Texas drought and beyond
22-23 October 2012

Ground-based measurements of soil water storage in Texas

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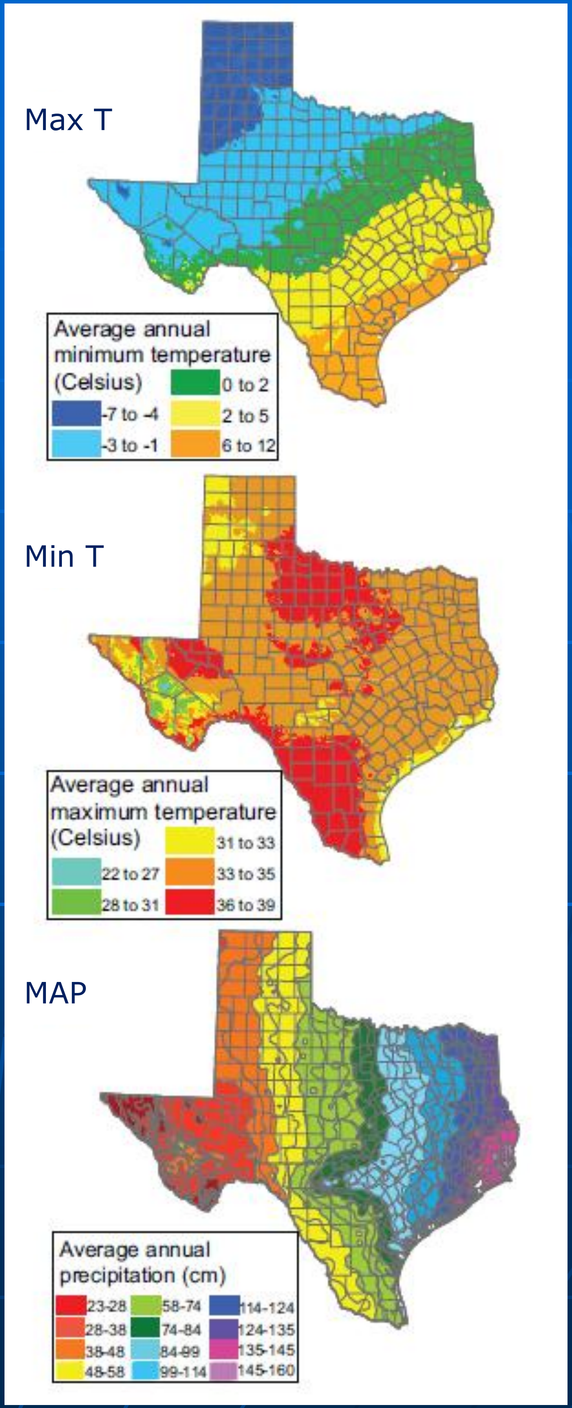
Ground-based soil moisture

- Why do we need it?
- How do we modeling it?
- How can we measure it?
  - Current technologies
  - What's in Texas
- What can we do with it?



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Soil Moisture Cycles

Soil moisture is dynamic:

- The very nature of these dynamics sustain our environment
- We need to monitor, observe and predict its behavior

WET	⟷	DRY
Flood potential	RAINFALL	Drought
Landslides	EROSION	Dust
Weak	SOIL STRENGTH	Hard
Latent heat	SOLAR ENERGY	Sensible heat
Energy-limited	TRANSPIRATION	Water-limited
Carbon storage	ECOHYDROLOGY	Stress, mortality, fire
Oxygen limitations	MICROBIAL ACTIVITY	Nutrient limitations

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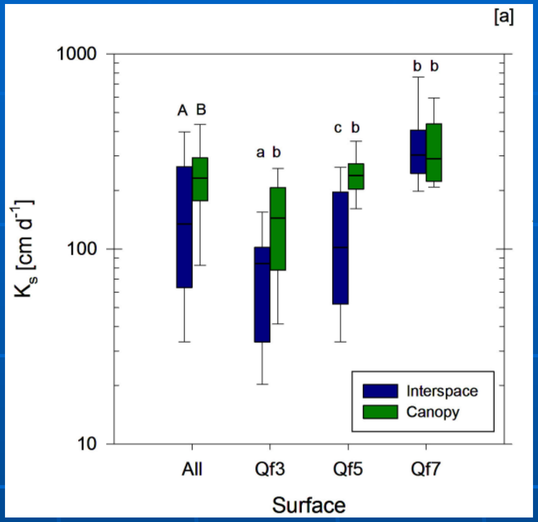
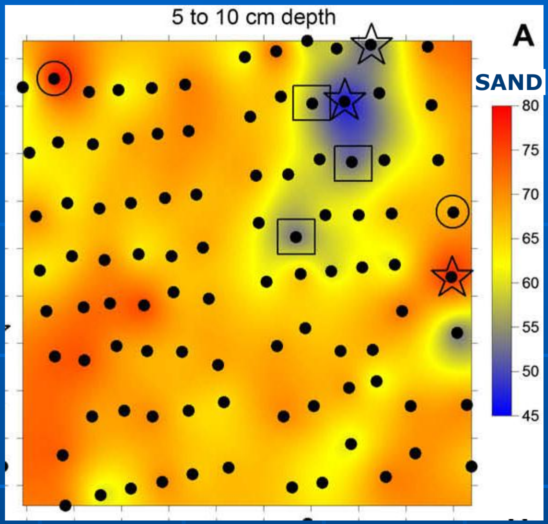
Variability of Soil Properties

