IOWA STATE UNIVERSITY
Department of Agronomy

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Validating Soil Moisture with Farmers in Mind: A New Validation Approach for Soil Moisture Remote Sensing and Modeling in the Corn Belt

Overview:

- Assessed three microwave satellites & three reanalysis models in the U.S. Corn Belt with respect to crop development and management practices from 2016 to 2020.
- Estimated thermal time and crop progress and condition reports from the USDA NASS were used to define irregular critical transition periods of crop development and management decisions.
  - Contrary to calendar timelines (e.g., annual or monthly time segments), these critical transition periods separate the growing season into five dynamic segments: **pre–planting**, **active–management**, **wet–minimal–management**, **dry–minimal–management**, and **post–harvesting.**
- The validation process utilized 20 in-situ volumetric water content measurements–with post processed quality control–between 2016 to 2020 at a depth of 5 cm in the South Fork of the Iowa River, Iowa, known as the South-Fork SMAP Core Validation Site.

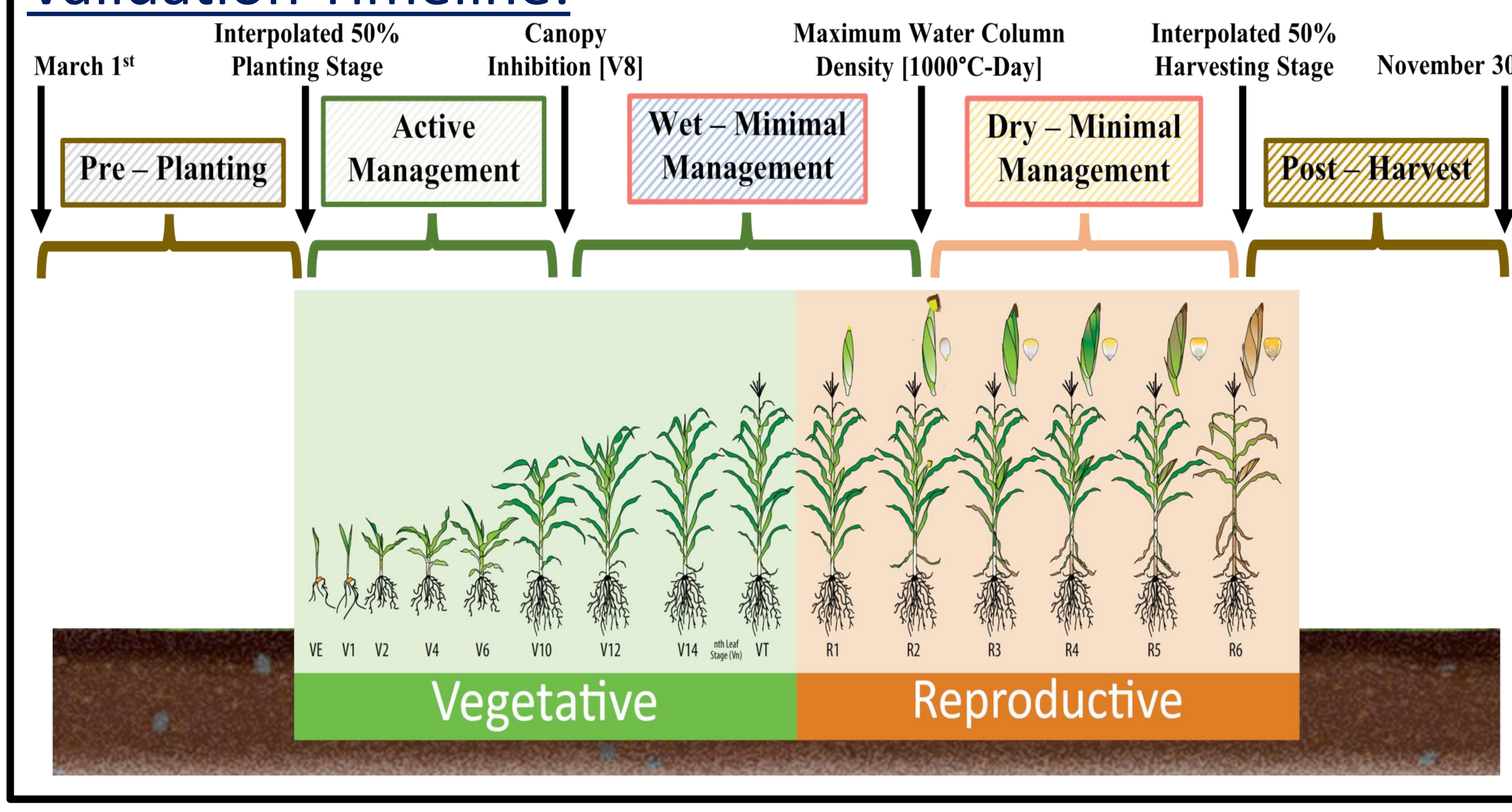
Motivation:

Evaluating soil moisture information should consider when key crop development stages occur and ultimately when decisions based upon soil moisture status must be made by farmers.

Question:

Do current soil moisture estimators have an Unbiased Root Mean Square Error (unRMSE) at or below 0.04 $[\mathrm{m^3 m^{-3}}]$?

Validation Timeline:



Materials and Methods:

In-Situ Site:

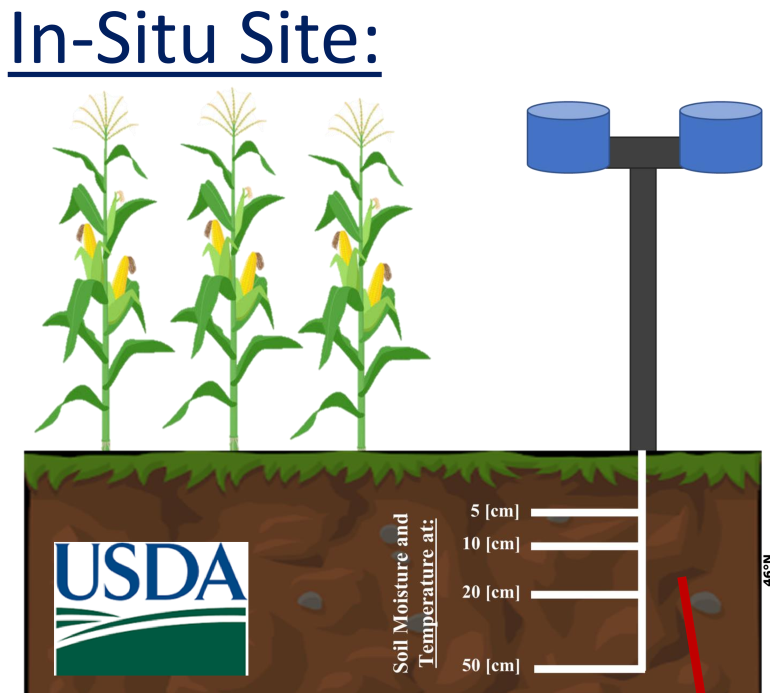


Figure 1 (above): A diagram of a South Fork Core Validation Site station. Although not in the field, these stations are on the edge of agricultural fields collecting soil moisture and precipitation data.

Figure 3 (bottom): Individual insets of the validation network in Iowa with the approximate grid(s) or footprint(s) representation of the respective satellites and models. The SMAP inset represents a "perfect" matchup while the METOP/MERRA-2 inset reflects a "poor" representation.

