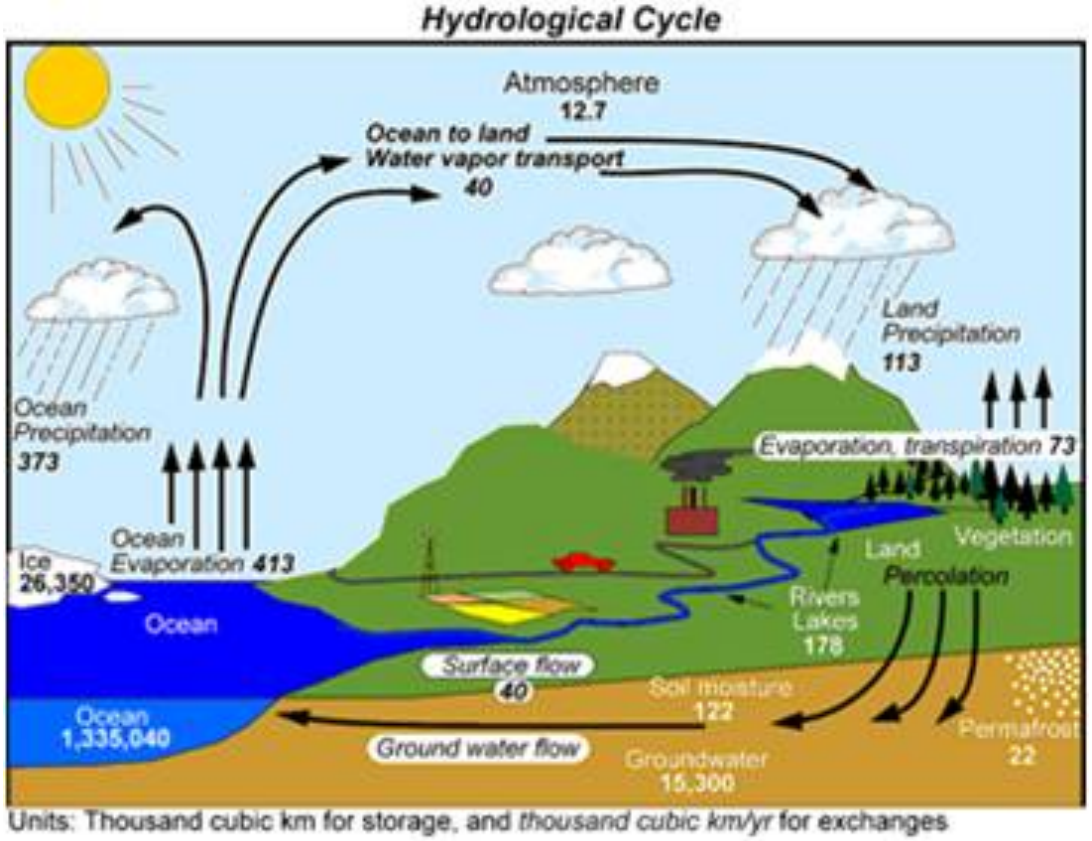
ECMWF/EUMETSAT NWP-SAF
Satellite data assimilation
Training course, 4 April 2017

Use of satellite data for land surface analysis

Patricia de Rosnay

Introduction: Land Surfaces in Numerical Weather Prediction (NWP)

- 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

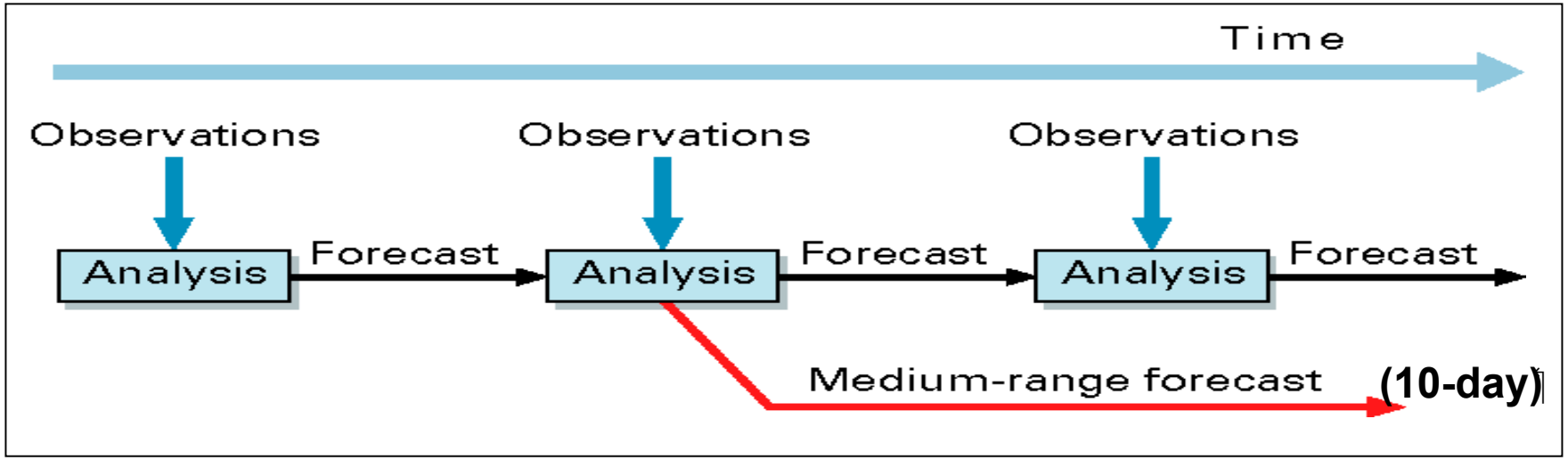


Trenberth et al. J. Hydrometeorol., 2007

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

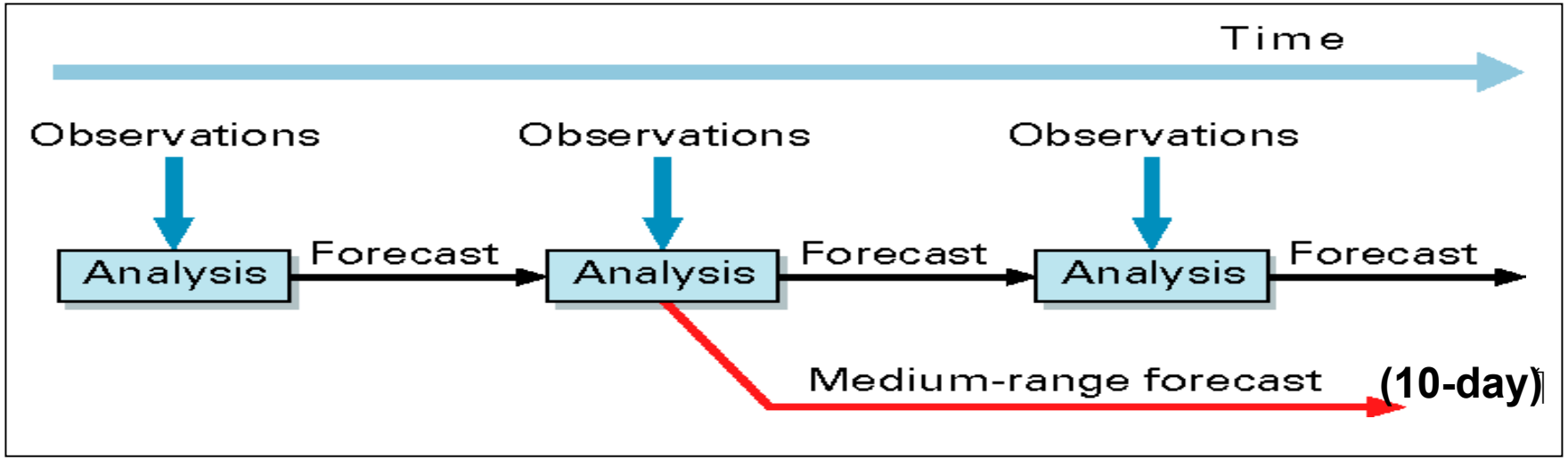
(Beljaars et al., Mon. Wea. Rev, 1996, Koster et al., Science 2004, Koster et al. J Hydrometeorol. 2011)

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 ; 3D-Var for the Ocean (for ensemble and seasonal)**
  - **Land Data Assimilation System**

ECMWF Integrated Forecasting System (IFS)



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  - **4D-Var for atmosphere ; 3D-Var for the Ocean (for ensemble and seasonal)**
  - **Land Data Assimilation System**

Several Systems:

- **NWP (oper):** IFS (with 4D-Var and LDAS), 9km, version 43r1 (2016)
- **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

Introduction: Land Surface Data Assimilation (LDAS)

Snow depth

- Methods: Cressman (DWD, ECMWF ERA-I), 2D Optimal Interpolation (OI) (ECMWF operational and ERA5)
- Conventional Observations: *in situ* snow depth
- Satellite data: NOAA/NESDIS IMS Snow Cover Extent (ECMWF), H-SAF snow cover (UKMO in dvpt)

Soil Moisture

- Methods:
  - 1D Optimal Interpolation (Météo-France)
  - Simplified Extended Kalman Filter (EKF) (DWD, ECMWF, UKMO)
- Conventional observations: Analysed SYNOP 2m air relative humidity and temperature, **from 2D OI screen level parameters analysis**
- Satellite data : ASCAT soil moisture (UKMO, ECMWF, KMA), SMOS (dvpt ECMWF, UKMO, Env.Canada)

Soil Temperature and Snow temperature

- 1D OI for the first layer of soil and snow temperature (ECMWF, Météo-France)

Snow in operational forecasting systems

Example of the ECMWF system:

Snow Model: Component of H-TESSEL ; Single layer snowpack

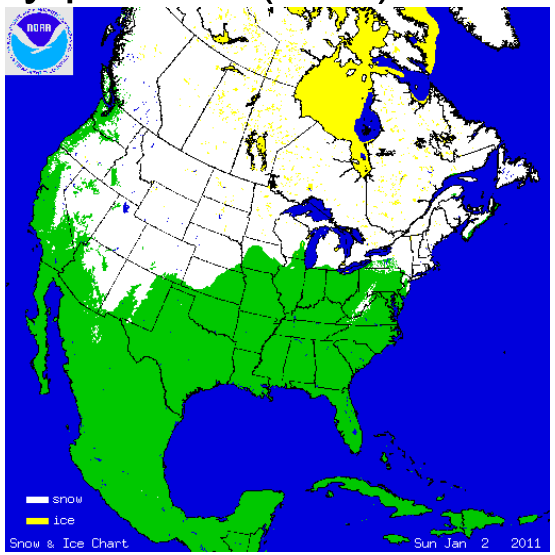
- Snow water equivalent SWE (m), *ie* snow mass
- Snow Density ρ_s
- Snow Albedo

} **Prognostic variables**

Snow depth (SD) is diagnostic: SD=SWE . ρ_w / ρ_s
with ρ_w water density

Observations:

- Conventional snow depth data: SYNOP and National networks
- Snow cover extent: NOAA NESDIS/IMS daily product (4km)



Data Assimilation:

- Optimal Interpolation (OI) in operational IFS
- Analysed variable: SWE, density

Snow Observations

Interactive Multisensor Snow and Ice Mapping System (IMS)

- Time sequenced imagery from geostationary satellites
- AVHRR,
- SSM/I
- Station data

Northern Hemisphere product

- Daily
- Polar stereographic projection

Information content: Snow/Snow free

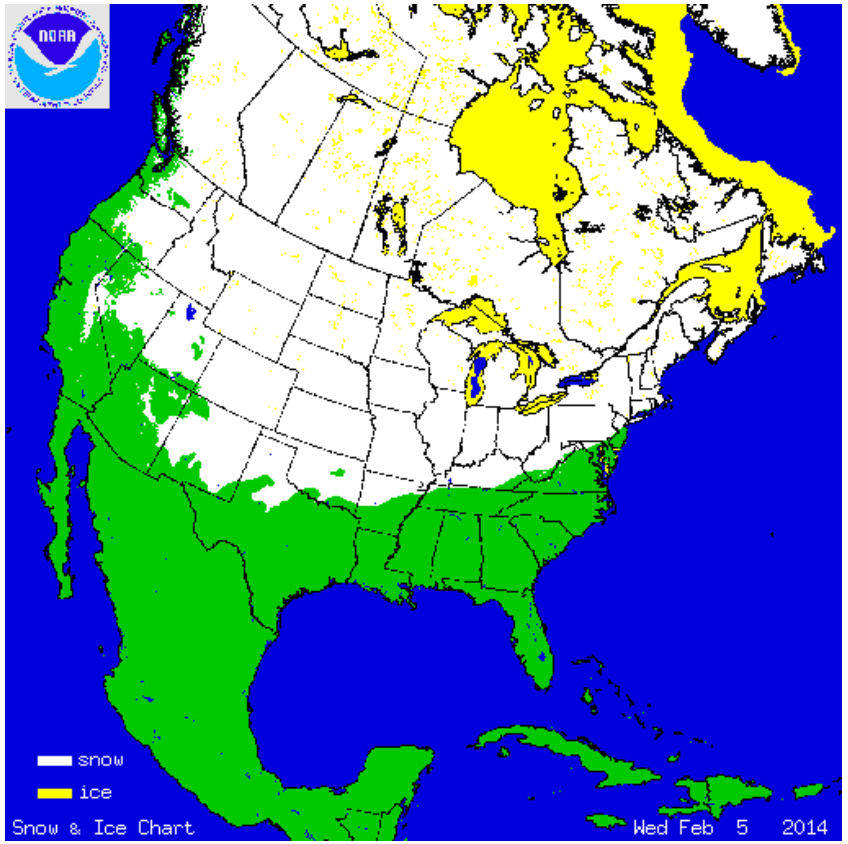
Data used at ECMWF:

- **24km product** (ERA-Interim)
- **4 km product** (operational NWP, ERA5)

Latency: available at 23UTC daily

More information at: http://nsidc.org/data/g02156.html

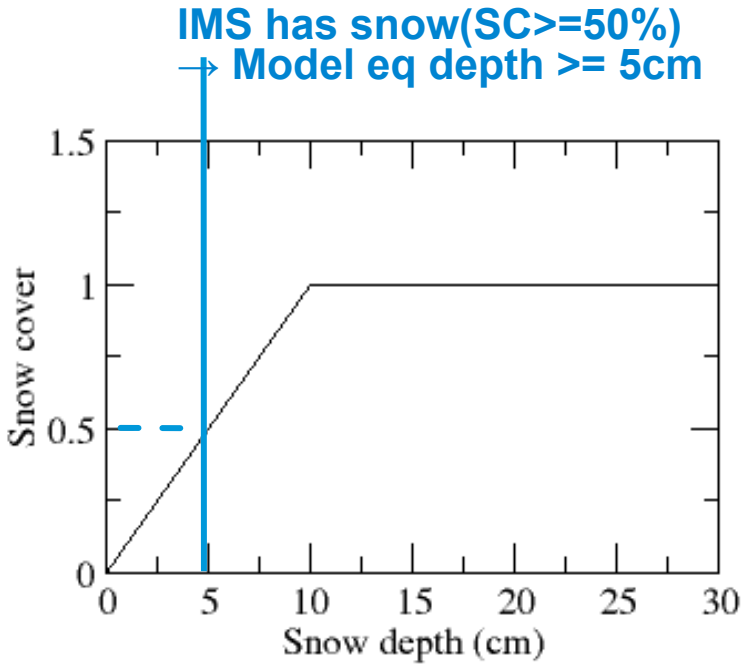
NOAA/NESDIS
IMS Snow extent data



IMS Snow Cover 5 Feb. 2014

Use of NESDIS/IMS snow cover data

- IMS snow cover (SC) means SC>50%
- But no quantitative information on snow depth
- Relation snow cover (SC)/Snow Depth (SD): SC=50% corresponds to SD=5cm
- Previously: direct insertion of 10cm when IMS has snow & model has no snow
- Issues with overestmated snow
- IFS revision for current cycle: assimilate IMS and account for IMS observation error



Model relation between Snow Cover (SC) and Snow Depth (SD)

NESDIS IMS \ Fst Guess	Snow	No Snow
Snow	x	**DA** 5cm
No Snow	DA	DA

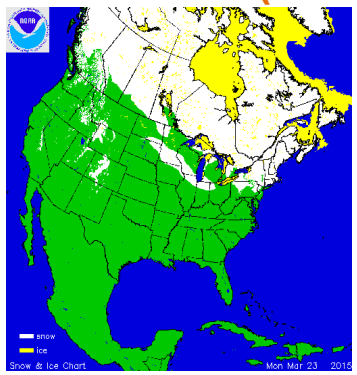
Use of IMS at ECMWF

Error specifications:

