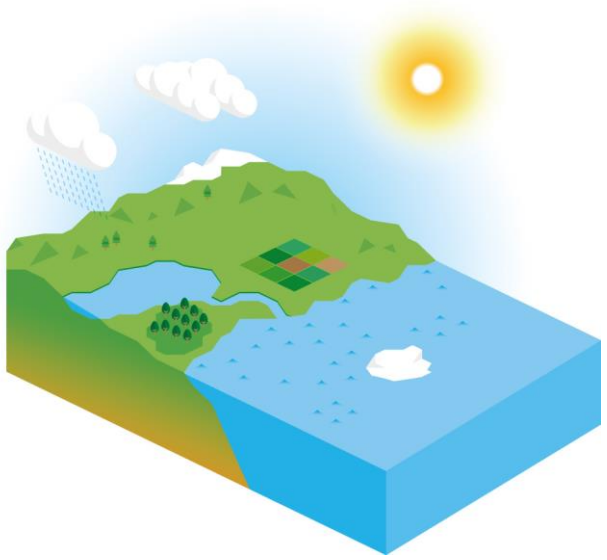
ESA Living Planet Symposium
Milan, 13-17 May 2019

SMOS soil moisture data assimilation for operational numerical weather prediction

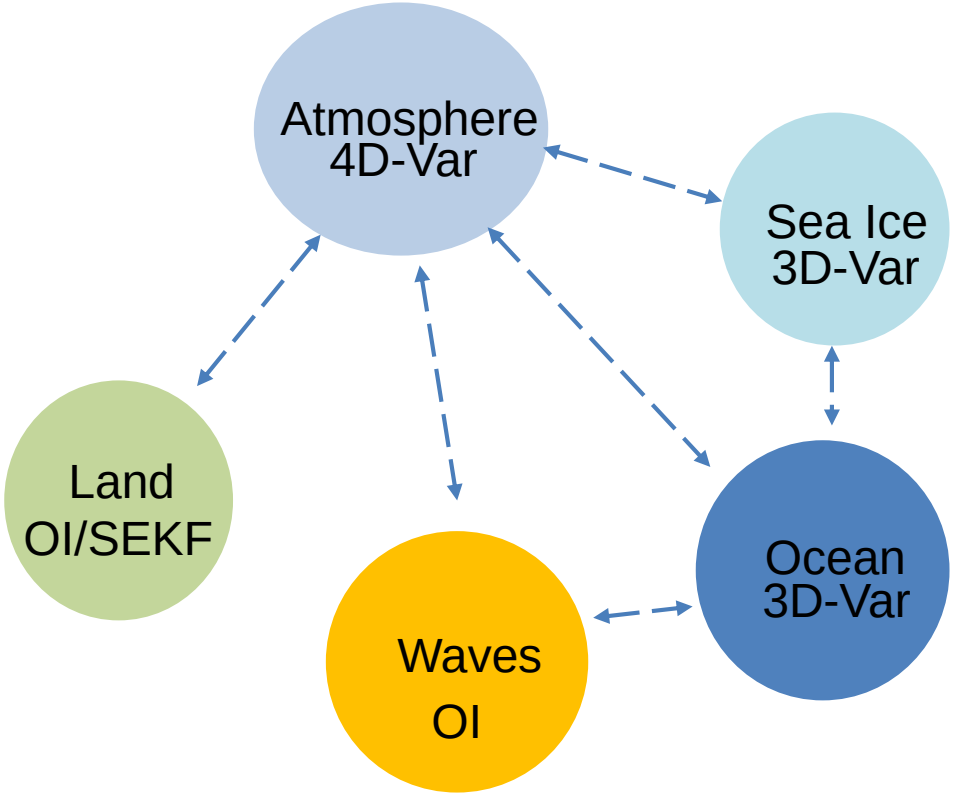
P de Rosnay, N Rodríguez-Fernández, D Fairbairn, J Muñoz-Sabater, H Lawrence, C Baugh, F Di Giuseppe, S English, C Prudhomme, M Drusch, S Mecklenburg

Thanks to: P Browne, P Weston, E Holm, L Isaksen, M Bonavita, I Mallas, A Bonet, C Albergel, G Balsamo, F Aires, C Prigent, Y Kerr, J-P Wigneron, and many other colleagues

Earth system approach



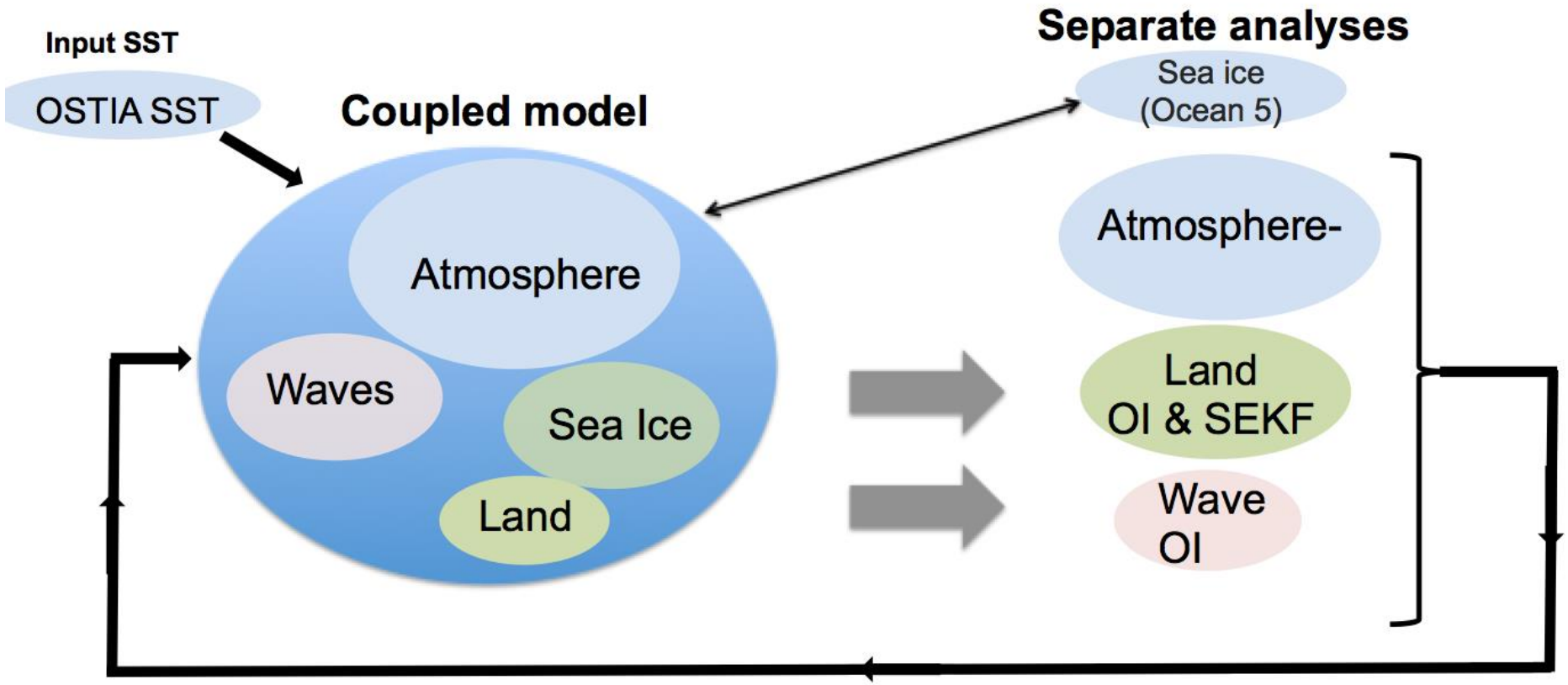
Integrated Forecasting System (IFS)



