A geomagnetic field model for year 2001 with daily estimations of dipole terms

Vincent Lesur, Alan Thomson and Susan Macmillan
(British Geological Survey, West Mains Road, Edinburgh EH9 3LA Scotland. Contact: V.Lesur@bgs.ac.uk)

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ABSTRACT
We describe derivations of spherical harmonic models of the main field (up to degree/order 20) and its secular variation (up to degree/order 10) using a full year of Ørsted data and applying new modelling techniques for degree 1 internal and external Gauss coefficients. The magnetospheric contributions and the internal dipole Gauss coefficients are re-calculated for each day where there are sufficient data, and therefore, there is no need to introduce annual/ semi-annual periodicity or the Dst index to describe the fast variations in time of these terms. The data set used consists of year 2001 Ørsted data, augmented for one model, with observatory data. The models are estimated using an iterative re-weighted least-squares algorithm to account for non-Gaussian data error distributions. Comparisons are made with the usual approach where the magnetospheric contributions are modelled up to degree/order 2; the zonal external terms varying with annual/semi-annual periodicity and the degree 1 external and associated induced internal terms modulated using the Dst index. Preliminary results indicate improvements to the fit to the data when this new technique is used.

Acknowledgements: We would like to thank the Ørsted science teams for the provision of these data.

1 MOTIVATION

The fast and very long variations in time of the external magnetic field and associated induced field in the Earth, are not well modelled by a combinations of annual/semi-annual and Dst dependence of the first internal and external Gauss coefficients. A consequence is, for example, that further filtering techniques need to be applied to the data for modelling the magnetic field that has its origin in the Earth's lithosphere. Using the Dst index to estimate over long periods of time a portion of the field generated in the magnetosphere is questionable since the base-line of this index is defined as a power series in time up to degree 2 where coefficients are calculated by least squares over five years of data. Similarly, the Dst index represents the axially symmetric disturbance field relative to the dipole axis, which may not be the same as the rapid variations in time of the magnetospheric field. The alternative approach we are presenting here estimates the first degree internal and external Gauss coefficients on a daily basis.

3 RESOLUTION

The formal Standard Deviation Estimates (SDE) of the zonal internal and external Gauss coefficients of degree 1 computed for each day (model 1) can be compared with the SDEs of the same Gauss coefficients computed for a full year with secular variation, Dst & annual/semi-annual dependence (model 2). Figure 1 & 2 show these SDEs for internal and external zonal Gauss coefficients respectively where Dst_av is the average Dst over a day. Clearly, the G10 and Q10 terms computed in model 1 are as robust as those computed in model 2.

In model 1, the estimates of the non-zonal Gauss coefficients of degree 1 (i.e. G11, H11, Q11, S11) are not reliable because we cannot separate space and time variations of the external magnetic field with only one day of data and using a narrow 6 hours local time window. Using all local times would solve the problem but then we may have to model the ionospheric field and variations in a

