Standardizing USCRN Soil Moisture Observations For Near Real Time Applications

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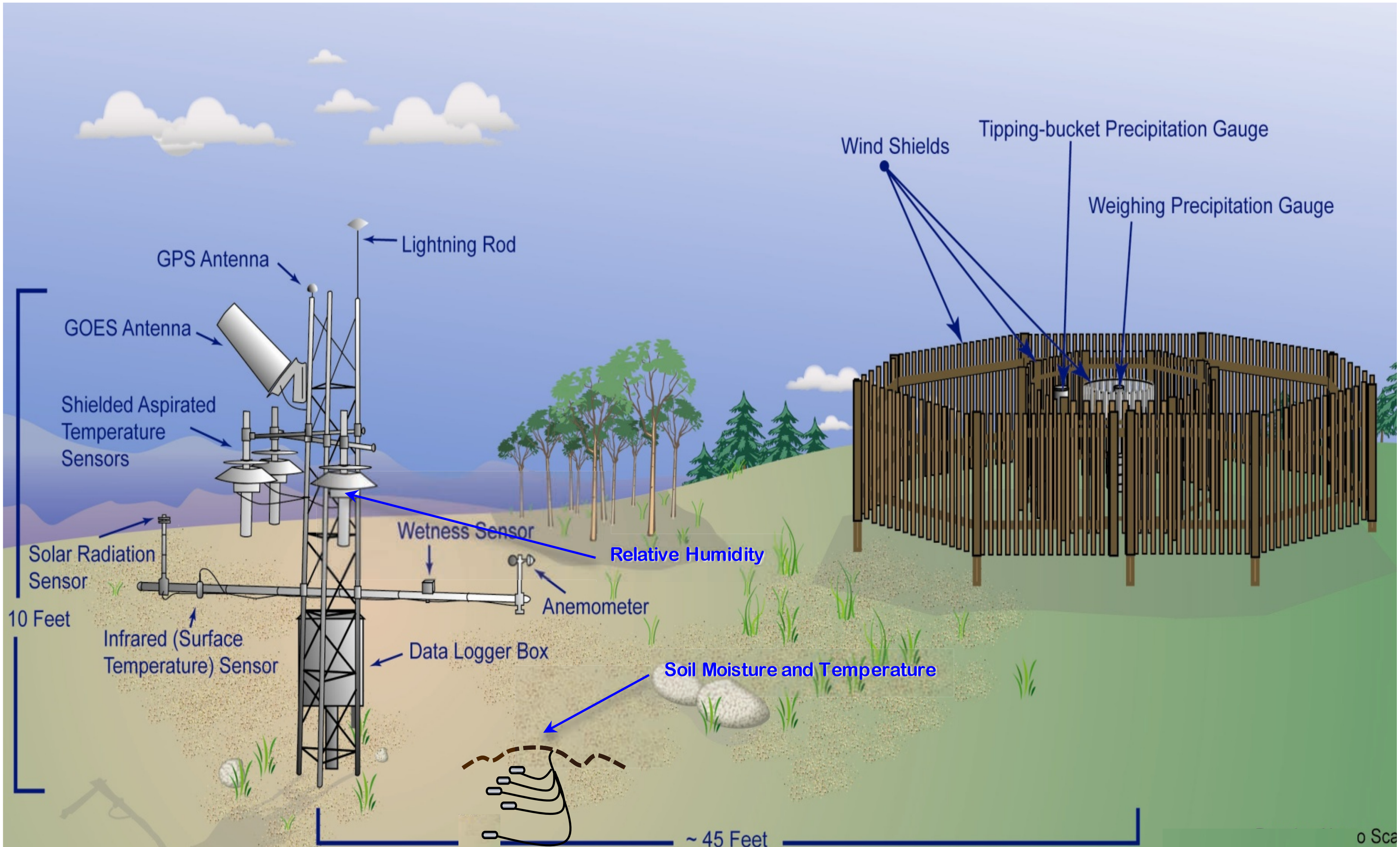
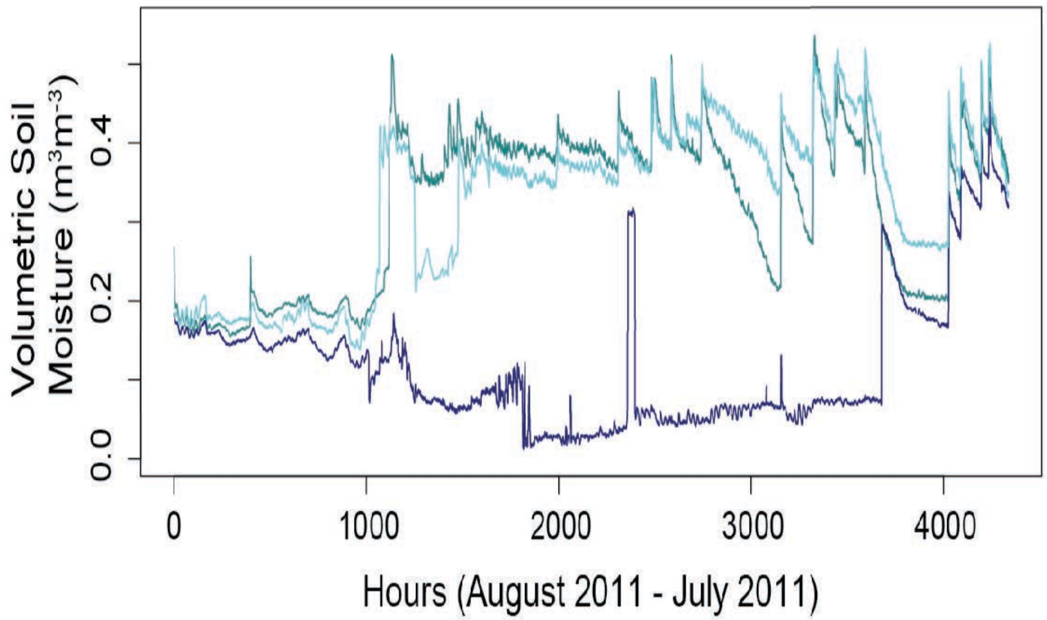
The USCRN is configured to monitor above and below ground conditions from open areas.



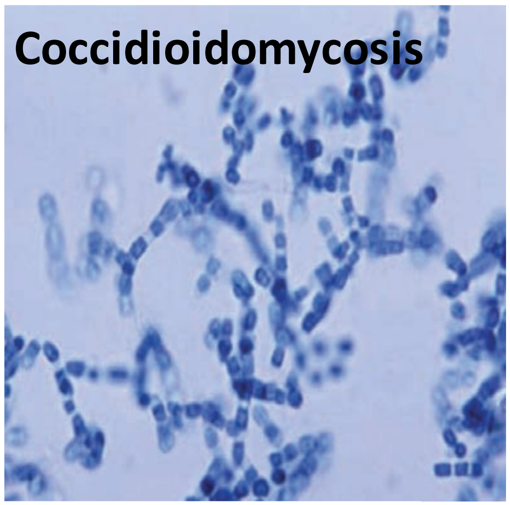
Soil conditions (moisture and temperature) are observed **redundantly** at each depth from three holes, using the Stevens Hydra probe.

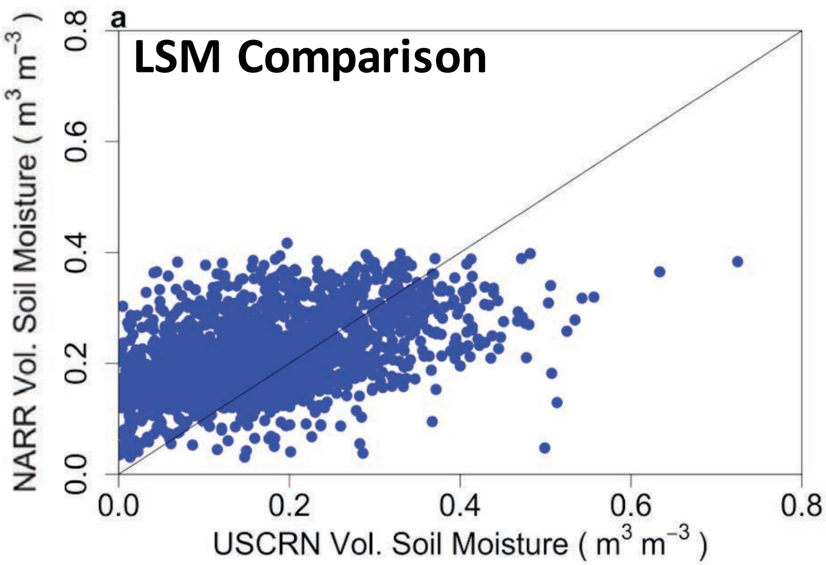
Redundancy aides quality control efforts.

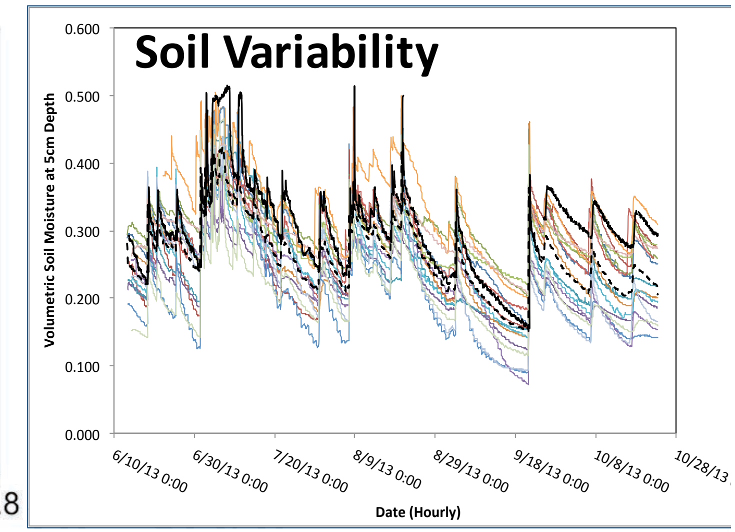
- Detect degraded/failing sensors
- Preserves data continuity
- Identify catastrophic events
- Manual reviews are conducted monthly

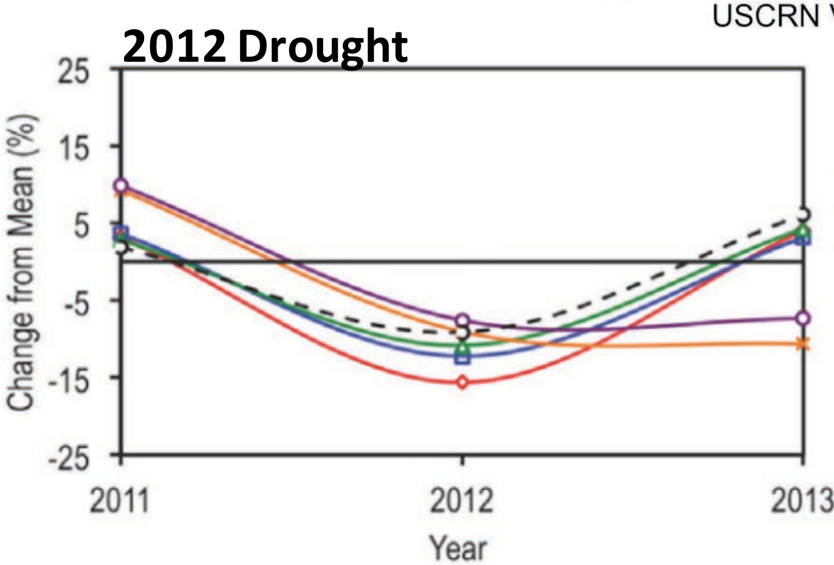


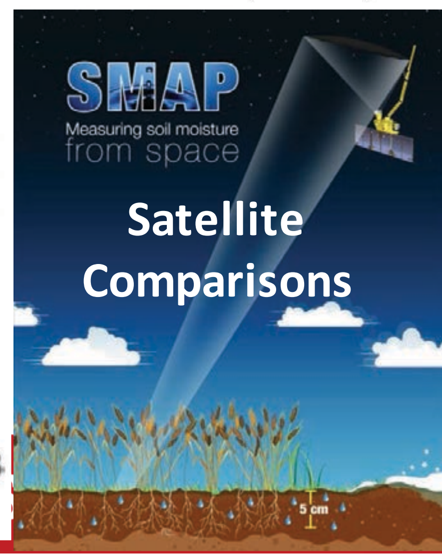
USCRN scientists have applied soil observations in numerous applications from modeling and satellite comparisons to soil extremes and linkages to human health.

