Phytoplankton and Iron: Validation of a Global Three-Dimensional Ocean Biogeochemical Model

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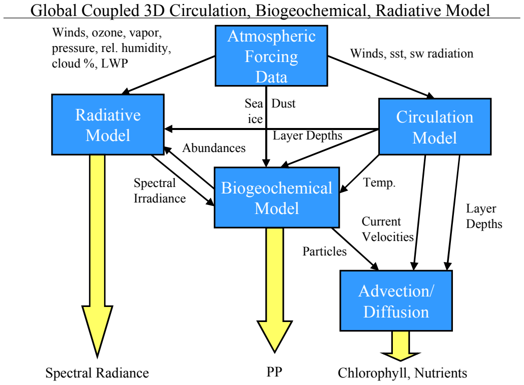
Abstract

The JGOFS program and NASA ocean color satellites have provided a wealth of data that can be used to test and validate models of ocean biogeochemistry. A coupled three-dimensional general circulation, biogeochemical, and radiative model of the global oceans was validated using these in situ data sources and satellite data sets. Biogeochemical processes in the model were determined from the influences of circulation and turbulence dynamics, irradiance availability, and the interactions among four phytoplankton functional groups (diatoms, chlorophytes, cyanobacteria, and coccolithophores) and four nutrients (nitrate, ammonium, silica, and dissolved iron).

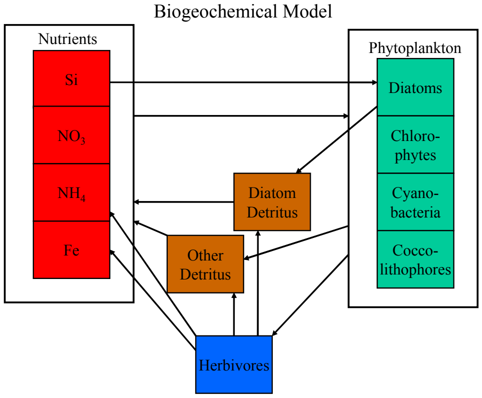
Annual mean **dissolved iron** concentrations in the model were positively correlated with observations ($P < 0.05$) over the 8 (out of 12) major oceanographic basins where data were available. Basin scale model **chlorophyll** seasonal distributions were statistically positively correlated with SeaWiFS chlorophyll in all 12 oceanographic basins ($P < 0.05$). The global mean difference was 3.9% (model higher than SeaWiFS).

While the overall patterns of **phytoplankton functional group** distributions exhibited broad qualitative agreement with in situ data, quantitative comparisons were mixed. Three of the four phytoplankton groups exhibited statistically significant correspondence across basins. Diatoms did not. Some basins exhibited excellent correspondence, while most showed moderate agreement, with two functional groups in disagreement with data and the other two in agreement. The results are encouraging for a first attempt at simulating functional groups in a global coupled three-dimensional model but many issues remain.

Global Coupled 3D Circulation, Biogeochemical, Radiative Model

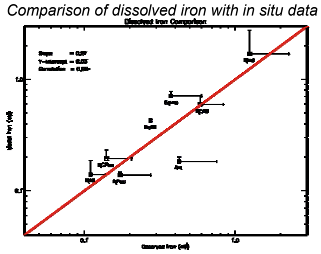


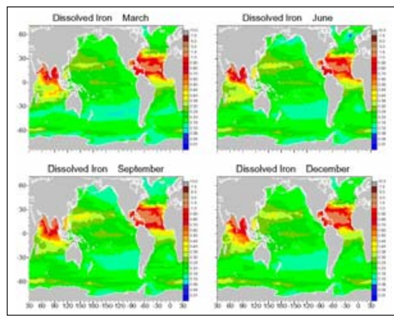
Biogeochemical Model



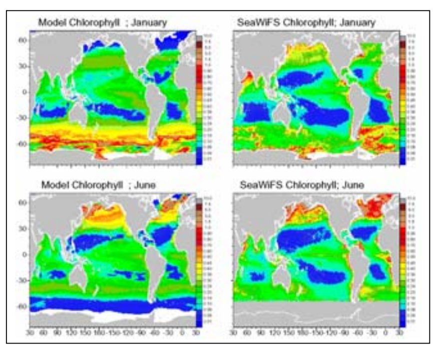
Results

Comparison of dissolved iron with in situ data





Initial conditions for dissolved iron concentrations were taken from Fung et al. (2000) and surface atmospheric fluxes were derived from Ginoux et al. (2001). Annual mean model log dissolved iron concentrations were positively correlated with observations ($P < 0.05$). Low concentrations were simulated in the North and North Central Pacific, North Atlantic, and Antarctic, and high values in the North and Equatorial Indian and the North Central Atlantic. Seasonal distributions of model dissolved iron concentrations show areas of high iron concentration are located near areas of high dust input. Low concentrations are apparent in the South Pacific central gyre region and the southern-most portions of the Antarctic.



