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FLake – A Lake Parameterisation Scheme for Numerical Weather Prediction and Climate Models

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Abstract

A lake model intended for use as a lake parameterization scheme in numerical weather prediction (NWP), climate modelling and other environmental applications is presented. The model, termed FLake (http://lakemodel.net)[2], is capable of predicting the vertical temperature structure and mixing conditions in lakes of various depth on the time scales from a few hours to many years. It is based on a two-layer parametric representation of the evolving temperature profile and on the integral budget of energy for the layers in question. The structure of the stratified layer between the upper mixed layer and the basin bottom, the lake thermocline, is described using the concept of self-similarity (assumed shape) of the temperature-depth curve. The same concept is used to describe the temperature structure of the thermally active upper layer of bottom sediments and of the ice and snow cover. An entrainment equation is used to compute the depth of a convectively-mixed layer. A relaxation-type equation is used to compute the wind-mixed layer depth in stable and neutral stratification, where a multi-limit formulation for the equilibrium mixed-layer depth accounts for the effects of the earth's rotation, of the surface buoyancy flux, and of the static stability in the thermocline. Both mixing regimes are treated with due regard for the volumetric character of solar radiation heating. Simple thermodynamic arguments are invoked to develop the evolution equations for the ice and snow depths. In this way, the problem of solving partial differential equations (in depth and time) for the temperature and turbulence quantities is reduced to solving ordinary differential equations for the time-dependent parameters that specify the evolving temperature profile. The result is a computationally efficient bulk model that incorporates much of the essential physics.

Empirical constants and parameters of the proposed model are estimated, using independent empirical and numerical data. Importantly, they should not be re-evaluated when the model is applied to a particular lake. The only lake-specific parameters are the lake depth, the optical characteristics of lake water, the temperature at the bottom of the thermally active layer of bottom sediments, and the depth of this layer. These external parameters are not part of the model physics, however. In this way, the model does not require re-tuning, a procedure that may improve an agreement with a limited amount of data but should generally be avoided as it greatly reduces the predictive capacity of a physical model.

FLake is favourably tested against observational data through single-column numerical experiments. As a lake parameterization scheme, FLake is implemented, or on the way, into a number of NWP and climate models. Details of the implementation of FLake into the limited-area NWP model COSMO are outlined. First results from a numerical experiment with the coupled COSMO-FLake system, including the complete COSMO-model data assimilation cycle, are presented. Some challenging issues are briefly discussed.

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[2] Also http://nwpi.krc.karelia.ru/flake.