British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

IMPACT OF SWARM DATA ON GLOBAL MAGNETIC FIELD MODELS

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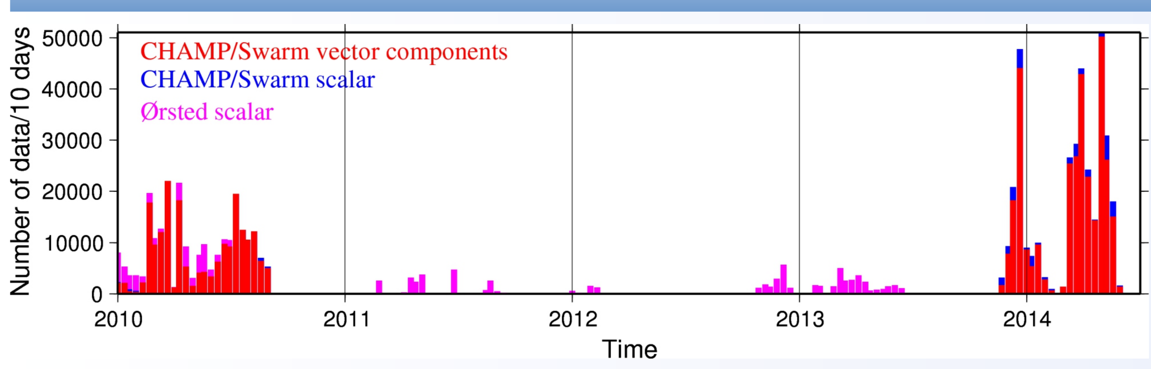
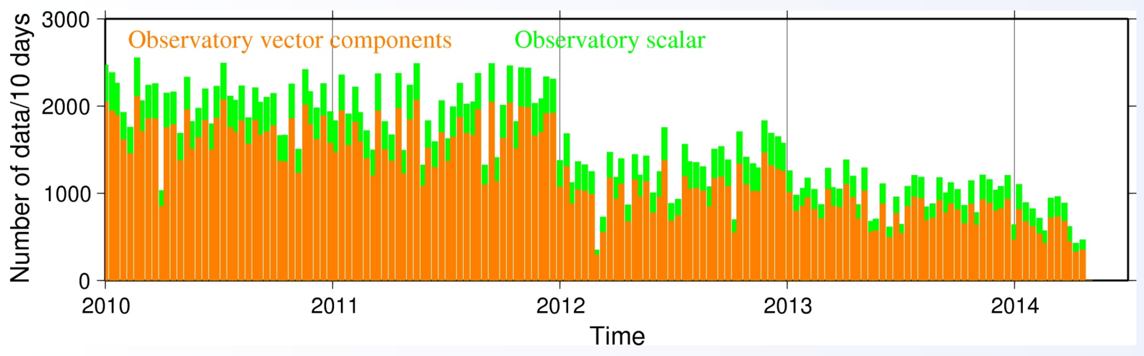
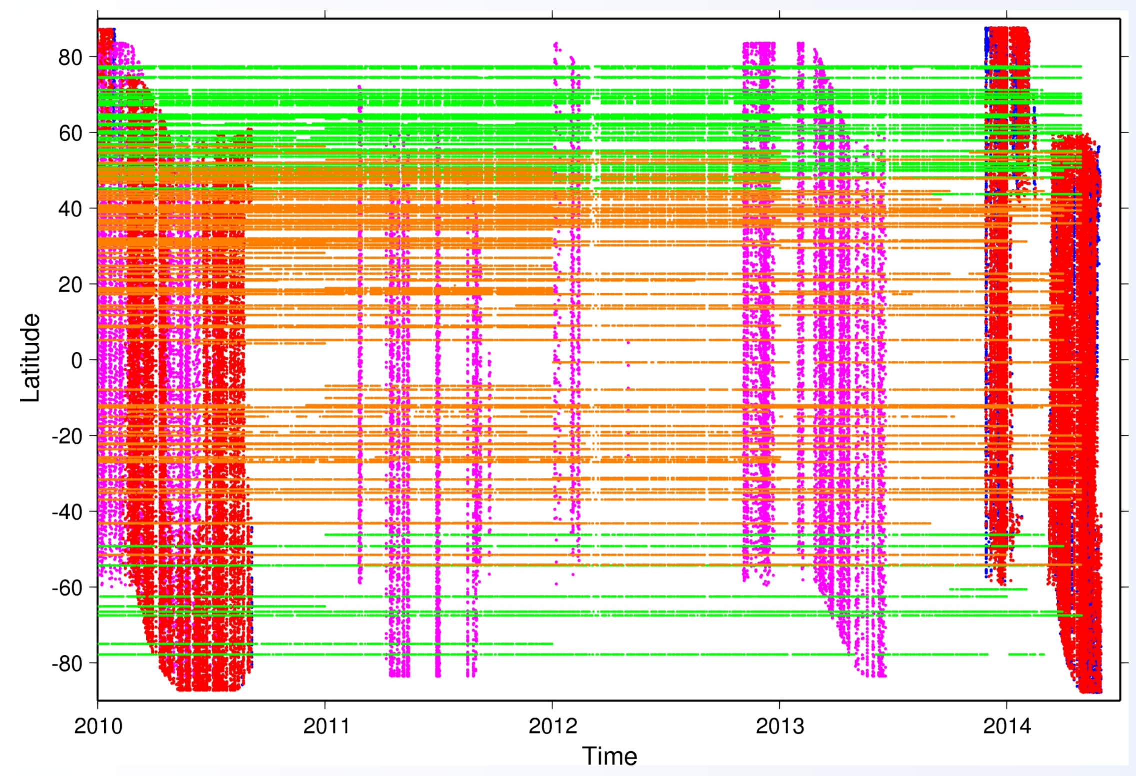
We investigate the impact of early Swarm data on global magnetic field models. Since November 2013, Swarm has been providing satellite vector magnetic data, the first since the end of the CHAMP mission over three years ago. We describe two models of the Earth's magnetic field, one of which incorporates Swarm data. Both models include data from the CHAMP and Ørsted satellites and from observatories. All data are similarly selected on the basis of local time, solar zenith angle, upstream solar wind conditions and magnetic activity. The different data are weighted according to their type, location and estimation of content of signal not being modelled. The time-varying large-scale magnetospheric field is co-estimated with the internal field.

