The Influence of Solar Activity Rhythms on Precipitation Cycles during Climate Change in Central Yakutia

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Abstract. The study of global climate warming remains open the questions about predicting process patterns and the used methods. The impact of solar activity on the Earth natural processes is being studied. The revealed features of solar activity fluctuations are consequences of the physics of the phenomenon itself, as well as delays in reactions to fluctuations in various geophysical layers of the Earth. Eleven-year cycles of precipitation dynamics observed at the Yakutsk meteorological station in comparison with solar activity cycles are described. The total number of cycles, according to the weather station, for the period from 1934 to 2018 is eleven. They are compared to eight solar activity cycles. A wavelet transformation of a series of atmospheric precipitation reveals the relationship between precipitation and solar oscillations. Even and odd precipitation cycles are highlighted, in line with Hal’s law of magnetic polarity. Positive precipitation anomalies have been found to be consistent with the maximums of odd-numbered solar cycles and the minimums of even-numbered cycles, while negative anomalies are found to be consistent with the minimums of odd-numbered and maximums of even-numbered cycles. Highlighting cyclic components can be useful in studying changes in humidity due to climate perturbations. The obtained results can be used to make climate and hydrological forecasts for the central region of Yakutia.

1. Introduction
The planet climate is currently warming actively, with the melting of polar and mountain ice caps. Despite the obvious threats of warming, the very problem of predicting the patterns of its development remains a subject of heated debate among experts. Their viewpoints are diametrically opposed. If we look at the regional forecasts of the Institute of Permafrost Studies of the P.I. Melnikov Branch of the Siberian Branch of the Russian Academy of Sciences (Russia), we can see that since 2018 we have been experiencing a cooling that is comparable in scale to the Small Ice Age, which peaked in the middle of the XIX century.

At the same time, the problem of climate change and the forecast of these changes remains one of the key human problems that still have not been resolved [1].
2. Task definition
According to M.S. Eigenson, the roots of the problem lie in the area of solar-terrestrial relations [2]. However, despite the wide popularity of these bonds, the response of natural processes to oscillations of solar activity cycles remains less certain [1]. As I.V. Maximov writes "...the same cause in different solar cycles alternately leads to different and opposite effects in the Earth atmosphere. This is undoubtedly one of the most mysterious phenomena that we now face on Earth" [3].

It seems that the reasons for the contradictions identified by I.V. Maximov lie both in the geophysical features of the solar activity cycle itself and in the inertia of the Earth's geospheres. According to J. Hal, even and odd eleven-year cycles have different magnetic polarity (Hale's sunspot polarity law). It is probably this feature of eleven-year cycles that underlies the different responses of the natural environment (climate, landscape, geological environment as a whole) to the modulation of adjacent eleven-year cycles - even and odd. The aim of this paper is to study the impact of an eleven-year cycle on natural processes. In addition to the Fourier analysis and wavelet analysis of rows of raw meteorological information [4, 5], it is necessary to carry out a graphical analysis of these rows by comparing the movements of the curves of these rows with the curve of Wolf number.

We have taken a multi-year average annual rainfall range at the Yakutsk meteorological station for the period from 1934 to 2018 as the baseline.

3. Materials and discussion
During the Fourier analysis a three-part view of the non-stationary stochastic process was used:

\[ X(T) = d(t) + p(T) + r(t) , \]

where \( d(t) \) – the deterministic part, \( p(T) \) – the periodic part, \( r(t) \) – stochastic part, then the periodical component [6] (figure 1).

In the wavelet analysis the Morlet wavelet was used [7]

\[ \psi(t) = e^{-\frac{t^2}{2}} e^{i\omega t} \]

The wavelet transformation of a number of precipitation events is shown in Figure 2. The influence of solar oscillations is clearly shown there, and the spectra of the eight peaks in the Wolf number series are highlighted as green spots in the chart.

A graphical comparison of the movements of the average annual precipitation curve in Yakutsk and the solar activity curve in Wolf numbers (figure 1, figure 2) shows the following.

![Figure 1. Comparison of precipitation dynamics a) and solar activity b).](image-url)

Between 1934 and 2018, 11 waves of strengthening and weakening the dynamics of atmospheric humidification appeared in Yakutsk, which periodically changed the development of natural processes
from humid to arid, and vice versa. Humidification anomalies developed against the background of eight eleven-year solar activity cycles, which manifested themselves over the same period of time (cycles 17 - 24). Three cycles - 17-19 - were associated with the increasing branch of the century-old cycle of the solar activity, and four cycles - 20-23 - with the decreasing branch.

From the diagrams presented (figure 1), we can see that the first maximum atmospheric humidification (in the range of curves considered) on the precipitation scale appeared in Yakutsk in the 1930s. It is synphasic to the maximum odd-numbered eleven-year seventeenth solar cycle. However, the consequent minimum precipitation did not show itself on the minimum of the solar cycle, but earlier on the branch of the recession. Moreover, the subsequent positive anomaly of humidification occurred at the minimum of the even eighteenth cycle, and the subsequent wet dry phase appeared in phase with the maximum of the even eleven-year cycle 18, i.e. mirroring the wet phase at cycle 17 peak.

The next wet anomaly was recorded on 18th cycle of decreasing branch near 19th cycle minimum and the next dry phase is recorded on 19th cycle decreasing decline branch near 19th cycle maximum. Further on, on the decreasing branch of the century solar cycle (cycles 20-23) and at the beginning of the increasing branch of the new 24th century cycle, positive anomalies of precipitation, judging by the course of the curves, tend to the maximums of odd-numbered eleven-year cycles and the minimums of even-numbered cycles, while negative anomalies, on the contrary, tend to the minimums of odd-numbered cycles and the maximums of even-numbered cycles.

![Wavelet transformation of the precipitation curve](image-url)

**Figure 2.** Wavelet transformation of the precipitation curve.

Thus, it can be concluded that despite some "turbulence" happened in the course of the atmospheric precipitation curve against the background of a century-long increase in solar activity in the course of a century-long cycle (the end of a branch of a century-long cycle rise of the 20th century), on the whole there is a fairly clear pattern. The positive anomalies in precipitation tend to the maximums of odd-numbered eleven-year cycles and the minimums of even-numbered cycles, while the negative anomalies, on the contrary, tend to the minimums of odd-numbered cycles and the maximums of even-
numbered cycles. The latter is well explained by nothing more than Hale's sunspot polarity law - the presence of different magnetic polarities in even and odd eleven-year cycles.

4. Conclusion
Given that the eleven-year cycle of solar activity is a fairly stable phenomenon in the life of the sun and has been recorded by instrumental observations for three hundred years, it seems that the pattern we have identified can be used as a geophysical basis for the development of long-term climate and hydrological forecasts for Central Yakutia.

5. References
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