Developing Integrative Soil Moisture Products to Improve Drought Monitoring in the United States

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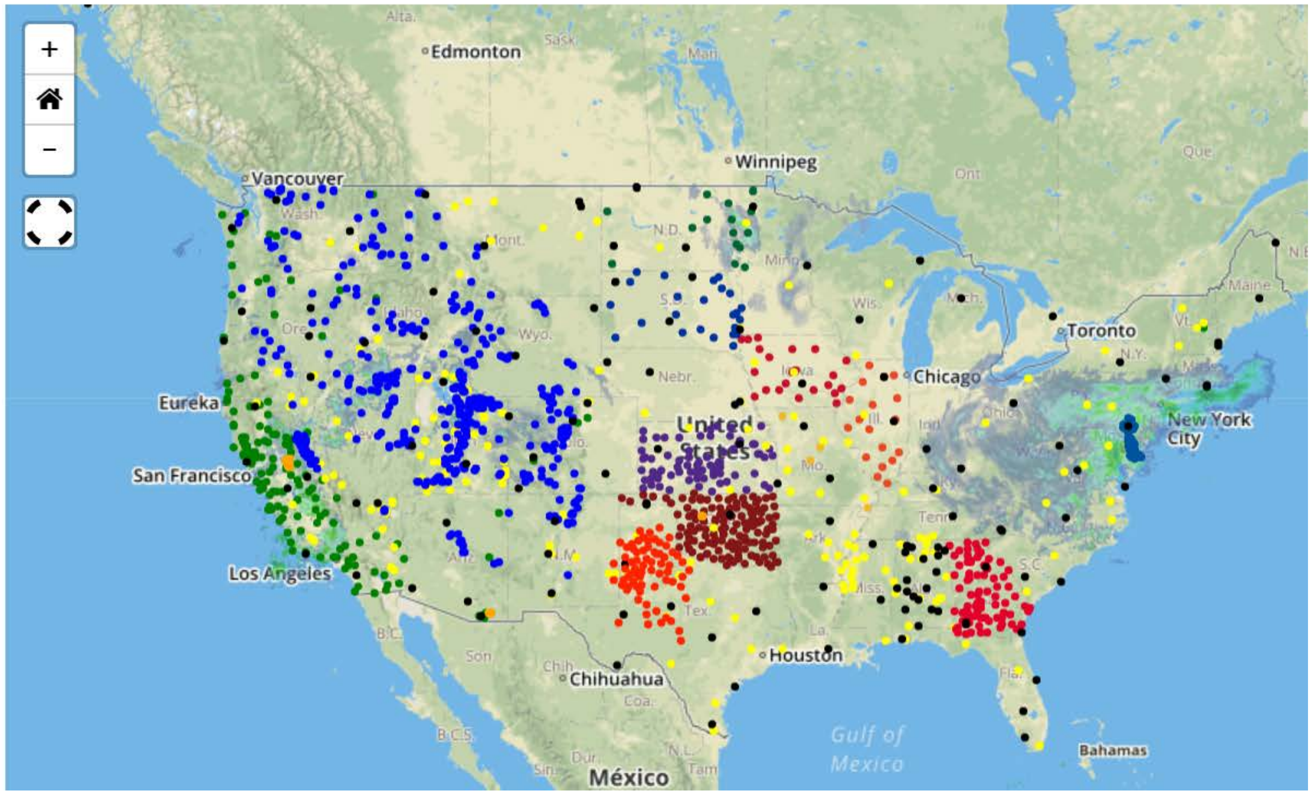
I saw you,
I knew
-Winnie the Pooh

National Soil Moisture Network

- Daily observations from 1,500+ *in situ* monitoring stations

Soil Moisture Networks

- Delaware Environmental Observing System
- Illinois Climate Network
- Iowa Environmental Mesonet
- Kansas Mesonet
- Missouri Agricultural Weather Database
- North Dakota Agricultural Weather Network
- NOAA HMT
- Oklahoma Mesonet
- SCAN
- Snotel
- SOILSCAPE
- South Dakota Mesonet
- University of Georgia Weather Network
- USCRN
- West Texas Mesonet



