Re-derivation of D_{st}

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In deriving the geomagnetic D_{st} index, there are several steps:

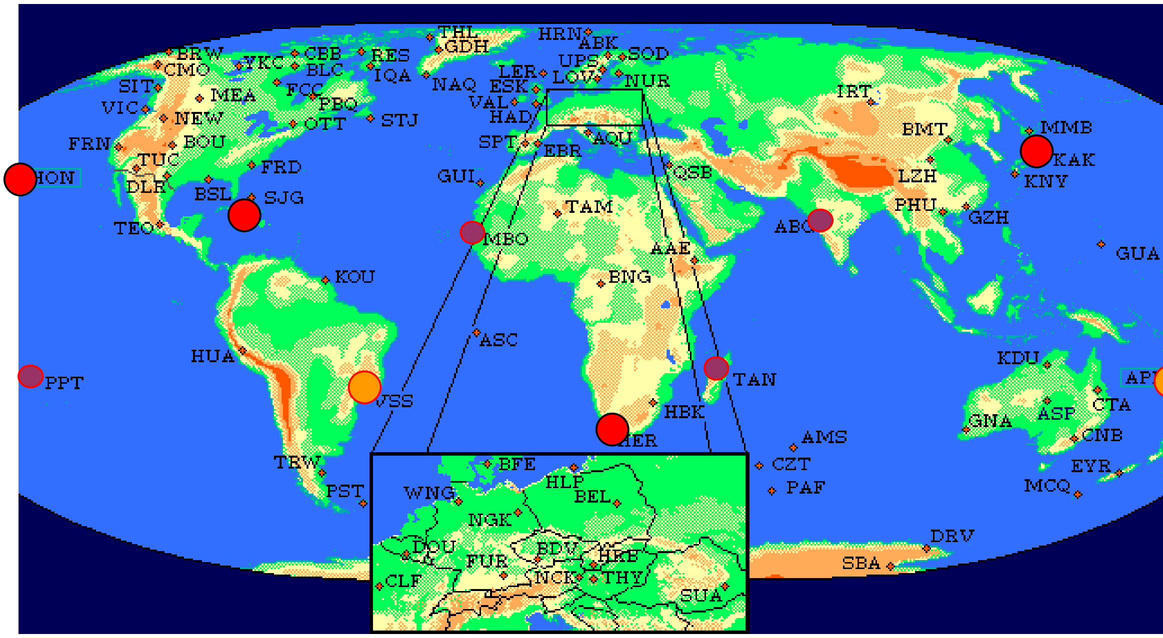
1) Selecting observatories at low latitude, yet still away from the equatorial electrojet.

2) Removing the ‘main field’.

3) Removing the solar-diurnal regular variation.

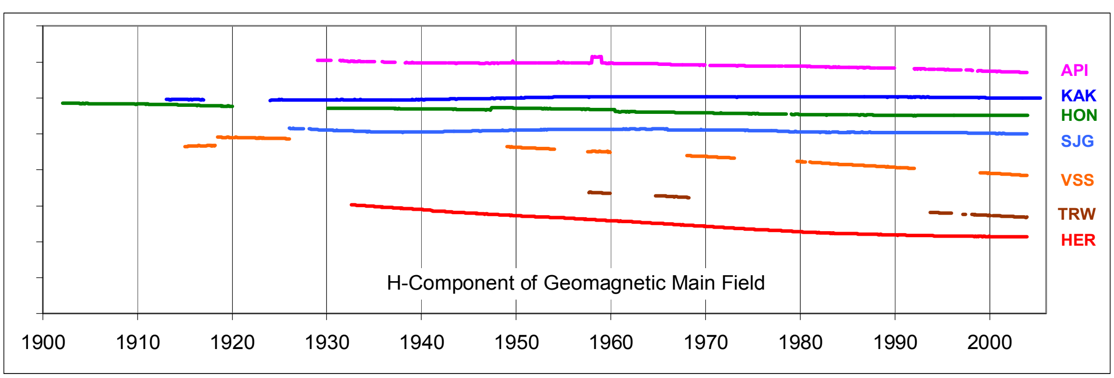
Each of these steps must be done with care. The commonly used procedures have problems (which I shall address shortly). In this talk I shall outline an approach that largely removes these problems.

