Building a Coordinated National Soil Moisture Monitoring Network

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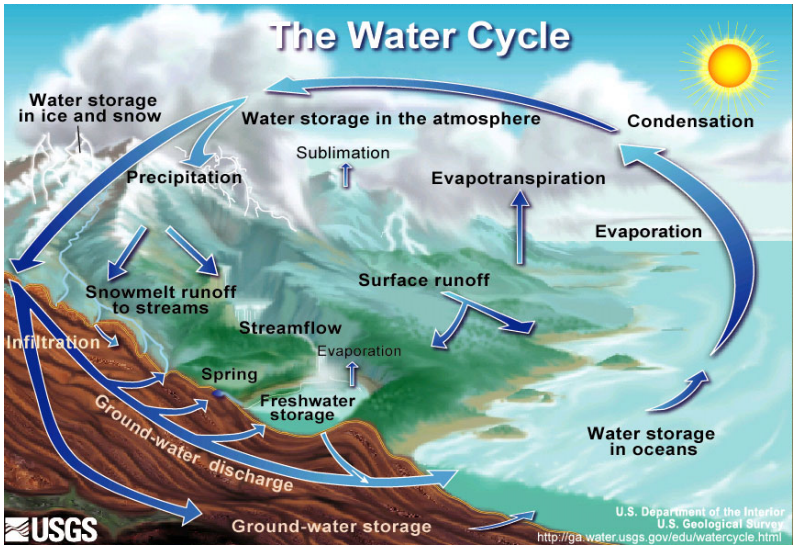
Midwest Drought Early Warning System Kickoff Meeting
February 11th, 2016

Meeting a critical need

Soil moisture data are critical for assessing:

- Drought conditions
- Flood potential
- Estimates of crop yields
- Water supply forecasting
- Hydrologic models
- Water budgets
- Impacts of climate change



Water Cycle Figure: http://water.usgs.gov/edu/watercycle.html

Motivation

- President's Climate Action Plan
- National Drought Resilience Partnership
- Develop a Coordinated National Soil Moisture Network

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For Immediate Release — June 25, 2013

FACT SHEET: President Obama's Climate Action Plan

President Obama's Plan to Cut Carbon Pollution
Taking Action for Our Kids

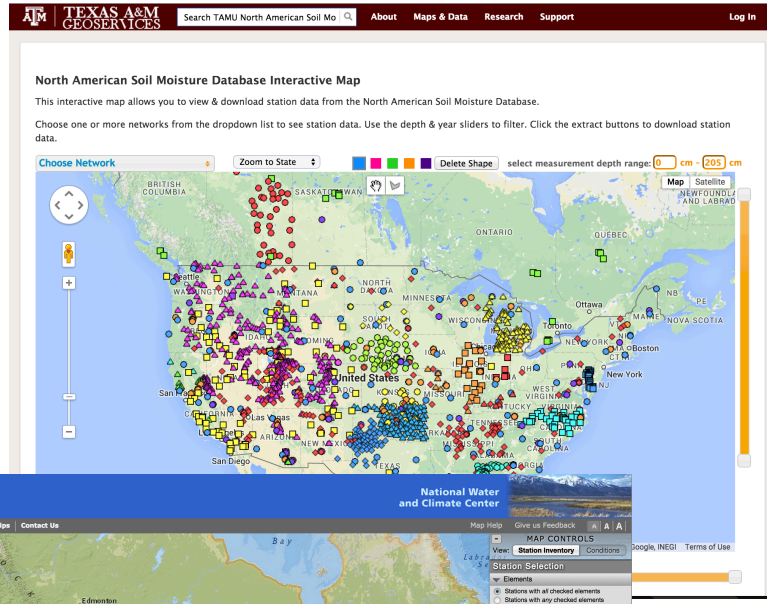
We have a moral obligation to leave our children a planet that's not polluted or damaged, and by taking an all-of-the-above approach to develop homegrown energy and steady, responsible steps to cut carbon pollution, we can protect our kids' health and begin to slow the effects of climate change so we leave a cleaner, more stable environment for future generations. Building on efforts underway in states and communities across the country, the President's plan cuts carbon pollution that causes climate change and threatens public health. Today, we have limits in place for arsenic, mercury and lead, but we let power plants release as much carbon pollution as they want – pollution that is contributing to higher rates of asthma attacks and more frequent and severe floods and heat waves.

