Evaluation of the IGRF-DGRF candidates

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Abstract

We evaluate the IGRF and DGRF candidates to the IGRF-11. Of the seven DGRF-2005 candidates, six present reasonable agreement at mid- and low- latitudes, whereas at high latitudes only three candidates agree. We recommend that the six acceptable models are averaged in space, down-weighting at high latitudes those which have an apparent anomalous behavior. Regarding the IGRF-2010 we show that some candidates are anomalous. Some weighting process should be set before averaging. There is a large scatter of predictive SV candidates for the 2010-2015 period. None of the candidates is convincingly more accurate than any other. We suggest to simply average the models.

1 Introduction

We evaluate the candidates to the IGRF-11. Considering the large number of candidates, we mainly compare the candidates with the candidate G, provided by the GFZ. We compared the DGRF-2005, IGRF-2010 and SV-2010-2015 candidates in the section 2, 3 and 4, respectively. We conclude and give our view on the derivation of the IGRF/DGRF in the last section.

2 DGRF-2005

Figure 1 presents the power spectra of differences between the G candidate model and the other models. It clearly shows that the three model candidates A, B and G are very similar. The candidates C,E and F present some differences detailed below. The D candidate model spectra of differences is outside the scale of Figure 1: this model is significantly different from the G models as well as from the other candidate models.

The three models A, B and G are based on very different modeling and data selection techniques. They nonetheless are very similar and therefore they likely represent a fairly good approximation of the core field for that epoch. Figure 2 presents the differences in the vertical down component between the candidate models and the G model. The D candidate is clearly anomalous. The discrepancy between the candidates C, E, F and the reference model G, are mainly concentrated at high latitudes. The B and G candidates are the most similar with differences never exceeding 8.11 nT at any place at the Earth's reference surface.

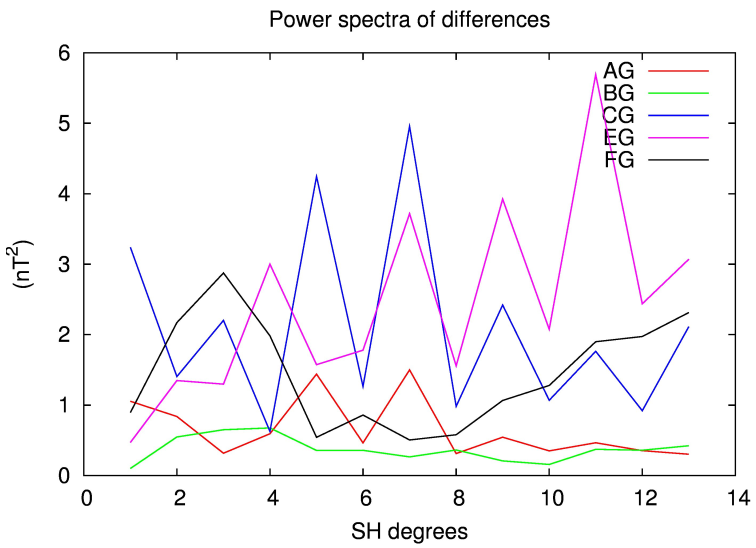

Figure 1: Power spectra of the DGRF-2005 candidate model differences relative to G candidate.

