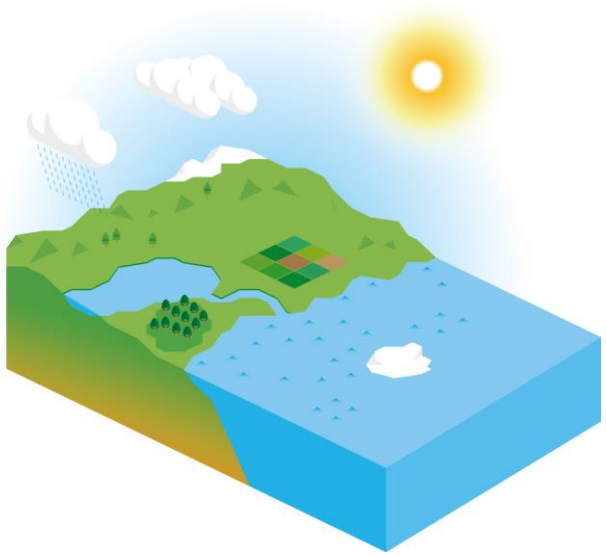
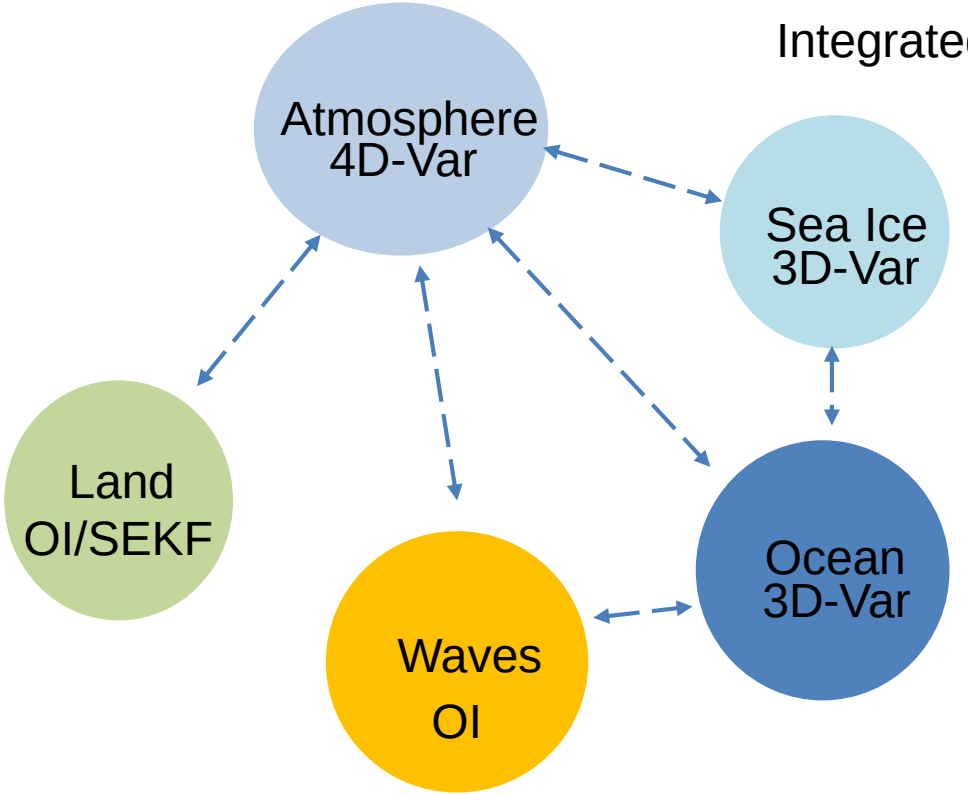
ECMWF land surface status

Michail Diamantakis
on behalf of
Patricia de Rosnay and Gianpaolo Balsamo

Thanks to the ECMWF coupled assimilation and coupled processes teams and many others

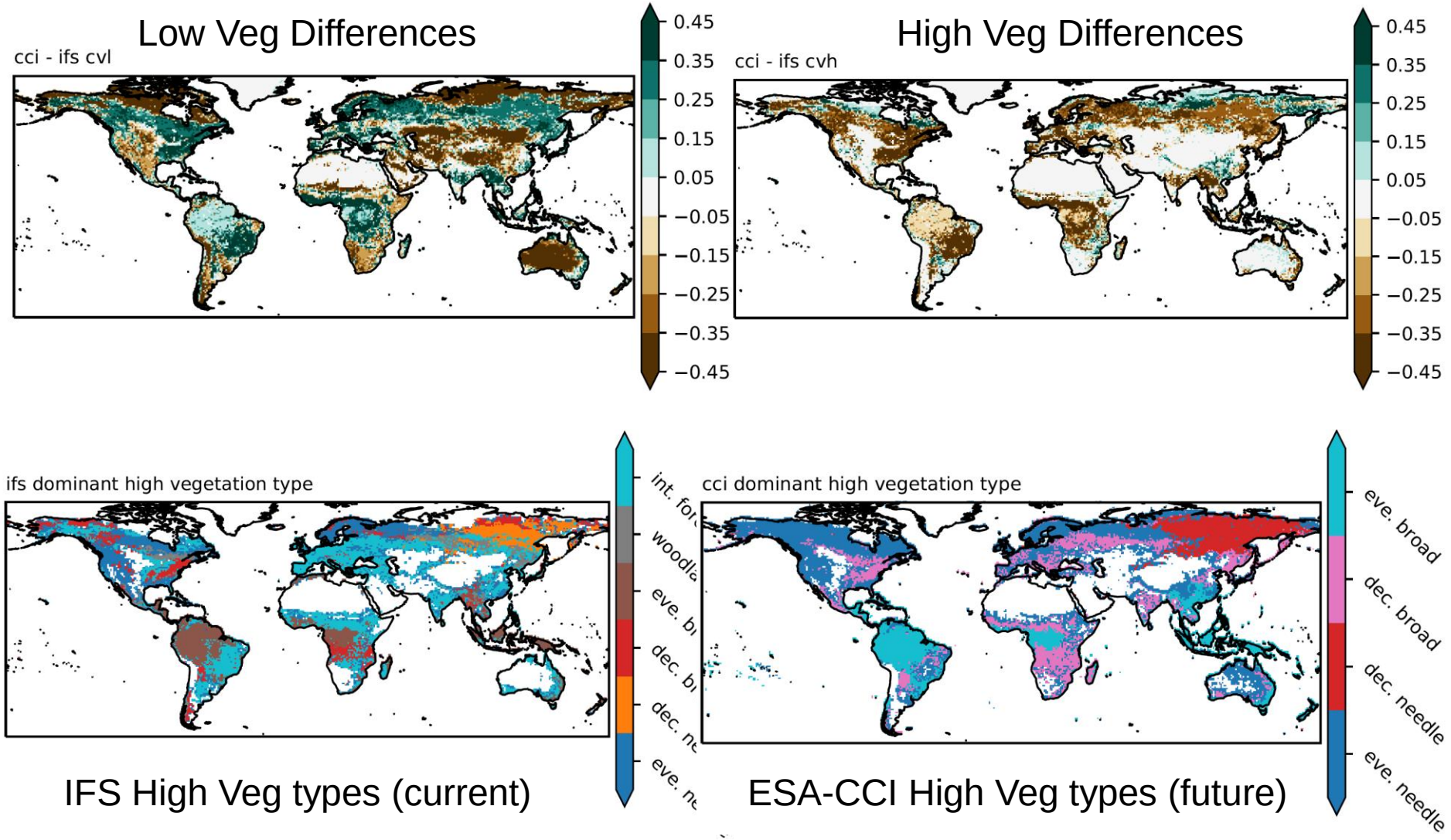
Embracing an Earth System approach





- Consistency of the infrastructure and coupling approaches across the different components
- Modularity to account for the different components in coupled assimilation

Land use maps: Differences ESA-CCI vs GLCC1.2 (current IFS)



- An increase in low vegetation and decrease in high vegetation fraction.
- Hybrid types (interrupted or mixed forest) would disappear.

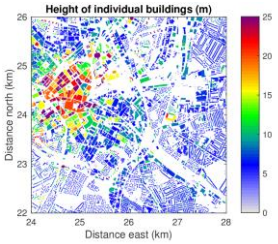
➔ substantial impact via (roughness, albedo, canopy resistance..)