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

Current operational NWP system at ECMWF

weakly coupled land-atmosphere-wave and sea ice assimilation



→ **Importance of the interface observations for consistent initialisation of coupled land-atmosphere forecasts**

→ **Soil moisture observations highly relevant for coupled assimilation**

Soil moisture satellite observations

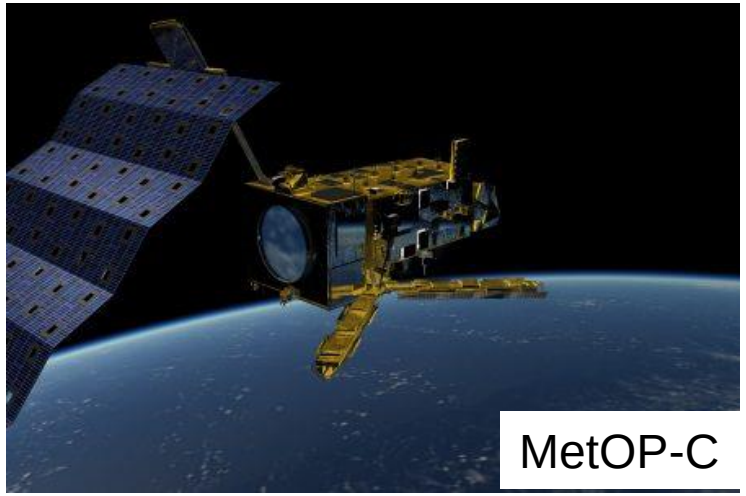
Active microwave data:

ASCAT: Advanced Scatterometer

On MetOP-A (2006-), MetOP-B (2012-), MetOP-C (2018-)

C-band (5.6GHz) backscattering coefficient

EUMETSAT Operational misison



MetOP-C

Passive microwave data:

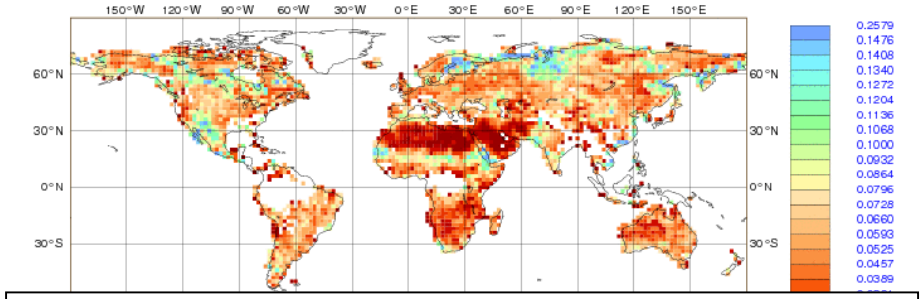
SMOS: Soil Moisture & Ocean Salinity (2009-)

L-band (1.4 GHz) Brightness Temperature

ESA Earth Explorer, edicated soil moisture mission

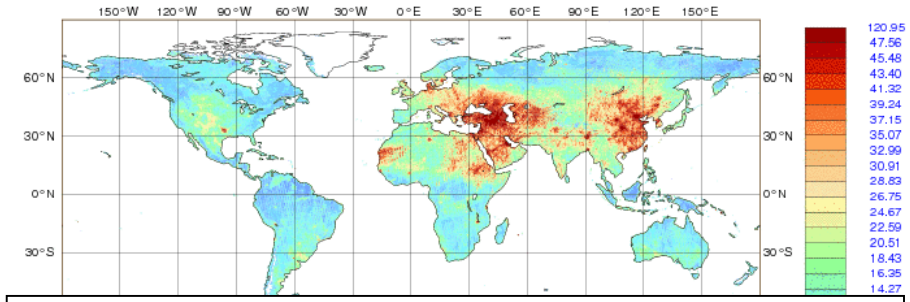
SMOS

Data from **SMAP** (Soil Moisture Active Passive), NASA soil moisture mission, also available



ASCAT soil moisture (m^3m^{-3})

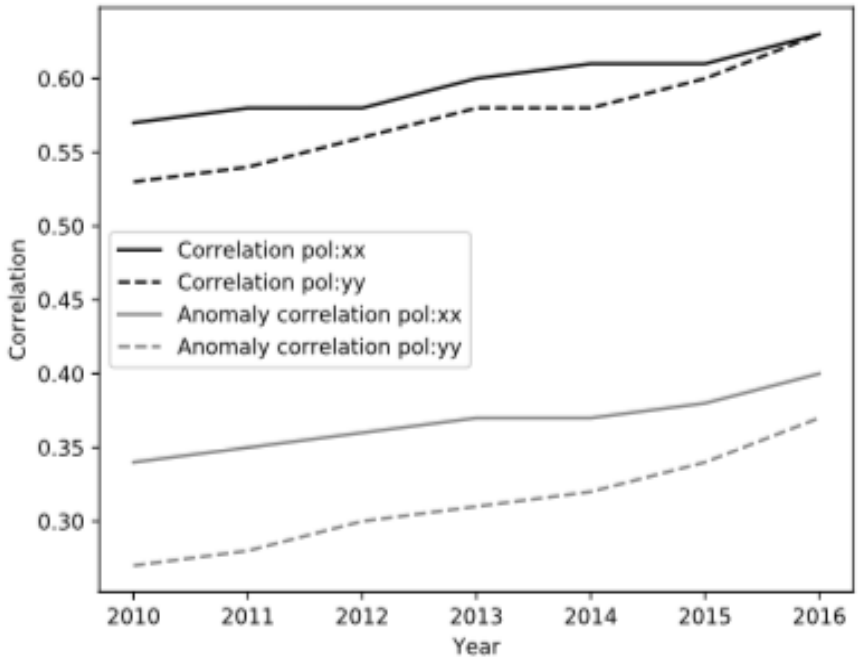
Stdev(O-B)
Sept. 2013



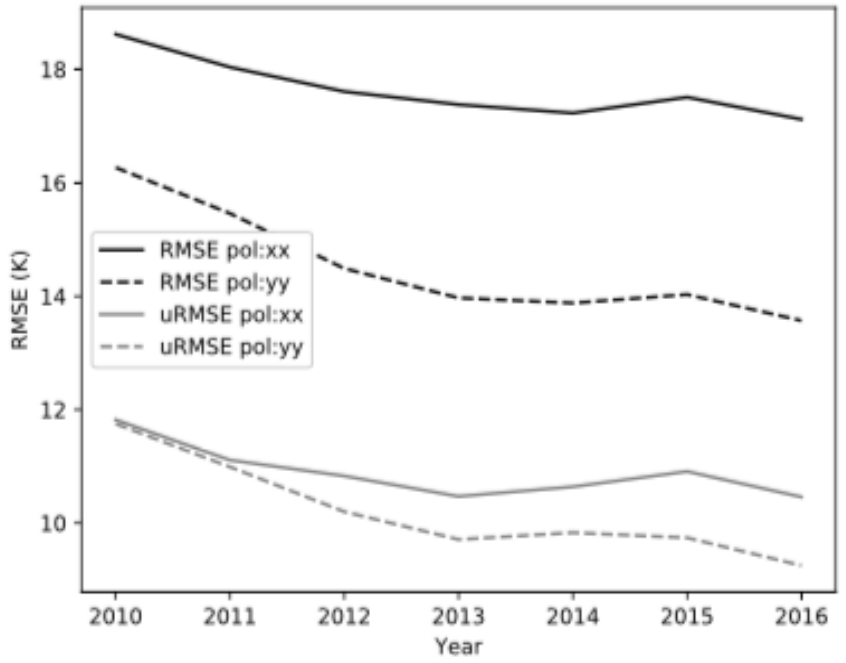
SMOS Brightness temperature (K)

