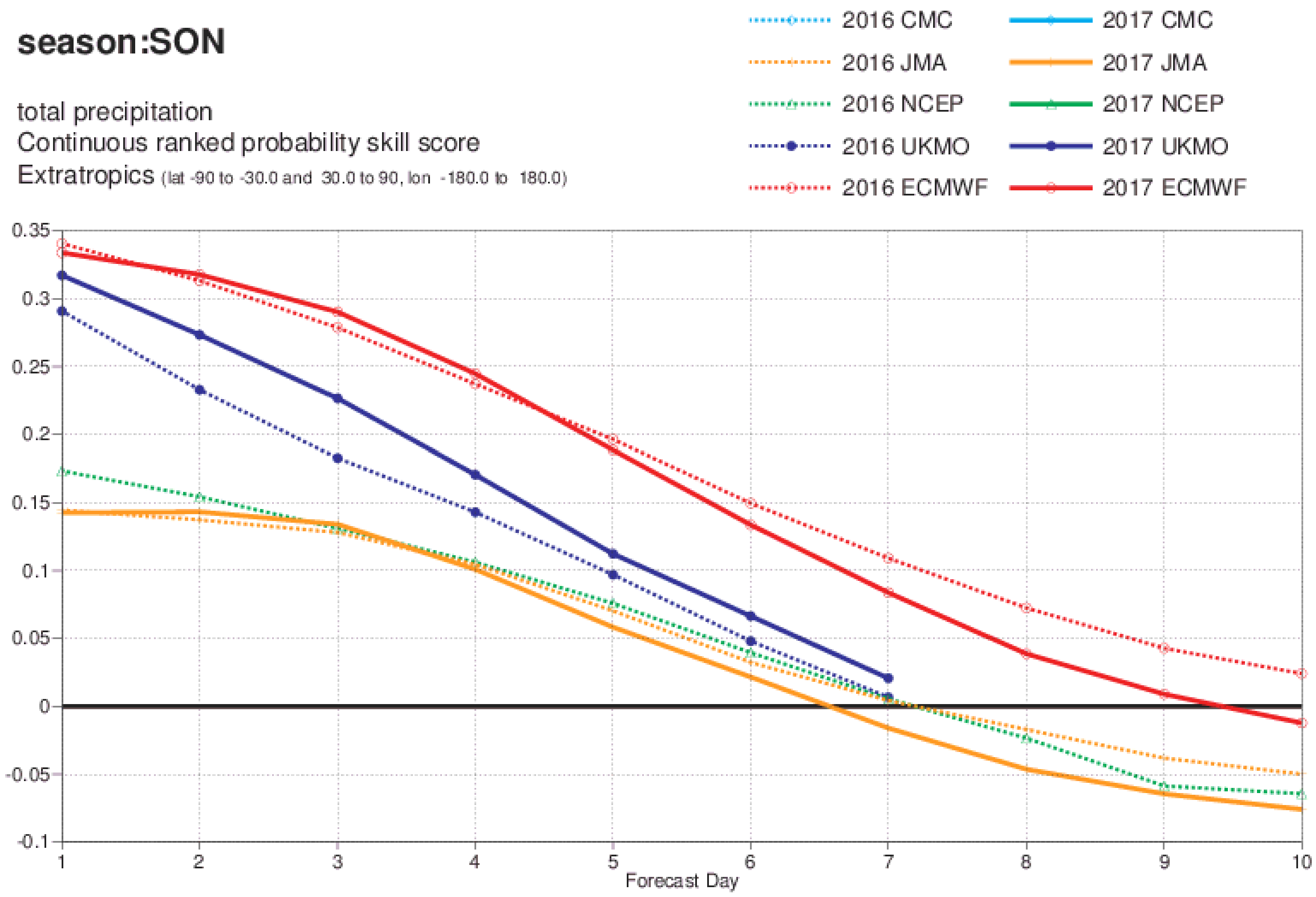
# HEPEX
# Earth System modelling @ECMWF – Implications for HEPEX and hydrology

Florian Pappenberger
Gianpaolo Balsamo
Christel Prudhomme
Carlo Buontempo
Hannah L. Cloke
EFAS@ECMWF

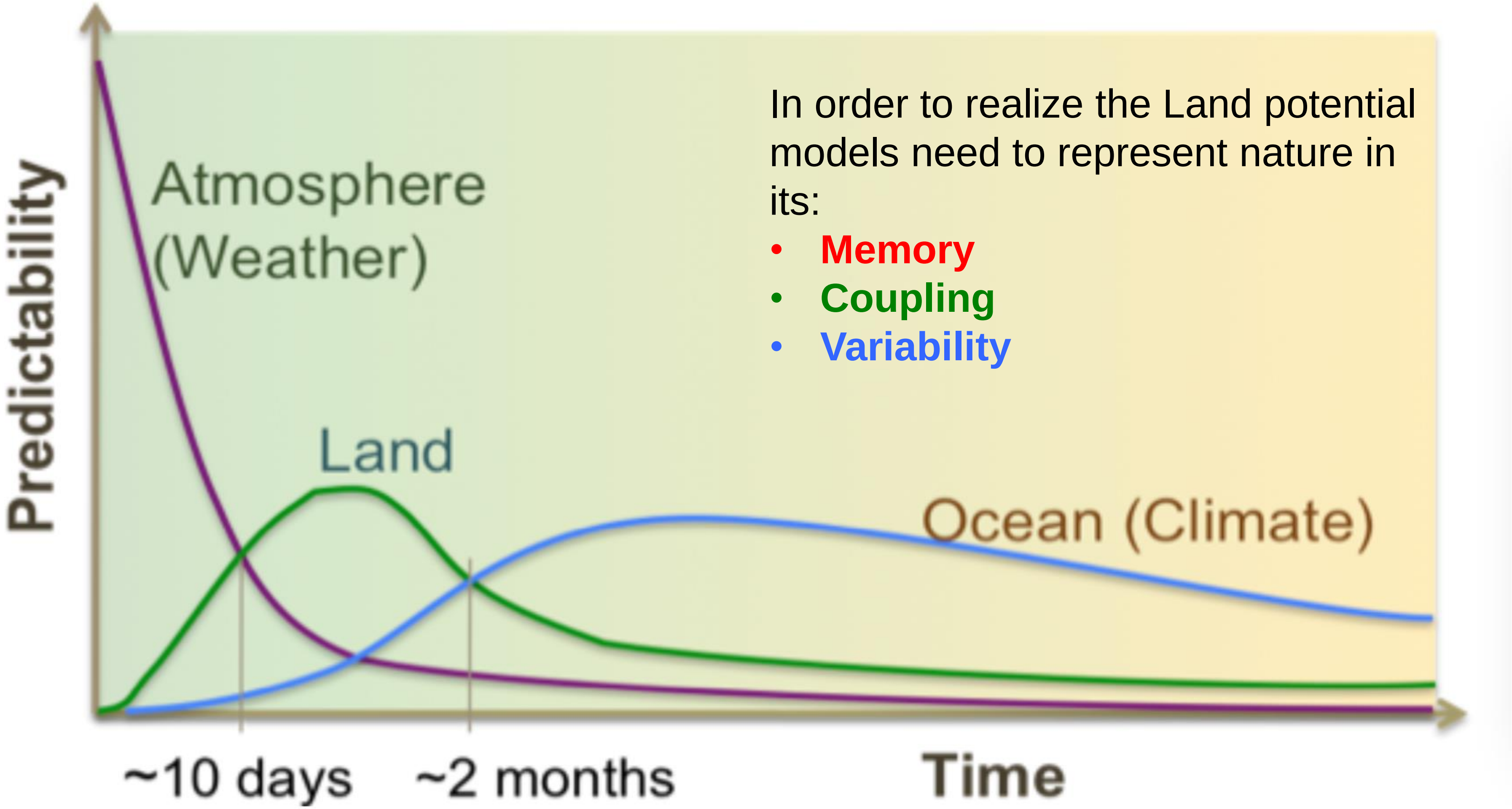
Florian.pappenberger@ecmwf.int, @FPappenberger

ECMWF

# How far can be  predict into the future??



# Why increased attention on Land and Hydrology by NWP Centres?

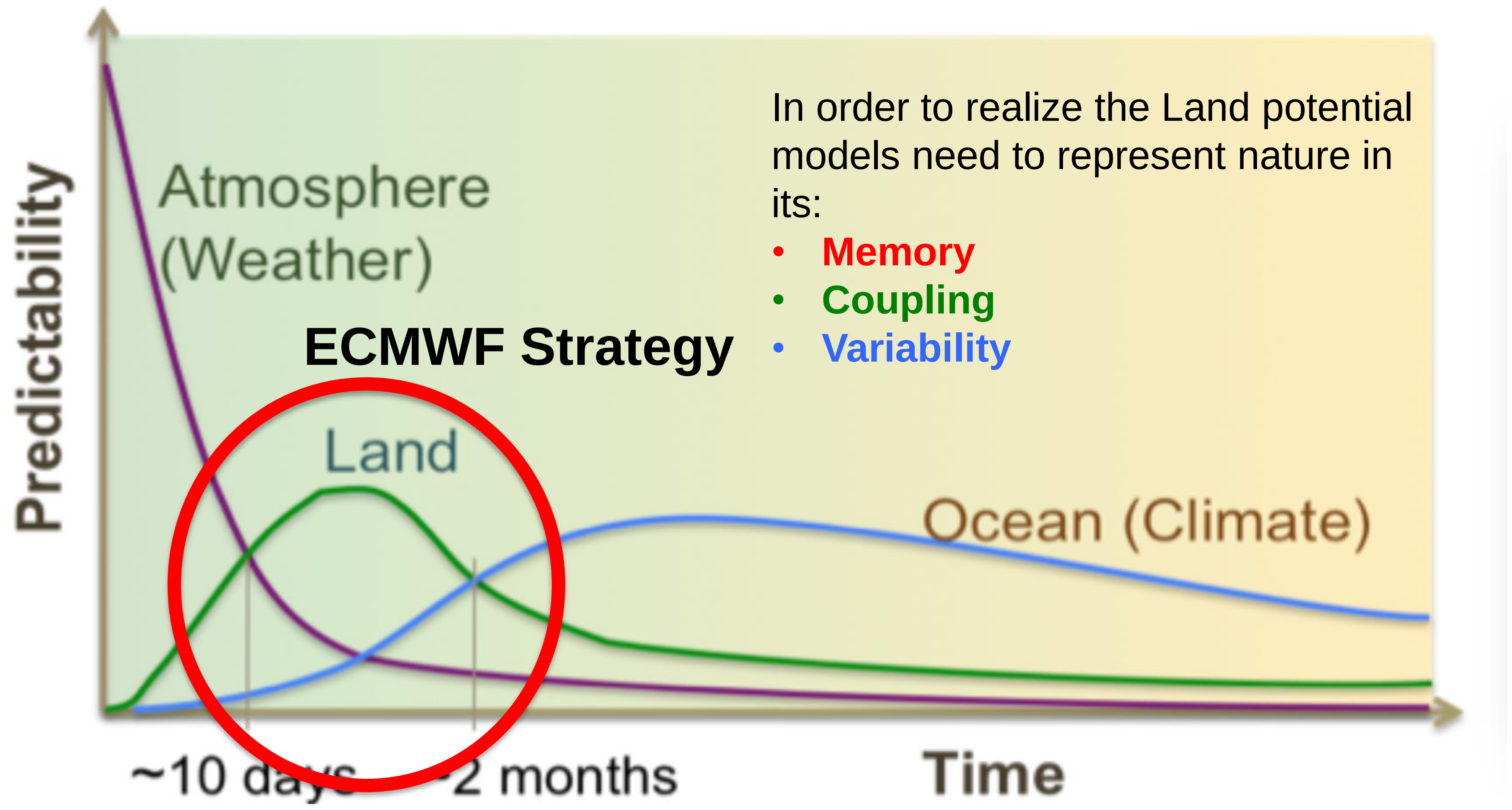



In order to realize the Land potential models need to represent nature in its:

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

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

# Why increased attention on Land and Hydrology by NWP Centres?

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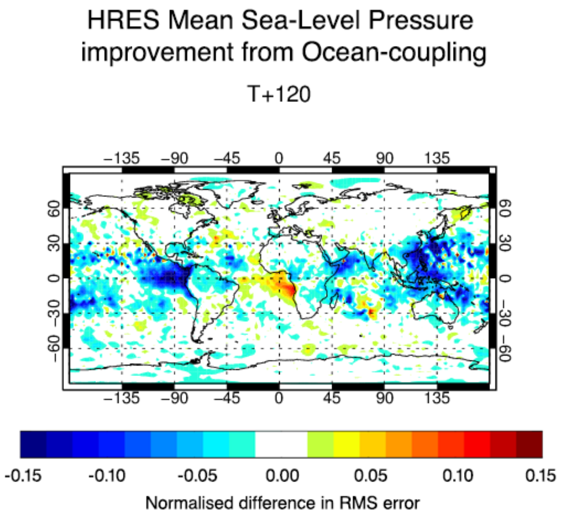
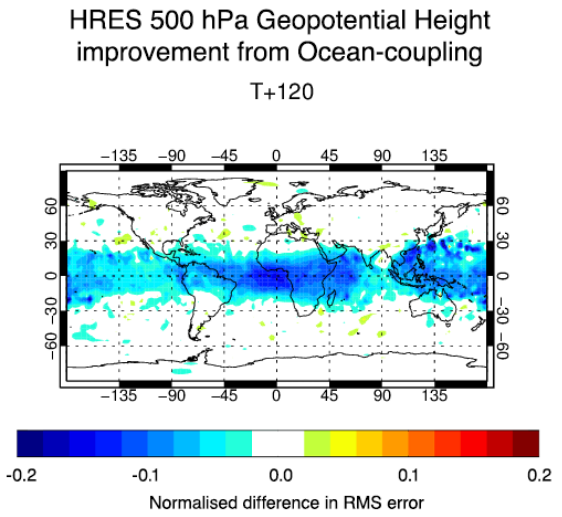
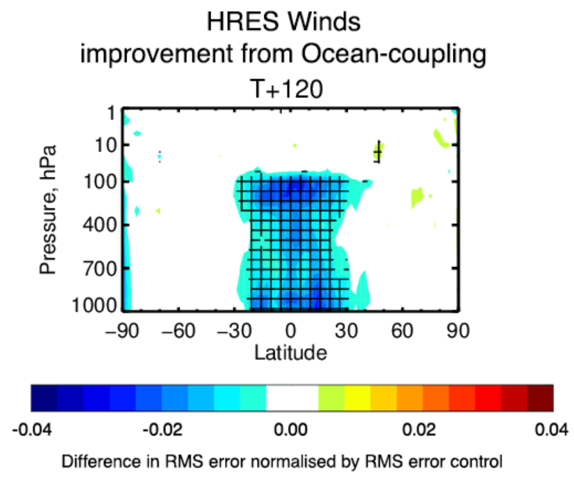
Dirmeyer et al. 2015: http://library.wmo.int/pmb_ged/wmo_1156_en.pdf

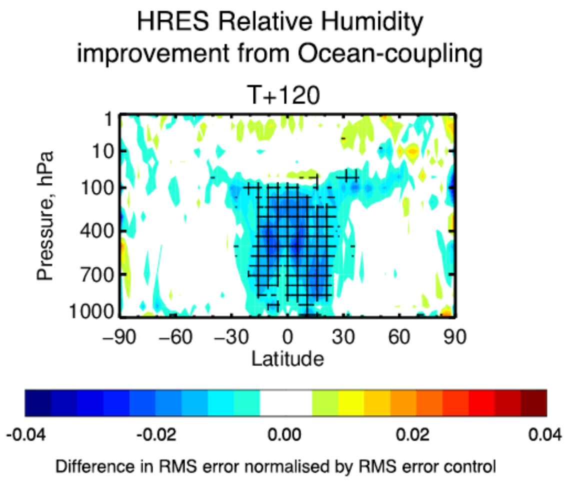
# On the relative contribution of land and ocean on ECMWF day-5 forecast

## Forecast improvements at Day+5 (**1 year**)
## Coupled-Ocean vs Uncoupled (only skin-interaction)

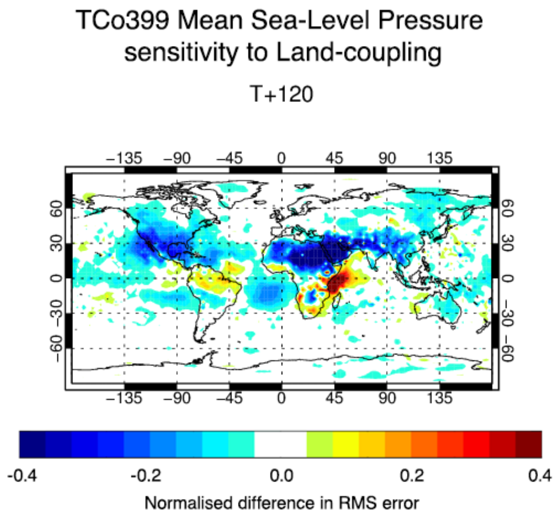


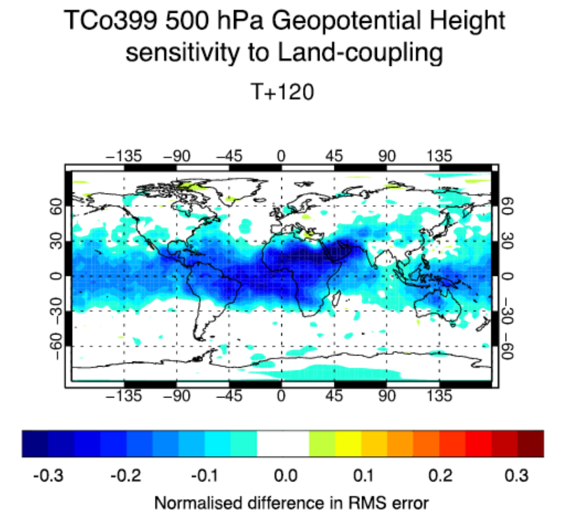



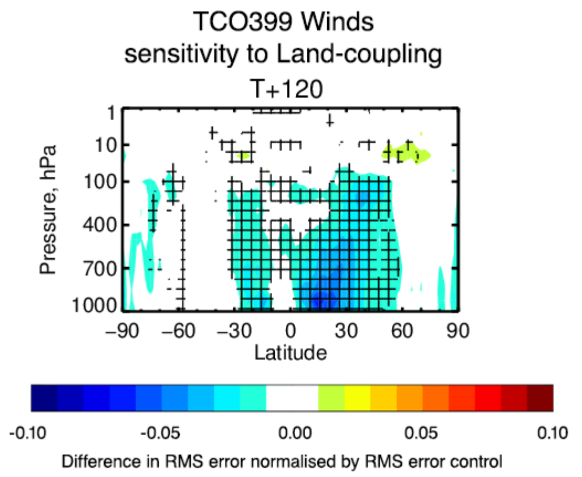



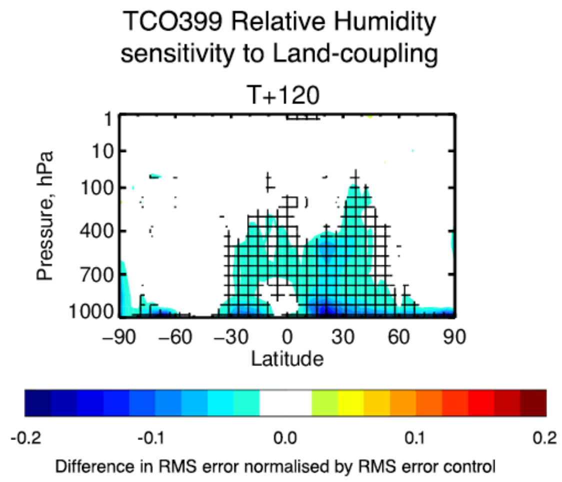




## Forecast improvements at Day+5 (**1 year**)
## Coupled-Land vs Uncoupled (only skin-interaction)



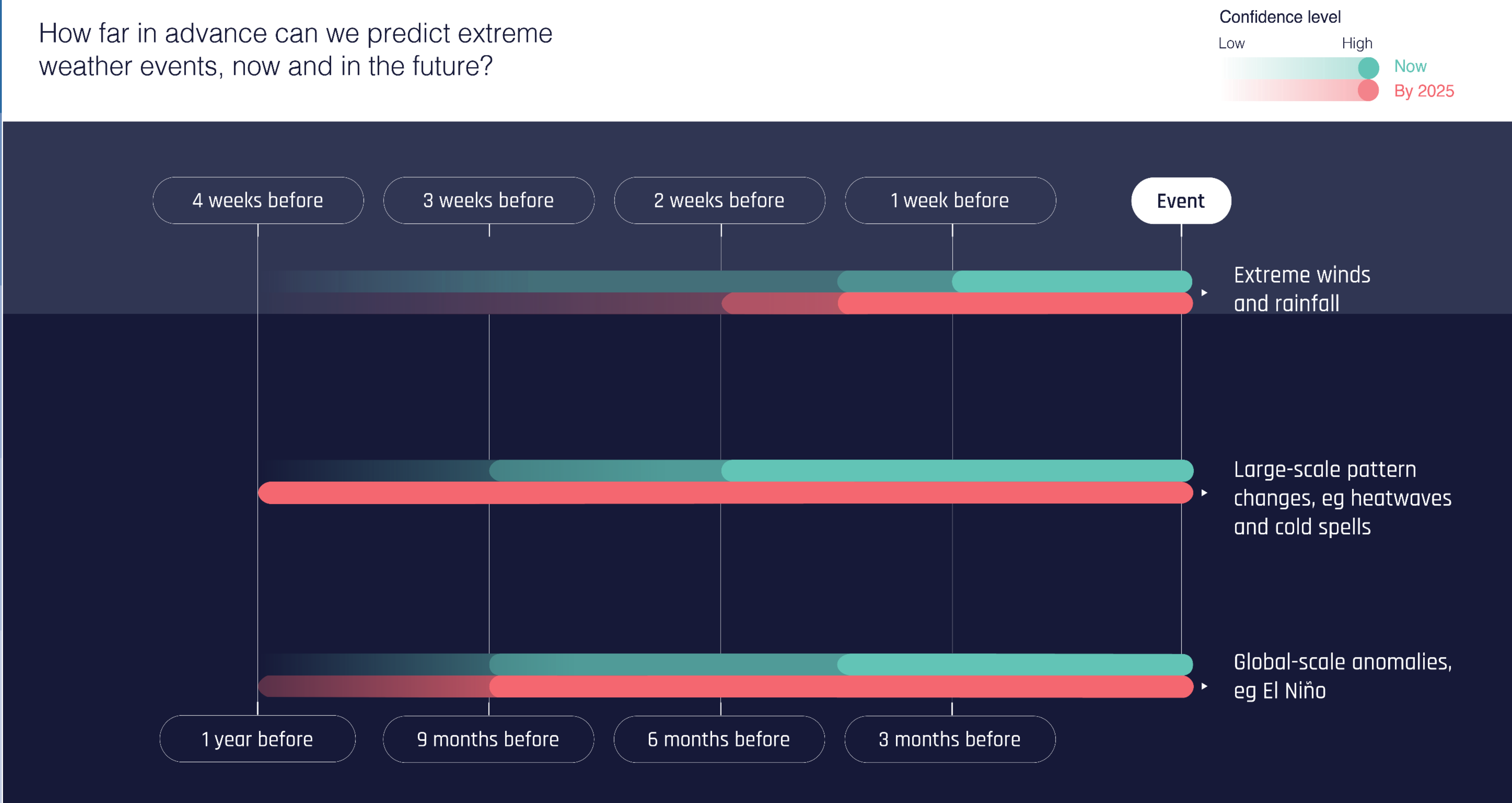




Balsamo et al. 2017 WGNE-Blue-book

# THINKING AHEAD

How far in advance can we predict extreme weather events, now and in the future?



