Project: **975**

Project title: **OCTANT**

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Report period: **2020-01-01 to 2020-12-31**

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 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. By means of transient simulations from the end of the last glacial maximum (LGM) to the present day we investigate the relevance of radiocarbon as a proxy for deep ocean ventilation changes. In parallel we develop tracer methods aimed at assessing water mass fractions and ventilation pathways.

Activities during 2020 covered several aspects: theoretical investigations, assessment and analysis of available transient experiments, and paper redaction. Most of the computing time is being used for deglaciation experiments including OCTANT tracers while experiments aimed at unravelling water mass contributions also called for some resources.

2 Report on work performed

PARTIAL AGES AND WATER-MASS COMPOSITION

Partial ages [1] record the time spent in specific ocean regions. We have been able to demonstrate that the knowledge of partial ages is sufficient for obtaining essential ventilation metrics. Indeed, the mass fractions (mixing ratios) of any arbitrary number of source waters as well as their ages may be directly computed from the partial ages anywhere in the domain.

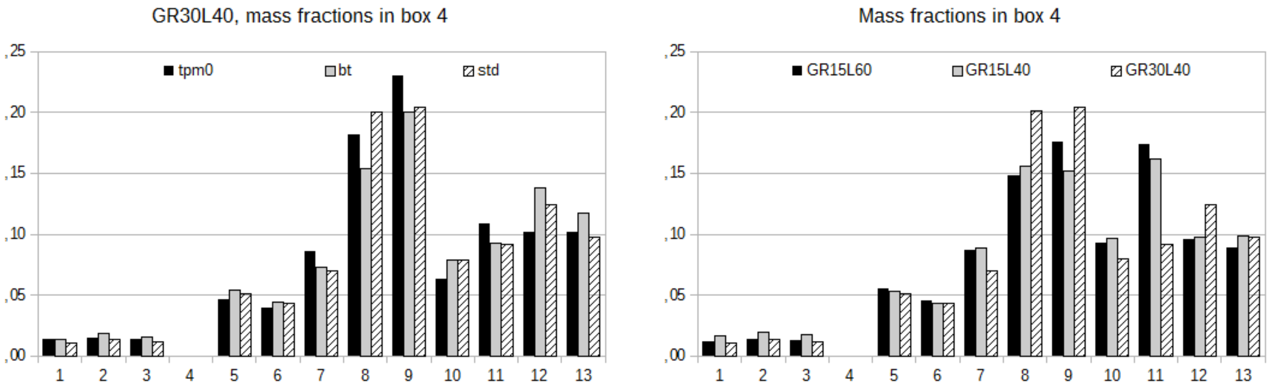

Fig 1. Mas fractions in box 4 (intermediate depths in EEP) computed with partial ages. Left: results with MPIOM-GR30L40 for three different mixing schemes (standard - std, tides - bt, and enhanced mixing along topographic features - tpm0). Right: results for three different resolutions (standard mixing scheme).

The mixing ratios averaged in the Eastern Equatorial Pacific (EEP) between 1500 and 2500 m depth are reproduced in Fig. 1. The largest contributions are from western boxes (8 & 9). The 'topographic' mixing scheme (tpm0; Fig. 1, left panel) leads to increased upwelling (i.e., from box 7, below 2500m in the EEP) and larger contribution from the deep western Pacific (box 9). Increasing the horizontal resolution (Fig. 1, right panel) leads to stronger upwelling (from 7), larger contributions from the deep northern Pacific (box 11), and weaker transport from the west (boxes 8 & 9). Such a tool is valuable for interpreting results from experiments with HAMOCC.

CALENDAR AGE UNCERTAINTY OF MARINE RADIOCARBON SAMPLES

We already presented limitations to the use of radiocarbon as a proxy for ventilation of the deep ocean [2]. Additional complexities arise from uncertainties related to the reservoir age (2019 report) as well as from the calibration procedure.

Dating of deep-sea cores mostly relies on radiocarbon anomalies from which a conventional radiocarbon age is derived. A calibration procedure [3] allows then obtaining the calendar age once a correction for the reservoir age (i.e., the apparent aging of ocean surface water due to slow radiocarbon air-sea exchange) is applied. However, the relationship between the conventional radiocarbon age and the calendar age is not monotonic. Hence a radiocarbon age may lead to a wide range of calibrated dates [4].

At the moment, we are developing a method for calibrating the modeled deep radiocarbon ages and assessing the uncertainties of the associated calibrated ages over the deglaciation. The uncertainties are evaluated by taking advantage of available realizations of the transition from the LGM as different ice-sheets formulations (reconstructions ICE-6G_C and GLAC-1D; interactive) and model configurations (addressing vertical mixing, bathymetry and land-sea mask) provide a range of ocean responses. The impact of planktonic foraminifer species-specific habitat [4] is also considered. In combination with the suite of model states this allows obtaining a range of reservoir ages over time.

The calibration step then provides a time resolution [4] for each deep ocean conventional radiocarbon age. The time resolutions of the calibrated dates are then computed over the whole deglaciation transition. Such study is of relevance for model assessment against reconstructed fields as well as for assimilation procedures which are being developed (e.g., PAGES-CVAS initiative). Unfortunately we are not yet able to provide illustration of this work as further development of the post-processing codes are needed.

Publications

The work of the previous years led to two publications:

1. Deleersnijder et al. (2020) investigates the appropriate boundary conditions to apply when computing the age of tracers. In our framework two variables are needed for each age. The boundary conditions to be used for these two variables are not independent. In this paper a method leading to coherent boundary conditions is presented.
2. Mouchet et al. (subm.) illustrates how radiocarbon metrics depart from the one obtained with ideal ventilation tracers. It is shown that the ventilation record is highly tracer-dependent. When considering ideal ventilation tracers the deep ocean is nearly uniquely contributed to by surface waters from the North Atlantic and the Southern Ocean. In contrast, radiocarbon at depth has contributions from the whole ocean surface. This should be considered when reconstructing past events by means of radiocarbon anomalies.

[1] Mouchet, A., Cornaton, F., Deleersnijder, E., Delhez E. Partial ages: diagnosing transport processes by means of multiple clocks. *Ocean Dynamics* **66,** 367–386, doi: 10.1007/s10236-016-0922-6, 2016.

[2] Mouchet A., Mikolajewicz, U., Deleersnijder, E. Deep ocean ventilation as depicted by radiocarbon. Submitted to Earth and Planetary Sciences Letters.

[3] Reimer, P. J., et al. IntCal13 and Marine13 radiocarbon age calibration curves 0–50,000 years cal BP, Radiocarbon, 55, 1869–1887, doi:10.2458/azu_js_rc.55.16947, 2013

[4] Svetlik, I., et al. The Best possible Time resolution: How precise could a Radiocarbon dating method be? Radiocarbon, 61(6), 1729-1740. doi:10.1017/RDC.2019.134. 2019.

[4] Roche, D. M., Waelbroeck, C., Metcalfe, B., Caley, T. FAME (v1.0): a simple module to simulate the effect of planktonic foraminifer species-specific habitat on their oxygen isotopic content, Geosci. Model Dev., 11, 3587–3603, https://doi.org/10.5194/gmd-11-3587-2018, 2018.

[5] Deleersnijder E, Draoui I, Lambrechts J, Legat V, Mouchet A. Consistent Boundary Conditions for Age Calculations. Water. 12: 1274, doi: 10.3390/w12051274. 2020.