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NATURAL ENVIRONMENT RESEARCH COUNCIL

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INVESTIGATION OF GLOBAL LIGHTNING AND THE IONOSPHERE USING HIGH FREQUENCY INDUCTION COILS

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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 1904) 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 is available on request.

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: Installation of Channel 1 (North) induction coil at Eskdalemuir [55.314° N, 356.794° E] in the Scottish Borders, UK. Left: 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). Centre: Completion of the breakout box (mounted on the post). 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.

Data Analysis

Schumann resonances (SR), 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 [1].

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).

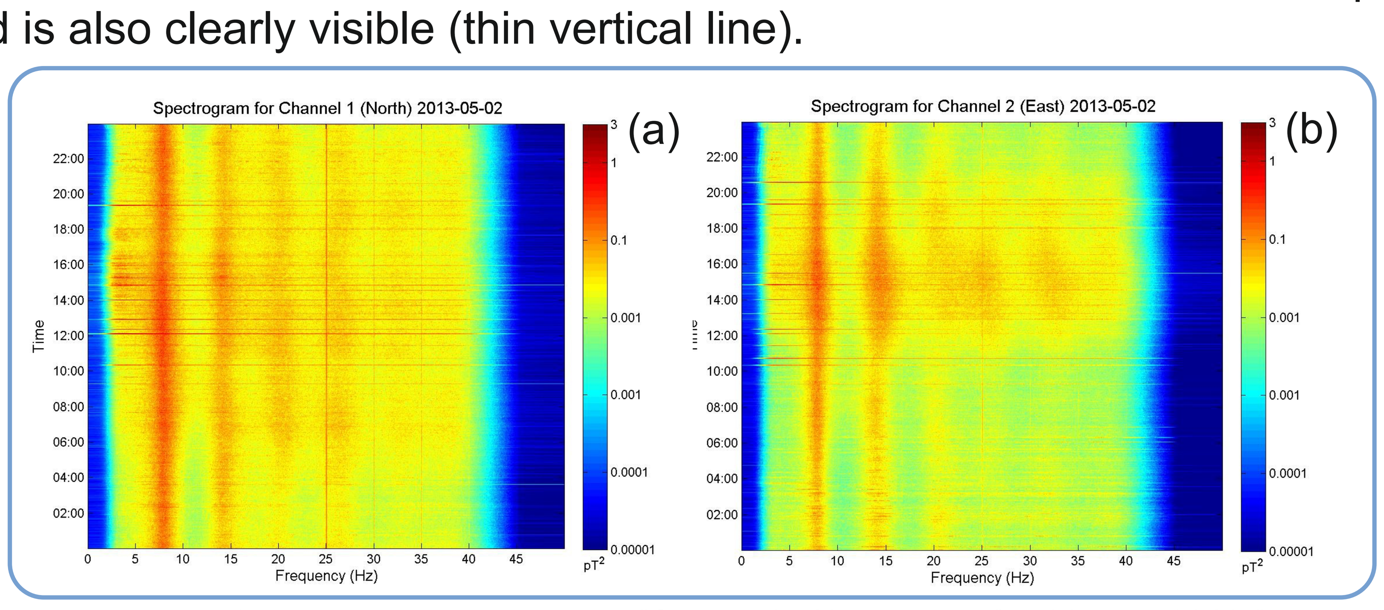

Figure 2: Butterworth bandpass-filtered (3–40Hz) data for 02-May-2013 for (a) Channel 1 (North) and (b) Channel 2 (East).

