2nd ALADIN Forecasters meeting

Interactive lakes in NWP

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22 October 2015 IPMA, Lisboa

Authorship

- This short presentation aims to be a summary of the status of the work of a small scientific community sometimes known as the ***Lake Folks***, structured around the LAKE ***workshops on "Parametrization of Lakes in Numerical Weather Prediction and Climate Modelling"***
  - Zelenogorsk (Russia) in 2008
  - Norrköping (Sweden) in 2010,
  - Helsinki (Finland) in 2012
  - Évora (Portugal) in 2015

- In particular, in this presentation I use materials provided by:

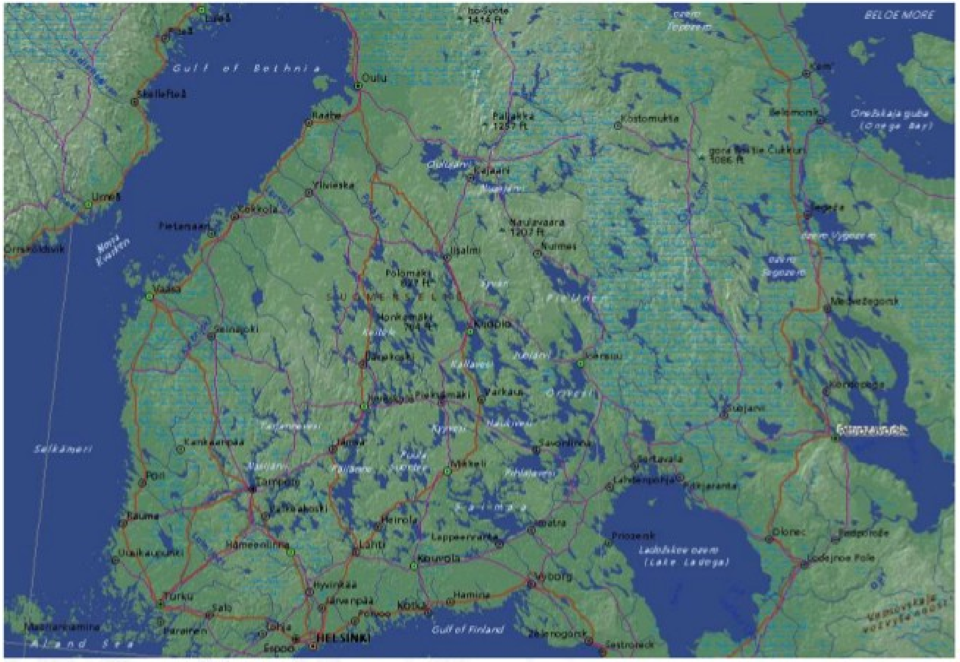
Dmitrii Mironov (DWD),
Gianpaolo Balsamo (DCMWF),
Patrick Le Moigne (Météo-France),
Ekatherina Kourzeneva (FMI),
Margarita Choulga, (RSHU)
Miguel Potes (U. Évora)
Laura Rontu (FMI)
Victor Stepanenko (U. Moscow)
Gabriel Rooney (UK)

LAKE 2015 in Évora
http://www.lake15.cge.uevora.pt

Why lake schemes in NWP models?

- Some regions can be highly influenced by the presence of lakes
  - The boreal zone (9.2% of the area of Sweden and 10% of the area of Finland are covered by lakes)
  - Eastern Africa and of the American Great Lakes region
  - In many regions (Mediterranean, Brasil, ...), dams and reservoirs have been constructed.

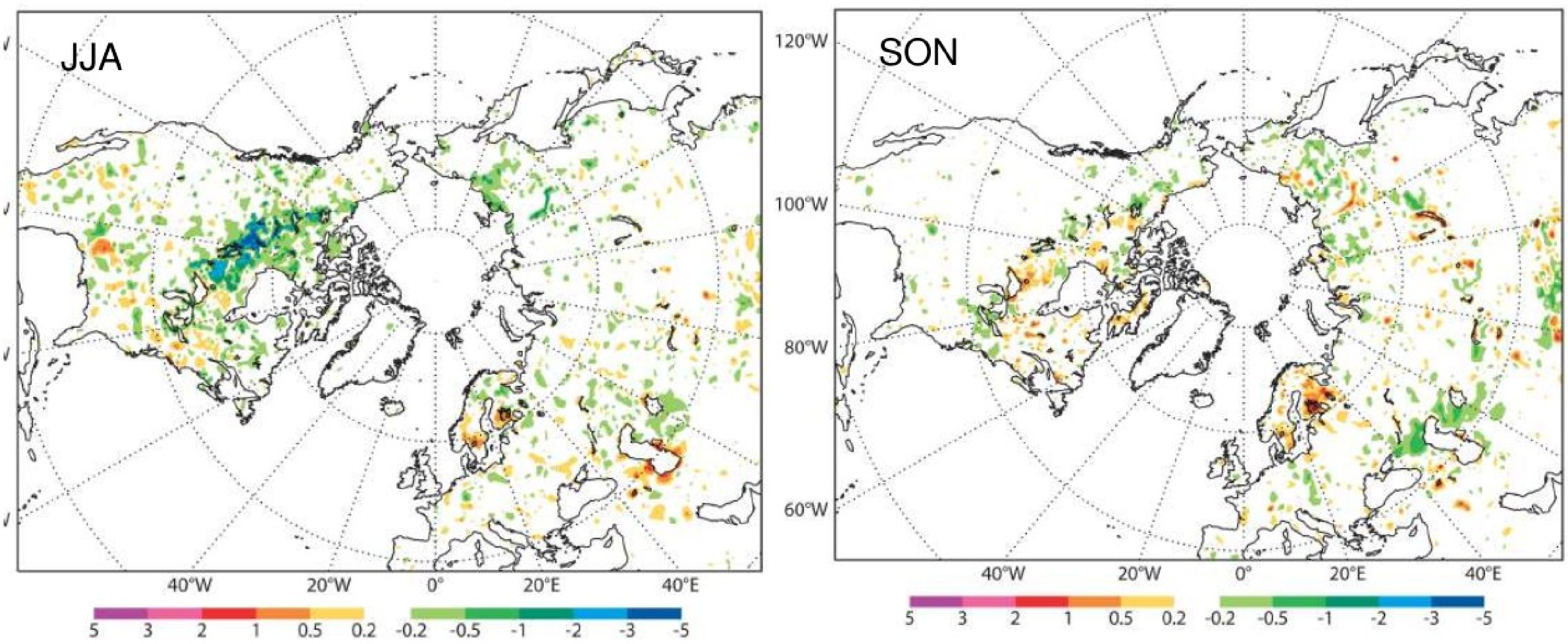
An accurate prescription of lake surface temperatures becomes more important as the horizontal resolution of the weather forecast models increases.



Lake Regions: Finland, Karelia

How Important is the lake representation?

Example from first tests in ECMWF



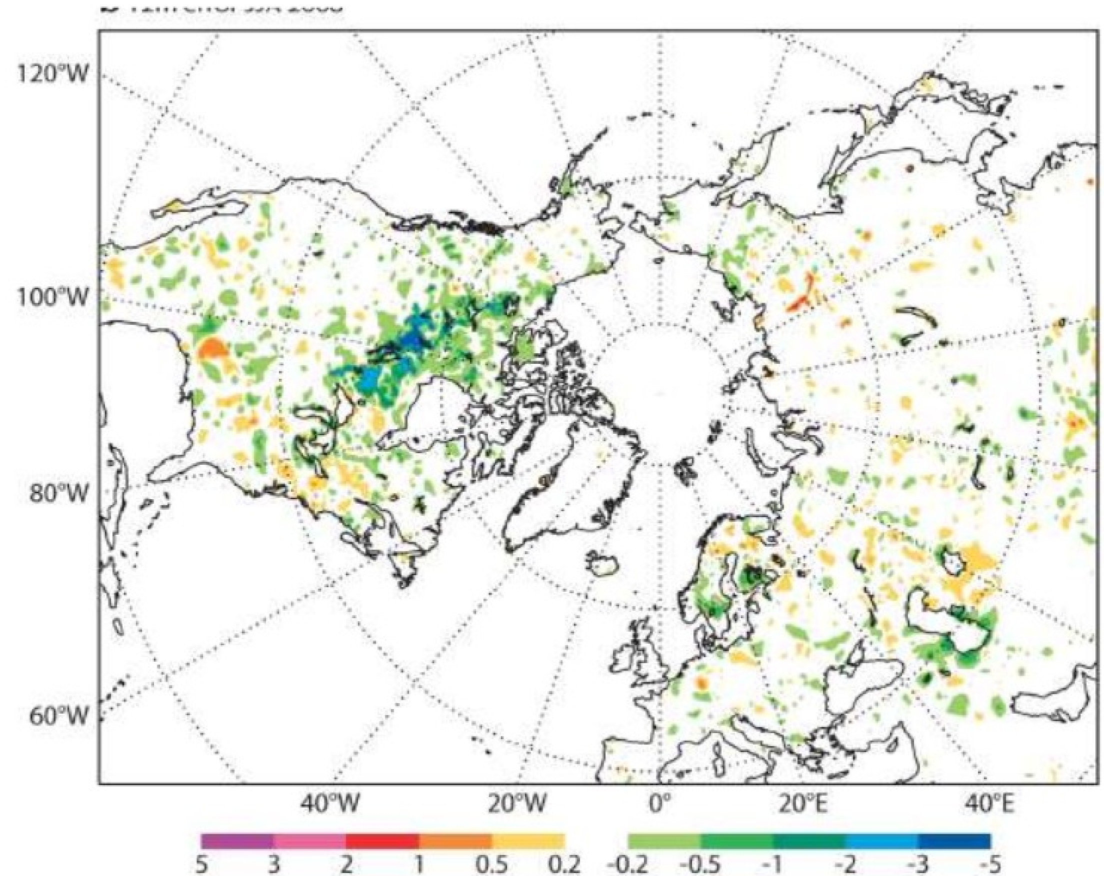
Sensitivity of 48-hour near surface temperature forecast (LAKE – NOLAKE)
- Sets of 10-day forecasts covering one full year (1988) at 50 km resolution with the operational IFS. Two experiments were performed with (LAKE) and without (NOLAKE) FLake activated.

Balsamo, G., R. Salgado, E. Dutra, S. Boussetta, T. Stockdale, M. Potes, (2012). Tellus

How Important is the lake representation?