Global mean comparison between SMOS TB and ECMWF TB for 2010-2016

SMOS continuous bias correction and long term monitoring



(a) Correlation



(b) Root mean square error

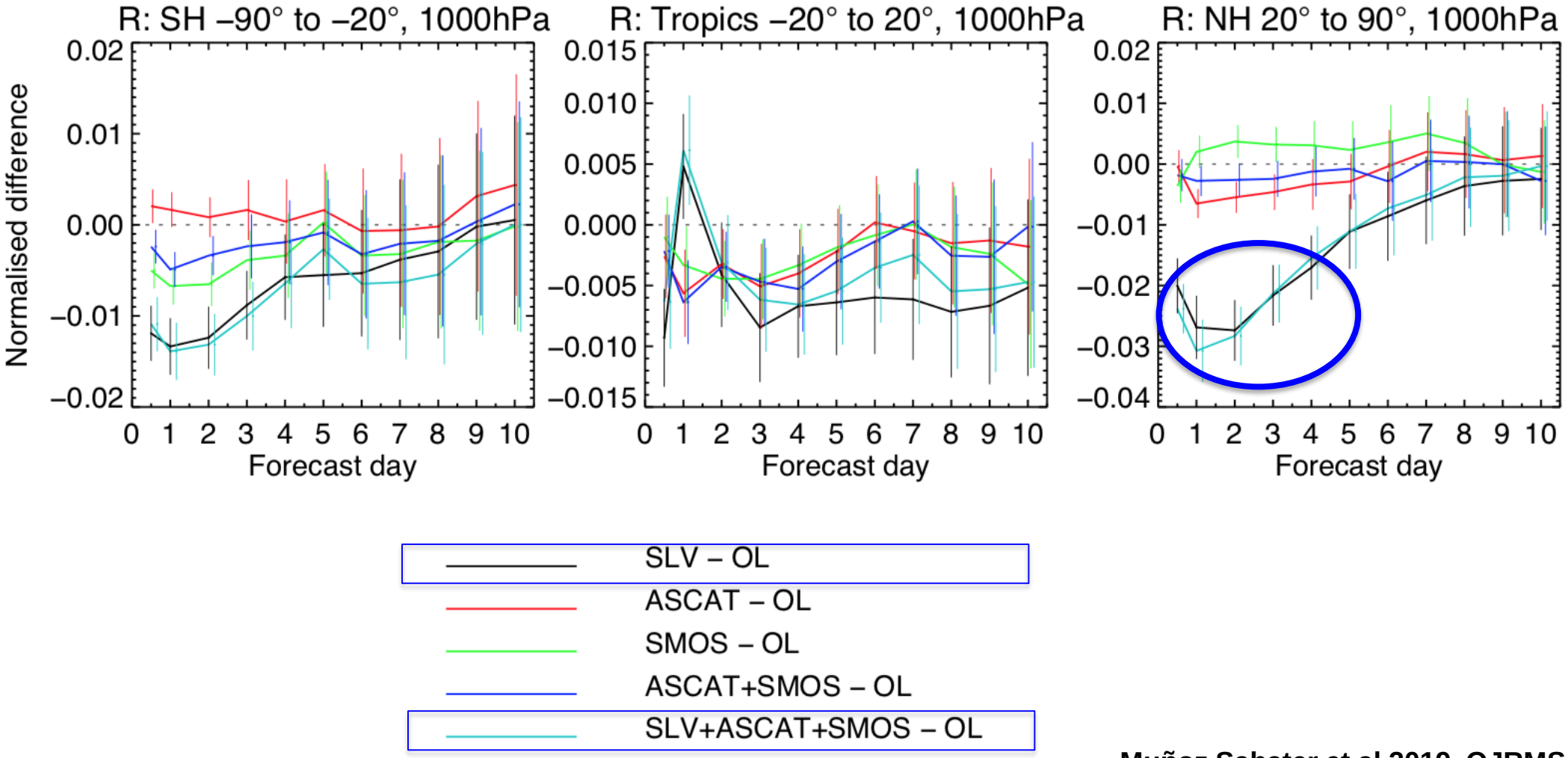
Consistent improvement of agreement between SMOS and ECMWF reanalysis from 2010 to 2016 at both polarisations

(de Rosnay et al 2019, RSE, in review)

L-band assimilation in ECMWF IFS

SMOS TB assimilation

Atmospheric forecasts evaluation for MJJAS 2013



Muñoz Sabater et al 2019, QJRMS, in review

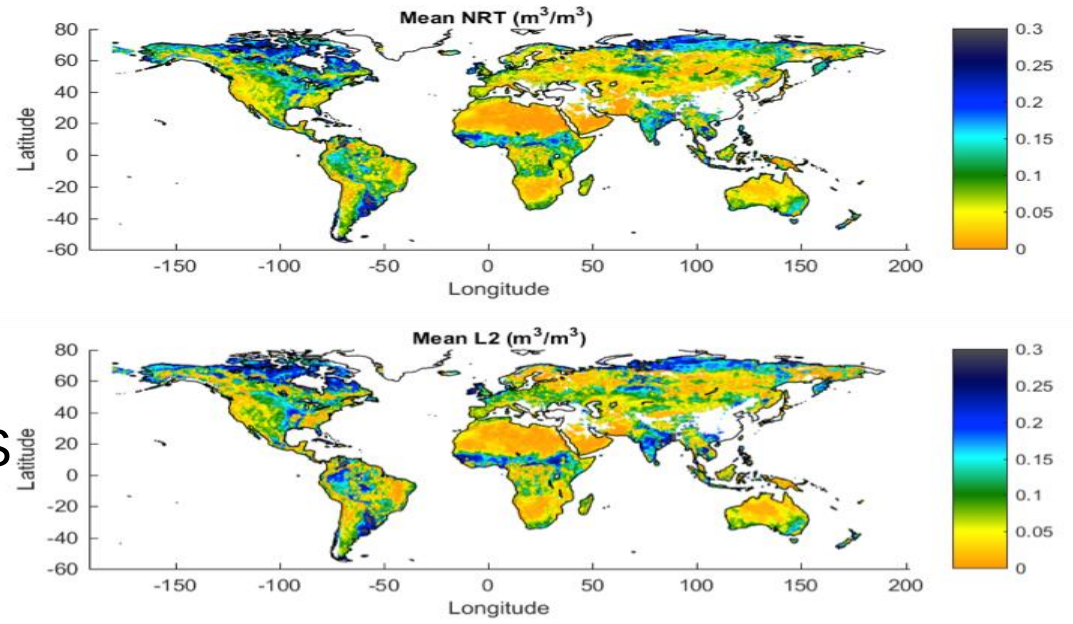
ESA level 2 SMOS NRT Soil Moisture product based on Neural Network (2016)

