Soil Moisture and the Drought in Texas

Todd Caldwell

Bridget Scanlon

Michael Young

Di Long

Water Forum III: Droughts and Other Extreme Weather Events

October 14, 2013

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. How are we modeling soil moisture?

IV. How are can we validate these models?

V. How can we move forward?

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

2011: ~$6 billion in losses from the agricultural sector

The perplexity of drought

WHEN DID IT START?

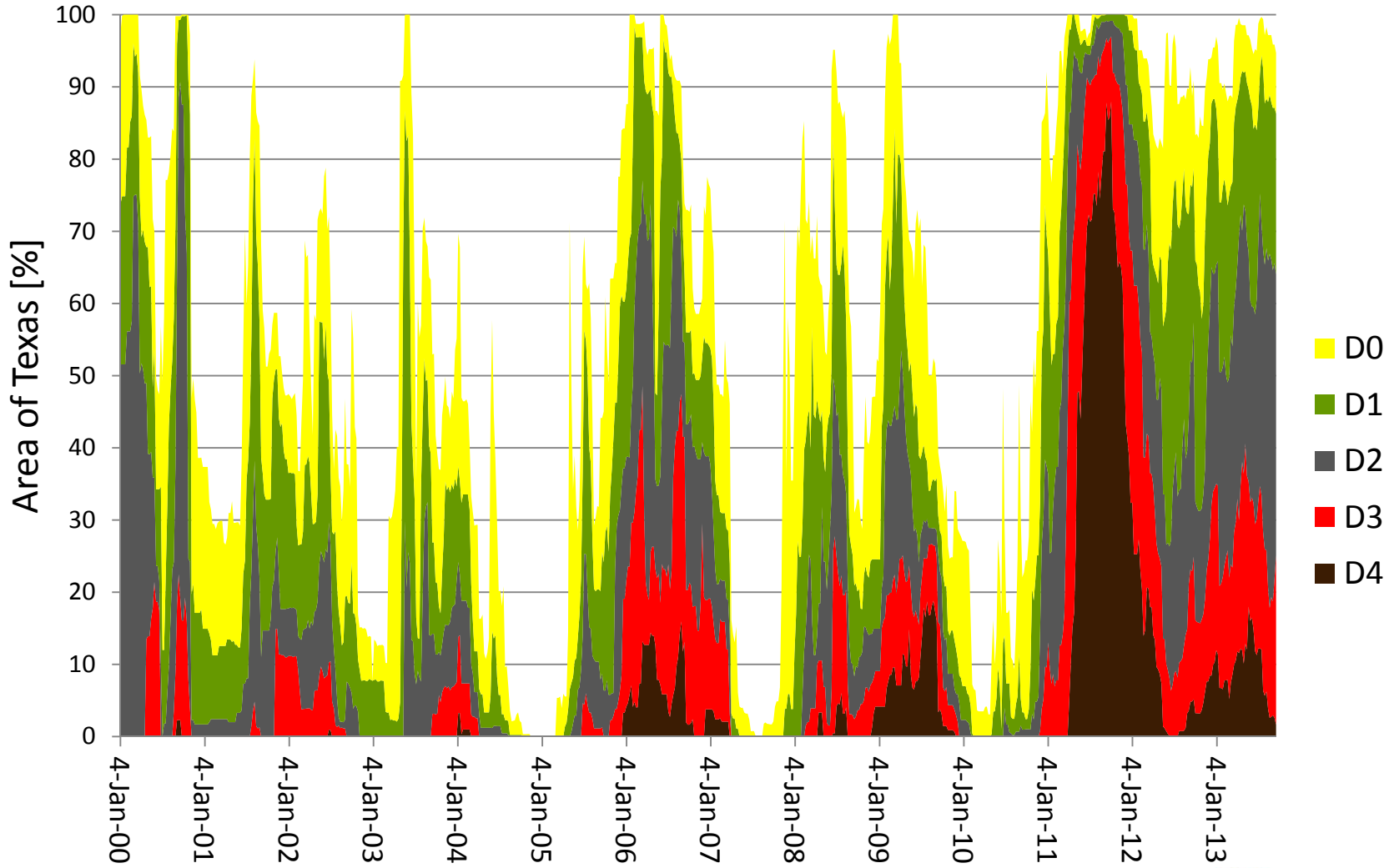
WHEN DID IT END?

