Analysis of Vegetation Water Content in Temperate and Boreal Forests

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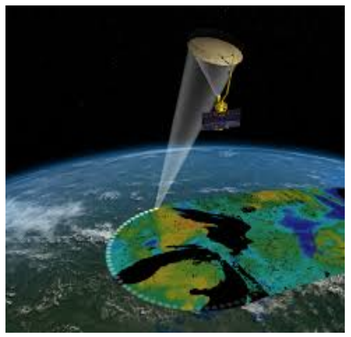
Introduction

Research Question: How does the calculation of vegetation water content affect SMAP soil moisture retrievals?

Retrievals of soil moisture from space are limited when vegetation is present, as the vegetation water content (VWC) dominates the soil moisture signal. This interference by vegetation results in the exclusion of soil moisture data in forested regions. Here, we examine how VWC is calculated in temperate and boreal regions to understand the seasonality of this interference.



The Soil Moisture Active Passive (SMAP) satellite launched in 2015 and retrieves soil information daily.

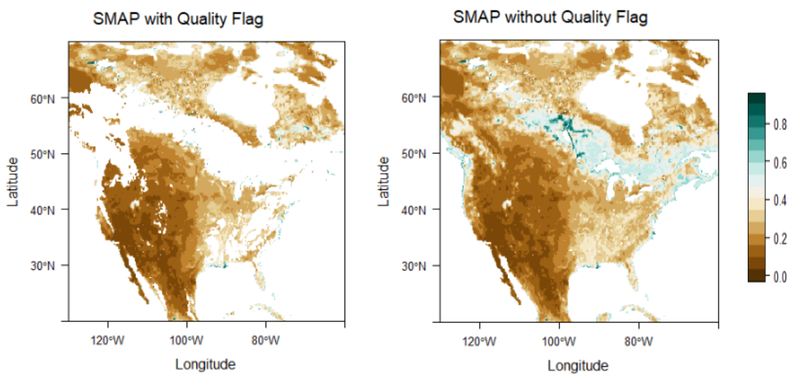


Figure 1: (left) SMAP (2015-2018) soil water content (%SWC) that excludes data where VWC > 5 kg m-2, and (right) SMAP SWC (%) for all retrievals.

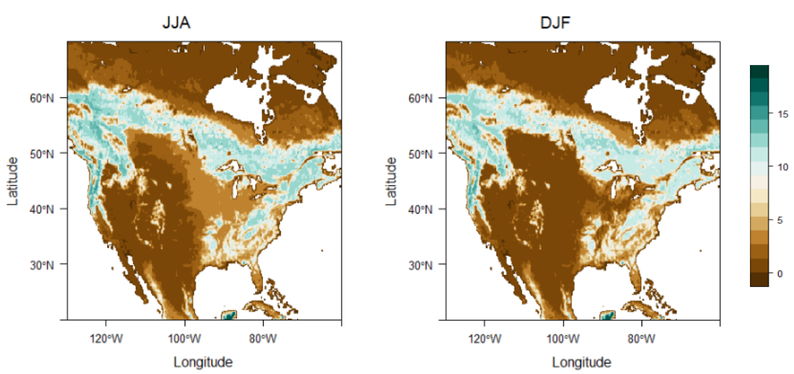


Figure 2: (left) Climatological (2015-2018) summer (JJA) SMAP VWC and (right) winter (DJF) VWC (kg m-2).

Calculation of Vegetation Water Content

$$Vegetation\ Water\ Content = \{1.9134 \times NDVI^2 - 0.3215 \times NDVI\} + \{stem\ factor \times (\frac{NDVI_{max} - NDVI_{min}}{1 - NDVI_{min}})\}$$

Plant Functional Type	Stem Factor
Evergreen Needleleaf Forest (ENF)	15.96
Deciduous Broadleaf Forest (DBF)	12.77

Chan (2013) [1]

The vegetation water content equation includes two terms: canopy water content (CWC) and stem water content (SWC). CWC is the product of leaf area and average leaf water content and can be estimated using satellite-derived Normalized Difference Vegetation Index (NDVI). SWC is a measure of the water content in the woody stems of trees. It is approximated from a combination of past field observations, leaf area index, NDVI and a stem factor from literature values.

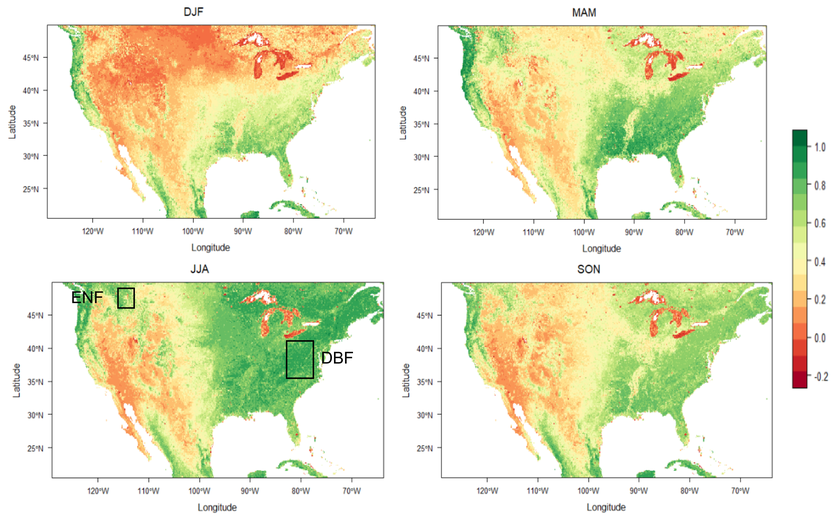


Figure 3: Seasonal variability of the Normalized Difference Vegetation Index (NDVI) between 2015 and 2018. Boxed areas indicate regions analyzed for vegetation water content calculations.

