# The Scale Value of the H variometer at Helsinki

Leif Svalgaard, September 2013

The diurnal variation [$S_R$ or less accurately called *Sq*] of geomagnetic elements can be used to check the *scale-value* of the magnetometers. The instantaneous value at time *t* of element $E(t)$ is usually written $E(t) = E_0(t) + s * \Delta E(t)$ where $E_0(t)$ is the 'baseline' value and the 'scale-value' *s* translates the ordinates $\Delta E(t)$ of the trace reckoned from the baseline trace [to use the classical analogue instrument terminology] to physical units. Computing for each day the differences between the instantaneous [or hourly mean – the distortion caused by averaging over an hour is but slight] values and the daily mean removes the effect of the [slowly varying] secular values and of random [unknown] changes in the baseline.

The average, over an interval –such as a month or a year, of the differences as a function of time within the day is the average diurnal variation [what used to be called the daily 'inequality']. It is well-known that the average *range*, i.e. the difference between the maximum and minimum values of the average diurnal variation is extremely well correlated with appropriate solar activity indices [e.g. F10.7 microwave flux, sunspot number, or the group number (number of active regions on the solar disk)], as was discovered by Wolf [1856] and subsequently extensively verified by many workers [e.g. Bartels 1946], in fact, having the highest correlation of all indices. Figure 1 shows the yearly average ranges for Declination D and Horizontal Force H at Helsinki:

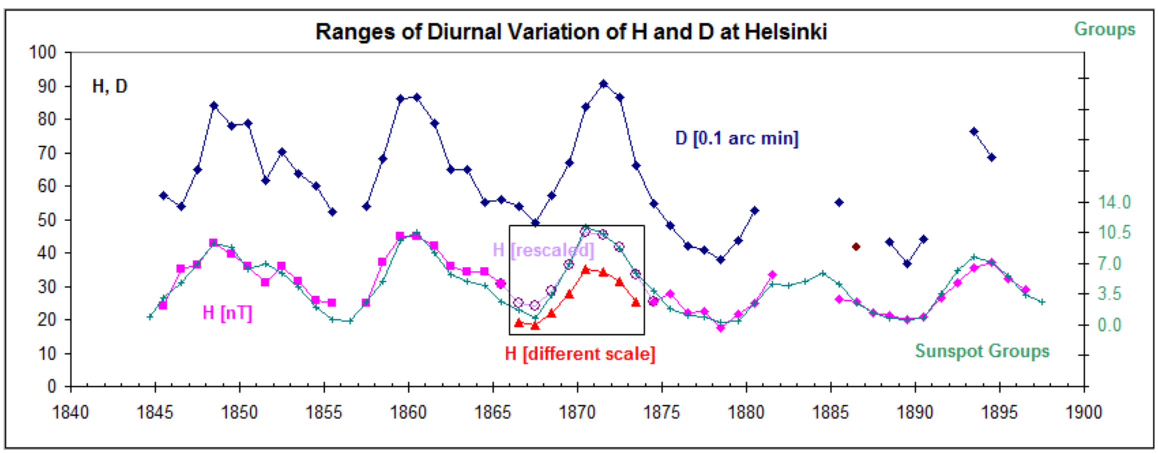


Figure 1: Yearly average Ranges for Declination D [in 0.1 arc minute units], blue curve, and for Horizontal Force [in nT units], pink curves. Because of the strong seasonal variation only years with no more than a third of the data missing are plotted. The green curve [with '+' symbols] shows the number of active regions [sunspot groups] on the disk scaled to match the pink curves (H). As expected the match is excellent, except for the interval 1866-1873, where the H-range would have to be multiplied by 1.31 for a match, purple open circles. The brown (outlier) data point [1886] for D is discussed later in text.

The Group numbers used in Figure 1 are derived from the recent re-evaluation of solar activity [http://ssnworkshop.wikia.com/wiki/3rd_SSN_Workshop]. It seems that the scale value for H during the interval 1866-1873 must be different from that used for the rest of the H-data, specifically only 1/1.31 = 0.762 of the value used by Nevanlinna in constructing the Helsinki series. The range of the Declination during that interval matches that of H when H is re-scaled by the factor 1.31. The ranges of D and H generally vary together [with solar activity] being due to the same current system, indicating a problem with the scale-value of H. Wolf and Wolfer collected measurements of the diurnal range of the Declination from four stations operating during 1836-1922, shown in Figure 2, and confirming the large size of the sunspot cycle peaking in 1870:

