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Natural periodicities and Northern Hemisphere-Southern Hemisphere connection of temperature changes during the last glacial period: EPICA and NGRIP data sets revisited

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We investigate both the European Project for Ice Coring in Antarctica Dronning Maud Land (EDML) and North Greenland Ice-Core Project (NGRIP) δ^{18}O data sets to study both the time evolution of the so-called Dansgaard-Oeschger events and the dynamics at longer timescales during the last glacial period, considering the interval $20 - 120$ kyr B.P., since this is the interval in which significant temperature changes, that are the focus of the present work, are observed. To identify the main periodicities and their amplitudes, we applied the Empirical Mode Decomposition (EMD), a technique designed to investigate non-stationary data, by which both the δ^{18}O time series are decomposed into a finite number m of oscillating intrinsic mode functions (IMFs) as

$$\delta^{18}O = \sum_{j=0}^{m-1} C_j(t) + r_m(t) \tag{1}$$

where $C_j(t)$ are the IMFs and $r_m(t)$ is a residue which provides the mean trend. We extract the proper modes of both the data sets confirming that natural cycles of abrupt climate changes exist and their occurrence cannot be due to random fluctuations in time. It is shown that the time behavior at the typical timescales of Dansgaard-Oeschger events is captured through signal reconstructions obtained by summing five EMD modes for NGRIP and four EMD modes for EDML. The reconstructions obtained by summing the successive modes can be used to describe the climate evolution at longer timescales, characterized by intervals in which Dansgaard-Oeschger events happen and intervals when these are not observed. Using EMD signal reconstructions and a simple model based on the one-dimensional Langevin equation, it is argued that the occurrence of a Dansgaard-Oeschger event can be described as an excitation of the climate system within the same state, while the longer timescale behavior appears to be due to transitions between different climate states. Finally, on the basis of a cross correlation analysis performed to investigate the North-South asynchrony, it is found that the clearest correlation occurs between the long-scale reconstructions at a lag of $\simeq 3.05$ kyr, which supports the view according to which the Antarctic climate changes lead that of Greenland, but on a longer time-scale than previously reported. The novelty introduced by this work is represented by the fact that we use EMD reconstructions to investigate the climate dynamics at different timescales and to highlight the behaviour of the climate system in order to describe transitions between two different stable states. We also suggest that the results of correlation analysis could be explained in the framework of seesaw models but building up a model which take into account our EMD filtered long timescales series. The results presented could be also useful for theoretical modeling of the climate evolution in order to study which kind of mechanisms are involved and to clarify the role of the ocean into coupling mechanism between the two hemispheres.