Example from first tests in ECMWF (in climate mode)
Impact of interactive lakes on the T2m

- *A positive impact in spring and summer particularly over the North American lakes region and the European large lakes areas.*
- *In Winter, deteriorates T2m over central Canada while it improves in the eastern North America*
- *In Autumn the impact is milder, with improvement over Scandinavia*
- *Overall the impact is positive*

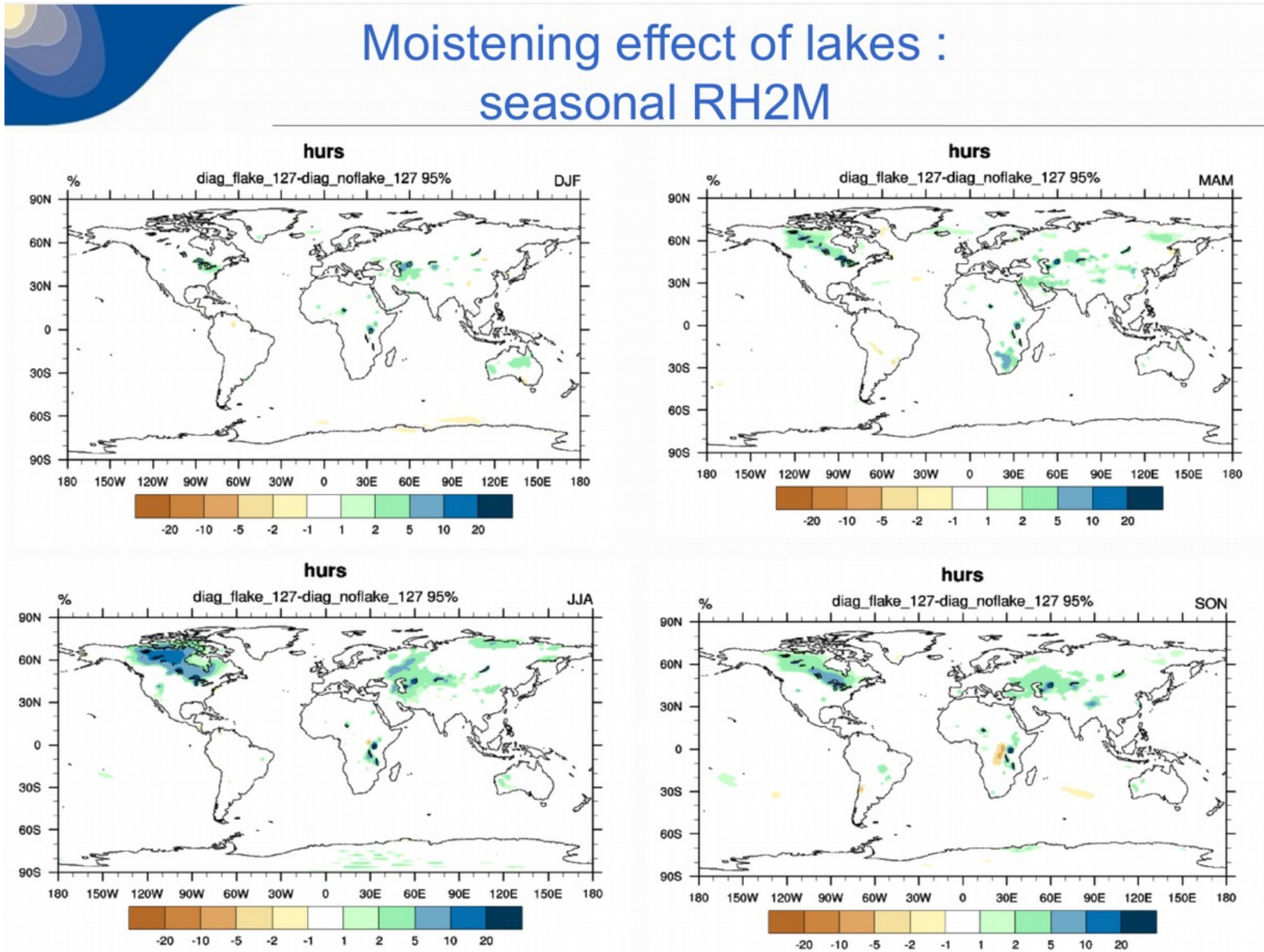


Impact of 48-hour T2m forecasts (valid at 00 UTC) for LAKE compared to NOLAKE, verified against the ECMWF T2m analysis: Mean Absolute Error difference for JJA 2008. Negative values indicate an improvement (MAE reduction)

How Important is the lake representation?

Example from CNRM-CM (Climate Run)

Le Moigne, 2105



Types of Lake Parametrization Schemes

- Full 3D lake models, like ocean models. Very expensive computationally
- Multi-layer 1D models.
  - K-models with convective adjustment
  - TKE evolution - 1.5 turbulence closure models

  Also expensive, but there are some examples
- One-layer models. Don’t account for stratification. Large errors
- A compromise between **physical realism** and **computational economy**

A two layer-model with a parametrized vertical temperature structure

↓

FLAKE

Developed by Dmitrii Mironov ***: Let's go to the source***

Comparison between models are made in the framework of Lake MIP (Setepanenko et al., 2011, 2103)

The Flake model

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Lake Parameterization Scheme *FLake* in NWP Models COSMO and ICON: Status and Plans

Dmitrii Mironov

German Weather Service, Offenbach am Main, Germany

(dmitrii.mironov@dwd.de)

4th Workshop "Parameterization of Lakes in Numerical Weather Prediction and Climate Modelling"
and COST ES1404 WG3 Meeting, Évora, Portugal, 7-9 May 2015

The Lake Parameterization Scheme "FLake"

The scheme (Mironov 2008, Mironov et al. 2010, Kirillin et al. 2011) is based on the idea of self-similarity (assumed shape) of the evolving temperature profile. Instead of solving partial differential equations (in *z*, *t*) for the temperature and turbulence quantities (e.g. TKE), the problems is reduced to solving ordinary differential equations for time-dependent ***parameters*** (variables) that specify the temperature profile. These are (optional modules)

- the mean temperature of the water column,
- the surface temperature,
- the bottom temperature,
- the mixed-layer depth,
- the shape factor with respect to the temperature profile in the thermocline,
- the depth within bottom sediments penetrated by the thermal wave, and
- the temperature at that depth.

In case of ice-covered lake, additional prognostic variables are

- the ice depth,
- the temperature at the ice upper surface,
- the snow depth, and the temperature at the snow upper surface.

