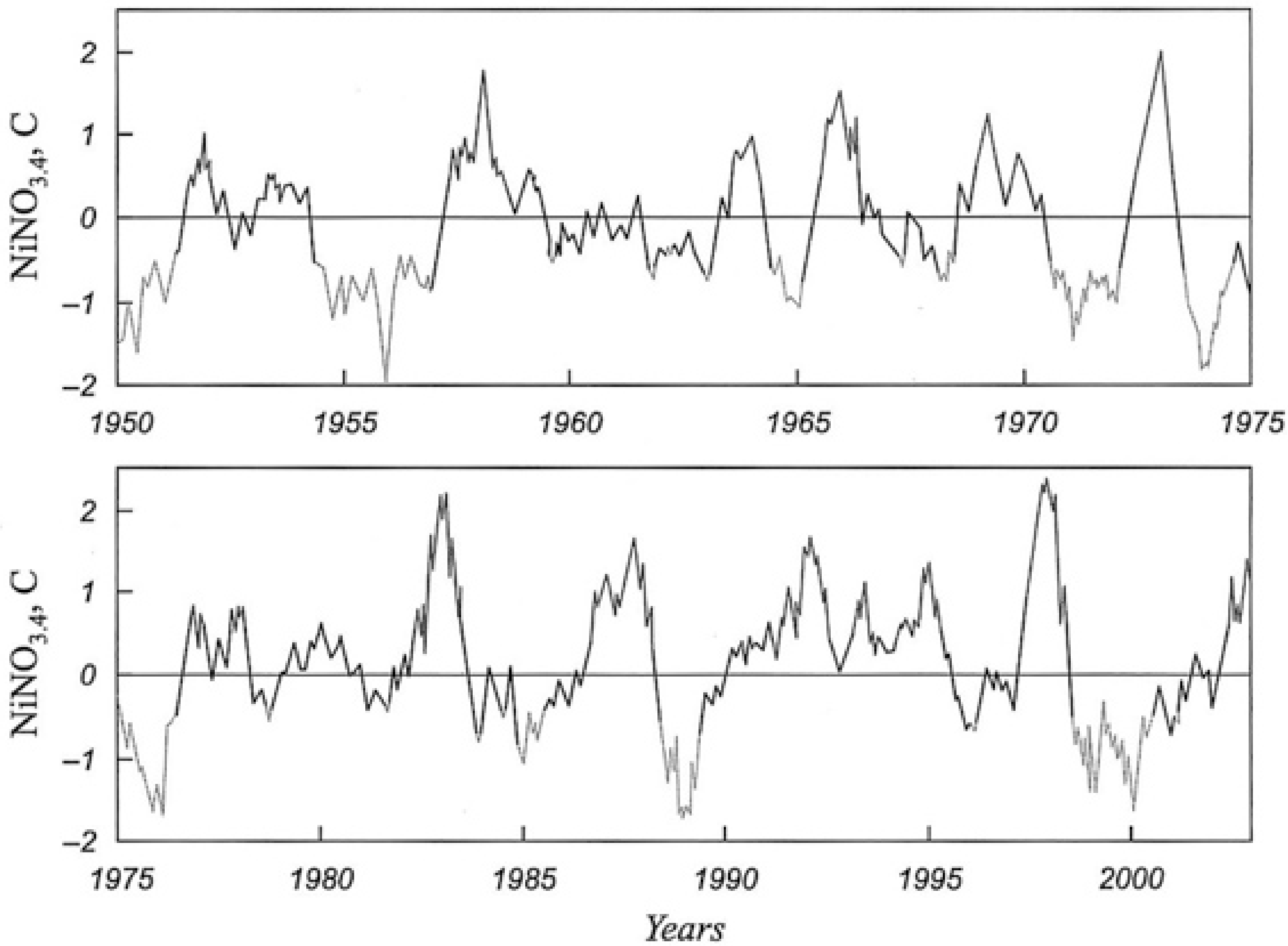


Correlation between sea surface temperatures and Zimbabwean maize yields [Conway, 2008]



African mean temperature anomalies for the past 100 years [Conway, 2008]

NiNO$_{3.4}$, SSTa Index



Time series of the monthly mean Niño – 3.4 index (SST anomaly averaged 5°S – 5°N, 170° – 120°W), °C. El Niño and La Niña events are highlighted with bold red and blue lines, respectively. El Niño and La Niña conditions of insufficient duration to qualify as events are indicated by red and blue x's, respectively [Goddard, 2005].

In the work [Voiskovsky, 2006] the author estimate quantitatively influence of solar and geomagnetic activity and El Niño phenomenon on origin and evolution of tropical cyclones (TC) by definition of correlation depth between solar and geomagnetic activity and basic characteristics of TC in a north-western part of the Pacific Ocean (N-WPO).

It is shown that during 1945 – 2005 there were periods in some regions when high (up to 75 %) coefficients of TC parameter correlations with solar and geomagnetic activity indexes were observed. In other regions there was no such correlation, but there was TC parameter correlation with an index SOI characterizing El Niño phenomenon.

Coefficients of correlation between a tropical cyclogenesis (TC) phenomenon and different indicators describing solar (Wolf numbers) and geomagnetic activity (A_a and A_p) and El-Niño influence (SOI index) in N-WPO were defined.

Mexican Space Physics in Veracruz in 1982 (right to left: Javier Otaola, Ruth Gull, the fourth – Ignacio Galindo, Jurate Mikalayunene, Hydromet Lithuania)

Received correlation coefficients show that there can be connection between solar-magnetospheric activity and TC – particle precipitation leads to decrease of transparency of the upper atmosphere which results in decrease of solar energy penetration to the atmosphere and reduce a probability of TC appearance.

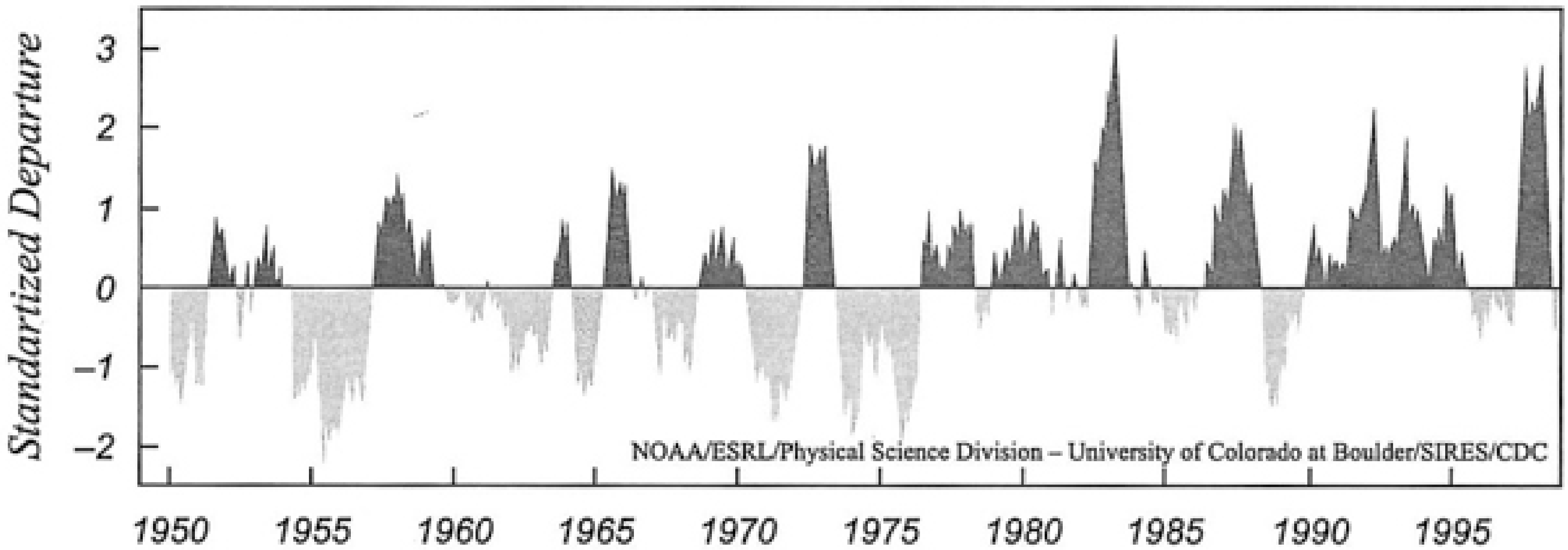
In his report [Khorozov S.V., Budovy I.I., Medvedev V.A., Belogolov V.S. Solar Activity Oscillations are the Main Climate Formation Factor on a millennium scale. 2008] S.V. Khorozov suggests a three-layered warm-balance physical-statistical model of the Ocean-Atmosphere system built on the basis of the fact that solar activity influences El Niño formation and accounting circulation factor, imitating satisfactorily a yearly average state of global and regional climatic systems.

According to the authors, the model can be used to explain other famous and large-scale events in the past and also to predict them in future. According to their estimations, well-expressed phenomenon El Niño will be probable in 2010 – 2012.

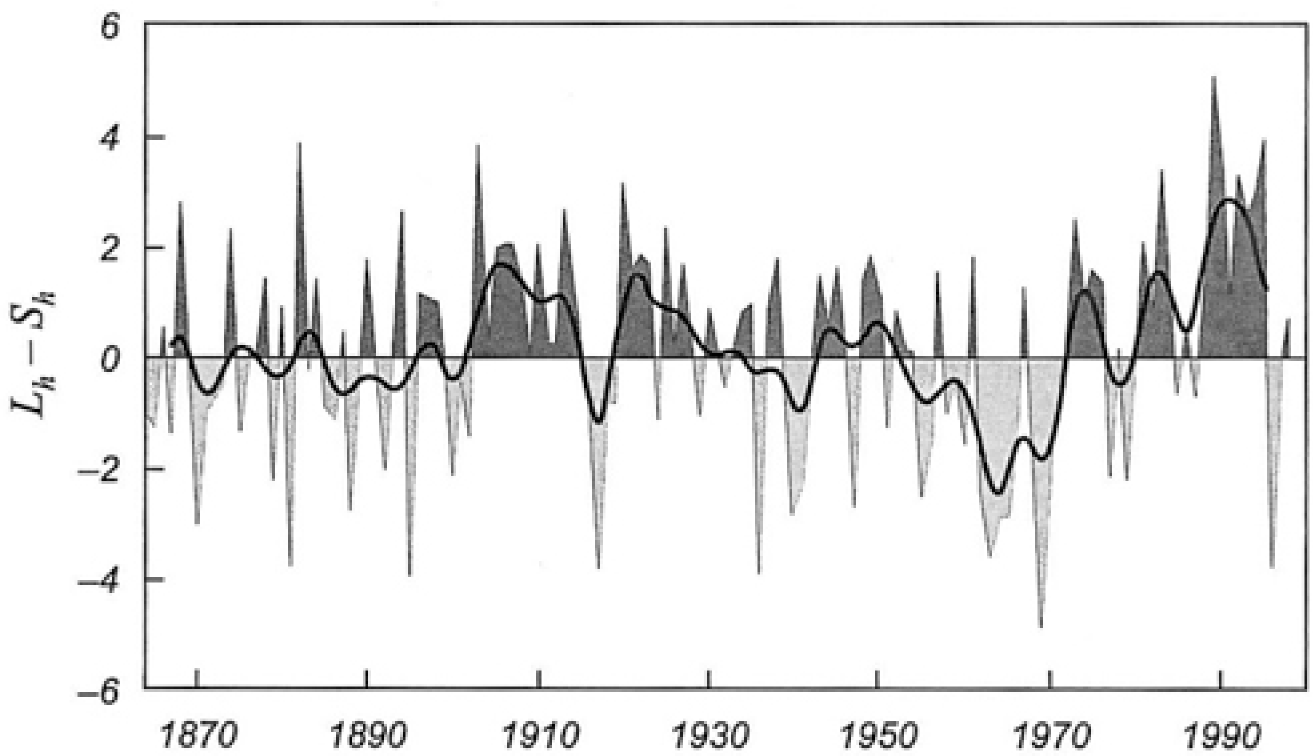
The authors connect this phenomenon in particular, with droughts and conflagrations (in Indonesia and Australia), heavy showers and floods (Peru), appearance of warm water near the central American Coast and, consequently, sudden decrease of fish resources in this region expected during these years.

Minimum of yearly average temperature in 2011 in St. Petersburg, Kaliningrad and Ekaterinburg will also correspond to it.

We should also expect increase of tropic storm number in the Atlantic Ocean and, consequently, increasing risk of their coming out on the American continent in 2013 – 2015.



a



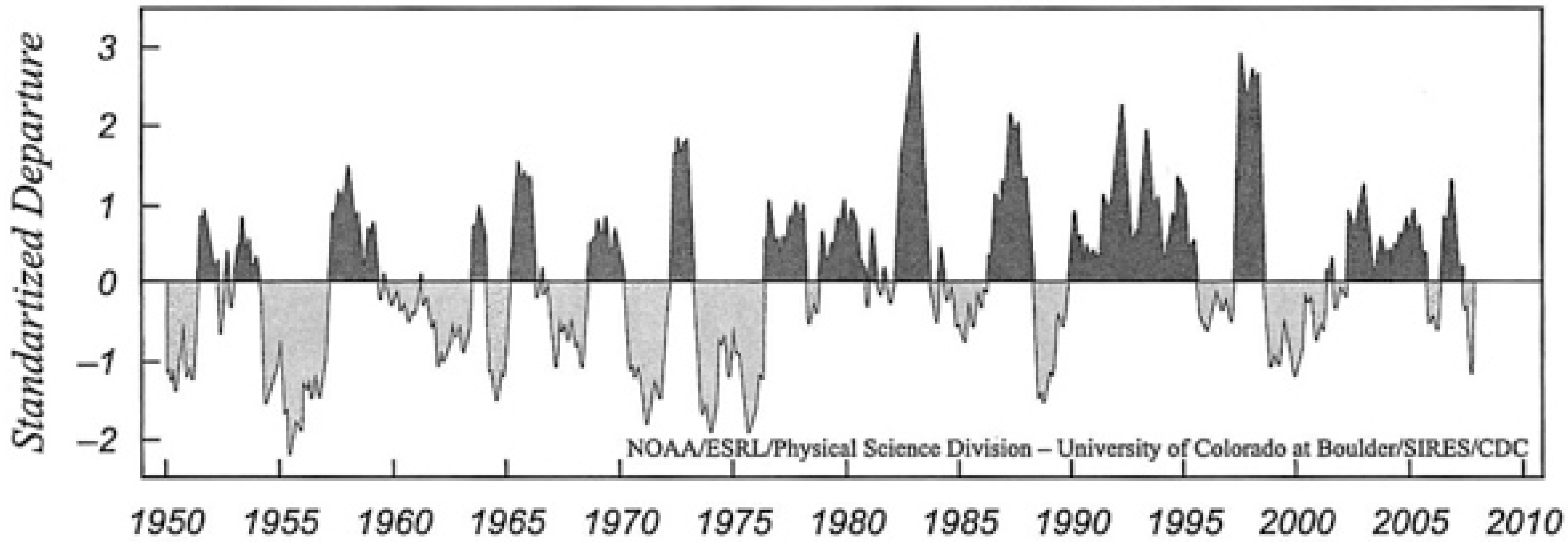
b

(*a*) ENSO time-series 1950–1998 (Wolter & Timlin 1998) [Convay, 2008].
(*b*) North Atlantic Oscillation Index time-series for December – March 1864 – 1998.
The multivariate ENSO index is a weighted average of the main ENSO features contained in six variables: sea-level pressure, the east – west and north – south components of the surface wind, sea surface temperature, surface air temperature and total cloudiness. The NAO index is the anomaly (millibars) in mean pressure difference between Iceland and the Azores.
Both ENSO and NAO exhibit substantial year-to-year and decadal natural variability [Saunders, 2009].

The climatic phenomenon El Niño with all its manifestations in different parts of the World is a complex operative mechanism. We should especially underline that interaction between the ocean and the atmosphere arouses a series of processes which are further responsible for El Niño appearance.

The conditions of El Niño phenomenon appearance are not fully studied yet. We may say, that El Niño is a globally influencing climatic phenomenon not only in the scientific sense of this word, but it also influences greatly the World economy. El Niño influences substantially people's everyday life in the pacific Ocean basin – many people can suffer from sudden rains or long-lasting droughts.

El Niño influences not only people, but animals as well. So, during El Niño there are problems with anchovy catching at the Peruvian coast. It happens because anchovies were caught earlier by many fishing flotillas, and a small negative impulse is enough to make this wavering system out of balance. Such El Niño influence has the most damaging influence on a food chain including all animals.



The alternation of La Niña (down) and El Niño (up) events. (The Multivariate ENSO Index is based on six variables measured across the Pacific) [Conway, 2008]

Decrease of storm number in North America is a positive effect of El Niño. As opposite to it, in other periods during El Niño a number of storms increase. They are partially those regions where such natural disasters usually happen rare enough.

Weather stations in Mexico, whose data were used by the authors

Station name	Latitude			Longitude			Altitude, m
	°	′	″	°	′	″	
Sinaloa							
Acatitan	24	2	30	106	40		130
Choix Estacion	26	46		108	24		225
Culican	24	48		107	24		40
El Fuerte	26	26		108	38		84
El Nudo	25	35		108	28		9
El Varejonal	25	4		107	24		122
Higuera	25	57		109	18		9
Ixpalino	23	51		106	37		100
Jaina	25	55	30	108	2		110
Los Mochis	25	46		109			14
Ruiz Cortinez	25	42		108	44		15
Santa Cruz	24	28	49	106	57	20	118
Sanalona	24	48		107	8		135
Santa Rosa	25	54		108	46		20
Costa Rica	24	33		107	22	20	0
Lateral 56	24	28		107	10		24.5
Sataya	24	32	30	107	38		7
Alto de Culicancito	24	28		107	32		23
El Rosario	22	59		105	51		35
Guamuchil	25	28		108	5		50
Guasave	25	34	30	108	28		18
El Playon	25	13		108	13		5
Badiraguato	25	21		107	32	30	230
Guatenipa	25	20		107	14		290
Potrerillos	23	33		105	50		1470
Rosamorada	25	23		107	50		180

Station name	Latitude			Longitude			Altitude, m
	°	′	″	°	′	″	
Siqueiros	23	25		16	13		170
Sonora							
San Jose	28	50	18	111	39	42	29
Sonoita	31	52		112	51	9	350
Tres Hermanos	27	11	38	109	11	44	88
Trincheras	30	24		111	32		505
Ures	29	40	50	110	57	10	370
Carbo	29	40	50	110	57	10	464
Yecora	28	22	17	108	55	40	1552
Agua Prieta	32	19	37	109	32	28	1220
Arizpe	30	20	9	110	10	2	830
Bacanuchi	30	35	56	110	14	19	1060
Banamichi	30	0	13	110	12	54	640
Batacosa	27	31	46	109	24	4	230
Hornos	27	42	47	109	54	15	50
Las Panelas	27	24	43	108	52	36	162
Palo Verde	28	47	44	111	27	59	79
Quitovac	31	31	40	112	43	56	388
Tezocoma	27	39	30	109	12	45	320
El Carrizal	29	5	31	111	44		49
Querobabi	30	3	2	111	1	17	655
Cuauhtemoc	30	52	32	111	31		590
Santa Ana	30	32	27	111	6	59	700
Hermosillo	29	4	58	110	55	10	230
La Angostura	30	26	20	109	23	8	860
Alvaro Obregon	27	49	18	109	53	9	116
Punta de Agua	28	25	59	110	23	34	245
Imuris	30	46	40	110	53	13	820

Station name	Latitude			Longitude			Altitude, m
	°	′	″	°	′	″	
La Colorada	28	48	7	110	34	36	390
Guaymas	27	55		110	54		8
Naco	31	19	32	109	56	52	1300
Cananea	30	58	48	110	17	27	1600
Colonia Oaxaca	30	43	47	109	3	23	1000
Linderos	26	54	30	109	45	18	1020
Baja California							
Bahia Tortugas	27	43	30	114	58	40	16
Boca del Salado	23	17	6	109	26	7	10
Buenavista	25	6	36	111	47	55	25
Cabo San Lucas	22	53	11	109	54	52	45
El Aguajito	24	56	50	111	8	8	190
Camondu	26	4	37	111	50	27	270
El Carrizal BC	23	46		110	19		180
El Ojo de Agua	26	20	24	111	56	24	185
El Paso de Iritu	24	45	57	111	7	30	125
El Pilar	24	28	1	110	59	10	135
El Rosarito	26	29	15	111	39	30	130
El Triunfo	23	48	20	110	7	40	460
Iraki	24	53	10	111	18	30	140
La Angostura	25	3	45	111	3	20	240
La Paz	24	10		110	17	26	0
La Poza Grande	25	49	48	112	5	20	20
La Poza Honda	25	20	34	111	34	18	100
La Ribera	23	35	4	109	33	14	30
La Soledad Norte	24	49	15	110	47	40	340
Lagunillas	24	2	22	110	22	18	60
Las Cruces	25	22	45	111	49	16	35

Station name	Latitude			Longitude			Altitude, m
	°	′	″	°	′	″	
Loreto	28		30	111	20	57	15
Los Planes	24	5	55	109	59	24	35
Patrocinio	26	49	26	112	48	38	193
San Antonio Sur	23	48	38	110	2	20	360
San Bartolo	23	44		109	51	42	330
Punta Abreojos	26	43	56	113	34	44	10
San Javier	25	53	43	111	34	18	400
San Jose de Gracia	26	29	23	112	42	45	165

3.2.8. Solar activity changes and possible influence of them on biological processes

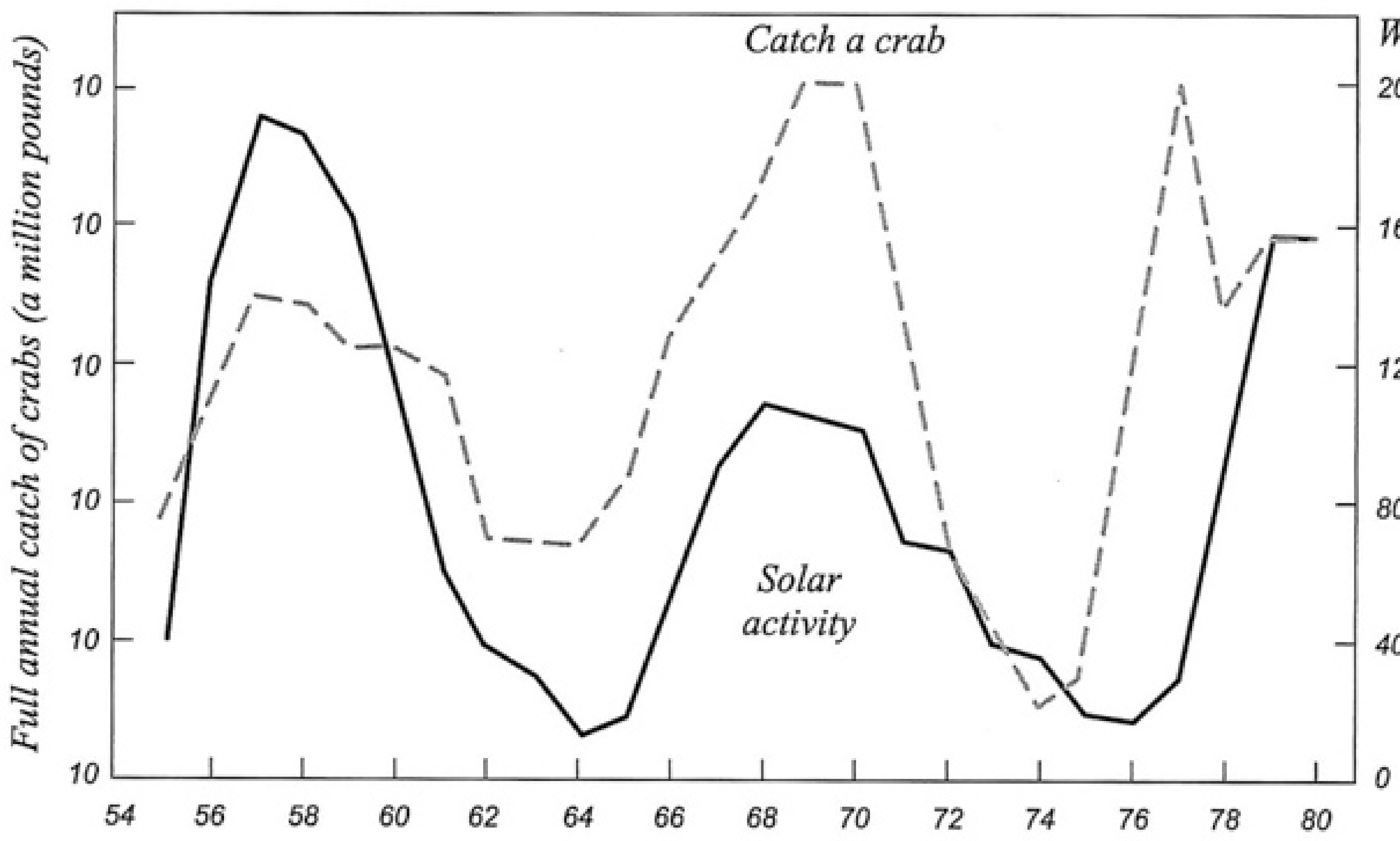
One of the fundamental problems of modern solar-terrestrial physics is revealing connection mechanisms between solar activity and operation of different objects of biosphere including a human.

Many data in literature resources about influence of external fields on biological objects are scattered to different scientific specialties, interpreted in different ways and do not have a satisfactory theoretical explanation which would permit to make adequate mathematical models of processes under study.

A.L. Chijzhevsky was the first who found out solar activity influence on diseases in the twenties. He is considered to be a founder of heliobiology. Since that time researches have been made, scientific data proving influence of solar activity and magnetic field changes on human health have been collected.

That is why, participants of the interdisciplinary seminar Biological Effects of Solar Activity (April, 6 – 9, 2004, Pushchino-on-Oka) made a decision in which they emphasized importance and currency of studying influence of solar and magnetosphere process dynamics on the Earth's biosphere and importance of such influence forecasting.

«The fact of such influence existence is out of doubt, however, it will take a lot of time and forces to work out such technique of making experiments and processing received solar bioeffect data which would provide regularity of such effects in different periods of time and on different places on the Earth.



Solar activity and catch crab

For example, biological experiments revealing weak magnetic fields tell us about importance of a variable component in a 1 Hz range and higher during the time when the majority of geomagnetospheric indexes describing disturbance of the Earth's magnetosphere has a characteristic storage time which is about 1 hour.

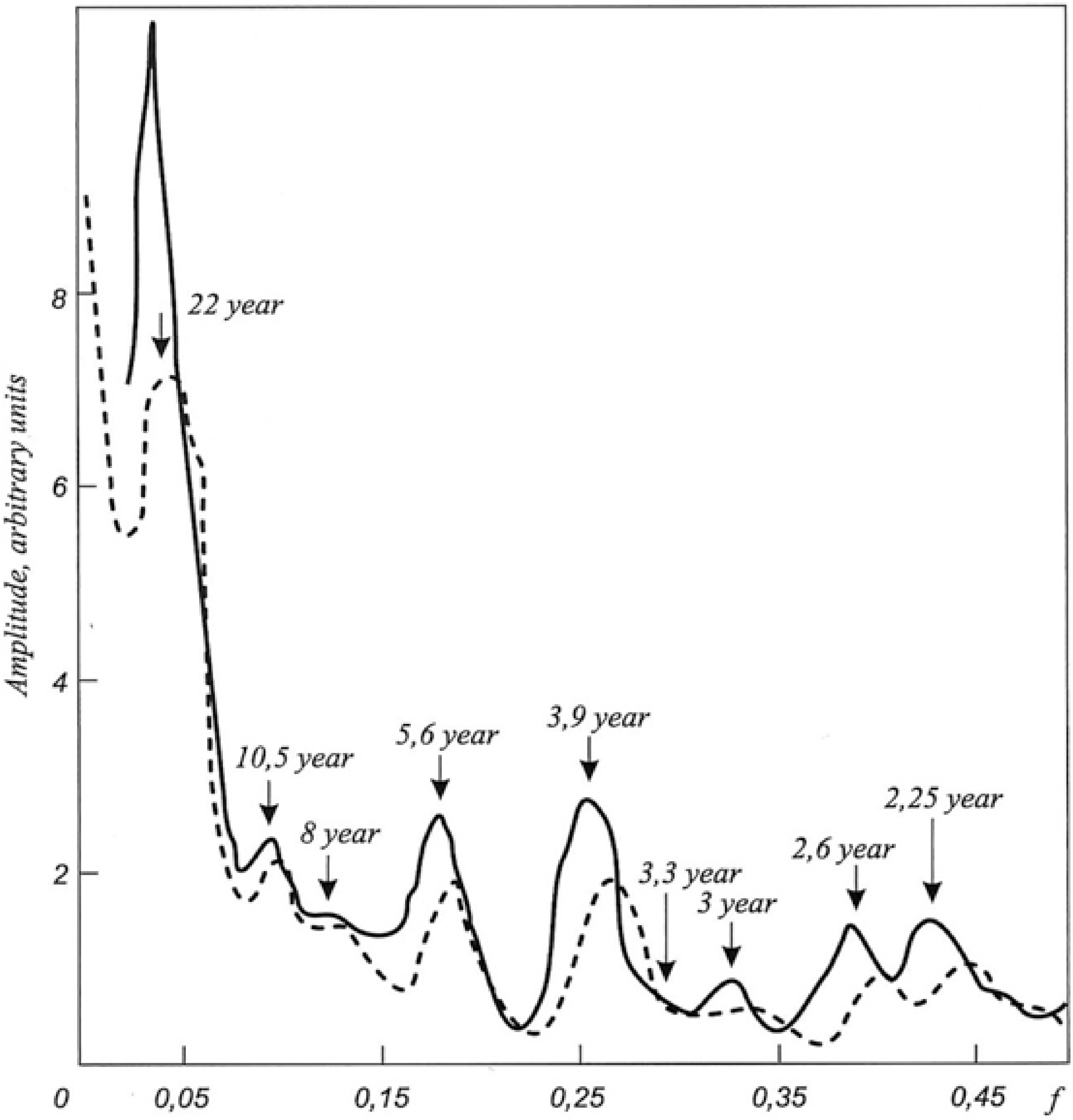
That is why analysis of terrestrial magnetic data with 1 c resolution (for example, Pc-pulsation) is of great interest. It is necessary to continue research to reveal mechanisms of solar disturbance influence on circumterrestrial processes, magnetosphere, ionosphere, atmosphere and biosphere including a human organism».

The life on our planet is connected with the Earth's rotation round the axis determining a daily rhythm and the Sun's rotation which season change on the Earth depend on. The majority of living organisms perceive seasonal rhythm as season change. It determines growth, development and death of plants. The Earth's rotation round the axis conditions rhythmical change of environment factors – temperature, light, relative air moisture ,barometrical pressure, atmosphere electric potential, cosmic radiation and gravitation.

All environmental factors mentioned above influence living organisms' life processes. Among them alteration of light and darkness is of great importance.

Plant metabolism – carbon dioxide absorption in the day time and oxygen release at night – depends on diurnal rhythm.

Animals' daily rhythms are revealed as alteration of wakeful and active periods with sleeping and quiescent periods. (Some animals'seasonal rhythms also have alteration of activity and rest).



The power spectrum of fluctuations in the thickness of annual rings of trees in the Tien Shan Mountains (NV Lovelius, Russia) [Lovelius,]

All living organisms on the Earth were developed under influence of daily or seasonal rhythms. But have they always had such duration as now? Many scientists think that millions of years ago the Earth rotated quicker and a day was shorter. Friction of substance in ocean tidal waves and in a solid body of the Earth was the reason of deceleration of the Earth's rotation. The ocean tidal waves have already stopped the Moon's rotation as it is lighter than the Earth.

Under the influence of solar cyclic activity and the Earth's rotation round the axis and round the Sun periodicity of the phenomena occurring in the nature appeared. It is revealed in weather change, volcanic explosion, earthquakes, floods, etc. This periodicity has created the rhythm in living organisms which makes up the essence of their life.

It is noted according to the results of many researches in different countries that patients' health is aggravated, firstly, after a solar flare, secondly, when a magnetic storm begins.

We can explain it by the fact that several minutes after the begin of a solar flare solar particles reach the Earth's atmosphere and arouse processes influencing an organism's operation. The Earth's magnetospheric storm itself begins about a day later.

Available data (unfortunately, often fragmentary ones) show that among all the diseases which are subject to influence of magnetospheric storms cardiovascular diseases take the first place, as their connection with solar and magnetic activity was more evident.

Scientific groups compared dependence of quantity and severity of cardiovascular diseases on many factors (atmosphere pressure, air temperature, precipitation, cloudiness, ionization, radiation regime, etc.), but true and stable connection of cardiovascular diseases with chromospheric flares and geomagnetic storms is revealed specifically.

During magnetic storms subjective symptoms of patients' health aggravation were revealed, blood pressure arose and coronary circulation deteriorated more often which was accompanied by a negative ECG dynamics.