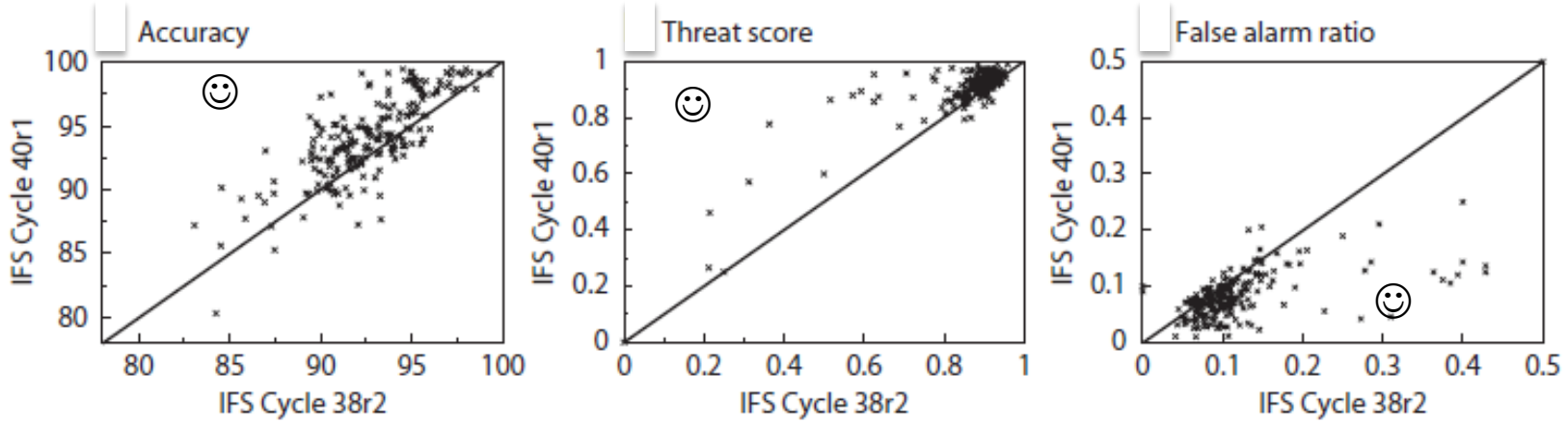
BG:	σ_b	= 3cm
SYNOP	σ_{SYNOP}	= 4cm
IMS	σ_{ims}	= 8cm

Snow analysis: Forecast impact

Revised IMS snow cover data assimilation (2013)

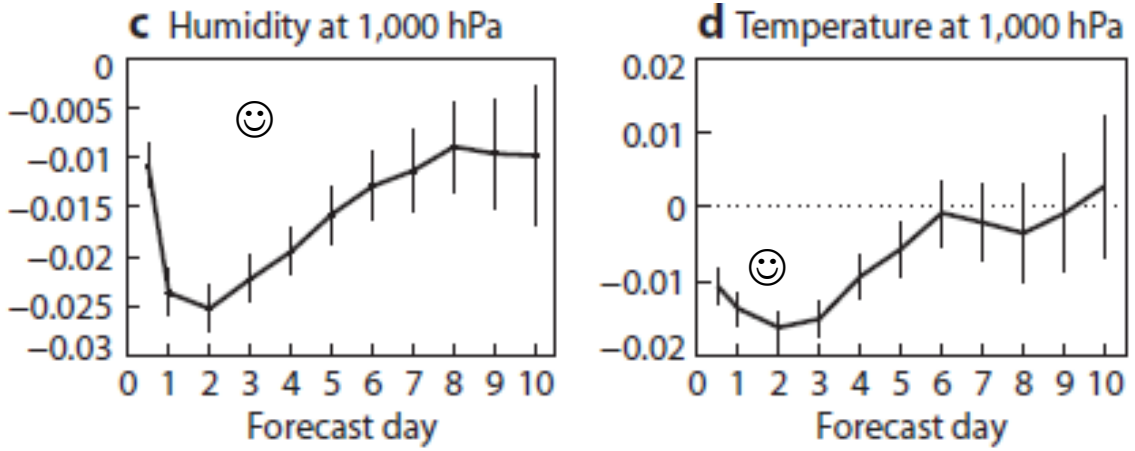


Impact on snow October 2012 to April 2013 (251 independent *in situ* observations)



Impact on atmospheric forecasts

October 2012 to April 2013 (RMSE new-old)



→ Consistent improvement of snow and atmospheric forecasts

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

Simplifed EKF soil moisture analysis

For each grid point, analysed soil moisture state vector x_a:

$$\boldsymbol{x}_a = \boldsymbol{x}_b + \boldsymbol{K}\,(\boldsymbol{y} - \mathcal{H}[\boldsymbol{x}_b])$$

$\boldsymbol{x}$ background soil moisture state vector,
$\mathcal{H}$ non linear observation operator
$\boldsymbol{y}$ observation vector
$\boldsymbol{K}$ Kalman gain matrix, fn of
H (linearsation of $\mathcal{H}$), **P** and **R** (covariance matrices of background and observation errors).

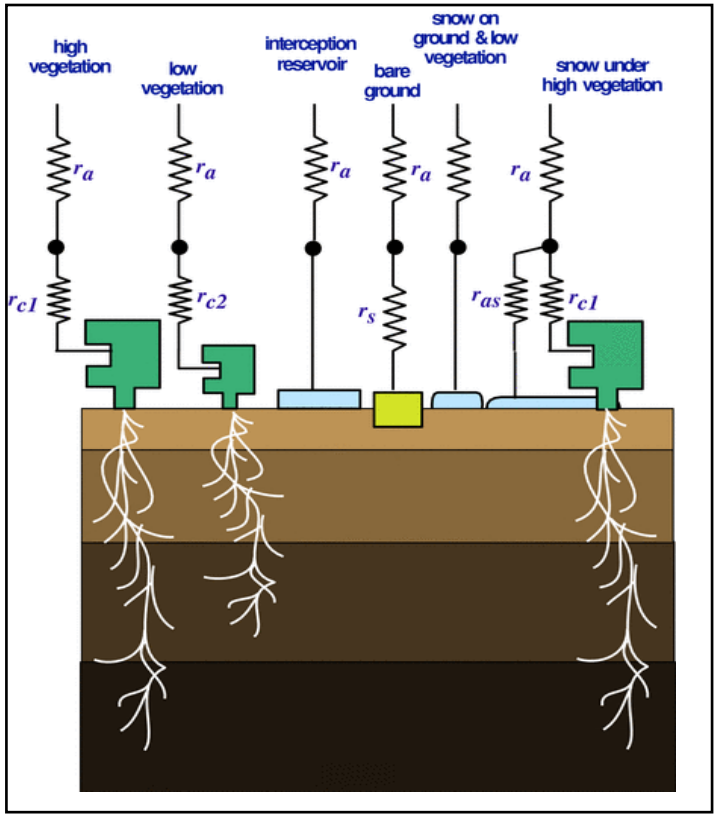
Used at ECMWF (operations and ERA5), DWD, UKMO

Observations used at ECMWF:
For operational NWP:

- Conventional SYNOP pseudo observations (analysed T2m, RH2m)
- Satellite MetOp-A/B ASCAT soil moisture

Research: SMOS Data Assimilation

The simplified EKF is used to corrects the soil moisture trajectory of the Land Surface Model



Drusch et al., GRL, 2009
de Rosnay et al., ECMWF News Letter 127, 2011
de Rosnay et al., QJRMS, 2013

Satellite data for NWP soil moisture analysis

Active microwave data:

ASCAT: Advanced Scatterometer

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

C-band (5.6GHz)

NRT Surface soil moisture

Operational product

→ ensured operational continuity

Passive microwave data:

SMOS: Soil Moisture & Ocean Salinity

L-band (1.4 GHz)

NRT Brightness Temperature

Dedicated soil moisture mission

→ Strongest sensitivity to soil moisture

Active and Passive:

SMAP: Soil Moisture Active Passive

L-band TB 2015

Dedicated soil moisture mission

STATISTICS FOR SOIL MOISTURE FROM METOP-B/ASCAT

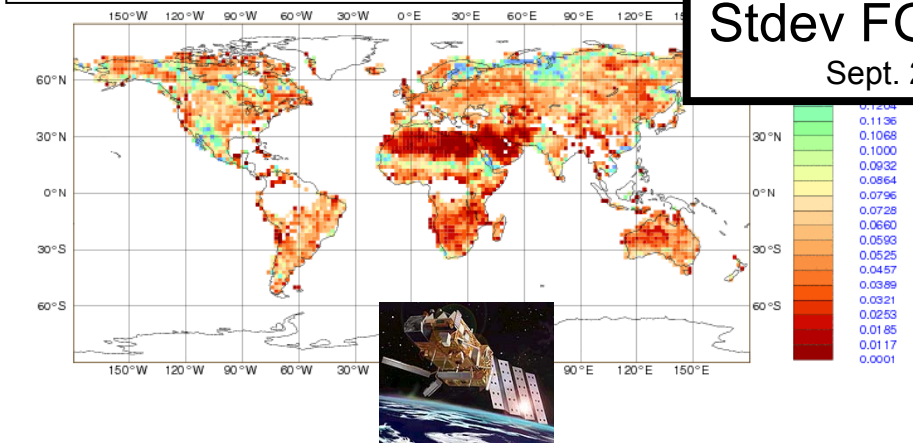
STATISTICS FOR RADIANCES FROM FROM SMOS

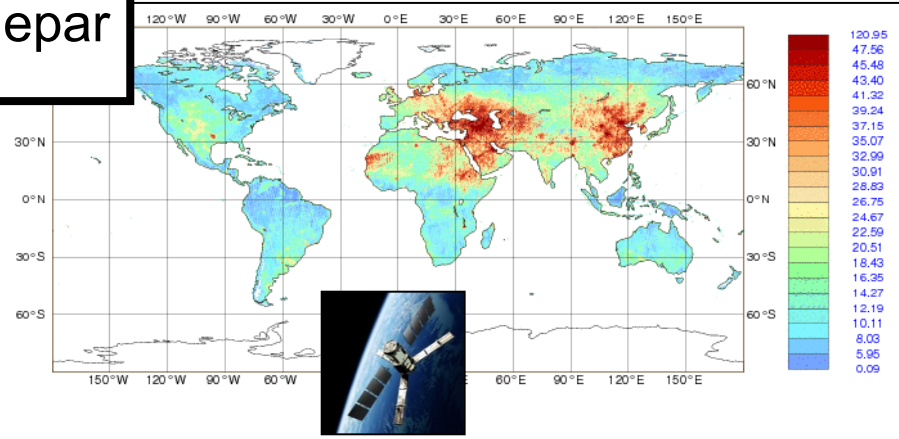
Operational Monitoring of surface soil moisture related satellite data:

ASCAT soil moisture (m^3m^{-3}) SMOS Brightness temperature (K)

Stdev FG_depar

Sept. 2013





Passive microwave remote sensing

Soil Moisture and Ocean Salinity mission

SMOS ESA Earth Explorer mission (2009-present)

L-band (1.4 GHz) instrument. Optimal frequency for soil moisture remote sensing

Sun-synchronous, quasi-circular orbit at altitude 758 km. 06.00 hrs local solar time at ascending node. Three days revisit at Equator

Dual polarisation: H and V in the Earth reference, xx and yy in the antenna frame reference

Multi-angular measurements 0 to 60°

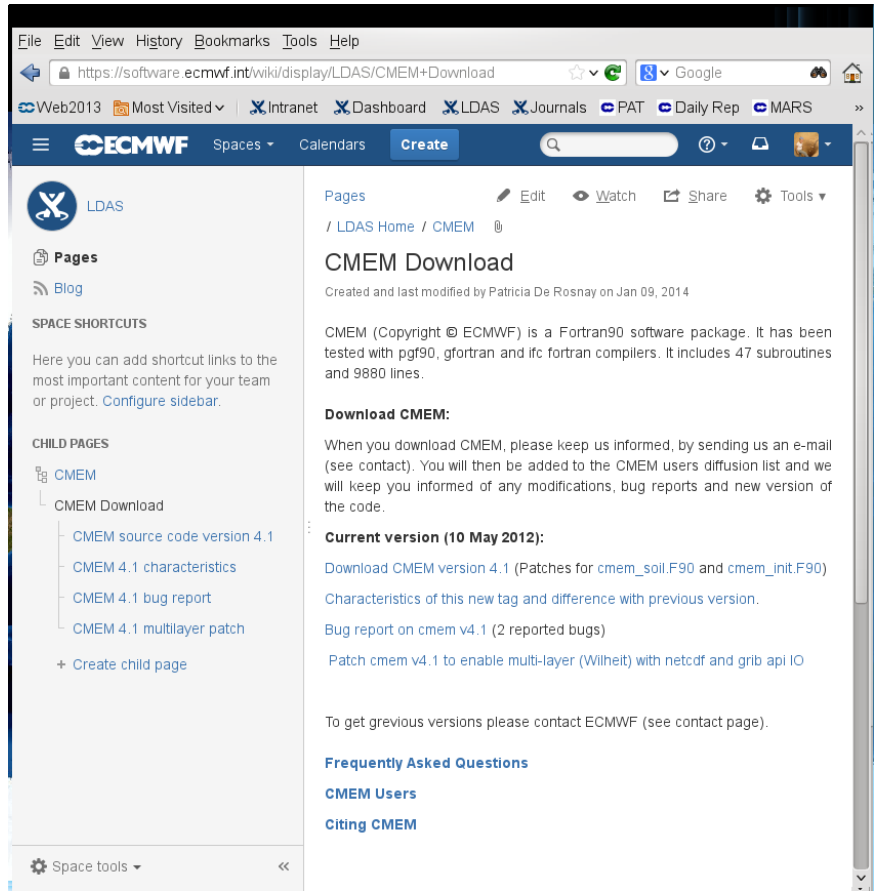
ECMWF and ECCC: developments to use NRT SMOS Brightness Temperature (TB) data

→ Use observation operator to simulate L-band TB: Community Microwave Emission Modelling Platform (CMEM)

Microwave emission modelling

- → **Forward operator: microwave emission mode**
- **ECMWF Community Microwave Emission Modelling Platform (CMEM)**
- I/O interfaces for the Numerical Weather Prediction Community.

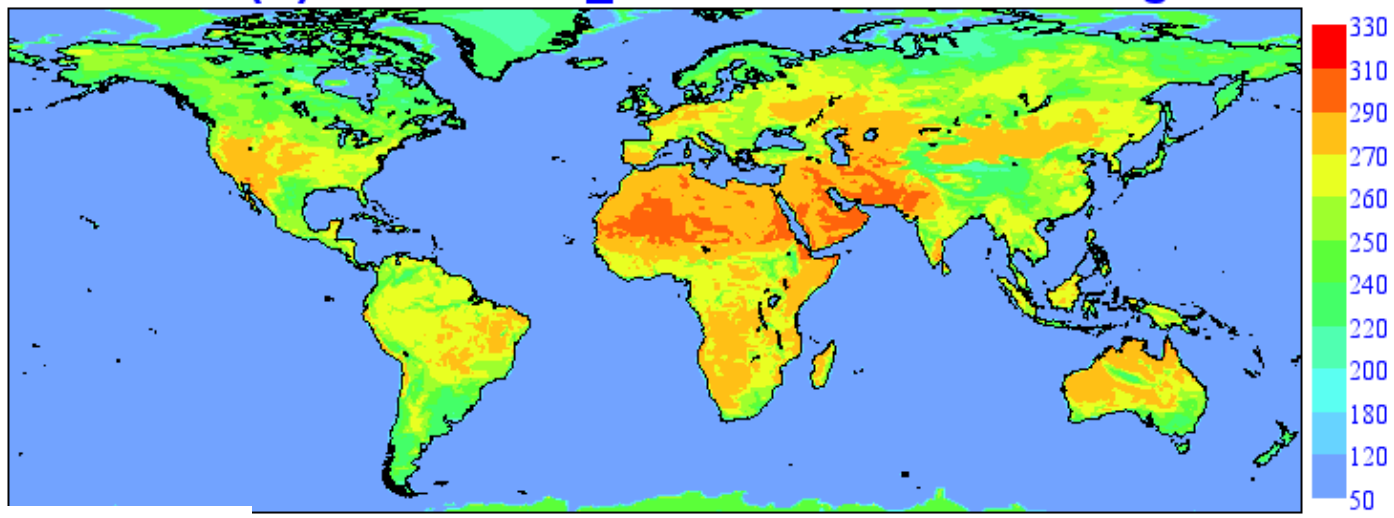
https://software.ecmwf.int/wiki/display/LDAS/CMEM



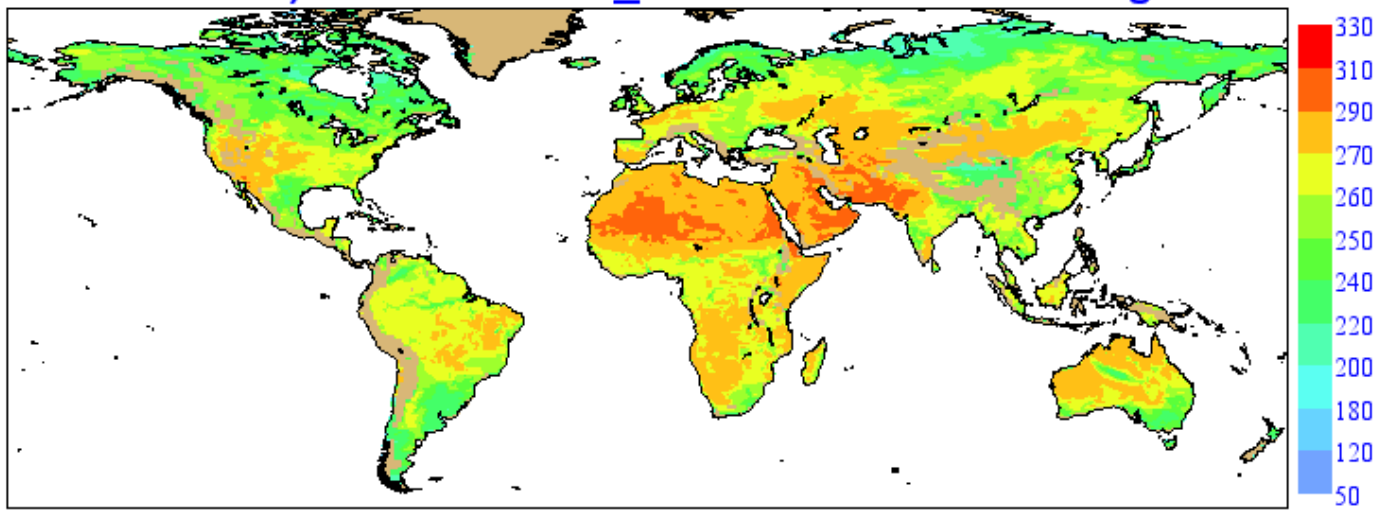
References:
Drusch et al. JHM, 2009
de Rosnay et al. JGR, 2009
de Rosnay, ESA Report, 2009