Schematic representation of the evolving temperature profile

Surface or mixed layer temperature, θ_s

Bottom temperature, θ_b

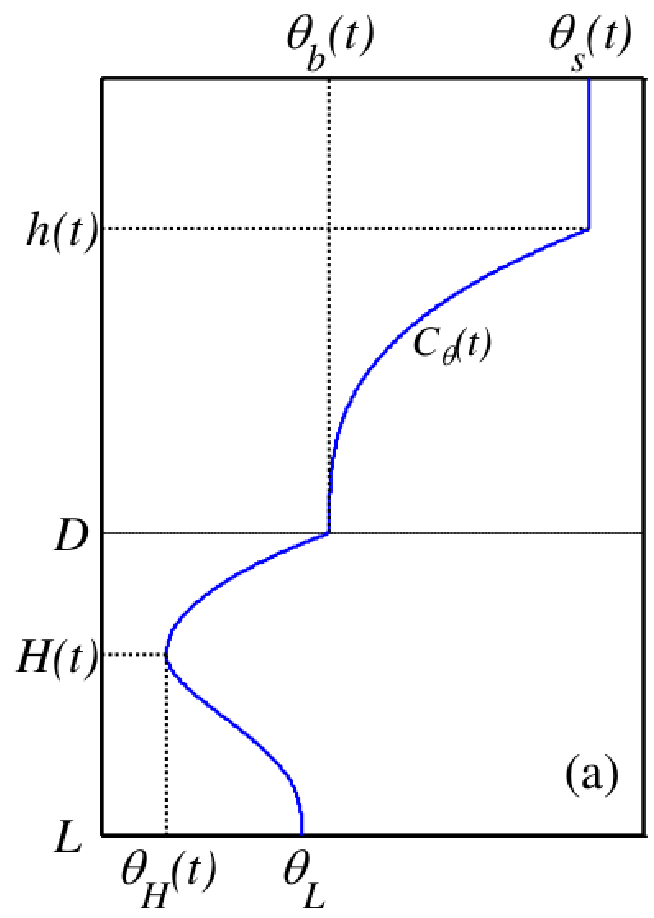
Mixed layer depth, h

Shape factor , C_T

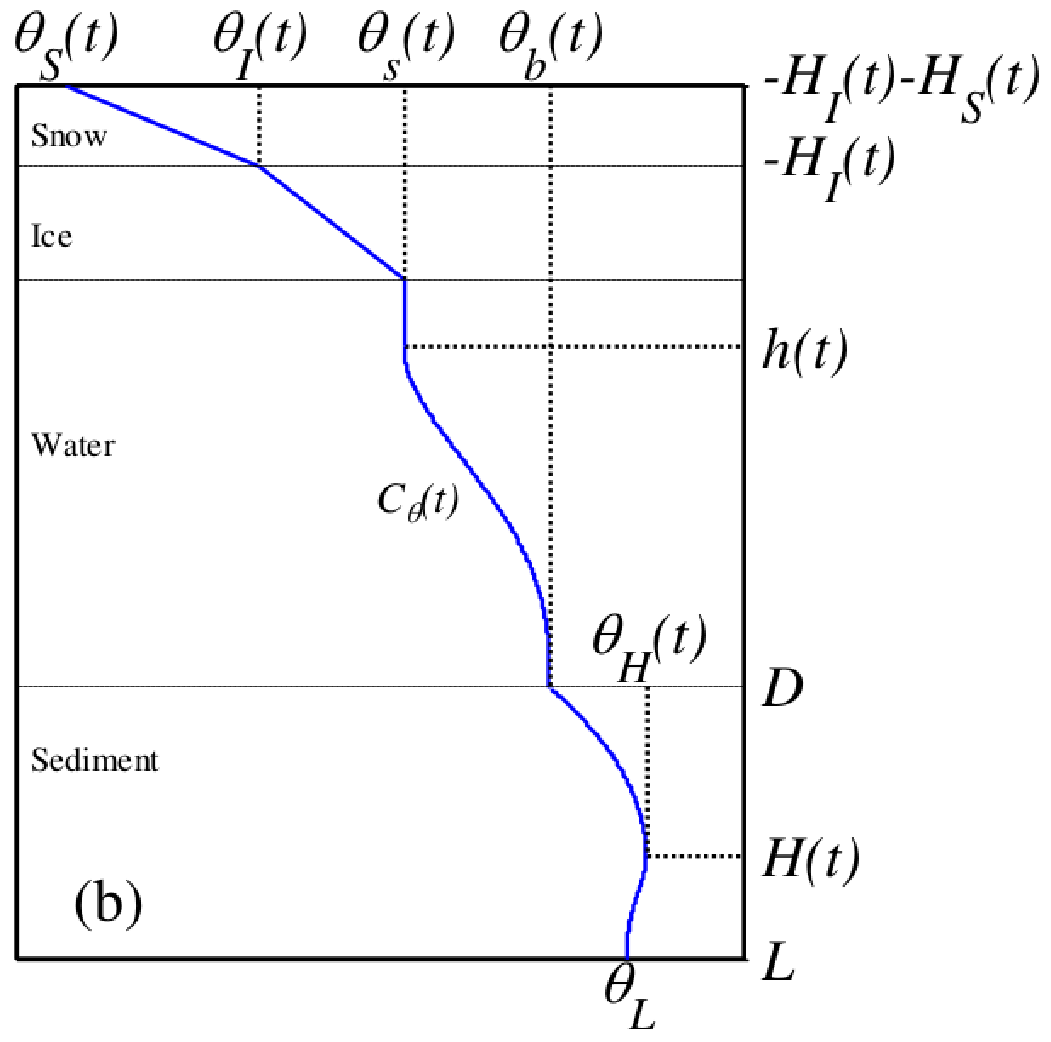
Mean water temperature, $\bar{\theta}$

Only 4 independent

Evolution are computed by integral budgets of heat and kinetic energy.



(a) The evolving temperature profile is characterised by several time-dependent variables, namely, the temperature $\theta_s(t)$ of the mixed layer, its depth $h(t)$, the bottom temperature $\theta_b(t)$, and the temperature-profile shape factor $C_\theta(t)$. Optionally, the depth $H(t)$ within bottom sediments penetrated by the thermal wave and the temperature $\theta_H(t)$ at that depth can be computed.



(b) For ice-covered lakes, additional variables are the temperature $\theta_I(t)$ at the ice upper surface and the ice thickness $H_I(t)$, and (optionally) the temperature $\theta_S(t)$ at the snow upper surface and the snow thickness $H_S(t)$.

FLake in NWP and Climate Models: External Parameters

- **lake fraction** (area fraction of an atmospheric model grid box covered by lake water)
- **lake depth**

Data set is developed by Kourzeneva (2010), Kourzeneva et al. (2012), and Choulga et al. (2014).

Let's go to the source

Status and progress in GLDB developments

Margarita Choulga, RSHU
Ekaterina Kurzeneva, FMI

GLDBv1

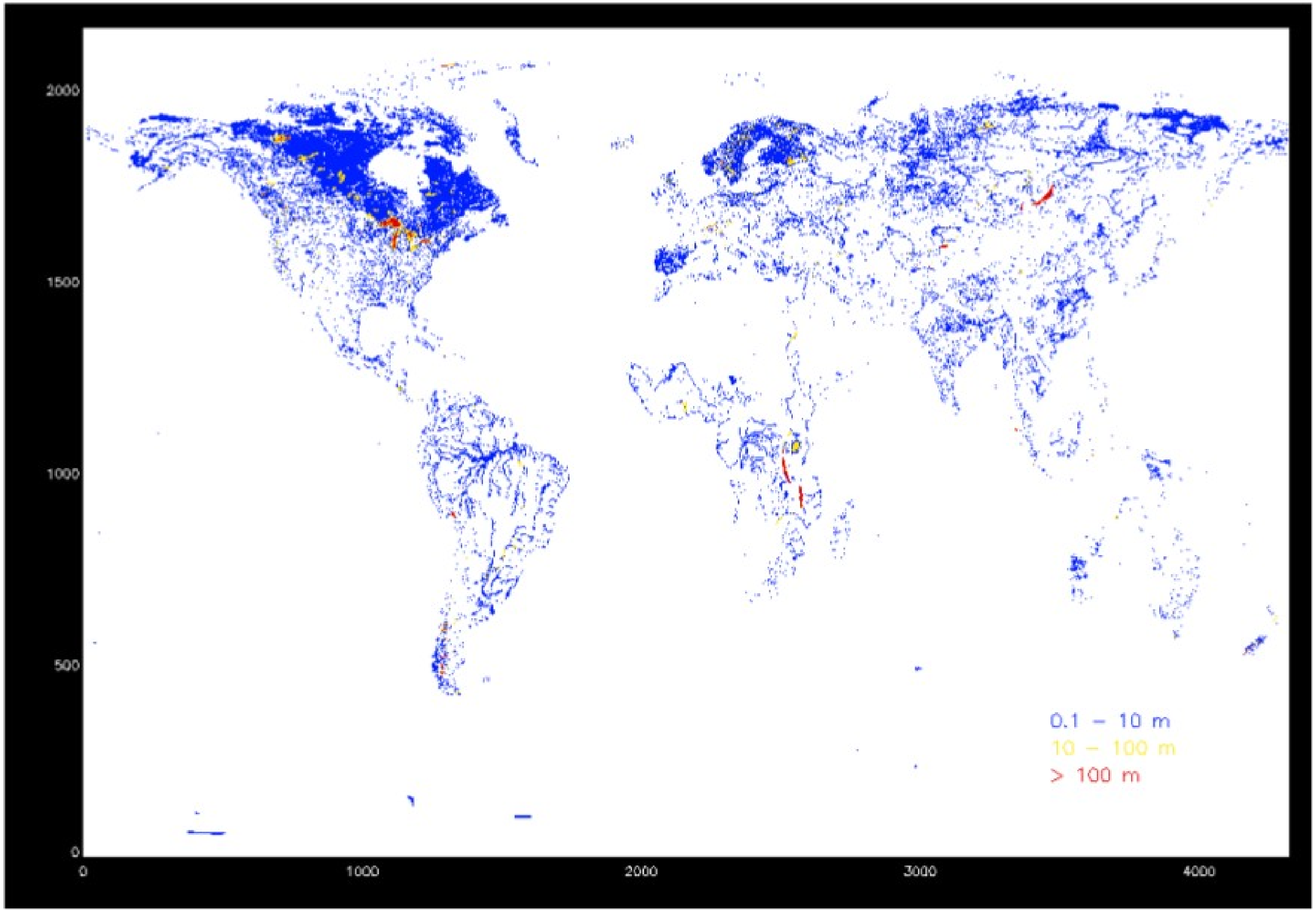
- The **individual lake list** consist of ≈ **13’000 lakes**.
- The global gridded lake depth data set includes information about real lake depths and “default” lake depth.
- The additional global gridded data set containing coded information about sources of data was made.
- **Only** data on **freshwater lakes** are processed (data on saline lakes are skipped).
- The **“default” lake depth** is set to the value of **10 m**.

GLDBv3

- The **individual lake list** from GLDBv1 was **increased by ≈ 1'500 lakes**.
- The global gridded lake depth data set from GLDBv1 was completed with **indirect estimates of the mean lake depth** from the geological origin **for the whole world** (we additionally allocated **233 regions** with homogeneous geological origin of lakes).
- The **analytical equations** approximating statistical dependencies distributions **of the mean lake depth** for different climate zones depending on the lake area were **updated**.
- The additional global gridded data set containing coded information about sources of data was updated.
- All data (on **fresh-water and saline lakes**) are processed.
- The "default" depth for fresh-water lakes and saline lakes is different – **"default" fresh-water lake depth** is set to the value of **10 m** and the **"default" saline lake depth** is set to the value of **5 m**.
- Were introduced: **list of artificial (man-made) lakes and reservoirs** with unknown depths – the "default" depth value of **10 m**; **list of crater and caldera lakes** – the "default" depth value of **50 m**.

Global map of lake depth

Lake depth data from GLDBv1 implementation in ECMWF at 30sec arc resolution



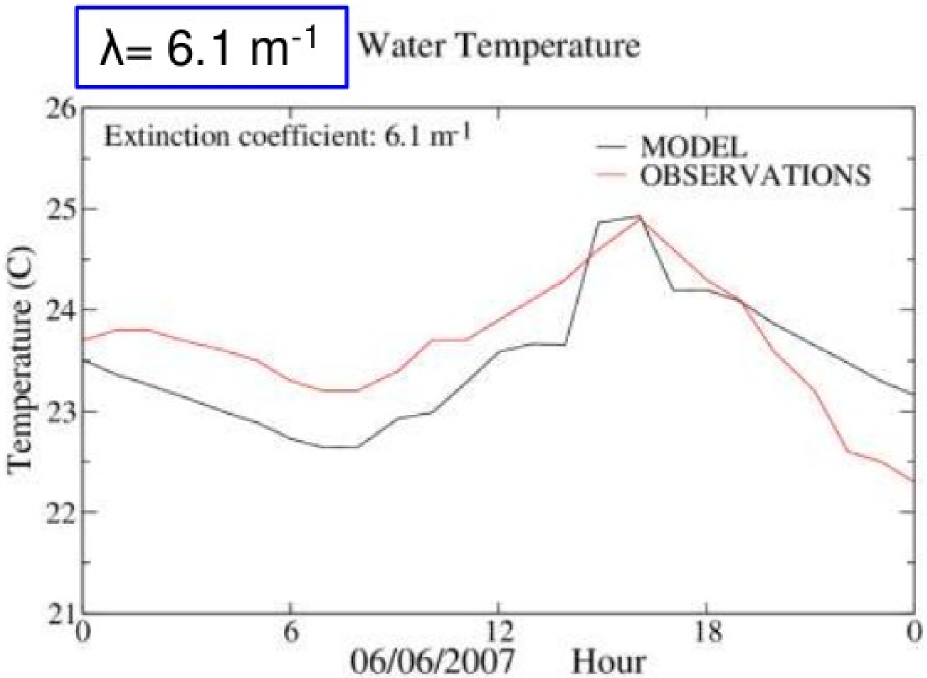
FLake in NWP and Climate Models: External Parameters

