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Climate of the Past Discussions

Interactive comment on "Holocene evolution of the North Atlantic subsurface transport" *by* Janne Repschläger et al.

Janne Repschläger et al.

jr@gpi.uni-kiel.de

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Response to the reviewer on behalf of all co-authors

Response to Referee #2

We acknowledge the comments made by Referee #2 on our manuscript. While generally positive about the results presented Referee #2 criticizes that the freshwater influence mainly discussed as controlling factor for subtropical subsurface transport is too limited and that also other mechanisms should be addressed as driving factors for Holocene changes in the inter-gyre transport.

We propose to revise the discussion by including a more detailed paragraph describing changes in the atmospheric circulation mainly referring to changes in NAO patterns

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and its influence on the STG/SPG system (e.g. Olsen et al., 2012). Following the suggestion of Referee #1, also changes in MOW strength and its potential influence on the AF/AC position will be discussed. Finally, more studies (e.g.Blaschek et al., 2015) about the influence of early Holocene meltwater pathways will be included into the discussion.

Furthermore, Referee #2 proposed to extent the reconstruction of the warm water transport route with cores further south/north or east/west. Unfortunately, high-resolution Holocene studies investigating changes along the warm water route including surface and subsurface temperature and salinity reconstructions are limited. (Farmer et al., 2011) published Holocene surface and subsurface temperature and salinity time series from core MD99-2251 positioned at the eastern flank of Reykjanes Ridge underneath the inflow pathway of the NAC towards core RAPID 12-1 K. The dataset of core MD99-2251 shows the same long-term evolution over early to Mid Holocene evolution as the dataset of (Thornalley et al., 2009) and we thus will mention it in a revised manuscript. In order to highlight the connection to the Labrador Sea, a comparison between our time series and surface water datasets of (Solignac et al., 2004) will be added to one of our figures as proposed in our response to Referee #2. However, the sparse number of high-resolution subsurface temperature and δ18Ow reconstructions emphasizes the need of further studies and indicates the novelty of our study.

A further aspect raised by Referee #2 was the strongly shortened methods section in the manuscript, that heavily relied on a previous publication (Repschläger et al., 2015). Indeed the methods section has been shortened very strictly in order to avoid self-plagiarism. However, we agree that it should be possible to follow the new manuscript independently. Thus the missing information will be provided in a revised version of the paper using a revised paragraph also requested by Referee #1:

“For our study we used core GEOFAR KF16 taken at 38°N, south of the Azores Islands at the Mid Atlantic Ridge, from 3060 m water depth. This position in the vicinity of the AF is ideal to trace changes in STG position and associated varying influence of subtropical and temperate waters (Repschläger et al., 2015). The age model for core GEOFAR KF16 is published in (Schwab et al., 2012). Results are compared to published data from the subtropical (Bahr et al., 2013; Cleroux et al., 2012) and subpolar North Atlantic (Thornalley et al., 2009) along the warm water route. We combine published δ18O data of planktonic surface and subsurface dwelling foraminifera G. ruber w. (Schwab et al., 2012) and G. truncatulinoides (Repschläger et al., 2015) with new Mg/Ca records from the same species. All measurements were conducted on samples of the size fraction 315-400 μm on monospecific samples of 10-25 specimens of G. ruber w. and 15 specimens of mixed left and right coiling G. truncatulinoides. Stable isotope analyses were carried out at Leibniz Laboratory for Radiometric Dating and Stable Isotope Research at Kiel University. For analyses a Finnigan MAT 523 mass spectrometer coupled with a Kiel I carbon preparation device was used and results were calibrated to the Vienna Pee Dee Belemnite (V-PDB) scale. The 2 σ standard deviation (std) obtained from 10 replicates of downcore samples was +/- 0.11 ‰ for G. ruber w. and +/- 0.12 ‰ for G. truncatulinoides. Mg/Ca analyses followed the cleaning procedure of (Martin and Lea, 2002; Repschläger et al., 2015), using reductive and oxidative cleaning. Measurements were carried out with a simultaneous inductively coupled plasma-optical emission spectrometry (ICP-OES) instrument with radial plasma observation. Potential shell contamination or coatings by authigenic minerals were monitored using additional Fe, Al and Mn measurements. Analytical 2 σ std was +/-0.20 mmol/mol Mg/Ca for G. ruber w. and +/-0.14 mmol/mol Mg/Ca for G. truncatulinoides. To convert Mg/Ca values into water temperature estimates, we used the principle equation format Mg/Ca = b exp (a*T) with species-specific variables a=0.76 and b=0.07 for G. ruber w. and a=0.78 and b=0.04 for G. truncatulinoides (equation for mixed subsurface dwellers) published by (Cleroux et al. 2008). The summed analytical and calibration 2 σ std is +/- 1°C for G. ruber w. and +/- 2°C for G. truncatulinoides. The calibrated Mg/Ca temperature estimates for both species in our core top samples match well with modern surface and subsurface (200 m depth) temperatures at the

