Issues on lake modelling and data assimilation for SRNWP

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Outline

- Importance of lakes for SRNWP
- Modelling efforts around FLake in Europe
- Current developments on lake database and climatology
- Towards a lake data assimilation system
- Priorities for future activities
- Summary

Importance of lakes for SRNWP

- Increase in resolution of our NWP models : AROME/HARMONIE Δx=2.5 km : ALARO Δx=5 km : UKMO Δx= 4.0/1.5 km : COSMO Δx=7.0/2.8 km : ECMWF Δx=15 km
- A number of lakes become resolved scale features and/or non-negligible sub-grid fraction
- Significant contribution to surface turbulent fluxes : possible impacts on local weather and local climate
- Need to either prescribe and/or predict the surface temperature of inland water bodies
- Requirements : lake model and/or lake surface temperature analysis (i.e. suitable observations)

Example : inland water in AROME

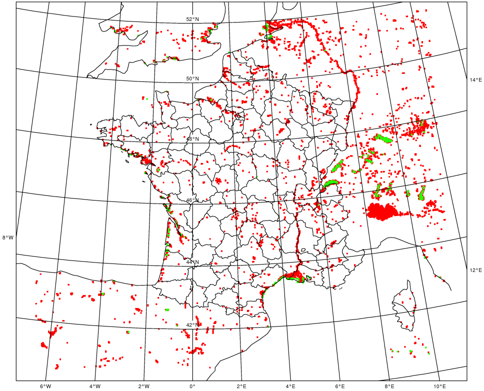


Figure: Inland water fraction > 0 - LST available

FLake (1)

Necessary compromises for NWP :

- One dimensional parametrisation scheme
- Physical realism - low computational cost
- Small number of input and tunable parameters (initialisation, robustness, applicability)

The Fresh water Lake model FLake (Mironov, 2008) :

- Two-layer model with parameterised vertical temperature structure
- Temperature profile in the thermocline = parameterised through an "universal" function of dimensionless depth, using the temperature difference across the thermocline $\Delta\theta = \theta_s(t) - \theta_b(t)$ and its thickness Δh

$$\frac{\theta_s(t) - \theta(z,t)}{\Delta\theta(t)} = \Phi(\zeta) \qquad \zeta = \frac{z - h(t)}{\Delta h(t)} \tag{1}$$

METEO FRANCE
Toujours un temps d'avance

FLake (2)

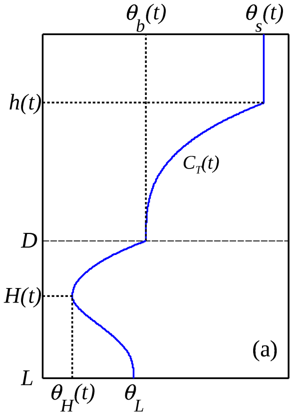


Figure: Schematic representation of the temperature profile

FLake (3)

Prognostic variables :

- Mean temperature of the water column
- Bottom temperature
- Mixed-layer depth
- Shape factor with respect to the temperature profile in the thermocline
- Ice depth and temperature at the ice upper surface
- *Depth within bottom sediments and associated temperature*
- *Snow depth and temperature at the snow upper surface*

FLake (4)

Current status in the consortia :

- ECMWF : Included in the IFS. Planned for operational use in 2011. Lake depth physiography from E. Kourzeneva. Lake temperature climatology derived from ERA-I with a "lake planet"
- UKMO : On-going developments for coupling. Planned for operational use in the global model (2011 ?)
- COSMO : Should become operational very soon
- HIRLAM : already used. Validation tests in the NWP LAM at SHMI
- ALADIN/LACE : available within SURFEX. Coupled runs with AROME about to start. Validation studies against experimental datasets.

FLake (5)

External parameters (to be prescribed)

- Lake fraction in the model grid-box
- Lake depth
- Optical properties of lake water (solar extinction coefficient)
- Depth of thermally active layer of bottom sediments
- Depth of sediment layer

Default values for the last three parameters can be used.

