Land surface modelling: why, where and how

Surface processes, lake model, climate files

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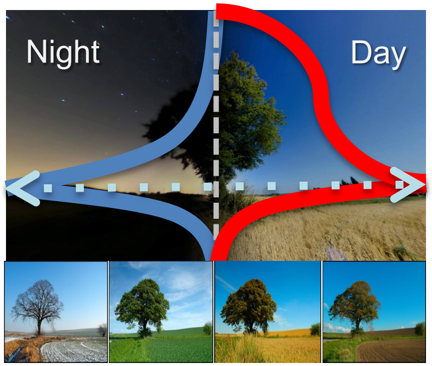
Joe McNorton,
and many more colleagues

Photo from https://www.ft.com/content/

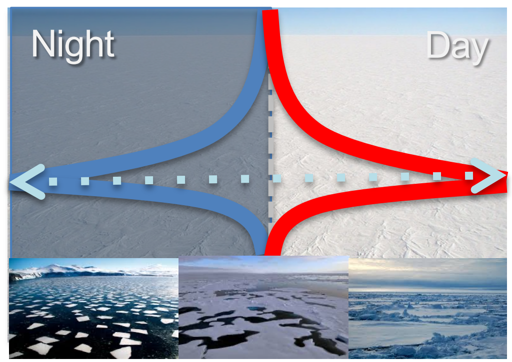
Modelling surface heterogeneity and coupling with the atmosphere

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**.



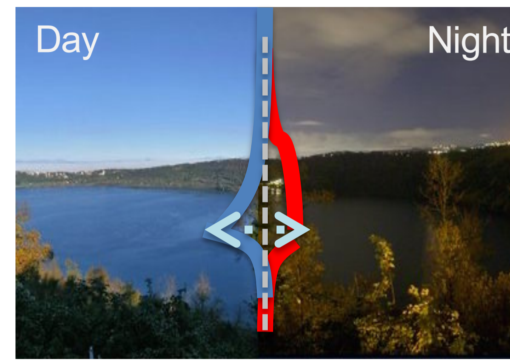
Over Land

- 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



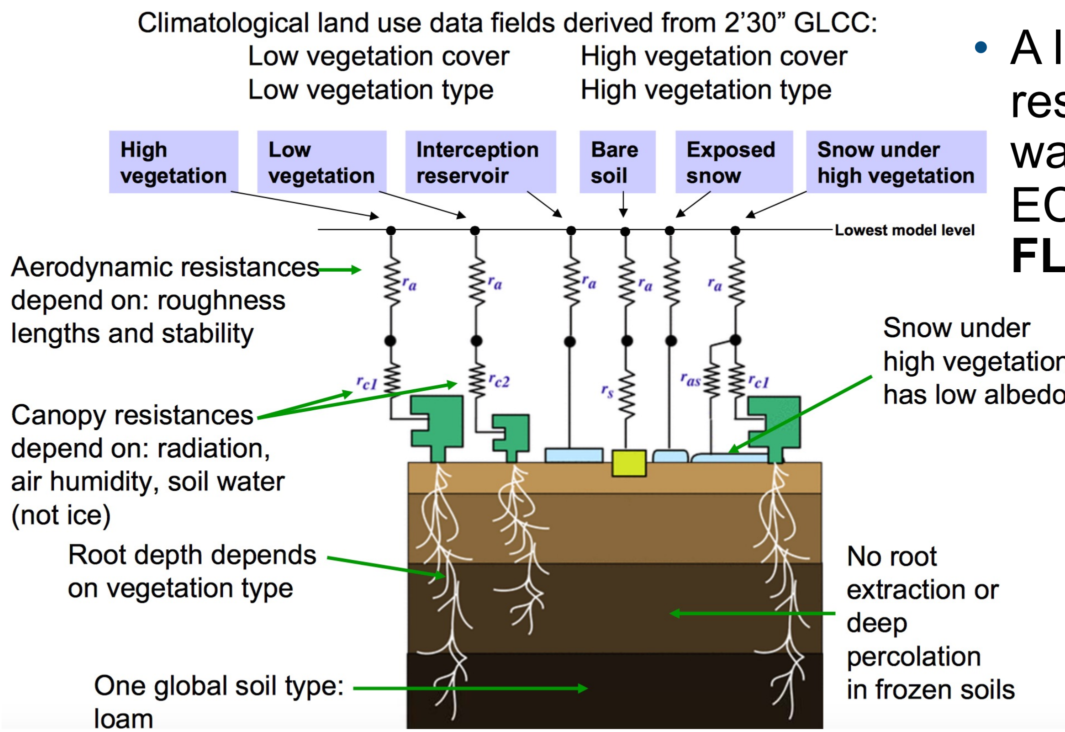
Over Water-bodies

- Lakes have large thermal inertia
- Different albedo & roughness

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

Tiling scheme

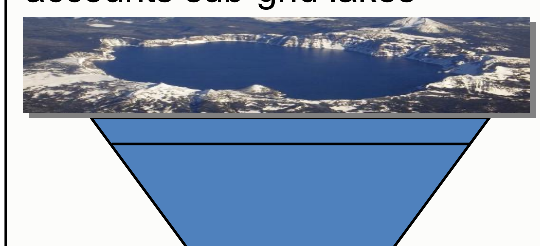
- To represent **surface heterogeneity**, the Tiled ECMWF Scheme for Surface Exchanges over Land incorporating land surface hydrology (**ECLand**) is used (Balsamo et al., 2012; IFS Documentation, 2017).
- ECLand computes **surface turbulent fluxes** (of heat, moisture and momentum) and **skin temperature** over different tiles (vegetation, bare soil, snow, interception and water) and then calculates an **area-weighted average** for the grid-box to **couple with** the **atmosphere**.



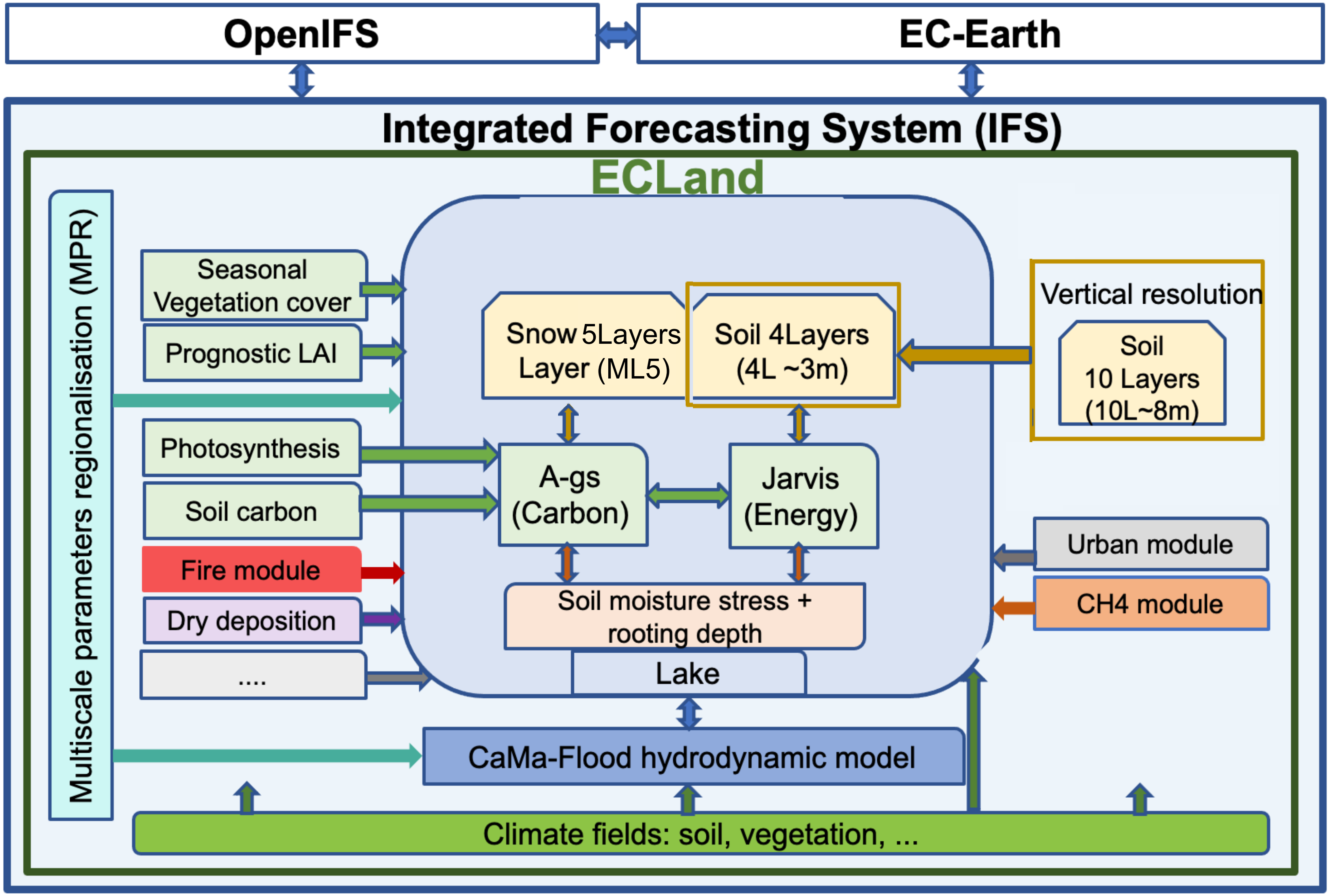
- A lake **tile**, representing lakes, reservoirs, rivers and coastal waters, was introduced (Dutra et al., 2010) in ECLand in **2015** by including the **FLake model** (Mironov et al., 2006).

Balsamo et al. (2010, 2012, 2013)
Dutra et al. (2010)
Mironov et al (2010)

Lake tile (9)
accounts sub-grid lakes



ECMWF surface model status



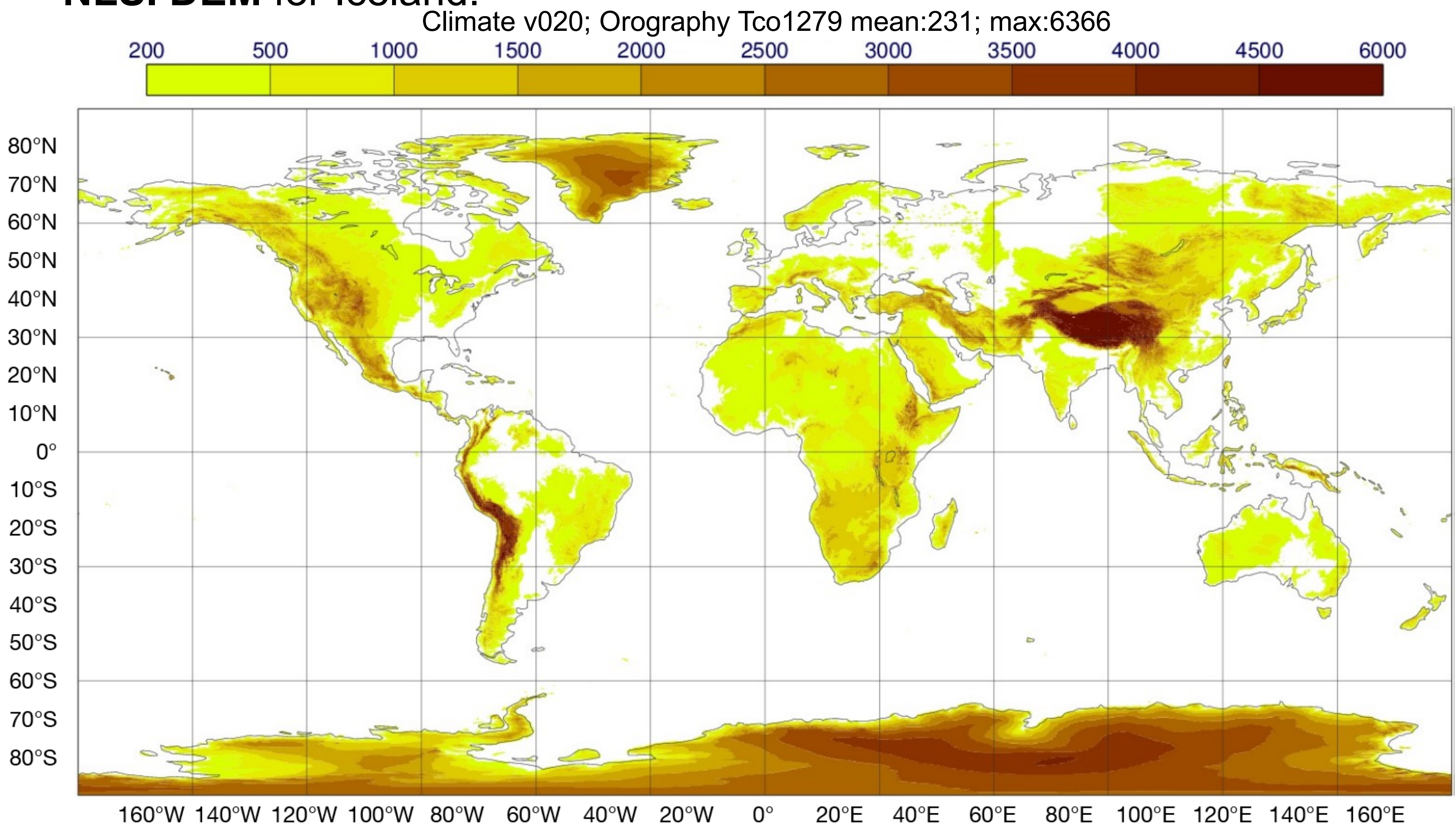
Climate fields (do not depend on initial condition or forecast step!) are used to **trigger** different **parametrizations**.

MODEL cycle 48r1

- ✓ Climate fields v020
- ✓ Lake model
- ✓ Snow multilayer model

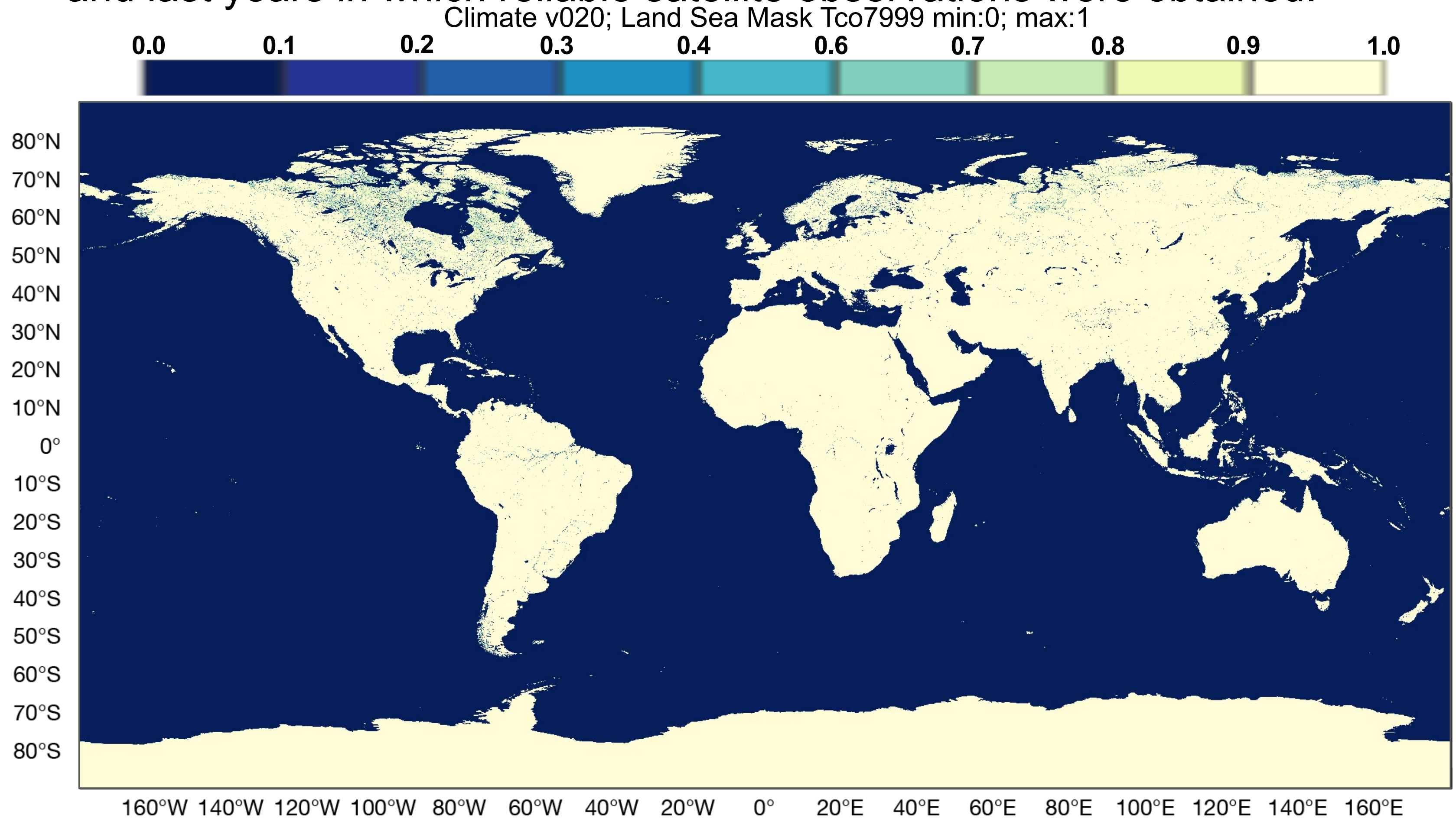
Orography

Sources of the model orography in the IFS: **SRTM30** (60N-60S), **GLOBE** (90N-60N), **Antarctic RAMP2** (60S-90S), **BPRC** for Greenland, **IMO & NLSI DEM** for Iceland.



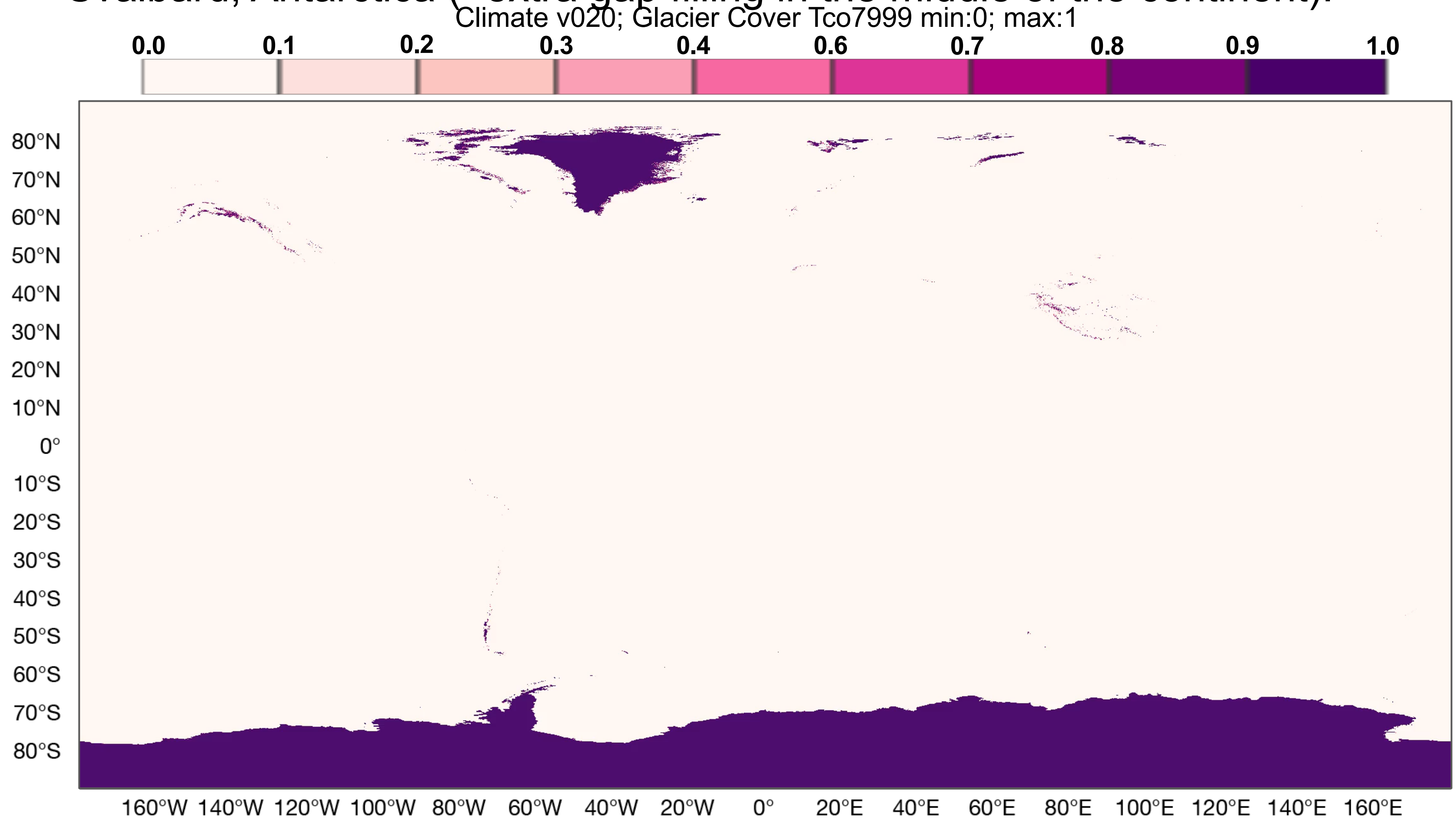
Land Sea Mask (permanent water)

Main source is the **Joint Research Centre Global Surface Water** dataset at **30 m resolution** that shows changes in water classes between the first and last years in which reliable satellite observations were obtained.



Glacier cover

Main source is **GLIMS** (Global Land Ice Measurements from Space, shapefile, 2017) **with** regional **corrections** for Greenland, Iceland, Svalbard, Antarctica (+extra gap filling in the middle of the continent).

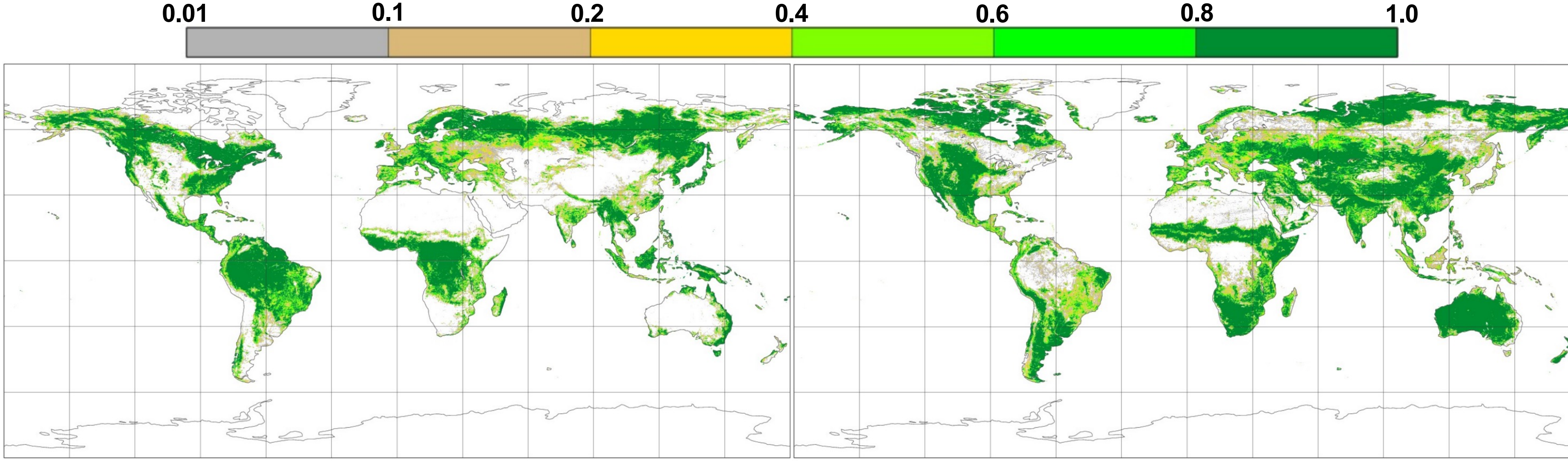


High and Low vegetation cover

Main source is **GLCC** (Global Land Cover Characteristics version 1.2).

