SOLAR ACTIVITY AND WATER CONTENT OF CLOSED LAKE ECOSYSTEMS

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Abstract

The question of "helio-dependence" of water level fluctuations within the closed type lakes in the Ukrainian West Polesie nature protected areas has been considered in the paper. The method of correlation analysis was used to define the interrelation between helio- and geophysical processes in the part that provides the ecological safety of the territory. The analysis has shown that the Total Solar Irradiance Index is more informative than the one including sunspot numbers.
Keywords: solar activity, sunspot numbers, total solar irradiance, closed type lake, water content changes, "helio-dependence".

1 Introduction

Today, the urgency of the problem of the impact of climate change ("global warming") on the state of the components of the geosystem requires a special study of the effects of the influence of factors of different origin, including anthropogenic and natural. However, if the influence of anthropogenic factors on the environmental stability of the environment is being studied very actively, the effects of the influence of factors of natural origin have been studied much less. This is especially true for such a specific issue as the impact of solar activity (SA) on the water content in lake ecosystems. This problem is very relevant today for the nature reserves of the West Polesie of Ukraine, given the considerable lowering the water level in the closed lakes in this territory. First of all, it concerns the largest in Ukraine freshwater lake Svityaz located on the territory of the transboundary (Polish - Byelorussian - Ukrainian) bioreserve "West Polesie".

The authors investigated the degree of «helio-dependence" of water level fluctuations in Lake Svityaz in accordance with the developed concept of studies of solar-terrestrial communications, the structure of which is presented in Figure 1 [1]. Only underground springs and meteorological conditions form the water balance of these type lakes (closed). In addition, their functioning is characterized by quasi-stationarity, ecological stability and self-regularity. The relevance of such studies in nature conservation areas is generally due to some contradictions in current estimates of the long-term dynamics of water levels of these lakes and the reasons for their fluctuations. In addition, specifically for the territory of Western Polesie the main question is the following: is the fluctuations in the water level caused by natural factors or anthropogenic interference with hydrology? [1]. Moreover, a long-term prediction of Svityaz Lake water level, from the ecological safety point of view, is also a topical issue owing to the fact that this lake is the main source of fresh water for ensuring the sustainability of this large region.

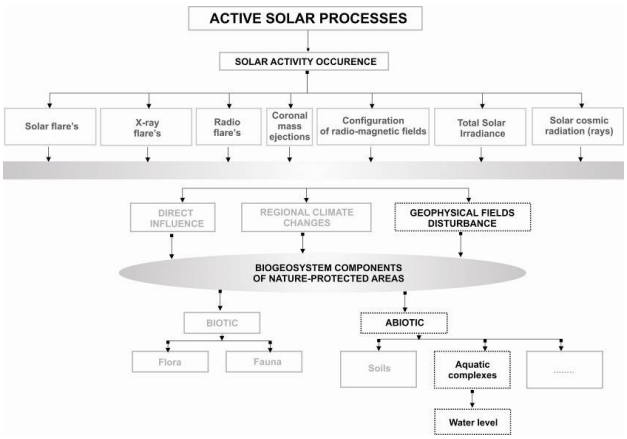


Figure 1. A concept of studying the solar-terrestrial links within the nature protected areas

2 Basic material

State of Researches of the Problem. In the present-day science, there is an opinion that it's necessary to take into account the influence of space factors, especially SA processes, on the geosphere and biosphere state [2]. There is a system of direct and indirect physical links between helio- and geophysical processes. The Earth receives from the Sun not only light and heat what provide sufficient level of lightening and temperature of its surface and therefore provides ecosystems stability. Also, the surface is influenced by the ultraviolet and x-ray, solar wind, solar and galactic cosmic rays etc.

V. Vernadsky was one of the first to show that the evolution of the geosphere (biosphere) proceeds under the influence of cosmic physical factors, and, cosmic rhythms affect terrestrial processes at all levels of the geo- and biosphere organization. Thanks to these fundamental studies, the problem of "geo-efficiency of SA processes" was outlined [2, 3].

