AGU Spring 2008 – GP53A-07
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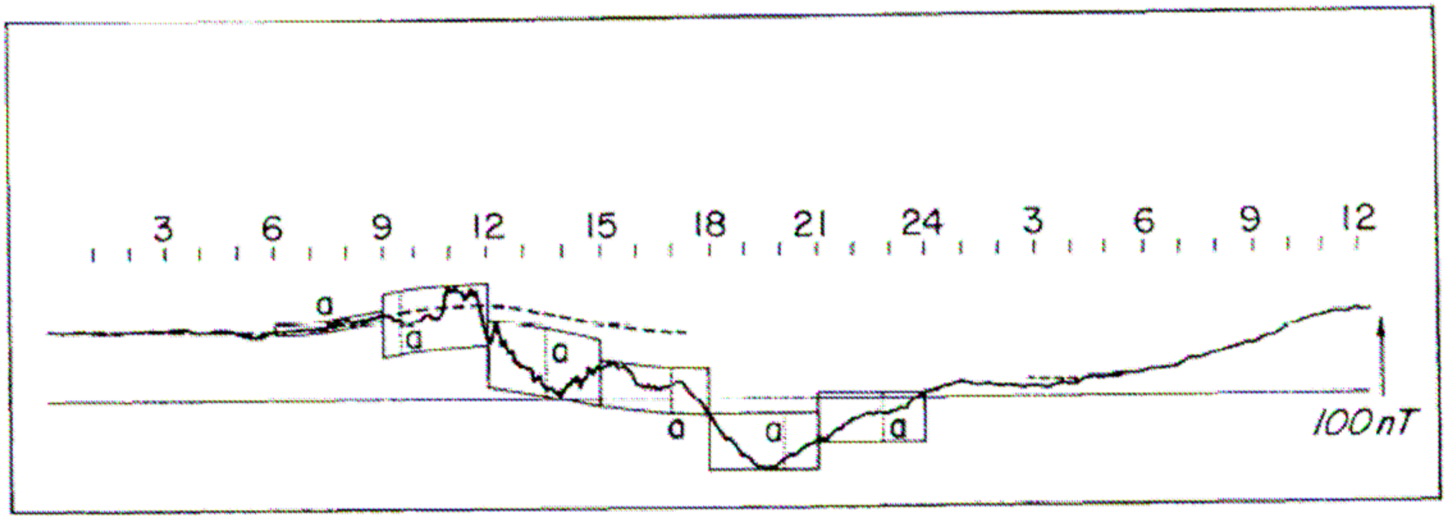
The IDV and IHV Indices: Derivation and Stability

