SOME POLARITY CONDITIONS IN CORPUSCULAR EVENTS

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Abstract. We present some refinements of the previously reported magnetic polarity conditions in solar-terrestrial relations. Appropriately selected subsets were used from the longest available data sets, the geomagnetic aa-index and the surface air temperature. The solar corpuscular impacts have conspicuous effects in the tropospheric behaviour. We reported previously a new kind of semi-annual fluctuation and opposite tropospheric responses to the effects coming from different regions of the Sun as well as their dependence on the orientation of the solar main magnetic dipole. It is shown in the present paper that the semi-annual fluctuation governed by shock and fluctuating disturbances (which originate from the lower-latitude solar regions) exhibits sign reversals in consecutive cycles. The effect can be detected only in the absence of recurrent disturbances (coming mainly from the polar regions). This complex phenomenon implies that the corpuscular events may preserve some of their polarity conditions of their specific solar origin even at the Earth's distance, and on the other hand the small-scale structure of the IMF plays an important role in the link between the solar particles and the tropospheric response.

1. Introduction

In Sun–weather relationships the effects of corpuscular fluxes are not really understood for the time being. Some new aspects were presented in our previous studies (Baranyi, Ludmány, and Terdik, 1995; hereafter Paper I; Baranyi and Ludmány, 1995a, Paper II and 1995b, Paper III; Baranyi and Ludmány, 1996, Paper IV, and references therein).

By considering that only a little is known theoretically about the possible meteorological effects of corpuscular radiation, we approached the field without any *a priori* expectations, we searched for any conspicuous behavioural pattern attributable to solar particles. The previous results and the further steps published in this paper alone obviously can not provide the complete theory of the physical mechanism of how corpuscular events may influence the atmospheric circulation. However, they can help us to find the important or characteristic parameters and circumstances of the relevant but unknown mechanism.

The specific impact of the solar corpuscular radiation on the terrestrial atmosphere can be pointed out if any solar-terrestrial phenomena or regularities exhibited dependence on the polarity conditions of solar magnetic fields; this might be regarded as a signature of some solar particle effect.

Studying the correlation coefficients between the aa-index of geomagnetic activity and the surface temperature data of 136 European stations, the following results have been obtained: (1) The efficiency of the solar impact exhibits a semi-annual

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fluctuation, this means enhancements of aa index-temperature correlations around equinoxes. (2) The disturbances coming from the Sun's polar and equatorial regions release opposite meteorological responses. (3) Both previous regularities depend on the orientation of the Sun's main magnetic dipole field (the dipole cycle) in such a way that the (1) feature (the semi-annual fluctuation) is only detectable in the years of parallel solar and terrestrial magnetic dipole fields, whereas the (2) feature exhibits sign reversals of correlations following solar polarity reversals. The whole complex of phenomena depends on the geographical position; in the present material it is mainly confined to European middle latitudes. This may hint at some indirect mechanism, probably through affecting atmospheric circulation.

The difference between the above (1) and (2) properties is that the semi-annual fluctuation (the (1) feature) was studied on all geomagnetic disturbances regardless of their types, but the (2) feature is based on the distinction between the disturbances of polar (recurrent) as well as equatorial (shock and fluctuating) origin. We suspect that the apparent absence of the semi-annual fluctuation in years of antiparallel solar and terrestrial fields is not a signature of its real absence, but perhaps, the different types of geomagnetic disturbances may neutralize each other in the periods of antiparallel fields. By comparing the above results we may expect that a given type of solar disturbance may cause opposite tropospheric effects in alternating dipole cycles. This hypothesis is the generalization of the above features in some sense and this was checked in the present work.

2. Data Sets and Their Separations

As in the previous papers, the solar corpuscular impact was taken into account through the monthly means of the geomagnetic aa-index introduced and analyzed by Mayaud (1972), see also Legrand and Simon (1989) and Simon and Legrand (1989), Terdik (1996), and Paper I. The atmospheric response was studied by using monthly means of surface temperatures. They were taken from a comprehensive meteorological database, the Global Historical Climatology Network (GHCN, Vose *et al.*, 1992). One-hundred thirty-six European temperature data sets were used from this data base for those stations for which the time-span of the registrations was not shorter than 80 years in the period 1868–1987.