Climate v020**; High Vegetation** Cover Tco1279
mean:0.33; max:1

Climate v020; **Low Vegetation** Cover Tco1279
mean:0.43; max:1



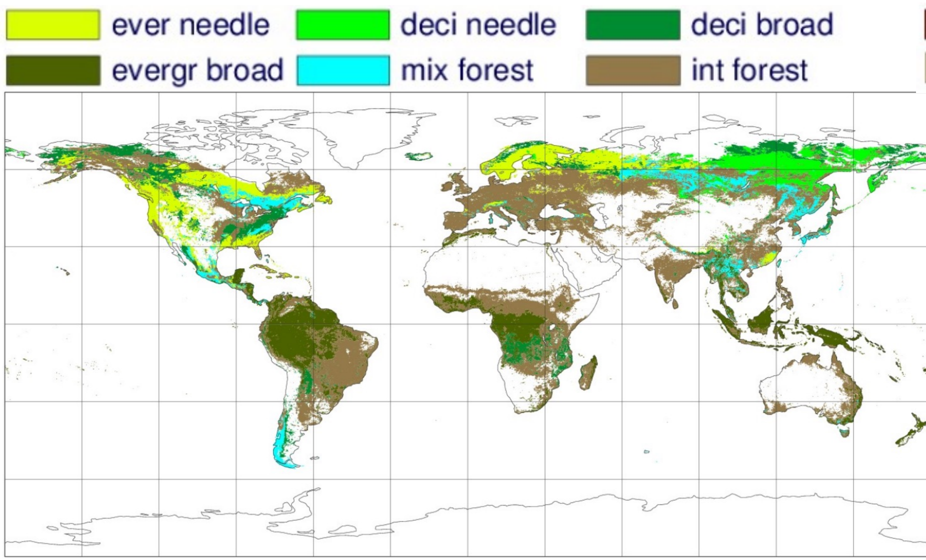
Index	Vegetation type
3	Evergreen Needleleaf Trees
4	Deciduous Needleleaf Trees
5	Deciduous Broadleaf Trees
6	Evergreen Broadleaf Trees
18	Mixed Forest/woodland
19	Interrupted Forest
–	Remaining land points without high vegetation

Index	Vegetation type
1	Crops, Mixed Farming
2	Short Grass
7	Tall Grass
9	Tundra
10	Irrigated Crops
11	Semidesert
13	Bogs and Marshes
16	Evergreen Shrubs
17	Deciduous Shrubs
20	Water and Land Mixtures
-	Remaining land points without low vegetation

High and Low vegetation type

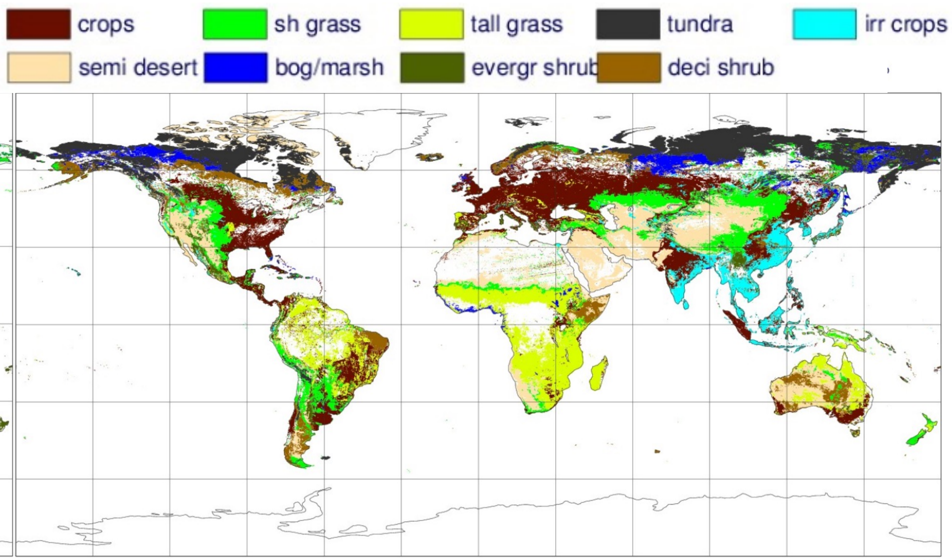
Main source is **GLCC** (Global Land Cover Characteristics version 1.2).

Climate v020; **High Vegetation** Type Tco1279



Index	Vegetation type	Percentage of land points
3	Evergreen Needleleaf Trees	5.4
4	Deciduous Needleleaf Trees	2.5
5	Deciduous Broadleaf Trees	5.6
6	Evergreen Broadleaf Trees	13.1
18	Mixed Forest/woodland	3.0
19	Interrupted Forest	24.8
–	Remaining land points without high vegetation	45.2

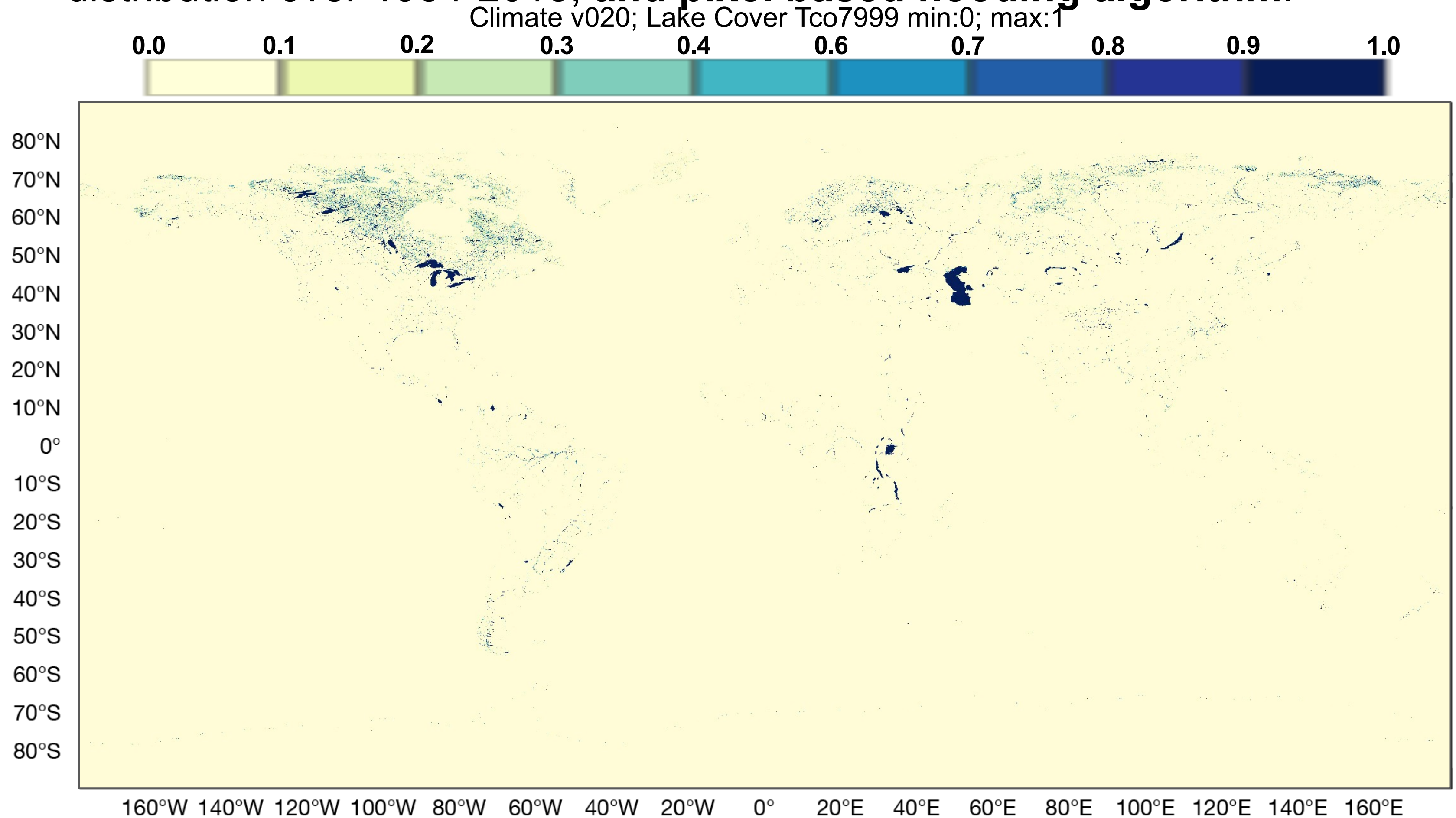
Climate v020; **Low Vegetation** Type Tco1279



Index	Vegetation type	Percentage of land points
1	Crops, Mixed Farming	18.2
2	Short Grass	9.0
7	Tall Grass	12.9
9	Tundra	6.0
10	Irrigated Crops	4.0
11	Semidesert	11.7
13	Bogs and Marshes	1.5
16	Evergreen Shrubs	1.2
17	Deciduous Shrubs	4.0
20	Water and Land Mixtures	0
-	Remaining land points without low vegetation	31.2

Lake cover (permanent water)

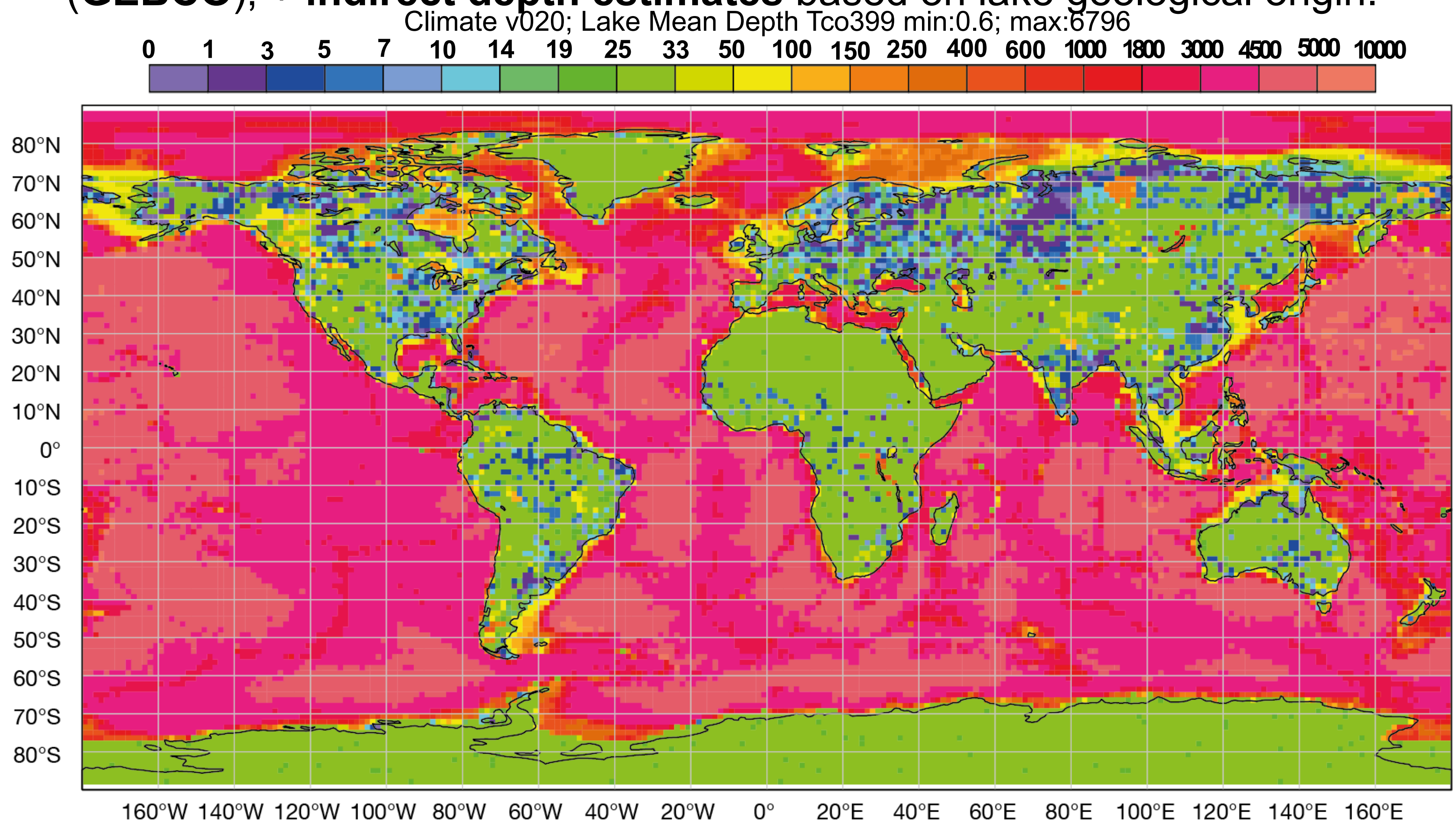
Based on **LSM**, which is mainly using the Joint Research Centre Global Surface Water dataset at 30 m resolution that shows changes in water distribution over 1984-2018, **and pixel based flooding algorithm**.



Lake mean depth

Lake depth, m	1- 7	Annual cycle amplitude changes for 1 K when depth changes for	1 m
	7-16		2 m
	16-40		3 m

Main source is **GLDB.v3** (Global Lake DataBase) completed with Great Lakes bathymetry (**ETOPO1**), Caspian Sea, Azov sea, ocean bathymetry (**GEBCO**), + **indirect depth estimates** based on lake geological origin.

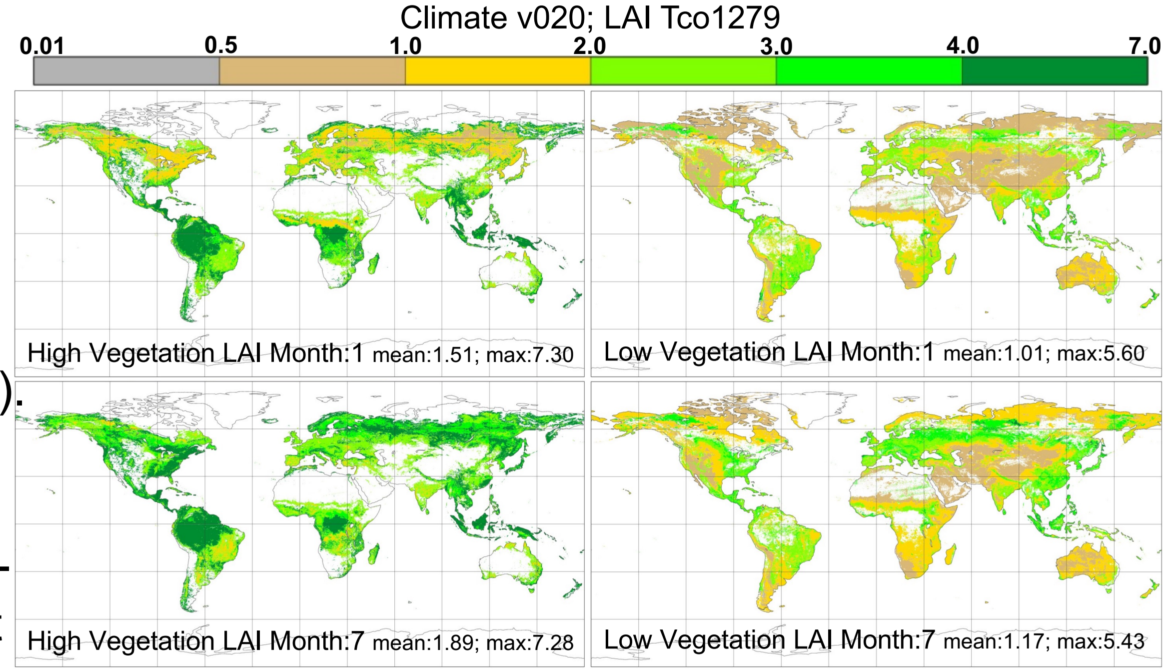


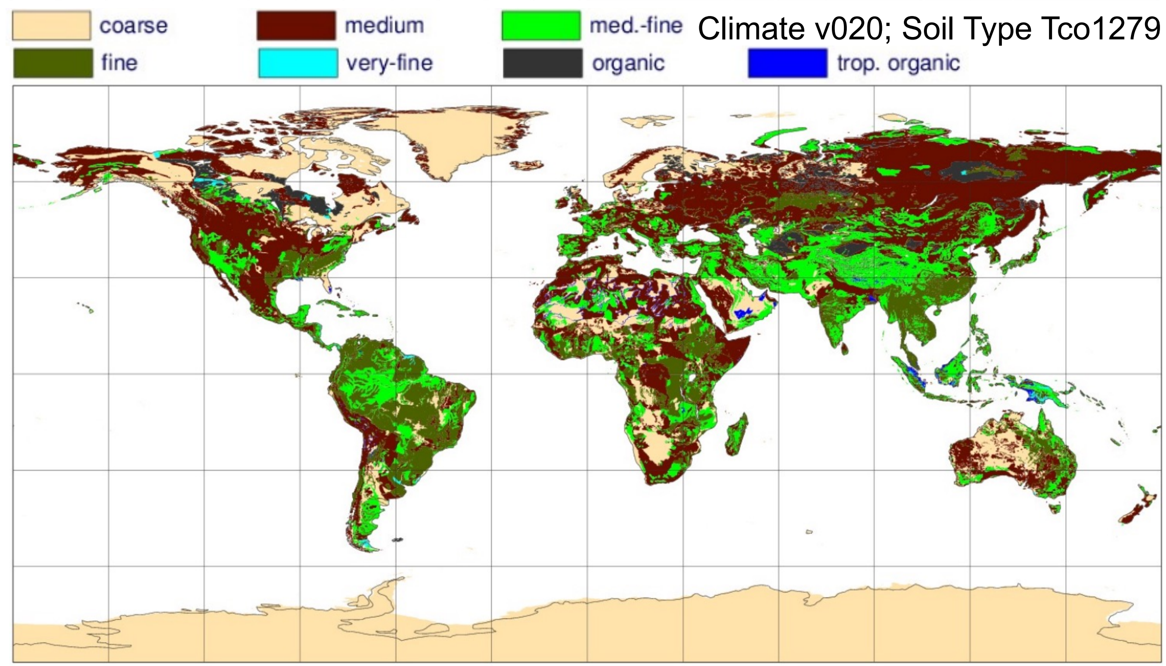
Other covers

LAI – monthly climatology is based on **MODIS** MOD15A2 LAI product at 1 km resolution (MODIS grid).

Albedo – derived from a 5-year **MODIS** climatology at 0.05 degree resolution (regular latitude/longitude grid).

Soil type – derived from FAO DSMW (FAO/ UNESCO Digital Soil Map of the World) 30-100 cm layer at ~10 km resolution.





Climate field generation technique

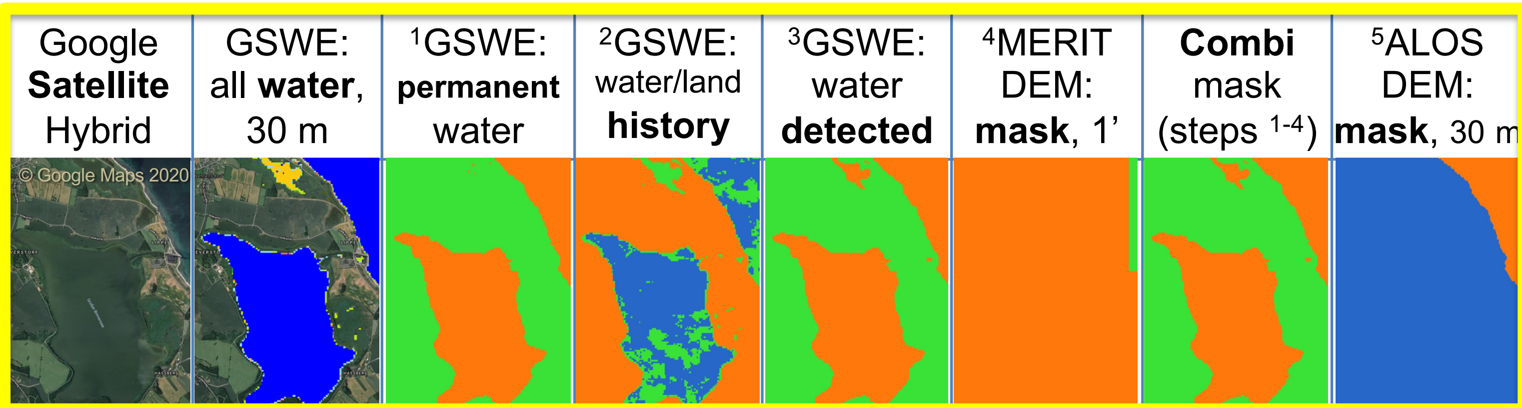
- The ECMWF model uses a series of **climate fields**, that **do not depend** on **initial condition** or **forecast step**.
- The **processing** of the data is done **offline** with a series of programs that are part of the so-called “**climate package**”.

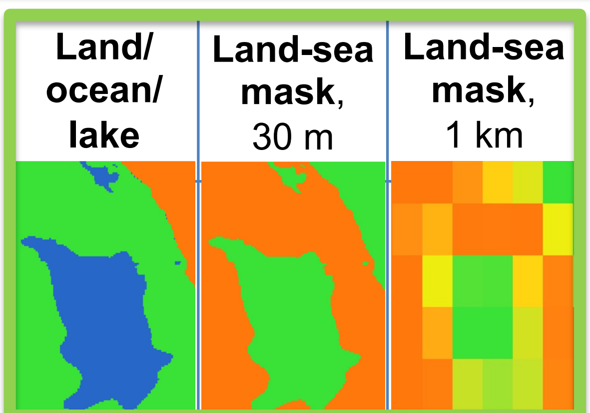
1. Initial dataset (at any resolution in any format)
2. Converted to a regular grid at ~1 km resolution
3. Converted to GRIB file format
4. Filtered with ~5 km, resolution kept ~1 km
5. Interpolated to the IFS grid (i.e. gaussian grid) by average/ dominant/ mode

Initial datasets conversion: LSM example to a regular grid at ~1 km resolution

use of Google Earth Engine platform

Main initial dataset is the Joint Research Centre (JRC) Global Surface Water dataset at 30 m resolution that shows changes in water distribution over 1984-2018 (available through Google Earth Datasets).





LSM	Operational (GlobCover 2006)	gc2009 (GlobCover 2009/ GSWE)	GSWE
Native resolution	300 m	300 m/ 30 m	**30 m**
Base year	2005/2006	2009/2016	**2018**
Mean water/ lake fraction	0.66432/ 0.00507	0.66363/ 0.00532	**0.66581/ 0.00687**

Higher lake fraction - glaciers and permafrost areas are melting.

Consistency check importance: LSM/CL orography check example

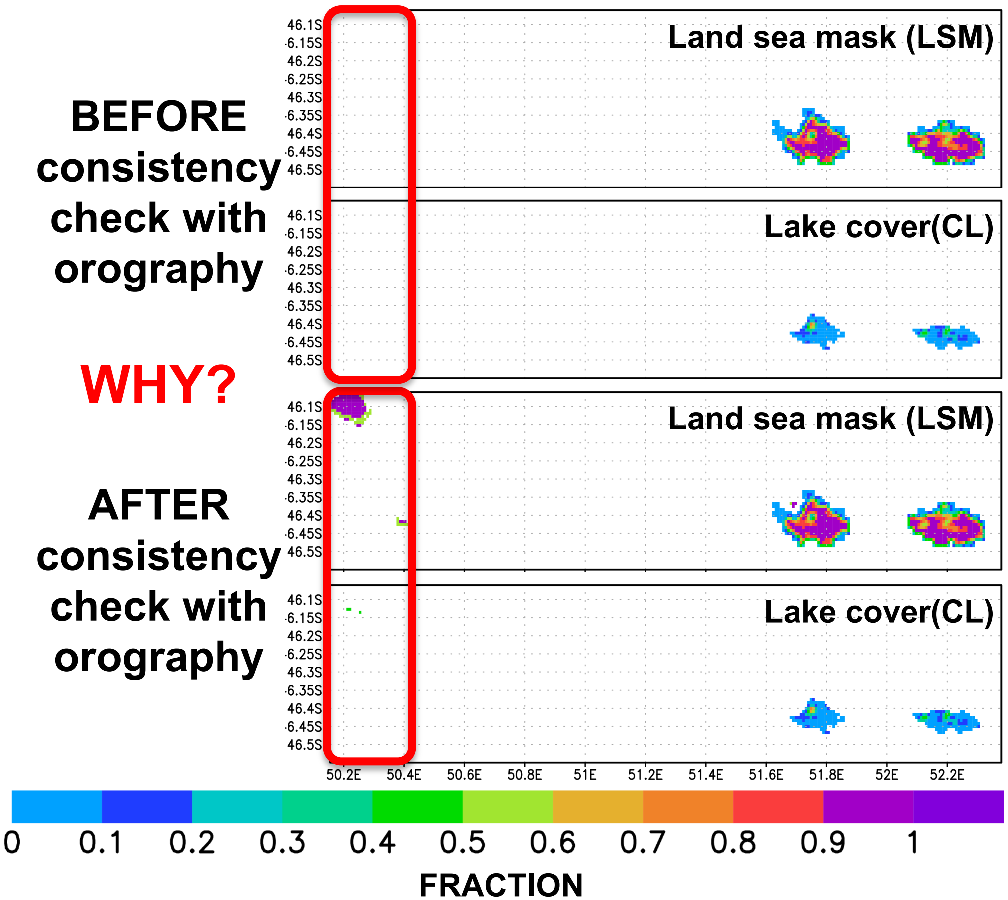
Different main **initial datasets**: (i) **Land sea mask and lake cover** - JRC Global Surface Water dataset, (ii) **Orography** – SRTM30.