# Earth surface modelling components @ECMWF

- **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**

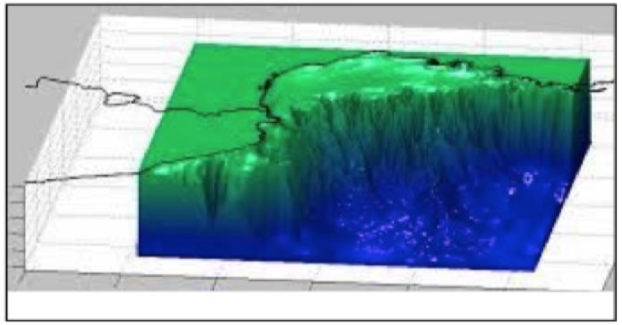
  The Louvain-la-Neuve Sea Ice Model

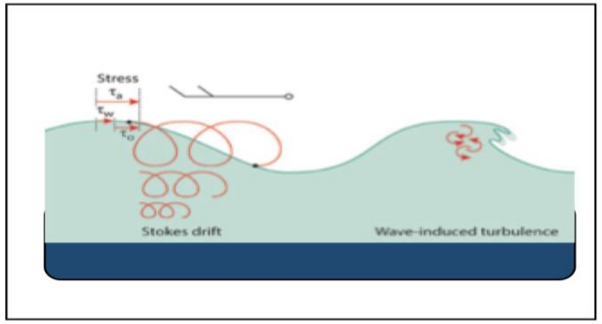
  Fichefet and Morales Maqueda (1997)

  Bouillon et al. (2009)

  Vancoppenolle et al. (2009)

  ORCA025_Z75 : 0.25° x 0.25°






| *Atm/L and resol.* | **ECMWF Config. in 2017** |
|---|---|
| *80 km* | ERAI* |
| *32 km* | ERA5*<br>SEAS5 |
| *18 km* | ENS |
| *9 km* | HRES$^{+}$ |

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)

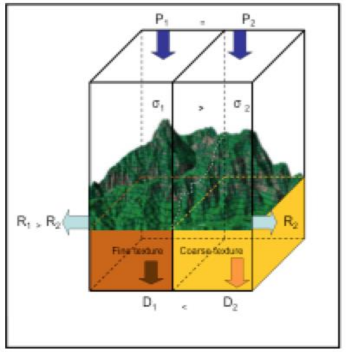
- **Enhance ML**

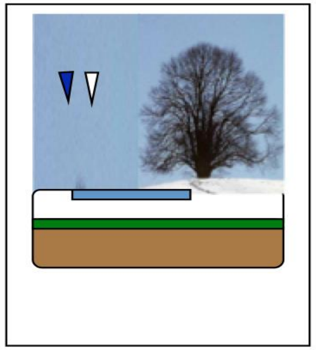
  Snow ML5

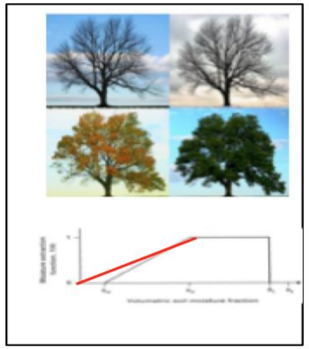
  Soil ML9

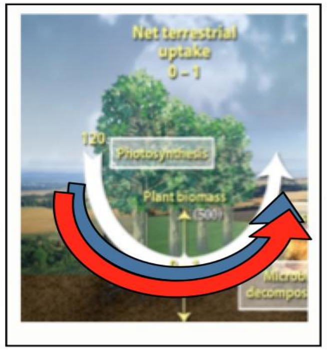
  Dutra et al. (2012, 2016)

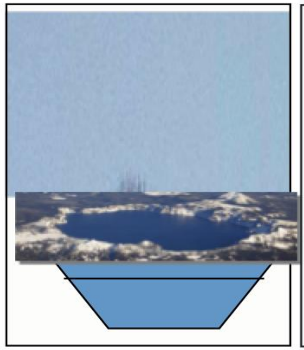
  Balsamo et al. (2016)

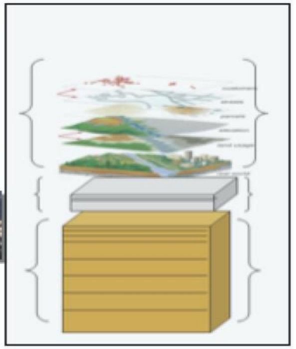






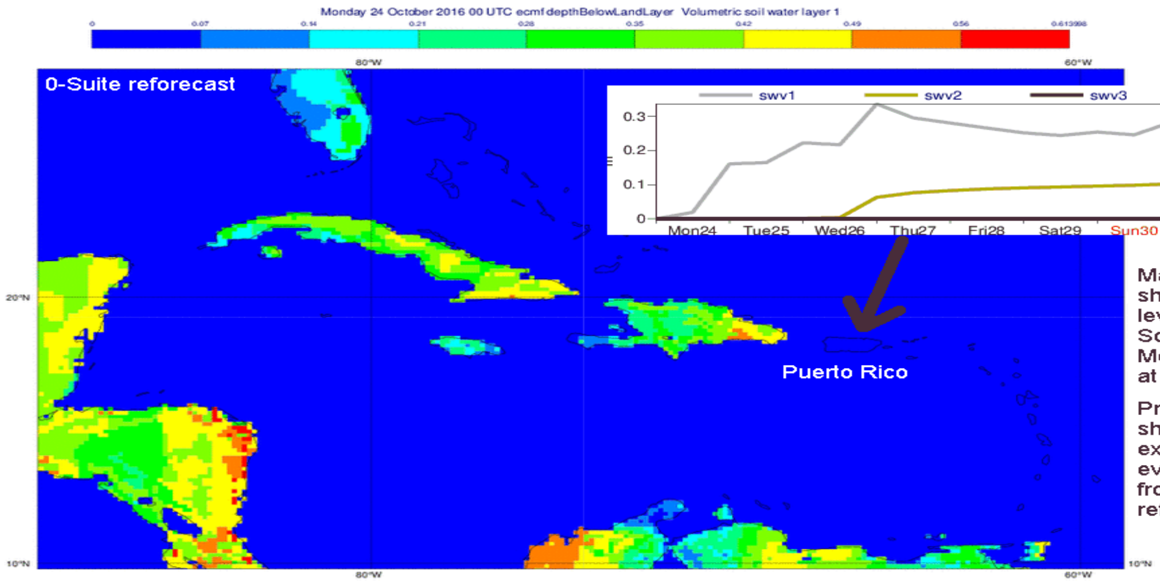





Land surface 1D-model soil, snow, vegetation, lakes and coastal water (thermodynamics).
Same resol. as Atm.

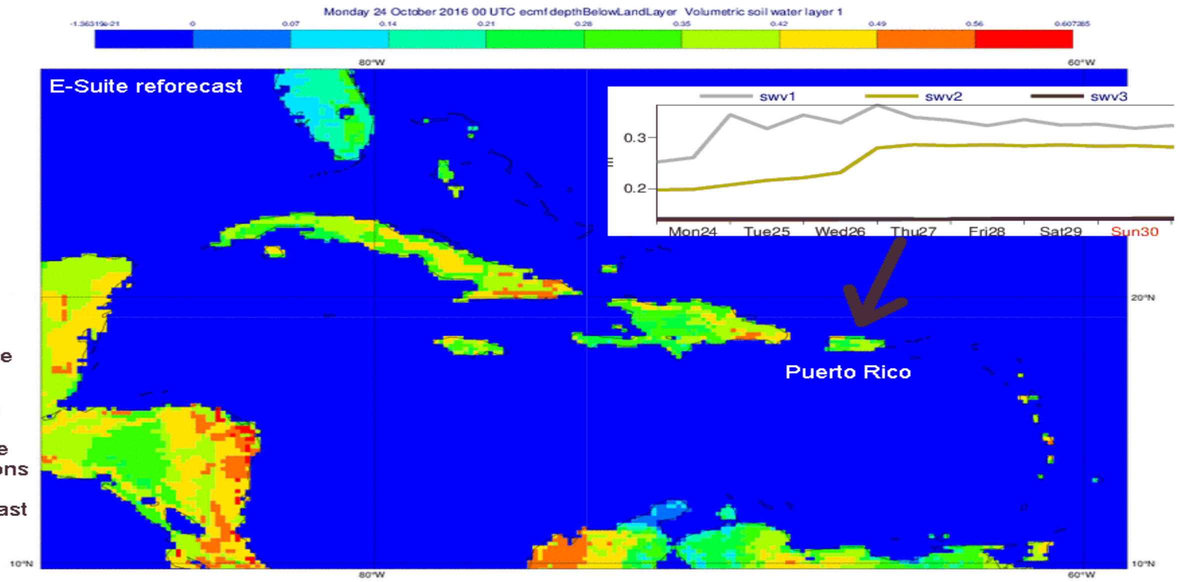
# ERA5-Land: a 9-km land reanalysis (high-resolution downscaling, water conserving)

ERA5/Land benefits from the R&D done in EartH2Observe H2020 project and Copernicus, is based on the new ERA5 and it run at 9-times higher resolution than ERA-Interim and 3.5-times higher resolution than ERA5. ERA5/Land will match the highest resolution currently operational at ECMWF (HRES 9km)



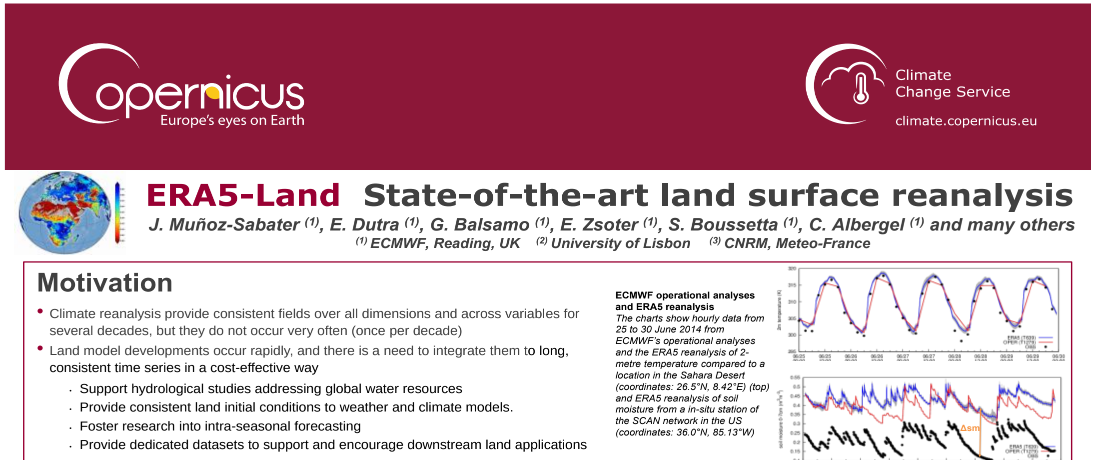

Maps show level 1 Soil Moisture at T+0

Profiles show example evolutions from a reforecast




**Munoz-Sabater et al** on ERA5-Land description and performance

**Dutra et al** on high resolution downscaling and performance


Copernicus Europe's eyes on Earth

Climate Change Service climate.copernicus.eu

**ERA5-Land State-of-the-art land surface reanalysis**

*J. Muñoz-Sabater [1], E. Dutra [1], G. Balsamo [1], E. Zsoter [1], S. Boussetta [1], C. Albergel [1] and many others*

