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An intercomparison of soil moisture derived from SMAP and SMOS over eight sites in the Northeast Brazil

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INTRODUCTION

Northeastern Brazil (NEB) is known for being exposed to severe droughts, mainly in its semiarid portion where often these events generate massive losses of agricultural production [1]. The amount of available soil moisture in the root zone is a critical factor for crop growth [2]; therefore, the accurate knowledge of soil moisture is a key aspect to monitor the progress of agricultural droughts. Currently active and passive microwave sensors are the best technologies for retrieving soil moisture from space. The SMOS launched in early November 2009 by ESA, and the SMAP launched in January 2015 by NASA are among the satellites most widely used for soil moisture retrieval at global scale.

In the NEB, despite the great potential of the sensors aboard both satellites, very few works have been published using soil moisture derived from the SMOS data [3,4], whereas the SMAP-derived soil moisture has not yet been validated against in-situ observations. Recently, Paredes and Barbosa [5] demonstrated that the SMOS-derived soil moisture is suitable to track the agricultural drought dynamics at low-elevation flatlands of the NEB. Accordingly, one could suppose that the SMAP data also could has potential to do so; but it must be taken into account that the retrieval algorithms for SMAP and SMOS are different [6]. In order to provide useful information on similarity between surface soil moisture estimates from SMAP and SMOS, an intercomparison of soil moisture derived from SMAP and SMOS was conducted at the NEB.

STUDY AREA

For this study, eight benchmark sites located within four main biomes of the NEB were selected (Figure 1, Table 1).

MATERIALS AND METODS

For each benchmark site, the SMOS Soil Moisture Level 3 Product [7] developed and disseminated by the SMOS Barcelona Expert Center (http://bec.icm.csic.es/) was used to estimate the surface soil moisture to a daily timescale for both ascending and descending passes. The BEC-L3 SM estimates were obtained implementing a simple extraction to pixel level (i.e., the SMOS grid center nearest to benchmark site was chosen). Next, the daily BEC-L3 SM data was weekly averaged using the arithmetic mean from 19/Jan/2015 to 20/Feb/2017 (i.e., 111 weeks). Similarly, the SMAP L3 Radiometer Global Daily 36 km EASE-Grid Soil Moisture v4 Product [8] developed and disseminated by the NASA National Snow and Ice Data Center Distributed Active Archive Center (http://nsidc.org/data/SPL3SMP) was also used. Furthermore, for the same benchmark sites, the weekly maximum NDVI from the Proba V S10 TOC product (http://www.vito-eodata.be), and weekly accumulated rainfall from the CHIRPS v2 product (http://chg.geog.ucsb.edu/data/chirps/) were retrieved and used here. Soil physical characteristics were taken from the SoilGrids 1 km (https://www.soilgrids.org/) [9].

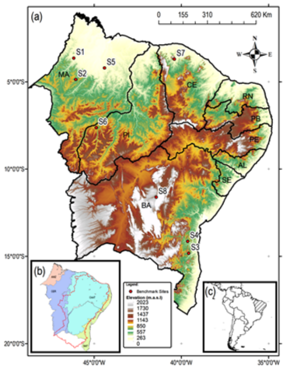

Fig. 1. Locations of benchmark sites and state division of the NEB (a); main biomes of the NEB [AMZ, Amazonia; CER, Cerrado; MAT, Atlantic Forest; and CAAT, Caatinga] and the Sertão region [polygon delimited by the red line] (b); and relative location of the NEB respect to South America (c).

Table 1. Main characteristics of benchmark sites.

