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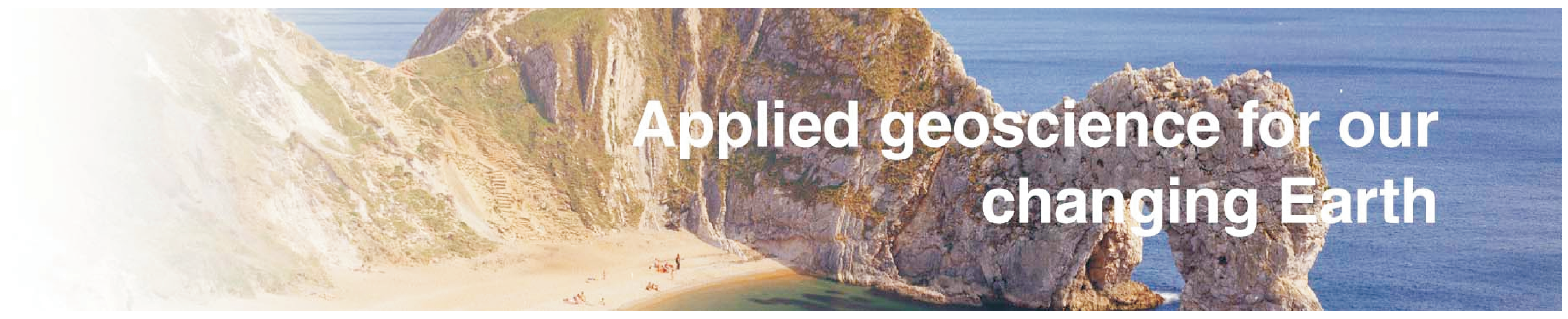

Improving time-dependent parameters of magnetic field models

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An important part of modelling the Earth's magnetic field is to accurately characterise its temporal variation, in particular the secular variation, and secular acceleration. These quantities are sensitive to the data selection and the time-dependent parameterisation and we present modifications to these strategies. When selecting satellite data for magnetic field modelling it is normal practice to use less disturbed data collected when the local time is between certain hours during the night and perhaps additionally when the data are not sunlit. However this approach results in gaps in the temporal data distribution which are likely to compromise the model parameters that depend on time. If the solar zenith angle is also a selection criterion, parameters which depend on location will also be compromised as an annual signal is introduced into the data distribution at high latitudes. Here we strive for a more continuous coverage in time. Rather than eliminating large amounts of data which are normally considered to be too noisy to include in the model, we downweight these data. This builds on work done previously involving small-scale noise.

Motivation

Most global magnetic field models being produced at the moment rely on magnetic data collected from magnetic survey satellites e.g. CHAMP and Oersted. Researchers are now extracting higher resolution models, both in the space and time domains, and are pushing the data to their limits. The time domain is of particular interest as it reveals information about processes in the core and as we strive to include the higher frequency variations from the core in our models (e.g. quartic spline nodes 6 months apart - Olsen *et al*, 2009; 400 days apart - Lesur *et al*, 2008) the overlap with the time variations with origins in the ionosphere and magnetosphere increases.

Survey satellites have near-polar orbits and precess slowly in local time e.g. CHAMP samples all local times in 4-5 months and Oersted in 2.2 years. Data for deriving magnetic field models are typically selected according to magnetic activity indices and by local time. The local time “window” is usually a few hours on the night-side and the dawn-side of midnight, in order to avoid the day-side excitation of the ionosphere, and the partial ring current signal present after dusk. Here we investigate taking 12-hour local time windows to ensure a more even coverage in time.