nationalsoilmoisture.com

Current Project Objectives

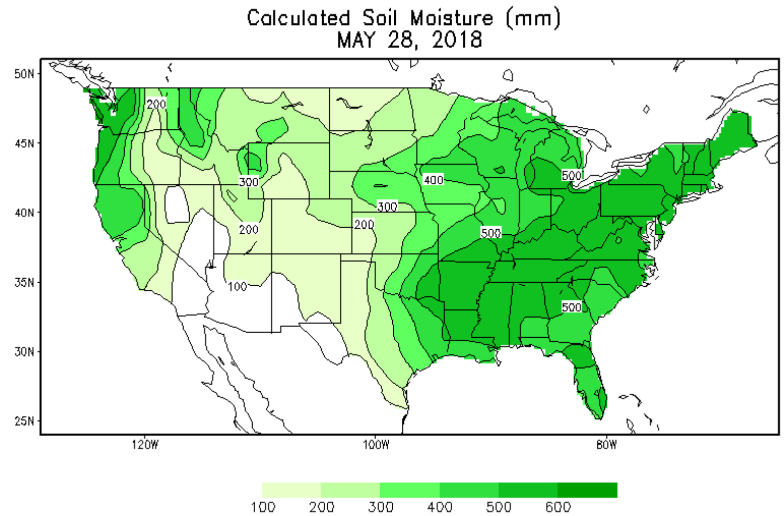
NA17OAR4310148

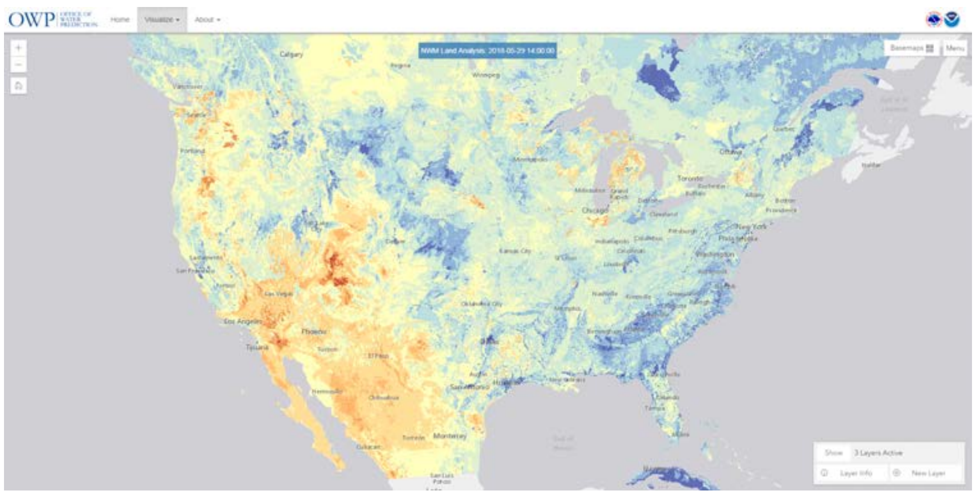
Leverage ongoing NSMN efforts, integrate diverse sources of soil moisture information to improve near real-time drought monitoring across CONUS

1. Assess the fidelity of various *in situ* soil moisture observations and satellite remote sensing- and model-based soil moisture products
2. Integrate remote sensing and modeled soil moisture information with *in situ* measurements to develop a national-scale, near-real time soil moisture product for drought monitoring
3. Design and develop a proof-of-concept cyber infrastructure for delivery of the gridded soil moisture product

Soil Moisture Drought Monitoring – Models

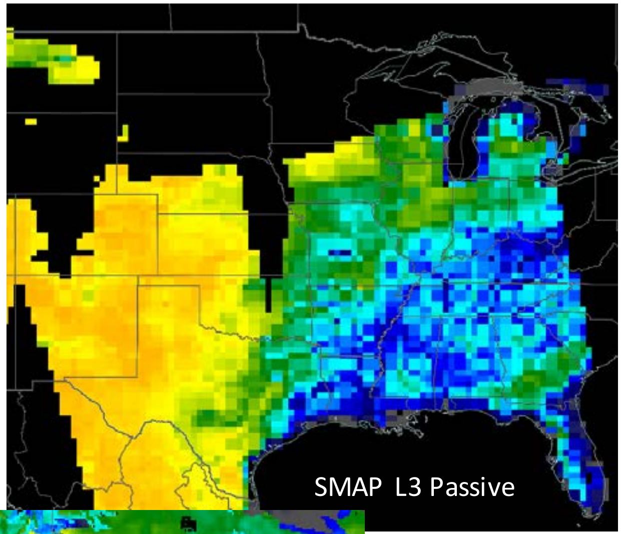
- CPC one-layer "leaky bucket" hydrological model
- NLDAS-2
- National Water Model – WRF-Hydro
- Noah MP
- SMAP L4 surface and root zone

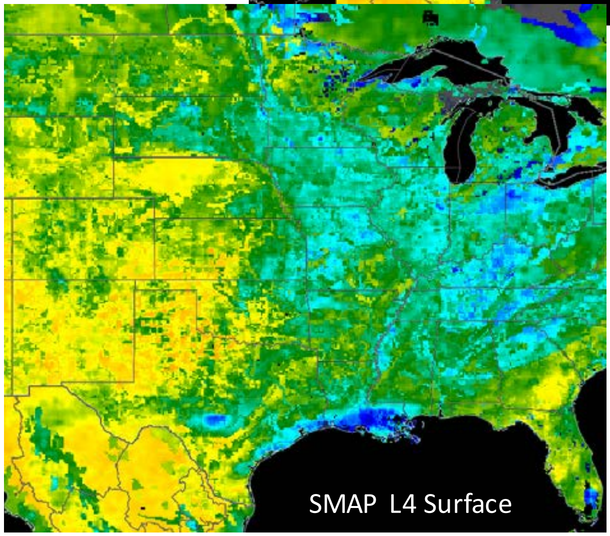




Soil Moisture Drought Monitoring – Remote Sensing

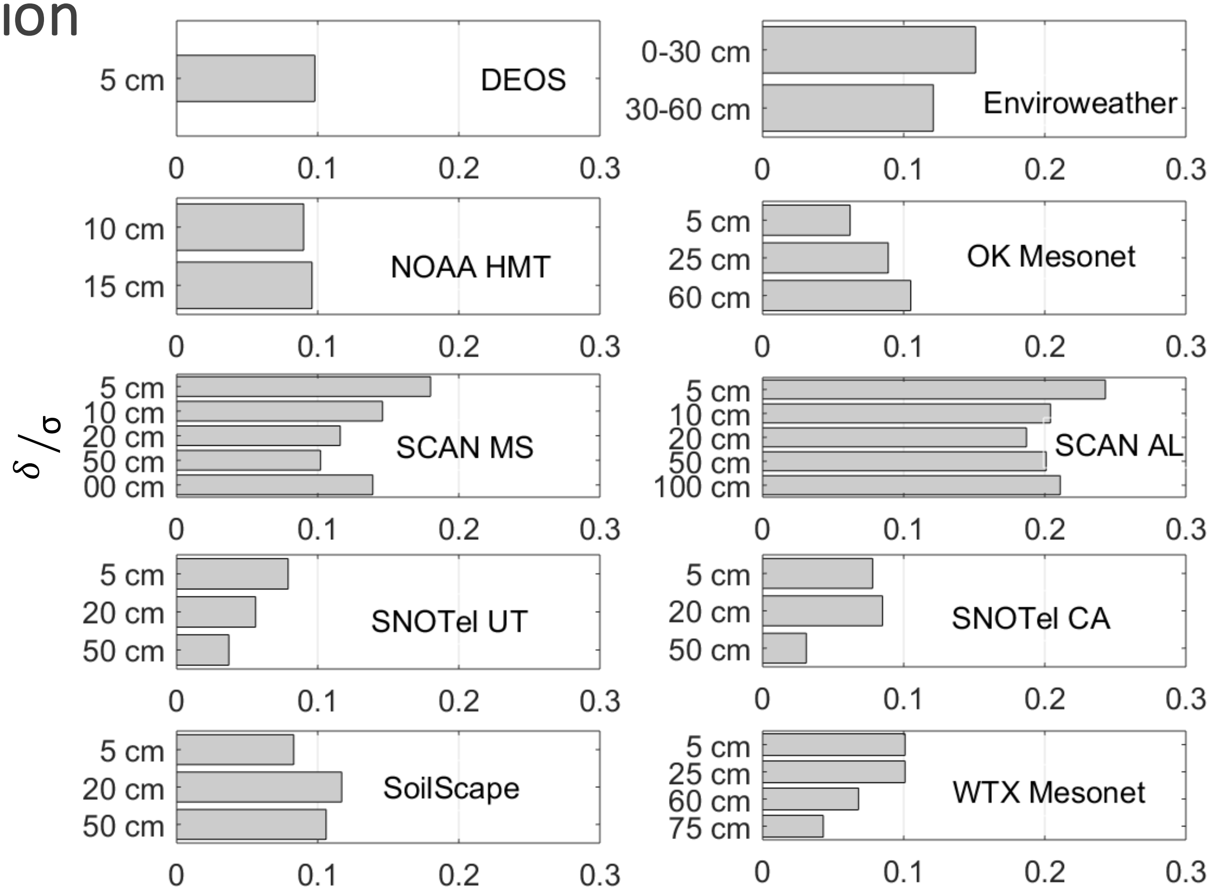
- SMAP L3 Radiometer
- SMOS L3 Global Map
- SMAP/Sentinel-1 L2 Radiometer/Radar
- ESA CCI merged passive/active





