Role of phytoplankton adaptation in functioning of a coastal ecosystem: southern North Sea

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In a nutshell
Here, we describe a novel trait-based adaptive model, and its successful implementation to a coastal system, southern North Sea. By means of a scenario analysis, we show that key features of the system critically depend on adaptive potential of the phytoplankton assemblage.

The ecosystem model
The study site, southern North Sea, is a dynamic ecosystem characterized by steep gradients and interactions with a number of earth system components, necessitating a coupled model framework. In this study, we used FABM (Framework for Aquatic Biogeochemical Models, Bruggeman & Bolding 2014), for coupling to hydrodynamical models GOTM (General Ocean Turbulence Model) and GETM (General Estuarine Transport Model).

Relevance of Adaptation
In order to gain a better understanding of the effects of different ‘adaptability’ forms in our model, we considered 3 scenarios:

1) NA: Non-adaptive
2) PA: Only photoacclimation
3) PA+OU: Photacc. + Optimal Uptake

Simulations in 1-D suggest incrementally increasing estimates of bulk gross primary productivity rates (GPPR*phytoplankton-C) and nutrient consumption rates with increasing levels of adaptability.

Next, we wanted to find out the variation of the roles of photoacclimation and optimal uptake across realistic nutrient and light gradients found in the study system, the southern North Sea. For this purpose, we ran the same 3 scenarios at different 1-D setups of a range of water depths, where background turbidity and winter nutrient concentrations were also described as functions of depth, based on observations (Ebenhöh et al. 2004, Topcu et al. 2011, Kerimoglu et al. in prep).

The scenario analysis reveals that the importance of photo-acclimation and optimal uptake significantly varies across different light and nutrient regimes, and that for accurate estimations of the bulk GPPR, consideration of adaptation processes can be crucial, as indicated by up to 3-fold differences between NA and PA+OU models.

Scaling up from 0-D to 1-D and 3-D
The phytoplankton model was tested and parameterized against chemostat experiments where phytoplankton were forced with marginal resource supply ratios (Wirtz et al. in prep.)

Non-phytoplankton processes (grazing, sinking, turbidity, benthic remineralization and denitrification, etc) were parameterized based on the skill of the 1-D (GOTM) implementation obtained at the Helgoland-Roads (Kerimoglu et al. in prep)

When coupled to a 3-D hydrodynamical model (GETM), simulated spatio-temporal dynamics of key system variables and process rates were reasonable (figures are examples for the year 2005). Comparison with station data is in progress.

Summary
A new adaptive phytoplankton model was developed and validated. The adaptive phytoplankton model was scaled up by coupling to a number of earth system components, and was successfully tested. It was shown that consideration of adaptation processes can be very crucial.