A Global Crustal Field Model from Combined Ørsted and CHAMP Satellite Data (Model BGS/G/L/0406)

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A global lithospheric field model to spherical harmonic degree 60 is presented (BGS/G/L/0406). This model is based on a selection of quiet-time Ørsted and CHAMP satellite data from 2001-2005. We describe the internal and external field model parameterization that is required to best isolate the crustal field signature from the data set. A variety of quiet-time data selection issues are also examined and we analyze the distribution of measurement and model residual noise in a Sun-fixed coordinate system. We also comment on future work aimed at minimizing ionospheric fields in the polar caps, where the largest measurement noise is observed.

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Improved Data Selection Project Goals: (2005-2006)

Re-investigate the use of 'old' and 'new' magnetic indices to aid quiet satellite magnetic data selection
- low (*Dst*), mid (*Kp*) latitudes, polar cap (*PC*), auroral electrojet (*IE*) ...

Re-examine value of other "common" filters for satellite data
- vector latitude cut-off, night-side local time, solar wind data, solar zenith angle ...

Improve geographical and temporal data distribution
- filling gaps by iterative data selection inequal area tesserae.

Examine spherical harmonic spectra & make inter-model comparisons
- noise distribution, power spectra smoothness, inter-model coherency
- lithospheric field maps & geophysical/geological interpretation

Data

'Model A': Orsted and Champ data for 2001.0-2002.5
(relative comparisons, testing data selection methods)

'Model B': Orsted and Champ data for 2001.0-2005.0
(for final model: BGS/G/L/0406)

SH Parameterisation – *a non trivial external field*

n=60 internal model, linear SV to n=13

n=1 external model, linear SV
annual and semi-annual variation included,
Dste/Dsti, or VMD, instead of Dst dependence of external and internal (induced) dipole field
IMF By modelled in sun synchronous frame

weighting to equalise data in equal area tesserae; L1/L2 norm
no damping orregularisation

DataFilter	*Usage – Earliest? - Comments*
Kp	Everyone:Kp<2+orless
Am	CohenandAchache1990
A-sector	CohenandAchache 1990
AE	Ravatetal 1995:AE<50nT; AE only available upto1997
IMF Bz, By	LangelandHinze1998:Bz>0, symmetric By
|B residual|	Pass by passatsamegeographical location, Ravatetal: |B residual|^2<80 nT^2, Langeletal 1990: |B residual|<20nT;Alsdorfetal1994
LocalTime	Langel1990:1500-0900 nightside
Solarzenith angle	Select datawhenSunisbelowhorizon(ionosphericcurrents)
Dst	Commonuse from Magsatera onwards
RC	Olsen (fromobservatories inmidnightlow-latitude sector)
PC	Ritteretal2002
Em	Ritteretal2004:Em<0.8
IE	Ritteretal2004: onlyuseful+/-2hoursfrom Imagemagnetometer chain
VMD	Lesur2005,Dst comparison (better baselinecontrol?, finertime resolution)
Bperp	Vennerstrom2003,field component perpendicular tomainfield tracksFAC
dBy/dt	Proportional toFAC(Luhretal, 2003)forpolar orbit spacecraft

Index Data Used in Selection: Some Examples

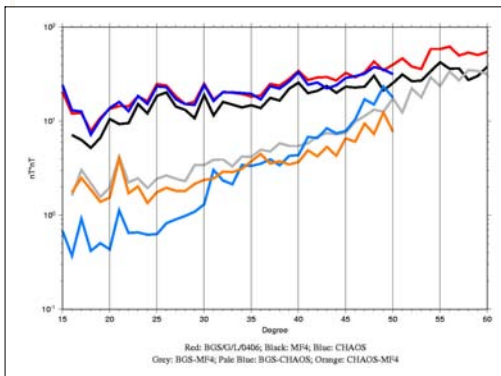
Index Issues:
- Quality & Calibration
- Baseline stability (e.g. *Dst*)
- Availability(e.g. *AE*, *PC*)
- Time Resolution (usually hourly mean at best)
- Location (e.g. equator/pole)

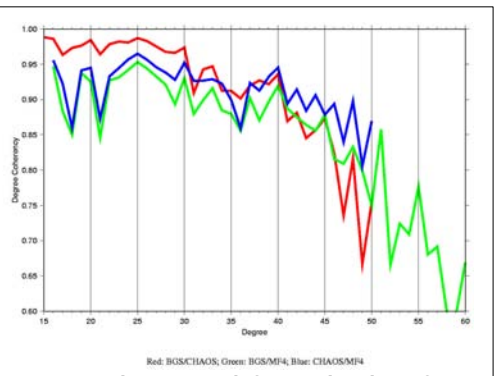
Data Selection Options: *What Is Best For Models?*

