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

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## ABSTRACT

Currently, there are several satellite systems of coarse spatial resolution that observe the Earth in the microwave region of the electromagnetic spectrum. They provide operational soil moisture products, among them AMSR-E/LPRM, ASCAT, SMOS. This work aims at answering the following questions: 1) are these products comparable? , 2) how does one evaluate their quality and if they are realistic in view of the lack of in situ data at their spatial scale? To answer these questions, we have analyzed time series of the soil moisture product for the different systems mentioned above. Two types of analysis were performed: a) analysis of spatial anomalies and their correlations, b) analysis of temporal anomalies and application of the Triple Collocation method for error estimation. Land cover maps, precipitation data and NDVI time series were used as ancillary information.

***Index Terms*** - soil moisture, microwave satellite

## 1. INTRODUCTION

Remotely sensed soil moisture (SM) studies have mainly focused on retrievals using active and passive microwave (MW) sensors. In this line of work, Argentina is strongly involved in MW satellite mission developments. Its participation in SACD/Aquarius mission is known, as well as 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. Although several coarse resolution SM products from different missions (passive and active) are available, the lack of an appropriate in situ network for SM validation has hampered their use for monitoring purposes (droughts and floods) and their assimilation in atmospheric and meteorological models. With this motivation in mind, we started to look at SM products evaluation methods ([1], [2]) that do not require a large in situ network.

The objective of this work is to use spatial and temporal correlation analysis and Triple Collocation (TC) error analysis to evaluate patterns and behavior of coarse resolution SM products in the Pampas Plains. The following sections describe the land cover and rain patterns of the area, the data sets and time period analyzed, the correlation analysis on spatial anomalies of the three products and TC error estimates and their interpretation based on available, ancillary data and vegetation characteristics of the area.

## 2. 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 [3] 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 hydrological 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 [4]. Most of the Pampas region is significantly affected by cyclical drought and flood episodes that impact both crop and cattle production.

## 3. SOIL MOISTURE DATA SETS AND PREPARATION

Data sets are listed in Table 1. This work was done for the Jan 2010-Oct 2011 period. Precipitation anomalies correspond to a dry to normal period [5]. 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. Also, ASCAT data was converted to volumetric units using ancillary soil porosity data [6]. Areas where SM products are known to have little to no skill, 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.

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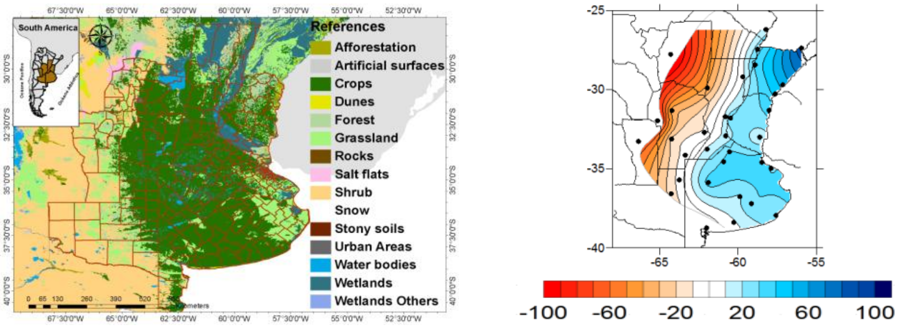

**Fig. 1**. a) Pampas Plains land cover categories (adapted from [3]) and b) an example of the spatial distribution of the P-EP for the period 1970-2006 for the month of October.

| *Sensor* | *Products* | *Period* | *Orbit* |
|---|---|---|---|
| AMSR-E | LPRM L3 SM product, V. 5 gridded 0.25deg lat/lon, optical depth (VOD) , Units[vol/vol] | 2002-2011 | Descending 2:30 AM |
| SMOS | L.MEB L2 SM product, V.500 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] | 2007-2012 | Descending 10:00 AM |

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

## 4. METHODOLOGY

### 4.1 SM retrieval algorithms

Two of the products (AMSR-E/LPRM [7] and SMOS [8]) are derived from different passive microwave systems, and although both algorithms are based on the zero order radiative transfer algorithm (RT0), they differ significantly in the way the model is solved for the two unknowns, that is, 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 the daily absolute values differ considerable in SM intensity and distribution, but also monthly means show considerable differences. As an example, the October 2010 monthly mean for the three products is shown in Figure 2. Although 2010 is a dry year, ASCAT shows very uniform low values, SMOS also shows low values, but with some differences between the west and east (as expected) and LPRM shows overall high values, but with a west-east pattern (drier-wetter).

### 4.2. Spatial anomaly correlation analysis

The difficulty in comparing absolute values of products when no adequate in situ network is available leads to the analysis of anomalies. Standardized seasonal anomaly composites of AMSR-E (LPRM), SMOS and ASCAT were computed over a nominal growing season (September 2010-March 2011). Spatial anomaly correlations were computed. These estimates show how similarly each of the data sets represents wet (dry) SM anomalies over the study domain. This type of analysis does not provide direct information with respect to interannual or interseasonal relationships between data sets.

### 4.3. Soil moisture anomaly time series and triple collocation

The triple collocation (TC) technique, developed by [9], is being used to estimate the root mean square error (RMSE) in remote sensing 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). The soil moisture anomaly time series were defined as the deviations of the original time series from their seasonal climatology. 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. In this study, the data set chosen as the reference is ASCAT.

