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Advances in Space Research 36 (2005) 2428–2433

ADVANCES IN SPACE RESEARCH
(a COSPAR publication)

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Case study of September 24–26, 1998 magnetic storm

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Received 19 October 2002; received in revised form 9 September 2003; accepted 6 November 2003

Abstract

We compute global magnetospheric parameters based upon solar wind data obtained from the WIND spacecraft upstream. Using the paraboloid magnetospheric model, calculations of the dynamic global magnetospheric current systems have been made. The solar wind dynamic pressure, the interplanetary magnetic field, the strength of the tail current, and the ring current control the polar cap and auroral oval size and location during the magnetic storm. The model calculations demonstrate that the polar cap and the auroral oval areas are mainly controlled by the tail current. The substorm onset at 0630 UT on September 25, 1998 happened near the minimum in the main phase field depression. The substorm expansion onset time is also marked by a sudden enhancement in the solar wind dynamic pressure and an enhancement in the tail current. The magnetic signatures of these two effects cancel each other, which explains why the D_{st} profile shows no strong time variation during the substorm. Evidence for the substorm expansion includes not only the signature in the AL index but also the strong asymmetry of the low latitude magnetic disturbances (substorm positive bay signature). Model calculations were checked by comparison with the GOES 8 and 10 magnetic field measurements.

Keywords: Magnetic storm; Magnetospheric current systems

1. Introduction and event overview

Investigation of the magnetospheric storms is of great interest as it enables revealing relative contributions of the magnetospheric current systems to the magnetic disturbances at the Earth's surface and onboard spacecraft. A correct taking into account of the contribution of each current system to the magnetic field allows prediction of the magnetic situation in the Earth's environment and the character and value of magnetic disturbance on ground. These predictions will enable avoiding of the unexpected situations of breaking on ground equipment and spacecraft devices.

Recent publications dealing with one of the most interesting events, the magnetic storm on 9–12 January, 1997, shows a lack of consensus around the problem of a relative contribution by various current systems to the magnetospheric magnetic field. The most contradictory item is taking into account the influence of the magnetotail current system. So, in the paper by Turner et al. (2000) the contribution of the magnetotail current system to D_{st} is estimated to be ~25%. Meanwhile, in the paper by Alexeev et al. (2001) the contribution of the magnetotail current system in the course of the overall storm is estimated to be ~50%, and a prevailing 60% in the main phase. This paper notes a significant difference between models of the magnetospheric magnetic field, especially when determining a quiet contribution to D_{st} by all the magnetospheric current systems.

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0273-1177/$30
doi:10.1016/j.asr.2003.11.023

