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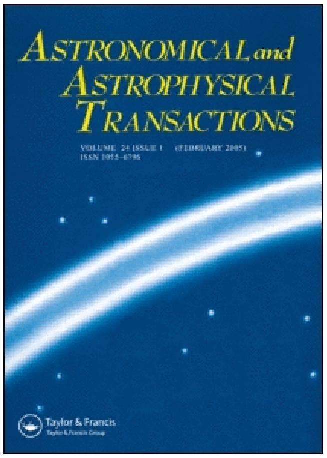

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SOLAR ACTIVITY-CLIMATE COUPLING AND ATMOSPHERIC CIRCULATION

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Long series of various climate parameters and their relation to solar activity have been analysed. A sudden variation in the character of the solar activity–climate coupling has been revealed during the change of the global circulation epochs in the North hemisphere.

KEY WORDS *aa*-index, atmospheric circulation, climate season, Wolf number

1 INTRODUCTION

While studying the effect of solar activity on the climate, we have noticed (like many other authors) that the explicit relationship between various meteorological parameters and the Sun changed drastically in certain periods during the past century. This non-stationary behaviour not only made the analysis much more difficult, but sometimes even made skeptics deny the existence of any relationship at all. The effect may be partly due to the averaging of meteorological data over too-large areas which do not uniformly respond to solar and geomagnetic disturbances (Obridko *et al.*, 1995). However, this cannot fully account for the problem, for sometimes even long series of parameters recorded at one and the same station look puzzling. Our analysis has shown that variations in solar activity–climate coupling occur, in particular, during the change of the global circulation epochs. Thus, in an attempt to form the longest possible series of continuous meteorological observations the investigator obtains an arbitrary mixture of data that is relevant to different epochs and manifest different types of coupling.

2 CLIMATE SEASONS

The first meteorological parameter to be considered is the duration of the six climate seasons: pre-spring, spring, summer, autumn, pre-winter, and winter. These are the seasons isolated by meteorologists to statistically describe the annual behaviour of circulation during the current century. (Savina, 1987). These data are juxtaposed with the corresponding indices of solar activity: the Wolf numbers and the geomagnetic *aa* index that shows the disturbance of the Earth's magnetospnere. The data series covers the time interval 1899–1985, with moving averages taken over three years.

Figure 1 illustrates the duration of the spring climate season (solid curve) and the geomagnetic *aa* index (dashed curve) as a function of time. One can see that prior to 1919 the two curves are closely related and change in phase. The correlation breaks immediately before and reappears after 1919. The correlation after 1919 is as good as before, but the curves change in antiphase. Around 1958 the correlation breaks again to restore in 1970 with opposite sign. The other five seasons display similar behaviour: the seasonal duration before 1919 correlates perfectly well with the geomagnetic activity index, *aa*, varying either in phase, or in antiphase, depending on the season. After a transition period in 1919–1925, the correlation is reversed and it changes again during 1955–1965. If the seasonal duration and the geomagnetic *aa* index change in phase before the transition period, the variation becomes antiphase after the transition.

As shown by Savina (1987), this is when the circulation epochs interchange. She has isolated three such epochs in the current century. The first epoch (up to the 1920s) is characterized by relatively predominant meridional circulation. In the second epoch (up to the 1950s), the main circulation type is zonal, and it is again replaced by meridional in the third epoch. The author shows that these epochs can also be treated as climatic, because they manifest themselves in other climate parameters, in particular, in variations of the zonal mean air temperature at high latitudes (72.5–87.5°).

Thus, the observed "violations" of the solar–terrestrial coupling pattern can be attributed to transition of the entire circulation and climate system of the northern hemisphere from one epoch to another.

