United States Department of Agriculture
Natural Resources Conservation Service

Developing a Coordinated National Soil Moisture Network in the United States

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Meeting a critical need

Soil moisture data are critical for assessing:

- Drought conditions and operational drought monitoring
- Flood potential
- Experimental land surface modeling
- Estimates of crop yields
- Water supply forecasting
- Operational hydrologic models
- Impacts of climate change

Goal

- President's Climate Action Plan
- National Drought Resilience Partnership
- National Integrated Drought Information System (NIDIS)
- Develop a Coordinated National Soil Moisture Network
- "As a U.S. Drought Monitor author, I want to see a map of percentile ranking of current volumetric water content (VWC) at discrete and common depths, related to the 30-year record, for sites colored using the drought monitor legend so that I can determine the necessary changes to be made to this week's DM map"

Data-rich: Data-challenged

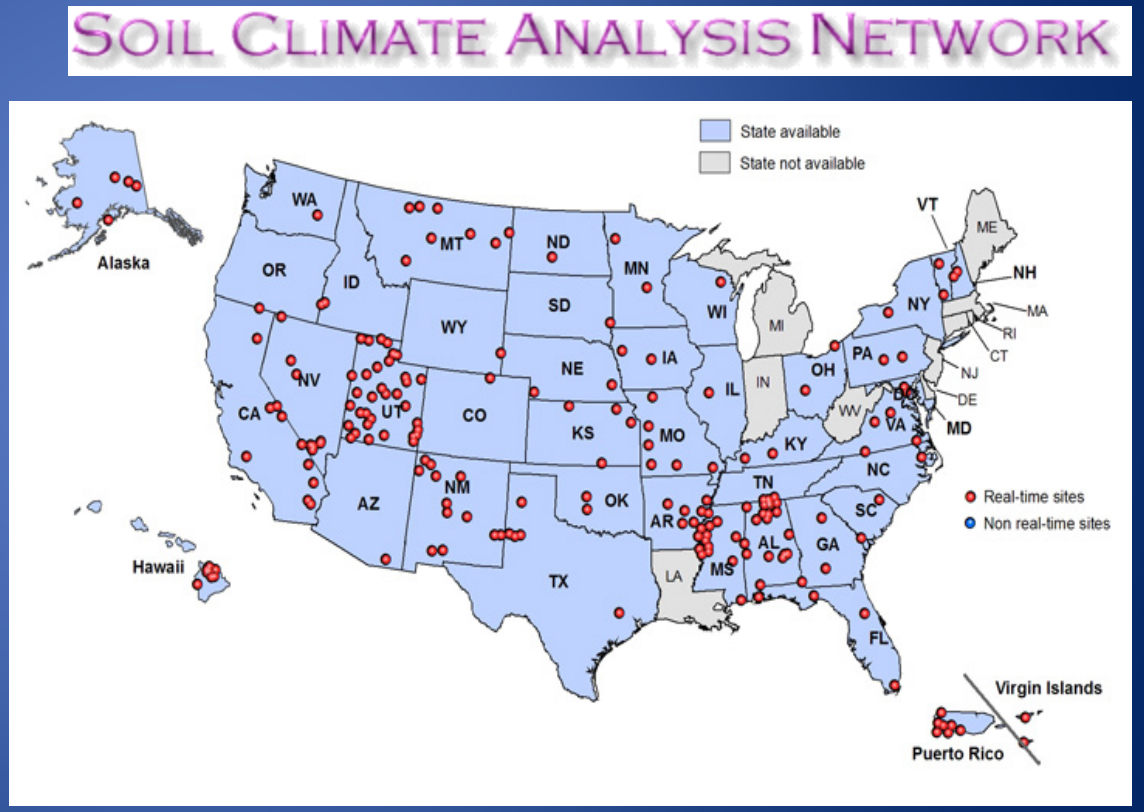
- Many sources of information
- Highly variable:
  - Spatial distribution
  - Vertical data collection
  - Sensor types
  - Scale
  - Time
  - Data storage (format, distribution)
  - Applications

Integration

- In situ stations collecting point data
- Remote sensing at various scales
- Models