Island **was missed** because of **less observations** due to:
- location (middle of the ocean),
- meteorological conditions (prevailing clouds).

BEFORE consistency check with orography

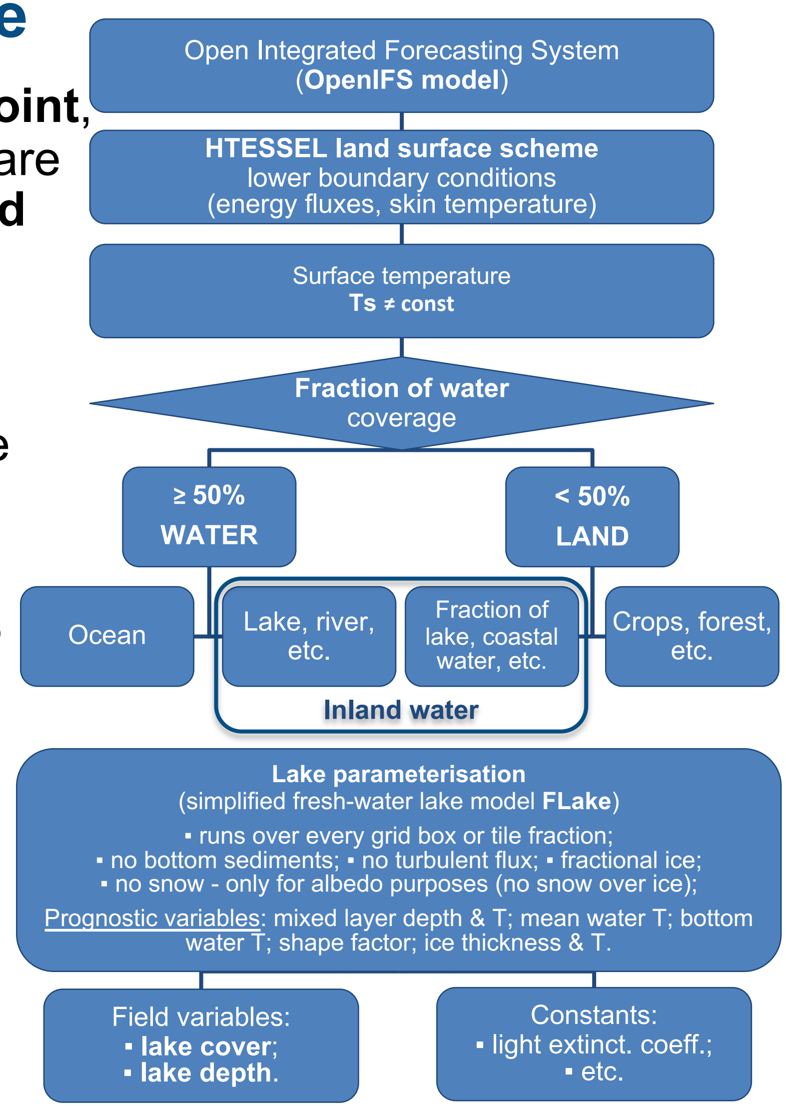
WHY?

AFTER consistency check with orography



Lake parametrization: FLake

- **FLake** model runs **on each** surface **grid-point**, whether the simulation results in this point are used later or not (resulting **fields** are **stored** in the **MARS** archive).
- FLake **runs** with **no bottom sediment** and **snow modules** (snow accumulation over ice is not allowed and snow parameters are used only for albedo purposes).
- Lake **ice** can be **fractional** within a grid-box with inland water: **10 cm** of ice = 100% of a grid-box or tile is **covered with ice**; **0 cm** of ice = 100% of the grid-box is covered by **water**; linear interpolation in between) (Manrique-Sunen et al., 2013).
- The **water balance equation** is **not included for lakes** and the lake **depth** and surface **area** are kept **constant** in time (IFS Documentation, 2017).



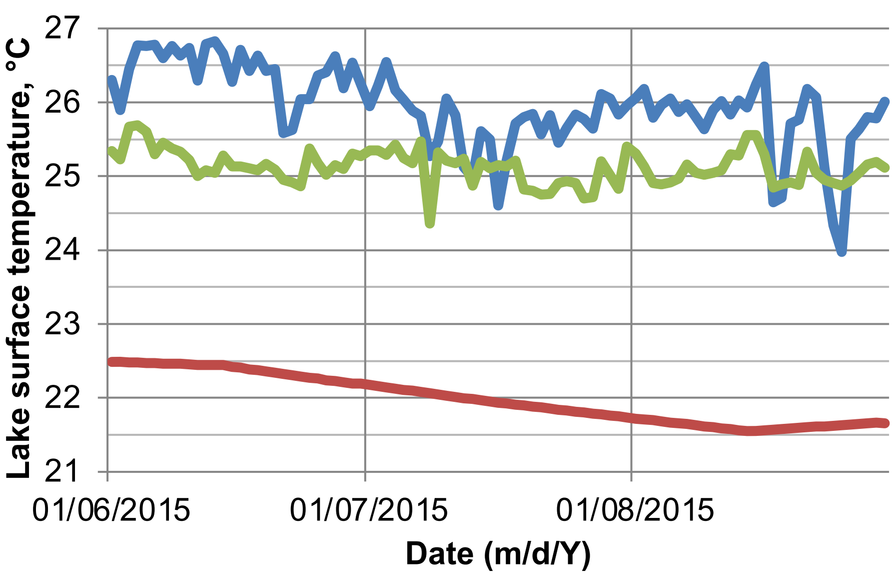
- FLake also requires input fields - **fractional** lake **cover** and lake **depth** (preferably bathymetry; accurate and up-to-date, **global & continuous**). (**no missing values!**)

Lake parametrization: impact locally on surface temperature's diurnal cycle

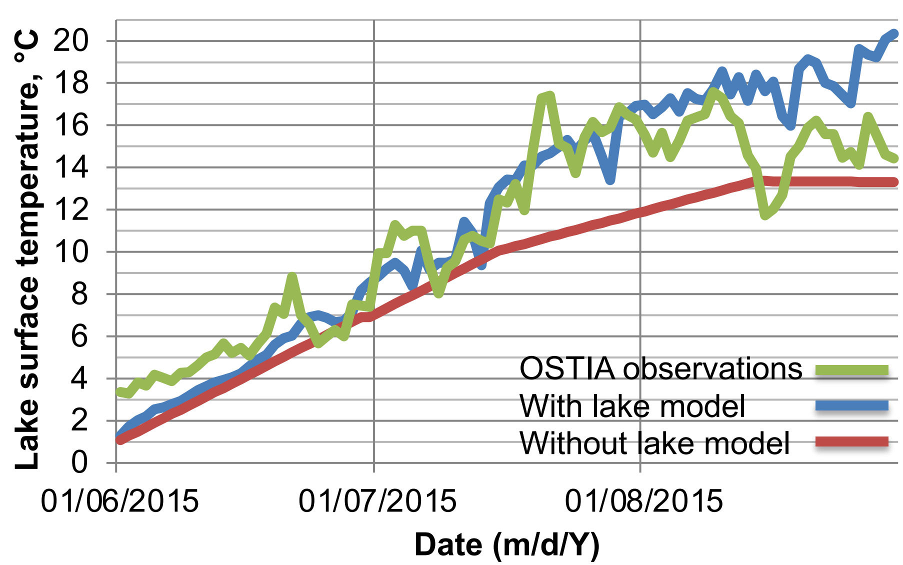
Large improvements:

- **reducing** the lake temperature **bias for big** and **deep lakes** (e.g. Lake Victoria, Great Bear, Titicaca);
- generally more **realistic** temperature **diurnal variability**.

Lake Victoria (Africa)

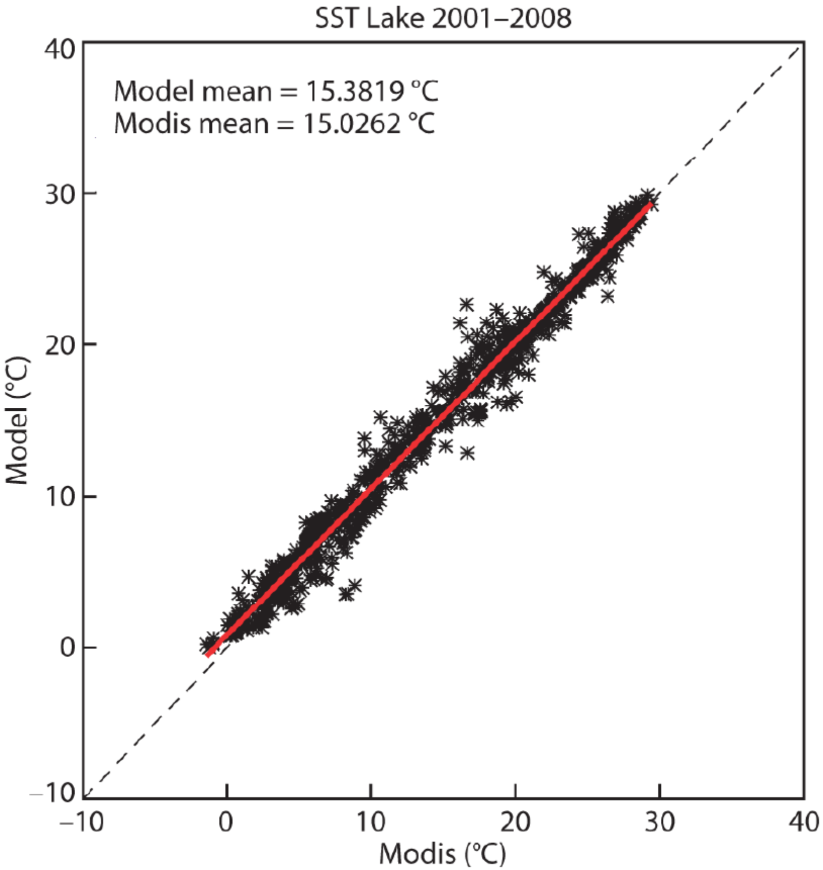


Lake Baikal (Russia)



Thanks to Gianpaolo Balsamo

Lake parametrization: impact globally on lake surface temperature



(Balsamo et al., 2012)

- **In-situ**: *MODIS* Terra/Aqua satellite global composite based on the Level 3 Mapped Thermal IR sea surface temperature product, which senses the *sea/lake water temperature*, *resolution ~4 km*.
- **Model**: *FLake* model driven by *ERA-Interim* 3-hourly atmospheric forcing, *resolution ~80 km*.
- **Period**: 2001.01.01-2008.12.31.
- **Comparison** in terms of annual mean surface water temperature values:
  - ✓ largely *unbiased* simulation over grid points where the model lake fraction is ≥ 10 %:
    - ❖ **good correlation** between **modelled** and **observed** annual mean R = 0.98;
    - ❖ **BIAS** (modelled – observed) is **reduced**, is < 0.3 K;
  - ✓ largest differences are found over Caspian sea and southern regions of the North-American Great Lakes (positive BIAS) and over Norwegian lakes (negative BIAS) → consistent with model intrinsic **limitations over deep waters**.

Thanks to Gianpaolo Balsamo

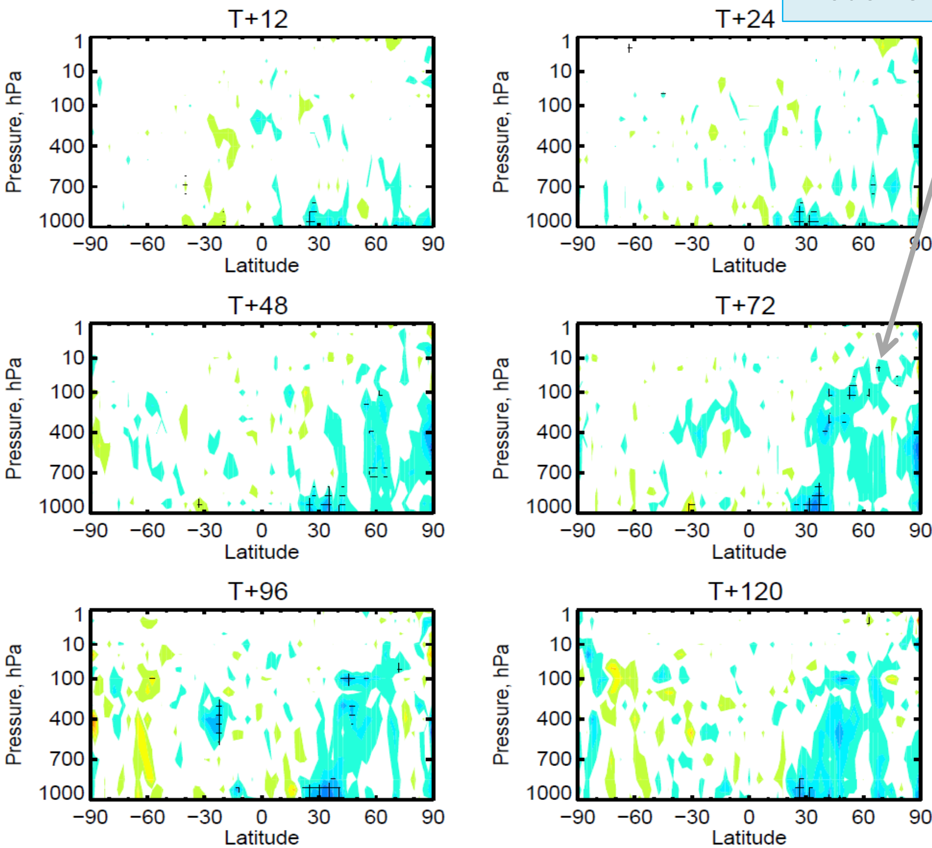
Lake parametrization: impact in NWP analysis cycles

AN cycling and initialisation: temperature scores

Propagation of the **positive impact** to **higher** model **levels** up to **day 5**!

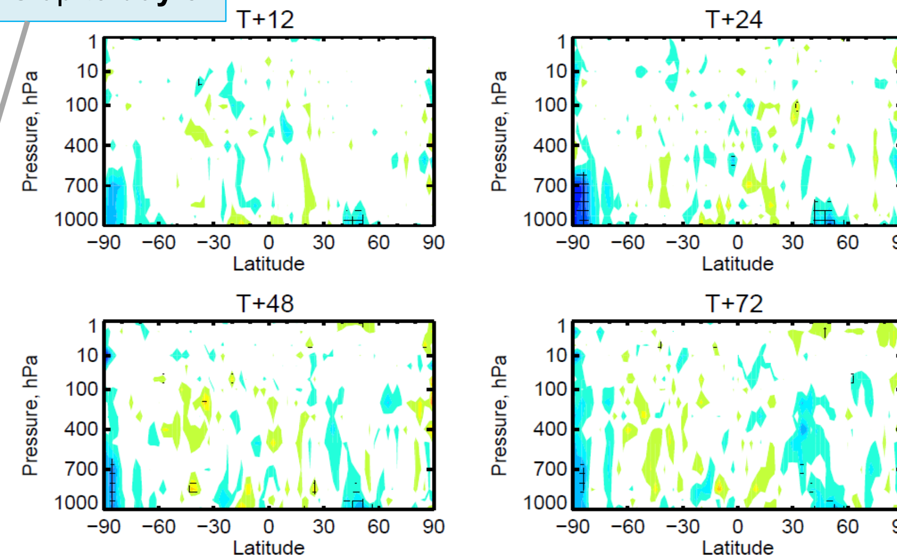
Summer experiment

15−Jun−2013 to 5−Jul−2013



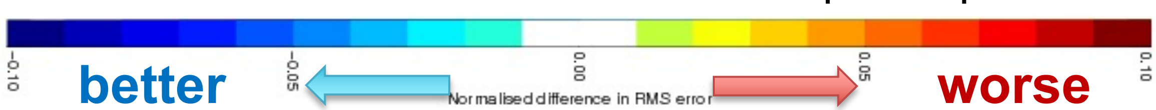
Winter experiment

1−Dec−2013 to 31−Dec−2013



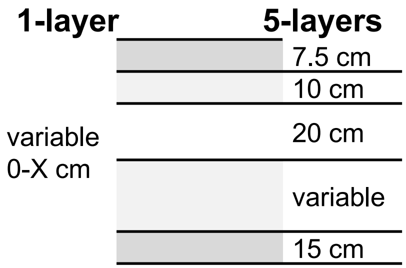
Transition period lake open water / ice covered modelling is **very challenging** and requires a **careful initialisation**.

Sea-ice is probably in a **similar situation** (predictive skill is severely affected by the lack of atmospheric predictability in winter).



Thanks to Gianpaolo Balsamo

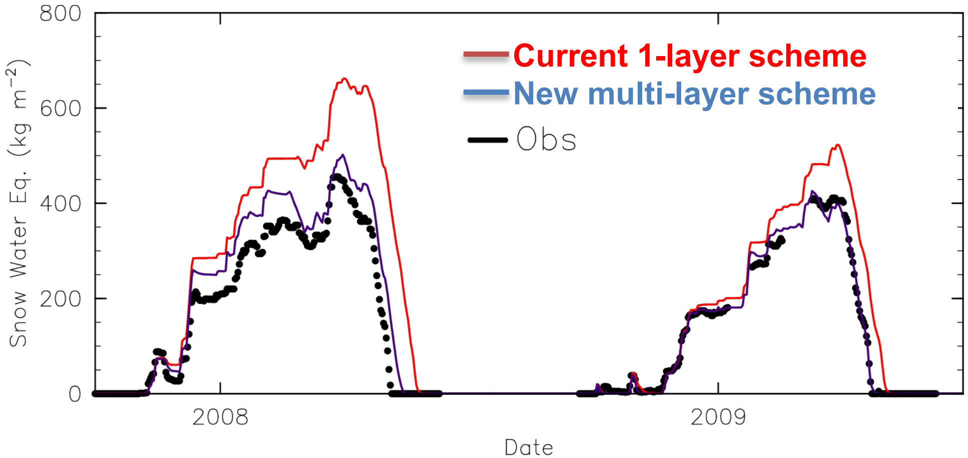
Snow parametrization: enhanced vertical resolution



The **snow temperature and density** representation (based on Arduini et al., 2019, JAMES) in a 5-layer scheme can take into account …

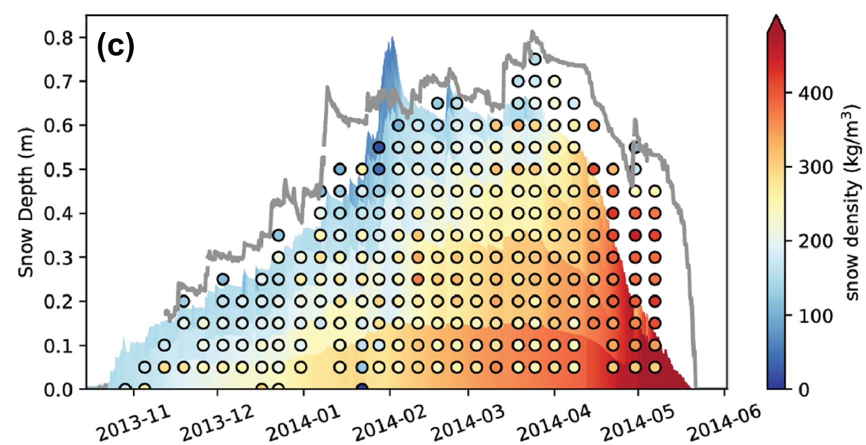
the coupling to the atmosphere and to the underlying soils with dedicated timescale that can better represent accumulation and melting.

Simulations of Snow Water Equivalent (SWE- kg m^{-2}) for the 2007/2009 winter season at Col de Porte (French Alps) comparing observations (black symbols) with current 1-layer (red) and new 5-layers (blue) snow models.



the strong vertical gradients of these quantities occurring within a deep snowpack.

Figure shows vertical profiles of **snow density** from the model (contours) and observations (dots) at Sodankyla station (Finland).



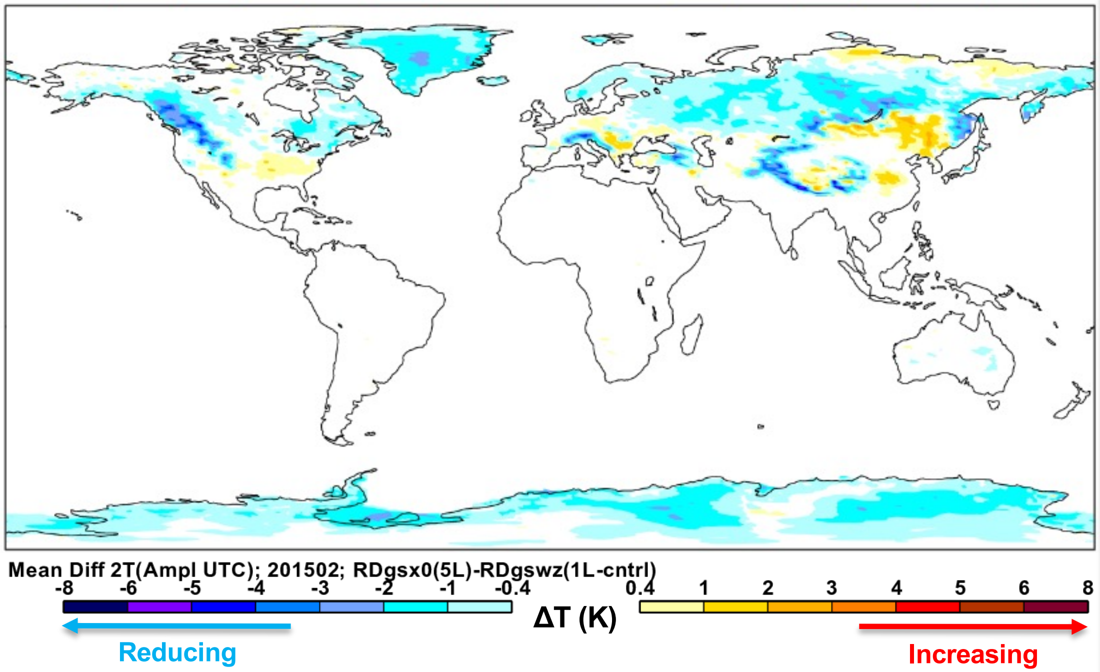
Complex density stratification (e.g. decrease of density with depth) cannot be represented – extra information on snow microstructure is needed!

Thanks to Gabriele Arduini

Snow parametrization: impact

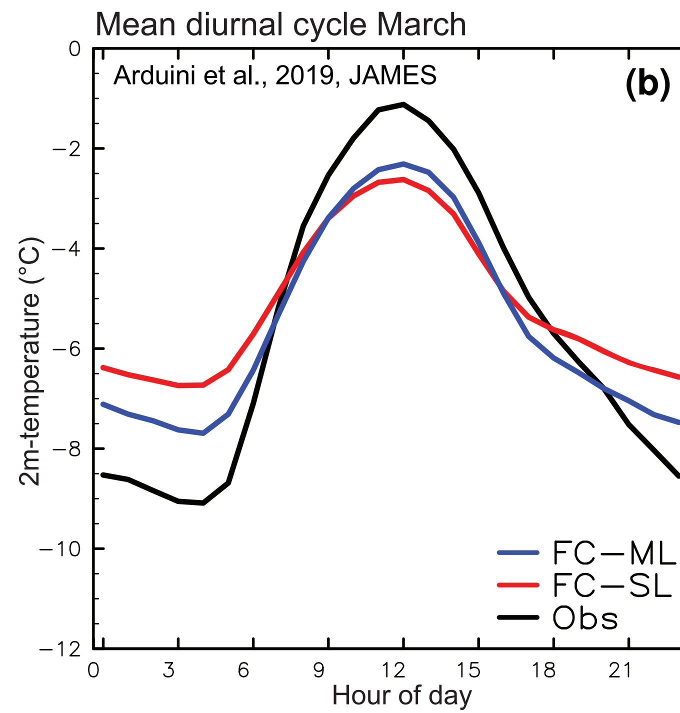
Multi-layers snow scheme impact in coupled forecasts.

