# Holocene evolution of the North Atlantic subsurface transport

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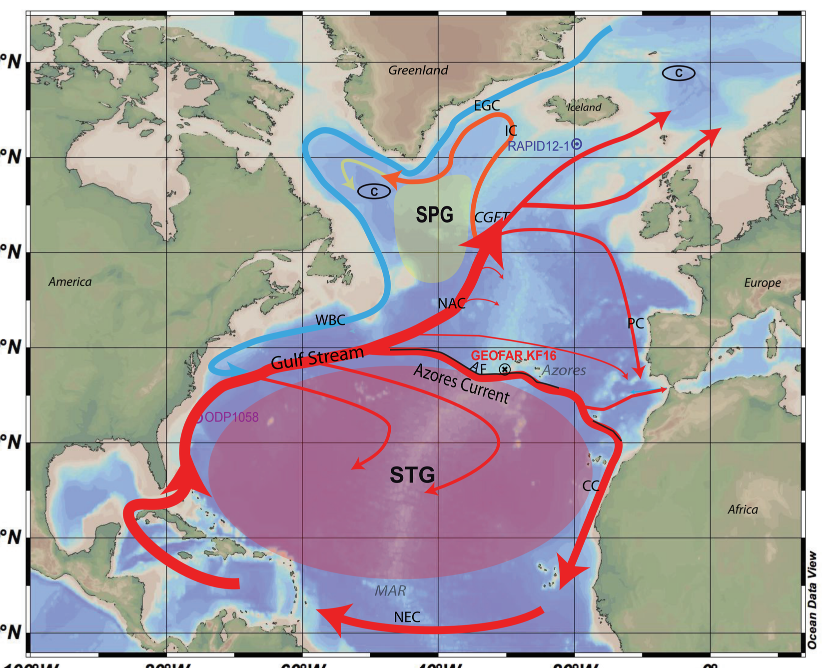
The transport of warm waters from the subtropics into the subpolar North Atlantic (NA) strongly affects the climate variability of Europe and governs the strength of NA deepwater convection and resulting AMOC strength. Holocene reconstructions of surface water circulation in the North Atlantic indicate that short term freshening events in the subpolar gyre (SPG) can be counterbalanced by interactions with subtropical gyre (STG) and thus stabilize the deepwater convection in the Labrador Sea. The latter is assumed to be an important stabilizatin of the Atlantic Meridional Overturning Circulation (AMOC). Under anticipated anthropogenic warming and predicted melting of ice sheets it is important to better understand this coupling in order to predict future climate scenarios.

