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Holocene paleoceanography of the Bay of Biscay: Evidence for west-east linkages in the North Atlantic based on dinocyst data

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ABSTRACT

Paleoceanographical changes during the Holocene were reconstructed from the study of core MD95-2002 situated in the northern Bay of Biscay, which is marked by the direct influence of the northeastern return branch of the North Atlantic Drift. Palynological data, sea-surface condition estimates based on dinocyst assemblages and stable isotope measurements in planktic and benthic foraminifera reveal a strong influence of freshwater/meltwaters from both the proximal European sources and the more distal Laurentide Ice Sheet, which experienced delayed deglaciation. The data also indicate the setting of a climate optimum between 7 and 5.5 ka followed by a cooling trend, which is consistent with insolation changes and other regional records of climate changes. Superimposed on the long term trends, the reconstructions of sea-surface conditions evidence large amplitude changes at centennial to millennial time-scales, with seven episodes of cooling and low salinity since 11 ka that generally match episodes of dense sea-ice cover in the Labrador Sea. The west to east transfer of the sea-ice and/or meltwater signal across the North Atlantic evidenced from core MD95-2002 points to strong linkages between western and eastern North Atlantic, probably in relation to the North Atlantic Oscillation (NAO) mode of variability.

1. Introduction

Oxygen isotope records from Greenland ice cores have highlighted high frequency climate variations during the last glacial period (Dansgaard et al., 1993) in contrast to the Holocene, which has long been considered relatively stable from a climatic point of view. Nevertheless, in the context of the current global warming, the scientific community has intensified the study of climate changes during the present interglacial in order to document the natural variability of climate under "warm" regime and to better assess on the actual impact of the anthropogenic forcing. In particular, special attention has been paid to the North Atlantic and adjacent lands as they represent key areas with regard to poleward heat transport through the North Atlantic Drift (NAD) as a major component of the Atlantic Meridional Overturning Circulation (AMOC) (cf. Carton and Hakkinen, 2011).

Bond et al. (1997) were the first to highlight climate variability in the Holocene from marine records of the northern North Atlantic (cf. Andersen et al., 2004a). Since then, millennial-scale variability of climate parameters has been detected in Holocene records based on various tracers, including coccoliths, foraminifers, and dinocysts (e.g. Giraudeau et al., 2010; Bond et al., 2001; Hall et al., 2004; Solignac et al., 2006, 2008). However, some inconsistencies in the timing, periodicity and amplitude of the variations, as well as in the signature of early Holocene climatic optimum and long-term trend, have been noticed by several authors (e.g., Eynaud et al., 2004; Solignac et al., 2006; de Vernal and Hillaire-Marcel, 2006). The amplitude and the timing of the climatic optimum referred to as "Hypsithermal" differ from one site to another, but it seems well recorded and consistent along the main path of the NAD (e.g., de Vernal and Hillaire-Marcel, 2006). The heterogeneity in the Holocene records reflects complex dynamics of ocean and climate in the North Atlantic during the Holocene.

In this context, the goal of the present study is to further document the climate variability of the present interglacial from the reconstruction of hydrographic conditions in the northern Bay of Biscay. For this purpose, we analysed core MD95-2002 retrieved from a site located under the direct influence of the northeastern return branch of the North Atlantic Drift (NAD) (Frew et al., 2000). The coring site is characterized by high sedimentation rates, especially during Termination I, during which they reach up to 50 cm/kyrs (Zaragosi et al., 2001; Auffret et al., 2002; Zaragosi et al., 2006). Here, we reconstructed sea-surface conditions based on the analysis of dinocyst assemblages (e.g., Eynaud, 1999; Rochon et al., 1999; Penaud et al., 2009; de Vernal et al., 2013). Isotopic measurements of planktic foraminifera (*Globigerina*

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bulloides and *Globorotalia truncatulinoides*) have been made to provide complementary information on the properties of the sub-surface water masses.

2. Environmental setting

Core MD95-2002 (47°27′N; 08°32′W) was retrieved during the IMAGES 101 expedition of RV *Marion Dufresne* in May–July 1995 (Bassinot and Labeyrie, 1996; Auffret et al., 2002).

It was collected at 2174 m water depth on the Meriadzec Terrace, in the northern part of the Bay of Biscay 600 m above the Biscay abyssal plain (Eynaud et al., 2007) (Fig. 1). The deep relief in the Bay of Biscay constitutes the seaward prolongation of the Berthois Spur that forms a morphological boundary along the Celtic and Armorican margins (Bourillet et al., 2006) that splits the sedimentary load from the shelf towards the Celtic Fan westward and the Armorican Fan eastward. These fans are two of the three major deep-sea fans of the French Atlantic Margin (Zaragosi et al., 2000). During low-stands of eustatic sea-level, they were mainly fed by discharges from the "Fleuve Manche paleoriver" that drained a large part of northwestern Europe (Eynaud et al., 2007). This important fluvial paleosystem, which extended from the southern North Sea to the Bay of Biscay, comprises the English Chanel, a portion of the continental "canyon-dominated" slope, and the two deep-sea turbidite systems mentioned above (i.e. Celtic and Armorican Fans) (cf. Toucanne et al., 2011).

Presently, surface waters are under the direct influence of the warm NAD, which contribute to the North Atlantic gyre (e.g., Sutton and Allen, 1997). At the study site sea-surface temperature (SST) and salinity (SSS) are 11.7 ± 0.6 °C and 35.54 ± 0.05 and 17.5 ± 1.0 °C and 35.58 ± 0.10 in winter and summer respectively (World Ocean Atlas, 2001; Conkright et al., 2002). The Slope Current (SC) also carries warm and salty waters of the Eastern North Atlantic Water (ENAW) that occupies the water column down to 800 m (e.g., Lazure et al., 2008).

