5-year of operational validation of H SAF soil moisture products: insights and open issues

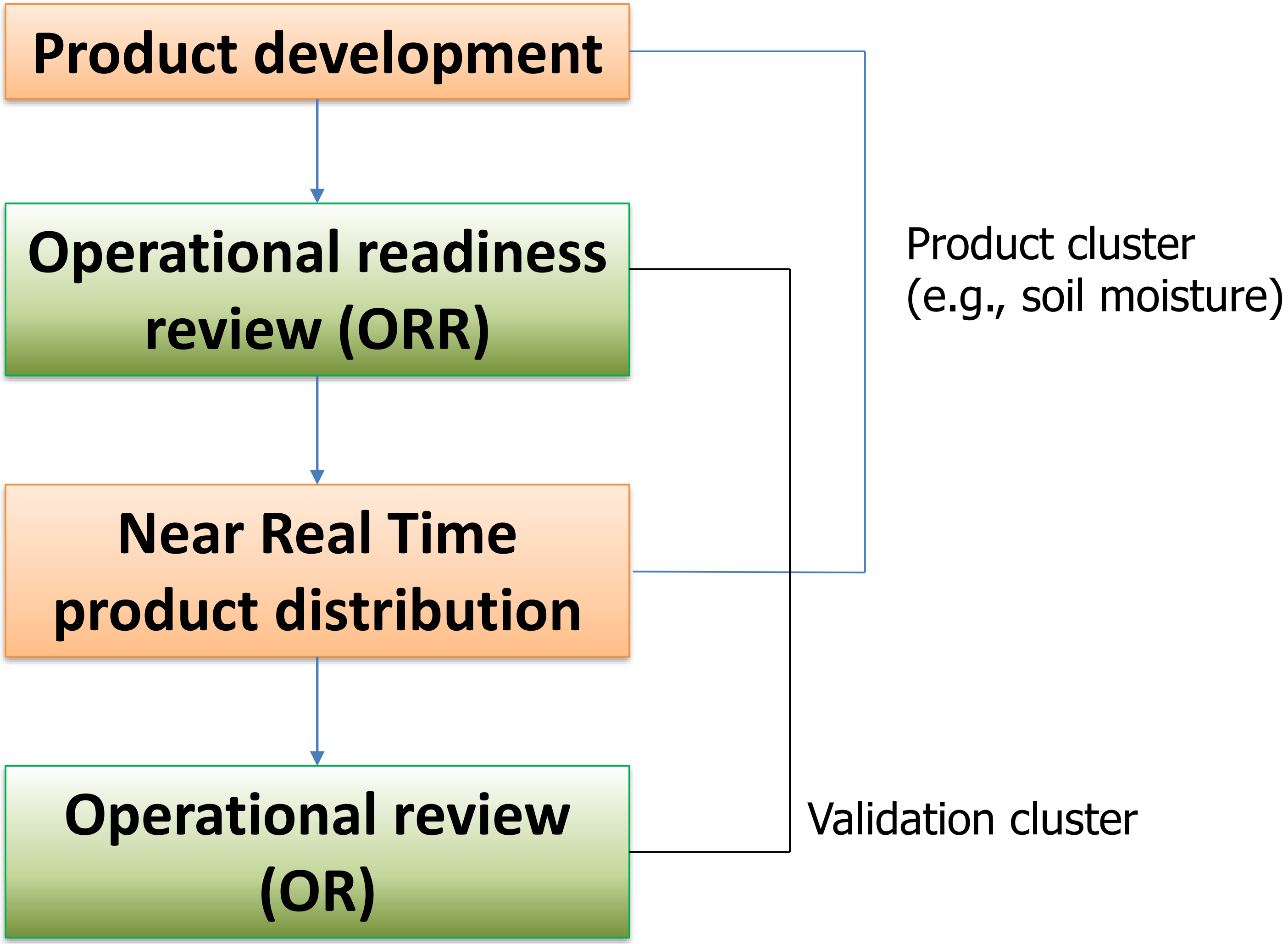
Reading (UK)
25-28 November 2019

Validation Cluster

EUMETSAT H SAF

hepex

H SAF: from product development to product validation



Principles of the OR

- Continuous in time (every year)
- Should include the direct validation of the product and “hydro-validation”
- Consistent over years
- Consistent in space
- Reliant upon robust procedures

Which products do need validation and hydro-validation?

Different institutions are responsible and take part to the validation activities which are important as much as the product development

Validation is carried out as: direct validation (by the identification of three different quality levels: threshold, target, optimal) of the products and hydro-validation

The validation is carried out for NRT products but also include data records.

- Satellite Surface Soil Moisture from radar scatterometer ASCAT NRT (H16, H101, H102, H103)
- Disaggregated Surface Soil Moisture (SSM) product derived from the global ASCAT NRT product (H16) (H08)
- Soil Moisture Profile Index in the roots region by surface wetness scatterometer assimilation method (H14)

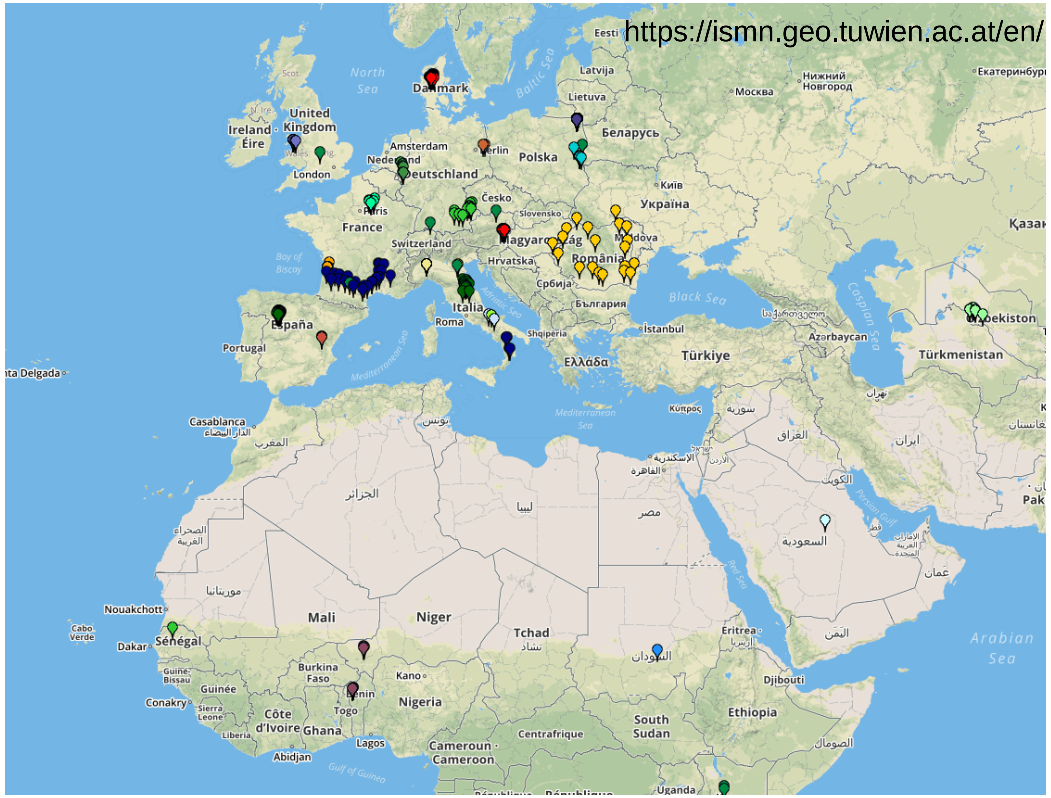
Institutions involved in the validation activities