We also provide an update on efforts to collate and check ground-based observatory measurements in support of the Swarm mission. These are particularly important for bridging the gap between CHAMP and Swarm as they provide the only accurate vector observations of the magnetic field during that time.

Data selection







Every 20th satellite data, vector in preference to scalar, and observatory hourly means are used.

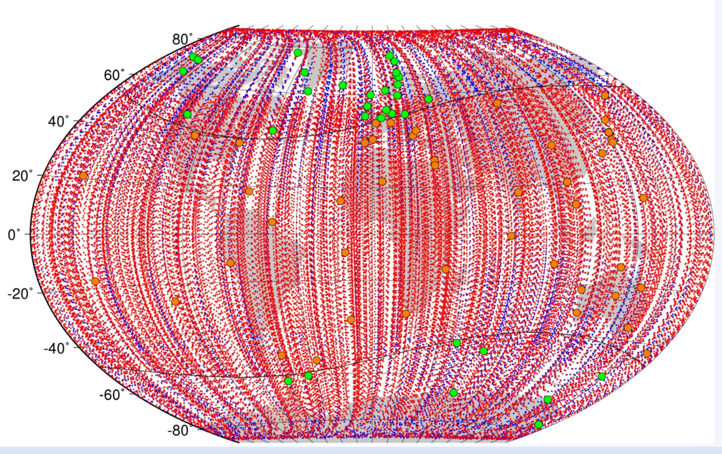
SWARM: local time 2230-0500 between dipole lat ±50° else only above dark ionosphere, Kp ≤ 2-, upstream solar wind (speed ≤ 450 km/s, IMF |Bx| ≤ 10 nT, |By| ≤ 3 nT, 0 ≤ Bz ≤ 6 nT), RPRO (reprocessed) in preference to OPER (operational) files, highest version #, B (vector) and q (attitude) flags = 0 (nominal), platform flag = 0 or 1 (nominal or "thruster latch valves open but not activated"), F (scalar) ≠ 0 nT, F flag ≠ 255 ("not enough samples to generate F")