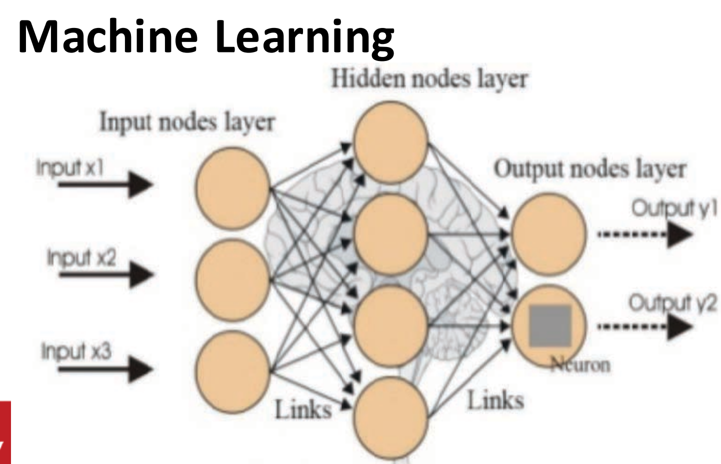




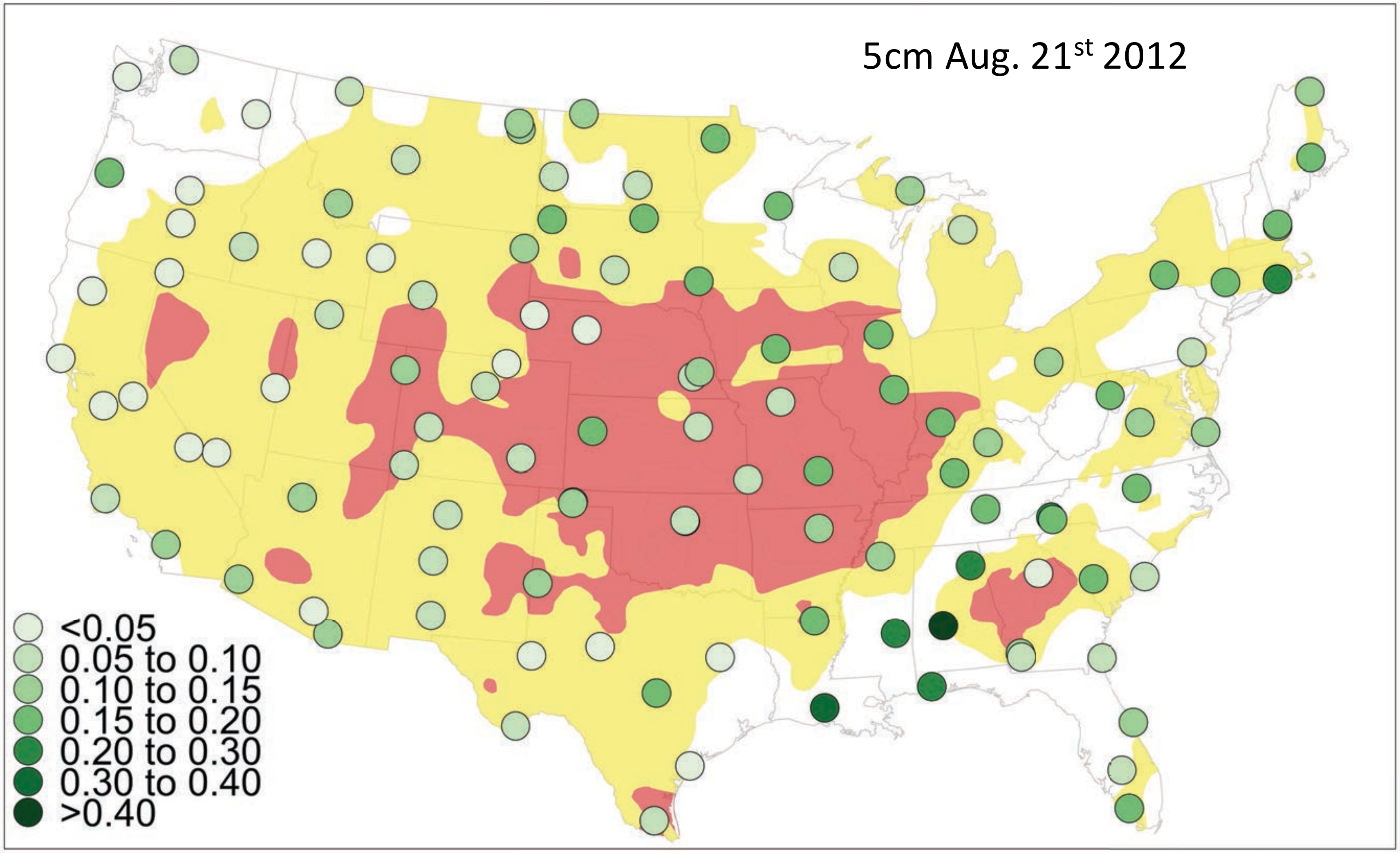








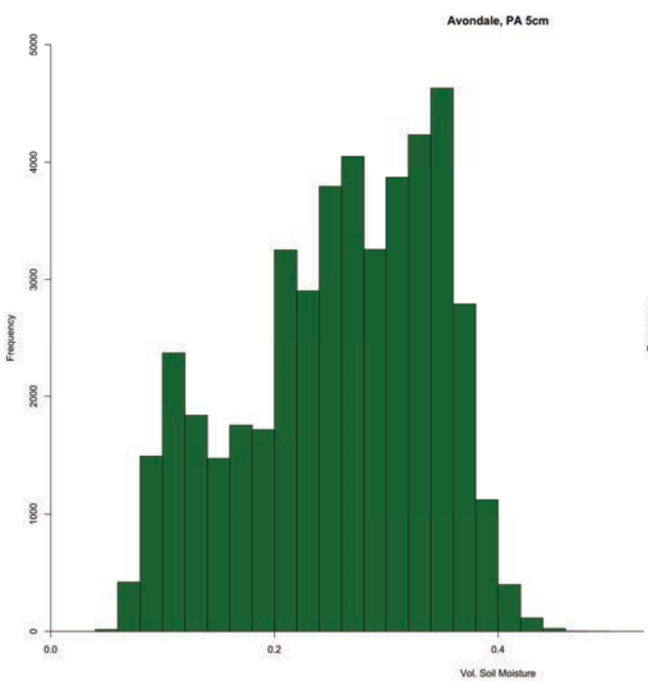
A reemerging theme was the sensitivity of soil moisture observations to location (i.e., soil type, vegetation cover and elevation) and local/regional climatic variations.

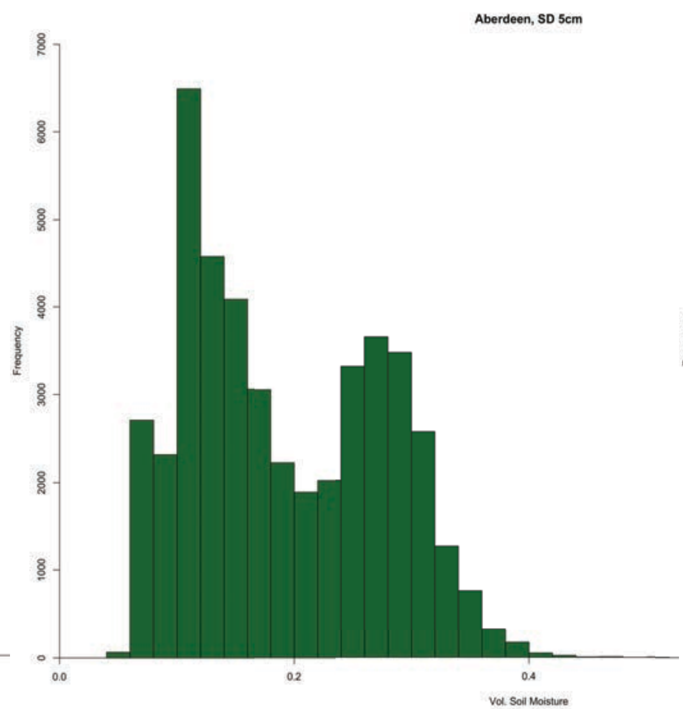


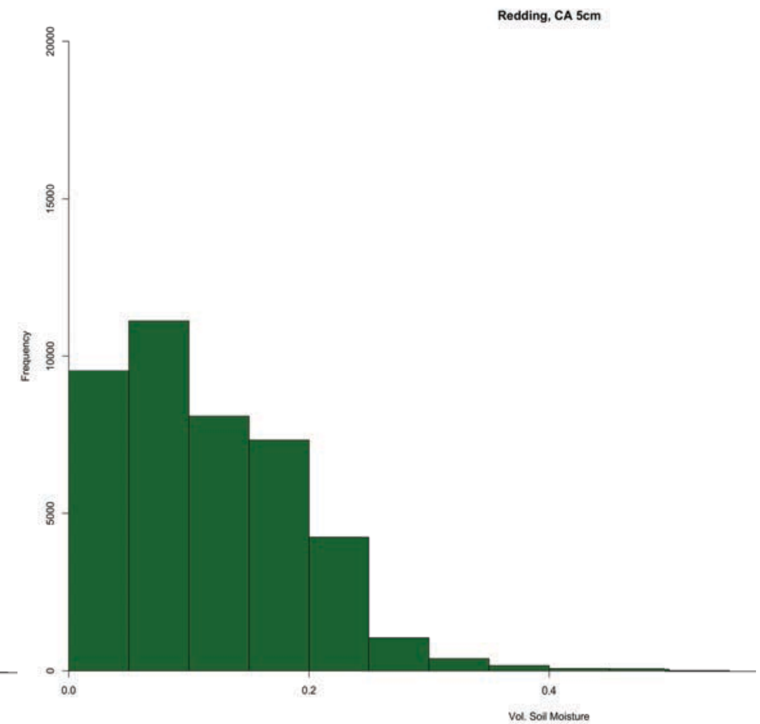
Standardizing Soil Moisture

One way to make these observations more meaningful is to place them into historical context by standardizing the measurements with respect to typical conditions.

