THE UNIVERSITY OF TEXAS AT AUSTIN
JACKSON
SCHOOL OF GEOSCIENCES

Soil Moisture, Drought and Water Resources in Texas

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MOISST: Advancing Soil Moisture Science and Application

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THE UNIVERSITY OF TEXAS AT AUSTIN
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?

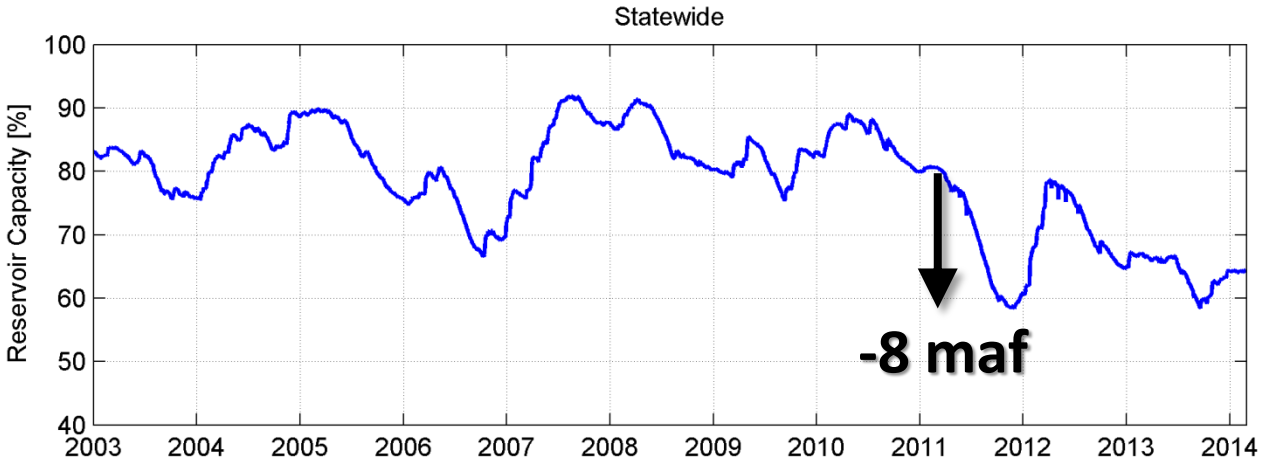
We cannot have drought without socio-economic impact. Otherwise, it's just desert

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

Droughts are defined differently by impact

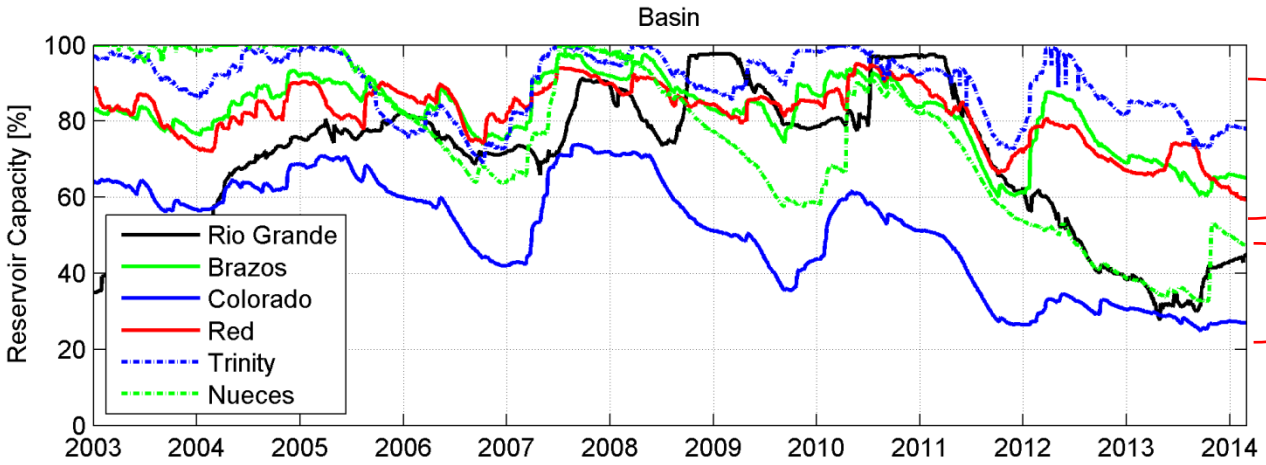
- Meteorological drought
  - Significant negative departure from normal precipitation
  - Shortage of precipitation (or moisture supply) over some period of time (weekly, monthly, seasonal, or annual time scales).
- Agricultural drought
  - Period of moisture deficiency that is sufficient to have a lasting 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



Reservoir Storage

- 18 maf 2010
- 22 maf 2060



Rebounded
Brazos, Red, Trinity

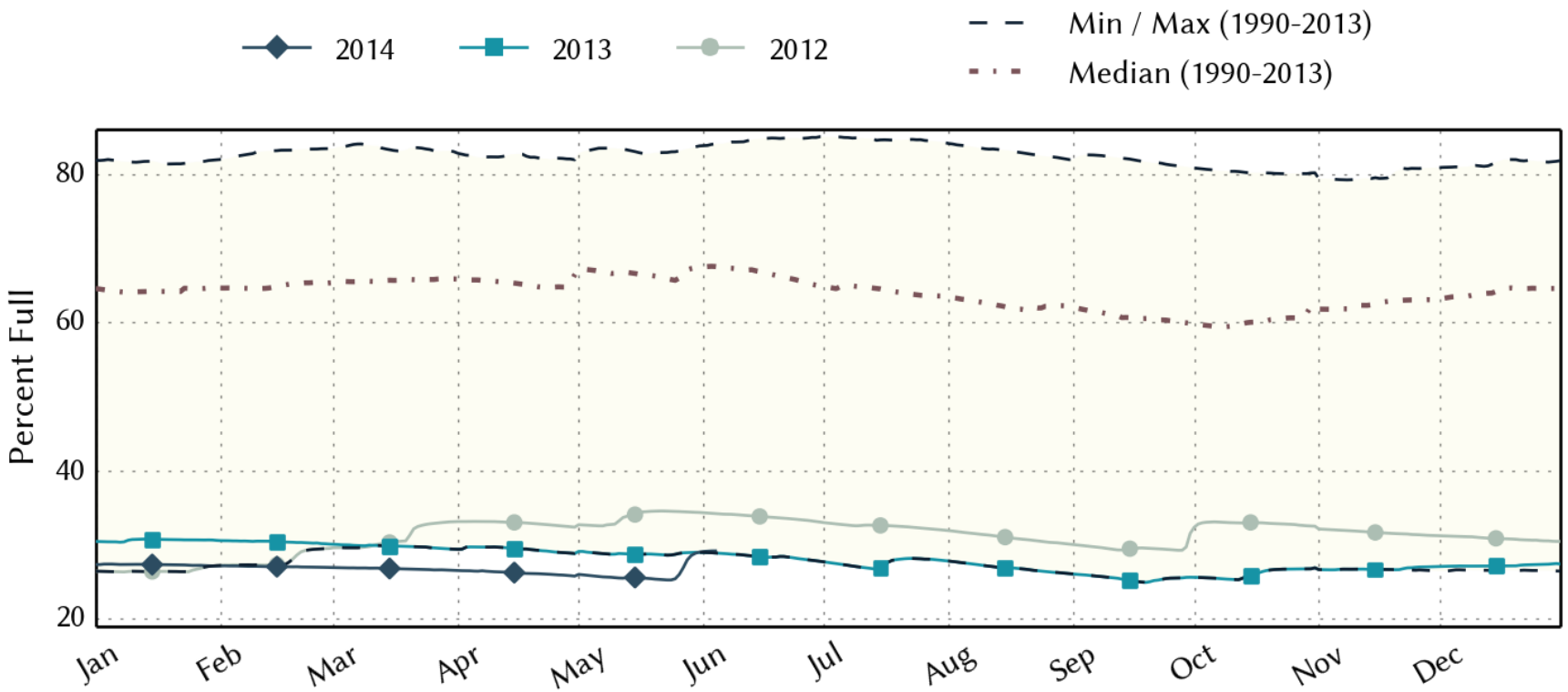
Continuous decline
Rio Grande, Colorado, Nueces

