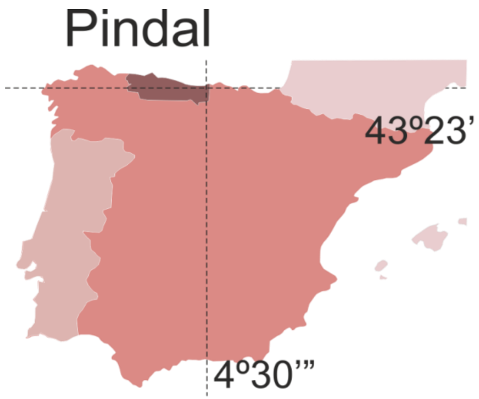
On the role of cave-soil in the carbon cycle. A first approach.

Soledad Cuezva, Tamara Martin-Pozas, Angel Fernandez-Cortes, Juan Carlos Canaveras, Ivan Janssens, Sergio Sanchez-Moral



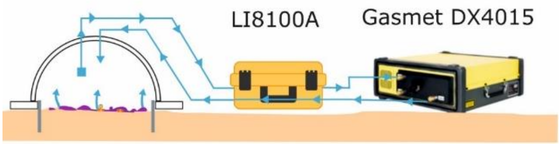
Objectives: The aim of this preliminary study is monitoring the carbon fluxes, CO_2 and CH_4, from cave soil directly exchanged with the cave atmosphere.

Study site: Pindal Cave (Asturias, north of Spain), is a touristic shallow cave with Paleolithic (Magdalenian) paintings.

Particular environment: absence of light, small thermohygrometric variation and large CO_2 oscillation.

Annual:	average	range
Cave air temperature, ^{0}C	11.7	2
Cave air CO_2, ppm	700	1000

Methods:

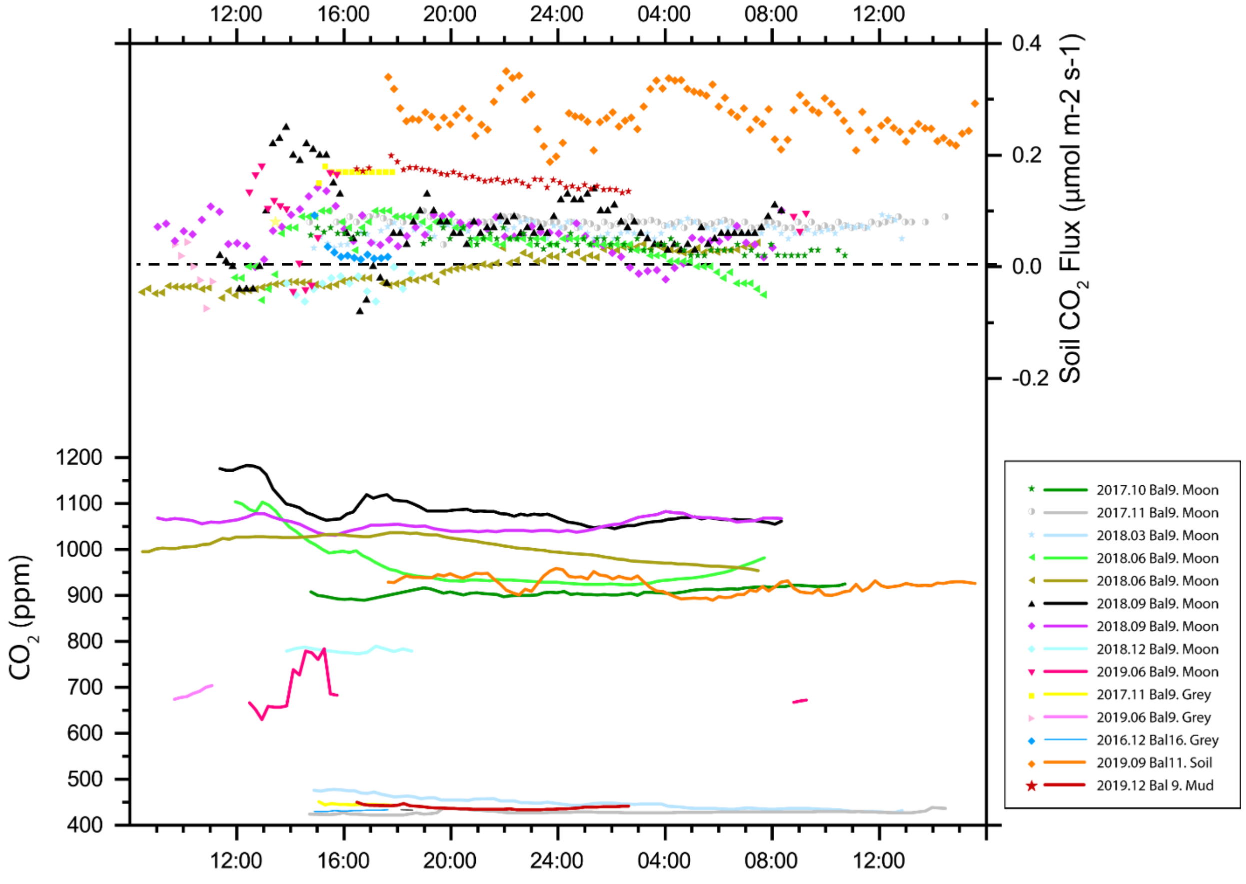


(1) In situ real-time automatic monitoring of CO_2 and CH_4 cave-soil fluxes: Seasonal campaigns with daily continuous monitoring by a closed chamber-based gas exchange system (LICOR Automated Soil Gas Flux System LI-8100A), equipped with a Long-Term Chamber 8100-104), in conjunction with a compatible Gasmet FTIR gas analyser (Gasmet DX4015).

