Solar Drivers of Interplanetary and Terrestrial Disturbances
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What Are the Solar Drivers Responsible for Helio–Meteorological Effects?

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Abstract. Solar activity events that influence the lower atmosphere of the Earth have been considered as a function of various geographical factors. Certain regions have been isolated, where meteorologic characteristics are closely related to solar activity. The summer duration in one of these regions is shown to correlate well with solar activity characteristics, such as the Wolf number, and the geomagnetic aa–index. A hypothesis is suggested that there are certain zones through which solar activity controls the entire Earth atmosphere. The ways to locate such zones are discussed. One of the zones (100 W, 60 N) has been investigated to determine some characteristics of its internal structure. It is shown that seasonal variations of the correlation coefficients for temperature and W are similar at the stations stretched along one and the same meridian, and differ essentially at the stations spaced in longitude. For the temperature and aa–index, the relation is vice versa. Seasonal variations are similar at the stations spaced in longitude and differ at those spaced in latitude.

1. The Concept of Heliometeorologic Weather Control Zones

The effect of solar activity on the Earths atmosphere depends on a number of physical factors that determine energy variations and generation of atmospheric vortices. This effect increases with geomagnetic latitude. The largest changes in the zonal circulation intensity and the earliest reconstruction of atmospheric processes are observed at the geomagnetic poles, where the conditions for penetration of corpuscular solar fluxes are most favorable (Vorobyeva 1973). The influence of the Sun is best pronounced in the vortex generation regions, where the atmospheric parameters display a large dispersion. One may suggest the existence of specific zones in the atmosphere where the effect of solar activity is the largest.

It should be noted that the influence of solar and geomagnetic factors on the atmospheric circulation strongly depends on the original baric field, its anomalies, and the season. Every solar and geomagnetic disturbance transforms the baric field, taking into account its initial state and the physical and geographic properties of the region. Proceeding from previous text, we can state that:

– specific regions are expected to exist in the atmosphere, in which the effect of solar and geomagnetic activity on the local meteorologic conditions is especially pronounced. These regions are obviously located in the precipitation zones of energetic particles in the vicinity of large magnetic anomalies (Mustel 1987). The presence of baric anomalies is also important;

– the principal coupling mechanism is, obviously, of corpuscular/ geomagnetic character, and the effect may depend on whether we have an even or an odd solar cycle;

– one can also expect a dependence on quasi-biennial oscillations, i.e. variation of the correlation coefficients with a characteristic time of the order of 1–3 years.

Since a significant local effect in these regions may result in global-scale (though less pronounced) consequences, we shall call them Heliometeorologic Weather Control Zones (HMWCZ).

2. Heliometeorologic Weather Control Zones in East Siberia

For this analysis we have used the smoothed monthly mean Wolf numbers, R, and the geomagnetic aa-index. As a meteorologic parameter, we have used the summer duration in several regions in Siberia, i.e. the number of days from melting to settling of the snow cover (snow-less period). Correlation with the summer duration has been analyzed for the time interval of 1939 through 1991 for several points in the East Siberia . Their location is shown on the map in Fig. 1. This area has been deliberately chosen because is has a large geomagnetic anomaly and a particle precipitation zone, and therefore it is very likely where a heliometeorologic weather control zone may exist.

The correlation coefficients for the annual mean Wolf numbers and aa-indices, and the summer duration at the stations listed above are small, though the correlation coefficients differ essentially from station to station. The situation changes significantly if we discriminate between odd and even cycles and the exceptional position of Turukhansk is obviously beyond doubt, and the correlation coefficient of 0.669 is high enough for this kind of studies. The correlation between the summer duration and the monthly mean helio-geophysical indices is still better in spring and in summer. The correlation coefficient between the Wolf numbers in April and the summer duration in the same year for odd cycles is −0.718. The correlation coefficient between the aa-index in June and the summer duration in the same year for the even/odd pairs of cycles is −0.737.

