4th workshop on Remote Sensing and Modelling of Surface properties
Saint Martin d'Hères, 14-16 March 2016

Assimilation of land surface satellite data for Numerical Weather Prediction at ECMWF

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Introduction: Land Surface for Numerical Weather Prediction (NWP)

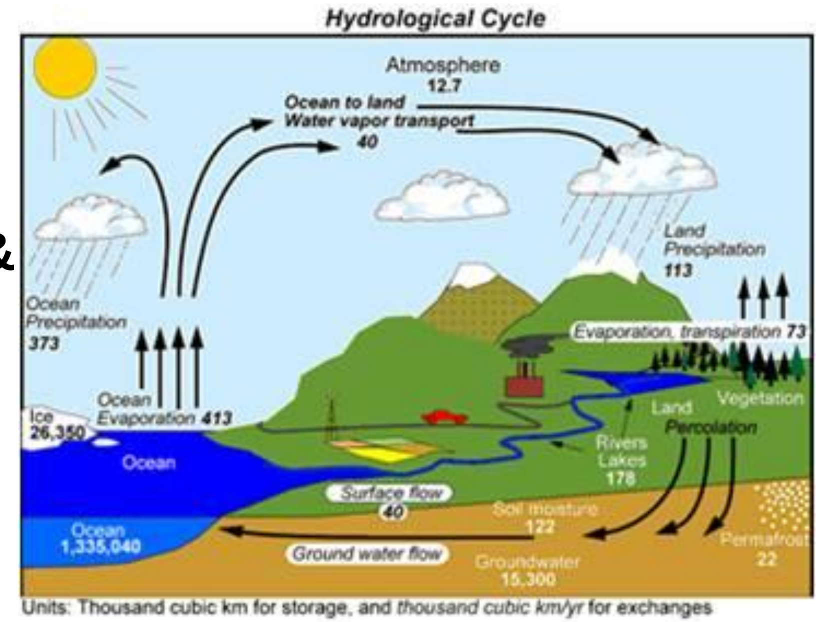
Land surfaces:

- Processes: Continental hydrological cycle, interaction with the atmosphere on various time and spatial scales
- Boundary conditions at the lowest level of the atmosphere
- Crucial for near surface weather conditions,

whose high quality forecast is a key objective in NWP

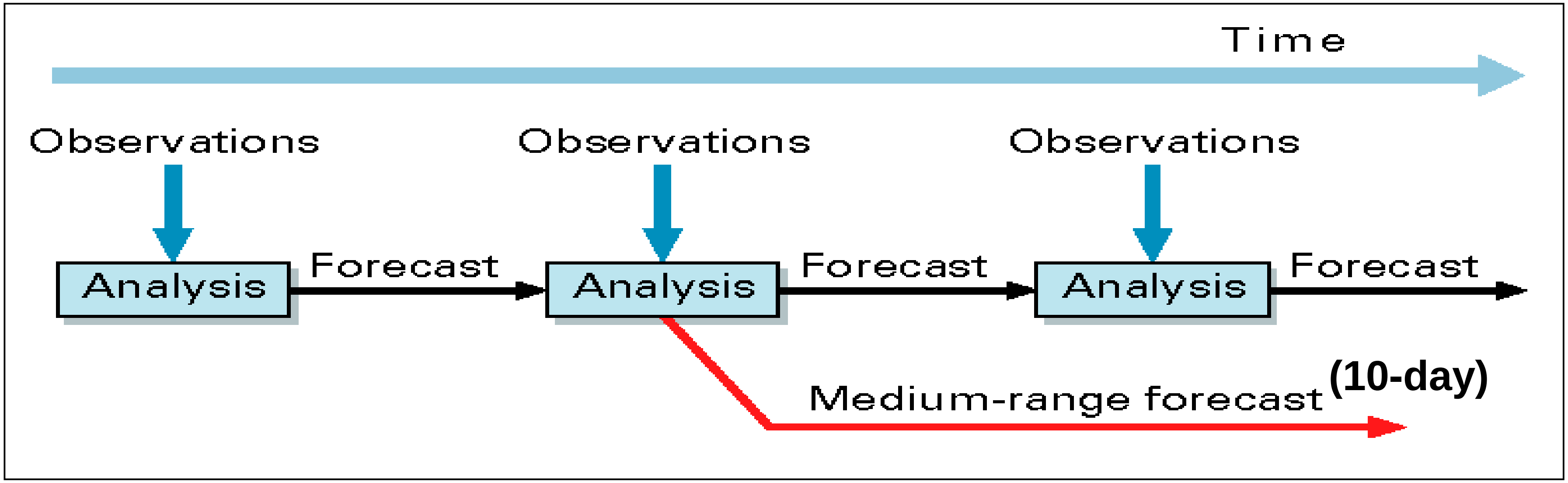
→ **Land surface processes modelling & initialization are important for NWP at all range (short to seasonal)**

(Beljaars et al., Mon. Wea. Rev, 1996, Koster et al., 2004 & 2011)



Trenberth et al. (2007)

ECMWF Integrated Forecasting System (IFS)



- **Forecast Model:** GCM including the H-TESSEL land surface model (fully coupled)

- **Data Assimilation → initial conditions of the forecast model prognostic variables**
  - **4D-Var for atmosphere**
  - **Land Data Assimilation System**

