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SCHOOL OF GEOSCIENCES

Texas Soil Observation Network: TxSON Linking Soil Moisture to Water Resources in the Texas Hill Country

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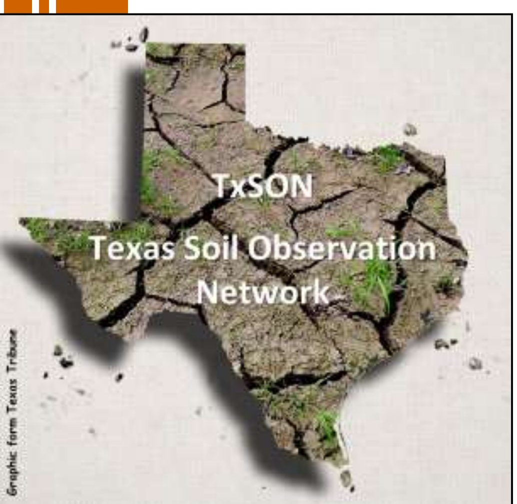

CAHMDA/DAFOH

10 September 2014, Austin, TX

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BUREAU OF ECONOMIC GEOLOGY

Soil Moisture and the Drought in Texas

I. How is drought linked to water resources?

II. Where does soil moisture fit into the picture?

III. At what scale is soil moisture operational?

IV. How are can we validate these products?

V. How can stakeholders use soil moisture?

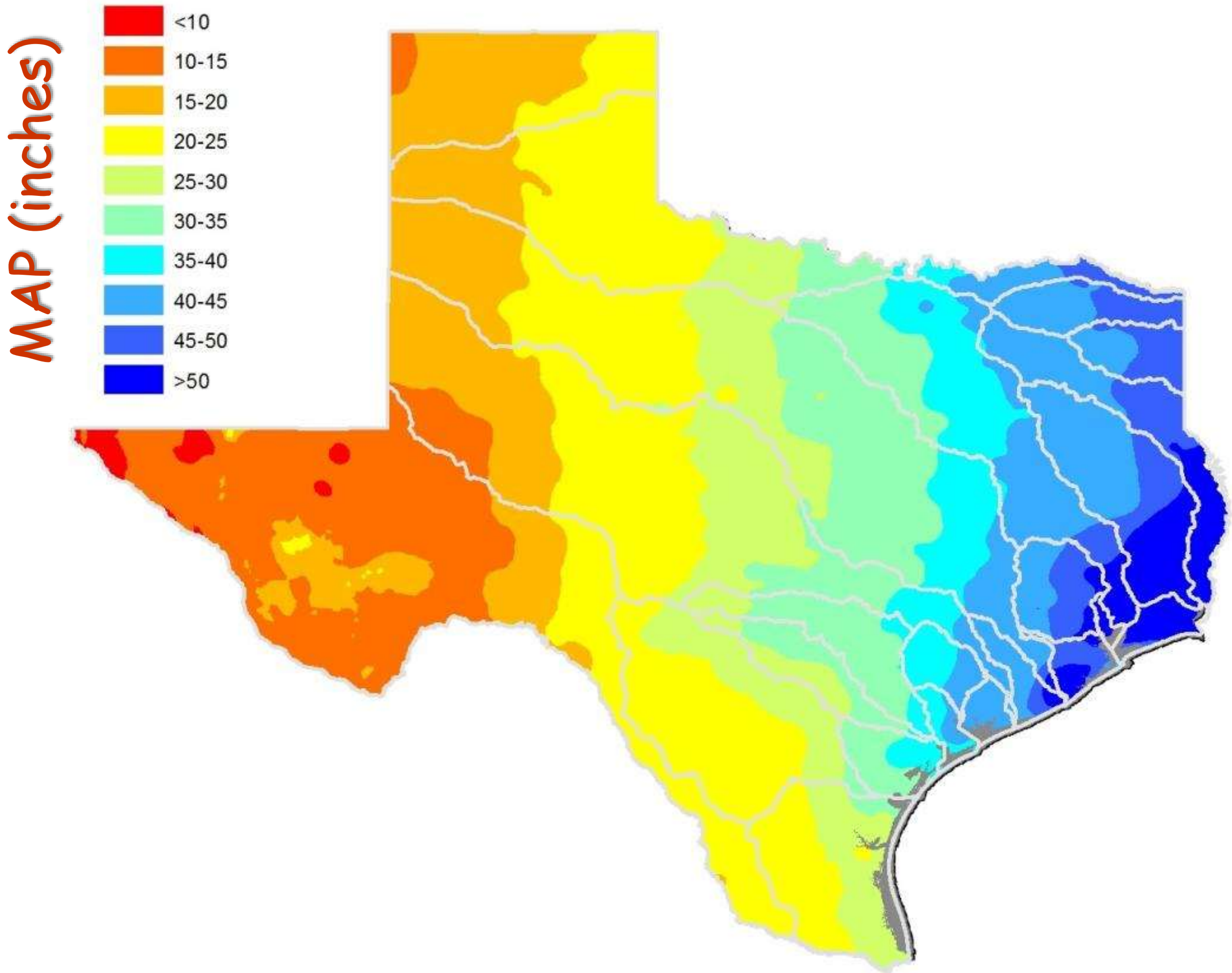
We cannot have drought without socio-economic impact. Otherwise, it's just desert

2011: ~$8 billion in losses from the agricultural sector

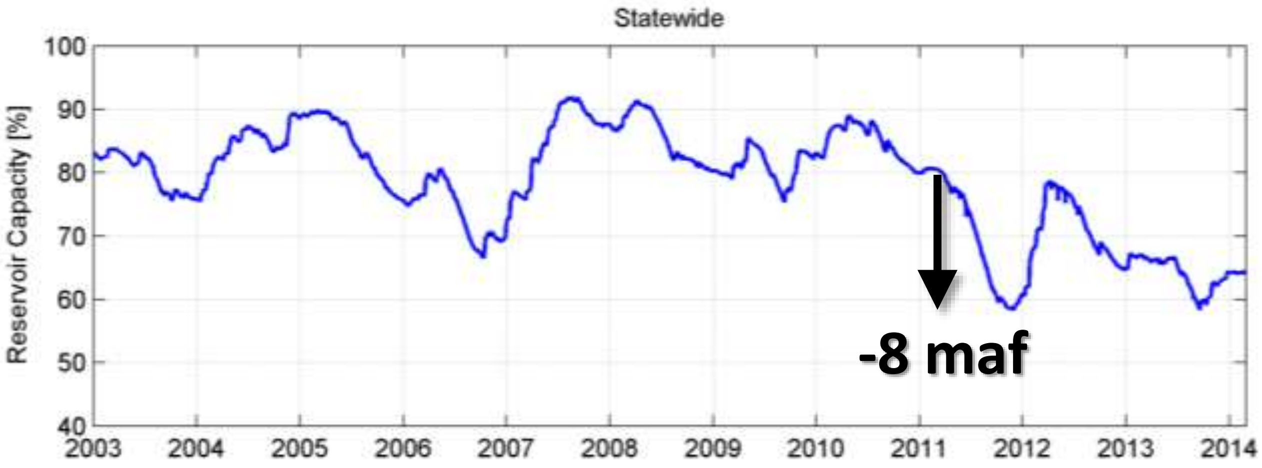
Droughts are defined differently by impact

- Meteorological drought
  - Significant negative departure from normal precipitation
  - Shortage of precipitation (or moisture supply) over some period of time (weekly, monthly, seasonal, or annual time scales).
- Agricultural drought
  - Period of moisture deficiency that is sufficient to have a lasting and adverse impact on plant growth or crop yield
- Hydrologic drought
  - Prolonged precipitation deficiencies on water supply from surface or subsurface sources
- There is an inherent time-lag between meteorological, agricultural and hydrological drought