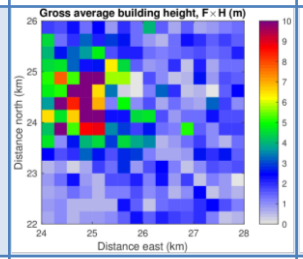
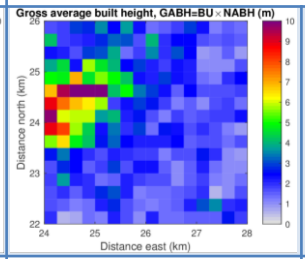
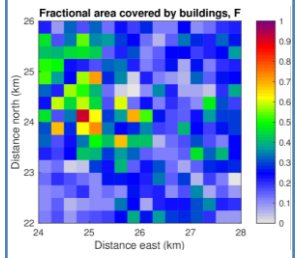
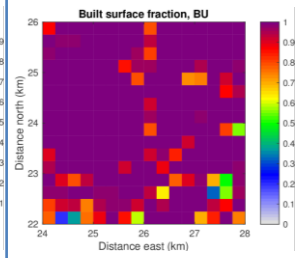
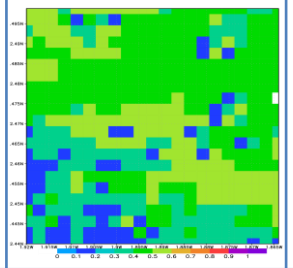
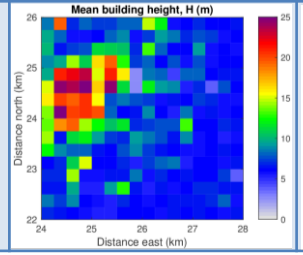
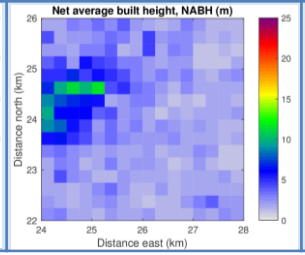
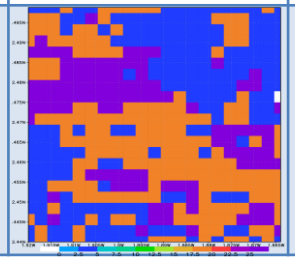
ECMWF

Mapping urban areas for future tiling extension

Collaboration (+plots)
Robin Hogan

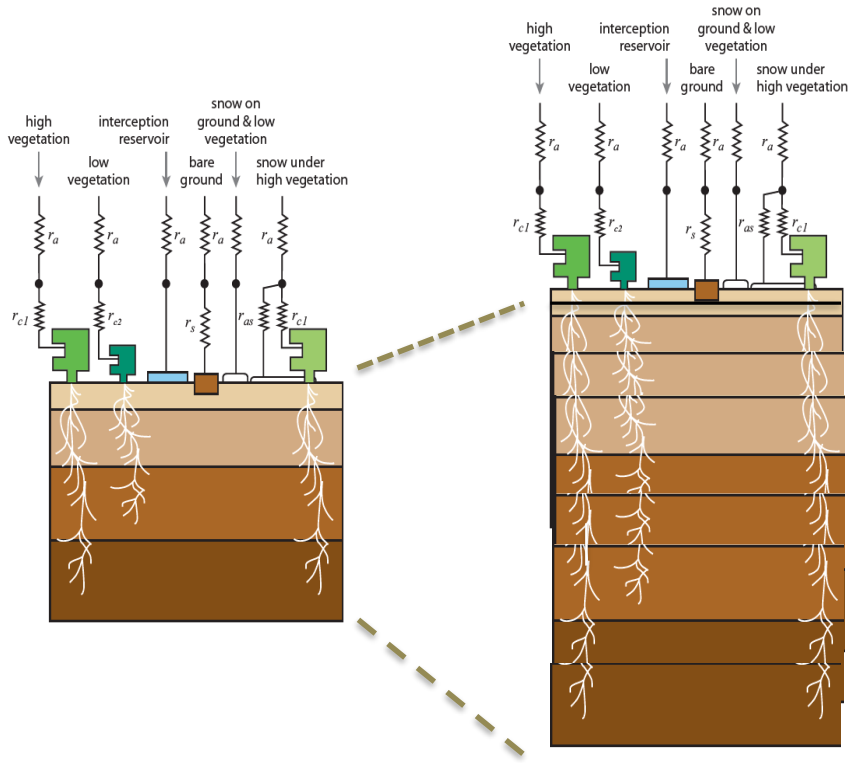
Birmingham, UK
(most common city)
building **height**:
- centre = 25 m
- suburbs = 7 m



Characteristic	EMU (reference)	Global Human Sett-lement Layer (JRC)		ECOCLIMAP-SG (Meteo-France)	
Data type	lidar	satellite + machine learning		satellite + table (flexible!)	
Resolution	meters, local	250 m, not yet global		300 m, global	
Build-up volume (Area x Height)			good correlation	No data	
Build-up area			major over-estimation! (buildings are mixed with roads)		over-estimation of suburbs (table is based on big cities!)
Building height			strong under-estimation! (~0.5m!)		over-estimation of suburbs (~25.0m!)

Important: to collect **globally all urban parameters** needed **for** the **model**

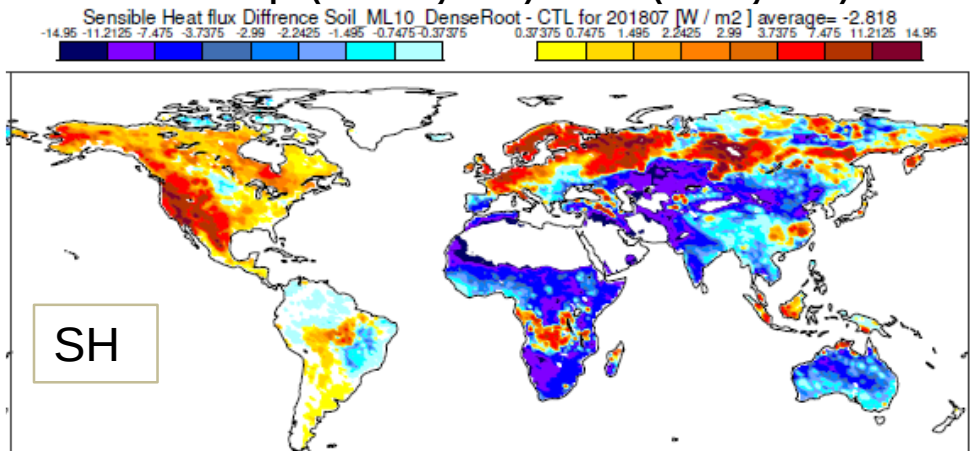
Extended soil vertical discretisation



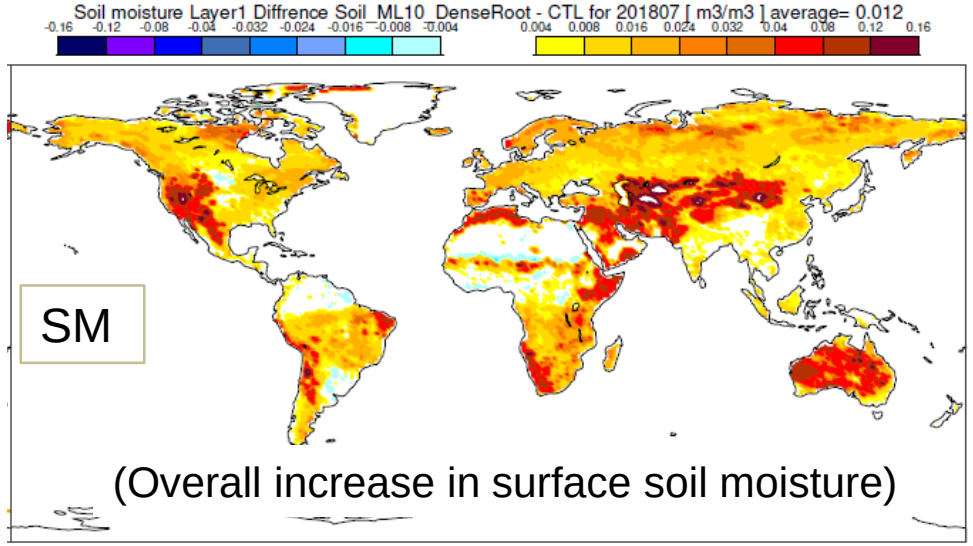
4 Layers:
2.89m

10 Layers:
8m

Exp (10Layers) –Ctl (4Layers)



(Sensible heat flux decrease over Northern Europe and increase over arid and semi-arid areas)



(Overall increase in surface soil moisture)

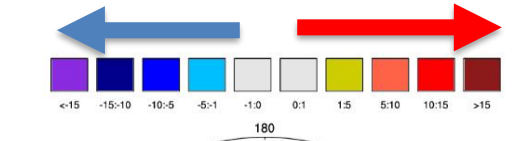
Expected: improve surface soil moisture (better correspondence with satellite observation, deeper soil allow access to bigger root zone reservoir,
➔ Improve coupling in soil and with the atmosphere

