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Is there a need to revise the aa index?

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The *aa* Index

The three-hourly *aa* index, retrospectively calculated from 1868 [1], provides one of the longest continuous global geophysical data sets that can be used in the analysis of magnetospheric and ionospheric phenomena. Designed to cancel out systematic LT and annual variations, *aa* is derived according to:

- *K* indices from 2 geomagnetically near- **a**ntipodal magnetic observatories
- equivalent **a**mplitudes (nT) and scale factors to correct for differences in geomagnetic latitude and local induction effects (providing aa_n and aa_s)
- average of aa_n and aa_s

Further LT cancellations can be gained by applying:

- 8-point (24 hour) running mean (aa^*) [2]

Years	Northern Observatory	Scale Factor
1868-1925	Greenwich	1.007
1926-1956	Abinger	0.934
1957-	Hartland	1.059

Years	Southern Observatory	Scale Factor
1868-1919	Melbourne	0.967
1920-1979	Toolangi	1.033
1980-	Canberra	1.084

Figure 1: Locations of the aa_n (top) and aa_s (bottom) observatories. The years when each were used for derivation of *aa* are shown in the table. The scale factor for each observatory is also shown.

Discontinuities in the *aa* Index

Detailed studies on long term changes in activity have identified small, step-like baseline changes at specific times throughout the data set. Although very small, these have resulted in doubts for some researchers over the use of *aa* in long-term studies. One method of identifying possible discontinuities is to investigate the occurrences of *K*=0 (Fig 2). There is a clear change after 1982, which may be related to increased noise levels at Hartland, but this needs further investigation.

