2nd Workshop on Parameterization of Lakes in Numerical Weather Prediction and Climate Modelling
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The Lake Model Intercomparison Project (LakeMIP): present state and perspectives

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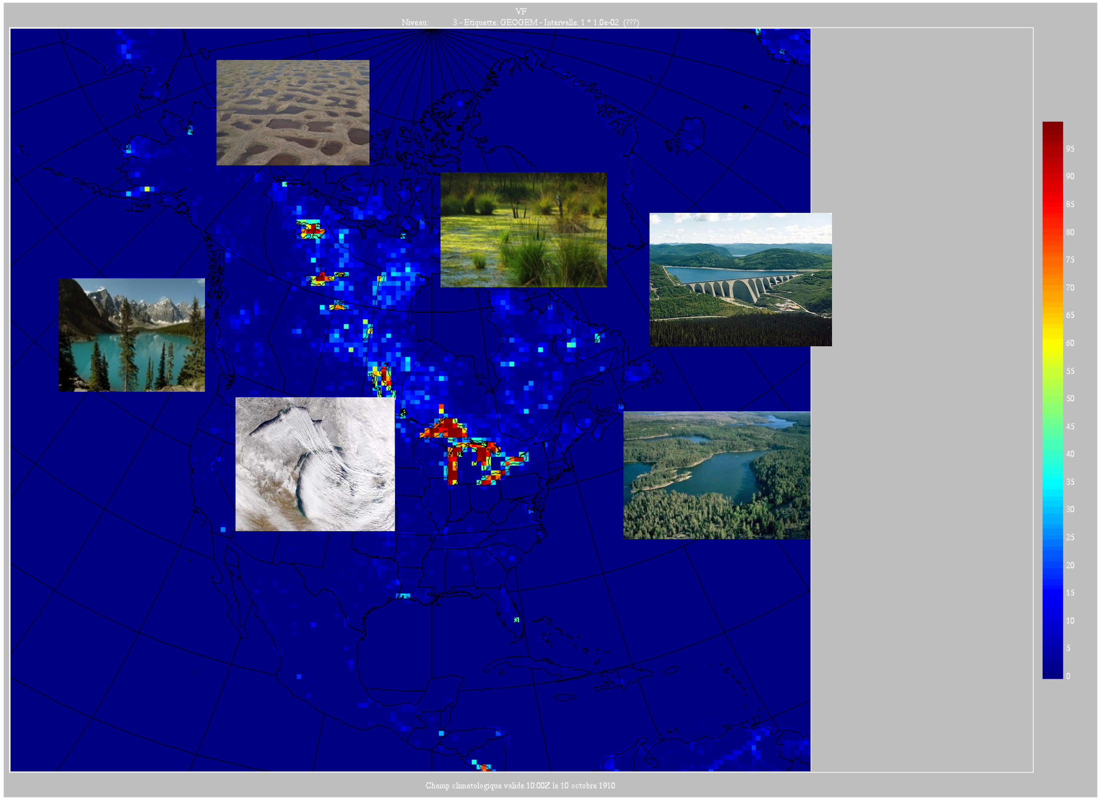
LakeMIP: born in Zelenogorsk 2 years ago

• The Lake Model Intercomparison Project (LakeMIP) was initiated by participants of the "Parameterization of Lakes in Numerical Weather Prediction and Climate Modelling" workshop, 18 - 20 September 2008, St. Petersburg (Zelenogorsk), Russia.

LakeMIP: motivation

• Although numerous lake models exist, their validity range is rarely properly estimated by developers and by model users...

But: in regional and, especially, in global models simulation domains often cover different climatic and geomorphological zones with very different lakes.

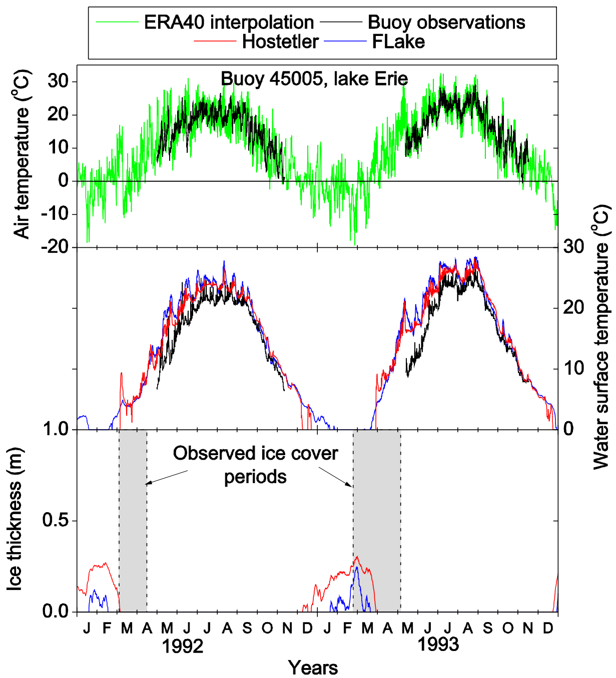


How can we be sure that lake models are valid in all these lakes?

