Evaluation of candidates for IGRF-10, including a retrospective assessment of IGRF-9 SV models for the 2000-2005 period

(Stefan Maus, NGDC, 17-Nov-04)

Recognizing that certain spherical harmonic (SH) coefficients are particularly difficult to estimate and predict, the following study focuses on the actual coefficients. The first two figures show the deviations of all coefficients from the mean. Then, the secular variation proposed for selected coefficients G10, G11, H11, G22, and H33 is displayed in the context of their long term behavior since 1960.

Further insight can be gained from the retrospective evaluation of the IGRF-9 SV candidates. The analysis shows that quadratic model predictions fared better than linear ones. Also, while the discarded Izmiran-1 model was indeed the worst model, including it would have actually improved the IGRF-9 SV model.

Coefficient differences from the mean

The coefficients for IGRF and SV candidates were compared against the straight averages of models A1, B3, C1 and D1. The coefficients were numbered 1=G10, 2=G11, 3=H11, 4=G20, etc.

Main field in 2005

Figure 1 shows the candidates for the main field in 2005. Model groups A and B are similar, while C and D exhibit larger differences to the mean. The deviations of models C and D are not consistent and appear almost anti-correlated. A spike in coefficient G30 for models A is due to a correction for presumed ionospheric induced fields on the night side, which was not applied by the other groups.

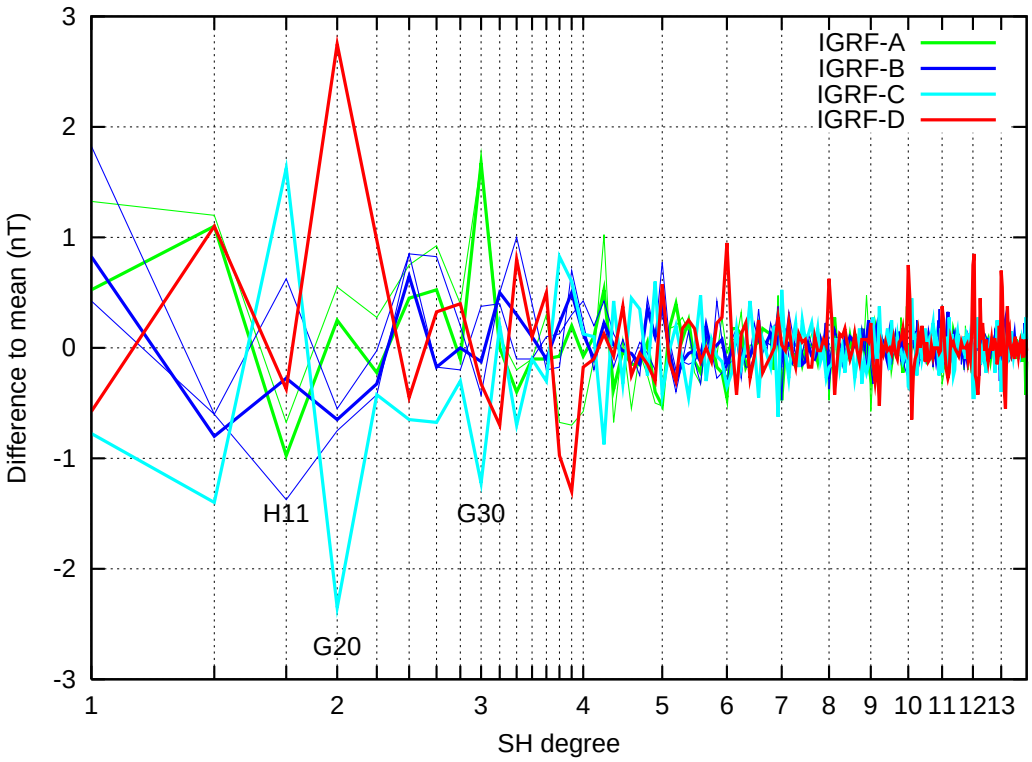

Figure 1: Coefficient differences to the mean of models A1, B3, C1, and D1. The thin lines represent models A2, B1 and B2 which are multiple submissions by the same groups.

Secular variation 2005-2010

Figure 2 shows the candidates for the secular variation 2005-2010. In this case, no particular group of models stands out. However, the model SV-B1, based solely on CHAMP data, is quite different from the rest. This difference could have several reasons, in particular:

(1) It could be due to the attitude uncertainty in CHAMP data, even though a correction for this effect was applied

(2) There could be a genuine recent change in the secular acceleration, which is not detected by the other models because they either do not include the secular acceleration, or they include data prior to 2000.5.

