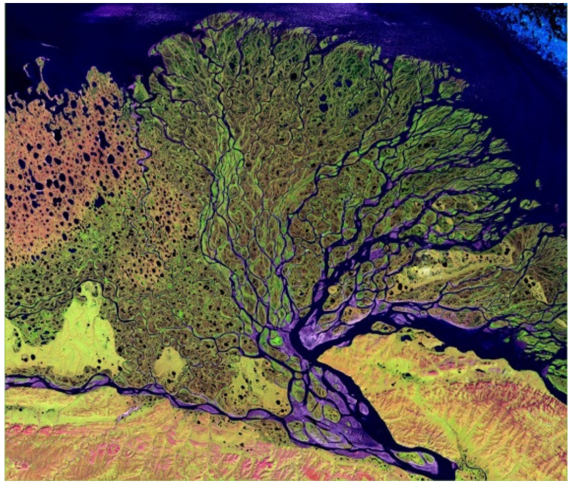
Introducing inland water bodies and coastal areas in ECMWF forecasting system:

Gianpaolo Balsamo

Outline:

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



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Annika Nordbo (U Helsinki), Ekaterina Kourzeneva (FMI), Viktor Stepanenko (MSU)
and others (see slides/references)

Introducing inland water bodies and coastal areas in ECMWF forecasting system

Abstract

A representation of **inland water bodies and coastal areas** in NWP models is **essential to simulate large contrasts** in albedo, roughness and heat storage. Land-water contrasts, despite not being a dominant feature, are **present over a large part of inhabited land** and can affect turbulent heat fluxes towards the atmosphere and the planetary boundary layer evolution.

A lake and shallow coastal waters parametrization scheme introduced in the ECMWF Integrated Forecasting System is expected to become operational in near-future. Its sensitivity and impact from regional to global scale will be presented. Results from fully coupled runs suggest that inland water bodies can

(a) effectively regulate the amplitude of **temperature diurnal cycle**,

(b) produce a shift in the **seasonal temperature evolution**, and

(c) introduce an important **source of tropospheric moisture**.

Those effects are shown to improve significantly the forecasts of near surface temperature and humidity nearly at all forecast ranges considered, from a day to a season ahead.

ECMWF

The ECMWF HTESSEL scheme (main tiles)

- Hydrology - Tiled ECMWF Scheme for Surface Exchanges over Land

van den Hurk et al (2000)

Viterbo et al (1999)

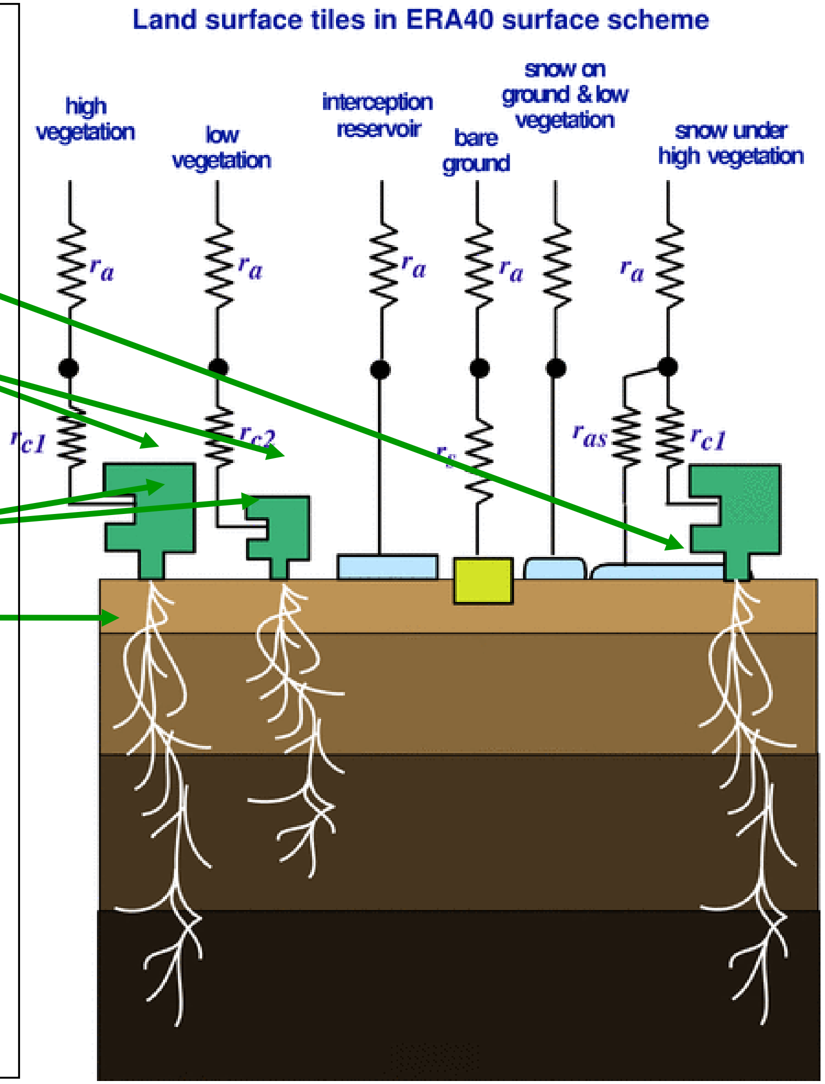
Viterbo and Beljaars (1995)

Treatment of snow under high vegetation

Canopy resistances, including air humidity stress on forest

High and low vegetation treated separately

Variable root depth



- **Lake tile**

Mironov et al (2010),

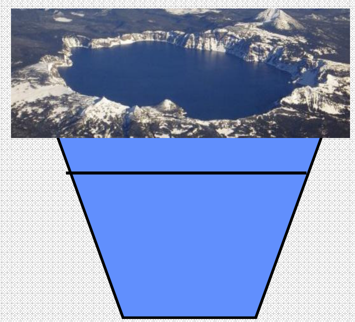
Dutra et al. (2010),

Balsamo et al. (2010)

Balsamo et al. (2012)