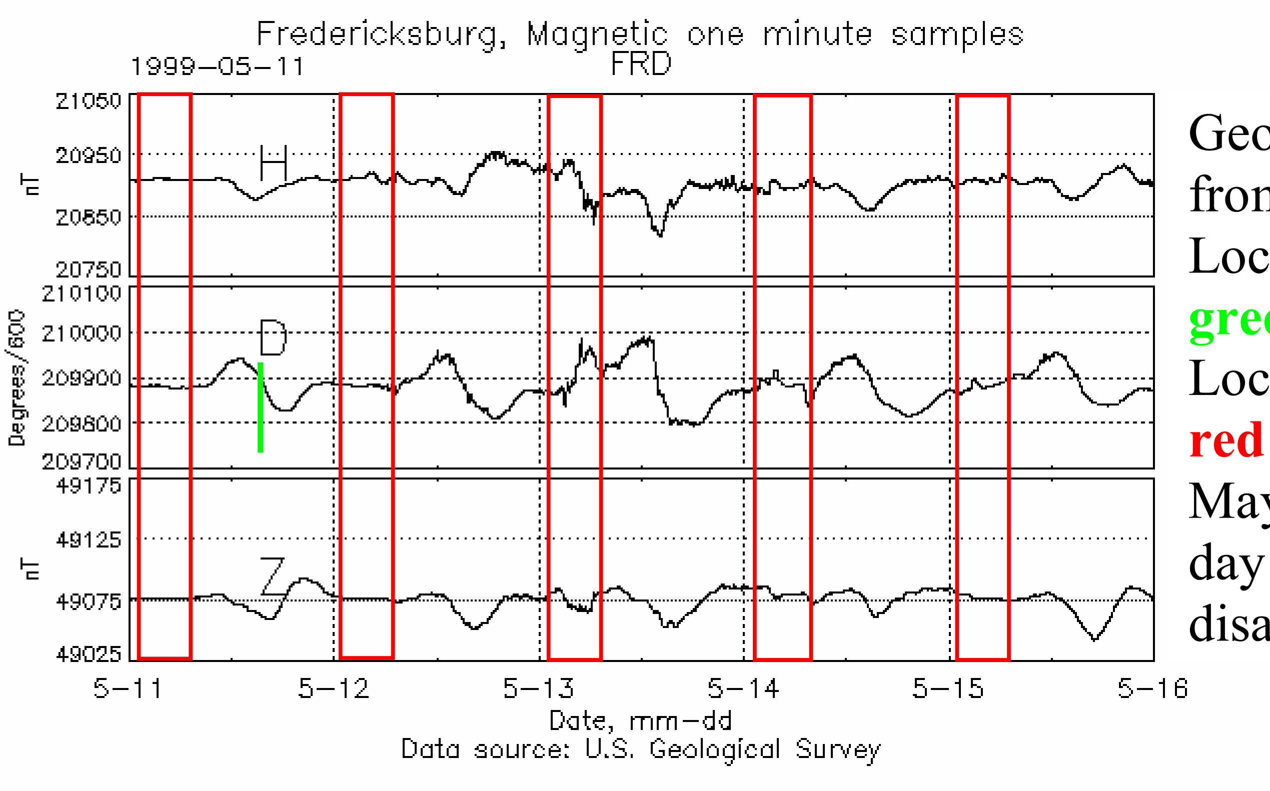
Abstract We review the recently introduced geomagnetic activity indices: IDV (InterDiurnal Variability) and IHV (InterHourly Variability). Their salient features are the use of night-time data only to cleanly avoid the effect of the daily 'quiet- time' variation and the use of only hourly values of the magnetic elements. Since the two indices have different dependencies on interplanetary magnetic field strength (B) and solar wind speed (V), they can be used to deduce B and V separately affording us a way of estimating solar wind properties in the past ~180 years. In addition, they provide a valuable check on the calibration of other long-term indices, e.g. the aa-index, which has been found in need of a recalibration. We discuss the physical meaning of the indices, e.g. show that IHV is directly proportional to the power input to the ionosphere [POES Hp-index]. We discuss the construction and stability with time of the indices and the several pitfalls to avoid.

Quantifying Geomagnetic Activity, the problem:



Magnetogram of the Horizontal Component at a mid-latitude station

The irregular, regular diurnal variation caused by a current system in the E-layer at 110 km height reflects the variation of solar FUV radiation [and solar zenith angle] and not that of the solar wind. So if we aim to quantify [construct an *index*] the superposed irregular variations caused by the solar wind interaction with the Earth, we must first ***identify and eliminate the diurnal variation***. An expert human observer can do this consistently, but this is hard to automate, and expert human observers are hard to come by.

