AN ERRONEOUS DST INDEX IN 1971

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ABSTRACT

Recently it has been shown (Takalo & Mursula 2001a,b) that the diurnal UT variation depicted by the *Dst* index mainly results from an insufficient and asymmetric spatial coverage by the four *Dst* stations. Moreover, it was found that the *Dst* index exhibits an exceptionally large UT variation in 1971.

In the present paper we study the UT variation of the *Dst* index, especially in order to compare the year 1971 with other times. We calculate the autocorrelation function of the *Dst* index and the diurnal UT variation by the superposed epoch analysis from the hourly *Dst* values. Both methods verify the exceptionally strong UT variation in 1971.

We also recalculate the *Dst* index and compare this recalculated index with the original one. We conclude that the large UT variation in 1971 originates from an erroneous derivation of the original *Dst* index in this year.

1. INTRODUCTION

The *Dst* index is derived from the four magnetometer stations whose locations are shown in Table 1 and Figure 1. At the latitudes of the stations the H component of magnetic perturbation is dominated by the intensity of the equatorial ring current.

Station	IAGA code	Geographic Lat.	Geographic Long.
Hermanus	HER	34.42°S	19.23°E
Kakioka	KAK	36.23°N	140.18°E
Honolulu	HON	21.32°N	158.00°W
San Juan	SJG	18.12°N	66.15°W

Table 1. Geographical coordinates of the four Dst stations.

Major disturbances in *Dst* are negative due to increased energy content of the ring current during geomagnetic storms. Once the IMF turns northward the ring current begins to recover and *Dst* begins a slow rise back to its quiet time level. Positive variations are mostly caused by the compression of the magnetosphere during the initial phase of magnetic storms.

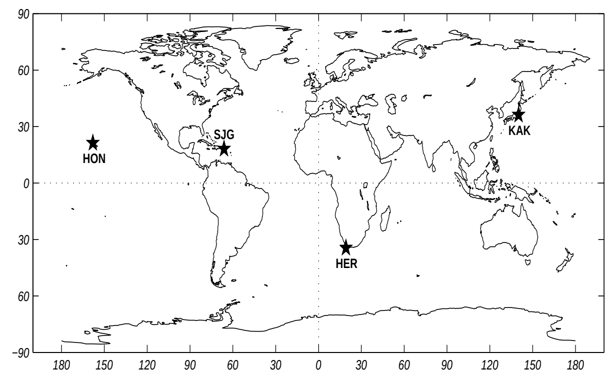

Figure 1. Map showing the locations of the Dst stations with respective IAGA codes.

For a long time it has been known that the *Dst* index has a small diurnal UT variation which has been ascribed to various physical reasons. Recently it was shown that the form of this variation is mainly due to the insufficient and asymmetric spatial coverage of the *Dst* stations (Takalo & Mursula 2001a,b). Moreover, the same authors showed that the *Dst* index exhibits an exceptionally large UT variation in 1971 which was suggested to be due to an erroneous weighting of the stations in the *Dst* index for that year.

Following the original derivation of the *Dst* index, we have recalculated the index (to be called the model *Dst* index). We compare this model index with the original *Dst* index in order to study the UT variation in particular during the exceptional year 1971.

2. DERIVATION OF THE MODEL DST INDEX

In the derivation of the model *Dst* we have followed the information given on the official *Dst* index homepage by WDC-C2 (2000). Hourly values of the H component of the four magnetic stations were obtained from WDC-C1 (2000).

2.1. Removing the secular variation

For each observatory, annual mean values of H were calculated from the five internationally selected quietest days of each month. The baseline H_{base} was defined for each year using five annual values; a second-order polynomial was fitted to the annual values of the studied year and the four preceding years. To remove the secular variation, the baseline value was subtracted from the observed hourly H value to form the deviations ΔH.

2.2. Removing the diurnal solar quiet (S_q) variation

The average UT variation during the five quietest days of each month gives the first estimate of the S_q variation for each day of that month. A linear trend was evaluated and subtracted from the S_q variation. In this manner any non-cyclic change, which may be included in *Dst* variation, is excluded from S_q.

