British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Forecasting Secular Variation from CHAMP to Swarm

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The ability to generate accurate forecasts of magnetic field change over a five year period is an active area of research. Models of the main field and its secular variation (SV) have been relatively poorly constrained without global high-quality vector satellite data during the three year period from the de-orbiting of CHAMP to the launch of Swarm. We examine forecasts of main magnetic field change between 2010.0 and 2014.0 using the latest BGS field model based partly on the first data from Swarm (see accompanying poster by Macmillan and Hamilton), which for the purposes of this analysis, we regard as the 'true' model.

We compare the forecasts of the International Geomagnetic Reference Field (IGRF) and World Magnetic Model (WMM), both released in late 2009, to our main field model to establish how close each one is to the 'true' variation of the field over the past four years. We also show the comparison to the SV forecast from a steady core flow and acceleration (SF/SA) model using magnetic data from 2007-2010. In addition, we show the comparison with the recently released DMSP-MAG-1.

1. Main Field and SV Models

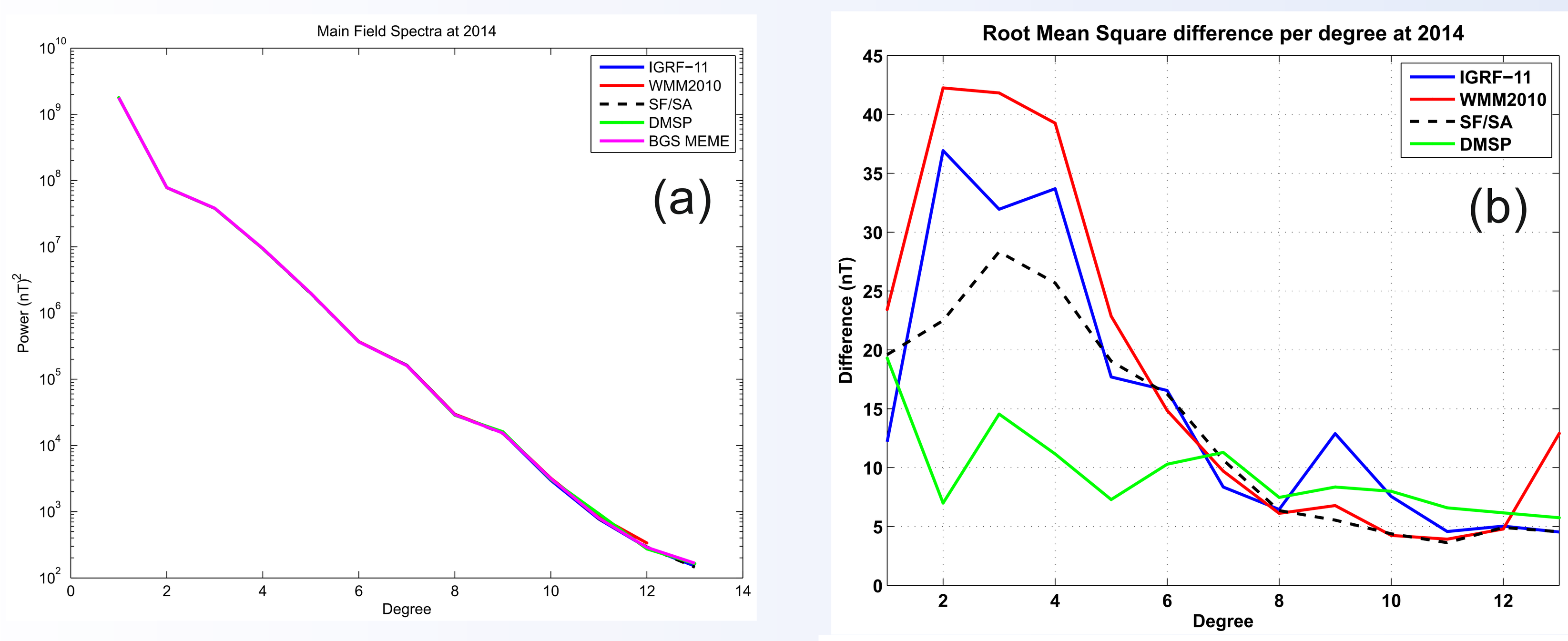
We use the Gauss coefficients (up to degree and order 13) computed for 2014 from five different models in this analysis:

- **BGS MEME**: Derived from CHAMP, Ørsted, Swarm and observatory data [1]
- **IGRF-11**: International Geomagnetic Reference Field (2010-2015) [2]
- **WMM2010**: World Magnetic Model (2010-2015) [3]
- **DMSP-MAG-1**: Defence Meteorological Satellite Program data [4]
- **SF/SA**: SV forecast based on a steady core flow and acceleration model [5]

The BGS MEME model is assumed to represent the 'true' field at 2014.0. The WMM and IGRF models are quinquennial models defined at 2010 with an estimate of annual SV for five years. The DMSP-MAG-1 model is derived from magnetometer measurements on the Defence Meteorological Satellites and valid at 2012.0 with a SV and secular acceleration estimate. The SF/SA model is an SV forecast derived from a steady core flow and acceleration model. The magnetic data used to create the SV model are from CHAMP and observatory data over 2007-2010. The SF/SA model for 2014 was created by using the IGRF-11 model at 2010.0 and advecting the core field forwards for 4 years (e.g. see [Ref. 5]).

