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CLIMATIC AND OCEANOGRAPHIC CHANGES IN THE AZORES REGION DURING THE LAST 74.7 KA

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ABSTRACT: In this study, we reconstruct the complex palaeoclimatic and palaeohydrographic history of the North Atlantic Ocean during the Upper Pleistocene-Holocene, through a high-resolution *Globigerinoides ruber* - *Globigerinoides elongatus* plexus study. The studied core (ATA13-OF-KT1) was collected southwest of the Azores islands near the present-day boundary of the Subtropical Gyre/Azores Front Current System (STG/AFCS). Quantitative and stable isotope data of the *G. ruber* - *G. elongatus* plexus chromotypes and selected morphotypes showed cyclic oscillations of the STG/AFCS boundary linked to climatic variability at orbital and millennial scales, during the last 74.7 ka.

KEYWORDS: Foraminifera, stable isotopes, palaeoclimatology, palaeoceanography, subtropical Gyre, Azores Front/Current System

1. INTRODUCTION

The Atlantic Meridional Overturning Circulation (AMOC) is known to be the surface and deep-water movements system that controls the North Atlantic hydrography (Fig. 1; Lynch-Stieglitz et al., 2007; Bonfardeci et al., 2018). The Azores Current (AC), originating as the eastern branch of the Gulf Stream, flows to the south of the Azores archipelago throughout the year, centred at 34°N (Schiebel et al., 2002a-b).

This current is limited to the north by the so-called Azores Front (AF) that separates the warmer and oligotrophic waters belonging to the Subtropical Gyre (STG) from the northernmost colder and nutrient-rich Eastern North Atlantic Central Water (ENACW) (Gould, 1985; Schiebel et al., 2002a-b; Schwab et al., 2012; Repschläger et al., 2015). Moreover, the AC represents the main surface waters input for the Mediterranean basin and its intensity is strongly forced by the Mediterranean Outflow Water (MOW) (Schwab et al., 2012).

Globigerinoides ruber (d'Orbigny, 1839) gr. *alba* and *rosea*, and *Globigerinoides elongatus* (d'Orbigny, 1826) are common species in tropical/subtropical biogeographic provinces (Bé and Torderlund, 1971; Bé, 1977) and they have been extensively used to reconstruct past sea-surface temperature and salinity. However, these two species exhibit morphological variability linked to different environmental conditions (Aurahs et al., 2011; Schiebel & Hemleben, 2017). In this study, we test the link between environmental conditions and morphological variability of the *G. ruber* - *G. elongatus* plexus and its response to climatic changes at orbital and millennial-scale (Bonfardeci et al., 2018). The main aim of this work was to analyse latitudinal shifts in the Subtropical Gyre/Azores Front Current System (STG/AFCS), using the quantitative abundance and isotopic variations of the different *G. ruber* - *G. elongatus* (eco-) morphotypes as sensors.

2. MATERIAL AND METHODS

The ATA13-OF-KT1 core (35°24.956'N - 37° 15.749'W; bathymetry= 3,431 m; length= 4.03 m), collected with a Kullenberg gravity corer during the Oceanograflu 2013 cruise, was sub-sampled every 1 cm, with a total of 402 samples.

The quantitative analyses on *G. ruber* - *G. elongatus* plexus of ATA13-OF-KT1 core were performed on the >125 and 250-315 μm size-fractions. Stable isotope analyses were performed every 2 centimetres, in the size -fraction 250-315 μm, on about ten specimens of *G. ruber* s.s., whereas further analyses on different morphotypes were carried out in two strategic intervals: 0-18.5 cmbsf and 42.5-60.5 cmbsf (Bonfardeci et al., 2018). The isotope analyses were performed at the LSCE (Laboratoire des Sciences du Climat et de l'Environnement - Gif-sur-Yvette, France).

