ISSN 0351–2657
HOBUD7 29(1) 1 (2005)

GEOEFFECTIVE AND CLIMATE-INFLUENCING SOLAR AND INTERPLANETARY CONDITIONS

T. BARANYI and A. LUDMÁNY

Heliophysical Observatory of the Hungarian Academy of Sciences,
H-4010 Debrecen, P.O.Box 30, Hungary

UDC 523.62-726:523.31-852
Conference paper

Abstract. Several connections have been detected and demonstrated between solar magnetic conditions and climatic responses which hint at a highly complicated mechanism of sun-climate relations through plasma streams. The present contribution overviews our results about the possible factors of this mechanism. The main factor is the negative value of the interplanetary magnetic B_z component which exhibits a fairly complex behaviour. Its strength is influenced by the solar dipole cycle, the nature of ejected plasma (CME or fast stream), the magnetic topology of the CME and the position of the Earth (Rosenberg-Coleman and Russell-McPherron effects). The persistence of the negative B_z is also effective. The impacts of these features can be pointed out in the climatic responses.

Key words: Solar cycle - interplanetary magnetic field - climate

1. Introduction

The solar impact on weather and climate has been treated for a long time in terms of irradiance variability. There exists, however, another channel of energy transfer between the Sun and the atmosphere: that of the ejected plasma streams. At first glance the weight of the irradiance channel seems to be much larger because the rate of energy transferred by electromagnetic radiation is about seven orders of magnitude higher than that carried by plasma streams. However, the variation rate of the plasma streams may be comparable with the magnitude of the quiet plasma flow whereas the variation rate of the radiative flux is less than a percent of the quiet value. Therefore it may be assumed that the solar activity impact is equal or more efficient in this latter case, or in other terms, its signature may be more expressed in the meteorological records than those resulted by the radiation fluctuation. This assumption motivated a detailed search for any signatures of solar impact among the climatic data.

The first result was the detection of a semiannual behaviour (instead of the expected winter maximum of weather response): 119 year Hungarian surface temperature data exhibited enhanced correlation with the geomagnetic aa-index around the equinoxes, whereas the precipitation behaved oppositely (Baranyi and Ludmány 1992) see Fig.1.

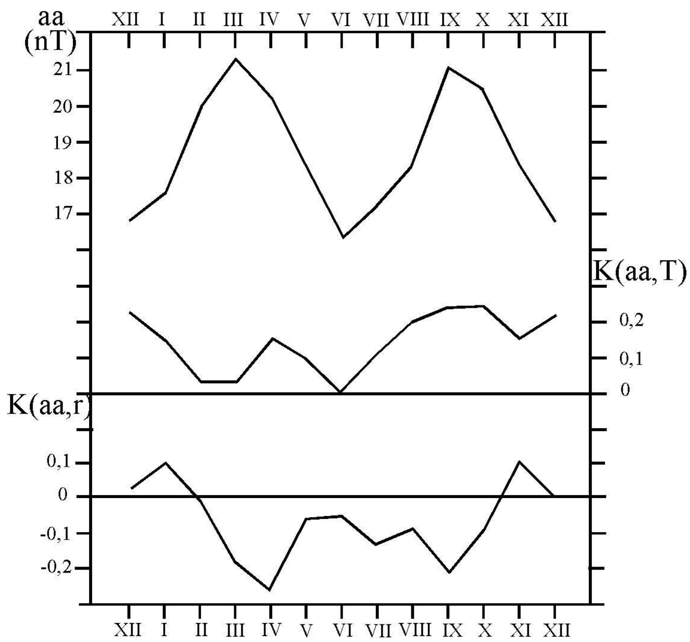

Figure 1: Annual variation of the aa-index (upper row), temperature-aa correlation (second row) and precipitation-aa correlation (third row) in Hungary between 1868 and 1987.

The check of the effect on a broader European region revealed its polarity condition: it was detectable in the years of parallel solar and terrestrial magnetic fields and untraceable in antiparallel years, (Baranyi et al 1995, see Fig. 2).

