

# Investigation of global lightning using Schumann resonances measured by high frequency induction coil magnetometers in the UK

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In June 2012, the British Geological Survey (BGS) 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 in the Extremely Low Frequency (ELF) range in a passband from around 0.1 Hz to 100 Hz.

The Eskdalemuir Observatory is one of the longest running geophysical monitoring sites in the UK (in operation since 1904) and is located in a rural valley with a quiet magnetic environment. BGS intend the coils to become part of our long term scientific monitoring of the magnetic field, in this case for ionospheric and magnetospheric research. The data are freely available on request and we are interested in collaboration with other institutes and researchers.

## 1. Instrumentation



Figure 1: Installation of Channel 1 (North) induction coil at Eskdalemuir [55.314° N, 356.794° E] in the Scottish Borders, UK. Left image: 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 image: 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 (mounted on the post) and sent to a logging computer in a vault approximately 150m away not shown).

The instrumentation consists of two induction coil magnetometers manufactured by Elan around 1990. The coils were previously part of the Natural Environment Research Council's (NERC) national geophysical equipment pool and were available for loan to any UK university or research institute for induction studies. In 2008, they were decommissioned by NERC and passed to BGS.

The instruments were refurbished by the Geomagnetism engineering team, fitted with new connectors, tested and installed at the Eskdalemuir observatory (see Figure 1). The system consists of two coils (North-South and East-West orientated), connected to a single Guralp digitizer located a few meters away from each coil. The digitizer is linked to a breakout box to provide power and to convert the output signal from the digitizer for wired transmission to a computer logger located in a vault approximately 150m away.

The data from the induction coils are recorded at 100Hz by the onsite computer where it is collated into hourly files. The data is automatically collected once per hour by the main Edinburgh office and stored on the BGS SAN.

The induction coil data are processed once per day for quick look purposes and the spectrogram images uploaded to the BGS Geomagnetism public website at: <http://www.geomag.bgs.ac.uk/research/inductioncoils.html>

The system has been in full-time operation in a commissioning phase since July 2012 and has achieved about 90% availability. From an analysis of the bottlenecks in the system, the logging computer will be upgraded with a faster processor and disk drive, the operating system updated and a newer version of the digitizer software installed in the next three months. This should make the system more stable, allowing our goal of greater than 99% availability to be achieved.

Note, Data are measured as raw ASCII values, with calibration files for the coils and the conversion coefficients for digitizer then used to correct to SI units.

## 2. Science Objectives

There are currently two main science objectives for the coils: 1) monitoring of the ionosphere and related phenomena via the Schumann resonances; and 2) monitoring of the magnetosphere via low frequency pulsations.

The Schumann resonances are a set of spectral peaks in the extremely low frequency portion of the Earth's electromagnetic field spectrum, caused by lightning discharges from within the cavity formed by the Earth's surface and the ionosphere [1], and should appear as distinct peaks around 7.86 Hz (fundamental), 14.3 Hz, 20.8 Hz, 27 Hz, 34 Hz and 39Hz. However, in reality the peaks tend to be diffuse due to the effects of a leaky cavity [2] and ground roughness/absorption etc. (see Figure 2). We also detect a strong narrow peak at 25 Hz, which is a harmonic of the UK electrical power system and other smaller signals which are unaccounted for at 30 Hz, 35 Hz and 40 Hz.

There are a number of features in the data that BGS wish to investigate, including the diurnal and seasonal variation of the Schumann resonances. For example, it has been suggested that lightning activity is related to climate variability [3]. We will look for solar cycle and climate variations in both the ionospheric and magnetospheric signals. It will also be interesting (over the long term) to compare Schumann resonance amplitude/width data with other measures of geomagnetic variability measured at longer time scales by other magnetometer measurements eg. to see where the power in the spectrum lies and how it relates to source mechanisms.

