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EURISGIC

Carrington as a Benchmark: Comparisons of the September 1859 Storm Using Newly Digitised Data for London

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1. Introduction

The geomagnetic storm that commenced on 2 Sep 1859 is widely regarded as the greatest known storm[1,2,3,4]. Dubbed the Carrington storm, after the astronomer Richard Carrington who observed its precursor (solar flare), it was also the first set of events to suggest a link between solar and geomagnetic activity. One could say it marks the birth of Space Weather.

At this time very few magnetic observatories were operating around the world and even fewer were attempting to record continuous measurements. Surprisingly, two independent London observatories were doing just that - Kew (KEW) and Greenwich (GRW) - and the storm was recorded as variations on photographic paper at both locations. At the peak of the storm the variations were so great that the traces ran off the paper and unfortunately data were lost from both. The original records are held at the British Geological Survey where a campaign to digitise all the analogue records from historical observatories has been on-going since 2007. Here, we have attempted to acquire one-minute means for the Carrington storm from high resolution photographed images of the original magnetograms. This work is described and some preliminary results are presented.

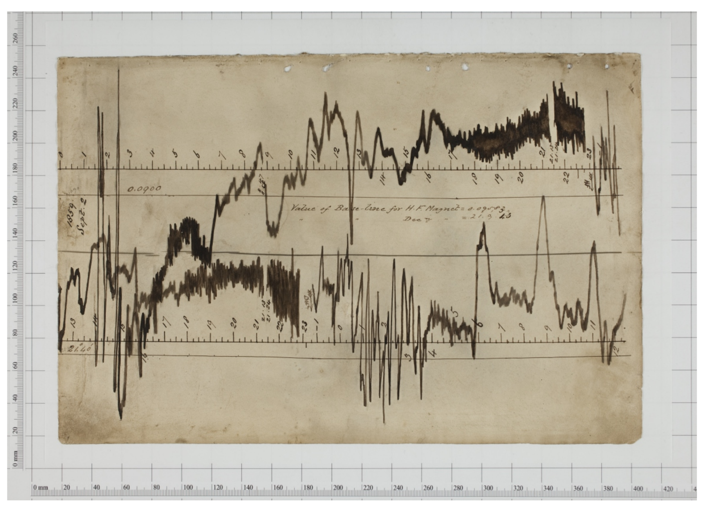

Figure 1: GRW Declination (*D*) and Horizontal Intensity (*H*) magnetograms during part of the Carrington Storm

2. Digitising the Carrington Storm

A brief summary of the labour intensive process to extract one-minute values is:

- Engauge Digitize (ED) (open source software) is used to trace the plots.
- Most disturbed periods require manual selection of the points.
- Traces are made of variations, baselines, scale bars, time axis and mm scales.
- Start and end times, baseline values and scale factors are also required.
- All lines traced are exported as coordinates in pixels by ED to a csv file.
- Post processing software was developed to transform the output into meaningful time stamped values that are corrected for any misalignments.

The difficulties encountered specific to this storm include:

- Sections of very faded traces due to excessive handling over the years.
- As previously noted there are periods when the trace goes off the paper.
- KEW scale information is unclear: the amplitude of the published solar flare effect (*sfe*) at 11.15UT on 1 Sept[5] was used to derive the scale value.
- *H* and *Z* are recorded in 'parts of the whole', requiring both scale and absolute baseline information to compute values: when absolute values were missing, annual means were used.

