Hydrodynamics of Lake Victoria: Vertically Integrated Flow Models in COMSOL Multiphysics® Software

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Abstract

Lake Victoria is the largest tropical lake in the world and is very important for environment and economy in East Africa. The hydrodynamic processes in the shallow (40-80 m deep) water system are unique due to its location at the equator which makes Coriolis effects noticeable also for vertical transport. The limited river inflow, and the large surface area compared to its volume make Lake Victoria vulnerable to climate changes. A model of the circulation patterns, mixing, dispersion and stratification will be necessary to devise strategies for management of the natural resources. The goal of this project is to improved water quality of Lake Victoria.
COMSOL Multiphysics® software supports models for the different processes to be included, and we are developing interfaces used by the geo-hydrodynamical community, such as the Digital Elevation Map (DEM) file format. However, much data remains to collect and coordinate before the goal is reached. It turns out that modern depth soundings covering the whole lake may not be available so scarce and old data have to be used initially. To assess the data collected, a modeling approach can be employed. Data for river in- and outflow as well as evaporation and rainfall have been collected for many years and can be correlated with data series for lake water levels in the simulation model.
As a first step we have built a vertically integrated St. Venant shallow water model to look at the effects of bottom topography on large-scale flow patterns and the water level variation. The COMSOL® coefficient form PDE represents streamline artificial viscosity, Coriolis forces, and bottom friction, with boundary conditions representing river in- and outflow. The topography model must have continuous gradients, and a combination of Kriging with Delaunay triangulation is used to produce the surface model. Results of the long-time simulations will be presented as well as numerical experiments with other approximate flow models to represent the moving water surface.

Reference

1. Project Report, LVBC (2008). Lake Victoria Basin Comission
2. G. Ji. Z, Hydrodynamics and water quality. Modeling rivers, lakes and estuaries. Book, John Wiley & Sons, Inc.
3. Y. Song, A coupled regional climate model for the Lake Victoria Basin of East Africa, International Journal of Climatology, 24, 57 - 75 (2004). Fredrick H.M. Semazzi, Lian Xie and Laban J. Ogallo

Figures used in the abstract

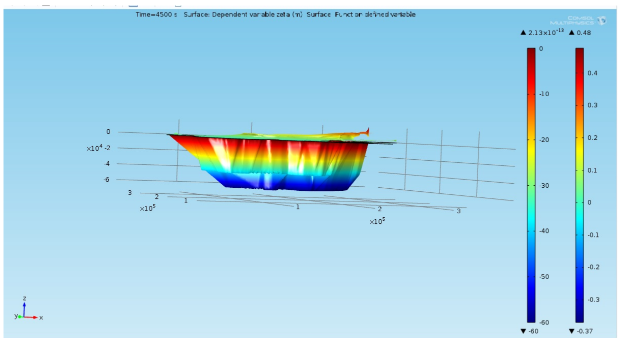

Figure 1: Lake victoria depth model by Delaunay triangulation.

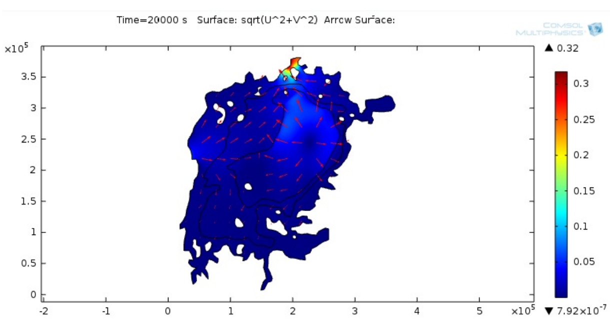

Figure 2: Average anual flows with bathymetry.

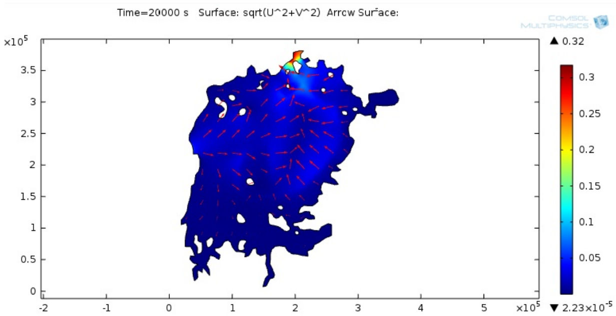

Figure 3: Average anual flows without bathymetry.

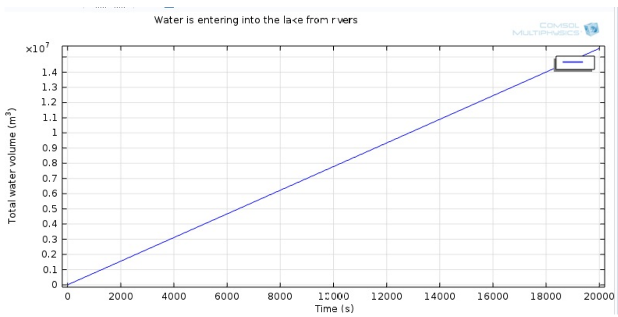

Figure 4: Water is entering into the lake from river basins.