An assessment of SMOS version 6.20 products through Triple and Quadruple Collocation techniques considering ASCAT, ERA/Interim LAND, ISMN and SMAP soil moisture data

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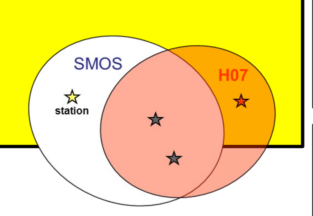
ABSTRACT – In this work, the following soil moisture products have been compared: *1) H-SAF SM-OBS-1 large scale saturation degree (SD) product derived from ASCAT data; 2) Level-2 product derived from the L-band SMOS (Soil Moisture and Ocean Salinity) radiometric data; 3) ERA/Interim LAND model outputs derived from ECMWF (European Centre for Medium-Range Weather Forecasts); 4) ISMN (International Soil Moisture Network) ground measurements*. The Triple Collocation (*TC*) represents a very useful tool for validating remotely sensed products; in this work, since four sources have been considered, a Quadruple Collocation (QC) approach has been also applied in order to jointly estimate the error standard deviation of the four sources making reference to a common scale as for its magnitude. Both Europe and North Africa have been considered and the data have been acquired from June, 2010 to May, 2014. Moreover, the preliminary results of a TC analysis between SMOS, ASCAT and *SMAP (soil Moisture Active/Passive)* soil moisture products are shown for the same region of interest considering the period between April and December, 2015 .

2. Available data

- **ASCAT**: the **SM-OBS-1 H-SAF Soil Moisture Index (SMI)**, produced by means of the TU-Wien algorithm with a spatial resolution of 25 km.
- **SMOS**: the **reprocessed L2 product (generated by algorithm version620)** that provides volumetric **Soil Moisture Content (SMC)** in [$m^{3/m3}$]; L2 SMC data are sampled over the ISEA4h9 grid, which has a spacing in the order of 15 km.
- **ERA/Interim LAND**: the volumetric soil moisture content [m3/m3] produced by a global atmospheric reanalysis combined with an ocean and a land surface model with precipitation adjustments based in GCPC V2.2
- **ISMN**: the soil moisture [m3/m3] measured by stations placed in Denmark, England, Finland, France, Germany, Italy, Poland and Spain; 5 cm depth data are considered.
- **SMAP**: the SMAP_L2 half-orbit products, which provides soil moisture [m3/m3] with a grid resolution of 36 km

3. Collocation method

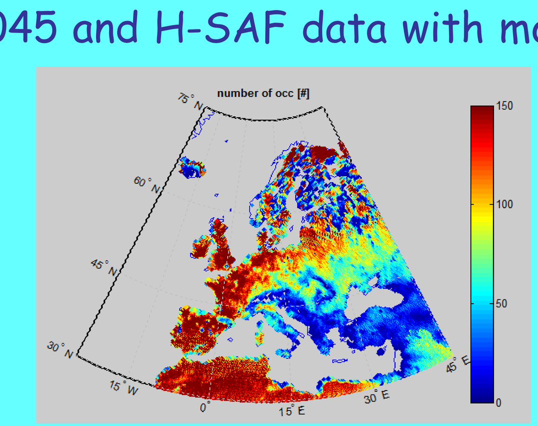
- Considering the satellite products, for each SMOS grid point, the closest ASCAT/H-SAF and SMAP grid points are searched for and the same nearest neighbor approach has been adopted to collocate the ERA/Interim LAND modeled data.
- ASCAT/H-SAF *SMI* retrievals have been converted into volumetric moisture [$m^{3/m3}$] using a soil porosity map available from the Global Land Data Assimilation System (GLDAS) website
- As for the ISMN, the measurements have been up-scaled to the satellite resolution, i.e. the in-situ measurements within the satellite field of view