The semiannual effect in itself should have been a signature of plasma impact (it cannot be expected from irradiance impacts) and the polarity-

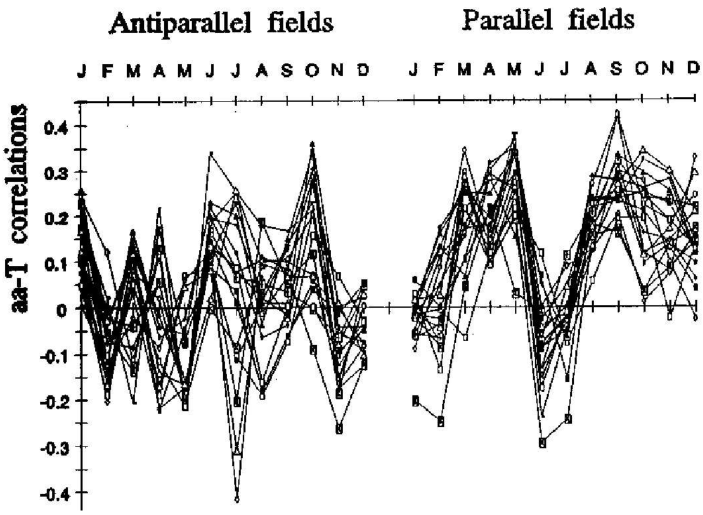

Figure 2: Annual variation of the temperature-aa correlation in 19 European stations between 1868 and 1987 by separating the years of parallel and antiparallel solar/terrestrial magnetic fields.

dependence corroborated it. Further broadening of data sampling to 136 European stations (Fig. 3) confirmed the effect with a certain spatial constraint, apparently is more pronounced in regions close to the Atlantic atmospheric circulation pattern (Baranyi and Ludmány, 1995a).

It can only be mentioned here that further studies also confirmed the role of solar plasma impacts: differences have been detected between atmospheric responses given to fast streams and eruptive events (CMEs) whereas the above mentioned polarity-dependent semiannual fluctuation is resulted by the latter type of plasma flow (Baranyi, Ludmány, 1995b). The plasma induced tropospheric processes can be regarded to be existing effects.

2. Agents between the Sun and Earth

The next task was to reveal the underlying mechanisms which should be a more complicated task than in the irradiance paradigm. In this latter case the entire globe is affected, the impact only depends on the intensity variation, this is a purely scalar impact. In contrast, however, the plasma

