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Space weather prediction: forthcoming turbulent years?

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ABSTRACT

Based on the analysis of historical and statistical data for the period between 12th and 19th centuries, it was established that a risk of social instability episodes (riots, revolutions) increases at the decay phase of even and at the rise phase of odd 11-year cycles of solar activity. The probability of large-scale armed conflicts increases with approaching the maximum of Kondratiev's long-wave cycle (about 55 years). If these patterns are implemented in some regions, then the most turbulent year will be 2024 ± 1. Immediately after the forthcoming 11-year solar activity maximum, around the year 2026, the global temperature is expected to start decreasing. The extreme value, about 0.3°, will have been achieved by approximately the year 2035. By the end of the century, the temperature is expected to restore.

Key words: space weather, space weather prediction, influence of space weather on climate and social processes

1 Introduction

It is widely accepted that for the stable and optimal functioning of all biological systems, prediction is necessary; this is the well-known thesis about the "anticipatory reflection of reality". Modern natural science generally provides broad opportunities for prediction. Some of them have firmly entered everyday life, such as the usual weather forecast service. For other practically important cases – earthquakes – the development of prediction is at an early stage. Space is also a source of danger: if the Tunguska catastrophe of 1908 had occurred four hours earlier, nothing would have remained of St. Petersburg... Nowadays, all dangerous asteroids, even very small ones, are continuously monitored. In 2051, a particularly dangerous approach of the asteroid Apophis to Earth is expected. However, the service for tracking approaching asteroids is not entirely reliable: the Chelyabinsk superbolide was missed on 15 February, 2013, with explosion of 0.4 megatons.

Near space is associated not only with large-scale catastrophes. In everyday life, the effects of solar activity – space weather – have long been known. Some of them cause discomfort and some are dangerous. Here, for example, are the consequences of a large magnetic storm with a sudden onset, which is one of the frequent variants of changes in space weather (bibliography on the effects listed below is presented in Vladimirskii, 2017):

- the number of road accidents on the day of a magnetic storm on busy highways increases by about 10%; a similar effect exists in civil aviation;
- the frequency of myocardial infarctions in cities increases on such days; the number of ambulance calls increases (~15%);
- on the same days, the risk of suicides increases; the frequency of admissions of patients to psychiatric hospitals increases;
- some terrorists are hidden suiciders, so the number of terrorist attacks increases on the days of magnetic storms;
- on the same days, many people, due to an increase in the intensity of anxiety and depressive states, change their behavior in a risky situation; as a result, the value of stocks on the stock exchange decreases (Krivegova, Robotti, 2003).

Even from the brief list above, it is generally clear that it would be useful to foresee magnetic storms. It seems that for the first time in history, such a prognostic service arose in France in the second half of the 1930s: doctors M. Faur and G. Sardue, along with astronomer G. Vallot, regularly informed hospitals in the south of the country about the onset of unfavorable days. Nowadays, such a prognostic service operates in the USA (Pevtsov, 2016). The consumers of this information are institutions that operate power transmission networks and pipelines: during magnetic storms the risk of emergencies in these systems increases (American physicians seem to be not interested in such a prediction).

2 Technology of short-term space weather prediction

Magnetic storms vary greatly in their magnitude. The effects listed above in the noosphere are caused by large storms; a special index characterizing their "power", Dst, is at least 100 nT. The algorithm for predicting such isolated events is easy to understand by looking through a guide to space