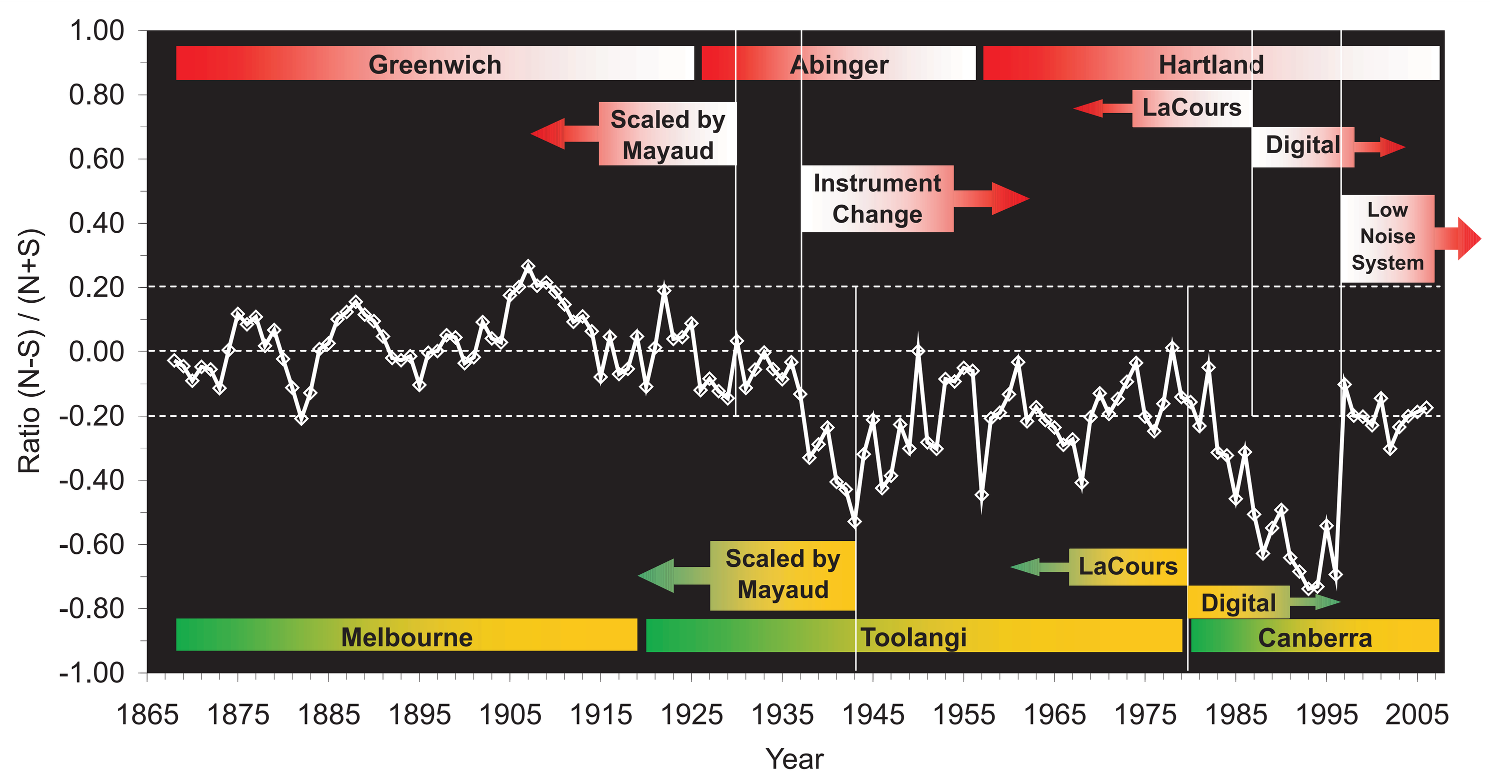


Figure 2: Comparison between the number of annual occurrences of K=0 for northern observatories (N) and those from the southern observatories (S) from 1868 to 2006 [updated from 6]. Times of known changes to observatory operations are also shown. In a perfect system N-S/N+S would be zero. Steps and drifts outside the +/-0.2 band indicate a change in the sensitivity at one of the observatories.

Significant deviations also occur in 1938 and 1997 and, compared with independent data (Fig 3), it is clear that these discontinuities are in the northern data, when known instrumental changes took place. Further evidence of this is shown in Fig 4. Comparing *aa* in 1996 derived using northern data from the old and new systems running in parallel, gave differences of 0.9nT in minimum *aa*, and 0.7nT in the annual mean. Since 1996, *aa* is back to being close to its 1900 state, as far as *K*=0 ratios are concerned, and thus, now may be a good time to consider correcting the deviations that have occurred in between.

