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RESPONSE OF THE NORTHERN AND SOUTHERN POLAR CAP GROUND-BASED MAGNETIC FIELD TO IMF

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Abstract. IZMIRAN electrodynamic model (IZMEM) of geomagnetic variations for the northern polar region was developed using the data of magnetic observatories for the period 1968-1969; the northernmost station was Thule. The same model for the southern hemisphere was derived from the data of magnetic observatories and automatic magnetometers for the period 1978-1980 and 1983-1984; the southernmost station was at the corrected geomagnetic latitude $\Phi = - 89.1^{o}$. At present we have a possibility to use the data of polar stations (for the period of 1997-1998) such as P01, P04, P05, P06 (American AGO), Vostok and Sude (Russian bases), McMurdo (New Zeland station), Dumont D'Urville (French observatory) to obtain a new regression model and to compare it with that one obtained from Antarctic magnetic observatories and automatic magnetometers about 25 years ago. The regression coefficients for the same latitudes of the northern and southern hemispheres have been compared as well. There are noticeable variations of regression coefficients for the stations of longitudinal profile along geomagnetic latitude ~ 80°: P01, P04, McM.

Introduction

IZMIRAN electrodynamic model (IZMEM) of geomagnetic variations for northern and southern polar regions was derived from a large quantity of high latitude ground-based geomagnetic data (above ±57° corrected geomagnetic latitude) at all magnetic local times (MLT). At present a comprehensive database of magnetic data from an array of 16 magnetic stations in Antarctica is available for an analysis. We have used the data of polar stations ($|\Phi| > 80^{o}$): P1, P4, P5, P6 (American AGO), Vostok, Sude (Russian bases), McMurdo (New Zeland station) and Dumont D'Urville (French observatory) to obtain a regression model where the regression coefficients relate any ground-based geomagnetic field component to changes in Interplanetary Magnetic Field (IMF) measured near the Earth's magnetosphere:

$$H = K_{By}\times By + K_{Bz}\times Bz + H_0,$$

where H is the hourly value of one (X, Y, Z) component of the geomagnetic field on the Earth's surface; By and Bz are hourly values of the IMF components. The period with the best data coverage, 1997-1998, has been chosen for regression analysis. We have developed a new regression model and performed a comparison of new regression coefficients with those obtained from Antarctic magnetic observatories and automatic magnetometers about 25 years ago (IZMEM model, the period of 1978-1984). The regression coefficients $K_{By}$and K_B for the same latitudes of the northern and southern hemispheres have been compared. There are noticeable variations of $K_{By}(\Phi, MLT)$ and $K_{Bz}(\Phi, MLT)$ for the stations of longitudinal profile along geomagnetic latitude ~ 80°: P01, P04, McMurdo (McM). Geomagnetic coordinates of the stations and total number of hourly geomagnetic fields are presented in Table 1.

Table 1

Station	Geomagnetic		1996	1997	1998	1999
	Latitude	Longitude				
P01	-80.14°	16.71°	4797	5178	6686	3652
P04	-80.00°	41.64°	2475	2082	7816	-
McMurdo	-79.94°	327.53°	8199	7757	8451	7947

Modeling of geomagnetic variations at high latitudes

We postulate that the magnetosphere-ionosphere coupling can be considered as a black box, which accepts changes of IMF and the solar wind plasma parameters (Bx, By, Bz, velocity V, and density n) as input signal, and induces ground-based geomagnetic perturbations as an output signal. This approach has already been used in many works [*Feldstein and Levitin*, 1986; *Papitashvili et al*., 1994 and references therein]. A number of interplanetary parameters are known to be associated with magnetospheric interaction. It is well known impact of the IMF By and Bz components on the magnetic field on the Earth's surface. The division of Bz into negative and positive values may represent disturbed and quiet geomagnetic conditions, respectively, though a northward Bz can induce a strong polar cap current as well. The IMF Bx component has been found to show little correlation with geomagnetic variations. Therefore, we can compute the regression coefficients K_{Bx}, but may disregard their contribution to the model. We have tried a number of the solar wind parameters (V, n, temperature T and some of their combinations) to find a better correlation with ground-based data and concluded that V^2 and nV^2 show significant correlation. They may represent "quasi-viscous" interaction of solar wind plasma with the magnetosphere; the nV^2 is proportional to the dynamic pressure of the solar wind. We use a regression model, where the regression coefficients relate any ground-based geomagnetic field component H(Hx, Hy, Hz) to changes of the corresponding IMF parameters:

$$H(\Phi, MLT) = K_{By}(\Phi, MLT)\times By + K_{Bz}(\Phi,MLT)\times Bz + H_0,$$

where $H_0 = K_v(\Phi, MLT)\times V^2 + K_n(\Phi, MLT)\times n\times V^2 + K_0(\Phi, MLT)$. This part of the equation may be used for the average conditions in the solar wind ($n = 4$ cm^{-3}, $V = 450$ kms^{-1}) and in this case the model has only two input parameters: Bz and By IMF components.