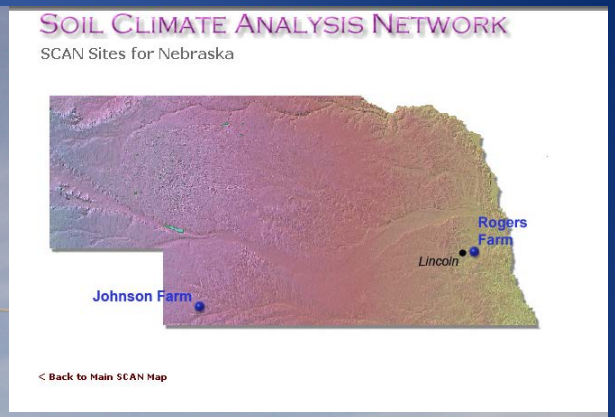
Soil Climate Analysis Network

- **SCAN** (Soil Climate Analysis Network)
  - 221 sites in 40 States and US Territories
  - Soil-climate monitoring
  - Uses meteor burst telemetry
  - Critical for drought monitoring

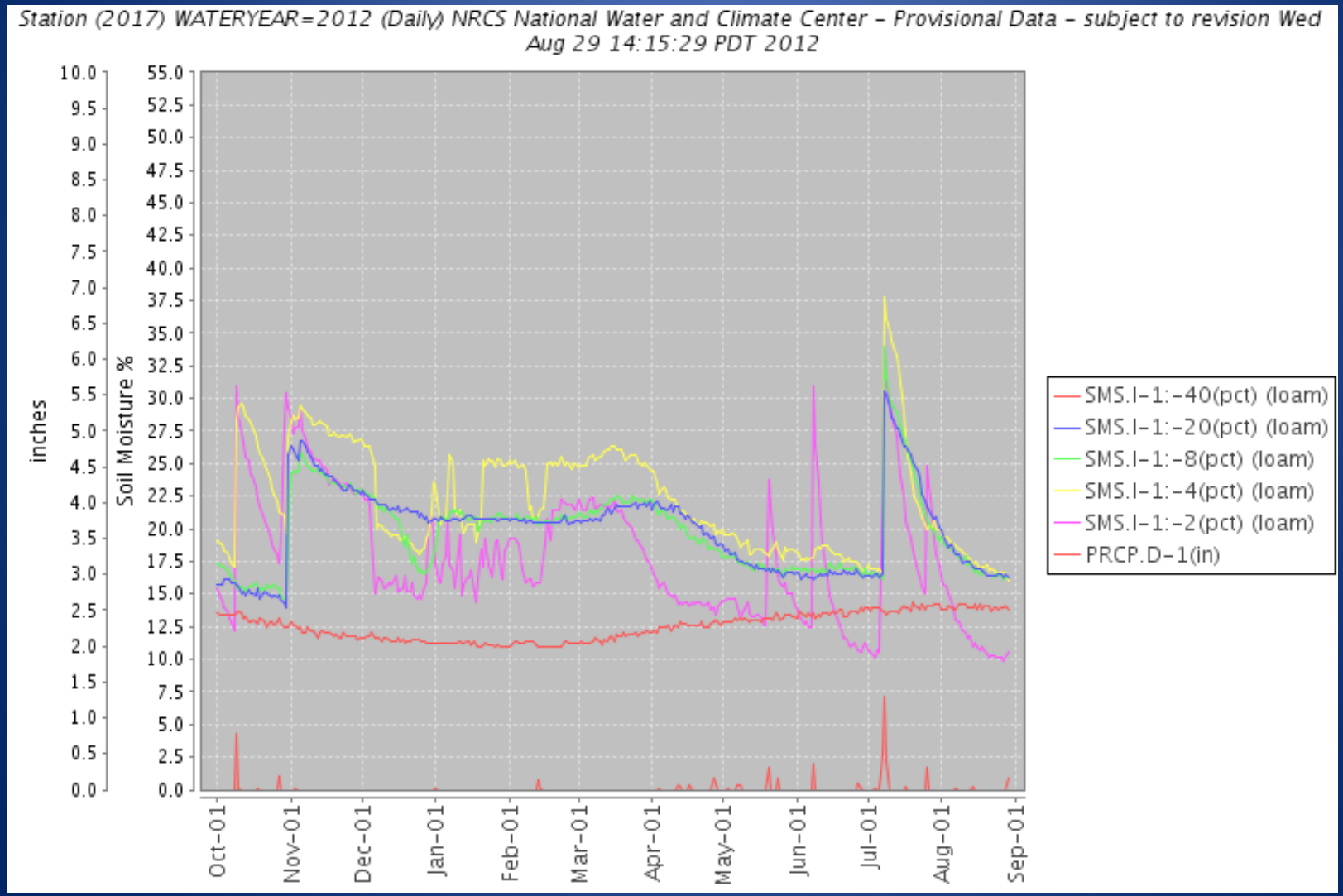


www.wcc.nrcs.usda.gov/scan/

Johnson Farm, Nebraska SCAN Site



