THE THEX-MEX'18 DATASET: UNDERSTANDING THE SOIL MOISTURE DYNAMICS OF AGRICULTURAL FIELDS IN CENTRAL MEXICO FROM SATELLITE OBSERVATIONS

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ABSTRACT

The National Aeronautics and Space Administration (NASA) Soil Moisture Active Passive (SMAP) satellite was launched in January 2015. In order to validate the soil moisture retrieval algorithms that fully exploit the unique capabilities of SMAP, the algorithms need to be tested over different conditions worldwide. In response to this need, the Terrestrial Hydrology Experiment 2018 in Mexico (THEx-MEX 18) was conducted in Huamantla, Tlaxcala, Mexico over a six-month period. Ground crews collected soil moisture data, crop measurements, and biomass samples in support of this campaign. The objective of THEx-MEX was to create a soil moisture network over an agricultural area in Mexico, understand the spatial distribution of soil moisture, and compare the SMAP soil moisture retrievals with in-situ measurements. This work details the field data collection as well as data calibration and analysis. A first comparison between in-situ data and SMAP retrievals of soil moisture is presented. It is demonstrated that absolute soil moisture values can be delivered by satellite observations. SMAP soil moisture estimates closely follow dry down and wetting events observed during the field experiment.

***Index Terms*—** Soil moisture, downscaling, tropical forest, NASA SMAP, ESA Sentinel-1

1. INTRODUCTION

Accurate knowledge of soil moisture (SM) is crucial in hydrology, micrometeorology, and agriculture for estimating energy and moisture fluxes at the land surface. Soil Vegetation Atmosphere Transfer (SVAT) models are typically used to simulate energy and moisture transport in soil and vegetation. Although SVAT models capture the biophysics of dynamic vegetation fairly well, SM estimates still diverge from reality due to errors in computation, and uncertainties in model parameters, forcings, and initial conditions. The model estimates of SM can be significantly improved by using remotely sensed observations that are sensitive to soil moisture changes, such as microwave brightness (T_B) and/or backscattering coefficient (s0) at frequencies < 10 GHz. For soil moisture studies, observations at L-band (1.2 – 1.4 GHz) are desirable due to larger penetration depth and system feasibility. The ESA Soil Moisture and Ocean Salinity (SMOS) and the NASA Soil Moisture Active/Passive (SMAP) missions include active and/or passive microwave sensors at L-band provide global observations, with a repeat coverage of every 2-3 days. Because of the major roll of SM in agricultural applications, the validation activities of SMAP SM estimates is essential over rainfed agricultural areas; particularly, for countries with limited databases of soil moisture such as Mexico. A field experiment was designed in Central Mexico to monitor rainfed cornfields covering a complete growing season of different fields. These fields were used to determine the quality of the soil moisture data products at 36 and 9 km. The experiment included also intensive ground sampling regime consisting of manual sampling of vegetation parameters such as LAI, biomass, geometrical parameters of the corn plant and soil moisture measurements using TDR sensor, theta probes, and gravimetric samples. Analyses using the data from these experiments have produced various results regarding the SMAP validation and related science questions. The data set has been used for analyzing the multi-scale parameterization of the surface roughness, and validation of SMAP SM.

2. THE THEX-MEX'18

2.1 Site description

The agricultural fields are located in Huamantla, Central Mexico (19º 18' 51.09'' N; 97º 51' 27.91''W). Huamantla is a small city in Huamantla Municipality located in the eastern half of the Mexican state of Tlaxcala. The municipality's economy is still heavily agricultural, with almost a third of its workforce dedicated to crops and livestock. Over half of the municipality's territory is used for farming and grazing but agriculture's role has been diminishing. In 2009, the municipality had 24,424 hectares under cultivation with crops such as corn, beans, wheat, animal feed, peaches and rye. Livestock includes cattle (mostly dairy), pigs, sheep, goats and domestic fowl. The climate of Huamantla is characteristically temperate (subhumid). Rainfall occurs from May to October, ranging from 500 mm per year East to 800-1000 mm in the Southwest. Rainfall variations in the mid-summer months can lead to extended droughts. Average monthly temperatures fluctuate within a narrow range, with January being the coldest month (0-9 ºC) and April or May generally the warmest (19-27 ºC). Huamantla soils are generally sandy and highly drained, though some soils are gravelly or rocky. Depth varies from 10 cm in the Lithosols of the west and north central regions to deep Fluviols on the plains of Huamantla.

Figure 1. Geographical location of Huamatla, Tlaxcala, Mexico.