Difference of the minimum 2-metre temperature for Feb 2015 between **coupled** simulations performed using the multi-layer and 1-layer snow schemes.



1-year continuous forecast initialized in Jan 2015
Upper troposphere nudged towards ERA-Interim reanalysis

Mean diurnal cycle of 2-metre temperature from observations and forecasts in **day 2** with the 1-layer and multi-layer snow schemes.



31 forecasts initialized everyday March 2017
Forecast lead time: t+27 to t+48
No data assimilation

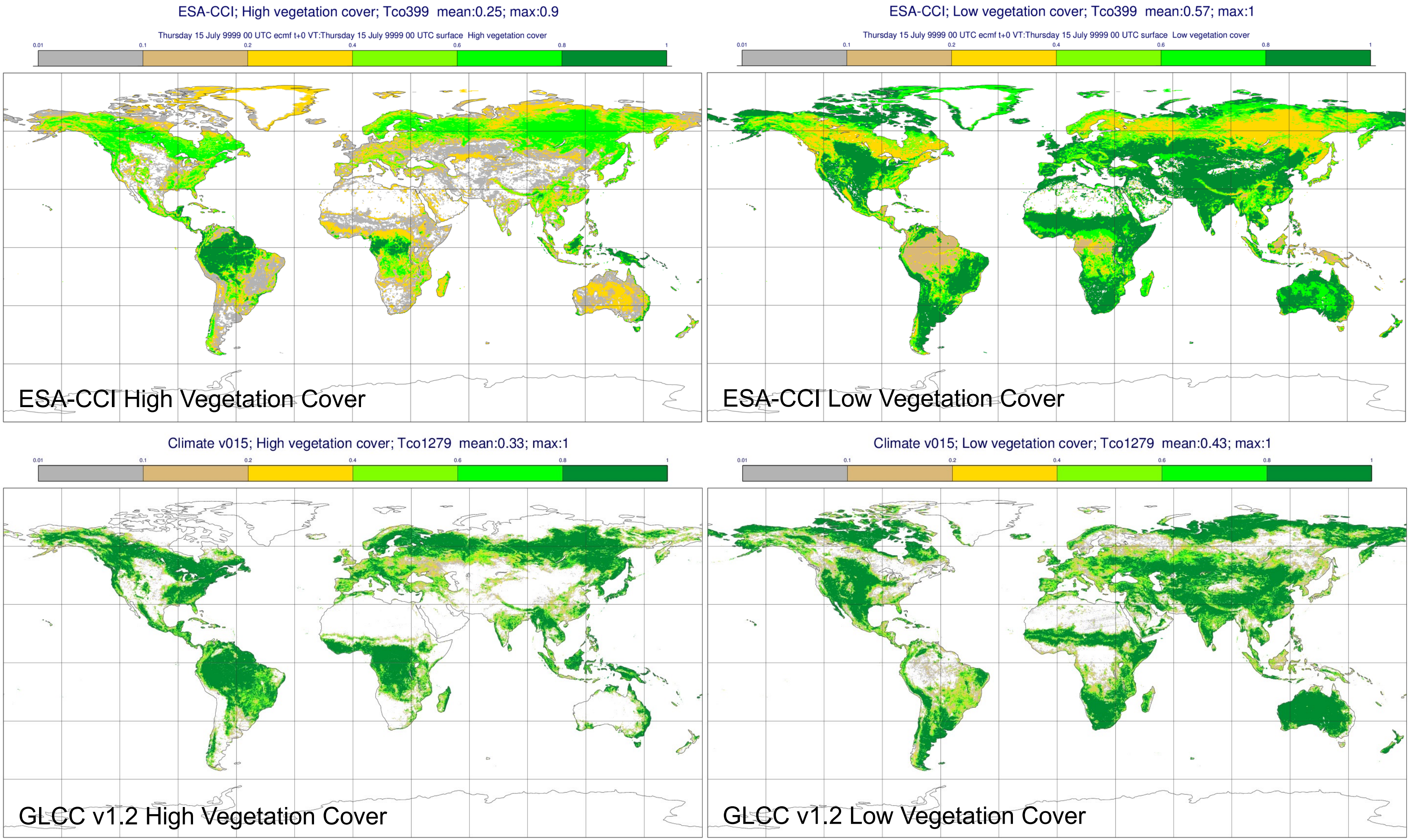
Thanks to Gabriele Arduini

MODEL cycle 49r1

- ✓ Climate fields v021
- ✓ Soil moisture update
- ✓ Snow and frozen soil parameter update
- ✓ 2 m temperature interpolation update
- ✓ Urban model
- ✓ Wetland model

ECMWF

Vegetation developments: cover based on ESA-CCI

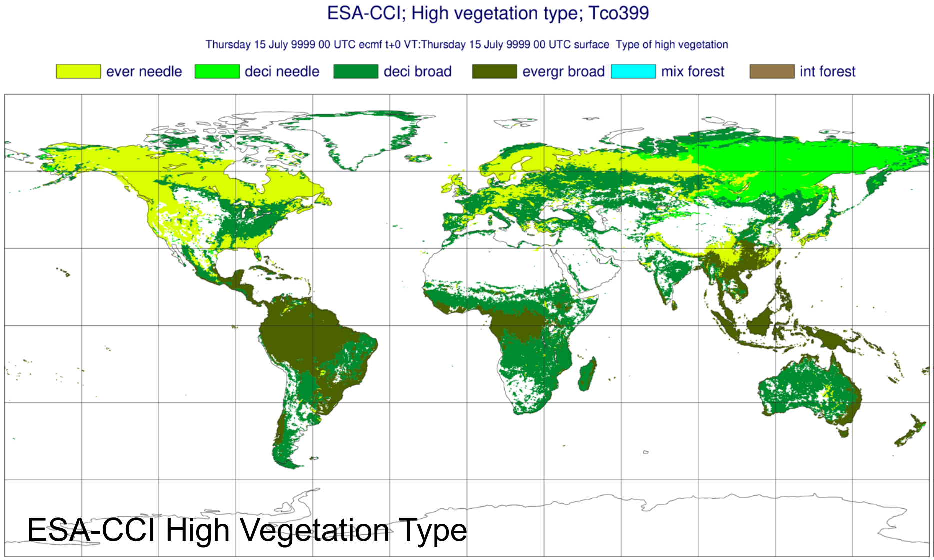


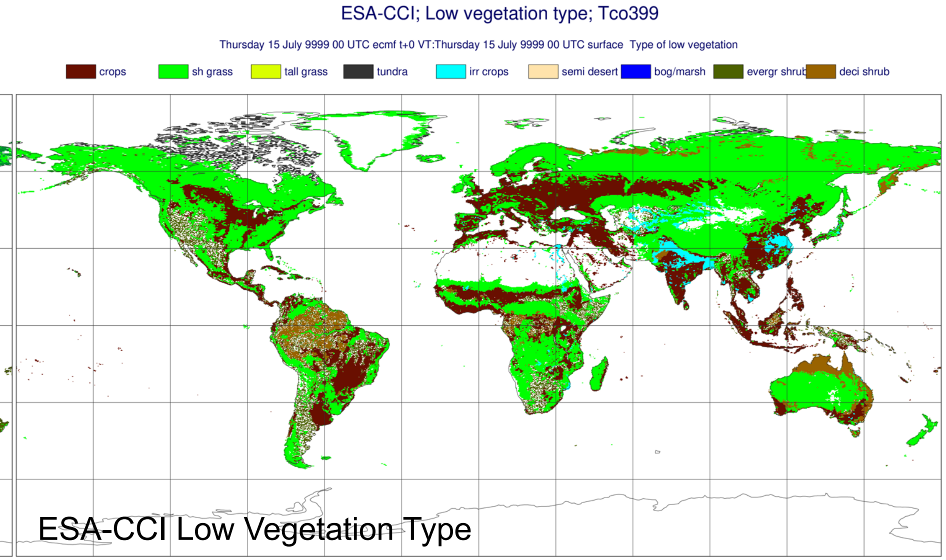
ECMWF

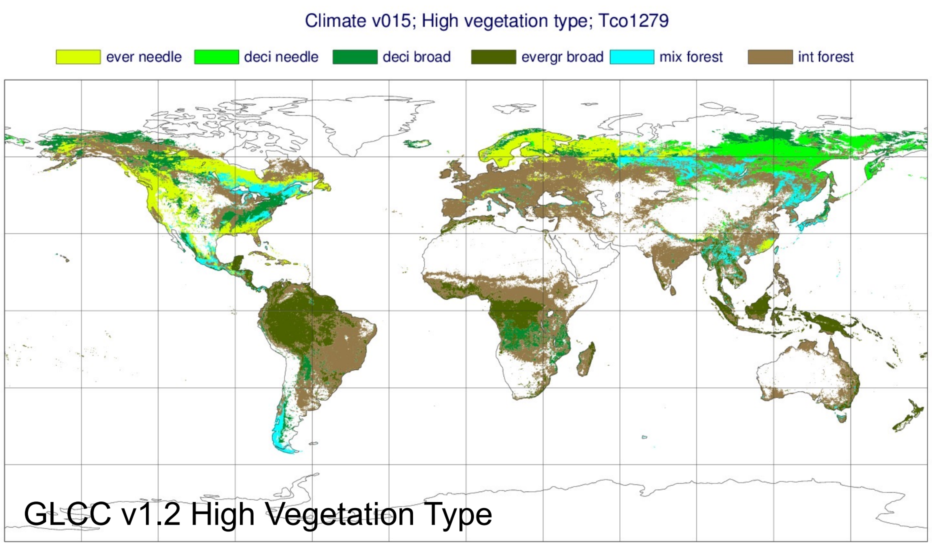
A substantial **increase in low vegetation** and **decrease in high vegetation** fraction.

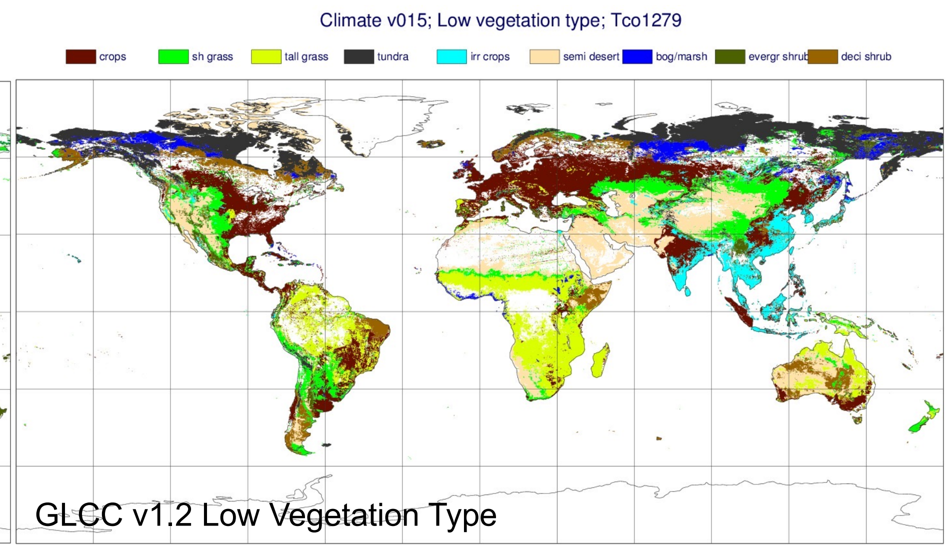
Thanks to Souhail Boussetta

Vegetation developments: type based on ESA-CCI





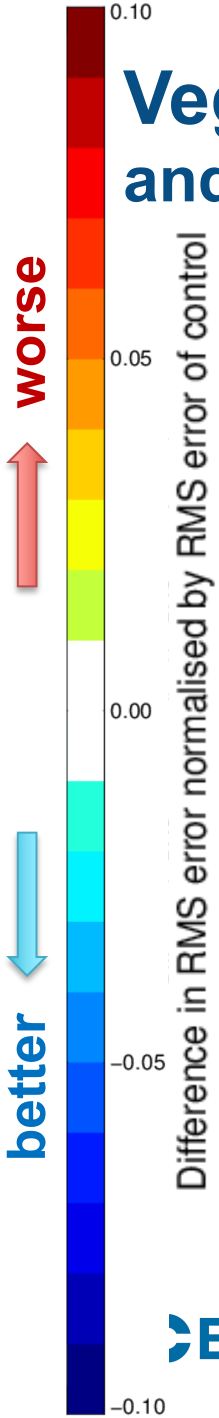




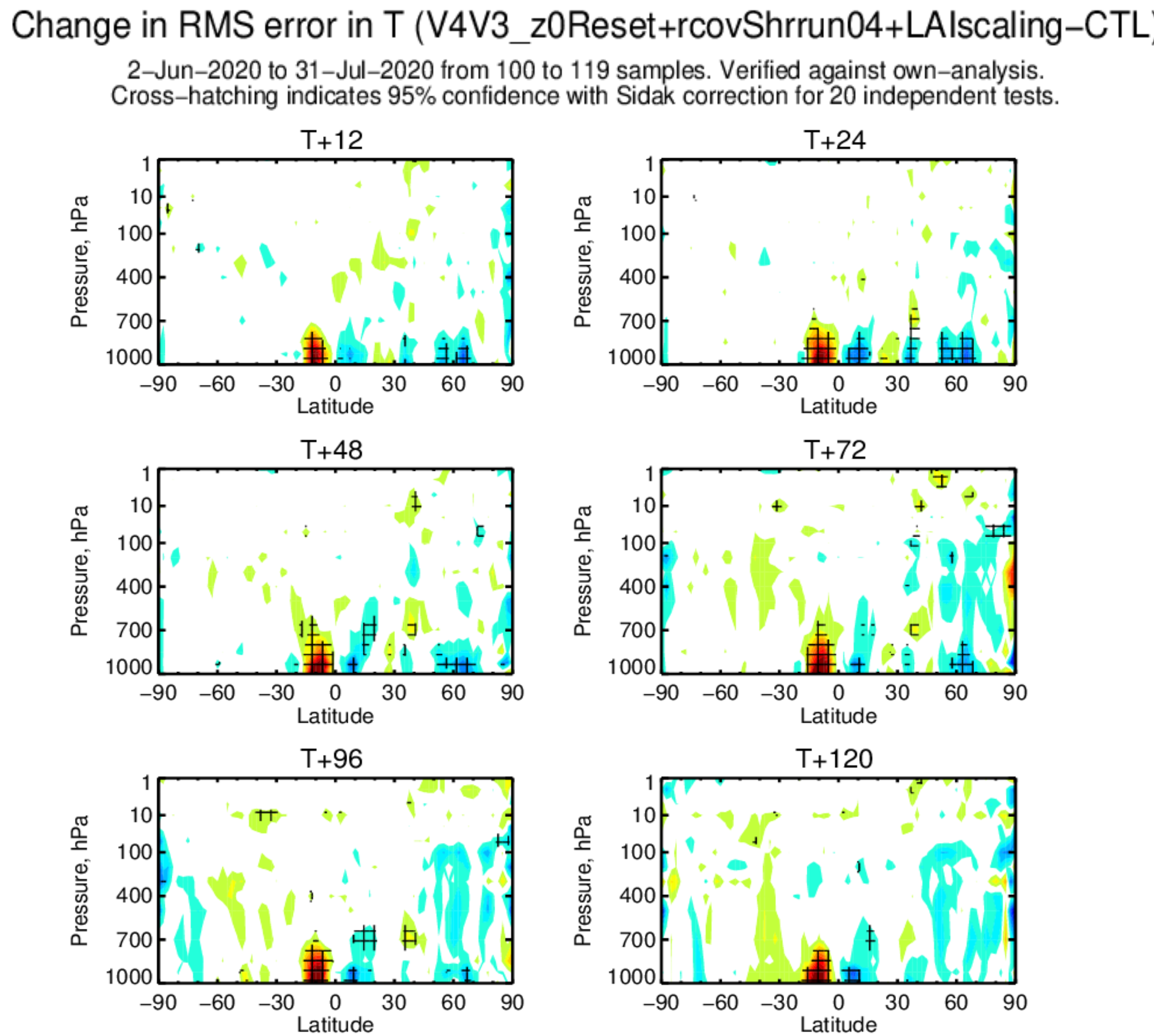
Hybrid HVT (interrupted or mixed forest) **disappear**. **Increase in grass and shrub** types with respect to crops.

==> expected **substantial impact** via (**roughness, albedo, canopy resistance**…)

Vegetation developments: impact with new maps and adjusted related model parameters

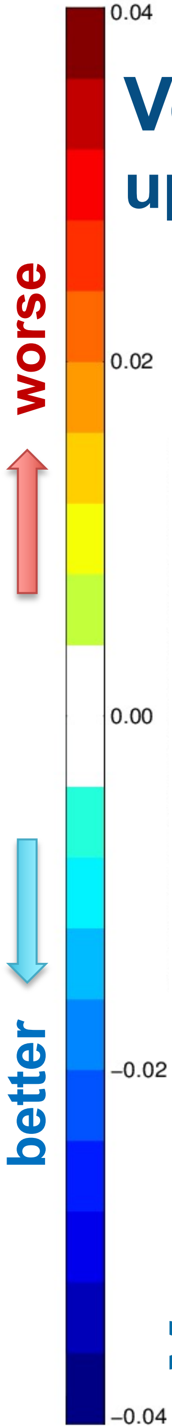


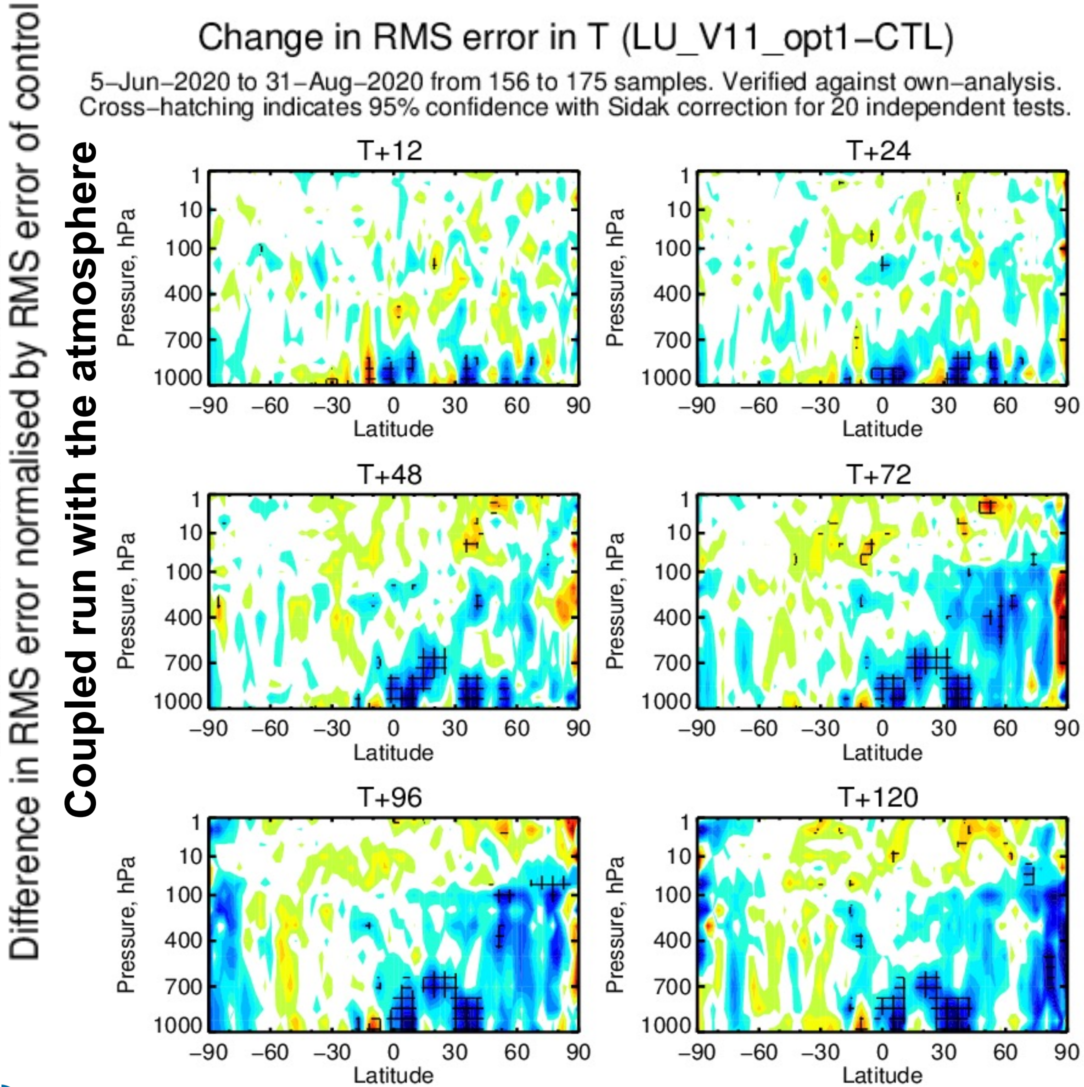
Coupled run with the atmosphere



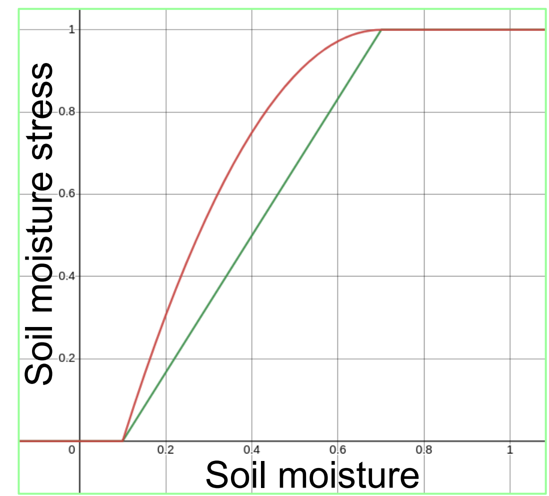
Thanks to Souhail Boussetta

Vegetation developments: impact with the updated soil moisture stress on top





Updated soil moisture stress



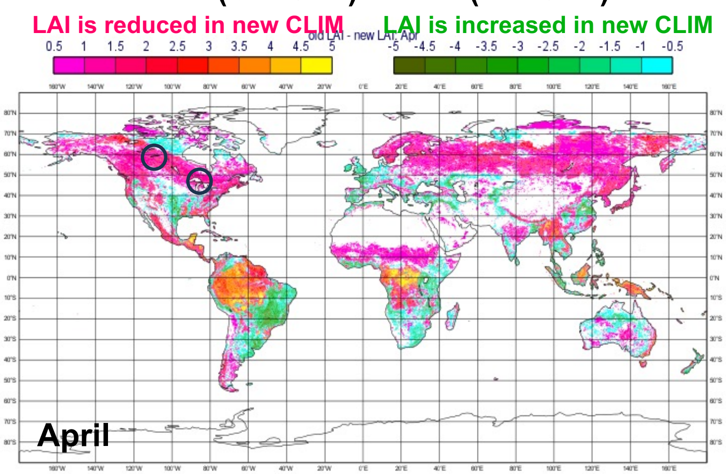
* Physically consistent with the soil matric potential.
* Allow higher evapotranspiration under drier conditions.

