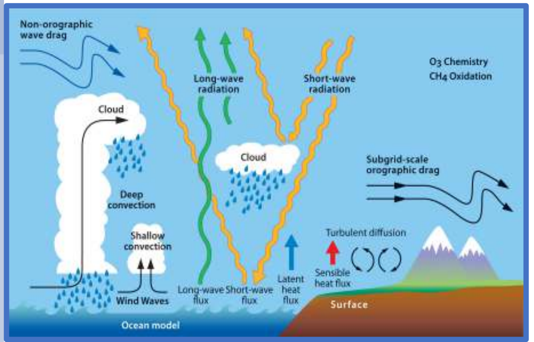
Land surface modelling and data assimilation in support to ECMWF progress

Gianpaolo Balsamo, Gabriele Arduini, Souhail Boussetta, Margarita Choulga, Emanuel Dutra, David Fairbarn, Joe McNorton, Cinzia Mazzetti, Patricia de Rosnay, Christel Prudhomme, Irina Sandu, Jamie Towner, Peter Weston, Nils Wedi, Ervin Zsoter

Presented at the workshop NWP in Portugal

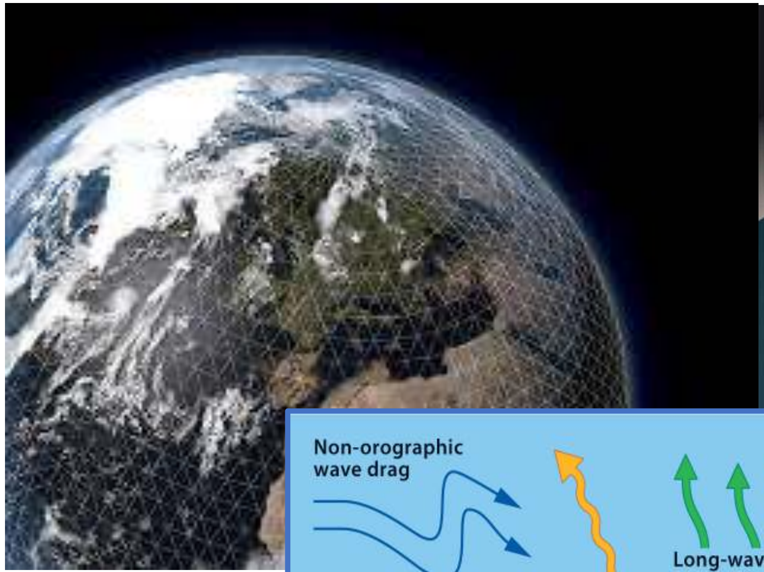
Evora 10-11 November 2021

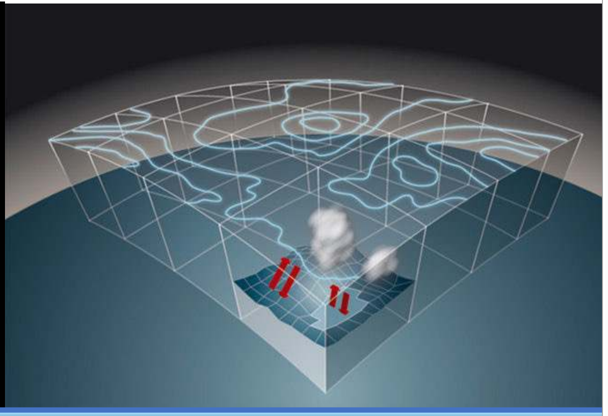


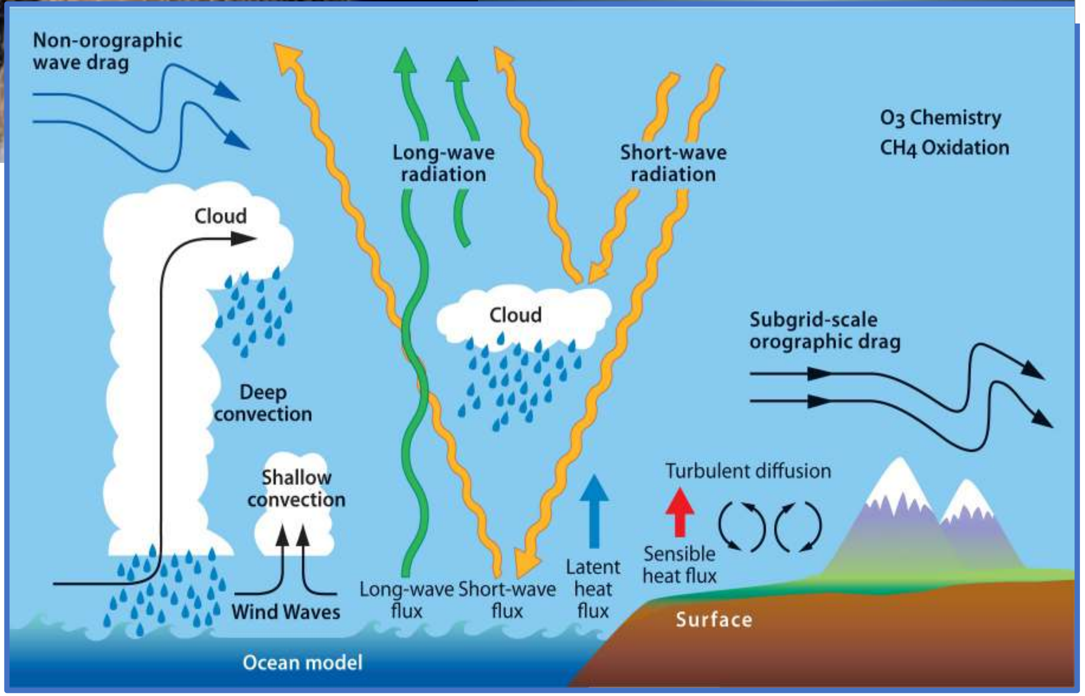
ECMWF

The ECMWF Integrated Forecasting System

Earth System Modelling components @ECMWF

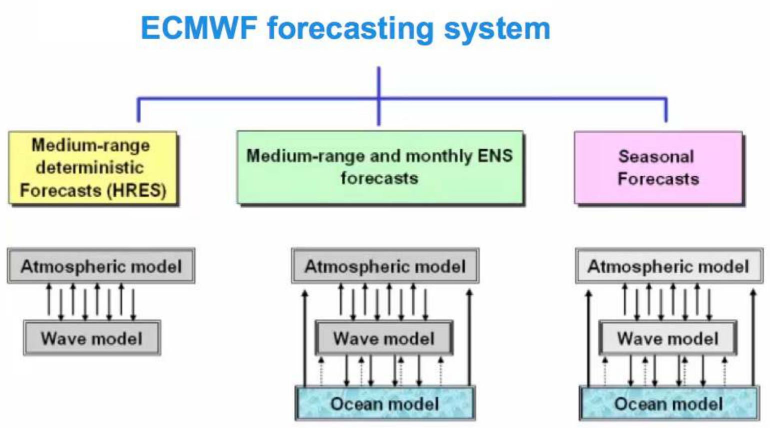






Atmospheric advection, Bottom and Top boundary conditions 2D

TCO-grid



Atmospheric physics 1D column (**137 vertical layers**) radiation, convection, diffusion. Clouds and microphysics

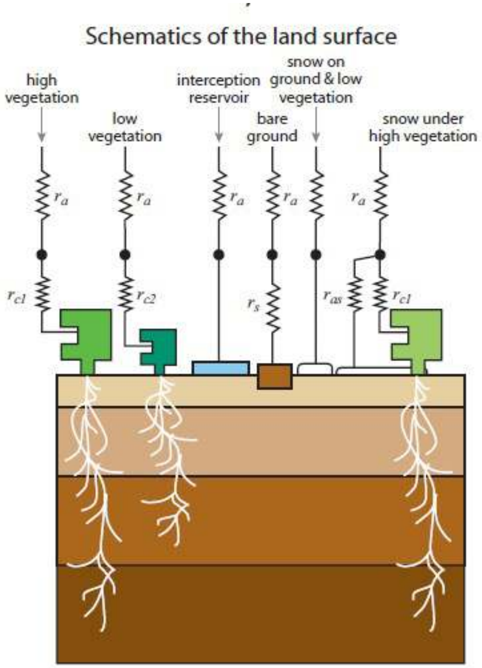
Land surface 1D-model soil (**4 vertical layers**), snow, vegetation, lakes and coastal water (thermodynamics). Same resolution as Atmospheric grid

Atm/Land resolution	**ECMWF Config. in 2021**
32 km	ERA5* SEAS5+
18 km	ENS+
9 km	HRES+

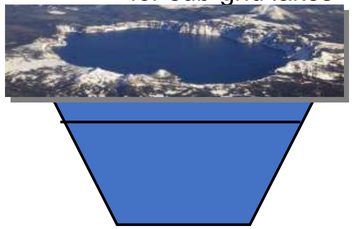
Ocean 3D-Model Surface Waves and currents, Sea-ice.
(ocean-uncoupled)
+(ocean-coupled)*

Portuguese NWP contributions to ECMWF: A strong legacy

Pedro Viterbo
ECMWF
(1986-2005)



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



Isabel Trigo
ECMWF SAC
(2018-)

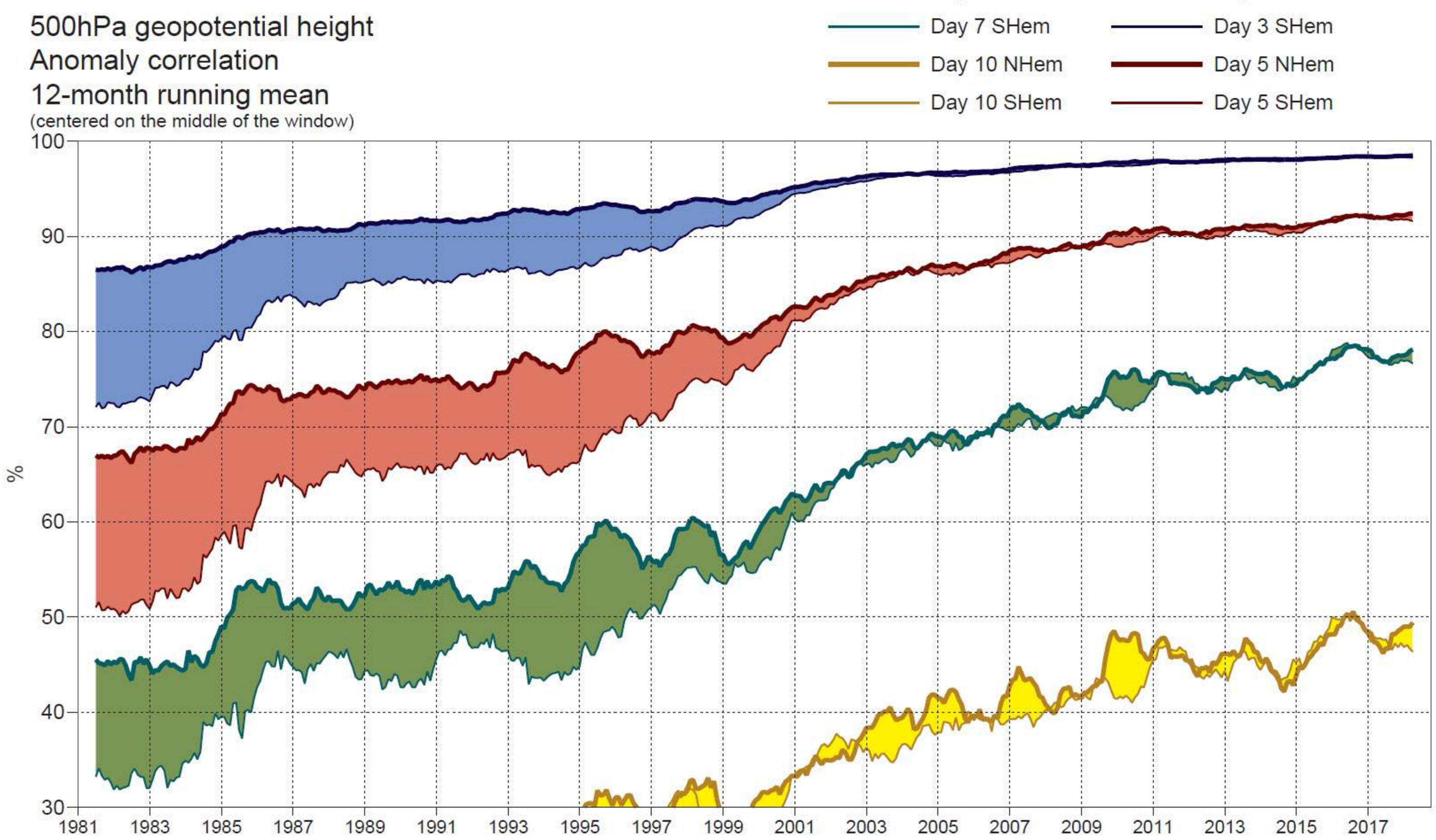
Miguel Miranda
ECMWF Council
(2016-2020)

Emanuel Dutra
ECMWF
(2011-2017)

Rui Salgado
ECMWF
(2011)

…and Several others…

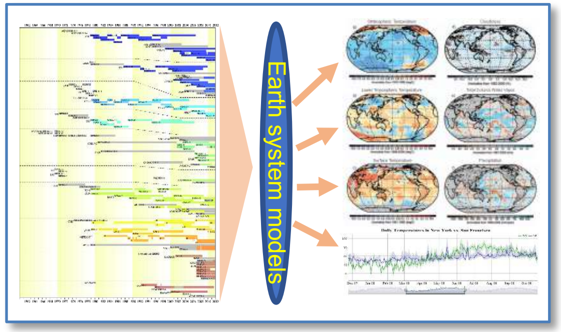
Supporting global NWP Integrated Forecasting System progress



ECMWF

Bauer et al 2015 https://www.nature.com/articles/nature14956

Supporting the quality of new reanalysis and seasonal forecasting

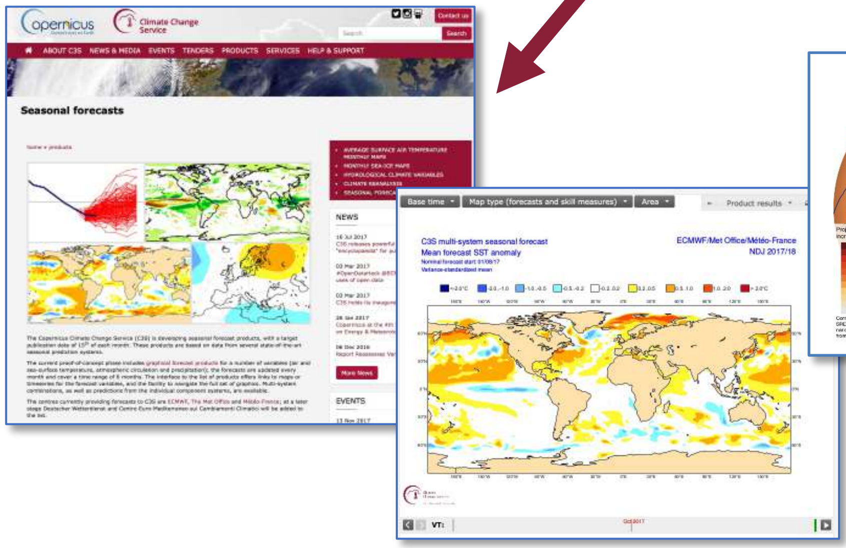


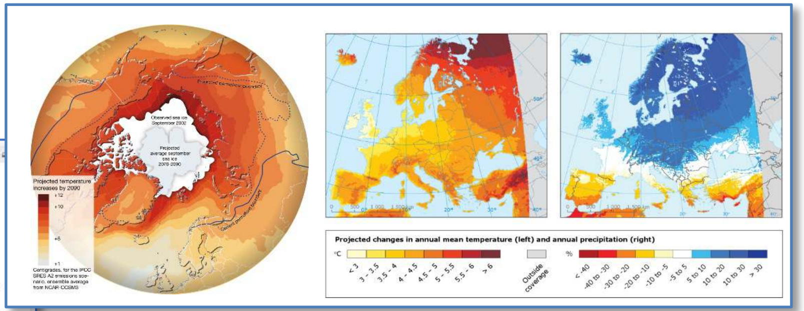
Observations and climate reanalyses

Seasonal forecast data and products

Climate model simulations

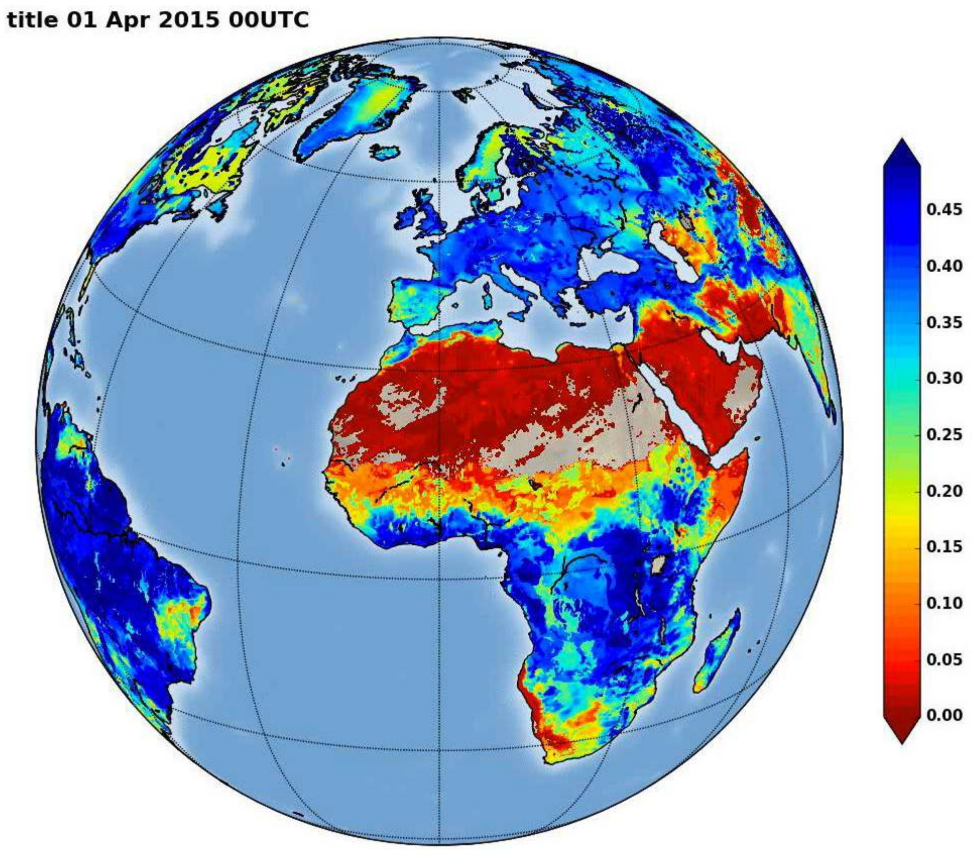
Sectoral climate impact indicators





http://climate.copernicus.eu

ERA5 and ERA5-Land operational reanalyses have replaced ERA-Interim



	ERA-Int	Era-Int/Land	ERA5	ERA5-Land
Period covered	Jan 1979 – NRT(*)	Jan 1979 – Dec 2010	Jan 1979 - NRT	Jan 1979 - NRT
Spatial resolution	~79km / 60 levels	79 km	~32 km / 137 levels	~9 km
Model version	IFS (+TESSEL)	HTESSEL cy36r4	IFS (+HTESSEL)	HTESSEL cy43r1
LDAS	cy31r1	NO	cy41r2	NO
Uncertainty estimate	-	-	Based on a 10-member 4D-Var ensemble at 62 km	Based a 10-member atmospheric forcing at 31 km
Output frequency	6-hourly Analysis fields	6-hourly Analysis fields	Hourly (three-hourly for the ensemble)	Hourly (three-hourly for the ensemble)

Copernicus Europe's eyes on Earth — European Commission

Thanks to Hans Hersbach, Joaquin Munoz-Sabater, ERA Team

ERA reanalyses support climate change studies with focus on land surface

SPECIAL SMAP COLLECTION

Skill and Global Trend Analysis of Soil Moisture from Reanalyses and Microwave Remote Sensing

C. ALBERGEL,* W. DORIGO,+ R. H. REICHLE,# G. BALSAMO,* P. DE ROSNAY,* J. MUÑOZ-SABATER,* L. ISAKSEN,* R. DE JEU,@ AND W. WAGNER+

* European Centre for Medium-Range Weather Forecasts, Reading, United Kingdom
+ Department of Geodesy and Geo-Information, Vienna University of Technology, Vienna, Austria
# Global Modeling and Assimilation Office, NASA Goddard Space Flight Centre, Greenbelt, Maryland
@ Department of Earth Sciences, Faculty of Earth and Life Sciences, VU University Amsterdam, Amsterdam, Netherlands

(Manuscript received 6 November 2012, in final form 31 January 2013)

ABSTRACT

In situ soil moisture measurements from 2007 to 2010 for 196 stations from five networks across the world (United States, France, Spain, China, and Australia) are used to determine the reliability of three soil moisture products: (i) a revised version of the ECMWF Interim Re-Analysis (ERA-Interim; ERA-Land); (ii) a revised version of the Modern-Era Retrospective Analysis for Research and Applications (MERRA) reanalysis from NASA (MERRA-Land); and (iii) a new, microwave-based multisatellite surface soil moisture

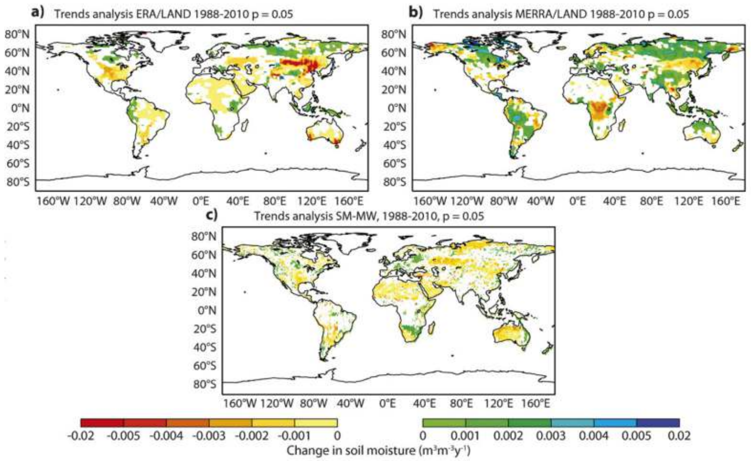


FIG. 6. The 1988–2010 trends in monthly surface soil moisture ($m^3\,m^{-3}\,yr^{-1}$) for (a) ERA-Land, (b) MERRA-Land, and (c) SM-MW (adapted from Dorigo et al. 2012). Only significant trends ($p = 0.05$) based on the Mann–Kendall test are shown.

nature geoscience ARTICLES
https://doi.org/10.1038/s41561-021-00833-x

Check for updates

Attribution of global lake systems change to anthropogenic forcing

Luke Grant[1]✉, Inne Vanderkelen[1], Lukas Gudmundsson[2], Zeli Tan[3], Marjorie Perroud[4], Victor M. Stepanenko[5,6], Andrey V. Debolskiy[5,6,7], Bram Droppers[8], Annette B. G. Janssen[8], R. Iestyn Woolway[9], Margarita Choulga[10], Gianpaolo Balsamo[10], Georgiy Kirillin[11], Jacob Schewe[12], Fang Zhao[12], Iliusi Vega del Valle[12], Malgorzata Golub[13], Don Pierson[13], Rafael Marcé[14,15], Sonia I. Seneviratne[2] and Wim Thiery[1,2]

Lake ecosystems are jeopardized by the impacts of climate change on ice seasonality and water temperatures. Yet historical simulations have not been used to formally attribute changes in lake ice and temperature to anthropogenic drivers. In addition, future projections of these properties are limited to individual lakes or global simulations from single lake models. Here we uncover the human imprint on lakes worldwide using hindcasts and projections from five lake models. Reanalysed trends in lake temperature and ice cover in recent decades are extremely unlikely to be explained by pre-industrial climate variability alone. Ice-cover trends in reanalysis are consistent with lake model simulations under historical conditions, providing attribution of lake changes to anthropogenic climate change. Moreover, lake temperature, ice thickness and duration scale robustly with global mean air temperature across future climate scenarios (+0.9 °C °C$_{air}^{-1}$, −0.033 m °C$_{air}^{-1}$ and −9.7 d °C$_{air}^{-1}$, respectively). These impacts would profoundly alter the functioning of lake ecosystems and the services they provide.