… at the plant level



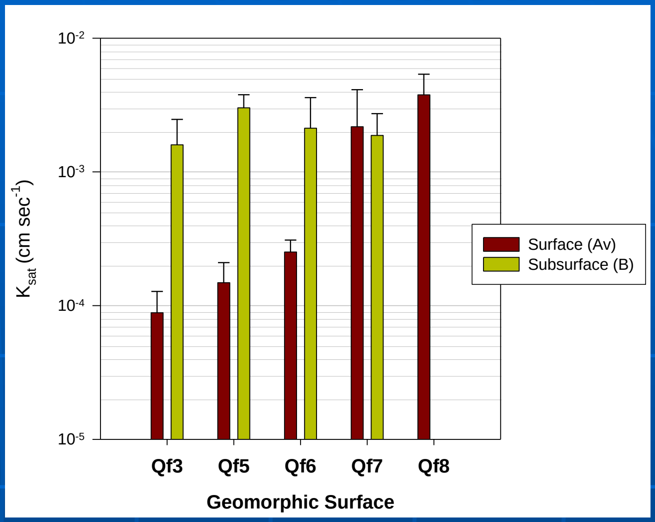
Caldwell et al. (2012), WRR, 48, W09551, doi:10.1029/2012WR011963.

… at field scale

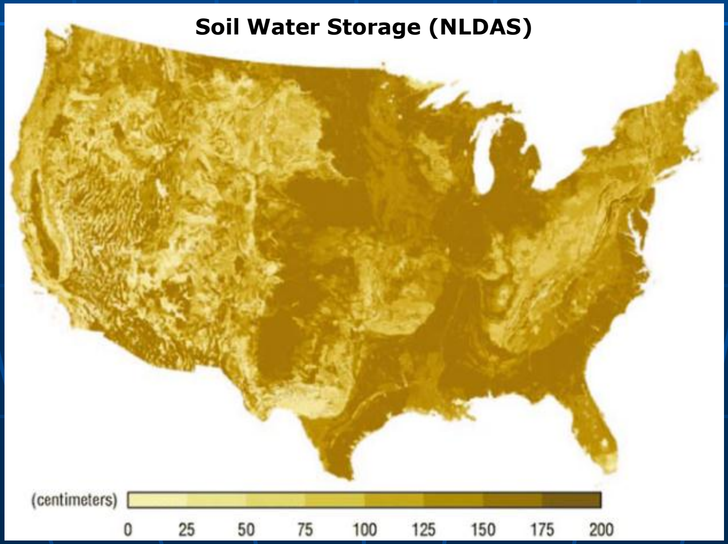


Young et al. (2009) J. Arid Environ. 73:733-744

… at watershed scale



Young et al. (2004), Vadose Zone J. 3:956-963



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Sensor Technologies and Scale

