COMPARING SOIL MOISTURE RETRIEVALS FROM SMOS, ASCAT AND AMSR-E OVER THE PAMPAS PLAINS

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Motivation and Framework

- Remotely sensed soil moisture (SM) studies have mainly focused on retrievals using **active and passive microwave** (MW) sensors.
- Argentina is strongly involved in MW satellite mission developments: 1) SACD/Aquarius mission, 2) SAOCOM radar SM mission under development by CONAE (http://www.conae.gov.ar). The **main purpose** of this mission is the retrieval of SM in the **Pampas Plains**, a huge area dedicated to agriculture and cattle raising.
- SM products from different missions (passive and active) are available, but the lack of an appropriate in situ network for SM validation has hampered their use for monitoring purposes (droughts and floods) in the **Pampas Plains** and their assimilation in atmospheric and meteorological models.
- The current development of an Aquarius soil moisture product using a bayesian scheme based on a zero order Radiative Transfer (RT0) approach (see oral presentation in SM session WE3.06)

Objective

To evaluate the performance and relative agreement of the estimations of available global time series of the passive SM products derived from AMSR-E, ASCAT, and SMOS over the Pampas Plains. To this end, we will use methods that do not require in situ networks (not available in this area): a) analysis of anomalies, b) error estimation using Triple Collocation (TC).
Specifically, we want to answer the following question: how does one evaluate product quality in view of the lack of in situ data at their required spatial scale using TC?

The Pampas Plains

Argentina's Pampas (27-40º S, 57-67º W) is a wide plain of over 50 million ha of fertile lands suitable for cattle and crop production. Figures 1 a) and b) show a land cover map of the area [1], and the spatial distribution of the difference between precipitation (P) and evapotranspiration (EP) means (mm) of the period 1970-2006 for the month of October (growing season), as a reference of the moisture characteristics of the area, drier in the west and wetter in the east. Although this spatial distribution is present along the whole growing period, the P-EP values and distribution varies month to month [2]. Most of the Pampas region is significantly affected by cyclical drought and flood episodes that impact both crop and cattle production. Different ecological regions cover the area, each one has specific characteristics regarding precipitation patterns and agricultural practices.

