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Review of satellite data usage for soil moisture analyses at ECMWF

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Introduction: Land Surface for Numerical Weather Prediction (NWP)

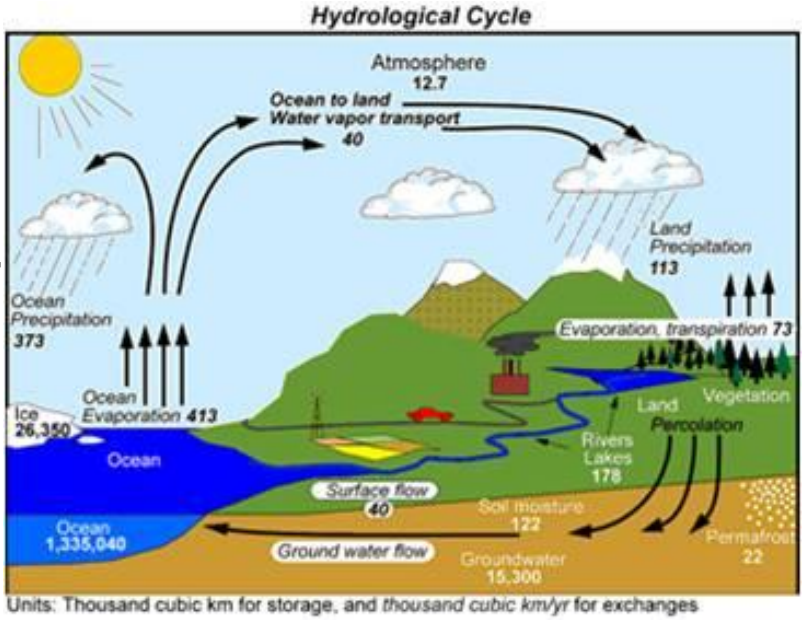
Land surfaces:

- Boundary conditions at the lowest level of the atmosphere
- Processes: Continental hydrological cycle, interaction with the atmosphere on various time and spatial scales
- Strong influence on 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)

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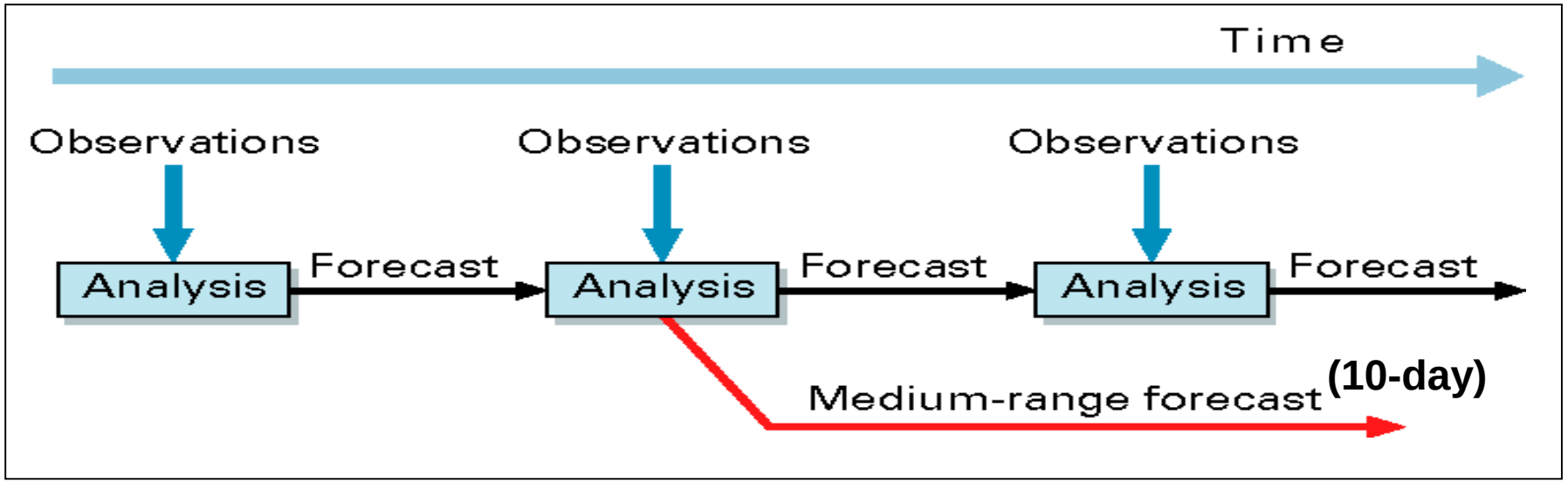
ECMWF Integrated Forecasting System (IFS)