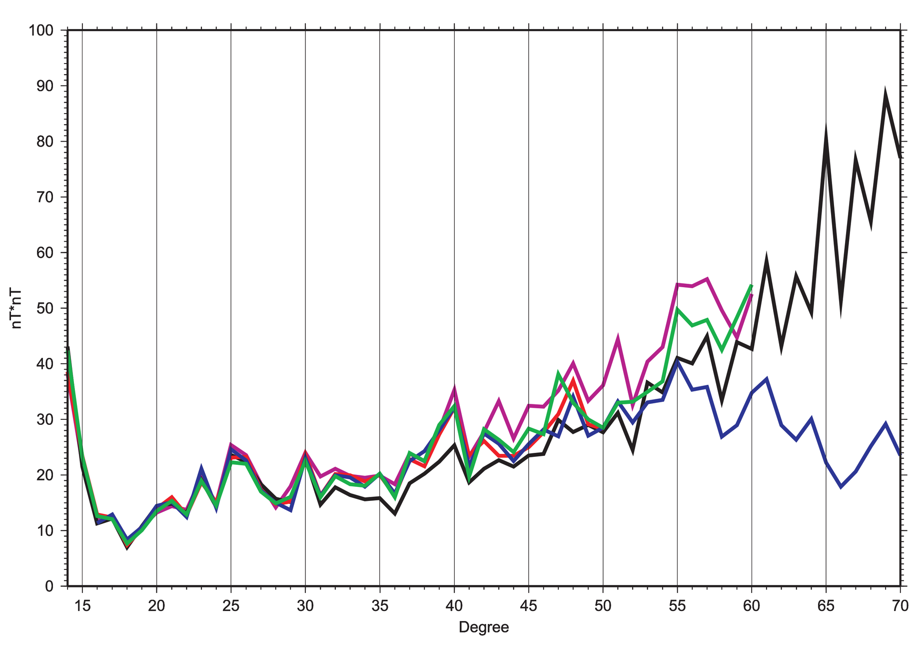
Improvement to satellite data weighting using LAVA indices and along-track noise estimators

The LAVA (Local Area Vector Activity) index is designed to capture rapid external field variations. The INTERMAGNET database contains about one hundred observatories, unevenly distributed across the Earth. For each observatory, we determine its external variation field by subtracting the quiet night-time level. We then determine the absolute value of this variation field at each minute, vector component, and observatory over the model duration. By binning the absolute variations we produce probability density curves for each observatory. We determine the deciles of each distribution and these determine the integer values of the LAVA