British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

XXIV IUGG General Assembly
Perugia, Italy July 2007
Session: ASV035 Poster: 10036

Using observatory data to characterise geomagnetic daily variations

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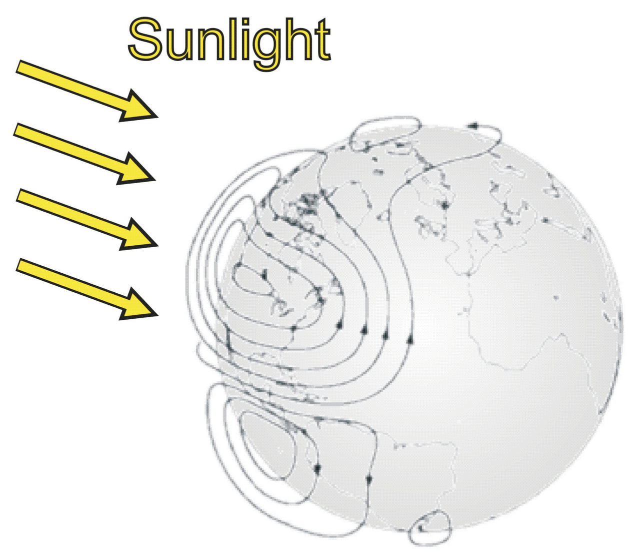


Fig. 1: Cartoon of ionospheric current vortices during northern hemisphere summer. (Adapted from http://geomag.usgs.gov/intro.php)

Summary

We use data from several geomagnetic observatories to derive a series of Fourier harmonic models of the daily magnetic field variations. We form the models from datasets comprising selected numbers of International Quiet Days from each month, from different years in the solar cycle, and across a range of geomagnetic latitudes. The performances of the models are assessed by comparing their predictions with the input data. We comment on the improvement in daily magnetic field estimates over purely main field models for different seasons, solar cycle phases, and geographic latitudes. We also investigate how the models depend on the number of International Quiet Days used. Comparisons are made with the Comprehensive Model version 4; a global model that, unlike our approach, separates ionospheric sources using satellite data as well as observatory data.

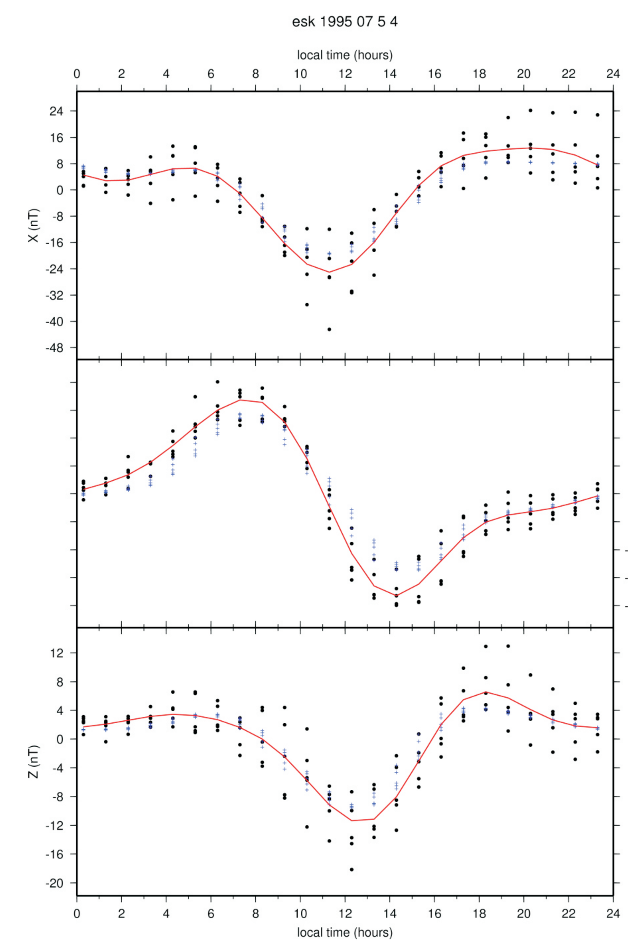


Fig. 2: Example of daily variations in X (top), Y (middle), and Z (bottom) components of data from Eskdalemuir on 5 quietest days in July 1995 (black dots). Red lines are our FHM derived from the data, blue crosses are hourly values derived from the comprehensive model.