## 5. RESULTS AND DISCUSSION

Figure 3 shows standardized seasonal anomaly composites for the period 2010-2011. The three algorithms present very similar spatial patterns, 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.

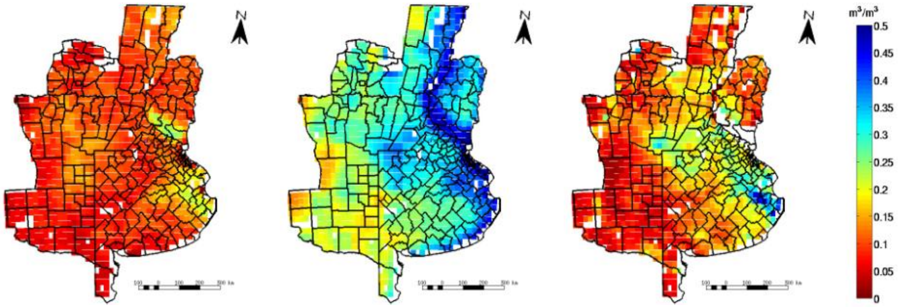

**Fig. 2**. Average Soil Moisture Values for the period October 2010 of (left to right): ASCAT, AMSR-E/LPRM and SMOS.

| | *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.

Figure 4 shows the TC error estimates at each LPRM grid point over the entire study domain. 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 on this paper. In order to study the overall dispersion of the TC RMSE estimates two measures of statistical dispersion are also included in Table 3. Large differences between the standard deviation (the classical estimator of dispersion) and the MADN (normalized median absolute deviation) (a more robust estimator of dispersion), point to the presence of outliers in all three data sets. 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, areas close to the coast 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.

Figure 5 (a) shows the correlation coefficient between the soil moisture anomaly time series of SMOS and LPRM calculated for the period Jan-2010 to Oct-2011. Grid points which exhibit a non significant correlation coefficient at the 5% confidence level are shaded black. Figure 5 (b) shows the difference in LPRM and SMOS TC error. 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)).

Further work is being done to deepen the understanding of the TC error structure using AMSR-E LPRM and SMOS optical depth products, MODIS NDVI and LAI products and TRMM data and also extending the analyzed period.

| | *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.

## 6. REFERENCES

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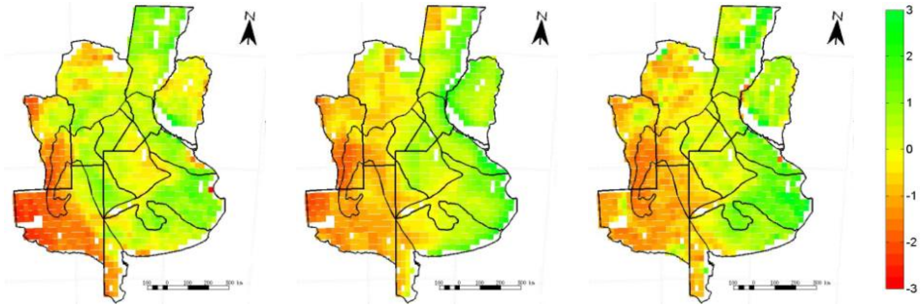

**Fig. 3**. Standardized seasonal anomaly composites for the period 2010-2011 of (left to right): ASCAT, AMSR-E/LPRM and SMOS.

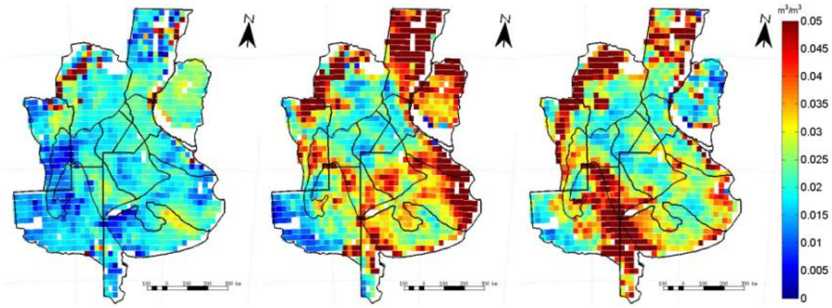

**Fig. 4**. TC error estimates for the period Jan-2010 to Oct-2011 for (left to right): ASCAT, AMSR-E/LPRM and SMOS.

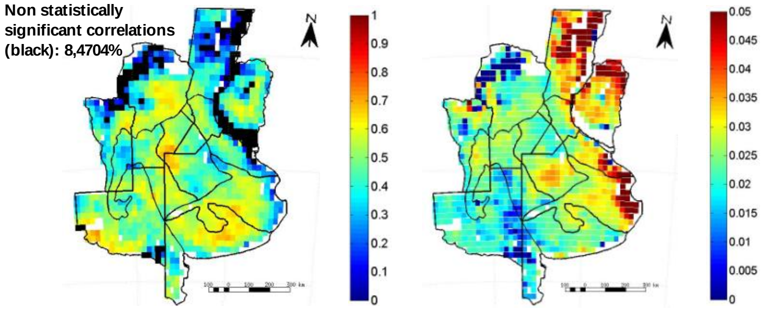

**Fig. 5**. (a) Correlation coefficient between AMSR-E/LPRM and SMOS soil moisture anomaly time series, (Non statistically significant correlations (black): 8,4704%). (b) Difference in AMSR-E/LPRM and SMOS TC error.