To verify possibility (2), a Oersted-only model with data after 2000.5 is included as a yellow line in Figure 2. This model has a higher noise level, probably due to the poorer data coverage of the late Oersted data. However, it appears to confirm the CHAMP result, suggesting that this difference is due to a genuine recent shift in secular acceleration. For the coefficient H33 there is a significant difference between model groups A/D and B/C which is further illustrated in Figure 7.

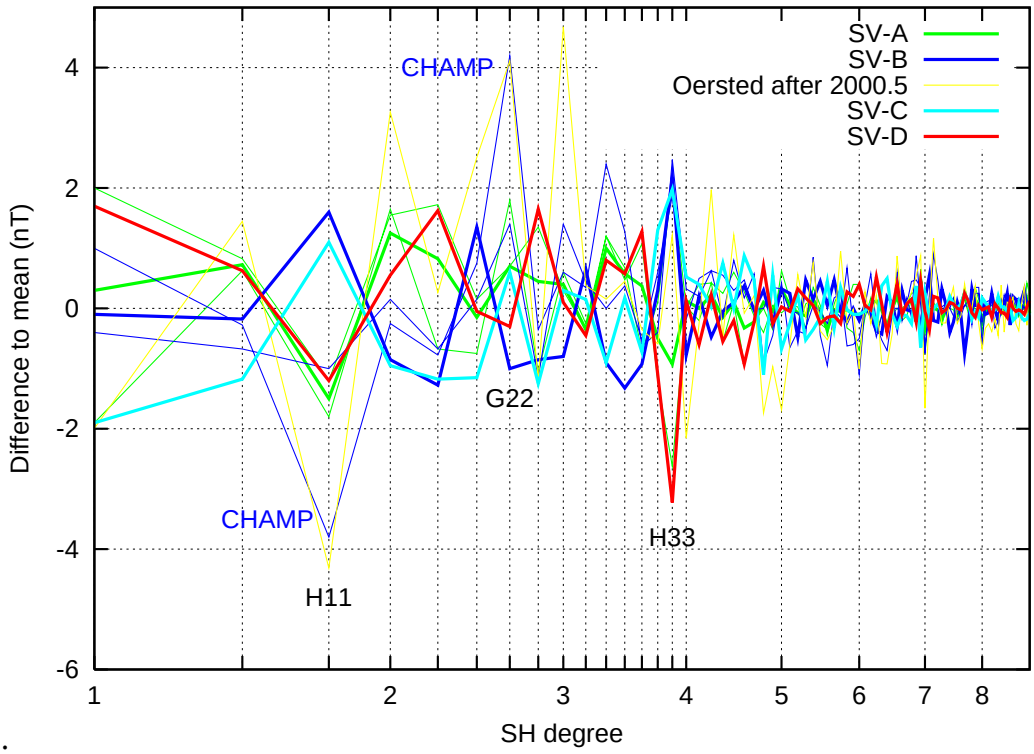

Figure 2: Secular variation coefficient differences to the mean of models A1, B3, C1, and D1. The thin lines represent models A2, A3, B1 and B2 which are multiple submissions by the same groups. The yellow line is a model from Oersted data of the same period as the CHAMP data.

A closer look at individual coefficients

Plotting the changing values of individual coefficients over the past couple of decades shows that these changes are not entirely chaotic. Therefore, it is interesting to see the predicted SV of a coefficient in the context of its change in the past.