- This is generally done with a 30 year dataset, which most soil monitoring networks lack





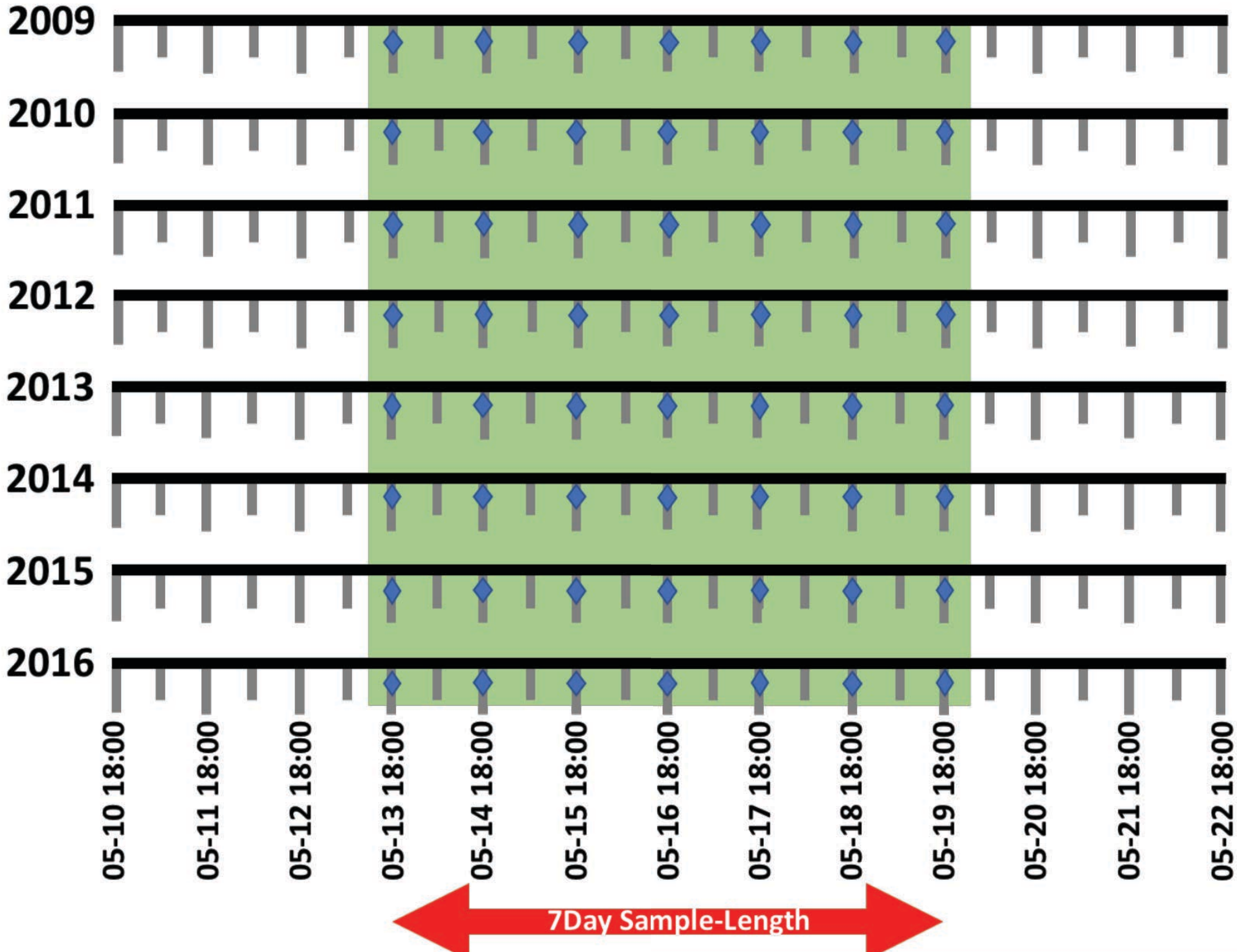


From the literature, it may be possible to estimate climatological conditions from shorter term datasets using a sampling approach described by Applequist et al. (2010) and Ford et al. (2016)

Sampling Approach

The sampling approach of Applequist et al. (2010), is an average of observations over a sampling window that spans across available years.

In this 7-Day example, a hourly soil moisture climatology for May 16th 18:00 UTC is computed from an average of the **56** (blue diamonds) hourly observations



Goals of Standardizing

The aim is to make soil moisture observations more useful in decision support, monitoring, and modeling applications, moreover; standardized dataset would ideally be available in **near-real** time at an **hourly frequency**.

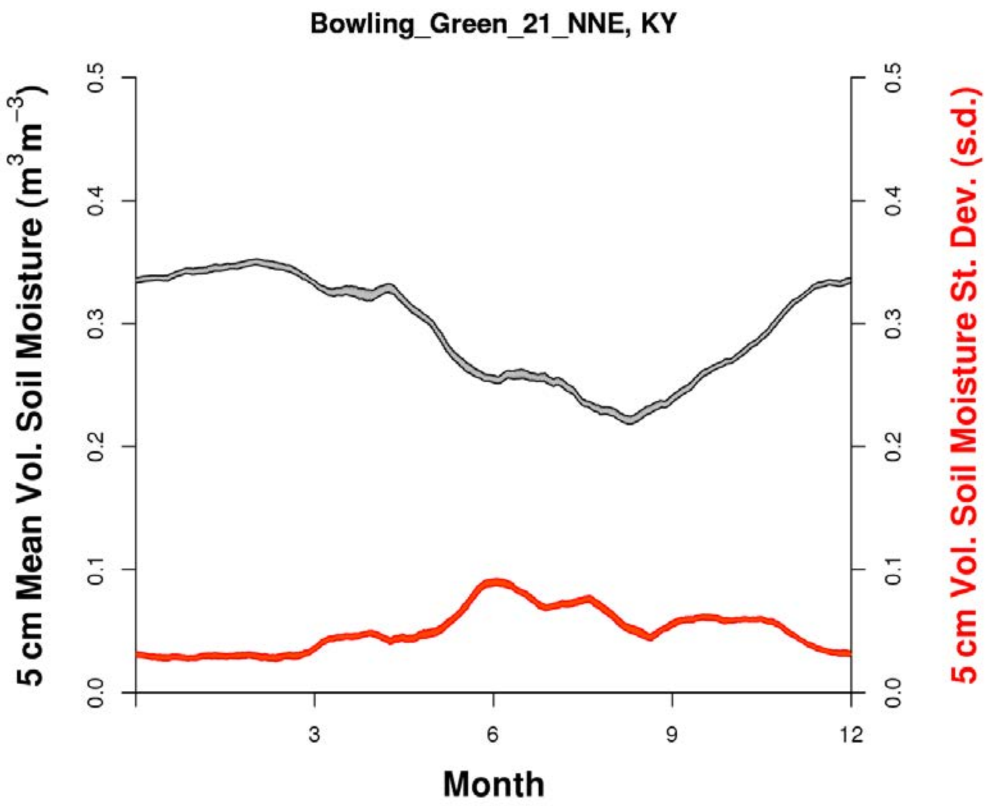
- Improves monitoring and enhances situational awareness.
  1. Availability of timely soil moisture conditions
  2. Permits a wide range of monitoring metrics (i.e., percent of drought-hours over the past week).

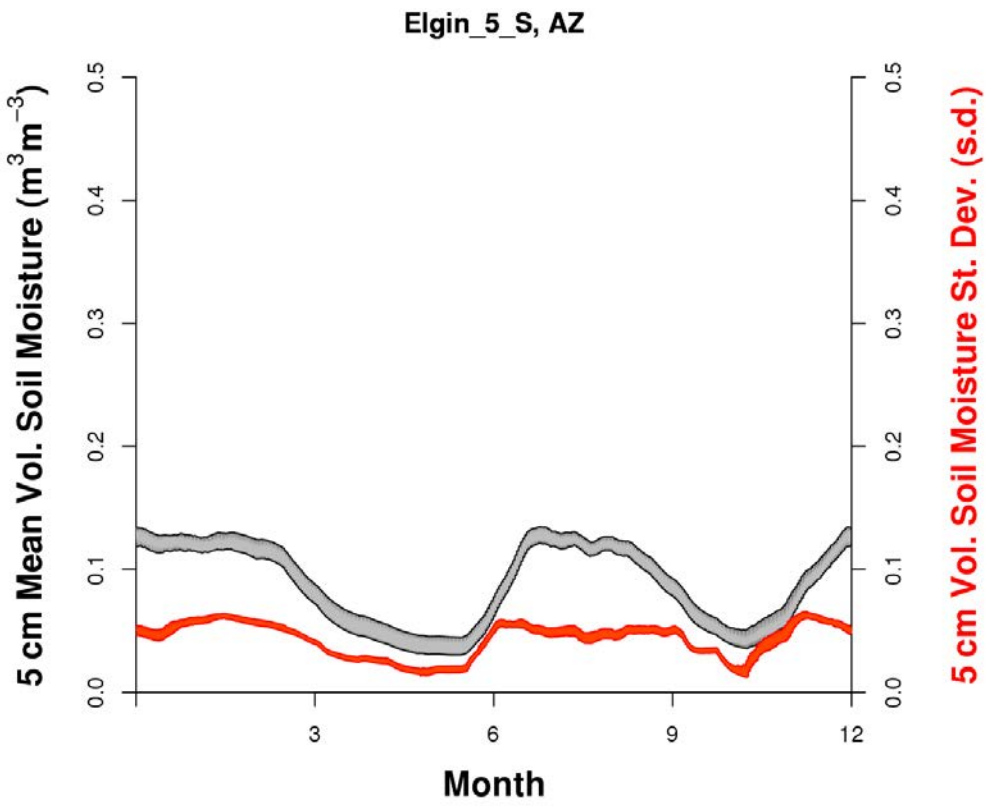
- Eases temporal alignment with remotely sensed products (i.e., satellite and radar).
  1. Non-stationary satellite passes can be periodic and short in duration.
  2. Hourly resolution radar products

- Allows for direct model comparisons and assimilation of soil moisture data from research to operational uses.
  1. Numerical models tend to report at hourly frequency
  2. Assimilation efforts routinely include variables representing conditions over specific hours (i.e., 3 or 6 hourly steps).

Climatology Examples

A 31-day sample length climatology for Bowling Green, KY and Elgin, AZ show reasonable results.