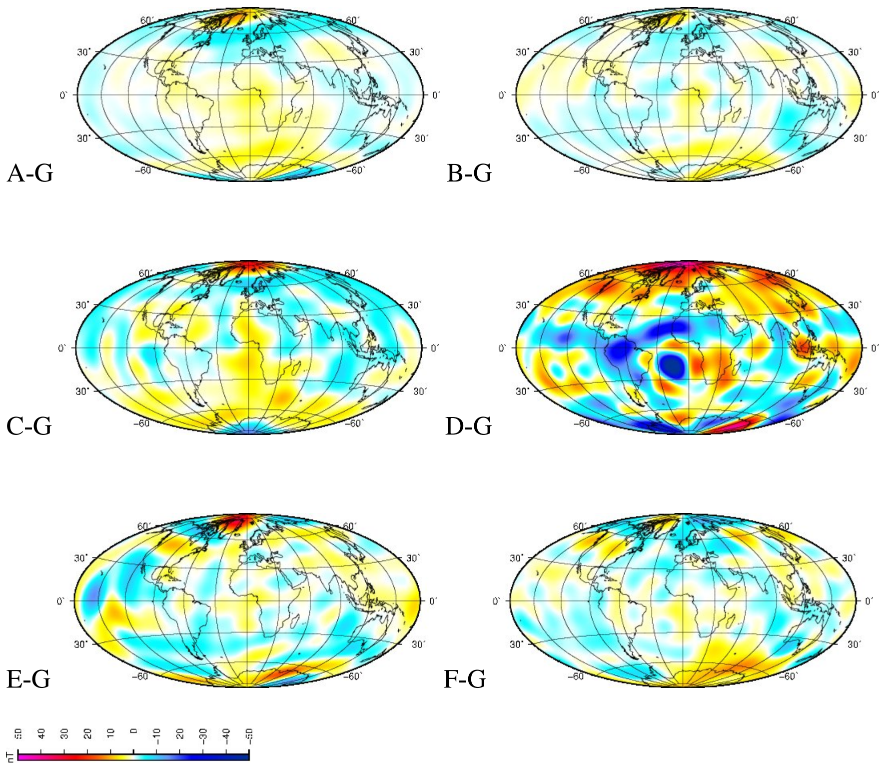

Figure 2: Vertical down component differences between A-to-F candidate models and G candidate model to the DGRF-2005.

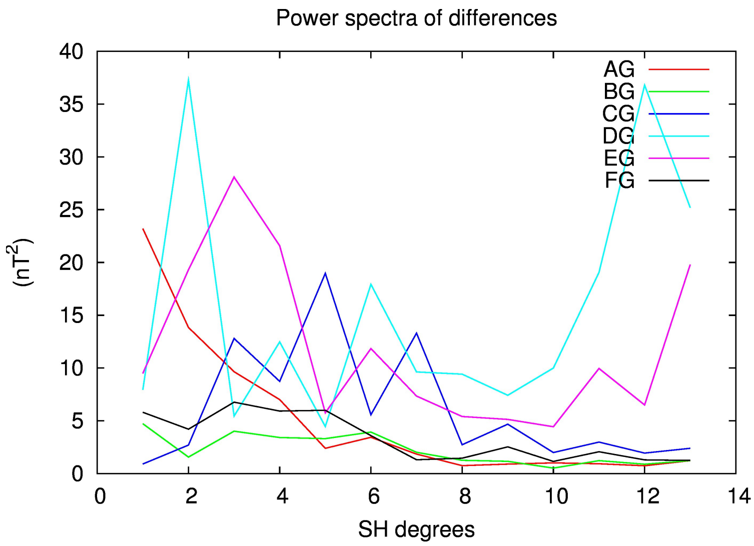

Figure 3: Power spectra of the IGRF-2010 candidate model differences relative to G candidate.

3 IGRF-2010

Figure 3 presents the power spectra of differences between the G candidate model and the other models. It clearly shows that the three model candidates B, F and G are similar. The candidates A,C, D and E present some differences.

Figure 4 presents the differences in the vertical down component between the candidate models and the G model. The two models B, F are based on the same data selection technique and may not be fully independent estimates. They are also the most similar candidates with differences not exceeding 14.9 nT. Differences between B and G candidates do not exceed 15.5 nT. The D and E candidates are clearly anomalous. The A candidate differs from the others in its first degrees. Candidates C and F have anomalous behavior near the poles. A common feature of some of these differences is a positive/negative anomaly in the South-Atlantic. This is an anomaly of the G model relative to the other candidates.

