Parameterization of continental surfaces in coupled Earth System Modelling: Introduction

Which surface processes influence Earth System predictability?

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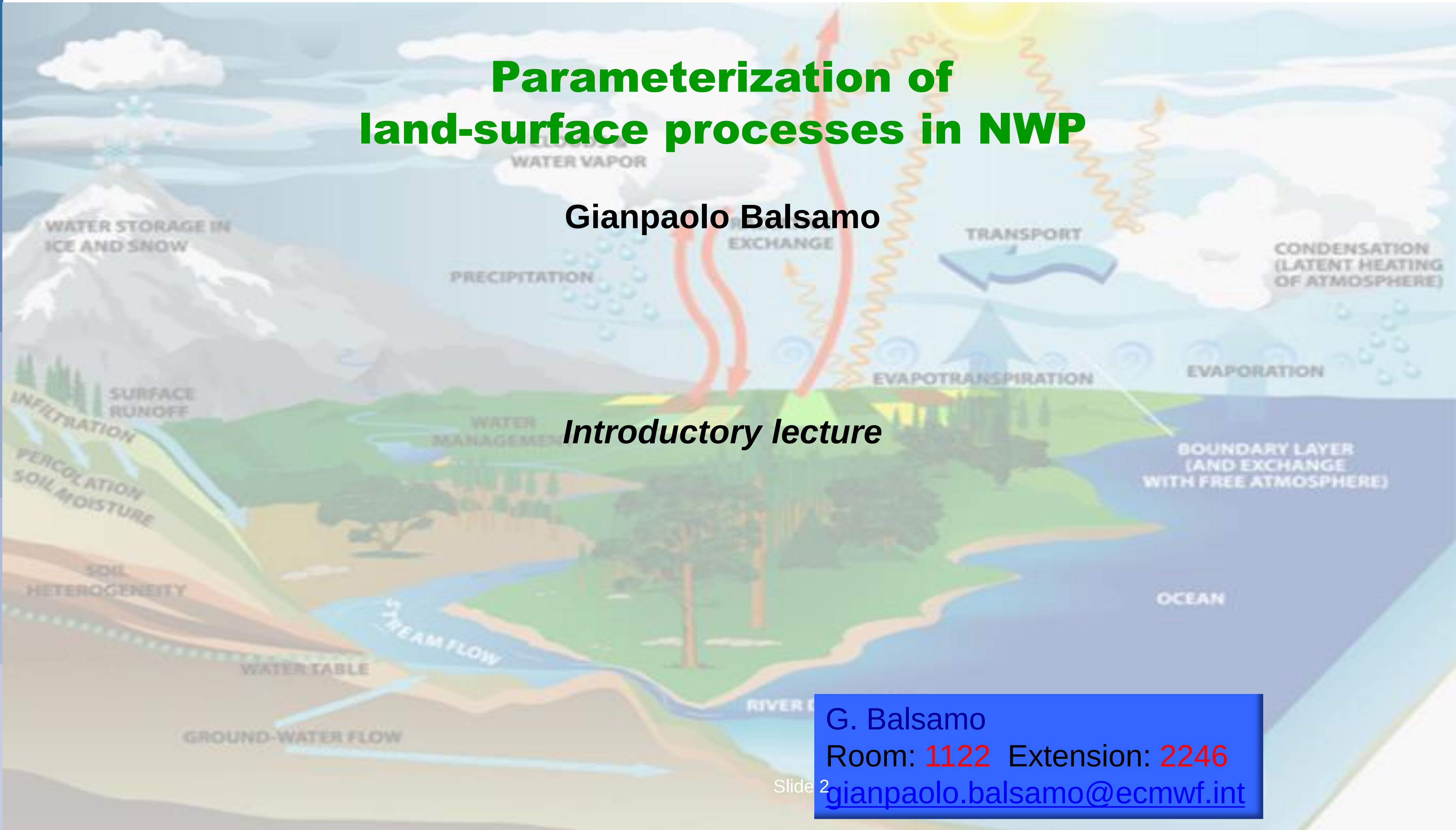
Parameterization of land-surface processes in NWP

Gianpaolo Balsamo

Introductory lecture



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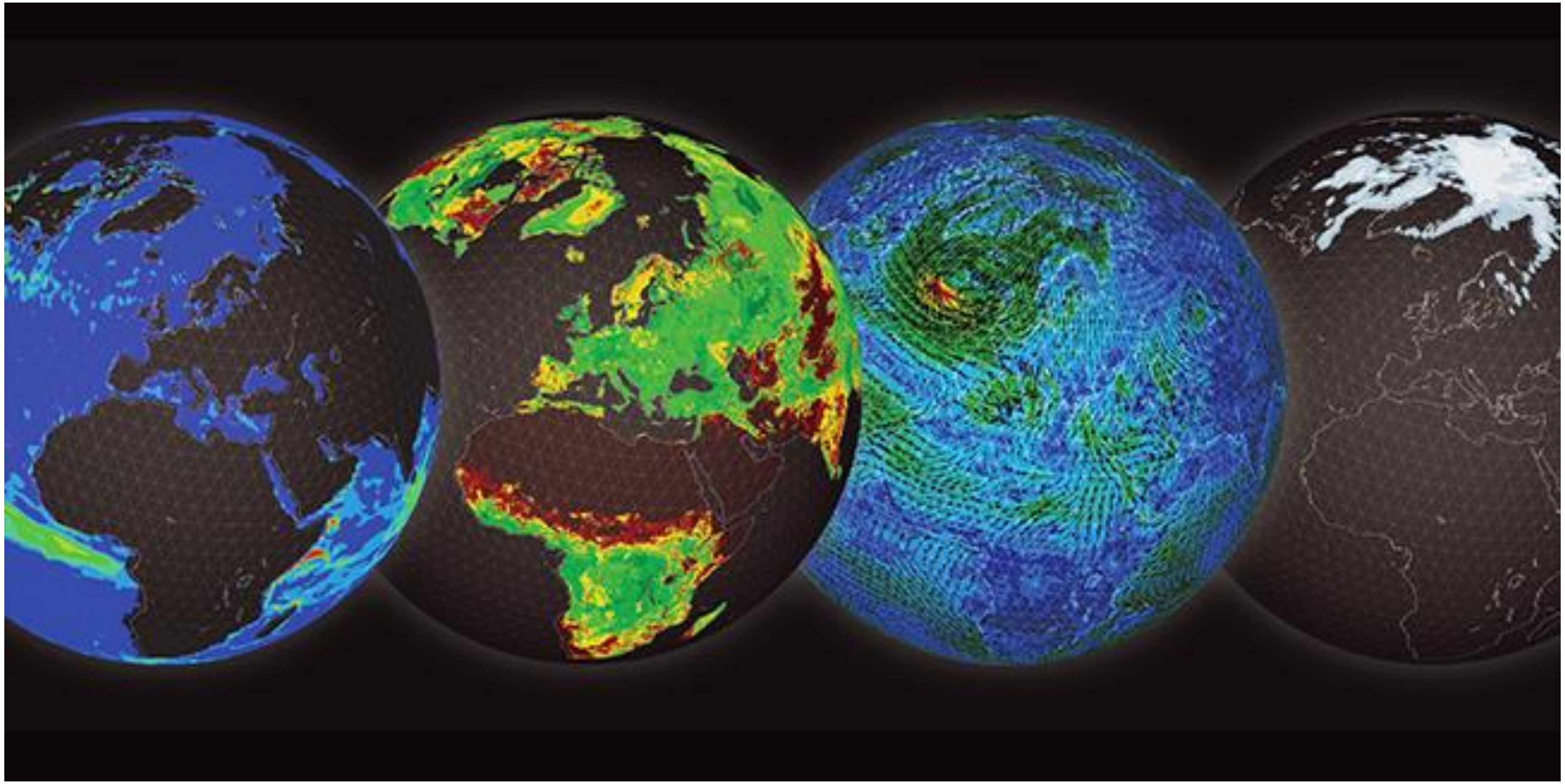
Context

- Why Numerical Weather Prediction had to embrace Earth System Modelling?
  - It is much nicer and represent nature better? Do we gain?
- Biosphere, Hydrosphere, Cryosphere, and Atmosphere: Do they all matter the same?
  - Can we attempt a quantitative evaluation? What are the caveats?
- Diurnal and Seasonal amplitude improvements
  - How much are they drivers to accurate predictions?
- What else is in the “hat” and where do we need (r)evolutionary ideas?
  - Bridging gaps between modelling communities
  - Bringing new EO data to guide model development
- Roadmap to Global Environmental Monitoring and Prediction
  - If we can imagine it, probably we can do it?

Multi-spheres concept in modelling & prediction



ECMWF 2016 Annual Seminar Earth system modelling for seamless prediction:
On which processes should we focus to further improve atmospheric predictive skill?
http://www.ecmwf.int/en/annual-seminar-2016

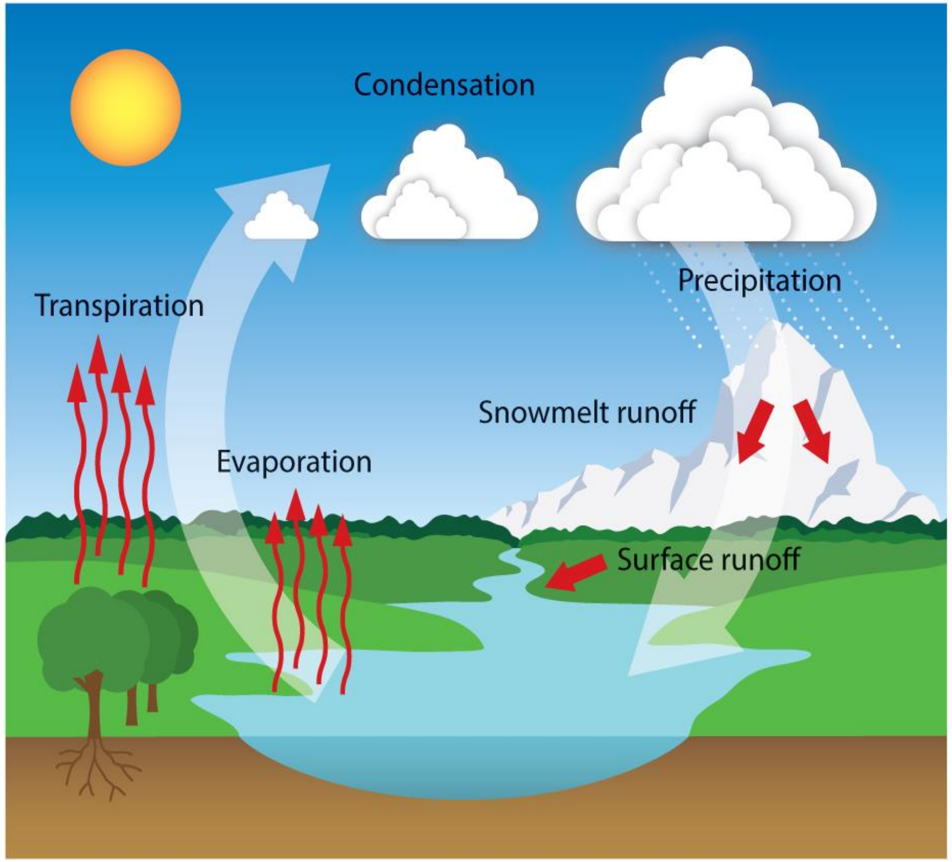
ECMWF STRATEGY 2016-2025

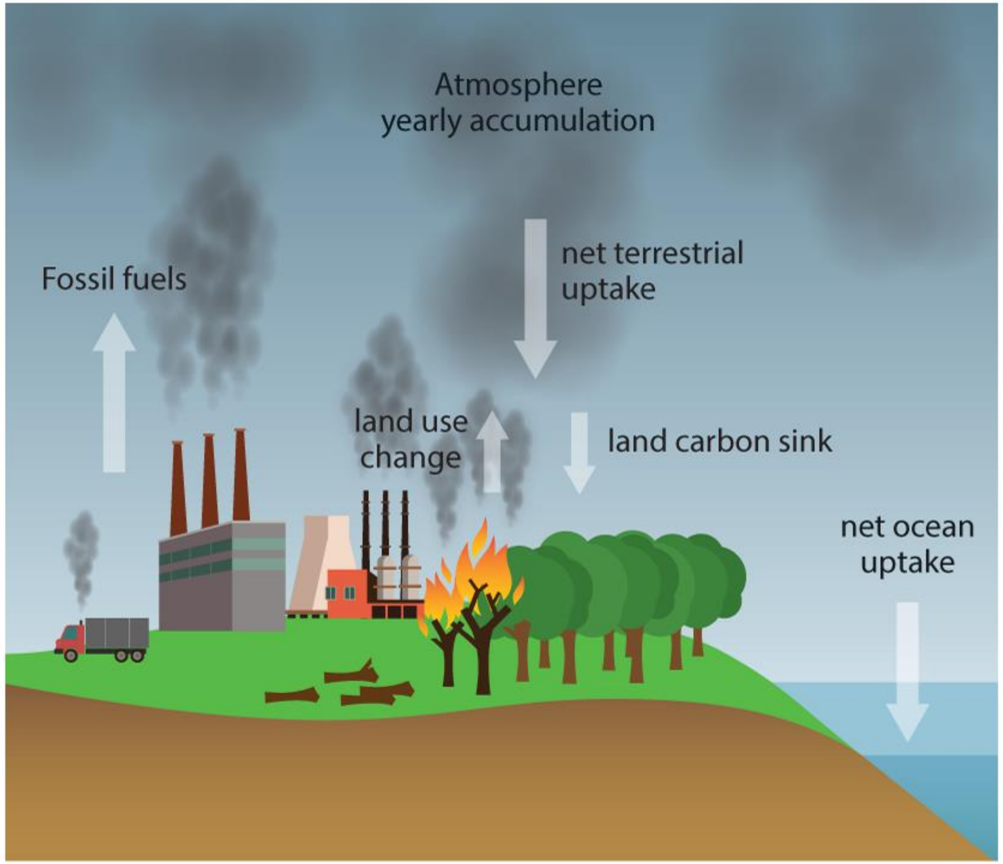
EARTH SYSTEM APPROACH

ENSEMBLE MODELLING AND ASSIMILATION. GOAL: 5KM

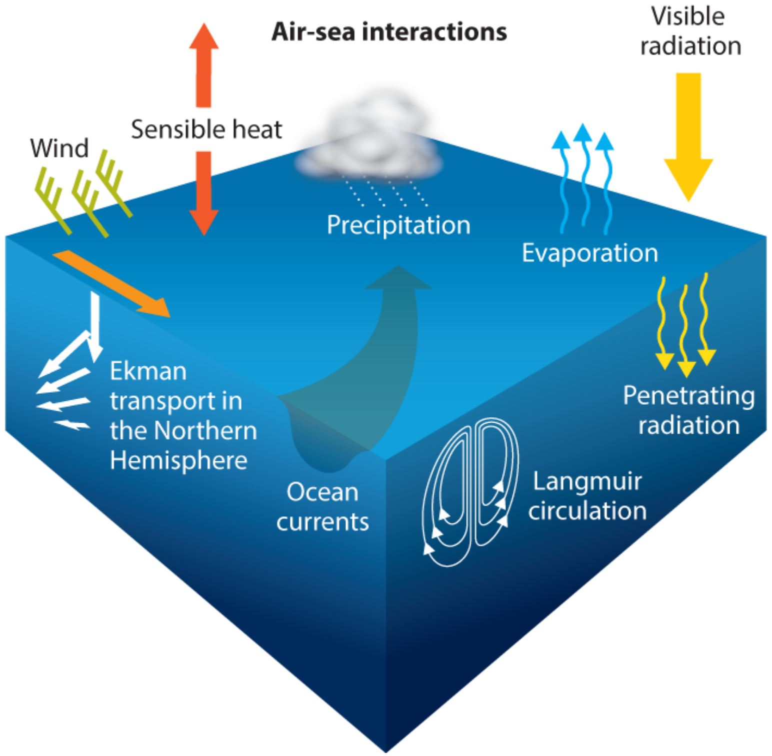
SCALABILITY ACROSS WHOLE NWP CHAIN

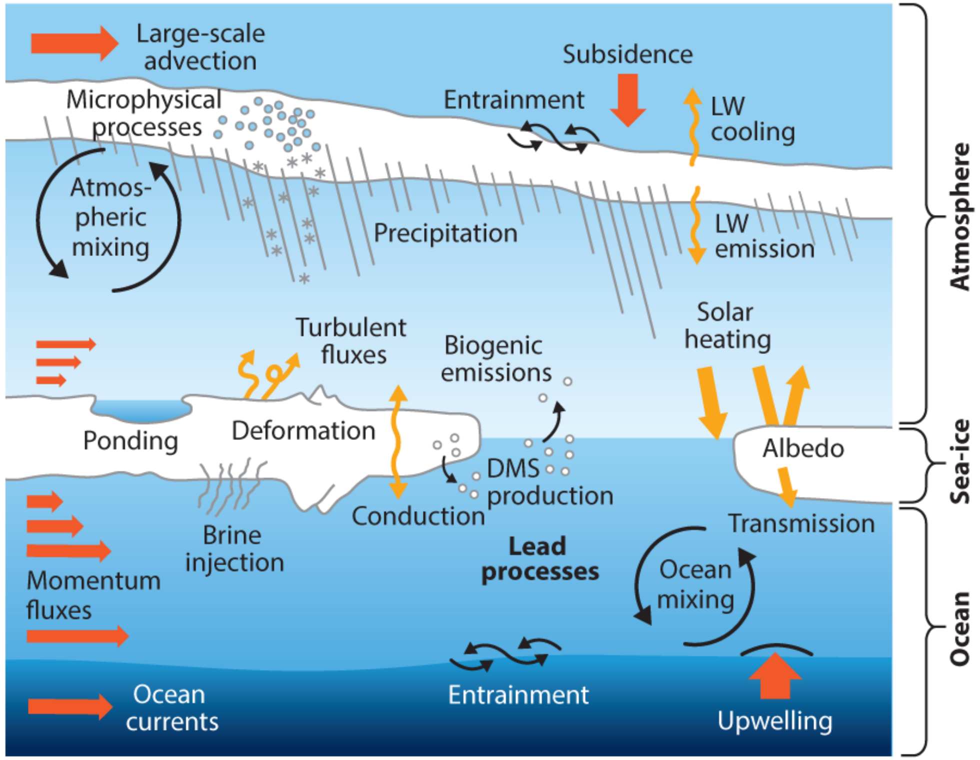
Natural Land & Human-activity @ECMWF:
How can/will natural land modelling include LUC