Thus, Turukhansk can be considered an HMWCZ. This is due to its location relative to the magnetic anomaly, to the cyclone and anti-cyclone formation zones, and to the precipitation regions of the Earth radiation belt particles. The location of Turukhansk near the long-lived atmospheric circulation anomalies (blocking) may affect the atmospheric circulation as a whole (Lau 1988).

Further investigation has shown that in odd cycles, the Wolf numbers are even more closely related to summer duration on the following than on the same year (the correlation coefficient is −0.811). The analysis of the corresponding cross-correlation function shows that a year's shift provides the highest correlation. The annual mean Wolf numbers in odd cycles also display a good correlation with the summer duration on the following year (the correlation coefficient is −0.743). This may be regarded as manifestation of quasi-biennial oscillations observed both in the Sun, and in many atmospheric parameters on the Earth. If corroborated, this effect may be successfully used in weather fore-

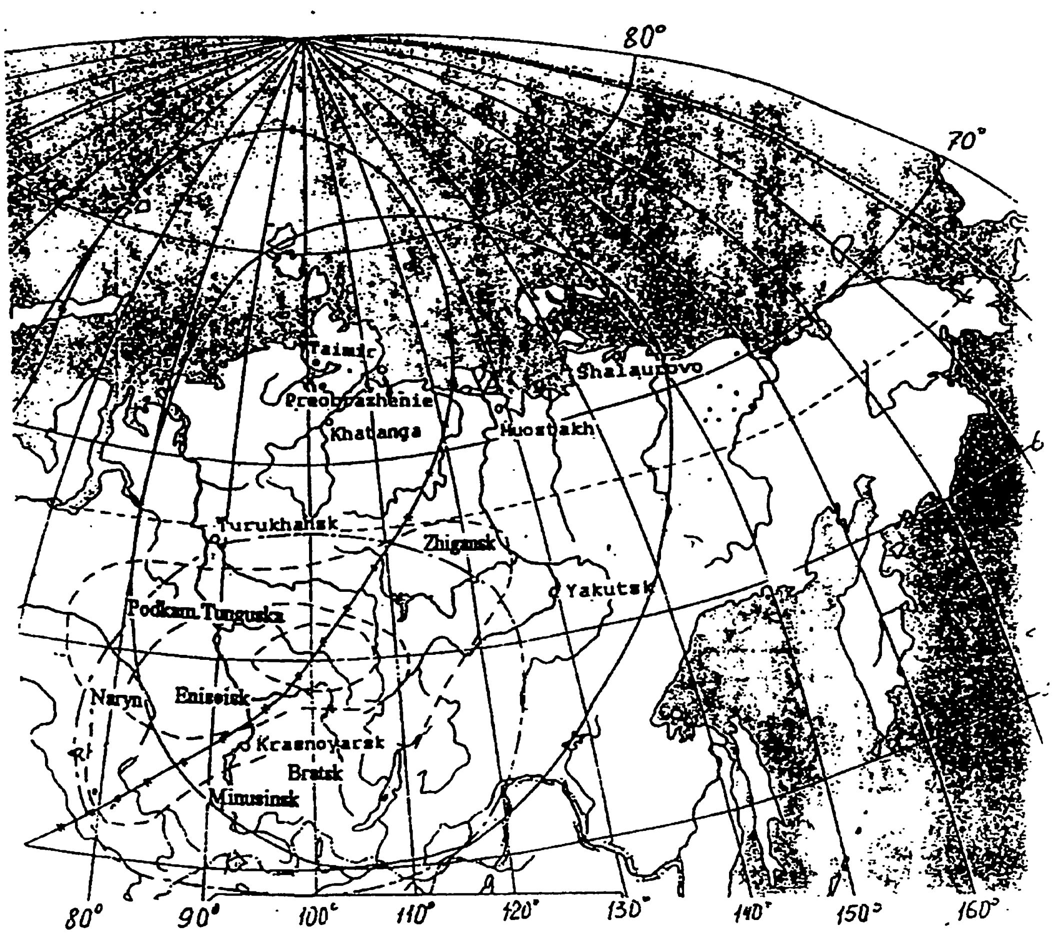

Figure 1. The map of locations of meteorologic stations, the vast geomagnetic anomaly, and the particle precipitation zone. —||— the circulation anomaly zone; — - — the zone of low pressure after magnetic storms; - - - - the particle precipitation zone. ———the magnetic anomaly zone.

casts. The cross–correlation between the summer duration and the monthly mean aa–index in the even/odd (e/o) pairs of cycles. The maximum correlation is observed when the shift is zero.

