Comparison of the candidate models for IGRF-11

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1 – Introduction

Eight groups submitted candidate models for the 11th IGRF generation. The first seven groups proposed models for Main Field epoch 2005.0 (i.e. DGRF) and epoch 2010.0 (i.e. IGRF-MF), and all of them proposed candidate models for the secular variation between 2010.0 and 2015.0 (i.e. IGRF-SV).

In the following I present the results of inter-comparison tests between these candidate models. Acronyms are presented below:

Model A is DTU
Model B is NOAA/NGDC
Model C is BGS
Model D is IZMIRAN
Model E is EOST/LPGNantes/LATMOS/IPGP
Model F is IPGP/EOST/LPGNantes/LATMOS
Model G is GFZ
Model H is GSFC/JCET

In addition, I added a mean model, denoted as Model Z, as well as an updated version of IGRF-10, denoted as Model Y.

2 – Tests on DGRF models

The table 1 below summarizes the results of the inter comparison between each of the seven candidates models and the “mean” one. The main field is predicted at the Earth's surface, up to degree and order 13, on an equisurface grid (mean spacing at the equator is about 1 degree). Rms differences are computed between each one of the seven candidate models and a mean model Z (mean of A, B, C, D, E, F, G), and the adopted IGRF-10 model at epoch 2005.0 (model Y).

Results are found in the Table 1. Rms differences between each candidate models are of the order of a few nT for all three components and for the field intensity, with the exception of the candidate model D, for which rms differences are about three times larger than any other candidate models. The differences to the mean model Z allow candidate models to be 'classified' into three categories. Models A, B and G display very similar rms differences to the mean model, of the order of 2 nT for the total intensity. Models C, E and F have also comparable figures, of the order of 3 nT for the total intensity. The last model D has a much larger rms difference, equal to 8 nT for the intensity. All models present very similar differences (in terms of rms) to the adopted IGRF-10 model.

These tests are completed by plotting differences between the magnetic field predicted between each models (Figure 1). The largest field differences, between model Z and each of the A, B, C, E, F, G candidate models are located

in polar areas, with differences being lower than 20 nT. Model D displays larger differences, up to 50 nT. The mean of the difference is +/-1 nT, except for model D (-6.2 nT).

X / Y / Z / F	A		B		C		D		E		F		G	
A			1.27	0.84	2.42	1.63	7.22	5.82	3.01	1.99	2.52	3.40	1.53	1.16
			1.71	1.54	3.21	2.91	11.18	9.64	4.03	3.69	1.77	3.36	2.19	2.09
B	1.27	0.84			2.85	1.53	7.10	5.61	2.88	2.03	2.00	1.52	1.13	0.93
	1.71	1.54			3.59	3.16	10.84	9.52	3.86	3.55	2.77	2.69	1.63	1.54
C	2.42	1.63	2.85	1.53			7.25	6.01	3.74	2.48	3.68	2.34	2.98	1.77
	3.21	2.91	3.59	3.16			11.40	9.51	5.01	4.41	4.82	4.56	3.89	3.41
D	7.22	5.82	7.10	5.61	7.25	6.01			7.07	6.20	7.32	5.57	7.09	5.61
	11.18	9.64	10.84	9.52	11.40	9.51			10.86	9.62	11.23	9.91	10.74	9.42
E	3.01	1.99	2.88	2.03	3.74	2.48	7.07	6.20			2.73	2.35	3.09	2.28
	4.03	3.69	3.86	3.55	5.01	4.41	10.86	9.62			4.15	3.81	4.15	3.87
F	2.52	3.40	2.00	1.52	3.68	2.34	7.32	5.57	2.73	2.35			2.21	1.78
	1.77	3.36	2.77	2.69	4.82	4.56	11.23	9.91	4.15	3.81			3.23	3.15
G	1.53	1.16	1.13	0.93	2.98	1.77	7.09	5.61	3.09	2.28	2.21	1.78		
	2.19	2.09	1.63	1.54	3.89	3.41	10.74	9.42	4.15	3.87	3.23	3.15		
Z A B C D E F G	1.61	1.18	1.44	0.91	2.49	1.67	5.97	4.87	2.37	1.98	2.10	1.46	1.61	1.15
	2.35	2.09	1.94	1.80	3.46	2.87	9.26	8.03	3.31	3.06	3.05	2.93	2.20	2.06
Y (IGRF-10)	5.69	4.72	5.59	4.72	5.54	4.73	8.33	7.85	5.93	5.20	5.94	5.26	5.86	4.96
	9.27	6.60	9.18	6.35	9.07	6.29	13.28	9.77	9.52	6.53	10.00	7.29	9.48	6.75
X A B C E F G	1.13	0.76	0.98	0.57	2.34	1.38	6.97	5.69	2.27	1.67	1.76	1.37	1.25	0.95
	1.52	1.46	1.22	1.11	3.02	2.68	10.80	9.37	3.13	2.83	2.52	2.46	1.74	1.63

