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RELATION OF THE POLAR CAP VOLTAGE TO THE GEOPHYSICAL ACTIVITY

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Abstract. More than 1000 values of the electric potential difference between the dawn and dusk sides of the polar cap have been obtained from the electric field measurements onboard the Dynamics Explorer 2 satellite during one and a half years. Statistical relations of the potential drop to geomagnetic indices and solar wind parameters are examined. The growth rate of the storm time depression is found as a function of the potential drop and *Dst*.

1. Introduction

In average the spatial distribution of the electric potential in the ionosphere has a two-cell structure [*Heppner*, 1977; *Heppner and Maynard*, 1987], with the maximum potential at dawn and minimum one at dusk. The potential drop *U* between the dawn and dusk (commonly referred to as convection potential) is a key parameter for describing the state of the magnetosphere-ionosphere system. Under quiet conditions the convection potential *U* is about 40 kV. During geomagnetic disturbances *U* grows, reaching sometimes ~200 kV [*Russell et al.*, 2001].

In spite of fundamental nature of this parameter, few statistical studies of the convection potential have been performed so far. *Reiff et al*. [1981], *Wygant et al.* [1983] and *Doyle and Burke* [1983] used 33, 55, and 66 potential measurements, respectively, from the AE, S3-3 and S3-2 satellites to find relation of *U* to B_zIMF. *Boyle et al*. [1997] obtained several hundred measurements of U from the DMSP satellite and suggested approximations relating *U* to the IMF, solar wind velocity, and *Kp* index. *Weimer* [1995] using the DE 2 data built spatial distribution of the potential under various IMF orientations.

In this paper we use more than 1000 measurements of *U* from the Dynamics Explorer 2 (DE 2) for statistical study of the convection potential to various solar wind parameters and geomagnetic indices.

2. Data

DE 2 flew on the polar orbit at altitudes of 300-1000 km. The period of revolution was 98 min. Only two electric field components were measured: the component along the velocity and the vertical one. The electric field was sampled with a half-second resolution, i.e. with a spatial resolution of about 4 km. The data from August, 1981 till February, 1983 (about 10 million measurements at high latitudes) were processed. We aimed to find the potential drop between the centers of the dawn and dusk convective vortices. In order to estimate the position of the centers, we found preliminarily spatial distribution of the potential from DE 2 data. The potential was found as the electric field integrated along the trajectory of the satellite. As a boundary condition we adopted the potential to be zero at the latitude of 50°. The potential was averaged in spatial bins of 1° of latitude and 2 MLT hours. The results for two ranges of B_zIMF are shown in Figure 1. Similar patterns were obtained in [*Feshchenko and Maltsev*, 2001] by another method.

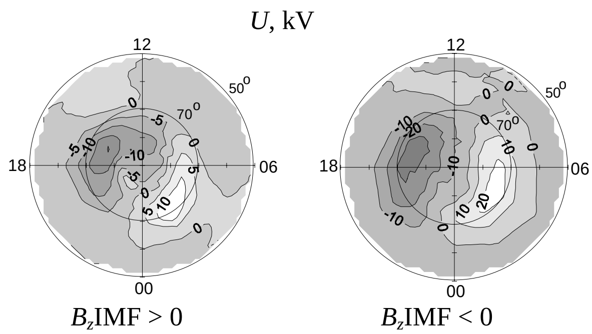

Figure 1. Electric potential distribution for the northward (the left) and southward (the right) IMF.

According to Figure 1, we chose the measurements with the *U* maximum located at 4±4 MLT and *U* minimum located at 18±4 MLT. Only large-scale potential structures were treated, i.e. with minimum-to-maximum distance of 10-60° (~1000-10000 km). These criterions were satisfied for 1100 measurements of the potential drop. Since the longitudinal size of the region studied is quite large (8 MLT hours at each side) and the vortex center position is a function of geophysical conditions, the obtained potential drops are in average somewhat smaller than the real potential difference between the vortex centers.

The values of *U* were correlated with geomagnetic indices and solar wind parameters taken from the OMNI database.

3. Relation of *U* to geophysical parameters

Table 1 shows the relation of the convection potential *U* to the following parameters: hourly *AE* , *Dst* , and corrected Dst_0 indices ($Dst_0 = Dst - 8 P_{sw}^{1/2}$ [*O'Brien and McPherron*, 2000; *Maltsev and Reshenov*, 2002]), three-hourly *Kp* index, B_zIMF component, southward IMF component B_s (which is equal to B_z under $B_z < 0$ and to zero under $B_z > 0$), dawn-to-dusk electric field *Ey*

$= -VB_z$, modulus of B_yIMF, solar wind velocity V, proton density n, dynamic pressure $P_{sw} = mnV^2$, the solar wind parameters being hourly averaged.

One can see from Table 1 that the correlation coefficient k is the highest for the *AE* index, while for n, V, P_{sw}, and $|B_y|$ the correlation is poor.

Table 1. Relation of U to various parameters (k is the correlation coefficient)

$U = 0.089\ AE + 38$	$k = 0.49$
$U = 13.3\ Kp + 26.4$	$k = 0.37$
$U = -6.9\ B_s + 54.9$	$k = 0.3$
$U = 13.6\ Ey + 56.7$	$k = 0.3$
$U = -0.75\ Dst_0 + 50.8$	$k = 0.29$
$U = -0.55\ Dst + 60$	$k = 0.22$
$U = 3.3\ \|By\| + 55.5$	$k = 0.1$
$U = 0.09\ V + 29.5$	$k = 0.09$
$U = 5\ P_{sw} + 51.5$	$k = 0.09$
$U = 0.4\ n + 62.9$	$k = 0.006$

Figure 2 shows the dependence of U averaged in bins on various parameters. One should keep in mind that all geophysical parameters strongly correlate with each other. This can explain the non-monotonous dependence of U on B_zIMF. The increase of U with the growth of the northward IMF is probably caused by the simultaneous growth of the solar wind velocity V. The dependence $U(V)$ under the northward B_zIMF is clearly seen on the right panel of Figure 2. Fitting for the total data set yields the following approximation formula

$$U = 14.7 - 6.9\ B_s + 0.085\ V$$

with the correlation coefficient $k = 0.36$. Fitting to other combinations of the parameters (to $E_{yr} = -VB_s$, to V^2) yields a smaller value of the correlation coefficient.

