Fourth International Conference on Earth System Modelling
4ICESM-137, 2017

Influence of light absorption by marine biota on climate projections under rising CO_2

H. Paulsen (1,2), T. Ilyina (1), J. Jungclaus (1), K.D. Six (1), and I. Stemmler (1)
(1) Max Planck Institute for Meteorology, Hamburg, Germany (hanna.paulsen@mpimet.mpg.de), (2) International Max Planck Research School on Earth System Modelling, Hamburg, Germany

Phytoplankton in the euphotic zone absorbs incoming shortwave radiation and transfers it into heat. This biologically induced radiative heating affects the ocean and climate state, as shown by numerous modeling studies. In a warmer climate, many models project a reduction in primary production, mainly due to a reduced supply of nutrients to the surface ocean. Yet, some primary producers – for instance nitrogen fixing cyanobacteria – may benefit from climate change, such as warmer temperatures and lower pH. Hence, it is largely unknown how changes in the phytoplankton distribution and related modifications of light absorption may affect the evolution of climate under rising CO_2.

We address this topic using the Max Planck Institute Earth System Model (MPI-ESM). In a first step, we run two idealized 1% CO_2 increase scenarios, one with and one without including the feedback from biology on ocean temperature via light absorption, and assess the changes in climate relative to the preindustrial control states. In a second step, we test the hypothesis that cyanobacteria, which we include as a prognostic phytoplankton group in the biogeochemical model (Paulsen et al., 2017), may benefit in a high CO_2 world. We modify the growth parameterization of cyanobacteria (pH-dependent growth rate, temperature adaptation, utilization of dissolved organic phosphate) and study how the thereby altered evolution in the phytoplankton distribution modifies the feedback on climate.

First results show that the simulated decline in phytoplankton concentrations in the tropical and subtropical ocean under increasing CO_2 amplifies the surface heating signal in the tropics. This is because lower phytoplankton concentrations within the subtropical gyres cause deeper penetration of shortwave radiation and hence a heating of the subsurface water below the mixed layer. This relatively warmer water is transported equatorward via the shallow meridional overturning cell and eventually upwelled at the equator. Instead of a surface cooling - which one would expect from a reduced phytoplankton light absorption - this advective process leads to a surface heating effect in the tropics, regionally by up to 0.4 K. Associated implications for climate include a stronger reduction of the Walker circulation and regionally enhanced changes in precipitation. The increase in cyanobacteria concentrations, which is simulated in the additional scenario in some limited regions, slightly counteracts the heating effect, however, does not override the impact of the otherwise overall declining trend in phytoplankton.

Our model results indicate that tropical climate is sensitive to changes in the distribution of phytoplankton light absorption. While a more comprehensive ecosystem model would be needed to project the peculiarities of the response of different phytoplankton groups, our experiments suggests that a potential future decline in phytoplankton concentrations in the tropics and subtropics could amplify tropical climate change.

References:
Paulsen, H., Ilyina, T., Six, K. D., & Stemmler, I. (2017). Incorporating a prognostic representation of marine nitrogen fixers into the global ocean biogeochemical model HAMOCC. Journal of Advances in Modeling Earth Systems.