Thanks to Souhail Boussetta

Vegetation developments: impact on CO_2 with new Leaf Area Index climatology

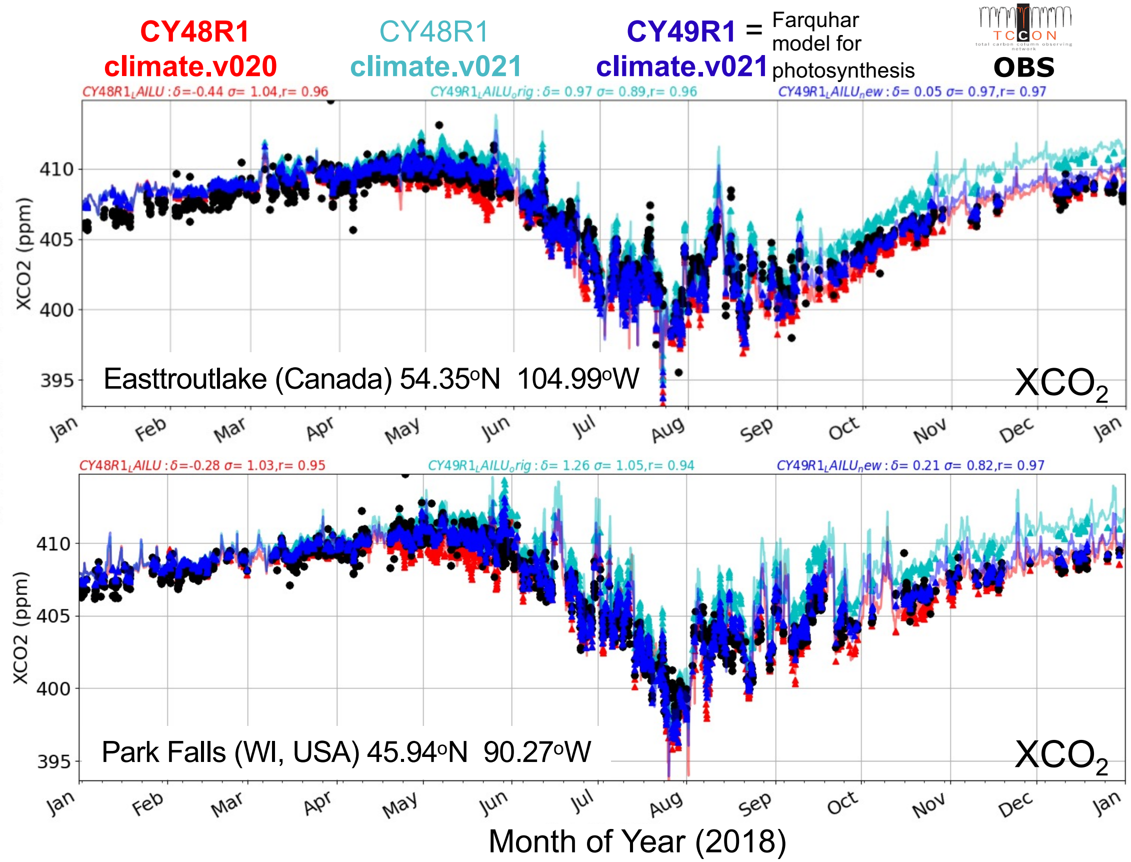
- LAI is crucial for photosynthesis uptake – seasonal cycle (phase, amplitude) are associated with overall LAI magnitude and temporal dynamics.
- New LAI monthly climatology is based on Copernicus CGLS-LAI 2010-2019.

LAI climatology
Current (CY48R1) – New (CY49R1)



Better prediction of XCO_2 with new LAI climatology and an updated photosynthesis model.

To account for inter-annual variability and feedbacks with climate forcing – need to have Near Real Time LAI.

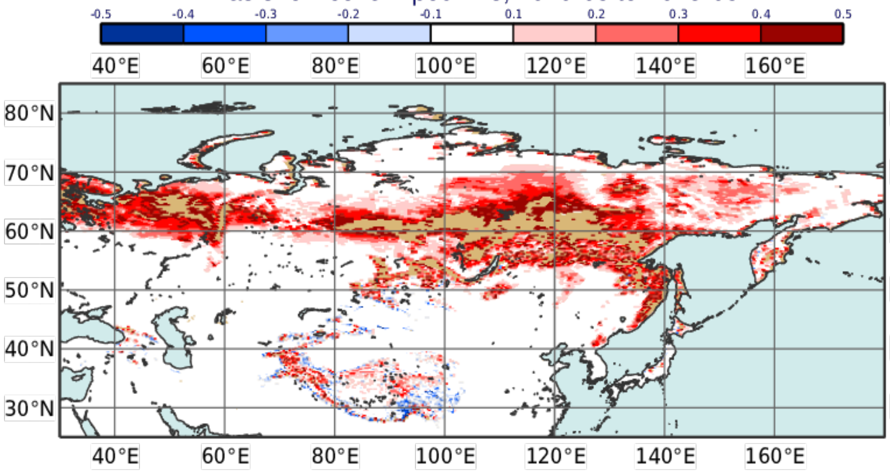


Thanks to Anna Agusti-Panareda

Snow cover impact of new land-use & new snow-forest albedo: bias difference for 2010-2018

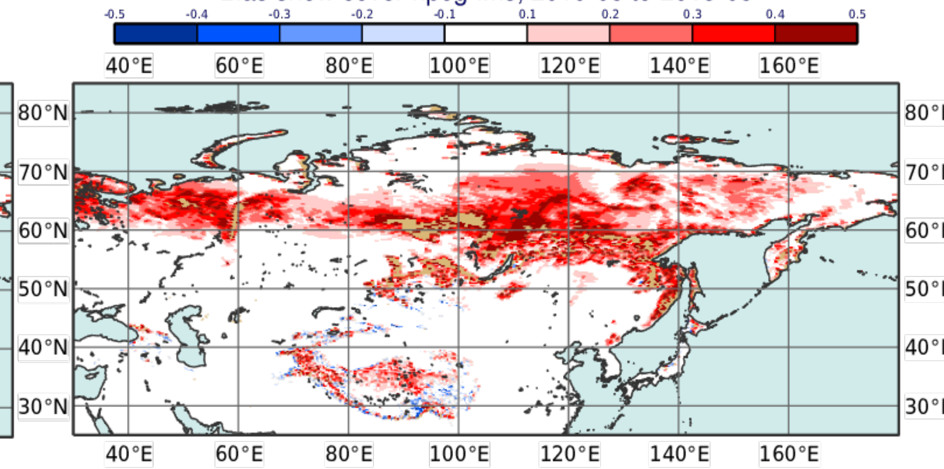
CTL (= snowML + clim.v20)

Bias snow cover hpo9-ims, 2010-05 to 2018-05



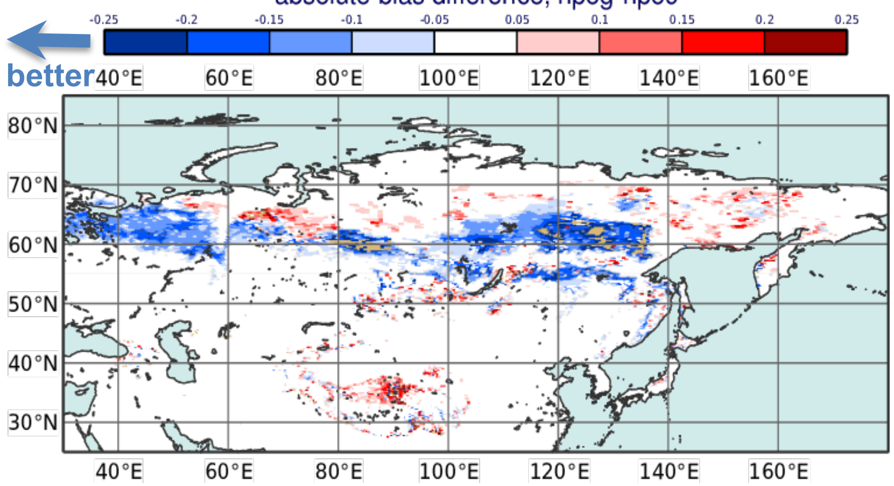
CTL + newLanduse + newAlbedo$_{SnowForest}$

Bias snow cover hpog-ims, 2010-05 to 2018-05



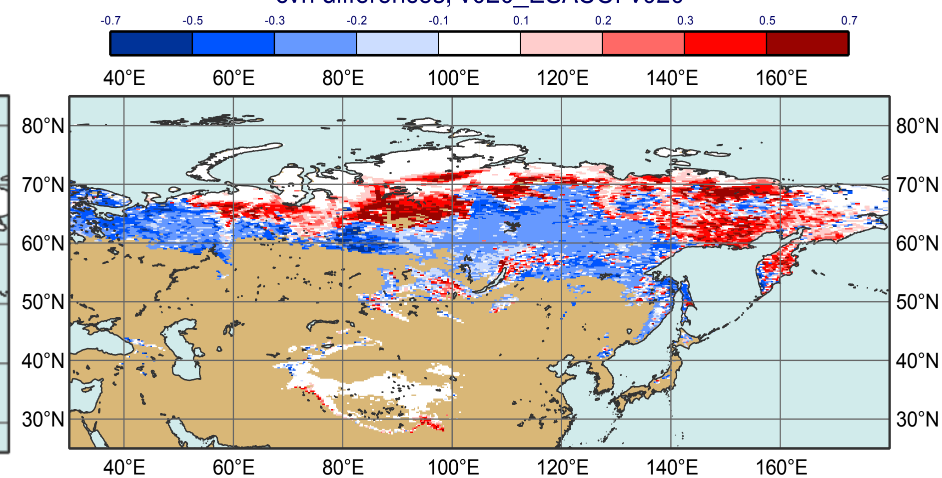
[CTL + newLanduse + newAlbedo$_{SnowForest}$] - CTL

absolute bias difference, hpog-hpo9



Forest fraction difference

cvh differences, v020_ESACCI-v020



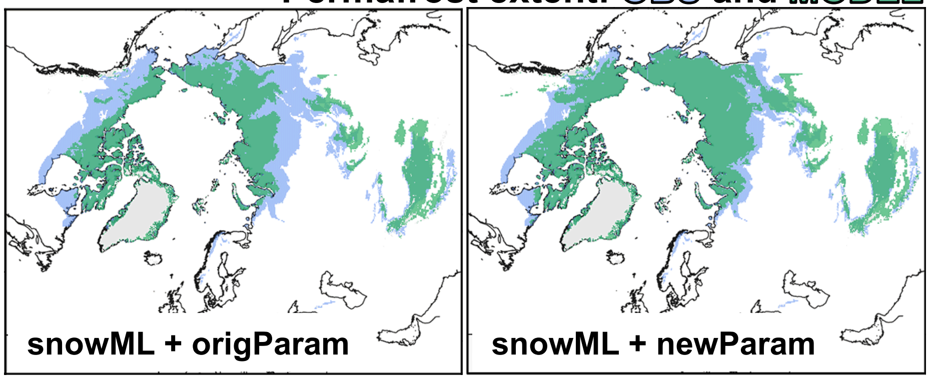
Makes use of **MODIS monthly forest** albedo **+ open-area snow-albedo**.
Avoids using **look-up table** values **for** the **snow-forest** areas **albedo**.

Thanks to Gabriele Arduini

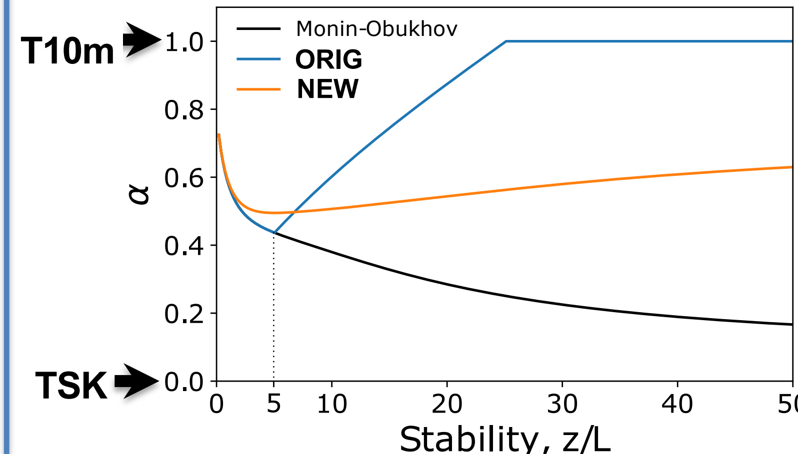
Snow and frozen soil parameter update

* Improved permafrost extent (Cao, Arduini and Zsoter, 2022).
* Improved river discharge in permafrost areas (Zsoter et al., 2022).

Permafrost extent: OBS and MODEL

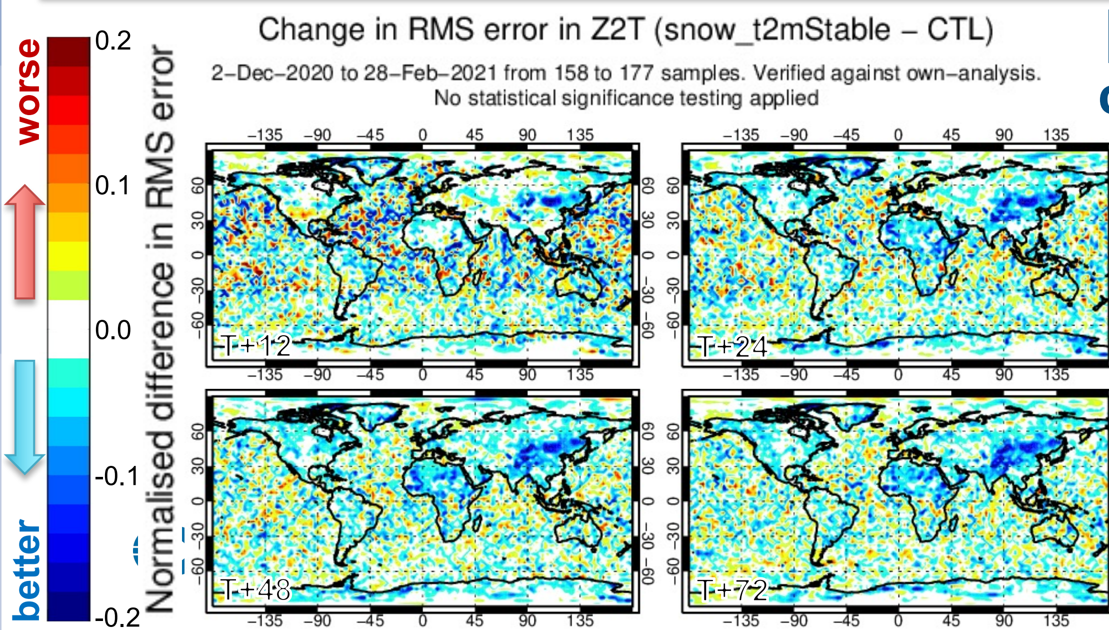


2 m temperature interpolation update

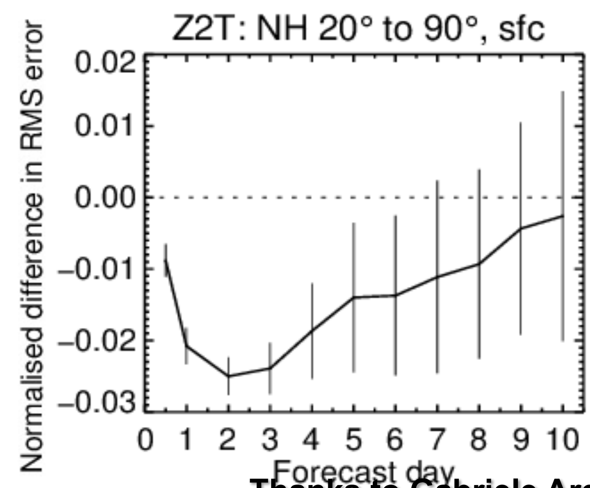


NEW function is smoother than **ORIG** especially for relatively high stability (i.e. stable conditions).

Impact combined

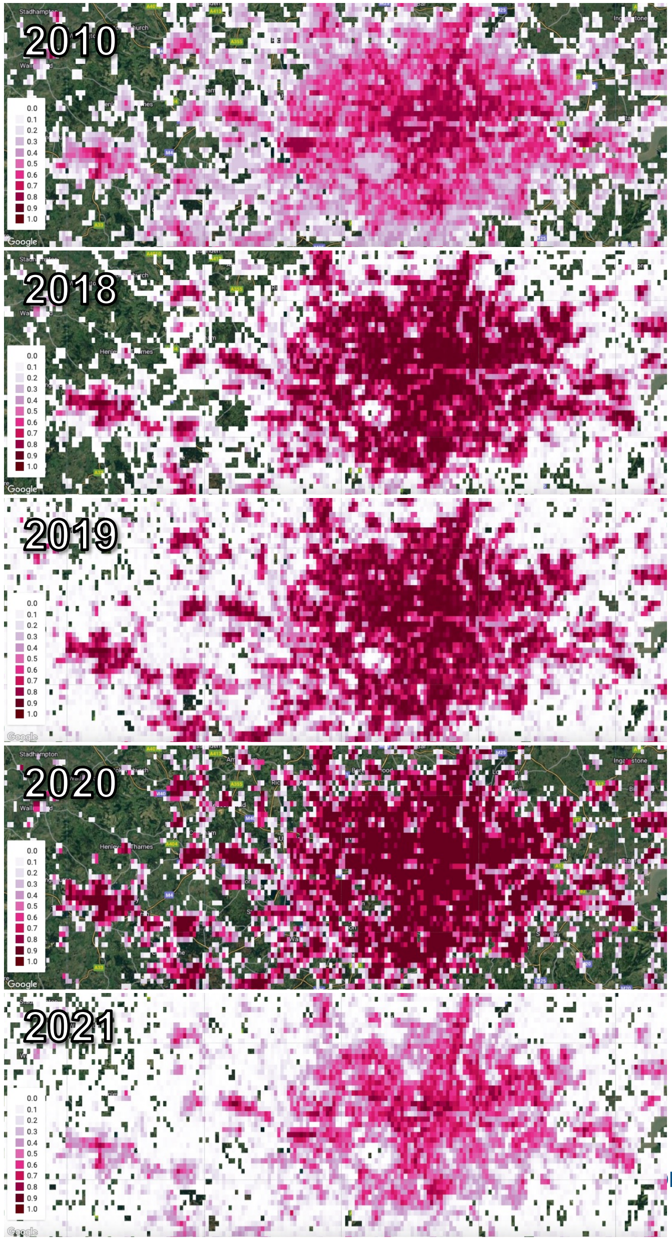


Analysis experiment: winter DJF (v11)



Thanks to Gabriele Arduini

Urban representation: London, UK



ECOCLIMAP-SG (300 m)
Sum of building, road and impervious fractions

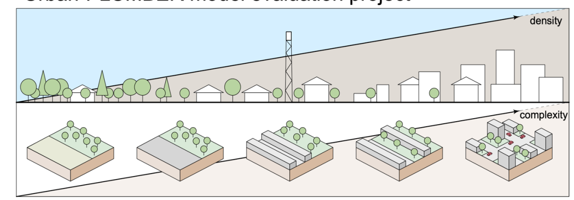
Tsinghua (30 m)
Impervious surface fraction

Copernicus Global Land Cover: **CGLS**-LC100, v3 (100 m)
Urban/ built up (i.e. buildings and other man-made structures) fraction

ESA CCI Land Cover (300 m)
Urban areas fraction

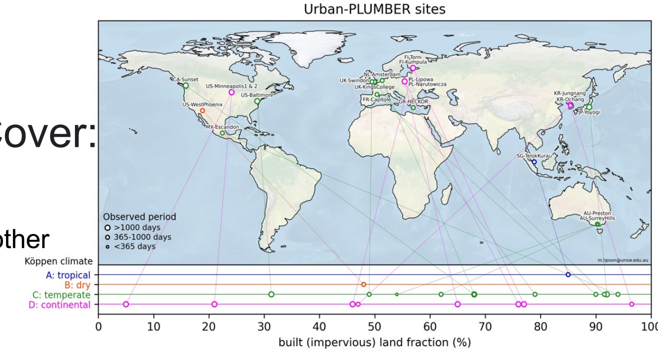
World Cover (10 m)
Built-up fraction

Urban-PLUMBER model evaluation project



Urban-PLUMBER collected **morphological information** for **20 cities** globally.

Urban-PLUMBER sites

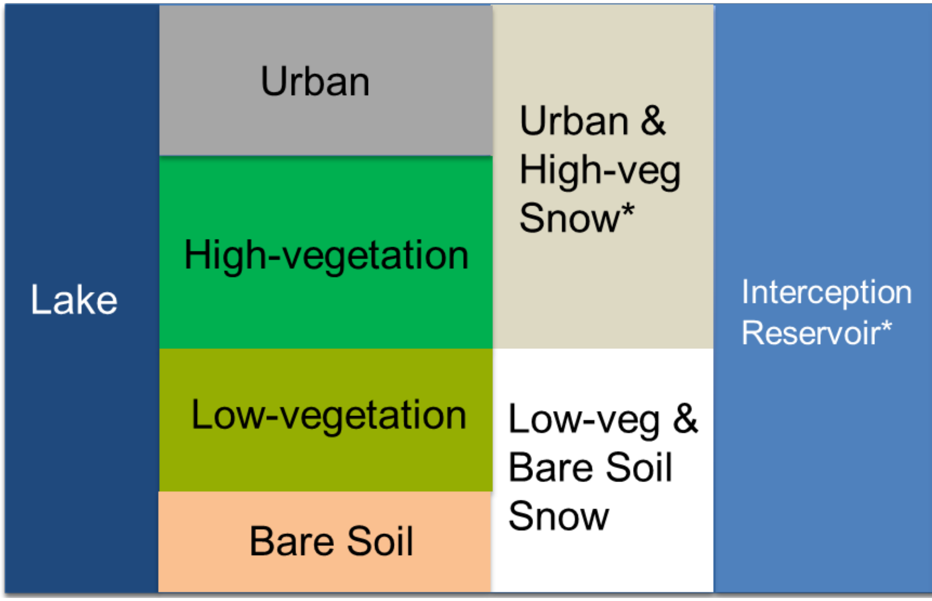


Errors aggregated globally.
[GlobalDataset – PLUMBER]

Global dataset	Year	BIAS	MAE	RMSE
ECOCLIMAP-SG	2010	-0.008	0.151	0.199
Tsinghua	2018	0.183	0.203	0.245
Copernicus CGLS	2019	0.199	0.211	0.249
ESACCI-LC	2020	0.199	0.206	0.254
WorldCover	**2021**	**0.058**	**0.119**	**0.147**

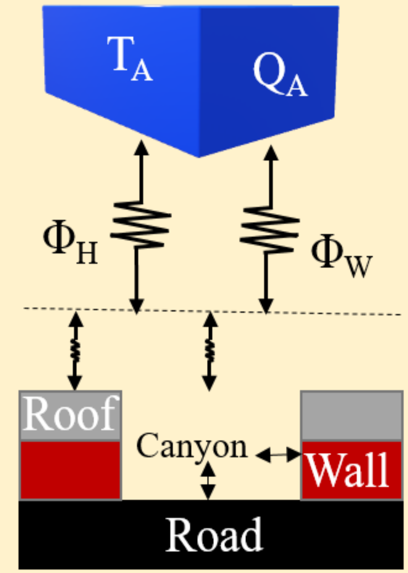
Averaged from native grid to regular 1 km grid.

Urban parametrization at ECMWF



Single Layer Canopy

- Basic assumption of urban geometry e.g. infinite canyon.
- Considers fluxes from multiple surfaces.
- Shadowing and roughness lengths computed.



