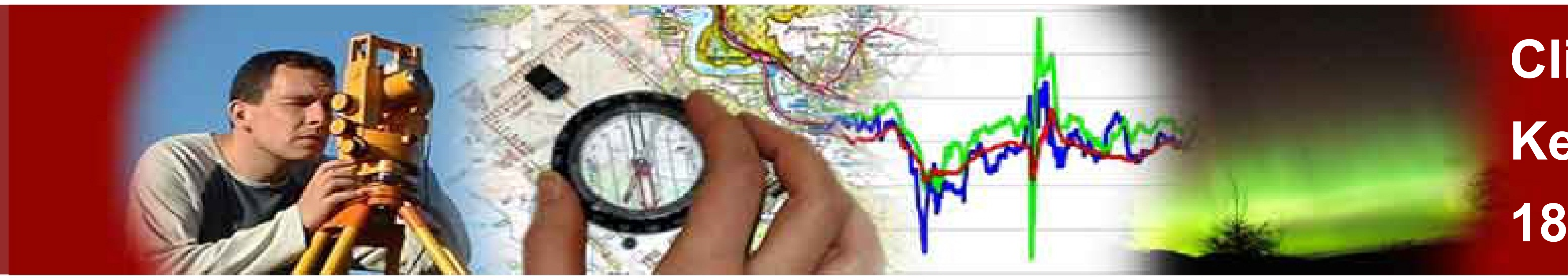
British
Geological Survey

NATURAL ENVIRONMENT RESEARCH COUNCIL



Climate Change Seminar

Keyworth

18th January 2007

Monitoring Climate Variability with Broadband Magnetometers

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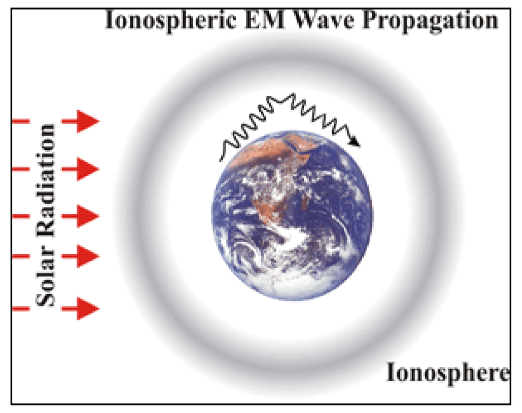


Electromagnetic waves originating from lightning refract between the ionosphere and the conducting earth. Attenuation of these waves in the atmosphere is small at particular frequencies, and such waves circumnavigate the planet. Constructive interference gives rise to resonances at periods related to the circumference of the Earth. *Www.iihr.uiowa.edu/projects/schumann/Index.html*

Introduction

The ionosphere acts as a natural 'upper' electrical conducting surface that, together with the conducting Earth below, forms a waveguide within which electromagnetic resonances can be established. Known as Schumann resonances, the amplitude of both the fundamental (~7.8Hz) and harmonics are influenced by upper tropospheric water vapour content and by global temperature.

Resonances are of short duration (a few seconds) and are triggered by lightning strikes anywhere on the globe (particularly from equatorial electrical storm activity). The frequency of lightning flashes is therefore a simple measure of changing atmospheric conditions on many time scales. Schumann resonances are, however, only one atmospheric electromagnetic phenomenon. Other more exotic phenomena (only recently discovered) include 'Sprites', which connect tropospheric storm systems upwards to the ionosphere, the upper Atmosphere and to solar-driven 'space weather' and 'solar climatology'.

A lightning discharge in the troposphere (lower image) is accompanied by a discharge from the top of the thunder cloud upwards towards the ionosphere (upper image). This is a 'Sprite' - a new and important component of the atmospheric electrical circuit.
Images courtesy of M. Fullekrug (Bath)

Magnetometers have been used by a number of researchers to monitor variations in the atmospheric electrical circuit, although observations have typically been made only on short campaign bases. The value of a magnetometer is that one instrument in one location can be used to derive information on the global atmospheric electrical circuit and on changing climatic conditions (particularly global equatorial temperature and tropospheric water vapour changes). Magnetic measurements are also an independent monitor of long-term changes in atmospheric conditions.

Because of the scientific and public interest in climate change and the BGS commitment to long term monitoring, the Seismology and Geomagnetism Programme has been testing an induction coil magnetometer system, at Eskdalemuir magnetic observatory (Scottish Borders). The induction coil has been in continuous use since Autumn 2006 and we are currently testing and accumulating data over the long term in support of climate monitoring.