Oceans & marine cryosphere @ECMWF:
How climate modelling fed into weather





Earth surface modelling components @ECMWF

Atm/L and resol.	**ECMWF Config. in 2017**
80 km	ERAI*
32 km	ERA5* SEAS5
18 km	ENS
9 km	HRES$^+$

- **NEMO3.4**

  NEMO3.4 (Nucleus for European Modelling of the Ocean)

  Madec et al. (2008)

  Mogensen et al. (2012)

  ORCA1_Z42: 1.0° x 1.0°

  ORCA025_Z75 : 0.25° x 0.25°

- **EC-WAM**

  ECMWF Wave Model

  Janssen, (2004)

  Janssen et al. (2013)

  ENS-WAM : 0.25° x 0.25°

  HRES-WAM: 0.125° x 0.125°

- **LIM2**

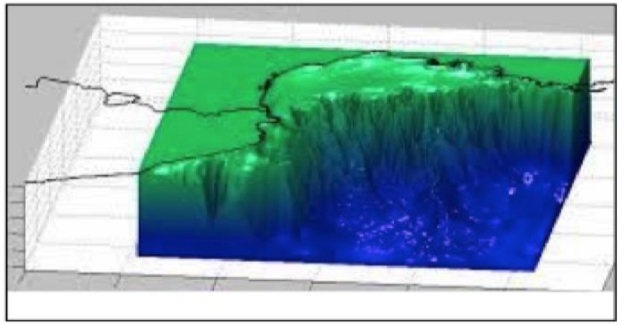
  The Louvain-la-Neuve Sea Ice Model

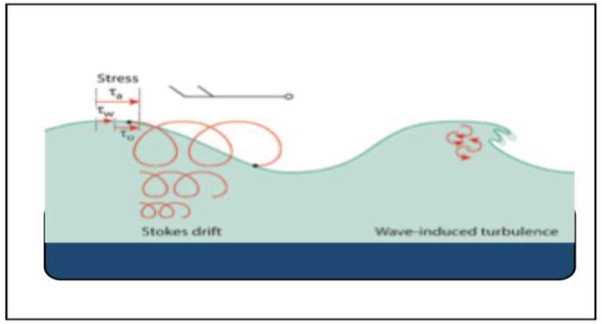
  Fichefet and Morales Maqueda (1997)

  Bouillon et al. (2009)

  Vancoppenolle et al. (2009)

  ORCA025_Z75 : 0.25° x 0.25°





Ocean 3D-Model Surface Waves and currents, Sea-ice.
(ocean-uncoupled)
$^+$(coupled in 2018)

- **Hydrology-TESSEL**

  Balsamo et al. (2009) van den Hurk and Viterbo (2003)

  Global Soil Texture (FAO)

  New hydraulic properties

  Variable Infiltration capacity & surface runoff revision

- **NEW SNOW**

  Dutra et al. (2010)

  Revised snow density

  Liquid water reservoir

  Revision of Albedo and sub-grid snow cover

- **NEW LAI**

  Boussetta et al. (2013)

  New satellite-based

  Leaf-Area-Index

- **SOIL Evaporation**

  Balsamo et al. (2011),

  Albergel et al. (2012)

- **H_2O / E / CO_2**

  Integration of

  Carbon/Energy/Water

  Boussetta et al. 2013

  Agusti-Panareda et al. 2015

- **Lake & Coastal area**

  Mironov et al (2010),

  Dutra et al. (2010),

  Balsamo et al. (2012, 2010)

  Extra tile (9) to for sub-grid lakes and ice

  LW tiling (Dutra)

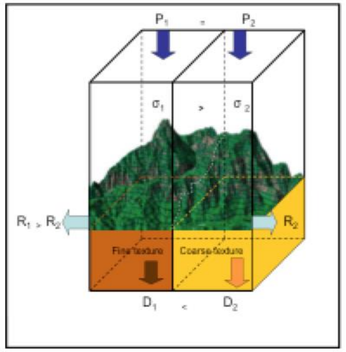
- **Enhance ML**

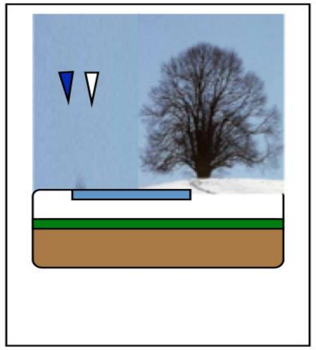
  Snow ML5

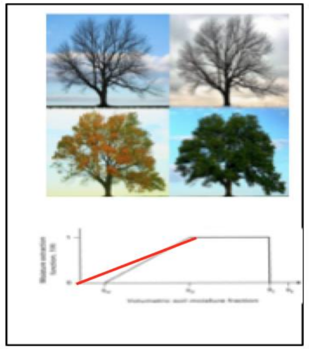
  Soil ML9

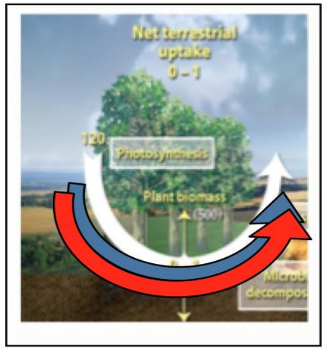
  Dutra et al. (2012, 2016)

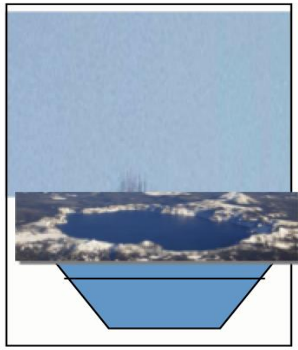
  Balsamo et al. (2016)

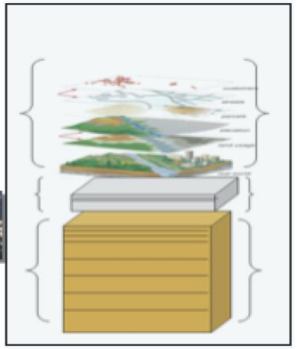








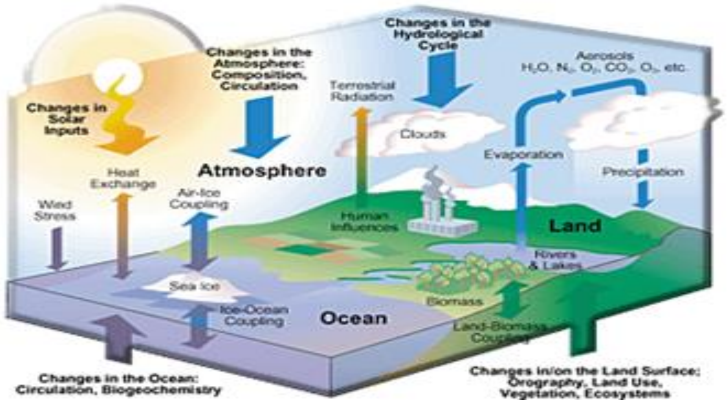




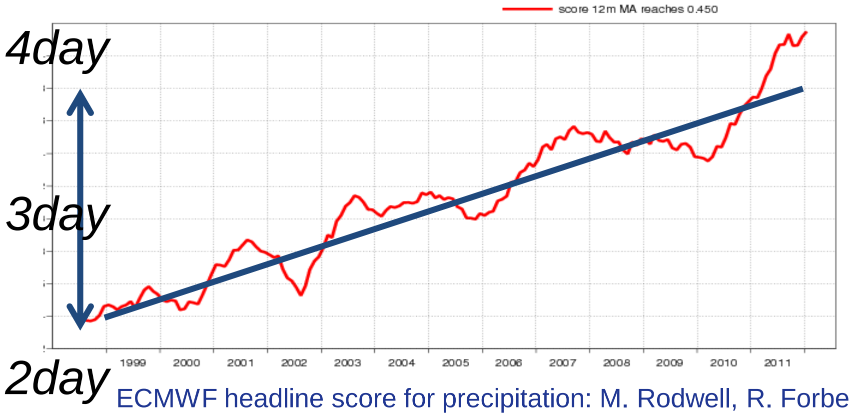
Land surface 1D-model soil, snow, vegetation, lakes and coastal water (thermodynamics).
Same resol. as Atm.

The water and Carbon cycle

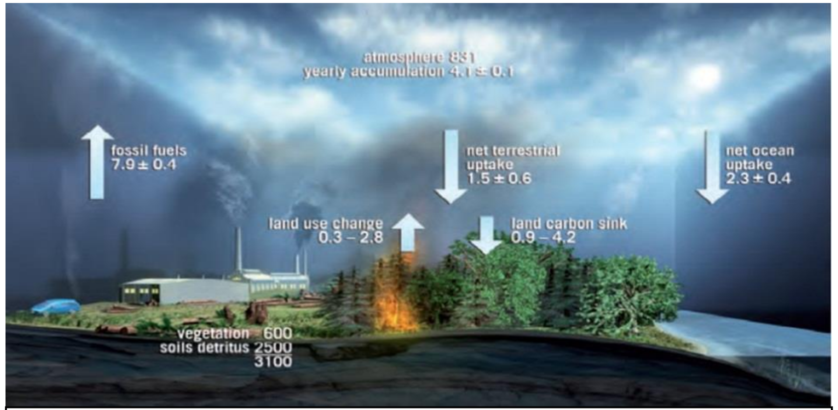
- **Numerical Weather Prediction models have considerably evolved over time with respect to how they represent the land surface and its interaction with the atmosphere**



Precipitation forecasts improvements support (1 day/decade in skill gain) refined LSMs



ECMWF headline score for precipitation: M. Rodwell, R. Forbes



CO2 budget (from ESA – BIOMASS mission report)

- **The needs of unification of NWP and Climate model are a driver to develop land surface schemes with increased realism**

Evolving towards Earth System Models

- **Enhanced Earth surface complexity is supported by quality of atmospheric forcing**

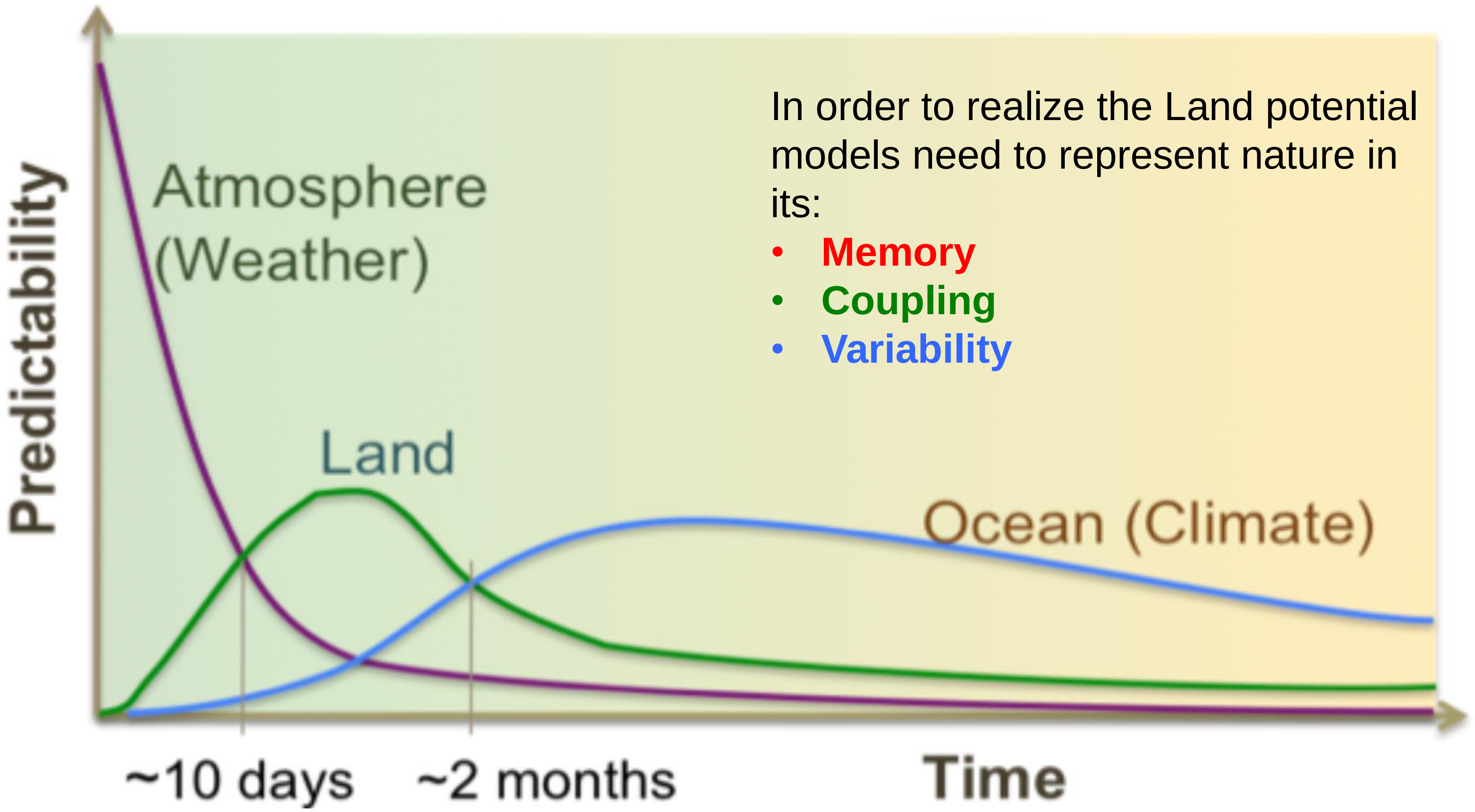
Impact of Earth Surface in Global Environmental prediction

- The surface is characterized by many slow processes
- A slow process makes initial condition a priority: they need to be accurate to extract predictability from the modelling components
- Can we say all surface predictability rely on initial condition accuracy?
- What is the value of surface process representation in models?

Value of Earth Surface Global Environmental prediction

- The surface is where we live and it sustains all human activities.
- Forecasting the surface state has value per se (e.g. floods, droughts, biomass-anomalies, sea-state, ice & snow conditions all matters for users).
- Most importantly better surface can sustain medium/extended range skill.
- But can we prove it experimentally? And which surface process does what?

Earth surface role in medium-range and S2S



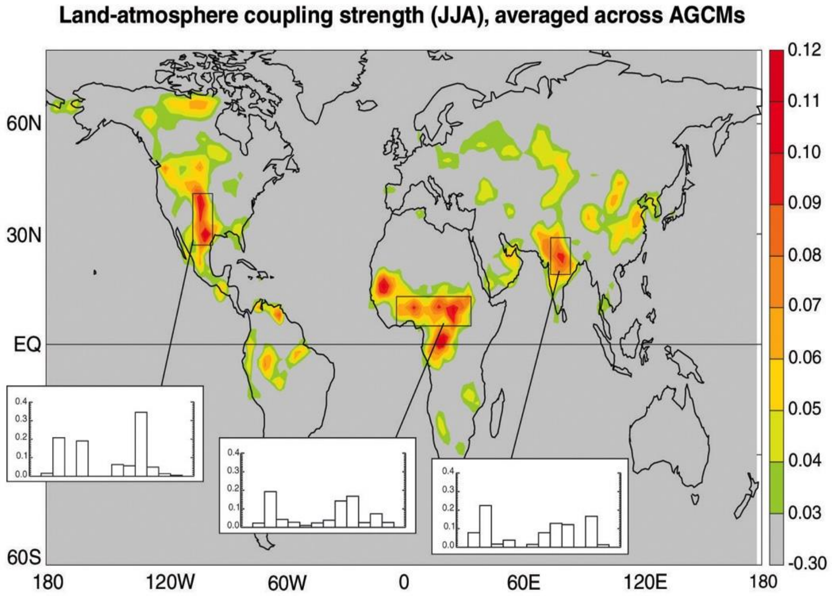
In order to realize the Land potential models need to represent nature in its:

- **Memory**
- **Coupling**
- **Variability**

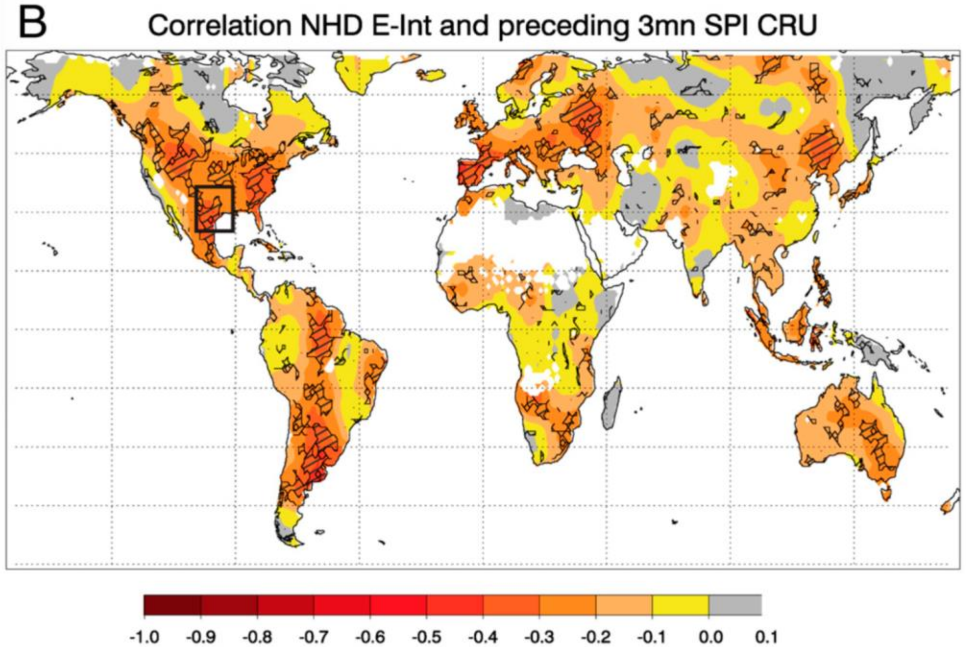
Dirmeyer et al. 2015: http://library.wmo.int/pmb_ged/wmo_1156_en.pdf

Earth surface role, experimental evidence (soil moisture)