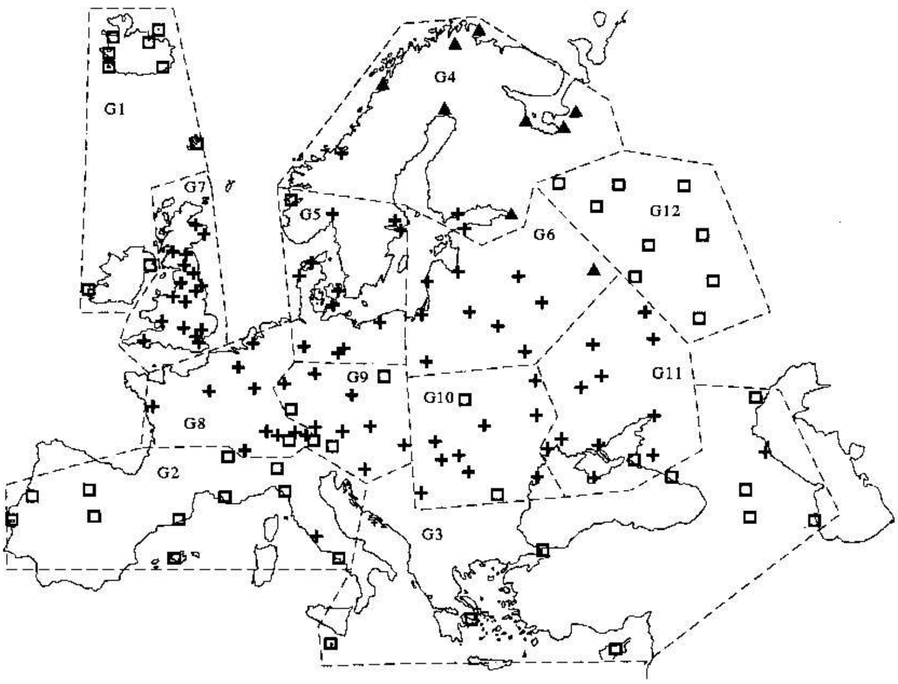

Figure 3: The symbols denote the detectability of the semiannual effect in the temperature of 136 European stations in the years of parallel solar and terrestrial fields. Plus: the semiannual fluctuation is detectable; Triangle: the correlation curve has an annual character; Square: none of the regularities are detectable.

effects should also be of vectorial nature. One should find those agents which can be messengers between the solar and terrestrial atmospheres in such a way that their efficiency exhibits semiannual variation (equinoctial maxima) in the years of parallel solar and terrestrial fields and no such variation in antiparallel years.

The well known semiannual fluctuation of the geomagnetic activity has been thoroughly analyzed and several mechanisms are proposed to explain it, of which only two mechanisms may be related to polarity changes: the Russell-McPherron (RM) effect (Russell and McPherron, 1973) and the Rosenberg-Coleman (RC) effect (Rosenberg and Coleman, 1969). These are also the main suspects here. The key parameter of geoefficiency is the B_z

component of the interplanetary magnetic field. If it has a negative value in the GSM (Geocentric Solar Magnetospheric System) then substantially more energy can be transferred into the terrestrial environment through solar/terrestrial magnetic field line interconnection than by zero or positive B_z values. Substantial negative GSM B_z can happen in two different ways. Either the IMF B_z component has a significant negative value in the Geocentric Solar Ecliptic System (GSE) which does not vanish in the GSM, or the GSE B_y component (which lays in the ecliptic plane) projects negative B_z component into the GSM. This latter condition plays a role in the above mentioned two effects.

The RM effect means that negative GSM B_z is projected by negative (sunward) GSE B_y during spring and positive (outward) GSE B_y during fall. This is a pure geometrical transformation which should work in both parallel and antiparallel cases. The RC effect means that the annually varying heliographic latitude of the Earth exposes it to different B_y domains with varying weights: in antiparallel years the geoeffective sectors predominate (in the above terms) whereas in the parallel years the durations of the opposite sectors are longer which is not favourable to the semiannual effect.

To reveal the mechanism behind the above mentioned tropospheric response annual or semiannual behaviour should be searched in the solar plasma streams and the interaction conditions.

3. Analysis of Data

The longest set of interplanetary data can be taken from the OMNI database containing spacecraft measurements since 1963. This interval comprises three entire dipole cycles. These data are displayed in Figure 4 to demonstrate the above mentioned effects. The RM effect (upper row) means that we get higher geomagnetic activity level in spring from negative B_y and in fall from positive B_y, and this is valid both in parallel and antiparallel periods. The RC effect (lower row) means that in antiparallel years the Earth resides longer in $B_y < 0$ regions during spring and in $B_y > 0$ regions during fall which is the condition of the semiannual fluctuation of geomagnetic activity whereas this is not the case during parallel fields.