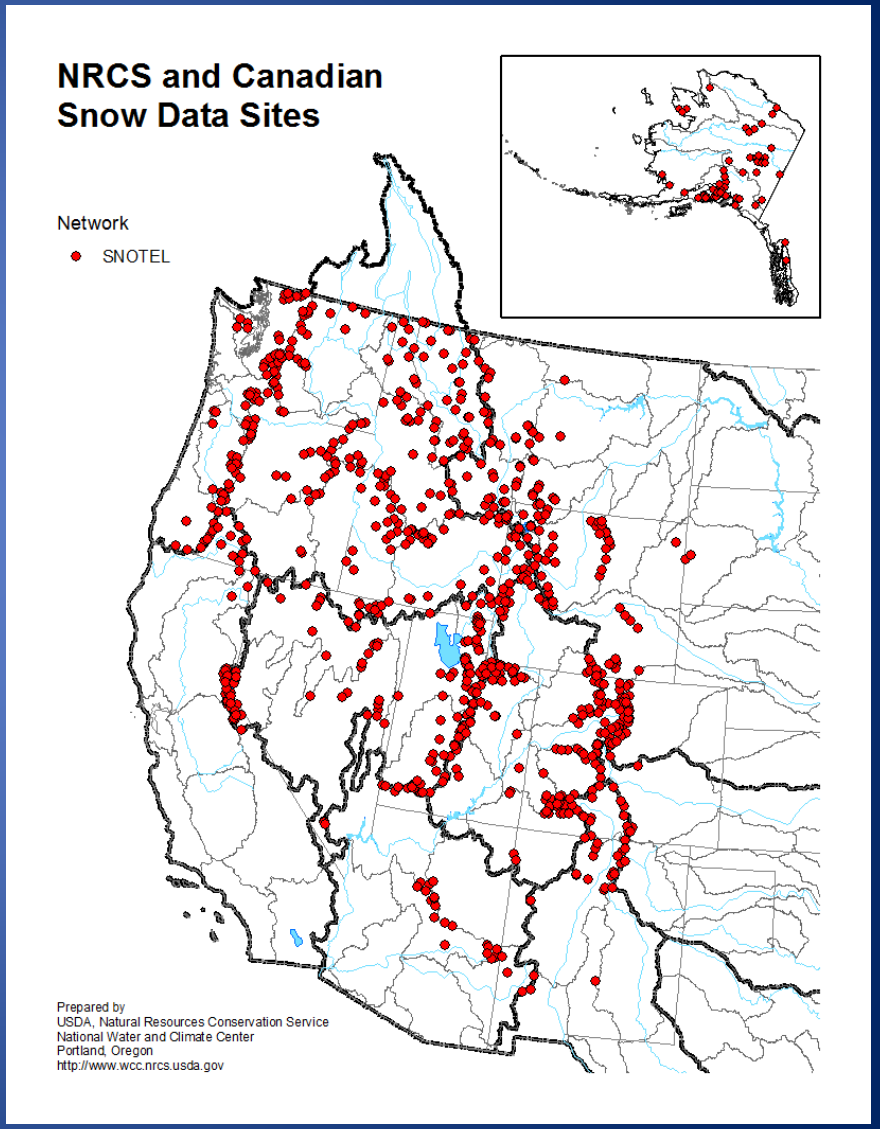
SCAN Data Plot



Colorado SCAN Site NUNN

NRCS SNOTEL Network

- SNOTEL network
  - 13 Western States
  - 885 sites (includes SnoLite)
  - More than 16 million observations/year
  - Data transmitted in near real time every hour for most stations
- Snow courses = 1 measurement/ month SWE and depth
- SNOTEL = 720 transmissions/month of multiple sensors
- Safety