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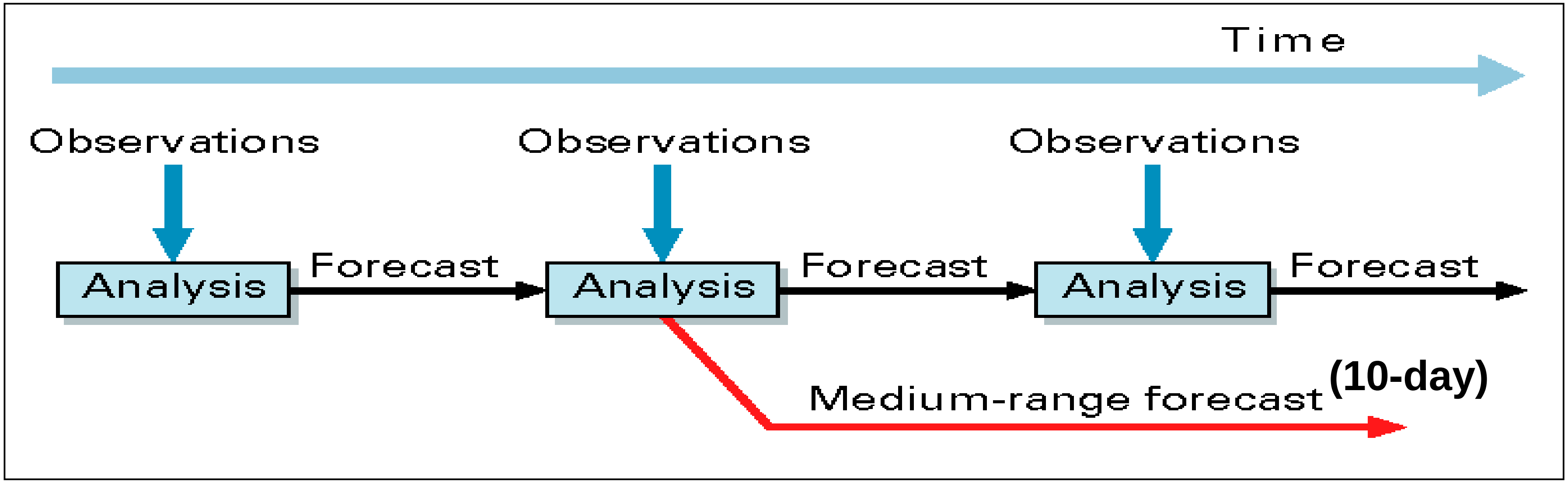

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Several Systems:

- **NWP (oper):** IFS (with 4D-Var and LDAS), 16km, version 41r1 (2015)
- **ERA-Interim:** IFS (with 4D-Var and LDAS), 79km, version 31r1 (2006)
- **ERA5:** IFS (with 4D-Var and LDAS), 39km, version 41r2 (2016)

} **Weakly coupled DA**

- ERA-Interim-Land: 79km
- ERA5-Land: 39 km

H-TESSEL LSM simulations forced by ERA→ model only: no LDAS

ECMWF Land Data Assimilation System (LDAS)

Snow depth

Methods: Cressman for ERA-Interim, 2D Optimal Interpolation (OI) for NWP & for ERA5

Conventional observations: *in situ* snow depth

Satellite data: NOAA/NESDIS IMS Snow Cover Extent (daily product).

Soil moisture (SM)

Methods: - 1D Optimal Interpolation in ERA-Interim (also used at Météo-France)

- Simplified Extended Kalman Filter (EKF) for NWP and for ERA5

Conventional observations: Analysed SYNOP 2m air relative humidity and air temp.

Satellite data: Scatterometer SM for NWP (ASCAT) & for ERA5 (ERS/SCAT &ASCAT)

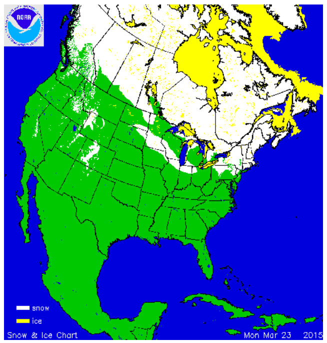
ESA SMOS brightness temperature in development, research NASA SMAP

Soil Temperature and Snow Temperature

1D-OI using analysed T2m as observation (NWP, ERA-Interim, ERA5)

Snow analysis: Forecast impact

Revised IMS snow cover data assimilation



Impact on snow October 2012 to April 2013 (using 251 independent in situ observations)

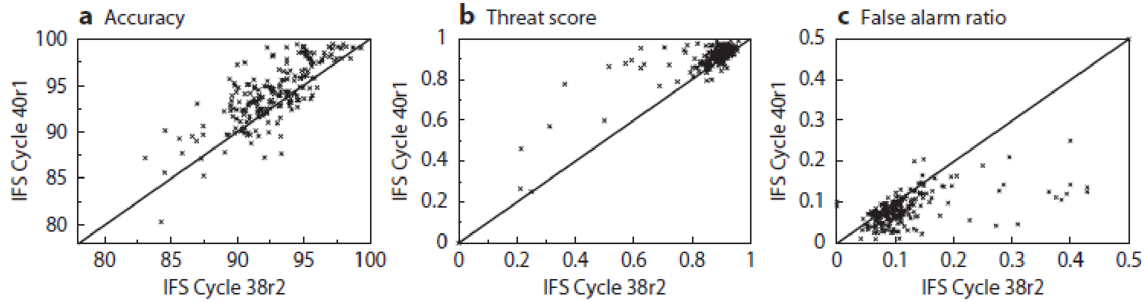
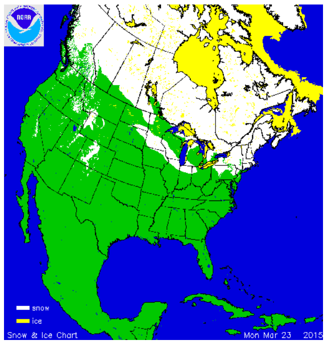


Figure 2 Snow analysis scores for the revised IFS 40r1 snow analysis versus the IFS 38r2 analysis for (a) accuracy, (b) threat score, and (c) false alarm ratio in the period October 2012 to April 2013. Each cross represents the scores computed against 251 independent in situ snow depth observations for a given date. The scatter plots show the results for each of the 212 days from 1 October 2012 to 30 April 2013. The black line represents the one-to-one line.

Snow analysis: Forecast impact

Revised IMS snow cover data assimilation



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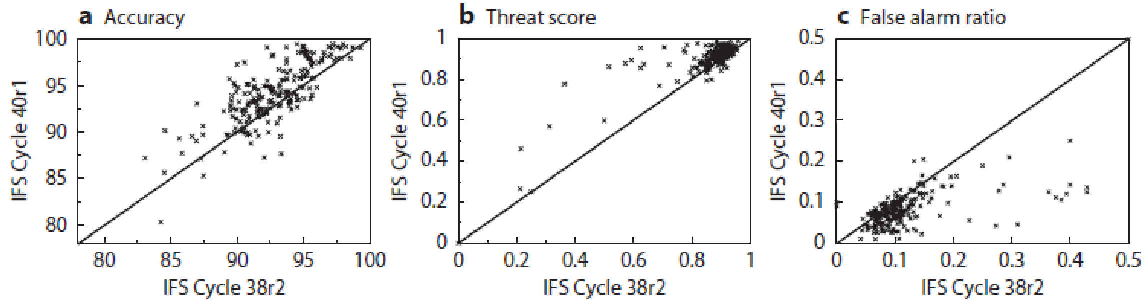

