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Increased Amazon freshwater discharge during late Heinrich Stadial 1

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ABSTRACT

The temporal succession of changes in Amazonian hydroclimate during Heinrich Stadial 1 (HS1) (ca. 18–14.7 cal ka BP) is currently poorly resolved. Here we present HS1 records based on isotope, inorganic and organic geochemistry from a marine sediment core influenced by the Amazon River discharge. Our records offer a detailed reconstruction of the changes in Amazonian hydroclimate during HS1, integrated over the basin. We reconstructed surface water hydrography using stable oxygen isotopes ($\delta^{18}O$) and Mg/Ca-derived paleotemperatures from the planktonic foraminifera *Globigerinoides ruber*, as well as salinity changes based on stable hydrogen isotope (δD) of palmitic acid. We also analyzed branched and isoprenoid tetraether concentrations, and compared them to existing bulk sediment ln(Fe/Ca) data and vegetation reconstruction based on stable carbon isotopes from *n*-alkanes, in order to understand the relationship between continental precipitation, vegetation and sediment production. Our results indicate a two-phased HS1 (HS1a and HS1b). During HS1a (18–16.9 cal ka BP), a first sudden increase of sea surface temperatures (SST) in the western equatorial Atlantic correlated with the slowdown of the Atlantic Meridional Overturning Circulation (AMOC) and the associated southern hemisphere warming phase of the bipolar seesaw. This phase was also characterized by an increased delivery of terrestrial material. During HS1b (16.9–14.8 cal ka BP), a decrease in terrestrial input was, however, associated with a marked decline of seawater $\delta^{18}O$ and palmitic acid δD. Both isotopic proxies independently indicate a drop in sea surface salinity (SSS). A number of records under the influence of the North Brazil Current, in contrast, indicate increases in SST and SSS resulting from a weakened AMOC during HS1. Our records thus suggest that the expected increase in SSS due to the AMOC slowdown was overridden by a two-phased positive precipitation anomaly in Amazonian hydroclimate.

1. Introduction

Heinrich Stadial 1 (HS1; 18–14.7 cal ka BP) is associated with a marked slowdown in the Atlantic Meridional Overturning Circulation (AMOC) together with a rearrangement in the poleward heat transport (Dahl et al., 2005). This millennial-scale event changed the latitudinal position of the thermal equator, affecting the location of the tropical rain belt (Street-Perrott and Perrott, 1990; McGee et al., 2014; Schneider et al., 2014) and of the mean position of the Intertropical Convergence Zone (ITCZ) (Marshall et al., 2013). HS1 is known to have triggered an increase in precipitation over the Amazon Basin through an enhanced penetration of moist easterly trade winds into the basin. The extensive compilation of tropical South American hydroclimate records presented by Zhang et al. (2016) clearly shows wet conditions during HS1 especially over the western Amazon Basin and the tropical Andes (Blard et al., 2011; Kanner et al., 2012; Mosblech et al., 2012; Cheng et al., 2013), and Northeastern Brasil (Wang et al., 2004; Dupont et al., 2010; Stríkis et al., 2015; Zhang et al., 2015).

However, the Amazon Basin-wide integrated signals reflected in marine sediment cores collected under the influence of the Amazon River discharge (Maslin and Burns, 2000; Maslin et al., 2011)

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partially showed conflicting results with continental records (Kanner et al., 2012; Mosblech et al., 2012). Temperature and glacio-eustatic corrected oxygen stable isotopes ($\delta^{18}O$) from the planktonic foraminifera *Globigerinoides sacculifer* suggest a negative anomaly in precipitation between 20.5 and 17 cal ka BP, and during the Antarctic cold reversal (ca. 14.5–12.9 cal ka BP) continuing into the Younger Dryas (ca. 12.8–11.5 cal ka BP) (Maslin et al., 2011). With the cautious assumption that *G. sacculifer* $\delta^{18}O$ signal can be used as a precipitation indicator, the results presented in Maslin et al. (2011) are partially inconsistent with stalagmite records from the western Amazon Basin (Kanner et al., 2012; Mosblech et al., 2012) where evidence of wetter conditions existed during HS1 (starting around 18 cal ka BP) and again during the Younger Dryas.

Here we present a high temporal resolution multiproxy study based on marine sediment core GeoB16224-1 retrieved off French Guiana. The site is influenced by the Amazon River freshwater and terrigenous discharge (Fig. 1). We use planktonic foraminiferal (*Globigerinoides ruber* and *G. sacculifer*) $\delta^{18}O$ and Mg/Ca together with hydrogen stable isotopes (δD) from palmitic acid to reconstruct the uppermost water column hydrography in response to changes in Amazon River outflow. We also analyzed the branched and isoprenoid tetraether (BIT) index, and compared it to existing data from bulk sediment ln(Fe/Ca) and carbon stable isotopes ($\delta^{13}C$) of *n*-alkanes from the same core, to decipher the interaction among soil discharge, riverine sediment transport, and continental vegetation from the Amazon Basin. Additionally, we present *G. ruber* and *G. sacculifer* $\delta^{18}O$ data from multicore GeoB16212-2 retrieved in the Amazon submarine delta on the Brazilian continental shelf directly off the Amazon River mouth (Fig. 1), in order to identify whether *G. ruber* records the hydrography of the Amazon-influenced low-salinity surface layer or the normal saline subsurface. Our data from GeoB16224-1 focus on the Last Glacial Maximum (LGM)-HS1 interval (22-14 cal ka BP) and provide an integrated picture of the response of Amazonian hydrology covering HS1. The amount and diversity of the proxies used identify regional changes in precipitation, overcoming the limitation of previous studies.

