GEOG Climate Science Lab

TEXAS A&M UNIVERSITY




Validation of European Space Agency's ECV Soil Moisture using the NASMD

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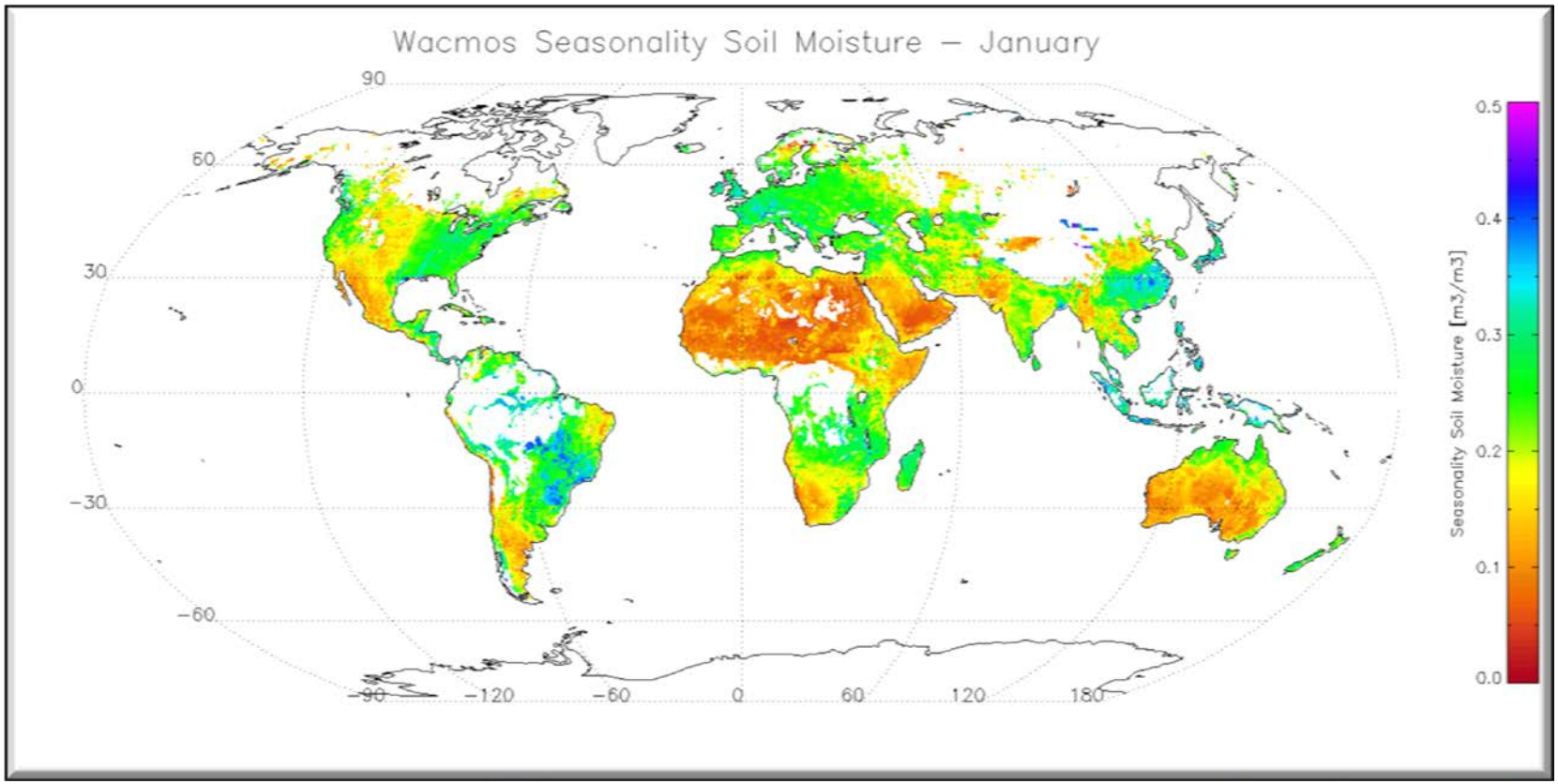
http://climatology.tamu.edu

http://facebook.com/GeogCSL

MOISST, June 2015

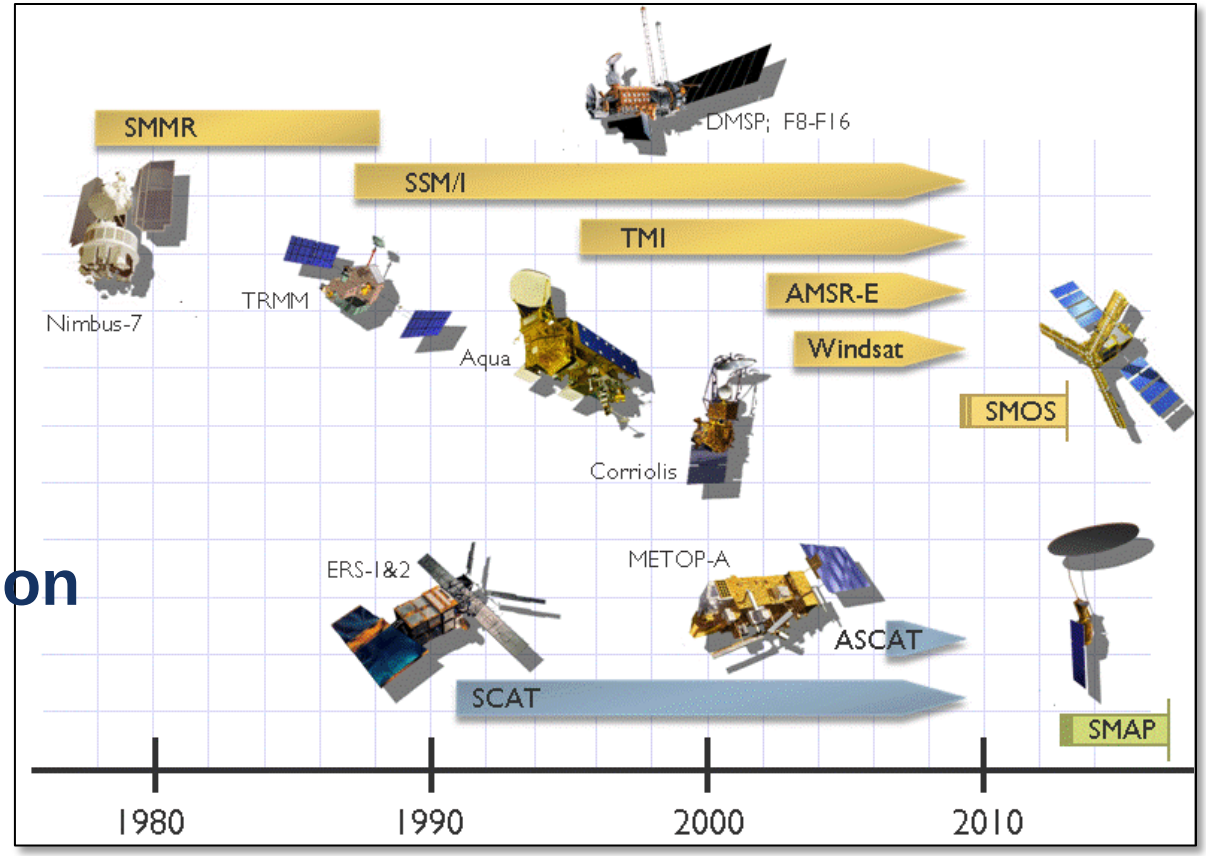
Research Goal

The purpose of this study is to evaluate the European Space Agency's (ESA) global SM dataset by comparing it with observed SM data.



ESA Essential Climate Variable (ECV) Soil Moisture

- Global coverage
- 1979 to 2010 (32 years)
- Daily temporal resolution
- 0.25° spatial resolution



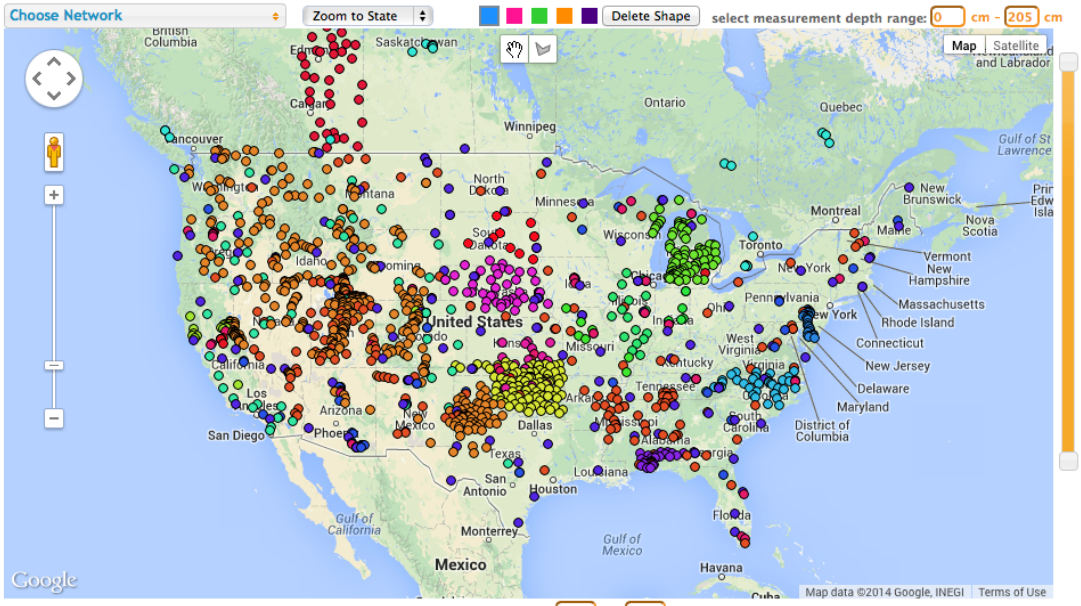
soilmoisture.tamu.edu

TAMU North American Soil Moisture Database

North American Soil Moisture Database Interactive Map

This interactive map allows you to view & download station data from the North American Soil Moisture Database.

Choose one or more networks from the dropdown list to see station data. Use the depth & year sliders to filter. Click the extract buttons to download station data.



Help me download this data!

1385 Stations have been selected

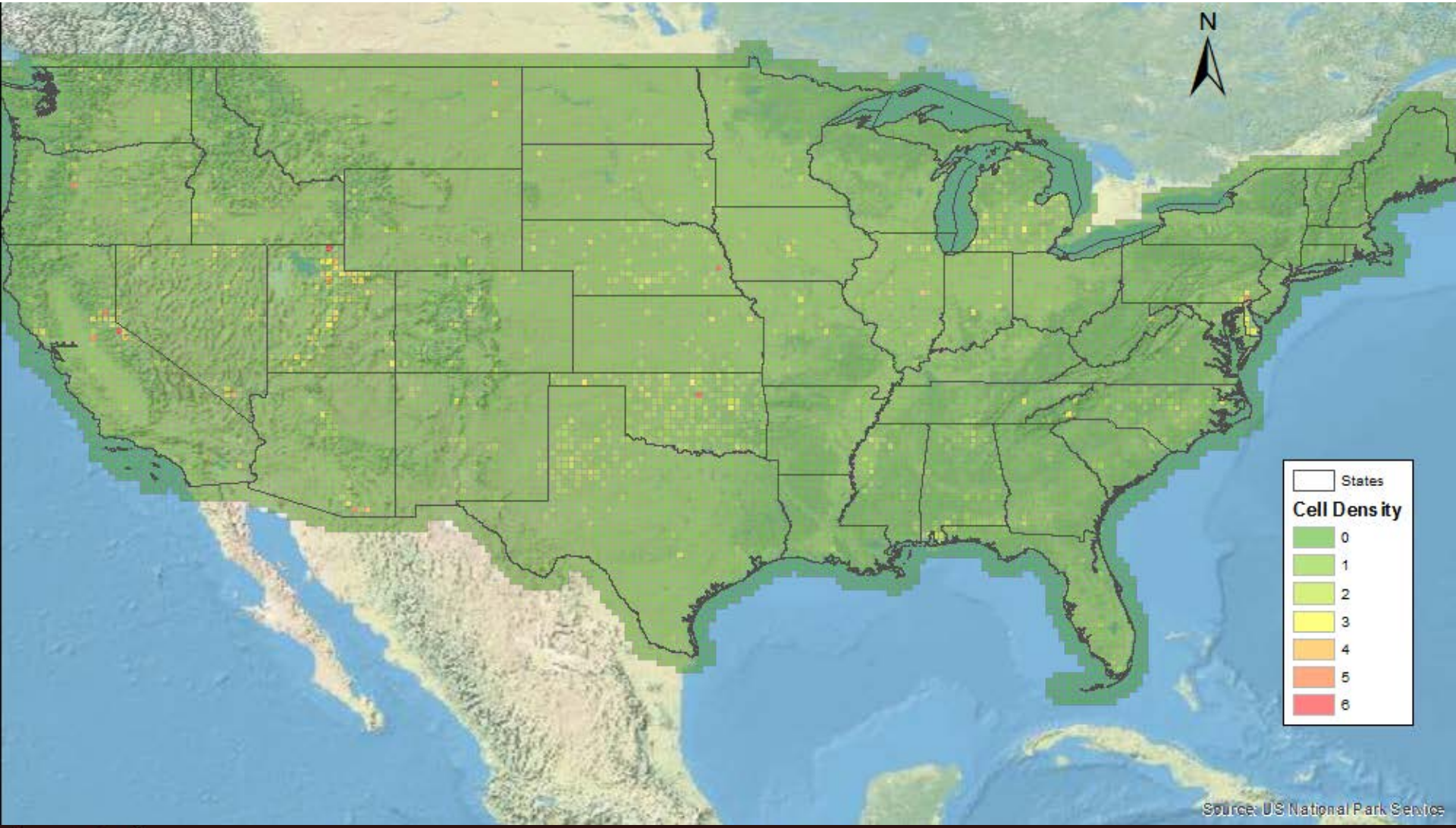
- Alberta Agriculture and Rural Development
- AmeriFlux
- Atmospheric Radiation Measurement
- Automated Weather Data Network
- Central Plains Experimental Range
- CHILI
- Climate Reference Network
- Cosmic Ray Soil Moisture Observing Station
- Delaware Environmental Observing System
- ECONET
- Fluxnet Canada
- GPS Soil Moisture
- Illinois Climate Network
- ISGMN
- MAW-Missouri
- MAWN
- NOAA HMT
- Oklahoma Mesonet
- SNOTEL
- Soil Climate Analysis Network
- Soilscape
- South Dakota Automated Weather Network
- TW Daniels Experimental Forest
- Water and Environmental Research Center
- West Texas Mesonet