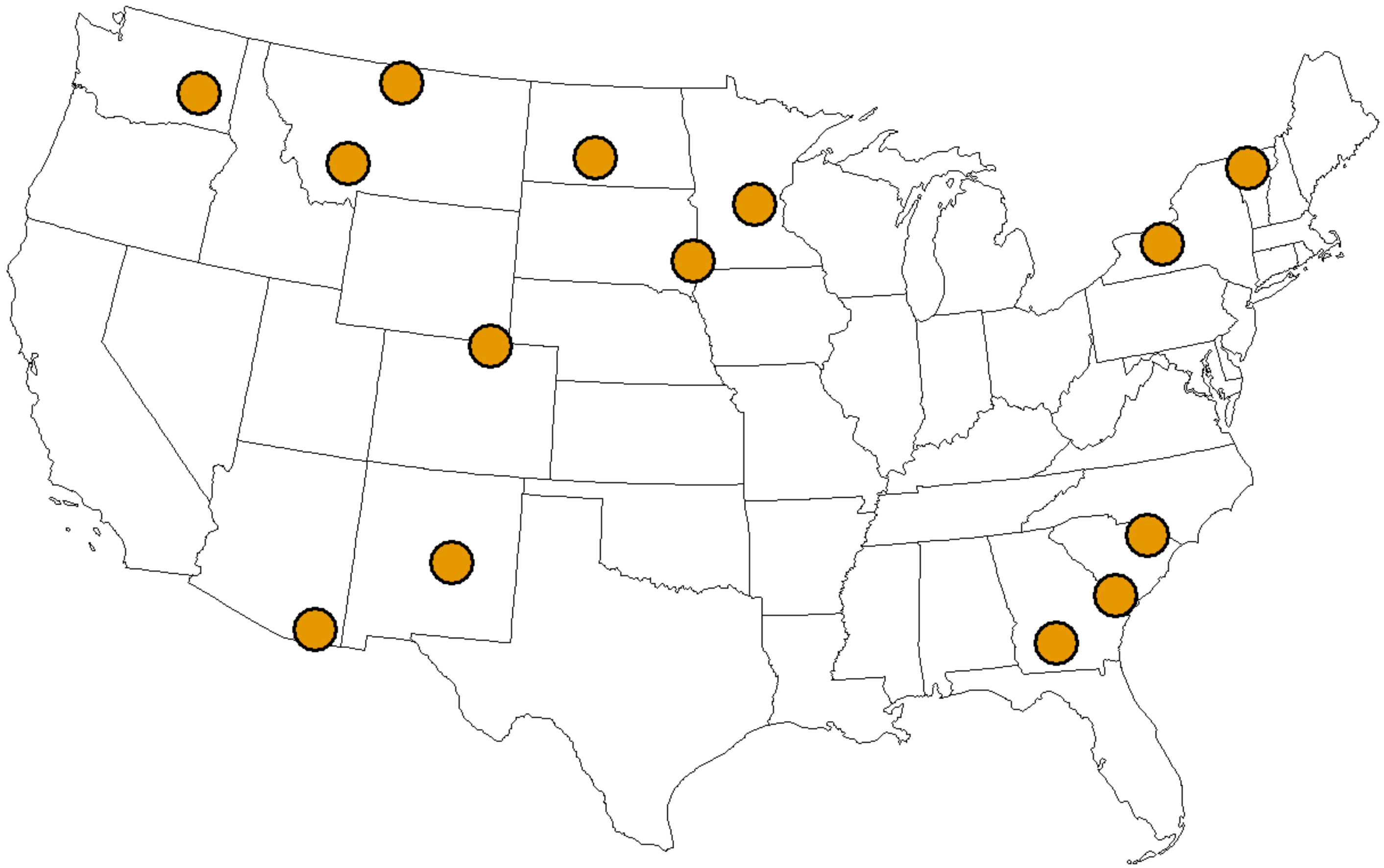


Climatology Validation

Sensitivity tests were evaluated at 14 SCAN sites to determine the appropriate sample length for hourly soil moisture climatologies, and the degree to which the most recent 7-years is representative of the longer dataset

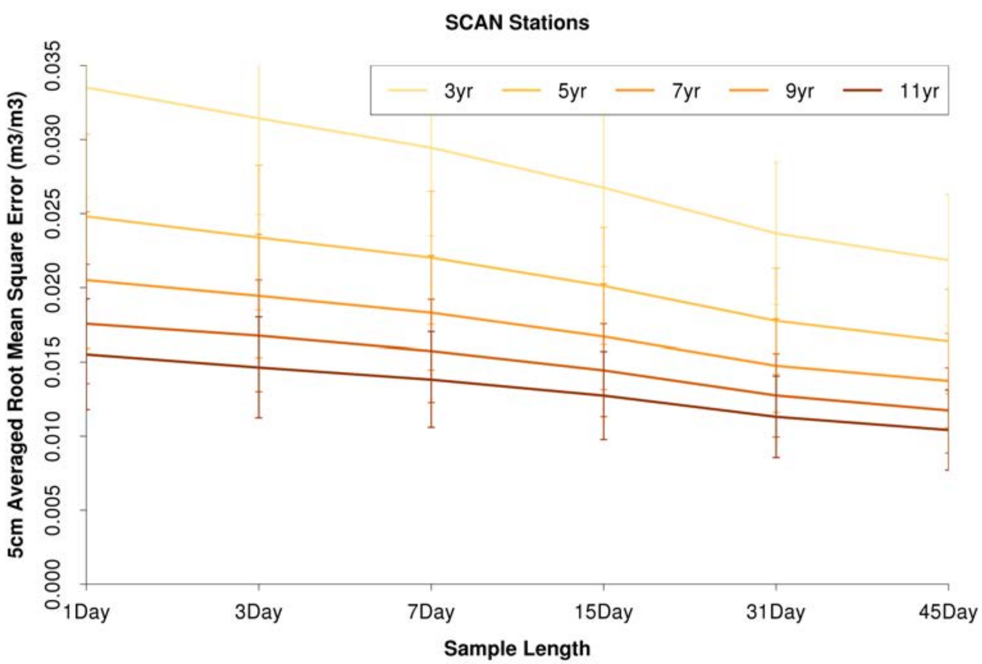
Monte Carlo simulations

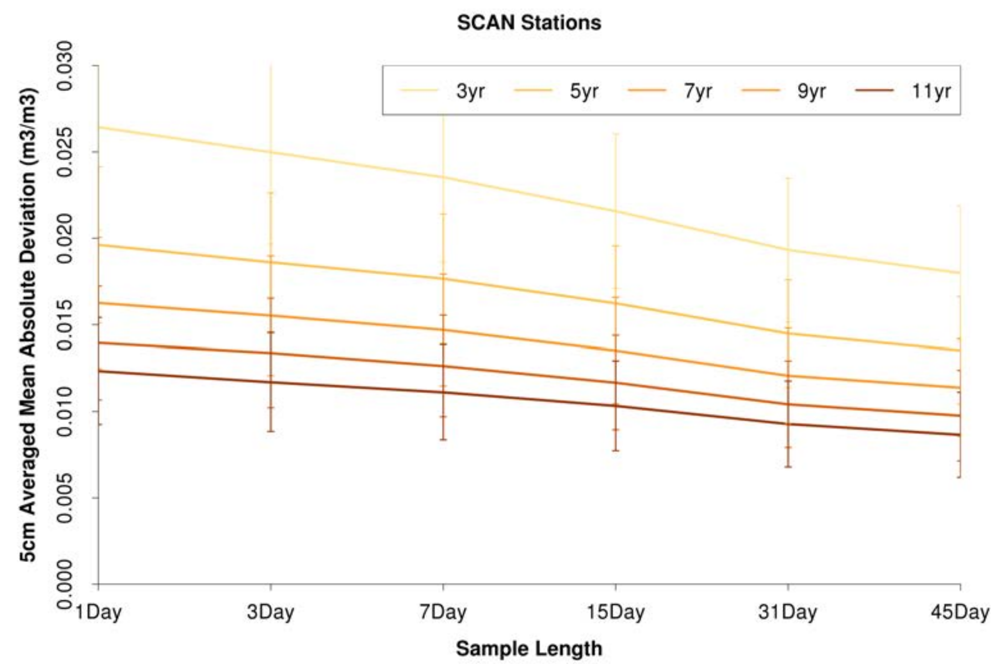
- 3, 5, 7, 9, and 11 randomly drawn years a 1000 times.
- Climatologies using sample lengths of 1, 3, 7, 15, 31, and 45 days were computed.
- Total of 30,000 Monte Carlo runs per SCAN station.



Sensitivity Results

Sensitivity results indicate we can construct a reasonable soil moisture climatology with the last 7 years of data based on an analysis of SCAN data.

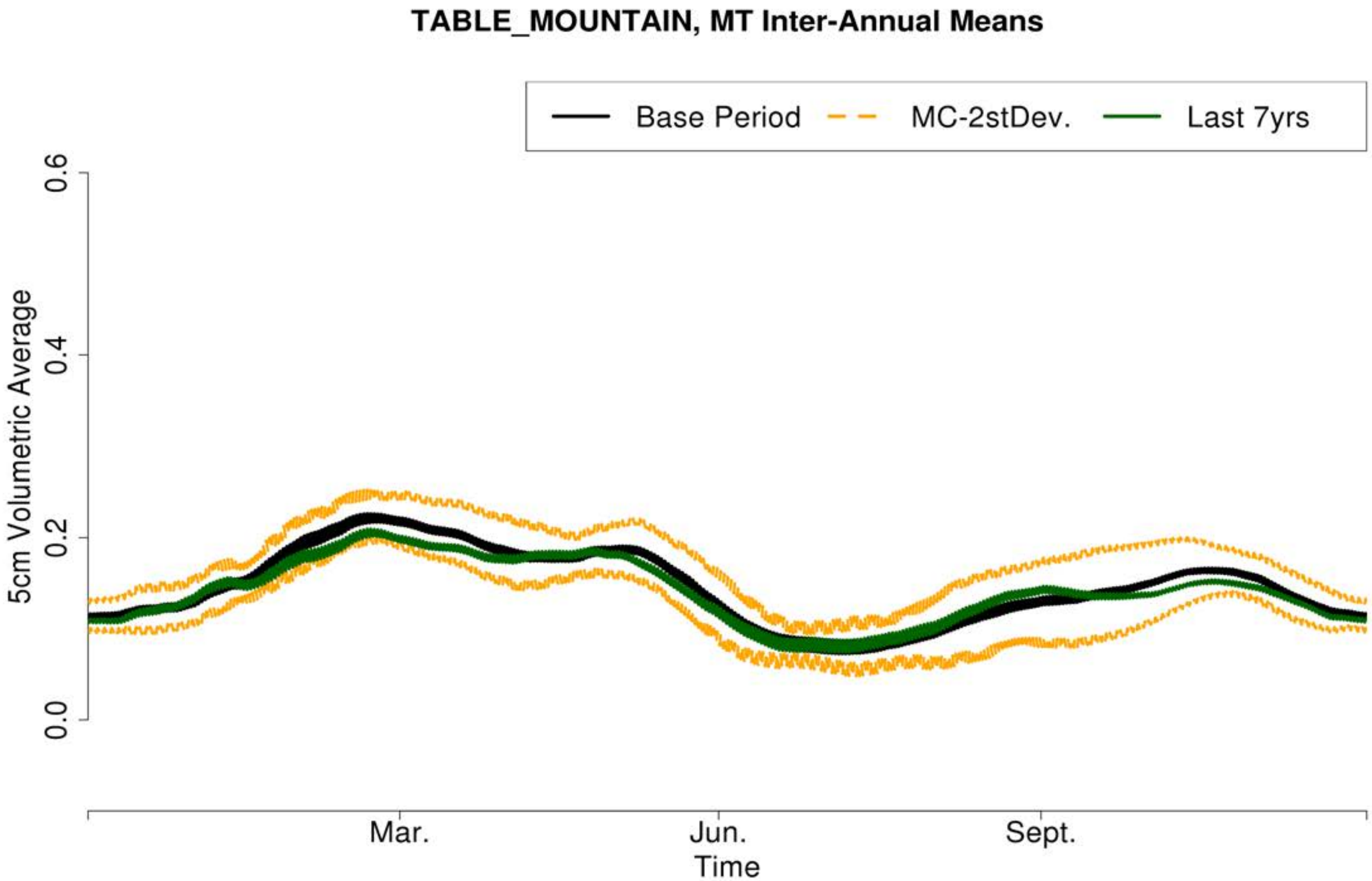




The improvement in error levels off after 7-years using a 31-day sample length.

Last 7-Years

The most recent 7-year period was within 0.4 standard deviations of the randomized 7-year Monte Carlo mean.



U.S. Drought Monitor Comparison

Weekly USDM conditions and status change were extracted for each USCRN station over the period of record.

- Hourly standardized observations were averaged over 7 and 14 day lengths ending on the USDM reporting date and time.

