British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

INVESTIGATION OF Pc1 PULSATIONS USING HIGH FREQUENCY INDUCTION COILS MAGNETOMETERS

Ciarán D. Beggan[1] [ciar@bgs.ac.uk], Kittiphon Boonma[2], Gemma Kelly[1] and Alan Thomson[1]
[1]British Geological Survey, West Mains Road, Edinburgh, United Kingdom
[2]School of GeoSciences, University of Edinburgh, United Kingdom

Introduction

In June 2012, the British Geological Survey Geomagnetism team installed two high frequency (100 Hz) induction coil magnetometers at the Eskdalemuir Observatory, in the Scottish Borders of the United Kingdom. The induction coils permit us to measure the very rapid changes of the magnetic field.

The Eskdalemuir Observatory is one of the longest running geophysical sites in the UK (beginning operation in 1908) and is located in a rural valley with a quiet magnetic environment. The data output from the induction coils are digitized and logged onsite before being collected once per hour and sent to the Edinburgh office via the Internet. We intend to run the coils as a long term experiment. The data are available on request.

In this poster we show some initial results relating (a) spectral features from the magnetosphere and ionosphere observed in the data and (b) a comparison of manual versus automated Pc1 pulsation detection.

Data Analysis

Schumann resonances, caused by continuous lightning discharge from within the cavity formed by the Earth's surface and the ionosphere, are visible around 7.8 Hz, 14.3 Hz, 20.8 Hz, 27 Hz, 34 Hz and 39Hz. Spectrograms of the data (i.e. power distribution at each frequency over time) show the typical diurnal variation of the diffuse bands of the Schumann resonances.

The North-South channel is stronger than the East-West channel, due to the prevailing direction of the global lightning waves travelling from the equatorial regions (Figure 2 and Figure 3). The global diurnal lightning variation in power over 24 hours is particularly clear in the Channel 2 (East) coil. In Figure 2, the strong horizontal lines are from 'local' lightning activity between 1000-2000UT around the UK. The induced 25 Hz harmonic of the UK power grid is also clearly visible (thin vertical line, particularly Channel 1).