Thus, as shown above, the search for solar/meteorological coupling will not provide reliable results, unless we take into account specific relations between the "corpuscular" mechanism and the geographical factor. The Turukhansk region combines 5 factors discovered independently by different authors (see Fig. 1). These are:

1 a powerful magnetic anomaly (Mustel, 1987);

2 increased flux of charged particles (Ginzburg, Kurnosova, Logachev, 1961);

3 maximum fall of atmospheric pressure after 25 strong magnetic storms (Mustel, 1987);

4 long–lived meteorologic anomalies in the atmospheric general circulation (Lau, 1981);

5 a high correlation between solar, geomagnetic and meteorologic indices.

Thus, a heliometeorologic weather control zone (80–120 E, 60 N) exists in the Turukhansk region. Other similar zones may be expected with anomalies 1–4 listed above. For example, a high correlation between the vegetation period and the Wolf numbers has been revealed at Exdalemoore (3 W, 55 N) that is situated in such a heliometeorologic weather control zone (King, 1973).

3. Analysis of Temperature Dependencies

Taking into account that the effect of solar activity on various meteorological parameters is different and, besides, it depends on the station coordinates, we have examined the internal structure of an HMWCZ (100 W, 69 N) with reference to the direct temperature series.

Table 1.

Station	Geogr.coord .	Corr.coeff.	Geomagn.coord.
Turukhansk	88 E,66 N	0.873	96 E,136 N
Podkam.Tunguska	90 E,62 N	0.573	98 E,131 N
Zhigansk	120 E,66 N	0.468	128 E,130 N
Eniseisk	92 E,58 N	0.432	99 E,127 N
Bratsk	102 E,56 N	0.473	109 E,123 N
Minusinsk	92 E,53 N	0.111	98 E,122 N
Naryn	82 E,58 N	0.251	89 E,129 N

Table 2.

Station	o/o	o/e	e/o	e/e	geogr.coord.	geom.coord.
Turukhansk	0.937	0.917	0.702	0.872	88 E,66 N	96 E,136 N
Eniseisk	0.661	0.694	0.464	0.604	92 E,58 N	99 E,127 N
Bratsk	0.706	0.951	0.855	0.741	102 E,56 N	109 E,123 N
Minusinsk	0.303	0.516	0.243	0.756	92 E,53 N	98 E,122 N
Naryn	0.002	0.520	0.448	-0.003	82 E,58 N	89 E,129 N
Zhigansk	0.280	-0.057	0.223	0.171	120 E,66 N	128 E,130 N
Vilyuisk	0.428	0.001	0.066	0.039	120 E,63 N	127 E,127 N

Correlation has been analyzed between the monthly temperatures and the monthly W and aa values for the time interval of 1891–1975 (the data taken from Science & Applications reference book on climate in the USSR, 1982). The correlation coefficients for monthly temperatures and monthly W and aa–indices, calculated separately for the odd and even solar cycles. Variation of these coefficients from month to month for every station will be called seasonal variation for the given station. It was found out that seasonal variations of the correlation coefficients for temperature and W are rather similar at the stations situated along one meridian and differ essentially along the latitude. For temperature and aa–index the situation is vice versa: seasonal variations are similar along one latitude and differ along the meridian. In particular, it is obvious when examining correlation between the seasonal variations.

Table 1 shows these coefficients for aa–index for the case of odd solar cycles. Correlation is considered with the Vilyuisk station (geographic coordinates — 120 E, 63 N. geomagnetic coordinates — 127 E, 127 N).

Table 2 provides correlation coefficients for seasonal variations of W. Correlation is considered with Podkamennaya Tunguska (geographic coordinates: 90 E, 62 N; geomagnetic coordinates: 98 E, 131 N). One can see relationship along the meridian.