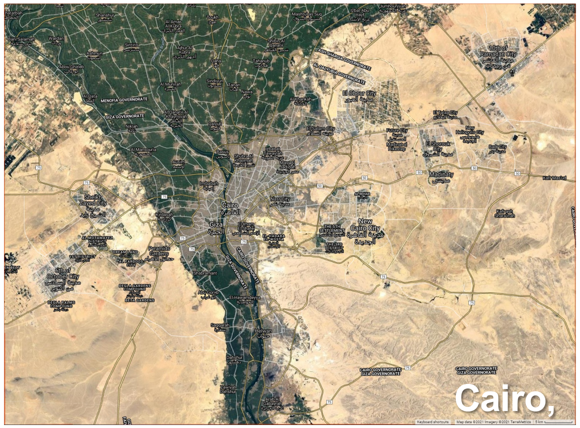
Proposed scheme based on previous studies (Harman *et al.*, 2004; Porson *et al.*, 2010; Oleson *et al.*, 2008)

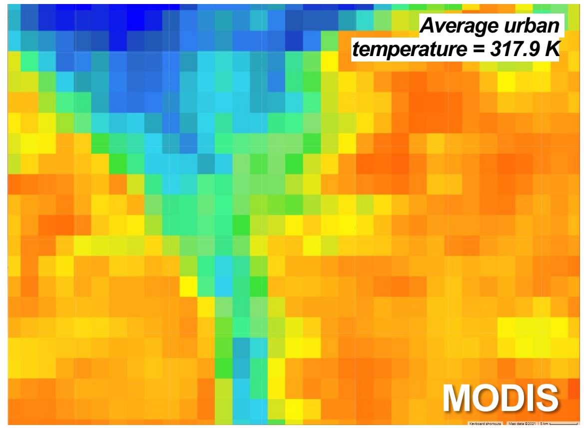
- ✓ **Infinite canyon assumption** with global fixed heights/aspect-ratio/road-building-ratio **influences radiation** (accounting for geometry) and **surface roughness length** (not accounting for geometry).
- ✓ Different surface types (i.e. **roof, wall, road**) are **considered**.
- ✓ Hydrology and **run-off** treated as a **fixed value** to represent **drainage**.
- ✓ **Moisture** storage is **reduced** to low values with **high run-off** and **limited soil penetration**.
- ✓ **Urban heat capacity** and **thermal conductivity** formed as a hybrid **with** the **upper-most soil** layer.

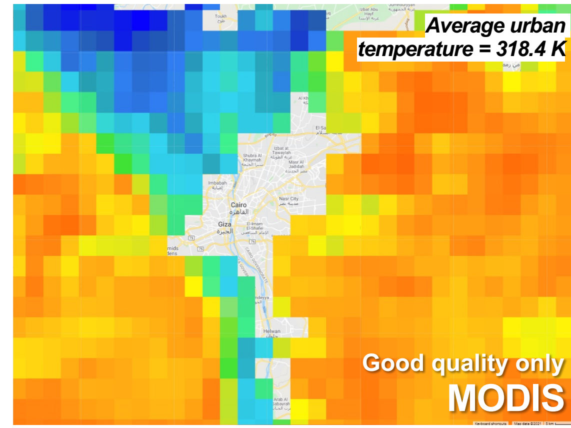
For more information see: McNorton et al., 2021

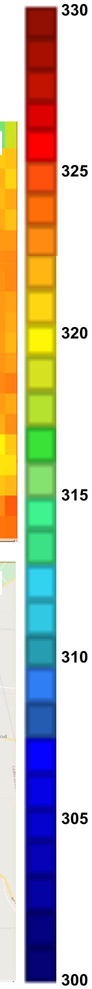
Thanks to Joe McNorton

Urban skin temperature: regional validation against MODIS AquaDay data <u>*01/07/2018*</u>





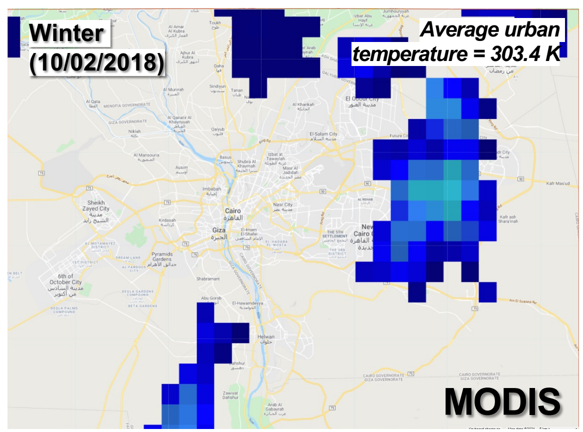


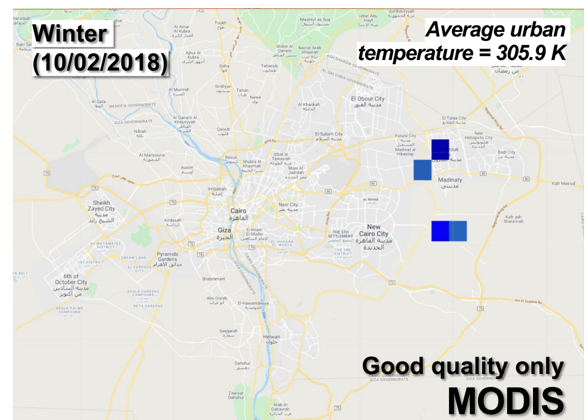


For IFS model skin temperature verification MODIS AquaDay land surface temperature (LST) is used: **all** available data, only **good** quality data (average LST **error ≤ 1K**).

Often **over big urban** areas MODIS data is **not good** quality.

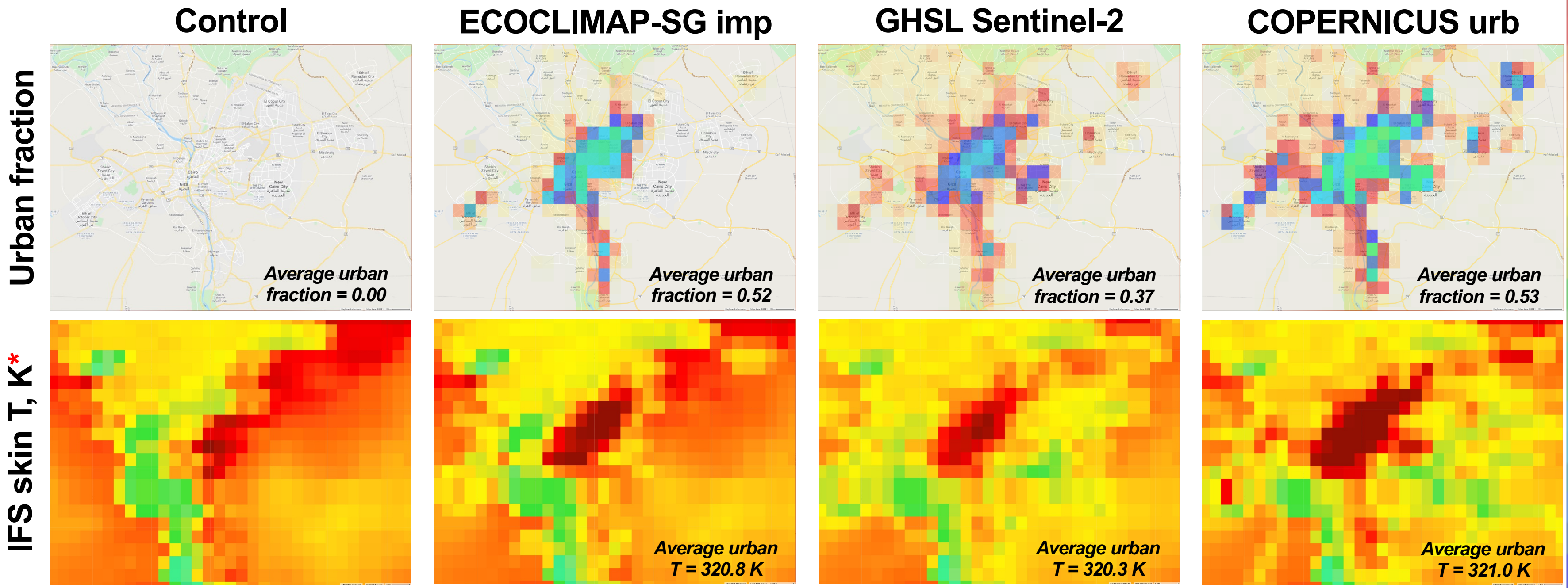
MODIS has **better coverage** during **summer** than winter.

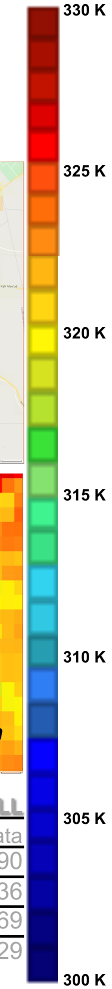




For comparison IFS model data includes **only** model **land** grid-cells **masked** with **MODIS available** data.

Urban skin temperature: regional validation against MODIS AquaDay data *01/07/2018*

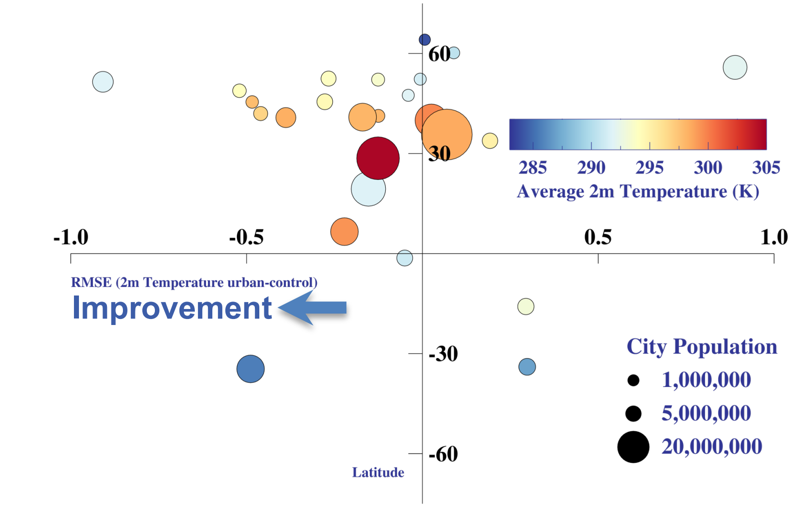


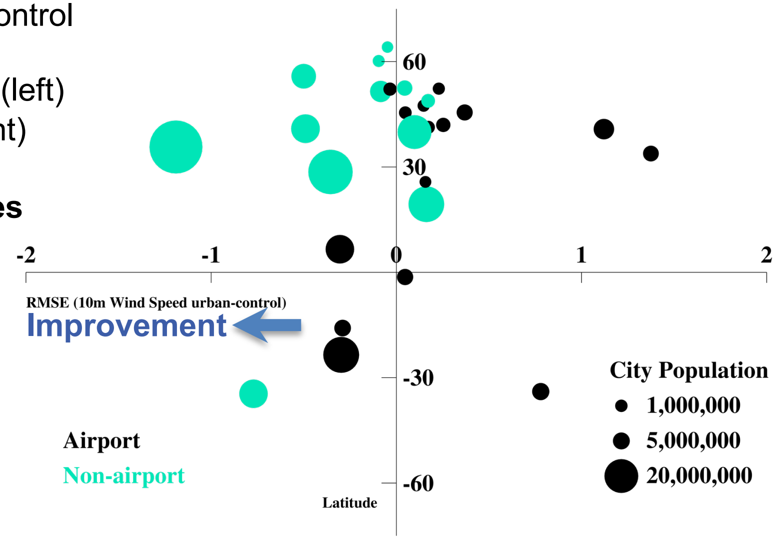


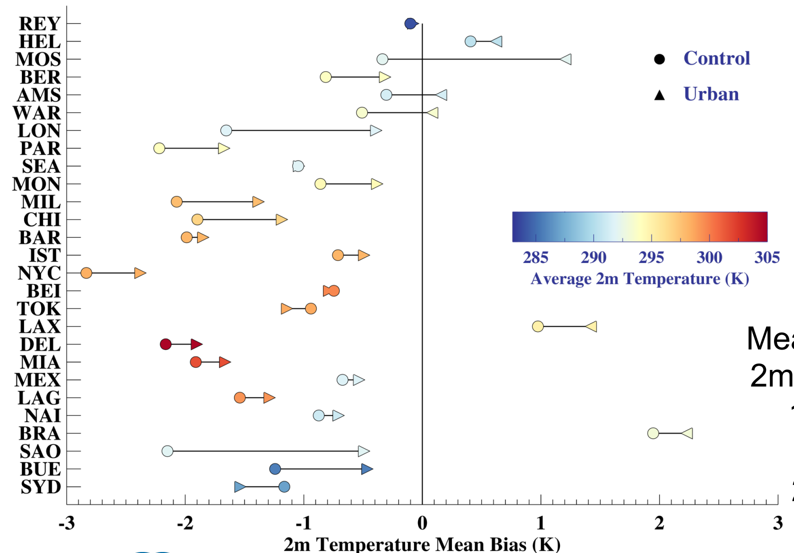
MODIS	Control GOOD	Control ALL	ECOCLIMAP-SG imp GOOD	ECOCLIMAP-SG imp GOOD	ECOCLIMAP-SG imp ALL	ECOCLIMAP-SG imp ALL	GHSL Sentinel-2 GOOD	GHSL Sentinel-2 GOOD	GHSL Sentinel-2 ALL	GHSL Sentinel-2 ALL	COPERNICUS urb GOOD	COPERNICUS urb GOOD	COPERNICUS urb ALL	COPERNICUS urb ALL
Cover	max	max	max	data	max	data	max	data	max	data	max	data	max	data
COUNT	496	556	496	186	556	245	496	453	556	513	496	430	556	490
BIAS	3.27	3.71	2.65	4.88	3.36	5.96	1.55	**1.69**	2.29	2.47	1.91	2.25	2.92	3.36
MAE	4.08	4.44	**3.73**	5.66	4.32	6.54	4.04	**4.36**	4.50	4.82	4.62	4.92	5.33	5.69
RMSE	5.58	5.88	**5.27**	6.95	6.03	7.93	5.48	**5.73**	6.00	6.24	6.02	6.30	6.97	7.29

Urban parametrization: impact on 2 m temperature and 10 m wind

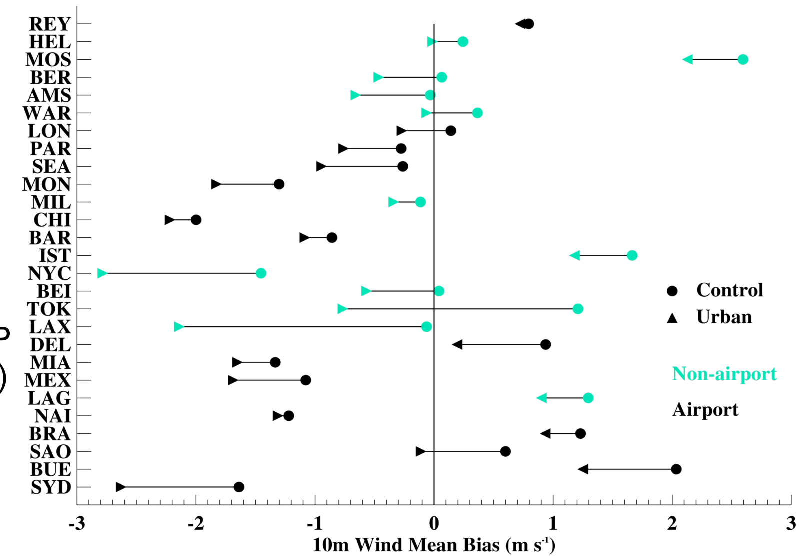
ΔRMSE Urban-Control
vs SYNOP
2m Temperature (left)
10m wind (right)
JJA 2018
27 Urban Sites







Mean Bias vs SYNOP
2m Temperature (left)
10m wind (right)
JJA 2018
27 Urban Sites



For more information see: McNorton et al., 2023

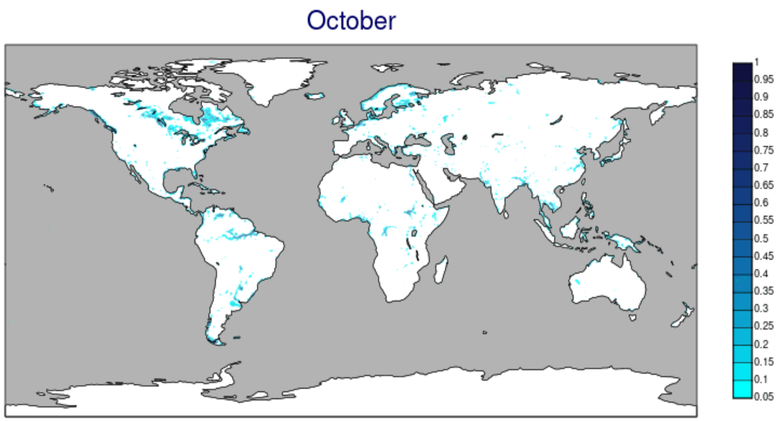
Thanks to Joe McNorton

Wetland parametrization at ECMWF (CAMS2-52a)

CH_4 wetland model is a simple parametrization from CAMS41 based on:

- Temperature (Q_{10} function : 2.337 and soil Temperature : T)
- Proxy for substrate (PFT dependent soil respiration : Re0)
- Wetland fraction (f_{wet} 0-1)
- Fluxes are globally scaled using a global methanogensis rate (S)

$$f_{CH_4} = S \cdot f_{wet} \cdot \mathrm{Re0} \cdot q_{10}^{\frac{T-25}{10}}$$

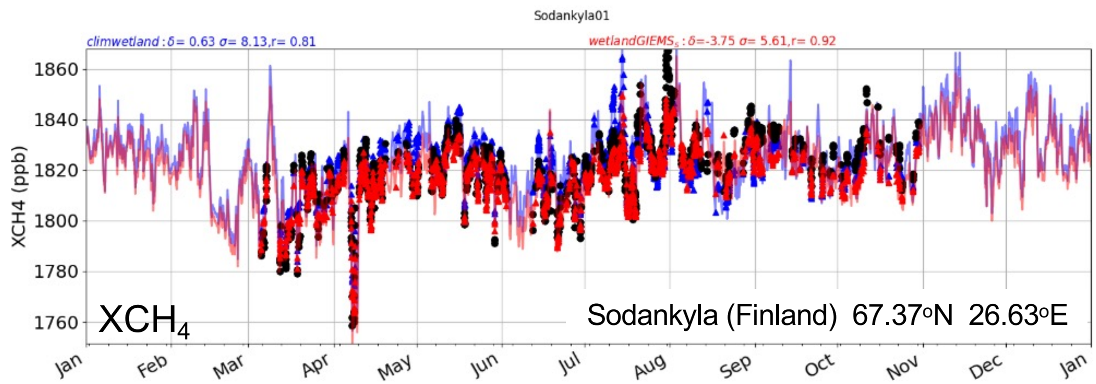


* Use of dynamic **inundation** maps (CAMA-Flood model) and GIEMS satellite product of **wetland** extend in NRT (new CAMS contract).
* Optimization of *s* factor with TROPOMI satellite data in IFS flux inversion system.

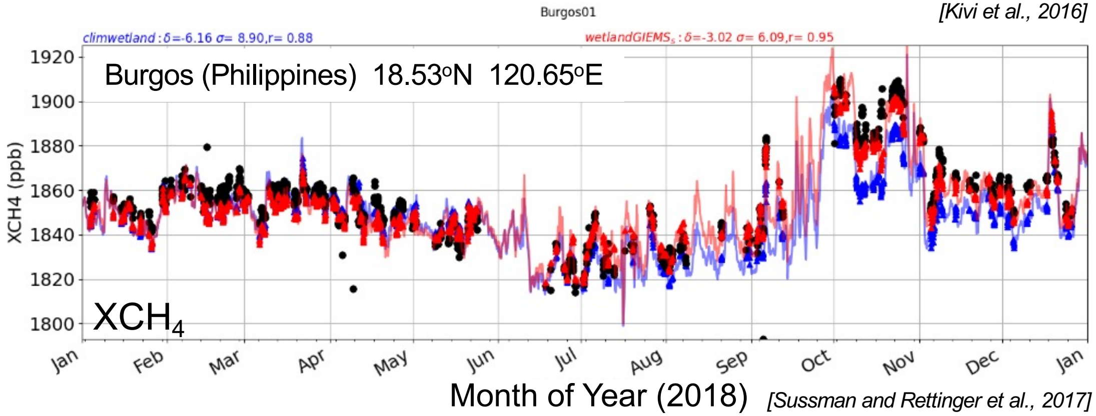
Climatology
LPJ-WHyMe
Inversion
(Spanhi et al., 2011)

IFS wetland model
(GIEMS+CaMaFlood)
(Pringent et al. 2007, Yamazaki et al. 2014)

TCCON OBS



[Kivi et al., 2016]



[Sussman and Rettinger et al., 2017]

Developments from CAMS41 and CAMS52a (V. Bastrikov, P. Peylin, F. Maignan, C. Pringent, A.Agusti-Panareda) and ECMWF CP team (Joe McNorton, Margarita Choulga, Gianpaolo Balsamo)

Thanks to Anna Agusti-Panareda

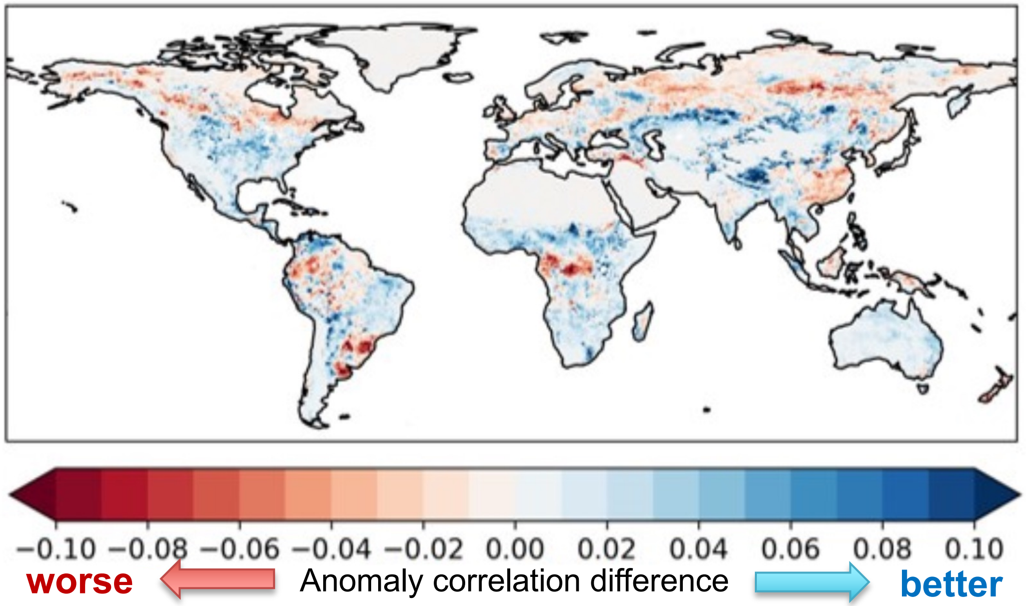
MODEL cycle FUTURE
+ ongoing developments

- ✓ Time-varying vegetation
- ✓ Dynamic Leaf Area Index
- ✓ Irrigation model
- ✓ Time-varying water
- ✓ Climate fields vFUTURE
- ✓ Soil vertical resolution increase
- ✓ Residential CO_2 emissions
- ✓ Fire model

ECMWF

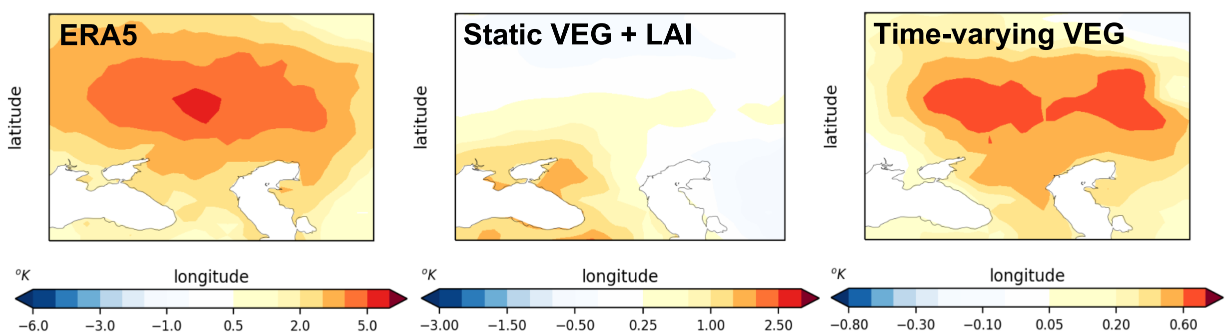
Time-varying vegetation: impact

Vegetation interannual variability is based on LULC ESA-CCI (yearly) and CGLS-LAI (monthly) for 1993-2019.



Anomaly correlation difference with regards to DOLCE Flux product of the Evaporation (Time varying LAI – static LAI) for 1993-2019.

Blue areas indicate improvement (better correlation), red areas – still some issues over boreal forest.



