British Geological Survey

NATURAL ENVIRONMENT RESEARCH COUNCIL

Collection, quality control and delivery of ground-based magnetic data during ESA's Swarm mission

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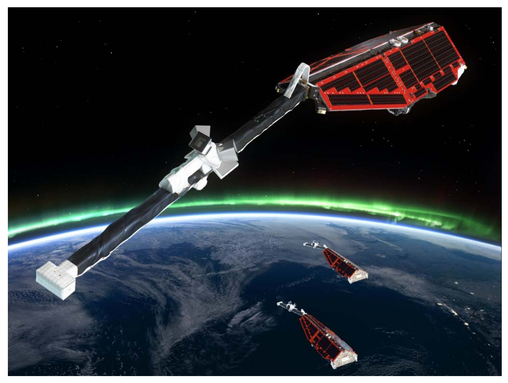

Introduction

Ground-based magnetic data are used in a variety of ways when analysing satellite data. Selecting satellite data often involves the use of magnetic disturbance indices derived from ground-based stations and inverting satellite magnetic data for models of fields from various sources often requires ground-based data. Ground-based data can also be valuable independent data for validation purposes.

We summarise data collection and quality control procedures in place at the British Geological Survey for global ground-based observatory and repeat station data. Whilst ongoing participation in the ICSU World Data System and INTERMAGNET facilitates this work, additional procedures have been specially developed for the Swarm mission. We describe these in detail.

Data collection

Ground-based magnetic field vector observations typically involve combining data from one or more continuously recording, temperature-controlled variometers and total intensity meters with manual absolute observations, all taken in a magnetically clean environment and reduced to the absolute observing position.

Data collection activities for the Edinburgh World Data Centre (WDC) for Geomagnetism are a continual process and rely on manual interventions. These range from the annual email solicitation for new observatory and repeat station data and processing and checking of data received, to regular checking of the BGS ftp server set up to receive data and the INTERMAGNET ftp server for new definitive data. The data are made available from the BGS WDC. Only definitive observatory data are put in the WDC.

For repeat station data, around 20 countries, mostly in Europe, are each submitting an average of 10 to 15 records per year. These are manually checked and added to a file which can be accessed from the BGS WDC.

There is a long delay in the production of definitive observatory data. To fill the gap INTERMAGNET has developed a new type of data called quasi-definitive (QD) data. A QD data monitoring tool has been set up by BGS and reports are sent to INTERMAGNET observatory operators once per month. Other observatories are producing timely close-to-definitive data.

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Intermagnet quasi-definitive data completeness
report for 2016 as of 15-04-2016
    JFMAMJJASOND
abk ***---------
ars ***---------
asc **94--------
asp **4---------
bel **----------
bou **----------
box **----------
brw **----------
cki ***---------
clf **----------
cmo **----------
cnb ***---------
csy **----------
cta **----------
cyg 9**3--------
dlt **----------
dou *-----------
ebr **----------
esk **91--------
eyr *-----------
frd **----------
gan ***---------
gng ***---------
gua **----------
had **91--------
her ***---------
hon **----------
hrn ***---------
hyb *-----------
jco **9---------
kak **----------
kdu *-4---------
kep **94--------
khb ***2--------
kny **----------
kou **----------
ler **91--------
lon **----------
lrm **----------
lyc ***---------
lzh *-----------
mab *-----------
maw *-----------
mbo **----------
mcq ***---------
mgd ***---------
mmb **----------
naq -6*---------
new **----------
ngk *3*---------
nvs ***1--------
pet ***0--------
pst **94--------
sbl **91--------
sfs ***4--------
sit **----------
sjg **----------
spt **----------
tam **----------
tdc ***---------
thy ***5--------
tuc **----------
ups ***---------
vss 1-----------
wng 9*----------
Notes: -=0%      0=1-9%    1=10-19%  2=20-29%
       3=30-39%  4=40-49%  5=50-59%  6=60-69%
       7=70-79%  8=80-89%  9=90-99%  *=100%

