ON THE DIURNAL VARIATION OF THE Dst INDEX

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ABSTRACT

Using a simple model for the asymmetric ring current, we show that the main reason for the diurnal UT variation of Dst index is the uneven distribution of the Dst network stations. The model takes into account the four Dst stations and the strong disturbance due to the partial ring current in the 18 LT sector. We also note that the Russell-McPherron (RMP) effect is in phase (out of phase) with the modelled diurnal variation of the Dst index around vernal (autumnal) equinox, thus increasing (decreasing) the diurnal variation in the Dst index in Spring (Fall) . However, the RMP effect is not responsible for the overall diurnal UT variation of the Dst index.

1. INTRODUCTION

The Dst index is intended to describe the evolution of the ring current although there is some influence from other current systems as well [1]. It is calculated from the horizontal component of the magnetic field measured at four low- to mid-latitude observatories. It is known since long that the Dst index has a diurnal UT variation [2 - 8]. We show this variation for the years 1957-98 in Fig. 1. The diurnal UT variation is calculated by a superposed epoch analysis from the hourly Dst values. It is seen that the average diurnal UT variation for this 42-year interval is about 2.5 nT. The maximum of this variation (minimum disturbance) is at 13 UT and the minimum (maximum disturbance) at 22 UT. There is also a secondary minimum at about 06 UT and a small secondary maximum at about 02 UT.

Mayaud [2] and Takalo and Mursula [8] have shown that the phase of the diurnal UT variation is independent of season and concluded that this variation is probably due to the uneven local time distribution of the partial ring current and the non-uniform longitudinal distribution of the Dst stations. In this paper we present a model for the diurnal UT variation in the Dst index. This model is based on these two ideas, the uneven longitudinal location of the Dst stations and on the fact that the horizontal field at each

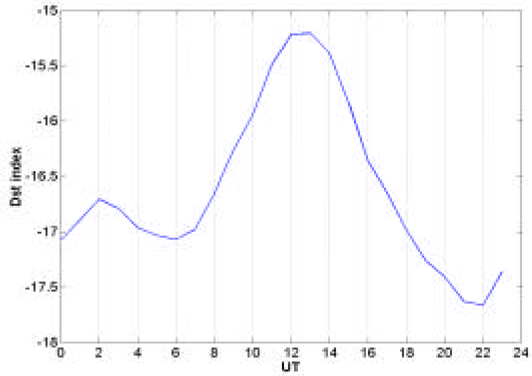

Fig. 1. The diurnal UT variation of the Dst index in 1957-1998.

station has a maximum disturbance around 18 local time (LT) when the effect of the partial ring current to the horizontal magnetic field and to the Dst index is largest [9, 10]. We also find that Russell-McPherron (RMP) [11] effect modifies the diurnal pattern of Dst, but show that it is not a principal reason for the overall diurnal variaion of the Dst index.

2. DIURNAL VARIATION AT Dst STATION

Cummings [9] studied the diurnal variation of magnetic field at Dst stations. He analysed the horizontal field magnitude of the two Dst stations, Honolulu (HON) and San Juan (SJG), and showed that the diurnal frequency histogram of values with $-?H = H_{QD} - H \geq$ 100 nT is centered at 18 LT for low latitude stations.

The characteristic superposed diurnal UT variation of Kakioka (KAK) for the years 1970-72 is plotted in Fig. 2a. The solid curve corresponds to all days in 1970-72, and the dashed curve to the international quiet days in 1970-72 (60 days/year). It should be noted that the morning hours in the quiet-day curve are biased such that the H values are too low. This is because the tails of the previous more disturbed days still slightly affect the next, more quiet days. When we subtract the quiet-day curve from the all-day curve, we get the UT variation of the difference ?H shown in Fig. 2b. Note that the biasing effect leads to too high values of

? H during morning hours. There is a clear minimum of KAK at about 09 UT. Since the LT time at KAK is about 9 hours ahead of the UT time, this minimum is at about 18 LT. Accordingly, the maximum disturbance is observed in the early evening LT sector in accordance with Cummings [1966]. This result is confirmed by similar analyses for Hermanus (HER), HON and SJG. The maximum disturbances (? H minima) are at 17-18 UT for HER at 6-7 UT for HON and at 22-23 UT for SJG. Taking the time difference between LT and UT for these stations all these minima correspond to the local early evening (18-19 LT) at the sites of the stations.