North American Soil Moisture Database

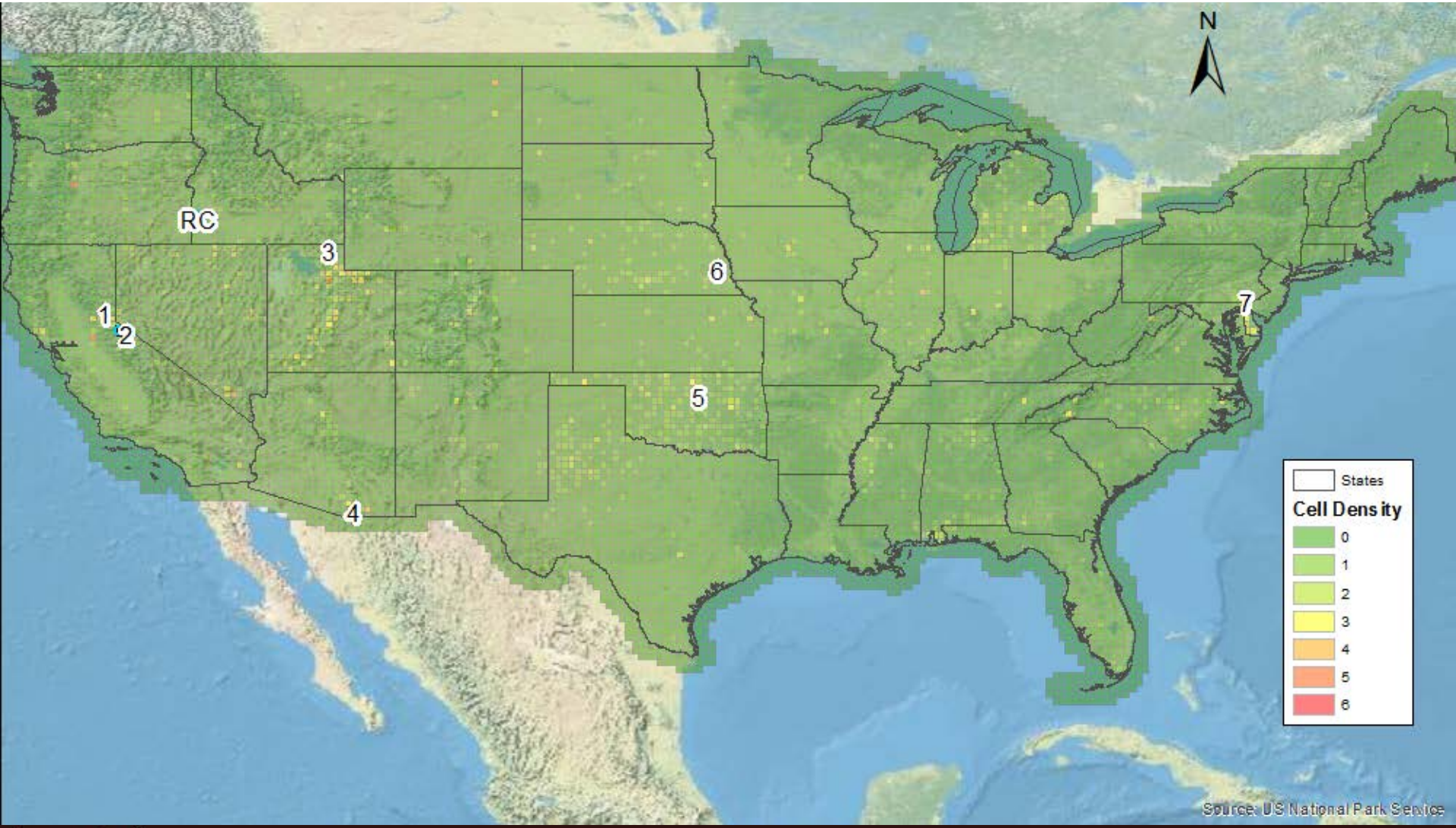
- We have identified >1800 stations
  (+2000 more from industry)
- Currently 1478 stations are at:
  soilmoisture.tamu.edu

- Although many of these stations are only available since the 1990s, some are available prior to the 1950s
- Includes a variety of sensors, soil water variables, depths, sampling frequencies

NASMD Station Density



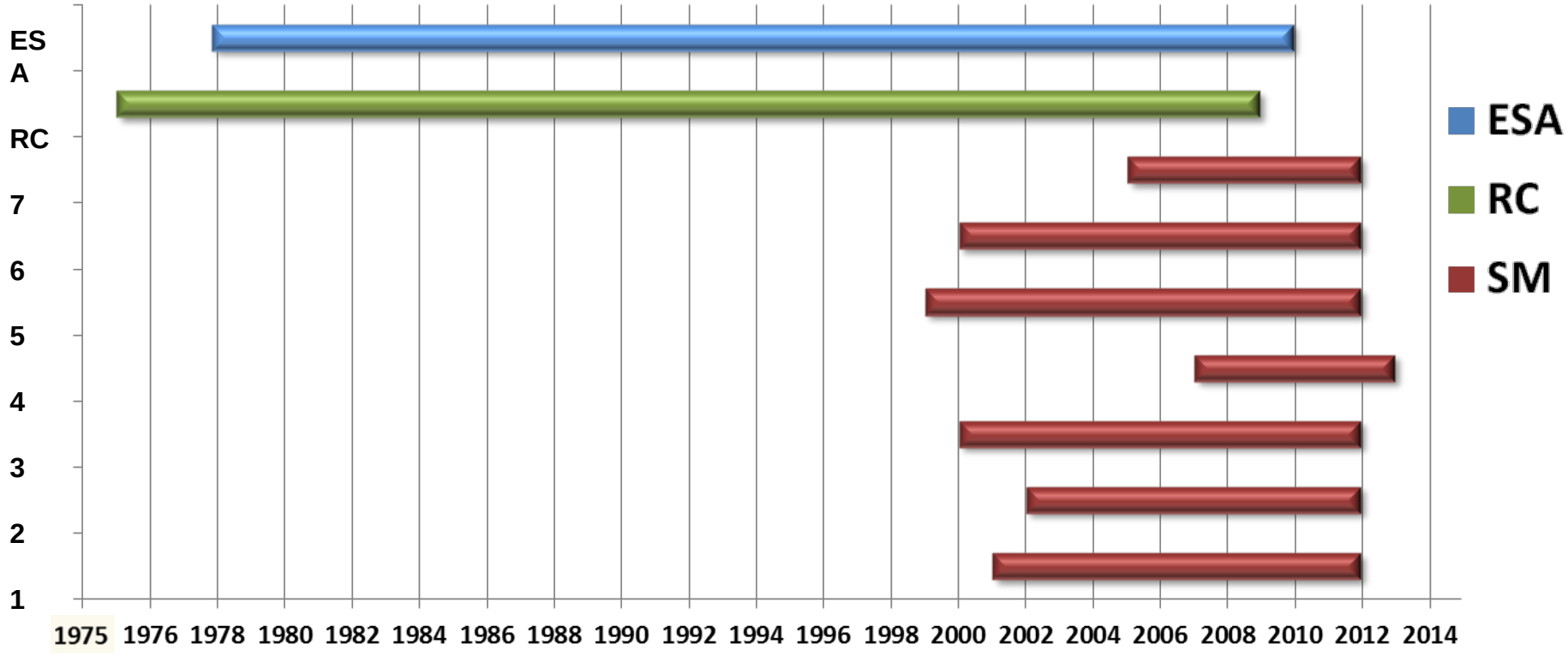
NASMD Station Density



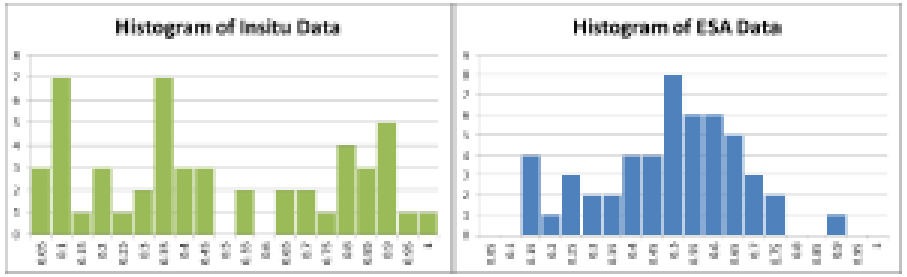
In situ soil moisture sites: Basic information including Land Use/Land Cover and Elevation per site

Grid #	Site #	StationID	depth1 cm	Network	StationName	City	County	State	LULC	LULC Desc	Elevation (ft)
1	1	0250350212	5.1	SNOTEL	Independence Lake	Tahoe National Forest	Nevada	California	42	Evergreen Forest	8352
	2	0250370512	5.1	SNOTEL	CSS Lab	Soda Springs	Nevada	California	42	Evergreen Forest	6855
	3	0250460412	5.1	SNOTEL	Independence Creek	Sierraville	Sierra	California	42	Evergreen Forest	6456
	4	0250620312	5.1	SNOTEL	Independence Camp	Truckee	Sierra	California	42	Evergreen Forest	7003
	5	180190711	10	NOAA HMT	Onion Creek	Truckee	Nevada	CA	42	Evergreen Forest	1886
2	1	0250390512	5.1	SNOTEL	Blue Lakes	Markleeville	Alpine	California	42	Evergreen Forest	8057
	2	0250400512	5.1	SNOTEL	Ebbetts Pass	Toiyabe National Forest	Alpine	California	52	Shrub/Scrub	8765
	3	0250440412	5.1	SNOTEL	Carson Pass	El Dorado National Forest	El Dorado	California	52	Shrub/Scrub	8353
	4	0250570312	5.1	SNOTEL	Burnside Lake	Markleeville	Alpine	California	52	Shrub/Scrub	8129
	5	0250580312	5.1	SNOTEL	Forestdale Creek	Markleeville	Alpine	California	42	Evergreen Forest	8017
	6	0250610312	5.1	SNOTEL	Spratt Creek	Markleeville	Alpine	California	42	Evergreen Forest	6115
3	1	252480612	5.1	SNOTEL	Tony Grove Lake	Richmond	Cache	Utah	41	Deciduous Forest	8386
	2	0252500912	5.1	SNOTEL	Klondike Narrows	Richmond	Cache	Utah	41	Deciduous Forest	7400
	3	0252520912	5.1	SNOTEL	Tony Grove Rs	Richmond	Cache	Utah	52	Shrub/Scrub	6250
	4	0252540112	5.1	SNOTEL	Temple Fork	Uinta-Wasatch-Cache National Forest	Cache	Utah	52	Shrub/Scrub	7406
	5	0252630712	5.1	SNOTEL	USU Doc Daniel	Garden City	Cache	Utah	41	Deciduous Forest	8270
4	1	70050212	5	Climate Reference Network	Elgin 5S	Elgin	Santa Cruz	Arizona	52	Shrub/Scrub	4811
	2	180030813	10	NOAA HMT	Black Oak	Patagonia	Santa Cruz	AZ	52	Shrub/Scrub	1556
	3	180060812	5	NOAA HMT	Canelo	Elgin	Santa Cruz	AZ	52	Shrub/Scrub	1505
	4	180090813	5	NOAA HMT	Elgin	Elgin	Santa Cruz	AZ	52	Shrub/Scrub	1470
	5	180120813	5	NOAA HMT	Freeman Springs	Patagonia	Santa Cruz	AZ	52	Shrub/Scrub	1537
5	1	70800212	5	Climate Reference Network	Stillwater 2 W	Stillwater	Payne	Oklahoma	71	Herbaceuous	890
	2	70810212	5	Climate Reference Network	Stillwater 5 WNW	Stillwater	Payne	Oklahoma	82	Cultivated Crops	888
	3	10759412	5	Oklahoma Mesonet	Marena	Coyle	Payne	Oklahoma	71	Herbaceuous	3341
	4	10999412	5	Oklahoma Mesonet	Perkins	Perkins	Payne	Oklahoma	21	Developed, Open Space	958
	5	11149412	5	Oklahoma Mesonet	Stillwater	Stillwater	Payne	Oklahoma	41	Deciduous Forest	892
6	1	240670112	18	AmeriFlux	Mead Irrigated	Mead	Saunders	Nebraska	82	Cultivated Crops	361
	2	240680112	18	AmeriFlux	Mead Irrigated Rotation	Mead	Saunders	Nebraska	82	Cultivated Crops	362
	3	240690112	18	AmeriFlux	Mead Rainfed	Yutan	Saunders	Nebraska	82	Cultivated Crops	363
	4	40329812	10	Automated Weather Data Network	Mead	Mead	Saunders	Nebraska	82	Cultivated Crops	1200
	5	40330412	10	Automated Weather Data Network	Mead Agrofarm	Mead	Saunders	Nebraska	82	Cultivated Crops	1151
7	1	150130612	5	Delaware Environmental Observing System	Hockessin	Hockessin	New Castle	Delaware	21	Developed, Open Space	253
	2	150140812	5	Delaware Environmental Observing System	Mt. Cuba	Hockessin	New Castle	Delaware	41	Deciduous Forest	294
	3	150150812	5	Delaware Environmental Observing System	Bucktoe	Kennett Square	Chester	Pennsylvania	41	Deciduous Forest	347
	4	150181112	5	Delaware Environmental Observing System	West Bradford	Marshallton	Chester	Pennsylvania	41	Deciduous Forest	335
	5	150271112	5	Delaware Environmental Observing System	West Chester	West Chester	Chester	Pennsylvania	21	Developed, Open Space	417

