Interactive lakes in the ECMWF Integrated Forecasting System

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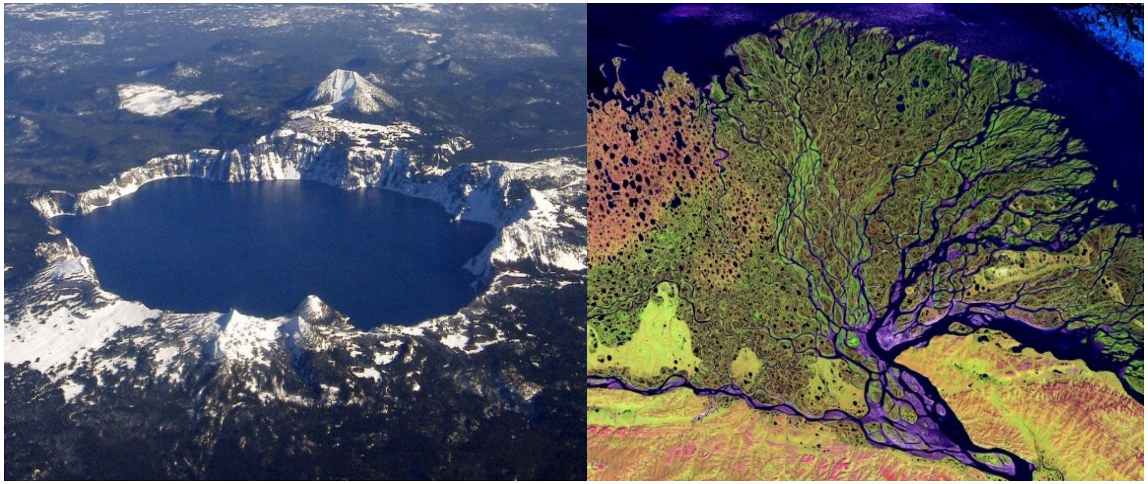


Outline:
Introduction
lake and land contrasts
forecasts impact when considering lakes
Summary & outlook

Interactive lakes in the ECMWF Integrated Forecasting System

Abstract:

From Spring 2015 the operational global weather forecasting system at ECMWF includes a prognostic state evolution for inland water bodies, which is based on the **FLake parametrization** used at DWD (Mironov et al. 2010). The roadmap to operational deployment and the originalities of this implementation will be described. Those include the treatment of **all sub-grid and resolved lakes, reservoirs, rivers and shallow coastal waters** and their initialization with the available Near-Real-Time remote-sensing information or via retrospective offline simulations obtained in reanalysis mode. Perspectives for further developments (e.g. treatment of fractional freezing) will be also briefly presented.

Introduction

A representation of **inland water bodies and coastal areas** in NWP models is essential to simulate large contrasts of albedo, roughness and heat storage

A lake and shallow coastal waters parametrization scheme has been introduced in the ECMWF Integrated Forecasting System combining

HTESSEL

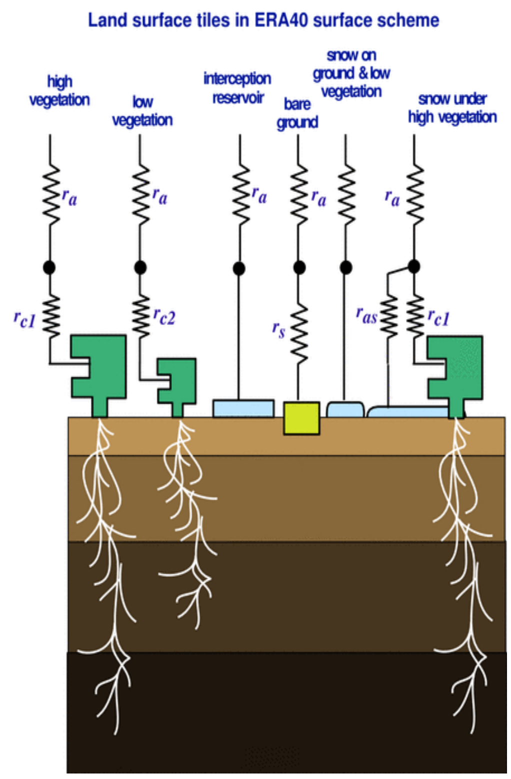
Hydrology - Tiled ECMWF

Scheme for Surface Exchanges over Land

+

FLake

Fresh water Lake scheme



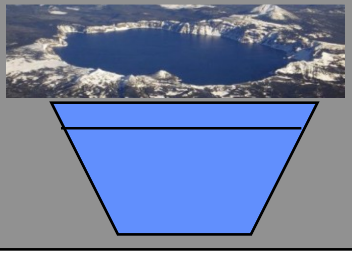
- **Lake tile**

Mironov et al (2010),

Dutra et al. (2010),

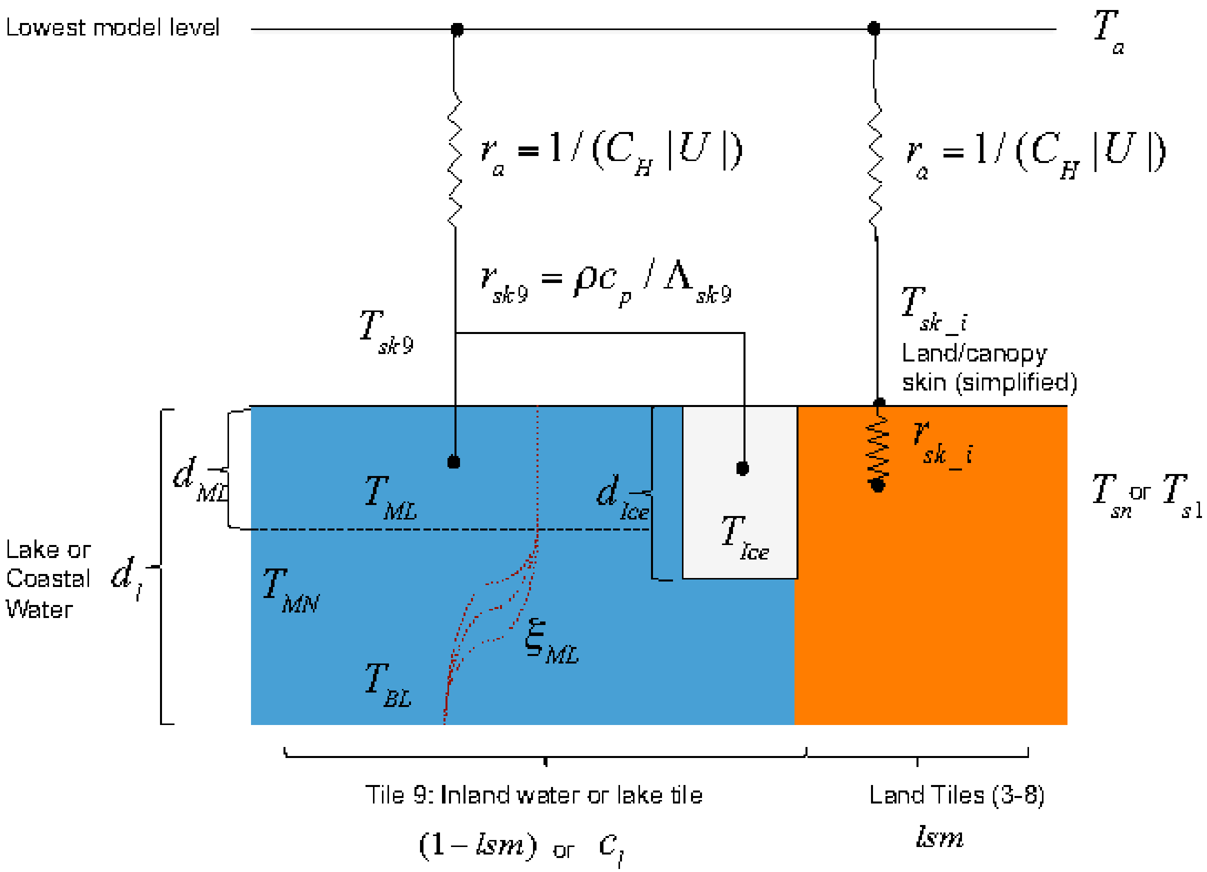
Balsamo et al. (2010, 2012, 2013)