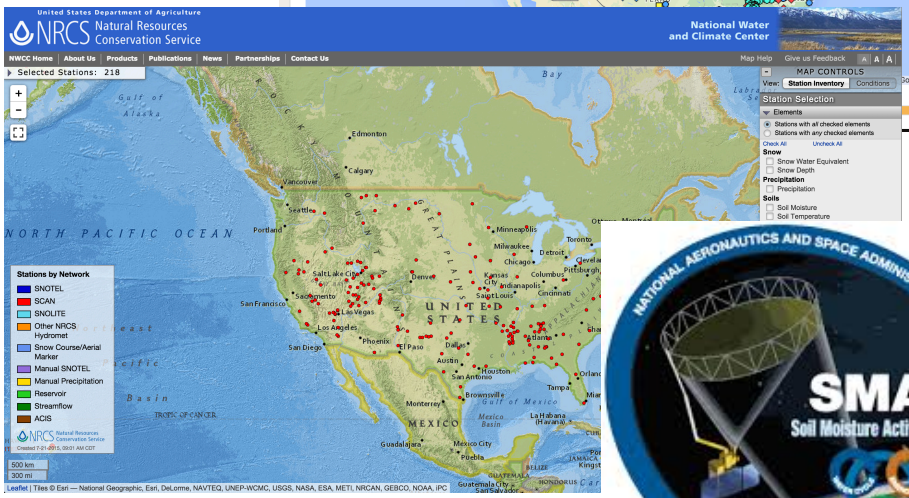
Managing Drought: Leveraging the work of the National Disaster Recovery Framework for drought, the Administration will launch a cross-agency National Drought Resilience Partnership as a "front door" for communities seeking help to prepare for future droughts and reduce drought impacts. By linking information (monitoring, forecasts, outlooks, and early warnings) with drought preparedness and longer-term resilience strategies in critical sectors, this effort will help communities manage drought-related risks.

President's Climate Action Plan: https://www.whitehouse.gov/sites/default/files/image/president27sclimateactionplan.pdf

Current Soil Moisture Data Sources

- SCAN & CRN
  - In situ
  - National coverage
  - Real-time & historical
  - Limited web service access
  - Multiple depths
- NASMD
  - In situ
  - Historical
  - National coverage
  - Multiple depths
- SMOS, NLDAS, SMAP
  - Satellites & models
  - National coverage
  - Near real-time
  - Near surface data





Lots of data, hard to integrate…

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

Limitations of Datasets

- Different in situ networks provide differing data sets
- 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

Pilot Use Cases

1. Operational Drought Monitoring: NOAA, U.S. Drought Monitor
2. Experimental Land Surface Modeling: NOAA/ NOHRSC, Snow Modeling
3. Operational Hydrological Modeling: NOAA RFCs

