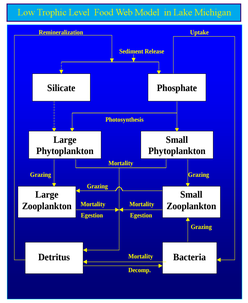
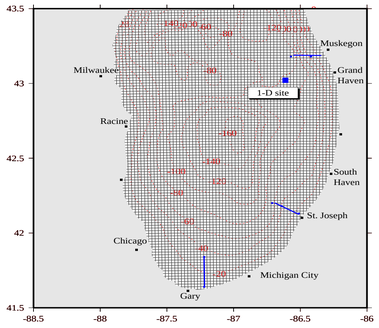
ABSTRACT

A lower trophic level food web model was developed based on the observed biological structures in Lake Michigan. This model was coupled into the Princeton Ocean Model (POM) and used to examine the impacts of physical forcing and suspended sediments on the lake ecosystem. Driven by observed meteorological forcings, the 1-D model reproduced the basic pattern of the seasonal variation of nutrients, phytoplankton, and zooplankton, detritus and bacteria over a two-year period of 1994-95. The model shows that the temporal and vertical distributions of biological variables had a close linkage to the seasonal development of stratification, formation and collapse of thermocline, and episodic wind mixing/cooling. The 3-D model experiments were focused on process studies of the impacts of suspended sediments on the lake ecosystem in early spring of 1998. Driven by real-time meteorological forcings and satellite-derived suspended sediment concentration, the model shows that the suspended sediments had a significant impacts on the spatial distribution and temporal variation of the plankton community by changing the light limitation and nutrients availability. The model-predicted cross-shelf distribution of Chlorophyll-a on selected sections were directly compared with water samples, satellite-derived pigments, and PSS data. Further comparisons are needed for the verification of the model results.

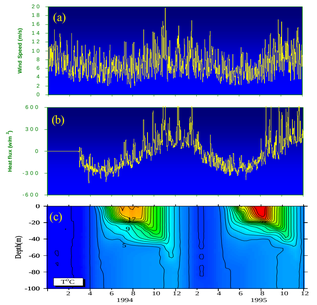


In the 1-D experiments, both phosphorus and silicate were considered as limiting nutrients. The 3-D experiments focused on the plume events in early spring of 1998. The silicate was excluded in the experiments because it was not a limiting nutrient during that period. Large and small phytoplankton mainly represented diatom and flagellates, respectively, while large and small zooplankton were copeped and cilicate/hetero-flagellates. A microbal food web was included to link with detritus, microzooplankton and nutrients. Phosphate released from sediments was included only for the 3-D experiments.

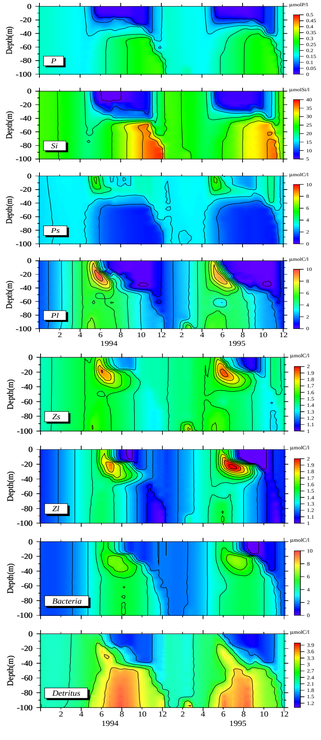


The model domain covered the entire area of Lake Michigan with a horizontal resolution of 2 km and 20 σ-levels in the vertical. Total grid numbers were 131x251. Three transects at Gary, St. Joseph, and Muskegon, where the interdisciplinary surveys were conducted, were selected for the model and data comparision. The 1-D experiments were carried out at the Grand Haven long-term monitoring station. Both 1-D and 3-D model experiments were driven by real-time wind and heat flux under the wintertime climatological initial condictions.

