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High-Resolution Isotopic Monitoring of Cave Air CO_2

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This study aims at characterising the ventilation patterns in Spannagel Cave, a high-alpine cave system in the Zillertal Alps, Austria. A Thermo Scientific *Delta Ray* Isotope Ratio Infrared Spectrometer was installed in a chamber ca. 100 m behind the cave entrance to monitor pCO_2 and $\delta^{13}C$ and $\delta^{18}O$ of CO_2 at high temporal resolution (up to 1 s). The air temperature was independently monitored inside and outside the cave.

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The data show two distinct patterns in terms of CO_2 concentration and its isotopic composition, which are closely coupled with the temperature difference between the cave interior and the outside atmosphere. This gradient controls the direction of air flow in the cave on a seasonal to synoptic timescale (chimney-type ventilation).

The summer circulation is characterised by CO_2 closely resembling atmospheric values ($pCO_2 = 399 \pm 12$ *ppm,* $\delta^{13}C = -8.5 \pm 0.7$ *permil,* $\delta^{18}O = 8.1 \pm 2.5$ *permil*). The winter circulation mode features generally higher CO_2 concentrations and lower isotopic compositions ($pCO_2 = 409 \pm 14$ *ppm,* $\delta^{13}C = -10.1 \pm 0.7$ *permil,* $\delta^{18}O = 2.3 \pm 1.5$ *permil*).

The high temporal resolution of stable isotope data allows tracking cave air ventilation changes, including transient and short-lived ones. Moreover, the data make it possible to address concomitant geochemical processes, such as the input of atmospheric CO_2 and the degassing of CO_2 from seepage water. These processes would not be possible to quantify without the new generation of laser-based isotope ratio instruments represented by the *Delta Ray*.