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Impact on atmospheric forecasts

October 2012 to April 2013 (RMSE new-old)

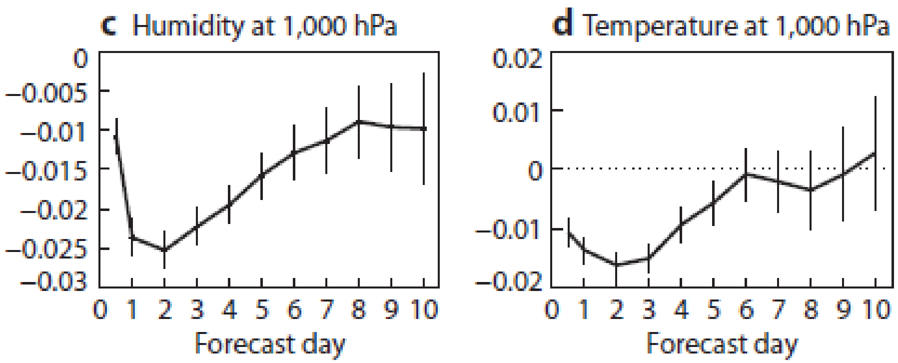


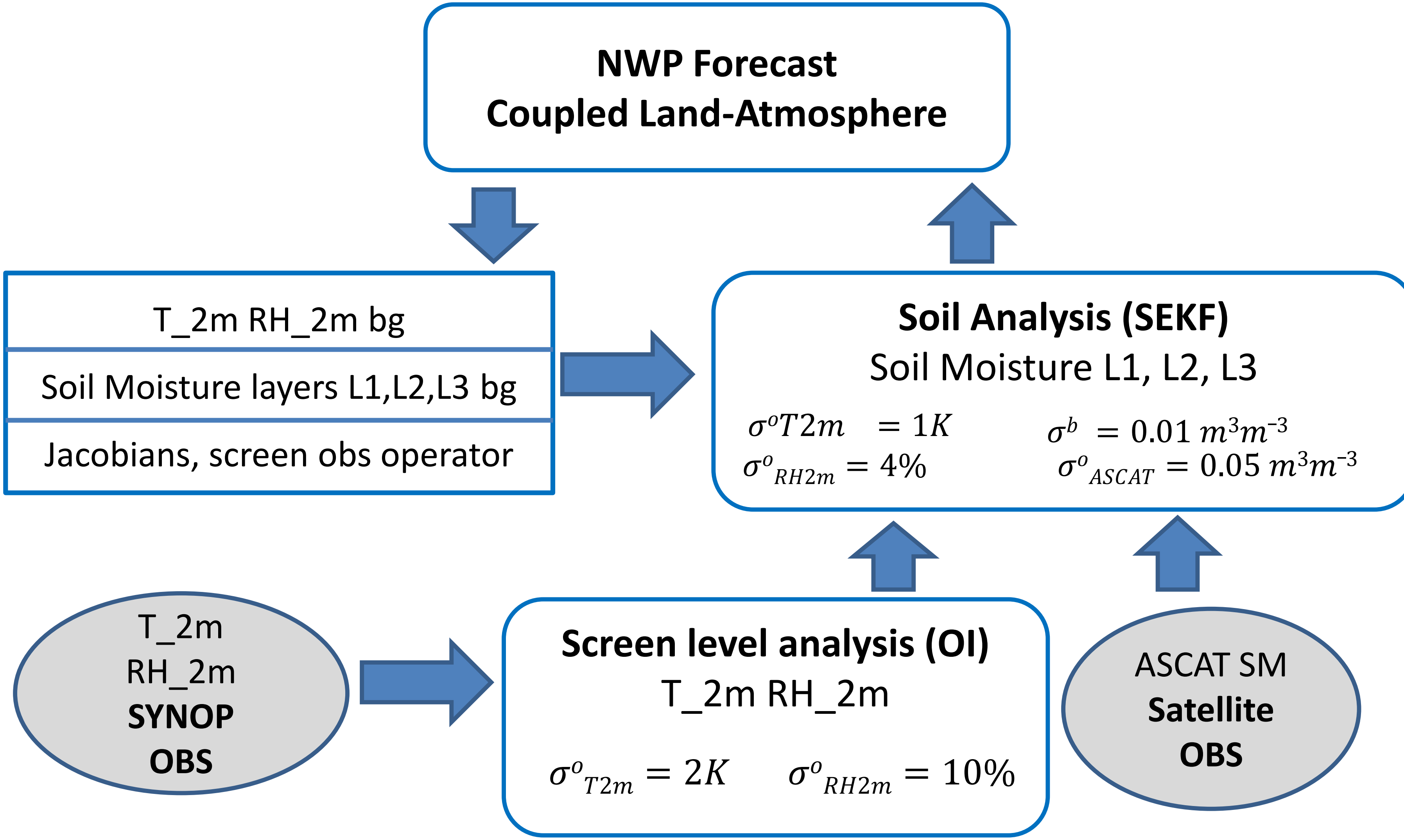
Figure 4 Impact of the revised snow analysis on the normalised root mean square error difference between IFS Cycles 40r1 and 38r2 (40r1 minus 38r2) for (a) humidity forecasts at 850 hPa;

→ Consistent improvement of snow and atmospheric forecasts

de Rosnay et al., ECMWF NL 143, Spring 2015

Soil Analysis in the IFS

ECMWF IFS cycle 41r2

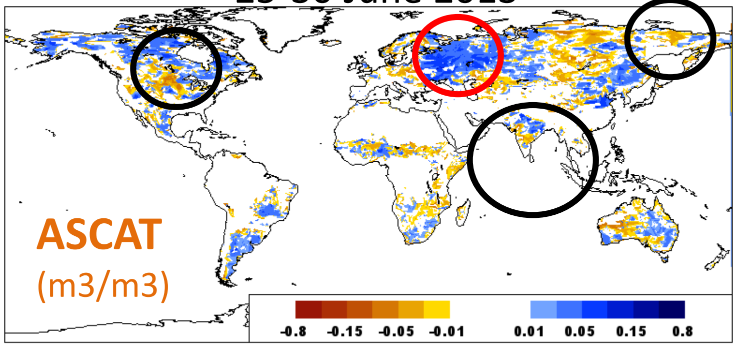


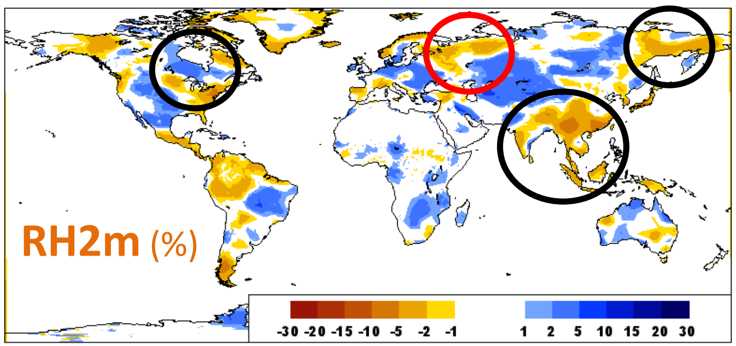
→ Operational soil moisture data assimilation: combines SYNOP and satellite data

