British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

# Should archaeologists be concerned about naturally varying magnetic fields?

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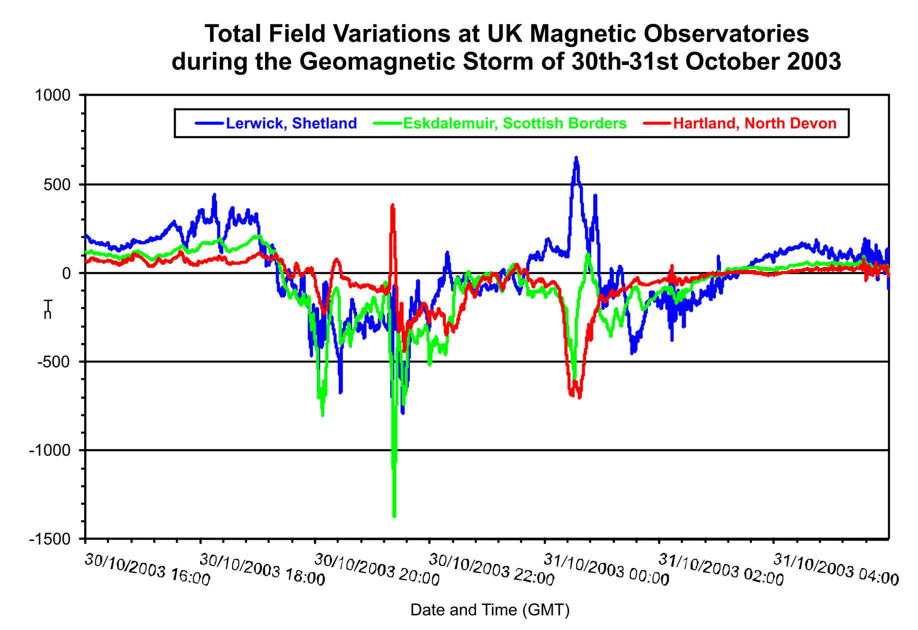
## Earth's time-varying field

Magnetic surveys of archaeological sites can be influenced by the natural time variations of the Earth's magnetic field.

At any one location in the UK the magnetic field varies by 10s of nanoteslas (nT) every single day, and by 100 to 1000s of nT during magnetic storms.