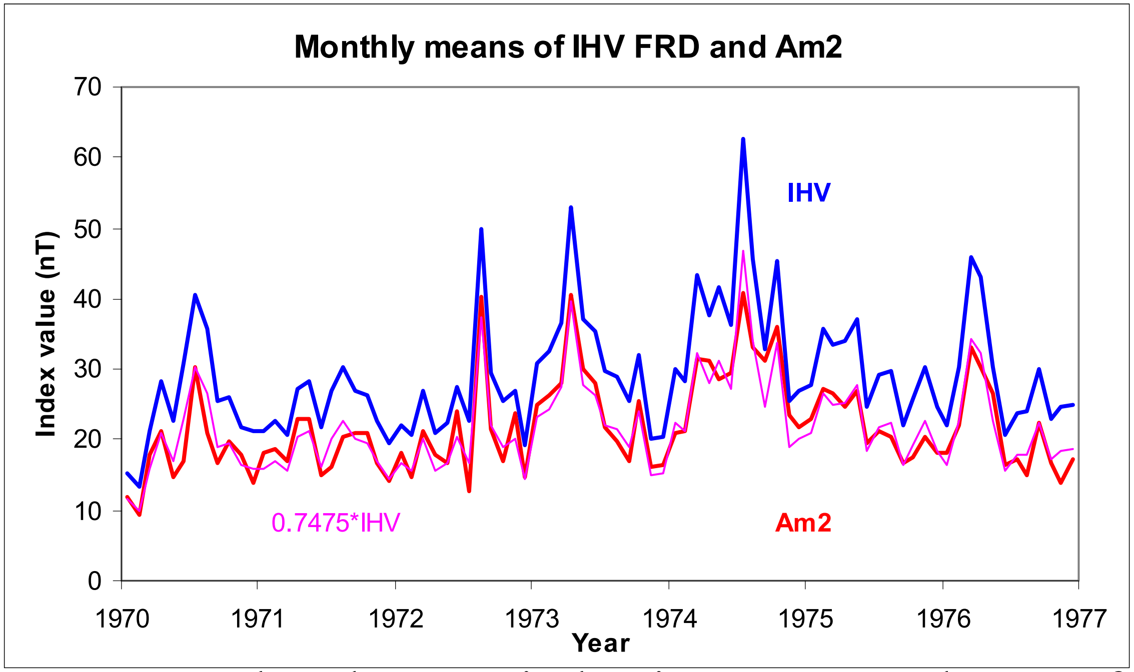


Geomagnetic records from Fredericksburg. Local noon marked by **green** vertical line. Local night hours in **red** boxes. May 11, 1999 was the day "the solar wind disappeared".

Here we see how the diurnal variation itself varies from day to day. A radical solution to the problem is to use only local ***night*** hours where the FUV-radiation related variation is absent. Throwing away 75% of the data removes 99% of the problem. By using several stations spaced in longitude one can get full UT-day coverage of pure night time data.

Several years ago, Ed Cliver and I realized that disposing of the daily variation meant that the fine time resolution needed to identify that variation was no longer necessary and that simple hourly values [available since the 1830s] would suffice. Within the night interval there are many ways one could characterize the variability: e.g. RMS deviations or [what we decided to use] the sum of absolute values of differences from hour to hour. We called the latter the InterHour Variability Index (IHV). We can calculate IHV for each of the geomagnetic components, although we initially have concentrated on the Horizontal Component (*H*).

This realization opens up the treasure trove of hourly values from the dozens of geomagnetic observatories that have tabulated such values for the past more than 150 years, and removes the need for expert [but still subjective, labor-intensive, and non-reproducible] human observer scaling of the records [which may even not exist anymore]. Thus a new class of geomagnetic indices, based on hourly values, has become available from ourselves and several other groups, and has put reconstructions of solar wind properties from geomagnetic records on a much firmer footing, allowing questions of absolute calibrations to be addressed and largely resolved.



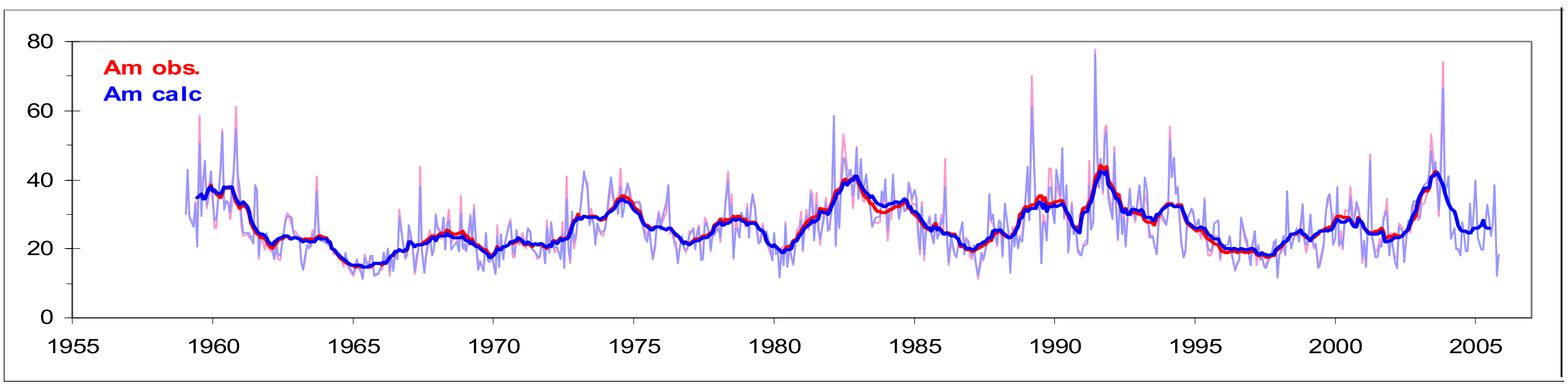
Comparison of IHV and the am-index for the same two three-hour intervals as Fredericksburg's local night time used for IHV.