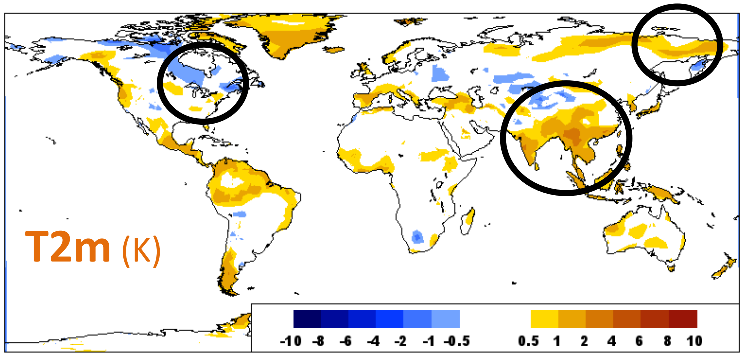
ASCAT Soil Moisture data assimilation

Innovation (Obs- model)

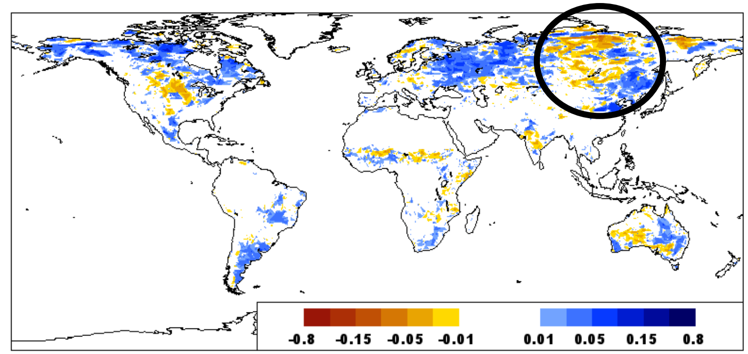
25-30 June 2013



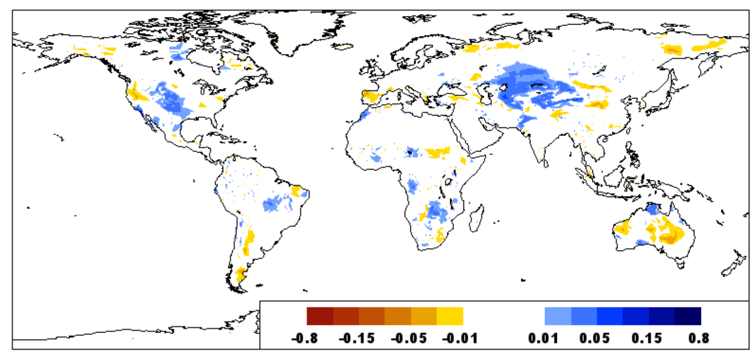




Accumulated Increments (m^3/m^3) in top soil layer (0-7cm)



Due to ASCAT



Due to SYNOP T2m and RH2m

New ECMWF Re-analysis ERA5
Assimilation of Scatterometer data record
ERS/SCAT and MetOp ASCAT reprocessed SM

Preparation tests:
Use of EUMETSAT ASCAT-A reprocessed data (25km sampling)

	FG departure Mean m^3m^{-3}	**FG departure StDev** m^3m^{-3}
Using NRT ASCAT	0.013	0.05
Using Reproc ASCAT	0.006	0.044

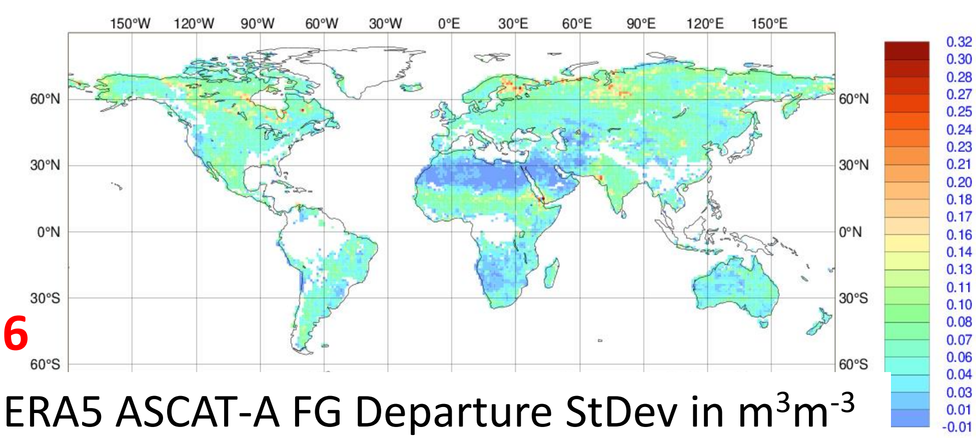
(FMA 2010)

→ Reprocessed ASCAT soil moisture:
Reduced background departure statistics both in mean and Stdev

Land Satellite DA in ERA5:

- **scatterometer soil moisture from 1991**
- **reprocessed IMS snow cover 4km product from 2004**