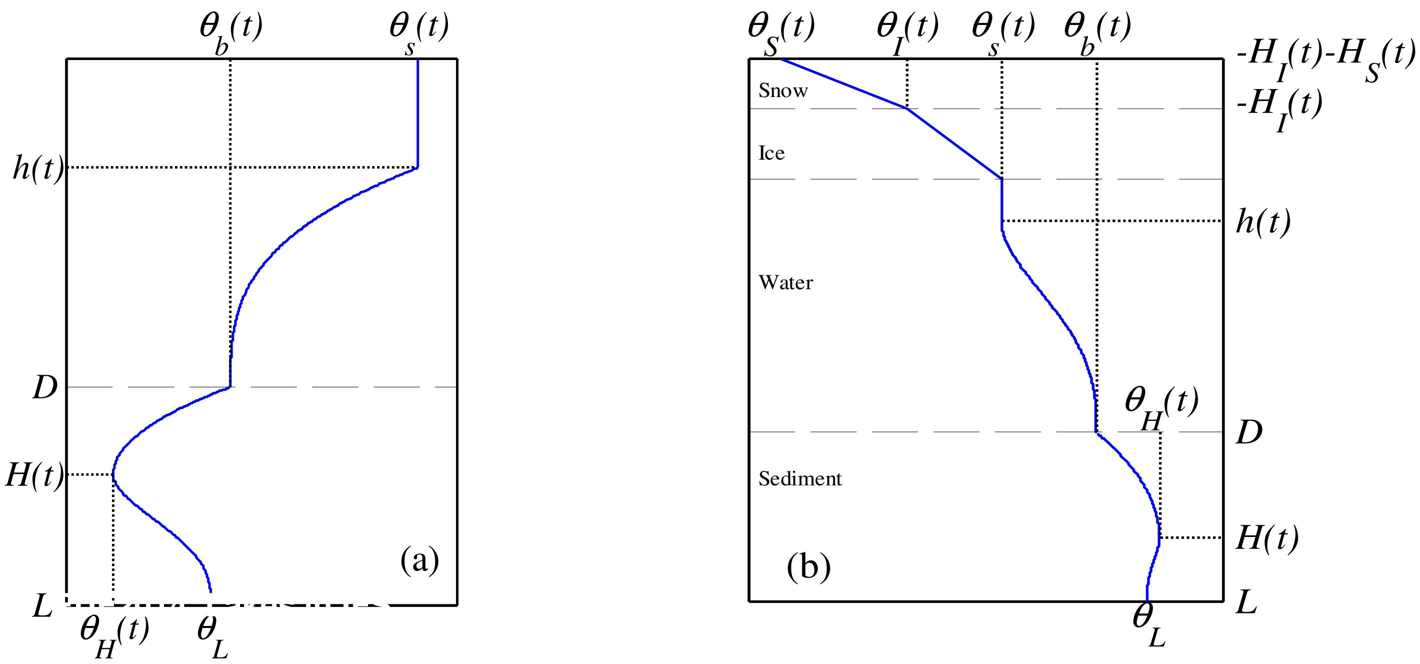
Balsamo (2013)

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



Lake model (parameterization scheme) FLake

- FLake is a two-layer bulk model (parameterization scheme) based (i) on a **self-similar** parametric representation of the evolving temperature profile within lake water, ice and snow (the idea of “assumed shape” of the temperature-depth curve) and (ii) on the integral budgets of heat and kinetic energy for the layers in question.
- FLake is a computationally efficient shallow-water model (it solves a number of ordinary differential equations) and that incorporates much of the essential physics. No (re-)tuning!
- FLake description in Mironov (2008) and **Mironov et al. (2010, BER)**
- FLake web page including an Online FLake version at http://lakemodel.net



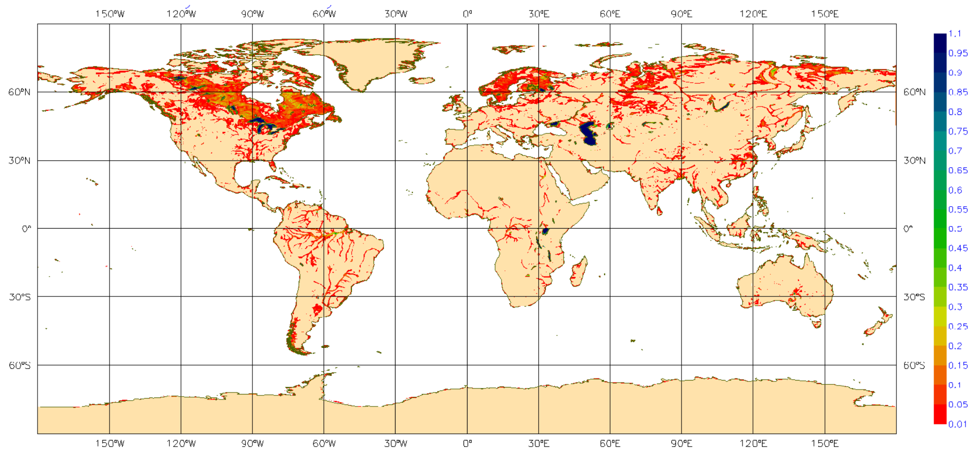
CMWF

Representing lakes in ECMWF model

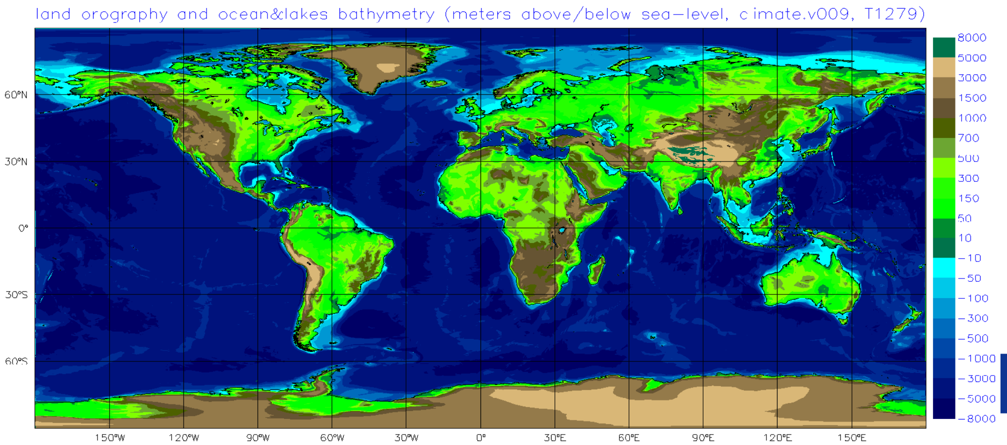
Dutra, 2010 (BER), Balsamo et al. 2010 (BER)

