RESIDUAL 11-YEAR SIGNAL IN COEFFICIENTS OF MAIN FIELD MODELS

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Several recently developed main geomagnetic field models, based on both observatory and satellite data (*e.g.*, IGRF, CHAOS, GRIMM, COV-OBS), as well as the historical model *gufm1*, were designed to describe only the internal part of the field, except for the COV-OBS that also accounts for the external dipole. We analyze data and coefficients from two main field models namely *gufm1* (Jackson *et al.*, 2000) and COV-OBS (Gillet *et al.*, 2013), by means of low pass filters with a cutoff period of 11-year, to evidence a residual signal with seemingly external sources, superimposed on the internal part of the field.

Key words: main field models, 11-year external signal, Gauss coefficients.

1. INTRODUCTION

Previous studies, published by Chapman and Bartels (1940), Yukutake (1965), Bhargava and Yacob (1969), Alldredge (1976), Courtillot and Le Mouël (1976), Alldredge *et al.* (1979), Yukutake and Cain (1979), Demetrescu *et al.* (1988), Verbanac *et al.* (2007), Wardinski and Holme (2011), Demetrescu and Dobrică (2005), Dobrică *et al.* (2013), Demetrescu and Dobrică (2014), showed that the annual means time-series provided by geomagnetic observatories contain an 11-year (quasi)periodical signal, related to solar activity.

That signal originates from the fact that during a geomagnetic storm the horizontal component of the field is depressed, sometimes by several hundred nT, while during the storm recovery phase the field gradually reaches the value prior to storm, being not compensated in the annual mean by any corresponding increase. This makes that annual means in years of high solar activity, characterized by strong/numerous geomagnetic storms, be smaller than in the years of low solar activity, characterized by less intense storms, hence a solar-cycle-related signal would be present in the time-series of observatory annual means. The signal in the horizontal component should be anticorrelated to the solar activity. Data recorded at observatories are used, together with satellite data, to model the main geomagnetic field and, inherently, the 11-year signal contaminating input data will leak into the model, as Figure 1 shows. We compare in that figure the 11-year signal in the time-series of annual averages at 27 European observatories and the 11-year signal in the time-series provided for the same locations by the *gufm1* (Jackson *et al.*, 2000) and COV-OBS (Gillet *et al.*, 2013) main field models, with the evolution of the solar activity as given by the sunspot number time-series. A low-pass running average filtering was used to isolate the signal (Demetrescu and Dobrică, 2005; 2014). The present study is looking for a residual signal, related to external variations at the 11-year time-scale, in the coefficients of the two long time-span models mentioned above, that are based on observatory data. The coefficients of the two models are available at http://www.epm.geophys.ethz.ch/~cfinlay/ and, respectively, at http://www.spacecenter.dk/files/magnetic-models/COV-OBS/.

2. METHOD

In processing time-series of the model coefficients, a Hodrick–Prescott (HP) filter (Hodrick and Prescott, 1997) was used, according to which a time-series y_t is a sum of a long-term component g_t, called trend, and a cyclic component c_t:

$$y_t = g_t + c_t, \text{ for } t = 1,...T.$$

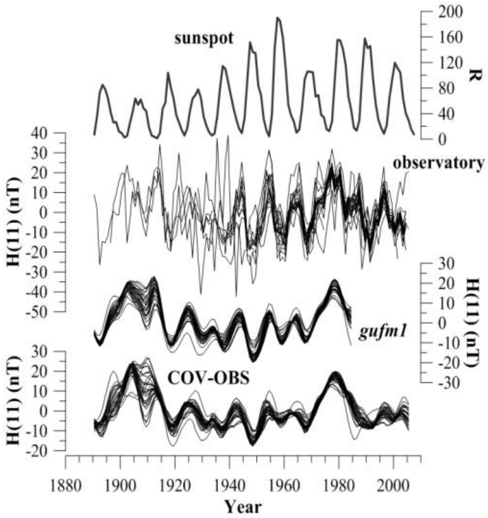

Fig. 1 – The time-series of sunspot number R (upper plot) and external effects in data recorded at observatories (middle plot) and in data provided by *gufm1* and COV-OBS (lower plots).