3. RESULTS

For the age model developing four AMS ^{14}C dating and the $\delta^{18}O_{\textit{G. ruber} \text{ s.s.}}$ record were combined. The AMS ^{14}C analyses were preferentially carried out on surface-dwelling species (*Globigerinoides* spp.). A reservoir age correction (R_{surf}) of 400 a was used, except for the 39-40 cmbsf level, corresponding to the Heinrich event 1 (H1), where a R_{surf} of 800 was adopted (Bard et al., 1998; Siani et al., 2001). According to the tuning strategy, *G.*

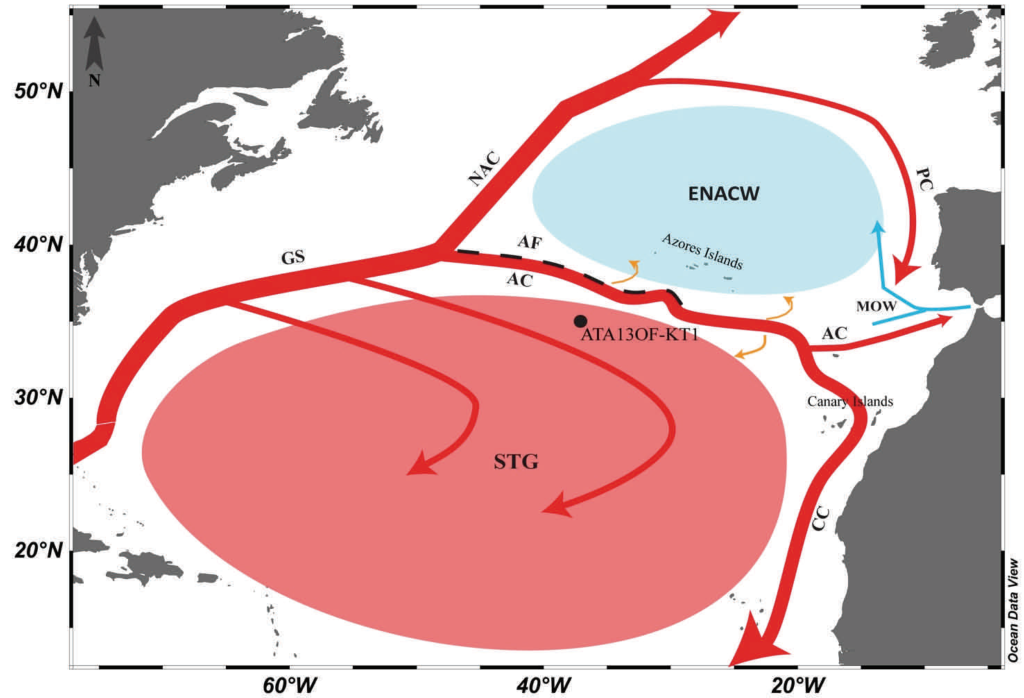

Fig. 1 - Present North Atlantic surface hydrography and ATA13-OF-KT1 core location (modified from Bonfardeci et al., 2018). GS=Gulf Stream; NAC=North Atlantic Current; AC=Azores Current; AF=Azores Front; PC=Portuguese Current; CC=Canary Current; MOW=Mediterranean Outflow Water; STG=Subtropical Gyre; ENACW= Eastern North Atlantic Central Water.

ruber gr. *alba* and $\delta^{18}O_{G. ruber\ s.s.}$ maxima and minima were aligned to the NGRIP $\delta^{18}O$ (North Greenland Ice Core Project members, 2004) and the MD95-2042 $\delta^{18}O_{G.\ bulloides}$ records (Lisiecki & Stern, 2016). Mean sedimentation rate of 5.6 cm ka^{-1} (temporal resolution of 178.5 a cm^{-1}) was calculated, with an uncertainty of 2-3 ka (Lisiecki & Stern, 2016). The time interval covered by the ATA13-OF-KT1 core record spans from 74.7 to 2.75 ka BP (Bonfardeci et al., 2018).

