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DEPENDENCE OF THE CUSP LATITUDE ON VARIOUS PARAMETERS

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Abstract. Processing the database of *Fairfield et al.* [1994] allows to obtain dependence of the cusp position on the five factors: *Dst* and *Kp* indices, the solar wind dynamic pressure, the vertical component of the interplanetary magnetic field, and the dipole tilt angle. The model dependence agrees rather satisfactorily with the observed one.

1. Introduction

Ostapenko et al. [1996] used the database of *Fairfield et al.* [1994] for studying statistical connection of the magnetic field at the distances from 3 to 10 R_E with *Dst* and *Kp* indices, the dipole tilt angle ψ, as well as with the solar wind dynamic pressure p, and the z-component of the interplanetary magnetic field (*IMFz*), the z-axis being antiparallel to the Earth's dipole. The database includes more than 13,000 three-component magnetic measurements at these distances. Components of the external magnetic field in the magnetosphere are presented as polynomials of the fourth order of geocentric distance, the polynomial coefficients being found as a linear combination of the five above-mentioned parameters. The model gives the relative error about 50%. The model by *Tsyganenko* [1989] depending on *Kp*-index and dipole tilt yields the error ~100% in this region for the same database.

Here we use the model by *Ostapenko et al.* [1996] for examining the cusp variations.

2. Calculation of the cusp position

The cusp position on the magnetopause was determined from the condition $\mathbf{B} = 0$. Coordinates of this point in the northern hemisphere expressed in R_E have the following dependence on all the five parameters (providing their magnitudes deviate from the average ones not greater than by the value of their dispersion):

$$x = 8.23 - 0.53\frac{Dst + 16.8}{25.0} - 1.07\frac{p - 2.30}{1.90} + 0.00\frac{Kp - 2.31}{1.36} - 0.03\frac{IMFz - 0.0}{3.69} - 3.43\sin\psi \tag{1}$$

$$z = 6.67 + 0.71\frac{Dst + 16.8}{25.0} + 0.23\frac{p - 2.30}{1.90} - 0.26\frac{Kp - 2.31}{1.36} + 0.07\frac{IMFz - 0.0}{3.69} + 2.53\sin\psi \tag{2}$$

where *Dst* and *IMFz* are in nT, and p in nPa. Every fraction in (1) and (2) presents a normalized value of the corresponding parameter, the second term in the numerator is the average magnitude of the parameter, the denominator is the dispersion. The positive tilt angle ψ corresponds to summer conditions. The cusp on the magnetopause is located in average at the geocentric distance of 10.6 R_E This is slightly beyond the outer boundary of the region where our model is valid ($r < 10$ R_E) but we expect that the error is not large.

After mapping the point $\mathbf{B} = 0$ to the ionosphere we obtain the latitude:

$$\Lambda = 75.8^o + 1.55\frac{Dst + 16.8}{25.0} + 0.75\frac{p - 2.30}{1.90} - 0.63\frac{Kp - 2.31}{1.36} + 0.60\frac{IMFz - 0.0}{3.69} + 5.9\sin\psi \tag{3}$$

An example of the magnetic field lines in the plane of the noon-midnight meridian calculated for the tilt angle of 30° (summer being in the northern hemisphere) is shown in Figure 1. The field lines come out beginning from the northern latitude of 60° through each 2°. One can see that there is no conjugancy between the northern and southern hemispheres when the dipole is tilted. Field lines going from the northern latitudes of 76° and 78° appeared to be unclosed. Perhaps, the fourth order of the polynomials is not sufficient for describing the external magnetic field near the magnetopause.