index. We then interpolate the LAVA indices from the three nearest observatories to the geographic ground position of the satellite. Sometimes, the observatories are widely spaced and the interpolation is probably less useful. In the future we will use non-INTERMAGNET observatories to the LAVA indices' geographic coverage.

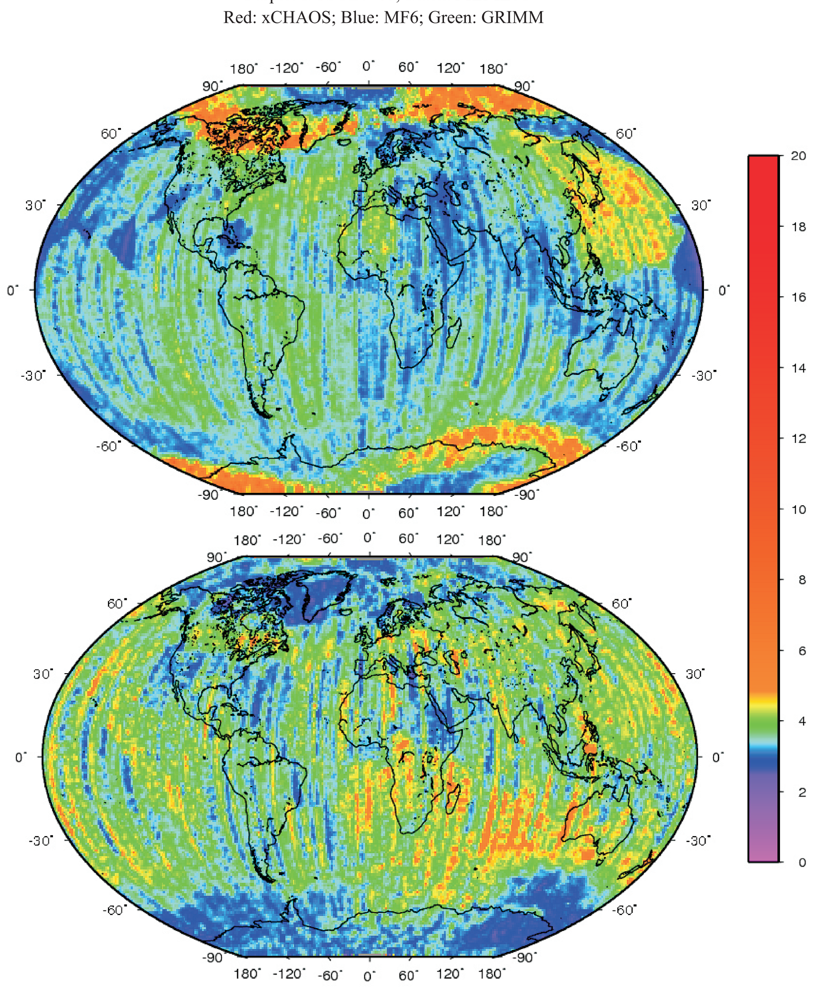
We also use the sample standard deviation as a measure of any localised external field activity and of any varying measurement noise. The satellite data are selected for field modelling at a 20-second sampling interval, from the basic 1 second measurement data set. The standard deviation is then computed from the twenty measurements centred on the sample point, i.e. on a track segment of around 150 km length.

