BOREAL ENVIRONMENT RESEARCH 15: 97–99
ISSN 1239-6095 (print) ISSN 1797-2469 (online)

Helsinki 30 April 2010

Towards improved representation of lakes in numerical weather prediction and climate models: Introduction to the special issue of *Boreal Environment Research*

Dmitrii Mironov[1)]*, Laura Rontu[2)], Ekaterina Kourzeneva[3)] and Arkady Terzhevik[4)]

[1)] *German Weather Service, Frankfurter Str. 135, D-63067 Offenbach am Main, Germany (*corresponding author's e-mail: dmitrii.mironov@dwd.de)*
[2)] *Finnish Meteorological Institute, P.O. Box 503, FI-00101 Helsinki, Finland*
[3)] *Russian State Hydrometeorological University, Malookhtinsky pr. 98, RU-195196 St. Petersburg, Russia; and Météo-France, 42, avenue Gaspard Coriolis, F-31057 Toulouse, CEDEX 1, France*
[4)] *Northern Water Problems Institute, Karelian Scientific Centre, Russian Academy of Sciences, Aleksander Nevsky st. 50, RU-185030 Petrozavodsk, Russia*

Mironov, D., Rontu, L., Kourzeneva, E. & Terzhevik, A. 2010: Towards improved representation of lakes in numerical weather prediction and climate models: Introduction to the special issue of *Boreal Environment Research*. *Boreal Env. Res.* 15: 97–99.

Lakes strongly affect the structure and the transport properties of the atmospheric boundary layer and therefore the surface fluxes of heat, water vapour, and momentum. In today's numerical weather prediction (NWP) and climate models, the effect of lakes is either entirely ignored or accounted for very crudely, impairing the quality of simulation of the boundary-layer structure. The lake parameterization problem becomes particularly pressing as the horizontal resolution of the atmospheric models is refined. Small-to-medium size lakes that are sub-grid scale features in low-resolution models become resolved grid-scale features in high-resolution models. The use of a horizontal grid size of about three kilometres or even less has already become a common practice in short-range weather forecast. In NWP and climate models with coarser resolution, the presence of small-to-medium size lakes cannot be ignored either due to their aggregate effect on the grid-scale surface fluxes. Physically sound lake models (parameterization schemes) are required to account for the effect of lakes on the state of the atmosphere. Apart from being physically sound, lake models must be computationally efficient.

In order to discuss various aspects of the lake parameterization problem, the workshop "Parameterization of Lakes in Numerical Weather Prediction and Climate Modelling" was held in Zelenogorsk, near St. Petersburg, Russia, on 18–20 September 2008. The workshop was attended by forty researchers who shared their experience, reviewed the state of the art, and discussed challenging problems and strategy for further development. The presentations of the workshop participants were focused on (but not limited to) lake parameterization schemes for NWP and climate modelling, external-parameter data sets, availability and quality of observational data on lake temperature and lake ice characteristics and data assimilation issues, and stand-alone applications of lake models. The list of participants, abstracts of the presentations and the presentations themselves, and minutes of final discussion can be found at the workshop web page http://netfam.fmi.fi/Lake08.

Two-way coupling of lake models to NWP

and climate models, where the components of the coupled system affect each other, received much attention during the workshop. In NWP and climate modelling, the lake surface temperature is a major concern as the variable that communicates information between the lake and the atmosphere. Details of the vertical temperature distribution in lakes are of minor importance while computational efficiency is critical. Then, simplified lake models seem to suffice. A two-layer integral (bulk) model, where the structure of the upper mixed layer and of the underlying thermocline is parameterized through the concept of self-similarity (assumed shape) of the temperature profile, offers a good compromise between physical realism and computational economy. The model, termed FLake (*see* http://lakemodel.net), holds much favour in NWP and climate studies. It finds some use in other applications like lake ecosystem and water quality modelling, where a sophisticated physical module is often not required because of large uncertainties in describing lake chemistry and biology. When details of the vertical temperature distribution, e.g. accurate estimates of the near-bottom temperature in stratified lakes, become important, a more sophisticated lake model is needed. The application of finite-difference heat transfer models with the eddy temperature diffusivity computed in one way or another, e.g. with a k-ε turbulence closure scheme, was addressed. Apart from two-way coupling to atmospheric models, stand-alone applications of lake models were reported. In stand-alone mode, a lake model is forced by the atmospheric model output but does not feed back on the atmosphere state (one-way coupling). Stand-alone applications of various lake models reported at the workshop include simulations of lake response to various atmospheric forcing scenarios characteristic of different climate conditions, lake ecosystem modelling, and water quality studies.