Objective 1: *In Situ* Data Validation

- Relative observation error estimated as the ratio of error variance (δ) to real variance (σ) of daily soil moisture (Dirmeyer *et al.* 2016)
- $^{\delta}/_{\sigma}$ related to autocorrelation of daily soil moisture
- Surficial soil moisture exhibits higher proportion of random observation error
- Further results suggest in-ground observations exhibit less relative observation error than surface-based remote sensing observations



Relative observation error of daily, summer (JJA) soil moisture from *in situ* monitoring networks.

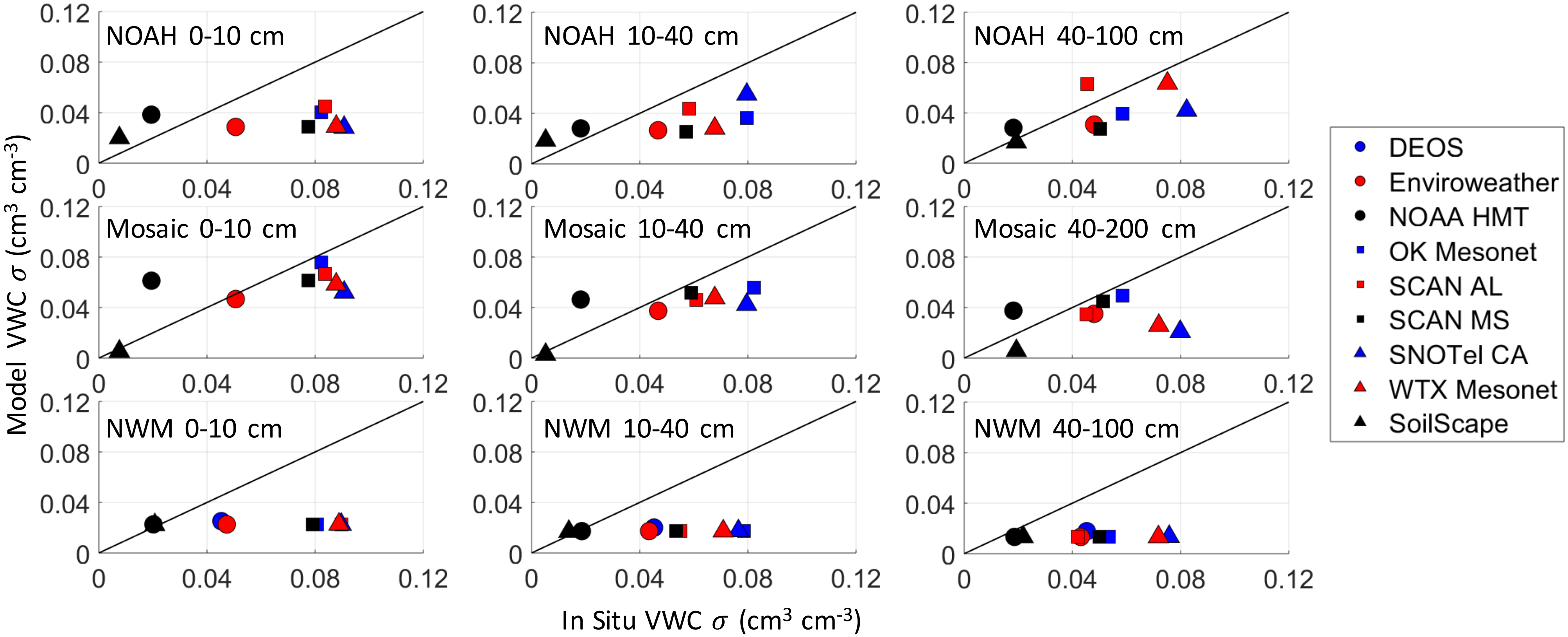
Comparison Methods

1. Determine a fixed period for each network over which to compare model/satellite datasets
2. Vertically interpolate observations to model layers, use shallowest sensor (< 10 cm) for satellites
3. Average daily soil moisture (VWC or percentiles of VWC) over all *in situ* stations within each model/satellite grid cell

	DEOS	Enviroweather	NOAA HMT	OK Mesonet	SCAN (MS & AL)	SNOTel (UT & CA)	SoilScape	WTX Mesonet
CPC	4	10	10	10	10	10	5	10
NLDAS-2	4	10	10	19	14	14	5	16
NWM	4	10	10	10	10	10	5	10
SMAP L4	3	3	3	3	3	3	3	3
SMAP L3	3	3	3	3	3	3	3	3
SMOS L3	4	7	7	7	7	7	5	7
ECV	4	10	10	19	14	14	5	16
SMAP/Sent-1	3	3	3	3	3	3	3	3