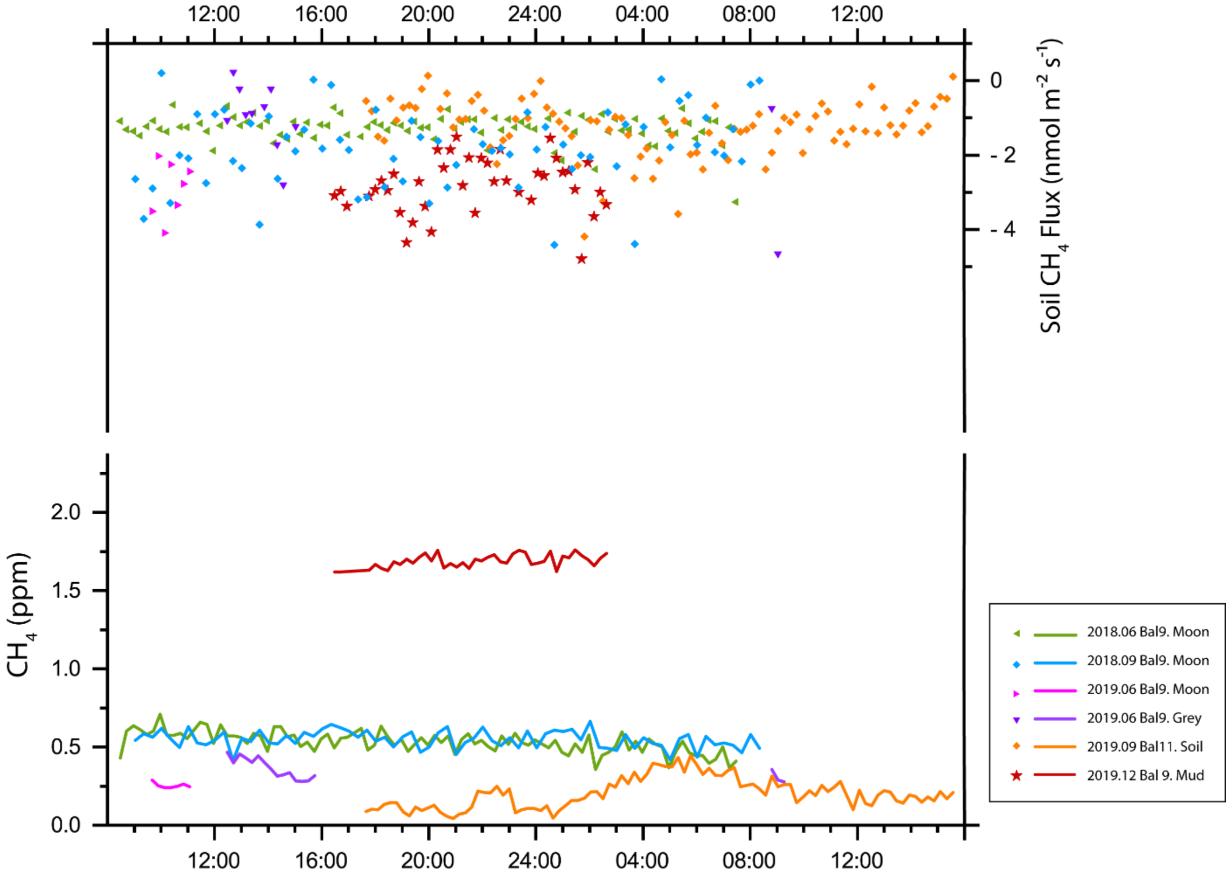
(2) Microbial Analyses: Structural and functional characterization by meta-barcoding analyses of bacteria 16S rRNA genes and Shotgun Metagenomics.

