Modeling Coccolithophores in the Global Oceans

Watson W. Gregg
Global Modeling and Assimilation Office
NASA/Goddard Space Flight Center
Greenbelt, MD 20771
watson.gregg@nasa.gov

Nancy W. Casey
Science System and Applications, Inc.
Lanham, MD
nancy.casey@gsfc.nasa.gov

Deep-Sea Research II Special Issue
Submitted March, 2006

Abstract

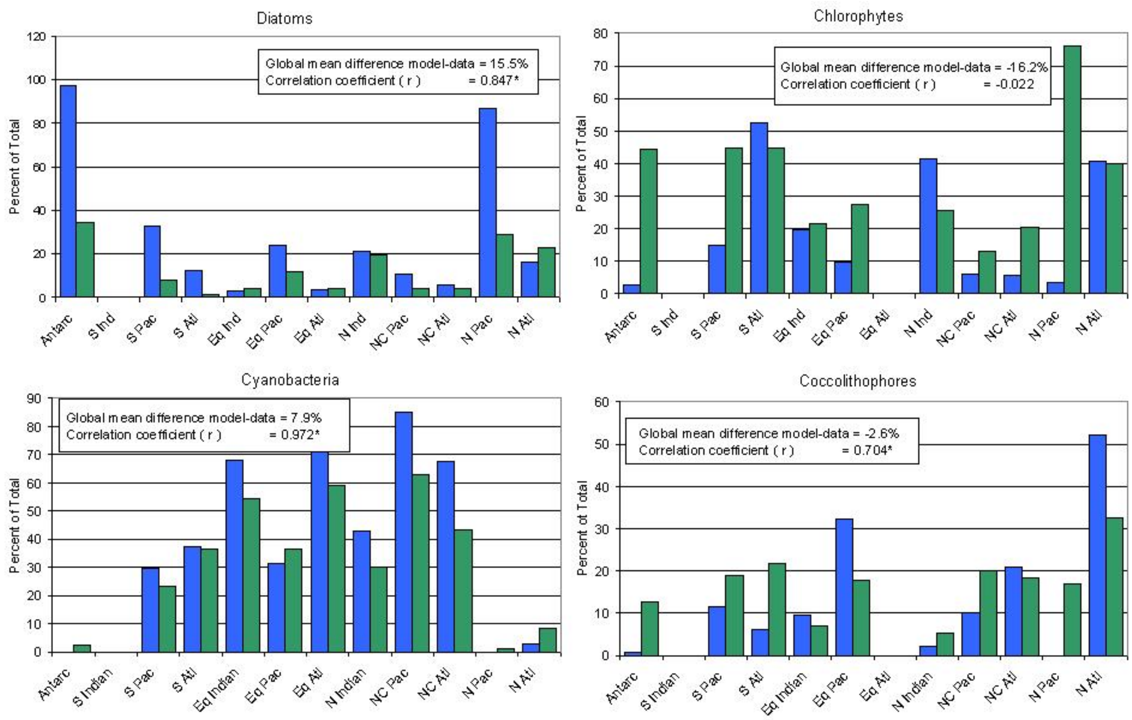
Coccolithophores are important ecological and geochemical components of the global oceans. A global three-dimensional model was used to simulate their distributions in a multiphytoplankton community context. The realism of the simulation was supported by comparisons of model surface nutrients and total chlorophyll to in situ and satellite observations. Nitrate, silica, and dissolved iron surface distributions were positively correlated with in situ data across major oceanographic basins. Global annual departures were +18.9% for nitrate (model high), +5.4% for silica, and +45.0% for iron. Total surface chlorophyll was also positively correlated with satellite and in situ data sets across major basins. Global annual departures were -8.0% with SeaWiFS (model low), +1.1% with Aqua, and -17.1% with in situ data. Global annual primary production estimates were within 1% and 9% of estimates derived from SeaWiFS and Aqua, respectively, using a common primary production algorithm.

Coccolithophore annual mean relative abundances were 2.6% lower than observations, but were positively correlated across basins. Two of the other three phytoplankton groups, diatoms and cyanobacteria, were also positively correlated with observations.