As in the previous works, two subgroups of years were selected in which the solar main dipole field had opposite directions. The years of unambiguous field directions were taken from the paper of Makarov and Sivaraman (1986). We called a year 'parallel' in which the solar and terrestrial magnetic fields are parallel throughout the year. But in the present work we went a step further: two further subdivisions of years were made according to Simon and Legrand (1989), who divided dipole (poloidal) cycles into two parts: years of dipole phase and multipole phase. These phases are distinguished by the occurrences of different disturbance types.

The geomagnetic disturbances can be categorized on the basis of their temporal runs, their specific shapes allow one to associate a given geomagnetic event with a certain solar feature (Legrand and Simon, 1989, 1991; Simon and Legrand, 1989). The recurrent activity is associated with the polar coronal holes, and this is the dominant type of activity during the dipole phase, a few years before sunspot minimum. The shock activity and the fluctuating activity are associated with solar sources around the sunspot activity belts, these types of disturbances characterize the multipole phase, a few years around sunspot maximum. By using the above classification scheme, the meteorological impacts of the different particle streams, or implicitly, the different solar events and features, can be at least partly separated.

If we consider only the multipole phase, i.e., the years with no recurrent activity, then we can study the net effect of the solar lower-latitude regions. It is supposed that the shock activity is the dominant feature in this interval, as it causes larger geomagnetic disturbances. So we can study its effect if we consider only the years with no recurrent activity. This means 21 years in the antiparallel intervals (1890–1994, 1909, 1914–1917, 1935–1939, 1956–1957, 1972, 1978–1980) and 28 years in the parallel cases (1874, 1876–1982, 1900–1904, 1924–1926, 1945–1948, 1960–1961, 1965–1968, 1982, 1987). It should be noted that the dipole phase cannot be studied in this way because there are no purely recurrent years with no effect from the equatorial belt.

3. Semi-Annual Fluctuation

Correlation coefficients of the aa-index and temperature were computed for all calendar months involved for the two separated data sets, and the annual distribution of these correlations was plotted. We expected that the results would show the same semi-annual fluctuation (with larger scatter because of the smaller data sample) in the parallel years as in the whole 51-year set of parallel intervals. At the same time we looked for an opposite semi-annual fluctuation in the antiparallel case, as previous results show that the correlations reverse their signs if the orientation of the solar main dipole is reversed.

Figure 1 shows the annual distributions of correlations for the stations where this sign reversal can be detected. It can be seen that four middle groups of the region studied (with some exceptions) show the searched for regularities quite well. This is the region, where all previously reported effects were most remarkable and detectable (see, e.g., Figure 3 in Paper IV), i.e., this is the region where the solar corpuscular impacts are most influential. The diagrams can be compared with Figure 3 in Paper IV, the present I, II, III, IV notations of groups correspond to G5, G7, G8, G9, respectively, in Paper IV. As we omitted here the non-involved regions for simplicity, the locations of the stations are depicted in Figure 2.

A question may arise that it would be quite enough to represent the behaviour of these areas with some selected data sets, because nearby stations may be linked