Koster et al. 2004 Science
Land-coupling (SM-T) in Northern Hemisphere JJA

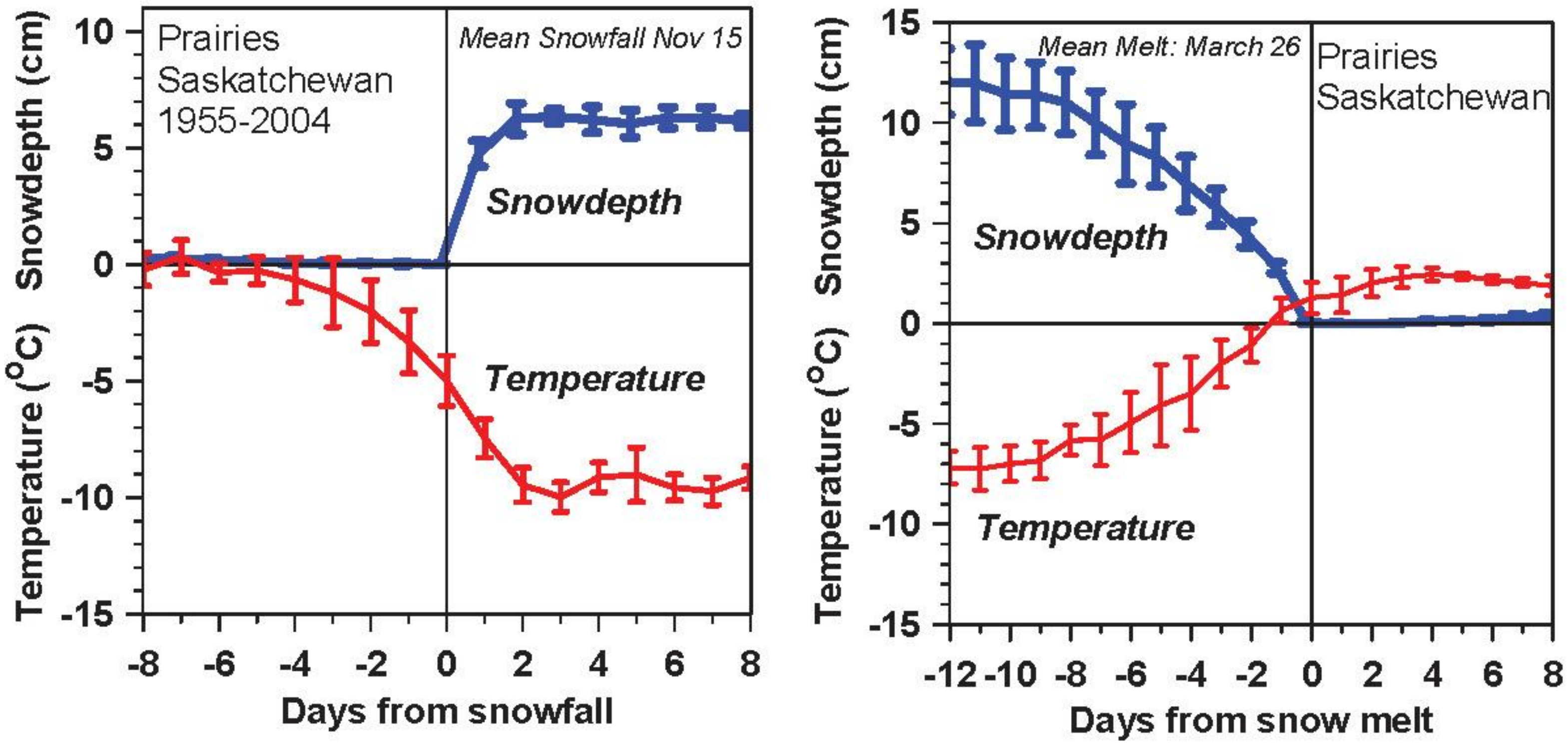

Land-atmosphere coupling strength (JJA), averaged across AGCMs

Mueller and Seneviratne 2012 PNAS
Hot-Days correlation with 3-month antecedent P deficit


Correlation NHD E-Int and preceding 3mn SPI CRU

Albergel et al. 2013JHM show dominance of significant drying trends for soil moisture in both reanalysis and satellite-based soil moisture dataset, with possibly larger areas of land surface predictability

Earth surface role, observational evidence (snow)



Snow reflects sunlight; shift to cold stable BL

- ***Local climate switch between warm and cold seasons***
- ***Winter comes fast with snow***

Betts et al. 2014

Earth surface role, literature (sea-ice)

“Arctic sea ice …has strong feedback effects on the other components of the climate system”

Vihma 2014, Survey in Geophysics

“Arctic sea ice change includes global scale impacts, as well as regionally changing interaction mechanisms and Trends”

Doscher et al. 2014, ACP

Weather forecasts impact of soil/snow processes improved representation

- **Hydrology-TESSEL**

  Balsamo et al. (2009)
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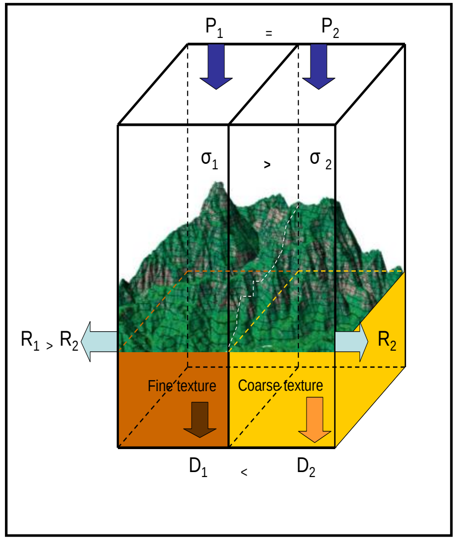
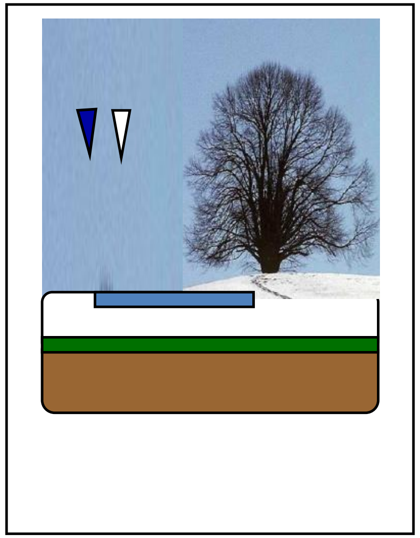
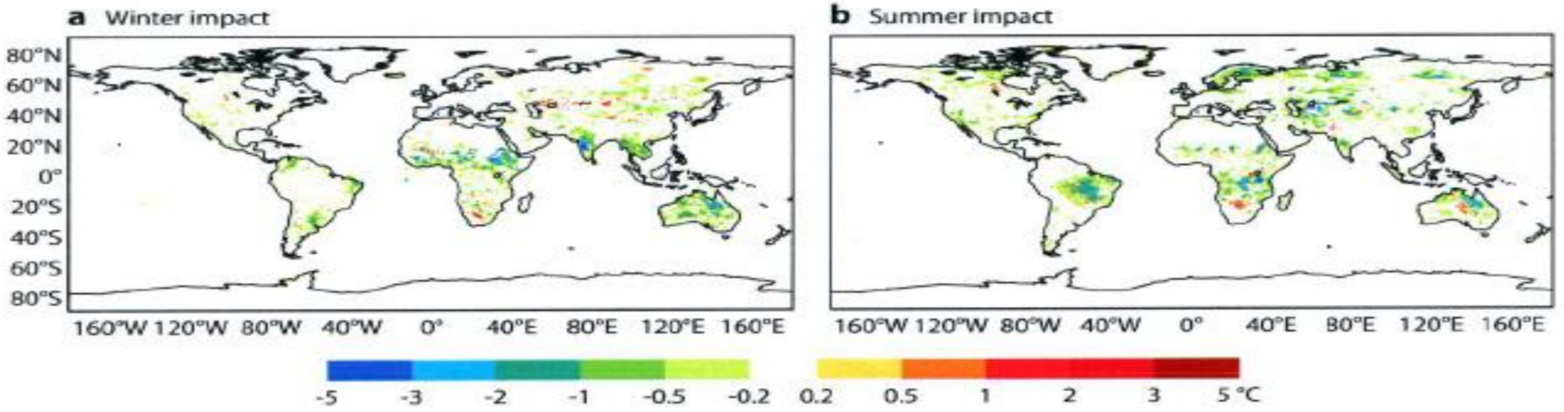




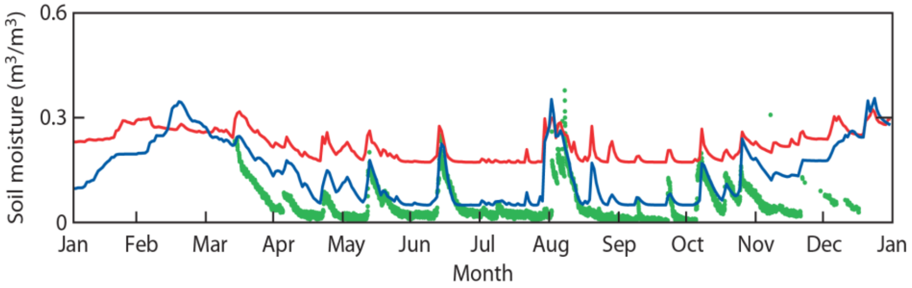
Forecast Impact (+36-hour forecast, mean error at 2m temperature)



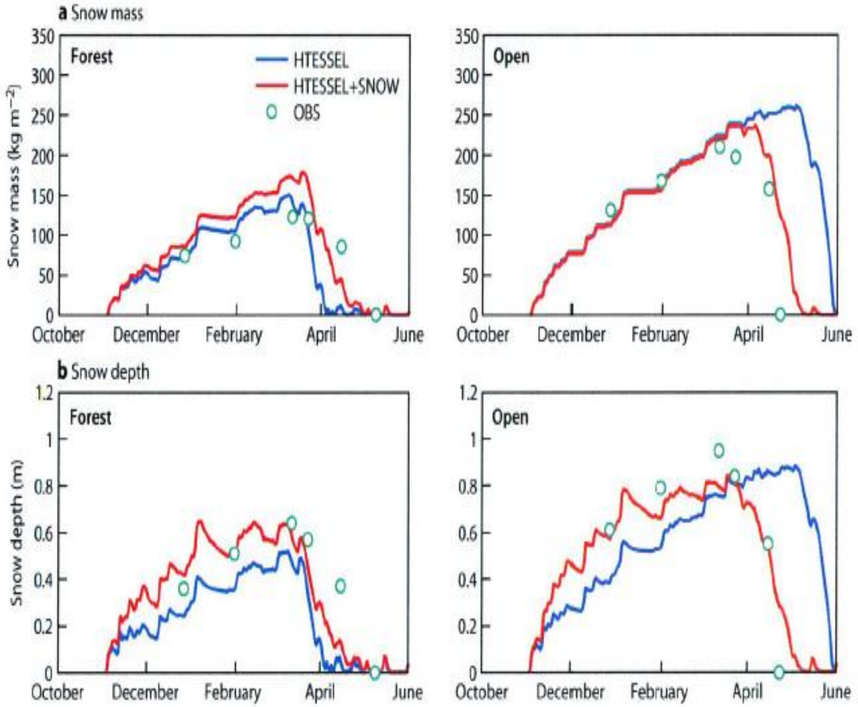
Improving 2m temperature **Degrade 2m temperature**

Soil moisture and Snow-pack modelling evaluated in-situ

Balsamo et al 2009 JHM, Dutra et al. 2010 JHM

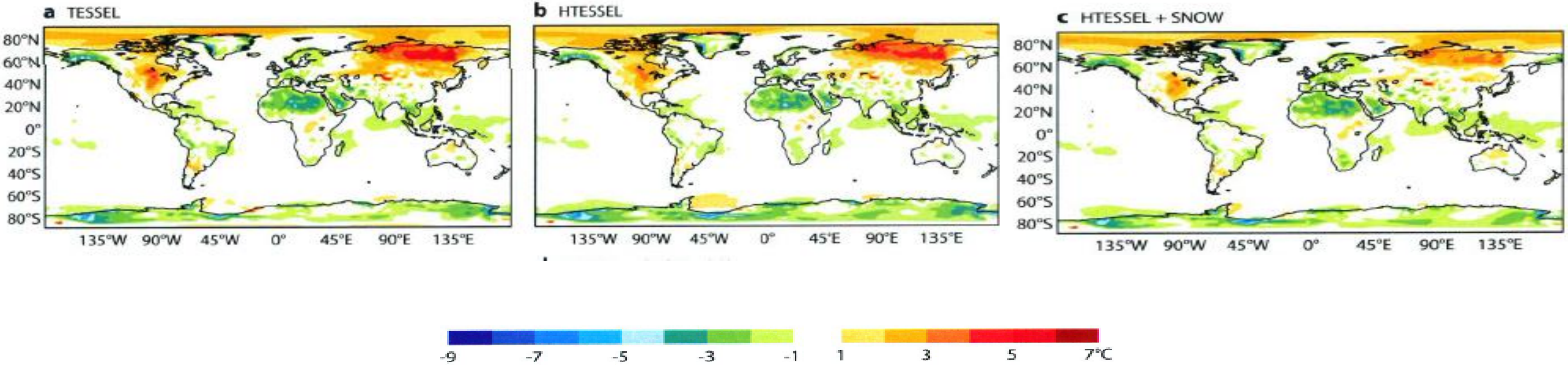


Evolution of soil moisture for a site in Utah in2010. **Observations**, **old**, and **new** schemes.



Evolution of snow mass and depth at SNOWMIP 2 observational sites in the new and old scheme

Climate improvements from land developments (soil, snow, vegetation)

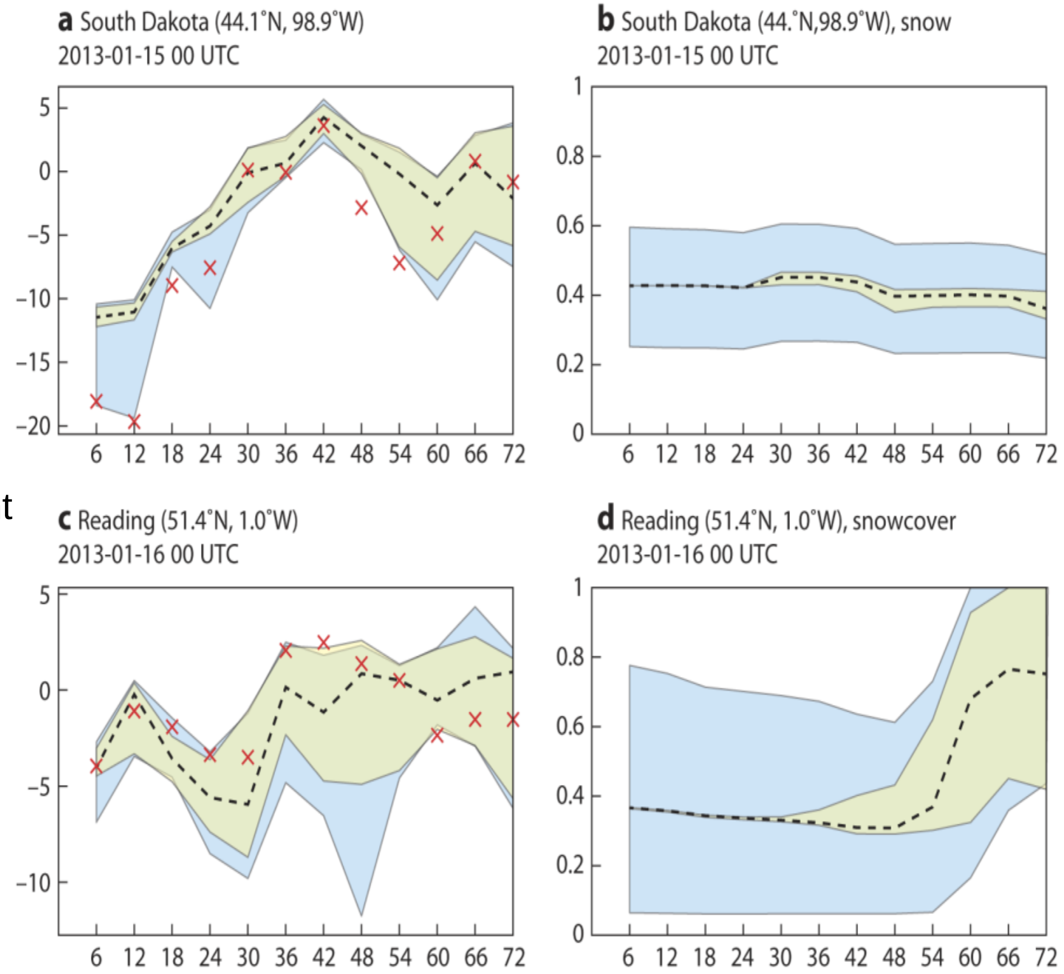


simulations colder than ERA-Interim

Warmer than ERA-Interim

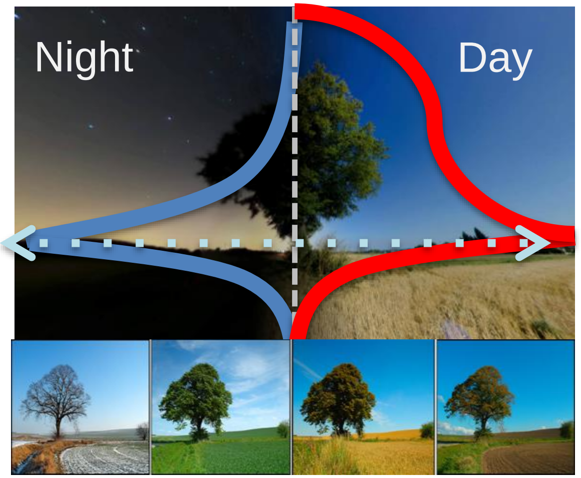
Representing land-related forecast uncertainties