By weighting the satellite vector data using the inverse sum-of-squares of the LAVA and along-track standard deviation we have been able to produce a global magnetic field model with a lower noise spectrum than other models (Thomson *et al*, 2009, **figure below**).

The geographical distribution of the combined standard deviation and LAVA down-weight factors for the period 2000 to 2007 for X and Z CHAMP data is **shown below**.



Purple: BGSGL0706; Black: MEME08
Red: xCHAOS; Blue: MF6; Green: GRIMM

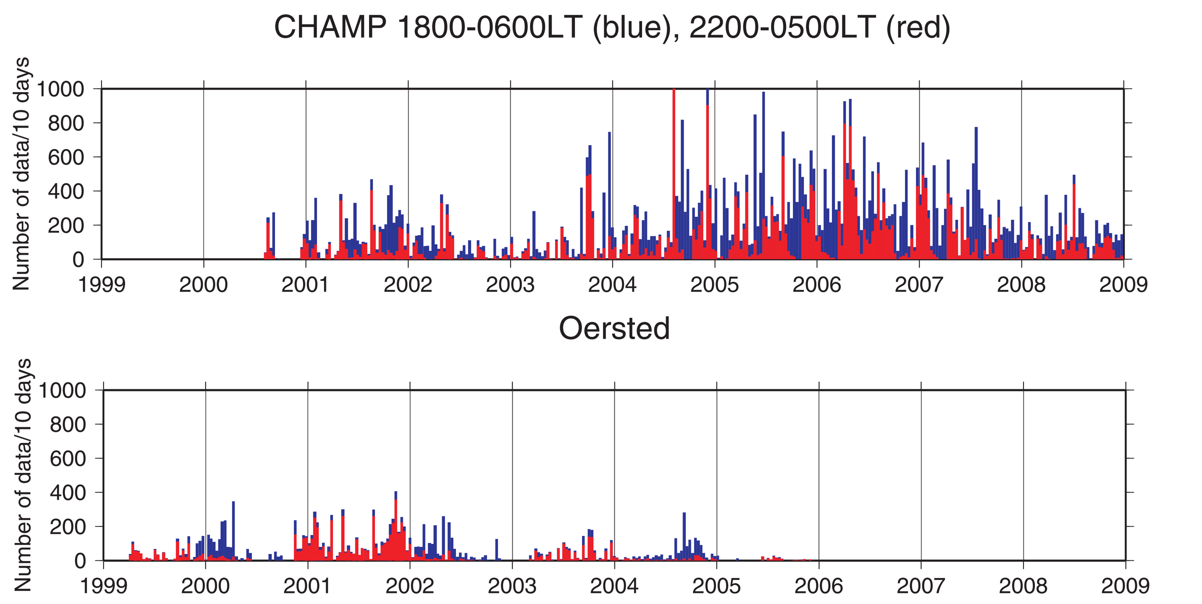


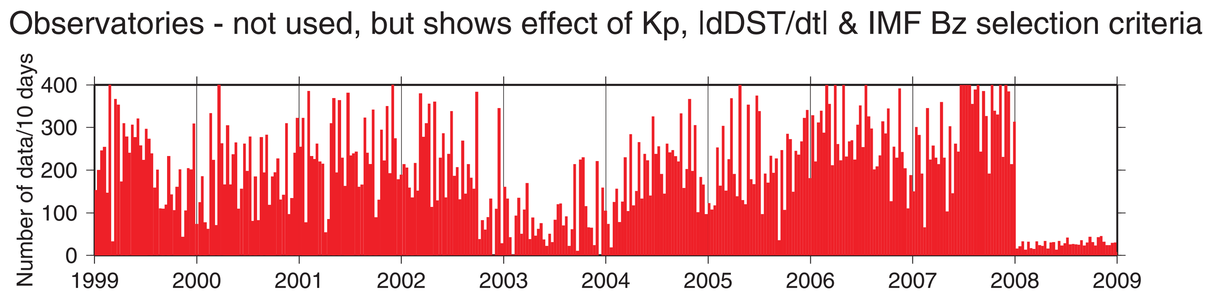
Improvement to satellite data distribution in time

By using 12-hour local time (LT) selections there should nearly always be a satellite half-orbit on the night-side. One might think solar zenith angle would be the better way to determine whether satellite data were sunlit but this leads to hemispherical differences in spatial data distribution e.g. satellite data are not selected in the polar areas during their respective summers.

Two selections were made - one with LT 1800-0600, the other with LT 2200-0500. In both cases we use 60-second sampling and vector data at all latitudes when Kp <2-, |dDST/dt| < 5 and 0<IMF Bz<5.The CHAMP data in 2008 are preliminary. The resulting vector data distributions in time are **shown below**. Scalar data are only used when no vector data are available.

The Oersted data distribution still has gaps and we think this is because the star camera sometimes malfunctioned when the satellite was in a near dawn-dusk orbit. Without star camera data it is not possible to derive vector data. Gaps in both distributions are also caused by periods of magnetic activity e.g. peak of the magnetic activity cycle in 2002-2003.