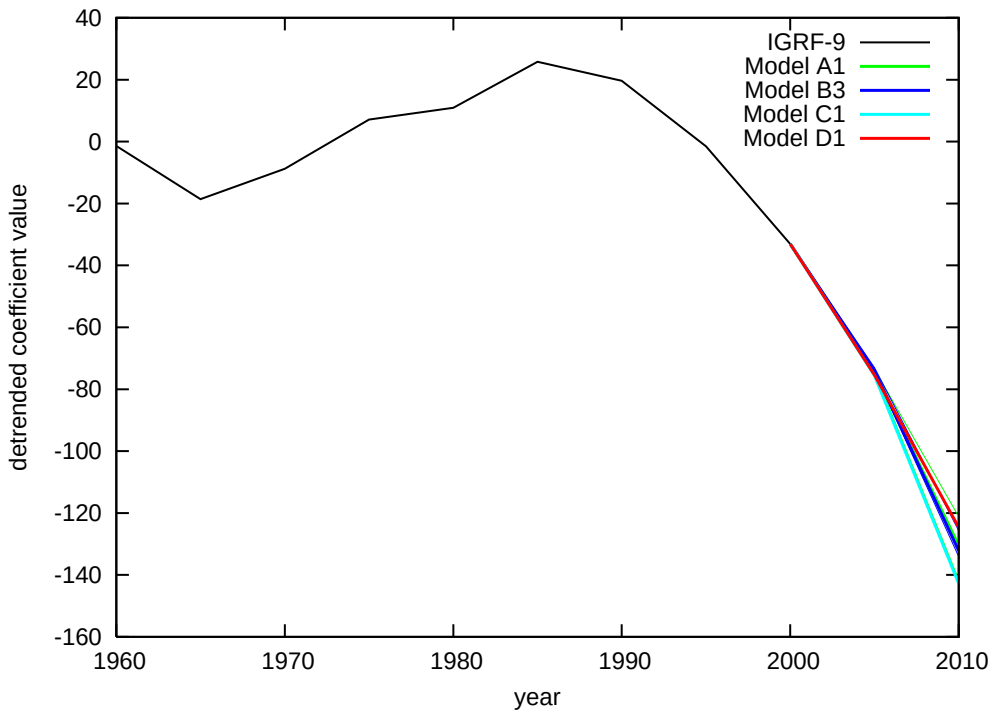

Figure 3: G10 coefficient after subtracting the trend of -30420 + 20.8(t-1960). Model C1 predicts the weakest axial dipole decay.

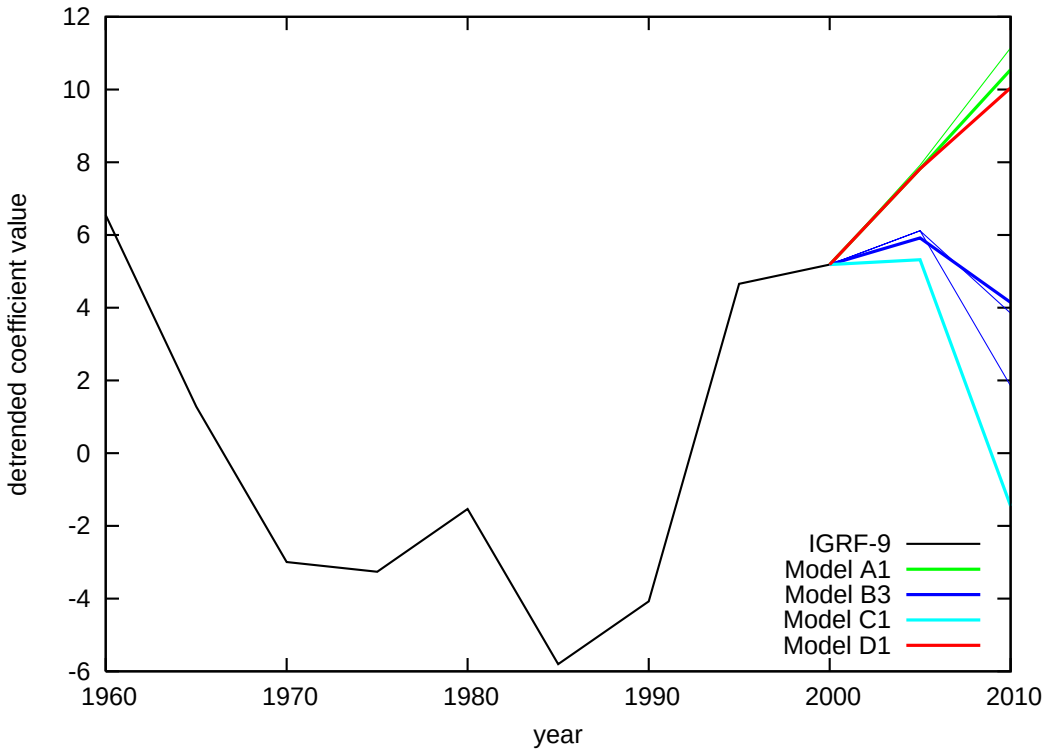

Figure 4: G11 coefficient after subtracting the trend of -2176 + 11.1(t-1960).