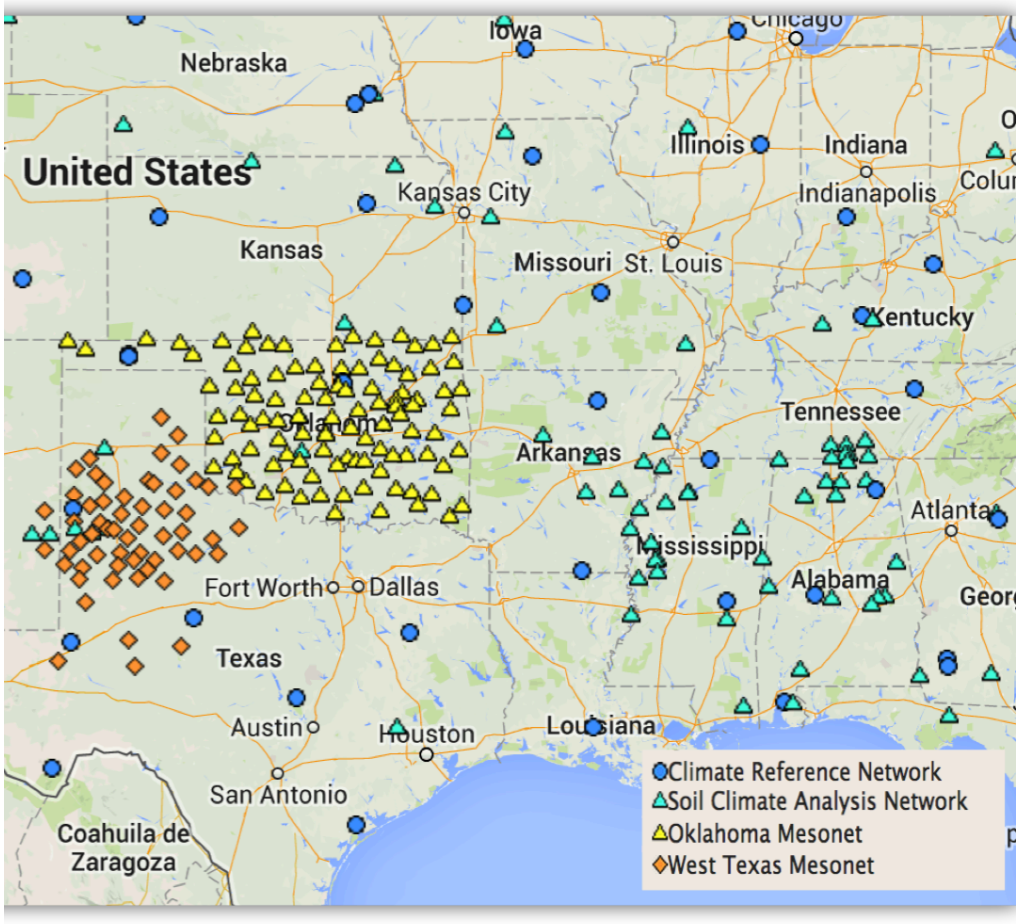
Pilot Goal

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 30 yr record, for sites colored using the drought monitor legend so that I can determine the necessary changes to be made to this week's Drought Monitor map.

