Project: **975**

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

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The main objective of OCTANT is investigating to what extent the temporal evolution of the ocean circulation during Heinrich events (massive discharges of icebergs to the ocean which occurred during and at the end of the last glacial period) may be inferred from deep-sea sediment cores.

In that purpose we have implemented in the Max Planck Institute Ocean General Circulation Model (MPIOM) isotopic ratios commonly measured in sediment cores ($\delta^{13}C$ and $\Delta^{14}C$) as well as ventilation age (England, 1995) and partial ages (Mouchet et al., 2016). The tracer module is currently being validated. However preliminary results with $\Delta^{14}C$ evidenced the need to reconsider mixing parametrization and process in MPIOM. Planned work up to the end of the year includes careful assessment of the optimal representation of mixing processes in the deep ocean in both coupled and uncoupled MPIOM versions.

Model development

Since our project addresses the deep ocean over long time periods with the fully coupled MPI Earth System Model (MPI-ESM) simple formulations for tracer cycles have to be adopted while retaining the most relevant processes at the climatic time-scale.

For radiocarbon we adopt the method of Toggweiler et al. (1989). Air-sea exchange for ^{13}C and ^{14}C is set after Wanninkkhof (1992) with ^{13}C fractionation factors from Zhang et al. (1995).

Modeling $\delta^{13}C$ necessitates accounting for biological processes in the ocean. The export production model of Mouchet (2011) has been implemented. It considers a standing biomass stock whose growth is driven by the availability of nutrient (P) and light and which is limited by grazing and mortality. The decay products are immediately distributed and remineralized at depth following Najjar et al. (2007). A constant fractionation factor for the assimilation of ^{13}C is used.

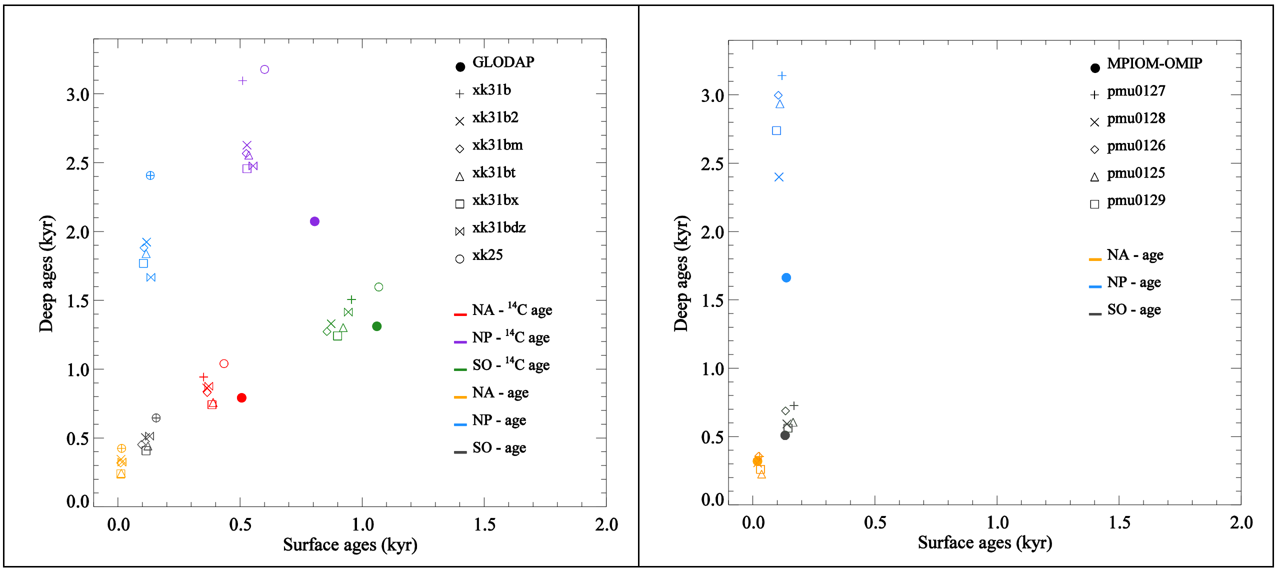

Figure 1 Mean deep (>1400m) versus mean surface (< 400m) ages in the North Atlantic (NA), the North Pacific (NP), and the Southern Ocean (SO) for MPIOM-OMIP (uncoupled; left) and MPI-ESM (coupled; right). For MPIOM-OMIP both ventilation and radiocarbon ages are illustrated while for MPI-ESM only ventilation age is available. The large difference between ventilation and radiocarbon ages is due to the the slow air-sea equilibration time for ^{14}C (Broecker and Peng, 1974). The various symbols correspond to the different sensitivity experiments to mixing parametrization or processes (identical symbol in left and right panels means the same mixing parametrization is used in both uncoupled and coupled experiments). For uncoupled experiments (left) reconstructed radiocarbon ages (GLODAP; Key et al., 2004) are also reported (filled circle). Ventilation ages for the uncoupled experiment performing best (considering ^{14}C age, salinity and temperature) are reproduced (filled circle) with the results from coupled experiments.