- **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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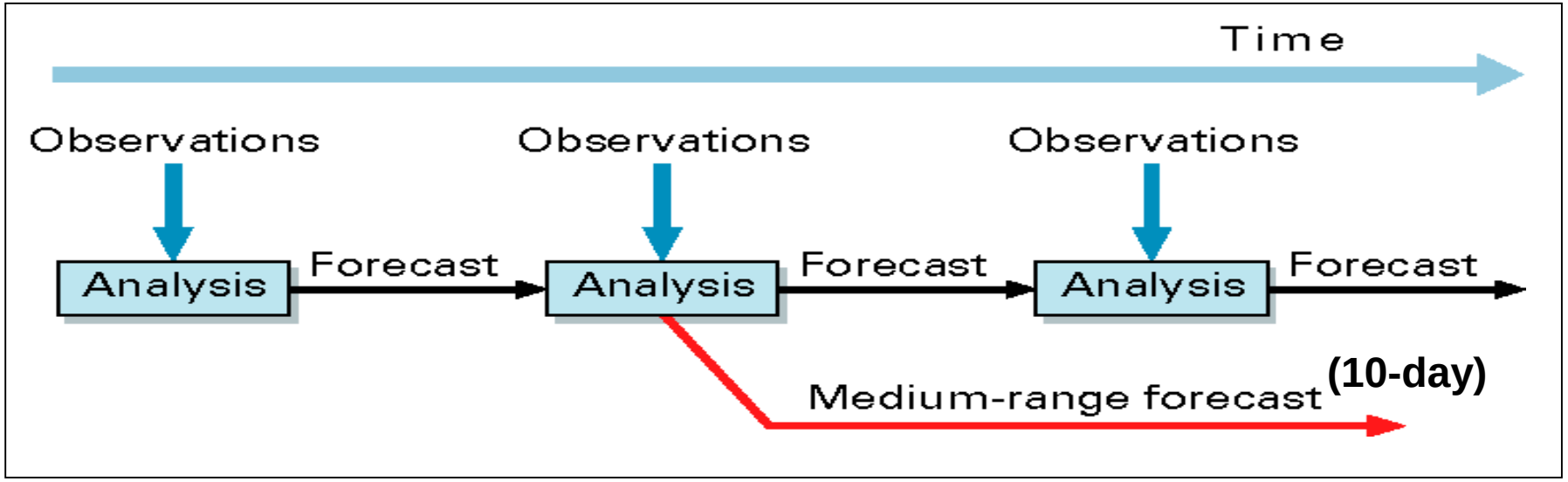
ECMWF Integrated Forecasting System (IFS)



- **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

Several Systems, including:

- **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 (next reanal.):** IFS (with 4D-Var and LDAS), 32km, version 41r2 (2016)

} **Weakly coupled DA**

- ERA-Interim-Land: 79km
- ERA5-Land: HighRes TBD

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

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ECMWF Land Data Assimilation System (LDAS)

Soil moisture (SM)

Methods: - 1D Optimal Interpolation in ERA-Interim

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

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

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

SMOS brightness temperature in dvpt, research NASA SMAP

Snow depth

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

Observations: *in situ* snow depth and NOAA/NESDIS IMS Snow Cover

Soil Temperature and Snow Temperature

1D-OI using T2m analysis increments

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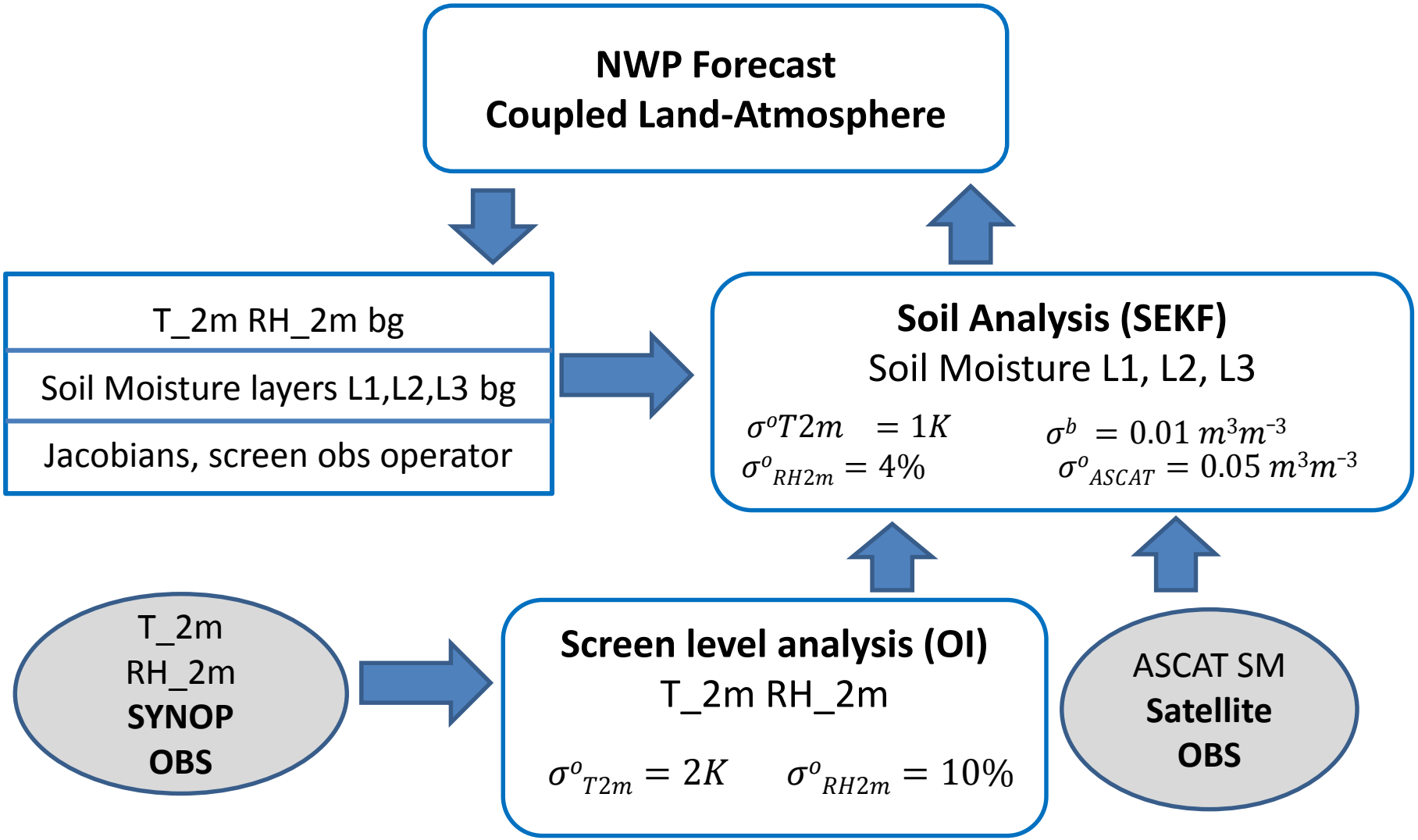
Soil Analysis in the IFS