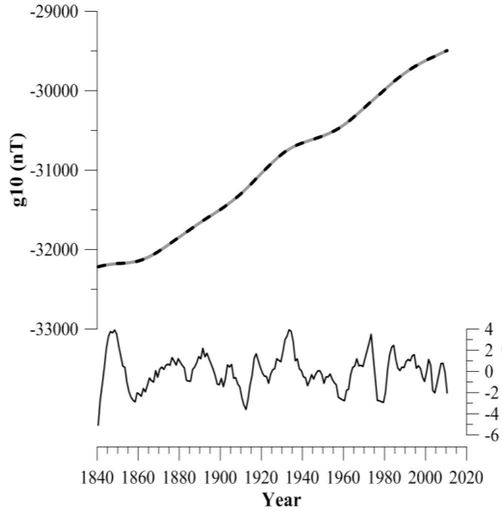

Fig. 2 – Upper plot: Evolution of COV-OBS g10 (dashed black) and of the long-term component (gray); lower plot: evolution of the cyclic component.

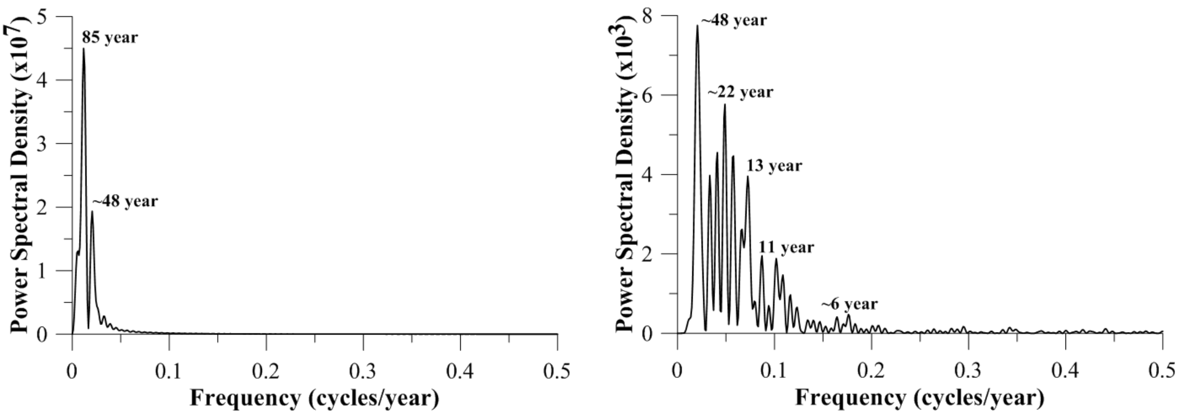

Fig. 3 – Power spectrum of the long-term component (left) and of the cyclic component (right) of g10.

The result of applying the HP filter to the time-series of the g10 coefficient of COV-OBS is given in Figure 2. The calculation of the long-term component is equivalent to a smoothing by means of a cubic spline function. The difference between the initial time-series and the long-term component represents the cyclic component. The long-term component contains a (quasi)periodical signal at the time scale of ~80 years, while the cyclic component contains signals at the time-scales of 11 and 22 years (Fig. 3). To isolate the 11-year signal in the cyclic component, an 11-year window running averages filter was applied.

