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The role of geomagnetic observatory data during the Swarm mission

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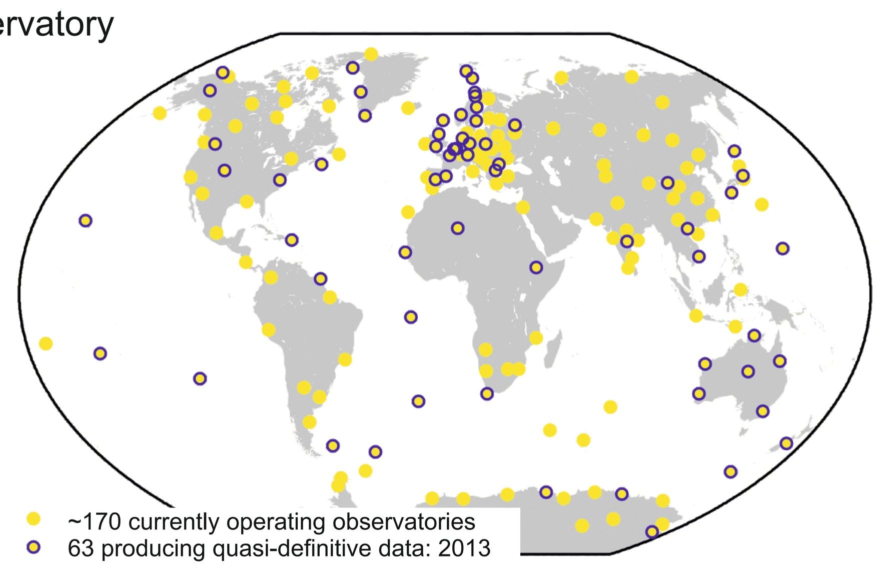
1. Summary

The ESA Swarm mission will measure magnetic signals from all sources of the geomagnetic field with unprecedented accuracy. The scientific use of Swarm data is greatly enhanced when used in combination with observatory data and indices and this has increased interest in ground based measurements. As part of the Swarm Level-2 data activities, plans are in place to distribute such data along with the satellite data [1]. Here, we also discuss how observatory data can be used for the Calibration/Validation of Swarm.