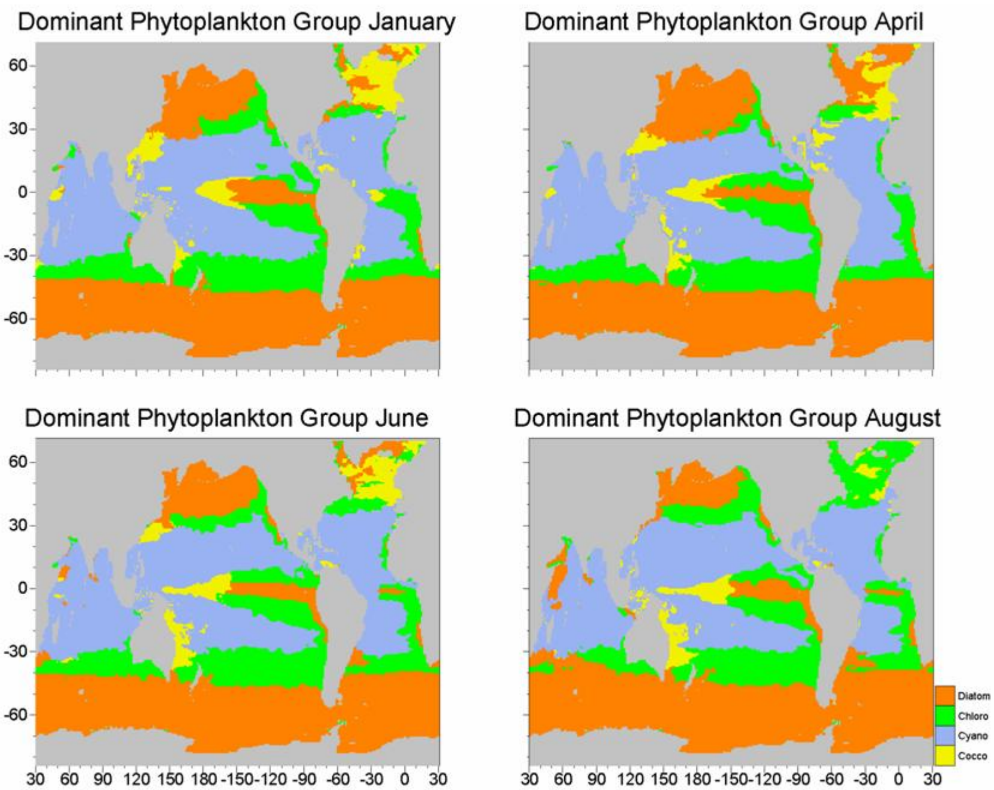
Distributions of coccolithophores were dependent upon interactions and competition with the other phytoplankton groups. In this model coccolithophores had a competitive advantage over diatoms and chlorophytes by virtue of a greater ability to utilize nutrient and light at low values. However, their reduced maximum growth rates and higher sinking rates placed them at a disadvantage when nutrients and light were plentiful. In very low nutrient conditions, such as the mid-ocean gyres, coccolithophores were unable to compete with the efficient nutrient utilization capability and low sinking rate of cyanobacteria, despite their higher maximum growth rates.

Comparisons of simulated coccolithophore distributions with satellite-derived estimates of calcite concentration and coccolithophore blooms showed some agreement, but also