2.2 In-situ data collection

The Terrestrial Hydrology Experiments in Mexico (THEx-MEXs) are a series of experiments conducted over different Mexican biomes to monitor the dynamics of soil and vegetation. During the THEx-MEX'18, 5 different corn fields over their complete growing season, from April 13 to October 13, 2018, were characterized in the region of Huamantla, Central Mexico. There two three primary methods of soil moisture data collection during the THEx-MEX'18 field campaign (Fig. 2): a temporary in situ network, manual soil moisture measurements at specific points of the fields and concurrent manual physical sampling. Throughout the entire growing season of corn in the area, we operated a total of 5 soil moisture stations. These stations record precipitation and soil moisture and soil temperature every 20 min at a depth of 2.5, 5, 10, 20, and 30 cm with TDR probes installed horizontally. This provides an integrated estimate for soil moisture profile up to 30cm depth. Precipitation gauges were installed to capture the high intensity rainfall that is received during summer. Additionally, every 3 weeks, vertical measurements of SM were collected using Theta-probes to characterize the spatial variability of near-surface SM at each field. The final element of the ground-based soil moisture data collection was concurrent physical samples at depths of 2.5, 5, 10, 20, 30, and 60 cm, conducted by field sampling teams every 3 weeks. These samples were also used to calculate the soil specific bulk density and produce specific calibration equations for the TDRs and theta probes at each site.

Figure 2. Implementation of vegetation and soil measurement protocols.

The planting dates were from early April to end May, depending upon the corn cultivar planted. Soil roughness measurements, including root mean square height (s) and correlation length (l), were conducted across and along the rows during bare soil conditions of the 5 representative fields. This study used observations from ten 2D surface profiles, in the direction perpendicular and parallel to the row structure of the field with a 1.5m-long mesh board for each roughness measurement. The surface profile from each mesh board was digitized to calculate s and l (Yang, Tien, Casanova, & Judge, 2005), individually. Each soil roughness measurement was acquired by averaging all values of s and l.

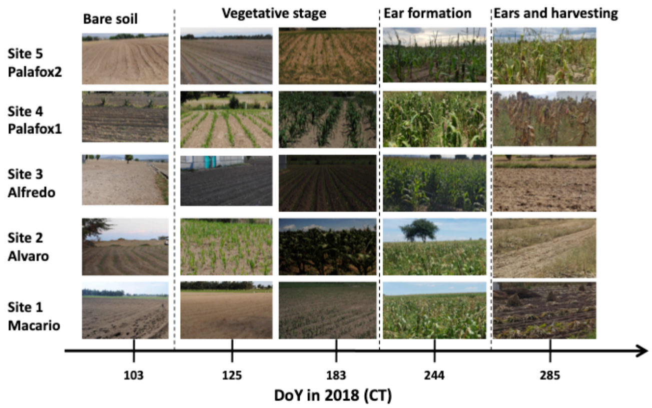


Figure 3. Growing stages for each representative site in Huamantla, Mexico.

The fields were planted using a multirow typical cultivators to make the vegetation density as uniform as possible in the fields. For all fields, the row spacing was about 80 cm, with approximately seven plants per meter. Every 3 weeks, destructive vegetation samplings were conducted, including the measurements of vegetation water content, volumetric densities, and geometrical descriptions of vegetation components, such as stems, leaves, and ears, over all fields [REF].