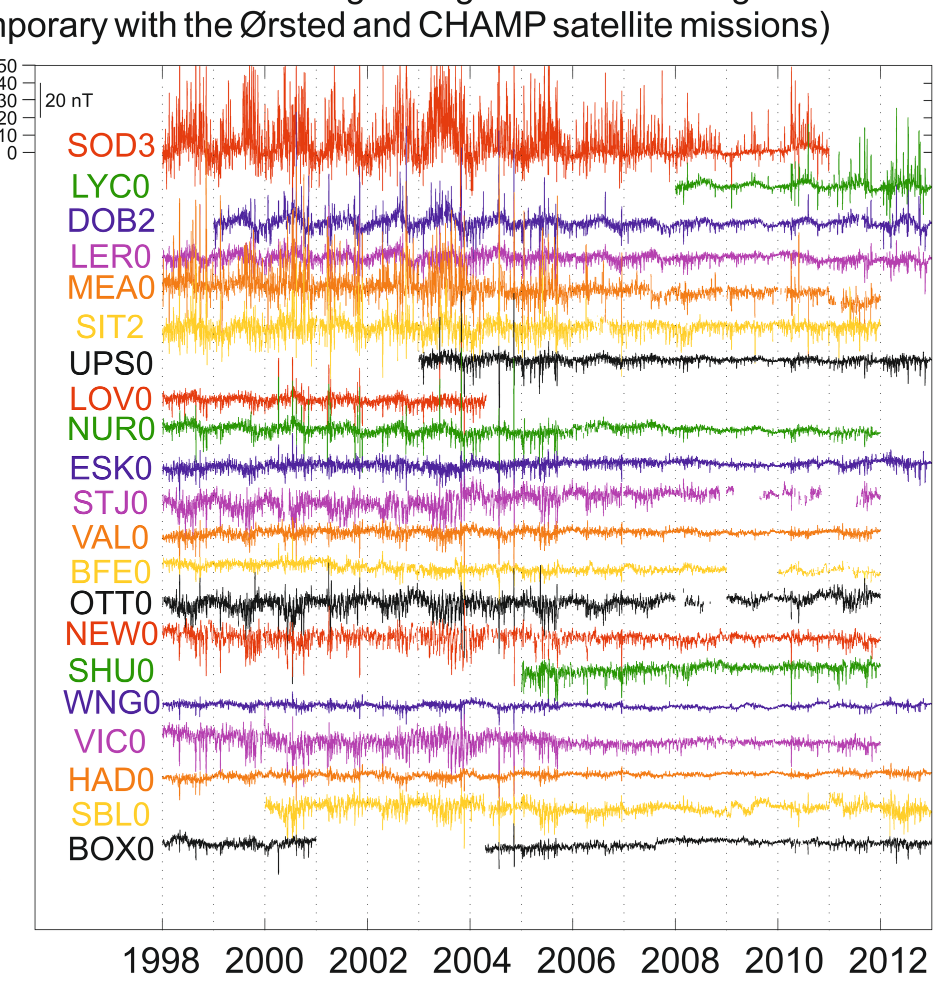
2. Timeliness of observatory data

- Every 3 months during the whole of the Swarm mission we aim to update files of observatory hourly mean values.
- During the first 6 months of the mission we aim to update files of observatory minute mean values to provide independent data for ground-truthing purposes.
- Advantage is taken of INTERMAGNET and other efforts in Norway, France & UK to improve the timeliness of quasi-definitive (QD) observatory data.
- QD data aims to be within 5 nT of definitive data (averaging on a monthly basis) and available within 3 months of measurement. The map shows the observatories producing such data as of August 2013. If your observatory is currently not contributing to this effort but is able to, you can either:
  (1) start transmitting QD data if you are in INTERMAGNET
  (2) contact Susan Macmillan to set up a direct data link with BGS.



3. Quality of Observatory Data

- 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.
- This pre-processing and modelling removes all signals that can be modelled, except at high latitudes, and the misfits represent measurement artefacts on the 0-10 nT scale.
- Tests using hourly mean data from observatories in geomagnetic latitude range 53-64° and spanning 1998-2012 (contemporary with the Ørsted and CHAMP satellite missions) resulted in misfits in the geomagnetic south component shown right (ordered by geomagnetic latitude).
- High quality data is reflected by values being:
  a) Close to zero (more so the lower the latitude),
  b) No discernible discontinuities present
  c) Coherent with geomagnetic latitude if large.
- Observatory data series can be iteratively split and poor quality data excluded to achieve this.
- See Poster 5.2-42p for more details

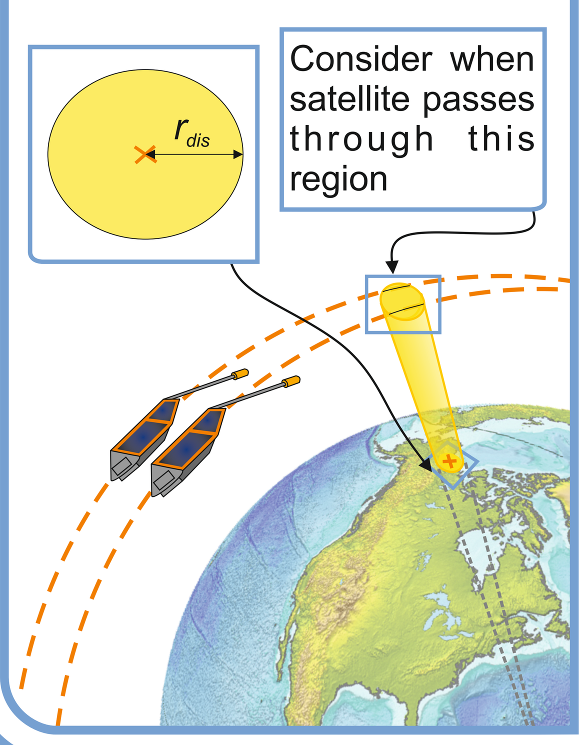


4. Ground-truthing Swarm data for Cal/Val?

- The Calibration/Validation (Cal/Val) period, forming the first 3 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.