Scale of Interest ≠ Scale of Observations

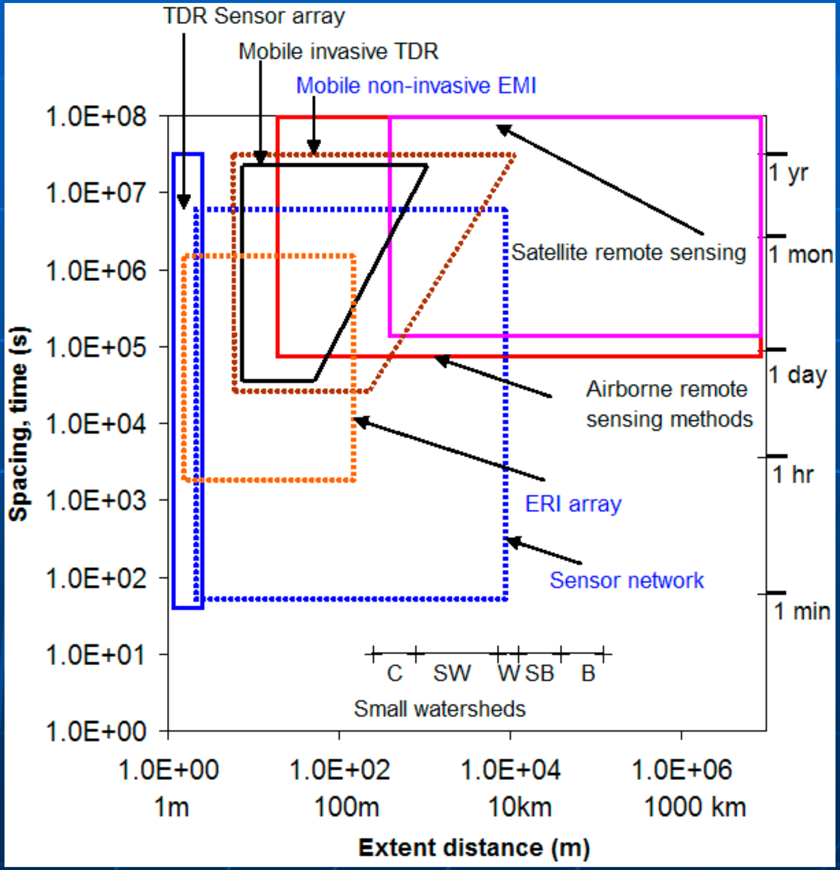
Spatial Support

- LSM operate at >km²
- Satellite observations are coarse and shallow
- Ground-based measurements are 'points'

Temporal Support

- LSM operate at hourly time scales
- Satellite paths are lower frequency
- Ground-based measurements are cover nearly any range

Effectively merging these scales is a challenge on many levels



Robinson et al., 2008, Vadose Zone J., 7:358-389

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Soil depiction in NLDAS-1

CONUS-SOIL

- STATSGO (1:250,000)
  - 1 km grid
  - Dominant soil series
- 16 textural classes
  - 12 are actually soil
- 11 layers to 2m depth

Miller and White, 1998, Earth Interactions, Paper 2-002.

NLDAS

- ⅛° grid (~14 km)
- %Class over each grid
- Noah, Mosaic, VIC
  - Uniform soil texture from top 5cm layer

Mitchel et al., 2004, JGR, D07S90, doi:10.1029 /2003JD003823.

	Mosaic	Noah	SAC	VIC
Soil Layers	3	4	2 buckets	3
Depth (cm)	10, 40 200	10, 40, 100, 200	-	10 + 2 variable
Output	θ (z)	θ (z)	SWS	SWS

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Soil hydrology in NLDAS-1

Mosaic and Noah

- Soil hydraulic properties for 12 soil classes
  - Mosaic PTF (Rawls et al., 1982)
  - Noah PTF (Crosby et al., 1984)
- Flux between layers quasi-Richards' equation
- Uniform soil with depth

TABLE 3. Means and Standard Deviations for the Four Hydraulic Parameters in Each Textural Class

Class	n	b Mean	b S.D.	$\log \Psi_s$ Mean	$\log \Psi_s$ S.D.	$\log K_s$ Mean	$\log K_s$ S.D.	Θ_s Mean	Θ_s S.D.
Sandy loam	124	4.74	1.40	1.15	0.73	−0.13	0.67	43.4	8.8
Sand	14	2.79	1.38	0.84	0.56	0.82	0.39	33.9	7.3
Loamy sand	30	4.26	1.95	0.56	0.73	0.30	0.51	42.1	7.2
Loam	103	5.25	1.66	1.55	0.66	−0.32	0.63	43.9	7.4
Silty loam	394	5.33	1.72	1.88	0.38	−0.40	0.55	47.6	5.4
Sandy clay loam	104	6.77	3.39	1.13	1.04	−0.20	0.54	40.4	4.8
Clay loam	147	8.17	3.74	1.42	0.72	−0.46	0.59	46.5	5.4
Silty clay loam	325	8.72	4.33	1.79	0.58	−0.54	0.61	46.4	4.6
Sandy clay	16	10.73	1.54	0.99	0.56	0.01	0.33	40.6	3.2
Silty clay	43	10.39	4.27	1.51	0.84	−0.72	0.69	46.8	6.2
Light clay	148	11.55	3.93	1.67	0.59	−0.86	0.62	46.8	3.5
All classes	1448	7.22	3.86	1.59	0.70	−0.42	0.64	45.7	6.1

Parameters: b is the slope of log Ψ versus log (Θ/Θ_s) regression, Ψ in centimeters H_2O; log Ψ_s is the intercept of log Ψ versus log (Θ/Θ_s) regression, Ψ in centimeters H_2O; log K_s is the log of the saturated hydraulic conductivity in inches per hour; Θ_s is the saturated water content in percent (volume/volume).