Obvious impacts to our surface water reservoirs

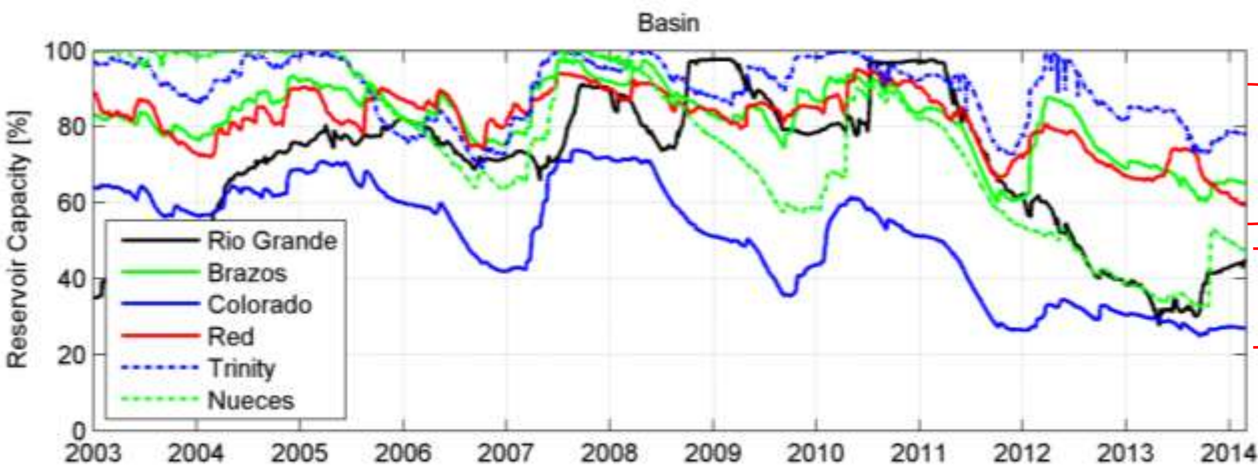


Obvious impacts to our surface water reservoirs



Reservoir Storage

- 18 maf 2010
- 22 maf 2060



Rebounded
Brazos, Red, Trinity

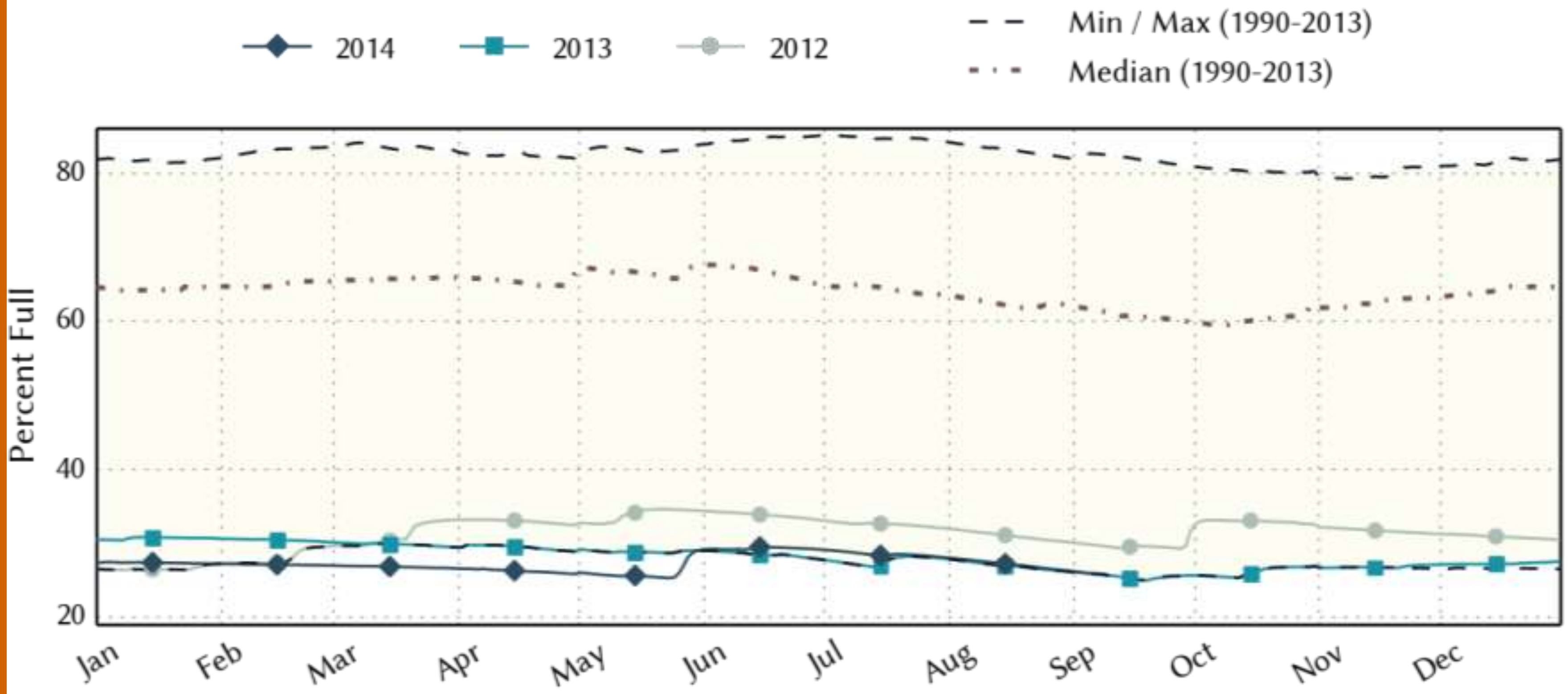
Continuous decline
Rio Grande, Colorado, Nueces

http://waterdatafortexas.org

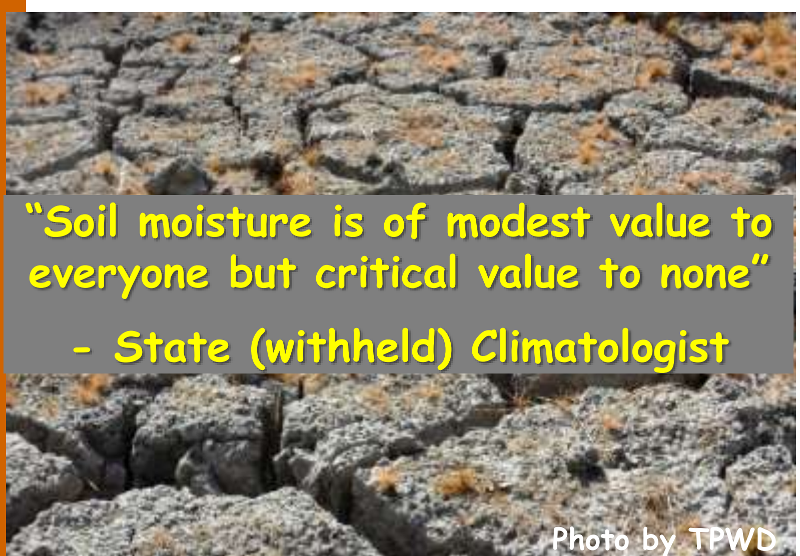
Obvious impacts to our surface water reservoirs

Colorado River Basin Reservoirs

Monitored Water Supply Reservoirs are 25.8% full on 2014-09-09



PROBLEM: The perplexity of drought beyond 2012



How much precipitation do we need to get out of drought?

Despite near-normal rainfall, why are reservoir levels NOT recovering?

How much water can we release for ag?

- **How much water do we have?**

How can we account for all the water in Texas?

$$\sum IN - \sum OUT = \Delta STORAGE$$

$WATER_{IN}$	-	$WATER_{OUT}$	=	$\Delta STORAGE$
▪ Precipitation*		▪ Consumption*		▪ Reservoirs*
▪ Snowpack		▪ ET*		▪ Groundwater*
▪ Streamflow		▪ Streamflow*		▪ Soil Moisture*
▪ Groundwater		▪ Groundwater*		

Storage components

$$PPT - (Q + C + ET) = \Delta R + \Delta GW + \Delta\theta$$

How about those storage terms?

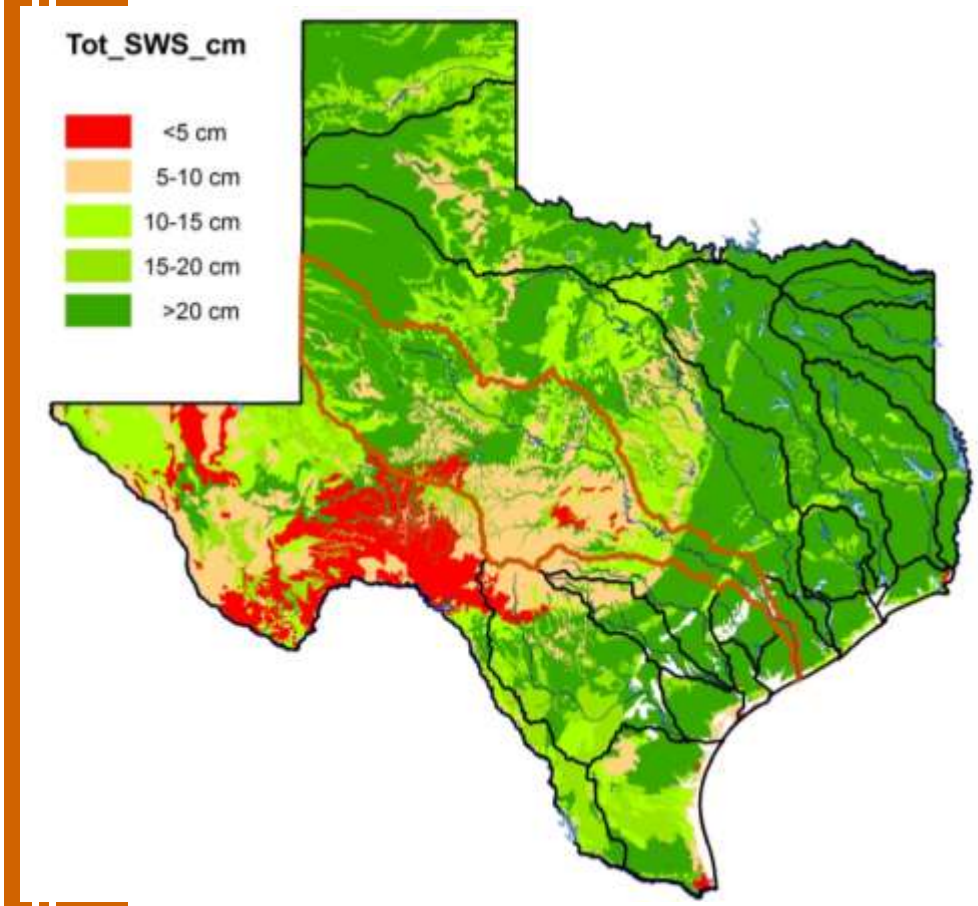
- Reservoir Storage (ΔR): observable
- Groundwater storage (ΔGW): somewhat observable
- Soil moisture storage ($\Delta\theta$): ???