Table 1 - rms differences (in nT) between candidate models for DGRF and a mean model Z (based on the 7 candidate models), the IGRF-10 (model Y) and a mean model X (based on A, B, C, E, F, G models)

In order to test the possible omission of model D in the final DGRF model, I computed model X, based on the mean of the six A, B, C, E, F and G models. I compared this alternate model to the other ones (last line of Table 1). The rms differences are somehow lower for all 6 models, and larger for model D, as expected. The rms differences between model X and model Z are equal to 1.00, 0.82, 1.55, and 1.34 nT for X, Y, Z and F, respectively. Again, differences are plotted on Figure 2.

There is a very small difference between model X and model Z. Although model D presents a distinct pattern, its possibly associated errors may be diluted and counterbalanced by the other six models. Even if the rejection of model D could be justified, one would need to test the accuracy of models Z and X versus observations before taking any decision.

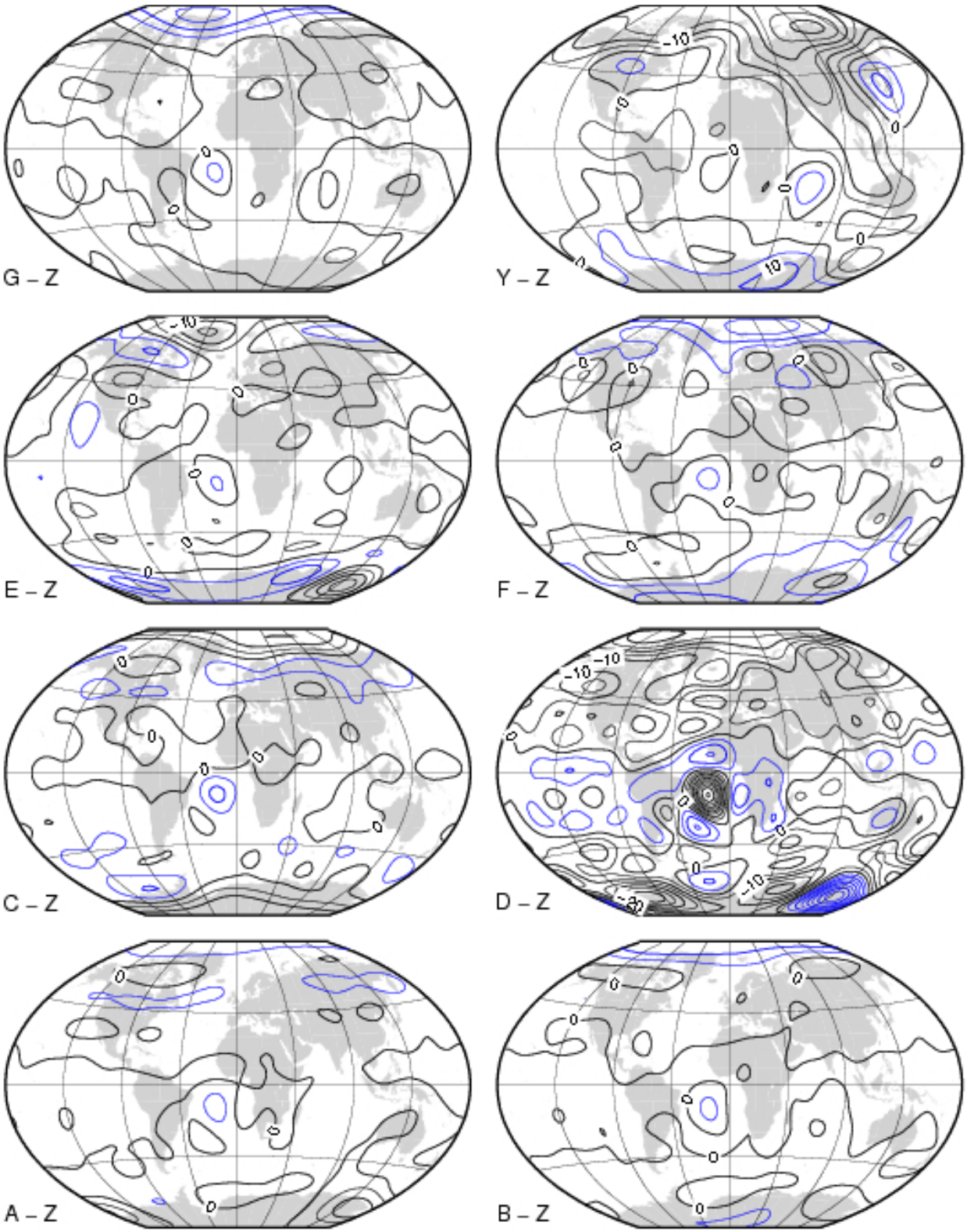

Figure 1 – Differences at the surface of the Earth between the seven DGRF models and their mean (model Z). Isocontours are every 5 nT. Also shown the differences of the mean model to IGRF-10.