First the station distribution



The stations used for the standard D_{st} index are predominantly in the Northern hemisphere. I propose to use two more stations in the South. An additional four stations (two in each hemisphere) would be even better and improve the longitudinal coverage.

These stations are INTERMAGNET stations and data is available in near real-time as well as back in time.



Removing the 'Main Field'

A common practice is to calculate an average "quiet" field using the "five quiet days" per month, except that some of these days may not be quiet at all; they just happen to be the least disturbed during that month.

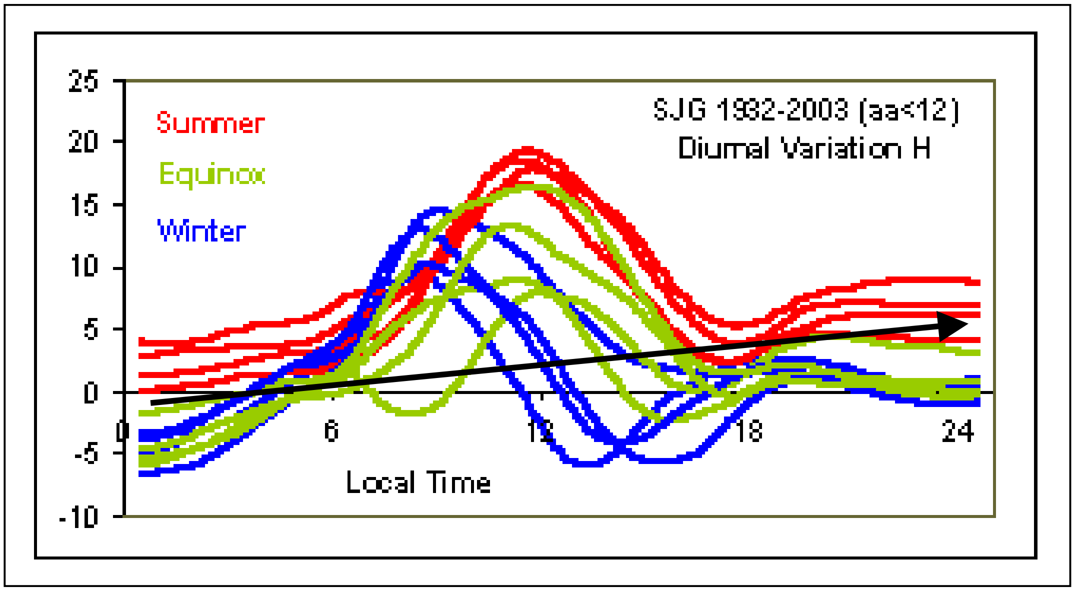
I have chosen instead to only days where *no* 3-hour interval had an *aa*-index value exceeding 12. I compute the yearly averages of the day number within the year and of the geomagnetic component field value for all these "truly" quiet days within the year.

A 2^{nd}-order polynomial fit to these yearly pairs of numbers for five years centered on the year within which we wish to derive the main field is then used to interpolate the main field for any given day within that year.

Occasionally, a discontinuity (e.g. caused by moving the instruments to a new building) must be identified and removed manually.