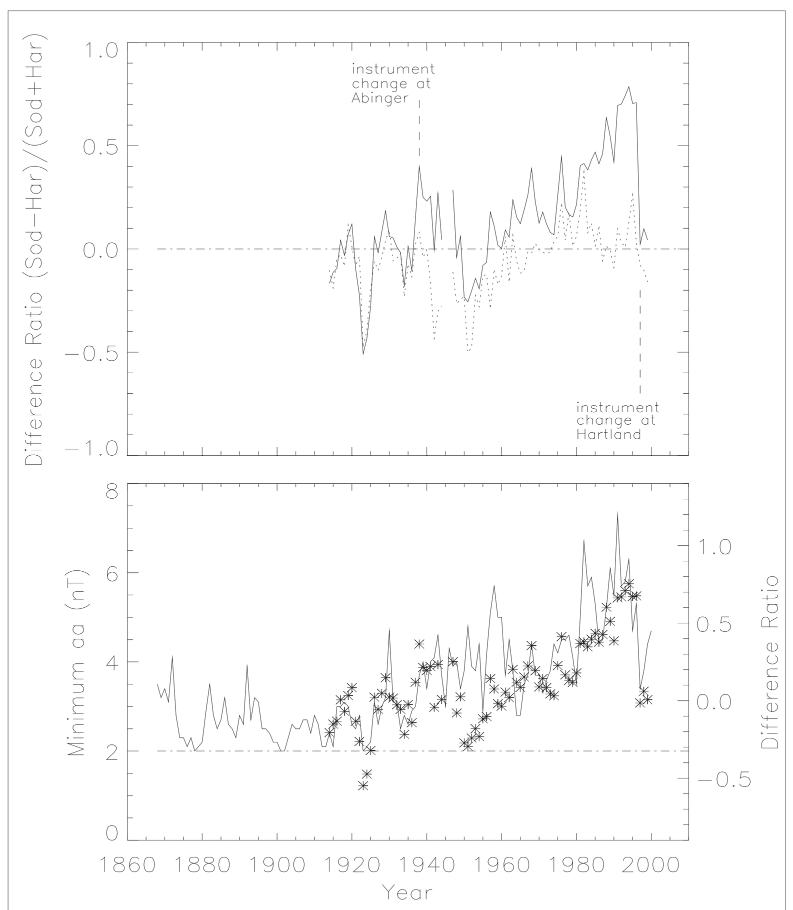


Figure 3: Top - the ratio of annual occurrence of *K*=0 for Sodankyla observatory compared with those of the aa_n (solid line) and aa_s (dashed line) observatories. Bottom - the variation of the monthly minimum aa^* (solid line) with the Sodankyla/aa_n observatory ratio over-plotted (asterisks). [6]

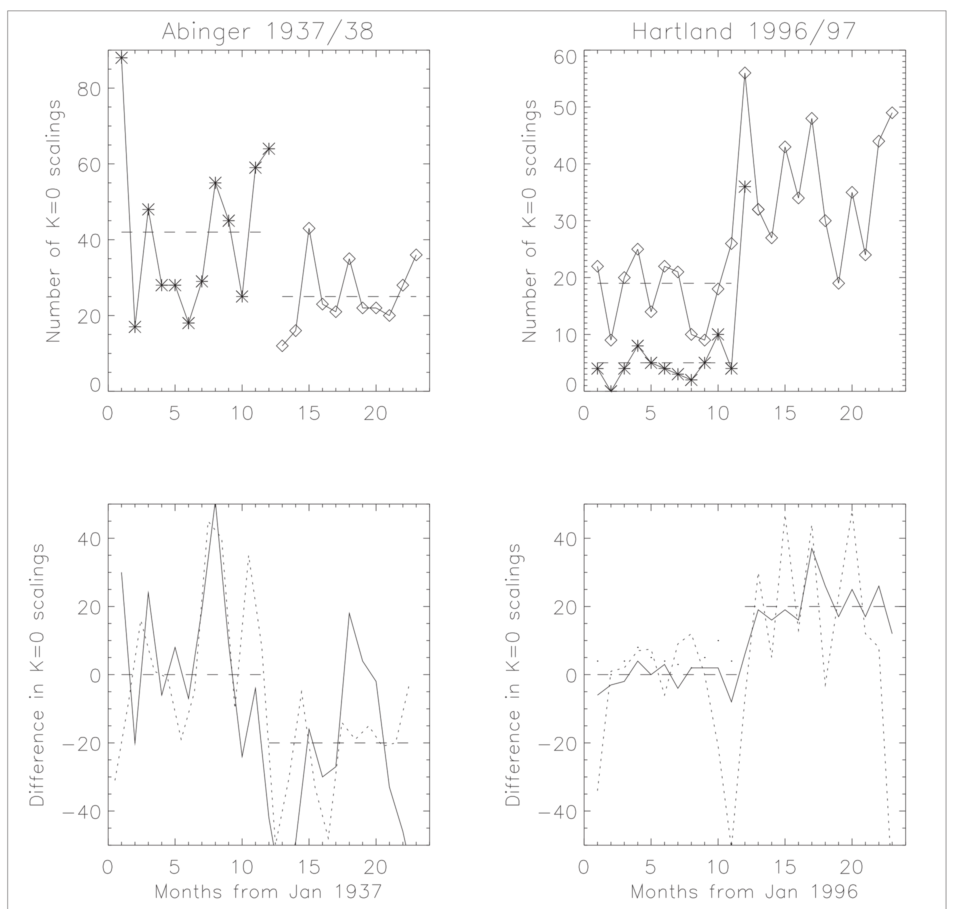


Figure 4: The variations of *K*=0 occurrences at Abinger (1937-38) and Hartland (1996-97) when known instrumental changes took place. Top panels show the number of occurrences before (asterisks) and after (diamonds) the change. Bottom panels show the differences between them and those of two independent observatories in each case. [6]

