British Geological Survey

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Building a Raspberry Pi magnetometer network for schools in the UK

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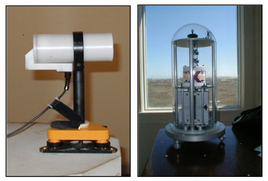
Summary

As computing and geophysical sensor components have become increasingly affordable over the past decade, it is now possible to design and build a cost-effective system for monitoring the Earth's natural magnetic field variations, in particular for space weather events.

Modern fluxgate magnetometers are sensitive down to the sub-nanoTesla (nT) level, which far exceeds the level of accuracy required to detect very small variations of the external magnetic field. When the popular Raspberry Pi single-board computer is combined with a suitable digitiser it can be used as a low-cost data logger. We adapted off-the-shelf components to design a magnetometer system for schools and developed bespoke Python software to build a network of low-cost magnetometers across the UK.

1. Observatory instrumentation



Proton Precession

Suspended tri-axial variometer

There are three UK geomagnetic observatories. These operate fluxgate variometers to measure the vector change of the main field, and proton precession magnetometers to measure the absolute scalar strength.

We can replicate the variometer part with a Raspberry Pi (Rpi) and 3 fluxgate magnetometers but have no true absolute level.

Table 1 shows the differences in performance between a scientific instrument and the Rpi system.

Raspberry Pi with digitiser

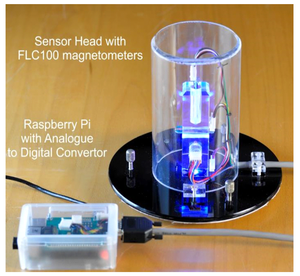
Tri-axial variometer

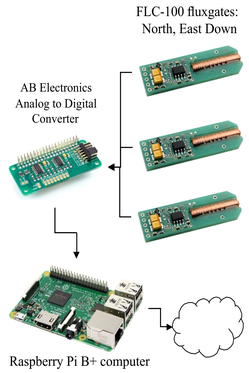
	Observatory	Raspberry Pi
Purpose	Long-term absolute broadband measurement of full magnetic field	Short-term short period variation of the magnetic field vector
Site stability	Bespoke magnetically clean site with temperature control	Unrestricted sites with multiple unwanted noise sources; no temperature stablisation
Accuracy	Typically 10 pT/sqrt(Hz) at 1 sec	Around 1.5 nT/sqrt(Hz) at 10 secs
Cost	£15,000 UKP	£150 GBP

Table 1: Summary of differences between scientific-level and Raspberry Pi magnetometer performance

2. Rpi instrumentation

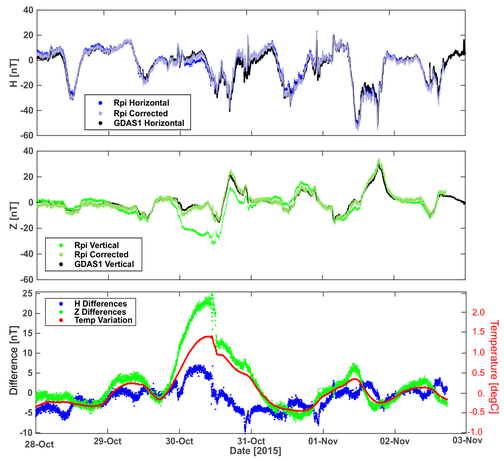
We built 10 systems based on an initial prototype. These consist of three FLC-100 magnetometers from Stefan Mayer, a B-version Pi and an AB Electronics digitiser. A thermistor monitors ambient temperature. The mounting is made of non-magnetic Perspex.





3. Rpi magnetometers under test

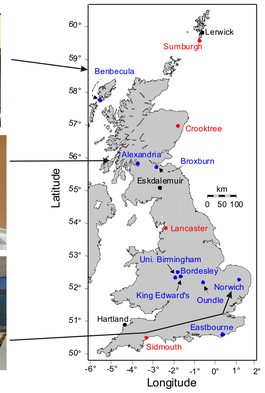
The ten systems were tested at Eskdalemuir observatory in 2015. They were placed in a non-magnetic lab, ~100 m away from the GDAS1 scientific instrument (above). Around 6 weeks of data were collected.



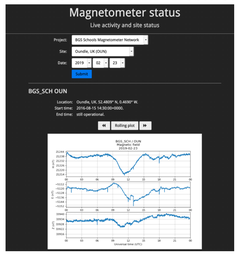
The figure (above right) shows six days of data from one of the Rpi systems. The horizontal (H) and vertical (Z) components are compared to the GDAS1 system. The bottom panel shows the differences along with the temperature change measured. The variation is mostly long period and strongly correlated with temperature, affecting Z relatively more than H. The Rpi data can be corrected by solving for the temperature-related coefficients. The short-period noise is around 1.5 nT in both components.

The step on 30-Oct was caused when the data were manual retrieved, entering the room.

4. Off to school ...

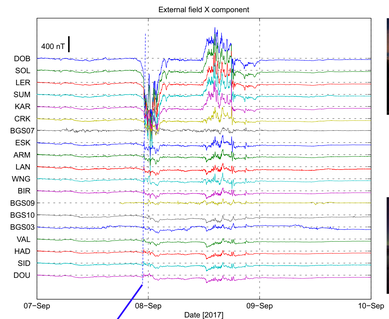


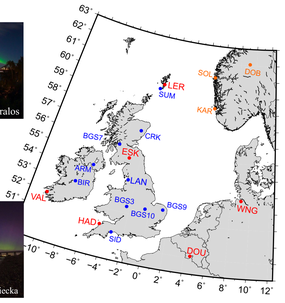
https://aurorawatch.lancs.ac.uk

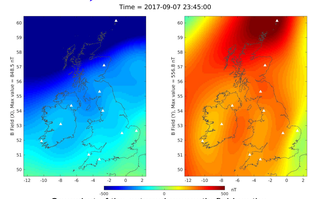


The ten systems were deployed to schools in the UK over 2016/17. The data are sent back every 2 minutes to the AuroraWatch site run by Lancaster University. They are freely available for viewing online or download.

5. Citizen science: Sep 2017







Snapshot of the external magnetic field as the auroral electojet crosses northern Scotland

The largest geomagnetic storm of recent years was 7/8th September 2017. The Rpi magnetometers captured the signal really well (upper left), in comparable detail to the observatories and variometers around the North Sea (above). The time-series was turned into a map/animation of the storm (left). It has been used for space weather studies at BGS.

Reference: Beggan, C. D. and Marple, S. R. (2018), Building a Raspberry Pi school magnetometer network in the UK, Geoscience Communications, 1, 25-34, https://doi.org/10.5194/gc-1-25-2018

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