Other Spectral Features

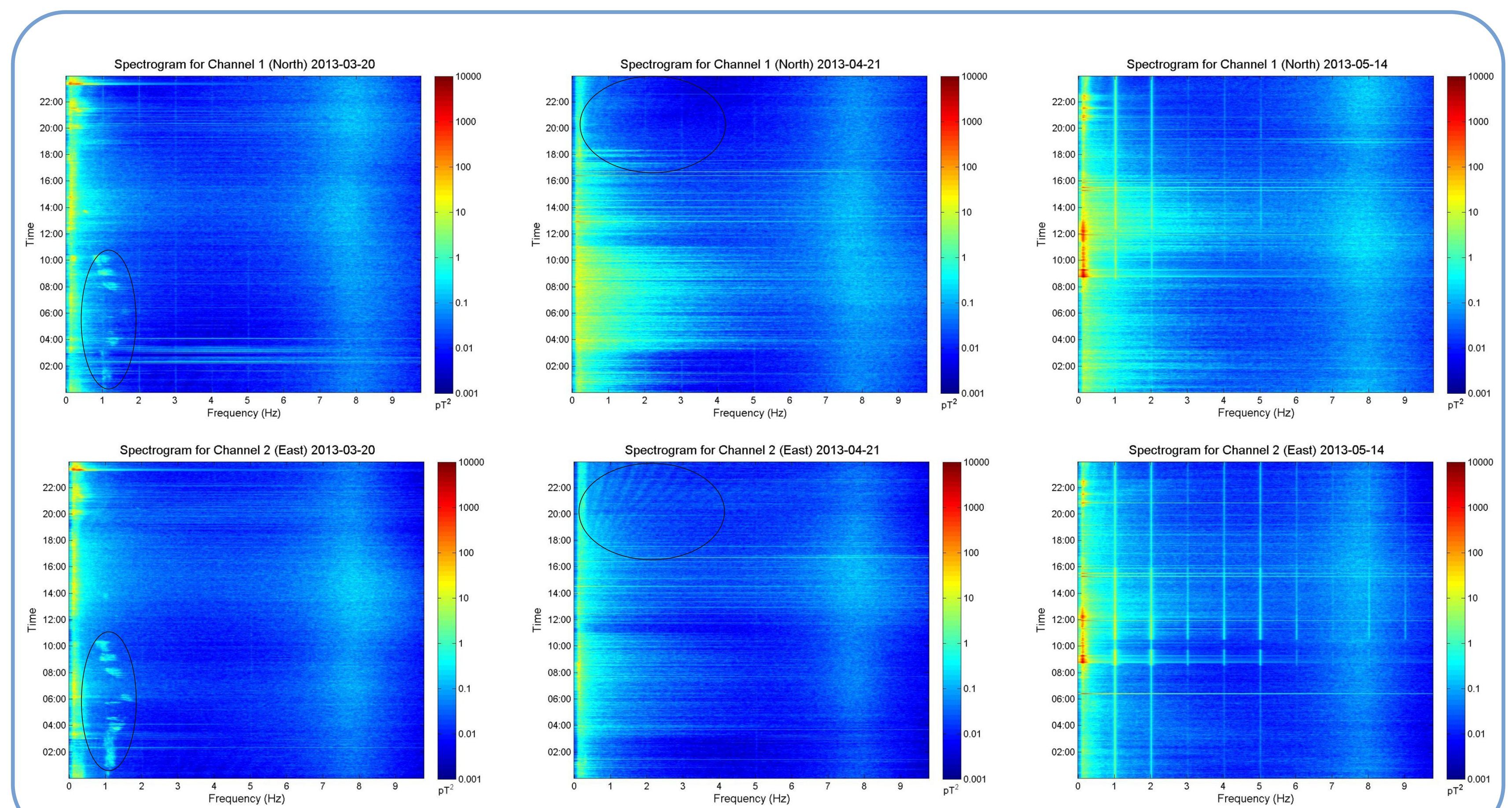

Figure 3: Butterworth bandpass-filtered (0.1–10Hz) spectrograms. Note, the first Schumann Resonance is visible around 8 Hz.
Left panes: magnetospheric pulsation activity.
Centre panes: Fine Spectral Resonance Structures [e.g. 2], in Channel 2.
Right panes: unexplained man-made interference presumably from local electrical devices. Channel 2 is particularly sensitive to these effects.

Detecting the influence of the Madden-Julian Oscillation

Anyamba *et al.* (2000) [3] showed there is an effect from meteorological variability in the troposphere on the amplitude of the Schumann Resonances. Intraseasonal oscillations in tropical deep convection (the so-called Madden-Julian Oscillation) affects the frequency of global lighting storms which create the Schumann Resonances. The MJO is characterised as an eastward moving "pulse" of cloud and rainfall near the equator that typically recurs every 30 to 60 days. Following the methodology of [3], we examined the variation of the 10 Hz spectral peak amplitude (i.e. between SR1 and SR2) for four separate hours each day (02-0300UT, 08-0900UT, 14-1500UT and 20-2100UT) using 11 months of data. We then compared the frequency content against a standard MJO index (called RMM1 & 2) computed by the Australian Bureau of Meteorology [4].

Figure 4 shows (a) the RMM indices and (b) the variations of the 10 Hz amplitudes (upper panels), and the analysis from three 120-day long periods in different seasons (lower panels). For example, in (c) the summer season (Jul-Sep 2012), a 40 day MJO period exists. This is also found in the daytime 10 Hz amplitudes. Red noise tests (not shown) indicate the periods of the peaks are significant (i.e. above the 95% noise level). The relationship between the MJO and SR is weaker during (d) winter and (e) spring.

