SUB-CENTENNIAL VARIATIONS IN THE HORIZONTAL COMPONENT OF THE GEOMAGNETIC FIELD. PRELIMINARY RESULTS

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The study is based on H geomagnetic data returned by the long-term model of the main geomagnetic field *gufm1* (Jackson *et al*., 2000) in a grid of 2,5×2.5 degrees of latitude/longitude, for the time interval of the model validity (1590–1990). Each time series returned by the model was first subjected to a Hodrick and Prescott (HP) analysis (1997), to separate a decadal variation from a so-called trend, and then the trend to a Butterworth (1930) filtering, to retrieve inter-decadal (20–30 years time scale) and sub-centennial variations (60–90 years time scale). Characteristics of the latter are discussed pointing to external primary sources (magnetospheric ring current and ionospheric polar current systems).

Key words: geomagnetic field models, multi-decadal oscillations, external current systems.

1. INTRODUCTION

It is common knowledge that in the annual averages of geomagnetic elements provided by geomagnetic observatories there is an external residual variation, not averaged out, that results in an 11-year-solar-cycle variation in H and Z time series of observatory annual means. In Fig.1 we present, as an example, the evolution of the Dst geomagnetic index during the moderate geomagnetic storm of August 22–27, 2005, showing that the depression of the geomagnetic field during the main phase of the storm is not compensated in the annual average by any increase of the field during the recovery phase of that storm. Indeed, Demetrescu and Dobrică (2014) showed the presence of this variation in case of H time series provided by 24 observatories with long activity (100–150 years). They also detected variations at two other time scales, namely 'inter-decadal' (20–30 years) and 'sub-centennial' (60–90 years) ones, as they were coined later (Ștefan *et al*., 2017, Dobrică *et al*., 2021) and noticed that, not accounting for these variations before modelling the main field using observatory and/or historical data, they appear in the field evolution described by long-term models of the main field, such as *gufm1* (Jackson *et al*, 2000), or COV-OBS (Gillet *et al*., 2013). In Fig. 2 we show the 11-year-solar-cycle variation in observatory and long-term geomagnetic field models data, compared to the solar sunspot number.

2. DATA AND METHOD

In the present paper, we analyze time series of the geomagnetic field returned by the *gufm1* model in a grid of 2.5×2.5 degrees of latitude/longitude of the European continent. Like Dobrica *et al*. (2018), we use the Hodrick and Prescott (1997) type of analysis that separates the cyclic variation at a decadal time scale from the trend in data, followed by a Butterworth filtering (Butterworth, 1930) of the trend to extract the inter-decadal and the sub-centennial variations. We focus here on the sub-centennial variation, as having the largest amplitudes (see further below) and draw some preliminary conclusions on that variation in the geomagnetic field.

Fig. 3 illustrates the above-described filtering procedure used in this paper for a point corresponding to the position of the Niemegk geomagnetic observatory (IAGA code NGK), central to the European network of observatories. The analysis also involved the magnetic declination (not swown), a less studied geomagnetic element (see Stefan *et al.*, 2023).

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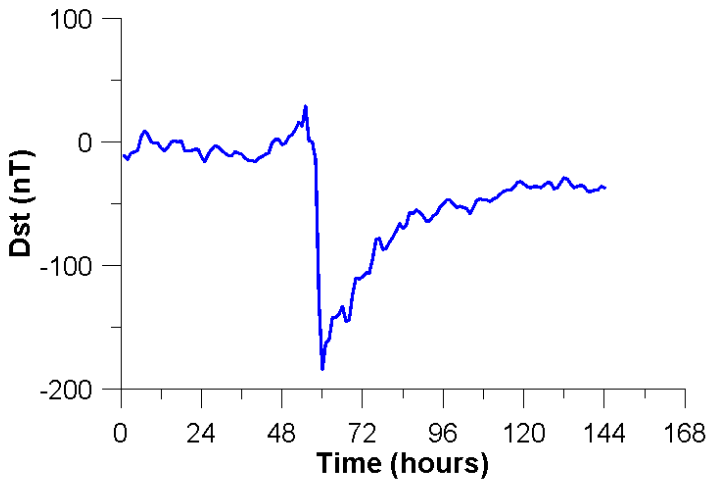

Fig. 1 – The evolution of certain geomagnetic storm, illustrated by means of the Dst geomagnetic index characterizing the moderate storm of August 22–27, 2005.