Designed by CESBIO/Estellus, Implemented by ECMWF

- Neural Network used to retrieve SMOS L2 SM from NRT brightness temperature
- Trained on SMOS L2 Soil moisture

→ NRT (4h latency) SMOS L2 SM

- Available in NetCDF, since March 2016 on ESA SMOS Online Dissemination service*https://smos-ds-02.eo.esa.int/oads/access*



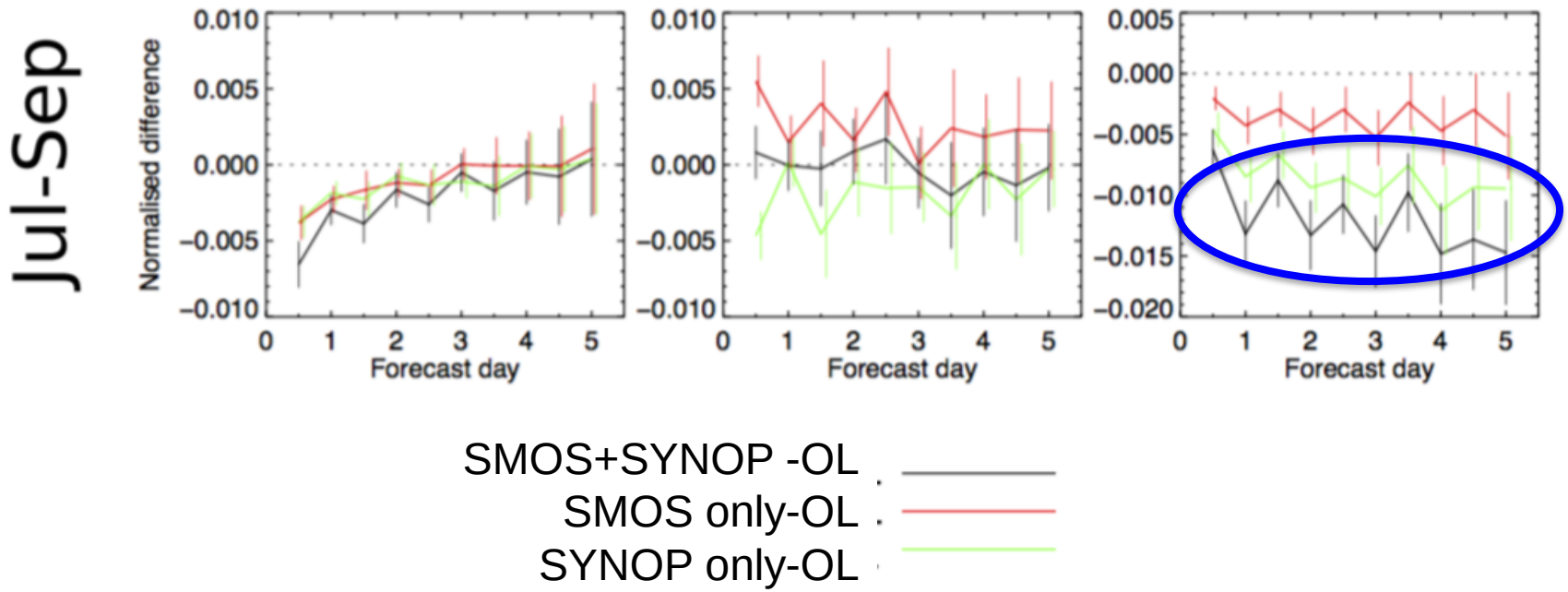
L2 NRT vs L2 (v6.20) soil moisture
L2 NRT vs situ stations (USCRN, SCAN) R= 0.71

Poster on Tuesday, South hall floor 0:
A4.13: EO for Hydrological Events Poster Session

Rodriguez-Fernandez et al, HESS 2017

SMOS Neural Network SM assimilation in H-TESSEL

- Offline assimilation in H-TESSEL and initialisation of stand-alone atmospheric forecasts (2012)
- Reference H-TESSEL with no assimilation: Open Loop (OL)
- Impact on two-meter air temperature forecasts (JAS 2012)



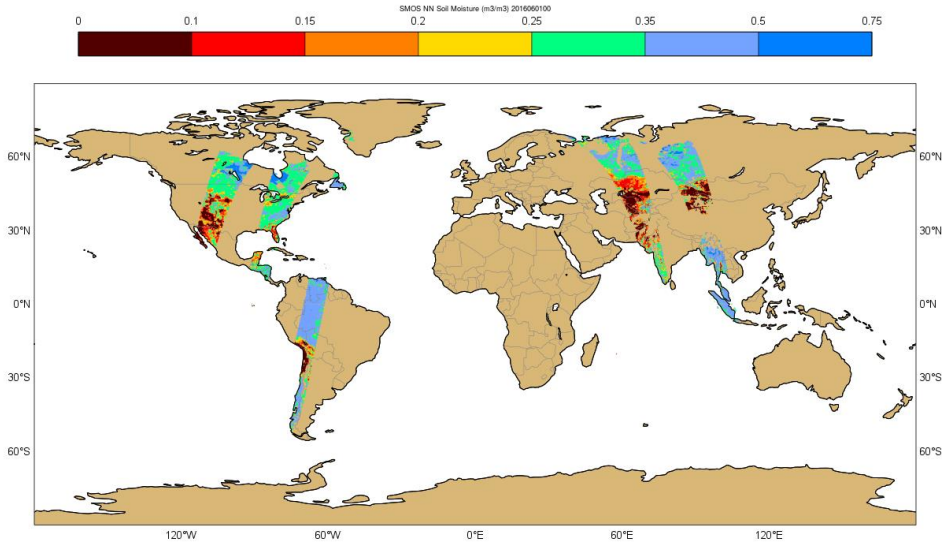
→ Proof of concept of SMOS NN assimilation for NWP initialisation

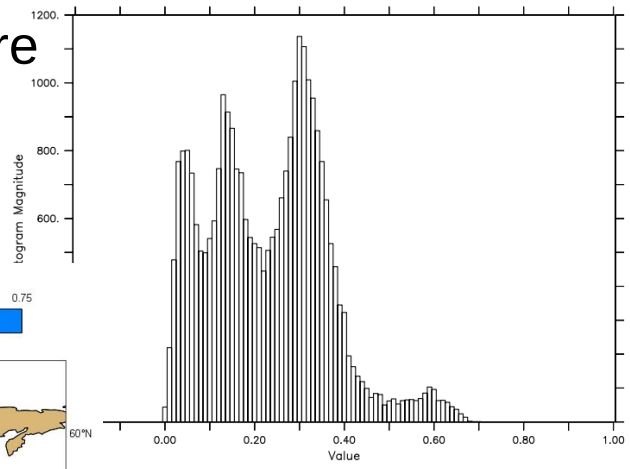
Rodriguez-Fernandez et al, Remote sensing, in review, 2019

