RECONSTRUCTION OS MONSOON PRECIPITATION OVER CENTRAL-EASTERN BRASIL DURING THE LAST 28 KY

Nicolás M. Stríkis[1], Francisco W. Cruz[1], Ivo Karmann[1], Hai Cheng[2,3], Xianfeng Wang[5], Marcos S. de Paula[1], Valdir, F. Novello[1], Augusto S. Auler[6]
strikis@gmail.com

[1]Instituto de Geociências, Universidade de São Paulo, Rua do Lago, 562, CEP 05508-080, São Paulo-SP, Brazil.
[2]Institute of Global Environmental Change, Xi'an Jiaotong University, Xi'an, Shaanxi 710049, China
[3]Department of Geology and Geophysics, University of Minnesota, Minneapolis, MN 55455, USA.
[5]Lamont-Doherty Earth Observatory of Columbia University.
[6] Instituto do Carste, Rua Barcelona, 240/302, Belo Horizonte, MG 30360-260, Brazil

Corresponding author Postal address: Rua do Lago, 562, - Cidade Universitária, São Paulo-SP. CEP: 05508-080. Tel.: 55-11-3091-4213; Fax: 55-11-3091-4207.

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ABSTRACT

Well dated high resolution oxygen isotope record of speleothems in central-eastern Brazil spanning from 1.3 to 28 ky B.P. reveals that the occurrence of abrupt variations in monsoon precipitation is direct tied to sea surface temperature of the North Atlantic. At millennial time scale, abrupt events of increased monsoon precipitation occurs synchronously with abrupt cold events recorded in high latitude areas of North Hemisphere, which in turns is possible related to weakening of the Atlantic Meridional Overturning Circulation (AMOC). During late Glacial and deglacial periods the monsoon precipitation record of northern Minas describes an antiphase relationship with others paleoprecipitation records located in southern Brazil and in the tropical Andean Altiplanos, with a dry phase during the early stages of MIS 2 (28 ~ 20 ky B.P.). This antiphased pattern within the same hemisphere suggest a migration of ZACS mean position to southwest due to intensification of Bolivian High and Nordeste Low upper level features in response to changes in Hadley and Walker circulation cells. Theses changes were primarily related to colder Sea Surface Temperatures in Atlantic ocean and increased rainfall over western Amazon region.

1. INTRODUCTION

In the last decade, the use of oxygen isotope geochemistry in speleothems on paleoprecipitation reconstruction brought important insights to the paleoclimate studies. Due to the great capacity of caves in capturing the response of external environmental parameters variations, like rainfall oscillations using calcite oxygen isotope composition; and the precise

geochronology control obtained by U-Th dating, speleothems have been used to track, with high precision, the relative variations of monsoon intensity over the world.

The South America monsoon system (SAMS) is responsible for more than 50% of precipitation in the continent and, for many regions in Brazil, like central-eastern and northeast areas, corresponds to almost all the annual total precipitation (~ 90%). The espacial-temporal variation of SAMS under strong climate changes, like the stadial and interstadials events that occurred during the last glaciation remains unknown.

Understanding how abrupt climate changes may modify the geographic pattern of precipitation distribution over South America may be the cue to understanding the Neotropical speciation pattern (Strikis, P. C.; personal communication). Here we present a high resolution paleoprecipitation reconstruction for the central-eastern Brazil, at north of Minas Gerais state, that provide important insights about the geographic distribution of monsoon rainfall over South America since the early stages of MIS 2, in the last 28 ky.

2. SITE DESCRIPTION

The stalagmites used in this study were collected in two distinct caves: Lapa Grande (14°22’45.91’’S; 44°17’19.72’’W) and Lapa Sem Fim (16°08’52’’S; 44°36’38’’W). The caves are located in northern Minas Gerais state, here after northern Minas, central-eastern part of Brazil and distant from each other about 200 km.

The present day climate at the study site is tropical semi-humid according to Köppen-Geiger classification with a mean annual precipitation of 958 mm, recorded from 1953 to 2005 at a meteorological station located 1 km from the cave (source: www2.ana.gov.br). The regional precipitation is due to activity of the South Atlantic Convergence Zone (SACZ), which is one of the main features of the SAMS, occurring during the austral summer, associated with intense convective activity in the Amazon region (Garreaud et al., 2009). The SACZ extends southeastward from the core of the continent to the South Atlantic. Once the monsoon season comes to an end, rainfall practically ceases from May to October.