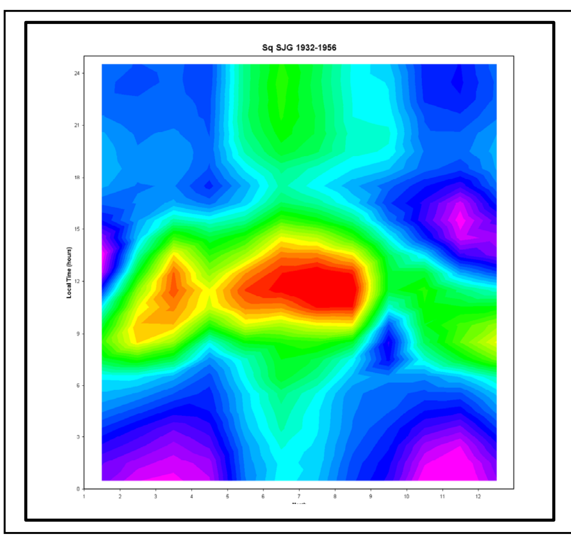
Removing the Solar-Diurnal Variation

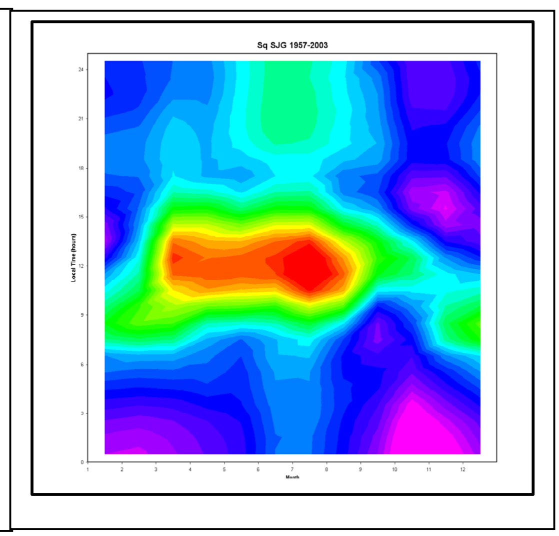
The daily variation is complex and varies with season (solar zenith angle) and phase of the sunspot cycle (EUV flux). Here as average H-component values minus the interpolated main field for SJG:



And as contour plots (X=month, Y=local time):

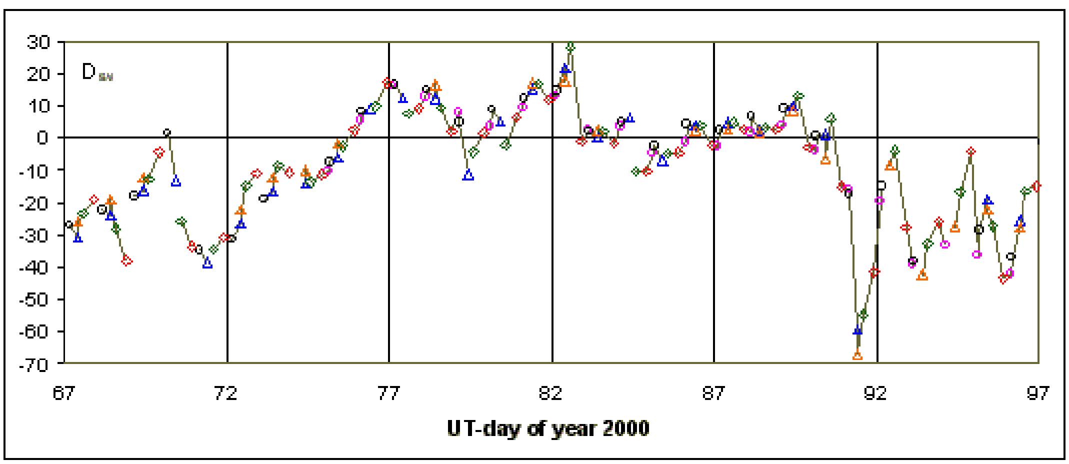
(SJG 1932-1956) (SJG 1957-2003)





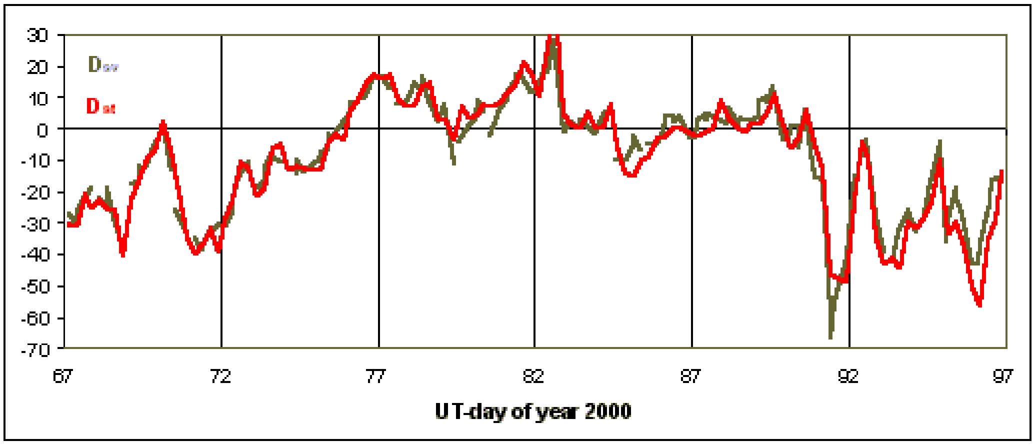
People have tried to describe this complicated variation by a combination of linear terms and a smoothed 2D Fourier expansion as function of time of year and time of day. This is not satisfactory, as the (un-modeled) day-to-day variation of the daily variation is as large as the variation itself.

