Supplementary material of:

Unprecedent cave ice melt in the last 6100 years in the Central Pyrenees (A294 ice cave)

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The Cotiella massif belongs to the South-Central Pyrenean Unit, and consists of Upper Cretaceous limestones, Paleocene and Eocene limestones and marls (Fig. S1). Its formation is due to the tectonic inversion of the Cotiella basin, where sediment accumulated from the mid-Coniacian to the lower Santonian, reaching approximately 6 km in thickness. The tectonic inversion began in the late Cretaceous and persisted till the Lower Miocene. The Cotiella, Gavarnie, Millares, and Bielsa thrusts constitute the sequence of inversion structures from top to bottom. Within this region, the Cotiella and Gavarnie thrusts, affecting the sedimentary cover, are tilted to the south due to the emplacement of the lower thrusts, Millaris and Bielsa, affecting the basement rocks. This inversion follows a general foreland breaking sequence. Consequently, the base of the Cotiella thrust sheet descends to the south, revealing over 3 km of structural relief (Séguret, 1972; García-Senz, 2002; Martínez-Peña and Casas-Sainz, 2003; López-Mir et al., 2015, 2016).

The entrance to the cave is located within the Maciños Limestone Formation, situated in the Reduno anticline, according to López-Mir et al. (2015). The Maciños Formation, also known as the Cotiella Maciños Formation, is composed of red to orange calcarenites with variable quartz content and gravel-bearing sandstones. The Aguasalenz Formation comprises well-stratified limestones and marls, exhibiting significant facies variations along the Cotiella basin (López-Mir et al., 2015).

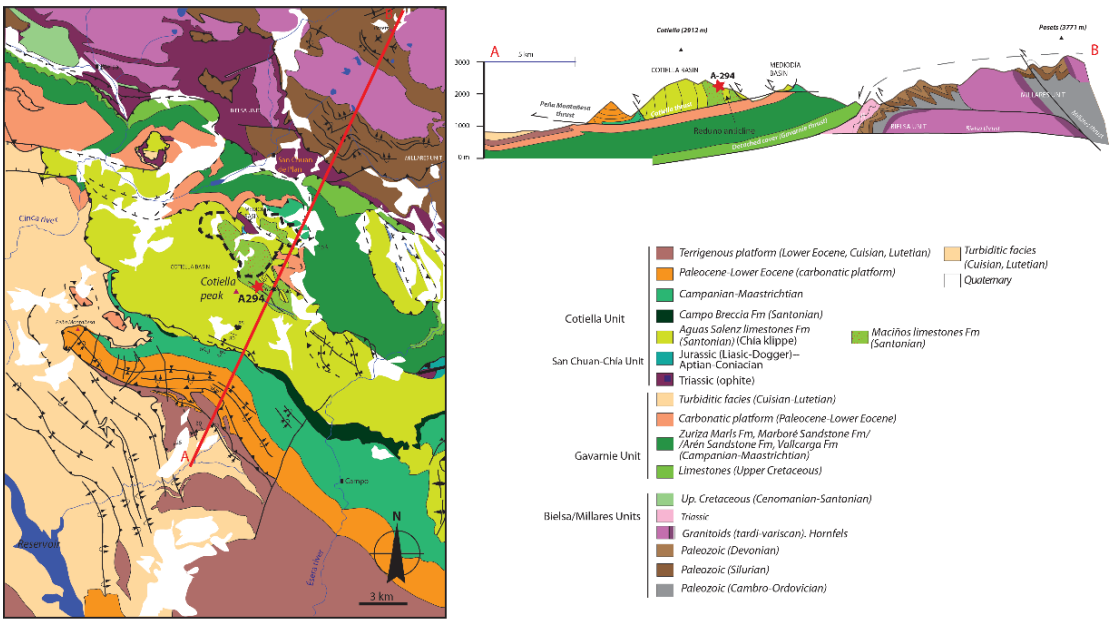

Figure S1: Simplified geological map of the Cotiella area based on IGME Bielsa (179) Ríos et al., (1982) and Campo (212) Robadoret al. (1999) and López-Mir et al. (2015), and cross-section (red line on the map). Red star in the cross-section indicates the location of the A294 ice cave.

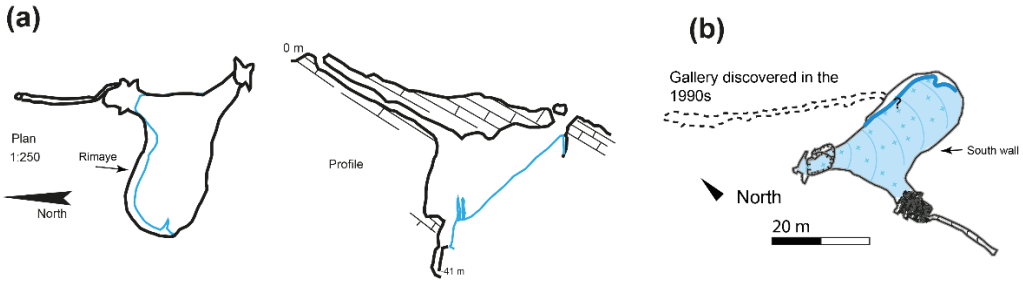

Figure S2. a) A294 cave topography in 1978 digitalized from a map of the Grupo de Espeleología Cataluña Aragón (G.E.C.A). b) Corrected North orientation and topography, and probable extension of the rimaye in that year.