In order to make these transition (or "reconstruction") periods more explicit, we have carried out a detailed analysis by calculating the moving correlations over time intervals of various duratios. Correlations were calculated for a mask of n years (from m to $m+n-1$), where m covered the whole data volume, i.e. changes from 1899 to 1985-$n+1$. The calculations were performed for n intervals of various lengths, from 5 to 11. Longer intervals were not worth considering, because the sought periods were short enought to be lost due to superposition effects. On the other hand, correlations on intervals smaller than 5 are meaningless. The analysis of results shows that the most representative correlations are those obtained over the intervals of 5–7 years and smoothed by a sixth order polynomical to eliminate random fluctuations due to the shortness of the correlation interval. The transition periods are most pronounced in spring and in autumn. Our earlier work dealing with other meteorological parameters (Dmitrieva *et al.*, 1996), shows that during these seasons the effect of solar activity is most pronounced, and this is when the summer and winter types of circulation interchange. The same conclusion was draun by other authors who studied the active energetic zones (Girskaya *et al.*,

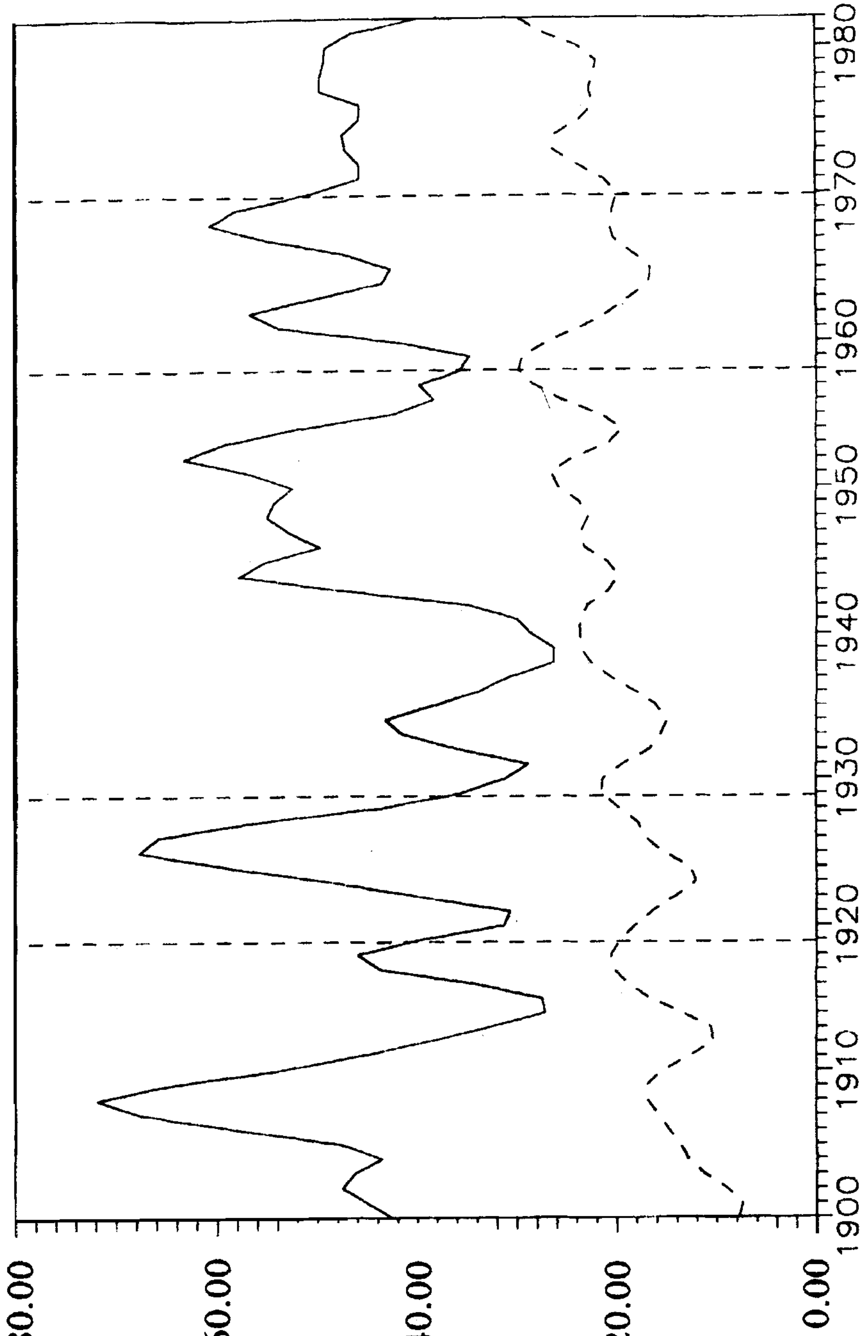

Figure 1 Duration of the spring climate season (solid curve) and the geomagnetic *aa* index (dashed curve).