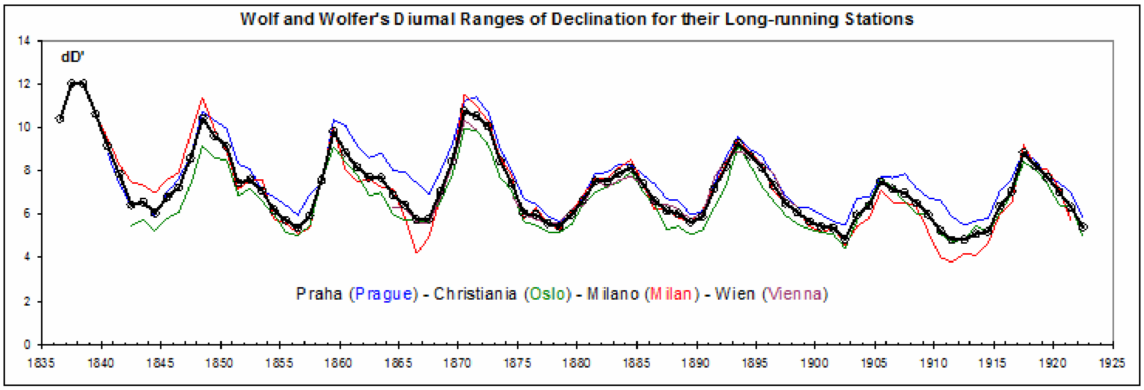


Figure 2: The diurnal range (in 0.1 arc minutes) of the Declination reported by Wolf and Wolfer in 'Mitteilungen' for Prague (blue), Oslo (green), Milan (red), and Vienna (purple). The heavy black curve shows the average of the four stations.

The strongest case can, obviously, be made comparing the diurnal range of H at Helsinki directly to that of H at other stations. In Figure 3 we show a comparison with Greenwich (GRW, brown), Prague (PRA, blue), and Colaba (CLA and replacement station Alibag ABG, green). Because not all stations observed hourly values all the time, the ranges have been matched to Helsinki (HLS, pink, outside the interval 1866-1873):

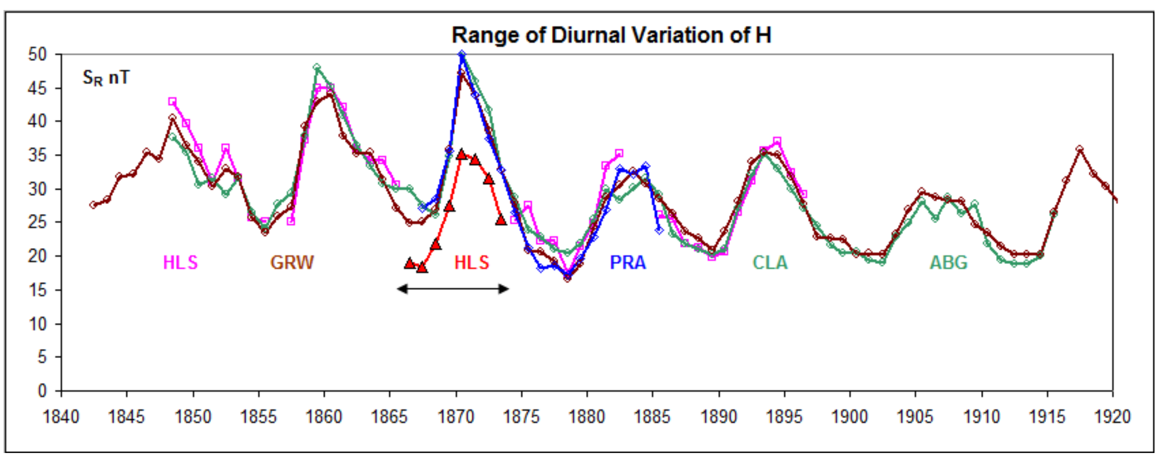


Figure 3: The diurnal range (in nT) of the Horizontal Force for Prague (blue), Colaba+Alibag (green), Greenwich (brown), and Helsinki (pink). For 1866-1873, HLS (red triangles) is clearly seriously too low.

The general decline of the ranges [for both D and H] may be related to the increase (~5%) of H at all stations through the 19th century, which decreases ionospheric conductivity.