CIMA (Italy)
IRPI-CNR (Italy)
Météo-France (France)
IMGW (Poland)
TU Wien (Austria)
IRM (Belgium)
NIMH (Bulgaria)
BAFG (Germany)
OMU (Turkey)
DPC (Italy)

ECMWF (UK)
TU-Wien (Austria)

In situ validation (CDOP2)

In situ soil moisture stations with data in the interval 2007-2019



Taken from International Soil Moisture Network (ISMN)
Dorigo et al. (2010)

Advantages:

- Very accurate and reliable if well maintained (i.e., SMOSMANIA, Parrens et al 2012, HESS)

Disadvantages:

- subjected to malfunctions
- often discontinued
- point scale type of information
- limited spatial and temporal coverage

Triple collocation (CDOP3)

Triple Collocation (TC)

A technique able to provide the error variance $Var(\varepsilon_X)$, $Var(\varepsilon_X)$, $Var(\varepsilon_Z)$ of three estimates, $\widehat{\boldsymbol{\theta}_X}$, $\widehat{\boldsymbol{\theta}_Y}$, $\widehat{\boldsymbol{\theta}_Z}$ of the same variable $\boldsymbol{\theta}$.

$$\hat{\Theta}_X = \alpha_X + \beta_X(\Theta + \varepsilon_X)$$
$$\hat{\Theta}_Y = \alpha_Y + \beta_Y(\Theta + \varepsilon_Y)$$
$$\hat{\Theta}_Z = \alpha_Z + \beta_Z(\Theta + \varepsilon_Z)$$

Assumptions

$$\mathrm{Cov}(\Theta, \varepsilon_i) = 0$$
$$\mathrm{Cov}(\varepsilon_i, \varepsilon_j) = 0$$
$$i, j \in \{X, Y, Z\}$$
$$i \neq j$$

Error variances

$$\mathrm{Var}(\hat{\Theta}_X) - \frac{\mathrm{Cov}(\hat{\Theta}_X, \hat{\Theta}_Y)\,\mathrm{Cov}(\hat{\Theta}_X, \hat{\Theta}_Z)}{\mathrm{Cov}(\hat{\Theta}_Y, \hat{\Theta}_Z)}$$
$$\mathrm{Var}(\hat{\Theta}_Y) - \frac{\mathrm{Cov}(\hat{\Theta}_Y, \hat{\Theta}_X)\,\mathrm{Cov}(\hat{\Theta}_Y, \hat{\Theta}_Z)}{\mathrm{Cov}(\hat{\Theta}_X, \hat{\Theta}_Z)}$$
$$\mathrm{Var}(\hat{\Theta}_Z) - \frac{\mathrm{Cov}(\hat{\Theta}_Z, \hat{\Theta}_X)\,\mathrm{Cov}(\hat{\Theta}_Z, \hat{\Theta}_Y)}{\mathrm{Cov}(\hat{\Theta}_X, \hat{\Theta}_Y)}$$

Stofflen (1998)

Recently extended to estimate the **Signal-to-Noise Ratio (SNR)**

$$\mathrm{SNR}_X = \frac{\mathrm{Var}(\Theta)}{\mathrm{Var}(\varepsilon_i)} = \frac{1}{\dfrac{\mathrm{Var}(\hat{\Theta}_X)\,\mathrm{Cov}(\hat{\Theta}_Y, \hat{\Theta}_Z)}{\mathrm{Cov}(\hat{\Theta}_X, \hat{\Theta}_Y)\,\mathrm{Cov}(\hat{\Theta}_X, \hat{\Theta}_Z)} - 1}$$

$$i, j, k \in \{X, Y, Z\}$$
$$i \neq j \neq k$$

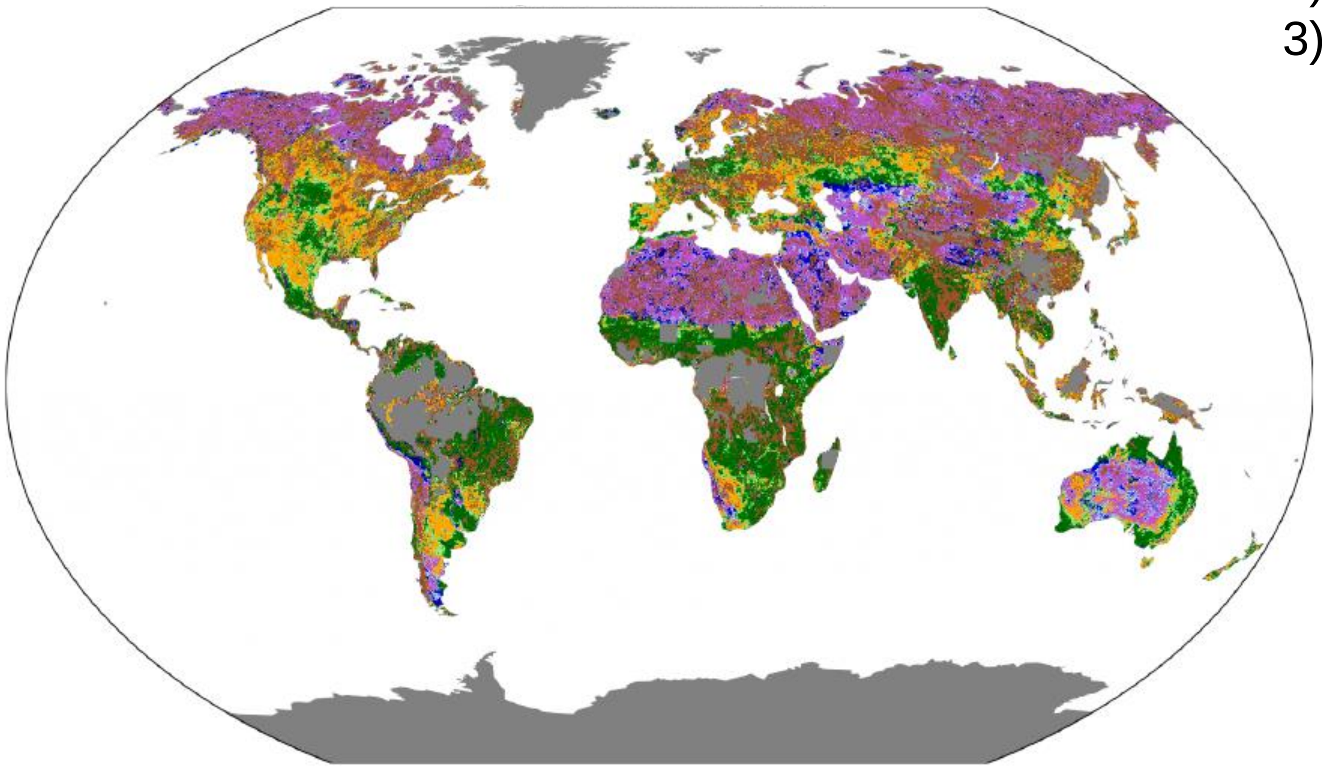
N.B:
TC does not (necessarily) rely upon in situ stations and can provide consistent results in space and time from year to year