Cave soil carbon flux monitoring

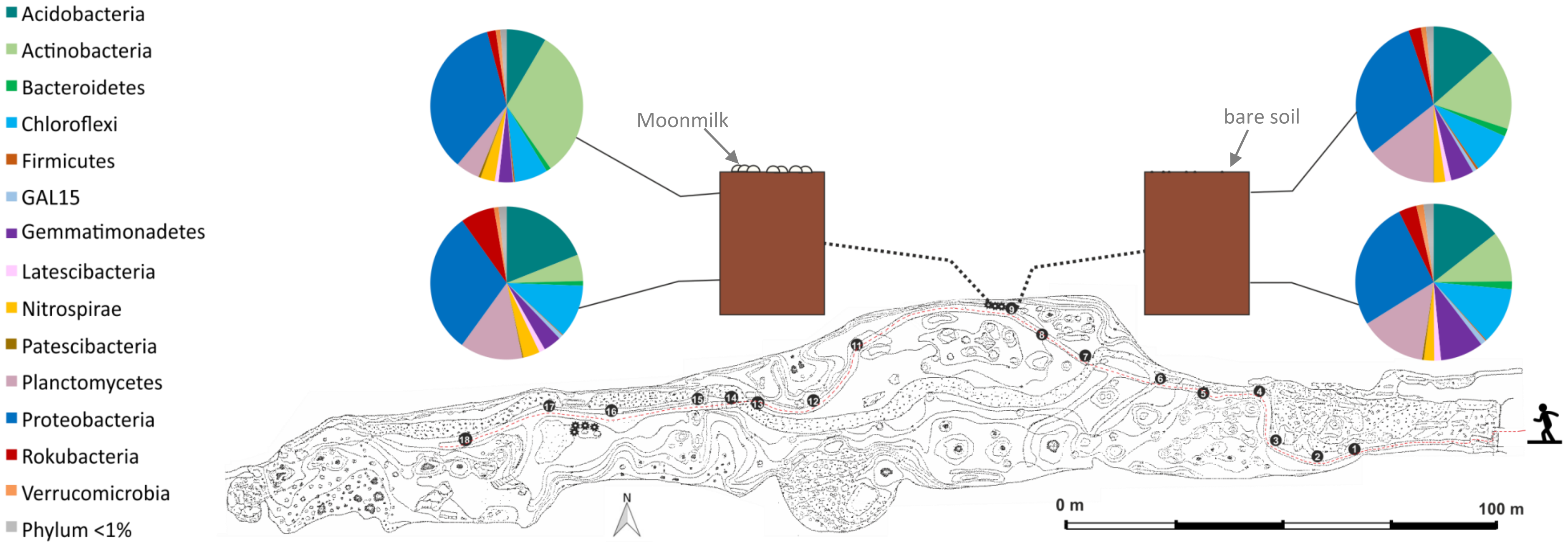
- Predominance of CO_2 emission flux, with daily variations in magnitude, and occasionally alternating emission or uptake.
- The daily-averaged CO_2 flux ranges from +0.1 to +0.25 µmol m^{-2} s^{-1}, but less than 0.1 µmol m^{-2} s^{-1} in presence of moonmilk deposits on the soil surface.



- CH_4 uptake flux from cave soil.
- The daily-averaged CH_4 flux ranges from -1 to -3 nmol m^{-2} s^{-1}.

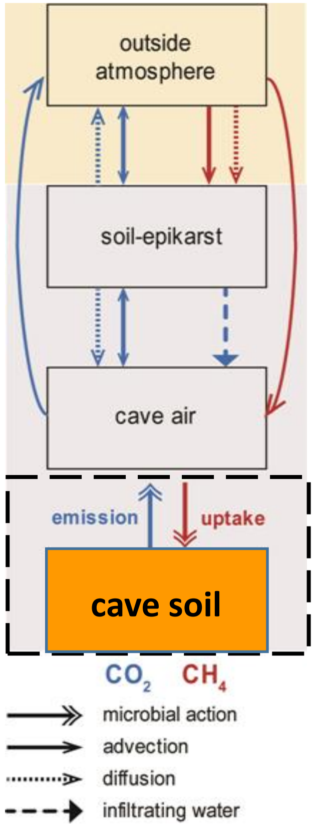


Cave soil bacteria phylogenetic characterization



Proteobacteria, Acidobacteria, Planctomycetes and Chloroflexi **were the major phyla in the soil samples, with an increase of** ***Actinobacteria*** **in the most superficial ones.**

- The CO_2 emission flux observed are the result of respiration by chemotrophic microorganisms.
- *Crossiella* found in *moonmilk* have the ability to capture CO_2 from the underground atmosphere, resulting in precipitation of calcium carbonate as a by-product of the action of carbonic anhydrase.
- Methanotrophic bacteria were represented by *Rokubacteria* (NC10) that mediates the anaerobic oxidation of methane (AOM) coupled to nitrite reduction.
- CH_4 is consumed by the action of methanotrophic bacteria of NC10 phylum.



Final remarks

The results reveal that the cave soil in Pindal cave is acting as net uptaker of CH_4 and as an emitter / sink of CO_2 alternately. Their uptake and turnover rates appear to be meaningfully high.

These preliminary results confirm that cave-soil is playing an outstanding role in the processes of production and consumption of CO_2 and CH_4, that may be partially determining the strong variations of these major GHGs in natural subterranean ecosystems.

This research line is crucial to achieve a more accurate assessment of the effective contribution of karst ecosystems to the global carbon cycle.

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Universiteit Antwerpen Soledad Cuezva Ivan Janssens

mncn CSIC Tamara Martin-Pozas Sergio Sanchez-Moral

Universidad de Almería Angel Fernandez-Cortes

Universitat d'Alacant Universidad de Alicante Juan Carlos Canaveras