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A Millennial Record of Rainfall And ENSO Variability in Stalagmites From a Mid-Ocean Island in the South Pacific

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Improved understanding of ocean-atmosphere interactions that control interdecadal ENSO variability prompted recently a renewed interest in the acquisition of highly resolved proxy ENSO records. Corals possessing annual growth increments have extended the ENSO archive several centuries beyond the existing instrumental data but much longer records are needed to constrain the interdecadal periodicities and unravel their underlying causes. To this end, paleoclimate proxies archived in stalagmites from tropical Pacific settings have not been harnessed to the task of ENSO paleo-reconstructions although stalagmites elsewhere have offered valuable paleoclimate insights. Here we report the results of an investigation of stalagmites from a water-table cave on Niue Island in the South Pacific (19° 00' S; 169° 50' W) located at the epicenter of oceanic ENSO. Century-long instrumental records on Niue provide a frame of reference and indicate that the interannual and interdecadal air temperature variability is negligible but the rainfall is fully engaged in the wheels of ENSO such that El-Niño and La-Niña events correspond with droughts and abundant rainfall, respectively. Seasonal monsoon and trade rainfalls exhibit a marked contrast in their oxygen isotope compositions. Rainfall amount governs microbial soil activities resulting in convergent ¹⁸O and ¹³C depletions and enrichments in the drips that are transferred to the calcite stalagmites in the Niuean caves. A detailed study of four actively growing stalagmites whose chronology overlaps with the instrumental records confirms that interannual and decadal-scale ENSO variability is clearly expressed in the annual couplets widths and stable oxygen and carbon isotope time-series

records of continuous layered stalagmites. Acquisition of a chronology for USM1 stalagmite posed radiometric dating challenges. The U concentration, in the range of 44.2 to 97.5 ppb, is relatively low by comparison with typical stalagmite values. Therefore dating by $^{230}\text{Th}/^{234}\text{U}$ method was impractical considering the youthfulness of the stalagmite and the amount of available material. Three dating techniques were used to derive a robust chronology: (i) $^{226}\text{Ra}/^{234}\text{U}$ by TIMS; (ii) radiocarbon by AMS, and (iii) couplets counting. In conjunction, the three dating methods indicate that the 160 mm stalagmite section spans a time interval from 1540 to 360 years AD. Interannual and interdecadal-scale variability are the largest components of variance in the millennial-long oxygen isotope time series. Processed in the frequency domain to quantify the variance, the data yield mean periodicities of 5.5 yrs and 30 yrs thus matching modern interannual ENSO and interdecadal IPO periodicity bands. Importantly, previously unidentified cycles of about 200 yrs and 500years duration are clearly discerned in both the oxygen and carbon isotope records. The low frequency cycles exhibit phase alternations between strong ENSO events manifested in severe droughts that are succeeded by rare ENSO events and abundant rainfall. Phase transitions occurred at about 1500, 1300, 1100, 900 and 500 yrs AD. The new millennial record of ENSO offers valuable data of interest to the climate dynamics community investigating the factors controlling ENSO variability through time.

1115 Radioisotope geochronology

1620 Climate dynamics (0429, 3309)

3305 Climate change and variability (1616, 1635, 3309, 4215, 4513)

3344 Paleoclimatology (0473, 4900)

Paleoceanography and Paleoclimatology [PP]

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