Extra tile (9) to account for sub-grid lakes



FLake model in ECMWF forecasting system

- Flake model (Mironov 2008, Mironov et al. 2010) is fully integrated in ECMWF systems
- All water points are treated independently from the fractional coverage.
- A water and ice tile are dedicated to lake a shorelines



- Flake is **operational on** the **12 May 2015**
- Flake will be part of the new ECMWF reanalysis in the **ERA5 in 2016**

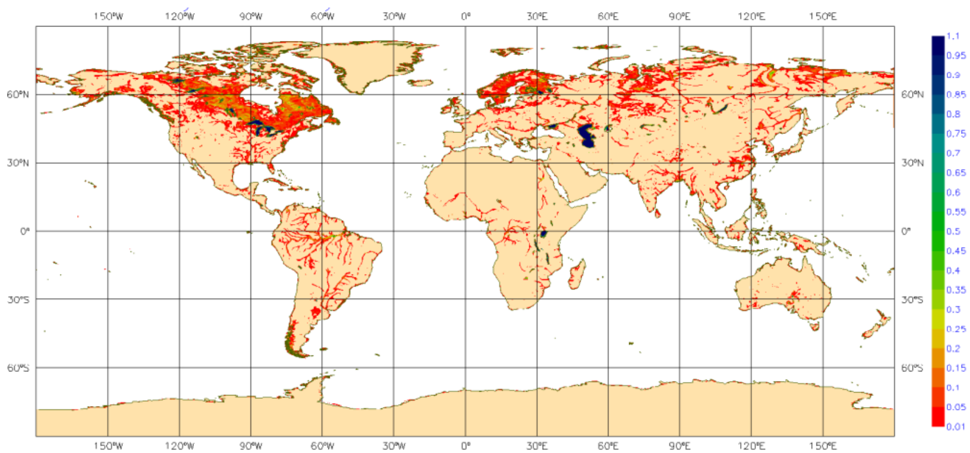
ECMWF

Lake cover and lake depth at global scale

Dutra, 2010 (BER), Balsamo et al. 2010 (BER)

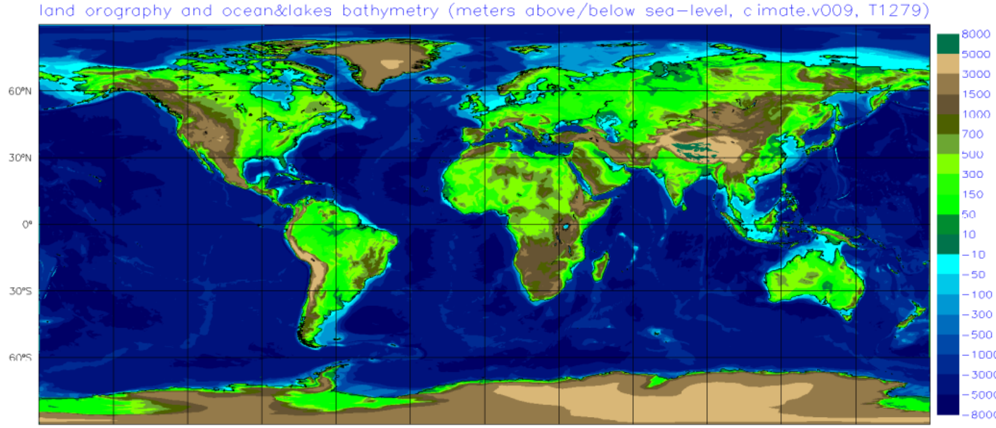
Motivation: a sizeable fraction of land surface has sub-grid lakes: different radiative, thermal Roughness characteristics compare to land → affect surface fluxes to the atmosphere

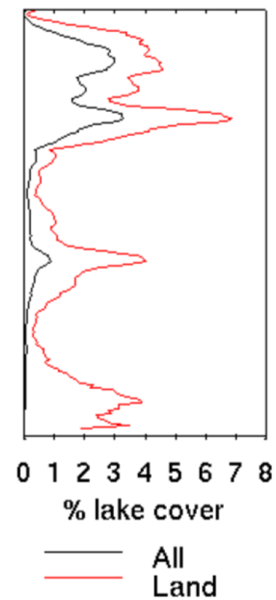
LAKE COVER FRACTION



LAKE & SEA BATHYMETRY

land orography and ocean&lakes bathymetry (meters above/below sea-level, cimate.v009, T1279)





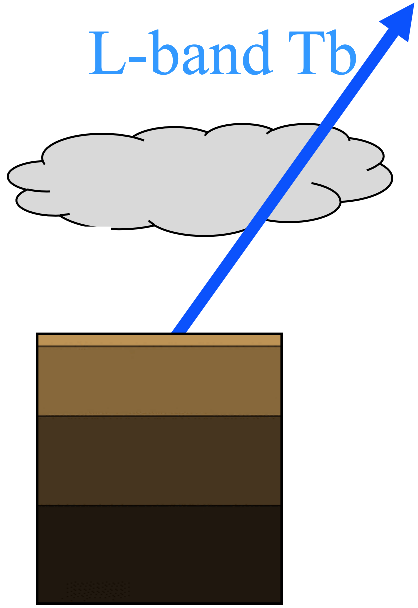
Nº Points 0.05< Clake<0.5

Canada	309/754 **41%**
USA	175/482 **36%**
Europe	170/385 **44%**
Siberia	104/467 **22%**
Amazon	81/629 **13%**
Africa	74/584 **13%**

- Lake cover and lake bathymetry are important fields to describe size and volume of the water bodies that are associated to thermal inertia
- source: ESA-GlobCover/GLDBv1

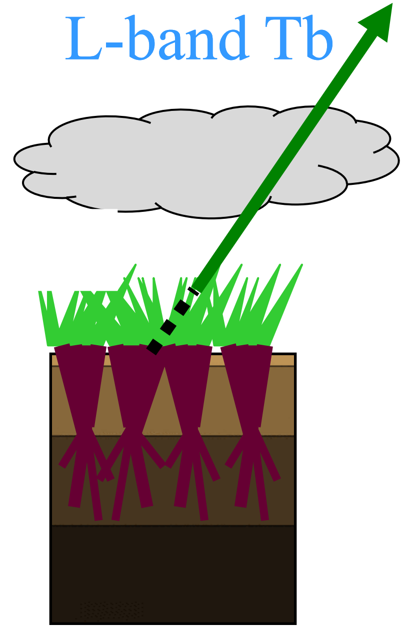
ECMWF

Microwave Remotely sensing from space: Relevance of open-water in forward modelling



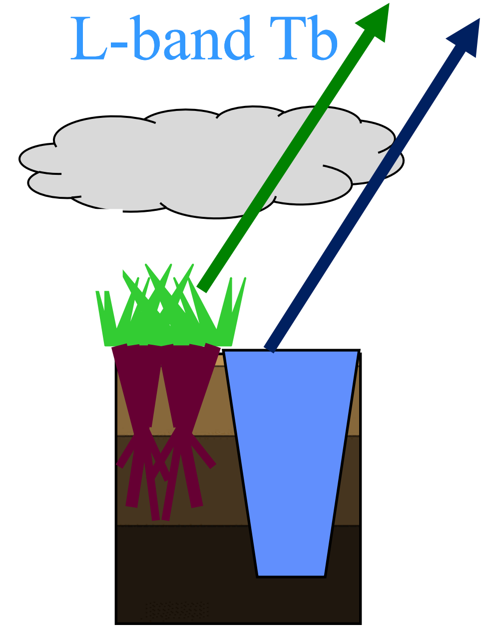
<u>Soil moisture</u> modifies
soil dielectric constant → emissivity ε

$$T_{b\_soil} = \varepsilon \, T_s$$



<u>Vegetation</u> attenuates
soil emission + emits its own TB

T_b influenced by
vegetation layer [f(LAI)]



<u>Lakes</u> create a strong cold signal,
masking the signal of soil

T_b varying with lake
temperature [f (T_skin)]

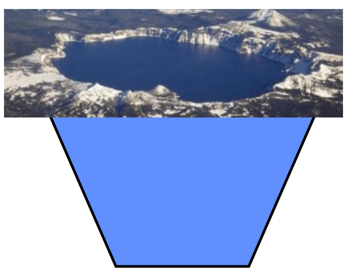
	Sounding soil depth	Frequency	Wavelength	Atmospheric absorption
L-band Tb	**~5 cm**	1.4 GHz	21 cm	**Negligible**
C-band Tb	~1cm	6.9 GHz	5 cm	Low (except rainy area)