Anyway, most of the terrestrial processes depend on cyclical changes of SA level. Today, the following periods of solar cycles (SCs) are confirmed, namely: 11 years (most distinct), 22, 30-40, 80-90, 500 and 1800-

1900 years. Therefore, it's natural to assume the existence of cycles solar origin in the water content fluctuations in closed type lakes. Investigations of "geo-efficiency" of SA processes within the "Sun-climate-geosphere" system show the intensification or weakening of geophysical processes during the solar cycle's maxima and minima [2, 3].

Dependences of water level dynamics (for the period 1850-1992) in closed-type lakes on cosmic factors in various limits of change of parameters of cosmic rays and SA (area of sunspots, index F10,7, HL-index) are considered on the example of the lakes of Patzcuaro (Mexico), Chudskoye (Estonia) and others [8–12]. Long-term (> 11 years) and short-term (2-4 years) oscillations of these processes were studied by spectral and autoregressive spectral analysis. As a result, significant changes in the water level with periods equal to 2.6-4.1, 9-11.2, 22 and 80-90 years have been established [4, 5].

Materials and methods. This paper presents the results of studies of «helio-dependence" of the water content in the closed-type Lake Svityaz during 22th-24th SCs, which also takes into account data on precipitation and air temperature, and more general dependences between space parameters and geophysical ones for the period 18th-21th SC [6, 7]. The authors performed these studies on the basis of data on regional geophysical processes (hydrological, climatic) and on the parameters of the SA during 22th-24th SCs. In particular: average annual values of air temperature (1929-2004, 1985-2005, 1969-2017, 2010-2017), monthly mean values (2010-2017) of water level in Lake Svityaz, precipitation, Wolf numbers and total solar radiation (TSI) (information from 7 satellites during 1978-2017).

The interaction of solar radiation with the atmosphere, geosphere and terrestrial hydrosphere determines the weather and climatic regimes of the Earth. Therefore, monitoring of TIC variability is an important part of climate change research, including in the context of the impact of SA on water content in closed lakes. Since 1978, NOAA has been creating a database using direct satellite monitoring (7 experiments: Nimbus7 / ERB1, SMM / ACRIM12, ERBS / ERBE3, UARS / ACRIM24, SOHO / VIRGO5, ACRIMSAT / ACRIM36, and SORCE / TIM7)] (Figure 2). Analysis of this database proves that the changes in SA parameters are the important stimulus for climate change in the Earth's surface atmosphere and changes in the state of the geosphere and biosphere components.

Figure 3 show a long-term dynamics of water level H_0 for Svityaz Lake, and also the regional annual air temperature T_{avr} during 22th-24th SCs, accordingly. Dynamics of relative changes of δW (relative to the Wolf numbers maximum W_{max} in the 22th SC), δH_0 (relative to maximum difference of average annual H_0 above the sea level during 22th-24th SCs) and δV (relative to maximum difference of precipitations average annual amount V_{max} during 22th-24th SCs) is shown on Figure 4.

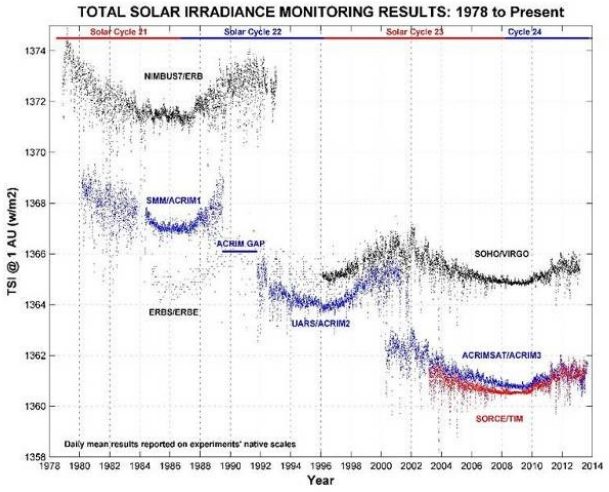
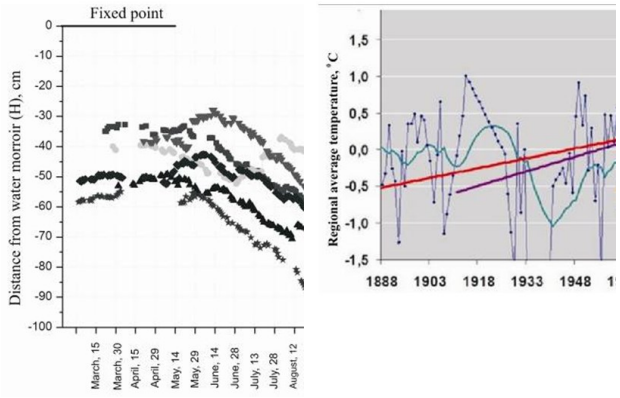