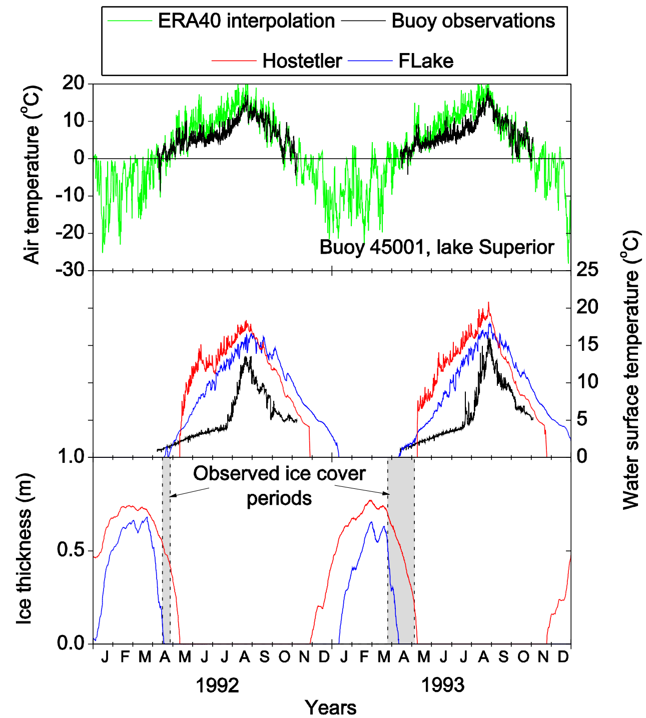
LakeMIP: motivation

• In fact, there are evidences of the contrary: popular lake models, such as Hostetler's and Flake, have difficulties with large and deep lakes.

Lake Erie, 13 m



Lake Superior, 261 m



So, questions arise…

• How these and other models will behave in very shallow, or very turbid lakes, in tundra ponds, in volcanic, mountain, tropical lakes…?

• Can we find optimal lake models for each major type of lakes?

→ need for lake model intercomparison and validity range testing!