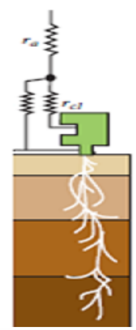
Introducing FLake under tiling approach

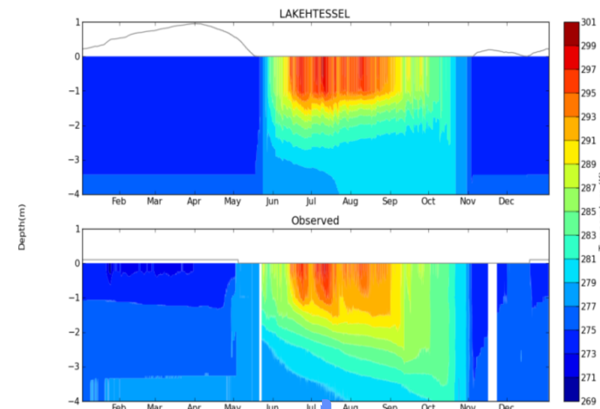
Manrique-Suñén et al. (2013, JHM)

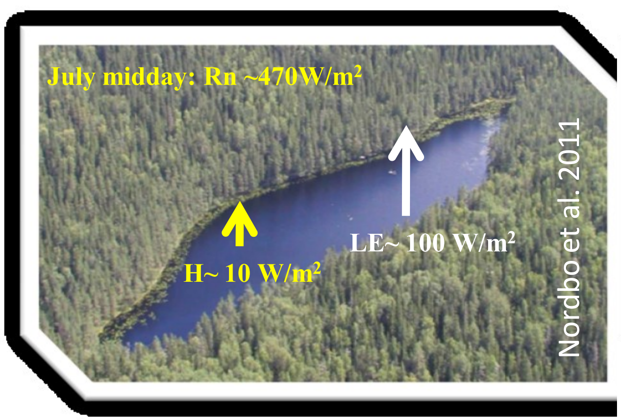
Using the Meteorological forcing from ERA-Interim reanalysis the model was run for the year 2006 over a Finnish lake and a near by forest

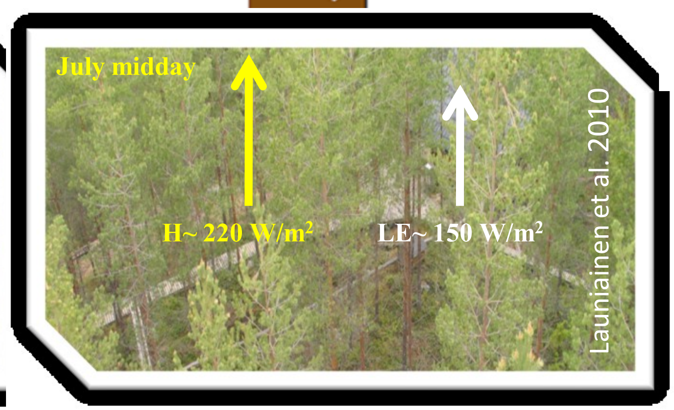
Lake profile evolution











Alake specialized site tested in collaboration with A. Nordbo, I. Mammarella (U. Helsinki)

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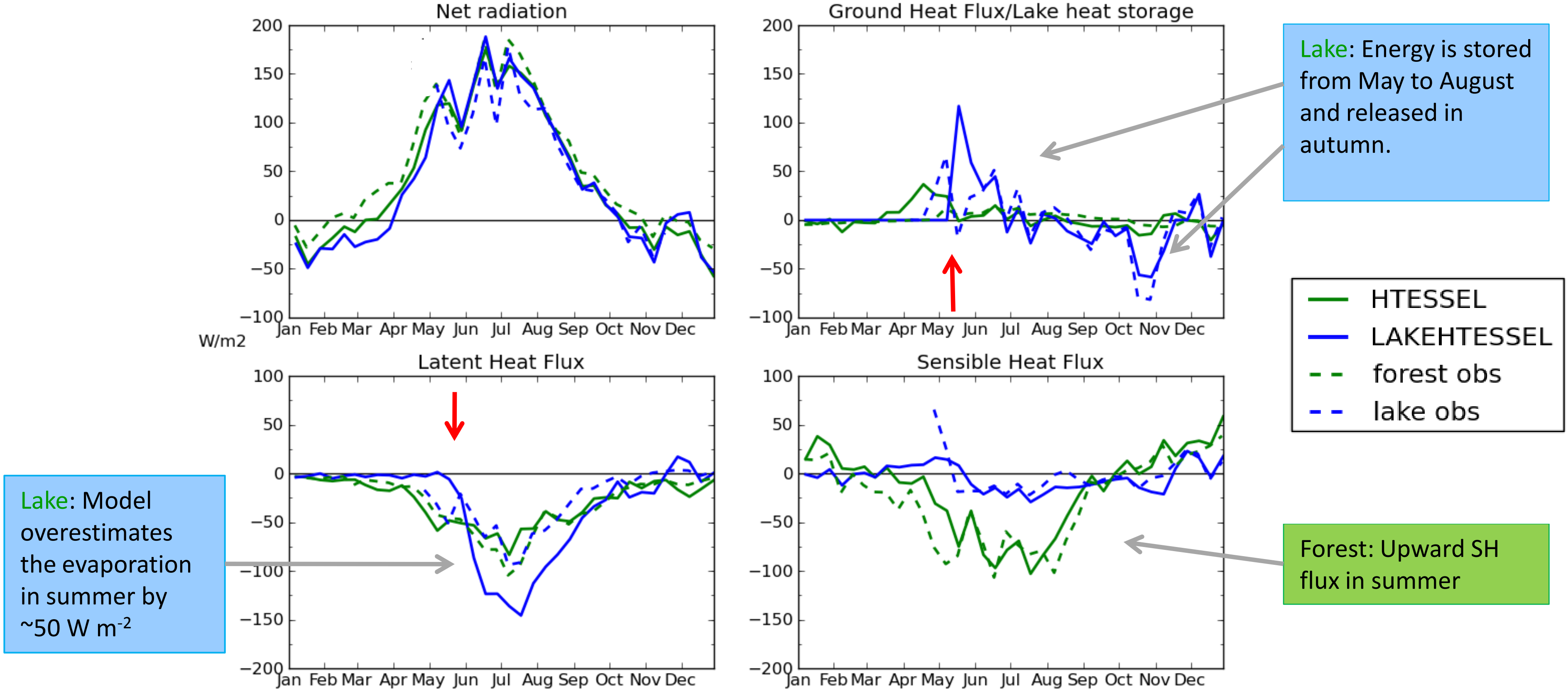
Energy fluxes: Seasonal cycles

Manrique-Suñén et al. (2013, JHM)