Russian heat wave of summer 2010

(Thanks to Magdalena Alonso Balmaseda, Retish Senan)

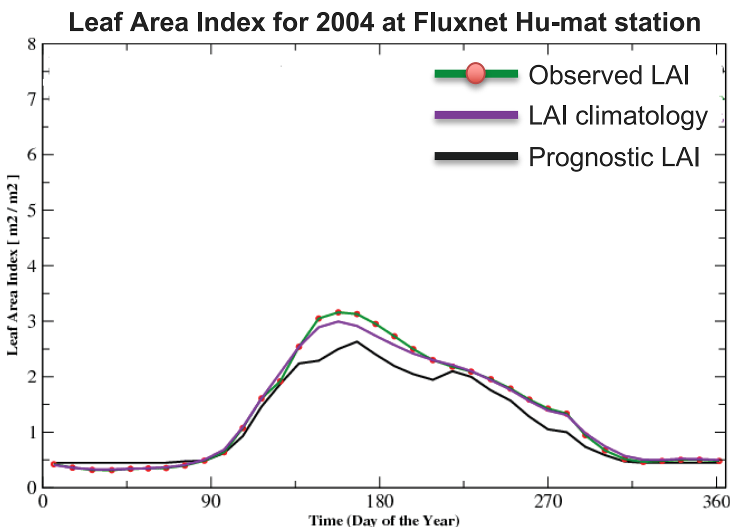
Consistent impact on extreme 2 m temperature in seasonal forecasts.

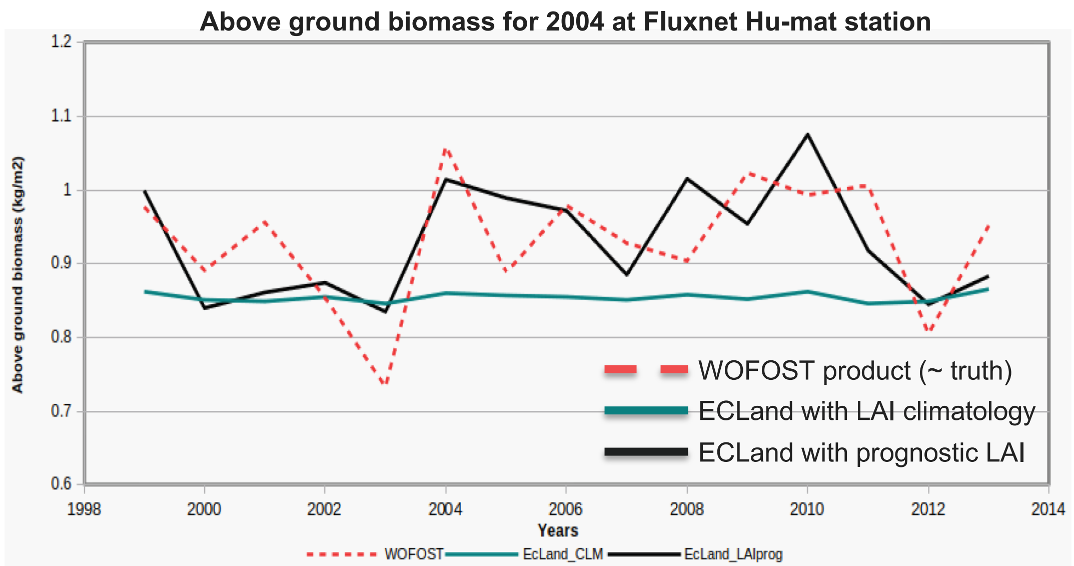
Coupled seasonal forecast comparison with ERA5 – there is an improvement with time-varying vegetation (i.e. forecast is closer to ERA5).

Thanks to Souhail Boussetta

Dynamic Leaf Area Index: impact

In-situ evaluation of the vegetation related variables when using prognostic LAI model.





Observed, climatological and prognostic **LAI** are **well correlated within** a **year**.

Only **use** of **prognostic LAI** allows ECLand model to **reproduce interannual variability** in above ground biomass.

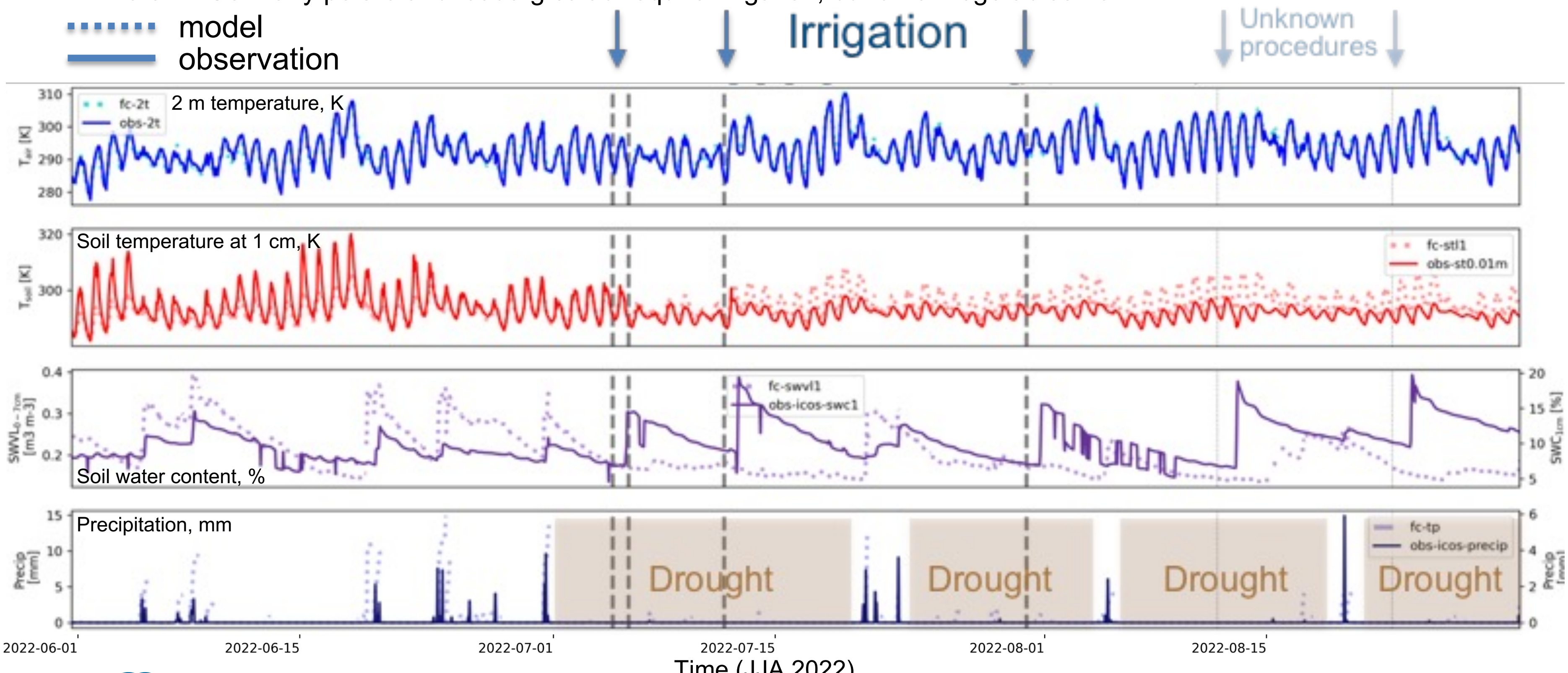
Thanks to Souhail Boussetta

Irrigation representation: TERENO

- Model well captures precipitation events and responds by increase in soil water content.
- Model misses increases in soil water content in case of irrigation.
- **Objectives**: (i) predict **droughts**, (ii) create reliable **irrigation map** and **calendar**, (iii) create a reliable **crop type map** → to know where and when to apply irrigation.

Note: in Germany potato and iceberg salad require irrigation, but other vegetables not.

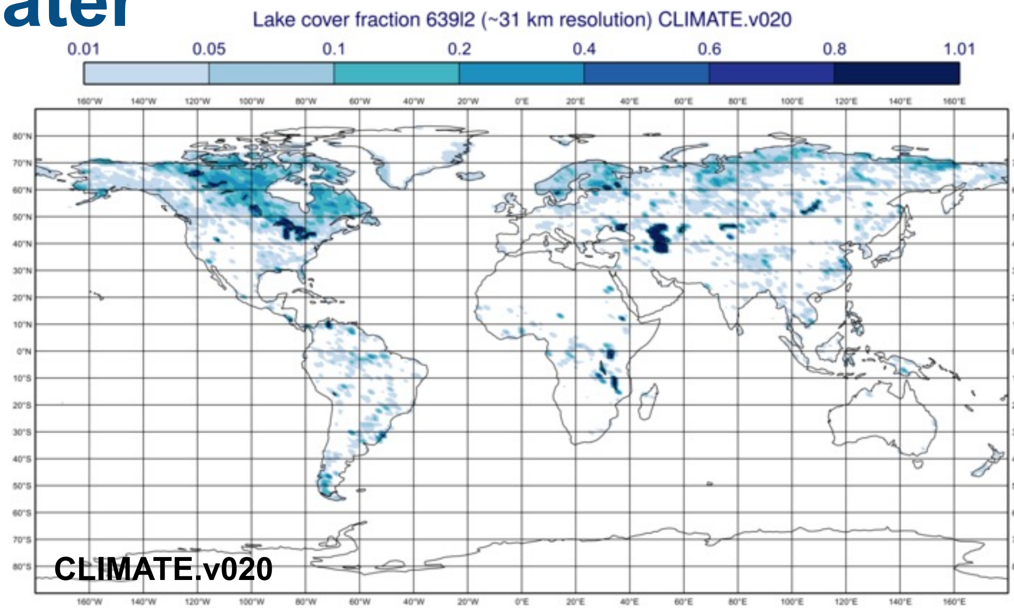
50.865906, 6.4471445
TERENO Rur/ICOS DE-RuS, Selhausen, Juelich, Germany (potato field)



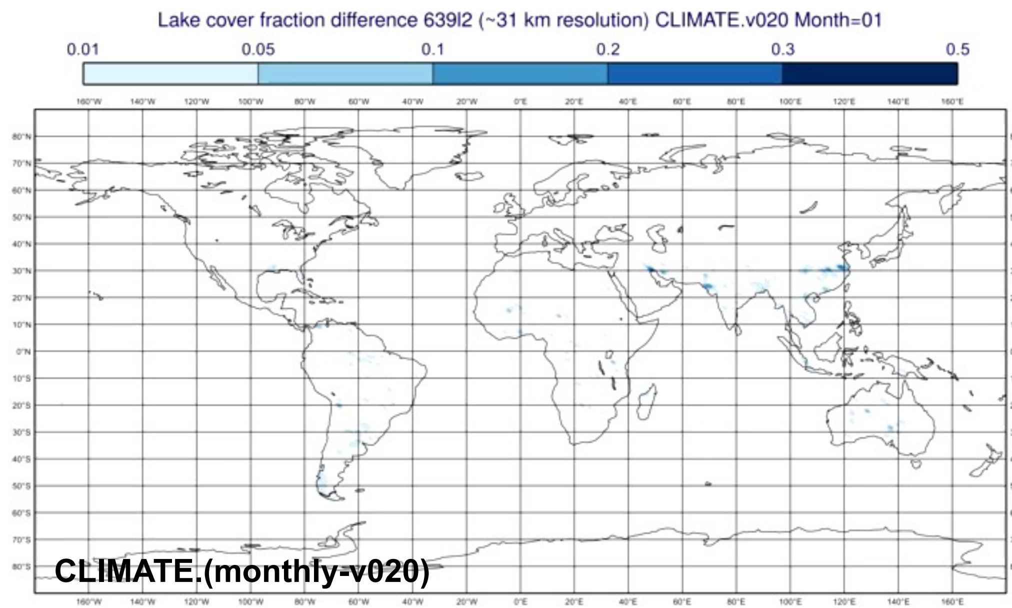
Thanks to Florentine Weber

Temporal varying water

- **<u>CLIMATE.v020</u>**
(permanent water)
main source **JRC Global Surface Water Mapping Layer v1.2** water transition map (nominal **resolution 30 m**, 1984-2018);
corrected over **glacier regions**.



- **<u>CLIMATE.v020+monthly</u>**
(permanent + seasonal water)
main source in addition **JRC Monthly Water History v1.3** monthly maps (nominal **resolution 30 m**, 2010-2020);
fraction ≥ permanent water.



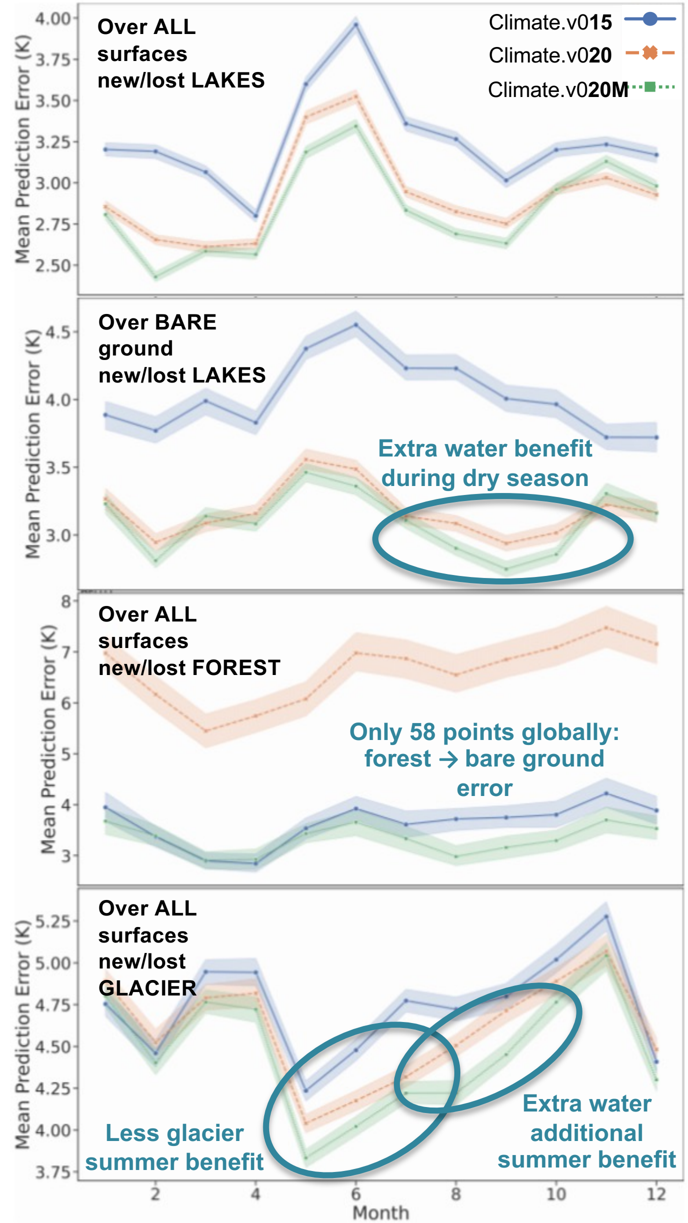
Represent water year cycle more **realistic** than static map → step **towards dynamic inundation model.**

Temporal varying water: impact assessment

To **assess** IFS **benefit** of **new**/upgraded **lakes** fully connected **neural network** model using **ERA5**, **MODIS** and **climate** field data was **trained** over **2016**, and **forecasted 2019** land **skin temperature** at **~31 km** resolution.

Table shows errors averaged over LAKES changed areas.

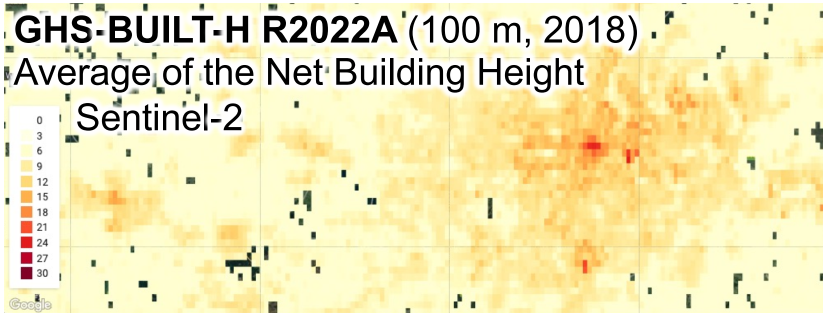
Climate fields	Mean Abs. Error, K	Std. Deviation, K
v015: **old**	3.27	3.23
v020: **current**	2.95 **-0.3K ↓**	2.64
v020M: **current + monthly lakes**	2.87 **-0.4K ↓**	2.58

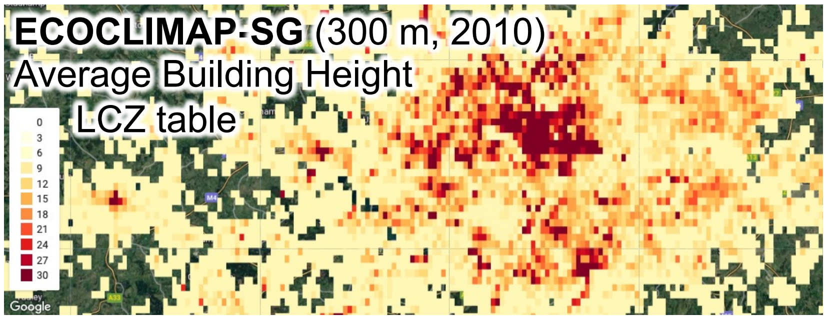


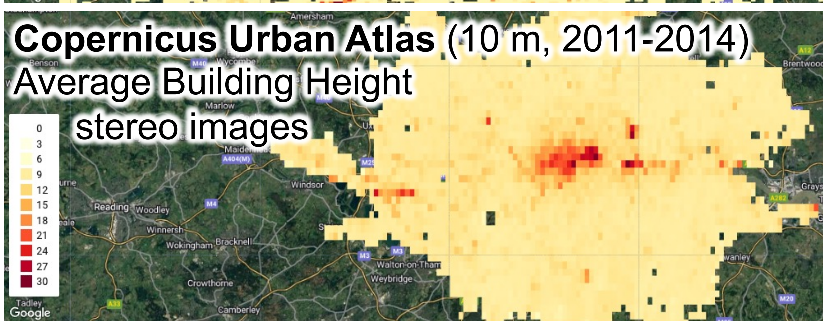
Better/timely inland water can substantially impact surface weather.

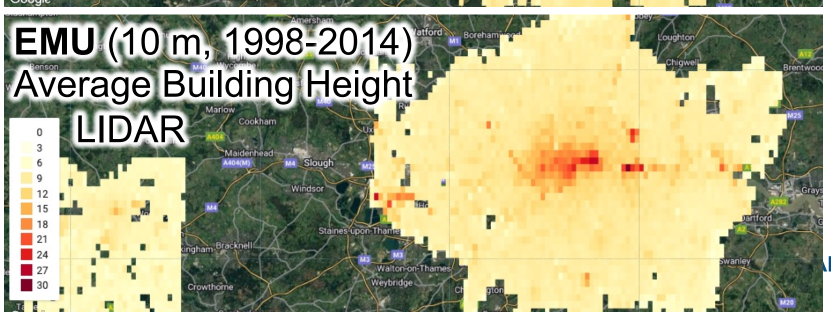
- *Need to separate fresh and saline lakes.*
- *Challenging to assess benefit due to satellite data cloud contamination!*

Building height representation: London, UK









GHSL-Sentinel2 2018, Globe | **EMU building polygons 2006, UK**

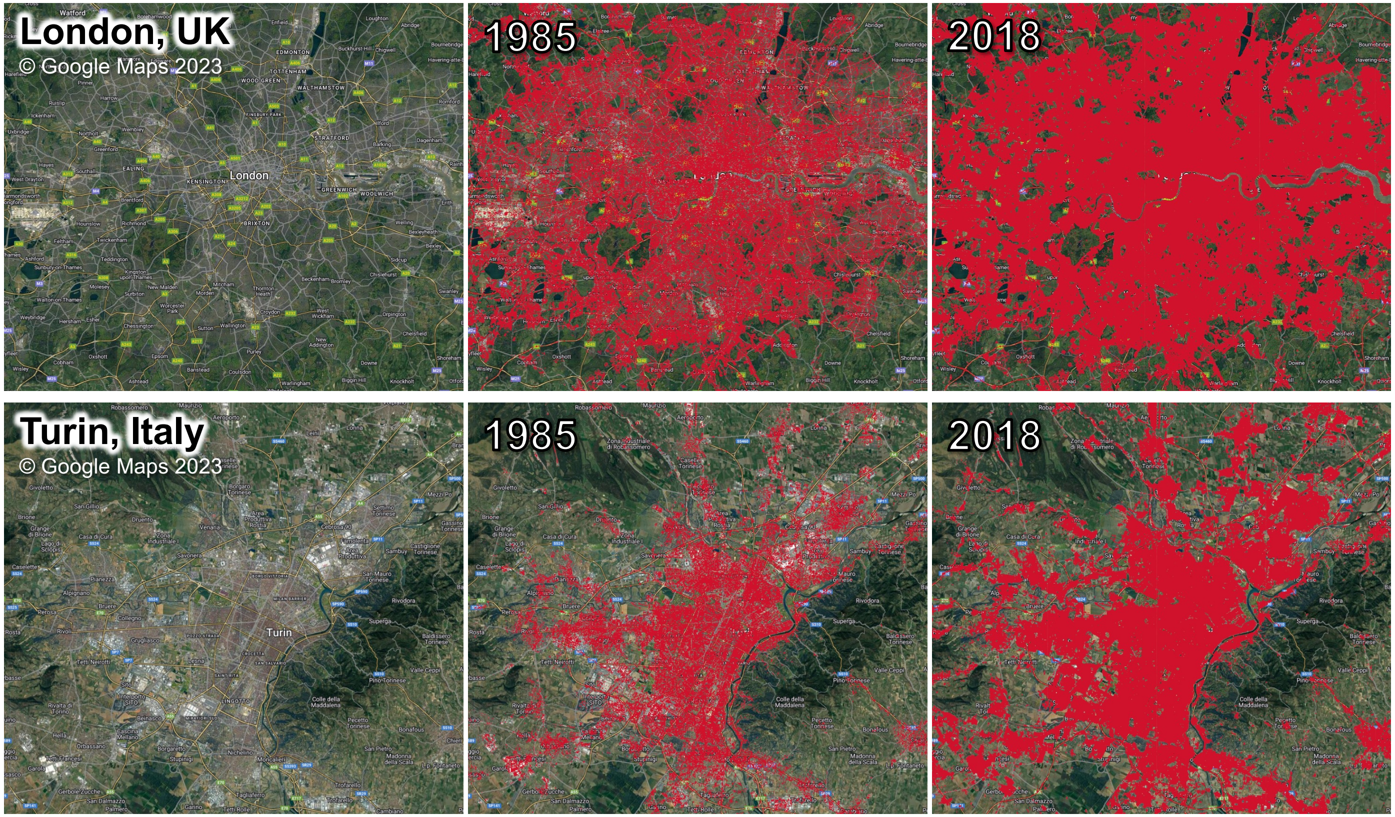
Average building height is taking into account **only buildings** (streets not included!).

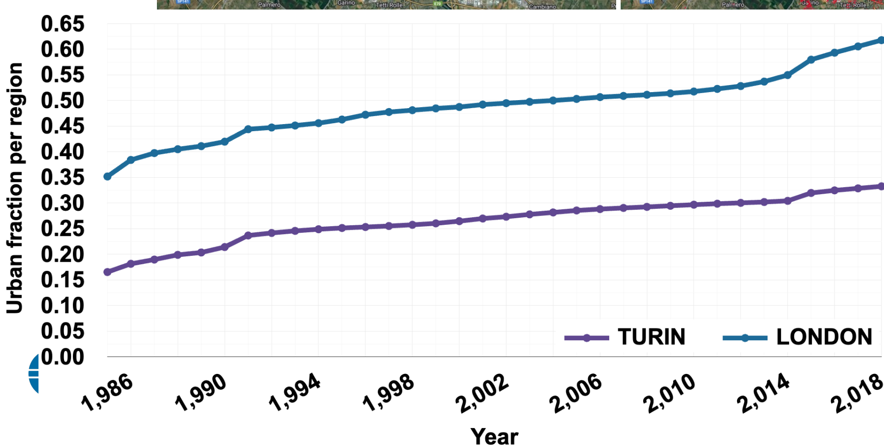
Global datasets **exist** (based on satellite information), but their **verification** with regional datasets is very **uncertain** (due to time gap).

High accuracy measurements (e.g. LIDAR) are **costly** and **become** rather quickly **outdated with** constant **transformation** and expansion **of urban** areas.