4. Isolation of Critical Seasons

Thus, all stations can be divided into several groups of more or less closely related stations (with higher or lower correlation coefficients of seasonal variations). These groups differ for W and aa–indices. For a group of closely related stations, the correlation between monthly temperatures and W is maximum in September. The question of contribution of different seasons arises in other cases as well. We have analyzed the annual mean temperature as a function of the monthly W and aa–indices. Like in the case considered above, seasonal variations of these coefficients are similar at the stations situated at one latitude (see Fig. 4*a* and 4*b*). Seasonal variations of these correlation coefficients for W are similar at the stations stretched along one meridian. The zones of maximum gradients of the ground–level pressure fields in the Northern hemisphere, revealed in the report by Girskaya at al. (1985), practically coincide with our heliometeorological weather control zones. During a year, the maximum pressure gradients drift along the meridian, and at the latitude of the HMWCZ under consideration they are recorded in September. This corroborates our hypothesis that the effect of solar activity is best pronounced in the atmospheric circulation.

5. Conclusions

A significant local correlation in geomagnetic weather control zones may result in a weaker global correlation, because these are the zones of blocking in the general atmospheric circulation (Knox 1981; and Rex 1950). We believe that the response of the climate to solar agents in HMWCZ generalizes to the atmosphere as a whole (Lau 1981; Lau 1988; Wallace & Blackmon 1983). The distribution of solar effects inside the zone may show the direction in which the atmospheric disturbance propagates. Taking into account W, the maximum influence of solar