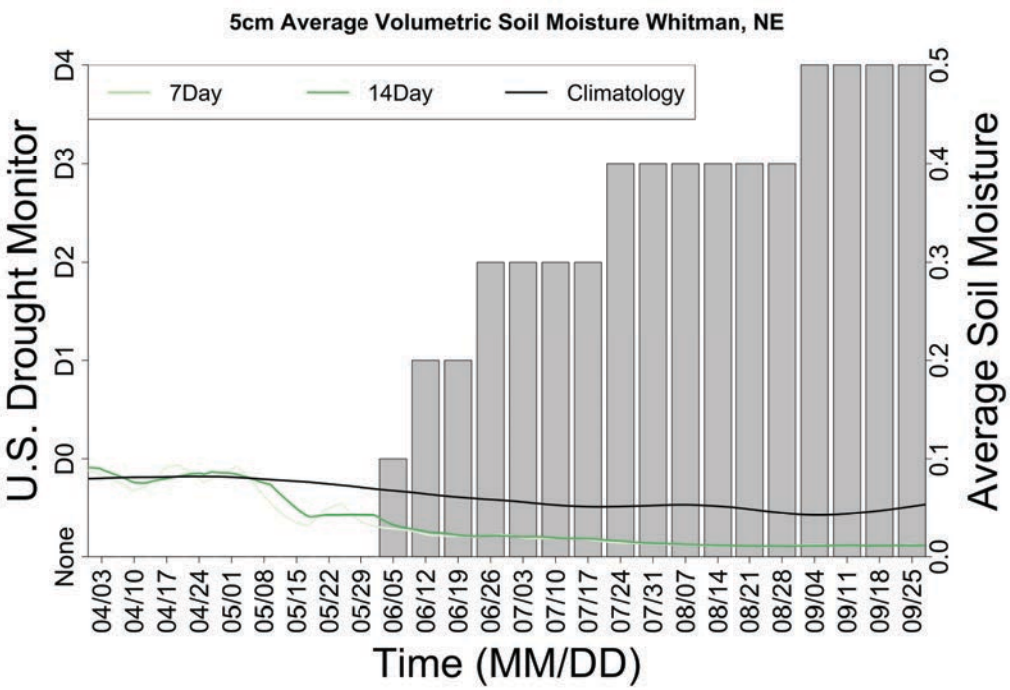
Category	Description	Possible Impacts
D0	Abnormally Dry	Going into drought: • short-term dryness slowing planting, growth of crops or pastures Coming out of drought: • some lingering water deficits • pastures or crops not fully recovered
D1	Moderate Drought	• Some damage to crops, pastures • Streams, reservoirs, or wells low, some water shortages developing or imminent • Voluntary water-use restrictions requested
D2	Severe Drought	• Crop or pasture losses likely • Water shortages common • Water restrictions imposed
D3	Extreme Drought	• Major crop/pasture losses • Widespread water shortages or restrictions
D4	Exceptional Drought	• Exceptional and widespread crop/pasture losses • Shortages of water in reservoirs, streams, and wells creating water emergencies

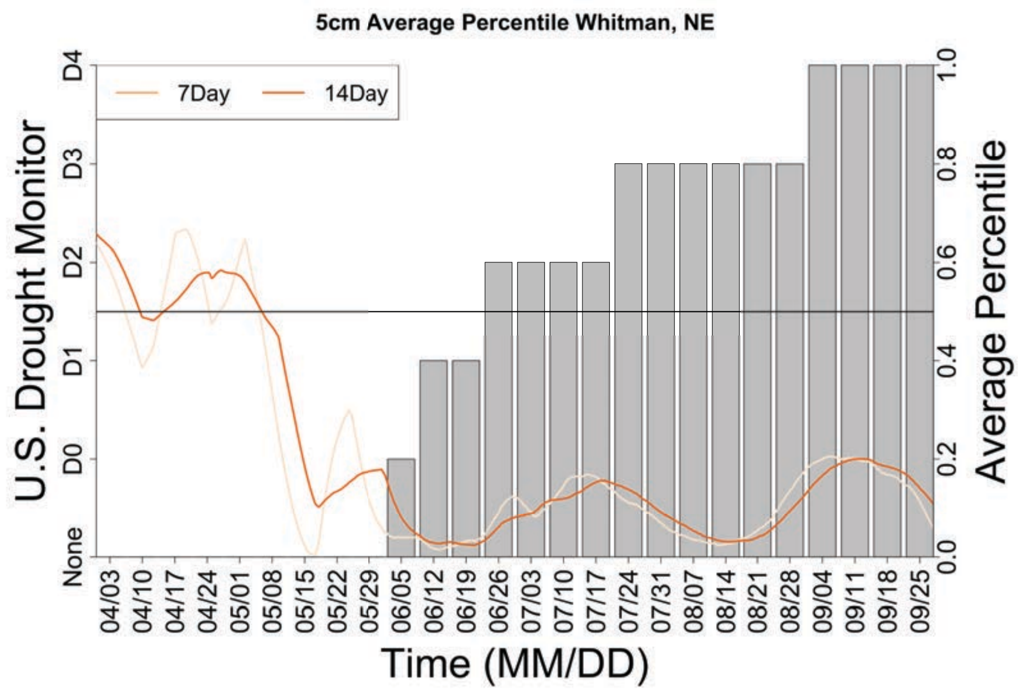
Evaluate how well does USCRN volumetric and standardized measures compare with the USDM.

Case Studies; Whitman, NE

Drought conditions intensified at Whitman, NE during the summer of 2012.

- Soil moisture conditions dropped from ~0.08 to 0.04 by mid-May and slowly declined the remaining summer (0.01).
- Percentiles dropped from 50% down to below 20% where it hovered for the remaining period.

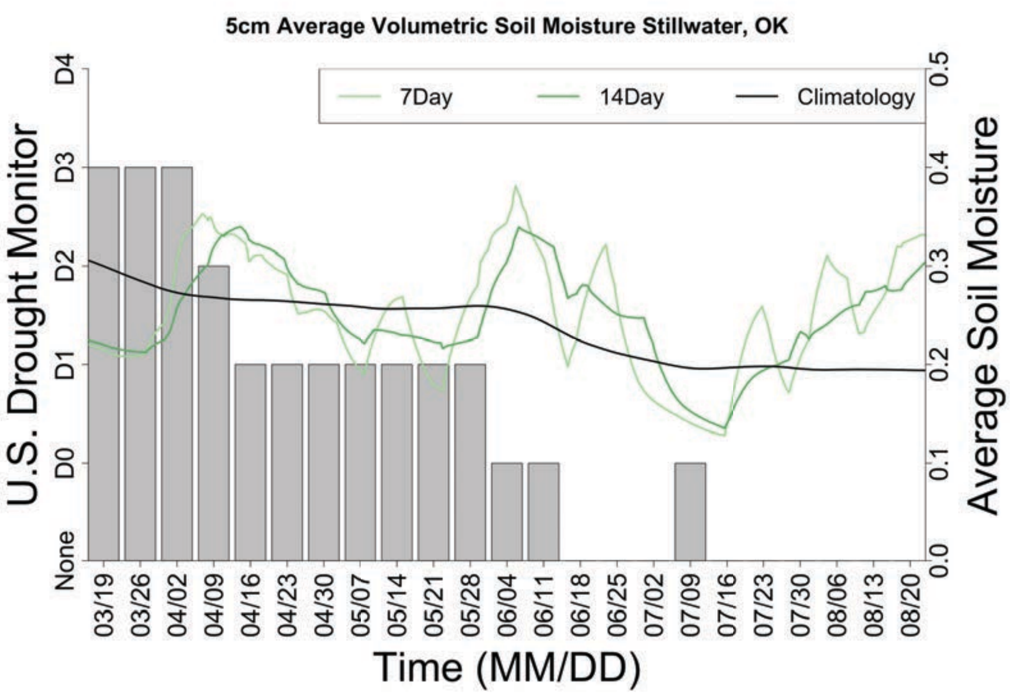


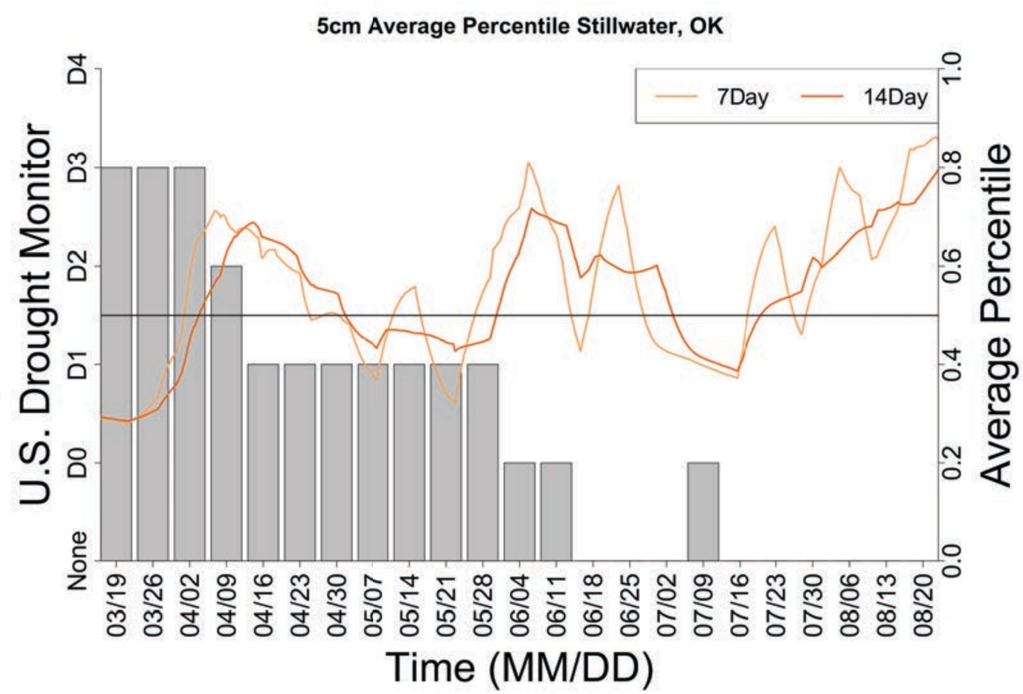


Case Studies; Stillwater, OK

Drought conditions moderated at Stillwater, OK over 2013.

- Soil moisture conditions hovered around average despite dropping to its lowest value on July 16th.
- Percentiles show a positive trend throughout the summer of 2013 with its lowest point in early March during D3 conditions.