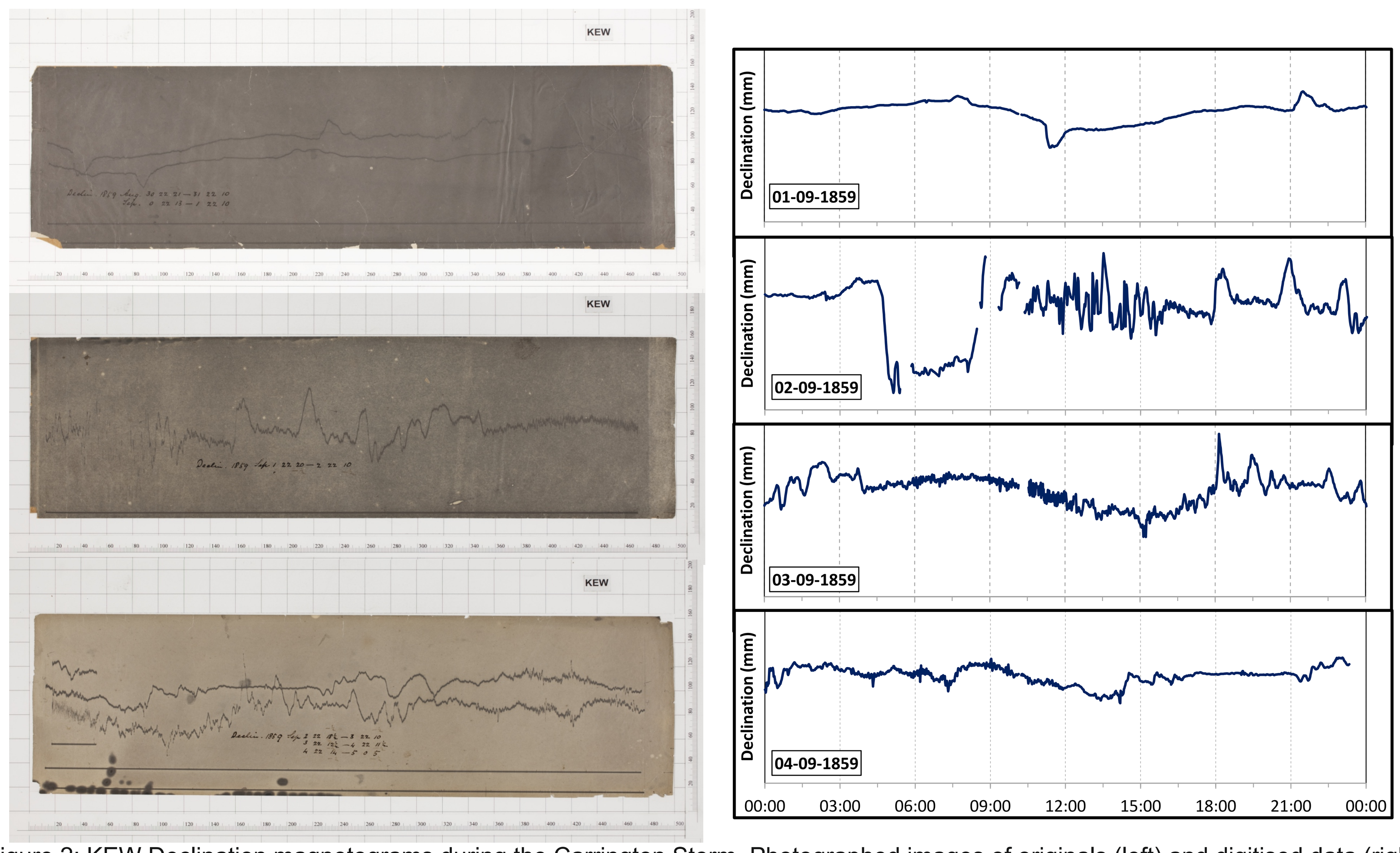

Figure 2: KEW Declination magnetograms during the Carrington Storm. Photographed images of originals (left) and digitised data (right)

3. Comparing GRW and KEW

Previous tests to verify the method have not been conclusive. All digitised values acquired so far, including those presented here, are therefore preliminary only. Final results will be published following confirmation/correction of the method.

GRW and KEW results have been compared. It has been found that for *D* and *H*, the KEW variations are greater than those at GRW by a factor of 1.1. Likely errors are the scale information for KEW and the digitisation process itself. GRW *Z* variations are greater than those at KEW and further examination indicates an un-natural diurnal drift in the GRW measurements. This is shown below where a 200nT variation, on the quiet days before the storm, dwarf the 30nT *sfe* at the time of the Carrington flare.