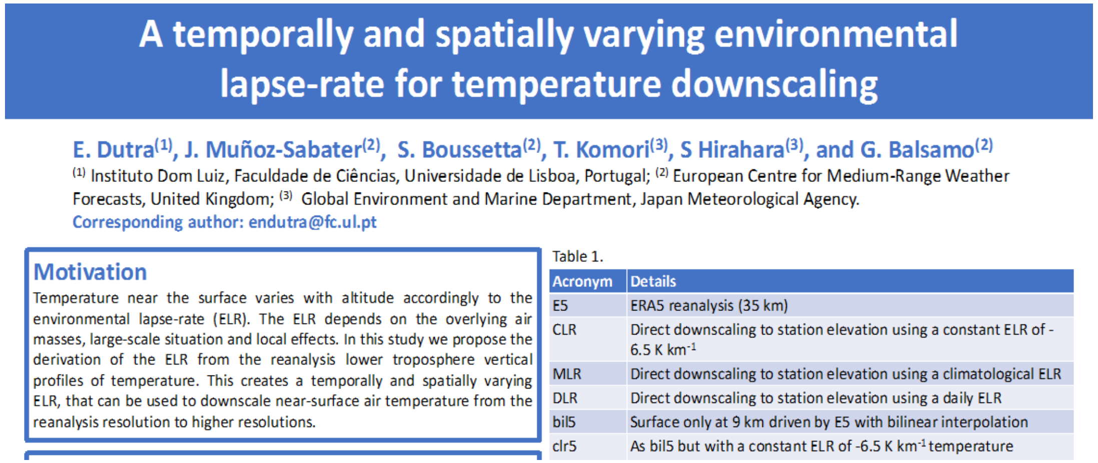
*[1] ECMWF, Reading, UK [2] University of Lisbon [3] CNRM, Meteo-France*

**Motivation**

- Climate reanalysis provide consistent fields over all dimensions and across variables for several decades, but they do not occur very often (once per decade)
- Land model developments occur rapidly, and there is a need to integrate them to long, consistent time series in a cost-effective way
  - Support hydrological studies addressing global water resources
  - Provide consistent land initial conditions to weather and climate models.
  - Foster research into intra-seasonal forecasting
  - Provide dedicated datasets to support and encourage downstream land applications

**ECMWF operational analyses and ERA5 reanalysis**

*The charts show hourly data from 25 to 30 June 2014 from ECMWF's operational analyses and the ERA5 reanalysis of 2-metre temperature compared to a location in the Sahara Desert (coordinates: 26.5°N, 8.42°E) (top) and ERA5 reanalysis of soil moisture from a in-situ station of the SCAN network in the US (coordinates: 36.0°N, 85.13°W)*


**A temporally and spatially varying environmental lapse-rate for temperature downscaling**

E. Dutra[1], J. Muñoz-Sabater[2], S. Boussetta[2], T. Komori[3], S Hirahara[3], and G. Balsamo[2]

[1] Instituto Dom Luiz, Faculdade de Ciências, Universidade de Lisboa, Portugal; [2] European Centre for Medium-Range Weather Forecasts, United Kingdom; [3] Global Environment and Marine Department, Japan Meteorological Agency.

Corresponding author: endutra@fc.ul.pt

**Motivation**

Temperature near the surface varies with altitude accordingly to the environmental lapse-rate (ELR). The ELR depends on the overlying air masses, large-scale situation and local effects. In this study we propose the derivation of the ELR from the reanalysis lower troposphere vertical profiles of temperature. This creates a temporally and spatially varying ELR, that can be used to downscale near-surface air temperature from the reanalysis resolution to higher resolutions.

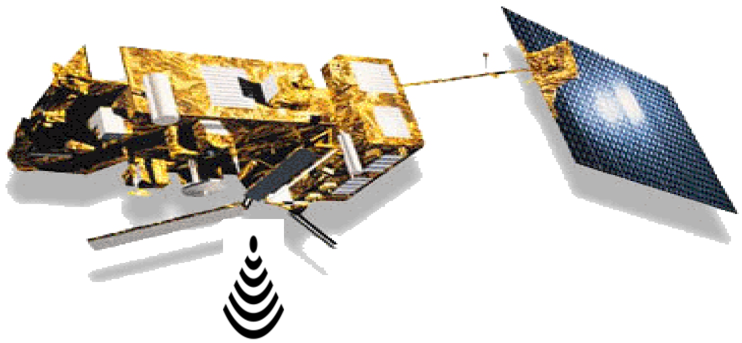
Table 1.

| Acronym | Details |
|---|---|
| E5 | ERA5 reanalysis (35 km) |
| CLR | Direct downscaling to station elevation using a constant ELR of -6.5 K km$^{-1}$ |
| MLR | Direct downscaling to station elevation using a climatological ELR |
| DLR | Direct downscaling to station elevation using a daily ELR |
| bil5 | Surface only at 9 km driven by E5 with bilinear interpolation |
| clr5 | As bil5 but with a constant ELR of -6.5 K km$^{-1}$ temperature |

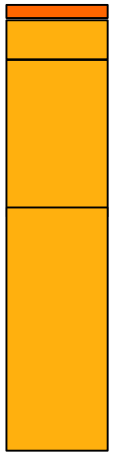
Thanks to Joaquin Munoz-Sabater and ERA-Team

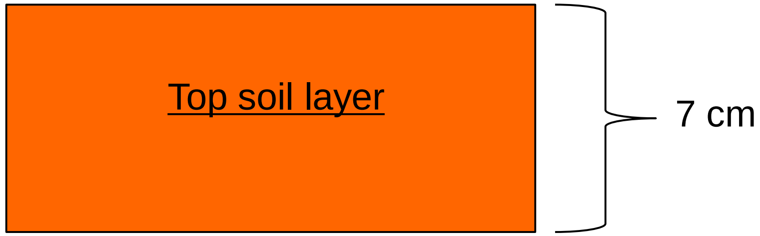
# Future enhanced soil model vertical resolution to increase use of satellite data

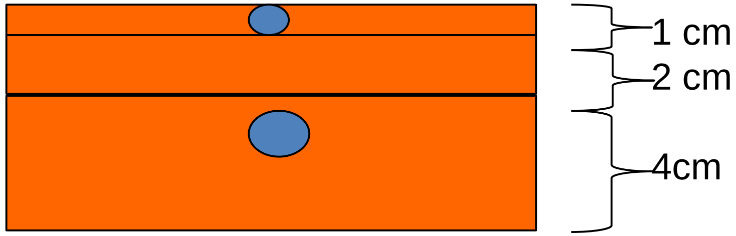
The model bias in Tskin amplitude shown by *<u>Trigo et al. (2015)</u>* motivated the development of an enhanced soil vertical discretisation to improve the match with satellite products.



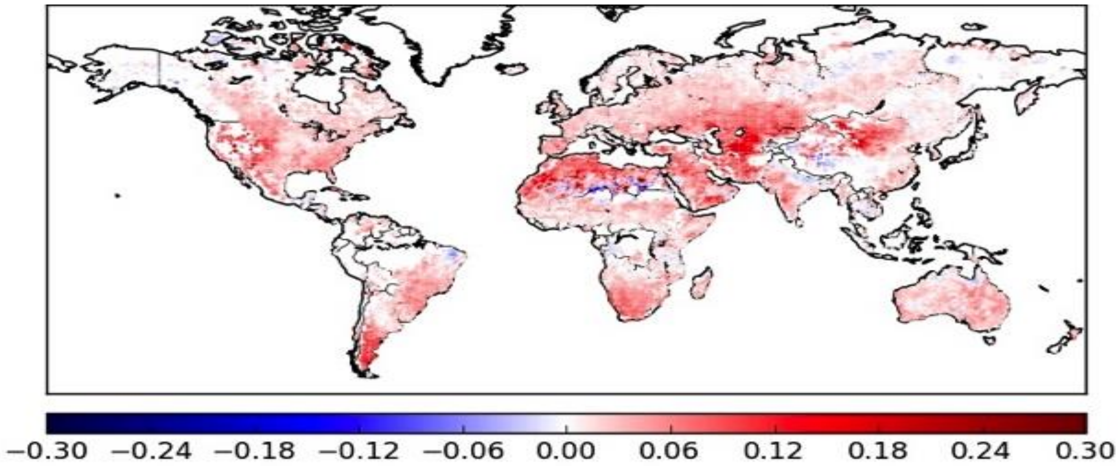
<u>4-layers:</u>
**# 0-7 cm**
# 7-28 cm
# 28-100 cm
# 100-289 cm






<u>9-layers:</u>
**# 0-1 cm**
**# 1-3 cm**
**# 3-7 cm**
# 7-15 cm
# 15-25 cm
# 25-50 cm
# 50-100 cm
# 100-200 cm
# 200-300 cm




Thanks to Clément Albergel

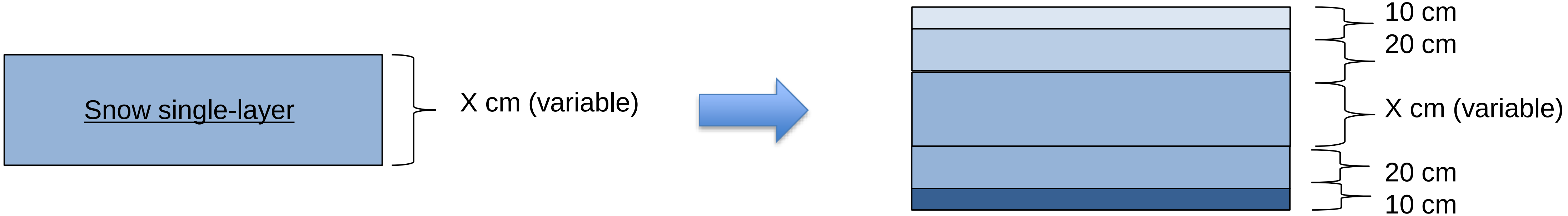
Comparison with ESA-CCI soil moisture remote sensing (multi-sensor) product.(1988-2014). A finer soil model improves the correlation with measured satellite soil moisture

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

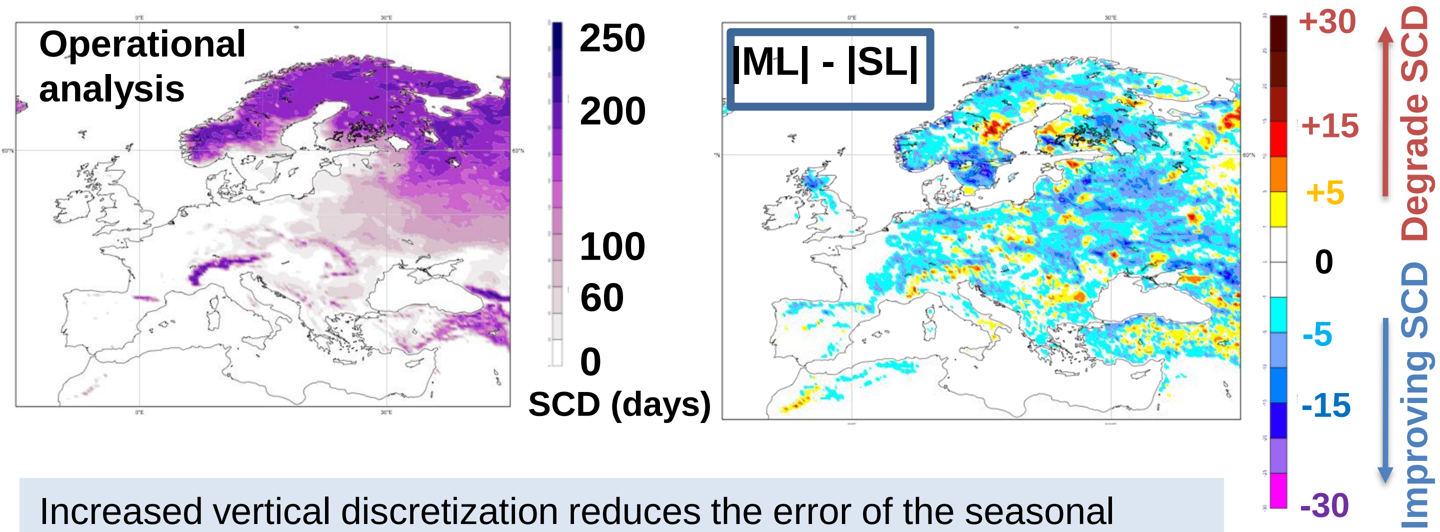
Dorigo et al. (2017 RSE)