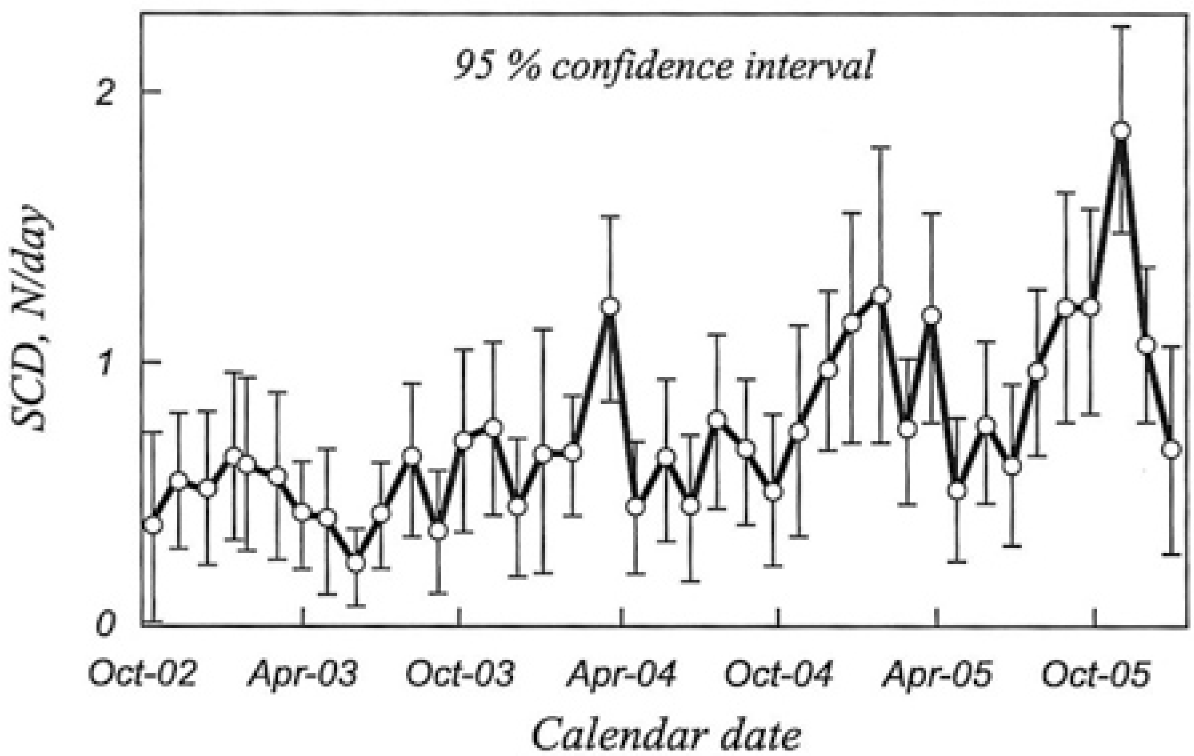
The research showed that during the day of a solar flare a number of cases of myocardial infarction arises. It reaches maximum next day after a flare (about twice as much in comparison with calm days). A magnetospheric storm aroused by a flare begins in the same day.

Researches of heart rate during a long period of time among large groups of patients showed absence of heart rate abnormalities during weak disturbances of the Earth magnetic field.

But during the days with middle or heavy geomagnetic storms heart rate abnormalities happen more often than in the days when there are no magnetic storms. It concerns observations of people in a quiescent state and during physical activity.

Observations of patients with essential hypertension showed that a part of patients had reacted a day before a magnetic storm. Al the rest felt unwell in the beginning, middle or end of a geomagnetic storm.

All this is well supported by the results of Azerbaijani scientists who have studied possible influence of changes of space weather conditions on the sudden cardiac death mortality [Babaev, 2007]. This study was undertaken to investigate whether there was any relation between space weather changes (solar, geomagnetic and cosmic ray activities) and the number of sudden cardiac death (see next figure) in Baku and surrounded big urban area (Absheron Peninsula), which are located in the middle latitudes.

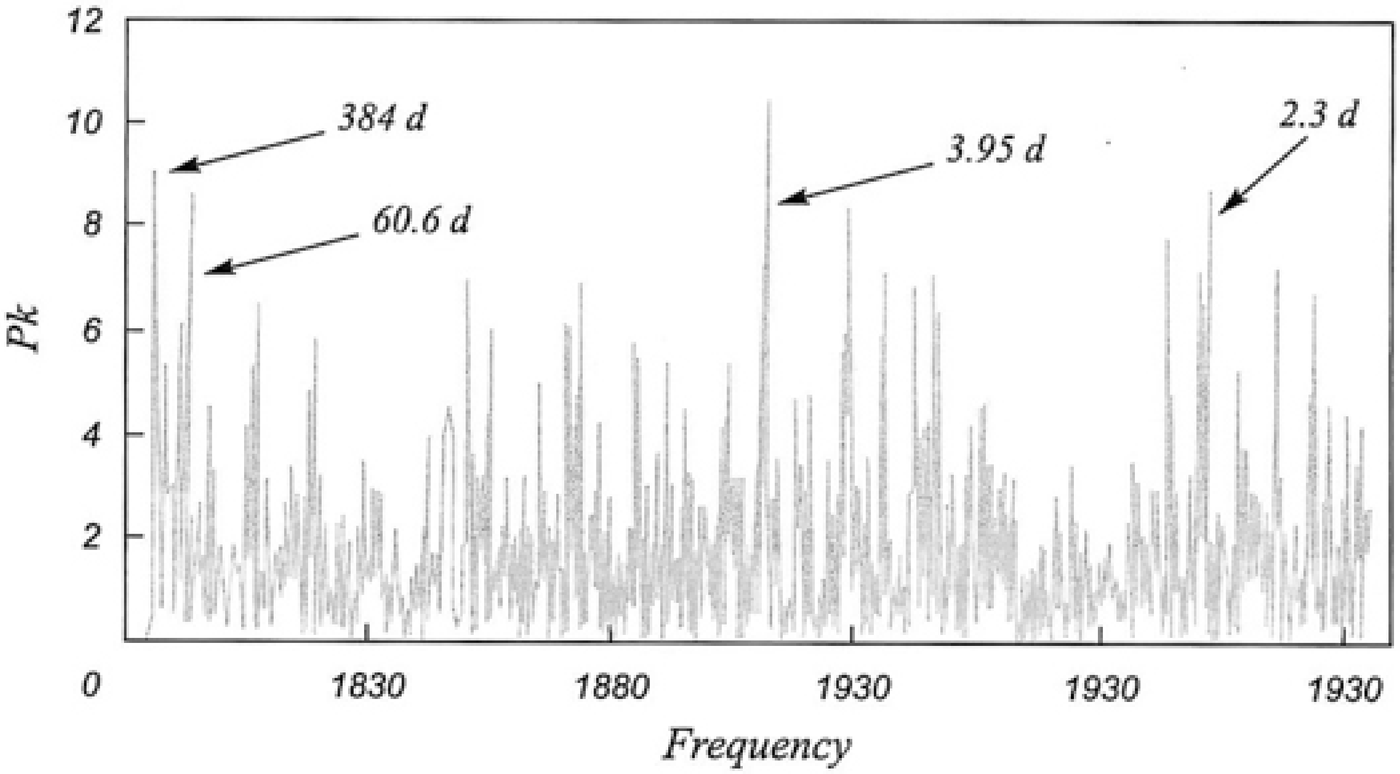


Changes of daily averaged of sudden cardiac deaths in months (Baku data [Babaev, 2007])

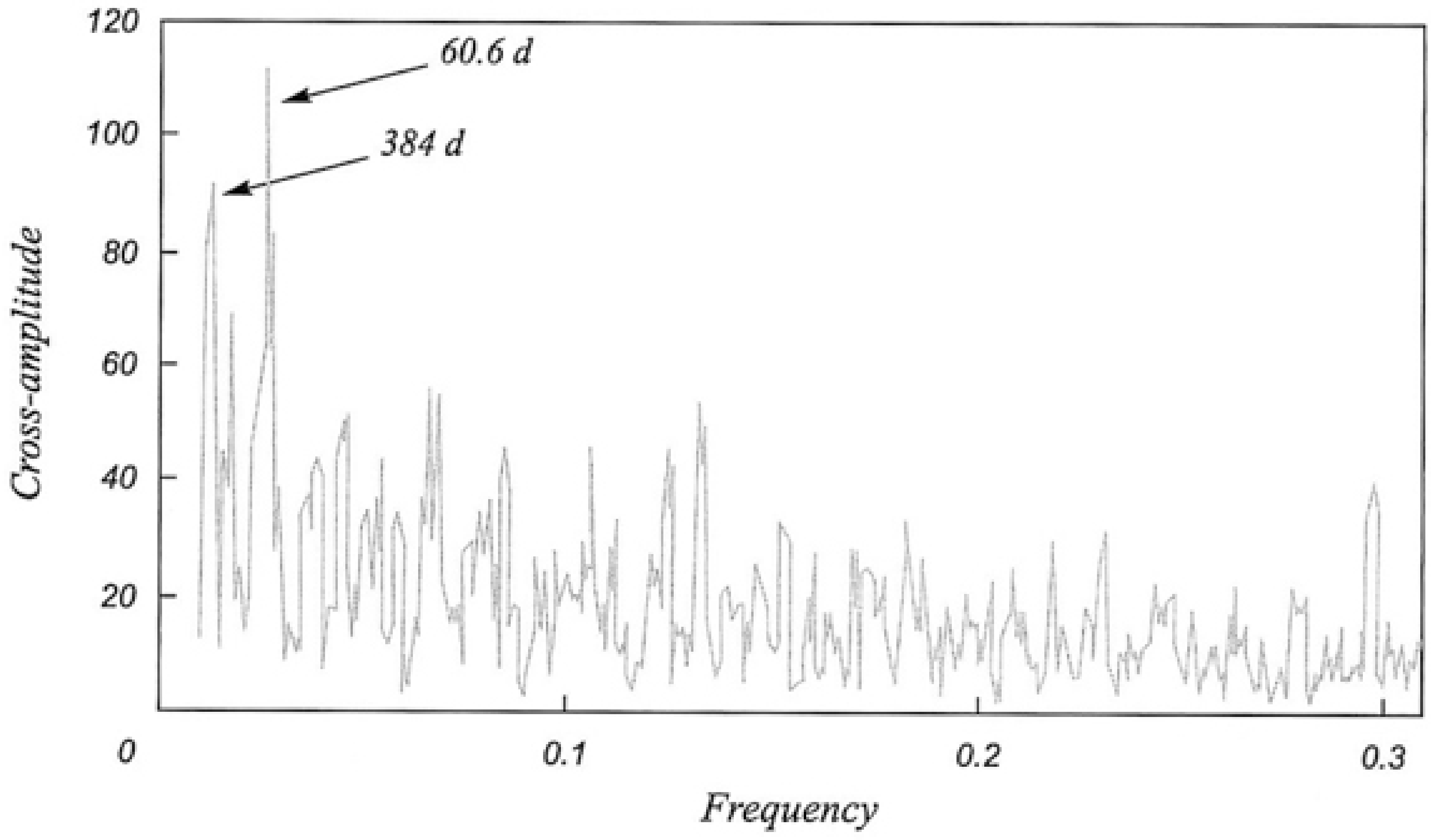
Sudden cardiac death [Priori, 2006] (also called a cardiac arrest) is an unexpected death due to cardiac causes, an abrupt loss of heart function, occurring in a short time period (generally within one hour of symptom onset) in a person with known or unknown cardiac disease in whom no previously diagnosed fatal condition is apparent.

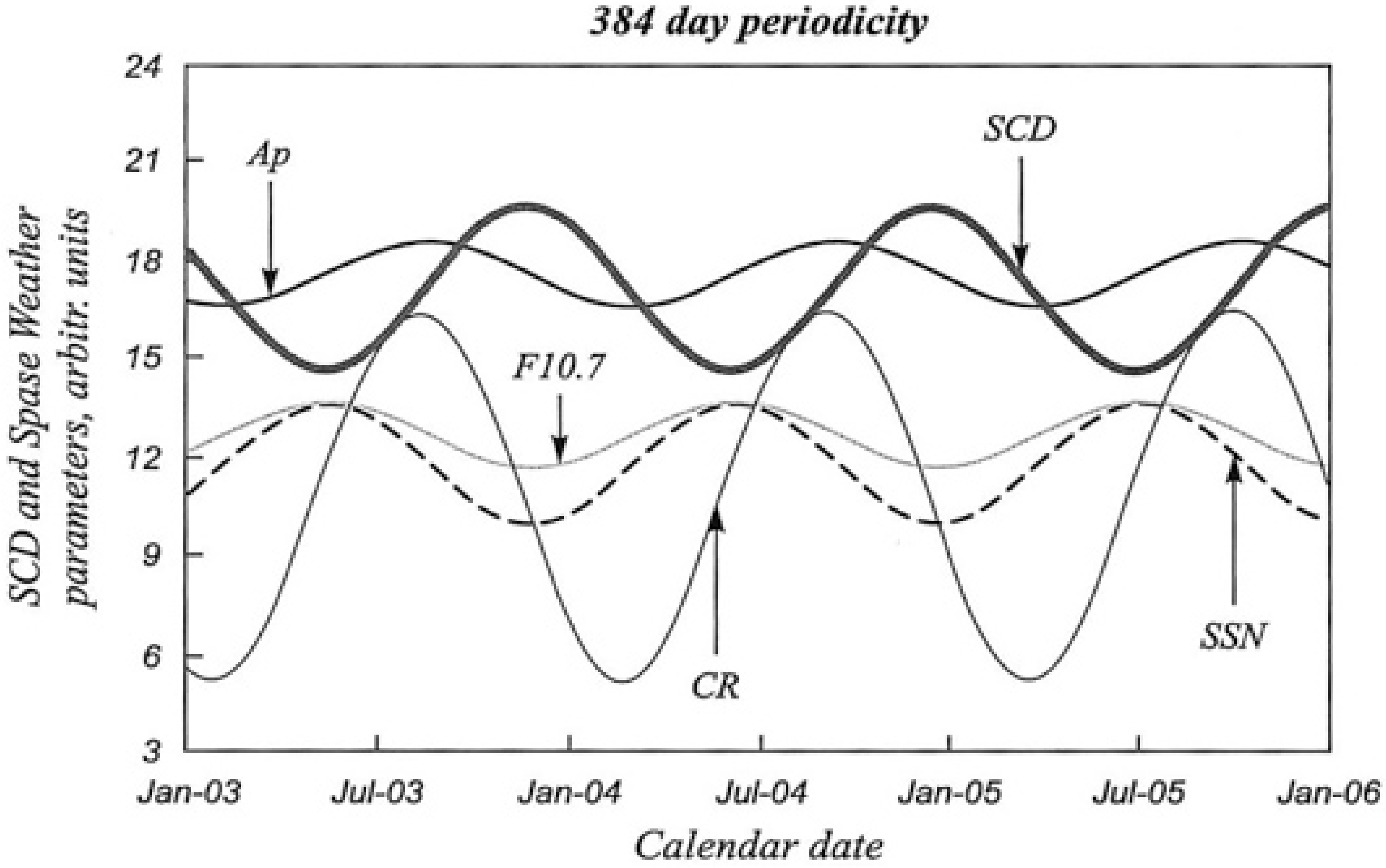
Approximately half of all cardiac deaths can be classified as SCDs. SCD is a major health problem that is received much less publicity than heart attack. All known heart diseases can lead to SCD but most cases of SCD are related to cardiac arrhythmias. Most of the cardiac arrests that lead to sudden death occur when the electrical impulses in the diseased heart become rapid (ventricular tachycardia) or chaotic (ventricular fibrillation) or both.

This irregular heart rhythm (arrhythmia) causes the heart to suddenly stop beating. Some cardiac arrests are due to extreme slowing of the heart. It occurs as the first expression of cardiac disease in many individuals presenting as out-of-hospital patients with cardiac arrest. The time and mode of death are unexpected.



Power spectrum of periodicities found in SCD data [Babaev, 2007]





Fourier curves for SCDand some space weather parameters [Babaev, 2007]

Several millions of people a year die because of SCD without being admitted to a hospital or an emergency room. Therefore, it is very actual problem to study how external physical factors (which can play also a role of trigger) may affect SCD mortality alongside factors of pure medical and social nature.

Results were outlined [Babaev, 2007]:

- Number of SCD displays certain periodicities wellknown in solar-terrestrial relations;
- SCD mortality is affected by changes in solargeomagnetic (inversely) and cosmic ray (directly) activities. Fourier analyses of SCD number and proper space weather parameters revealed that SCD mortality is low in the days with high solar and geomagnetic activity while it increases in the days with high level cosmic ray (neutron) activity
- Correlation and cross-correlation analyses between SCD and selected space weather parameters (sunspot number, Ap geomagnetic index, neutron activity level) have also revealed statistically significant but inverse correlation with solar and geomagnetic activity parameters. SCD number changes in concert with cosmic ray activity;
- These results are in agreement with conclusions of several papers on thematic, for example, [Stoupel, 2006] (see: references herein) and [Szczeklik, 1983].

Researches in different countries showed that a number of accidents and injuries connected with transport also rise during solar and magnetic storms. Time of reaction to different photo and sound stimuli increases, quickness of wit comes down, a possibility to make an incorrect decision becomes more obvious.

In some countries observations of influence of magnetic and solar storms on patients suffering from mental diseases were held. Connection between people's visits to mental institutions and disturbances of the Earth magnetic field was clear.

It is necessary to note that ill and healthy organisms react differently to changes of cosmic and geophysical conditions.

Characteristics of biological energy, immune protection, state of different organism physiological systems of depresses, tired, emotionally instable people become worse; mental strain appears.

But a psychologically and physically healthy organism finds itself in condition to rebuilt inner processes in correlation with changing environmental conditions.

In this case an immune system is activated, nervous processes and an endocrine system are reformed consequently, and capacity of work is kept or even rises. Subjectively a healthy person perceives it as general well-being mend, mood improvement.

Meanwhile, the question about influence of solar activity and a full series of physical agents transmitting such influence is still opened.

The majority of works devoted to a human organism adaptation to natural fields concern two utmost cases – solar activity periodicity manifestations in the results of medical statistics and statistics of disasters or external field influence on very healthy people, such as cosmonauts and sportsmen.

The general mass of healthy working people is not covered by scientific research. Moreover, absolute majority of researches of solar activity influence on a human were held without a strict mathematic apparatus.

In the work [Ragulskaya, 2005] the author proved the existence of statistically nonrandom reaction of a comparatively healthy organism (not to speak of an ill one) to solar activity variations and the leading role of solar-terrestrial interactions in formation of organism rhythms.

The technique of measuring, processing and an instrumental base for studying influence of different external factors on a human organism including solar activity variations and environmental factors connected with them have been worked out.

For seven years of monitoring an experimental base covering more than 100.000 daily measures of functional parameters of a constant group of people on the background of more than 350 magnetic storms has been formed.

Non randomness of coincidence of biophysical and geomagnetic events on the level of 0.01 statistic significance has been proved.

This spectral analysis has revealed coincidence of all basic periods of individual and group biological parameters on different latitudes that proves the existence of global regulating environmental factors.

Ragulskaya found coincidence of all basic periods of resuscitation cases with periodicity of data of the IZMIRAN monitoring biophysical experiment and periods of atmospheric pressure variations, geomagnetic activity rise and increase of sunspot number.

It is found out that flare processes on the Sun and following changes in a spectrum of natural very low-frequency electromagnetic fields, cosmic rays and atmospheric pressure fluctuations arouse a human's stable and producible reaction on the level of operation of separate systems (vegetative nervous system, inner organs, changes of cardio cycle parameters) and of the organism as a whole.

The existence of amplitude, latitude, timely, trigger and cumulative effects of solar activity variation influence on the organism are found out.

Trigger effect. A human organism reaction under influence of natural external fields has a trigger character. In this case when geophysical fields change suddenly amplitude of physiological reactions does not practically depend on increase of external field amplitude, but is determined by inner characteristic of a biosystem.

Latitude effect. Experiments made simultaneously on different latitudes showed coincidence (in a 24 hour range) of measured physiological parameter variations with 0.7 correlation coefficients between series of data at the 0.01 significance level. A fixed reaction is a mass all-round one and keeps its characteristics while an object of study changes from a separate human organ to socially organized groups. When geophysical latitude of experiment place increases it raises a percentage of reacting people (from 50 – 60 % in Odessa and Kiev to 90 % in St Petersburg) and makes amplitude of reaction 1.4 times higher.

Timely effect. During the analysis of long-term (yearly) series of observations a growth trend of monthly average values of an individual rate of the majority of observed people's physiological indicators in the period of solar activity increase and maximum (1998 – 1999 and 2000 – 2002) has been revealed as well as a decrease trend of monthly average values of an individual rate on the phase of solar activity decay (2003 – 2005).

This effect reflects integral influence of solar activity variations on a human organism and biosphere and is conditioned with peculiarities of adaptation processes under a long-term weak external influence, but not qualitative difference of magnetic storms in different phases of solar activity.

Cumulative effect. The experiments showed the existence of a synergetic cumulative effect – simultaneous influence of external factors becomes greater and effective, even if amplitude of each of these separate factors is too small for a stress-reaction to begin.

It is shown that there are general planetary external factors ruling rhythms of a human organism. Only variations of natural external fields (the magnetosphere, ionosphere and atmosphere) aroused in their turn with solar magnetic field variations can be such factors.

According to the results of the experiment, anthropogenic fields, local and unique in each city, do not contribute to formation of a spectrum of general collective reaction.

About 70 % of biological parameter emissions fall on solar activity processes (flares and coronal holes) and magnetic storms, 10 – 20 % react to sudden changes of atmospheric pressure.

Correlation is opposite in dependence of blood pressure on external parameters – the majority of sudden rises of blood pressure is connected with sudden changes of atmospheric pressure while magnetic fields play a role of a modulator of physiological amplitude frequency characteristics.

However, multivariate analysis of bioeffective external fields has showed that not only flares and magnetic fields are biologically effective, but disturbances having reached the Earth but not aroused development of magnetic storms.

3.2.9. Solar activity influence on economic processes

There are two things which many people try not to think of – that prosperity periods are inevitably broken by crises and that globalization of World economy will inevitably meet the World crisis, so great, how far globalization processes have gone.

The Great Depression in the USA [Klinov, 2002], the leader of the World economy, did not only impact on economy of developed capitalistic countries tightly connected with the USA, but touched even the USSR, the country separated from the World which tried to built up a self-sufficient economic model. In the work [Klinov, 2003] the author suggested a modern conception of large cycles of economic growth in connection with regularities of scientific and technical progress (STP), estimated temps of collecting and wasting scientific and technical potential and made a forecast for the first quarter of the 21st century.

Solar activity influence on economic processes reflects in this or that degree economical theories of N.D. Kondratiev, F Lawson, K. Freeman, G. Kendrick, T. Christensen, D. Dzhorgenson, R. Sitroh, R. Gordon and R. Solow. In the end of 18 century William Herschel, an English scientist, a founder of stellar astronomy, who built up the first model of the Galaxy and discovered Uranus tried to find connection between a sunspot number, crop failures and prices for bread and determined rather a large correlation between them.

Solar activity influence on economy is out of doubt. In 1989 a magnetic field left Canadian capital Ottawa and Quebec without electricity for 8 hours. In 1997 a solar storm cut off television satellite Telstar 401 of AT&T Company. Next year a storm destroyed work of satellite Galaxy IV which managed automatic cash terminals and aviation tracking systems. In 2000 Japan satellite Asko damaged by a solar storm failed and sank in the Pacific Ocean.

Magnetic fields tell on work of mobile phones, arouse failures in the Internet, automatic systems, disturb high-frequency aviation radio communication. On Russian railways there have been events connected with failures of automatic devices.

In the second half of the 20th century in connection with launching spacecrafts and nuclear tests especially with those which were made in the upper atmosphere an ozone layer protecting the Earth from sun strokes began to melt quickly.

Coincidence of several cycles of solar activity (11, 22, 80 – 90, 320 – 400 and 720 – 900 year ones) in the beginning of the 21st century has led to more global ecological changes.

In the end of 19th century Jevons, an English scientist, developed a theory connecting forming of economic cycles with solar activity. According to it, years of rich crops repeats each ten or eleven years and «it seems possible that trade crises are connected with periodic weather change touching all parts of the World and appearing, probably, as a result of increased hot waves got from the Sun in general every ten years or so».

Javons supposed that «Periodic failures are really psychological phenomena depending on changes of low spirit, optimism, pother, disappointment and panic. But it is probable that mentality of business circles, although forming the main contents of the phenomenon, can be determined by external events, especially, circumstances connected with crops».

In economics and sociology some processes were noted [Adler, 2005; Ayrapetyan, 2003; Ivashenko, 2001], their phase alteration tells us if not about their cyclicity, but about a wavy character, as there are no cycles here which would have cyclic parameters.

First of all an industrial 7 – 12 year cycle was found out. In this cycle K. Marks separated four phases which change each other consequently – crisis, depression, revival, recovery. An industrial cycle got the name after K. Juglar, he analyzed fluctuations of interest rates and prices in France, Great Britain and the USA, found coincidence of them with capital investment cycles which in their turn initiated change of the gross national product (GNP), inflation and employment. There are 11 Juglar cycles in the period since 1787 to 1932. Insurance market operates cyclically with a period of 7 – 10 years. J. Kitchin's cycles are cycles of inventory movement with a period from 2 to 4 years [Voropinova, 2001].

Kuznets's cycle or long swings possessing the largest amplitude in building has a 20-year cycle. S.Kuznets discovered interacted fluctuations of indicators of national income, consumer's expenditure, gross investment to industrial equipment, buildings and installations with long-term intervals of fast growth and deep recessions or stagnancy.

N.D. Kondratiev (1892 – 1938) created an economical theory of long waves, large conjuncture cycles (40 – 60 years). He pointed to polycyclicity of economical dynamics, «The real process of economical dynamics is a single one. But if analyzing and dividing this process to simplest elements and forms we admit the existence of different cycles in this dynamics. But together with it we should admit that these cycles interlace and exert this or that influence on each other». Moreover, Kondratiev found interconnection of economical cycles with cyclic processes in other spheres of societies.

Volume of country production – the gross national product (GNP) – is the fullest indicator of joint economic activity. In 1962 Angus Maddison's work was published. In his work the author gives values of the gross national product of different countries of the World for the period 1870 – 1960. In the time interval 1879 – 1954 we can separate seven global economical cycles. So, an average duration of such a cycle is 11 years.

The analysis of given data shows that in more than 90 % of cases economical indicators have degraded during the years of extreme values of solar activity (minimums and maximums) or during a time period corresponding to its decreasing (descending parts of Schwabe's quasi-eleven year cycle).

There were no economical crises during periods of increasing solar activity [Konstantinovskaya, 2001; Kalashnikov, 2002]. We should say that similar action of solar minimums and maximums is not something new.

Fast growth of World economy since the second part of 20th century has led to absence of brightly expressed minimums of the GNP values in the given period of time, which, however, does not mean absence of cyclicity. In the given period of time cycles can be separated according to decrease of the GNP growth rate. Extreme characteristic of SA value does not have to lead to sudden change of economical growth indicator; its influence can be manifested with some delay, and the existence of economic crises on descending parts of SA cycles can be connected with that.

There are rather reliable data about dynamics of the GNP specific value of the most powerful economical empire of the second part of the 20th century – the USA. The analysis of given data confirms the supposition that solar maximums are followed by slowdown or fall of American economy growth rate. It is necessary to note that in the second part of the 20 century a global economic cycle is not of a sinusoidal character – a relatively short-term economic recession (about 2 years) is followed by a much longer period of its growth.

Certainly, there are hand-made crises – it is enough to remember oil crises [Bushuev, 2002] aroused by OPEC policy, the first of which shocked the World economy in seventies, and the second became one of the reasons of the USSR breakdown.

The USSR economic development indexes were made with a help of a method of principal components based on data about dynamics of 10 basic economic sectors. The indexes corresponded well to national indicators, but in a larger degree they were correlated with a structure of planned Soviet economy of that time.

Then dynamics of these indexes was analyzed with a help of the Track method. In a result a trend and two precise cyclic components – 10 – 11 and 4-year ones – were revealed.

A trend showed a stable tendency of growth rate slowdown since the middle of the 50s and 4 % yearly economic recession since 1986. Further together with slowdown of economic growth rate in the USSR a role of periodic components in economic dynamics became more substantial, as because of growth rate less than 4 % per a year (1974 – 1990) about 35 – 50 % of economic dynamics fell on cyclic oscillations.

It is curious that by the beginning of 1970s 4-year cyclicity had dominated, but in a result of its decay and increase of 10-year cycle amplitude 10-year cyclicity took the first place. Further there was more and more promotion of 10-year cycles amplitude of which had reached 3.5 percentage points by the end of 1980.

The further analysis of economic dynamics with a help of making forecast and retro forecast with the Track method showed that it is possible to separate two trend components – evolutional (system) and transformational (handmade). It was shown that 20 – 50 % of recession of the middle of the 90s fell on the evolutional component. Roots of the system crisis are in the middle of 1970s when slowdown of Soviet economy growth rate beginning since 1950s accelerated suddenly.

If in the beginning of 1980 there had not been some stabilization it would have turned a disaster for national economy of the USSR. Only in 1986 when stabilization potential ran out crisis phenomena began to dominate in economy again and were over only in the end of the 90s after Gaidar's reforms.

It is announced in the web site message of TESIS X-ray observatory on board of Russian satellite Coronas-Foton that the beginning of today's World financial crisis coincided in time with a period of abnormally low solar activity which should have changed by a rise about a year ago.

It is said in the message, «current solar minimum which is the deepest in this century coincides to a high precision with development of financial crisis, the most large-scale in history, and World economy transition to global recession state».

Scientists note that possible solar influence on social processes can be explained by the fact that during solar maximums there were revolutions of 1905 and 1917 in Russia, the beginning of the Second World War (1939) and events of 1991 coinciding to within a month with maximum of 22-year solar cycle. Processes of social and economical activity slowdown are, on the, contrary, connected with solar minimums, although physical mechanisms of solar influence on social processes are unknown yet.

Doctor Sergey Bogachov, the leading research officer of PhI RAS (Physical Institute after Lebedev RAS), one of observatory builders, said that «we can consider the current solar cycle abnormal since about the middle of 2008 – it is just the period (if to base on historic duration of cycles) when a solar activity decay phase should have been changed by a growth phase.

Now it is obvious that it has not happen. Can we think about any parallels between this moment of solar transition to abnormal activity state and beginning of abnormal processes in the World economy? I do not know. 99 % we cannot. But the question is very interesting and can be the subject of more detailed statistic research.

A long period of solar calmness made scientists recall of a short boulder period which had coincided with so called Maunder solar Minimum from 1645 to 1715. It was time of a disastrous cooling when southern seas were frozen and ice covered European rivers (including the Moscow River) during summer months, and bursts of deaths because of mass crop failures were observed».

Scientists think that «such long activity decay can have… serious consequences, as it is capable to destroy climatic balance of our planet». Bogachov reminded that a traditional method of definition of the solar activity level is based on Wolf numbers calculation. But basing on this criterion it is impossible to understand if a new cycle has begun. Separate spots appear, among them there are even spots of new polarity (a cycle change is signalized by change of sunspot magnetic field polarity), but these events are so rare that it is impossible to understand a common tendency basing on them.

Bogachov has noted that such observations say that «nowadays there are new conditions on the Sun to begin a new cycle – a magnetic field of the preceding solar cycle has been destroyed and one of magnetic zones of a new activity cycle of an opposite polarity has been formed». But a cycle itself has not begun yet as a new belt does not manifest activity. We cannot understand reasons yet. Either the field is too weak or the Sun needs formation of both activity zones for the cycle beginning.

It is clear that solar activity does not exert direct influence on economic and social processes [Abramov, 2001; Ivanov, 2002], which is different from climatological and biological processes. There is no a direct mechanism of influence as it seems to some infatuated researchers. Nevertheless, if solar activity changes influence people and temperature, river inflows and precipitation amount, atmosphere circulation [Babkin, 2004] and solar radiation, all these tell on economy of a separate country and World economy as well, if we desire it or not [Bushuev, 2002].

3.2.10. Possible mechanisms of influence of cosmophysical factors on climatological processes

In 2001 NASA in the work "NASA Research Strategy for Earth System Science: Climate Component" (Ghassem Asrar, Jack A. Kaye,* and Pierre Morel) published the memorandum **«NASA Earth Science Research Questions»**:

How is the global earth system changing?

- *How are global precipitation, evaporation, and the cycling of water changing?*
- *How is the global ocean circulation varying on interannual, decadal, and longer timescales?*
- *How are global ecosystems changing?*
- *How is stratospheric ozone changing, as the abundance of ozone-destroying chemicals decreases and that of new substitutes increases?*
- *What changes are occurring in the mass of the earth's ice cover?*
- *What are the motions of the earth and the earth's interior, and what information can be inferred about earth's internal processes?*

What are the primary forcings of the earth system?

- *What trends in atmospheric constituents and solar radiation are driving global climate?*
- *What changes are occurring in global land cover and land use, and what are their causes?*
- *How is the earth's surface being transformed, and how can such information be used to predict future changes?*

How does the earth system respond to natural and human-induced changes?

- *What are the effects of clouds and surface hydrologic processes on the earth's climate?*
- *How do ecosystems respond to and affect global environmental change and the carbon cycle?*
- *How can climate variations induce changes in the global ocean circulation?*
- *How do stratospheric trace constituents respond to change in climate and atmospheric composition?*
- *How is global sea level affected by climate change?*
- *What are the effects of regional pollution on the global atmosphere, and the effects of global chemical and climate changes on regional air quality?*

What are the consequences of change in the earth system for human civilization?

- *How are variations in weather, precipitation, and water resources related to global climate change?*
- *What are the consequences of land cover and land use change for the sustainability of ecosystems and economic productivity?*
- *What are the consequences of climate and sea level changes, and increased human activities on coastal regions?*

How well can we predict the changes to the earth system that will take place in the future?