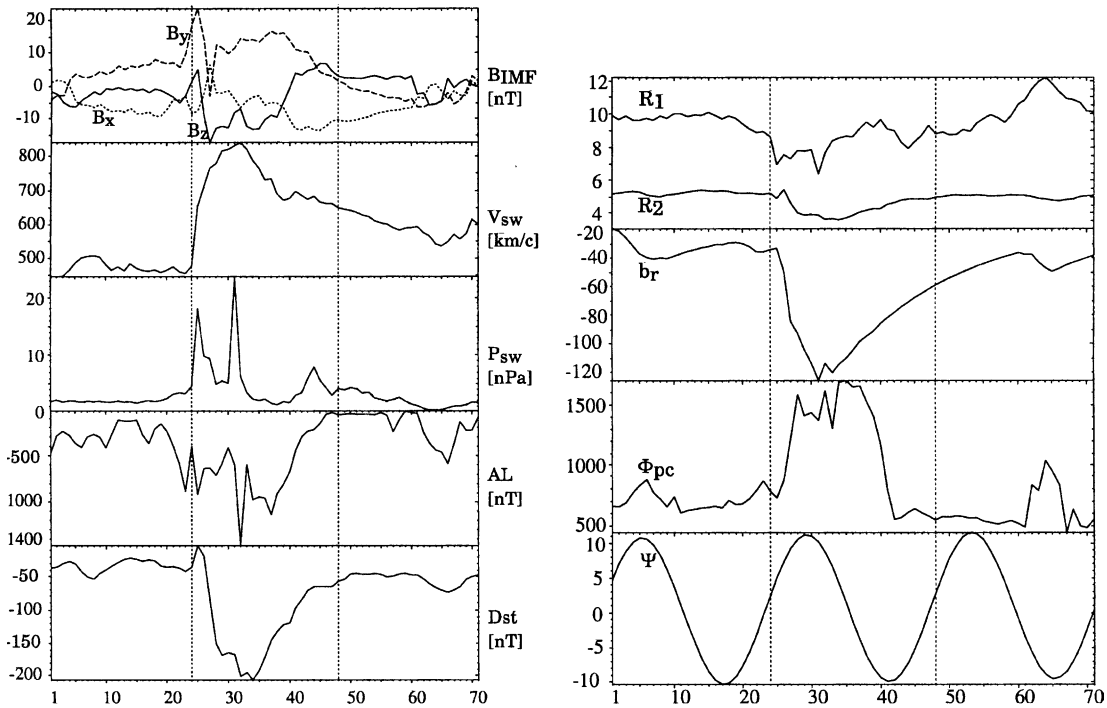

Fig. 1. Solar wind data, D_{st}, AL (left panel), and the model parameters R_1, R_2, both in R_E, b_r, (nT), $\Phi_{pc} = \Phi_\infty$ (MWb), and Ψ [°] (right).

The magnetic storm on 24–27 September, 1998 is also one of the most interesting events (see Fig. 1). An arrival of a dense cloud of the solar wind plasma at 23:45 on 24 September was accompanied by a northward turning of the IMF, remaining in this direction for 1 h 45 min. This leads to an interesting phenomenon in the Earth's magnetosphere, e.g. to a significant decrease of the polar cap for 30 min (Clauer et al., 2001). After 01:30 UT the IMF had a strong negative north–south component. Moreover, on 06:00 UT 25 September the second shock wave of the solar wind dense plasma encountered the magnetosphere. At almost the same time a significant substorm activity was detected (AL index). The tail current system enhancement and Increasing of the magnetopause current give the contributions to the D_{st}, which cancel each other. Consequently, the solar wind pressure jump weakly influenced the dynamics of the D_{st} variation. This behavior of the D_{st} index once more attracts attention to the question about the dynamics of the magnetospheric current systems and their relative contributions to the magnetic field at the Earth's surface.

In this paper we will develop previously created approaches to magnetospheric modelling. Generalization of the methods of calculations of the model input parameters will be used. In particular, the tail current magnetic flux will be calculated by AL, solar wind pressure and electric field variations, instead of AL in the previous papers (Alexeev et al., 1996, 2001). The approaches used in the event-oriented modelling will be amplified in this study. Thus, unlike previously developed models (Alexeev et al., 1996, 2001), the current one represents only the magnetic field dynamics during specific events after the fitting procedure.

2. Model, submodels, calculation of the parameters

In the paraboloid model the magnetic field and D_{st} index are calculated in two stages. Various current systems unambiguously depend on the concrete parameters, and a fixed set of these parameters unambiguously defines the magnetic field over the entire magnetosphere. The dipole magnetic field, B_d, depends on only one parameter – the dipole tilt angle ψ. The magnetic field of the shielding currents on the magnetopause, B_{cf}, depends on the dipole tilt angle ψ and the distance R_1 to the subsolar point. The tail current magnetic field, B_t depends on ψ R_1, on the distance R_2 to the inner edge of the tail current sheet, and on the magnetic flux in the magnetotail lobe Φ_∞. The ring current magnetic field, B_r, depends on ψ and on the total energy of the particles in the ring current and, as a consequence, on the magnetic field strength at the Earth's center b_r, produced by these particles. Thus, the magnetic field in the paraboloid model is calculated In the form presented by Alexeev and Feldstein (2001),

$$\vec{B}_m = \vec{B}_d(\psi) + \left(1 + \frac{M_{rc}}{M_E}\right)\vec{B}_{cf}(\psi, R_1) + \vec{B}_t(\psi, R_1, R_2, \Phi_\infty) + \vec{B}_r(\psi, b_r),$$

where M_{rc} and M_E are the magnetic moments of the ring current and of the geomagnetic dipole, correspondingly.