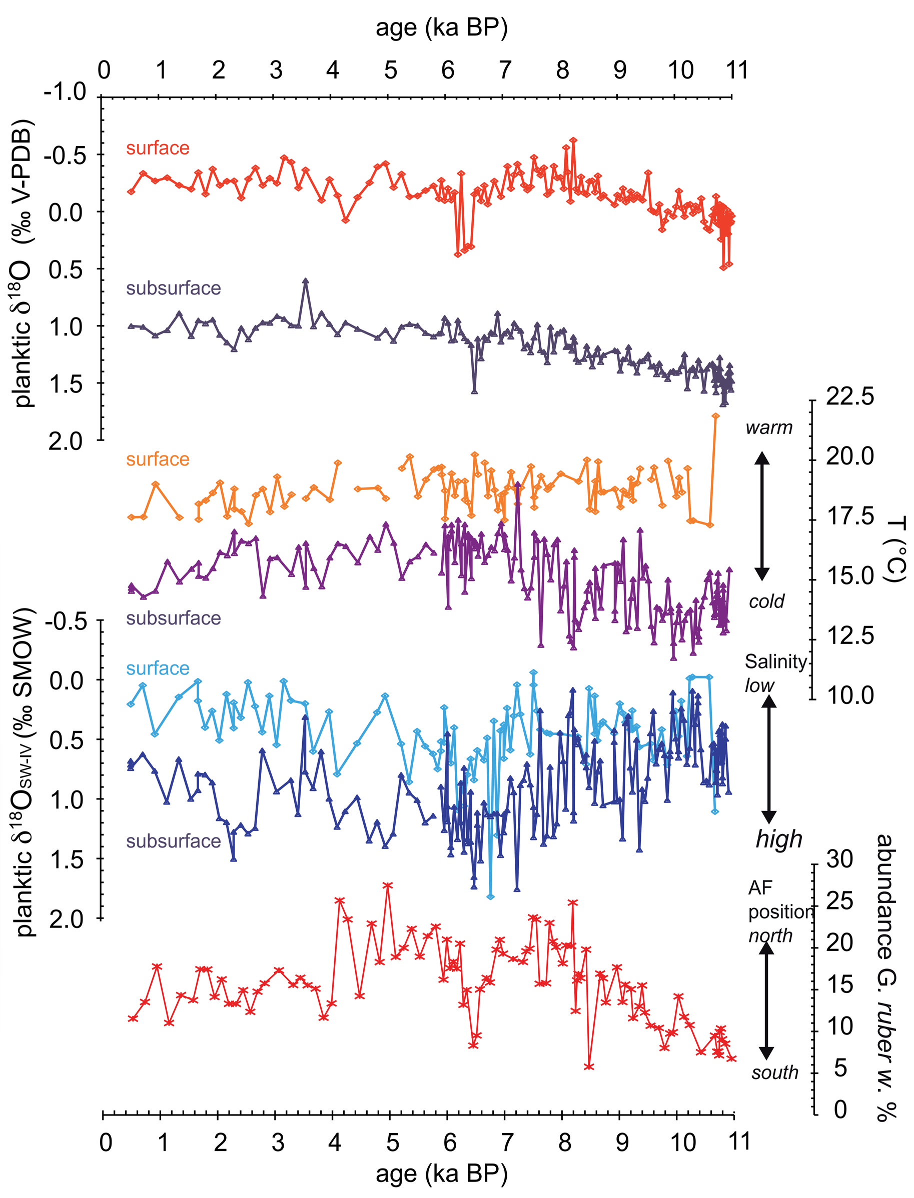
This study focuses on the reconstruction of the surface and subsurface transport between the subtropical and polar NA during the Holocene. It is based on a sediment core situated in the subtropical North Atlantic at the interface between subpolar and subtropical waters. Surface and subsurface water mass properties are reconstructed by the use of Mg/Ca and stable oxygen isotope ratios from surface and subsurface dwelling foraminifera with changes in STG position traced by the use of the abundance of *G. ruber* w. in addition.