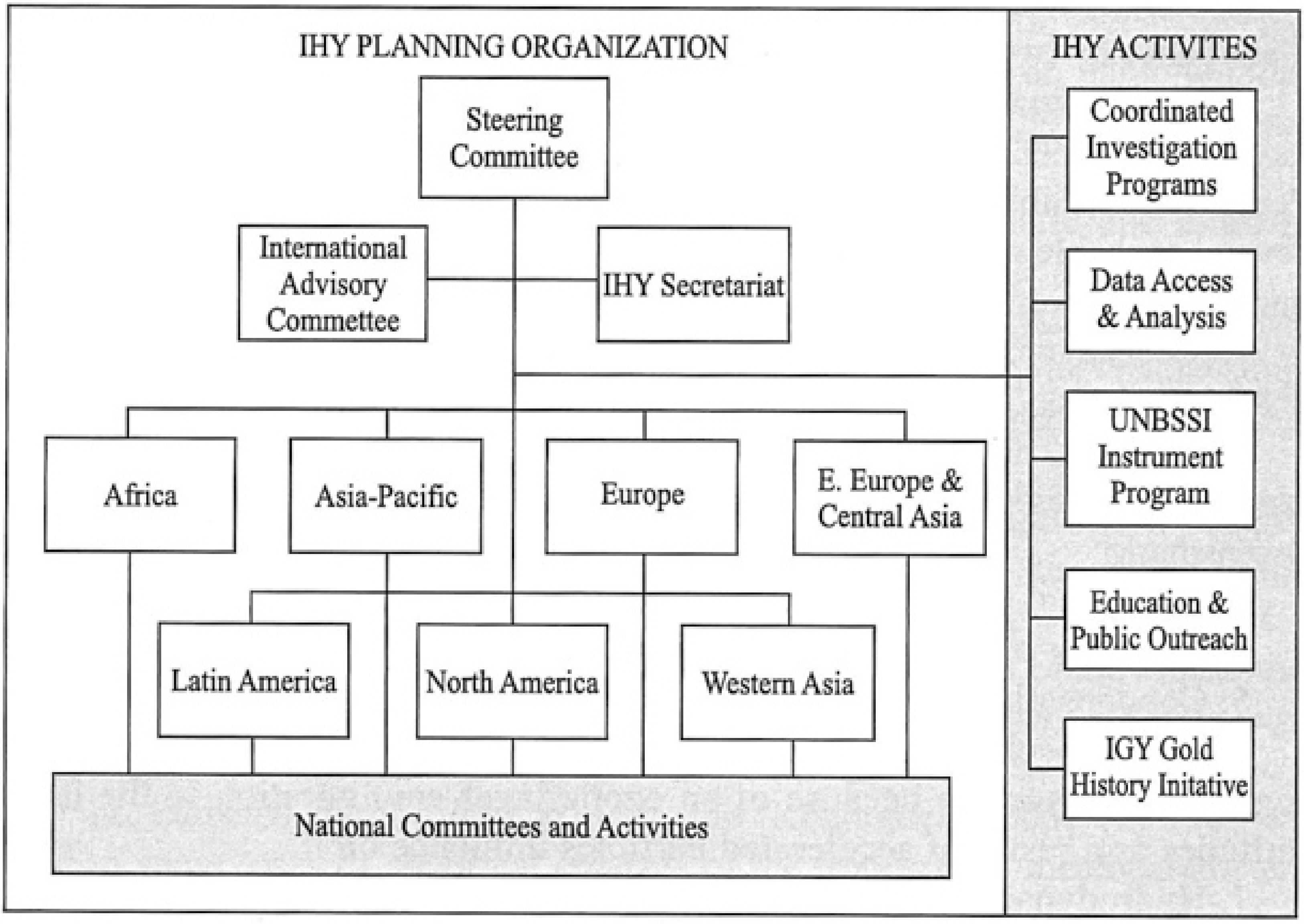
- *How can weather forecast duration and reliability be improved by new spacebased observations, data assimilation, and modeling?*
- *How well can transient climate variations be understood and predicted?*
- *How well can long-term climatic trends be assessed or predicted?*
- *How well can future atmospheric chemical impacts on ozone and climate be predicted?*
- *How well can cycling of carbon through the earth system be modeled, and how reliable are future atmospheric concentrations of carbon dioxide and methane predicted by these models?*

Although now, not all links of solar-terrestrial connection chain are equally researched, in general, a picture of Solar-Terrestrial connections is rather obvious.

In many ways, an understanding of possible mechanisms of influence of cosmophysical factors on climatological processes came from studies that were conducted during 2007 – 2008, the International Heliophysical Year (IHY).

The International Heliophysical Year (IHY) will celebrate the 50th anniversary of the International Geophysical Year (IGY). IHY is one of the four Earth-related activities that will participate to this anniversary together with International Polar Year (IPY), Electronic Geophysical Year, and International Year of Planet Earth.

The results obtained during the IHY, have greatly expanded our understanding of the real impact of space weather models for climate. Nevertheless, now, quantitative solutions with badly known (or unknown) initial and boundary conditions are found difficult because of absence of knowledge of concrete physical devices which provide energy transmission between separate links.



Scheme of the International organizational structure of IHY

Together with search of physical devices an information aspect of solar-terrestrial connections are researched. Connections manifest themselves in two ways depending on if energy of solar disturbances inside the magnetosphere is redistributed smoothly or abruptly, in leaps and bounds.

In the first case Solar-Terrestrial connections are manifested in a form of rhythmical oscillations of geophysical parameters (700-year, 22-year, 11-year, 27-day, etc.).

In the second case, abrupt configurations are connected with a so-called trigger mechanism which can be applied to actions or systems in an unstable, close to critical state. In this case a small change of a critical parameter (pressure, current intensity, particle concentration, etc) leads to qualitative change of a process or initiates a process.

(For example, formation of extra tropical cyclones during geomagnetic disturbances. Energy of geomagnetic disturbance is transformed to energy of infrared radiation. The latter creates additional weak heating of the troposphere, in a result of which its vertical instability is developed.

In this case, energy of developed instability can exceed energy of initial disturbance by two orders [Artekha, 2001]).

According to the works [Ariel, 1986; Artekha, 2005; Gulinsky, 1992; Blanka-Mendosa, 1992 – 1997; Dorman, 1987; Libin, 1989; Dorman, 1991; Peres-Peraza, 1994; Libin, 2009; Obridko, 2008; Pudovkin, 1996 and others] there are several probable mechanisms of heliophysical and cosmophysical factor influence on the lower atmosphere and the Earth:

1. Mechanisms based on a solar constant (astronomic and meteorological) change [Nikolsky].

2. Change of atmosphere transparency under the influence of different extra terrestrial processes, in particular, under galactic cosmic ray action. [Stozhkov; Swensmark]

3. Additional infrared radiation during magnetic storms.

4. Influence of a solar wind on atmospheric electricity parameters.

5. Condensation mechanism [see in the review Pudovkina, 1992].

6. Ozone mechanism and intensity changes of ultraviolet radiation reaching the Earth surface because of an ozone layer configuration in the large latitudes as a result of accelerated particles influence on it.

7. Hydrodynamic interaction of the upper and lower atmosphere.

8. Solar dynamo model. Substance transmission inside the Sun in a result of its rotation and convection. Interaction with a solar magnetic field brings dynamo (an electric current generator transforming mechanic energy to energy of a magnetic field) into action. When charged particles move together with interstellar substance, a magnetic field connected with them moves too.

9. Infrasound (acoustical fluctuations of a very low frequency). (Infrasound appears in aurora regions in the large latitudes and spreads in all latitudes and longitude. So, it is a global phenomenon.

4 – 6 hours after the beginning of a World magnetic storm fluctuation amplitude in the middle latitudes rises slowly. After its maximum it is miniaturized evenly during several hours.

Infrasound is generated not only during auroras, but during storms, earthquakes, volcanic explosions, so, there are constant oscillations in the atmosphere which are collided by oscillations connected with a magnetic storm).

10. Micro pulsations or short-period oscillations of the Earth magnetic field (with frequencies from several Hz to several kHz). (Micro pulsations with frequency from 0.01 to 10 Hz work on biological system, in particular, a

human's nervous system (2 – 3 Hz) increasing time of reaction to a disturbing signal, influence psychics (1 Hz) arousing melancholy, horror, panic without any reasons. Increase of diseases frequency and cardiovascular patients' complications is also connected with them).

11. Parametrical influence of solar activity on thermobaric and climatic characteristics of the troposphere.

(In the work [Zherebtsov, 2008] the author gives the analysis results of peculiarities and regularities of the troposphere temperature regime changes during the period of changing heliogeophysical activity and long-term changes of temperature and heat content of the troposphere.

He has researched influence of atmospheric and oceanic circulation changes on processes in the system Atmosphere-Ocean-Cryosphere – circulation in the ocean and energy exchange of the atmosphere with the ocean.

Revealed regularities are fully explained in the framework of the model and mechanism of solar activity influence on the troposphere characteristics suggested by the authors earlier).

12. Directed spiral (whirling) radiation [Kondratiev, 2005]. (In 1981 we noticed some cases of abnormal changes of the troposphere meteoparameters under the influence of solar activity [Kondratiev, 2982], but only in 2003 analyzing the whole set of high-altitude observations of solar emission influence on atmospheric parameters we identified manifestations of influence of not an electromagnetic or gravitational, but wavy, spiral (whirling) radiation flux from active regions (AR).

Intensity of this specific radiation grows substantially during crossing an active region (AR) through the central part of the solar disk (A latitude zone ±20° is regarded).

Spiral (whirling) radiation (SWR) (as it comes out of its effects) influences mainly dynamic and structural medium parameters bringing (for example, in the Earth's atmosphere) additional energy to air vorticity, giving the air a comparatively small impulse and a considerable moment of the impulse, because a whirling field from a local photospheric research (for example, a spot with a geometrically correct form) can light 10^5 km^2 squares locally in different region of the Earth simultaneously.

Effects of SWR influence on the atmosphere and, as it seems, other spheres should be regarded for the part of the Earth lighted by the Sun and the shadowy part separately, as SWR is characterized by a comparatively high penetrating capability and interacts with a solid lithosphere cover using it as a spherical lens.

According to estimations [Kondratiev, 2005, 2008] and natural phenomena (for, example, craters) a focusing effect exceeds losses by several orders during movement of SWR field quantum (spirons) along the lithosphere spherical waveguide.

A high-speed (supersonic) concentrated whirl with a 30 – 50 m focus spot and voluminous density of energy on the whirl periphery up to 14 G/sm^3 (after focusing) has been created in focus situated on the surface of the Earth spheroid or near the Earth before or after spheroid boundary.

On the basis of data of high-altitude observations in 21, 22 and 23 cycles of solar activity (SA) its influence on radiation, optical, microphysical, and meteorological atmosphere characteristic have been researched with a stress on the study of SA influence on dynamic (circulation) processes and changes of microphysical state of vapor molecular ensemble.

Contributions of spiral (whirling) radiation (SWR) and a proton flare flux to dynamic processes in the lower troposphere are illustrated by the example of the event of 10/20/89.

Observations of abnormal disturbances in typical daily movement of meteo-elements, as well as movement of their synoptical periods, have led to clearing up the reason of appearance of power-intensive disturbances in synoptical processes in the troposphere.

It seems that directed spiral (whirling) radiation and solar proton fluxes are basic and comparable force factors of solar activity influence on the troposphere and the lower stratosphere; however, only the first factor influences effectively all the components – the atmosphere, hydrosphere, magnetosphere, lithosphere, biosphere and technosphere).

13. Cosmic rays and the atmosphere conduction [Stozhkov]. (Ions formed by CR provide the atmosphere conduction. Current which flows in the atmosphere is one of the basic elements of a global electric chain which supports a constant negative charge of the Earth.

Lightning discharges of thunderclouds are a generator of electric charges of the atmosphere. Thunderstorm clouds are formed in the atmosphere fronts where formation and division of cloud charges take place. Positive and negative ions formed in the lower atmosphere by CR and natural radioactivity of the Earth is the source of thundercloud charges.

These ions stick to aerosol particles concentration of which is high in the atmosphere (more than 104 sm^{-3}). On charged aerosol particles water drops grow slowly as they climb up with ascending air.

According to A.I. Rusanov, a Russian scientist, negative charges are separated from positive ones in a result of the following – water drops on negative centers grow ~10 000 times faster than on positive ones.

In a result of this process the lower part of the cloud is charged negatively and the upper one positively. Lightning discharges appear when a so-called extensive air shower up to 106 charged particles formed by a high-energy cosmic particle moves through the cloud.

Lightning charges happen on tracks of ionizing particles of extensive air shower. So, CR is a necessary constituent part of thunderstorm electricity and lightning discharges formation processes.

Charged particles fluxes in the Earth's atmosphere intensify or reduce a process of cloud formation. During powerful flares of solar CR a charged particle flux in the Earth's atmosphere increases, cloud density grows and precipitation amount increases. During CR Forbush decrease when a particle flux in the atmosphere decreases, precipitation level becomes lower.

In 1998 Danish scientists found out a very interesting phenomenon using observations of clouds from satellites – square covered with clouds on our planet changes in correspondence of value changes of a CR flux which falls on our atmosphere. Every year a CR flux value becomes lower by (0.01 – 0.08) %.

A negative trend is a result of explosion of a close supernova. This explosion happened at the distance of several tens of parsec (1 parsec is 3.08×10^{68} sm) several tens of thousands of years ago.

Consequently, the square covered with clouds decreases slowly. This decrease should make temperature on our planet rise. We know that for the last 100 years temperature on the Earth surface has risen by ~0.50 C. So, CR flux decrease can be responsible for the effect of global warming.

In this case practically in all mechanisms a warmth flux from outer resources – solar flares, interaction of solar plasma and the Earth's magnetosphere, geomagnetic storms, geomagnetic convection, penetration of particles to polar regions, generation of additional quantity of nitrogen dioxide and ozone by solar and galactic cosmic rays in the lower stratosphere, solar activity influence on the atmosphere electric field, etc. – is a substantial factor of any discussed mechanisms.

Anyway, the resource is situated outside the Earth.

B.Komitov in the book «The cycles of Sun, Climate and Civilization» [Komitov, 2001] wrote, that in the theory of «global antropogenic climate warming» significant facts are ignored:

1. 1000 years ago the climate of the Northern hemisphere was essentially warmer as the present and in this time Greenland really was a «green land».

2. The solar activity is the main factor for the changes and cyclic variations of the climate in Holocene (the last 10 – 11,000 years after the «Wurm ice epoch»).

3. There are four periods of deep climatic colding during the last 10,000 years, wich are mentioned as "litle ice epochs". They are caused by the powerful 2200 – 2400 years solar cycle. The last «litle ice epoch» was during the second half of 17th century.

4. The very warm climate of the Earth during the 20th century is caused by the highest level of solar activity for the last 800 years.

5. A 2200 – 2400 years basic quasy-cycle of the historycal processes exist. It is caused by the cyclic behaviour of the solar activity and climate

3.3. Modeling the interaction of cosmophysical and climatological processes

Researches devoted to problems of connection between the climate and changeability of solar activity and a solar wind can be divided into three groups:

1. climatic changes during hundreds and thousands of years;
2. changes correlating with 22-year and 11-year solar activity cycles;
3. changing during several days or weeks.

In any case during the study of short-period and long-period atmospheric processes account of solar activity influence with applying data of indexes of geomagnetic activity, cosmic ray intensity, etc, is very important.

In each case this influence character depends greatly on the spectrum of electromagnetic and corpuscular solar radiation, on a current state of the solar magnetic field and interplanetary magnetic field, on the Earth heliolatitude and a geographical region of atmospheric processes under study.

That is why during modeling the solar activity impact on atmospheric processes it is necessary to account any additional information, because using only Wolf numbers for establishing long-term interdependencies is not always justified.

The results of researches of cosmophysical and climatological (meteorological) processes given in the past chapters prove the existence of cause-and-effect relations between solar activity and other processes.

That is why we can admit that parameters describing atmospheric processes (in particular, for example, temperature $T(t)$) can be presented as the sum of preceding values of $T(t)$, solar activity $W(t)$, geomagnetic activity $K_p(t)$, solar radiation $R(t)$, and cosmic ray intensity $I(t)$, or an autoregressive model:

$$T(t)=\sum_{i=1}^{p}\alpha_i T(t-i)+\sum_{j=1}^{q}\beta_j W(t-j)+\sum_{k=1}^{s}\gamma_k I(t-k)+\sum_{l=1}^{m}\delta_l K_p(t-l)+\xi_t \quad (10)$$

$T(t)$ – is a predicted temperature value, where p, q, s and m are a model order for each used series determining a backsight of each process for prediction of temperature estimation, α_i, β_j, γ_k и δ_l are AR-model parameters.

In this case, while new data appear, one can observe renewal of autoregressive estimations and a possibility to predict temperature one step further appears.

(Predictions for future consist in searching for a future value as weighed sums p of preceding $T(t)$ counting, q counting $W(t)$, $S(t)$ and $I(t)$ and m counting $K_p(t)$).

There are two ways of building a model

1. On the basis of collected data set of temperature, solar activity and cosmic ray intensity (a size of each is NO) a matrix for a system of linear equation (10) is made up; $\{\alpha\}$, $\{\beta\}$, $\{\gamma\}$ and $\{\delta\}$ vectors are determined from its solution.

But in this case it is necessary to take into account that autoregression coefficients can be determined practically for each accumulation interval.

Using monthly average data for the period 1950 – 2004 it is possible to receive about 600 equations. Consequently, for yearly average data an equation number decreases up to 54-k, where k is a maximal autoregression order.

If $k = 5$ an equation number makes approximately 50, and in this case we can try just to solve an equation system (10) supposing that noise ξ_t is minimal.

A system solution is actually a solution of system $N = N_0 - k - 1$ of equations (11) given below, where P_i means a surface temperature T, averaged about the region, if there are measures of several stations j.

So, during estimating forecasts of temperature in Mexico, scientists used temperature values received on 30 – 40 meteostations in each of researched regions (See a list of basic Mexican meteostations (except Takuballa in Mexico city) in the table below).

2. If an equation (10) number is higher than an unknown $\{\alpha\}$, $\{\beta\}$, $\{\gamma\}$ and $\{\delta\}$ number and it is impossible to make supposition about a minimal value, a system solution adds up to solution of equation system (12), connected not with values of solar activity, temperature, geomagnetic activity and cosmic ray intensity, but with their covariance functions A_{tj}.

$$\begin{pmatrix} P_k \dots P_{k-q} W_k \dots W_{k-s} K_{p_k} \dots K_{p_{k-r}} I_k \dots I_{k-m} \\ \vdots \\ P_{k+i} \dots P_{k+1-q} W_{k+1} \dots W_{k+1-s} K_{p_{k+1}} \dots K_{p_{k+1-r}} I_{k+i} \dots I_{k+1-m} \\ \vdots \\ \vdots \\ \vdots \\ \vdots \\ \vdots \\ \vdots \\ \vdots \\ P_N \dots P_{N-q} W_N \dots W_{N-s} K_{p_N} \dots K_{p_{N-r}} I_N \dots I_{N-m} \end{pmatrix} \begin{pmatrix} \alpha_1 \\ \vdots \\ \alpha_q \\ \vdots \\ \beta_s \\ \gamma_1 \\ \vdots \\ \gamma_r \\ \delta_1 \\ \vdots \\ \delta_m \end{pmatrix} = \begin{pmatrix} P_{k+1} \\ \vdots \\ P_{N+1} \\ \vdots \\ W_{N+1} \\ K_{p_{k+1}} \\ \vdots \\ K_{p_{N+1}} \\ I_{k+1} \\ \vdots \\ I_{N+1} \end{pmatrix} \quad (11)$$

$$\begin{pmatrix} A_{11} & . & . & A_{14} \\ . & A_{22} & & . \\ . & & A_{33} & \\ A_{41} & & & A_{44} \end{pmatrix} \begin{pmatrix} \alpha \\ \beta \\ \gamma \\ \delta \end{pmatrix} = \begin{pmatrix} a_0 \\ b_0 \\ c_0 \\ d_0 \end{pmatrix} \quad (12)$$

It is clear in this case that, for example, for a region averaged temperature:

$$P(t) = \sum_{j=1}^{N} T(t)_{i,j} / N$$

$$P(t-1).P^*(t-1) = \begin{pmatrix} P_{t-1}^2 & P_{t-1}.P_{t-2}\dots\dots\dots P_{t-1}.P_{t-q} \\ P_{t-q}.P_{t-1} & P_{t-q}.P_{t-2}\dots\dots\dots {P_{t-q}}^2 \end{pmatrix} \quad (13)$$

Analogical expressions are received for other parameters W, S, K_p and I applied for building up a prognostic model. Covariance values A_{ij} and a_0, b_0, c_0 and do can be considered as known – they are calculated from the real data.

So, the system (12) is a system of linear equations for defining unknown coefficients {α}, {β}, {γ} and {δ} regression equation (10) and is always solved if only a covariance matrix determinant differs from zero.

Noise exception is an advantage of the second way of an equation system solution, as mutual noise covariances with other processes are equal to 0.

So, setting oneself model orders for q, s, r and m temperature, solar activity, geomagnetic activity and cosmic ray intensity it is possible not only to predict average values of temperature one step further (distance of this step will be determined only by a discretion data quantity Δt) but to help to estimate contribution of this or that process to forecasted temperature.

It is true, if values of one of the searched parameters {α}, {β}, {γ} or {δ} are small (much less than errors of their measurements), one can disregard the process itself in the model.

So, during analysis of yearly average dependences between temperature and geomagnetic activity, the values were disparagingly small in comparison with errors and in absolute value.

A detailed analysis has showed that it is unacceptable to use only K_p-index to build up a prognostic model.

On the basis of values of averaged temperature in the northern part of Russia for 1950 – 2008 and Mexico for 1950 – 2004, solar activity for 1945 – 2008, geomagnetic activity for 1945 – 2004 and cosmic ray intensity for 1960 – 2007 scientists determined values of the model parameters and estimated $T(t)$ values for 2004, 2005, 2006 and 2007 which were later compared with the real $T(t)$ values for the same years.

The analysis was based on monthly and yearly average values of $T(t)$, $W(t)$ and $I(t)$, and a two-year drift $W(t)$ relative to $T(t)$ was entered to yearly average data in advance (when using monthly average values a drift was not entered).

It is necessary to note that a number of predictors (the model order) should not exceed (as it is shown in the work [Rozhkov, 1979]) one tenth of a sample volume, which can be explained by possible correlation connection between variables, on one hand, and sample limitation, on the other.

The received data show that α, β and δ values for the whole period are practically not changed.

Moreover, $T(t)$ values defined for 2004 – 2007 (in the framework of a prognostic model with coefficients α, β and δ) differ from the real $T(t)$ values less than by 12 – 25 % for prognosis for 1 year, 27 % for two years and 30 % for three years.

A temperature forecast for 2008 given in 2005 was justified with a 40 % error; the same forecast given in 2007 was justified with a 30 % error.

So, the use of standard ARSS-models for working out forecast for temperature (and any other climatological parameters) based on preceding values and observation data of solar activity, geomagnetic activity and cosmic ray intensity has good prospects.

The results of researches for the last years in this direction demonstrate rather good correlation of calculated and experimental values not only of $T(t)$, but of stormicity $P(t)$, precipitation amount, ice square in the Baltic and White Seas and in the Arctic.

That is why further working out of such a model will permit to predict yearly average meteorological characteristics for one year further with 25 – 30 % precision.

To get less precise estimations a two-parameter model is enough:

$$P(t)=\sum_{i=1}^{q}\alpha_i P(t-1)+\sum_{k=1}^{p}\beta_k W(t-k)+\xi_t \tag{14}$$

So, the use of all existed spectral apparatus and comparison of results of various spectral calculations got by different researchers in different countries show that solar cyclic activity and its influence on the Earth's atmosphere are the source of the mechanism of impact on atmosphere circulation, water content of closed lakes.

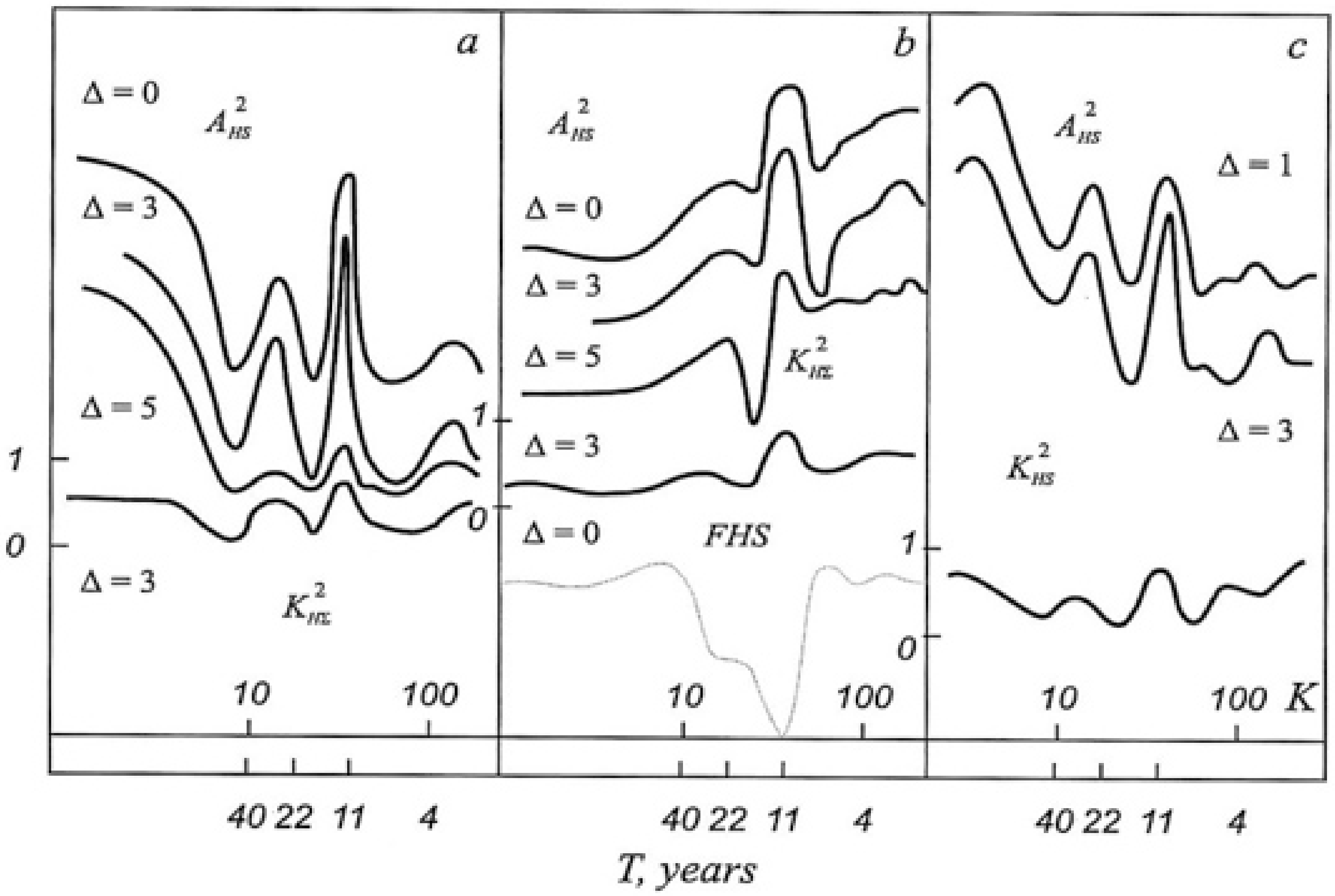
Thereby, behavior analysis of retardation between atmospheric processes and solar activity show the existence of constant drifts from 12 to 36 months between processes which correlates well with other technique calculation results.

It is necessary to emphasize that mutual autoregressive analysis for the whole data set and for even and uneven solar activity cycles separately results in an interesting picture.

Brightly expressed 4 – 7 year, 10 – 12 year and 80 – 90 year variations of ice square are observed in uneven cycles (on the background of weaker expressed 400 and 720-year variations), 20 – 30 year, 80 – 90 year and 400-year variations prevail in even cycles.

The analysis of surface temperature measuring in Mexico (Sonora, Tacubaya, Baja-California and Sinaloa), Estonia (Tartu), Sweden (Stockholm), Lithuania (Kaunas) and Moscow for 1910 – 2007 demonstrates precise coincidence of separated frequencies (correlating to 2 – 4 year and 9 – 11 year periodicities) and good coincidence of 2 – 3 year retardations between processes.

In this case, dynamics of oscillation behavior also coincides – if 9 – 11 year oscillations exist always, 2 – 4-year oscillations are more casual that also correlates well with behavior of analogical solar activity oscillations.



Power spectrums (A), coefficients of coherence (K^2) and phase spectrums (FHS) for solar activity and atmospheric processes

In a result of analysis of observation data of precipitation in Estonia, Lithuania and Russia for 1910 – 2007 and solar activity (sunspot square S) good coincidence of process behavior – the existence of 11-year and 22-year constituents and a quasi-biennial wave in analyzed data – was found out.

On the basis of solar radiation measurements in different points of the Earth surface in the period from 1950 to 2007 an attempt to estimate possible modulation of solar radiation by solar activity observed on the Earth was made.

It is found out that in a broad frequency band in observation data of solar radiation on the Earth oscillations with periods 2, 11 and 22 years tightly connected with solar activity are observed.

In connection with that results of analysis of carbon dioxide contents in the Earth atmosphere and solar activity are of great importance (using HL-index and the total sunspot squares).

The autoregressive analysis made by the authors demonstrates precise coincidence of separated frequencies (correlating to 2 – 4 year, 9 – 11 year, 22 – 35 year, 380-year periodicities) and good coincidence of 2 – 3 year retardations between processes.

In this case, dynamics of oscillation behavior also coincides – if 9 – 11 year and 22-year oscillations of carbon dioxide exist always, 2 – 4-year oscillations are more casual that also correlates well with behavior of analogical solar activity and atmosphere temperature oscillations.

Comparison of given results with analogical researches of solar activity influence on a surface temperature, lake level, precipitation amount and heavy earthquake quantity show not only qualitative, but quantitative (to a precision of retardation) correlation.

Besides, it is found out that during joint analysis of temperature in different places of the Earth and solar activity a choice of solar activity indexes does not play a decisive role – so, the authors consider sunspot square in the subequatorial zone of the Sun the most acceptable index for calculations.

That is why, during solving problems of revealing mechanisms of large-scale processes in the atmosphere or trying to build up prognostic models of climatological or hydrological processes it is necessary to take into account solar activity changes, processes in the interplanetary medium and cosmic radiation variations observed on the Earth.

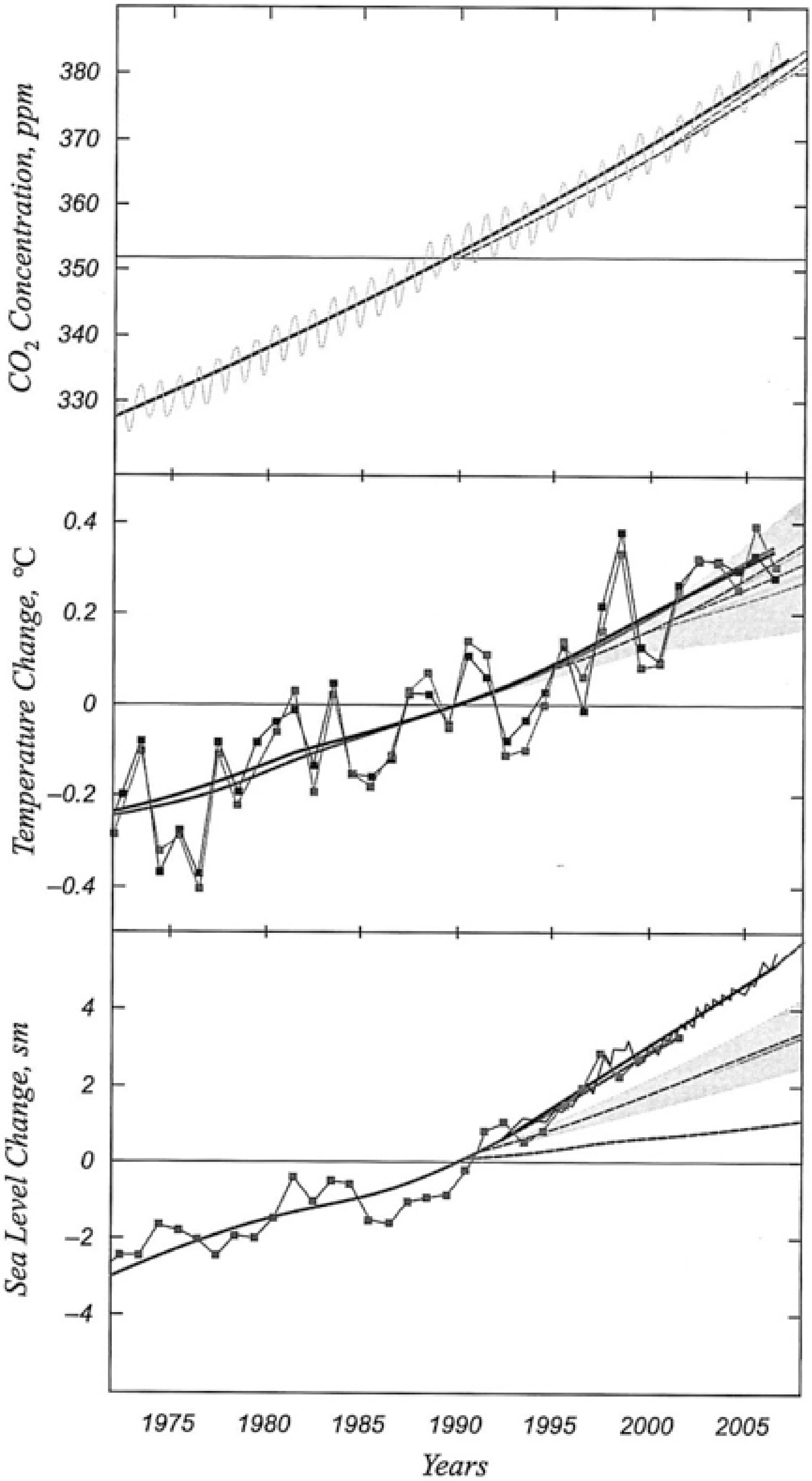
In the work [Rahmstorf, 2007] a group of scientists from different countries analyzed a lot of forecasts of climatological characteristics made by different authors during the last 15 years and compared these forecasts with that what had really happened during 15 years.

