Zooplankton and the ocean carbon sink

Role of zooplankton dynamics for carbon export and air-sea CO_2 exchange: ocean biogeochemical simulations

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In Short

- Discrepancy between models and observations of the ocean carbon sink, possibly related to ecosystem processes
- Zooplankton dynamics in Earth System Models are oversimplified
- We will test the sensitivity of the ocean carbon sink to different parameter choices for zooplankton processes

Carbon dioxide (CO_2) emissions from fossil fuels and land-use change amounted to 11.2 PgC yr^{-1} in 2016 and force anthropogenic climate change. Ocean and land sinks provide an extremely valuable service to humankind by each drawing down about 25% of anthropogenic CO_2 emissions, thereby slowing the rate of anthropogenic climate change. On time-scales longer than a century the ocean will be the main repository for anthropogenic CO_2 emissions and the Southern Ocean is the main conduit by which this CO_2 enters the ocean.

However, initial results from the US research programme SOCCOM (Southern Ocean Carbon and Climate Observations and Modeling) that applied a large array (about 200) of profiling floats with biogeochemical sensors throughout the Southern Ocean, suggest that the CO_2 uptake might be smaller than previously assumed. In particular, SOCCOM floats reveal larger outgassing in winter. On-going research suggests that this discrepancy between models and new observations could be linked to the rudimentary representation of zooplankton in biogeochemical models.

Organic matter formed through photosynthesis by phytoplankton in the surface mixed layer is transported to depth by sinking of particles formed through aggregation and grazing processes, by vertical migration of zooplankton and by advection of dissolved organic matter. Sinking particles consist mostly of faecal pellets and macroscopic aggregates and are remineralized by bacterial degradation. The sinking rates and thus depth of remineralization determine the time-scale for which carbon is removed from the surface ocean where gas-exchange with the atmosphere occurs. However, zooplankton not only control the amount of sinking particles by their faecal pellet production, but also exert a strong control on the maximum possible biomass of phytoplankton, and release dissolved carbon during sloppy feeding, excretion and respiration. Furthermore, zooplankton grazing on particles ("gate-keeping") also leads to the destruction of phytodetrital aggregates and faecal pellets.

In the Marine Ecosystem Model Intercomparison Project (MAREMIP) we revealed large discrepancies among models on global and regional future changes in primary and export production [1]. Climate-induced changes in particle formation and destruction have equally large effects on the projected amount of carbon exported to the deep ocean as changes in primary production [1]. Yet, the models disagree on

- the relative importance of various particle formation (aggregation versus zooplankton grazing) and destruction processes,
- the relative importance of phytoplankton groups (nanophytoplankton, diatoms) for particle formation, and even on
- the direction of export change [1].

This comes as no surprise, as physiological responses of phytoplankton to climate change and processes of particle formation/destruction are either not represented or oversimplified in models, despite their importance for atmospheric CO_2 concentration.

One discrepancy in REcoM2 is that with the chosen parameter values, zooplankton grazing in the tropics (nanophytoplankton is the main primary producer) is reasonably well represented, but there is too little grazing on diatoms (the main primary producers in high latitudes, Fig 1). With two zooplankton classes, the parameters can be chosen as such that one class represents microzooplankton and mainly feeds on nanophytoplankton, whereas the second zooplankton class can feed on larger size classes, i.e. on diatoms and on the newly introduced microzooplankton. We expect that such a structure and parameter choice will lead to stronger zooplankton grazing also in high latitudes. In response to the revealed discrepancies, we have coded a second group of zooplankton in the model and have successfully run initial tests. It is the aim

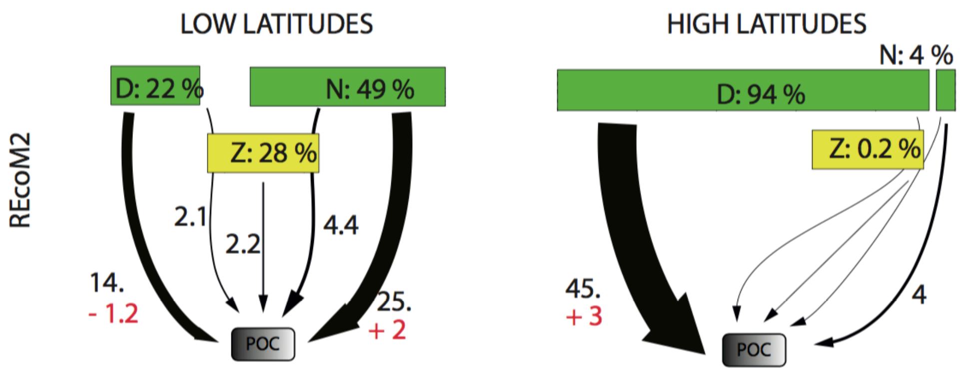

Figure 1: *Diagrammatic depiction of the ecosystem structure and the particle formation mechanisms in the low latitudes (< ±30° N/S, on the left) and in the high latitudes (>60° S, on the right) for in the ecosystem model REcoM2. Shown are the 2012-2031 average (black numbers) and the changes between the 2012-2031 period and the 2081-2100 period (red numbers). The green boxes show diatom (marked with D) and nano-phytoplankton (N) biomass, the yellow boxes (Z) zooplankton biomass, all given in percent of total biomass. The arrows within the panels denote from left to right: diatom aggregation, grazing on diatoms, zooplankton mortality, grazing on nanophytoplankton and nano-phytoplankton aggregation. The fluxes are given in percent of total net primary production (NPP). Figure taken from [1].*

of this project to investigate the sensitivity of the system to parameter values chosen for the zooplankton.

For the work proposed here we apply a global version of FESOM, coupled with the biogeochemistry and ecosystem model REcoM2 [2] [3]. When used at coarse resolution, the AWI-CM (with FESOM at its ocean component) is comparable to other CMIP5 models in terms of its representation of the mean climate and climate variability. The biogeochemistry and ecosystem model REcoM2 coupled to the MITgcm ocean circulation model has been successfully used for studies on recent and future changes in the carbon cycle [2]. FESOM runs with REcoM2 have proven to be well suited for studies on the global and regional scale. Recent code developments in REcoM2 coupled to the MITgcm ocean circulation model will be transferred to the REcoM2 code coupled to FESOM.

WWW

https://www.awi.de/en/science/biosciences/marine-biogeoscience/main-research-focus/mathematical-modelling.html

More Information

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