CMEM Simulations of L-Band Brightness Temperature (TB)

ECMWF TB (K) ori WaWsWi_TOA H 2010070106 at angle 30



ECMWF TB K) clean WaWsWi_TOA H 2010070106 at angle 30



July 2010
TOA TBH

Global

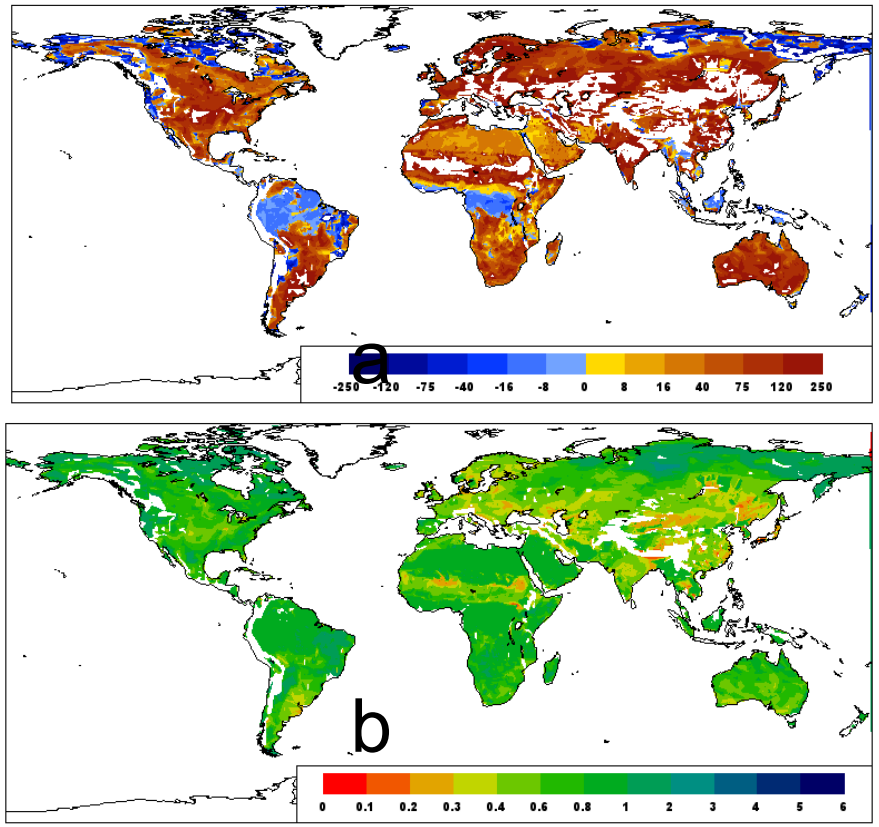
Land only and
after QC
(remove areas with snow, frozen conditions and orography)

SMOS Bias correction (BC)

Cumulative Distribution Function CDF-matching → matches mean and variance of two distributions.

$$TB_{SMOS}^{*} = a + b\, TB_{SMOS}$$
$$\text{with } a = \overline{TB}_{ECMWF} - \overline{TB}_{SMOS}\,(\sigma_{ECMWF}/\sigma_{SMOS})$$
$$b = \sigma_{ECMWF} / \sigma_{SMOS}$$

Matching parameters
on each grid point
for each month

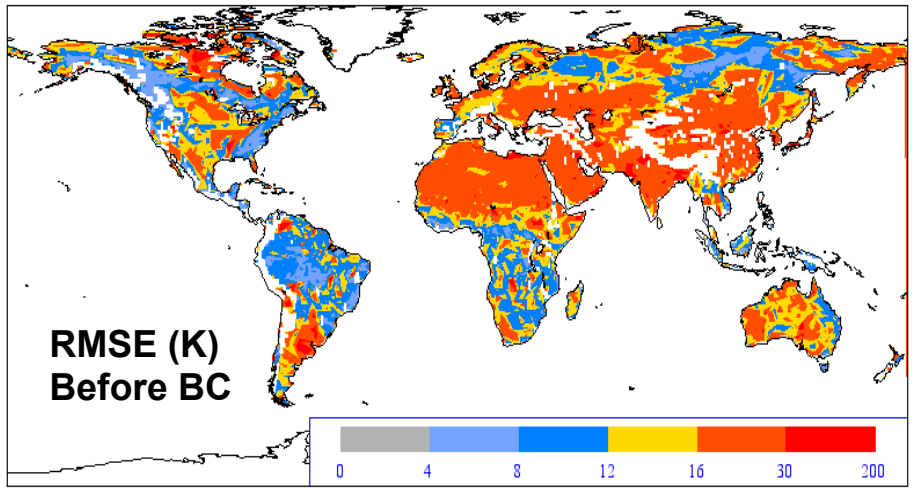


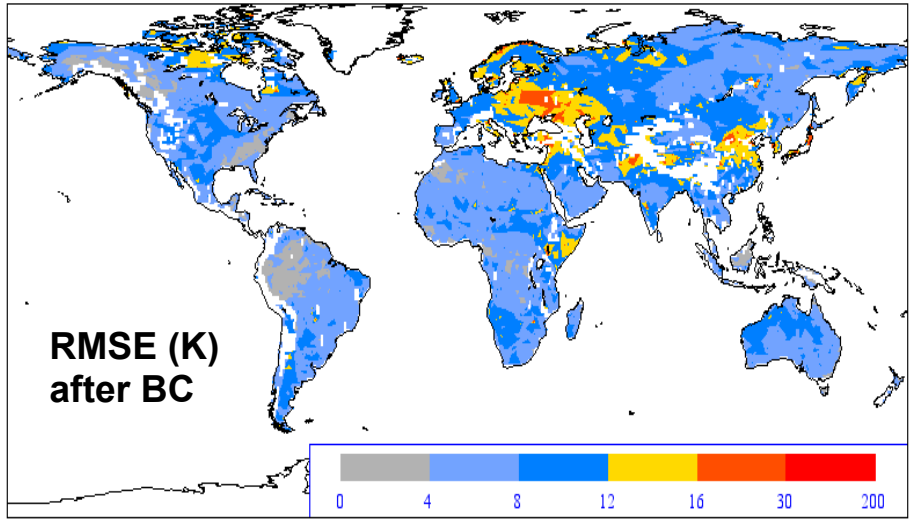
- Based on ECMWF re-analysis: CMEM forward TB
- Long term data sets: January 2010 – March 2014
- Computed at 40km resolution (SMOS resolution)
- Monthly CDF: 3-month moving window
- Multi-angular and dual polarisation CDF

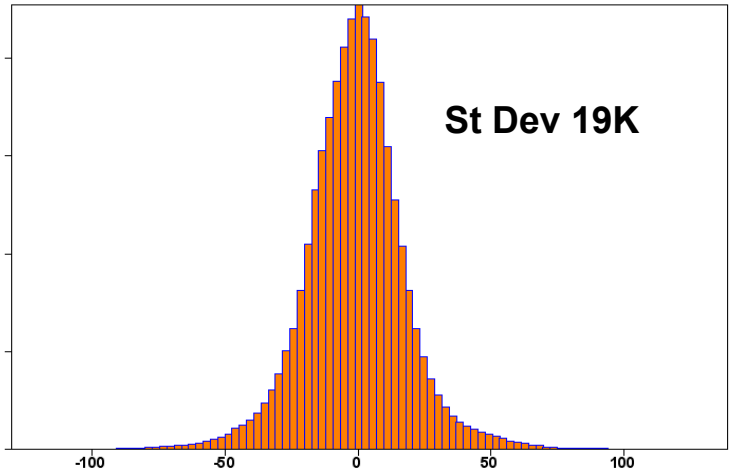
SMOS forward operator and Bias correction

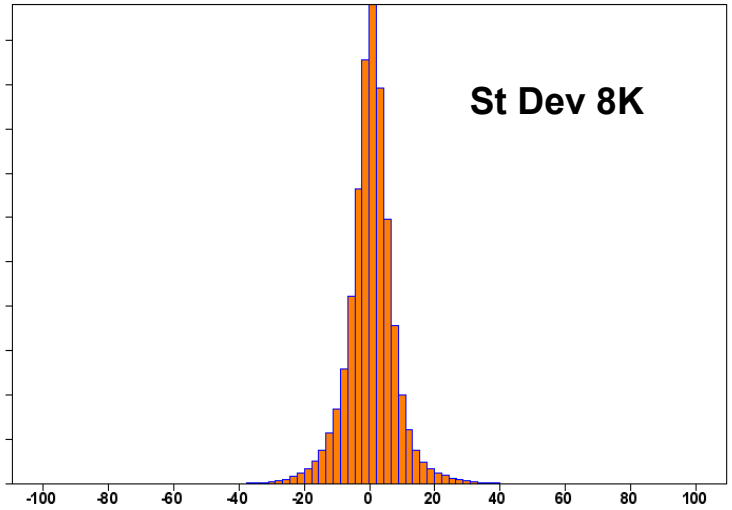
Comparison between SMOS and ECMWF TB:
First Guess departure statistics

Jul 2012



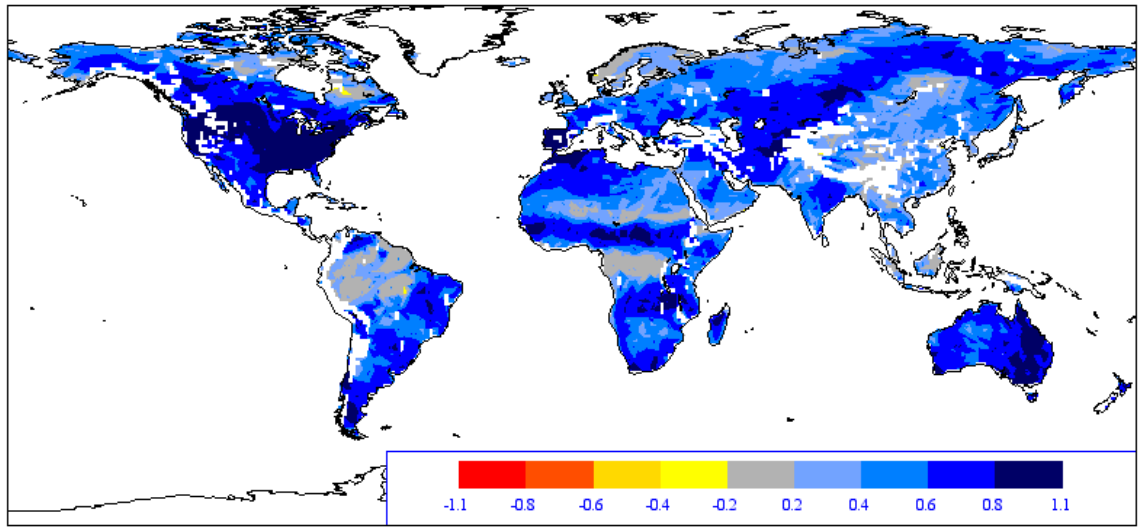


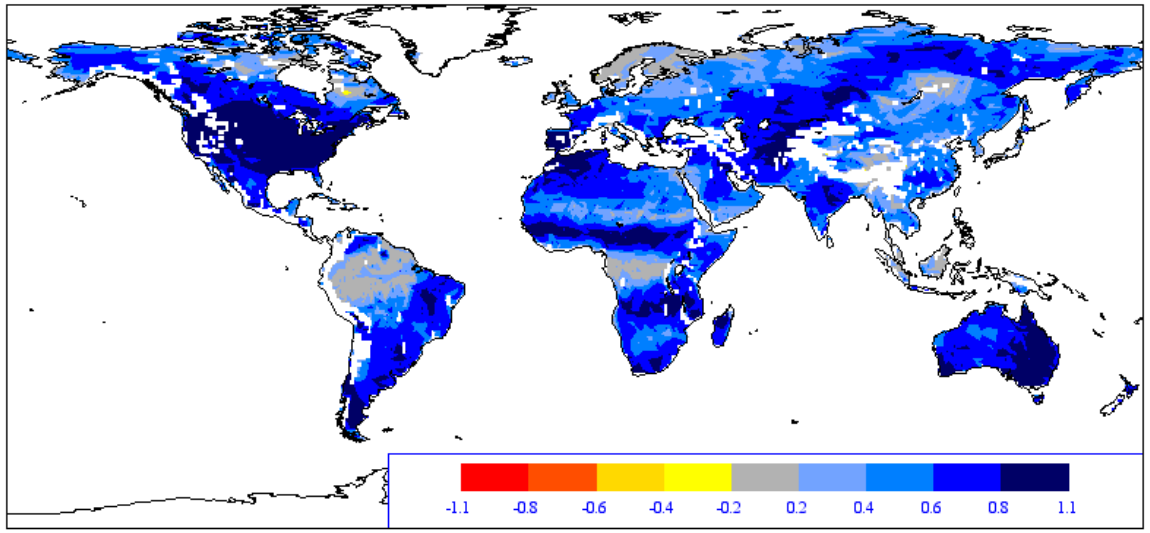




SMOS forward operator and Bias correction

Correlation (2012)





TBxx 40 degrees

Before SMOS BC (0.52)

After SMOS BC (0.57)

Monthly CDF-matching
→ improves correlation

Comparison between SMOS and ECMWF TB

Long term comparison between:

- SMOS NRT TB (proc v505 reprocessed and NRT data sets) and
- ECMWF-CMEM re-analysis using latest physiographic data base (IFS CY41R1).

	RMSE (K)	R	Anomaly R
2010	8.68	0.545	0.277
2011	8.03	0.565	0.285
2012	7.78	0.567	0.302
2013	7.40	0.595	0.315

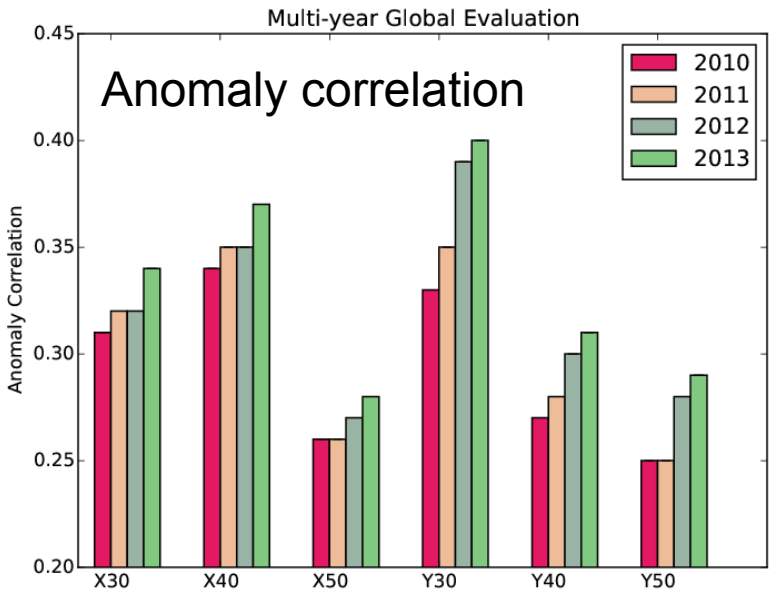
Table: Global mean statistics, after bias correction, considering xx and yy pol at 30,40,50 degrees incidence angles.

