Southern Illinois University
CARBONDALE

The Observation Record Length Necessary to Generate Robust Soil Moisture Percentiles

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Soil Moisture Mapping

- Water resource management, drought monitoring/forecasting, flood forecasting, etc.
- Large-scale monitoring necessitates standardization/normalization
- Volumetric water content percentiles widely used to evaluate/display large-scale soil moisture conditions

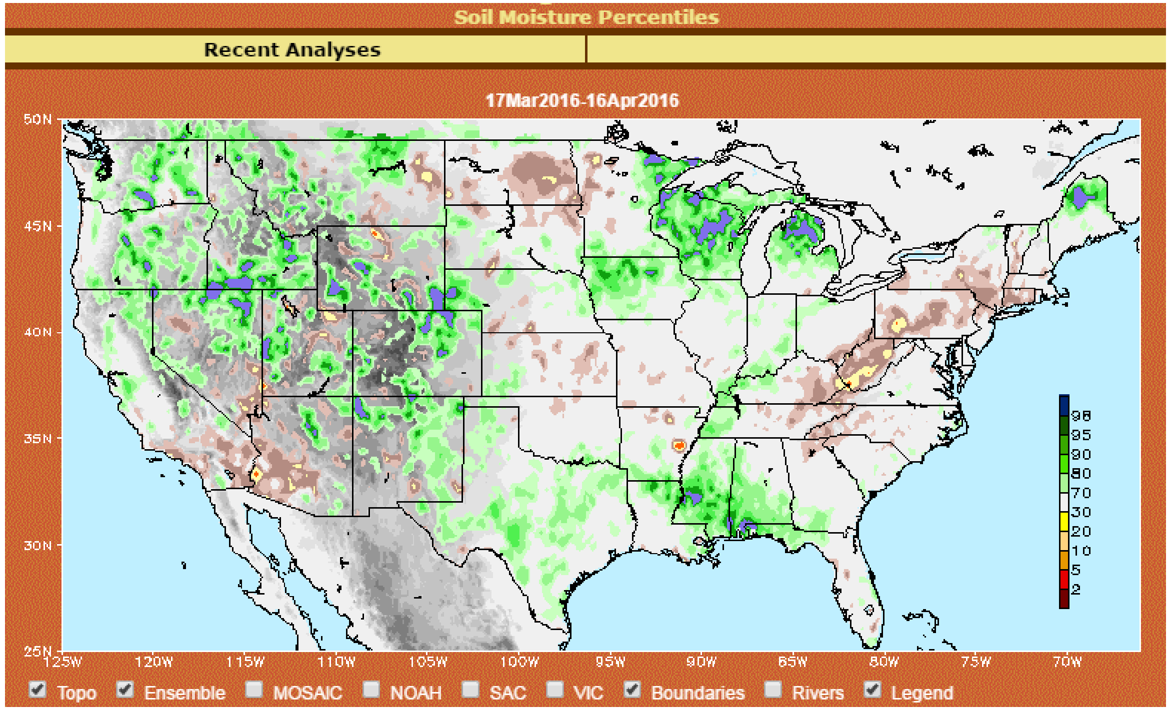
The North American Soil Moisture Database: Development and Applications