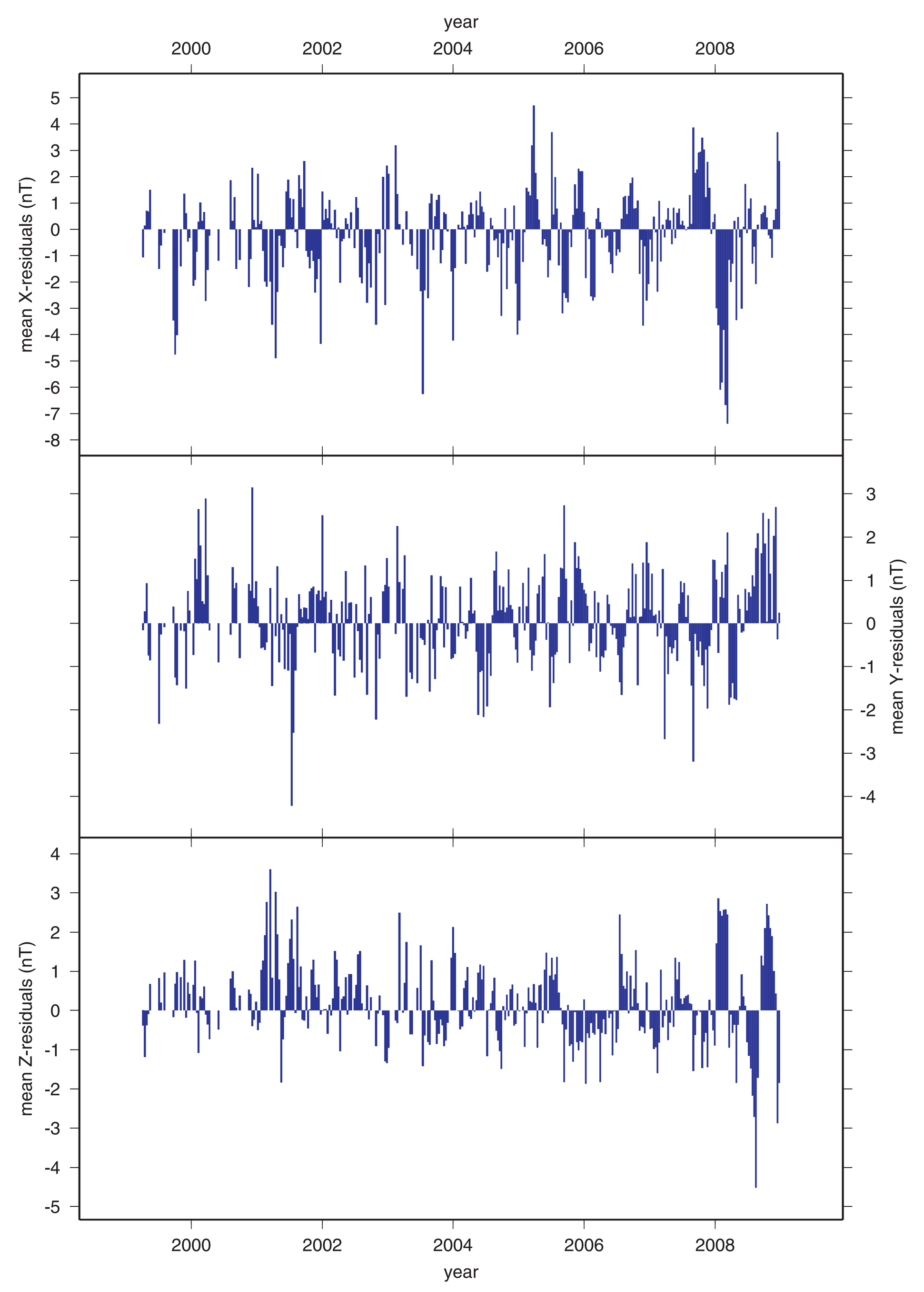




Model

The model parameters used here are the same as in Thomson *et al* 2009 except that an even knot interval of 200 days is used for the linear spline. The intention for the next revision is to implement quartic splines.