2. Regional setting

2.1. Amazon continental margin hydrology

Core GeoB16224-1 was retrieved from the continental margin of French Guiana. The core site is influenced by the Amazon freshwater discharge (Muller-Karger et al., 1988; Lentz, 1995), and the North Brazil Current (NBC) (Johns et al., 1998) (Figs. 1 and 2b). Minimum Amazon River discharge occurs in November (ca.

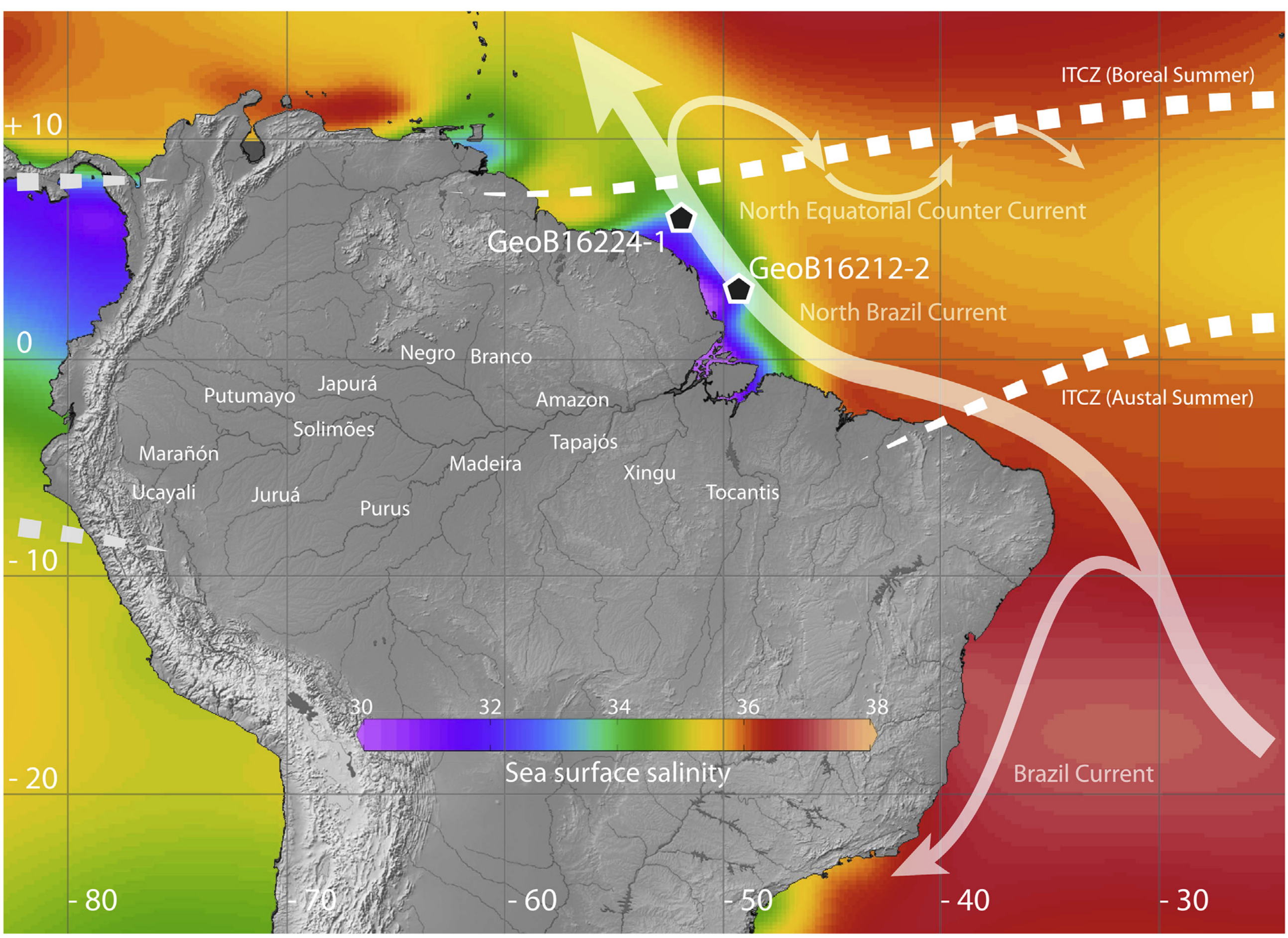

Fig. 1. Location of the marine sediment cores investigated in this study (black pentagons, gravity core GeoB16224-1 and multicore GeoB16212-2). The main surface currents are schematically represented by the white arrows (Peterson and Stramma, 1991). Both core sites are under the influence of the Amazon low salinity plume and the northwestward-flowing North Brazil Current. The dotted lines display the approximate locations of the Intertropical Convergent Zone (ITCZ) over the Atlantic Ocean during boreal (June–August) and austral (December–February) summers. Annual salinities are displayed in the color shading (Levitus et al., 2013). (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)