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Simulating the Dispersal of Invasive Clams in a Freshwater Lake Using a Three-Dimensional Hydrodynamic Model; a prototype for Simulating Invasions in Marine Ecosystems

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Simulating the Dispersal of Invasive Clams in a Freshwater Lake Using a Three-Dimensional Hydrodynamic Model

A Prototype for Simulating Invasions in Marine Ecosystems

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Abstract

The discovery of several populations of an invasive Asian clam (corbicula fluminea) in Lake Whatcom, the drinking water source for approximately 100,000 people in Northern Washington State, created a need among elected officials, local government staff, and the public for a better understanding of lake hydrodynamics during the reproductive season for the Asian clam, and for times when Quagga and Zebra mussel invasions are likely. Seasonal vertical thermal stratification of the lake and a desire to predict likely locations of additional clam populations or of new populations of mussels led to the choice of a model that could be configured for three-dimensional hydrodynamic analysis to predict likely trajectories of larvae after spawning. The General Estuarine Transport Model (GETM) was chosen. GETM is a standard model widely used for near-shore oceanographic modelling where stratification and steep bottom topography are similar to the physical conditions in Lake Whatcom.

Setting

Lake Whatcom, which discharges to Bellingham Bay in the Salish Sea, is a deep freshwater lake in the Cascade foothills of Northwestern Washington State. In 1998, Lake Whatcom was listed as an impaired water body for dissolved oxygen, phosphorous and fecal coliform by the Washington Department of Ecology and a Total Maximum Daily Load (TMDL) study was initiated in 2001. In September 2011 the presence of the mollusk Corbicula fluminea, commonly called Asian clam was identified in Lake Whatcom. Based on the size of clams the City of Bellingham concluded that the clams have likely been present in the lake for several years. Preliminary surveys were conducted and areas of clam infestation were identified.

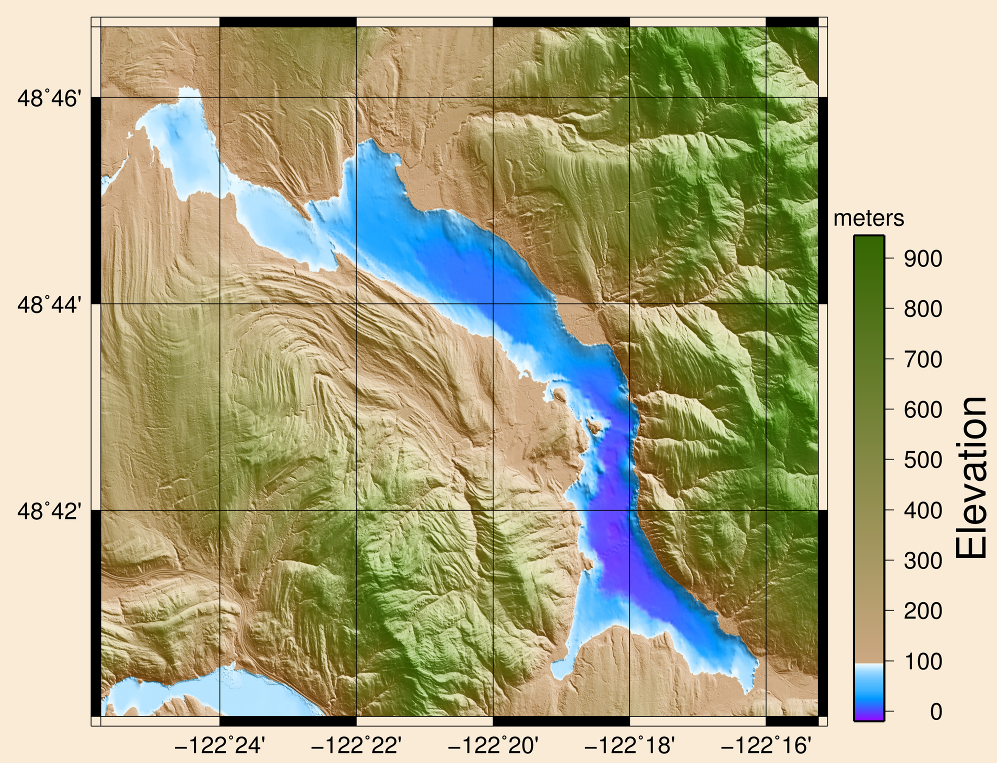

Figure 1: Lake Whatcom

Methods

Three computational grids were constructed in GETM, each for a specific modeling task. For modeling for the purpose of tracking, analysis, and visualization of clam larvae dispersion, soundings data were transferred to a 185-by-599 cell horizontal grid of 25 meter-square cells. For this task, depths were divided into 21 regularly-spaced terrain-following (σ-coordinate) vertical layers.