Figure 2. TSI satellite data during 1978-2014 [8].



a) b)

Figure 3. Dynamics of water level (H_0) monthly fluctuations in Svityaz Lake during 2010-2017 (a). Changes of regional average annual air temperature T_{avr} and their linear approximation during last 120, 100, 45 and 25 years (different inclination angles) (b).

The main task of current research is to estimate the degree and dynamics (for 22th – 24th SCs) of dependencies (by correlation coefficients r ($r_{V/W}$ $r_{H/V}$, $r_{H/W} = f(W,$ SC)) between the average values of H_o, CA (W, TSI) and regional climate (V, $T°_{n.avr,}$ $T°_{n.max}$) and compare them with respect to environmental ecological state and safety.

Results and discussions. A spectral-correlation analysis was used to study the "helio-dependency" of Svityaz Lake water content fluctuations. Basing on calculations of correlation coefficients r between $H_{o,}$ W, V and TSI, the following conclusions were formulated:

1. Svityaz Lake water system is a complicated fluctuating system with different periods of water content

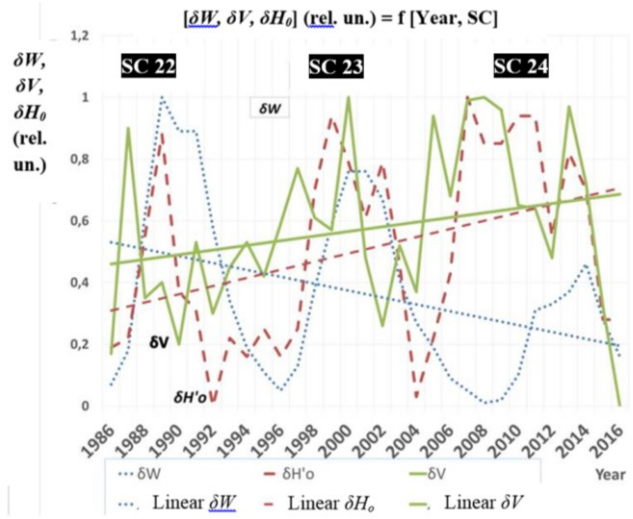
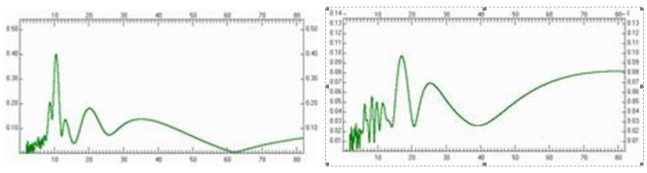


Figure 4. Relative changes (relative units) of Wolf number δW, of amount precipitations δV, and water level δH_0 average annual values as well as their linear trends during 22th-24th SCs.

changes and long-term (multiple-year) tendencies of its changes. The last depends on many external factors, viz. climatic (air temperature, precipitations), solar processes etc. Regional microclimate, mainly, influences the water level seasonal fluctuations (the water level during March-November 2010-2017 decreased as compared to 2015 by 39,3 cm).