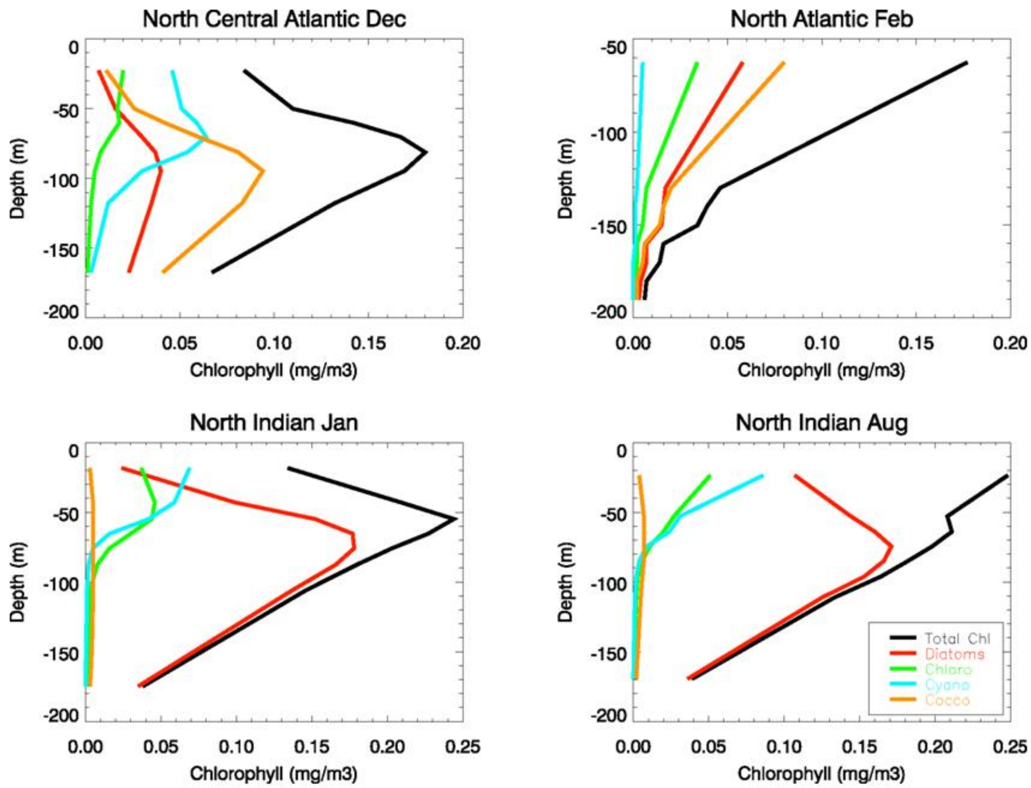
areas of departure. Most notably, coccolithophores were nearly absent in the model in the North Pacific, but calcite estimates suggested widespread abundance in summer. In situ observations supported their existence suggesting a deficiency in the model. On the other hand, vast blooms observed in the North Atlantic were well-represented by the model. Comparisons of phytoplankton groups with satellite estimates indicated good agreement of diatoms in one estimate, and poor agreement in general in another. Comparisons of phytoplankton group primary production with other models showed wide disparity. There was apparently little convergence at the present time among models and satellite estimates, which may be typical for an emerging field of research. The present effort represented a quantitative comparison with in situ observations, and although the results were encouraging, there were improvements needed. Disparities with other estimates, from both models and satellites, suggested that further intercomparison and research is important.