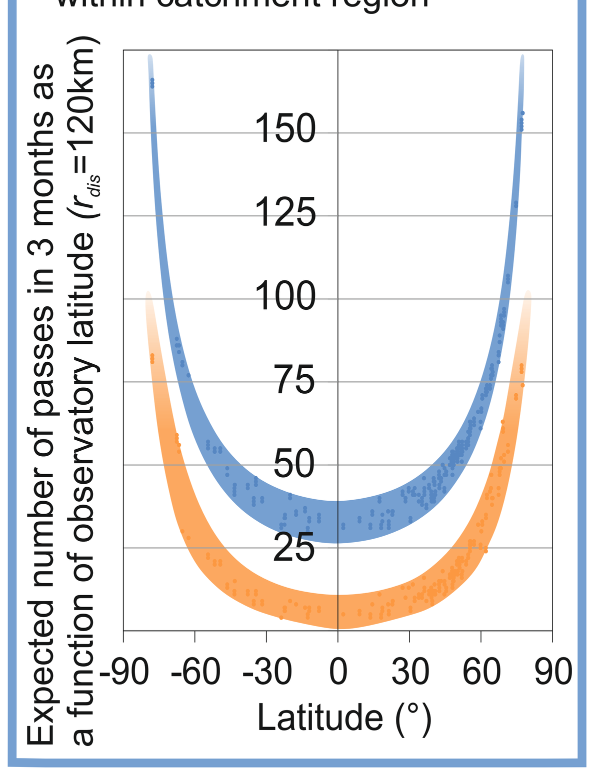
a) Approach

- 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} = 120km balances number of passes in 3 months with maximum distance from observatory



b) Number of passes

- Number of passes in 3 months depends on observatory latitude, r_{dis} and position of satellite orbital insertion.
- Range of expected number of passes shown below in:
  BLUE= **either** lower satellite within catchment region
  ORANGE= **both** lower satellites within catchment region



c) Method

<u>*For satellite during pass:*</u>
Calculate & remove along-track core field contribution to data.
B_{sat} = resulting mean satellite B_z

<u>*For observatory during pass:*</u>
Obtain QD minute mean during closest approach to observatory.
Calculate & remove core field contribution.
B_{obs} = resulting mean observatory B_z