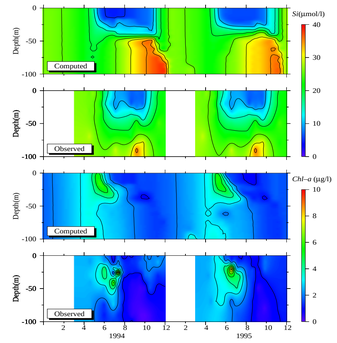
1-D EXPERIMENT



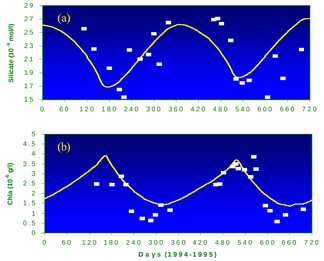
Time series of real-time wind speed (a), surface heat flux (b), and vertical distribution of model-predicted temperature (c) in 1994 through 1995 at the Grand Haven station. The wind and heat flux data were processed using a 40-h low-passed filter.



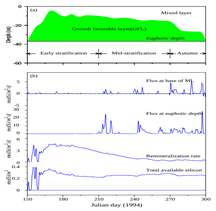
Time sequences of the vertical distributions of phosphate (*P*), silicate (*Si*), small phytoplankton (*Ps*), large phytoplankton (*Pl*), small zooplankton (*Zs*), large zooplankton (ZL), bacteria (B), and detritus (D) at the Grand Haven station in 1994 through 1995.



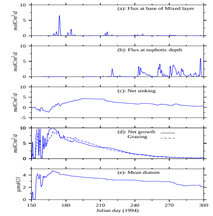
Comparisons between model-predicted and observed concentrations of the silicate (upper panel) and chlorophyll-a (lower panel) at the Grand Haven station in 1994 through 1995.



Comparison between model-predicted and observed concentrations of vertically-averaged silicate (a) and chlorophyll-*a* (b) in 1994 through 1995 respectively. Solid lines: model-predicted. Dots: observed.

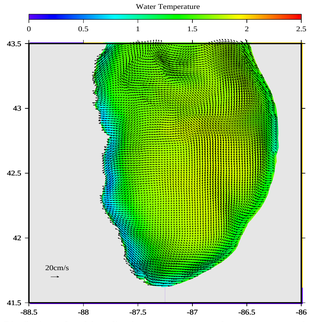


Evolution of the growth favroable layer (GFL), silicate fluxes at the base of the mixed layer and at the euphotic depth, nutrient remineralization rate from detritus, and total available silicate and phosphate in the GFL in spring of 1994.

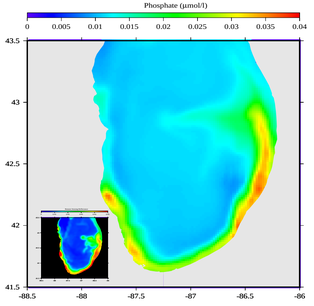


Evolution of the phytolankton flux at the base of the mixed layer and euphotic depth, net phytoplankton sinking, net growth and grazing of phytoplankton, and mean distribution of phytoplankton in the GFL in spring of 1994.

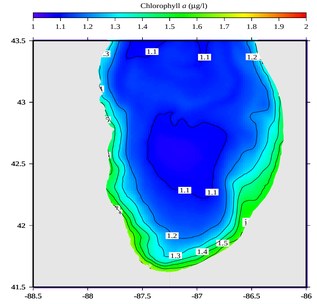
3-D EXPERIMENT



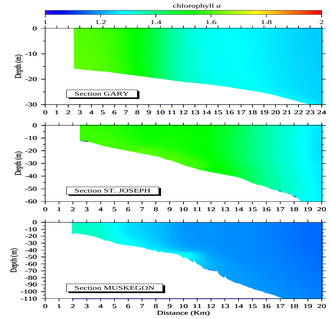
Distributions of model-predicted water temperatue and current vectors at the surface in southern Lake Michigan on March 15 1998.



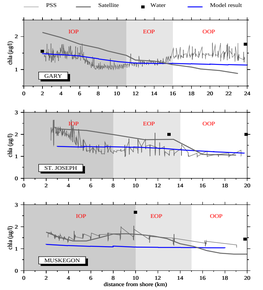
Distribution of the phosphate at the surface in southern Lake Michigan on March 15 1998. The image in the lower-left panel shows the distribution of remote sensing reflectance (RSR) on the same day.