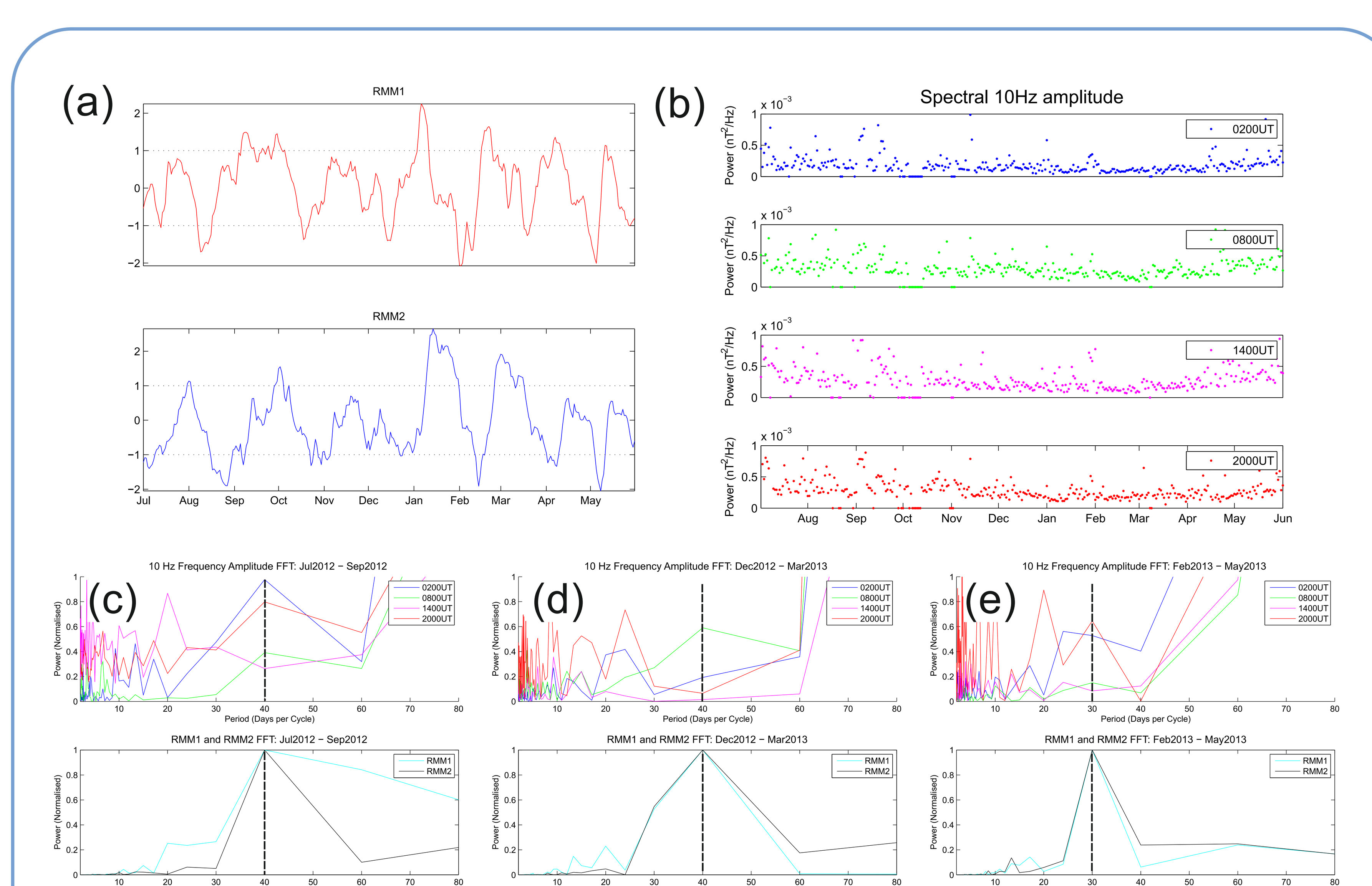

Figure 4: (a) Variation of the MJO Indices (RMM1 & 2) over 11 months. Values between dashed horizontal lines indicate weak MJO activity. (b) Variation of the amplitude of the 10 Hz spectral peak for each hour (02-0300UT, 08-0900UT, 14-1500UT and 20-2100UT) over 11 months. (c) FFT of the 10 Hz amplitudes for the selected hours for 120 days between July and September 2012 and the RMM indices for the same period. A 40 day period exists in both the RMM and daytime 10 Hz amplitudes. (d) FFT of the 10 Hz amplitudes for each hour for 120 days between December 2012 and March 2013 and the RMM indices. Only the 0800UT curve shows a similar period. (e) FFT of the 10 Hz amplitudes for each hour for 120 days between February and May 2013 and the RMM indices for the same period. A 30 day period exists in both the RMM and 2000UT 10 Hz amplitude.

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

This poster as a pdf: http://nora.nerc.ac.uk/

References

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[4] MJO Monitoring: http://www.bom.gov.au/climate/mjo/ [accessed 18-Jun-2013]