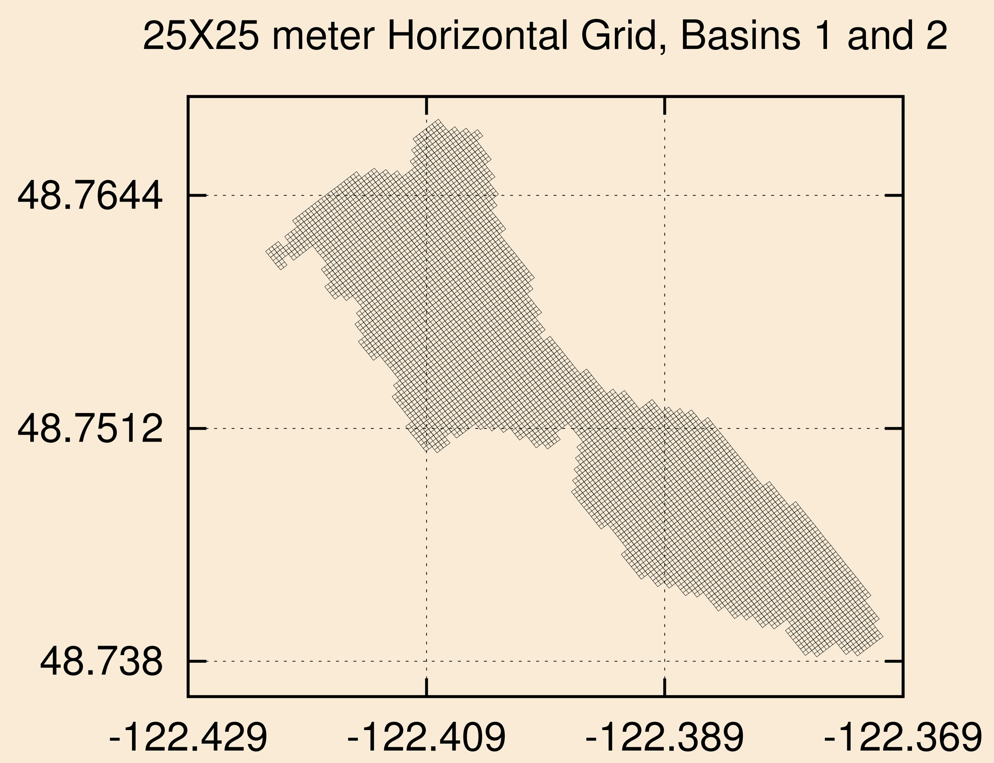

Figure 2: Horizontal Grid Size - Upper Lake

A similar 93-by-300 cell grid, but with 50 meter-square horizontal cells and 11 vertical layers was constructed for analyzing and visualizing the role of wind stress as a cause of inter-basin water exchanges. This grid was also transferred from the 39-degree rotated soundings. Wind data was collected from stations placed on privately owned docks on the lake.