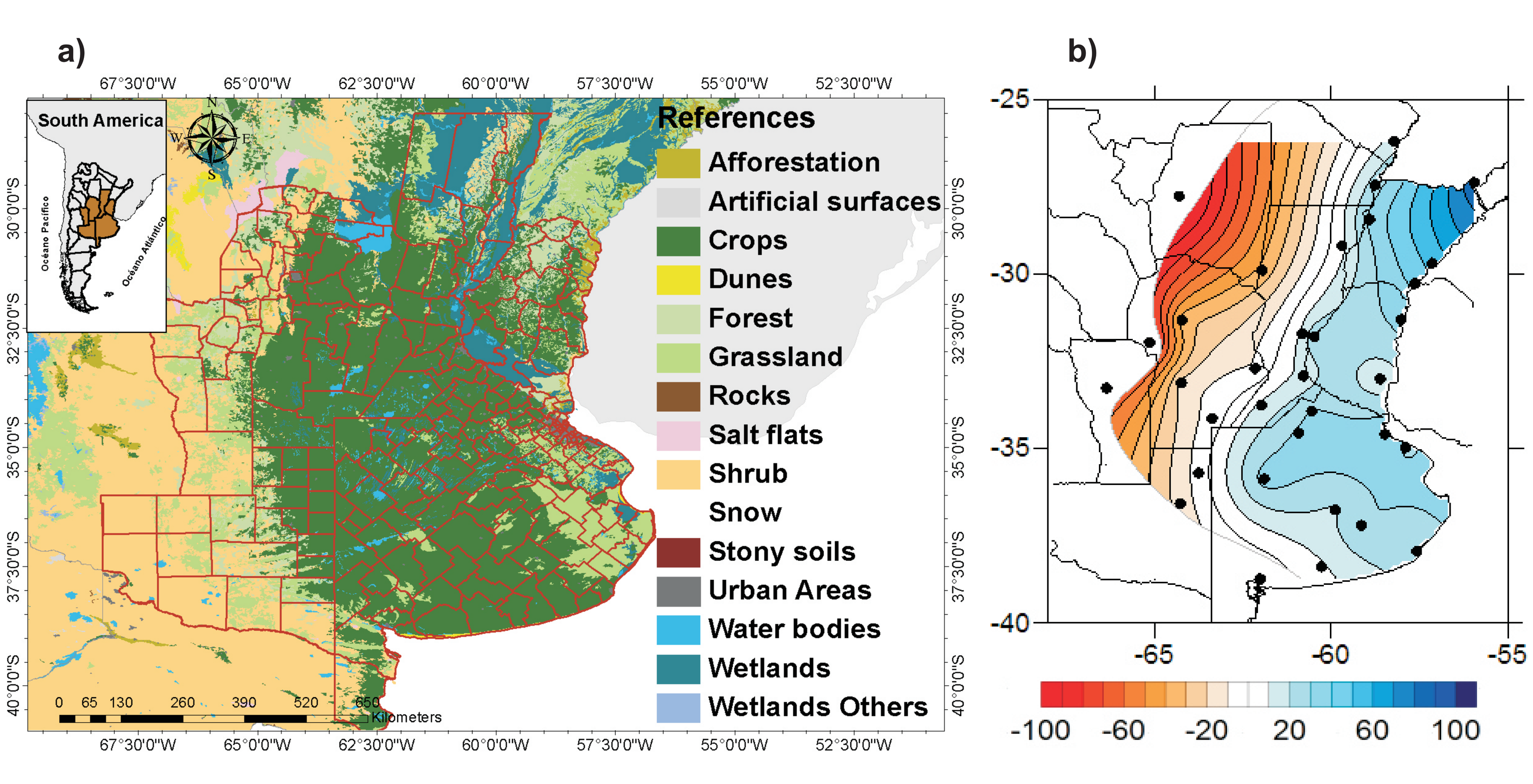

Figure 1. a) Pampas Plains land cover categories (adapted from [1]) polygons in red indicate counties boundaries and b) an example of the spatial distribution of the P-EP for the period 1970-2006 for the month of October (adapted from [2]).

Data and Methods

Table 1 summarizes the data sets used and the period analyzed.

Sensor	*Products*	*Period*	*Orbit*
AMSR-E	LPRM L3 SM product, V. 5 gridded 0.25deg lat/lon, optical depth (VOD) , Units[vol/vol]	2010-2011	Descending 2:30 AM
SMOS	L.MEB L2 SM product, V.551 DGG ISEA 25km grid Units[vol/vol]	2010-2011	Ascending 7:30 AM
ASCAT	TU WEIN SM product, V. 1.2 WARP 5.5, soil saturation 0-100, convert to Units[vol/vol]	2010-2011	Descending 10:00 AM

Table 1. Data sets for anomaly correlations and TC error analysis.

Two of the products (AMSR-E/LPRM [3] and SMOS [4]) are derived from different passive microwave systems, and although both algorithms are based on radiative transfer RT0 algorithms, they differ significantly in the way the RT0 is solved for the two unknowns (SM and vegetation optical depth (VOD)). The third product, ASCAT SM, is obtained from an active microwave sensor and the retrieval is based on a time series approach.

Not only daily absolute values differ considerable in SM values between products, but also monthly means show considerable differences. As an example, the October 2010 monthly means for the three products are shown in Figure 2. In this example, ASCAT shows very uniform low values, SMOS shows low values but some differences between the west and east (as expected) and LPRM shows a similar spatial pattern but overall higher values.

It is important to remark several points,

1. The triple collocation (TC) technique, developed by [5], is being used in this paper to estimate the root mean square error (RMSE) of the products. This technique is used here to estimate the RMSE of the soil moisture anomaly time series generated by ASCAT, SMOS and AMSR-E (LPRM). Specifically, TC estimates the standard deviation of the error term of a given soil moisture anomaly time series with respect to the true soil moisture anomaly time series (not known).
2. The soil moisture anomaly time series were defined as the deviations of the original time series from their seasonal climatology.
3. For each data set, the seasonal climatology was calculated as a 31 day moving average, where the averages are based on data from the whole period of study for the 31 day window surrounding each day of the year.
4. The SM products are gridded differently and thus, to allow comparisons, SMOS and ASCAT data sets were resampled to match the 0.25° spatial grid of LPRM. Areas where SM products are known to have bad performance (such as coastal areas, salt fields, and water bodies) were screened prior to performing any analysis on the data. Additionally, all data sets were filtered using a 5 days moving window.
5. ASCAT was chosen as the reference data set in the shown figures. All the combination were analized.