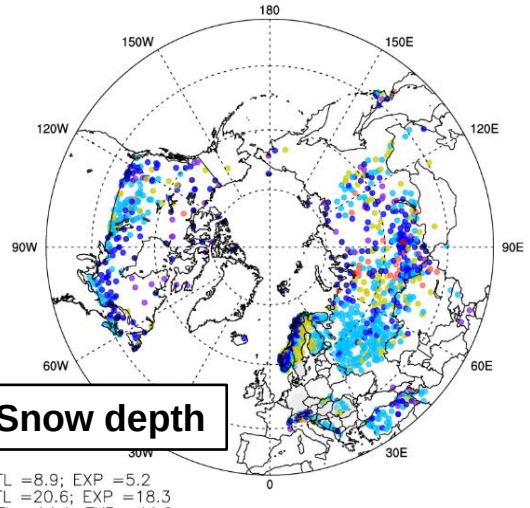
ECM

Multi-layer snow on land foreseen for next operational cycle 2020

Global offline 2014 to 2018

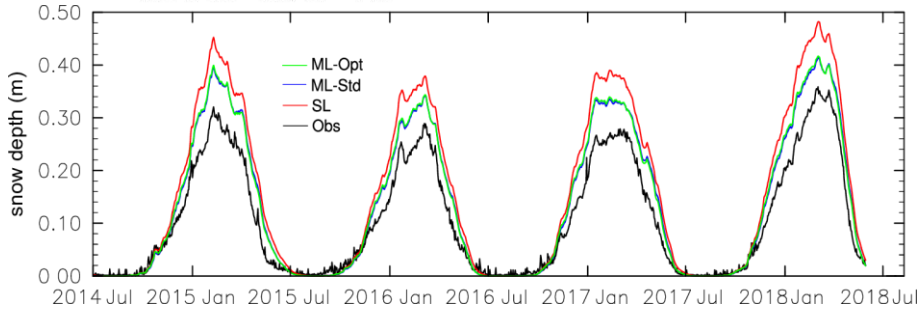
Reduced RMSE — Increased RMSE





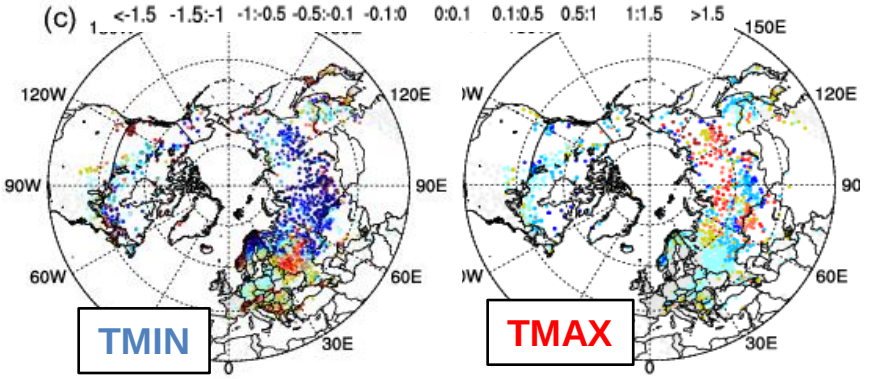
Snow depth

bias :: CTL =8.9; EXP =5.2
rmse:: CTL =20.6; EXP =18.3
mae :: CTL =14.1; EXP =11.9

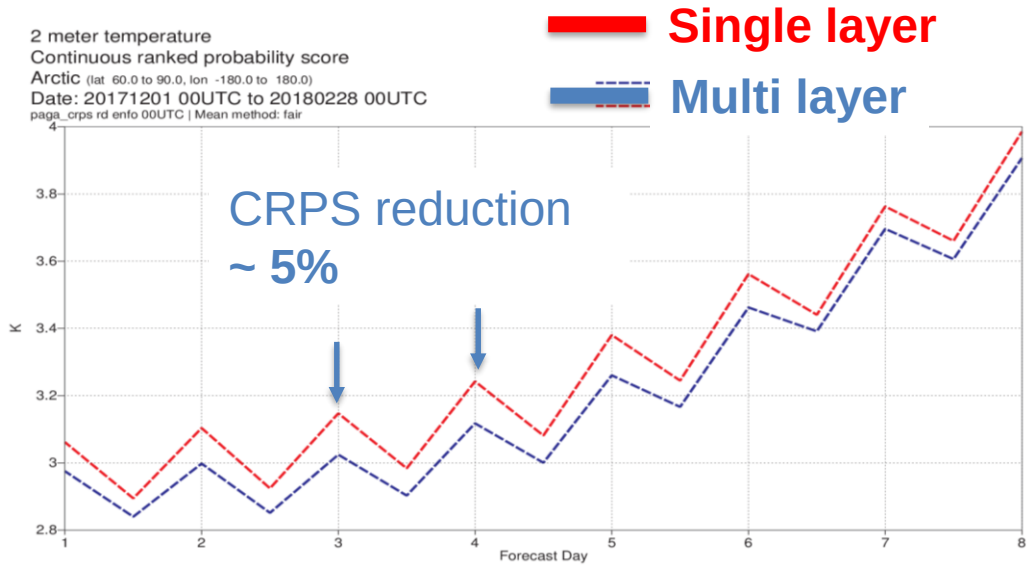


Deterministic FC: Diurnal cycle and biases of T2m

Reduced bias — Increased bias



Ensemble FC (20 members): CRPS T2m over 60N (Arctic)



Advantages of a Multi-layer snow for future Data Assimilation

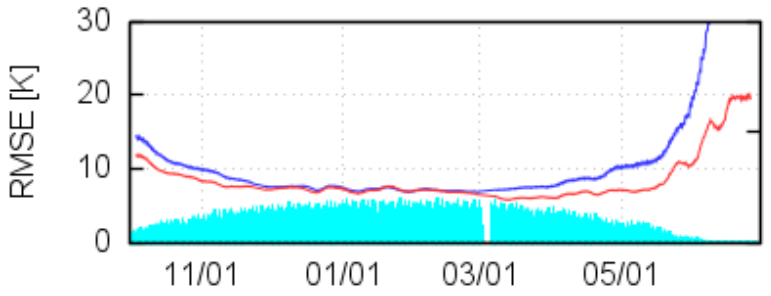
Coupling a microwave observation operator (CMEM) with multi-layer snow

HTESSEL-ML5:HUT-M
HTESSEL-SL1:HUT-S

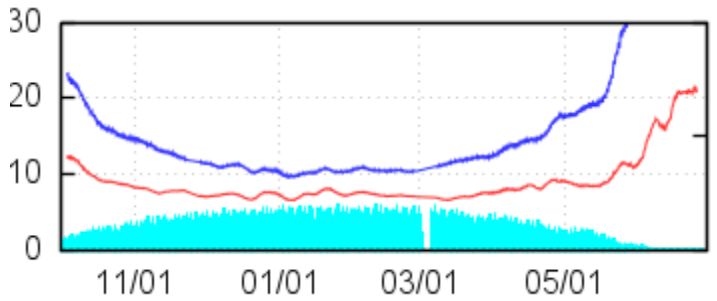
Single vs Multi-layer snow pack (H-TESSEL) & emission (CMEM/HUT)

STDV of TB(OBS) – TB(CMEM + HTESSEL)
snow-covered area [Global] (w/o glacier)
1 Oct 2017 – 30 Jun 2018

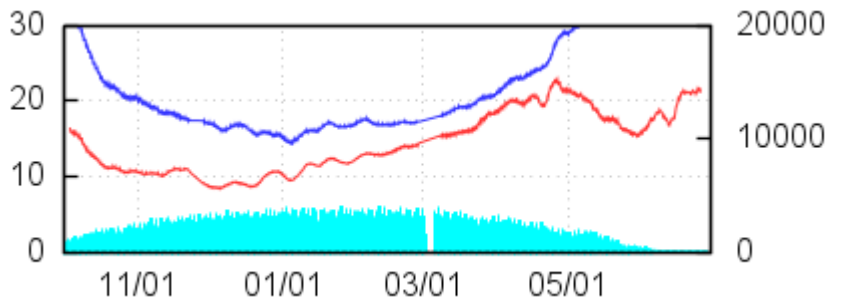
6.925GHz (V)



10.65GHz (V)

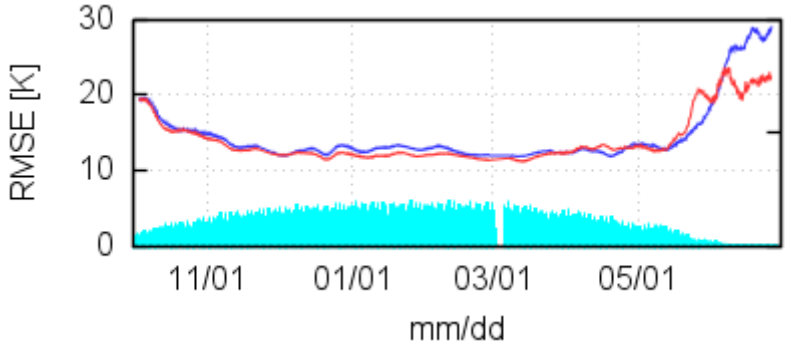


18.7GHz (V)