For each year, these monthly and hourly values (12×24 values) forming the so-called S_q^o matrix, were replaced by the 2-dimensional inverse Fourier transform:

$$S_q(s,t) = \sum_{m=0}^{N_1-6} \sum_{n=0}^{N_2-18} A(m,n) e^{i2\pi \frac{sm}{N_1}} e^{i2\pi \frac{tn}{N_2}}, \quad (1)$$

where s and t describe month and hour, respectively and $N_1 = 12$ and $N_2 = 24$. Only $(N_1-6)+(N_2-18)$ coefficients were included in Eq. (1) to low-pass filter the data. The amplitudes $A(m,n)$ were calculated using the 12×24 S_q^o values as follows

$$A(m,n) = \sum_{s=0}^{N_1-1} \sum_{t=0}^{N_2-1} S_q^o(s,t) e^{-i2\pi \frac{sm}{N_1}} e^{-i2\pi \frac{tn}{N_2}}. \quad (2)$$

According to these expressions, it is possible to calculate the S_q variation at any UT hour of each month of a year. The procedure was applied for each observatory separately.

2.3. Hourly equatorial *Dst* index

For each observatory the disturbance variation $D(t)$ was then defined by

$$D(t) = \Delta H(t) - S_q(t). \quad (3)$$

Values of $D(t)$ from the four observatories were averaged and thereafter normalized to the average of cosines of the dipole latitudes of the observatories.

3. EXCEPTIONAL YEAR 1971 IN THE ORIGINAL DST INDEX

The *Dst* index exhibits a very large UT variation in 1971 (Takalo & Mursula 2001a,b). This is seen in Figure 2 where the annual average of the amplitudes of the superposed UT variations are depicted (Takalo & Mursula 2001a). The range of the UT variation in 1971 stands out clearly from the rest of the years. While the range remains below the level of 5 nT in other years, in 1971 it is more than 9 nT.

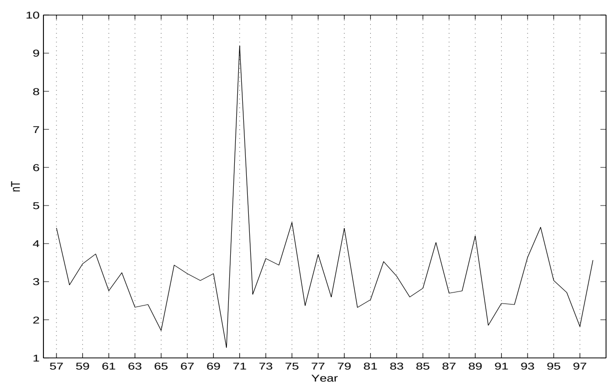

Figure 2. Annual average range of the diurnal UT variation of Dst in 1957-1998 (Takalo & Mursula 2001a).

Figure 3 depicts the diurnal UT variation calculated by the superposed epoch analysis (SEA) from the hourly *Dst* indices for the years 1970-1972 separately. Figure 3 shows clearly that the UT variation in *Dst* is exceptionally large in 1971. While the years 1970 and 1972 resemble the long-term average UT variation fairly well, the year 1971 deviates from it greatly and depicts a very large diurnal variation.

The autocorrelation functions (ACF) of the *Dst* index are depicted in Figure 4 for the years 1970-1972 separately. Again, the year 1971 is very different from the other years. The strong diurnal variation is seen as a persistent rapid fluctuation of the ACF curve. The ACFs for *Dst* in 1970 and 1972 do not have such a behaviour.

4. MODEL DST INDEX IN 1970-1972

The diurnal UT variation in the model *Dst* is depicted in Figure 5 for the years 1970-1972. It has roughly the same pattern each year. Accordingly, the model *Dst* index gives a very different UT variation for 1971 than the original *Dst* index while the curves for 1970 and 1972 are quite similar (compare to Fig. 3).

The ACFs of the model *Dst* index for the years 1970-1972 are depicted in Figure 6. Unlike the ACF of the original *Dst*, the model *Dst* ACF has no strong UT variation in 1971. Moreover, apart from the diurnal

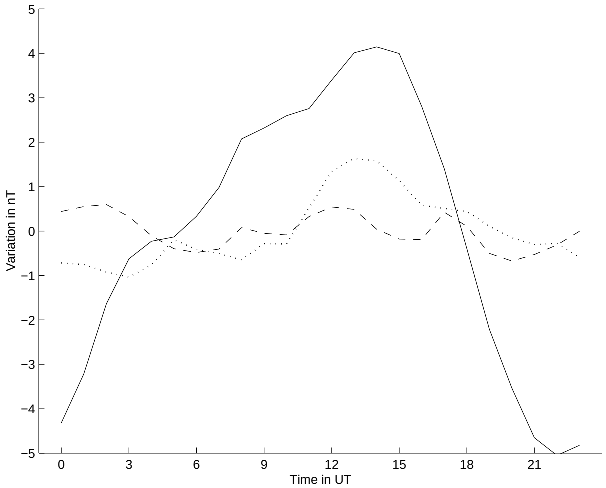

Figure 3. Diurnal UT variation in the Dst index for 1970 (dashed), 1971 (solid) and 1972 (dotted).