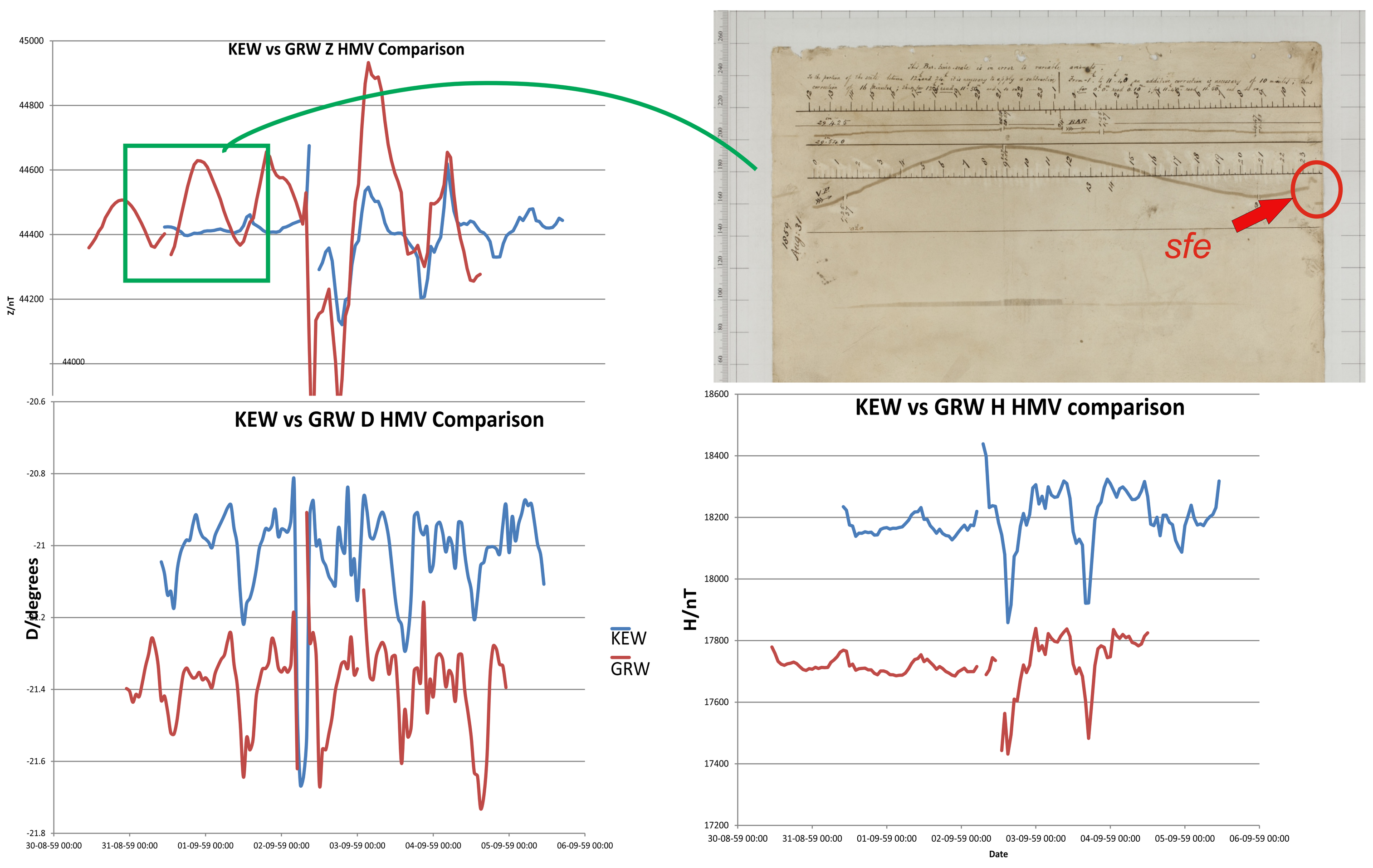

Figure 3: GRW and KEW hourly mean values calculated from the digitised one-minute data. Top right is an image of the original GRW magnetogram showing un-natural drift in the *Z* component.

There is also a 1-2 minute discrepancy in the one-minute time stamps, which may be post processing errors or limitations in ED. Despite the small differences found here there is, overall, a good agreement between the two London sites.

4. Comparing with Other Observatories

Previously digitised data from Finland and Russia[6] have been compared with GRW and KEW. Observatories are Helsinki (HEL), St Petersburg (STP) and Barnaul (BAR), all at higher latitudes than London. The plots show good correspondence between all the observatories.