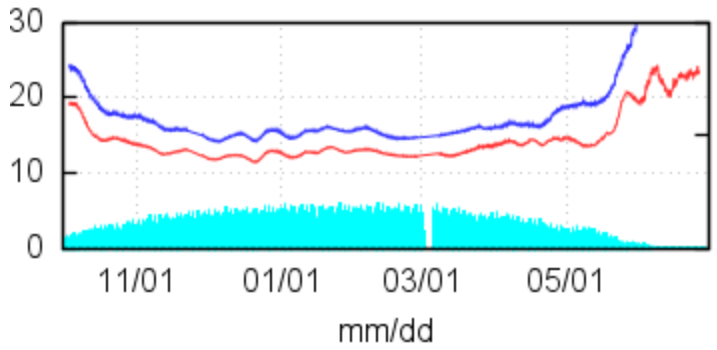


☺

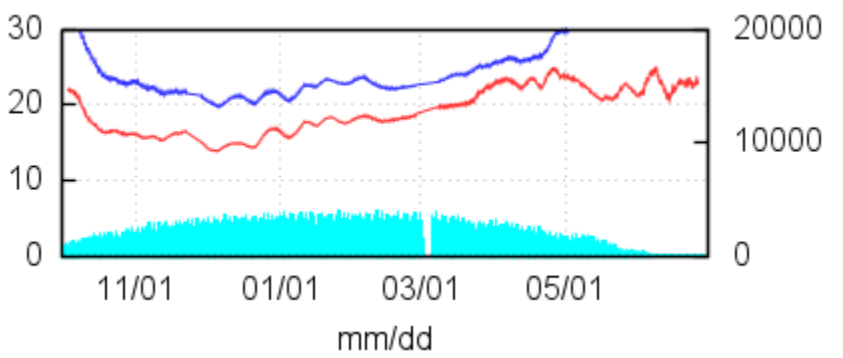
6.925GHz (H)



10.65GHz (H)



18.7GHz (H)



☺

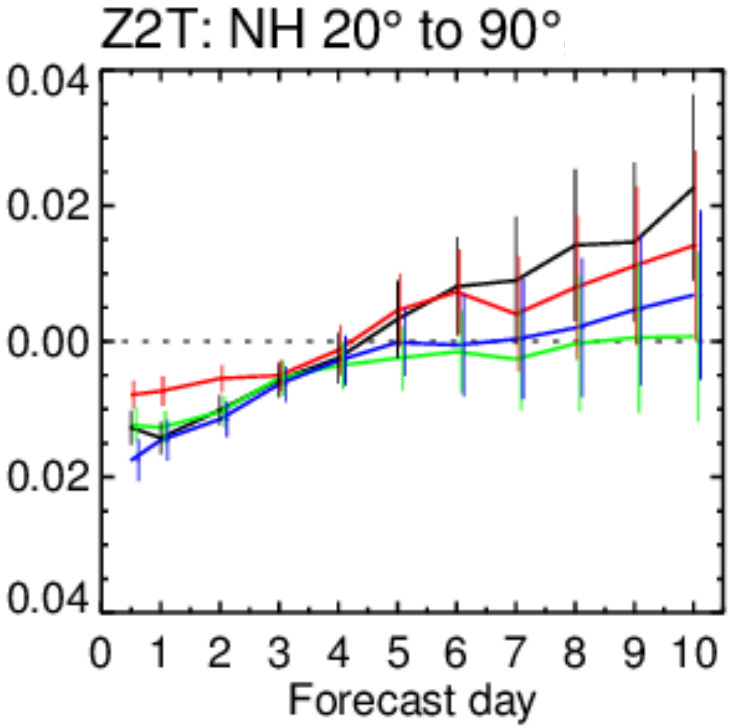
ECMWF

Yoichi Hirahara et al.

Current snow data assimilation and impact of observations (OSEs)

Winter 2014-2015 (December to April) - Assess the impact of the snow observing system

Expts	SYNOP	National Data	IMS snow cover
0- OL (no snow data assimilation)			
1- Snow DA: SYNOP+IMS	✓		✓
2- Snow DA: SYNOP+Nat (all in situ)	✓	✓	
3- Snow DA SYNOP+Nat+IMS (all)	✓	✓	✓

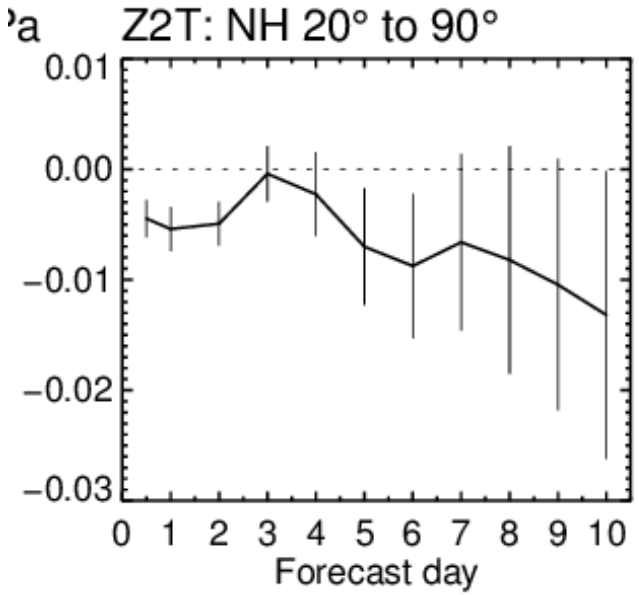


Impact on T2m Forecasts:
Normalized RMSE for T2m FC difference compared to the reference (OL)

SYNOP+IMS (1-0)
SYNOP+Nat (2-0)
SYNOP+Nat+IMS (3-0) -> oper

Best T2m Forecast when all observations, combining in situ and IMS, are assimilated.

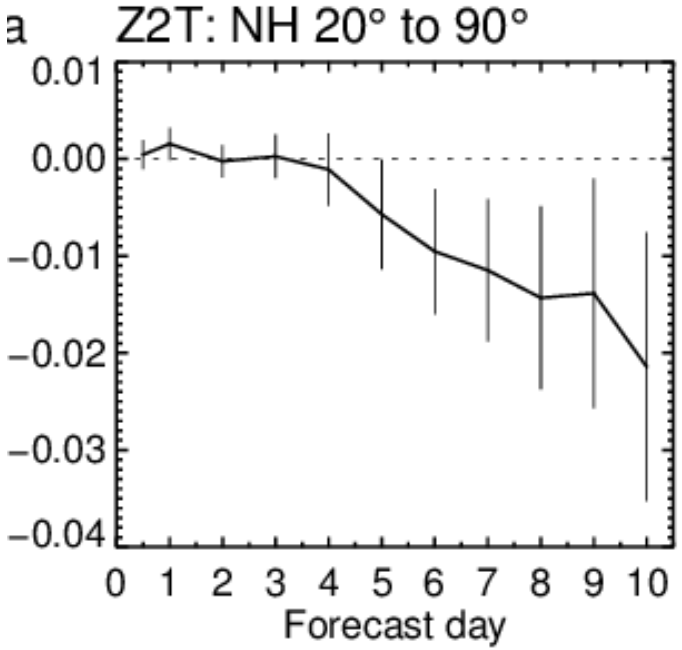
Impact of IMS satellite snow cover assimilation (case 3-2)



All data assimilated (Synop+Nat+IMS)
compared to all in situ data assimilated (SYNOP+Nat)
-> Further T2m forecasts error reduction,
significant at short range

Impact of National data (case 3-1)

All data assimilated (SYNOP+Nat+IMS)
compared to SYNOP+IMS assimilation
-> Further T2m forecasts error reduction at medium range

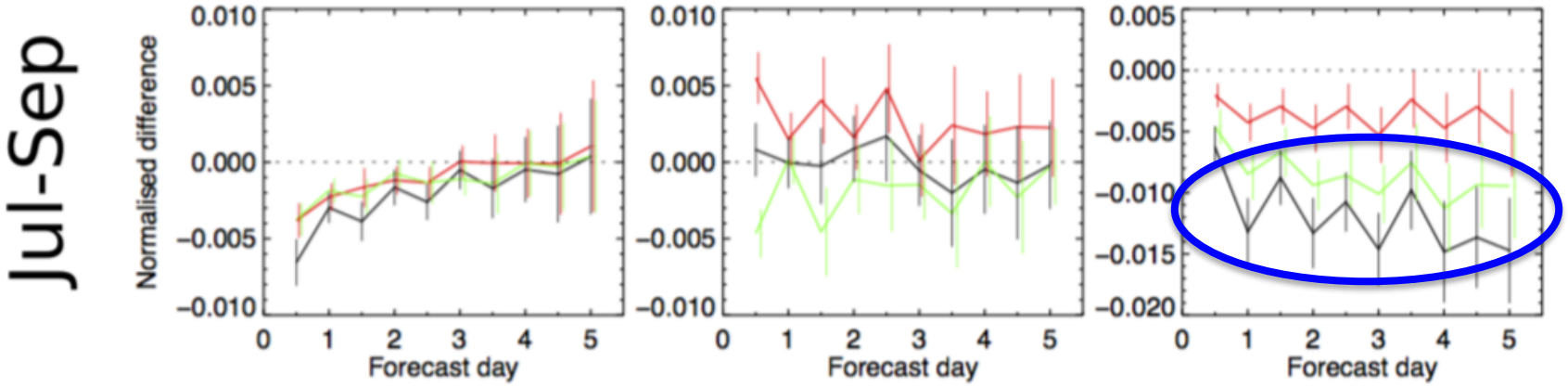


Contribution & complementarities of each observation types to improve T2m forecasts at short and medium ranges