Distribution of model-predicted chlorophyll-a in southern Lake Michigan on March 15 1998. The chl-a concentration was higher near the coast and lower in the interior, with a noticeable cross-shelf gradient at the edge of the plume. The cause of this was related to the ratio of euphotic depth to mixing depth as shown in the figure of *Deu*/*Dm*.

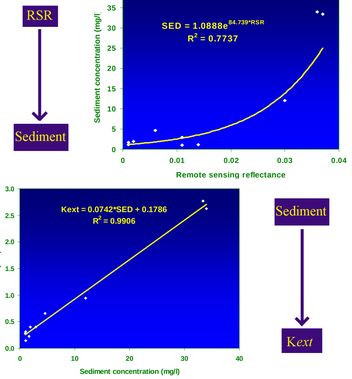


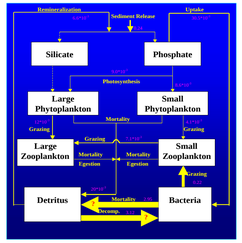
Vertical distributions of model-predicted chlorophyll-a on three selected transects at Gary, St. Joseph and Muskegon on March 15 1998. The chl-a concentration was vertically well mixed, which was consistent with cross-shelf distribution of temperature.



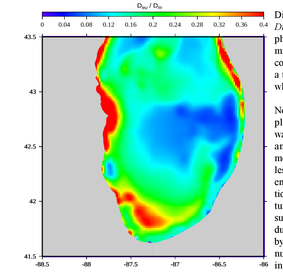
Comparison of model-predicted chlorophyll-*a* with water samples, PSS, and satellite-derived pigment measurements on three selected transects at Gary, St. Joseph, and Muskegon on March 15 1998.

Procedure of the conversion of the RSR to suspended sediment concentration and light attenuation coefficient





The daily-averaged fluxes of biological variables within the lower trophic level food web on March 15 1998. The calculation was conducted at a selected point on the St. Joseph transect. the importance of bacteria foold web can be shown from the large flux goes from bacteria to small zooplankton. Qustion mark here is uncertainty about the large flux goes between detritus and bacteria.



Distribution of the ratio *Deu*/*Dm*, where *Deu* is the euphotic depth and *Dm* is the mixing depth. A possible high concentration of chlorophyll-a tended to occur in the area where the ratio was large.

Note: During the springtime plume event, the turbidity was high in the coastal area and the euphotic depth in most of the coastal region was less than 50 cm. The existence of the high concentration of chlorophyll in high turbidity area near the coast suggests that primary production there was controlled by light intensity, available nutrients, and turbulent mixing.

SUMMARY

- The 1-D modeling experiments show that the vertical and seasonal distributions of biological variables in Lake Michigan were driven mainly by physical processes associated with seasonal development of stratification, formation and collapse of the thermocline, and wind mixing/cooling.
- The 3-D modeling experiments suggest that the suspended sediment in the reflective, recurrent coastal plume had a significant impact on the spatial distribution and temporal variation of the plankton in Lake Michigan. The significant difference of plankton community structures inside and outside the plume was directly associated with light limitation, nutrient availability, and turbulent mixing.
- Both 1-D and 3-D model results have captured the basic patterns of the ecosystem in Lake Michigan. More field data are needed to quantify the importance of the microbal food web to the food web balance in Lake Michigan, especially during plume events in spring

Papers in Preparation:

C. Chen, R. Ji, M. Jiang, D. J. Schwab, D. Beletsky, T. Johengen, and G. L. Fahnenstiel. A Coupled Biological and Physical Model of Lake Michigan: 1-D Experiments.

Ji, R., C. Chen, D. Schwab, J. Budd, and D. Beletsky. Influences of Suspended Sediments on the Ecosystem in Lake Michigan: A 3-D Coupled Bio-Physical Modeling Experiment.

The PDF file of this poster and animation can be viewed at the web site: http://whale3.marsci.uga.edu/research_projects.

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