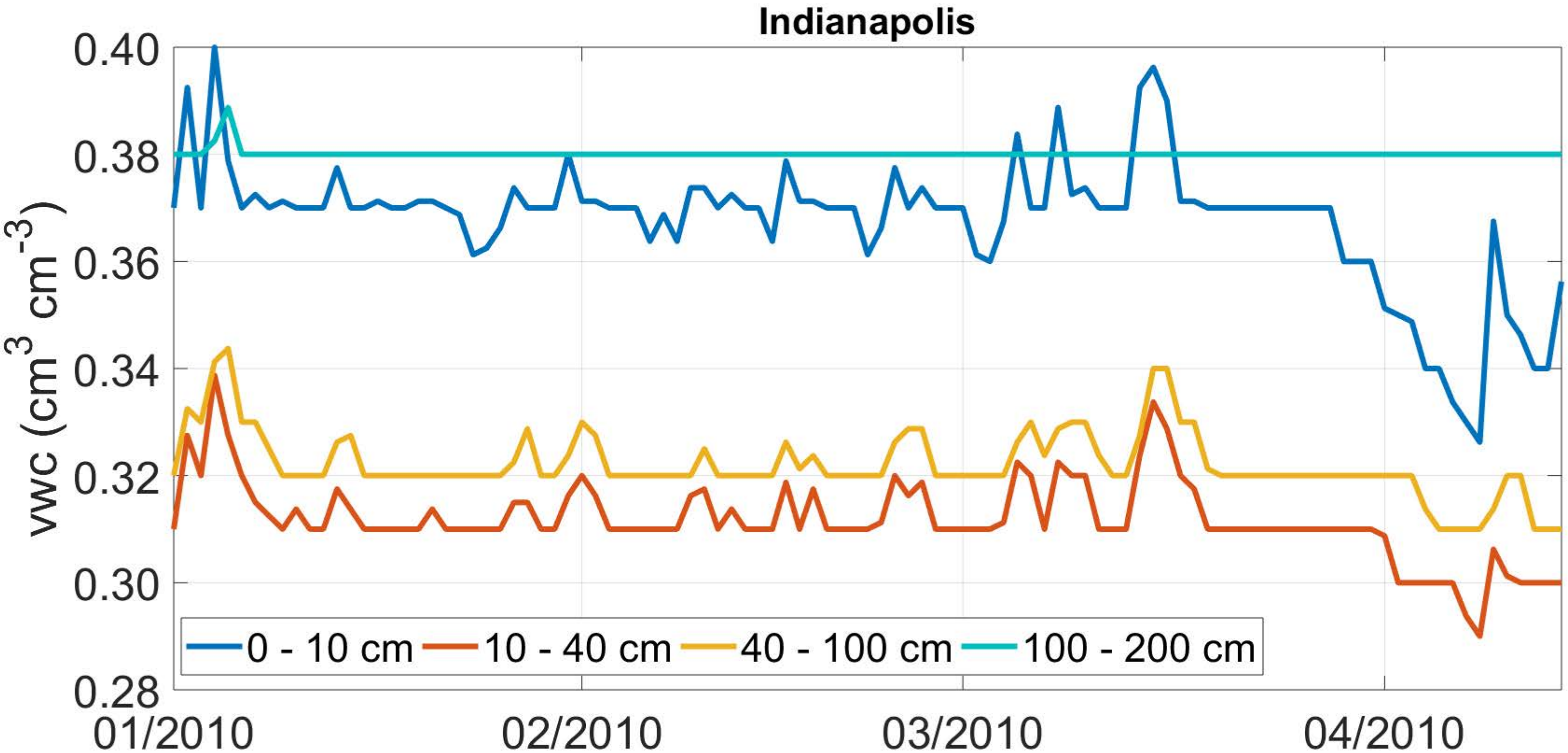
Record length (years) for *in situ*-model/satellite soil moisture comparison.