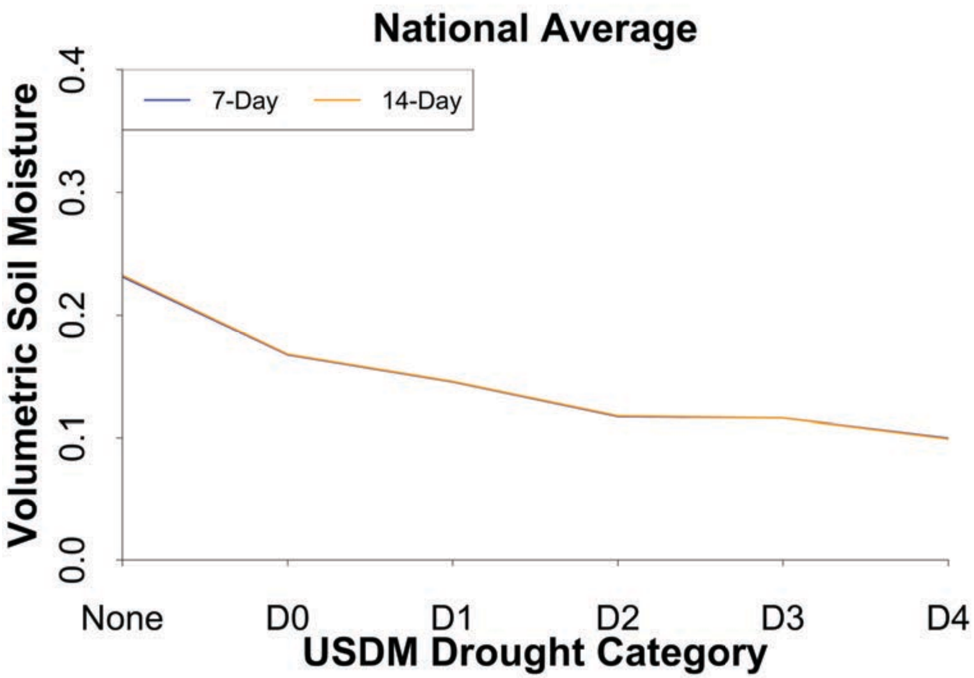


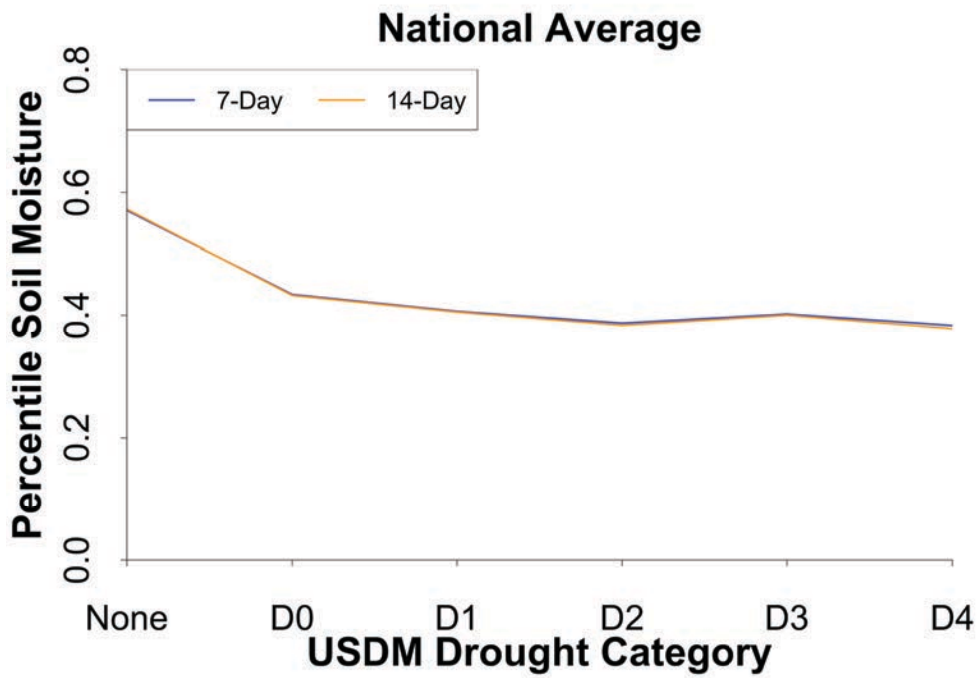


National USDM

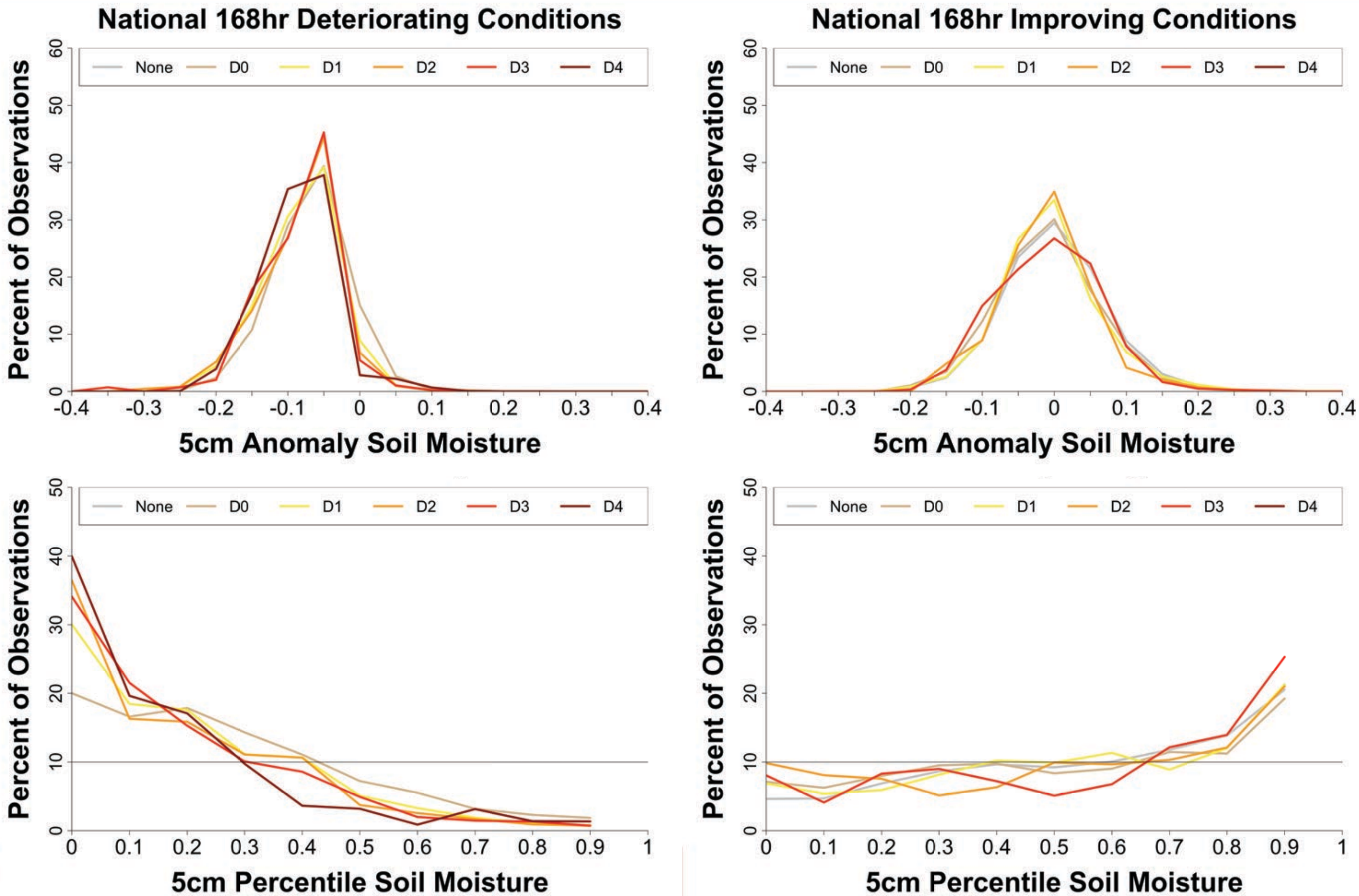
Weekly averages of Volumetric and percentile soil moisture both decreased with higher categories of drought conditions.

- Volumetric measures continued to slightly decrease with higher categories of drought
- Percentiles measures show an initial drop that levels out around