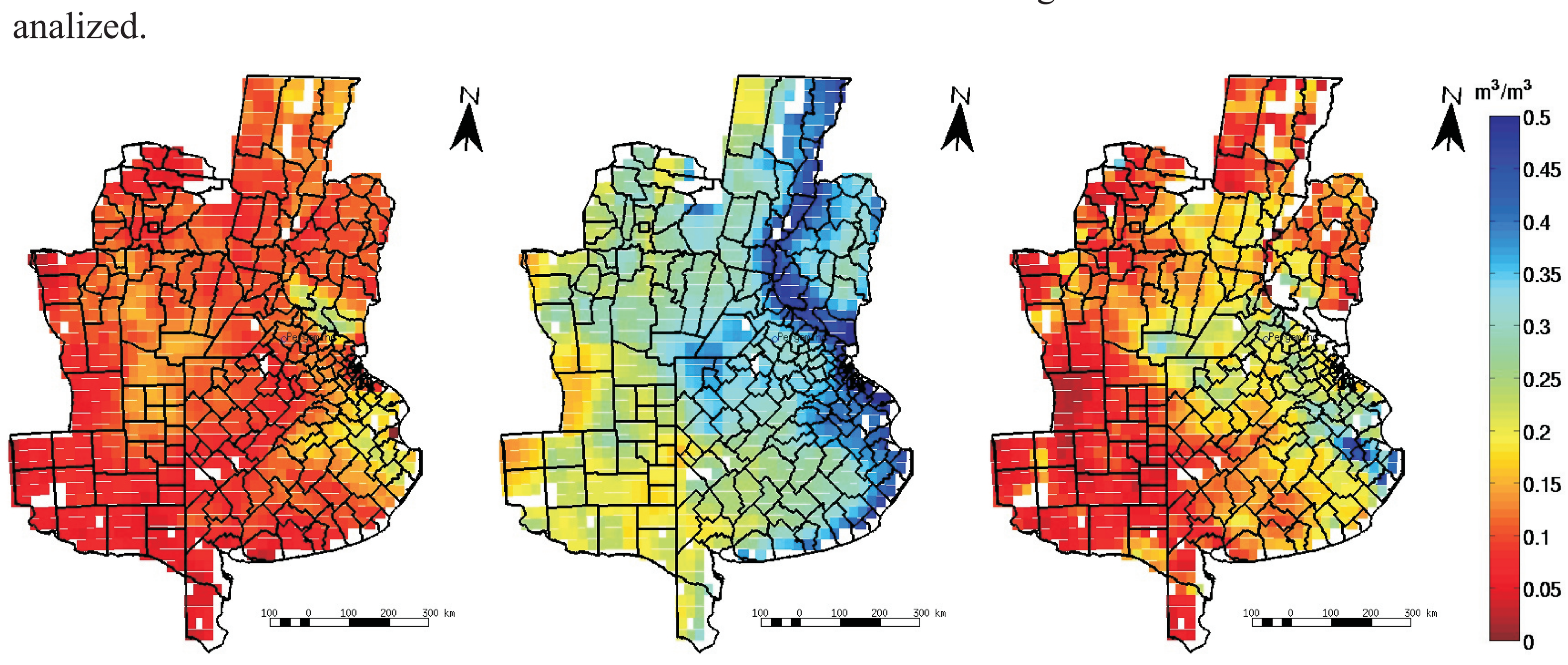

Figure 2. Average Soil Moisture Values for the period October 2010 of (left to right): ASCAT, AMSR-E/LPRM and SMOS. (Polygons in black indicate counties boundaries)

Time Series Comparison

Figure 3 shows standarized seasonal anomaly composites for the period 2010-2011. As seen, the three algorithms present very similar spatial patterns (previously unnoticed in Fig. 2), which are consistent with ancillary information that indicates dry (wet) conditions over the west (east) of the study region respectively. This qualitative statement is supported by the highly significant (at the 99% confidence level) positive correlation coefficients between each pair of standardized seasonal anomaly composites, as shown in Table 2.