Below the SC, from about 800 to 1300 m, a branch of the warm but very salty (35.7) Mediterranean Overflow Water (MOW) overlies the Labrador Sea Waters (LSW), which is characterized by salinity ranging from 35 to 35.5 (Cossa et al., 2004). Diluted LSW salinity signal in the eastern part of the Bay of Biscay is episodically induced by a diapycnal mixing favored by the proximity of the continental slope (van Aken, 2000).

3. Material and methods

3.1. Stratigraphy and chronology of the core

Core MD95-2002 consists of 30 m of hemipelagic clays. Detailed X-ray of the core shows no lamination, nor evidence of turbidity currents or erosion within the Holocene section (Auffret et al., 2002). The core was the subject of many studies that established a robust chronology spanning the last 30,000 years (Zaragosi et al., 2001, 2006; Eynaud et al., 2007, 2012). The late Pleistocene chronostratigraphical framework is based on 20 AMS ^{14}C dates from monospecific *Neogloboquadrina pachyderma* left coiled (Npl) or *Globigerina bulloides* (Gb) populations. The stratigraphy is also constrained from the $\delta^{18}O$ record and planktonic foraminifer assemblages (Zaragosi et al., 2000, 2001). For the chronostratigraphy of the Holocene section, we have combined the 2 AMS ^{14}C dates published by Zaragosi et al. (2006) and 4 additional AMS ^{14}C dates obtained from *Globigerina bulloides* samples (Table 1). The age vs. depth relationship was established from the ^{14}C ages using the CLAM software (Blaauw, 2010; http://chrono.qub.ac.uk/blaauw/clam.html), which uses calibrations similar to that of CALIB 7.0.2. The calibration was made from Marine13 (cf. Reimer et al., 2013) taking into account a marine reservoir effect of 405 years. No additional

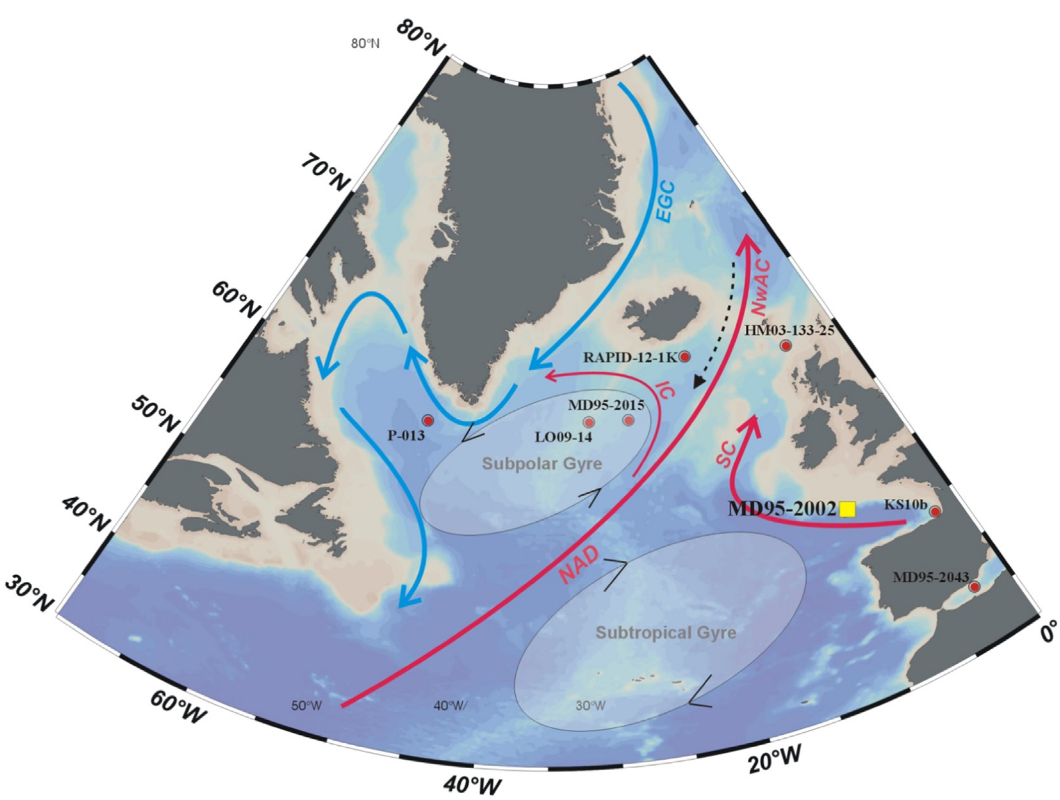

Fig. 1. Location of the study core MD95-2002 (large square: 47°27′N; 08°32′W; 2174 water depth) and other cores to which we refer in the text (small circles: LO09-14, Andersen et al., 2004a; RAPID-12-1K – Thornalley et al., 2009; MD95-2015 – Eynaud et al., 2004; HM03-133-25- Solignac et al., 2008; HU90-013-013P – Solignac et al., 2004; KS10b – Mojtahid et al., 2013; MD95-2043 – Fletcher et al., 2012). The main surface currents are indicated as follows: Irminger Current (IC), North Atlantic Drift (NAD), Norwegian Atlantic Current (NwAC), Slope Current (SC), East Greenland Current (EGC). Dashed black lines represent the Iceland Scotland Overflow Water (ISOW).