It was cleared up that the changes of carbon dioxide contents in the atmosphere were predicted well, and temperature changes were predicted rather reasonable. All these indicators arose in correspondence with the trends revealed earlier.

But the average level of the World Ocean rose faster than it had been expected.

From 1990 to 2005 it rose by 4 sm, although only 2 sm had been predicted. (It can be so that the reason of some deviation of observed values from predicted ones is inner variability of the climatic system itself, result of its component interaction dynamics unknown to us).

Researchers from the international group think that for prediction of future climatic changes scientists base on autoregressive models like, for example, the authors of the book. These models are built on the basis of data which have been already observed during the previous years and on understanding interconnections of physical processes occurring on our planet surface.



Changes of contents of CO_2 in the atmosphere (at the top), average temperature on the Earth surface (in the middle) and average level of the World Ocean (in the bottom) since 1973 to nowadays [Rahmstorf, 2007]

The forecast for the World Ocean level (a low panel of the diagram [Rahmstorf, 2007]) appeared to be the least satisfactory. For the last time this level has gone up much faster than it had been supposed by the IPCC model.

The real increase (according to satellite measures) since 1993 to 2006 made up at the average 3,3 ± 0,4 mm per a year, while the most probable value of the model was less then 2 mm per a year.

The authors of research [Rahmstorf, 2007] note that rise of the ocean level for the last 20 years was faster than for any 20 years during the preceding 115 years. Observed values correspond to utmost figures given in the model as unlikely and connected with so-called «vagueness in a state of ice on land». And although simple heat expansion of water mass makes the basic contribution to the ocean level rise while global temperature increases, it seems that glacier melting plays an underestimated role.

The authors come to the conclusion that we should treat scientific prognoses of the climate change very seriously.

Changes of carbon dioxide contents in the atmosphere and temperature changes were predicted rather well. As for the ocean level (the least satisfactory variant of the forecast), the reality appeared to be more threatening than it had been predicted.

Nevertheless, the forecast results got in the whole series of works (and by the authors as well) are in agreement with the real data and fit themselves on the curves (see the picture below) got in the work [Rahmstorf].

These results permit to use an autoregressive prognostic model for forecasting climatological processes (temperature, water content of closed lakes and seas, stormicity, ice square, precipitation amount) rather reasonably taking cosmic ray intensity into account.

The thin solid lines mean the real data, the thick solid ones mean the averaged real data which show the basic trend. The dotted lines are data of forecasts and given confidence intervals (areas colored with grey). Temperature and the ocean level changes are given as deviation of a trend line in the place of its crossing a 1990 mark (taken as a zero).

In worlds of love we are adulterous comets,
The trodden orbits shut away from us!
In vain the earth will give our dreams her fuss,
Away from midnight suns we're lost and homeless.

In Lethe baptized not, our bitter spirit
With reminiscences bears down on us.
The universal bitterness still lasts.
It smolders in our breast, poetic shivering.

All those whose eyes see only in the dark,
Alive and buried deep in earthen chark,
All those whose roots grow up, exiles in this land,

Whose dreams are clear, who prophesy the names,
Shall never find that joy the world so craves –
Their temporal love will drown in earthly quicksand.

Maximilian Voloshin,
Coctebel, 1909

4. INFLUENCE OF AFRICAN DUST AND COSMOPHYSICAL PHENOMENA ON HURRICANES GENESISS

The links between the Space Weather and Meteorological Weather have been often discussed not only for the last century [Mason and Tyson, 1992; Mazzarella and Palumbo, 1992], but also for several centuries ago [Rodrigo et al, 2000], and even before some thousands of years ago [Neff et al, 2001]. A great deal of efforts have been done to clarify the mechanism of all complicated interconnections between the cosmophysical and climatic phenomena at earth, some of them recently summarized by [Benestad, 2006, Kanipe, 2006, Haigh et al, 2005 and Fastrup et al, 2001]. In the last years more and more investigations show that the solar activity have noticeable impact on the meteorological parameters [Ney 1959, Gray et al, 2005; Kristjansson et al, 2002, 2007; Laut, 2003; Tinsley, 1996, 2000; Tinsley and Beard, 1997] and cosmic rays [Marsh and Svensmark, 2000; Kudela et al, 2000; Gierens and Ponater, 1999; Dorman, 2006; Mavromichalaki et al, 2006, Ran 2009, Raibeck and Yiou, 1980, Yiou et al., 1997].

Besides some indications appeared that several purely meteorological processes in the terrestrial atmosphere are connected with the changes in the CR intensity, and influenced by solar activity, and magnetosphere variations [Kudela and Storini, 2005, Marsh et al 2000, Kristjansson et al 2002].

One of the main goals of Space climate research is to know how and when the periodicities of space phenomena do modulate terrestrial Climatic changes. Some insights have been obtained: for one side, the solar Hale cycle (20 – 25 years). Changes in solar activity for the last 500 years have been studied [Raspopov et al., 2005], with the aim of revealing a possible contribution of solar activity to climatic variability. On the other hand, quasiperiodic climatic oscillations with periods of 20 – 25 years have been revealed in the analysis of parameters such as ground surface temperatures, drought rhythm, variations in sea surface temperature, precipitation periodicity, etc. [Ol', 1969; Cook, Meko, and Stockton, 1997; Pudovkin and Lybchich, 1989; Pudovkin and Raspopov, 1992; White, Dettinger, and Cayan, 2000; Roig et al., 2001; Raspopov et al., 2001, Khorozov et al., 2006].

To understand the involved physical mechanisms it is required, as a first step, of confident observational or experimental facts. Nevertheless, to clarify the mechanism of all the complicated interconnections between the cosmophysical phenomena and climatic phenomena at earth, a great deal of efforts have been done; for instance, Fastrup (2001), Haigh et al. (2005), Benestad (2006), Kanipe (2006).

One of the principal difficulties in quantifying the role of the space phenomena on climate changes has been the absence of long-term measurements of both, the climatic and space phenomena. Consequently, people often recur to the use of proxies. In the last years more and more investigations show that the solar activity [Tinsley B.A. 2000, Kristiansen, 2002] and Cosmic Rays, have noticeable impact on the meteorological parameters. However, the influence of cosmophysical phenomena on climatic phenomena is currently debated [e.g., Haigh, 2001, Shindell, 2001].

Previous work by means of a correlational analysis [Elsner and Kavlakov, 2001; Kavlakov, 2008a, b; Pérez-Peraza et al, 2008a], mentioned here below (section 4.2), seems to indicate that certain extraterrestrial phenomena could have some kind of relation with the occurrence of Hurricanes. It is even speculated that such kind of correlations could seat the basis of deeper studies to use the results as indicators of hurricanes precursors. To give to those results a higher meaning, it is convenient to carry out spectral studies of the different involved times series to delimitate with more preciseness the existence of those potential relationships. That is, to find incident cosmophysical periodicities that may modulate terrestrial phenomena Though the AMO (Atlantic Multidecadal Oscillation) has been linked with the frequency of Atlantic hurricanes, however, in the present context, little attention has been given to such a large scale climatic phenomena: as the question about the role of the Sun in modulating these phenomena has not been clarified, it requires further assessment. In section VII we describe the behavior of the main periodicities presented by the AMO in relation to some solar activity phenomena and Galactic Cosmic Rays (GCR). So, special mention must to be done regarding the ***links between Geo-external forcing and Hurricanes***.

4.1. North Atlantic hurricanes

Hurricanes are considered one of the most astonishing meteorological phenomena in our planet. Strong winds, clouds of great size and intense storms unite to advance for the ocean and to reach mainland, razing with everything to their passage, fallen trees, damages in buildings, changes in the natural landscape and, fatal victims, are alone some of the consequences that these unpredictable events can generate. Due to the great intensity that they reach, with winds that can overcome the 350 kilometers/hr, they are classified as true natural disasters: whole towns disappear under the force of the impetuous winds. No device achieves, nowadays, to counteract its force; the man has become a simple spectator. Hurricanes have always been associated with the damage that causes mainly translated in human and material losses, but it is necessary to stand out that they also brings such benefits as the increase in precipitation in regions where the agricultural development depends on the precipitation, as well as the recharge of the dams and the bodies of water, vital for the development of the populations.

The word hurricane has its origin in indigenous religions of the old civilizations. The Mayan named to their god of the storm as *Hunraken*. Taino people, a culture of the Caribbean, called Hurricane to a God that they considered malicious. Nowadays, hurricanes are not considered wicked forces but due to their great force, and great potential for loss of lives and material damages, they are considered one of the most powerful phenomena in the nature.

The tropical hurricanes are the only natural disasters to which are assigned a name. These names are known well before they happen and as well as their possible effects, contrary to other natural phenomena as the earthquakes, tornados and floods. Gilberto, Katrina, Mich and Isidoro, to name some of the most recent, are examples that remember a very particular image, for the severe damages that caused. These phenomena present common characteristics, although each one shows particular features.

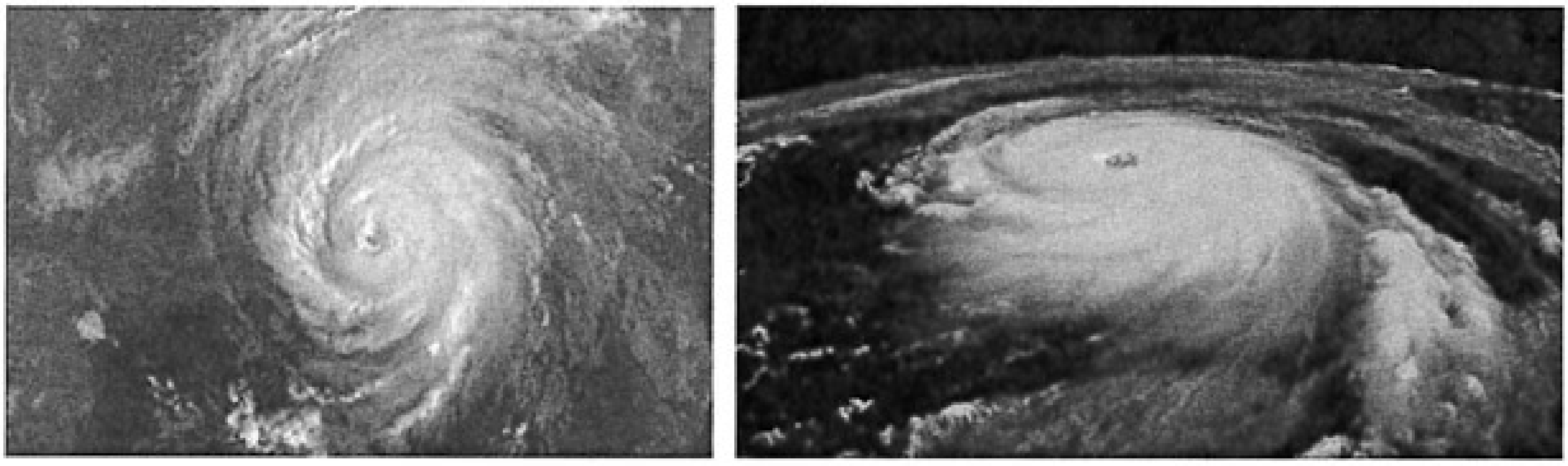
The destruction caused by the hurricanes in the Caribbean and Center America is a force that has modified the history and that it will follow it making in the future in these regions. The danger is born from a combination of factors that characterize to the tropical cyclonal storms: elevation of the level of the sea, violent winds, and strong precipitation. For their location, an example on this, is the Peninsula of Yucatan which is affected in a direct or indirect way by most of the hurricanes that are formed in the Western Caribbean. The hurricanes can have a diameter as long as the peninsula itself, so that practically any hurricane that is formed affects in more or smaller measure the oriental coast of the peninsula. [Wilson, 1980, Pereira, et al, 2000].

To give an idea of hurricanes power, the energy concentrated in the vortex system is estimated to be $> 10^{16}$ J: if we consider that the air over a surface with a diameter of ~800 km has a mass of $\sim 2\times 10^{12}$ tons, turning with average velocity of ~15 to 20 ms^{-1}, we could easily calculate an energy of $\sim 10^{11}$ KWh). This corresponds to the energy released during the explosion of more than 2000 Atomic bombs of the Hiroshima type. That explains the devastating effect of the hurricanes when it touches a populated area.

North Atlantic hurricanes frequently strike the Caribbean islands, Mexico, and the United States. Only one hurricane hitting over their coasts could take hundred human lives and can cause damages for billions dollars. And practically every year one or two such hurricanes devastate these regions. They rank at the top of all natural hazards [Elsner and Kara, 1999]. The hurricane KATRINA, destroying not only the city of New Orleans but vast areas from the states of Louisiana and Alabama is an example of that. The tropical hurricanes are sometimes driven by weak and erratic winds, that makes even more difficult to predict them. Published warnings have substantially improved entailing a decrease of the deaths.

So, today a lot of efforts are devoted to understand better the hurricane formation and intensification to unveil connections with other physical processes, as could be for instance the fact that there has been a low Atlantic hurricane activity in the 1970s and 1980s compared to the past 270 years, but increasing destructiveness over the past 30 years. Also, even if, since the beginning of the

1990 there is a general trend to increase the frequency of tropical cyclones, there are however some years with do not follow such a tendency, as it was the case of 2006. It is hope that the conglomeration of different researches with very different focus contribute, in overall, to the task of improving the prediction of its complicated trajectories for a better foresee of hurricane appearances, prediction of their probable devastation, and then, to warn with enough time the threatened population.



Pictures of hurricane KATRINA, taken from a satellite. Katrina was the deadliest category-5 hurricane to strike the United States since 1900. [Perez Peraza at. al., 2011]

Hurricanes are perturbations that take place in tropical regions where the waters of the ocean are relatively warm (temperatures around the 26 – 27 °C). They are characterized by a great center of low pressure, around which the air at great speed rotates embracing an extension of several hundred of kilometers. Hurricanes have a certain anatomy and their classification depends on the intensity of the winds, on the atmospheric pressure and on the potential damages that they may cause. Powered by the intensive solar heating, producing fast evaporation in the second semester of each year, large upward hot high velocity circular wind streams are born over the hot equatorial waters of the oceans, with a velocity higher than 60 Km/hr, and reaching rotational velocities beyond 350 Km/hr. *Tropical Cyclone* is the scientific term for a closed meteorological circulation of enormous mass of atmospheric air rotating intensely, that is developed on tropical waters. These systems to great scale, non frontals and of low pressure happen on areas of the world that are known as tropical basins of *hurricanes*.

Therefore, the Tropical Cyclone is a low-pressure system that is located over hot waters of tropical oceans (between the tropics of Cancer and Capricorn and at least 4 – 5° away from equator). The intensive heating, low pressure and resulting powerful evaporation increase fast the rotational wind speed. This huge system moves generally from East to West and slightly to the North, but deviations to the East are not exceptions. These exceptions are dangerous especially for the West coast of Mexico and USA. Generally these cyclones are known under the name of hurricanes. if they are formed over the Atlantic and North-eastern Pacific Oceans.

We use hereafter indifferently the terms cyclone and hurricane. If they are born over the western Pacific Ocean, they are called Typhoons. Because of the earth rotation, they rotate counter clockwise in the North Hemisphere and clockwise in South Hemisphere.

In the first moments of the formation of Tropical Cyclones, when the circulation of the closed isobar reaches a speed of 18 ms^{-1}, (i.e. < 34 kt or 61 km/h), the system is denominated as *Tropical Depression* (TD). This is considered as a tropical hurricane in formative phase. If the sustained speed of the wind ranges from 18 to 32 ms^{-1} (34 till 63 kt, i.e. 62 – 115 km/h) it is called a *Tropical Storm* (TS) and a certain name is given. Likewise, when the speed of the wind exceeds the 119 Km/h, or ≥ 33 ms^{-1} (≥ 64 kt) the system takes the name of Hurricane (or Typhoons). That is the speed accepted to define the beginning of a hurricane over the Atlantic and a typhoon over the Pacific. They have a defined nucleus of pressure in very low surface that can be inferior to 930 hpa. Every year develops an average of 10 tropical storms in the Ocean Atlantic, the Caribbean or the Gulf of Mexico, and about 6 of those which end up becoming hurricanes. In a three year-old period, the North Atlantic coasts receive an average of five hurricanes, two of those which are considered bigger hurricanes. In general, the tropical depressions and tropical storms are less dangerous than the hurricanes; however, they can still be mortal. The winds of the depressions and tropical storms are not the most dangerous thing.

The intense rains, floods and the severe natural phenomena, as the tornados, are the biggest threat. Hurricanes can then be described as turbulence phenomena caused by a current of hot air that is formed in the summer in the tropic and that it goes to the North Pole compensating the difference in temperature between the Ecuador and the Pole. One counter current of the north to the south, compensates the difference in pressure. This circulation of winds north-south and south-north at level of the north hemisphere, together with the daily circulation of the earth that causes the trade winds, are the main factors from the point of view of the winds to create situations that can form hurricanes. Another condition for the formation of a hurricane is the temperature of the surface of the ocean, as energy source to give form to the phenomenon, which should be

≥ to 26 °C. Under these conditions, it is the column of hot and humid air originated in the ocean the one that becomes the nucleus around which rotate the winds and form later the so called "eye" of the hurricane.

The adjacent air is gradually involved in the rotation and the diameter of the whole vortex spreads to 500 – 1000 km. With the further increase of the circular velocity, reaching sometimes 150 – 160 kt (80 ms^{-1}), the whole vortex spread out to a gigantic ring with a diameter of several hundred kilometers. As we said before, in its center there is a relatively calm region called the "Eye" of the hurricane. Around it, the rotational velocity is the greatest and decreases out of the center. With the increase of the circular velocity, the whole vortex spread out to a gigantic ring with a diameter of several hundred kilometers (Table 4.1). In his East-West motion the whole system sweeps a lane about 1000 km wide. It gradually intensifies its rotational wind velocity, simply cooling the hot oceanic surface (e.g. Kerry, 2006). Lingering over the ocean sometimes 20 – 30 days, these systems describe complicated trajectories. The lost of energy of the phenomenon usually happens when the hurricane moves inside coastal areas and it goes into to the continent.

Table 4.1. Basic Hurricane Parameters

Parameter	Range	Average	Unit
Diameter (D)	200 – 1300	500	km
Eye	6 – 80	50	km
Rot. velocity (V)		0	ms^{-1}
Duration	1 – 30	8	days
Kinetic Energy	4 – 8	6	Twh
Surface winds:		> 33	ms^{-1}
Energy Source	Latent Heat Release		
Equivalent Energy	2000 Bombs Hiroshima Type		
Lives (North Atlantic)	200,000 from year 1700		
Damages (North Atlantic)	1180 bill $ from year 1900		

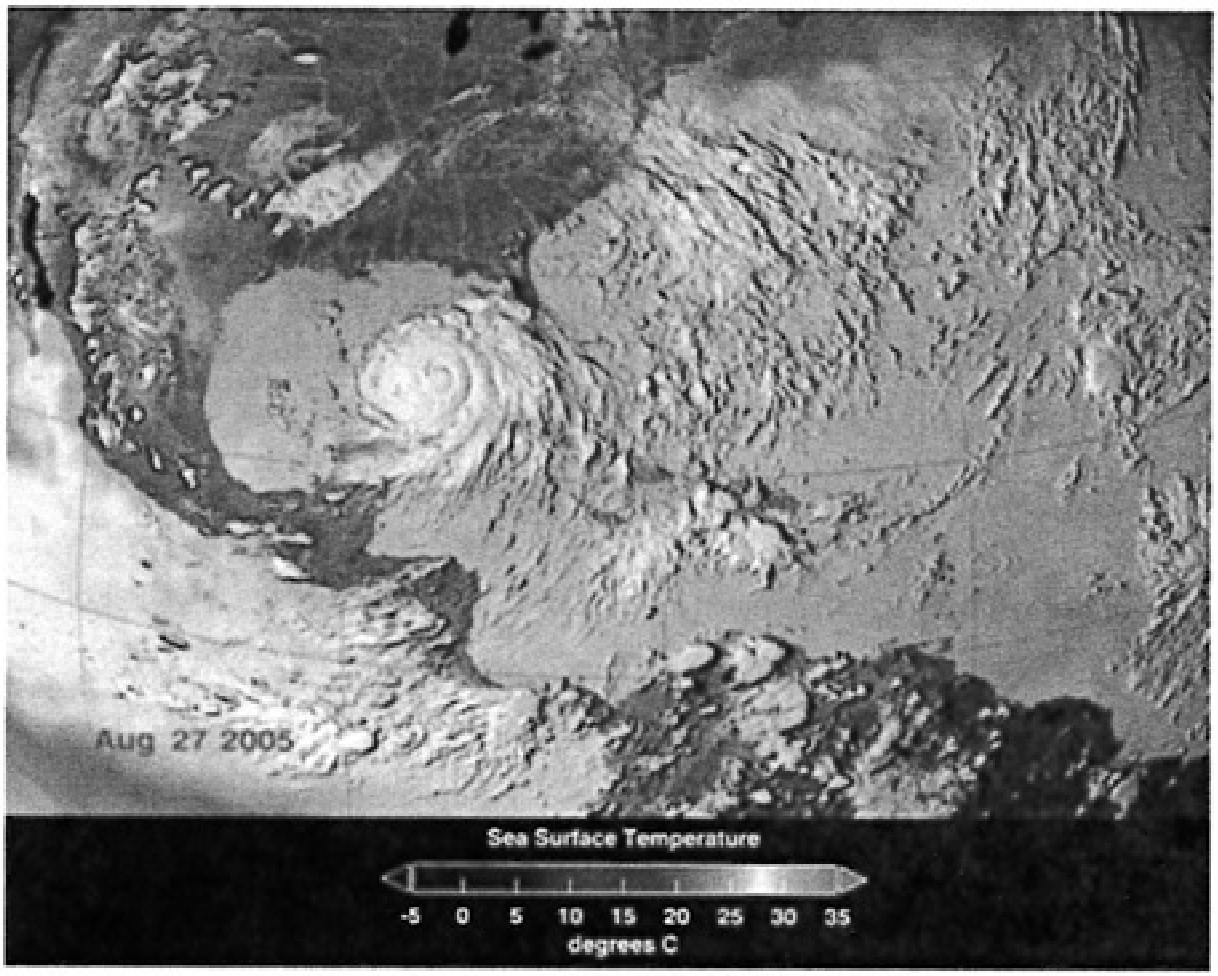
The energy that requires a hurricane to maintain its activity comes from the liberation of heat that takes place in the process of condensation of the vapor of water that it evaporates from the surface of the ocean, forming nebulosity and intense precipitation. When a hurricane enters in the continent it loses intensity quickly when stopping the process of strong evaporation from the surface. The hurricane works like a vapor machine, with hot and humid air providing its fuel. When the sunrays heat the waters of the ocean, the humid air warms; it expands and begins to rise as they make it the globes of hot air. More humid air replaces that air and that same process begins again. The rotation of the earth eventually gives it a circular movement to this system, the one that begins to rotate and to move as a gigantic spinning top. As in all hurricane, this turn is carried out in having felt clockwise in the south hemisphere and counter clockwise in the north hemisphere.

All the tropical depressions that grow deriving in hurricanes originate practically under the same conditions, and they conserve the same meteorological characteristics to the long of the life. The physical differences that can be presented from an event to other reside in the speeds that each event can reach and the time that these they can stay.

Recent studies on the formation of hurricanes point out like cause, the violent circulation of air in them and the transformation of the liberated caloric energy when it condenses the vapor of water contained in the air that ascends from the surface in a very extensive area. Such a condition implies having an appropriate provision of latent heat, and of some mechanism that trigger and maintain the upward vertical movement required to produce the condensation of the vapor, and with it the liberation of that latent heat. These requirements are satisfied when the temperature of the seawater in a specific area is as we said before, equal same or higher to 26 °C, when the distance of the same one to any coast or island is superior to 400 km, and when inside that same region, convergence associated to any perturbation exists, be tropical wave, polar watercourse, inter-tropical convergence line or area. The conditional instability is an atmospheric state that favors the formation of a hurricane in a potential region; it has been a clear relationship between the presence of the instability and the favorable months for the formation of the tropical hurricanes.

The temperature in the ocean and the high relative humidity in the stocking and low troposphere are also requirements for the development of the hurricane. Figure (see below). shows a map of the superficial temperature of the sea for the summer in the north hemisphere. The yellow, the orange, and the red colors demonstrate the temperatures of the quite hot water to sustain hurricanes.

Another necessary condition for the organization of the circulation inside the region in which ascents of air and the liberation of latent heat of vaporization take place, is that they happen in a superior latitude at 5°, since in an inferior latitude the organizing effect of coriolis (rotate of the earth) it has very low values. It is for this reason that the hurricanes are formed and are intensified when they are located on tropical or subtropical oceans in both hemispheres where the force of rotation of the earth is sufficiently strong, so that the rotation movement begins around the center of low pressure and whose temperatures of water at surface level are around 26.5° or warmer. In second Fig. it is shown the main development region for tropical cyclones is the basin bounded by 25 and 60 degrees W longitude and by 8 and 23 degrees N latitude where effects of Ocean heat content on hurricane genesis are almost constant).



Hurricane Katrina and the Sea Superficial Temperature (SST)

Depending on the rotational velocity, which extreme exceeds 165 knots (> 300 km/h), the hurricanes themselves are classified in several ways, generally based upon the vortex wind velocity and their destructive power. In 1969, the Organization of United Nations requested the evaluation of the damages generated by the passage of the hurricanes in a certain type of housings. Starting from it, the North American engineer Herber Saffir and the then director of the National Center of Hurricanes of United States, Robert Simpson, developed a mensuration scale to qualify the potential damages that it can cause a hurricane, considering the minimum pressure, the winds and the tide after its passage. This is now know as the Saffir-Simpson scale and consists of seven categories: Tropical Depression, Tropical Storm and five categories of hurricanes going from hurricanes type – 1 up to type – 5 (Table 4.2).

Control Geographic Basin, where the water surface temperature is practically constant [Perez Peraza at. al., 2011]

Independently of hurricane category, the damages they potentially may cause are more intense when their translation speed is small or almost zero, provided they stay longer time over one location.

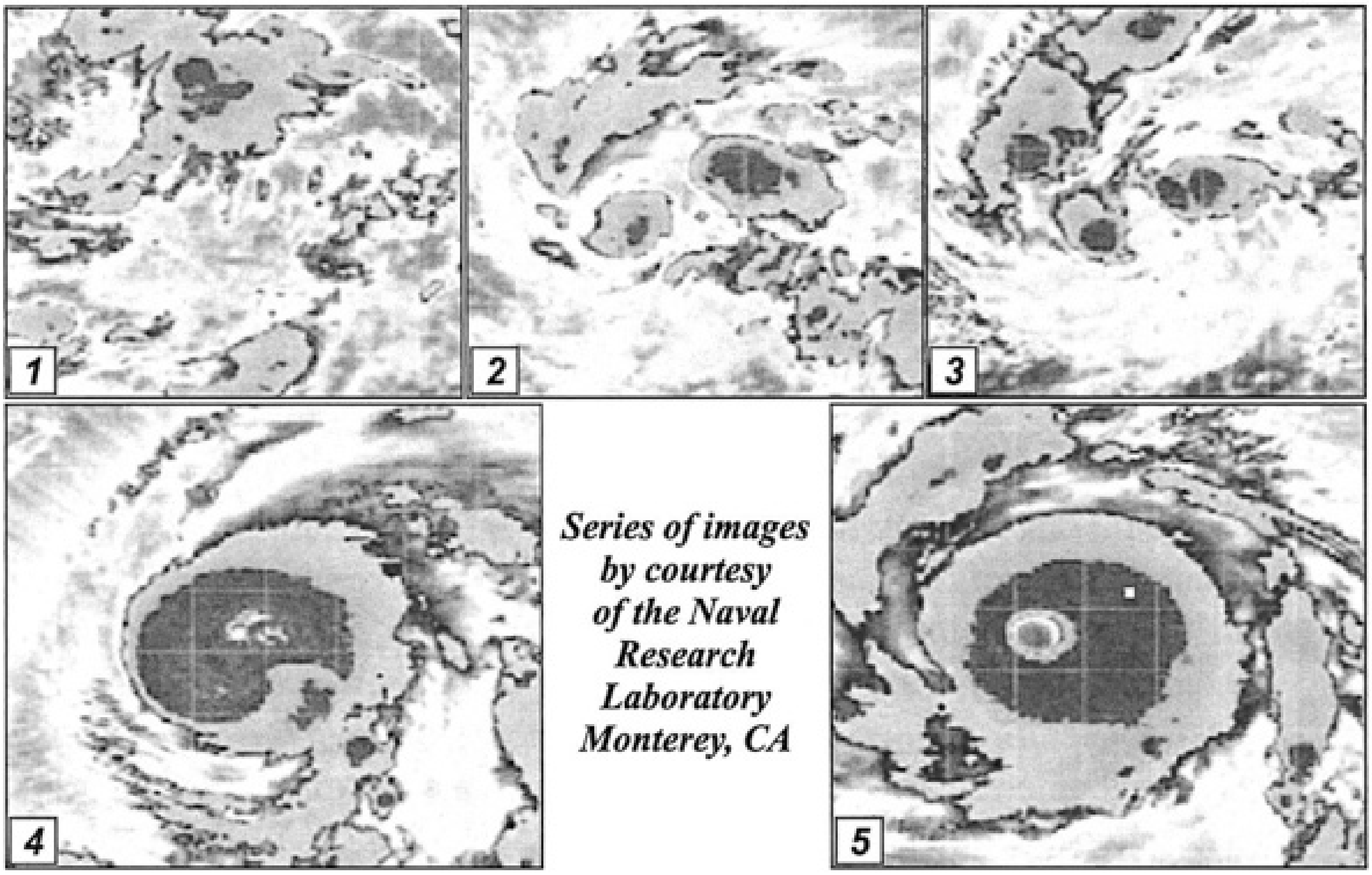
Table 4.2. Saffir-Simpson scale

MAX Rot. Range		Wind Range, km/h	Velocity Range, m/s
Storm	Knots		
TD	30 – 34	56 – 62	15 – 17
TS	35 – 64	63 – 118	18 – 32
H1	65 – 82	119 – 153	33 – 42
H2	83 – 95	154 – 177	43 – 49
H3	96 – 113	178 – 209	50 – 58
H4	114 – 135	210 – 249	59 – 69
H5	> 135	> 249	> 69

According to this scale, hurricanes evolution is as follows:

- *Birth (tropical depression):* first it is formed a peculiar atmospheric depression because the wind begins to increase in surface with a maximum speed of 62 km/h or less; the clouds begin to be organized and the pressure descends until near the 1000 hectopascales (hpa).
- *Development (tropical storm):* the tropical depression grows and it acquires the characteristic of tropical storm, what means that the wind continues increasing to a maximum speed of 63 to 117 km/h; the clouds are distributed, in hairspring form and it begins to be formed a small eye, almost always in circulate form, and the pressure decreases to less than 1000 hpa. It is in this phase when it receives a name corresponding to a list formulated by the World Meteorological Organization (Committee of Hurricanes). Formerly, each hurricane was denominated with the name of the saint of the day in that it had been formed or it had been observed. It fits to clarify that if a hurricane causes an important social and economic impact to a country, the name of that hurricane doesn't appear in the list again.
- *Maturity (hurricane):* the tropical storm is intensified and it acquires the characteristic of Hurricane, that is to say, the wind reaches the maximum of the speed, being able to reach even 370 km/h, and the cloudy area expands obtaining its maximum extension between e 500 and 900 km of diameter, producing intense precipitations. The eye of the hurricane, whose diameter varies from 24 to 40 km, is a calm area free of clouds. The intensity of the hurricane in this stage of maturity graduates by means of the scale of 1 – 5 of the Saffir-Simpson scale.
- *Dissipation (Final Phase):* The pressure in the center of the system begins to increase and the winds fall gradually accompanied by a weakening of the system. In this stage the hurricanes that penetrate to land become extra-tropical hurricanes. A central factor in the end of a hurricane is the lack of energy sustenance provided by the warm waters. Another is that when arriving to earth, the friction with the irregular surface of the land provokes cloudy expansion of the meteor and it causes its detention and dissipation in strong rains. An additional factor is that the hurricane meets with a cold current.

On figure (see below) it is shown the main development region for tropical cyclones is the basin bounded by 25 and 60 degrees W longitude and by 8 and 23 degrees N latitude where effects of Ocean heat content on hurricane genesis are almost constant) we present some images that were taken in a period of 6 days, during the stages of development of a hurricane: in photo *1* – we see a good tropical disturbance that favors a tropical depression. 12 hours later, in photo *2*, we see a tropical depression that continuous with their escalation. In photo *3*, the hurricane Floyd has been intensified in a tropical storm. In photo *4* one can already observe to Floyd like a hurricane of category – 1 and in photo *5* it is already observed as category – 4.



