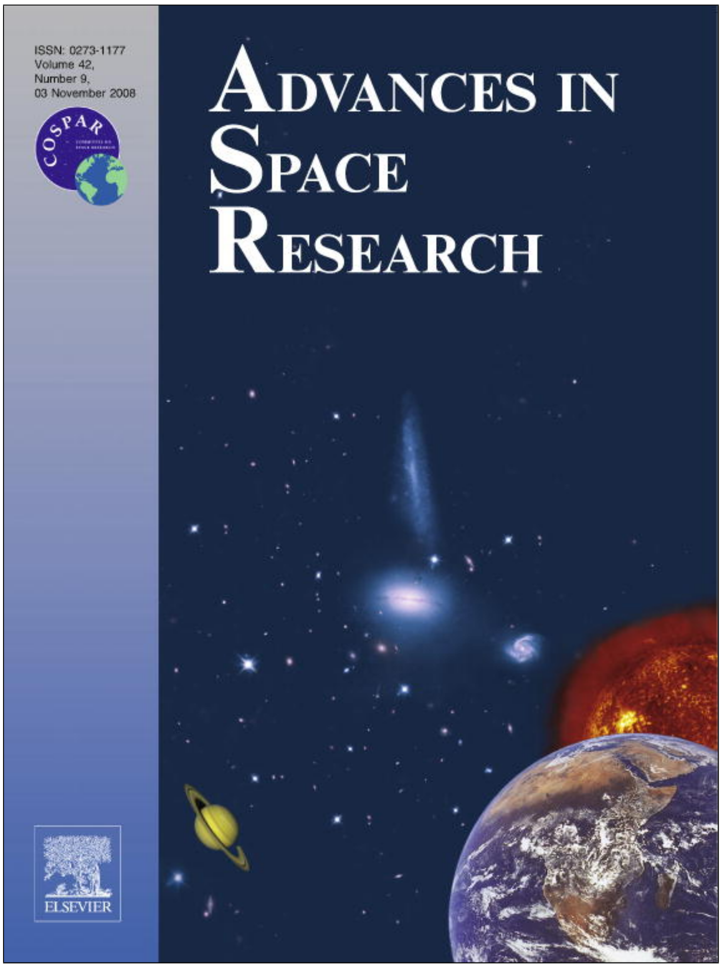
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Solar, geomagnetic and cosmic ray intensity changes, preceding the cyclone appearances around Mexico

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Abstract

Recently it has been suggested that there exist specific changes in the cosmic ray intensity and some solar and geomagnetic parameters during the days, preceding the hurricane appearances over the North Atlantic Ocean. To understand better these phenomena, data for all hurricanes born not only over the Atlantic but also over the Pacific waters in the last 55 years that hit the Mexican borders were elaborated. As basic hurricane parameters the maximum rotational velocity and the estimated total energy were used. To avoid any interference all hurricanes, overlapping the preceding ones with more than 20 days were not included. Then the behavior of the cosmic ray (CR) intensity, the sunspot (SS) numbers, and the geomagnetic parameters (AP) and (KP) in 35 days prior and 20 days after the cyclone start were investigated. The CR, SS, AP and KP showed much more intensive disturbances in the periods preceding and following the hurricane appearance. For SS this disturbance gradually increase with the hurricane strength. A characteristic peak in the CR intensity appears before the hurricane start. But its place varies between 5 and 20 days before that start. Specific changes were observed in the SS. For major hurricanes they begins sometimes more than 20 days in advance. The AP and the KP show series of bursts, spread over the whole period of 30 preceding days. The obtained results from the performed correlational analysis are enough interesting to motivate a further statistical analysis with more precise techniques: in particular a common periodicity of 30 years found in the number of tropical storms landing into Mexico, the averaged rotational wind velocity and the ACE must be studied in connection with the solar Hale cycle. Using coherence wavelet spectral analysis we present a comparative study between one terrestrial and one cosmophysical phenomena that presumable influence hurricanes development: African dust outbreaks versus cosmic rays for all North Atlantic tropical cyclones. It is shown that the cosmophysical influence cannot be considered as a negligible effect.

Keywords: Hurricanes; Solar activity; Cosmic rays; Geomagnetic activity

1. Introduction

In the second semester of each year, high velocity circular winds are born over the hot equatorial waters of the oceans. Such a large mass of atmospheric air that is rotating intensely is called tropical cyclone. It 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). 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. Generally these cyclones are known under the name of hurricanes if they are formed over the Atlantic and North-eastern Pacific Oceans. If they are born over the western Pacific Ocean, they are called typhoons. Because of the earth

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rotation, they rotate counter clockwise in the North Hemisphere and clockwise in South Hemisphere. The intensive heating, low pressure and resulting powerful evaporation increase fast the rotational wind speed. When such a speed is 18 ms^{-1}, (i.e. <34 kt or 61 km/h), the system is defined as tropical depression (TD), if the ranges from 18 and 32 ms^{-1} (34 till 63 kt, i.e. 62–115 km/h) it is called a tropical storm (TS) and a name is given. At speeds $\geqslant$64 kt ($\geqslant$33 ms^{-1}) the system is defined as *hurricane* (*H*). That is the speed, accepted to define the beginning of a hurricane over the Atlantic and a typhoon over the Pacific. The adjacent air gradually is 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. 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. 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 system describe complicated trajectories.

Depending again 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 (e.g. Hernandez-Cerda et al., 2001). 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. The energy concentrated in the vortex system is enormous. If we consider that the air over a surface with a diameter of 800 km has a mass of 2×10^{12} tons, turning with average velocity of ~15 to 20 ms^{-1}, we could easily calculate an energy of ~10^{18} J or ~10^{11} KWh. And that is 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. Only one hurricane hit over the Coasts of Caribbean islands, USA or Mexico could take hundred human lives and could cause damages for billions dollars. And practically every year one or two such hurricanes devastate these regions. So, today a lot of efforts are devoted to understand better the hurricane formation and intensification and to improve the prediction of its complicated trajectories. To contribute to such a big task, is then the main goal of this work. The average characteristics of the North Atlantic hurricanes are shown in Table 1.

All that provokes our interest for a detailed study of many collateral phenomena and their statistical comparison with the development of these formations, which sometimes give unexpected possibilities. Investigating data, recorded in the past, it is expected a better foresee of hurricane appearances, to forecast their possible trajectory, to predict their probable devastation and most important: to warn on time the threatened population. In earlier works (Elsner and Kavlakov, 2001; Kavlakov, 2005a,b) it was investigated the interconnections between some CR intensity changes, solar activity variations and Geomagnetic disturbances and with possibilities of Atlantic hurricane appearance.

Table 1
Range and average values of hurricane parameters

	Basic hurricane parameters			
	Parameter	Range	Average	Unit
D	Diameter	300–1000	500	km
E	Eye	30–80	50	km
V	Rot. velocity	30–70	50	ms^{-1}
U	Lin. velocity	2–10	5	ms^{-1}
T	Duration	1–20	8	days
E	Energy	–	1000	Bombs Hiroshima
L	Lifes	North Atlantic	200,000	from year 1700
L	Damages	North Atlantic	180 bill$	from year 1900

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). In the last years more and more investigations show that the solar activity (Gray et al., 2005; Kristjansson et al., 2002; 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), have noticeable impact on the meteorological parameters. Now, continuing our earlier research we are trying to find more representative connections between the parameters, mentioned above and some of the processes of the cyclonal appearance and development. This is done here, on the basis of data for all cyclones, born over Atlantic and Pacific Oceans in the period of 55 years (from 1951 to 2004) and crossed Mexico coasts and borders.