Soil Moisture Dataset Validation – Model Variability

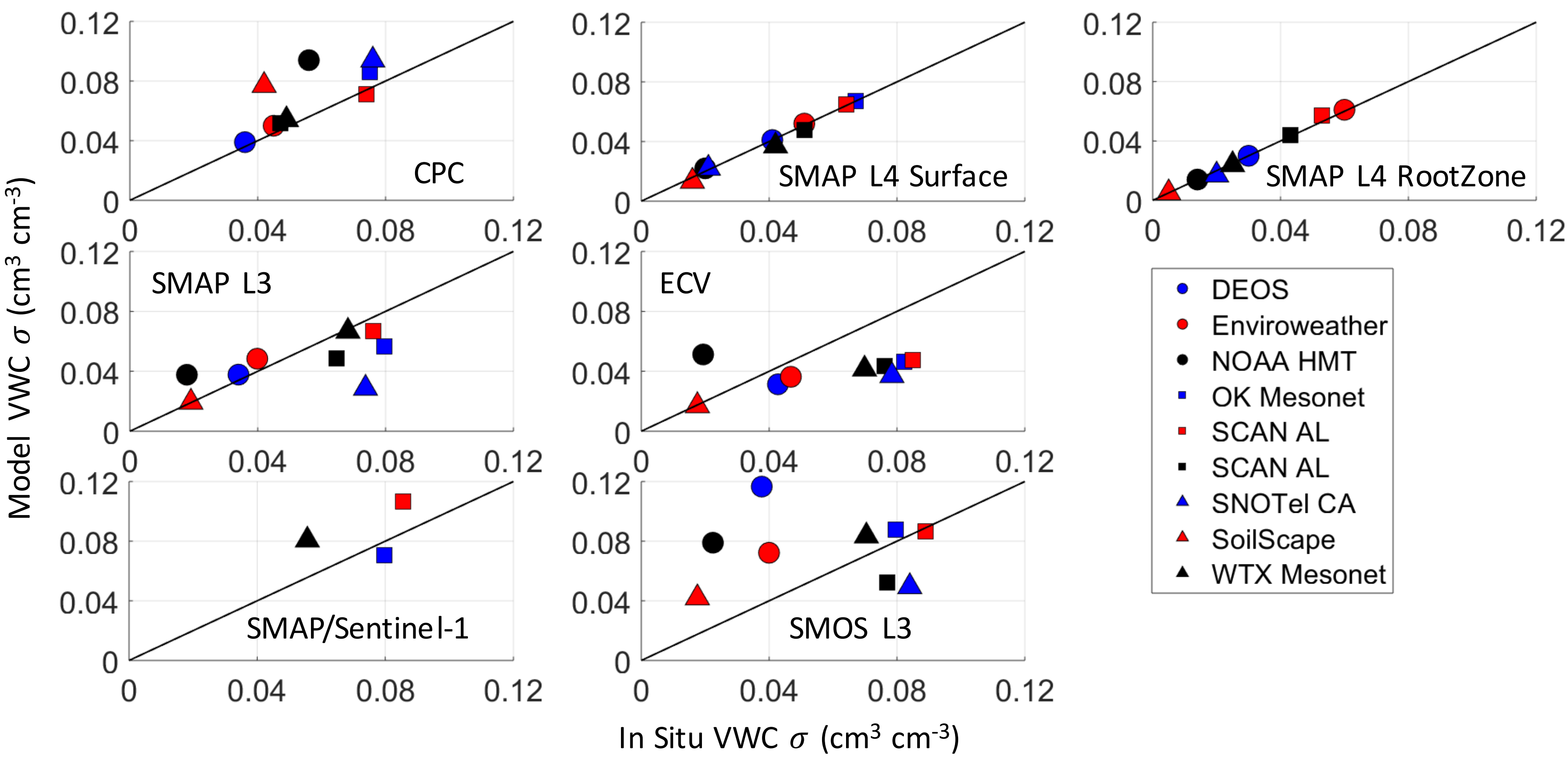


Standard deviation of daily summer (JJA) soil moisture from model datasets (y-axis) and *in situ* stations (x-axis).