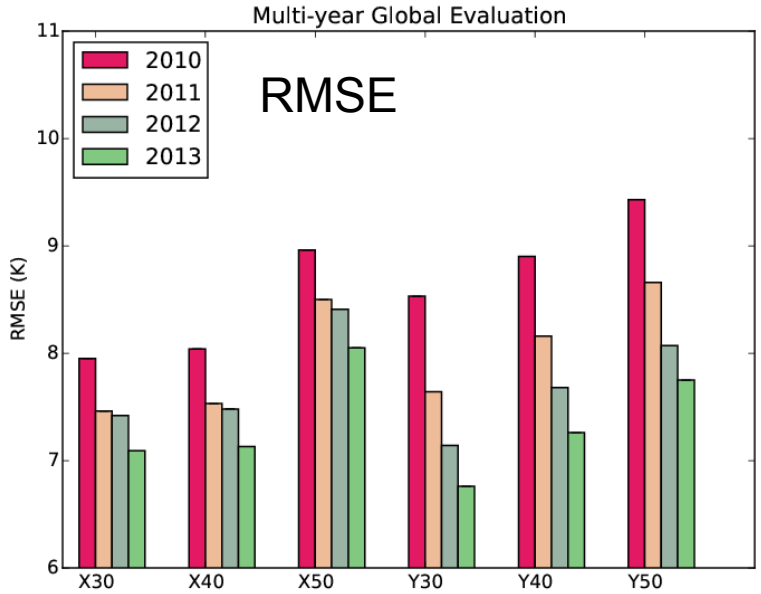
Consistent improvement of agreement between SMOS and ECMWF reanalysis from 2010 to 2013

SMOS Forward modelling and Bias correction

- CMEM: ECMWF Community Microwave Emission Modelling Platform
  → 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





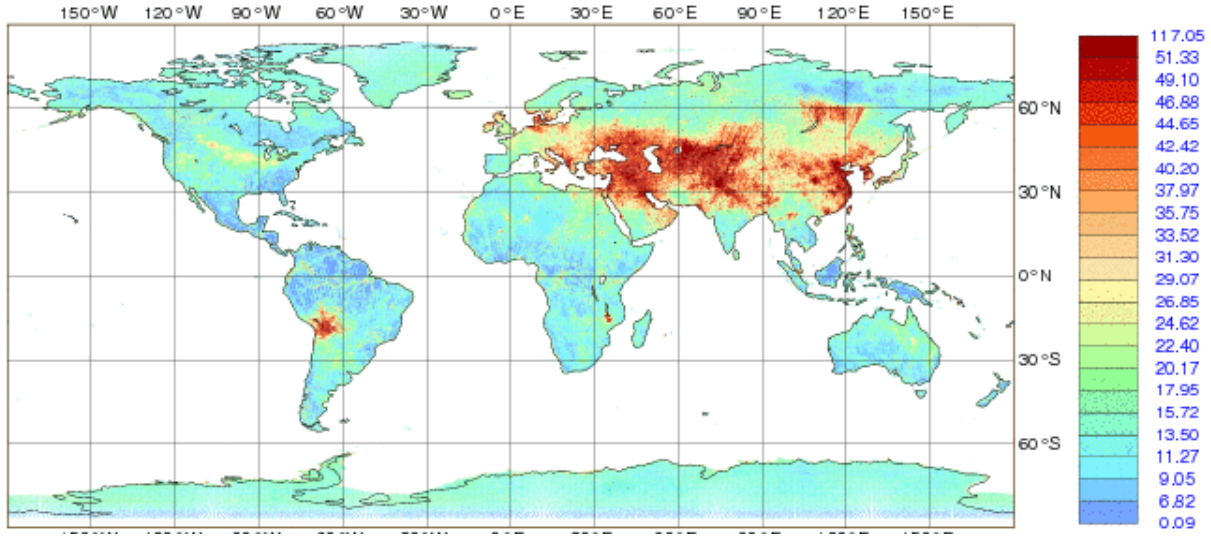
Polarisation (xx or yy) and incidence angle (30, 40, 50) **Polarisation (xx or yy) and incidence angle (30, 40, 50)**

SMOS Monitoring

Near real time (NRT) monitoring of SMOS TB at ECMWF
(Muñoz Sabater et al. ECMWF Newsletter & IEEE TGRS 2011)

RFI (Radio Frequency Interference) sources impact on FG departures (Obs-model) : large standard deviation (StDev); Lots of RFI sources switched off in Europe, new sources identified in 2012,major issue in Asia.

STATISTICS FOR RADIANCES FROM FROM SMOS
STDV OF FIRST GUESS DEPARTURE (ALL)
DATA PERIOD = 2013-01-20 21 - 2013-02-22 21
EXP = FGA5, CHANNEL = 1 (FOVS: 36-45)
Min: 0.086 Max: 117.052 Mean: 15.794
GRID: 0.25x 0.25



StDev first guess departure (Obs-Model)
In Kelvin for Jan-Feb 2013

Satellite data for NWP soil moisture analysis

Active microwave data:

ASCAT: Advanced Scatterometer

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

C-band (5.6GHz)

NRT Surface soil moisture

Operational product

→ ensured operational continuity

Passive microwave data:

SMOS: Soil Moisture & Ocean Salinity

L-band (1.4 GHz)

NRT Brightness Temperature

Dedicated soil moisture mission

→ Strongest sensitivity to soil moisture

Active and Passive:

SMAP : Soil Moisture Active Passive

L-band TB 2015

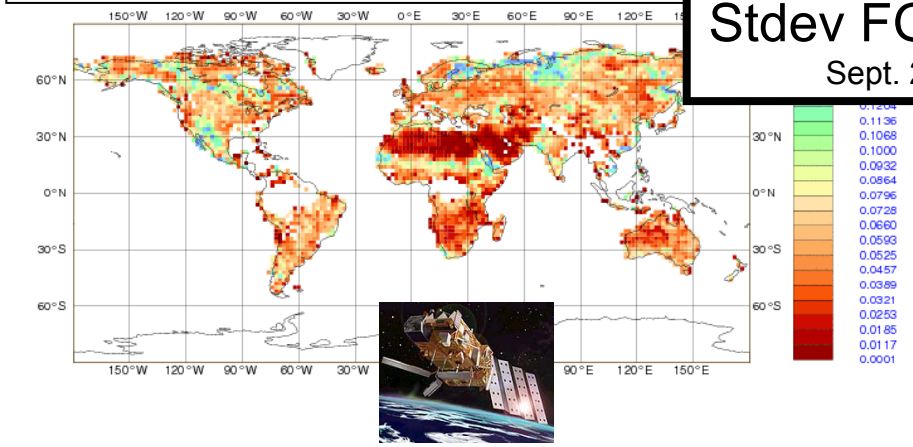
Dedicated soil moisture mission

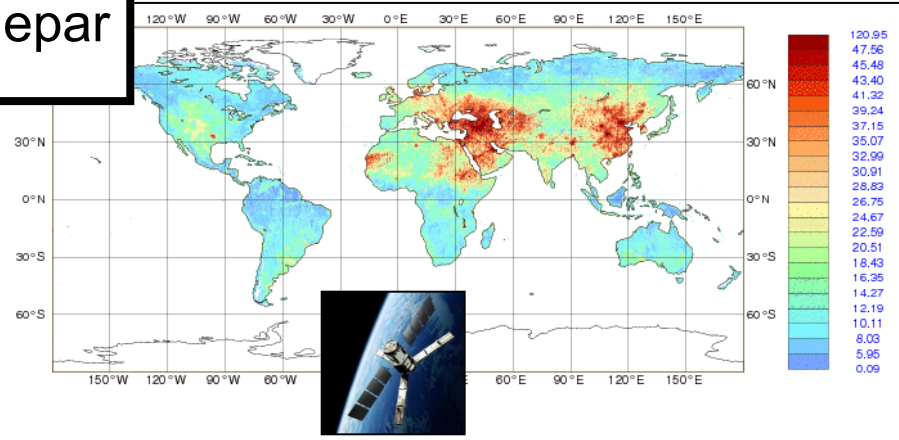
Operational Monitoring of surface soil moisture related satellite data:

ASCAT soil moisture (m^3m^{-3}) SMOS Brightness temperature (K)

Stdev FG_depar

Sept. 2013





ASCAT soil moisture

- ASCAT is a soil moisture index (0-1) ; models soil moisture variable is a volumetric quantity (m^3m^{-3})
- Systematic differences between model and observations
- Data assimilation aims at correcting for the model random errors, so a bias correction method is necessary to match the observations 'climatology' to that of the model

→ **For soil moisture data assimilation systems simplified Bias correction method often used**

Cumulative Distribution Function Matching: CDF-Matching (e.g. Scipal et al. WRR 2008, Draper et al, JGR 2009)

ECMWF: Revised in 2011 to account for seasonal cycle (de Rosnay et al., ECMWF Res. Memo. 2011)

ASCAT Bias Correction (CDF matching)

- ASCAT soil moisture index ms_{ASCAT}
- Model soil moisture θ (m^3/m^{-3})

→ Simple Cumulative Distribution Function (CDF) matching (Scipal et al., 2008)

$$\theta_{ascat} = a + b\, ms_{ascat}$$

with $a = \overline{\theta}_{model} - \overline{ms}_{ascat}\,(\sigma_{model}/\sigma_{ms\_ascat})$

$b = \sigma_{model} / \sigma_{ms\_ascat}$

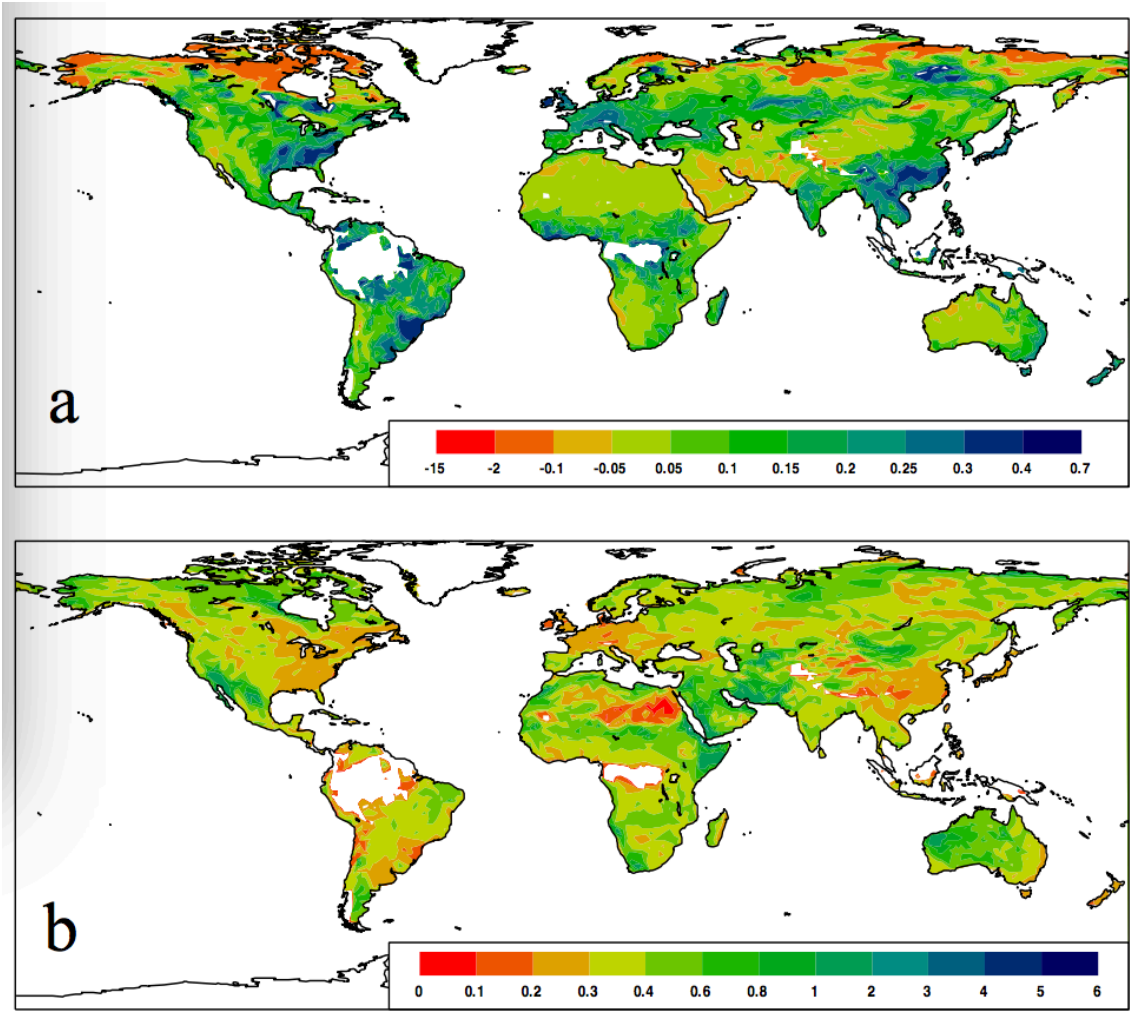
→ Matches mean and variance

a and b are CDF matching parameters computed **on each model grid point**

ASCAT CDF-matching has two objectives:

→ **ASCAT index converted to model equivalent volumetric soil moisture**

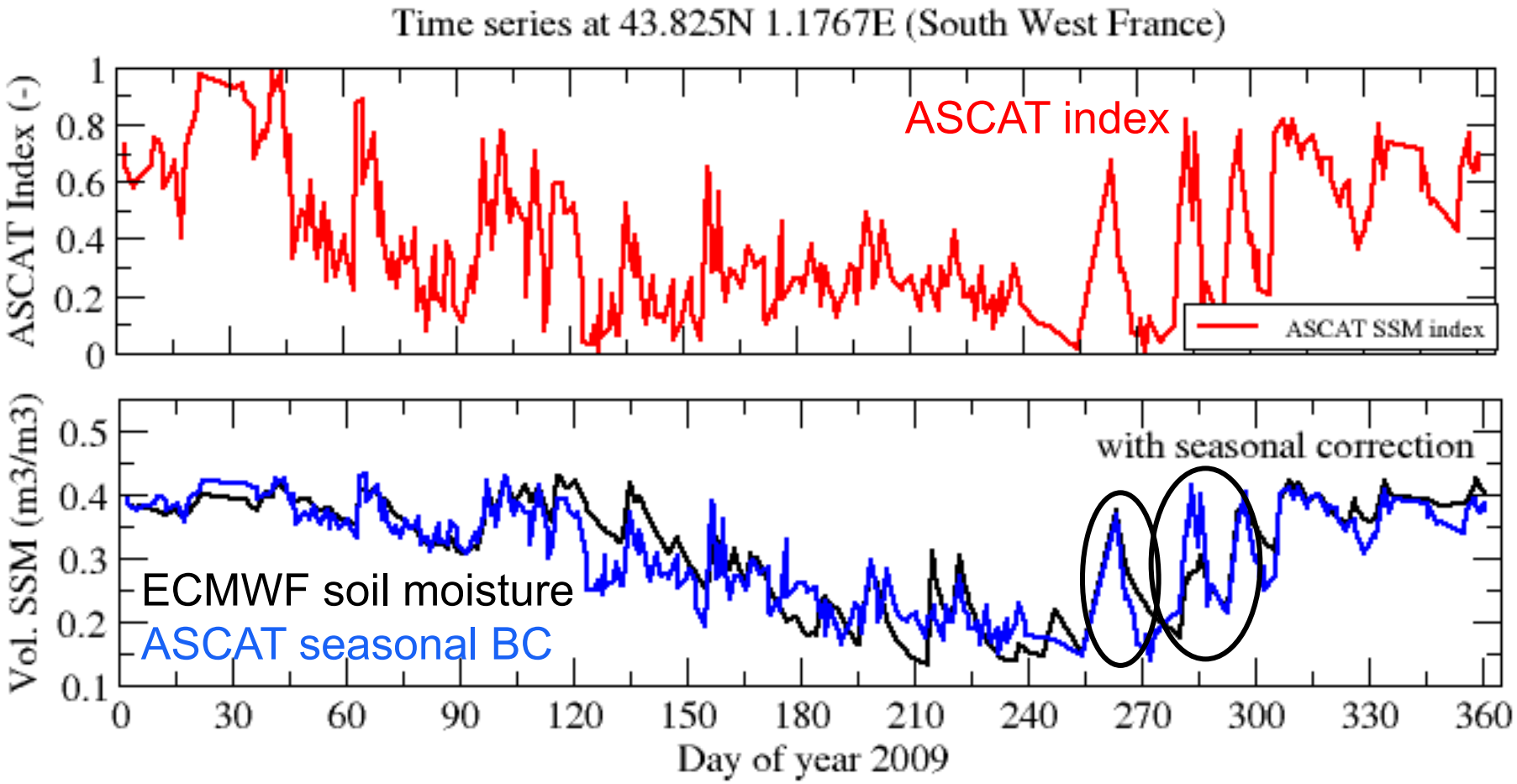
→ **Bias correction**



ASCAT matching parameters
(de Rosnay et al., ECMWF Res memo R43.8/PdR/11100, 2011)

ASCAT Bias Correction (CDF matching)