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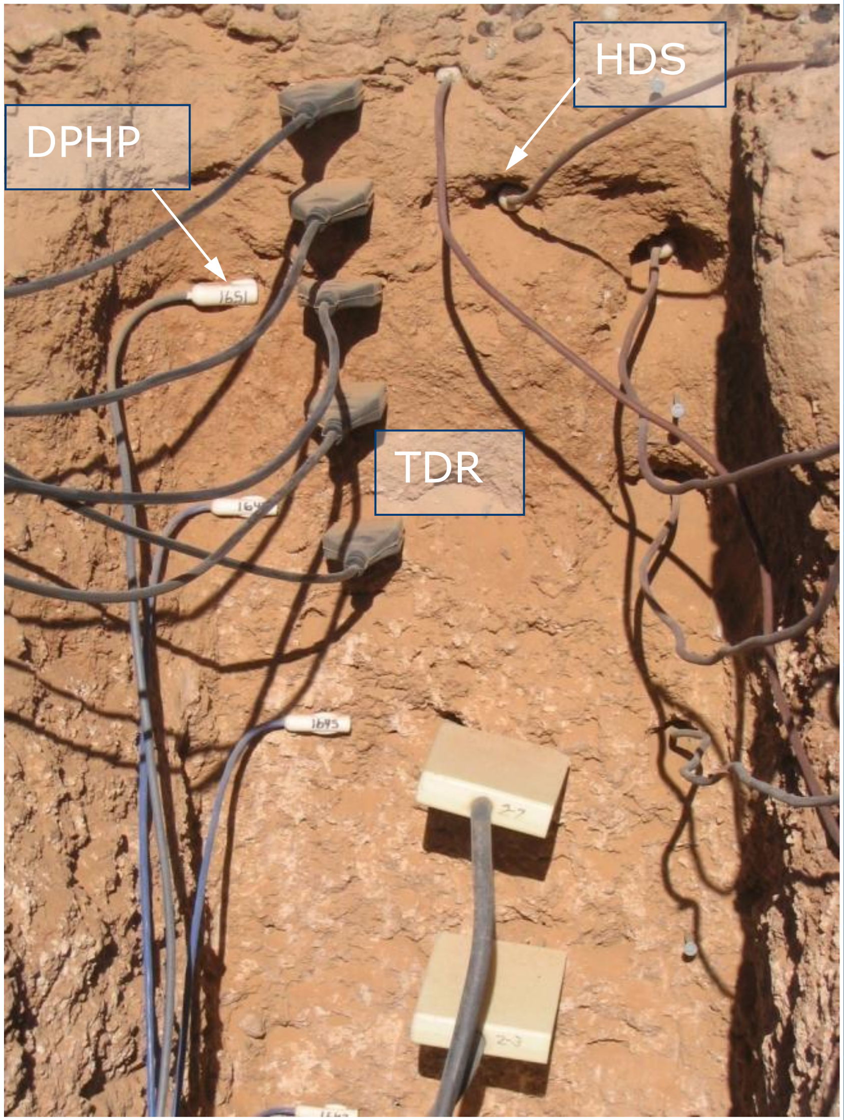
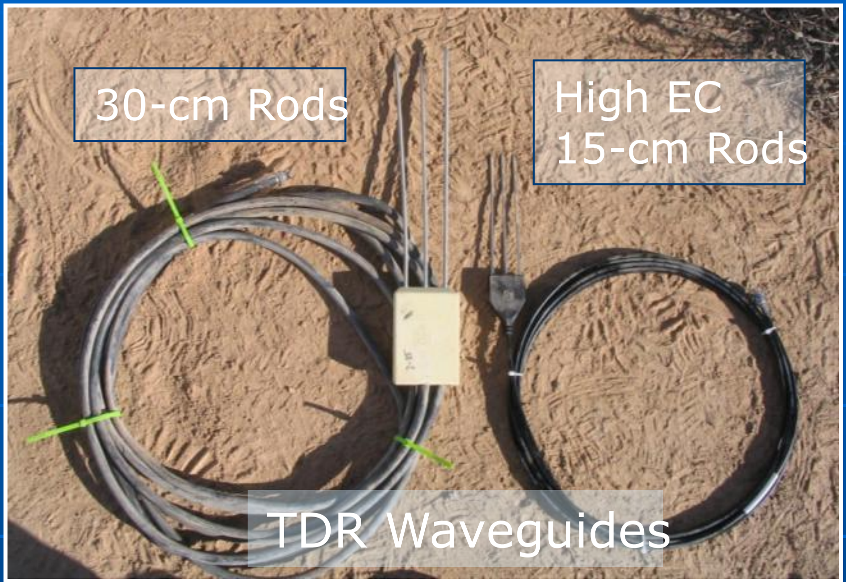
Soil Moisture Sensors





<u>Soil Monitoring</u>
Water content (TDR, DPHP)
Matric potential (HDS)
Soil temperature (HDS)
Permittivity/EC (TDR)
Thermal diffusivity & conductivity (DPHP)

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Additional DIELECTRIC Sensors

ADVANTAGES

DISADVANTAGES

- There is NO standard for soil moisture measurements
- No single probe can function across all environments
- All electrical sensors indirectly infer soil moisture