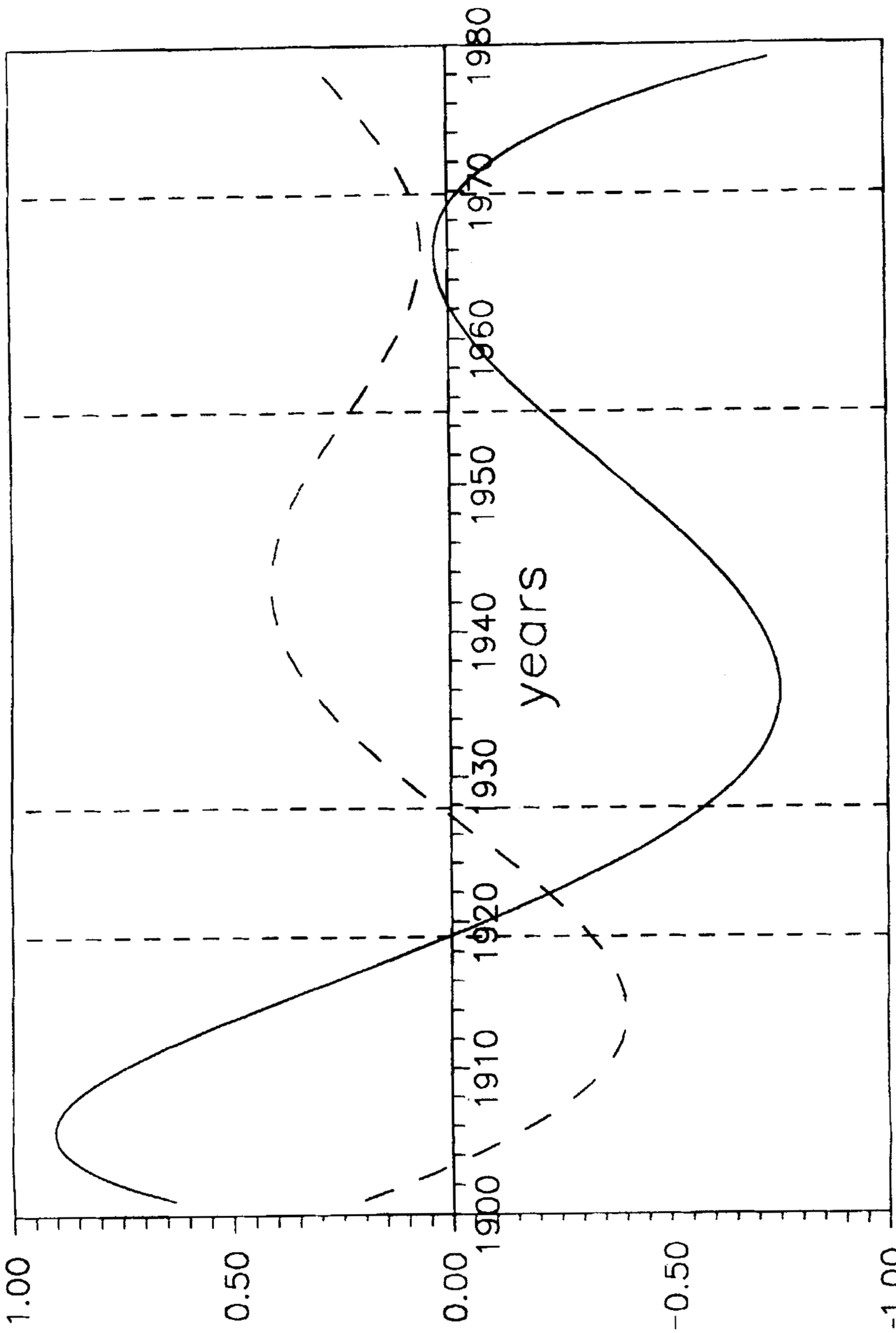

Figure 2 Moving correlations between climate seasons and geomagnetic *aa* index. Spring, solid curve; autumn, dashed curve.

1985). According to our calculations, the transition periods fall on the years 1918–1928 and 1955–1970 (see Figure 2). Other climate characteristics can be expected to behave likewise.

3 TEMPERATURES

By way of example, we have considered the annual mean temperature as a function of solar activity at Minusinsk, Eniseisk, Podkamennaya Tunguska, and Turukhansk (Siberia), in the vicinity of an active weather control zone (the term introduced by Obridko *et al.*, 1995). In order to reduce the inevitable "noise", the temperature data were smoothed between the maximum and the minimum values of a solar cycle. For this purpose, the temperature curve was divided into sections between $y_{\rm min}$ and $y_{\rm max}$ and between $y_{\rm max}$ and $y_{\rm min}$, respectively, and the method of best approximation of the second-order curve was applied to each section. (Here $y_{\rm min}$ and $y_{\rm max}$ are the years of the solar minimum and maximum, respectively.) So, we find here the same periods as described above, in spite of the fact that the ground-level temperatures at particular points do not directly represent the global circulation processes, and the correlation is more pronounced with the solar, rather that geomagnetic, indices. The annual temperature correlates with the Wolf numbers, changing either in phase or in antiphase at various stations. The character of the correlation is reversed at all stations during 1919–1925 and 1955–1964 (Figure 3). The moments of "reconstruction" may, naturally, vary from station to station, but they never fall outside the cited intervals.

4 CONCLUSIONS AND DISCUSSION

One can see that the character of the relationships between solar activity and various climate parameters can change drastically with the circulation epoch. These changes must be taken into account in the analysis of the solar–meteorological coupling. This means, in particular, that a series of observational data can only be considered homogeneous if it falls within one and the same circulation epoch. Otherwise the data relevant to different epochs must be analysed independently.

It is interesting to find out whether the changes of circulation epochs bear any relevance to longer-period variations of solar activity. It should be noted that such changes in the present century take place in the growth phase of the geomagnetic *aa* index, immediately after the maximum of the secular cycle of the Wolf numbers. Unfortunately we have no information about circulation processes in the remote past. However, proceeding from the data discussed above and from the analysis of chronicles carried out by Dmitrieva *et al.* (1995), one can arrive at the conclusion that the character of the Solar activity–climate coupling changes at the minimum of the secular solar cycle, which is probably associated with the change of circulation processes in the Earth's atmosphere.