Bad: *X*
- Don't use *Dst*
- Nosuccess with testing d*By*/dt (a FAC proxy: J_{FAC}=0.106* d*By*/dt, e.g. Stauning *et al*, 2003)
- Very restrictive filters (e.g. *Kp*<1)

Neutral:
- Reducingmaximum vector latitude below 50 degree geomagnetic
- Zenith angle filterON for low and middle latitudes
- Projected-*F* (i.e. linear inverse problem), rather than |*B*|
- Small changes inthe ref. "pre-model" (e.g. IGRF+δg_{8n}^{m})

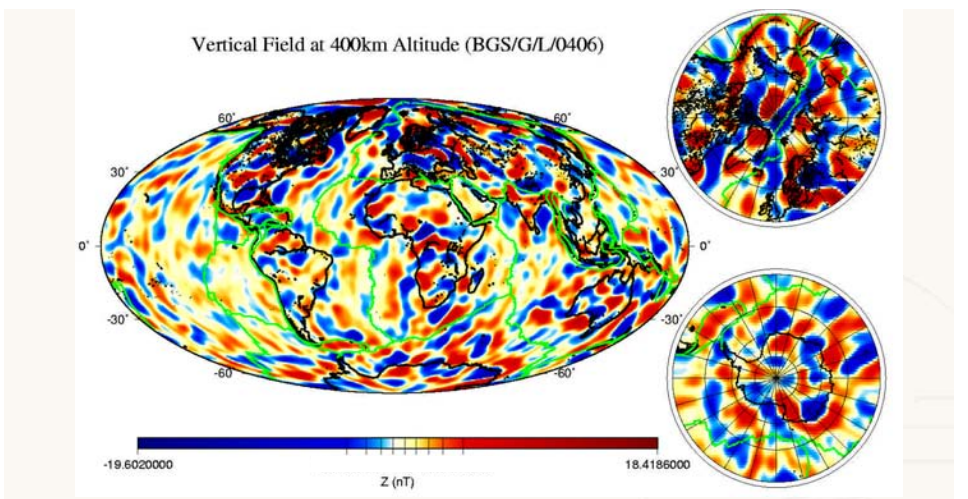
Good: ✓
- d*Dst*/dt, or d*VMD*/dt
- Vector data< 50 deg geomag.
- *IE* and *PC* indicesfor auroral andpolar latitudes,not *Em*
- Zenith angle ON and LT filter OFFat highlatitudes
- *Sector-A* and d*Dst*/dt at low/mid latitude
- L1 (Laplacian) residual norm
- 2 sigma filter w.r.t "pre -model"
- Iterative data selection to fill holes with slightly noisier data

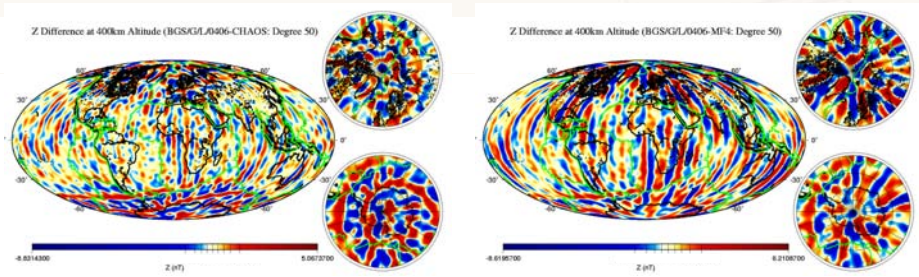


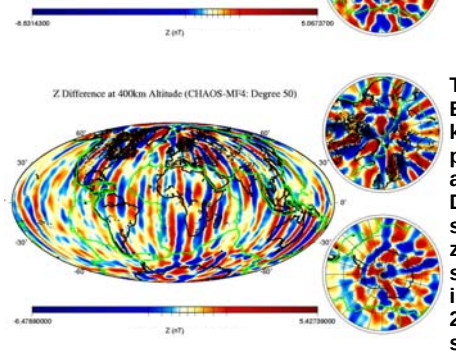


Power spectra (left) of BGS model BGS/G/L/0406 and other reference models. There is close agreement with the CHAOS model, for N<40, and spectral peaks and troughs are similar to MF4 (Maus *et al*), allowing for level difference to around N=55. Power spectra of model differences (pale blue, grey and orange) support these observations.

