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Corrected hourly values from Eskdalemuir observatory and the implications for studies on the long term changes in geomagnetic activity

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Introduction

The UK observatory hourly values published in yearbooks were digitised in the 1970s, using data entry by groups of prisoners. These were made available for research purposes via the WDC for geomagnetism. It has recently been discovered [1] that the hourly values from Eskdalemuir (ESK) observatory for years 1911 to 1931 are 2-hour running means, instead of the original hourly values published in the yearbooks (see Fig 2). Unfortunately there was no record of the original digitised data. This filtering was carried out to centre the data at 30 minutes past each hour instead of at 0 minutes, for homogeneity with the data from 1932 onwards. It may also have been the belief at the time, that the raw data from the yearbooks were spot values rather than estimated mean values, and averaging would have been appropriate. In any case the original raw digitised data should also have been stored. Following this discovery a campaign to re-digitise the ESK yearbook data began.

Figure 1: Aerial view of Eskdalemuir magnetic Observatory. Measurements started in 1908.

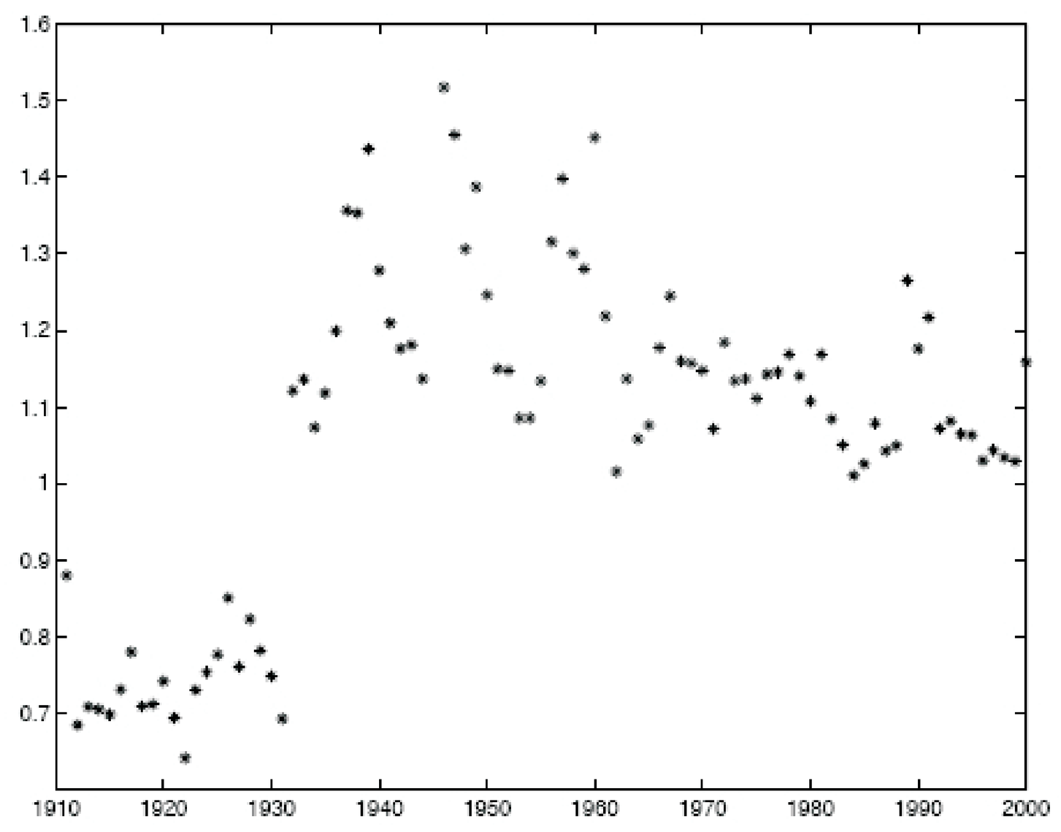

Figure 2: Ratios between ESK and Niemegk (NGK) annual mean *IHV* indices showing clear step in variability from 1931 to 1932 [1].