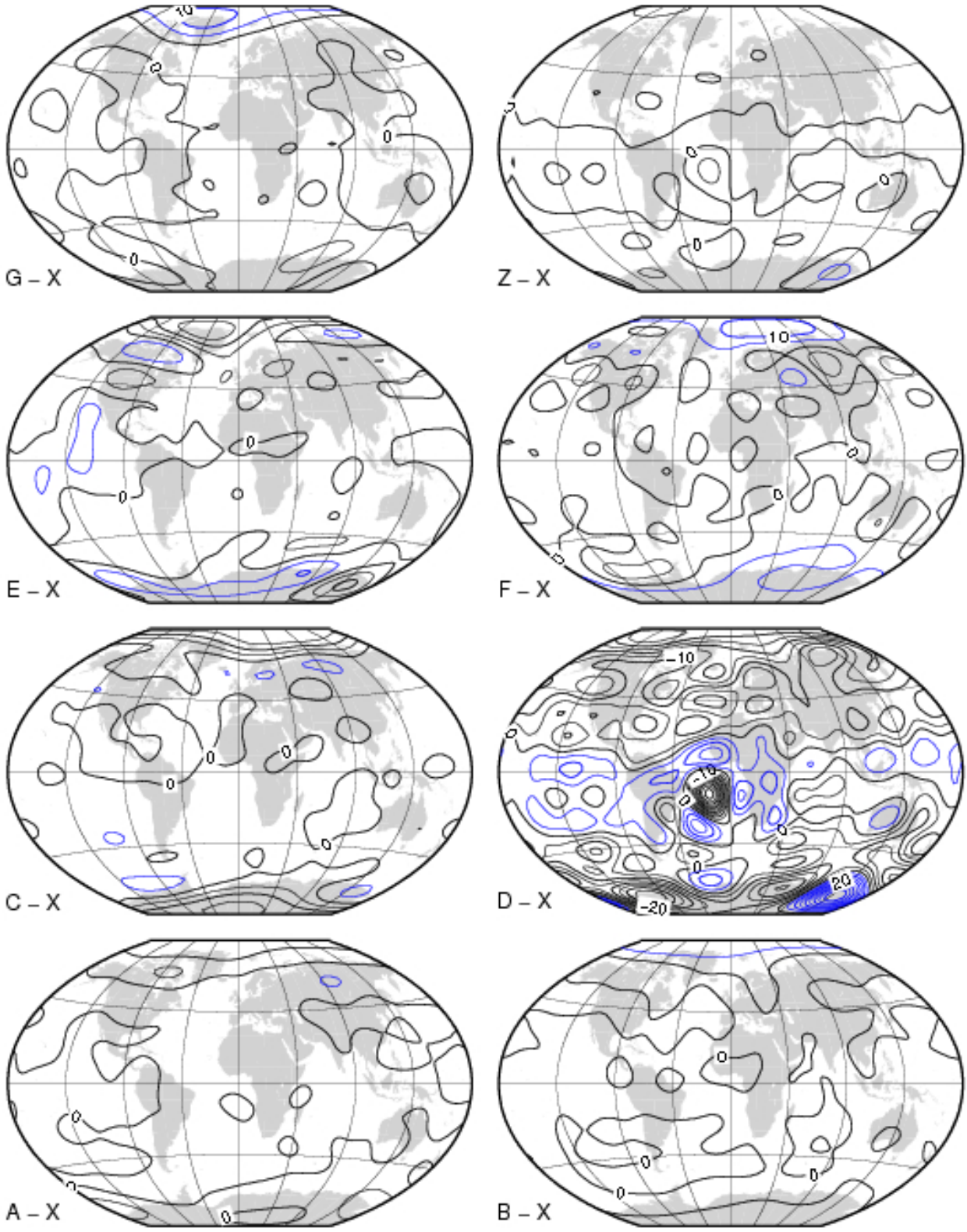

Figure 2 - Differences at the surface of the Earth between the seven DGRF models and the mean model X (based on A, B, C, E, F, G). Also shown the difference between model X and Z. Isocontours are every 5 nT.

3 – Tests on IGRF models, Main Field

Similar tests are performed on the seven candidate models for the Main Field. Results of these comparisons between models are given in Table 2 and plotted on Figure 3. Model Y is the IGRF-10 model updated to 2010.0 using its own secular variation.

X / Z \ Y / F	A		B		C		D		E		F		G	
A			2.62	1.86	4.88	2.96	6.67	6.17	7.37	5.42	4.73	1.99	3.80	2.86
			4.94	3.21	8.20	6.93	10.62	7.95	11.32	8.52	6.23	5.19	6.35	4.48
B	2.62	1.86			4.70	2.22	7.02	6.13	6.93	5.37	2.81	1.75	2.36	2.67
	4.94	3.21			6.11	5.78	10.27	8.31	10.07	7.57	3.93	3.37	4.08	2.95
C	4.88	2.96	4.70	2.22			9.60	6.06	6.14	4.93	5.71	2.65	5.28	2.44
	8.20	6.93	6.11	5.78			12.56	11.22	8.80	7.21	7.53	7.32	6.63	6.51
D	6.67	6.17	7.02	6.13	9.60	6.06			10.28	7.81	7.79	6.21	7.25	6.24
	10.62	7.95	10.27	8.31	12.56	11.22			14.54	11.67	11.19	9.03	10.55	8.48
E	7.37	5.42	6.93	5.37	6.14	4.93	10.28	7.81			7.61	5.13	6.57	5.00