It is now easy to understand some of the features in the diurnal UT variation of the Dst (see Fig. 1) on the basis of the ? H curves of the individual Dst stations. The absolute diurnal minimum in the Dst index at about 21-22 UT is caused by the minima of HER and SJG while the secondary minimum at about 06 UT is caused by the minima at HON and KAK. The diurnal maximum in the Dst index is at 12-13 UT because at that time none of the Dst stations is located at late afternoon LT sector and two stations (HON and SJG) have their diurnal maxima close to this time.

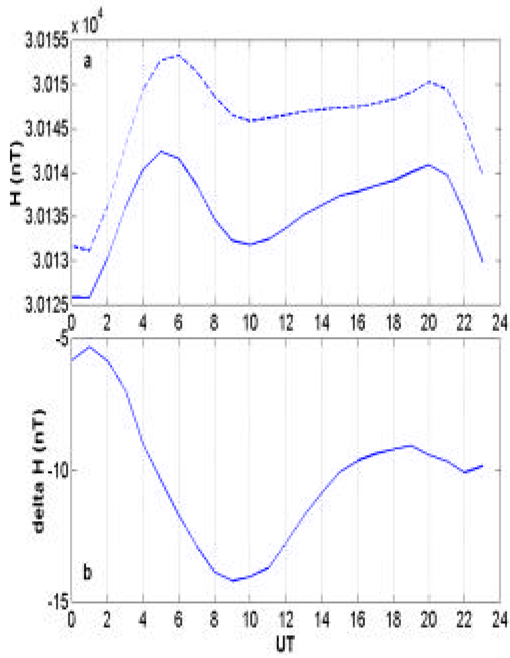

Fig. 2. a) The diurnal UT variation of the H component of the magnetic field at KAK. Solid line represents all days of 1970-72 and dashed line the international quiet days of 1970-72. b) Difference ? H of the curves in Fig. 2a.

3. THE MODEL

We model the diurnal variation of the horizontal field at one station with the following formula [8]

$$\Delta H^m(t) = -k \exp(\cos(t - UT_{LGM} + D)) , \qquad (1)$$

where UT_{LGM} is the UT time of the local geomagnetic midnight at the site of the station, and D (here D = 6 hours) is the time difference of the diurnal maximum disturbance from the local geomagnetic midnight (LGM). The coefficient k is a normalization factor, including also the reciprocal of the cosine of the station's mean geomagnetic latitude. The form of this function is shown in Fig. 3 for KAK with UT_{LGM} =15.06. The diurnal minimum is found at about the same UT time as for the original KAK data (see Fig. 2b).

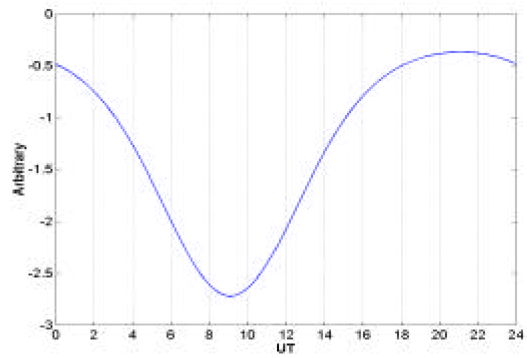

Fig. 3. The form of ? H^m as calculated from Eq. (1) for KAK.

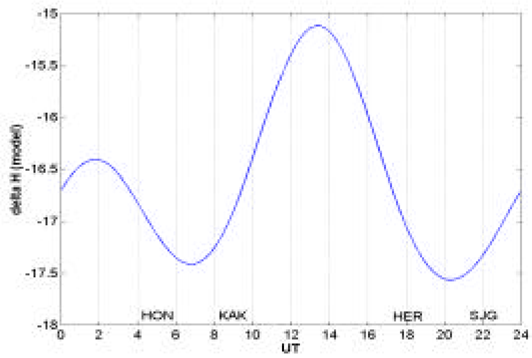

Fig. 4. The superposition of the ? H^m values of all the four Dst stations.