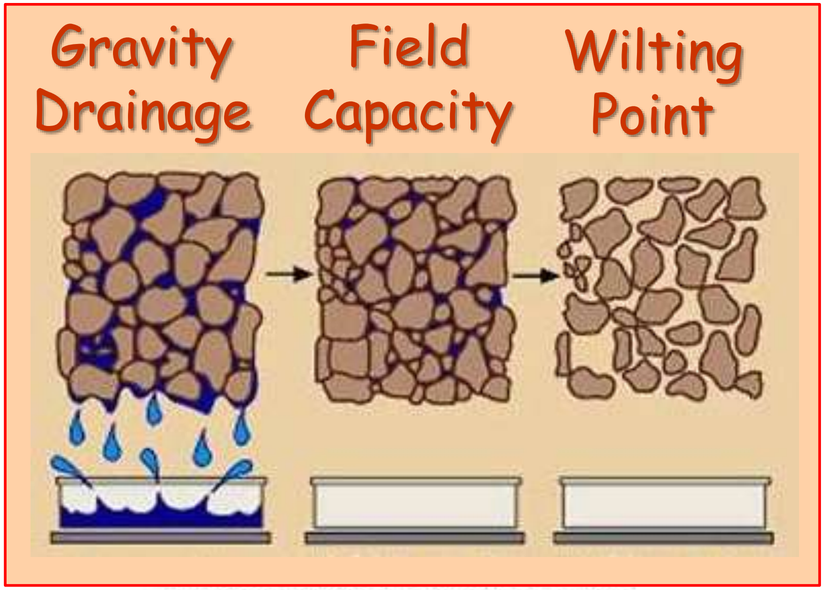
We have uncertainty in our inputs (PPT)

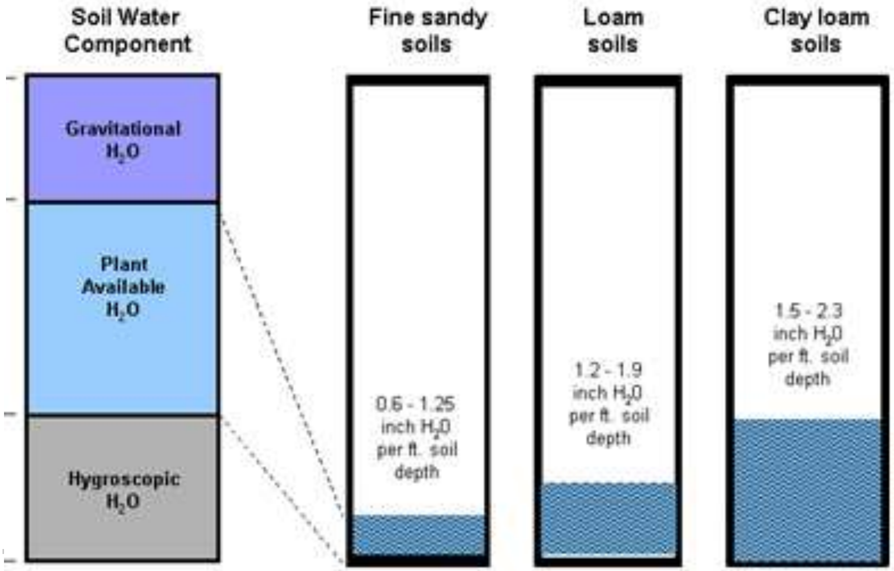
Unknowns in our outputs: crop consumption & ET

Unknowns in our storage: soil moisture

What is soil moisture storage?







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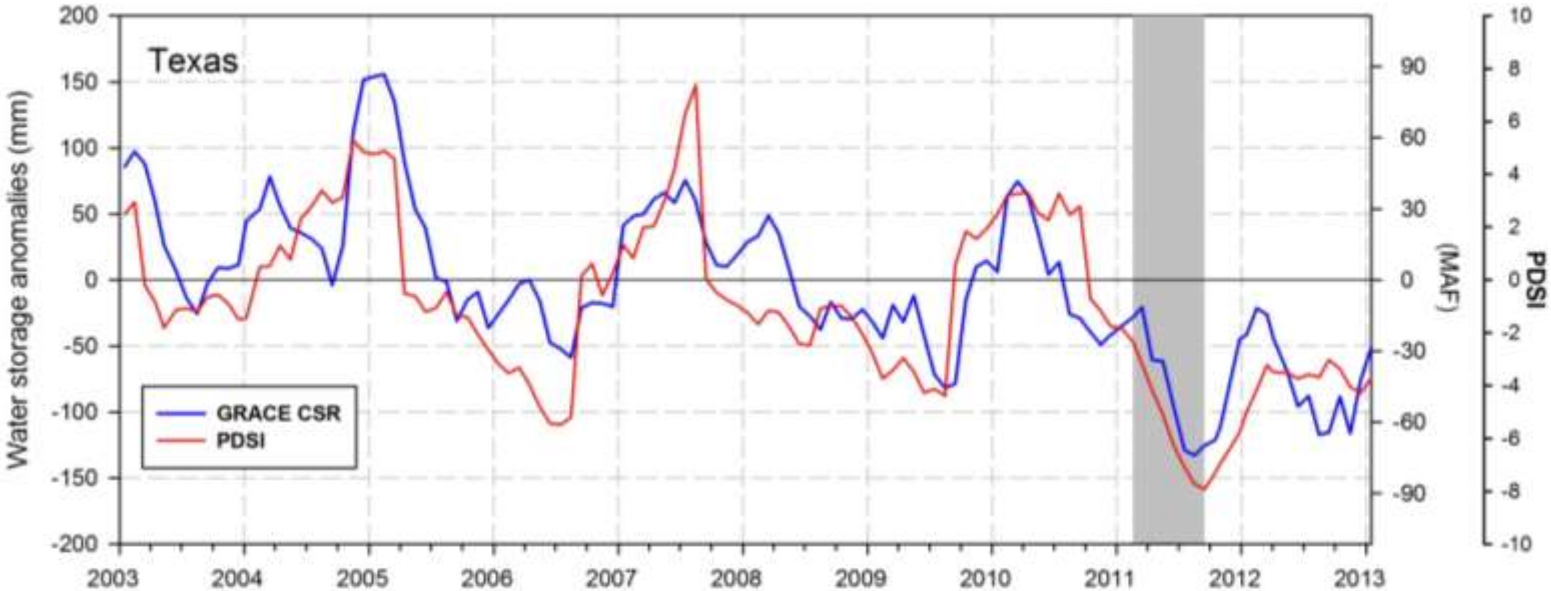
Using GRACE to estimate total water storage

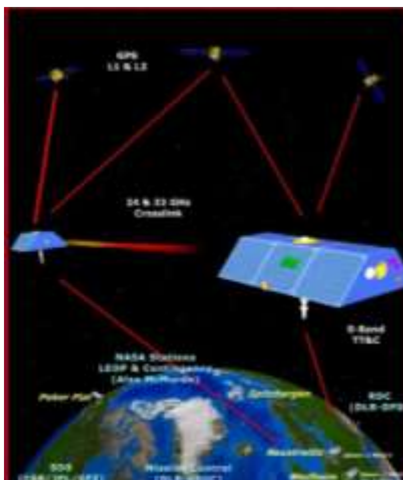


Majority of depletion appears to be in soil moisture storage

$$\Delta Total\ Water\ Storage = \Delta Reservoir + \Delta Soil\ Moisture + \Delta Groundwater$$