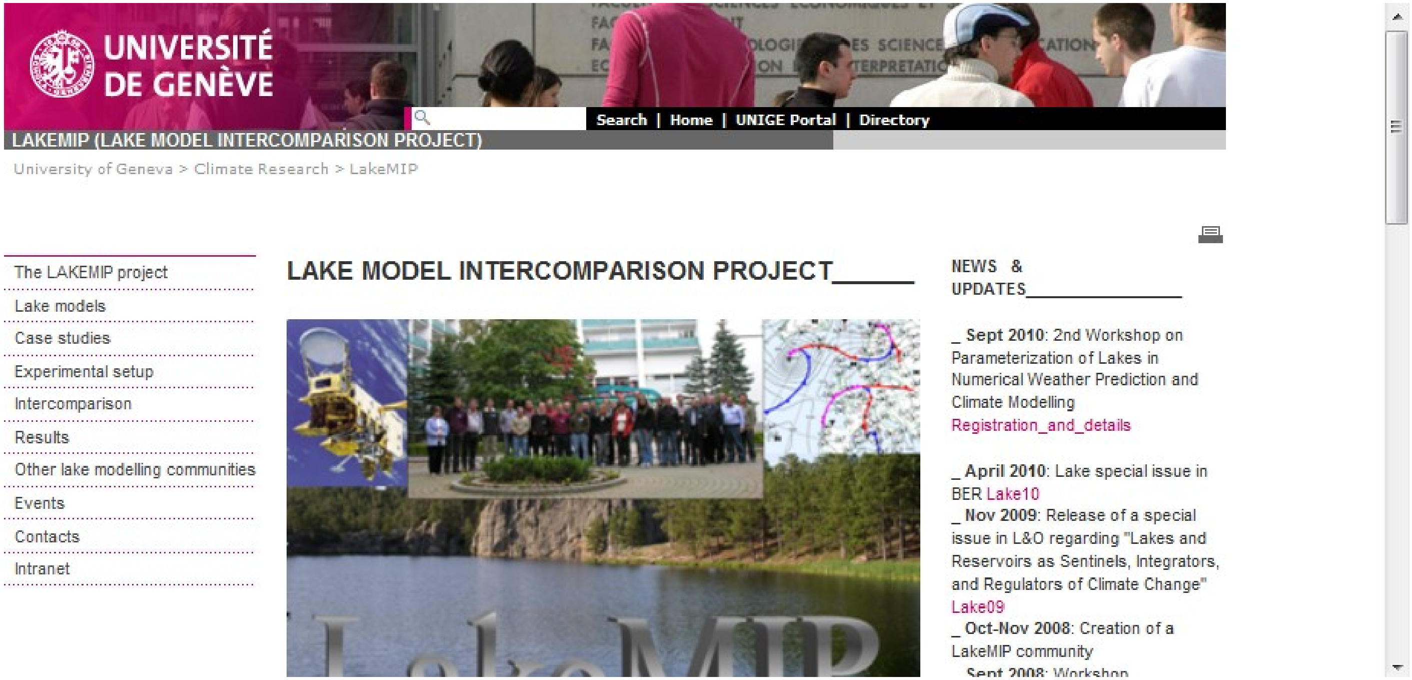
LakeMIP: project scope

• The Lake Model Intercomparison Project (LakeMIP) addresses multiple research issues related to numerical modelling of atmosphere-lake interactions, which are useful not only for weather and climate matters, but also for limnological studies in terms of both physical adequacy and numerical efficiency.

• **The project is voluntary and open to all researchers, interested in testing their lake models in standardized conditions and in comparing their performance with other models.**

• Project coordinators: Viktor Stepanenko, Stéphane Goyette, Andrey Martynov

• The LakeMIP web site: ***http://www.lakemip.net*** ***The site is going to be updated and upgraded soon!***



LakeMIP: project scope

• Goals of the project:

- To assess the range of applicability of existing 1D model formulations, i.e. their capacities and limitations in reproducing lake-atmosphere interactions as well as internal lake thermodynamics. This includes the identification of the key physical processes to be taken into account in lake models in order to further improve their performance in lake-atmosphere interaction and in limnological studies.

- To simulate the interaction mechanisms between lakes and the atmosphere in the framework of weather and climate models of different spatial domains, resolution and dimensionality.

• The project is intended to evolve in two phases:

1) During the first phase, LakeMIP1, the intercomparison of different one-dimensional models, using observations on a number of lakes representing a wide range of climate and lake mixing regimes, is being performed.

2) The second phase, LakeMIP2, will aim at studying the impacts of lakes on regional-scale weather and climate using coupled lake-atmosphere models.

For the first phase of the project, a set of lake types was elaborated. At this step, only non-tropical lakes were considered.

For each lake type, a lake with ready available, high quality limnological and meteorological observations was selected.

LakeMIP: participants and models

Currently, eight researchers / groups with eight 1D lake models participate in LakeMIP

Lake model	The type of model	Run by	References
SIMSTRAT	finite-difference, k-ε	Marjorie Perroud	Goudsmit *et al*. 2002
LAKEoneD	finite-difference, k-ε	Klaus Jöhnk	Jöhnk and Umlauf 2001
LAKE model	finite-difference, k-ε	Viktor Stepanenko	Stepanenko and Lykosov 2005
DYRESM	finite-difference	Marjorie Perroud	Imberger and Patterson 1981
Hostetler's model	finite-difference	Andrey Martynov Zachary Subin	Hostetler 1993
MINLAKE96	finite-difference	Xing Fang	Fang and Stefan 1996
FLake	parameterized temperature profile	Andrey Martynov	Mironov 2008, Mironov *et al.* 2010
Goyette's model	mixed-layer temperature	Marjorie Perroud Stephane Goyette	Goyette *et al.* 2000

LakeMIP: participants and models

Welcome to Zachary Subin, a new LakeMIP participant, who joined us on this Workshop with his independent realization of the Hostetler model!

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Welcome to Zachary Subin, a new LakeMIP participant, who joined us on this Workshop with his independent realization of the Hostetler model!

Another excellent news (arrived today at 3:32 AM):

Marjorie Perroud, now postdoc at GLERL, confirmed her further participation in the project!

LakeMIP: 1st phase lakes

For the first phase of the project, a set of lake types was elaborated. At this step, only non-tropical lakes were considered.

For each lake type, a lake with ready available, high quality limnological and meteorological observations was selected.

LakeMIP is always looking for lakes with good meteorological and limnological observations!