When we superpose the form of Eq. (1) for the four Dst stations as a function of UT time, we obtain the diurnal UT variation ? H (model) depicted in Fig. 4. This curve has been scaled to have the same mean and standard deviation as the 42-year averaged diurnal variation of the Dst index shown in Fig. 1. The stations are marked in the figure according to the UT time of their 18 LT sector. We note that the overall form of the diurnal UT variations in Figs. 1 and 4 are very similar. However, the morning (2 UT) maximum is higher and the two diurnal minima more equal in the model curve. We believe that these differences are mainly due to the hemispheric asymmetry of the Dst index and the seasonal differences [8].

4. THE INFLUENCE OF SEASON AND IMF POLARITY ON THE UT VARIATION

The seasonal UT variations of Dst index are depicted in Figure 5. These curves differ from those of AE and am indices strongly in two ways. First the maximum of the Dst diurnal UT variation (minimum disturbance) is, independent of the season, always at about noon UT (12-14 UT). This is caused by the aforementioned uneven longitudinal distribution of the Dst stations. Only for Fall and Winter UT variation there is a submaximum in the morning UT sector (0200 UT). This, in turn, is caused by increasing weight during southern Summer of the only southern hemisphere station, Hermanus, in the formation of the Dst index [8]. The average diurnal UT variation of the Dst index has a minimum (maximum disturbance) in the late evening (20-22 UT), close to the expected diurnal minimum at 2230 UT of the Russell-McPherron effect for the toward IMF sector during vernal equinox. Accordingly, the RMP effect tends to increase the amplitude of the diurnal variation in Spring, because the Spring RMP is the same phase with the diurnal UT variation of the Dst.

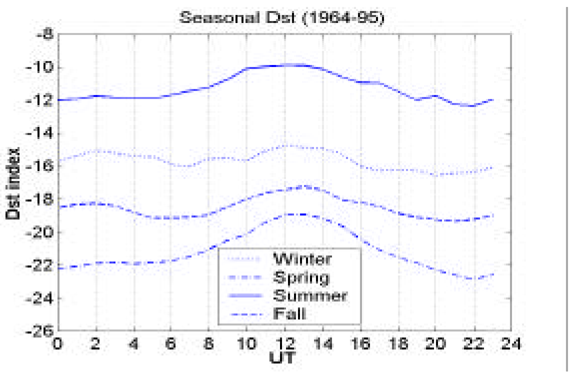

Fig. 5. The diurnal variations of Dst index in 1964-1995 for Winter (November-January), Spring (February-April), Summer (May-July), and Fall (August-October).

On the other hand, the RMP effect tends to decrease the diurnal variation of the Dst index in Fall, because the Fall RMP is in antiphase with the average UT variation of the Dst index [8]. To further confirm this situation we plot in Figure 6a the diurnal UT variation for toward and away sectors of Dst for the years 1964-1995. A UT day was called here a toward sector, TS (away sector, AS) if the IMF was in the first (third) quadrant at least 15 hours during that day. Using the aforementioned definition for toward and away days there are 1937 toward days and 1760 away days of the total 11688 days during this time interval. Notice that with this definition both the TS days and AS days are less disturbed than an average day, except the morning hours of toward sector. In Figure 6b we show the separations of TS and AS from the average. This figure shows that the maximum response of Dst to the RMP is lagging some hours those for the RMP seen in IMF Bz. The average B_S (negative B_Z in GSM coordinates) for these TS and AS days are depicted in Figure 7. This figure confirms the phase and antiphase condition for toward and away sector, respectively. Notice that the minimum, especially for BS of away sector is quite wide (07-14 UT). It should be mentioned that the correlation between average Dst diurnal UT variation for the years 1964-95 and diurnal Bs variation for toward sector component (away sector component) is 0.73 (-0.74).

