ARTICLE IN PRESS

PALAEO-07991; No of Pages 8

Palaeogeography, Palaeoclimatology, Palaeoecology xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Palaeogeography, Palaeoclimatology, Palaeoecology

journal homepage: www.elsevier.com/locate/palaeo

Holocene changes in Antarctic Intermediate Water flow strength in the Southwest Atlantic

Ines Voigt [a,*], Cristiano M. Chiessi [b], Alberto R. Piola [c], Rüdiger Henrich [a]

[a] MARUM – Center for Marine Environmental Sciences and Faculty of Geosciences, University of Bremen, D-28359 Bremen, Germany
[b] School of Arts, Sciences and Humanities, University of São Paulo, São Paulo, Brazil
[c] Servicio de Hidrografia Naval and UMI-IFAECI, University of Buenos Aires, Buenos Aires, Argentina

ARTICLE INFO

Article history:
Received 15 December 2015
Received in revised form 7 September 2016
Accepted 26 September 2016
Available online xxxx

Keywords:
Antarctic Intermediate Water (AAIW)
Southwest Atlantic
Holocene
North Atlantic Deep Water (NADW)
AAIW-NADW see-saw
Sortable silt

ABSTRACT

Antarctic Intermediate Water (AAIW) is an essential component of the Atlantic meridional overturning circulation (AMOC) contributing to balance the southward flow of North Atlantic Deep Water (NADW). However, the role of AAIW in Holocene abrupt climate changes remains poorly understood. Here we reconstruct changes in the flow strength of AAIW based on a high temporal resolution paleocurrent record from the Southwest Atlantic. Superimposed on a slight increase in AAIW strength at ~7 ka BP, a succession of millennial-scale AAIW variations is recognized in our paleocurrent records indicating a highly variable intermediate water circulation throughout the Holocene. Although variations in the strength and position of the Southern Westerlies Winds (SWW) are proposed to greatly influence the formation and circulation of AAIW, we cannot confirm such a potential SWW-AAIW linkage since our records of AAIW flow strength do not correlate to Holocene shifts of the SWW across the Atlantic. However, our data shows a good correspondence with abrupt variations in the AMOC with enhanced (reduced) northward advection of AAIW during periods of reduced (enhanced) NADW circulation. These results provide evidence for a Holocene AAIW-NADW see-saw. Thus, although the exact forcing mechanism remains unresolved, we suggest that Holocene perturbations in AAIW exerted a significant impact on the AMOC.

1. Introduction

In the modern ocean, Antarctic Intermediate Water (AAIW) is mainly formed in the Southeast Pacific and Southwest Atlantic (Piola and Gordon, 1989) (Fig. 1A). Around the tip of South America intermediate water is originated by subduction of cold and fresh Antarctic Surface Water across the Antarctic Polar Front, and by contributions of Sub-Antarctic Mode Water that originates from deep winter convection north of the Subantarctic Front (Garabato et al., 2009). AAIW is advected through the Drake Passage with the Antarctic Circumpolar Current and northward along the western slope of the Argentine Basin into the adjacent South Atlantic subtropical gyre (Fig. 1A). Thereby, the injection of cold and fresh AAIW into the South Atlantic subtropical gyre is thought to have important implications for the Atlantic heat and salinity budget, and hence can modulate the rate of North Atlantic Deep Water (NADW) formation (Rintoul, 1991; Graham et al., 2011). The AAIW that is modified to warm, salty varieties by air–sea fluxes and interior mixing in the Atlantic is thus an important component of the upper limb of the Atlantic meridional overturning circulation (AMOC) exerting a significant influence on the inter-hemispheric heat exchange (Lumpkin and Speer, 2007) (Fig. 1).

Abrupt changes in the northward flow of AAIW associated with AMOC reduction have been hypothesized for North Atlantic deglacial cold periods, Heinrich Stadial 1 and Younger Dryas (Marchitto et al., 1998; Zahn and Stüber, 2002; Rickaby and Elderfield, 2005; Came et al., 2008; Pahnke et al., 2008; Thornalley et al., 2011; Xie et al., 2012; Huang et al., 2014). However, controversy still persists as to whether the northward flow of AAIW is waxing or waning during Heinrich Stadial 1 and Younger Dryas.

