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MODELS AT GEOSYNCHRONOUS ORBIT

Author(s):

M. F. Thomsen
L. A. Weiss
D. J. McComas
M. B. Moldwin
G. D. Reeves

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An Observational Test of Magnetospheric Field Models at Geosynchronous Orbit

M. F. Thomsen, L. A. Weiss, D. J. McComas,
M. B. Moldwin, and G. D. Reeves

Los Alamos National Laboratory, Los Alamos, New Mexico, U.S.A.

ABSTRACT

The global nature of the Tsyganenko 89 [Tsyganenko, 1989] magnetospheric magnetic field model is tested by comparison of the model-predicted field orientations with the field orientations derived simultaneously at two different locations in geosynchronous orbit from the axis of symmetry of the plasma electron distribution function (30 eV - 40 keV). The results for the particular time interval studied are inconclusive because the Tsyganenko 89 model does not describe the field at one of the satellites well enough, but the procedure itself appears promising.

INTRODUCTION

The configuration of the geomagnetic field is an indicator of the response of the magnetosphere to the solar wind input. A number of empirical magnetospheric field models are currently in use which estimate the magnetic field direction and magnitude at any point within the magnetosphere under a variety of conditions. Such models are typically parametrized by a small set of variables (e.g., Kp, Dst, equatorward edge of the auroral oval, etc.) which are related to various measurable quantities. Hence, by monitoring those variables, one could hope to use the models to monitor the global state of the magnetosphere. One difficulty with this approach is that some of the relevant parameters have fairly coarse temporal resolution. Moreover, they are not always readily available. As an alternative, one can monitor the magnetic field at various points within the magnetosphere to determine empirically and in near-real-time which model best describes the current magnetospheric configuration, thereby allowing the global state of the magnetosphere to be monitored essentially continuously. In order for such a monitoring program to be effective, it is necessary to know how "global" magnetospheric field changes really are; i.e., at how many different points in space must the measurements be made in order to characterize adequately the magnetospheric configuration?

This report represents a preliminary step toward addressing this question. Specifically, using simultaneous measurements of the magnetic field orientation at two different locations in geosynchronous orbit, we test whether or not a single parameterization (i.e., Kp level) of the Tsyganenko 89 magnetic field model [Tsyganenko, 1989] can adequately describe the field configuration at both locations at the same time. The Tsyganenko field models [Tsyganenko and Usmanov, 1982; Tsyganenko, 1987, 1989] have previously been compared with *in situ* measurements [e.g., Tsyganenko, 1989; Fairfield, 1991], but to our knowledge, this is the first attempt to check its global character.

OBSERVATIONS

Since 1989, Los Alamos National Laboratory has placed three magnetospheric plasma analyzers (MPA) into geosynchronous orbit. These instruments provide ongoing simultaneous measurements of the geosynchronous environment at three longitudinally separated locations. While there are no magnetometers onboard the satellites, the symmetry axis of the three-dimensional plasma distributions can be used to indicate the direction (but not the strength) of the magnetic field vector, as described in greater detail below.

Each MPA consists of a spherical section electrostatic analyzer followed by six separate channel electron multipliers placed to detect particles entering the analyzer from six nearly contiguous polar angle sectors (relative to the spacecraft spin axis). As the satellite spins, the analyzer plate voltage is swept 24 times each revolution, providing a measurement at 24 azimuthal directions at each of the 40 logarithmically spaced energy channels for each of the six polar angle detectors. Hence, in one spin of the spacecraft a three-dimensional particle distribution is measured, consisting of 6 polar $\times$ 24 azimuthal $\times$ 40 energy bins. By changing the polarity of the plate voltage, the same analyzer is used for either ions or electrons. The energy range for both species is ~ 1 eV to ~ 40 keV. Although it requires only one 10-s spin to acquire a full 3-D measurement of one species, telemetry limitations permit a repetition rate of one full spectrum only every 172 s. The MPA is described more completely by *Bame et al.* [1993] and *McComas et al.* [1993]. For this paper we concentrate on the electron measurements, although in principle the same approach can be used with the ion distributions.

