One of the most important characteristics of the geomagnetic field is its secular variation. Nowadays, it can be observed a decreasing of the dominant axial component of the dipole field of 16 nT/yr at least since 1840 AD (Finlay et al., 2016). For earlier times the paleomagnetic and archaeomagnetic reconstructions are a very useful test for the past of the field.

In this work, we focus our study on the last 10 ky, covering almost the entire Holocene, analyzing in detail the increases and decreases of the dipole field energy. For this purpose, we have selected four representative paleomagnetic reconstructions: SHA.DIF.14k (Pavón-Carrasco et al., 2014), CALS10k.2 (Constable et al., 2016), BIGMUDI4k (Arneitz et al., 2019) and SHAWQ2k (Campuzano et al., 2019).

3. DISCUSSION

Focusing on SHA.DIF.14k and CALS10k.2 paleoreconstructions, since they are the ones that cover the entire 10 ky, we study the long-term over the last 10 ky. Analyzing the dipole Gauss coefficients (Fig.1) we can assure that the long-term behavior is observed only in the axial dipole. We take the long-term of the $g_1$ (Fig. 6) and analyze the increasing and decreasing time intervals. There are two decreasing times: from 7000 BC to 4500 BC and between around 100 BC and present time, and only one increase is registered in the $g_1$ which occurs between 4500 BC and around 100 BC in both models.

The behavior of the long-term can be seen as a succession of decays and pulses. For evaluating these processes we assumed that the decreasing intervals are dominated by the diffusion following an exponential decay (Merrill et al., 1998). We can compute a characteristic time, $\tau$, by fitting the long-term of $g_1$ to a decreasing exponential function ($g_1 \propto e^{-t/\tau}$). The results for SHA.DIF.14k are $\tau = 7800 \pm 1200$ years for the first decay and $\tau = 15300 \pm 1800$ years for the present decay. Meanwhile, in CALS10k.2 the values obtained are $\tau = 25700 \pm 2600$ years and $\tau = 19300 \pm 1600$ years for the first and second decays, respectively. There is a great difference in the characteristic times in the 7000 BC to 4500 BC decay that may be attributed to the lack of data at the earliest times since the results for the present decay of the $g_1$ are closer. These results for diffusion times are the same order of magnitude as the diffusion times for the dipole field in the geodynamo ($\tau_b = 10^{5}-10^{6}$ years) (González-Lopez, A.1, Campuzano, S.A.2 / Instituto de Geociencias, IGEO (CSIC – UCM), C/ Severo Ochoa 7, Edificio Entrepabellones 7 y 8, 28040, Madrid, Spain / 3 Istituto Nazionale di Geofisica e Vulcanologia (INGV), Via di Vigna Murata, 605, 00143, Rome, Italy)

If now we consider that the diffusion is always present, the increasing interval of $g_1$ between 4500 BC and 100 BC is affected by $\tau$. In order to get the 'real' increase of the $g_1$ we eliminate the correspondent diffusion in each time point as the exponential decay fitted in the previous decay (7000 BC - 4500 BC). The hypothesis we make is this 'pulse', i.e. the 'real' increase of $g_1$ is comparable with the charge of a capacitor, since we have fitted the decay interval as its discharge ($g_1 \propto 1 - e^{-t/\tau}$). This simple model allows us to obtain characteristic times of 'charge' of the axial dipole of around 300 and 500 years and 1660 and 3000 years for SHA.DIF.14k and CALS10k.2, respectively. We can also compute a maximum theoretical value of $g_1$ which would be reached if the charge is completed. However, this does not occur and the observed minimum value before the present decay is around 24% in SHA.DIF.14k and 64% in CALS10k.2 of the theoretical value obtained with the fit.

4. CONCLUSIONS

In this work, we analyzed the secular variation of the dipole field during the Holocene. We have performed a detailed frequency analysis using three different techniques, Fourier Transform, Empirical Mode Decomposition and wavelet analysis that allow us to determine the following characteristic parameters:

- A period of around 1400 years observed especially in CALS10k.2 and BIGMUD4k, and with lower power in SHA.DIF.14k that could be related to the 1550 year cycle observed by Wilson et al. (2011).
- Between 600 - 800 years which is observed in the four selected paleoreconstructions during the whole time window.
- The shortest period is observed around 200 - 300 years, especially in BIGMUD4k and SHAWQ2k.

For the long-term, we hypothesize that it is controlled by a succession of ‘pulses’ and decays and we modeled them as the charge and discharge of a capacitor. We obtained coherent re- results for the characteristic times of diffusion of $g_1$ for the present day decay in SHA.DIF.14k and we modeled them with values between 13 - 15 ky. This simple model results in characteristic times of the same order of magnitude as the diffusion times for the dipole field in the geodynamic theories.

References

Nilsson et al. (2011).