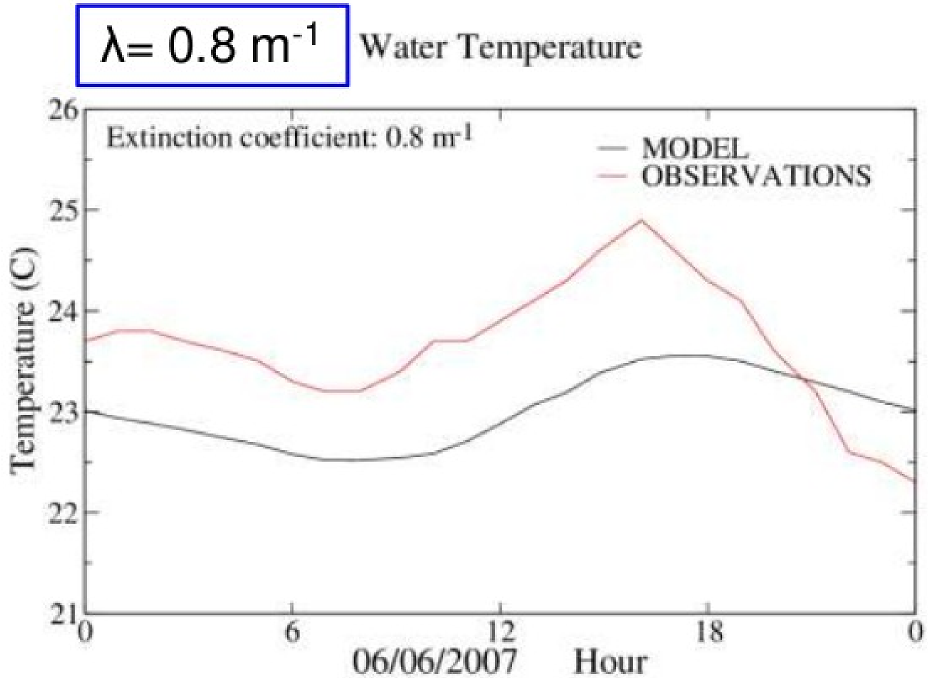
- **lake fraction** (area fraction of an atmospheric model grid box covered by lake water)
- **lake depth**

Data set is developed by Kourzeneva (2010), Kourzeneva et al. (2012), and Choulga et al. (2014).

- Default values of wind fetch, optical characteristics of lake water (extinction coefficients with respect to solar radiation), depth of the thermally active layer of bottom sediments and temperature at that depth (not needed if bottoms sediment module is switched off)

How important is the the extinction coefficient





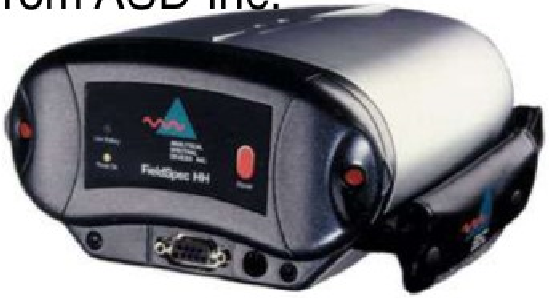
Example of a study about the sensitivity of water surface temperature to the Extinction coefficient.
Observations at Alqueva reservoir (in Portugal). Figures show two extreme cases

Potes, et al., 2012 (EMS Young Scientist Award)

Determination of the extinction coefificient

An optical fibre was used to measure in-water radiance, at several levels, in order to calculate the extinction coefficient (spectral).

portable spectroradiometer (FieldSpec UV/VNIR) from ASD Inc.



THAUMEX EXPERIMENT, August 2011

Le Moigne et al., 2013

State of art
on interactive Lakes implementations in Numerical Weather Prediction Models in Europe
ICON/COSMO (DWD), IFS (ECMWF), SURFEX (MF), UM (UK), HIRLAM

FLake within COSMO-EU/DE (DWD)

Flake is used operationally at DWD since 15 December 2010 within COSMO-EU (ca. 7 km horizontal mesh size), and since 18 April 2012 within COSMO-DE (ca. 2.8 km mesh size).

- Results of testing of COSMO-FLake are neutral to slightly positive.
- Verification against observational data indicate an improvement of some scores such as 2m-temperature in regions where many lakes are present (e.g. Scandinavia).
- The use of FLake allows to avoid some unwanted situations, e.g. an artificial cold air outbreak. This may occur in winter when a lake that is frozen in reality (low surface temperature) is treated as open water (high surface temperature) within COSMO due to the shortcomings of water surface temperature analysis scheme.

(Returning to the presentation of Mironov, LAKE 2015, in Évora)

FLake within ICON-NWP (DWD)

Flake is used operationally at DWD since 20 January 2010 within ICON-NWP (ca. 13 km horizontal mesh size)

- Tiled surface scheme is currently used, effect of SGS lakes with FR_LAKE>0.03 is accounted for
- The performance of FLake within ICON (and COSMO) is monitored

Monitoring of FLake Performance

- FLake prognostic variables (+ FR_ICE and surface fluxes) are retrieved from the DWD data bank (initial values form 00 UTC) and plotted
- Sanity check is performed and a warning e-mail message is sent if things go wrong (OK is sent if things look good)
- Monitoring results from the last week are available via DWD Intranet, results from the last months are stored in the archive

FLake in SURFEX

General context

➲ **Improvement of lake parameterization in MF models**

Due to the increase of horizontal resolution in models
Need to improve the diurnal cycle over lake areas
A step forward to data assimilation

➲ **SURFEX implementation of FLake model**

Salgado and Le Moigne, 2010

➲ **Field Campaigns validations**

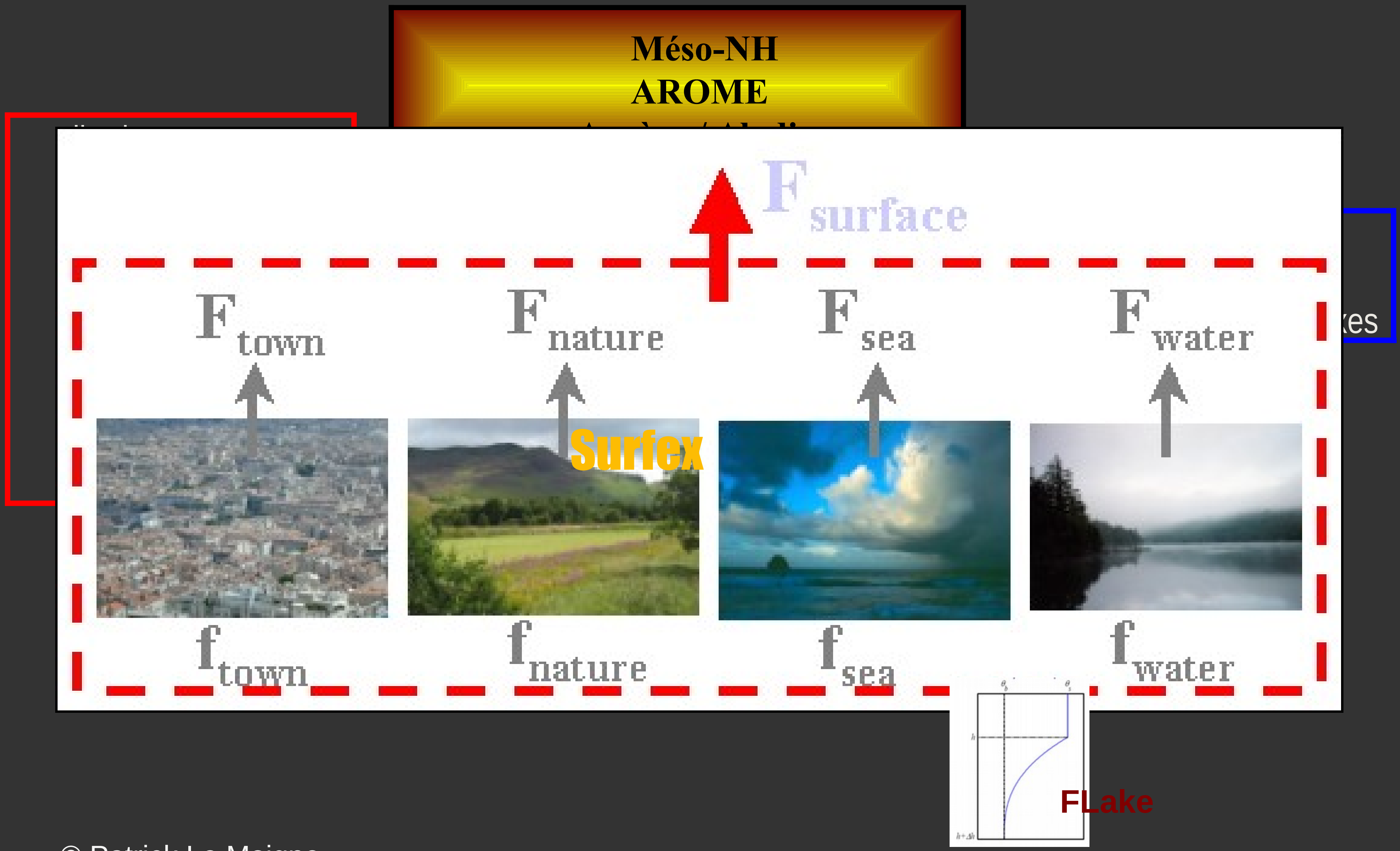
THAUMEX, South-France : Le Moigne et al., 2013

➲ **CNRM-CM implementation**

Improve lake representation in global climate model
A component of the next IPCC exercise with CNRM-CM