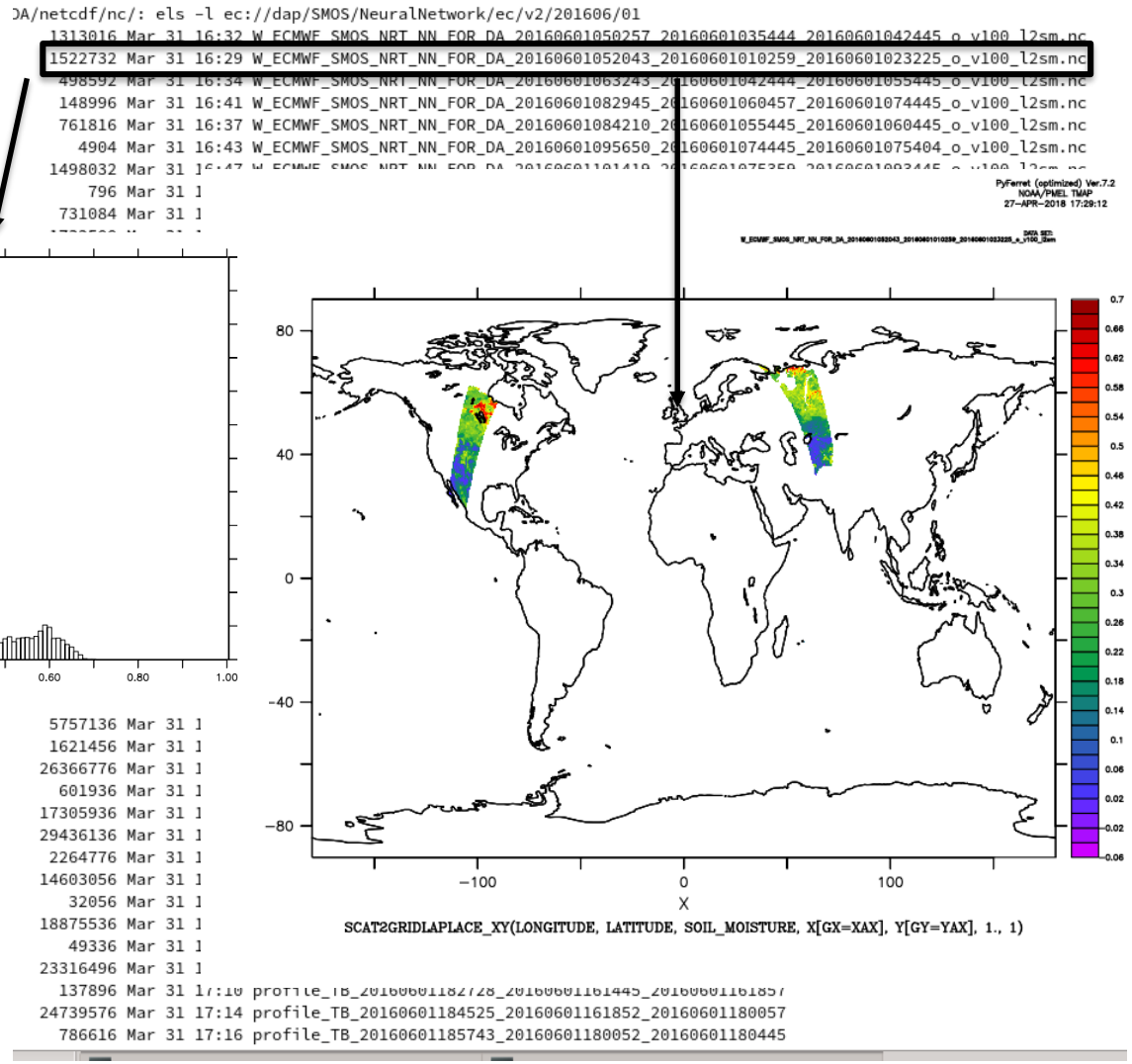
ECMWF

ECMWF level 2 SMOS Neural Network soil moisture (2018)
For data assimilation purposes

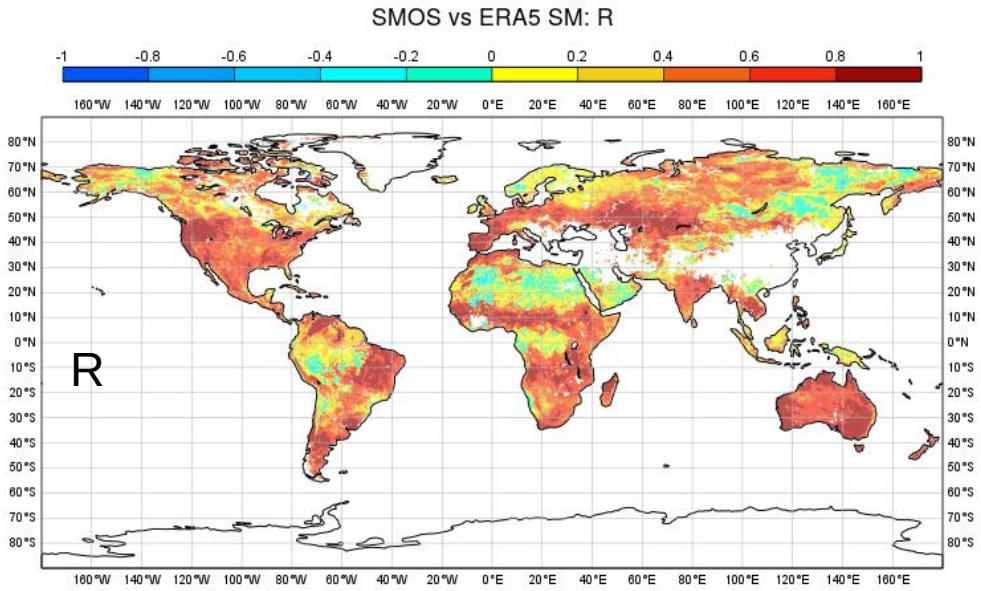
- NN Trained on ECMWF soil moisture
- SMOS soil moisture with no bias compared to ECMWF soil moisture
- NRT processing
- → suitable for data assimilation