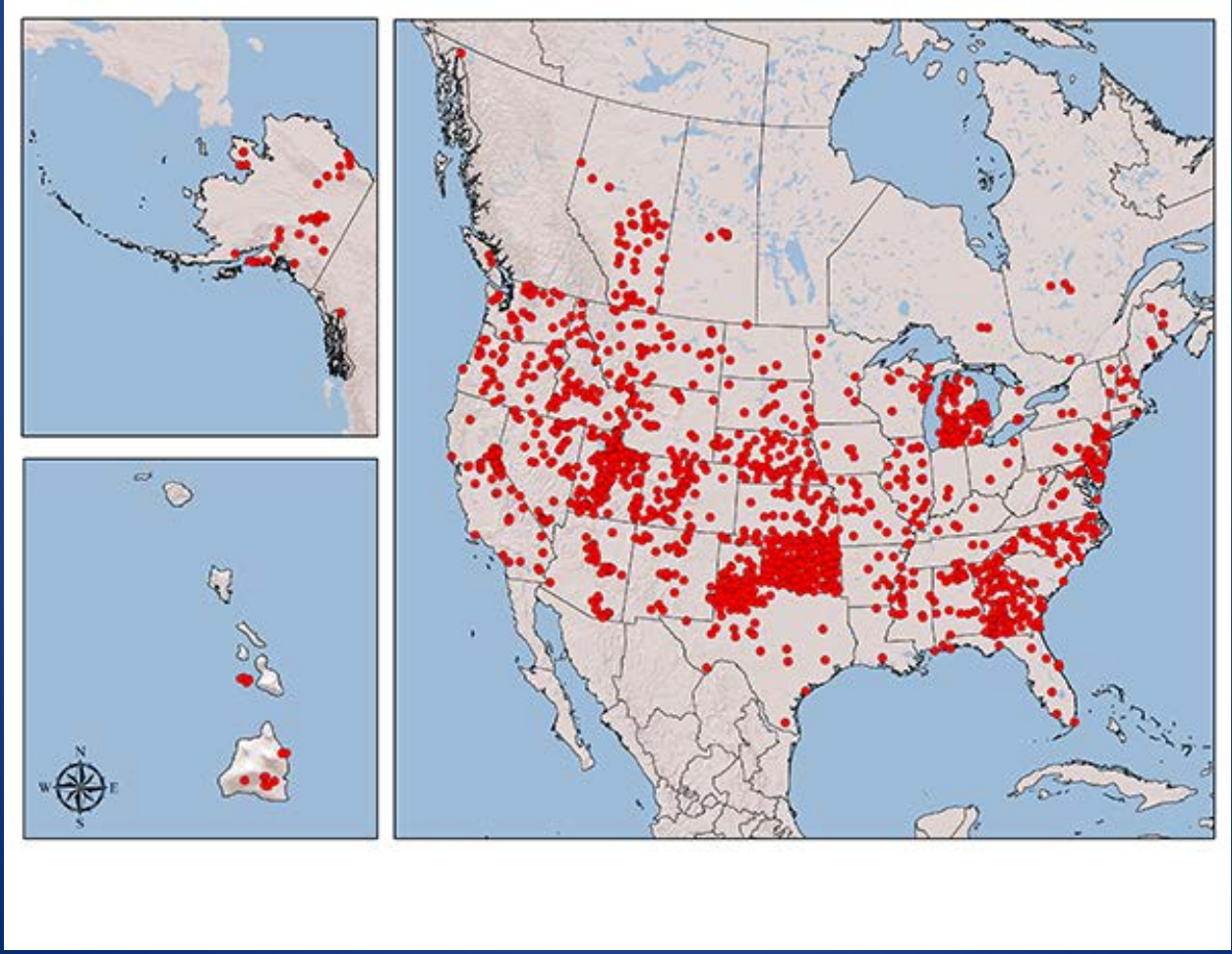


http://www.wcc.nrcs.usda.gov/snow/

Selected Representative In Situ Soil Moisture Networks in the United States

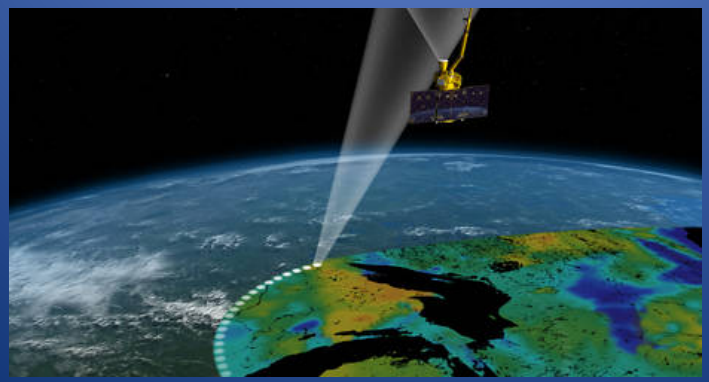
Network Name	Geographic Region	Number of Stations	Period of Record	Observing Depths (cm)
Agricultural Research Service (ARS)	Oklahoma	44	2005-present	5, 25, 45
AmeriFlux	United States	39	1997-present	Variable
Atmospheric Radiation Measurement (ARM)	Kansas, Oklahoma	17	1996-present	5, 15, 25, 35, 60, 85, 125, 175
Automated Weather Data Network (AWDN)	Nebraska	52	2006-present	10, 25, 50, 100
Climate Reference Network (CRN)	United States	114	2009-present	5, 10, 20, 50, 100
Cosmic Ray Soil moisture Observing Station (COSMOS)	United States	54	2008-present	Variable
Delaware Environmental Observing System (DEOS)	Delaware	29	2004-present	5
**Georgia Automated Environmental Monitoring Network (GAEMN)	Georgia	79	1992-present	Variable
Illinois Climate Network (ICN)	Illinois	19	1988-present	5, 10, 20, 50, 100, 150
Kansas Mesonet	Kansas	15	2008-present	5, 10, 20, 50, 100
Michigan Enviro-weather (Automated Weather Network, MAWN)	Michigan, Wisconsin	80	2000-present	5, 10
