Carbon Cycling in Lake Superior:
Observations, Models and Impacts on the Regional Carbon Balance
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Introduction
Lake Superior is the largest freshwater lake in the world and carries 5% of the world’s surface freshwater. Similar to an ocean this lake has long residence times (175 yrs) and has circulation patterns mostly dictated by wind stress. Lake Superior also possesses qualities that are specific to lakes: it mixes to the bottom each year and unlike gyres of the ocean it has variable currents and horizontal circulation is driven by short term winds.

Internal carbon cycle in Lake Superior is believed to be greater than external inputs and it is tightly coupled by physical processes.

Our objective is to use modeling approach to estimate the carbon budget of Lake Superior and its possible impacts in the regional carbon budget.

Because there is very little known about lake superior carbon cycle mainly due to its long and harsh winters and availability of limited data from spring and summer months, we are using modeling approach to estimate processes that dictate carbon budget in the lake and determine whether it is a sink or source of carbon into the atmosphere.

Model Development
- Physical Model
  - MITgcm configured to Lake Superior bathymetry
  - Forced with interpolated meteorological data for 2006 (Schwab and Seiler, 1996)
  - Horizontal resolution: 10 km and 2 km
  - 2 km to better predict nearshore processes
  - ~29 vertical levels; top 10 layers 5m thick
  - Mixing scheme: KPP(V), Smagorinsky(H)
  - Ice Mask

- Biogeochemical Model
  - Ecosystem Model includes two phytoplankton groups (Dulskiwicz et al., 2005)
  - Lake Superior is mainly phosphorus limited.
  - Phosphorus is used as primary currency
  - Silicic acid is not limiting
  - Fixed ratios are used to connect P, O₂ and C
  - Working with 10km resolution

Preliminary Results
Satellite SST and predicted SST are in good agreement. Model successfully captures thermal bar development in June and highest temperatures are observed in August with a cool down starting in October.

Chlorophyll (ug/L) observed vs. Model Predictions
In comparison to observed data, model under predicts chlorophyll values lake wide in April. In coastal waters the chlorophyll values are higher than observed data. In general model prediction is not as uniform as the observed data suggest.

Model does a better job of predicting chlorophyll in August. Values are generally in good agreement with some spatial differences. Model over predicts chlorophyll in southeastern part of the lake and under predicts northwestern part of the lake. Near Nipigon river chlorophyll levels are similarly high but model shows more geographically confined patterns

Phosphorus and Chlorophyll interactions
Model predictions suggest that stratification and phosphorus limitation dictate duration and strength of the phytoplankton blooms. In summer months (August shown here) usually a deep chlorophyll maximum develops. The predicted amount and depth of this deep chlorophyll maximum is similar to that of the published work (Barbiero and Tuchman, 2004).

Questions/Future Directions
- Currently we are developing a better understanding of the factors that influence the pCO₂ in the lake and working to improve both chlorophyll and pCO₂ predictions. We are investigating the role of DOC in the lake and if and how it affects pCO₂ concentrations.
- Determine the parameters that need to be added and/or adjusted to make the ecosystem model work better.
- Understand and implementallocations in the lake.
- To better understand how much the carbon cycle is influenced by interannual variability.
- Working towards our goal to estimate the impact of Lake Superior in the regional carbon budget.

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