Series of images of the Hurricane Floyd, 1999 [Perez Peraza at. al., 2011]

Tropical cyclone intensification depends on many factors [DeMaria et al., 1999] including oceanic heat content and proximity to land, etc. The hurricanes are formed and are intensified when they are located on tropical or subtropical oceans in both hemispheres where the force of rotation of the earth (Coriolis) it is sufficiently strong so that the rotation movement begins around the center of low pressure and whose temperatures of water at level of the surface are quite warm. The main regions are not stable as for their location, since this obeys the position of the centers of maximum marine heating, those that in turn are influenced by the cold currents of California and the equatorial warm counter current in the Ocean Pacific, as well as for the drift of the ramifications of the warm current of the "Gulf Stream". Also, they do not stay for themselves on land, independently of the superficial temperature

An analysis of the trajectories of tropical hurricanes shows that there is not coastal area of Mexico that is free of the threat of the tropical depressions that arrive in many cases to the hurricane intensity. In the Gulf of Mexico and in the Pacific the coast of the country is vulnerable to the effects of the tropical storms, although their behavior in both coasts is something different. The depressions that are generated in the southeast of Mexico, specifically in the Bank of Campeche, they generally go toward the north, while those of the Caribbean travel toward the west until touching the costs of Central America, or those of the Peninsula of Yucatan. When they cross it, they vanish, but not enough to be annulled, due to the narrowness of the peninsula, so when arriving to the Gulf of Mexico they find the warm water again that reefed them, recovering their fury and continuing their devastating work.

In a study on the activity of the depressions in the North Atlantic during the first half of last century, some investigators found that more than 78 % of those happened in the Gulf of Mexico took place starting from 1932, and only 36 % has reached the hurricane force; the duration of these depressions has been of 4.4 days and that of the hurricanes of 2.2 days. The closed form of the Gulf conditions their short duration and low frequency, since the storms reach rapidly the land and then vanish. The Peninsula of Yucatan is the most affected by the depressions and, of the total previously mentioned a 46 % affected the peninsula. In the last two decades it has been increased the frequency and intensity of the hurricanes in this region; they should stand out Gilberto in September, 1988 and Mitch in October, 1998.

The season of hurricanes gives principle when the climatic equator moves in direction of the poles carrying with it high temperatures that heat the air and the seawater, giving place this way to the emergence of an area of low pressure. This generally happens between the months of May and November.

Summarizing, for a hurricane may be formed there need to be present certain elements:

- *Pressure*: witnesses or preexistence of a convergence zone in the low levels and low superficial pressure, of synoptic scale.
- *Temperature > 80° F*: At this temperature, the water of the ocean is evaporating at the required quick level so that the system is formed. It is that evaporation process and the eventual condensation of the vapor of water in form of clouds the one that liberates the energy that gives the

force to the system to generate strong winds and rain. And, since in the tropical areas the temperature it is usually high, they constantly originate the following necessary element.

- *Humidity*: As the hurricane needs the evaporation energy like fuel, there must to be quite a high humidity, which happens with more easiness on the sea, so their advance and increment in energy happen there more easily, weakening when arriving to mainland.
- *Wind*: The presence of warm wind near the surface of the sea allows there to be a lot of evaporation and that it begins to ascend without big setbacks, originating a negative pressure that crawls to the air in hairspring form toward inside and up, allowing that the evaporation process continues. In the high levels of the atmosphere the winds should be weak so that the structure stays intact and the cycle is not interrupted
- *Gyre (or Spin)*: The rotation of the earth gives a circular movement to this system, which begins to rotate and to move as a gigantic spinning top. This turn is carried out in sense contrary to that of the pointers of the clock in the north hemisphere, and in favorable sense in the south hemisphere.

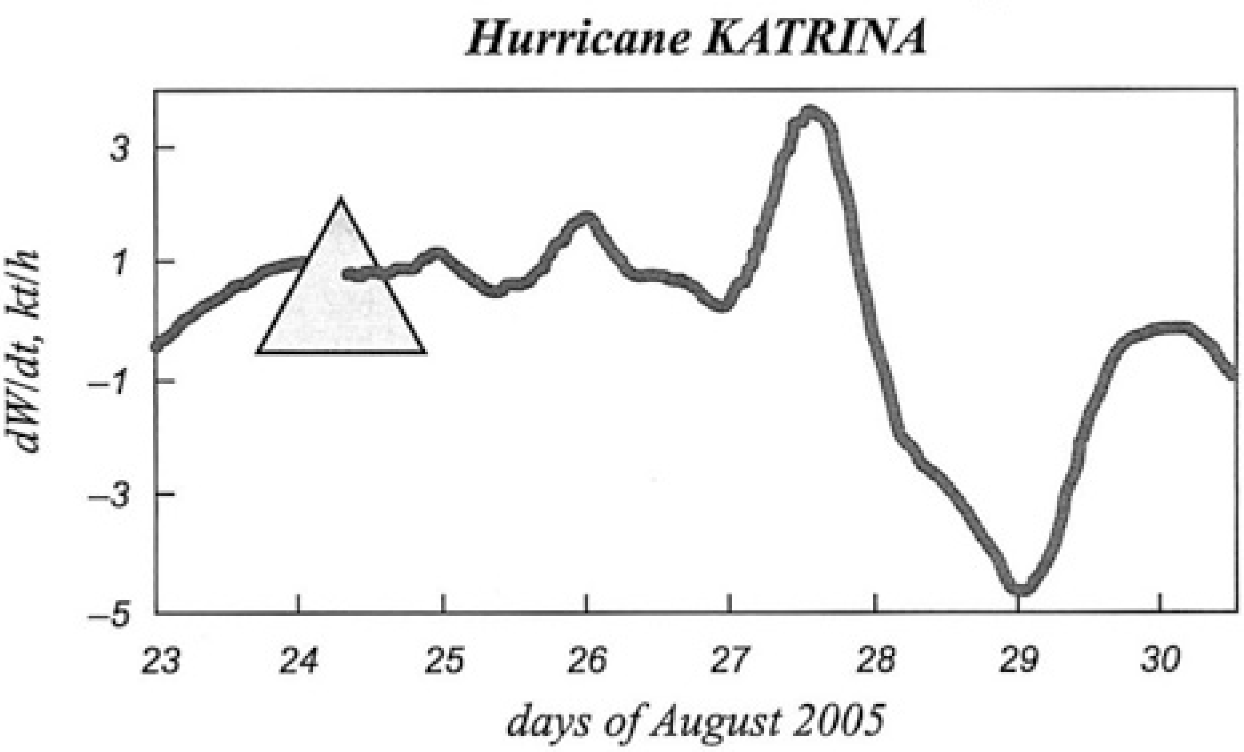
Finally it is worth mentioning that Meteorologists have records of North Atlantic hurricanes that date back into the 19th century. Over the last half-century, these records are based on a wide range of measurements including ship and land reports, upper-air balloon soundings, and aircraft reconnaissance. Lately, it was also included radar imaging and satellite photographs. The geographical position of the Eye center and the rotational velocity is measured and published every 12, and lately every 6 h.

4.2. Correlational study of North Atlantic cyclones

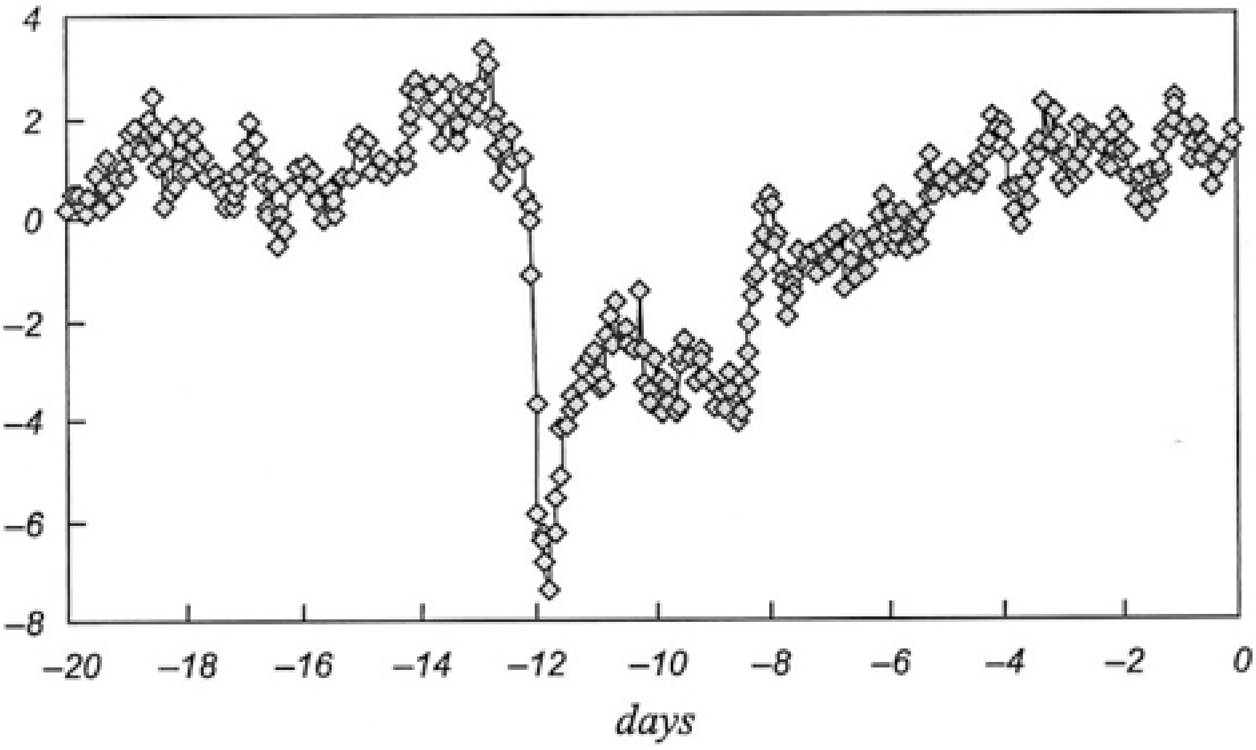
Correlational works between solar and climatic parameters give often interesting results [e.g. Chernavskaya et al., 2006]. Within this context, in a series of works [Elsner and Kavlakov, 2001; Kavlakov, 2008a, b; Pérez-Peraza et al, 2008a, b] several efforts have been addressed to find possible interconnections between the appearance and development of Atlantic hurricanes and changes in geomagnetic activity and sharp Cosmic Rays (CR) decreases, namely Forbush Events (FE), which in turn are well known to be related to Solar Activity changes (SS index). The authors tried to examine the eventual connection of CR, SS, A_p and K_p changes with the processes developing in the atmosphere, far before the formation of North Atlantic hurricanes.

Their main hypothesis is that any specific changes of the collateral parameters during the days, preceding the cyclone appearance could be used as an indicative precursor for an approaching hurricane event. In order to reveal any possibility for immediate (not delayed) relationship between them, it was used simultaneous data to find statistical dependencies between the specific sharp changes in the geomagnetic field and cosmic rays intensity and the corresponding values of the hurricane intensification. Their efforts were especially concentrated not only in North Atlantic hurricanes, but in particular those which struck the East Coast of Mexico. All such hurricanes, recorded in the period 1950 – 2007 were analyzed.

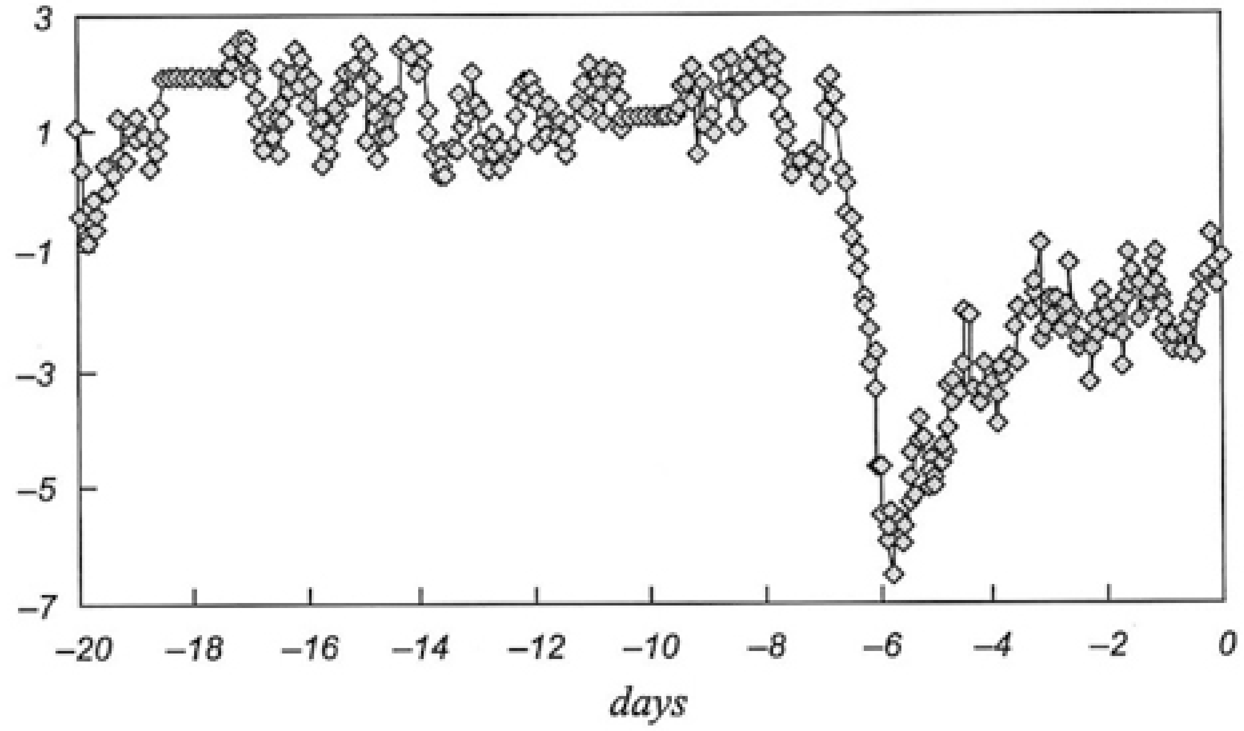
In order to reveal any possibility for immediate (not delayed) relationship between hurricanes and cosmo-geophysical parameters it was used simultaneous data to find statistical dependencies between the specific sharp changes in the geomagnetic field and cosmic rays intensity and the corresponding values of the hurricane intensification: for instance, investigating the daily intensification of KATRINA, it has been noticed that a strong geomagnetic change (through changes in K_p and A_p indexes), was recorded 5 days before its maximum value (see below). From the other side, some repeatedly observed coincidences between the Hurricane appearances and preceding sharp Cosmic Rays (CR) decreases, namely Forbush Events (FE) (as for example Hurricane ABBY 1960 and CELIA 1970 (see below) suggested a possibility for closer relationship between the Forbush Effects (FE) and hurricane intensification.



A strong Geomagnetic Disturbances (shown with a triangle) was recorded 5 days before the maximum intensification



A Forbush Event (7.6 %) 12 days before the start of hurricane ABBY 1960



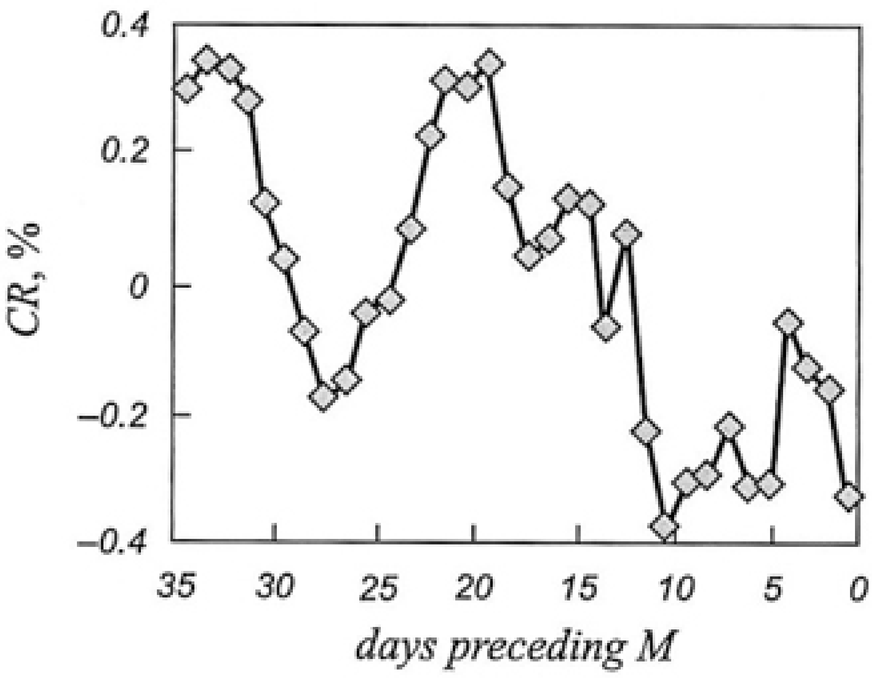
A Forbush Event (6.57 %) 6 days before the start of hurricane CELIA 1970

These facts provoked the interest of the previously mentioned authors for a detailed study of such collateral phenomena and their statistical comparison with hurricane phenomena. Within that context they were looking for signatures of coadjutant hurricane forecasting to conventional meteorological models, well before the period at which those models usually produce their predictions: it had been analyzed the behavior of the (CR) intensity, Sunspots (SS) and geomagnetic indexes (A_p) and (K_p) in long intervals preceding the development of the North Atlantic Cyclones, that means, before the first observations of the just born cyclonical system. Two approaches have been done to attack the problem.

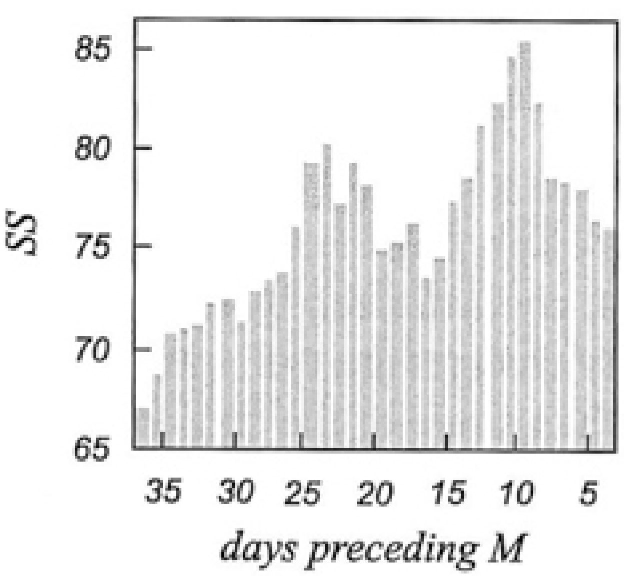
4.2.1. Parametrization of hurricane activity in terms their intensity (maximum rotational velocity)

In Elsner and Kavlakov (2001) variations in geomagnetic activity in the magnetosphere have been statistically linked to hurricane intensity over the North Atlantic. Based on daily hurricane intensity, a positive correlation between the averaged K_p index of global geomagnetic activity and hurricane intensity as measured by maximum sustained wind speed was identified. Later [Kavlakov 2005], analyzed all "major hurricanes" (categories – 3, 4, 5), that is, with a maximum rotational velocity over 95 knots (170 km/h), during the period 1954 – 1999. To avoid any overlapping influences over the investigated parameters, spread in front of the hurricanes, only those, with a time separation between them exceeding 35 days were selected. Only 39 hurricanes were found period filling those conditions, in that 45 years. Cosmic Ray intensity data was taken from 14 Neutron Monitors CR stations encircling the Atlantic Ocean and situated in Europe, North and South America, characterized by their continuity and stability. The general trend of CR intensity changes are well inter-correlated for all nearby stations. During the periods when some of the stations were not working, a corresponding statistical weighting of the data was applied. The full set of daily sunspot numbers was obtained from the website of the National Geophysical Data Center in Boulder, Colorado, USA. The AP and K_p indices which describe the status of the geomagnetic field, were taken from the website of GeoForschungs Zentrum, Potsdam, Germany, as a sum of the 8 absolute 3-hourly values each day over the same 45 year period.

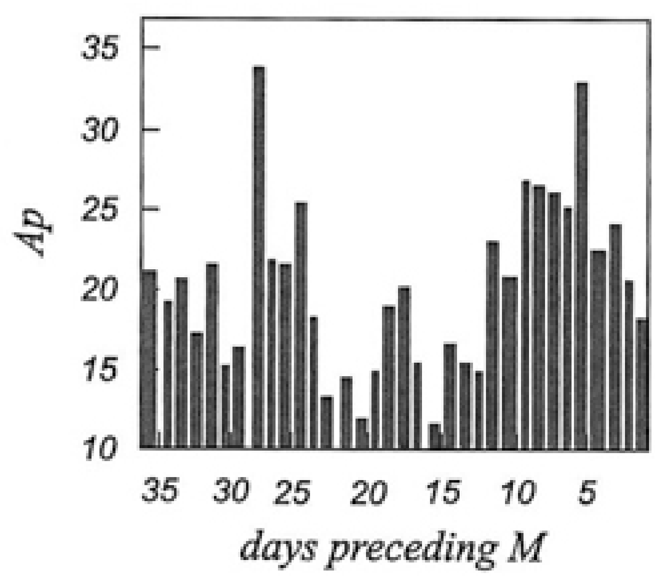
From the whole data set for CR intensity, SS number, A_p and K_p indices, it was extracted only those, included in the 34-day intervals, preceding the day when every one of the examined hurricanes reaches its maximum rotational velocity, namely the *M*-day in that work. Data was overlapped and averaged them separately for all these variables. Results based on daily hurricane intensity are summarized in the next three figures. Changes of the CR in the intervals of 34 days before the *M*-day are depicted in Fig. 8: the statistical error is in the limits of the size of the points. Two figs. (see below) show the changes of the SS and AP indices (K_p index follows sensibly the same trend than the A_p one).



Changes of CR intensity preceding the *M*-day [Perez Peraza at. al., 2011]



Values of the SS index preceding the *M*-day



Values of the A_p preceding the *M*-day

The obtained results show that specific changes in the solar activity, CR intensity and geomagnetic field precede the appearance of these major North Atlantic Hurricanes. It can be seen from previous figs. of this chapter, that there is a change of intensity of the FE-type just 8 – 12 days before the time of hurricane maximum intensity. The corresponding amplitude of these changes is often well noticeable even in the case of separate individual events. SS and A_p indexes show an out of normal trend around 8 – 12 days before the *M*-day. In particular it is found that that 2 – 3 days before and after the maximum K_p values, the hurricane intensification is much higher than the average.

It is important to emphasize that these changes are persistently accompanying the days preceding the major hurricane maximum intensity. The existence of stable pre-cursors for the chosen types of hurricanes, exceeding Category – 2 has been evidenced in that work: The obtained specific changes of these parameters should be taken in consideration, when complicated processes in the upper atmosphere are used to determine the hurricane formation. Potentially, that should contribute to hurricane development forecasts.

The combination of the special changes of SS and A_p with a Forbush decrease of the global CR intensity, as shown for example on previous fig. must raise the attention to the places, where generally hurricanes are born. That is especially true for the summer period, when such simultaneous changes could be taken as an early indication for elevated probability of a major hurricane formation. Of course, the basic observations of all meteorological parameters should be taken in consideration first.

4.2.2. Parametrization of hurricane activity in terms of their intensification

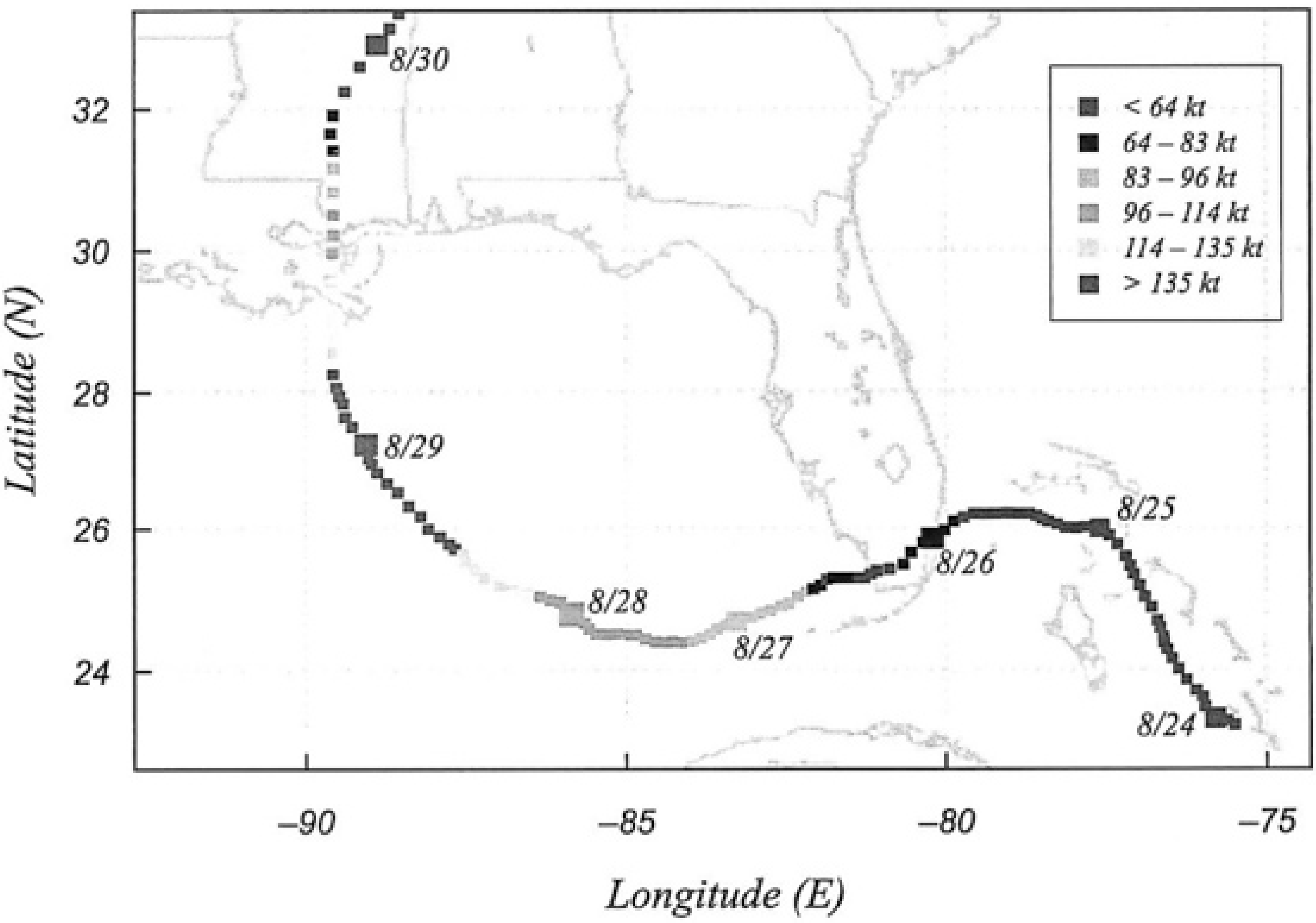
First derivative of the rotational velocity, assuming that changes in the rotational speed reflects any energy impute in hurricane dynamics. [Kavlakov et al 2008a, b, c].

The earlier work described in the previous section is expanded by focusing on hourly intensification rates rather than daily hurricane intensity. Results appear to be more general in that there is no need to separate the tropical cyclones by category. Intensification (or intensification rate) is the change of intensity with time. The terms "intensifying" and "deepening" refer to positive intensification while the terms "decaying" and "filling" are used for negative intensification.

Here, the interest is the study of hurricane intensification rates around the time of a major geomagnetic disturbance and whether there is, on average, a statistically higher rate during these disturbances; the K_p index is widely used in ionospheric and magnetospheric studies and is recognized as measuring the magnitude of worldwide geomagnetic activity. The same goal is pursuit with sharp CR decreases (FE).

The authors considered the maximum wind speed (intensity) for all tropical cyclones (hurricanes and tropical storms) over the North Atlantic, which includes the Atlantic Ocean, Gulf of Mexico, and the Caribbean Sea, during the period 1951 – 2005. The data are derived from the Huricane Data base (HURDAT or best-track) [Neumann et al., 1999] maintained by the National Hurricane Center (NHC). HURDAT consistings of 6-hourly positions and intensities.

The 6-hourly values were converted to 1-hourly values using cubic spline interpolation. As an example, fig. (see below) shows the 1-hr position and intensity for Hurricane Katrina in 2005.



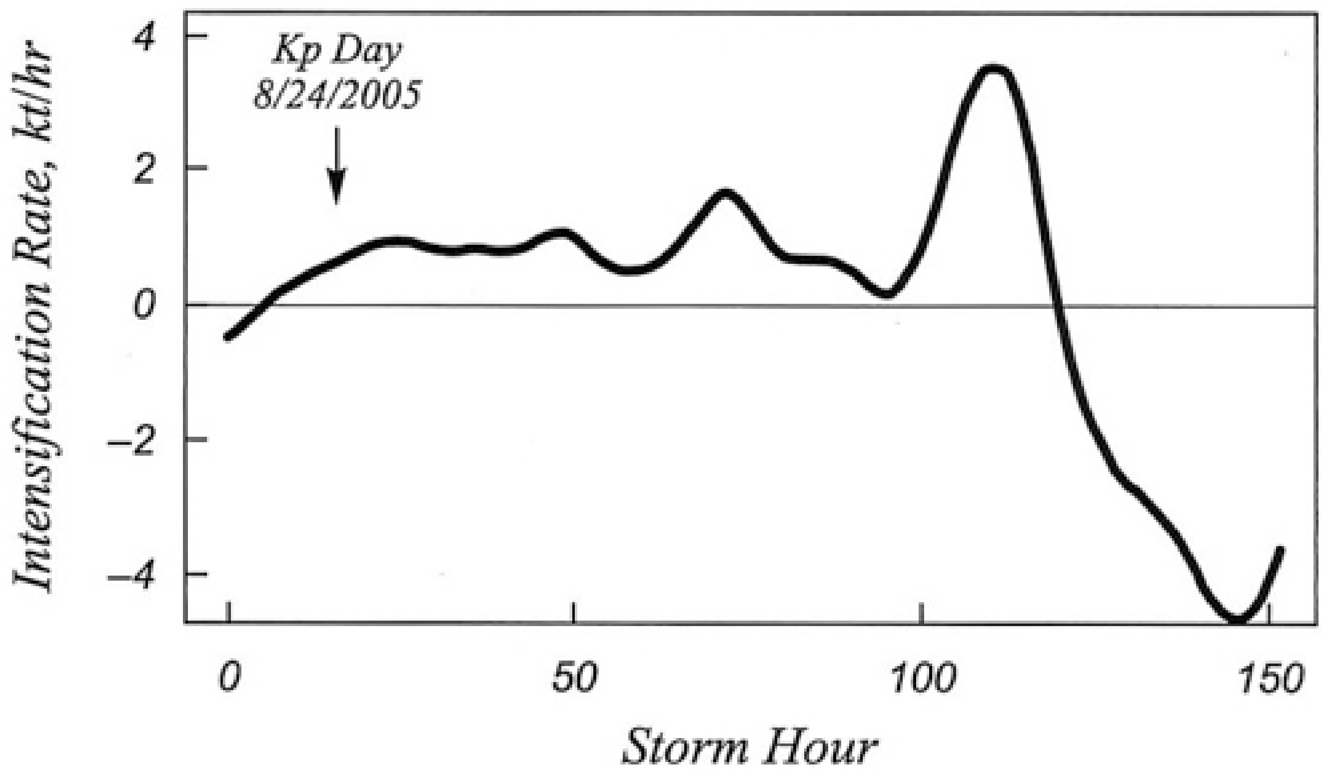
Track of Hurricane Katrina. The positions are every hour (interpolated from the mostly 3 hr reports) beginning at 2100 UTC on August 23rd over the southern Bahamas. Color denotes storm intensity as indicated by the maximum sustained wind speed (kt). The date (month/day) is shown at the 0000 UTC time

Tropical cyclone intensification is a time derivative quantity. While it was tempting to use a simple finite difference procedure to approximate the derivative, the order of the error on this approximation procedure is commensurate with the derivative value. Then, the hourly intensification rate was estimated from an asymmetric 6-point (3 left, 2 right) 3-degree Savitzky-Golay first derivative filter [Savitsky and Golay, 1964] that reduces the error. Hourly intensification rates are obtained for all tropical cyclones (hurricanes and tropical storms) for a total of 105,638 hours over the period 1951 – 2005. Below fig. shows a time series plot of the hourly intensification for Hurricane Katrina.