Digitisation Method

1. All yearbooks were located - some were transferred from the BGS archive at Hartland observatory and others from ESK.
2. Tests were carried out with different scanning hardware and different Optical Character Recognition (OCR) software packages to minimise the digitising errors.
3. Monthly tables for each component, i.e. intensities in the North (*X*), East (*Y*) and Vertical (*Z*) directions, for each month over 23 years (~800 tables) were electronically scanned. Some of the books were in poor condition (Fig 3) and it became evident that the OCR process would take much longer than originally thought.

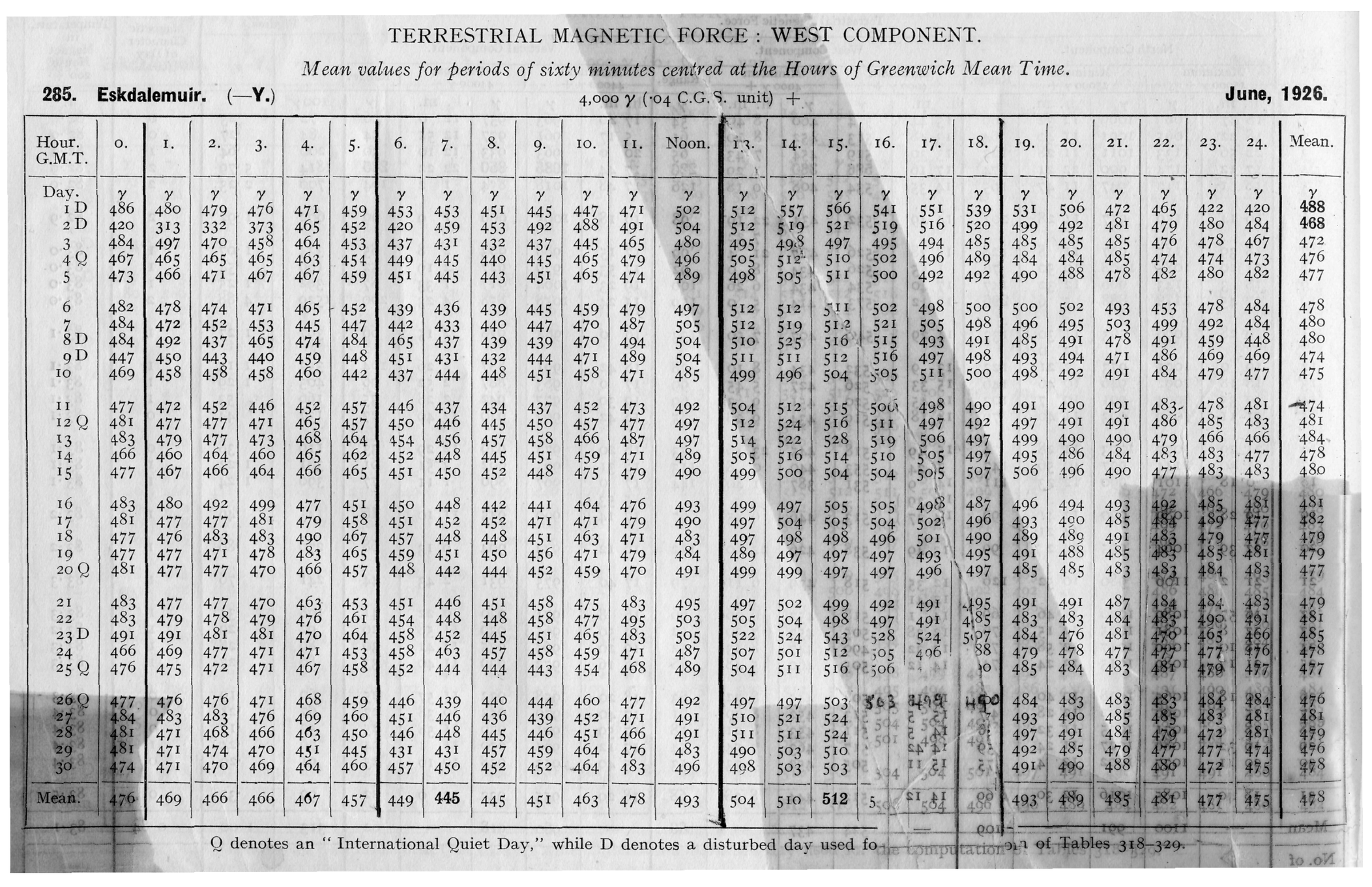
TERRESTRIAL MAGNETIC FORCE : WEST COMPONENT.
Mean values for periods of sixty minutes centred at the Hours of Greenwich Mean Time.
285. Eskdalemuir. (—Y.) 4,000 γ (·04 C.G.S. unit) + June, 1926.
Q denotes an "International Quiet Day," while D denotes a disturbed day used fo[r] computation of Tables 318–329.