http://waterdatafortexas.org

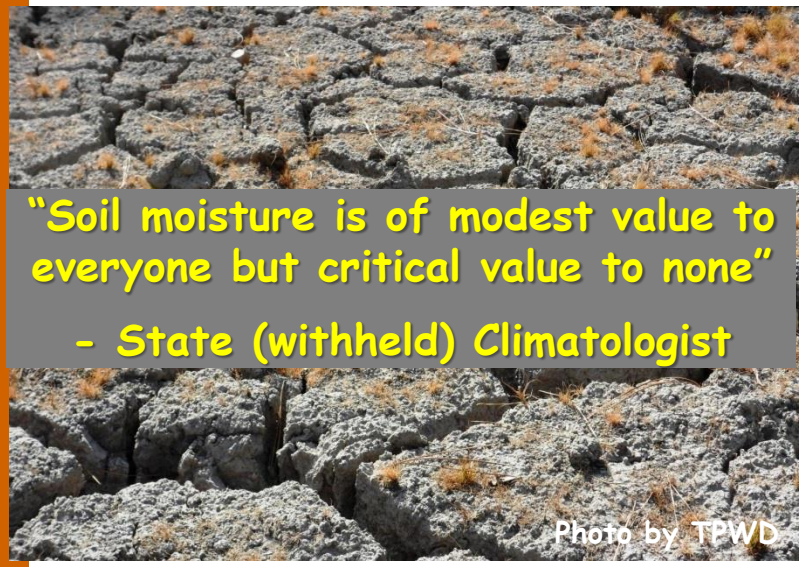
Obvious impacts to our surface water reservoirs

Colorado River Basin Reservoirs

Monitored Water Supply Reservoirs are 29.2% full on 2014-06-03



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?

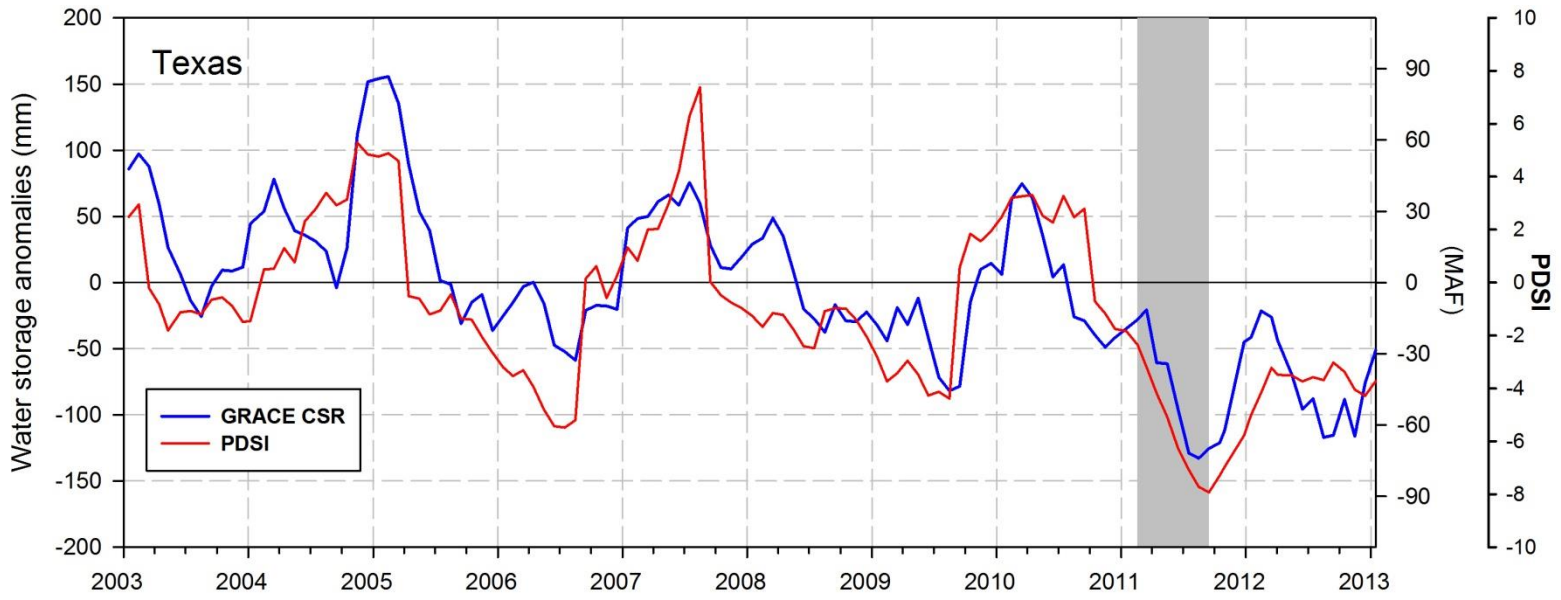
- Reservoir Storage (ΔR): observable
- Groundwater storage (ΔGW): somewhat observable
- Soil moisture storage (Δθ): ???

We have uncertainty in our inputs (PPT)

Unknowns in our outputs: crop consumption & ET

Unknowns in our storage: soil moisture

Using GRACE to estimate total water storage

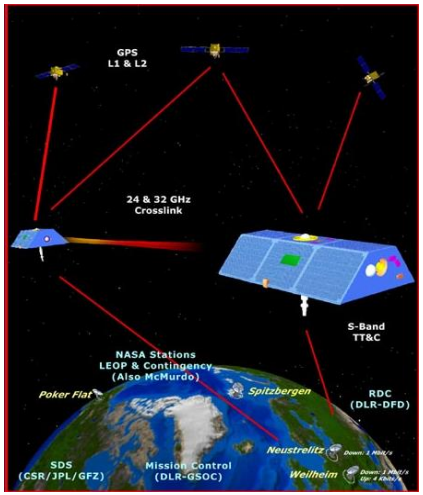


Majority of depletion appears to be in soil moisture storage

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

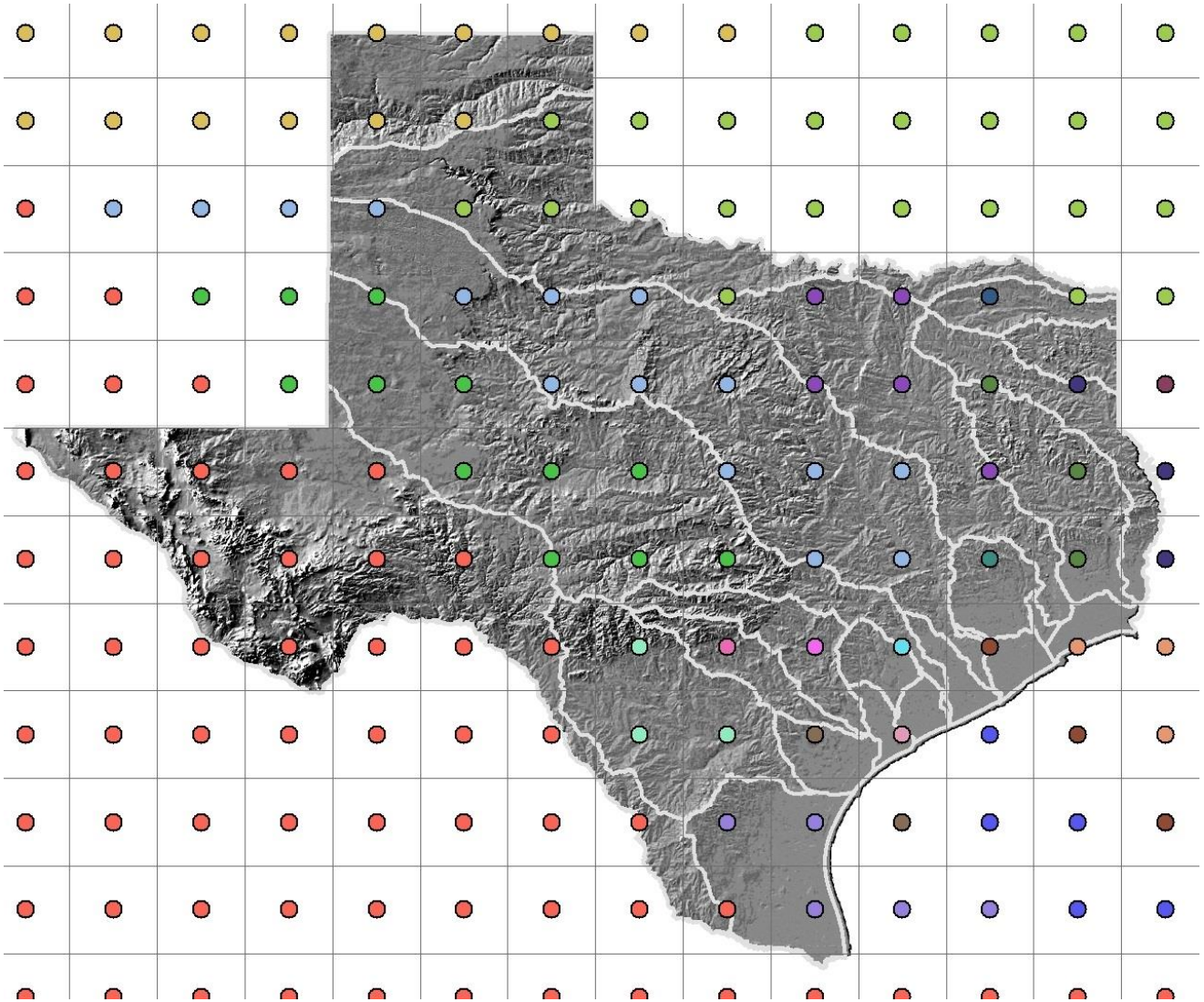
$$\Delta TWS = \Delta R + \Delta SMS + \Delta GW$$