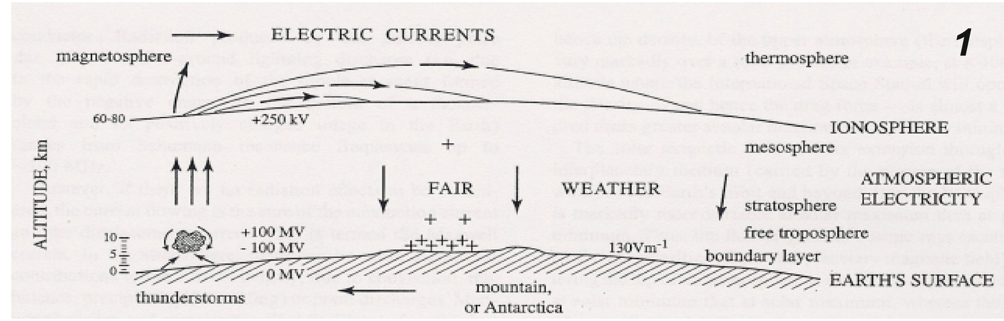
In comparison with the requirements on standard observatory geomagnetic measurements for monitoring deep Earth processes, the frequency range of interest (>1Hz) is relatively high. Therefore, in addition to monitoring climate modulated data, we are also learning about this type of magnetometer and are gaining valuable technical experience which may enhance future observatory operations and scientific data products.

In this poster we discuss aspects of atmospheric electrical science and climate variability, through examples from the published literature, and we describe the BGS installation at Eskdalemuir.

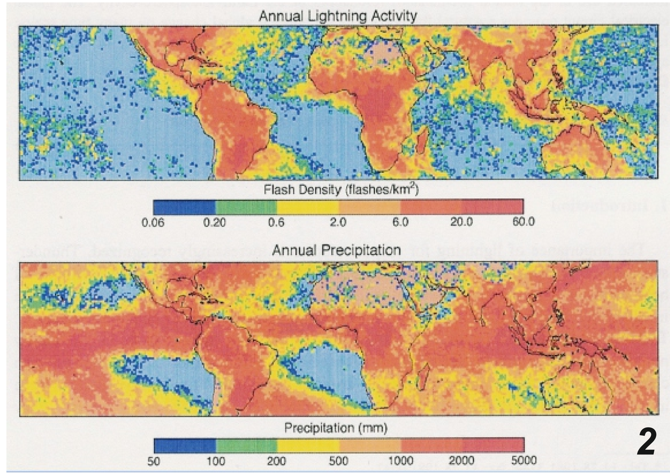
Acknowledgements. We would like to acknowledge the help of Dr Martin Fullekrug of the University of Bath (PPARC) and support from the NERC Geophysical Equipment Pool (University of Edinburgh). Future work will be partially supported by a BGS University Collaboration Scheme (BUCS) award. Our BGS colleagues Allan McKay, Colin Pringle, Tom Shanahan and Chris Turbitt are thanked for their support.

Why Use Magnetometers to Monitor Climate Change?
Some Recently Published Scientific Results

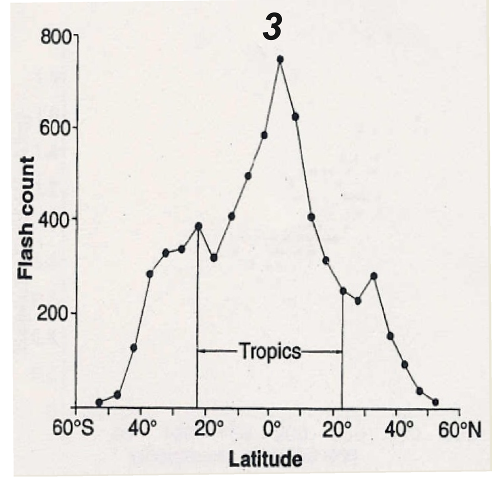
1. The global atmospheric electrical circuit, indicating the role of thunderstorms, the ionosphere (and by association, solar-controlled magnetospheric processes), and the fair weather electric field. High frequency (>1Hz) electromagnetic phenomena associated with this circuit are measurable with induction coil magnetometers. (*M. J. Rycroft et al, J. Atmos. Sol. Terr. Phys., 62 (2000), 1563-1676.*)