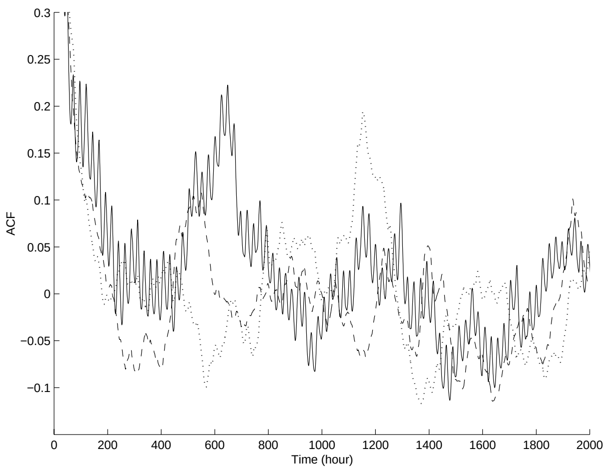

Figure 4. Autocorrelation functions of the Dst index for 1970 (dashed), 1971 (solid) and 1972 (dotted).

variation, the overall form of the ACFs for the model and original *Dst* closely resemble each other for all the three years.

Table 2 lists the correlation coefficients between the model and original *Dst* index, as well as between the calculated ACFs and SEA curves for the years 1970-1972 separately.

The correlation between the model and original *Dst* index, as well as between their ACF curves is excellent for 1970 and 1972 but slightly smaller in 1971. The correlation of the SEA curves nearly vanishes in 1971. In 1970 and 1972 the diurnal UT variations of the two data sets correlate fairly well.

Correlation coefficients(%)			
Year	*Dst*	ACF	SEA
1970	99.57	99.45	56.92
1971	96.88	95.42	3.72
1972	99.28	99.55	63.54

Table 2. Correlation between the model and original Dst indices in 1970-1972.

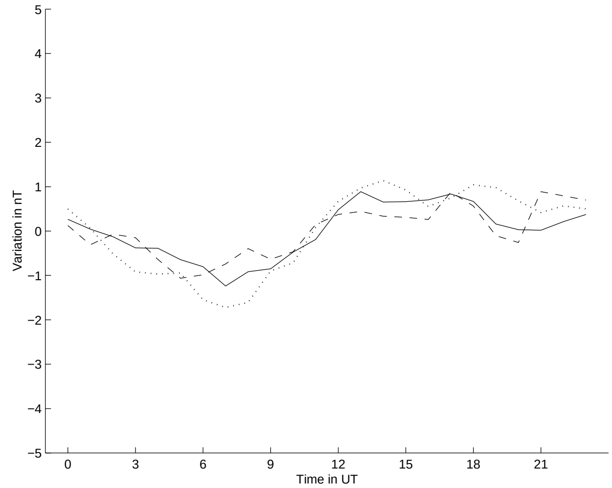

Figure 5. Diurnal UT variation in the model Dst for 1970 (dashed), 1971 (solid) and 1972 (dotted).

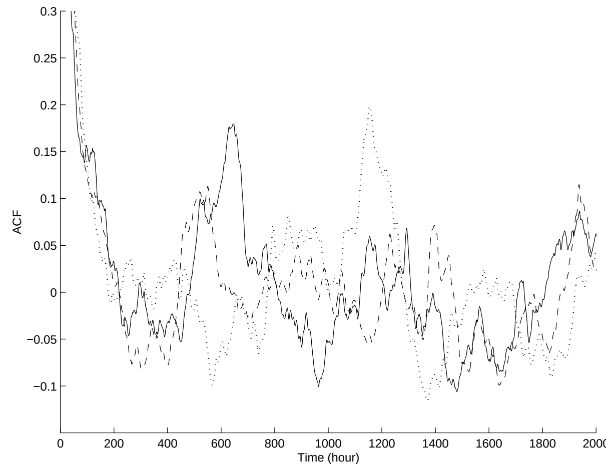

Figure 6. Autocorrelation functions of the model Dst for 1970 (dashed), 1971 (solid) and 1972 (dotted).

5. POSSIBLE REPRODUCTION OF THE ERROR IN 1971 USING THE MODEL DST

After an extensive analysis of various options, we suggest that the large UT variation in the original *Dst* in 1971 results from an erroneous weighting of the solar quiet (S_q) variation at some of the four *Dst* stations.