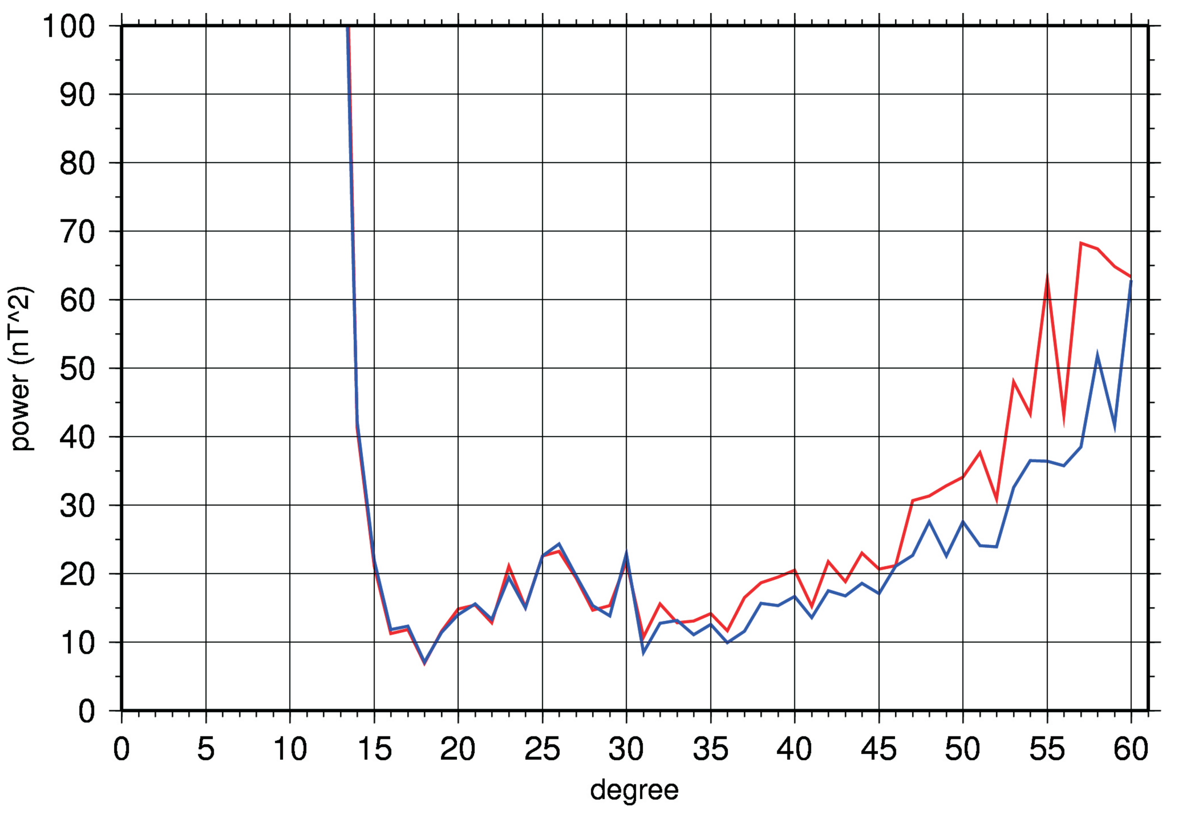
It is of interest to see how the model residuals vary in time. The **plot below** shows 10-day mean residuals from the model fitted to the selected satellite data in the 12-hour LT window. The variations with time of the mean residuals are probably due to inadequate model parameterisation for the internal field in the time domain. Despite noisier data being included in the model fitted to the 12-hour LT selection of data, the absolute misfit only increased from 3.47 nT to 3.95 nT.



Effect on model spectra

The **figure below** shows the power spectrum by degree from the models fit using the LT 2200-0500 selection (red curve) and LT 1800-0600 (blue curve). Despite the inclusion of noisier data, the increased amount of data reduces the power in the time-independent coefficients above about degree 30.

We believe this is possible because of the down-weighting of the additional data by the combined LAVA index and along-track standard deviation. The square-root of the mean variance assigned to the input data for the inversion is approximately 6.7 nT for the LT 2200-0500 data but 12.0 nT for additional data in the LT 1800-0600 selection. Provided the noise in the data can be estimated, the inclusion of more data should reduce the noise in the high-degree coefficients. However, the effects of including unwanted signals, for example the asymmetric features in magnetospheric fields, have not been estimated here.



Conclusions

Satellite data selections should be a compromise between removing unmodellable signal and the need for even coverage in time and space. At the moment the emphasis is on removing the unmodellable signal.

In this poster we have looked at the effects of local-time selection, and weighting of satellite data for deriving magnetic field models, which have let us to the following conclusions:

Data with increased noise or sources not fully modelled can be downweighted using LAVA indices at nearby observatories and along-track standard deviation. Power spectra of resulting models are lower than those from other models. However, a more detailed analysis of the time-distribution and relative importance of the different components of the weight scheme is required.

The inclusion of suitably weighted data from a wider range of local times has been shown to reduce the power in higher spherical harmonic degrees and could be used to improve the robustness of our estimation of small scale lithospheric features.

Opportunities provided by the SWARM mission

With the addition of data from the SWARM satellites, as well as Oersted and CHAMP data, several new modelling opportunities arise:

The data coverage issues raised in this poster will be mitigated somewhat by the greater local-time coverage of the mission, although some consideration of local-time selections windows will still be required to prevent large temporal variations in data density.

Simultaneous data from the three SWARM satellites will allow us to better understand the origins of the signals and noise not presently captured or dealt with by BGS magnetic field models.

Acknowledgements and References

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