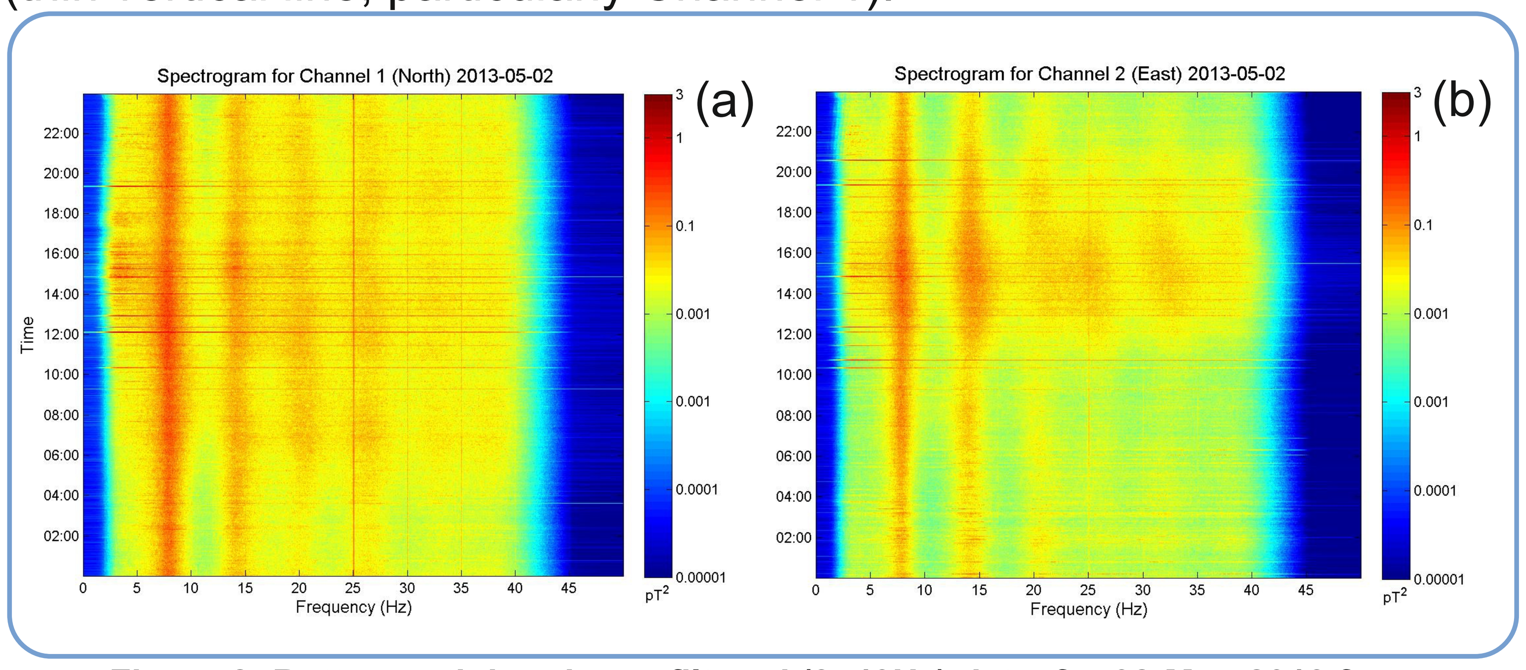


Figure 2: Butterworth bandpass-filtered (3–40Hz) data for 02-May-2013 for (a) Channel 1 (North) and (b) Channel 2 (East). Five Schumann resonances are visible.

Instrumentation

The instrumentation consists of two induction coil magnetometers, N-S and E-W orientated (Figure 1), connected to a Guralp digitizer. The digitizer converts the output signal for wired transmission to a computer logger located in a vault. The data from the induction coils are recorded at 100Hz by the onsite computer where they are collated into hourly files. The data are automatically collected once per hour and permanently stored on the BGS network. Daily processing produces a set of spectrograph images for display on the BGS Geomagnetism website (see web address or QR code below).

Figure 1: Left: Location of Eskdalemuir [55.314° N, 356.794° E] in the Scottish Borders, UK. Centre: The coils (white tube, foreground) are located in a rural valley (background), protected from wind, rain and snow under a non-magnetic wooden cover (shown upright in midground). Right: Looking eastward to the enclosed coil under wooden cover. The signal is digitized close to the coil before being converted to a higher voltage at a breakout box and sent to a logging computer in a vault approximately 150m away to the south.