3. RESULTS

The speleothems were dated by U-Th method using inductively coupled plasma-mass spectrometry (ICP-MS) technique at the University of Minnesota. Most dates, 66 out of 80, present errors (2σ) <1%. The northern Minas record (also referred here as central-eastern Brazil) is a combination of 8 stalagmites from two distinct caves: Lapa Grande (LG3; LG11; LG12) and Lapa Sem Fim (LSF3; LSF15; LSF16; LSF17 and LSF3). The combined oxygen and carbon isotope profile are present in Fig. 1.

4. DISCUSSION

During the recorded period, that spans since the late glacial, in the early stage of MIS 2 (≈ 28 ky B.P.) until the late Holocene (~ 1.3 ky), abrupt events of strong increase monsoon

precipitation in northern Minas has a striking match witch stadial cold events Heinrich 2, 1, Young Dryas and also with the Bond events (Fig. 1). In the same way, abrupt decrease in monsoon precipitation are synchronic with interstadial warm events Dansgaard-Oeschger 2 and Bølling-Allerød. Increase in monsoon precipitation during the millennial-scale cold event is also observed in other paleoclimate records of tropical South America (Baker et al., 2001; Cruz et al., 2006; Cruz et al., 2009) witch (make science not witchcraft) which in turns are in antiphase with monsoon precipitation records of tropical areas at the Northern Hemisphere (Yuang et al., 2004; Wang et al., 2005; Bar-Matthews et al., 2003) (Fig. 1 and 2).