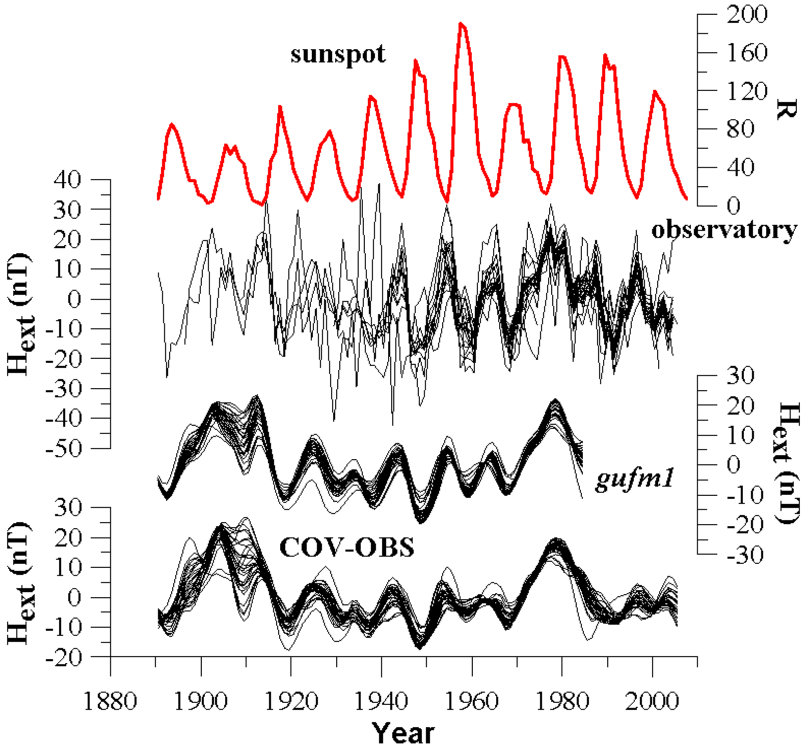

Fig. 2 – Decadal variation in observatory annual means and in long-term main field models *gufm1* and COV-OBS, as compared to the sunspot number time series.