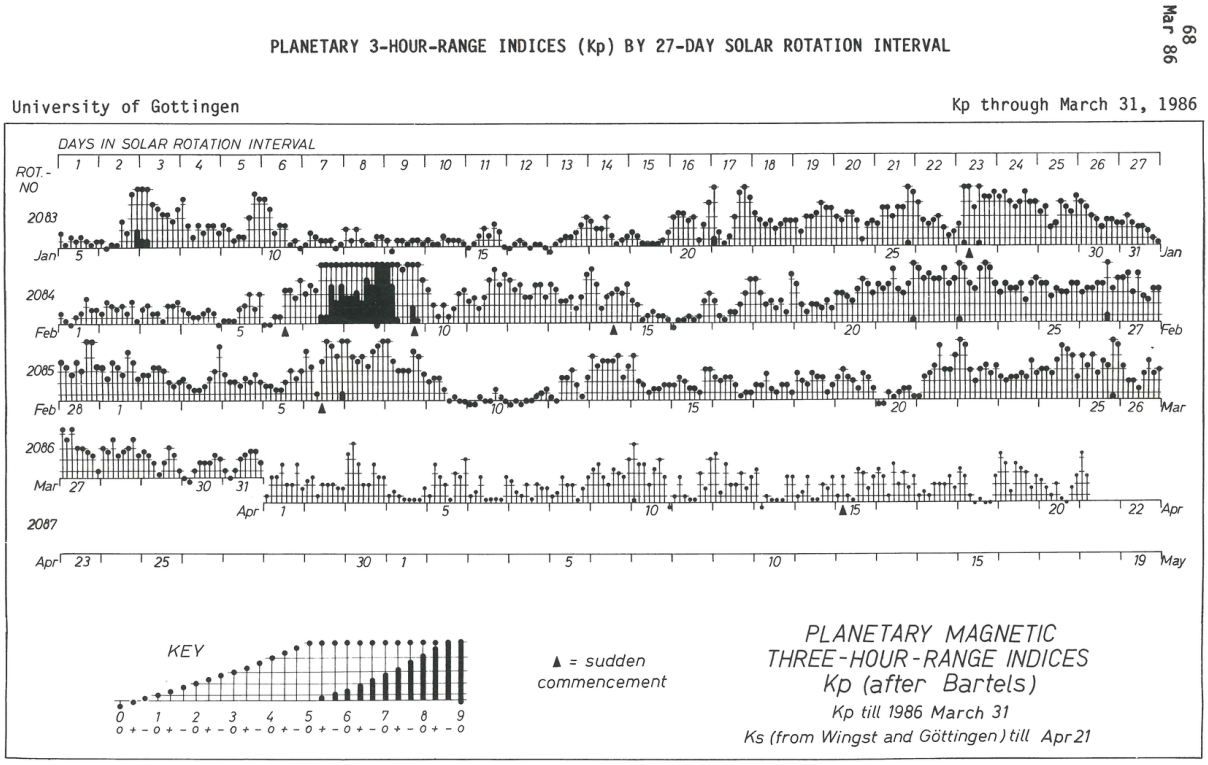

Fig. 1. A fragment of the 27-day calendar of the geomagnetic activity index Kp for January–March 1986. In each row, the values of the 3-hour index Kp are plotted on the vertical axis; the scale is indicated at the bottom left. Over the course of three rotations (the leftmost numbers 2003, 2004, 2005), the Kp index synchronously increases on days No. 21–26 (upper scale).

physics (e.g., Lazutin, 2012). If a flare is recorded on the visible disk of the Sun (this is an explosive release of energy accumulated in the solar magnetic fields), then the corresponding electromagnetic "signal" will be registered after eight minutes. But the plasma cloud ejected during the explosion will reach Earth only after 1.5 days. It will cause a strong disturbance in the magnetosphere and ionosphere: this is a magnetic storm. A prolonged disturbance lasts about a day. All this time, the intensity of magnetospheric ultra-long radio waves and infrasound remains increased in the environment. These factors, which have a high penetrating power, directly affect the brain and psyche. They are responsible for the noted above consequences of magnetic storms of this type.