HOW BAD WAS IT?

Most natural disaster have defined extent, impact, and duration:

- Fires, hurricanes, floods…
- Drought does not

Texas is no stranger to drought



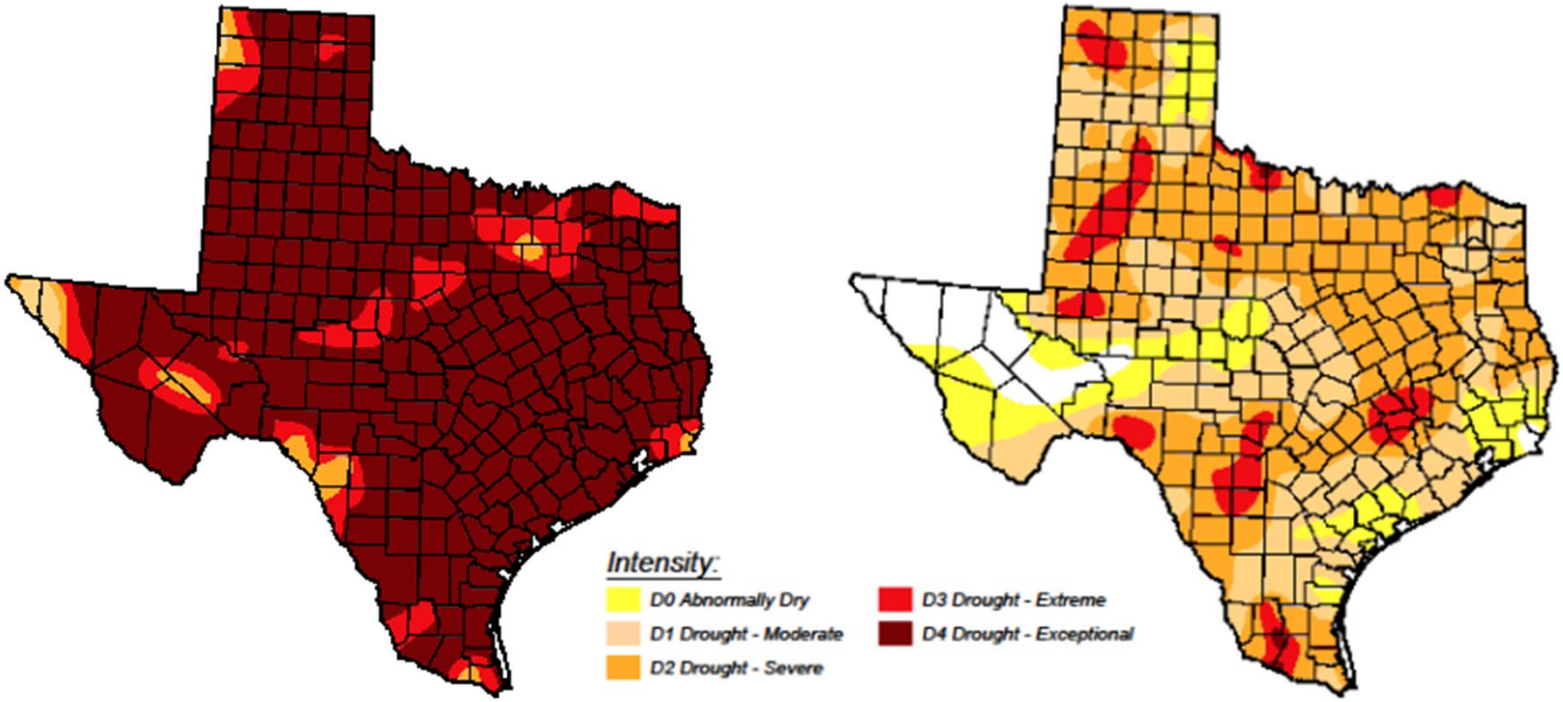
2011 Drought: it was bad, but is it over?