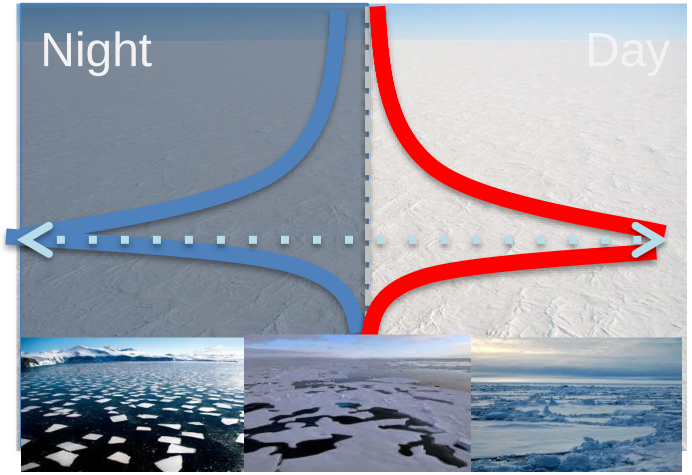
- EDA/ENS system includes land surface components (CY40R1) and perturbation also to the assimilated observations (CY40R3)
- Accounting for land surface uncertainties (particularly for snow) enhances the ensemble spread of 2m temperature prediction and its usefulness for forecasters
- The uncertainty is situation dependent and perturbations permit to capture the occurrence of extremes
  (e.g. clear sky nights combined
  with snow covered surface
  can generate very cold temperatures)
- Small snow cover errors → large temperature impact



Modelling surface heterogeneity and coupling with the atmosphere

- The processes that are most relevant for near-surface weather prediction are also those that are most interactive and exhibit positive feedbacks or have key role in energy partitioning





Over Land

- Snow-cover, ice freezing/melting have positive feedback via the albedo
- Vegetation growth and variability interact with turbulence & moisture
- Vertical heat transport in soil/snow

Over Ocean/Cryosphere

- Transition from open-sea to ice-covered conditions
- Sea-state dependent interaction wind induced mixing/waves
- Vertical transport of heat

Over Water-bodies

- Lakes have large thermal inertia
- Different albedo & roughness

Spatial heterogeneity calls for high-resolution horizontal/vertical to represent the surface-atmosphere coupling

Energy fluxes: diurnal cycle impact of lakes

Manrique-Suñén et al. (2013, JHM)

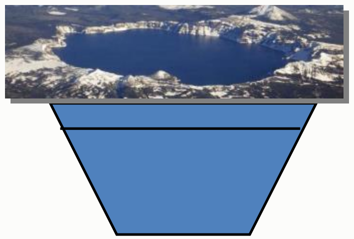
- **Lake tile**

Mironov et al (2010),

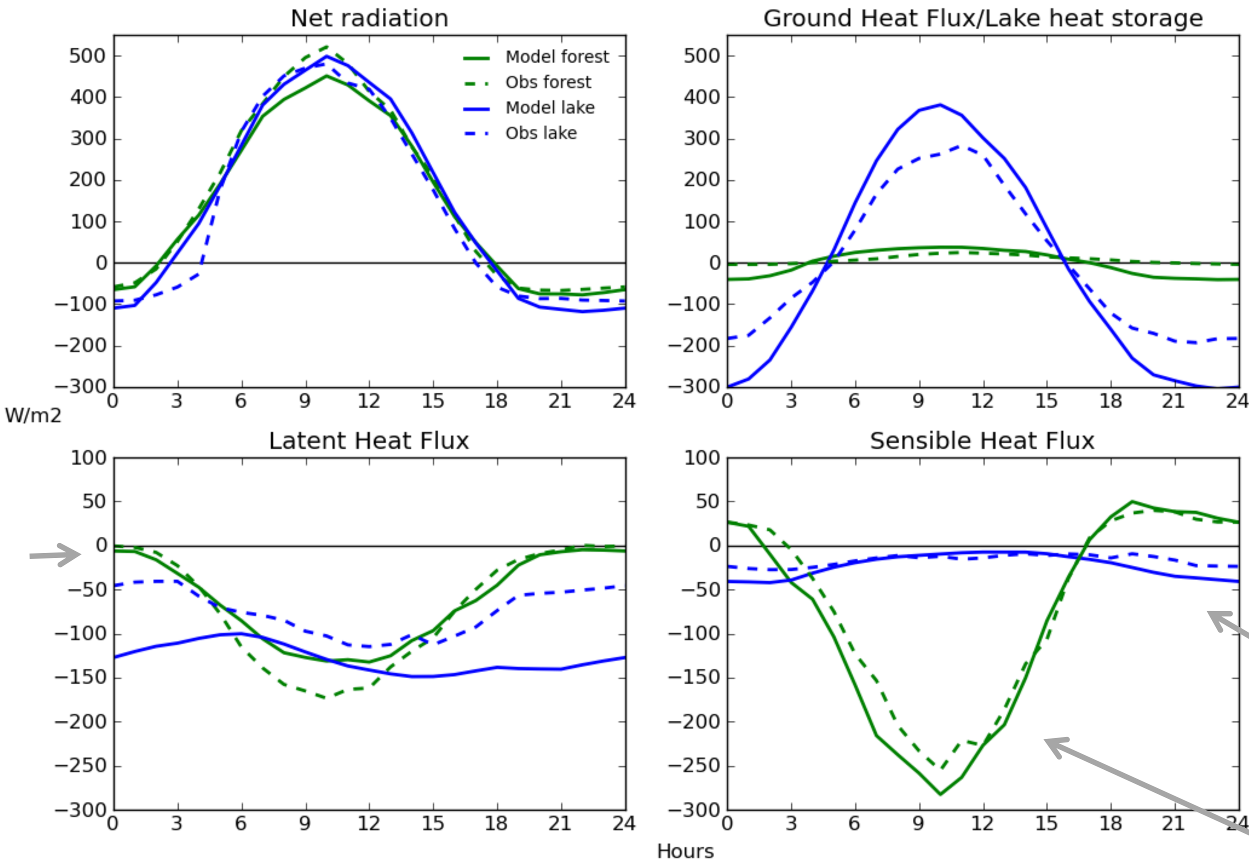
Dutra et al. (2010),

Balsamo et al. (2010, 2012, 2013)

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



Monthly diurnal cycle of energy fluxes for July



HTESSEL
LAKEHTESSEL
forest obs
lake obs

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

Lake LH diurnal cycle: over-estimation in evaporation

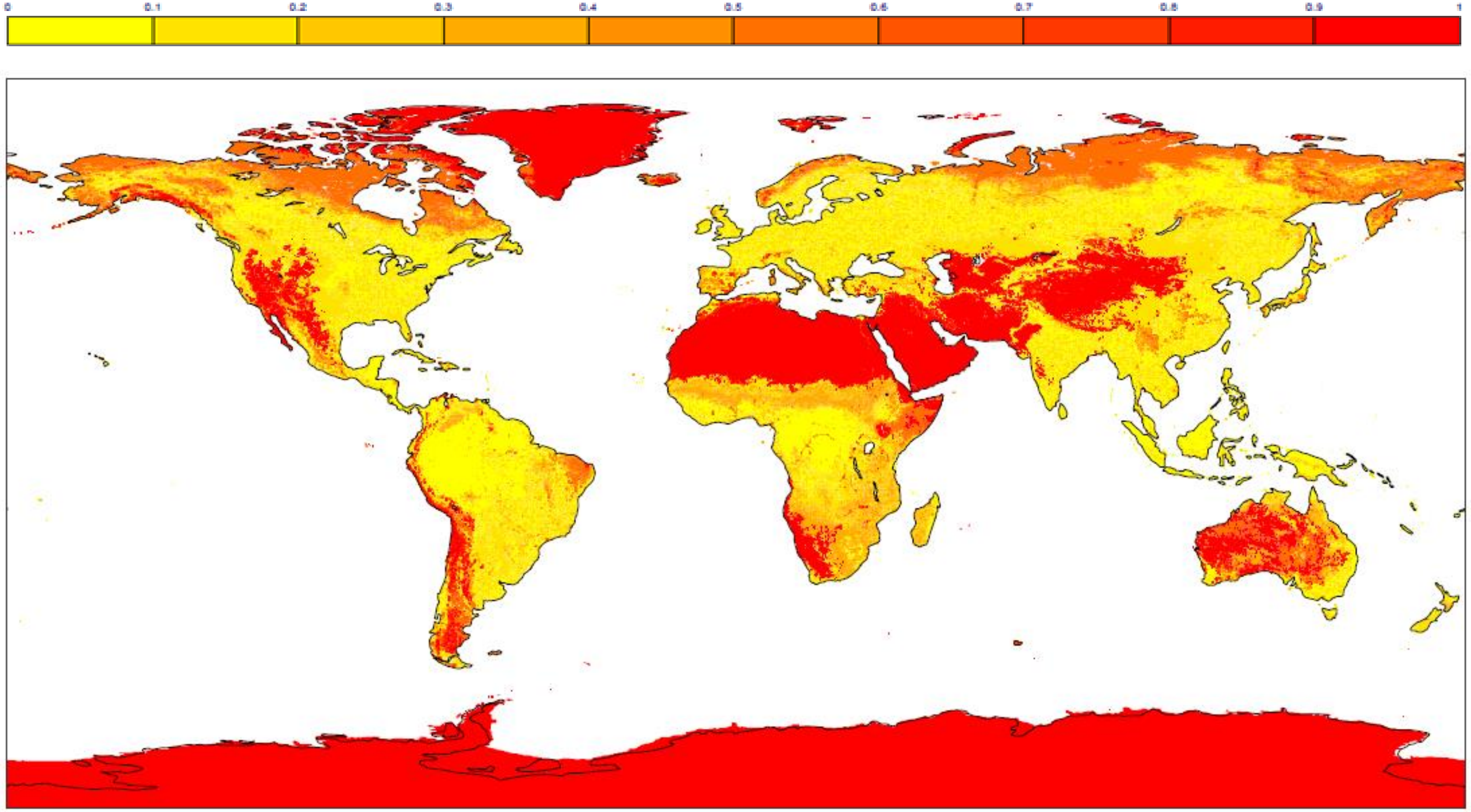
Very good representation by the model of diurnal cycles and particularities of each surface

Lake SH maximum is at night

Forest SH maximum is at midday

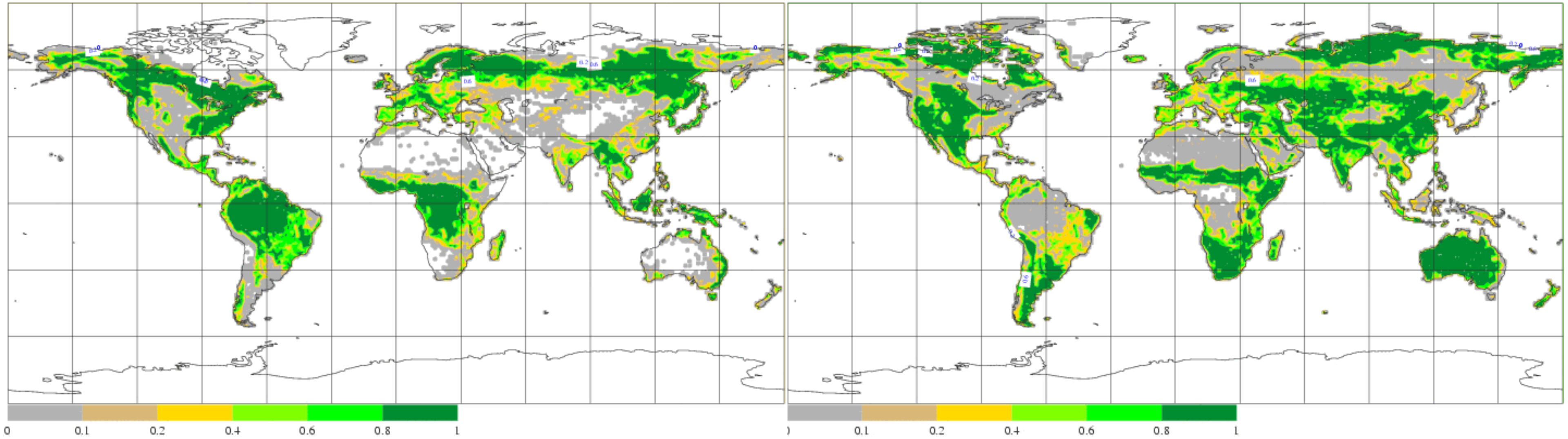
Main difference between lake & forest sites is found in energy partitioning

Bare ground fraction



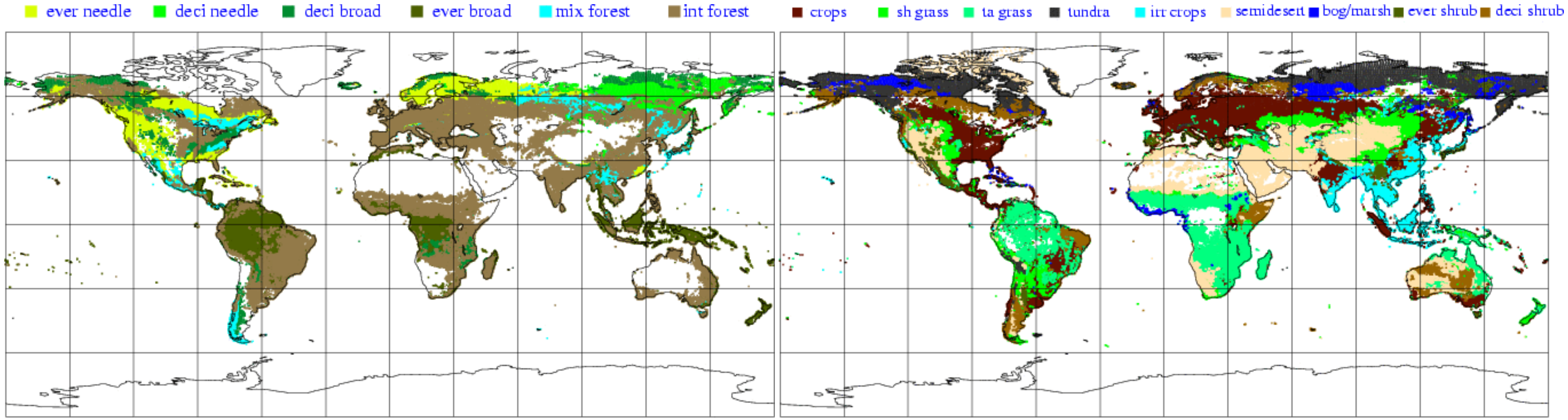
Calculated from GLCC 1km and assigned vegetation covers

High and Low vegetation fractions



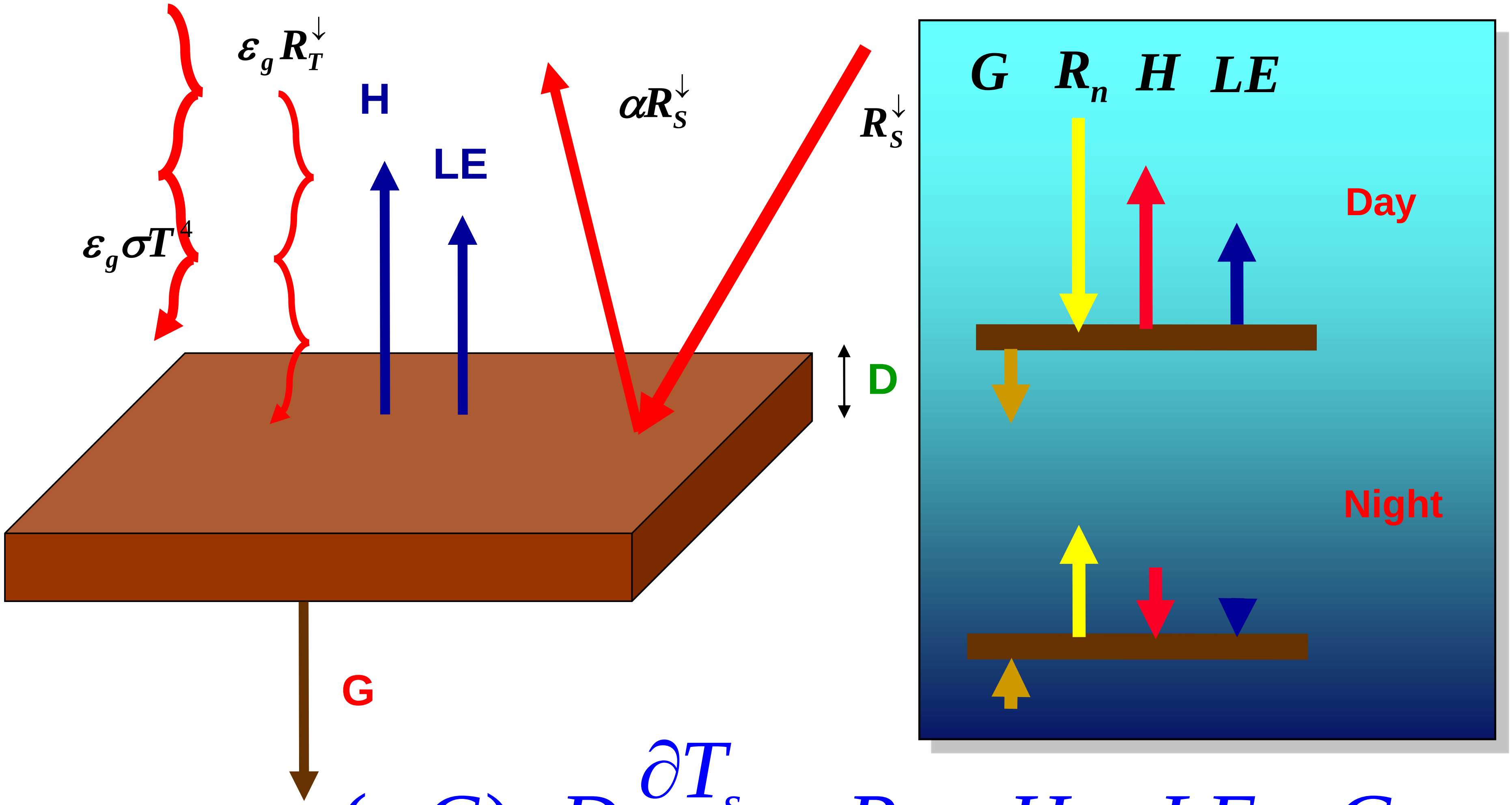
Aggregated from GLCC 1km

High and Low vegetation types



Aggregated from GLCC 1km

Schematics for the Energy flow



$$(\rho C)_g D \frac{\partial T_s}{\partial t} = R_n + H + LE + G$$

HTESSEL skin temperature equation

$$(1-\alpha_i)R_S^{\downarrow} + \varepsilon_g R_T^{\downarrow} - \varepsilon_g \sigma T_{sk,i}^4 +$$
$$\rho C_{h,i} u_L (C_p T_L + gz - C_p T_{sk,i}) +$$
$$\rho C_{h,i} u_L \left[a_{L,i} q_L - a_{s,i} q_{sat}(T_{sk,i}, p_s) \right] +$$
$$\Lambda_{sk,i}(T_s - T_{sk,i}) = 0$$