Figure 3: An example of a poor quality image of one table of hourly values scanned from the ESK yearbooks.

4. Examples were sent to three different commercial specialist companies. They all recommended direct data entry as opposed to using OCR. One company was commissioned to carry out this work.
5. The digitised data were processed to compute Declination (*D*) and Horizontal Intensity (*H*) from *X* and *Y* and a two-point running mean filter was applied to enable comparison with the existing WDC data.
6. Many errors in the digitised data were discovered at this stage (Fig 4), indicating a poor job was carried out by the data entry company. Manual corrections were required as follows:
   - step 1 to correct all the absolute differences of >10 nT (complete)
   - step 2 to correct differences of >1nT (work in progress).

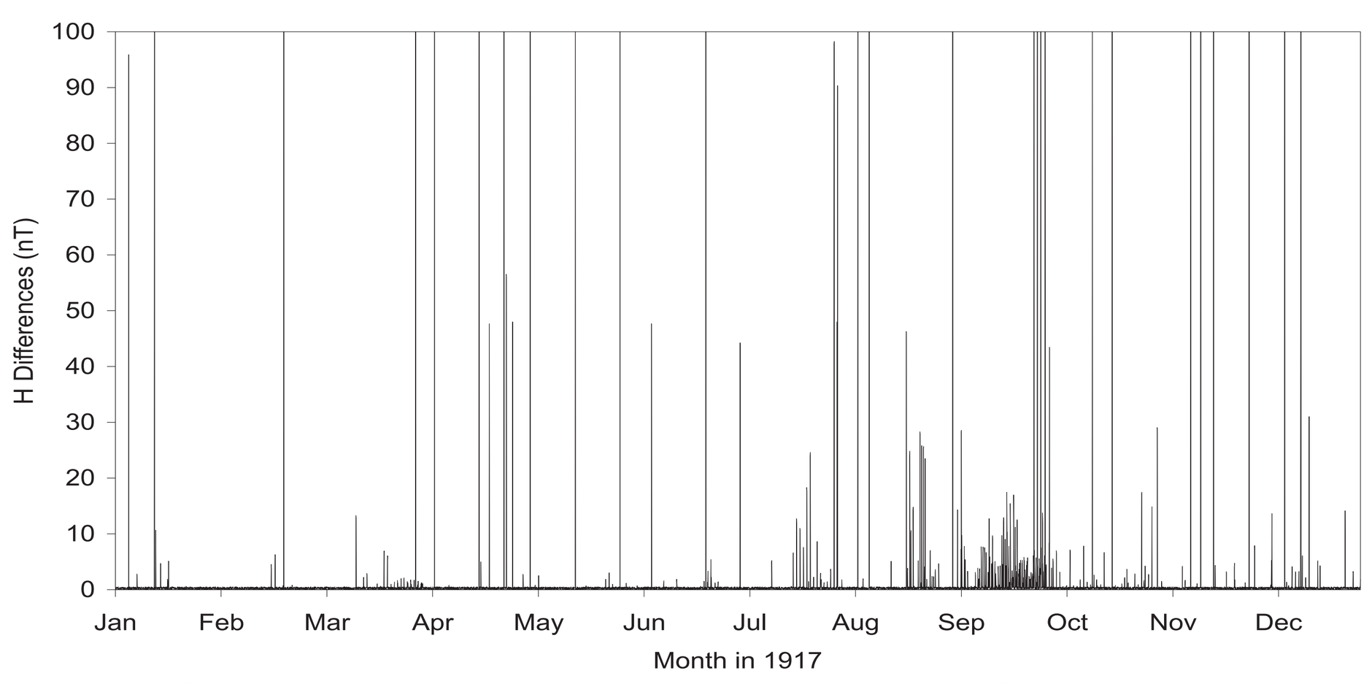

Figure 4: The number of errors in an example year after data entry. Absolute differences between the WDC *H* and the digitised, transformed and filtered *H* values are shown.