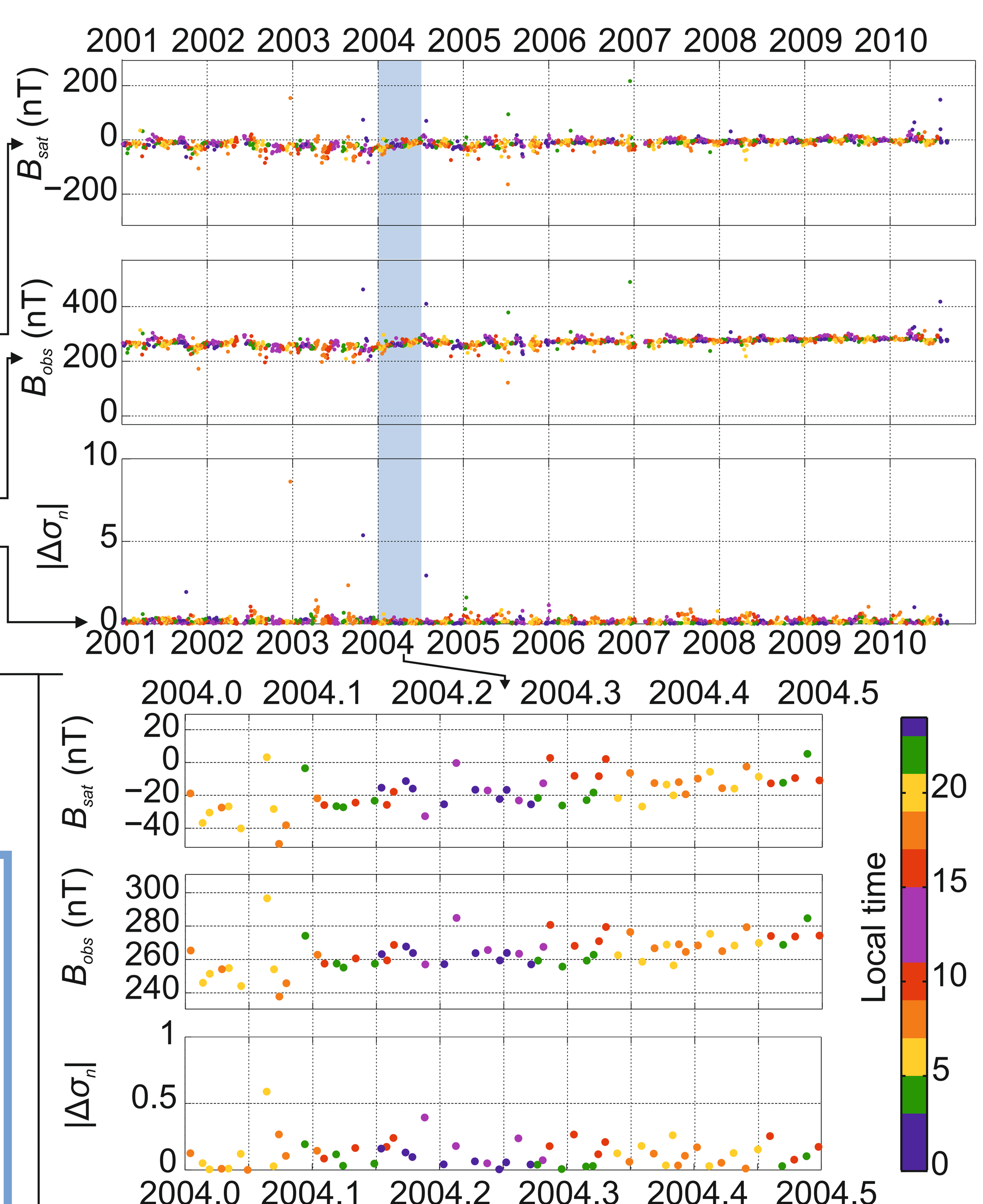
<u>*For ALL passes over 1 observatory:*</u>
1. Group all B_{sat} ; Group all B_{obs}
2. Linearly detrend.
3. Calculate mean, $\overline{X}$, and standard deviation, σ, of each group.
4. Normalise each individual B_{sat} or B_{obs} by σ
5. Calculate absolute difference between normalised B_{sat} and B_{obs}, $|\Delta\sigma_n|$, for each pass,

$$|\Delta\sigma_n| = \left|\left(\frac{B_{sat}-\overline{X}_{sat}}{\sigma_{sat}}\right)-\left(\frac{B_{obs}-\overline{X}_{obs}}{\sigma_{obs}}\right)\right|$$

5. Satellite passes and one observatory

- Analyse data from all passes made by CHAMP over ESK observatory between 2001-2011.
- CHAMP second data used to calculate normalised B_{sat} for each pass.
- Definitive minute-mean data used to calculate normalised B_{obs} for each pass.
- $|\Delta\sigma_N|$ generally <0.5.
- Seen more clearly when comparing individual passes.
- Similar results found for >100 observatories.