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

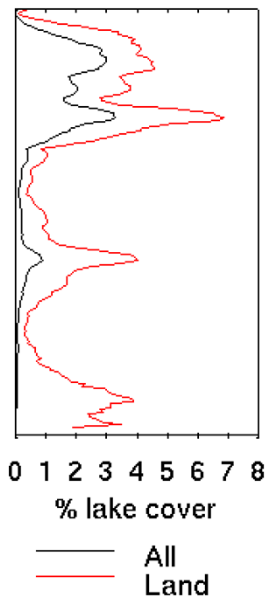
LAKE COVER FRACTION



LAKE & SEA BATHYMETRY



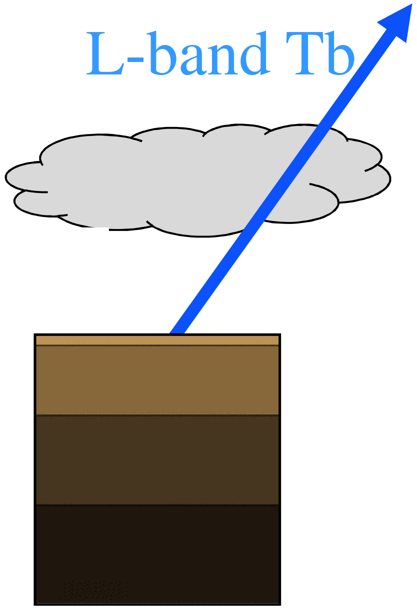
Nº Points 0.05< Clake<0.5



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

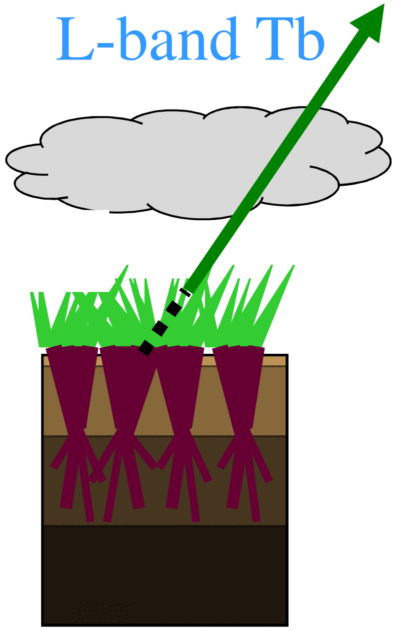
- Lake cover and lake bathymetry are important fields to describe size and volume of the water bodies that are associated to thermal inertia
- source: ESA-GlobCover/GLDBv1

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



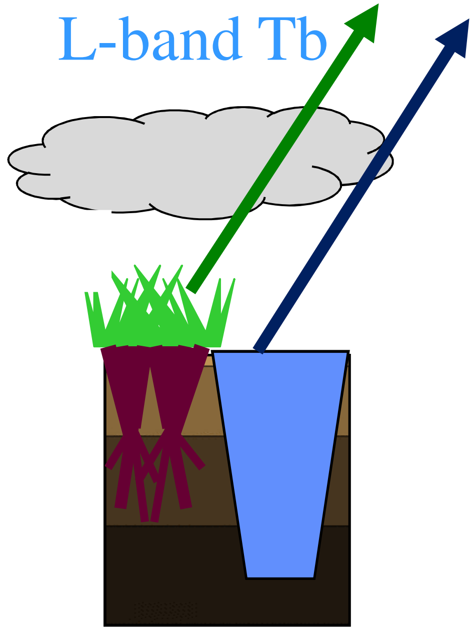
Soil moisture modifies
soil dielectric constant → emissivity ε

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



Vegetation attenuates
soil emission + emits its own TB

T_b influenced by
vegetation layer [f(LAI)]



Lakes 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)

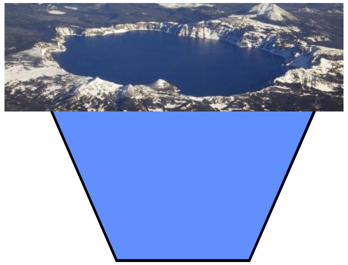
Lake model at ECMWF: under tiling approach

Manrique-Suñén et al. (2013, JHM)

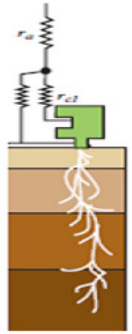
Meteorological forcing: ERA-Interim reanalysis

Model was run for the year 2006, doing 3 iterations

LAKEHTESSEL



HTESSEL

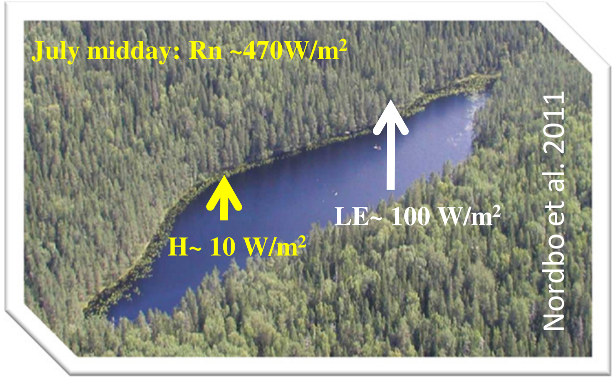


- An originality aspect of the ECMWF implementation of FLAKE is the inclusion under the land surface model tiling which permits to treat all lakes and coastal water that remains sub-grid.
- This extent the application to a large portion on land area

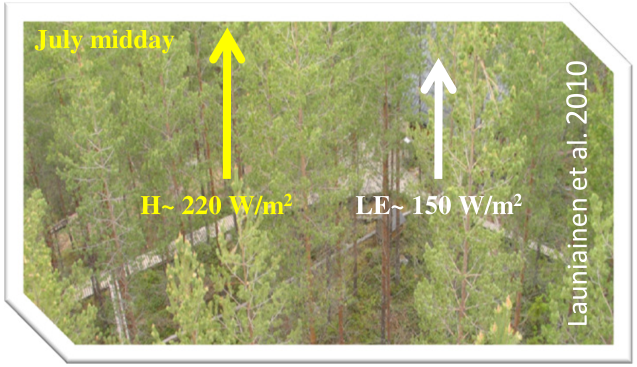
A Finnish lake case study

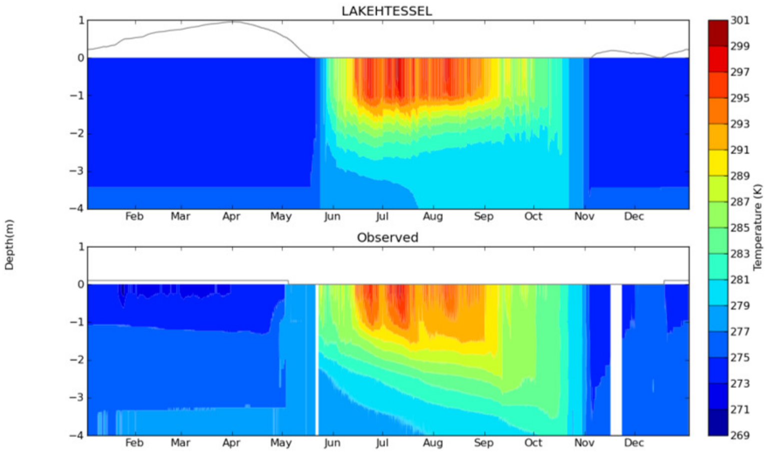
Manrique-Suñén et al. (2013, JHM)

LAKEHTESSEL



HTESSEL





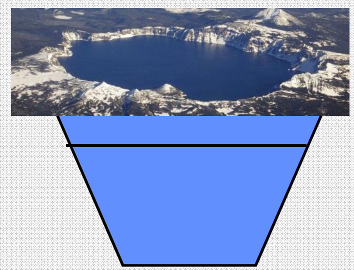
Over a lake specialized site observations can be compared with FLake (Mironov et al. 2010) model output as provided by the LAKEHTESSEL model version.