LakeMIP: 1st phase lakes

Some lake sites, studied and projected in LakeMIP

Climate (latitude)	**Lakes deep or shallow**	**Lake**	**Country**	**Mixing regime**	**Lake average /maximal depth (m)**
Mid-latitude non-freezing lakes	Deep	Geneva	Switzerland France	Monomictic	153 / 309
Mid-latitude freezing lakes	Deep	*Laurentian Great Lakes **(Michigan)***	Unites States	Dimictic	(19-147) / (64-406)
	Shallow	**Sparkling Lake**	United States (Wisconsin)	Dimictic	11 / 20
	Very shallow	**Kossenblatter**	Germany	Polymictic	2 / 6
Arctic	Shallow	Toolik lake	United States (Alaska)	Dimictic	7 / 25

LakeMIP: 1st phase settings

• For each studied lake
 - Standard forcing and validation datasets were produced, using available observations.
 - Simulation protocols were established, with initialisation settings, lake parameters and output data format descriptions.

• Lake models were used with their respective surface flux and radiation absorption parameterizations.

• "Off-line“ simulations were carried out: meteorological data were used for surface forcing. Key forcing parameters are : screen air temperature and humidity, surface wind force and direction, surface pressure and solar and atmospheric surface incoming radiation.

• Lake measurements used for validation of simulation results: water surface temperature, water temperature profiles (if available), ice and snow cover thickness are used for validation of simulation results.

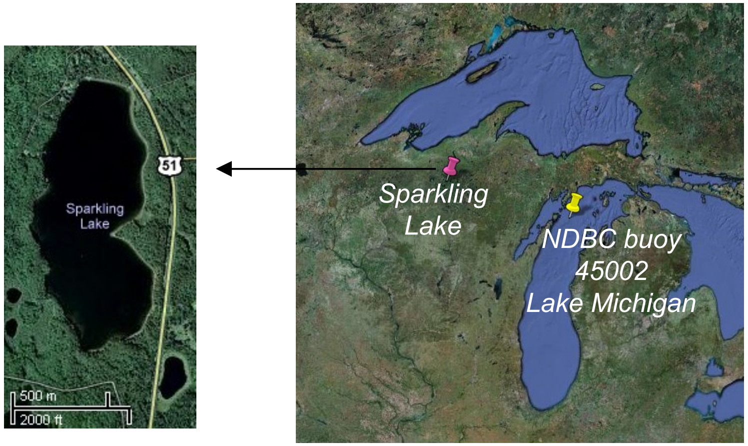
• Comparison of simulation results was carried out collectively by LakeMIP members (mostly by Viktor Stepanenko).

LakeMIP: Sparkling lake

• Sparkling Lake, Wisconsin, USA. This medium-sized dimictic forest lake that has been monitored since more than 20 years by the NTL LTER project of the University of Wisconsin. Meteorological and limnological data of exceptional quality are available for several consecutive annual cycles.

• Lake parameters are: latitude 46.003 N, longitude 89.612 W, area: 0.64 km^2, mean depth: 10.9 m, maximum depth: 20 m,
average Secchi depth: 7.5 m (water transparency: 0.27 m^{-1}). Simulation period: 4 years, 2002 - 2005.

