Borehole-based study of CO2-rich air transport in the vadose zone of a Mediterranean karst system (Malaga, southern Spain)

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The characterization of CO₂ transport, and other C compounds (CH₄, DIC, organic matter, etc.), in the vadose zone of a karst aquifer is key in order to quantify sources and sinks of carbon. In karst environments, most of the studies are focused on the dynamics of CO₂ in caves, but only a few studies are related to field measurements of the CO₂ content in boreholes, which provides direct insights about the vadose zone. Located at the east of the Nerja Cave (Malaga, Andalusia), one of the most important tourist caves in Spain, the vadose zone was accessed by 9 boreholes drilled into the vadose zone of a Triassic carbonate aquifer, with depths ranging between 15 and 30 m. The karst network in the study area is characterized by a great vertical heterogeneity, with significant cavities and voids at specific intervals. Groundwater levels at different altitudes are a consequence of this heterogeneity. Similarly, CO₂ distribution and transport are clearly determined by the complex karst network.

Our study aims to identify significant horizontal gradients of CO₂ in the karst vadose air, both spatial and temporally. We present monthly measurements of CO₂ concentration, relative humidity, air temperature and ²²²Rn inside boreholes. In addition, we present CO₂ results from an 18 hours-atmospheric air injection test. Linking them to the geophysical knowledge of voids in the study area, the results allow us to identify lateral fluxes of CO₂-rich air in the vadose zone and how these fluxes are favoured by the incidence of the main karst discontinuity orientations. We observe different ventilation patterns: in spring the vadose air seems to be stored in specific orientations, while in summer there is a lower convective ventilation. The results contribute to explain the temporal variations of the chemical composition of recharge water in karst systems, as well as to support studies on the global carbon budget.