The regular solar-diurnal variation is effectively absent during the night-hours, so I suggest to bypass the problem by only using night hours and calculate D_{sv} as the observed value minus the interpolated main field, H_0, with no empirical adjustments of any kind:

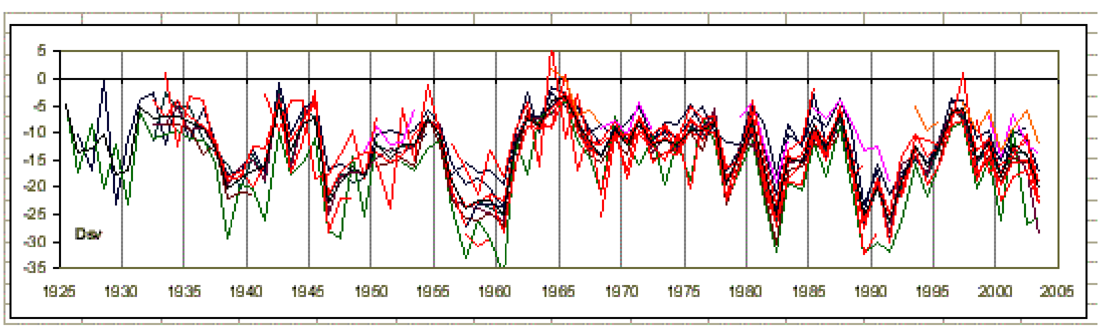


The Southern Hemisphere station data are shown with “reddish” colored symbols (VSS - pink circles; API - orange triangles; HER - red diamonds) and the Northern Hemisphere stations with “bluish” (SJG - black circles; HON - blue triangles; KAK - green diamonds).

We can compare this simple version (grey) with the official D_{st} (red). The match is quite good:



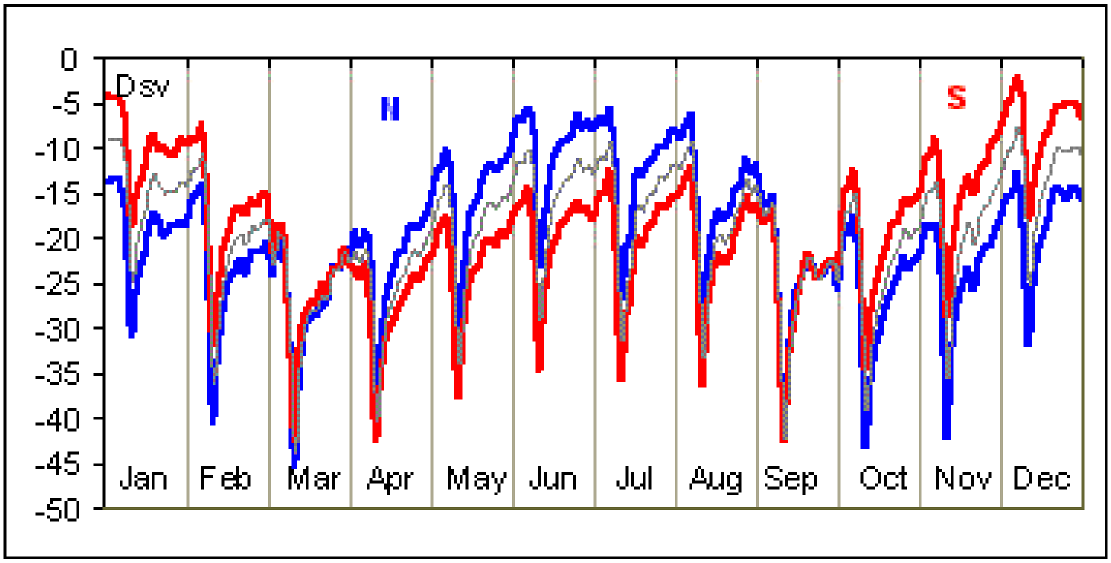
I have identified 14 stations (7 in the Northern Hemisphere - SJG, HON, KAK, SSH, MBO, TKT, ABG; 7 in the Southern Hemisphere - HER(CTO), API, TAN, PIL, PPT, TRW, VSS) in a latitude band suitable for derivation of D_{st} and with long-term coverage. Calculating the simple Dsv as H - H_0 with no other adjustments we get (yearly averages):