Collaboration with Annika Nordbo & Ivan Mammarella (U. Helsinki)

- **FLake**

Mironov et al (2010),
Dutra et al. (2010),
Balsamo et al. (2010)
Balsamo et al. (2012)

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

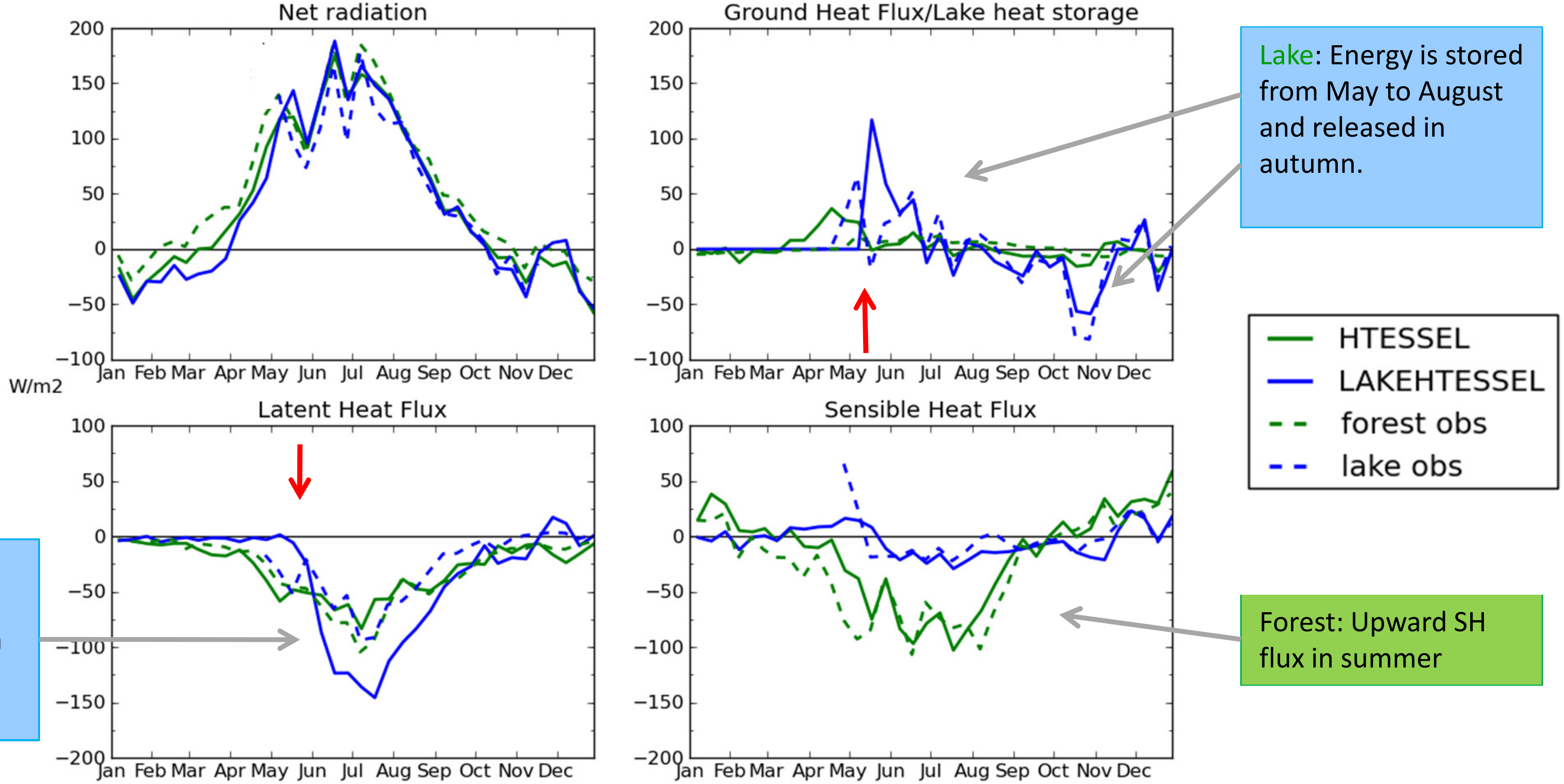


ECMWF

Energy fluxes: Seasonal cycles

Manrique-Suñén et al. (2013, JHM)

Seasonal cycle of 10 day averages of energy fluxes



Lake: Energy is stored from May to August and released in autumn.

Lake: Model overestimates the evaporation in summer by ~50 W m^{-2}

Forest: Upward SH flux in summer

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!

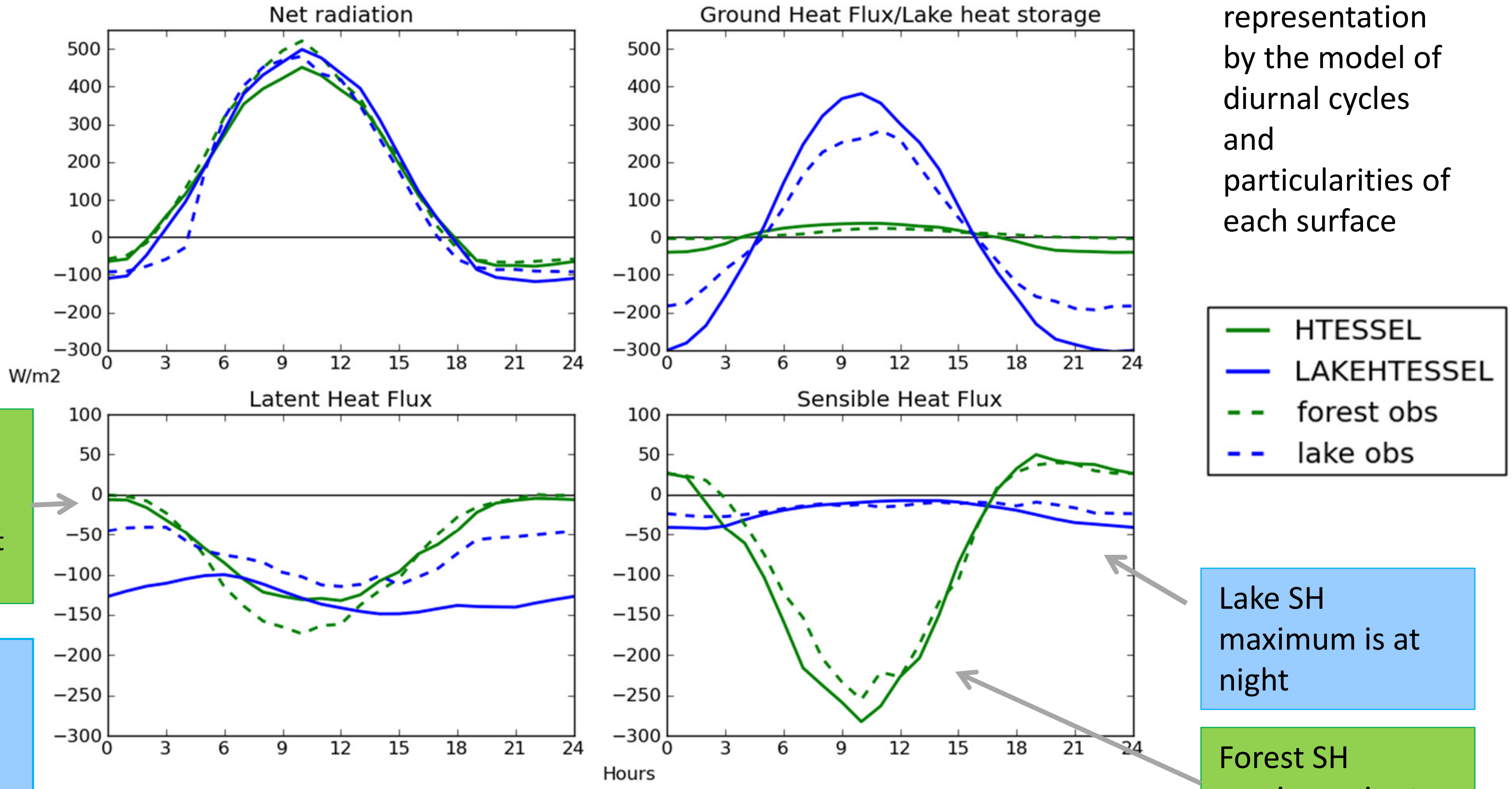
Main difference between both sites is found in the energy partitioning into SH and G