In the intervals of 35 days before and 20 days after the start of every one cyclone the behavior of the CR, solar activity and geomagnetic status are carefully examined and discussed. A basic part of these results is presented here. The evaluation of the obtained enormous amount of graphs coefficients and dependencies still continue.

Correlational works between solar and climatic parameters give often interesting results (e.g. Chernavskaya et al., 2006). Within this context, it should be emphasized that the pretension of the present work is limited also to a *correlational analysis*. The obtained results are enough exciting for motivating us to jump to a next step, by means of more precise statistical analysis techniques, and if there are still promising results to go to the next step, that is to clarify the mechanism of all complicated interconnections between the cosmophysical phenomena and climatic phenomena at earth. It should be mentioned, however, that a great deal of efforts have been done with this goal, some of them recently summarized by Benestad (2006), Kanipe (2006), Haigh et al. (2005) and Fastrup et al. (2001).

2. Data

2.1. Hurricanes

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.

In this work data were used for all recorded cyclones in the Atlantic Ocean and in the Pacific Ocean from January 1, 1950 till December 31, 2004 that fill the following requirements:

– During their development their maximum rotational velocity V_{max} reaches at least 35 knots (that means we include in our investigation not only the hurricanes, but also the tropical storms, as defined in the Saffir-Simpson scale).
– During their displacement they have touched either the Mexican coasts or the Mexican borders.

On the Web there are a lot of cyclone data (http://www.aoml.noaa.gov/hrd/hurdat/Track-Maps.htm, http://www.aoml.noaa.gov/hrd/hurdat/TrackMaps.html, http://stormcarib.com/climatology/#links, http://weather.unisys.com/hurricane/atlantic/index.html, http://www.aoml.noaa.gov/hrd/hurdat/Track-Maps.htm). We carefully examined data and chosen from them.

2.2. Sunspot numbers (SS)

Solar activity is characterized by different indexes, among one of them it is the daily number of sunspots number (SS). A full set of daily sunspot numbers for the period 1950–2004 was obtained from the web site of the National Geophysical Data Center in Boulder, Colorado, USA (http://www.ngdc.noaa.gov/stp/SOLAR/ftpsunspotnumber.html#american, http://www.ngdc.noaa.gov/stp/SOLAR/ftpsunspotnumber.html#international).

2.3. Cosmic rays (CR)

In our earlier investigation we use data from several Neutron Monitors (NM) situated around the Atlantic Ocean. But the gain of the statistics, achieved in this way, was suppressed by the difficulties of sticking together the different data, available in different intervals. So, we decided that only one, but long running NM with more than 50 years continuous measurements could be much more suitable. That is why we took the whole set of Climax NM data received on Climax CR station, (39.37N; 106.18W; alt. 3400 m and 2.97 GeV cut-off rigidity). It appeared that they covered the period 1951–2004 with negligible instrumental changes, low percentage of missing data and wonderful stability. For the whole period of 54-years (19,724 days) only 399 days are without any data, or only 2.02%. That is a 97.98% of effective measured CR intensity. We carefully interpolated the missing data. It must be emphasized that the map of cosmic ray intensity isolines at height about 200 km (e.g. Khorozov et al., 2006) shows that the region of our concern in the North Atlantic is crossed practically by the same isoline, which includes Deep River, Climax, Mexico and others.

The general interconnection between the data of practically all NM data, measured on the same isoline, permits us to consider the CLIMAX data as globally representative. The Climax data were taken from http://ulysses.sr.unh.edu/NeutronMonitor/00ClimaxCorr.html.

The values presented in counts per hour were transformed in daily percent deviation from the general 55 years average value (394,600 counts/h or 9,470,400 counts/day). The statistical error then is 0.032% for a single day. In most cases we averaged over many days, and the error generally is below the size of the point, presented on the graph.

2.4. Geomagnetic activity index (KP) and (AP)

The daily values of KP and AP indexes characterizing the geomagnetic activity used in this work are taken from the web page of GeoForschungs Zentrum, Potsdam and compared with those of National Geophysical Data Center in Boulder, Colorado, USA. Full data set for our 55-years long period were available on both web sites (http://www.ngdc.noaa.gov/stp/SOLAR/ftpsunspotnumber.html#international, http://ulysses.sr.unh.edu/NeutronMonitor/00ClimaxCorr.html).

3. Data processing

3.1. Cyclone characteristics

After careful examination of the track of every cyclone in that 55 years interval, we found 119 cyclones born over the Pacific and 59 cyclones born over the Atlantic Ocean obeying the conditions mentioned in Section 2.1.

Every cyclone was characterized with:

1. Origin – Atlantic (A), or Pacific (P).
2. Start – (D0) [year, month, day], when the circular wind velocity (V), measured on the ocean surface has reached 35 nodes.
3. Geographical position – [B($\phi 1, \lambda 1$)] of the cyclone eye center, when the start occurs.
4. Maximum rotational speed V_{max} reached during the cyclone development.
5. Hurricane rank after the Saffir-Simpson Scale, corresponding to the V_{max} value.
6. Duration in days (L).
7. Total cyclonal energy (CE).

The daily averaged rotational velocity was taken as a characteristic of the cyclonal energy. The sum of these daily values was accepted as proportional to the total cyclonal energy (CE).

3.2. Preliminary comparison between yearly averaged parameters

To obtain a basic view for the yearly changes of our parameters, we introduced a yearly cyclonic energy $[CE(y) = CE_1 + CE_2 + \cdots + CE_n]$, characterizing the total energy of all cyclones. CE_i is the estimated energy of "i" cyclone appeared in the year (y). The CE(y) and the CE(y) [smoothed], plotted together with the average yearly values of the parameters CR, SS, KP, and AP are depicted in Fig. 1. The correlation coefficients between these parameters are shown in Table 2.

3.3. The cyclone classification

If the start of the next cyclone occurs less than 20 days after the start of the preceding one, the less powerful of them is defined as "overlapped". The overlapped cyclones were not included in our calculations.

So, 78 from all 119 Pacific and 44 from all 59 Atlantic cyclones (112 from all the 178 hurricanes) were classified as "not overlapped" in our 55 years period. Depending on their Saffir-Simpson rank (V_{max}) they were subdivided in: 6 separate groups (rank 5, 4, 3, 2, 1, TS); 3 compound groups (rank $5+4$, $3+2$, $1+TS$), and 2 compound groups (rank $5+4+3$, $2+1+TS$) (Table 3).