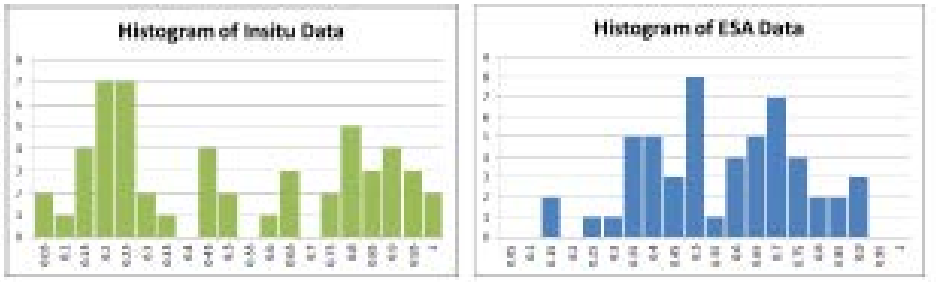
Period of Record

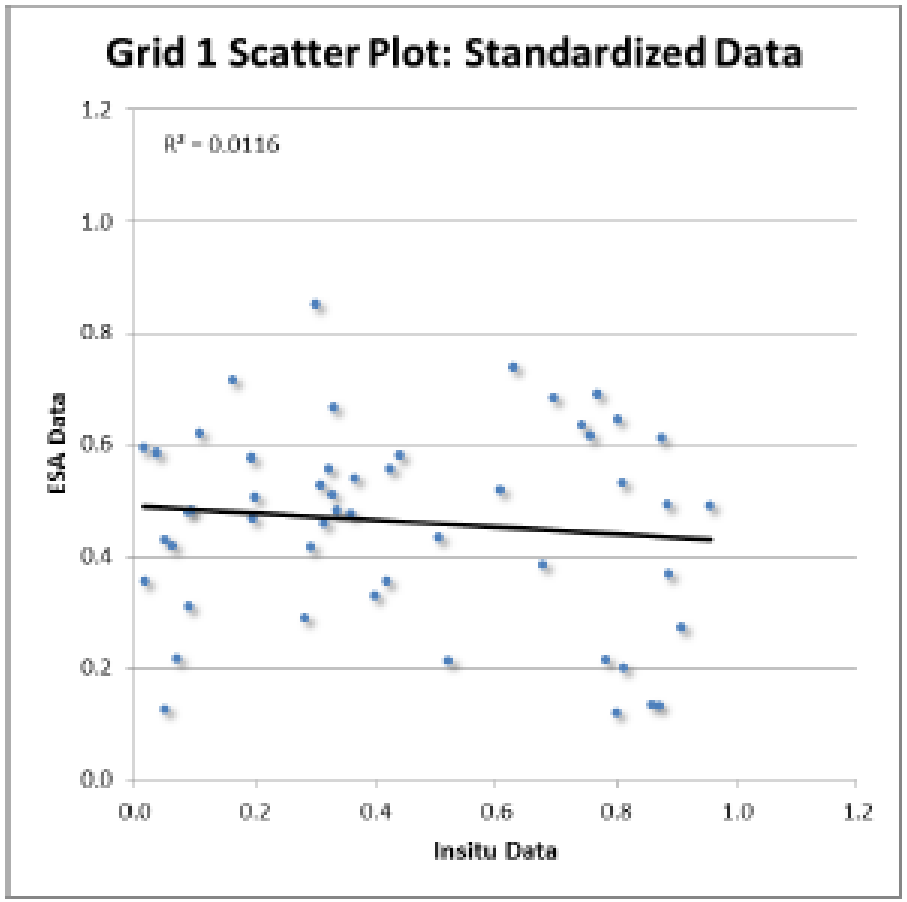


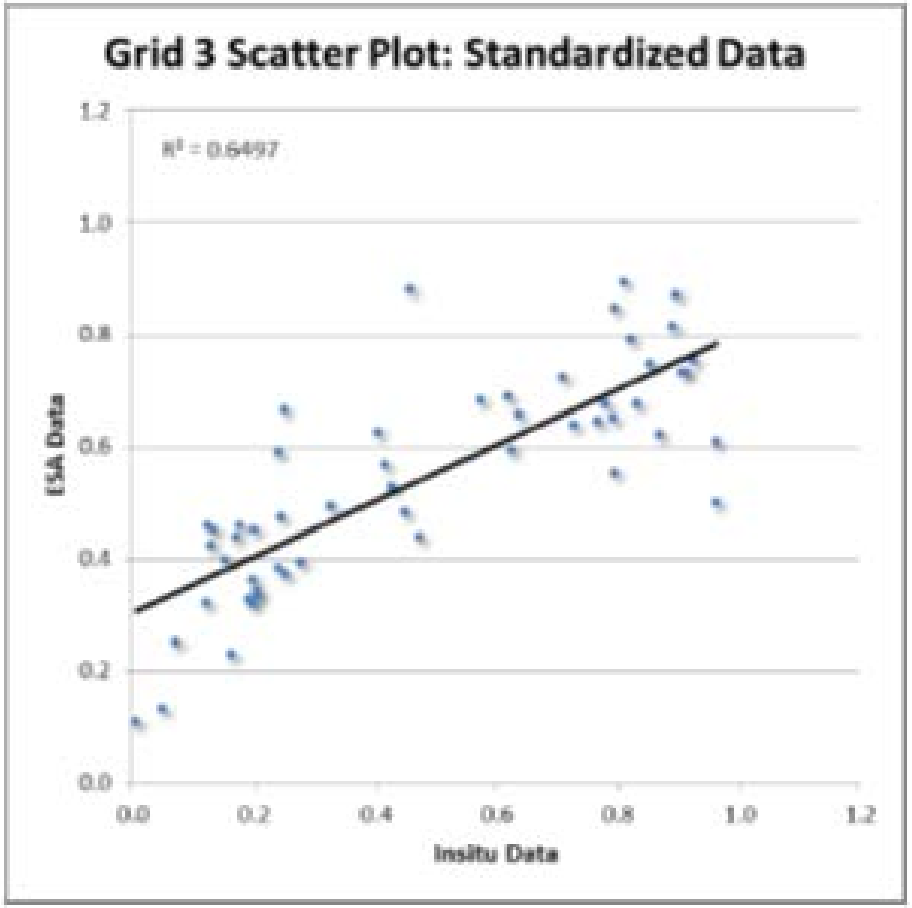
California



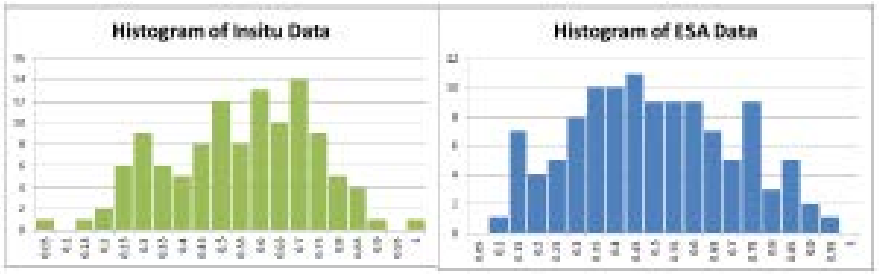
Utah



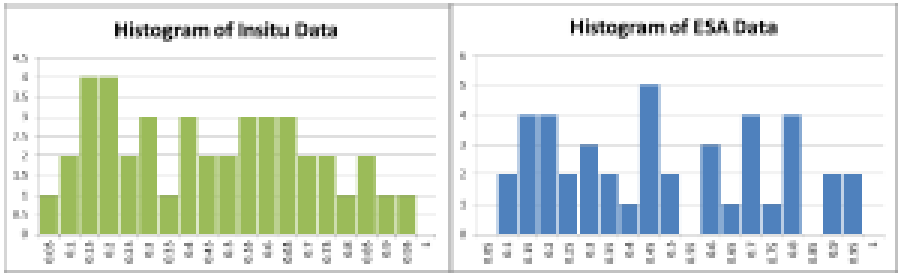


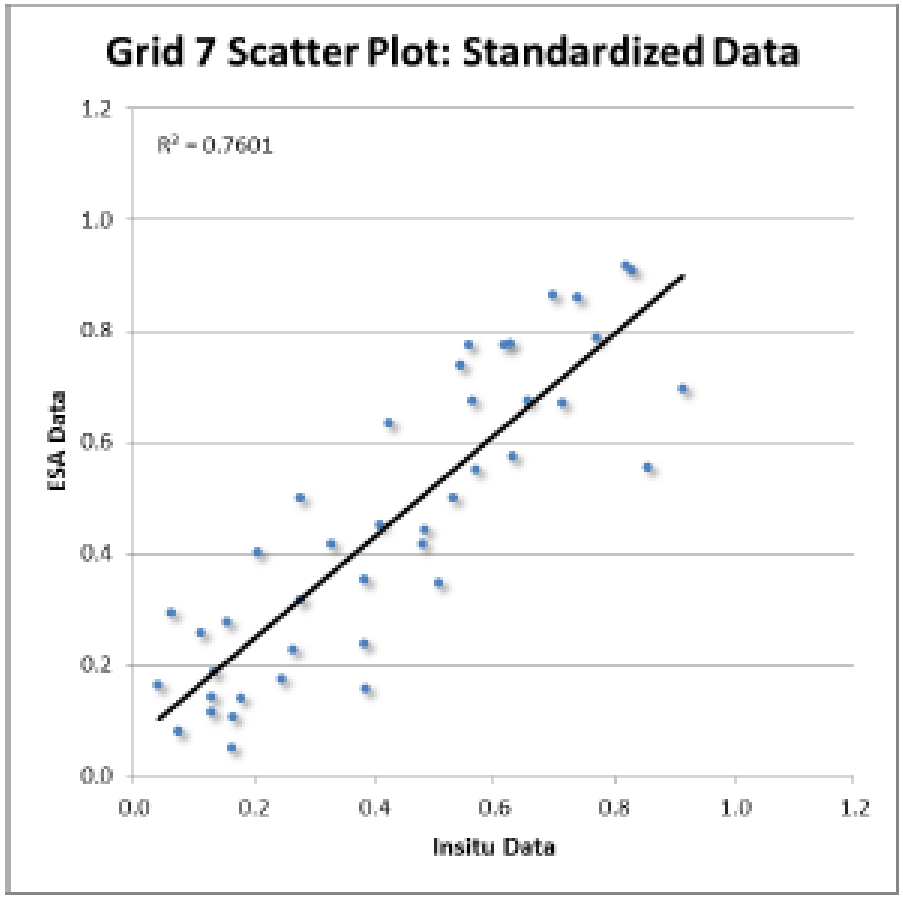


Oklahoma

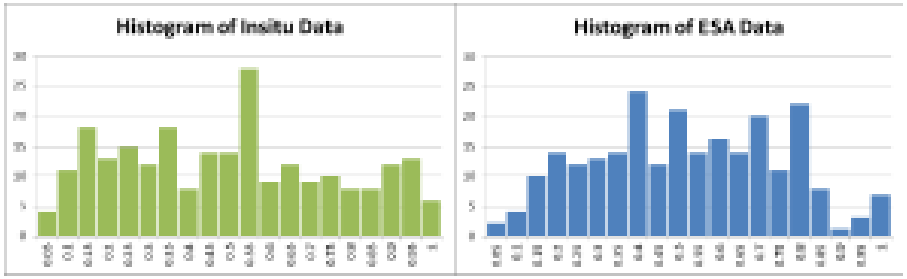


Delaware

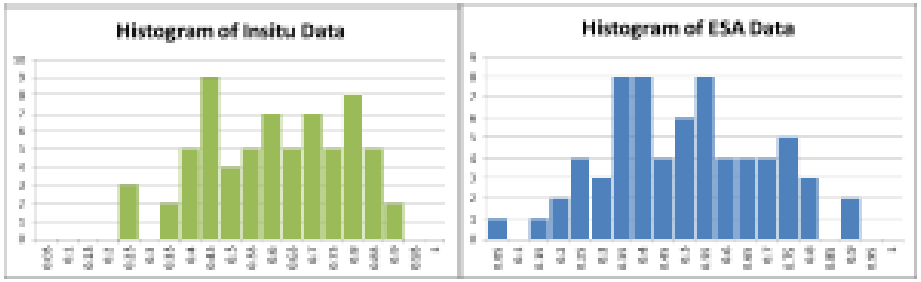


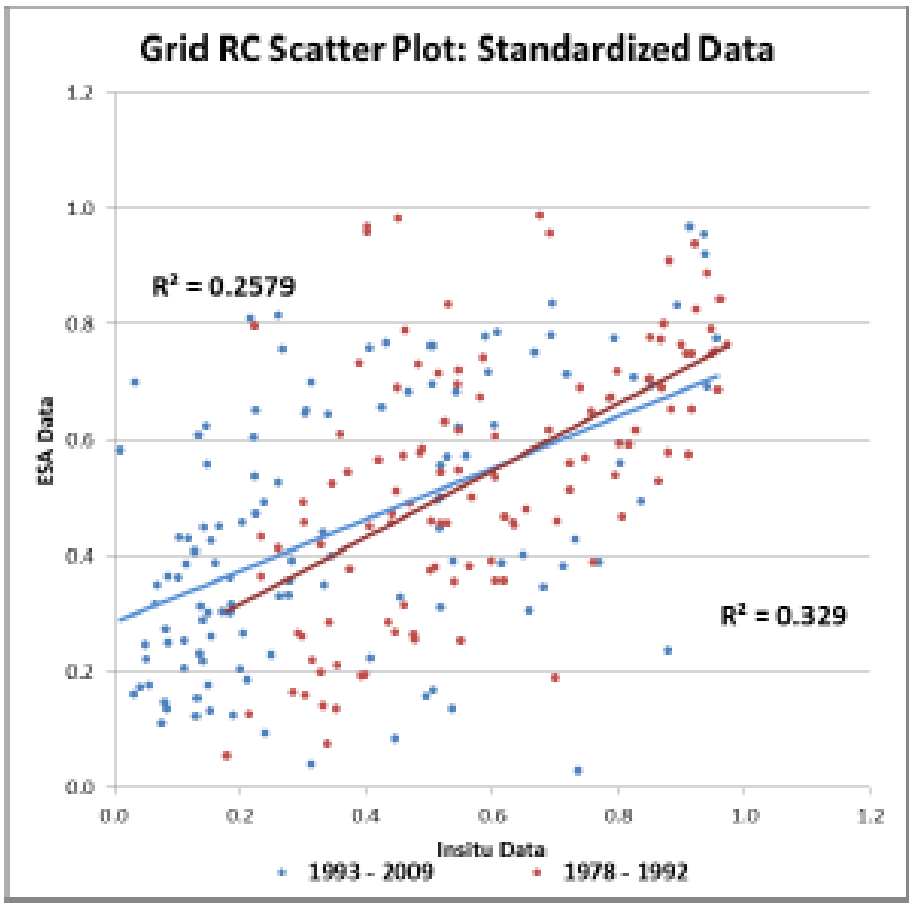


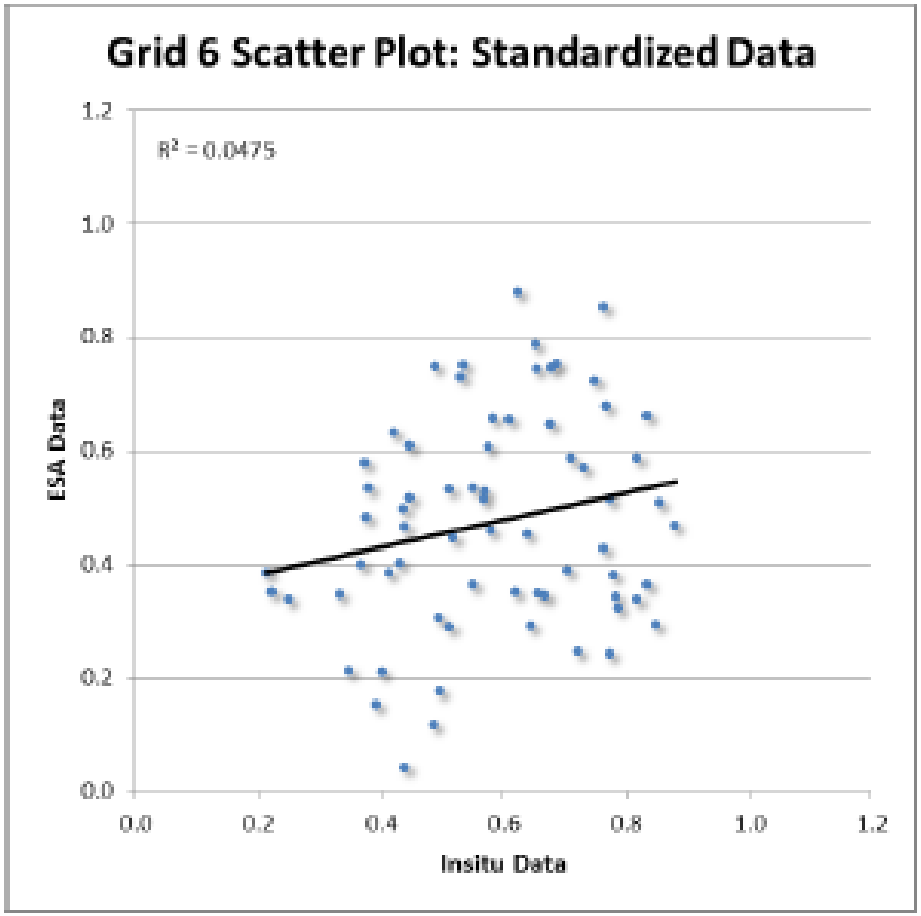
Reynolds Creek



Nebraska



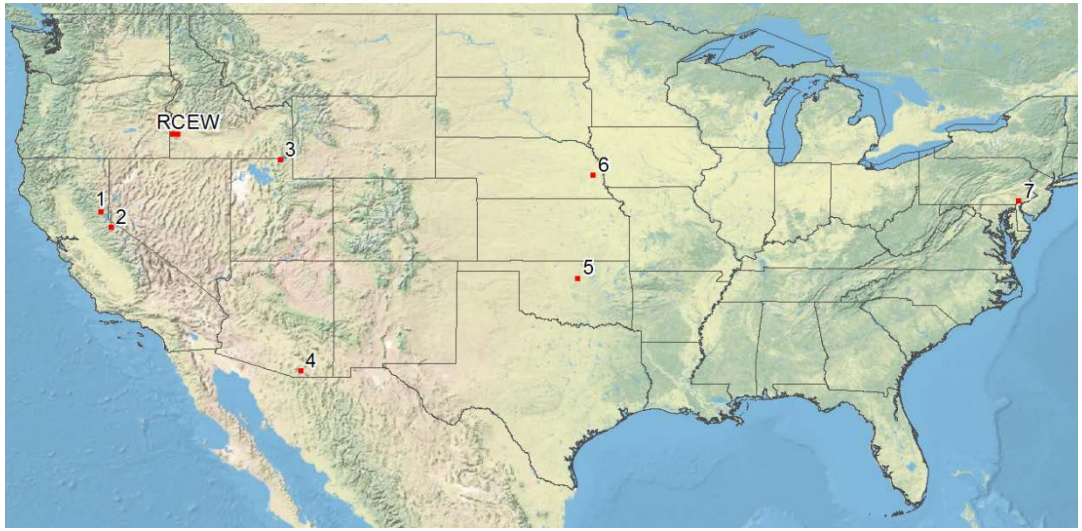




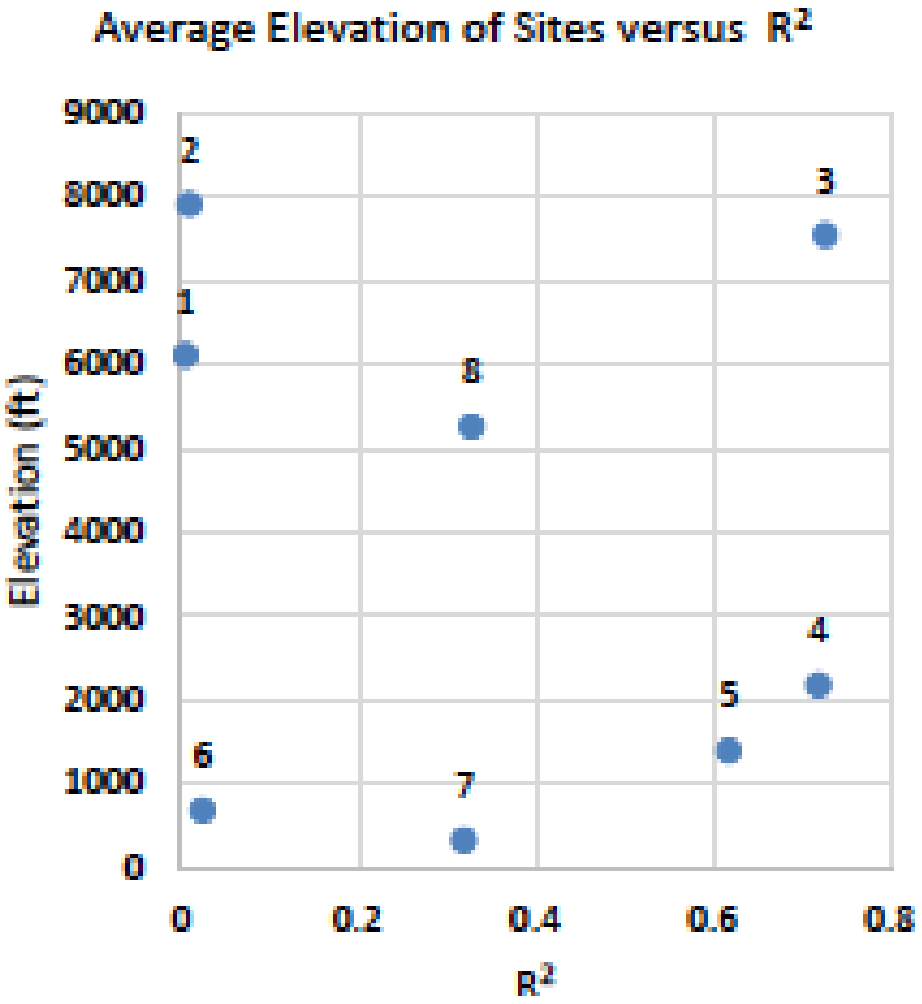
Evaluation Summary

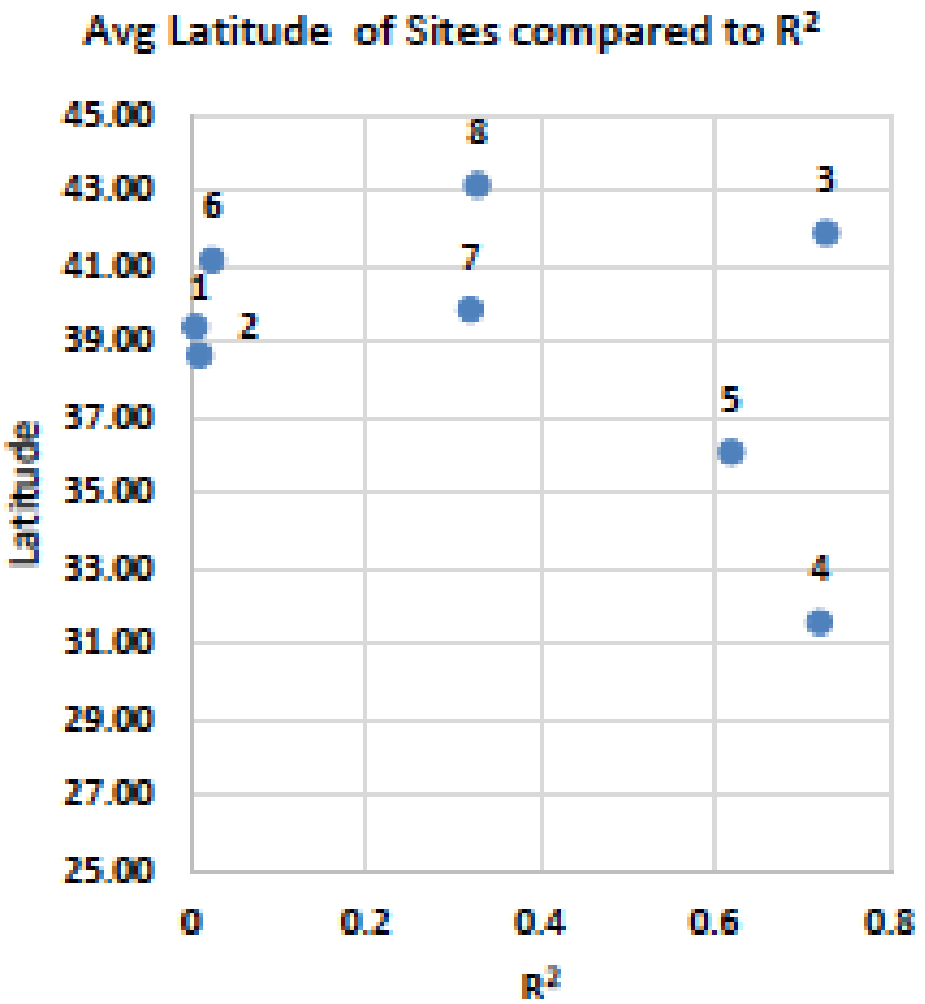
Percentile - Wetness	1	2	3	4	5	6	7	RC
Average difference	-0.015	0.004	-0.064	0.052	0.051	0.110	-0.027	-0.018
RMSE	0.362	0.345	0.200	0.180	0.140	0.248	0.132	0.234
MAE	0.301	0.274	0.167	0.142	0.114	0.199	0.107	0.189
R^2	0.012	0.003	0.650	0.397	0.608	0.048	0.760	0.315
Index of Agreement (d)	0.345	0.380	0.829	0.783	0.865	0.524	0.929	0.747
Coefficient of Efficiency (E)	-0.459	-0.553	0.572	0.205	0.438	-1.176	0.718	0.217
