Field And Numerical Investigation of High Frequency Temperature Profiles in Lakes

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Measured temperature profile in Lake Maxinkuckee, Culver, Indiana
Measured temperature in Lake Michigan (Beletsky et al, 2001)
Research goals
Study the effect of intermittent wind events on the thermal structure in large lakes

Imboden and Wuest (1995)
Research goals
Study the seasonal evolution of thermal structure in large lakes

Image source: Dr. John R. Schott
Research goals
Study its effect on transport processes in large lakes

Thermal bar formation

Image source: Dr. John R. Schott

March 28-April 14, 1972
180 m offshore, 3 m depth:
1.7 C --> 5.9 C
7.4 km offshore, 33 m depth: 0.8 C --> 1.4 C
(Mortimer 2004)
Research goals

Study the generation of internal waves and their role in mixing

Temperature at 10 m depth on day 0.0 with a resolution of 1.25 km
Whiting phenomenon: Calcium Carbonate Precipitation
Reason: Lake bottom is made of limestone
Solubility: At the end of summer, solubility is low.
http://earthobservatory.nasa.gov/
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Aquatic invasive species (AIS)

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

http://www.glerl.noaa.gov/res/Programs/ais/
http://massbay.mit.edu/exoticspecies/ballast/index.html
Zebra mussels
## Economic Impacts of AIS in Great Lakes

<table>
<thead>
<tr>
<th>Species</th>
<th>Estimated Loss (US $s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea lamprey</td>
<td>13.5 million annually</td>
</tr>
<tr>
<td>Zebra mussels</td>
<td>6.5 billion over 10 years</td>
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</tbody>
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(Lovell et al. 2006)
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- Stanford Unstructured Nonhydrostatic Terrain Following Adaptive Navier-Stokes Simulator
- Grid elements (horizontal plane): Triangular
- Vertical grid elements: Prisms
- Parallel implementation using MPI and C
Cases considered for validation

- Cases considered (Beletsky et al, 1997):
  1. Circular Lake with parabolic bathymetry
     Grid Resolutions used:
     0.50 km, 1.25 km, 2.50 km, 5.00 km, variable resolution (50 m to 2.00 km resolution)
  2. Circular Lake with flatbottom
     Grid Resolutions used:
     1.25 km
  3. Lake Michigan
     Grid Resolutions used: 50m to 2500m (growth rate 1.25), 1 km, 2.5 km & 5.0 km
Atmospheric forcing & initial temperature distribution

- Meteorological forcing:
  Wind stress: 0-0.01/0.3 N/m² (18 hrs), 0.01/0.3 N/m² (18-23 hrs), 0.01/0.3-0 N/m² (23-29 hrs), 0 N/m² (29+ hrs)
  Wind characteristics: Northerly, Spatially uniform
- Heat Flux: None
Results (temperature) for dt= 50s, 75s, 100s, 150s, 200s, 250s
Case: Paraboloid bathymetry high wind stress
Resolution: 1.25km

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Temperature at 10 m depth Case: Paraboloid-high windstress
Thermal stratification after 1.2 days of mixing
Resolution: 50 m to 2 km @ 1.25 dt=30 s

Thermal stratification after 5 days of mixing
Resolution: 50 m to 2 km @ 1.25 dt=30 s
Thermal stratification after 10 days of mixing
Resolution: 50 m to 2 km @ 1.25 dt=30 s

Thermal stratification after 15 days of mixing
Resolution: 50 m to 2 km @ 1.25 dt=30 s
References

- Jachec, S. M., 2007, Understanding the evolution and energetics of internal tides within Monterey Bay via numerical simulations, PhD thesis.