P. Le Moigne, J. Colin, B. Decharme

Implementation of FLake in SURFEX

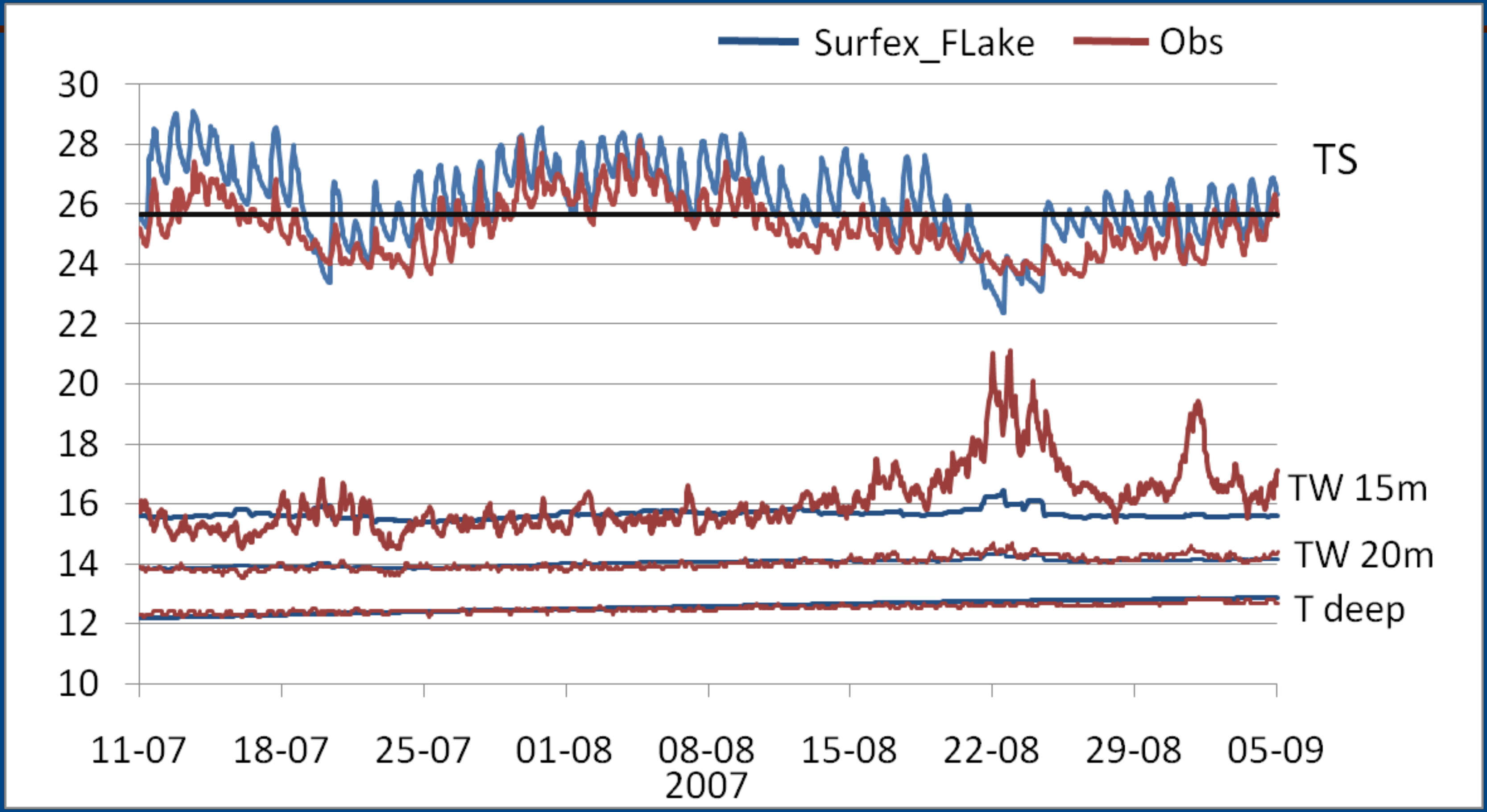


Flake inside SURFEX (technical aspects)

- Although not in Meso-NH norms, the original FLake code was remained as it is in http://nwpi.krc.karelia.ru/flake/ (for future compatibility)
- An interface (flake_interface.f90) to communicate with SURFEX is used.
- FLake code is prepared for single-column applications. So, The flake_interface calls the flake routines inside a DO loop over the horizontal grid points where lakes are present.
- The coupling is explicit.
- The fluxes are computed before the advance of flake variables, namely of the Surface Temperature.
- The fluxes of momentum and of sensible and latent heat may be computed using the routines provided by FLake (SfcFlx routines) or by the SURFEX WATER_FLUX routine.
- All the routines for the pre and pos processing have been modified in accordance.

(Salgado & Le Moign, 2010)

Validation of Water Temperature against Alqueva data



- TS_FLK_WFLX > TS_Obs
- Good correlation
- Bias de TS_FLK_WFLX > TS constant (for this period Ts_WATFLX ~ mean(Ts_obs))

	correlation	Bias	RMSE
FLK_WFLX	0.85	0.9	1.1
WATFLUX	0.0	0.2	1.2

FLake in SURFEX / CNRM-CM

Model settings

- The limitation of depth to 60m for FLake is mandatory
- The too long ice cover duration was improved by limiting the albedo of ice to 0.4
- The setting of the light extinction coefficient to 0.5 (clear water) improved significantly surface temperature annual cycle
- Using a skin temperature module improved slightly the results

Global evaluation

- FLake was coupled to CNRM-CM model
- High cooling effect of ~3K particularly during summertime
- Associated to a moistening effect : +10 % in JJA and +5% in MAM and SON
- More QE in JJA : +15W/m² due to a moister air
- Less QH in JJA : -15W/m² due to thermal effects (inertia)
- Weak impact on precipitation, surface pressure
- Over Great Lakes region,
    - DJF evaporation bigger : lakes not frozen compared to ground covered by snow
    - Wind speed impact localized : bigger all the time due to roughness effects
    - Relatively high impact on radiative budget components

Interactive lakes in the ECMWF Forecasting System: results from the first season

Gianpaolo Balsamo, Emanuel Dutra, Irina Sandu, Anton Beljaars and several others
Research & Forecast Departments, ECMWF

Lakes in IFS system: a collaborative effort involving Member-state scientists

Operational implementations

Lake model (FLake) for resolved and sub-grid water bodies was successfully implemented in the IFS cycle 41r1, on the 11th of May 2015.

- **Tiling extension** including separate long-wave energy balance for each tile, account for sub-grid lake ice cover, land-use coupling coefficients is foreseen for future cycle in 2016.
- No snow and no bottom sediments

- Lakes were successfully implemented in the ECMWF IFS system in May 2015 and preliminary results are encouraging
- This development added a tile that was previously missing (also small lakes are represented thanks to the tiling approach)

Research results

Lake modelling research at ECMWF was conduct in collaboration with DWD/FMI/MF/IPMA/U.Lisbon/Evora/Moscow:

Balsamo, G., 2013: Interactive lakes in the Integrated Forecasting System. ECMWF Newsletter 137, page 30-34. http://old.ecmwf.int/publications/newsletters/pdf/137.pdf

Manrique-Suñén, A., A. Nordbo, G. Balsamo, A. Beljaars, and I. Mammarella, 2013: Representing Land Surface Heterogeneity: Offline Analysis of the Tiling Method. J. Hydrometeor, 14, 850–867. doi: http://dx.doi.org/10.1175/JHM-D-12-0108.1

Balsamo, G., R. Salgado, E. Dutra, S. Boussetta, T. Stockdale, M. Potes, 2012: On the contribution of lakes in predicting near-surface temperature in a global weather forecasting model, Tellus-A, 64, 15829, DOI: 10.3402/tellusa.v64i0.15829

Dutra, E., V.M. Stepanenko, G. Balsamo, P. Viterbo, P.M. Miranda, D. Mironov, C. Schär, 2010: Global offline lake simulations: Validation and Impact on ERA-Interim, Bor. Env. Res., 15, 100-112.

Balsamo G., E. Dutra, V.M. Stepanenko, P. Viterbo, P.M. Miranda, D. Mironov, 2010: Deriving an effective lake depth from satellite lake surface temperature data: A feasibility study with MODIS data, Bor. Env. Res., 15, 178-190.

Transferring Research to Operations

Lakes research and development at ECMWF (2010-2014) in collaboration with DWD/MF/FMI/U.Lisbon/IPMA/Evora/Moscow supported the implementation and verification aspects.

In 2013-2015 technical work enabled operational implementation in May 2015:

Operational use required **PROBLEM SOLVING & DOCUMENTATION** and involved a lot of work in particular for:

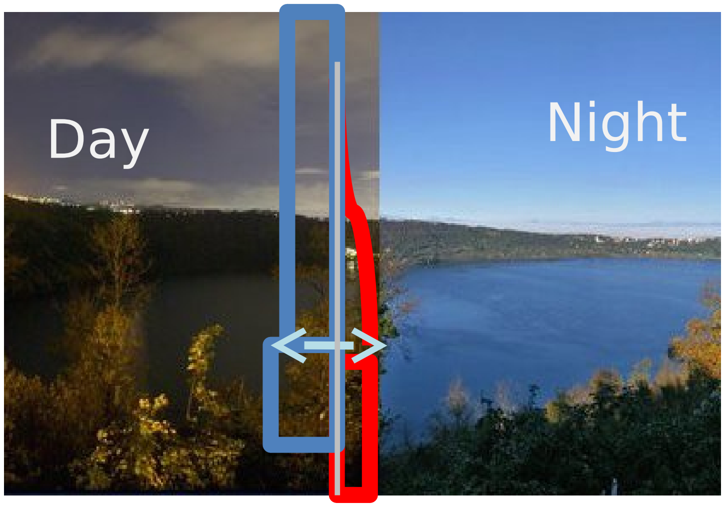
COLDSTART procedures for all ECMWF forecasts and past reforecasts

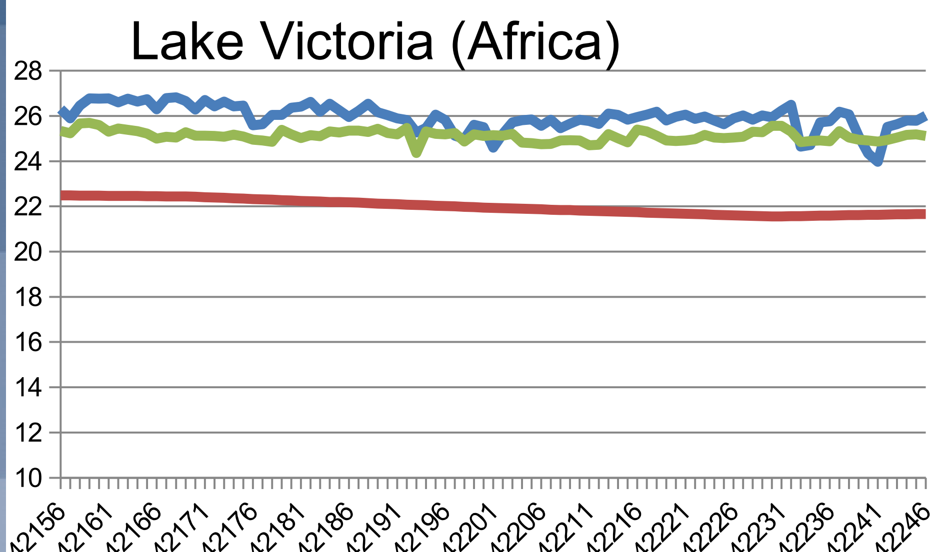
INITIALISATION procedure active for Caspian Sea, Azov Sea, US Great Lakes