In the work described above [Kavlakov 2005] it was investigated the behavior of K_p and some other parameters *before the start day of the hurricane.*

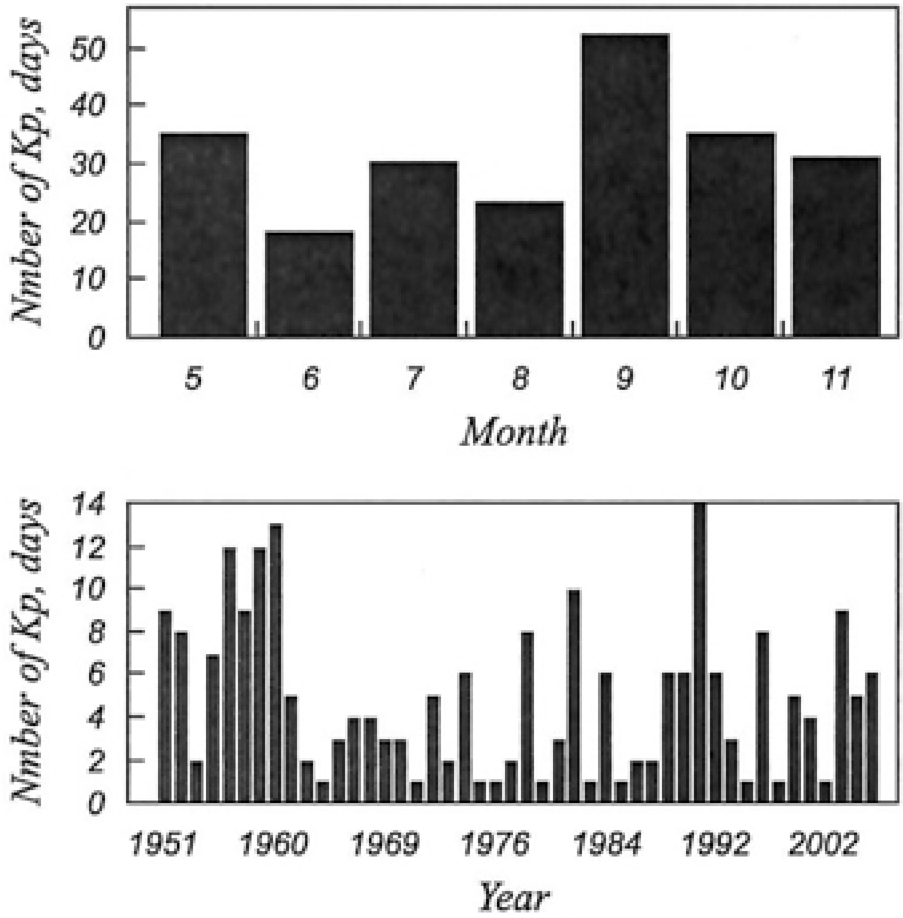
In subsequent works [Kavlakov et al 2008 a,b,c] the basic position was re-arranged: it was taken as "0" days, not the day when a hurricane starts, but the opposite – the day with a high K_p peak, and so, they registered all the hurricane activities around it.

Data of K_p were obtained from the U.S. National Oceanic and Atmospheric Administration (NOAA) web-site. Interest is on days surrounding a K_p maximum event (called here a K_p day). A K_p day is defined as one in which the daily K_p index exceeds 420, or more than 70 % above the long-term average. In this way we identify 224 K_p days during the hurricane season months of May through November over the period 1951 – 2005, overlapping active storm hours.

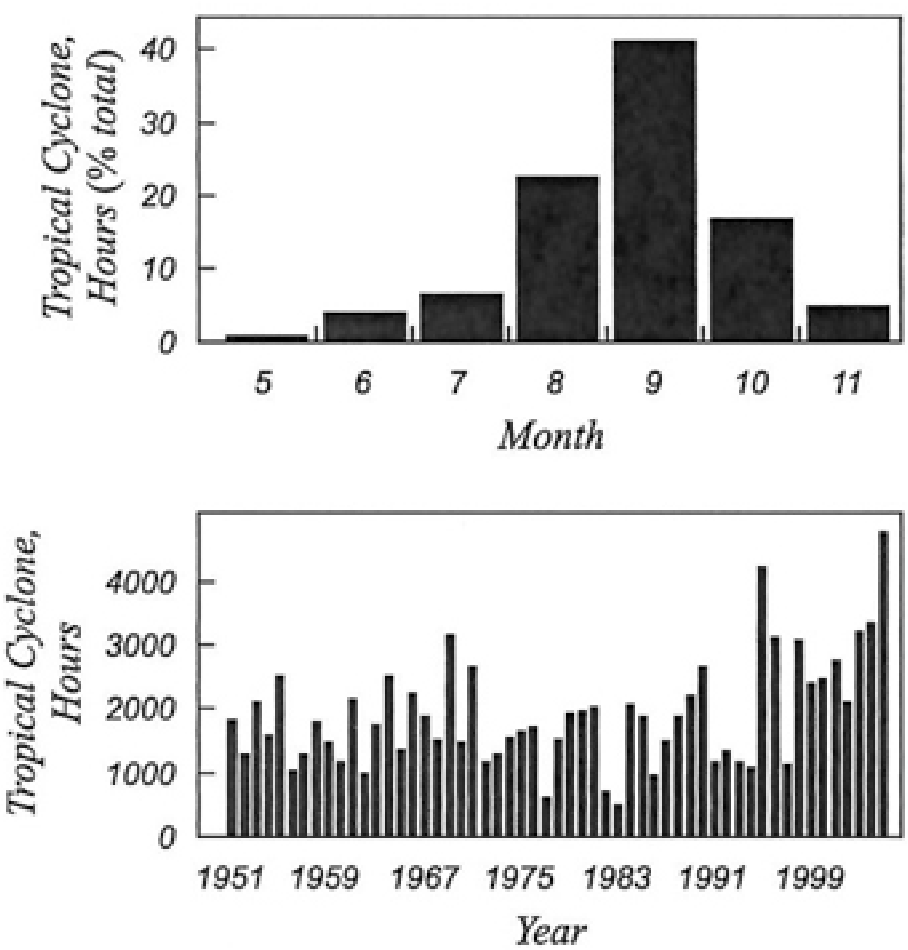


Intensification rate for Hurricane Katrina. The intensification rate in kt/hr is given every hour for the lifetime of the tropical cyclone until it passes north of 33 degrees N latitude. The arrow locates a K_p day. The location is 0900 UTC on 8/24/2005 when the K_p index reached a value of 8.7 steps. [Perez Peraza at. al., 2011]

The monthly distribution of K_p days (see below fig.) showing how many of the 224 K_p days fall in each of the months is fairly uniform with a maximum during September and a minimum in June (for example, 35 occurred during the month of May and 9 occurred in 1951). The annual distribution shows the well-known 22-year solar cycle. There is no significant long period trend in these counts. In contrast, the hurricane season is strongly peaked around the month of September and there is an increasing trend over time in the number of tropical cyclone hours (Fig.).



Distribution of K_p days by month and year. A K_p day is defined as one in which the daily K_p index exceeds 420. By this definition there are a total of 224 K_p days in the period 1951 – 2005 [Perez Peraza at. al., 2011]



Tropical cyclone hours. The monthly distribution and annual counts of tropical cyclone hours for the North Atlantic over the period 1951 – 2005 [Perez Peraza at. al., 2011]

4.2.3. Cyclone Intensification around K_p "0" days (days of $K_{p\,max}$)

We statistically analyze the relationship between geomagnetic disturbances and hurricane intensification by *averaging intensification rates over 5 days centered on the K_p* day and comparing this mean intensification with the overall average intensification. From all 105,638 hours of tropical cyclone activity, the mean intensification rate is +0.0342 kt/hr which equals 4.1 kt over any 5-day period. This compares with a mean intensification rate of +0.0713 kt/hr or 8.56 kt over the 5-day period based on 10,995 hours of intensification (108 separate tropical cyclones) plus and minus 2 days of the K_p day. We note larger intensification rates surrounding the K_p day, on average, for tropical cyclones weaker and stronger than hurricane intensity (64 kt). Results are shown on Table 4.3.

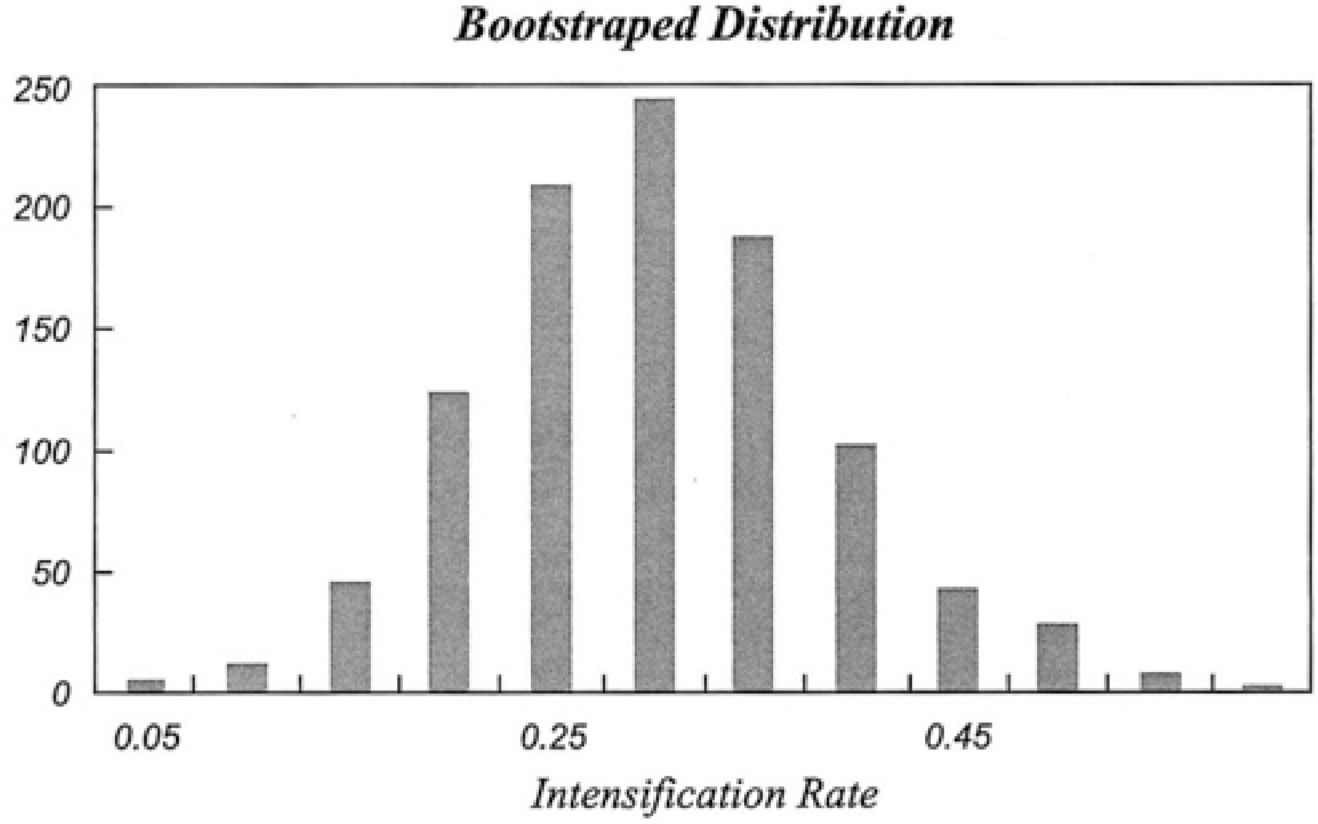
Table 4.3

	"0" days	Cyclones		Average dW/dt, kts/hour	Average dW/dt, kts/5 days
		n	hours		
Over whole Atlantic region					
All		603	105638	0.0342 ± 0.006	4.10 ± 0.07
$K_{p\,max}$	224	108	10995	0.0713 ± 0.008	8.56 ± 1.02
FE	166	96	7691	0.0546 ± 0.0095	6.5 ± 1.1
Only over hot waters					
All		131	17579	0.313 ± 0.04	37.6 ± 1.9
$K_{p\,max}$	224	26	2230	0.543 ± 0.12	65.1 ± 14.4
FE	166	25	2104	0.363 ± 0.216	43.6 ± 25.9

To test the significance of these differences we randomly assign days as K_p days and compare the mean intensification rate (bootstrapped rate) over the 5 days centered on these random dates. We repeat this procedure many times (200 – 1000) and count the number of bootstrapped rates that exceed +0.0713 kt/hr. The number of times the rate is exceeded divided by the total number of bootstrapped rates is the *p*-value. We find a *p*-value of 0.12 for all cyclones, 0.13 for weak cyclones, and 0.10 for strong cyclones. The obtained number distribution is shown on Figure.

We note larger intensification rates surrounding the K_p day, on average, for tropical cyclones weaker and stronger than hurricane intensity of 64 kt.

While suggestive, the results are inconclusive regarding the relationship between geomagnetic disturbances and hurricane intensification.

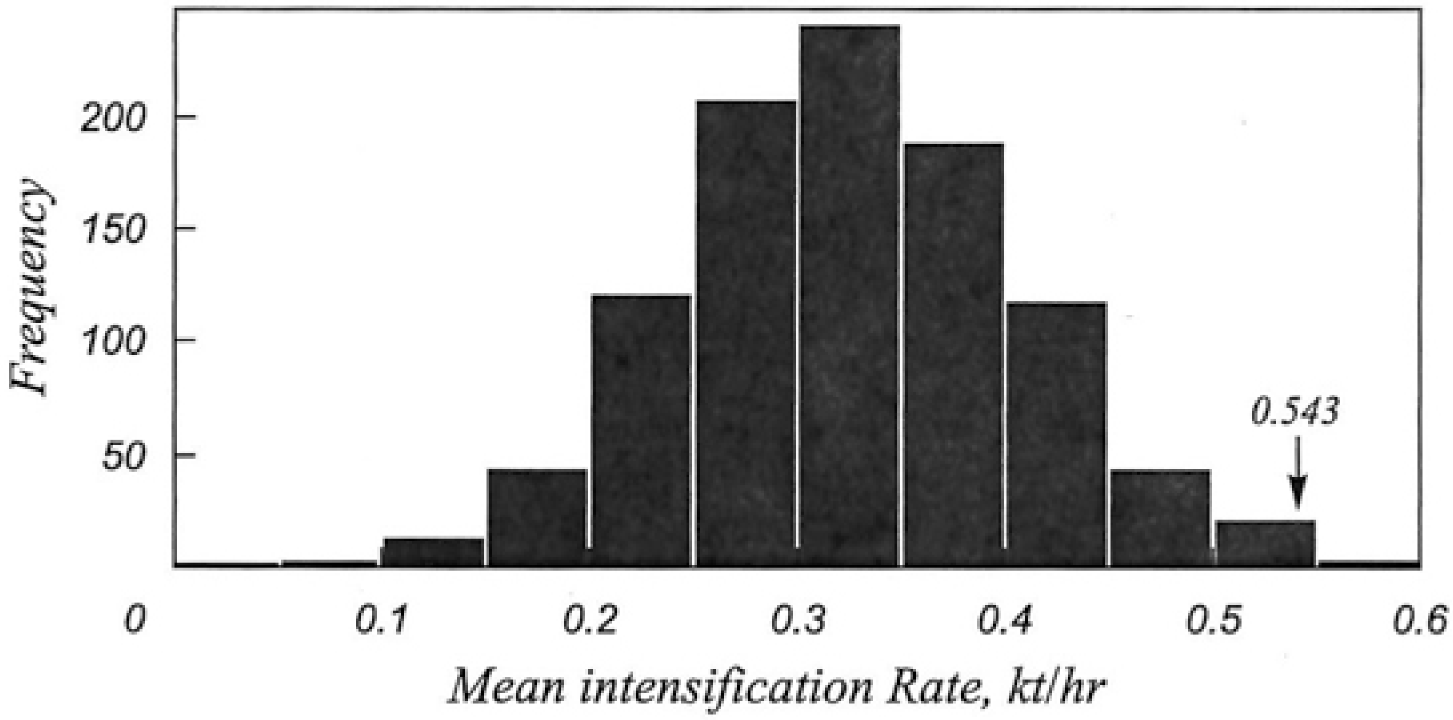


Distribution of "bootstrapped" rates [Perez Peraza at. al., 2011]

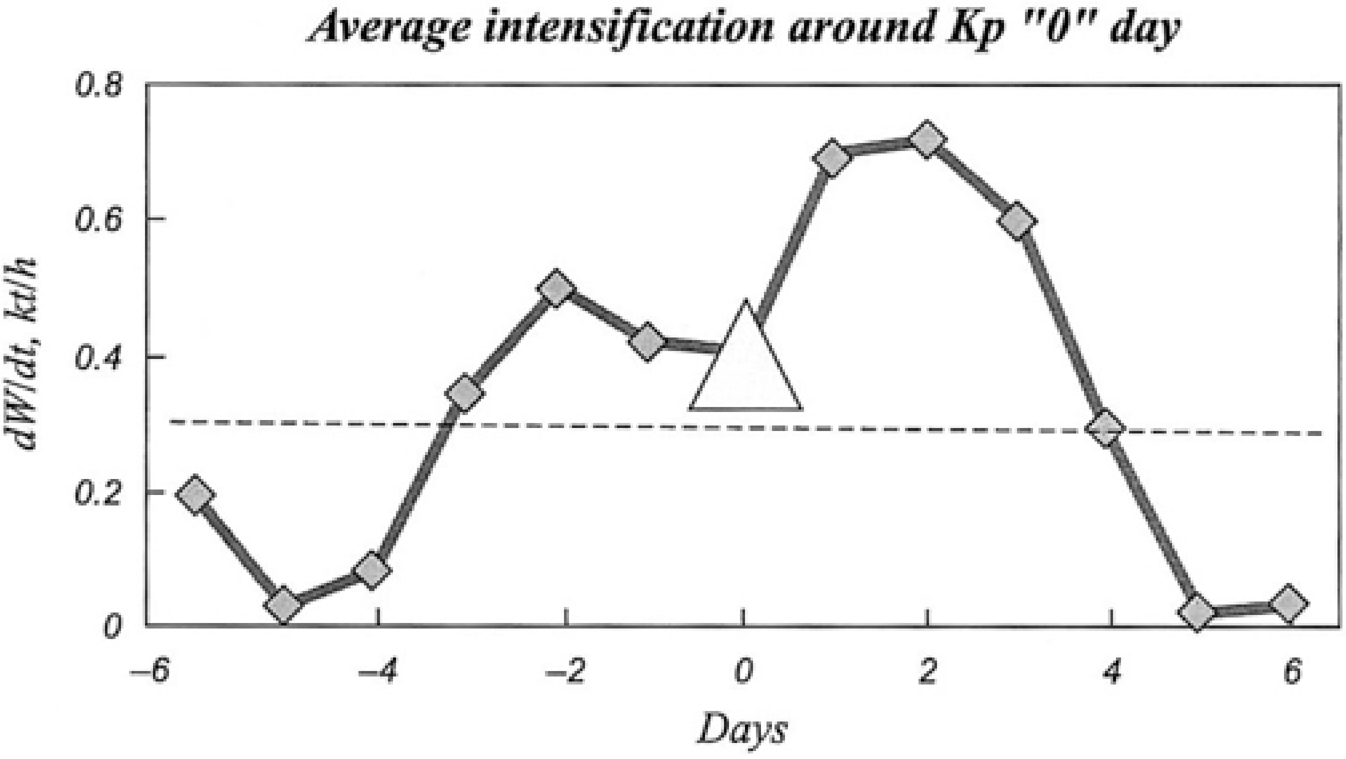
Tropical cyclone intensification depends on many factors [DeMaria and Kaplan, 1999] including oceanic heat content and proximity to land. These factors will confound our ability to identify a significant geomagnetic signal in the data. In order to provide some control, authors repeated the previous analysis using only cyclones confined to the open waters of the tropical Atlantic. In this way we consider only storm hours far from land over a fairly uniformly warm part of the basin. The chosen control region is part of the main development region for tropical cyclones and is bounded by 25 and 60 degrees W longitude and by 8 and 23 degrees N latitude (Fig., see below). In this way it is controlled for effects of sea-surface temperature on hurricane genesis and for ocean heat content.

In contrast to the 105,638 hours of the whole basin, within the control region there are only 17,579 cyclone hours over the 55-year period. As expected the mean intensification rate is considerably higher at 0.313 kt/hr (37.6 kt/5 days). The mean intensification for the 5 days centered on a K_p day is 0.543 kt/hr (65.1 kt/5 days). This is based on 26 separate tropical cyclones, including Tropical Cyclone Dog in 1952 and Tropical Cyclone Iris in 2001. We repeat the bootstrap procedure as described above for determining the statistical significance.

Below (see Fig.) shows the histogram of mean intensification rates for 1000 bootstrapped rates. The actual rate is noted with an arrow. The *p*-value is 0.007 indicating a significant increase in intensification around K_p days relative to the average. Similar results are noted for tropical cyclones greater than and tropical cyclones less than 64 kt., although the significance is more pronounced for the weaker cyclones.



Histogram of bootstrapped intensification rates over the control region. The mean intensification rate ± 2 days of the K_p day is 0.543 kt/day, which is greater than all but 7 of the 1000 bootstrapped rates [Perez Peraza at. al., 2011]



Lag plot of mean intensification around K_p "0" day. The triangle indicates the position of the K_p "0" day. The influence of the geomagnetic disturbance appears most pronounced over a 7-day period centered on the K_p day [Perez Peraza at. al., 2011]

The 2-day window surrounding the K_p day is arbitrary, so we also consider the mean hurricane intensification for storms before, during, and after the K_p day. Figure shows the mean intensification rate as a function of lag time from the K_p "0" day. We note that the effect appears most pronounced for lags from –3 to +3 days, with a peak at + 2 days.

Summarizing, it was found in the analyzed work that, intensification is related with the geomagnetic disturbances mainly in the North Atlantic higher latitudes. It is understandable why the K_p effect is less pronounced over the regions with overheated surface water, where more of the cyclones are born (Table 4.3). There, the dominant factor is the energy extracted of the water surface. That reduces all other accompanying factors participating in the cyclone formation. Over the whole basin, where generally the primary creating and supporting effect of water surface temperature is reduced, these other factors became more active.

What must be kept in mind from this work is that it was found that 2 – 3 days before and after the maximum K_p values, the hurricane intensification is much higher than the average.

It probably will not be long
Till old green world is tethered
When greedy yellow sands will come
From young and flaming desert.
They'll cover seas and oceans
Paris and Rome and Athens
We shall believe in divan stars
Half wide tribes on our camels.
When the alien spaceships appear and pass
Over gorgeous golden green cover
They will register our planet at last
By the name "Terra Sahara".

Nikolay Gumilev "Sahara",
autumn – winter 1918

5. ESTIMATION OF RISKS AND ADVANTAGES CONDITIONED BY GLOBAL CLIMATIC CHANGES

5.1. Risks for the humanity existence

Existing risks are various and conditioned by various factors which characterize peculiarities of certain types of activity and specific traits of vagueness in conditions of which this activity is realized. These factors are called risk formation factors. This term means essence of processes and phenomena which promote appearance of this or that risk and determine its character.

Nowadays researchers` basic attempts are directed to specification of a list of risk formation factors for certain risk types and to working out techniques for estimation of influence of these factors on dynamics of corresponding risks.

For example, climatic risks and factors influencing them are practically not researched in Russia. In the same time, according to American specialists` researches, in the USA climatic risks exert substantial influence on industrial production which costs up to one trillion dollars (from seven trillion which are the yearly gross product of the USA).

In the work [Makhov, 2007] four types of strategic risks for the nearest 50-100 years which the humanity as a whole and Russia in particular meet nowadays are regarded.

Residents in Key West, Florida, fleeing Hurricane Georges on 26 September 1998. Georges claimed the lives of 4000 people across the Caribbean, caused economic damages of J6.3 billion (second highest natural catastrophe loss of the year) and insured losses of J2.1 billion (largest of the year). (Image used with permission of Associated Press.) [Saunders, 2009]

1. Cosmic risks. It means danger of the Earth collision with other cosmic bodies – meteors, asteroids, comets. (They are different in size, contents, physical peculiarities and velocities).

Meteors are stone and iron bodies, fragments of larger bodies – comets and asteroids. They are several tens of meters in diameter. Facing the Earth the energy free itself arousing an explosion, and a crater which is several times larger than a meteor diameter appears on the collision place.

Asteroids are small planet-like bodies of the solar system. The most famous asteroid, which size was 10 km in diameter fell down 65 million years ago in the region of the Yucatan Peninsula. According to one of the hypotheses, this collision was the reason of extinction of dinosaurs.

Comets are cosmic bodies which consist of a solid core, gaseous head and tail. The core is tens of kilometers in diameter (Comet Halley was 14×7 km), a head can be several hundreds of thousands of kilometers size across, a tail length can reach several hundreds of millions of kilometers.

Collisions with cosmic bodies can lead to disasters of different scales. In a result of a global disaster (a meteorite of 1 km in diameter is enough) a stroke will annihilate everything within a radius of 1000 km of the impact point, conflagrations will cover wide territories, a great deal of ash and dust will be emitted to the atmosphere, and then it will precipitate during several years. Solar rays will not be able to penetrate to the Earth surface, and a sudden cooling will destroy many species of plants and animals, photosynthesis will be stopped. The Earth magnetic field will also be disturbed, dynamic of tectonic processes will change, volcanic activity will increase.

Organization of measures to prevent a threat of collision with cosmic bodies includes two stages [Mikisha, 1999]

a. monitoring of objects (searching and identification of cosmic objects);
b. neutralization of dangerous objects with a help of the whole system (deviation of a threatening object from an orbit of meeting with the Earth, screening the Earth from collision with a threatening object and, at least, annihilating of an threatening object).

2. Resource risks. These are risks connected with depletion and exhaustion of natural resources and with environmental pollution. When regarding these risks it is convenient to divide resources to the following types [Mikisha, 1999]

- fuel and energy resources (oil, coal, natural gas, nuclear energy, hydro energy, solar energy, wind energy);
- raw material resources (metals, minerals, alloys);
- natural resources connected with environment (land, water, forest, bio-resources).

3. Demographic risks. These are mainly risks connected with today` s global demographic transition, a process of transition from the state of high indicators of birth and death rates to the state of low coefficients of birth and death rates.

4. Climatic risks. These are risks connected with climatic changes and studied in this book. They are, first of all, extreme natural phenomena (climatic and weather abnormalities) and also risks connected with change of yearly average global temperature – a problem of global warming.

As it was shown in the last chapters, there are two basic approaches to researching the Earth climate.

The first approach is empirical, statistical. It means that on the basis of data about past climatic changes an attempt is taken to restore the planet climate history in the past and predict these changes in future. The basic methods here are the following

a. geological methods of stratigraphy (radiocarbon analysis of fossilization, rocks, glaciers, organic residues), paleotemperature methods;
b. historical evidences (data records, chronicles, archeological finds)
c. direct instrumental observations and estimations (building up of statistic prognostic models).

Satellite image of winter storm Thalia hitting northwest Europe on 21 January 1995. Windspeeds of up to 160 km h^{-1} were recorded. Thalia was the first of four cyclones to bombard the region between 21Jan uary and 2 February 1995. This led to the heaviest rainfall in France in 150 years, 250 000 people being evacuated in The Netherlands, and severe flooding on the Rhine and Mosel. The catastrophe left 37 people dead, and cost J600 million in insured losses and J1.9 billion in economic losses. (Image courtesy of DLR, the German Aerospace Research Establishment.) [Saunders, 2009]

The second approach is theoretical. It is connected with building of mathematical climate models. There are three basic groups of natural climate formation factors; in correspondence with them it is possible to structure the model types.

Frame 6 from the film "Flood" / Flood / (2007)

Heliophysical and astrophysical factors are conditioned by influence of other Solar system bodies on the Earth – solar luminosity, solar activity, gravitational influence, tilt of the Earth axis to the orbit plane, As these factors are fundamental among mechanisms responsible for climate formation, they are taken into account in all climate models (at least, in majority of models) in this or that degree.

Geophysical factors are connected with peculiarities of the Earth as a planet – form, size and mass of the Earth, velocity of its rotation round the axis, gravitational and magnetic fields, structure and inner processes (including tectonic activity), inner warmth resources (and a geothermal warmth flux and volcanism determined by them), the atmosphere contents. These factors are studied separately, as a rule, with separate methods, but accounted in climate models as parameters.

Circulation factors are connected with processes inside the system consisting of the atmosphere, hydrosphere (ocean and glaciers), lithosphere (land) and biosphere – redistribution of energy and substance inside the system. It is considered that just circulation factors are responsible for appearance and frequency of extreme natural phenomena.

Flooding in Moscow November 7, 1824 in the square near the Bolshoi Theater
(the artist Fedor Alekseev)

For reliable estimations common circulation models are used, as a rule – two- and three-dimensional models for the atmosphere, ocean and their joint system. The class of such models is the most multiple, as besides the climate, they are used for meteorological forecasts (weather forecast).

These models use equations of hydro thermodynamics describing transfer of energy and mass in the atmosphere and in the ocean, or movement of air and water masses participating in energy redistribution. Solutions of such equations are unstable locally – small disturbances of different nature (imprecision of initial conditions, inner and outer noise impact, etc.) grow in time or in space very quickly and, at least, make a long-term forecast inconsistent.

In models of the ocean circulation besides hydro thermodynamic equations the equations describing state and change of sea ice (crystallization, melting) are used. A role of the ocean in climatic changes is high because of its inertness which is larger than that of the atmosphere; that is why during research of slow processes from several years to several decades the ocean process modeling is of a great importance.

Because of a great number of factors it is impossible to build up a general climate model today. That is why all existed models account only a part of factors, all the rest are just parameters or not regarded at all. It tells on results of modeling and forecasts made with a help of such models. And it is necessary to consider here that a role of some factors, processes and interactions is not fully studied yet, a lot of processes cannot subject to adequate generally-accepted explanation, and some phenomena and interdependences are hidden from observers.

Every year a number of new observations and factors grow, but vagueness is kept and even grows, as climatic models are very sensible to small changes.

It makes a problem of prediction of natural processes more complicated, because *the climate is a complex nonlinear self-organizing system changing from time to time*. Similar systems usually demonstrate an unstable character, which predetermines the existence of unpredictability horizon which subjects to expansion with a big difficulty. All these condition limitedness of theoretical physical climate models and the results received with their help.

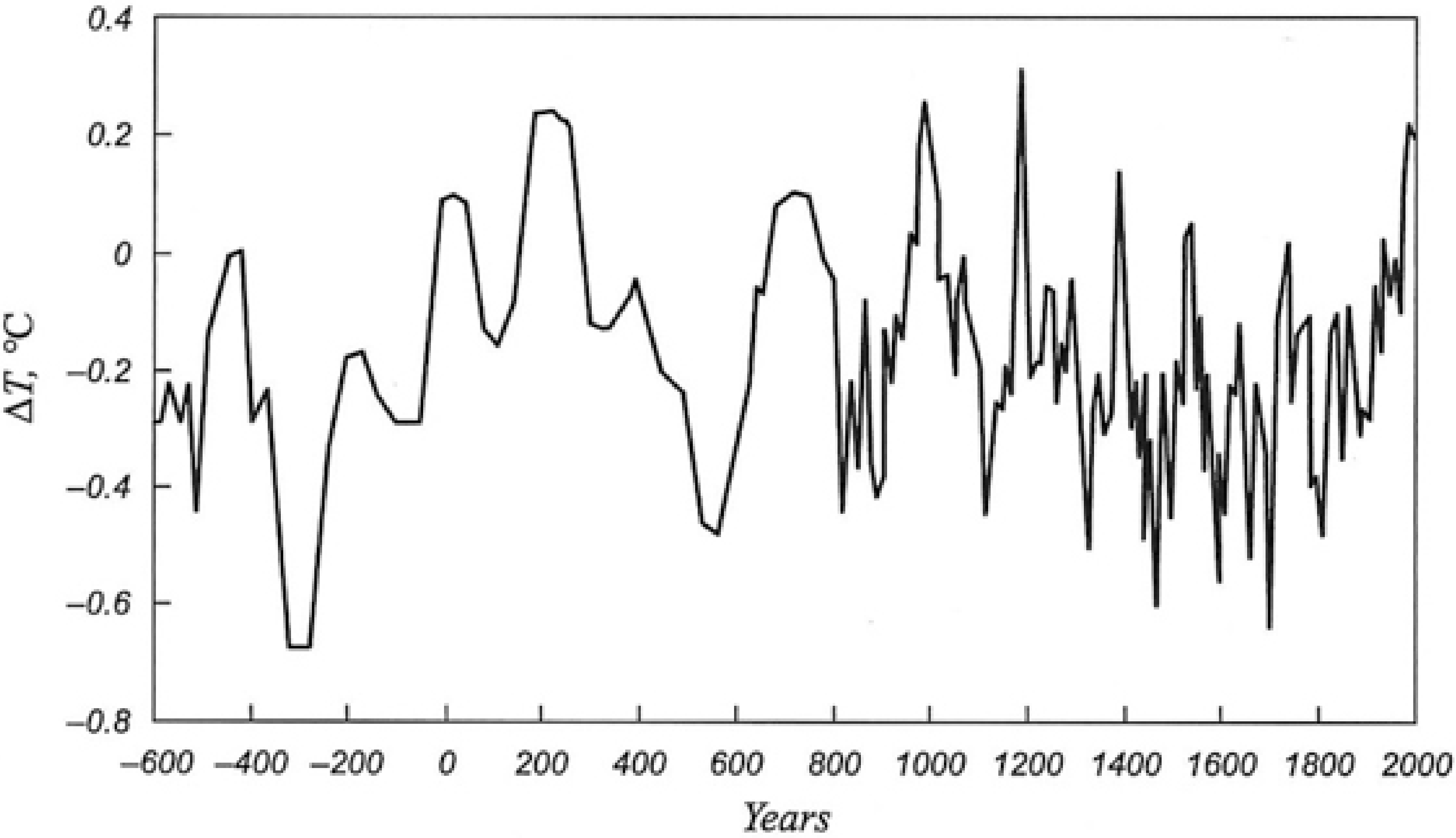
5.2. Risks and advantages connected with global warming

The figure (see below) shows a detailed picture of temperature fluctuations over the last 2.5 thousand years. Which at this time were the main climatic events? Firstly, it is an unusual cold, the time has historically coincides with the time of early antiquity. Other outstanding climatic events are warming the Roman period. Then again, a significant cooling of the Great Migrations.

