# RELEVANCE OF THE TOPOLOGIES OF SOLAR EJECTED PLASMAS IN TROPOSPHERIC PROCESSES

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## ABSTRACT

The lower atmosphere has a quite complex pattern of responses to the ejected solar plasmas depending on the magnetic topologies of their solar sources. The present contribution overviews the relevant properties of the upstream plasmas which can intermediate between the solar features and the atmosphere. The analysis of the magnetic field involved the strength and sense of its components as well as the duration of a certain sense of the components. Any equinoctial enhancements similar to that of the atmospheric response were also searched. The comparison of the properly selected atmospheric and solar wind features results in a few candidates for the role of mediation between the solar and terrestrial atmospheres. Besides the generally accepted role of the IMF Bz and bulk velocity, the IMF By component is proven to be of crucial importance. Under certain conditions it exhibits a semiannual behavior, a dependence on dipole cycle and a direct impact onto the terrestrial atmospheric current system, thus it is apparently a key factor in solar-terrestrial relations.

## 1. INTRODUCTION

A concise overview has been reported about the complex problem of atmospheric responses to plasma impacts at the previous SOLSPA conference [16]. This report summarized a system of previous results, a consistent behavioral pattern exhibited by the atmosphere to solar plasma effects. A surprising common feature of these effects is that the terrestrial response is apparently sensitive to magnetic polarity conditions on the Sun, it can distinguish between consecutive (odd and even) cycles as well as between plasmas of toroidal and poloidal origin.

In order to get a deeper comprehension of this pattern we should scrutinize the possible mediators between the solar and terrestrial atmospheres. We assume that the ejected plasmas may have such geoeffective properties, which preserve information about the mentioned conditions of the solar sources. To survey the possible candidates of these properties a systematic investigation is being carried out, this is a comprehensive analysis, which will be reported in detail elsewhere. Here we only present a preliminary report about the most intriguing feature found: the possible source of the polarity-dependent semiannual fluctuation.

The complex phenomenon can be summarized briefly as follows. The correlation of the terrestrial surface temperature and the geomagnetic aa-index has a semiannual fluctuation with maximums at the equinoxes [1]. This response is restricted to specific geographic areas, and it can be detected in those years when the solar and terrestrial main magnetic dipole fields are parallel (called parallel years) and it is absent in antiparallel years [2, 3]. If we find any similar behavior in the upstream plasmas then it may lead to the real mechanism of the above pattern.

## 2. ANALYSIS OF PLASMA CLOUD DATA

Previous studies were based on as long data sets as possible, the aa-index and temperature databases allowed study a 119-year period. The time-interval of the present study is restricted to the spacecraft era the data were taken from the OMNI database [13]. As in all previous investigations, those years when the solar and terrestrial dipole fields were oppositely directed, the antiparallel years, were separated from the parallel years on the basis of the data of Makarov and Sivaraman [17].

A further distinction should also have made. As was mentioned above, the terrestrial response has proven to be sensitive to the solar origin. Namely, the response depends on whether the ejected plasma is a fast stream (poloidal origin, from a coronal hole) causing recurrent geomagnetic disturbance or it is a CME (toroidal origin, from the activity belt) causing shock or fluctuating geomagnetic activity. These results will not be treated here (for the details see [4]), but we mention that the distinction is made on the basis of the database of Legrand and Simon [14], who were able to classify all geomagnetic events as recurrent, shock or fluctuating ones.

We focus on the differences between antiparallel and parallel years and only those years are considered when no recurrent activity was detected. This involves the first period of the solar cycle when the polar coronal holes are restricted to high latitudes and their streams do not reach the Earth. The reason of this restriction is that in this way we can separate the effect of CMEs from that of high-speed streams. On the basis of the above assumptions the following years are considered: 1972, 1977-80 in antiparallel case and 1966-68, 1982, 1987 in parallel case. Further restriction is that we omitted the large CMEs causing shock activity. The large CMEs are rare but they may have extreme large magnetic fields, which may distort the mean values.

Fig. 1 shows the annual behavior of the mean Bz component of fluctuating activity measured in the Geocentric Solar Magnetospheric system (GSM) in antiparallel and parallel years. Negative and positive cases of the By component are separated. This is the only case we have found in the mentioned systematic search when a semiannual fluctuation shows up in the parallel instead of antiparallel years. The relevant IMF parameters are taken into account only for those hours when Kp>3, these data are also taken from the OMNI database. Thus, this figure contains information about the behavior of the magnetic field components during fluctuating activity, i.e. for plasmas coming from the activity belt of the Sun.