The $d^{18}O_{\ G.\ ruber\ s.s.}$ reached maxima values (from 2.1 to 0.8‰) during MIS 4 and 2 stages (Fig. 2), whereas decreased in correspondence with warmer MIS 1 and MIS 5.1 phases (from 1.7 to 0.4‰). High frequency/low amplitude fluctuations observed in the $d^{18}O_{G. ruber\ s.s.}$ record were linked to sub-orbital climatic oscillations, such as Heinrich and Dansgaard-Oeschger events.

G. ruber gr. *alba* increased in abundance during warm climate phases (MIS 5.1 and MIS 1) with maxima percentages (10-20 %) during the Holocene (Fig. 2), whereas minima (2-12.5 %) were observed during MIS 4 and MISs 3.1/2 transition.

Within the *G. ruber* - *G. elongatus* population, *G. elongatus* became dominant (up to 50 %) during warmer periods (MISs 5.1, 3.3, 3.1 and 1) and during the Bølling/Allerød–Younger Dryas interval, *G. ruber* cyclostoma type reached maximum abundances during insolation minima and glacial periods (MIS 4 and MIS 2), with a remarkable peak for H7, and it was almost absent in interglacial MIS 5.1 and especially in MIS 1 (Bonfardeci et al., 2018).

4. DISCUSSION AND CONCLUSIONS

Abundance fluctuations of *G. ruber* gr. (*alba* and *rosea*), as well as of the *G. ruber* - *G. elongatus* plexus morphotypes, testify that the Azores region climate and hydrography were strictly controlled by orbital and sub-orbital forcing, during the last 74.7 ka. In particular, *G. ruber* gr. (*alba* and *rosea*) reached highest abundance during climatic phases in which the insolation signal was closely in phase with the obliquity (Laskar et al., 2004). Therefore, this latter group of species has been used as monitor for the expansion/reduction of the North Atlantic STG (Repschläger et al., 2015; Bonfardeci et al., 2018). *G. ruber* gr. *alba* (Fig. 2) increases in abundance, coeval with $\delta^{18}O_{G.\ ruber\ s.s.}$ lightening, indicate that during the final part of MIS 5 and the Holocene the Azores region was interested by warmer, stratified and oligotrophic surface waters, due to the STG expansion. Conversely, during the glacial stages (MISs 4 and 2) and the Heinrich events, cooler, nutrient-richer and saltier waters, forced by STG reduction, dominated this region, as testified by *G. ruber gr. alba* decreases and $\delta^{18}O_{G.\ ruber\ s.s.}$ weighting (Bonfardeci et al., 2018).

Analysing the quantitative distribution of each ecomorphotype in the *G. ruber* - *G. elongatus* plexus, *G. ruber* cyclostoma type represents the best cooler waters indicators, reaching maxima abundance during the MISs 4 and 2, whilst *G. elongatus*, increasing in abundance during interglacial periods (latest part of MIS 5.1 and MIS 1), can be considered as the best warmer waters indicator in the Azores region. According to Bonfardeci et al., (2018), the difference between the amount of *G. elongatus* and *G. ruber* cyclostoma type represents a