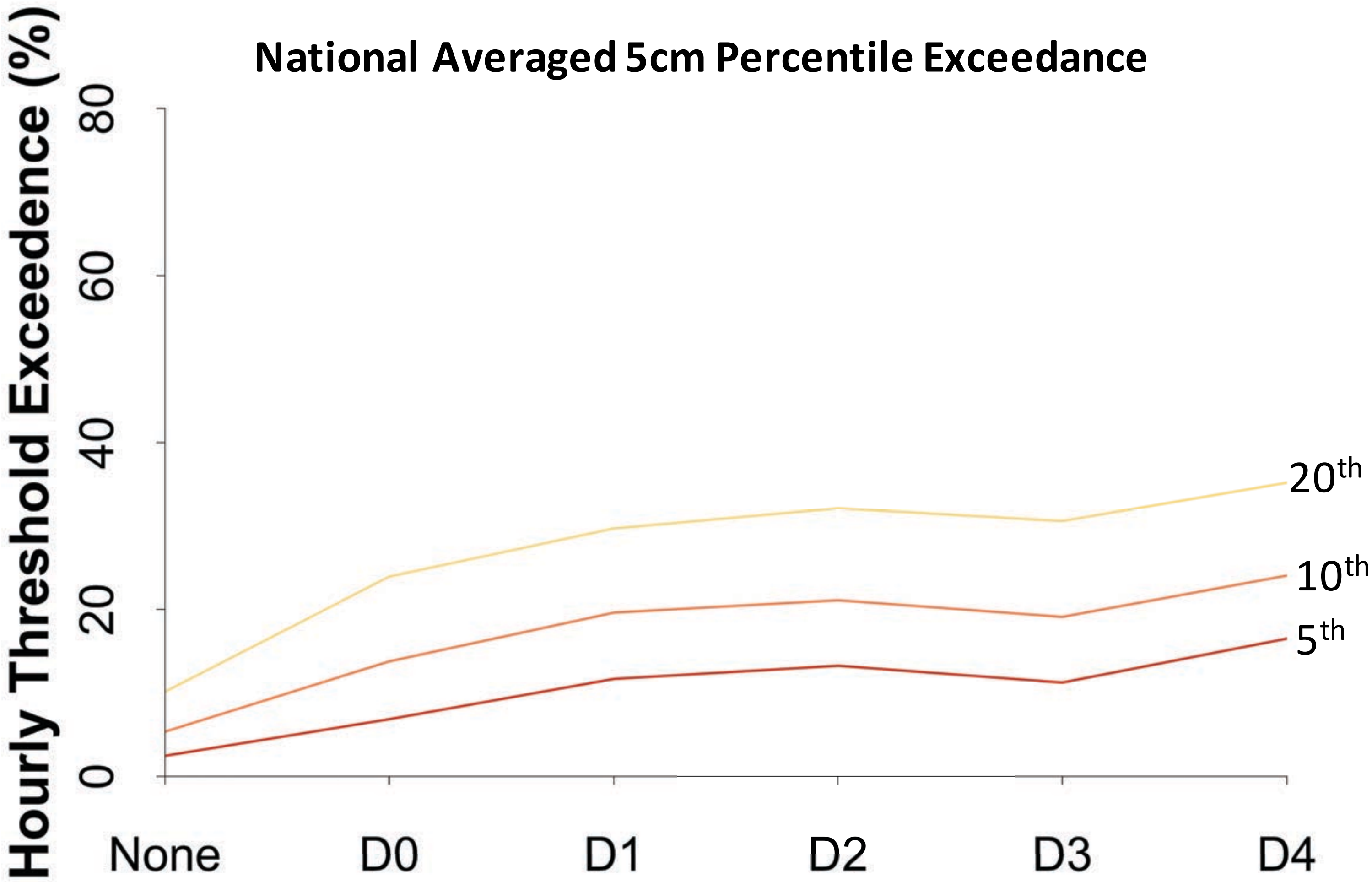


National USDM

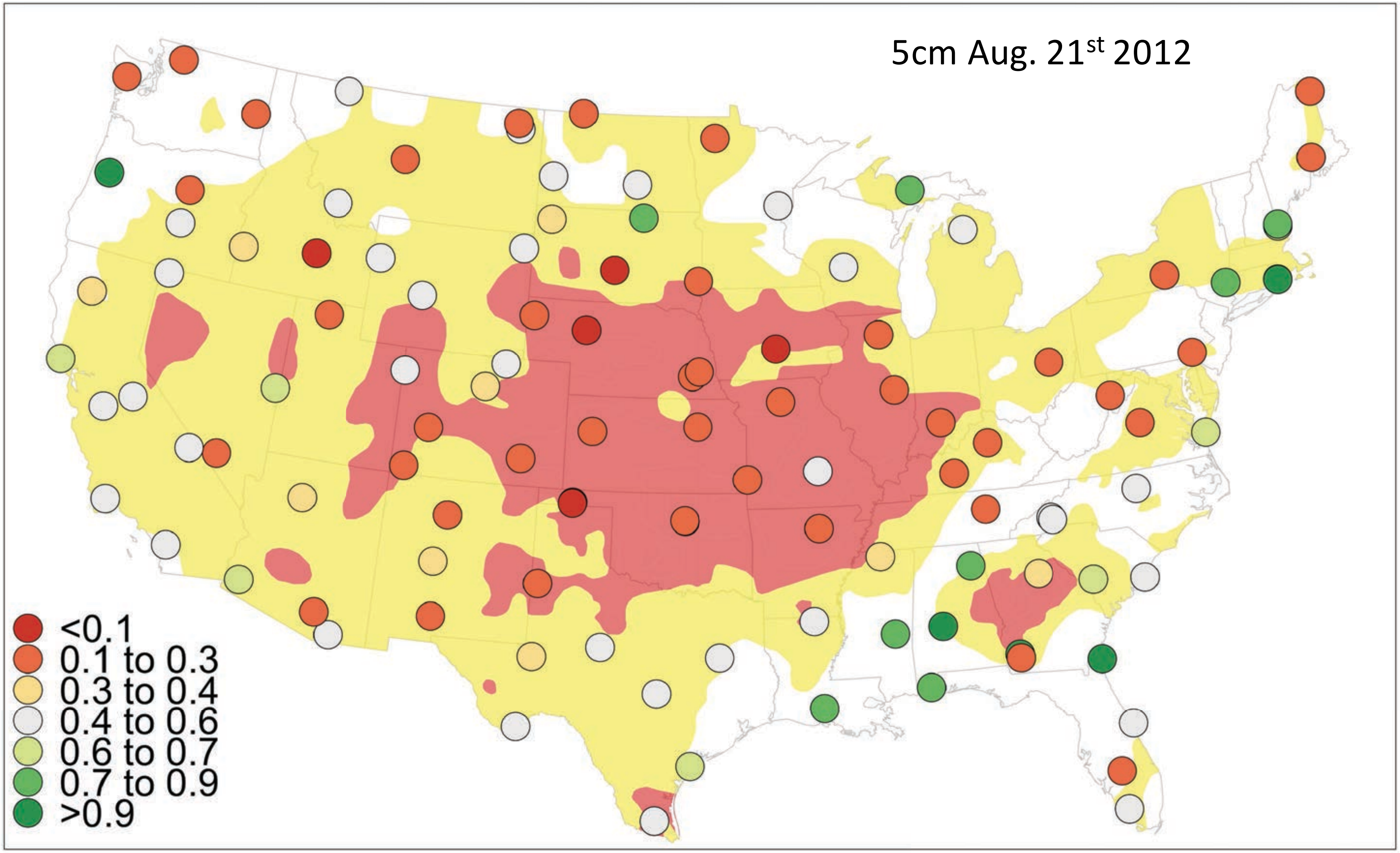


National USDM

Counts of hourly percentile exceedances provide a measure of drought severity.



National USDM



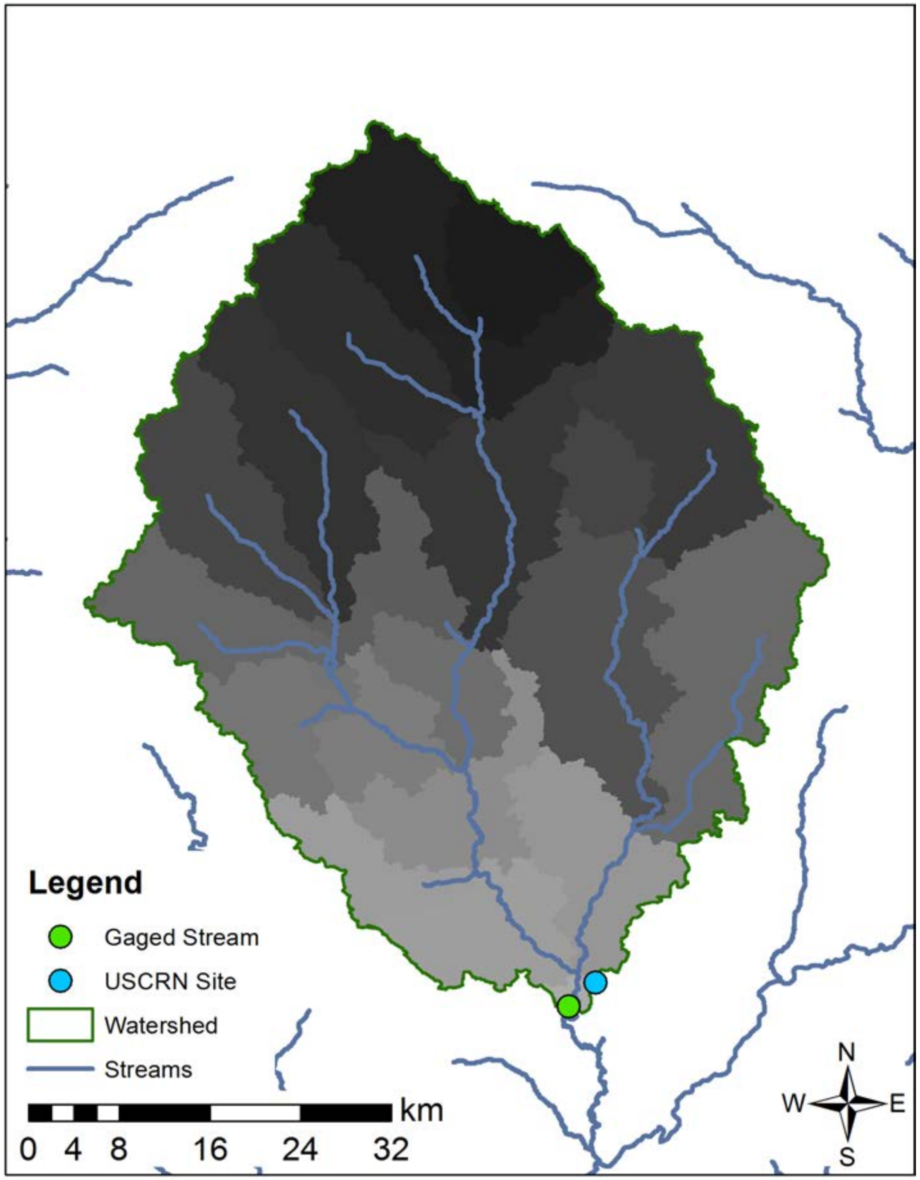
Hydrological Analysis

How well do volumetric and standardized soil moisture observations compare with stream flow?

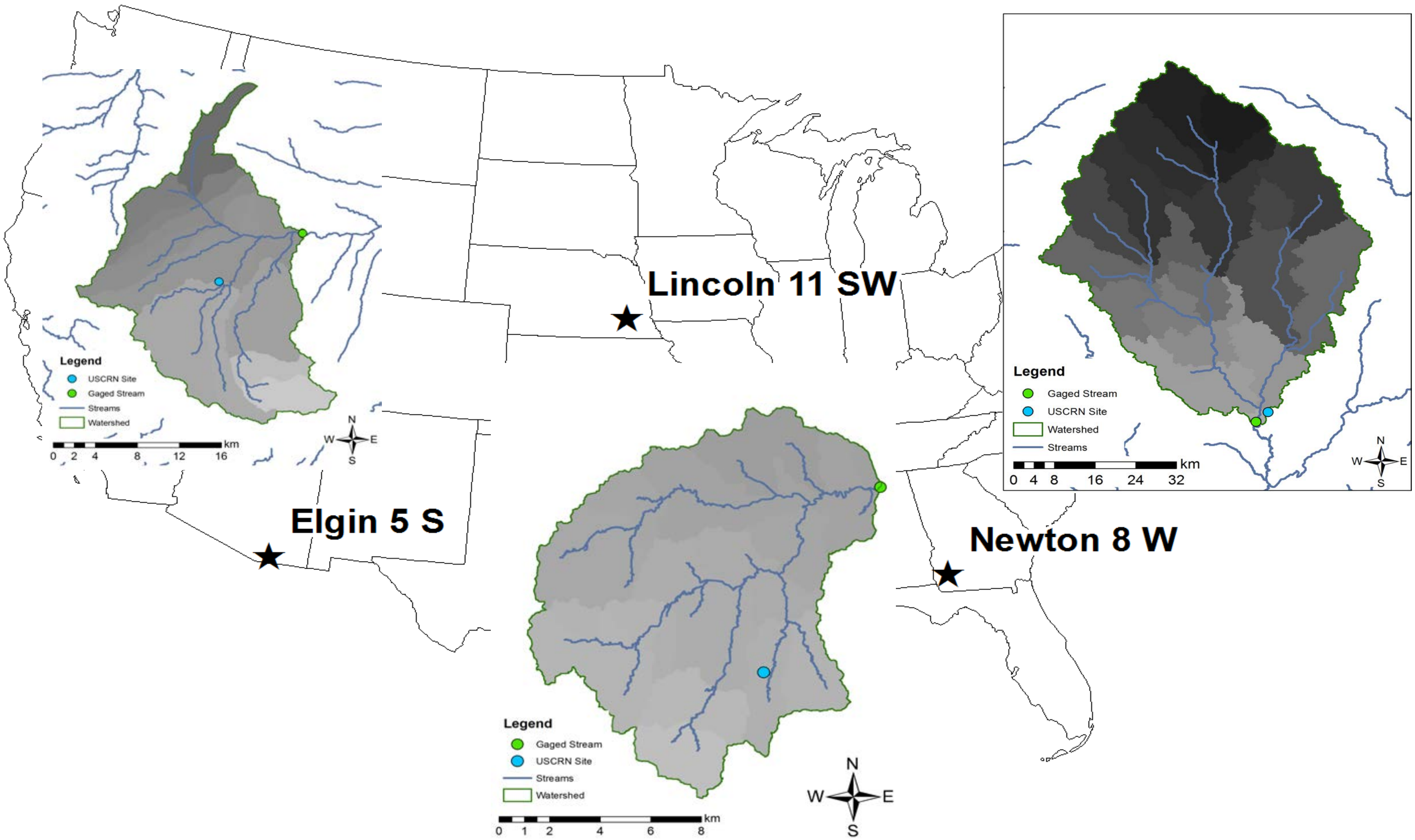
Delineated watersheds that drain the USCRN station and surrounding region.

Pulled USGS stream gage data and identified instances of high flow; stream discharge rates exceeding the 95th percentile.

The Newton, GA station is within the Ichawaynochaway Creek watershed, which drains an area of 2573 km^2



USCRN Watersheds

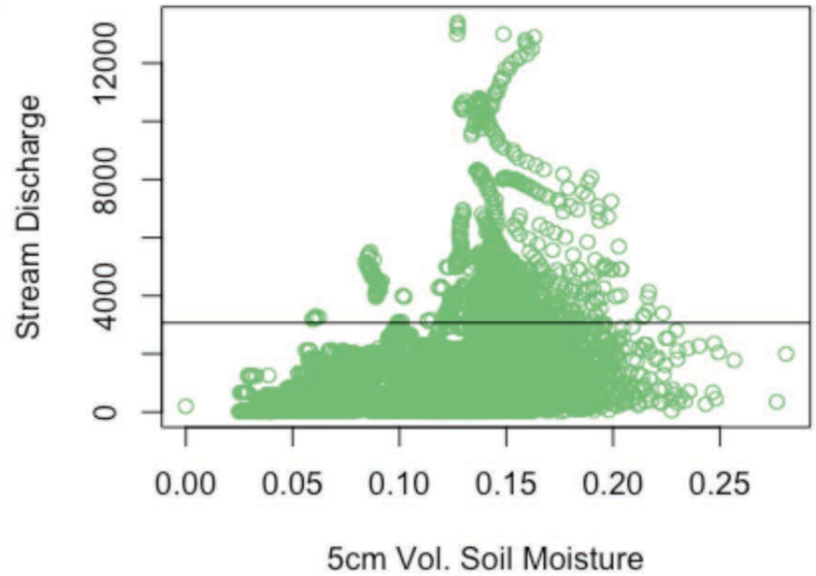


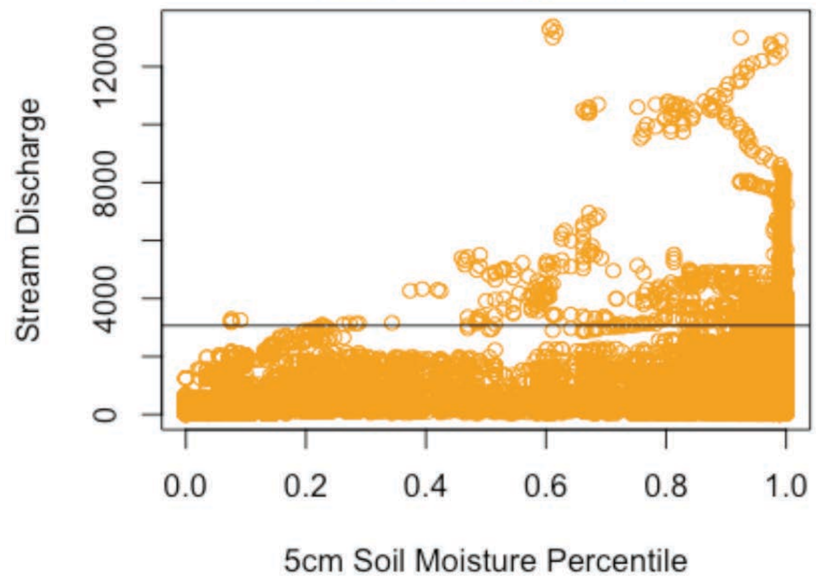
Discharge Rates by Soil Conditions

The USGS gaged stream that drains the Newton, GA station has a 95th percentile discharge rate of 3070 ft^3.