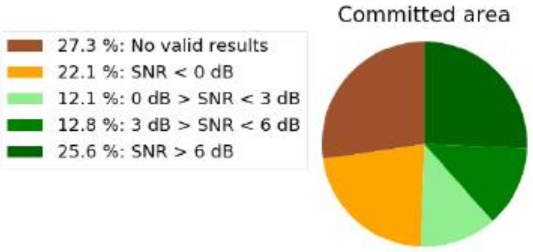
Draper et al. (2013)
McColl et al. (2014)

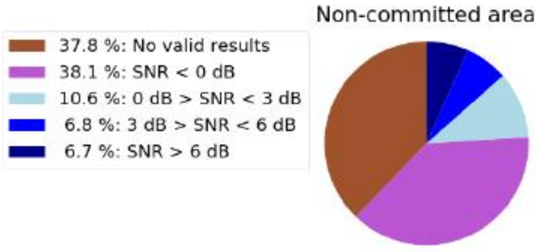
H16 Validation Period: 2017-06-01 -> 2018-05-31

$$SNR_i[dB] = 10 \log \frac{Var(\Theta)}{Var(\varepsilon_i)}$$

H16 Signal to Noise Ratio (Global)







We used three datasets theoretically holding the assumptions of TC:
1) ASCAT product (H16, H101, H102, H103)
2) CCI Passive Soil Moisture L3S SSMV V04.4
3) GLDAS NOAH L4 3 hourly 0.25 x 0.25 degree V2.1

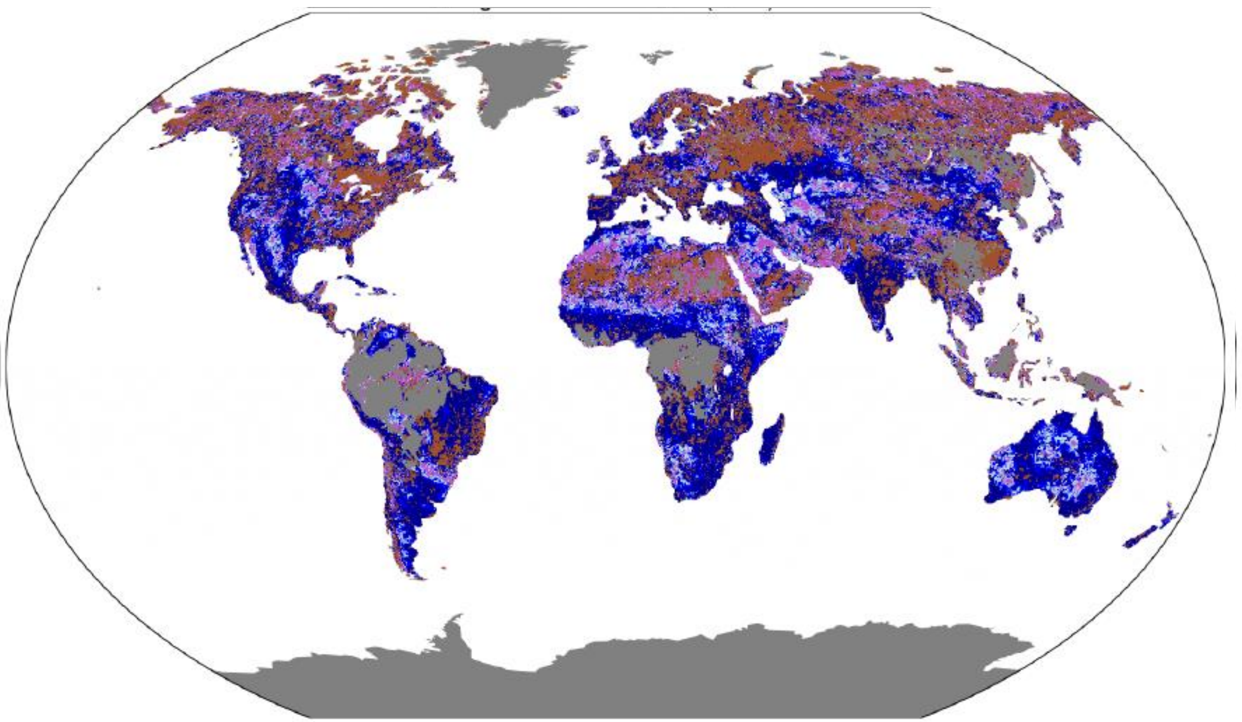
- Overall very good behavior in semi arid environments and mid-latitudes (i.e., signal variance much larger than the noise variance)
- Problems over very arid regions (inverted relationship between backscatter and soil wetness), mountains and frozen surfaces and dense forests
- Almost 40% of points SNR> 3 dB, 50%> 0 dB over the committed area

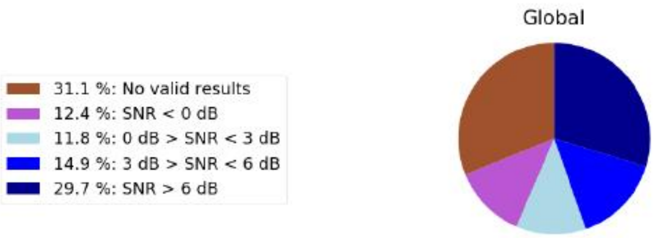
0 dB: signal variance = noise variance
+/- 3 dB: signal variance = double / half noise variance