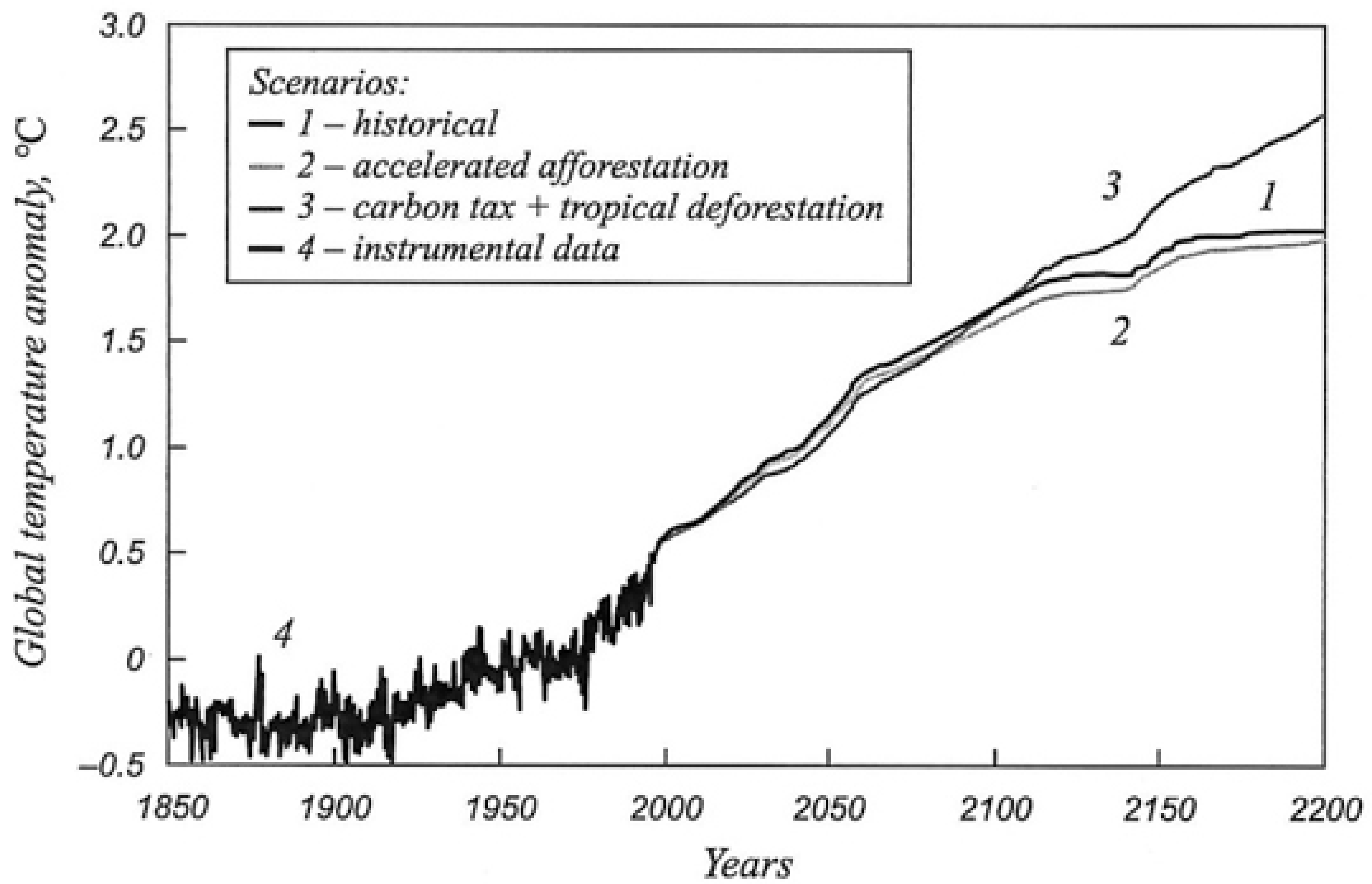
Finally, the peak at the turn 1 and 2 millennia – Medieval Climatic Optimum. He gained fame, in particular through development of the Normans in Greenland.

Then he showed a clear trend to a decrease in temperature. The coldest periods were noted in the XV and at the end of the XVII century. It must be said that the July 28, 1601 in Moscow went on a sleigh. Summer frosts were repeated for three consecutive years, as a result, Russia came the monstrous crop failures. Even more difficult period came in the late XVII century.

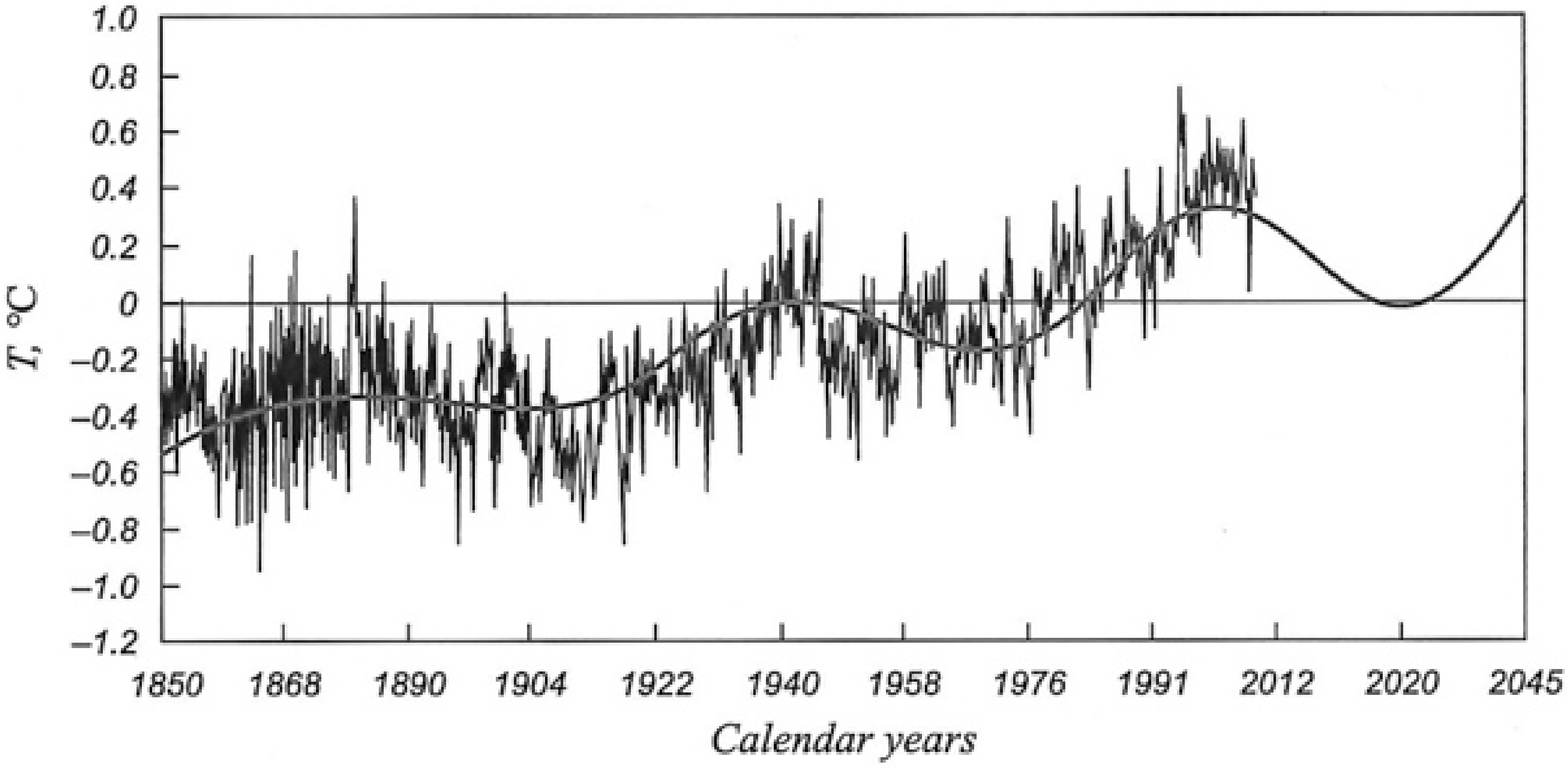
Past 10 years, the XVII century – the coldest in the last few thousand years. The population of Finland, Estonia, Livonia, northwestern Russia, Scotland, Denmark, Northern Germany during this time reduced by 30 – 40 %. Then the temperature was gradually increased.



History of climate in the last 2.5 thousand years [Klimenki, 2009]



History and projections of global temperature anomaly (relative to 1951 – 1980) and forecasts various scientists until 2200 [Klimenki, 2009]



The best-fit single sine wave along a linear trend.
[http://www.appinsys.com/GlobalWarming/GW_TemperatureProjections.htm]

Leitens, Geisberht "Little Ice Age"

Have you ever seen such a Holland?
Pieter Breugel, "Hunters in the Snow"

Raising the temperature from the end of XIX century until the present time – is 0.5 – 0.6 °C. True, it depends on what period in which to compare. If we talk about the temperature of the last five years, it's a 0.8 °C, because the last five years was very warm. If we compare the value of twenty years, it will be really 0.6 – 0.7 °C. It is important that the entire planet awaits warming.

Total, for the last 150 years a positive trend of rising of the Earth yearly average temperature has been observed, by today it has arisen by 0.8 ± 0.2 °C.

Scientists have several points of view in what way yearly average temperature will behave in future, among which there are two basic ones:

- Temperature will continue to rise, at least, up to 2100.
- Temperature will have stopped rising by the middle of the 21st century, after this moment it will drop.

This opinion discrepancy is connected with an absence of a stable position about the reasons of the warming; arguments and debates take place. A part of researchers think that warming is connected with an impact of human activity, other say about natural reasons, the third insist on necessity to consider both – natural and anthropogenic influences.

Existing methods do not permit to reveal a reason of warming with a high precision degree. It seems that the main constituent of yearly average temperature rise is natural, it is responsible for 70 – 90 % of temperature rise value, and anthropogenic activity can be responsible for 10 – 20 % with 10 – 20 % errors and vagueness [Libin, 2009].

Debates about consequences of warming for the Earth as a whole and for the humanity in particular are even more furious. Opinions are antipodal – from utmost pessimistic to neutral and even optimistic ones.

It is understandable – economical and political interests of countries and private groups are often behind these positions. And it is not simple to clear up what researches of warming problems are objective and which ones are ordered.

That is why, first of all, we will try to separate those possible consequences which are practically not argued [Malkov, 2005, Makhov, 2007]:

- melting of sea ice and retreatment of continental glaciers,
- rise of the World Ocean level on account of glacier melting and heat penetration of the upper ocean layer,
- possible latitude drifts of climatic zones,
- more intensified warming of the land and, as a result, more intensified heat penetration of soil.

These are direct results of warming, and it is not clear yet in what way they will influence a human being and his economic activity or what will be ecological and economical consequences.

As it is noted in Makhov` s work [Makhov, 2007], besides negative consequences, reports of Intergovernmental Panel on Climate Change (IPCC) consider positive ones including consequences for separate regions. (If we understand right, climatic models of common circulations, radiation models and biological models were used in these researches).

In IPCC reports the forecast and analysis of possible risks for the nearest century up to 2100 are given. It is considered that yearly average temperature of the Earth surface will arise by 1 – 4 °C, and the ocean level will become 15 – 95 sm higher by the end of 21st century.

Risks and possible consequences for a human being.

1. Influence on ecosystems:

a. change of geographical locations of ecosystems and biocenoses (latitude drift to the North);
b. change of species composition of plants and animals (in a result of conflagration, diseases, plant pests increase);

c. possible change of bioproductivity – productivity of some plants and animals will fall, that of other ones will arise;
d. changes of soil and land characteristics (bog reclamation, salinization, over wetting erosion, desertification, congelation melting).

2. Influence on hydrology and water resources:

a. growth of drought number in arid zones can arouse water deficit;
b. frequent floods in the middle and moist zones will lead to sinking of territories and infrastructure destructions;
c. rise of the ocean level will lead to flooding of some territories (shelves, small islands, coastal zones).

3. Influence on agriculture:

a. quantity growth of insects-pests and agent of diseases will lead to drop of productivity of some crop types;
b. rise of carbon dioxide concentration can lead to rise of productivity of some crop types and to drop of productivity of other crop types.

4. Influence on a human health:

a. growth of number of inflectional diseases (fever, malaria, cholera, plague);
b. thermal load;
c. intensity of air pollution.

5. Social and economical consequences:

a. removal of negative consequences will demand expenses;
b. migrations from regions with unfavorable climatic changes to more favorable regions are possible;
c. warming in the middle and cold territories will permit to economize energy on domestic heating;
d. retreat of Arctic ices will give a possibility to research the Arctic and open new trade routes (the North seaway);
e. damage from losses of some tourist zones is possible.

6. Political consequences:

a. some states will be in a more advantageous position than others, changes in alignment of forces can take place;
b. struggle for territories and resources can be intensified.

All these consequences have a conditional and probabilistic character – they reflect only one of possible scenarios of development of events, the real situation can be better and worse as well. In a certain sense this scenario will permit to estimate a scale of possible changes in connection with climatic oscillations and gives us an idea about the position of some international scientific organization on this question.

G.D. Oleynik, a chairman of the Committee of the Federation Council for the North and small ethnic communities, said in his speech on the First World Summit of regional governments devoted to problems of the climate changes (Sant-Malou, France, October, 29 – 30, 2008),

«The climatic changes are worldwide independent on reasons arousing them. They result in necessity of international cooperation of these forces and mechanism which makes the country to take corresponding measures in the framework of such cooperation, especially in northern regions…

Dynamics, scales and character of the climatic changes and their consequences for economy are different with substantial vagueness conditioned by stochasticity of natural phenomena themselves, their interaction with economic and social systems as well as by discrepancy of economic effects of global warming. The climatic changes can be favorable for some territories and, on the contrary, unfavorable for others; and this situation can change to the opposite one in course of time or according to other scenarios.

So, solving a problem of smoothing the climatic changes demands working out some special national strategy of stable economical development of northern regions, oriented to life improving (in a wide sense of the word) which should be a source of means and mechanism of economic complex and population adaptation to the climate changes and reducing risks of such changes».

5.3. Possible reasons of global warming connected with solar activity variations

It is necessary to say that we began to talk about global warming after the first estimations of surface temperature behavior in the high latitudes and solar activity [Libin, 1995].

Within a year 15 trillion kilojoules of solar energy reach the Earth. Solar radiation is partially absorbed and reflected by the atmosphere. In a result, about 5.000 kilocalories (20.000 kilojoules) energy covers each square kilometer of the Earth surface, 30 % of this energy is reflected to the cosmos. The rest energy determines meteorological processes.

If to be exact, solar energy (solar rays) is absorbed not by the atmosphere, but mainly by the ocean and land. Warming of the Earth surface arouses convection – ascending warm air is replaced by descending cool air. During vapor condensation cloudiness appears in ascending air.

Because of rotation of the planet the Corioli forces act on moving air. They twist ascending air counterclockwise forming cyclones and descending air (anticyclones) is twisted clockwise in the Northern hemisphere. In the Southern hemisphere rotation directions are opposite. Convection covers the whole Earth` s troposphere, and on its upper border a part of heat energy goes to the cosmos as infrared radiation with maximum on millimeter wave lengths.

The height on which the atmosphere becomes transparent for heat radiation (thickness of the troposphere) changes from 4 km near poles to 12 km near the equator. Exact values depend on moisture (vapor concentration), and also on contents of other gases absorbing infrared radiation, first of all, carbon dioxide and methane.

A vertical energy flux existing everywhere is added by a slower transmission of warmth from tropics to poles, as the planet luminosity by solar rays is maximal at the equator. It changes each year regularly in each latitude of the planet. It is followed by the weather change.

Weather is determined by many parameters (pressure and air moisture, velocity and direction of a wind, cloudiness), but a surface temperature is the most important among them. It is measured reliably all over the planet for more than a century.

An average temperature (based on many-year data) for each season is a rather stable climate characteristic. Yearly change of an average temperature is one month delay in phase from a luminosity sinusoid as a result of thermal inertia of the ocean and land.

Then, diverting our attention away from these regular seasonal temperature changes we have analyzed the character of their abnormalities or weather fluctuations of temperature relative to its climatic average.

Statistical processing of temperature variations resulted in a lot of surprises what our multiple works tell about; the basic ones are given in this book.

Analysis of 380-year variations of solar activity, temperature and CO_2 made by the authors leads to a tendency that these three processes are situated on a brunch of 400-year variation growth, maybe it is global warming!

Scientists of Pulkovo astronomic observatory accentuate the importance of this problem; they also consider that solar activity influence on a series of events including global weather and climate variations is a proved fact.

The term cosmic weather which has been used during last decades characterizes the whole complex of external (relative to the Earth) geoeffective factors the basic of which are solar magnetic field variations and grandiose phenomena aroused by these changes.

Fluxes of high energy particles appearing during solar flares and coronal mass emissions can destroy radio communication, hamper radio navigation, lead to power supply failures and damage equipment of cosmic apparatuses in a short-term aspect. Besides, these fluxes are dangerous for cosmonauts and air travelers, the manager of the observatory said.

Solar activity modulates a flux of galactic cosmic rays which influences cloud formation of the Earth and its reflectance to an energy flux coming from the Sun and can arouse long-term trends of the Earth climate which lead sometimes to great weather abnormalities.

Timely watch and prediction of solar activity changes and terrestrial phenomena aroused by it permit to reduce economical risks and to work out an optimal strategy for prevention of natural disasters.

That is why the project of Constant Cosmic Solar Patrol (PKSP) worked out in the Roscosmos is very important and will have been realized on the basis of orbit satellites in the framework of the Federal Cosmic Program by 2015. The constant cosmic solar patrol has to provide monitoring of solar ionizing radiation changes in a soft X-ray and utmost ultraviolet spectrum sphere.

And there is one more note. Today there is an opinion among reputable geologists that a level of the World Ocean periodically became lower or higher, in a result of which water covered large parts of continents, except mountains, or ebbed again.

Such global floods are called a thalassocratic phase of the Earth development (from Greek thalassa means sea, kratos means power). Such last flood is considered to have happened about 100 million years ago during the epoch of dinosaurs.

Offlap of that time with characteristic fossil organisms discovered in the inland regions proves that North America (from the Gulf of Mexico to the Arctic) was flooded by the sea. Africa was divided into two parts by a shallow strait crossing the Sahara. So, each continent was shortened to a large archipelago size.

A curious book Our Future under the editorship of Ms Gro Harlem Brundtland, the Prime-Minister of Norway of that time, was published in the middle of the 80s.

The authors of the articles, famous scientists, predicted that in the beginning of the 21st century because of global warming about half of glaciers of the Antarctic and Greenland would melt and the risen ocean would flood several tens of world ports and coastal fertile or industrial low places and several great rivers would overflow the banks…

So, what is it? The next disaster?

What real threats should we expect for from global warming (even repeating periodically, we do not feel better about it)?

5.4. The climate changes and national security of Russian Federation

V.M. Katsov, B.M. Meleshko and S.S. Chicherin, the leading Russian scientists, write in their report The Climate Variations and National Security of Russian Federation, «Global warming makes up a situation for Russian Federation (RF) (with account of its geographical position, peculiarities of economic potential, population problems and geopolitical influence) when it is necessary to be aware of national interests relative to the climate variations and threats to national security connected with that and also to work out corresponding home and foreign policy.

Neglecting the problem of global climate variations, inactivity justified by references to insufficient study is unreasonable and can lead to serious risks for stable development and security of the country».

One of the bright examples of transformation of scientific problems to political ones is the Arctic which is of great interest for RF and other countries including those situated outside the Arctic.

During last decades rather quick changes of the Arctic climate are observed (more variations are expected in the 21st century, see more detailed information below). These variations can radically aggravate existing or give birth to new intergovernmental problems connected with search and production of energy resources, use of transport seaways and bioresources, delimitation of continental shelf, environment, applying of maritime law, etc. and become a factor of maritime activity destabilization in this region [Katsov, 2007].

A univocal estimation of consequences of expected warming for RF (profitable or not, as a whole) is impossible with account of interaction of different factors on its huge territory. Meanwhile, in N. Stern` s report [Stern, 2006] the author says that 2 – 3 °C warming will be a favorable factor for Canada, RF and Scandinavia situated in the high latitudes, due to intensity of crop capacity, reduction of death rate from low temperatures, shortening of heating period and, possibly, growth of tourism.

It is necessary to make all-round analysis of possibilities and resources of adaptation of the country to the climate variations, to consider existing results of home or foreign researches and to stop discussing if global warming exist or not, at least, at a state level.

During the last decades substantial climate changes connected with global warming is really observed on the Earth. Global climate change conditions growth of quantity and scale of natural disasters, exerts substantial impact on life conditions of population and does great harm to national security on the territory of Russia.

It is enough to say that natural disasters occurring on the Earth during the last decade have done more than 800 billion dollars harm and more than billion 200 million people appeared to be their victims.

With account of a world-wide character of the problem of global climate change, only during this year it has been twice discussed at the highest political level on the General Assembly UNO in February, 2008, and on the summit of the European Community in Brussels in March, 2008.

It was accentuated that global climate change can lead to geostrategic variations, appearing of new economical interests connected with struggle for access and control of energy resources in connection with possible improvement of access to hydrogen resources in the Arctic and growth of possibility of serious potential conflicts on this basis.

The observed global warming on the planet makes up a situation for Russia when it is necessary to estimate results of possible non-anthropogenic (and, possibly, anthropogenic as well) disasters and to work out programs of complex security of the territory and population of Russia considering these phenomena.

It is established by instrumental observations that in the 20th century and in the beginning of the 21st century temperature on the Russian territory grew so fast as never before for 200 thousand years – a yearly average temperature which was at the mark ~15 °C during many thousands of years has arisen by more than 1 °C since 1900 including 0.5 – 0.6 °C only for the last 10 years.

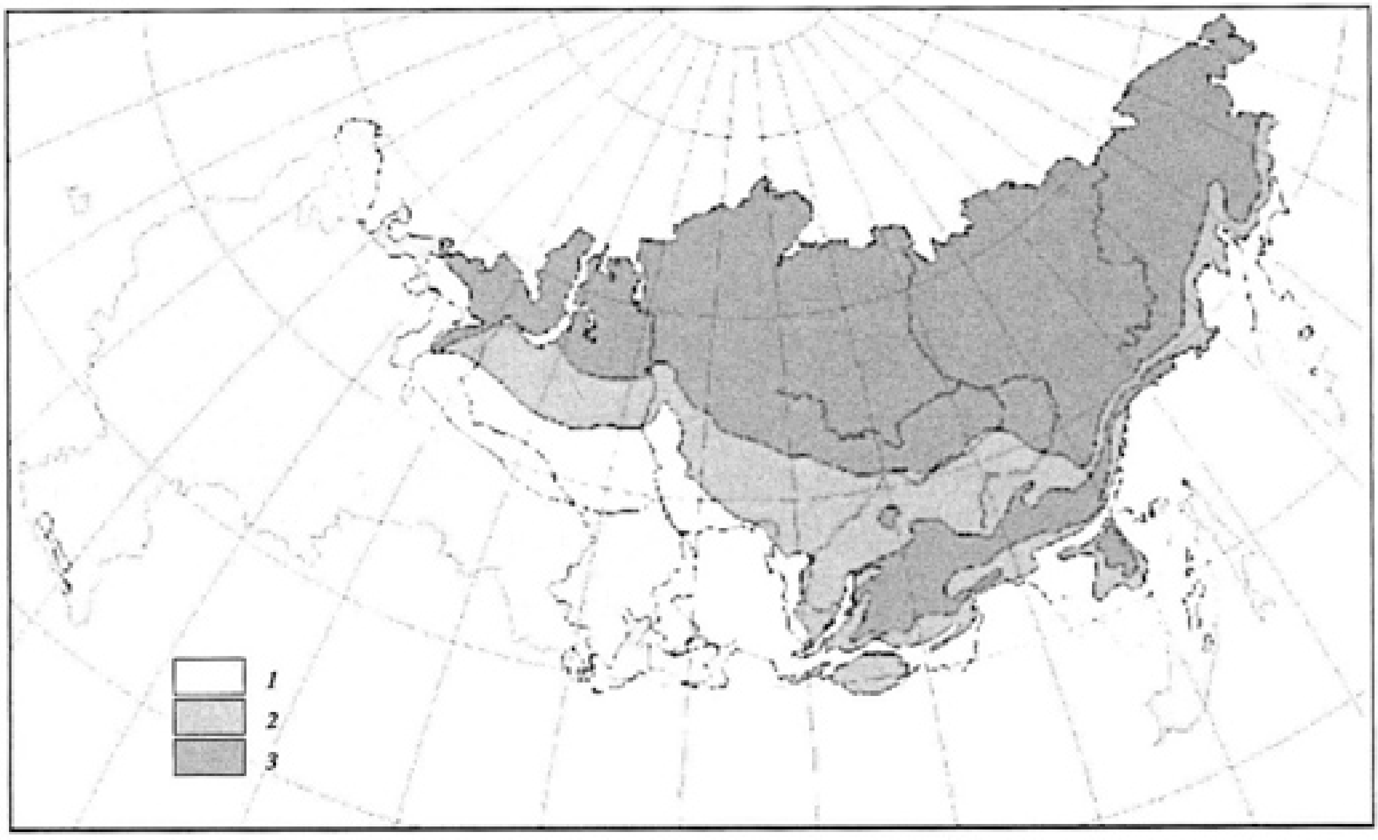
(It is necessary to note that observed growth rate of an average temperature in the northern latitudes twice higher than in the middle latitudes).

The prognosis of the climate change made by the authors show that an observed warming trend will be kept at least, till 2060. According to our estimations, a yearly average air temperature in the northern latitudes can have arisen by 2 – 3 °C by 2060.

In the work [Tsalikov, 2008] the author gives some generic data on condition changes on the Russian territory, occurring during the 20th century connected with global warming on the Earth.

As R.H. Tsalikov writes in his report, consequences connected with permafrost recession (permafrost covers up to 65 % of the country square) take the first place. A lot of cities and villages of Western and Eastern Siberia, pipelines and gas pipelines, highways and railways, transmission and communication lines are found on the permafrost.

In case if an average temperature will increase by 4 °C irreversible changes will take place in the permafrost regions.



Permafrost zones (dark ones) [Anisimov, 2008]

In Russia the common square of permafrost extension is ~10,7 mln km^2 which makes up about 63 % of the country territory (see the picture). In the region of permafrost extension on the territory of RF more than 80 % of discovered reserves of oil, about 70 % of natural gas, huge deposits of coal and peat are concentrated, a ramified infrastructure of fuel and energy companies` objects is built.

As it is described in the works [Anisimov, 1997, 1999, 2008], during the twentieth century a rise of temperature of upper many-year frozen soil and increase of depth of seasonal fire-setting have been observed, moreover, during the last three decades these processes have been accelerated. Since the beginning of 1970s temperature of frozen soil has become 1.0 – 1.5 °C higher in central Yakutia and 1 °C higher in Western Siberia while an air temperature has become 1.0 – 2.5 °C higher.

(No doubt that these changes are conditioned by global processes, as on the North of Alaska warming also occurred, even more intensified [Osterkamp, 1999]. Since the beginning of the 20th century to 1980s the temperature of upper frozen rocks became 2 – 4 °C higher and, at the average, by 3 °C more during the next 20 years up to 2002. In north-western Canada [Majorowicz, 1997] the upper layer of permafrost has become 2 °C warmer during the last two decades.

The data of abnormal regions where a fall of temperature prevailed on the background of global climatic warming for a long time is especially of a great interest. North East of Canada is one of such regions. It is noteworthy that since the middle of 1990s temperature of the upper frozen soil in this region has become almost 2 °C higher which proves the point of view, due to which all the changes are conditioned by global warming).

Nowadays in West Siberia intensive melting of frozen soil is observed (up to 4 sm per a year). Melting of frozen soil will lead to growth of non-anthropogenic and emergency anthropogenic cases numbers because of building and construction fall, communication destructions.

When a yearly average air temperature becomes 2 °C higher pile capacity will become 50 % lower, and about one forth of standard domestic houses built in the period 1950 – 1970 in such cities as Yakutsk, Vorkuta and Tiksi can subject to threat of destruction.

Risk for infrastructure objects is especially great where frozen soil contains a great quantity of ice. Such regions are a substantial part of the Lena valley, West-Siberian Plain, the Chukchi Peninsula and a large part of European north island territories where large oil-and-gas complexes, transmission lines, the Bilibinskaya NPS are situated.

According to estimations [Tsalikov 2008], it is expected that by 2060 the permafrost zone will have moved by 150 – 200 km which is proved by the results of forest advance to the north on the territory of Russia and Canada [Libin 2007].

Nowadays in West Siberia because of permafrost degradation about 35 thousand of pipeline and gas pipeline breakdowns connected with loss of stability of bases, mounting deflection, pipeline breaking take place every year.

Permafrost melting will result in landslides on melting slopes and a slow thawed soil flow, and also in substantial gaps on account of soil consolidation and carry-over of it with water.

R.H. Tsalikov writes in his work, «It is evident that operating helipads and airfields which are necessary for food, post, petroleum and lubricants delivery to northern regions, medical aid and people rescue will be useless.

Preparation of transport infrastructure of northern territories in new climatic conditions is becoming a very actual problem.

Destruction of underground storage walls will result in substantial problems. Mining operations (oil, gas, metals) have been organized on northern territories for tens of years.

A great amount of base oil was lost during accidents and leakage of pipelines, but not distributed in the soil and stayed in the ground frost bound. During permafrost melting new biocenoses can be poisoned with oil.

These situations are called timely chemical bombs. This term means retardation of harmful effect. These bombs can be of a metal character – a great amount of harmful heavy metals is contained in wastes and trades of mining production on permafrost.

On the North we have already met the problem when agricultural fertilizers and pesticides washed away during the thaw were found in the surface waters

Permafrost melting is especially dangerous in Novaya Zemlya in the zones of radioactive waste storage locations and on the Yamal peninsular in the region of perspective oil production».

During research of precipitation amount on the Earth during the last 80 years the authors found one more problem [Perez-Peraza 2005, Libin 2007]. According to the authors` results, global warming will condition 6 – 7 % growth of yearly average precipitation amount relative to nowadays on the Russian territory in a cold period, and 3 % growth on the Mexican territory [Perez-Peraza 2008].

As a result of forecasted temperature and precipitation variations a substantial rise of yearly river inflow in northern regions and lake levels are expected by 2050 [Perez-Peraza 2008].

The increase in temperature affects all the stronger. Ice in the Arctic is melting faster than predicted by current climate models. Such a conclusion was made by scientists from the analysis of the first data collected by the European satellite Cryosat-2, which is studying the arctic ice and map trends in the region. The results of the analysis, presented at the annual meeting of the American

Geophysical Society. In summer 2010 the area of ice in the Arctic has decreased to its lowest value since 1979 – 10.9 million square kilometers. This is 10.6 % lower than the average in the period from 1979 to 2000. The area of Arctic ice is continuously decreasing over the past 19 years.

That is why problems connected with floods and flowages which take the first place today among all natural disasters according to total yearly average damage will become an important consequence of the climate variations for northern territories of Russia. Precipitation and inflow increase will make up serious problems to protection of people and territories from flood.

Such floods have already been observed lately. Among them there are unusual floods in a result of which Lensk city was almost absolutely destroyed in May, 2001; partial sinking of several large European cities in the summer of 2002; the greatest and longest floods fixed in Western Europe in the summer of 2003.

As it is shown in the work [Tsalikov 2008], in connection with global warming a serious problem appears conditioned by Arctic ice melting. «It is shown on navigators` ice maps of the 19th century that in 1890 solid Arctic ices covered the whole Barents Sea and spreaded to the Iceland coast blocking the Fram Strait.

On the satellite photo of the same region made in 2003 one can see that waters reach the Spitsbergen archipelago and stretch in the Barents Sea up to the coast of Novaya Zemlya».

It means that for the last 100 years ice cover in this part of the Arctic decreased by almost one third. The same satellite photos show cogently that Arctic ice cover grew short by 25 % since 1979 to 2003.

