

Optimality based models of phytoplankton size structure in the North Pacific

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Phytoplankton size structure is an important factor determining trophic transfer and export production in the ocean. To model phytoplankton size structure, conventional ocean models usually discretize the phytoplankton community into a number of size classes, which is usually computing intensive. In addition, the flexible behaviors of phytoplankton physiology such as flexible intracellular nitrogen-to-carbon ratios and chlorophyll-to-carbon ratios should be also considered. Here we present a new ecosystem model which combines the flexible behavior of phytoplankton physiology and an innovative approach of modeling the mean and variance of a continuously distributed phytoplankton size. The key features of the new type of ecosystem model include: 1) A tradeoff exists phytoplankton photosynthesis and nitrogen uptake. Phytoplankton cells are assumed to optimize the energy allocation between light harvesting and nitrogen uptake. 2) By assuming a continuous lognormal distribution of phytoplankton size, key phytoplankton physiological parameters such as nutrient uptake rate, photosynthesis rate, minimal nutrient quota, etc. follow validated size-scaling laws. Then the net growth rate of the bulk phytoplankton community can be expressed as a function of the net growth rate at mean log size and the second derivative of net growth rate evaluated at the mean log size based on moment closure approximations. 3) A killing-the-winner strategy is adopted to maintain phytoplankton size diversity. This model is coupled with a 3D regional ocean circulation model (ROMS) in the North Pacific and can reproduce the large-scale patterns of oceanic circulation, temperature, and salinity, nitrate and chlorophyll fields. As expected, nutrient concentration is the major factor controlling distributions of phytoplankton mean size and size variance. Sensitivity analysis suggests that the ecosystem model is very sensitive to the type of grazing functions and zooplankton mortality closure terms.

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