In Fig. 2 the rank distributions of the Atlantic and the Pacific cyclones are presented. Obviously the Pacific cyclones are mostly low ranked. Their places of birth in the Pacific are dispersed along the Mexican West coast while the Atlantic cyclones are spread rather far from the Mexican East coast. From that it is easily understandable why the Atlantic cyclones are predominant in the highest

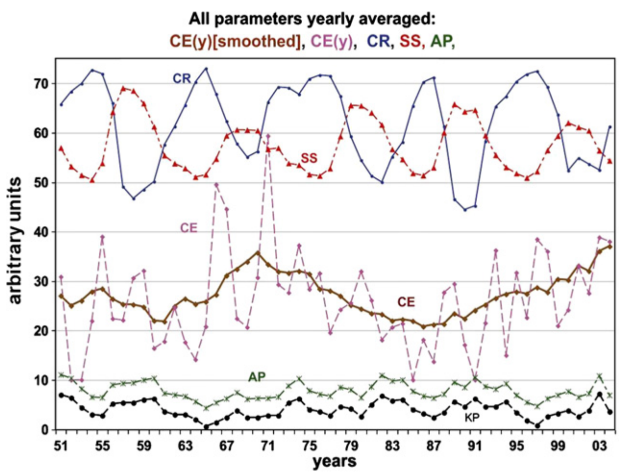

Fig. 1. Average yearly values of CR, SS, KP, AP, total cyclonal energy (CE) and CE smoothed.

Table 2
Correlation coefficients

CE	SS	CR	AP	KP
	−0.13	0.30	−0.32	−0.31

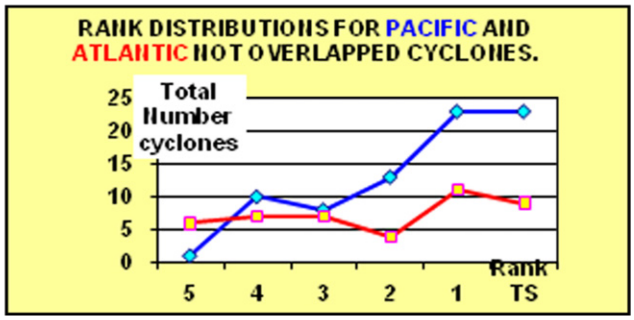

Fig. 2. Distribution of Atlantic and Pacific cyclones according their categories.

ranks, while the Pacific cyclones are abundant in the lowest ranks.

3.4. Days preceding the hurricane start

Our 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 dangerous event. That contributes to our interest, concentrated on these days. To have a general view on the behavior of all parameters (SS, CR, AP, KP) 35 days before and 20 days after the cyclone start we investigated them separately for every one of our 122 cyclones, creating 488 graphs. Of course it is very difficult to present all them. On the basis of such a vast amount of data, we then proceed to evaluate the averaged time between the appearance of these specific CR, SS and AP changes and the cyclone formation and then to determine the size and the time distribution of these changes and their interconnection. So, from our large amount, we chose three graphs, presenting the changes of CR, SS and AP for the most powerful cyclones (Allen, Gilbert and Mitch) in the 55 years period (Fig. 3). There is a remarkable disturbance in CR intensities, appearing 5–20 days preceding the cyclone starts. It is accompanied with one or two clearly pronounced Forbush decreases. The SS changes reach 150–200 SS units, sometimes even with more of 20 days in advance, and the AP values show consecutive picks, spreading over the whole period of 30 preceding days, reaching sometimes 100–120 AP units (the KP graphs repeat closely those of AP, reason why they are not presented). Looking at the shape of these graphs, it can be seen that these parameters fluctuate considerably for every single cyclone not only in size, but also in time of appearance. To understand better these changes an averaged curve over all years has to be obtained. That is not an easy task, because the picks in all the parameter values

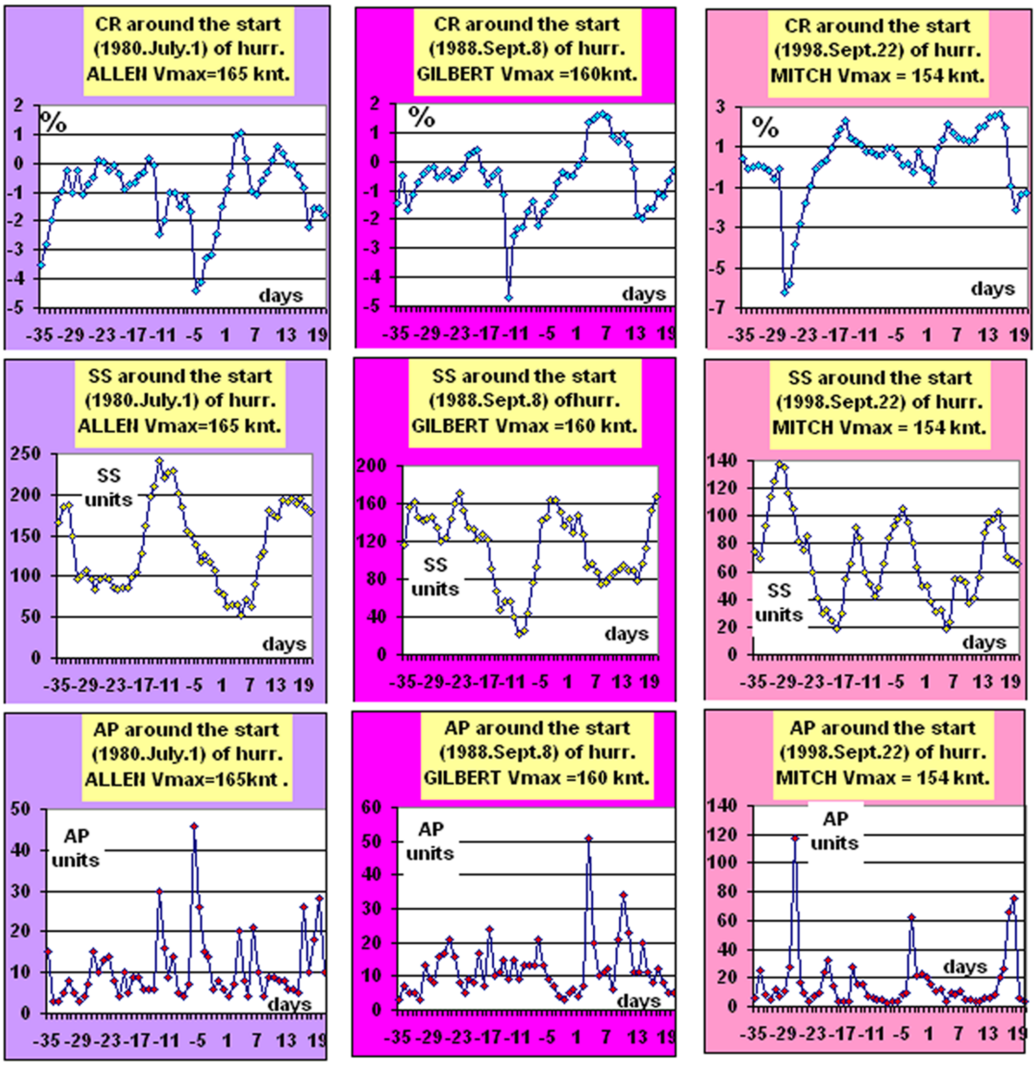

Fig. 3. Time behavior of CR, SS and AP during three intense hurricanes: Allen, Gilbert and Mitch.

are different not only in size, but also in time of appearance.

A rough estimation of our parameter changes preceding the appearance of the cyclones was done dividing the whole 30 days preceding period in three continuous intervals (every one of 10 days). The deviation (the difference between the maximum and minimum values of SS, CR, AP, KP) in every interval was averaged for all 122 cyclones together. The distribution in two groups (see Table 3) for all 39 major cyclones M ($M = H5 + H4 + H3$) and for all 83 minor (small) cyclones S ($S = H2 + H1 + TS$) separately was used. The results are shown on the graphs of Fig. 4. It is noticeable that, generally the highest SS disturbances appeared 30–21 days before the cyclone start, while for CR, these disturbances reach systematically their maximum in the 20–11 days interval.