Missouri Agriculture Weather Network (MAW)	Missouri	8	2002-present	5, 10
**New Jersey Mesonet	New Jersey	10	2003-present	5
NOAA Hydrometeorological Testbed	Western U.S.	25	2004-present	Variable
North Carolina EcoNet	North Carolina	36	1999-present	20
Oklahoma Mesonet	Oklahoma	113	1998-present	5, 25, 60, 75
**Remote Automated Weather Stations (RAWS)	Western U.S.	50	1983-present	Variable
Snowpack Telemetry (SNOTEL)	Western U.S.	414	2000-present	Variable
Soil Climate Analysis Network (SCAN)	United States	203	1996-present	5, 10, 20, 50, 100
South Dakota Automated Weather Network (SDAWN)	South Dakota	11	2000-present	5, 10, 20, 50, 100
UA Fairbanks Water and Environmental Research Center (WERC)	Alaska	24	2000-present	Variable
West Texas Mesonet	Texas, New Mexico	64	2000-present	5, 20, 60, 75

Texas A&M University North American Soil Moisture Database



Remote Sensing Observations

- NOAA – soil moisture remote sensing through microwave and thermal infrared observations
- NASA – Recent launch of Soil Moisture Active/Passive (SMAP) satellite
- University of Arizona - Cosmic-Ray Soil Moisture Observing System (COSMOS)