ECMWF IFS cycle 41r2



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

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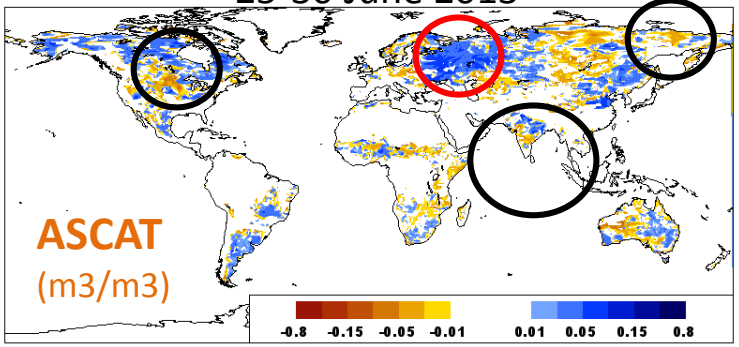
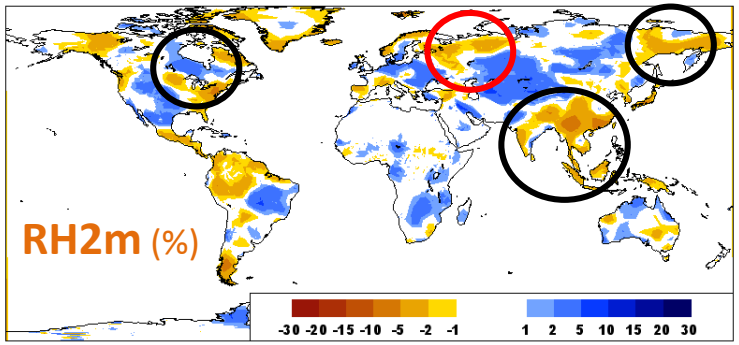
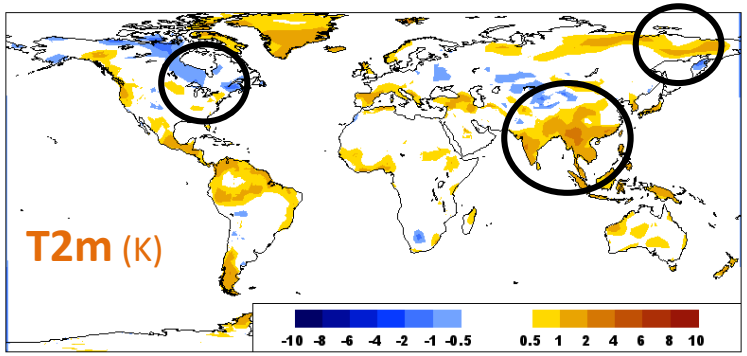
ASCAT Soil Moisture data assimilation

Innovation (Obs- model)

