Speleoclimatology of Florida Caves: Proxy Calibrations of Climate

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Introduction

Speleoclimatology is a new field of cave paleoclimate research in which caves are instrumented to continuously monitor how they inhale and exhale gases, how overlying climate changes percolate downwards via soil water chemistry, and how drip water (soil) chemistry is translated into calcite dripstone (stalagmite) isotope and chemical compositions that paleoclimatologists analyze and interpret as past climate changes. In most cases, these paleoclimate recorders (what we call paleoproxies such as ^{18}O, ^{13}C, Sr/Ca, Ba/Ca, Mg/Ca) are not firmly calibrated in the current environment.

In October 2007 we instrumented multiple micro-meteorological time-series stations inside and on top of a wild cave (Hollow Ridge) in northwest Florida near Marianna, the Chipola River and the famous Florida Caverns State Park. Hollow Ridge cavern is protected by the Southern Cave Conservancy, Inc. (SCCi). Speleothems (stalagmites) extending back to 70,000 years ago have been collected and analyzed from several caves in the vicinity. The purpose of this work is to establish quantitative equations 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.

Experimental

A station atop Hollow Ridge monitors continuous wind direction and velocity, barometric pressure, temperature, relative humidity and rainfall. Two stations inside the cave monitor these same parameters plus air ^{222}Rn and CO_2 partial pressure. One station is near the entrance in the main tunnel leading into the interior and the other station is deep within the more stagnant portion of the cave interior. In addition to these monitoring stations, occasional "snapshot" canisters of gases, air-$^{13}CO_2$ and drip water chemistry are obtained throughout the cave. The instrumentation is designed to enable mass balance solutions to the overall calcite precipitation reactions:

Drip Chemistry $Ca^{2+} + 2\,HCO_3^- \rightarrow CaCO_3$ (calcite speleothem) + CO_2 (degassed carbon dioxide) + H_2O
Since cations 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.

Results and Discussion

^{222}Rn concentrations outside the cave are zero. ^{222}Rn inside the cave air varies diurnally from ten to several hundred dpm/L, reflecting a balance between (1) ^{222}Rn sources (^{222}Rn outgassing from wallrock limestone hosted uranium-series decay products: $^{222}Rn \leftarrow {}^{226}Ra \leftarrow {}^{230}Th \leftarrow {}^{234}U \leftarrow {}^{238}U$), (2) physical loss (air exchange by cave breathing) and (3) radioactive loss (decay of ^{222}Rn with a 3.82 day half-life). By assuming the source (1) is constant (to be tested) and modeling the diurnal cycles of ^{222}Rn and CO_2 we can establish diurnal flushing rates (air turnover times), CO_2 loss rates and thus calcite precipitation rates. Incorporating the diurnal CO_2 cycles and three $^{13}CO_2$ snapshots validates a ^{13}C value of -22.4 per mil for soil gas CO_2, reflecting overlying C3 plants. Future work will include monitoring rainfall and drip water isotopes and major element chemistries, and then farming artificial dripstones formed under these drips to calibrate the paleoproxies.

Conclusions

Instrumentation of a wild cave in NW Florida with continuous monitoring MicroMet and air and drip chemistry stations will permit calibration of paleoproxies used to interpret past climate changes from dripstone paleorecords.

References

[1] Kowalczk *et al*., EOS Trans. AGU 88(52), Fall Meet. Suppl., Abstract PP43A-0999 (2007)
[2] Froelich *et al*., EOS Trans. AGU 88(52), Fall Meet. Suppl., Abstract PP43A-0998 (2007)