3. Discussion

Newell and Meng [1989] using satellite measurements over three years period studied seasonal variations in the dayside polar cusp latitude. The observed average latitude of 76° agrees with the value our expression (3) gives. The average summer cusp latitude appeared to be 2.5-3° higher than the winter latitude, so that the cusp exhibits about 0.06° magnetic latitude shift for each degree increase in dipole tilt angle. Our expression (3) yields ~0.10° shift. As for the influence of the other parameters, *Dst* index gives, according to (3), the most contribution to the cusp variation. Note that the ring current is unlikely to affect the cusp position significantly. A possible cause of the cusp relation to *Dst* is the cross-tail current which can essentially contribute to *Dst* [*Maltsev et al.*, 1996]. Dependence of the cusp latitude on *Kp* and *IMFz* is probably due to the effect of region 1 Birkeland currents.

Formula (3) is obtained for the range of *Dst* from -42 to 8 nT, nevertheless its application to intense storms yields the values not very different from the observed cusp latitudes. For instance, *Bering et al.* [1991] found the dayside polar cusp at the latitude of <60° during the December 19, 1981 storm with $Dst_{min} \approx -250$ nT. Substituting such *Dst* into (5), assuming $\psi = -30°$, and neglecting the other factors, we get $\Lambda = 58.3°$.

The November 24, 1981 storm was characterized by stable conditions from 06 to 09 UT [*Yahnin et al.*, 1994]: *Dst* = -70 nT, *Kp* = 2, *p* = 0.77 nPa, *IMFz* = -4.5 nT. Substituting these values to (3) and assuming ψ = -20°, we obtain $\Lambda = 69°$. This value is close to the observed latitude of 70°. Note that the model by *Tsyganenko* [1989] yields for *Kp* = 2 the cusp latitude of ~76°.

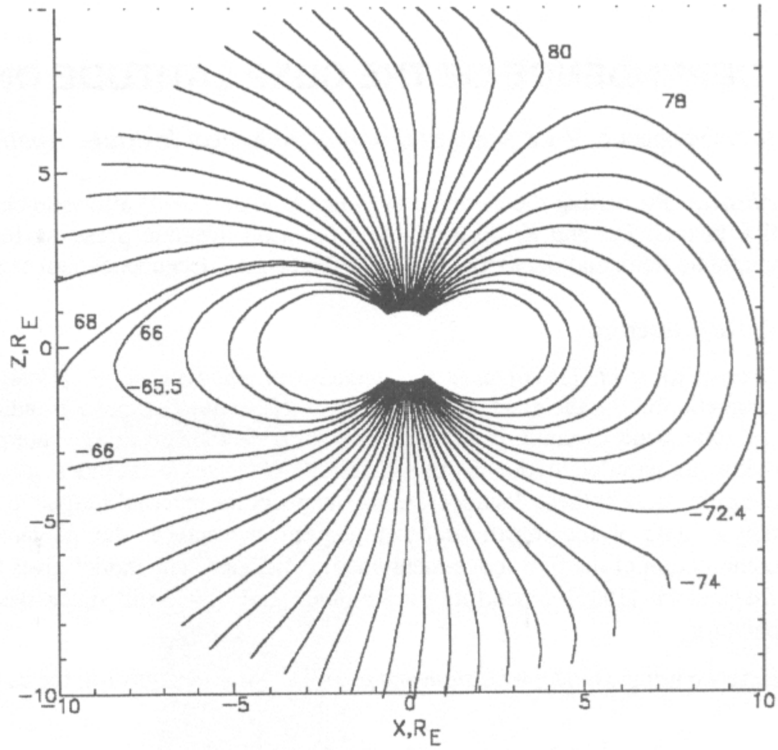

Figure 1. Magnetic field lines in the plane of the noon-midnight meridian.

4. Conclusions

Formula (3) allows to estimate the relative contribution of each of the five parameters (*Dst, Kp, p, IMFz*, and the tilt angle ψ) to the latitude of the ionospheric projection of the polar cusp. The average calculated latitude of ~76° agrees with observations. One degree equatorward shift of the cusp can be caused by one of the following reasons: the 10° decrease in the dipole tilt angle; the 16 nT drop in *Dst*; the 2.5 nPa decrease in *p*; the 2.2 growth in *Kp*; the 6.1 nT decrease in *IMFz*.

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