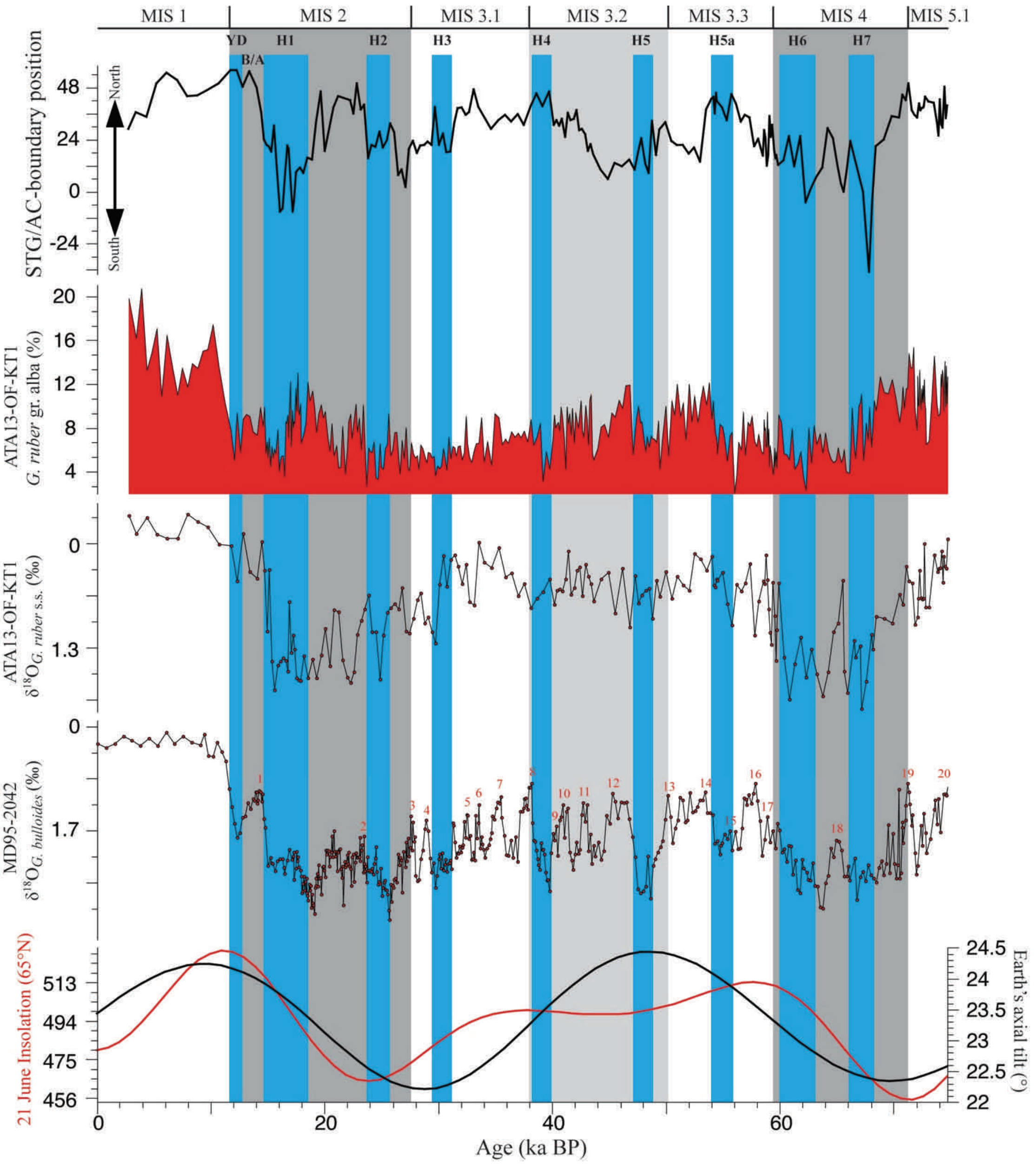

Fig. 2 - STG/AC-boundary position (% *G. elongatus-G. ruber cyclostoma* type), *G. ruber* gr. *alba* (125 μm size fraction) and $\delta^{18}O_{\ G.\ ruber\ s.s.}$ records of ATA13-OF-KT1 core record (modified from Bonfardeci et al., 2018). These latter records are compared to the 21 June insolation at 65°N (red curve) and obliquity (black curve) signals, calculated for the interval between 74.7 and 0 ka BP (Laskar et al., 2004), as well as to the MD95-2042 $\delta^{18}O_{\ G.\ bulloides}$ (Lisiecki and Stern, 2016) record. Grey vertical bars refer to the glacial stages (MISs 2 and 4) and cool-temperate sub-stage MIS 3.2 (light grey). H= Heinrich event (Heinrich, 1988; Lisiecki and Stern, 2016); Red numbers= Dansgaard/Oeschger (D/O) events (Dansgaard et al., 1993; North Greenland Ice Core Project members, 2004; Lisiecki and Stern, 2016); YD= Younger Dryas stadial; B/A= Bølling/Allerød interstadial.

powerful tool to track STG expansion/reductions and related STG/AFCS boundary latitudinal shifts (Fig. 2).

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