## Regional setting

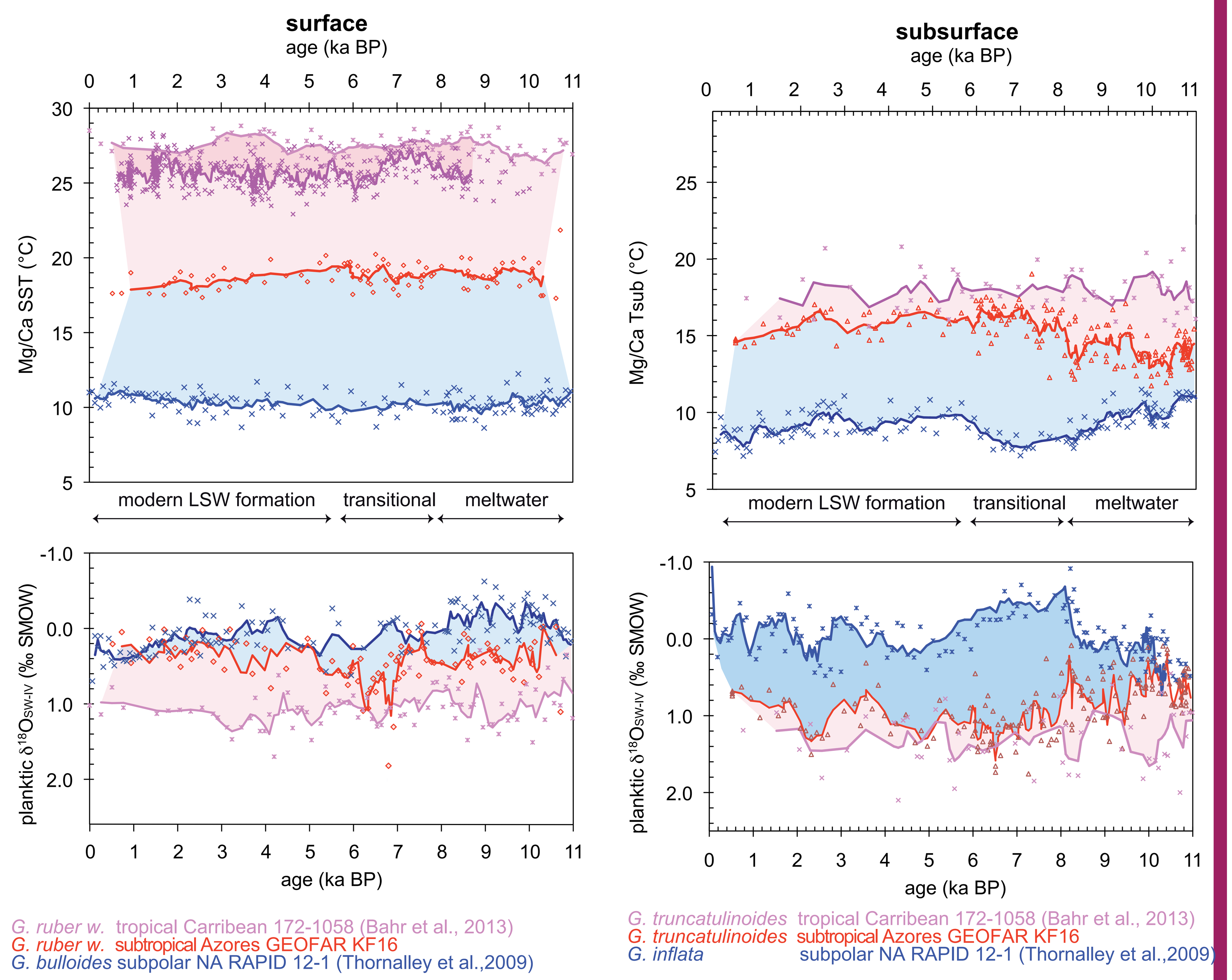



Coring site GEOFAR KF16 (38°N, 31.13°W) is situated at the northern boundary of the low productivity STG (Figure 1), which is formed by the AC system. The position of the AC is modulated by wind strength [Volkov and Fu, 2010], enhanced/decreased westerlies lead to a southward/northward movement of the AC. The Azores Front (AF) seperates warm 18°C Mode Water and cool subpolar Eastern North Atlantic Water (ENAW) (14°C) in the AC system

## Results




## Discussion




## Methods

Published stable isotope data |Repschläger et al., 2015] is combined with Mg/Ca SST reconstructions on G. ruber w. and G. truncatulinoides carried out on 15 -30 individuals. Samples were cleaned following the standard procedure of Martin and Lea [2002], Mg/Ca values of G. ruber w. and G. truncatulinoides were converted into water temperatures using the equations published by Cléroux et al. [2008]. Combined calibration error and analytical error amounts to 1°C for G. ruber w. and 2°C for G. truncatulinoides. Changes in salinity are reconstructed from the δ18O carbonate record by removing the temperature effect, known from the SST, using the formula of Shackleton (1974) to obtain δ18Ow. The δ 18Ow further was corrected for sea level changes using the benthic δ18O stack of Waelbroeck et al., (2002).

The abundance of the foraminifera species G. ruber w. is used as an indicator for the influence of oligotrophic STG waters. High G. ruber w. abundances reflect a northward movement of the changes in the STG position.

RESULTS from core GEOFAR KF16 indicate changing stratification modes:

• Early Holocene (11-8 ka BP) difference between SST and Tsub and similarity between $\delta^{18}O_{w\text{-}ivc}$ point towards thermal stratification

• Mid Holocene (8-6 ka BP) weaker thermal and haline differences suggest stronger variability in stratification

• Late Holocene (6-0 ka BP) pronounced differences in T and $\delta^{18}O_{w\text{-}ivc}$ indicate a strong thermohaline stratification

Comparison between data from the tropical North Atlantic, the subtropical Azores coring site and the subpolar North Atlantic indicate