The larger scatter in the candidates to the IGRF-2010 compared to the candidates to the DGRF-2005, comes from the small extrapolation from the last available data values in 2009.5, to the reference date 2010. This extrapolation makes it difficult to robustly estimate a model of the magnetic field for 2010. This is illustrated in Figure 5 giving the vertical down component of the differences between GRIMM-2x and CHAOS-3 for the years 2009, 2009.5, 2010. It is clear that the two parent models agree well as long as data are available and start to diverge when extrapolated. The A candidate model is CHAOS-3 for year 2010, whereas the G candidate is GRIMM-2x for year 2009.0 extrapolated using the estimated SV for the same year (i.e. the acceleration is neglected as it is clearly unreliable toward the end of the parent model). This difference of approach explain the larger differences between the candidate models A, G than between their respective parent models for year 2010. Because of the lack of robustness of derived models for year 2009, it is rather difficult to say which between using a model with a complex time dependency as candidate A, or using a model with a simpler constant acceleration as candidate B, or assuming no acceleration as candidate G, gives

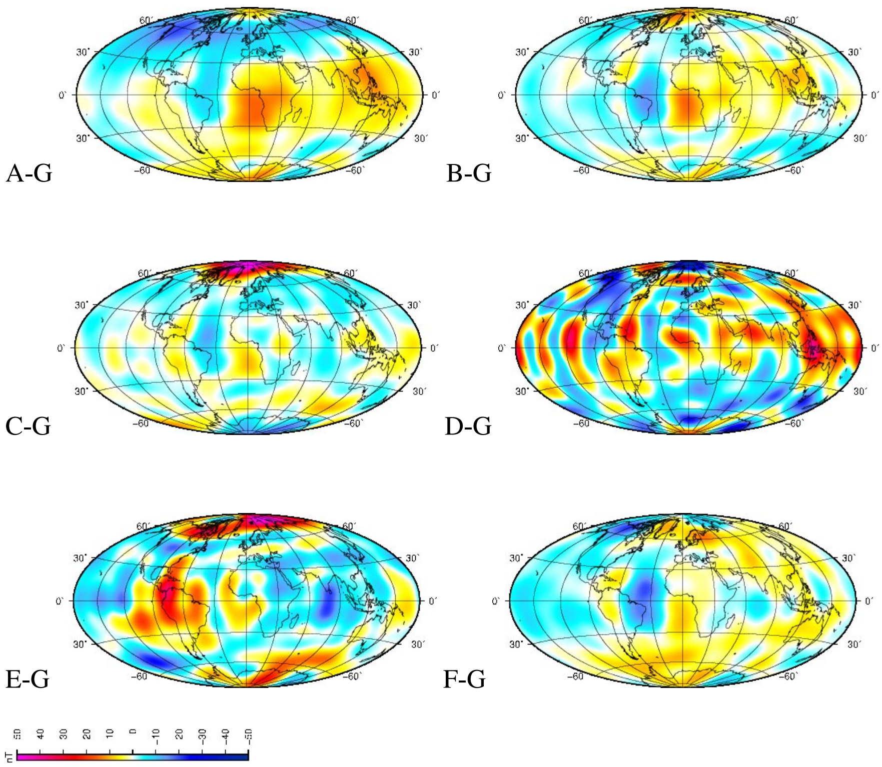

Figure 4: Vertical down component differences between A-to-F candidate models and G candidate model to the IGRF-2010.

