The role of deep convection on the dynamics of the North Atlantic phytoplankton community

In recent years, observations of a significant winter phytoplankton stock and blooms in the absence of stratification have challenged the classical picture of phytoplankton dynamics in the North Atlantic. To explain phytoplankton winter survival, it has been suggested that deep convection can sustain low primary production by frequently returning plankton cells to the euphotic zone. For this mechanism to work, the convective vertical velocities have to superimpose the sinking rate of phytoplankton cells and cell photosynthesis has to compensate for respiratory and other losses. In this thesis, different modeling approaches are used to investigate several aspects of the bio-physical interplay between deep convection and phytoplankton growth. Simple water column models for phytoplankton have suggested that phytoplankton cannot grow in highly turbulent deep mixed layers, conditions typical for deep convective regimes. To investigate this discrepancy between observations and model studies, a modeling approach commonly used in population models was applied to a spatial grid, where the advective flow was explicitly represented. The result shows that indeed phytoplankton can persist in highly turbulent deep waters and suggests that it is the convective overturning within the mixed layer, that enables cell to thrive under these conditions.

To investigate the role of acclimation during winter and during the onset of the spring bloom, an adaptive Individual-Based Model (IBM) was developed, allowing to test the phyto-convection hypothesis in relation to individual physiological rates. The model in-cooperates an adaptive parameterization for respiration and a mechanistic sinking model, both of which have been suggested as important contributors to phytoplankton losses during the winter. While cell sinking was found to be only of lesser importance, respiration had a large impact on phytoplankton survival during winter and especially during the onset of stratification. In contrast to the non-hydrostatic model coupled to the IBM, ecosystem models are hydrostatic and are therefore not able to capture convective motion as such. Due to the coupling of deep convection and phytoplankton winter survival in the north Atlantic, this can lead to an underestimation of winter phytoplankton biomass. As a first step to improve the winter phytoplankton representation, a simple parameterization assuming average mixed layer light levels throughout the whole mixed layer, was implemented into an ecosystem model and validated with a non-hydrostatic convection model. The new parameterization improved the model fit to observational data substantially. The increased standing stock during winter led to higher carbon export, in particular during the onset of thermal stratification in spring. The finding of this thesis have important implication for our understanding of carbon sequestration during winter and for the role of the North Atlantic as a carbon sink, in particular in a scenario of climate change.

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