To reveal the fine structure of these changes all parallel averaged daily values of CR, SS, AP, and KP were correspondingly arranged. The cyclones were subdivided in groups as shown in Table 3. A "running average" method, smoothing the obtained curves over 9 adjacent values was used: an averaged parameter over all hurricanes did not enhance the peaks, but mostly reduced them, though a more pronounced disturbances could be noticed before the appearance of more powerful cyclones. The graphs obtained for hurricanes sorted depending on their category and smoothed, averaging over 9 adjacent values, are shown in Figs. 5–7. Some of the results, obtained for CR changes around the cyclone start are shown in Fig. 5. The same behavior of the changes for SS is observable in Fig. 6. Investigating separately all the four parameters averaged for every one group, we obtained 84 new averaged graphs. It is interesting that the pre-cyclonal wave amplitude in AP and KP values remains relatively stable before all cyclones and does not depend much on their power. But that wave slightly changes its phase with the cyclonal power. The corresponding changes of AP for three groups of cyclones and for all of them together are depicted in Fig. 7 (the changes of KP are similar).

In order to find the dependence of the peak parameters on the hurricane category we overlapped the highest peaks of CR, SS and AP in category 5, 4, 3, 2 and in the 20 days

Table 3
Cyclones sorted depending on V_{max}

DISTRIBUTION	Saffir-Simpson Scale	Rank		H5	H4	H3	H2	H1	TS	All
		Vmax	Knots.	>135	114-135	96-113	83-95	65-82	35-64	>35
		Vmax	km/h	>249	249-210	209-178	177-154	153-119	118-63	>63
ALL CYCLONES	6 groups	Cyclone	quantity	7	17	15	17	34	32	122
ATLANTIC	6 groups	Cyclone	quantity	6	7	7	4	11	9	44
PACIFIC	6 groups	Cyclone	quantity	1	10	8	13	23	23	78

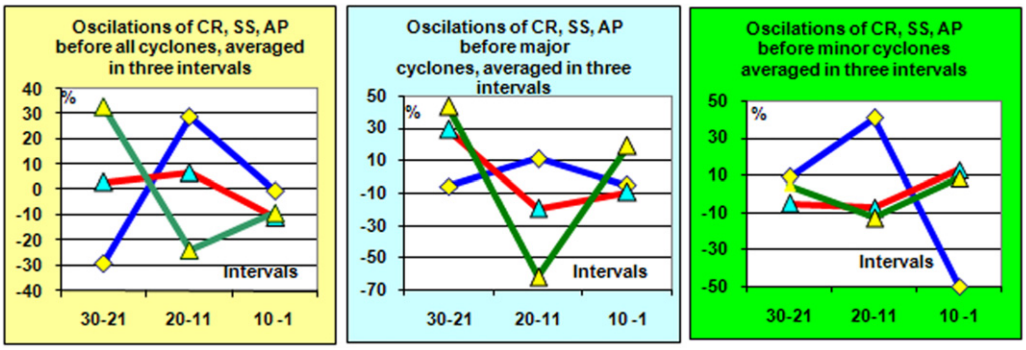

Fig. 4. Deviation of the maximum and minimum values of SS, CR, AP in intervals of 10 days, for the average of all cyclones (122), the major cyclones (39) and the minor cyclones (83).

intervals before the cyclone appearance. The graphs are shown in Fig. 8 elaborating all 122 hurricane cases together, where the concept of Relative Max or Min has been introduced to measure the size of the peaks measured from their backgrounds. So, on the graphs we have: for CR $-2.5–0.3 = -2.8\%$, for SS $120–70 = 50$ SS units and for AP $55–12 = 43$ AP units. In Fig. 9 these peaks were obtained separately for hurricane categories 5, 4, 3, 2. From the graphs in Fig. 9 we have estimated the dependence of the relative peak size on the hurricane category. The results are shown on the graphs of Fig. 10. There, the relative peaks size in the categories 5, 4, 3 and 2 shows a well expressed change with the hurricane category. That fades away for the lowest category 1 and for the thunder storms (the lighter gray lines in the graphs). The trend deeper MIN in CR intensity values as well as higher MAX in SS for higher hurricane categories is within our expectation. For the analysis of the time distribution of the preceding peaks, we located the place of the highest MAX (for SS and AP) and the deepest MIN for CR in the interval of 20 days before the start of the cyclone. The distributions for these extremes are shown in Fig. 11 in the combined graphs for all elaborated cyclones. It is interesting to notice the predominant MIN for CR at the beginning of this interval around the 18th–19th day. The Max for SS and AP are concentrated in two peaks around 5th and the 16th preceding days.

4. Results

What could be seen on the presented graphs confirms our preliminary suggestion that there is an interconnection between these parameters and the appearance of the cyclones – especially the most powerful of them. Results can be summarized as follows:

- The presence of specific peaks in the CR, SS, AP values, measured in the 20 days interval, preceding the hurricane start was confirmed.
- That is especially valid for the major hurricanes, but it is noticeable in considerable part of lower rank cyclones.
- It was shown that for high ranking hurricanes the size of these parameter changes parallel with the hurricane rank.
- The averaged Min in the CR values, preceding the entire hurricanes categories is located around the 19th preceding day.
- The averaged Max in the **SS** value appears around the 5th and around the 16th preceding days. The Max for AP appears also in these two places – around the 5th and around the 16th preceding days.
- A tendency of coincidence peaks of cyclonic energy with a rise and fall periods are observed during most of solar cycles.

5. Discussion

In Fig. 1, the curve presenting the yearly change of total energy (CE and CE smoothed) released from all the cyclones has an interesting form. It could be well approximated with two overlapping sinusoids: one of them – with a period approximately 3.3 years, the other one – about 30 years.

Furthermore, based on worldwide analysis of Accumulated Cyclone Energy (ACE), it has been recently shown (Klotzbach, 2006) the existence of a large increasing trend in tropical cyclone (TC) intensity for the North Atlantic basin, and a considerable decreasing trend for the North-

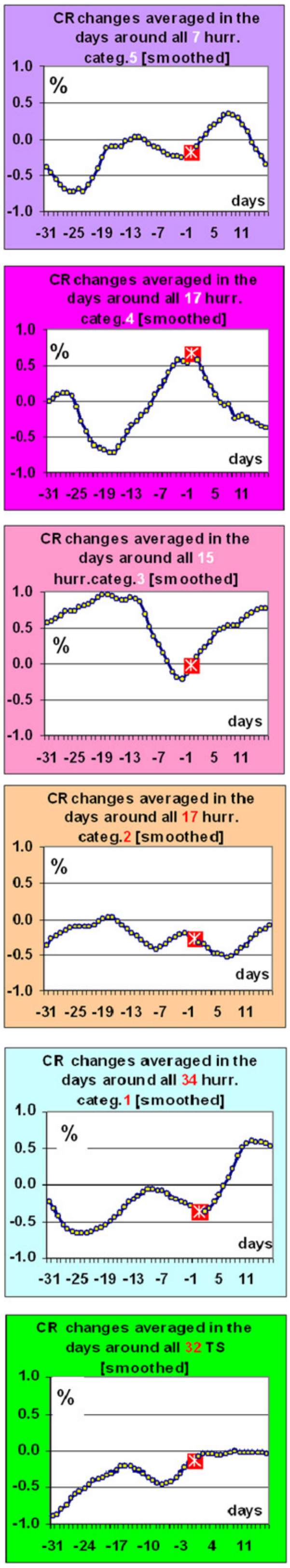

Fig. 5. A running average smoothing of the obtained CR curves over 9 adjacent values for hurricanes of category 5, 4, 3, 2, 1 and TS.