NWM Variability

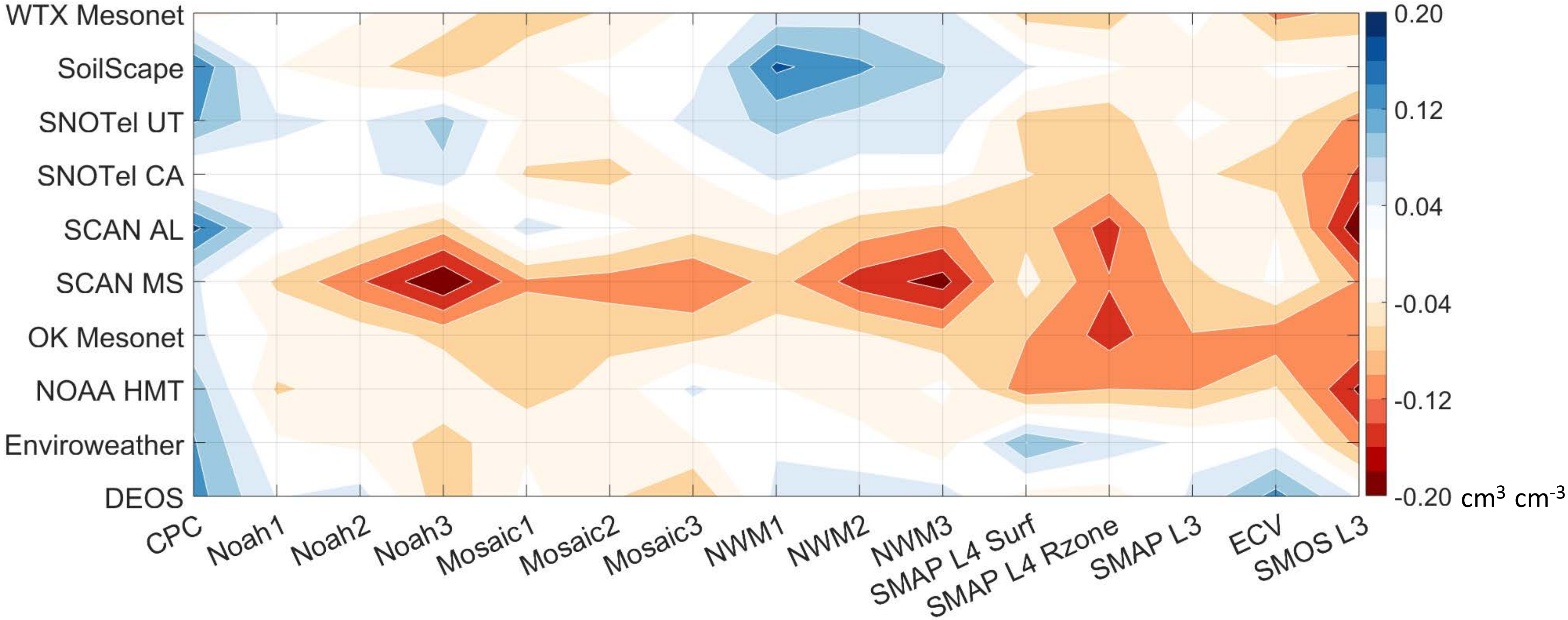


Soil Moisture Dataset Validation – Satellite Variability



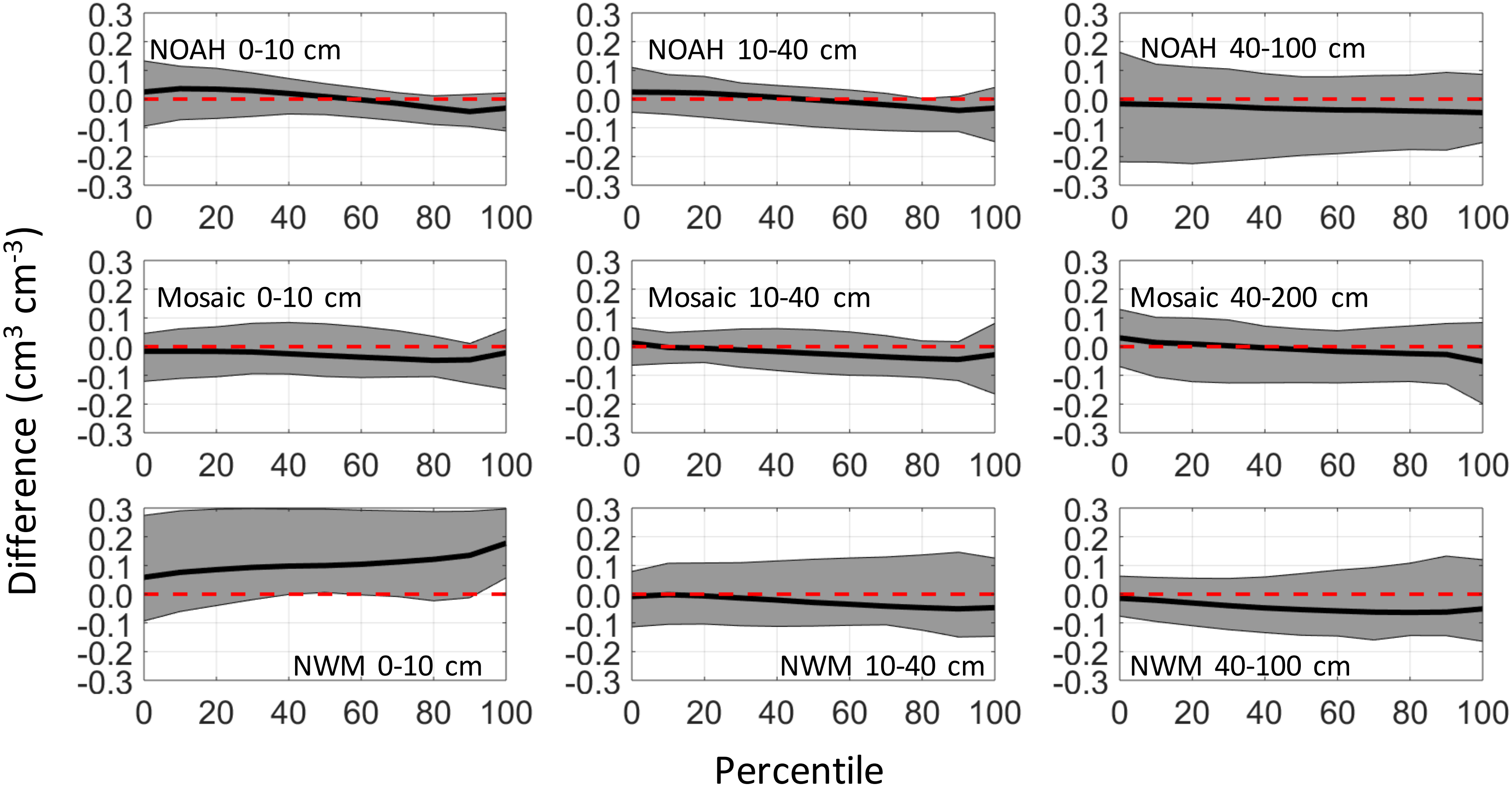
Standard deviation of daily summer (JJA) soil moisture from satellite datasets (y-axis) and *in situ* stations (x-axis).

Soil Moisture Dataset Validation – Difference (bias)

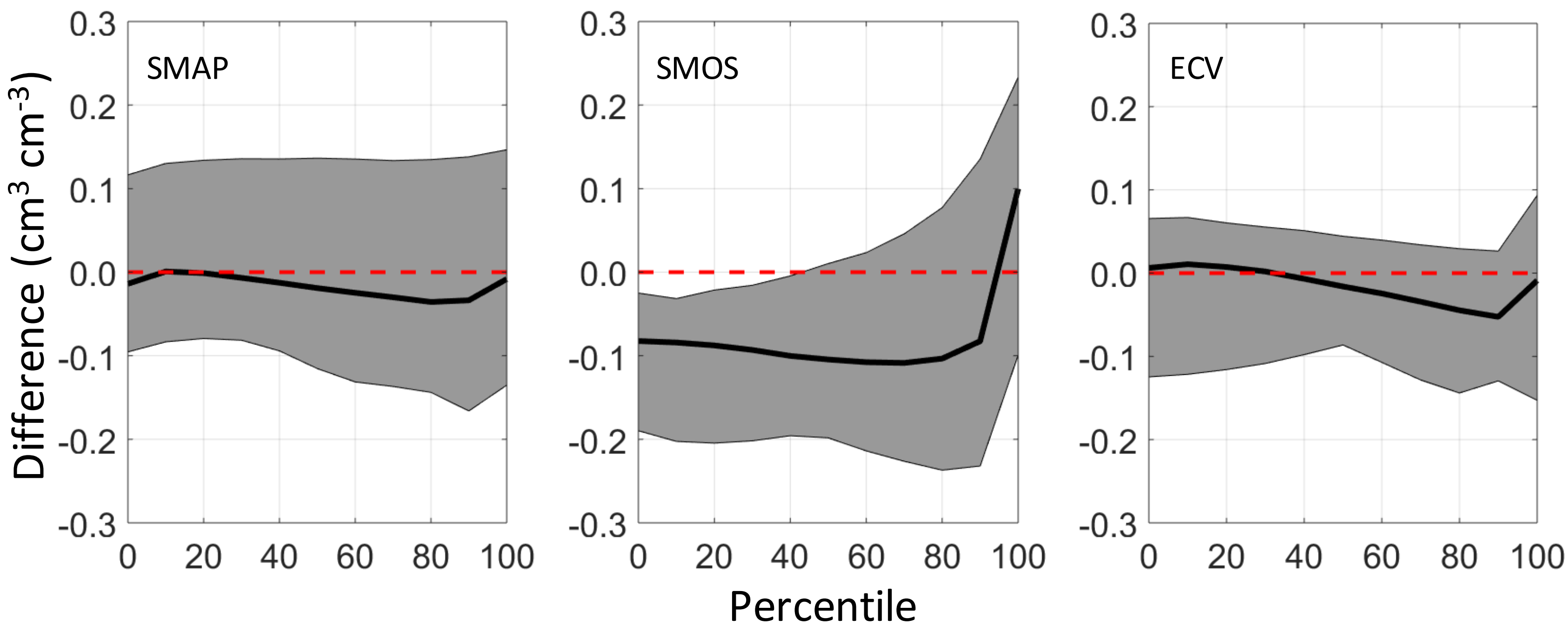


Model/Satellite JJA VWC bias, by network and dataset.