Decagon 5TE

- Soil T, θ, and EC_{actual}

Stevens' HydraProbe

- Soil T, θ, and $EC_{apparent}$

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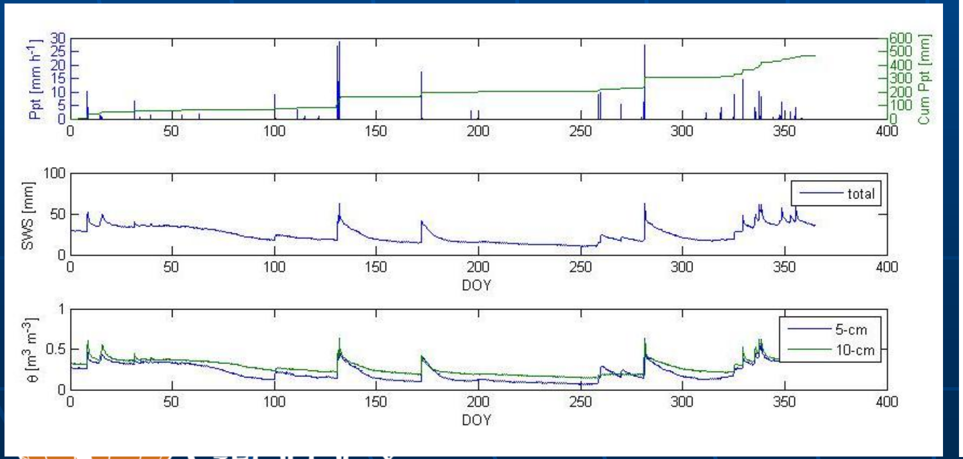
Ground-based soil moisture networks

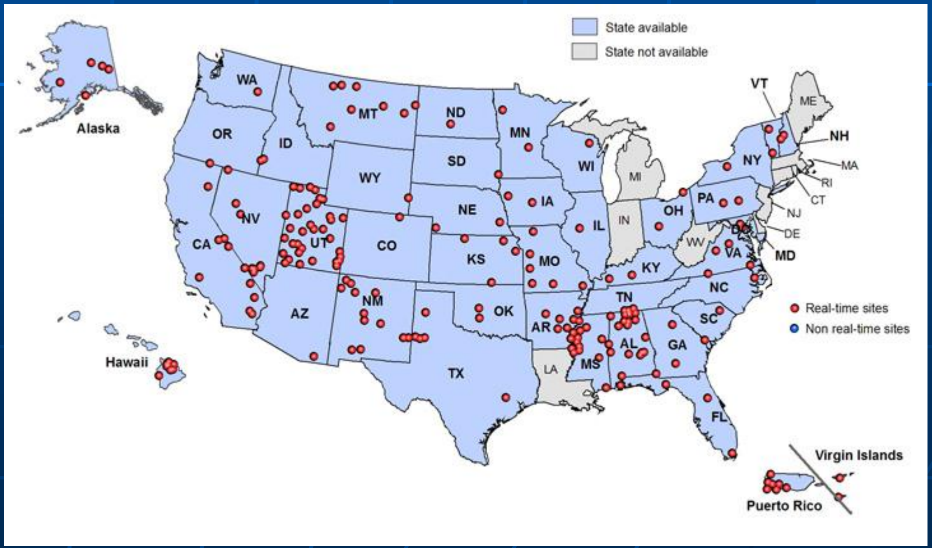
Network	Sensor	US Sites	TX Sites	Year
SCAN	HydraProbe	140	5	~2005
USCRN	HydraProbe	144	7	~2008
COSMOS	Neutron scatter	50	2	2010
AmeriFlux	Dielectric	215	1	2005
NEON	??	20	1	~2011

- Oklahoma Mesonet: 127 sites, heat dissipation sensors
- Illinois Climate Network: 19 sites, neutron probe and sensors
- High Plains Regional Climate Center: 14 sites (NE), Theta probe
- Critical Zone Observatories: 6 sites, miscellaneous sensors

Soil Climate Analysis Network (SCAN)

- Evolution of SNOTEL (USDA/NRCS)
- Technique
  - Frequency domain dielectric sensor
  - Vertical footprint: 5, 10, 20, 50, 100 cm depths
  - Horizontal footprint: < 2 m^2
- Plus/minus
  - Soil characterization (+)
  - Supplemental MET data (+)
  - Discrete depths(+/-)