Each forecast model was compared to the BGS MEME model. The standard metrics are assessed: power spectra, root-mean-square differences, degree correlation (Figure 1) and maps of spatial differences (Figure 2).

2. Spectral Analysis at 2014.0



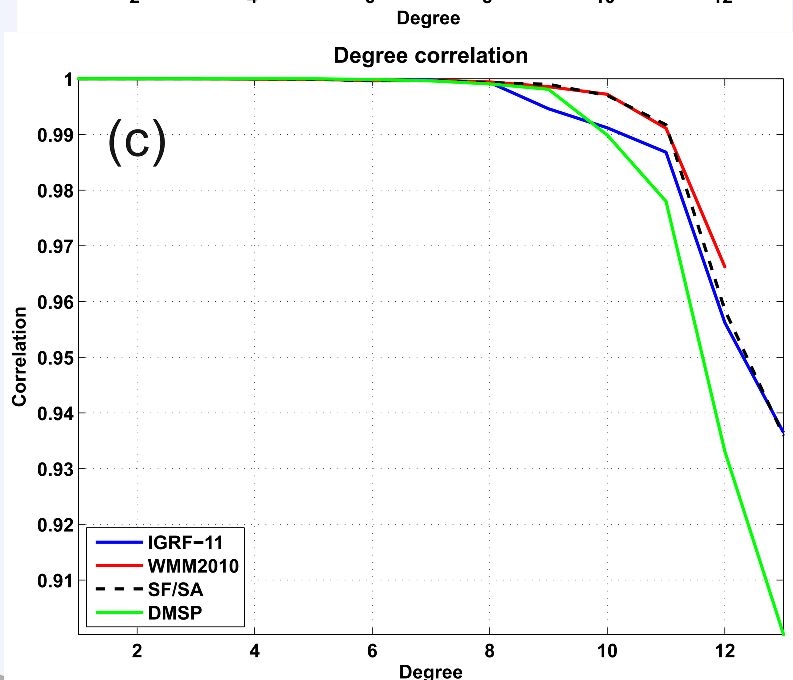


Figure 1: (a) Power spectra at 2014.0. (b) Root mean square difference per degree between each model and the BGS MEME model at 2014. (c) Degree correlation between each model and the BGS MEME model at 2014.