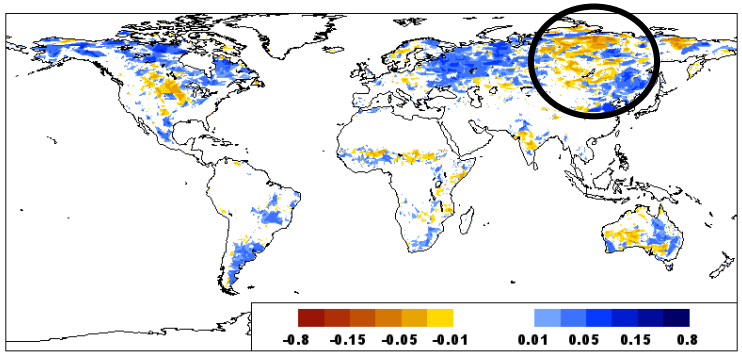
25-30 June 2013



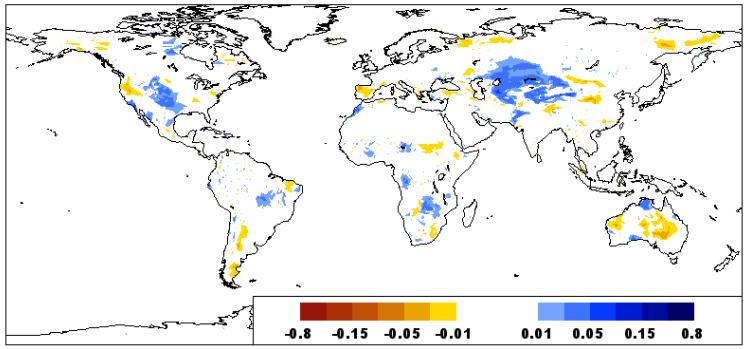




Accumulated Increments (m^3/m^3) in top soil layer (0-7cm)



Due to ASCAT



Due to SYNOP T2m and RH2m

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Future ECMWF Re-analysis (ERA5)

Assimilation of Scatterometer soil moisture data ERS/SCAT and MetOpA/B ASCAT

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

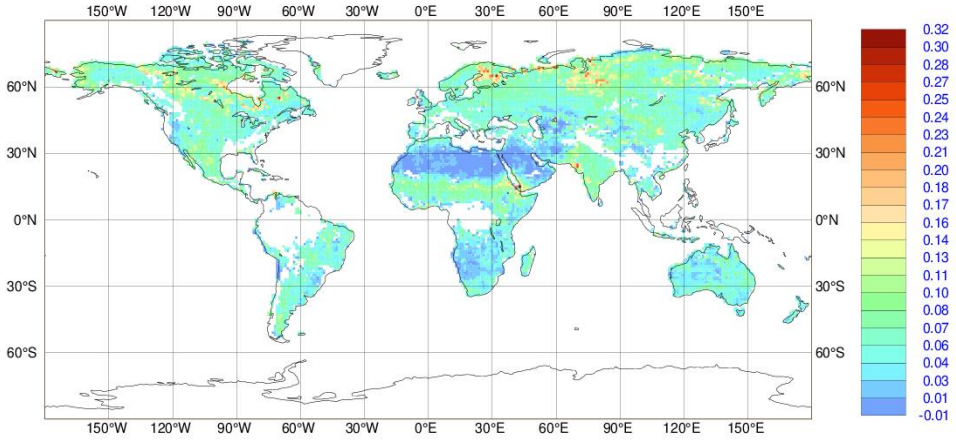
	FG departure Mean m^3m^{-3}	FG departure StDev m^3m^{-3}
Using NRT ASCAT	0.013	0.05
Using Reproc ASCAT	0.006	0.044

(FMA 2010)

→ Reprocessed ASCAT has reduced background departure statistics both in mean and Stdev

ERA5 production (C3S) started (will be available end of 2017)

ASCAT surface soil moisture first guess departure (Obs-Model) in m3/m3 for JJAS 2014



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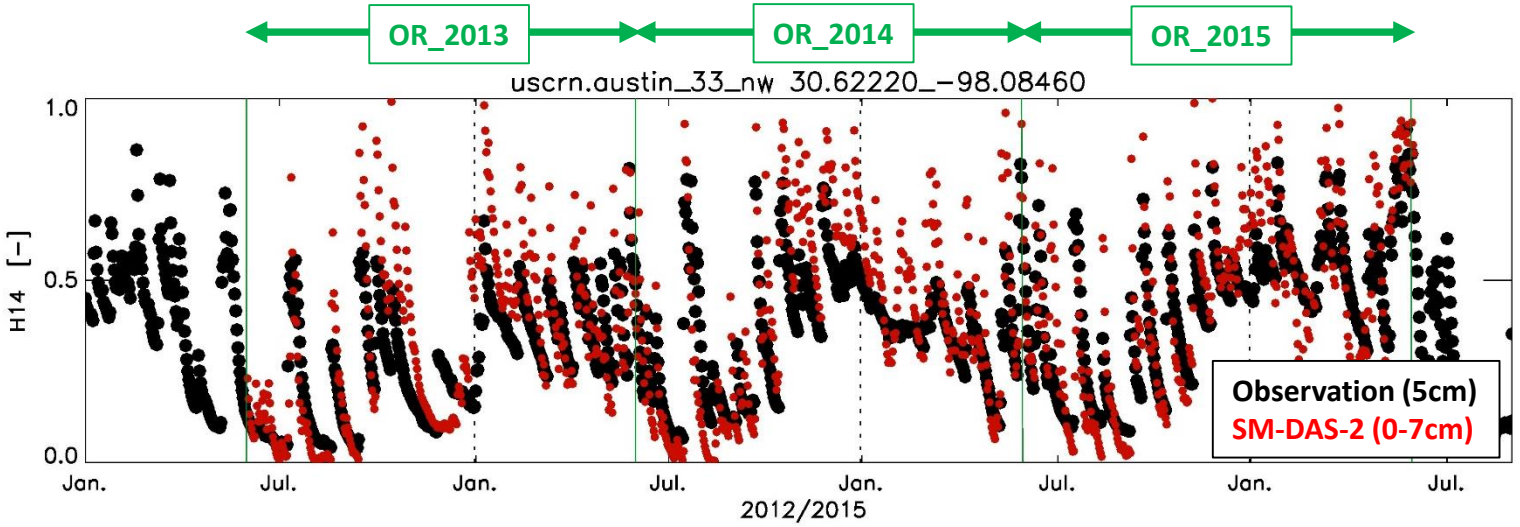
EUMETSAT H-SAF soil moisture