	11.32	8.52	10.07	7.57	8.80	7.21	14.54	11.67			10.55	8.73	9.29	7.77
F	4.73	1.99	2.81	1.75	5.71	2.65	7.79	6.21	7.61	5.13			2.80	3.25
	6.23	5.19	3.93	3.37	7.53	7.32	11.19	9.03	10.55	8.73			4.96	3.79
G	3.80	2.86	2.36	2.67	5.28	2.44	7.25	6.24	6.57	5.00	2.80	3.25		
	6.35	4.48	4.08	2.95	6.63	6.51	10.55	8.48	9.29	7.77	4.96	3.79		
Z (mean of 7)	2.65	2.00	1.80	1.73	4.13	1.84	6.42	5.17	5.74	4.32	3.22	1.91	2.22	2.13
	4.92	3.35	2.89	2.00	5.32	5.25	9.12	7.42	8.23	6.47	4.31	3.81	3.40	2.81
Y (IGRF-10)	53.78	51.24	53.16	50.70	51.28	50.68	55.00	51.97	49.97	50.27	53.13	50.73	53.10	50.83
	93.66	66.07	91.79	65.44	89.99	63.19	94.29	67.08	88.56	62.93	92.12	65.60	91.79	65.97

Table 2 - rms differences (in nT) between candidate models for IGRF (epoch 2010) and a mean model Z (based on the 7 candidate models) and the IGRF-10 (model Y) updated to correct epoch.

Models B and G have similar differences to the mean model, and model D is the more distant one. Rms differences are of the same order than for the DGRF candidate models, although they are slightly larger. All models are equally different when compared to IGRF-10 model.