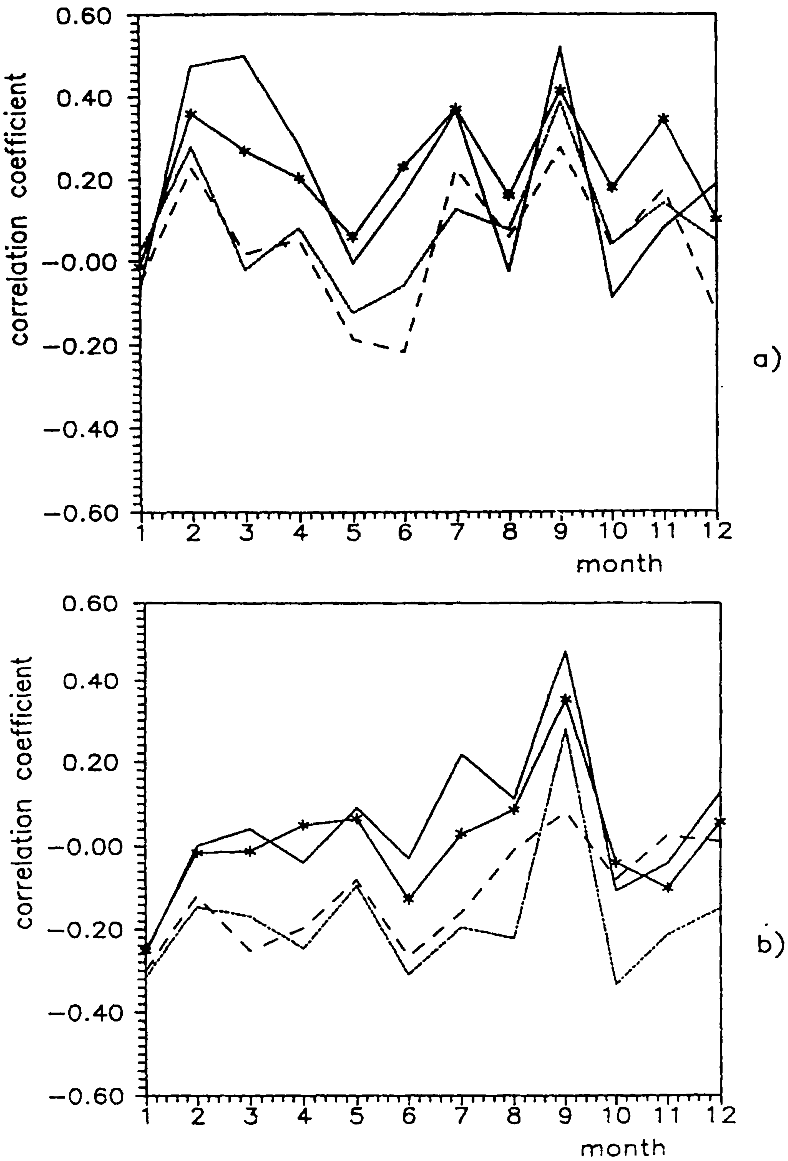

Figure 2. Seasonal variation of correlation coefficients for the monthly mean aa–index and the annual mean temperature for the even/odd (*a*) and even (*b*) solar cycles: ———Zhigansk, — — — Podkamennaya Tunguska, —*— Turukhansk, - - - - Vilyuisk.

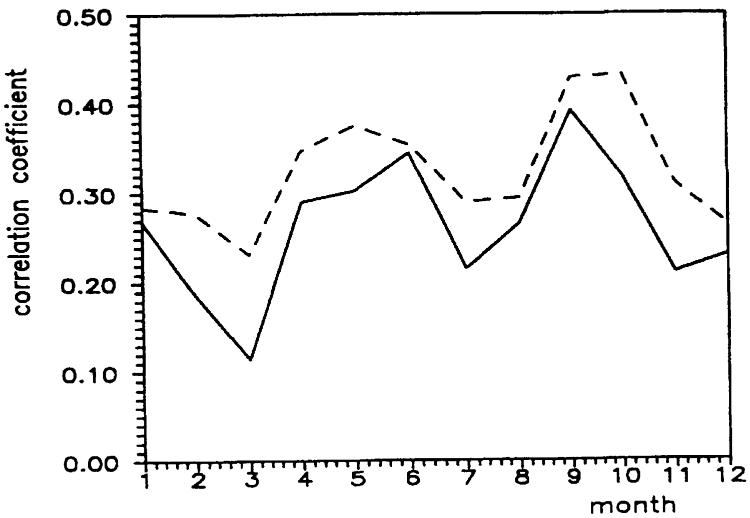

Figure 3. Seasonal variation of correlation coefficients for the monthly mean W values and the annual mean temperature for the odd/even solar cycles: ——Zhigansk, – – – Vilyuisk.

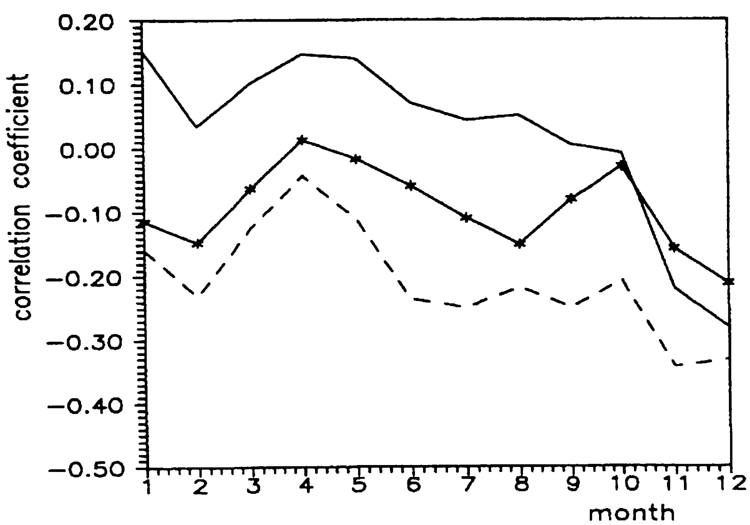

Figure 4. Seasonal variation of correlation coefficients for the monthly mean W values and the annual mean temperature for the odd/even solar cycles: ——Eniseisk, —∗— Turukhansk, – – – Podkamennaya Tunguska.

activity on the climate in HMWCZ is recorded in autumn and the disturbance propagates along the meridian. Thus, we may suggest that this disturbance in HMWCZ will spread all over the atmosphere. In transient periods (autumn and spring), the atmospheric disturbance depends on geomagnetic activity. It propagates along the latitude

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