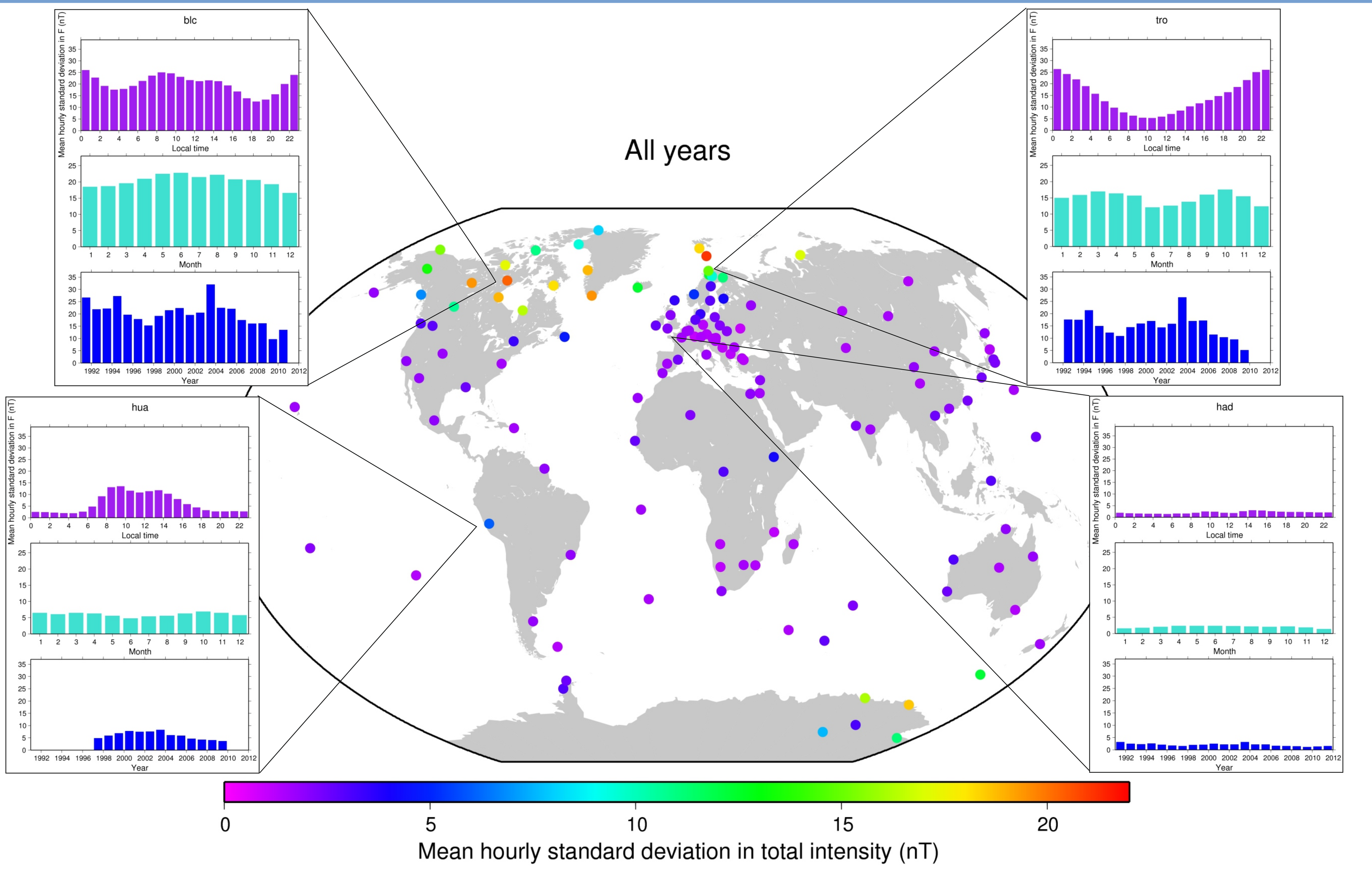

*An example magnetogram showing the total field (F) variations in the UK during a magnetic storm. At Eskdalemuir in southern Scotland the total field changed by about 1250 nT in just 6 minutes!*

## Magnetic observatories

In the UK continuous magnetic data are available from BGS observatories at Lerwick (Shetland), Eskdalemuir (Dumfries & Galloway) and Hartland (Devon).

At each observatory a tri-axial fluxgate magnetometer (*top right*) measures variations in the magnetic field using three orthogonal sensors. A proton precession magnetometer (*bottom right*) measures the strength of the field.

## Characterising global magnetic field variations




The global characteristics of the time-varying field are quantified using 2 metrics: hourly standard deviation & rate of change/minute. One-minute mean F values over 21 years from 150 observatories are used.

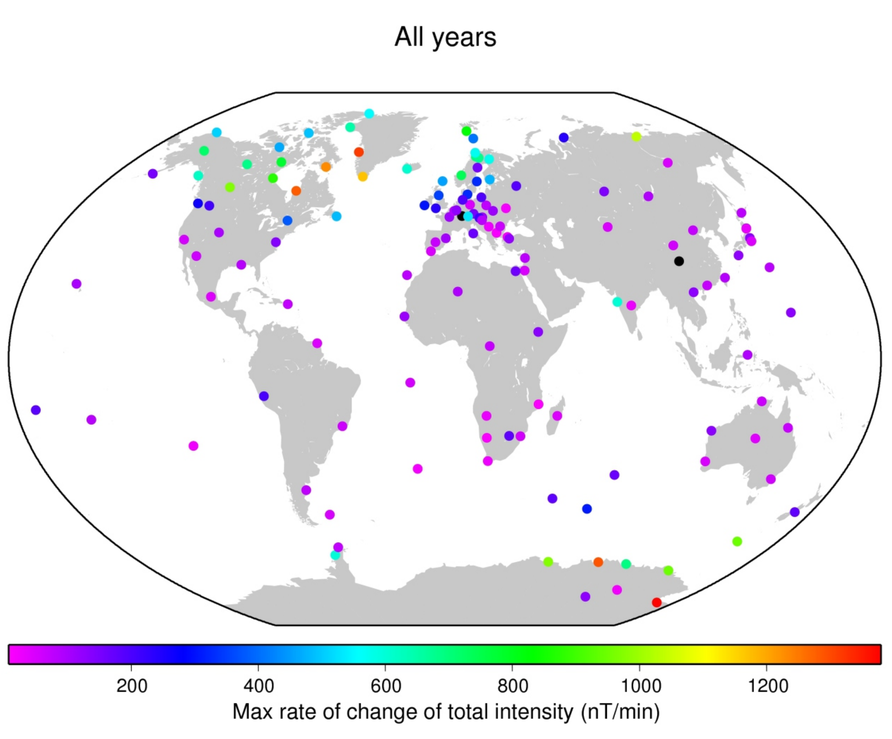
The spatial pattern is dominated by the auroral ovals, where energetic charged particles from the solar wind are accelerated down the magnetic field lines and energise the current systems in the upper atmosphere. There is also an ionospheric current system associated with the magnetic dip equator and this accounts for the larger variations at Huancayo (HUA).