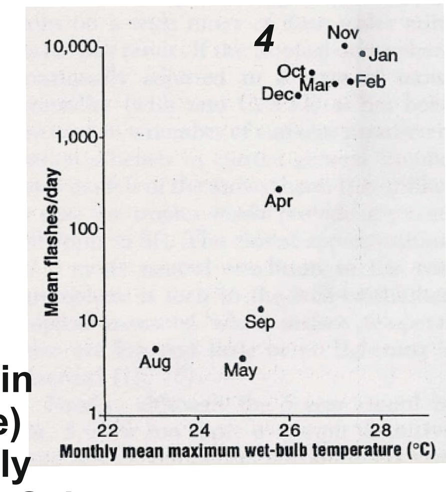
2. The distribution of lightning and the correlation with rain fall.
(*E. R. Williams, Atmos. Res., 76 (2005), 272-287.*)



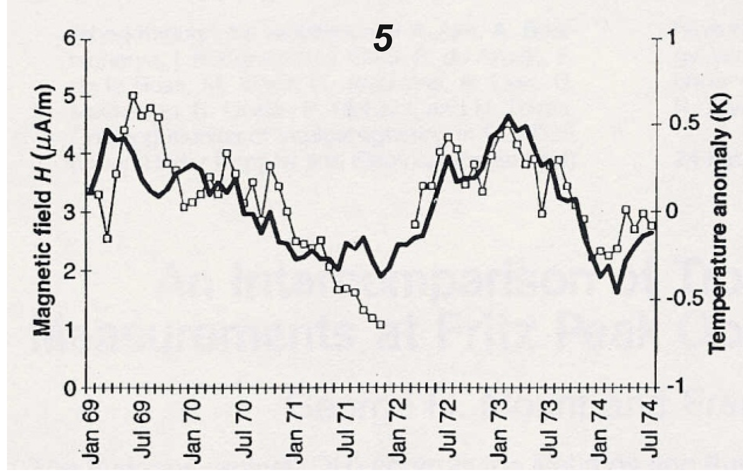
3. Most lightning flash activity is equatorial.
(*E. R. Williams, Science, 256 (1992), 1184-1187.*)



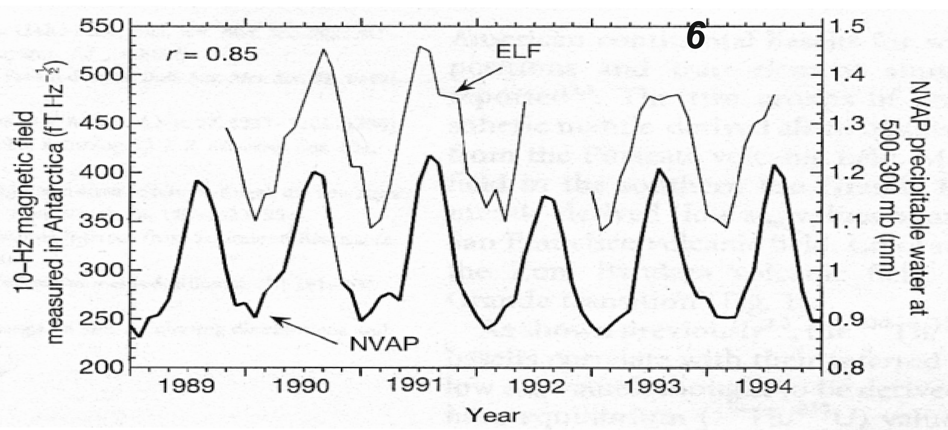
4. Linear correlation between lightning flash rate and temperature (here for Australia, in 1988).
(*E. R. Williams, Science, 256 (1992), 1184-1187.*)



5. Monthly surface air temperature anomaly in N. America (heavy line) correlates with monthly mean amplitude at the Schumann resonance. (*E. R. Williams, Science, 256 (1992), 1184-1187.*)



6. 10Hz amplitude (*ELF*) of magnetic field spectrum correlates with global water vapour (*NVAP*) concentration, with linear correlation $r \sim 0.85$.
(*C. Price, Nature, 406 (2000), 290-293.*)



In Summary

The correlation between climate and natural electromagnetic resonances is such that