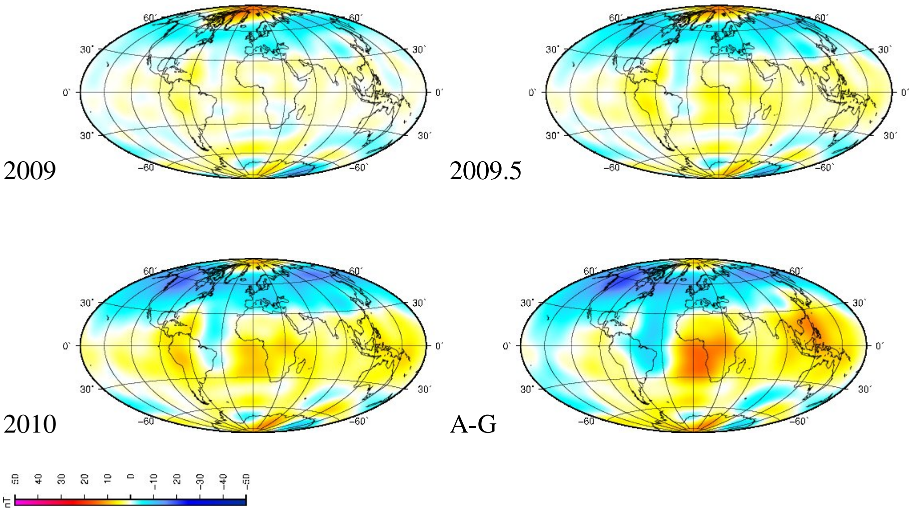

Figure 5: Vertical down component differences between CHAOS-3 and GRIMM-2x models for years 2009.0, 2009.5 and 2010.0. Is also shown the differences between A and G candidates to the IGRF-2010.

the best results. Often, a technique that seems more appropriate for one given Gauss coefficient fails for some others.

4 SV-2010-2015

Figure 6 presents the power spectra of differences between the G candidate model and the other models. Because, the derivation of the G candidate is rather different from the other candidates, we also present in Figure 7 the power spectra of differences between the H candidate model and the other models. It clearly shows that the two model candidates D and H are similar. The candidates A and G present some significant differences when compared to candidate H.

The progresses made in the magnetic field modeling these last years have shown the high time variability of the SV and of the magnetic field acceleration. These progresses highlight the difficulties in predicting the temporal magnetic field behavior. It results that the SV candidate models for years 2010-2015 present large differences. As we are not able yet to model precisely the variability of the SV at SH degrees larger than 5 or 6, the differences in the SV candidates are present mainly in the first three SH degrees.

Figures 8 displays the vertical down component of the magnetic field SV differences at the Earth's surface for the candidates A to G relative to candidate H. These differences are large at mid-latitudes and present mainly a sectorial geometry. To illustrate the complexity of the temporal behavior of the magnetic field SV and the difficulties in predicting it, we used the maximum entropy method to extrapolate SV Gauss coefficients forward up to 2013, and backward to 1997. The parent model GRIMM-2x SV Gauss coefficients between 2001 and 2009 were used as input data. The results for the Gauss coefficients g_1^0, h_1^1 and h_3^3 are shown in Figures 9. Clearly form the estimated standard deviation of the GRIMM-2x model Gauss coefficients, we see that a very large range of prediction are acceptable for year 2012.5. We also see that the Maximum Entropy Prediction (M.E.P) method pedicts estimates that are often differ-

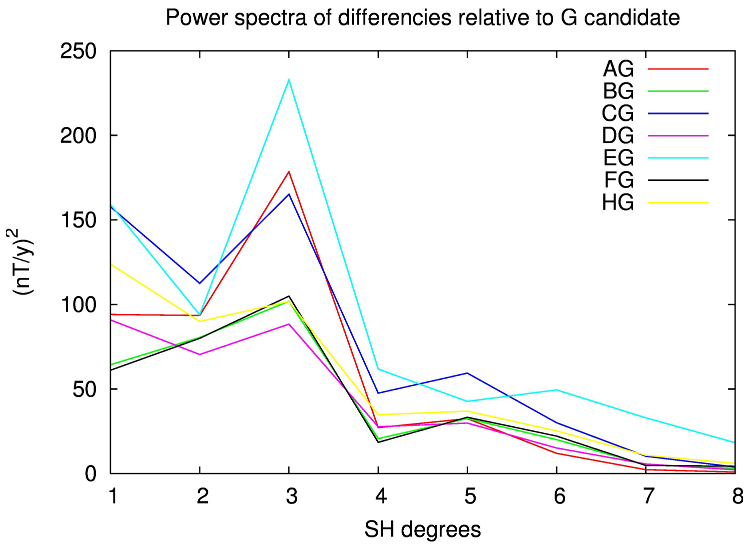

Figure 6: Power spectra of the SV 2010-2015 candidate model differences relative to G candidate.