Grid-box quantities

$$H = \sum_i C_i H_i$$

$$E = \sum_i C_i E_i$$

$$T_{sk} = \sum_i C_i T_{sk,i}$$

C_i Tile fraction

Ground heat flux

$$(\rho C)_g \frac{\partial T_s}{\partial t} = -\frac{\partial G}{\partial z} = \frac{\partial}{\partial z} \lambda_T \frac{\partial T}{\partial z}$$

$(\rho C)_g$	**Soil volumetric heat capacity**
λ_T	**Thermal conductivity**
$k = \dfrac{\lambda_T}{(\rho C)_g}$	**Thermal diffusivity**

For an homogeneous soil,

$$\frac{\partial T_s}{\partial t} = k \frac{\partial^2 T}{\partial z^2}$$

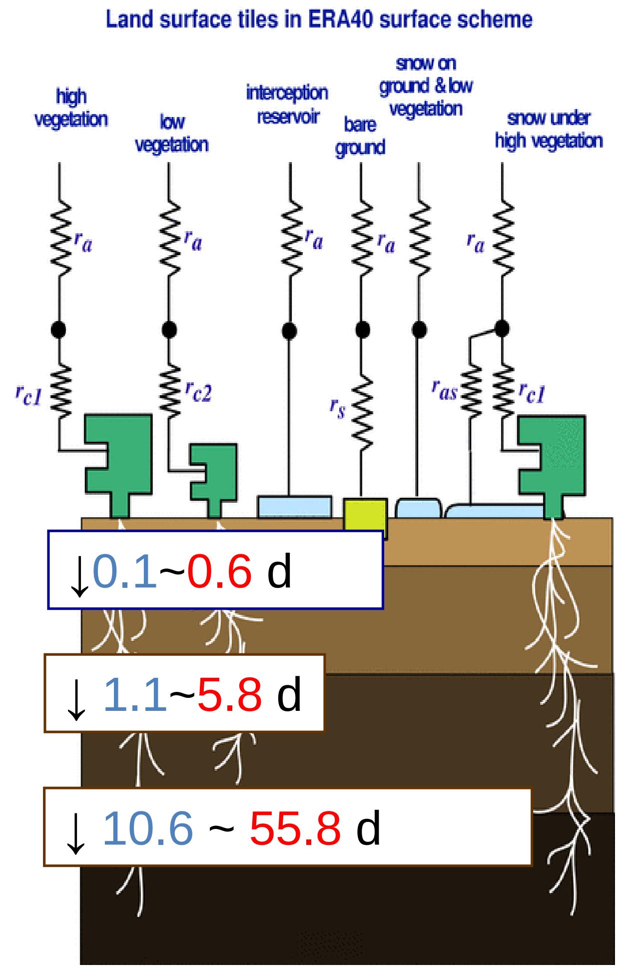
HTESSEL heat transfer

Solution of heat transfer equation with the soil discretized in 4 layers, depths 7, 21, 72, and 189 cm.

No-flux bottom boundary condition

Heat conductivity dependent on soil water

Thermal effects of soil water phase change



↓0.1~0.6 d

↓ 1.1~5.8 d

↓ 10.6 ~ 55.8 d

Time-scale for downward heat transfers in wet/dry soil

Schematics of the water flow

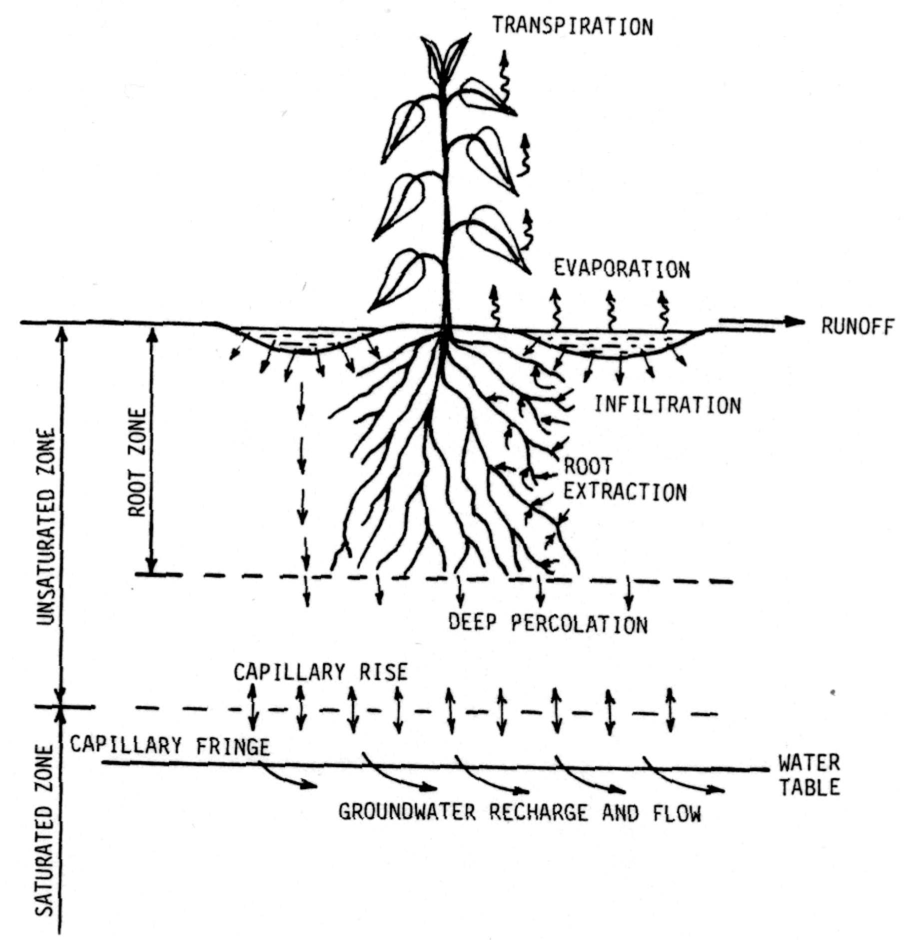


Fig. 17.1. The water balance of a root zone (schematic).

Hillel 1982

$$\rho_w \frac{\partial \theta}{\partial t} = -\frac{\partial F}{\partial z} + \rho_w S_\theta$$

θ soil water $[\ ] = m^3 m^{-3}$

F Soil water flux $[\ ] = kg m^{-2} s^{-1}$

S_θ Soil water source/sink, ie root extraction

Boundary conditions:

Top **See later**

Bottom **Free drainage or bed rock**

Root extraction

The amount of water transported from the root system up to the stomata (due to the difference in the osmotic pressure) and then available for transpiration

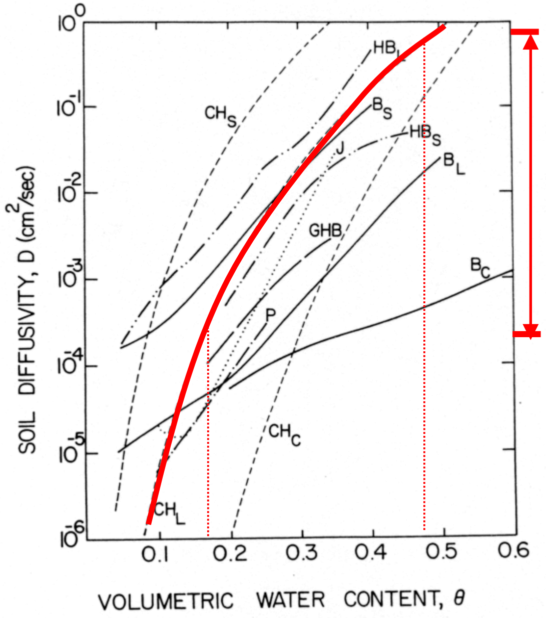
Soil water flux

$$\boldsymbol{F} = -\rho_w \left(\lambda \frac{\partial \boldsymbol{\theta}}{\partial \boldsymbol{z}} - \gamma\right)$$

λ hydraulic diffusivity $[\lambda] = \boldsymbol{m}^2 \boldsymbol{s}^{-1}$

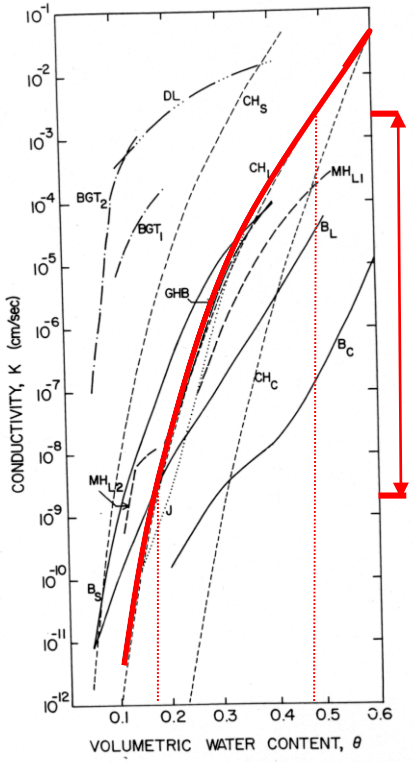
γ hydraulic conductivity $[\gamma] = \boldsymbol{ms}^{-1}$

Darcy's law



> 3 orders of magnitude

Fig. 2. Examples of the dependence of soil hydraulic diffusivity on volumetric soil water content for loam (HB_L, Hanks and Bowers, 1962); (J, Jackson, 1973); (GHB, Gardner *et al.*, 1970); silt loam (HB_S, Hanks and Bowers, 1962); clay (P, Passioura and Cowan, 1968); results approximated from Gardner (1960) for sand (B_S), loam (B_L), and clay (B_C); relationship from Clapp and Hornberger (1978) for sand (CH_S), loam (CH_L), and clay (CH_C).



> 6 orders of magnitude

Fig. 3. Examples of the dependence of hydraulic conductivity on volumetric soil water content for sand (DL, Day and Luthin, 1956); (Black *et al.*, 1970, 0–50 cm-BGT_1, 50–150 cm-BGT_2); loam (J, Jackson, 1973); (MH_{L1} and MH_{L2}, Marshall and Holmes, 1979); (GHB, Gardner *et al.*, 1970); results approximated from Gardner (1960) for sand (B_S), loam (B_L), and clay (B_C); relationship from Clapp and Hornberger (1978) for sand (CH_S), loam (CH_L), and clay (CH_C).

Mahrt and Pan 1984

HTESSEL hydrology scheme

A spatially variable hydrology scheme is being tested following Van den Hurk and Viterbo 2003

Use of a the Digital Soil Map of World (DSMW) 2003

Infiltration based on Van Genuchten 1980 and Surface runoff generation based on Dümenil and Todini 1992

$$w(h) = w_r + \frac{w_{sat} - w_r}{(1+\alpha h)^{1-1/n}}$$

$$K(h) = K_{sat}\frac{\left[(1+\alpha h^n)^{1-1/n} - \alpha h^{n-1}\right]^2}{(1+\alpha h^n)^{(1-1/n)(\lambda+2)}}$$

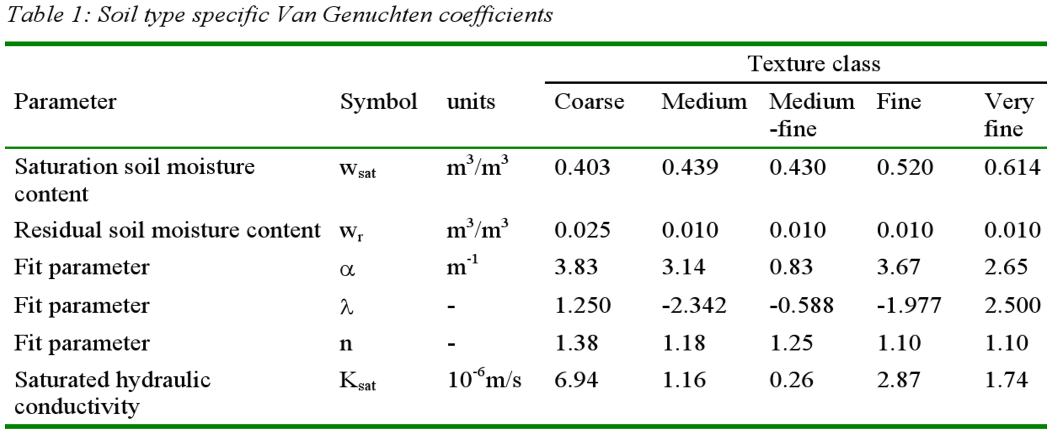


Table 1: Soil type specific Van Genuchten coefficients

Parameter	Symbol	units	Texture class				
			Coarse	Medium	Medium -fine	Fine	Very fine
Saturation soil moisture content	w_{sat}	m^3/m^3	0.403	0.439	0.430	0.520	0.614
Residual soil moisture content	w_r	m^3/m^3	0.025	0.010	0.010	0.010	0.010
Fit parameter	α	m^{-1}	3.83	3.14	0.83	3.67	2.65
Fit parameter	λ	-	1.250	-2.342	-0.588	-1.977	2.500
Fit parameter	n	-	1.38	1.18	1.25	1.10	1.10
Saturated hydraulic conductivity	K_{sat}	10^{-6}m/s	6.94	1.16	0.26	2.87	1.74

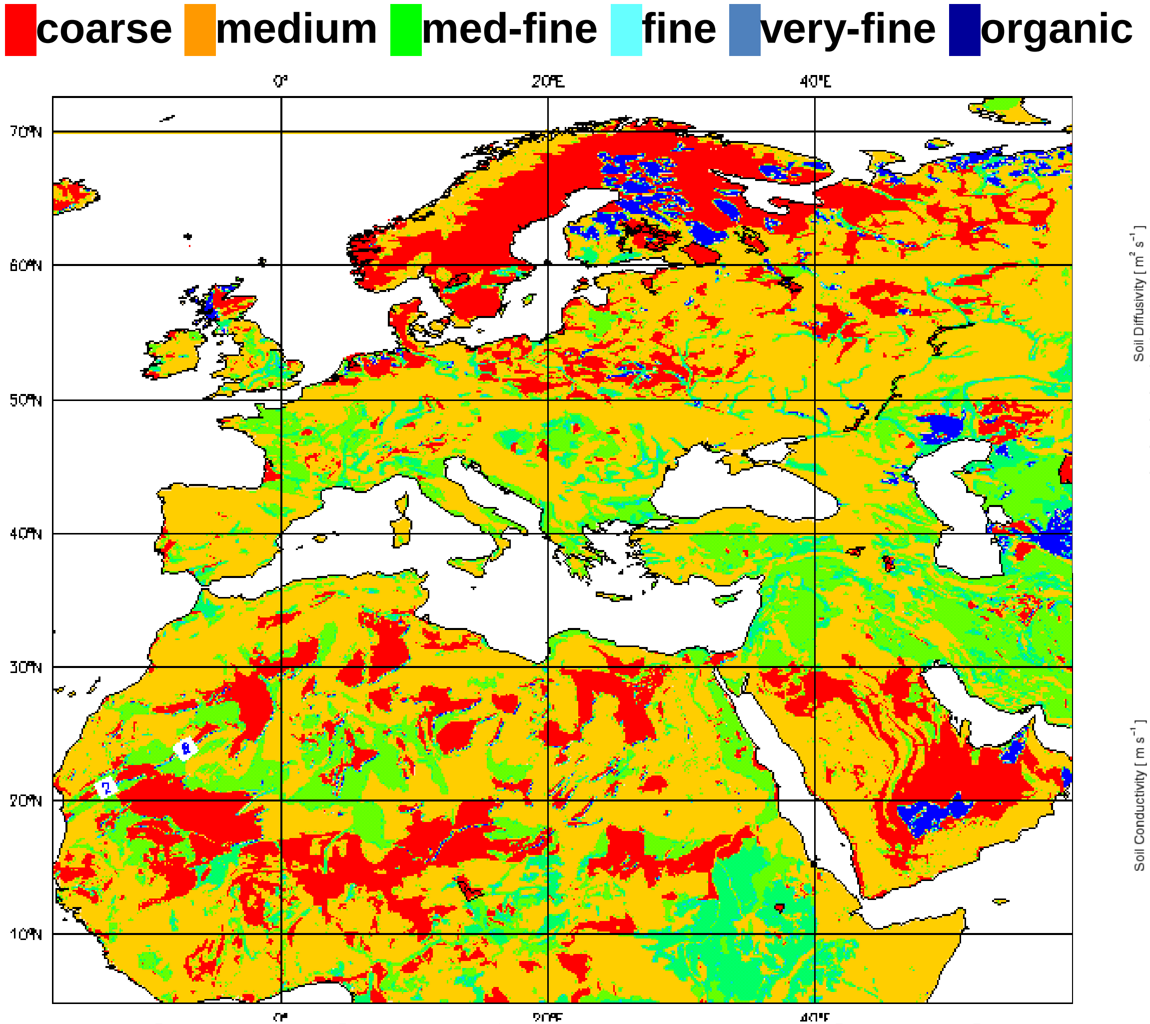
$$S = 1 - \left(1 - \frac{W}{W_{sat}}\right)^b$$

$$b = 0.01 \le \frac{\sigma_o - \sigma_{\min}}{\sigma_o + \sigma_{\max}} \le 0.5$$

$$R_s = T - \left(W_{sat} - W\right) + W_{sat}\left[\left(1 - \frac{W}{W_{sat}}\right)^{1/(b+1)} - \left(\frac{T}{(b+1)W_{sat}}\right)\right]^{b+1}$$

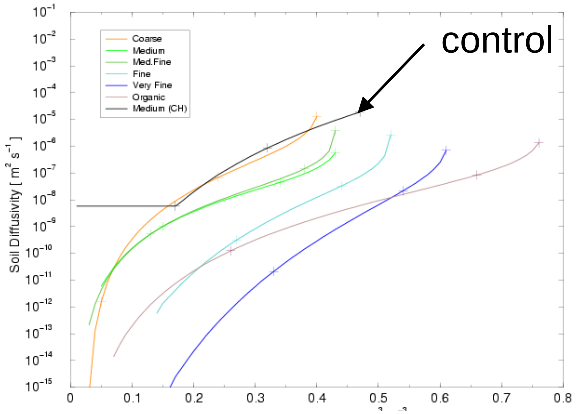
Van den Hurk and Viterbo 2003

HTESSEL hydrology scheme(2)