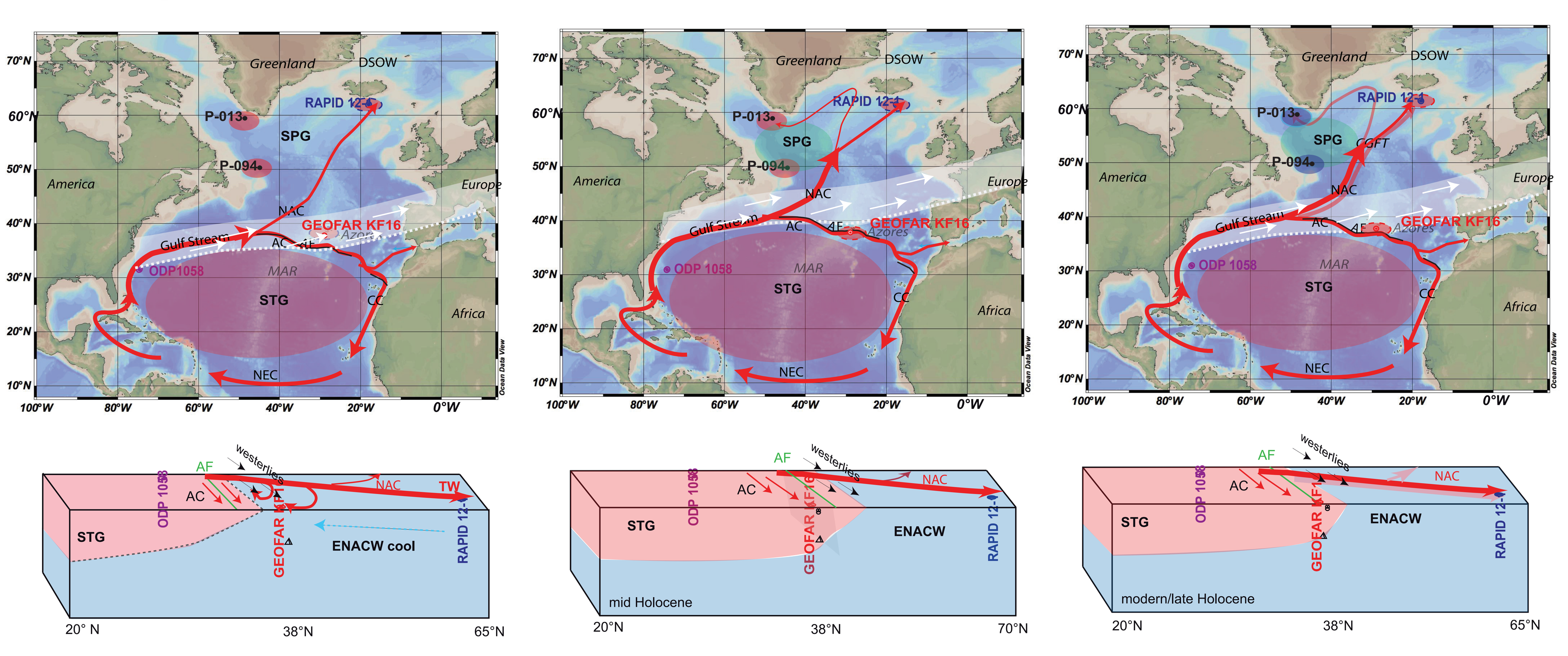
a) Stable transport of warm surface waters from tropical into subpolar regions during the Holocene, with only minor variablility in salinity

b) Increasing subsurface warm water transport during the Holocene seemingly related to the onset and stabilization of LSW formation

c) AF movements and subsurface transport seem to be decoupled, indicating that the main system change is driven by the decreasing influnce of meltwater until 7 ka BP.

d) After 7 ka BP anti-phasing between subsurface salinity and northward displacement of the Azores Front, suggests an increased inflow of warm and saline waters into the subpolar region during weak westerly wind phases that are associated with warm conditions in the Labrador Sea area. Subsequent cooling in the Labrador Sea during the last 4 ka (Solignac et al., 2004) (Figure 3d)) is accompanied by a retreat in the Azores Front position indicating that the driving force now includes changes in the atmospheric circulation dynamics.

## Conceptual model




## Conclusion

• The North Atlantic surface water transport from the tropics into the subpolar region remained relatively stable over the last 11 ka BP.

• The onset of northward transport of warm water at the subsurface seems started at 7 ka BP and seems to play a major role in the onset of the Labrador Sea Water formation and in the stabilization of the modern Labrador Sea Water formation mode and thus is a main driver in Holocene climate variability

• Comparison of different potential forcing mechanisms suggests a freshwater control on the early to Mid-Holocene ocean transport changes

• Late Holocene variability seems to be associated with changes in the atmospheric circulation

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