CHAMP: same except for flags

Ørsted: same except for flags and local time 1800-0600 for 2010 onwards

Observatories: local time 0100-0200 all latitudes, Kp ≤ 2+, upstream IMF Bz ≥ -2 nT, dDst/dt ≤ 5nT/hr, vector data between dipole lat ±50° else pseudo-scalar (observed vector projected

2013.5 onwards



What we should have done with Swarm B (VFM 1 Hz) data: ignore B and q flags. Strange latitude-dependent effect possibly attributable to use of these flags.

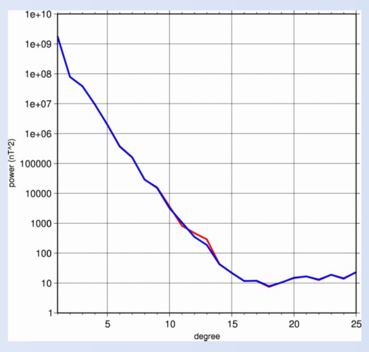
Model determination and analysis

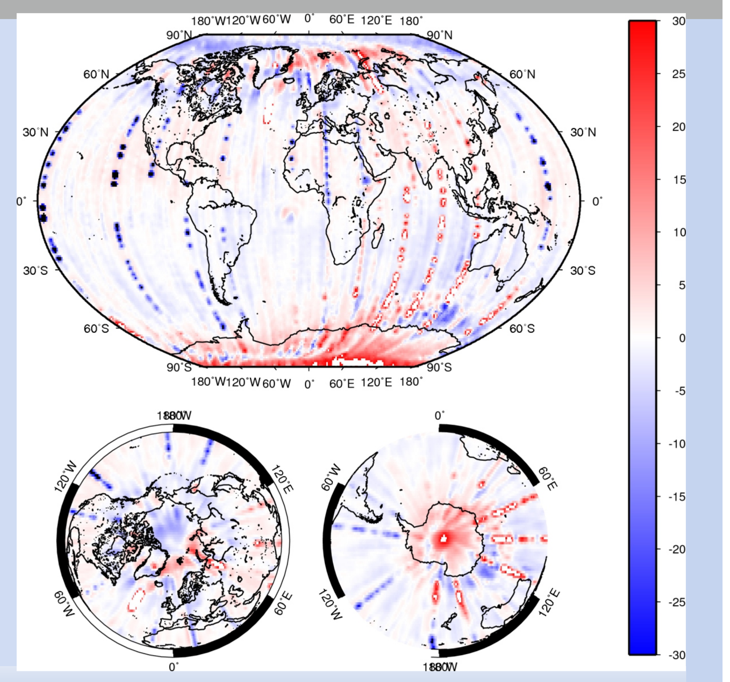
- Satellite data weighting is a function of location (by equal-area tesserae, similar effect as cos (lat)), along-track standard deviation and abnormal magnetic activity as determined from nearby ground-based observatories [1]
- Several models derived to investigate inter-data type weighting. Overall satellite : observatory data weighting averages out at 10:1 for this model
- Spherical harmonic models of internal (degree 60) and external (degree 1) potentials fitted
- Temporal basis functions for internal fields are piecewise linear
- Variety of temporal basis functions and different coordinate systems for external fields
- Iterative reweighted least squares

Misfit statistics

	Satellite mean	Satellite std	Observatory mean	Observatory std
X	-0.42	30.47	-0.07	5.96
Y	-0.04	21.48	-0.07	3.77
Z	0.75	19.92	-0.06	3.73

Main-field spectra at 2014.0. Red line is BGS model without Swarm data, blue with Swarm data.

