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Paleohydrological changes during the last deglaciation in Northern Brazil

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Abstract

We here report a reconstruction of hydrological balance variations in Northern Brazil for the last 20 ka deduced from the δD values of aquatic and land plant molecules extracted from the sediment infill of Lake Caçó. Our reconstructed precipitation, lake water isotope ratio and evaporation–evapotranspiration isotope effect allows us to obtain an estimate of moisture balance, and, to a lesser extent, precipitation amount and seasonality changes. During the end of the Last Glacial Maximum (LGM, between ca 20 and 17.3 ka), high δD values and smaller fractionation of leaf waxes indicate an arid to semi-arid climate with a long lasting dry season. An abrupt change towards much wetter conditions occurred within ca 500 years from 17.3 to 16.8 ka, as shown by a 50‰ decrease in D/H ratios and a marked increase in H isotopic fractionation of leaf waxes. This abrupt isotopic change coincides with a major transformation from savanna-dominated vegetation to humid rain forest around the lake, based on pollen data. Comparisons with other paleo-precipitation records from South American sites indicate that Lateglacial humid conditions were controlled by intensification of the ITCZ and/or a southward shift of its mean position across our study site. Our isotope data show only a small rise in aridity during Younger Dryas event (13–11.5 ka). Although the Holocene was not screened in details, D/H ratios of terrestrial and aquatic compounds show near constant offsets, suggesting stable and relatively humid climate conditions during this period.

1. Introduction

The tropics are key areas for past and present climate dynamics because this region is the main heat engine and water vapour source of the Earth. Recent studies indicate that past variations in the water vapour cycle over tropical South America are closely related to oceanic and atmospheric circulation patterns at global scale (Peterson et al., 2000; Wang et al., 2004; Cruz et al., 2005). Nonetheless, there is not yet a clear consensus on the role of the tropics in driving global climate variability and on the possible extratropical feedbacks (Stoecker et al., 2003). An important atmospheric system that controls the tropical climate variations is the InterTropical Convergence Zone (ITCZ). Previous studies have indicated that the mean positioning of the ITCZ has shifted significantly on seasonal, decadal and longer timescales (Martin et al., 1997; Ronchail et al., 2002; Wang et al., 2004). In order to track past ITCZ shifts and changes in intensity, we have explored the sedimentary infill of Lake Caçó. This lake is located in Northern Brazil, on the eastern edge of Amazon rain forest, where the ITCZ shifts from its winter to summer position (Fig. 1). It is therefore highly sensitive to mean positioning of the ITCZ.

There are major controversies remaining on the occurrence of wet/dry episodes in South America and their impacts on continental ecosystems, biological diversity and biogeochemical cycling (CH_4, CO_2 and H_2O). For example,

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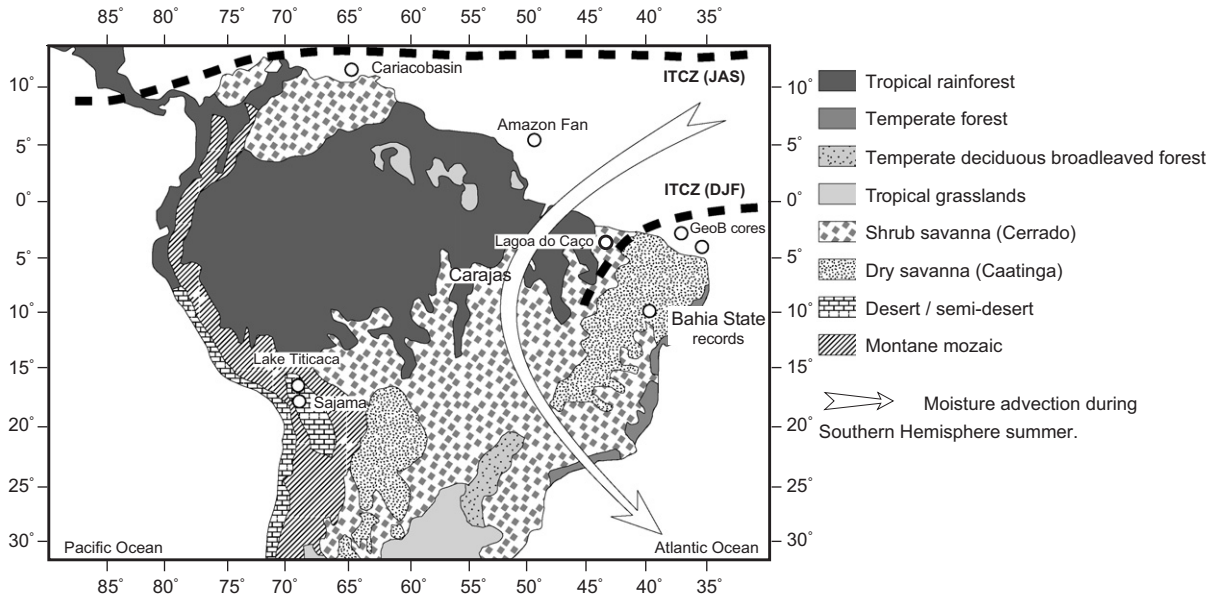

