

NEW GEOMAGNETIC INDEX (*IDV*) MEASURING MAGNITUDE OF INTERPLANETARY MAGNETIC FIELD

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Abstract: We present a new long-term geomagnetic index (the *IDV* index) which has the property that it is a proxy of the magnitude of the interplanetary magnetic field at the Earth. The index is constructed (for any given station) as the monthly (or yearly) average of the differences (taken without regard to sign) of the hourly mean values of the hour near local midnight between two consecutive days. It is similar to the classical *u*-measure except that the differences are between one-hour mean values rather than daily means. The *IDV* index has a strong correlation ($R^2=0.83$) with the magnitude, B , of the IMF, but is uncorrelated ($R^2=0.01$) with the solar wind speed, V . Because other indices (e.g. *aa* and our own *IHV*) are strongly correlated with BV^2 , the *IDV* index fords a way of separating the influence of B and V and thus determining both.

Definitions:

Inter-Diurnal Variability index IDV for day ‘d’:

$$\text{IDV}_d = |X_{d+1,h} - X_{d,h}|, \text{ for given hour } h$$

<IDV> over one month or longer

$$\mathbf{u, Dst, IDV} \quad \langle \mathbf{a}_1 \rangle = \beta_1 + \alpha_1 \langle \mathbf{B} \rangle \quad (1)$$

Inter-Hour Variability index IHV for day ‘d’:

$$\text{IHV}_d = \sum |X_{d,h+1} - X_{d,h}|, \text{ } h \text{ from } h_0 \text{ to } h_{0+5}$$

<IHV> over one month or longer

$$\mathbf{ak, aa, am, ap, IHV} \quad \langle \mathbf{a}_2 \rangle = \beta_2 + \alpha_2 \langle \mathbf{B} \rangle \langle \mathbf{V} \rangle^2 \quad (2)$$

Where X is any component of the geomagnetic field. For this paper we use the **Horizontal** component.

Data: The data is hourly averages of the geomagnetic field components observed at mid-latitudes. Fig.1 has an insert showing the location of the stations (geomagnetic observatories).

Building a Composite: Figure 1 shows the yearly $\langle \text{IDV} \rangle$ for nine stations based on $h = 23^{\text{h}}\text{-}24^{\text{h}}$ local time. The differences between the curves are mostly due to differences in latitude. All stations had data for 1946-1973. Figure 2 shows the average value of $\langle \text{IDV} \rangle$ for all stations over that interval as a function of both geographic latitude (crosses) and geomagnetic latitude (circles). It does not matter much which is used, given the scatter of the data points. The line shows $18 \text{ nT} \times \cos(\text{latitude})$. The station Sitka (SIT) is too close to the auroral zone and is not used. $\langle \text{IDV} \rangle$ for $h = 23.5^{\text{h}}$ is shown in blue, for $h = 8.5^{\text{h}}$ in red. $\langle \text{IDV} \rangle$ can be defined for any hour. In this paper we use the night-time values. Scaling all stations by the average over 1946-1973 to the German station Niemegk (NGK) reduces the scatter significantly as seen in Figure 3.

Correlation with IMF B:

Figure 4 shows that yearly means of the composite IDV-index has a high correlation ($R^2 = 0.826$) with yearly means of the magnitude, B , of the interplanetary magnetic field (IMF) during 1964-2003. There is no correlation between IDV and the solar wind speed, V ($R^2 = 0.0111$). Using the regression line from Figure 4 (a), we compute B from IDV and compare the calculated values with observed values of B in Figure 4 (b). Figure 4 (c) just shows that the yearly means $\langle B \rangle$ and $\langle V \rangle$ are themselves uncorrelated.

Comparison with Bartels's u-measure: The u-measure has a strong correlation ($R^2 = 0.84$) with our IDV index for the interval (1890-1935) where they overlap (Figure 5a). Reliable values for the u-measure exist back to 1872. We use these to extend IDV back to 1872. For completeness we note that the Dst index has correlations with $\langle B \rangle$ and $\langle V \rangle$ similar to those of the IDV-index as shown in Figures 5 (b) and (c).

Inferred IMF magnitude back to 1872: Using the regression line from Figure 4 (a) and the regression u-IDV from Figure 5 (a), we reconstruct yearly mean values of $\langle B \rangle$ for the interval 1872-2003 shown in Figure 6. The observed yearly means are shown by the green curve.

The IHV-index: the IHV-composite for the nine stations is shown in Figure 7. The IHV-index correlates extremely well ($R^2 = 0.9793$) with the well-known *aa*-index for the years since about 1956-57. Unfortunately, the two indices are quite different before 1957, with the *aa*-index being too low. It is not clear why. Several independent lines of evidence all agree that the problem is with *aa*. We shall simply use the IHV-index as measured.

Correlation with BV^2 : The IHV-index correlates well with the product $\langle B \rangle \langle V \rangle^2$ ($R^2 = 0.869$), Figure 8 (b). Figure 8 (c) shows the correlations with $\langle B \rangle$ and $\langle V \rangle$ separately. Using the regression line from Figure 8 (b) we can reconstruct the product $\langle B \rangle \langle V \rangle^2$ and compare with the product derived from directly measured values of $\langle B \rangle$ and $\langle V \rangle$. The result is shown in Figure 8 (a).

Inferring the Solar Wind Speed, V: Combining the regression lines from Figure 4 (a) and Figure 8 (b) we get

$$V = 380 \text{ km/s } [(IHV - 4.03)/(IDV + 4.65)]^{1/2}$$

Applying this relation to IHV and IDV back to 1964 yields a reconstructed $\langle B \rangle$ ($R^2 = 0.83$ with observed $\langle B \rangle$) and a reconstructed $\langle V \rangle$ ($R^2 = 0.77$ with observed $\langle V \rangle$) as shown in Figure 9.

B and V back to 1890: If we then assume that the regressions hold for other times than the spacecraft era, we can use them to reconstruct Band V back as far as we have IHV and IDV indices. The result back to 1890 is shown in Figure 10.

And even earlier... Data exist back to the 1840s for several stations. We are actively engaged in obtaining these old measurements, in checking them, (and to use a fashionable word) ‘reanalyzing’ them) to extend the inferred value of B and V back to ca. 1840. Earlier data may exist and be useful.