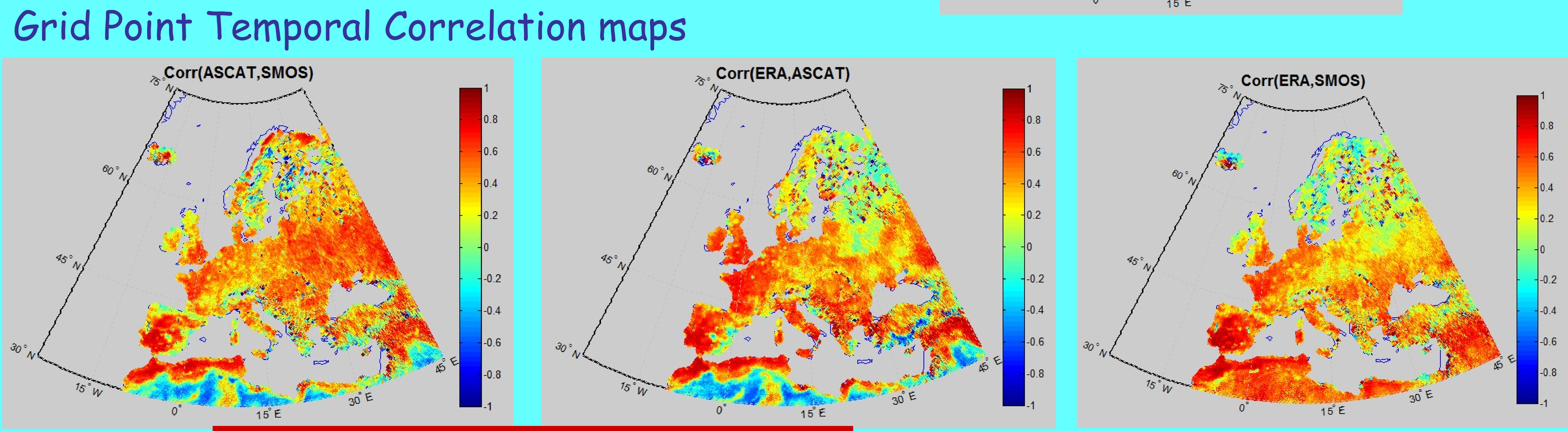
4. Comparison between SMOS-ASCAT-ERA/Interim Land

- SMOS data with (Data Quality indeX) DQX > 0.045 and H-SAF data with more than 3 bad quality flags up have been discarded.

Few co-locations (likely because of RFI) in some countries (e.g. Italy, Greece)



- Grid Point Temporal Correlation maps



Negative correlation in desert areas when considering ASCAT data.

5. Triple and Quadruple Collocation

- Three (or Four) systems X, Y, Z (and W) measure the true *SMC* $\theta(r,t)$ with zero mean value and variance σ^2

$$x = \theta + \delta_x$$
$$y = s_y(\theta + \delta_y)$$
$$z = s_z(\theta + \delta_z)$$
$$w = s_w(\theta + \delta_w)$$

δ_x, δ_y, δ_z (δ_w) represent the random observation errors, 1, s_y, s_z, s_w are observation gains

Drift is assumed additively combined by space dependent and time dependent functions

$$\theta(r,t) = Z(r,t) + m_r(r) + m_t(t)$$

- $m_{t(t)}$ fitting the spatial mean vs time by an harmonic function (Evaluated only over the European territory)
- $m_{r(r)}$ estimated by averaging maps over time