The Holocene (11.7 ka BP to the present) has also been punctuated by a series of sub-millennial-scale North Atlantic cold events (Bond et al., 2001; Wanner et al., 2011a). Drift ice deposits recorded in North Atlantic sediments led to the suggestion that a significant part of the Holocene millennial-scale climate variability was driven by solar forcing, with changes in NADW formation as a possible amplifying mechanism that could contribute to their global imprint (Bond et al., 2001). High-resolution Holocene sedimentary records from the subpolar North Atlantic (Bianchi and McCave, 1999; Hall et al., 2004) indeed indicate a highly variable flow of Iceland Scotland Overflow Water (ISOW) (a precursor water mass of NADW) throughout the Holocene. However, these records do not provide an entirely consistent picture as times of reduced ISOW flow do not coincide with peaks in IRD deposition (Wunsch,

* Corresponding author.
E-mail addresses: ivoigt@marum.de (I. Voigt), chiessi@usp.br (C.M. Chiessi), apiola@hidro.gov.ar (A.R. Piola), henrich@uni-bremen.de (R. Henrich).

http://dx.doi.org/10.1016/j.palaeo.2016.09.018
0031-0182/© 2016 Published by Elsevier B.V.

Please cite this article as: Voigt, I., et al., Holocene changes in Antarctic Intermediate Water flow strength in the Southwest Atlantic, Palaeogeogr. Palaeoclimatol. Palaeoecol. (2016), http://dx.doi.org/10.1016/j.palaeo.2016.09.018