3. RESULTS AND DISCUSSION

In Figure 4 the residual signals, related to solar activity, are plotted for the first 15 coefficients of *gufm1* and COV-OBS, representing the dipole, quadrupole and, respectively, octupole. One can notice that time intervals with richer, more uniformly distributed data (generally after 1940), the amplitude of the 11-year variation in the two models is very close. Also, the variation of the three coefficients representing the dipole has larger amplitudes in case of *gufm1* than in case of COV-OBS between 1840 and 1900, probably because in this time interval COV-OBS rely only

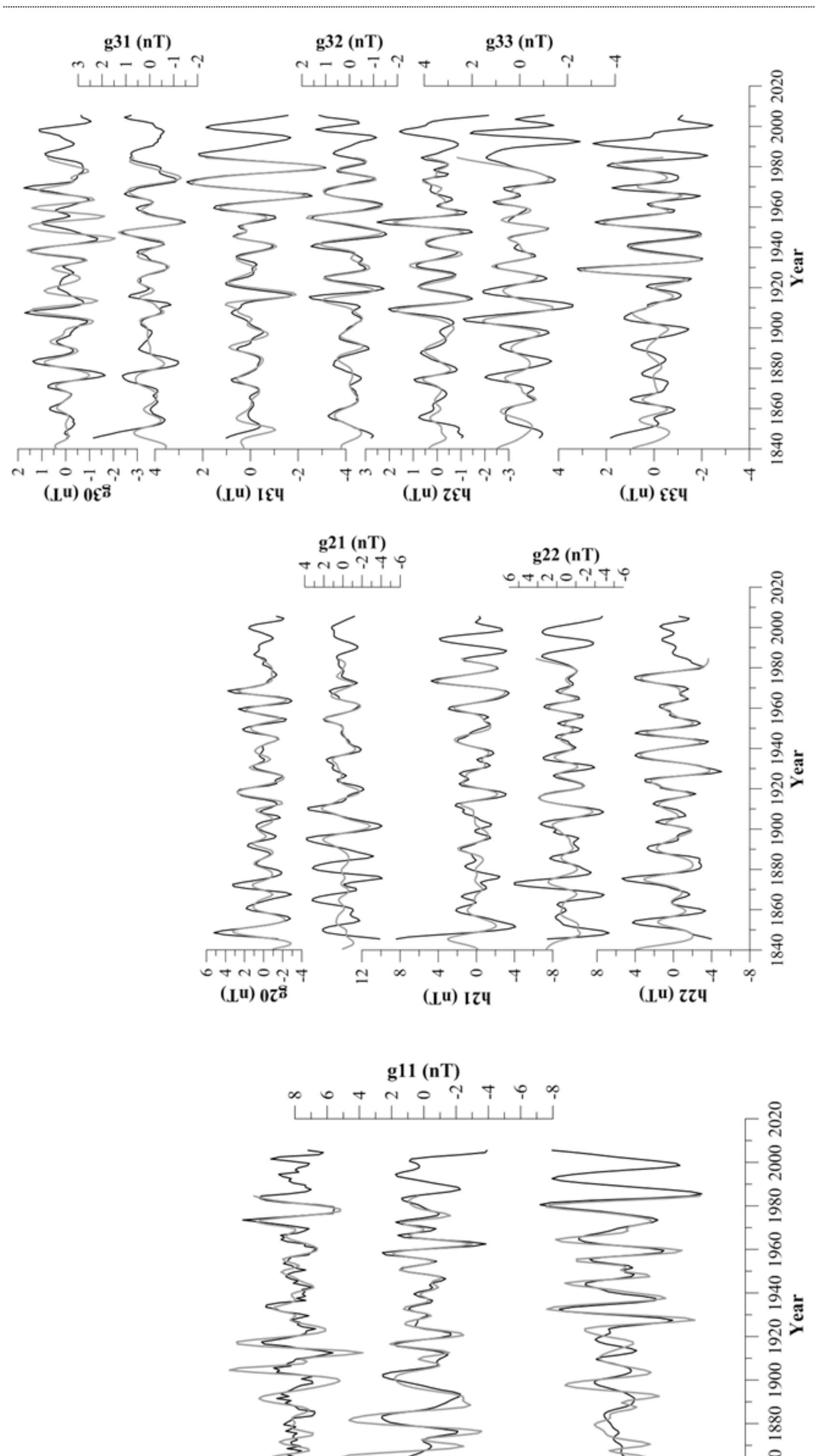

Fig. 4 – External effect in the *gufm1* (grey) and COV-OBS (black) main field models, for the case of dipole (left), quadrupole (middle), and octupole (right).

