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Changes in the balance of soil respired CO_2 (root vs. soil organic matter) during the Younger Dryas event; evidence from three European cave sites

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The main goal of this study was to understand better the response of soil carbon to a major climate transition and to examine the influence of variable temperature sensitivity of different carbon sources. New radiocarbon measurements for portions of three speleothems from European cave sites (La Garma and El Pindal caves, N. Spain; Sofular cave, Turkey) deposited during the late-Glacial to early Holocene were used to investigate these processes. These data were used to improve the interpretation of δ^{13}C in stalagmites, which can be influenced not only by the temperature and moisture changes (reflected in major climatic transitions), but also by several different processes (e.g. variable degassing and limestone dissolution, soil evolution, hydrological effects). Pollen data indicate that C3 plants persisted at all three sites since the late-Glacial. There is however a marked increase in δ^{13}C during the Younger Dryas (YD) in all three stalagmites, indicating a climate driven change in carbon cycling dynamics. In principle this change could reflect stronger degassing due to drier conditions or more closed system behaviour (higher 'dead carbon proportion' (dcp) due to greater limestone dissolution). Closed system modeling indicates that greater limestone dissolution should result in higher δ^{13}C and lower initial ^{14}C activity as a result of dilution by 'dead' carbon. In practice, initial ^{14}C activity of stalagmite carbonate during the YD in all three speleothems follows the atmospheric ^{14}C age plateau, indicating open system behaviour, with little evidence for lowering of ^{14}C activity that would be expected to result from enhanced limestone dissolution. This is interpreted as a change in the balance of soil-respired CO_2. Soil CO_2 is a combination of soil organic matter (SOM) and plant-root respiration. In the latter process, plants cycle only ambient atmospheric CO_2 (relatively high ^{14}C activity). By contrast, microbial decomposition of soil organic matter typically involves breakdown of older (low ^{14}C activity) carbon. Our data indicate that there is a change in the balance between these two sources as a result of temperature and moisture change during the YD. Overall, soil respiration rates were reduced during the YD (less biogenic C input and therefore higher δ^{13}C), and were dominated by live root respiration of ambient atmospheric carbon. In the Holocene, CO_2 from decomposition of soil-stored carbon overwhelms CO_2 from root respiration at all three sites. This is consistent with an analysis of published speleothem ^{14}C data from several European cave sites. Speleothems from cold-wet sites in N. Europe show clear evidence for progressive ageing and storage of recalcitrant carbon in soils, resulting in lower ^{14}C activity and dcp-time trends that are consistent with radioactive decay of soil-stored carbon. By contrast, at warmer S. European sites, there is no evidence for build-up and storage of recalcitrant SOM (high ^{14}C activity, low dcp in speleothems), indicating that organic matter is rapidly cycled through the soil. Global warming is likely to impact high latitude northern hemisphere sites that can release large quantities of stored carbon, resulting in a positive climate feedback.