Seasonal cycle of 10 day averages of energy fluxes



Sign convention: Positive downwards

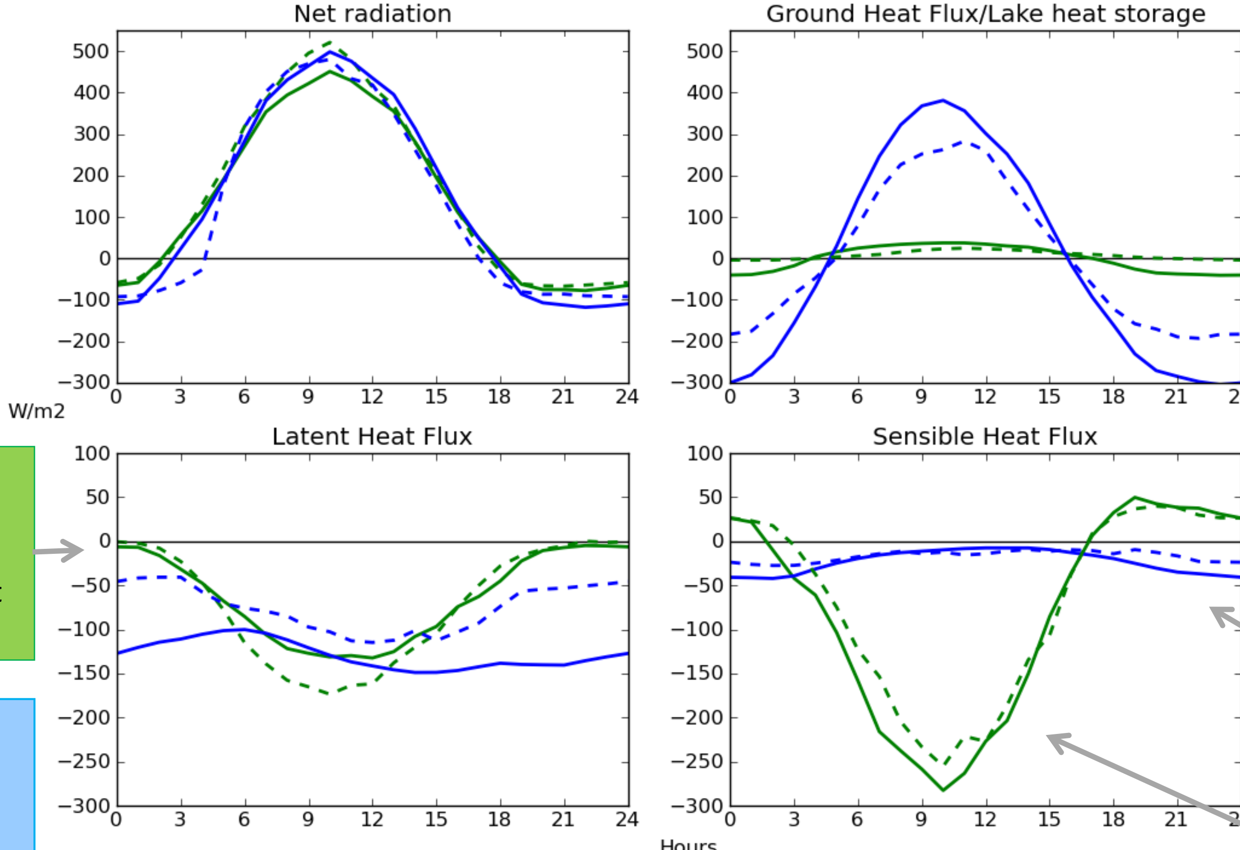
The timing of the lake's energy cycles is influenced by the ice cover break up, and it is delayed by 14 days in the model. This suggest that ice-initial condition will benefit from EO data constraint!

Main difference between both sites is found in the energy partitioning into SH and G

Energy fluxes: Diurnal cycles

Manrique-Suñén et al. (2013, JHM)

Monthly diurnal cycle of energy fluxes for July



Very good representation by the model of diurnal cycles and particularities of each surface

Forest evaporation is driven by vegetation, so it is zero at night

Lake LH diurnal cycle: overestimation in evaporation

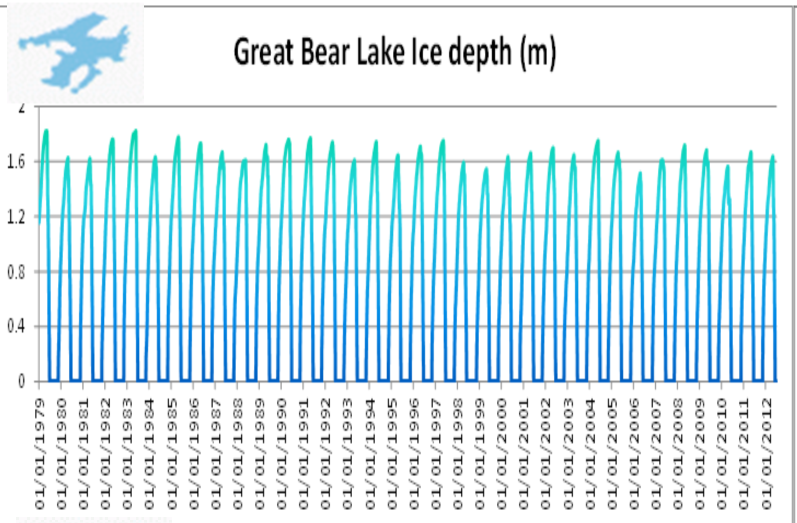
Lake SH maximum is at night

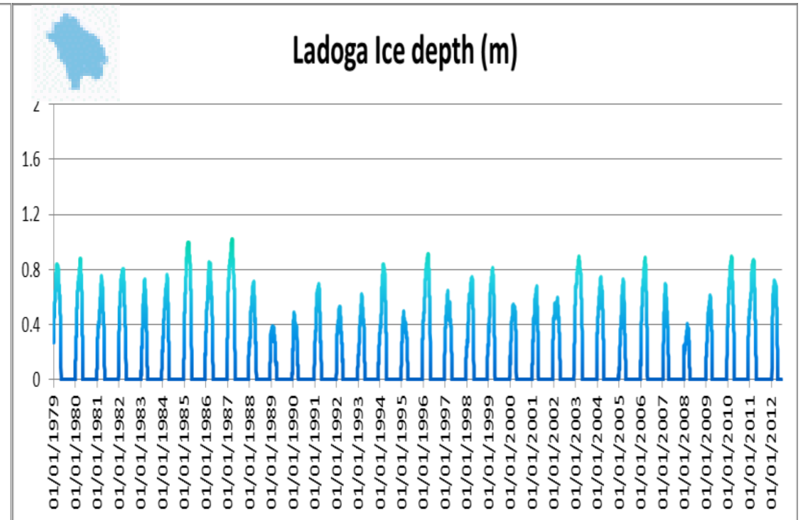
Forest SH maximum is at midday

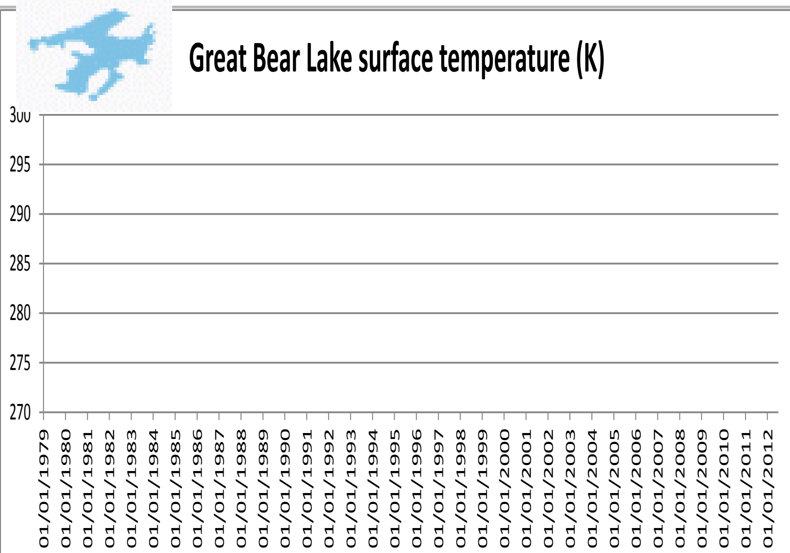
Main difference between both sites is found in the energy partitioning into SH and G