Such an uncorrected [or unknown] scale-value inhomogeneity is not unique to H. Figure 4 shows the diurnal variation of H and D for three years (1854, 1865, and 1886) with the same sunspot number (namely about 25). Since the amplitude of the diurnal variation depends mainly on the sunspot number (driven by the FUV flux from active regions), the amplitudes should be the same for each year. In fact, for the H component, the amplitudes *are* the same. Not so for the D-component. The variation in the ranges of D for the year 1886 has only about half the amplitude as the other years:

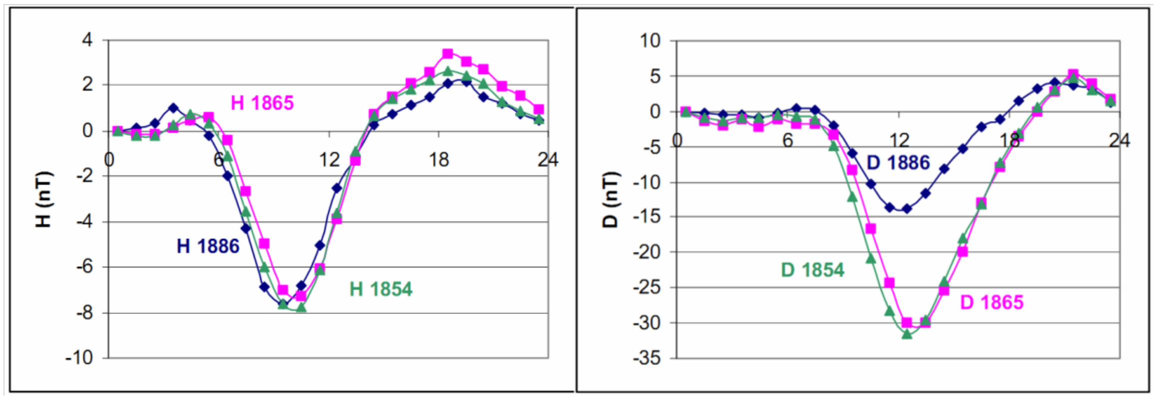


Figure 4: Diurnal variation of H [left] and of D [right] at Helsinki for three years with sunspot number ~25.

Actually, looking closely, it seems that the problem exists from Oct. 1885 through May 1887. And in fact, the variations shown were really computed for Oct. the previous year through May the following year. It is very hard to escape the conclusion that there is an error by a factor of two during the interval 1885 Oct - 1887 May. In August 2003 I emailed Nevanlinna alerting him to this problem, but, unfortunately, no corrective action resulted from this. It is now clear that scale-value problems also exist for the H component and that corrective action is mandatory before use of the Helsinki data.

An example of the deleterious effect of using the defective data is Nevanlinna's [2004] attempt of deriving a range index akin to *aa* and *ap* from the Helsinki series, Figure 5:

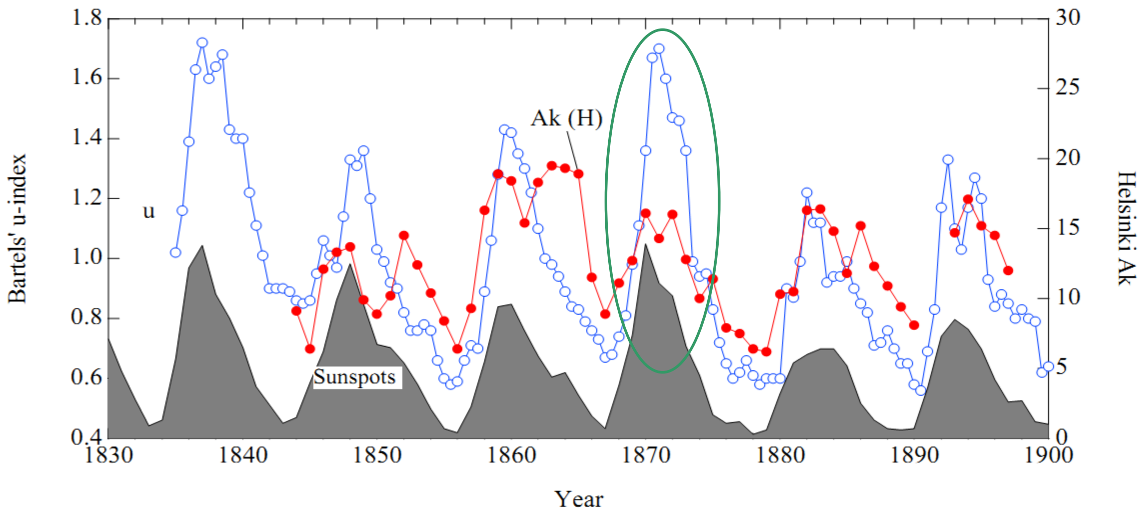


Figure 5: Annual means of Helsinki Ak(H) and Bartels' mid-latitude activity index *u*. Sunspot numbers are shown at the bottom. The green oval shows the discrepancy.