September 27, 2011

None	D0-D4	D1-D4	D2-D4	D3-D4	D4
0	100	100	99	97	86

September 26, 2013

None	D0-D4	D1-D4	D2-D4	D3-D4	D4
6.6	93	80	49	8.0	0.3



http://droughtmonitor.unl.edu

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**

The perplexity of drought beyond 2012

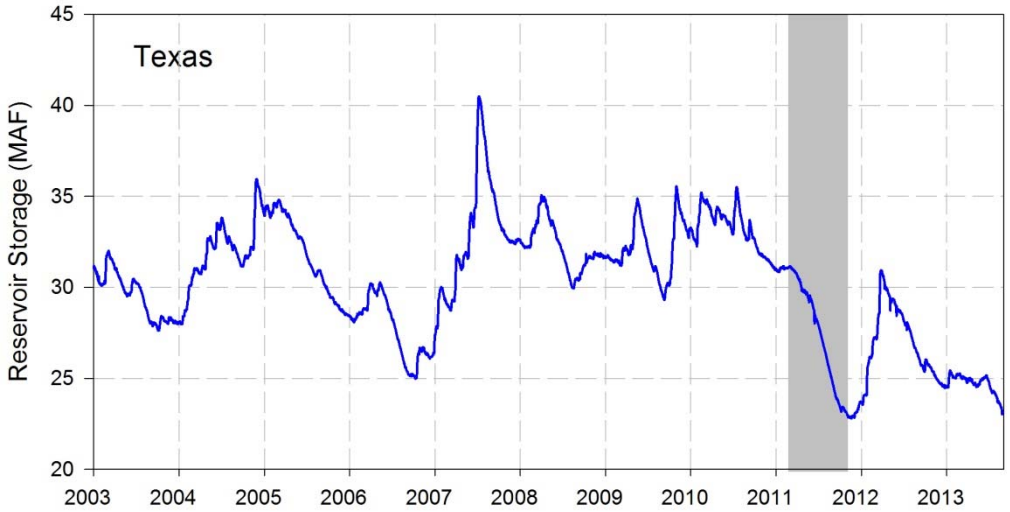
DESPITE NEAR-NORMAL RAINFALL, WHY THE RESERVOIR LEVELS STILL DROPPING?

HOW MUCH PRECIPITATION DO WE NEED?

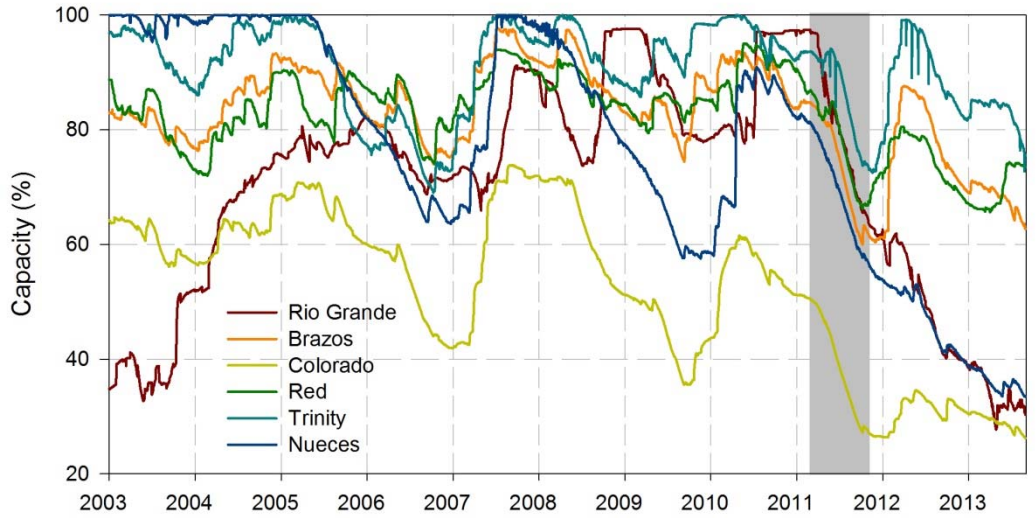
HOW MUCH WATER CAN WE RELEASE?