H14 Validation Period: 2017-06-01 -> 2018-05-31

$$\mathrm{SNR}_i[\mathrm{dB}] = 10\log\frac{\mathrm{Var}(\Theta)}{\mathrm{Var}(\varepsilon_i)}$$

H14 Signal to Noise Ratio (Global)





We used three datasets theoretically holding the assumptions of TC:
1) ASCAT product (H16, H101, H102, H103)
2) CCI Passive Soil Moisture L3S SSMV V04.4
3) GLDAS NOAH L4 3 hourly 0.25 x 0.25 degree V2.1

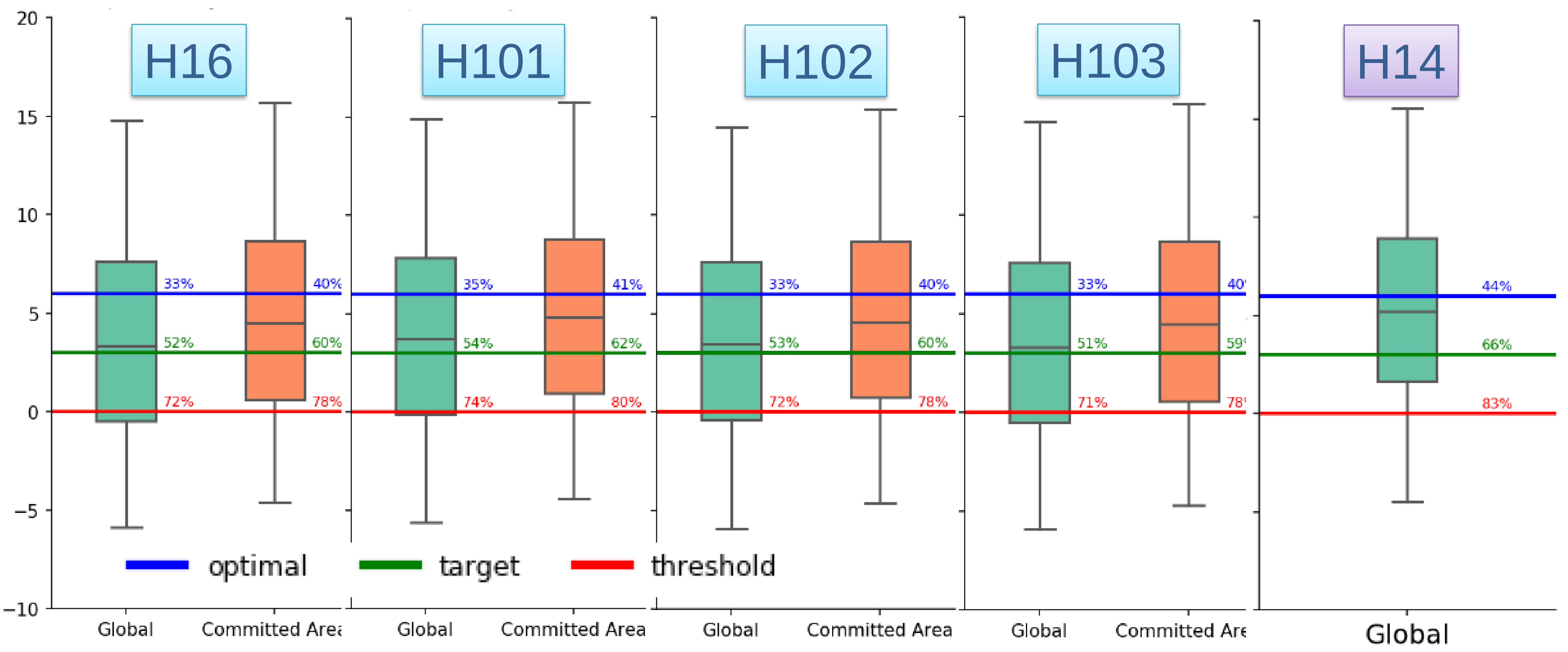
- Overall very good performance
- Lower performance over arid environments and northern latitudes
- Almost 45% of points SNR>3 dB, 65%> 0 dB, globally

0 dB: signal variance = noise variance
+/- 3 dB: signal variance = double / half noise variance

Product validation H16, H101, H102, H103, H14

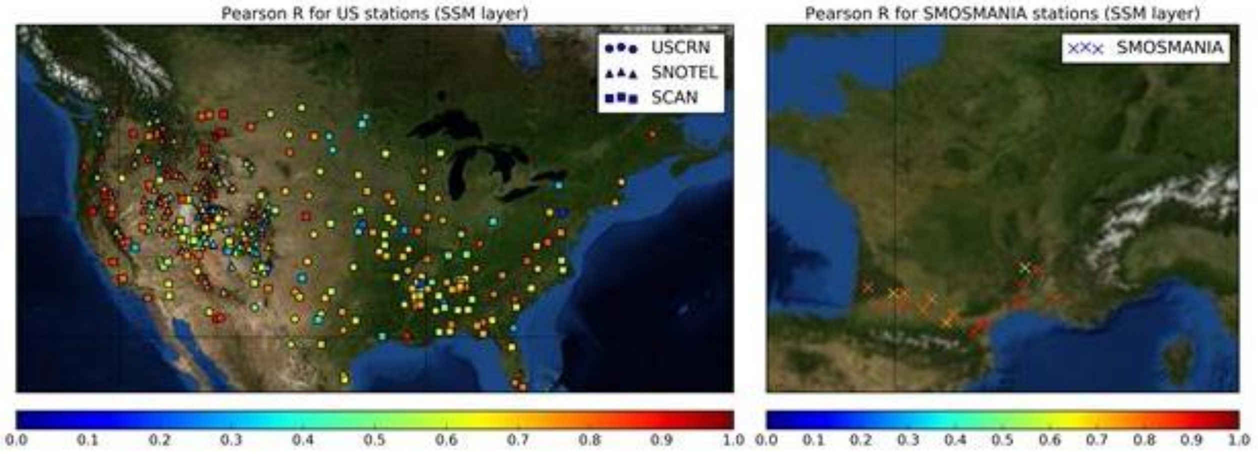
Signal-to-Noise-Ratio (DB)