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

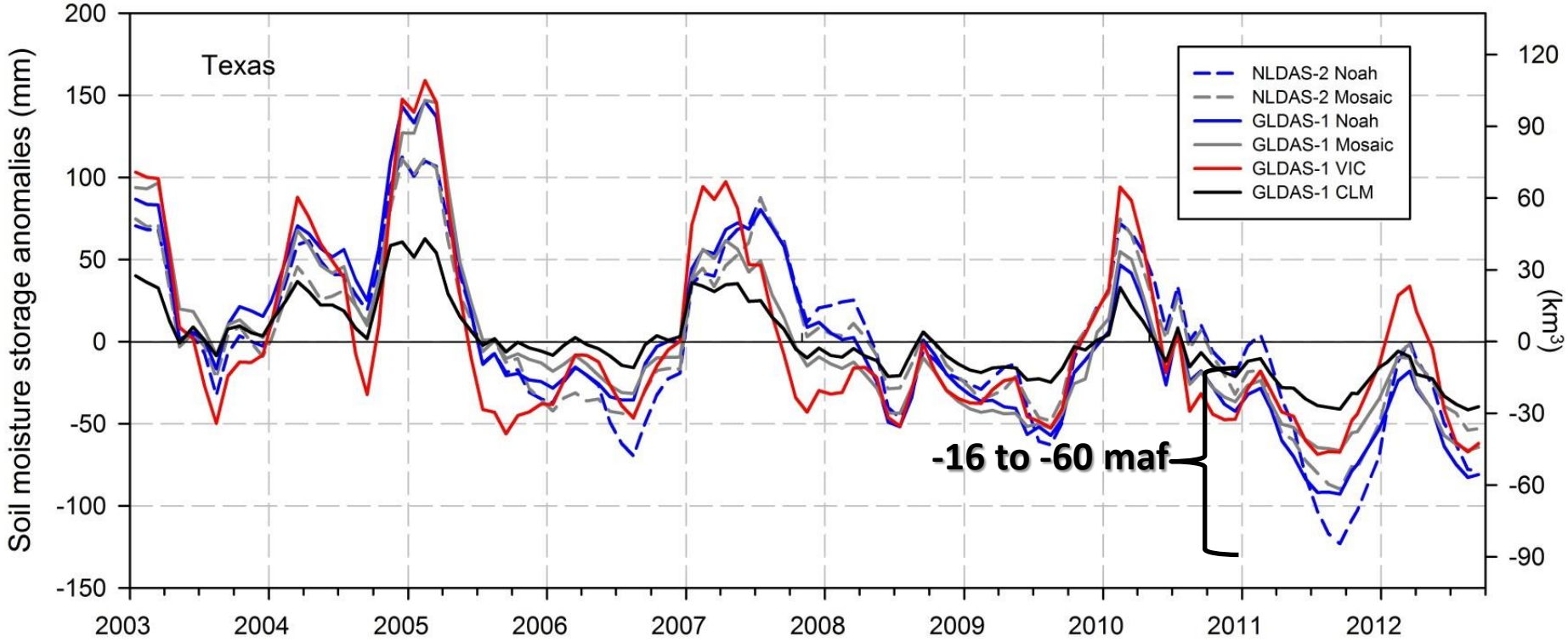


Source: Long et al., 2013

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 – the soil reservoir is *BIG*