Count	51	56	53	32	115	67	42	242

- Good agreement in Utah (3), Oklahoma (5), and Delaware (7)
- Moderate agreement in Arizona (4) and Reynolds Creek.
- Poor agreement in California (1 & 2) and Nebraska (6)

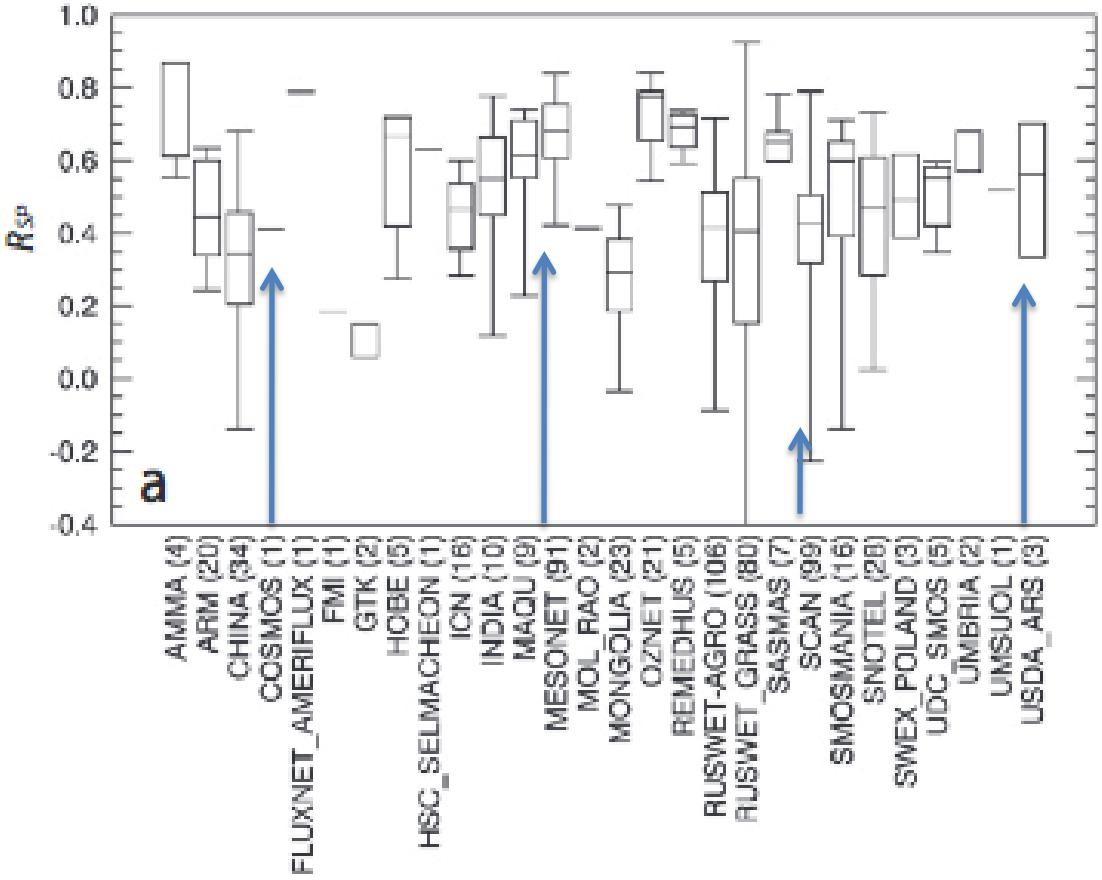


Causes of Variations in Agreement





Summary of Results



Contents lists available at ScienceDirect

Remote Sensing of Environment

journal homepage: www.elsevier.com/locate/rse

Evaluation of the ESA CCI soil moisture product using ground-based observations

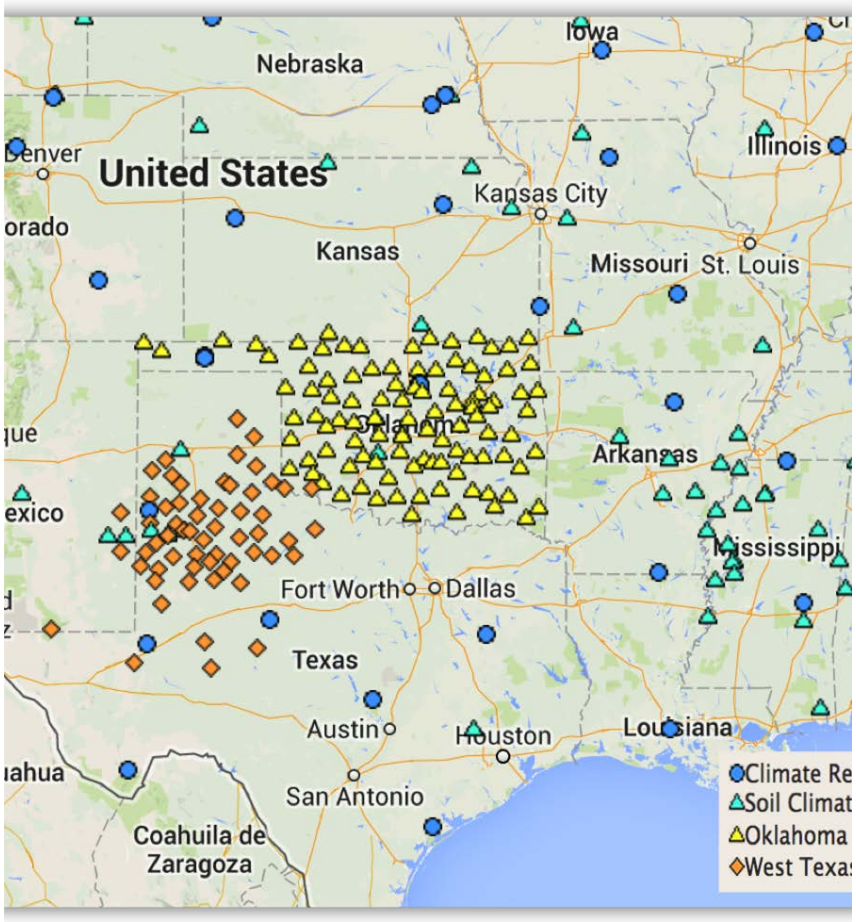
W.A. Dorigo [a,*], A. Gruber [a], R.A.M. De Jeu [b], W. Wagner [a], T. Stacke [c], A. Loew [c], C. Albergel [d], L. Brocca [e], D. Chung [a], R.M. Parinussa [b], R. Kidd [a]

- Many issues account for the significant variability in agreement:
  - calibration
  - scaling/representativeness
  - stability of satellite product
  - period of record
  - variations in soil, vegetation, etc.
- Our results agree with other studies (Dorigo et al. 2015)