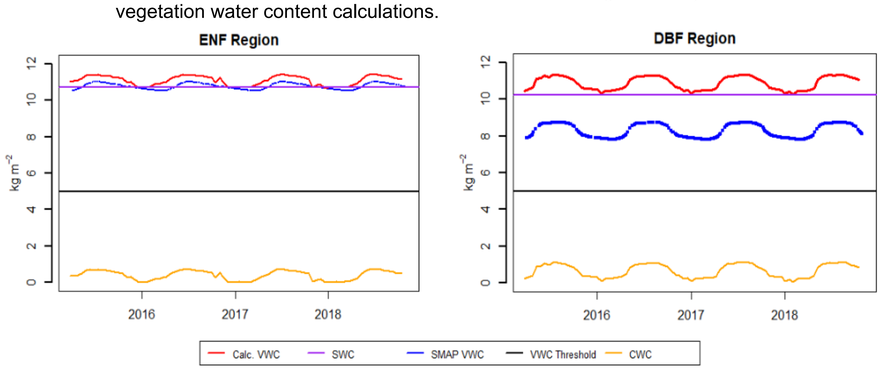


Figure 4: Comparison of calculated and SMAP vegetation water content. For the ENF region, calculated vegetation water content was much closer to SMAP VWC than for the DBF region, where SMAP underestimated when compared to the calculated VWC.

Sensitivity Analysis

ENF Region – BELD Data [3]	Height (m)	Percentage
Maple	11	0.11%
Birch	14.25	0.23%
Conifer	45	4.24%
Pine	26.4	42.05%
Poplar	21.6	0.32%
Average H (m)	23.65	

DBF Region – BELD Data	Height (m)	Percentage
Maple	27.25	4.62%
Birch	17.25	1.05%
Conifer	12	0.26%
Ash	24	1.33%
Mulberry	15	0.04%
Pine	19.75	3.68%
Plane	29.5	0.36%
Poplar	13.5	0.31%
Oak	27.5	11.87%
Elm	22.75	2.34%
Average H (m)	19.89	

Table 2: Average heights of tree species found in both ENF and DBF regions that were used to calculate the average stand height of each region.

$$Vegetation\ Water\ Content = CWC + SWC$$
$$CWC = 0.23 + 1.18(NDVI)$$
$$SWC = 0.4V\ where\ V\ is\ wood\ volume$$
$$V = 11.6h - 17$$
$$where\ h\ is\ the\ average\ stand\ height\ of\ a\ region$$

Hunt (2018) [2]

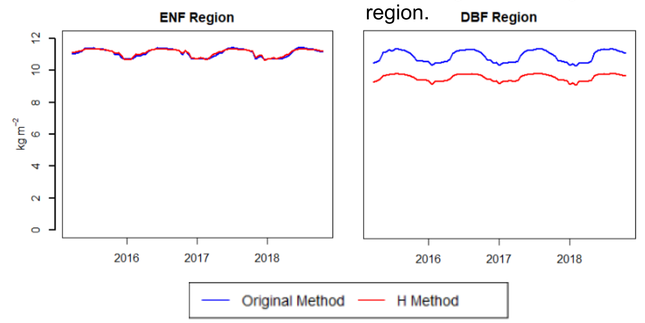


Figure 5: Comparison of methods for calculating vegetation water content. Original method uses equation 1. H method accounts for tree height when calculating stem water content.

Conclusions

Current methods of calculating vegetation water content are driven by plant stem factors that are not always representative of all vegetation in an area. The DBF region showed more sensitivity to average stand height than the ENF region. This suggests that methods for calculating vegetation water content could be revised in order to better embody how much water is within different trees and plants.

Acknowledgments

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References

[1] Chan, S.; Bindlish, R.; Hunt, R.; Jackson, T.; Kimball, J, 2013: Soil Moisture Active Passive (SMAP) Ancillary Data Report. Vegetation Water Content, SMAP Science Document No. 47, 18 pp.
[2] Hunt, E. R., Li, L., Friedman, J., Gaiser, P., Twarog,E., and Cosh, M., 2018: Incorporation of stem water content into vegetation optical depth for crops and woodlands. *Remote Sens,* **10.**
[3] Pierce Jr., T E., E. J. Kinnee, AND C D. Geron. Development of a 1-km vegetation database for modeling biogenic fluxes of hydrocarbons and nitric oxide. Presented at Sixth International Conference on Air Surface Exchange of Gases and Particles, Edinburgh, England, July 3-7, 2000.