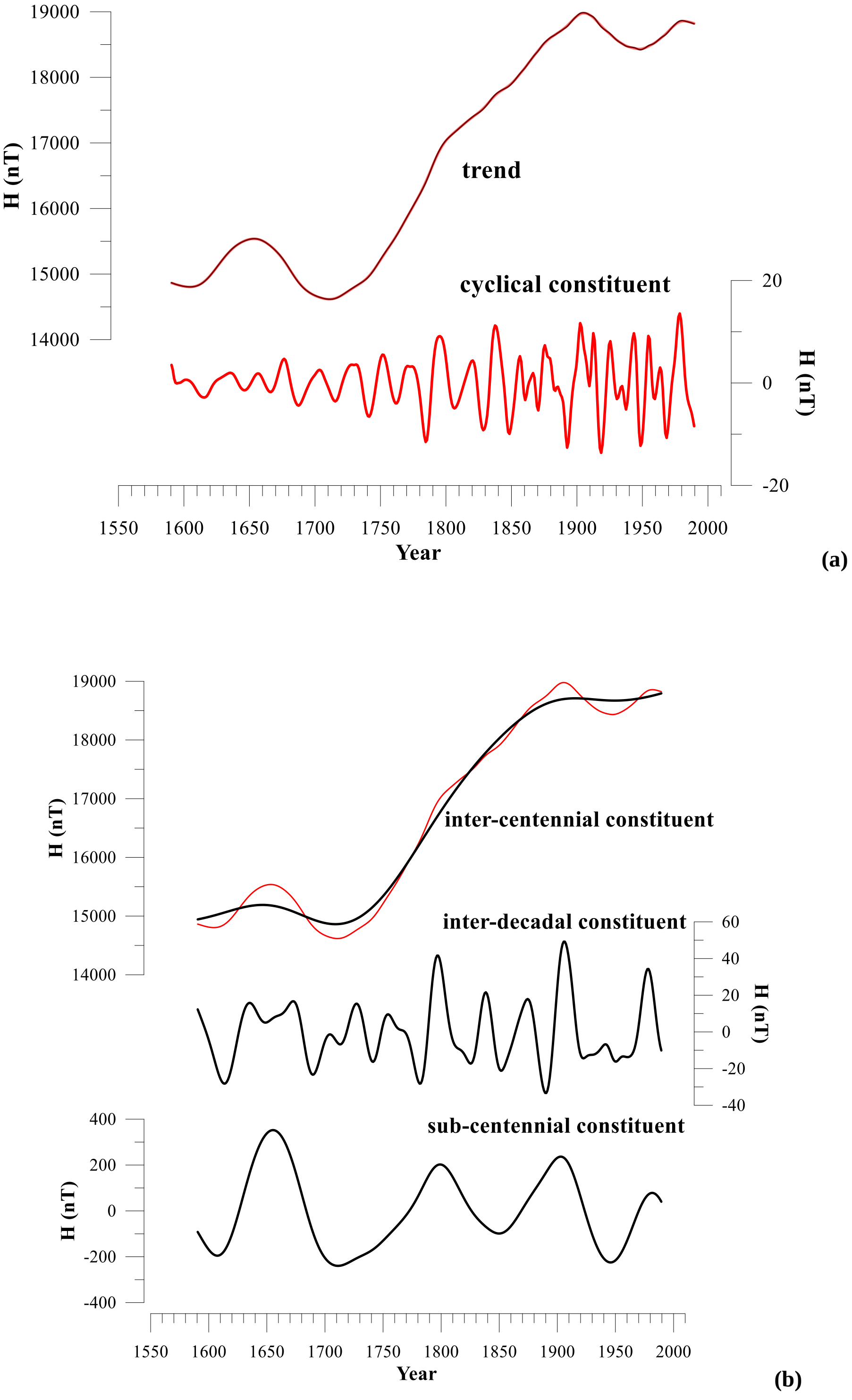

Fig. 3 – Filtering procedure: (a) HP filter; (b) Butterworth filter. Illustration for a point corresponding to Niemegk geomagnetic observatory (IAGA code, NGK).

3. RESULTS AND DISCUSSION

Fig. 4 shows the evolution of the sub-centennial constituent for several latitudes between 40 and 70°N. A few characteristics can be distinguished at this stage, namely the oscillatory character, with amplitudes amounting to 800 nT in case of low – mid-latitude points, much higher than in case of the other swub-centennial variations, namely decadal (cca 30 nT) and inter-decadal (cca 100 nT) ones (see Fig. 3). In case of high-latitude points of the grid (>50°N), several other oscillations appear. This general behavior points to external sources, namely the magnetosphere ring current and, respectively, the polar ionosphere currents that form as a result of the interaction between the solar wind and the magnetosphere. Time-longitude plots (Hovmöller, 1949) of the three oscillatory features (Fig. 5) also point to the same external origin, showing elongated strips of the same amplitude, slightly inclined with respect of the geographical coordinates. They probably reflect induction effects of the mentioned external current systems that are organized by the orientation of the geomagnetic axes; a separate quantitative study is however necessary, having in view their large amplitudes (Demetrescu *et al.*, 2023, in preparation). For the moment, we remind the reader the oscillations seen in the heliosphere-magnetosphere environment by Demetrescu *et al.* (2010) that point to oscillations in the external current systems. Another important conclusion refers to the certain diminishing of period in the recent times, from 130 years in the time span 1620–1750, to 110 years in the time span 1870–1980, illustrating a certain variation in the past of the effectivity of the solar activity.