National Soil Moisture Network Pilot

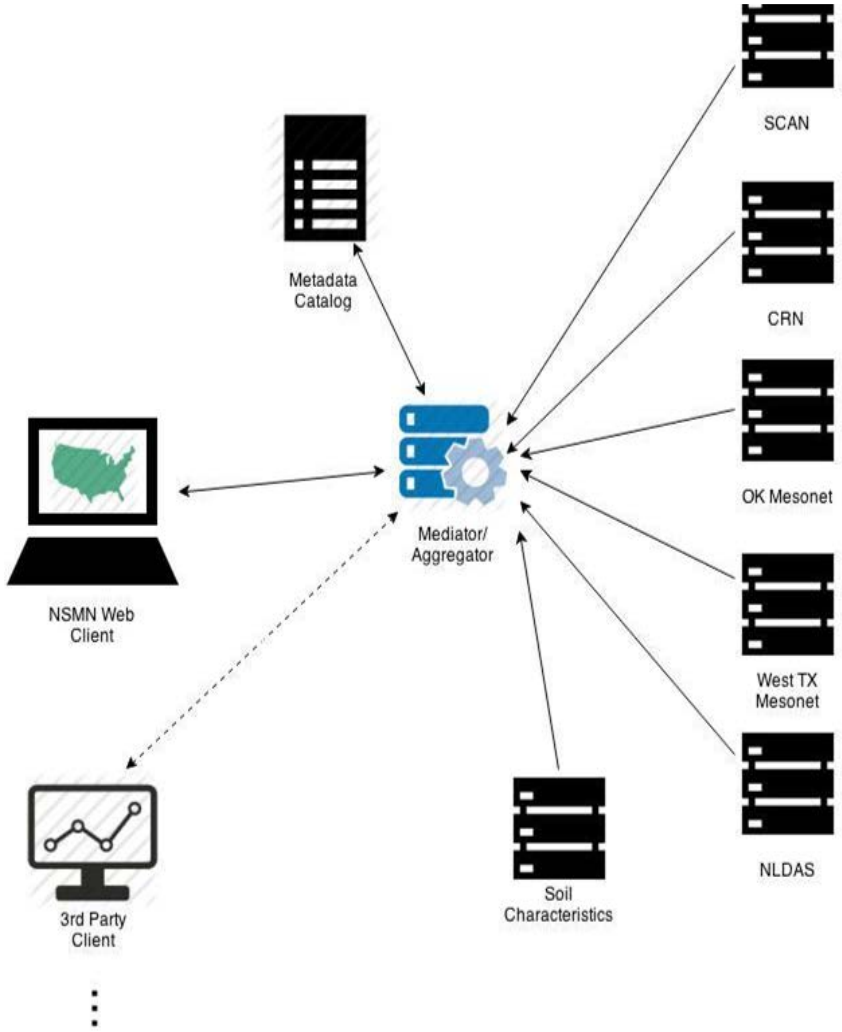
- **Pilot project funded by NIDIS to develop a Coordinated National Soil Moisture Network- President Obama's Climate Action Plan**

- In-Situ:
  - Climate Reference Network
  - SCAN
  - Oklahoma Mesonet
  - West Texas Mesonet
- Modeled:
  - NLDAS-2 model-derived soil moisture from: Noah, Mosaic, SAC and VIC



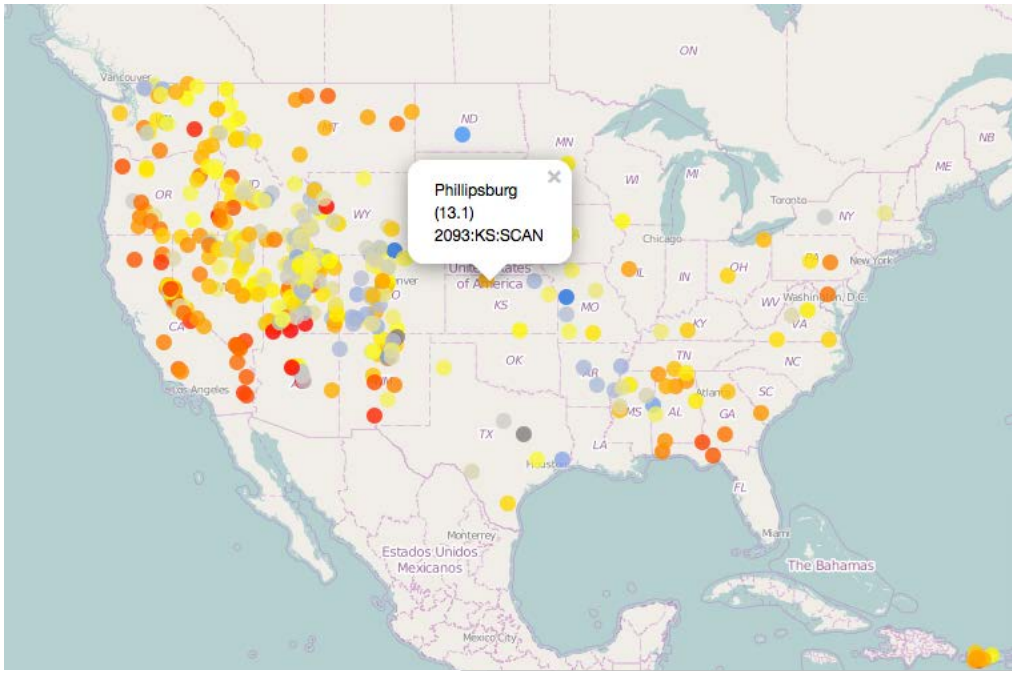
System Architecture

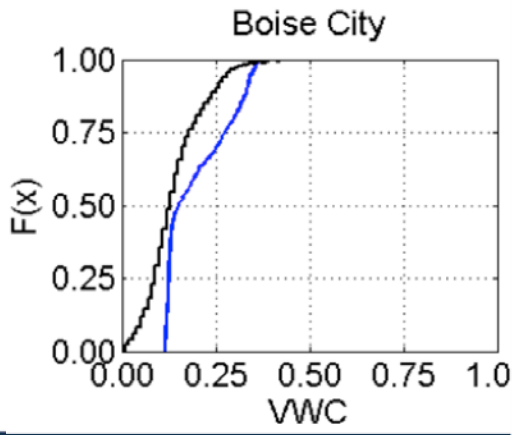
- Site metadata and soil characteristics web service - Re-factor NASMD
- Catalog of data sets and service metadata
- CRN web service - NCDC ArcServer
- SCAN web service - AWDB SOAP
- OK Mesonet web service
- West TX Mesonet web service
- NLDAS web service - USGS Geo Data Portal
- Algorithm development for calculating percentiles, aggregating datasets
- Service mediator/aggregator
- Map-based visualization web tools

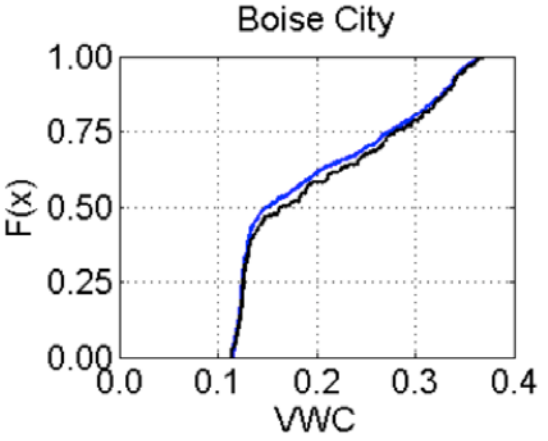


Progress

- Gathered and completed QA/QC of station metadata
- Web services established for CRN, West TX and OK Mesonets
- Mediator coded to access and process SCAN data
- Interactive map display prototype
- Analysis of historical record needed for representative SM percentiles







Project Timeline

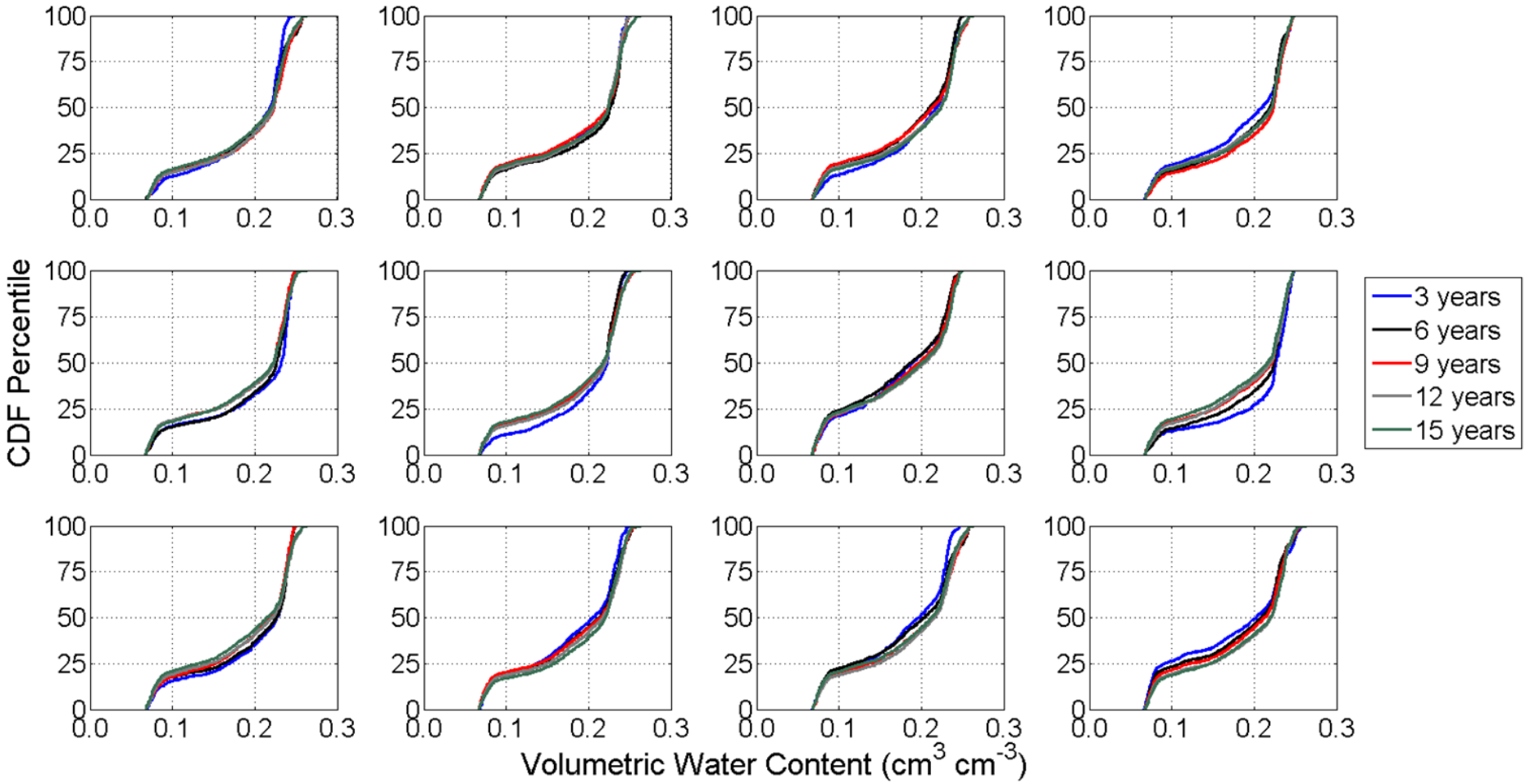
- System Planning - December 2014
- Start Pilot Development - January 2015
- Midway Progress Report - April 1, 2015
- Development Completed- July 1, 2015
- Demo Pilot- July/August 2015
- Final Project Report- August 31, 2015
- Phase 2 of development will start in Fall

Acknowledgements

- We gratefully acknowledge our project sponsors:
  - NSF Climate & Large-scale Dynamics (CAREER ATM-1056796)
  - National Integrated Drought Information System (NIDIS)
  - Department of Interior South Central Climate Science Center
  - NOAA SCIPP RISA

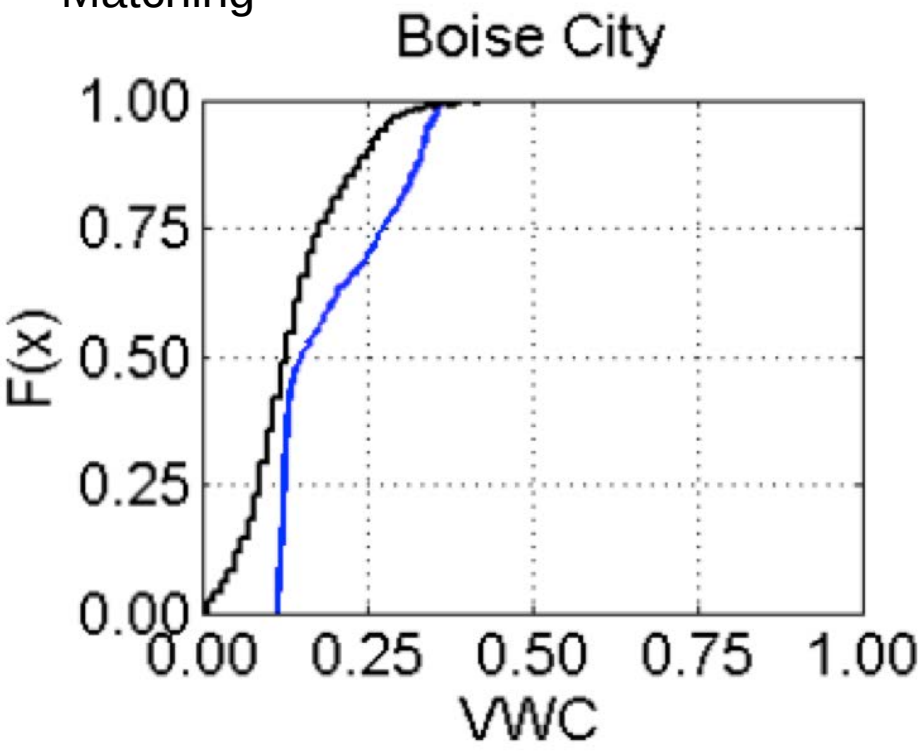
SOUTH CENTRAL
CLIMATE SCIENCE CENTER

Soil Moisture Percentiles

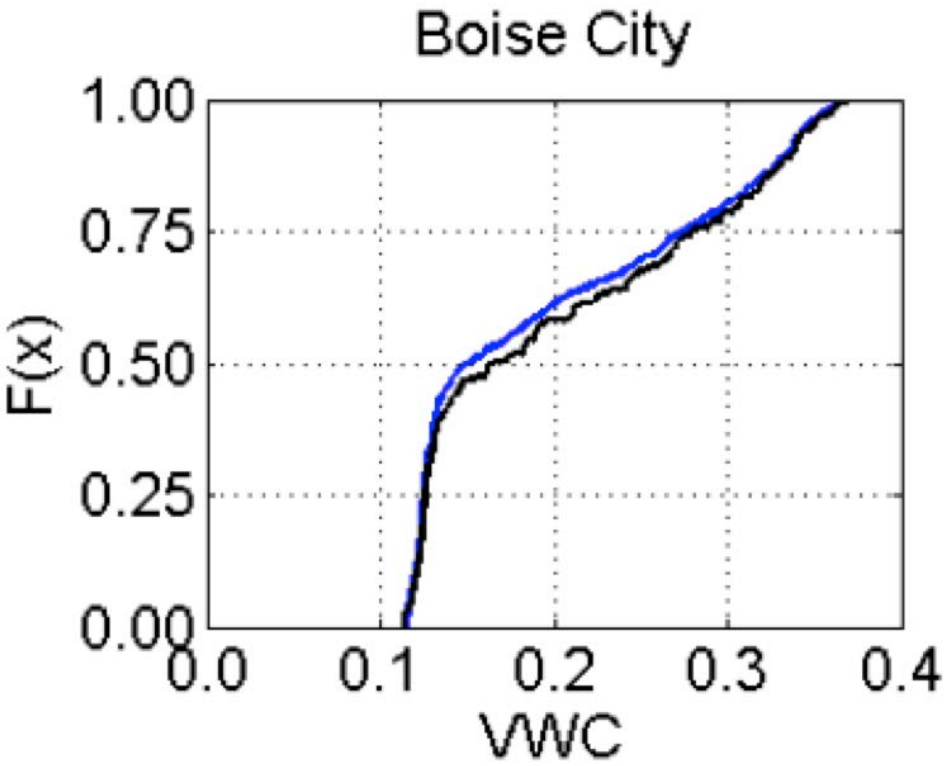


CDF Matching

Before CDF Matching



After CDF Matching



Grid Site Climate Networks

1	1	SNOTEL
	2	SNOTEL
	3	SNOTEL
	4	SNOTEL
	5	NOAA HMT
2	1	SNOTEL
	2	SNOTEL
	3	SNOTEL
	4	SNOTEL
	5	SNOTEL
	6	SNOTEL
3	1	Cosmic Ray Soil Moisture Observing Station
	2	SNOTEL
	3	SNOTEL
	4	SNOTEL
	5	SNOTEL
	6	SNOTEL
4	1	Climate Reference Network
	2	NOAA HMT
	3	NOAA HMT
	4	NOAA HMT
	5	NOAA HMT

5	1	Climate Reference Network
	2	Climate Reference Network
	3	Cosmic Ray Soil Moisture Observing Station
	4	Oklahoma Mesonet
	5	Oklahoma Mesonet
	6	Oklahoma Mesonet
6	1	AmeriFlux
	2	AmeriFlux
	3	AmeriFlux
	4	Automated Weather Data Network
	5	Automated Weather Data Network
	6	Cosmic Ray Soil Moisture Observing Station
7	1	Delaware Environmental Observing System
	2	Delaware Environmental Observing System
	3	Delaware Environmental Observing System
	4	Delaware Environmental Observing System
	5	Delaware Environmental Observing System

39 Different SM Station
8 different Climate Networks

Brazos River at Seymour, TX in August 2011
Brazos River Authority

North American Soil Moisture Database

- NASMD includes national, regional, state and local networks. It also includes in situ soil moisture data collected during field campaigns, and research projects.