$$\Delta TWS = \Delta R + \Delta SMS + \Delta GW$$

$$50\ maf = 6\ maf + 70\text{-}80\ \%\ TWS + 4\text{-}8\ maf$$



Source: Long et al., 2013

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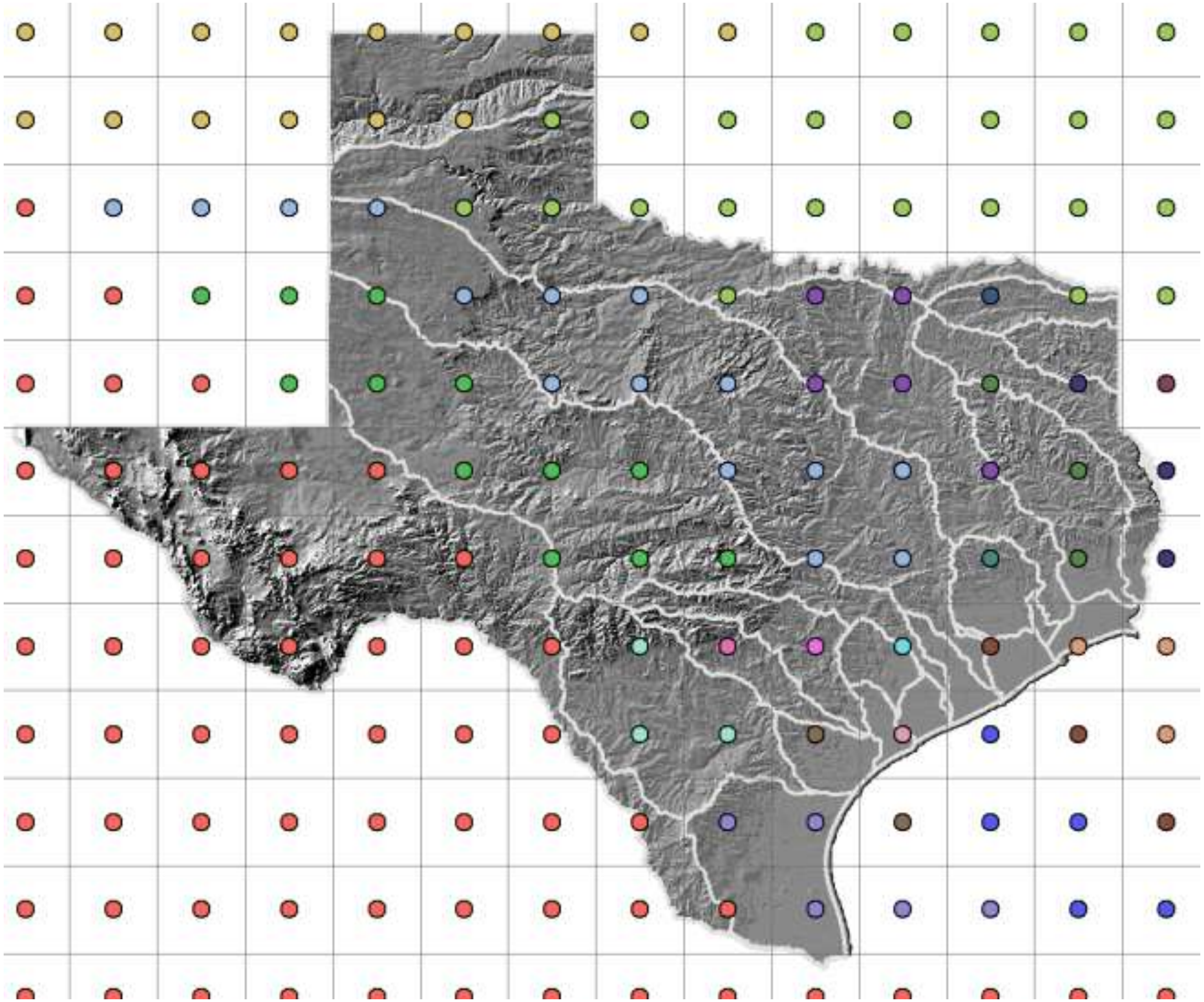
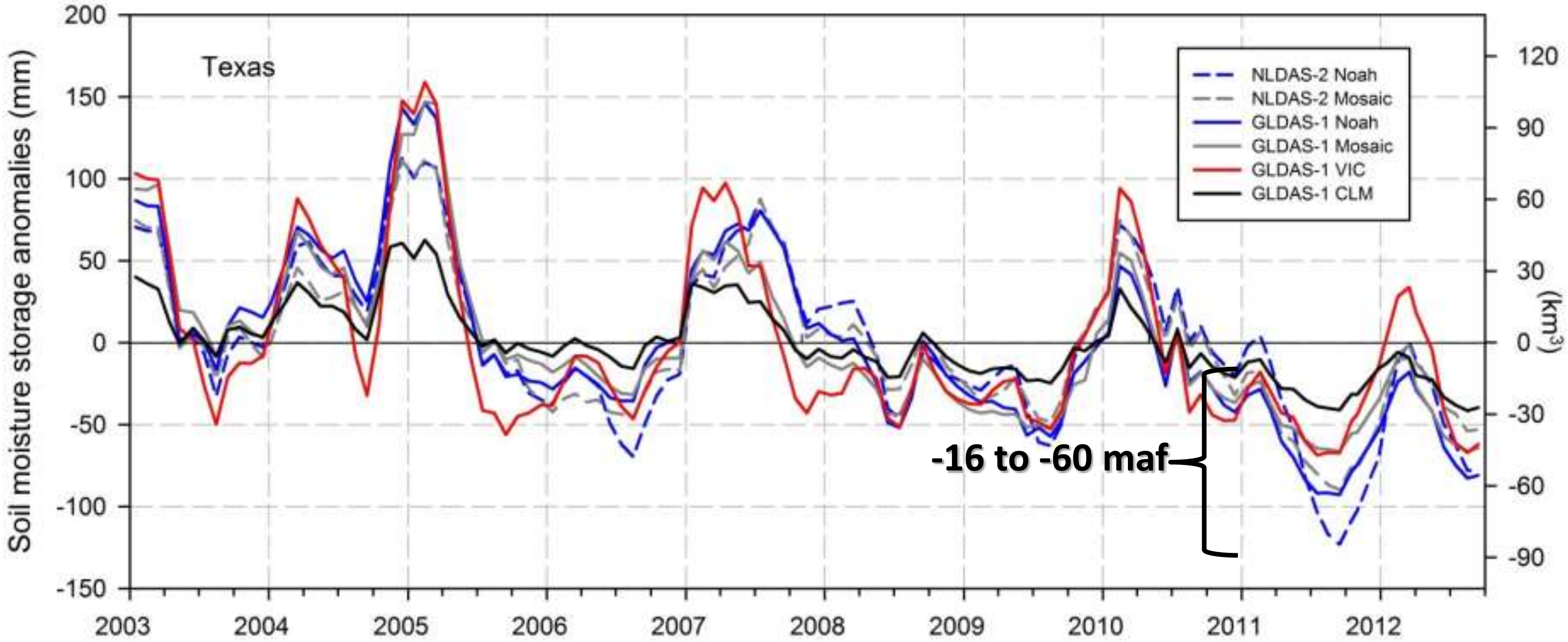
Changes in Total Water Storage: GRACE 1^{o} Grid



Texas Drought: Soil moisture deficit in Texas



Soil moisture from multiple LSM indicate that depletion in 2011 could range from 20% to 100% of TWS from GRACE – <u>the soil reservoir is *BIG*</u>

Uncertainty in soil moisture storage between models is high

Source: Long et al., 2013

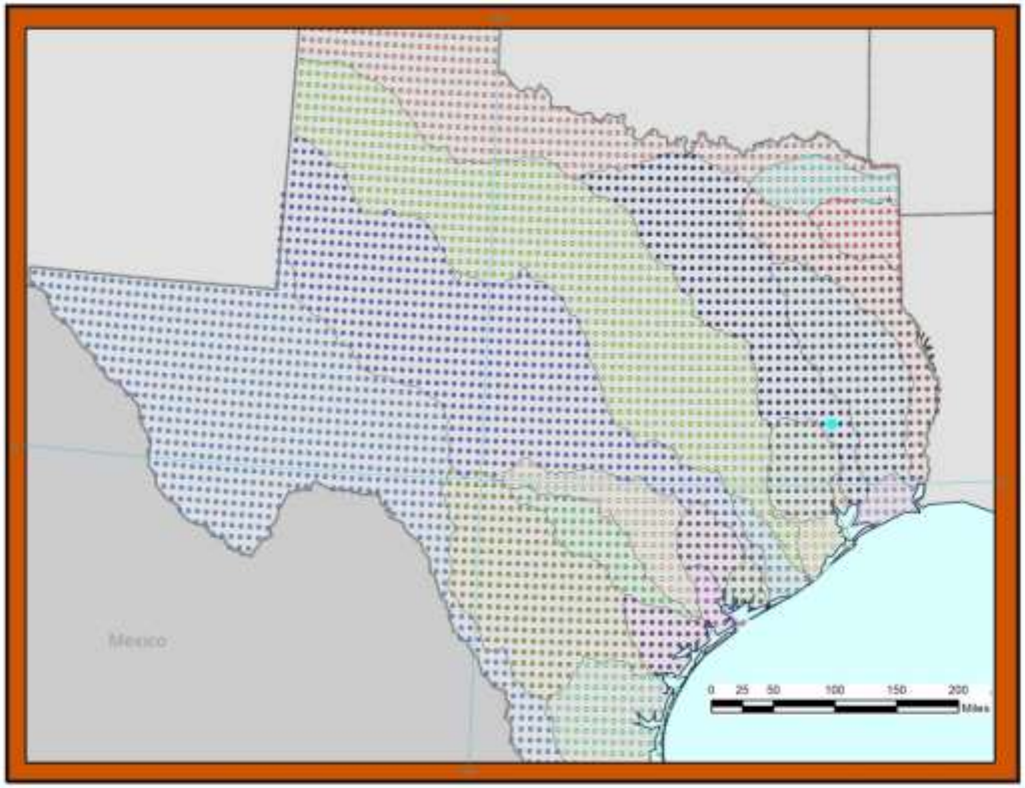
NLDAS-2: Noah output and forcings

Primary Forcing Data at Hourly Time Steps (NARR)	
Precipitation (PRISM)	Solar Rad
Convective Available PE	PET
Air T and RH (2m)	Wind Speed (10m)