SMOS Neural Network (NN) Soil Moisture assimilation in H-TESSEL

NN trained on offline H-TESSEL runs forced by ERA-Interim

Impact on two-meter air temperature forecasts (JAS 2012)
(Reference H-TESSEL with no assimilation: Open Loop 'OL')



SMOS+SYNOP -OL
SMOS only-OL
SYNOP only-OL

- Offline soil DA research tool (24h DA window, uncoupled model, uncoupled atmosphere, B)
- No screen level, soil temp & snow analysis
- Uses of ERA-Interim Screen analysis as inpu 'SYNOP'
- Stand-alone atmospheric forecasts

→ Proof of concept of SMOS NN assimilation for NWP initialisation

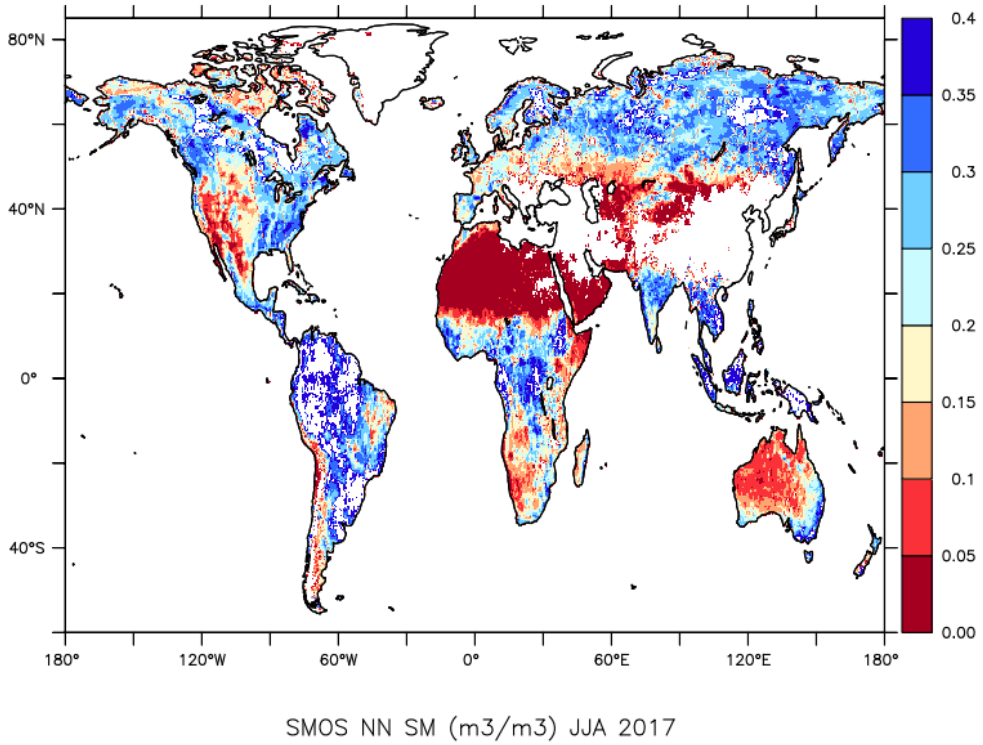
Rodriguez-Fernandez et al, Remote Sensing, 2019

ECMWF

SMOS Neural Network (NN) Soil Moisture assimilation in the IFS

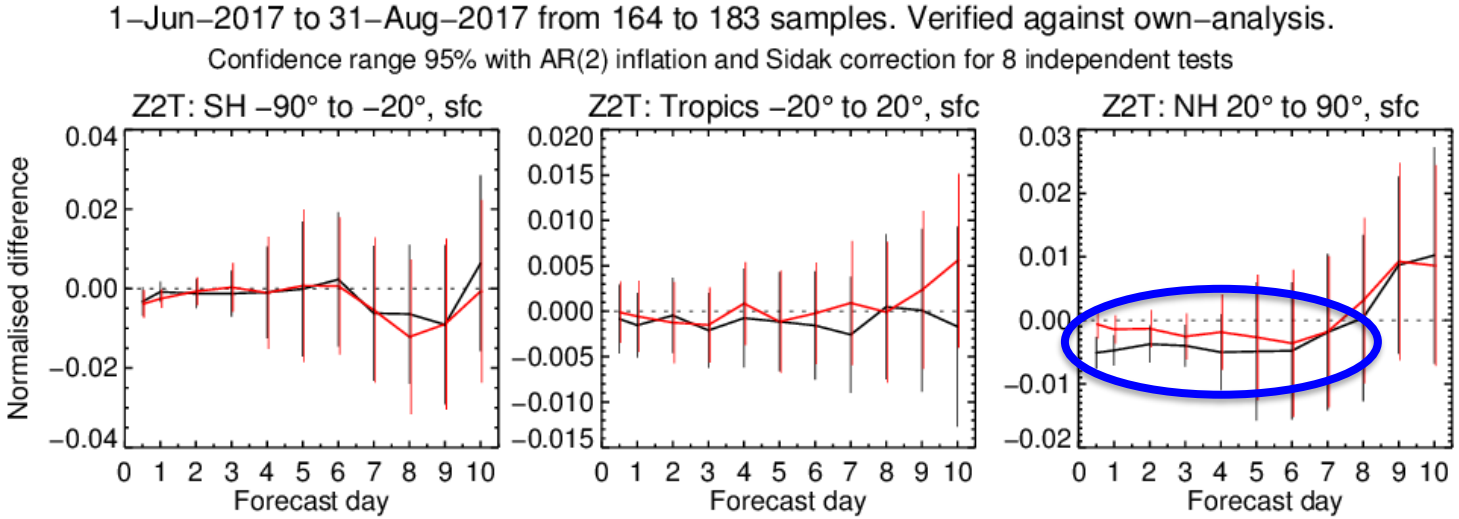
EC SMOS: NN trained on operational IFS

Implemented in the IFS with the new EDA-SEKF soil analysis



SMOS NN SM (m3/m3) JJA 2017

Atmospheric impact (T2m)



EDA&SMOS - CTRL

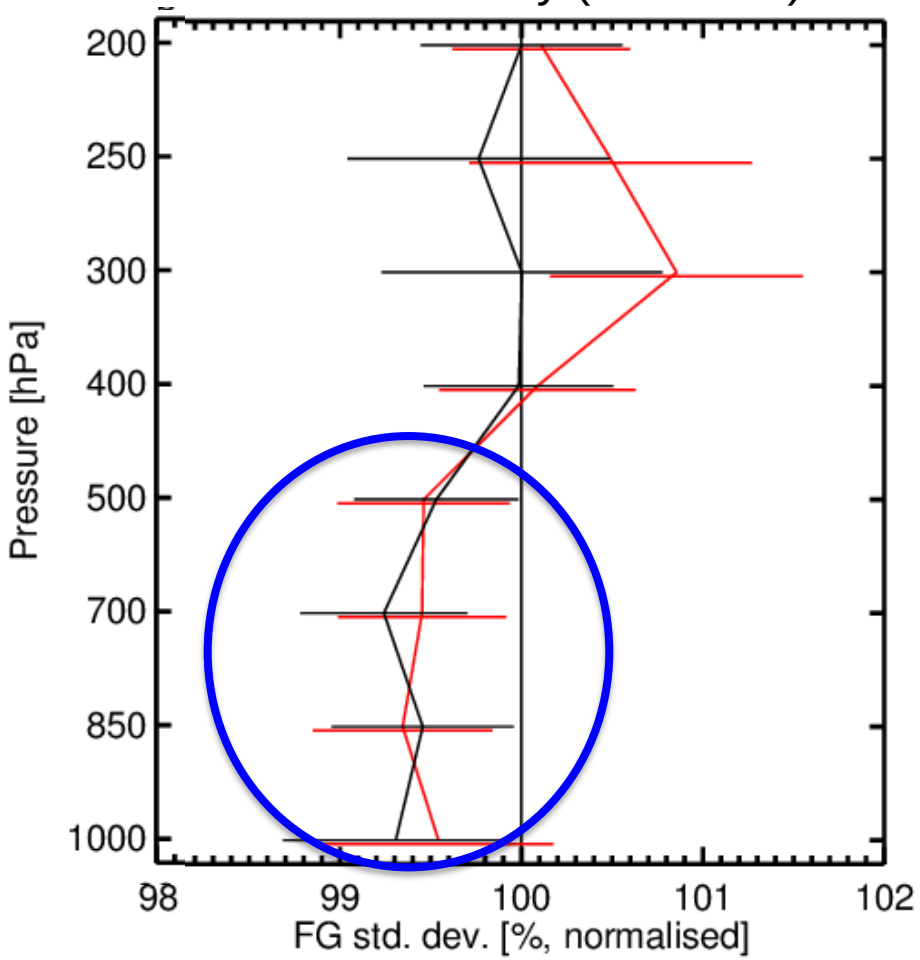
SMOS – CTRL

(CTRL: IFS cycle 45r1)

de Rosnay et al, in prep, 2019

IFS impact (EDA-SEKF and SMOS neural network)