# Future enhanced snow model vertical resolution: impact in cold regions climate

Increased vertical discretization of the snowpack (**up to 5 layers**) permits a better physical processes representation

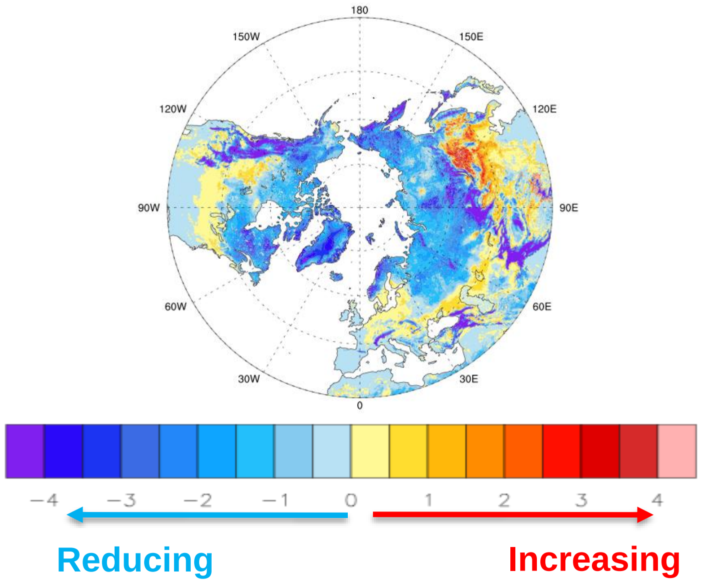



**Snow cover duration (SCD) over Europe 2016/2017**




Increased vertical discretization reduces the error of the seasonal snow cover duration by 5 to 15 days (evaluated in ERA5-Land mode)

**Difference in $T_{skin}$ minimum winter (DJF)**




Potential for reducing the 2m temperature diurnal-cycle bias

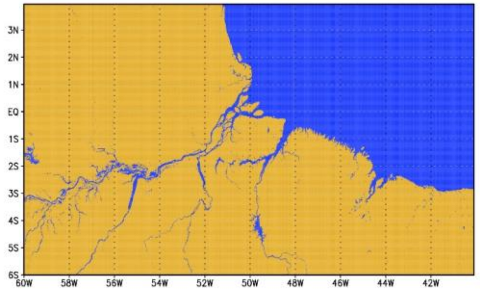
ECMWF

Thanks to Gabriele Arduini, Souhail Boussetta, Emanuel Dutra

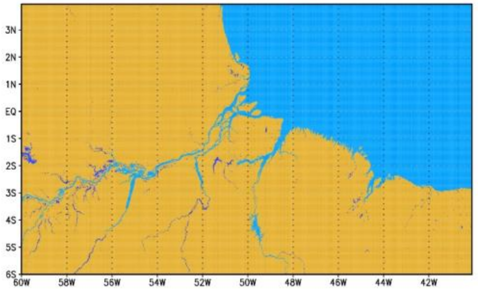
# Mapping the surface at 1km: water bodies and changes over time

Classifying automatically inland water bodies is a complex task.  A 1-km water bodies cover and bathymetry have been produced

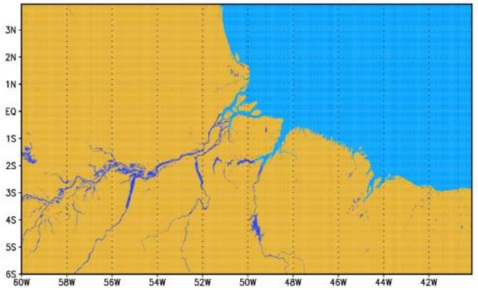
ESA GlobCOVER
has no water class



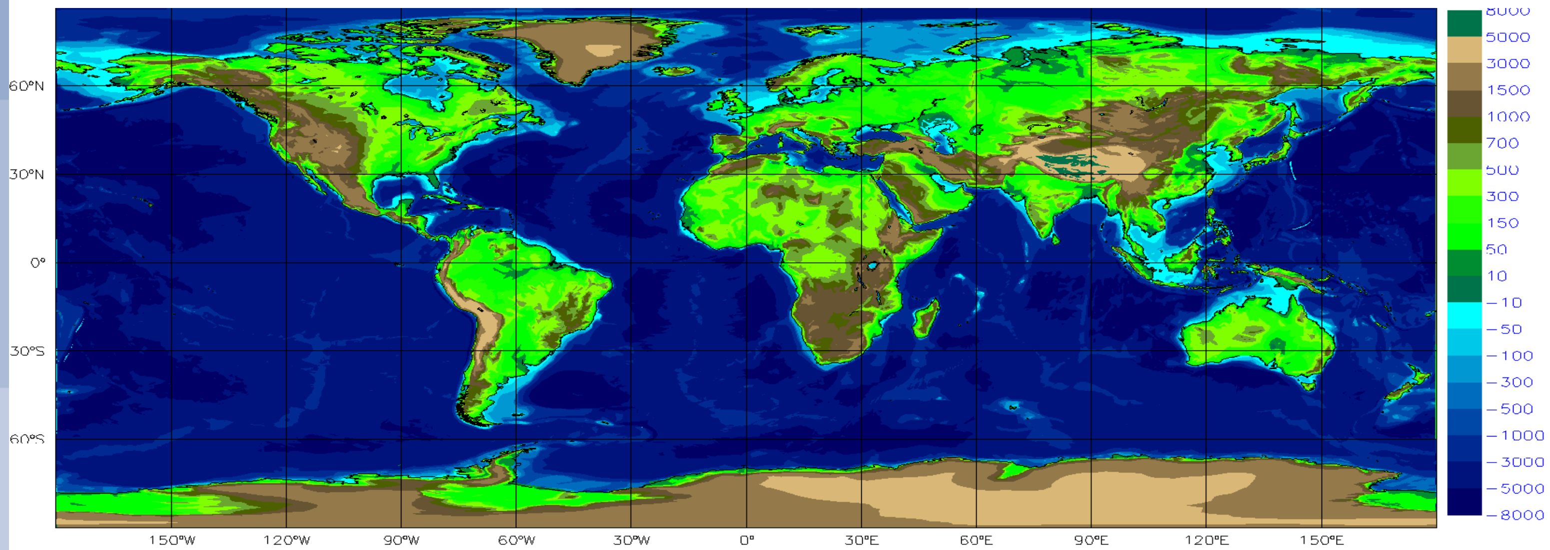
Flooding allows classify,
problems w. large rivers



New classification algo
works well at 1km



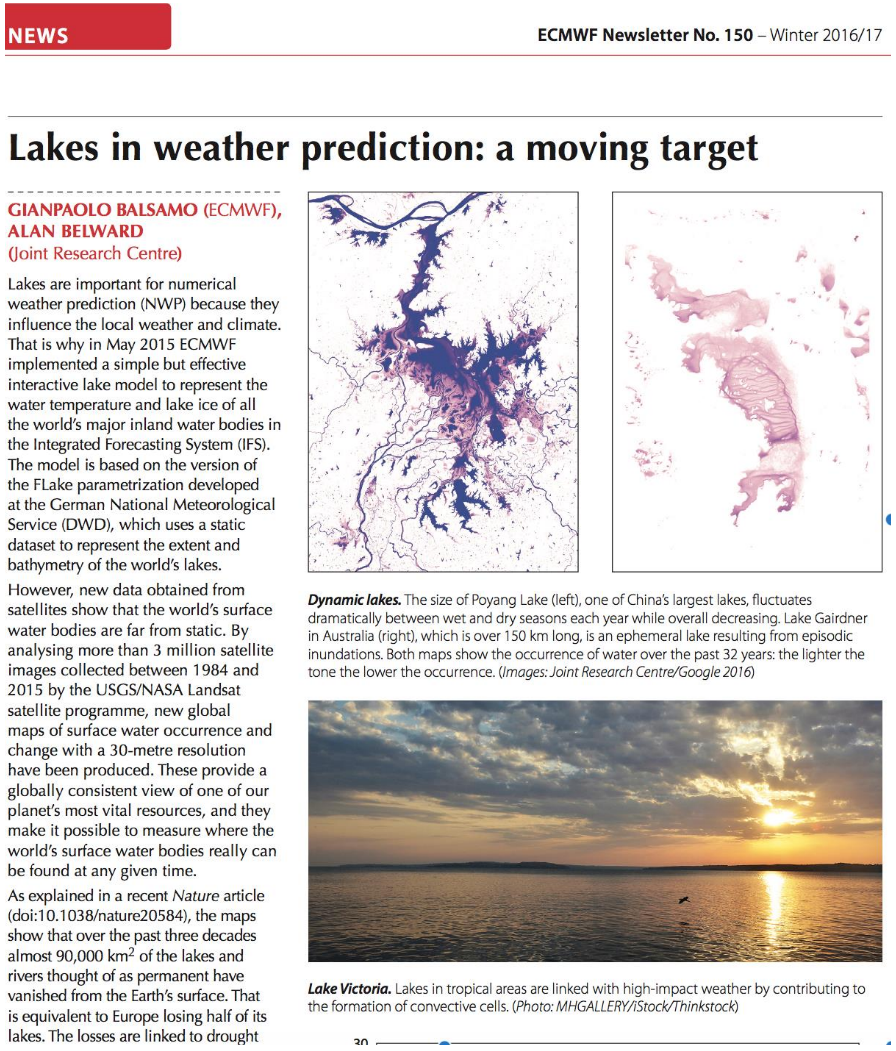
A new 1-km global bathymetry and orography map (SRTM+/GEBCO/GLDB)




ECMWF

Thanks to Margarita Choulga, Souhail Boussetta, Irina Sandu, Nils Wedi

ESA GlobCOVER is combined with JRC/GLCS
to detect Lake cover changes



NEWS

ECMWF Newsletter No. 150 – Winter 2016/17

## 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*)

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# Mapping the surface at 1km: urban cover, its expansion and uncertainties

Classifying automatically urban areas (fraction and height) is an extremely complex task. Urban areas expand each year