ERA5 production of the NRT stream (June 2014 to NRT) started in Jan. 2016



ERA5 ASCAT-A FG Departure StDev in m^3m^{-3}

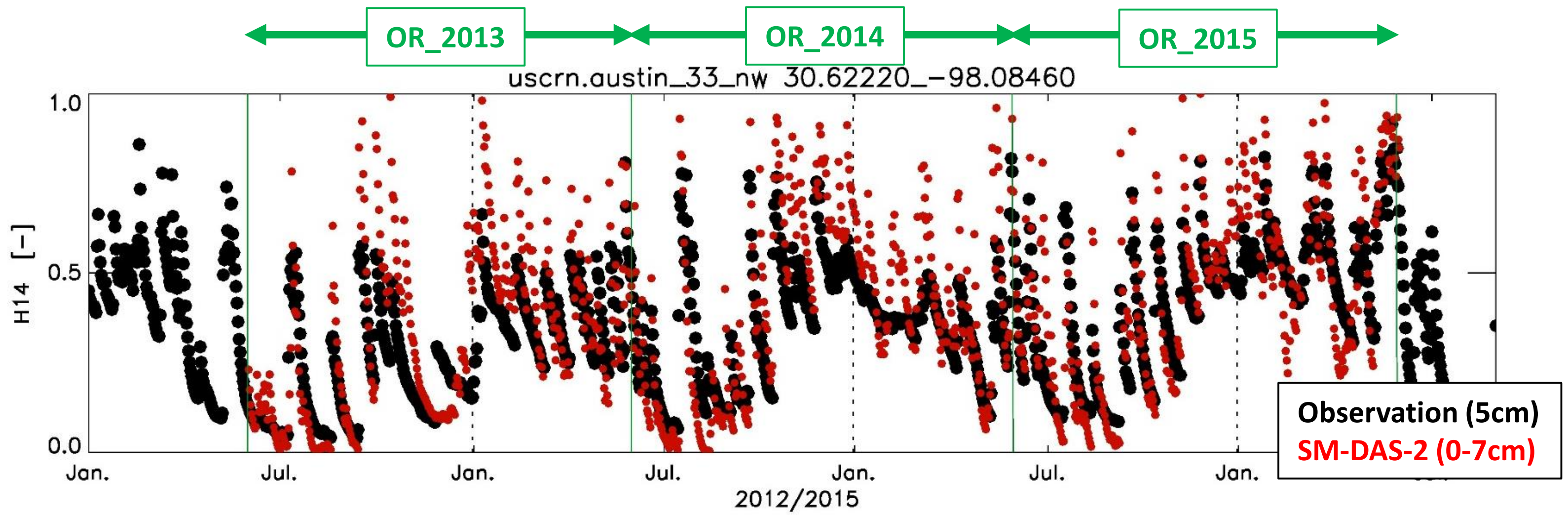
EUMETSAT H-SAF soil moisture

Scatterometer root zone soil moisture based on data assimilation

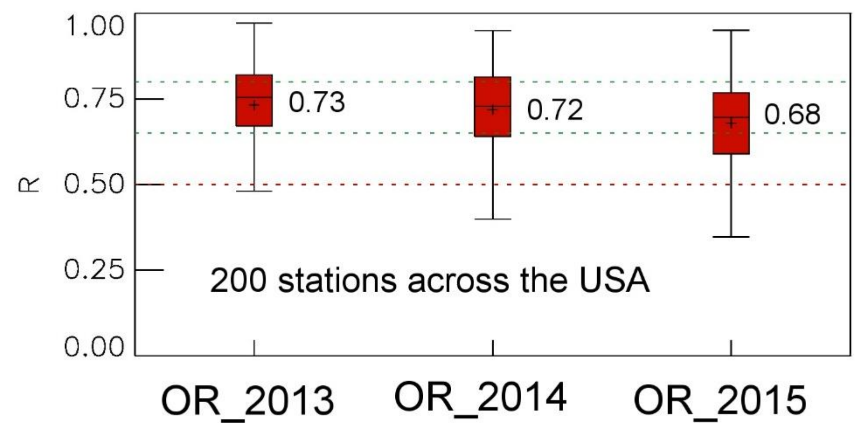
Albergel et al.

Evaluation of SM-DAS-2/H14

Surface and root zone liquid soil moisture content



Accuracy requirements for product SM-DAS-2 [R]			
Unit	**Threshold**	**Target**	**Optimal**
Dimensionless	0.50	0.65	0.80



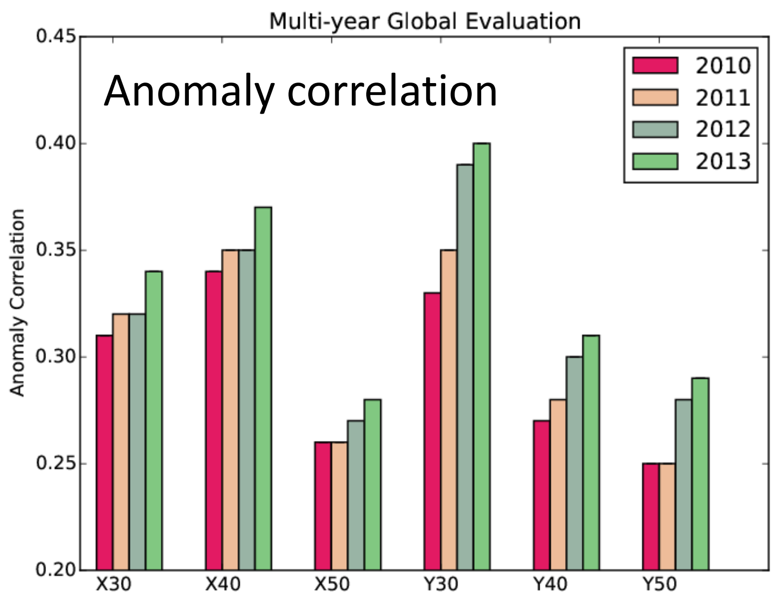
The EUMETSAT Network of Satellite Application Facilities

H SAF Support to Operational Hydrology and Water Management

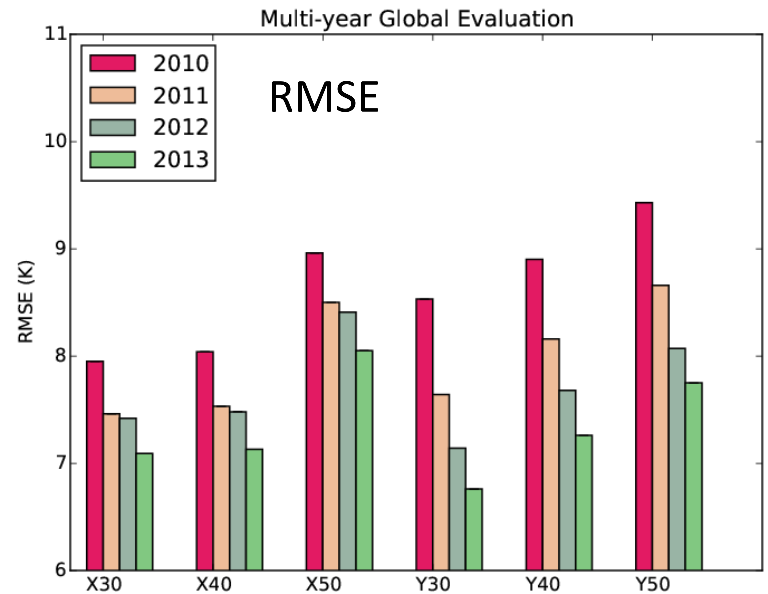
SMOS Forward modelling and Bias correction