Aircraft humidity (JJA 2017)

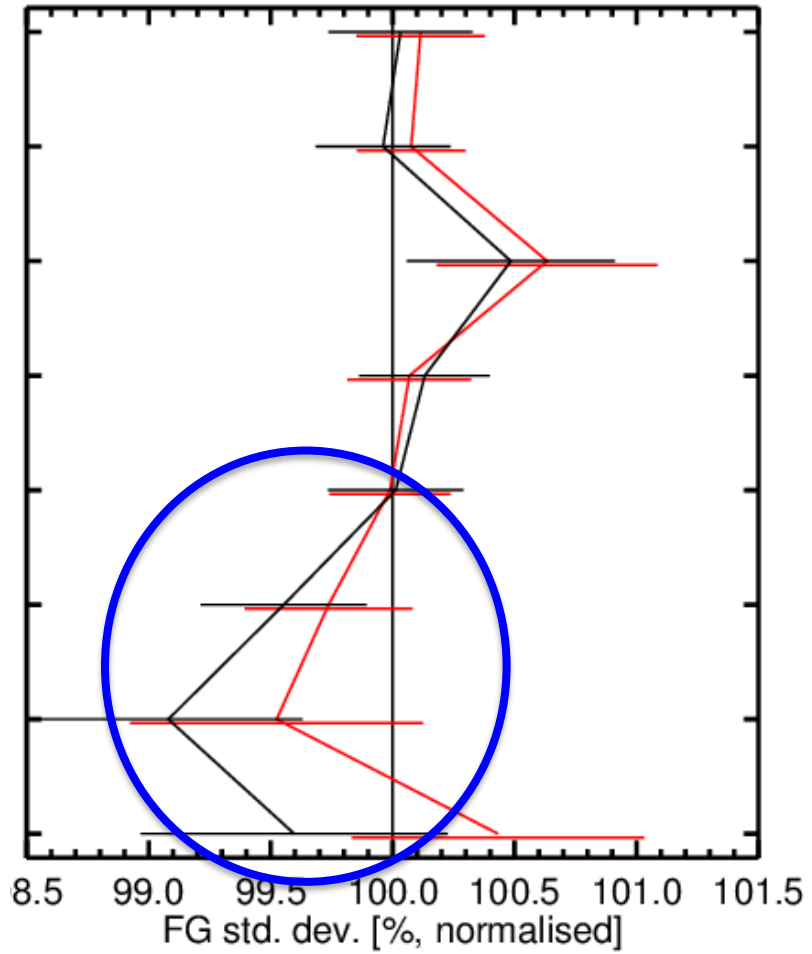


SMOS impact

EDASEKF+SMOS impact

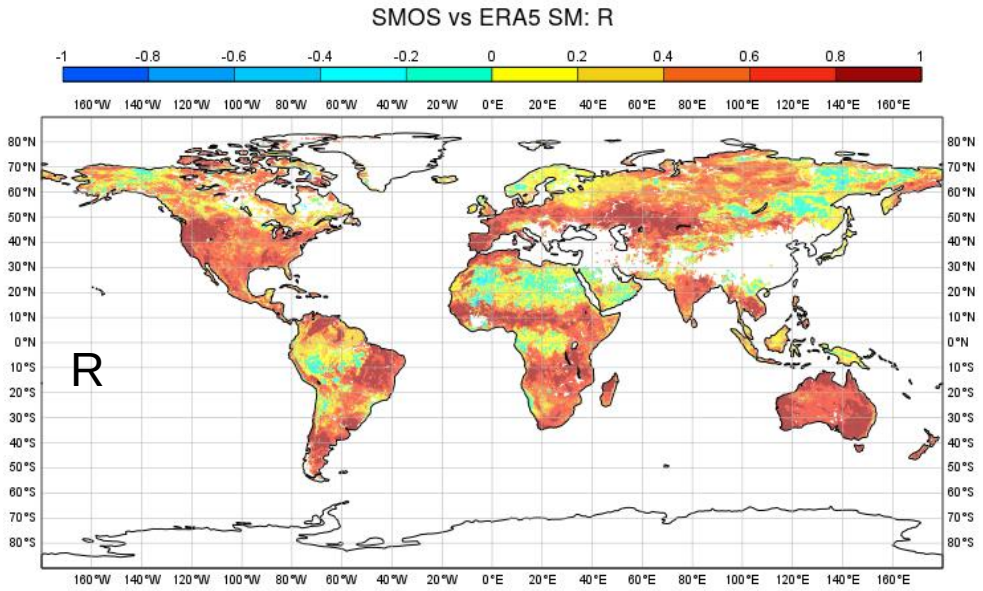
Improved fit
low troposphere

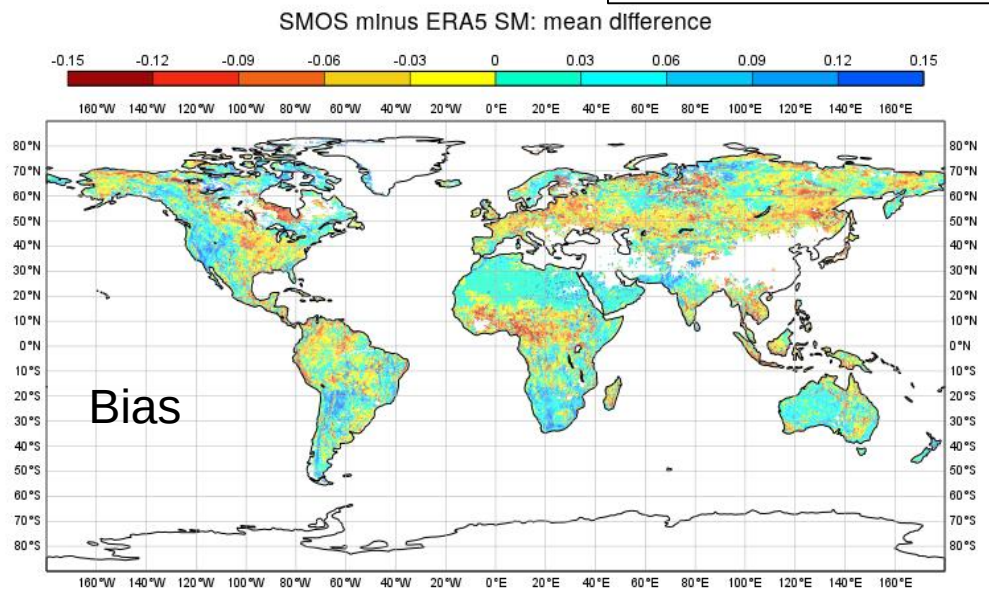
Aircraft temperature (JJA 2017)