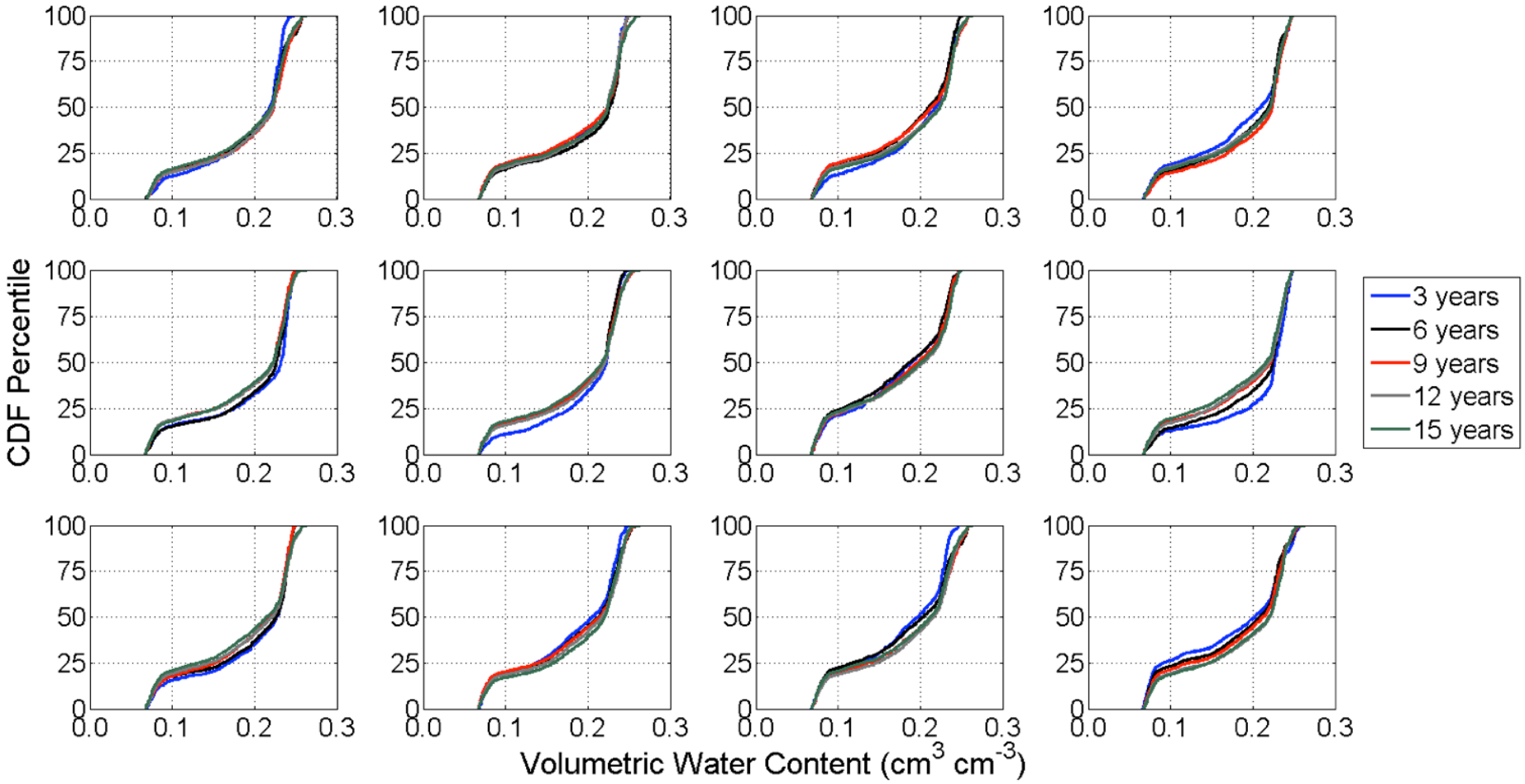
Pilot Data Sets

- In Situ:
  - Climate Reference Network
  - SCAN & SNOTEL
  - Oklahoma Mesonet
  - West Texas Mesonet

- Processing:
  - Normalize data
  - Depth binning
  - Percentiles reduce impact from different sensors & methods