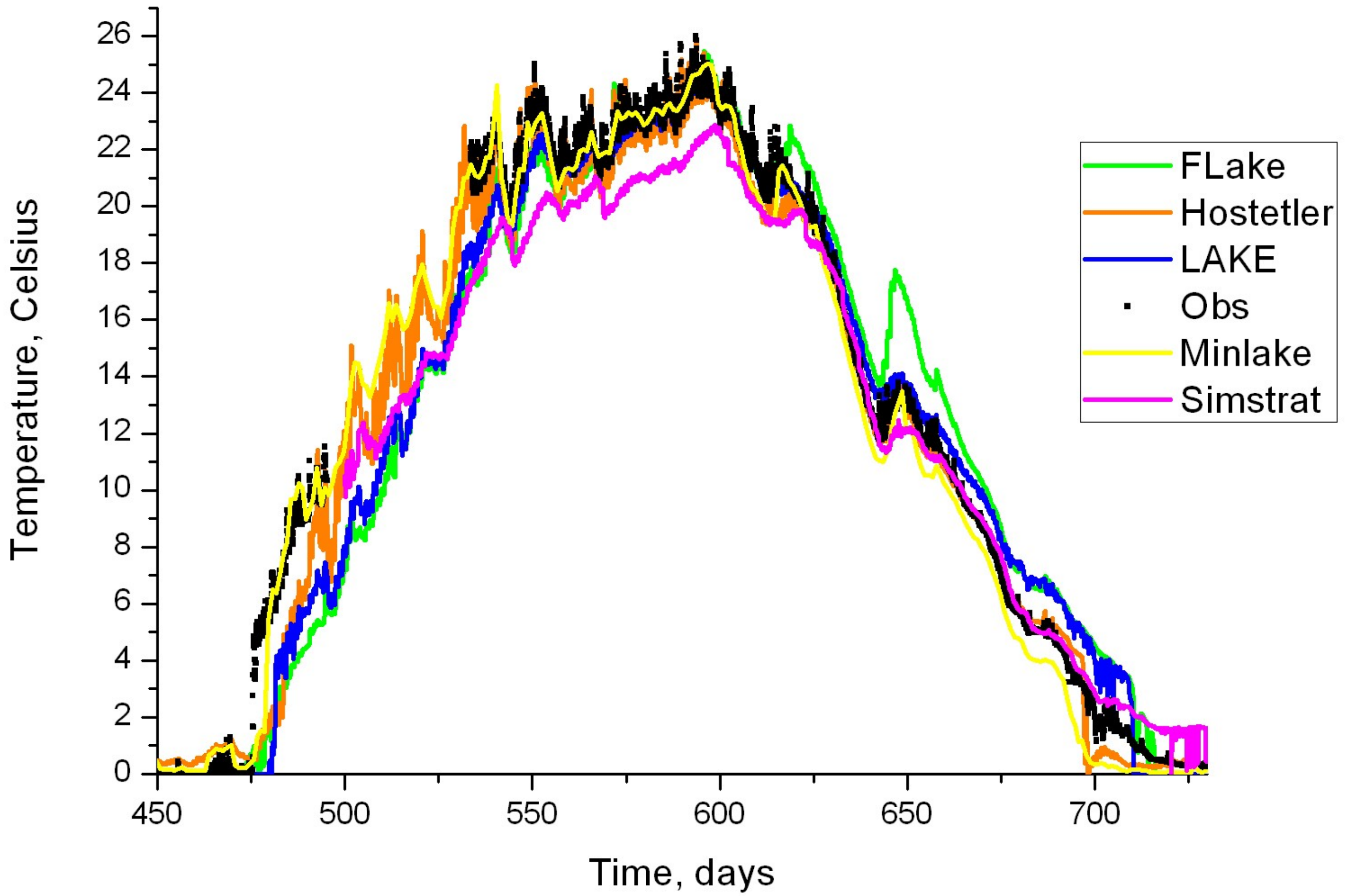
• Five different lake models were compared, using similar model configuration and same atmospheric forcing. Of those, the SIMSTRAT model was launched only for open-water periods (ice cover is not represented by this model), other models were run continuously for the whole simulation period. The timestep was 1 hour for all models, except MINLAKE96 (1 day).



Position of two simulated lakes:
Sparkling Lake (left)
Lake Michigan (right)

LakeMIP: Sparkling lake

Time series of Lake Sparkling water surface temperature in 2003, modeled and observed



• All the models designed for simulating ice-cover conditions performed satisfactorily well in calculating the surface temperature.

• Both k-ε models, LAKE and Simstrat, underestimate surface temperature by by 2 to 3 ºC during warming periods (late spring and early summer) in all 4 years.

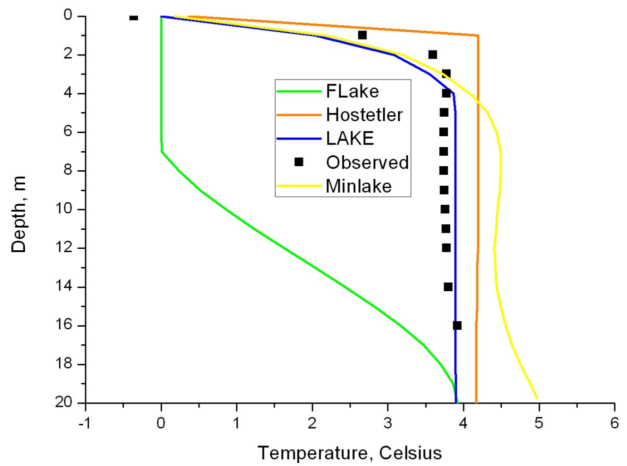
LakeMIP: Sparkling lake

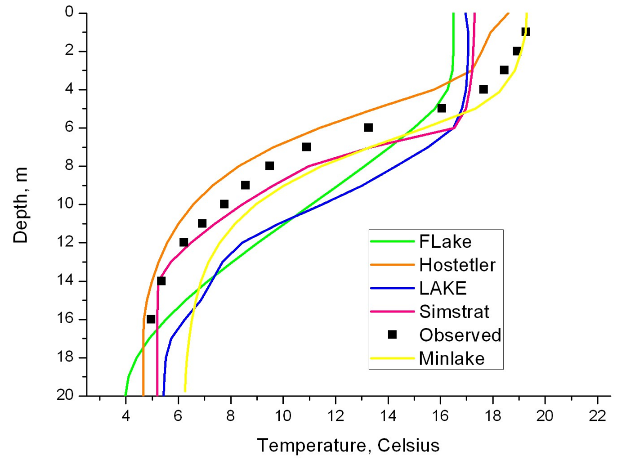
•Temperature profiles for March and June represent periods of late ice-cover and early summer heating, respectively.