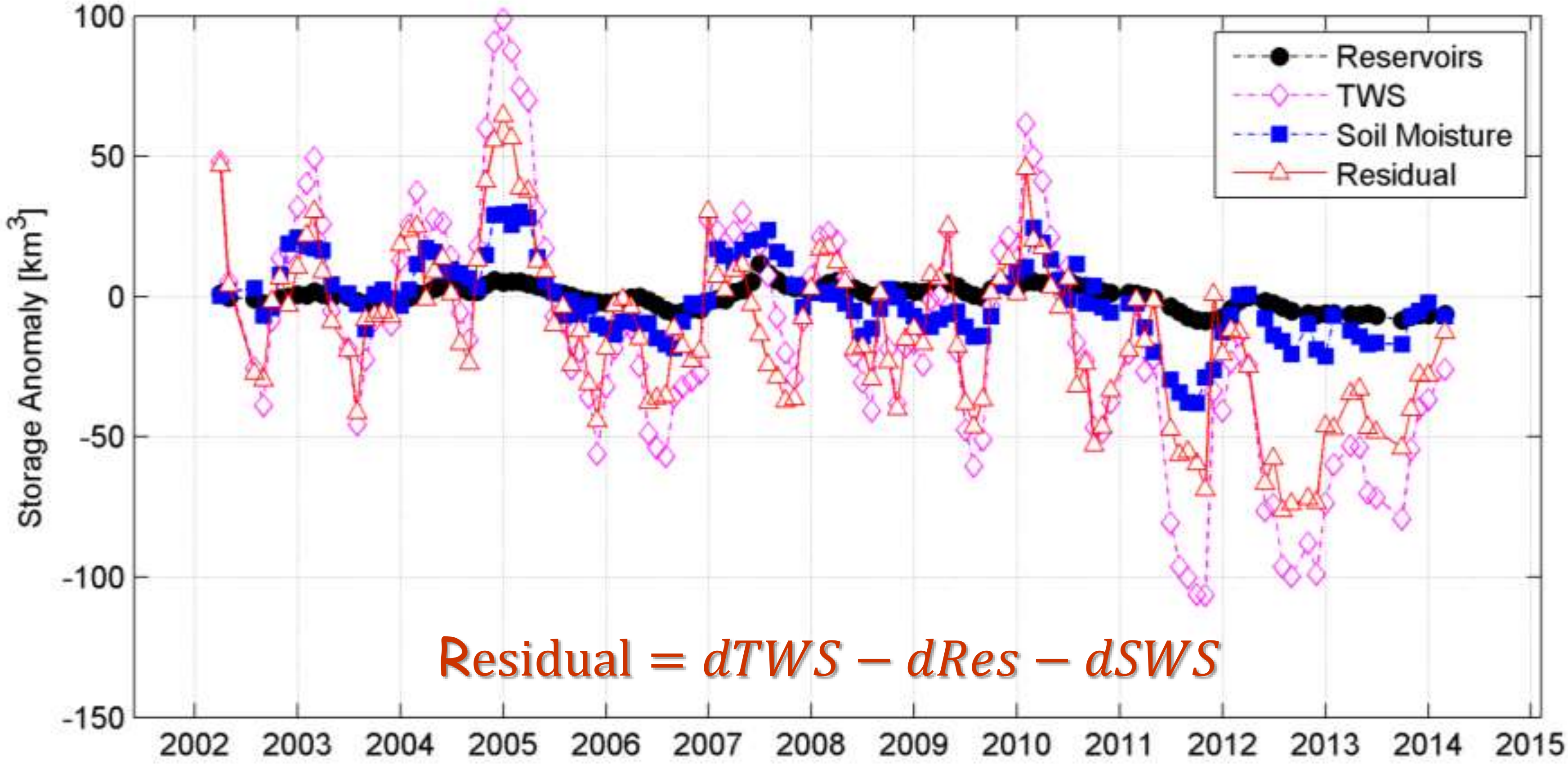
Noah Output

- GRIB outputs at hourly and monthly values (1/8°)
- 52 fields of parameters
- Soil Moisture Storage (4):
  - 0-0.1 m 0.1-0.4 m
    0.4-1.0 m 1.0-2.0 m

http://disc.sci.gsfc.nasa.gov/hydrology/data-holdings

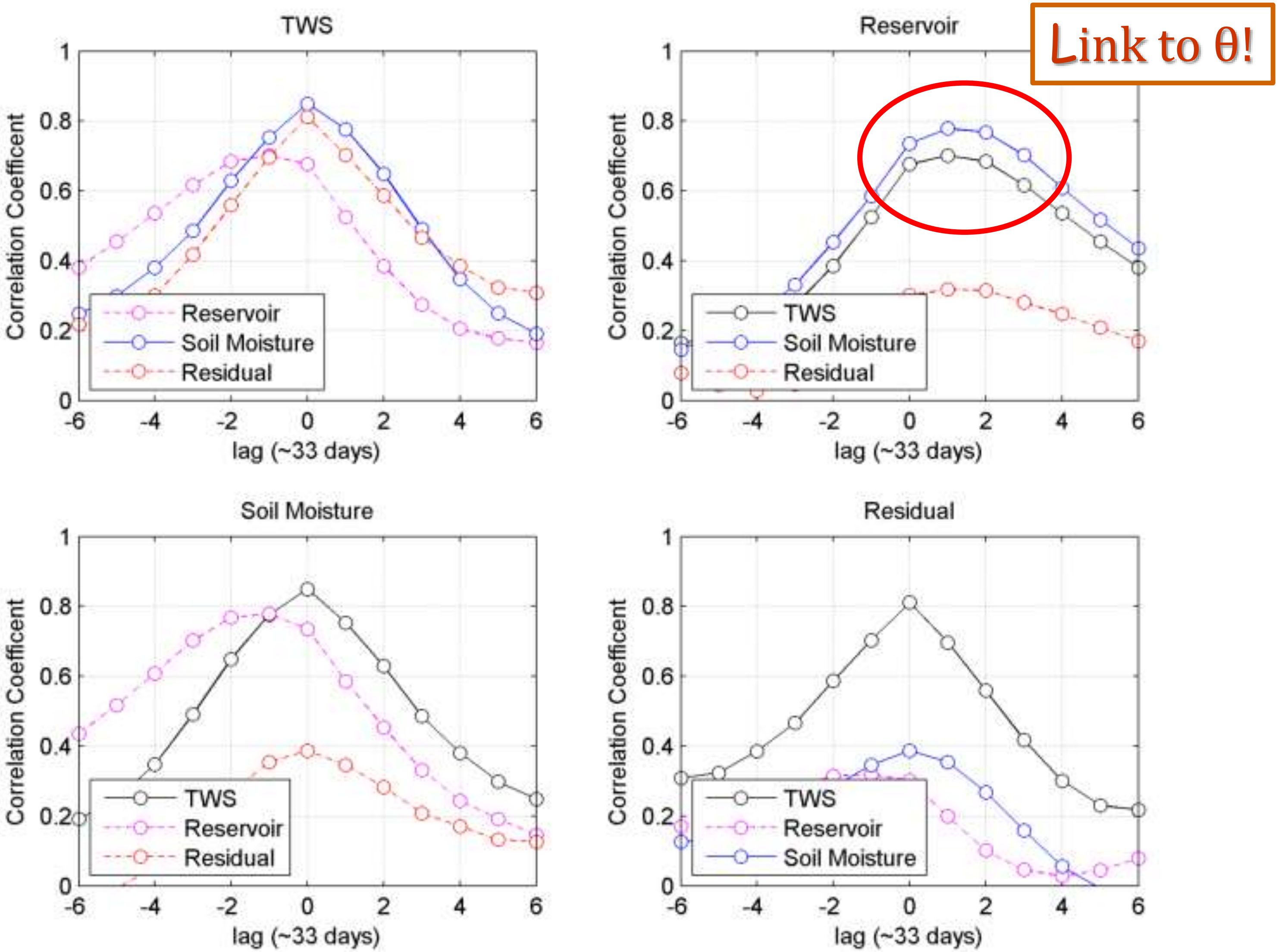


Changes in Total Water Storage: Statewide



$$\text{Residual} = dTWS - dRes - dSWS$$

Cross-correlation from monthly anomalies: 2003-2013



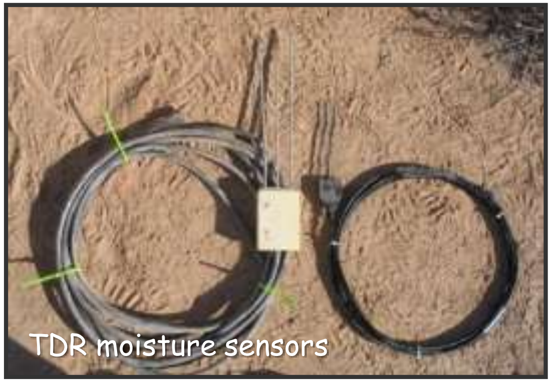
What have we done to communicate our results?

- We have shown that soil moisture storage is a huge 'reservoir' in Texas
- We have shown the merit of both remote sensing products and land surface models
- We have shown the associated error in remote sensing and uncertainty in LSM
- We have explained soil moisture to Stakeholders
- Now, we can increase monitoring networks:

  - Texas Soil Observation Network (TxSON)

Validating Noah/SMAP – in situ soil moisture

- Buried sensors
  - SCAN/USCRN sites
  - Neutron access tubes (HPWD)
  - Small sampling area, calibration
- Above-ground sensors
  - Cosmic ray attenuation (COSMOS)
  - Big footprint (300'), mobile platform
- Remote sensing
  - Passive/active microwaves (AMSR-E/SMAP)
  - Gravity (GRACE)
  - Big footprint (30-100 km)
  - Shallow penetration (<5cm)
  - Infrequent visits


TDR moisture sensors


COSMOS at Freeman Ranch, TX

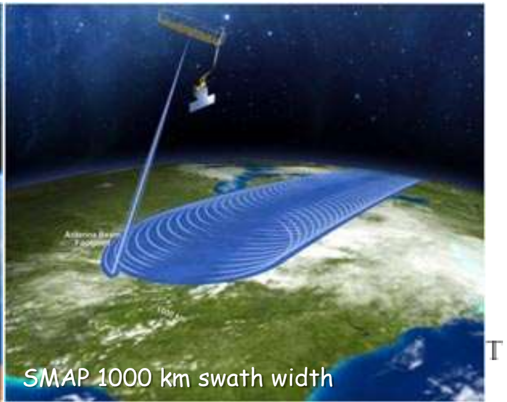

COSMOS Rover System

How can we measure soil moisture from space?

- NASA Soil Moisture Active/Passive (SMAP) Mission
  - ***First dedicated θ-satellite***
  - Global coverage at 3, 9, 36 km resolution
  - November 5, 2014 launch date
- 1000 km swath provides data ~50 hours globally to 5 cm depth
- JSG is partnering with NASA Jet Propulsion Laboratory, to improve on-ground data collection

Together, we're building TxSON!

