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Seifert, Miriam; [Nissen, Cara](#) ; Rost, Björn; Vogt, Meike; Völker, Christoph; Hauck, Judith

Publication date:

2023-04-27

Permanent link:

<https://doi.org/10.3929/ethz-b-000655645>

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Originally published in:

EGUsphere, <https://doi.org/10.5194/egusphere-egu23-6828>

EGU23-6828, updated on 21 Feb 2024

<https://doi.org/10.5194/egusphere-egu23-6828>

EGU General Assembly 2023

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Look ahead! Future projections of phytoplankton communities are altered by interactive effects of environmental drivers

Miriam Seifert¹, Cara Nissen¹, Björn Rost^{1,2}, Meike Vogt³, Christoph Völker¹, and Judith Hauck¹

¹Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung, Marine Biogeosciences, Germany

(miriam.seifert@awi.de)

²Universität Bremen, FB2, Bremen, Germany

³Institute for Biogeochemistry and Pollutant Dynamics, ETH Zürich, Zürich, Switzerland

Phytoplankton growth is controlled by environmental drivers such as nutrients and light availability, temperature, and the carbonate system. Thereby, changes in one driver can modify the response towards another driver. These interactive effects are usually not considered in large-scale ocean biogeochemistry models, potentially leading to incomplete projections of future phytoplankton biomass. In the presented work, we first parameterized growth sensitivities to changes in the carbonate system. We then used the results of a meta-analysis on interactive driver effects in published phytoplankton laboratory studies to develop model parameterizations for dual driver interactions (carbonate system versus temperature, carbonate system versus light). The parameterizations were tested in the biogeochemistry and phytoplankton functional type model REcoM under present-day and future conditions. While future phytoplankton biomass decreases by a similar amount with and without driver interactions (5-6%), interactive driver effects become visible on a group-specific level. Once driver interactions are considered, the biomass of diatoms and small phytoplankton decreases by -8.1% and -5.0%, respectively, and the biomass of coccolithophores increases by +33.2% from present-day to future conditions on a global scale. In comparison, the biomass of diatoms, small phytoplankton, and coccolithophores changes by 0.0%, -9.0%, and -10.8%, respectively, in simulations without driver interactions. Hence, projections of the global future phytoplankton community shift towards a larger share of small phytoplankton and coccolithophores and a smaller share of diatoms if interactive driver effects are taken into account. Regionally, the effect of driver interactions is largest in the Southern Ocean, where diatom biomass decreases (-7.5%) instead of increases (+14.5%). In conclusion, our study reveals that model projections of future phytoplankton biomass may miss out important information on the future phytoplankton community composition and group-specific direction of change if driver interactions are not considered.