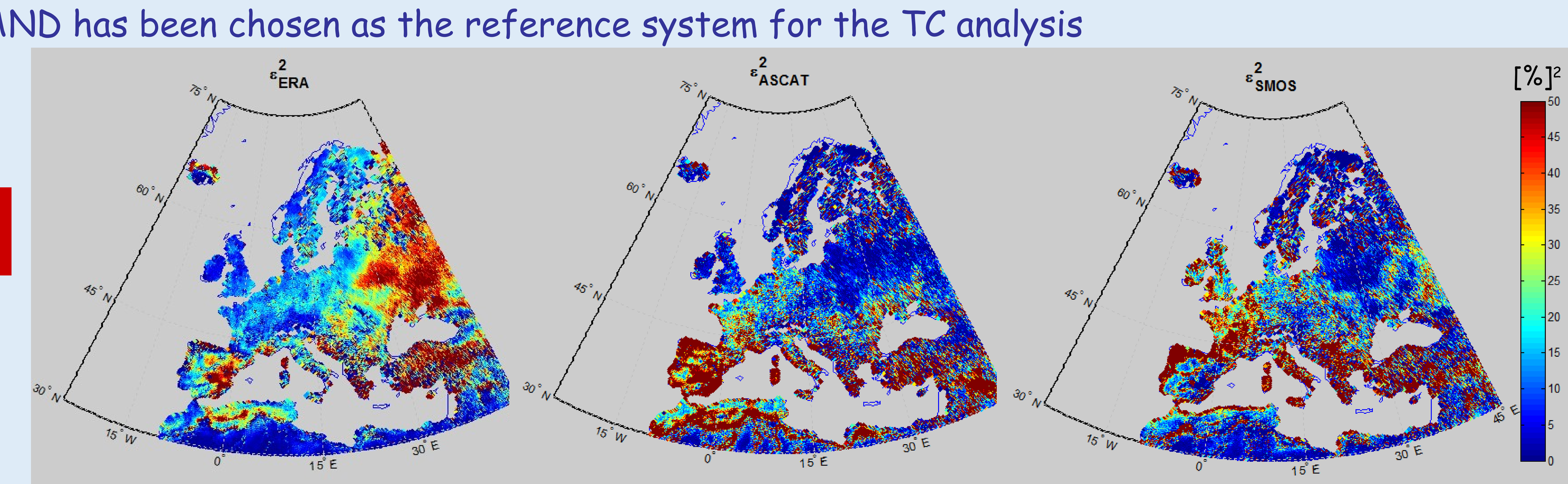
- Assuming that noise is uncorrelated with zero means, from a set of observations it is possible to estimate noise variances ε_x^2, ε_y^2, ε_z^2, ε_w^2

6. Triple Collocation Results

June, 2010 – May, 2014

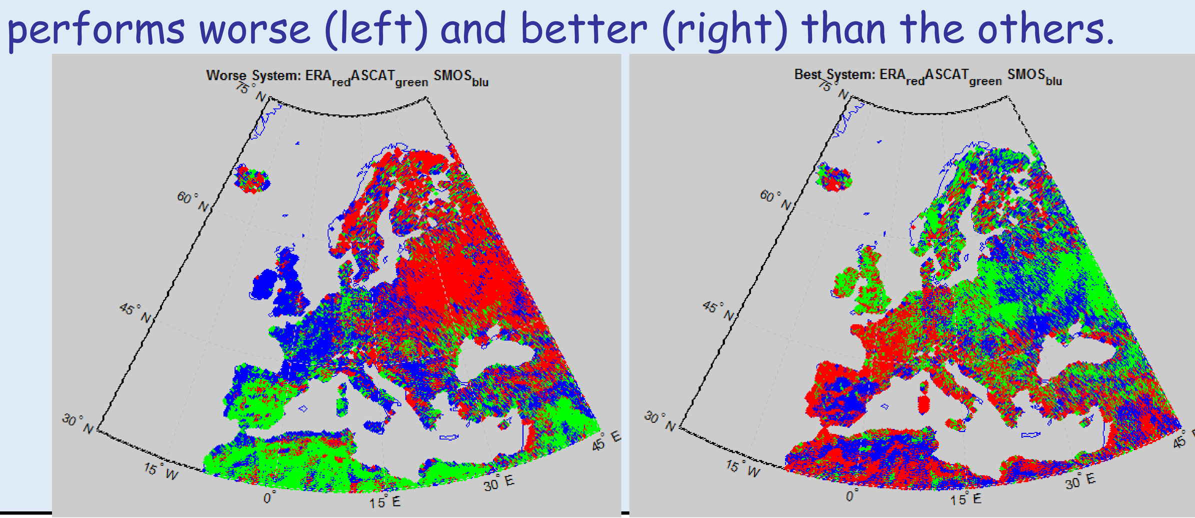
- The ERA Interim/LAND has been chosen as the reference system for the TC analysis

Error Variance of the systems



- RGB level slicing depicting what system performs worse (left) and better (right) than the others.