Model Validation – Difference by Percentile

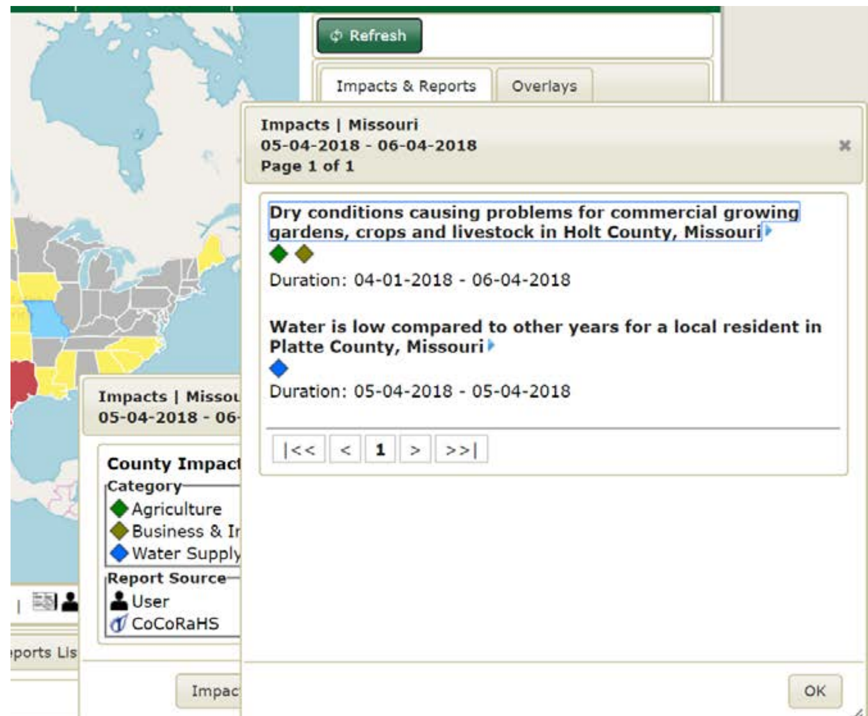


Satellite Validation – Difference by Percentile



Drought-focused Comparison: Drought Impacts

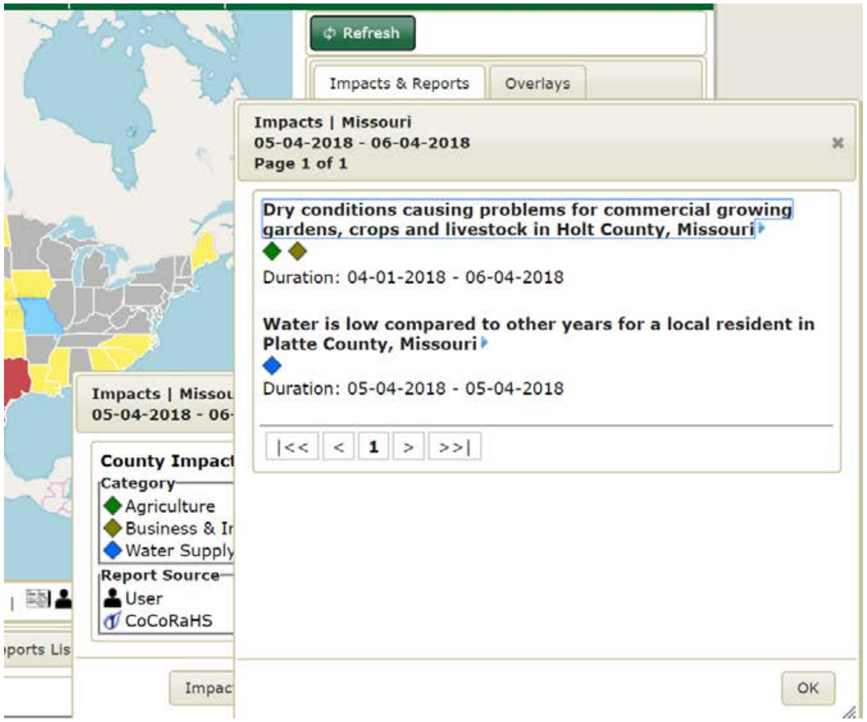
1. NDMC Drought Impact Reporter: county-level impact reports
2. Reports collected (including impact start date) for 2008-2017 for all counties in which an *in situ* station resides
3. Duplicate impacts, impacts that occurred at great lags to drought conditions were removed
4. Daily VWC at all *in situ* stations or model/satellite grid cells over the counties averaged to achieve one, network-level dataset
5. Percentiles computed from daily VWC record, averaged to a weekly time step



http://droughtreporter.unl.edu/map/

Drought-focused Comparison: Drought Impacts

1. Calculate rate at which datasets show drought conditions (< 20th percentile) corresponding to drought impacts
2. Drought "hit rates" computed for lead times ranging from 1 to 8 weeks prior to reported impact start date
3. Drought impact accuracy score is the integral of all drought hit rates, from 1 to 8 week leads; provides a measure of the reliability of datasets to show drought leading up to a drought impact