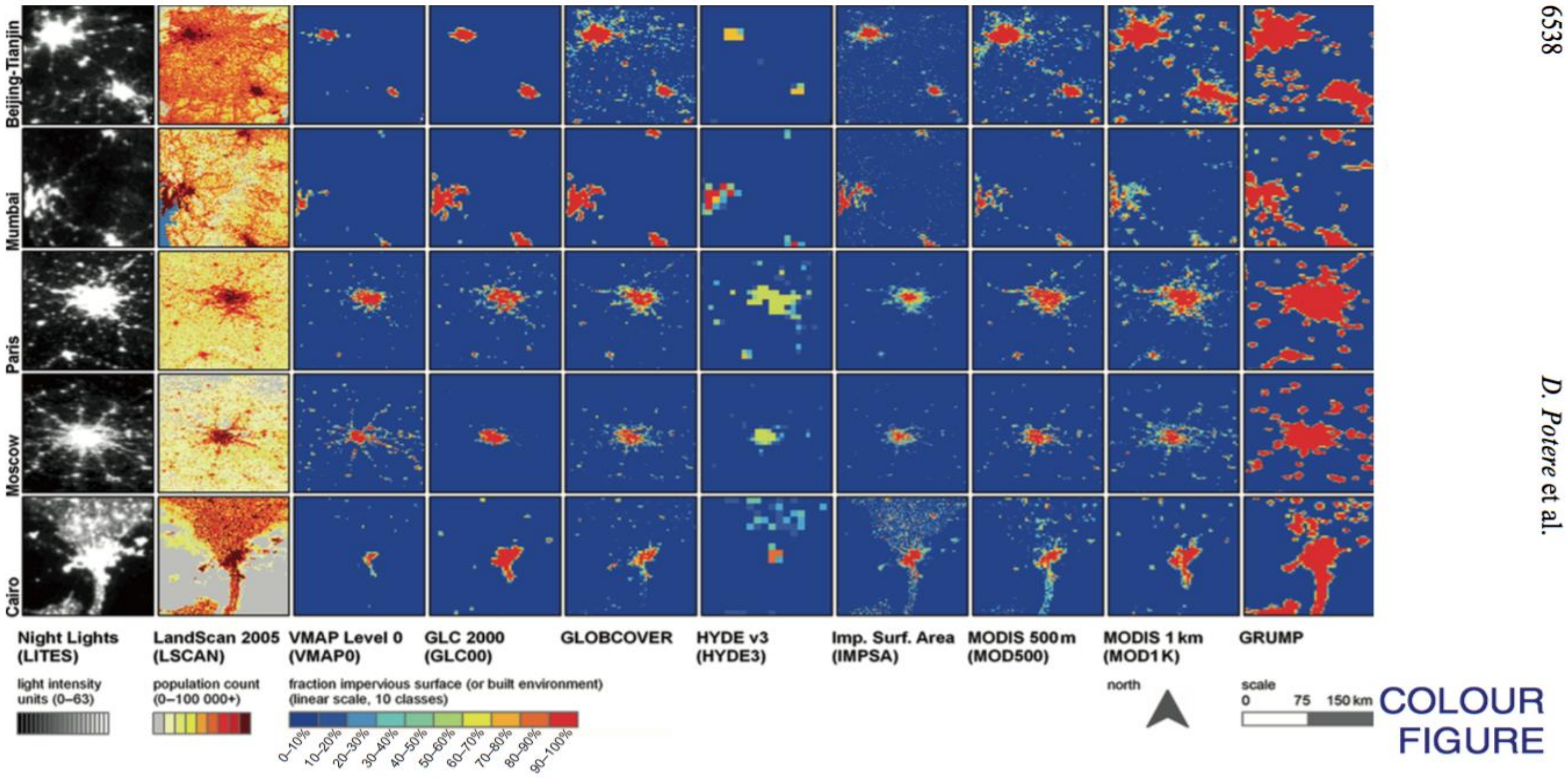
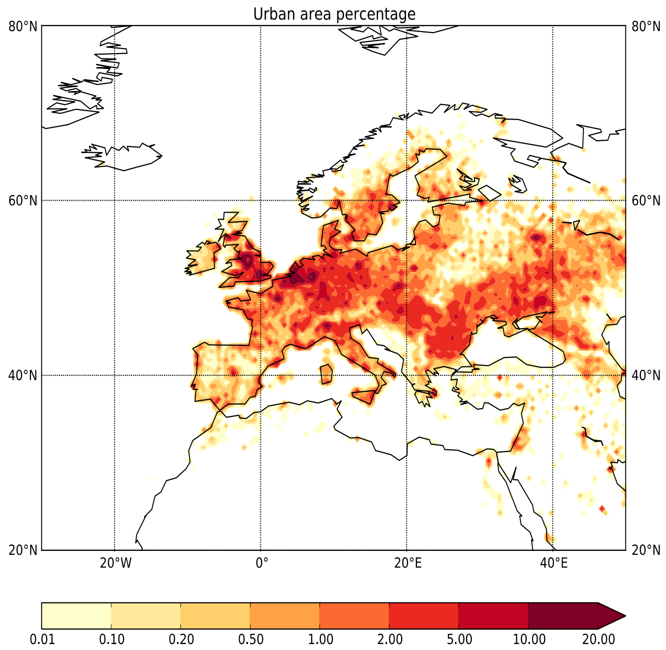



Figure 1. The eight global urban maps and two urban-related maps for Beijing-Tianjin, China (top row), Mumbai, India (second row), Paris, France (third row), Moscow, Russia (fourth row), and Cairo, Egypt (bottom row). LITES, LSCAN and IMPSA are at native 30 arc-second resolution, HYDE3 is at native 5 arc-minutes, and the remaining maps have been aggregated from 30 arc-seconds to 1.5 arc-minutes for display. This aggregation effectively converts their legends from binary (urban/rural) to continuous (percentage urban).

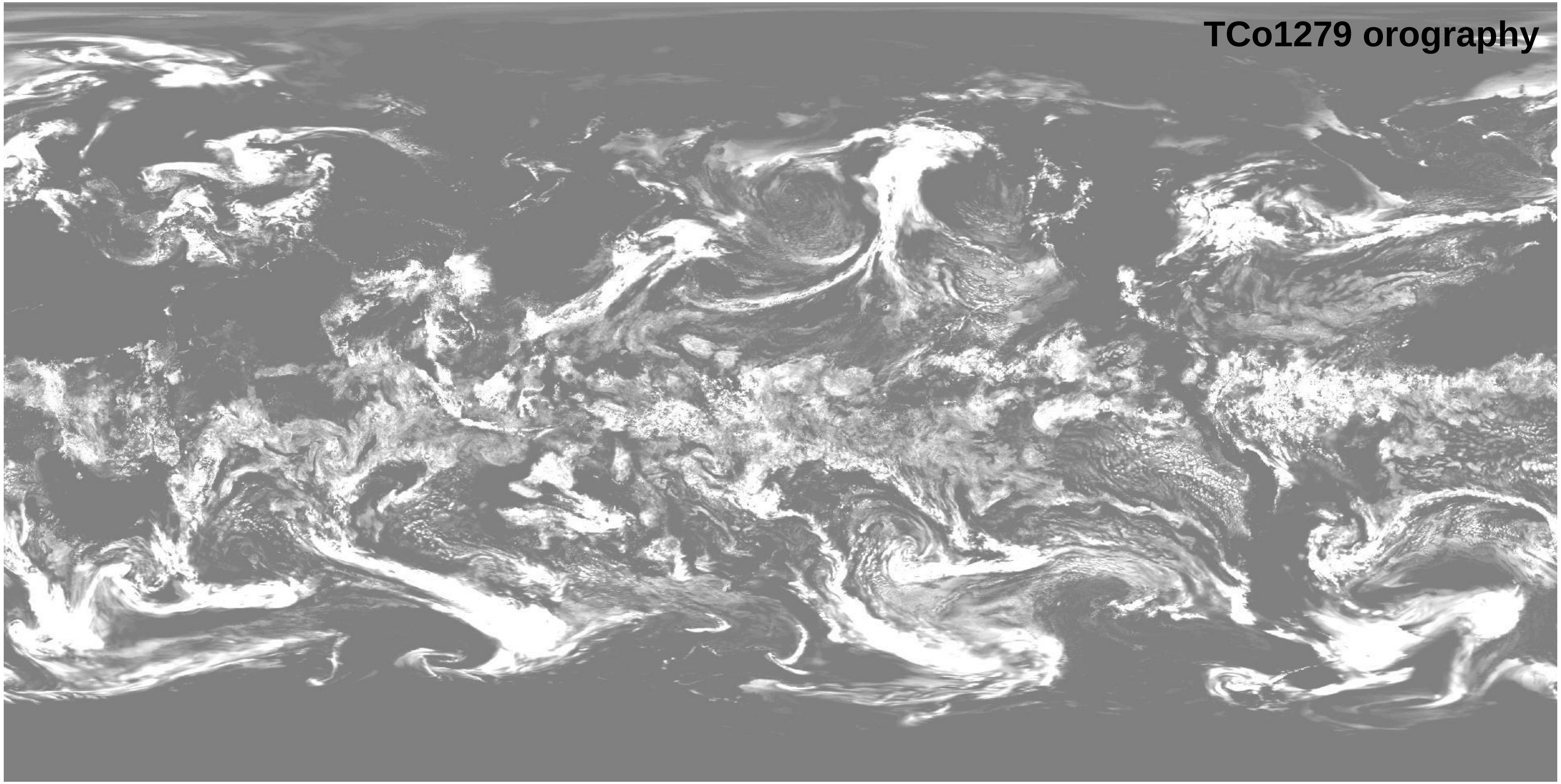
- Urban area dataset comparison on selected cities (Potere et al., 2009 IJRS) reveal large uncertainties and discrepancies




- Urban area (a, in %, from ECOCLIMAP Masson et al., 2003) see:
- Balsamo et al. 2014 ECMWF TM729
- CHE H2020 Project http://www.che-project.eu

ECMWF

# Current km-scale: TCo1279 (~9km) highest global operational NWP today

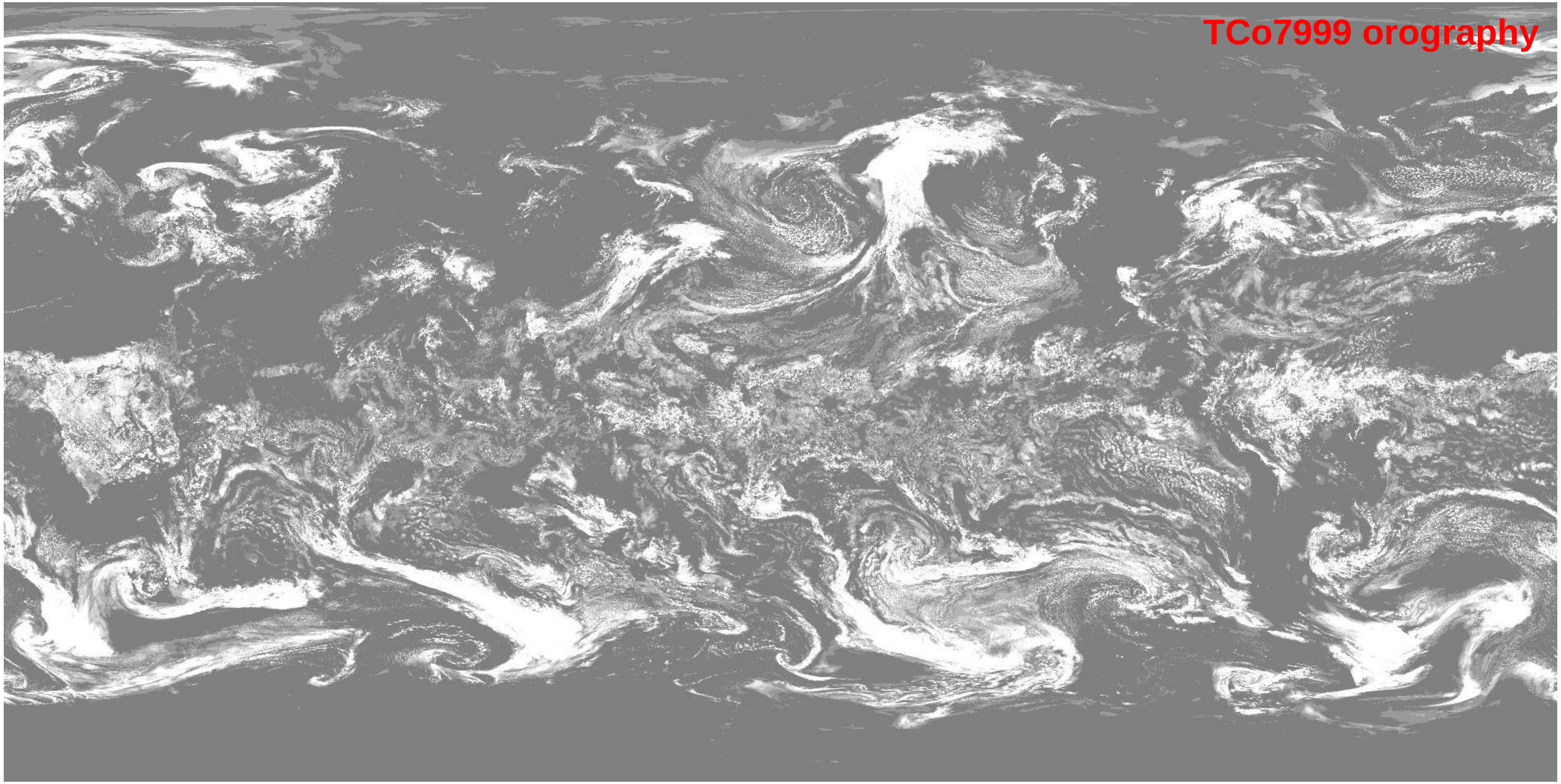



(12h forecast, *hydrostatic*, with deep convection parametrization, 450s time-step, 240 Broadwell nodes, ~0.75s per timestep)