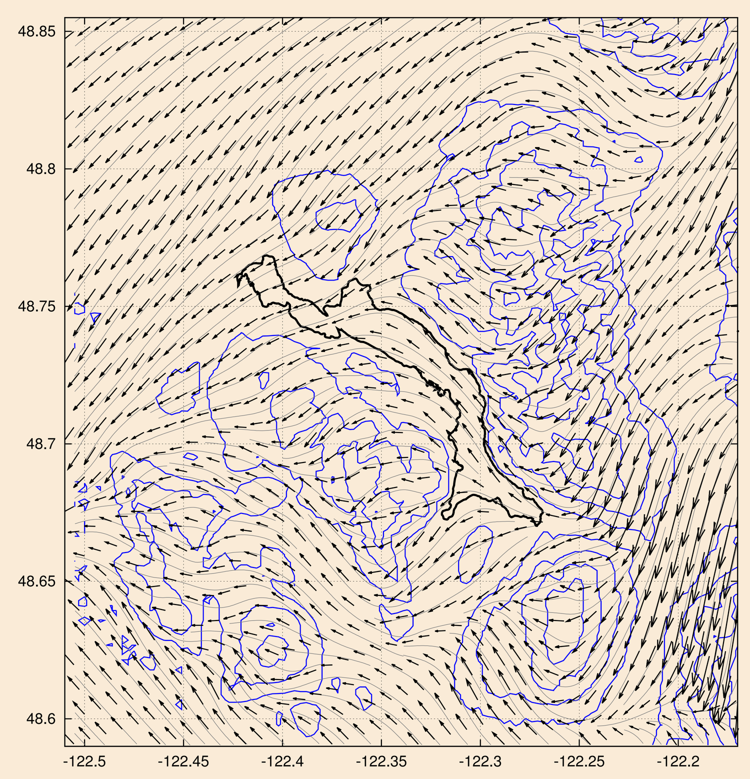

Figure 3: Local airflow patterns from regional easterly wind.

A third 125-by-150 dimension grid with 200 meter-square cells was constructed from 30-meter resolution SRTM1 (Space Shuttle Radar) terrain elevation data of the region surrounding Lake Whatcom. These gridded elevation data were also divided into 21 vertical layers. This topographic elevation grid was used in a novel approach to derive wind area-wide stress boundary conditions for the lake surface from wind speed and direction data measured at a single point on the lake.

Results

For clam larvae dispersion simulations corresponding to the assumption that most of larvae are released in a short period of time, a passive tracer was inserted into the water at model cells corresponding to seven locations where clams had been found and one location where the possibility exists of future clam infestation.

Initial tracer concentration was calculated so that a total of 1,000,000 units of tracer were released at each location using horizontal cell area and depth. By measuring subsequent tracer concentrations, it was possible to characterize the transport and fate of 1,000,000 hypothetical clam larvae both graphically and mathematically.