SMAP Radar/radiometer



SMAP 1000 km swath width

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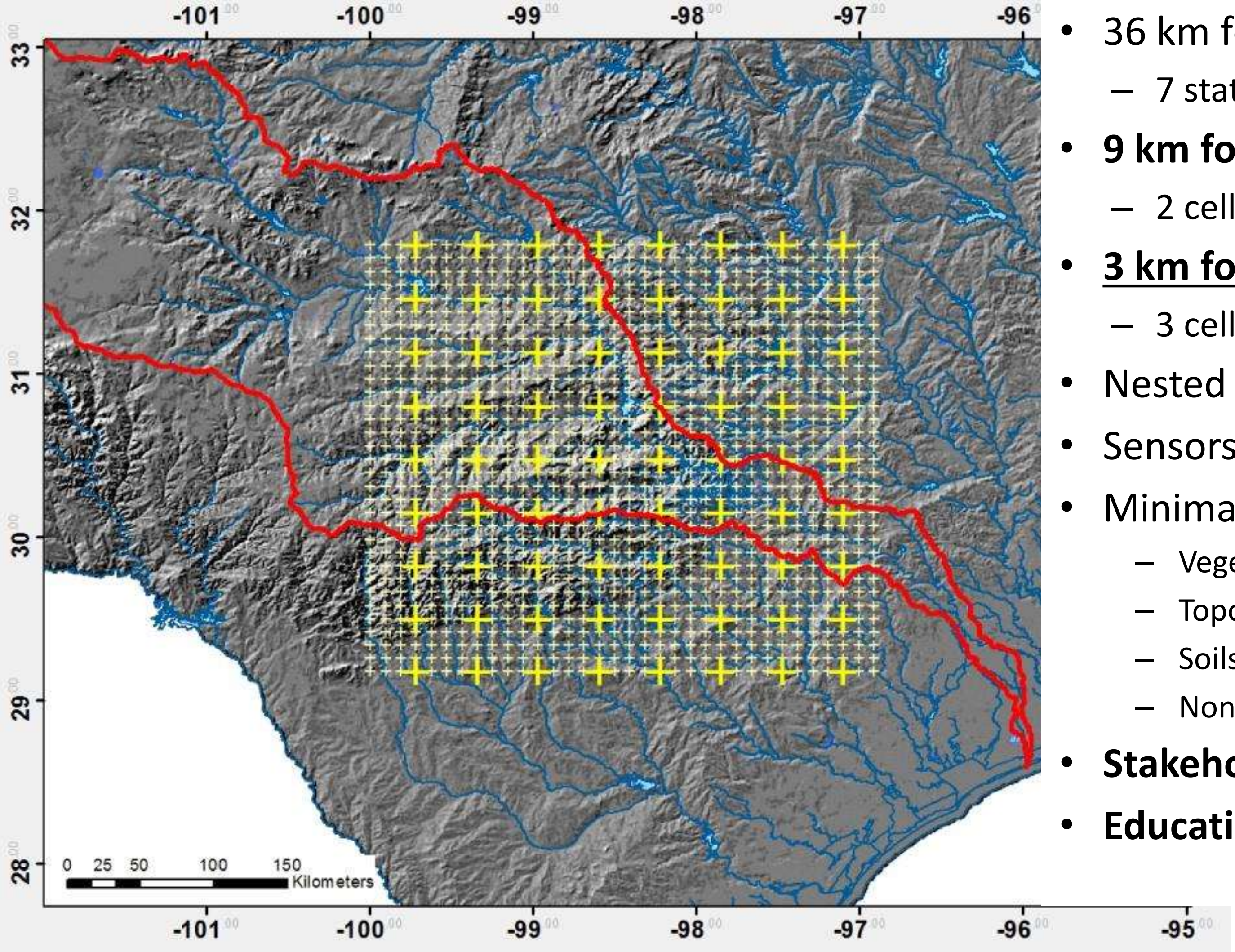
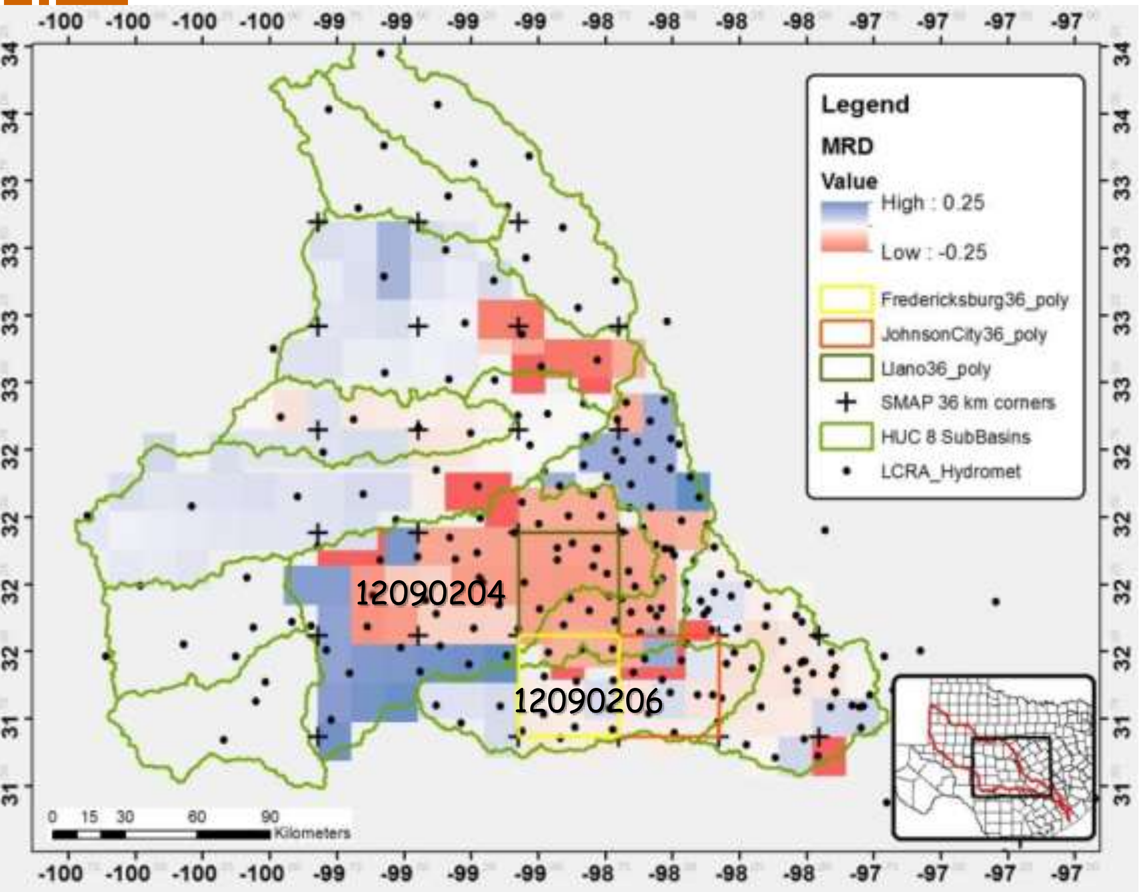
SMAP EASE-2 Grid: Middle Colorado Basin, TX



Ideal Core Cal/Val Site:

- 36 km footprint (yellow)
  - 7 stations (existing LCRA)
- **9 km footprint**
  - 2 cells each with 7 stations
- **3 km footprint**
  - 3 cells each with 7 stations
- Nested design: 37 total stations
- Sensors at 5, 10, 20 and 50 cm
- Minimal variability in:
  - Vegetation
  - Topography
  - Soils/geology
  - Non-urban
- **Stakeholder interests**
- **Educational outreach**

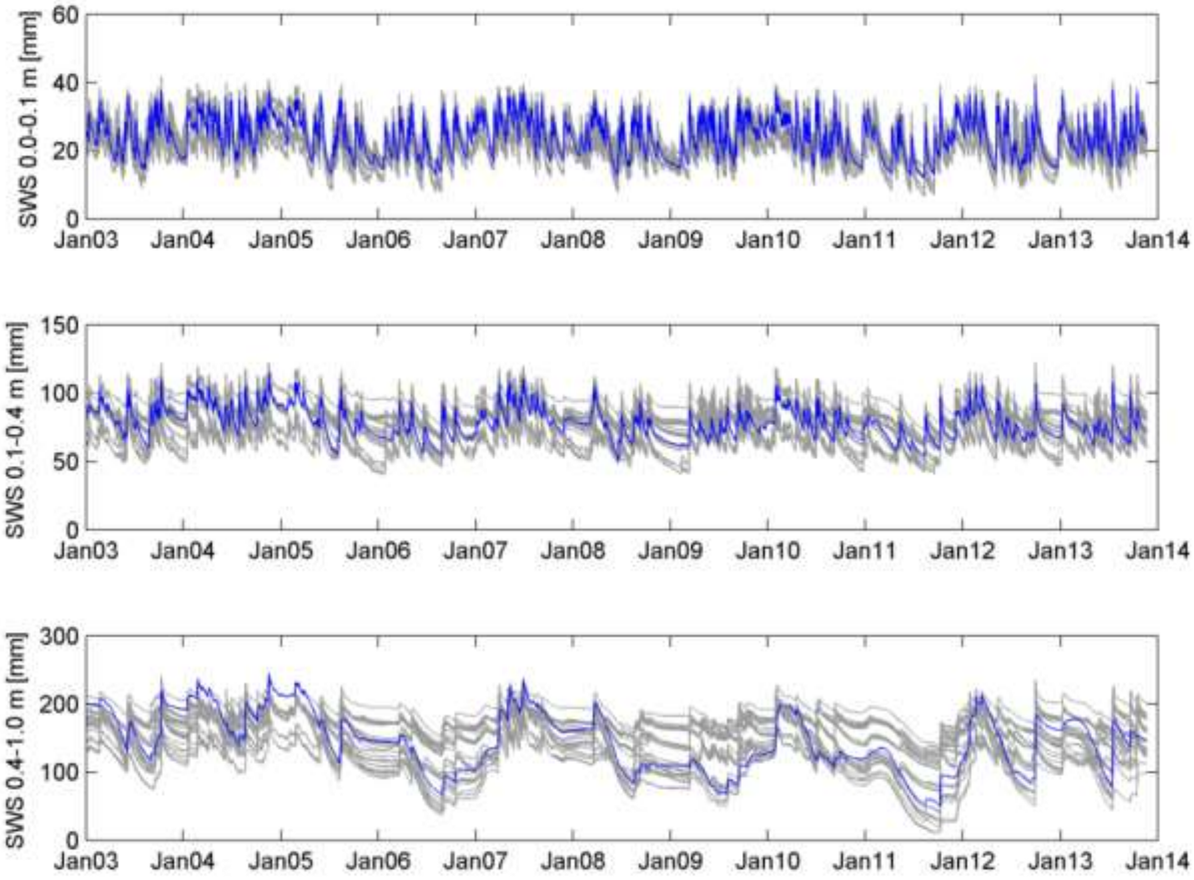
Core Cal/Val: Mean relative difference (SWS)