Welcome to the Data Hosting Facility of the
International Soil Moisture Network

soil moisture cci

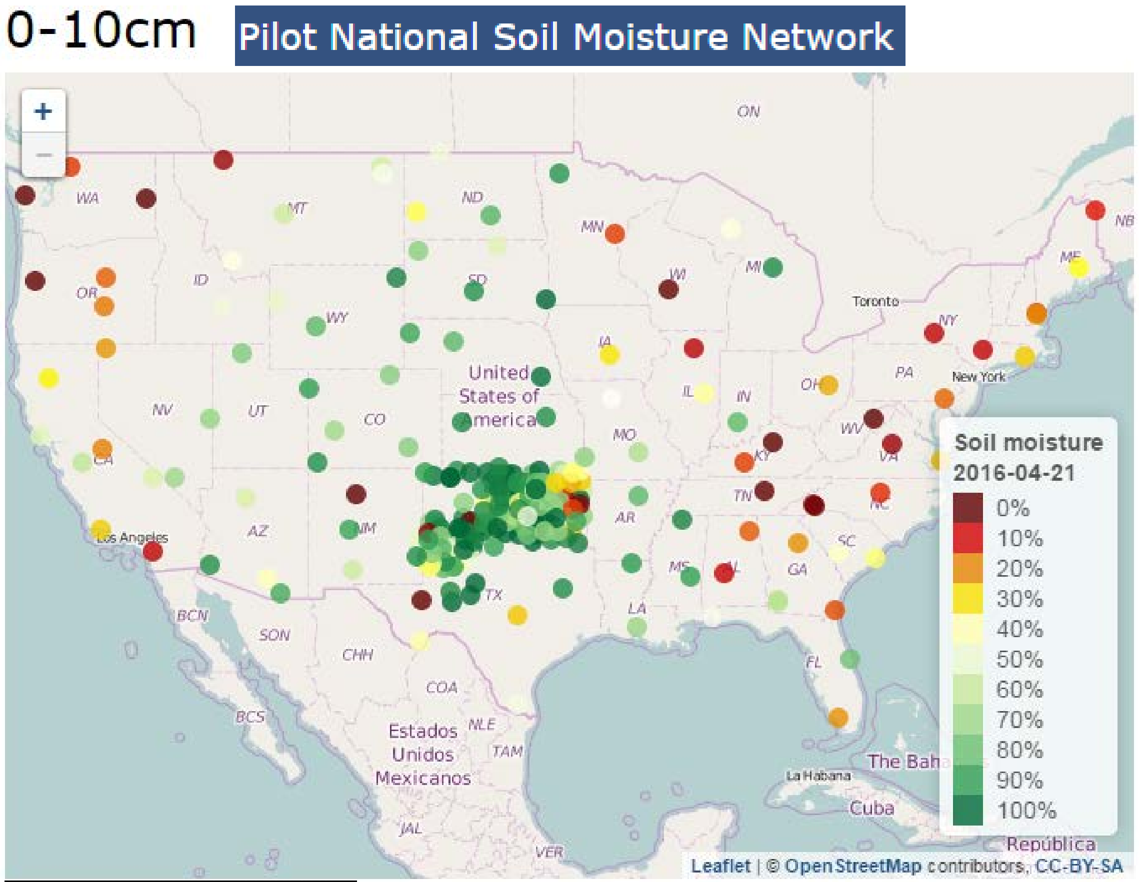
SMAP SOIL MOISTURE ACTIVE PASSIVE

smos



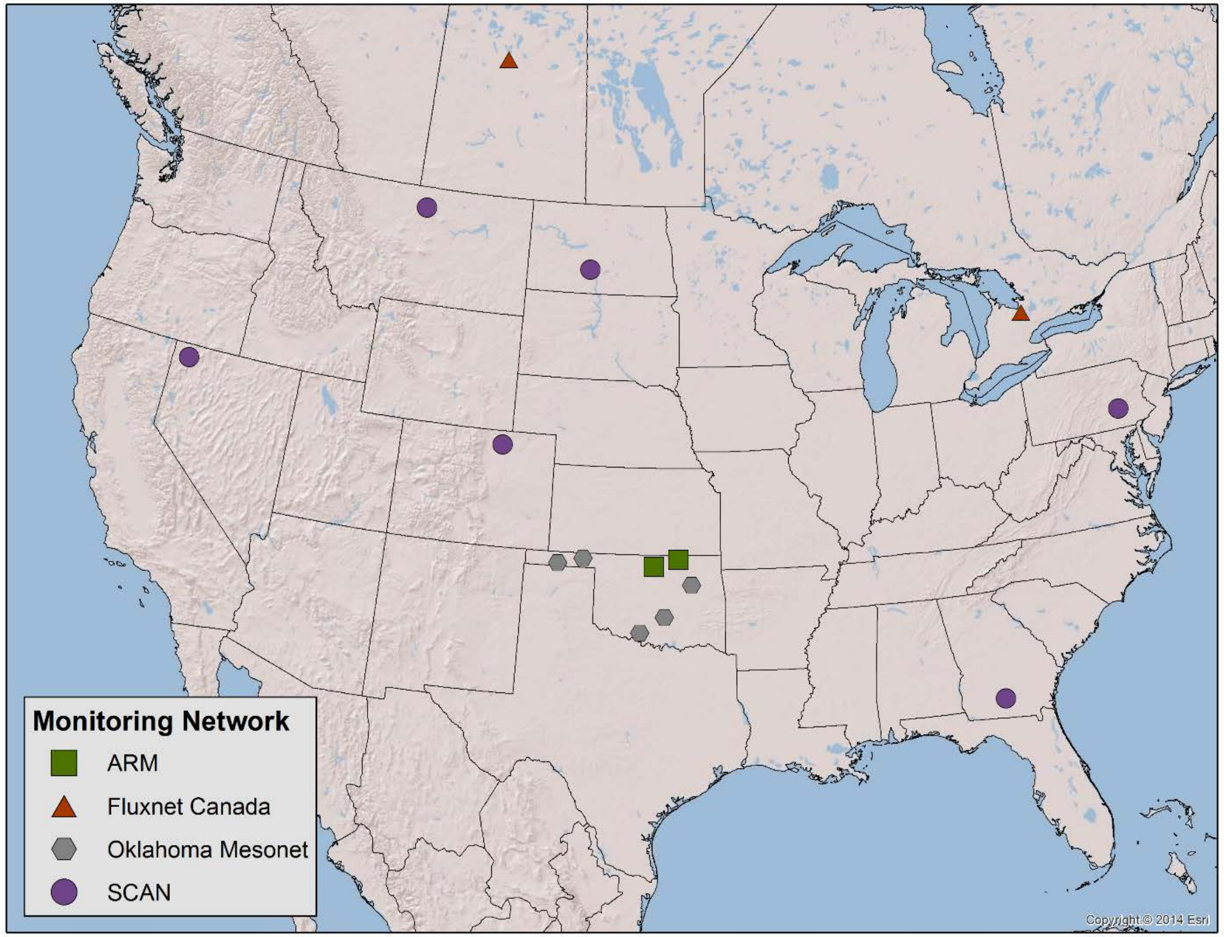
Soil Moisture Mapping

- Efforts to assemble and homogenize *in situ* datasets for scientific community
- Observation datasets do not have a consistent record length, most <20 years
- Period of record sufficient to produce a stable distribution from which to generate percentiles?
- Seek to determine the record length necessary to generate stable soil moisture percentiles from daily soil moisture observations



Soil Moisture Data

- 13 stations with continuous, mostly-complete 15+ year record
- 2 stations (Canada) with continuous, mostly-complete 13-year record
- Surficial (5 – 10 cm), middle (20 – 30 cm), and deeper (50 – 75 cm) depths



Methods

- From 15-year record, select *n* years of daily volumetric water content ($cm^3\ cm^{-3}$) data
- Generate a distribution based on *n* years of data; note the 1^{st}, 2^{nd}, 3^{rd} quartiles & 5^{th} & 95^{th} percentiles
  - Repeat the process 300x using bootstrapping procedure
- Increase the number of years (*n*) by 1 and repeat

Carried this out at each station, each measurement depth (3 total), and for each calendar month

