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Amplified tropical warming under rising CO_2 due to the decline of phytoplankton and related changes in light absorption

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Phytoplankton in the euphotic zone absorbs incoming light and transfers it into heat. This biologically induced radiative heating affects the ocean and climate state, as shown by modeling studies. Under rising CO_2, models project a reduction of phytoplankton in the tropical and subtropical ocean. Yet, some phytoplankton groups, in particular N2-fixing cyanobacteria, may benefit from climate change. We apply the Max Planck Institute Earth System Model (MPI-ESM) to investigate how changes in the phytoplankton distribution affect light absorption and thereby feed back on climate. We run idealized 1% atmospheric CO_2 increase scenarios — with and without including the active feedback from biology on ocean temperature via light absorption. We include N2-fixing cyanobacteria as a prognostic phytoplankton group in the biogeochemical model, test how cyanobacteria evolve in a high CO_2 world given potential adaptation mechanisms, and assess how cyanobacteria's evolution influences climate via changes in light absorption.

We project an overall decline in bulk phytoplankton and cyanobacteria in the tropical and subtropical ocean. Also the tested adaptation mechanisms of cyanobacteria (pH-dependent growth, temperature adaptation, DOP uptake) do not prevent the overall decrease of cyanobacteria in a high CO_2 world. The related decrease in water turbidity regionally amplifies the surface heating signal in the tropics by up to 0.5 K (20%) under quadrupling CO_2. This is because deeper penetration of light heats the subsurface water that feeds the shallow meridional overturning cells and that is upwelled at the equator and the eastern boundaries. The regional increase in cyanobacteria in the eastern tropical Pacific slightly weakens the heating effect, however, does not override the impact of the otherwise declining phytoplankton. The results show that climate-change induced alterations in biological light absorption can, in turn, alter climate change — a feedback which has been largely overlooked until now.