High Resolution Time Series Cave Ventilation Processes and the Effects on Cave Air Chemistry and Drip Water: Speleoclimatology

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Introduction

In order to understand how ancient speleothems (stalagmites) grew and incorporated their calcite paleoclimate records, it is essential to establish the micrometeorology and air & drip water chemistry of contemporary caves. Speleothem records of climate change provide regional histories with annual resolution back many thousands to hundreds of thousands of years. Here we describe how a NW Florida cave inhales and exhales gases, how the overlying seasonal climate changes (temperature, winds, rainfall) are transmitted downwards via soil gases and drip waters, and how drip water (soil) chemistry is translated into calcite dripstone (stalagmite) isotope and chemical compositions. The goal of this work is to establish quantitative relationships between long-term (decadal and century to millennial scale) regional temperature and rainfall changes to the oxygen and carbon isotopes incorporated into dripstone calcite, and the wet/dry climate influences of overlying soil water chemistry on drip water chemistry and isotopes incorporated into speleothems as a function of precipitation rates – transfer equations we call "paleoproxy calibrations of the present": ^{18}O, ^{13}C, Sr/Ca, Ba/Ca, Mg/Ca.

Experimental

In October 2007 we instrumented micro-meteorological time-series stations inside and on top of Hollow Ridge Cave (HRC) in NW Florida (Marianna, near the Florida State Caverns). Stalagmites extending back 70,000 years have been analyzed from several caves in the area. A station atop Hollow Ridge monitors wind direction and velocity, barometric pressure, temperature, relative humidity and rainfall. Two stations inside the cave (one near to and one far from the entrance) monitor these same parameters plus air ^{222}Rn and CO_2 partial pressure. Occasional "snapshot" gas sampless for cave air-$^{13}CO_2$ and drip water chemistry are also obtained. The experimental design enables mass balance solutions to the overall calcite drip-precipitation reaction: $Ca^{2+} + 2HCO_3^-$ (drip water) → $CaCO_3$ (speleothem) + CO_2 (degassed) + H_2O. Since cations, isotopes and dissolved-CO_2 (HCO_3^-) are brought to the cave roof by dripping soil solutions with high pCO_2 and low pH (from soil carbon degradation and limestone dissolution), degassing of CO_2 inside the cave is a prerequisite for calcite precipitation and speleothem formation from roof drips. Thus caves must exhale CO_2 to form stalagmites. When and how caves breathe dictates how and when calcite precipitates.

Results and Discussion

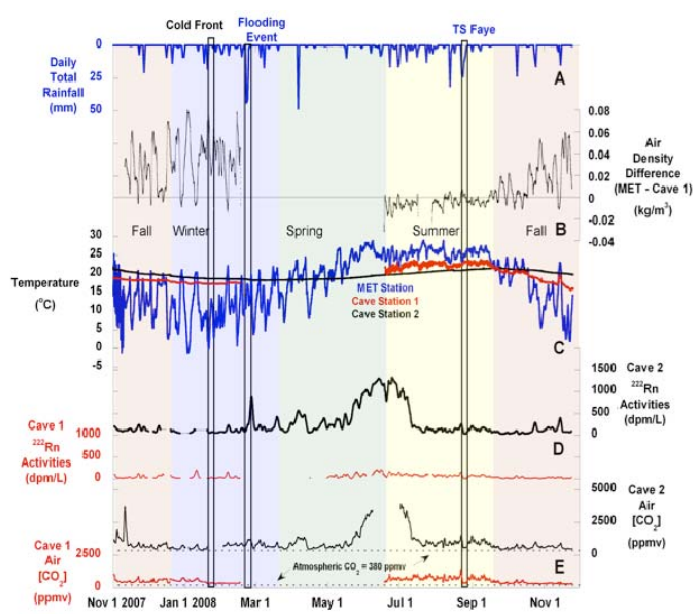

Figure: Time series of micro-met conditions above and inside HRC. Cave-1 is near the entrance; cave-2, in the back. Rainfall (A), air density difference (B), air and cave temperatures (C), cave air ^{222}Rn (D), and cave air CO_2 (E). ^{222}Rn is zero in outside air but very high in soils (~5,200 dpm). Cave air $^{13}CO_2$, drip data and winds not shown. Cave air is flushed diurnally in winter by density-driven ventilation (low Radon and CO_2); during Spring & Fall by both density and winds; and during Summer only by winds (stagnant). Diurnal and event-driven changes display time delays that permit modeling of cave ventilation and calcite precipitation processes.

Conclusions

New calcite in HRC likely carries fall-winter signals dominated by fronts, far from "annual average climate".

References

[1] Kowalczk, A. & P. N. Froelich, EOS Trans. AGU 89(53), Fall Meet. Suppl., Abstract PP51C-01521 (2008)