Uncertainty in soil moisture storage between models is high

Source: Long et al., 2013

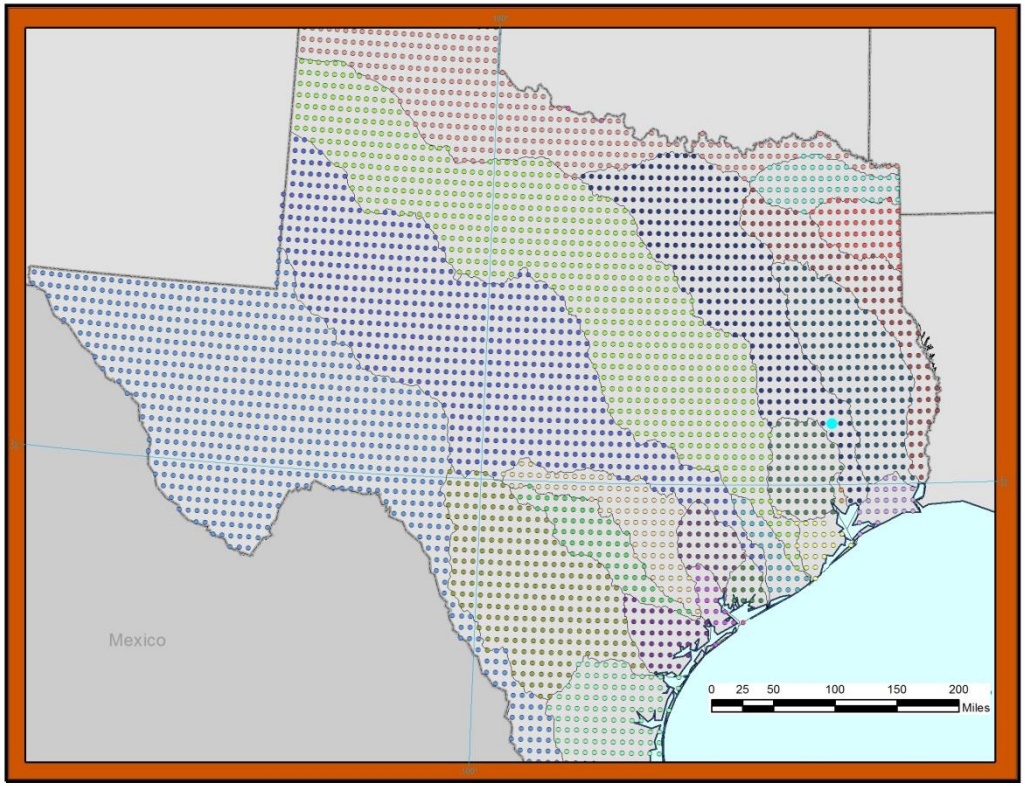
NLDAS-2: Noah output and forcings

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

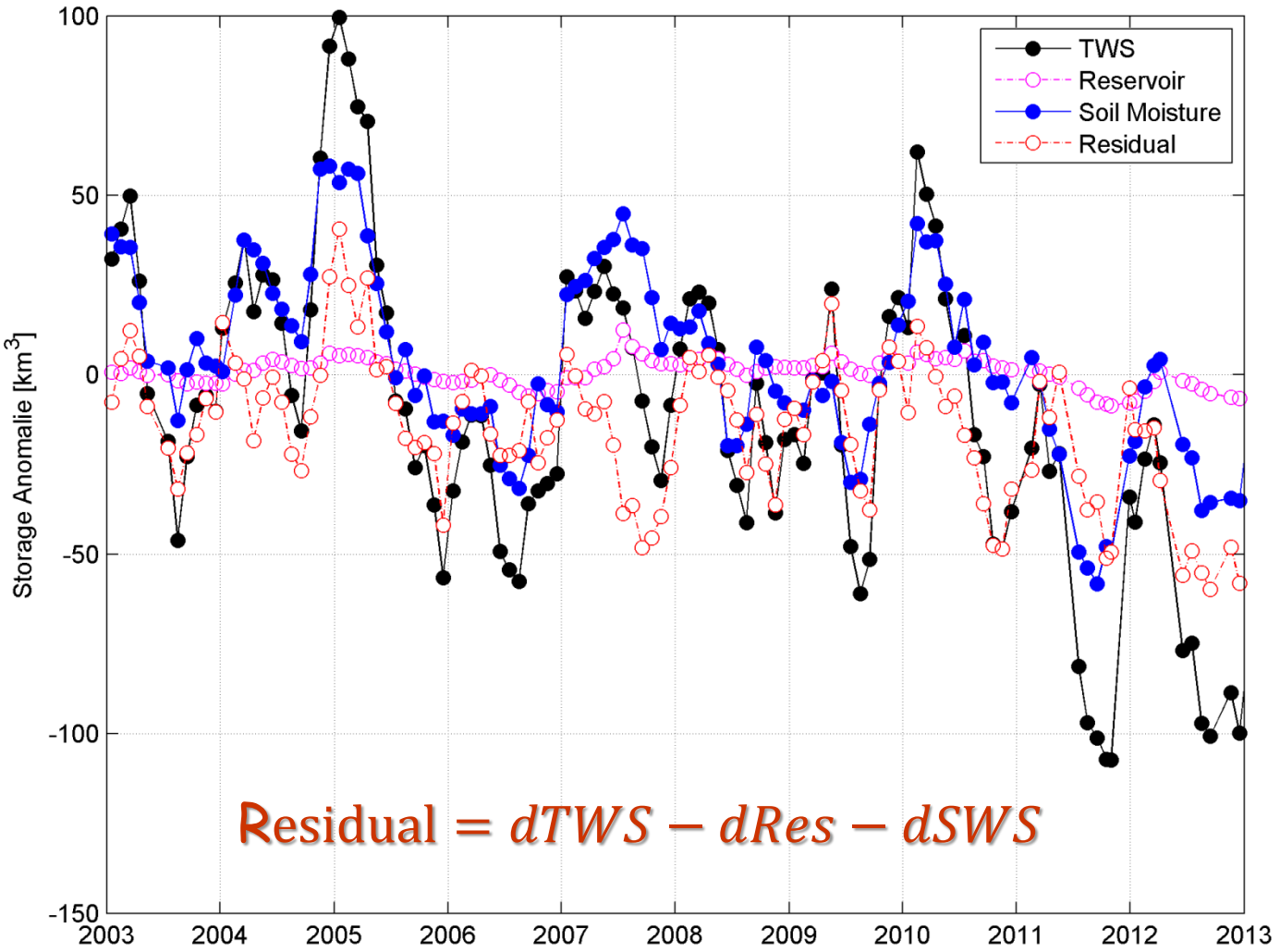
Noah Output

- 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

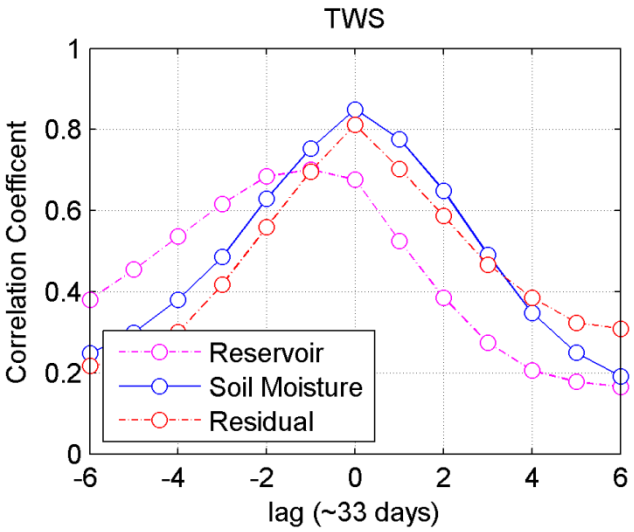
http://disc.sci.gsfc.nasa.gov/hydrology/data-holdings

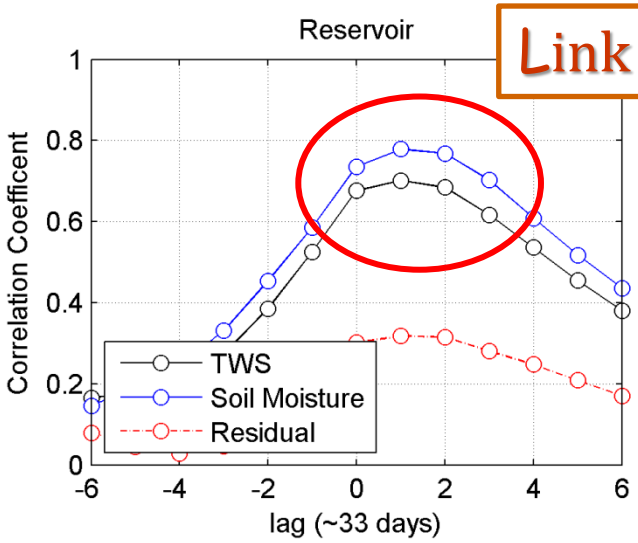


Changes in Total Water Storage: Statewide

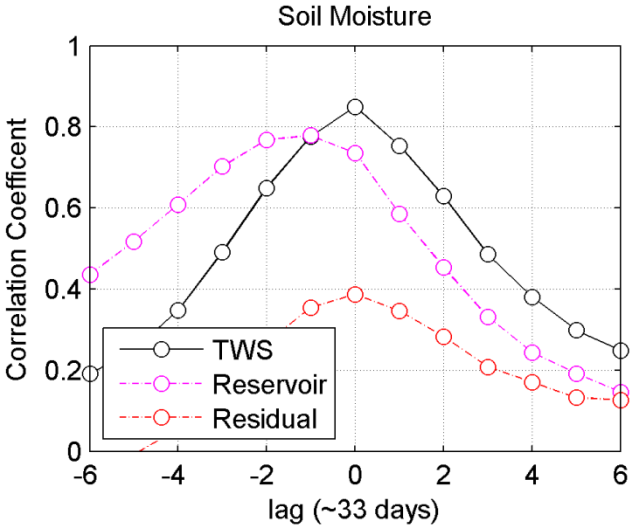


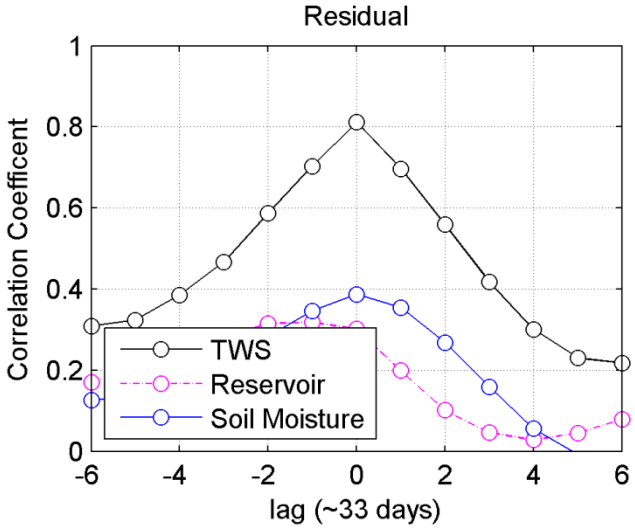
Cross-correlation from 2003-2013





Link to θ!