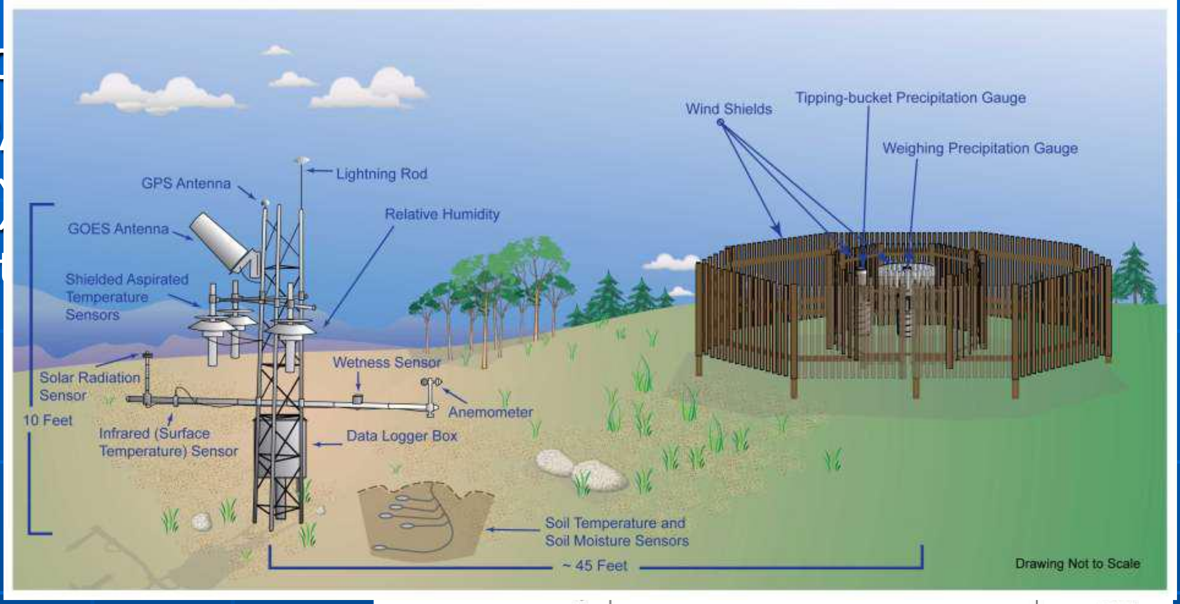




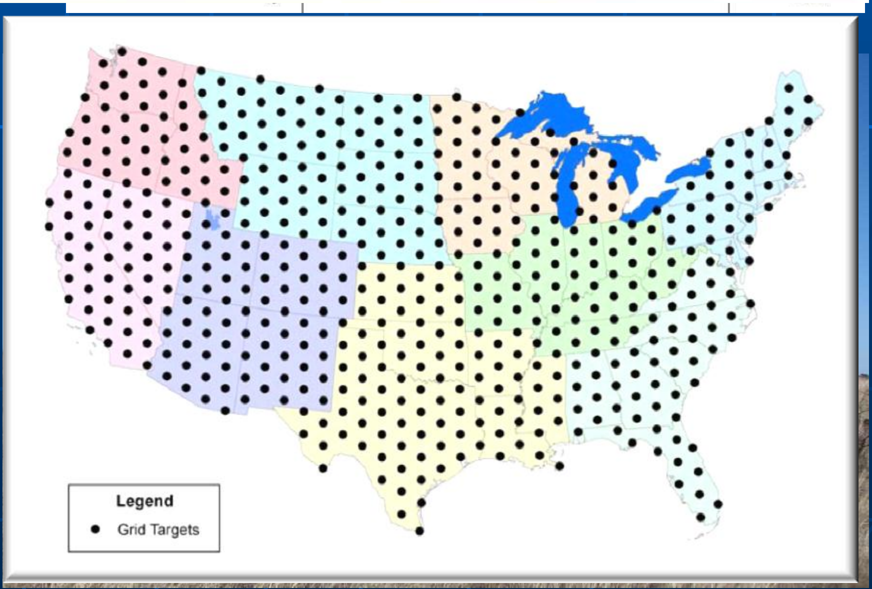
http://www.wcc.nrcs.usda.gov/scan/

US Climate Reference Network (USCRN)

- NOAA project to monito
long-term temperature,
- Technique (from SCAN)
  - Frequency domain dielect
  - Vertical footprint: 5, 10,
100 cm depths
  - Horizontal footprint: < 2



- Plus/minus
  - Discrete depths (+)
  - Supplemental Met data (+)
  - Most stations have just 5 and 10-cm sensor (-)
  - Soil disturbance (-)
  - Indirect measurement (-)
  - USRCRN plans 538 (130 km grid) across the US – may include SM



http://www.ncdc.noaa.gov/crn/

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AmeriFlux Network

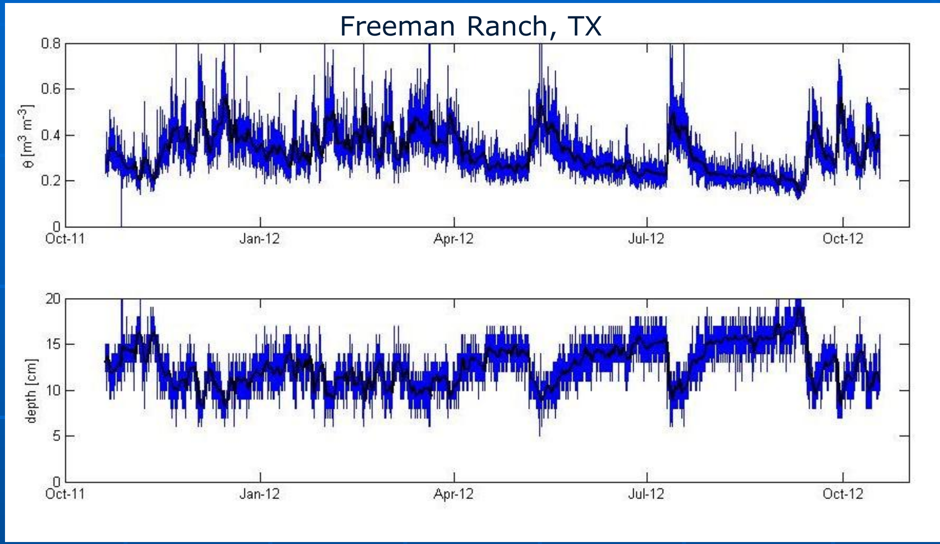
- DOE project to monitor net ecosystem carbon and water flux
- Technique
  - Primarily Eddy covariance
  - Soil moisture is hit/miss
  - Vertical footprint: 2 cm depth
  - Horizontal footprint: < $2\ m^2$
- Plus/minus
  - Water vapor, carbon and energy flux is measured (+)
  - Discrete depth (+/-)
  - Complicated system (-)