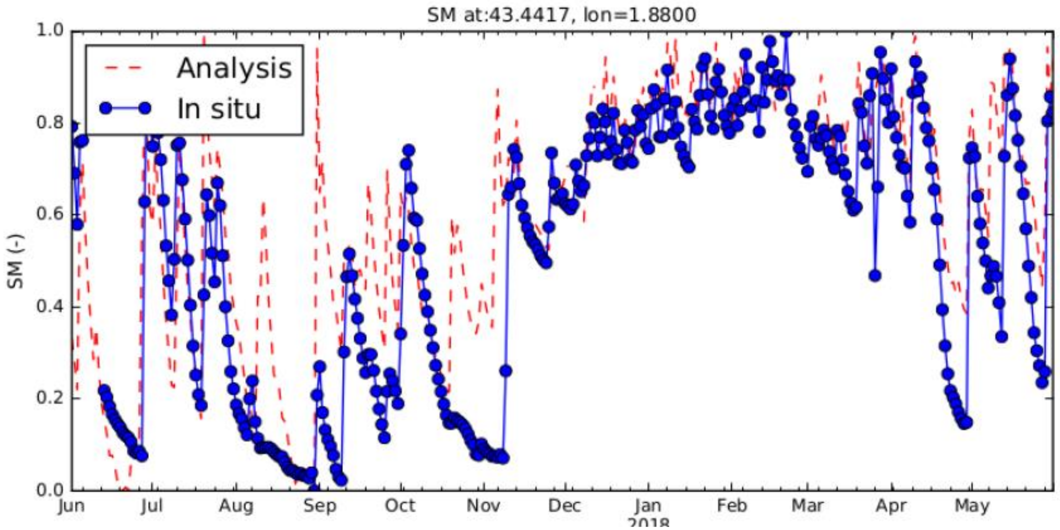
Validation Period: 2017-06-01 → 2018-05-31