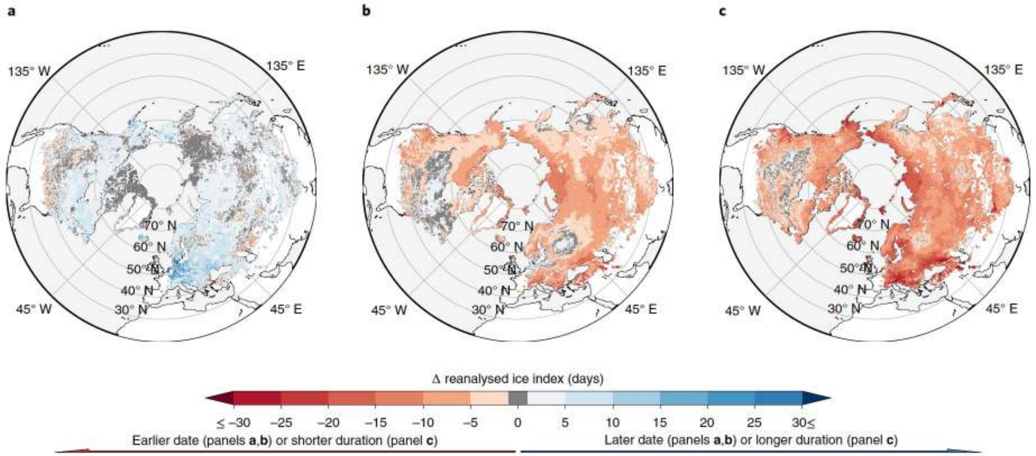
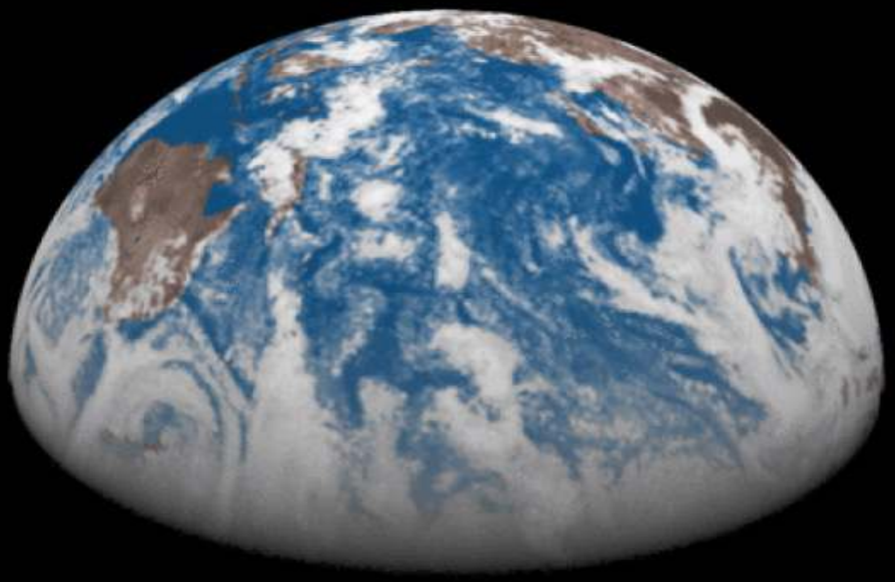


Fig. 1 | Reanalysed historical lake ice changes. a–c, Changes (Δ) in ice onset (**a**), ice break-up (**b**) and ice duration (**c**) in 40 years across baseline (1981–1990) and recent (2010–2019) periods as obtained from ERA5-Land.

Reconstructing the past & Getting inspired for the future



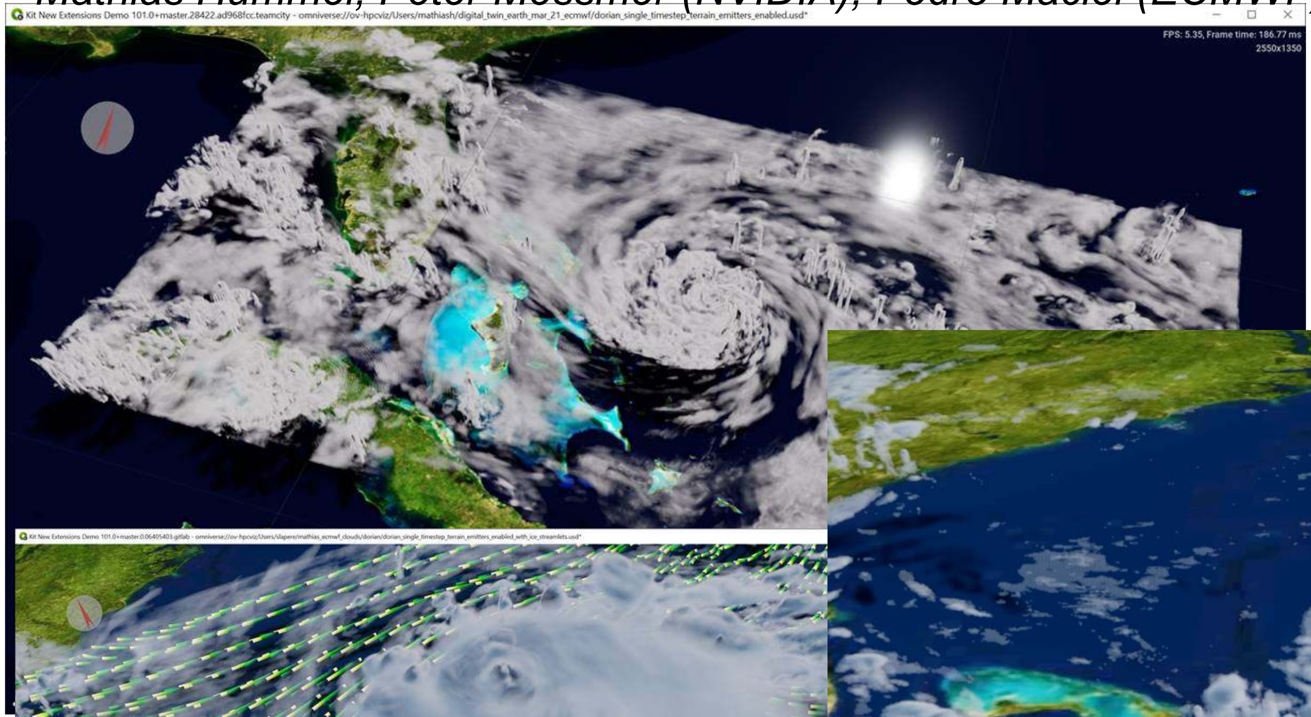
"Earth rise" photo take 20th July 1969 and its Digital Twin from ECMWF - Philippe Lopez et al. (2020, BAMS). Digital Twins will be developed within DestinE Programme.

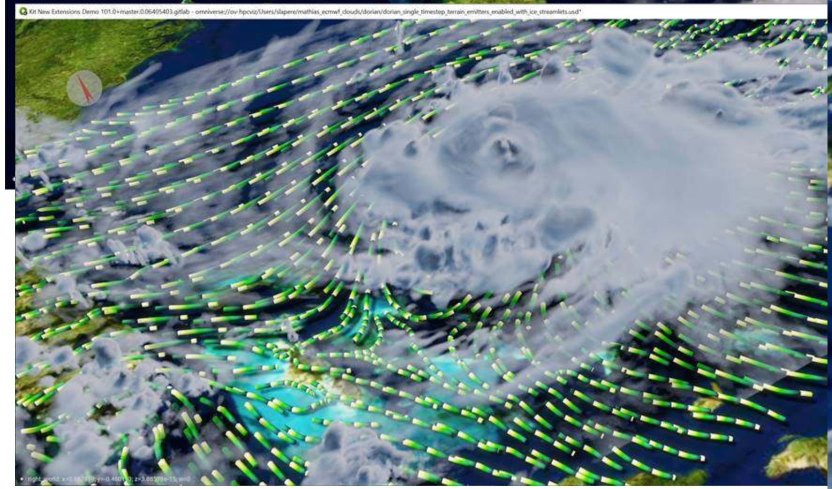
European Centre for Medium-range Weather Forecast, Reading UK (HQ), Bologna IT (BOND), Bonn DE (BRIDGE)

https://www.ecmwf.int/en/about/media-centre/news/2021/ecmwf-becomes-multi-site-organisation

Supporting global km scale modelling for Destination Earth Programme

Mathias Hummel, Peter Messmer (NVIDIA); Pedro Maciel (ECMWF)





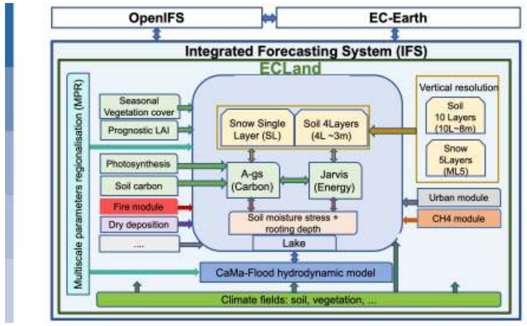
Hurricane Dorian August 2019 –
1km forecast run on Summit HPC

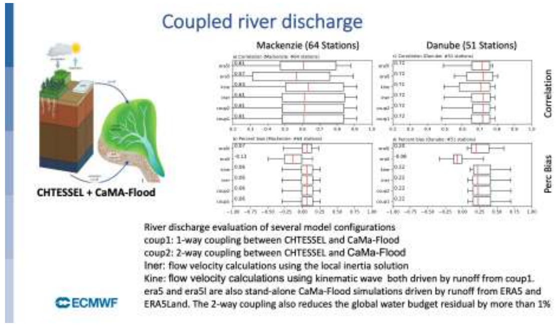
ECMWF

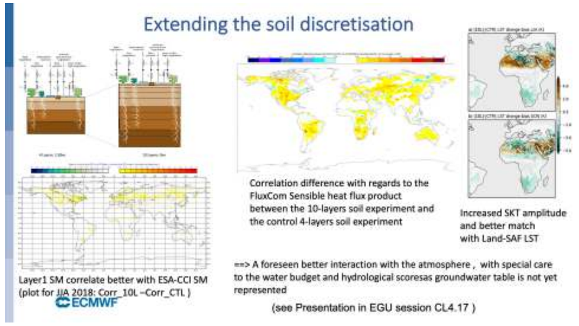
A number of new developments prepare for future ECMWF activities

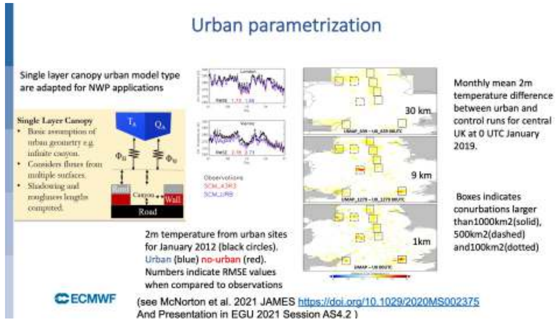
ECLand: ECMWF land surface modelling system

Souhail Boussetta, Gianpaolo Balsamo, Gabriele Arduini, Emanuel Dutra, Joe McNorton, Margarita Choulga, Anna Agusti-Panareda, Anton Beljaars, Nils Wedi, Joaquìn Munõz-Sabater, Patricia De Rosnay, Irina Sandu, Ioan Hadade, Glenn Carver, Cinzia Mazzetti, Christel Prudhomme, Dai Yamazaki, Ervin Zsoter, 2021: ECLand: an ECMWF land surface modelling system, *MDPI Atmosphere, Special Issue "Representation of Land Surface Processes in Weather and Climate Models"* https://www.mdpi.com/2073-4433/12/6/723



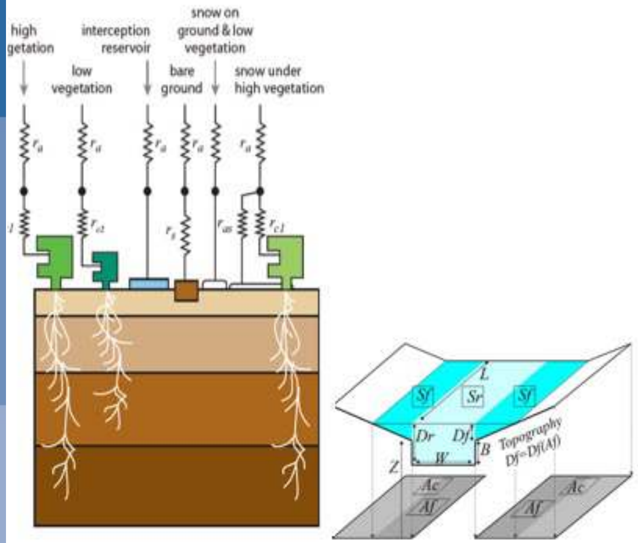


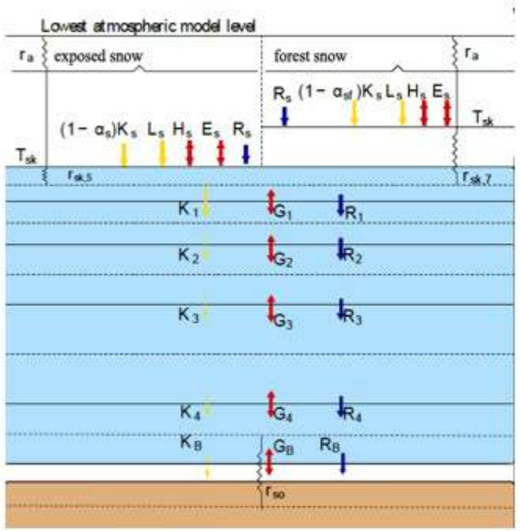


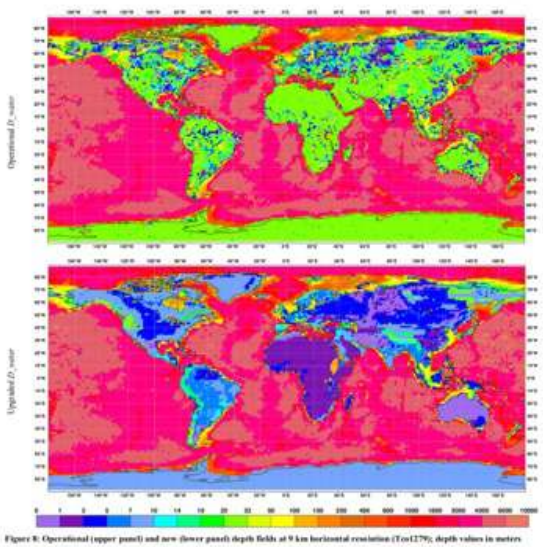


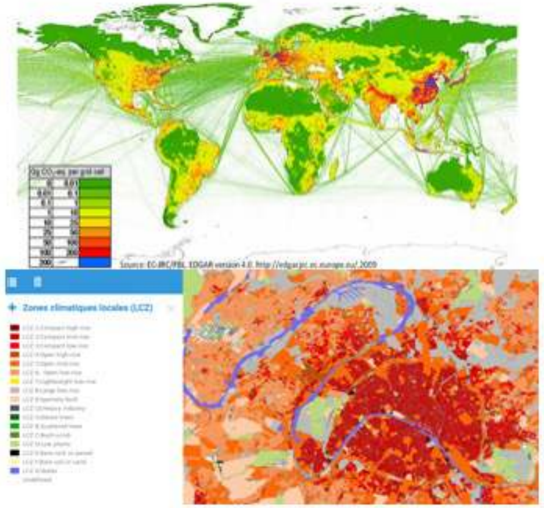
ECMWF

Land hydrology, biosphere and anthropogenic surface modelling









•HTESSEL-CAMA-Flood

- •Improvements
  - •River discharge coupled to runoff passive in 2019
  - •Post-processing of tiles diagnostics in 2020
- Collaborations
  - CMEMS
  - CONTROL
  - Global Routing
  - HTESSEL-Calibration
- Offline/Coupling test
  - Ongoing offline testing

•SNOW ML5

- •Improvements
  - •ML5 Snow physics passive in 2019
- Ongoing/Planned
  - ML GRIB input/output (collaboration with FD/IFS)
  - ML coupled to ice (APPLICATE)
  - Snow Albedo revision (SnowAPP/APPLICATE-2)
  - Blowing snow (ISSI-BJ-HTP)

Orsolini et al. (2019)
Arduini et al. (2019)

•WATER Tile Mapping

- •Improvements
  - •GLDBv3 + new LSM/CL ready in 2020
- Ongoing/Planned
  - Extend to other physiography fields
  - Focus ESA-CCI Maps
  - Orography and Bathymetry at native 1km
  - Choulga et al. (2019) on Water Mapping

URBAN Tile+CO2 Mapping

- •Improvements
  - City mapping (C3S ITT)
  - Multi-cities OSM
  - CO2 mapping
  - CO2 uncertainties
  - CO2 ensemble
- Offline/Coupling test
  - Ongoing CHE Tier-2 runs

McNorton et al. (2019) on CO2 model error specification

Choulga et al (2020) on CO2 emissions & uncertainties

Improved efficiency

- ECLand inherits the same "array-blocks" data structures as all other IFS components
- Capable of extracting good performance out of modern processors.
- Can work independently on distinct array-blocks => a reduction in memory consumption + improved load balancing.
- MPI implementation also in the offline => enables efficient simulation at very high resolutions

		(Forecast days/day)	
Resolution	I/O	Control	Parallel
9km (HRES and ERA5Land)	hourly	102	2875
1km (VHRES)	daily	N/A	300

Increased realism in water cycle reservoirs representation at 1km (snow case)

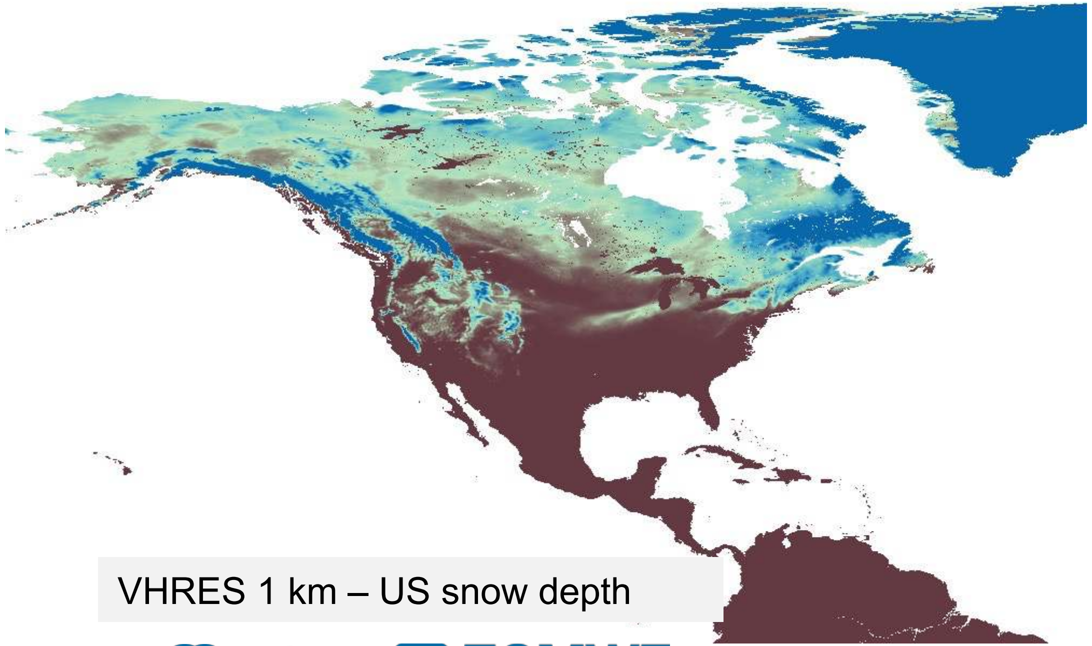
Ioan Hadade, Gabriele Arduini, Souhail Boussetta, Margarita Choulga et al.

