

ASSESSMENT OF THE STATE OF NATURAL WATER RESOURCES AND PREDICTION OF THEIR DYNAMICS IN NEAREST DECADES

Ago Jaani¹, Igor Libin², Mykolas Mikalajūnas³, Jorge Perez-Peraza⁴, Olga Sizova²

¹ Ministry of the Environment of Estonia, Narva str. 7a, 15172, Tallinn

E-mail: ago.jaani@envir.ee

² International Academy of Appraisal & Consulting, 1-st Shchipkovsky str. 1, 115093, Moscow

E-mail: libin@bk.ru, post@maok.ru

³ Vilnius Pedagogical University, Studentų str. 39, LT-08106, Vilnius

E-mail: geogr.kat@vpu.lt

⁴ National Autonomy University of Mexico (UNAM), Ciudad Universitaria Del. Coyoacan, Mexico D.F., CP 04510, Mexico

E-mail: perperaz@tonatiuh.igeofcu.unam.mx

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Abstract. The permanent monitoring of the state of water resources in the territory of the Russian Empire was started in the lakes Chud and Ladoga as far back as the beginning of the 19th century. Some time later, similar monitoring was started in the Lake Baikal.

Since the 70ties of the 20th century, Ago Jaani from Estonia has been the most authorized researcher of the Lake Chud. Thanks to him, at the beginning of the 90ties, an international group of researchers from Russia, Mexico, Estonia and Lithuania undertook a task to assess the water resources of the Lake Chud and Lake Pátzcuaro (Mexico) (Либин, Речи, 2008).

A few international experiments for investigation of water level fluctuations (related with Solar activity) in the Chud and Pátzcuaro lakes were carried out in the Mexican, Russian and Estonian territories (1988–2006). Based on the results of these experiments and observation data for more than 100 years, attempts were made to work out a prognostic model allowing a rather precise estimation of water resources in the mentioned countries.

References 45. Table 1. In English, summary in Lithuanian.

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Introduction

As far back as the 30ties of the last century, the famous Russian scientist L. A. Chizhevsky (Чижевский, 1976) and American physician Henry Clayton (Clayton, 1933) offered an assumption about the dominant impact of Solar activity on a complex of phenomena and mechanisms taking place in the atmosphere and hydrosphere of the Earth.

Beginning with the 80ties of the last century, the problem of the impacts of Solar activity on the weather conditions and hydrological processes has been many times discussed in scientific literature (Borzet, Ehlert, von Storsh, 2008; Gough, 1986; Libin, Mikalajūnas, Yudakhin, 1987; Perez-Peraza et al., 1999; Анализ, 2007; Ариэль, Шахмейстер, Мурашова, 1986; Биелекова, 1984; Витинский, Копецкий, Куклин, 1986; Дорман и др., 1978; Дорман и др., 1987а; Дорман и др., 1987б; and others). The first attempts to obtain quantitative estimates of water resources of the Lake Chud in relation with the oscillations of Solar activity were taken by the authors in 1989 (Либин, Яани, 1989; Либин, Яани, 1990). Yet available mathematical models at that time were not adequate for answering the question on the relationship between the water level and Solar activity.

The present work is an attempt to find out the unstationary and quasi-stationary correlation links between hydrological processes and Solar activity.

Application of qualitatively different statistical methods (Perez-Peraza et al., 1999; Гулинский и др., 1992; Либин и др., 1996а; Либин и др., 1996б; Либин, 2005) and calculation techniques in finding out the links between various processes and the existence of original scheme for simulation of the mechanism of interrelations between heliophysical and geophysical processes allowed obtaining fairly reliable results.

1. Analytical methods

The assessment of water resources is based on determining the delays, specifying their magnitudes and analysing general cycles of the data of water resources in closed aqua-systems (lakes) and Solar activity.

For this purpose, the authors used the traditional methods of spectral analysis (modified according to the assumption about quasi-stationary character of the studied processes) and methods of autoregressive spectral analysis (suitable for unstationary processes).