Other Spectral Features

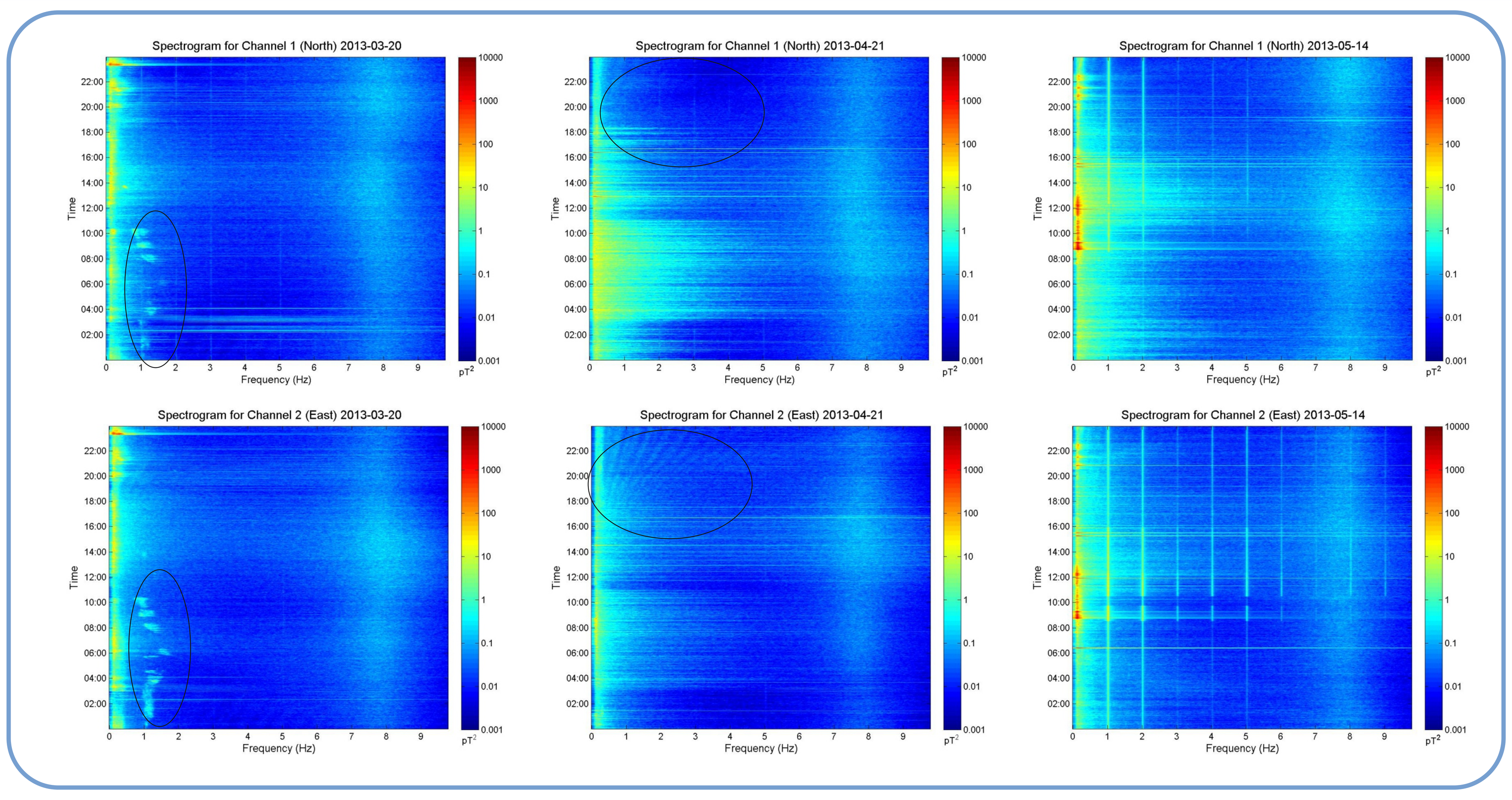


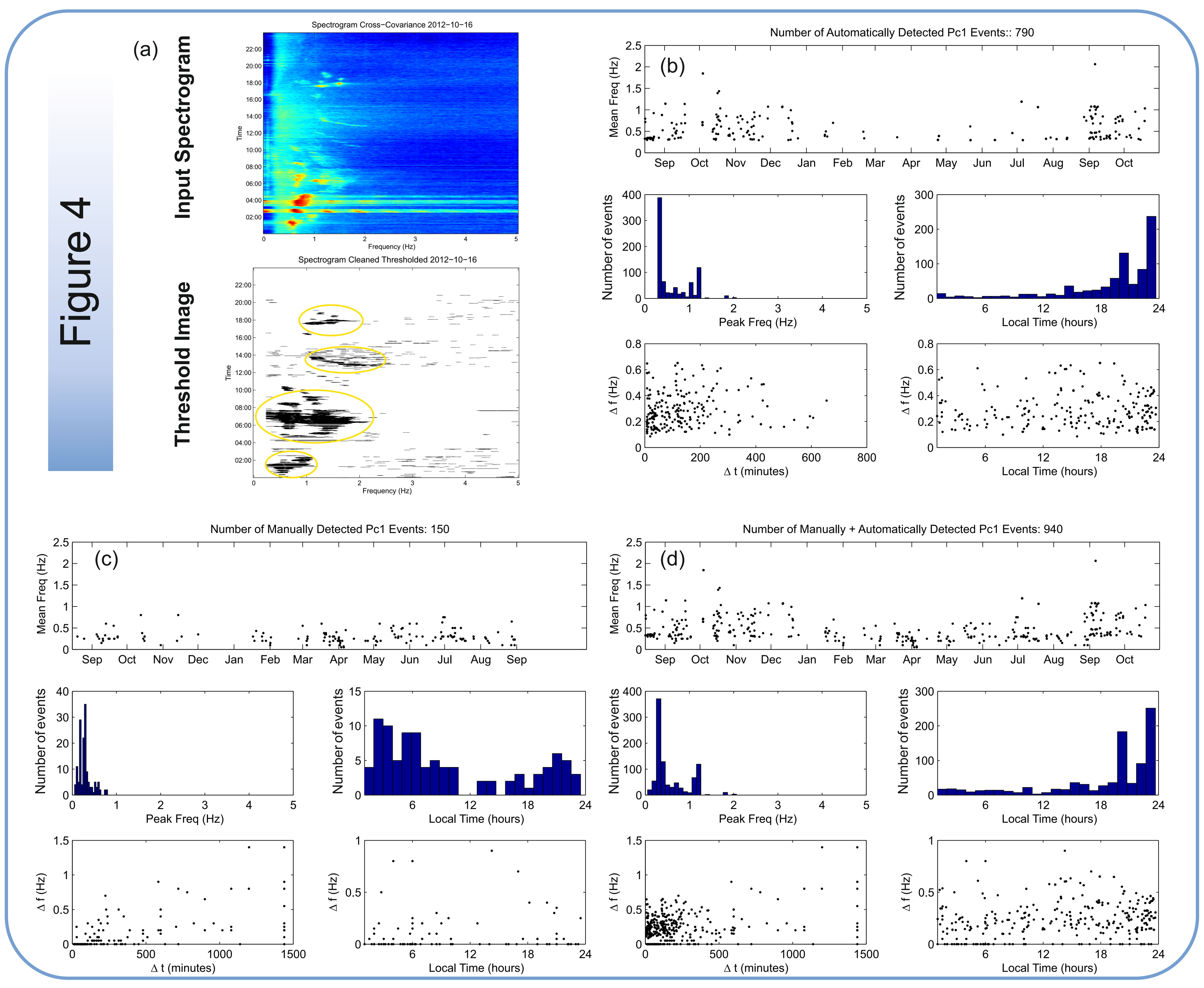
Figure 3: Butterworth bandpass-filtered (0.1–10Hz) spectrograms. Note, the first Schumann Resonance is visible around 8 Hz as a diffuse band. Circles show the process of interest.
Left panes: Magnetospheric pulsation activity from local midnight to 10.00UT.
Centre panes: Fine Spectral Resonance Structures from ionospheric Alfvenic resonances particularly in Channel 2.
Right panes: Unexplained man-made interference - presumably from local electrical devices. Again, Channel 2 is particularly sensitive to these effects.