These results may be somewhat embarrassing for the interpretation of the meteorological response because an antiparallel predominance can be

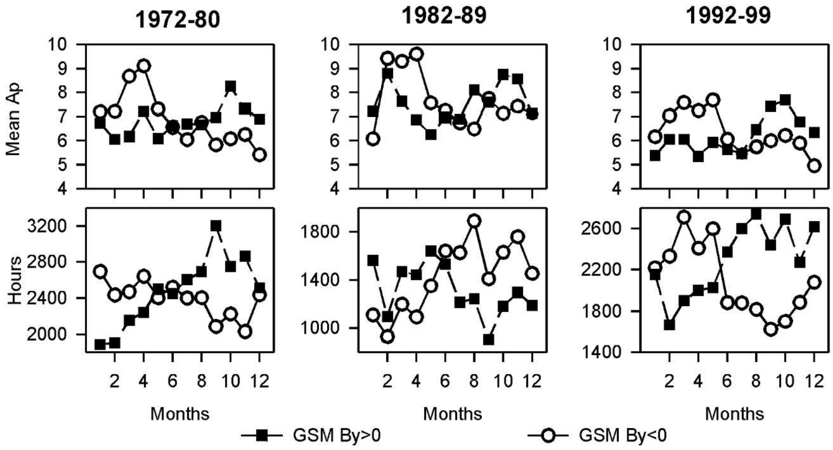

Figure 4: Annual dependence of the geomagnetic activity from the positive vs negative B_y values (upper row: Russell-McPherron effect), and the number of hours spent in sectors of positive and negative B_y (lower row: Rosenberg-Coleman effect). The years of antiparallel and parallel solar/terrestrial fields are separated.

seen. By the way, from the point of view of the geomagnetic activity proper this may be perhaps obvious, if we consider its polarity-dependence, i.e. the parallel-antiparallel separation of the upper curve in the Figure 1., see the Figure 5 in which the semiannual fluctuation is more expressed in antiparallel years.

There is, however, a further interesting circumstance. As was mentioned in the introduction, the considered effect, the polarity-dependent (parallel field preferring) semiannual response of the atmosphere can be attributed to CMEs so it is appropriate to restrict the study to these events. This was done in such a way that only the ascending phases were taken into account when the geoeffective events are resulted by CMEs. If we plot the the monthly mean GSM and GSE B_z values for the $K_p > 3$ events by separating the parallel/antiparallel years (Fig.6.) it turns out that in the CME-generated disturbances the semiannual effect is missing in antiparallel years. It is present, however, in parallel years which means that in the GSM system stronger negative B_z belongs to negative B_y by spring and to positive B_y by fall as is the case in the Russell-McPherron effect.

The cause of this disappearance can also be read from the lower panel

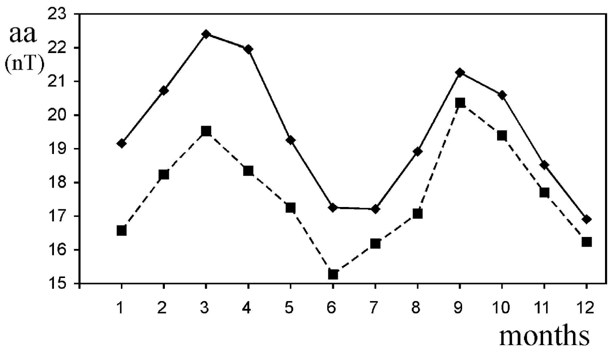

Figure 5: The semiannual variation of the geomagnetic activity in the years of antiparallel (solid line) vs parallel (dashed line) solar/terrestrial magnetic fields.

of Fig.6. The magnetic topologies of the CMEs are such that in the GSE system in antiparallel years the strong negative B_z coincides with positive B_y by spring and with negative B_y by fall and, as a result, the conditions of the Russell-McPherron effect are compensated, which is not the case in parallel years.

Thus, in fact there exists a semiannual mechanism which favours the parallel years and its main feature is the central role of the IMF B_y component. Thus, our original question ("What may be the reason of the atmospheric semiannual response preferring the parallel years?") can be reformulated in the following way: "How can any atmospheric processes be sensitive to the sign of the interplanetary B_y magnetic component?"