Global lake database

- Availability of global databases : GLCC, ECOCLIMAP, GLWD but lack of information about individual lake parameters
- Development of a global gridded lake depth dataset (E. Kourzeneva, RSHU with HIRLAM and Météo-France collaborations) from various data sources :
  - Dataset for individual lakes : 13 000 freshwater lakes, 220 saline lakes
  - Global physiographical maps : ECOCLIMAP2 (after removing artifacts)
  - Bathymetry for large lakes with variable depth (ETOPO1)
- Resolution is 30" and default lake depth set to 10 m
- Data projected on model grid using a probabilistic approach (software available)

Global lake depth database (1)

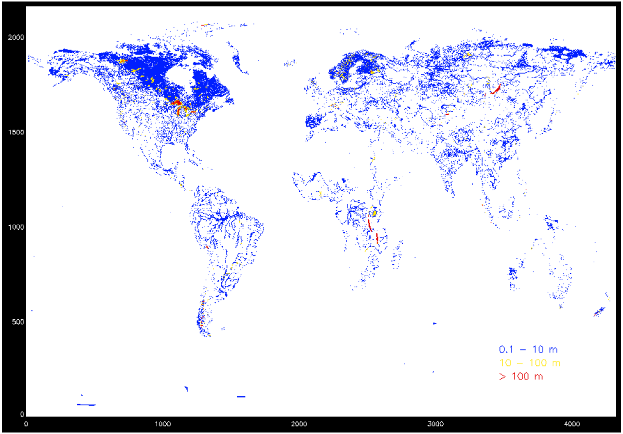


Figure: Kourzeneva database

Global lake depth database (2)

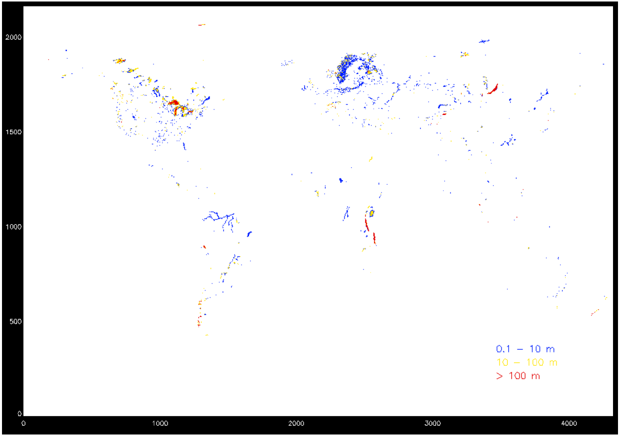


Figure: Where real information is known

Global lake depth database (3)

- The additional dataset for S (the reliability of information):
  S=1 - a ”spot-lake” was not recognized,
  S=2 - a ”spot-lake” was recognized but with missing information,
  S=3 - a ”spot-lake” was recognized,
  S=4 - a river

- Useful to estimate the quality of data.

Romania =>

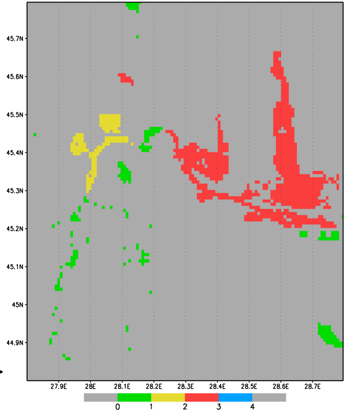
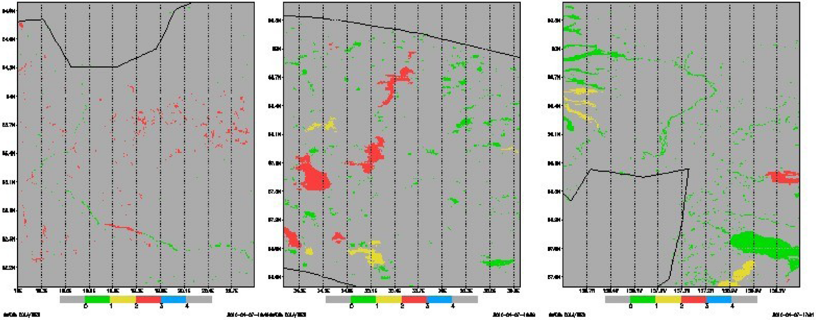


Figure: Data provided with quality flags

Remaining issues (1)

- Include new lakes into the dataset for individual lakes
- Define a methodology for an indirect estimation of lake depth (e.g. lake origin)
- Improve coastlines in maps (some large lakes do not exist !)
- Improve bathymetry for the largest lakes
- Account for saline lakes (some of them could dry)
- Distinguish between lakes, rivers and estuaries, and coastal lagoons
- Mapping of extinction coefficients (satellite data ?)

