# Investigation of Temperature Dynamics in Shallow Lakes Using Three-dimensional CFD Model

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**Key words:** Three-dimensional hydrothermal model, Shallow lake, OpenFOAM

## Abstract

Inland water bodies such as lakes and reservoirs are very important parts of the continental land surface. In the management and operation of lakes and reservoirs, analysing and predicting the mixing characteristics and temperature profile are required. Temperature is very important parameter in water bodies. The changes in water temperature can have a profound effect in heat storage of lakes and water quality as well. In addition, shallow lakes and reservoirs response to atmospheric conditions very fast.

In this study, a three-dimensional time-dependent hydrodynamic and heat transfer model of Lake Binaba(Figure 1), a shallow and small dam reservoir in Ghana, emphasizing the simulation of dynamics and thermal structure has been developed. Most numerical studies of temperature dynamics in reservoirs are based on one- or two-dimensional models. These models are not applicable for reservoirs characterized with complex flow pattern and unsteady heat exchange between the atmosphere and water surface. Continuity, momentum and temperature transport equations have been solved. Proper assignment of boundary conditions, especially surface heat fluxes, has been found crucial in simulating the lakes hydrothermal dynamics. This model is based on the Reynolds Average Navier-Stokes equations, using a Boussinesq approach, with a realizable $k-\varepsilon$ turbulence closure to solve the flow field. The thermal model includes a heat source term, which takes into account the short wave radiation and also heat convection at the free surface, which is function of air temperatures, wind velocity and stability conditions of atmospheric boundary layer over the water surface. The governing equations of the model have been solved by OpenFOAM; an open source, freely available CFD toolbox. As its core, OpenFOAM has a set of efficient C++ modules that are used to build solvers. It uses collocated, polyhedral numerics that can be applied on unstructured meshes and can be easily extended to run in parallel. A new solver has been developed to solve the hydrothermal model of lake. In addition, the boundary condition(Figure 2) over water surface were improved to include the real conditions of atmosphere in the model. Simulated and measured temperature profiles in the probe locations show reasonable agreement. The model might be able to predict the circulation patterns as well as the temperature distribution in the water body. The simulated temperature profiles could be used to compute total heat storage of small shallow lakes and reservoirs in order to estimate evaporation from water surface.

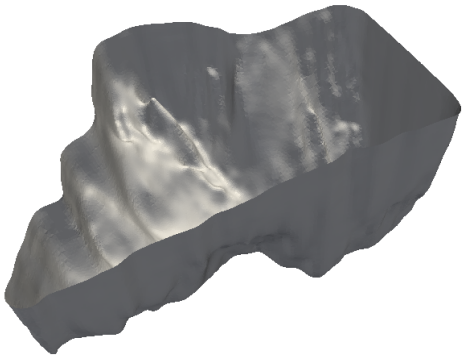

*Figure 1:* Bathymetry of Lake Binaba(Not to scale)

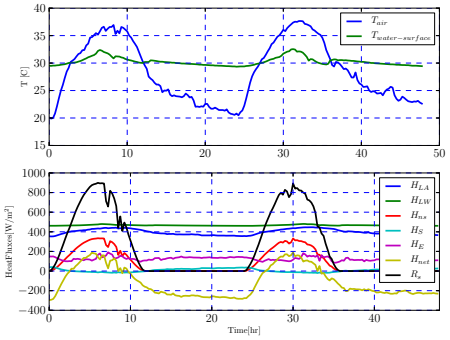


*Figure 2:* Time-dependent bounday conditions over water surface

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