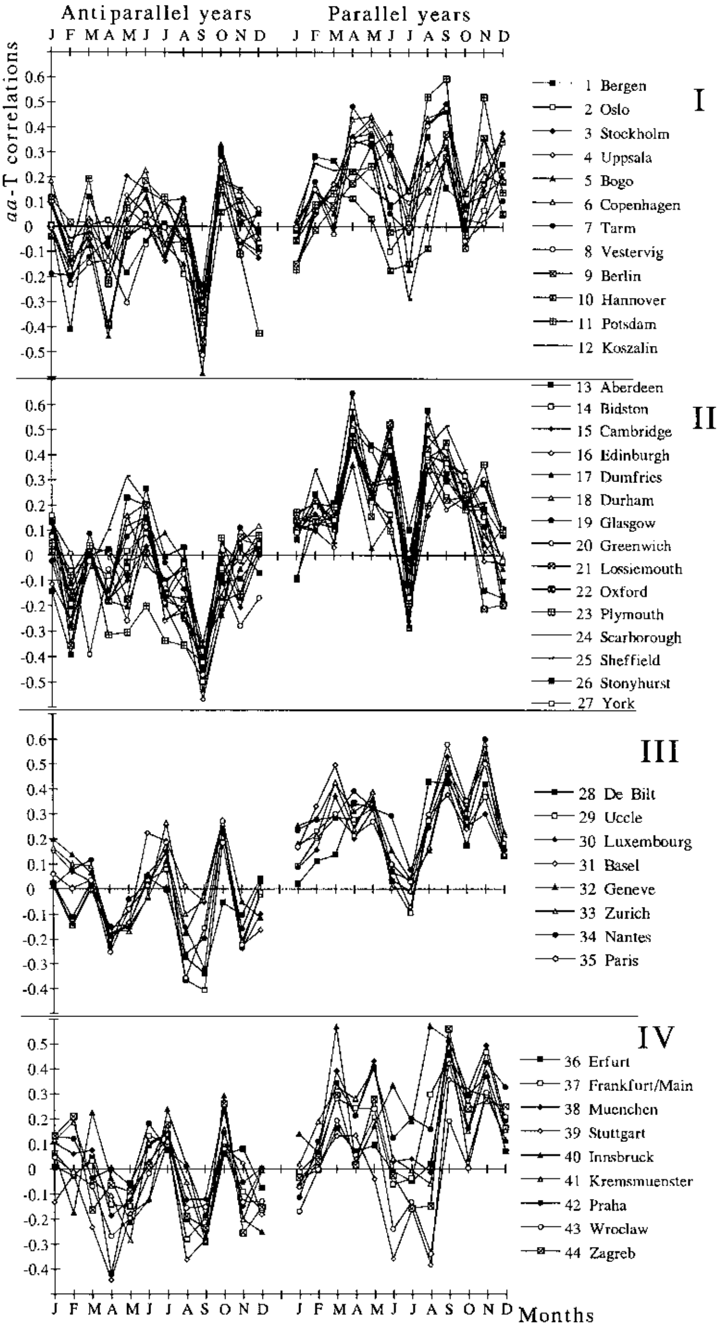

Figure 1. Annual distributions of $aa-T$ correlations in periods of antiparallel and parallel orientations of solar vs terrestrial main magnetic dipole fields in those years when there is no recurrent geomagnetic activity. An alternating negative and positive semi-annual character is perceivable.

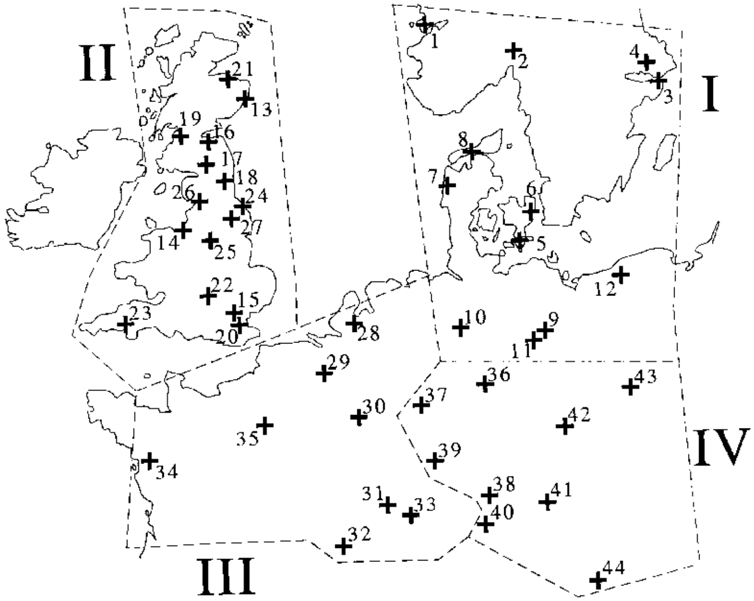

Figure 2. Locations of the European meteorological stations involved in the present study.

so that their records are not independent. However, we finally decided to deal with all involved stations because the present paper, like the previous ones, addresses among others the problem of what is the extent of the atmospheric circulation pattern which transmits the influence of the particles to the local weather. We can only present the coverage of this area with all stations involved, as they all together can depict the dominant tendencies. On the other hand, outside of this region the stations do not exhibit the reported properties even if they are relatively close to some stations involved. Furthermore, we do not want to make any arbitrary selection among the data.