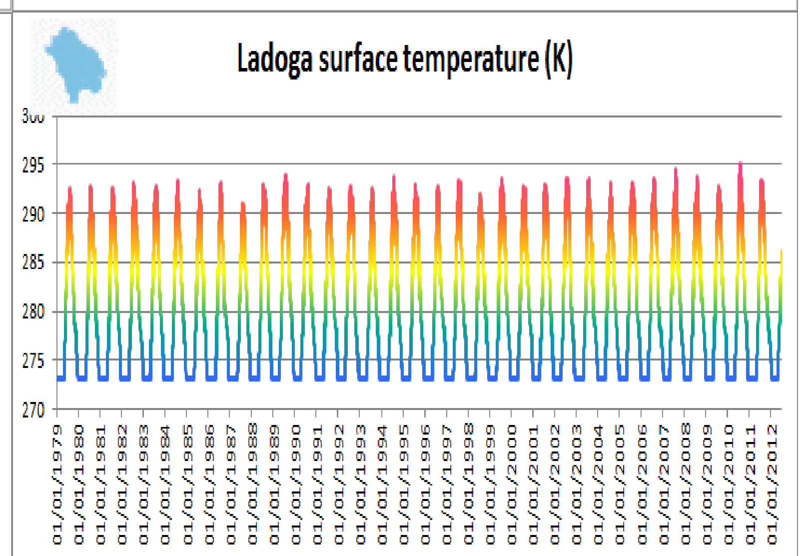
ECMWF

Global Lake temperature & ice conditions over the past 35 years





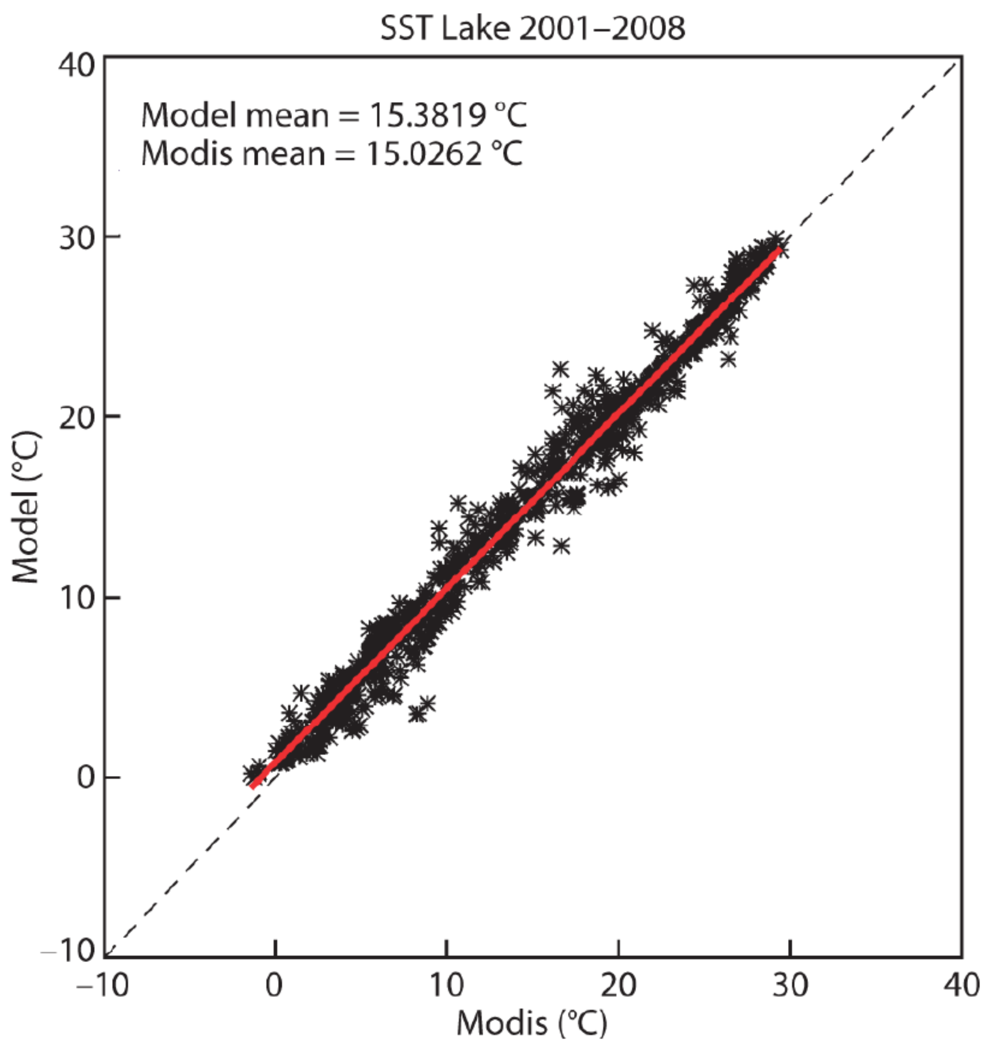




- ERA-Interim driven lake simulations of the lake model permit to reconstruct the lake temperature and ice evolution
- This is a necessary step to feed initial conditions for the reforecasts activity (ENS and MF/SF)
- Question: How to validate the result globally?

Lakes surface temperature (global validation)

Balsamo et al. (2012, TELLUS-A) and ECMWF TM 648



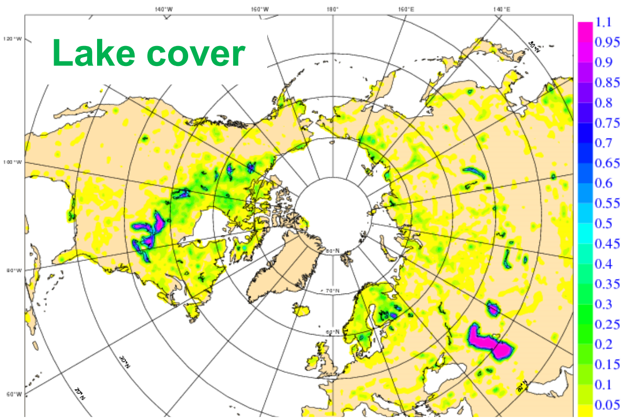
- FLAKE Lake surface temperature is verified against the MODIS LST product (from GSFC/NASA)
- Good correlation

  R=0.98
- Reduced bias

  BIAS (Mod-Obs) < 0.3 K

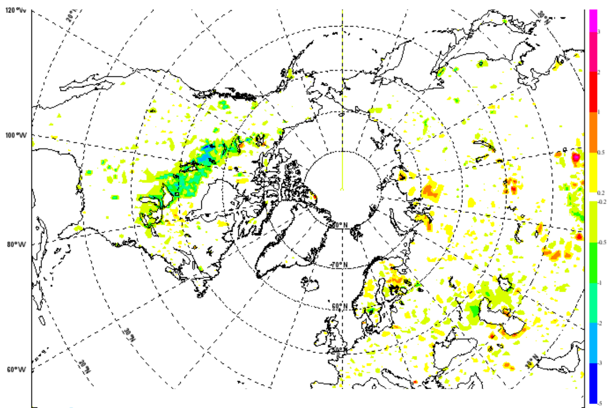
Impact of lakes in NWP forecasts

Balsamo et al. (2012, TELLUS-A) and ECMWF TM 648



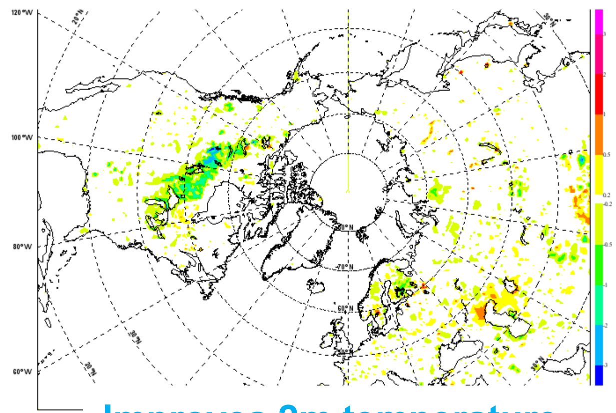
- **Forecasts sensitivity and impact is shown to produce a spring-cooling on lake areas with benefit on the temperatures forecasts (day-2 (48-hour forecast) at 2m.**

Forecast sensitivity



Cooling 2m temperature
Warming 2m temperature

Forecast impact



Improves 2m temperature
Degrades 2m temperature

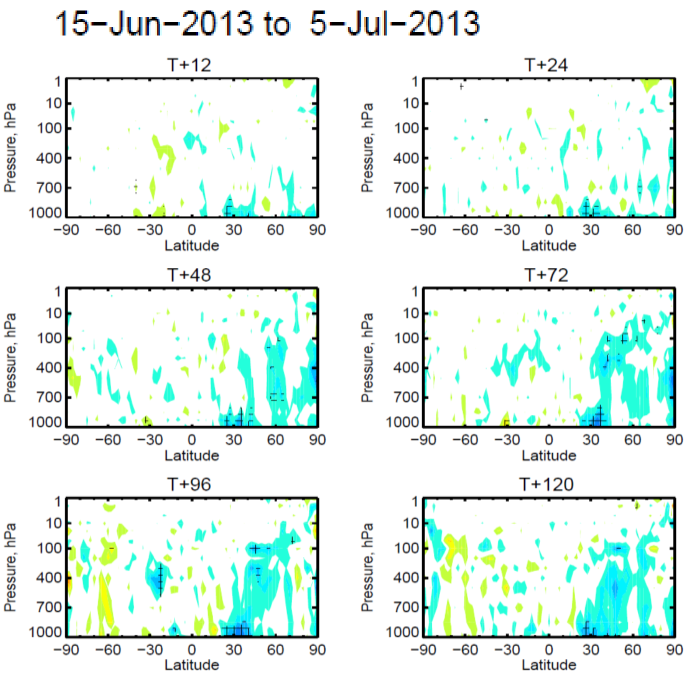
ERA-Interim forced runs of the FLAKE model are used to generate a lake model climatology which serves as IC in forecasts experiments (Here it is shown spring sensitivity and error impact on temperature when activating the lake model).