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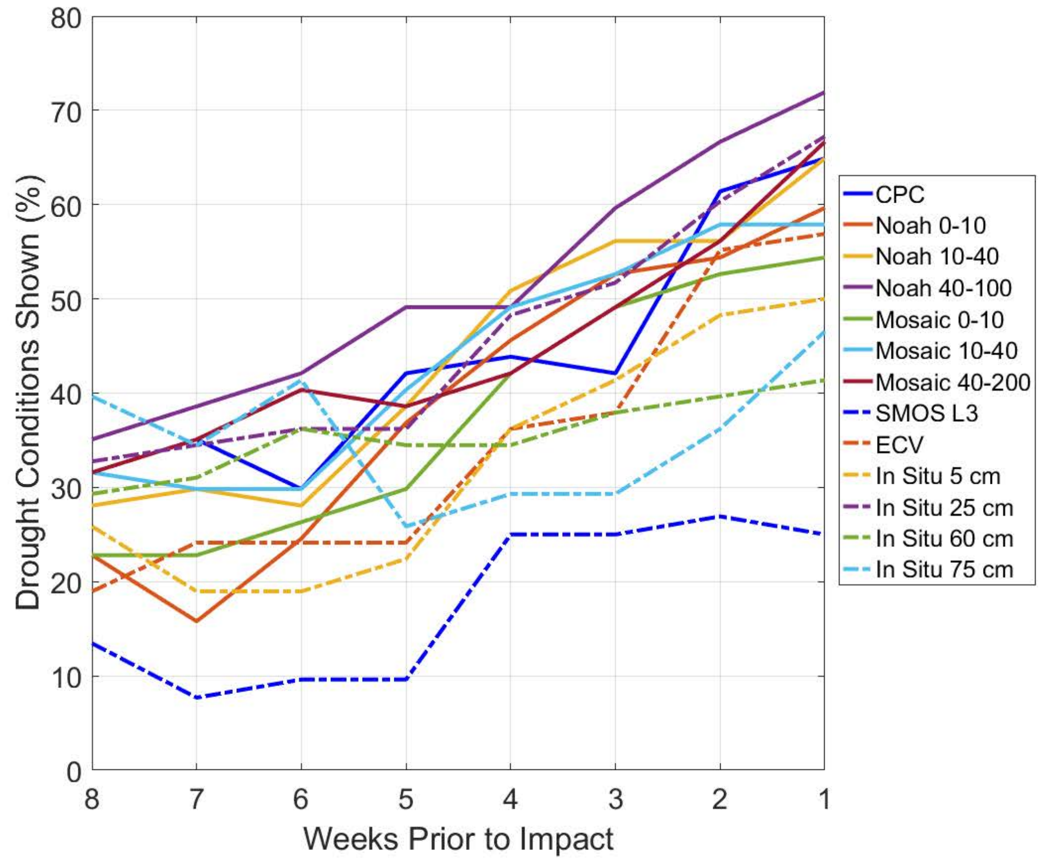
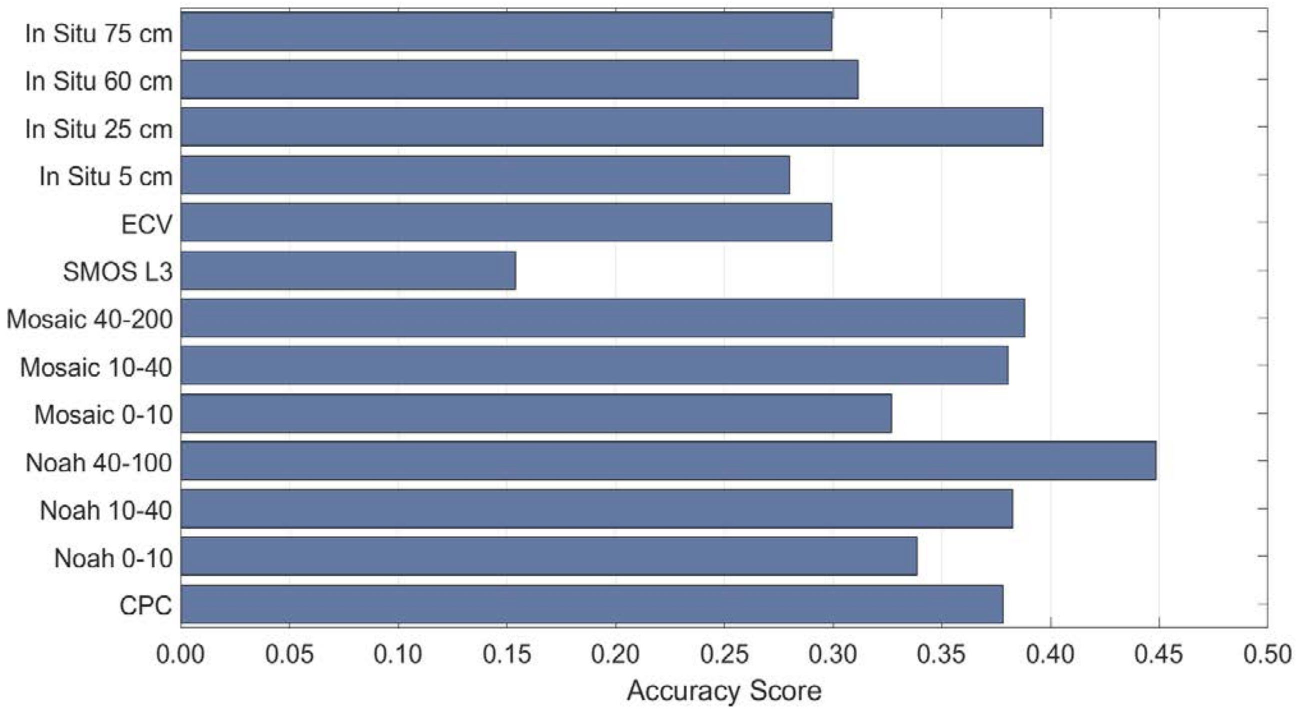
Drought-focused Comparison: Drought Impacts

- Figure shows the percent of drought impacts reported in West Texas for which each soil moisture product showed drought conditions (< 20th percentile), as a function of the time (# weeks) prior to the reported drought impact.



Drought-focused Comparison: Drought Impacts



Top panel shows accuracy scores by dataset for drought impacts over SCAN AL network. Right table shows the average drought impact scores for all datasets, averaged over all networks.

Dataset	Average Drought Score
CPC	0.502
Noah 0-10 cm	0.403
Noah 10-40 cm	0.441
Noah 40-100 cm	0.474
Mosaic 0-10 cm	0.471
Mosaic 10-40 cm	0.490
Mosaic 40-200 cm	0.505
SMAP L4 Surface	0.395
SMAP L4 Root Zone	0.419
SMAP L3	0.288
SMOS L3	0.222
ECV	0.303
In Situ 0-10 cm	0.340
In Situ 10-20 cm	0.359
In Situ 20-50 cm	0.339
In Situ 50-100 cm	0.453

Conclusions so far…

- Ratio of error variance (Dirmeyer *et al.* 2016) a solid means for assessing the fidelity of *in situ* networks/stations
- NDMC drought impacts provide tangible evidence of drought; however, working with impact reports comes with several complexities/difficulties
- For most areas: 50-100 cm *in situ* sensors show drought corresponding to reported impacts at higher rates than more surficial layers
- Models – particularly 10-100 cm layers – show drought corresponding to reported impacts at higher rates than satellite datasets
- SMAP L4 products match best *in situ* daily VWC variability; SMAP L3 exhibits the lowest difference (bias)

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Next Steps

- **Soil moisture percentile comparison**
- **USDM drought status comparison**
- **Expansion to 1,500+ stations**
- **Development/application of integration methods**

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NOAA MAPP Modeling, Analysis, Predictions, and Projections
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