Red: ERA-LAND; green: ASCAT/H-SAF; blue: SMOS.



7. Quadruple Collocation Results

QC	ISMN ERA/LAND H-SAF SMOS	
s [%]	4.78	5.07
s_{H-SAF} [%]	2.17	1.74
s_{SMOS} [%]	0.94	0.99
s_{ERA} [%]	1.19	1.20
e_{ISMN} [%]	4.96	4.03
e_{H-SAF} [%]	4.07	5.98
e_{SMOS} [%]	5.82	5.32
e_{ERA} [%]	3.23	2.95

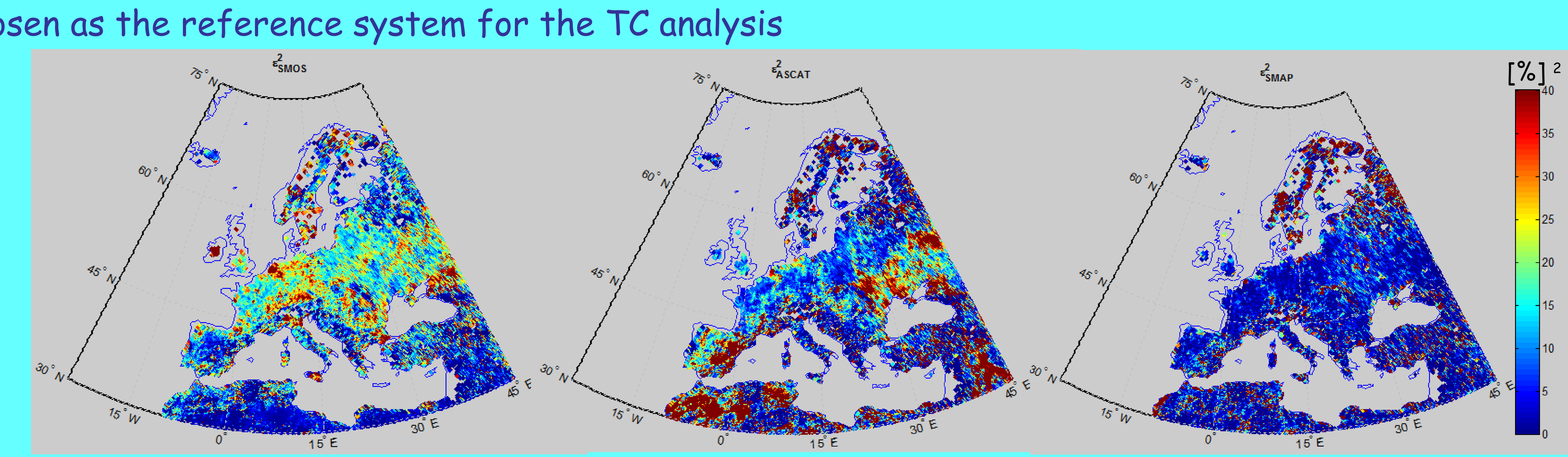
- all the estimates are expressed in the scale of ISMN
  - the gains and the error standard deviations are referred to the scale of a unique system (ISMN in our case)
- second column refer to temporal anomalies
  - data without spatial $m_{r(r)}$ and temporal $m_t(t)$ drifts
- third column refer to data retaining the seasonal variability
  - data without spatial drift $m_{r(r)}$