Magnetic storms with a gradual onset are a special type of magnetosphere – ionosphere disturbances. Such events are caused by the Earth's passage through a solar wind stream with an increased speed. A characteristic feature of such magnetic storms, moderate in scale, is the tendency to recur with a period of the Sun's axial rotation of about 27 days. Optical observations allow us to foresee the occurrence of such events (a day or two before). The approach of an active region (sunspots) to the central meridian is noted (the bases of the mentioned stream are located near the active region). The Earth's entry into such a stream is expected after about three days. The prediction is further facilitated if we take into account the periods of occurrence of such storms. This can be clearly seen in the periodogram shown in Fig. 1. Here, time is divided into intervals equal to the period of the Sun's rotation, and these intervals are arranged sequentially one below the other, from top to bottom. On each line, the 3-hour planetary index of magnetic activity Kp is plotted. Magnetic storms are bursts of this index. Storms with a gradual onset are located one below the other, while storms with a sudden onset are distributed here according to a random law.

All the above is attributed to the years of moderate solar activity. During this time, magnetic storms of both types can be predicted about a day before with a high degree of reliability.

3 Difficulties in long-term space weather – climate prediction

The situation changes dramatically if the level of solar activity increases, approaching its 11-year maximum. In such epochs, the number of active regions on the Sun increases, and the spatial structure of the solar wind becomes more complex; powerful flares usually occur independently in different active regions. Accordingly, the frequency of magnetic storms increases sharply: they can follow each other almost continuously, sometimes overlapping (the biological effects of one such case were studied in detail by Chibisov et al., 1998). Predicting the occurrence of individual magnetic storms becomes practically impossible.

But the prediction of intervals of such intense disturbances becomes relevant. Clearly, it is important to know the year of the 11-year maximum of solar activity. But these max-

ima differ greatly in many respects: their amplitude changes over time by dozens of times; even – odd cycles (according to the Zurich numbering) are completely different and form 22-year cycles. According to some signatures, they are also combined in threes (the Brickner cycle) and fives (about a 55–60-year cycle). There is extensive literature on all these issues.

The proposed algorithms for long-term prediction in one way or another rely on the basic idea of the "maximum resonance" of the Solar system (Molchanov, 1973; Pudovkin et al., 1977). Due to the phenomenon of synchronization, in the process of evolution, the Solar system has entered a special cooperative dynamic mode: variations in solar activity occur "consistently" with the motion of planets, with the displacement of the Sun relative to the barycenter of the system; changes in heliogeophysical indices are described by a set of stable periods.

It seems that the most organic to this model is the prediction of Meyer (1998) in which variations in solar activity are approximated by trigonometric functions with several discrete frequencies. It is noteworthy that such a theoretical curve reproduces the long-term decrease in the activity of Spörer (1480) and Maunder (1675). The continuation of the curve into the future (and this is a prediction) shows the presence of a similar minimum in the second half of the 21st century (this event will be discussed below).

A detailed review of the results of long-term space weather prediction cannot be presented in a short article. Below, only three cases are considered that, in our view, deserve special attention.

4 Social instability

Is it possible to foresee the most large-scale crises in world historical dynamics: revolutions? A century ago, several independent authors almost simultaneously gave a positive answer to this question: major revolutions occur in the years of 11-year maxima of solar activity, and the onset of these maxima can be predicted (for details and bibliography, see Vladimirskii, 2013). Fierce discussions on this conclusion have continued for many decades and are not over to this day (Breus et al., 2017). To a large extent, this is due to deep ideological (philosophical) disagreements: to what extent is it acceptable to treat revolution as a socio-mental disorder (Samokhvalov, 2018)? And in general, can nature significantly influence the spiritual life of mankind, history? And if there are observations indicating such an influence, is it possible to imagine a mechanism for such an impact? The current situation is as follows: using the latest technologies, the largest revolutionary upheavals proved to be associated with the 11-year maxima of solar activity for the 18th–20th centuries with complete certainty (Ertel, 1996). For an earlier era, the 12th–17th centuries, this conclusion was confirmed using the restored Wolf numbers and P. Sorokin's indices of social instability (Vladimirskii, 2020). Meanwhile, important details were revealed: the "onset of episodes of social instability" occurs when the Wolf numbers at the maxima of activity exceed 70. In the dynamics of instability "bursts", a "fine structure" was found, shown in Fig. 2. The mentioned bursts turn out to be recorded with increased probability during the decline phase of the even 11-year cycle and during the