2. The results of previous studies during 1929-2004 showed a clear 11-year cycle of oscillation of the spectrum of the number of sunspots W and almost absence cycle of 83 years. Speaking about the analysis of the spectrum of fluctuations in the water level, one can note the existence of a long-term trend (83 years) of H_o decrease, which may be due to the atmosphere circulation (Figure 5) [1]. The existence of cycles of 8-12 years within H_o and W the spectra of oscillations during 1929-2004 was also proved, when the 11-year cycles of W and V are almost similar, and their ratio is equal to $r_{V/W} \approx 0{,}76$.



a) b)

Figure 5. Fluctuations spectrum: a) sunspot number W; b) Svityaz Lake water level H_o (Y axis presents the amplitude % from the average value, X axis – period, years)

3. Approximation of parameters δW, δV and δH_0 changes during 22th-24th SCs (Figure 4) and comparative analysis of their linear trends (Figure 6) had showed a positive correlation between a long-term (during three SCs) changes of parameters δH_0 and δV. And, they showed the negative correlation between parameters δH_0 and δW that indicates on strong dependence between Svityaz Lake water level and precipitations amount.

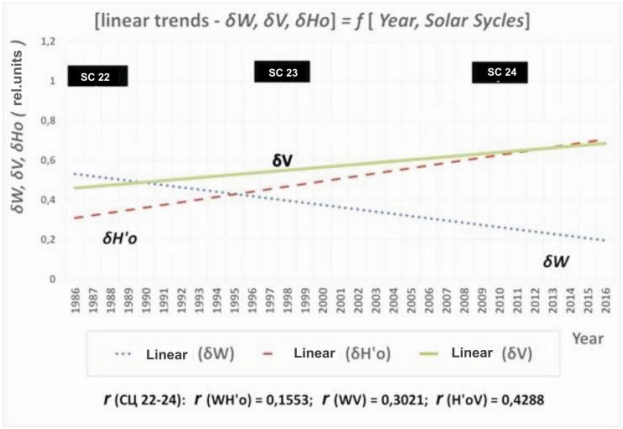
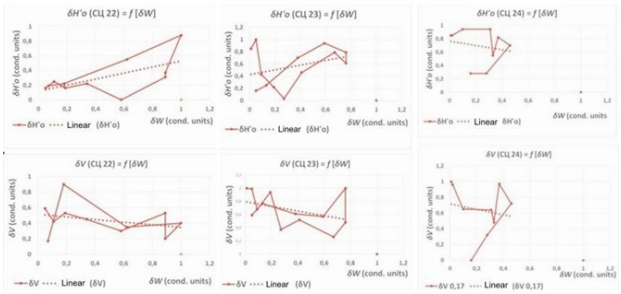


Figure 6. Linear approximation of relative changes trends during 22th-24th SCs (1986-2016) of average annual values: Wolf number δW, precipitations amount δV and water level δH_0.

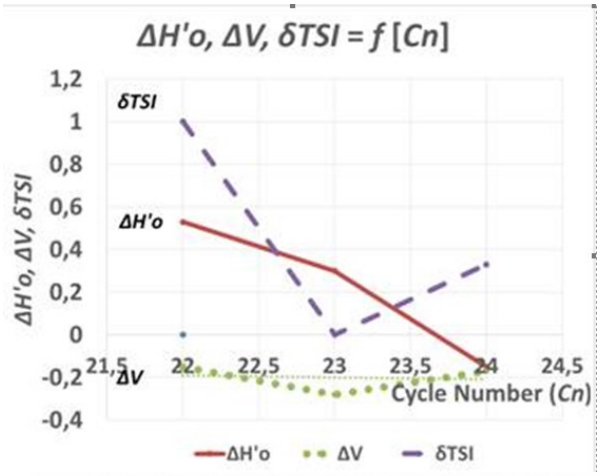
4. The dynamics of water level relative fluctuations δH_0 (relative to maxima) and precipitations amount δV had been defined within each of the 22th-24th SCs during the processes of increase and decrease (solid line) of relative change of parameter W (Figure 7) as well as of their linear trends (dotted line).



a) b) c)

Figure 7. Fluctuations dynamics of water level δH_0 and precipitations δV relative changes towards maximum during each SC under the process of increase and decrease of W relative change (dotted line-linear trends)*:* a) *in 22th SC,* b) *in 23th SC,* c) *in 24th SC*.