The temporal patterns vary with local time (top panels), season (middle) and year (bottom). They also vary spatially. The local time variations at high latitudes are mainly caused by energy release from the magnetotail (catapult effect), hence are larger during the night (though this is not the case when close to the geomagnetic pole as at Baker Lake (BLC). At lower latitudes the day-time variations are slightly larger and this is due to the ionising and heating effects of the Sun on the upper atmosphere.

The seasonal variations are caused by favourable geometry around about the equinoxes for energy transfer from the solar wind to inside the magnetosphere. The yearly variations are caused by the 11-year solar cycle.

This map shows how the second metric (maximum rate of change) varies globally. Again, the auroral oval regions and equatorial electrojet areas are greatest. Note that values in excess of 1200 nT/min have been recorded in the auroral regions and 400 nT/min in the UK. As expected the two metrics are correlated (r = 0.789).

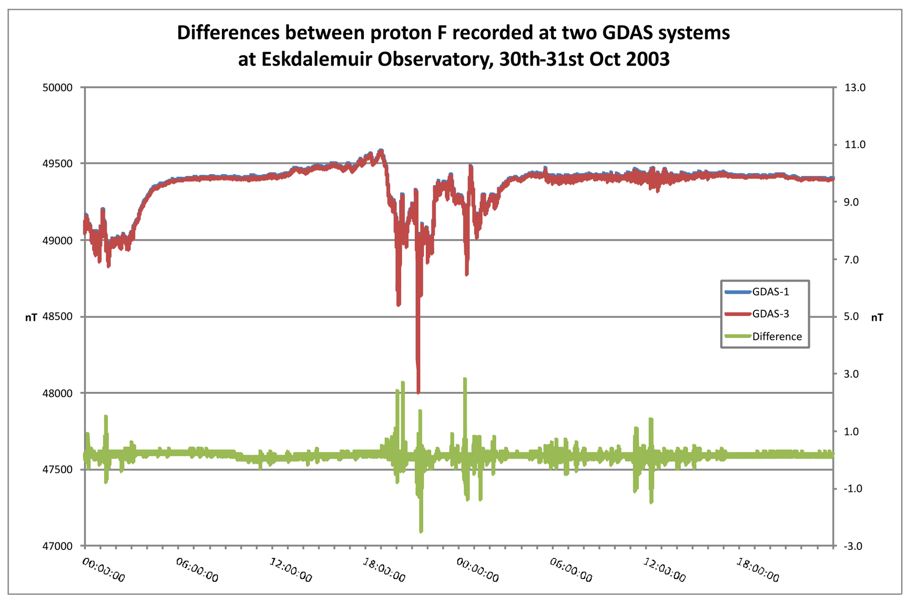
Typical values are much lower and in the UK one can expect 1-5 nT/min during every day. However this still means that if using a base station, synchronising it with the survey instrument is very important when detecting sub-nT signals.




Running a base station several 10s of metres from a survey location may introduce errors during magnetic storms.

In this example, right, the readings from two proton magnetometers at Eskdalemuir observatory are compared during a significant magnetic storm.

The protons are spaced approx. 450 m apart. The greatest difference seen between 10-second values was 1.5 nT.




## Implications

- Single sensor surveys at archaeological sites in or near the high latitude auroral zones, especially during the local night time (fortunately unlikely from a practical point of view) in March and October, during the maximum and descending phases of the 11-year solar activity cycle, are the most vulnerable. Next maximum is expected in 2013/14.
- Surveys done close to the dip equator are also vulnerable.
- Distance to base station should be kept at a minimum and synchronising instruments is important.
- Spatially incoherent signals may be difficult to deal with in the post-survey analysis and independent data, from a nearby observatory or variometer station, could be helpful.

## Where to find magnetic data

The World Data Centre for Geomagnetism operated by the British Geological Survey in Edinburgh is a good first point of contact for magnetic data and metadata from observatories around the world.

www.wdc.bgs.ac.uk

In the UK, magnetic data are available from the observatories operated by the BGS at Lerwick, Eskdalemuir and Hartland.

Email: enquiries@bgs.ac.uk
Or from: www.intermagnet.org

ICSU WORLD DATA SYSTEM

Poster for meeting "Recent Work in Archaeological Geophysics" on 4 Dec 2012 in London organised by the Near Surface Geophysics Group of the Geological Society