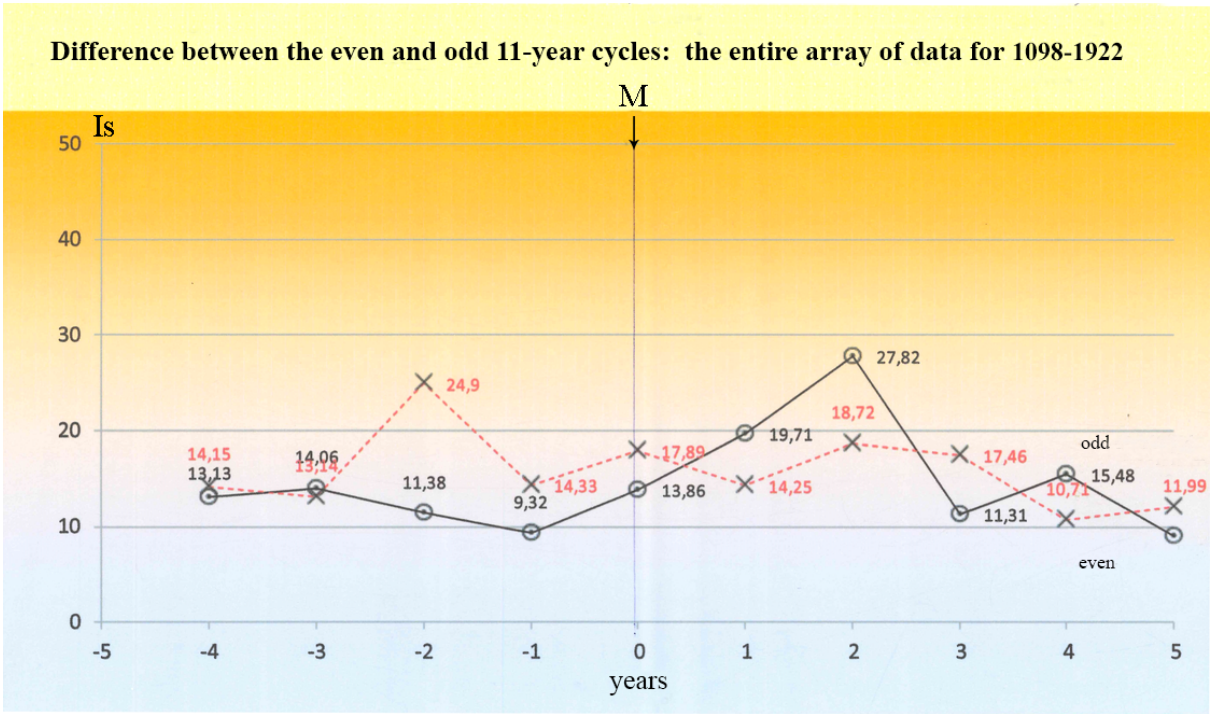

Fig. 2. Variations of P.A. Sorokin's index of social unrest (along the vertical axis) on average over the 11-year solar activity cycle; the even (on the graph ⊙, $n = 50$) and odd (on the graph X, $n = 43$) cycles are considered separately. Data for Europe for the 11th–20th centuries are according to Vladimirskii (2020). Disturbances of social stability are most likely during the decline of the even cycle and the rise of the odd cycle (along the horizontal axis, −2 and +2 years, respectively).