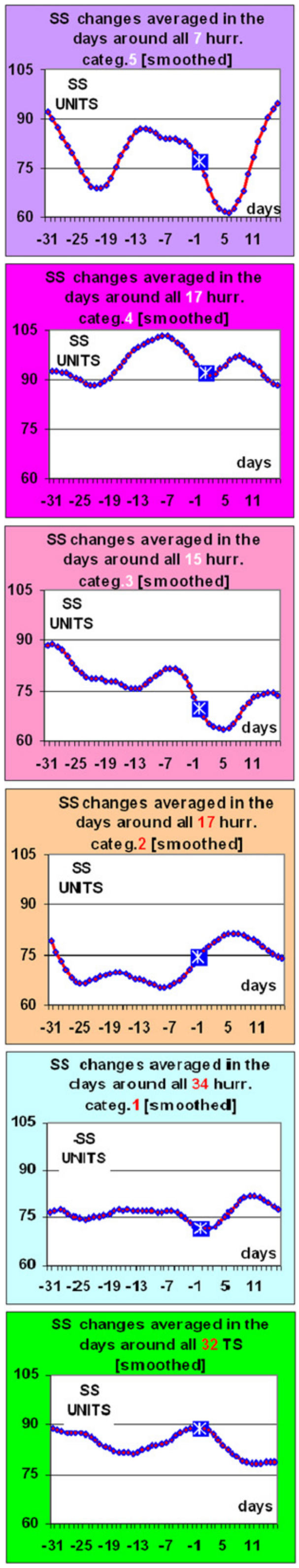

Fig. 6. A running average smoothing of the obtained SS curves over 9 adjacent values for hurricanes of category 5, 4, 3, 2, 1 and TS.

east Pacific. In the particular case of TC landing into Mexican coasts, we show in Fig. 12 the same tendency: a frequency increase in the Atlantic and a decrease in the Northeast Pacific during the last decade. The sum for the two basins is dominated by the Atlantic trend.

It can be seen from Fig. 1 that a similar increasing trend is followed by the total cyclone energy CE during the last

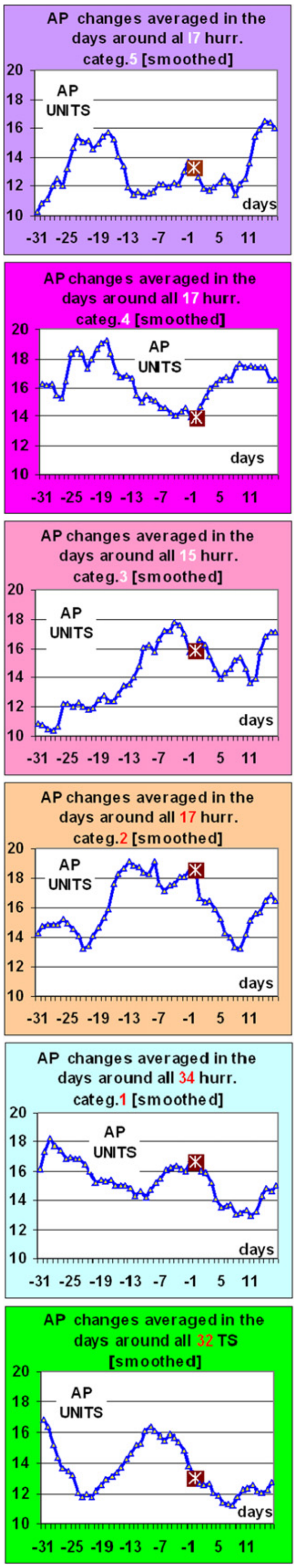

Fig. 7. A running average smoothing of the obtained AP curves over 9 adjacent values for hurricanes of category 5, 4, 3, 2, 1 and TS.

years. Also, it should be noted that in both curves (Fig. 12 and the CE smoothed curve in Fig. 1), there is a cyclical behavior dominated by a quasi-30 year's wave. It is worth mentioning that an analysis of the total number of TC and the number of category 4–5 (Saffir-Simpson scale), in the Northwest Pacific basin, also shows such a cyclic behavior (Webster et al., 2006), as it does other index of TC intensity, namely the potential destruction index (PDI) (Chan, 2006).

Besides, it can be seen in Fig. 1 the regularity exhibited between the outstanding peaks of a cyclonic energy and the rise and fall periods of the 20th solar cycle, as well as the tendency of coincidence peaks of cyclonic energy with a rise and fall periods during other solar cycles. It should be reminded that active processes on the Sun: CME, flares and related to them Forbush effects and geomagnetic storms have also the occurrence peaks on the rise and decline phases of a solar cycle: one would expect then, that the selective account of cosmophysical factors would allow obtaining a better correlation dependences. However, the yearly averaged SS, CR, AP, KP has a low correlation factor with CE, as was shown in Table 2. Nevertheless, among the factors that may in principle have a physical connection with tropical cyclones (TC) development, a very weak anticorrelation of -0.3 is found (Webster et al., 2006) between storm intensity and sea surface temperature (SST), similarly to those of our parameters of Table 2; in contrast, the number of TC of category 4–5 shows positive correlations, ranging from 0.55 to 0.65 with vorticity (rotational flow), vertical wind shear and the lower tropospheric moist static energy (amount of available thermodynamic energy in the atmosphere) (Webster et al., 2006).

Obviously our parameters SS, CR, AP, KP are not the basic driving factor for hurricane appearance and development. However, there is no doubt that the results confirmed our preliminary suggestion that there is some kind of interconnection between these parameters and the appearance of tropical cyclones – especially with the most powerful of them: here, the chosen long preceding period of 35 days permits to reveal the behavior of these parameters long before the cyclone appearance. Specific precursors exist persistently before the cyclone start. During the time of major cyclone development specific changes are also noticeable. Obviously, a considerable change in the solar activity and the depending on it, CR intensity and Geomagnetic field activities, precede the appearance of intense cyclones, though the preceding time fluctuates vastly from event to event.