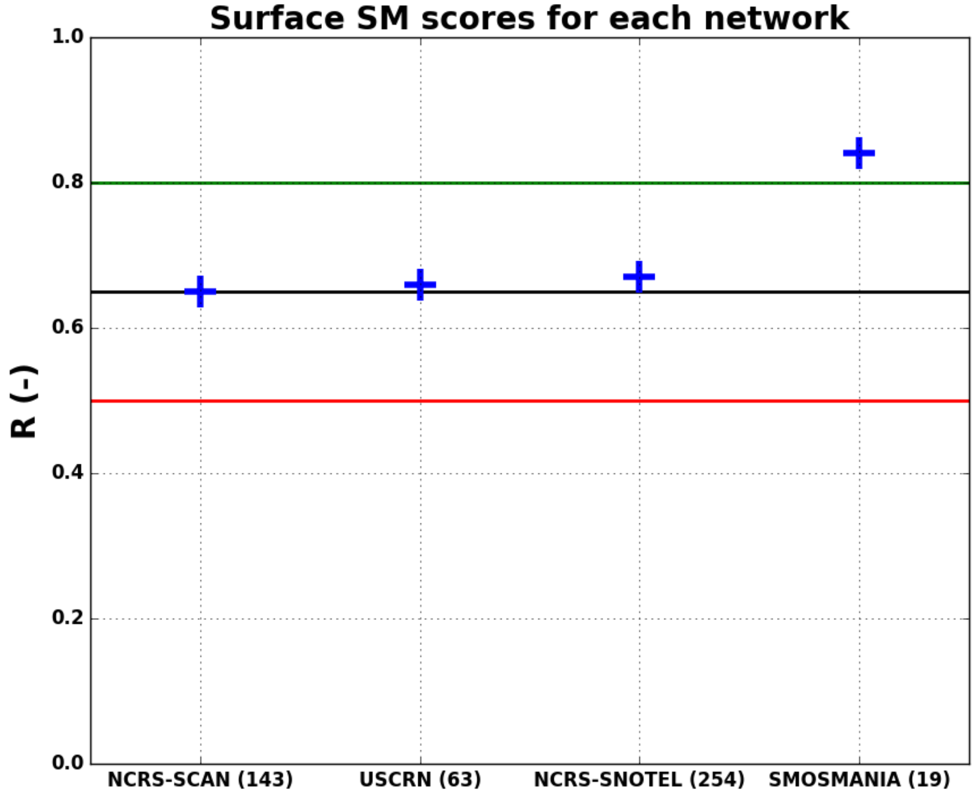


In situ validaiton H14

Validation Period: 2017-06-01 → 2018-05-31

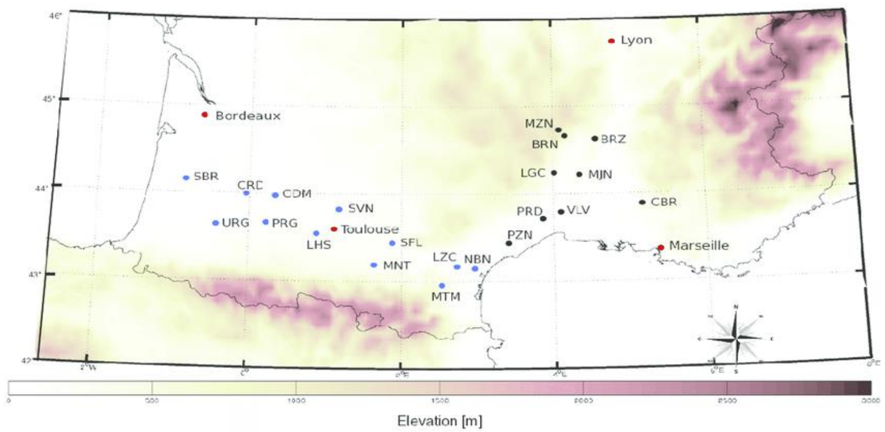






Surface Soil Moisture Validation Results

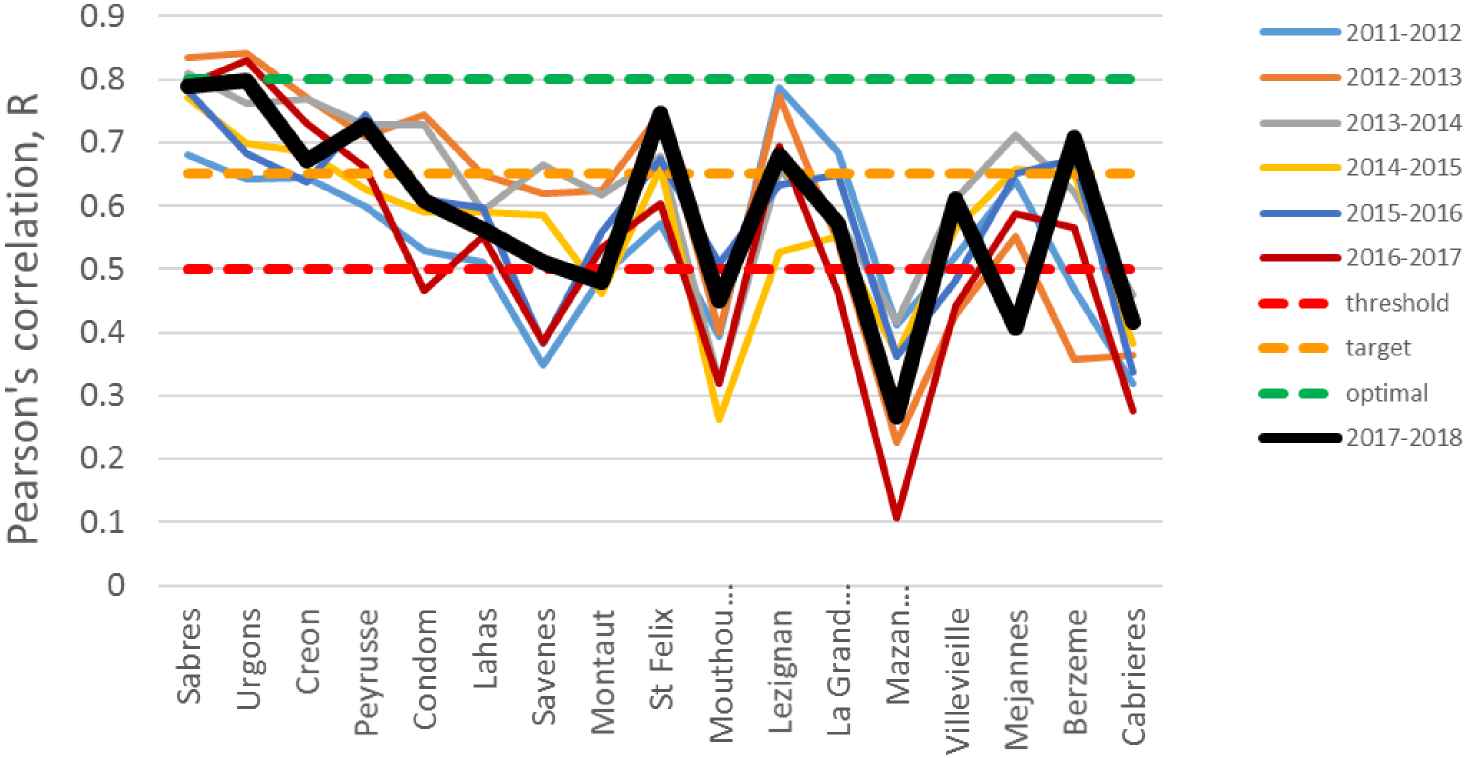
In situ validation H08



18 stations

In situ observations				
Requirement (CC)			Median Correlation Coefficient (CC)	
Threshold	Target	Optimal		
			Period	SMOSMANIA
			JJA	0.19
			SON	0.42
0.50	**0.65**	**0.80**	DJF	0.56
			MAM	0.61
			June 2017 - May 2018	**0.59**

Validation Period: 2017-06-01 → 2018-05-31



Hydro-validation

Hydro-validation concerns the use of H SAF soil moisture products for hydrological applications: floods, droughts, landslides etc.… (Slovakia, Poland, Bulgaria, Germany, Italy do excellent works and are focused mainly on floods)

Hydro-validation is complicated from the impact of additional variables on the final performance of the products:

- Floods (models, quality of discharge observations, assimilation technique etc…)
- Droughts (missing of reliable benchmark against which validate the results)
- Landslides (they are not only linked to the meteorological forcing)

So far, the activities have been carried out by single case studies mainly related to assimilation of the products into different rainfall-runoff models for different study periods with different data assimilation techniques (risk of case specificity)

Data assimilation experiment in Northern Italy (1)

Laiolo et al., 2016 - Cenci et al 2016

Hydrological model
Continuum (physically based, distributed)

Satellite Products
3 SM PRODUCTS DERIVED FROM ASCAT (H07, H14, H08)
SMOS SM PRODUCT

Assimilation scheme
1. NUDGING – MODEL SCALE
2. NUDGING – SATELLITE SCALE
3. ENSEMBLE KALMAN FILTER– MODEL SCALE

modelled discharge with DA compared with: Observed discharge and “Open Loop” run (without DA)

Period of analysis
July 2012 to June 2014

Fig. 1. Study areas. Overview of the catchments under investigation: OB (red), CS (light blue), and MG (purple).