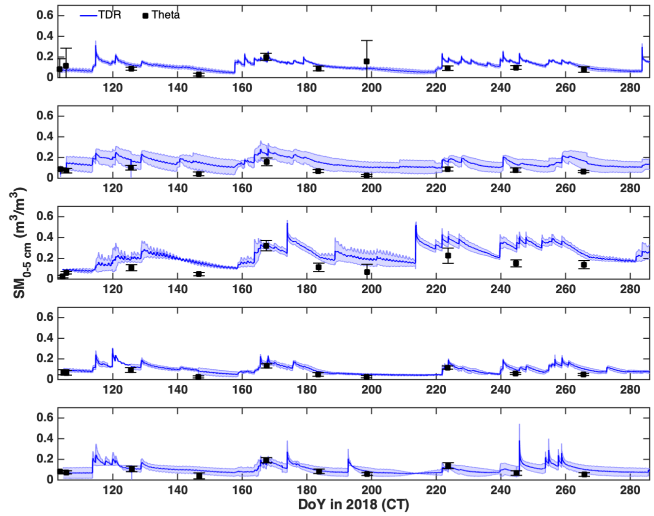
3. SATELLITE DATASET

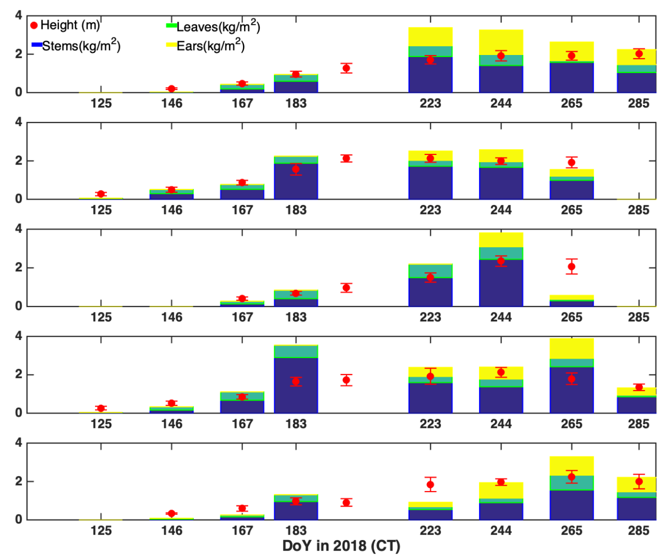
In this paper, we examined the T_B products NASA SMAP_L1CTB (version 4, V4) with a grid resolution of 36 km and NASA SMAP retrieved SM derived from 36-km passive observations. The downloaded datasets include SM estimates and brightness temperatures at H (T_{BH}) and V (T_{BV}) polarizations for both SMAP ascending and descending passes. The SMAP satellite acquires observations in an ascending orbit at 6 pm and in a descending orbit at 6 am, local time. The T_B was directly extracted from the products SMAP_L1CTB provide values of T_B at 40° incidence. A total of 134 data collected by SMAP radiometer were downloaded over the study region.

Figure 4. SMAP TB and SMAP SM retrievals at 36 km.

4. PRELIMINARY RESULTS

4.1. Analysis of field data





5.2. Comparison of SMAP SM at 36 km with in-situ SM

Fig. 3 shows the comparison between the SMAP retrievals of SM and VWC at 36-km resolution. Overall, the SMAP retrievals followed the same trend as in-situ measurements. The SMAP SM clearly captured the drydown periods, particularly, those that remained more than 10 days (see DoY 130-158 and 260-283). Regarding VWC, the peak of the SMAP retrievals matched the maximum value of VWC recorded during the field campaign.

Table I. Bias, Root Mean Square Difference (RMSD), unbiased Root Mean Square Difference (ubRMSD), and correlation coefficient (R) of the comparison between in-situ measurements and SMAP retrievals.

Parameter	Bias	RMSD	ubRMSD	R
SM (m^3/m^3)	0.094	0.104	0.046	0.74

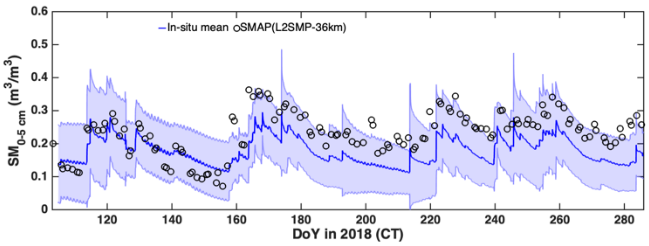


Figure 7. Comparison between in-situ measurements and SMAP retrievals.

Parameter	Bias	RMSD	ubRMSD	R
VWC (kg/m^2)	0.910	1.048	0.527	0.98

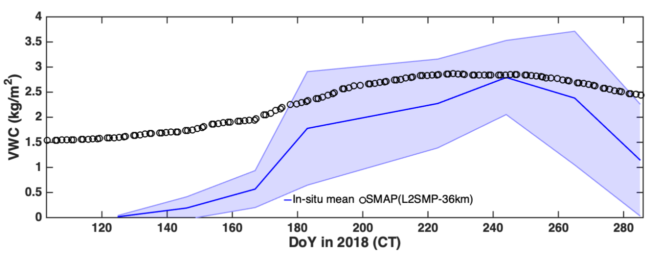


Figure 8.

Table I presents the bias, the root mean square difference (RMSD), the unbiased RMSD, and the correlation coefficient (R) between SMAP retrievals and in-situ measurements. The SMAP SM retrievals were close to the mission requirements (uncertainty of 0.04 m^3/m^3). As well, the SMAP SM retrievals were highly correlated to in-situ measurement. This statistics indicates that it is possible to use SMAP SM retrievals into the downscaling algorithm to produce SM at 1-km resolution over Huamantla, Mexico.

5. REFERENCES

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