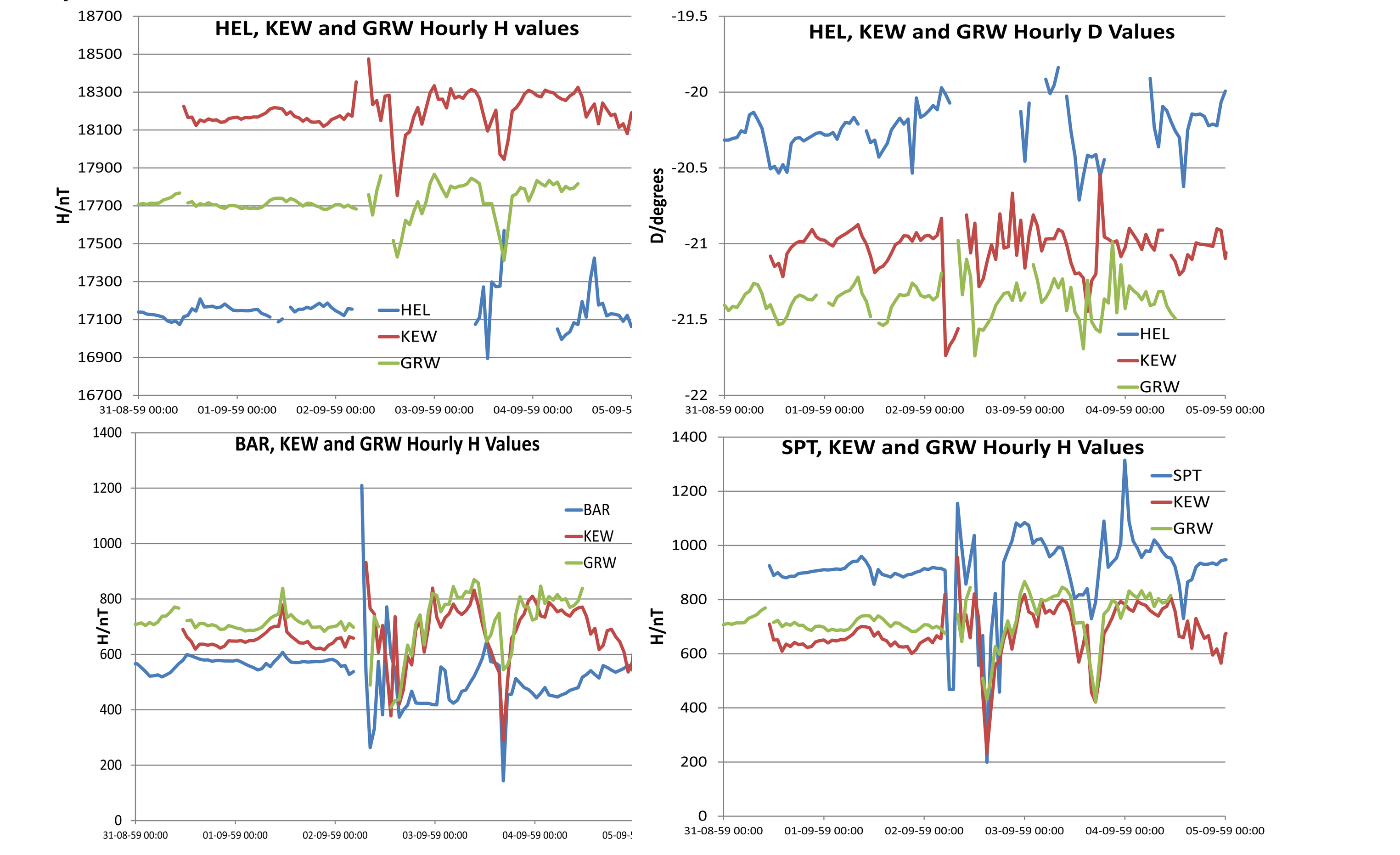

Figure 4: GRW and KEW hourly spot values compared with those of HEL (top) and with STP (bottom right) and BAR (bottom left).

5. dB/dT for the Carrington Storm and Conclusions

- Absolute values for d**B**/dt (in the horizontal plane) were generated from both GRW and KEW data and are shown below.
- These results indicate that, although the accuracy of the amplitude of d**B**/dt is not yet certain, the overall pattern is consistent between the London observatories.