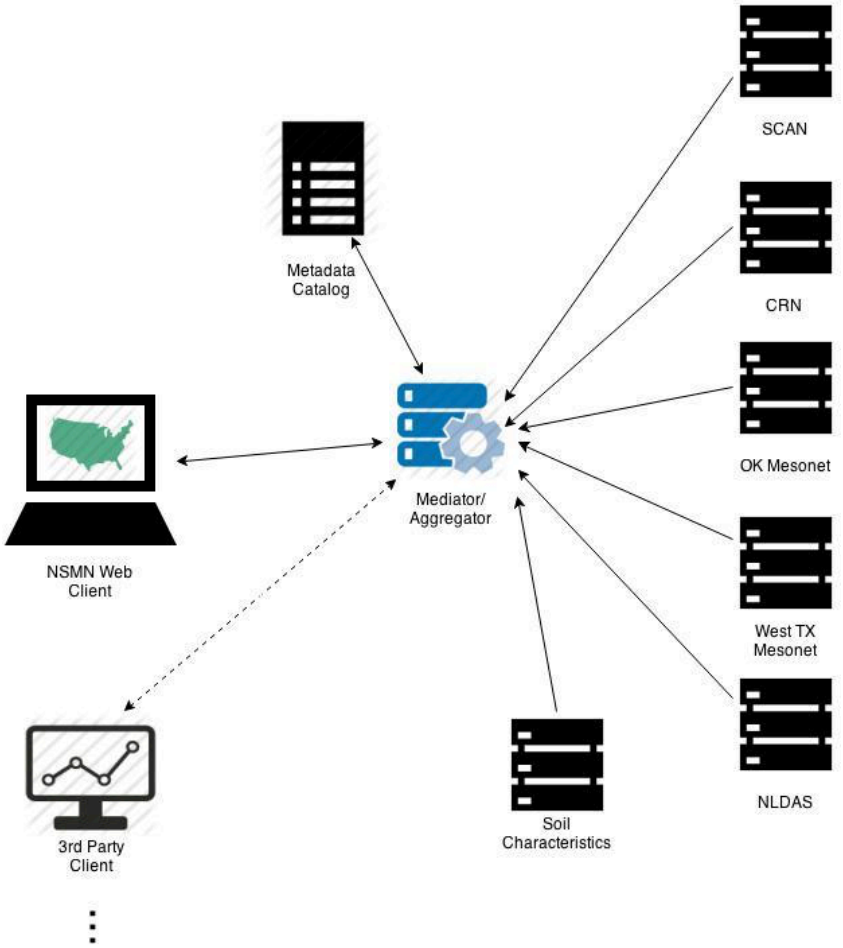


Soil Moisture Percentiles

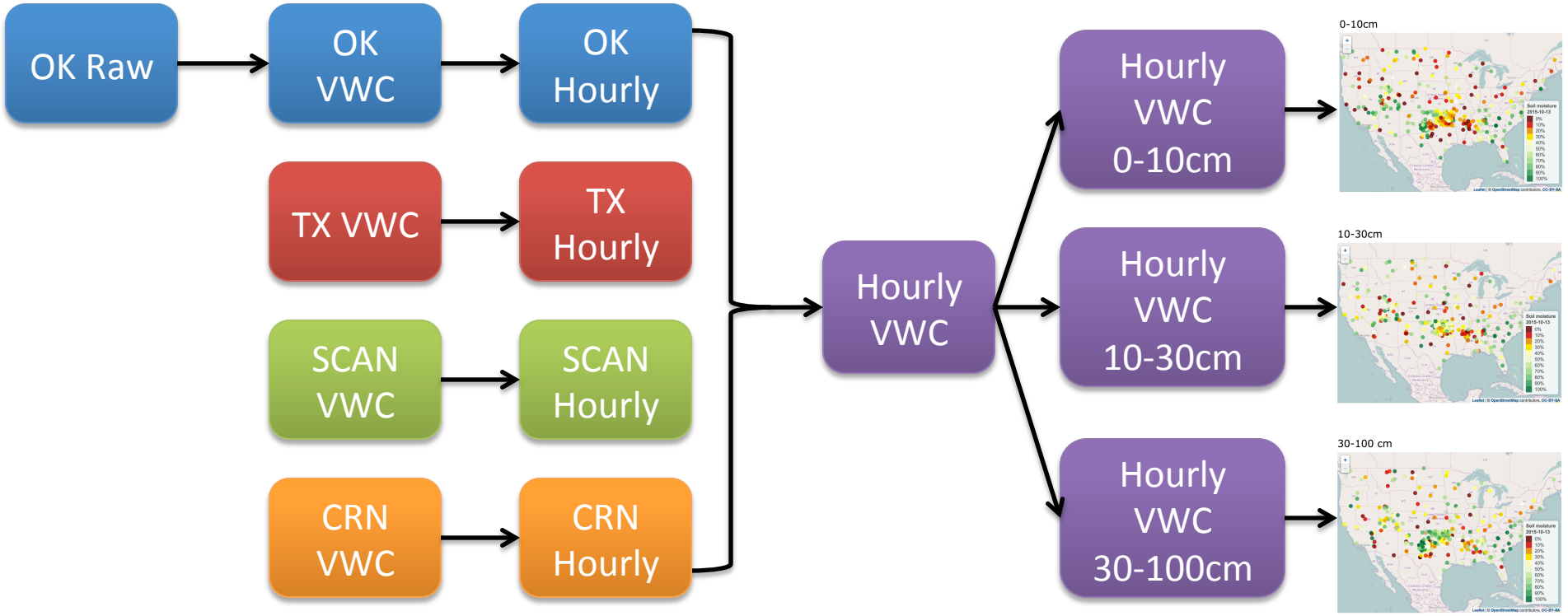


Goal System Components

- Site metadata and soil characteristics web service
- Registry 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
- Algorithm development for calculating percentiles, aggregating datasets
- Service mediator/aggregator
- Map-based visualization web tools