Impact of lakes in NWP analysis cycles

- **AN cycling and initialisation**

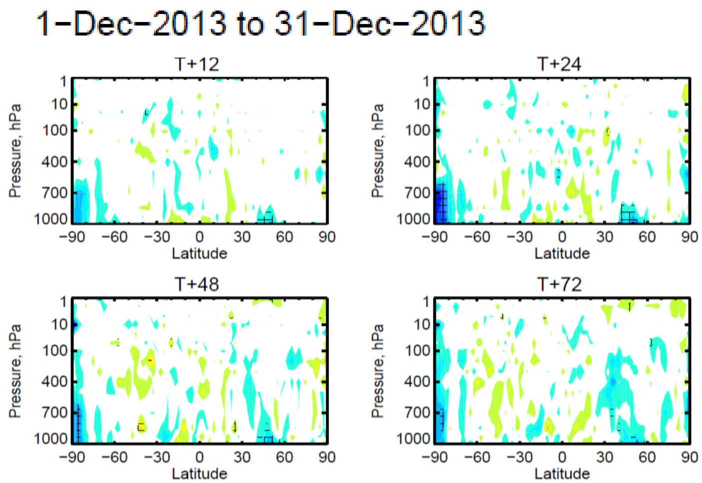
Summer experiment

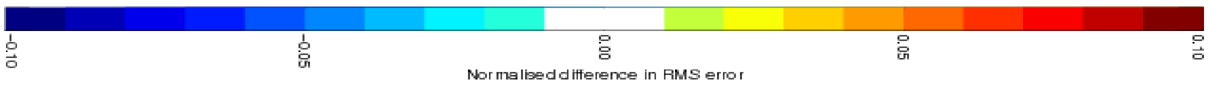
(Temperature scores)



Winter experiment

(Temperature scores)





- Modelling transitions of lake open water to lake-ice is very challenging and may require a careful initialisation
- Sea-ice is probably in a similar situation (predictive skill severely affected by lack of atmospheric predictability in winter)

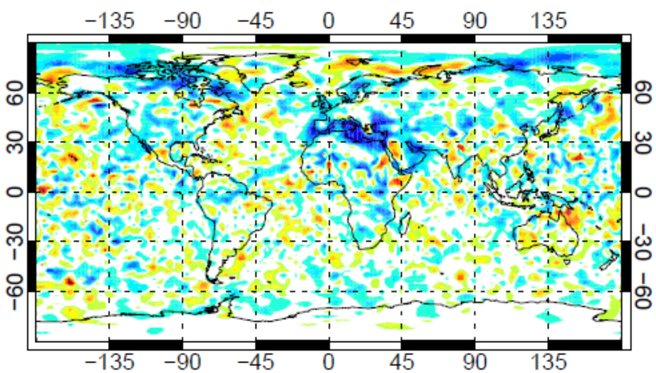
Updated results from Balsamo (2013, ECMWF Autumn Newsletter)

Impact of lakes in NWP analysis cycles (II)

Summer experiment

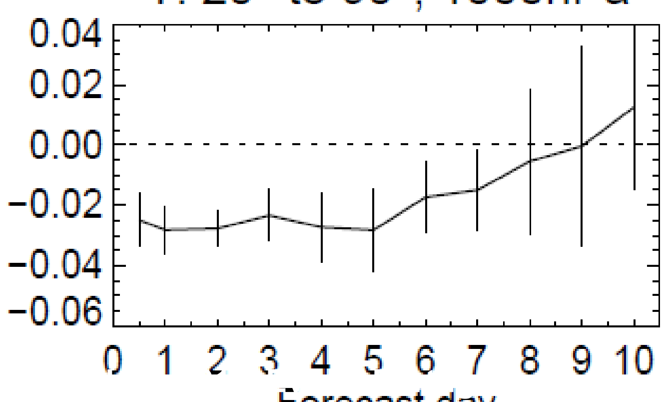
(Temperature scores)

T+48; 1000hPa



15-Jun-2013 to 5-Jul-2013

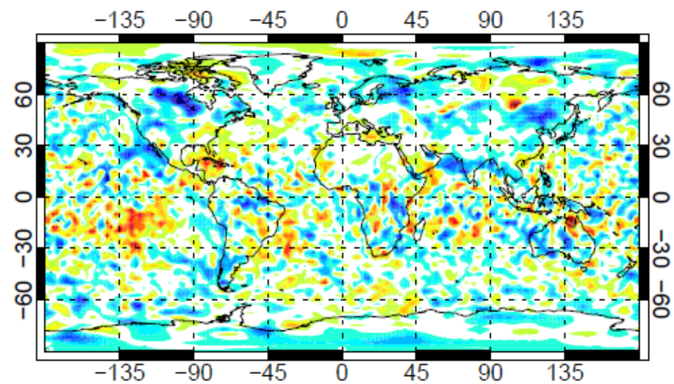
T: 20° to 90°, 1000hPa



Winter experiment

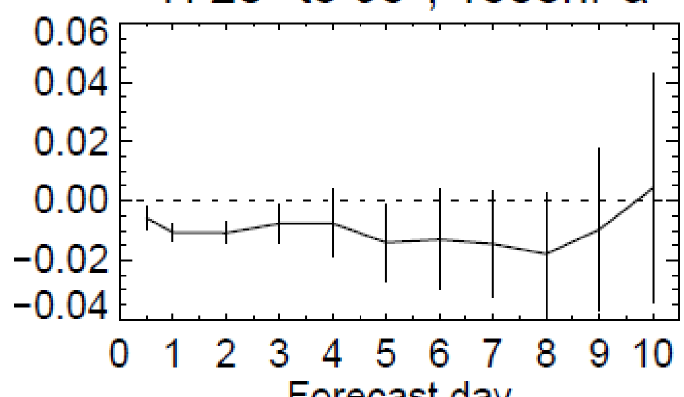
(Temperature scores).

T+48; 1000hPa



1-Dec-2013 to 31-Dec-2013

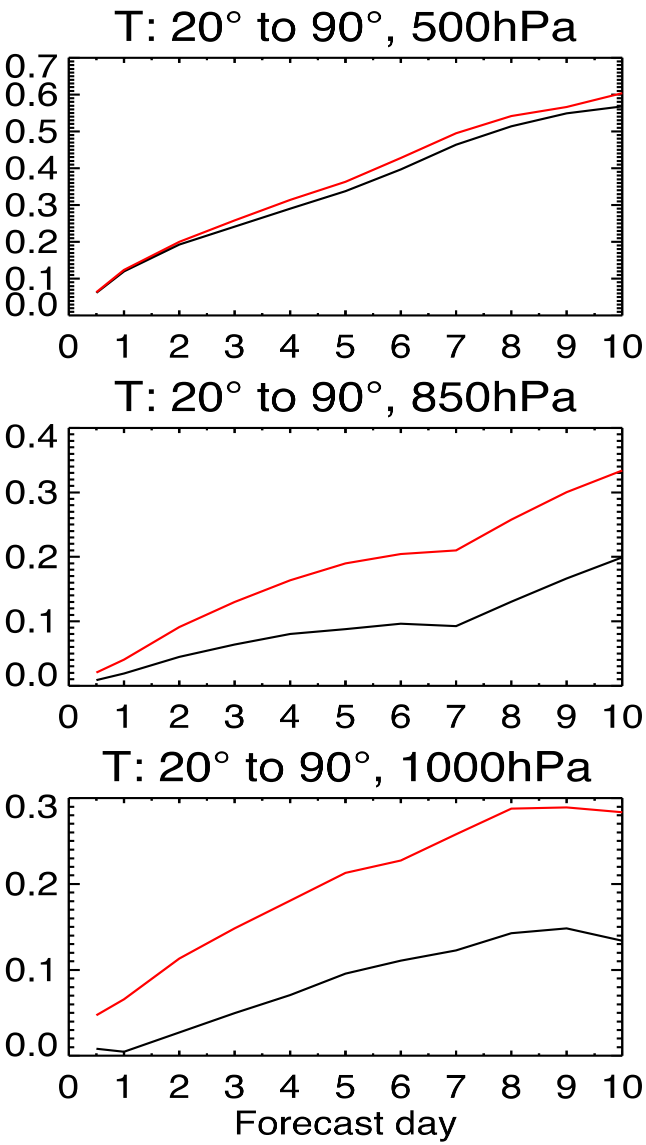
T: 20° to 90°, 1000hPa



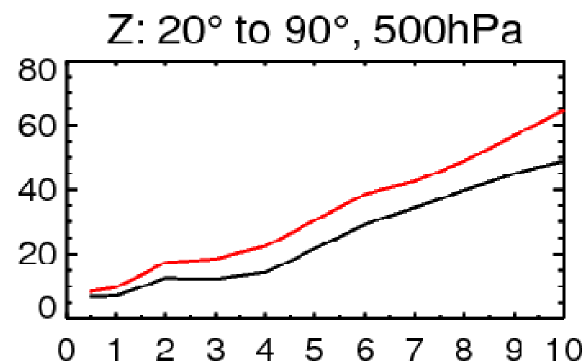
- Forecast of 2m temperature are improved in proximity of lakes and coastal areas
- In summer The impact is estimated in 2-3% relative improvement in RMSE of T1000hPa significant up to 7 days
- Winter RMSE impact is positive as well but of around 1%

ECMWF

Impact of lakes in NWP analysis cycles (III)



- In summer lake impact is not confined to the surface layer but propagates upwards reducing the mean model temperature error over Northern hemisphere (e.g. at 850 hPa)
- Part of the signal is also detected in Z500 (geopotential height at 500 hPa)



- Z500 gets meteorologists attention!