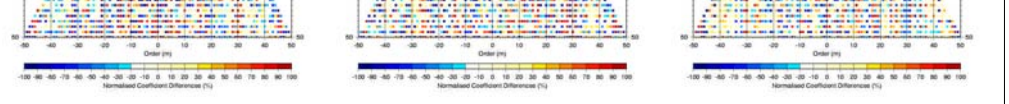
Degree coherence re-inforces the view of a good agreement between BGS/G/L/0406 and CHAOS (Olsen *et al*, 2006) certainly to degree 30. Above degree 40 the BGS model shows less coherence with the other models, possibly as a result of greater power in this model and the relatively simple external field model.







The top plot shows the vertical field from model BGS/G/L/0406 at 400 km (degrees 16-50). Many known lithospheric features are seen. The other plots show pairwise differences between the BGS and reference models at the same altitude. Differences with respect to CHAOS are a marked south polar anomaly field and "auroral zone" features at high latitudes. There is a significantly more complex external field model in CHAOS and there are no *PC* index data from 2003 onwards to constrain the BGS model at the south pole. With respect to MF4, differences are possibly more accentuated in the north-south direction. This is also true when comparing CHAOS and MF4.

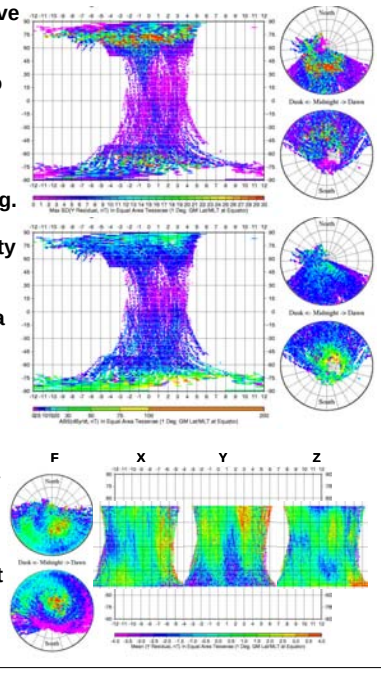


A sensitivity matrix analysis (coefficient differences normalised by average coefficient at each degree) demonstrates the close similarity between BGS/G/L/0406 and CHAOS below degree 30, apart from low orders (left). Vertical stripes are seen (centre) in comparing BGS/G/L/0406 and MF4, a pattern similar to (but larger than) that observed between CHAOS and MF4 (right).

The *Y* standard deviation (*SD*) is calculated over 20 successive 1-sec samples, centred on each Ørsted point used in the modelling and binned in 1 degree geomagnetic latitude and MLT tesserae (right). The minimum per bin is close to zero so the plot shows the maximum *SD* per bin. The *SD* is an indication of the *a priori* uncertainty for each sample used and reflects activity primarily in the auroral zone. *X* data are similar and *Z, F* are typically an order of magnitude smaller. Such data could be used as weight factors in future modelling.

Stauning *et al* (2003) estimate the field aligned current density from 0.1*d(By)/dt. The plot (right) shows this for Ørsted data, binned and averaged in 1 degree GM Lat/MLT tesserae. The main active regions are pole-wards of the *SD* plot. These data could be used as a selection criterion in future models.

The plot to the right shows BGS model misfit (data-model) in a sun fixed system (GM latitude and MLT). *X* is dipole north and *Z* is vertically down in this system. The *X* and *Z* plots are shown displaced w.r.t. *Y* for clarity, but cover the same range of MLT. There are clearly large scale features not captured by the simple BGS/G/L/0406 external model. We note that the positive *F* in both polar hemispheres could be consistent with a tail field that is towards the Earth in the north (same sense as main field) and away in the south. The *Z* component also shows this feature (positive down to Earth in north, and negative away in south) at mid latitudes, and near midnight. Consistent with this is largely +ve *X* field in the same region.



Further Developments

Have we exhausted the scope of geomagnetic & other indices for 'quiet-time' satellite magnetic data selection ?

Not quite …

New Indices/Data

Wider longitude Auroral zone monitor – *raid the INTERMAGNET database?*

Problems in southern polar cap using PC – *revision of PCS dataset?*

Otherwise we will try …

1. Data weighting

A priori weighting of data at high latitude – e.g. *using noise model (sample SD)?*

2. More Comprehensive Model Parameterisation

Particularly external field, because of misfit – *polar ionosphere + tail currents*