4. Relation of the growth rate of the storm time depression to the convection potential

The storm intensity is described by the *Dst* index determined as the H component disturbance averaged over several low-latitude observatories. It is usually assumed to consist of two parts

$$Dst = DCF + Dst_0$$

where *DCF* is a fast varying (on the time scale of several minutes) part, Dst_0 is a slowly varying part (the characteristic time scale is several hours). *DCF* depends on the solar wind dynamic pressure:

$$DCF = a\ P_{sw}^{1/2}$$

where $a \approx 8$ nT/nPa$^{1/2}$ [*Maltsev and Rezhenov*, 2002].

Dst_0 is commonly described by the following equation

$$\frac{dDst_0}{dt} = S - L$$

where S and L are the source and loss terms, respectively. The loss term is usually presented as $L = -Dst_0/\tau$ where τ is the relaxation time of the order of 10 hrs.

It is well-known that the source of the storm time depression is the magnetospheric convection. Consequently, S must depend on the convection potential U. Because of a scarce amount of U measurements, investigators commonly examine S as a function of solar wind parameters [e.g. *Burton et al*., 1975; *Pudovkin et al*., 1985; *Feldstein*, 1992; *Maltsev*, 2003]. In this section we try to find S as a function of U (and *Dst*).

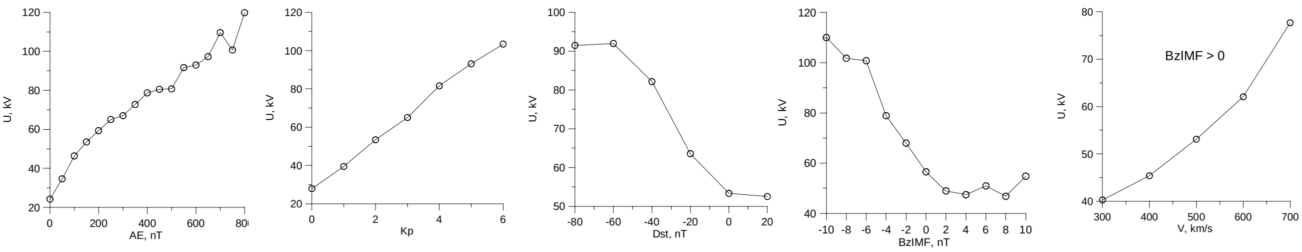

Figure 2. Statistical dependence of the convection potential U on *AE*, *Kp*, *Dst*, B_zIMF, and solar wind velocity V (under B_zIMF > 0).

Note, that *DCF* yields a comparatively small contribution to *Dst*, i.e. about 10-20% for an average storm. The OMNI database contains the plasma data (the velocity and density) for about 70% of the hours considered. In order not to decrease the number of the data, we neglected the *DCF* and adopted $Dst \approx Dst_0$. As the derivative $dDst/dt$ the difference $\Delta Dst = Dst(t+1) - Dst(t)$ was adopted, where t is time in hours.

Figure 3 (the left panel) shows contours $dDst/dt = \Delta Dst$ = const in the plane of *Dst* and U. The values of ΔDst were averaged in bins with the size of 30 nT of *Dst* and 20 kV of U. Figure 3 (the right panel) shows the approximation by the following formula

$$\frac{dDst}{dt} = 0.53 - 0.034\ Dst - 0.00044 \times Dst \times U - 0.00041 \times U^2,$$

the numerical coefficient being fitted from the total data set. One can see that the approximation is satisfactory in spite of rather low correlation coefficient ($k = 0.1$). We also considered other versions, including terms U and

Dst^2, however, the relative contribution of these terms appeared to be small.

5. Conclusions

1) By relating more than 1000 values of the convection potential drop U to geomagnetic indices and solar wind parameters, we have shown that the dependence $U = 38 + 0.089\ AE$ yields the best correlation. A slightly smaller correlation is provided by the dependence $U = 14.7 - 6.9\ B_s + 0.085\ V$, where U is in kV, B_s is the southward IMF component in nT, V is the solar wind velocity in km/s.

2) The growth rate of the storm time depression is related to U in accordance with the following empirical expression $dDst/dt = 0.53 - 3.4\times10^{-2}\ Dst -$
$- 4.4\times10^{-4}\ Dst\ U - 4.1\times10^{-4}\ U^2$, where t is in hrs.

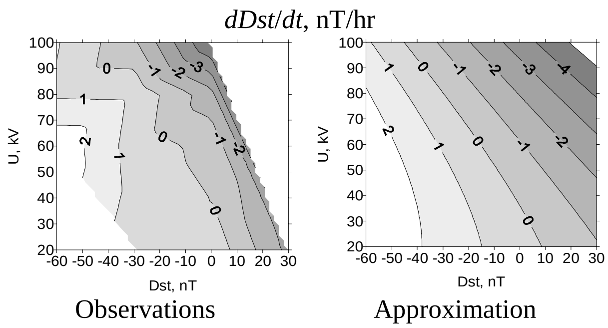

Figure 4. Contours $dDst/dt$ = const in the plane of Dst and U.

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