The arrays of IMF and geomagnetic data were subject to regression analysis for each of 24 magnetic local time (MLT) hours of each day over the entire season of the year. The resulting magnetic local time daily variation of the regression coefficients K and H_0 around the daily mean value H_0^{mean} were obtained. A better correlation was revealed when the same hour mean values H and solar wind parameters were compared.

With this model we assume that the ground-based geomagnetic disturbances are proportional to the variations of the IMF components and there is a variety of physical mechanisms that transfer energy from the solar wind plasma to the high-latitude magnetosphere and ionosphere. The "regression modeling" approach has several advantages:

- total values of geomagnetic field components are used in the analysis, and there is no subjective selection of a perturbation baseline;
- the technique uses a great number of measurements made by a limited number of magnetic observatories at different local times due to the Earth's rotation, therefore, 24 values of Ki are found for each observatory;
- only the IMF values are required to model geomagnetic variations and then electrodynamic parameters can be obtained using ad hoc algorithm, in which the regression model of geomagnetic variations is used as input for numerical solution of the second-order partial differential equation $\nabla\times(\Sigma \cdot \mathrm{grad}\varphi) = \nabla\times[n_r\times \mathrm{grad}\Psi]$ [*Feldstein and Levitin*, 1986]. Here φ is the electrostatic potential, Σ is the tensor of ionospheric conductivity, n_r is a unit radial vector and Ψ is the equivalent current function, uniquely related to geomagnetic perturbations on the Earth's surface.

Results and Discussion

It is necessary to take into account that the solar wind parameters used to develop any model are measured by only one satellite along its passes but not in the whole near-Earth space. Moreover, using geomagnetic field measured by different apparatus may influence the amplitudes of extracted geomagnetic variations. The relations between geomagnetic field variations and solar wind parameters may be different for the northern and southern polar caps and during different phases of the solar cycle.

In the regression analysis we used the digital data of three components of geomagnetic field vector measured at the magnetic observatory (McM) and offset points of field registration (P01, P04) for the period of 1997-1998 with the best data coverage, and IMF data form OMNIWEB (http://omniweb.gsfc.nasa.gov). We calculated the coefficients K and H_0 from the correlation equations

$$H(\Phi,MLT) = Ky(\Phi,MLT)By + Kz(\Phi,MLT)Bz + H_0$$

for any observation point located at the same latitude of the southern polar cap and compared the obtained coefficients with those of the 'old' IZMEM model calculated for the same latitudes for the northern and southern polar caps. Below we demonstrate the daily variations of $K_{By}(\Phi,MLT)$ and $K_{Bz}(\Phi,MLT)$ for local southern summer and P01, P04, McM located at latitude 80^0 where DP(By) current system is observed [*Feldstein and Levitin*, 1986]. In this way we are enable to compare the spatial-temporal distribution of the variable part of the Earth's magnetic field in two hemispheres and to model large-scale geomagnetic variations and corresponding magnetosphere-ionosphere current systems. As most of the correlation relations between geomagnetic activity and solar wind parameters were derived from the data of observatories located in the northern hemisphere, using Antarctic data allows us to estimate the accuracy of controlling magnetospheric electromagnetic conditions by dynamic geomagnetic field in the northern high latitudes only.

Figure 1 shows K_{Bz} variations for H (left) and D (right) components of measured geomagnetic variation vector for 24 MLT hours (stations P01, P0, McMurdo) and IZMEM models for northern and southern hemispheres ($|\Phi| = 80^0$) for Bz IMF < 0 (upper row) and for Bz IMF > 0 (lower row). One can see that the variations of the regression coefficients for the stations located at nearly the same latitude ($|\Phi| \sim 80^0$) but at various longitudes are similar. Undoubtedly, for more accurate modeling of geomagnetic variations in the polar caps, it is necessary to have data from the stations, which are apart by not more than 2-3^0 in latitude and 15^0 in longitude.

