Hydrodynamic Model of Missisquoi Bay
What it can tell us about lake stratification and residence time of the bay

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Background

- Phosphorus in warm waters can create ideal conditions for algal bloom formation.
- High Phosphorus levels have been continuously present in Missisquoi Bay (Figure 1).
- We want to study how the physics of Missisquoi Bay can affect algal bloom formations.
- Lake Residence Time: Average time that water is retained in the defined boundaries of the lake.
- Lake Stratification: When water separates into layers based on water temperature and density. The cold water is more dense and sits on the bottom of the lake, while the warm water has a lighter density and remains at the surface.

Methods

- 3D simulation of Missisquoi Bay was created using SUNTANS (Stanford Unstructured Non-Hydrostatic Terrain Following Adaptive Navier Stokes Simulation).
- SUN TANS was modified for four different Missisquoi Bay simulations and run for a two week period in late August to early September.

Table 1. Simulation Parameters

<table>
<thead>
<tr>
<th>Simulation</th>
<th>Causeway Opening</th>
<th>River width</th>
<th>River Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>300m</td>
<td>100m</td>
<td>4.25 m³/s</td>
</tr>
<tr>
<td>No Causeway</td>
<td>1300m</td>
<td>100m</td>
<td>4.25 m³/s</td>
</tr>
<tr>
<td>High River Flow</td>
<td>300m</td>
<td>100m</td>
<td>28.3 m³/s</td>
</tr>
<tr>
<td>Wide River</td>
<td>300m</td>
<td>500m</td>
<td>4.25 m³/s</td>
</tr>
</tbody>
</table>

Conclusions

1. The water level at the causeway controls the water velocities of Missisquoi Bay.
- An overall study on water movement in Lake Champlain needs to be done.
2. Stratification varies spatially in the bay and is dependent upon heat flux and water velocity (Figure 5).
- Temperature and Velocity Profiles can display how daily trends differ between points and simulations (Figures 3-4).
3. Water residence time in the south half of the bay is shorter than the north half of the bay (Table 2).
4. Bottom velocities near the river are dependent upon the relative temperatures of the bay and river (Figures 3-4).
- Implications for sediment re-suspension and transport.
5. The model velocity output was within the same magnitude of the actual velocity, validating our model.

Acknowledgements

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References


Table 2. Residence Time for each Simulation in weeks.

<table>
<thead>
<tr>
<th>Simulation</th>
<th>Mean</th>
<th>Surface Layer</th>
<th>Bottom Layer</th>
<th>North Half</th>
<th>South Half</th>
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<tr>
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<td>18</td>
<td>24</td>
<td>300</td>
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<td>23</td>
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<td>9.5</td>
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<td>11</td>
<td>13</td>
<td>100</td>
<td>5.4</td>
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<tr>
<td>Wide River</td>
<td>22</td>
<td>19</td>
<td>25</td>
<td>300</td>
<td>10</td>
</tr>
</tbody>
</table>

Figure 1. Historic Phosphorus levels in Missisquoi Bay from 1990 to 2011, with target concentration indicated by black line.

Figure 2. Grid layout and points of data analysis.

Figure 3. Temperature Profiles at Different Locations of the Bay for the example day.

Figure 4. Velocity Profiles at different locations of the bay for the example day.

Figure 5. Original Bay wind speed, heat flux in comparison to temperature changes at Point 1 and Point 3.

Figure 6. Grid of Simulation.