As we are interested in the long-term behavior of the index we compare monthly means, and find a simple but very strong linear relation ship:

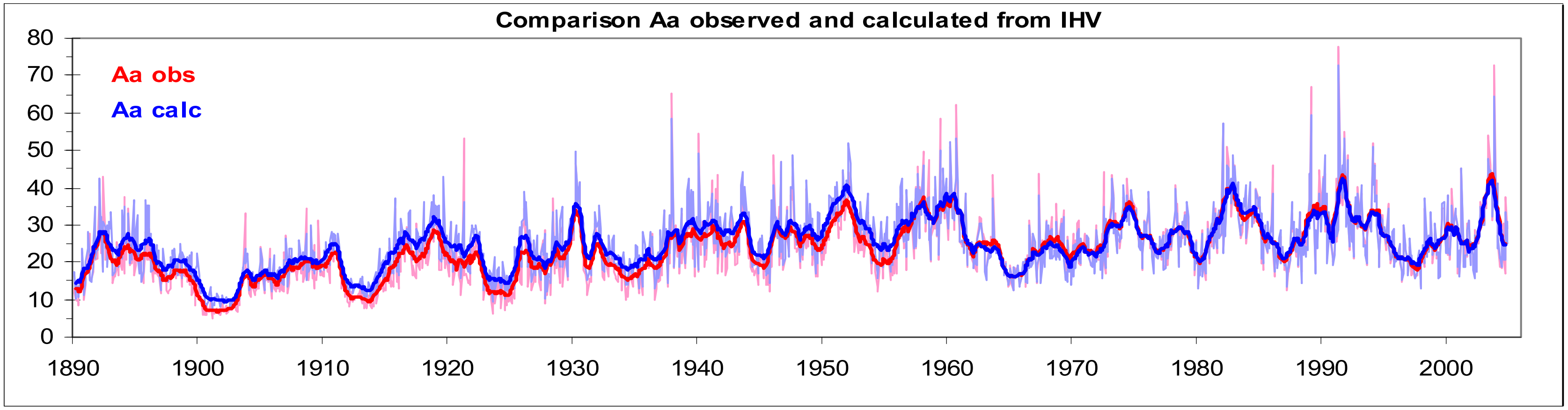
$$Am = 0.7475\ IHV$$

One the proceeds to construct a ***composite index*** using all available stations.

It turns out that the IHV index is a very good proxy for the best global mid-latitude geomagnetic index. Mayaud's *am*-index (back to 1959):

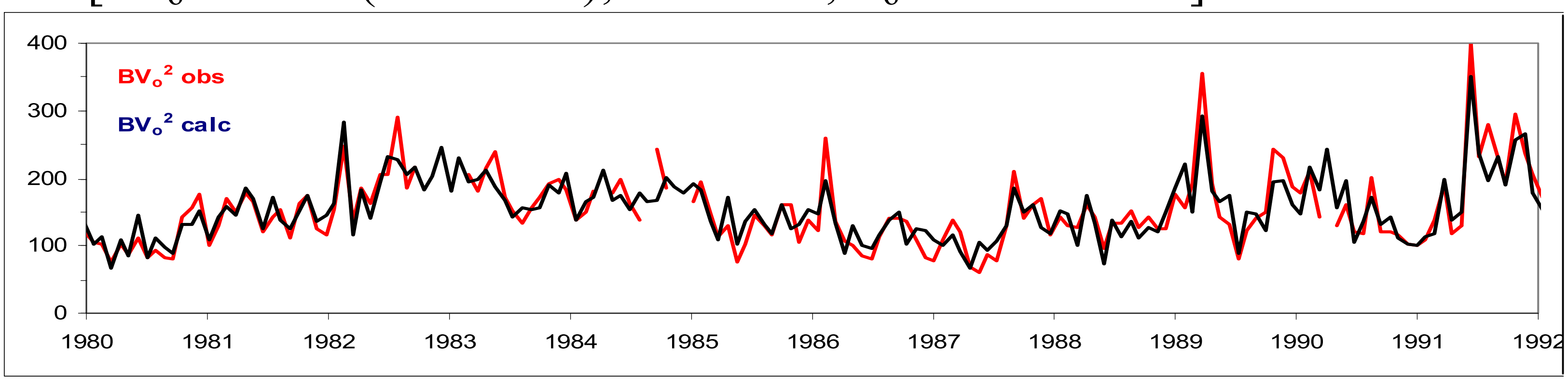


But we can go back much further than that and compare with the *aa*-index:

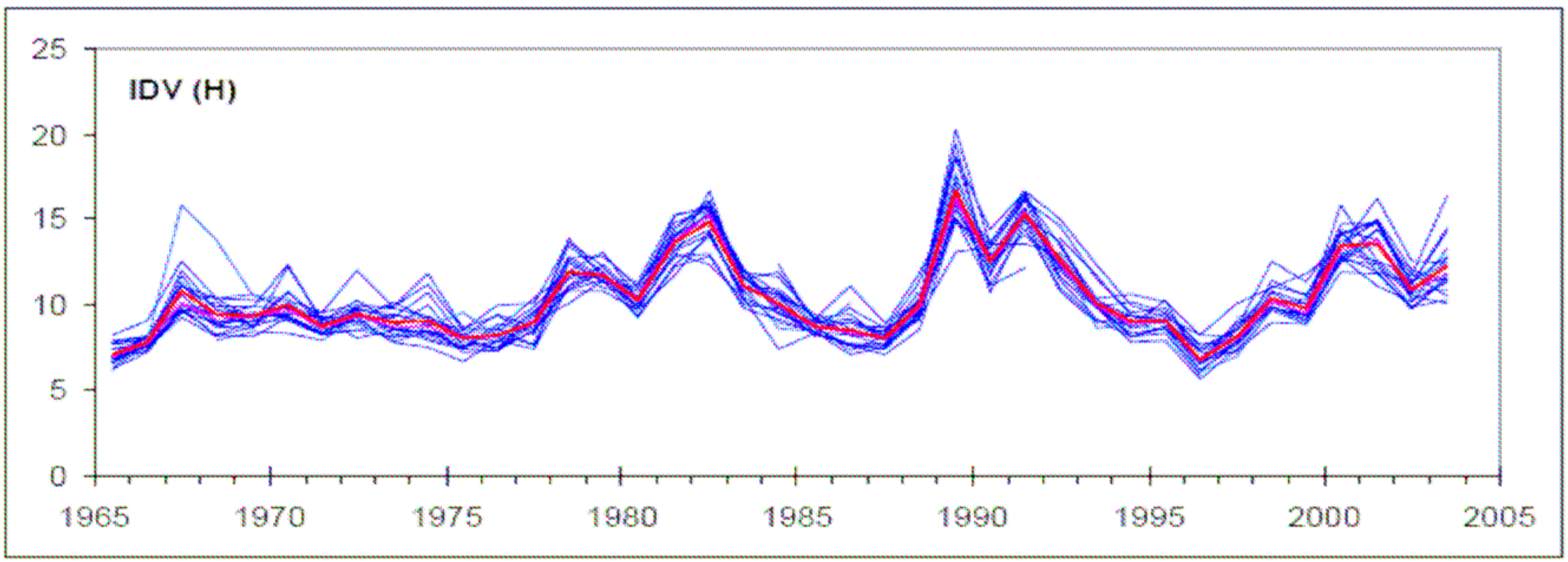


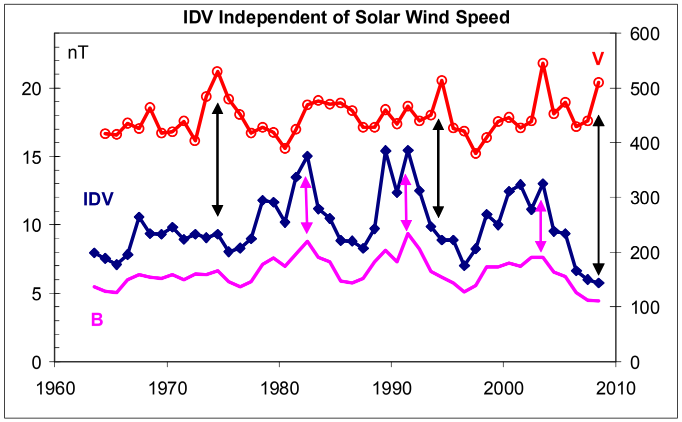
It then becomes evident that with respect to IHV (and we surmise, to *am*), the *aa*-index is ***too low*** before 1957. [Several other groups have now confirmed this, e.g. Lockwood *et al.*, Jarvis, Rouillard *et al.*, Mursula *et al.*].