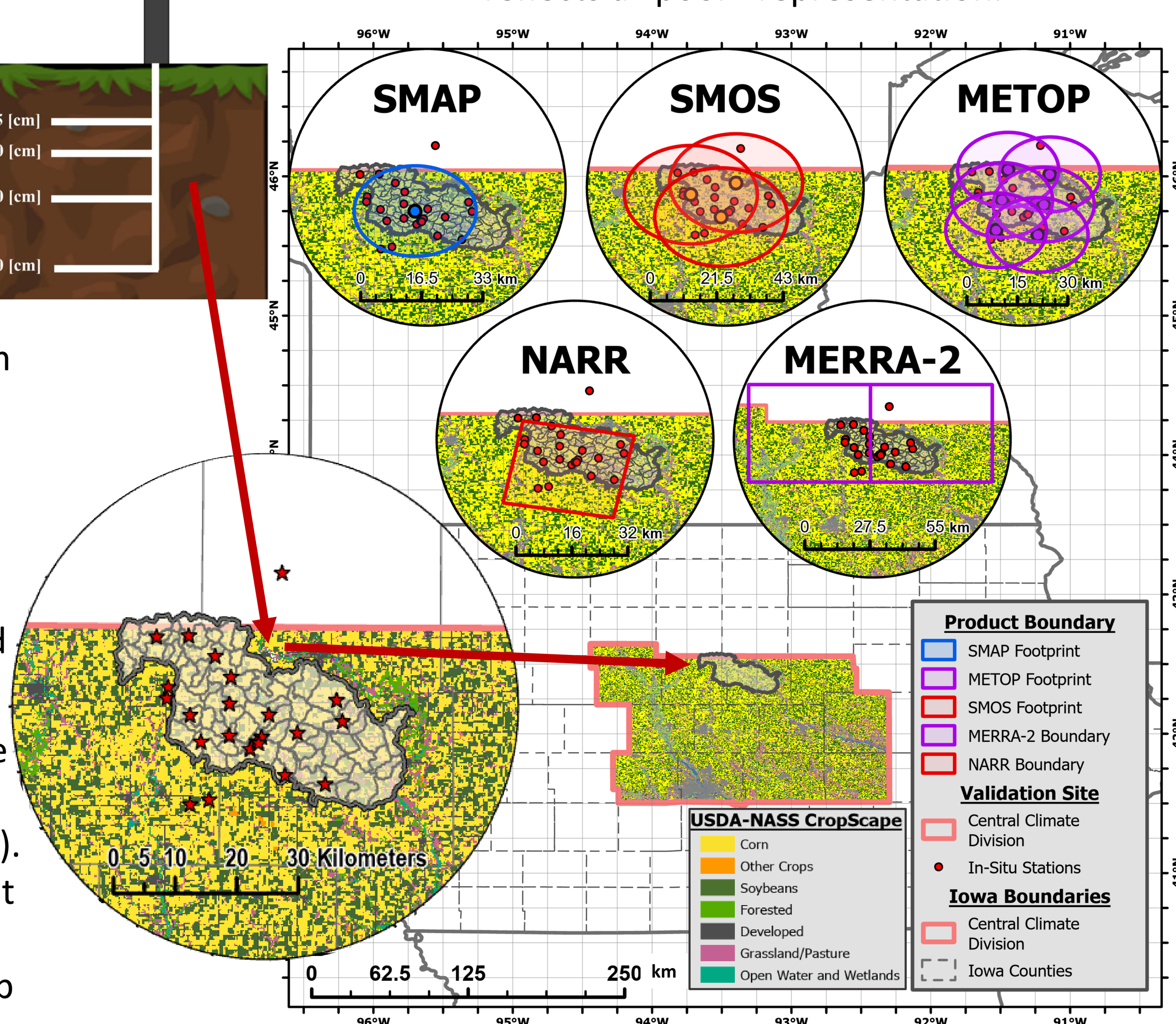


Figure 2 (right): Inset of the validation network with individual stations (red stars). Background colors represent USDA-NASS CropScape estimated land-use and crop cover data.

Soil Moisture Estimators:

Characteristic	MERRA-2	NARR	WEPP	SMAP	SMOS	MetOp/ ASCAT
Organization	NASA	NCEP	USDA-ARS	NASA	ESA	EUMETSAT
Latency	Monthly	Monthly	-	< 24 hours	8-12 hours	< 6 hour
Model/Penetration/ Emitting Depth (cm)	0-5	0-10	0-10	~5	~5	~1 to 2
Temporal Resolution	Hourly	3-Hourly	Daily	Varies	Varies	Varies
Temporal Domain	1980 to present	1979 to present	-	March 2015 to present	June 2010 to present	Varies to present
Spatial Resolution	~50 x 55 km	32 x 32 km	-	33 x 33 km	43 x 43 km	30 x 30 km
Spatial Domain	Global	North America	Watershed Based	Global	Global	Global

Metrics:

$$\textbf{bias}\ [\mathrm{m^3 m^{-3}}] = \overline{\textbf{Predicted} - \textbf{Actual}}$$

The mean difference between "ground truth" and estimator.
(-) indicates dry bias
(+) indicates wet bias

$$\textbf{unRMSE}\ [\mathrm{m^3 m^{-3}}] = \sqrt{\left(\sqrt{\overline{\textbf{Predicted} - \textbf{Actual}^2}}\right)^2 - \textbf{bias}^2}$$