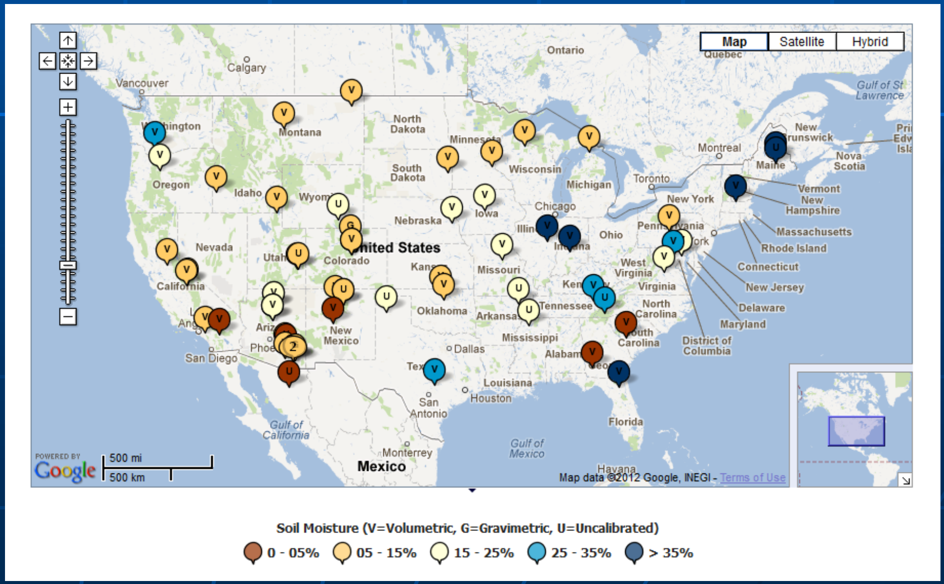
Gamboa, Panama

http://ameriflux.ornl.gov

COsmic-ray Soil Moisture Observing System (COSMOS)

- Technique
  - Monitor cosmic-ray neutrons above soil surface
  - Vertical footprint: 15-70 cm
  - Horizontal footprint: ~350 m
- Plus/minus
  - Largest footprint (+)
  - No soil disturbance (+)
  - Direct measurement (+)
  - Variable and shallow depth (-)



