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Coral δ^{18}O evidence for Pacific Ocean mediated decadal variability in Panamanian ITCZ rainfall back to the early 1700s

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ABSTRACT

In Central America, seasonal and interannual shifts in the position of the Intertropical Convergence Zone (ITCZ) control the hydrologic budget. To better understand long-term changes in regional ITCZ-driven precipitation we re-examined a coral δ^{18}O record from a *Porites lobata* coral head near Secas Island (Core ID: S1) (7°59′ N, 82°3′ W) in the Gulf of Chiriquí on the Pacific side of Panamá. Linsley et al., (1994) originally published the 277-year time series and first described the presence of a narrow-band decadal cycle (period near 9–12 years) in δ^{18}O. The original study did not present potential drivers for the decadal cycle, although they ruled out the influence of the sun spot cycle. Our re-analysis of this record supports the original interpretation that coral δ^{18}O is largely responding to variations in precipitation and associated river discharge, but with a new proposed mechanism to explain the decadal mode. There is no similar decadal cycle in gridded instrumental sea surface temperature from the area, suggesting that the decadal coral δ^{18}O signal results from hydrologic changes that influence coastal $\delta^{18}O_{seawater}$. The decadal component in S1 δ^{18}O is also coherent with a decadal mode embedded in the Pacific Decadal Oscillation (PDO) Index that we suggest has tropical origins. We speculate that the coral's temporary δ^{18}O deviation (1900–1930) in the decadal mode from the corresponding bands in rainfall and the PDO can be ascribed to a weak PDO in addition to local Panama gap wind variability and its effect on moisture transport from the Atlantic to the Pacific. Ultimately, the Secas Island coral δ^{18}O series records ITCZ-driven precipitation dictated by both the Atlantic and Pacific basins.

1. Introduction

Central American climate is strongly influenced by changes in the position of the Intertropical Convergence Zone (ITCZ). The ITCZ, a band of convecting atmospheric cells that encircles Earth, is located where the northern and southern trade winds converge near the equator (Philander, 1990; Schneider et al., 2014). Global precipitation is largely constrained by ITCZ position with its migration towards the warming hemisphere on seasonal and longer time-scales evident in both modern and paleoceanographic records (Schneider et al., 2014)(Fig. 1). In addition to seasonal shifts of the ITCZ, extratropical mechanisms such as the decadal-scale evolution of mid-latitude and equatorial Pacific Ocean surface ocean temperatures collectively referred to as the Pacific Decadal Oscillation (PDO), can influence ITCZ position (Schneider et al., 2014; Newman et al., in press).

The meridional movements of the ITCZ, particularly over Central America and more specifically the Pacific coast of Panamá, are responsible for seasonality in precipitation (Fig. 1). Although multiple climate models are able to reproduce these ITCZ movements, model dynamics are based on limited data and lack a long term observational context for evaluating the interannual and low frequency decadal and secular (long-term) variability underlying the typical seasonal shifts (Kumar et al., 2003; Soden and Held, 2006). There are few high-resolution seasonal reconstructions of ITCZ variability, and even fewer records extending back to the pre-industrial era. Coral-derived geochemical time series may be able to fill this data void by providing records of past precipitation on interannual and longer, low frequency time-scales.

The pronounced rainfall gradient associated with seasonal meridional ITCZ oscillations over the Gulf of Chiriquí combined with very low amplitude annual sea surface temperature (SST) variability make this region an excellent location to study long-term precipitation patterns using coral skeletal oxygen isotope analyses (δ^{18}O). Coral δ^{18}O is known to be primarily influenced by both SST and the δ^{18}O of the seawater, which is linearly related to local sea surface salinity (SSS)(Fairbanks et al., 1997). In some regions, like the Gulf of Chiriquí, precipitation and river discharge lead to seawater δ^{18}O variability that has a significantly greater effect on