ECMWF

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

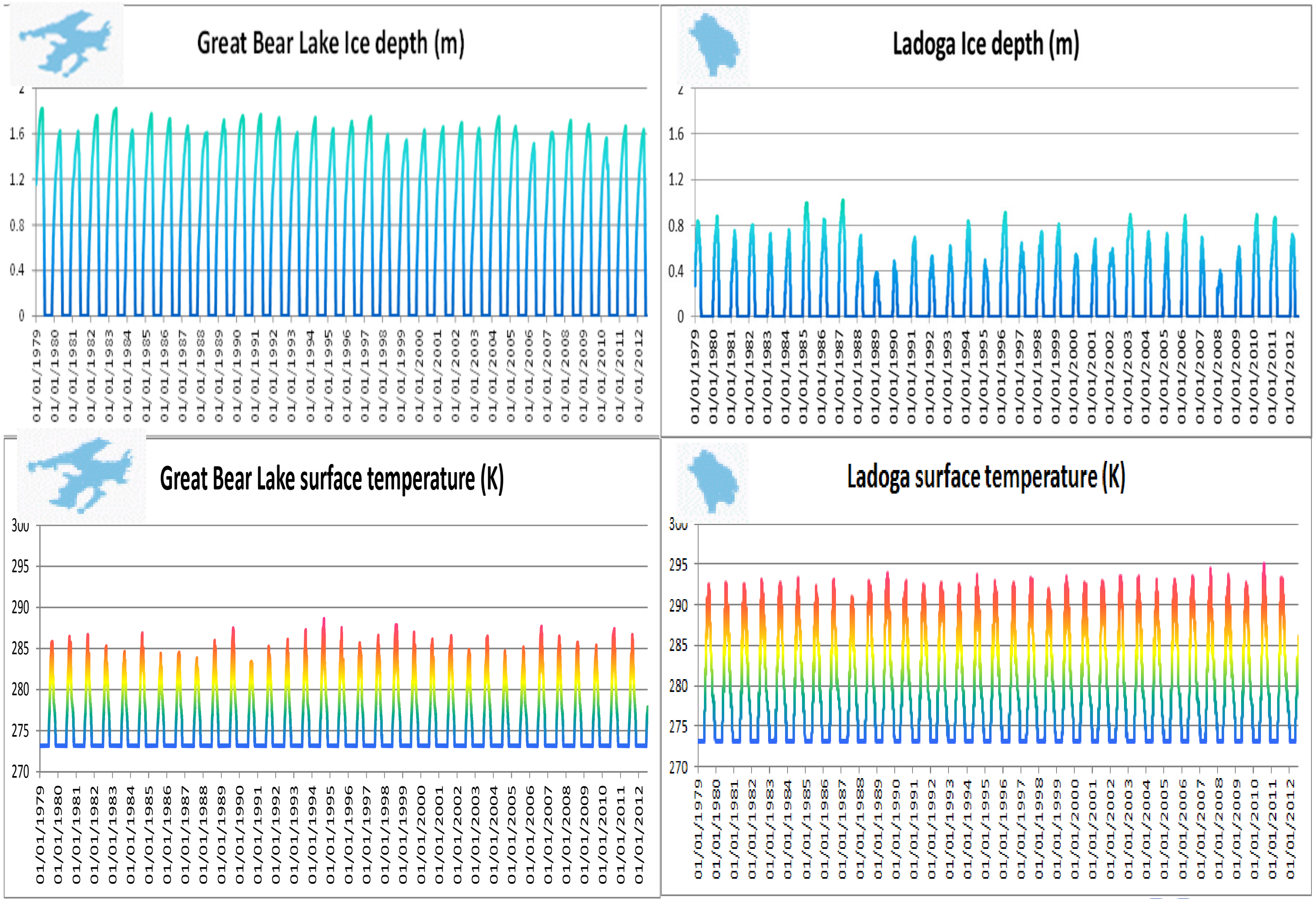
Lake SH maximum is at night

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

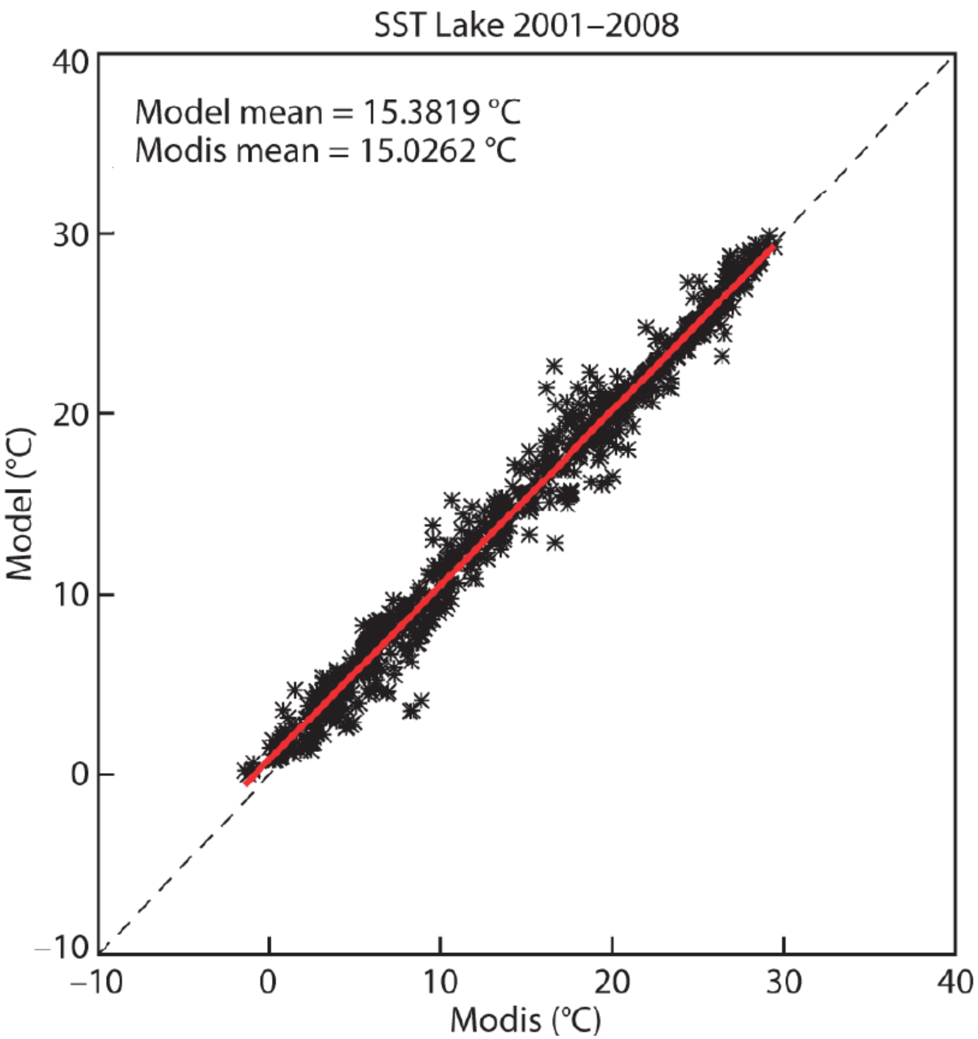


- ERA-Interim driven lake simulations of the lake model permit to reconstruct the lake temperature and ice evolution
- This is a necessary step to feed initial conditions for the reforecasts activity (ENS and MF/SF)
- Question: How to validate the result globally?

ECMWF

Lakes surface temperature (global validation)

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



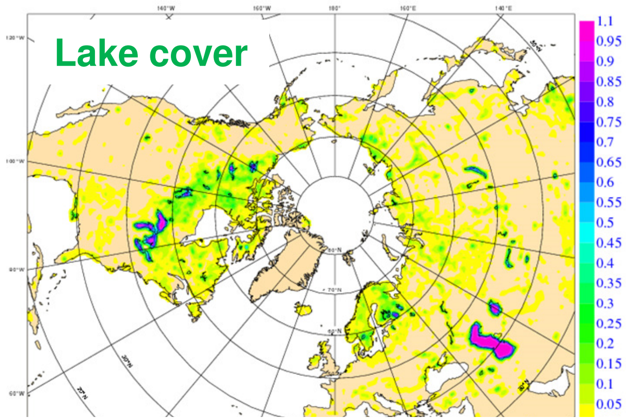
- FLAKE Lake surface temperature is verified against the MODIS LST product (from GSFC/NASA)
- Good correlation

  R=0.98
- Reduced bias

