Validation of SMAP Level 3 soil moisture data products using ground-based measurements at agricultural sites

Claire Villanueva-Weeks[1], Dr. Jingjing Li[1], Dr. Andreas Collainder[2]
1: Geosciences and Environment, California State University Los Angeles
2: Radar Science, Jet Propulsion Laboratory, Caltech

ABSTRACT

Soil moisture is an important climate driver in surface-atmosphere feedback, water storage replenishment, vegetation health, and food security. Advances in radar science and remote sensing allow measurement of soil moisture using satellite observation. The SMAP satellite (soil moisture active passive) observes global soil moisture through spaceborne retrieval at daily timescales. These retrievals are validated with ground measurements to ensure adequate performance of the satellite. Measuring the soil moisture content of agricultural soil is paramount to determining vegetation health, potential food availability, and monitoring climate events. To investigate and assess SMAP performance of the level 3 soil moisture data products, satellite retrieval will be validated with ground-based soil moisture measurements at five agricultural sites in Argentina, Canada, Spain, and the US. Statistical measures were used to determine the efficacy of the soil moisture products. A site studied in Canada produced ubRMSE values within the mission requirement for both the AM and PM retrievals along with the PM retrievals of another site studied in Spain. Four of five sites contained large gaps where in situ data was not retrieved or was flagged as poor quality. Factors such as seasonal variation of vegetation conditions make agricultural sites particularly challenging for retrieval.

INTRODUCTION

- **Surface soil is top 0-5 vertical cm of soil**
- **Soil moisture an important climate driver in surface-atmosphere feedback, drought and water storage replenishment, vegetation health, and food security.**
- **Measuring the soil moisture content of agricultural soil is paramount to determining vegetation health and potential food availability.**
- **To investigate and assess SMAP performance of the level 3 soil moisture data products, they will be validated with ground-based soil moisture measurements at five agricultural sites in Argentina, Canada, Spain, and the United states for the period of April 1, 2015 to July 31, 2019.**

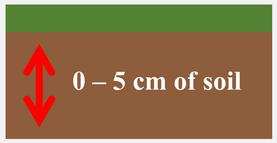

Figure 1. Surface soil vertical 0-5 cm

DATA

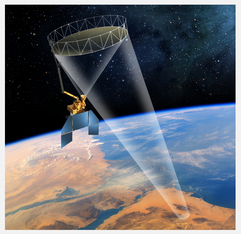

Figure 2a. The SMAP Satellite

Figure 2b. Stevens HydraProbes used at most sites

- ***in situ* data was obtained from ground based measurements that were collected either every 15 minutes or every hour, depending on site.**
- **The soil moisture value obtained at the time closest to the SMAP L3 retrieval time was used for the comparison.**
- **SMAP native resolution is 40 km, but the data is assimilated to the 9 km x 9 km EASE-Grid Projection.**
- **SMAP L3 data is comprised of a daily composite of SMAP L2 soil moisture derived from SMAP L1 interpolated brightness temperatures.**

METHODS

- **Statistical measures, including unbiased root mean square error values (ubRMSE), root mean square error values (RMSE), bias, and correlation coefficients (R), were used to determine the efficacy of the retrieved soil moisture products.**

$$RMSE_{fo} = \sqrt{\overline{(f-o)^2}} \quad \begin{matrix} f = in\ situ\ data \\ o = SMAP\ retrieval\ data \end{matrix}$$

$$Bias = \overline{\sum(o-f)}$$

$$ubRMSE_{fo} = \sqrt{\overline{(f-o)^2} - Bias}$$

$$R = \frac{1}{n-1}\sum_{i=1}^{n}\left(\frac{f-\bar{f}}{\sigma_f}\right)\left(\frac{o-\bar{o}}{\sigma_o}\right)$$

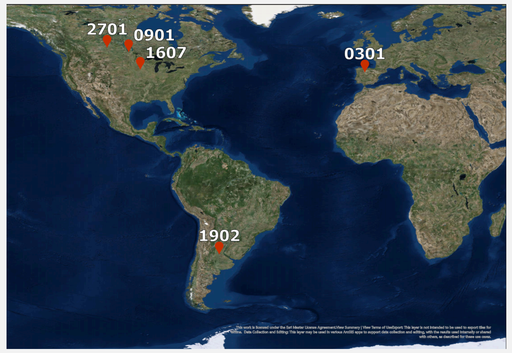

Figure 3. Map of the five sites with site ID labels

Table 1: Location and relevant climate information of each site.

	Site 0301	Site 0901	Site 1607	Site 1902	Site 2701
Location	La Boveda de Toro, Spain	Dufferin, Manitoba, Canada	Buckeye, Iowa	Monte Buey, Cordoba, Argentina	Saskatchewan, Canada
Notes	Relatively warmer climate, high precipitation, little slow	Cold climate, snow is common during winters	Cold winters, snow is common during winters	Relatively warmer climate, precipitation falls as rain	Cold winters, snow is common during winters