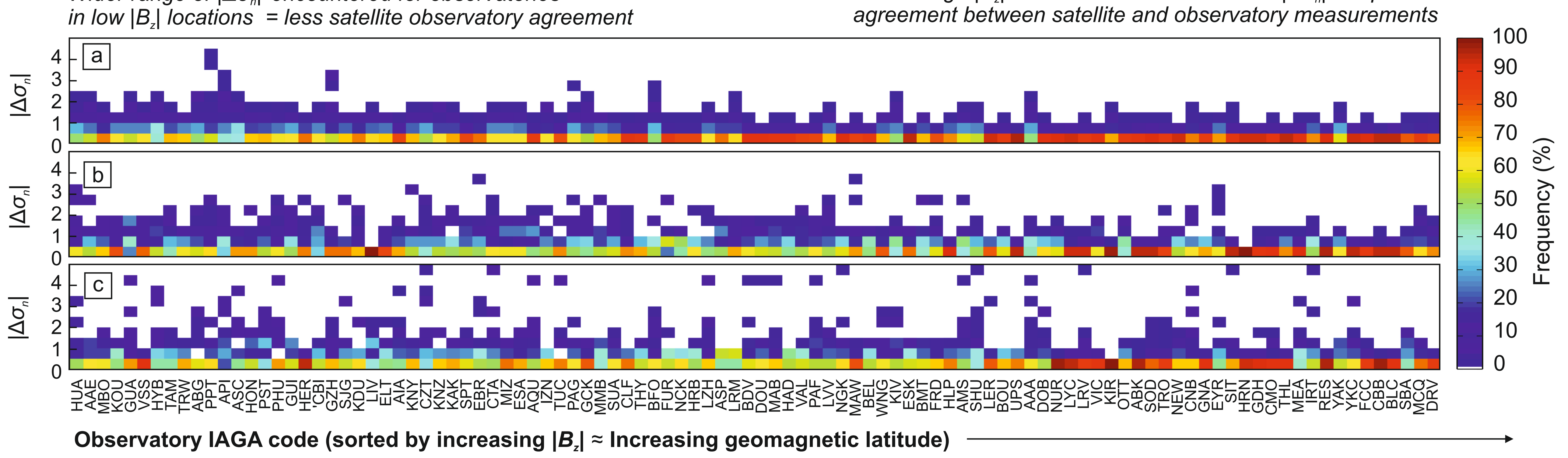
Good correlation between B_{obs} and B_{sat} for CHAMP at all local times and at different disturbance levels. Similar findings expected for Swarm, but difficult to predict how QD data might compare.



ESK $\lvert\Delta\sigma_N\rvert$ frequency	<0.5	<1.0	<2.0	≥2.0
% of 2001-2011 passes	94.8	98.9	99.6	0.4

6. Normalised frequency distribution of $|\Delta\sigma_n|$

- The Cal/Val period of Swarm is only 3 months; compared with the full 2001-2011 period analysed in Box 5, there are far fewer passes for analysis and a greater chance of unrepresentative $|\Delta\sigma_n|$ results.
- Using the minute-mean data for >100 observatories and CHAMP passes between 2001-2011 the normalised frequency distribution of $|\Delta\sigma_n|$ is shown here when:
  a) all passes 2001-2011 are analysed toegther;
  b) for 3-months beginning 2009.0;
  c) for 3-months beginning 2009.75.
- There is a general trend in normalised $|\Delta\sigma_n|$ frequency distribution with observatory $|B_z|$ when 2001-2011 period considered.
- Less clear trend in frequency distribution when considering limited number of months and distinct variation seen between different 3-month periods.



CONCLUSIONS: Ground-truthing is possible and over 3 months it will be useful to look for spurious $|\Delta\sigma_n|$ pass signals at individual observatories. A rough global correlation between the normalised $|\Delta\sigma_n|$ distribution and $|B_z|$ is also expected. Over a longer period the observatory data may be useful for detecting and long-term drifts in the Swarm data.

7. References

[1] Macmillan, S. and Olsen, N., 2013. Observatory data and the Swarm mission. Accepted for Swarm special issue of *Earth, Planets and Space*