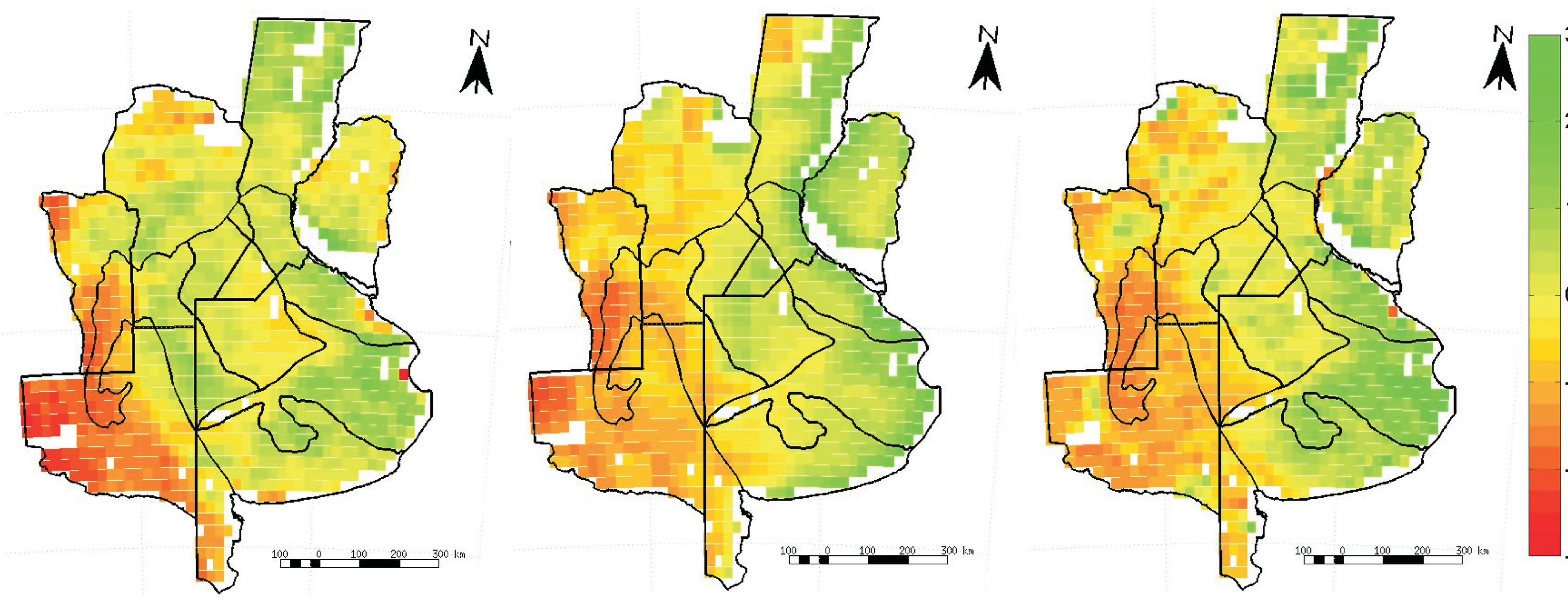

Figure 3. Standarized seasonal anomaly composites for the period 2010-2011 of (left to right): ASCAT, AMSR-E/LPRM and SMOS.

	Correlation	*p-value*
SMOS vs LPRM	0,7605	<0,01
SMOS vs ASCAT	0,6192	<0,01
ASCAT vs LPRM	0,6088	<0,01

Table 2. Spatial anomaly correlation coefficients and corresponding p-values.

The fact that average SM values present large visual discrepancies and spatial anomalies are highly correlated, point to a TC analysis. Figure 4 shows the TC error estimates. Domain average calculations shown in Table 3 reveal that the ASCAT soil moisture anomaly time series exhibits the lowest average RMSE of the three data sets. This is also the case when the TC error analysis is performed on the same three data sets, but using either LPRM or SMOS as the reference data set (results of this analysis are not shown due to the length constraints). Therefore, using TC as the performance metric, ASCAT is the product which presents the lowest RMSE with respect to the true soil mositure anomaly time series.