- NIDIS cannot answer any of these questions
- We think they're intimately tied to soil moisture storage

Texas Reservoir Capacity



Reservoir Depletion:
8 MAF



Rebounded:
Brazos, Red, Trinity

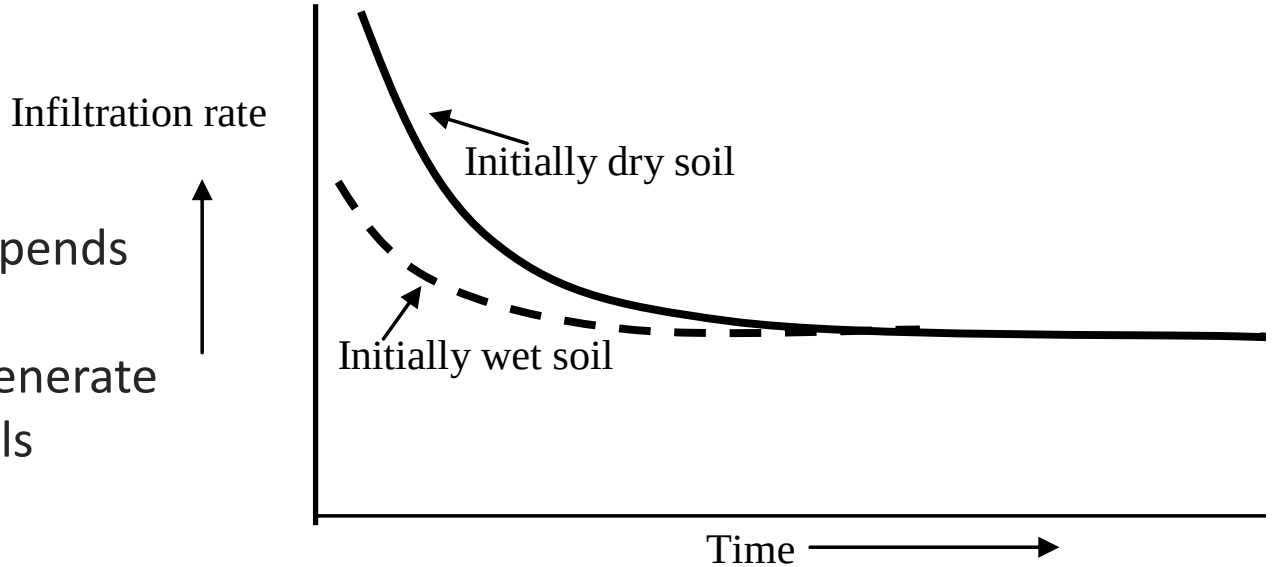
Declining:
Rio Grande, Colorado, Nueces

