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## A coupled multi-proxy and process modelling approach for extraction of quantitative terrestrial ecosystem information from speleothems

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Terrestrial ecosystems are intimately linked with the global climate system, but their response to ongoing and future anthropogenic climate change remains poorly understood. Reconstructing the response of terrestrial ecosystem processes over past periods of rapid and substantial climate change can serve as a tool to better constrain the sensitivity in the ecosystem-climate response.

In this talk, we will present a new reconstruction of soil respiration in the temperate region of Western Europe based on speleothem carbon isotopes ( $\delta^{13}\text{C}$ ). Soil respiration remains poorly constrained over past climatic transitions, but is critical for understanding the global carbon cycle and its response to ongoing anthropogenic warming. Our study builds upon two decades of speleothem research in Western Europe, which has shown clear correlation between  $\delta^{13}\text{C}$  and regional temperature reconstructions during the last glacial and the deglaciation, with exceptional regional coherency in timing, amplitude, and absolute  $\delta^{13}\text{C}$  variation. By combining innovative multi-proxy geochemical analysis ( $\delta^{13}\text{C}$ , Ca isotopes, and radiocarbon) on three speleothems from Northern Spain, and quantitative forward modelling of processes in soil, karst, and cave, we show how deglacial variability in speleothem  $\delta^{13}\text{C}$  is best explained by increasing soil respiration. Our study is the first to quantify and remove the effects of prior calcite precipitation (PCP, using Ca isotopes) and bedrock dissolution (open vs closed system, using the radiocarbon reservoir effect) from the speleothem  $\delta^{13}\text{C}$  signal to derive changes in respired  $\delta^{13}\text{C}$  over time. Our approach allows us to estimate the temperature sensitivity of soil respiration ( $Q_{10}$ ), which is higher than current measurements, suggesting that part of the speleothem signal may be related to a change in the composition of the soil respired  $\delta^{13}\text{C}$ . This is likely related to changing substrate through increasing contribution from vegetation biomass with the onset of the Holocene.

These results highlight the exciting possibilities speleothems offer as a coupled archive for quantitative proxy-based reconstructions of climate and ecosystem conditions.