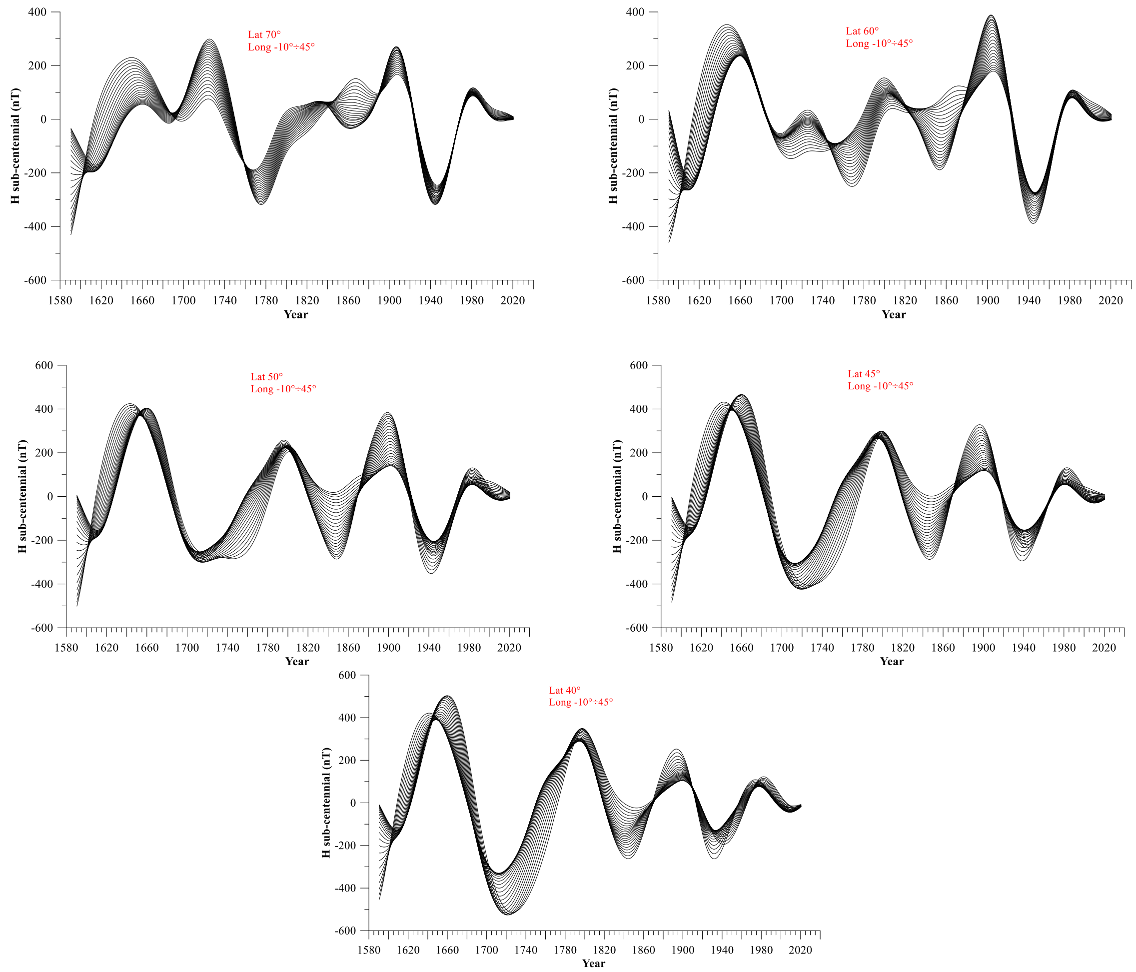

Fig. 4 – The evolution of the sub-centennial constituent for several latitudes between 40° and 70°N.