http://www.waterdatafortexas.org/

Soil Physics and Drought Response

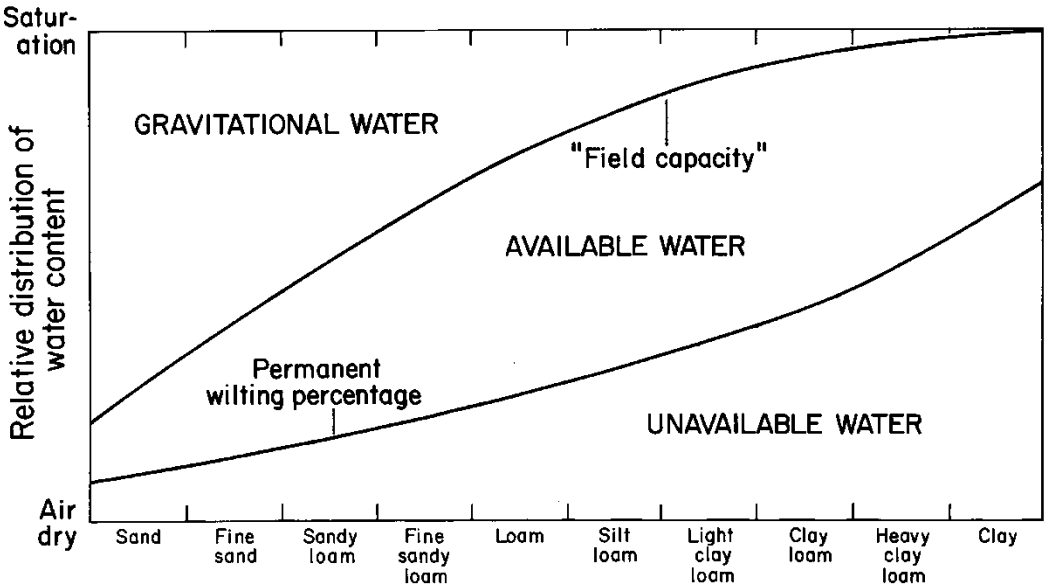
Infiltration rates depends on soil moisture :

- It is difficult to generate runoff on dry soils

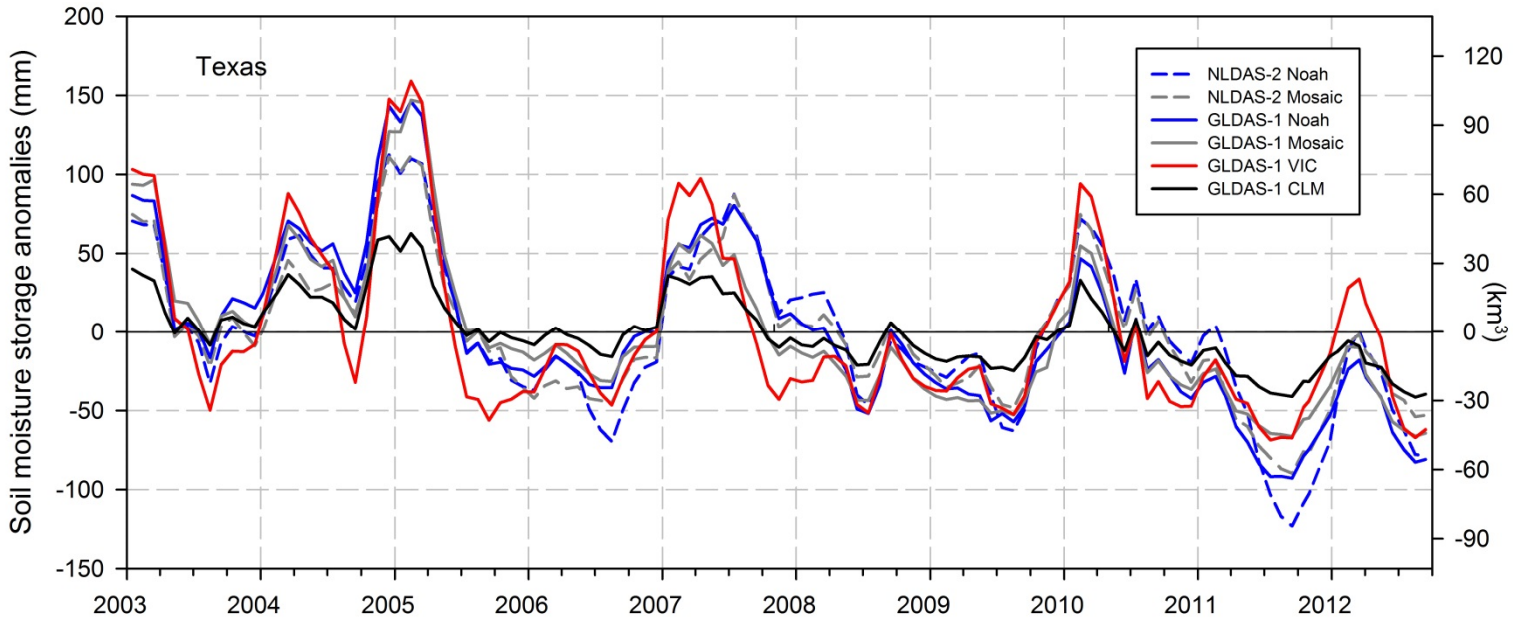


Storage depends on soil texture and moisture:

- A dry soil has a lot of capacity to retain precipitation before it can reach its holding capacity



Texas Drought: Soil Moisture Deficit in Texas

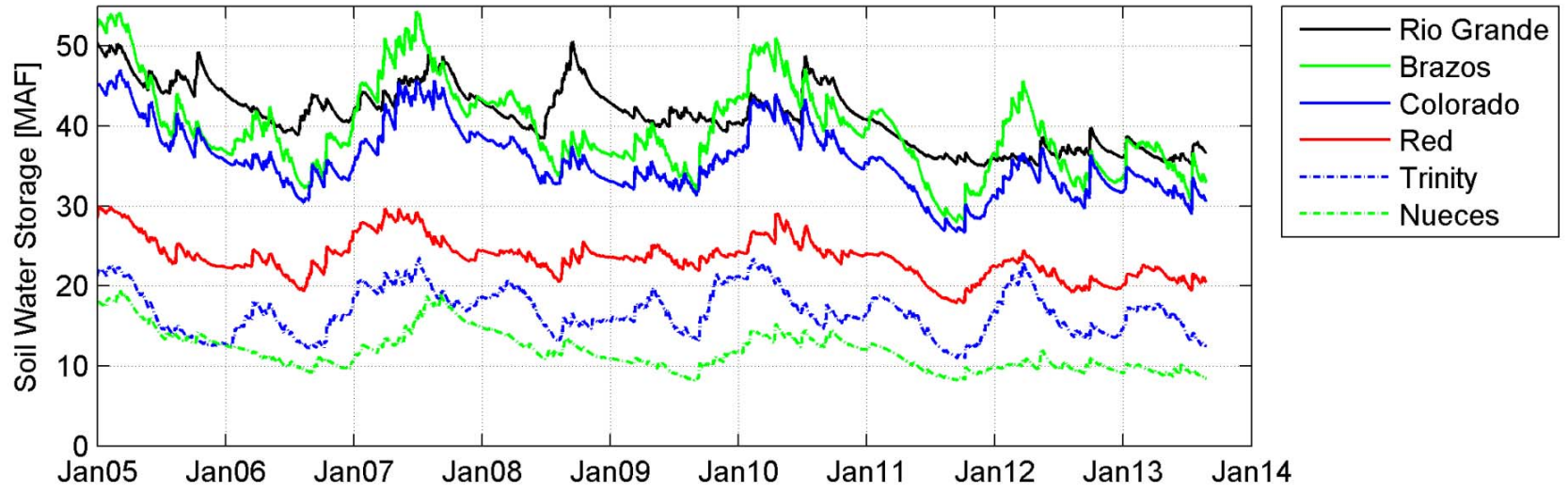


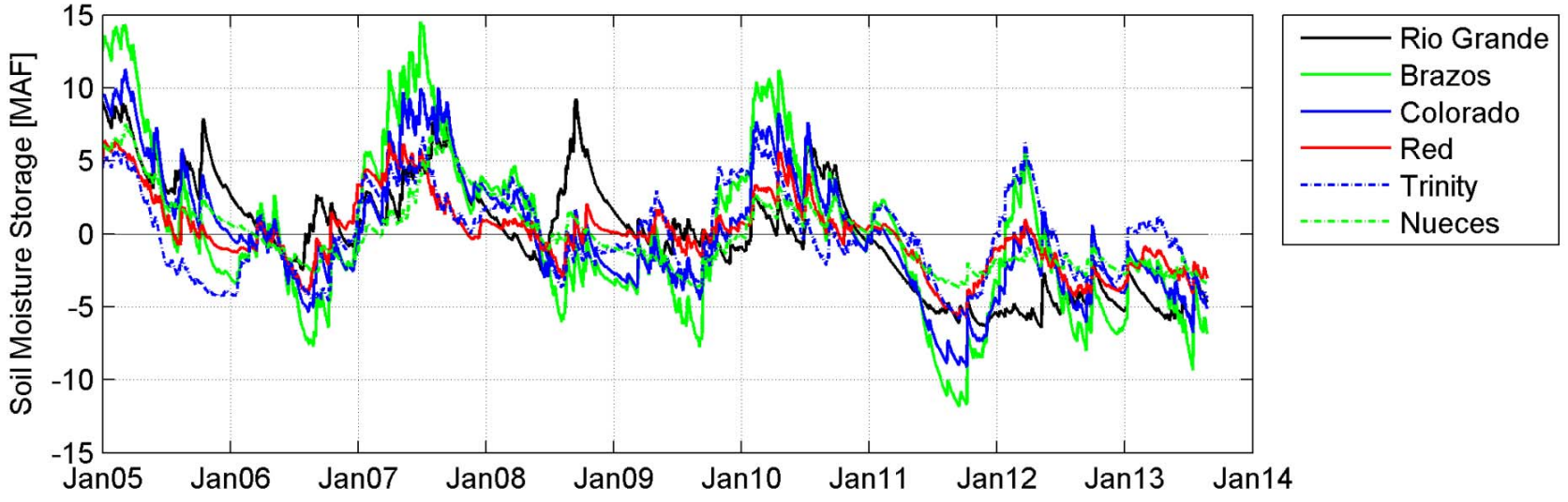
- GRACE: total water storage depletion of 50 MAF (62 km^3) in 2011
- Soil moisture depletions ranges from 20% to >100% to total
- Texans consume 18 MAF per year; soil moisture 11 to 67 MAF!

Source: Long et al., 2013

TGC2

Basin-scale soil water storage (NLDAS-2 Noah)





Slide 11

TGC2 I'm going to work on this one - and try to get 2009 to present on a single graph. right now, I'm not sure it says much - without some idea of 'how full the soil should be'