Modeling

- Major land surface models:
  - The Noah
  - Variable Infiltration Capacity (VIC)
  - Sacramento (SAC)
  - Mosaic
  - Catchment
  - CPC Leaky Bucket (CPC LB)
  - Simple Biosphere (SiB)
  - Tiled ECMWF Scheme for Surface Exchanges over Land (TESSEL) LSMs
- NASA and NOAA – The North American Land Data Assimilation System (NLDAS-2) - multi-model approach

Coordination of Data Collection

- Models and remote sensing data provide spatial coverage of soil moisture for the U.S., but have coarse resolution
- Models generally only model near-surface soil conditions
- Models need to be calibrated to in situ measurements
- Different in situ networks provide differing data sets

Kansas City Workshop November 2013

- Presented representative networks and models from various Federal, State and University groups.
- Next steps:
- Established a working group to address issues of scale and spatial distribution for networks, remote sensing platforms and modeling efforts
- Developing a nation-wide product from existing soil moisture data as a template for guiding a larger-scale effort
- Initiating a pilot soil moisture monitoring system for smaller regions to integrate all available soil moisture data types and assess how the data would be used by researchers, agencies and different sectors

Pilot Data Sets

In Situ:

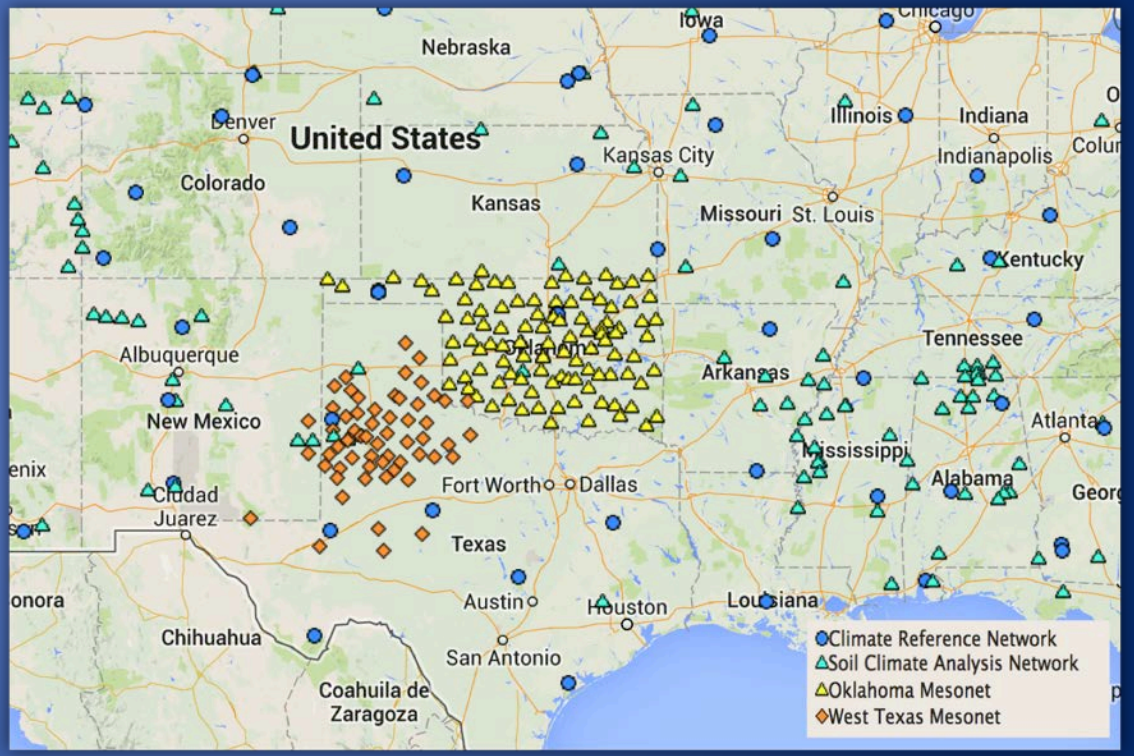
- Oklahoma Mesonet
- West Texas Mesonet
- US CRN
- SCAN

Station Metadata:

- NASMD

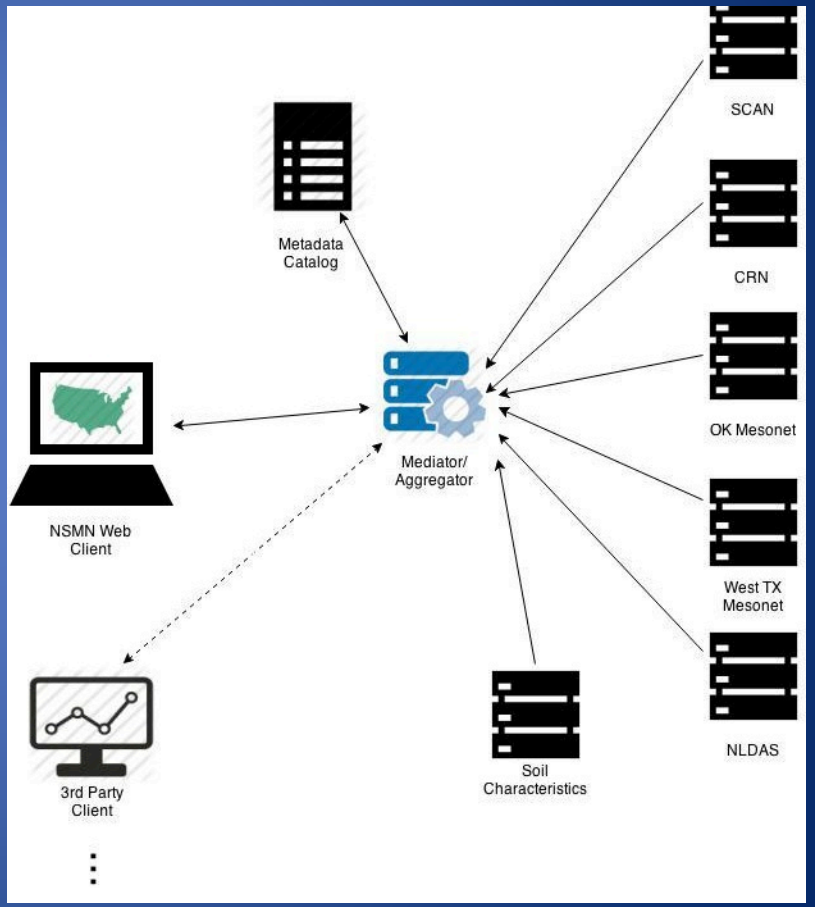
Modeled/Assimilated:

- NLDAS-2 model-derived soil moisture from Noah, Mosaic, SAC and VIC



Pilot System Components

- Site metadata and soil characteristics web service - Re-factor NASMD
- Catalog of data sets and service metadata
- CRN web service - NCDC ArcServer (does not include soil moisture)
- 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