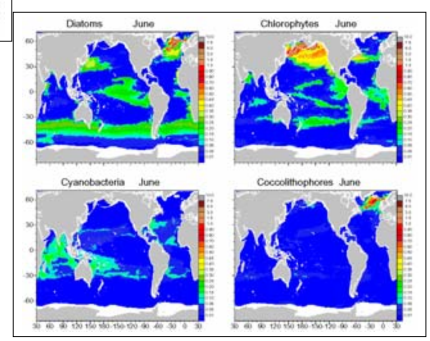
Comparison of chlorophyll with SeaWiFS

Imagery of simulated chlorophyll shows that generally, large-scale features are represented in the model and conform to SeaWiFS data: vast areas of low chlorophyll in the mid-ocean gyres, elevated chlorophyll in the equatorial and coastal upwelling regions, and large concentrations in the sub-polar regions. The large scale features of the seasonal variability are represented as well: blooms of chlorophyll in local spring/summer (June) in the high latitudes, followed by retreat in the local winter (January), expansion of low chlorophyll regions associated with the central gyres in local summer, followed by contraction in winter.

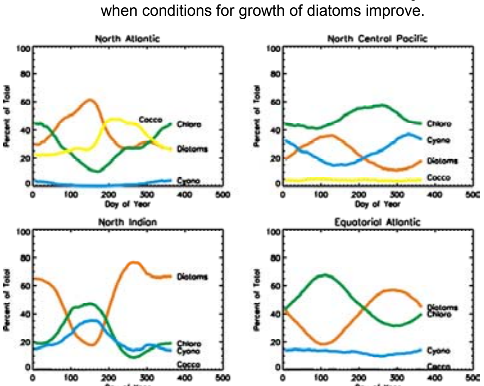
Correlation analysis shows that statistical significance is achieved seasonally between the model and SeaWiFS in every oceanographic basin ($P < 0.05$). The global annual mean difference between SeaWiFS and the model is 3.9%. The global mean root-mean-square difference (RMS) is 184%.

Phytoplankton group distributions

Phytoplankton group distributions were initialized as equal and homogeneous concentrations throughout the model domain both horizontally and vertically. In June after 26 years of simulation, the three phytoplankton functional groups arrived at distributions that generally conform to expectations: diatoms predominate high latitudes (except the North Pacific), coastal, and equatorial upwelling regions, cyanobacteria predominate the central ocean gyres, and chlorophytes and coccolithophores inhabit transitional regions. Coccolithophores are predominant in the North Atlantic south of Iceland in June. High abundances have been observed here in several observational studies. Diatom and coccolithophore abundances overlap in the North Atlantic, while diatoms predominate the Antarctic Ocean and southern sub-polar transition region. Chlorophytes predominate the North Pacific and the edges of the equatorial upwelling regions outside the area dominated by diatoms. Cyanobacteria are generally distributed throughout the central gyres at low concentrations, but have some larger abundances in the Equatorial and North Indian, western North Central Atlantic, and South Pacific. The predominance of cyanobacteria in the mid-ocean gyres is well established.



Seasonal variability of phytoplankton groups in 4 regions, chosen to be representative of the range of most conditions in the global oceans. The groups are shown as proportion of the total in percent. The North Atlantic exhibits a classic pattern of seasonal succession. Diatoms predominate early in the year as the mixed layer begins to shallow and light becomes readily available. They give way to dominance by coccolithophores in mid summer as the mixed layer stabilizes at shallow depth and nutrients become limiting. Chlorophytes reach a minimum at the diatom/coccolithophore dominance crossover, and increase late in the season matching and eventually exceeding coccolithophore relative abundances. Cyanobacteria provide a low and steady proportion of the total population, but increase slightly in the dead of boreal winter. This is due to their reduced losses from sinking relative to the others. Their concentrations diminish again when conditions for growth of diatoms improve.



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Ginoux, P., M. Chin, I. Tegen, J.M. Prospero, B. Holben, O. Dubovik, and S.-J. Lin, 2001. Sources and distributions of dust aerosols simulated with the GOCART model. J. Geophys. Res. 106, 20255-20273.