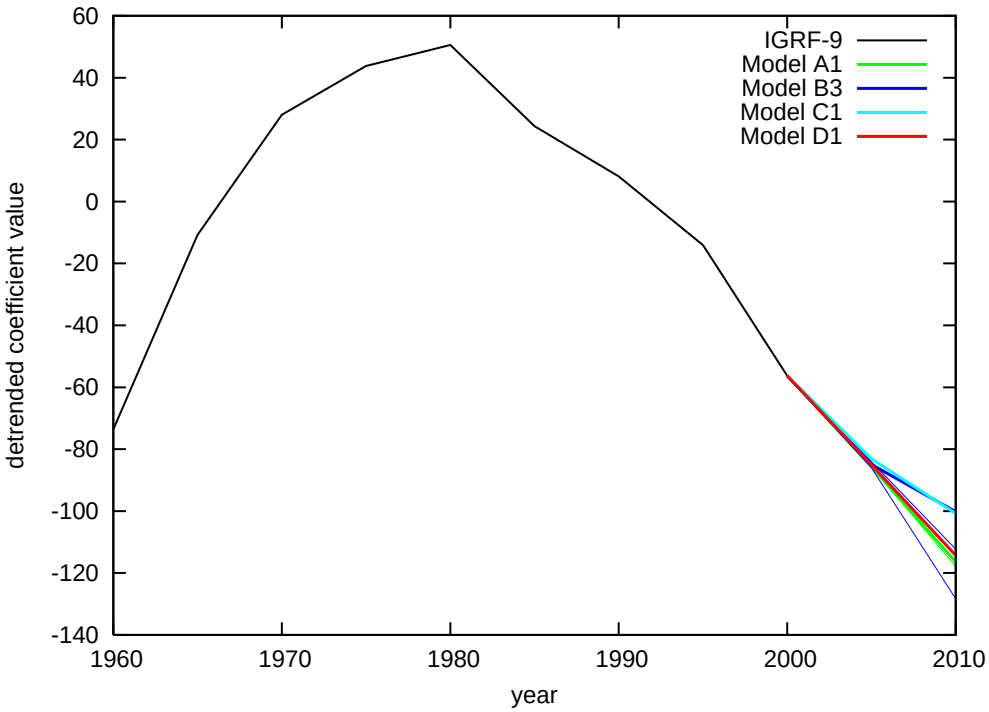

Figure 5: H11 coefficient after subtracting the trend of 5865 – 15.6(t-1960). The Champ-only model (lower thin blue line) predicts decreasing (more negative) SV while B3 and C1 predict an increase.