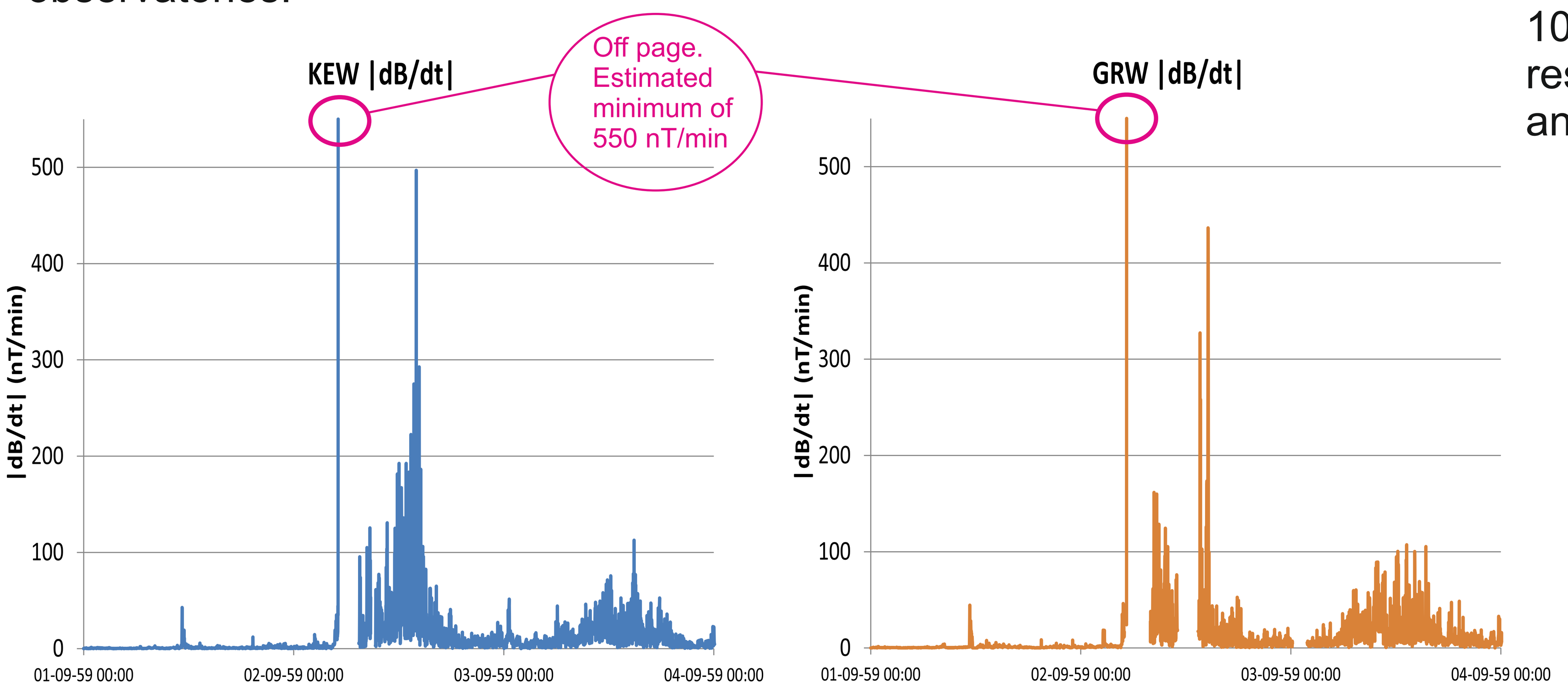

Figure 5 - |dB/dt| in nT/min at GRW and KEW for the September 1859 Storm

Balfour Stewart, the Kew Director later estimated that when the trace left the page the maximum deviation early on 2 Sept was in excess of 700nT[5]. At a modern day observatory (Hartland) of similar geomagnetic latitude to that estimated for London at this time (~51.5º N), the maximum measured |dH/dt| in the digital era has been 327 nT/min. A study on extremes[7] estimated that the 100 and 200 year return level for |dH/dt| to be ~600 and ~800 nT/min respectively for this latitude. The results shown here therefore indicate how rare an event the Carrington storm was.

To conclude:

- Preliminary estimates of one-minute values of *D, H* and *Z* at GRW and KEW have been derived
- Estimated |d**B**/dt| indicates individual events within the Carrington storm in excess of the peak of the March 1989 storm in the South of England
- The data gaps where the traces leave the page prevent final conclusion on the likely maximum |d**B**/dt|
- Further work is required to confirm the digitisation method and the results

References:
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