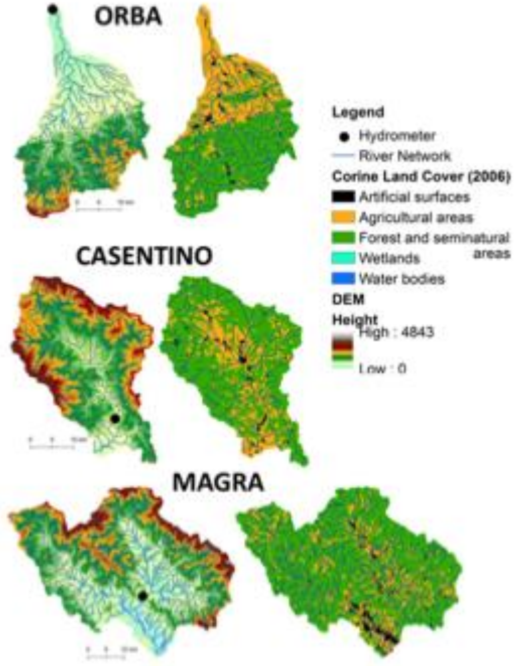
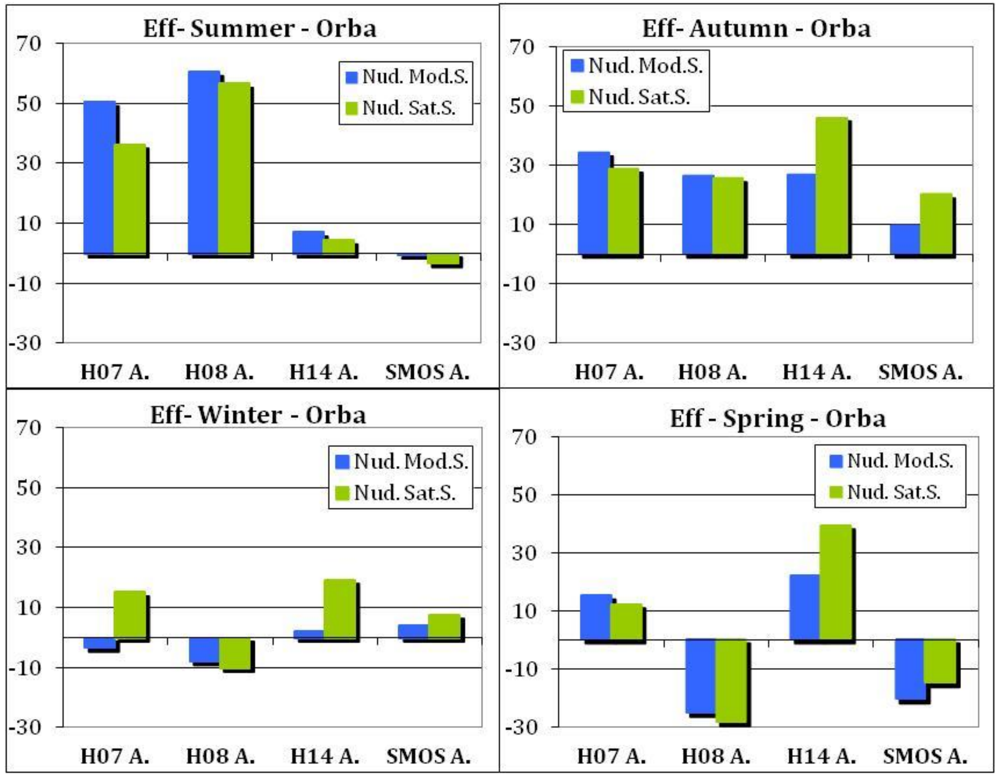
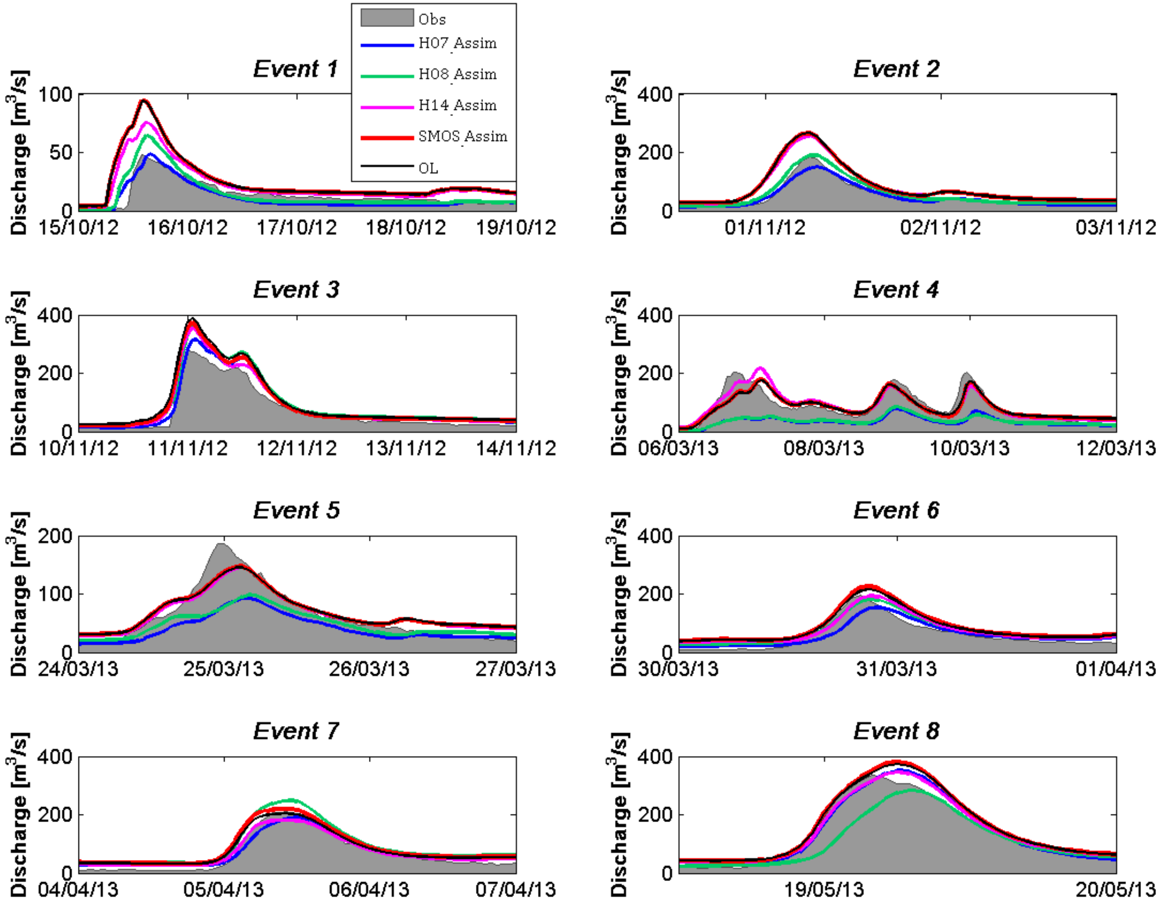


Fig. 2. Study areas: Details of the catchments under investigation: gauging stations (left column), the topography (left column), the Corine land cover—Level I (right column) and the hydrography (both columns).

Data assimilation experiment in Northern Italy (2)





Improvements with respect to OL in terms of RMSE were high especially in **summer and autumn** while in winter some problems occurred (snow, frozen soil)

Data assimilation experiment in Central Italy

Azimi et al. (2019), Journal of Hydrology

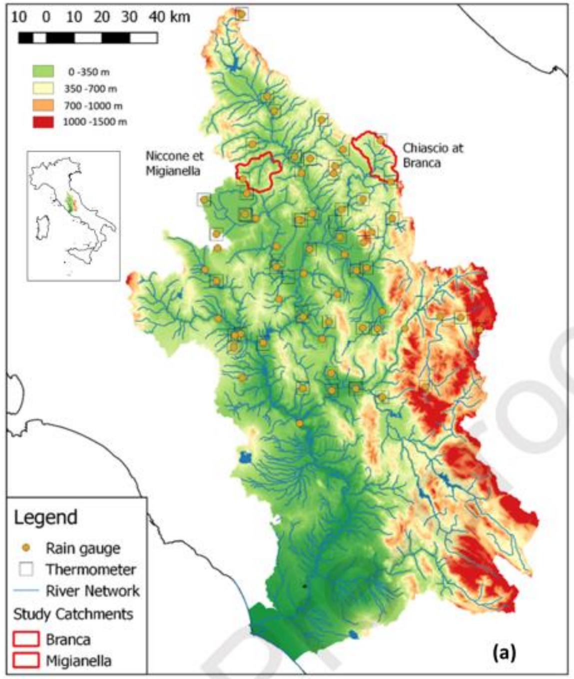
Hydrological model:
SWAT (physically based, distributed)

Satellite Products
- SCATSAR (Sentinel 1 + ASCAT)(Bauer-
- Marschallinger 2018),
- SMAP L3
- H SAF H113 (data record)

