Project: **975**

Project title: **OCTANT – Modeling the chronology of deep ocean circulation changes during abrupt climate transitions**

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Report period: **2018-01-01 to 2018-12-31**

1 Project Overview

The main objective of OCTANT is investigating to what extent the temporal evolution of the ocean circulation during abrupt events may be inferred from deep-sea sediment cores. In that purpose we implemented in MPIOM isotopic ratios commonly measured in sediment cores as well as several age tracers allowing tracking water masses and their role in ventilation.

In the present report period we investigated the water mass reorganization in the ocean during the deglaciation and how this process is recorded by different tracers. We focused on the difference between radiocarbon-based metrics commonly used in field studies and the true ventilation. Understanding such departures is crucial for improving our understanding of past climate changes and how such changes are recorded in deep-sea cores.

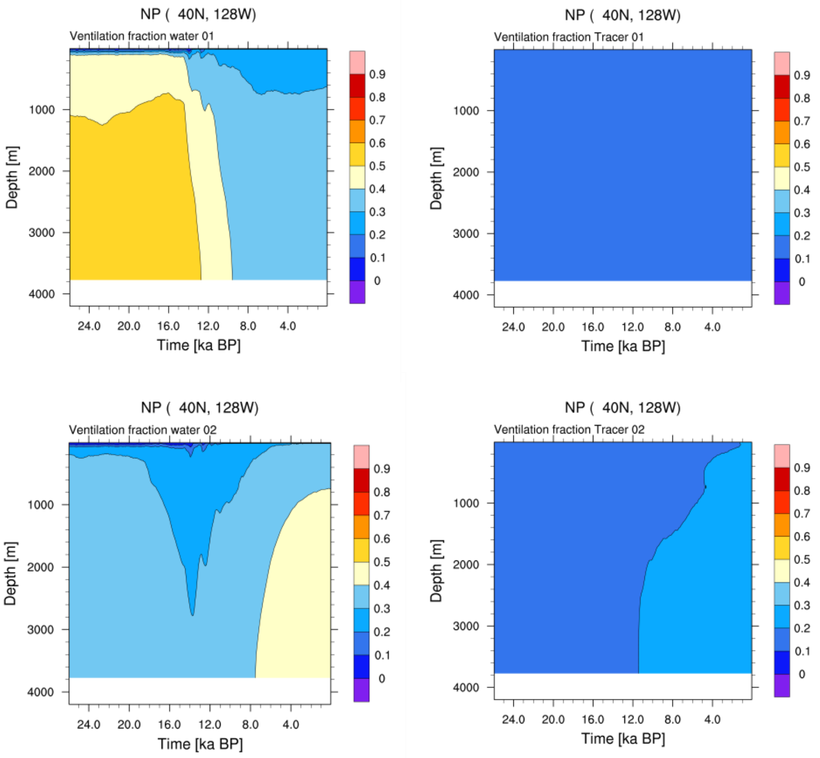
2 Report on work performed in 2018

Several transient experiments covering the late glacial, the entire deglaciation and the Holocene were performed with MPI-ESM including the novel features of interactive calculation of the directions for river runoff [1] and a smooth automatic calculation of model topography [2]. The initial states for these experiments were prepared by running the model over several thousand years under conditions prevailing at 26 ka BP. The long spin-up is required for radiocarbon and age tracers. The transient experiments were then constrained with prescribed time varying ice sheets, melt water input derived from ice sheet changes, topography derived from the reconstructions as well as, variations of the Earth orbital parameters and reconstructed atmospheric greenhouse gas concentrations and ^{14}C levels. Sensitivity experiments addressing vertical mixing, the evolution of topography, and the ice sheet reconstructions were also carried out. Additional experiments including ^{13}C and ^{18}O are being launched. They suffered from some delay due to a conservation issue (now fixed) related to the automatic adjustment of ocean volume.

Dye tracers tagging surface water from specific regions (map in Fig. 1) allow evidencing the reorganization of water mass during the transition. Such a result is illustrated in Fig. 1 (left column) for the North Pacific. The ventilation fractions (i.e. the fraction of total age contributed to) of dyes 01 and 02 exhibit contrasted behaviors: contribution from the North Atlantic dominates in the early part of the deglaciation while the contribution from the Southern Ocean is larger in the Holocene. This figure also illustrates that the use of radiocarbon as a ventilation tracer is problematic. It clearly questions the classical interpretation of deep ocean radiocarbon being determined from the North Atlantic and Southern Ocean.

Derived quantities such as benthic-planktonic and projection ages which allow a direct comparison with field studies are readily obtained from model outputs (Fig. 2). Despite several issues with predicted ocean circulation in the early stages of the deglaciation there is a qualitative agreement between model results and data-based studies [3] that the ventilation rate of the deep Pacific started to decrease at the onset of the deglaciation to increase again in the early Holocene (Fig. 2). This figure also indicates that all standard methods applied for reconstructing deep ocean ventilation from radiocarbon produce large artefacts, some of similar size as the signal.

Validation with proxy records being nontrivial, the work performed so far will be of great help in the validation of the model simulated climate and circulation changes during the deglaciation.



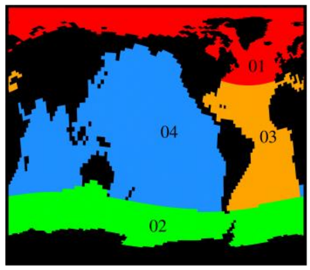


Figure 1 *Evolution over the deglaciation of ventilation fractions in the North Pacific Ocean as reported by true ventilation dyes (left col.) and radiocarbon-like dyes (mid col.). The top row corresponds to surface water from the North-Atlantic & Arctic (region 01 in the map above) while the bottom row illustrates the contribution from the Southern Ocean surface (region 02).*

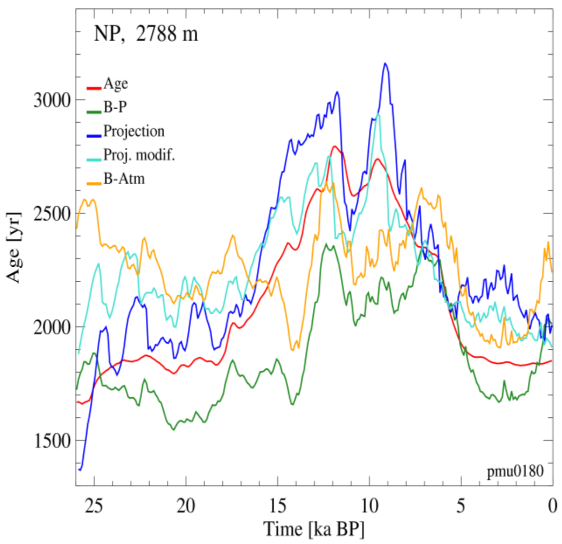


Figure 2 *Evolution over the deglaciation of the ventilation age (red) in the deep North Pacific (40N, 128W) from the experiment with ICE-6GC ice-sheet reconstruction [4,5]. This evolution is compared to radiocarbon-based standard methods: benthic-planktonic age (green), projection age (blue), modified projection age (cyan), and benthic-atmospheric age (orange).*

References

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