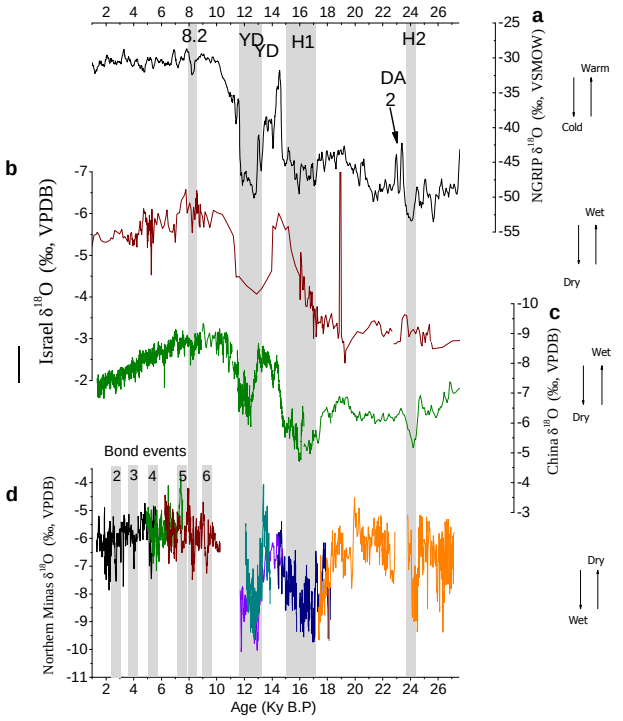


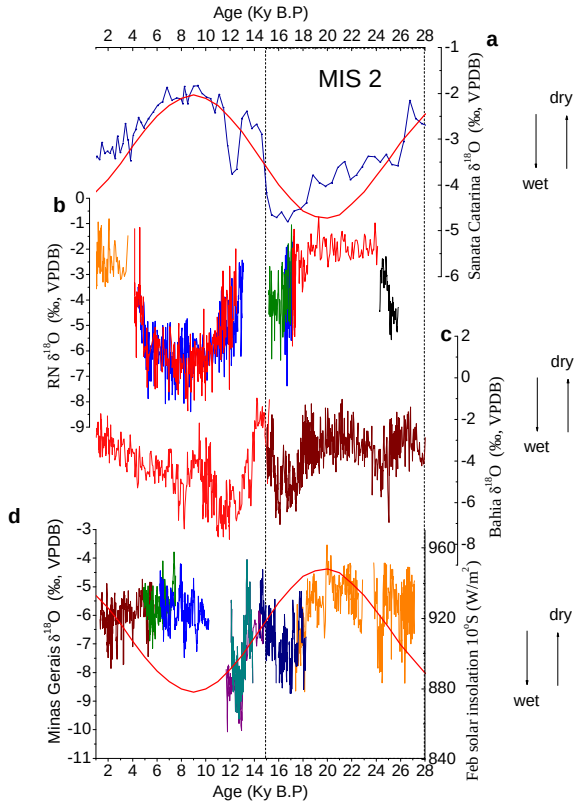
Fig. 1 – Comparison between: a) NGRIP oxygen isotope of the NGRIP ice core from Greenland ice core record; b) $\delta^{18}O$ record from Soreq cavem Isarael (Bar-Matthews et al., 2003); c) $\delta^{18}O$ record from eastern China (Wang et al., 2005; Wang et al., 2001); d) northern Minas $\delta^{18}O$ record.

The antiphase pattern of monsoon precipitation between North and South Hemisphere sustain the hypothesis that on millennial time-scale, changes in ocean heat circulation related to the bipolar see-saw mechanism may have changed the latitudinal position of the ITCZ. In this sense, cold conditions in high latitude areas of North Hemisphere, possible related to weakening of the Atlantic Meridional Overturning Circulation (AMOC), leads to an intensification of the subtropical anticyclones, which in turns promote a southward displacements of the ITCZ, strengthening the NE trade winds at northeastern Brazil coast and than increasing the convergence of moisture to Amazon Basin during the austral summer (Rahmstorf, 2002).

During the late glacial period, including the Last Glacial Maximum (LGM), the northern Minas isotope record pointed out to conditions as dry as those observed during the Bølling-Allerød and the Holocene. The end of LGM, that marks the beggining of Termination 1, also known as deglacial period, is marked by sharp wet event at 19.8 ky B.P. As can be seen in the Fig. 2, low SASM precipitation during the late glacial was also observed in the paleoprecipitation records of northeastern Brazil, at Rio Grande do Norte and southern Bahia states (Cruz et al., 2009; Barreto, 2010) in opposite with southeastern Brazil monsoon precipitation record from Botuvera cave (Cruz et al., 2006). Dry conditions during the LGM at northeastern Brazil was also observed in lacustrine records by Sifeddini et al. (2008). In agreement with our record, model simulations of the global climate performed by Wainer e Caluzet (2005) suggest spatial variations on the monsoon precipitation over South America, leading to an antiphase pattern between northeastern and central-eastern Brazil in relation to the southeastern part of the continent. Here we call attention to the weak coupling of monsoon

precipitation in northern Minas with the isolation curve described by the Milankovitch precession cycle, often taken as an important forcing on modulate monsoon precipitation in many paleoclimate records spread around the world. However, during the deglacial a decrease trend in the $\delta^{18}O$ values of northern Minas suggest a negative co-variation between monsoon precipitation intensity and solar insolation in the same way as occur in southern Bahia (Barreto, 2010) (Fig.2).

Fig. 2 – Comparison between: a) Bt-2 speleothem $\delta^{18}O$ record from Botuverá cave (Cruz et al., 2006); b) combined profile of northeastern Brazil speleothem $\delta^{18}O$ record (Cruz et al., 2009); c) combined profile from southern Bahia $\delta^{18}O$ isotope record; d) northern Minas isotope record.



Once solar insolation could not explain all the monsoon intensity variation over northern Minas, we argue that, probably the antiphase pattern observed between the areas located eastward from the current SACZ from those westward, including southeastern Brazil, occurs due southward migrations of the SACZ related to a strengthening of meridional circulation (Hadley cell) and an intensification of the Bolivia High in upper troposphere. In this context, aside of solar insolation variations at orbital time-scale, variation in the intensity of monsoon precipitation in some parts of Amazon basin may modulate the zonal circulation. Thus, an increase in monsoon precipitation in the area of Bolivia High would be related to an increase in moisture convergence to Amazon basin due to low sea surface temperatures in the North Atlantic during periods of ice expantion (Lee et al., 2009).

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