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Improving time-dependent parameters of magnetic field models

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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, particularly the secular variation, secular acceleration, annual and semi-annual variations. 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 estimators along a satellite track and larger-scale disturbance estimators (the "LAVA" index) derived from nearby observatory data. Examples of data selections and resulting global models are presented.

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.

The 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.

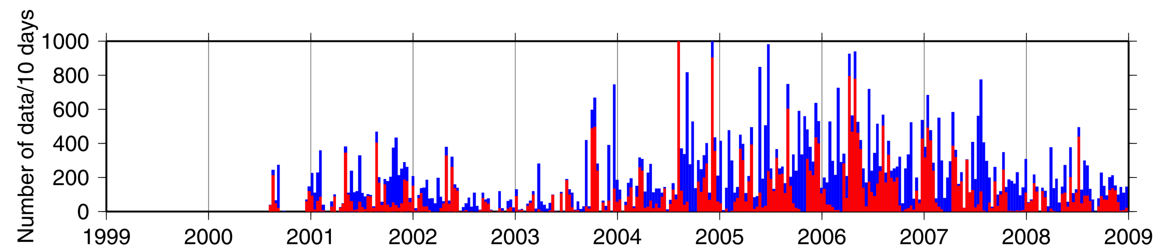
Improvement to satellite data distribution in time

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.

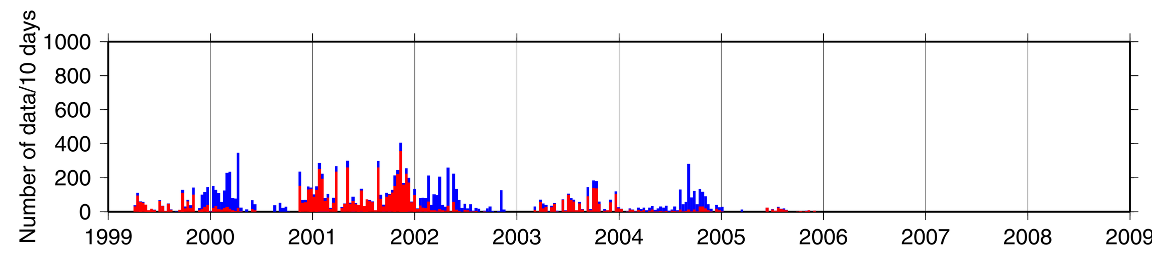
Two selections were made - one with LT 1800-0600, the other with LT 2200-0500. In both cases we use 60-second sampling and vector data at all latitudes when Kp <2-, |dDST/dt| < 5 and 0<IMF Bz<5.The CHAMP data in 2008 are preliminary. The resulting vector data distributions in time are **shown below**. 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.

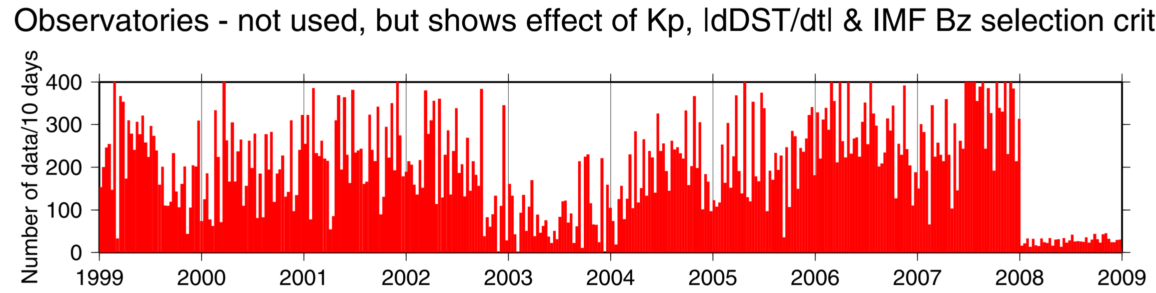
CHAMP 1800-0600LT (blue), 2200-0500LT (red)



