Project: **976**
Project title: **EU H2020 CRESCENDO; Marine Biogeochemical Processes**
Principal investigator: **Tatiana Ilyina**
Report period: **2018-01-01 to 2018-12-31**

1 Project Overview

The EU Horizon 2020 project 'CRESCENDO' (Coordinate Research in Earth Systems and Climate: Experiments, kNowledge, Dissemination and Outreach) aims to improve the process realism to foster the understanding of the Earth System. By improving the representations of both physical climate and key biogeochemical processes, CRESCENDO advances the future climate prediction reliability of Earth System Models (ESMs) and fosters the assessability of Earth system changes and environmental responses of potentially significant socio-economic and ecosystem relevance.

In the present report period, we studied relevant physical and biogeochemical processes that control the formation, variability and trend of the oceanic oxygen minimum zones (OMZs). Understanding and representing the oceanic oxygen cycle is crucial to improve the representation of the nitrogen and carbon cycles and potential biophysical feedback on the climate system. The model simulations in this project are **independent of DECK and scenario simulations of CMIP6**. We work in cooperation with the OCTANT project (with Anne Mouchet) and the MARMA project (with Joeran Maerz) for continuous model development.

2 Report on Computational Time 2018

We aim to understand to what degree the ocean physical model and the biogeochemistry model can be utilized to gain the best possible representation of the OMZs. Here we report two on-going projects.

Ocean Physics: Sensitivity on Vertical Mixing We have started conducting a suite of sensitivity experiments aiming on understanding the sensitivity of ocean biogeochemical tracer distributions to vertical resolution and mixing schemes. The TKE and TKE-IDEMIX mixing schemes [1] have been recently implemented into MPI-OM by Nils Brüggemann. Additionally, Anne Mouchet tested the impact of topographic mixing (TPMIX) to water mass distribution using advanced passive tracers (water mass age, see DKRZ project OCTANT). We applied these mixing scheme in a coarse resolution configuration of MPI-OM/HAMOCC, complementary to the simulations by Anne Mouchet in OCTANT, to study their impact on water mass properties and OMZ structures in the eastern tropical Pacific. We characterize water mass properties using quasi-conservative tracer PO_4^* (defined as $PO_4^* = PO_4 + O_2/172 - 1.48$),which allows to track contributions of different waters masses like the North Atlantic Deep Water (NADW), Antarctic Intermediate Water (AIW) or Antarctic Bottom Water (AABW) [6, shown for a cross section the Atlantic in Fig. 1]. Initial results show indeed differences in the distribution of key water masses AABW, AIW, and NADW for the different mixing schemes corresponding to a modulation of the large scale meridional overturing circulation. For example, TKE and TPMIX shows a weaker penetration of NADW to the south and a stronger contribution of AIW in lower latitudes as the reference experiment [5]. Analysis of these simulations is only preliminary and implications onto the biogeochemistry, in particular the OMZ is yet to be explored.

Ocean Biogeochemistry: Novel mechanistic sinking scheme for marine aggregates OMZ formation and variability are closely related to respiration through microbial degradation and remineralization of dissolved and particulate organic matter (DOM and POM, respectively). Algae fix carbon dioxide (CO_2) and form POM in the in the sunlit surface waters of the ocean, the euphotic zone. Marine aggregates are the main vector for the vertical transport and sequestration of POM, thus biologically bound CO_2, to the interior of the oceans and, hence, their remineralization directly affect the oxygen level of the ocean. Within this project, we therefore aimed at providing a better understanding of the influence of marine aggregates on the variability and formation of OMZs by i) advancing HAMOCCs representation of the so-called biological carbon pump by a novel, process-oriented *Microstructure, Multiscale, Mechanistic, Marine Aggregates in the Global Ocean* (M^4AGO) sinking scheme, ii) testing and advancing the M^4AGO sinking scheme and iii) performing transient model runs to assess the effect of the novel sinking scheme on the biological carbon pump and the oxygen level of the oceans under a changing climate. The novel and more realistic representation of marine aggregates with their varying microstructure and explicit incorporation of ballasting biogenic minerals and dust particles in the M^4AGO sinking scheme required unforeseeable further adaptations