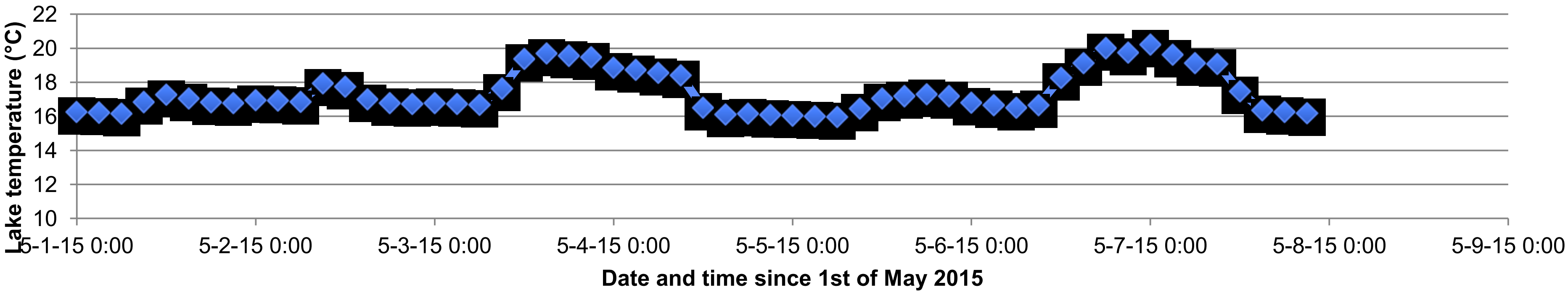
mean error of CY40R3 with lakes

mean error of CY40R3 without lakes

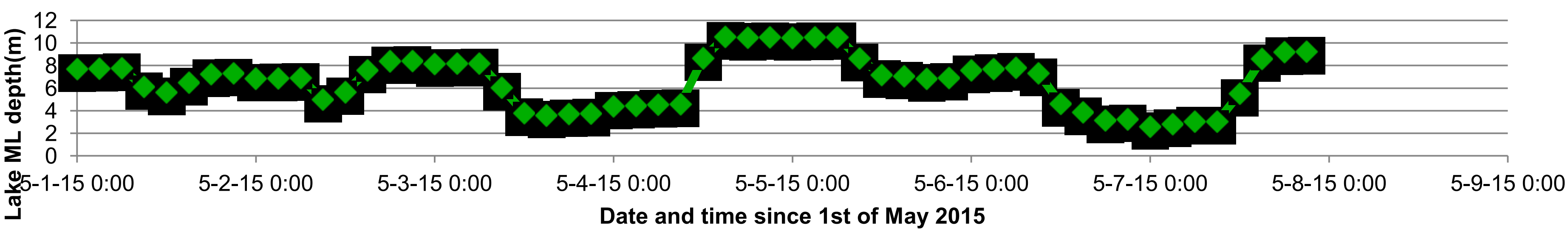
ECMWF

Lake temperature/ML depth in Alqueva?

Alqueva mixed-layer temperature forecast (day-1) in May 2015



Alqueva mixed-layer depth forecast (day-1) in May 2015



Pre-operational forecasts from e-suite HRES (16km global) Nearest point Latitude=38.16 Longitude=352.44. Valid for a lake depth=12 m

Summary & Outlook

- **The ECMWF land surface scheme and its extension to lakes**
  - The introduction of lakes and coastal subgrid waters enhances the capacity of representing natural Earth surface heterogeneity
- **Benefits of considering sub-grid lakes**
  - Each tile has its process description (no ad-hoc or effective parameters)
  - All inland water bodies considered independently from their size & shape
- **Atmospheric forecast impact**
  - The introduction of interactive lakes has beneficial impact on forecast accuracy
  - Impact is significant and detected in Northern Hemisphere scores.
- **Involvement with Lake Community even more essential now!**
  - Daily lake forecasts global at 16km (HRES) and 30 km (ENS-51 member) becomes operational on the 12th of May 2015
  - Operational daily runs will show also model short-comings, and needs of better observation and ancillary datasets, LDAS integrations, …

ECMWF step-wise approach to model complexity: “Lakes gestation time”

Complexity/Cost

Generality

Site runs (Offline)

2D runs (Offline)

Global (Offline)

Coupled GCM

Coupled GCM + DA

<u>Examples:</u>

Portugal & Finnish lakes

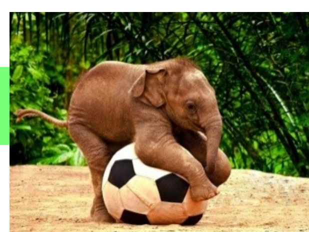
Great-Lakes Caspian-Sea

“Lake-Planet”

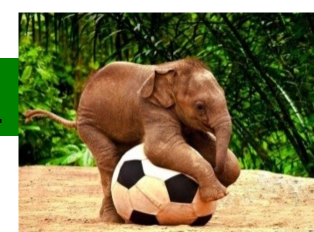
Forecasts +lakes/coasts

Analysis & Reanalysis

Lake-timeline: <u>2006-2010</u>

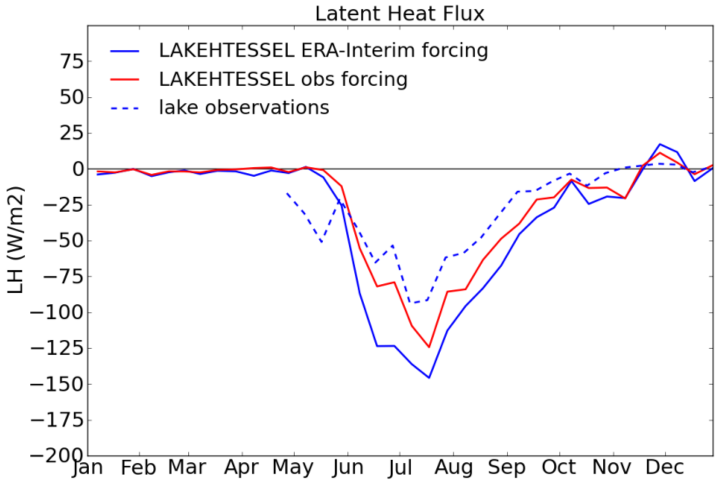


<u>2012</u>

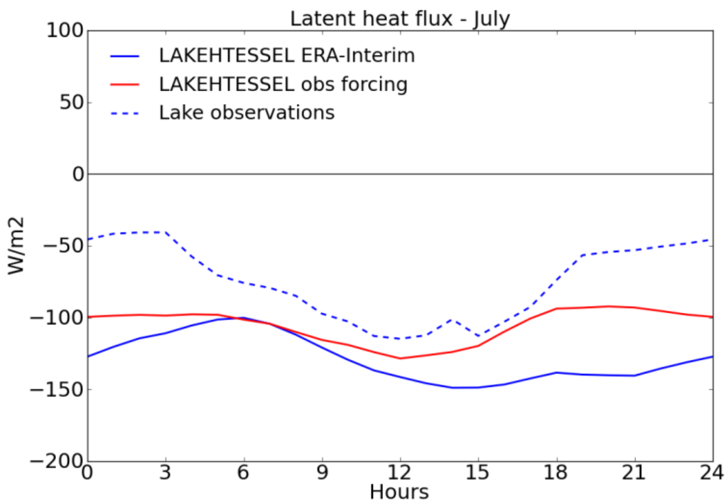


<u>2015</u>

Use of observed forcing vs ERA-Interim for the lake site: highlight tiling shortcoming



Seasonal cycle:
The use of observed forcing reduces the RMSE in evaporation from 32 W m^{-2} to 19 W m^{-2}



Diurnal cycle for July:
The evaporation is reduced, but errors remain at night. The model's transfer coefficients might not be appropriate for a calm situation

Manrique-Suñén et al. (2013, JHM)

ECMWF

Thank you for your attention!