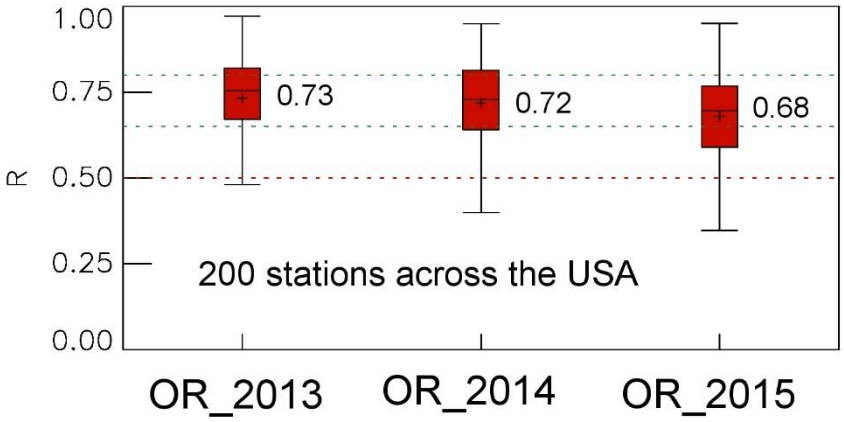
Scatterometer root zone soil moisture products based on data assimilation in dedicated LDAS suites

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

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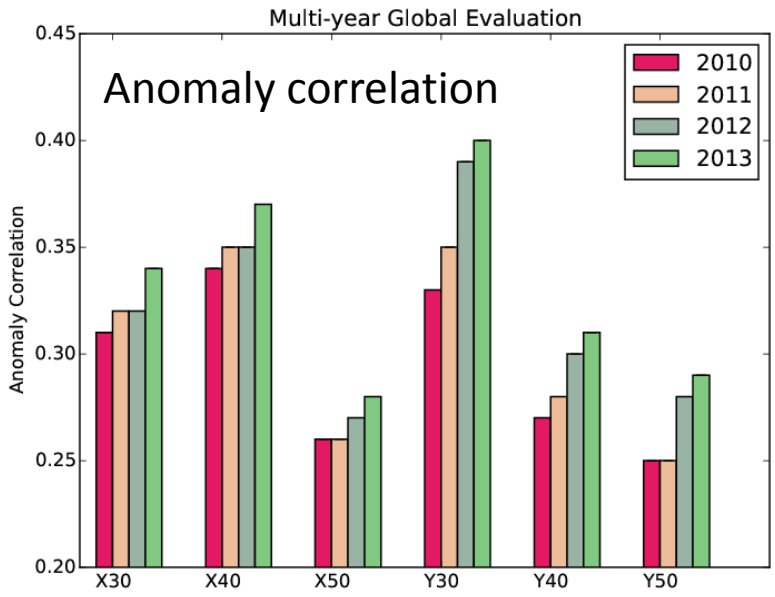
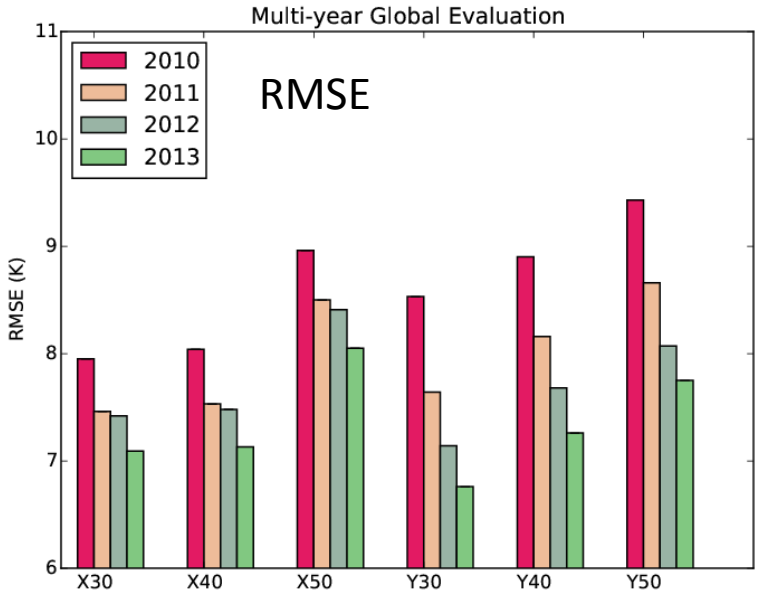
SMOS Forward modelling and Bias correction