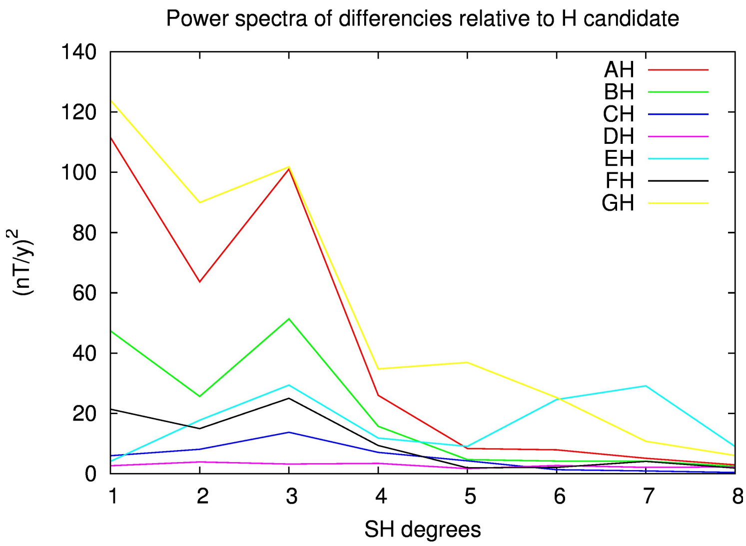

Figure 7: Power spectra of the SV 2010-2015 candidate model differences relative to H candidate.

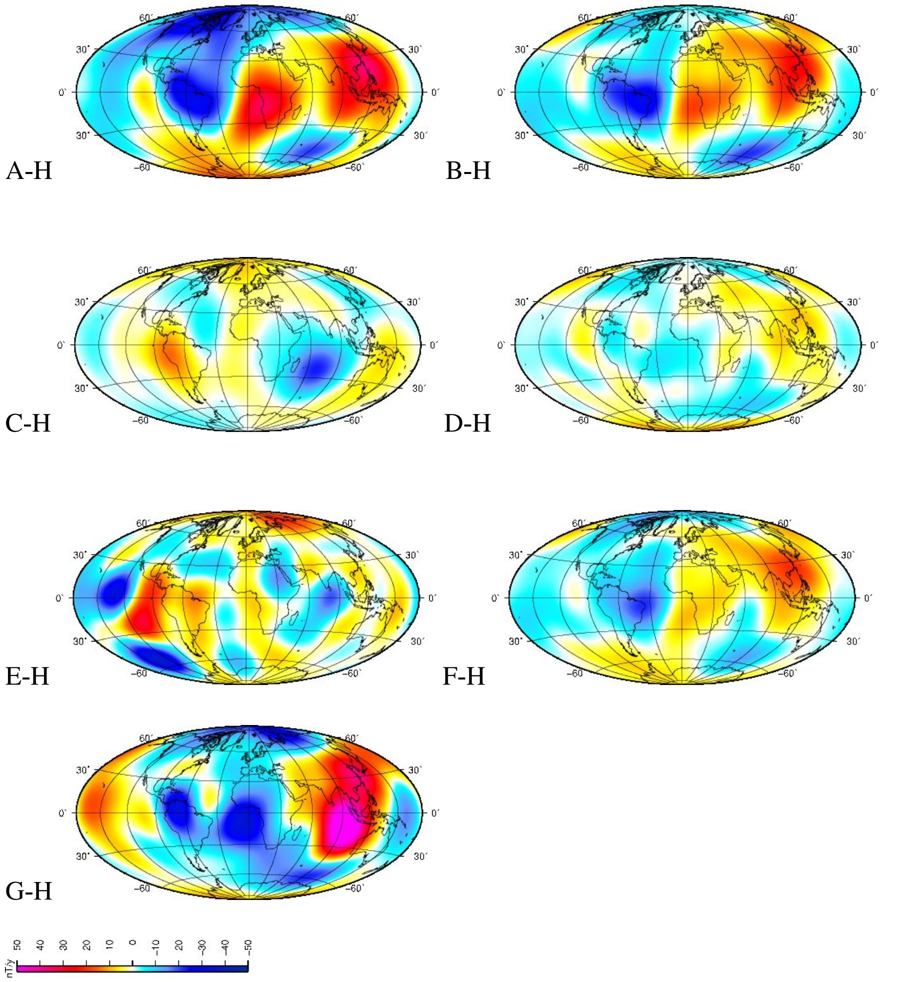

Figure 8: Vertical down component differences between A-to-G candidate models and H candidate model to the SV 2010-2015.