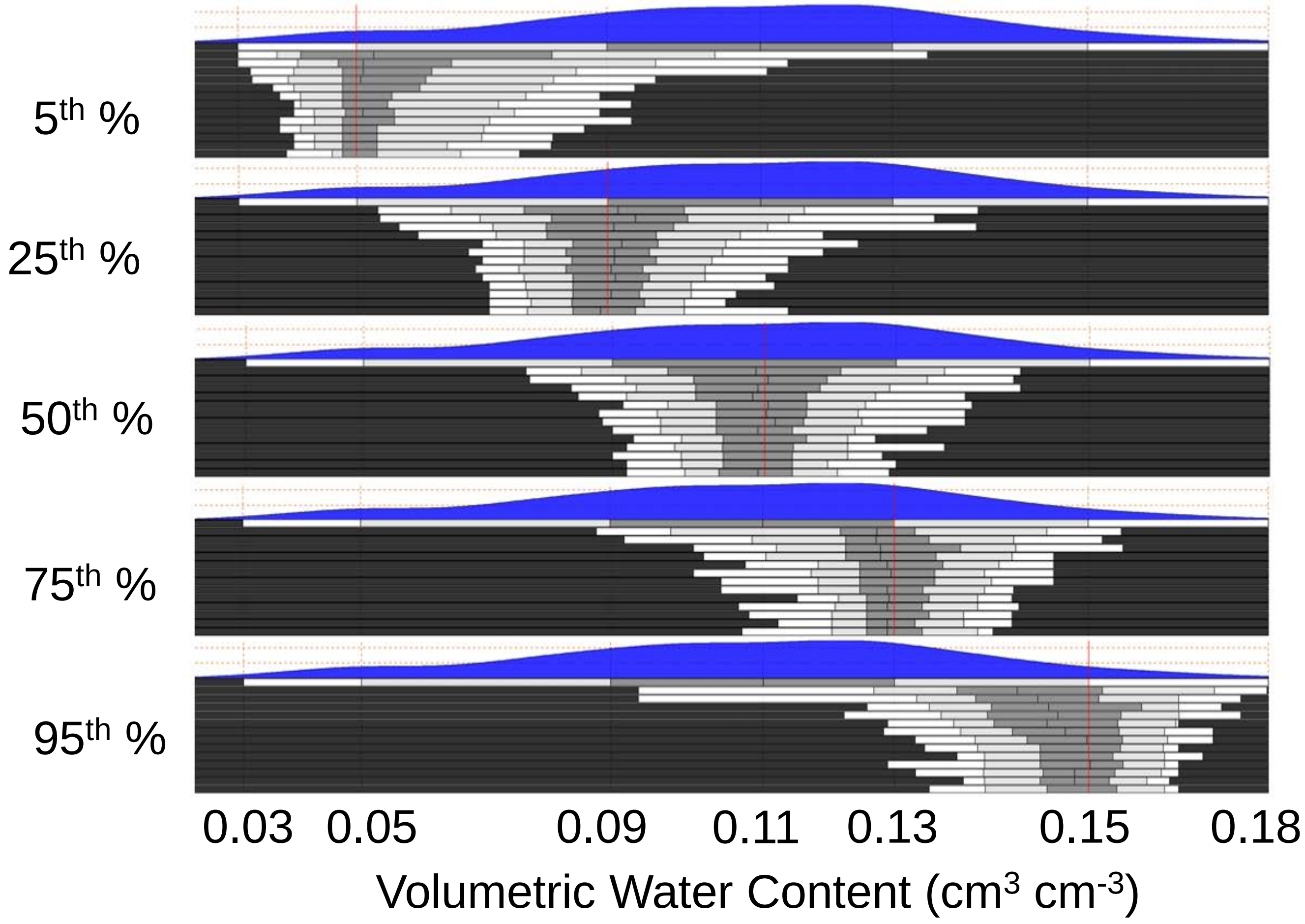
Methods

- For each condition (station, depth, month), we determine the number of years (*n*) after which no discernable change is detected
- Anderson-Darling test is used to determine significant differences between the distribution using *n* years and the distribution using *n*+1 years
- The value of *n* used to generate the distribution **after which** no significant change (based on A-D test) occurs is determined to be sufficient to represent the 15+ year soil moisture climatology and generate stable percentiles

Methods

- Distributions “converge” after 5 – 8 years, after which no significant differences exist (A-D test)
- In this case, 5 years of data is sufficient to estimate a distribution representative of the entire 15-year record

July 20 cm soil moisture – Little River, GA (SCAN)