Another important question is when did the ESK values change from spot values to mean values? From 1911, the heading at the top of each table states "... **at** each hour of GMT". From 1914 to 1917 the headings change to "... **for** each hour of GMT", but there is no explanation of what changed. From 1918 the headings change again to say "Mean values for periods of 60 minutes centred at the hours of GMT", but an examination of the data suggests there is no variation change from 1914 or 1918. Further investigation is required.

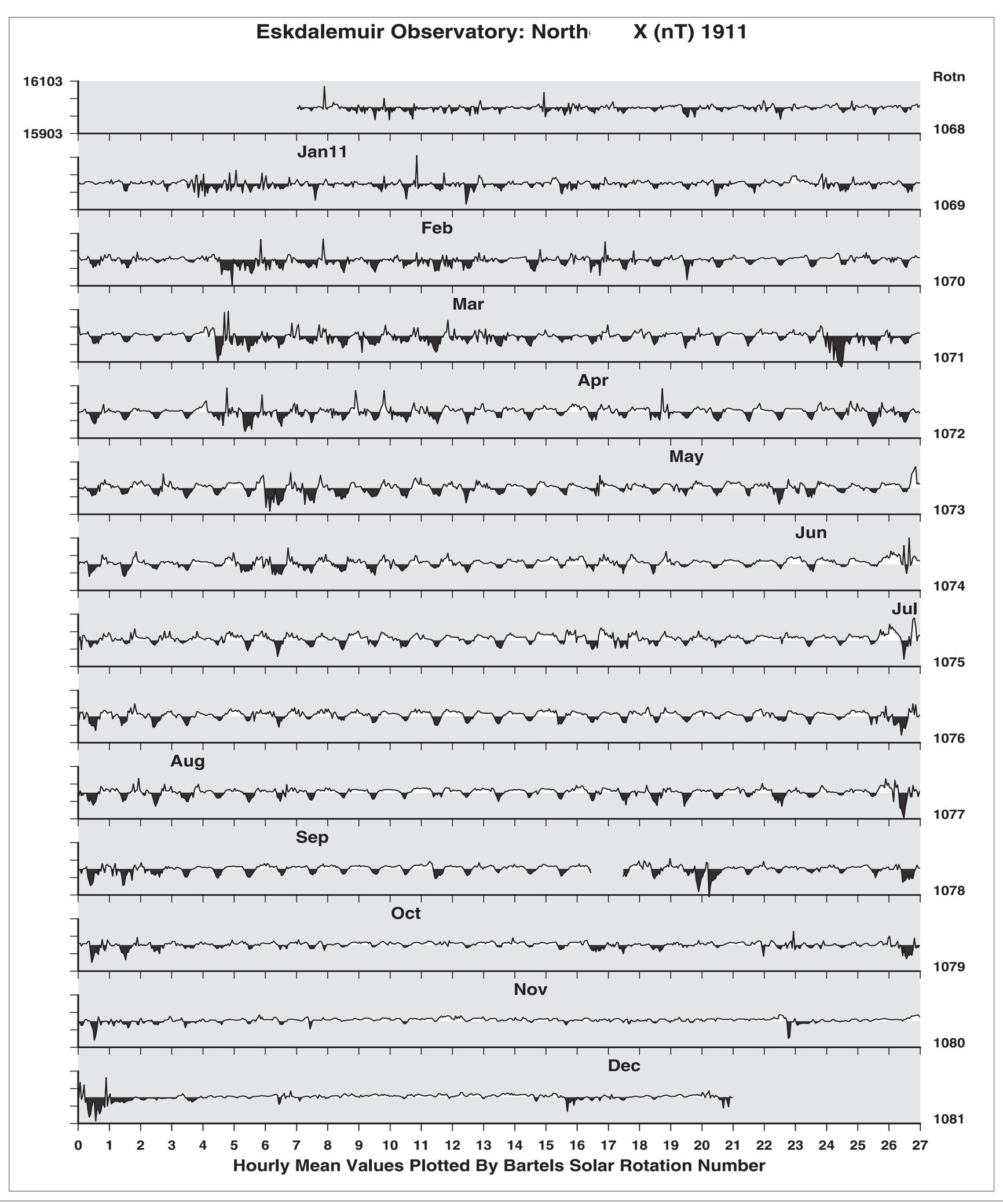

Figure 5: Plot showing one full year of fully corrected *X* data. The hourly values are plotted in panels of 27 days and by Bartels solar rotation number. 27-day activity recurrence patterns are evident as are diurnal variations particularly during local summer months.

Research using Observatory Hourly Values

Data sets of this type were originally used for studies into the main geomagnetic field and its secular variation, where the absolute level of the data and changes of the order of years to decades are the most important factors, rather than the variations from hour to hour. More recently, variations in the hourly values from long running observatories, like ESK, which was first established ~100 years ago, have been identified as important for studies on the long-term changes in geomagnetic activity and modelling of magnetospheric and ionospheric changes. Associated metadata are now very important due to the detail required from such studies.

Long-term change in daily variation

In a recent study [2], long series of geomagnetic hourly mean data from 14 observatories, including ESK, were used to compute 11-year average amplitudes of the regular diurnal variation of the geomagnetic field, *Sq*, at monthly intervals. The cause of the patterns in the long-term diurnal variation is related to changes in the solar irradiance spectrum in the EUV band. This is demonstrated in Fig 6, where it is clear that the extrema in the different time series coincide. Although the cause of the observed longer term upward trend in *Sq* amplitude is not certain, it is in agreement with the upward trend in a previous analysis [3]. In general, studies considering only geomagnetically quiet periods, will not be significantly affected by the filtered data. Additionally, the results of this study [2] will not be affected by the corrections carried out to the ESK data, since the shortest period fitted was 8 hours. Daily ranges from ESK hourly values will be affected, as in [3]. However, a number of other observatories were included, and so the ESK correction, almost certainly, will not change their conclusions.