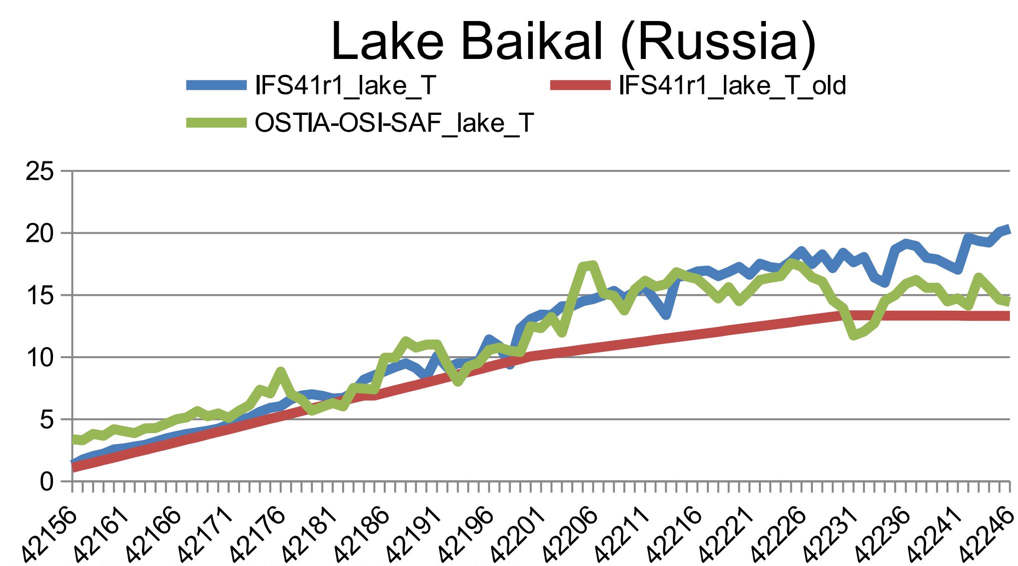
LAKE FILES GENERATION procedure to interpolate Lake Depth and Cover

IFS DOC Part IV-Chapter 8, extension of description to include the lake tile

https://software.ecmwf.int/wiki/download/attachments/48104914/IFSPart4.pdf



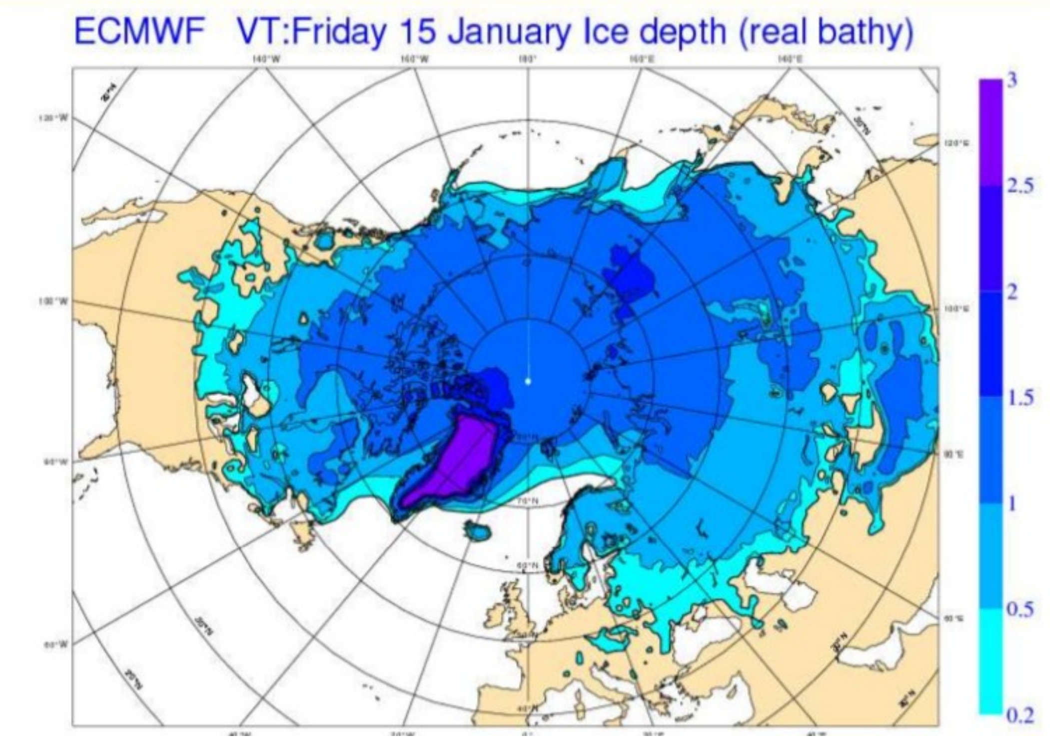




Large improvements reducing the bias of temperature for lakes such as Lake Victoria, Great Bear, Titicaca and generally more realistic variability

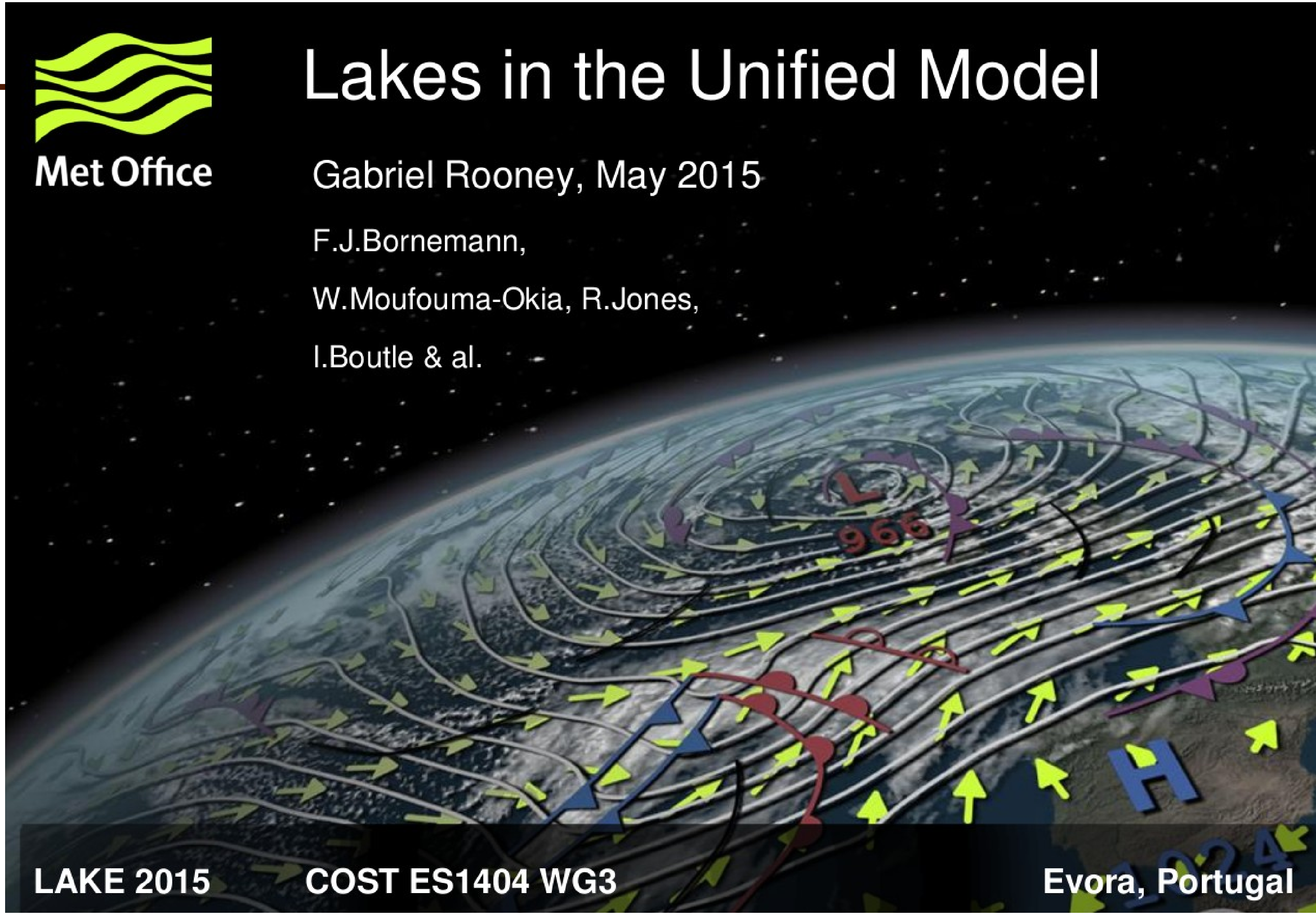
(Cold start)

- How to obtain initial values for cold starts?
  - 6 FLake variables (4 water + 2 Ice)
- Lake Planet experiment
  - lakes overall (lake fraction = 1 in all grid points)
  - Forcing ERA-Interim reanalysis (1989 - 2009)
  - 3 hourly atmospheric input data
  - N128 grid (resolution ~80km)
- A monthly climatology of FLake variables has been created



Example
Climatological Ice Depth (Above water)

(Balsamo et al., 2012)


Lakes in the Unified Model
Met Office
Gabriel Rooney, May 2015
F.J.Bornemann,
W.Moufouma-Okia, R.Jones,
I.Boutle & al.
LAKE 2015
COST ES1404 WG3
Evora, Portugal

ICT

Met Office

FLake – MetUM coupling

- MetUM : the **Met Office Unified Model** for weather and climate prediction
- Separate code repositories are combined into a single executable.
- Coupling through the MetUM / **JULES** land-surface tile scheme.
    - JULES : Best et al. *and* Clark et al. (GMD, 2011)
- **FLake** provides the subsurface temperature and conductivity for the lake tile.
    - Rooney & Jones (BER, 2010)
- *Lake depths* come from the dataset accompanying FLake.
    - Kourzeneva et al. (Tellus, 2012)
- *Initialisation* is based on the MetUM surface and soil temperatures.

Conclusions

- FLake/MetUM coupling and testing has been carried out successfully.
- FLake performance seems to be a gauge of atmosphere - surface coupling strength.
- Licensing issue is delaying further use of FLake!
- Lakes are a current area of interest, particularly the model representation of African lakes for NWP/climate modelling.