5. The dynamics of total solar irradiance relative changes $\delta TSI = \Delta TSI \,/\, TSI_{max}$ on relative changes of $\Delta H_0'$ and V during 22th-24th SCs, and the dynamics of correlation coefficients $r_{H0'/W}$, $r_{V/W}$ and $r_{H/V}$ are showed on Figure 8. These dependences evidences a significant influence of parameter TSI on precipitations amount (approximately linear dependence $\Delta H_0'$=f (ΔV) and "synchronicity" of δTSI and ΔV lines).



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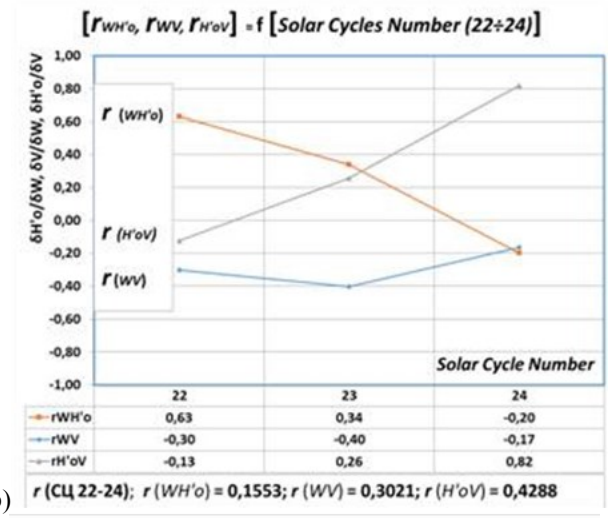

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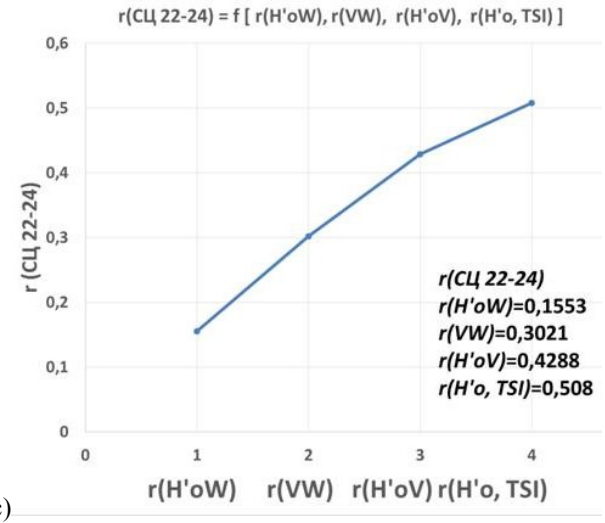

Figure 9. Dynamics of changes during 22th-24th SCs (1986-2016) of relative changes of water levels H_0', precipitations V and TSI (a). Dynamics of changes during 22th-24th SCs (1986-2016) of correlation coefficients between H_0', V and W (b). Estimation by coefficients of correlation $r_{H0'/W}$, $r_{V/W}$ and $r_{H/V}$, of degree of geo-effective influence of solar activity during 22th-24th SCs on the dynamics of water content in the closed lake Svityaz.

3 Conclusion

In this work, on the example of the deep-water closed Lake Svityaz located in the protected area of West Polissya of Ukraine, it is experimentally established that the total solar radiation is the prevailing natural factor of cosmic origin, which determines the degree of "helio-dependence" of fluctuations in the water content in the lake. This is because the total solar radiation determines the density of radiated solar energy and, accordingly, the temperature regime on the Earth's surface.

7 References

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