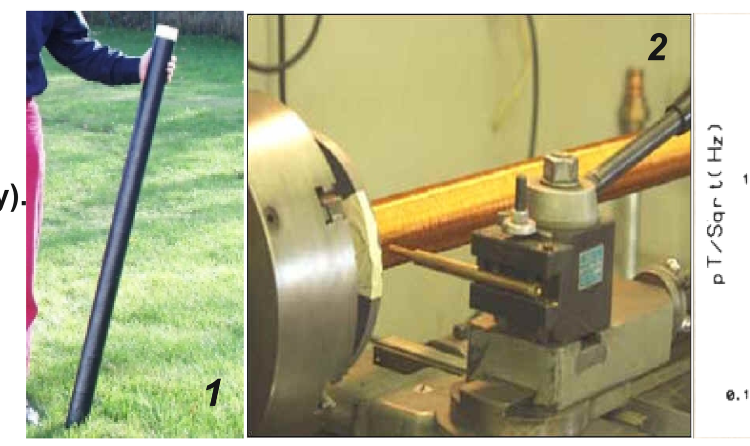
Increased Global Temperature & Water Vapour ➔ More (Equatorial) Thunderstorms ➔ More Lightning Flashes ➔ Increased Schumann Resonance Amplitudes

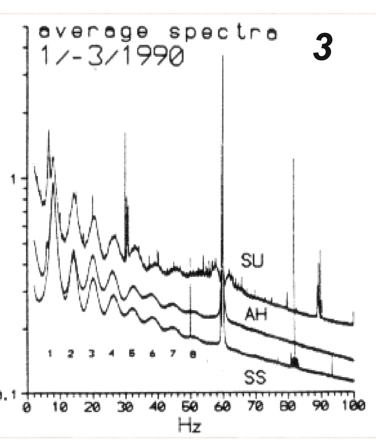
Induction Coil Magnetometers & Broadband Geomagnetism

1. A typical induction coil containing a high permeability alloy core (Metronix Inc.).

2. Winding ~70,000 turns (~15km) of copper on a coil (Iowa University).

3. A typical amplitude spectrum shows broad Schumann peaks and sharp features due to human activities: power line emission (50/60 Hz & non-linearities at 30/90 Hz) and a global submarine communication system (83 Hz). Three traces are shown, from Antarctica, Greenland and California.





Eskdalemuir Observatory: *Installing the 'Test-A' (May 2005) & 'Test-B' (Aug 2006) Induction Coil Systems*

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An aerial view of Eskdalemuir Observatory *(above)*. Both test sites are about 200m beyond the top right corner in this picture.

1. Simon Flower (BGS) transporting the '*Test-A*' induction coil system from the NERC equipment pool (Univ. of Edinburgh Geophysics Dept.).

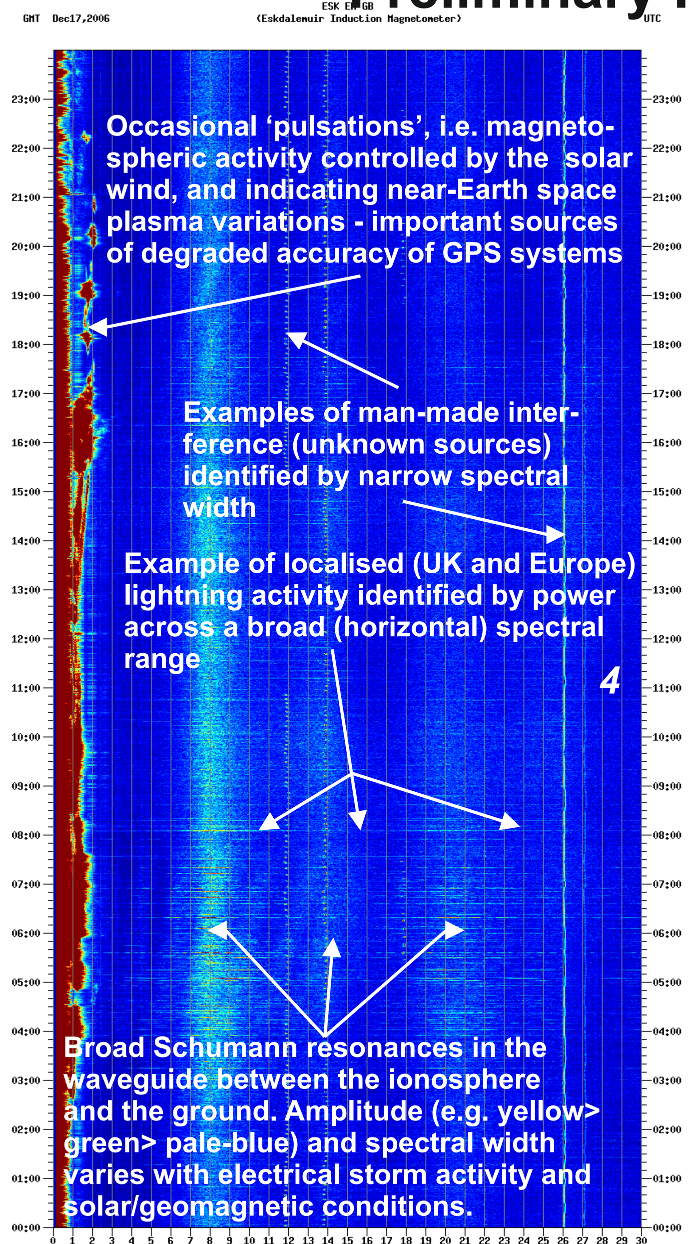
2. Identifying an appropriate site location for the induction coil at the observatory.