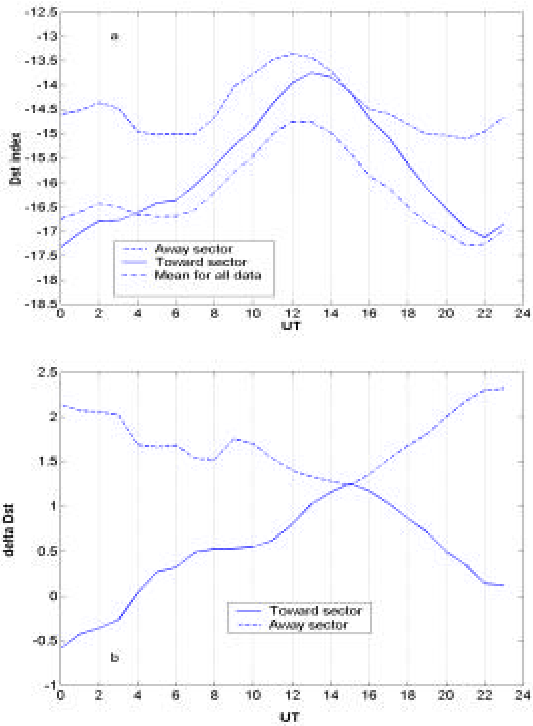

Fig. 6. a) The diurnal variation of Dst in 1964-1995 for toward sector (solid line), away sector (dashed line), and average of all data (dash-dotted line). b) Separations of the toward sector (solid line) and away sector (dashed line) from the average.

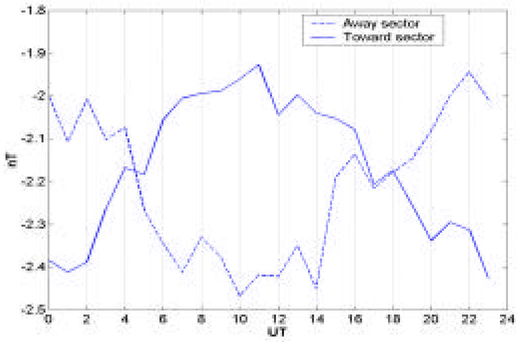

Fig. 7. The averages of the southward B_Z , i.e. B_S, for toward sector (solid line) and away sector (dashed line).

5. CONCLUSION

It has been shown earlier [2,8] that the diurnal variation of the Dst index is mainly caused by the uneven longitudinal placement of the four stations used for the derivation of the index. The partial ring current causes to the maximum disturbance to be registered around 1800 – 2000 LT at each individual station [Cummings, 1966]. Based on these two reasons we have developed a model, which shows that the diurnal disturbance minimum (Dst maximum) is at noon 1200 –1300 UT independent of the season.

Our sector-orientated analysis shows that the RMP is modifying the diurnal variation of the Dst. The response seen in Dst is lagging a few hours that of the maximum effect of RMP. Furthermore, the RMP effect is in phase (in antiphase) with the diurnal variation of the Dst index in Spring (in Fall). This causes the range of the diurnal variation to maximize in Spring. However, the RMP effect is not responsible for the overall diurnal UT variation of the Dst index.

6. REFERENCES

1. Campbell, W.H., Geomagnetic storms, the Dst ring-current myth and lognormal distributions, *J. Atm. Terr. Phys.*, 58, 1171-1187, 1996.

2. Mayaud, P.N., The annual and daily variation of the Dst index, *Geophys. J. R. Astron. Soc.*, 55, 193-201, 1978.

3. Mayaud. P.N., Derivation, meaning and Use of geomagnetic Indices, *Geophys. Monogr. Ser.*, vol. 22, AGU, Washington D.C., 1980.

4. Saroso, S., T. Iyemori, and M. Sugiura, Universal time variations in the a_p and Dst indices and their possible cause, *J. Geomag. Geoelectr.*, 563-572, 1993.

5. Takalo, J., R. Lohikoski, and J. Timonen, Structure function as a tool in AE and Dst time series analysis , *Geophys. Res.Lett.*, 22, 635-638, 1995.

6. Siscoe, G., and N. Crooker, Diurnal oscillation of Dst: A manifestation of the Russell-McPherron effect, *J. Geophys. Res.*, 1010, 24985-24989, 1996.

7. Cliver, E.W., Y. Kamide, and A.G. Ling, Mountains versus valleys: Semiannual variation of geomagnetic activity, *J. Geophys. Res.*, 105, 2413-2424, 2000.

8. Takalo, J. and K. Mursula, A model for the diurnal universal time variation of the Dst index, *J. Geophys. Res.*, 106, 10905-10914, 2001.

9. Cummings, W.D., Asymmetric ring current and low-latitude disturbance daily variation, *J. Geophys. Res.*, 71, 4495-4503, 1966.

10. Siscoe, G., and N. Crooker, On the partial ring current contribution to Dst, *J. Geophys. Res.*, 79, 1110-1112, 1974.

11. Russell, C.T., and R.L. McPherron, Semiannual variation of geomagnetic activity, *J. Geophys. Res.*, 78, 92-108, 1973.