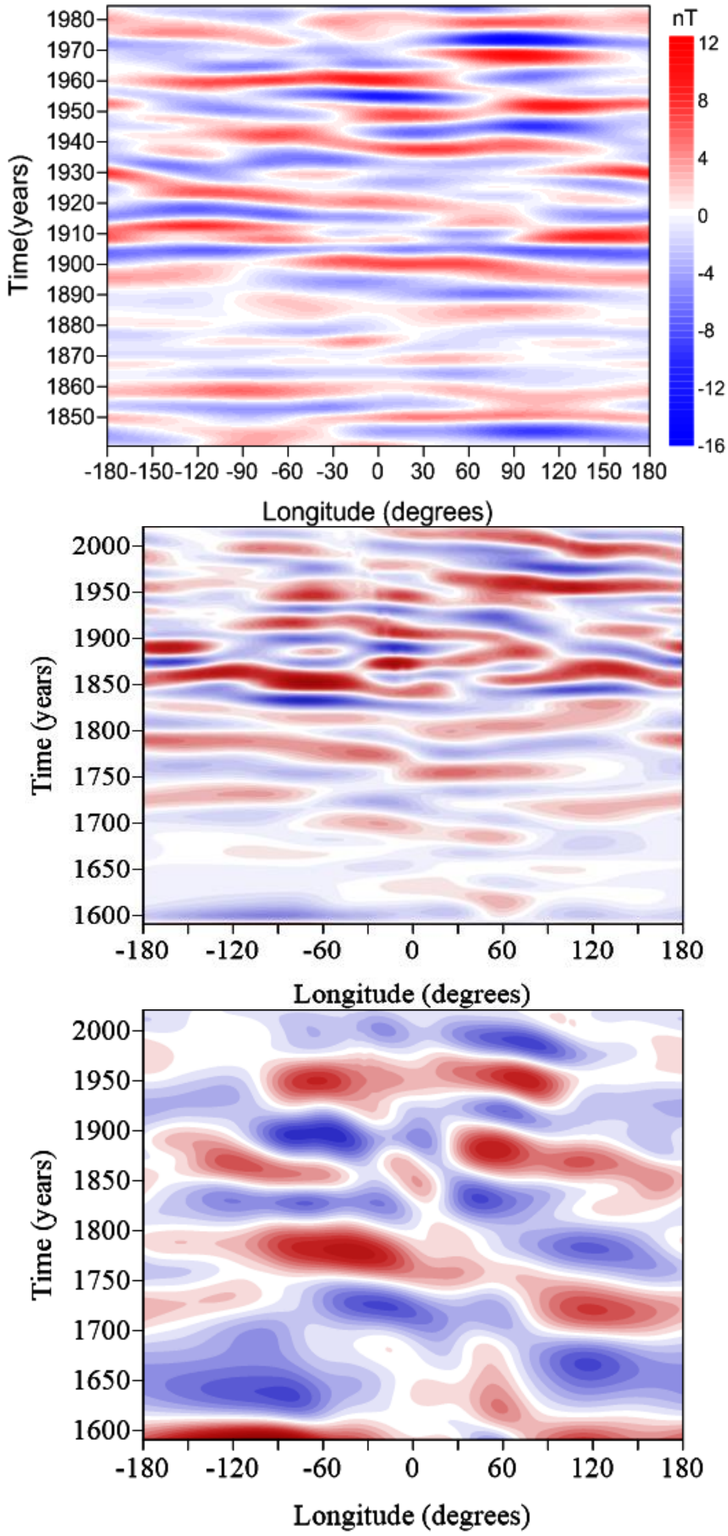

Fig. 5 – Time-longitude plots of the three oscillatory features. From top to bottom: decadal, inter-decadal and sub-centennial.

4. CONCLUDING REMARKS

In this paper have been discussed preliminary results on the sub-centennial variation seen in long-term model *gufm1* of the main geomagnetic field (Jackson *et al*., 2000). This variation has been noticed first in annual mean time series produced by geomagnetic observatories (Demetrescu and Dobrică, 2014).

Among the main conclusions we may emphasize: the oscillatory character, the latitude dependency of these variations, and the past variation of the frequency content. They all point to an external primary origin. Additional work is necessary to disentangle further details, such as the contribution of the induced response of the Earth's interior to the observed variations.

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