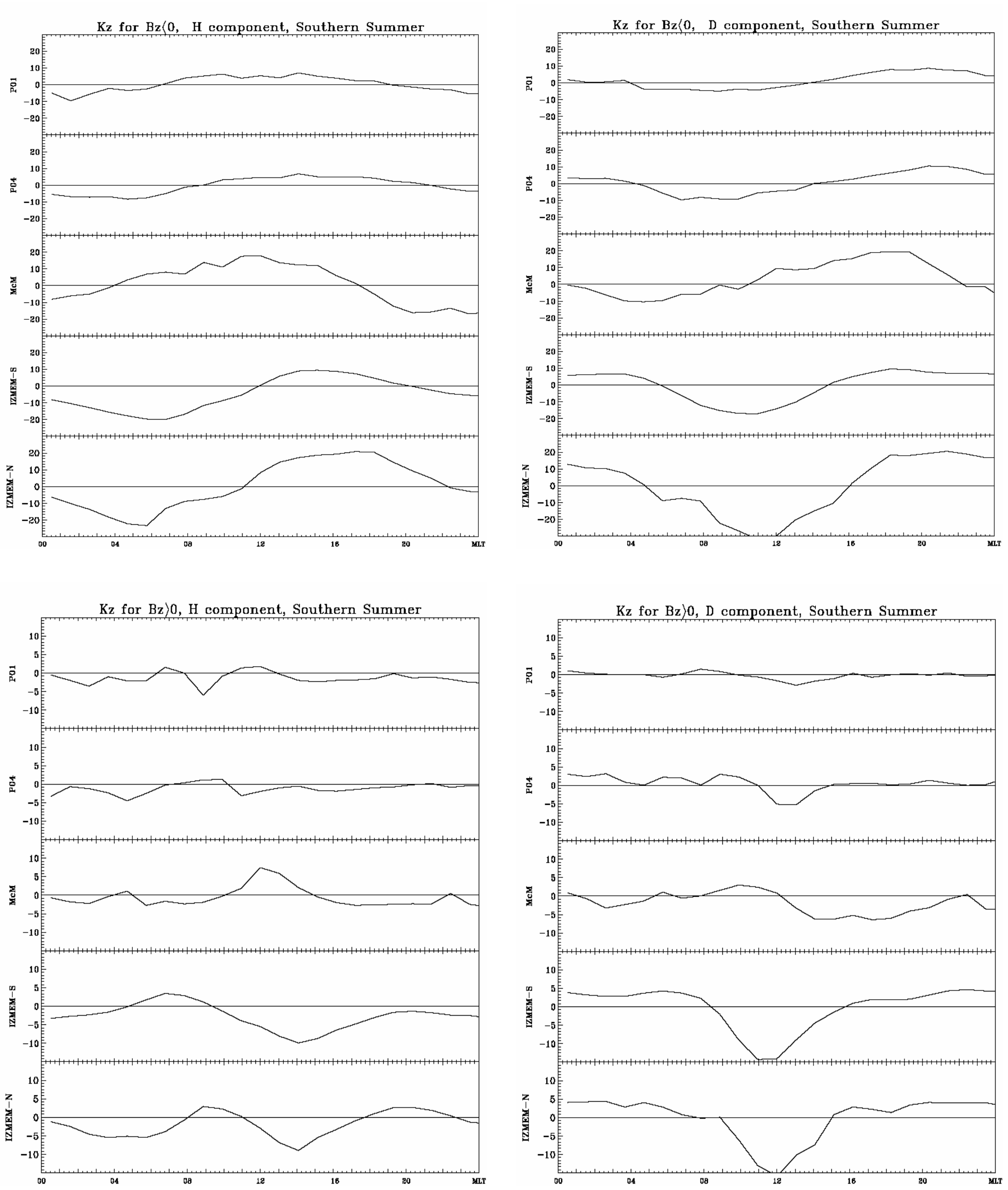

Figure 1. K_{Bz} variations for H (left) and D (right) components of measured geomagnetic variation vector for 24 MLT hours (stations P01, P04, McMurdo) and IZMEM modeled results for the southern (IZMEM-S) and northern (IZMEM-N) hemispheres ($|\Phi| = 80^0$), for Bz IMF < 0 (upper row) and Bz IMF > 0 (lower row).