rise phase of the odd one. Accordingly, the extreme values of the Sorokin index, 79.43, the Great French Revolution, were recorded during the decline phase of the even cycle, whereas the revolution in Russia, index 63.08, before the maximum of the odd one. In the considered time interval, the solar mean magnetic field is antiparallel to the geomagnetic one. This entire interval is characterized by an increase in the value of geomagnetic activity indices. The very relation of episodes of instability and variations in space weather (according to Vladimirskii, 2020, the correlation coefficient of the Sorokin index with Wolf numbers is +0.37, $p = 0.05$) now appears to be a special case: geomagnetic disturbance turned out to correlate with deep psychological processes: the typology of dreams (Ol'shevskaya, Kulichenko, 2019), the intensity of philosophical discussions on the Internet (Ozheredov et al., 2020). The world "explosions" of creative productivity in the rational sphere, which are key for historical and cultural evolution, were shown to occur at special time intervals of "calm" space weather: the 6th century BC (axial time), the Renaissance, the "Age of Geniuses" (Vladimirskii, 2021). Finally, in the most general terms, the mechanism of the influence of space weather on the psyche-behavior has become understandable. The most important thing here was the discovery of the influence of the already mentioned environmental factors of magnetic storms (ultra-long radio waves, infrasound) on the electroencephalogram (EEG) of the human brain (for a more complete discussion with bibliography, see Vladimirskii, 2020). Some details of this line of research make a strong impression: one of the considered types of magnetospheric radio waves (recorded as geomagnetic micropulsations Pc1) has a frequency exactly equal to the frequency of the δ-rhythm of the EEG; the frequency of the Schumann ionospheric resonance, about 8 Hz, is very close to the frequency of the α-rhythm on the EEG. Is it a resonant impact?

At present (2021), we are experiencing the stage of rising activity toward the odd maximum No. 25. The date of the onset of the maximum in published predictions somewhat differs. But the expected amplitude will definitely exceed 100 (Wolf numbers). If we choose one of the variants of detailed prognostic calculations for specific figures (Roshchina, Sarychev, 2014), then the maximum will fall on 2026. Taking into account the regularity reflected in Fig. 2, we conclude that the most risky years for the onset of social unrest are 2023–2024. The considered probable dynamics of geomagnetic disturbance for the studied decade is consistent with these dates. It is noteworthy that the prediction of social instability, made from the analysis of socio-political data, leads to close dates: 2021–2025 (Pantin, Lapkin, 2014). It seems that some events at the very beginning of the rise in activity already indicate the "restless" nature of the coming years. Reports on observations of "unidentified flying objects", which is an unambiguous sign of socio-psychiatric distress in society, have reappeared. A street crowd filled the premises of the US Congress...

The psychotropic factor of space weather postulated by A.L. Chizhevsky (magnetospheric radio waves, infrasound) changes on a global scale. The particular region in which the cosmic "signal" will become the spark of the beginning of riots – revolts – revolutions can be determined by a special socio-political analysis. Obviously, the onset of such events is the result of the joint action of several causes. Space weather is one of them.

5 Armed conflicts

As in the previous case, the presence of periodicity in the frequency of occurrence helps to foresee large-scale armed conflicts. The most impressive example is the concentration of all major (in terms of the number of losses) wars in Europe of the 16th–20th centuries on the ascending branch of the so-called Kondratiev long waves (Poletaev, Savel'eva, 1993). These oscillations in the world economy have been known for a century. If we construct a power spectrum of variations in the most important global economic indicators (investments, wholesale prices, innovations), then it always contains a period of about 50 years (Korotaev, Tsirel', 2014). But periods close to the period of these self-oscillations are present in many other phenomena. In culturology, this is the 60-year calendar of animals, creative productivity, change of stylistic features in art. In nature, this is the intensity of volcanic eruptions, climate changes, the frequency of occurrence of auroras at mid-latitudes, the frequency of meteorite falls. In space physics, the period of Kondratiev's waves is revealed in Wolf numbers; it is 1/3 of the orbital period of the Sun's motion relative to the center of mass of the Solar system and is one of its resonant periods with an exact value of 59.0 years (Vladimirskii, 2013). In the light of the stated above, it is not surprising that the synchronization of Kondratiev's waves with variations in solar activity was revealed (Ertel, 1997): the maximum of Kondratiev's waves coincides with every fifth 11-year maximum of Wolf numbers, with a mismatch of about one year (for details, see Vladimirskii, 2013, pp. 140–154). In general, it now seems that this cosmic cycle, for the average level of solar activity of 55 years, is the most important rhythm of world history.