The Offline Surface Modelling (OSM) **increased performance** allows to run the surface at **1km at ECMWF**

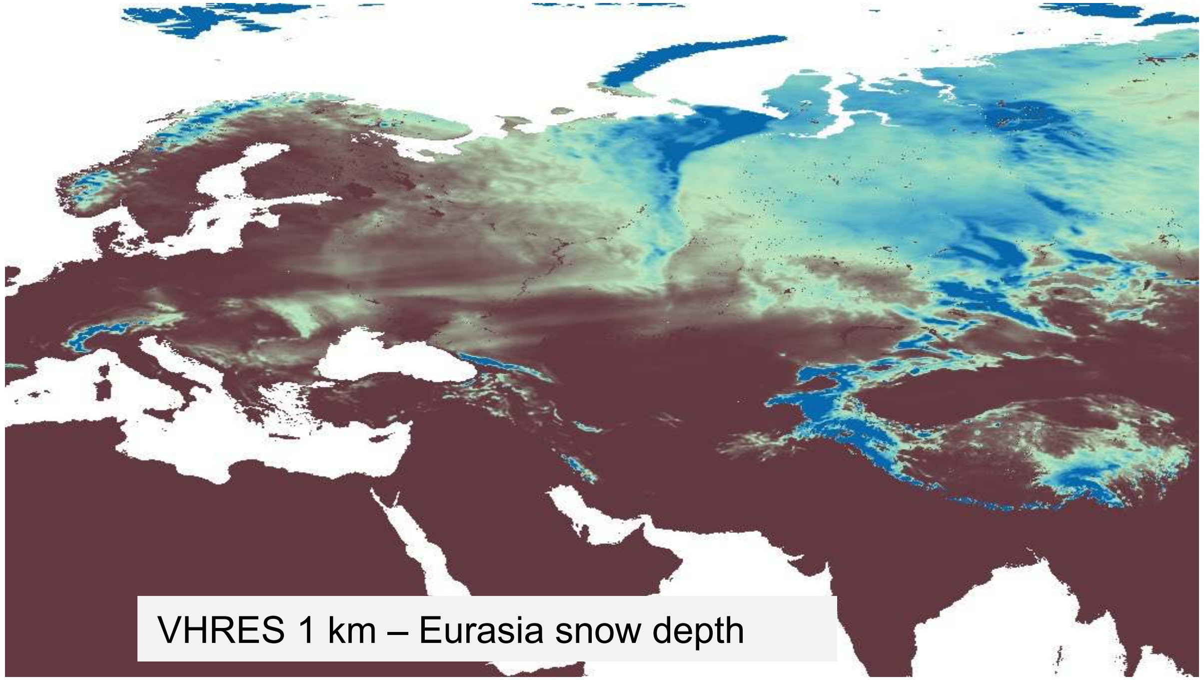
Towards 1km increase realism will bring benefits

- Land use and land cover (use of ESA-CCI)
- Coastal areas and lakes (use of GSWE)
- Snow over orography & catchment hydrology
- Improved skin temperature for data assimilatior

Resolution	Configurati on	Performance (simulated years per day)
9km (**HRES** & ERA5Land)	TCo1279	with MPI (**8 year/day**)
1km (VHRES) & prepare ERA 1k	TCo7999	with MPI (**0.8 year/day**)



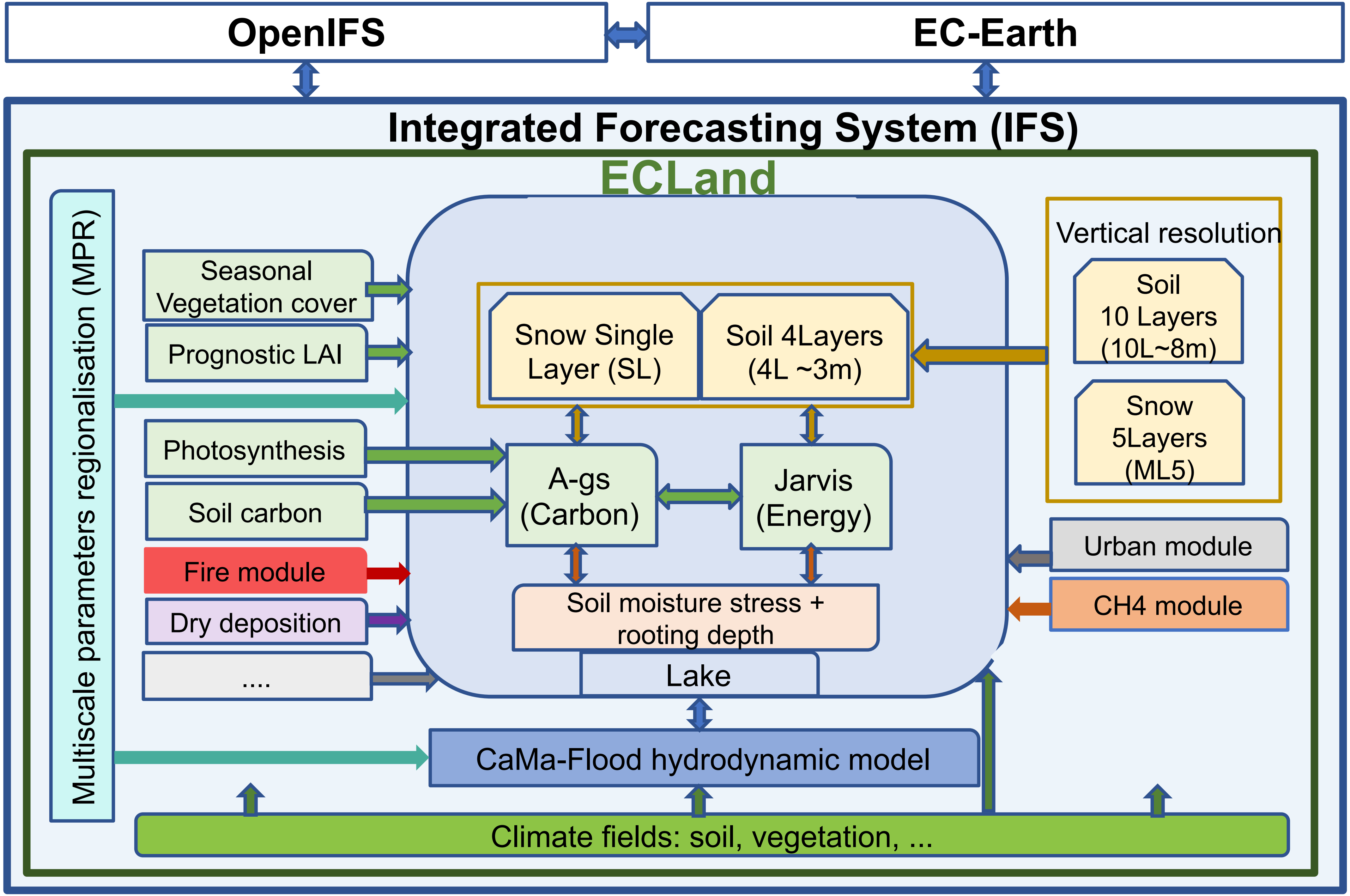
VHRES 1 km – US snow depth



VHRES 1 km – Eurasia snow depth

ECMWF

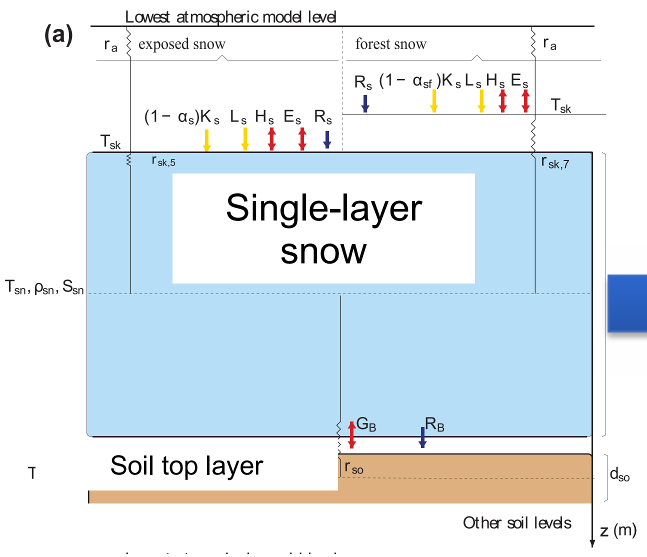
ECMWF

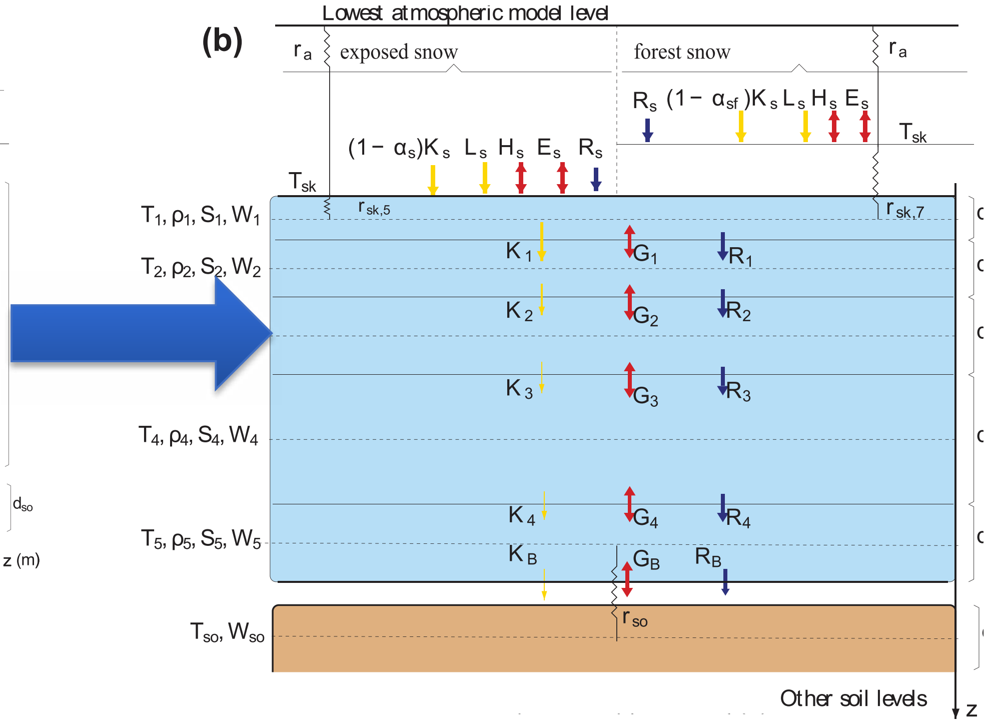


OpenIFS
EC-Earth
Integrated Forecasting System (IFS)
ECLand
Multiscale parameters regionalisation (MPR)
Seasonal Vegetation cover
Prognostic LAI
Photosynthesis
Soil carbon
Fire module
Dry deposition
....
Snow Single Layer (SL)
Soil 4Layers (4L ~3m)
A-gs (Carbon)
Jarvis (Energy)
Soil moisture stress + rooting depth
Lake
Vertical resolution
Soil 10 Layers (10L~8m)
Snow 5Layers (ML5)
Urban module
CH4 module
CaMa-Flood hydrodynamic model
Climate fields: soil, vegetation, ...

A 5-layer snow model to replace the single-layer representation in cycle 48r1

Gabriele Arduini, Day, et al.



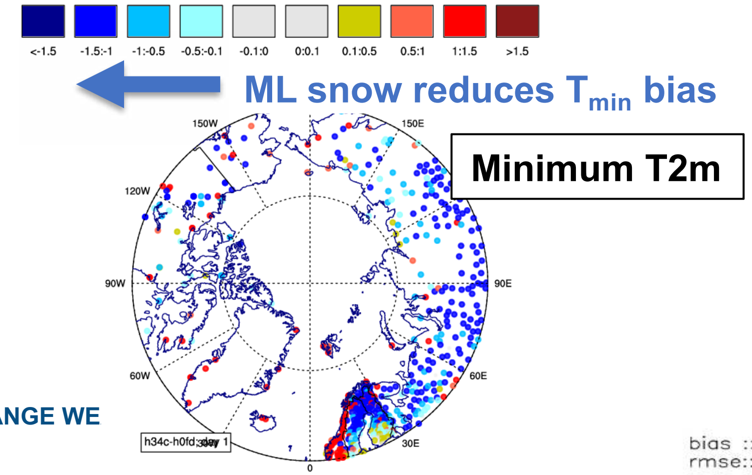


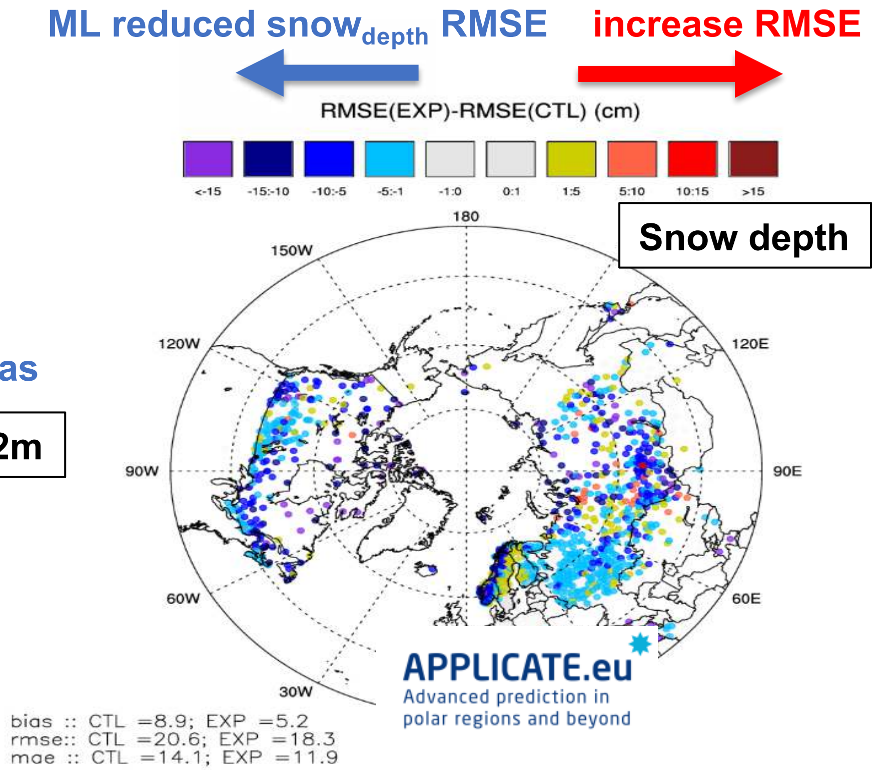
New multi-layer snow scheme:

- Targeted for cycle 48r1 (2022/2023)
- 5-layer snow scheme
- Prognostic liquid water content
- Improved snow physics

Arduini et al., JAMES, 2019;
Day et al., JAMES, 2020,
Boussetta et al., MDPI-Atm., 2021

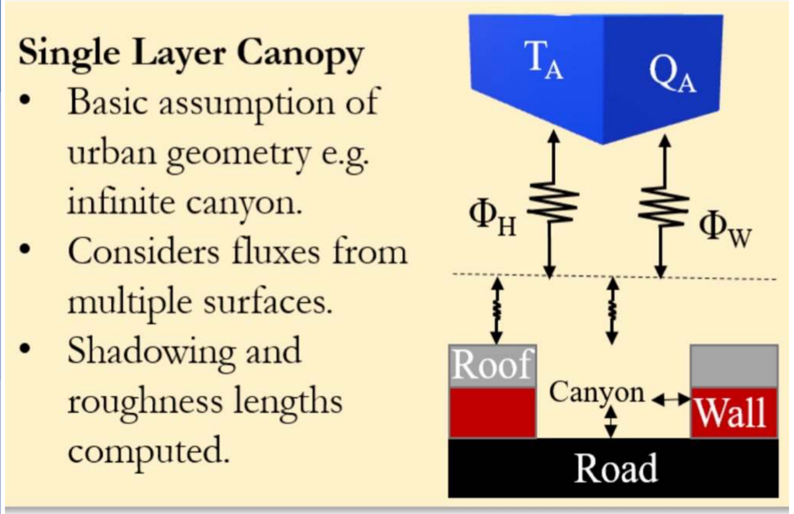
- Substantial improvement in **snow depth**
- Reduced error also in the forecasts of **minimum temperature** (+24h).
- Explorative work for snow on sea-ice.

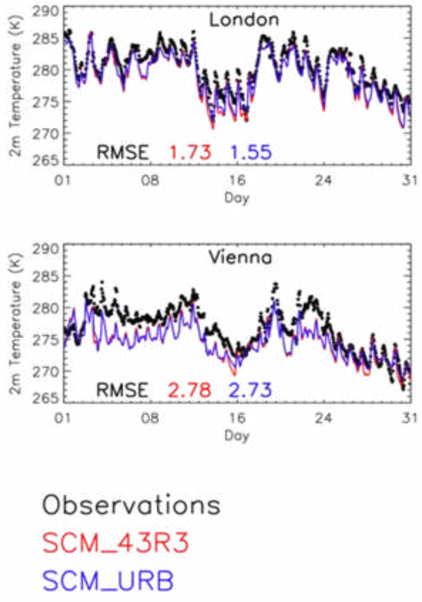




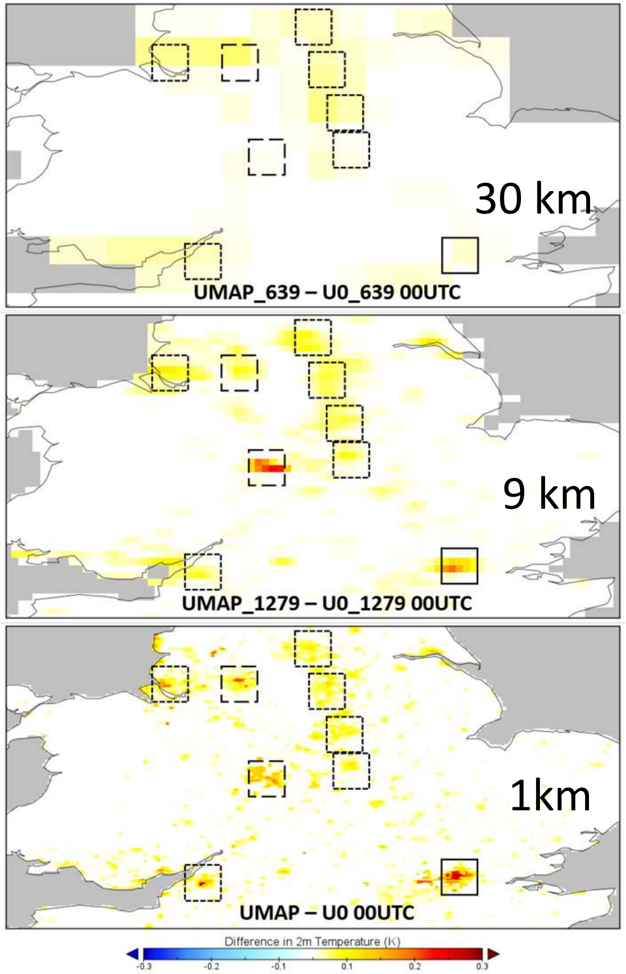
Can we simulate the cities heat-island effect in global NWP?

Single layer canopy urban model type are adapted for NWP applications





2m temperature from urban sites for January 2012 (black circles). Urban (blue) no-urban (red). Numbers indicate RMSE values when compared to observations



Monthly mean 2m temperature difference between urban and control runs for central UK at 0 UTC January 2019.

Boxes indicates conurbations larger than1000km2(solid), 500km2(dashed) and100km2(dotted)

A urban tile holds promise to locally enhance heatwave in cities in cycle 49r1

Joey McNorton, Margarita Choulga, Gabriele Arduini et al.


EL PAÍS NEWS

SUMMER IN SPAIN >

Spain prepares for record-breaking high temperatures as heatwave intensifies

Meteorologists say the thermometer could reach close to 47ºC in the south of Spain, while in Madrid it could exceed 40ºC for three consecutive days

A woman shades herself from the sun in Córdoba in Andalusia. SALAS / EFE

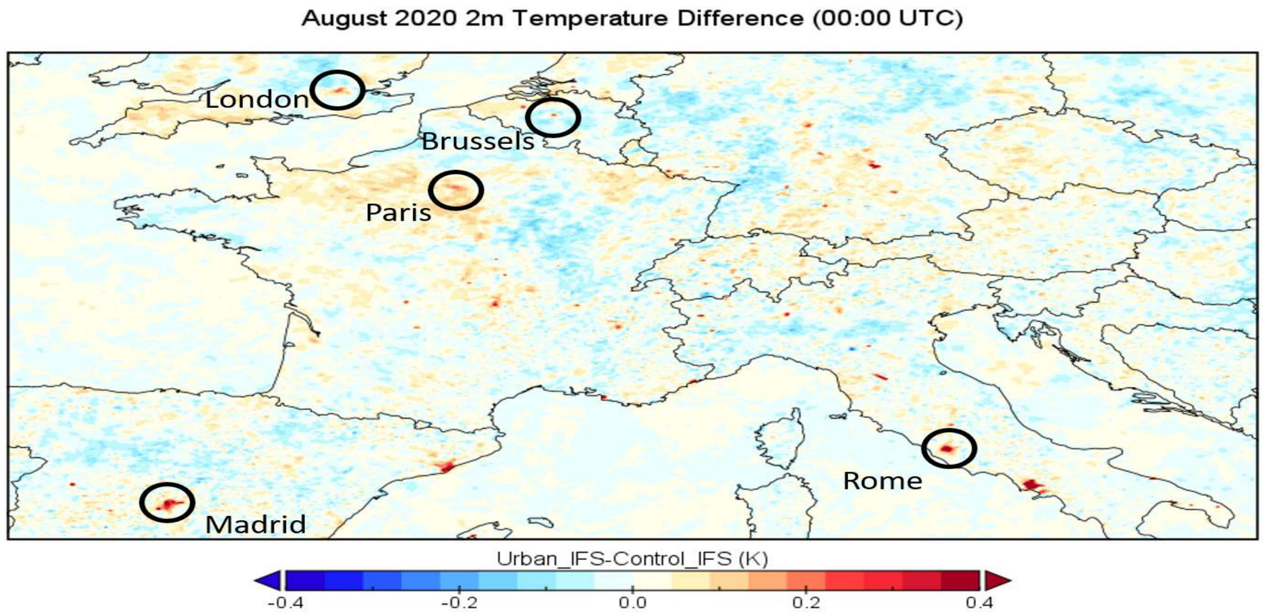
JAMES | Journal of Advances in Modeling Earth Systems®

Research Article | Open Access

An Urban Scheme for the ECMWF Integrated Forecasting System: Single-Column and Global Offline Application

J. R. McNorton, G. Arduini, N. Bousserez, A. Agustí-Panareda, G. Balsamo, S. Boussetta, M. Choulga, I. Hadade, R. J. Hogan

First published: 02 April 2021 | https://doi.org/10.1029/2020MS002375 | Citations: 2