Pilot Objectives

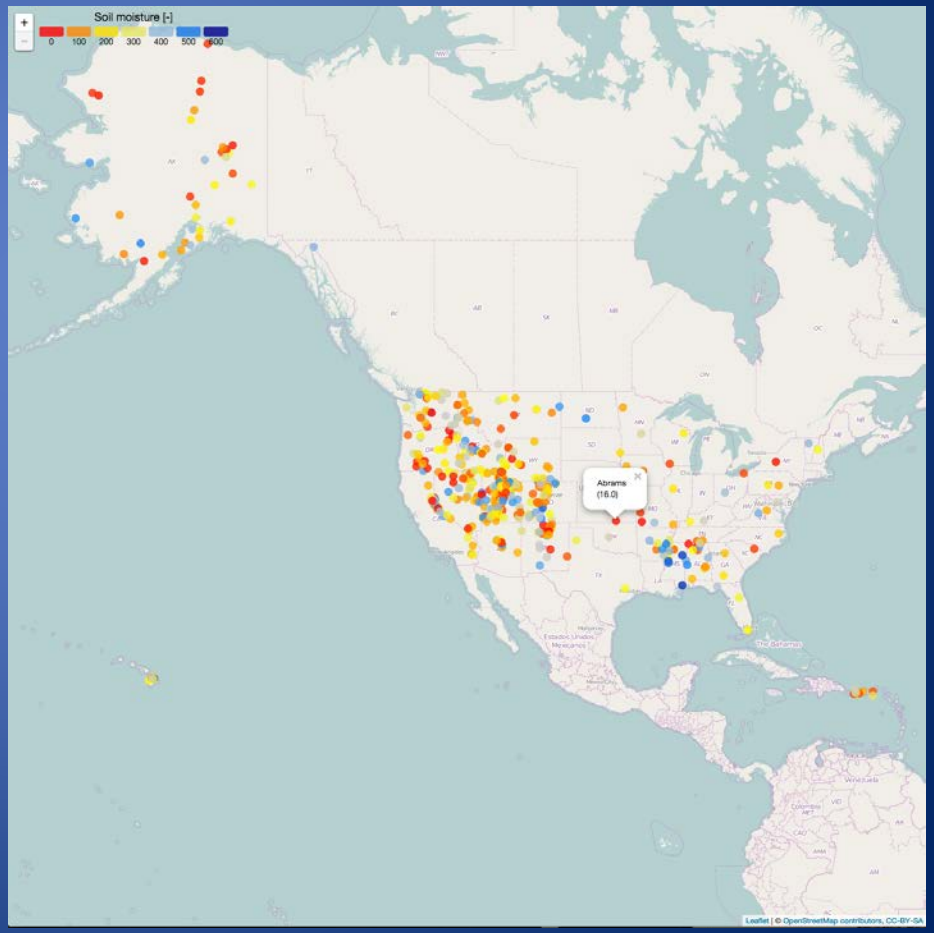
- Proof-of-concept near real-time soil moisture network implementation
- Demonstrate the potential usefulness of a coordinated effort
- Demonstrate the benefits of in situ soil moisture (and related products) to a broad range of end users
- Identify best practices for calibration/validation and metadata characterization
- Effectively leverage the full variety of existing networks and modeling efforts.

Pilot Timeline

- System Planning - December 2014
- Start Pilot Development - January 2015
- Submit Midway Progress Report - April 1, 2015
- Development Completed- July 1, 2015
- Demo Pilot - July/August 2015
- Final Project Report - August 31, 2015

Progress

- Gathering & QA/QC of station metadata
- Web services established for 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



Present efforts

- Calculation of baseline soil moisture conditions for calculating percentiles (in-situ + NLDAS)
- Access, aggregate and process TX, OK and CRN data
- Extend map to toggle between depths
- Calculate & display latest soil moisture percentiles
- Develop web service to provide aggregated soil moisture data

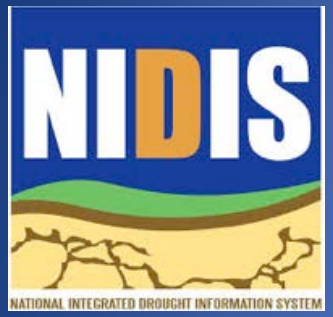
Lessons Learned

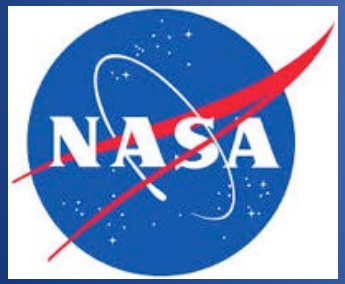
- Most major in-situ networks do not currently serve soil moisture via web services, including CRN (FTP only)
- Existing services often have little or no documentation
- Station metadata are not available via web services (soil parameters, sensor info, etc.)
- A wide range of sensor depths are used
- Network sites can be added or removed over time
- Although the period of record is relatively short, stable percentiles can be estimated for most stations

Toward a National Network

- How many/which networks to include in the NSMN - which agencies (federal & state) have in-situ networks
- Access issues (fees, access restrictions, etc.)
- How to perform QA/QC in real-time on distributed in-situ sensor data (and what to do with data that don't pass QA/QC)
- Which format and service protocol to use for dissemination of soil moisture data
- Integrate over depth or bin at common depths
- How to handle addition or removal of stations
- How to incorporate remotely-sensed soil moisture data (SMAP, SMOS, etc.)

National Soil Moisture Network





Thank you