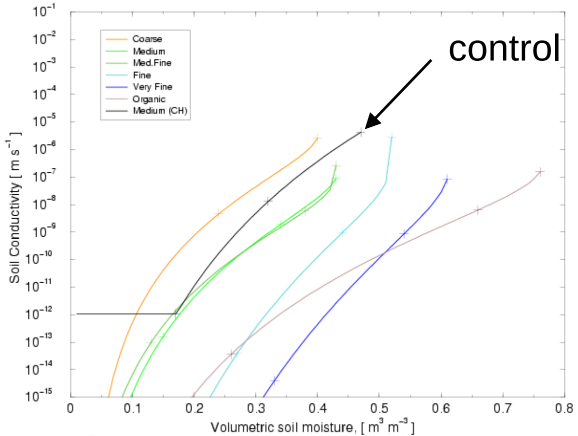


Dominant soil type from FAO2003 (at native resolution of ~ 10 km)

Soil Diffusivity



Soil Conductivity



ECMWF

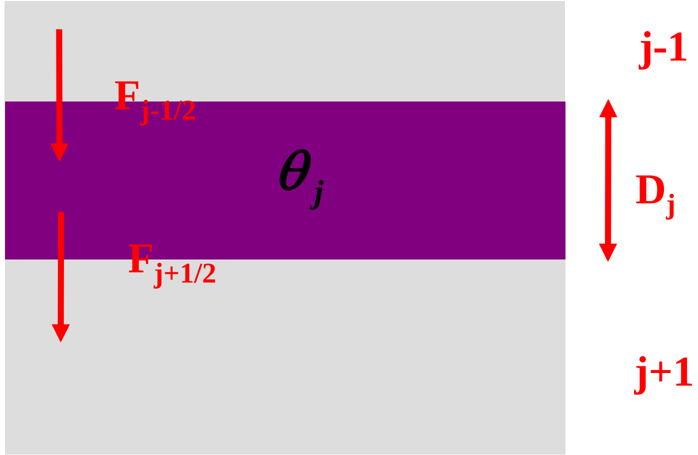
HTESSEL soil water equations

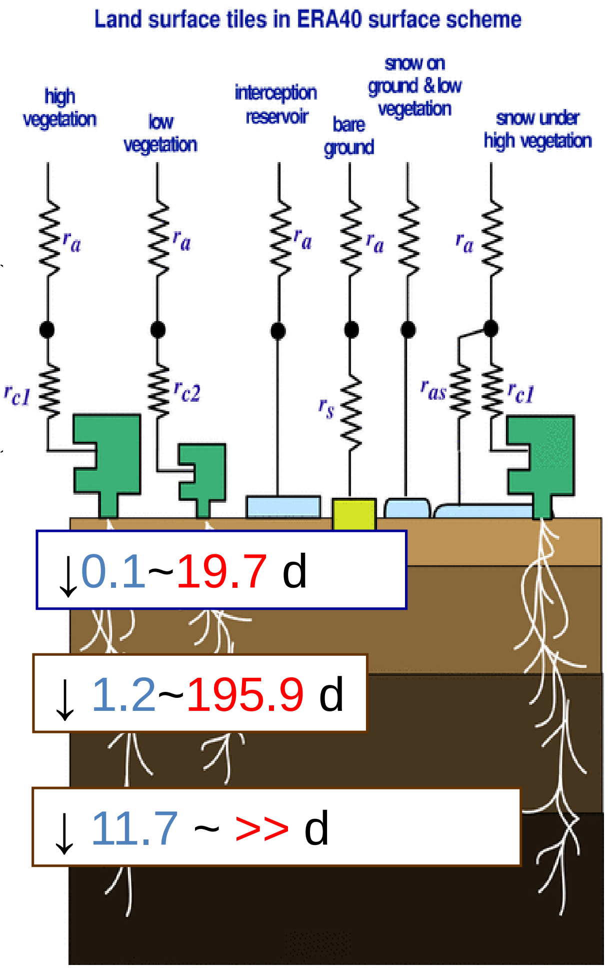
$$\rho_w \frac{\left(\theta_j^{n+1} - \theta_j^{n}\right)}{\Delta t} = -\frac{\left(F_{j+1/2}^{n+1} - F_{j-1/2}^{n+1}\right)}{D_j} + \rho_w S_{\theta,j}$$

$$F_{j+1/2}^{n+1} = -\rho_w \left(\lambda_{j+1/2} \frac{\theta_{j+1}^{n+1} - \theta_j^{n+1}}{0.5\left(D_j + D_{j+1}\right)} - \gamma_{j+1/2} \right.$$

Boundary conditions

$$F_{1/2} = T - Y_s + E_{1/2} \qquad F_{41/2} = \rho_w \gamma_{41/2}$$





↓0.1~19.7 d

↓ 1.2~195.9 d

↓ 11.7 ~ >> d

Time-scale for downward water transfers in wet/dry soil

Modelling inland water bodies

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

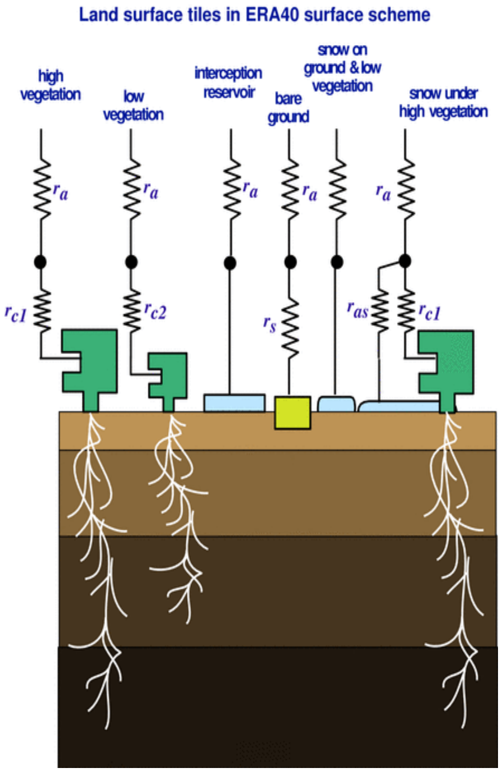
Hydrology - Tiled ECMWF

Scheme for Surface Exchanges over Land

+

FLake

Fresh water Lake scheme



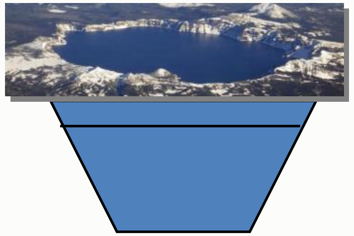
- **Lake tile**

Mironov et al (2010),

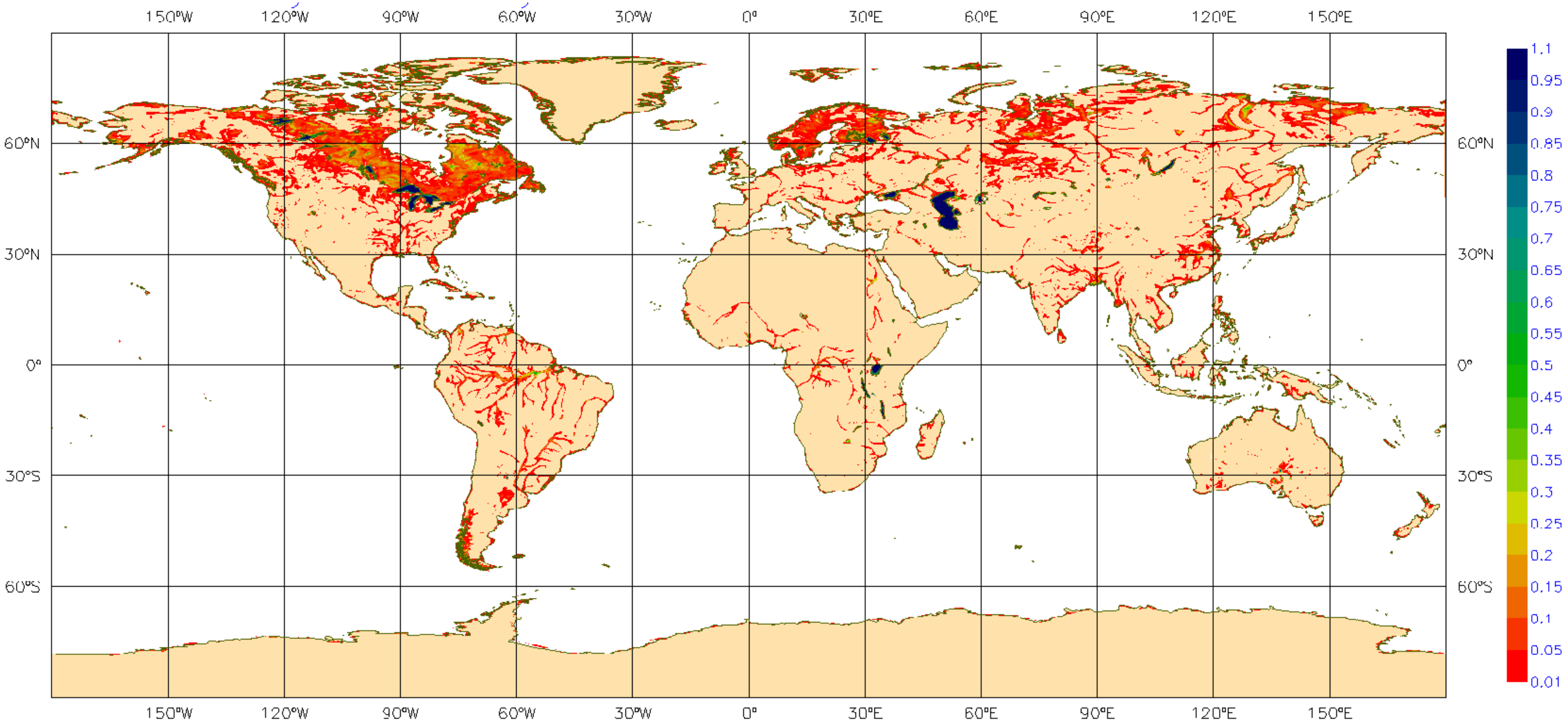
Dutra et al. (2010),

Balsamo et al. (2010, 2012, 2013)

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



Inland water bodies fraction

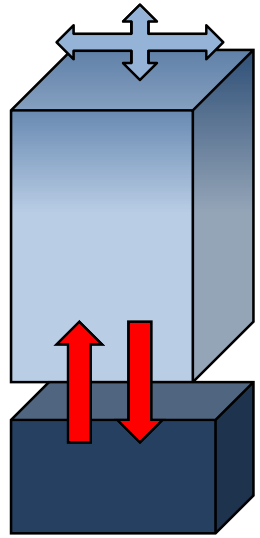


Aggregated from GLOBCOVER 300m

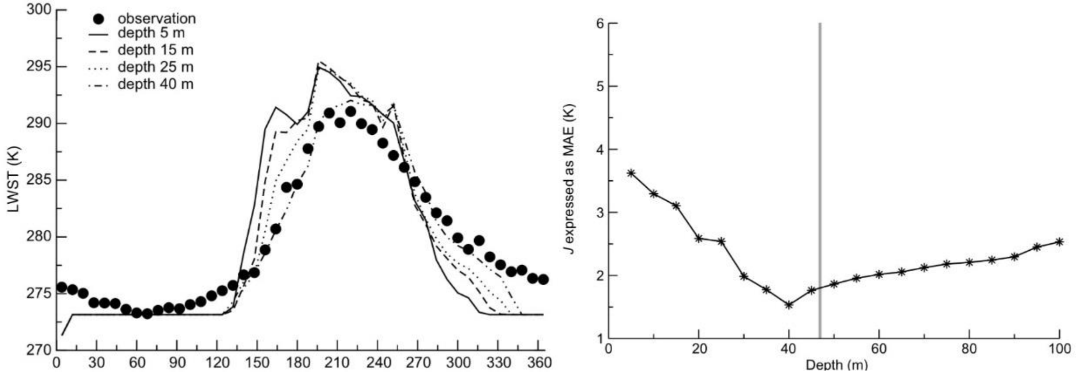
Water bodies heat storage

FLake (Mironov et al. 2010, BER) http://lakemodel.net a two-layer bulk model based on a self-similar parametric representation of the evolving temperature profile within lake water and ice

Introduced in the IFS by Dutra et al. (2010,BER), Balsamo et al. (2010,BER; 2012,TELLUS)



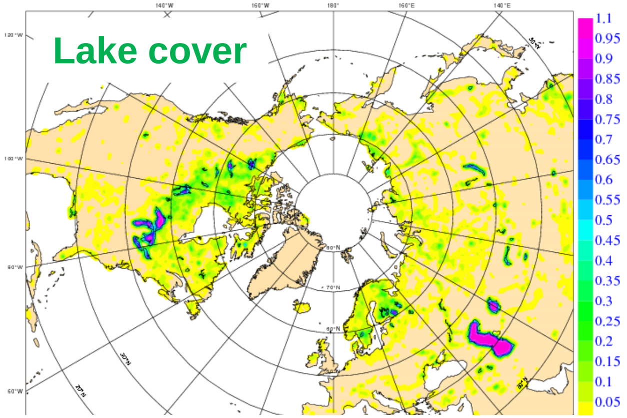
Lake depth is a scalar for lake temperature annual cycle



The relationship between the lake temperature (as observed by MODIS) and the lake depth can be used to infer the lake depth in an inversion procedure (Balsamo et al. 2010 BER)

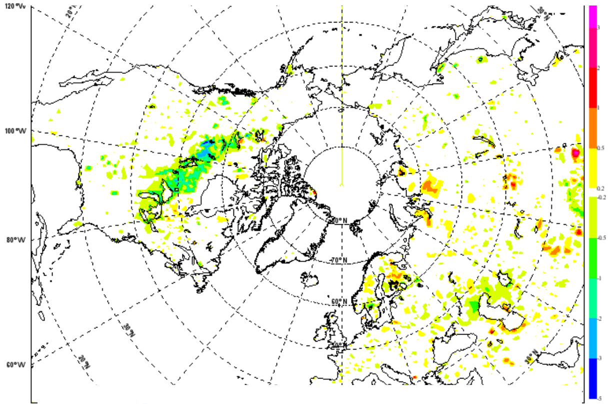
Impact of lakes in NWP forecasts

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



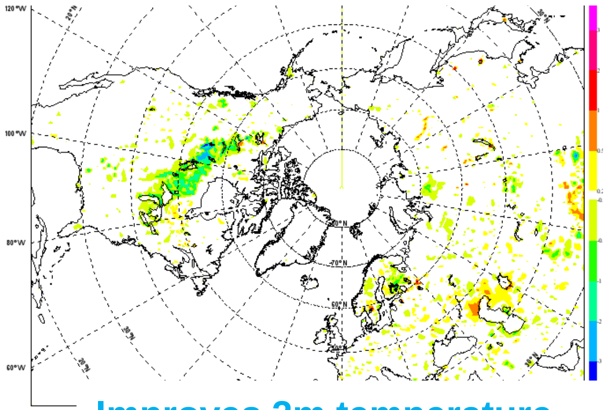
- **Forecasts sensitivity and impact of lakes is shown to produce a spring-cooling on lake areas with benefit on the temperatures forecasts (day-2 (48-hour forecast) at 2m.**
- **The lake surface temperatures are verified with MODIS LSTs as indicative of the heat-storage accuracy of the lake model**

Forecast sensitivity

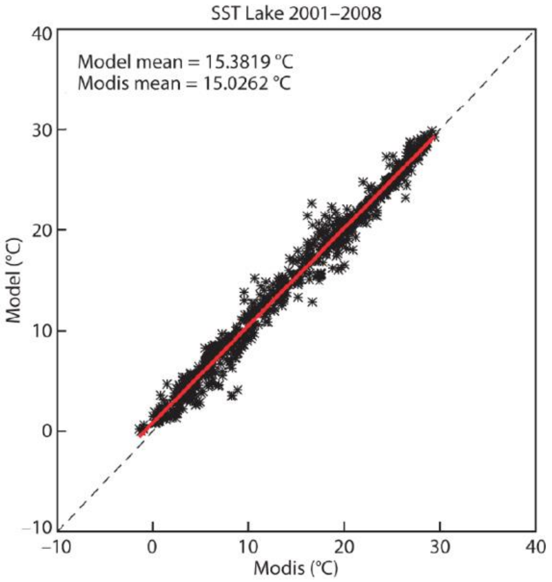


Cooling 2m temperature
Warming 2m temperature

Forecast impact



Improves 2m temperature
Degrades 2m temperature



ECMWF

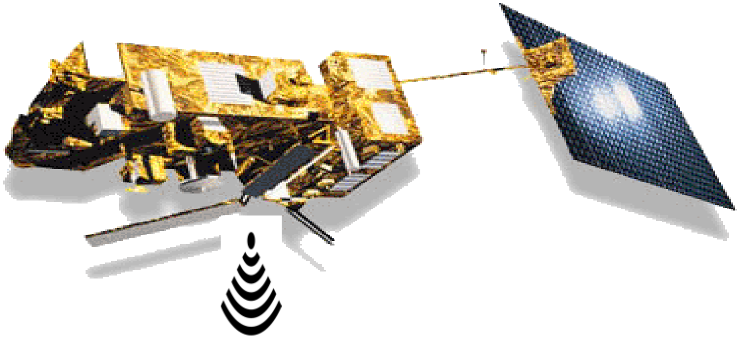
ECMWF surface model milestones

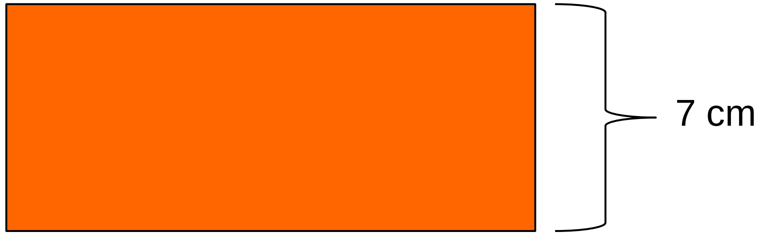
Vegetation based evaporation	1989
ML-soil (4 layers + …)	1993 / ERA15
Initial conditions for soil water	1994
Stable BL/soil water freezing	1996
Albedo of snow forests	1996
OI increments of soil water	1999
TESSEL, new snow and sea ice	2000 / ERA40
HTESSEL, revised soil hydrology	2007
HTESSEL+SNOW, revised snow	2009
HTESSEL+SNOW+LAI, seasonal vegetation	2010
CHTESSEL (carbon-land surface)	2012
LAKETESSEL (addition of lake tile)	2015
SEAMLESS Coupling Ocean-Sea-Ice	2018

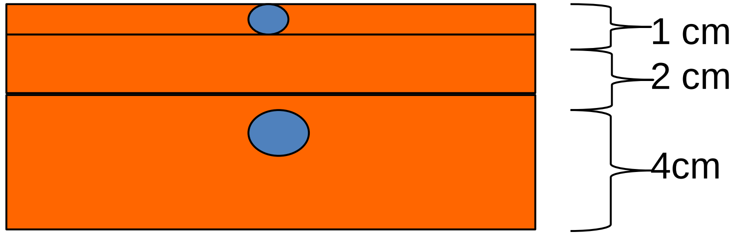
…what is next?