Introduction

The daily variations in the Earth's geomagnetic field are caused by (primarily) ionospheric as well as magnetospheric currents. Ionospheric current vortices in northern and southern hemispheres (fig. 1) arise from interaction of free charges (produced by solar EUV and SXR) with thermospheric winds. Current systems remain on sunlit side of Earth and cause regular daily variations in geomagnetic field as observatories rotate beneath (fig. 2).

Daily variations depend on solar illumination and so also on: latitude, season, and the ~11 year solar cycle. In this poster we explore how Fourier harmonic models of daily variations depend on these parameters.

Fourier harmonic models (FHMs)

Our models are derived from least-squares-fits of truncated Fourier series X (northward), Y (eastward), and Z (downward) components as the geomagnetic field:

$$B_t = a_0 + \sum_{n=1}^{4} a_n \cos\left(\frac{2\pi t}{nT}\right) + b_n \sin\left(\frac{2\pi t}{nT}\right)$$

where t is time, a_0 is average value of data, a_n and b_n are Fourier coefficients and T is fundamental period (24-hours). We follow previous FHMs (e.g. Campbell, 1989, Barraclough, 1989) and use the first 4 terms (which dominate, see e.g. Campbell, 1997).

Data used

Hourly mean values of X, Y, and Z were taken from northern hemisphere Intermagnet observatories over the range of latitudes and dates shown in Table 1.

Observatory	Latitude	Time-span
Eskdalemuir	55.3°	1980-2001
Ottawa	45.4°	1980-2000
Kakioka	36.2°	1980-2000
Honolulu	21.3°	1980-2000
M'Bour	14.4°	1980-2000
Bangui	4.3°	1980-2000

Table 1. Observatories and time-span of data used in models.

Data sets were formed for each month using a specified number of International Quiet Days (ISGI, 2007). Before fitting model coefficients, data were linearly de-trended. For results that are stacked by latitude, FHMs are shifted from Universal to Local Time.

Comprehensive model version 4 (CM4)

We use CM4 (Sabaka et al., 2004) for comparison. CM4 differs from our models. It is global, derived from 4-decades of satellite and ground measurements; it separates out sources of geomagnetic field (including ionosphere and magnetosphere). Spatial and temporal dependence is derived from vector and scalar data and the $F_{10.7}$ solar radio flux is used as proxy for solar activity.