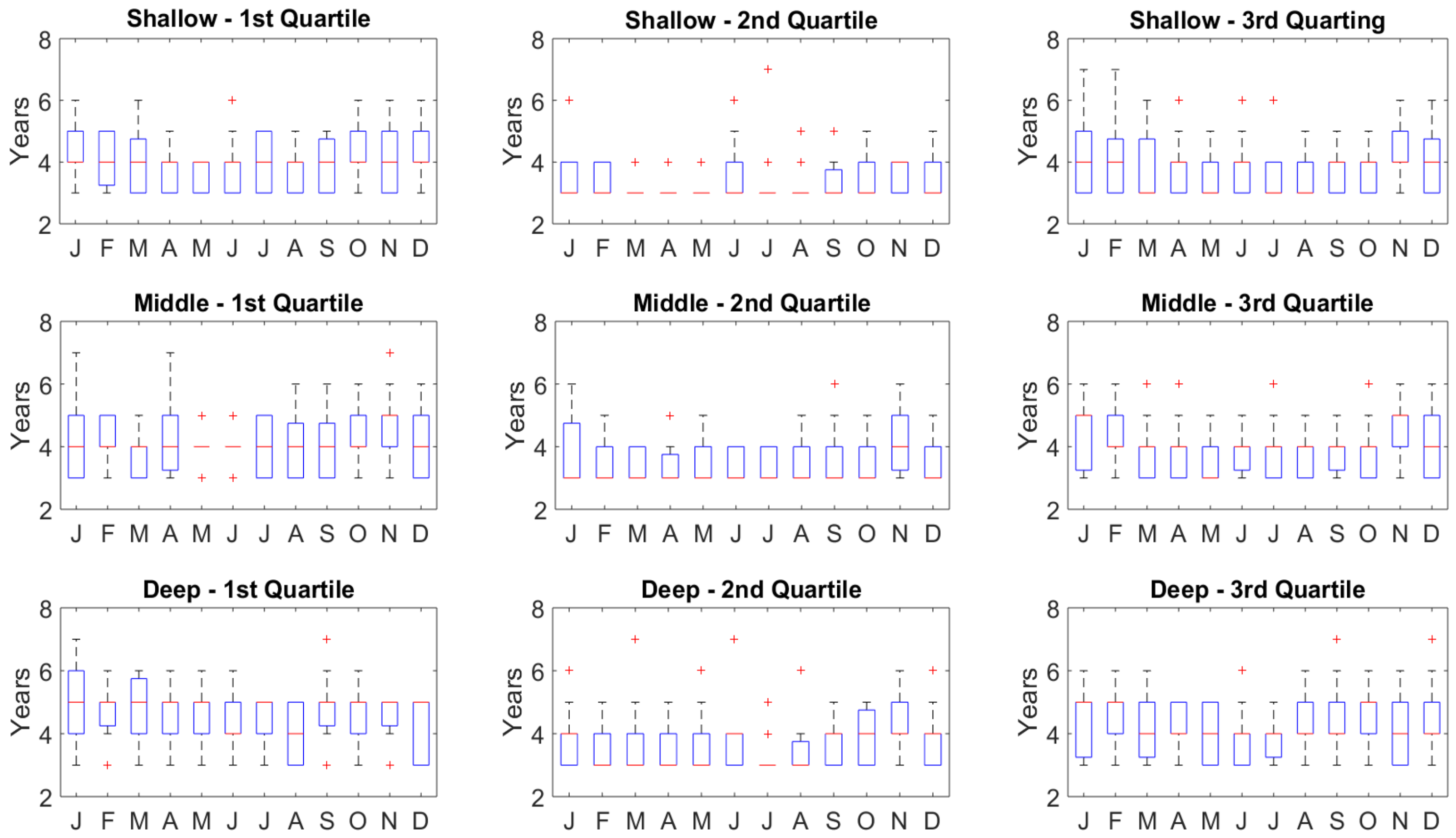


Results

1st Quartile	4.0 years
2nd Quartile	3.4 years
3rd Quartile	3.9 years

5 – 10 cm	3.7 years
20 – 30 cm	3.9 years
60 – 75 cm	4.2 years

- 6+ observation record years necessary for stable percentiles in only 10% of conditions tested