Oersted



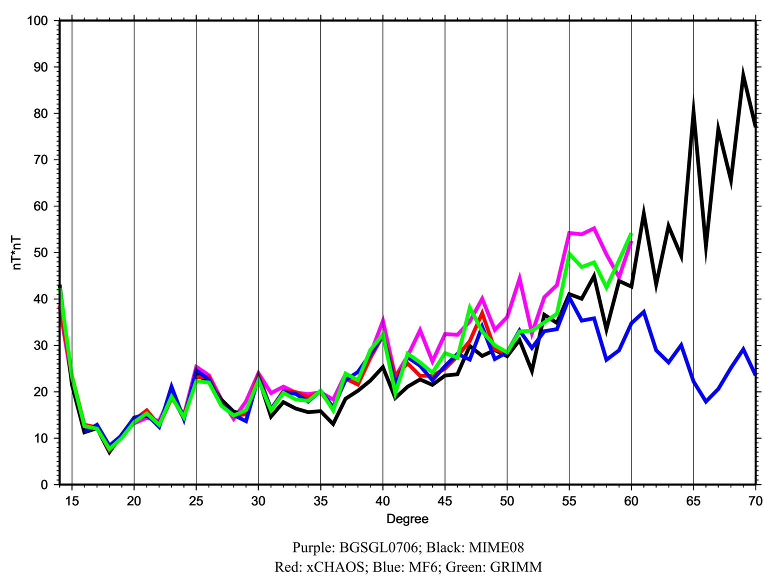
Observatories - not used, but shows effect of Kp, |dDST/dt| & IMF Bz selection criteria

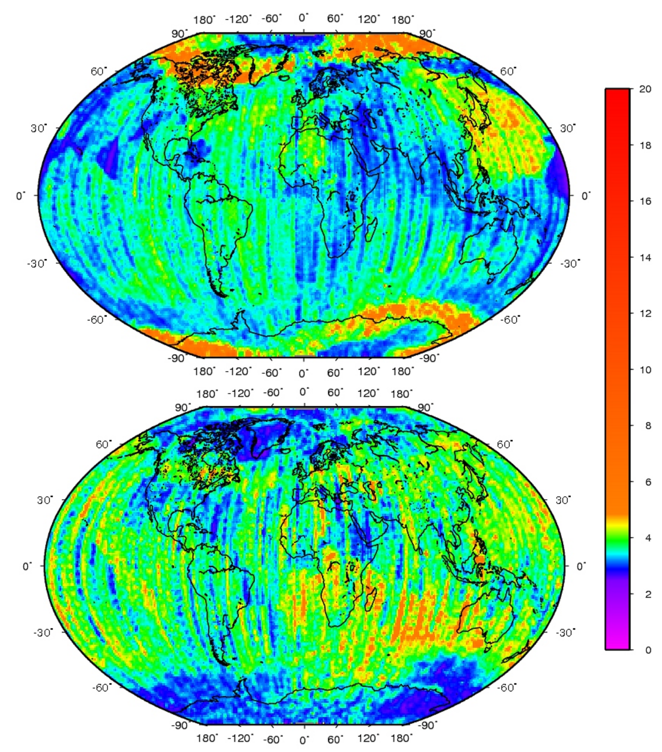


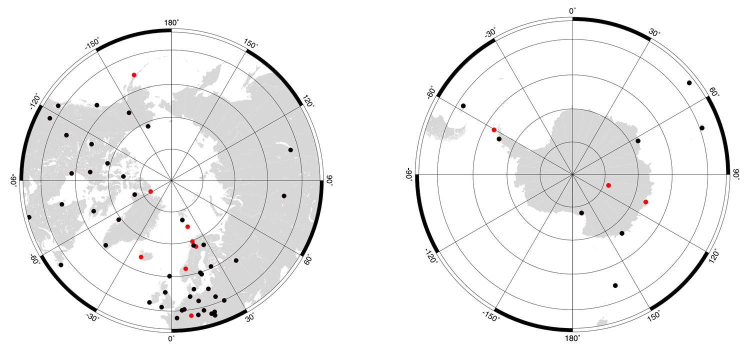
Improvement to satellite data weighting using LAVA indices

The LAVA (Local Area Vector Activity) index is designed to capture rapid external field variations particularly, but not exclusively, at high latitudes. By weighting the satellite vector data using this index 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 left**).