Figure 1

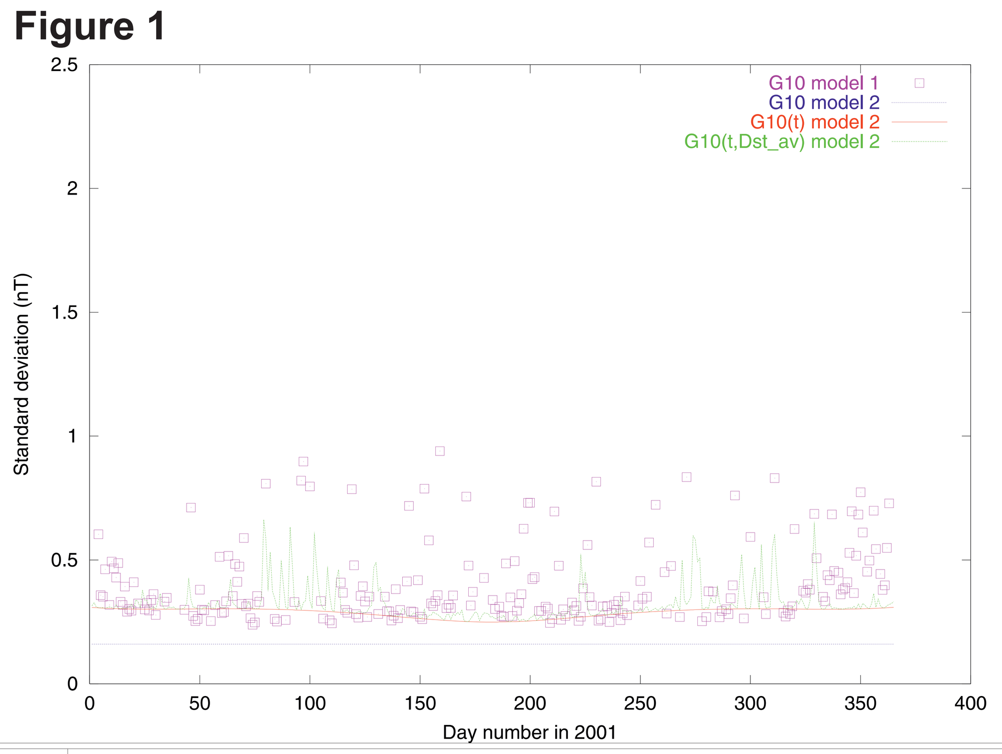
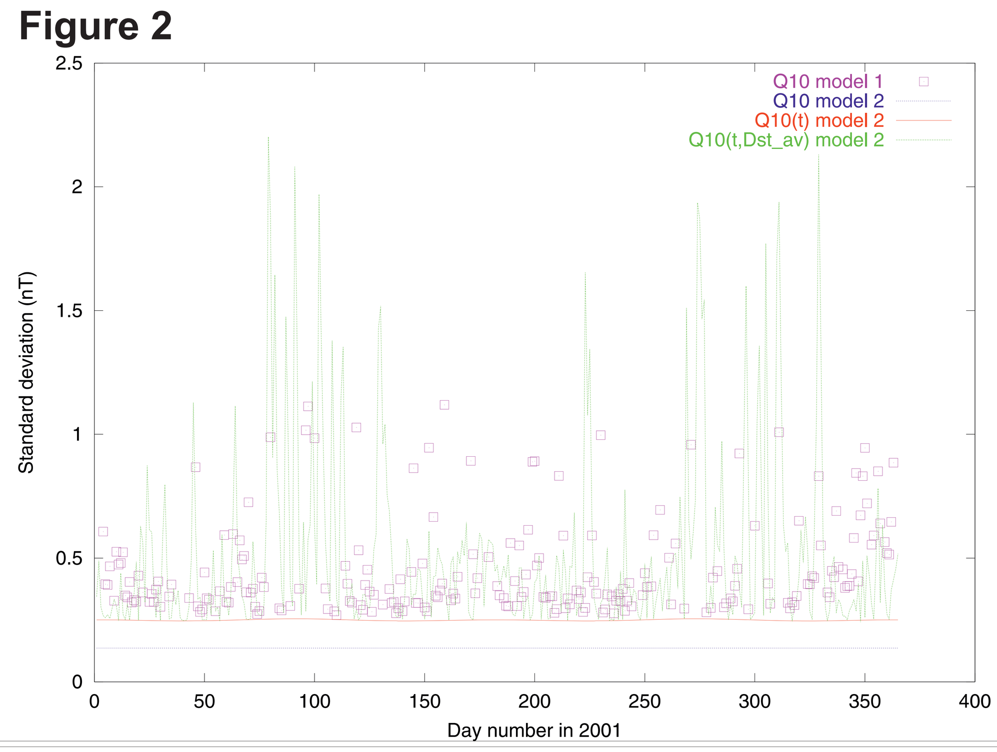