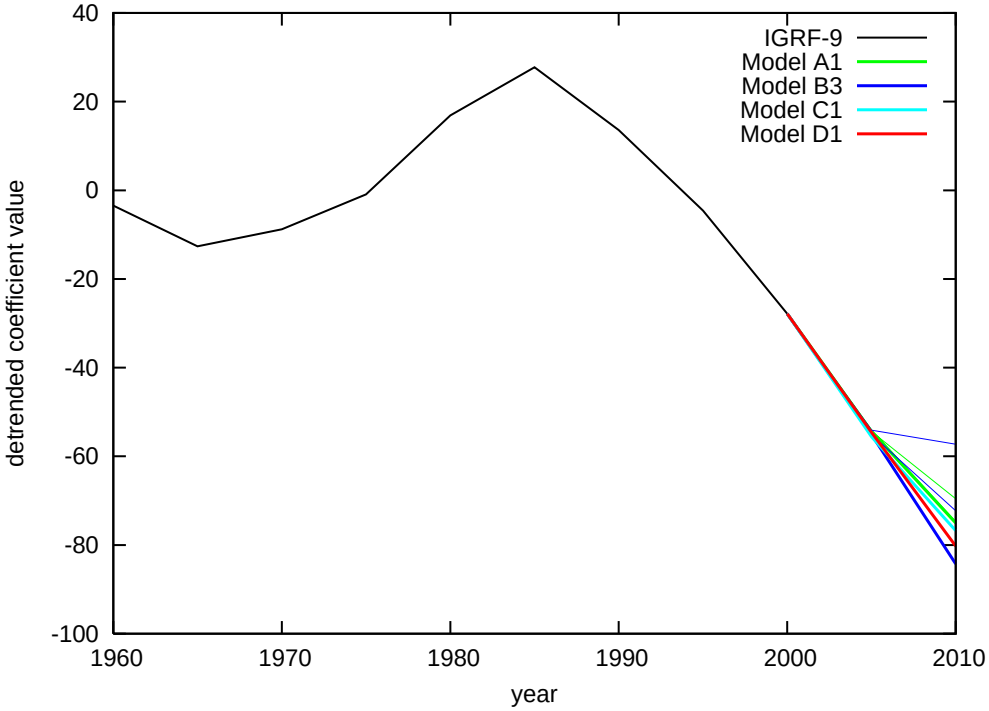

Figure 6: G22 coefficient after subtracting the trend of 1593 + 2.6(t-1960). The sudden increase in SV predicted by the CHAMP-only model (upper thin blue line) looks unlikely, although an even stronger change happened in 1985.

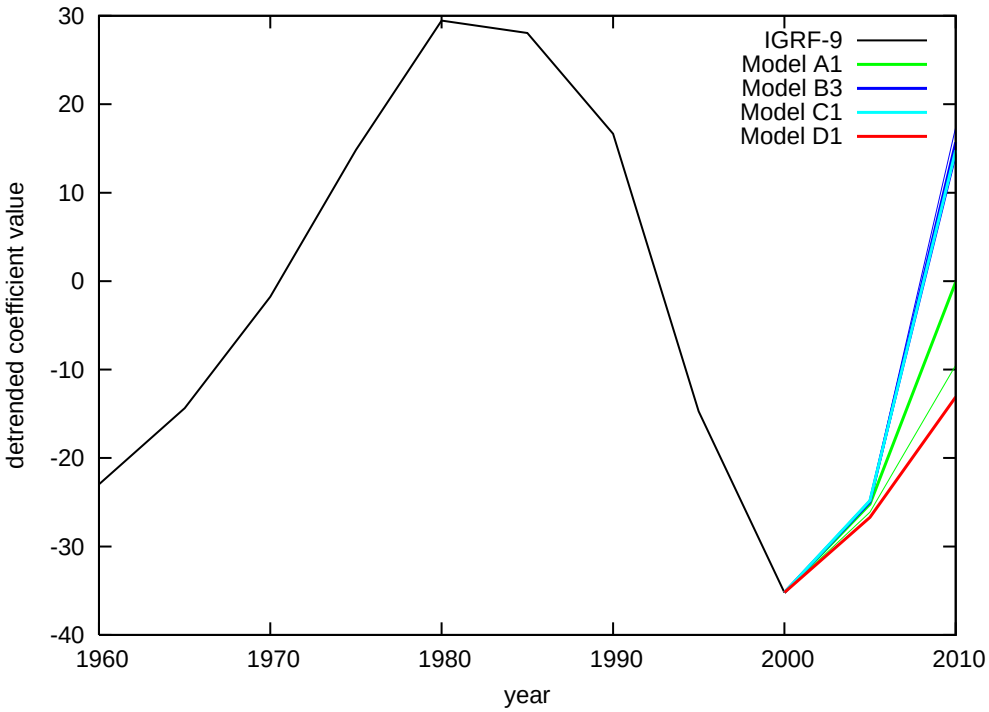

Figure 7: H33 coefficient after subtracting the trend of -107 – 8.7(t-1960). This coefficient is experiencing a strong acceleration. Consequently, the linear models predict a smaller change in the SV than the quadratic models.

For Figures 3-7, the values of a particular coefficient were taken from previous DGRFs since 1960 and plotted as a time series after subtracting a DC shift and a linear trend. With the same trend removed, the candidate values for 2005 and the predicted change to 2010 were plotted. The most interesting discrepancies are found for coefficients G11 (Fig. 4) and H33 (Fig. 7).

The coefficients for which the CHAMP-only model has large differences from the rest are H11 (Figure 5) and G22 (Fig. 6). The CHAMP predicted decreasing SV in H11 looks like a realistic alternative to the increasing SV predicted by the B3 and C1 models. For G22, on the other hand, the strong change in SV looks unlikely, although an even sharper change in the SV did indeed take place in 1985.

Retrospective evaluation of the IGRF-9 SV candidates

In adopting the IGRF-10, two difficult decisions have to be taken. One concerns the possible discarding or down weighting of seemingly inferior models, the other is whether the present secular acceleration can be used to forward predict the secular variation in 2007.5. A retrospective analysis of the IGRF-9 candidates for the SV 2000-2005 offers some insight on both issues.

