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Fine scale correlation between palaeoclimatic polar data and isotopic composition of speleothems from Corchia Cave (Central Italy)

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Abstract

The Arca Project aim is to investigate the extreme meltwater in terms of events from both palaeoclimatic and modern air-sea-ice interaction. Here we focus on the recognition of the expression of high-latitude Holocene palaeoclimatic variations in the medium-latitude palaeoclimatic archives. The climate in the Polar Regions and in the North West Europe is mainly controlled by the North Atlantic Oscillation (NAO), defined as the difference in atmospheric pressure at sea level between the Icelandic low and the Azores high (Hurrell & Deser, 2009; Olsen et al., 2012). The variation of NAO, expressed as NAO index positive (NAO+) or negative (NAO-), is strongly linked to the position of the Atlantic westerly wind jet (AWJ) and consequently to the storm tracks in the North Atlantic, which exert a strong effect on the amount of precipitation in western Europe and on the $\delta^{18}O$ of rainfall (Olsen et al., 2012; Smith al., 2016). During NAO+, the South Polar Gyre (SPG) current is stronger, it is more E-W oriented making the Atlantic inflow fresher (Thornalley et al., 2009), AWJ are stronger and their tracks migrate northwards leading to wetter and warmer conditions in the North of Europe and dryer in the South including the western Mediterranean (Cacho et al., 2001). Reversely on NAO- conditions the SPG current is weaker and N-S oriented making the Atlantic inflow saltier, AWJ are weaker and their tracks shift southward leading to wetter and warmer condition in the South of Europe and dryer in the North. (Fig. 1). Within the framework of the ARCA project we studied geochemical proxies ($\delta^{18}O$ and $\delta^{13}C$ isotopes and trace element variations) from cave carbonate deposits (speleothems) from the Corchia Cave in the Apuan Alps mountain chain (Central Italy, Fig. 1), in order to highlight the main climatic events occurred during the Holocene and their relationship with climatic variations at high latitudes. $\delta^{18}O$ values from continental carbonate in the Mediterranean are usually interpreted as indicating drier conditions during periods of increased values and wetter conditions for decreasing trends associated with a marked "amount effect" on rainfall (Bard et al., 2002; Drysdale et al., 2009). Similarly increasing $\delta^{13}C$ values are interpreted as lower biogenic CO_2 supply, which can result from either short soil–water residence times or minimal soil and vegetation cover above the cave (McDermott, 2004; Drysdale et al., 2004). The Apuan Alps are a mountain range abruptly rising from the narrow coastal plain of the Tyrrhenian seaboard to about 2000 m a.s.l. They represent a natural barrier to humid westerly air masses of North Atlantic provenance (Fig. 1), which bring annual precipitation reaching 3000 mm/yr.

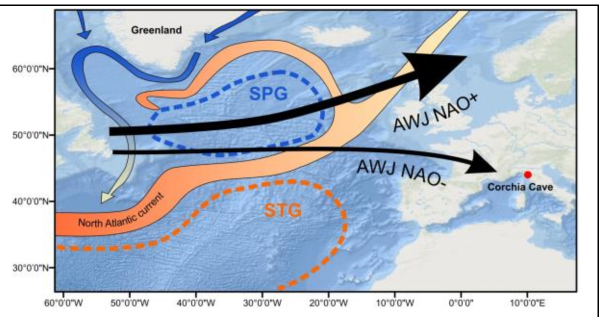

Figure 1: *Simplified North Atlantic climate system. SPG Sub Polar Gyre, STG Sub Tropical Gyre, orange to yellow and blue to light green curves are the major thermohaline ocean currents. Black arrows show Atlantic Wind Jet tracks: the thicker arrow shows the tracks of the stronger AWJ under NAO+ conditions, the thinner one shows the tracks of weaker AWJ under NAO- conditions. (modified by Smith et al., 2016). The red dot indicates the Corchia Cave position.*

The Antro del Corchia Cave is a complex karst system about 60 km long and 1200 m deep, mainly carved in the carbonate core of the Mount Corchia syncline Fig. 2a). Here the CC27 stalagmite was collected from the "Galleria delle Stalattiti" (Fig. 2b), a near-horizontal chamber located at ~840 m a.s.l., vertically overlain by ~400 m of karst rock. Consistently with its deep position within the cave system, the environment is characterized by highly stable air temperature (mean 7.7± 0.2 °C), slow drips showing substantial chemistry stability throughout the year in terms of both isotopic and trace element ratios (Baneschi et al., 2011; 2015). Such speleothems are also characterized by very slow growth and pure calcite deposition (Drysdale et al., 2004; 2009; Regattieri et al., 2014; Zanchetta et al., 2007).