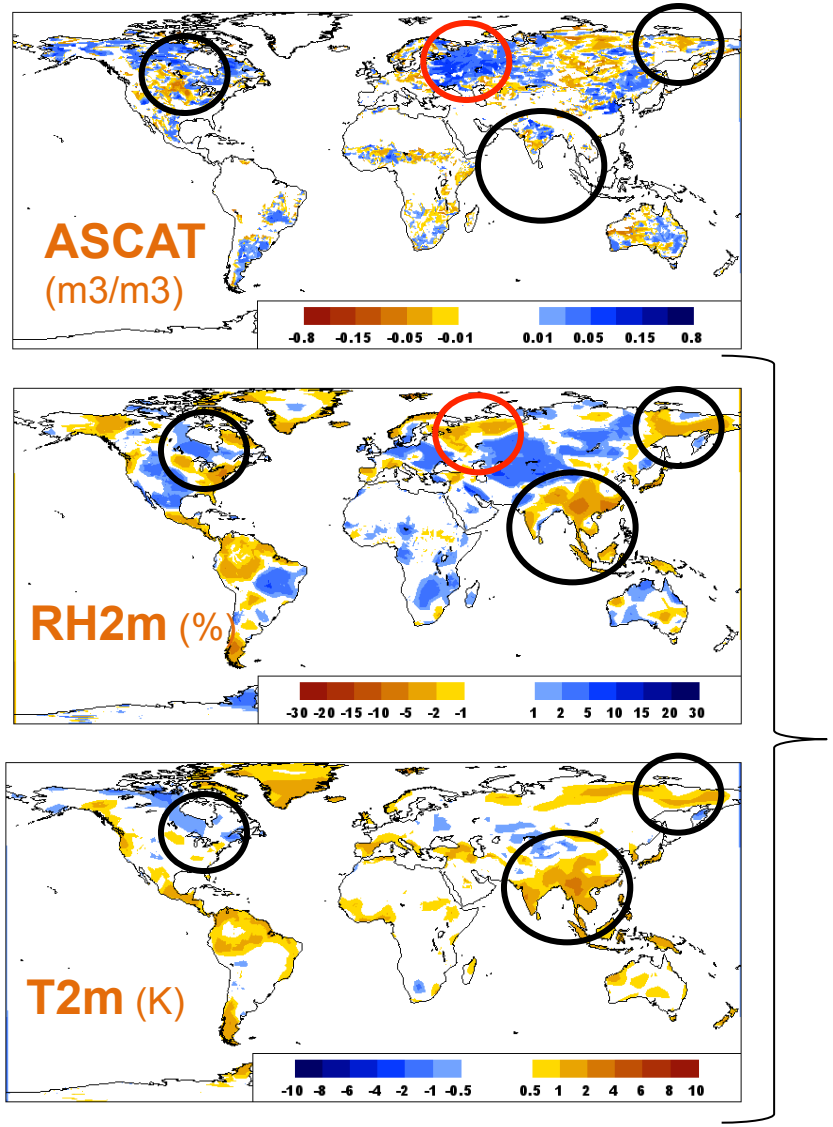
Efficient data assimilation relies on accurate bias correction



ASCAT Soil Moisture data assimilation for NWP

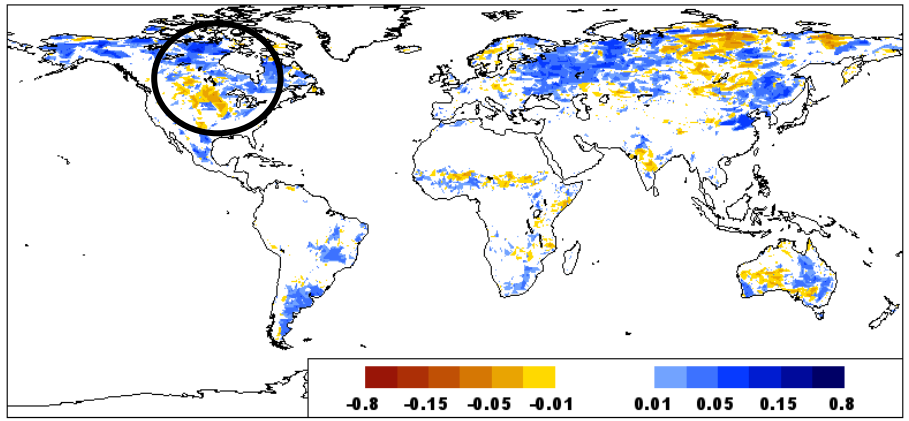
Innovation (Obs- model)

25-30 June 2013

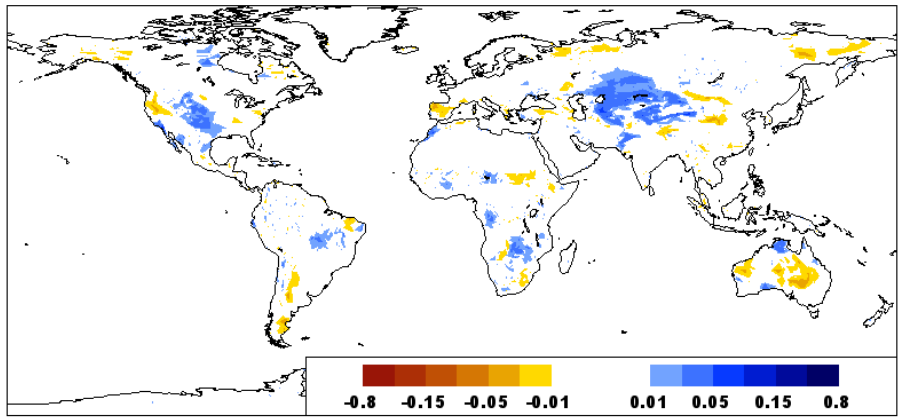


Accumulated Increments (m^3/m^3)

in top soil layer (0-7cm)



Due to ASCAT

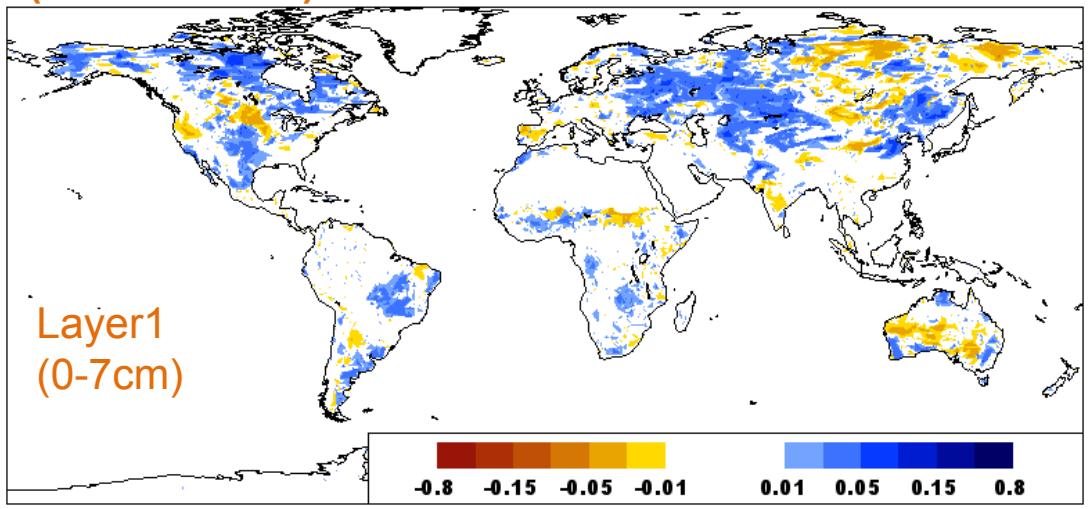


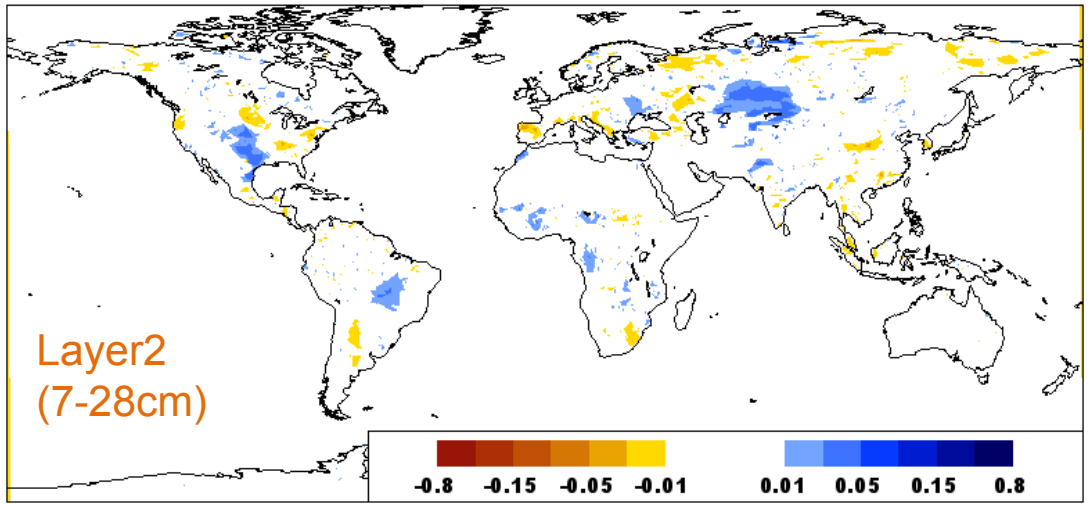
Due to SYNOP T2m and RH2m

ASCAT Soil Moisture data assimilation for NWP

Volumetric Soil Moisture increments (m^3/m^3) (accumulated)

25-30 June 2013





Vertically integrated Soil Moisture increments (stDev in mm)

	SYNOP	ASCAT
Layer 1	0.68	**1.43**
Layer 2	**1.48**	0.68
Layer 3	**4.28**	0.46

ASCAT more increments than SYNOP at surface
SYNOP give more increments at depth
→ For 12h DA window, link obs to root zone stronger for T2m,RH2m than for surface soil moisture observations

Root Zone Soil Moisture Retrieval

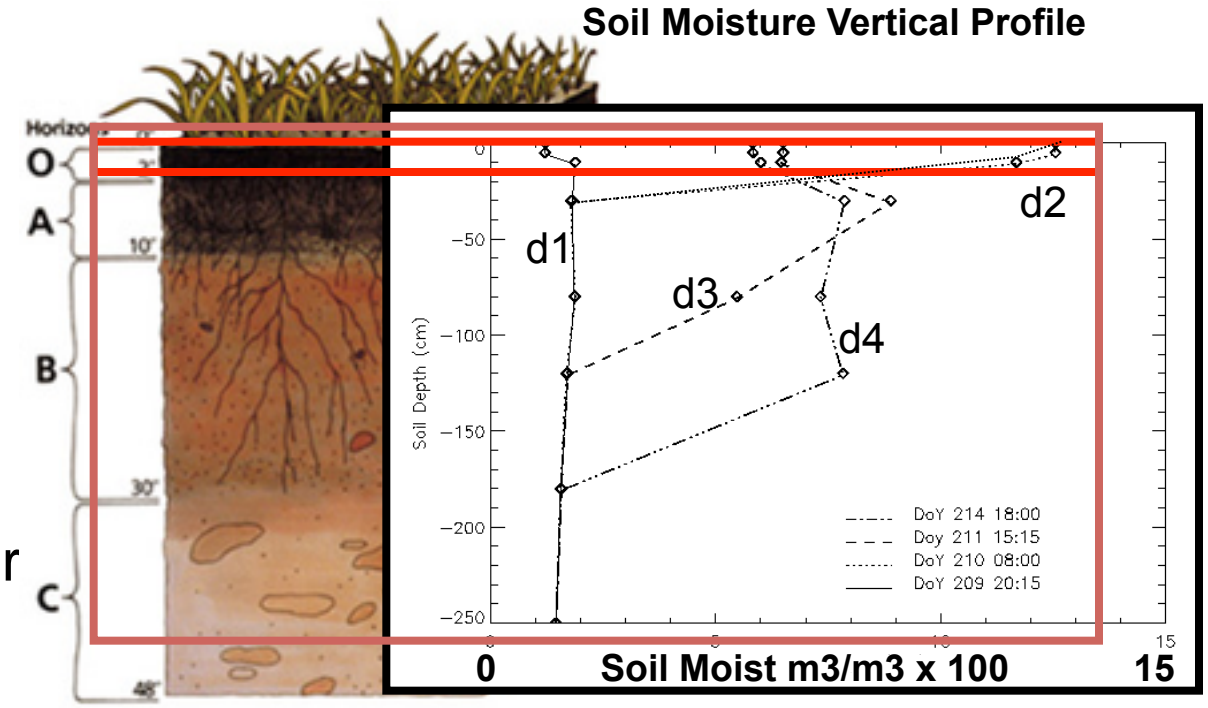
Satellite data → Surface information

Top soil moisture sampling depth: 0-2cm ASCAT, 0-5cm SMOS

Root Zone SM Profile

Variable of interest for Soil-Plant-Atm interaction, Climate, NWP and hydrological applications

Accurate retrieval requires to account for physical processes



→ Retrieval of root zone soil moisture using satellite data requires data assimilation approaches

ASCAT root zone retrieval based on data assimilation

The EUMETSAT Network of Satellite Application Facilities

H SAF Support to Operational Hydrology and Water Management

EUMETSAT Hydrology SAF

ECMWF Atmospheric conditions

SYNOP
T2m RH2m
analysis

ASCAT
Surface SM
Bias corrected

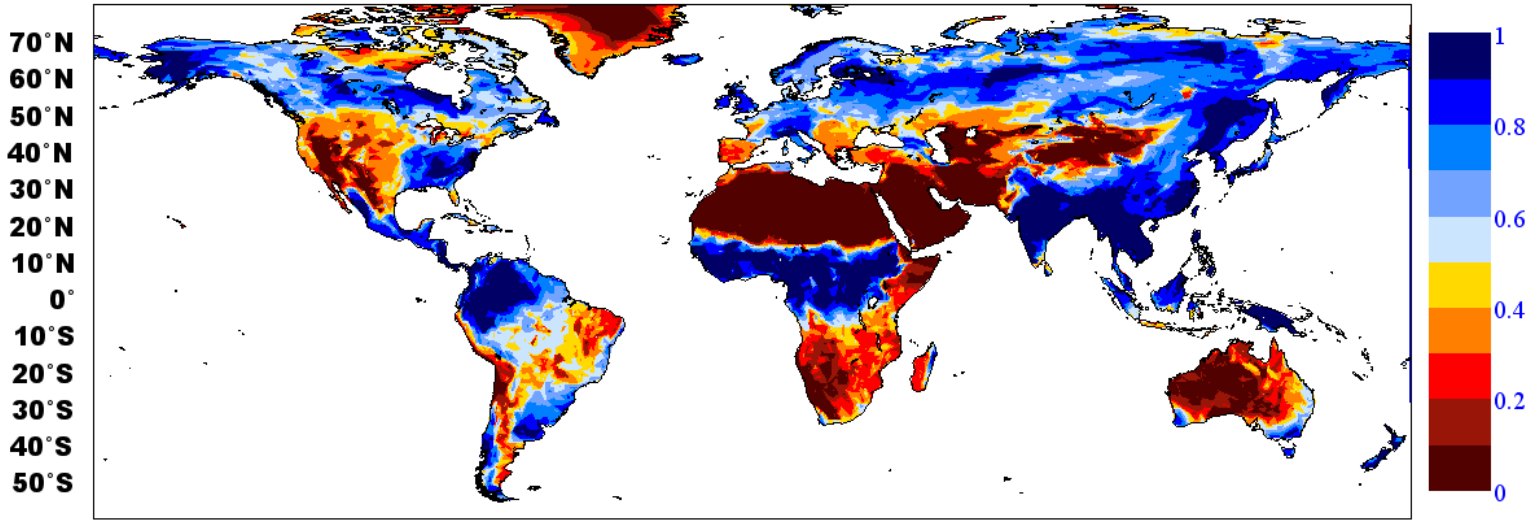
SEKF
Soil Moisture
Analysis

ASCAT Root Zone product (H14)

Quality Control → use data when:
- Topographic complexity ≤ 20
- Wetland Fraction ≤ 15
- Noise level ≤ 8
- processing flag=0

Analysed root zone
soil moisture on model levels
4 layers:
0-7cm
7-28 cm
28-100 cm
100-289cm

ASCAT root zone retrieval based on data assimilation



Assimilated ASCAT Surface (0-7cm) soil moisture index (0-1)

04 Sept 2012 00UTC

ASCAT Root Zone Soil Moisture Product (H-SAF H14):
Data assimilation used to propagate in space and time the ASCAT surface swath soil moisture information
- Daily Soil Moisture product valid at 00:00 UTC
- Daily Global coverage

H14 : Operational H-SAF since July 2012;