Originally only INTERMAGNET observatories were used to derive the LAVA indices, and also Vector Magnetic Disturbance (VMD) indices, but now they have been supplemented with non-INTERMAGNET observatories (**polar maps below** - black dots are INTERMAGNET observatories and red dots are other observatories recently added). This improves the quality of the satellite data weighting dependent on the LAVA indices and the VMD index used as input to the model to characterise the large-scale magnetospheric variations at 20-minute resolution. The satellite LAVA index for each sampled data point is interpolated from the LAVA indices from up to the 3 closest observatories with weighting by distance. The geographical distribution of the combined standard deviation and LAVA down-weight factors for X and Z CHAMP data is **shown below right**.

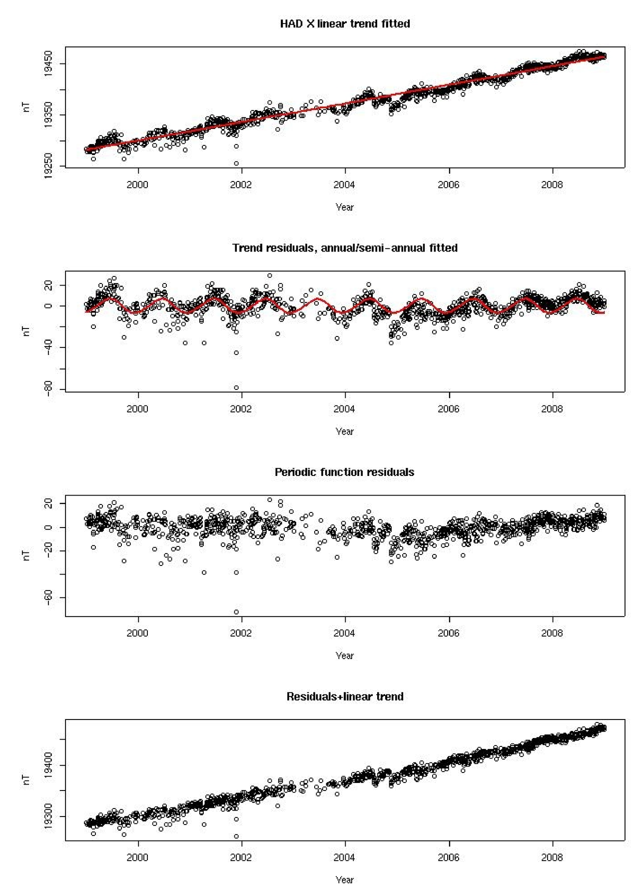




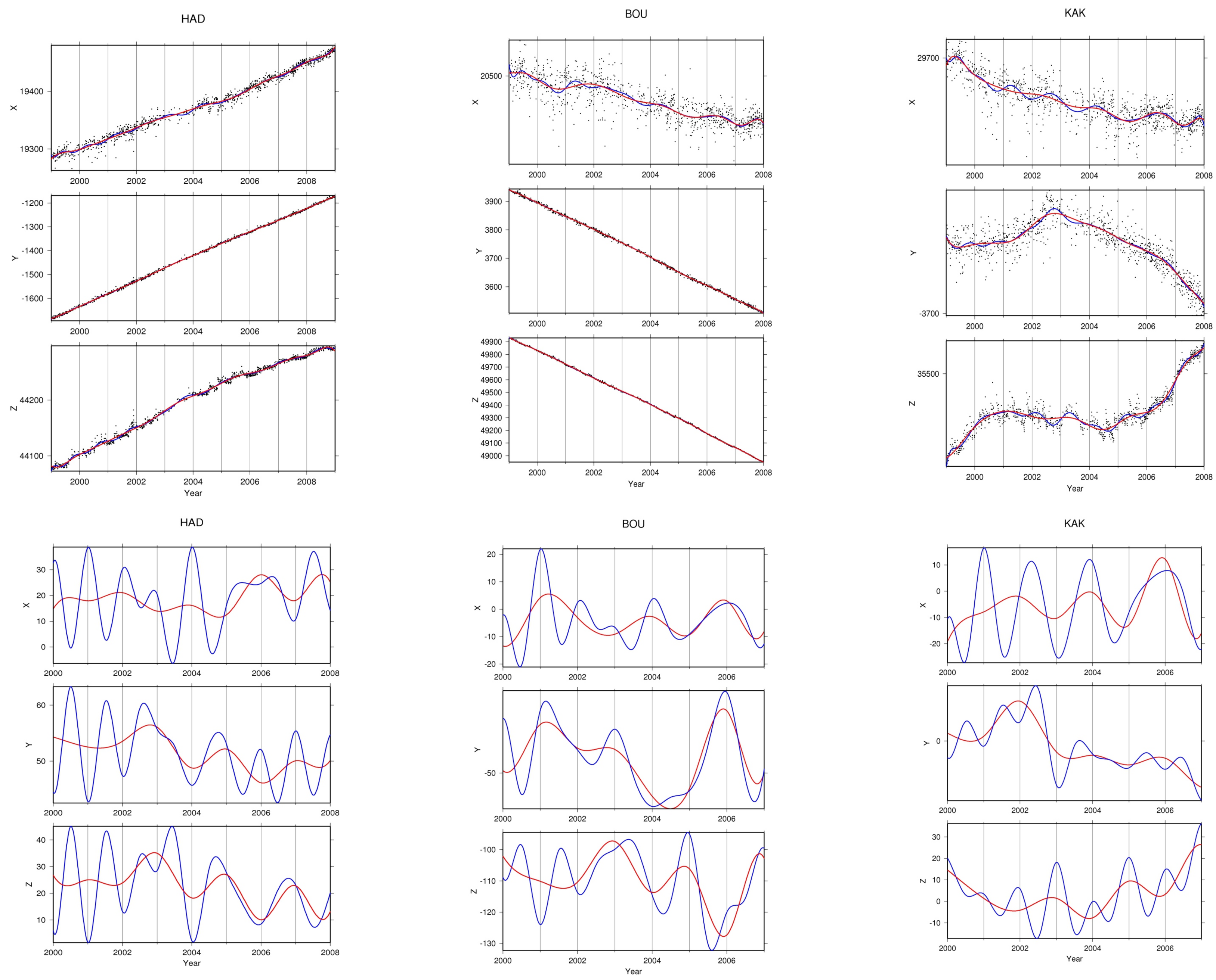


Use observatory data to determine model functions in the time domain?

Using observatory data selected in a similar way to the satellite data (Kp <=2-, |dDST/dt| <5, LT 0100-0200, IMF Bz>0), we can examine more closely the variations in the time domain. Quartic splines were fitted to each series of selected observatory hourly mean values from 1999 to 2008 (with annual and semi-annual variations removed as in the full spatio-temporal model there are parameters for these variations - **see plot right** for the X component at Hartland), and the knot positions were varied from 0.3 years to 3 years.