Azores coring site. Seasonal temperature effects on the foraminiferal Mg/Ca signal are assumed to play a subordinate role at our coring site (Cleroux et al., 2008; Repschläger et al., 2015). In addition, we assume that the subsurface temperature signal of G. truncatulinoides is predominantly determined by the conditions at the AF and not by the migration of G. truncatulinoides to shallower, warmer water depths or by thermocline shoaling (see supplementary information and (Repschläger et al., 2015)). Changes in salinity are reconstructed following the procedure described in Repschläger et al. (2015). The temperature effect, estimated from the Mg/Ca was removed from the foraminiferal δ18Ocarbonate using the general equation of Shackleton (1974) for both, G. ruber w. and G. truncatulinoides, in order to be consistent with the datasets used for comparison. A correction for VPDB to SMOW was included resulting seawater δ18Ow values discussed in the following. For estimation of δ18Ow uncertainties we followed the approach of Cleroux et al., (2011) and used their equation S8:

σ (δ18Ow-ivc) = ((σ (δ18Oforam))2+(σ (Temp))2*(0.23)2)1/2

leading to calculated 2 σ std of +/- 0.35 ‰ and +/- 0.68 ‰ for G. ruber w and G. truncatulinoides, respectively. Given the relative large error in temperature and δ18Ow reconstructions, we only used 5-point average time series for interpretation to investigate longer-term trends in the datasets. The δ18Ow records were corrected for ice volume, using the eustatic sea level curve of (Austermann et al., 2013) and are expressed as δ18Ow-ivc values throughout the text. Changes in the AF front were reconstructed using the relative abundance of G. ruber w. published by (Weinelt et al., 2015). Abundance counts possess a 2 σ std of +/- 2.5 %. As G. ruber w. is most abundant within the STG (Ottens, 1991; Schiebel et al., 2002; Storz et al., 2009), low/high abundances indicate a southward/northward movement of the AF relative to the coring site. Because the position of the AF is mainly related to changes in the westerly wind belt, the abundances of G. ruber w. indicate the relative contribution of subtropical water and can be used as tracer for the position of the northern STG rim and thus of the position of westerlies (see also argumentation in Repschläger et al., 2015) before. “ Changes in the AF front were reconstructed using the relative abundance of G. ruber w. published by (Weinelt et al., 2015) These abundance counts have an 2 σ STD +/- 2.5 %. As G. ruber w. is most abundant within the STG (Ottens, 1991; Schiebel et al., 2002; Storz et al., 2009), low/high abundances indicate a southward/northward movement of the AF relative to the coring site. Because the position of the AF is related to changes in the westerly wind belt, the abundances of G. ruber w. indicate the relative contribution of subtropical water and can be used as tracer for the position of the northern STG rim and thus of the position of westerlies (see also argumentation in Repschläger et al., 2015). "

Additionally to these 2 major critisisms raised by Referee #2, we will perform all technical corrections and text passages suggested to further improve the manuscript. In a revised version of the manuscript, we will add the following references:

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