It is difficult to suppose that the CR ionization of the upper atmosphere and the geomagnetic field disturbances, having billion times smaller energy than the oceanic thermal sources, could provoke atmospheric vortexes. Surely, they participate in the change of the atmospheric ionization together with the solar plasma. Maybe their effect could be defined as "triggering" for the hurricane formation. That change in the ion concentration in the upper layers either helps to go over certain threshold, or contribute continuously a specific starting level to be achieved. In fact, we should keep in mind the so called

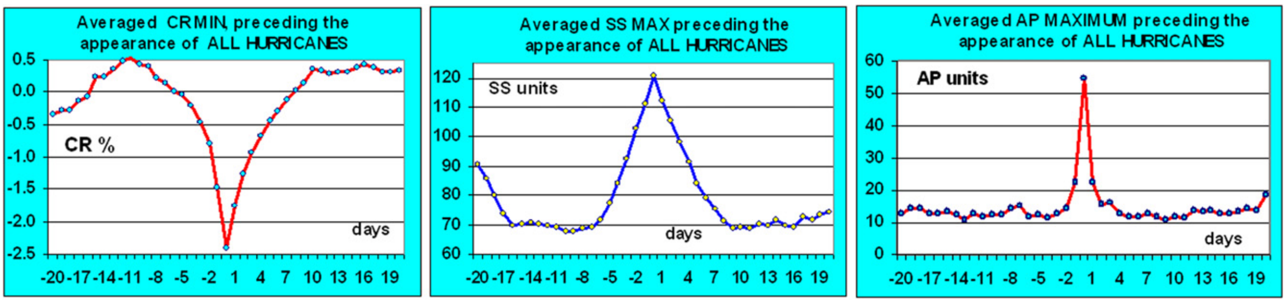

Fig. 8. Overlapping of the CR, SS and AP peaks of categories 2, 3, 4, 5 for all the 122 hurricanes, in the 20 days interval before the cyclone appearance to visualize the size of the peaks measured from their basis.

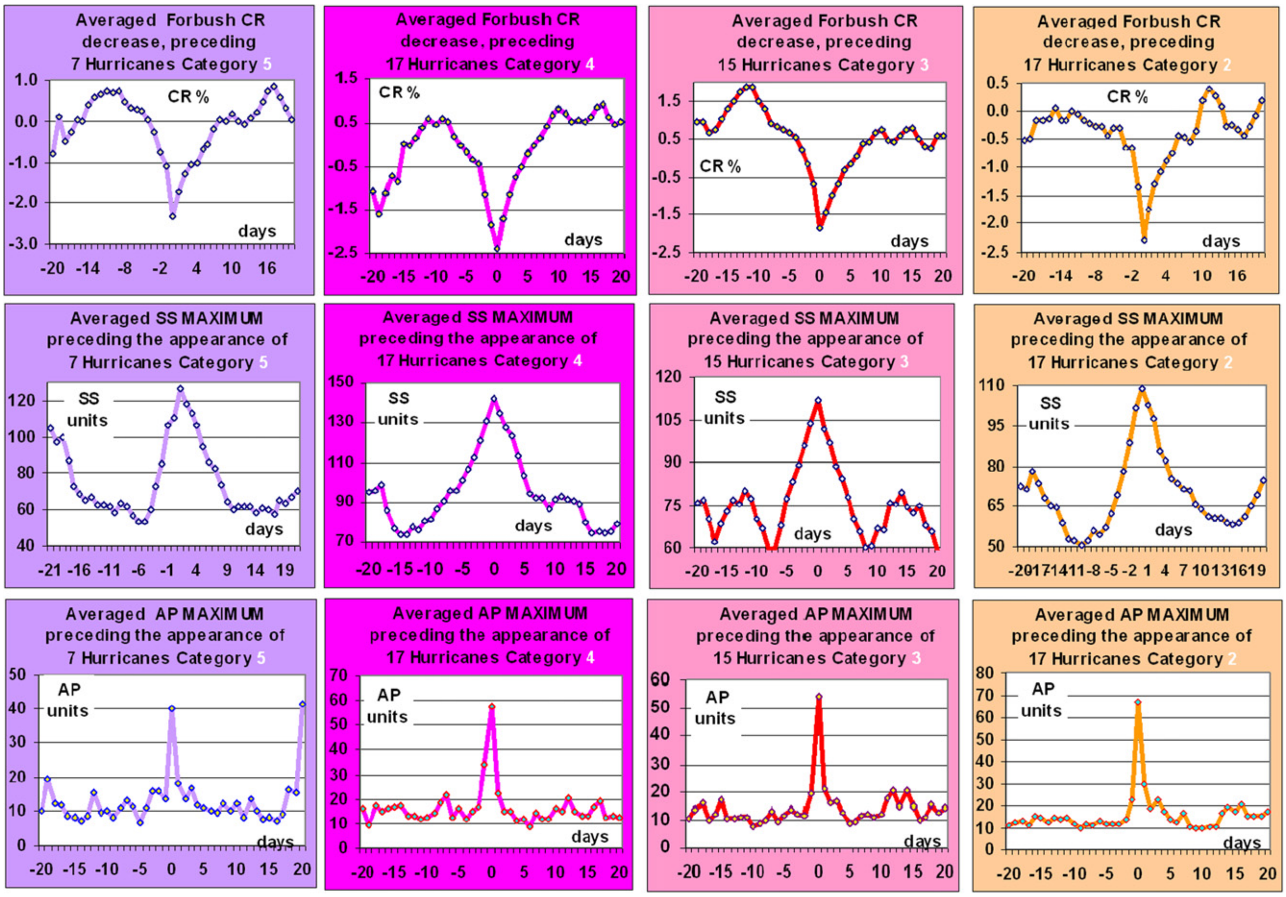

Fig. 9. Idem than Fig. 8 for each independent hurricane category.

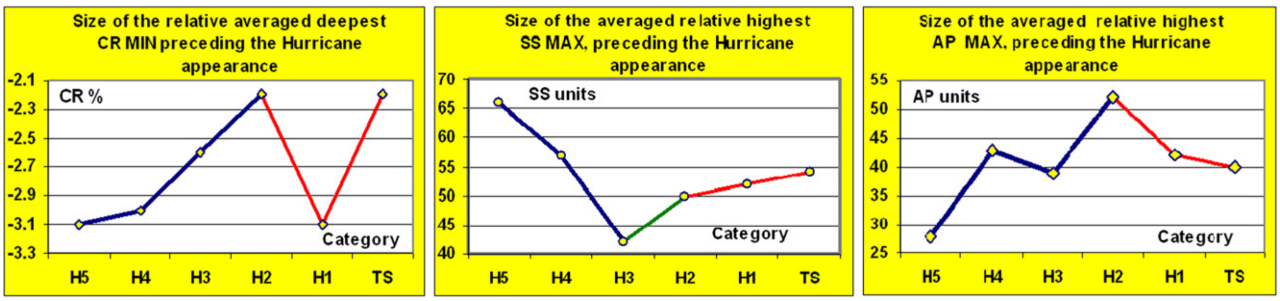

Fig. 10. Dependence of the relative peak size on the hurricane category.

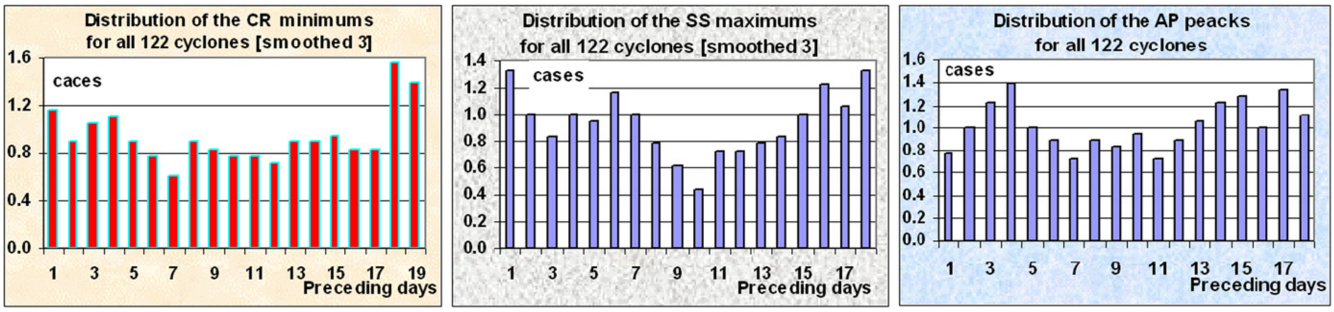

Fig. 11. Trend of the deeper MIN in CR intensity and the higher MAX in SS, for higher hurricane categories.