Here, I assume that the true SV 2000-2005 is given by the difference between DGRF-2000 and the equal average of IGRF-2005 models A1, B3, C1 and D1, divided by five years.

Table 1 gives the cumulated Mauersberger/Lowes power of the differences of the candidates to the true SV. Figure 8 displays the individual coefficient differences. Displayed in Figure 8 is also the adopted model (without IZMIRAN-1), as well as the equal average of all models. Figure 9 shows the most controversial (because rapidly changing) coefficient H33.

Model	Origin/Name	Power of difference (nT^2/a^2)
1	BGS	51.6
2	CM4	19.8
3	OSVM	29.6
4	POMME	17.6
5	IPGP	44.4
6	IZMIRAN-1	108.9
7	IZMIRAN-2	41.3
	Equal average model	11.7
	Adopted IGRF-9 SV	17.6

Table 1: Cumulative Mauersberger/Lowes power differences of the IGRF-9 SV candidates to the true SV.

It is interesting to see that a straight average over all models would have fared better than all individual candidates. Of the candidate models, POMME, predicting the SV for 2002.5 using quadratic terms, fared best. The second most accurate prediction was by CM4, which also used quadratic terms, but dated the SV to 2001.5 due to concerns with spline endpoints. Although the linear OSVM models were (from my experience) the most accurate main field models in the 2000-2003 period, their linear SV coefficients obviously provided an inferior estimate of SV 2002.5 as compared to the quadratic extrapolation from the possibly less accurate CM4 and early POMME models. This motivates the conclusion that accounting for secular acceleration can be more important than model accuracy. In particular, the SV should be predicted for the center of the model period, rather than for its start.

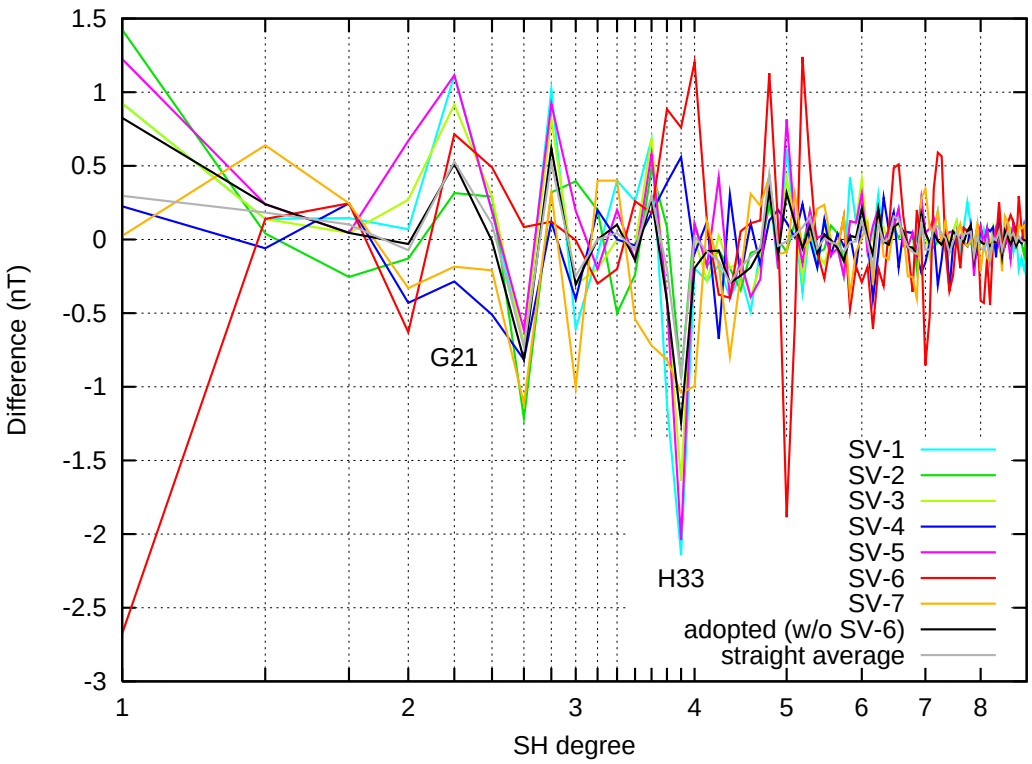

Figure 8: Secular variation coefficient differences to the 'true' SV in the 2000-2005 period inferred from the difference of DGRF-2000 and the mean of IGRF-10 candidate models A1, B3, C1, and D1.

