Geophysical Research Abstracts
Vol. 18, EGU2016-5031, 2016
EGU General Assembly 2016

Coherency of European speleothem δ^{18}O records linked to North Atlantic ocean circulation

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Speleothem δ^{18}O records can provide valuable information about past continental environmental and climatic conditions. In recent decades a European speleothem network has been assembled that allows us to reconstruct past climate variability in both space and time. In particular climate variability during the Holocene was investigated by these studies. The Holocene is thus an ideal period to apply sophisticated statistical methods to derive spatio-temporal pattern of common climate variability in the European speleothem record.

Here we evaluate a compilation of 10 speleothem δ^{18}O records covering the last 4.5 ka for their shared variability. The selected speleothem δ^{18}O records must satisfy certain quality criteria to be included: (i) a robust age model; (ii) a temporal intra-sampling resolution of smaller than 30 years; and (iii) the record should be published. A Monte Carlo based Principal Component Analysis (MC-PCA) that accounts for uncertainties in individual speleothem age models and for the different and varying temporal resolutions of each speleothem δ^{18}O record was used for this purpose. Our MC-PCA approach allows not only the identification of temporally coherent changes in δ^{18}O records, but it also facilitates their depiction and evaluation spatially. The compiled speleothem δ^{18}O records span almost the entire European continent (with the exception of the circum-Mediterranean region) ranging from the western Margin of the European continent (stalagmite CC-3, Ireland) to Northern Turkey (SO-1) and from Northern Italy (CC-26) to Norway (FM-3). For the MC-PCA analysis, the 4.5 ka period was sub-divided into eight 1 ka long time windows that overlap the subsequent time window by 500 years to allow a comparison of the temporal evolution of the common signal. In this study we only interpreted the 1^{st} principal component (PC) that depict the spatio-temporal pattern with the highest explained variability of all speleothem δ^{18}O records. Our MC-PCA results demonstrate that a common signal (expressed by the 1^{st} PCs) is shared by the investigated speleothem δ^{18}O records for each individual time window and that the 1^{st} PCs agree in the overlapping periods. This allowed us to construct a common speleothem record (CSR) for the last 4.5 ka. The CSR shows a strong millennial cyclicity in the investigated period.

We demonstrate that the large-scale changes in the European CSR, reflected by its millennial cyclicity, are in phase with the well-known Bond cycles during the last 4.5 ka that reflect changes of drift ice in the North Atlantic (Bond et al., 2001). Evidence for this link was also shown by Mangini et al. (2007) using a stalagmite from the Central Alps. Furthermore, the CSR shows a very good agreement with a recent, independently dated reconstruction for the strength of the sub-polar gyre (Thornalley et al., 2009) and we argue that these changes during the last 4.5 ka are likely caused by the variability of the atmospheric circulation affecting the interplay between the subpolar gyre and the subtropical gyre in the North Atlantic, as well as European speleothem δ^{18}O records.

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