Figure 2



4 COMPARISON OF GAUSS COEFFICIENTS

Figures 3 & 4 present the zonal Gauss coefficients of degree 1 computed in model 1 and 2. In figure 3, The spline fit to the G10 terms computed with model 1 roughly agree with the G10(t) computed with model 2 where variations in time are calculated using the linear secular variation coefficient and the annual/semi-annual dependence. However when the day-averaged Dst is introduced, the G10 are over-estimated in model 2 compared to model 1. In figure 4, the results are the opposite: spline fit and Q10(t) are different whereas there is a rough agreement in Q10 values estimated for both models when the averaged Dst is introduced. It seems that in model 2, when Dst index is used, the fit to the field induced in the Earth is lost for a better fit to the magnetospheric field.

Figure 3

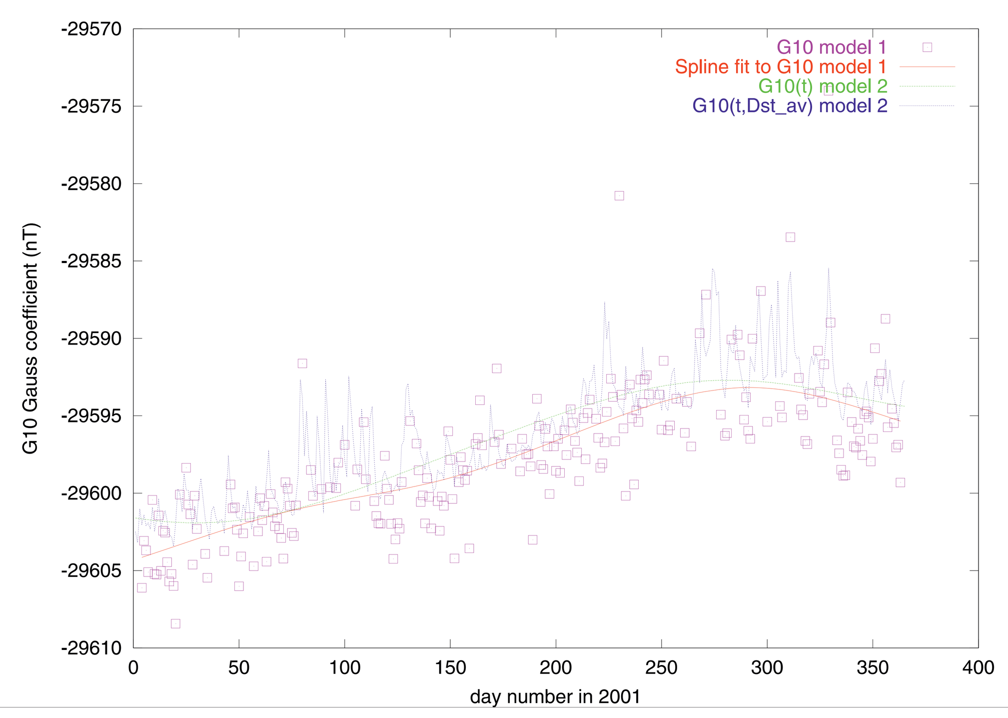
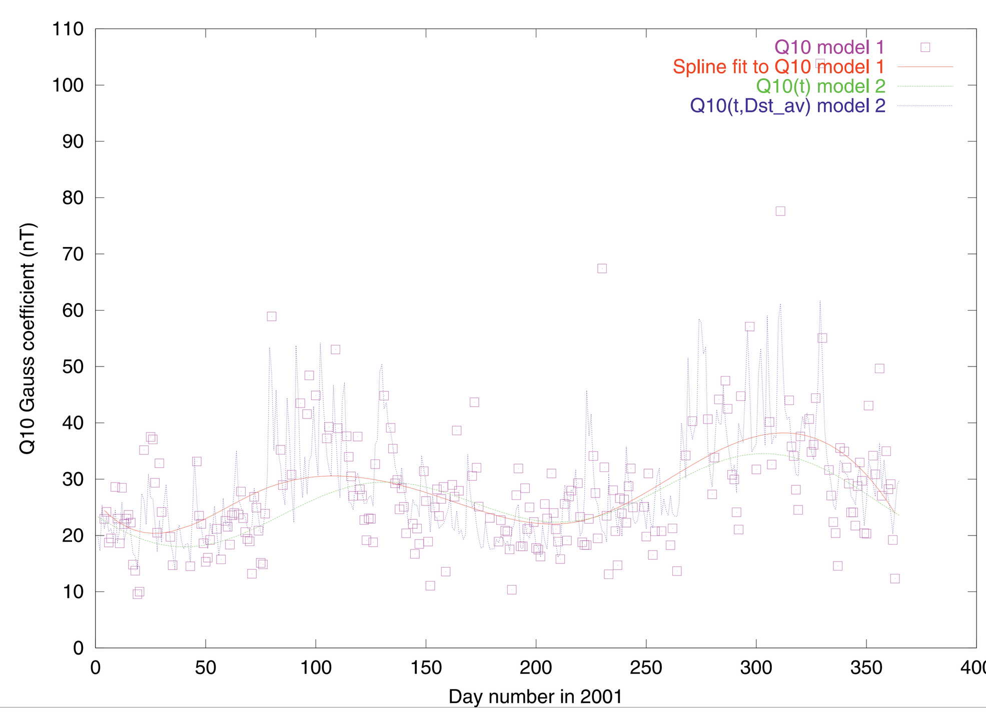