Manual versus Automatic Detection of Pc1 Pulsations

Continuous Pc1 pulsations occur over a frequency of 0.2 - 5 Hz and are caused by instabilities in the equatorial magnetosphere (e.g. Ref [1]). They are readily observed in the induction coil data (Figure 3, left panel). We investigated the occurrence of these pulsations in the dataset using two techniques. The first is manual identification by viewing each daily spectrogram. As this is time-consuming, an automatic system based on the methodology of Bortnik *et al.* (2007) was implemented. The automatic system detects events above a certain threshold in each line of the spectrogram. Events are checked for temporal and frequency continuity before being associated into a single Pc1 episode.

Figure 4 (a) shows an example spectrogram for the 16-Oct-2012 (Input spectrogram), which has strong pulsation activity. The pulsations peaking above the averaged daily background are shown in the Threshold Image. Four episodes were detected for this day (shown in yellow circles). Figure 4 (b, c and d) show some summary statistics for 14 months of data. Peak Frequency is the frequency with the greatest power; Mean Frequency is the average of the minimum and maximum frequency; Δf is the bandwidth and Δt is the length of the pulsation episode. The automatic method in (b) identifies more events overall compared to the manual method in (c), but is not consistent across the year. Figure 4 (d) shows the combined (and overlapping) statistics from both methods.

The automatic method works well in the autumn-winter period but not during the summer. This is mainly due to man-made interference (c.f. Figure 3, right). In addition, the times of the pulsation episodes are clustered around local evening compared to the manual method, suggesting a bias from the algorithm. Active magnetic conditions and spikes from local lightning activity also cause difficulties for detecting pulsations above the background noise.



References:
[1] Anderson, B., J., Erlandson, R.E. and L.J. Zanetti, (1992), A Statistical study of Pc1-2 Magnetic Pulsations in the Equatorial Magnetosphere 1. Equatorial Occurrence Distributions, *J. Geophys. Res.*, 97, 3075-3088
[2] Bortnik, J., J. W. Cutler, C. Dunson, and T. E. Bleier (2007), An automatic wave detection algorithm applied to Pc1 pulsations, *J. Geophys. Res.*, 112, A04204, doi:10.1029/2006JA011900

BGS Induction Coil website:
http://www.geomag.bgs.ac.uk/research/inductioncoils.html

This poster as a pdf:
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