- CMEM: ECMWF Community Microwave Emission Modelling Platform
  Also see M. Lange's presentation for new CMEM developments
  → produce reprocessed ECMWF SMOS TB for 2010-2013
- Comparison between ECMWF TB and SMOS NRT TB (both reprocessed)
- **Consistent improvement of SMOS data at Pol xx and yy, for incidence angles 30, 40, 50 degrees**

de Rosnay et al, in prep



Polarisation (xx or yy) and incidence angle (30, 40, 50)



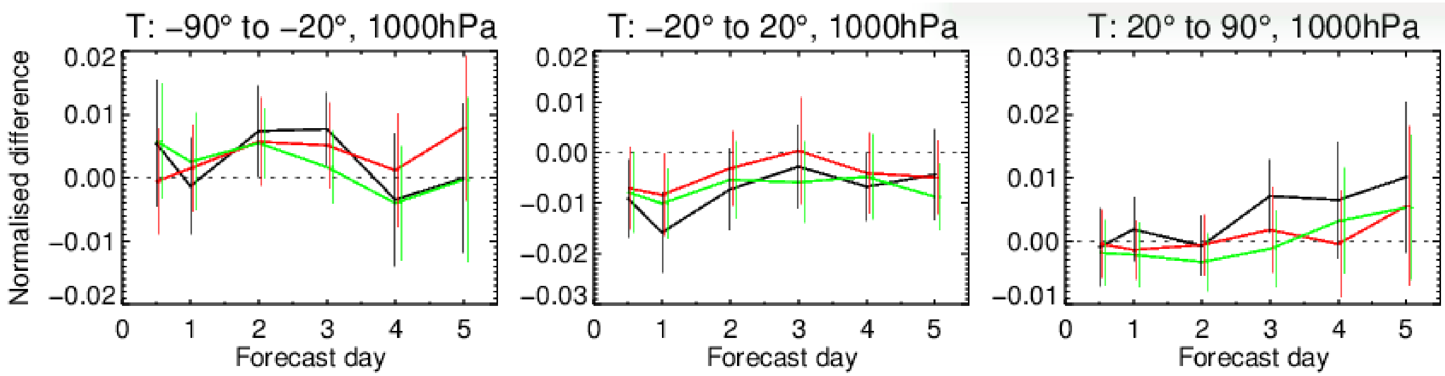
Polarisation (xx or yy) and incidence angle (30, 40, 50)

SMOS data assimilation: atmospheric impact

Muñoz-Sabater et al.

Normalized change in rms of fc error:

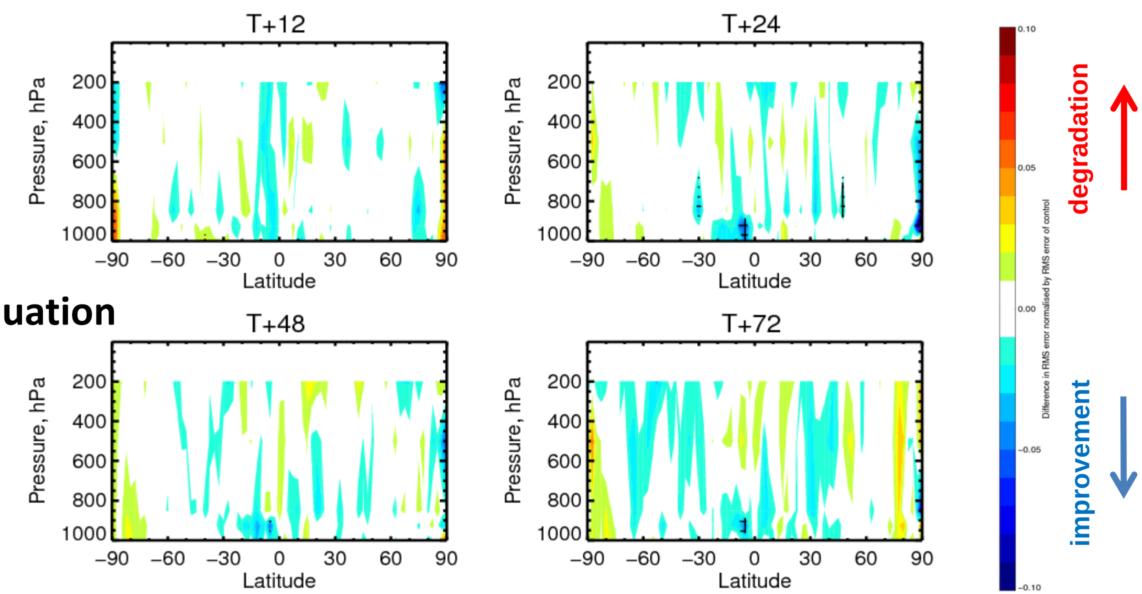
Config.1
Config.2
Config.3



SH- extratropics ***Tropics*** ***NH- extratropics***

Configuration 3

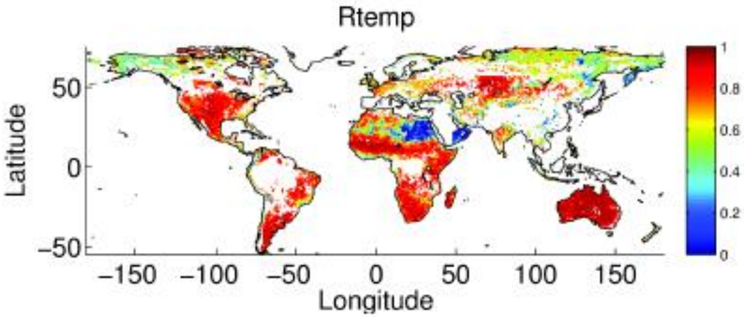
Based on short experiments
Longer experiment under evaluation



ESA SMOS soil moisture in Near-Real-Time based on Neural Networks

NRT designed and evaluated by CESBIO

(Rodriguez-Fernandez et al.)