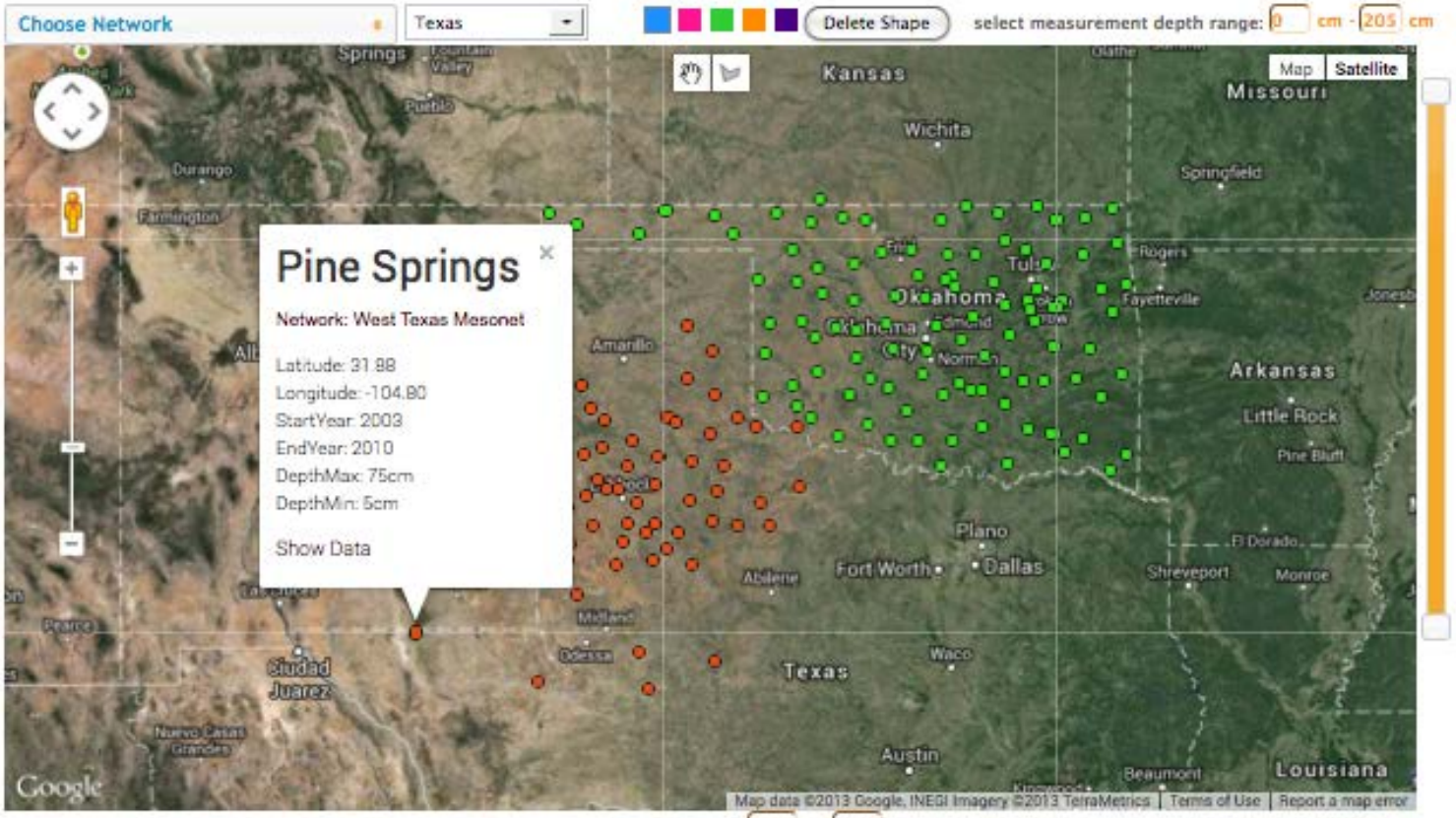
- Comprehensive meta-data has been developed for all of the stations including sensor, soil characteristics, surface vegetation, and details on instrument calibration.

- All data has gone through our customized QA/QC algorithm. Measurements failing the QC tests are rejected for further analysis.

North American Soil Moisture Database Interactive Map

This interactive map allows you to view & download station data from the North American Soil Moisture Database.

Choose one or more networks from the dropdown list to see station data. Use the depth & year sliders to filter. Click the extract buttons to download station data.

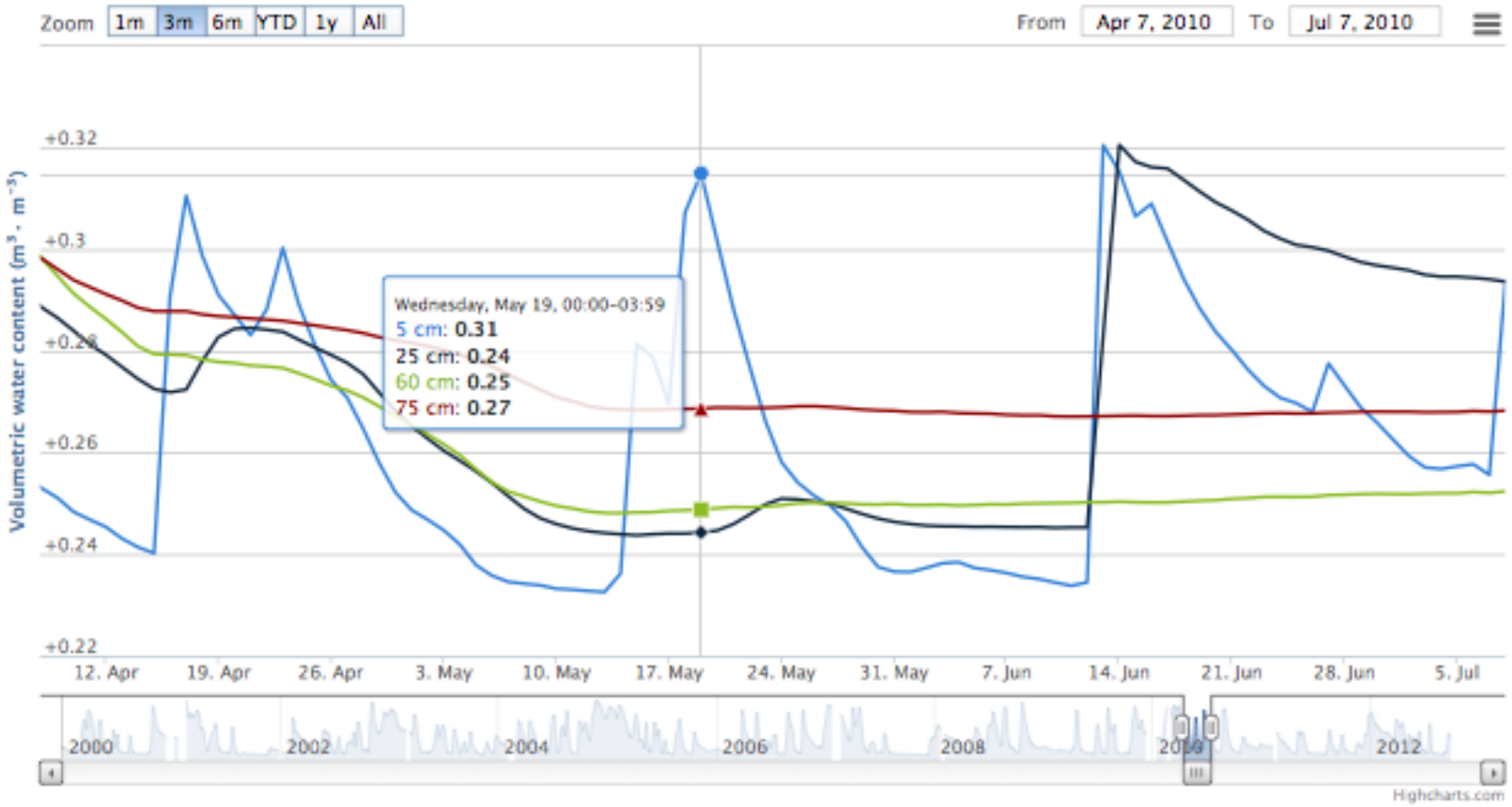


Slide to select data year range: 1991 - 2013

163 Stations have been selected

No.	All	Station	Network	Location	State
1	☐	Norman	Oklahoma Mesonet	Norman	Oklahoma
2	☐	Acme	Oklahoma Mesonet	Rush Springs	Oklahoma
3	☐	Ada	Oklahoma Mesonet	Ada	Oklahoma

Station Data



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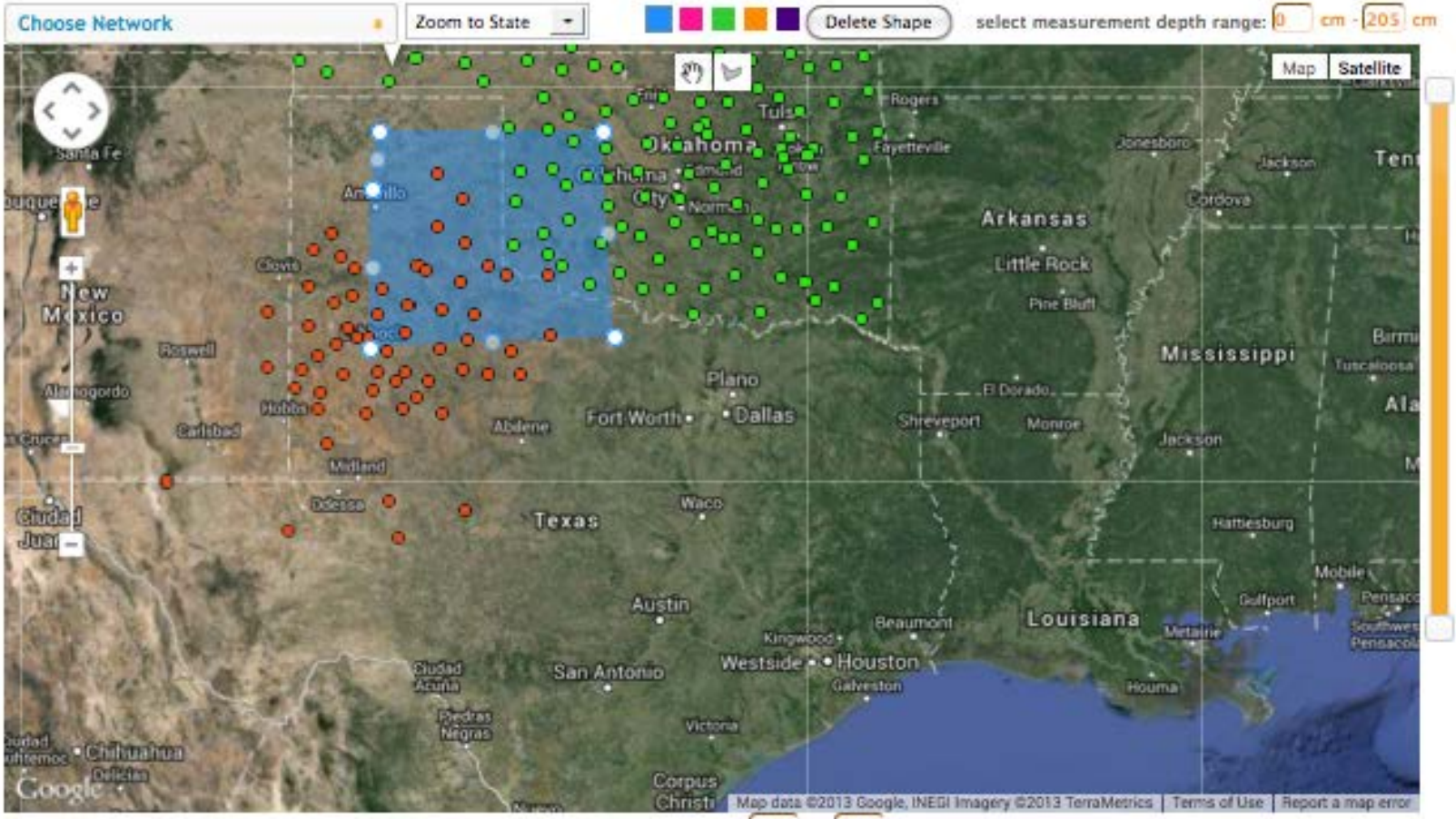


Slide to select data year range: 1991 - 2013

32 Stations have been selected

No.	All	Station	Network	Location	State
1	☐	Altus	Oklahoma Mesonet	Altus	Oklahoma
2	☐	Arnett	Oklahoma Mesonet	Arnett	Oklahoma

32 Stations have been selected

No.	All	Station	Network	Location	State
1	☑	Altus	Oklahoma Mesonet	Altus	Oklahoma
2	☑	Arnett	Oklahoma Mesonet	Arnett	Oklahoma
3	☑	Bessie	Oklahoma Mesonet	Bessie	Oklahoma
4	☑	Butler	Oklahoma Mesonet	Butler	Oklahoma
5	☑	Camargo	Oklahoma Mesonet	Camargo	Oklahoma
6	☑	Cheyenne	Oklahoma Mesonet	Cheyenne	Oklahoma
7	☑	Erick	Oklahoma Mesonet	Erick	Oklahoma
8	☑	Grandfield	Oklahoma Mesonet	Grandfield	Oklahoma
9	☑	Hobart	Oklahoma Mesonet	Hobart	Oklahoma
10	☑	Hollis	Oklahoma Mesonet	Gould	Oklahoma
11	☑	Mangum	Oklahoma Mesonet	Mangum	Oklahoma
12	☑	Medicine Park	Oklahoma Mesonet	Medicine Park	Oklahoma
13	☑	Putnam	Oklahoma Mesonet	Putnam	Oklahoma
14	☑	Tipton	Oklahoma Mesonet	Tipton	Oklahoma
15	☑	Weatherford	Oklahoma Mesonet	Weatherford	Oklahoma
16	☑	Abernathy	West Texas Mesonet	Abernathy	Texas
17	☑	Childress	West Texas Mesonet	Childress	Texas
18	☑	Clarendon	West Texas Mesonet	Clarendon	Texas
19	☑	Floydada	West Texas Mesonet	Floydada	Texas
20	☑	Goodlett	West Texas Mesonet	Goodlett	Texas

Extract Checked Stations

Extract All Selected Stations

No.	All	Station	Network	Location	State
1	☑	AURO	ECONET	Aurora	North Carolina
2	☑	BEAR	ECONET	Hendersonville	North Carolina
3	☐	BOON	ECONET	Boone	North Carolina
4	☐	BUCK	ECONET	Buckland	North Carolina
5	☐	BURN	ECONET	Burnsville	North Carolina
6	☐	CAST		yne	North Carolina
7	☐	CLA2			North Carolina
8	☐	CLAY			North Carolina
9	☐	CLIN			North Carolina
10	☐	DURH			North Carolina
11	☐	FLET			North Carolina
12	☐	GOLD		o	North Carolina
13	☐	HAML	ECONET	Hamlet	North Carolina
14	☐	HIGH	ECONET	High Point	North Carolina
15	☐	JACK	ECONET	Jackson Springs	North Carolina
16	☐	KINS	ECONET	Kinston	North Carolina
17	☐	LAKE	ECONET	Raleigh	North Carolina
18	☐	LAUR	ECONET	Laurel Springs	North Carolina
19	☐	LEWS	ECONET	Lewiston	North Carolina
20	☐	LILE	ECONET	Lilesville	North Carolina

Extract request queued. You will receive an email shortly.