Todd Caldwell, 8/30/2013

The perplexity of validating soil moisture

IS MODEL OUTPUT 'DATA'?

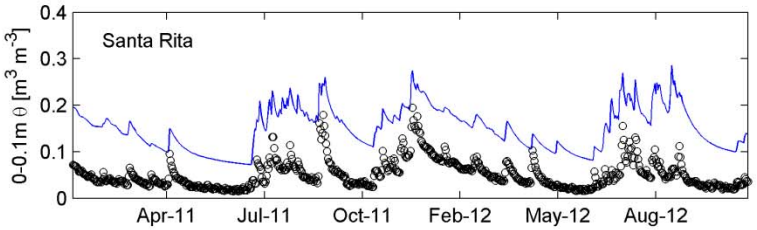
- It's so readily available, it must be
- Too bad we cannot validate it in the field…
- But we can do better

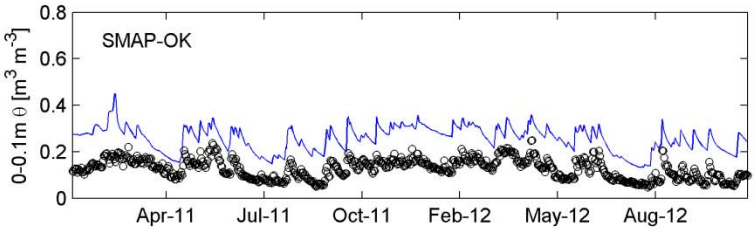
National Soil Moisture Networks

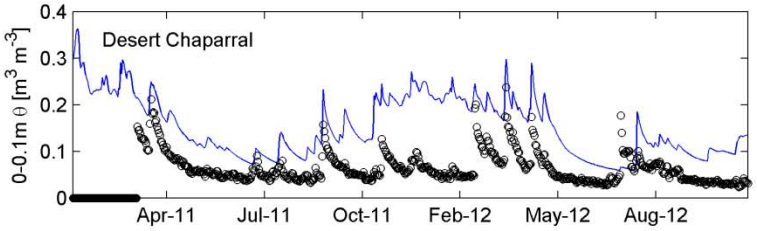
Network	Sensor	US Sites	TX Sites	Year
SCAN	HydraProbe	140	5	~2005
USCRN	HydraProbe	144	7	~2008
COSMOS	Neutron scatter	50	2	2010
AmeriFlux	Dielectric	215	1	2005
NEON	??	20	1	~2011