MRD using NLDAS for each HUC 8

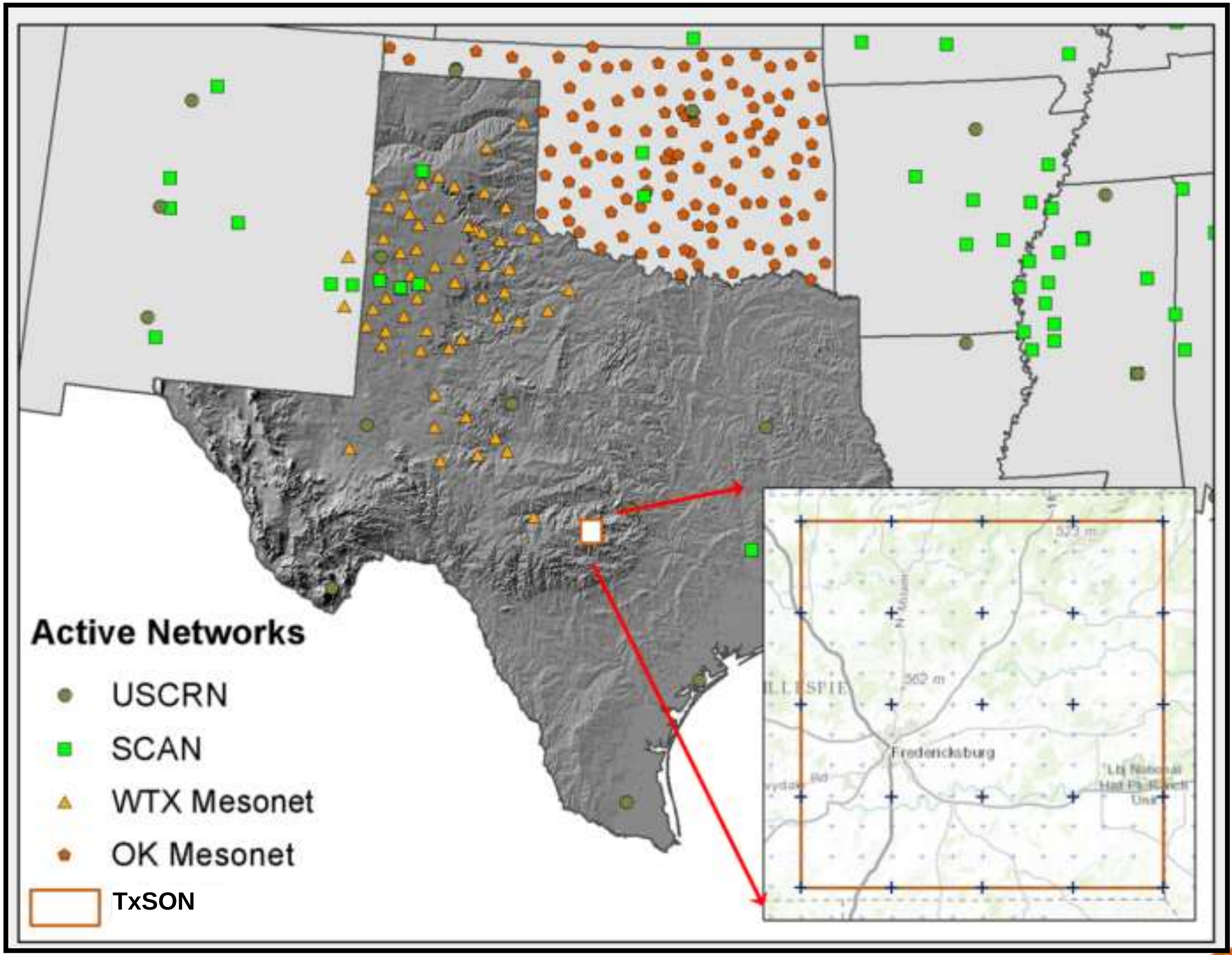
- Cool = wet (+ 25%)
- Hot = drier (- 25%)
- Neutral = within HUC8 mean and temporally stable

