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Biological-physical feedback mechanisms in marine systems: a model study involving cyanobacteria

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Biologically induced changes of physical oceanic properties provide potential positive and negative feedback loops. The expected increase of sea surface temperatures (SST) in many parts of the world ocean will lead to environmental conditions favoring surface floating cyanobacteria. Higher abundances of cyanobacteria at the ocean surface will lead to increased light absorption potentially leading to higher SST. In addition, an increase of surface floating cyanobacteria will lead to an increasing ocean surface albedo allowing less light to penetrate the ocean leading to decreasing SST. Cyanobacterial surface mats can also decrease the momentum input from the atmosphere by wind leading to a decrease in turbulence levels, less mixing and stronger stratification leading to higher SST.

In this work we study the effect of a changing phytoplankton community composition to one dominated by surface buoyant cyanobacteria on the physical oceanic properties. For this purpose we use a 1D water column model as well as a 3D circulation model and set up an idealized biological model taking into account the phytoplankton species' characteristics as well as the effect of biology on physics through changes in absorptivity, albedo and surface wind drag. We perform several numerical experiments in order to quantify the resulting effects on the physical properties of the upper ocean and to assess the resulting feedback loops. We particularly look at low- to mid-latitude ocean regions, since the largest effects are expected there.

The simulation results show that an increase of surface buoyant cyanobacteria leads to substantial changes in the seasonal cycle of the temperature distribution as well as in the dynamics of the mixed layer and in ocean circulation. In particular, the model results indicate that the effects due to altered absorptivity and biologically induced reduction of the wind drag are larger than the contrary effects due to changes in the surface albedo.