Analysis of Solar activity parameters (Wolf's index, the areas covered by the sunspots, intensity of coronal line with wave length 5303 angstroms, HL index, and Solar radiation at frequency 10.7 cm) and water levels in lakes was carried out combining the methods of correlation and Tuki spectral analysis (Perez-Peraza et al., 1999; Peppler et al., 2008; Андерсон, 1976; Бендат, Пирсол, 1983; Кей, Марпл, 1981; Фортус, 2007) as well as the methods of autoregressive spectral analysis (Дорман и др., 1987а, Дорман и др., 1987б, Либин, и др., 1992, Либин, 2005, Прилуцкий, 1988).

The analysis was based on the average monthly values of Solar activity (areas covered by sunspots, HL-index, and Solar radiation at frequency 10.7 cm), cosmic rays, subaerial temperature) (Friis-Christensen, Laseen, 1992) and water levels of isolated lakes in Mexico (Pátzcuaro), Estonia–Russia (Lake Chud) and Russia (the Caspian Sea and the Baikal Lake) for 1880–2006.

The choice of relevant intervals of analysis (we adhered to Solar cycles and slid across the database at the intervals of 5 years; thus only the last neighbouring results were partly interdependent), was followed by calculations using the standard procedure described in (Либин и др., 1994).

In spite of the variability of applied methods, it should be understood that reciprocal spectra of magnitude produce rather reliable quantitative estimates of the link between the observed processes and allow evaluating the shifts between them yet the plausibility of a number of derived relationships is on the verge of reliance.

It should also be born in mind that the reliability of the obtained results of calculating the reciprocal spectra of magnitude largely depends on the skills of researcher (choice of the analytical methods and approach to evaluation of the plausibility of obtained results).

For this reason, autoregressive spectral analysis first described by (Прилуцкий, 1988; Либин и др., 1992) was applied as an additional plausibility criterion.

The autoregressive analysis differs from the standard methods as it makes it possible to evaluate the relationships between the analysed series of data with 100% reliability within a frequency region and, what is still more important, it can be employed for analysis of quasi-stationary (and even sometimes unstationary) processes as are the ones represented by the data series on water levels and Solar activity.

On the other hand, it should be born in mind that all amplitude estimates derived by autoregressive analysis are relative and cannot be absolutely related with the initial series though temporal dynamics of amplitude estimates is quite comparable.

In other words, though we cannot absolutely reliably correlate the calculation results of amplitude spectra with the input data the pattern of their temporal dynamics is quite unambiguous.

2. Objects of investigation

2.1. The Lake Chud (Peipsijärv in Estonian) is one of the largest lakes in Estonia and Russia situated on the border between these two countries. It covers an area of 3,500 km² being the fifth largest lake in Europe. The total catchment basin of the lake (including the area of the lake itself) amounts to 47,800 km². The catchment basin extends in meridional direction for almost 370 km from 56°10' to 59°30' N. The average width of the basin is 160 km (the data about the Pskov–Chud Lake for 1983). The lake itself also extends in meridional direction for almost 140 km and is situated between 57°51'–59°01' N and 26°57'–28°10' E. It is composed of three parts differing in morphometric and regime characteristics yet constituting one body of water. The average long-term water level being 30 m, the volume of the water mass amounts to 25.07 m³. The lake is shallow: the average depth is about 7 m. The lake has about 240 tributaries the largest among them are: Velikaja (the area of the

catchment basin is 25,200 km²), Emaigi (9,960 km²), Vychandu (1,410 km²), and Zhelcha (1,220 km²).

The beginning of regular observations of the Lake Chud was related with high floods which inflicted great damages in 1840, 1844, and 1867 and with reduced catches. Academician K. Ber who headed the commission of 1851–1852 made a conclusion that the water level in the lake was gradually rising. Yet already in 1864, Academician G. Helmersen pointed out the beginning of the process of the water level fall. In 1896, I. B. Schpindler analysed the possibility of building the Chud–Baltic track but found no evidence proving the common opinion about the falling water level in the Lake Chud. It was discovered for the first time that the lake water level was fluctuating in the course of time. The discovery motivated the opening of the first hydrological stations on the Lake Chud in 1902. One of these old stations (in the Vasknarva village) is still operating.