SMOS NRT SM prototype vs SMOS L3 SM:
Average temporal correlation = 0.8

Input	STD	R	Bias
NN	**0.049**	**0.55**	-0.024
SMOS L3	0.064	0.50	-0.026

Average stats vs USDA SCAN in situ measurements → better than SMOS L3

NRT implemented in operations at ECMWF **(Muñoz-Sabater, Rodriguez-Fernandez et al.)**

- A SM product very similar to the current operational one but in Near-Real-Time
- ESA product distributed by GTS and EUMETCAST

→ **NRT high quality SMOS soil moisture product**

→ **Very relevant for the scientific community as well as for operational NWP and hydrological forecasts communities**

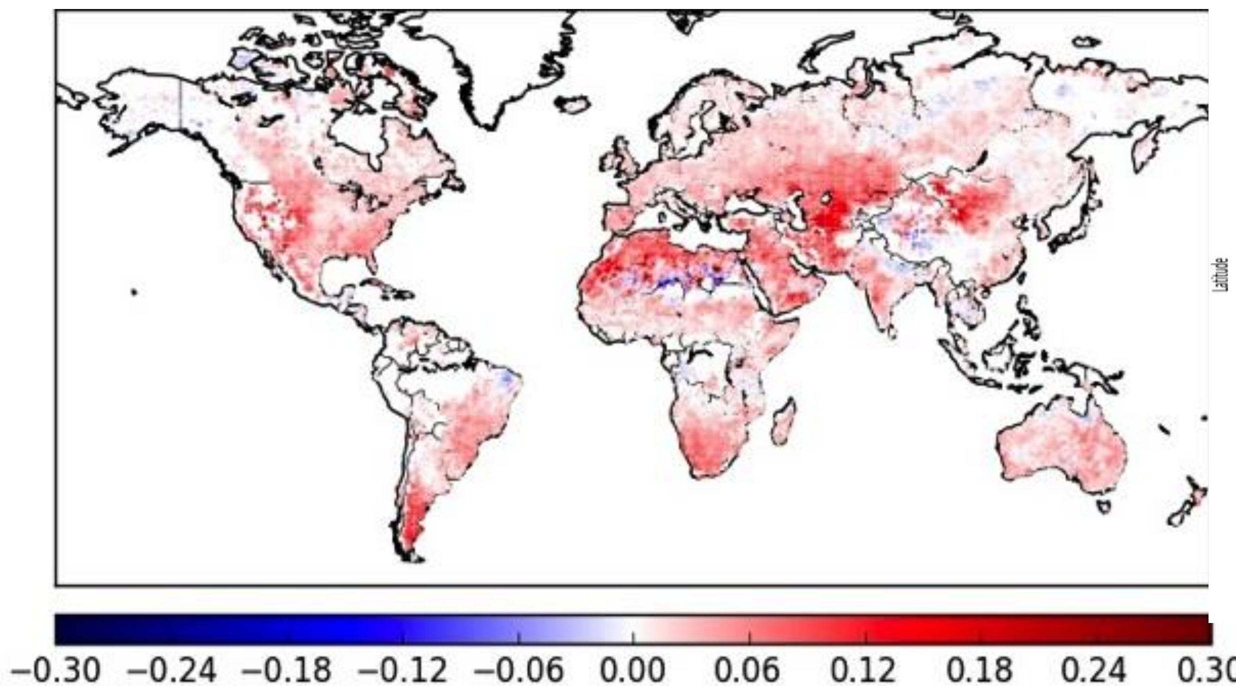
More information on NRT SM and SMOS Neural Network soil moisture Rodriguez-Fernandez et al.

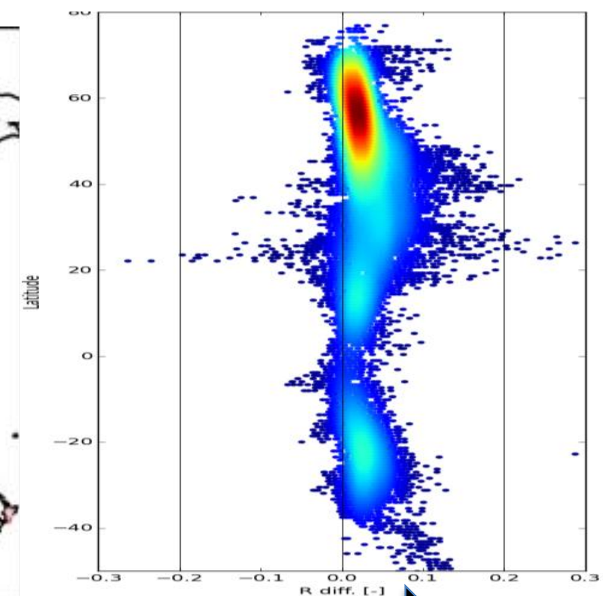
Impact of soil vertical resolution for satellite soil moisture

Tests with H-TESSEL soil resolution increased: top layer 0-7cm replaced by 3 layers 0-1cm, 1-3cm, 3-7cm

(Albergel, Balsamo)

