A Lake Model for Use in Numerical Weather Prediction Systems

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A lake model intended for use in NWP systems (also in climate modelling and other numerical prediction systems for environmental applications) is developed (Mironov 2003). The model is capable of predicting the surface temperature in lakes of various depth on time scales from a few hours to a year. It is based on a two-layer parametric representation of the temperature profile, where the structure of the lake thermocline is described using the concept of self-similarity (assumed shape) of the evolving temperature profile (Kitaigorodskii and Miropolsky 1970). 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. The proposed lake model incorporates (i) a flexible parameterisation of the temperature profile in the thermocline, (ii) an advanced formulation to compute the mixed-layer depth, including the equation of convective entrainment and a relaxation-type equation for the depth of a wind-mixed layer, (iii) a module to describe the vertical temperature structure of the thermally active layer of bottom sediments and the interaction of the water column with bottom sediments, and (iv) an advanced snow-ice module. Empirical constants and parameters of the proposed model are estimated, using independent empirical and numerical data. They should not be re-evaluated when the model is applied to a particular lake. 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.

In order to compute fluxes of momentum and of sensible and latent heat at the lake surface, a parameterization scheme is developed that accounts for specific features of the surface layer over lakes. The scheme incorporates (i) a fetch-dependent formulation for the aerodynamic roughness of the water surface, (ii) advanced formulations for the roughness lengths for potential temperature and specific humidity in terms of the roughness Reynolds number, and (iii) free-convection heat and mass transfer laws to compute fluxes of scalars in conditions of vanishing mean wind.

The new lake model and the new surface air layer parameterization scheme are tested against data through single-column numerical experiments. Figure 1 shows the water surface temperature θ_s as computed by the proposed lake model againsts data from measurements in Kossenblatter See, a shallow lake located in Land Brandenburg, Germany. In Fig. 2, fluxes of sensible Q_{se} and latent Q_{la} heat computed with the surface-layer scheme are compared with data from flux measurements in the atmospheric surface layer over the lake. Details of measurements are given in Beyrich (2000). As seen from Figs. 1 and 2, the model predictions show a good agreement with observations. The work is underway to further test the new lake model and the new surface layer parameterization scheme against data from measurements in/over different lakes, and to integrate the lake model and the surface-layer scheme into the full three-dimensional NWP system environment.

Acknowledgements. The work was partially supported by the EU Commission through the project INTAS-01-2132.

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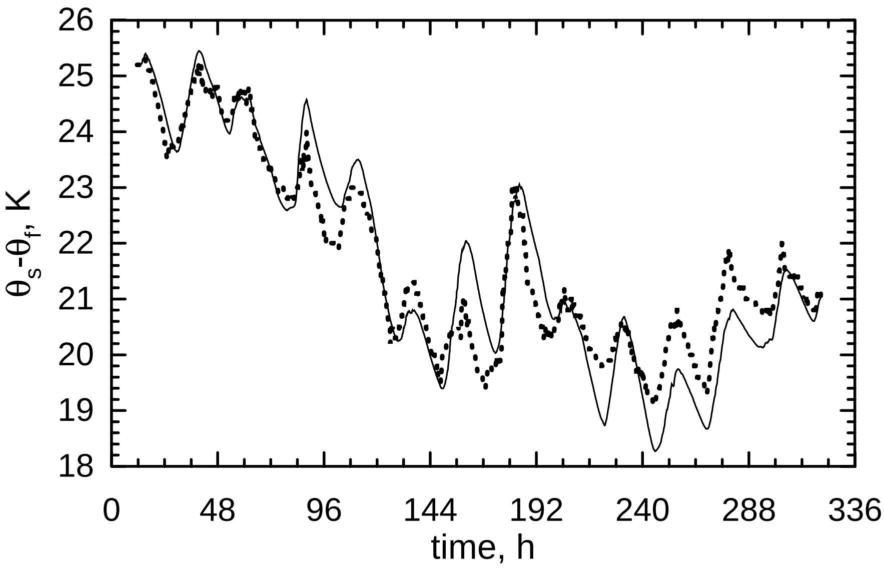

Figure 1. The water surface temperature ($\theta_f = 273.15$ K is the fresh-water freezing point) computed with the new lake model, solid curve, versus data from measurements in Kossenblatter See over the period from 8 to 21 June 1998, dotted curve.

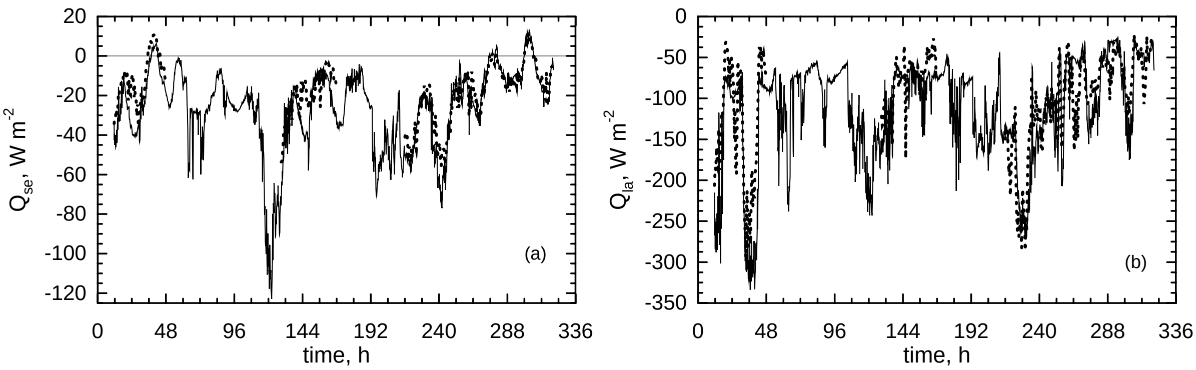

Figure 2. Computed with the surface-layer scheme, solid curves, and measured, dotted curves, fluxes of sensible heat (a) and of latent heat (b) over Kossenblatter See during the period from 8 to 21 June 1998.

References

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