RESULTS

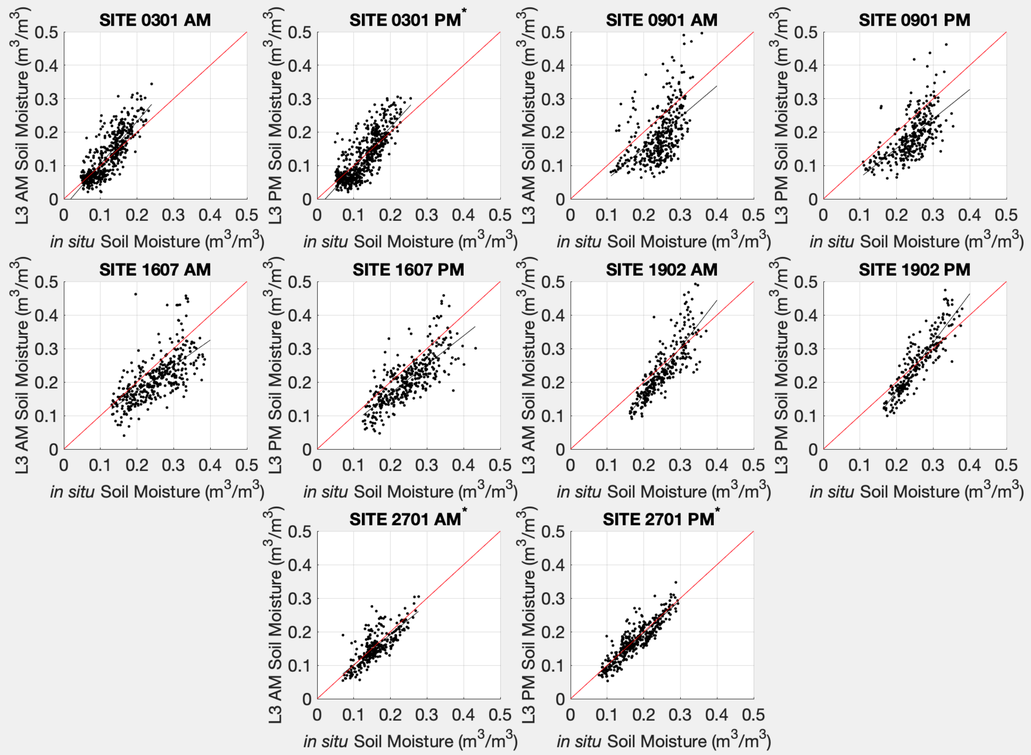

Figure 4: Correlation between SMAP L3 retrieval data and in situ data. Sites with ubRMSE values that meet the mission requirement of 0.04 m^3/m^3 are denoted with an asterisk (*)

Table 2: RMSE, ubRMSE, site bias, R, and sample size of each site. ubRMSE within the mission requirement of 0.04 m^3/m^3 are bolded.

ID	RMSE (m^3/m^3)		ubRMSE (m^3/m^3)		Bias		R		Sample size	
	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
0301	0.0418	0.0399	0.0408	**0.0399**	0.0091	-0.0018	0.8242	0.8133	467	591
0901	0.0857	0.0752	0.0690	0.0532	-0.0509	-0.0532	0.5396	0.6282	373	316
1607	0.0594	0.0617	0.0502	0.0467	-0.0318	-0.0404	0.6698	0.7637	261	357
1902	0.0524	0.0439	0.0498	0.0439	-0.0163	-0.0015	0.8423	0.8917	267	247
2701	0.0310	0.0257	**0.0307**	**0.0255**	-0.0042	-0.0034	0.7851	0.8858	267	340

DISCUSSION

- **A site studied in Canada (Site 2701) produced ubRMSE values within the mission requirement (0.04 m^3/m^3) for both the AM and PM retrievals along with the PM retrievals of another site studied in Spain (Site 0301).**
- **Four of the five sites studied contained large gaps where in situ data was not retrieved or was removed due to quality or temperature flagging.**
- **During their respective winter seasons precipitation may fall as snow and inhibit both SMAP retrieval and collection of ground-based data**
- **Large seasonal change in vegetation conditions makes retrieval over agricultural sites particularly challenging**

FUTURE DIRECTIONS

- **Incorporate analysis of SMAP L4 model derived soil moisture products**
- **Account for seasonality and other variation by examining performance on smaller scales during certain seasons or for specific environments or climate systems**

ACKNOWLEDGEMENTS

- **This work was supported by NASA DIRECT-STEM.**
- **Thank you to Dr. Andreas Colliander and JPL for providing the *in situ* reference data .**
- **Thank you to Dr. Jingjing Li and Dr. Andreas Colliander for all their guidance and help in this research.**

REFERENCES

- **Colliander, A., Cosh, M. H., Misra, S., Jackson, T. J., Crow, W. T., Powers, J., . . . Yueh, S. (2019). Comparison of high-resolution airborne soil moisture retrievals to SMAP soil moisture during the SMAP validation experiment 2016 (SMAPVEX16). Remote Sensing of Environment, 227, 137-150. doi:10.1016/j.rse.2019.04.004**
- **Figure 2b. HydraProbes, reliable soil insight. (n.d.). Retrieved from https://en.eijkelkamp.com/products/sensors-monitoring_uk/hydraprobes-reliable-soil-insight.html**
- **Figure 2a. SMAP Into Action: Satellite to Measure Soil Moisture From Space. (n.d.). Retrieved from https://www.globalchange.gov/news/smap-satellite-measure-soil-moisture-space**
- **USGS - U.S. Geological Survey, L. D. (n.d.). AppEEARS. Retrieved from https://lpdaacsvc.cr.usgs.gov/appeears/**