Figure 4



2 DATA SELECTION AND MODELS FOR YEAR 2001

- Satellite data downloaded February 2003
- Scalar and vector Ørsted data
- Hourly mean observatory data from 119 locations
- 23:00 to 05:00 LT
- *Kp* < 3, -80 nT < Provisional *Dst* < 20 nT
- Satellite and observatory data are rejected for sunlit ionosphere
- Scalar sat. data only over 60° geomag. Lat.
- Scalar obs. data only over 50° geograph. Lat.
- ACE Solar Wind Speed < 500 km/s
- |Interplanetary Field| < 10 nT in all components and Bz > -2 nT
- In a day, satellite and observatory data are rejected if less than 90 observatories contribute to the data set.

Data are fitted using re-weighted least-squares algorithm and L1 (Laplacian) measure of the misfit. Model comprises spherical harmonics up to degree 20 with linear dependence on time for coefficients up to degree 10 and observatory crustal offsets. Anisotropic error distribution is included for Ørsted vector data.

Model 1: External field modelled with degree 1 only. External and internal degree 1 Gauss coefficients estimated daily for 227 days in 2001. After convergence the final weighted misfit is: 1.46 nT

Average X satellite	residuals:	0.8 nT	with rms 7.1 nT
Average Y satellite	residuals:	0.4 nT	with rms 7.0 nT
Average Z satellite	residuals:	-0.2 nT	with rms 4.2 nT
Average F satellite	residuals:	-0.2 nT	with rms 5.2 nT
Average X obs.	residuals:	-0.2 nT	with rms 8.4 nT
Average Y obs.	residuals:	0.0 nT	with rms 4.9 nT
Average Z obs.	residuals:	-0.1 nT	with rms 3.8 nT
Average scalar obs.	residuals:	-0.5 nT	with rms 16.5 nT

Model 2: External field modelled up to degree 2. Dst dependence of the degree 1 external field with associated induced internal field. Annual and semi-annual dependence of the zonal coefficients of degree 1 and 2. After convergence the final weighted misfit is: 2.23 nT