It is very difficult, if not impossible, to ascertain which model or group of models is better than the other ones. Relative rms differences are very small together, and also very small when compared to the SV rms differences. In addition, all MF candidate models contain some predictive part, so it is possible that the observed differences are more related to the extrapolation procedure than to the model itself.

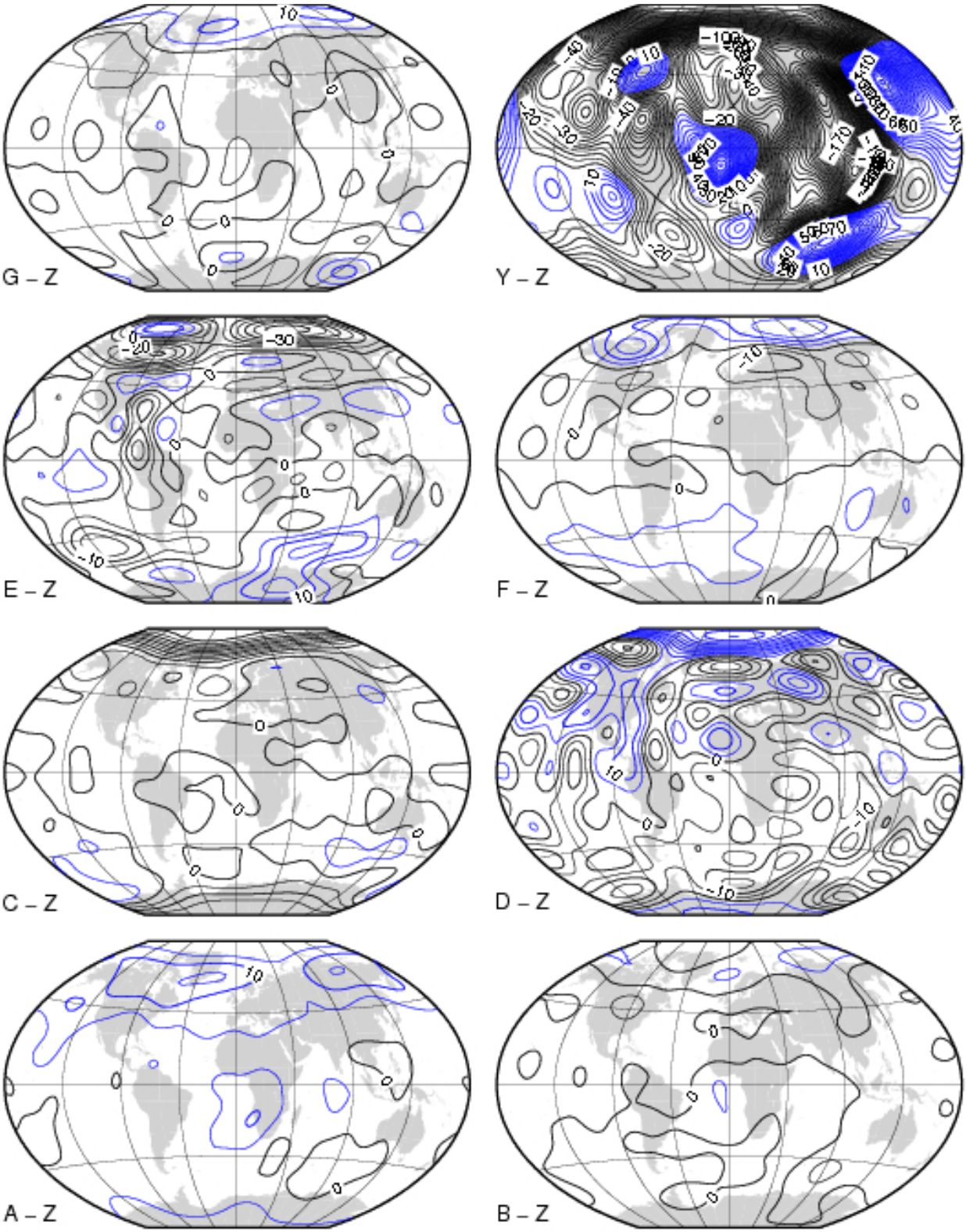

Figure 3 - Differences at the surface of the Earth between the seven IGRF-MF models and the mean model Z. Also shown the differences of the mean model to updated IGRF-10. Isocontours are every 5 nT.