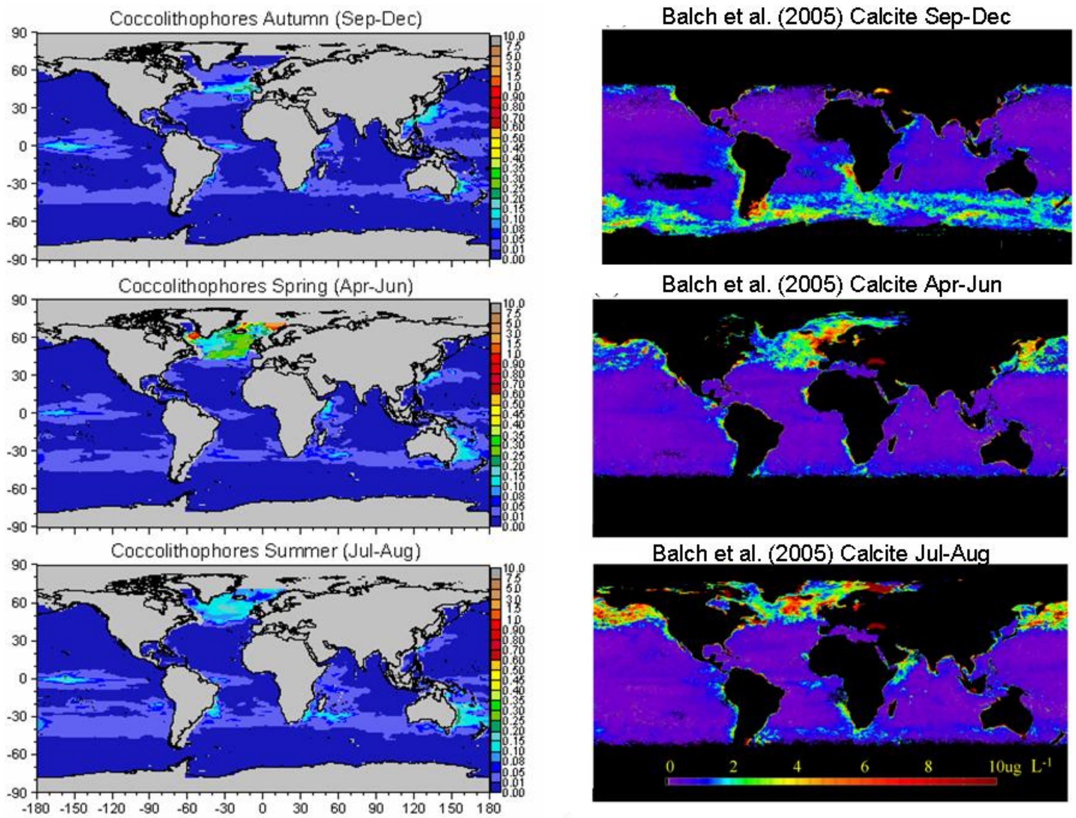
Relative abundances of phytoplankton groups and comparison with observations by basin (model is blue, data is green). Mean global differences and correlation coefficients between model and observations across basins are shown. An asterisk indicates the correlation is statistically significant at $P<0.05$. N=11 for diatoms and cyanobacteria correlations (all basins except South Indian). N=10 for coccolithophores and chlorophytes correlations (South Indian and Equatorial Atlantic had no data).



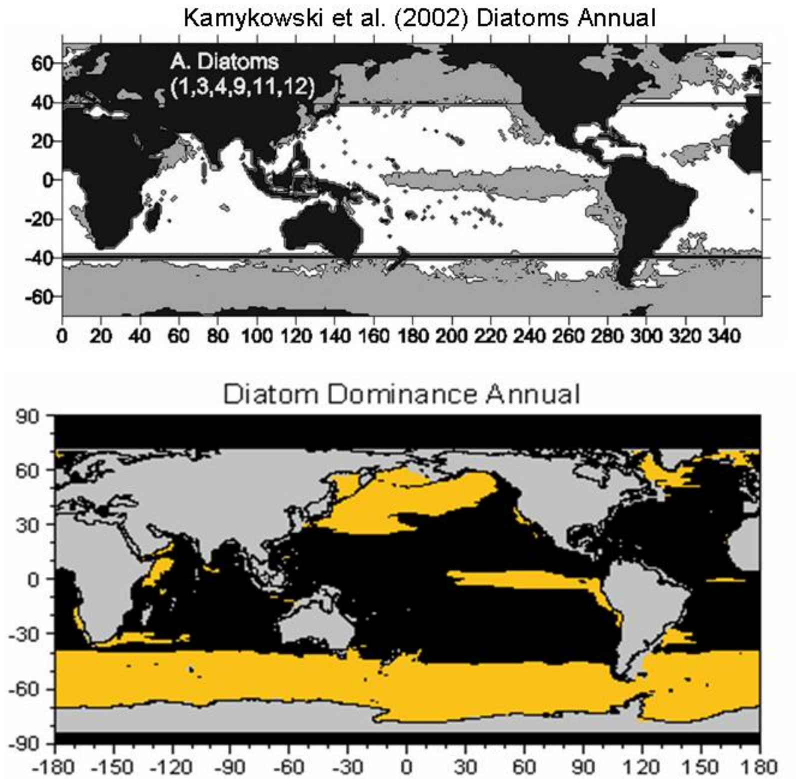
Dominant phytoplankton group in January, April, June and August.



Vertical distributions of total chlorophyll and phytoplankton groups in selected basins and seasons.



Comparison of coccolithophore distributions from NOBM (mg m^{-3}) and calcite concentrations from MODIS-Terra from Balch et al., (2005), with author's permission.



Comparison of annual diatom dominance distributions from ocean color and temperature satellites from Kamykowski et al., (2002; top), with author's permission, and NOBM (bottom).