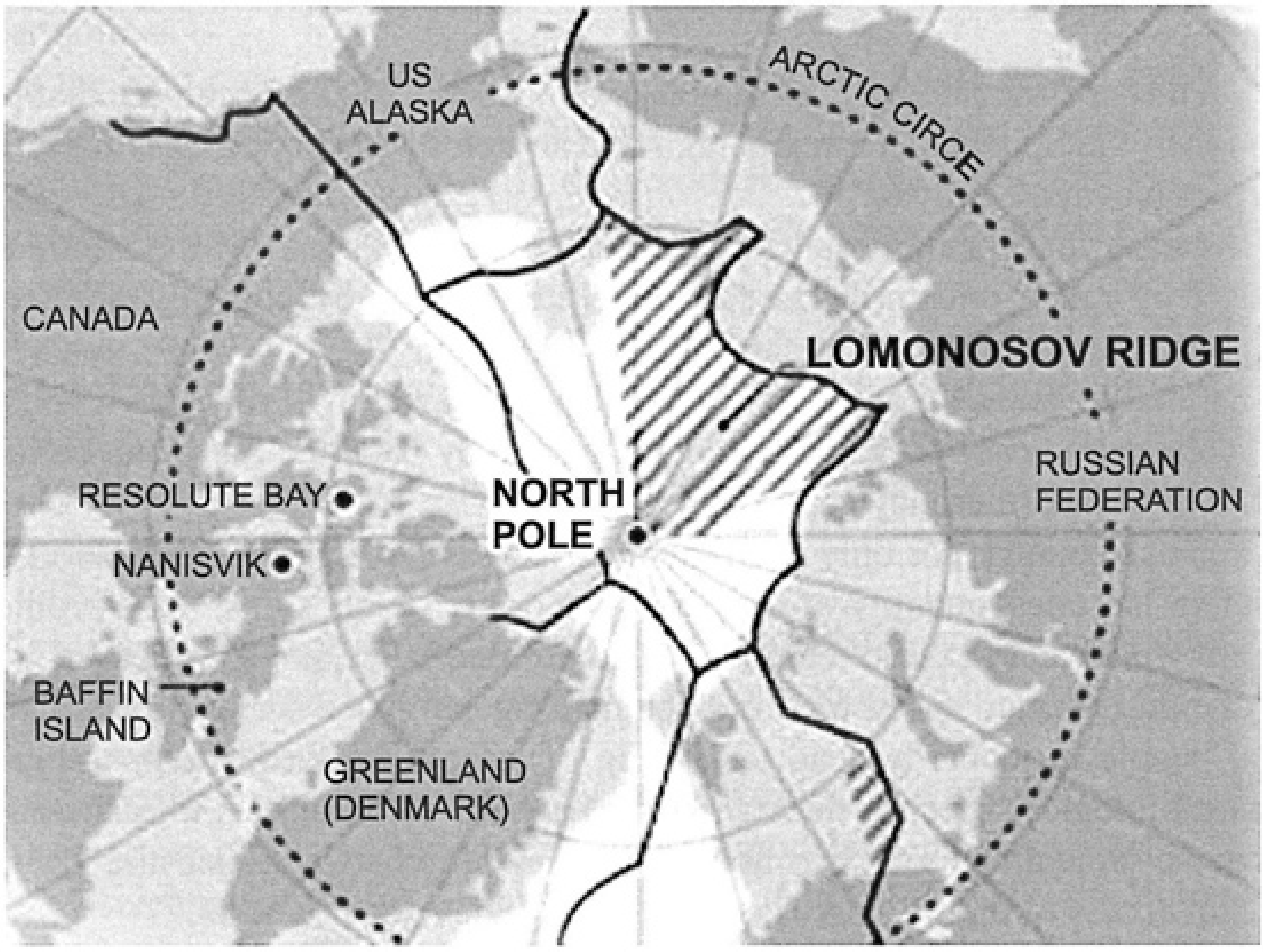
Estimation shows that by 2050 the northern seaway will have been opened 100 days per a year instead of 20 like today, and by 2070 the Earth can be fully deprived of a northern icy cap.

For our country not only a problem of increase of navigation scale in the northern latitudes, quantity of the Russian Northern Fleet ships, but a problem of safety on water in these regions is of great importance and significance.

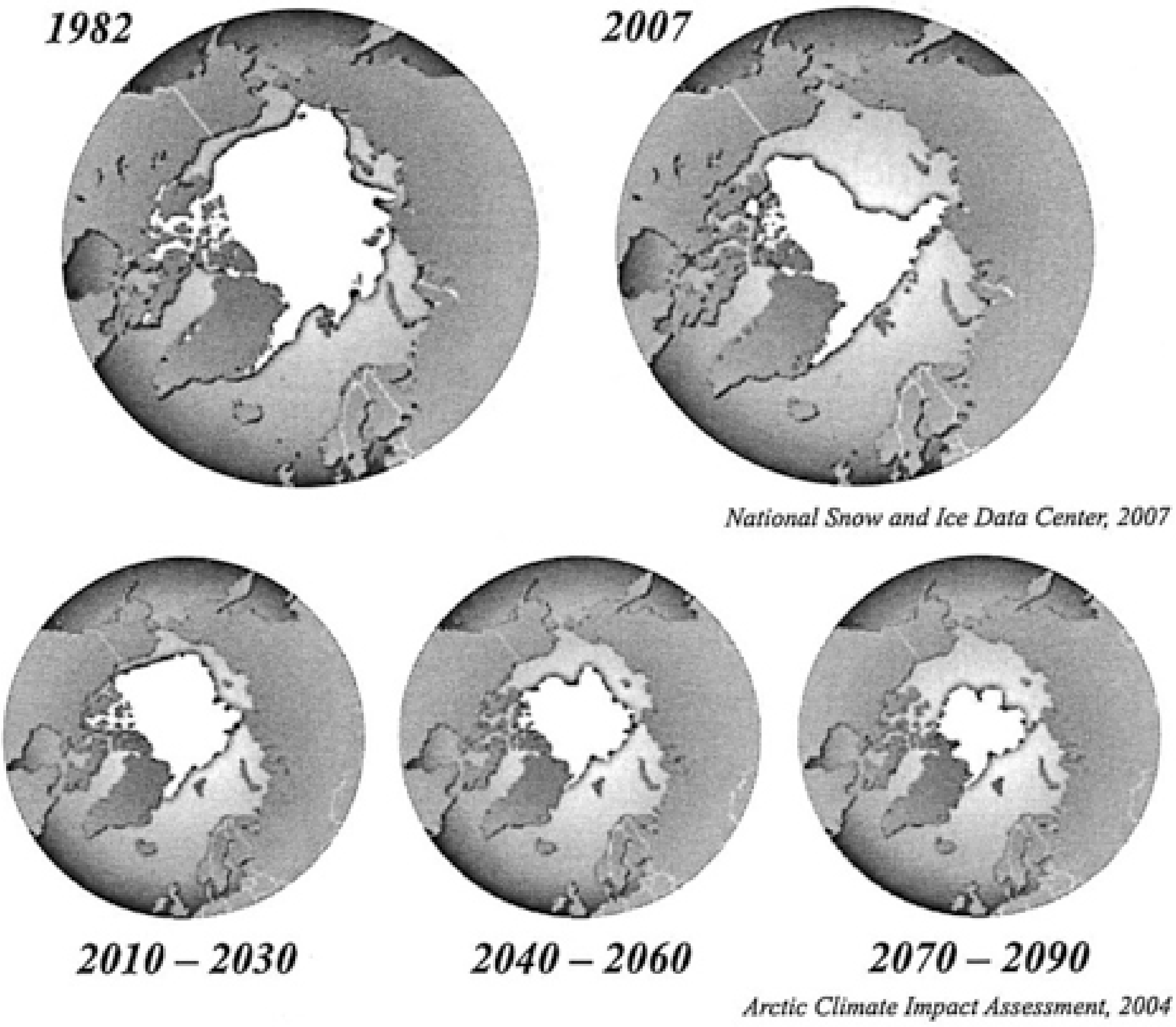
«Unprecedented speed of Arctic ice melting can place survival of northern local people in jeopardy, lead to sinking of large territories, disappearing of certain biological species, destruction of national communities infrastructure, but in the same time it will permit to open a new way between Asia and Europe, ease an access to fuel resources on sea shelf of the Arctic Ocean».

So, global warming is only beginning, that is why Russian economy should prepare to more serious tests.

Global warming

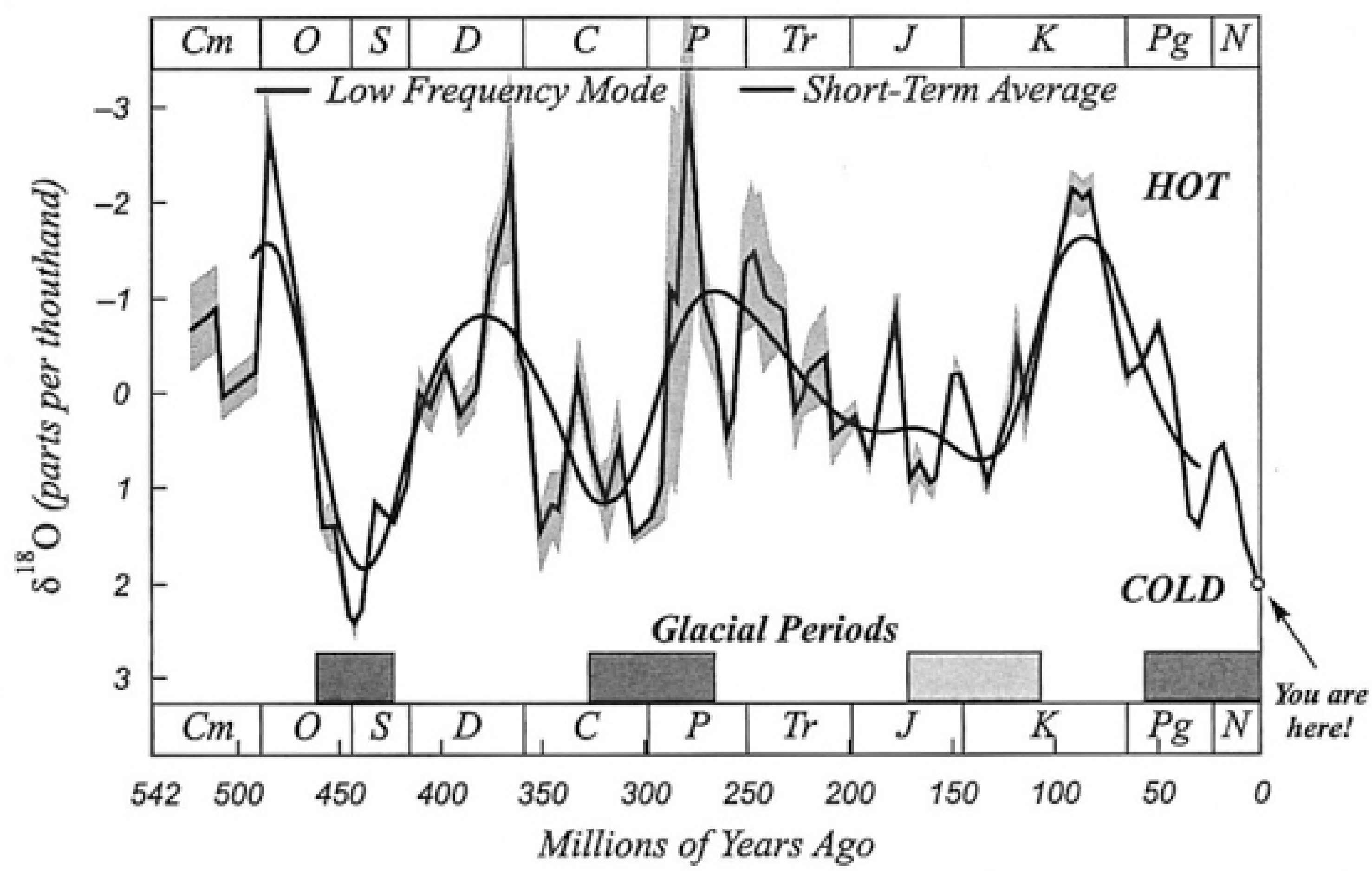


In the Arctic, almost disappeared old ice...



The decrease of Arctic sea ice, minimum extent in 1982 and 2007, and climate projections. UNEP/GRID-Arendal, 2007

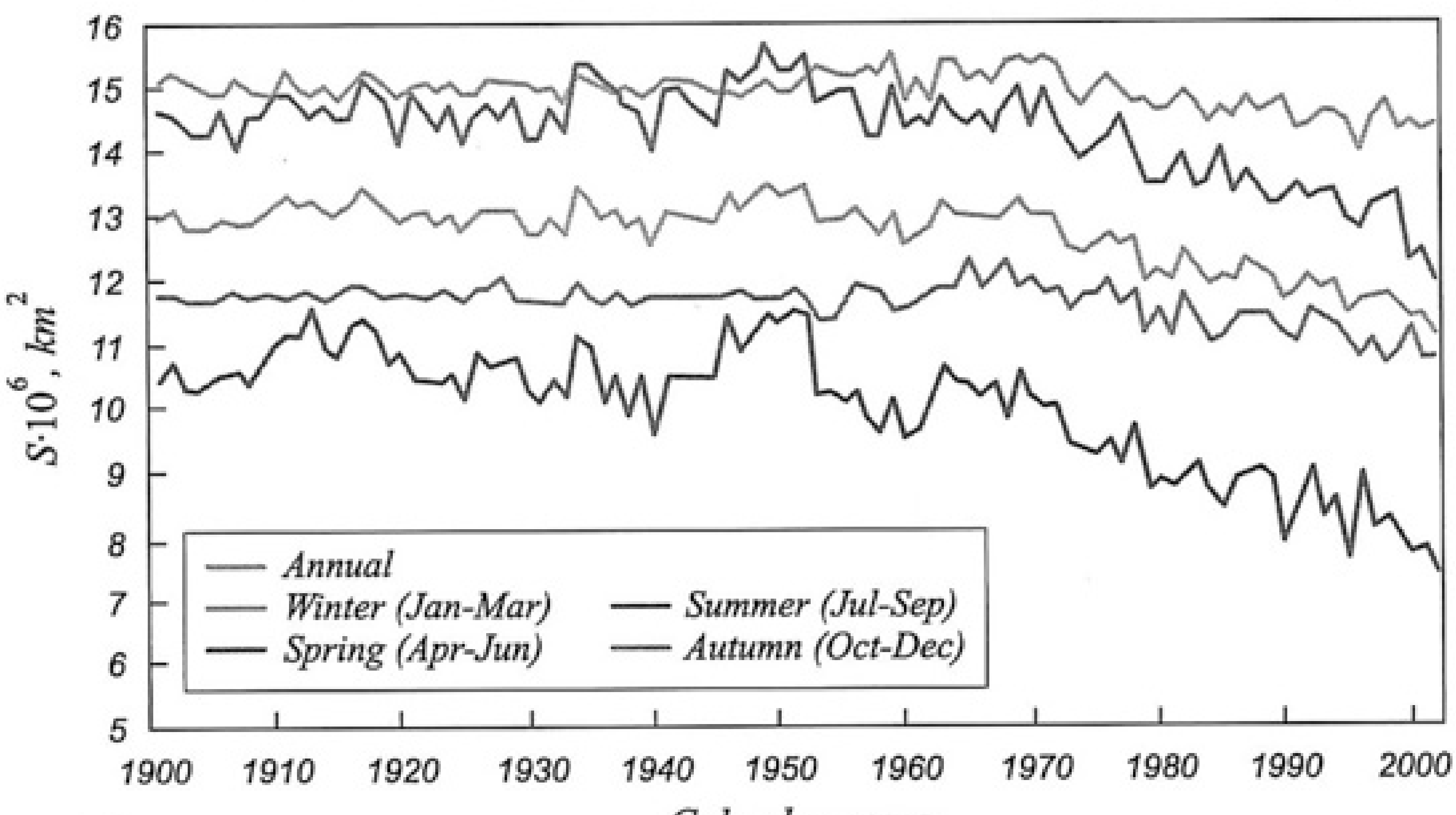
Phanerozoic Climate Change



Why heat? To say the truth, there is nothing abnormal in today's heat, climatologists think. And if to review archives, heat and drought in June-August of 2010 were predicted in autumn of the last year. James Hansen, an analytic NASA writes in his article published in December of the last year, «The following summer in Europe will be the hottest for the whole modern history of meteorological observations. For the last 12 months a daily average temperature of the Earth atmosphere has been the highest for the last 130 years.

Established hot weather will become a consequence of warm flow movement changes in the central zone of the Atlantic Ocean, where similar to the Pacific phenomenon La Niña an area of cool water appeared last year. This year the Atlantics releases much more warmth then usually which results in heating of the lower atmosphere. Mathematical models show that temperature will rise during the following months, and we, living in the Northern hemisphere, will have to survive the hottest summer for the whole history of modern meteorological observations».

Observed seasonal Arctic sea-ice extent (1900 – 2003)



Russian scientists agree with American colleagues` opinion. In winter of 2009 our estimations showed sudden rise of temperature in summer of 2010. Meanwhile, long-term forecasts of Hydrometeoservice of Russia for spring and summer of 2010 did not promise either such drought or sudden temperature rise. And this fact says not about disadvantages of modern science, but principal difficulties of the Earth climatic system which enters its own, sometimes very substantial amendments to our theoretical estimations. In this case, according to our data, there is a very small possibility of repeating of such an abnormal summer next year. Even on account of global warming which is responsible for the heat falling on Russia in a very small degree, such an arid summer will possibly be repeated once or twice in the nearest 100 years.

In some sense everything that happened over the European part of Russia this summer is a direct continuation of what happened in winter. Specialists of Hydrometeoservice of Russia call it reduce of western transfer over the Atlantic. The matter is in the following, large air masses formed over the ocean usually penetrate freely to the territory of Europe and Russia and bring warm rainy weather in winter and cold rainy weather in summer. But this year we observed a rare phenomenon – intensifying of cyclonic activity over the Atlantic Ocean and long-term maintenance of anticyclones over the European part of Russia. To say it in other words, cyclones from the ocean become blocked by powerful air fluxes which results in stable anticyclone weather over the European territory. In summer air the was formed not over the ocean as usual, but over the land. Such stable dynamic balance can last for a long time. In winter such processes bring stable frosty weather with minimal precipitation amount, in summer – bright dry weather with short breaks when a small cyclone manages to run a blockade. The Atlantics discharges all its accumulated power where this blockade boundaries are situated, in a result of it Eastern Europe becomes flooded by heavy showers. Such weather combination sets in with certain cyclicity. So, we observed such phenomenon in 1972 and in 1930s. More often just this weather type leads to heavy droughts and conflagrations.

Such abnormal situations appear relatively often. There is nothing unexpected in the process of such phenomena appearance for specialists of atmosphere physics. Because of absence of clouds such anticyclones are very stable. Sun warmth freely penetrating to the Earth surface warms the land; in its turn air is warmed from the land and feds the anticyclone which has grown to gigantic size this summer from below. The situation becomes more complex if a cyclone of the same power is near an anticyclone, as it has happened in Russia.

But the problem is that the science could not predict either 10, or 20, or 30 years ago, or cannot today how long such situations can last. A principal difficulty is that small changes are accumulated in atmospheric processes which are difficult to fix, but one day when a critical mass is accumulated these changes result in qualitative drift. So, the fact of stable anticyclone is not surprising. But its scale (square and duration) is surprising. There has not been such powerful and long anticyclone over the central region of Russia for the whole history of instrumental observations.

The situation formed in the summer of 2010 in Russia is not a direct consequence of global warming. Warming appears on account of natural and, in a less degree, anthropogenic reasons. When it gets warmer, a process of heating in the tropics goes slowly than in the polar latitudes. Correspondently, temperature difference becomes less, and less energy is left in the atmosphere to resolve a stagnant situation in Europe. So, global warming really could have contributed to abnormal heat duration.

Specialists in paleoclimatology [Kocharov, 2009] say that there have been such abnormalities earlier. According to Russian chronicles, between 1350 and 1380 Russia survived a whole series of terrible summer seasons with the same conflagrations of peat bogs. A chronicler wrote in 1371, «Darkness was lasting for two months. Darkness was so great that one could not see one sazhen before». Absolutely abnormal weather set in summer of 1841 – then a monthly average temperature arose by 4.6 degrees, or practically by the same as in summer of 2010. After that temperature got back to normal gradually. Today many scientists also hope basing on past examples that the climate will get back to normal in the nearest future.

Today the Earth has entered another cycle of atmospheric circulation with durative periods of relative stability – during the last years in Russia either long-lasting frosts or long-lasting rains were repeated in winter (earlier weather lasted for three-five days, then it changed). Now everything is not the same. Basing on the past meteorological observation data and the authors` conclusions we can predict bravely that there will not be any climatic drifts during the nearest decades. Autumn with its characteristic increase of precipitation amount, changeable weather, rather early frosts will set in the calendar period (or may be late a bit because now heating of the surface has been rather intensive). We do not have to expect any serious trends or deviations of the climate (besides slowly rising yearly average temperature). However, in Europe and in the European part of Russia we have entered a cycle of longer-term periods of atmospheric circulation that is why periods with long-lasting single-type climatic conditions are in store for us. The matter is that over the ocean in a result of intensified evaporation huge damp air masses were accumulated in summer of 2010; these masses will move to Europe as soon as a border between cyclone and anticyclone is broken. So, the autumn of 2010 will be very rainy and long-lasting, especially there will be much precipitation in October and November. Estimations show that the January and February of 2011 will be very cold and severe.

The academic co-society is rarely unanimous – global warming exists and it is impossible to stop it with either limitations to greenhouse gases emission or any other measures. NASA analytics think, «The climate in the first half of the 21st century will become warmer at a record pace. In the last century warming was 0.06 degrees per a decade. Up to the middle of this century this velocity will have been 2.0 – 2.5 times higher. After that the climate will begin to settle down. Warming maximum is expected in the first half of the next, 22nd century on the level of 1.0 – 1.5 degrees higher then today. In the nearest decades many people and countries will find themselves in climatic conditions in which they have never lived before and have no experience of such living».

Global warming will touch especially the Central regions of Russia which are the most sensible to climatic changes. Because of peculiarities of geographical position of Russia when a yearly average World temperature arises by one degree a yearly average temperature of Central Russia arises by 2.5 degrees.

Also one degree of a yearly average temperature rise is equivalent to 600 km forwarding of climatic conditions to south-west. Or now in a climatic relation Moscow is in the Ukrainian climatic zone, and if climatic tendencies are invariable in the beginning of 2030s the climate of Russia will correspond to that of Spain of north of Africa. But unlike the Mediterranean regions there is no sea in Russia capable to cool night temperature. As we have seen this summer, in general, minimal difference between day and night temperatures influenced growth of deaths from heat. The Spanish have a good possibility to have a rest from heat with a help of the sea, but in Moscow temperature did not deviate from a 27 degree mark even at night, which is considered to be dangerous, especially for old and not healthy people.

There is another question – is modern economy capable to endure these new natural conditions with long-lasting periods of heat and cold? An effective answer to the challenge of economical development connected with the climate variations which lately together with a problem of food supply and, especially, financial crisis have turned to one of the most actual problems not only on a national, but a global scale is possible only in the framework of integration of the problem of reducing climatic risks to a strategy of stable economic development.

On one hand, it supposes that economical development oriented to life improvement (in a wide sense) is a source of means and mechanism of economical complex and people adaptation to the climate variations and of reducing risks of such changes [Porfiriev, 2009].

On the other hand it supposes that risks of climatic variations are considered and estimated together with other risks of stable economic and society development, and the place of global warming problem in a series of the basic challenges to this development should be determined only on this comparative basis.

5.5. The climate oscillations are the reality. Climate Change and Space Weather

In the current epoch, the Sun is the source of most variations in our near space environment. These variations are called "space weather" and affect a variety of technological systems both ground and space based. Space weather does not appear to cause immediate and direct effects in the troposphere or biosphere of the planet. However, we have reason to expect that space weather might be more significant for the biosphere in the longer term.

Space weather refers to changes in the space environment and the effects that those changes have on mankind's activities. The primary source of space weather is the Sun. Variation in the electromagnetic and particulate output of the Sun is the main cause of changes in the Earth's upper atmosphere and surrounding regions such as the magnetosphere. These affect communications, navigation and many other space and ground based systems.

Solar Driven Global Climatic Change. Whilst a 0.1 % variation is unlikely to produce measurable climatic change (particularly with a period of just a decade), a 4 % variation would certainly be noticeable. Alternatively, a variation with a much longer period and amplitude under 1 % could well influence global climate. John Eddy and others [Eddy, 1978] have claimed such climatic changes have occurred in the past, one particular association being a colder epoch in Europe during an apparently complete absence of sunspots over a 70 year period in the 17th century. Such claims have generated interest particularly amongst those who challenge the majority belief of enhanced greenhouse warming caused by man's recent activities.

Terrestrial and oceanic hypervelocity impacts and climate change. This problem has been discussed so far is small, although the Terrestrial hypervelocity impacts and climate change of accounting seems essential. The Earth's atmosphere acts as a good shield against common impactors. Most potential impacts are from very small bodies. Their interactions produce the meteors that we see in the night sky. Small meteoroids are usually turned to dust, while their very high cosmic velocity is reduced to a very low terminal velocity in the atmosphere. The resultant dust particles drift down to the surface over several months or years. Each year our planet accumulates approximately 40,000 tons of extraterrestrial matter from these interactions.

A meteoroid needs to be several metres or even tens of metres in diameter to have a chance of making it to the Earth's surface with its space velocity unchanged. If is does so, the energy of impact causes near total vaporisation of the object, as well as excavating an impact crater much larger than the original diameter of the impactor. If the diameter of the impactor is about one kilometre, the amount of material vaporised and thrown into the atmosphere is sufficient to cause global changes [Gehrels, 1994].

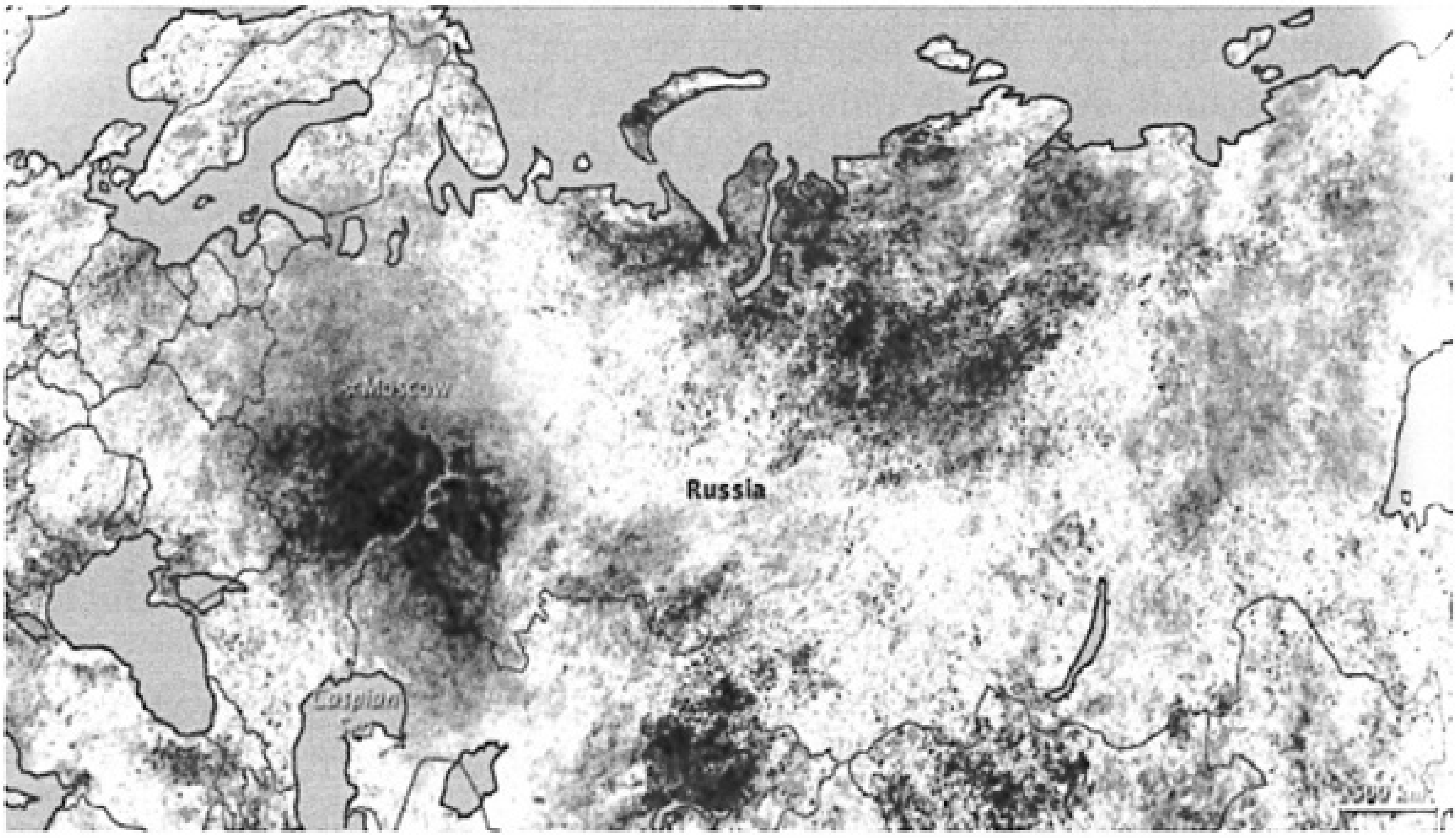
Hypervelocity impacts into the ocean are only just beginning to receive detailed study. The major effects here relate to the injection of massive quantities of water vapour into the stratosphere and higher atmospheric layers. Water vapour is a greenhouse gas, and the overall effect appears to be a substantial increase in the global temperature, just the opposite of what is expected for a continental impact. A more immediate and perhaps more frightening result of an ocean impact would be the production of massive tsunamis.

Additionally, you must take into account impacts from space debris which travels in Earth crossing orbits can be expected to cause global disturbances to the Earth's climate at intervals of the order of 100,000 years. Much larger disturbances, probably leading to massive biosphere extinctions, appear to have occurred at intervals of the order of 100 million years. Other space weather phenomena from outside the solar system (we have discussed in this book) which have the potential to cause global climate changes include galactic cosmic rays, nearby supernovae, interstellar dust clouds, binary star de-orbit. From the diagram (see below) shows that the present climatic situation is not unique. In Earth's history have been repeatedly observed and global warming (beyond current) and cooling. However, because this is what the present book.

Must be taken seriously by the current global warming, if only because it affects us living on Earth today. And especially for Russian citizens.

Given the sluggishness of the Russian authorities and their failure to sufficiently fund the science, both basic and applied.

Given that a third of the territory of Russia – the permafrost, and even a third – the zone of risky agriculture. Therefore, Gelioklimatology every day becoming more and more applied research.



As far as global climate change over the past 500 million years – admire, they are in front of you.

Arctic Ocean today
[http://sp.rian.ru/neighbor_relations/20101005/147696353.html]

A man has come overboard with his anthropogenic activity, but today he has not done a super serious harm yet to nature, and if not to do anything super natural, nature will manage with consequences of human activity.

The Sun has cycles which influence the climate. We are lucky, as we are witnesses of its very intensive phase.

Today we do not need ice breakers on the North so much which were the basis of the Northern navigation and economy thirty years ago.

And it is not a human fault. Nature if a self-controlling phenomenon, if not to finish it off, certainly.

The Sun is a decisive player in all these processes and will give us a lot of new puzzles.

It is obvious, that for some time we will observe temperature, lake level and precipitation amount rise…

Is the next Deluge in store for us? No one of existing theories gives a final answer.

Royal Leamington Spa, Warwickshire, on Good Friday, 10 April 1998. The town centre is under water and many cars are abandoned in roads. These floods affected a large swathe of central England and caused losses of J350 million. They illustrate a possible impact of global warming. Rainfall and torrential rain will rise, thereby increasing susceptibility to flooding.

[Saunders, 2009]

Journalist Andrey Zavolokin writes:

«In Noah` s Biblical life story it is said that the God left a covenant to the patriarch that all living beings on the Earth would never be annihilated by the Deluge. But there was no a covenant that we would never be slightly wet».

Julius Schnorr von Carolsfeld
160 illustrations of the Old Testament

“Water flooded the earth for forty days, and as it rose it lifted the boat off the ground. The water continued to rise, and the boat floated on it above the earth. The water rose so much that even the highest mountains under the sky were covered by it. It continued to rise until it was more than twenty feet above the mountains… And the waters continued to cover the earth for one hundred fifty days”.

The Old Testament. Flood. Genesis 7:17-24

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Words of gratitude

Human curiosity and thirst for creativity are different forms. One of them – science. Why do scientists are allowed to satisfy their curiosity by the state or society? This is despite the fact that in recent times of crisis, many leaders of some countries and even the heads of a number of universities are trying to abruptly reduce funding for scientific research.

It must be admitted that the scientific work is not romantic: this is routine. It's a constant experiments and observations, the protection of the results to colleagues, publishing results in specialized journals. And the constant search for funding to conduct research and publish the results.

This book could not be done without the International Academy of Appraisal and Consulting and its leaders Rector Eugeny Treyger and First vice-rector Tatyana Oleynik. Who, despite the financial difficulties of the Academy, found a way to support our research and our publications. Therefore, first of all, we are extremely grateful to them personally and the Academy for this support.

We would also like to express my appreciation to the Geophysical Institute of the National Autonomous University of Mexico (IG UNAM), under the "wings" which we started and we are working now. We remember wonderful man and scientist Javier Otaola, with which we began our research in Mexico.

We are grateful to Manuel Alvarez Madrigal, Oleg Gulinsky, Ago Jaani, Shtilyan Kavlakov, Amando Leyva Contreras, Mikolas Mikalaiunas, Víctor Velasco-Herrera, Konstantin Yudakhin, who participated in our research.

We would like to thank our computer layout designer Valery Rasenets, without which it is our book would not be such as it is.

A special thanks, we wish to express our charming interpreter Elizaveta Tokaeva which, by right, should be considered co-author of the book.

Igor Libin, Lev Dorman** and **Jorge Perez Peraza
Moscow – Tel-Aviv – Mexico city,
November 24, 2011

**UNIVERSIDAD NACIONAL AUTÓNOMA DE MÉXICO
(UNAM)**

**INTERNATIONAL ACADEMY OF APPRAISAL AND CONSULTING
(MAOK)**

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(natural scientific and economic aspects of global warming)**

Chief Editor Viktor Novokreschennikh

Translation Elizaveta Tokaeva

DTP Valery Rasenets

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Russia, 115093, Moscow, 1st Schipkovsky pas. #1

Contact phone number for the purchase of books
+7 (495) 974-1945, 974-1950
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Printed from the original models in the printing house «White Wind»
Russia, Moscow, 28, Schipok str.
Edition 250 copies

ISBN 978-5-905114-03-8