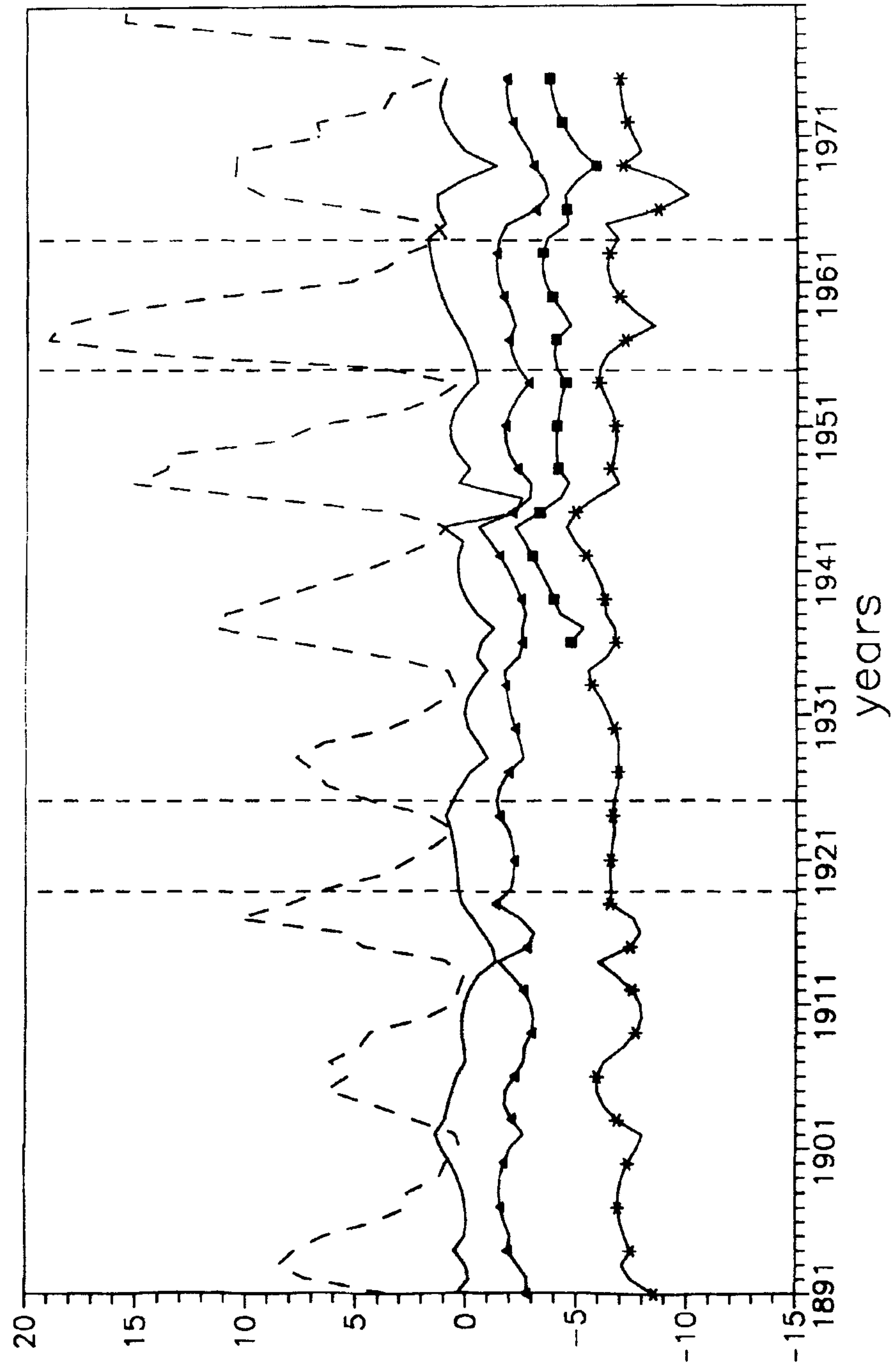

Figure 3 Annual temperatures at the Siberian stations (—, Minusinsk; —▲—, Eniseisk; —■—, Podkamennaya Tunguska; —*— Turukhansk) and Wolf numbers (dashed curve).

At every succeeding maximum of the secular cycle we see a different phase of the solar activity–climate coupling. However, this is true only for the epochs of high solar activity, whereas no definite relationship between the climate and the solar activity is detected at the cycle minima. Such a discrepancy implies major changes in the atmosphere that involve not only the type of circulation, but also the composition and stratification of the atmosphere.

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