ECMWF

Equivalent to 6.6 Megapixel camera

# Towards km-scale: TCo7999 test-case (~1.3km) highest NWP test @ECMWF




(12 h forecast, *hydrostatic*, no deep convection parametrization, 120s time-step, 960 Broadwell nodes, ~6s per timestep in SP)

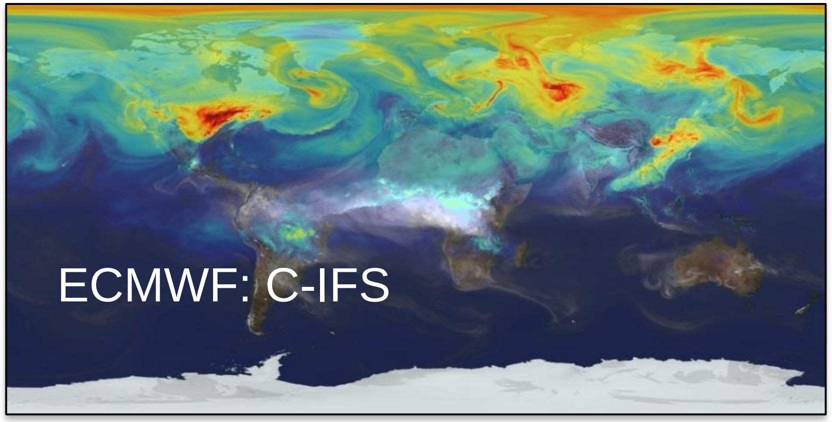
ECMWF

Thanks to Nils Wedi and NM-Team

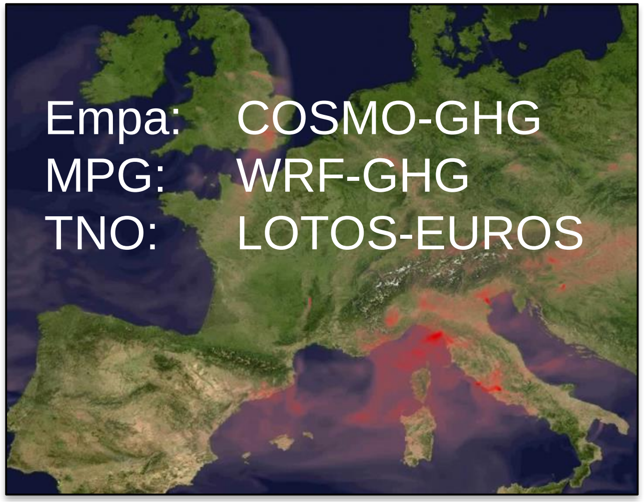
Equivalent to 256 Megapixel camera 

# Embracing multi-scale to evaluate uncertainties, from local to global

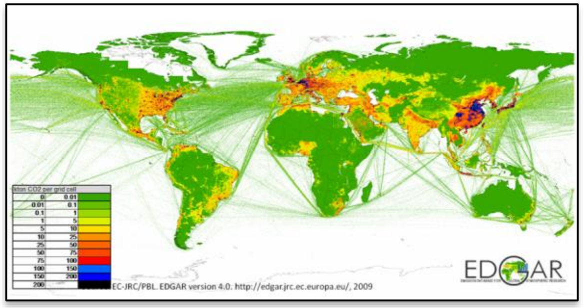
Global, ~ 9km resolution, ECMWF

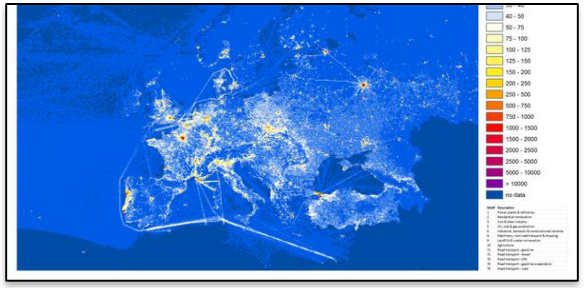



Europe, ~ 5 km, Empa, TNO, MPG

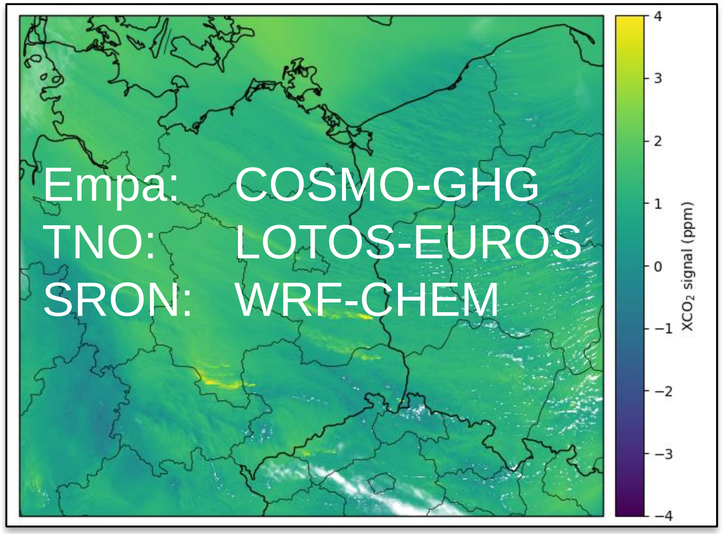



Global, Regional City emission

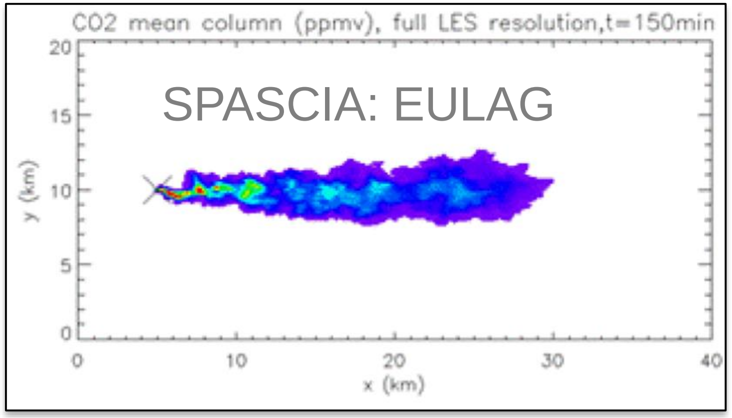


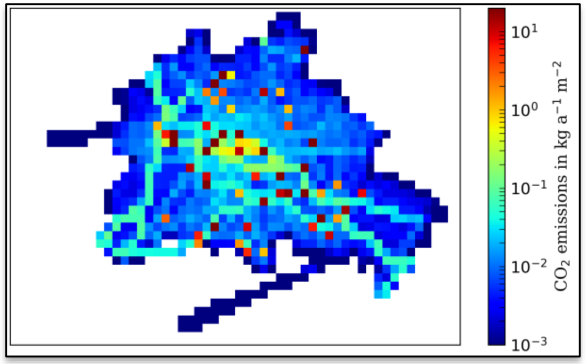


Regional, ~ 1 km, Empa, TNO, SRON




Point source, ~ 100 m, SPASCIA

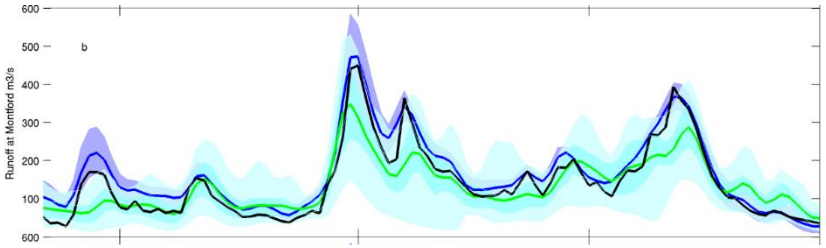



ECMWF

# Land surface uncertainty –

# LAND SURFACE – ATMOSPHERE FEEDBACKS

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RMetS
Royal Meteorological Society

## Improved seasonal prediction of the hot summer of 2003 over Europe through better representation of uncertainty in the land surface

David A. MacLeod,[a*] Hannah L. Cloke,[b,c] Florian Pappenberger[d] and Antje Weisheimer[d,e]

[a]Atmospheric, Oceanic and Planetary Physcis, Department of Physics, University of Oxford, UK
[b]Department of Geography and Environmental Science, University of Reading, UK
[c]Department of Meteorology, University of Reading, UK
[d]European Centre for Medium-Range Weather Forecasts, Reading, UK
[e]Department of Physics, National Centre for Atmospheric Science (NCAS), University of Oxford, UK

*Correspondence to: D. A. MacLeod, Department of Physics, Clarendon Lab, Parks Road, Oxford, OX1 3PU, UK. E-mail: macleod@atm.ox.ac.uk

Methods to represent uncertainties in weather and climate models explicitly have been developed and refined over the past decade and have reduced biases and improved forecast skill when implemented in the atmospheric component of models. These methods have not yet been applied to the land-surface component of models. Since the land surface is strongly coupled to the atmospheric state at certain times and in certain places (such as the European summer of 2003), improvements in the representation of land-surface uncertainty may potentially lead to improvements in atmospheric forecasts for such events.