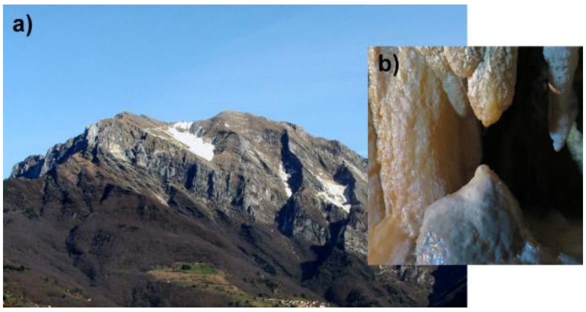

Figure 2: *(a) Mount Corchia; (b) speleothems in the "Galleria delle stalattiti".*

Figure 3 compares CC27 δ^{13}C and δ^{18}O data (a and b) with North Atlantic and subpolar climate records: the isotopic signal from Cueva de Asiul speleothems (North Spain, Fig. 3, d) related to the south polar oceanic dynamic (Smith et al., 2016); the hematite stained grain percentages (%HSG curve, Fig. 3 e) from four stacked ocean cores (Bond et al. 2001), related to iceberg surge and melting under cooler North Atlantic conditions; the isotopic signal from the Spannaghel Cave (Austria, Fohlmeister et al., 2013; Fig. 3 f); the variation in density offshore Iceland (Fig. 3 g), related to the SPG strength (Thornalley et al., 2009). CC27 δ^{13}C and δ^{18}O isotopic records show both short-term events and long-term trends, suggesting large climatic changes at centennial to millennial scale in the western Mediterranean throughout 6 ka to 2 ka. Isotopic values well correlate with the most well-known prominent periods of rapid climatic variation including the 4.2 ka (Weiss et al., 2001; Drysdale et al., 2006; Zanchetta et al., 2016) and the 5.2 ka dry events (Wanner et al., 2008; Zanchetta et al., 2015).

General trends of CC27 isotopic curves and the most prominent cold/dry events, have also shown to be very close to many important sub-polar and Atlantic records such as the cold 2, 3, 4 IRD events (light blue boxes in Fig.3), the variation of density offshore Iceland, and the isotopic values from the Cueva de Asiul speleothems. These factors indicate that at millennial scale the isotopic record from the Corchia cave is modulated by the variation in the North Atlantic

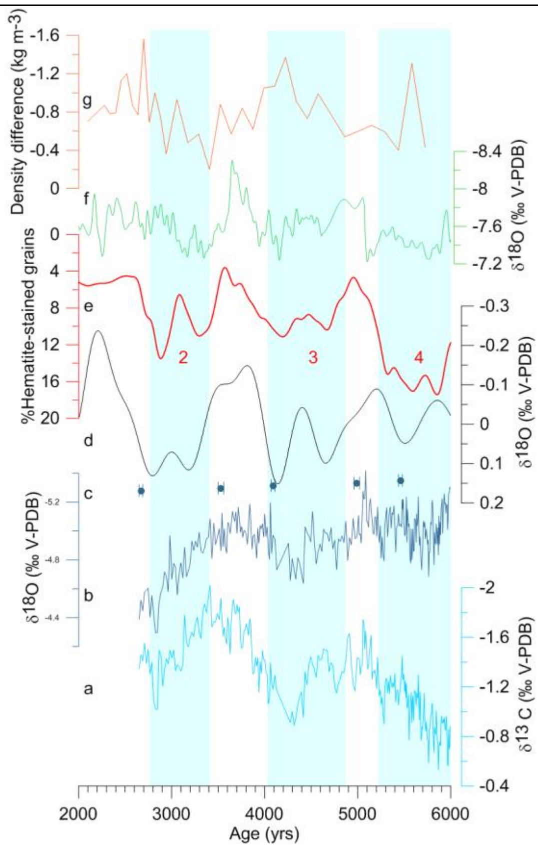

Figure 3: *(a) CC27 δ^{13}C record; (b) CC27 δ^{18}O record; (c) CC27 ages; horizontal bars show 2σ errors;(d) the combined Cueva de Asiul speleothems δ^{18}O record (Smith et al., 2016); (e) hematite stained grain percentages in the southerly transport of ice rafted debris (Bond et al., 2001); (f) changes in surface and subsurface density difference in the North Atlantic as proxy of freshwater flux to the subpolar North Atlantic (Thornalley et al., 2009). (g) the combined Spannagel Cave speleothems δ^{18}O record (Fohlmeister et al., 2013). Light blue boxes and numbers 2, 3 and 4 indicate each of the three IRD events of the North Atlantic. Ages are reported as AD 2000.*

way of changes in the position and strength of the westerlies and vapour advection to the Mediterranean from the North Atlantic, highlighting the tight climatic teleconnection.

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