Re-thinking spring blooms using optimized NPZD models

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Understanding the mechanisms controlling the spring bloom of phytoplankton is key to assessing uncertainties in trophic interactions and biogeochemical feedbacks within the context of climate change. The initiation of the North Atlantic spring bloom is receiving a wave of renewed scientific interest, as several new hypotheses have challenged its traditional explanation. According to the traditional critical depth hypothesis, the bloom initiates when the mixed layer (ZMLD) becomes shallower than the critical depth (Zcr, where integrated net phytoplankton growth is zero). Using an evolutionary algorithm, we optimized the parameters of a one-dimensional NPZD (Nutrient – Phytoplankton – Zooplankton – Detritus) model, in order to replicate annual cycles of satellite-based chlorophyll concentrations in the subpolar North Atlantic, with emphasis on the abrupt increase during the winter-spring transition. The optimized models represented the observations accurately. Taking advantage of the low computational cost and flexibility of our model configuration, a set of simple experiments was developed in order to isolate the effects of mixed layer fluctuations and grazing on the timing of the bloom. Our model experiments even achieved an accurate bloom onset using a constant ZMLD, suggesting that the shoaling of the mixed layer was not a requirement for the spring bloom initiation, but determined nutrient depletion and bloom termination. Nevertheless, the critical depth criterion for positive net growth (ZMLD < Zcr) held true for all of our model experiments, as expected. In order to assess the effects of changes in nutrients, zooplankton, light and temperature on net phytoplankton growth, we performed a model sensitivity analysis using a second-order Taylor approximation of the phytoplankton equation. Our results indicate that changes in light and zooplankton have a major effect on winter phytoplankton concentrations, while changes in nutrients mainly affected fall concentrations.