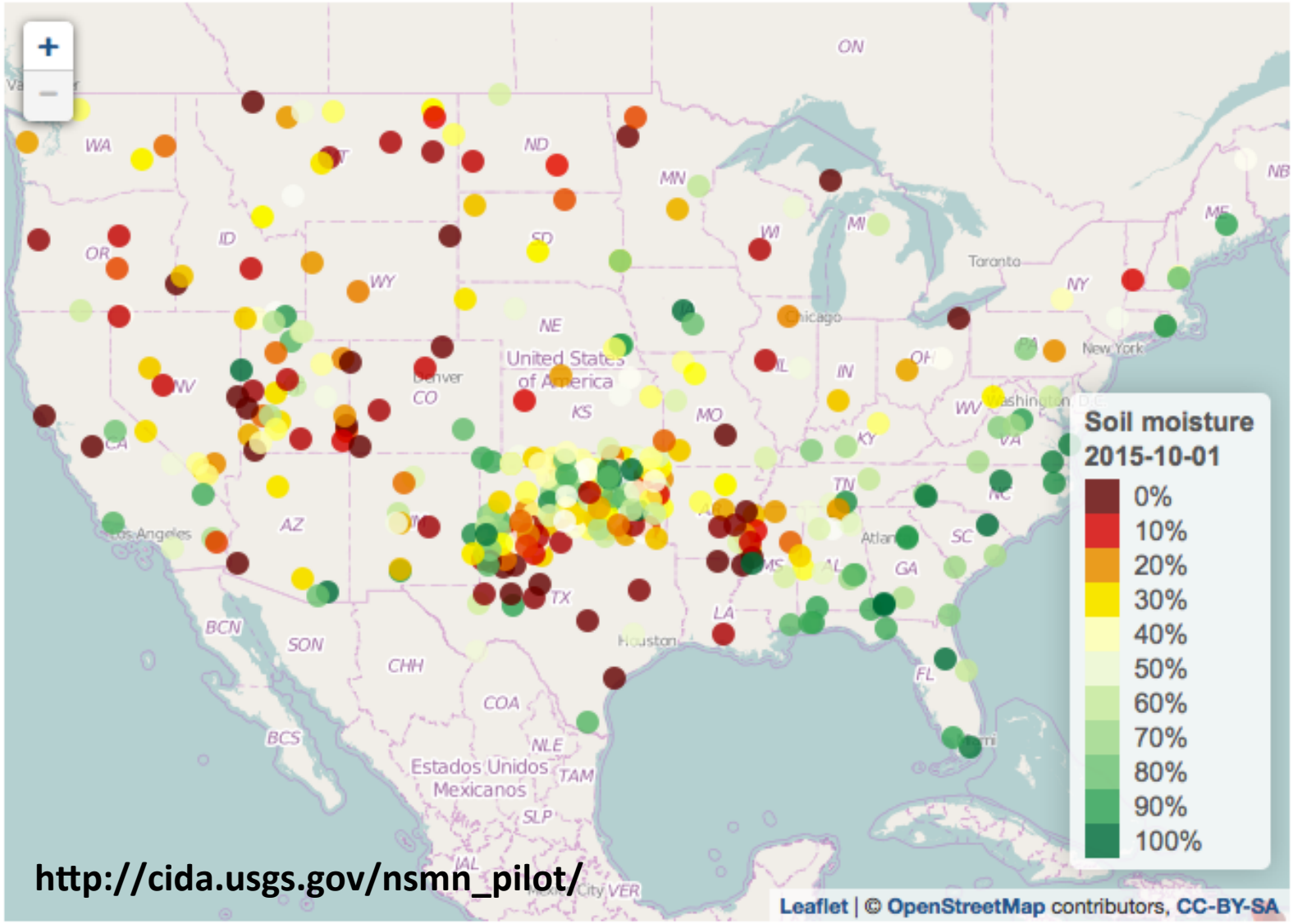


Data Processing Pipeline



National Soil Moisture Network

0-10cm



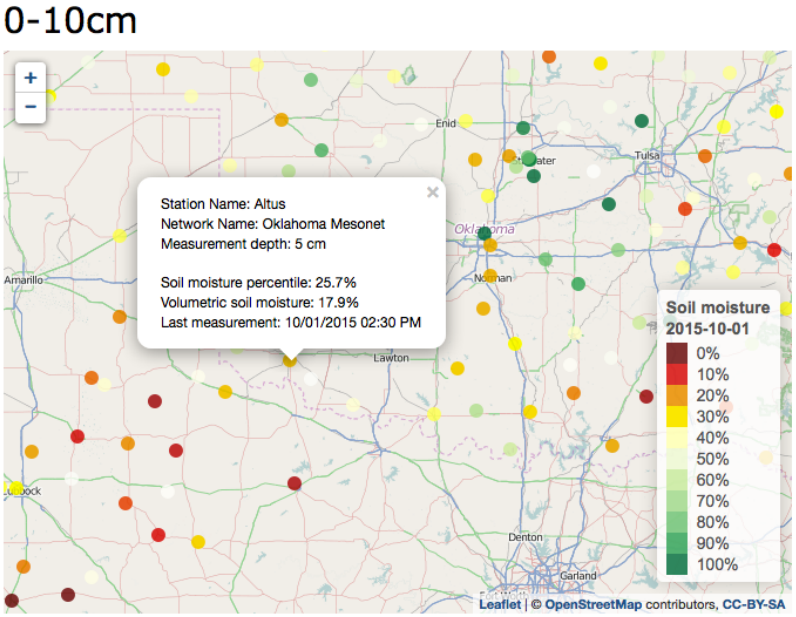
Work Completed

- Station metadata has been gathered
- Web services established for West Texas Mesonet, Oklahoma Mesonet and Climate Reference Network; TAMU is serving these data (temporary for pilot)
- Mediator coded to access and process all 4 networks
- Interactive map has been developed
- Analysis of historical data to calculate cumulative distribution functions (CDF)
- Quality control and percentile calculations have been automated
- Developed an SOS service for aggregated VWC data

http://cida.usgs.gov/nsmn/sos/ok_working.nc?service=SOS&version=1.0.0&request=GetCapabilities

Lessons Learned

- Most major in situ networks do not currently serve soil moisture via web services
- Existing services often have little or no documentation
- Existing services do not use standard formats or protocols
- Station metadata are not available via services
- Sites can be added or removed
- Although period of record is relatively short, stable percentiles can be estimated for most stations



Next Steps: Moving Beyond the Pilot

- Develop framework for National Network
- Workshop to be held in May 2016
- Build-out operational system infrastructure
- Survey federal, state, and local agencies to identify soil moisture data sources and new use cases
- Incorporating new data sources
- Integrate SMAP and NLDAS-2 data
- Build industry partnerships
- Develop new tools, visualizations, and data products

http://cida.usgs.gov/nsmn_pilot/

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RESEARCH LETTER
10.1002/2015GL066600

Key Points:
- In situ soil moisture detects flash drought earlier than U.S. Drought Monitor
- Four flash drought events in Oklahoma detected at 2–3 week lead using soil moisture
- Integrating soil moisture into drought early warning systems may aid in flash drought detection

Supporting Information:
- Supporting Information S1

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On the utility of in situ soil moisture observations for flash drought early warning in Oklahoma, USA