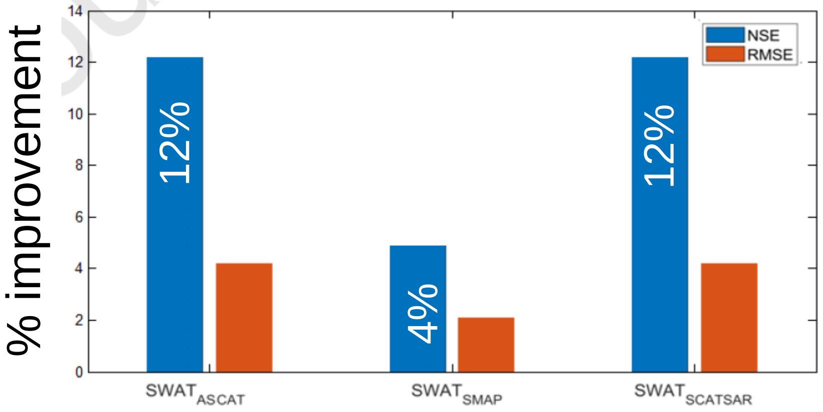
Assimilation scheme
Ensemble Kalman Filter

Study area
Two small catchments in Tiber River (Central Italy) with different vegetation conditions

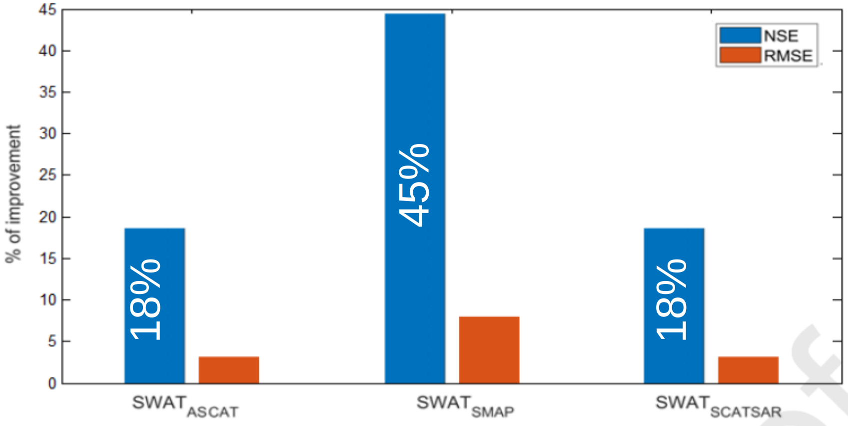
Period of analysis
2014 - 2017



Less vegetated catchment



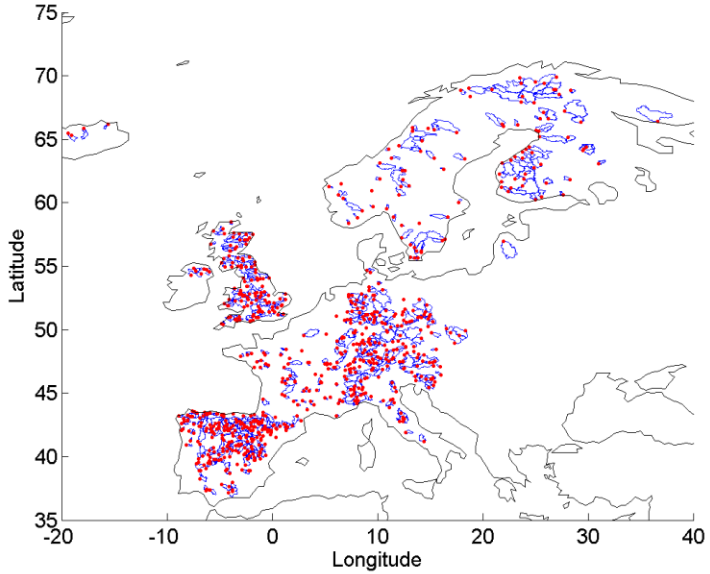
More vegetated catchment



Toward a large scale data assimilation experiment...

De Santis (2019) in preparation to be submitted to WRR

775 catchments located across Europe



Hydrological model

MISDc 2L Massari et al. (2018), Brocca et al. (2011)

Satellite Products

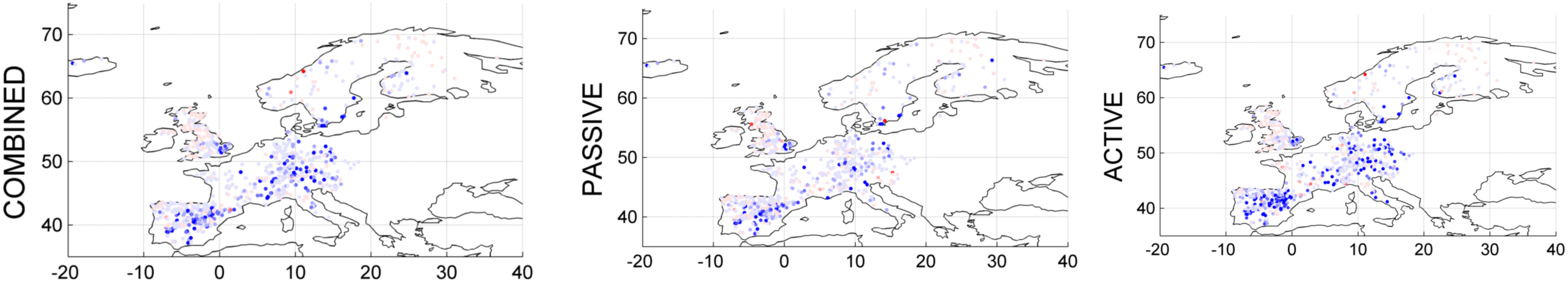
CCI active, passive and combined products

Assimilation scheme

Ensemble Kalman Filter

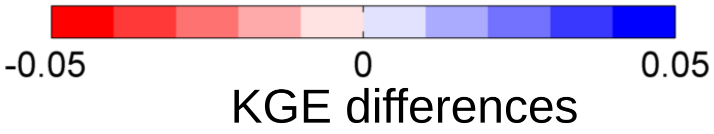
Study period

2002-2011



Klinge Gupta Efficiency index

(Gupta et al. 2009)



Conclusions

Direct validation. TC is an effective technique for soil moisture validation within the H SAF project which can overcome the problems related to in situ stations. However, good quality in situ stations are still very important and must not be overlooked thus an effort should be made from all the H SAF communities to maintain them and make them available.

Hydro-validation is an important part of the validation given that H SAF has a final goal the use of the products for hydrological applications.
It must be improved as in the current configuration can be very case specific. Possible solutions:

1) Perform large scale case studies involving a large number of catchments, hydroclimatic conditions, hydrological models and assimilation techniques
2) Diversify the validation by including landslides and drought
3) Structure the hydro-validation activities by creating super sites or super catchments characterized by richness of good quality observations (e.g., NASA)