The standard deviation about the average yearly mean (heavy black curve) is only 4 nT. No cosine (latitude) correction was employed.

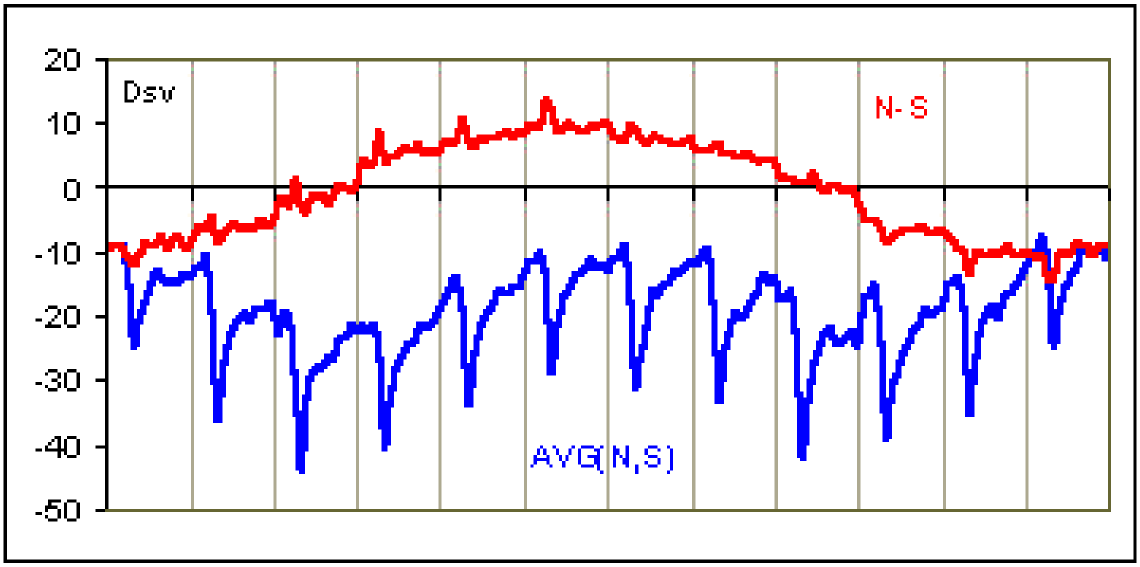
The Annual Variation

I have swept a problem under the rug - the Annual Variation. This is perhaps best illustrated with a superposed epoch analysis using Sudden Storm Commencements as key events:



The data interval is 1929-2002. The curves plotted within each month show 15 daily values superposed with the SSC on day four. D_{sv} derived from the Northern Hemisphere stations is shown in **blue**; the Southern Hemisphere in **red**. It is clear that during local summer, D_{sv} is more positive compared to local winter.

In the average of the two hemispheres, this annual variations cancels out:



The difference (N-S) shows the annual variation in its simple, pure form. The average, (N+S)/2, shows no annual variation. Instead, the well-known *semiannual* variation is evident.

The cause of the annual variation is not well understood, but that does not matter much for D_{sv} because it cancels out in the balanced average of the two hemispheres.

Because the official Dst index is the average of three Northern stations and only one Southern station, the annual variation does not cancel in a natural way and has to be explicitly removed, usually as part of the functions fitted for the removal of the solar diurnal variation.