Model validation

Radiocarbon allows assessing ventilation rates in the model since computed $\Delta^{14}C$ may be directly compared to the reconstruction from field measurements. Figure 1 (left) reproduces the mean radiocarbon ages in 3 ocean basins as obtained from ocean-only simulations with OMIP climatological forcing (Marsland et al., 2003). Ventilation age is also represented since it allows a direct comparison with the results from coupled experiment with MPI-ESM (Fig. 1, right) for which only ventilation age is available. It is readily seen from Fig. 1 that the standard MPIOM formulation (exps 'xk31b' and 'pm0127') leads to too large ages in the deep North Pacific.

We then performed several sensitivity tests by increasing the background mixing (exps 'xk31b2' and 'pm0128'), by increasing the Richardson-number dependent formulation (Pacanowski and Philander, 1981; exps 'xk31bm' and 'pm0126'), by activating tides (exps 'xk31bt' and 'pm0125'), or by combining the last two (exps 'xk31bx' and 'pm0129'). An additional test was performed in which the background mixing increases with depth (exps 'xk31bdz'; not fully equilibrated yet). The experiments started from the same initial state and lasted several thousand years – the time needed for the deep Pacific Ocean to reach equilibrium.

With increased mixing mean salinity in deep ocean is generally slightly improved (Fig. 2, left) but experiments in which tides are activated exhibit a warm bias in deep ocean basins (Fig. 2, right). Similar conclusions may be drawn from coupled experiments (not illustrated).

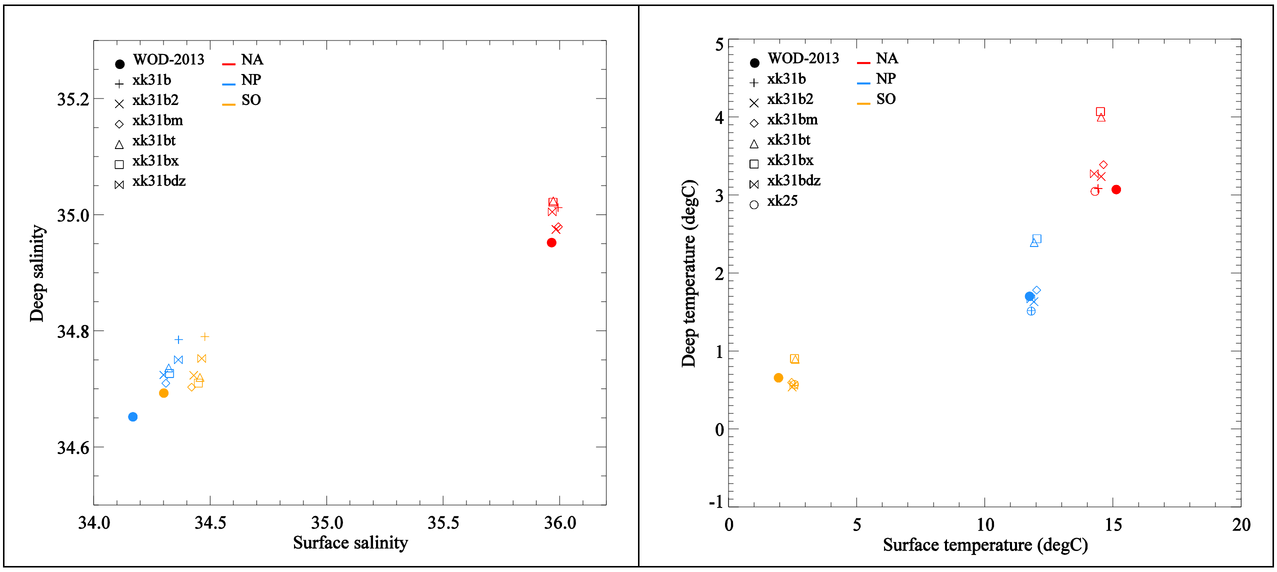

Figure 2 Mean deep (>1400m) versus mean surface (< 400m) salinity (left) and temperature (right) in the North Atlantic (NA), the North Pacific (NP), and the Southern Ocean (SO) for MPIOM-OMIP. Values from the World Ocean Atlas 2013 (Boyer et al., 2013) are reported with filled circles.

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