Using the restored Wolf numbers, Kondratiev's waves can be extrapolated into the past, and hence the volume of historical and statistical data on military conflicts can be significantly increased. One of the results is presented in Fig. 3. It shows the course of the world index of military activity, constructed by the American psychologist Wheeler (tabulated in Dewey, 1987), for the convolution of Kondratiev's waves from the 12th century (superposition of epochs, zero point denotes the maximum of Kondratiev's waves). It can be seen that the above-mentioned tendency for major wars to be located on the ascending branch of Kondratiev's waves is confirmed. To predict the situation for the coming years, it is necessary to superimpose the profile of the current Kondratiev wave on this graph. To its last maximum, which falls on the 11-year maximum No. 20, 1968 (Vladimirskii, 2013), we should add the dates of the next five maxima; thus, we come to the upcoming 11-year maximum No. 25 (2026), which was discussed above. From Fig. 3 it can be seen that before the very maximum of Kondratiev's waves, the Wheeler index increases. The risk of armed conflicts increases by 2023 (± 1 year). Thus, these are the dates of increased probability of the occurrence of social instability. In the next two decades, the danger of conflicts decreases.

The prediction of the dynamics of other social indicators is hampered by the poor study of the cycle under consideration. The physical reason uniting the 11-year periodicity

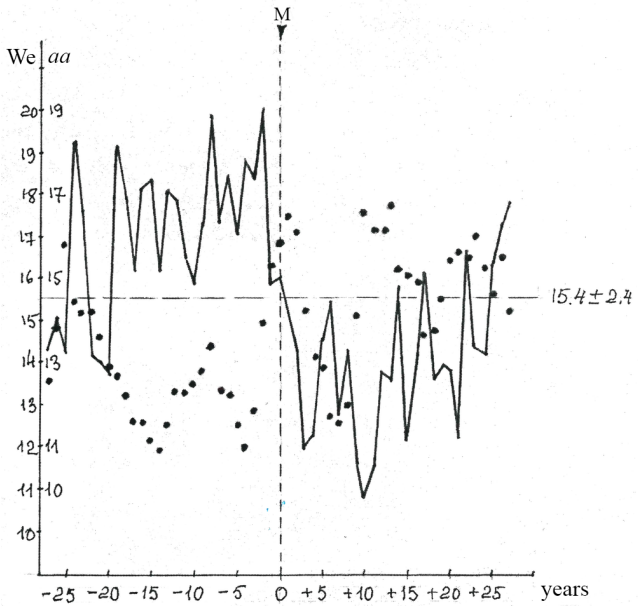

Fig. 3. Average course of A. Wheeler's index of military activity: along the vertical axis We (annual values, curve) – within the period of Kondratiev's long waves; zero on the horizontal axis corresponds to their maximum. Data of the 13th–19th centuries. Points indicate annual values of the *aa*-index of magnetic activity, synchronous with the Wheeler index over the past century (according to Vladimirskii, 2013, p. 151).

into Kondratiev's waves is still unclear. The dynamics of the harmonics of these waves, for example, the 3rd, about 18.5 years (the Kuznets cycle), is a subject of additional study. The hypothesis of S.Yu. Maslov about the change in the ascending – descending phases of Kondratiev's waves of the dominance in society of the main strategies for mastering reality – "syntheticity – analyticity" – requires additional analysis (Vladimirskii, 2013, p. 142).

6 Global cooling: an extremum around 2035

The title of this section is in glaring contradiction with the generally accepted (almost...) hypothesis about global continuous warming until the end of the 21st century. The observed warming is believed to be associated with an increase in the concentration of greenhouse gases (CO_2) in the atmosphere caused by human industrial activity. The thesis of warming has become an important point of political life. Significant resources are spent on the decarbonization of economy. Meanwhile, many experts, both domestic and foreign, have long noted that the accepted explanation of the causes of global warming has no scientific basis (see, for example, a discussion of the problem in Sorokhtin, 2007). It is imposed on the world community by supporters of the "green" movement.