In 1921, a hydrological station was installed in Mustvea. Today, it is the key station possessing a continuous and high quality data series. Using the information stored at all the stations, a fairly reliable data series of average monthly and yearly water levels in the Lake Chud (constituted of three parts) for the time frame of 102 years has been obtained:

- Daily field data from Mustvea station since 1921. (The lacking observation data for 1937 and 1941–1944 has been restored with high accuracy based on the observations on other stations);

- The average monthly values obtained by Mustvea station in some periods during 1903–1917 have been restored based on the correlation with the water level data from Vasknarva station;

- The average yearly values obtained by Mustvea station in 1885–1902 and 1918–1920 have been restored by correlation with the values of water level in the Emaigi River (correlation coefficient 0.92).

As was mentioned above, 1840–1844 were the “deluge” years in the 19th century. A high water level also was observed in 1867 (after 22 years) and presumably in 1979–1884. In the period of instrumental measuring, the highest water levels were observed in 1924–1928, 1957 and 1987.

The cyclic character of water level fluctuations was pointed out by A. Velner in 1940 and T. Eipre in 1971. A. Jaani (Jaani, 1973) suggested that presumably the maximal water levels occurred in the time spans of minimal Solar activity. He discovered long-lasting (19–34 years long) cycles of water level fluctuation (similar to the so called Brikner cycles) and short-lasting cycles (4–5 years long) within centuries.

In 1981, A. Reap (Reap, 1981) distinguished cycles lasting for 6.1–6.4, 10–11 and 80–90 years. Also he suggested that the 11-year cycle of runoff minimum in the North-Western rivers occurred 1–3 year after the peak of Solar activity and the maximum runoff occurred 2–4 years before the minimal Solar activity.

2.2. The Lake Baikal is one of the oldest lakes on the planet. Scientists assume that it is 25 million years old. Most of the lakes, glacial lakes in particular, exist 10–15 thousand years until they are filled with sediments and disappear from the face of the Earth. As distinct from many other lakes in the World, Baikal shows no signs of ageing. On the contrary, results of recent geophysical investigations imply that Baikal is an ocean in its rudimentary stage.

Any reference to the Lake Baikal brings back the fact known from the childhood that the lake contains up to 1/5 of the available drinking water of the planet. Though Baikal is inferior to the Great American lakes Superior and Huron and the Great lakes in Africa Victoria and Tanganyika in the area of the water surface it is an unquestioned champion among lakes in the volume and depth (by different estimates from 1,625 to 1,750 m).

The size of the lake is really impressive. The water surface of the lake occupying an area of 1,500 km² is larger than the territory of some countries as, for example, Belgium or Israel whereas the area of its largest island Olchon exceeds the area of European countries such as Andorra, Lichtenstein, San Marino, Monaco and Vatican put together.

Baikal is situated in a 1,500 km long and 500 km wide rift valley and contains 23,000 km³ of clean fresh water. The gigantic volume of water performs the role of stabilizer of the climate in the lake environs. Summers in the Baikal region are cooler and winters warmer than in other regions of East Siberia.

The area of the catchment basin of Baikal is more than half a million square kilometres. The water inflowing with the rivers Selenga, Barguzin and Upper Angara stays in the

lake for 400 hundred years before flowing out through the Angara River. This explains the uniquely clean water of the lake. A high concentration of oxygen in the lake water even at greatest depths can be pointed out as one of the most important differences of Baikal from other deep lakes. Perhaps due to this the ice cover develops on the Lake Baikal rather late (in January) and melts away only in June–July.

The first scientifically reliable evidence about Baikal appeared in the 17th century. In the middle of the 17th century the first “scheme of Baikal” was made. The regular scientific studies of Baikal in the second half of the 19th century were first of all associated with the names of Benedikt Dybowski and Viktor Godlewsky (exiles of Polish uprising of 1863–1864) who laid the foundations for investigations of bottom relief of Baikal, bottom sediments, temperature and ice regimes and Baikal winds.