The sudden change in 1866 of scale-value (sensitivity) of H is also readily seen in contour plots of the diurnal variation as a function of time as shown in Figure 6:

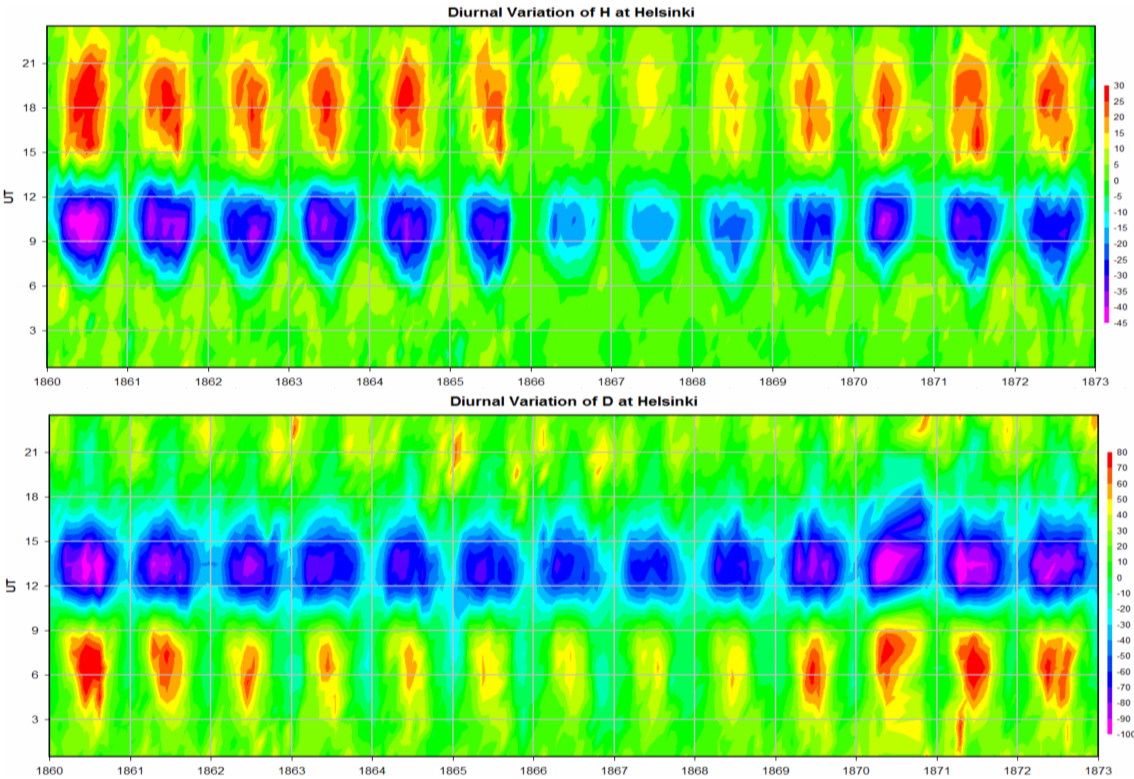


Figure 6: For each year 1860-1872 is shown a contour color plot of the amplitude of the diurnal variation as a function of month (horizontal axis) and of UT (vertical axis). The color scale is red for high values and violet-blue for low values.

We can calculate the IHV-index for any element, not just H, but also D [in force units] as well. Figure 7 neatly illustrates the problems with the scale-values for both H and D:

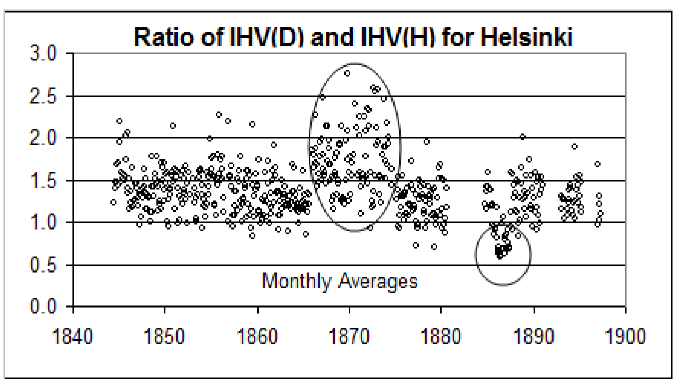


Figure 7: Monthly means of the Ratio of IHV(D in force units) and IHV(H) for Helsinki.

The ovals show where H scale-value is too small and where D scale-value is too small.

Conclusion: We have shown that the scale-values for the Helsinki magnetic data are in error at times. For H, the scale-value for 1866-1873 is too low by ~30% and for D too low during 1886 by a factor ~2. We urge Nevanlinna et al. to re-examine the original data and their reduction. And we urge Lockwood et al. to revise accordingly their analysis and derivation of IDV look-alikes where based on the Helsinki data.