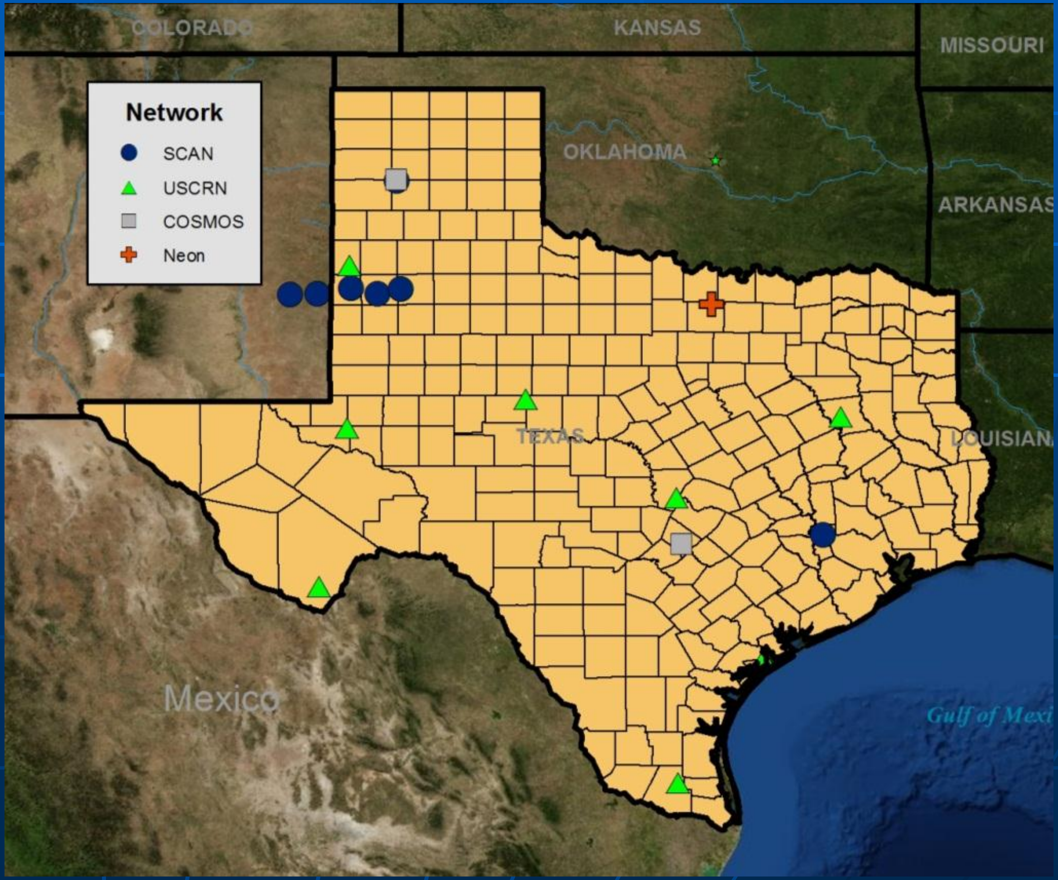


Freeman Ranch, TX

http://cosmos.hwr.arizona.edu

Current of Soil Moisture and Climate Observatories in the State of Texas

- USDA SCAN Sites
  - 140 nationally
  - 5 (4%) in Texas, ~9 planned
- NOAA USCRN Sites
  - 144 nationally, 538 planned
  - 7 (5%) in Texas
- NSF COSMOS Sites
  - 50 nationally, 450 planned
  - 2 (4%) in Texas
- AmeriFlux Sites
  - 212 nationally
  - 3 (1%) in Texas, ? planned



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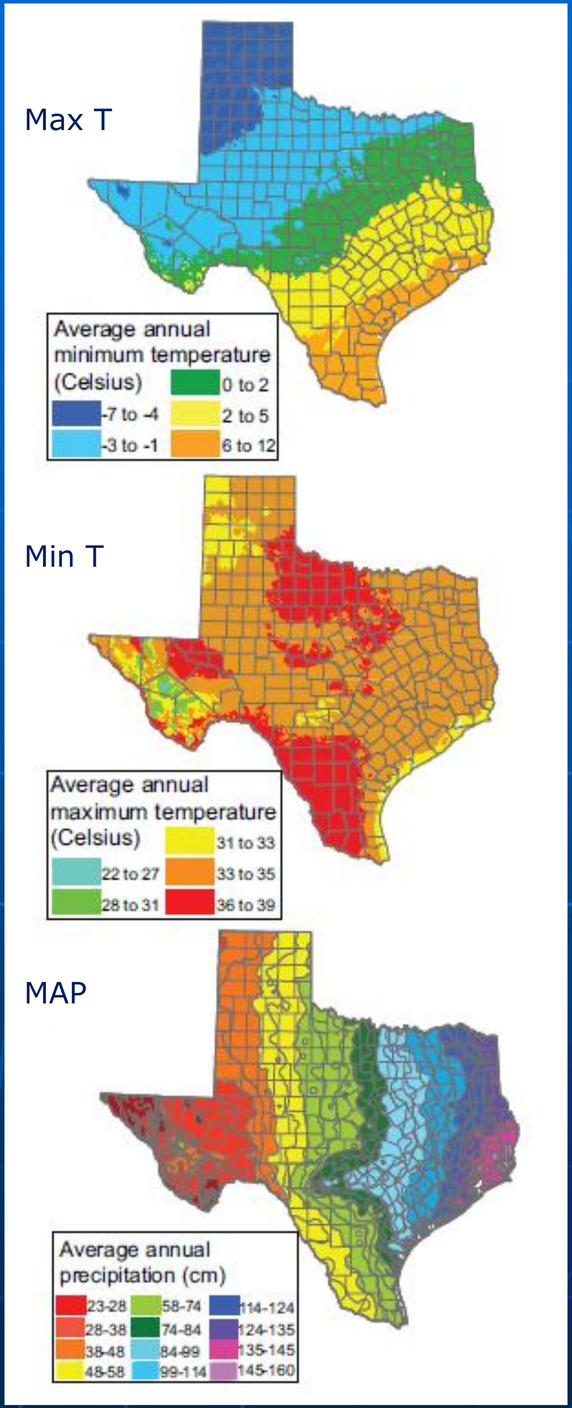
Recommendations for Texas

- Diversity of temperature and precipitation across Texas implies diverse soil moisture
- Ground-based networks exist in the US as do methods to scale their data.
  - SCAN/COSMO – below ground
  - USCRN/AmeriFlux – above ground
- The scientific community (us) need to:
  - Push heavily for more stations in Texas
  - Make this data available to the agencies and scientific groups using TNRIS
- We now have the unique opportunity to partner the university and stakeholders for both the good of Texas and the scientific community

Questions for discussion

1. Do we need more <u>observational</u> data to validate our models and predictions?
2. Would more refined maps of soils and their properties aid our predictive abilities?



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