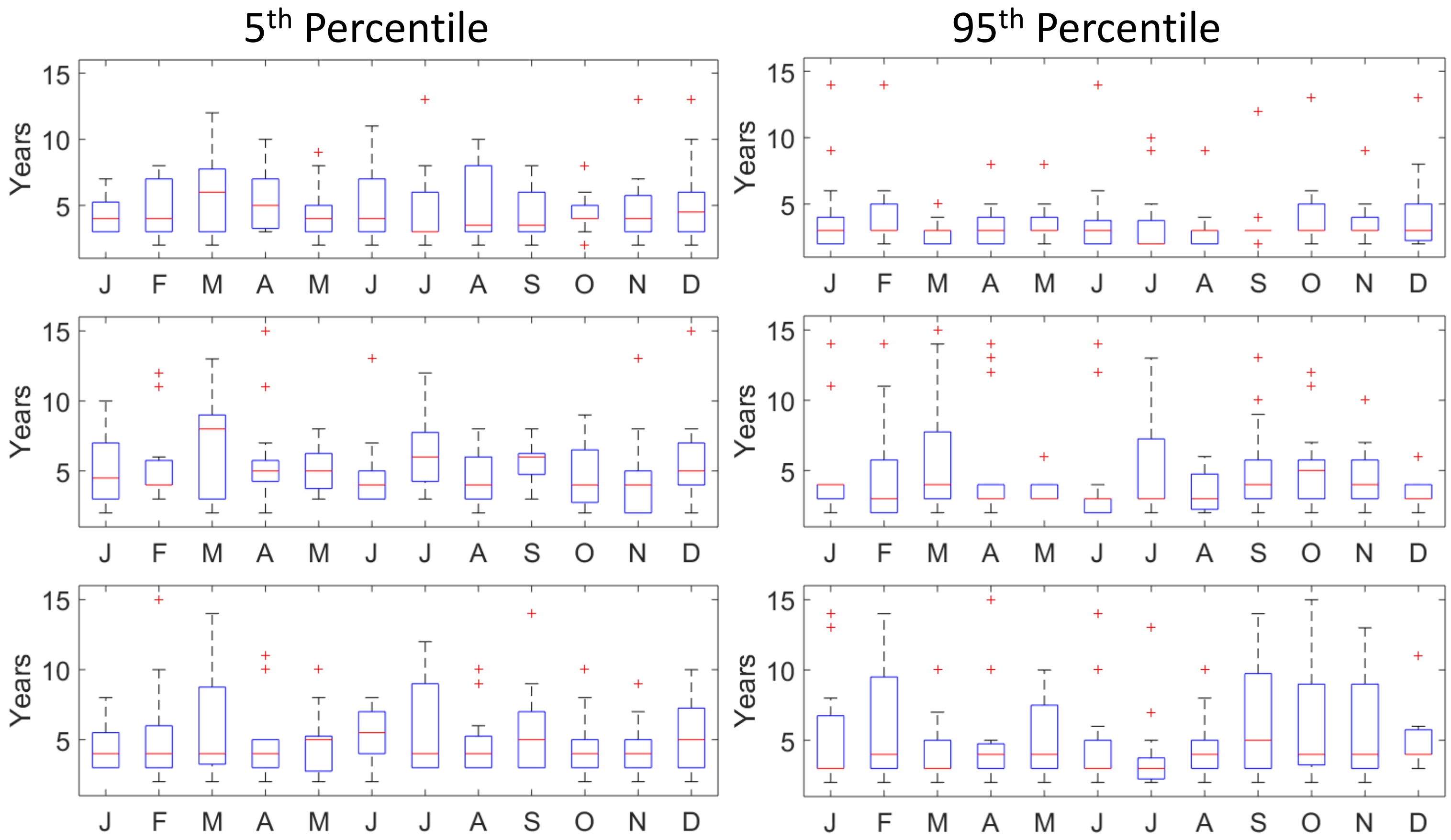
The number of observation record years deemed sufficient for generating a stable distribution, separated by quartile, measurement depth, and calendar month.