Averaged from native grid to regular 1 km grid.

Time varying urban: based on Tsinghua





Urban means **buildings and other** man-made structures (i.e. bridges, parking lots, etc.).

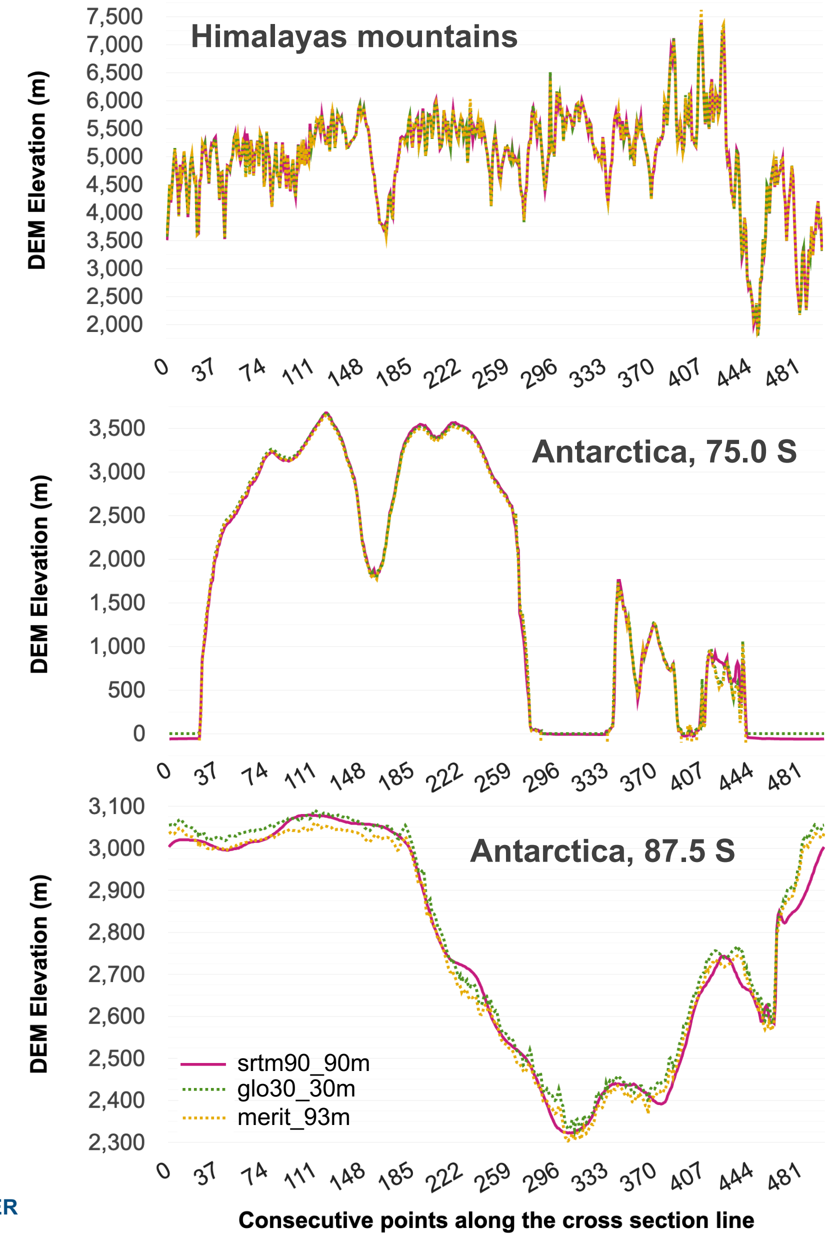
Plot shows **evolution of urban fraction** per region based on Tsinghua dataset (nominal resolution 30 m, yearly).

Global datasets with temporal evolution exist (based on satellite information), but **very few!**

No option for global verification!

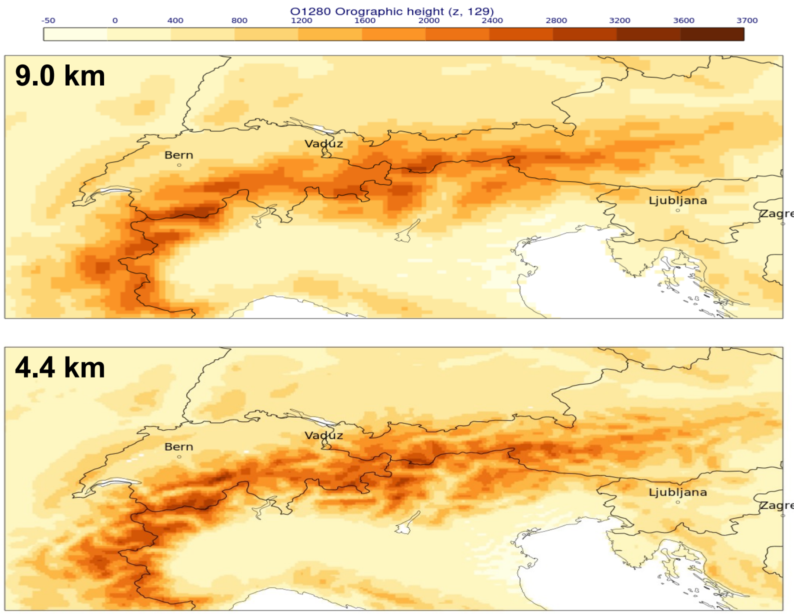
Orography upgrade: source

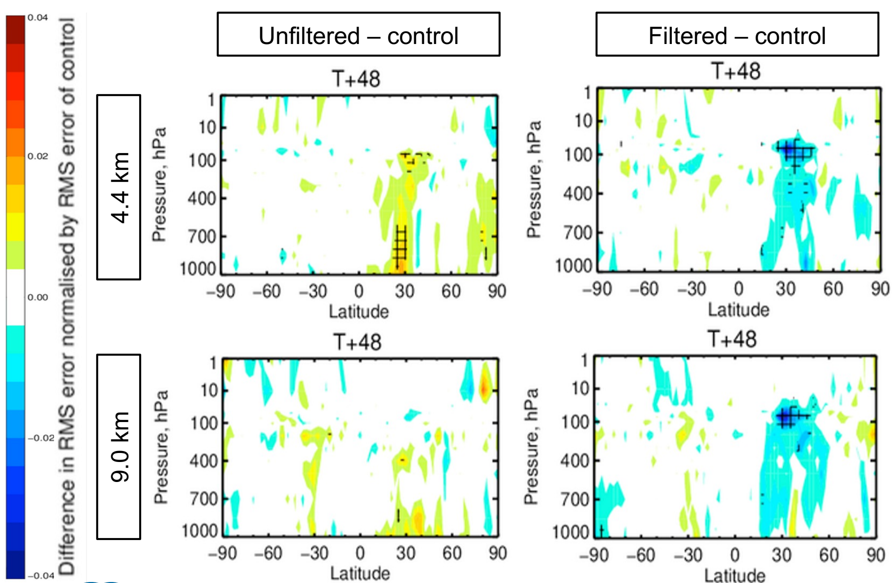
- **Orography** data in general has **high** nominal **resolution** ~30-90 m.
- **Globally** – is of **high accuracy**.
- **Regionally** – has **inaccuracies in** high **mountainous** areas and **flat plains** (important for hydrology to determine flow direction).
- **Biggest issue** – **missing** small **islands** in the middle of the ocean (important for surface temperature and wave generation and propagation).
- Regional comparison showed that **Antarctica** region is still quite **uncertain**.
- **High resolution features** are passed to NWP models through **sub-grid parameters** (e.g. standard deviation of elevation).

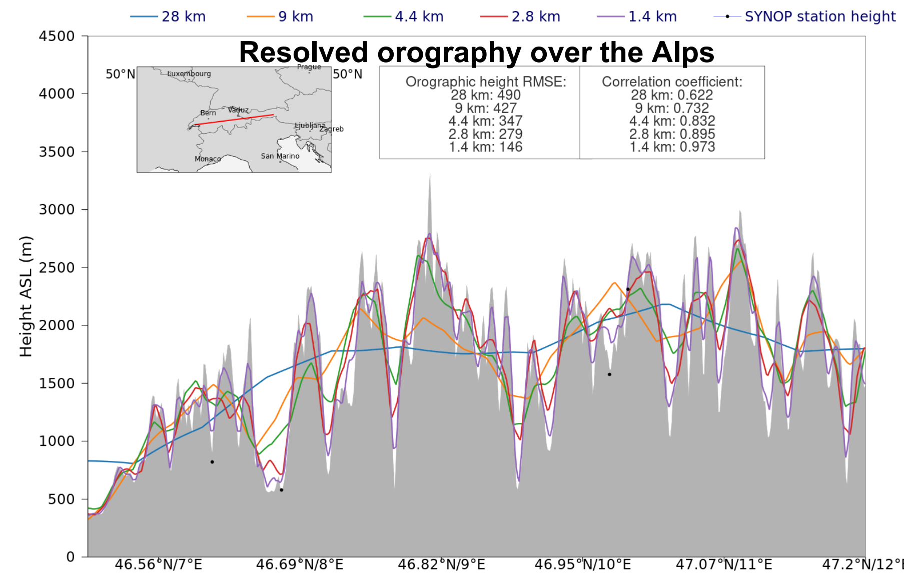


Orography upgrade: processing

- Several pre-filtering steps replaced with **conservative interpolation**.
- **Dampening** of small scales **reduces bias** from high amplitude gravity waves (e.g. Tibet plateau).
- **Spectral filtering improves large-scale circulation** also at 9 km.
- **Positive impact** of **new source** data.

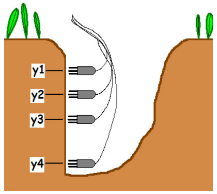


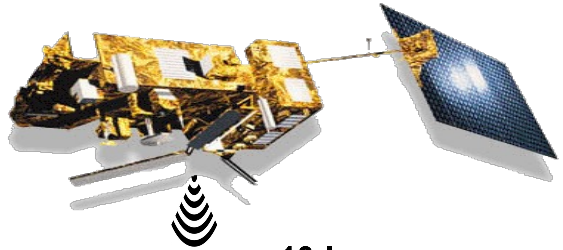


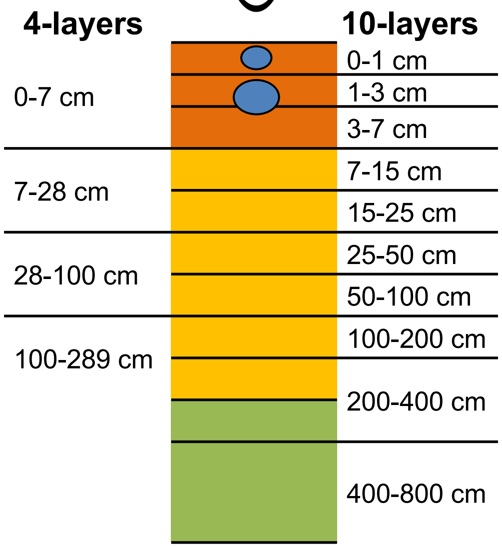


Thanks to Birgit Sützl

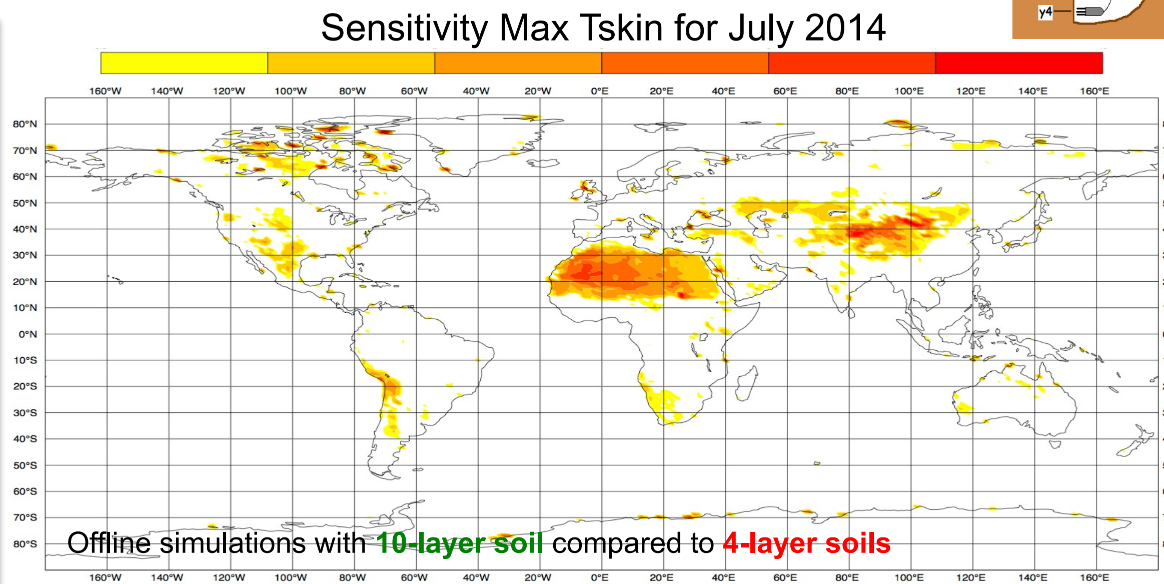
Soil parametrization: enhanced vertical resolution







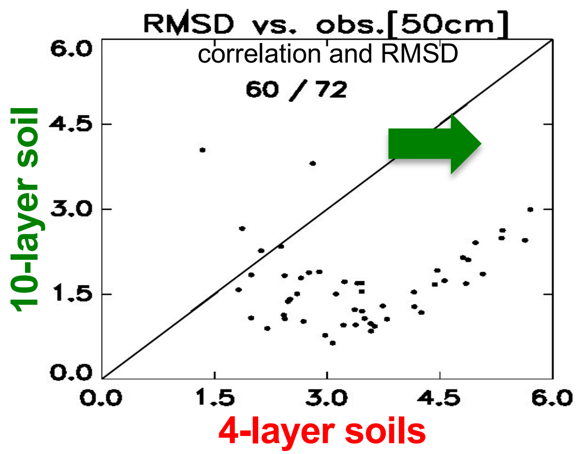
The model bias in Tskin amplitude shown by Trigo et al. (2015) motivated the development of an enhanced soil vertical discretisation to improve the match with satellite products.



Higher Tmax at the Land-Atmosphere interface up to 3 degrees warmer on bare soil (without symmetric effect on Tmin!).

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

Improved match to deep soil temperature.

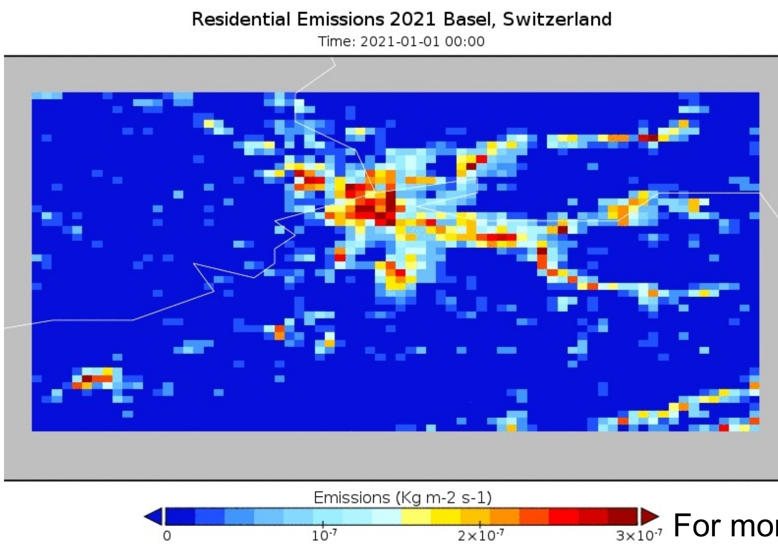


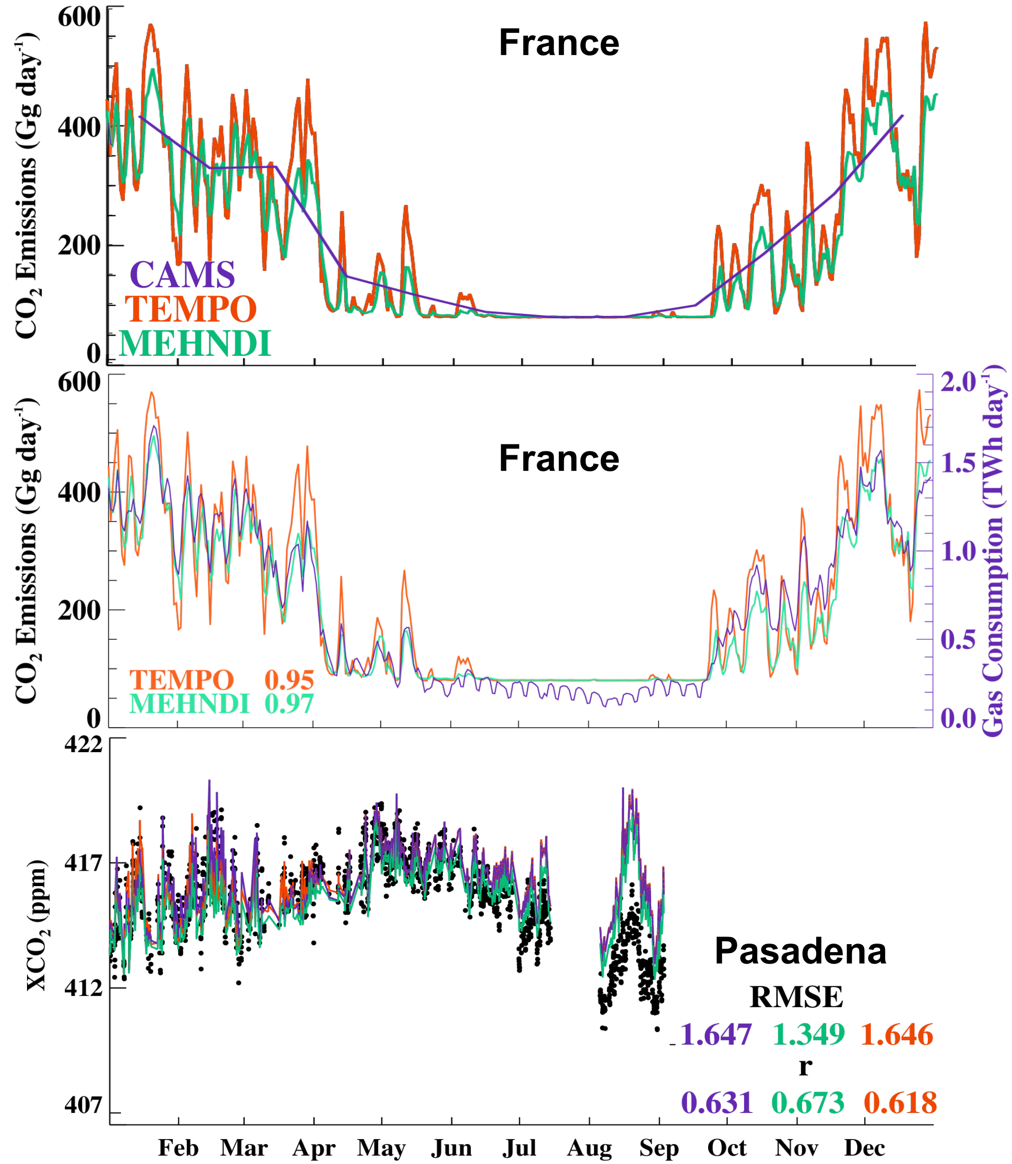
Correlation with in-situ soil temperature validate the usefulness of increase soil vertical resolution for monthly timescale (0.50 cm deep) - research continues using satellite skin temperature.

Thanks to Souhail Boussetta

Residential CO_2 emission model at ECMWF

- **MEHDNI** – residential CO_2 emissions model **based on heating-degree-days** and **urban cover**.
- **Compares well with** existing heating degree day **models**, improving temporal resolution of CAMS product (top).
- Results **agree well with gas consumption** data (middle).
- Once incorporated **in IFS, improves CO_2 concentrations** (validation with TCCON – bottom).

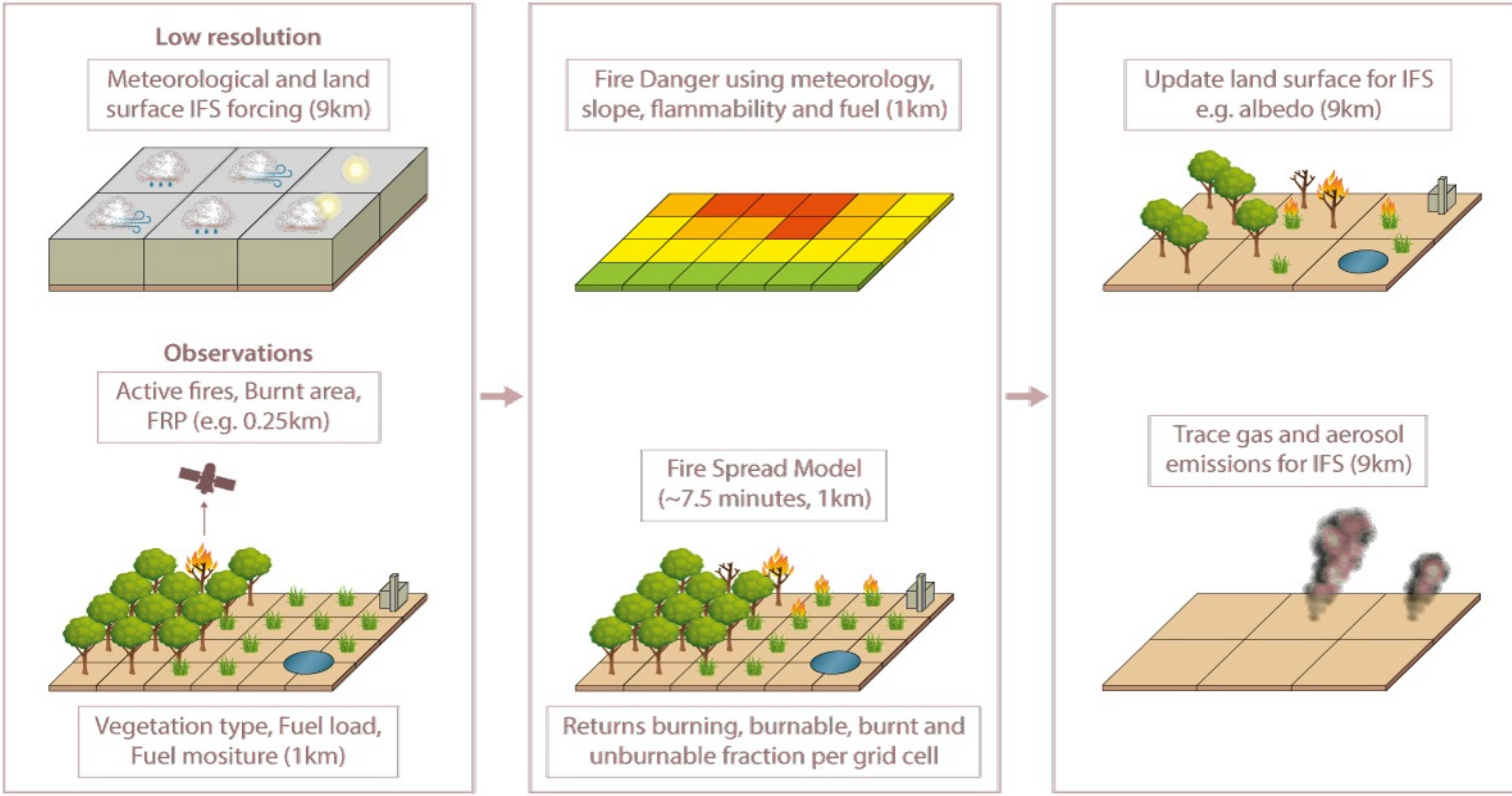




For more information see: McNorton et al., 2023

Thanks to Joe McNorton

Fire parametrization at ECMWF



Fire model is developed **for** (i) **operational** NWP and (ii) **fire danger** forecasting and **trace gas** emissions. Main **inputs** are (i) **meteorology** from NWP (9 km resolution, model), (ii) land surface **climate fields** (1 km resolution, static) and (iii) **active fire** data (1 km resolution, satellite NRT).

First results are an **improved fire prediction** compared to current Index and climatology.

Thanks to Joe McNorton