Name	Longitude	Latitude	Elevation*	Biome	Soil Texture Class**	Description
S1	-46.17	-3.64	69	Amazonia	SaClLo	Dense forest
S2	-46.06	-4.87	260	Amazonia	ClLo	Dense forest
S3	-39.58	-14.83	242	Atlantic Forest	ClLo	Forest
S4	-39.64	-14.14	170	Atlantic Forest	SaCl-ClLo-SaClLo	Forest
S5	-44.41	-4.21	74	Cerrado	SaLo	Savannah
S6	-44.88	-7.63	427	Cerrado	SaClLo	Corn monoculture
S7	-40.41	-3.70	124	Caatinga	SaLo	Caatinga
S8	-41.45	-11.61	741	Caatinga	SaClLo	Agreste Baiano

Note: * meters above sea level; ** based on texture classes of the USDA system

Datasets were organized as weekly time series due to that this temporal scale is usually used for agricultural drought monitoring. Pairwise comparisons between SMOS/SMAP surface soil moisture were carried out over the analyzed time-span. The Spearman correlation coefficient (R), Root Mean Square for Error (RMSE), and (B) Bias were used as statistical metrics [10]. The optimum value of R, RMSE, and B is equal to one, zero, and zero respectively, which indicates a perfect agreement between the soil moisture retrieval from SMOS and SMAP.

RESULTS

The SMOS-SMAP soil moisture pairs for the benchmark sites covering the period of January 2015 to February 2017 are shown in Fig. 2. Besides Figure 3 summarizes the variation of the R correlation between SMAP/SMOS-derived SM estimates and NDVI and rainfall in the benchmark sites for the same temporal scale used in Fig. 2.

DISCUSSION AND CONCLUSION

The higher (lower) correlations between SMAP-derived SM and SMOS-derived SM were found at sites S5 and S7 (S1 and S2), respectively. Overall, SMOS-derived SM tends to underestimate the variability of SMAP-derived SM of almost all the benchmark sites, with exception at S5 and S7 (Figs. 2 and 3).

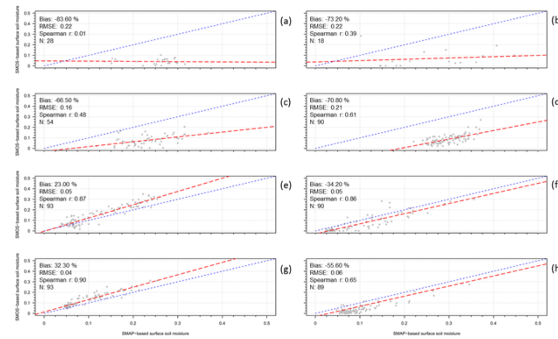

Fig. 2. SMAP-derived SM compared against SMOS-derived SM from January 2015 to February 2017 in the benchmark sites: (a) S1; (b) S2; (c) S3; (d) S4; (e) S5; (f) S6; (g) S7; and (h) S8. Blue line indicates 1:1 correspondence and dashed red line gives the linear regression best fit. N depicts the amount of SMOS-SMAP pairwise analyzed.

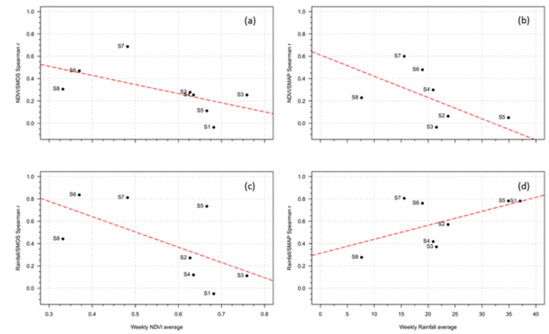

Fig. 3. For the period January 2015 to February 2017: (a) weekly NDVI average compared against NDVI/SMOS-derived SM Spearman r; (b) weekly rainfall average compared against NDVI/SMAP-derived SM Spearman r; (c) as panel (a), but for Rainfall/SMOS-derived SM Spearman r; (d) as panel (b), but for Rainfall/SMAP-derived SM Spearman r. Dashed red line depicts the linear regression best fit. .