4 – Tests on IGRF models, Secular variation.

For the secular variation tests, the field is first computed at the Earth's surface using IGRF-MF mean model at epoch 2010 and then at epoch 2011, with the mean MF model updated by each of the eight candidate models. Thus all three components as well as total intensity changes are predicted for all candidate models. Results of the tests are shown in Table 3 and on Figure 4.

	A		B		C		D		E		F		G		H	
A			3.36	3.37	8.75	8.26	6.17	7.09	10.24	8.70	4.75	4.35	7.13	10.91	7.39	7.95
			7.89	4.08	15.82	9.21	12.44	6.98	17.11	11.16	8.95	4.91	16.17	10.96	14.07	7.97
B	3.36	3.37			7.15	6.49	4.21	4.80	9.04	7.65	2.35	2.12	6.77	9.38	5.57	5.56
	7.89	4.08			11.94	8.23	7.89	5.76	13.96	10.71	3.94	2.74	13.92	10.47	9.66	6.81
C	8.75	8.26	7.15	6.49			3.73	3.48	5.13	5.29	5.38	4.73	10.64	11.10	2.81	3.05
	15.82	9.21	11.94	8.23			6.09	4.43	8.22	6.64	8.89	6.12	18.70	13.69	4.94	3.61
D	6.17	7.09	4.21	4.80	3.73	3.48			6.22	5.58	2.78	3.25	7.72	8.55	2.25	2.08
	12.44	6.98	7.89	5.76	6.09	4.43			9.54	7.71	5.16	3.80	14.05	11.08	3.54	2.58
E	10.24	8.70	9.04	7.65	5.13	5.29	6.22	5.58			7.67	6.31	12.16	11.60	5.49	5.36
	17.11	11.16	13.96	10.71	8.22	6.64	9.54	7.71			11.62	9.03	20.17	15.11	8.67	6.95
F	4.75	4.35	2.35	2.12	5.38	4.73	2.78	3.25	7.67	6.31			7.18	9.15	4.02	4.05
	8.95	4.91	3.94	2.74	8.89	6.12	5.16	3.80	11.62	9.03			13.92	10.96	6.93	4.58
G	7.13	10.91	6.77	9.38	10.64	11.10	7.72	8.55	12.16	11.60	7.18	9.15			9.04	9.54
	16.17	10.96	13.92	10.47	18.70	13.69	14.05	11.08	20.17	15.11	13.92	10.96			16.02	12.50
H	7.39	7.95	5.57	5.56	2.81	3.05	2.25	2.08	5.49	5.36	4.02	4.05	9.04	9.54		
	14.07	7.97	9.66	6.81	4.94	3.61	3.54	2.58	8.67	6.95	6.93	4.58	16.02	12.50		
Z	4.99	5.44	3.24	3.32	4.45	4.11	1.62	2.08	6.41	5.32	1.98	1.80	6.98	8.23	2.89	3.04
	10.00	5.22	5.74	4.08	7.50	5.08	3.19	2.57	9.77	7.65	3.12	2.40	13.03	10.04	5.10	3.63

Table 3 - rms differences (in nT/yr) between candidate models for IGRF-SV and a mean model Z (based on the 8 candidate models).

With the exception of model G, and to some extent, of model E, the rms differences between the candidate models and the mean one are of the same order.

The candidate models for SV are all predictive, and can not be tested versus data (unless we wait for another year or so). The past experience (in IGRF-9 if I well remember) showed that the mean model is often better than the individual candidates, because they are based on different data datasets, modeling techniques and extrapolation schemes. In addition, some groups noted the possibility of a jerk close to the end of the available dataset. When preparing our models (group E), we had for instance to remove the Del Rio observatory, because the recent evolution (in 2008) of the field in that observatory could not be reconciled to what had been recorded in the nearby ones, reflecting what we think is an undergoing jerk too.