ups **----------
vss 1-----------
wng 93----------
Notes: -=0%      0=1-9%    1=10-19%  2=20-29%
       3=30-39%  4=40-49%  5=50-59%  6=60-69%
       7=70-79%  8=80-89%  9=90-99%  *=100%
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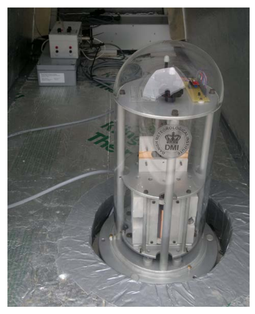
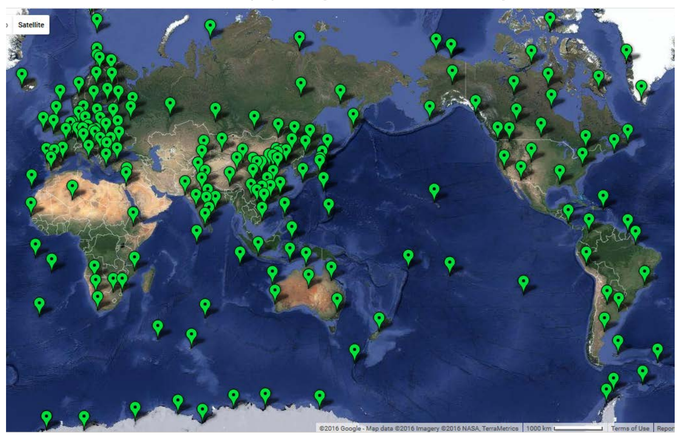
Infrastructure for a 1910s observatory (Eskdalemuir)

Infrastructure for a 2010s observatory (King Edward Point)

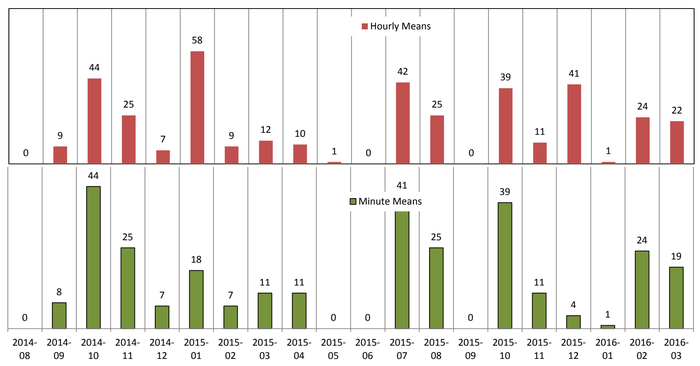
Tri-axial fluxgate variometer



Locations of currently operating observatories (according to IAGA)



Observatory-years of data added to WDC Edinburgh



Locations of magnetic survey sites in Europe

Making manual absolute observations with a fluxgate theodolite at a repeat station

Fluxgate theodolite and proton precession magnetometer – used at observatories and in field for absolute measurement of magnetic field vector angles (D, I) and total intensity (F)

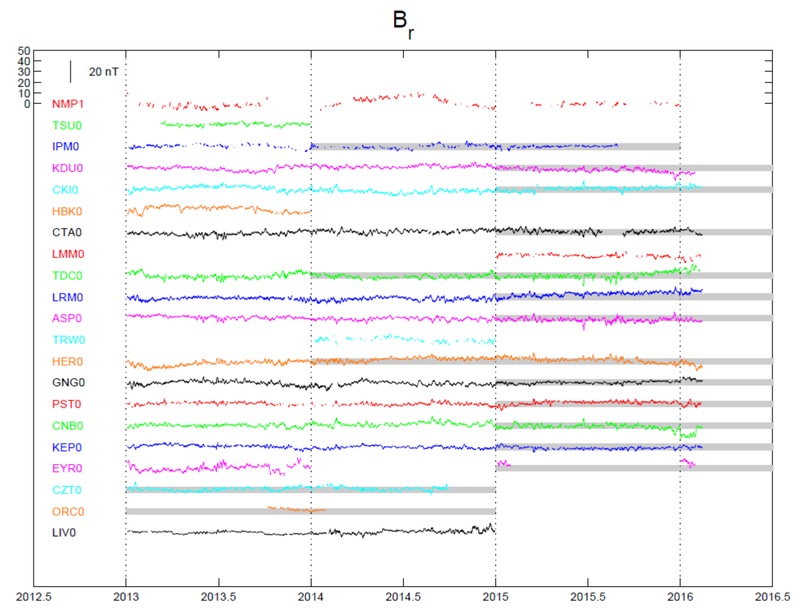
Quality control

Prior to use in magnetic field models, close-to-definitive observatory data are regularly collated from INTERMAGNET and other sources and combined with definitive data from WDC Edinburgh. As the observatory data are of variable quality it is necessary to make a manual selection and to eliminate poor quality data. Detecting such data in individual observatory time series is sometimes hard but looking at data from multiple observatories at the same time is more revealing.