These findings suggest that the soil moisture derived of both products tend to be similar in semiarid regions of the NEB, but in other environments that are rainy and forested such as Amazonia and Atlantic Forest they are dissimilar. This could be attributed to the fact that retrieval algorithms for both SMAP and SMOS have important limitations in the areas of tropical forest [11]. On other hand, it is interesting to remark that those sites dominated by sand surfaces showed soil moisture estimates similar (Table 1 and Fig. 2). Based on the results, one can conclude that SMAP and SMOS prove to be sensitive to surface soil moisture and reproduce moderately well the soil water balance dynamic in semiarid areas of the NEB. Furthermore, SMOS/SMAP soil moisture correlate relatively well with NDVI and rainfall in that same region.

REFERENCES

1. Marengo, J. A.; Torres, R. R.; Alves, L. M. Drought in Northeast Brazil—past, present, and future. Theor. Appl. Climatol. 2016, 1–12.

2. Martinez-Fernández, J.; González-Zamora, A.; Sánchez, N.; Gumuzzio, A. A soil water based index as a suitable agricultural drought indicator. J. Hydrol. 2015, 522, 265–273.

3. Rossato, L.; Angelis, C. F. Avaliação da umidade do solo em áreas densamente vegetadas sobre o Brasil, utilizando observações do sensor MIRAS/SMOS. In XVI Simpósio Brasileiro de Sensoriamento Remoto; 2013; pp. 9248–9255.

4. Ferreira, A. G.; Lopez-Baeza, E.; De Andrade, M. F. Soil Moisture Comparison between SMOS and MUSAG for a Brazilian Semi-Arid region. In 40th COSPAR Scientific Assembly; 2014; Vol. 40.

5. Paredes-Trejo, F.; Barbosa, H. Evaluation of the SMOS-Derived Soil Water Deficit Index as Agricultural Drought Index in Northeast of Brazil. Water 2017, 9, 377.

6. Miernecki, M.; Wigneron, J.-P.; Lopez-Baeza, E.; Kerr, Y.; De Jeu, R.; De Lannoy, G. J. M.; Jackson, T. J.; O'Neill, P. E.; Schwank, M.; Moran, R. F.; Bircher, S.; Lawrence, H.; Mialon, A.; Al Bitar, A.; Richaume, P. Comparison of SMOS and SMAP soil moisture retrieval approaches using tower-based radiometer data over a vineyard field. Remote Sens. Environ. 2014, 154, 89–101.

7. Gonzalez-Zamora, A.; Sanchez, N.; Martinez-Fernandez, Jose Gumuzzio, A.; Piles, M.; Olmedo, E. Long-term SMOS soil moisture products: A comprehensive evaluation across scales and methods in the Duero Basin (Spain). Phys. Chem. Earth, Parts A/B/C 2015, 83–84, 123–136.

8. O'Neill, P. E.; Chan, S. K.; Njoku, E. G.; Jackson, T. J.; Bindlish, R. SMAP Enhanced L3 Radiometer Global Daily 9 km EASE-Grid Soil Moisture, Version 1 2016.

9. Hengl, T.; de Jesus, J. M.; MacMillan, R. A.; Batjes, N. H.; Heuvelink, G. B. M.; Ribeiro, E.; Samuel-Rosa, A.; Kempen, B.; Leenaars, J. G. B.; Walsh, M. G.; others SoilGrids1km—global soil information based on automated mapping. PLoS One 2014, 9, e105992.

10. Paredes, F.; Barbosa, H.; Lakshmi-Kumar, T. Validating CHIRPS-based satellite precipitation estimates in Northeast Brazil. J. Arid Environ. 2016, 139, 26–40.

11. Rodriguez-Fernández, N. J.; Kerr, Y. H.; van der Schalie, R.; Al-Yaari, A.; Wigneron, J.-P.; de Jeu, R.; Richaume, P.; Dutra, E.; Mialon, A.; Drusch, M.. Long Term Global Surface Soil Moisture Fields Using an SMOS-Trained Neural Network Applied to AMSR-E Data. Remote Sens. 2016, 8, 959.