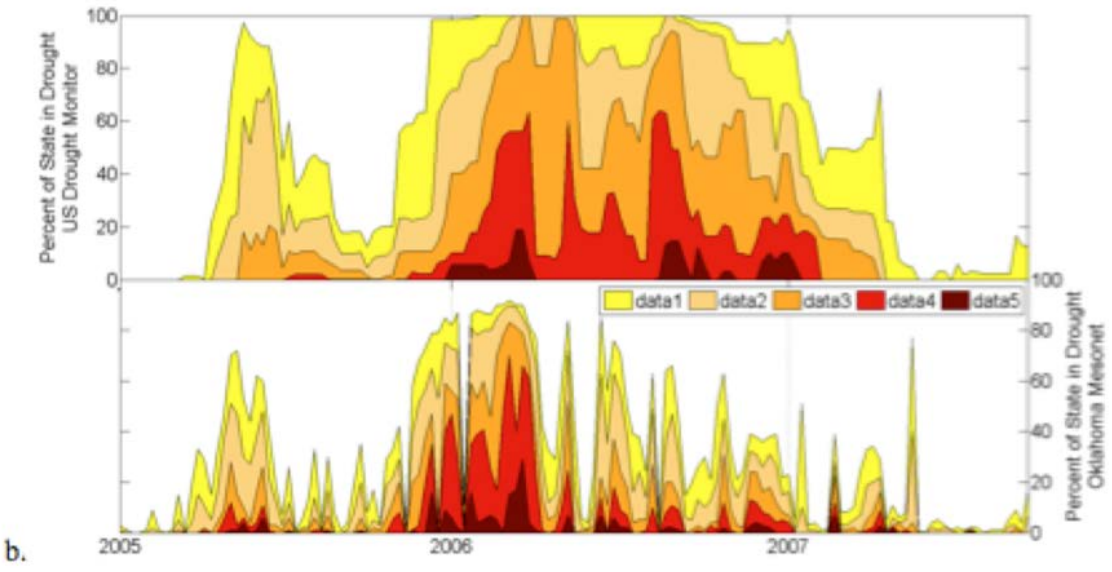
OK

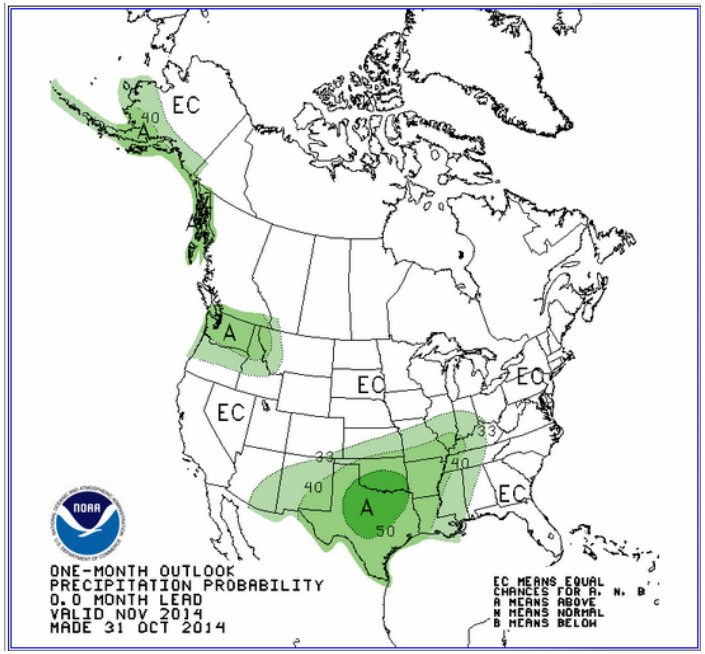
Extract Checked Stations

Extract All Selected Stations

NASMD Applications

- Seasonal climate/drought forecasting (CPC – soil moisture) (funded by SCIPP RISA)
- Drought monitoring and agricultural impacts (funded by South Central Climate Science Center)
- Extreme heat/heat wave persistence and human health (NSF proposal under development)





Acknowledgements

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Soil Moisture-Evaporative Fraction

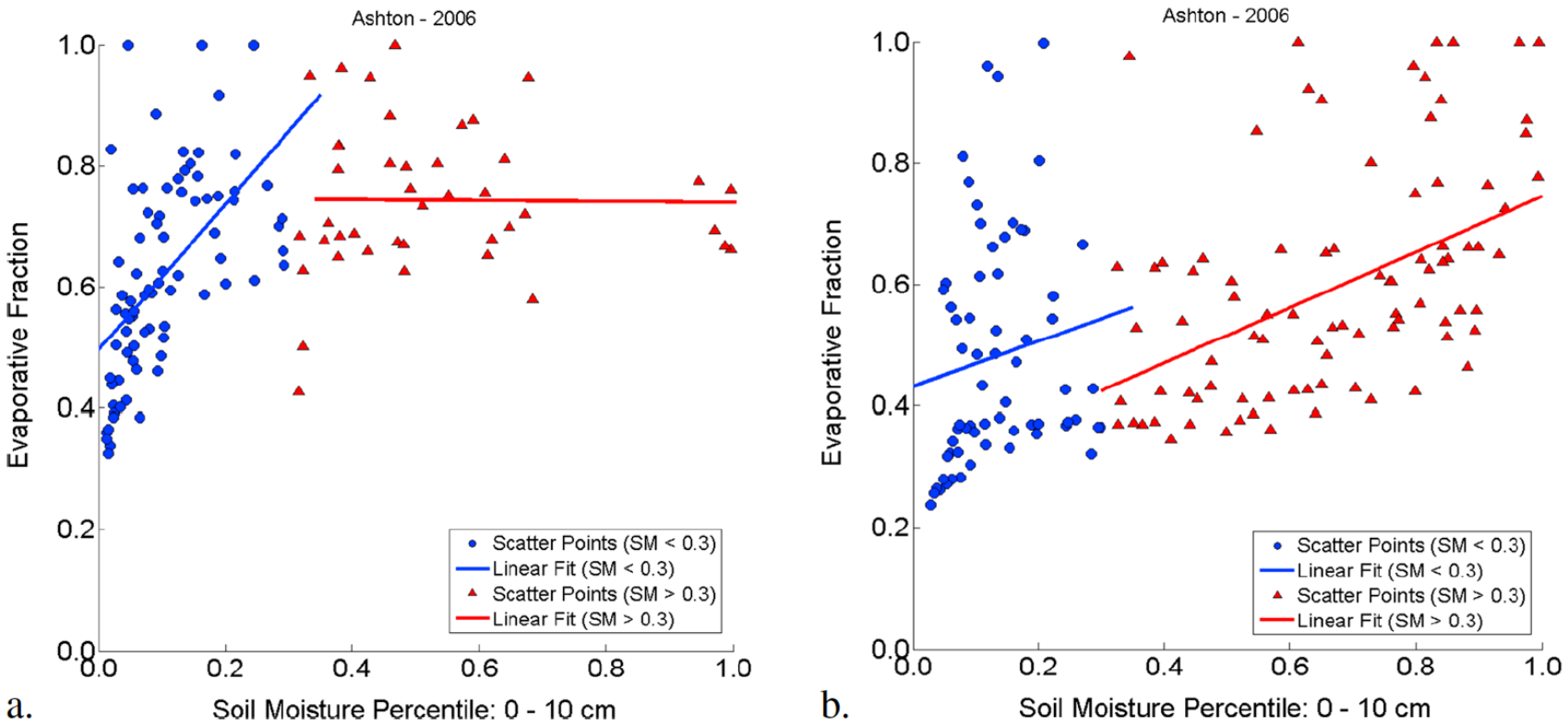


Figure 2. Soil moisture percentiles (0 to 10 cm) versus evaporative fraction in Ashton, Kansas based on (a) in situ observations and (b) VIC simulations. Each point represents a daily average; all days during the 2006 growing season are shown. The blue (red) line is the best fit line between SM and EF when SM is $<30^{th}$ ($>30^{th}$) percentile. Each graph contains 184 days (data points).

Ford, Wulff, and Quiring (2014) Assessment of observed and model-derived soil moisture-evaporative fraction relationships over the United States Southern Great Plains. *Journal of Geophysical Research–Atmospheres,* 119, 6279–6291, doi: 10.1002/2014JD021490

Soil Moisture-Extreme Temperatures

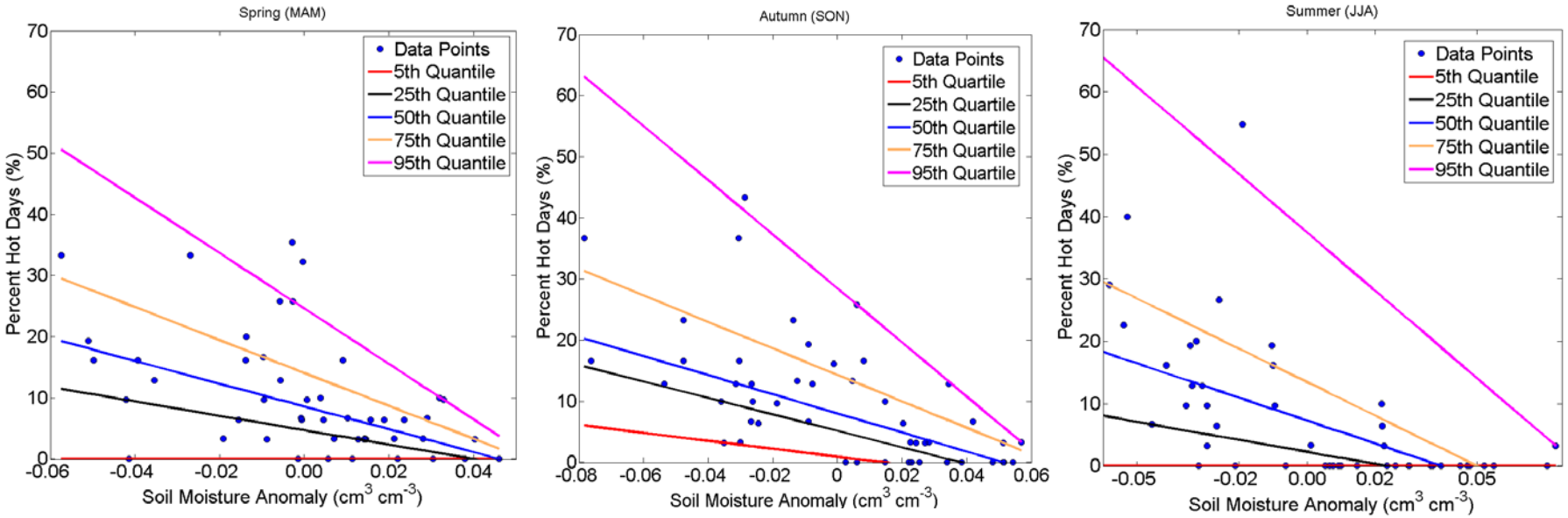
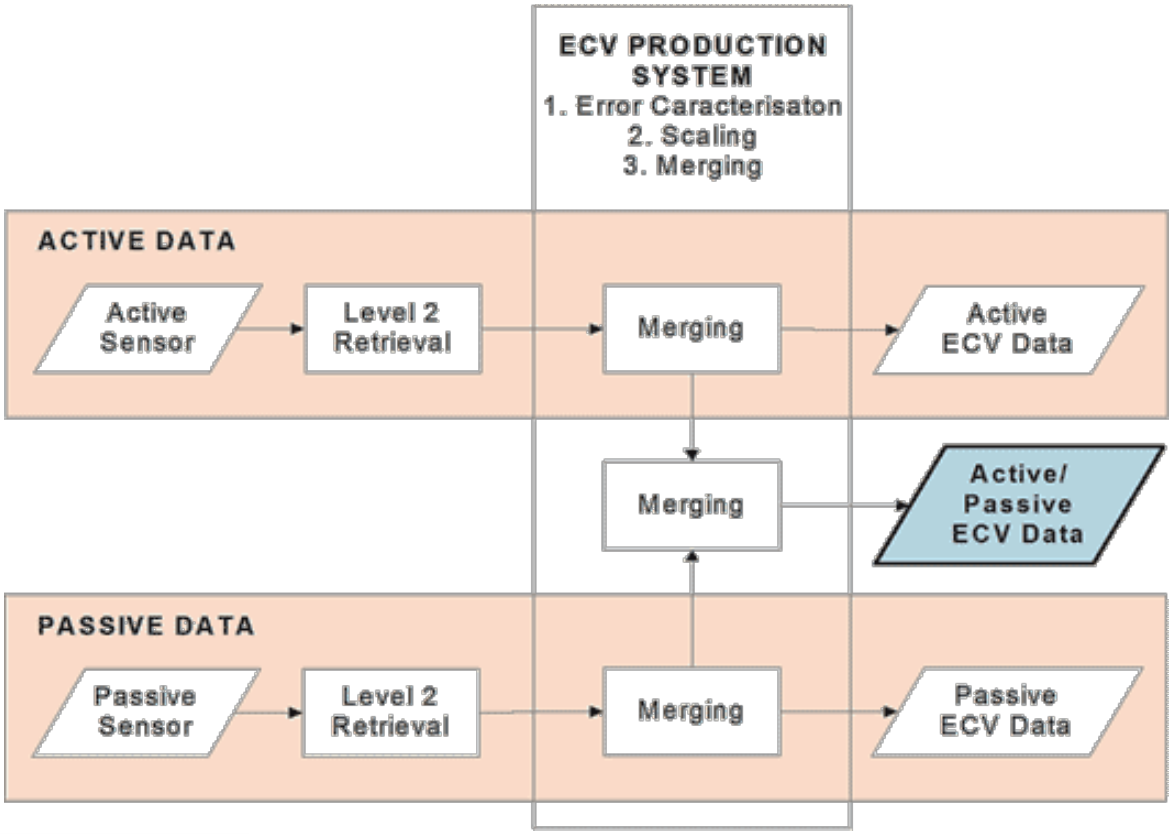


Figure 3. Scatter plots of monthly %HD and soil moisture anomalies from spring, summer and autumn. The regression lines represent the fit at the 95th, 75th, 50th, 25th and 5th quantiles.