Impact on Anomaly Correlation with ESA-CCI satellite soil moisture





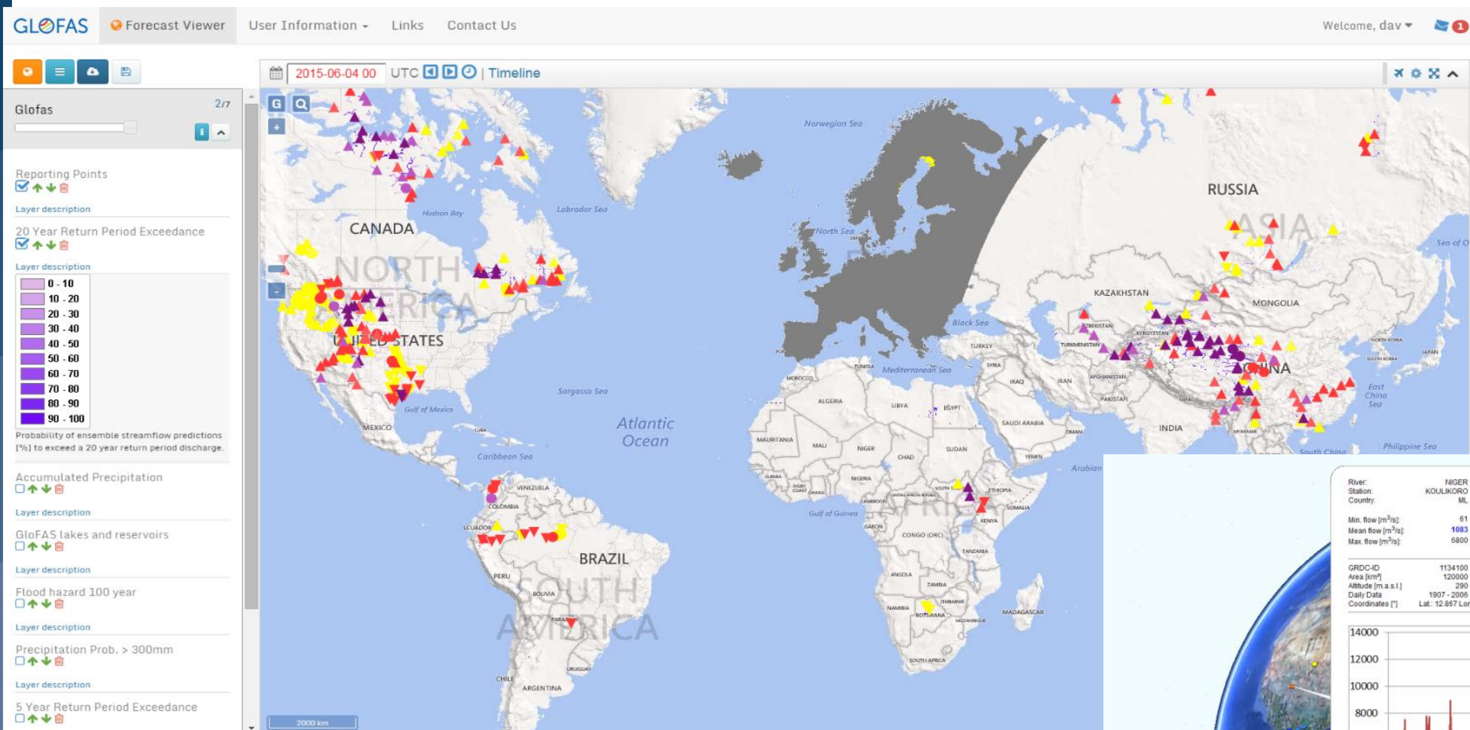
Globally Improved match to satellite soil moisture (shown is ΔACC calculate on 1-month running mean)

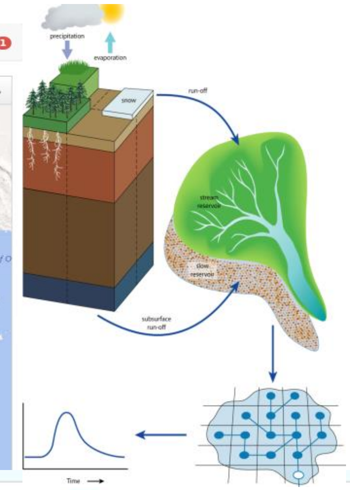
Anomaly correlation (1988-2014) measured with ESA-CCI soil moisture remote sensing (multi-sensor) product.
→ Provides a global validation of the usefulness of increase soil vertical resolution.

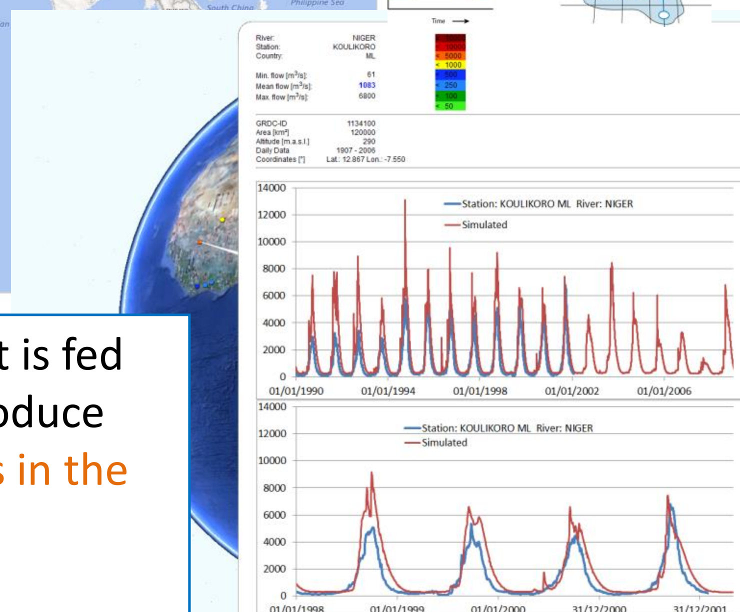
The Global Flood Awareness System

www.globalfloods.eu

florian.pappenberger@ecmwf.int







Output from global ECMWF NWP land-surface forecast is fed into a routing model (Simplified LISFLOOD (JRC)) to produce flood forecasts – benefiting from all the improvements in the ECMWF Integrated Forecasting System (model and assimilation)!

Summary

- Satellite data used for snow and soil moisture analyses at ECMWF
- Snow: NOAA NESDIS/IMS 4km snow cover data (multi-sensor product). No use of Snow Water Equivalent products used for NWP
- Soil moisture: ASCAT DA operational since May 2015 at ECMWF
- SMOS TB: preparation and tests for NWP, SMAP Early Adopter
- SMOS SM: NRT (NN) processor implementation, offline NN SM DA tests
- Flood forecasts: benefits from overall improvements in the ECMWF IFS, including soil and snow data assimilation.
- Longer term development for satellite observations usage:
  - Use of MW data to analyse snow depth
  - Future WCOM mission relevant for both SWE and SM
  - Integrated hydrological variables such as river discharges
  - Observation latency : crucial for NWP applications (<3h)
  - In situ data: essential for DA (snow,T2m, etc) and evaluation (SM)

Thank you for your Attention!

Useful links:

ECMWF LDAS: https://software.ecmwf.int/wiki/display/LDAS/LDAS+Home
ECMWF SMOS: https://software.ecmwf.int/wiki/display/LDAS/SMOS
ECMWF CMEM: https://software.ecmwf.int/wiki/display/LDAS/CMEM

ECMWF Land Surface Observation monitoring:
https://software.ecmwf.int/wiki/display/LDAS/Land+Surface+Observations+monitoring