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Abrupt temperature changes and contrasted hydrological responses during Greenland Stadial 1 in northern Iberia

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Greenland Stadial 1 (GS-1) was the last of a long series of severe cooling episodes in the Northern Hemisphere during the last glacial period, whose origin is attributed to the complex interaction of intense weakening of the Atlantic Meridional Overturning Circulation, moderate negative radiative forcing and an altered atmospheric circulation (Renssen et al., 2015). As a result, marine and terrestrial records from the North Atlantic region indicate a cooling of several degrees, being larger in high latitudes (up to 4˚C) and diminishing towards the southeast (0.5˚C) (Heiri et al., 2014). Here, we present the first stalagmite record that covers the entire GS-1 period in Southern Europe, providing an excellent and independent chronological framework and a high-resolution climate reconstruction of this event (Bartolomé et al., 2015). The stalagmite is from Seso Cave from the central Pyrenees (42˚27′23.08″N, 0˚02′23.18″E, 794 m asl) where a 3-year monitoring survey, together with the analyses of actively growing modern stalagmites, allows climate proxies in stalagmites to be calibrated to the instrumental record. Thus, analysis of oxygen isotopes in a modern stalagmite from Seso Cave suggests a strong dependence on air temperature through its influence on rainfall δ^{18}O, providing a reliable proxy for the temperature evolution during GS-1. According to these calculations, the δ^{18}O change of 2.14‰ during GS-1 is considered to represent a 1.3 ˚C drop of the annual temperature.

Besides reflecting GS-1 cooling in the Pyrenees, the Seso Cave stalagmite is used here to investigate the timing and forcing of a mid–GS-1 climate transition previously reported from northern European records (Lane et al., 2012). δ^{13}C and Mg/Ca of Seso samples show higher values between 12,920 y b2k and 12,500 y b2k, a gradual decrease until ca. 12,000 y b2k, and a period with lower values until the Holocene onset at 11,700 y b2k. This pattern, although still at low resolution due to a reduced growth rate, is reproduced in two stalagmites more from Central Iberia (La Galiana Cave, Soria province). Monitoring of Seso Cave shows low speleothem δ^{13}C and Mg/Ca values coinciding with increased infiltration into the cave as a result of a higher precipitation-evaporation balance in the region. This is consistent with well-documented processes by which slower drip rates enhance degassing and raise dripwater Mg/Ca ratios and δ^{13}C values. Therefore, these proxy data suggest a first phase of relatively drier conditions until 12,500 y b2k and a progressive increase in humidity afterward. This gradual transition from dry to wet conditions starting at 12,500 y b2k occurred during a progressive warming of the subtropical Atlantic Ocean (Schmidt et al., 2011) and a resumption of the Atlantic overturning circulation (Hughen et al., 2000) while conditions in Greenland were still cold. This, therefore, demonstrates a rapid coupling among terrestrial (atmospheric) and oceanic systems at the mid–GS-1 transition on the European continent. This second phase of GS-1 calls for a revision of the well established model of dry and cold stadials during the last glacial period.