Remaining issues (2)



Poland Karelia Alaska

Figure: Lakes not present in database (green)

Global lake temperature climatology (1)

- Useful for "cold start" runs with FLake and prescription of LST for NWP (small lakes not seen by global SST analyses)
- Methodology : run FLake over a long period of time (20 years) or a perpetual year with a prescribed forcing over the globe (GSWP2 : E. Kourzeneva ; ERA-I : R. Salgado)
- 10-day representation of the annual cycle for different classes of lake depth (1m to 50 m) or with a constant depth (30 m at ECMWF). Need to relax the bottom temperature towards T2m climatological mean

Global lake temperature climatology (2)

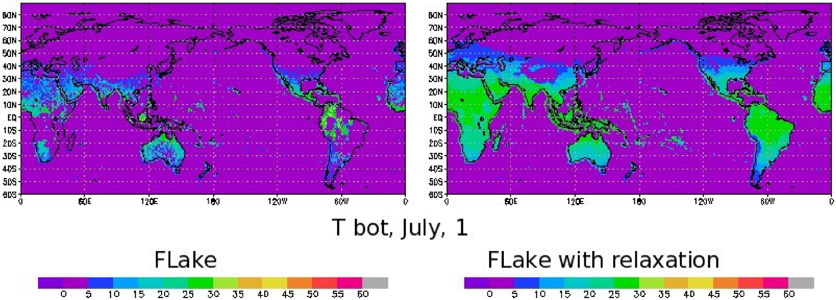
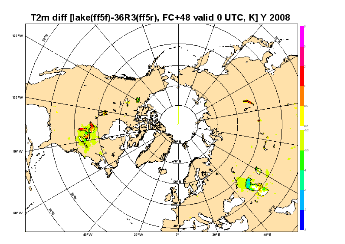


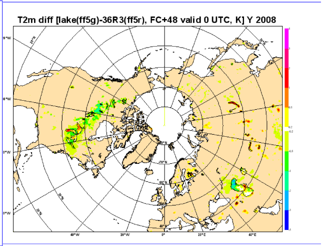
Figure: Sensitivity to the specification of bottom temperature

Impact study at ECMWF

Resolved lakes only

Resolved +Unresolved lakes





The sensitivity of 2m temperature forecasts (FC+48 shown here) see a co-located cooling over lakes (expect the Great Lakes). The addition of unresolved lakes extend the impact on large part of Northern Canada (where sub-grid lakes are vastly present).

Figure: Screen-level temperature forecasts

Towards data assimilation

Requirements :

- Methodology : single column assimilation using advanced techniques (e.g. EKF)
- Model prognostic variables : surface and bottom temperatures, mixed layer depth, shape factor
- Observations : satellite IR skin temperature (which instruments ? revisit time ?), screen-level temperature (?)

Preliminary studies :

- Compute Jacobians of observations with respect to control variables
- Perform experiments at instrumented site to evaluate the quality of the assimilation system

Questions :

- Length of assimilation ? Cycling of model errors ?
- What about large lakes ? Need for 2D spatialisation ?

Ongoing activities

- Intercomparison project LakeMIP : currently 3 models have been compared. Difficulties to simulate deep lakes.
- HIRLAM : Improvements to the current snow scheme in Flake. Development of a snow model (10-layer scheme) over lake ice.

Example

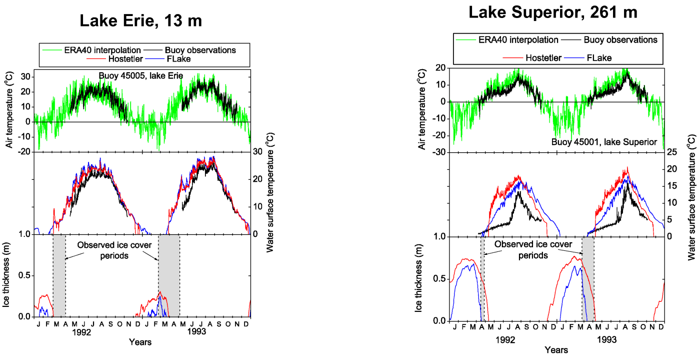


Figure: Lake models over Great Lakes

Possible improvements

- Improvement of snow over lake ice
- Inclusion of salinity in FLake
- Inclusion of a third layer in Flake (improved description of deep lakes)
- Fractional ice coverage over lakes (tiling approach ?)
- Define suitable data sets for assimilation (MODIS, North hydrology, ARC Lake)

Conclusions

- Strong involvement of the COSMO consortium (D. Mironov) on the development and promotion of a simple and realistic lake model : FLake (COSMO)
- FLake is now included in all models of the SRNWP consortia and evaluated in coupled mode
- Strong involvement of the HIRLAM consortium (E. Kourzeneva) on the development of a global lake depth database and lake temperature climatology (financial support from DWD, EU and Météo-France)
- NetFAM/MUSCATEN (+ EU project INTAS) has federated the research activities around lake modelling by organizing two dedicated workshops (Zelenogorsk, 2008; Norrköping, 2010)
- High priority should be given on the maintenance and improvement of the lake database : financial support is needed from european consortia !