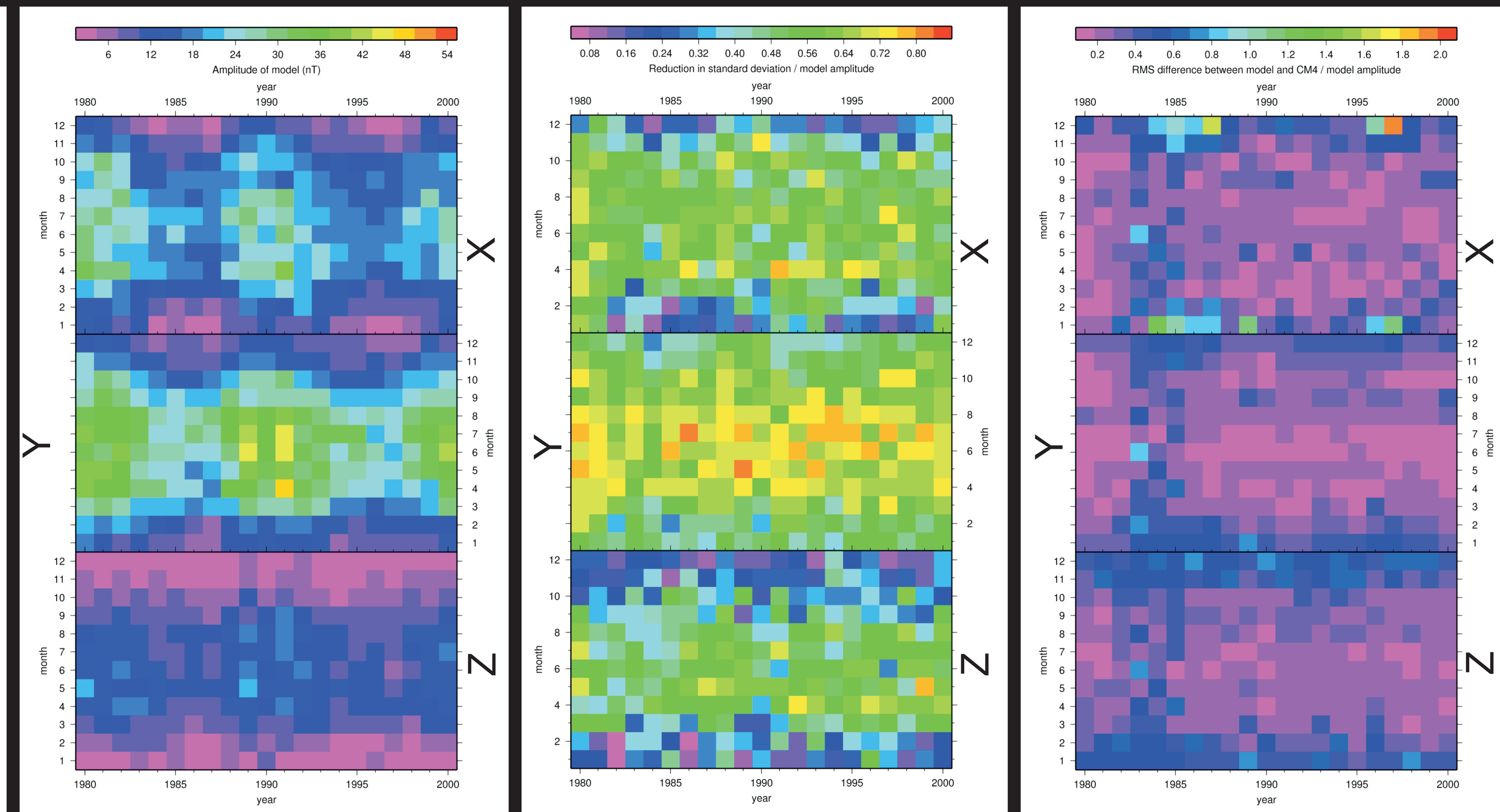
Unlike our models, observatory data is from quietest day of month and satellite data when $K_p<1^+$.

Amplitude of model

Reduction in standard deviation of data (after model subtracted) as fraction of model amplitude. Larger values imply better fit to data.

Root-mean-square difference between our model and CM4, as a fraction of the model amplitude. Lower values imply better agreement.

Results by year & month
Data from Eskdalemuir. Input data to model comprises of 5-quietest days in each month.