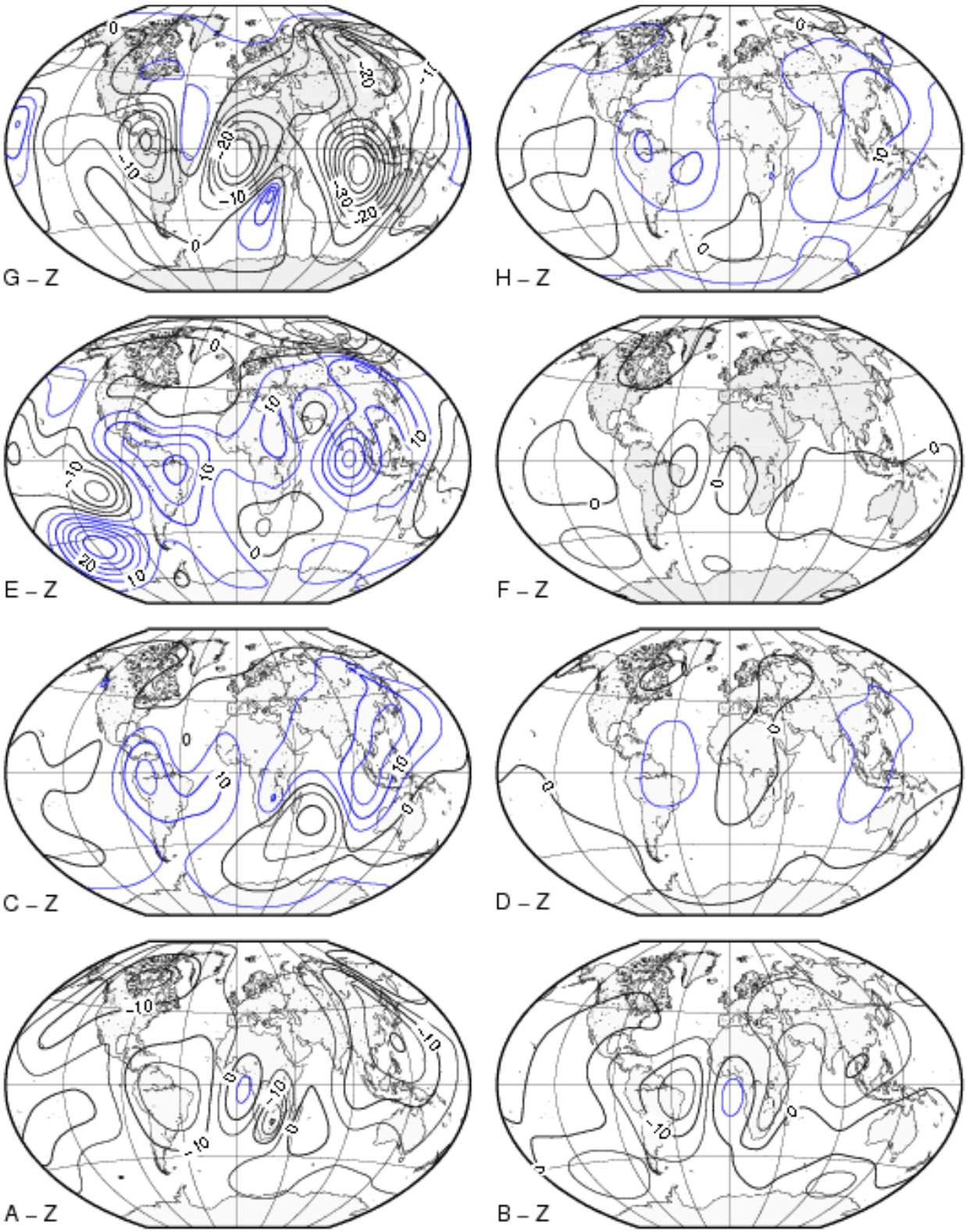

Figure 4 - Differences at the surface of the Earth between the eight IGRF-SV models and the mean model Z. Isocontours are every 5 nT/yr.

5 – Conclusions

I am not a member of the IGRF task force, and therefore I won't vote. My recommendation is the following.

- DGRF : reject model D if data-based tests are conclusive
- IGRF-MF: unweighted mean of all models
- IGRF-SV: unweighted mean of all models

In the future, I would like to see IGRF-MF candidate models submitted for a testable epoch (i.e. before extrapolation to desired IGRF epoch) and for the IGRF epoch. This would ease the comparisons.