Ellis Shelby (Orcid ID: 0000-0003-1372-4967)
Partin Judson, Wiley (Orcid ID: 0000-0003-0315-5545)

Extended cave drip water time series captures the 2015 – 2016 El Niño in Northern Borneo

Shelby A. Ellis*[1], Kim M. Cobb[1], Jessica W. Moerman[2], Judson W. Partin[3], A. Landry Bennett[1], Jenny Malang[4], Hein Gerstner[4], Andrew A. Tuen[5]

[1]School of Earth and Atmospheric Sciences, Georgia Institute of Technology, Atlanta, Georgia USA, [2]Human Origins Program, National Museum of Natural History, Smithsonian Institution, Washington, DC USA, [3]Institute for Geophysics, Jackson School of Geosciences, University of Texas at Austin, Austin, Texas USA, [4]Gunung Mulu National Park, Sarawak, Malaysia, [5]Institute of Biodiversity and Environmental Conservation, Universiti Malaysia Sarawak, Sarawak, Malaysia

*Corresponding author: Shelby Ellis, sellis39@gatech.edu

Key Points:

- **Three 12-year-long cave drip water $\delta^{18}O$ time series capture El Niño and La Niña events in Northern Borneo**
- **Estimates of karst residence times range from 3 to 18 months, with a secondary contribution from a longer-term reservoir at one drip site**
- **Drip water non-stationarity implies multiple stalagmites are required to reconstruct El Niño Southern Oscillation variability over time**

This article has been accepted for publication and undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process which may lead to differences between this version and the Version of Record. Please cite this article as doi: 10.1029/2019GL086363

Abstract

Time series of cave drip water oxygen isotopes ($\delta^{18}O$) provide site-specific assessments of the contributions of climate and karst processes to stalagmite $\delta^{18}O$ records employed for hydroclimate reconstructions. We present ~12 year-long time series of biweekly cave drip water $\delta^{18}O$ variations from three sites as well as a daily-resolved local rainfall $\delta^{18}O$ record from Gunung Mulu National Park in Northern Borneo. Drip water $\delta^{18}O$ variations closely match rainfall $\delta^{18}O$ variations averaged over the preceding 3-18 months. We observe coherent interannual drip water $\delta^{18}O$ variability of ~3 to 5‰ related to the El Niño-Southern Oscillation (ENSO), with sustained positive rainfall and drip water $\delta^{18}O$ anomalies observed during the 2015/2016 El Niño. Evidence of non-linear behavior at one of three drip water monitoring sites implies a time-varying contribution from a longer-term reservoir. Our results suggest that well-replicated, high-resolution stalagmite $\delta^{18}O$ reconstructions from Mulu could characterize past ENSO-related variability in regional hydroclimate.

Plain Language Summary

Cave stalagmites allow for the reconstruction of past regional rainfall variability over the last hundreds of thousands of years with robust age control. Such reconstructions rely on the fact that differences in the isotopic composition of rainwater set by regional rainfall patterns is preserved as the rainwater travels through cave bedrock to feed the cave drip waters forming stalagmites. Long-term monitoring of rainwater and cave drip water isotopes ground truth the climate to stalagmite relationship across modern-day changes in regional rainfall. Twelve years of monitoring data presented in this study identify individual El Niño-Southern Oscillation (ENSO) events in rainfall and cave drip water isotopic composition, providing a strong foundation for stalagmite-based climate reconstructions from this site.

1. Introduction

Stalagmite oxygen isotope reconstructions provide key insights into past terrestrial hydroclimate variability globally on seasonal to orbital timescales. In some tropical and subtropical regions where rainfall is dominated by strong vertical convection and infrequent year-round temperature variability, the ‘amount effect’ framework aids interpretations of stalagmite oxygen isotope records. Modern empirical observations classify the ‘amount effect’ as a correlation between high (low) rainfall rates on monthly and longer time scales with depleted (enriched) rainfall $\delta^{18}O$ (hereinafter $\delta^{18}O_R$) (Craig, 1961; Dansgaard, 1964; Rozanski et al., 1992). Using the amount effect framework, overlapping $\delta^{18}O_{stal}$ records from monsoon-vulnerable regions in South America (Cheng et al., 2013; Cruz et al., 2005), Australia (Griffiths et al., 2009), Oman (Burns et al., 1998), and India (Sinha et al., 2005) demonstrate interhemispheric anti-phasing in $\delta^{18}O_R$ variability from precession-driven (~19 – 23ky) orbital forcing. North Atlantic millennial-length Dansgaard-Oeschger (Dansgaard et