The accuracy performance that represents random error

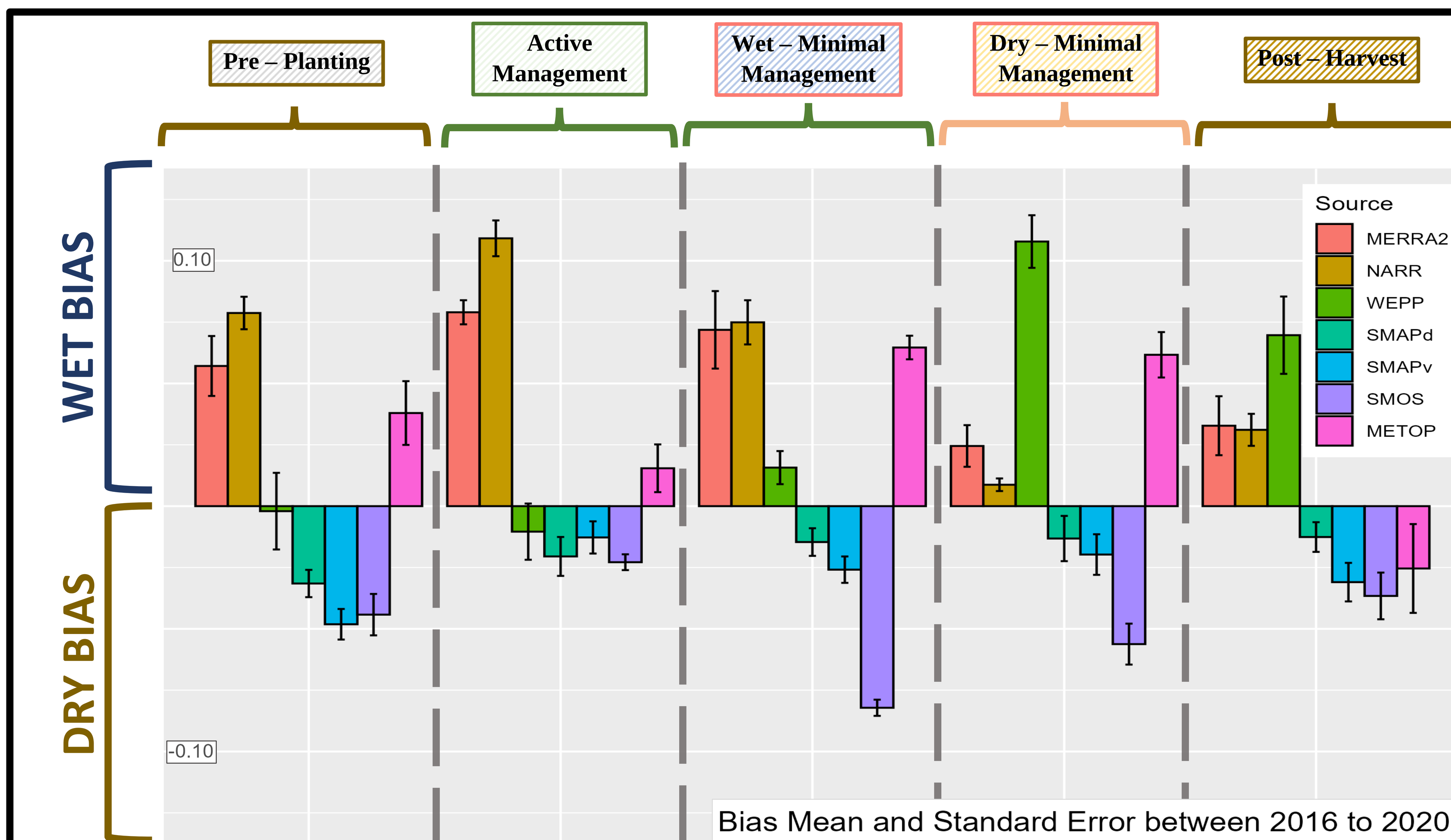
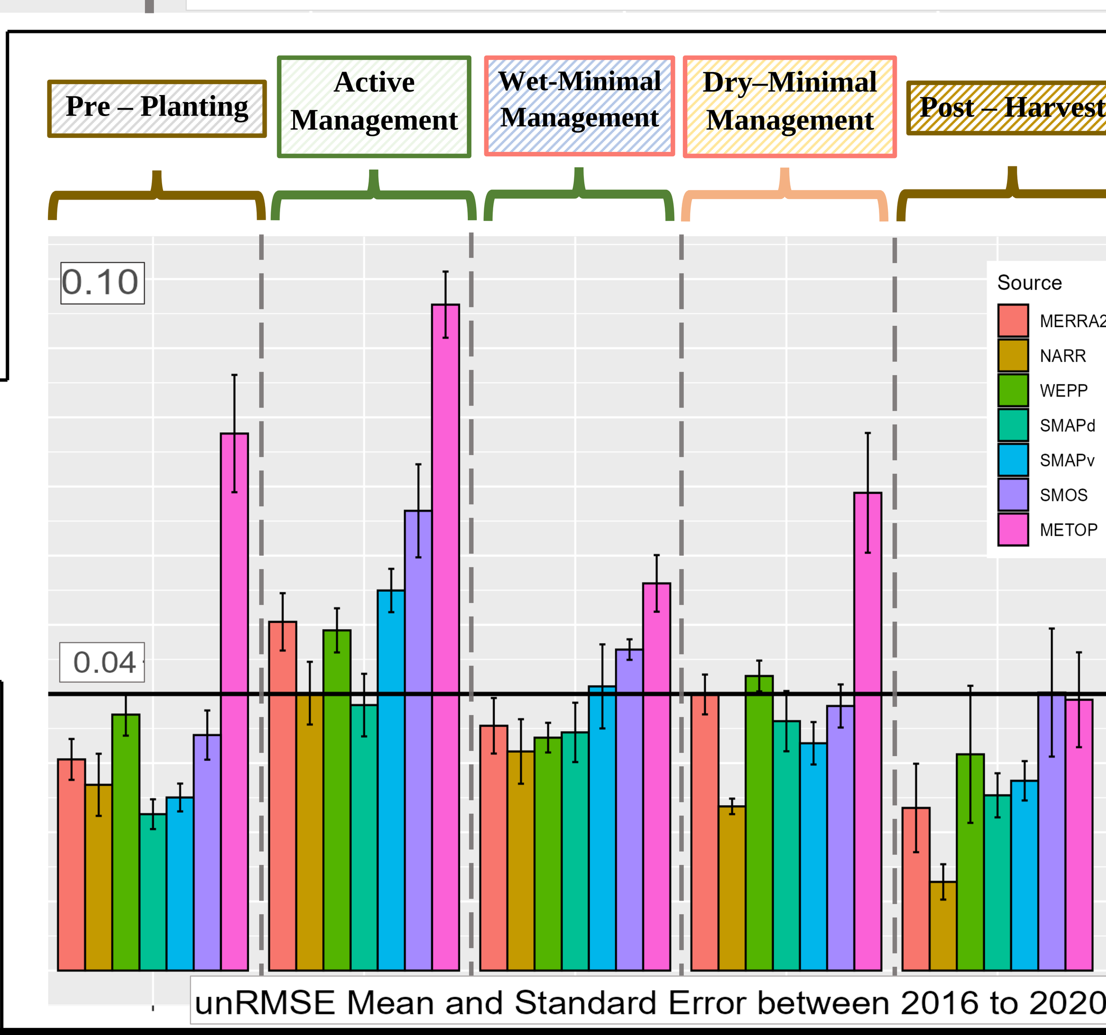


Figure 4 (above): Bias of soil moisture estimators to in-situ site measurements based on the crop growth and management timeline. Each bar represents the average bias with its standard error from 2016 to 2020.

Figure 5 (right): Unbiased Root Mean Square Error (unRMSE) for all estimators. Each bar represents the average unRMSE with its standard error from 2016 to 2020.



Results:

- On average, the two passive satellite products have a dry bias.
- However, the active satellite and reanalysis models have a wet bias.

Conclusion:

- On average, there is consistency in bias (dry or wet) throughout the year for a given estimator, but the magnitude changes.
- On average, there is some consistency in unRMSE at or above the threshold of 0.04 $[\mathrm{m^3 m^{-3}}]$, but the magnitude changes throughout the year.
- The crop–management–based timeline can show patterns associated with a year that would normally be "hidden" in an annual validation.

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