Long-term change in geomagnetic activity

The trend in magnetic activity over the last century has been investigated by many researchers using *aa* data [E.g 3,4,5]. It has been shown [5,6,7] that, despite a small contribution from instrumental discontinuities (see Figs 2-4), this trend is primarily due to solar, rather than observational, ionospheric or magnetospheric changes. Debate continues over the detail [E.g.8], although we feel that the upward trend should not be in doubt (Figs 5 and 6).

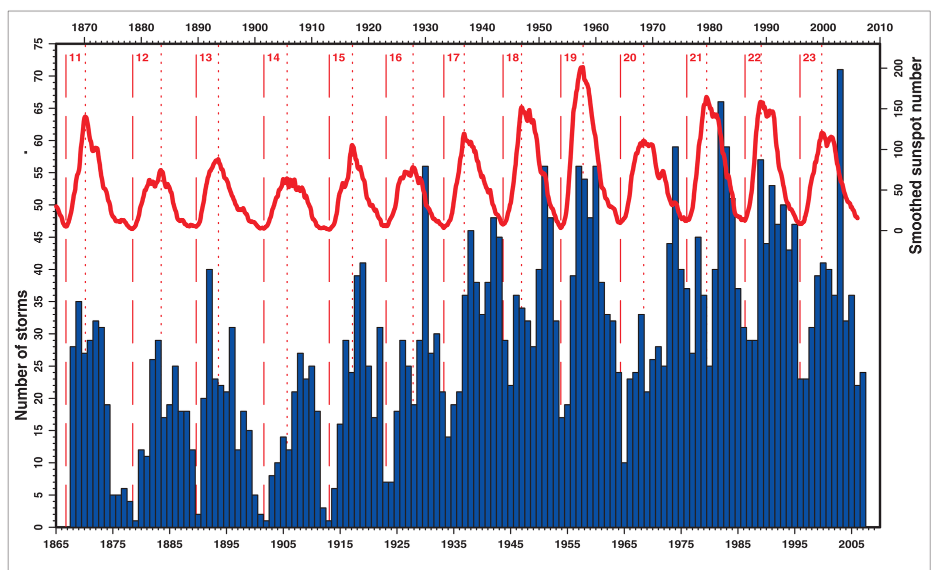


Figure 5: The annual number of magnetic storms (aa^* > 40nT) from 1868 to 2006 (2007 is estimated) with smoothed monthly sunspot number over-plotted (red line) and the minimum (vertical dashed line) and maximum (vertical dotted line) for each solar cycle.