Data assimilation with EKF for FLake: problems and perspectives

Ekaterina Kourzeneva

Why data assimilation for lakes is needed?

- To combine a lake model (parameterization) with lake observations
- To initialize prognostic variables of a lake model (parameterization)
- To correct model errors, which come from the uncertain initial state
- To get better knowledge about some unmeasured lake characteristics from measured ones (reanalysis)

Data assimilation for:

- Lake model: FLake, 1D aspect
- Lake observations: the lake surface temperature
- Method: Extended Kalman Filter

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Conclusions, perspectives:

- EKF algorithm to assimilate LWST in FLake gives promising results
- Components of vector H and matrix M evolve smoothly, show annual cycle: potential for simplifications
- Early spring observations are important, they may affect results on the deep water temperatures in summer
- Better specification of Q matrix (need observations of water temperature profiles)
- Study other components of EKF (B matrix, K vector), more a posteriori statistics
- Model bias corrections …
- Implementation … into SURFEX … HARMONIE

Verification

Towards a lake operational monitoring

June-July-August 2015 (91-days AN vs OSTIA-lake)

Lakes verification in the first three full months of operations show large improvements on the majority of lakes as verified with satellite products (OSTIA)

Lake AFRICA	RMSE	BIAS	CORRELATION	Mean Model	Mean Obs	Stdev Model	Stdev Obs
Victoria_IFS41R1	**0.957**	**0.826**	0.491	25.665	24.849	0.554415	0.230933
Victoria_IFS40R1	3.157	-3.14	0.328	21.743	24.849	0.322463	0.230933

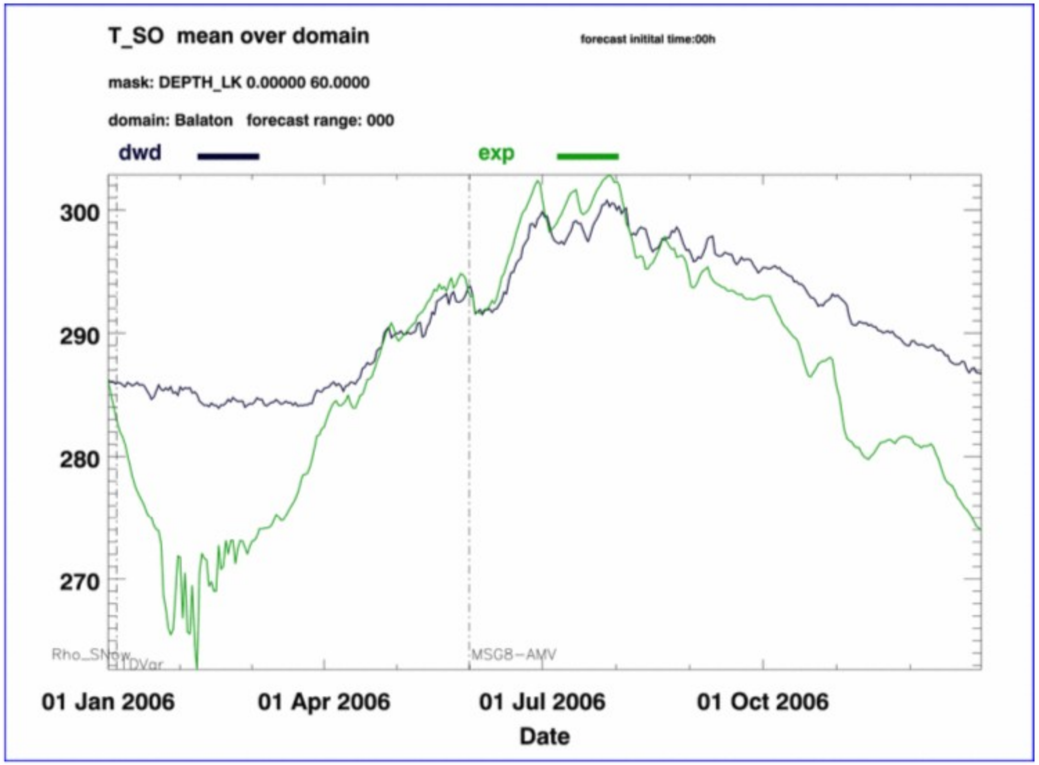
Lake CANADA	RMSE	BIAS	CORR	Mean Model	Mean Obs	Stdev Model	Stdev Obs
Great_Bear_IFS41R1	**2.875**	**1.877**	0.927	5.225	3.368	3.87317	1.96852
Great_Bear_IFS40R1	5.401	4.598	0.894	7.916	3.368	4.45394	1.96852

Lake S. AMERICA	RMSE	BIAS	CORR	Mean Model	Mean Obs	Stdev Model	Stdev Obs
Titicaca_IFS41R1	**0.611**	**-0.425**	0.822	12.322	12.742	0.739826	0.482809
Titicaca_IFS40R1	3.804	-3.789	0.752	8.995	12.742	0.463688	0.482809

Lake EU	RMSE	BIAS	CORR	Mean Model	Mean Obs	Stdev Model	Stdev Obs
Ladoga_IFS41R1	**2.45**	**2.051**	0.958	14.207	12.178	4.22985	4.60613
Ladoga_IFS40R1	1.443	-0.295	0.984	11.886	12.178	3.3881	4.60613

Lake sub-grid EU	RMSE	BIAS	CORR	Mean Model	Mean Obs	Stdev Model	Stdev Obs
Haukivesi_IFS41R1	**1.706**	**-0.02**	0.807	15.188	15.207	2.24239	2.88615
Haukivesi_IFS40R1	2.915	-2.733	0.964	12.504	15.207	3.44774	2.88615

Verification of Operational Results



Can we plot data from "operational-type" observations, at least for some lakes?

FLake in COSMO, results from parallel experiment, 1 January - 31 December 2006.
Lake Balaton, Hungary (mean depth = 3.3 m)

- Black – lake surface temperature from the COSMO SST analysis
- Green – lake surface temperature computed with FLake

Future work

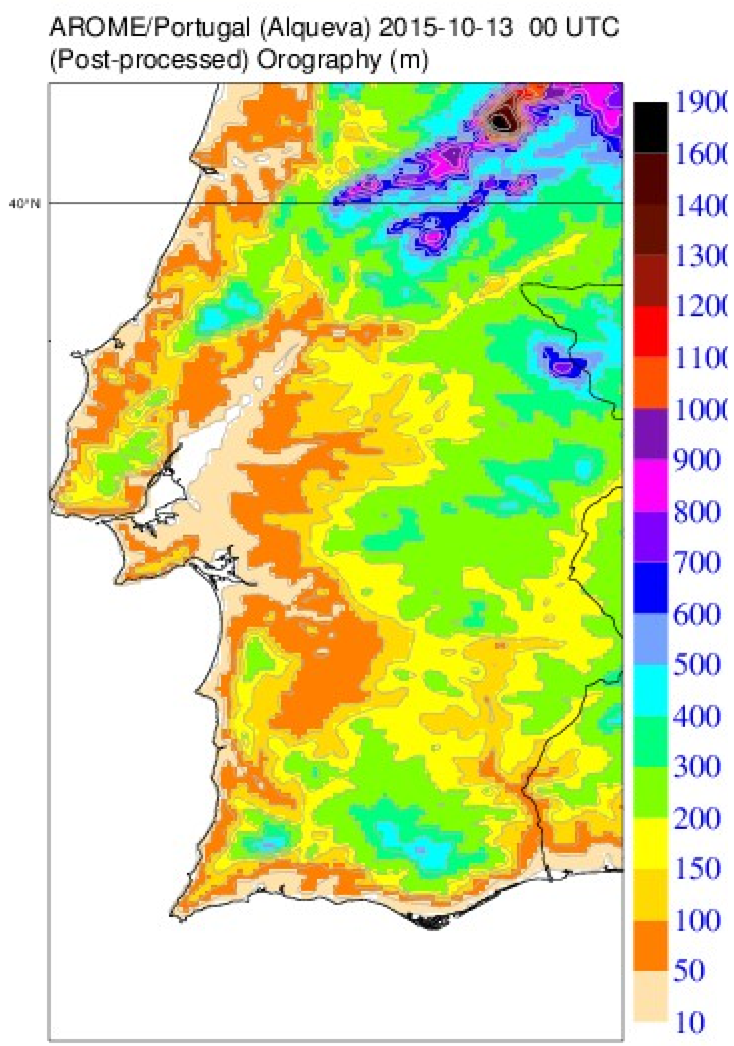
Test Flake in AROME Portugal

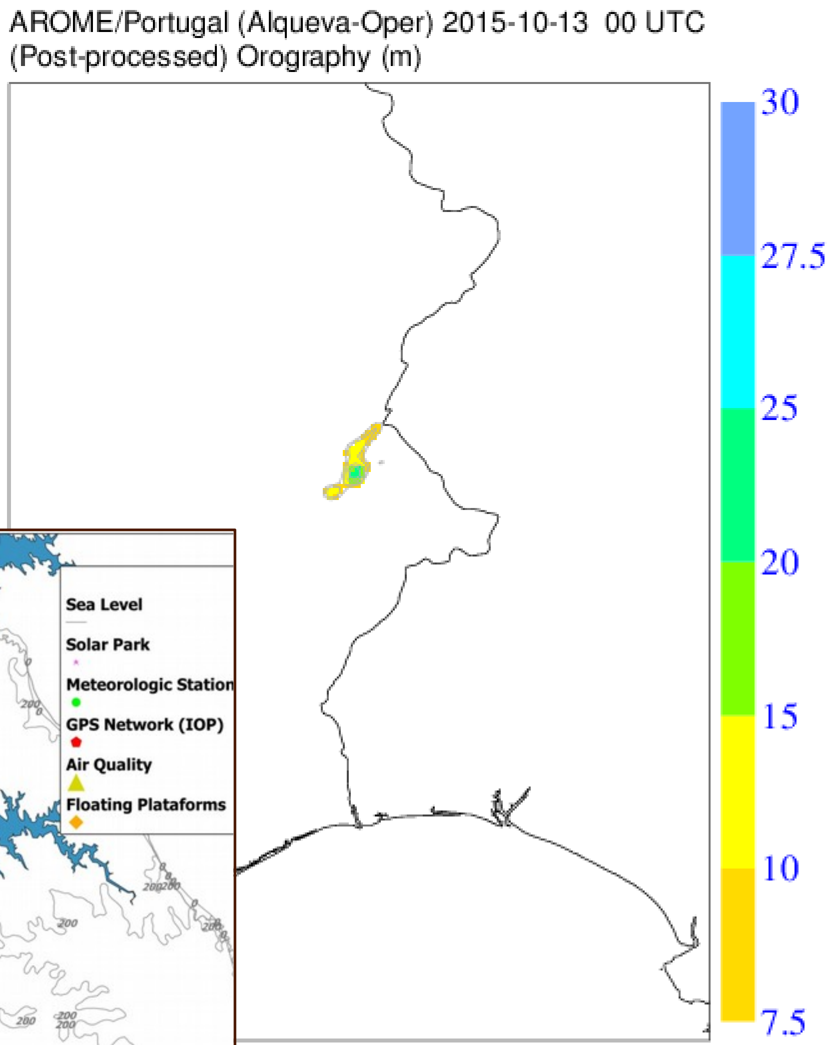
- Centered on the effects on a large man made lake (250 km^2): Alqueva
- Collaboration IPMA / UE
  - Maria José Monteiro, Manuel João Lopes, Rui Salgado, Carlos Policarpo
- Start in September 2015
- Steps:
  - Introduction of Alqueva in ECOCLIMAP and all physiography
  - Test / verify the impact
  - Activate Flake
  - Validate