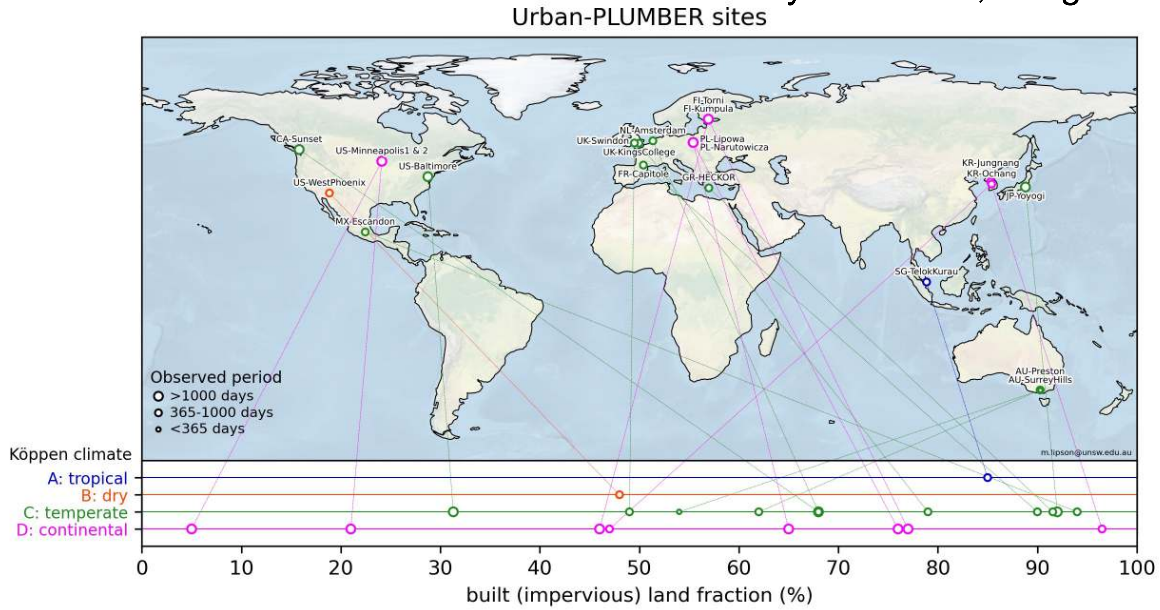
McNorton et al. 2021

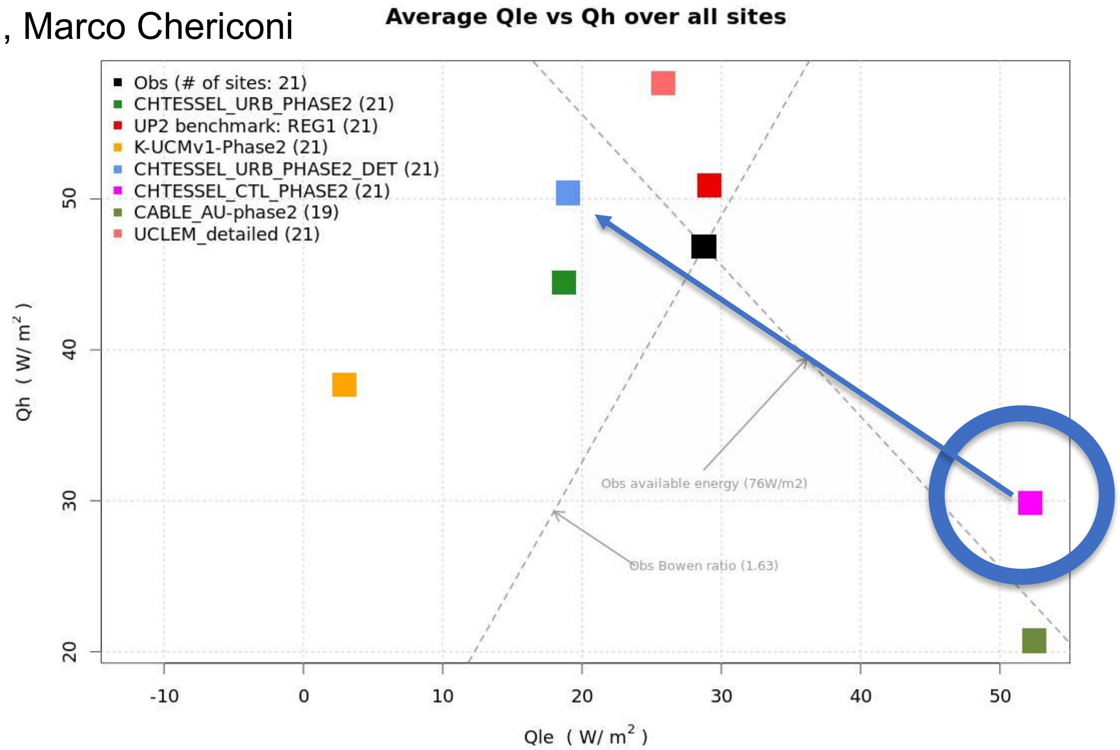
T2m sensitivity to Urban areas. First coupled 4km IFS runs with Urban tile. Average of FC+24 to +120 for the month of August 2020

Urban tile integrated in ECLand, foreseen for activation in cycle 49r1
SLIM project delivered a new Urban mapping software

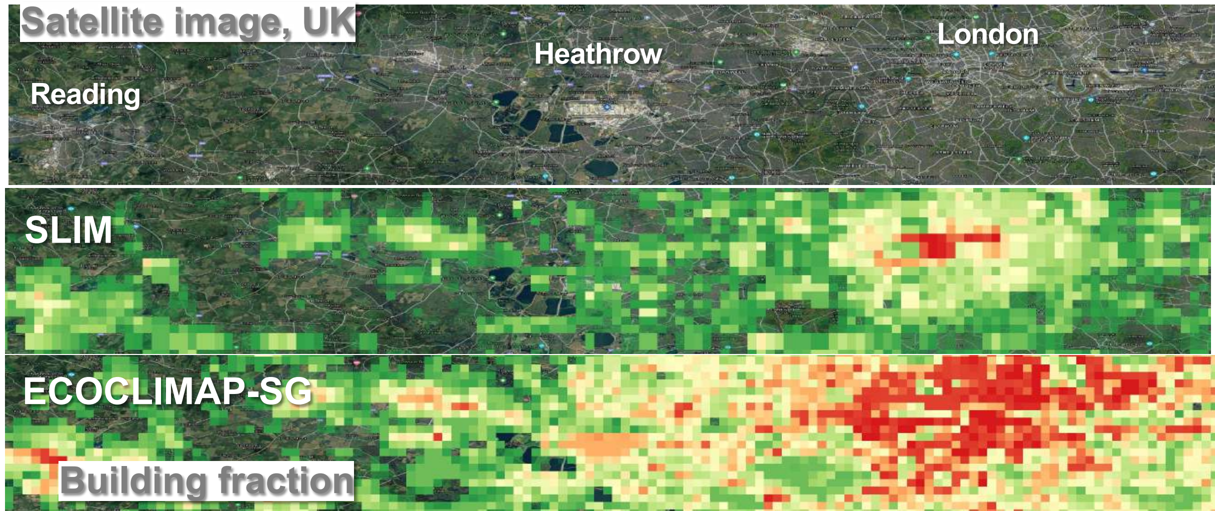
Urban model evaluation ongoing in PLUMBER with observed properties

Joey McNorton, Margarita Choulga, Marco Chericoni





- Urban Plumber evaluates urban models across 21 sites
- Preliminary results show a model improvement in the partitioning of Latent and Sensible heat flux
- Over next 2 years urban scheme will be used to activate online anthropogenic CO2 emissions in CAMS/CoCO2
- A key component to enable to implement the urban scheme will be the quality of urban mapping dataset

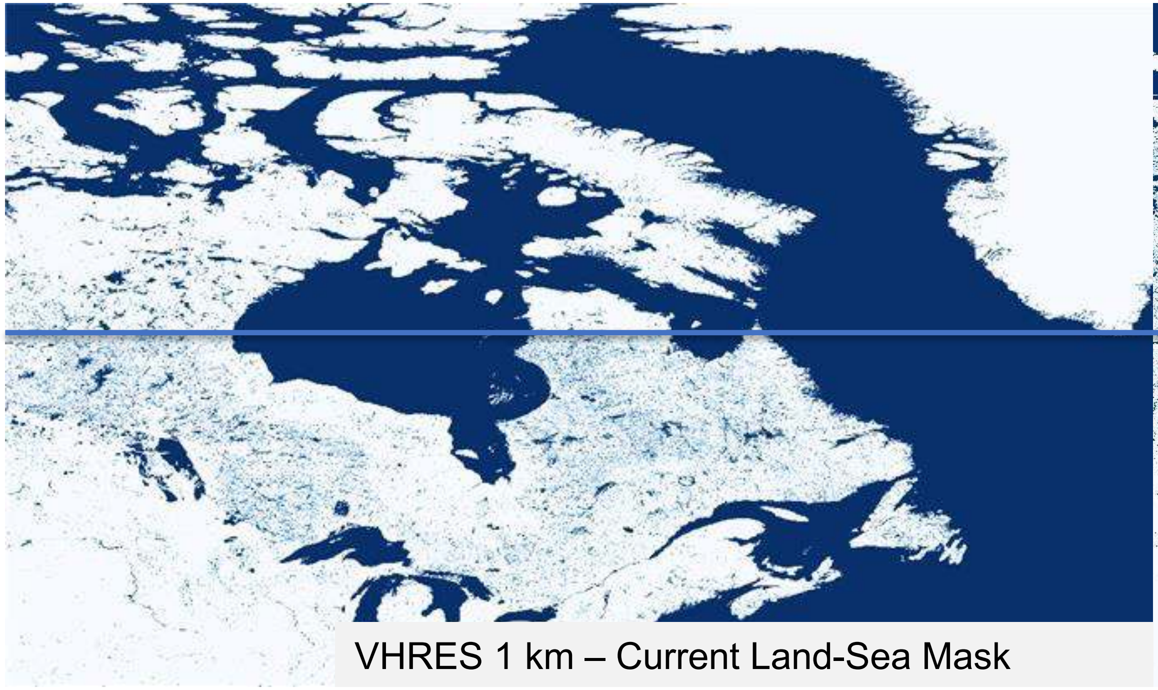


The role of km-scale resolution for inland water surfaces (the lake case)

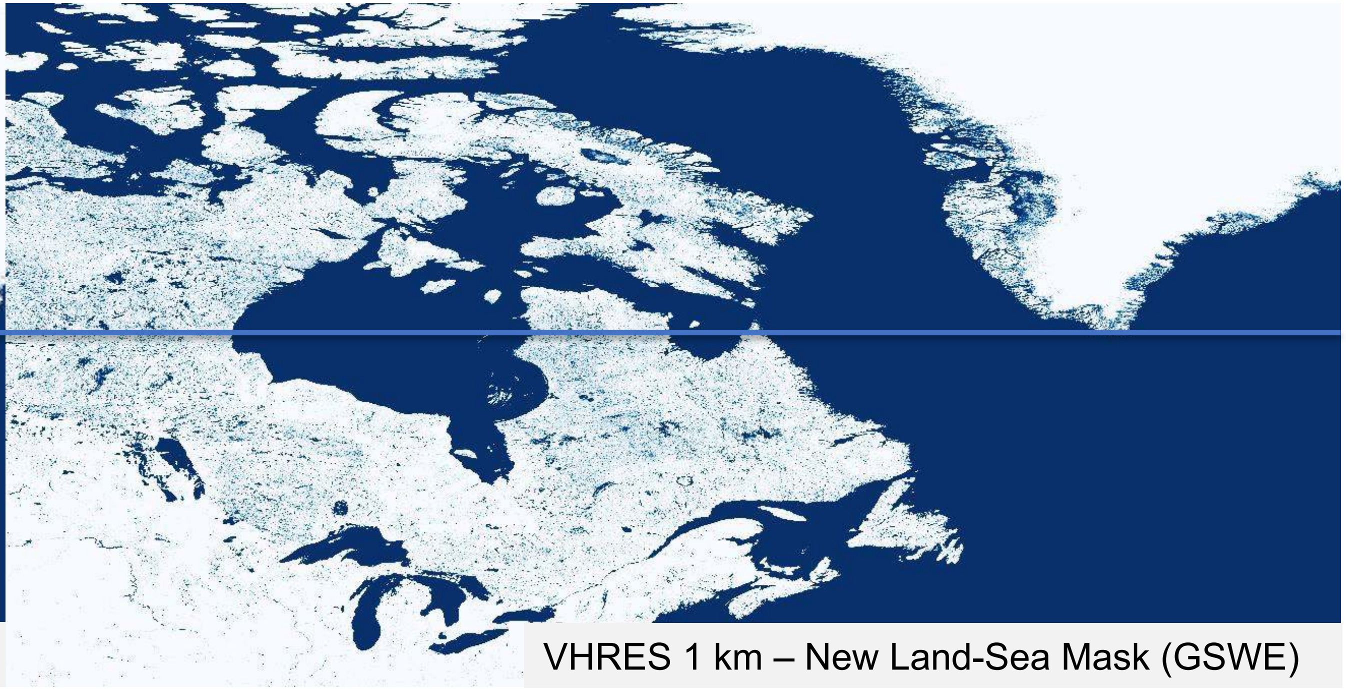
Margarita Choulga, Souhail Boussetta et al.

Moving towards native 1km enable resolving more of the inland water surfaces affecting the surface temperature

Mapping water surfaces correctly is essential to have an inter-consistent treatment of land surface



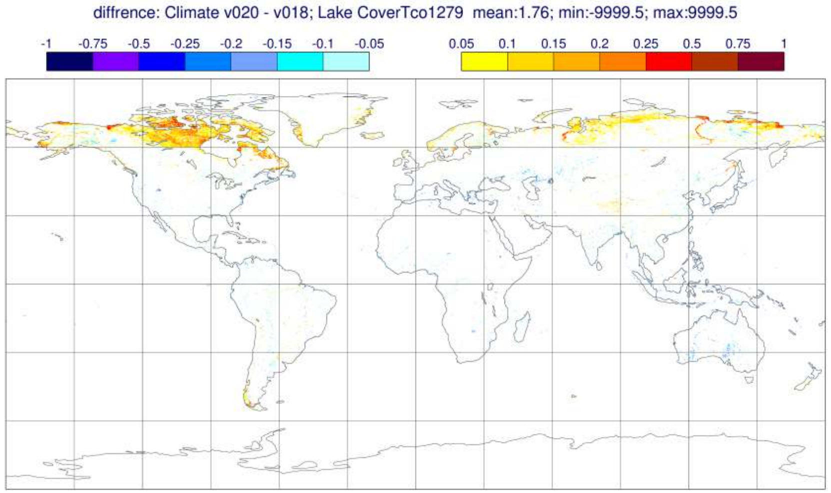
VHRES 1 km – Current Land-Sea Mask



VHRES 1 km – New Land-Sea Mask (GSWE)

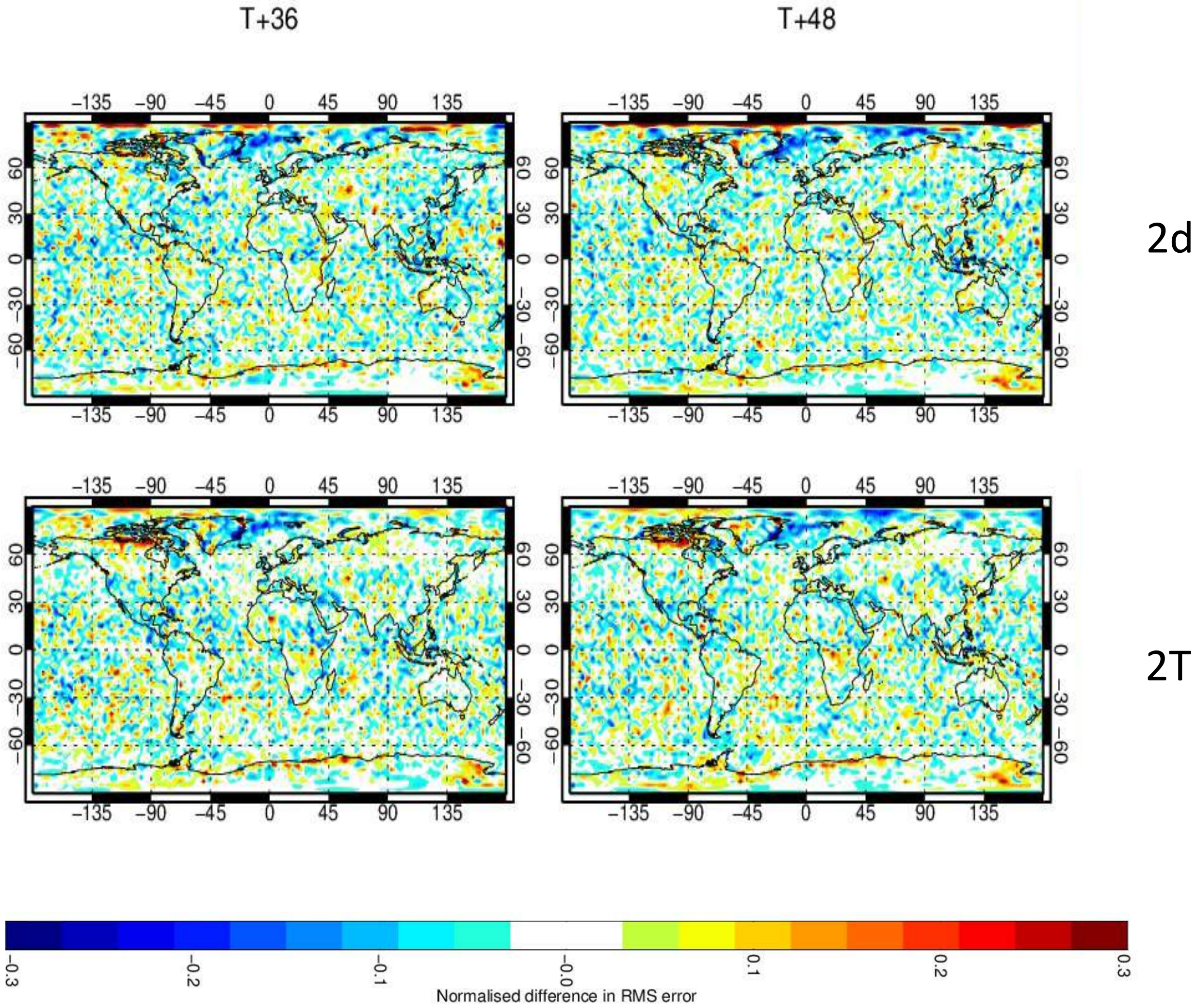
Choulga et al. 2021. Example of land sea mask obtained by the global 30m resolution GSWE aggregated to 1km on Google Earth Engine

Surface water update (climate v.020)

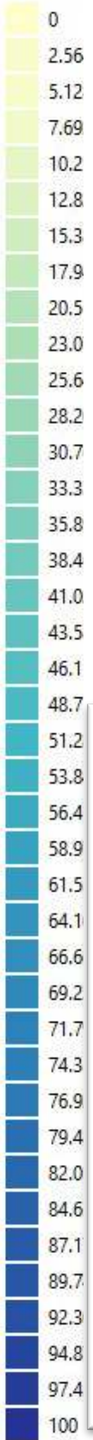


Lake cover difference between the new map based on GSWE and the operational map

RMSE difference (Summer)



Neutral to positive impact for 2T/2d RMSE for the Summer over the areas with differences in the water coverage



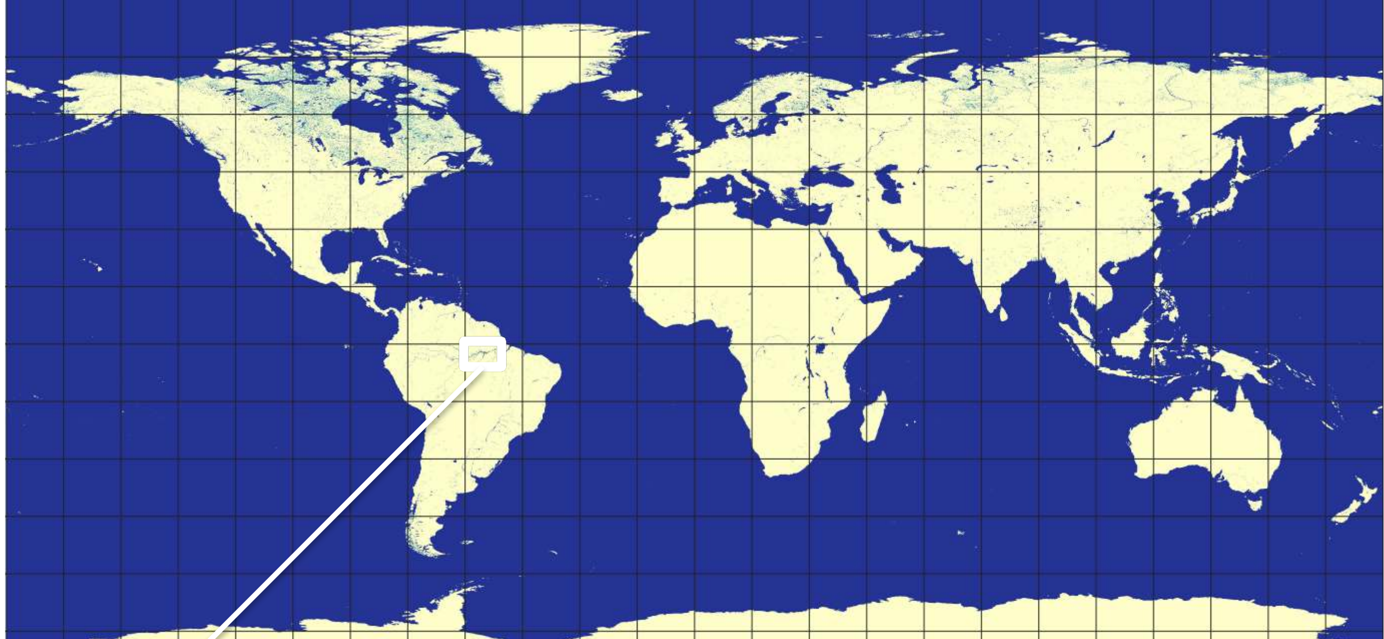
Towards time-varying water cover

Margarita Choulga et al.

New static **land sea mask**, **lake** and **glacier covers** based on permanent water 1984-2018 to be **operational** in cycle **48r1** (climate.v020) in 2022/Q4.

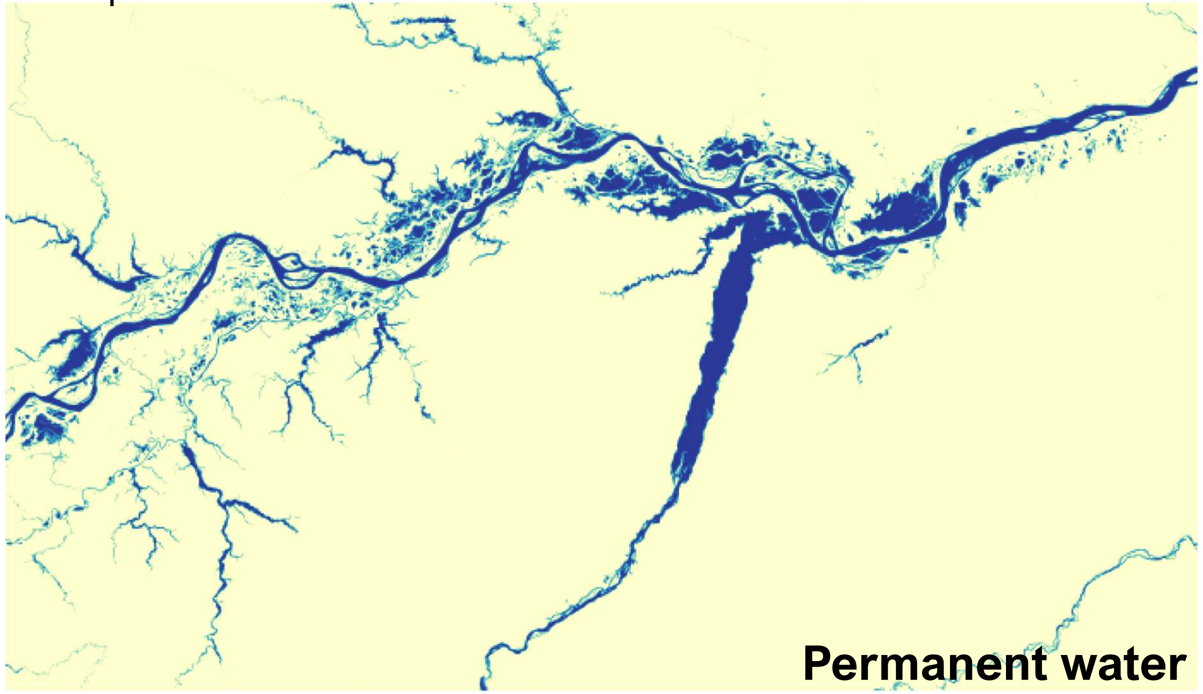
Monthly water distribution based on 2010-2020 monthly **30 m resolution** maps **represent** water year cycle more **realistic** than static yearly map → step **towards dynamic inundation model** (CAMA-Flood).