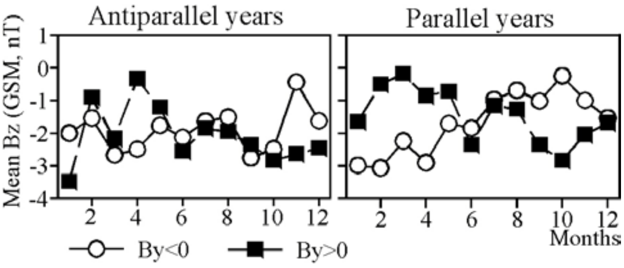

Fig. 1. Annual behavior of Bz and By components in the GSM.

### 3. CONSIDERATIONS ON IMF COMPONENTS

Fig. 1 shows a well known phenomenon in an unexpected form: the Russell-McPherron effect [20] in parallel years but not in antiparallel years. To explain the specific nature of this case we recall a scheme of this effect, which provides a geometrical explanation for the semiannual fluctuation of the geomagnetic activity, it formulates the conditions under which the IMF $B_y$ component reflects geoeffective negative $B_z$ component in the GSM. Consider the Figure 2., which shows the ecliptic, and the positions of the Earth at fall and winter. For the sake of simplification only the rotation axis is indicated which declines from the normal of the ecliptic by 23.5°, the axis of the GSM precesses about the rotation axis by 11°, so the angle between the GSM-axis and the ecliptic normal varies between 23.5±11 degrees daily. The figure shows a magnetic field directed outward from the Sun, when the Earth is at the autumn equinox. This field has a zero Bz component in the GSE system, but it has a positive (duskward) By which reflects a negative Bz in the GSM. For similar geometrical reasons, the sunward directed magnetic field (meaning negative Bz in GSE) reflects a negative Bz in GSM by spring. In brief: we get negative Bz from negative Bz (sunward field) in spring and from positive By (earthward field) in fall, whereas no Bz is reflected around the solstices, and this variation results in a semiannual fluctuation of mean Bz in GSM system. This is the Russell-McPherron effect.

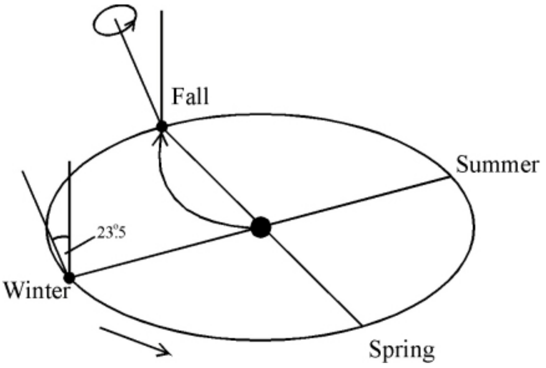

Fig. 2. Scheme to the Russell-McPherron effect.

If the Earth resides in such a sector which results in positive $B_z$ in GSM, then no impact will be resulted, this is an ineffective sector. If the effective and ineffective sectors (in terms of the above considerations) were statistically balanced then the role of the Russell-McPherron effect would be equally effective in the consecutive dipole cycles in the averages of the sector pairs, however, this is not the case.

In those years when the solar and terrestrial magnetic dipole fields are antiparallel, the field lines south of the neutral sheet point toward the Sun. Around the spring equinox the Earth is near to the southernmost heliographic latitude (6. March: -7.25$^{O}$), so it is merged more times in such sectors which are active in spring, i.e. the field is directed toward the Sun (By<0) and vice versa, in autumn it resides mostly in such sectors where the field is directed away from the sun (By>0). In the parallel years the rate of occurrence of the away and toward polarities is reversed. This is the Rosenberg-Coleman effect [18], which is based on the annual variation of the heliographic latitude of the Earth.

In the antiparallel years the conditions caused by the Rosenberg-Coleman effect are favorable for the Russell-McPherron effect, and the semiannual fluctuation of geomagnetic activity is remarkable. For the same reasons, however, in parallel years (when the solar and terrestrial dipoles are parallel) the Earth resides more times in unfavorable sectors, so the Russell-McPherron effect can only be effective in the shorter intervals of favorable sectors and the semiannual fluctuation is much less remarkable. The observable semiannual fluctuation of geomagnetic activity is a combination of the Rosenberg-Coleman and the Russel-McPheron effects as well as the polarity-independent Kelvin-Helmholz instability [10].

A comparison of parallel and antiparallel periods is given in Fig. 3 for the semiannual fluctuation of the aa-index, the stronger effect in antiparallel years is conspicuous.