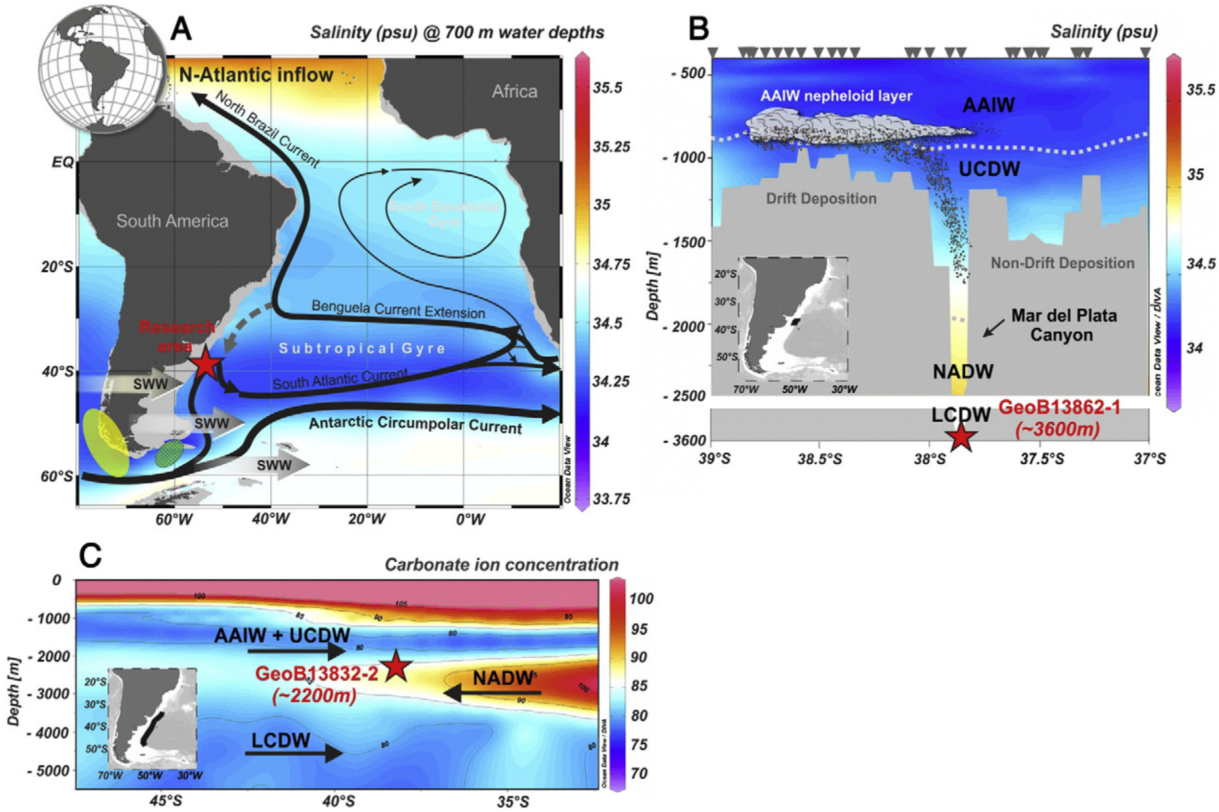

Fig. 1. A: Modern annual mean salinity (color shading) at 700 m water depth and schematic AAIW circulation (black arrows). The main AAIW source region is indicated by the yellow ellipse, and the region of strong AAIW mixing by the green ellipse. Grey arrows mark the prevailing Southern Westerly Winds (SWW). B: Along-slope salinity (color shading) section in the vicinity of the Mar del Plata Canyon (adapted from Voigt et al. (2013)). By crossing the Mar del Plata Canyon the suspended material of the AAIW nepheloid layer is released into the canyon which results in rapid and continuous deposition of sediments in the canyon. The red star indicates the location of core GeoB13862-1 whose terrigenous sortable silt fraction (10–63 μm) is used in this study to reconstruct paleo-variability of AAIW. C: Modern carbonate ion (CO_3^{2-}) concentration in the Southwest Atlantic. The red star indicates the location of core GeoB13832-2 ideally situated to monitor past changes of the interface between southern sourced waters (i.e., AAIW + UCDW) and northern sourced waters (i.e., NADW). AAIW – Antarctic Intermediate Water; NADW – North Atlantic Deep Water; UCDW – Upper Circumpolar Deep Water; LCDW – Lower Circumpolar Deep Water. Figures were prepared using Ocean Data View (http://odv.awi.de). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

2000; Hall et al., 2004). Accordingly, there is still a clear need to determine the forcing mechanisms for abrupt Holocene changes in the AMOC. Model simulations demonstrate that initial changes in AMOC strength can be related to perturbations in AAIW, thus supporting the hypothesis of a quasi-synchronous AAIW-NADW coupling under Holocene boundary conditions (Graham et al., 2011). However, high temporal resolution climate archives that confirm a possible AAIW-NADW linkage during the Holocene are sparse (Arz et al., 2001), rising a major question: To what extent was the AMOC affected by past perturbation in AAIW overturning circulation throughout the Holocene?

Here, we present a high temporal resolution Holocene paleocurrent record of AAIW flow strength based on an unconventional site in the Southwest Atlantic. Our data suggest millennial-scale changes in the flow strength of AAIW with a potential link to changes in NADW fluctuations during the Holocene.

2. Regional setting

The Southwest Atlantic is a key location in the global ocean conveyor belt (Fig. 1). Different water masses formed in remote areas of the world flow across the Southwest Atlantic and generate a highly complex vertical stratification structure. In the upper ocean, this structure is dominated by the encounter of the southward flowing Brazil Current and the northward flowing Malvinas (Falkland) Current that produces one of the most energetic regions of the world ocean, the Brazil-Malvinas Confluence (BMC) (Peterson and Stramma, 1991; Piola and Matano, 2001). In the deep ocean, the vertical stratification is dominated by contributions from intermediate- and deep water masses including (from top to bottom) Antarctic Intermediate Water (AAIW, ~500–1000 m), Circumpolar Deep Water (CDW, ~1000–4000 m) and Antarctic Bottom Water (AABW > 4000 m) (Stramma and England, 1999) (Fig. 1C). By penetrating into CDW, North Atlantic Deep Water (NADW, 2000–3000 m) vertically divides this water mass into two layers referred to as the upper CDW (UCDW) and the lower CDW (LCDW).

In this region strong contour currents shape the continental margin by eroding, transporting and depositing sediments. These currents generate various depositional and erosive features, which together are referred as a Contourite Depositional System (CDS) (Hernandez-Molina et al., 2009). Sedimentation processes within the CDS are primarily controlled by northward-flowing Antarctic water masses, that on the upper slope is dominated by AAIW (Hernandez-Molina et al., 2009; Preu et al., 2013) (Fig. 2). The Mar del Plata Canyon at the continental margin off northern Argentina intersects this CDS (Fig. 1B, 2B). The canyon does not present an obvious connection to the shelf or an on-shore river system (Krastel et al., 2011), and is therefore isolated from shelf-originated down-slope processes (Voigt et al., 2013) (Fig. 2).

Measurements of high turbidity which are part of the world ocean nepheloid layer composition database assembled by the Lamont-Doherty Earth Observatory indicate a very pronounced AAIW nepheloid layer (Voigt et al., 2013) (Fig. 2A). In addition, the OCCAM Global Ocean Model (Gwilliam, 1996) show flow velocities of ~15–20 cm/s at 1000 m water depth. Directly beneath the high velocity core of AAIW, toward the AAIW/UCDW interface, sediments from the nepheloid layer deposit and accumulate leading to the formation of drift deposits south of the Mar del Plata Canyon (Preu et al., 2013) (Fig. 2B). In contrast, modern sediments directly north of the canyon do not reflect

Please cite this article as: Voigt, I., et al., Holocene changes in Antarctic Intermediate Water flow strength in the Southwest Atlantic, Palaeogeogr. Palaeoclimatol. Palaeoecol. (2016), http://dx.doi.org/10.1016/j.palaeo.2016.09.018