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DEVELOPMENTS IN GEOMAGNETIC FIELD DATA RELEVANT FOR DEEP EARTH RESEARCH

SUSAN MACMILLAN (smac@bgs.ac.uk), CHRIS TURBITT, SIMON FLOWER, VICTORIA RIDLEY
British Geological Survey, West Mains Road, Edinburgh EH9 3LA, United Kingdom

SUMMARY

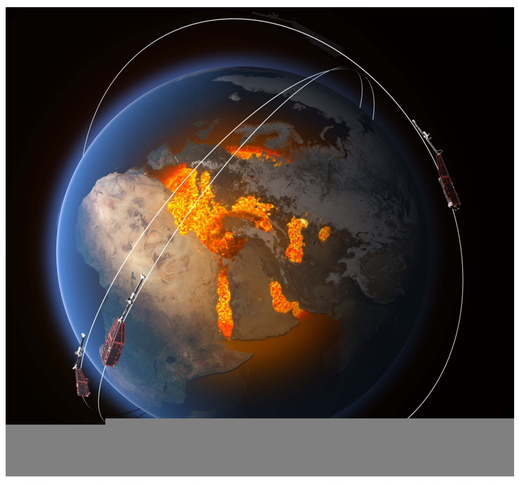
We report on four recent developments concerning observing the geomagnetic field and processing geomagnetic data:

- The successful launch of ESA's Swarm satellite mission
- Improvements to timeliness and quality of observatory data
- BGS's contributions to the Swarm calibration and validation phase and Level 2 Processing System
- Ongoing support for observatories in developing countries and remote regions

1. SWARM

1a. Launch & current status

- The European Space Agency (ESA) launched a new satellite mission called Swarm on 22nd November 2013.
- Each satellite is 9 m long, with a main body covered in solar panels and a trailing 4 m boom on which the sensitive magnetic field instruments sit - away from interference.
- The magnetic field is measured by two instruments: (1) by the scalar instrument at the end of the boom which measures the strength of the field and (2) the vector instrument near the middle of the boom, which measures the direction of the field, using star cameras for accurate orientation.



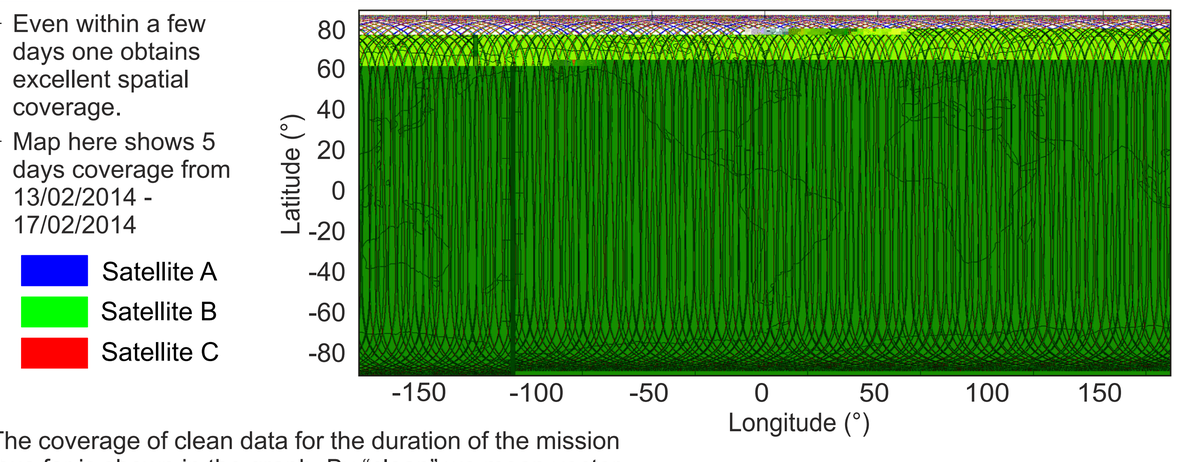
- The satellites also measure the electric field in the ionosphere using novel Langmuir probes and plasma instruments sited on the front of the satellites, giving complete measurement of the electromagnetic environment of the upper atmosphere for the first time.
- All satellites are reported to be in excellent shape and the same goes for their payloads. One redundant scalar sensor on satellite C is not working and, as a consequence of this, satellites A and C will now be the lower satellites flying side by side for mapping the crustal field, and satellite B will fly at a higher altitude, precessing at a different rate.