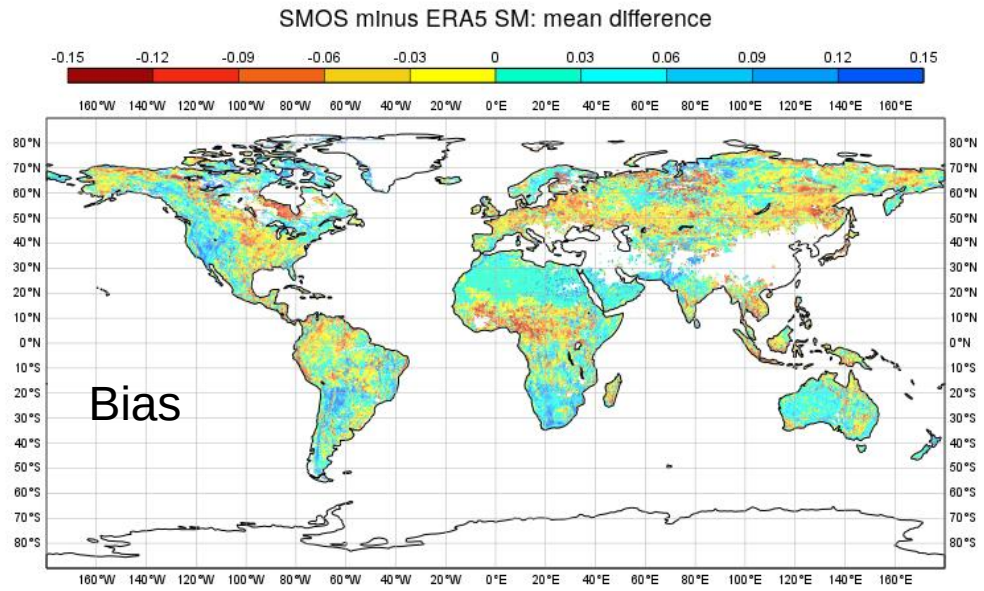


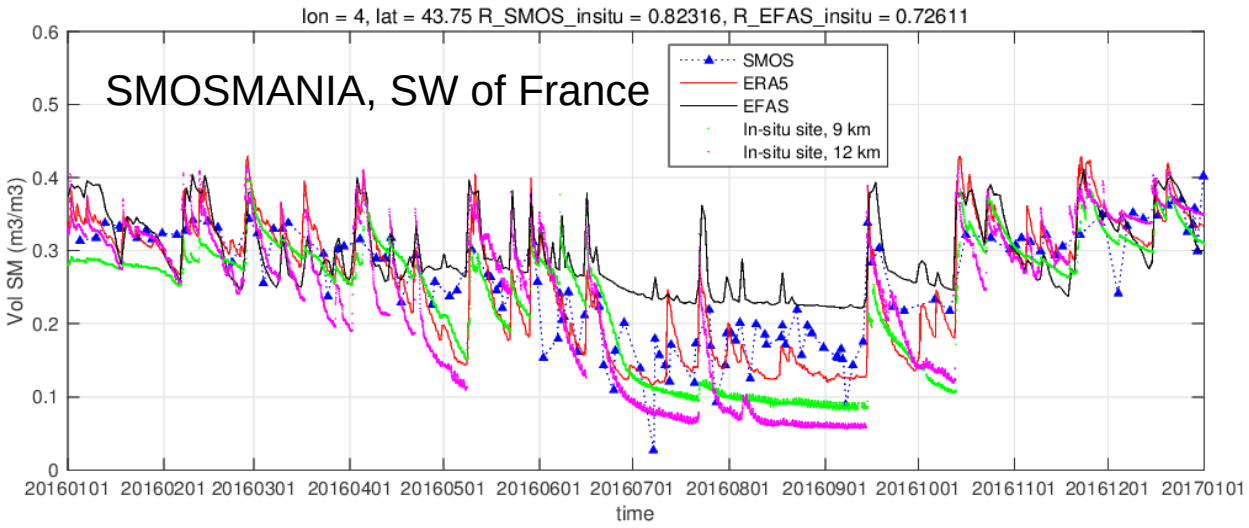




ECMWF level 2 SMOS Neural Network soil moisture compared to ERA5 e.g. in 2016



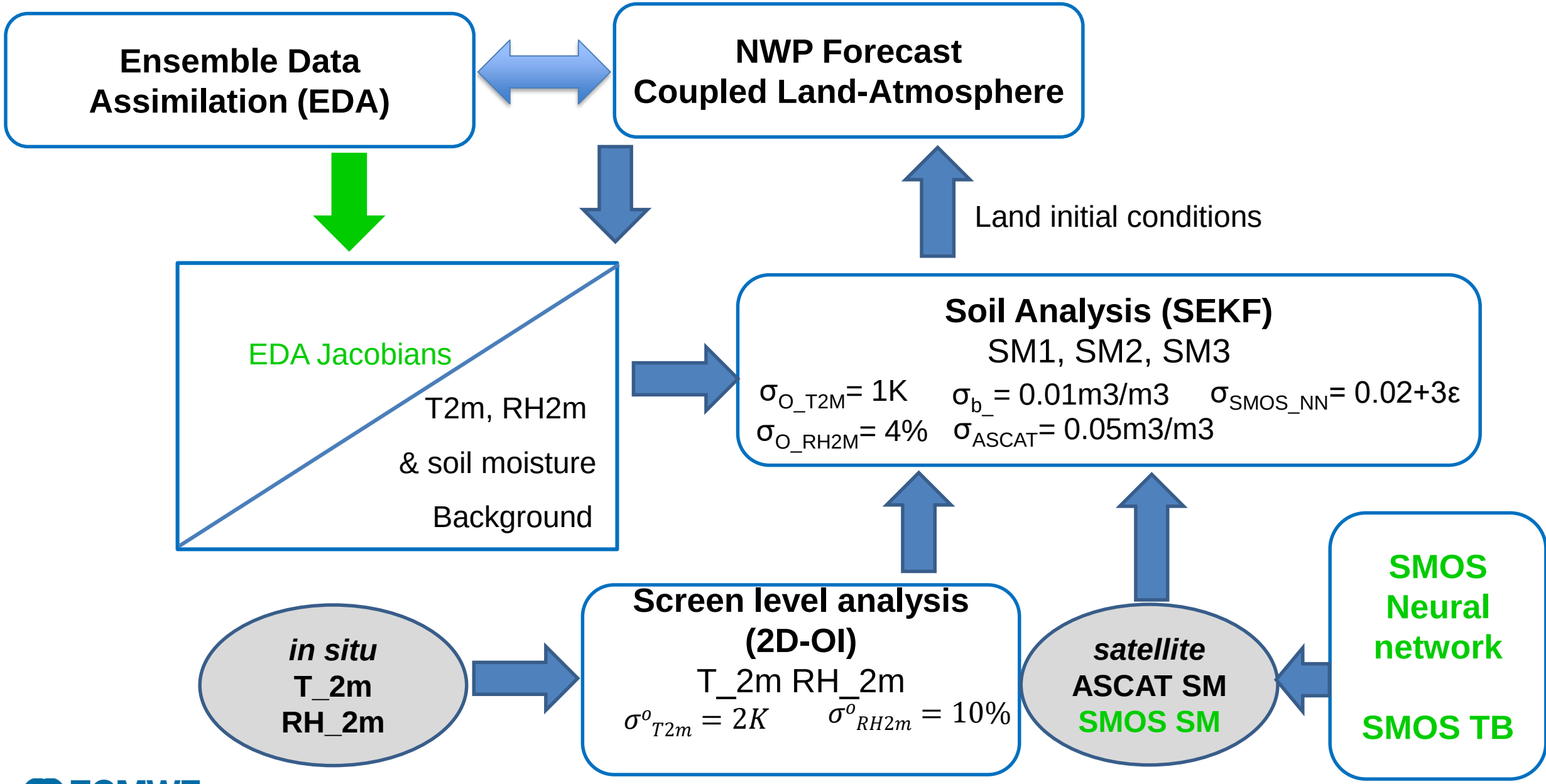




Comparison with the European Flood Alert System (EFAS) soil moisture

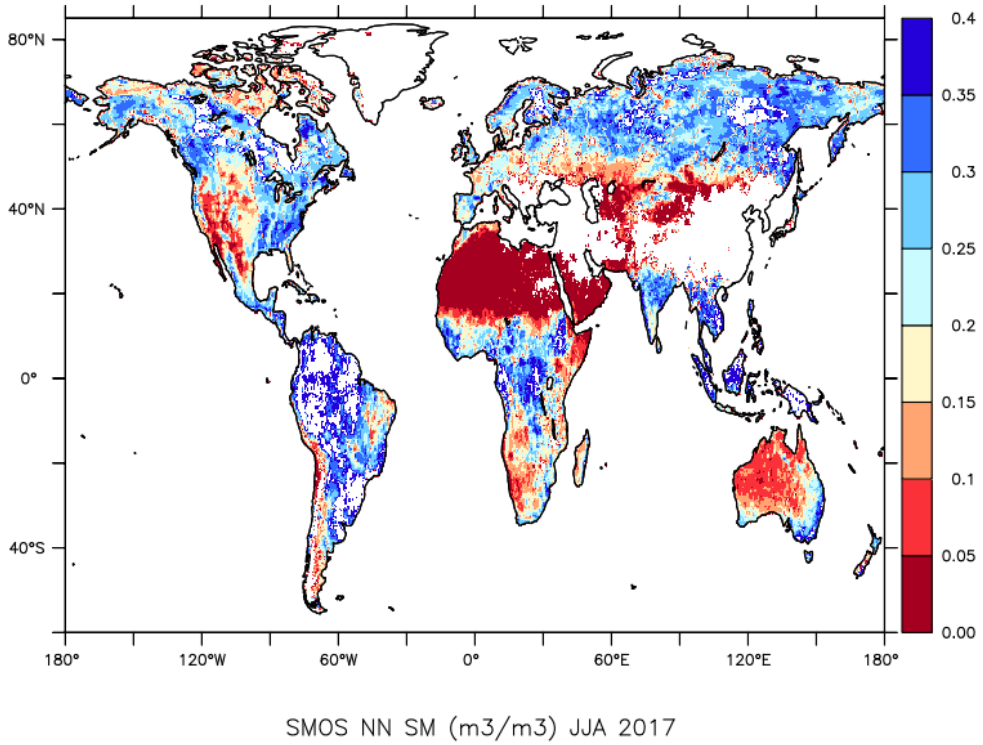
Lawrence et al. ESA report 2019, in prep

ECMWF Soil Analysis in IFS 46r1 (oper 11 June 2019)