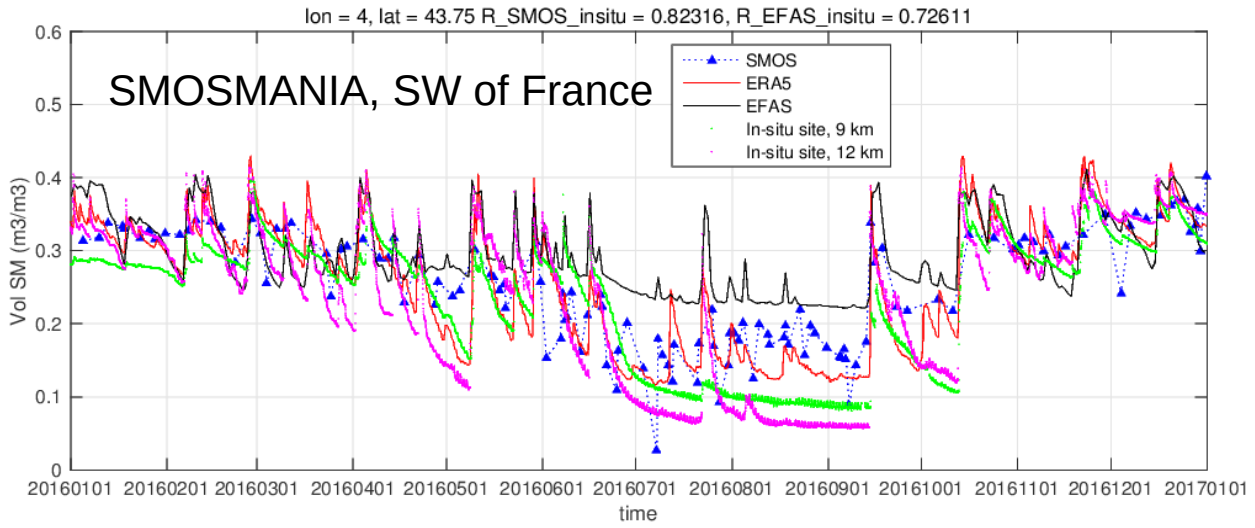


ECMWF SMOS Neural Network soil moisture compared to ERA5 in 2016

NN trained on operational IFS





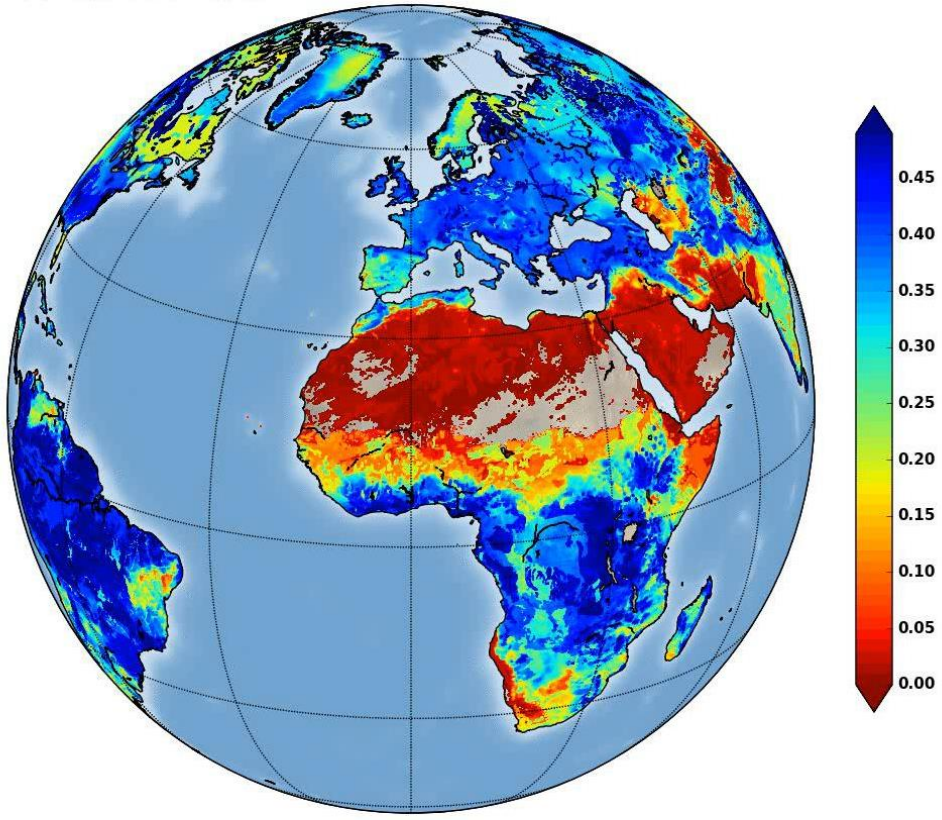


Comparison with the European Flood Alert System (EFAS) soil moisture

Lawrence et al. ECMWF/ESA report 2019

ERA5 reanalysis replaces ERA-Interim from 2019

ERA5, two operational land products:



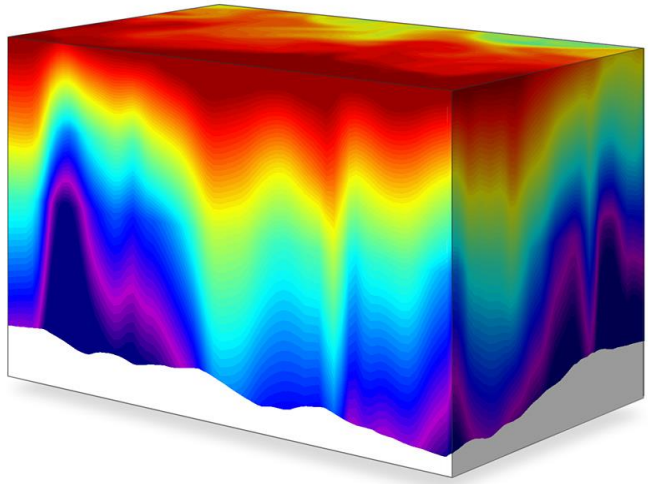
Land of ERA5: 31km with coupled land-atm. data assimilation

ERA5-Land: 10km without land data assimilation

	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
Output frequency	6-hourly Analysis fields	6-hourly Analysis fields	Hourly (three-hourly for the ensemble)	Hourly (three-hourly for the ensemble)

Hersbach et al., QJRMS submitted 2019

Summary: Ocean modelling upgrades, progress and plans



•NEMO4.0 (in progress)

•New elements
- •Major code restructuring

- Collaborations
  - Ocean-Model WG
  - JMMP
- Offline/Coupling test
  - Ongoing
  - Coupled testing foreseen end 2019

see Kristian's ppt

NEMO3.4 coupled documented in Mogensen et al, 2018, Effects of ocean on weather forecasts https://www.ecmwf.int/en/newsletter/156/news/effects-ocean-coupling-weather-forecasts

•EC-WAM upgrades

•New developments
- Ardhuin (2010) physics in 46r1
- Freak waves parameters upgraded (Peter) in 46r1
- Charnock change for strong winds in 47r1

- Collaborations
  - Imperial College (NERC-funded)
- Ongoing/Planned
  - NEMO4 wave effects
  - Grid-resolution/extension TCO grid (test planned)

Wave Physics impact documented in ECMWF news item for 46r1 https://www.ecmwf.int/en/about/media-centre/news/2019/upgrade-boost-quality-ocean-wave-forecasts

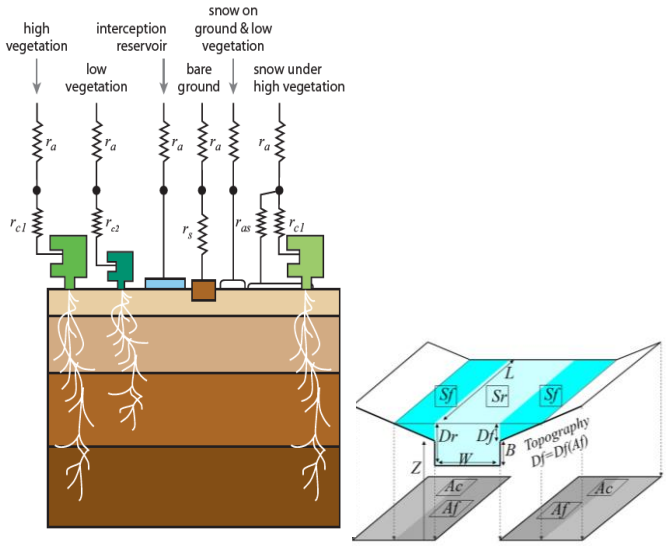
SI3 (in progress) + coupling tests

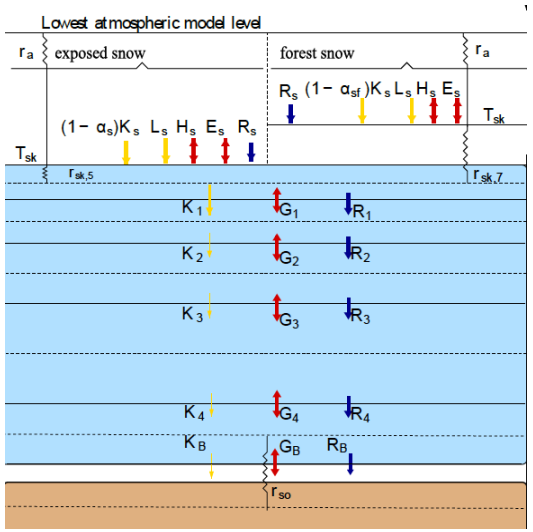
•New elements
- Multi-category ice model
- Thermo-halo-dynamics (salt-effects)
- Melt ponds and updated albedo
- Prather advection or UMx under testing
- EVP rheology

- Offline/Coupling test
  - Ongoing with LIM2 in APPLICATE (tight coupling)
  - Optimising performance SI3 w.r.t. LIM2
  - Coupled SI3 testing foreseen end 2019

Sea-ice coupling documented in Keeley, S and K Mogensen, 2018, Dynamic sea ice in the IFS https://www.ecmwf.int/en/newsletter/156/meteorology/dynamic-sea-ice-ifs