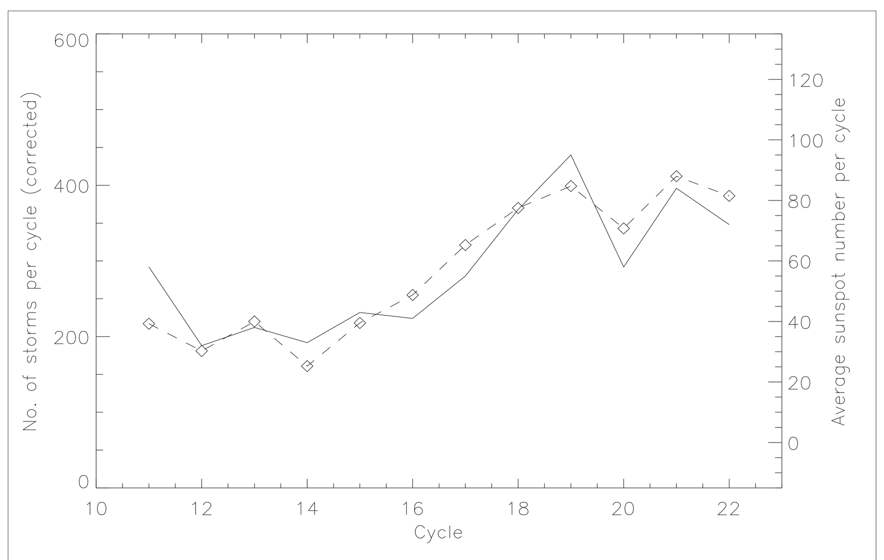
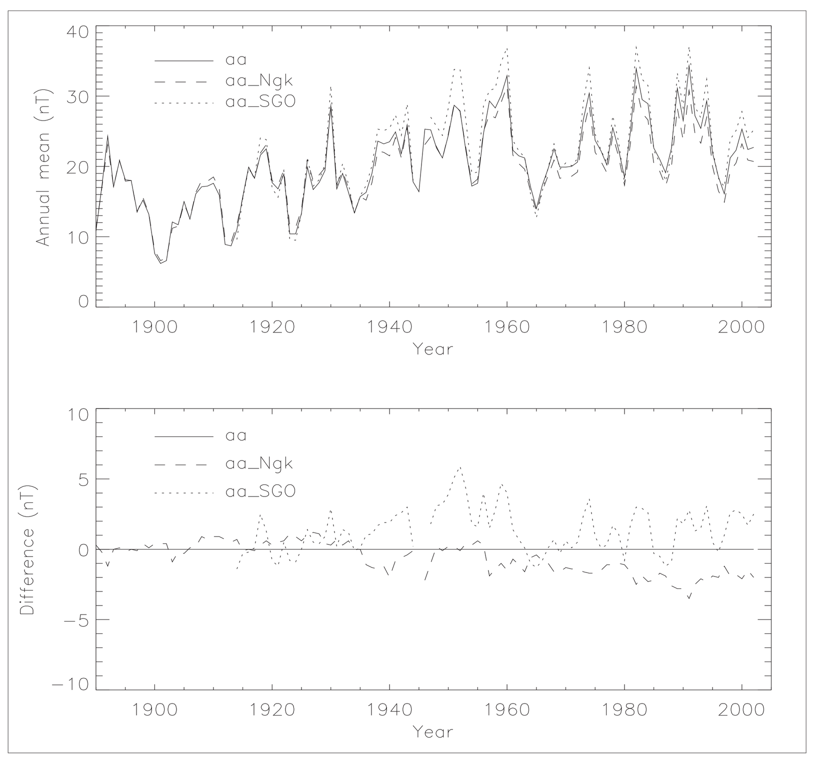


Figure 6: The number of magnetic storms (diamonds) per solar cycle (aa^* > 40nT and corrected for baseline changes) and the variation of the mean monthly sunspot number in each cycle (solid line). [6]

This debate, coupled with the fact that some researchers believe the *aa* should not be used in long-term studies, has given rise to the question of whether there is a need for an official IAGA or ISGI revision of the index.

Calibration and Reconstruction of *aa*



Recent work [9] to calibrate the *aa*, found an error in the drift between 1900 and 1960 of ~2nT. This, despite using a different technique, is consistent with findings from a reconstruction of *aa* [7], shown in Fig 7. Both studies highlight a possible scaling discontinuity from 1957.

Figure 7: The annual mean values of *aa* and two reconstructed series based on Sodankyla and Niemegk *K* indices combined with the official aa_s. The lower panel shows the differences between reconstructed and official

Summary

Information gained from these studies, and others, will be useful in making a decision on whether to correct the *aa* data. The main arguments for and against an official correction are given below.

PROS	CONS
• IAGA sanctioned correction would provide confidence to users • Correction made by unbiased data providers rather than individual researchers (with different goals) • Save time and effort in the long-term • Original data set will not be lost - correction only required for monthly or annual means, not 3-hour values • Process itself will enable the collection and cataloguing of improved metadata – an increasingly	• Modifications expected to be small - very little (if any) effect on existing results and conclusions • Very difficult job to do right (E.g. How would it be carried out? What is the benchmark for comparisons? Do we go back to raw data?) • Very time consuming process • Problem can be partly solved by accompanying the data set with appropriate metadata.

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