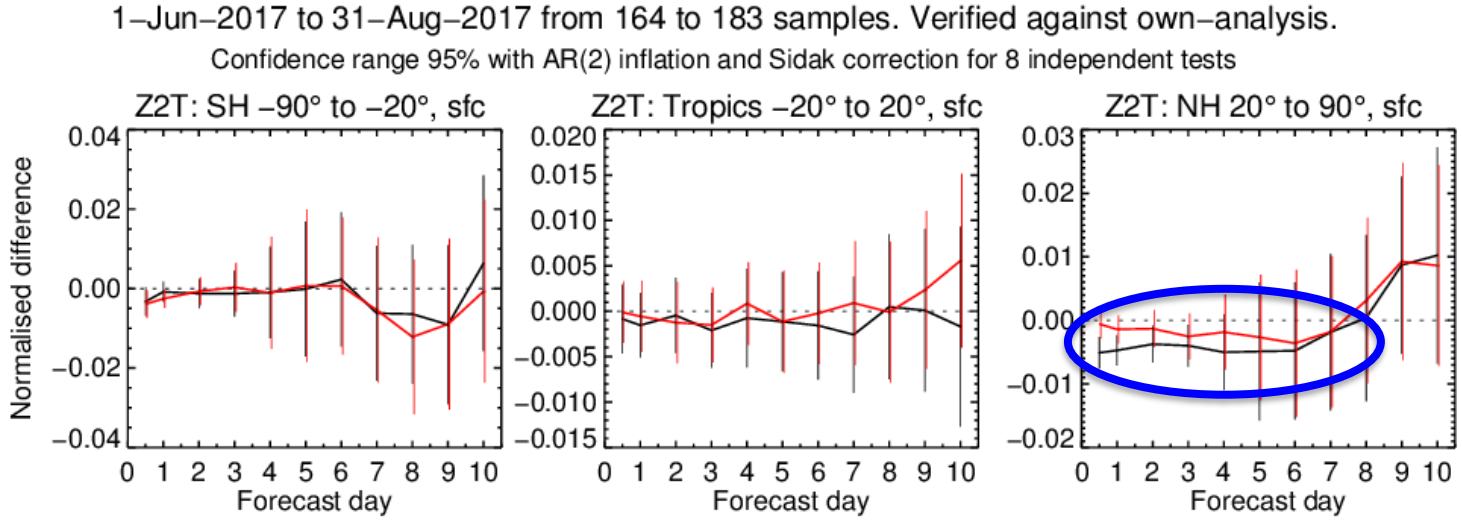
EDA SEKF and SMOS NN DA impact

- **Enhanced coupling:**
  - Use the EDA to compute the SEKF Jacobian
  - assimilate soil moisture from SMOS in coupled land-atmosphere forecasting system
- **Improved efficiency:**
  - CPU reduction (factor 3.6) from EDA SEKF, cost neutral for SMOS



SMOS NN SM (m3/m3) JJA 2017

Atmospheric impact (T2m)