Results

5 – 10 cm	4.9 years
20 – 30 cm	5.5 years
60 – 75 cm	5.2 years

5 – 10 cm	3.7 years
20 – 30 cm	4.4 years
60 – 75 cm	5.1 years

- 6+ observation record years necessary for stable percentiles in 30% of 5th percentile conditions and 15% of 95th percentile conditions

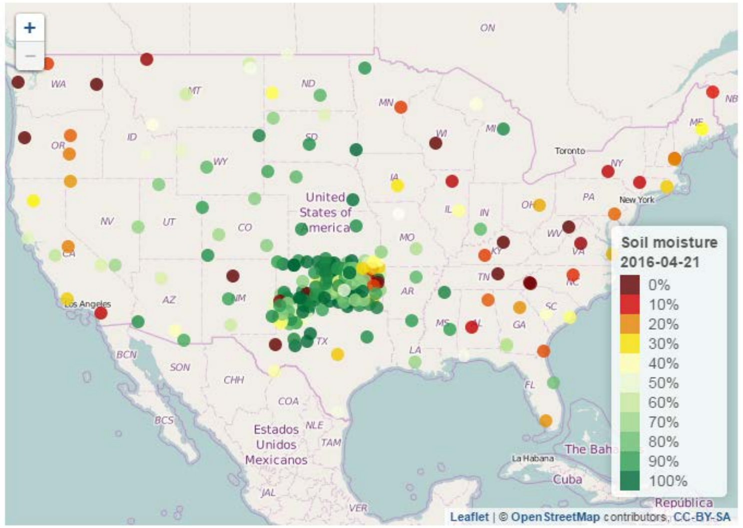


The number of observation record years deemed sufficient for generating a stable distribution, separated measurement depth, and calendar month.

Stable Extremes – Drought Monitoring

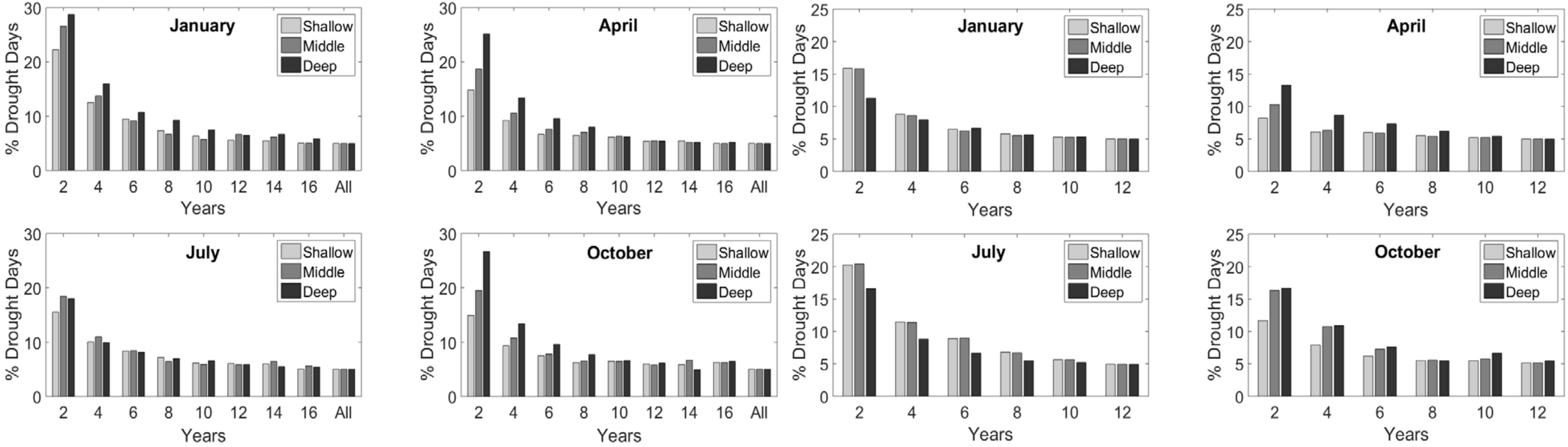
- Drought monitoring based on percentiles – at least 5% of observations are "extreme drought" regardless of record length
- Randomly select *n* data years and calculate 5th percentile, separately for each calendar month
- Compute % of daily observations from the entire record that is $\leq$ respective 5th percentile value
  - Repeat process 300x (bootstrapping)
- Increase *n*+2, repeat the entire process
- Track the percent of the entire data record that is classified as "extreme drought" based on the changing 5th percentile value

Category	Description	CPC Soil Moisture Model (Percentiles)
D0	Abnormally Dry	21 to 30
D1	Moderate Drought	11 to 20
D2	Severe Drought	6 to 10
D3	Extreme Drought	3 to 5
D4	Exceptional Drought	0 to 2



Stable Extremes – Drought Monitoring

Acme, Oklahoma (Mesonet) | Borden, Ontario (Fluxnet)



Average number of “extreme drought” days as a function of the number of years used to determine the 5th percentile threshold.