  BIAS (Mod-Obs) < 0.3 K

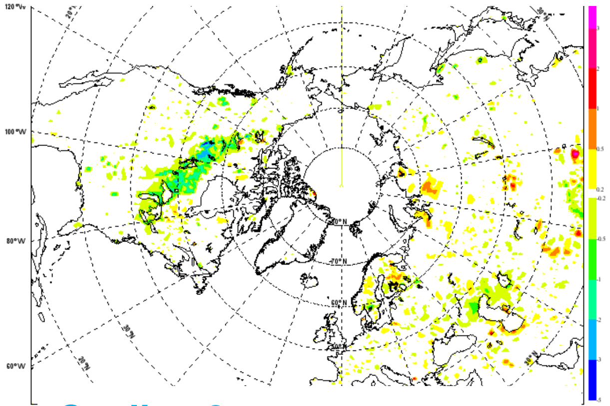
Impact of lakes in NWP forecasts

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



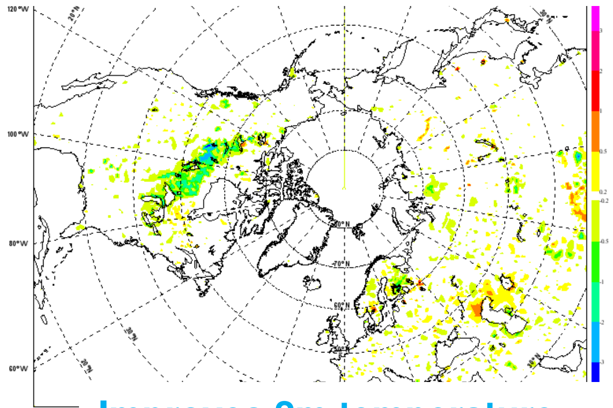
- **Forecasts sensitivity and impact is shown to produce a spring-cooling on lake areas with benefit on the temperatures forecasts (day-2 (48-hour forecast) at 2m.**

Forecast sensitivity



Cooling 2m temperature
Warming 2m temperature

Forecast impact



Improves 2m temperature
Degrades 2m temperature

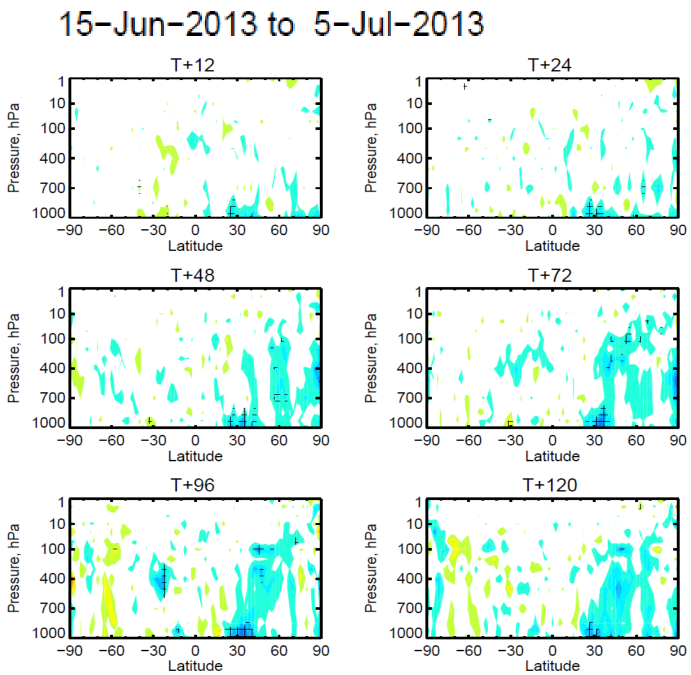
ERA-Interim forced runs of the FLAKE model are used to generate a lake model climatology which serves as IC in forecasts experiments (Here it is shown spring sensitivity and error impact on temperature when activating the lake model).