Fig. 1. Location of Lake Caçó site within the context of present day potential vegetation types encountered in Northern Brazil. Open circles indicate the sites discussed in the text. The Lake Caçó lies in a shrub savanna (cerrado) corridor inserted between the dry savanna (caatinga) to the east and the humid rainforest to the west. The Present day positions of the InterTropical Convergence Zone (ITCZ) during the austral summer (DJF) and austral winter (JAS) are depicted with a dotted black line. The trajectory of moisture advection during austral summer is illustrated with a white arrow.

a globally drier climate is suspected for the LGM. The extent to which this supposedly dry episode impacted the Amazon rainforest surface is strongly debated (Colinvaux et al., 2000; Turcq et al., 2002). Similar to the LGM, the tropical extension and influence of the Younger Dryas (YD) cold reversal, as defined in the Northern Hemisphere, is not fully elucidated in the South American tropics.

Most of these controversies arise from the lack of pertinent parameters allowing the quantitative estimate of humidity changes. For instance, broadly defined pollen classes include several taxa that can colonize various habitats. Furthermore, pollen data are interpreted as changes in vegetation distribution that are affected by atmospheric pCO_2, temperature, humidity and soil properties, thus avoiding any quantitative reconstruction. Similarly, marine sedimentary cores record regional conditions inland and buffer spatial discrepancies.

In order to address the question of humidity variations in Southern America since the last deglaciation, we apply for the first time in the South American tropics the combination of hydrogen isotopic composition (δD)[1] of aquatic and land plant molecules preserved in lake sediments. As it has recently been shown, the δD values of sedimentary palmitic (nC_{16}) and behenic (nC_{22}) acids as well as short chain *n*-alkanes capture the δD of meteoric waters (Huang et al., 2002, 2004; Sachse et al., 2004; Hou et al., 2006), that is related to precipitation amount in the tropics (Dansgaard, 1964). The δD of leaf wax lipids produced by land plants, such as triacontanic acid (nC_{30}) and other long chain fatty acids (Eglinton and Hamilton, 1967), although dependent on the δD of meteoric waters (Sachse et al., 2006), is also affected by evaporation and transpiration processes (Sauer et al., 2001; Liu and Huang, 2005). As a matter of fact, the δD of leaf wax lipids has been recently used to track humidity changes in tropical Africa from marine sediments (Schefuß et al., 2005). In a first approximation, the fractionation factor between the δD values of lipids from land plants and the calculated δD values of water allows us to estimate evapotranspiration. Here, we present the first hydrogen isotopic record from Lake Caçó sediments in North-eastern Brazil covering the last 20,000 cal. yr, which brings new insights into the interconnecting mechanisms between ocean-atmosphere-continent in the tropics.

2. Settings

The study site (Lake Caçó, Maranhaõ State, Brazil) is located about 80 km from the Atlantic coast and close to the Equator (Fig. 1, and 2°58′S, 43°25′W and 120 m above sea-level). The local present-day climate is tropical humid with pronounced seasonality. Average rainfall annually reaches 1500 mm and mostly occurs during the rainy season, from November to May (Ledru et al., 2006). Rainfall distribution and river discharge in this region are impacted by the seasonal migration of the InterTropical Convergence Zone (ITCZ; Fig. 1; Hastenrath, 1990). Modern δD of precipitation in Sao Luiz (the closest IAEA/WMO[2] station), range from −10‰ (during austral

[1] $\delta D = [D/H_{sample} / D/H_{standard} -] \times 1000$. VSMOW is the standard for δD, expressed as permil (‰).

[2] IAEA/WMO International Atomic Energy Agency/World Meteorological Organization (2004). Global Network of Isotopes in Precipitation. The GNIP Database. Accessible at: http://isohis.iaea.org