8. Preliminary TC results between SMOS, ASCAT and SMAP

April, 2015 – December, 2015

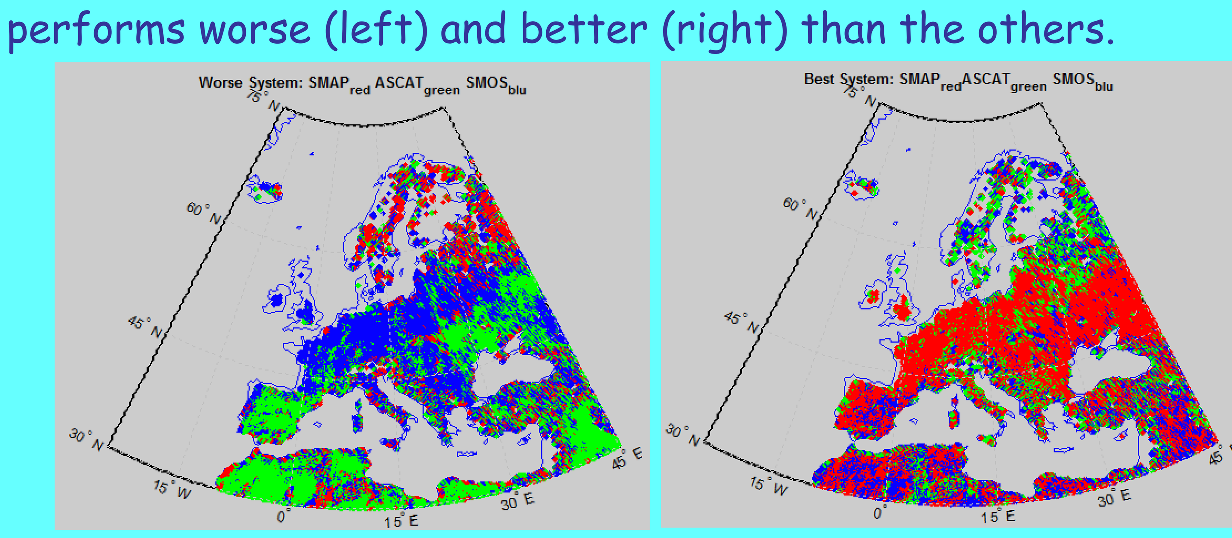
- SMOS has been chosen as the reference system for the TC analysis

Error Variance of the systems



- RGB level slicing depicting what system performs worse (left) and better (right) than the others.

Red: SMAP; green: ASCAT/H-SAF; blue: SMOS.



Conclusions

SMOS – ASCAT – ERA/Interim Land – ISMN

- When data including seasonal variability are considered, SMOS has a slightly better behavior than ASCAT/H-SAF, whereas the opposite occurs when looking to the SMC anomalies with respect to the seasonal trend
- ERA can take advantage from the rescaling with a global precipitation dataset (GPCP v2.2)
- ISMN may suffer from the difficulty to represent field of view SM

SMOS – ASCAT – SMAP

- From a preliminary *TC* analysis, SMAP is the system with best performances in the most part of the Europe
- Looking to the worse map system, ASCAT and SMOS generally present spatial patterns similar to the trends noticed in the *TC* with ERA/Interim Land

Future Steps: Since the area of interest is characterized by several issues (as the presence of Radio Frequency Interference, strong orography and desert zones), in future analysis, the filtering of the data will be strengthened considering also another satellite flags, like for example the chi-square information provided by SMOS.

References:

- N. Pierdicca, L. Pulvirenti, F. Fascetti, R. Crapolicchio, and M. Talone, "A comparison of ASCAT and SMOS soil moisture retrievals overEurope and Northern Africa from 2010 to 2013," International Journal of Applied Earth Observation and Geoinformation, vol. 45, pp. 135-142, 2016.
- N. Pierdicca, F. Fascetti, L. Pulvirenti, R. Crapolicchio, J. Muñoz-Sabater, "Analysis of ASCAT, SMOS, IN-SITU and LAND Model Soil Moisture as a regionalized variable over Europe and North Africa", Remote Sensing of Environment, vol. 170, pp. 280-289, 2015.
- N. Pierdicca, F. Fascetti, L. Pulvirenti, R. Crapolicchio, J. Muñoz-Sabater,"Quadruple collocation analysis for soil moisture product assessment", IEEE Geoscience and Remote Sensing Letters, vol.12, pp. 1595-1599, 2015.

For the SMAP L2 half-orbit 36Km radiometer soil moisture products:

- O'Neill, P. E., S. Chan, E. G. Njoku, T. Jackson, and R. Bindlish. 2015. SMAP L2 Radiometer Half-Orbit 36 km EASE-Grid Soil Moisture, Version 2. [from April to December 2015]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. doi:http://dx.doi.org/10.5067/3Q9102MCFF72. [January, 2016].

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