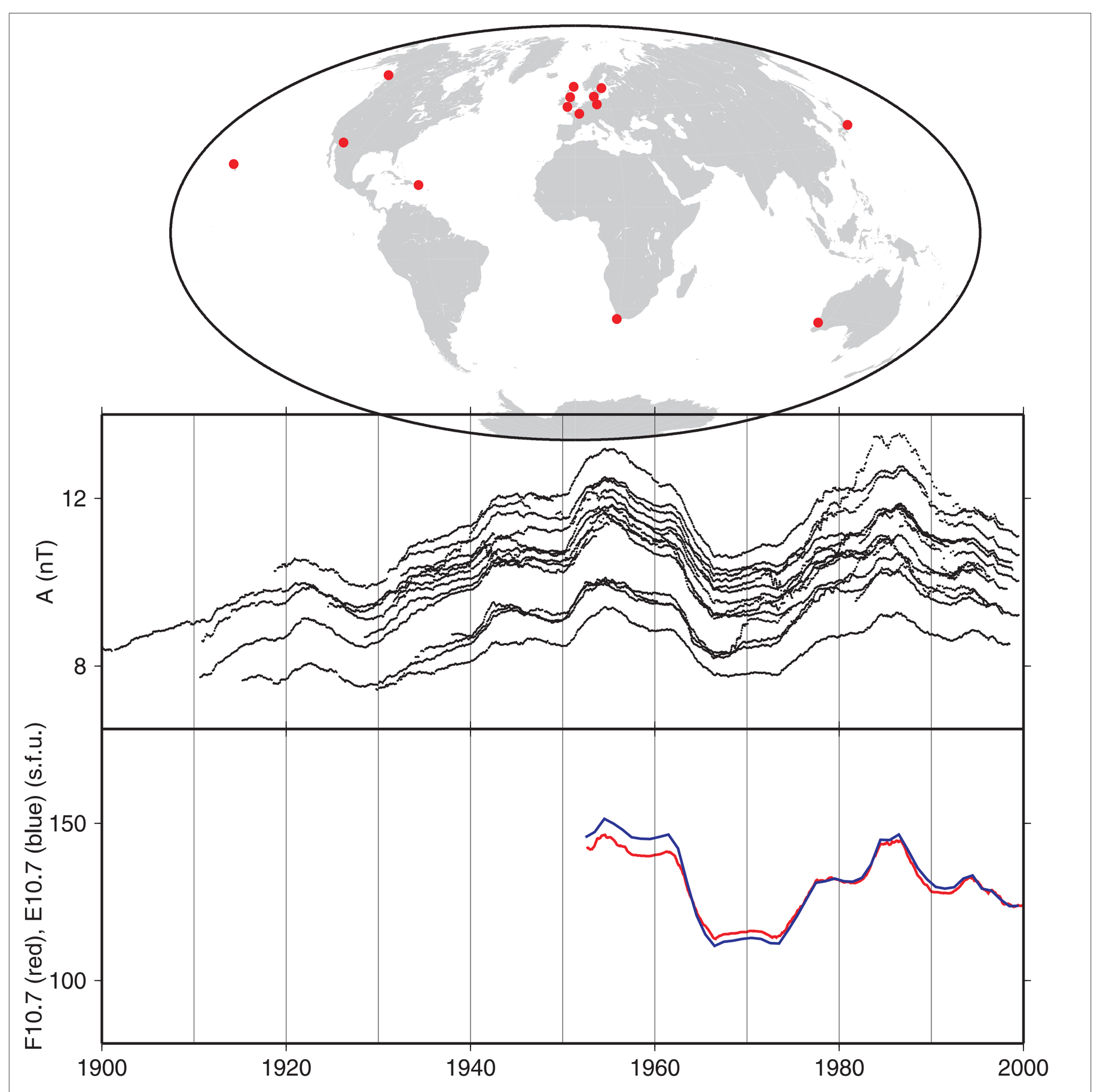

Figure 6: Top: Locations of 14 observatories with time series exceeding 70 years. Middle: The root mean square amplitudes of filtered *Sq* (from hourly values) at the 14 selected observatories. Bottom: solar irradiance proxies

Long-term change in geomagnetic activity

A proposed measure of geomagnetic activity from a single station is the inter-hour variability (*IHV*) index [4]. By definition, averaging neighbouring hourly values before computing this index will decrease the values of *IHV* obtained. The effect of correcting ESK data is demonstrated in a recent study [1]. The fact that the filtered data covered the first 21 years has exaggerated the long-term upward trend in ESK *IHV* [5] for *H* componenet. In [5] and also demonstrated in Fig 7, Lerwick (LER) *IHV(H)* seems to be a close match to the original ESK *IHV(H)*, leading to the speculation that the LER hourly values were also filtered in the early years, but this is not the case. LER data from the WDC, and those from Abinger, the third observatory operational in the UK at this time, match the values given in the corresponding yearbooks.