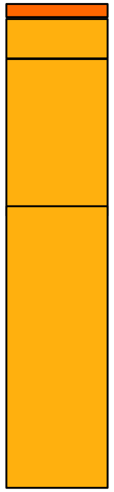
An enhanced soil vertical resolution

The model bias in Tskin amplitude shown by *Trigo et al. (2015)* motivated the development of an enhanced soil vertical discretisation to improve the match with satellite products.









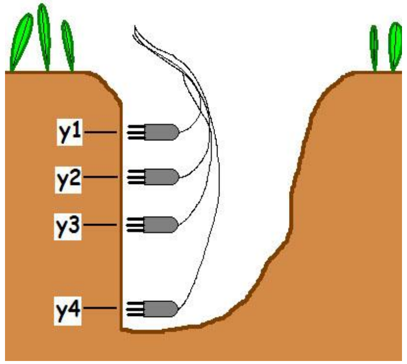
4-layers:

 # 0-7 cm
7-28 cm
28-100 cm
100-289 cm

10-layers:

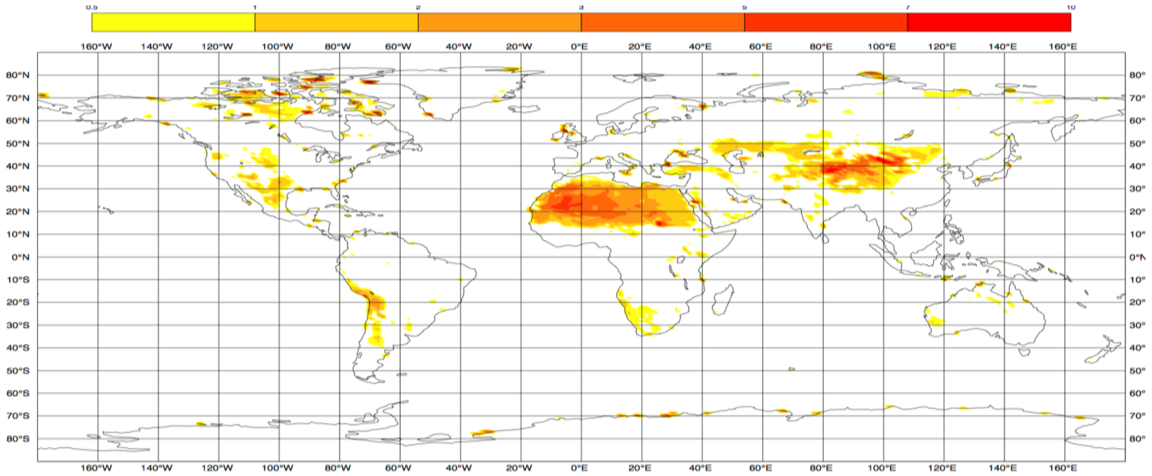
 # 0-1 cm
 # 1-3 cm
 # 3-7 cm
7-15 cm
15-25 cm
25-50 cm
50-100 cm

100-200 cm
200-400 cm
 # 400-800 cm



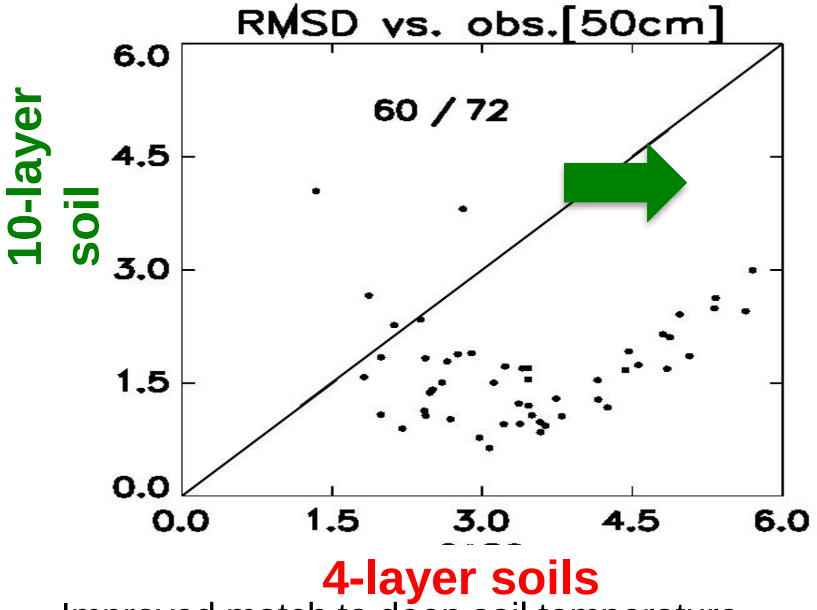
Impact of soil vertical resolution on soil temperature

Sensitivity Max Tskin for July 2014



Higher T-max at the L-A interface
up to 3 degrees warmer on bare soil
(without symmetric effect on Tmin!)
Offline simulations with **10-layer soil**
Compared to **4-layer soils**

In-situ validation at 50cm depth
(on 2014, 64 stations)
Results by Clément Albergel

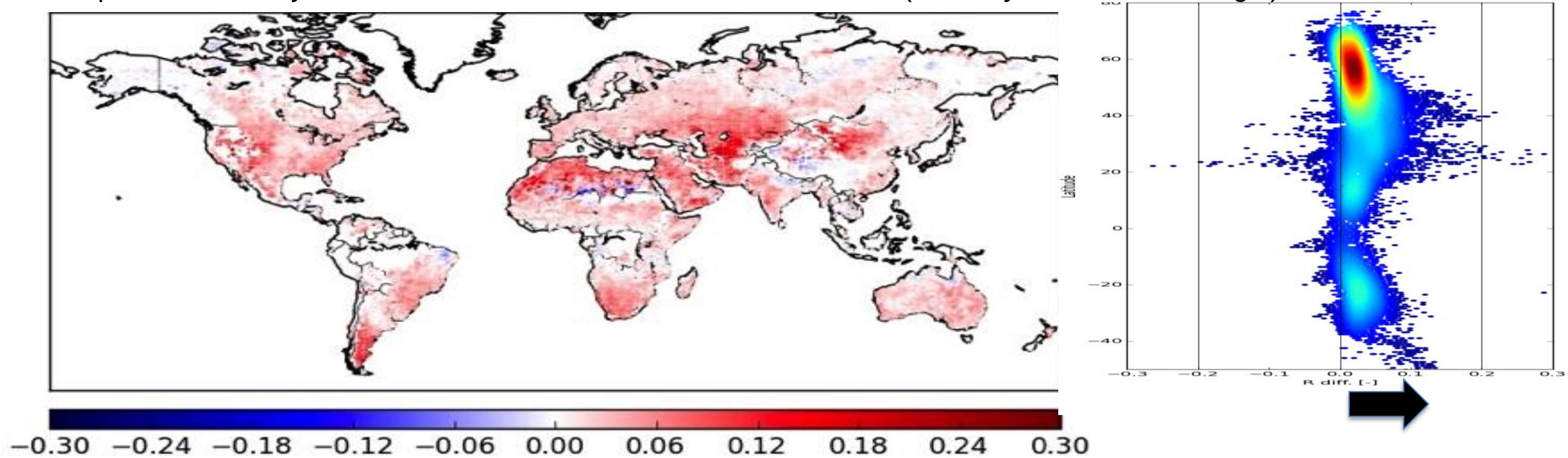


Improved match to deep soil temperature
(shown is correlation and RMSD)

Correlation with in-situ soil temperature validate the usefulness of increase soil vertical resolution for monthly timescale (0.50 cm deep). Research work will continue using satellite skin temperature data (2nd visit of René Orth ETH).

Impact of soil vertical resolution for satellite soil moisture

Impact on Anomaly Correlation with ESA-CCI satellite soil moisture (courtesy of Clément Albergel)



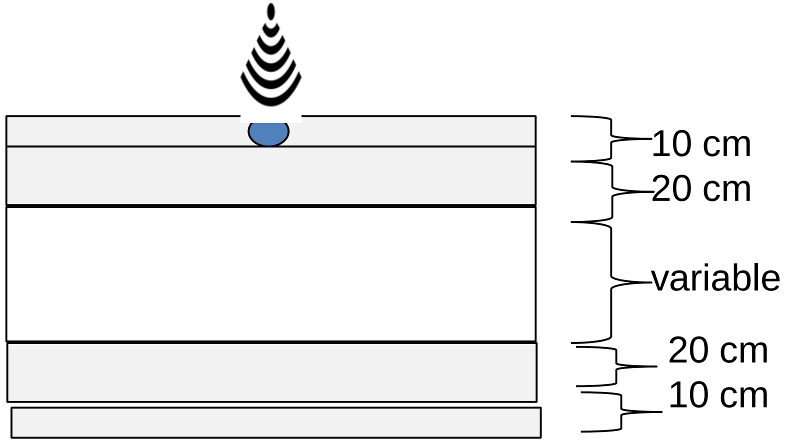
Globally Improved match to satellite soil moisture (shown is ΔACC calculate on 1-month running mean)

Anomaly correlation (1988-2014) measured with ESA-CCI soil moisture remote sensing (multi-sensor) product. This provide a global validation of the usefulness of increase soil vertical resolution.

An enhanced snow vertical resolution

The snow temperature representation in a 5-layer scheme can take into account the coupling to the atmosphere and to the underlying soils with dedicated timescale that can better represent accumulation and melting.

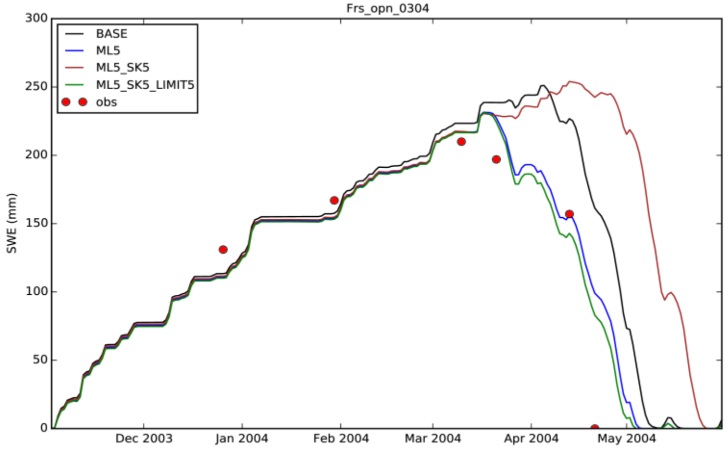
1-layers:
 # 0-X cm



5-layers:

from Emanuel Dutra

Simulations of Snow Water Equivalent (SWE- mm) for the 2003/04 winter season at the Fraser open site (USA Rocky mountains) comparing observations (red circles) with **current** 1-layer model (BASE-black), 5-layers **new** snow model (ML5-green).

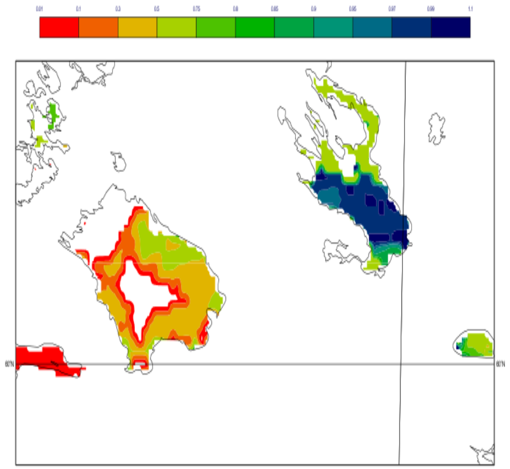


Lakes 3M Challenges Mapping, Monitoring, and Modelling for Prediction

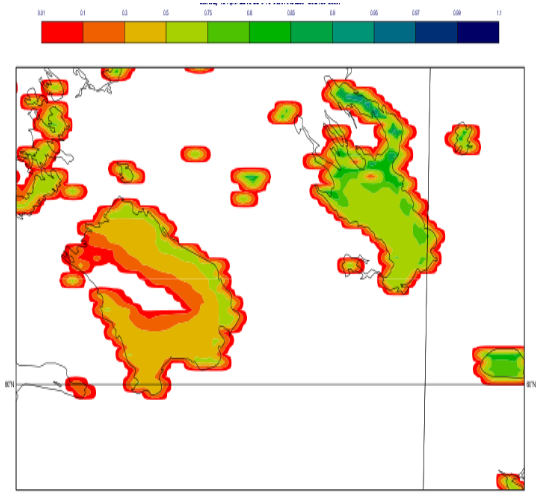
Interactive lakes became operational at ECMWF
On May 2015 in every day Forecasts

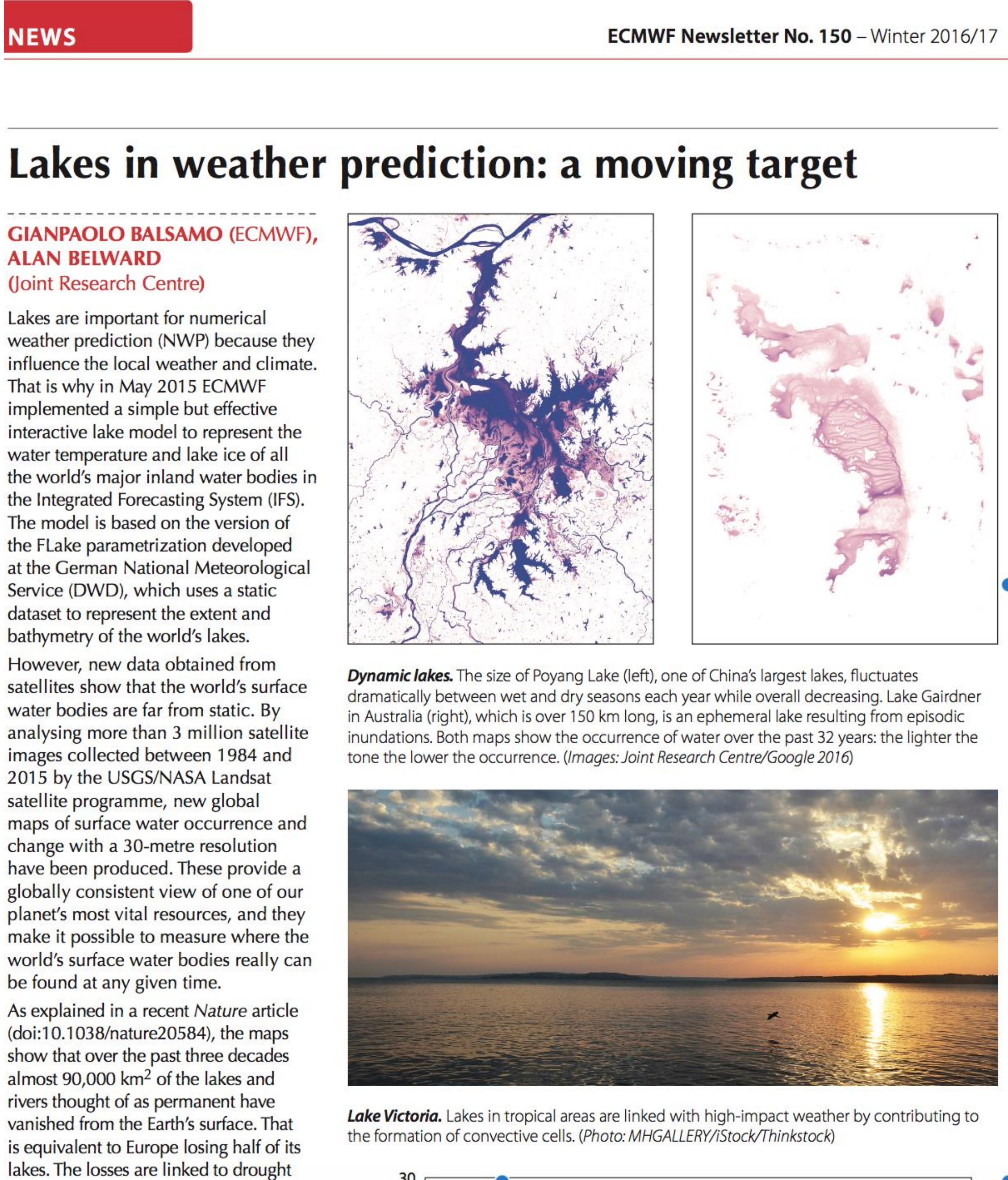
Here a case Study of 18 April 2016: The Largest
European Lakes: Lake Lagoda & Lake Onega

OSI-SAF Satellite Ice cover 18 April 2016



ECMWF IFS Lake Ice Cover (Ladoga melting faster)





Lakes in weather prediction: a moving target

GIANPAOLO BALSAMO (ECMWF),
ALAN BELWARD
(Joint Research Centre)

Lakes are important for numerical weather prediction (NWP) because they influence the local weather and climate. That is why in May 2015 ECMWF implemented a simple but effective interactive lake model to represent the water temperature and lake ice of all the world's major inland water bodies in the Integrated Forecasting System (IFS). The model is based on the version of the FLake parametrization developed at the German National Meteorological Service (DWD), which uses a static dataset to represent the extent and bathymetry of the world's lakes.