The 5cm volumetric soil moisture condition above this discharge rate tend to mostly occur about 0.15 m^3m^{-3}, which is not the wettest soil moisture condition.

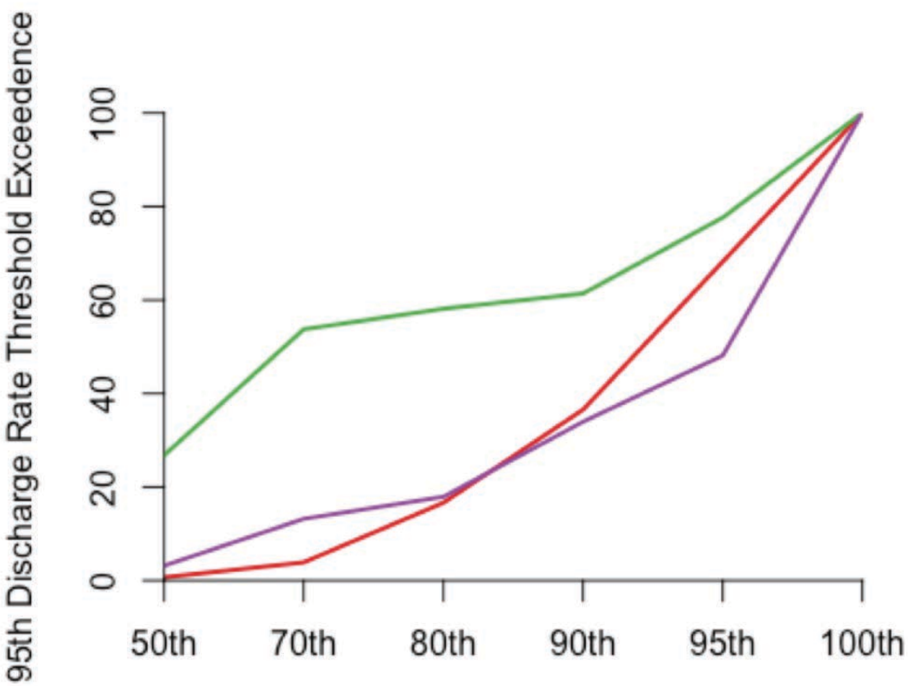
The percentile metric make a bit more sense in that most high flow discharge rates are above the 50th percentile.



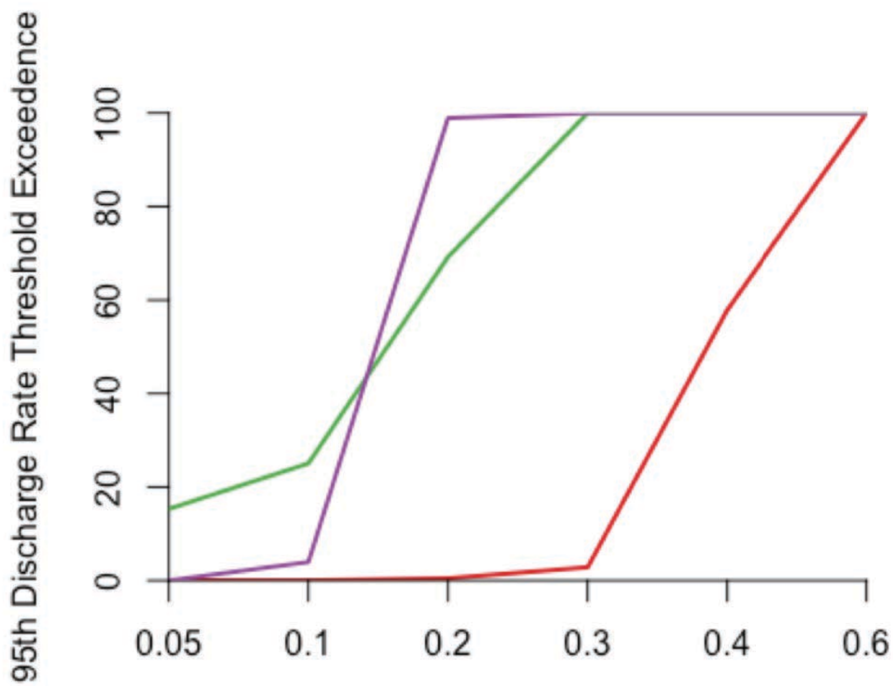


High Flow Analysis

The percentage of hours with high rates of flow, discharge exceeding the 95th percentile, is more consistent across the diverse stations for soil moisture percentiles than volumetric conditions.



5cm Percentile Soil Moisture



5cm Volumetric Soil Moisture

Summary

Overall, USCRN's hourly standardized soil moisture product provided a better assessment of hydrological conditions from both drought and high stream flow perspectives.

- Soil moisture metrics could be a leading indicator of drought trends.
- Frequency of exceedance aligned well with drought severity.
- Percentile were more spatially correlated than volumetric measures.
- Evaluations of hydrological conditions were easier using standardized metrics

Going forward,

1. Operationalize the hourly standardized product (in progress)
2. Continue development of drought indices
3. Evaluate deeper (than 10cm) depths response to drought onset and amelioration
4. Explore strategies to integrate remotely sensed and modeled data with observations.

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USCRN soil moisture accomplishments

- Soil Moisture Analyses and QC Developments
  - Bell, J. E., M. A. Palecki, C. B. Baker, W. G. Collins, J. H. Lawrimore, R. D. Leeper, M. E. Hall, J. Kochendorfer, T. P. Meyers, T. Wilson, and H. J. Diamond. 2013: U.S. Climate Reference Network soil moisture and temperature observations. J. Hydrometeorol., 14, 977-988. doi: 10.1175/JHM-D-12-0146.1
  - Palecki, M. A., and J. E. Bell, 2013: U.S. Climate Reference Network soil moisture observations with triple redundancy: measurement variability. Valdose Zone Journal, 12, p. vzj2012.0158. doi: 10.2136/vzj2012.0158
  - Wilson, T.B., Baker, C.B., Meyers, T.P., Kochendorfer, J., Hall, M., Bell, J.E., Diamond, H.J. and Palecki, M.A., 2016: Site-Specific Soil Properties of the US Climate Reference Network Soil Moisture. Vadose Zone Journal, 15(11). doi: 10.2136/vzj2016.05.0047
- Cooperation with satellite soil moisture retrieval efforts
  - Chan, S. K., R. Bindlish, P. E. O'Neill, E. Njoku, T. Jackson, A. Colliander, F. Chen, M. Burgin, S. Dunbar, J. Piepmeier, S. Yueh, D. Entekhabi, M. H. Cosh, T. Caldwell, J. Walker, X. Wu, A. Berg, T. Rowlandson, A. Pacheco, H. McNairn, M. Thibeault, J. Martínez-Fernández, Á. González-Zamora, M. Seyfried, D. Bosch, P. Starks, D. Goodrich, J. Prueger, M. Palecki, E. E. Small, M. Zreda, J. Calvet, W. T. Crow, and Y. Kerr, 2016: Assessment of the SMAP Passive Soil Moisture Product. IEEE Trans. Geosci. Rem. Sens., 54 (8), 4994-5007. doi: 10.1109/TGRS.2016.2561938
  - Coopersmith, E. J., M. H. Cosh, R. Bindlish, and J. Bell, 2015: Comparing AMSR-E soil moisture estimates to the extended record of the U.S. Climate Reference Network (USCRN). Adv. Water Res., 85, 79-85. doi: 10.1016/j.advwatres.2015.09.003
  - Chan, S. K., R. Bindlish, P. O'Neill, T. Jackson, E. Njoku, S. Dunbar, J. Chaubell, J. Piepmeier, S. Yueh, D. Entekhabi, A. Colliander, F. Chen, M.H. Cosh, T. Caldwell, J. Walker, A. Berg, H. McNairn, M. Thibeault, J. Martínez-Fernández, F. Uldall, M. Seyfried, D. Bosch, P. Starks, C. Holifield Collins, J. Prueger, R. van der Velde, J. Asanuma, M. Palecki, E.E. Small, M. Zreda, J. Calvet, W. T. Crow, and Y. Kerr, 2018. Development and assessment of the SMAP enhanced passive soil moisture product. Remote Sensing of the Environment, 204, 931-941. doi: 10.1016/j.rse.2017.08.025
- Comparison to reanalysis modelled soil moisture
  - Leeper, R. D., Bell, J. E., Vines, C., & Palecki, M., 2017: An Evaluation of the North American Regional Reanalysis Simulated Soil Moisture Conditions during the 2011 to 2013 Drought Period. Journal of Hydrometeorology, 18, 515-527. doi: 10.1175/JHM-D-16-0132.1

USCRN soil moisture accomplishments

- Development of approaches to soil moisture record extension in time and space
    - Coopersmith, E. J., M. H. Cosh, and J. E. Bell, 2015: Extending the soil moisture data record of the Climate Reference Network (CRN) and the Soil Climate Analysis Network (SCAN). Adv. Water Res., 79, 80 -90. doi: 10.1016/j.advwatres.2015.02.006
    - Coopersmith, E. J., Cosh, M. H., Bell, J. E., & Boyles, R., 2016: Using machine learning to produce near surface soil moisture estimates from deeper in situ records at US Climate Reference Network (USCRN) locations: Analysis and applications to AMSR-E satellite validation. Advances in Water Resources, 98, 122-131. doi: 10.1016/j.advwatres.2016.10.007.
    - Coopersmith, E.J., Cosh, M.H., Bell, J.E., & Crow, W., 2016: Multi-profile analysis of soil moisture within the climate reference network.Vadose Zone Journal, 15(1). doi: 10.2136/vzj2015.01.0016.
    - Coopersmith, E. J., Cosh, M. H., Bell, J. E., Kelly, V., Hall, M., Palecki, M. A., & Temimi, M., 2016: Deploying temporary networks for upscaling of sparse network stations. International Journal of Applied Earth Observation and Geoinformation, 52, 433-444. doi: 10.1016/j.jag.2016.07.013.
- Health application of USCRN soil moisture observations
    - Coopersmith, E. J., J. E. Bell, K. Benedict, J. Shriber, O. McCotter, and M. H. Cosh, 2017: Relating coccidioidomycosis (valley fever) incidence to soil moisture conditions, GeoHealth, 1, 51-63 (Cover Article). doi: 10.1002/2016GH000033