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Assessment of aerodynamic processes on subsurface in karst terrains by rapid multi-parametric surveys (case of Castanar Cave, Spain)

A. Fernandez-Cortes (1), S Cuezva (2), M Garcia-Anton (1), M Alvarez-Gallego (1), JC Canaveras (2), E Porca (3), V Jurado (3), C Saiz-Jimenez (3), and S Sanchez-Moral (1)

(1) MNCN-CSIC, Madrid, Spain (acortes@mncn.csic.es), (2) Univ. Alicante, Alicante, Spain (jc.canaveras@ua.es), (3) IRNAS-CSIC, Seville, Spain (saiz@irnase.csic.es)

The transfer of the isotopic signals and the trace element abundances in speleothems depends of the gas-aqueous-solid equilibrium conditions in the cave environment. Therefore, the speleothem paleoclimate interpretation requires of a previous knowledge about the influence of gas exchange and cave ventilation processes on the current speleothem growth, among other hydrogeochemical features related to the infiltration process.

Here, we propose an intense and rapid multi-parametric study (few-hours long surveys) that includes simultaneous and spatial-distributed sampling and measurements of: carrier (CO_2) and trace gases (^{222}Rn and CH_4), isotopic signal of CO_2 ($d^{13}C$) and temperature of a cave atmosphere (Castañar cave, west-central Spain), in order to achieve an early overview and better understand the relationships between surface weather and the cave microphysical environment. A portable stable carbon isotope ratio analyzer was used to rapidly and reliably detect $^{12}CO_2$ and $^{13}CO_2$ concentration anomalies and identify possible spatial changes in the isotopic composition of the cave air in relation to external soil and atmosphere. Additionally, an aerobiological sampling was conducted to quantify the level of airborne microorganisms (bacteria and fungi) in cave air. The spatial distribution of these microenvironmental parameters was modeled by geostatistical techniques.

Previous studies revealed that Castañar is a low-energy cave characterized by a very stable microclimate over an annual cycle; however a preferential cave area was identified due to soft but anomalous variations of the measured parameters. Despite it is a deep area, far from the single and most elevated entrance of the cave, some microenvironmental features at this cave site reveal a high connection degree with the outer atmosphere: 1) higher air temperature (+0.89^{o}C) and variations (+0.22^{o}C); 2) lower radon levels (roughly -5000 Bq/m^3) and 3) an elevated level of airborne microorganisms, in relation to nearby emplacements. The homogeneous spatial distribution of CO_2 content (3700-3950 ppm) and $d^{13}C$ signal of cave air at inner areas (-24.2 to -23.8‰) suggest the soil (-19.8 to -18.6‰) as the main CO_2 source, even in the most superficial areas near cave entrance and atmosphere (-9,85 to -11,65‰). A mixing model could be inferred with both an active ventilation and gas-exchange with exterior controlled by the geomorphology at surface and filtering by the soil membrane.

This methodological approach based on monthly samplings extended over, at least, an annual cycle could be potentially useful to discriminate or select the speleothems with more reliable climatic records, i.e.; distinguishing those located in the most microclimatic stable emplacements that should respond to secular changes on climate, from those exposed to short-term climatic changes that could be used as geo-indicators of early warning. Moreover, it provides guidance on conservation strategies of caves such as for the delimitation of specific and immediate cave protection areas in relation to the surface geomorphology.