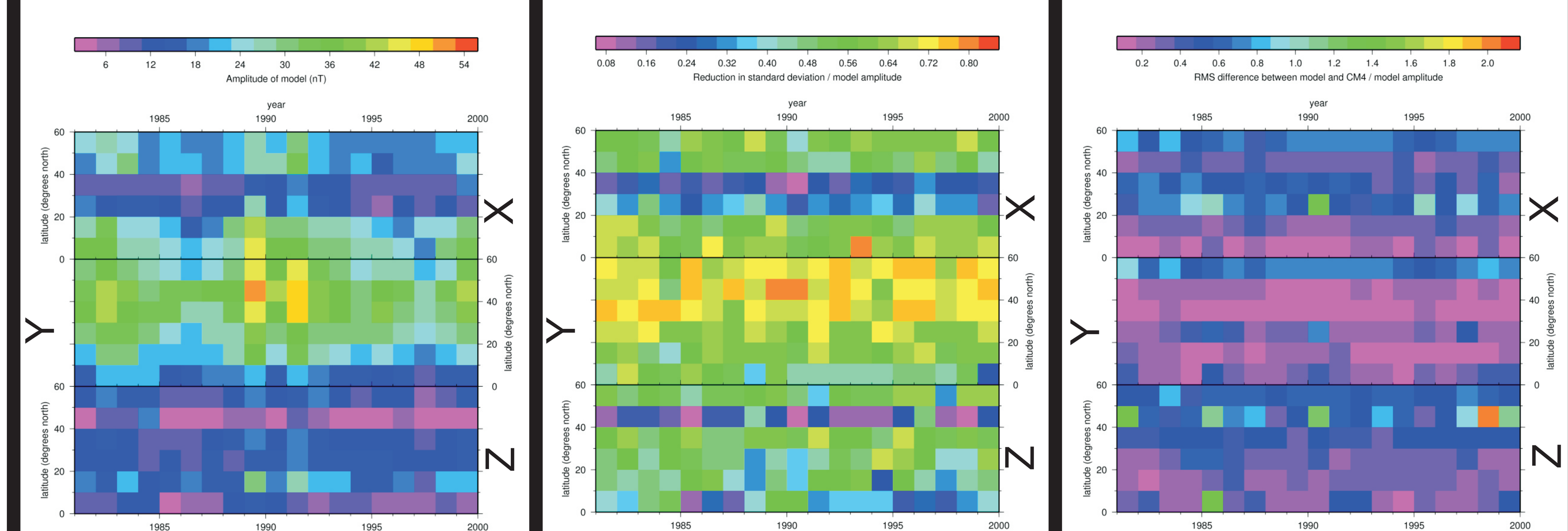


Amplitude (left column):
- Clear dependence on ~11 year solar cycle and season.
- Amplitude peaks during summer/solar-max and minimum at winter/solar-min.
- Seasonal variations dominate over solar-cycle.

Goodness of fit (middle column):
- Best in summer (largest amplitude) but little solar cycle dependence.

Compare with CM4 (right column):
- Agreement best in summer (following amplitude)
- No obvious solar cycle dependence
- Larger discrepancy around 1984.

Results by year & latitude
Data taken from June. Each latitude-row represents data from one observatory.



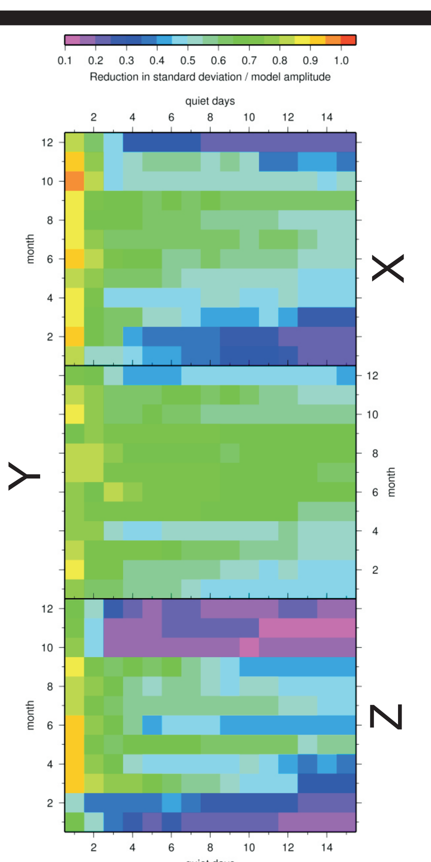
Amplitude of model:
- Clear latitude dependence.
  - Components behaviour consistent with current vortex (see fig. 1):
  - X peaks at higher/lower latitudes
  - Y peaks at mid latitudes.
  - Z more mixed.
- Latitude dependence dominates solar cycle dependence.

Goodness of fit:
- Best fit corresponds to largest model amplitude (best signal/noise).

Compare with CM4:
- Generally best agreement where signal strongest (largest amplitude).
- But not so good at higher latitudes (worse signal/noise)?

Generally, models avoid more active days (e.g. Campbell, 1989) or assume linear relationships with D_{st} and $F_{10.7}$ (Sabaka et al., 2004). However, activity cut-off is somewhat arbitrary. Here, we look at effect on 'goodness of fit' of varying quiet-days used.

- Goodness of fit falls quickly with increasing quiet-days due move from fitting one fundamental-period to best-fit of multiple periods.
- Subsequent quiet-days result in slower drop off due to increased activity degrading signal/noise.
- Summer months' signal/noise drops more slowly than winter's.



Results by quiet-days & month
Data taken from Eskdalemuir. Input data to model comprises selected quietest days in 2001.

Conclusions

- **Our results find variations in amplitude of model with season and latitude, and to a lesser extent with solar cycle.**
- **Or models' 'goodness of fit' generally follows model amplitude and indicates improved daily-variation-signal/noise in summer.**
- **Solar cycle appears to have smaller effect than seasons on the quality of the fit.**
- **'Goodness of fit' varies with latitude differently for each component.**

Future work

- **Use data from more observatories to get better statistics on results.**
- **Incorporate into future global models to obtain more accurate field predictions.**

References

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Acknowledgements

We thank the operators of the observatories whose data we have used (BGS, GSC, USGS, IRD, MRI).