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Fine-scale timing of environmental changes at the BA-YD transition in the Cariaco Basin revealed by molecular stratigraphy at sub-annual resolution

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Stadial and interstadial conditions have a heterogenous impact on tropical climate, influenced by the dominant feedbacks and climate forcing that occur globally and regionally during these transitions. In the tropical Atlantic at the onset of stadials there is a reduction in Atlantic Meridional Overturning Circulation and the Intertropical Convergence Zone (ITCZ) shifts southward, which alters rainfall patterns and nutrient input sources to the marine environment. However, our understanding of the timing and interplay of these processes on annual to decadal time scales is limited. Cariaco Basin is a well-studied location in which these fine-scale changes can be explored in annually varved sediments, which have been deposited since the Last Glacial Maximum. This lamination derives from the seasonal sediment input from predominantly terrestrial vs. marine sources due to the migration of the ITCZ. The onset of the Younger Dryas (YD) in the Cariaco Basin is expressed by dramatic changes in the elemental composition and sediment reflectance owed to the southward migration of the ITCZ, leading to decreased rainfall and increased trade-wind induced upwelling in the region (1). Here we focus on the transition from the Bølling-Allerød to the YD to obtain sub-annual resolution records of multiple molecular proxies representing terrestrial and marine paleoenvironmental conditions. Using a 60-cm section from core MD03-2621, which encompasses the transition into the YD, we examined short-term environmental changes using microXRF for elemental mapping and mass spectrometry imaging for biomarkers. The inputs of marine versus terrestrial sources is assessed by the ratio of short chain versus long chain fatty acids and reflects the southward shift of the ITCZ throughout the transition. The average chain lengths of fatty acids from waxes of higher land plants indicate a vegetation change, which lags $\sim$50 years behind reflectance, and shows significant pentadal-decadal cycles that were not reflected in previous lower resolution analysis (2). The Uk37 proxy shows no change in sea surface temperature (SST) during the YD onset, except for a notable drop of 2-3 °C immediately following the change in reflectance. The CCaT proxy based on the ratio of crenarchaeol versus caldarchaeol increases concurrently with reflectance and calcium counts while bromine and iron counts decrease. SST estimates based on the CCaT proxy diverge from those based on Uk37, indicating that other environmental factors, which also influence elemental changes, are captured in the distribution of these planktonic archaeal lipids. Interestingly, both molecular SST records differ from previous SST estimates based on foraminiferal Mg/Ca ratios that suggest a cooling at the YD onset (3). Our study will enable us to examine the leads and lags in terrestrial and marine proxies as they respond to abrupt climatic changes in the tropics. Combined with existing records and frequency analysis of our data, we will gain a more nuanced understanding of the dominant climate feedbacks that affect tropical and global climate at the onset of the Younger Dryas.

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(2) Hughen, K. et al., Science, 304, 2004.
(3) Lea, D. et al., Science, 301, 2003.