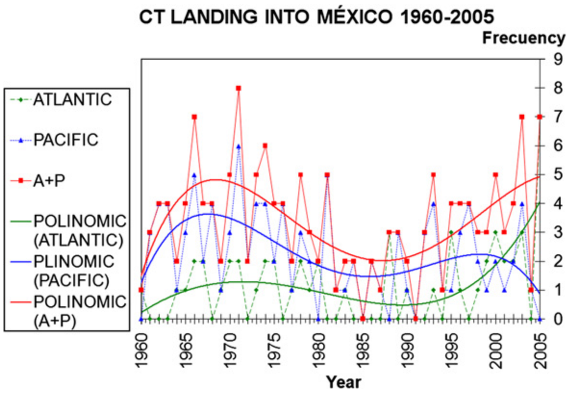

Fig. 12. Cyclical behavior of the TS landing in Mexico.

"*peck effect*" associated with the variability of solar outputs, mainly solar-wind disturbances, that make the geospheric system react in a highly non-linear way to the sporadic or intermittent signals produced by the interaction of the solar plasma and shock waves with the earth environment (Pérez-Peraza, 1990): such interaction is highly sensitive to the relative position between transient output events on the sun, the heliospheric neutral current sheet ant the orientation of the interplanetary magnetic field (IMF) at the earth. A kind of "*detonator*" for stratospheric cyclonic activity occurs when a boundary sector of the IMF crosses the earth, which effects spread in lower altitudes and in longitude and latitude. This indicates that our earth environment is such a sensitive system that even second order effects may disturb it. In the present case, it seems we are dealing with the same influence factor – the solar plasma from an elevated solar activity, since the presence of a peak in SS is usually well expressed. Therefore, because of the faster influence of SS over geomagnetic field and CR intensity, these could be taken as accompanying precursors.

Looking in the changes of the parameters accompanying farther the development of the cyclone after its start (especially in Fig. 6), we could deduce that their influence is not negligible. But it is still difficult to establish an acceptable mechanism unifying all these physical phenomena. Nevertheless, though this work only concerns cosmophysical aspects, it is worth noting here that these effects on hurricane development may be on the same order of importance that some terrestrial effects, as is the case of the dust cover originated in African dust outbreaks (Evan et al., 2006; Lau and Kim, 2006). At this regard we have done an spectral analysis of coherence by the wavelet method mentioned in next section, for North Atlantic tropical cyclones of all categories together versus cosmic rays (Fig. 13) and versus African dust outbreaks (Fig. 14) for the period 1982–2005: the upper panel of each figure shows the time series of the data involved. The significance level gray scale appears at the bottom of the figure, in particular the 95% significance level is inside the black contours occurrence. Horizontal arrows indicate a simple linear relationship between the variables. Arrows pointing to the right mean correlation (in phase) and an anticorrelation (in antiphase) is indicated by a left pointing arrow. Non-horizontal arrows refer to a more complicated (non-linear) phase difference. The uncertainties of the peaks appearing in the global coherence spectra are obtained from the peak full width at half maximum. It can be seen from Figs. 13 and 14 that the coherence between the total numbers of North Atlantic tropical cyclone and the cosmic rays is strong within the 1.3 and 1.7 years periodicities for long times. Variations seem to be in phase from 1987 to 1991 with coherence 0.6 when they switch to antiphase between 1996 and 2002 with coherence higher than 0.9. The coherence between the total numbers of North Atlantic tropical cyclone and the dust is around 0.7 within the 1.3 and 2 years periodicities, for long times with complex non-linear phases. We have found that the coherence at similar frequencies is better with cosmic rays than with dust. Cosmic rays and hurricane phenomena present an antiphase correlation, whereas dust and hurricane phenomena present a non-linear complex correlation. Such an exhaustive analysis is in process and preliminary results will appear in Pérez-Peraza and Velasco (submitted for publication).

Going back to the main question: could we forecast the creation of a dangerous vortex on the basis of preceding CR, SS, and AP peculiar data changes?

The answer is we are still not able to do that firmly. But, looking at our results we could be strongly alerted if a package of large SS and AP fluctuation, together with a

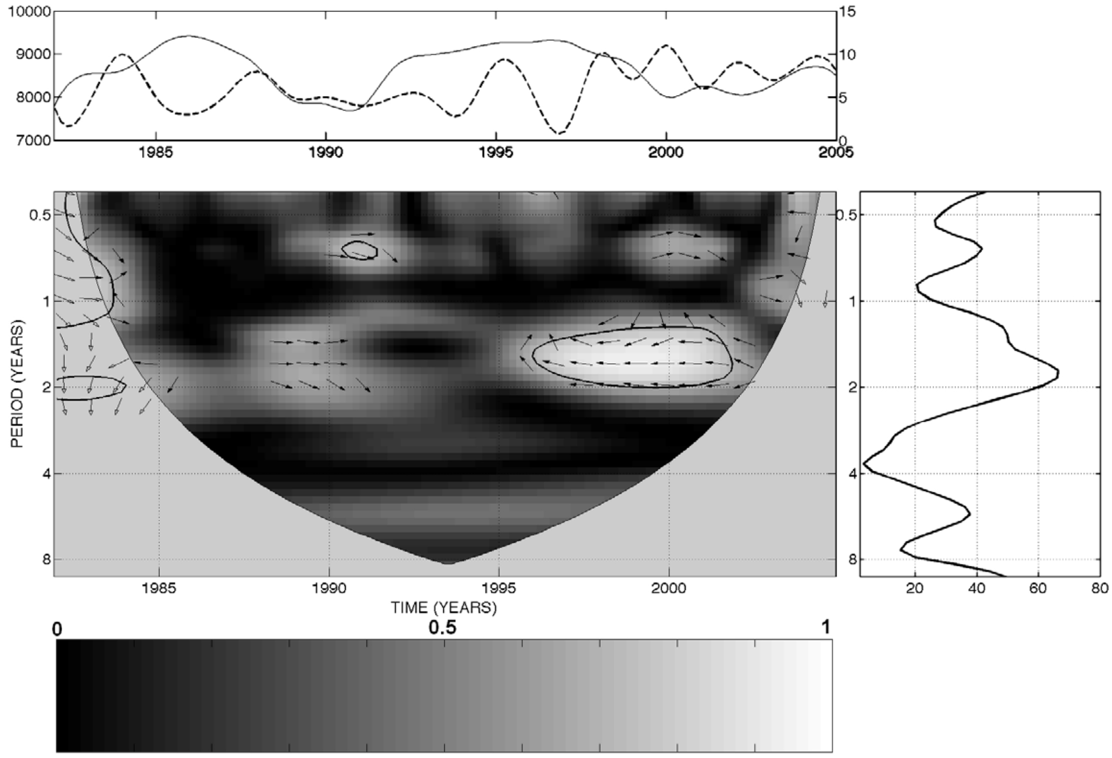

Fig. 13. Cosmic rays versus total number of North Atlantic tropical cyclones of all categories together. Coherence around the frequencies of 1.3 and 1.7 years: 0.6 in phase from 1987 to 1991 and ~0.9 in antiphase from 1996 to 2002, according to the scale of the bottom.