•The models capture well the temperature profiles formed towards the end of the ice-cover period, except for FLake that produces a deep mixed-layer under the ice. The latter is due to the scheme for the mixed-layer depth calculation in FLake which fixes the pre-ice value of this depth when the ice appears.

•The temperature profiles for June demonstrate the problem of both k-ε models: they produce strong mixing, forming the deep mixed-layer, and leading to decrease of the surface temperature and increase of the temperatures below. This is possibly due to the formulation of those models which employ boundary layer approximations in TKE and dissipation equations that may become inappropriate for relatively small lakes.

Mean monthly temperature profile in Lake Sparkling, March and June 2003, observed and simulated.





LakeMIP: “Lake Michigan”

• Lake Michigan: a large freezing lake, where complex 3D circulation patterns and internal wave motion strongly influencing the thermal regime.

• By conception, 1D lake models are not able to reproduce such phenomena explicitly. It is important to estimate the performance of such models in these lakes and the magnitude of related biases.

• In order to approximate the Lake Michigan atmospheric forcing, the data for the nearby Sparkling Lake were used. The average depth of Lake Michigan is 85 m. In simulations, the lake depth was set to 180 m in all models (except for FLake where 60 m were used due to model limitations) in order to reproduce the conditions at the NDBC 45002 buoy position (latitude 45.344N, longitude 86.411W).

• NDBS buoy 45002 (northern Lake Michigan) and the satellite-based GLSEA average surface water temperature were used for validation of simulation results.

• The numerical experiments were performed with three lake models: LAKE, Hostetler, and FLake.

LakeMIP: "Lake Michigan"

• Strong discrepancy between the simulations and observed values

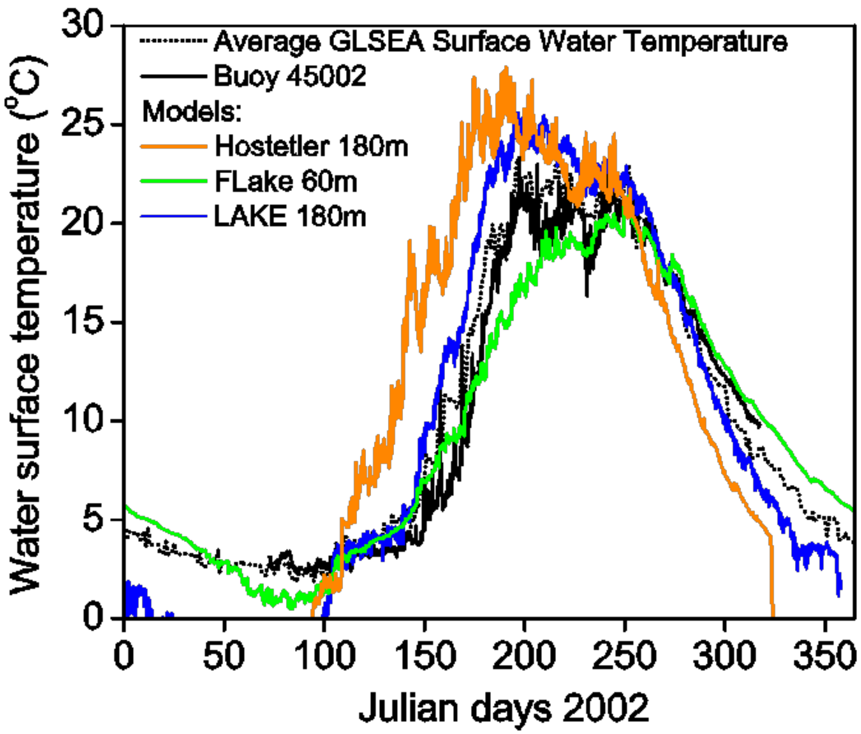
• None of these models with current parameterization perform in a satisfactory manner for such a deep lake.

• The two finite-difference models do not reproduce the observed ice-free winter conditions.

• Hostetler's model does not simulate the effect of a slow surface temperature increase under 4°C due to the enhanced buoyancy-driven mixing.

• The LAKE model captures it, but it overestimates the rates of temperature rise in the early summer and the temperature fall in autumn – probably due to omission of some mixing mechanisms in the water column.