Apparently, the only reasonable candidate for this role may be the Svalgaard-Mansurov effect. This is a complex response of the ionospheric currents in the polar region to the magnetic field in the ecliptic plane. Different directions of the B_y component may distort quite differently this current which is a constituent of the global atmospheric current system. This large current consists of the equatorial storm region as a generator, the Earth and air currents and it is closed in the polar region where the variations of the ionospheric currents certainly modify its regime. These currents have an impact on the cloud formation through the so called electroscavenging as described by Tinsley (2000) and this mechanism may be subject of the above interplanetary influences by transferring the solar impacts toward the troposphere.

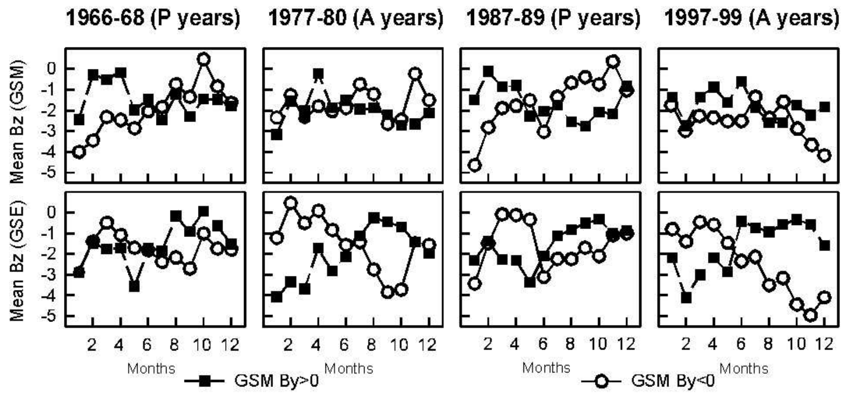

Figure 6: Annual variations of monthly mean B_z in the GSM and GSE systems during the ascending phases of sunspot cycles in $K_p > 3$ intervals, by separating $B_y > 0$ and $B_y > 0$ cases and parallel/antiparallel years.

4. Conclusions

Now it seems to be possible to suggest a chain of events and conditions which can establish a certain kind of connection between the solar activity events and the tropospheric processes through plasma streams with special regard to the semiannual response.

1. The magnetic field topologies of solar ejected plasmas are determined by solar activity properties (helicities and main dipole field polarity).

2. The geoefficiency of a plasma stream depends on the IMF negative B_z component.

3. Semiannual variation of the negative B_z component can be produced by the Rosenberg-Coleman effect (alternating solar N/S hemispheres) and the Russell-McPherron effect (superposition of two annual variations of the B_y component).

4. The semiannual (in fact two annual) variation of the B_y component is also responsible for the Svalgaard-Mansurov effect (impact on the polar current patterns).

5. The varying polar ionospheric currents also vary the global air-Earth current.

6. This latter current affects the cloud formation and, indirectly, the

weather (Tinsley, 2000).

This is a fairly complex mechanism which is based on several vectorial conditions. We claim that in this way the climate/weather features can in fact be influenced by solar plasma events.

5. Acknowledgements

The present work was supported by the grants OTKA T037725 and ESA PECS 98017.

References

Baranyi, T., Ludmány, A.: 1992, *J. Geophys. Res.* **97 (A10)**, 14923-14928.

Baranyi, T., Ludmány, A., Terdik, Gy.: 1995, *J. Geophys. Res.* **100 (A8)**, 14801-14805.

Baranyi, T., Ludmány, A.: 1995a, *Ann. Geophys.***13**, 427-436.

Baranyi, T., Ludmány, A.: 1995b , *Ann. Geophys.* **13**, 886-892.

Baranyi, T., Ludmány, A.: 2003, *J. Geophys. Res.* **108 (A5)**, 1212, doi: 10.1029/2002JA009553

Rosenberg, R.L., Coleman, P.J. Jr.: 1969, *J. Geophys. Res.* **74**, 5611.

Russell, C.T., McPherron, R.L.: 1973, *J. Geophys. Res.* **78**, 92.

Tinsley, B.A.: 2000, *Space Sci. Rev.* **94**, 231.