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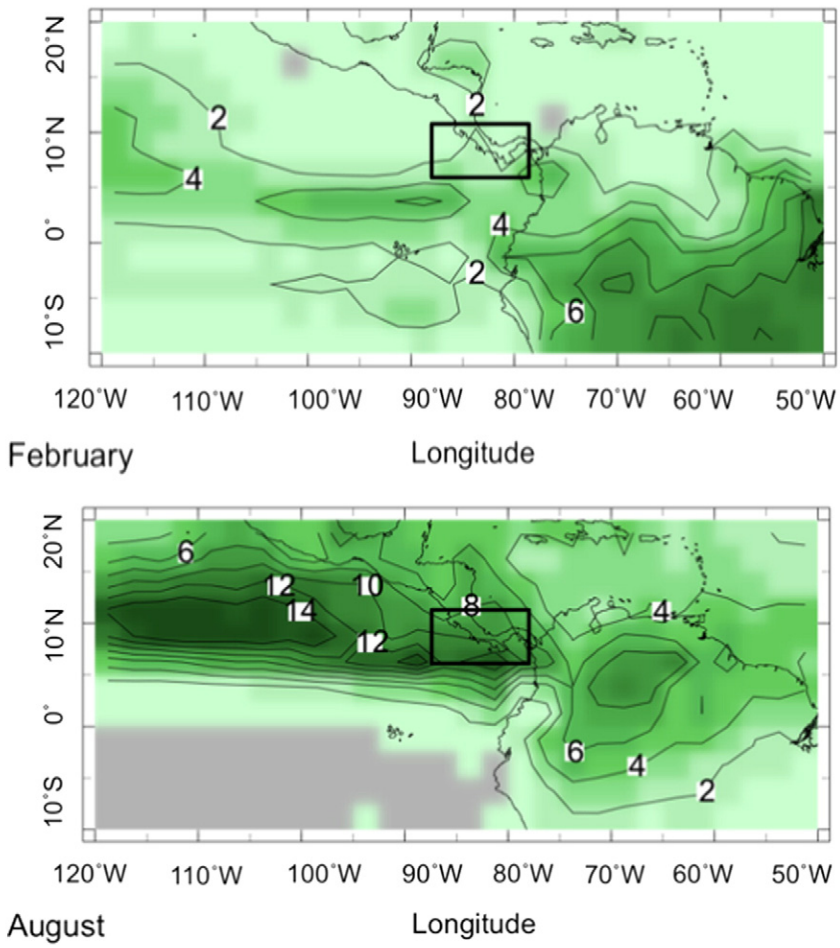

Fig. 1. Seasonal meridional shifts in ITCZ position control the duration and strength of the Central American wet season. Contours represent bands of equal rainfall (mm). The darker green region shows an area of high precipitation representing the location of the ITCZ. The band travels north towards Panamá in the boreal summer (lower panel). Our study site is located within the black box off the Pacific coast of Panamá. (Modified from Xie and Arkin, 1996, 1997).

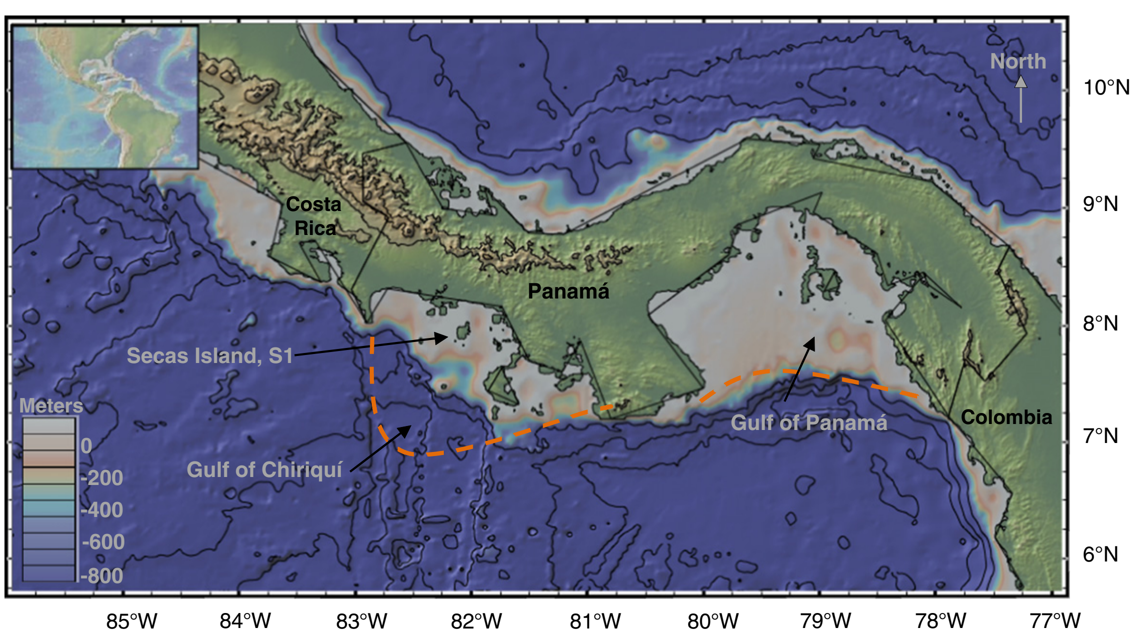

Fig. 2. The Isthmus of Panamá and coral study site at Secas Island (7°59′ N, 82°3′ W) with 1000 m contours. Secas Island is located within the Gulf of Chiriquí. The dotted lines outline the approximate boundaries of the major gulfs along the Pacific coast of Panamá. The North Equatorial Counter Current flows eastward towards the isthmus and Gulf of Chiriquí. Ocean currents also flow westward, away from the isthmus, in the Gulf of Panamá while the Gulf of Chiriquí remains calmer.