3. Spatial Analysis at 2014.0

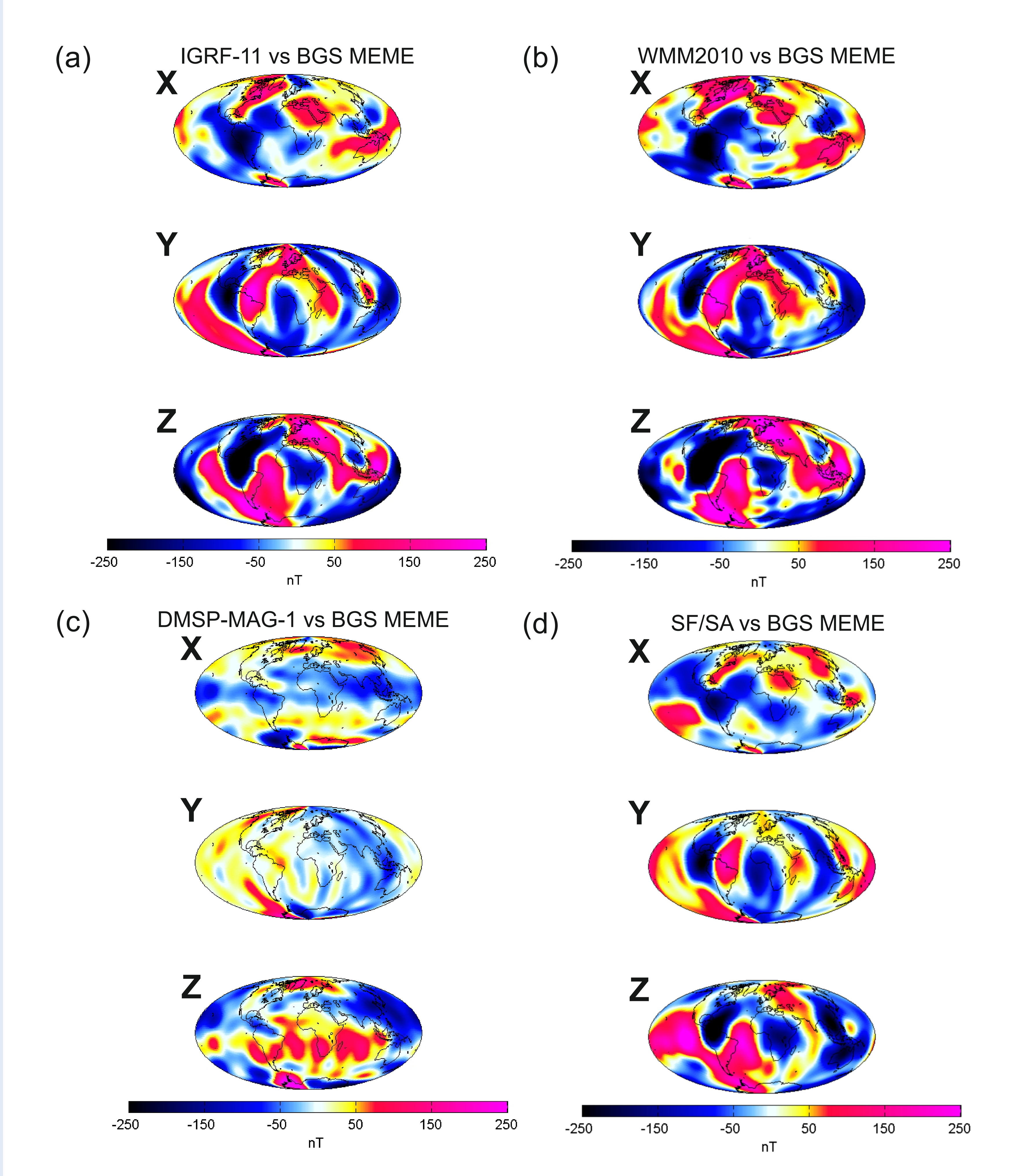


Figure 2: Spatial differences in the magnetic field between the BGS MEME model and (a) IGRF-11 (b) WMM2010, (c) DMSP-MAG-1 and (d) Steady Flow and Acceleration (SF/SA) forecast in the X (North), Y (East) and Z (Down) components.

4. Discussion / Conclusion

In Figure 1 the spectral analysis indicates that changes in degrees 2–4 are relatively poorly captured by WMM2010 and IGRF-11, while the SF/SA model tends to be better than both over all degrees. The DMSP-MAG-1 model performs best, which is unsurprising, as it is based on magnetic data up to 2013.5.

Figure 2 illustrates the spatial differences compared to BGS MEME. Again the IGRF-11 and WMM2010 have the largest differences, with similar patterns of mismatch. The SF/SA model shows smaller misfit in the X and Y components than the former. The DMSP-MAG-1 model has its largest differences in the Z component.

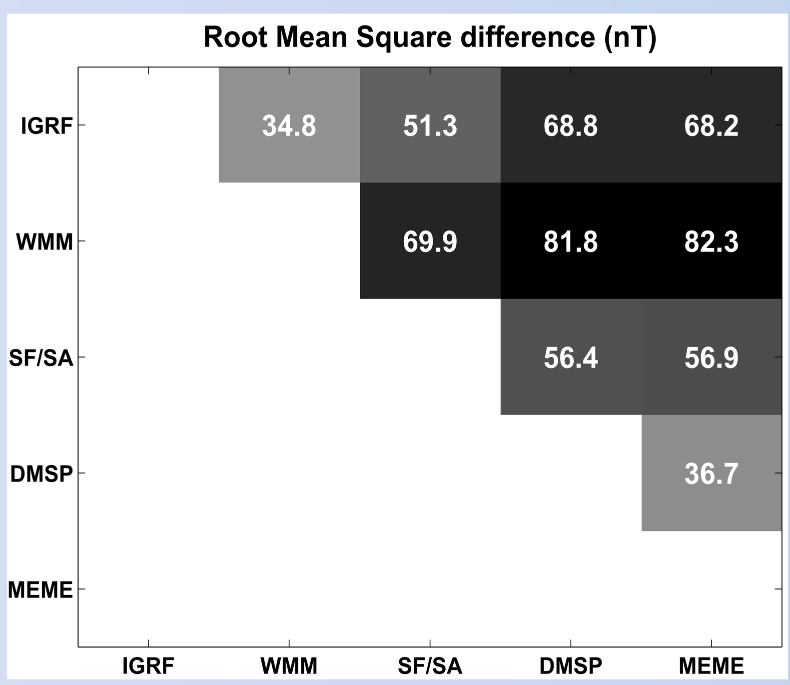


Figure 3: Root mean square differences between the five models at 2014.

Figure 3 shows the RMS differences between each model. The largest value (82.3 nT) is for the differences between WMM2010 and the BGS MEME model. The IGRF-11 has a slightly smaller difference (68.2 nT) while the SF/SA model has a difference of 56.9 nT.

Our conclusion is that the forecast from the SF/SA model has a smaller difference at 2014.0 when compared to the 'true' model than either IGRF or WMM.

References

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