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Paleoclimate variability since last deglaciation reconstructed for the North Iberian Peninsula: the El Pindal Cave speleothem record (Asturias, Spain)

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Previous geomorphologic studies of the northern Iberian Peninsula mountains (Pyrenees and Picos de Europa) suggested that the maximum glacial extent was reached at least 10 ka before the last global glacial maximum (LGM). These records have coarse temporal resolution and do not resolve rapid climate changes. To identify and describe the abrupt climate changes of the region since last deglaciation and to investigate the potential forcing mechanisms, we analyzed stable isotope (δ^{18}O and δ^{13}C) and elemental ratio (Mg/Ca, Sr/Ca and Ba/Ca) records from two well-dated stalagmites from the north coast of Spain (El Pindal cave, Asturias).

Modern precipitation at the study site was sampled at 48-hour intervals and analyzed for O-isotopes. The isotopes showed a high correlation with the North Atlantic Oscillation (NAO) index indicating that the oxygen isotopes in rain and drip-water are regulated by the moisture source and condensation height and temperature. If this correlation held for the whole record, the NAO effect is expected to be superimposed on the changes in δ^{18}O of source seawater from ice volume effects. Oxygen isotopic values in the speleothems are highest from 22.8 to 18.2 ka, coincident with the global

LGM. Exceptional correlation along that interval with atmospheric temperature over Greenland recorded in GISP2 core reveals an extreme sensitivity of this area to North Atlantic abrupt climate changes. A hiatus in speleothem growth occurs between 18.2 and 15.4 ka, likely pointing to a cold and dry period, which may be related to Heinrich Event 1. The Holocene δ^{18}O values are lower but highly variable, pointing to significant hydrological variability during the last 11 ka. Carbon isotopic values suggest they record vegetation changes, with C4 plants being more abundant during the glacial (less negative δ^{13}C values) and C3 plants dominant since 14.5 ka. Mg/Ca ratios rise sharply after 8ka. Today El Pindal cave is right on the coast and the mass balance for the drip waters suggests about 80% of Mg could be from sea salt aerosols. Thus, the 2-3 fold increase in Mg content may be due to sea level rise. Sr and Ba increases are associated with greater vegetation (eg mobilization by organic chelates). Thus, both Sr/Ca and Ba/Ca ratios point to warmer temperatures and perhaps denser vegetation from 7.5 to 5 ka, synchronous with the most recent humid period in North Africa.

The inferred climate variability from our speleothem records is coherent with paleoclimate reconstructions based on a new lacustrine record from the nearby Lago Enol (Picos de Europa, Asturias) and from marine sediments offshore the Galician coast. The integration of speleothem, lacustrine and marine climate – proxy paleorecords helps to evaluate the main feedbacks among the different climate systems (ocean-land-atmosphere) and differences in the timing and intensity of the abrupt changes in the continent and the oceans.