Summary

- Recent advent of datasets dramatically improve spatial extent to which we can monitor soil moisture
- The lack of a 30+ year *in situ* soil moisture record at most stations precludes solid understanding of the true anomaly of moisture conditions
- Important to understand the observation record length necessary to generate a stable distribution from which *in situ* soil moisture can be contextualized
- Use of 13 – 17 year record as “truth” or “climatology” is a significant limitation

Conclusions

- Sufficient record length ranges between **3 & 15 years**
- Majority of conditions demand **3 – 6 year** record
  - Longer records necessary for 1^{st} & 3^{rd} quartiles than the median
  - Longer records necessary for deeper measurement depths
- Extremes demand **4 – 8 year** record
- Important implications for soil moisture drought monitoring with relative short records

Acknowledgements: Mike Palecki, Jesse Bell, Ronnie Leeper

Network – Station	State/Province	Sensor Type	Soil Texture (5 – 10 cm)	Soil Texture (20 – 30 cm)	Soil Texture (50 – 60 cm)	Land Cover	Measurement Depths (cm)	Data Range
ARM – Lamont	Oklahoma	Heat dissipation	Clay	Clay	Clay	Pasture	5, 25, 60	1997 – 2012
ARM – Pawhuska	Oklahoma	Heat Dissipation	Sandy Loam	Sandy Loam	Sandy Loam	Grassland	5, 25, 60	1997 – 2012
Fluxnet Canada –Borden	Ontario	Water content reflectometer	N/A	N/A	N/A	Mixed Forest	5, 20, 50	1998 – 2011
Fluxnet Canada – Old Aspen	Saskatchewan	Water content reflectometer	Loam	Sandy Clay Loam	Sandy Clay Loam	Aspen Forest	7.5, 15-30, 30-60	1997 – 2009
Oklahoma Mesonet – Acme	Oklahoma	Heat dissipation	Sandy Loam	Sandy Clay Loam	Sandy Clay Loam	Pasture	5, 25, 60	1998 – 2013
Oklahoma Mesonet – Beaver	Oklahoma	Heat dissipation	Loam	Clay Loam	Clay Loam	Scrubland	5, 25, 60	1998 – 2013
Oklahoma Mesonet – Bixby	Oklahoma	Heat dissipation	Sandy Loam	Silt Loam	Silt Loam	Grassland	5, 25, 60	1998 – 2013
Oklahoma Mesonet – Byars	Oklahoma	Heat dissipation	Sandy Loam	Sandy Clay Loam	Sandy Clay Loam	Grassland	5, 25, 60	1998 – 2013
Oklahoma Mesonet – Goodwell	Oklahoma	Heat dissipation	Clay Loam	Clay Loam	Clay Loam	Scrubland	5, 25, 60	1998 – 2013
SCAN – Fort Assiniboine	Montana	Dielectric Impedance	Loam	Clay Loam	Loam	Pasture	5, 20, 50	1998 – 2014
SCAN – Little River	Georgia	Dielectric Impedance	Loamy Sand	Loamy Sand	Loamy Sand	Grassland	5, 20, 50	2000 – 2014
SCAN – Mahantango Creek	Pennsylvania	Dielectric Impedance	Loam	Silt Loam	Loam	Grassland	5, 20, 50	2000 – 2014
SCAN – Mandan	North Dakota	Dielectric Impedance	Silt Loam	Silt Loam	Silty Clay Loam	Grassland	5, 20, 50	1998 – 2014
SCAN – Nunn	Colorado	Dielectric Impedance	Sandy Loam	Sandy Loam	Sandy Loam	Pasture	5, 20, 50	1998 – 2014
SCAN – Sheldon	Nevada	Dielectric Impedance	Loam	Loam	Loamy Fine Sand	Scrubland	5, 20, 50	1997 – 2014