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Adjoint sensitivity of the air-sea CO_2 flux to ecosystem parameterization in a three-dimensional global ocean carbon cycle model

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An adjoint model is applied to examine the biophysical controlling factor of surface pCO_2 in different ocean regions. In the tropical Atlantic and Indian Oceans, the annual variability of pCO_2 in the model is highly dominated by temperature variability, whereas both the temperature and dissolved inorganic carbon (DIC) are dominant in the tropical Pacific. In the high latitude North Atlantic and Southern Oceans, DIC mainly regulates the annual variability of surface pCO_2. Phosphate addition significantly increases the carbon uptake in the tropical and subtropical regions, whereas nitrate addition increases the carbon uptake in the subarctic Pacific Ocean. With respect to changes in the physiological rate in the ecosystem model, the carbon uptake is sensitive in the equatorial Pacific, North Pacific, North Atlantic, and the Southern Ocean. Zooplankton grazing plays a major role in carbon exchange, especially in the HNLC regions. The grazing parameter regulates the phytoplankton biomass at the surface, thus controlling the biological production and the uptake of carbon for photosynthesis. Increase in phytoplankton growth rate due to climate warming suggests increase of carbon uptake in the equatorial and North Pacific and in the North Atlantic Oceans. In the oligotrophic subtropical regions, the air-sea CO_2 flux is sensitive to changes in the phytoplankton exudation rate by altering the flux of regenerated nutrients essential for photosynthesis.