Implementation of lakes in 40R3

AN cycling and initialisation

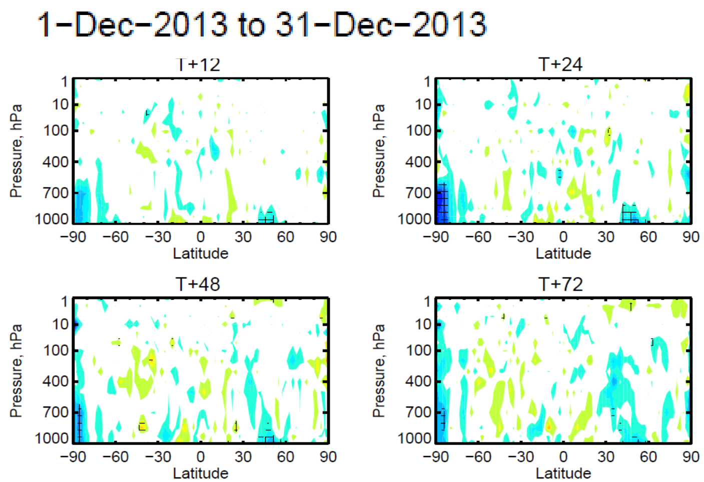
Summer experiment

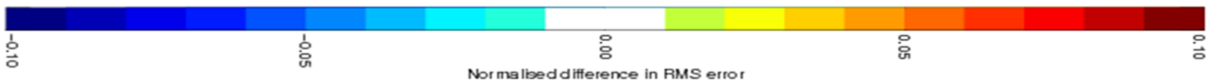
(Temperature scores)



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)

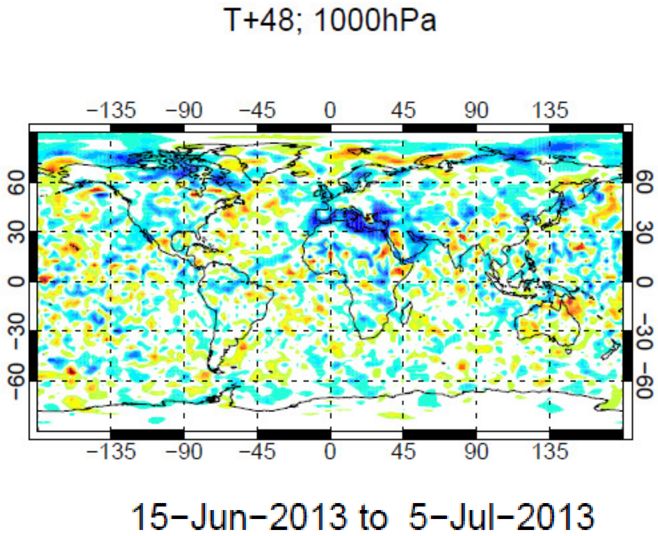
Updated results from Balsamo (2013, ECMWF Autumn Newsletter)

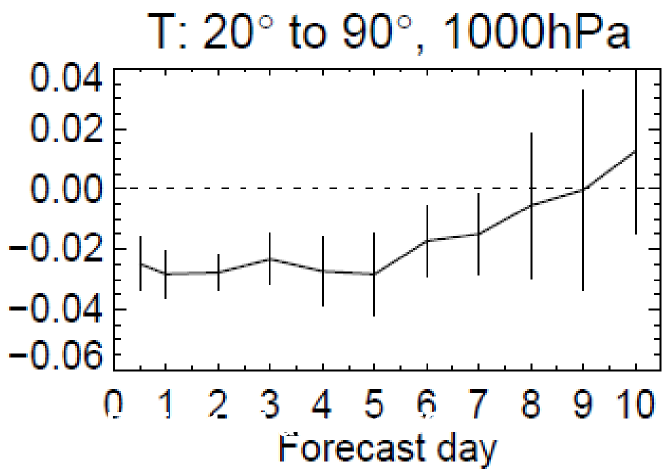
ECMWF

Implementation of lakes in 40R3 (II)

Summer experiment

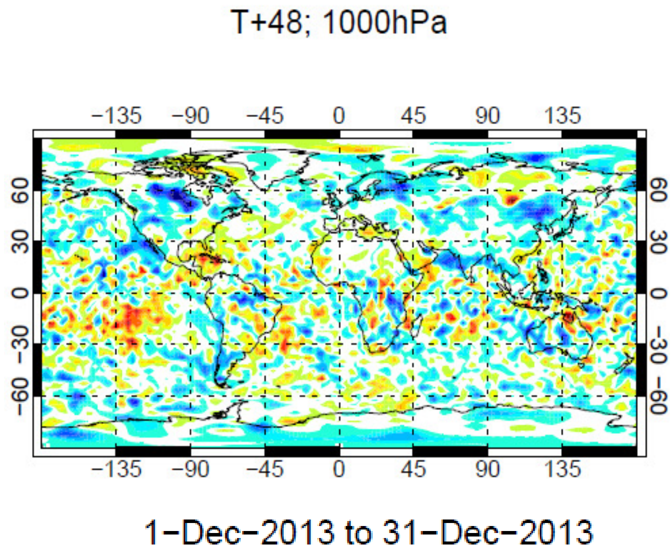
(Temperature scores)

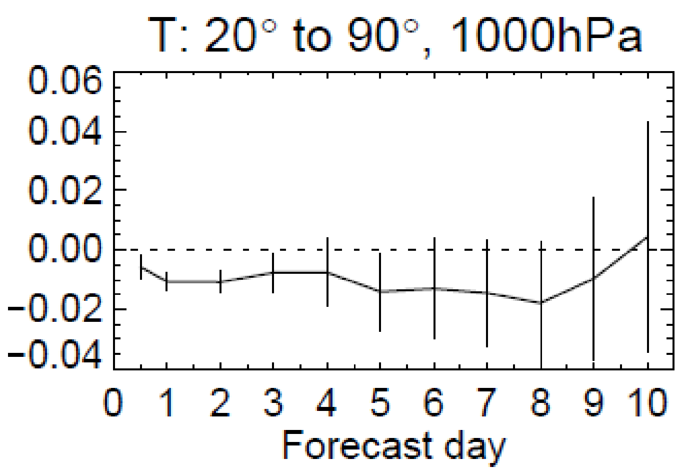




Winter experiment

(Temperature scores).