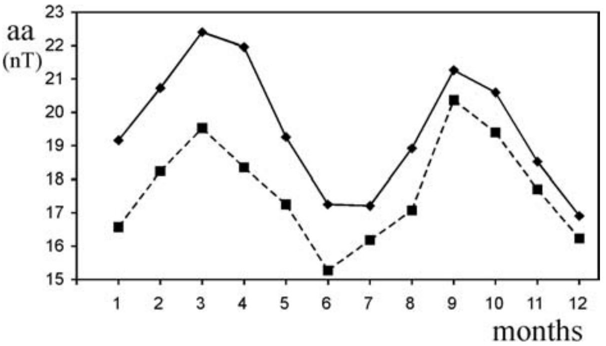

Fig. 3 Monthly means of aa-index in antiparallel years (solid line) and parallel years (dashed line) between 1868 and 1987.

If we restrict ourselves to the occurrence of CME-events (fluctuating activity), then the above outlined processes can also be detected on the presently studied intervals. Fig. 4 shows the numbers of those hours which have been spent by the Earth in different sectors. It is remarkable that during the fluctuating activity in antiparallel years the Earth resides mostly in By<0 regions by spring and in By>0 regions by fall, which is the condition of the Russell-McPherron effect, whereas no similar asymmetry can be detected in parallel years. These figures show the combination of the indicated effects.

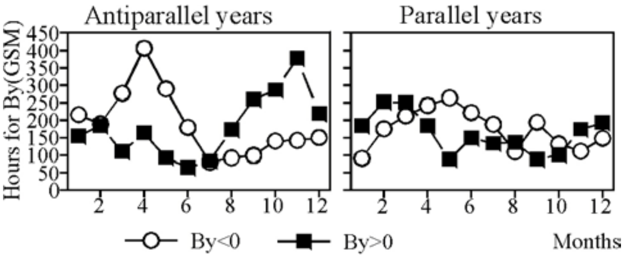

Fig. 4. Numbers of geomagnetically active hours spent by the Earth in sectors of negative and positive By. The period under study is the same as that of Fig.1.

Now we can return to the Fig. 1, its specific meaning can be formulated in the following way. If we restrict the analysis to the intervals of disturbances by CMEs then the conditions of the Russell-McPherron effect, namely the coincidence of Bz<0 with By<0 in spring and with By>0 in fall, are present in parallel years and not in antiparallel years, which is opposite to the above outlined standard picture.

## 4. MAGNETIC TOPOLOGIES OF CMEs

The presented behavior may help to get closer to the explanation of the previously reported phenomenon mentioned in the introduction, namely, that the terrestrial (atmospheric) response exhibits semiannual fluctuation in the parallel years, but not in antiparallel years. In the ejected solar plasmas the only similar pattern is that depicted in Fig. 1, the regular variations in the predominance of positive and negative By components.

This result apparently allows to draw some conclusions about the possible magnetic structure of the CMEs which cause the fluctuating activity. We indicated in [15, 16] the conjecture that the helical topology of the CMEs and their source regions may be the reason of the semiannual fluctuation in the atmospheric response. We refer to the growing number of evidences that significant plasma ejections originate mostly from distorted flux ropes, the helically kinked fields are the most probable sources of CMEs [9, 19]. On the other hand, the CMEs can transport the frozen-in helical topology of the source region [6, 7]. We also argued that the forefront of the inflating CME usually has significant Bz-values, which may also be increased by the inflation of the cloud for simple geometrical reasons [11]. Although the magnetic field of the CME may be more complex than a single kinked flux rope [12]. a dominant Bz component is generally present. This intrinsic Bz might have appeared to be responsible for the effect.

The present results indicate, however, that the key issue is the By component. Of course, the main cause of a geomagnetic disturbance may be the negative Bz [8], however, its magnitude alone does not exhibit a semiannual character, if we dont separate the By regions by polarities, then we dont get a distribution similar to Fig.1. We think that specific By/Bz combinations in CMEs may cause this peculiar manifestation of the Russell-McPherron/Rosenberg-Coleman effects. This structures need further scrutiny.

With this advancement we may also get closer to a possible scenario of solar plasma impacts on the atmosphere. The By component is a key factor in the modulation of global electric circuit and atmospheric circulation proposed by Tinsley [21,22,23]. In this mechanism the cloud formation is partly controlled by the global electric circuit in which different conductors take part, the Earth, the ionosphere the air-Earth currents and the currents of the polar region. These latter currents are directly influenced by the variability of the By through the Svalgaard-Mansurov effect. So the above features may provide a link between the solar active region structures and the terrestrial atmospheric events.

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