Surface temperature of northern Lake Michigan, simulated by LAKE, Hostetler's and FLake models

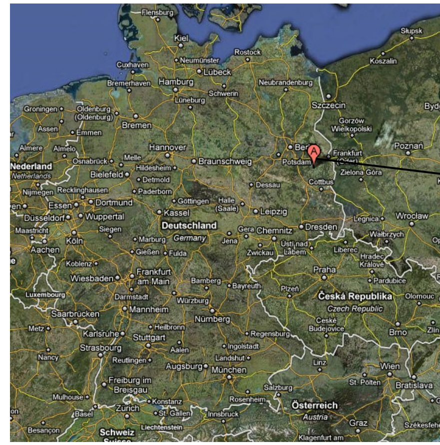


• The problems mentioned show the necessity of improved parameterizations for physical mechanisms, present in large and deep lakes. Development of such advanced parameterizations would require further intercomparison activity.

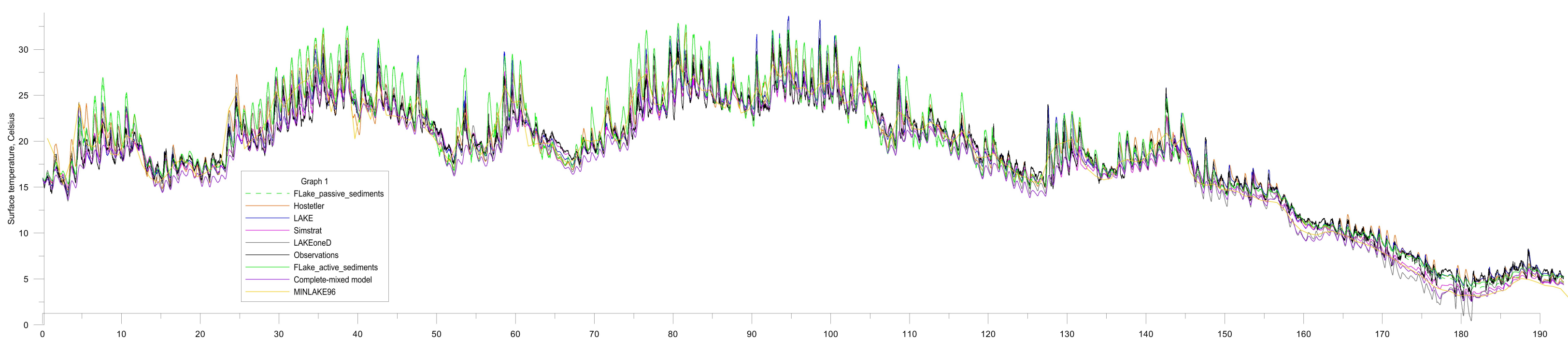
LakeMIP: Kossenblatter See

• Kossenblatter See, Germany is a shallow and very turbid lake.

• Lake parameters: latitude 52.13 N, longitude 14.1 E, area: 1.68 km^2, mean depth: 2 m,
average Secchi depth: 0.24 m (water transparency: 7.08 m^{-1}).
Simulation period: 1st of May - 11th of November, 2003



Position of Kossenblatter See



Details on Kossenblatter See simulations: see next presentation of Viktor Stepanenko

LakeMIP: publications, presentations

• Article in the BER Special Issue:

Stepanenko, V. M., Goyette, S., Martynov, A., Perroud, M., Fang, X. & Mironov, D.
First steps of a Lake Model Intercomparison Project: LakeMIP. *Boreal Env. Res.* 15: 191–202

• Posters at the EGU 2010, Vienna:

The Lake Model Intercomparison Project (LakeMIP) : an overview *(A.Martynov)*

LakeMIP : the Lake Model Intercomparison Project. First results and forthcoming experiments *(S. Goyette)*

Both posters can be viewed at this Workshop!

• *Publication on Kossenblatter See: submission this year?*

LakeMIP: further steps

- Within the 1st phase:

  - Completion of planned lakes: “Michigan”, Geneva with all participating models.

  - New lakes:
    - Lake Toolik (resume contacts with Sally MacIntyre?)
    - Mountain lakes: Alps and Ands – Stephane Goyette is contacting people…
    - Tropical lakes? GLION (Victor Stepanenko?)
    - Inland seas? Baltic Sea, Black Sea, Caspian Sea?
    - Lakes, presented on this Workshop?
      - Lake Valnea-Kottinen (flux measurements of good quality)
      - Thau lagoon (salty lake)
      - Great Slave Lake (large and deep northern lake)
  - New data sources
    - North Hydrology: LakeMIP is one of potential data users
    - Arctic Lake Monitoring System?

  - More attention to surface flux parameterization (see next presentation)

  - New tasks for off-line model intercomparison?
    - Sensitivity of lake models to errors and biases in external and initial parameters?