Unfortunately, regular reliable observations of water level in the Lake Baikal were started only in the 20ties of the last century by scientists from the Irkutsk State University. For this reason, only the data series from 1921 are used in the present work. However, there is a possibility to restore (though not with high reliability) the data about the Baikal water level back to 1880.

The data on the water level of Baikal are of paramount importance not only because the lake is one of the largest fresh water basins but also because dramatic fall (or rise) of water level represents a hazard for the unique ecology of the region. The Lake Baikal is a unique system self-regulating its water level. This process should not be interrupted. After the construction of the Irkutsk hydroelectric power plant, the average water level of Baikal has increased by 1 m. However, the amplitude of water level fluctuations and its maximal benchmarks remain within the old limits. In the last ten years, the water level in the Lake Baikal markedly fell down its minimal values reaching the ones that used to be before the construction of the power plant.

Since 2000, the state of the Lake Baikal “holding” a ten-year runoff of Volga, Ob, Yenisei, Lena, and Amur put together, has not undergone any marked changes though there have occurred some extraordinary situations. The first alarm bell pealed out in the middle of 2003 when the water level in Baikal became critical. This was caused by low water of its main tributaries since 1996. In seven years, 382 km³ of water was carried into Baikal by these rivers, i.e. only 90 % of the norm. In the first half of 2003, the lateral runoff into the Bratsk water reservoir was 1.5 times as low as normal. In 2002 and 2003, the water level in Baikal approached the minimal permissible value of 456.0 m. On May 8 and 9, the minimal average daily value of Baikal water level in 2003 was recorded (456.02 m). However, already in August of 2003, the water level rose and in October of 2003 reached 456.71 m. The situation normalized though a possibility of its recurrence remains.

Nevertheless, the drop of the water by the hydroelectric power plant which lasted from the October of 2007 till January 29 of 2008 again reduced the Baikal water level to almost 456 m. As a result, in April 2008 the water level of the lake could have fallen to the benchmark of the driest years. Fortunately, by the October of 2008 the water level restored. The described incident demonstrates the importance of distinguishing between the natural processes and anthropogenic impacts.

2.3. The Lake Pátzcuaro (central coordinates 19°35' N and 101°35' W) is an Alpine lake resting at the highest elevation (2,220 m above sea level). Its size is 20x14 km and the average depth being 50 m. Very clean fresh water is the greatest treasure of the lake. It is one of the main fresh water sources in the state Michoacán. The first mentioning of the Lake Pátzcuaro goes back to 1526 immediately after the conquest of the laky land by Spaniards and building of Pátzcuaro town. Regular observations of the water level in the lake started in 1921 on a hydrological station situated 3 km from Pátzcuaro and on a hydrological station on the Janitzio Island. Other hydrological stations were equipped on the western bank of the lake and in the Jaracuaro Island.

Beginning with the 30ties of the last century, the Government of Mexico has taken different measures in the field of lake monitoring and control and has made the necessary investments into the network of hydrological monitoring and complex monitoring of the surface and subsurface waters in the region of the Lake Pátzcuaro. Since then, the data about the water level in the lake have been fairly reliable.

3. Spectral and autoregressive analysis of the water resources (water levels in lakes)

For the first time, the results of preliminary estimates of spectral characteristics of water level of the Lake Chud and Solar activity were published in (Либин, Яани, 1989): the existence of statistically significant variations of water level, cycled 4–5, 11, 22, and 80–90 years, were reported.

The author has established that the delays of water level change in relation with Solar activity oscillate from 1.5 to 3–4 years and depend on the Solar activity. For odd cycles, the delay of maximum of water level is two years after the minimal Solar activity and for even cycles about three years. Moreover the structure of histograms of water level for odd and even cycles differs supporting the assumption about the dominance of 22-year cycles in hydrological processes (Либин, 2005).