ent from the candidate models. Finally, we also see that when compared with a model derived from observatory monthly mean data, the SV can be very different from what is expected by hint-casting. Because of the difficulties in predicting the magnetic field SV, we don't think that any of the candidate has to be rejected.

5 conclusion

Regarding the DGRF, because the candidate D is significantly different from the others, we suggest to exclude this candidate for deriving the final version of the DGRF. Otherwise, as some of the candidates are slightly anomalous over the polar regions, a possible approach is to average in space the candidates on a grid, down -weighting the anomalous candidates over the poles, and recover the final Gauss coefficients through a Spherical Transform.

For the IGRF-2010, candidates A, D and E are different from the others and we

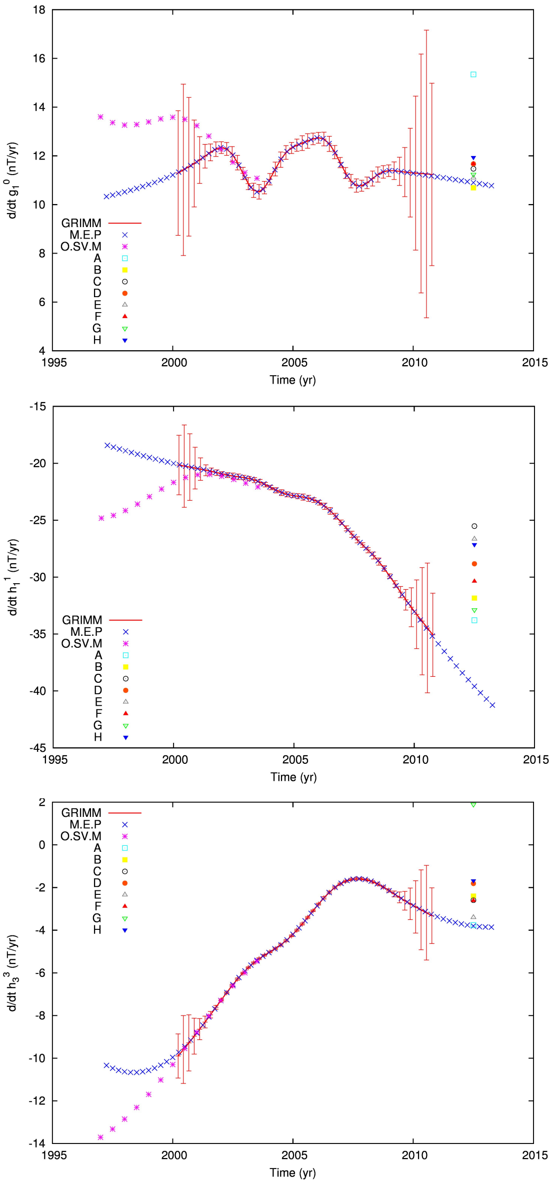

Figure 9: SV coefficients g_1^0, h_1^1 and h_3^3 as estimated by various field models, candidates and extrapolation processes where : GRIMM are the estimated coefficients and their errorbars as obtained by the GRIMM-2x parent model, M.E.P are the estimates obtained by applying the maximum entropy method, O.SV.M are the coefficients as obtained from a 50 years field model derived from monthly mean observatory data. The candidate estimates are labelled from A to H.

suggest to down-weight these three candidates. A process similar to what is proposed for the DGRF can otherwise be applied.

Regarding the derivation of the predictive SV. It is clear that none of the proposed methods can be pointed out as better than the others. We hence suggest to simply average the candidate, with possible a slight down-weighting of the models A and G for some of their coefficients.