

# Rescuing 100 Years of Data from the Toronto and Agincourt Magnetic Observatories

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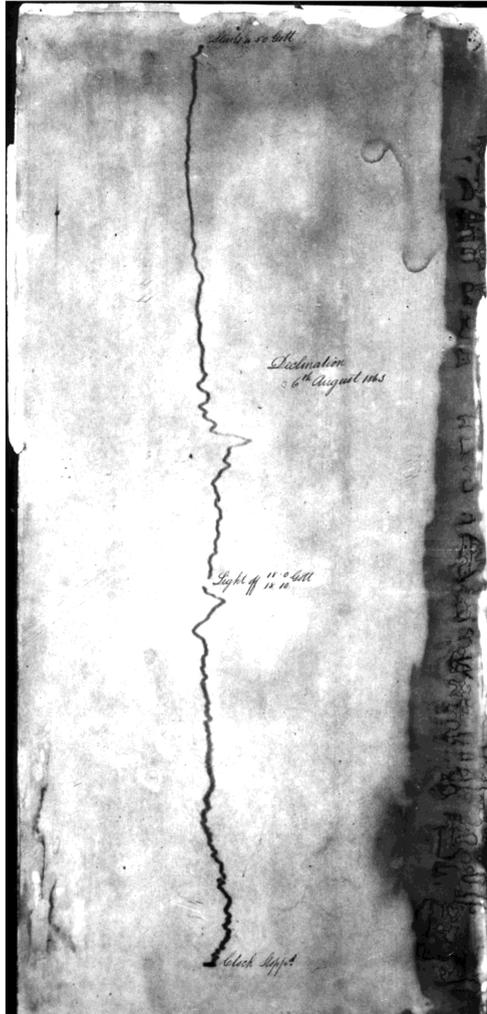


We have an ongoing project to digitize a geomagnetic record that began in the 1840s at the Toronto magnetic observatory, on what is now the campus of the University of Toronto. As the city of Toronto grew, the observatory was relocated to Agincourt in 1898, and finally to Ottawa in 1968. The record provides a rare opportunity for high resolution study of geomagnetic phenomena far into the past and over a long time scale. The magnetograms, originally recorded on photographic paper, were transferred to 35mm film in the 1980s. We are now converting these film copies to digital images and devising algorithms for unsupervised extraction of the time series data contained therein. Using the digital images,

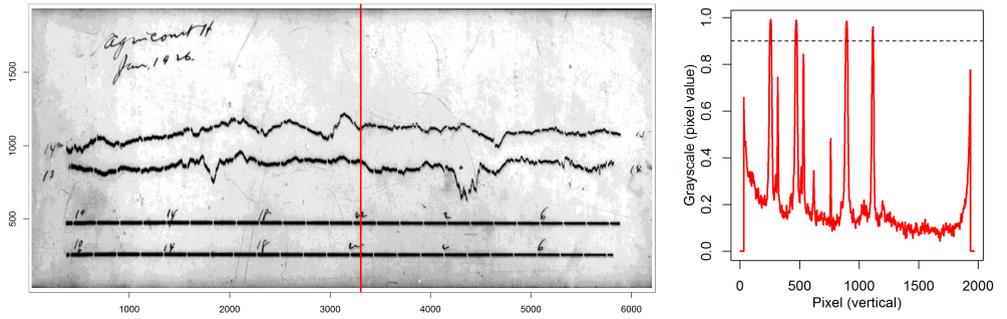
we are able to extract data with a time resolution of approximately 15 seconds, a magnetic resolution of approximately 0.1 nT, and 24-bit quantization. Spectra computed from the extracted time series are characteristic of spectra computed from current digital instruments, indicating that the extracted data are of high quality. Unsupervised extraction is important for reproducibility and because there are in excess of 32,000 images totalling about 500Gb of computer storage. However, given that perfect extraction performance is impossible due to varying image quality, artefacts such as hand-written notes, and quirks of the recording device, we are developing a semi-supervised approach to ensure data quality.