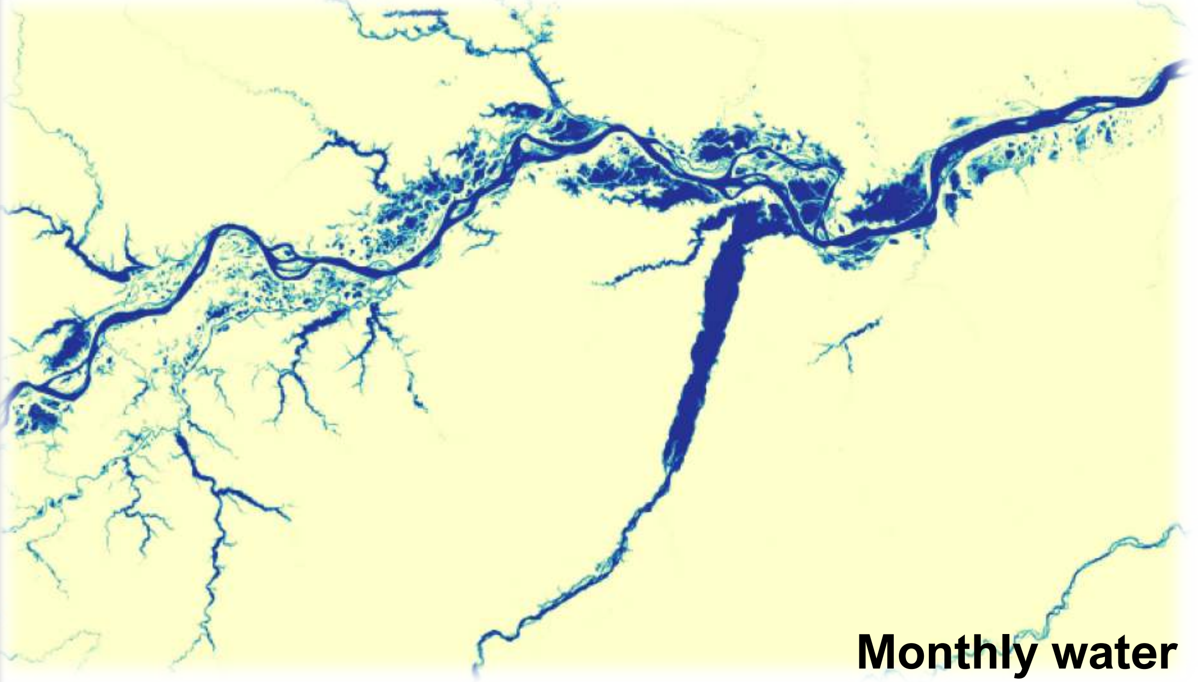
Similar work is ongoing for the Wetland & Rice fractions.

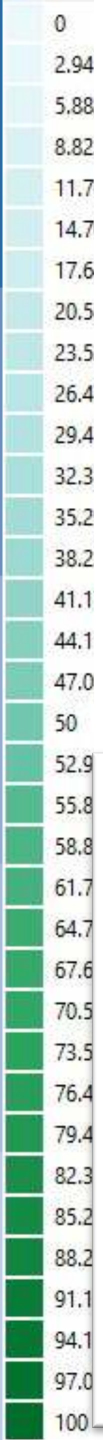


New Permanent water (operational in 48r1)

Example: Water fraction in **Amazon river** at **1 km resolution.**





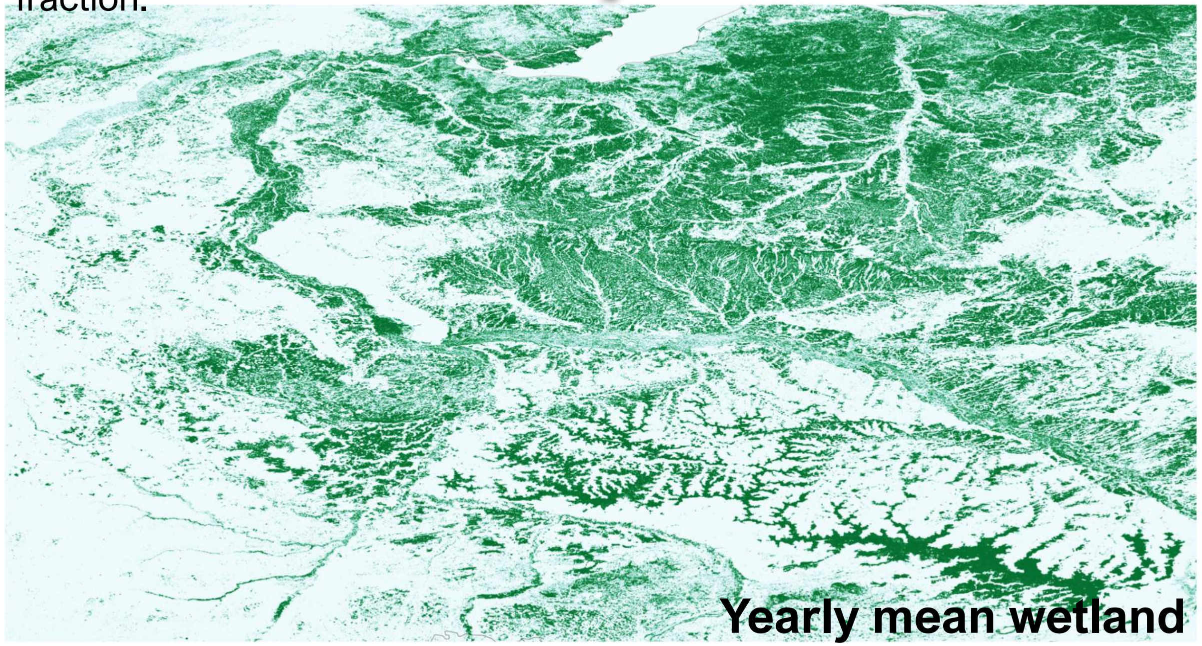


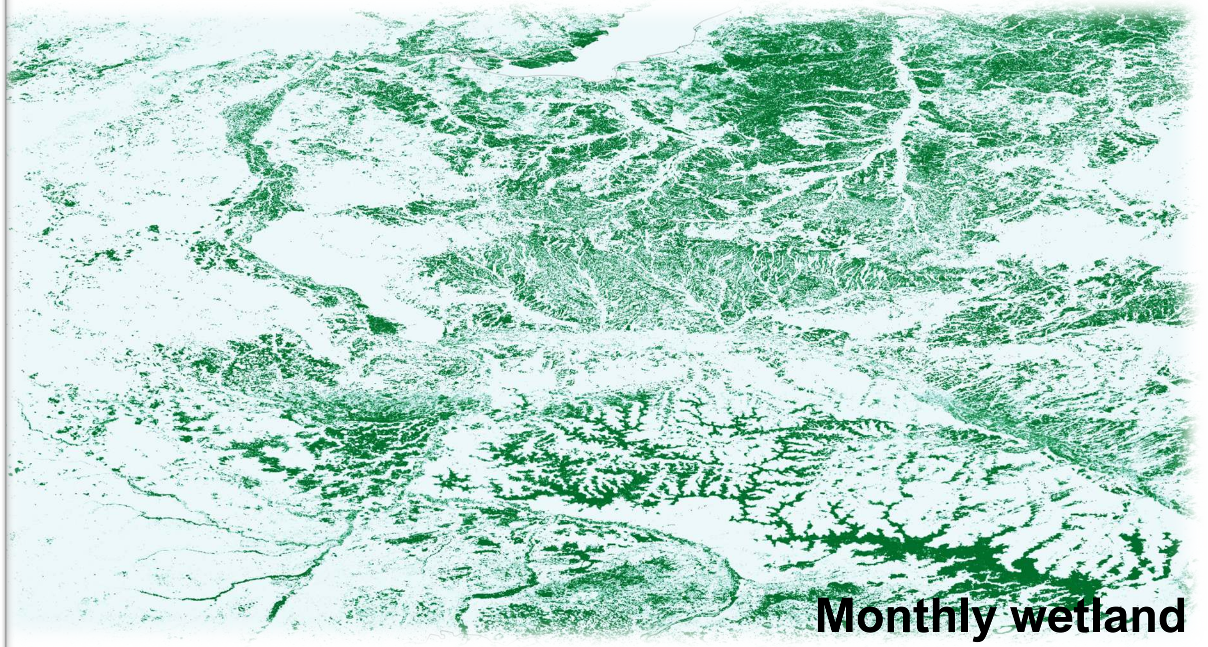
Towards yearly & monthly wetland

Margarita Choulga et al.

Created **monthly wetland** distribution maps: **yearly wetland** distribution based on 2019 Copernicus 100 m resolution map **+ monthly coefficients** based on 2000-2020 SWAMPSv3.2 25 km resolution daily wetland/water microwave data; global continuous **wetland type** and **rice** distribution maps → required **for** the best use of **dynamic inundation model** (CAMA-Flood), and to **correctly represent methane** emissions.

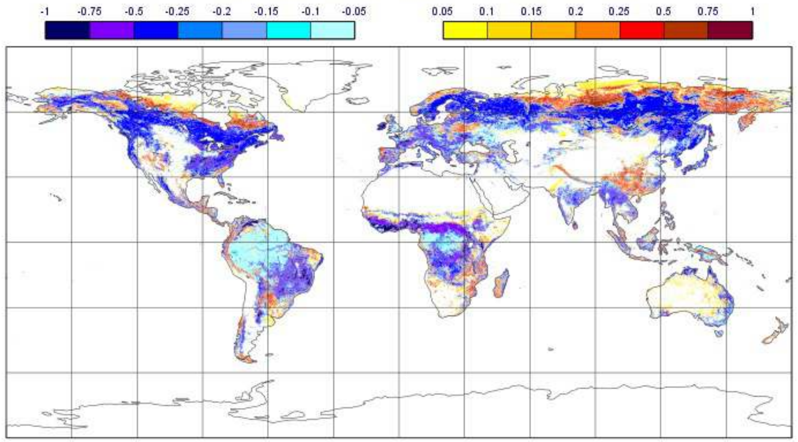
Figures below show **Russian (Yamalo-Nenets)** region (68.0/55.0°N, 60.0/84.0°E) at **1 km resolution** wetland fraction.



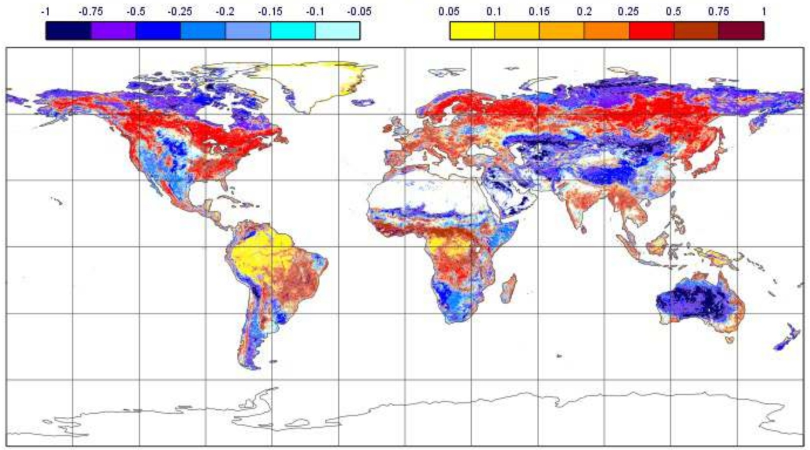


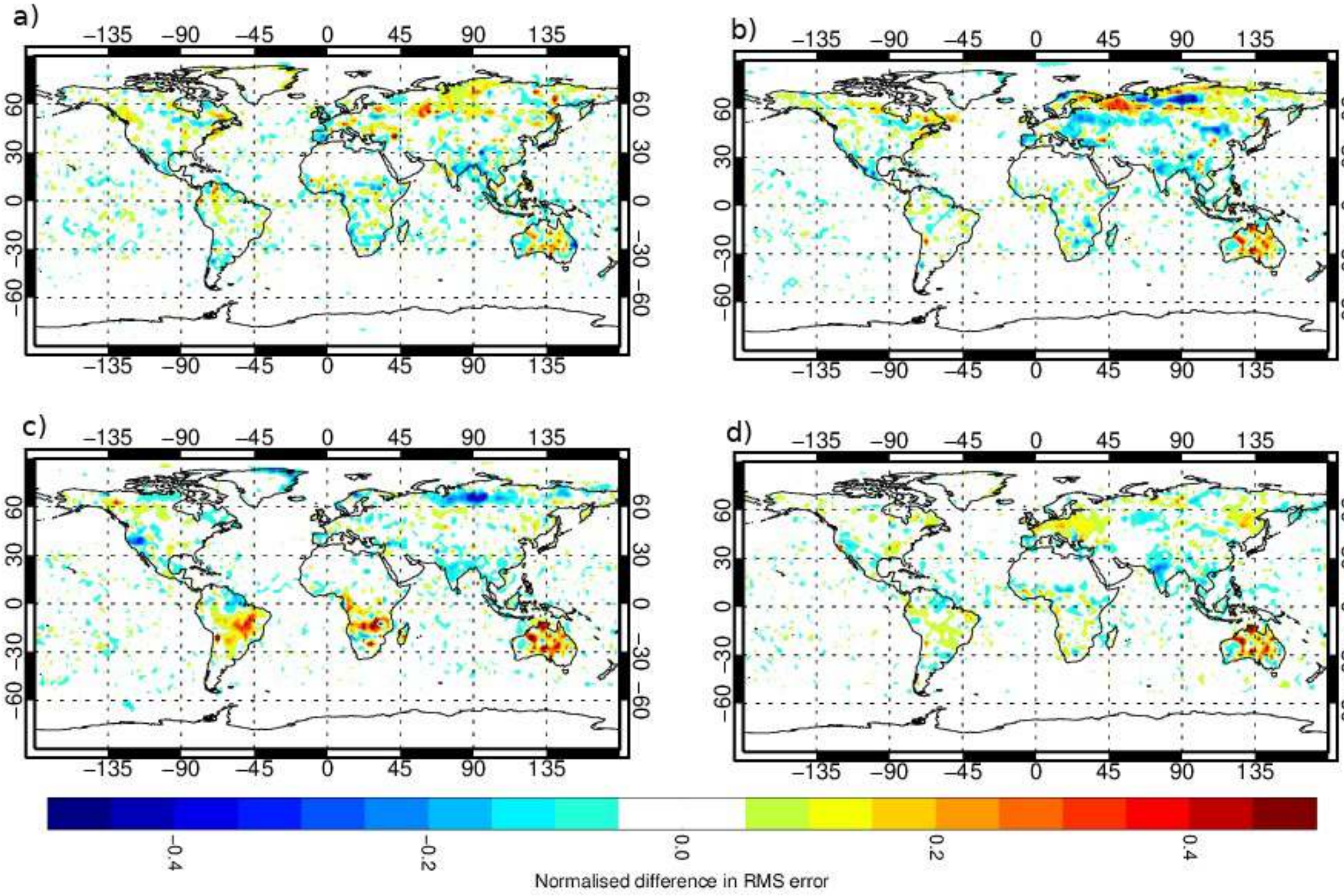
Updating Land Use and Land Cover

High vegetation cover difference ESA-CCI –GLCCv1.2



Low vegetation cover difference ESA-CCI –GLCCv1.2





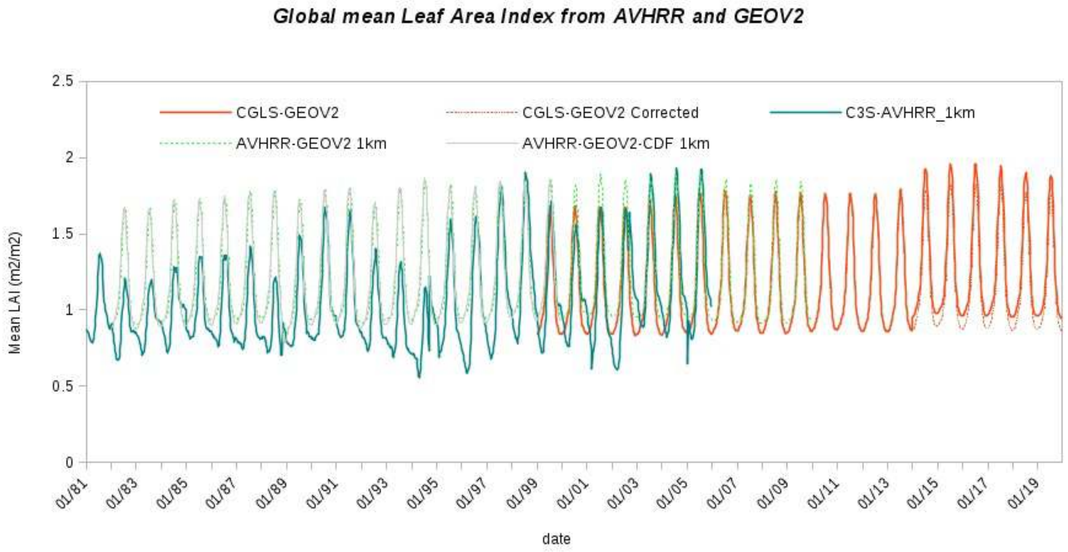
2m temperature normalised rmse difference of forecast simulations for 36h lead time using ESA-CCI LU/LC and new LAI disaggregation operator with a control simulation using the operational configuration for JF (a), MAM (b), JJA (c) and SON (d)

ESA-CCI LU/LC maps + new LAI disaggregation. See results from Emanuel Dutra

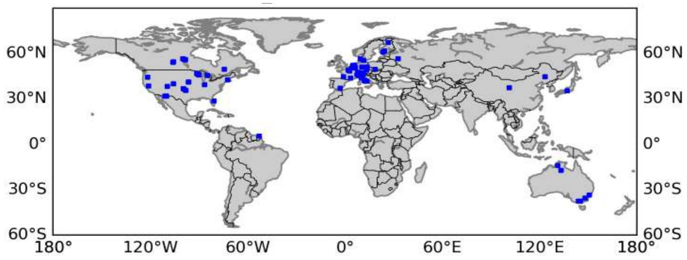
Towards time-varying vegetation & photosynthesis for reanalysis & CO_2

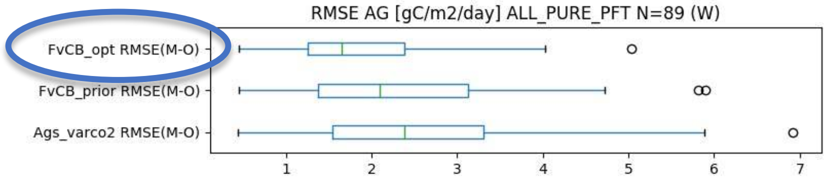
Souhail Boussetta, Anna Agusti-Panareda et al.

Harmonization of multi-source LAI 1993-2019 time series.

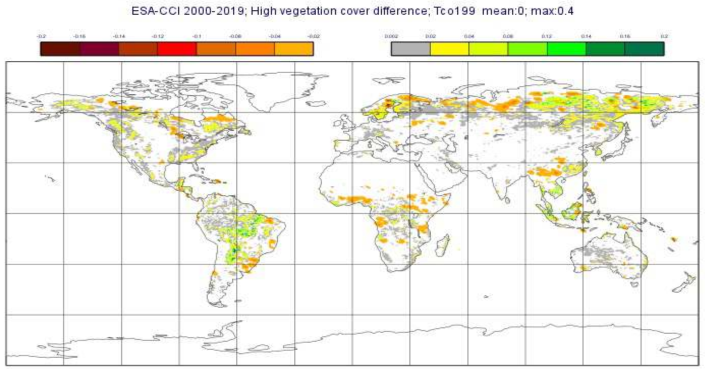


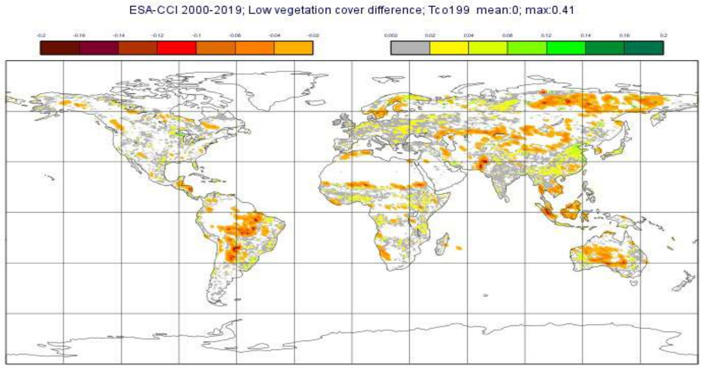
Optimisation for CO_2 (GPP) using FLUXNET (89) sites



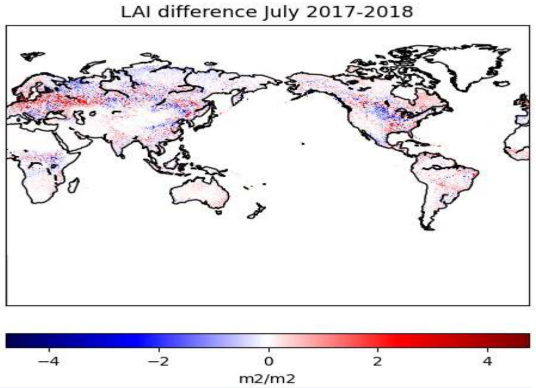


Vegetation cover differences between 2000 -2019 (right) for low & (left) high vegetation:



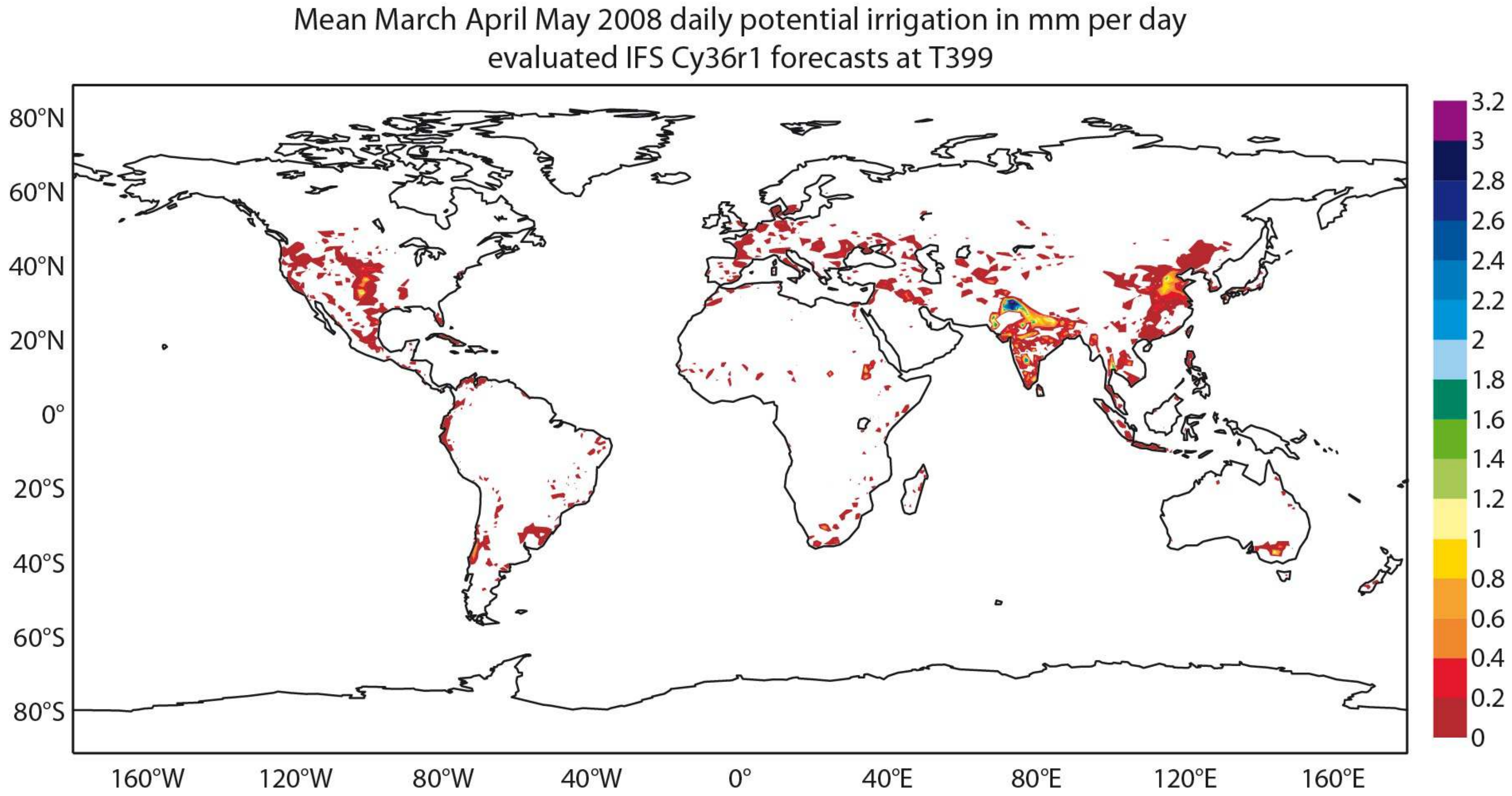


Europe drought can be detected in LAI (2018)



1993-2019 annual LU/LC and monthly LAI maps based on C3S/ESACCI data ==> new homogenised dataset

Towards the representation of irrigation at ECMWF: beyond potential irrigation



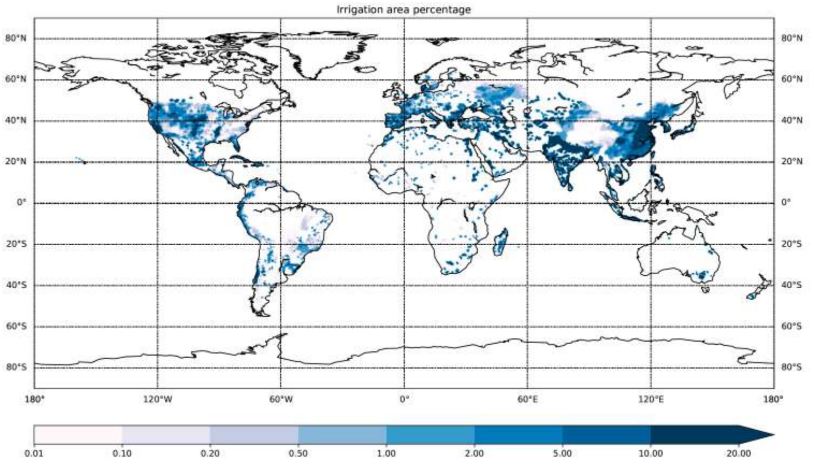
- Surface water balance

$$P - E - R = DW/dt$$

$$P+I - E - R = DW/dt + DA/dt$$

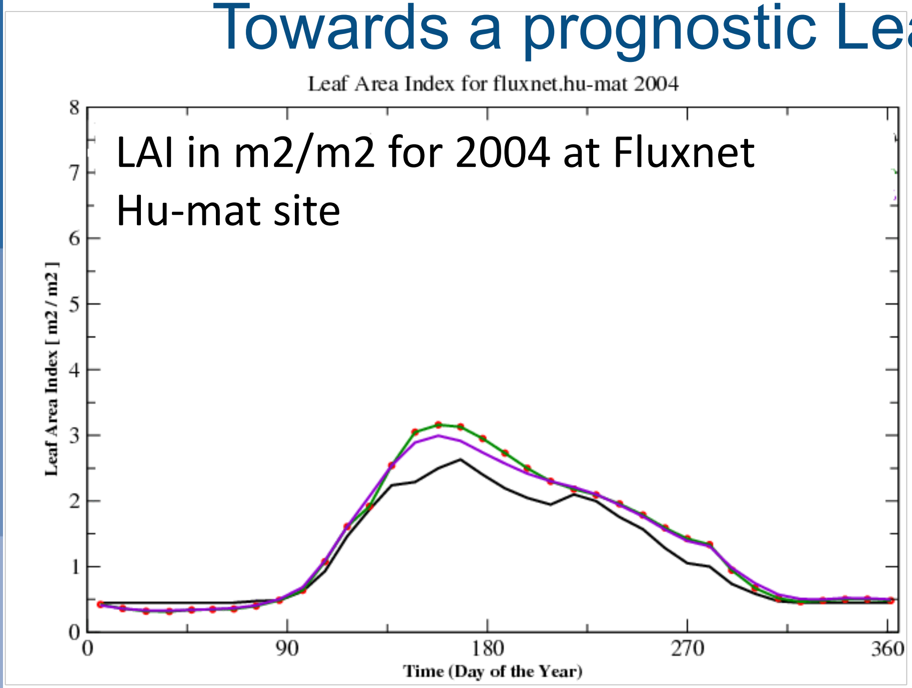
- An extra flux account for Irrigation

$$I = (PET - ET) * Irrigation\_switch$$

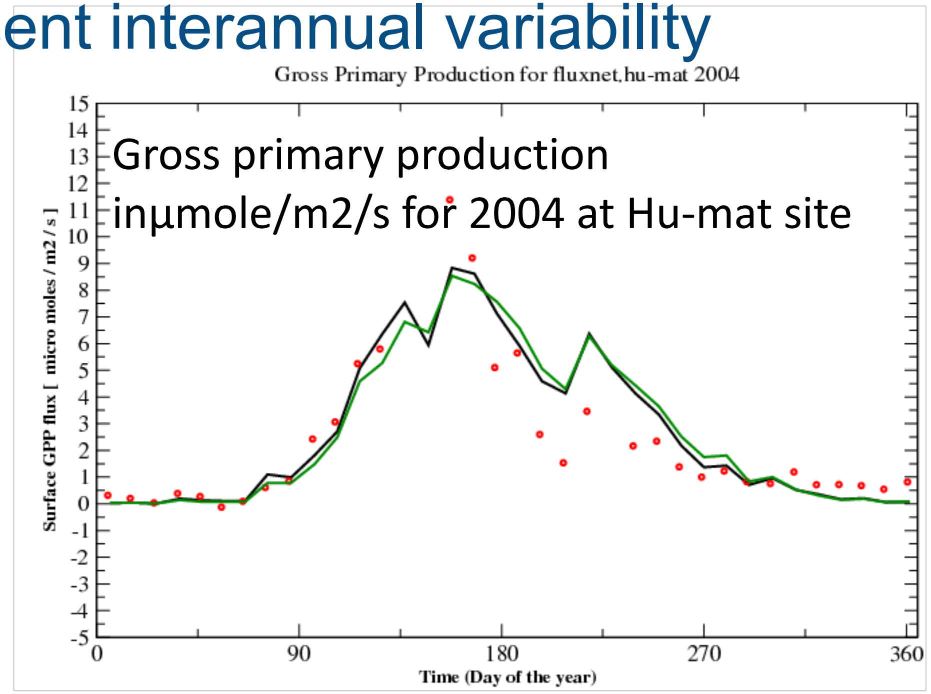


This irrigation flux is calculated based on water needs and on the irrigation fraction, but it does not attempt to represent human decision.

Towards a prognostic Leaf Area Index to represent interannual variability

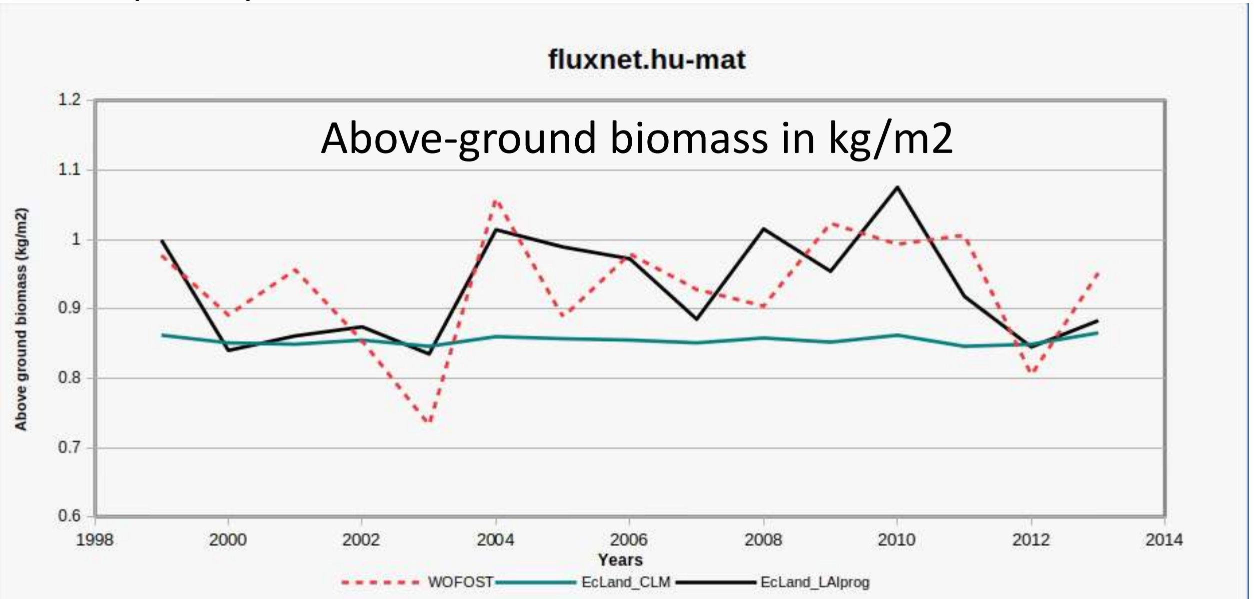


NRT obs(green with red dots) , climatology(purple), prognostic (black)



Obs (red dots), with prescribed LAI(green), with prognostic LAI (black)

WOFOST (red), ECLand with climatological LAI (green) and ECLand with prognostic LAI (black)



The model is able to reasonably simulate LAI and predict comparable Above-ground biomass with the JRC WOFOST products

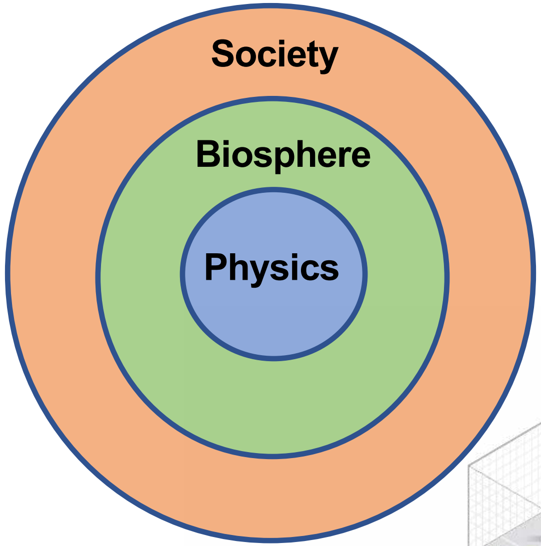
(Collaboration under ImagineS FP7 project)

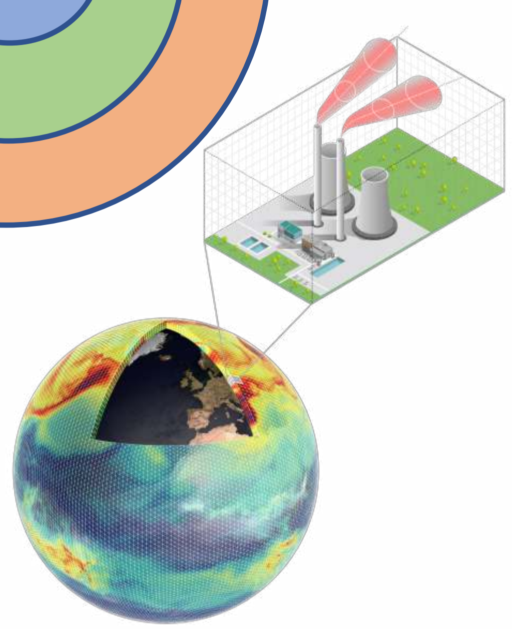
ECMWF

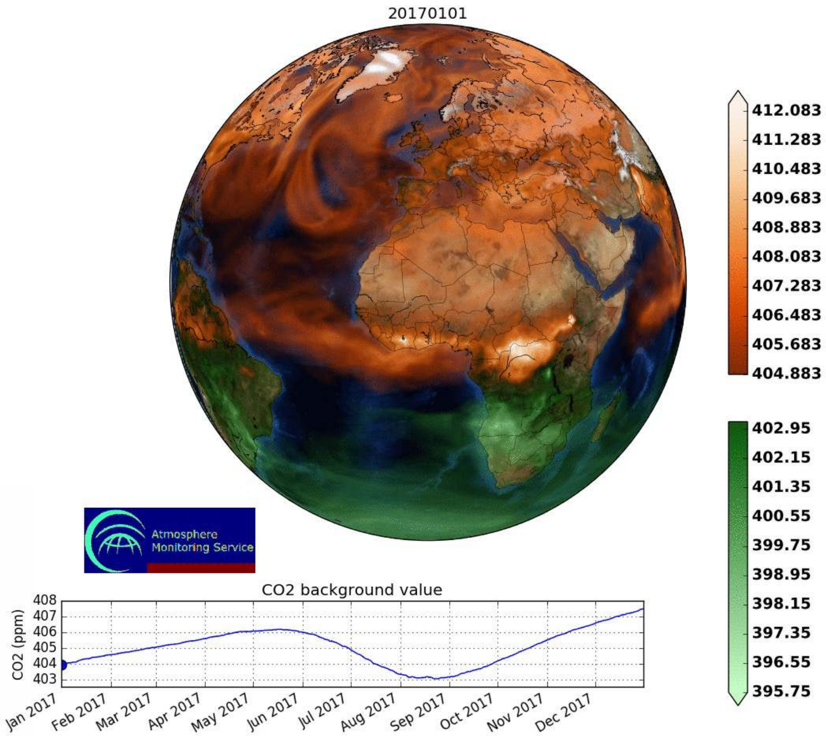
Supporting the Copernicus CO2 monitoring service as part of CAMS

Monitoring the CO2 in support of the Paris Agreement

Embracing Earth System Complexity







Atmosphere Monitoring Service

CO_2 Human Emissions

CoCO2 Prototype system for a Copernicus CO_2 service

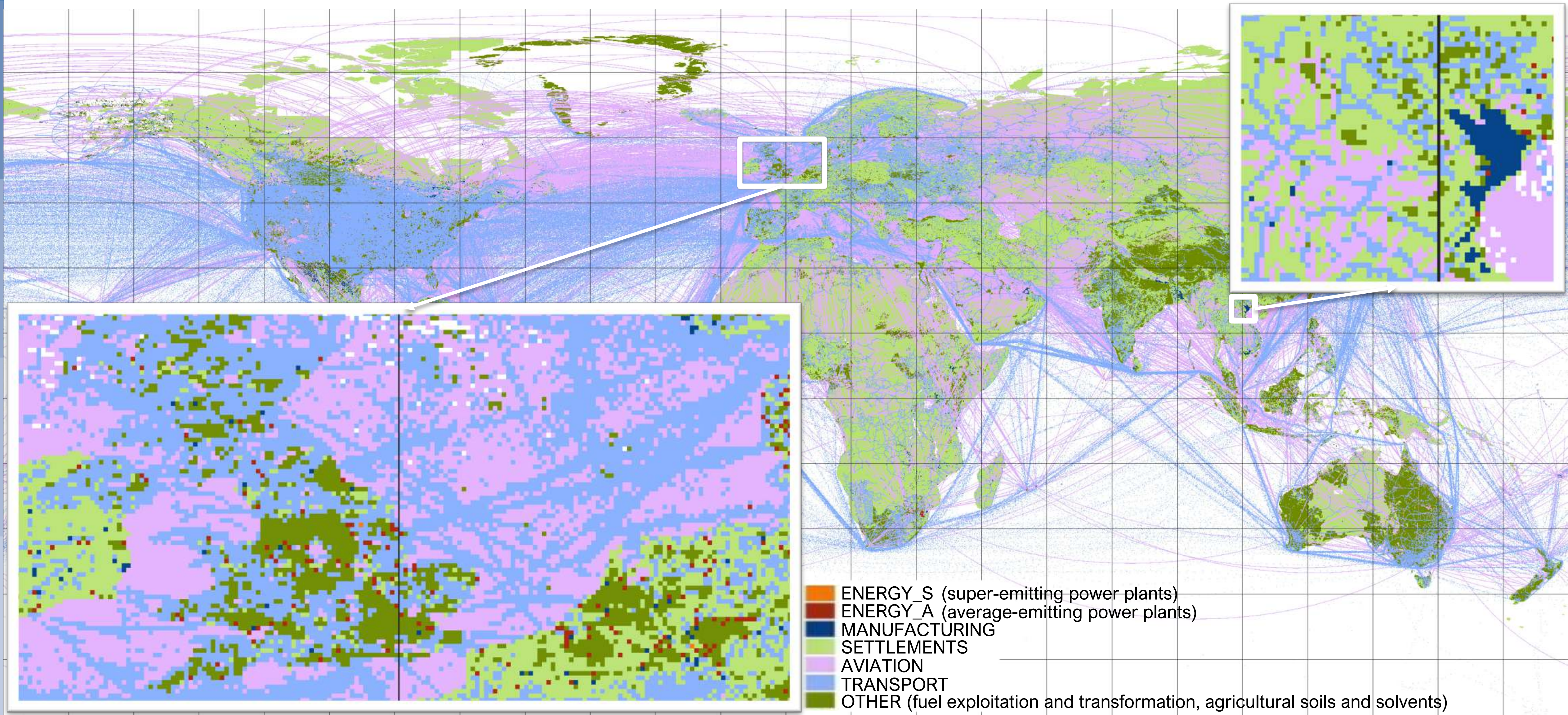
ECMWF

Including anthropogenic CO2 emissions

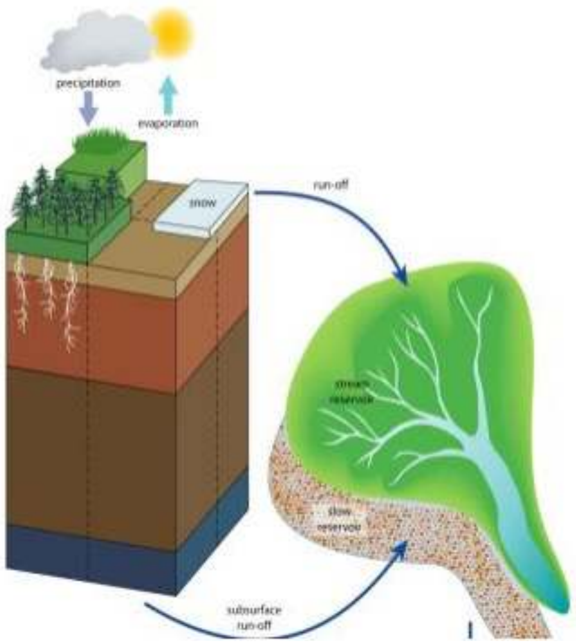
Margarita Choulga et al. 2021

Anthropogenic CO_2 emissions **uncertainties** based on country and emission type → use as **prior** uncertainties **to** generate an **ensemble** of CO_2 **forecasts** based on the operational IFS.