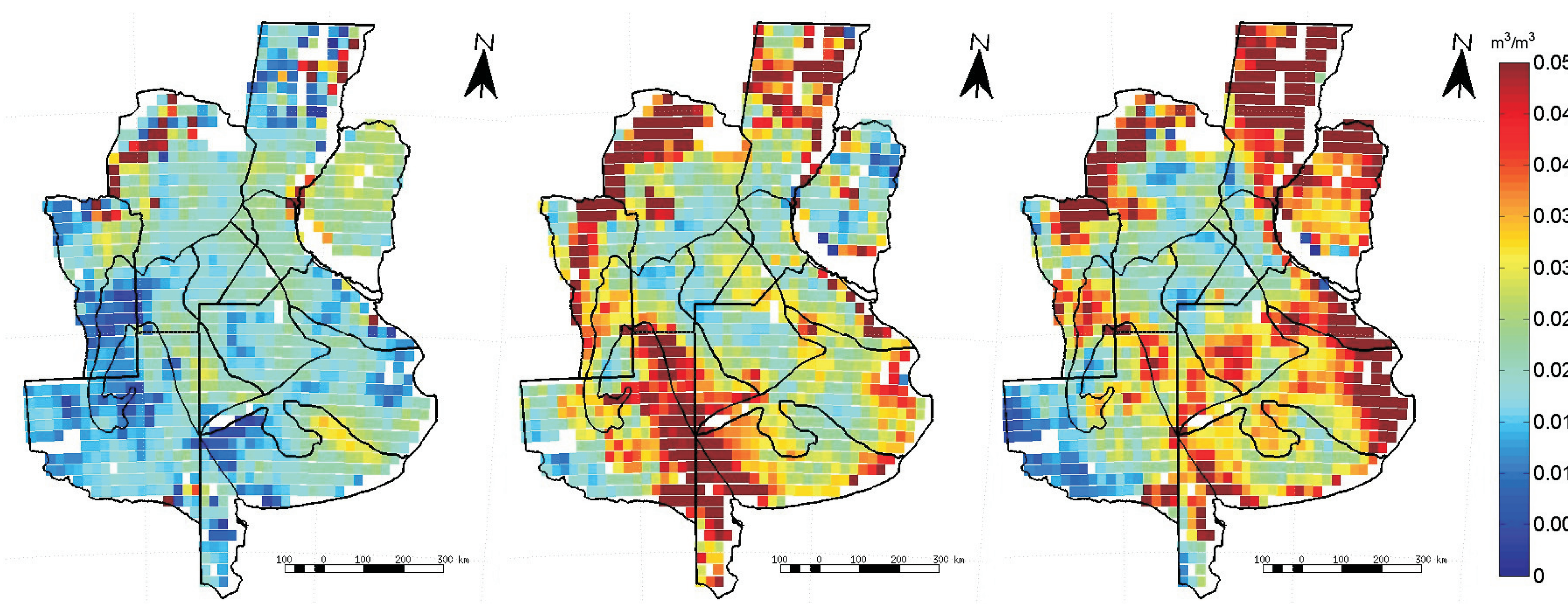

Figure 4. TC error estimates for the period Jan-2010 to Oct-2011 for (left to right): ASCAT, AMSR-E/LPRM and SMOS, scaled to ASCAT.

	ASCAT	*SMOS*	*LPRM*
Mean	0,0200	0,0631	0,0662
MADN	0,0054	0,0117	0,0138
SD	0,0151	0,5166	0,4149

Table 3. Mean, MADN (normalized median absolute deviation), SD (standard deviation) of the TC error estimates, from the ASCAT, AMSR-E/LPRM and SMOS, scaled to ASCAT. .

In order to study the overall spatial dispersion of the TC RMSE estimates two measures of statistical dispersion are also included in Table 3. From them several conclusions can be derived,

- ✦ Large differences between the standard deviation (the classical estimator of dispersion) and the MADN (a more robust estimator of dispersion), point to the presence of outliers in all three data sets (also seen in the anomalies).
- ✦ The spatial patterns of all three TC RMSE estimates are consistent with the land cover map (Figure 1(a)), that is, higher errors correspond to forest areas (vegetation attenuation of soil signal), areas close to the coast (border errors) and highlands.
- ✦ Similarities in the spatial error patterns of LPRM and SMOS algorithms are observed in the good visual correspondence between their TC RMSE maps (Figure 4). This is further indicated by the close values obtained for the domain mean, MADN and SD RMSE estimates shown in Table 3.

To further explore the validity of applying a TC analysis in this area and for these datasets, we compared a map of the correlation coefficients between AMSR-E/LPRM and SMOS soil moisture anomaly time series with the difference between their TC errors. Results are shown in Figure 5. Red (blue) shading indicates that LPRM TC error is greater (smaller) than the SMOS TC error. The maps show a good visual correspondence between areas which exhibit low correlation values (shaded blue in Figure 5 (a)) and areas with high absolute difference in the TC error estimates (shaded dark red or dark blue in Figure 5 (b)). Therefore both assessment techniques provide similiar qualitative information, regarding the mutual agreement of the given pair of soil moisture datasets.