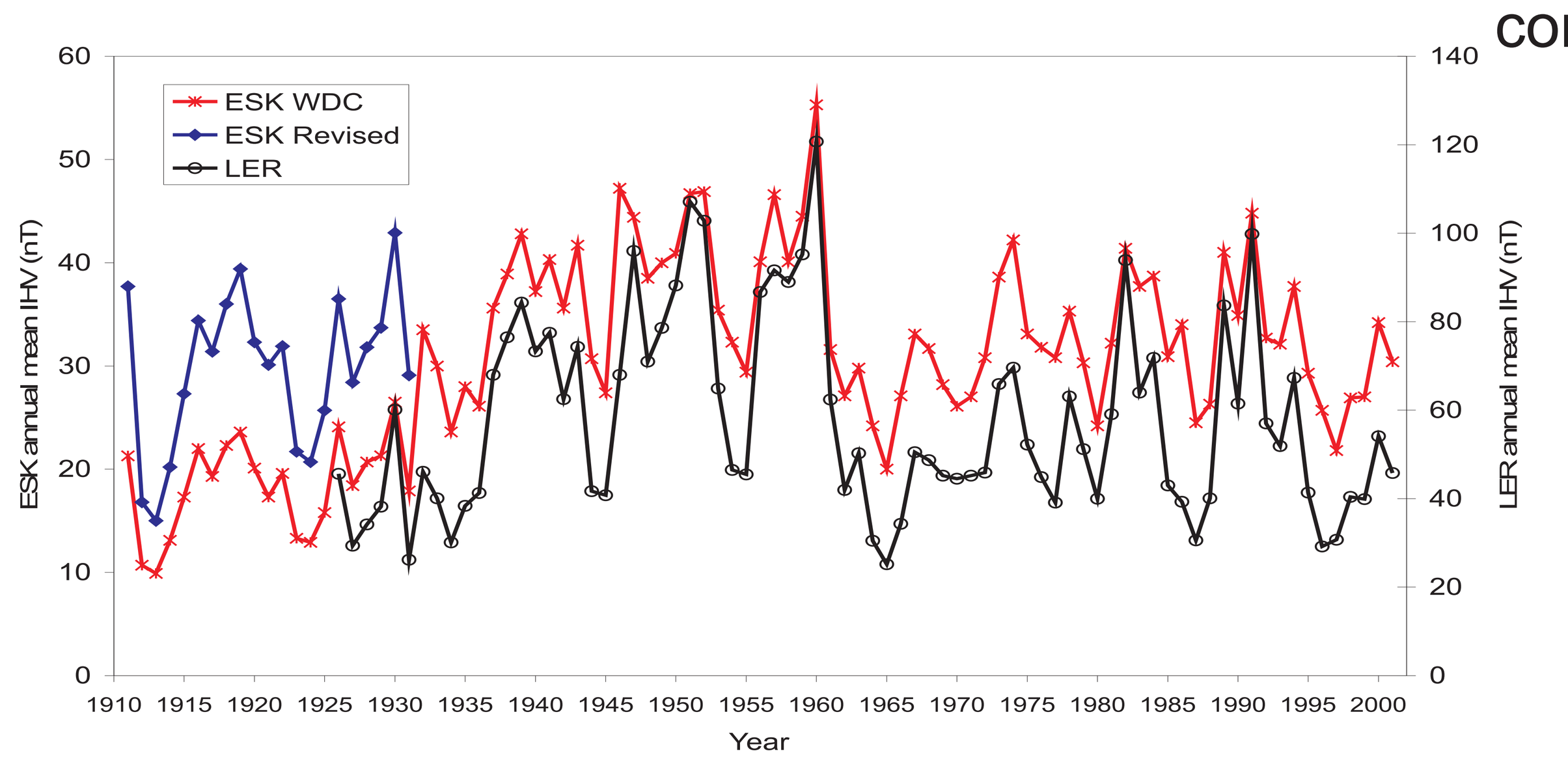

Figure 7: Plot of ESK *IHV (H)* computed with existing WDC data (red) compared with unfiltered digitised ESK *IHV (H)* for 1911 to 1931 (blue). LER *IHV (H)* from 1926 is also shown.

Conclusion and Recommendations

The effect of corrections to the ESK hourly data on the outcome of previous studies depends on the exact treatment of the data, some cases will be more significantly affected than others. The final corrections to the recently digitised data set should be completed and made available from the WDC for geomagnetism, Edinburgh, where the database of hourly values was transferred in 2007 (www.wdc.bgs.ac.uk). Research using these data, where the conclusions are solely based on the Eskdalemuir activity levels during 1911 to 1931 should be checked. Further work is planned to establish when the values changed from spot values to mean values, if indeed there was such a change.

REFERENCES

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[5] Clilverd, M.A, Clarke, E., Ulich, T., Linthe, J. and Rishbeth, H., 2005. Reconstructing the long-term *aa* index, *J. Geophys. Res.,* 110, A07205, doi:10.1029/2004JA010762