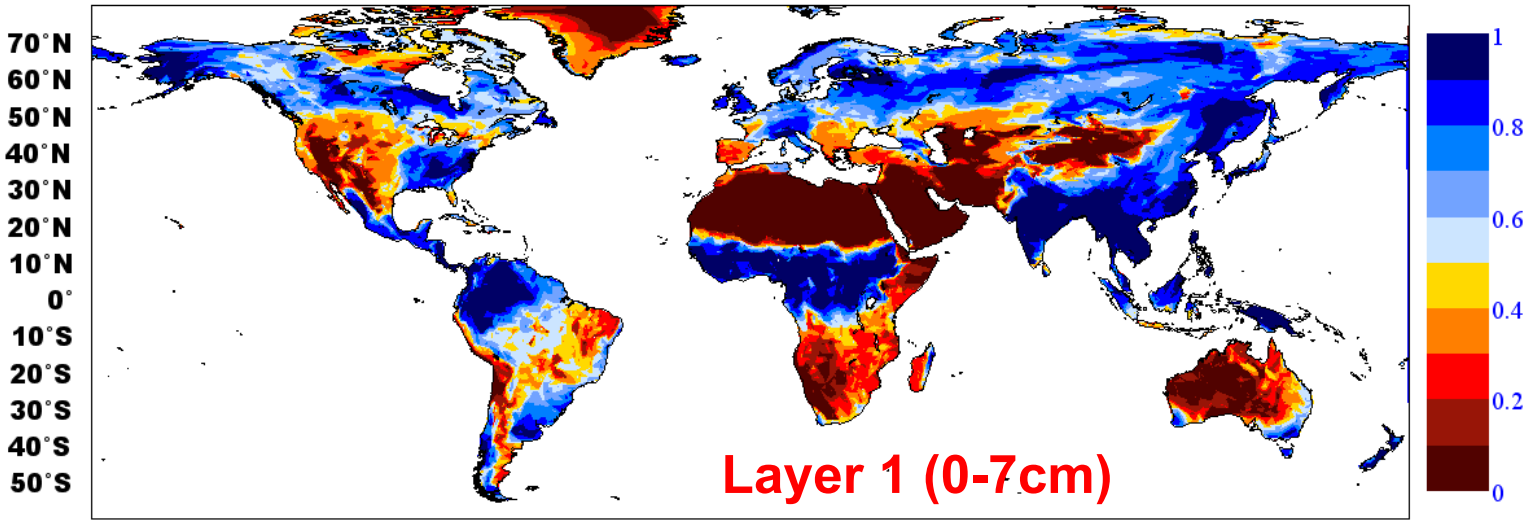
hsafcdop@meteoam.it

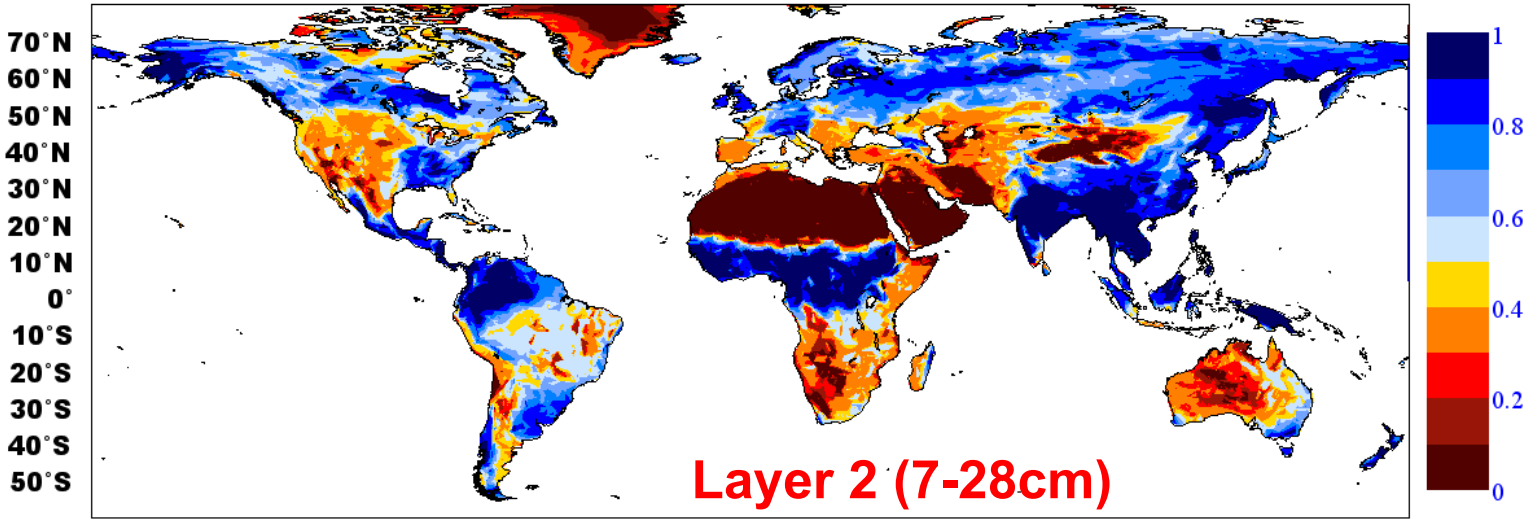
The EUMETSAT Network of Satellite Application Facilities

H SAF
Support to Operational Hydrology and Water Management

ASCAT root zone retrieval based on data assimilation

H14 available on 4 soil layers





Assimilated ASCAT soil moisture index (0-1)

04 Sept 2012 00UTC

The EUMETSAT Network of Satellite Application Facilities

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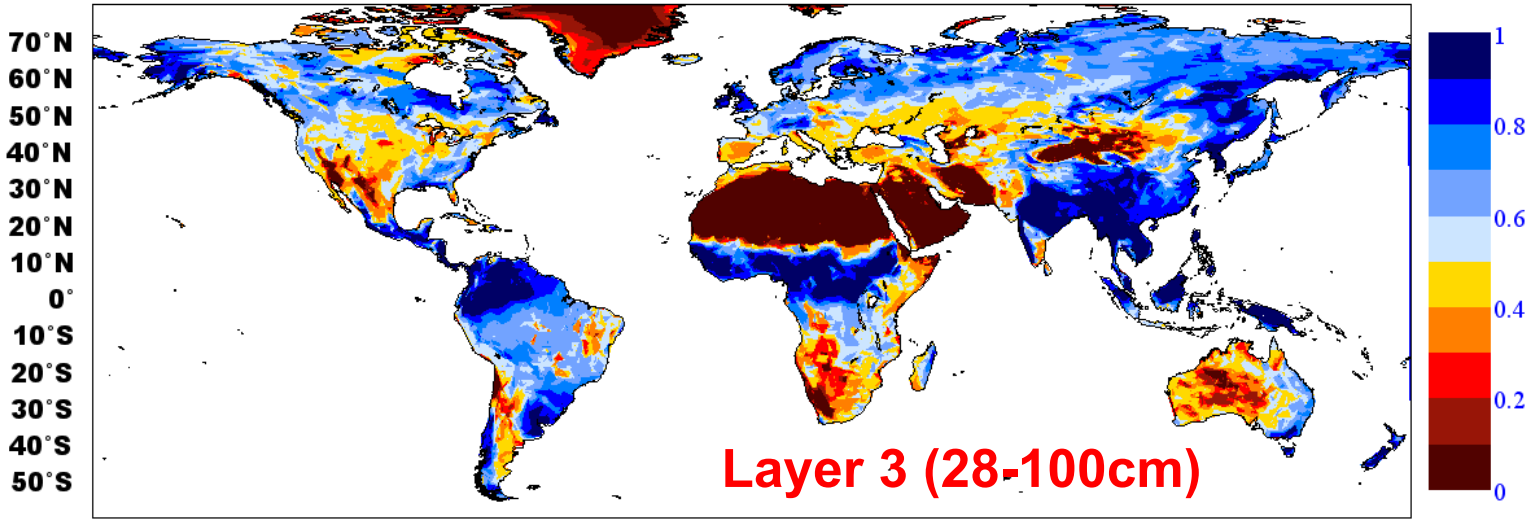
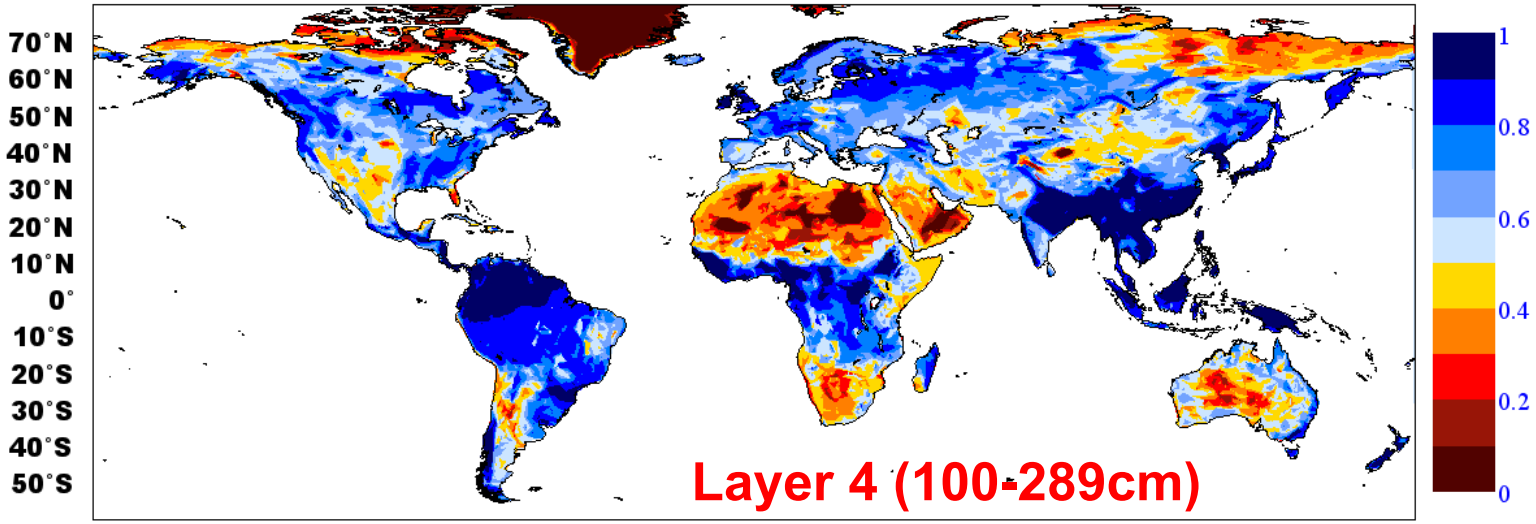
Support to Operational Hydrology and Water Management

ASCAT root zone retrieval based on data assimilation

H14 available on 4 soil layers





Assimilated ASCAT soil moisture index (0-1)

04 Sept 2012 00UTC

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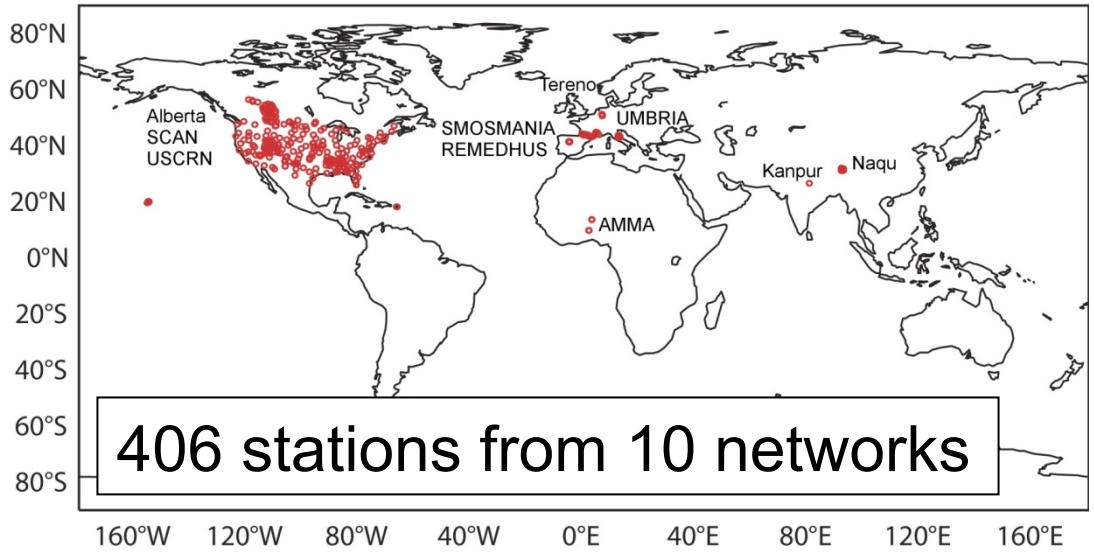
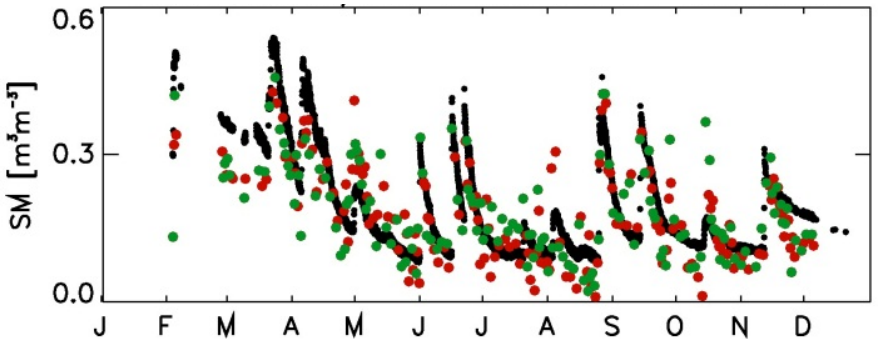
Support to Operational Hydrology and Water Management

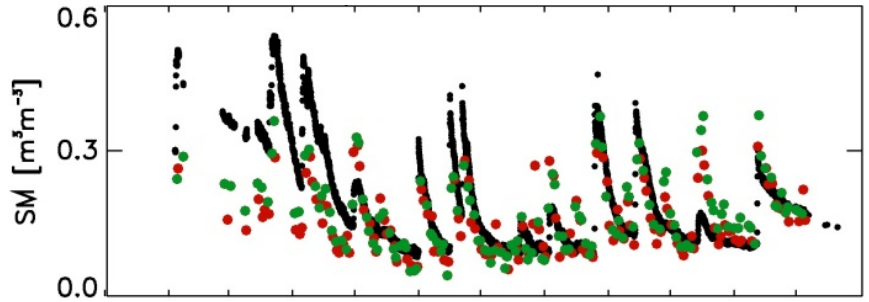
Comparison with in situ soil moisture data



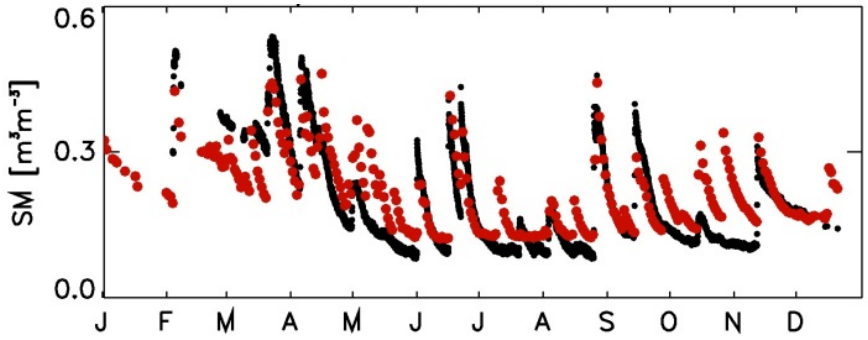
ASCAT



SMOS



H14



International Soil Moisture Network

Comparison of ASCAT, SMOS and H14

For each station, time series are compared

Updated after Albergel et al. Remote Sens Env. 2012

Validation with in situ soil moisture data

Normalized Product (nb stations with significant R)	H14 (333)	ASCAT (322)	SMOS (258)
Correlation	0.68	0.54	0.54
Bias (In Situ - Product)	-0.084	-0.005	0.027
RMSD	0.120	0.110	0.105

Updated after Albergel et al. RSE, 2012

Bias and RMSD expressed as soil moisture index (no unit)

Normalized Product (nb stations with significant R)	H14 (310)	ASCAT (291)	SMOS (234)
Correlation on Anomaly	0.56	0.41	0.42

- SMOS and ASCAT surface soil moisture have similar quality
- Assimilated product (H14) has a larger bias, but in terms of dynamics it shows the best agreement with in situ soil moisture data

Satellite data for NWP soil moisture analysis

Active microwave data:

ASCAT: Advanced Scatterometer

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

C-band (5.6GHz)

NRT Surface soil moisture

Operational product

→ ensured operational continuity

Passive microwave data:

SMOS: Soil Moisture & Ocean Salinity

L-band (1.4 GHz)

NRT Brightness Temperature

Dedicated soil moisture mission

→ Strongest sensitivity to soil moisture

Active and Passive:

SMAP: Soil Moisture Active and Passive

L-band TB 2015

Dedicated soil moisture mission

STATISTICS FOR SOIL MOISTURE FROM METOP-B/ASCAT

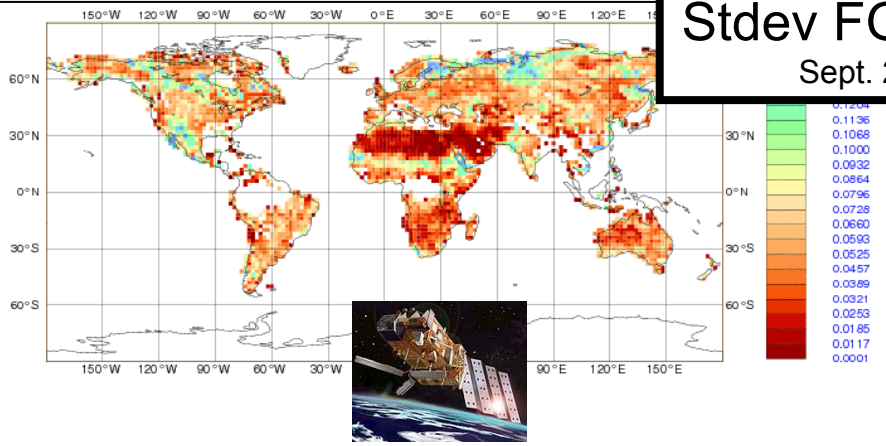
STATISTICS FOR RADIANCES FROM FROM SMOS

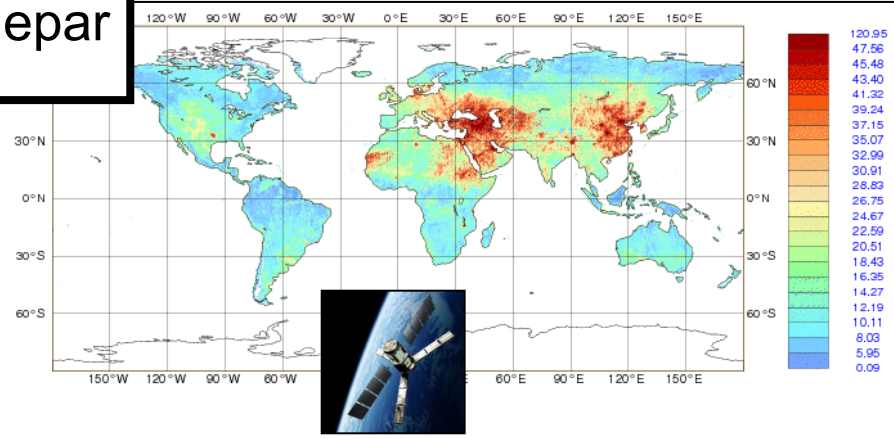
Operational Monitoring of surface soil moisture related satellite data:

ASCAT soil moisture (m^3m^{-3}) SMOS Brightness temperature (K)

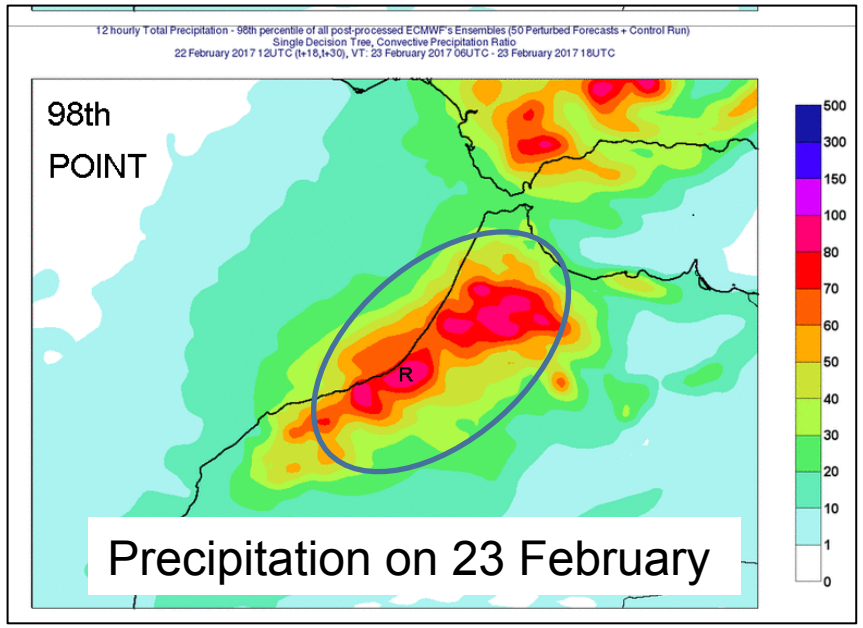
Stdev FG_depar

Sept. 2013





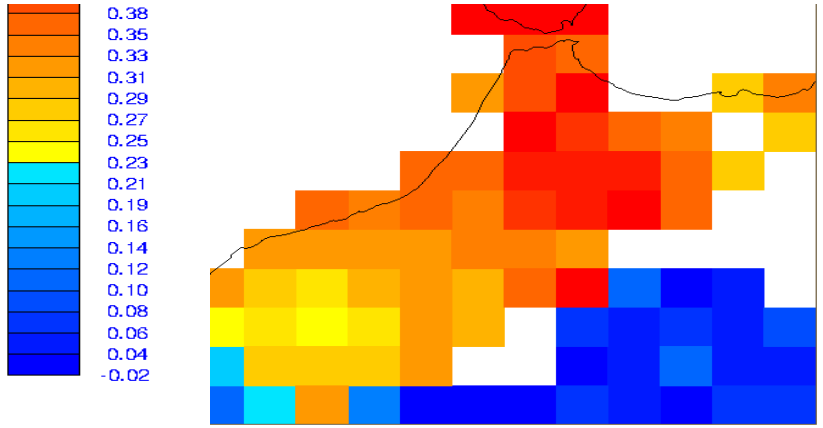
ASCAT in the IFS



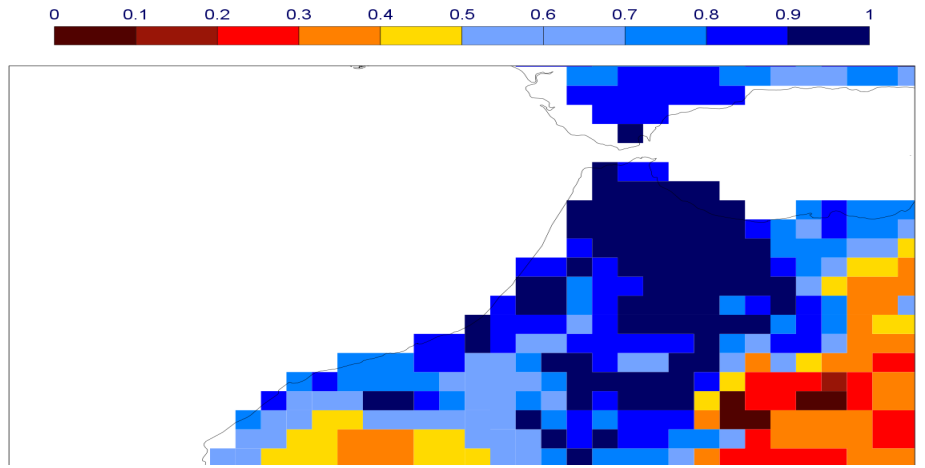
→ Both ASCAT and SMOS captured very well the event

Moroccan flood February 2017

ASCAT Soil Moisture m3/m3 23-28 Feb
Mean First Guess departure: Obs-Model (K)



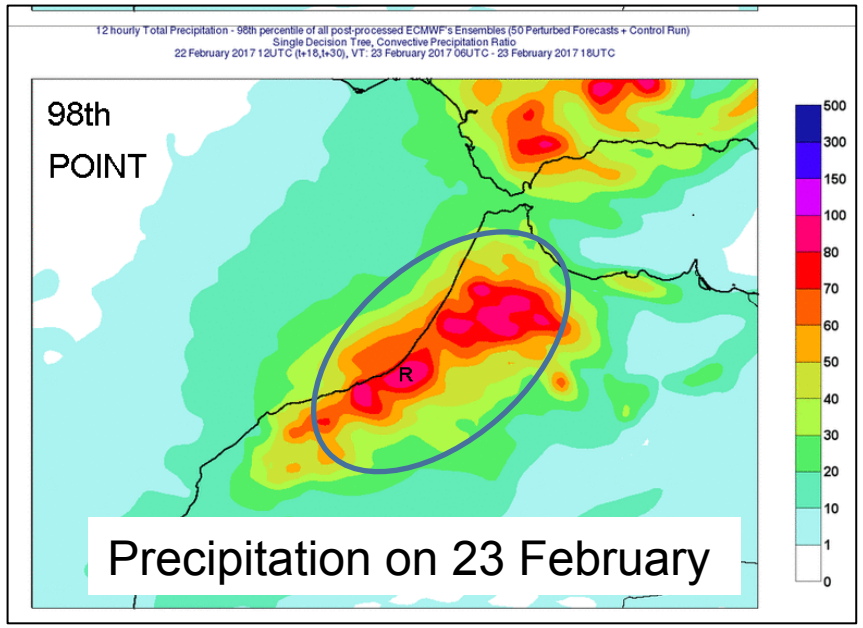
Red indicates that ECMWF is **too dry**, according to SMOS.



Propagated in the Root zone
-> H-SAF H14 Soil moisture in the root zone

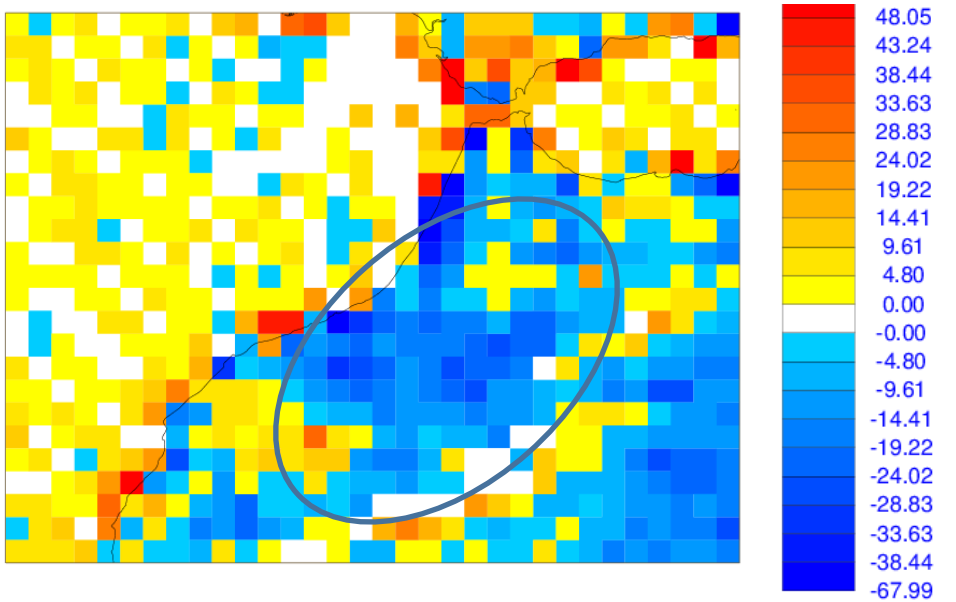
SMOS in the IFS

Moroccan flood February 2017

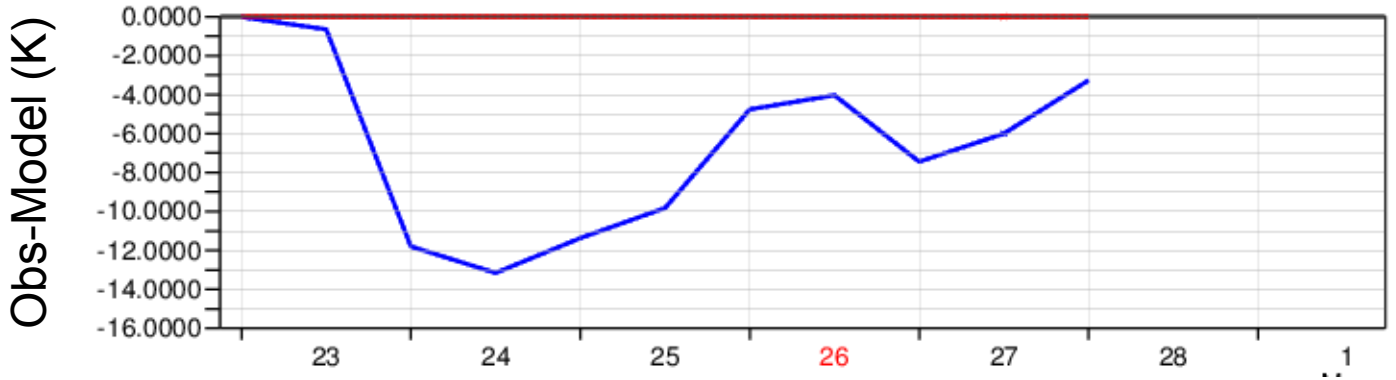


Precipitation on 23 February

SMOS TBh (30degrees) 23-28 Feb
Mean First Guess departure: Obs-Model (K)



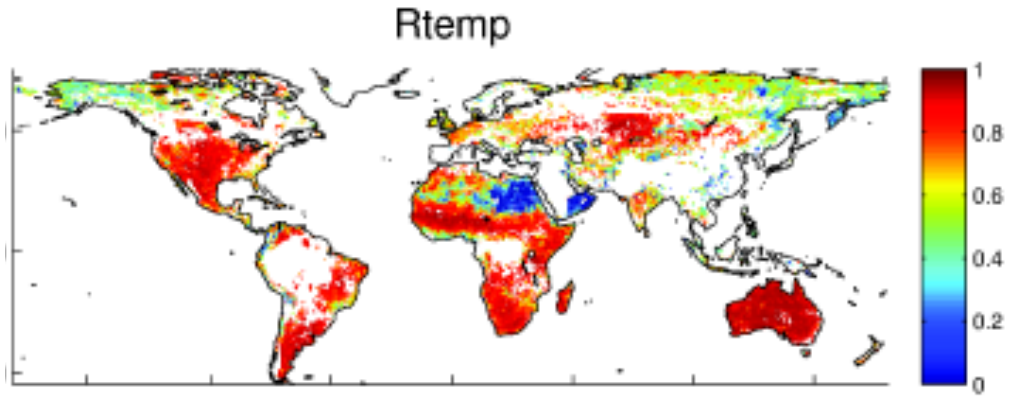
Blue indicates that ECMWF is **too dry**, according to SMOS.



First guess departure (Obs-Model) Morocco, 23-28 Feb 2017

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

NRT designed and evaluated by CESBIO (Centre d'Etudes Spatiales de la Biosphere)



(Rodriguez-Fernandez et al.)

SMOS NRT SM 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 in January 2016, operational ESA March 2016

- 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**

ECMWF esa CESBIO

Passive microwave remote sensing

Satellite missions relevant for soil moisture:

Skylab, NASA, L-band, 1973-1974 (but only 9 overpasses available)

SMMR, Nimbus7, C-Band (6.6 GHz) , X-band (10.7 GHz), 1978-1987 (Scanning Multichannel Microwave Radiometer)
TMI (TRMM Microwave Imager), X-band (10.7 GHz), 1997-2014
SSMI (Special Sensor Microwave Imager, DMSP F8-13), 19.3 GHz, 1987-

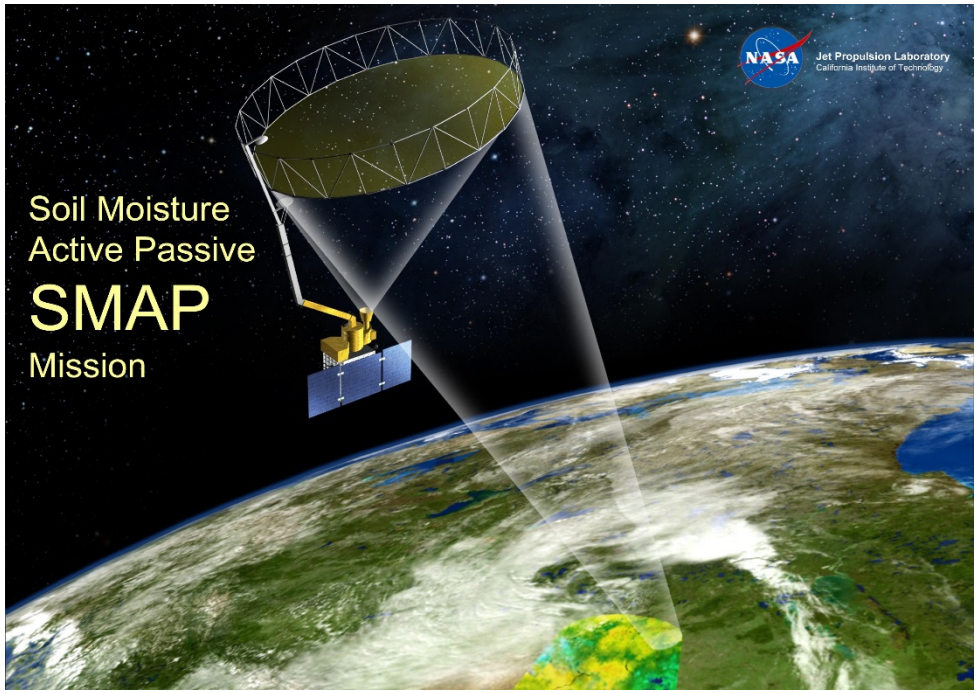
AMSR-E 2002-2011, (Advanced Scanning Radiometer on Earth Observing System, NASA, C-band (6.9GHz)

SMOS (Soil Moisture and Ocean Salinity Mission): ESA Earth Explorer, L-band (1.4 GHz), launched November 2009 **First satellite specifically devoted to soil moisture remote sensing**

AMSR-2 on GCOM-W1 (Global Change Observation Mission) launched in 2012

SMAP (Soil Moisture Active and Passive), NASA, L-band, launched in January 2015

SMAP

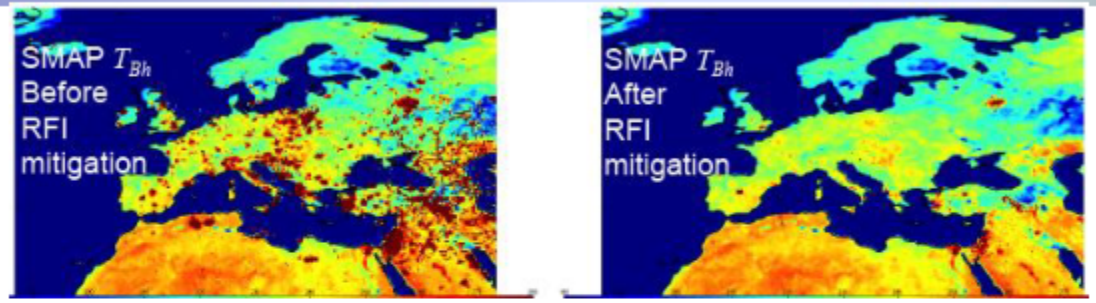


SMAP Launched on 31 Jan 2015

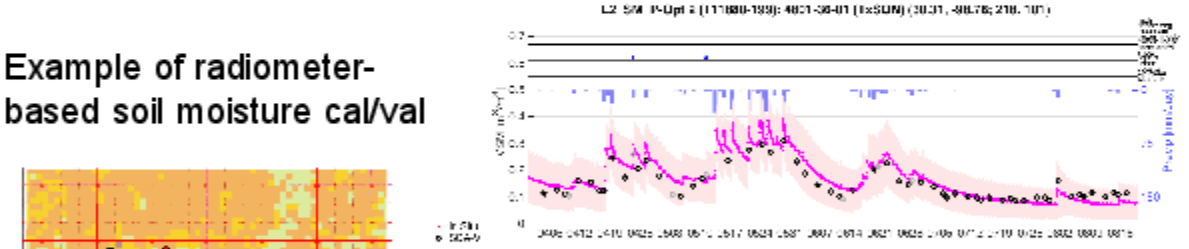
Antenna spin-up end of March

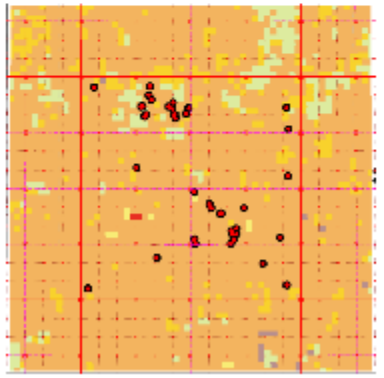
First public data distribution in July 2015