Summary: Land modelling upgrades, progress and plans





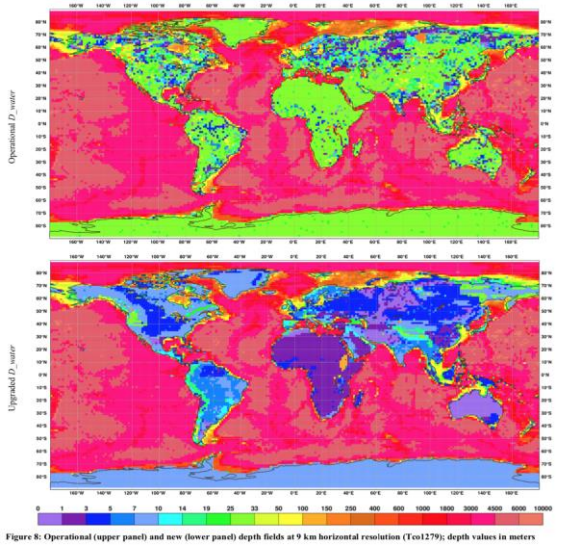
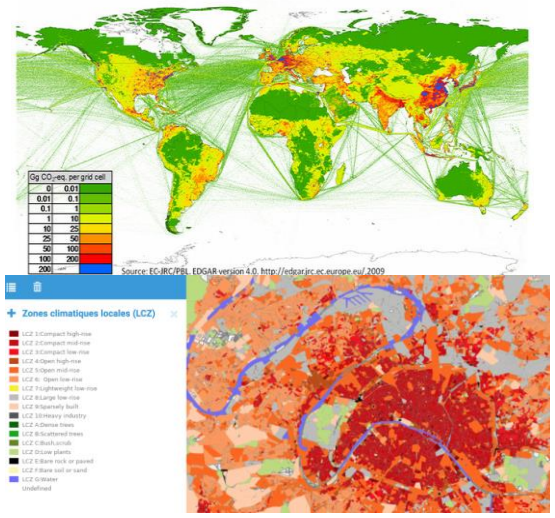


Figure 8: Operational (upper panel) and new (lower panel) depth fields at 9 km horizontal resolution (Tco1279); depth values in meters



•HTESSEL-CAMA-Flood

•Improvements
- •River discharge coupled to runoff passive in 46r1
- •Post-processing of tiles diagnostics in 47r1

- Collaborations
  - CMEMS
  - CONTROL
  - Global Routing
  - HTESSEL-Calibration
- Offline/Coupling test
  - Ongoing offline testing
  - ML10 soil coupled test 2020
  - Coupled inundation test 2020

•SNOW ML5

•Improvements
- •ML5 Physics
- •Arduini et al. (2019) passive in 46r1

- 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)

•WATER Tile Mapping

•Improvements
- •GLDBv3 + new LSM/CL ready for 48r1

- 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

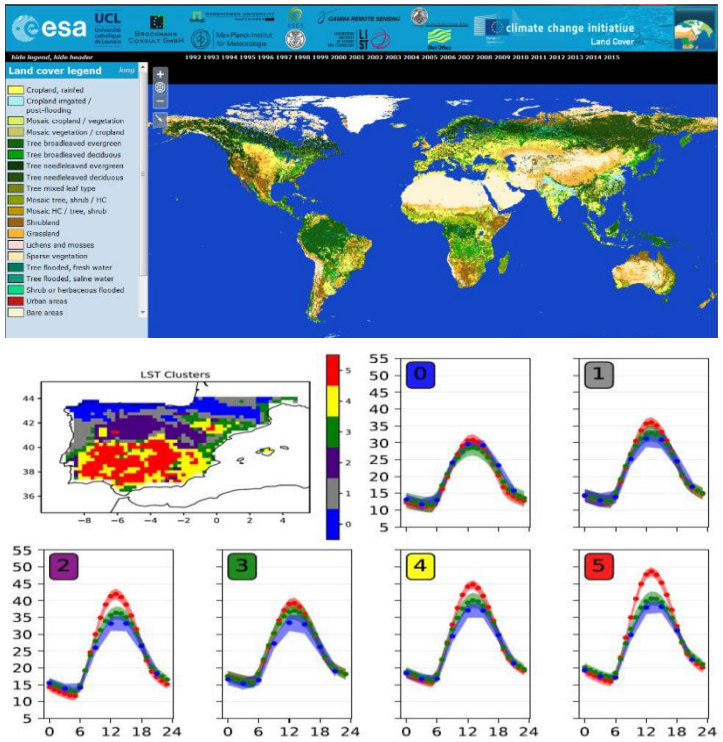
- Offline/Coupling test
  - Ongoing Tier-2 ENS
  - Prepare CHE-2

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

Choulga et al (2020) on CO2 emission uncertainties

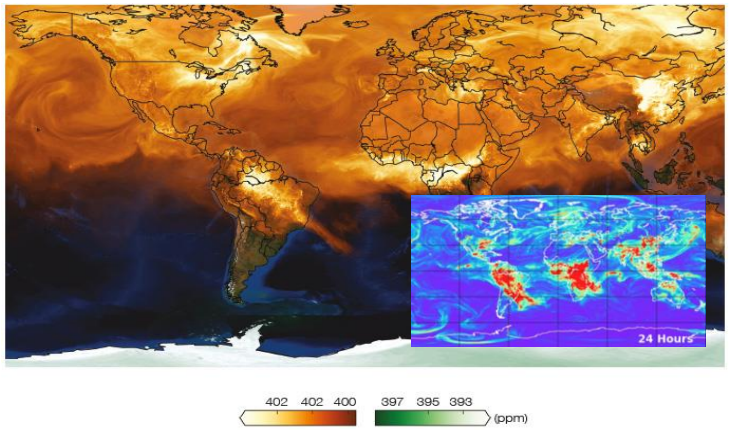
Involving EWGLAM surface community linking NWP & Copernicus Applications

ESA-CCI Land cover



Johannsen et al. 2019

CHE project



CHE+VERIFY GA

ISWG efforts

•C3S / CAMS / CEMS / ESA-CCI

•Collaborations
- •ESA & JRC (mapping)
- •MF-Toulouse (mapping)
- •LSCE-Paris (biosphere)
- •Imperial (Waves, biosphere)
- •U Lisbon & UFZ & MPI-Jena (LSM)

•Target
- •Updated/best surface for Weather/Hydrology/ESM
- •Offline portability for external testing

•CHE / CHE-2

- Collaborations
  - JRC CO2/Water/Urban
  - CHE/VERIFY Consortium
  - CHE Integration (WP5) Workshop
  - IG3IS/Transcom Workshop
  - CHE-2 proposal preparation
- Target
  - Reliable CO2 emissions with uncertainty estimations
  - Realistic Biosphere/Anthropogenic

•Member-States & External WGs

•Collaborations
- •METEO-FRANCE (Vegetation/Urban)
- •UKMO (Ocean/Ice/Snow)
- •DWD (Soil texture), NILU (Himalaya)
- •UU (ClimAfrica)
- •FMI (ISWG-4)
- •GEWEX & WGNE projects

•Target
- •Increase use of Earth Observations
- •Share priorities focus at ECMWF

Summary and outlook

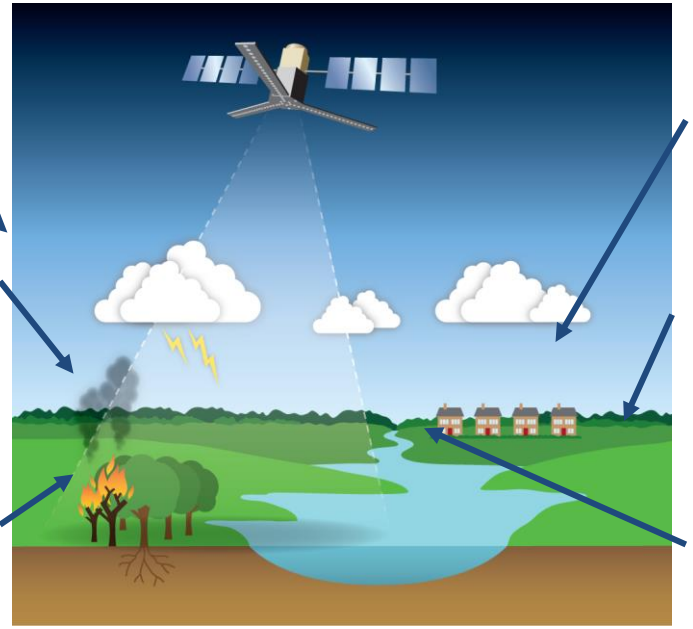
- Earth system approach → Coupling land-atmosphere-hydrology-ocean for NWP and reanalysis
- Multilayer model and DA, land surface mapping, SMOS NN DA, EDA-SEKF, ……
- The CO2 Human Emission EU-funded Project will drive forward requirements for a global km-scale Monitoring System

FIRE

Identify dry lightning ignition potential

Modulation of fire emissions

SMOS biomass load → fuel for burning



FLOOD

SMOS, ERA5, EFAS benchmarking

EFAS (Europe) & GloFAS (global) flood forecast systems initialisation

Flood forecasts and the role of soil moisture excess

Copernicus Emergency and Management Service(CEMS)