In order to incorporate a lake parameterization scheme into an NWP or climate model, a number of two-dimensional external-parameter fields are required. These are, first of all, the fields of lake fraction (area fraction of a given grid box of an atmospheric model covered by lake water) and of lake depth. A lake-depth data set, containing mean depths of many European and Asian lakes and of several lakes from the other parts of the world, was presented and critical issues related to the generation of external-parameter fields were discussed. For some regions (Siberia, Northern Canada), available data on the lake depth are scarce; even the mean depth of a very large number of lakes is not known, let alone detailed bottom topography. A difficult task of mapping the lake-depth information on the atmospheric model grid is further complicated by numerous uncertainties of the input data (e.g. of land-use data required to generate the lake-fraction field). A method to indirectly estimate the mean lake depth by minimising the difference between the observed and modelled lake surface temperature was presented. Although such an "effective" lake depth is lake-model dependent and is strongly affected by the quality of observations, the method holds considerable promise in view of the paucity of lake-depth data.

Observational data and data assimilation issues were addressed. There are data on lake water surface temperature and on lake surface state (open water versus ice and snow) from several sources. However, to the best of the workshop participants' knowledge, no global near real-time data from satellite and *in-situ* observations are currently available. As more and better observational data on lakes become available, improved assimilation schemes for NWP models become increasingly important. A number of approaches seem to be feasible, ranging from simple successive correction and optimal interpolation to an extended Kalman filter. The best-choice approach depends on the data availability and should give due consideration to several features peculiar to lakes, e.g. that lakes are separate entities that communicate with each other only indirectly by modifying the atmospheric boundary layer. Although only surface-temperature data may be assimilated, the entire prognostic temperature profile should be affected. Currently, a correct initialisation of the lake surface temperature (i.e. the temperature of the water, ice or snow surface) is of prime importance, whereas the surface-temperature changes during the forecast are less critical, at least in short-range NWP. Hence several today's NWP models use the assimilated values of the lake surface temperature and of the fractional ice cover in a diagnostic mode (the surface characteristics are kept constant over the forecast period), as they do for the sea surface. Building an integrated system that combines the diagnostic and prognostic approaches for the sea and lake surfaces is a challenge.

The workshop ended with the final discussion where several particular further steps were proposed (*see* "Discussion notes" at http://netfam.fmi.fi/Lake08 for details).

The Lake Model Intercomparison Project (LakeMIP, http://www.unige.ch/climate/lakemip) was launched. The project is aimed at assessing the performance of one-dimensional lake models of various complexity and at providing a hierarchy of models which would allow one to choose an optimal model as required by the application. The first step is to perform a series of stand-alone benchmark experiments for a number of lakes that differ in terms of their depth, geographical location, water transparency, etc. The choice of lakes strongly depends on the availability and quality of observational data required to verify the simulation results as well as of input data required to specify the atmospheric forcing (both observational and re-analysis data can be used). At a later stage of the LakeMIP implementation, performance of various lake models coupled to NWP and/or climate models should be tested.

Further work on external-parameter data sets was strongly recommended. It was proposed to raise this issue at the European level in order to better serve the needs of various NWP and climate modelling teams, to co-ordinate their efforts, and to provide financial support. The existing lake-depth data set should be extended to eventually cover the entire globe. Where direct estimates are missing, the above mentioned effective lake-depth estimation method may be used. For large lakes, gridded data, containing different depths for different regions of the lake, should be used whenever available. Apart from the data set itself, a software package should be developed to facilitate the usage of the external-parameter data in various atmospheric model configurations. The work outlined above is underway at Météo France. Results are expected to be available in 2010.

As a first step towards the assimilation of lake surface temperature observations into NWP models, a survey of available *in situ* and remotely sensed data was recommended. The EUMETSAT can be contacted to inquire about the real-time satellite data on the lake water surface temperature, ice and snow. Critical points in the lake model physics that call for further development were considered. In particular, an improved description of snow over lake ice is desirable. Finally, it was proposed that the next workshop on parameterization of lakes be held in 2010 and that the results reported at the 2008 workshop be published in a peer-reviewed journal.

This special issue of *Boreal Environment Research* contains 13 papers, including a paper by Krinner and Boike that did not originate from a presentation at the workshop in Zelenogorsk. A paper by Rooney and Jones is not included into the special issue; it appears in one of the regular issues of *Boreal Environment Research*. These papers address a wide range of topics, including two-way coupling of the lake model FLake to NWP and climate models, implementation of FLake as the lake parameterization module into several land-surface schemes, stand-alone applications of various lake models (FLake, eddy diffusivity, k-ε), assessment of the climate impact of possible future changes in high-latitude inland water surface area, external-parameter data for NWP and climate models, and the Lake Model Intercomparison Project.

The workshop in Zelenogorsk and the publication of the present special issue were supported by the Nordic Research Board through the Nordic Network on Fine-Scale Atmospheric Modelling (NetFAM) and the EU Commission through the project INTAS-05-1000007-431 and the EU Programme TEMPUS.