- 2nd phase: coupled models
  - Need for conceptual discussion and elaboration of general principles.

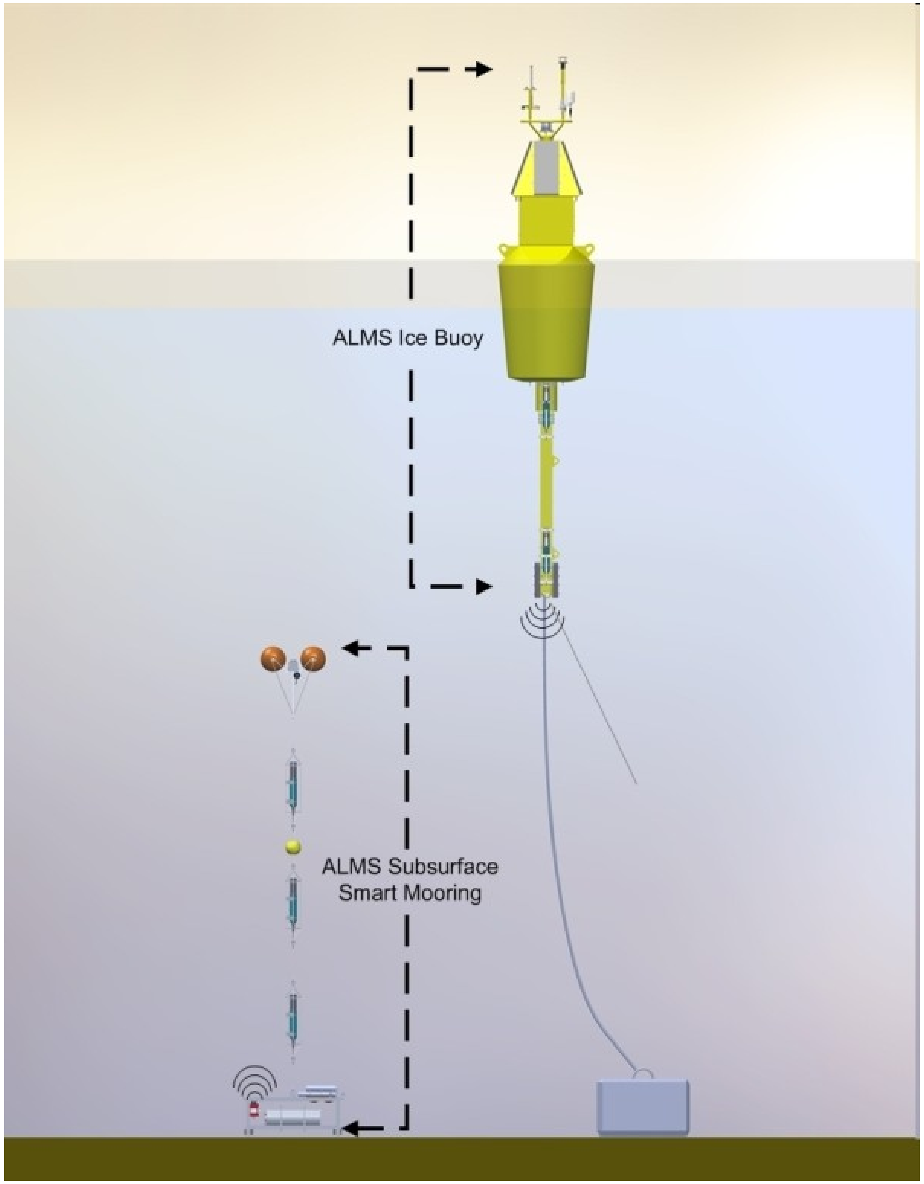
LakeMIP: further steps

Arctic Lake Monitoring System:

“a fully-automated Ice Buoy and subsurface mooring system for continuous year-round, real-time monitoring of:
weather conditions
lake ice cover (initiation, growth over winter, breakup in spring)
light penetration into the lake (through ice in winter)
lake water quality (chemistry, temperature, oxygen levels)”

Developed by Axys Technologies Inc. for Environment Canada, Water & Climate Research Centre and the Department of Geography at the University of Victoria.

To be deployed on a northern lake in Canada this year?



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LakeMIP: challenges

- Voluntary project with no official obligations, driven by personal motivation of participants
- Substantial amount of work for no immediate compensation
- Long way to taking decisions, long discussions. 2 lakes simulated by all models in 2 years
- Lack of official status (Stephane Goyette is in contact with WMO, recognition possible this year)
- Financial support to encourage present participants and to attract new ones?
- More formal project scope?