Noah SWS: Pedernales River Basin

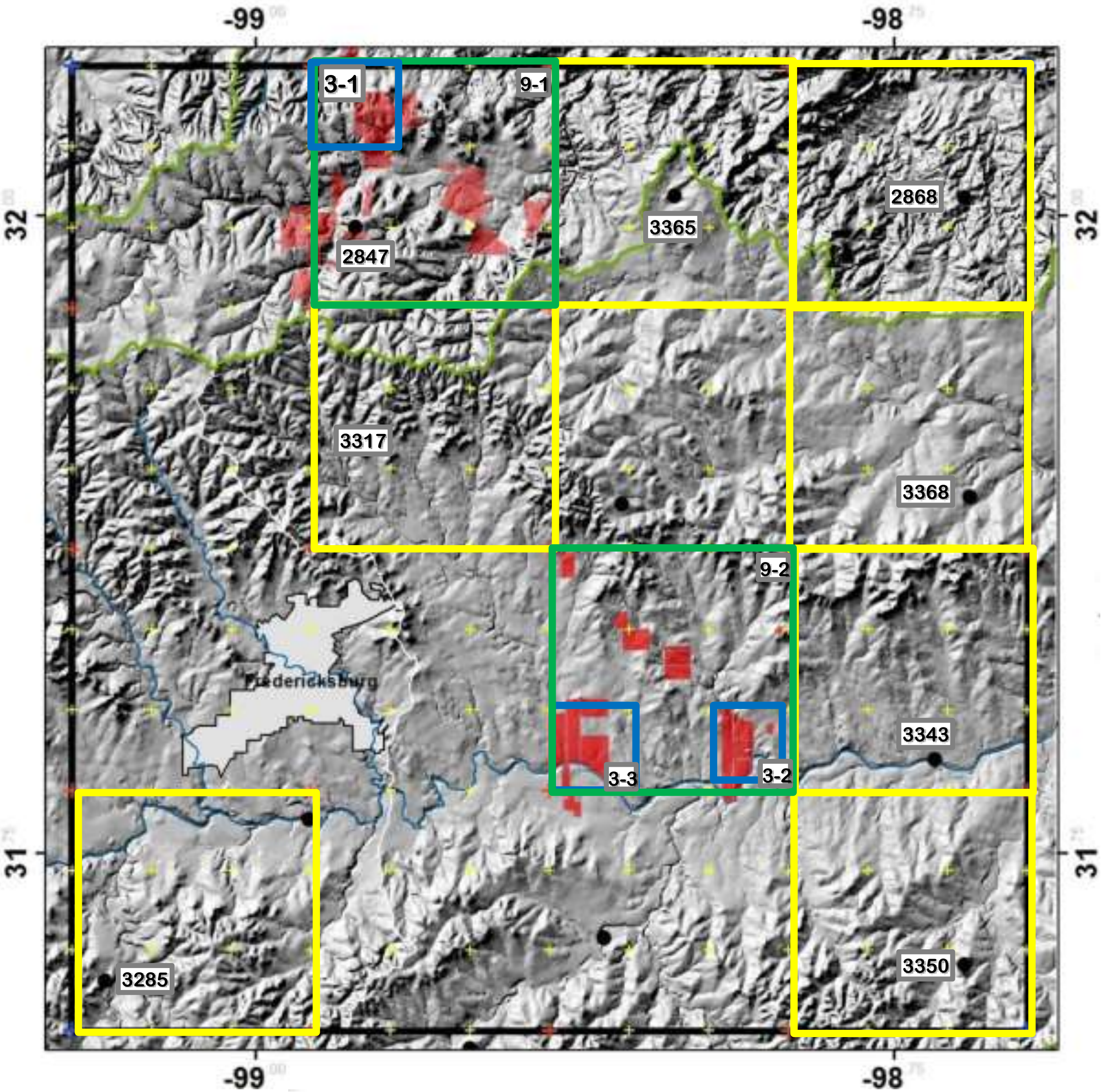


- HUC8 12090106
- Gray = all nodes within HUC
- Blue = MRD ~ 0

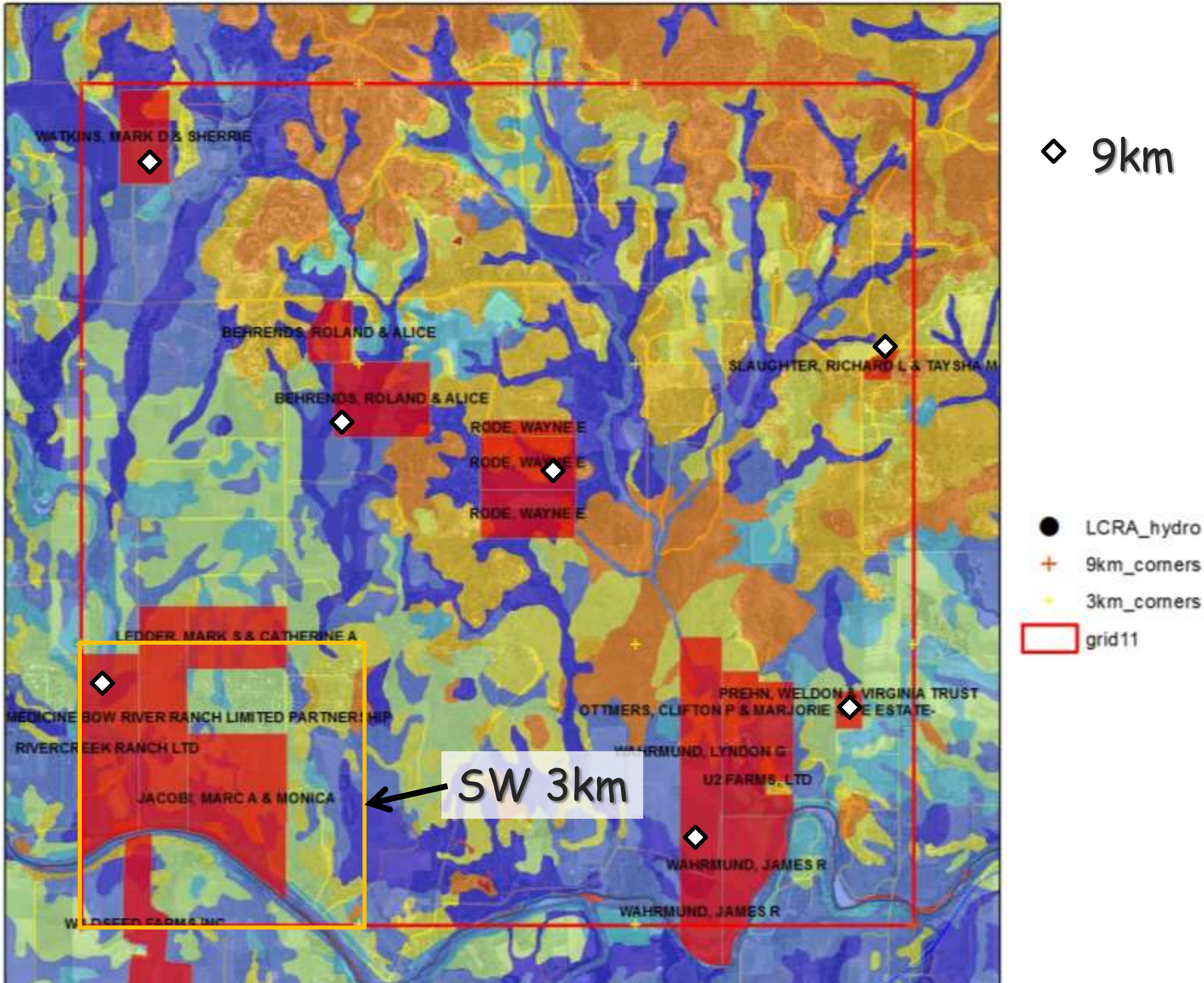
Texas Soil Observation Network: TxSON



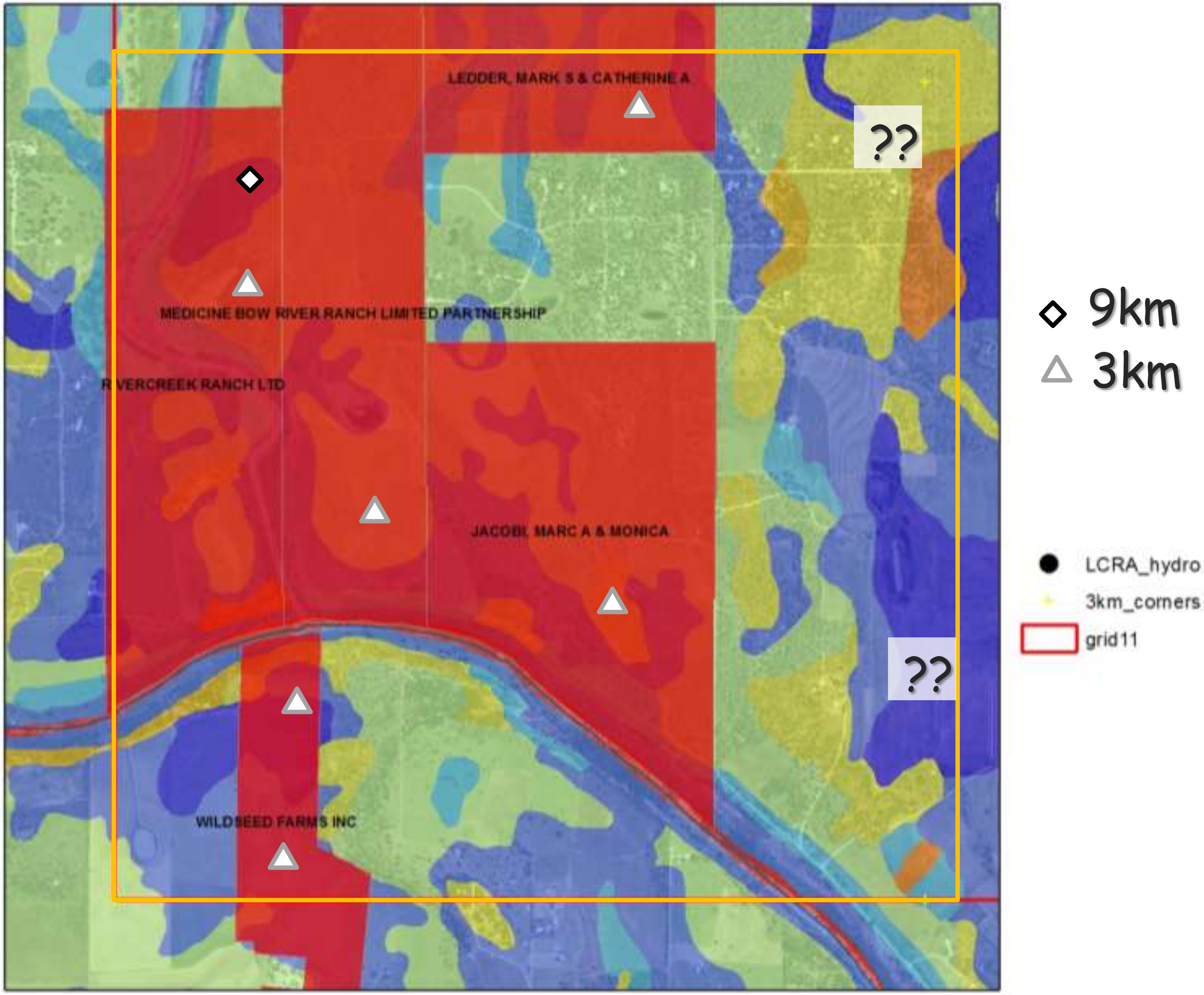
Fredericksburg 36 km Footprint (LCRA)



Grid 11 at 9km



SW 3km cell in Grid 11 (3 cells in all)



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TxSON in action

- Deal and console landowner
- 12” auger to ~3’
- Sample and describe soil
- CS-655 Sensor
  - 12 cm rods
  - High EC (<8 dS/m)
  - θ, EC, and T (SDI-12)

TxSON in action

- Insert CS-655 sensors at
  - 5, 10, 20, and 50 cm
- Add precip gage, cell modem, etc.

TxSON in action: 9km Grid 11

TxSON in action: 15 stations completed

- 7 of 7 LCRA Hydromet stations (36km cell)
- 5 of 7 micro-stations in Grid 11 (9km cell)
- 3 of 6 micro-stations in Grid 11 (3km cell)

Bureau of Economic Geology

TxSON in action: next month

2 full meteorological stations in Grid 11 (9km cell)

- 3 stations in 3km cell
- 6 in the other

2 full meteorological stations in Grid 2 (9km cell)

- 6 more microstations

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Summary (http://www.beg.utexas.edu/soilmoisture/)

Soil Moisture & Water Resources

- Soil moisture (model) and TWS (RS) both x-corr to reservoir storage
- Partitioning TWS is tricky
  - LSM show wide variability
  - Residual is compounded errors, groundwater, moho
- We need *in situ* data

- We need to **communicate** the importance of soil water storage

Texas Soil Observation Network (TxSON)

- Operational by November
- Land leases for 2, 9km grids
- Sensors are calibrated - paid by JSG donors
- Working on LSM at 0.04km^2
- Field campaigns planned for early Fall-Spring.
- Expansion throughout TX

http://www.beg.utexas.edu/soilmoisture/