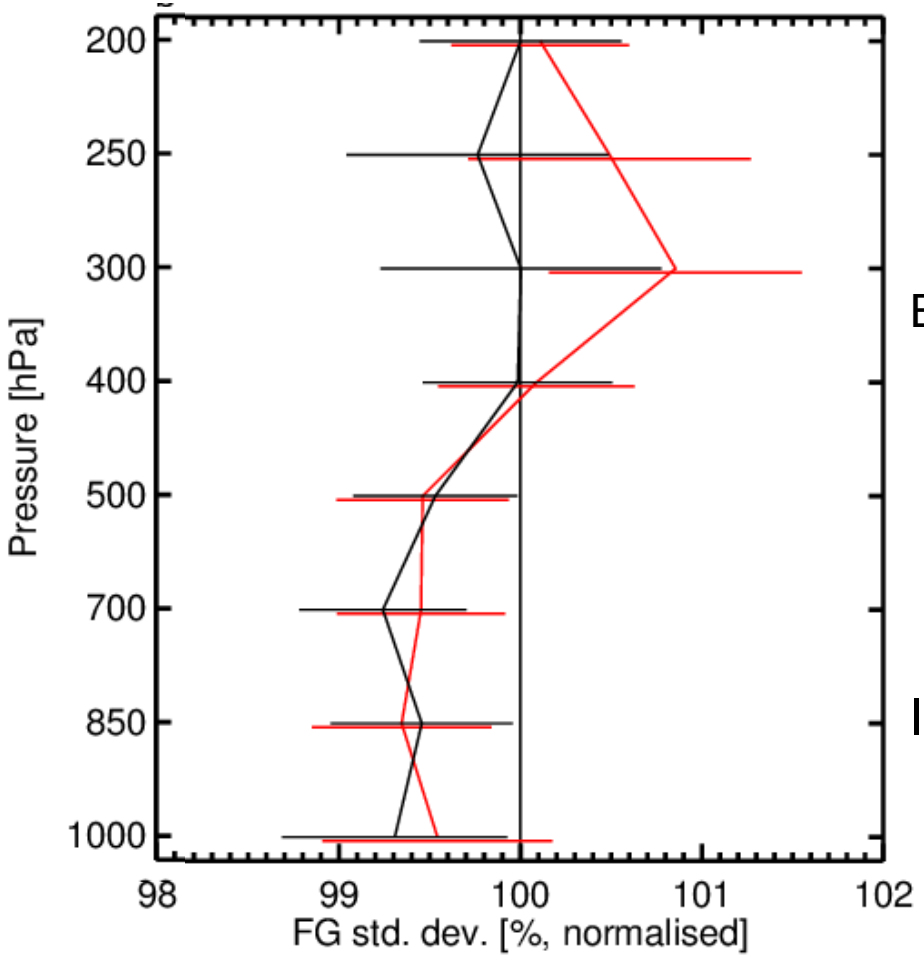
gykr EDA&SMOS - CTRL

gykk SMOS – CTRL

de Rosnay et al, in prep, 2019

SMOS neural network data assimilation:
Fit between IFS first guess and independent observations (obs-model)

Aircraft humidity (JJA 2017)

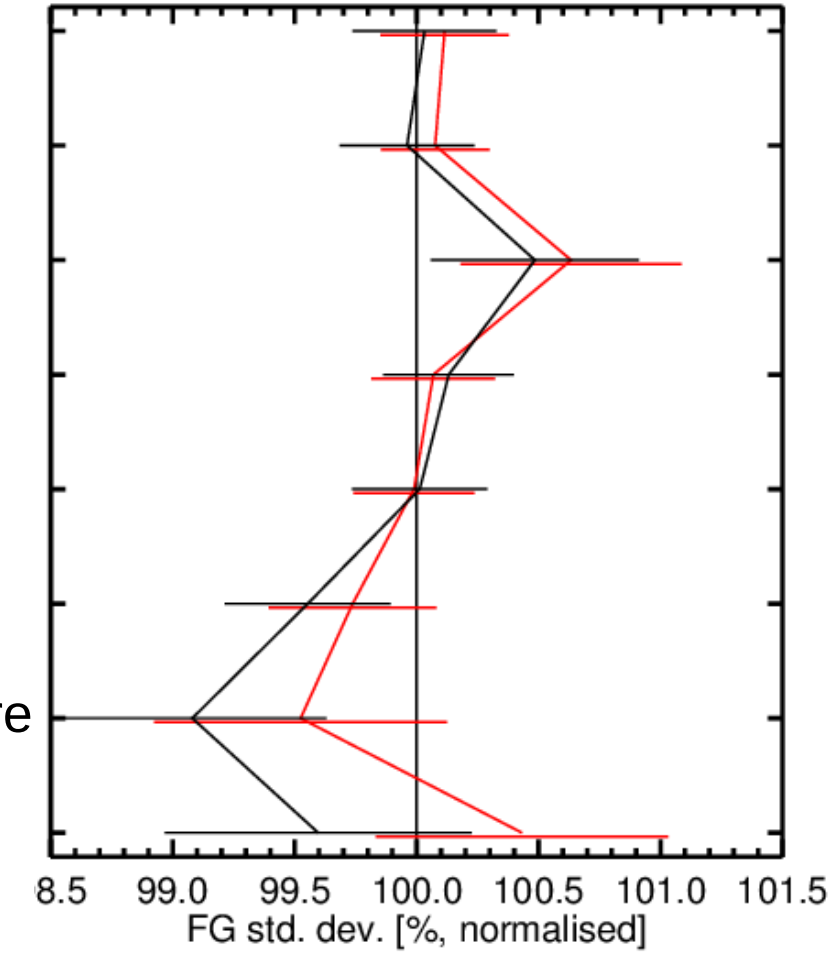


EDA_SMOS_DA minus CTRL

SMOS_DA minus CTRL

Improved fit in low troposphere

Aircraft temperature (JJA 2017)



Evaluation of surface and root zone soil moisture against in situ data

More than 300 stations in US and Europe (SCAN, USCRN, SNOTEL and SMOSMANIA)

Experiment	R		Ranom		uRMSD		Bias	
	surface	root Zone	Surface	root zone	surface	root zone	surface	root zone
CTRL (45r1)	0.617	0.65	0.518	0.428	0.052	0.031	0.06	0.058
SMOS DA	0.609	0.667	0.507	0.443	0.052	0.030	0.058	0.052
SMOS+EDA (46r1)	0.623	0.64	0.521	0.421	0.051	0.029	0.055	0.052

Slight but consistent improvement of soil moisture with SMOS+EDA compared to CTRL

Summary and perspectives

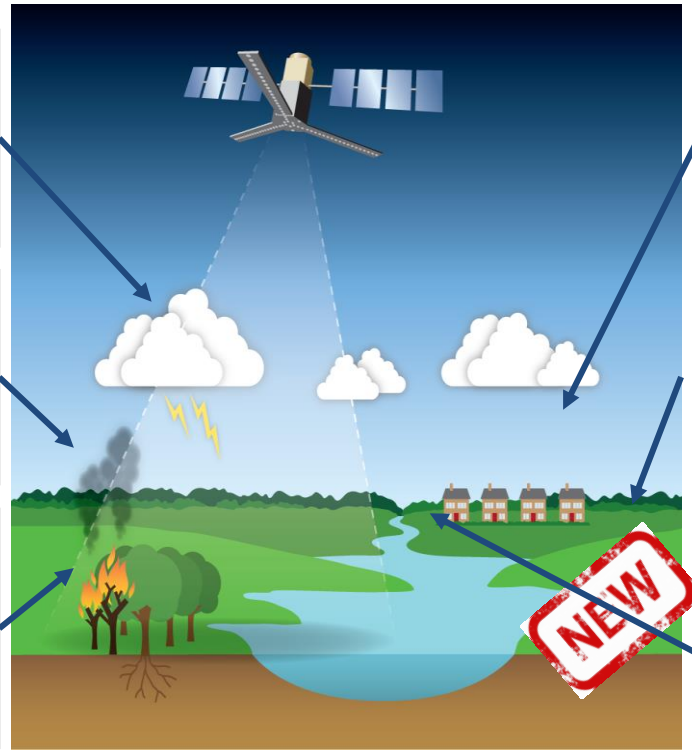
- **Operational** SMOS Neural Network assimilation in the ECMWF IFS in IFS cycle 46r1 from June 2019
- **Research and development**: SMOS Neural network impact study on flood and fire forecasting for the Copernicus Emergency and Management Service (CEMS)

FIRE

SMOS-NN soil moisture product will be used to identify dry lightning (ignition potential)

SMOS-NN soil moisture product will be used to study the modulation of fire emissions

SMOS biomass load product will be used to characterise the available fuel for burning



FLOOD

Benchmarking SMOS Soil Moisture with Analysis and Re-Analysis Datasets

SMOS Soil Moisture Initialisation in EFAS (Europe) & GloFAS (global) flood forecast systems

Flood Susceptibility and the Role of Soil Moisture Excess