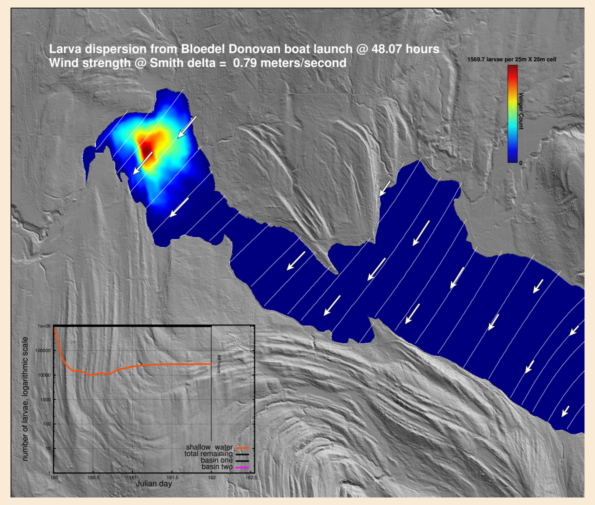

Figure 4: Larval dispersion from boat launch at 48.07 hours

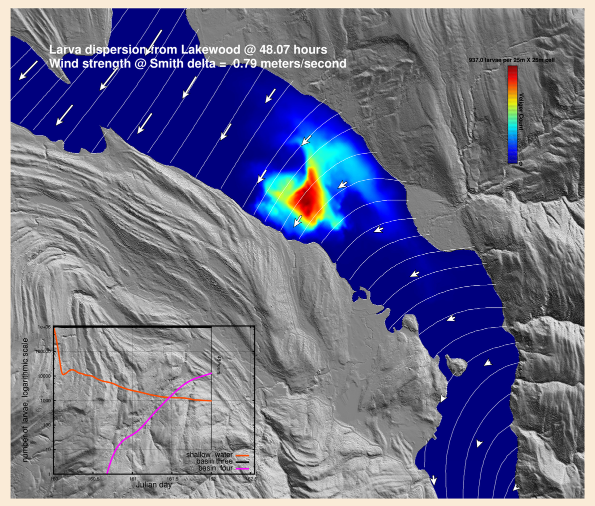

Figure 5: Larval dispersion mid-lake at 48.07 hours

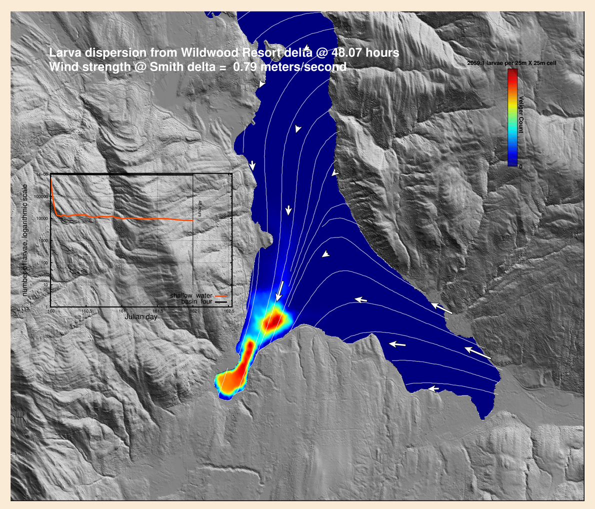

Figure 6: Larval dispersion southern lake at 48.07 hours

Future Research

Because application of this work to an estuarine environment would be straightforward–requiring the specification of open boundaries, the input of tidal elevations at open boundaries, and salinity profiles–it serves as a platform for similar studies of invasive species in the Salish Sea.

The Stanford unstructured-grid nonhydrostatic parallel coastal ocean model (SUNTANS) is being considered for this future work.

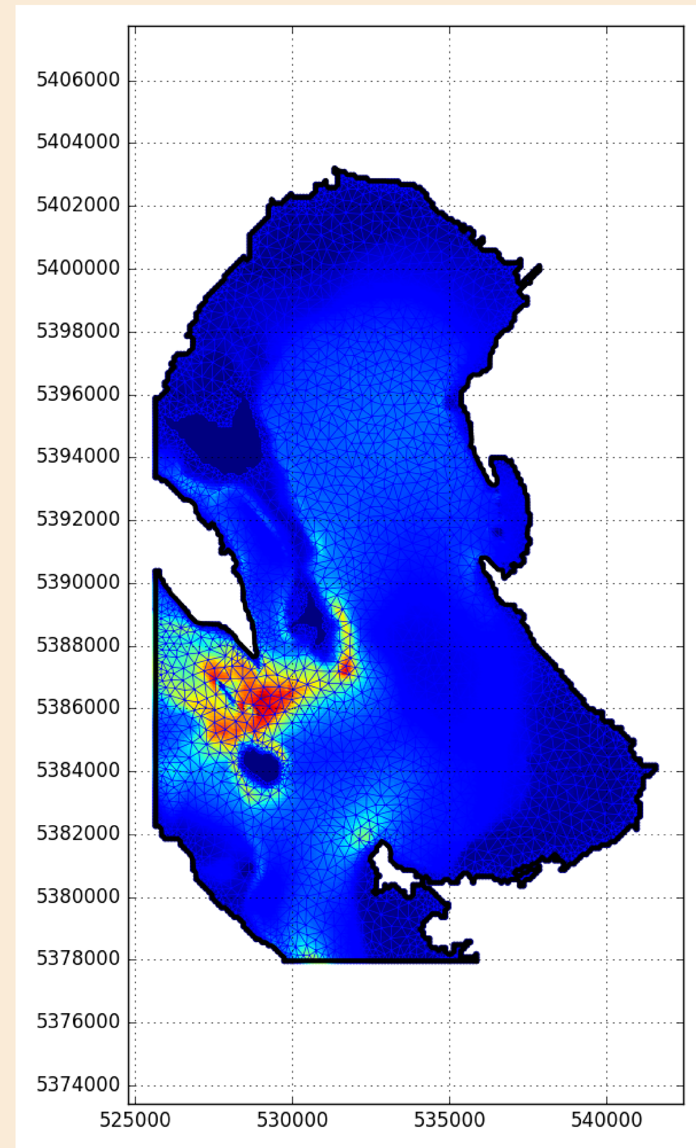

Figure 7: SUNTANS Bellingham Bay grid.

References

[1] H. Burchard and L. Bolding. General estuarine transport model, source code and test case documentation. *http://www.getm.eu*, 2012.

[2] Gerritsen M. Fringer, O. B and R. L. Street. An unstructured grid, finite-volume, nonhydrostatic, parallel coastal ocean simulator. *Ocean Modeling*, 14(3-4)(52):139–278, 2006.

Acknowledgements

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