1b. BGS contribution to L2PS

- ESA will produce advanced data products such as magnetic field models from the various sources through the Level 2 Processing System. BGS's role in this involves
  a) collating and checking observatory hourly means for an auxiliary Swarm product [1]
  b) producing daily "quick-look" products - various times series plots and maps of the satellite data [2]
  c) producing 1.5 hour magnetospheric field models on a daily basis [3]
  d) independent validation of preliminary Level 2 products as they become available [2]

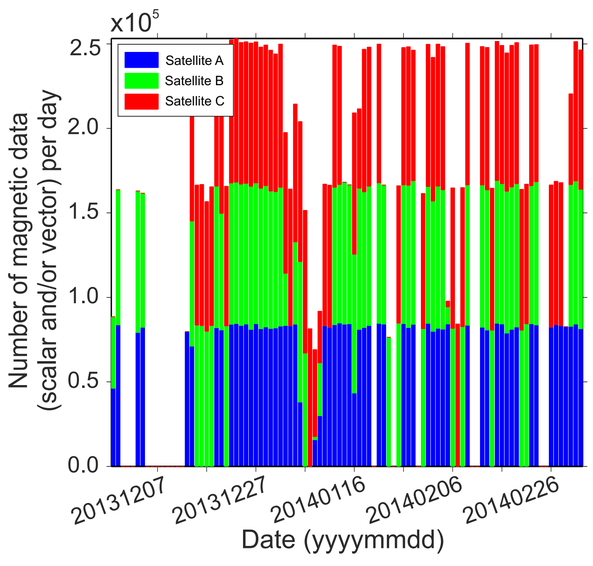
1c. Orbital analysis: launch to 02/03/2014

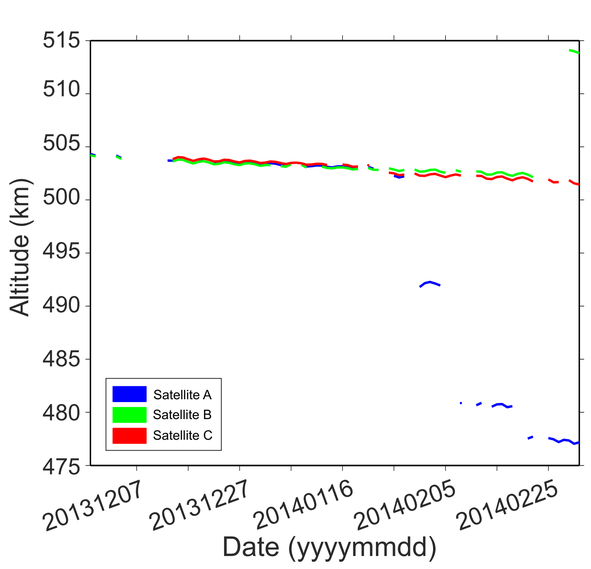
- Even within a few days one obtains excellent spatial coverage.
- Map here shows 5 days coverage from 13/02/2014 - 17/02/2014



The coverage of clean data for the duration of the mission thus far is shown in the graph. By "clean" we mean vector data that are flagged as "nominal" and additionally that the attitude data are "nominal" and that the platform telemetry indicates that the thruster valves are open but not activated. A check is also made for zero-valued scalar data.

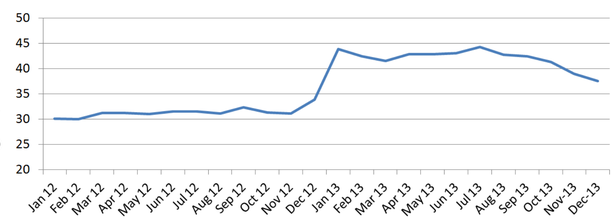
Satellite manouevres are visible in this plot of mean daily altitudes. Satellite B has recently been injected into a higher orbit.

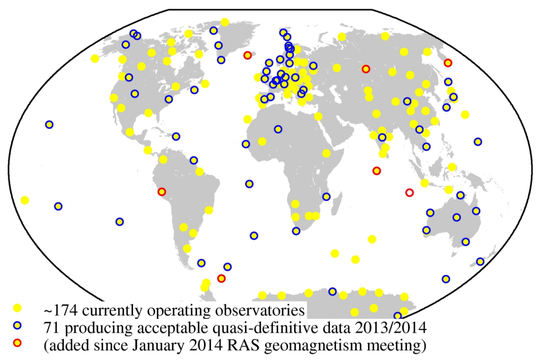




2. TIMELINESS AND QUALITY OF OBSERVATORY DATA

- Timeliness and quality of observatory data is important for forecasting future changes of the Earth's magnetic field.
- BGS operates a World Data Centre for geomagnetism and makes significant contribution to the INTERMAGNET programme (www.intermagnet.org) - a consortium of institutes and observatories around the world making measurements of the Earth's magnetic field to agreed quality standards.
- BGS has encouraged observatories to submit quasi-definitive (QD) data to INTERMAGNET within 3 months of measurement. The graph shows the increase in the number of observatories submitting QD data during 2012 and 2013, as a percentage of total number of INTERMAGNET observatories.
- QD data are combined with close-to-definitve, timely data from other good quality observatories. The map shows locations of all observatories producing QD or close-to-definitive data in a timely manner at start of 2014.