- CMEM: ECMWF Community Microwave Emission Modelling Platform. Used ERA-Interim forcing, H-TESSEL and CMEM to simulate forward ECMWF SMOS TB for 2010-2013.
- → Comparison between ECMWF TB and SMOS NRT TB
- **Consistent improvement of SMOS data at Pol xx and yy, for incidence angles 30, 40, 50 degrees**



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



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

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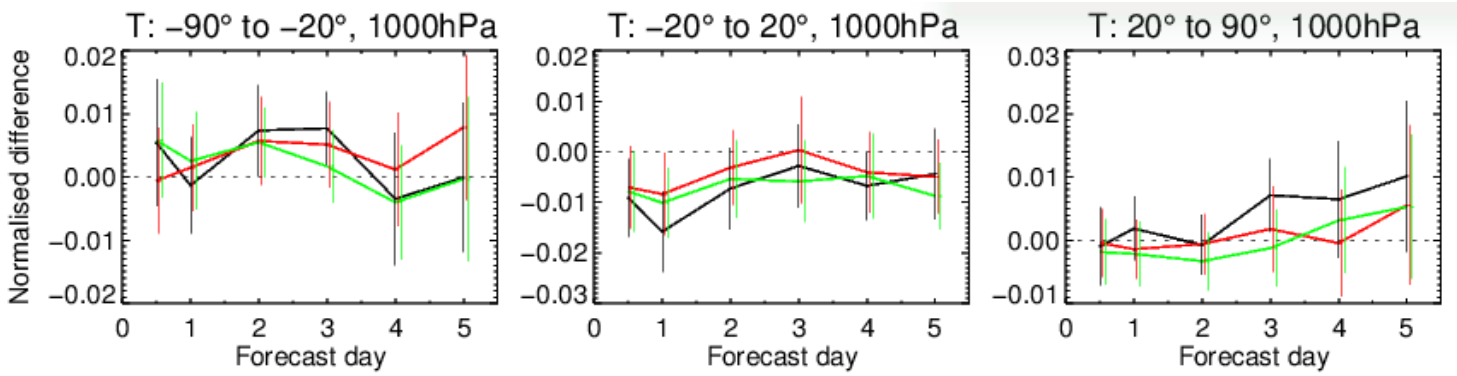
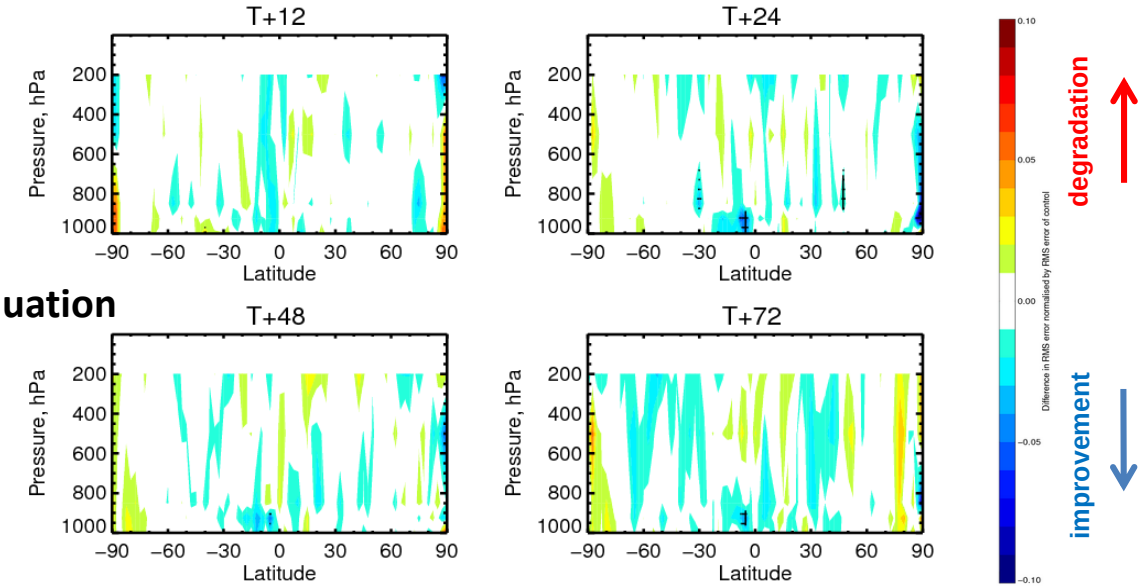
SMOS data assimilation in the IFS

Normalized change in rms of fc error:

Config.1
Config.2
Config.3



SH- extratropics *Tropics* *NH- extratropics*



Based on short experiments
Longer experiment under evaluation

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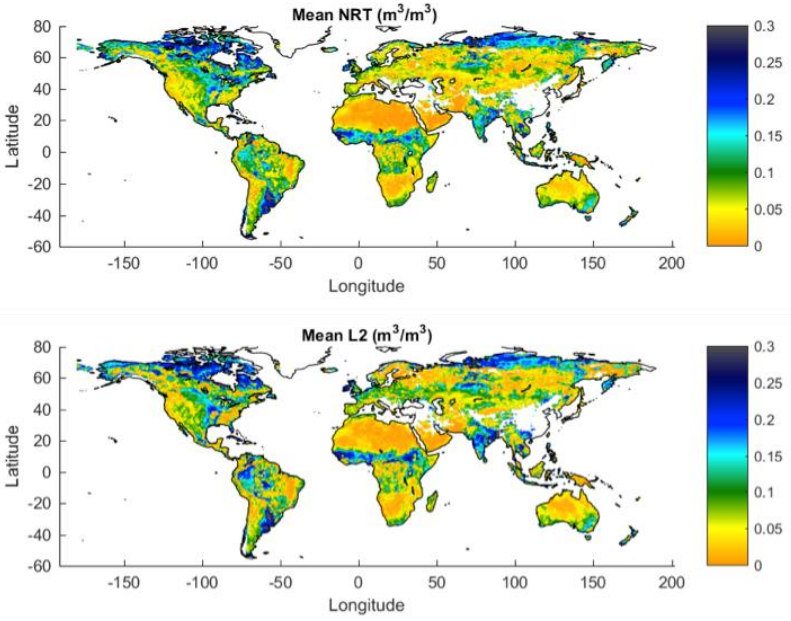
New level 2 SMOS NRT Soil Moisture product based on Neural Networks

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*
  also on EUMETCAST and GTS



Comparison between L2 NRT and L2 v6.20 soil moisture

Evaluation against in situ stations (USCRN and SCAN)
→ median correlation of 0.71

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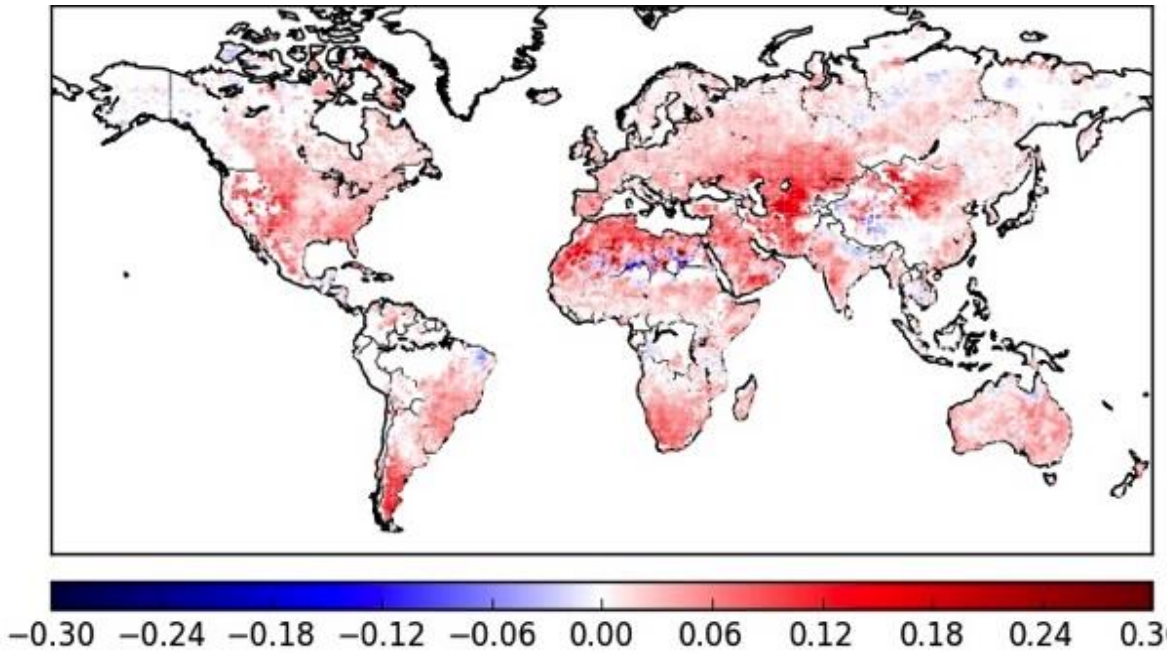
Impact of soil vertical resolution for satellite soil moisture

Tests to investigate possible H-TESSEL soil resolution increase:

H-TESSEL top soil layer 0-7cm replaced by 3 layers 0-1cm, 1-3cm, 3-7cm

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

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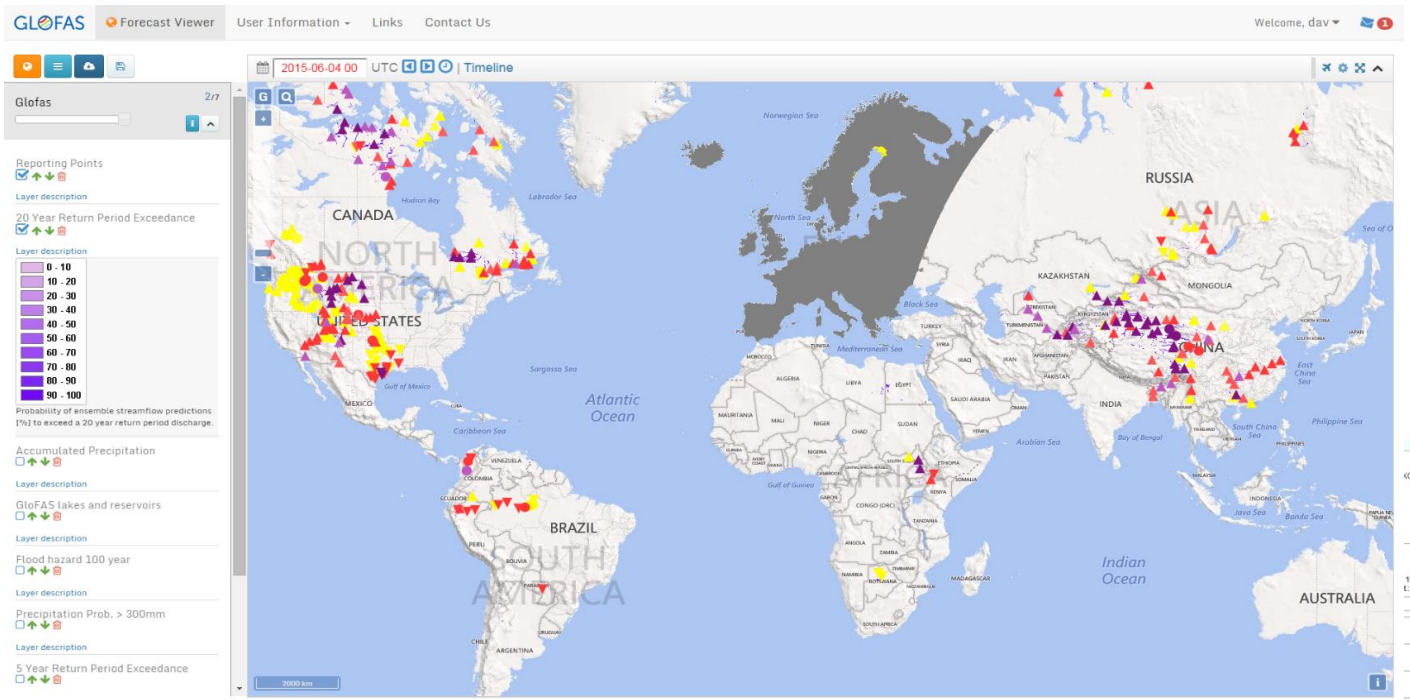
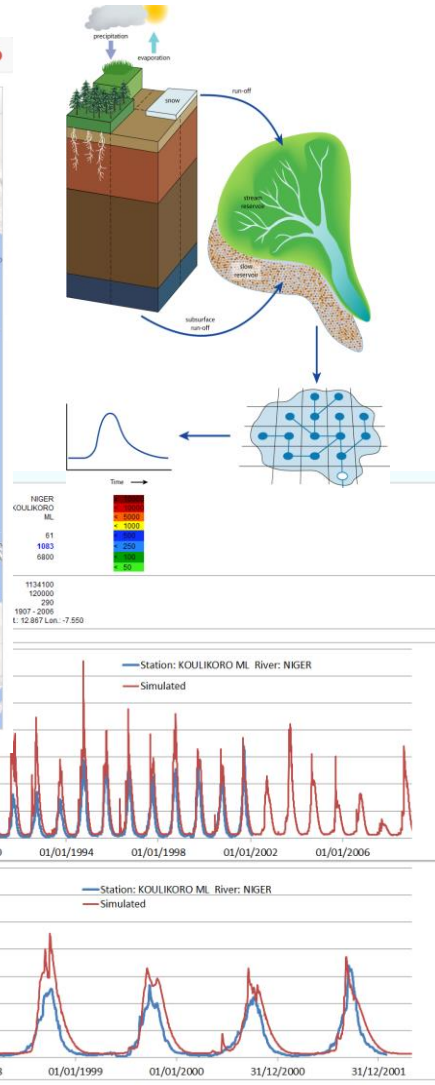
The Global Flood Awareness System

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)!

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Summary

- ASCAT SM: DA operational since May 2015 at ECMWF (also operational at UKMO, KMA)
- L-band TB: SMOS data assimilation in the IFS, SMAP Early Adopter
- SMOS SM: NRT (NN) processor implemented at ECMWF
- Reanalyses: ERA5 use of Scatterometer series ERS/SCAT and Metop ASCAT
- Root zone retrieval from ASCAT (H-SAF): H14 (NRT) and H27 Climate data record
- Flood forecasts: benefits from overall improvements in the ECMWF IFS, including soil moisture data assimilation.
- Longer term development for satellite observations usage:
  - Consistent snow and SM analyses
  - Integrated hydrological variables such as river discharges
  - Observation latency : crucial for NWP applications (<3h)
  - In situ data: essential for evaluation, importance of data exchange

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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

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