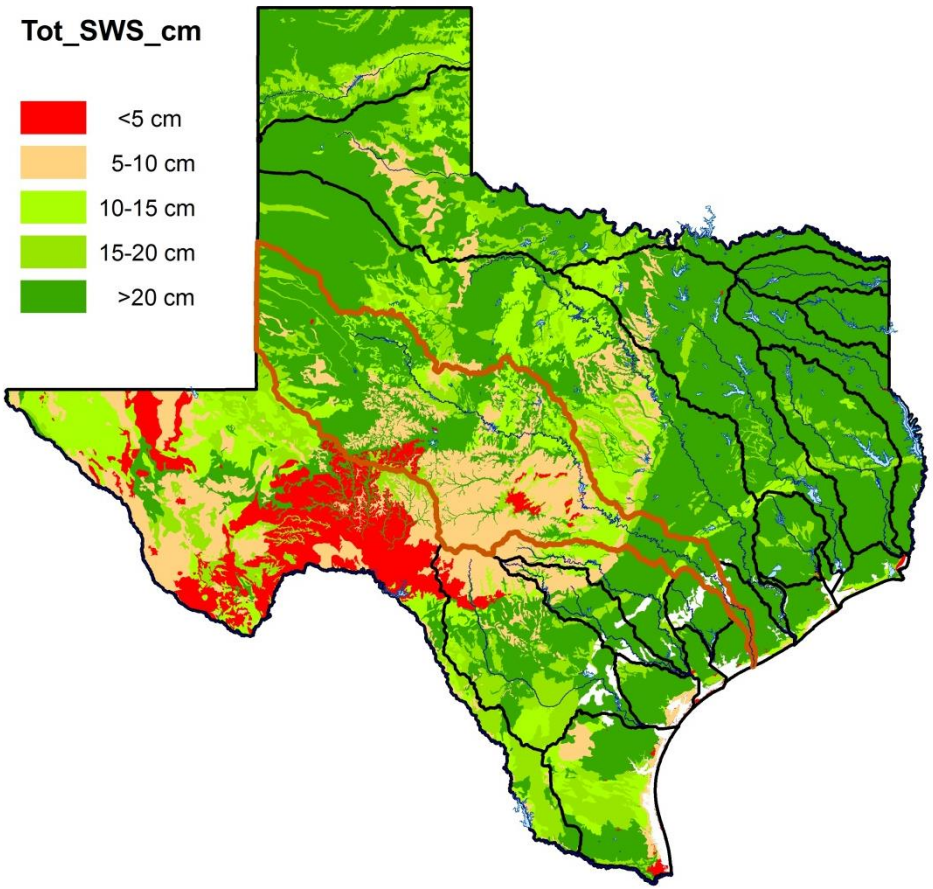


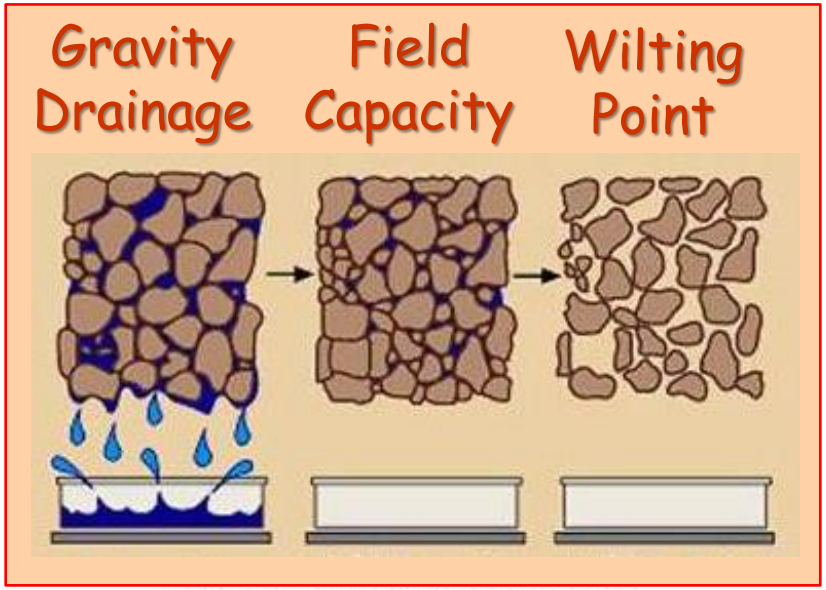


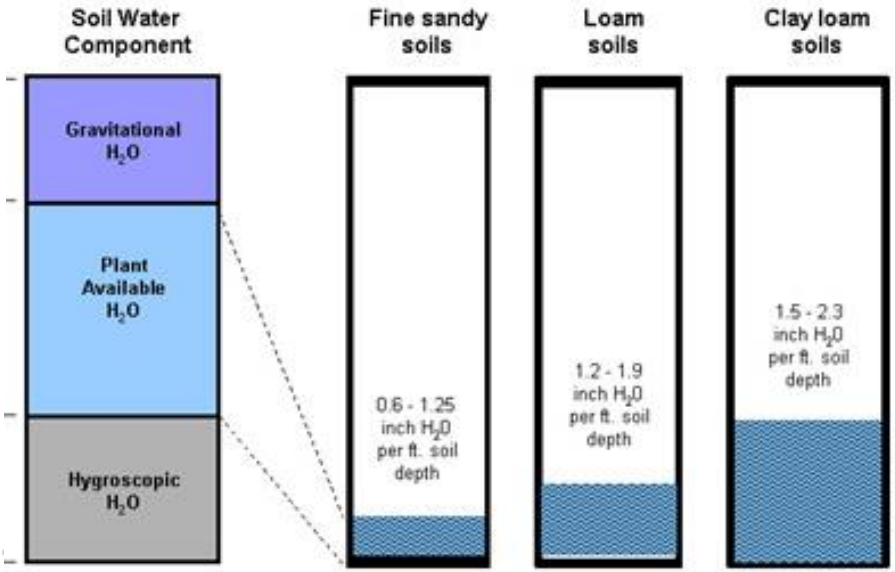
What have we done to communicate our results?

- 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)
  - Texas PET Network (TWDB)

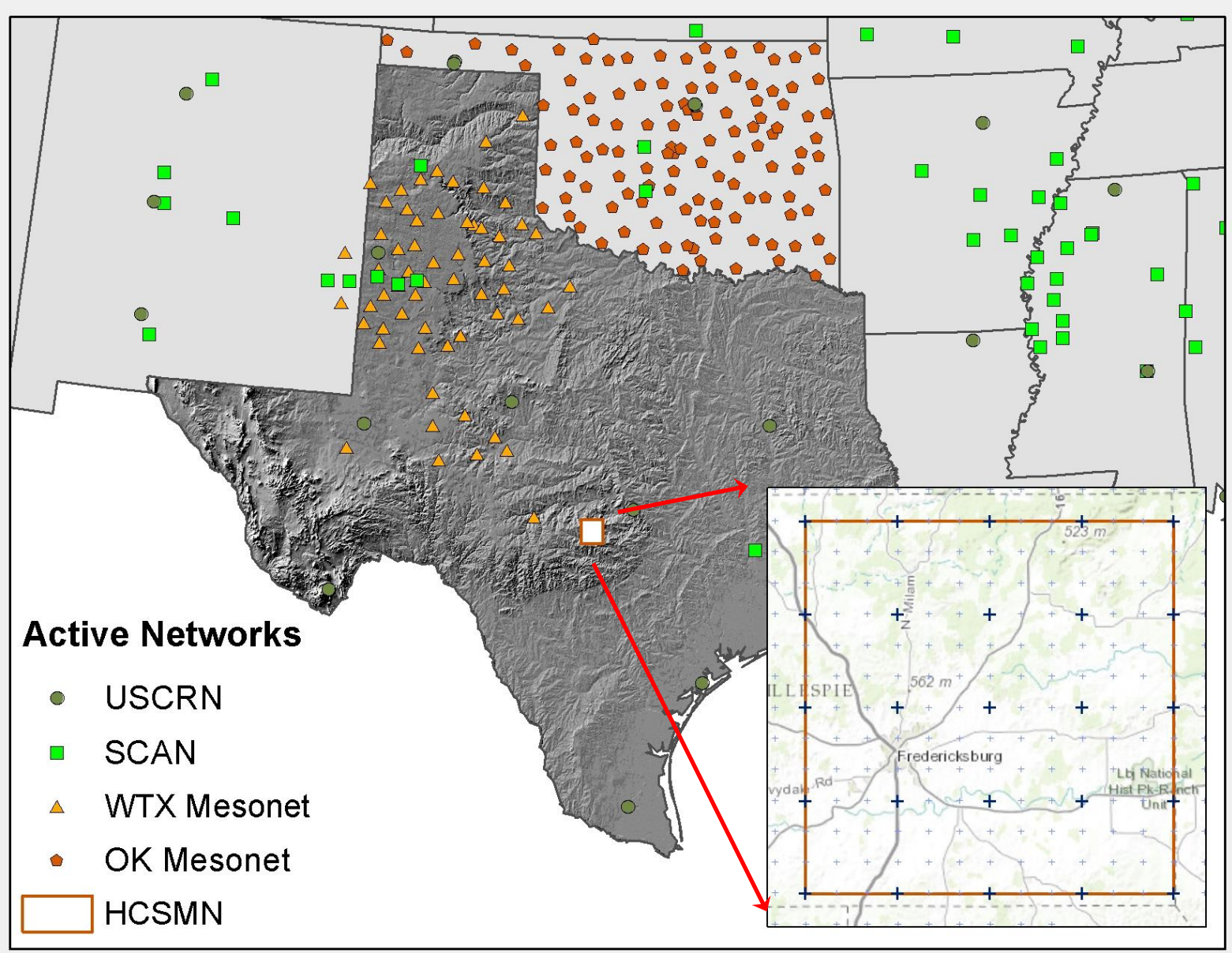
What is soil moisture storage?