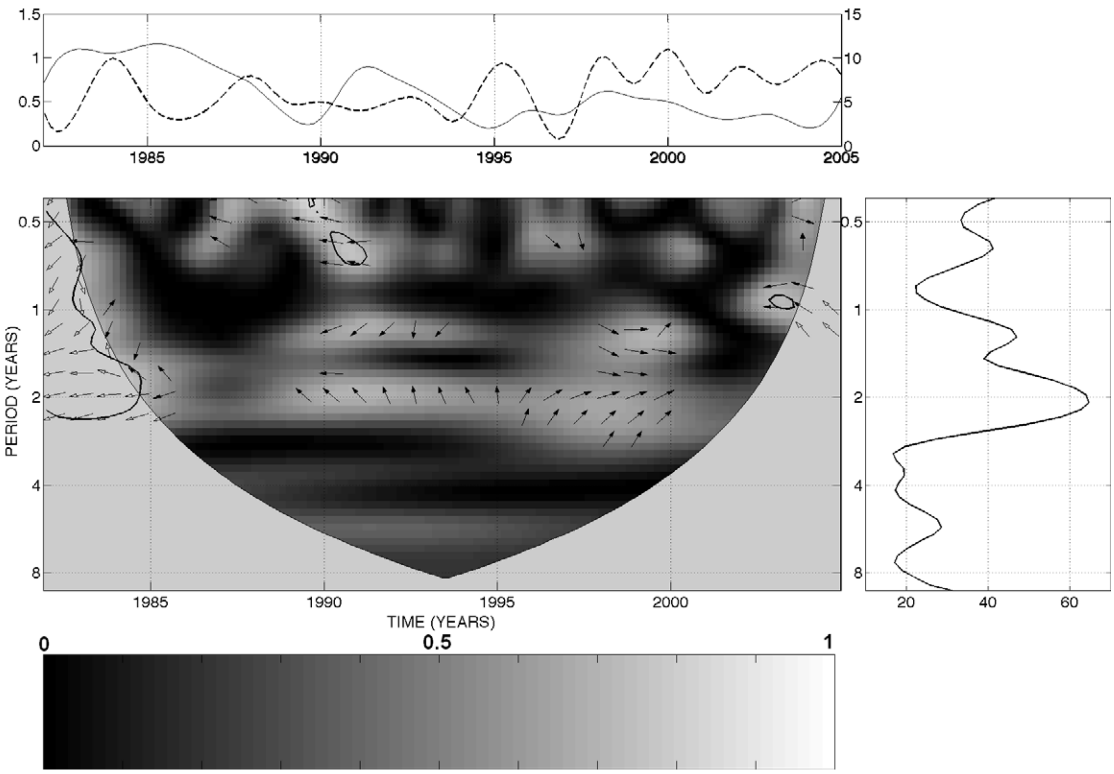

Fig. 14. African dust outbreaks versus total number of North Atlantic tropical cyclones of all categories together. Coherence around frequencies of 1.3 and 2 years: 0.7 with variable phases between 1982 and 2002, according to the scale of the bottom.

Forbush decrease appears at the end of the summer. Then investigating all the parallel atmospheric data we could be closer to the most probable prediction.

6. Conclusions

One of the main enigmas of solar-terrestrial physics is to know, how and when the periodicities of solar magnetic activity do modulate the terrestrial climatic changes. Some insights have been obtained: for one side, the solar Hale cycle (20–25 years) and changes in solar activity for the last 500 years have been studied (e.g. Raspopov et al., 2005), with the aim of revealing a possible contribution of solar activity to generation of climatic variability, and on the other hand, the quasiperiodic climatic oscillations with periods of 20–25 years have been revealed in analysis of parameters such as ground surface temperatures, drought rhyme, variations in sea surface temperature, precipitation periodicity, etc. (e.g. Ol', 1969; Cook et al., 1997; Pudovkin and Lyubchich, 1989; Pudovkin and Raspopov, 1992; White et al., 2000; Roig et al., 2001; Raspopov et al., 2001; Khorozov et al., 2006).

The *correlational* analysis developed in this work indicates the possibility of a certain relation between two time series, however, this is of global nature and does not furnish us precise information about when such a relation occurs: the fact that two data series (solar and climatic) have similar periodicities does not necessarily implies that one is the cause and the other the effect; besides, even if the correlation coefficient is very low, that does not means that there is no relation, but there is the possibility that such a relation could be of non-linear nature, or that there is a strong phase shift between the solar activity phenomenon and the plausible associated terrestrial effect. It is worth noting, that the TC landing into Mexico, the total number of TC and the number of category 4–5 in the Northwest Pacific basin, the potential destruction index (PDI) as well as the total cyclonal energy (CE smoothed) show a similar cyclic behavior of 30 years. Besides, the number of TC of category 4–5 shows positive correlations, ranging from 0.55 to 0.65 with vorticity (rotational flow), vertical wind shear and the lower tropospheric moist static energy. In contrast, as previously mentioned, there is a very weak anticorrelation of −0.3 between storm intensity and sea surface temperature (SST), similarly to those found for our parameters (Table 2).

A way to analyze two non-stationary time series to discern whether there is a lineal or non-linear relation is by means of the coherence wavelet method which furnish valuable information about when and which periodicity do coincide in time, and then about its nature, lineal or non-linear relation between the solar and terrestrial phenomena, provided there is not a noticeable diphase among them. The squared coherency is used to identify frequency bands within which two time series are covarying. Wavelet squared coherency is a measure of the intensity of the covariance of the two series in time–frequency space. If the coherence of two series is high, the arrows in the coherence spectra show the phase between the phenomena, arrows at 0° (horizontal right) indicate that both phenomena are in phase and arrows at 180° (horizontal left) indicate that they are in antiphase, it is very important to point out that this two cases imply a linear relation between the considered phenomena; arrows at 90° and 270° (vertical up and down, respectively) indicate an out of phase situation which means that the two phenomena have a non-linear relation. *Based on this explanations we may state that the wavelet coherence is especially useful in highlighting the time and frequency intervals where two phenomena have a strong interaction* (Velasco and Mendoza, 2007). This must be done with data of cosmic rays, solar indexes (wolf number, radio in 10.3 cm, coronal holes) versus parameters of the hurricanes (vorticity, linear velocity, duration, energy, PDI, ACE, storm intensity) as well as with climatic phenomena, presumable associated with hurricanes, as for instance the Atlantic Multidecal Oscillation AMO (Goldenberg et al., 2001), (SST), the lower tropospheric moist static energy, and vertical wind shear. There is the possibility that the periodicity of 30 years could be associated in a non-linear way to the solar Hale cycle (Raspopov et al., 2005) with a certain phase shift. Results concerning CR, SS and hurricanes analysis by the Wavelet method have been reported in (Pérez-Peraza et al., in press).

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