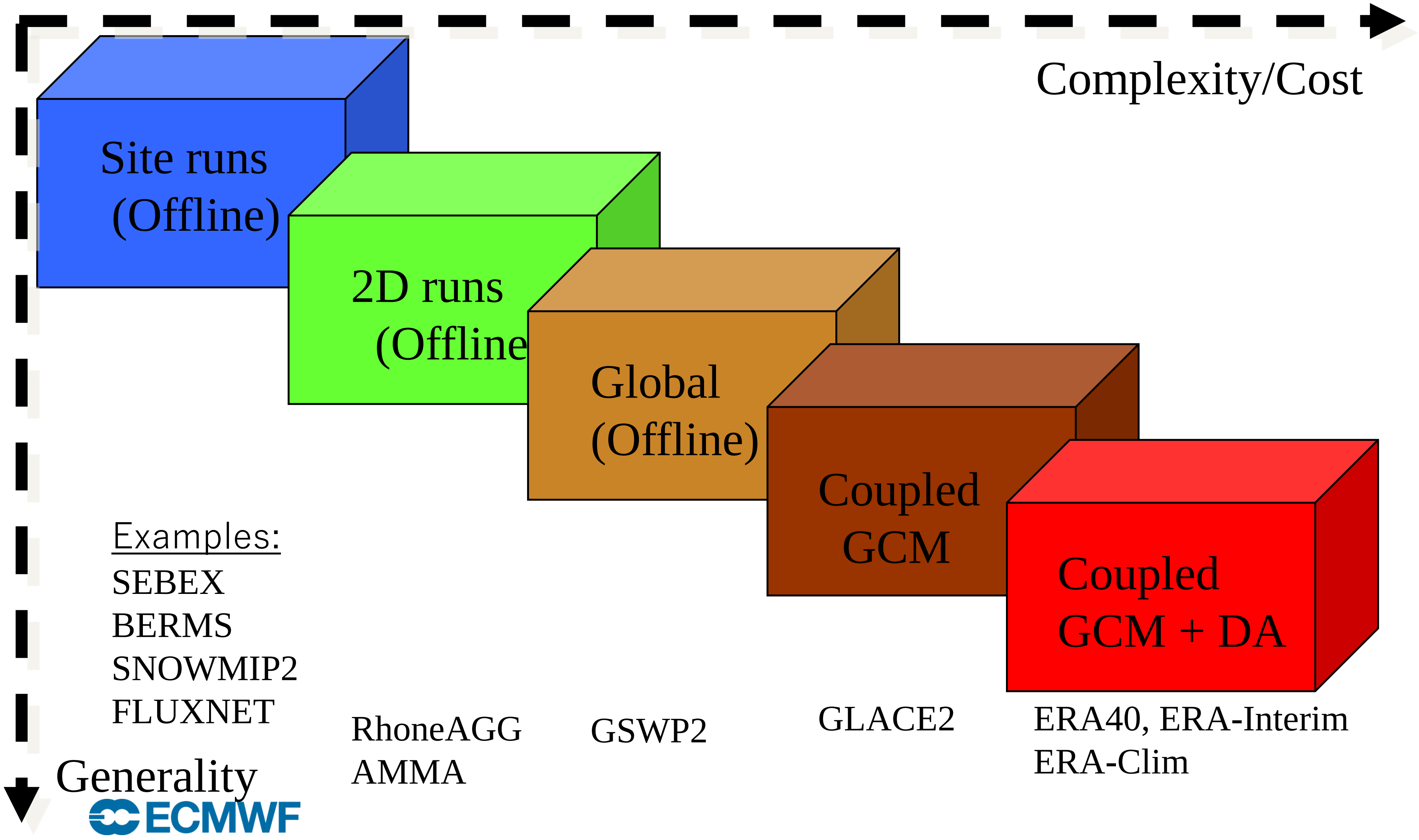
However, new data obtained from satellites show that the world's surface water bodies are far from static. By analysing more than 3 million satellite images collected between 1984 and 2015 by the USGS/NASA Landsat satellite programme, new global maps of surface water occurrence and change with a 30-metre resolution have been produced. These provide a globally consistent view of one of our planet's most vital resources, and they make it possible to measure where the world's surface water bodies really can be found at any given time.

As explained in a recent *Nature* article (doi:10.1038/nature20584), the maps show that over the past three decades almost 90,000 km^2 of the lakes and rivers thought of as permanent have vanished from the Earth's surface. That is equivalent to Europe losing half of its lakes. The losses are linked to drought

Dynamic lakes. The size of Poyang Lake (left), one of China's largest lakes, fluctuates dramatically between wet and dry seasons each year while overall decreasing. Lake Gairdner in Australia (right), which is over 150 km long, is an ephemeral lake resulting from episodic inundations. Both maps show the occurrence of water over the past 32 years: the lighter the tone the lower the occurrence. (*Images: Joint Research Centre/Google 2016*)

Lake Victoria. Lakes in tropical areas are linked with high-impact weather by contributing to the formation of convective cells. (*Photo: MHGALLERY/iStock/Thinkstock*)

Strategy for surface model development at ECMWF (applied)



Complexity/Cost

Site runs
(Offline)

2D runs
(Offline

Global
(Offline)

Coupled
GCM

Coupled
GCM + DA

Examples:
SEBEX
BERMS
SNOWMIP2
FLUXNET

RhoneAGG
AMMA

GSWP2

GLACE2

ERA40, ERA-Interim
ERA-Clim

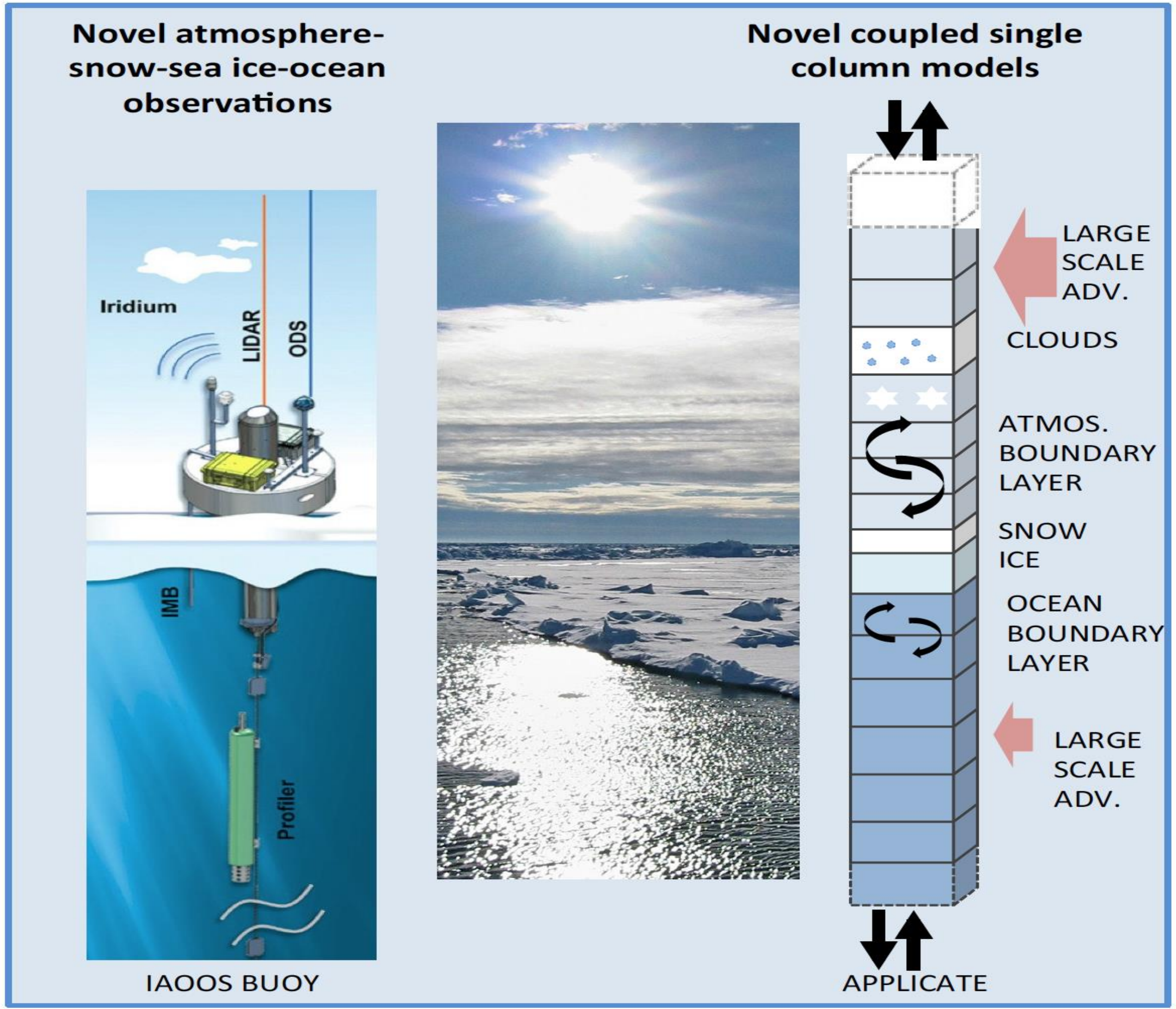
Generality

ECMWF

Using models as tool for process understanding: The need of observations for validation

(from APPLICATE Courtesy of Peter Bauer and Thomas Jung)

Coupled Single Column Modelling



Observation Towers (e.g. Dome-C)

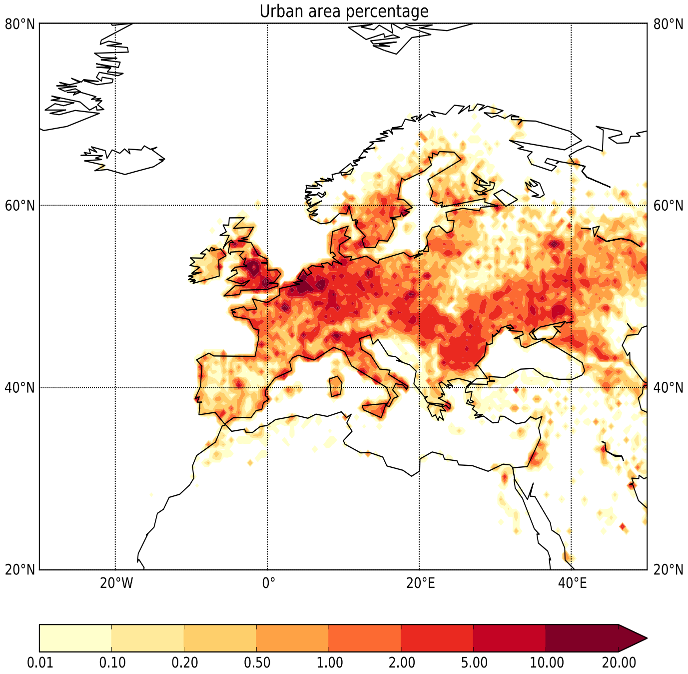
Perspectives

- Efforts to improve diurnal and seasonal cycles of surface state variables has transferred into weather and climate improvements and this it will continue (doing things better may not sound attractive but it pays off!)
- Surface complexity is needed and permitted by the overall skill of the atmospheric processes.
- Surface representation requirements for higher resolution will not saturate at a given scale.
- Earth-Observation from Satellites provide guidance for improving processes (not only useful in the data assimilation step, but also in the model development phase) and justify complexity.
- In-situ data will provide guidance on process-level fidelity of a scheme. That cannot be expected at global scale and therefore in-situ data will always be a crucial part of verification.
- Human influence on the surface (such as urbanization, irrigation) is yet to be represented in many models that can no longer assume natural surfaces to be static (priority not only at ECMWF).

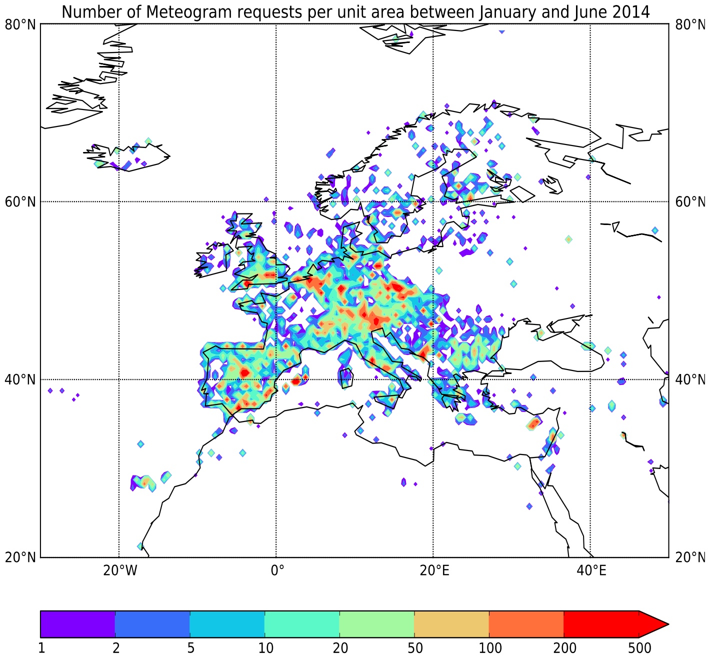
Today’s satellite images are very informative not only about natural land surface…

Motivation for enhancing urban modelling @ECMWF

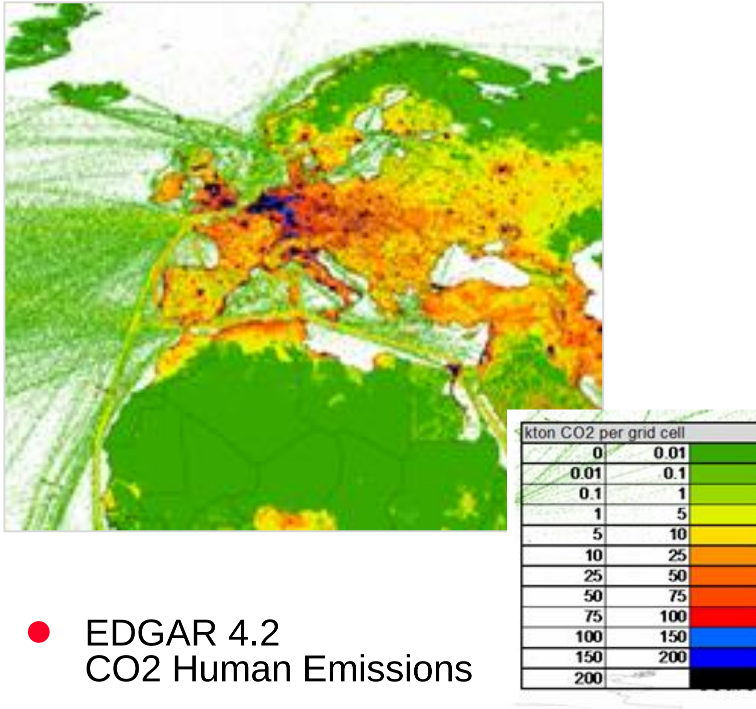
- Urban areas are important for the accurate prediction of extreme events such as heatwaves and urban flooding and need to be represented in ECMWF model.
- Best and Grimmond (2015) suggested that simple models may be well adapted to global applications
- Users lives urban areas and look at the forecast for urban locations.
- Urban maps combined with emission factors can provide first guess CO2 anthropogenic fluxes



- Urban area (a, in %, from ECOCLIMAP, Masson et al., 2003)



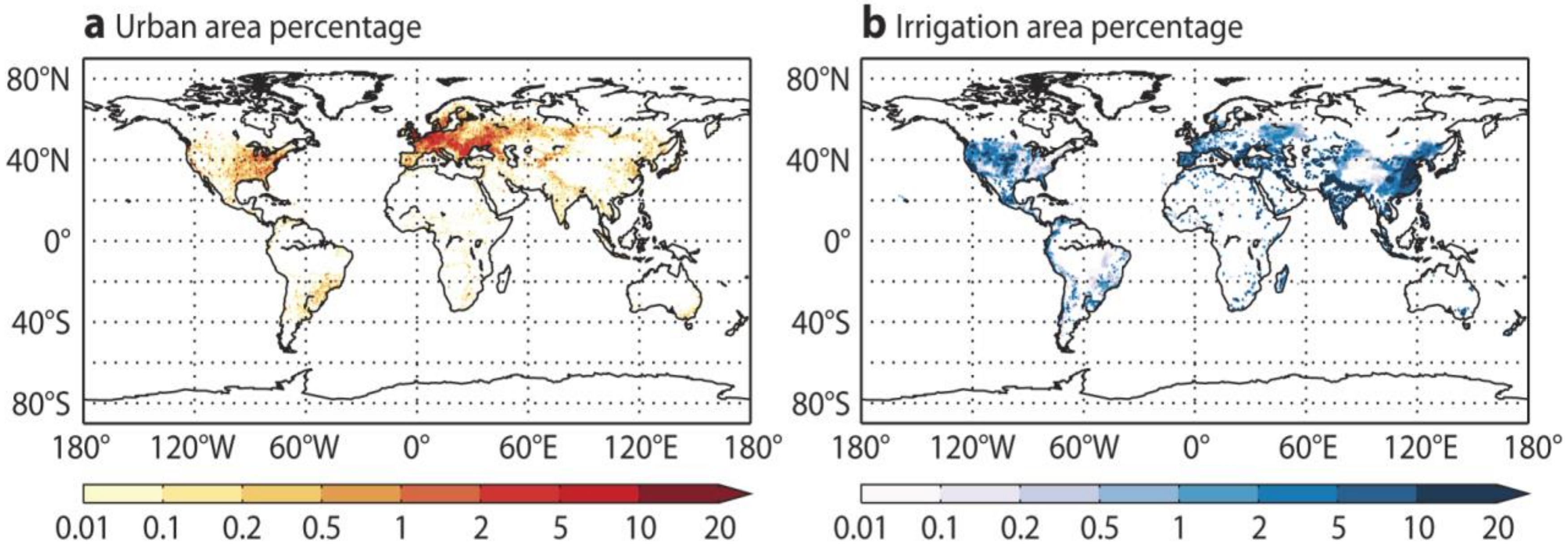
- Number of ECMWF Meteograms product requests from Member-States



- EDGAR 4.2
  CO2 Human Emissions

Missing surface components: An example

- Human action on the land and water use is currently neglected in most NWP models…



- Urban area (a, in %, from ECOCLIMAP, Masson et al., 2003) and
- Irrigated area (b, in %, from Döll and Siebert, 2002)
- Also water bodies are changing over time

The way forward

…modelling should be always guided by observations…
in case of land surface our senses are also amazing
instruments ☺

http://www.youtube.com/watch?v=jfa29pq6NFs