Comparing Dsv with Dst:

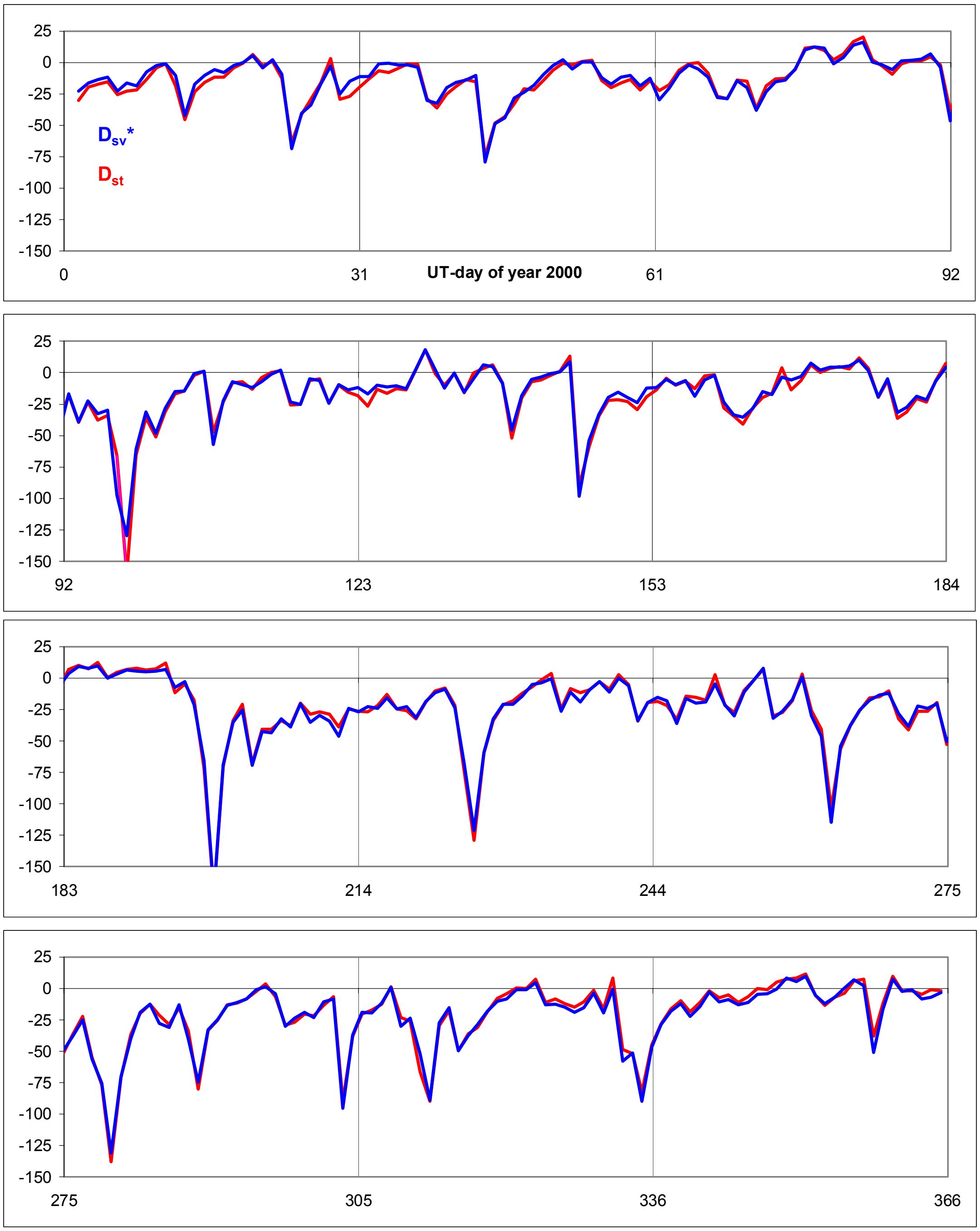


Figure 5

shows that our extremely simple derivation of Dsv does a very good job in reproducing the storm behavior.

Conclusion

It does not seem necessary to employ complicated and perhaps dubious fitting procedures to construct a storm-time ring-current index.

The key point is to use nighttime data only and to use the same number of stations in both hemispheres in order to remove the annual variation in a natural way.