From measurements of the full 3-D distribution function, we compute the various velocity moments, including the density, the vector velocity, and the 3×3 temperature matrix. Assuming that the distribution is gyrotropic in the frame of the bulk velocity, the temperature matrix can be diagonalized, with the diagonal elements representing the eigenvalues $T_{\perp}$, $T_{\perp}$, and $T_{\parallel}$. Since the two values of $T_{\perp}$ should be nearly identical, the eigenvalue that is most different from the other two is identified as $T_{\parallel}$, and the corresponding eigenvector is the vector direction of the magnetic field. In Figure 1 we illustrate the results of this procedure for one day of observations. Shown there are the density, perpendicular and parallel temperatures, polar angle of the field direction (relative to the spacecraft spin axis, which points always at the center of the Earth), and the azimuth angle of the field (relative to the meridian plane containing geographic north). From Figure 1 it is clear that when there is an appreciable anisotropy the field angles are fairly precisely determined, but there is considerable scatter when the distribution approaches isotropy.

Fig. 1 Moments derived from the hot electron distribution (30 eV - 40 keV).

The solid lines in the bottom two panels of Figure 1 show the corresponding field angles that would be predicted for the spacecraft position as a function of time by the Tsyganenko 89 field model. The two curves in each panel correspond to the two extreme activity ranges in the model ($K_p=0.0+$ and $K_p>5-$). It is clear from the figure that the greatest variability from activity range to activity range occurs in the polar angle of the field (θ_B) and this primarily on the night side (2000-0400 LT, or 1500-2300 UT). Hence, for this study we concentrate on this angle and seek times when we have simultaneous measurements from two satellites on the night side. This opportunity occurred for several months in 1993, during which time satellites 1990-095 and 1991-080 were within 4 hours of each other (at geographic longitudes of 6° and

70° , respectively), resulting in a four-hour interval every day in which both spacecraft were within 4 hours of local midnight. For this study we initially concentrated on observations made during the month of February because there was a wide range of magnetospheric

activity in which to make our comparison. Figure 2 shows the 3-hour Kp levels for the month.

RESULTS

Figure 3 illustrates our procedure and its results for one day. The top two panels show the polar angle of the field derived from the observed particle distributions at the two spacecraft when they were within ± 4 hours of local midnight. Shown as curves in each panel are the corresponding field angles predicted by the full range of parameterizations of the Tsyganenko 89 model. From each measured field direction we have derived an "effective Kp" by interpolating between the two model Kp values that yield field angles which bracket the observed one. For example, if the measured angle lay halfway between the angle expected from the model for Kp=1 and that for Kp=2, the effective Kp would be 1.5. This effective Kp is shown for both spacecraft in the bottom panel of Figure 3, along with the actual measured value of the Kp index, which is shown as the solid line.

For the example shown in Figure 3, during the time interval when both satellites were within 4 hours of local midnight, the

Fig. 2 Three-hour Kp history for the month of February 1993.

Figure 3. (Top, center) Magnetic field polar angle derived from 1991-080 and 1990-095 measurements. (Bottom) "Effective Kp" from observation/model comparisons. Solid line shows actual measured Kp.

effective Kp at the two locations was basically similar. In other words, the same global model was generally capable of describing the field at two locations $\sim 60^\circ$ apart in longitude. Unfortunately, for the month of data we examined in this way, this happy circumstance was very much the exception. The general problem we encountered with this process is illustrated in Figure 4, which shows a typical example of the field orientation measured at spacecraft 1990-095, compared with the Tsyganenko 89 predictions for different Kp levels. Particularly in the pre-midnight hours (1900-2300 UT), which are the crucial ones for the intercomparison with 1991-080, the measured field direction lay outside of the range of values predicted for any parameterization of the Tsyganenko model. In large part this is due to the fact that there was very little range to the model field inclination there, presumably because this location was quite near the location of the model current sheet. Thus it appears that the Tsyganenko 89 model was not particularly suitable for describing the field at this satellite during this time.

Figure 4. Magnetic field polar angle derived from 1990-095 measurements compared with the predicted angle for the six parameterizations of the T89 model.

CONCLUSION

While the specific test of the global validity of the Tsyganenko 89 model described above for the month of February 1993 was not very definitive, the general procedure itself appears promising. It is possible that a modified version of the same model or perhaps a different model altogether would provide a better test. It may also be that the Tsyganenko model is a more successful description of the field at 1990-095 for other epochs and the test could be done then. We are currently exploring these possibilities.

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