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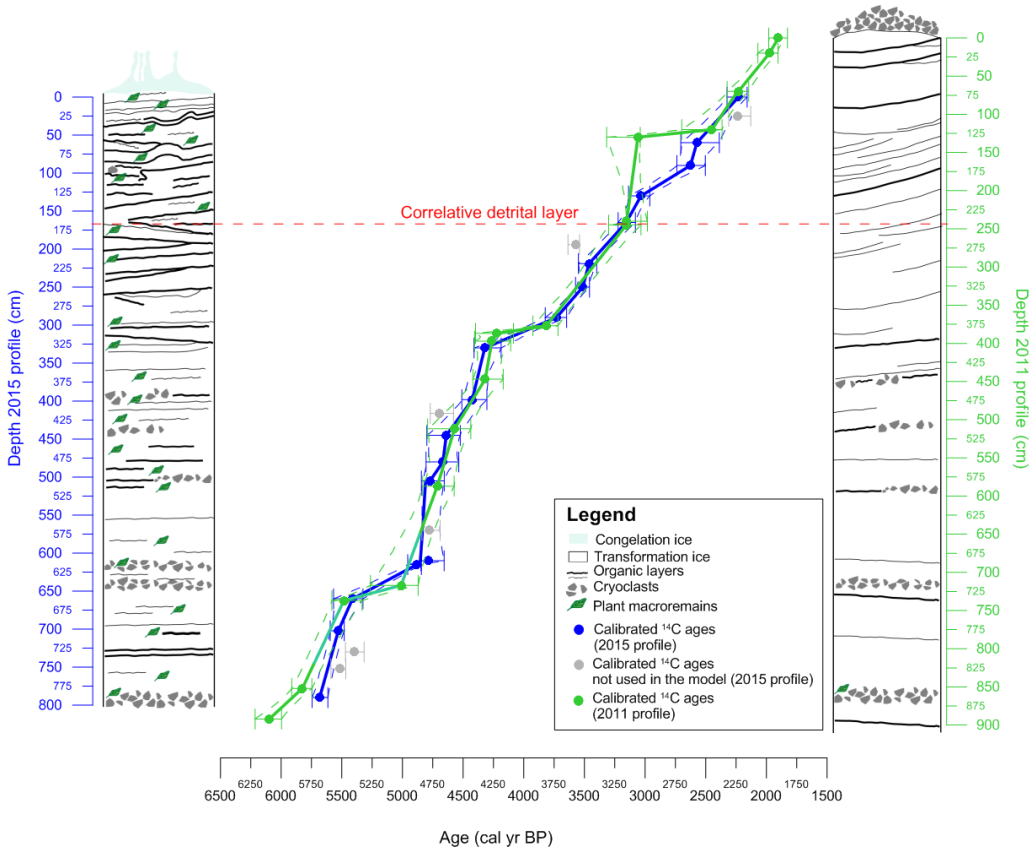

Figure S3: Comparison of stratigraphic logs and depth-age models obtained in 2011 (Sancho et al., 2018; right) and 2015 (Leunda et al., 2019, left).

Figure S4: General view of the ice deposit (upper image) and detail of the ice ramp (red square, lower image) after the snow had disappeared, and location of the ablation pit hole (green square, top left image) where the A294 R-Mid sample was taken for ^{14}C dating.