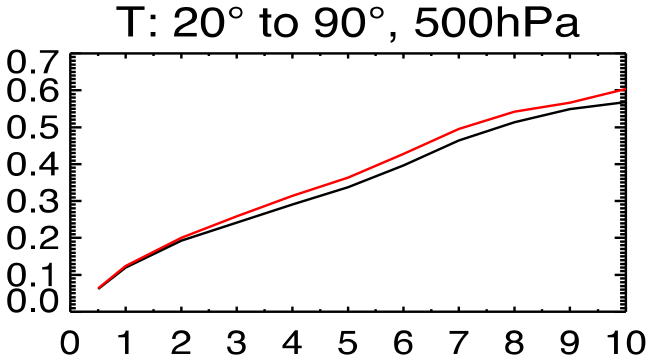


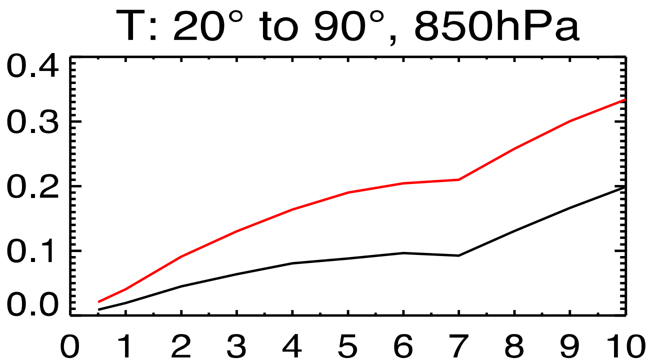


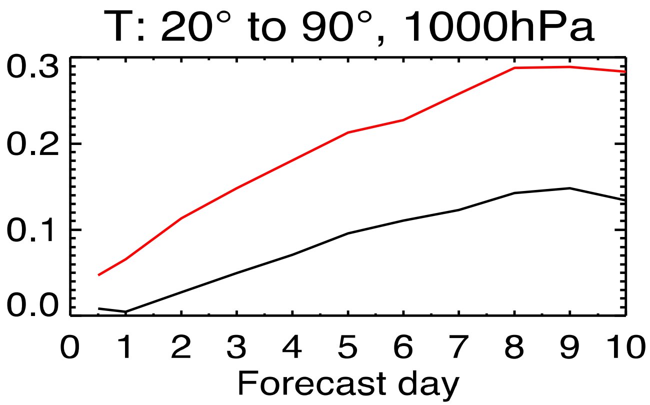
- Forecast of 2m temperature are improved in proximity of lakes and coastal areas
- In summer The impact is estimated in 2-3% relative improvement in RMSE of T1000hPa significant up to 7 days
- Winter RMSE impact is positive as well but of around 1%

ECMWF

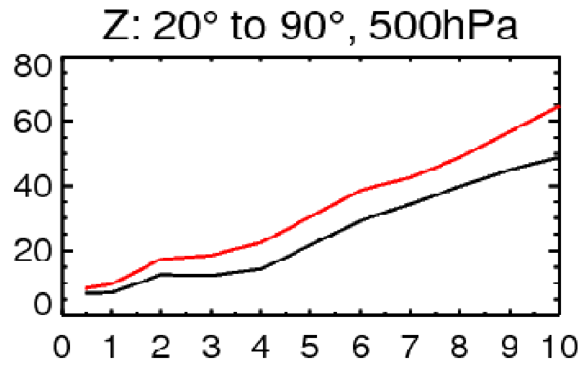
Implementation of lakes in 40R3 (III)







- 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)

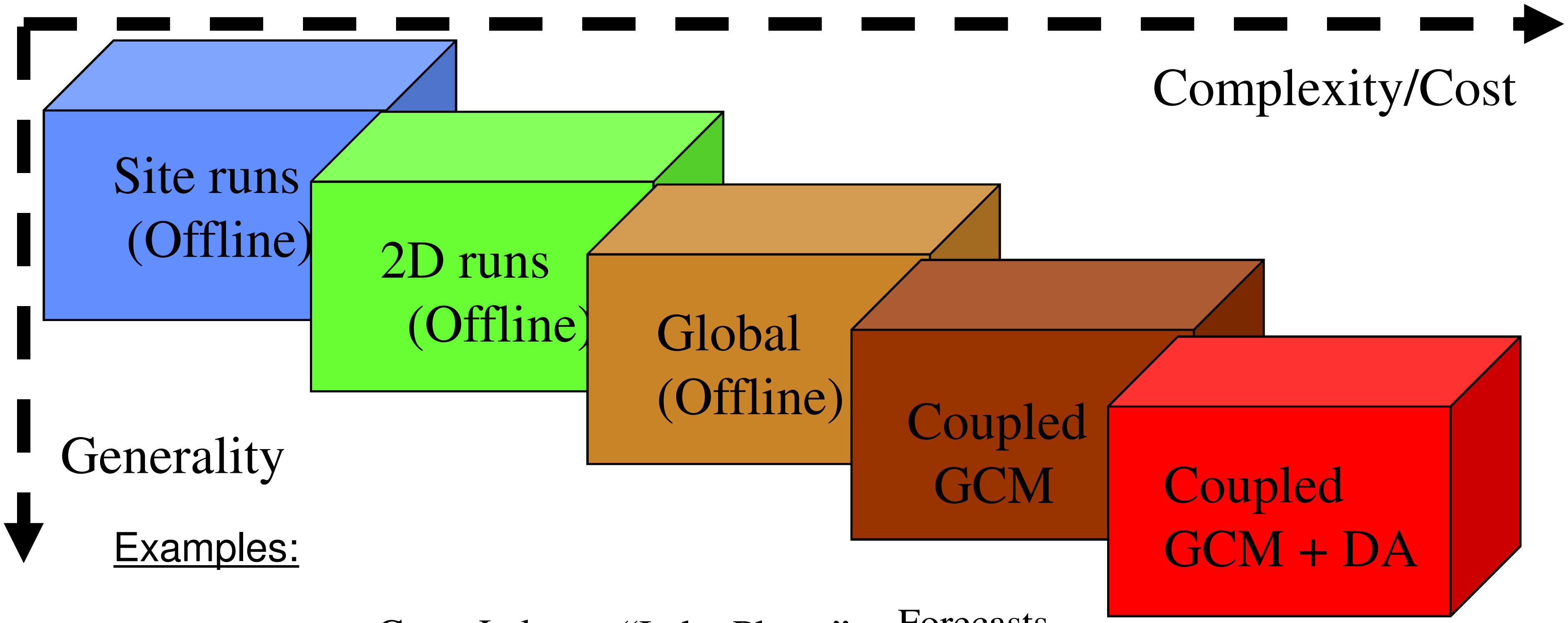


- Z500 gets meteorologists attention!

——— mean error of CY40R3 with lakes

——— mean error of CY40R3 without lakes

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



Examples:

Portugal & Finnish lakes

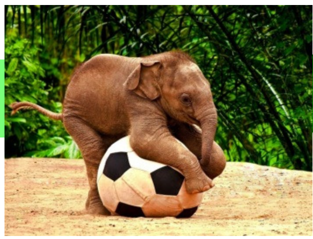
Great-Lakes Caspian-Sea

“Lake-Planet”

Forecasts +lakes/coasts

Analysis & Reanalysis

Lake-timeline: 2006-2010



2012

2014

Summary & Outlook

- **The ECMWF land surface scheme and its extension to lakes**
  - The introduction of lakes and coastal subgrid waters enhance 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
- **Initial condition and dedicated analysis and re-analyses for lakes**
  - Use of satellite based lake temperature and lake ice information has potential to improve further the impact of this modelling component.
  - Improved lake bathymetry dataset (GLDBv2, *Choulga et al. 2014)* and inverse modelling can optimize the lake impact.