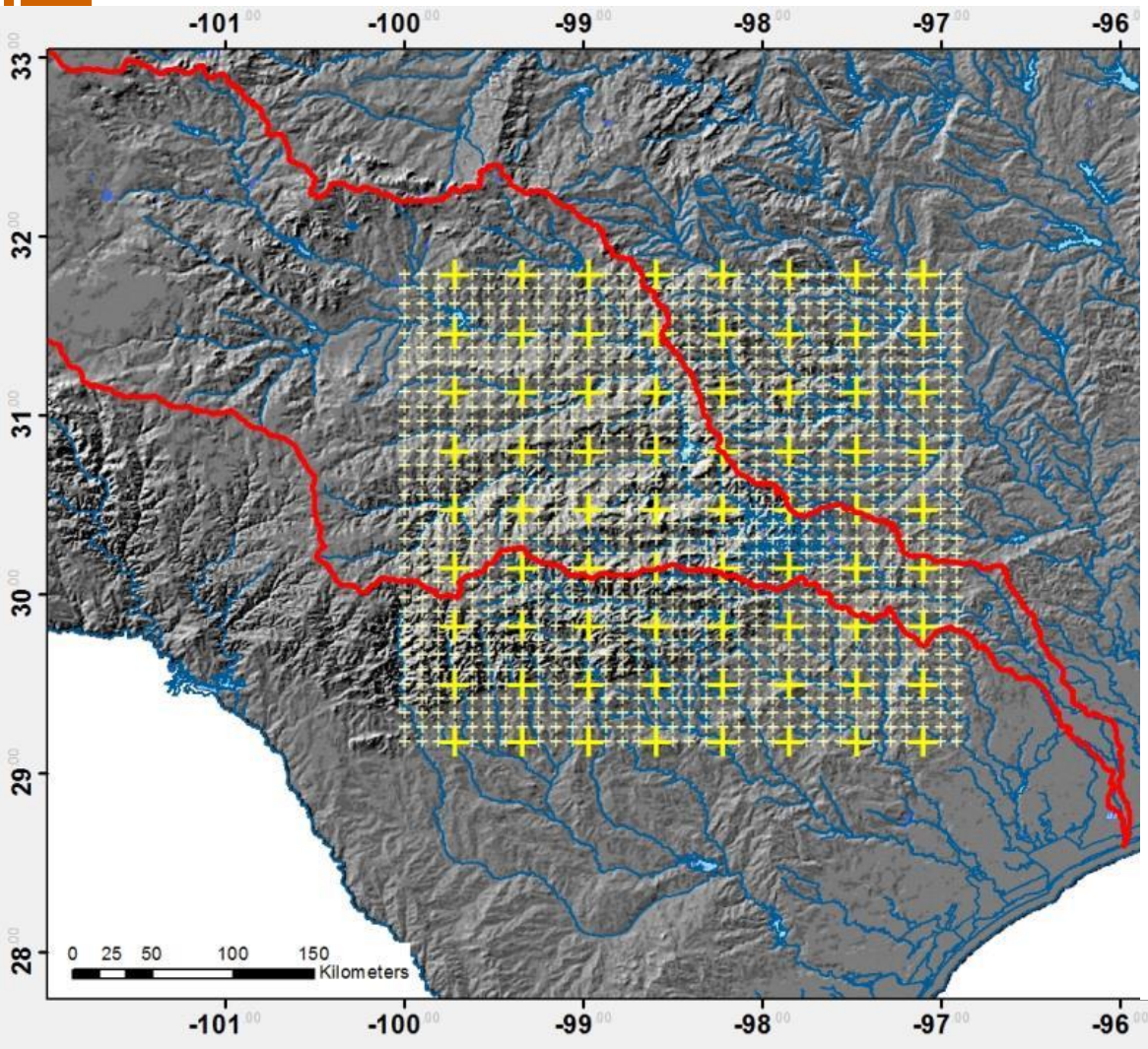




Texas Soil Observation Network: TxSON



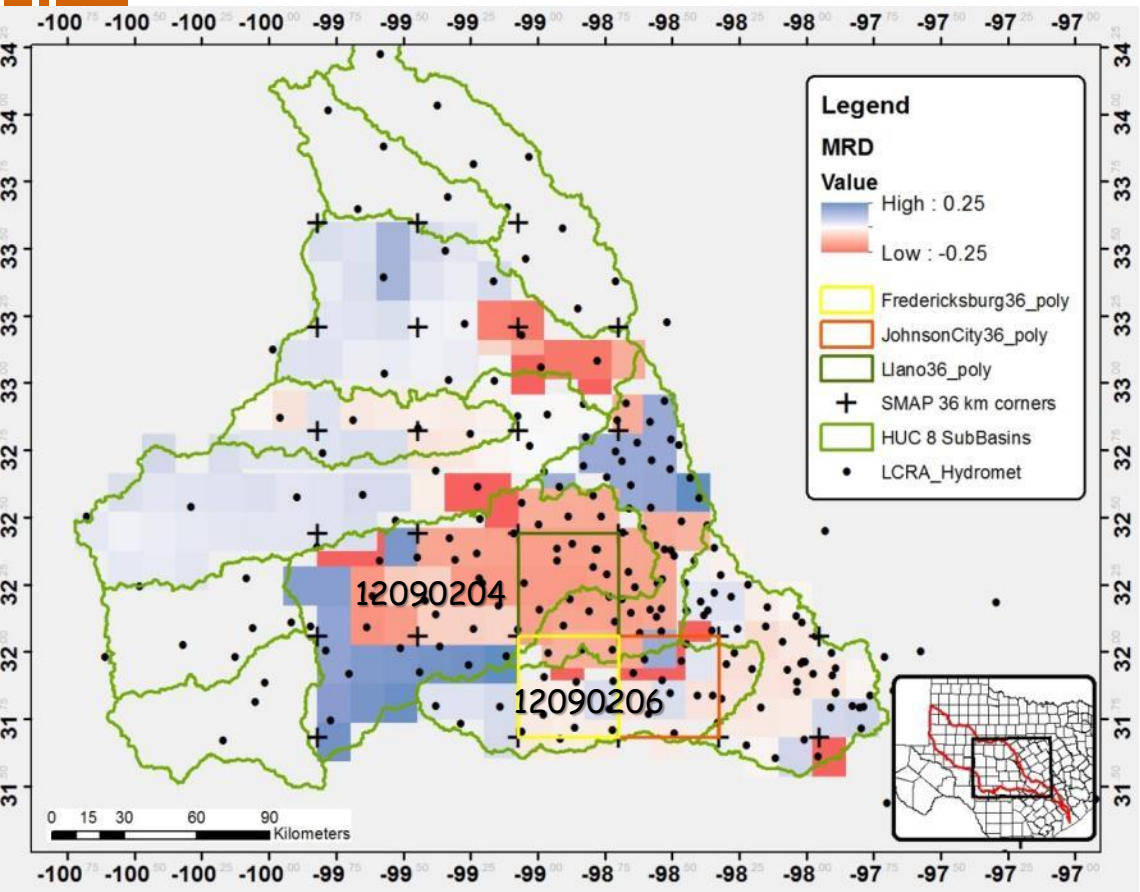
SMAP EASE-2 Grid: Middle Colorado Basin, TX