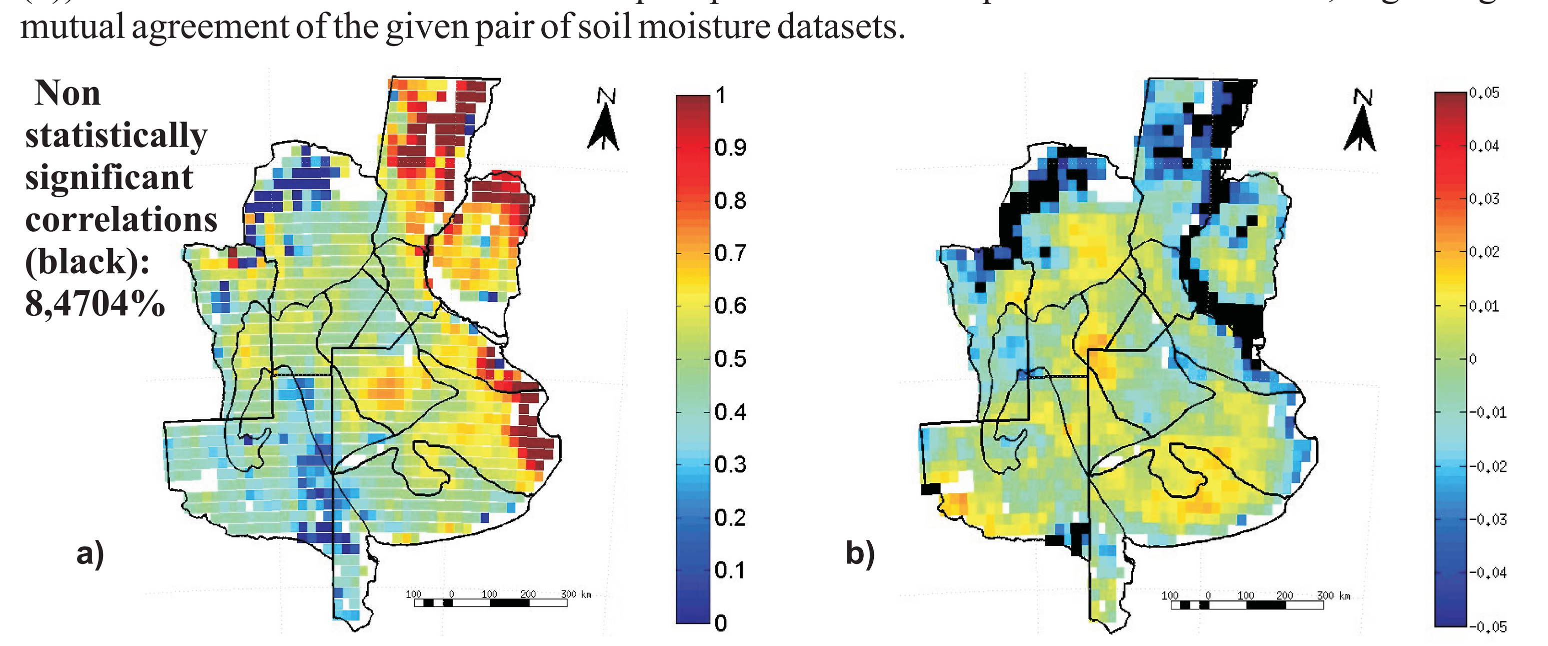

Figure 5. (a) Correlation coefficient between AMSR-E/LPRM and SMOS soil moisture anomaly time series. (b) Difference in AMSR-E/LPRM and SMOS TC error, scaled to ASCAT.

Comments

Several remarks regarding the analysis carried out for ASCAT, SMOS and LPRM SM estimations in the Pampas Plains can be underlined:

- ◎ There are difficulties in comparing SM absolute values (already known).
- ◎ Although quantitatively different, all three SM products present very similar and highly correlated spatial anomalies.
- ◎ For the period analized, ASCAT presented the best performance regarding TC RMSE estimates.
- ◎ Differences regarding the performance of the products are possibly related to land covers and growing seasons. Further studies are in progress to quantify errors considering specific land covers and their temporal state (growing season versus bare soil conditions) and also dry years versus wet years.

References

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