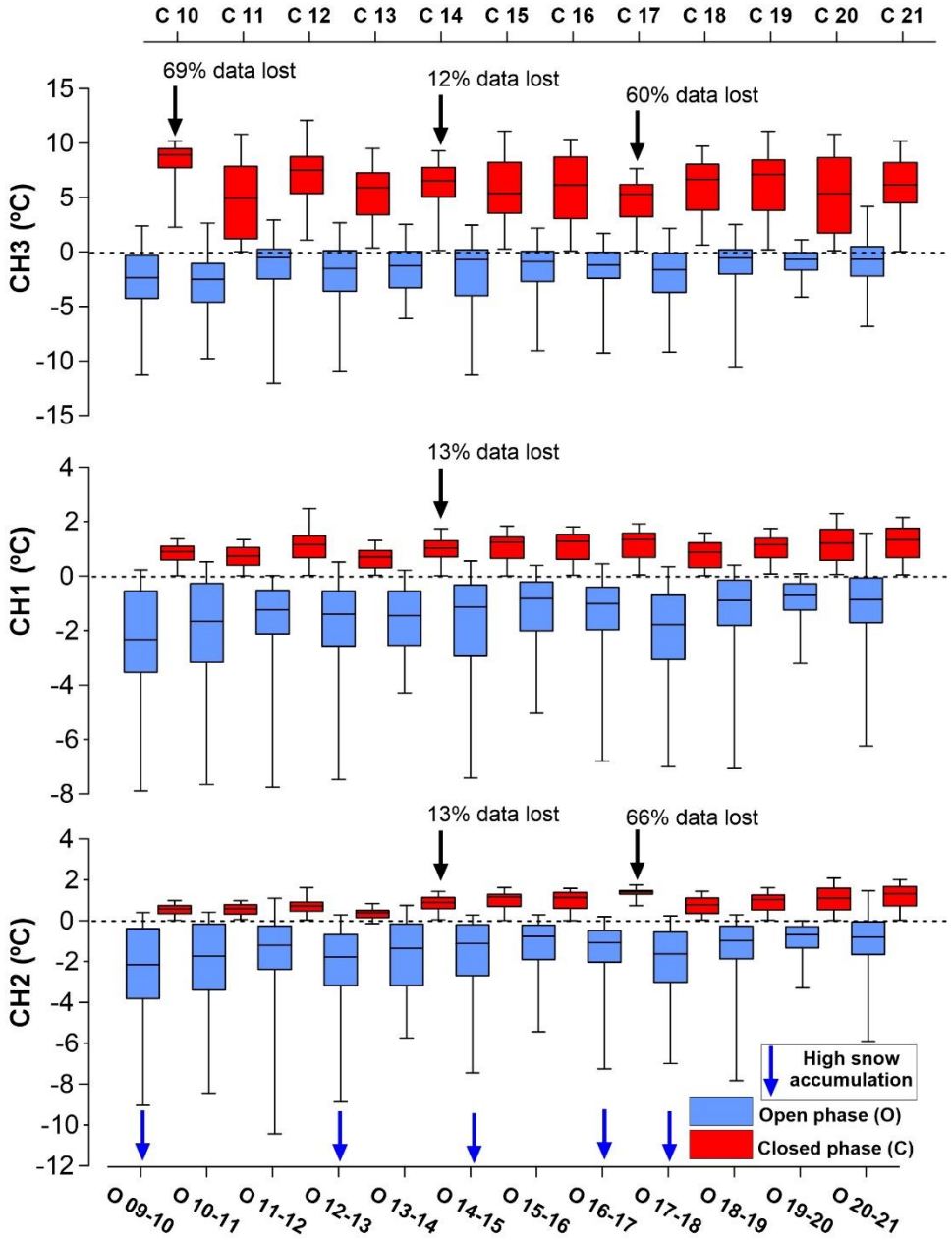

Figure S5. Box-plot of open (blue) and closed (red) phases in A294 between 2010 and 2021. The lost data correspond to sensor failures.

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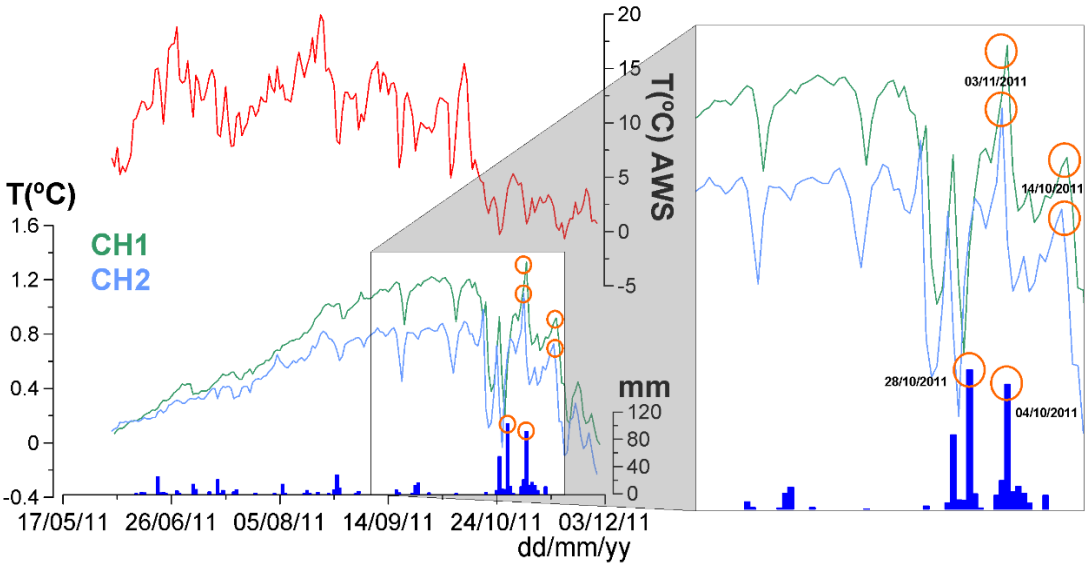

Figure S6. Example of extreme rainfall (>80 mm) recorded by the Armeña weather station and delayed increases in cave air temperature in A294. Red line is the external temperature, while green and blue lines represent the cave temperature variations recorded by the CH1 and CH2 sensors, respectively. Dark blue vertical bars represent precipitation events.

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