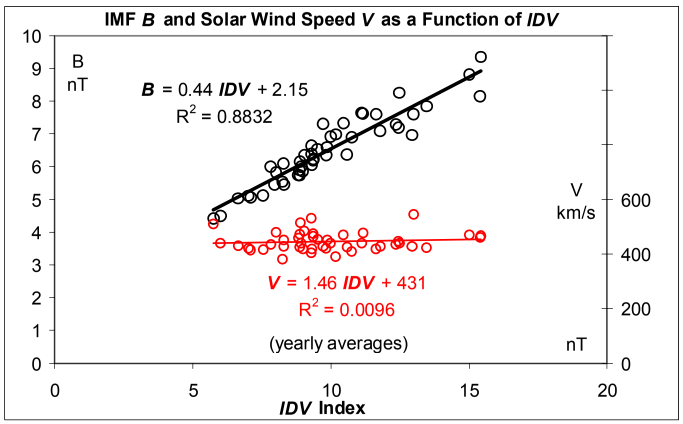
Just as the *am*-index is strongly correlated with the coupling function BV^2 so is IHV [$BV_o^2 = 4.34$ (IHV – 6.5); R^2 =:0.76; $V_o = V/100$ km/s]:

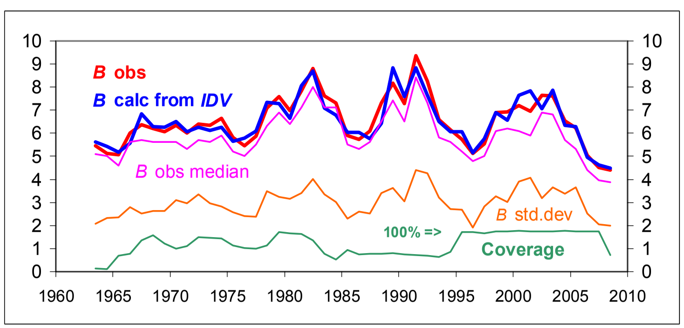


So, we now can infer the product BV^2 as far back [~1840] as IHV can take us. But we also wish to be able to separate B and V. The larger disturbances called geomagnetic storms afford us a way of doing just that. During a geomagnetic storm a ring current builds up in the inner magnetosphere, causing a long-lasting [up to days] depression of the Horizontal Components at low- to mid-latitude stations. IHV used the unsigned difference between one *hour* and the next. The InterDiurnal Variability Index, IDV, uses the unsigned differences between one *day* and the next, specifically for the midnight hour. And as for IHV we can do this for many stations and create a composite index:

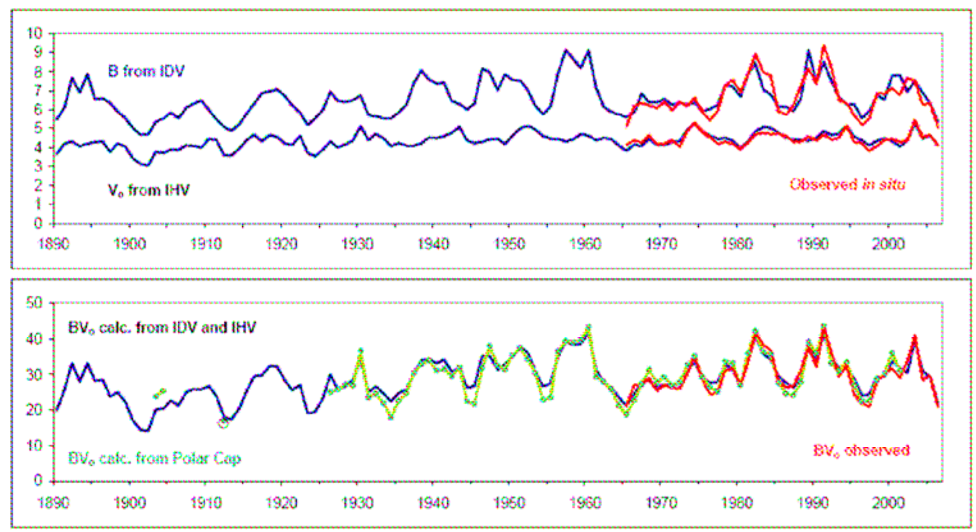






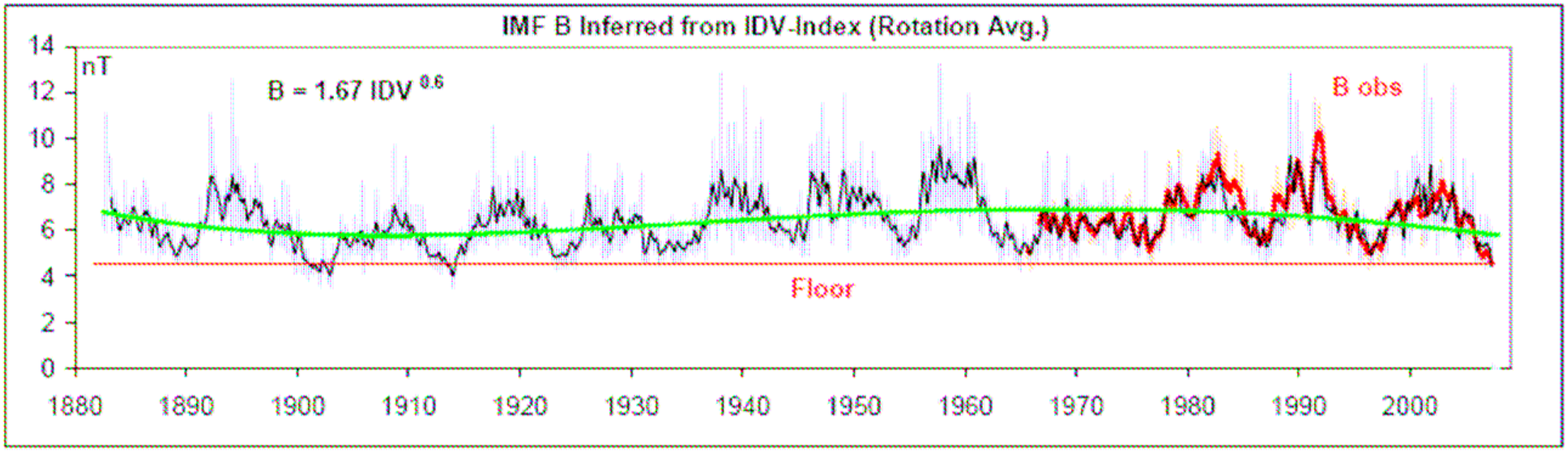


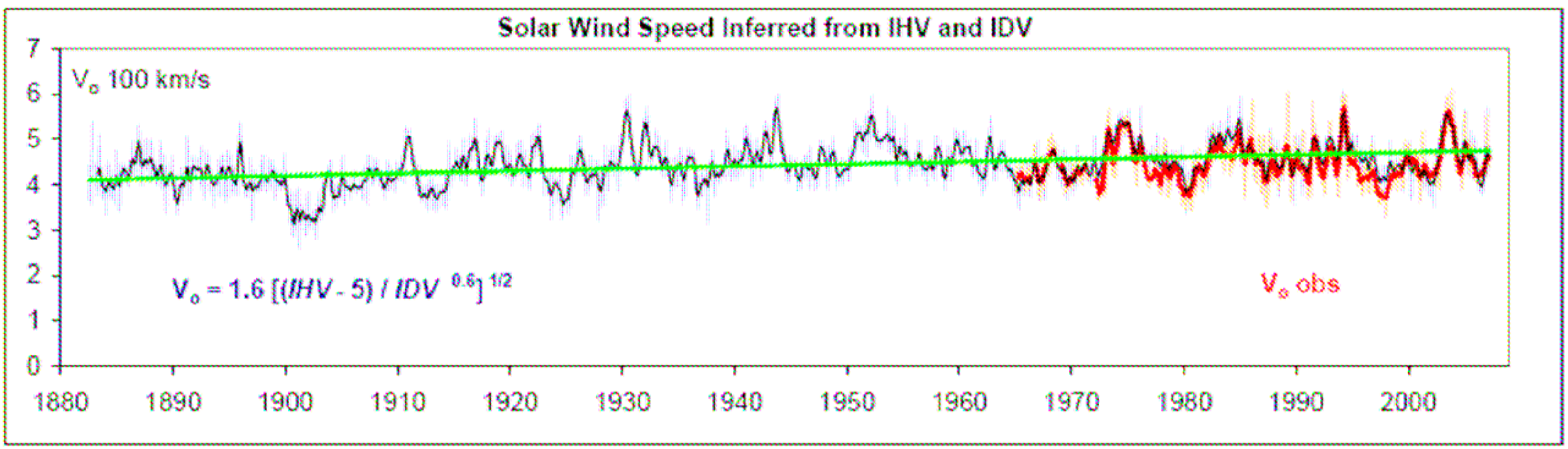
The IDV index has the useful property of being essentially ‘blind’ to the solar wind speed, but robustly correlated with IMF *B*. So, from IHV we get product BV^2; dividing by *B* from IDV we can now get *V*:



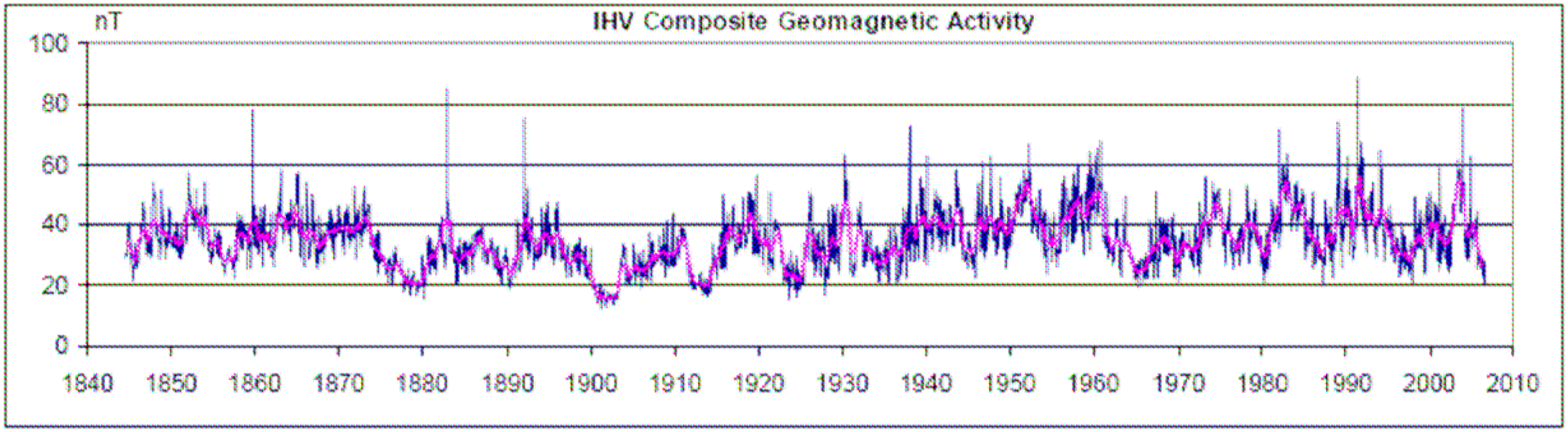
From the amplitude of daily variation of the polar cap current sheet we can get the product *BV* [LeSager&Svalgaard, 2004] and can use that as independent confirmation.

We can infer the solar parameters on even a rotational basis:





And extend the indices back to the 1840s:



It is noteworthy that activity in the 1860s was not substantially smaller than for recent solar cycles. The very low level in 1901-1902 is interesting, and with some luck we might experience similarly low values for the coming solar minimum [or the next]. This will allow us to check the relationships for such low values and remove the last vestiges of extrapolation outside of the domain on which the relationships were derived.

An unknown quantity [which should be addressed by the modelers] is how the decrease of the Earth's magnetic dipole field influences the effect of the solar wind on the Earth system. Such an influence would have to be incorporated into any long-term reconstructions.

Conclusions:

1. A new class of geomagnetic indices using hourly values and computed separately for night side and day side hours allows us the determine solar wind speed V and interplanetary magnetic field strength B since the 1840s
2. The separation of B and V is possible because different indices have different dependencies on V and B
3. The new indices allow secure calibration of traditional geomagnetic indices [which still have higher time resolution]
4. Because the new indices are objective and calculated from archived data, they can be calculated and checked by anybody
5. This allows the community to converge on generally accepted values of the long-term activity indices and the solar indices that produce them [we are almost there]
6. The old geomagnetic data from before ~1925 are very valuable and must be preserved and digitized

The End