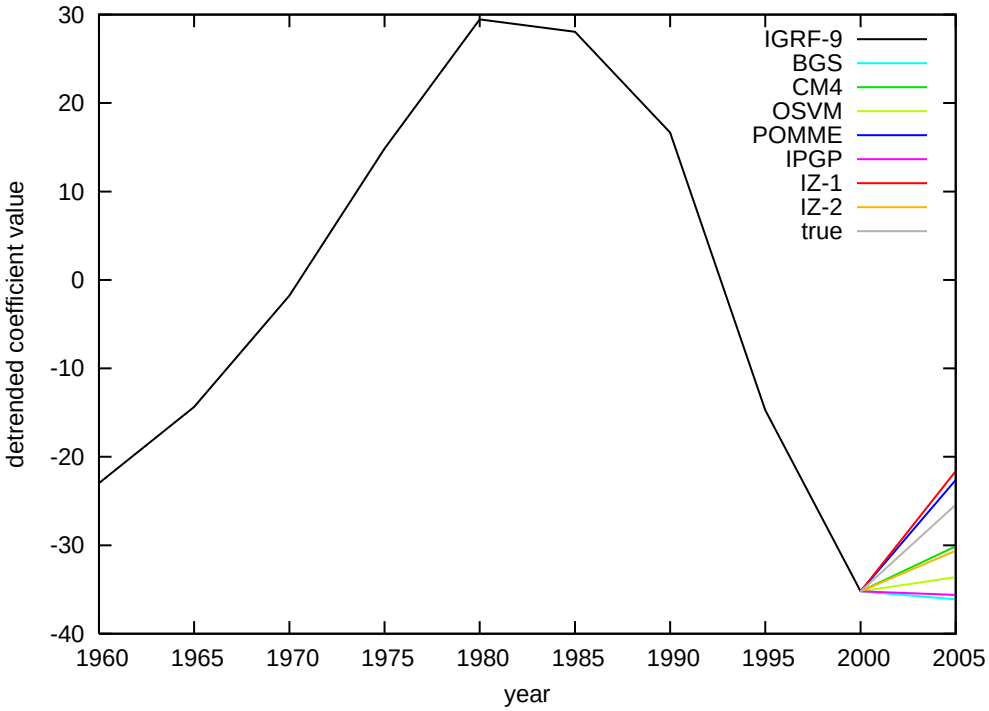

Figure 9: H33 coefficient after subtracting the trend of -107 – 8.7(t-1960). This coefficient is experiencing a strong acceleration. Consequently, the linear models underestimated the full change in the SV.

Summary

Main field 2003

For the main field in 2005 the satellite-only models of group A and B lie close to the mean of the candidates A1, B3, C1 and D1. Models of groups C and D exhibit unsystematic deviations to both sides of the mean. Particularly at higher degrees, model D is the noisiest, which is not entirely unexpected considering the unconventional treatment of satellite data.

As has been pointed out in Frank Lowes' evaluation, deviations in model D are largely compensated by opposite deviations in model C.

Recommendation: While there are obvious differences in the quality of the models, an equal average of models A1, B3, C1 and D1 is a good solution.

SV 2005-2010

The SV is difficult to predict and much can be said in favor of a plurality of different data sets and methods. This view is supported by the retrospective evaluation of the IGRF-9 candidates, which shows that a better SV prediction would have been obtained if the deviating IZMIRAN-1 candidate model had not been discarded.

For the SV candidates, the only model that clearly deviates from the rest is the CHAMP-only model. A model using Oersted data of the same period indicates that this is not an instrument problem but possibly due to a genuine recent change in the secular acceleration. To account for this possibility, I recommend including the model SV-B1, instead of the more conservative model SV-B3.

Since the quadratic models CM4 and POMME fared significantly better than the linear OSVM model for the SV in the 2000-2005 period, I would recommend using the SV-A3-2007.5 instead of the SV-A1-2005 model (if the authors of the group-A models agree).

Recommendation: In view of the significance of secular acceleration, and to account for a possible recent change in secular acceleration, I recommend an equal average of models SV-A3-2007.5, SV-B1-2007.5, SV-C1-2007.5 and SV-D1-2005.