3. Installing '*Test-A*' equipment. Shown are Simon Flower, Allan McKay (BGS) & Martin Fullekrug (Bath).

4. Electronics test and the first Schumann signal capture (right - Martin Fullekrug, Univ. Bath).

The '*Test-B*' set up (also a NERC equipment pool coil) is currently in continuous operation, at a location only a few metres from '*Test-A*', and uses internet links to Edinburgh, to deliver real-time data.

Preliminary Results: *'Test-A' and 'Test-B' Field Trials*

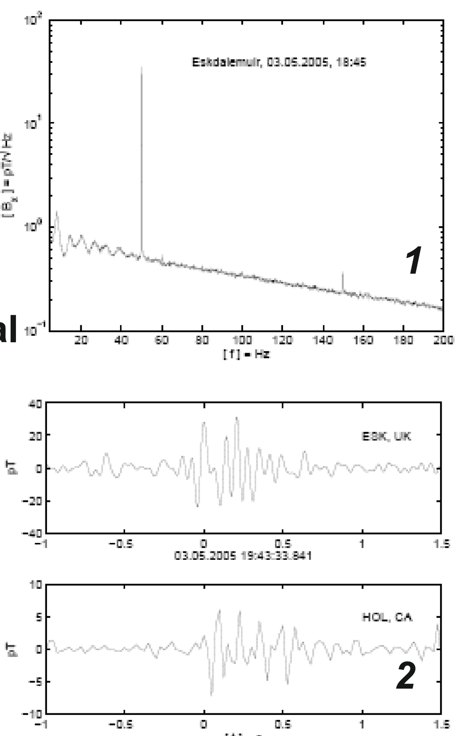


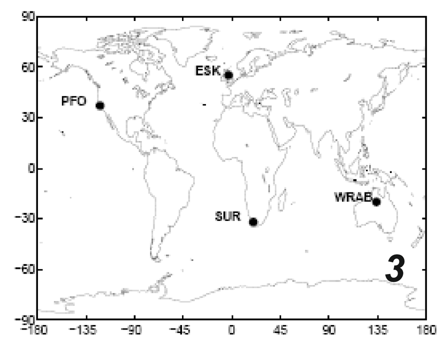
The three figures on the *right* are courtesy of Dr Martin Fullekrug, University of Bath:

1. A '*Test-A*' amplitude spectrum obtained in May 2005 (see installation above). The broad Schumann resonance peaks can be seen, along with the AC power signal at harmonics of 50Hz and 150Hz, superimposed on the naturally decaying geomagnetic spectrum (~1/frequency).

2. A comparison of recorded Schumann waveforms, obtained from Eskdalemuir and from Hollister, California, for a single equatorial lightning strike. The time-correlation is clear, but subtle differences reveal clues as to the source location.

3. The planned global monitoring network (PPARC funding applied for; BUCS support provisionally agreed), with 4 stations planned to be sited at existing geophysical observatories (including Eskdalemuir).





4 (above). An induction coil power spectrum ('*Test-B*') for December 17th, 2006. The horizontal scale is frequency (Hz) and the vertical scale is time (hrs:min). Each horizontal line is a 'snapshot' power spectrum, centred on that time, from data over a 15 minute time window. Colour denotes power (red = high, dark blue = low) in the spectrum, in arbitrary units. Important physical features (e.g. regional and global lightning activity, and near-Earth magnetospheric phenomena) are identified for this active geomagnetic day. *Similar daily real-time spectra are now available at www.geomag.bgs.ac.uk/sgram.*