In fact, climatic variations are caused by the combined influence of many causes. The most important of them is changes in solar activity (Nagovitsyn, 2017). In the 12th century, with an extremely high level of solar activity, agriculture was practiced in Greenland. The cooling in Europe in the 17th

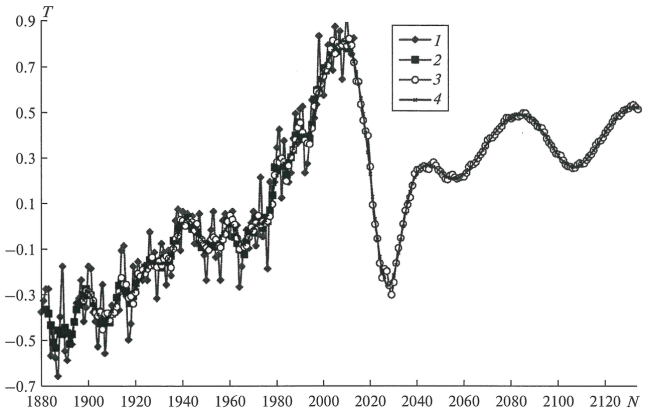

Fig. 4. Prediction of the global temperature averaged over 5 years. Along the vertical axis: temperature *T*, deviations from the average one; along the horizontal axis: years (according to Laptukhov, Laptukhov, 2015).

century coincided with the Maunder minimum of solar activity. Such a correlation suggests the onset of cooling in the coming decades due to the fact that by this time a significant decrease in solar activity is expected. It was such a decrease that was predicted in the aforementioned forecast by Meyer (1998). Other independent authors (there are at least a dozen of them) came to a similar conclusion. The prognostic data differ insignificantly. An example of the results of such calculations is presented in Fig. 4 (Laptukhov, Laptukhov, 2015). As can be seen, with an approach to the upcoming maximum of solar activity (2026), after 2020, a noticeable decrease in temperature to the level of the long-term average temperature is expected. The minimum will have been reached by around 2035. The particular region where a series of particularly severe winters should be expected is unknown. No theoretical model has been proposed so far that explains the relation between variations in solar activity and climatic changes. One of the ideas discussed in the literature is an increase in the average cloudiness on the planet with reduced solar activity.

The social consequences of a global decrease in temperature certainly deserve attention. According to literature data, a decrease in summer temperature in mid-latitudes by 1° leads to a decrease in grain yields by 2.5%. An aggravation of the competitive struggle for control over oil and gas fields is inevitable. And so on...

7 Conclusions

If we briefly summarize the stated above, then the following general picture takes place: some effects of solar activity – space weather – cause destructive and dangerous consequences in the environment. It is desirable to foresee them. The accumulated knowledge allows us to make appropriate predictions. Magnetic storms, if traditional solar observations are used, can be confidently predicted a day before. Social instability (riots, psychoses, revolutions) increase during the rise phase of the odd 11-year cycle of solar activity; in this regard, an increase in the risk of such events should be expected in 2024 ± 1. The danger of armed conflicts increases shortly before the onset of the maximum of the 55-year

cosmic cycle of Kondratiev's long waves. Accordingly, an increase in the probability of armed conflicts falls on 2023–2025. The particular region where the predicted situation will be realized should be the subject of special analysis: after all, the occurrence of such events is determined by the combined influence of several factors; the psychotropic cosmic agent most often serves as a signal for the release of accumulated "energy". Immediately after the 11-year maximum of solar activity around 2026, a slow global decrease in temperature will begin due to the entry of solar activity into the era of a long-term minimum of the Maunder type. The extremum, about 0.3°, will have been reached by around 2035, and by the end of the century, the temperature is expected to restore.

In his widely known brochure, Chizhevskii (1924) noted: "The state power should know about the state of the Sun at any given moment". The recommendation, which sounded comical at the time, a hundred years later seems serious and relevant.

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