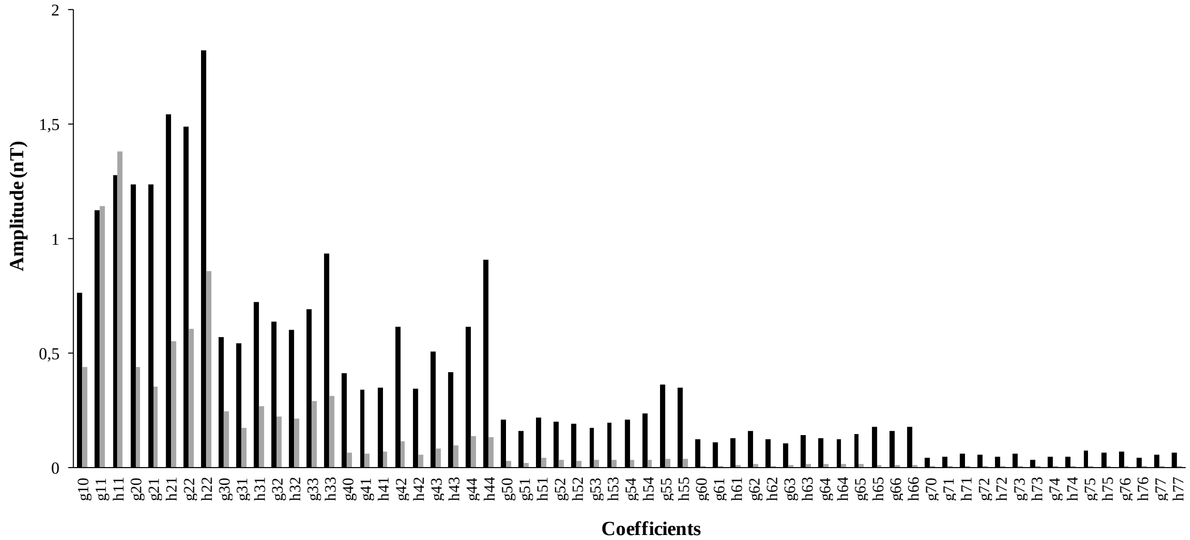

Fig. 5 – Mean amplitudes of the external effects in the Gauss coefficients to degree and order 7, in case of *gufm 1* (grey) and COV-OBS (black) main field models.

on observatory data, which are sparser and sparser as one goes back in time, while *gufm1* uses historical data in addition to observatory data.

The maximum amplitude of the residual signal in both models is of about 4-5 nT in case of dipole and quadrupole coefficients, and of about 3 nT in case of the octupole. A direct comparison of mean amplitudes of the 11-year signal in the coefficients of the two models is given in Figure 5 to the degree and order 7 of the spherical harmonic expansion. The mean amplitude of the 11-year signals is decreasing as the degree and order are increasing. The total effect is of 10-20 nT.

4. CONCLUSION

The present study rendered evident the contamination of the coefficients of two main field models that employed observatory data by a (quasi)periodical 11-year signal related to solar activity. While in individual coefficients the amplitude of the signal is of about 3–5 nT, decreasing with the degree and order of the coefficient, the total effect amounts to 10–20 nT.

The residual external signal in main field geomagnetic models may give information regarding the solar activity and its geoeffectiveness for times prior to geomagnetic observatories era. It is compulsory, however, that such signals be eliminated from models when used to infer information on secular variation space and time evolution.

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