Hourly spherical harmonic models are therefore used as a means of quality control. The models themselves are not particular useful for science but they are able to detect signals which are not coherent between neighbouring observatories.

All signals in the data that can be characterised or modelled, except at high latitudes, are removed from the data. What's left can be indicative of measurement artefacts. Poor quality data can then be excluded. Any unaccounted steps in the data become more visible and can be dealt with by splitting up time series so that different crustal biases are solved for in subsequent modelling work. Any long-term baseline drifts also become more visible and these are communicated back to the observatory operators. Cleaned-up hourly mean data are then made available from the ESA data centre and on the BGS geomagnetism ftp server once every 3 months.

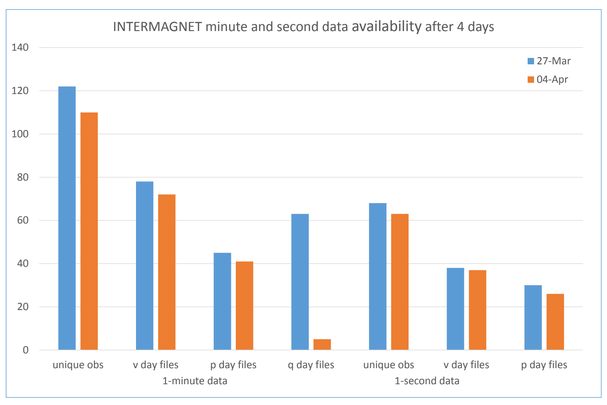
Examples observatory hourly mean QC plot for (top) for the vertical component some observatories in southern hemisphere and (bottom) dipolar north component northern hemisphere. Plots are produced every 3 months and made available at ftp://ftp.nerc-murchison.ac.uk/geomag/smac/IMAG_QD/



Next steps

Because of the excellence of the Swarm magnetic and plasma data there is now a growing user group concerned with rapid variations whose sources are outside the Earth. These users are less concerned about the data being definitive or close-to-definitive but require higher resolution and more rapid delivery, possibly daily 1-second files with 4-day delay to match that of Swarm.

The standard observatory product is 1-minute means, however with instrument and data-processing upgrades an increasing number of observatories are producing 1-second data. With the same latency as Swarm data, about 120 INTERMAGNET observatories are generating 1-minute means as either variometer (v) provisional (p) or even quasi-definitive (q) data. About 60% of these are producing 1-second data.



In combination with Swarm data, high resolution ground-based data are useful for both deriving models (e.g. of the ionospheric field, and magnetospheric field by 1-minute RC and VMD indices) and for space weather research. The "absoluteness" of the data is more important for the former use than the latter. BGS, relying on INTERMAGNET, is developing a product for dissemination through the ESA data server which should satisfy both communities. The Common Data Format (CDF), widely used for satellite data, is being considered. Advantage will be taken of the versioning system already in use within the ESA data server to allow 3-monthly updates of daily files.

Conclusions

- Observatory hourly mean data are already used to produce and validate several official Swarm L2 products
- There is now interest in higher temporal resolution data within the Swarm community
- Existing observatory data distribution channels, primarily INTERMAGNET and WDC, are important for developing new value-added products. The emphasis within INTERMAGNET on near-real-time and quality standards is particularly useful.
- Credit for institutes operating and funding observatories is important

What's currently required by the ESA data centre and the Swarm science community?

Close-to-definitive observatory hourly means spanning the complete satellite era are required, but in particular 2013 and onwards when Swarm is flying. These are used in the production and/or validation of models of the various sources of the magnetic field. They are supplied in the same coordinate system as the satellite data, i.e. geocentric.

BGS uses QD data in combination with WDC definitive data to produce files of hourly mean values with a latency of 3 months. Because the presence of noise, steps and drifts in the hourly mean time series masks the underlying small secular variation signals, BGS first undertakes quality control of these data.

Acknowledgements and References

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Macmillan, S. and Olsen, N., 2013. Observatory data and the Swarm mission. *Earth, Planets and Space*, **65** (11), 1355-1362. 10.5047/eps.2013.07.011.