Ideal Core Cal/Val Site:

- 36 km footprint (yellow)
  - 7 stations (existing LCRA)
- **9 km footprint**
  - 2 cells each with 7 stations
- **<u>3 km footprint</u>**
  - 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**

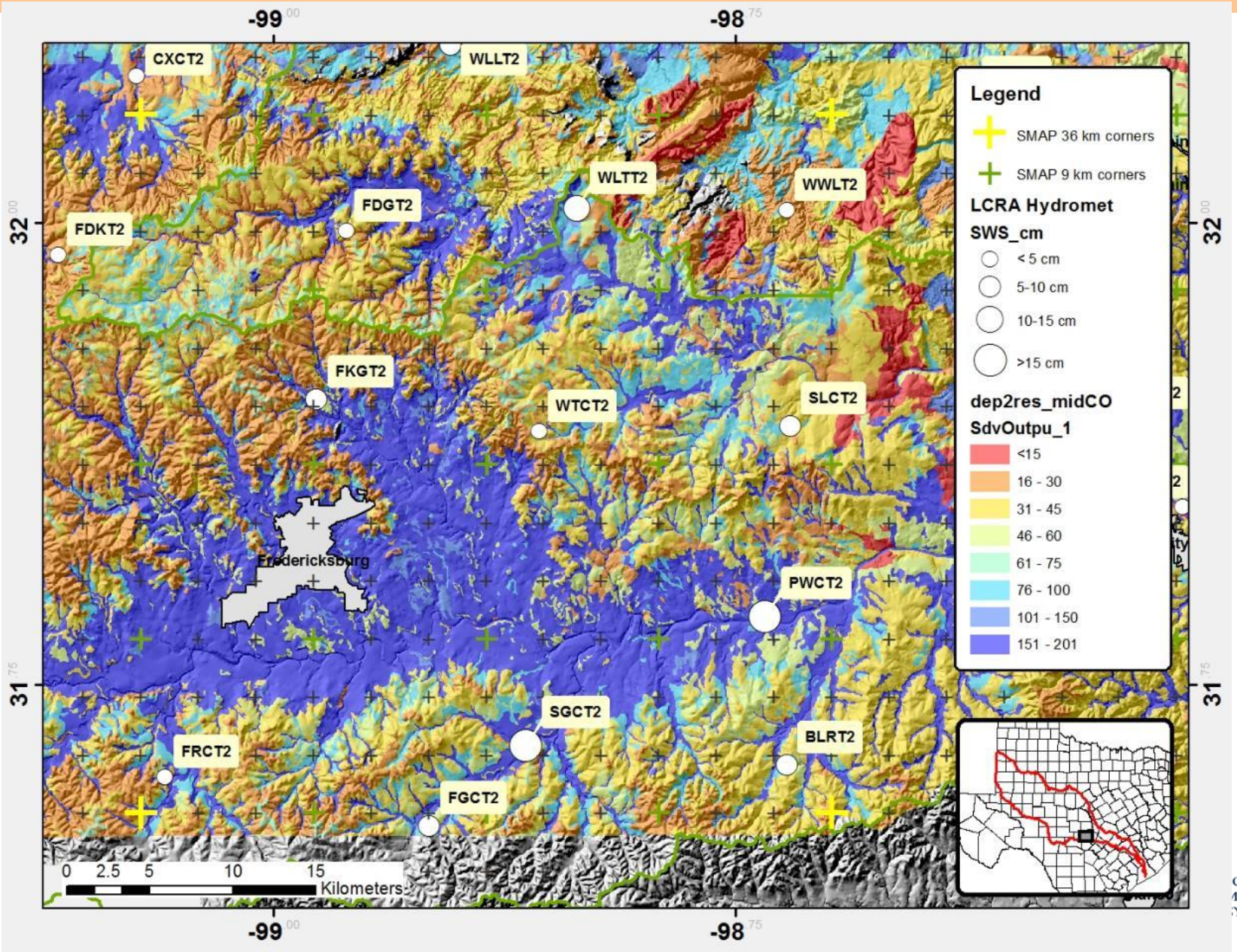
Core Cal/Val: Mean relative difference (SWS)