Comparison of the spectral analysis results obtained by the author with similar spectra of galactic and cosmic rays showed a rather good correlation not only of frequencies but of phases as well (See the works of Attolini, Ceccini, Galli, 1983; Attolini, Ceccini, Galli, 1984; Attolini, Galli, Cini Castagnoli, 1985; Pandey, Jain, Garde, 1983; Venkatesan, 1990; Джалиашвили и др., 1984; Джалиашвили и др., 1985; Дорман и др., 1987а; Зильс и др., 1987). According to the measured values of cosmic rays, in 1952–2006 there occurred variations well correlated with the Solar activity and subaerial temperature and cycled 5–6 months, 1 year and 11 years coinciding with the variations of Solar activity and temperature within the same time frame.

The estimates of spectral characteristics of water level fluctuations in the Lake Chud with the aid of APMA-model of the 7th order for the time frame 1921–2006 showed distinct patterns of water level fluctuations, cycled 1.0–1.2, 9.0–11.0, 21.5–22.8 and presumably 80–90 years, related with Solar activity. Similar results of spectral analysis from the Lake Pátzcuaro for 1932–2004 and Lake Baikal for 1927–2006 offer the same picture: the presence of cycles of 1–2, 9–11, 22 and 90 years.

It is absolutely evident that the discovered periodicities are related with Solar activity and include one type of delays in respect to Solar activity within odd and even cycles. Moreover, the calculations revealed that on the background of relatively stable yearly, 11-year, 22-year and 90-year variations of water level (as also other meteohydrological parameters) the instability of variations in other periods stands out. (The fluctuations within cycles of a few months to 4 years occur not in all cycles of Solar activity though well reiterate the Solar rhythmic).

To make certain about the reality (reliability) of the obtained estimates, a full autoregressive analysis of water level fluctuations of the three lakes and Solar activity was carried out in the following sequence:

1. ARMA analysis of water level fluctuations in the lakes Pátzcuaro, Chud and Baikal for each of the years of 1932–2006,
2. ARMA analysis of fluctuations of water level in the Lake Chud and Solar activity for the same period (based on the available data),
3. ARMA analysis of fluctuations of water level in the Lake Pátzcuaro and Solar activity (based on the available data),
4. ARMA analysis of fluctuations of water level in the Lake Baikal and Solar activity (based on the available data),
5. Combined multidimensional ARMA analysis of the water level fluctuations in the three lakes and other meteohydrological and hydrological parameters and variations of the intensity of galactic cosmic rays in the Earth (based on the available data for 1951–2006).

The behaviour of the water level in the lakes Pátzcuaro, Chud and Baikal in the time frame 1921–2006 revealed at least two amazing peculiarities: the 22-year fluctuations are very distinct and, what is more important, the fluctuations in the lakes Pátzcuaro and Baikal are in a counter-phase with the fluctuations in the Lake Chud. The estimates of the mutual correlation function for Pátzcuaro–Chud yield an anti-correlation of the order of 0.6 with a delay of the order of 1–2 years. Analysis of the behaviour of the lakes Chud and Baikal does not yield such a beautiful picture (the anti-correlation value is about 0.4) though a 22-year cycle in the behaviour of water level for Baikal also is apparent.

The obtained results are in a good correlation with the results on the Lake Chud reported by other researchers (Table).

It is rather difficult to identify the obtained analytical results in all studied datasets with the results reported in literary sources. It is necessary to know the level of reliability of estimates obtained by other authors. As regards our results, we can assure that the estimates of the distinguished periods, including the period of 28 years, obtained by independent methods (“Gusenica” method (Рождков, 1988)) and method of autoregressive analysis coincide.

Table. Cycles of water level fluctuations (the Lake Chud)

Author	Cycle (number of years)					
Jaani		5.1–8.0		19–34	80–90	
Reap		5.1–6.4	10–11		80–90	
Doganovski				26 and 33		
Libin, Jaani	2.6		11.2	22	80–90	
Libin, Jaani	2–4		9–11	22		
The present work on 3 lakes	2.6	5.4–7.0	11.0–12.8	22.1–23.0 28.0–35.0	84–91	300–380

Autoregressive analysis of water level fluctuations of the three studied lakes (based on average yearly values) has proved the existence of well-expressed fluctuations cycled 11, 22, 35, 90 and 380 years. Moreover, the coherence of the both processes is in general rather high. For 22-year and 90-year cycles of fluctuations, the coherence coefficient (square of the correlation coefficient of processes at a given frequency) is 0.75–0.85 (for 11-year and 35-year fluctuations it is 0.6 and for 380-year fluctuations regrettably is only 0.4).