Aknowledgements:

•This work would not have been possible without the support of many colleagues: ECMWF Research and Forecast departments and external collaborations with Dmitrii Mironov (DWD), Andrea Manrique-Sunen (UoR), Rui Salgado (U Evora), Annika Nordbo (U Helsinki), Ekaterina Kourzeneva (FMI), Viktor Stepanenko (MSU), and others…

Further readings:

See:

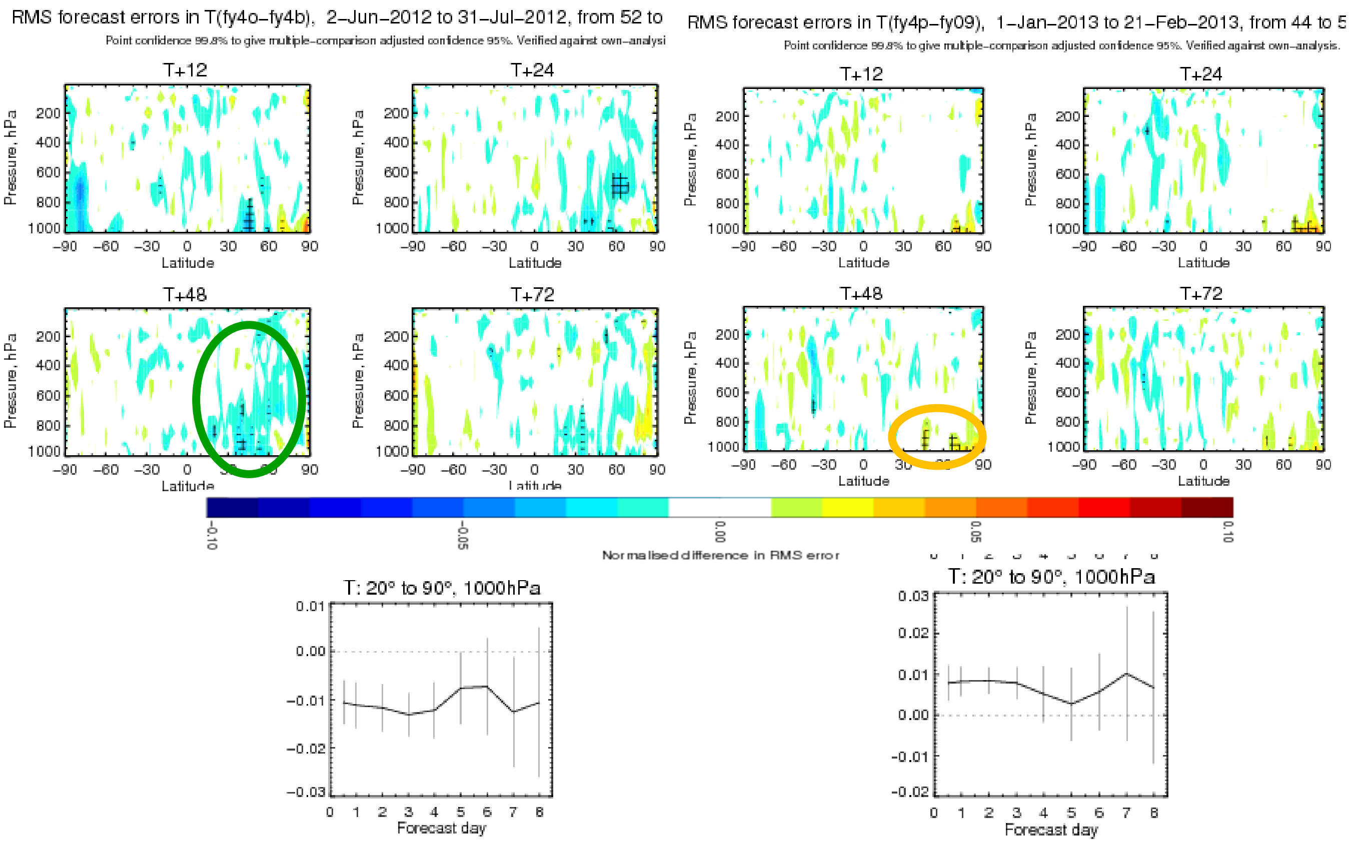
G. Balsamo, 2013: *Interactive lakes in the Integrated Forecasting System.* ECMWF Newsletter 11/2013; 137(Autumn):30-34.

Implementation of lakes in FC/AN/ENS

- **AN cycling and initialisation**

Summer experiment — *Winter experiment*

(Temperature scores) — *(Temperature scores)*



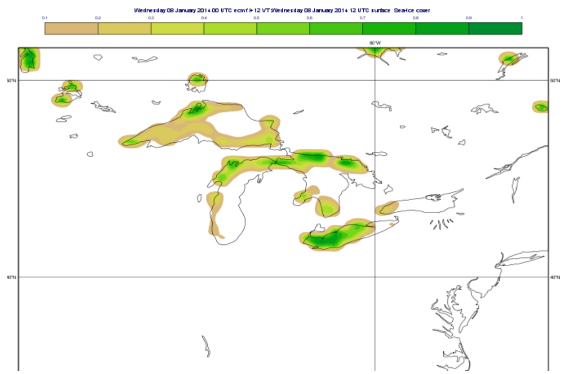
- Modelling transitions of lake open water to lake-ice is very challenging and may require a careful initialisation
- Sea-ice is probably in a similar situation (predictive skill severely affected by lack of atmospheric predictability in winter)

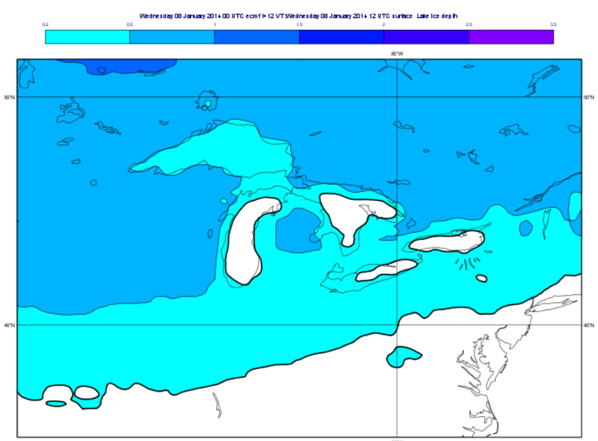
Balsamo (2013, ECMWF Autumn Newsletter)

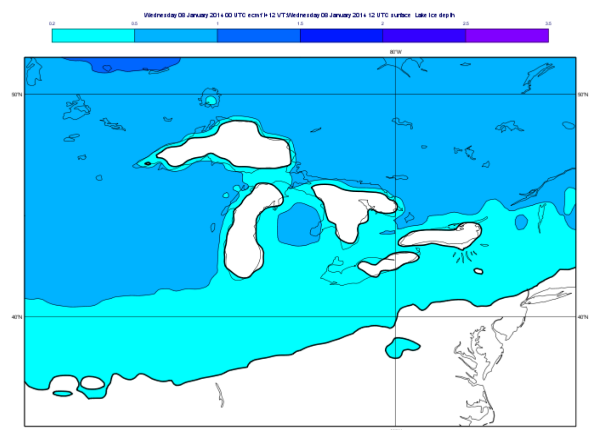
The initial conditions for lakes play a very important role, and are particularly relevant for lake icing/open water.

Initialization of inland water bodies

- **Initialization of lakes and coastal waters using satellite SST/LST and ice conditions is crucial for atmospheric forecast performance (lake forecast is a initial value problem) and constrain modelling errors**







- The model error are attributed to lack of fractional lake ice.
- The lake model freeze entire grid-box.
- Effective initialization of water (add a mix layer and an inertial heat) together with the ice cover was implemented.
- This led to a further improve in winter forecasts scores