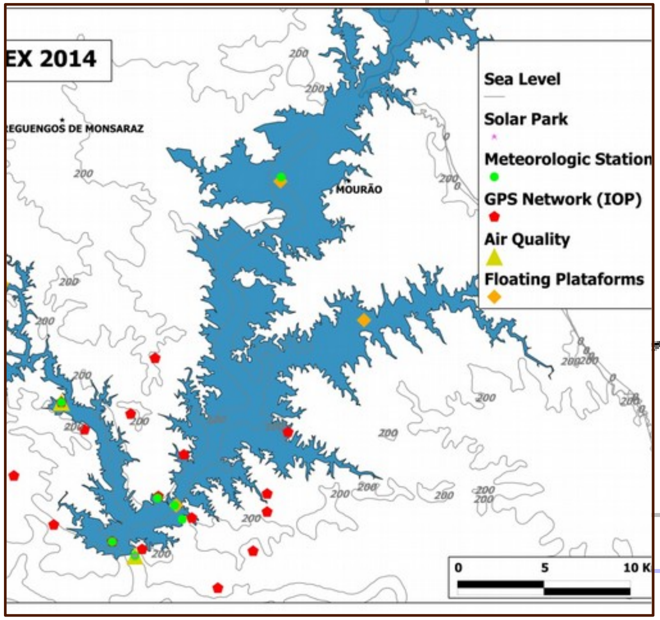
Instrumented Platform in Alqueva reservoir

Introduction of Alqueva in physiography

First step







- Future research will aim at introducing improved datasets (lake cover and bathymetry) and revise modelling assumption (e.g. average turbidity)
- Engaging with lake modelling and NWP community also for operational verification of the forecasts will be desirable
- Lake data assimilation will require dedicated efforts to improve from current simple procedures (nudging used for US Great-Lakes, Caspian and Azov Seas) and extension to more lakes.

Future Work: Explicit Treatment of Snow

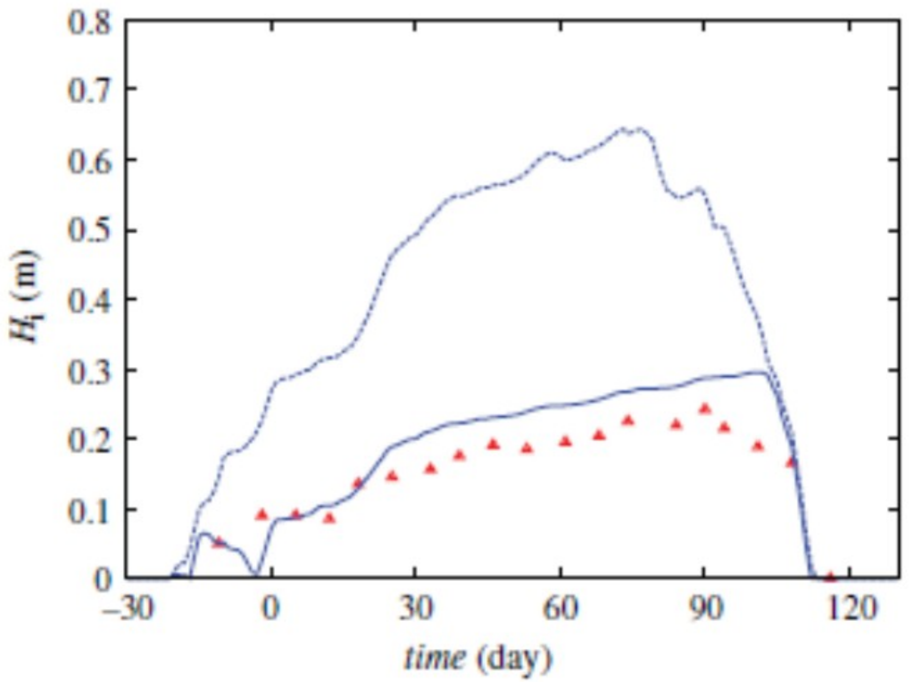


Fig. 9. Ice thickness in Lake Pääjärvi during winter 1999–2000, where day = 0 corresponds to 1 January 2000. Blue curves show results of simulations with FLake: solid curve – with a snow layer above the ice, and dashed curve – no snow above the ice. Red symbols show observational data.

Results of simulations with tuned snow density and snow heat conductivity (Mironov et al. 2012).

Mironov, 2015

Future Work: Extension to Salt Water

Work started (c/o DM), however… there are issues that require research efforts

- Equation of state (cf. salinity in the ocean)
- Bottom boundary condition for salt concentration
- Initial conditions (e.g. total amount of salt in lake)
- Lake water budget

Conclusions from LAKE2015

- There is considerable progress in using lake parameterization schemes within operational NWP models in many weather forecast centres of Europe.
  - A lake parameterization scheme FLake is used operationally within ECMWF IFS, UM, COSMO, ICON, and HIRLAM (the use of a lake parameterization scheme within a new NWP system HARMONIE is planned). MeteoFrance plans to represent lakes in the global NWP system ARPEGE. ECMWF plans to run a version of IFS with parameterized lakes for the ensemble forecasts.
- Using different forecasting systems, sensitivity studies are performed that showed a substantial impact of parameterized lakes on the forecast quality.
  - The improvement of some forecast skill scores is clearly shown, but more studies are needed as well as careful monitoring and analysis of operational results.

Conclusions from LAKE2015

- Lakes are an important component of climate system, and the impact of lakes depends on the scale considered. On regional scales, lakes influence the screen level temperature, cloudiness, and precipitation. On the global scale, lakes represent an important greenhouse gas source. The representation of CO2 and CH4 transport in lake models is recognized to be important.
  - Lake models including internal wave parameterizations are being developed in the community of limnologists, and some models are coupled to the atmospheric models (e.g. models of large lakes). However, development of fully coupled modelling systems operating on a global scale is still a long-term goal. An important co-operation with the community of limnologists is provided via LakeMIP project.
- The LakeMIP project makes considerable progress, being strengthened by the co-operation with the ASLO community. A large number of lake models participate in the inter-comparison studies ranging from simple force-restore-like models to sophisticated 3D models (such as POM and NEMO).
  - The LakeMIP community is open, new participants are welcome to join.

Conclusions from LAKE2015

- Observations are vitally important.
  - Operational measurements over selected lakes are needed to monitor the performance of lake parameterization schemes in operational NWP models and to validate lake models within the framework of inter-comparison projects.
  - Flux measurements, including measurements of greenhouse gas fluxes, are particularly valuable for model development and validation.
  - Measurements of water turbidity and of optical parameters of snow and ice should provide improved estimates of model parameters.
  - Regular in situ measurements in lake regions (such as SYKE measurements in Finland) and remote sensing observations may/should be used for data assimilation.
  - There are a lot of efforts being made to collect more observational data and improve their quality. These efforts urgently need harmonization.

Conclusions from LAKE2015

- Operational results should be provided regularly for several observational lake sites where measurements are conducted both on a regular basis and during the field campaigns (intensive observation periods). Possible candidates for such "super sites" are Lake Kuivajärvi site and Alqueva Reservoir site, data from Lake Ngoring may also become available.
- University of Évora agreed to collect simulation results from different NWP centres and to start the development of a monitoring system (which is a difficult task), first, for the Alqueva Reservoir site, and the other sites may be added later.
- The SYKE measurements in Finland may also be used, but the permission from SYKE should be requested.
- Some satellite products, such as OSTIA water surface temperature and ice fraction data for large lakes, may also be used for monitoring. The NWP centres require a list of sites to be monitored and the information on the site locations.

Conclusions from LAKE2015

- More greenhouse gas flux measurements over lakes are needed. There is an initiative at FMI to create “Lake Carbon Portal” that should provide access to the existing data from measurements as well as to several important links.
- Information about various field campaigns, which provide a large variety of data from measurements including optical measurements, snow and ice measurements over lakes, biological and hydrological measurements, should be collected and made available via the FLake web page.
- An overview of remote sensing products for lakes, paying special attention to the information on snow and ice should be written.

Conclusions from LAKE2015

- Further development of data assimilation systems for lakes, which is vitally important to correct model errors, is in progress. ECMWF operationally uses nudging to assimilate OSTIA data. This experience may be used by the other NWP groups.
- Experiments with the EKF to assimilate in situ SYKE measurements show high potential. The required computational resources are rather moderate, but operational implementation needs more studies.
- Further development of the global lake database (GLDB) is in progress. Various versions of GLDB (version 3 has recently been released) are extensively used by many researchers to generate external-parameter fields (lake fraction, lake depth) for NWP and climate models. The database is constantly updated by including new data. First steps are made towards the sub-kilometre resolution.
- In 2015, the work on the GLDB development is supported by the ALADIN consortium. Beyond 2015, financial support is required and should be sought.

Conclusions from LAKE2015

- There is an idea to apply for a COST Action dealing with the lake-parameterization and related issues. A COST Action should facilitate co-operation and support harmonization of model development, simulation and observation activities. A COST proposal is to be drafted by the end of 2016.
- The next workshop on parameterization of lakes in planned for 2017. Possible host countries are China, Latvia, and Germany.

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