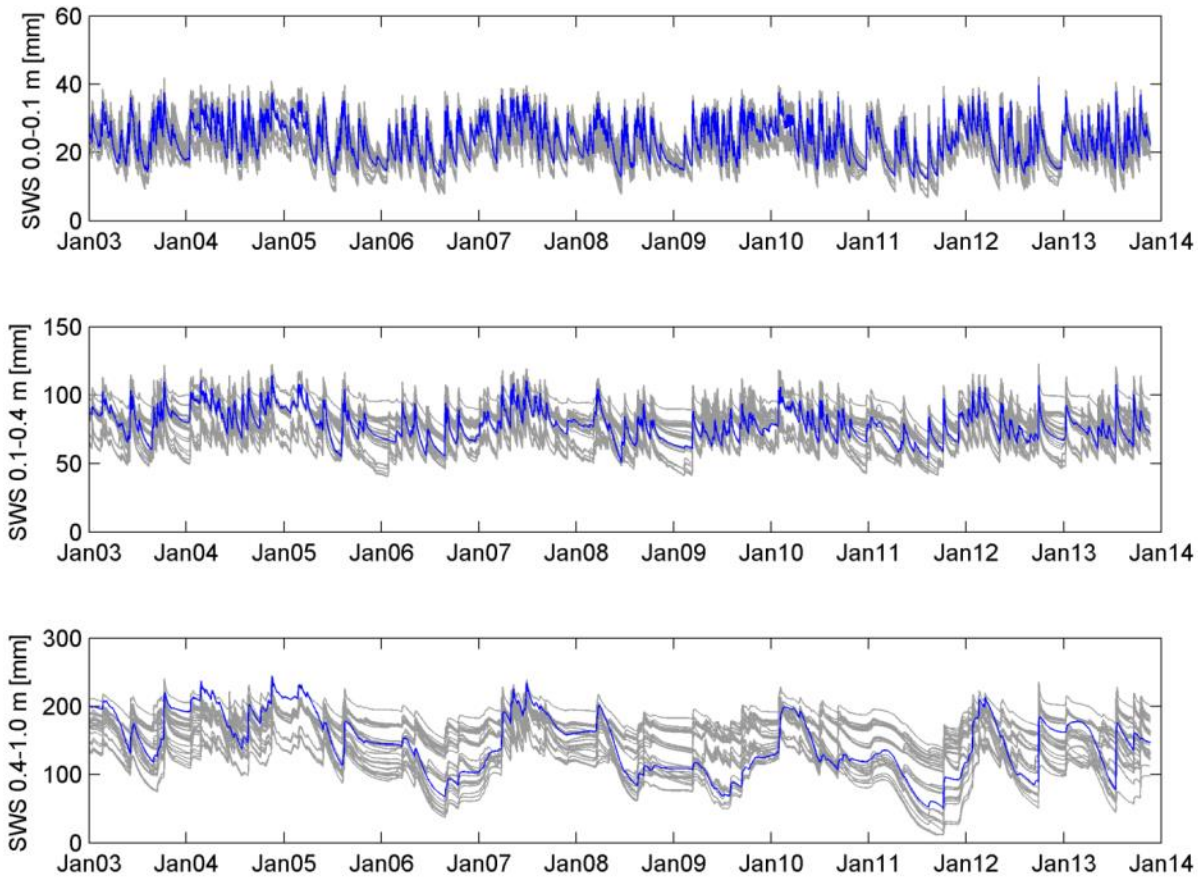
MRD using NLDAS for each HUC 8

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

Core Cal/Val: Fredericksburg, TX



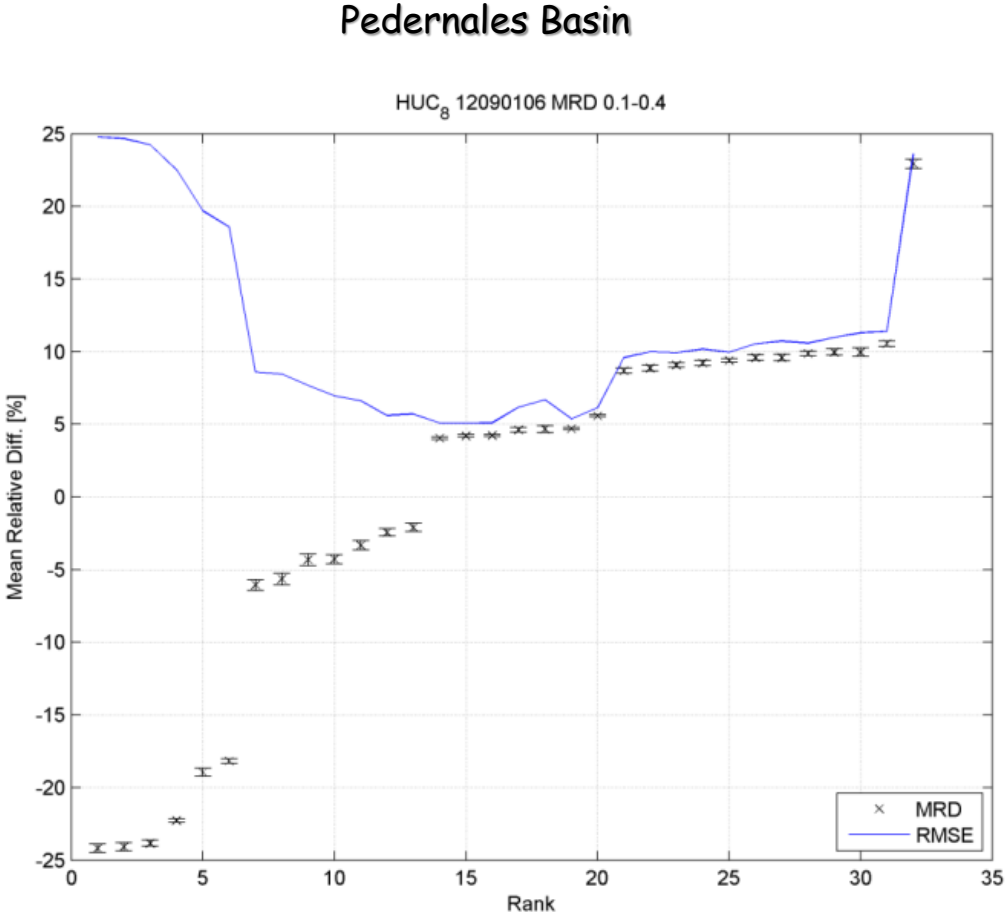
Noah SWS: Pedernales River Basin



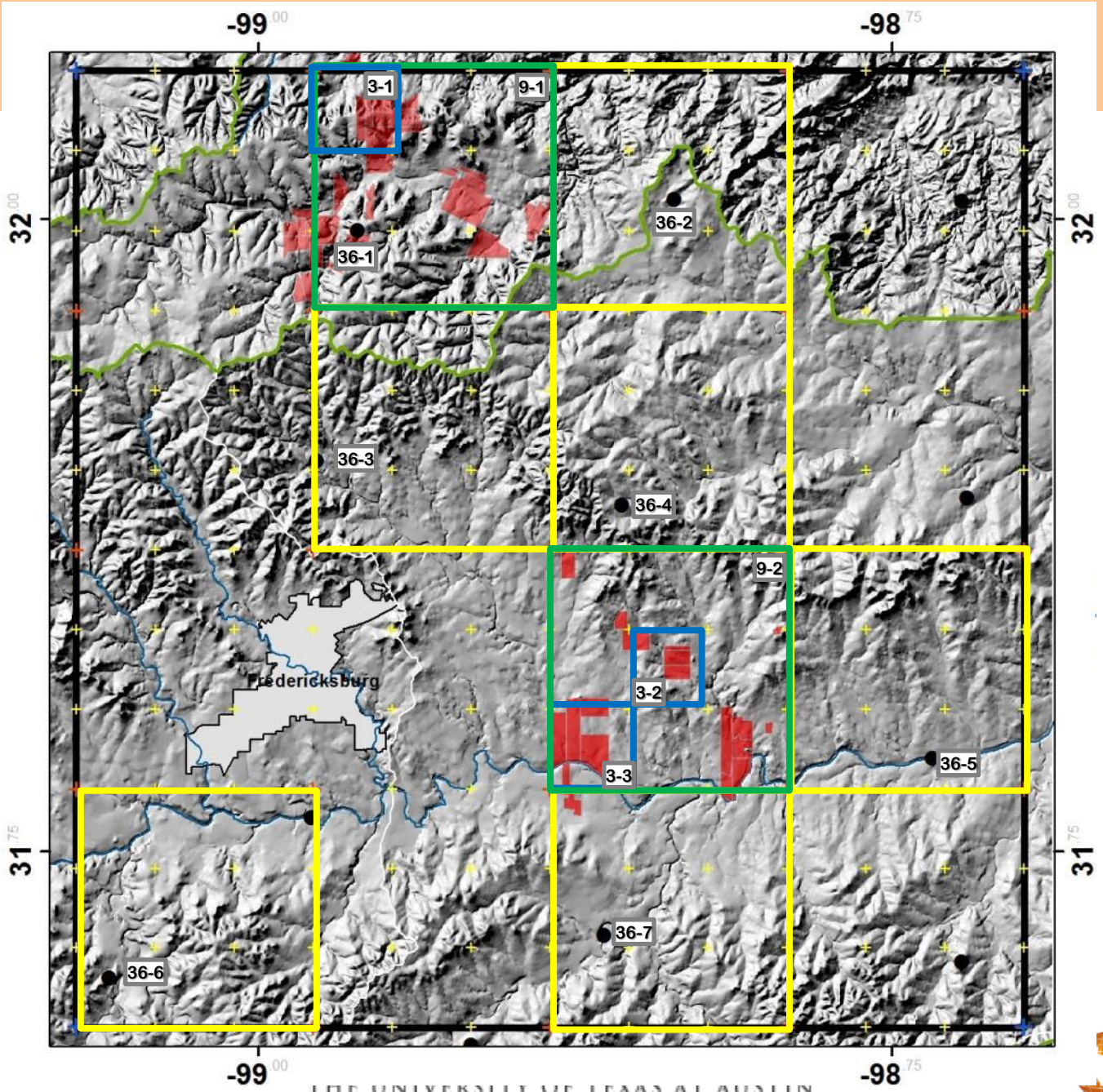
- HUC8 12090106
- Gray = all nodes within HUC
- Blue = MRD ~ 0

Soil water storage: Temporal Stability (Noah)

- Ideal cell: MRD = 0 (black symbols) and low RMSE (blue line)
- HUC8 12090106: five populations; two cells just below zero
- Or, long story short,
  - Active stakeholders: LCRA and HCUWCD
  - Lots of interested ‘donors’
  - Hill Country Science Mill
  - Plenty of soil
  - 13 wineries & 3 breweries



Fredericksburg 36 km



Fredericksburg 9 km

Bureau of Economic Geology

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 August
- Land leases for 2, 9km grids
- Sensors under calibration - paid by JSG donors
- Lots of work to do to meet SMAP rehearsal and launch!
- Working on LSM at 0.25km^2 to finalize locations
- Field campaigns planned for early Fall-Spring.

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

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