Radiometer Products: Reduced RFI Data Loss and High Performance

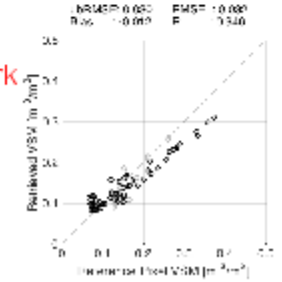


Example of radiometer-based soil moisture cal/val





Texas Soil Observation Network (TxSON):



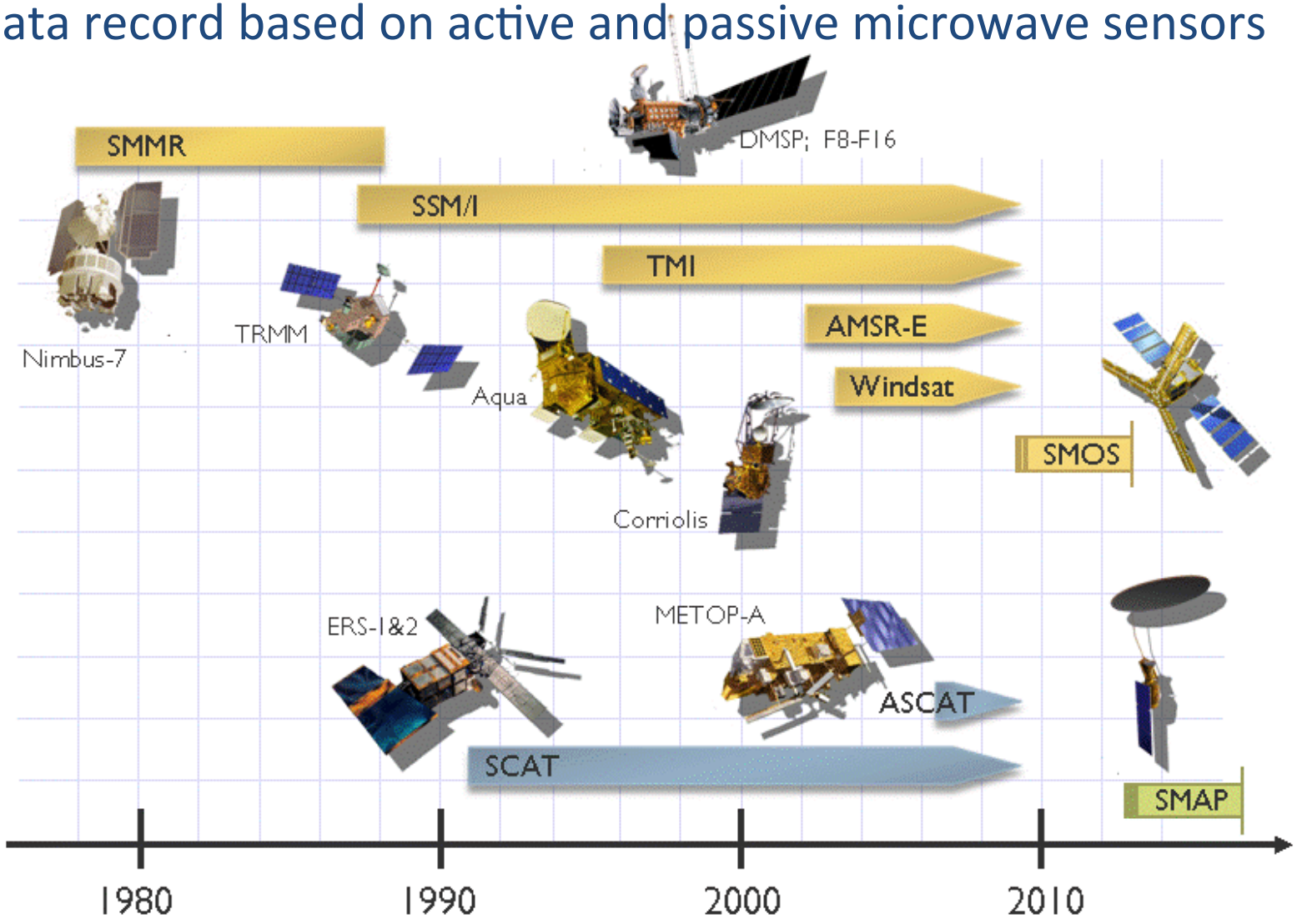
Pick example of a good comparison.

Shows height/upper-limit of what comparisons can be if algorithm and in situ representativeness errors can be minimized.

Slide from Dara Entekhabi, SMAP Science Team Lead

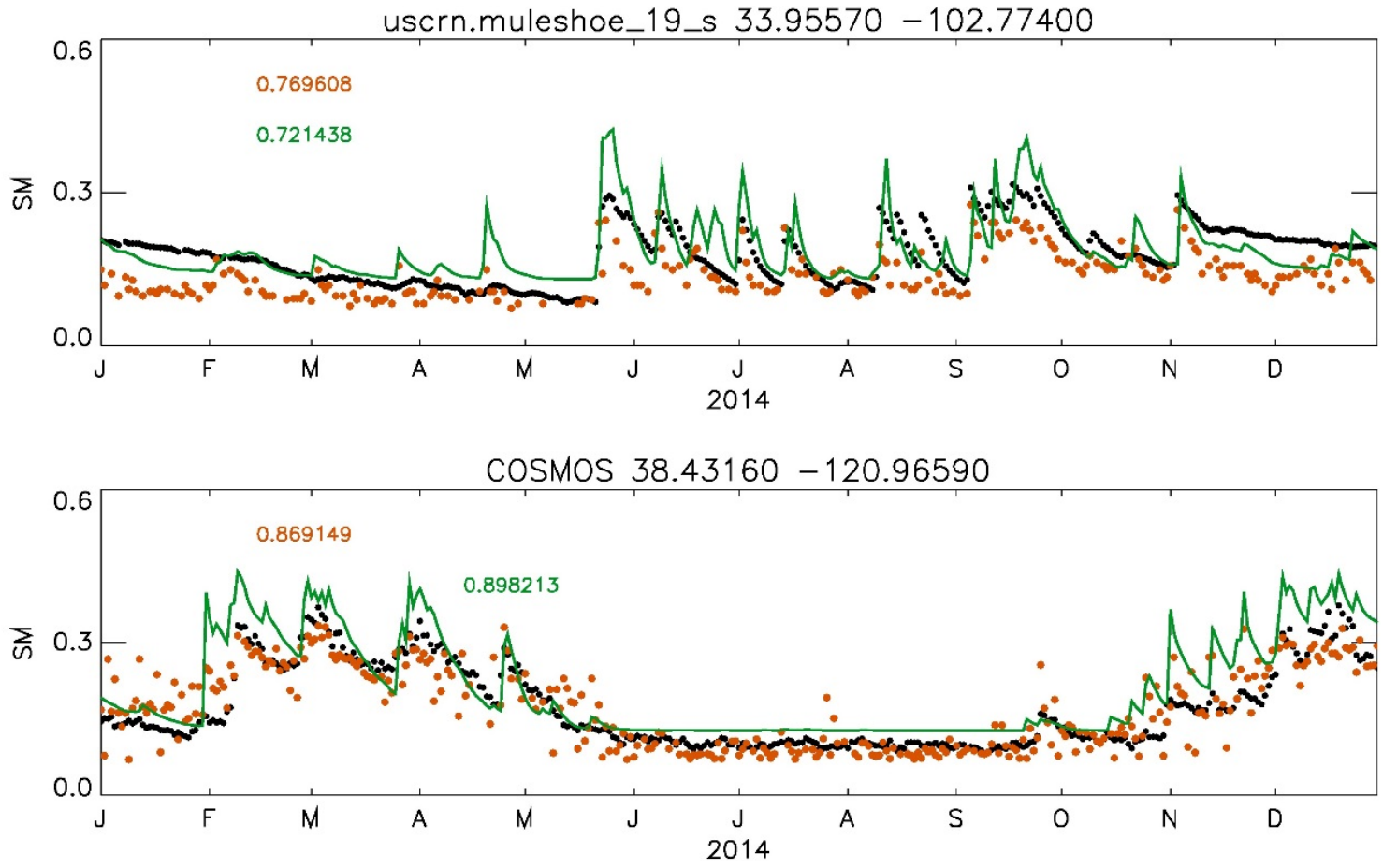
ESA Climate Change Initiative (CCI) Soil moisture:

Project overall objective: produce the most complete/consistent global soil moisture data record based on active and passive microwave sensors



http://www.esa-soilmoisture-cci.org

ESA-CCI SM & ERA-Interim/Land vs. in-situ measurements 2014 (based on daily data)



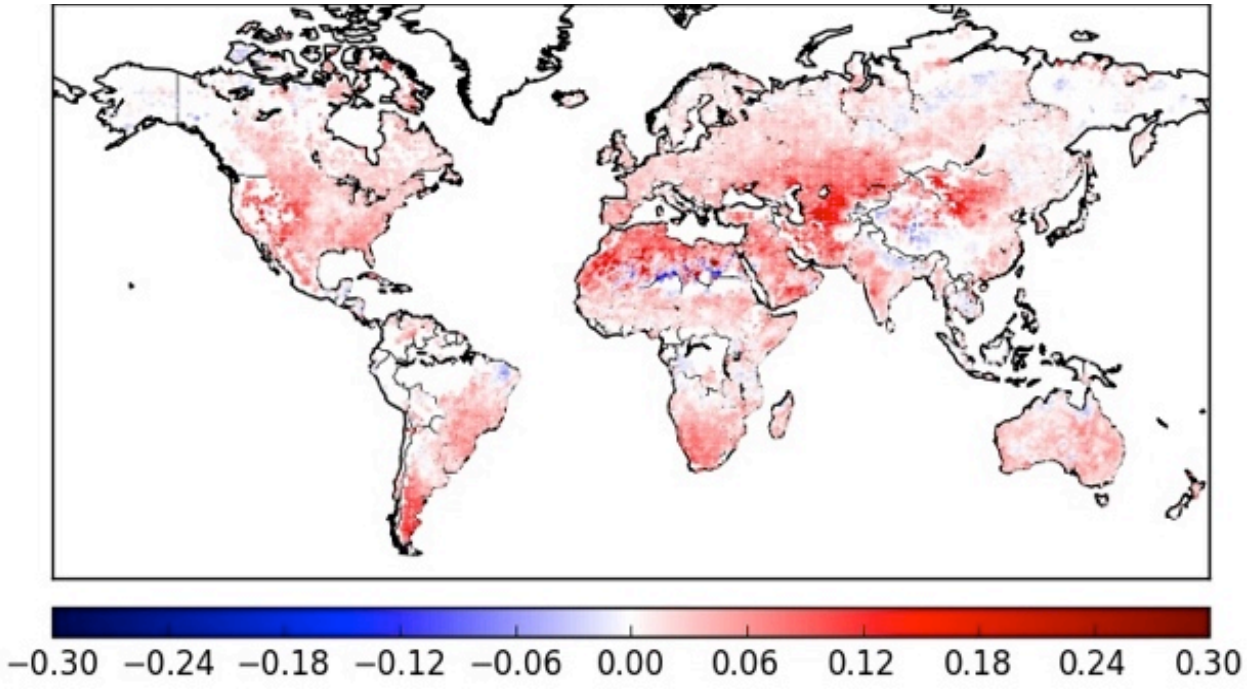
In-situ ESA-CCI-SM ERA-Interim/Land

Impact of soil vertical resolution for satellite soil moisture

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

(Albergel, Balsamo)

Anomaly Correlation between ECMWF surface soil moisture and ESA-CCI satellite soil moisture (diff between new-old)



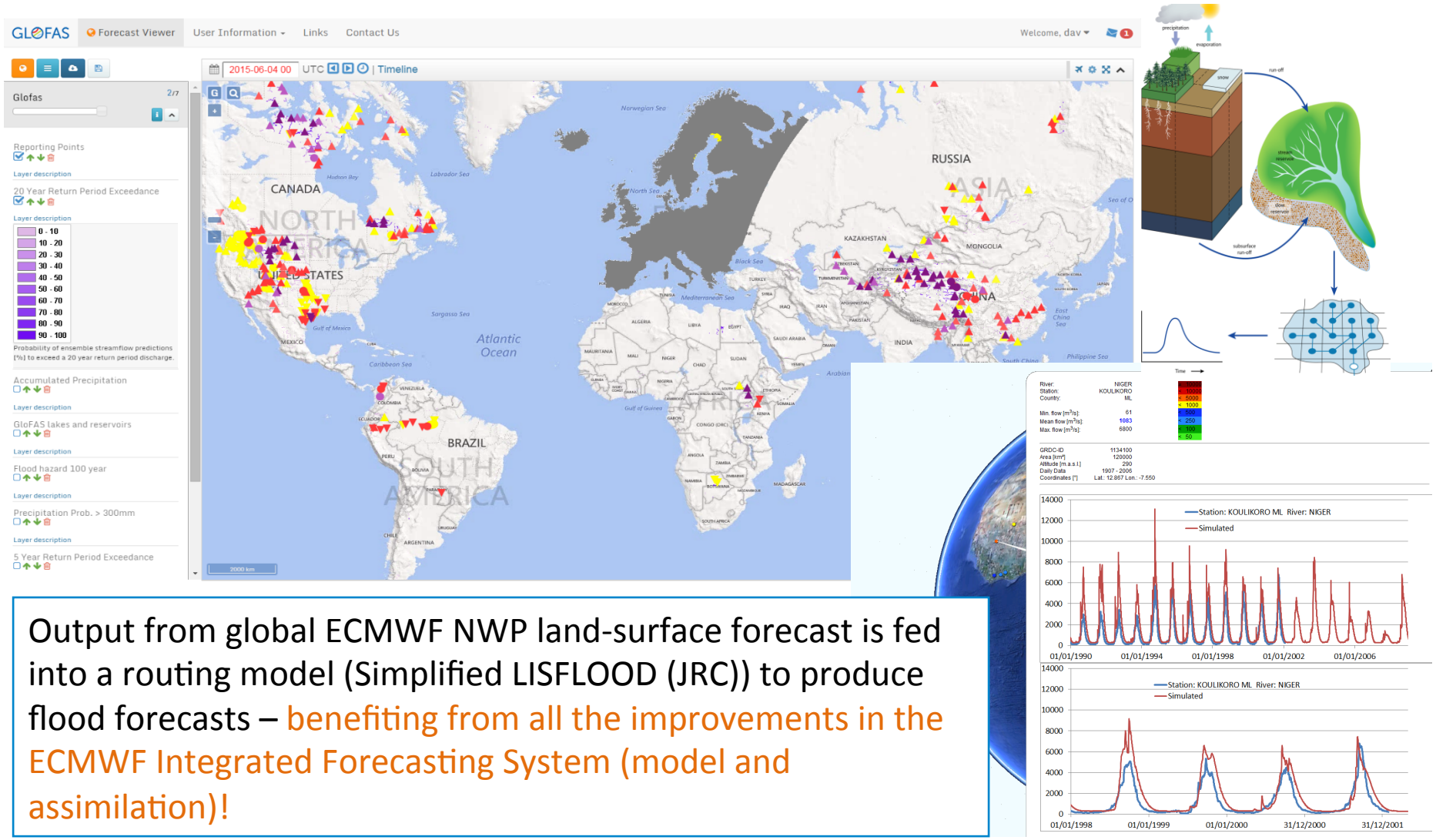
Globally Improved match to satellite soil moisture (shown is ΔACC calculate on 1-month running mean)

Anomaly correlation (1988-2014) measured with ESA-CCI soil moisture remote sensing (multi-sensor).
→ 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

- Most NWP centres analyse soil moisture and/or snow depth
- Land Data Assimilation Systems: run separately from the atmospheric 4D-Var
- Satellite data used for snow cover and soil moisture analyses
- Snow analysis: NOAA NESDIS/IMS snow cover data (multi-sensor product). No Snow Water Equivalent products used for NWP (yet)
- Soil moisture: ASCAT operational from April 2015 at ECMWF (also used at UKMO and KMA). SMOS under development (ECMWF, CMC), SMAP
- Future plans: SMOS technical test in operational framework
- Longer term: Assimilation of integrated hydrological variables such as river discharges: e.g. future Surface Water Ocean Topography

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