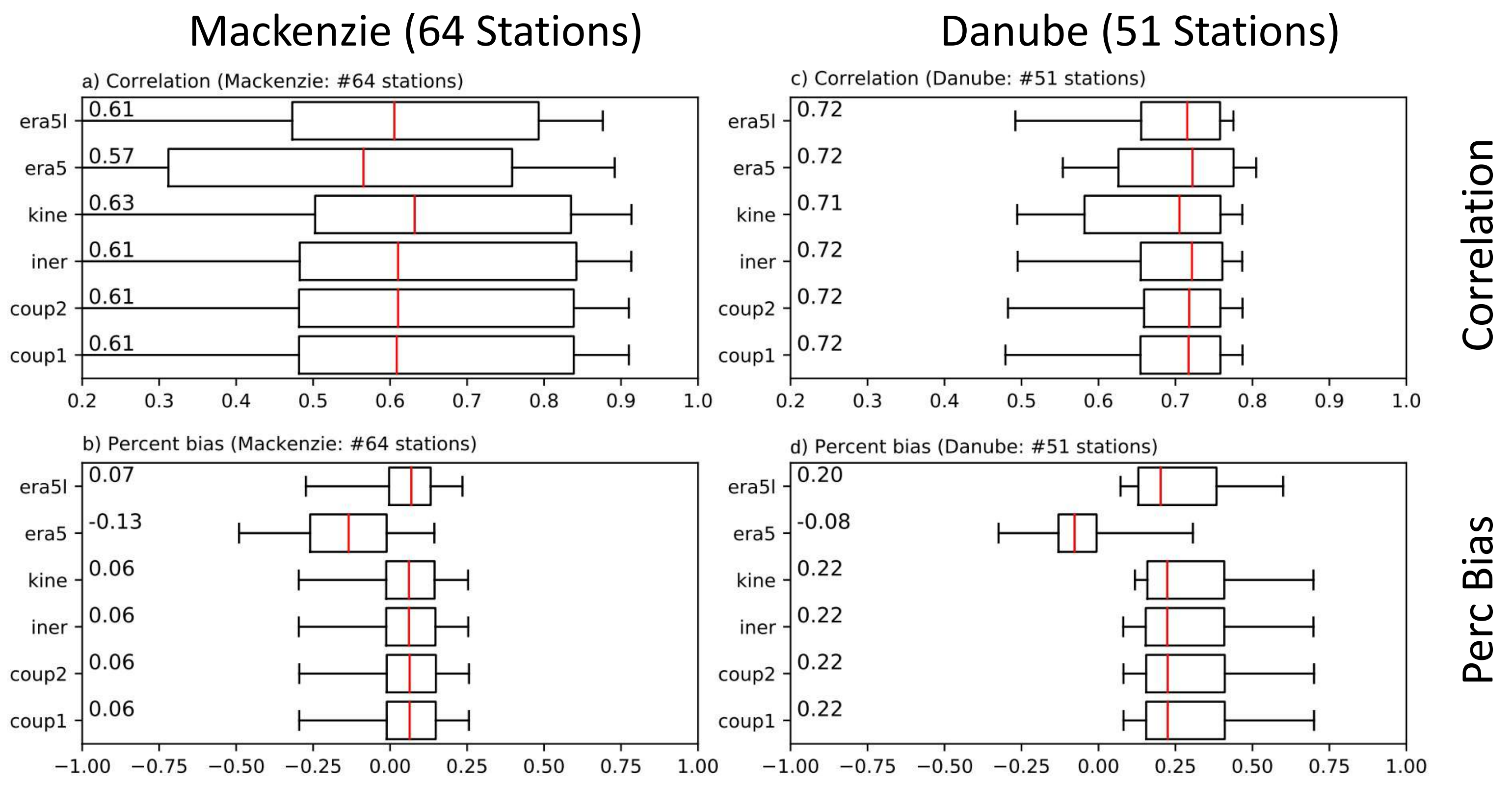
Figures below show which **emission** “group” contributes the most to the total uncertainty **per grid-cell.**



Coupled river discharge



CHTESSEL + CaMA-Flood



River discharge evaluation of several model configurations
coup1: 1-way coupling between CHTESSEL and CaMa-Flood
coup2: 2-way coupling between CHTESSEL and CaMa-Flood
Iner: flow velocity calculations using the local inertia solution
Kine: flow velocity calculations using kinematic wave both driven by runoff from coup1.
era5 and era5l are also stand-alone CaMa-Flood simulations driven by runoff from ERA5 and ERA5Land. The 2-way coupling also reduces the global water budget residual by more than 1%

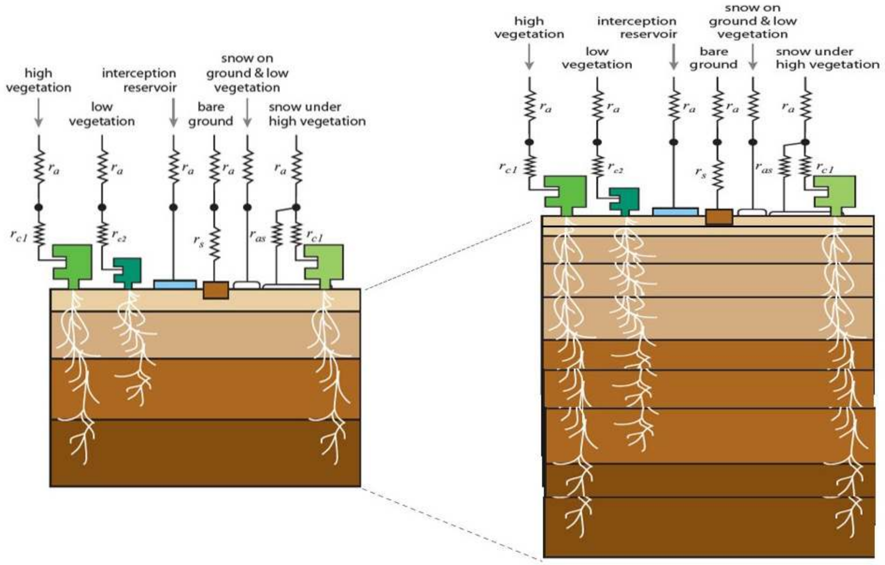
ECMWF

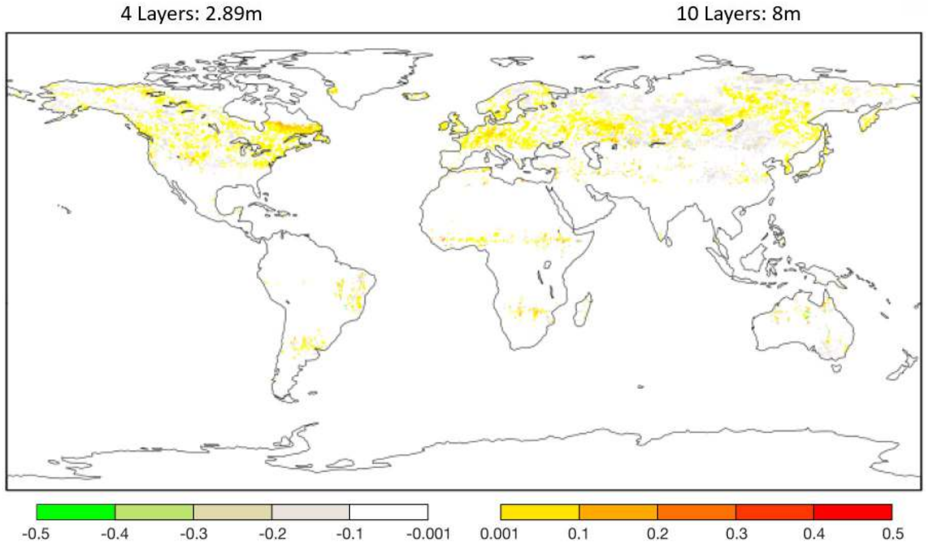
Toward an improved the soil and river-catchment hydrology representation

Development for cycle beyond 49r1, in collaboration with Emergency Management

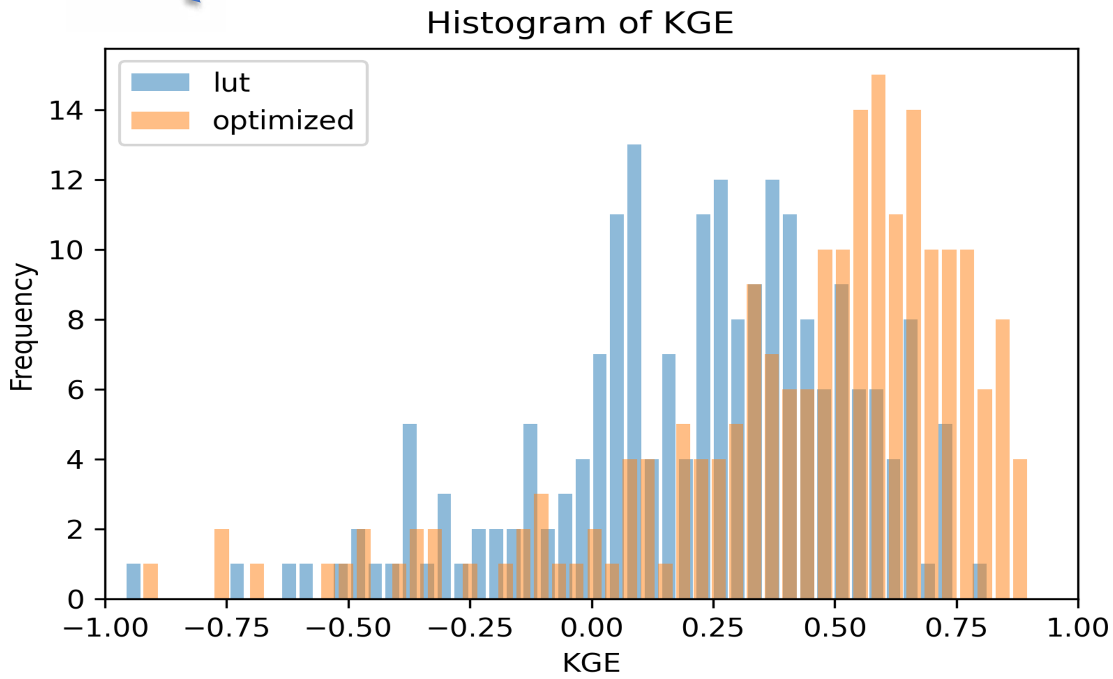
- Improving the soil vertical discretisation shows potential improvement for
  Better match with satellite surface soil moisture observation

1. Hydrological benchmarking in collaboration with GloFAS team shows the benefits of calibrating the soil hydrology using river discharges



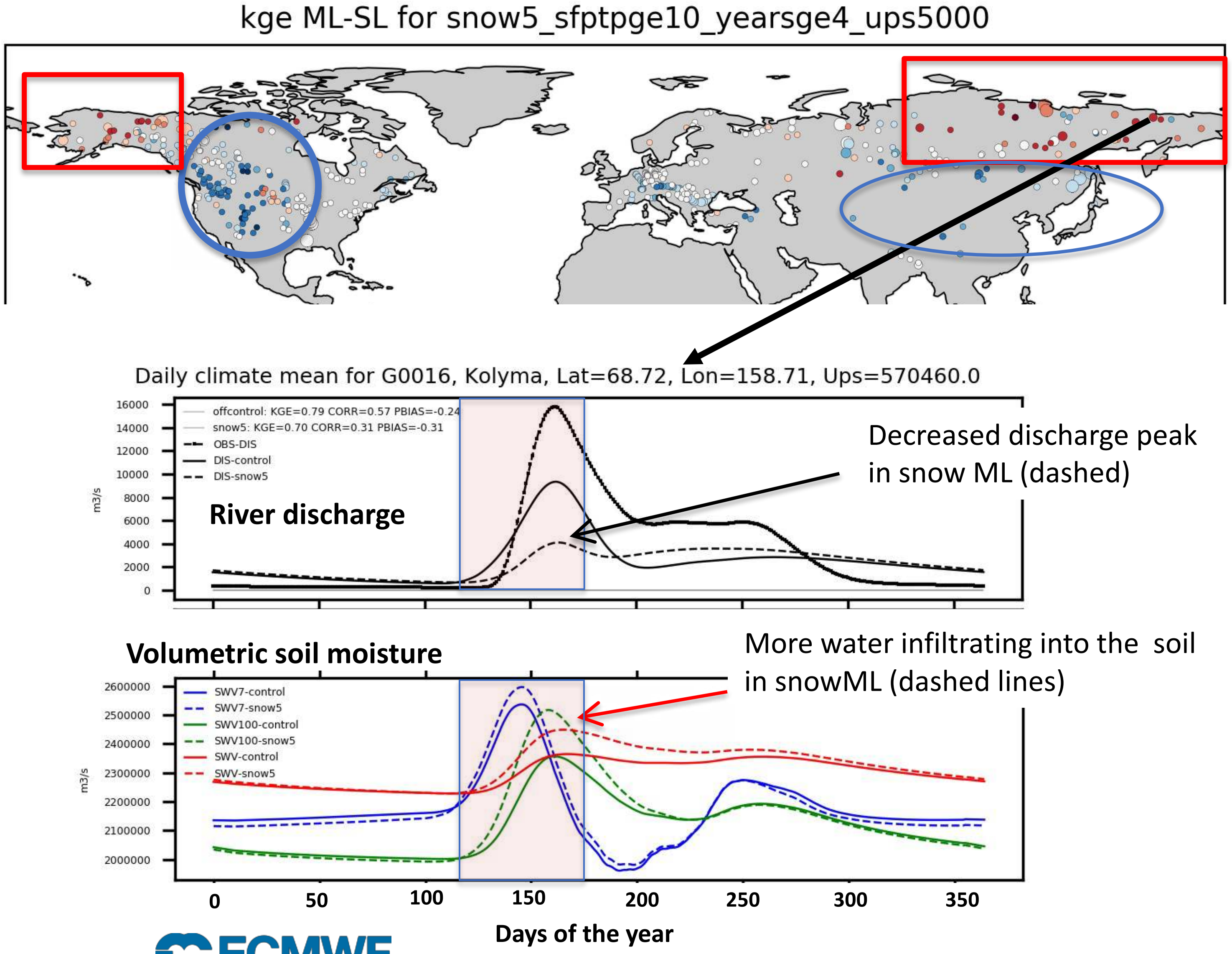


Improved correlation with the ESA-CCI surface soil moisture product between when using thinner surface layers (10-layer) & the current 4-layer scheme for JJA



Optimising the ECLand hydrological parameters can improve as tested on the river discharge

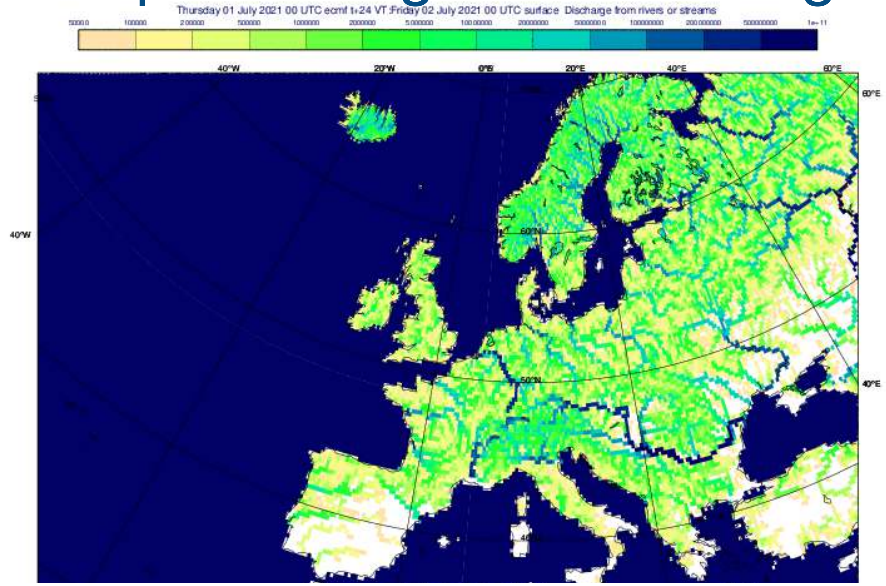
Evaluating land-surface model developments using river discharges observations, the example of the multi-layer snow scheme

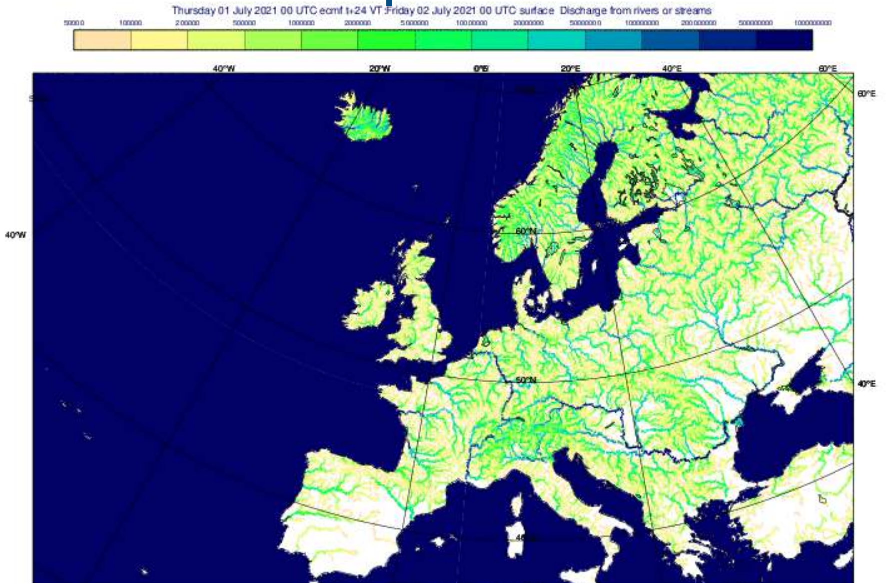


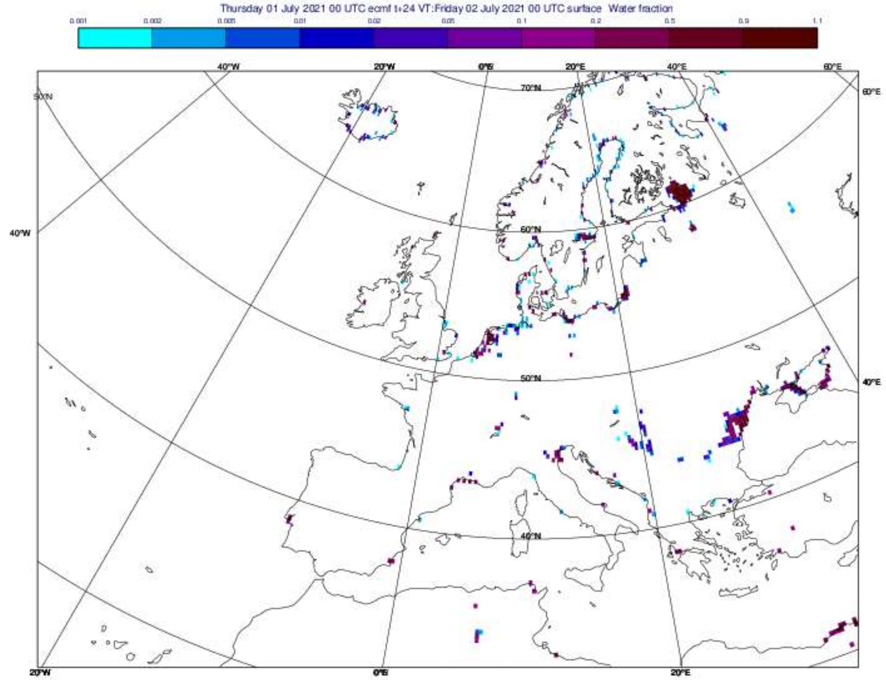
- More catchments show improvements, in particular over Rockies and mid-latitude Eurasia
- Many catchments in cold climates show lower KGE/correlation than the single-layer snow experiment (e.g. permafrost regions)
- In permafrost areas, the increase in water infiltrating into the soil due to warmer soil temperature in snowML, amplifies river discharge pre-existent biases.
- Different parametrizations for frozen soil are currently under testing

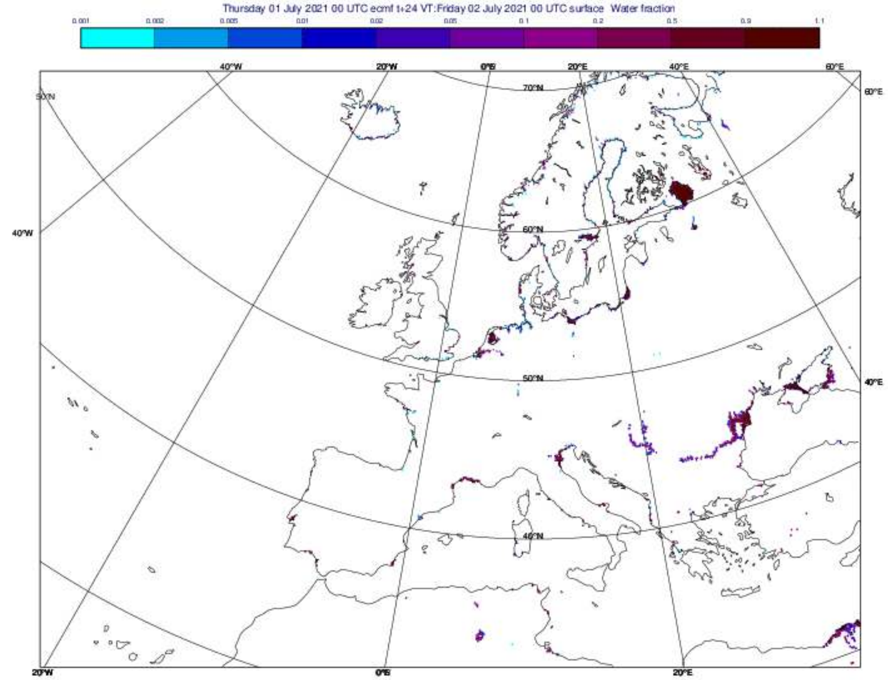
Zsoter, Arduini et al. in preparation

Representing river discharge & inundation: The European Flood 2021



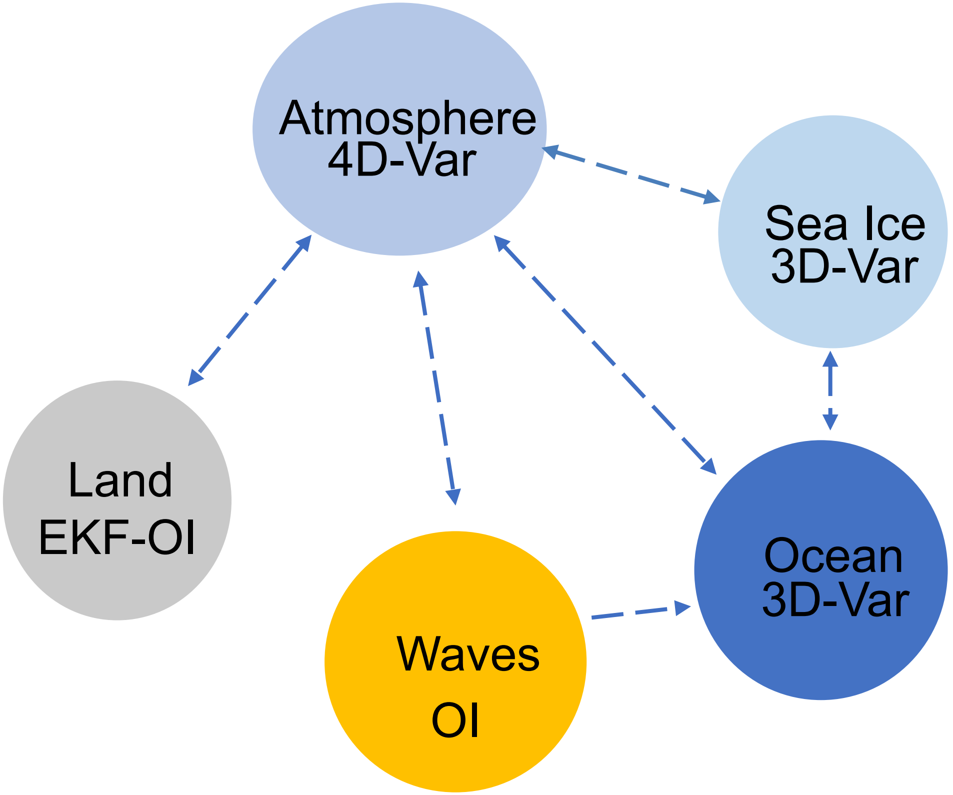






Coupled assimilation developments for NWP and reanalyses at ECMWF

Integrated Forecasting System (IFS)