Here we analyze seasonal retrospective forecasts for 1981–2012 performed with the European Centre for Medium-Range Weather Forecasts (ECMWF) coupled ensemble forecast model. We consider two methods of incorporating uncertainty into the land-surface model (H-TESSEL): stochastic perturbation of tendencies and static perturbation of key soil parameters

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doi:10.5194/hess-20-2737-2016


Hydrology and Earth System Sciences
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EGU

## Evaluating uncertainty in estimates of soil moisture memory with a reverse ensemble approach

**Dave MacLeod**[1], **Hannah Cloke**[2,3], **Florian Pappenberger**[4,5], **and Antje Weisheimer**[4,6]

[1]Atmospheric, Oceanic and Planetary Physics, Department of Physics, University of Oxford, Oxford, UK
[2]Department of Geography and Environmental Science, University of Reading, Reading, UK
[3]Department of Meteorology, University of Reading, Reading, UK
[4]European Centre for Medium-Range Weather Forecasts, Reading, UK
[5]School of Geographical Sciences, Bristol University, Bristol, UK
[6]Department of Physics, National Centre for Atmospheric Science (NCAS), University of Oxford, Oxford, UK

*Correspondence to:* Dave MacLeod (macleod@atm.ox.ac.uk)

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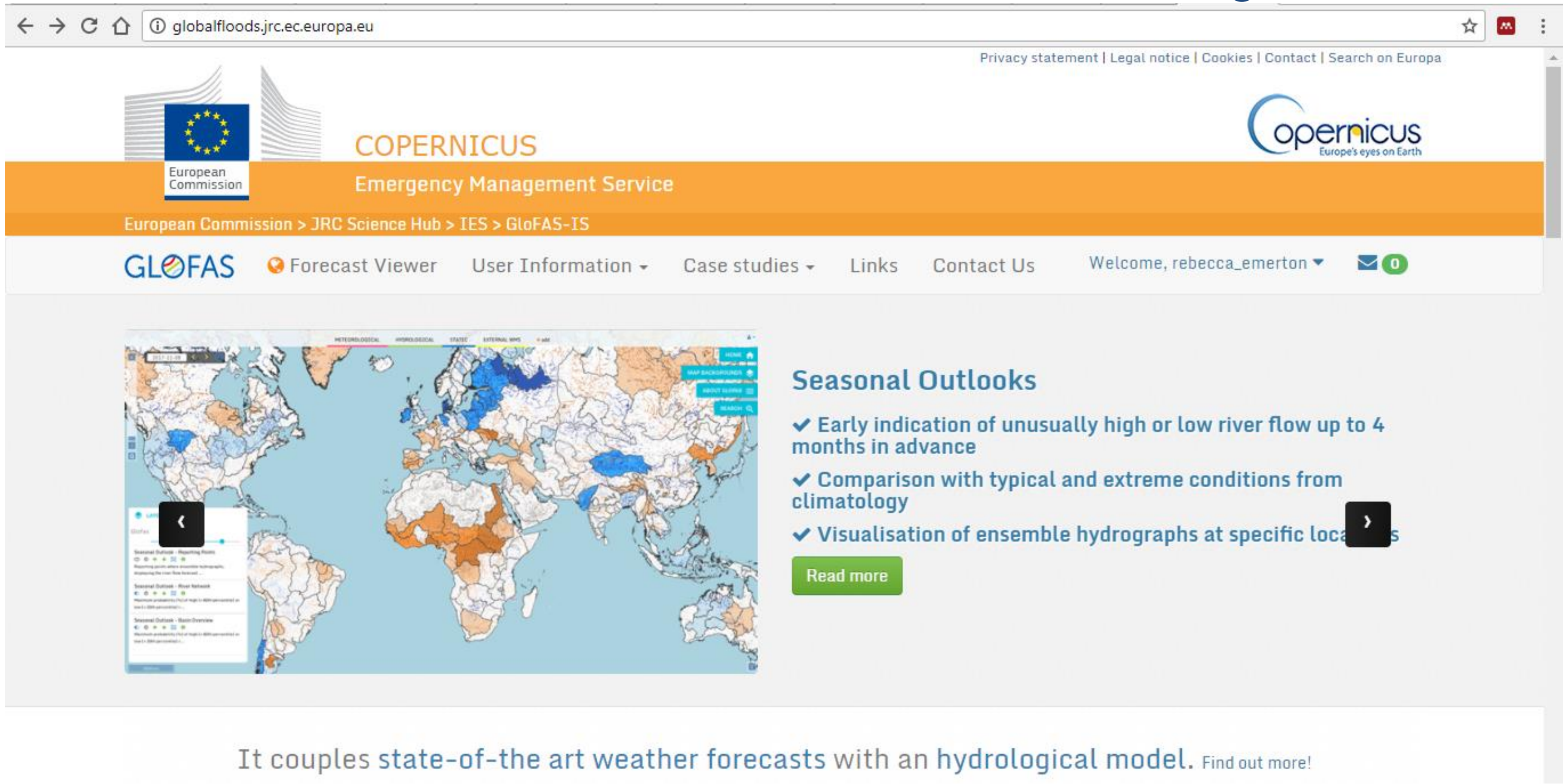
**Abstract.** Soil moisture memory is a key component of seasonal predictability. However, uncertainty in current mem-

prediction. The soil moisture reservoir has a memory considerably longer than most atmospheric processes, and as a

ECMWF

# GloFAS-Seasonal: Forecast Products

**www.globalfloods.eu**




Emerton et al (in prep) & here at HEPEX!

## WHAT WILL THE INFORMATION BE USED FOR?

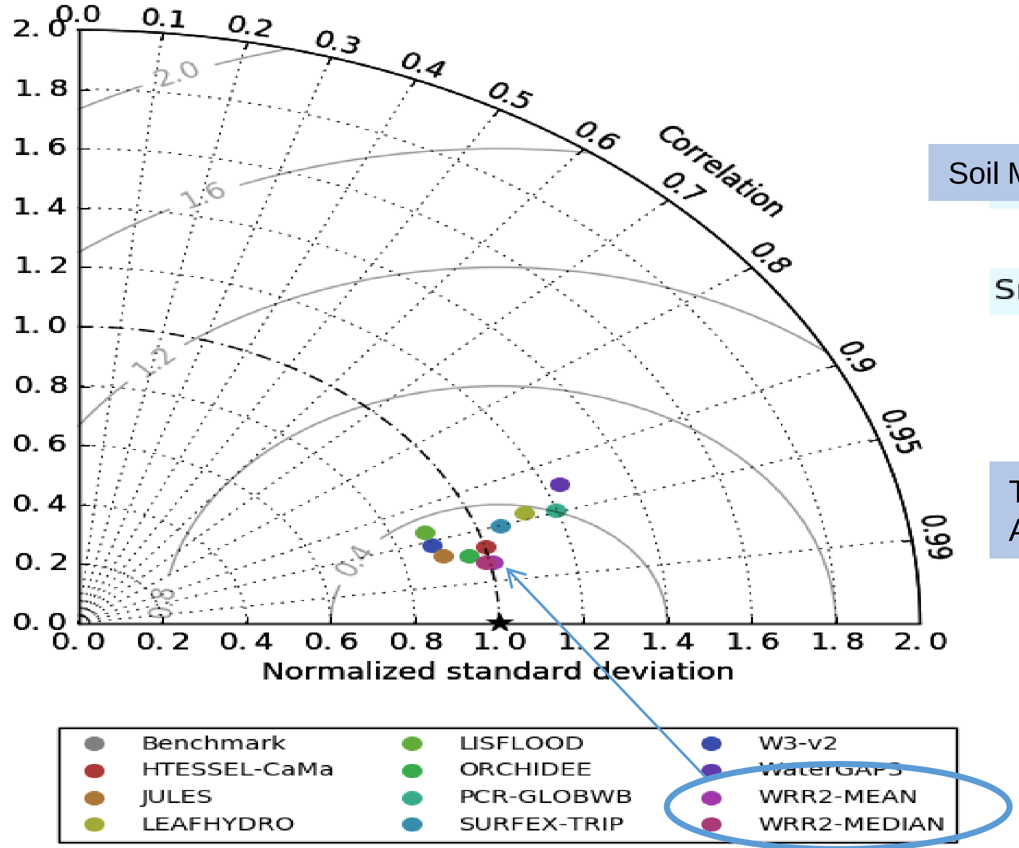
The wealth of climate information will be the basis for generating a wide variety of climate indicators aimed at supporting adaptation and mitigation policies in Europe in a number of sectors. These include, but are not limited to, the following:

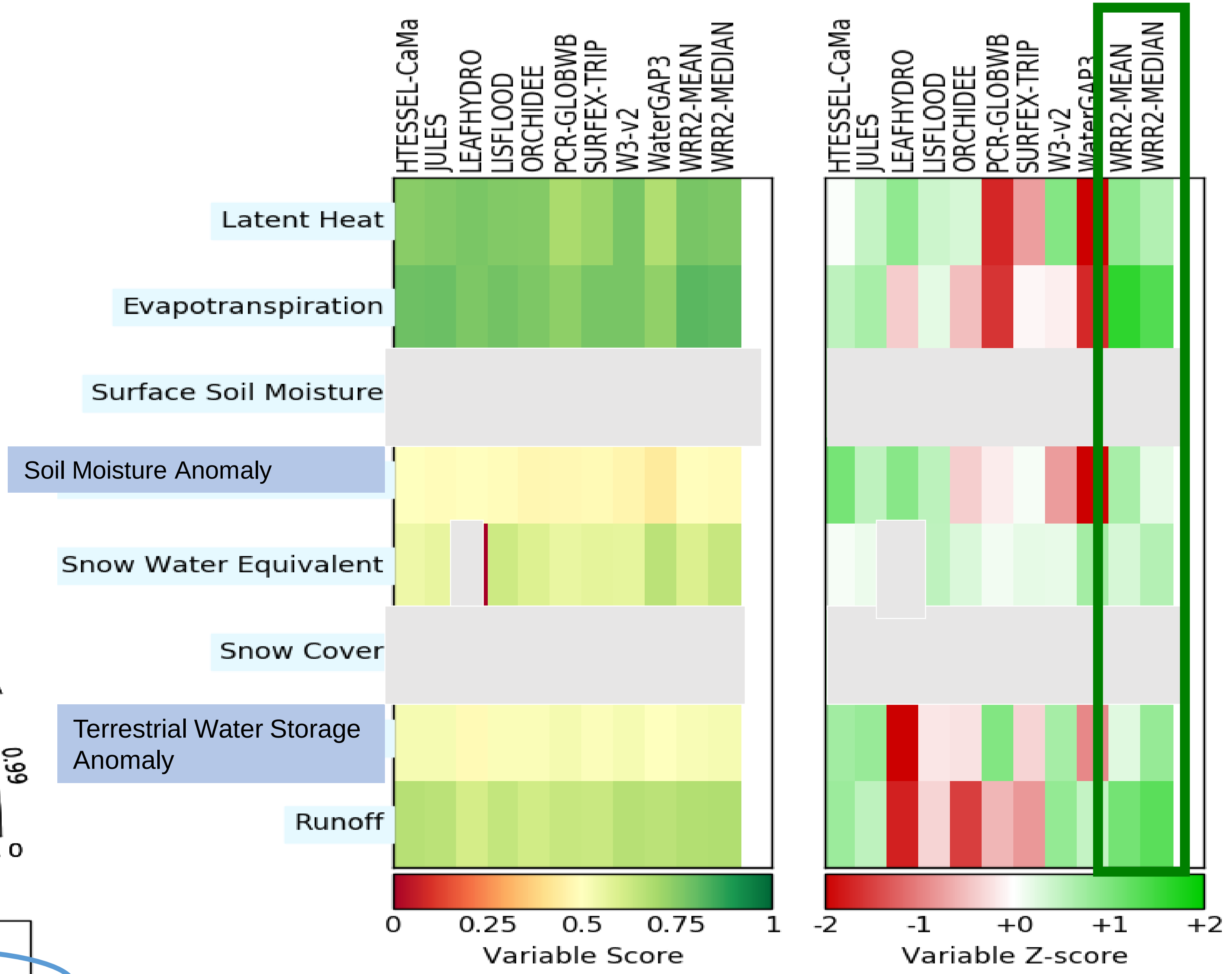

1) to provide **practical examples** of how C3S in general and CDS in particular could deliver information of relevance to specific sectors.
2) To provide examples of **good practice**. This means that the SISs should be built to the highest possible standards so that services developers could be inspired by them and look at them as quality benchmarks.
3) To provide information on **users needs**, and whenever possible address those. In particular SIS contract should develop and make available sector-relevant indicators and tools that were either unavailable or inaccessible before.

# EartH2Observe H2020 multi-model GHP/LSMs ensemble and its added value

## Multi-model mean/median outperforms single models for most of the variables

**Spatial distribution score of latent heat**




Thanks to Alberto Martinez, Eleanor Blyth, and E2O-Team

# Conclusions

- Land surface schemes are getting very advanced – high resolution e.g. 1km will happen (test runs are here, operational next)
- We are working towards a coupled and closed water cycle
- Uncertainty representation is a challenge in an operational environment (amount of data produced only allows for a limited number of ensembles) – but we can demonstrate that we can do it
- Earth System modelling approach is a viable way of improving weather forecasts (and delivers environmental forecasts at the same time)


Wildfire App; Webcrawler for Hydrological data, data extraction tool, innovative visualisation, Machine Learning (optimize data requests from MARS archive) and many more

http://esowc.ecmwf.int/