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Abstract Drought early warning systems are a vital component of drought monitoring and require information at submonthly time scales because of the rapidly evolving nature of drought. This study evaluates the utility of in situ soil moisture observations for drought early warning in Oklahoma. Soil moisture was used to identify drought events, and the results were compared with the U.S. Drought Monitor with respect to the identification of drought onset. Soil moisture observations consistently identify rapid-onset (flash) drought events earlier than the U.S. Drought Monitor. Our results show that soil moisture percentiles provide a 2–3 week lead time over the U.S. Drought Monitor based on five flash drought events that occurred in Oklahoma between 2000 and 2013. We conclude that in situ soil moisture observations are an important source of information for early warning of flash drought events in the Oklahoma.

1. Introduction

Drought is one of the most destructive and costly natural disasters, resulting in diminished agricultural production [*Hatfield et al.*, 2011; *Mallya et al.*, 2013; *Zhang et al.*, 2014], reduced water resources [*van Dijk et al.*, 2013; *Shukla et al.*, 2015], and deadly heat waves [*Hoerling et al.*, 2013; *Schubert et al.*, 2014]. In response, drought strategies are being developed worldwide, with a particular focus on comprehensive drought monitoring [*Hayes et al.*, 2011]. Historically, indices have been developed to characterize meteorological, agricultural, hydrological, and socioeconomic drought [*Vicente-Serrano et al.*, 2012]. The Standardized Precipitation Index (SPI) [*McKee et al.* 1993], for example, was recently recommended for characterizing meteorological drought worldwide [*Hayes et al.*, 2011].

How can Soil Moisture be used as a flash drought indicator?

What data products?

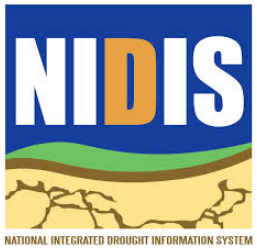
In which formats?

Station data vs. coverages?

Maps vs. plots?

How to access?

Acknowledgements



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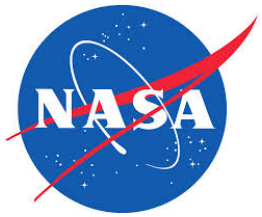

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