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Model estimating the effect of marginal ice zone processes on the phytoplankton primary production and air-sea flux of CO_2 in the Barents Sea

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This study is aimed to assess the impact of sea ice on the primary production of phytoplankton (PPP) and air-sea CO_2 flux in the Barents Sea. To get the estimations, we apply a three-dimensional eco-hydrodynamic model based on the Princeton Ocean Model which includes: 1) a module of sea ice with 7 categories, and 2) the 11-component module of marine pelagic ecosystem developed in the St. Petersburg Branch, Institute of Oceanology. The model is driven by atmospheric forcing, prescribed from the reanalysis NCEP / NCAR, and conditions on the open sea boundary, prescribed from the regional model of the atmosphere-ocean-sea ice-ocean biogeochemistry, developed at Max Planck Institute for Meteorology, Hamburg. Comparison of the model results for the period 1998-2007 with satellite data showed that the model reproduces the main features of the evolution of the sea surface temperature, seasonal changes in the ice extent, surface chlorophyll "a" concentration and PPP in the Barents Sea. Model estimates of the annual PPP for whole sea, APPmod, appeared in 1.5-2.3 times more than similar estimates, APPdata, from satellite data. The main reasons for this discrepancy are: 1) APPdata refers to the open water, while APPmod, to the whole sea area (under the pack ice and marginal ice zone (MIZ) was produced 16 - 38% of PPP); and 2) values of APPdata are underestimated because of the subsurface chlorophyll maximum. During the period 1998-2007, the modelled maximal (in the seasonal cycle) sea ice area has decreased by 15%. This reduction was accompanied by an increase in annual PPP of the sea at 54 and 63%, based, respectively, on satellite data and the model for the open water. According to model calculations for the whole sea area, the increase is only 19%. Using a simple 7-component model of oceanic carbon cycle incorporated into the above hydrodynamic model, the CO_2 exchange between the atmosphere and sea has been estimated in different conditions. In the absence of biological factors, the maximum value of the CO_2 flux (positive from the atmosphere into the sea) occurs in the MIZ during the period of ice melting. This is mainly due to the relatively low sea surface water temperature and salinity in MIZ, which increases the solubility of carbon dioxide in sea water. Accounting for the marine ecosystem leads to a sharp increase (5-10 times) in the absorption of CO_2 in the phytoplankton growth period in May-June. The following conclusions were also drawn: 1) spatial variability of CO_2 flux between ocean and atmosphere depends on the spatial variability of primary production greater than the variability of sea surface temperature; 2) marine ecosystems play a significant role in the formation of the exchange of carbon dioxide between the atmosphere and the sea in the high latitudes.
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