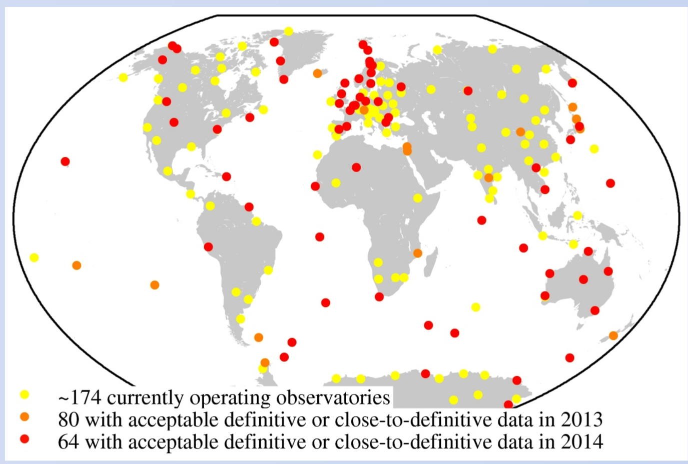




Map shows average spatial patterns in Swarm Z misfits. There is evidence of some noisy tracks, and difficulties in the polar regions.

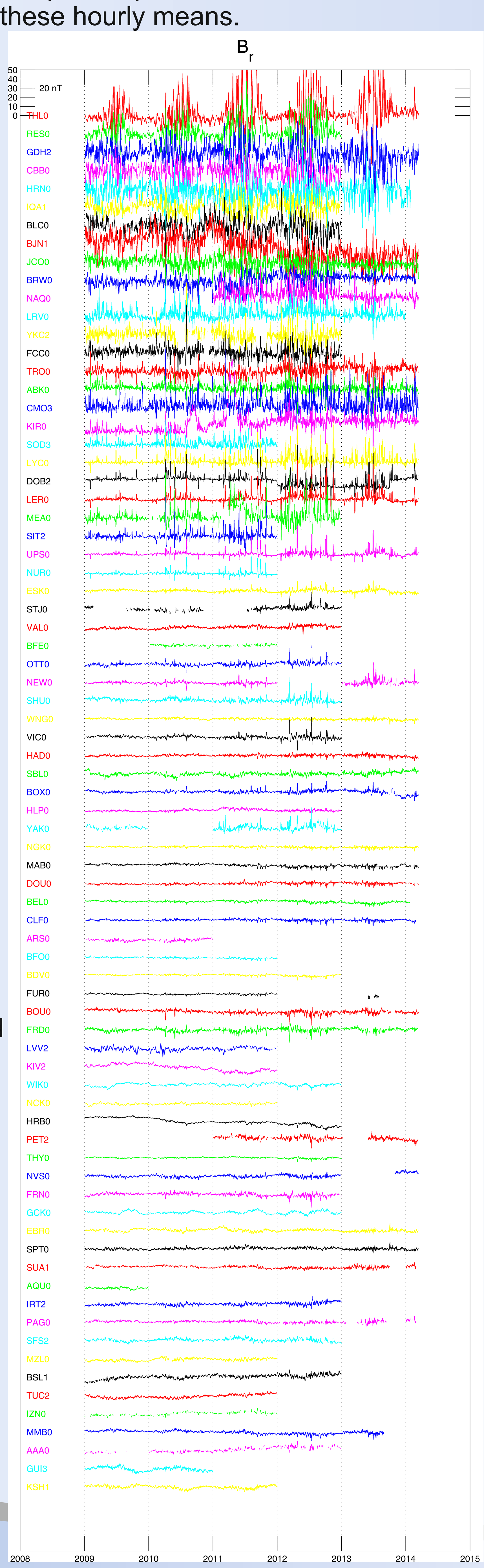
Ground-based data collation and QC

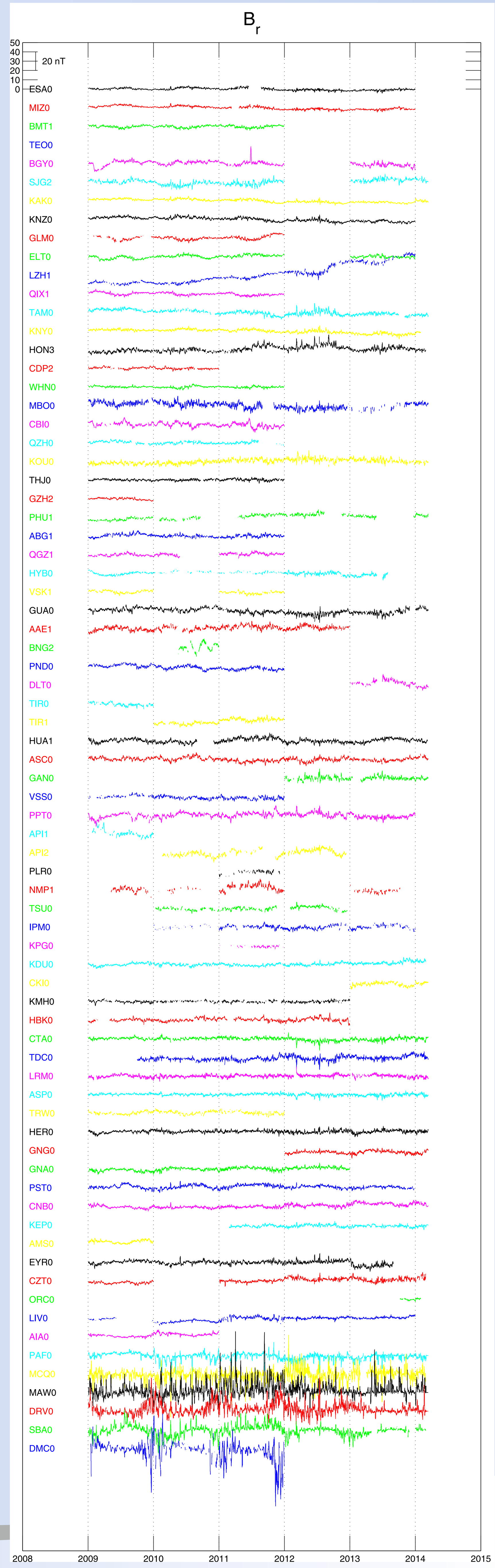
Prior to use in magnetic field models including Swarm data, close-to-definitive observatory data are regularly collated from INTERMAGNET and other sources and combined with definitive data from WDC Edinburgh. Hourly spherical harmonic models are used as a means of quality control [2]. All signals that can be characterised or modelled, except at high latitudes, are removed and the misfits (below) can be indicative of measurement artefacts. Some poor quality data have already been excluded and a few individual time series have been split to account for unmeasured jumps. Cleaned up hourly data are available from ftp.nmh.ac.uk/geomag/smac/AUX_OBS_2/ and the ESA data centre.



Most models before Ørsted: annual means
Ørsted and CHAMP: hourly means
Swarm: potential to model with minute means?

We plan to produce minute means consistent with these hourly means.





Acknowledgements and references

The Swarm mission and data centre are operated by ESA. GFZ Helmholtz Zentrum Potsdam runs the CHAMP data centre and the Danish Technical University operates the Ørsted satellite mission and data centre. Many institutes and agencies are involved in the operation of geomagnetic observatories around the world. INTERMAGNET and the World Data Centre (WDC) for Geomagnetism (Edinburgh) assist in quality control and dissemination of these observatory data. Magnetic activity indices are computed by GFZ Helmholtz Zentrum Potsdam, and the WDC for Geomagnetism (Kyoto). Solar wind data are measured by the ACE satellite and made available by NASA. This model could not have been produced without the efforts of all of these bodies.

[1] Thomson, Alan W. P., Brian Hamilton, Susan Macmillan and Sarah J. Reay, 2010. A Novel Weighting Method for Satellite Magnetic Data and a New Global Magnetic Field Model. GJI, 181, 250-260, DOI: 10.1111/j.1365-246X.2010.04510.x.
[2] Macmillan, S.; Olsen, N., 2013. Observatory data and the Swarm mission. EPS, 65 (11), 1355-1362. 10.5047/eps.2013.07.011.

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