The amplitudes of the processes show a relative excess of water level fluctuations in the Lake Chud (related with Solar activity) in comparison with the Caspian Sea (by 40–60%), Lake Baikal (80–90%) and Lake Pátzcuaro (100–120%).

The ARMA analysis of fluctuations of water level in the studied lakes and Solar activity led to a few conclusions which could be important for the future forecasts of water level:

- The fluctuations of water level in isolated lakes fully reiterate the dynamics of Solar activity fluctuations,
- The delays of fluctuation in respect to Solar activity coincide with the delays of other hydrometeorological processes and reflect a common mechanism of the influence of Solar activity on the Earth’s climate.

4. Evaluation of the current water resources in Russia, Mexico and Estonia and their forecast

The application of the today available spectral apparatus and comparison of the results of various spectral estimates show that the cyclic Solar activity and its influence on the Earth’s atmosphere is the main driving force of the mechanism of the influence on water level fluctuations of isolated lakes (Либин, 2005). The results obtained in different works allow using autoregressive forecast model, applied by the author (Либин, 2005), for prediction of the water level of isolated lakes. The accuracy of the model can be improved by specification of the used predictors (the current estimates yield quantitative forecasts with error of 35–40%).

The results of estimates based on a vast set of measured data show a probable interrelation of Solar processes and Earth’s atmosphere. Moreover, analysis of delays of atmospheric processes in respect to Solar activity shows the existence of stable shifts of 12 to 42 months between the processes what is in good correlation with the estimation results by other methods (Башкирцев, Машнич, 2004; Реап, 1986; Рождков, 1988).

Moreover, it has been discovered that for simultaneous analysis of water levels in the lakes in different parts of the Earth and Solar activity (as is the analysis of temperature oscillations) the choice of indices of Solar activity does not play the central role: the areas covered by sunspots in the near-equator zone of the Sun are the most acceptable index for estimates (as has been used by the authors earlier) (Либин, 2005).

For this reason, solutions of the tasks of discovering the mechanisms of large-scale processes in the atmosphere or the attempts to develop forecast models for climatologic or hydrological processes it is necessary to take into consideration the dynamics of Solar activity, processes in the interplanetary space and variations of cosmic rays observed in the Earth.

Based on the described results of autoregressive forecast model, the authors assume a slight rise of water level by 2020 related with Solar activity in the studied three lakes.

For Baikal, the estimate of the rise of water level is 1.0 %, for Chud 2.5 % and for Pátzcuaro 3.0 % (provided that there do not occur technogenic disasters leading to extreme water losses by the lakes as was the case with Baikal at the end of 2007).

Conclusions

The estimates of spectral characteristics of water level fluctuations in the Lake Chud with the aid of APMA-model of the 7th order for the time frame 1921–2006 showed distinct patterns of water level fluctuations, cycled 1.0–1.2, 9.0–11.0, 21.5–22.8 and presumably 80–90 years, related with Solar activity. Similar results of spectral analysis from the Lake Pátzcuaro for 1932–2004 and Lake Baikal for 1927–2006 offer the same picture: the presence of cycles of 1–2, 9–11, 22 and 90 years. Also one interesting feature occurred: the fluctuations in the lakes Pátzcuaro and Baikal are in a counter-phase with the fluctuations in the Lake Chud.

The delays of fluctuation in respect to Solar activity coincide with the delays of other hydrometeorological processes and reflect a common mechanism of the influence of Solar activity on the Earth's climate. The areas covered by sunspots in the near-equator zone of the Sun are the most acceptable index for estimates.