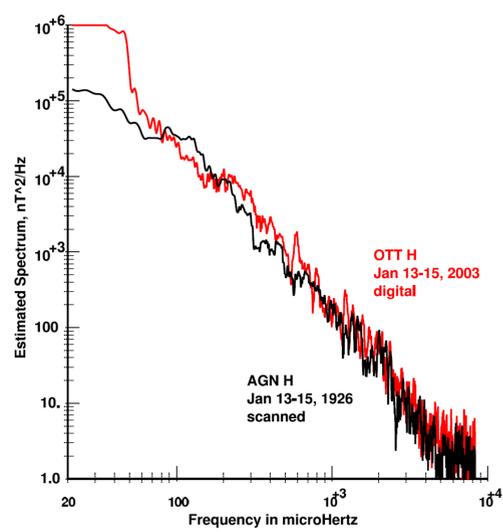
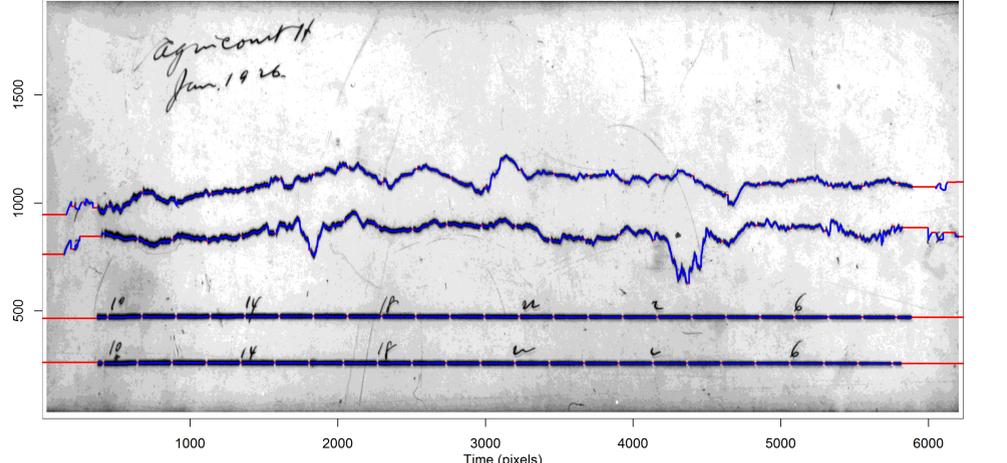
Above: Magnetic observatory locations.  
 Below: Dave Riegert and Dave Thomson examining a paper magnetogram from Agincourt recorded May 19-20, 1921.



A magnetogram recorded at the University of Toronto observatory, August 6-7, 1863.



Magnetograms recorded at Agincourt generally have two days recorded per paper (above, left). In this case, a vertical slice (in red) reveals that the pixel values of the traces and the baselines are all above 0.9, whereas values for handwriting, paper edges, etc. are all below 0.9 (above, right). We are investigating whether the distribution of the trace might improve classification performance for some magnetograms. Currently, our algorithm tracks the local maximum pixel values (below, blue), and keeps track of gaps in the trace (below, red), which occur hourly in this example. Values are recorded relative to baseline, and offsets in the hourly gaps between days enables unambiguous identification of the traces.



We estimate the time resolution of the scanned magnetogram (left) to be ~15 seconds/pixel. In order to estimate the instrument resolution, we linearly interpolated the data to one minute time resolution and estimated the power spectrum (black, above). We then compared the January 13-14 1926 spectrum to a spectrum estimate obtained from the digital

magnetometer data at Ottawa (red, left) for the same dates in 2003. The year 2003 was chosen for comparison because the monthly sunspot number (79.7) was similar to January 1926 (71.8). After scaling the Agincourt data, its spectrum matches the spectrum from the digital instrument at Ottawa very well — the shapes of the two spectra are similar, and the Agincourt spectrum doesn't exhibit noise saturation or spurious periodicities. Both spectra are flat between ~5 and 8.3 mHz, the Nyquist frequency limit for one minute resolution data. Based on the comparison to the Ottawa spectrum, the implied range of the scanned data is about 37 nT, or ~0.0976 nT/pixel. The range of the spectrum is  $1.2 \times 10^6$ , indicating a resolution of 20 bits. This implies an overall resolution of ~24 bits since the magnetometer has a range of at least 500 nT. These results suggest that the scanned data are of excellent quality, comparable to good modern digital instruments.

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