As we expected, the semi-annual fluctuation is perceivable in the parallel years, and a semi-annual character with negative coefficients can be detected in the antiparallel years. In the latter case there is a definite negative extreme value in September for all the groups, and a smaller one in April for the groups 8 and 9. This means, that in the years of parallel fields, the correlations of shock and fluctuating activities with temperature are positive, whereas in antiparallel years these correlations are negative in the central part of Europe. Comparing this result with the previous ones, it is likely that their effects are opposite to that of recurrent streams at the same time. This can explain why we cannot find semi-annual fluctuation in the whole 44-year antiparallel interval (as reported in Papers I and II) when the positive correlations with the recurrent activity can neutralize the negative correlations with the schock and fluctuating activity. In the parallel interval this neutralizing effect is not strong as the recurrent activity is much smaller, so the semi-annual fluctuation is detectable in both dipole and multipole phases.

4. Polarities in Polar vs Equatorial Corpuscular Events

It should be emphasized that the absence of the effect over large areas does not contradict the positive results in the areas displayed. The effect is perceivable only in those areas to which the previously presented 1–3 features (mentioned in the Introduction) are restricted. This may be explained by assuming that the corpuscular effects are not global; unlike irradiance, their impact is indirect. This does not modify the temperature directly, but it modifies the large-scale atmospheric circulation pattern, and this latter forms the local temperatures, so the effects may (or even should) be different at different locations (see Papers II and III).

Concerning the theoretical consequences of these results, they give a hint that the mechanism linking the solar corpuscular variations to surface temperature may be connected with the time-dependent nature of the IMF. We think that variations of scalar quantities cannot cause such sign reversals, only the magnetic properties can exhibit the necessary variability by the changing orientation of the $\mathbf{B}$ magnetic vector. A similar antiphase relationship was found between pressure variations associated with $+/-$ and $-/+$ sector boundary crossings by Rostoker and Sharma (1980). They worked out a possible scenario to explain their findings in which the sign of the B_y component of the IMF plays a decisive role through the Svalgaard –Mansurov effect (Svalgaard, 1973). We put our results into this framework and try to draw conclusions about the changing structure of the IMF. It is plausible that the orientation of the main dipole field plays an important role in the existence of differences between antiparallel and parallel cases, probably mainly due to north–south asymmetries and the Russel–McPherron effect. However, it is not likely that the main dipole field itself causes different effects in the dipole and multipole phases of the same dipole cycle. This is why we conclude that the particle streams coming from the activity belt may have a local magnetic field orientation which differs from that of the recurrent high-speed wind streams governed by the large-scale structure of the the IMF. This assumption is plausible, as it has been discovered by Bieber and Rust (1995) that the toroidal flux escapes from the Sun in a large amount mainly in relationship with CMEs. If the ejected flux could preserve its loop structure, it can be supposed that it can preserve its latitudinally extended shape of magnetic field lines. If our assumption is right, then the particle streams coming from the active regions could project a B_y component oppositely oriented to the geocentric solar magnetospheric coordinate system relative to that projected by the main dipole field. So the effects of sunspot activity and the polar regions would be opposite in the same dipole cycles, and after the polarity reversals all the effects would exhibit opposite behaviour. At a given time, the effect of corpuscular radiation would be determined by the dominant component of the IMF.

These results underline the importance of the distinction between spatially or temporally different features. Two consecutive cycles as well as their multipole and dipole phases cannot be treated in the same way in the case of corpuscular effects. The question of time- and activity-dependent magnetic structures demands further investigations by using the IMF and coronal data.

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