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Ago Jaani¹, Igor Libin², Mykolas Mikalajūnas³, Jorge Perez-Peraza⁴, Olga Sizova²

¹Estijos aplinkos ministerija, Talinas

²Tarptautinė vertinimo ir konsultavimo akademija, Maskva

³Vilniaus pedagoginis universitetas

⁴Meksikos nacionalinis autonominis universitetas, Meksikas

Gamtinių vandens išteklių būklės įvertinimas ir prognozė artimiausiems dešimtmečiams

Santrauka

Čiudo (arba Peipaus) ežero hidrologijos stotis turi sukaupusi 102 m. duomenis apie ežero vandens lygio svyravimus. Estijos mokslininkas Ago Jaani yra vienas rimčiausių šio ežero tyrinėtojų. Jo iniciatyva praėjusio amžiaus paskutiniame dešimtmetyje tarptautinė tyrinėtojų grupė (Rusija, Meksika, Estija, Lietuva) užsibrėžė tikslą įvertinti Čiudo (Estija, Rusija), Baikalo (Rusija) ir Pátzcuaro (Meksika) ežerų vandens resursus. Išnagrinėję daugiau kaip 100 metų stebėjimų seką ir atlikę kai kuriuos eksperimentus mokslininkai ėmė kurti prognozės modelį, kuriuo būtų galima gana tiksliai įvertinti tų šalių vandens resursus. Tam buvo naudojamosi tradiciniais spektrinės analizės metodais, pritaikius juos kvazistacionariam nagrinėjamų reiškinių pobūdžiui, taip pat autoregresine spektrine analize, kuri taikytina ir nestacionariems reiškiniams. Vandens lygio svyravimai buvo gretinami su Saulės aktyvumo, kosminių spindulių ir kitais kosmogeniniais veiksniais. Aptikta, kad vandens lygio svyravimai atsilieka nuo Saulės aktyvumo atitinkamų ciklų nuo 1,5 iki 3–4 metų, priklausomai nuo Saulės aktyvumo ypatumų. Nelyginio ciklo atveju aukščiausias vandens lygis būna praėjus 2 metams po Saulės aktyvumo minimumo, o lyginiame cikle – maždaug po 3 metų. Be to, vandens lygio histogramos lyginiais ir nelyginiais ciklais skiriasi: tai dera su esama nuomone, kad hidrologiniuose procesuose vyrauja 22 metų ciklas.

Įvertinus Čiudo ežero 1921–2006 m. laikotarpio vandens lygio svyravimo spektrines charakteristikas 7-tos eilės ARMA modeliu, išryškėjo akivaizdūs 1,0–1,2, 9,0–11,0, 21,5–22,8 m. ciklai ir šiek tiek blankesnis 80–90 metų ciklas, o tai labai panašu į Saulės aktyvumo cikliškumą. Analogiški Pátzcuaro ežero 1932–2004 m. ir Baikalo 1927–2006 m. spektrinės analizės duomenys pateikia panašų paveikslą: 1–2, 9–11, 22 ir 90 metų ciklus. Ypač ryškus 22 metų ciklas, bet įdomu, kad Pátzcuaro ir Baikalo vandens lygio svyravimų fazė yra priešinga nei Čiudo ežero (kai vienur žemiausias lygis, kitur – aukščiausias).

Gretinant vandens lygio svyravimą įvairiose Žemės vietose su Saulės aktyvumu geriausia naudotis vienu iš Saulės aktyvumo indeksų – dėmių plotu Saulės pusiaujinėje juostoje, tačiau platesniems tikslams (klimato ar hidrologinių procesų prognozės modeliams kurti) būtina įvertinti ne tik Saulės aktyvumo dinamiką, bet ir procesus tarpplanetinėje erdvėje, Žemę pasiekiančių kosminių spindulių svyravimą.

Remiantis autoregresinio prognozės modelio duomenimis, prognozuojama, kad atsižvelgiant į Saulės aktyvumo poveikį vandens lygis iki 2020 m. pakils Baikale apie 1,0 %, Čiudo ežere – 2,5 %, o Pátzcuaro ežere – 3,0 % (žinoma, jei neįvyks kokia nors technogeninė nelaimė, kai ežerai netenka daugybės vandens, kaip buvo Baikale 2007 m. pabaigoje).