A Numerical Experiment to Estimate Biological Effects of the Absorption of CO_2 in the North Pacific Surface Water

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Abstract

A one-dimensional chemical-biological model is constructed to evaluate the capacity of surface water to absorb atmospheric carbon dioxide. The model variables are the concentration of phytoplankton, zooplankton, bacteria, particulate and dissolved non-biological organic material (carbon, nitrogen, and phosphorus), nutrient (PO_4, NO_3, NH_4), total CO_2, alkalinity, and dissolved oxygen. The model contains the vertical advection with the constant upwelling rate and a vertical diffusion process. For phytoplankton, processes such as photosynthesis, mortality, extracellular release, sinking and respiration are considered. For zooplankton, grazing, respiration and mortality processes, and for bacteria the processes of uptake of non-biological organic materials, mortality, and respiration are taken into account. Decomposition of non-biological organic materials, sinking, nitrification, and exchange of CO_2 and O_2 with air are also included in the model.

The model is examined for North Pacific surface water (42°N, 175°E) and compared with the observed NOPACCS data (Northwest Pacific Carbon Cycle Study). The result reproduces the observation except for dissolved oxygen. The estimated carbon mass balance shows that most of the total inorganic carbon utilized for primary production is supplied within the surface layers by regeneration as well as from lower layer by vertical diffusive flux. The supply from air to be utilized for primary producion is only a few percent. Sensitivity analysis shows that vertical water velocity should be smaller than 10^{-6} (cm s^{-1}), and a vertical diffusion coefficient should be about 1 (cm^2 s^{-1}) to reproduce observed results. Among biological parameters, the mortality rate of zooplankton and bacteria have little effect on the biological pump, while the formation rate of calcium carbonate cell affects the result significantly. The limits and problems of the present one-dimensional model are also discussed.