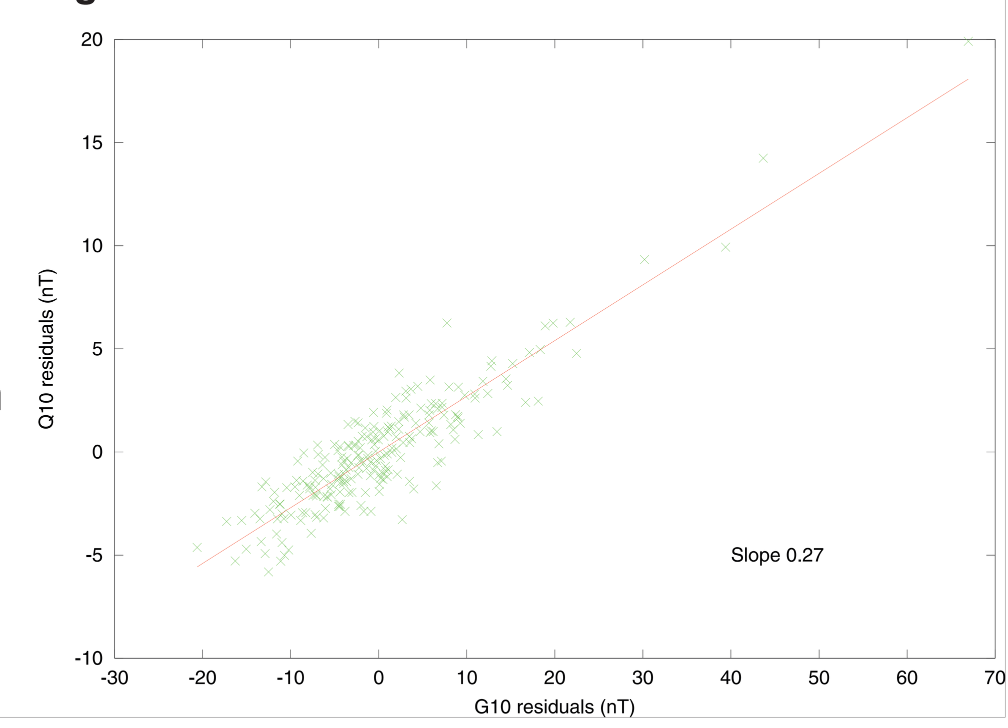
Average X satellite	residuals:	0.9 nT	with rms 9.6 nT
Average Y satellite	residuals:	0.4 nT	with rms 7.6 nT
Average Z satellite	residuals:	-0.1 nT	with rms 6.1 nT
Average F satellite	residuals:	0.1 nT	with rms 13.9 nT
Average X obs.	residuals:	-0.7 nT	with rms 14.0 nT
Average Y obs.	residuals:	0.1 nT	with rms 5.0 nT
Average Z obs.	residuals:	0.0 nT	with rms 3.7 nT
Average scalar obs.	residuals:	-8.2 nT	with rms 35.2 nT

5 OTHER RESULTS

The rapid variations in time of the external field induce a rapidly varying internal field. The ratio of the external rapidly varying Q10 over the internally induced G10 was found by Langel & Estes to be 0.27 and this value is used in model 2. In model 1, the residuals to the spline fit to Q10 shown in figure 4 plotted as a function of the residuals to the spline fit to G10 shown in figure 3, present a linear trend whith slope 0.27 (see figure 5). This is a confirmation of Langel & Estes results for the Ørsted satellite.

The other internal and external degree 1 Gauss coefficients computed in model 1 can be shown, on demand, by the presenting author. The same Gauss coefficients, calculated from 23/04/1999 to 16/11/2002 using only satellite data, can be shown.

Figure 5



6 Conclusion

- There is an improvement in the fit to the data in model 1 relative to model 2.
- When observatory data are included, there are enough data to resolve degree 1 internal and external Gauss coefficients on a daily basis.
- A better separation of time and space variations of the non-zonal degree 1 Gauss coefficients would be obtained by using all local times.
- The ratio of rapidly varying Q10 Gauss coefficients over the associated induced G10 Gauss coefficients is found to be 0.27.

Further Work:
The use of daily variations of the degree 1 external and internal Gauss coefficients is not sufficient to describe the variability of the magnetospheric field and its associated induced field. An alternative approach would be to use all local time data and, over a day, a spline representation in time of the degree 1 external and internal Gauss coefficients. From the results above, it seems that we will have enough data to solve for such a model but we may have to solve for the field that originates on the ionosphere as well.