We have studied the correlation of the original *Dst* with each of the four separate S_q variations that were calculated for the model *Dst* index. Table 3 lists the correlation coefficients between the original *Dst* and the S_q variations for 1970-1972.

The correlations between the original *Dst* and var-

Correlation coefficients(%)			
S_q var.	1970	1971	1972
HER	-1.22	-5.12	-2.41
KAK	-0.97	5.59	-0.77
HON	0.81	-16.30	-2.49
SJG	0.83	13.58	1.97

Table 3. Correlation between the original Dst index and the S_q variations at the four Dst stations in 1970-1972.

ious S_q variations are practically zero in 1970 and 1972, as expected. In 1971, the S_q variation at Honolulu (HON) and San Juan (SJG) strongly anticorrelates and correlates, respectively, with the original *Dst* index. Such correlations for 1971 could occur, e.g., if the S_q variation at HON was erroneously subtracted twice and that at SJG was not subtracted at all.

Accordingly, the second model *Dst* was derived using an erroneous weighting of the S_q variation, as suggested above. The SEA curves for the erroneous model *Dst* and for the original *Dst* index in 1971 are depicted in Figure 7. It is seen that the erroneous model *Dst* exhibits a very similar diurnal UT variation in 1971; correlation coefficient between the two curves in Figure 7 is 96.39%.

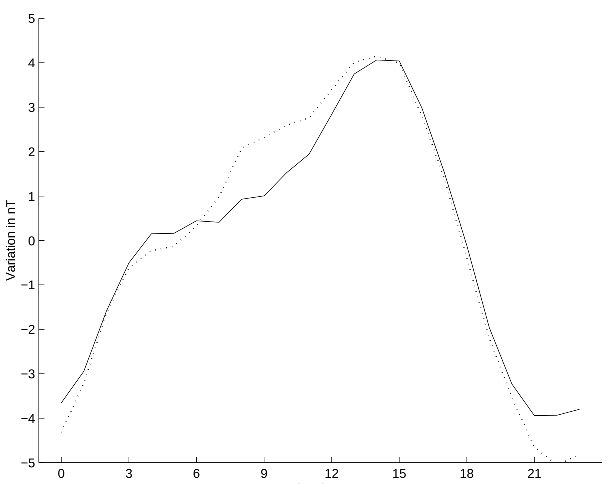

Figure 7. Diurnal UT variation in the original (dotted) and erroneously weighted model Dst (solid) for 1971.

Figure 8 depicts the autocorrelation functions of the original and the erroneously weighted model *Dst* for 1971. Both of the ACFs exhibit the large UT variation with the same phase; correlation coefficient of these two curves is 98.12%.

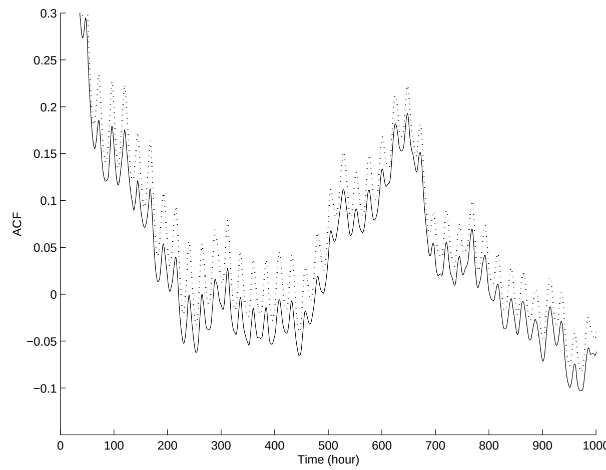

Figure 8. Autocorrelation functions of the original (dotted) and erroneously weighted model Dst (solid) for 1971.

6. SUMMARY AND CONCLUSIONS

The original *Dst* index has an exceptionally large UT variation in 1971. We have recalculated the *Dst* index (the model *Dst*) and compared this to the original *Dst*.

For years 1970 and 1972 the model and original *Dst* index show almost similar diurnal UT variations and autocorrelation functions. However in 1971, the model index contradicts the exceptionally large UT variation seen in the original index.

We conclude that the large UT variation in the *Dst* in 1971 originates from an erroneous derivation of the index in that year. We suggest a possible explanation for the error in the original *Dst*: when calculating the disturbance variation at San Juan (SJG) the S_q variation at Honolulu (HON) has been subtracted mistakenly instead of the S_q variation at SJG.

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