These plots show the quartic spline (**top**) and its first derivative (**bottom**) fitted to HAD, BOU and KAK selected data with annual and semi-annual signals removed, with knot interval 1 year (red) and 0.5 year (blue). Using 0.5 year knot interval results in unrealistic variations in SV. Whether this manifests itself in the full model where the spline is constrained by data from many observatories, as well as the satellite data, is not yet known.

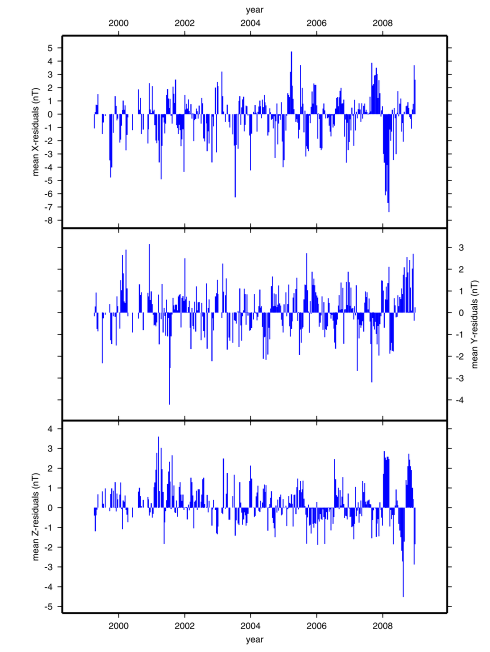


Model

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, with knot interval guided by results of analyses with observatory data as detailed above.

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 weighted misfit only increased from 1.27 nT to 1.52 nT.

Conclusions



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

Data with sources not fully modelled can be downweighted using LAVA indices at nearby observatories. Power spectra of resulting models are lower than those from other models.

The data selection criteria and knot interval for quartic splines used to model the internal field could be guided by analyses of observatory data.

More work required to produce BGS models which have an internal field continuous in the time domain.

Acknowledgements and References

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