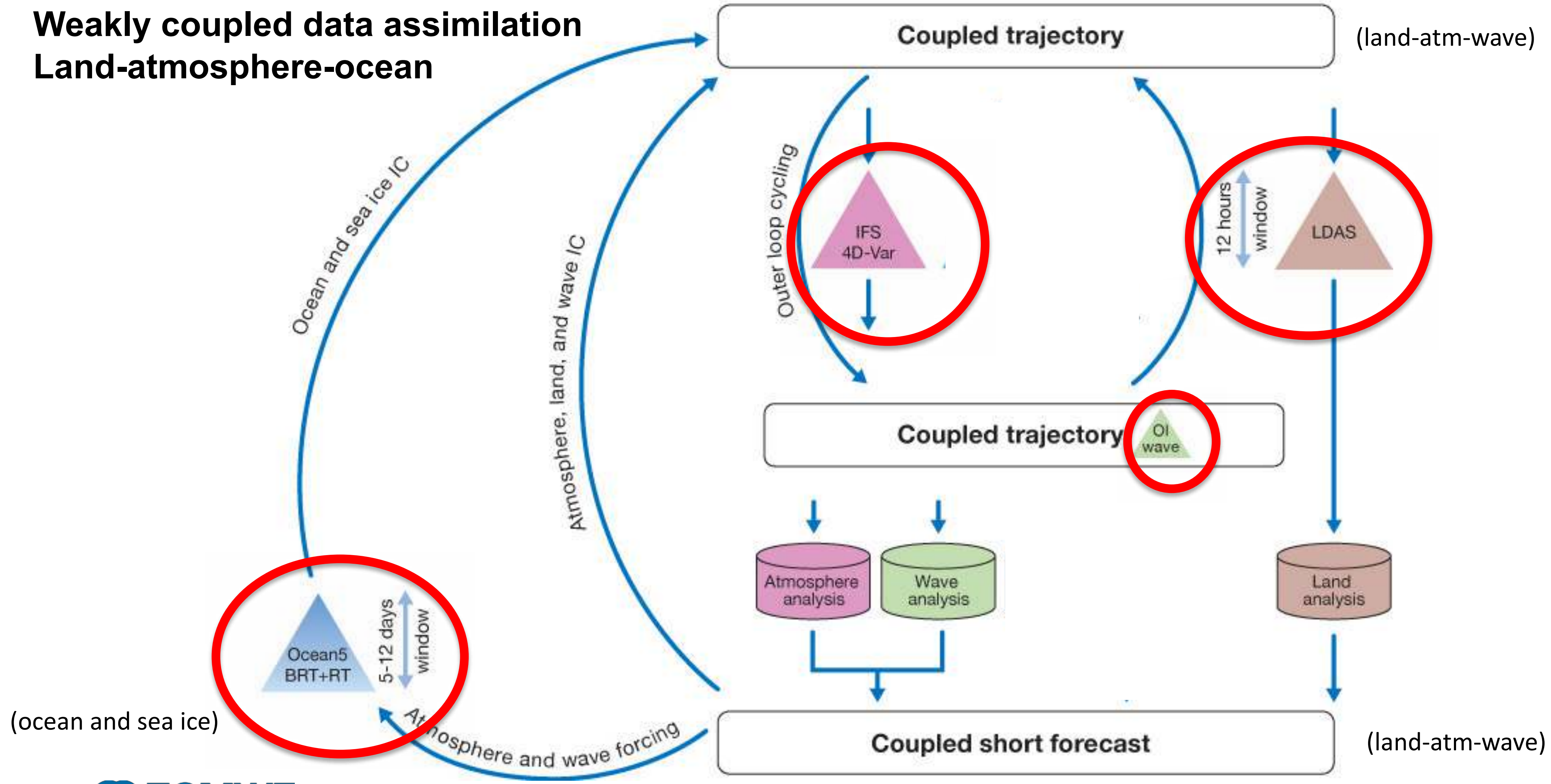


- Importance of the Earth system approach
- <u>Importance of interface observations</u> (e.g. snow, soil moisture, SST, sea ice)

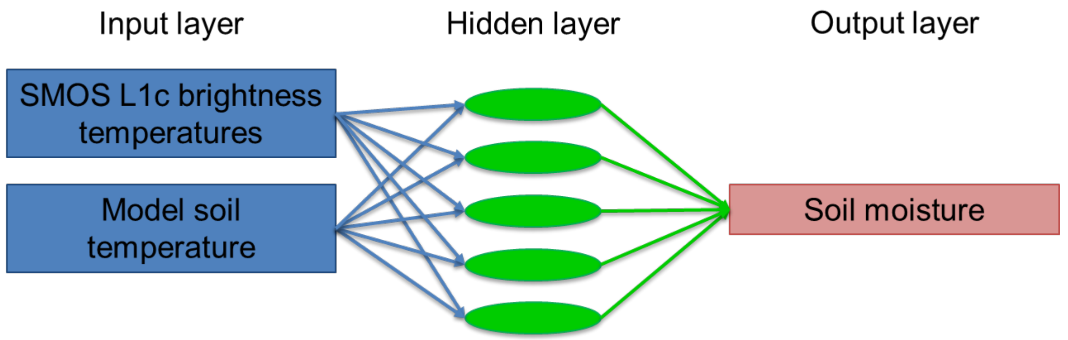
Coupled Assimilation for operational NWP at ECMWF

Patricia De Rosnay et al. 2021

Weakly coupled data assimilation
Land-atmosphere-ocean



SMOS neural network soil moisture assimilation



Rodriguez-Fernandez et al., HESS 2017, RS 2019

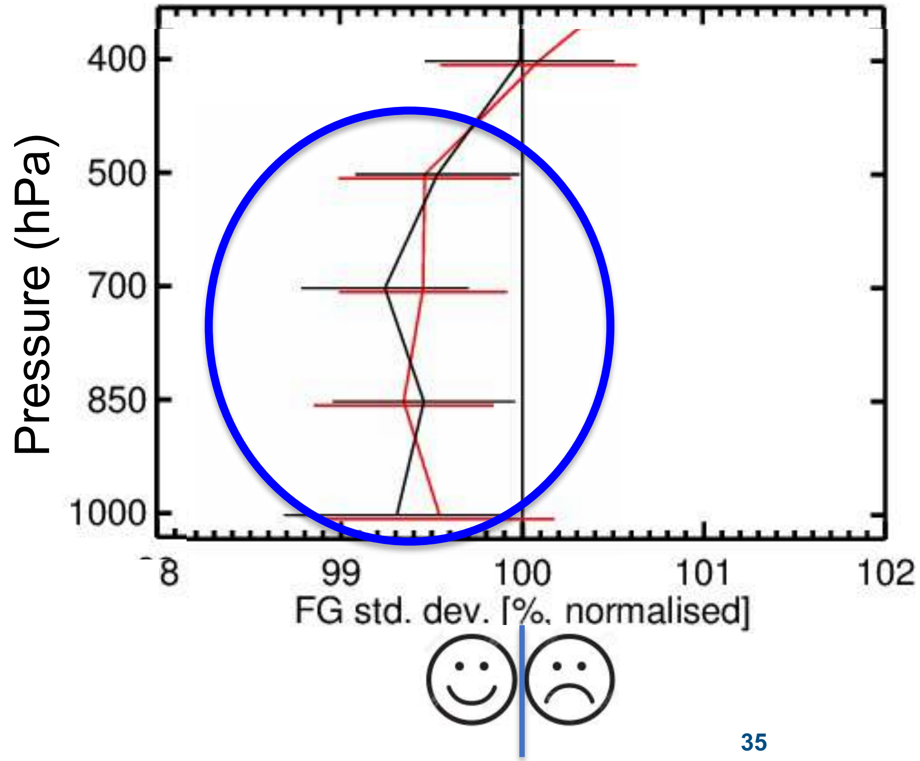
A priori training of the SMOS neural network processor
-> retraining when L1Tb or IFS soil change
Online training possibilities?

Further explore ML/AI for forward modelling for passive and active land observation usage

Aires et al., QJRMS 2021

SMOS DA impact

Aircraft humidity (JJA 2017)



ECMWF

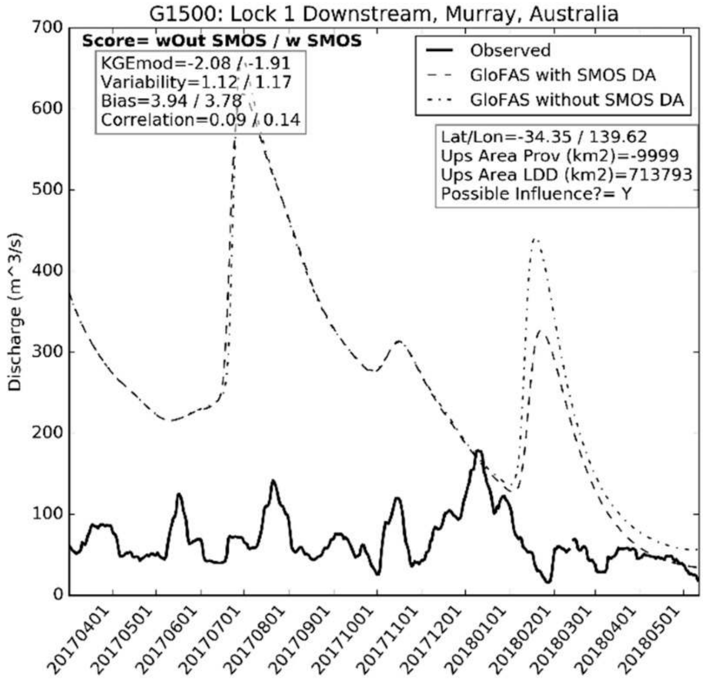
SMOS applications for the Copernicus Emergency Management Service (CEMS)

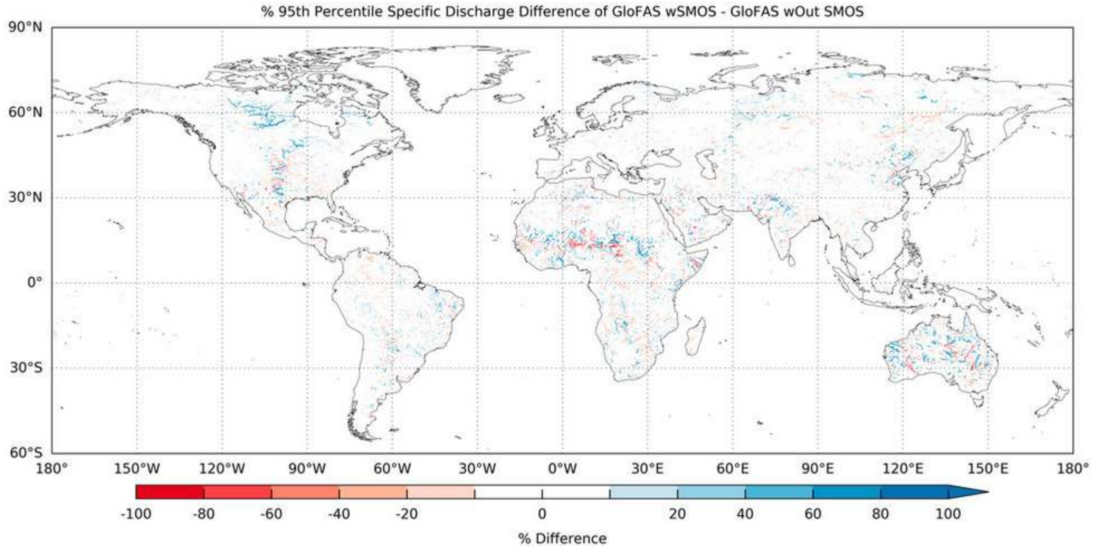
Data assimilation impact on hydrology

Emergency Management

- Data denial experiments with SMOS

Baugh et al. 2020 https://doi.org/10.3390/rs12091490





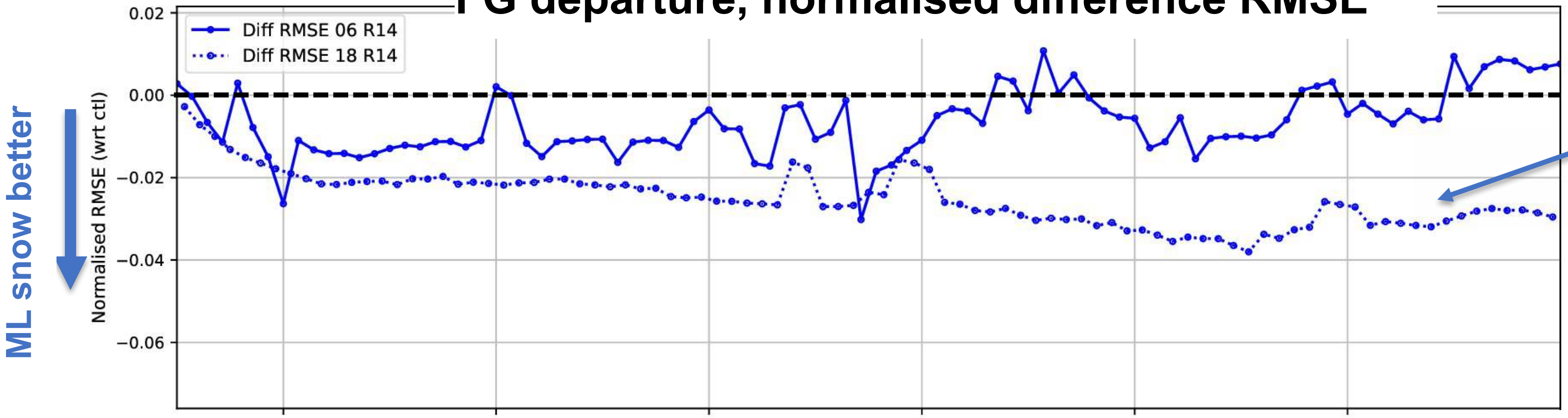
- Neutral impact of SMOS on river discharge
- Very small impact mostly on peak flow
- Poor representation of river regulation, irrigation & lake storage
- Further work will move towards coupled land-hydrology DA

ECMWF

Snow data assimilation with the new multi-layer snow scheme

Winter, 47r1.3, Tco399L137; 3 months analysis (DJF 2019/2020)

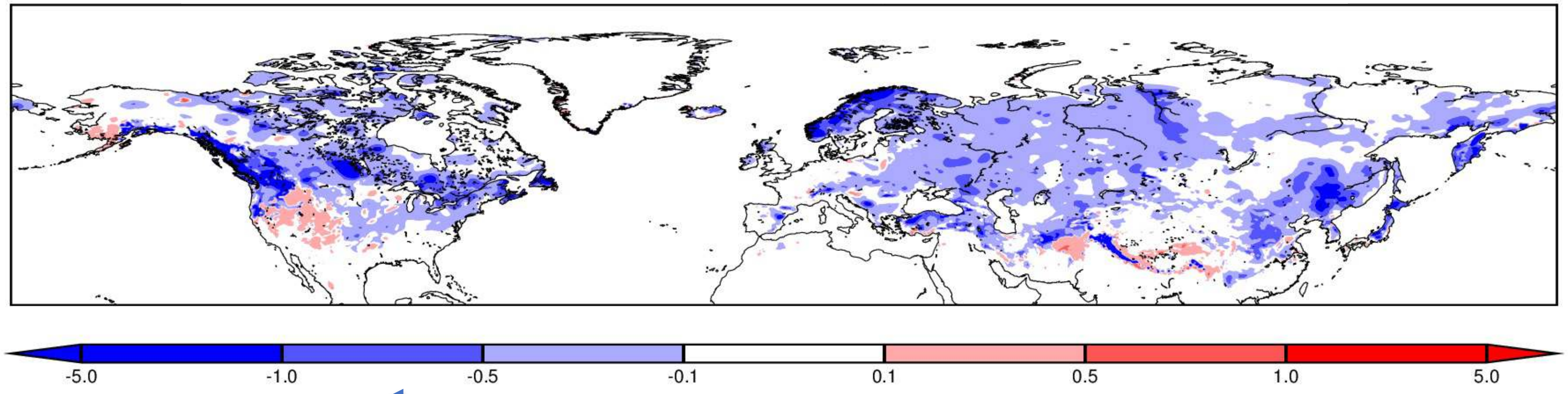
FG departure, normalised difference RMSE



2019-12-01 **2020-03-01**

~2-3% reduction of snow depth FG departure

RMSE diff in AN increments for Jan 2020, 06UTC/18UTC



cm

ECMWF

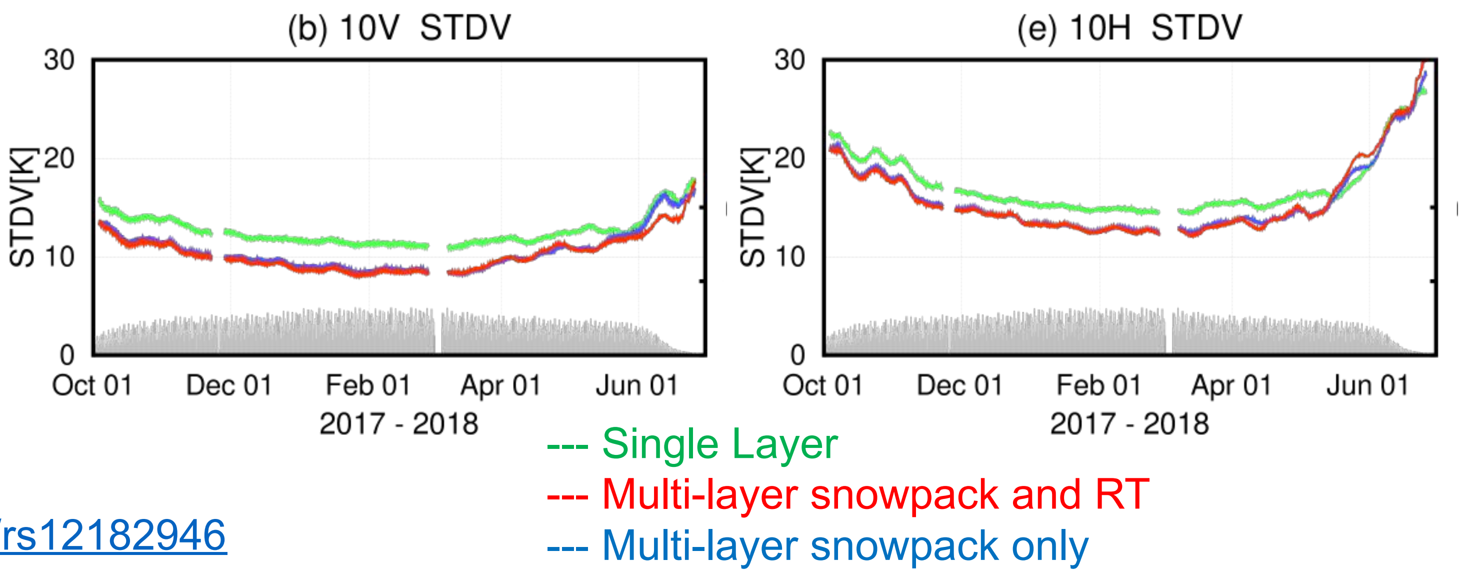
ML snow better

Simulating snow microwave radiances through an enhanced observation operator

- New interface between CMEM (surface) and RTTOV (atmosphere) radiative transfer schemes
- Multi-layer snow radiative transfer scheme (HUT, Lemmetyinen et al., 2010) in CMEM
- **Adapt to model cycle changes, take advantage to improve coupled DA**

Use the multi-layer snowpack model (Arduini et al JAMES 2019) to assess the impact of multi-layer approach on snow emissions against AMSR2 10GHz data

Multi-layer snowpack scheme leads to reduce STDV and gives higher correlation values between ECMWF forward and AMSR2 observed brightness temperatures at 10GHz



Hirahara et al., 2020 https://doi.org/10.3390/rs12182946

Summary of Coupled Modelling and Data Assimilation activities over Land

- ➢ Coupled Land-atmosphere modelling & assimilation at ECMWF for operational NWP and future generations of reanalyses (NWP, Copernicus Services, and high resolution Destination Earth)

- ➢ ECLand summarise the ongoing modelling efforts (Boussetta et al 2021, MDPI-Atmosphere) to support next generation NWP forecasting and climate/env reanalysis (Copernicus and DestinE)

- ➢ Consistent observation monitoring across the components is ongoing to support LDAS system

- ➢ Challenges of Earth System approach for NWP:
  - Observations availability, sustainability (e.g. snow, ocean)
  - Coupling through the observation operator (e.g. for snow surfaces) → opportunities to enhance the exploitation of satellite data

- Next steps: a more uniform ECMWF Land DA system & enhance exploitation of land observations

Perspectives

- A model refactoring and calibration is expected to improve hydrological performance
- Perspectives on NWP for:
  - improving of the water cycle, with particular attention to evaporation processes, transition seasons, and hydrological forecast skill.
  - better exploitation of very-high resolution (eg. SENTINEL 1-2-3) observational datasets, in particular skin temperature over land.
- Based on the new collaboration streams framework:
  - Perspectives for extended-range predition and improved reanalyses (link with C3S related developments).
  - Perspectives for a more complete representation of the carbon cycle (CO2 link with Farquhar, P-model,.. CoCO2, CAMS, CH4 link with soil hydrology).

A two-stream Land surface development concept

ECLand STREAM-I is a focused development stream with ECMWF code governance & maintenance

A coordinated code governance led by ECMWF to ensure lean scalable modular efficient code build upon

- **Distributed Source Code Architecture** (with github repository & git-tools version management)
- **Scalability Programme Efficiency Gain** (with time-to-solution evaluation and routines profiling)

A process-based scientifically-sound research agenda guide inclusion of new modules following 3 principles

- **Observability** (EO-data driven Calibration/Validation/Initialization)
- **Relevance** (Weather & Copernicus Applications Compliance)
- **Impact** (Coupled Earth System Forecast Performance & Key Products)

ECLand supports the ECMWF integrated approach in a **focused development stream** via purposely funded activity

ECMWF

ECLand: *STREAM-II* is a *parallel stream* with EQC and ECMWF operationalized *offline-multi-model framework*

A ***parallel stream*** will support blue-sky research, model diversity & inclusion.
Land Surface Models (LSMs) are essential in Earth System Modelling & Coupled Data Assimilation & there is expertise in several other domain-specific applications

Global Hydrological Models (**GHMs**) & Global Ecosystem Models (**GEMs**) community are important sources.
LSMs adopt clever & diverse solutions: CLASS, CH-TESSEL, CLM, ISBA-DF/ES, JULES-HYDRO, JSBACH, LPJGUESS, MPR, NOAH-MP, ORCHIDEE, TERRA, SURFEX, UTOPIA, VISIT, VPRM

- A common challenge (e.g. Land-use, Water-use, EQC) calls for a ***Community effort***
- ECMWF will support and participate to the community effort (e.g. PLUMBER and CIF)

ECLand will further support the modelling communities with a participated ***Offline-Multi-Model framework***. Why?

- ***ECMWF*** aim to provide best VHRES quality forcing + infrastructure to host (run), visualize & analyse the MM-results
- ***ECMWF*** aim to gain valuable information on the land surface uncertainty (important to guide Ensemble devs)
- ***LSM/GHM/GEM*** communities will provide a large basin of expertise & knowledge (important to ESM/ESAS devs)
- ***LSM/GHM/GEM*** communities will gain from participating in society-relevant operational services (faster R2O/O2R)