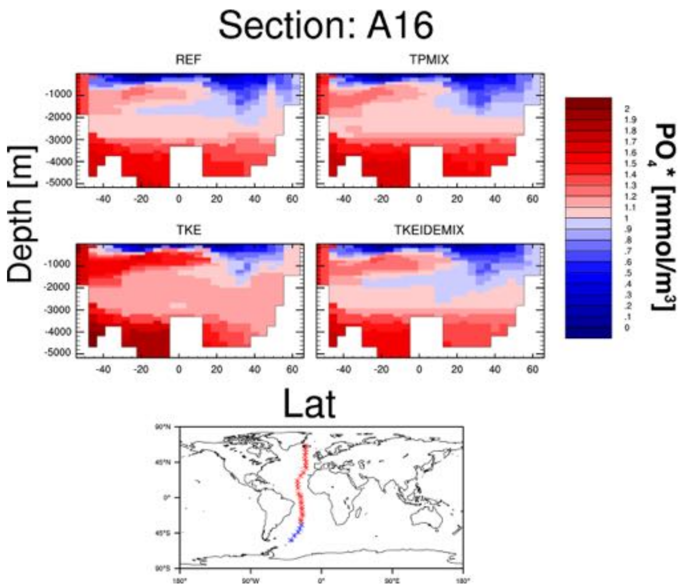

Figure 1: Meridional cross sections of PO4* from line A16 in the Atlantic Ocean from a suite of vertical mixing experiments.

in HAMOCCs core process representation and thus a longer test and tuning phase than previously anticipated. In contrast to the previous Martin formulation, the M^{4}AGO sinking scheme ties POM and minerals in agregates together which led us adopt a temperature-dependent remineralization of POM and dissolution of biogenically formed opal to improve the representation of the so-called rain ratios, the ratio between organic and mineral fluxes, with respect to an extensive sediment trap data set [4]. After an intensive tuning phase of HAMOCC advanced by M^{4}AGO in MPI-OM in an GR15-OMIP setup, we achieved to significantly improve the transfer efficiency pattern of POM for an equally well and partly improved representation of other biogeochemical states in HAMOCC (see Fig. 2 for the regionally highly variable, improved transfer efficiency pattern).

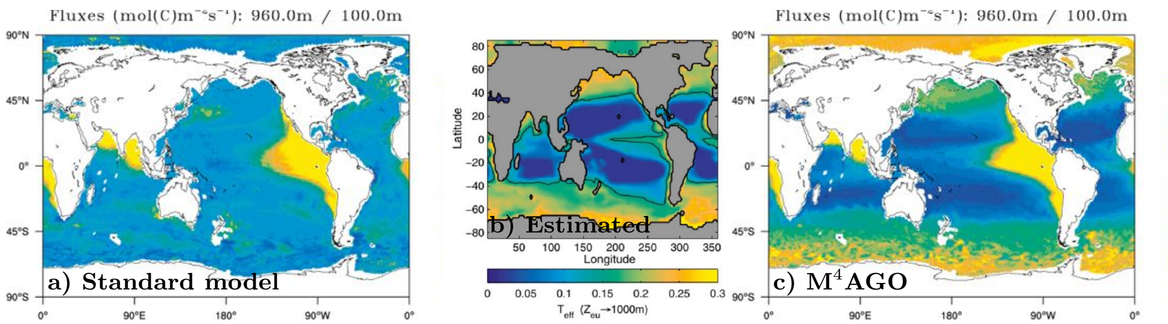

Figure 2: Transfer efficiency of POC from the euphotic zone to about 1000 m depth. **a)** HAMOCC standard model run with the Martin power law approach with linear increasing sinking velocity below the euphotic zone. **b)** Inversely estimated transfer efficiency by Weber et al. 2016 [7] based on phosphate climatology and satellite measurements **c)** HAMOCC model run with the novel M^{4}AGO sinking scheme. Note: The colorbar values are representative for all maps.

These results currently enter a publication [in preparation, 3] and the final model run will be the base for further parameter sensitivity studies and a transient run until the end of the year 2018. With the explicit representation of marine aggregates microstructure, porosity, composition and size spectra, we achieved to develop the prerequisites for the study of ambient density gradient effects on sinking of porous marine aggregates [2]. The representation of the underlying physical principles in HAMOCC is envisaged until the end of the year.

These model spin-up and sensitivity experiments are required independently of the CMIP6 DECK simulations. New model developments and improvements within CRESCENDO will be evaluated against CMIP6 simulations, but they will not be part of any CMIP6 MIPs.

References

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