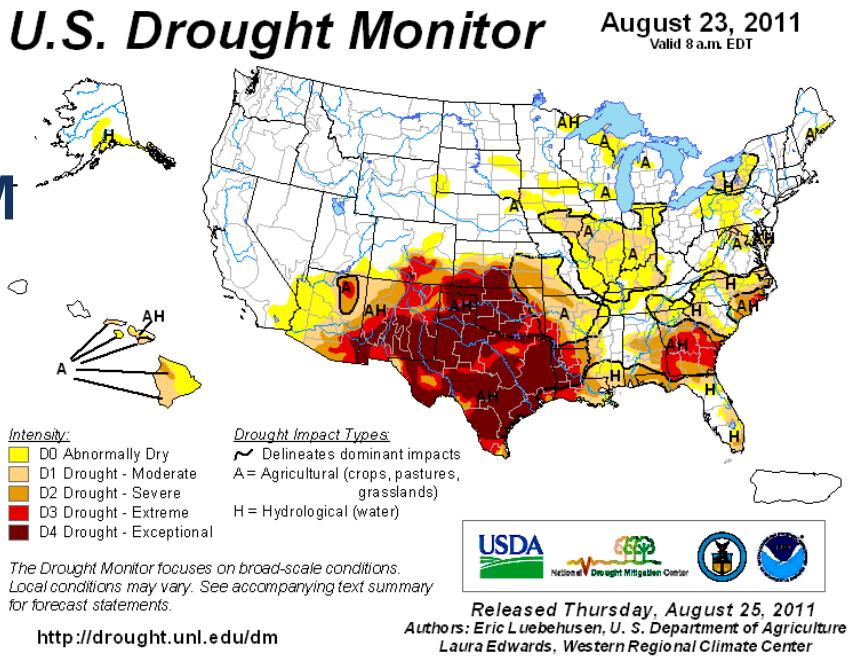
Ford & Quiring (2014) In situ soil moisture coupled with extreme temperatures: A study based on the Oklahoma Mesonet. *Geophysical Research Letters.* 41, doi:10.1002/2014GL060949

ESA Essential Climate Variable (ECV) Soil Moisture



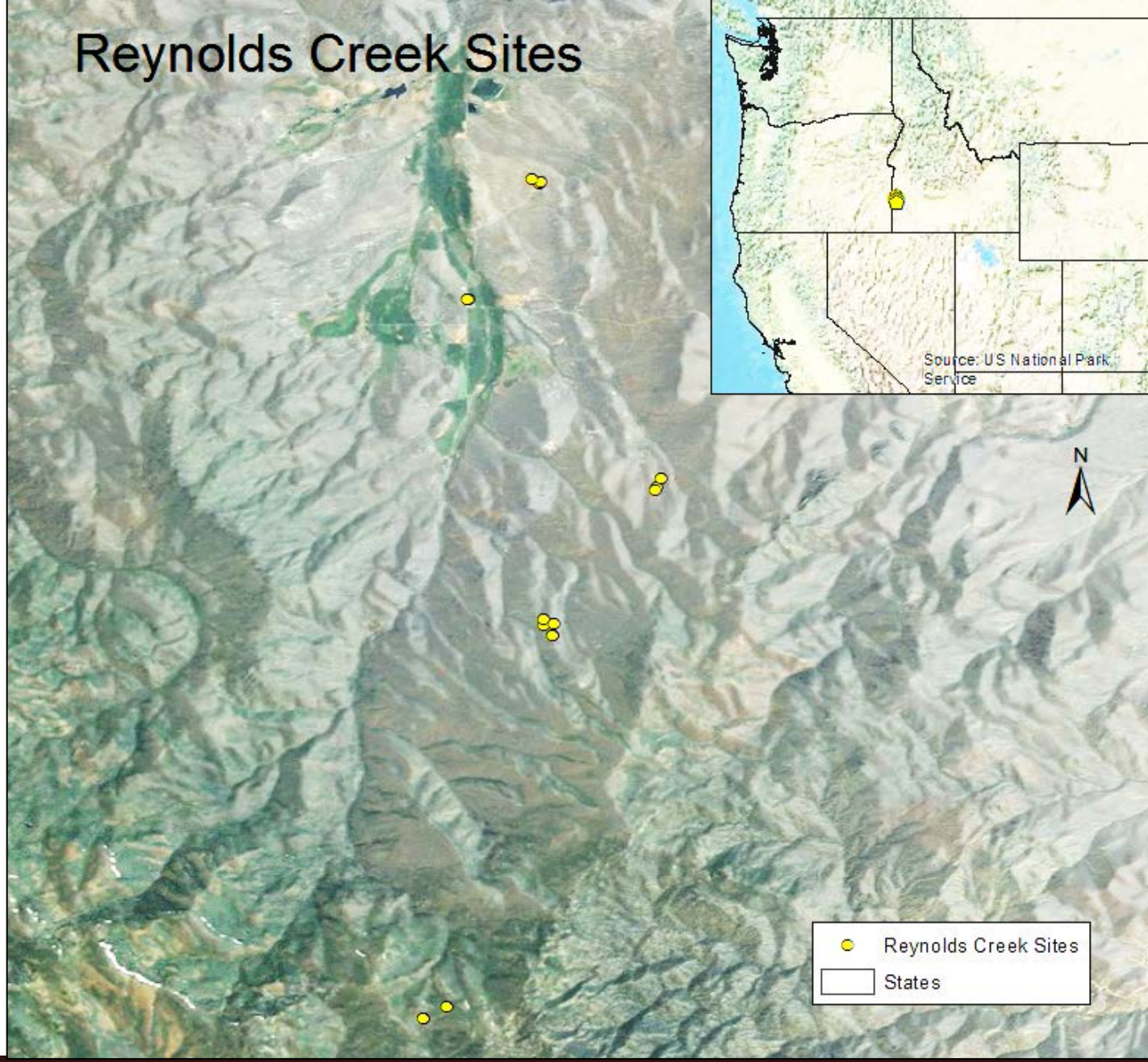
What do we need to learn?

- Causes of spatial and temporal variability in land-atmosphere interactions
- More realistic simulations of SM & land-atmosphere interactions
- Higher resolution data to investigate land-atmosphere interactions
- Calibration/validation of satellite and model-derived soil moisture

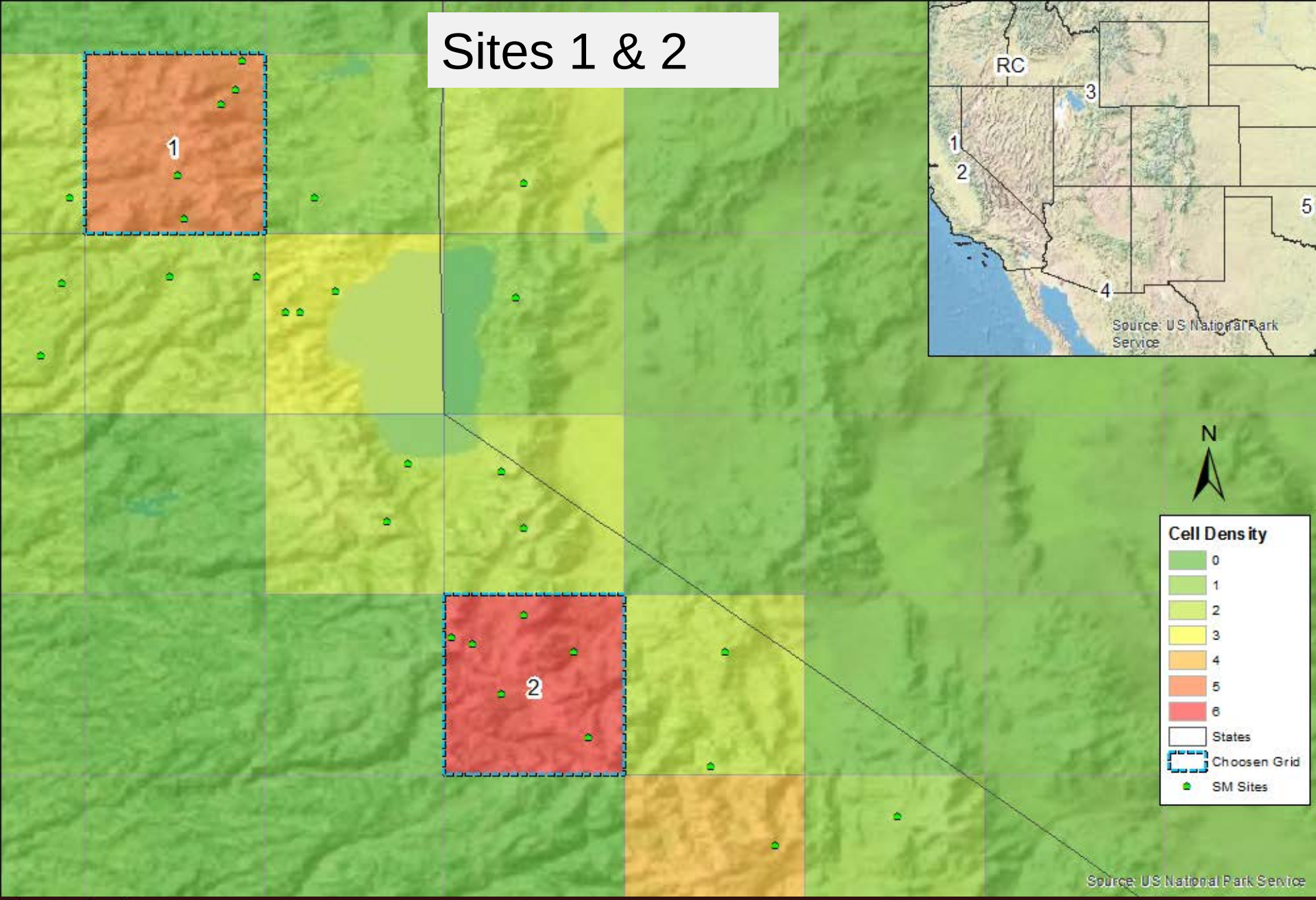


Reynolds Creek Experimental Watershed

- USDA-Agricultural Research Service
- 17 stations
- > 30 years



Sites 1 & 2

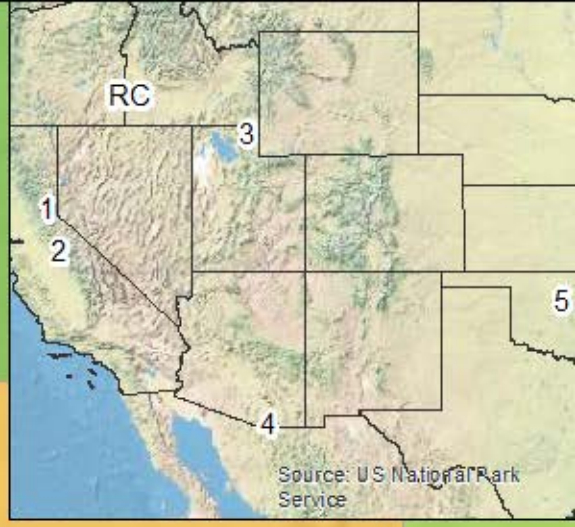

1
2
RC
3
1
2
4
5
Source: US National Park Service
N
Cell Density
0
1
2
3
4
5
6
States
Choosen Grid
SM Sites
Source: US National Park Service

Site 3


RC
3
1
2
Source: US National Park Service

3
N
Cell Density
0
1
2
3
4
5
6
States
Choosen Grid
SM Sites
Source: US National Park Service

Site 4


RC
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Source: US National Park Service

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Cell Density
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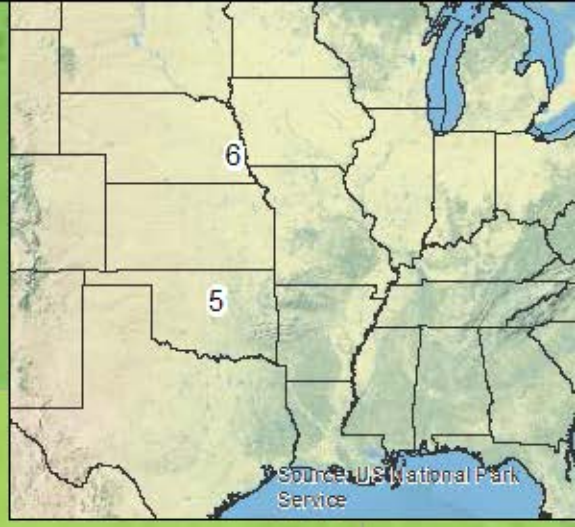
Choosen Grid
SM Sites
Source: US National Park Service

Site 5



5

N

Cell Density
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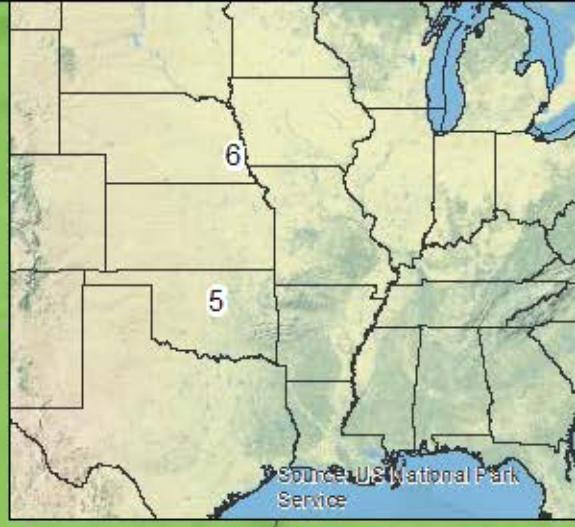
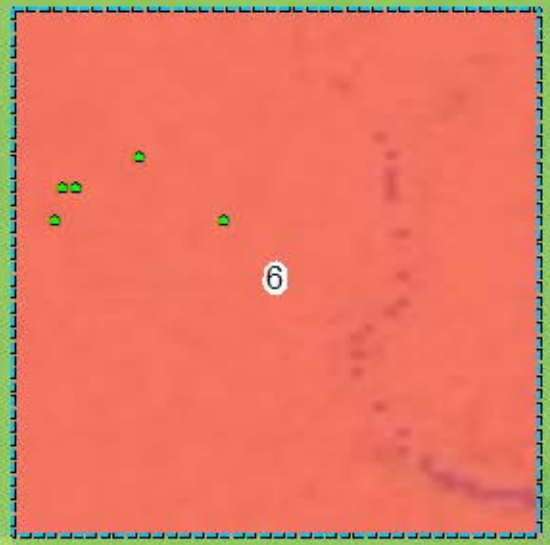
States
Choosen Grid
SM Sites

6

Source: US National Park Service

Site 6





N

Cell Density
0
1
2
3
4
5
6
States
Choosen Grid
SM Sites

Source: US National Park Service

Site 7


7
Source: US National Park Service

7
N
Cell Density
0
1
2
3
4
5
6
States
Choosen Grid
SM Sites
5
Source: US National Park Service

Reynolds Creek Sites

RC

N

Cell Density

- 0
- 1
- 2
- 3
- 4
- 5
- 6
- Reynolds Creek Sites
- States
- Choosen Grid

Source: US National Park Service