To compare the variations of the correlation coefficients we used the data of the obs. McMurdo for the period of 1996-1999. Figure 2 shows K_{Bz} variations for H (left) and D (right) components of measured geomagnetic variation vector for 24 MLT hours (McMurdo) in 1996-1999, for Bz IMF < 0 (upper row) and Bz IMF > 0 (lower row). These figures demonstrate that the level of the parameters entering the correlation equation is stable from year to year. One can see that K_{Bz} variations in three years (1997 – 1999) are rather similar but K_{Bz} variation in 1996 is different. This suggests that using this correlation model in some years, or periods of years may be incorrect. Plausible reasons of such a behavior of the regression coefficients are a subject of future investigation.

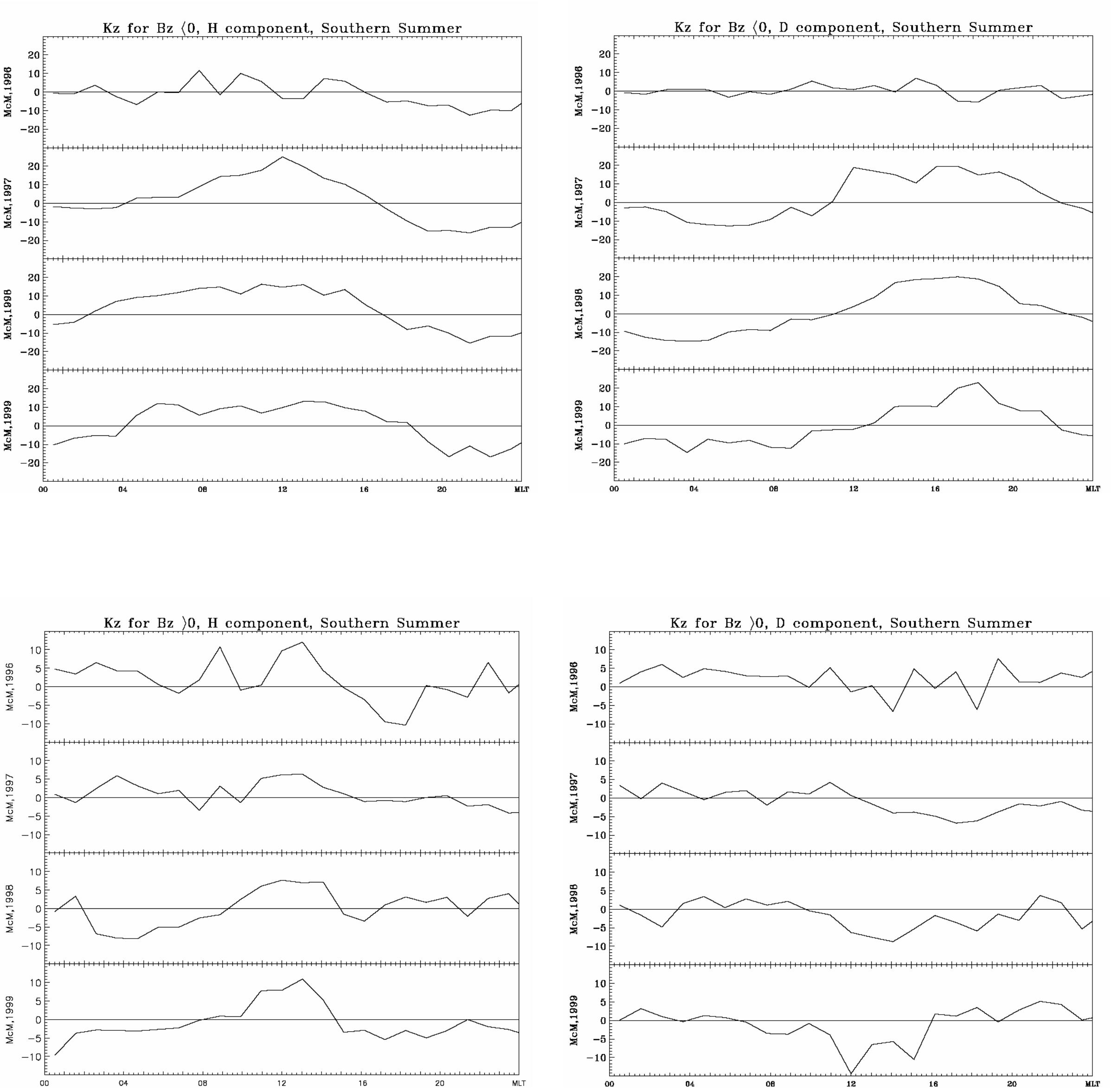

Figure 2. Kz variations for H (left) and D (right) components of measured geomagnetic variation vector for 24 MLT hours for McMurdo in 1996-1999 for Bz < 0 (upper row) and for Bz > 0 (lower row).

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