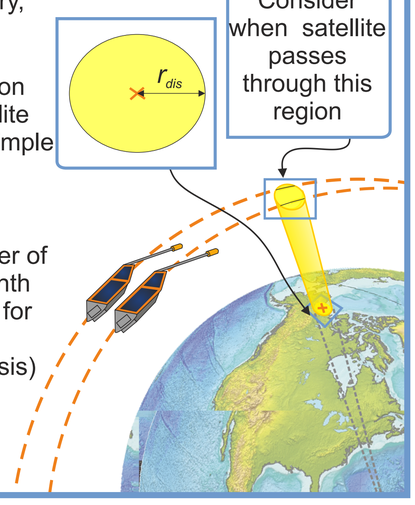
- These ground-based data offer the possibility of independent validation of Swarm data during the Cal/Val phase of the mission (see 3. Swarm Cal/Val).
- Another role for these data, along with definitive data, is combining them with Swarm data for deriving global magnetic field models. They are particularly important if modelling the ionospheric field as they help separate out the signals from the crust and core from the ionosphere.
- To aid quality control of global observatory data prior to joint analyses with Swarm data, misfits of spherical harmonic models can be inspected in the temporal & spatial domains [1].
- Cleaned-up hourly mean observatory data are regularly updated at ftp://ftp.nmh.ac.uk/geomag/smac/AUX_OBS_2/ and shortly also at the ESA Swarm data centre.

3. BGS CONTRIBUTION TO SWARM CAL/VAL

- The Calibration/Validation (Cal/Val) period, forming the first 6 months of the Swarm mission, will be used to confirm the instruments are operating as expected.
- Can Swarm measurements be ground-truthed with QD observatory data to aid the Cal/Val effort?
- The following method will be applied to each satellite during Cal/Val. We will look at how the global results
  a) vary between satellites
  b) compare with the results obtained when a similar approach has been applied to CHAMP data

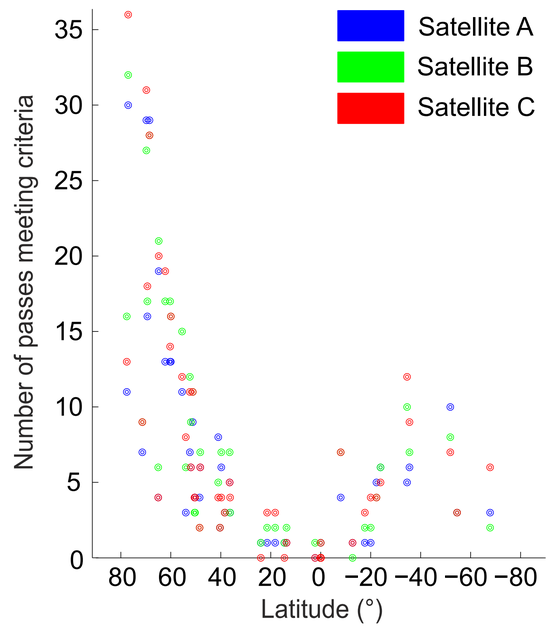
3a. Approach

- Radial distance from each observatory, r_{dis}, defined at Earth's surface
- Catchment region defined at satellite altitude using simple conical angular projection
- r_{dis} = 120 km balances number of passes in 3 month period (enough for meaningful statistical analysis) with maximum distance from observatory



3b. Overhead passes

- Number of passes in 3 months depends on observatory latitude, r_{dis} and position of satellite orbital insertion.
- Number of Swarm passes shown below for:
  a) Those made from launch until 01/03/2014
  b) r_{dis} = 120 km
  c) Where both observatory and clean SWARM vector data were available up to 02/03/2014



4. SUPPORTING OBSERVATORIES

- INDIGO is a project to support observatories around the world and is run by BGS and the Royal Meteorological Institute of Belgium. The objective is to increase the number of INTERMAGNET-quality digital observatories.
- BGS recently ran a training course for two observers from the Argentinian Servicio Meteorológico Nacional. This covered all aspects of running an observatory from maintaining instruments to final data production. Base Orcadas and Pilar observatories are now INTERMAGNET observatories.
- Other observatories supported by INDIGO are 2 in Mozambique, 1 in Costa Rica, 4 in Indonesia (picture: absolute hut at Pelabuhan Ratu), 1 in Russia.
- The GDASView data processing application was redeveloped during 2013 to simplify the production of definitive and quasi-definitive magnetic observatory data. GDASView is used extensively by overseas institutes, including Gan observatory in the Maldives, which joined INTERMAGNET recently (picture: variometer).
- Another new INTERMAGNET observatory is Cheongyang in South Korea (picture). Observatory staff were advised on data production and the INTERMAGNET application process during a BGS visit in 2013.

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[1] Macmillan, S.; Olsen, N.. 2013 Observatory data and the Swarm mission. *Earth Planets Space*, **65**. 1355-1362.

[2] Beggan, Ciaran D.; Macmillan, Susan; Hamilton, Brian; Thomson, Alan W.P., 2013. Independent validation of Swarm Level 2 magnetic field products and 'Quick Look' for Level 1b data. *Earth Planets Space*, 65, 1345-1353.

[3] Hamilton, B, 2013. Rapid modelling of the large-scale magnetospheric field from Swarm satellite data. *Earth Planets Space*, 65, 1295-1308.