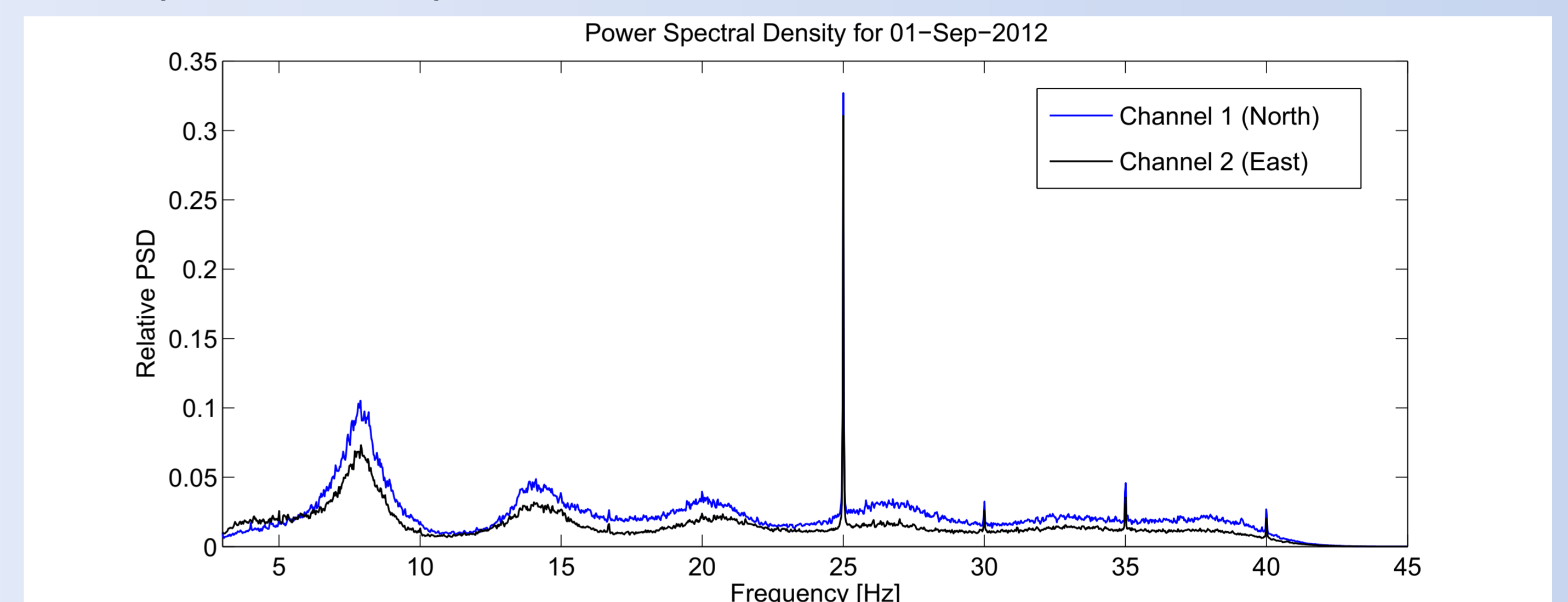


Figure 2: Power Spectral Density plot for two hours of data (00-02 UT 01-Sep-2012) recorded for the North and East channels. The signal has been passband filtered between 3-40 Hz. Six Schumann resonances can be detected and cultural noise from the UK electrical system at 25 Hz. The origin of the 30, 35 and 40 Hz signals are clearly manmade but of unknown origin.

## 3. Spectral Features

Spectrograms of the data (i.e. power distribution at each frequency over time) show the typical diurnal variation [e.g. 1]. The North-South channel is stronger than the East-West channel, presumably due to the prevailing direction of the global lightning waves from the equatorial regions (Figure 3 (a) and (b)).

The more subtle signs of magnetospheric pulsations can occasionally be observed, typically during magnetically quiet days (Figure 3 (c) and (d)). The magnetosphere pulses at 0.5-3Hz tend to be visible during local night time.

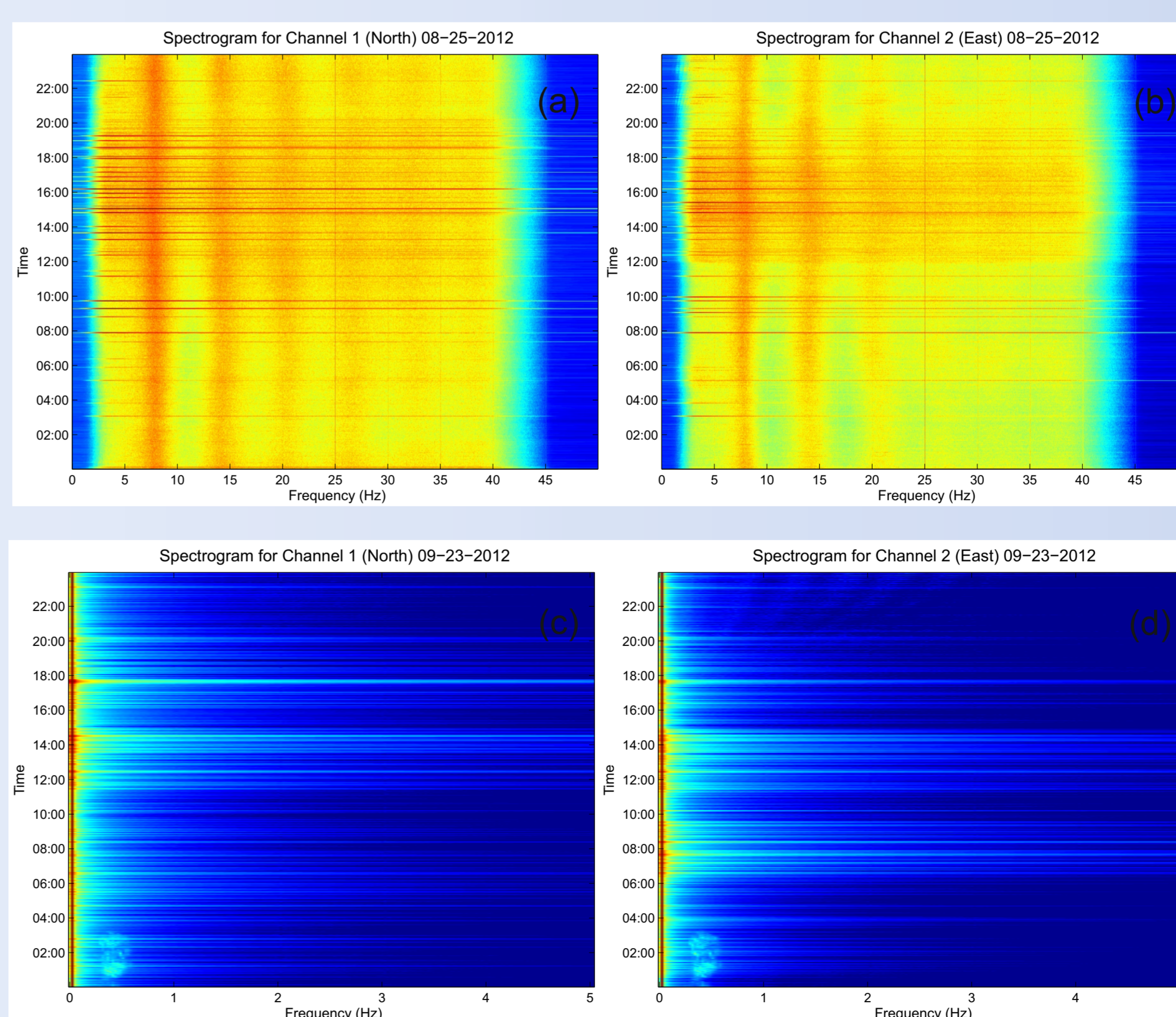


Figure 3: Example bandpass filtered spectrograms for the North and East channels.

(a)-(b): Butterworth bandpass filtered (3-40Hz) data spectrogram for 25-Aug-2012 showing local lightning activity between 1400-1600 UT at Eskdalemuir. Also visible is the global diurnal lightning variation in power over 24 hours.

(c)-(d): Butterworth bandpass filtered (0-5Hz) data spectrogram for 23-Sep-2012 showing magnetospheric pulsation activity at 20-24 UT. Also visible are unexplained features at 00-03 UT which appear to be low frequency but relatively band-limited.

### References

- [1] Füllekrug, M., 1995, Schumann Resonances in Magnetic-Field Components. *Journal of Atmospheric and Terrestrial Physics*, 57, pp. 479-484.
- [2] Simões, F., Pfaff R. and H. Freudenreich, 2011, Satellite observations of Schumann resonances in the Earth's ionosphere, *Geophysical Research Letters*, 38, L22101, doi:10.1029/2011GL049668
- [3] Williams, E.R., 1992, The Schumann resonance: a global tropical thermometer, *Science* 256, 1184-1186. doi:10.1126/science.256.5060.1184