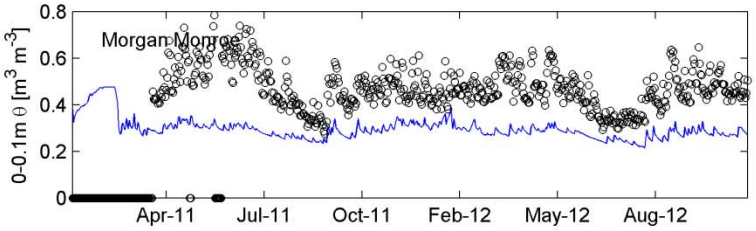
- West Texas Mesonet: 79 sites, 60 with soil moisture
- High Plains Water District: annual pre-plant soil moisture survey at 300 monitoring sites (neutron probe)
- Oklahoma Mesonet: 127 sites, heat dissipation sensors
- Illinois Climate Network: 19 sites, neutron probe and sensors
- High Plains Regional Climate Center: 14 sites (NE), Theta probe

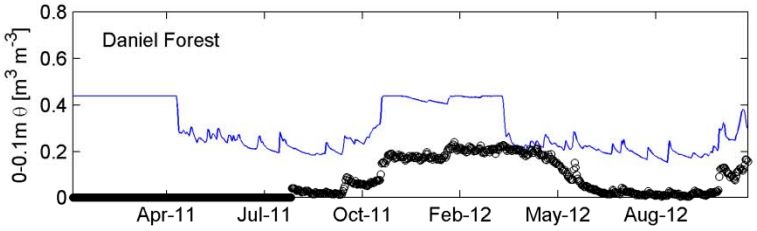
Validating Noah – COSMOS Network

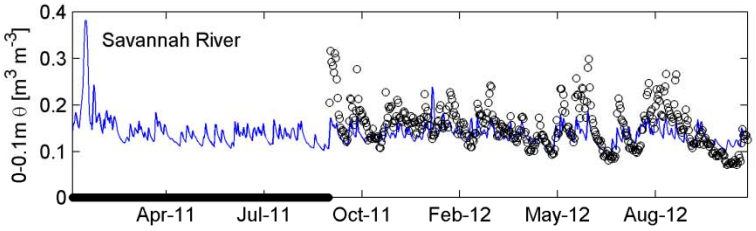


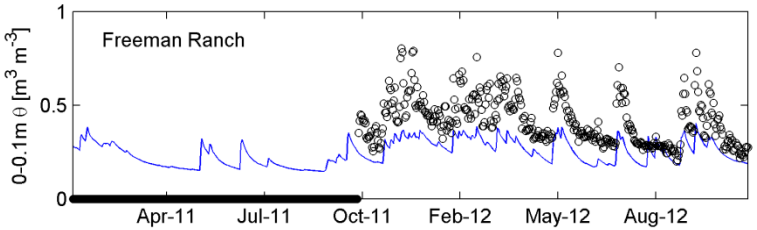


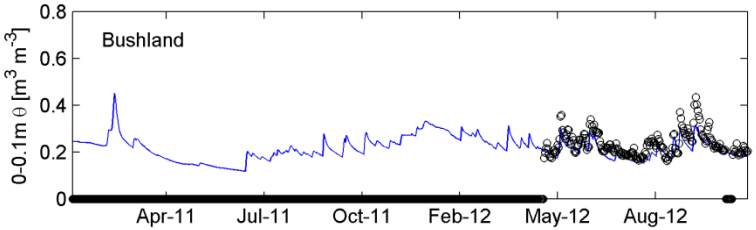










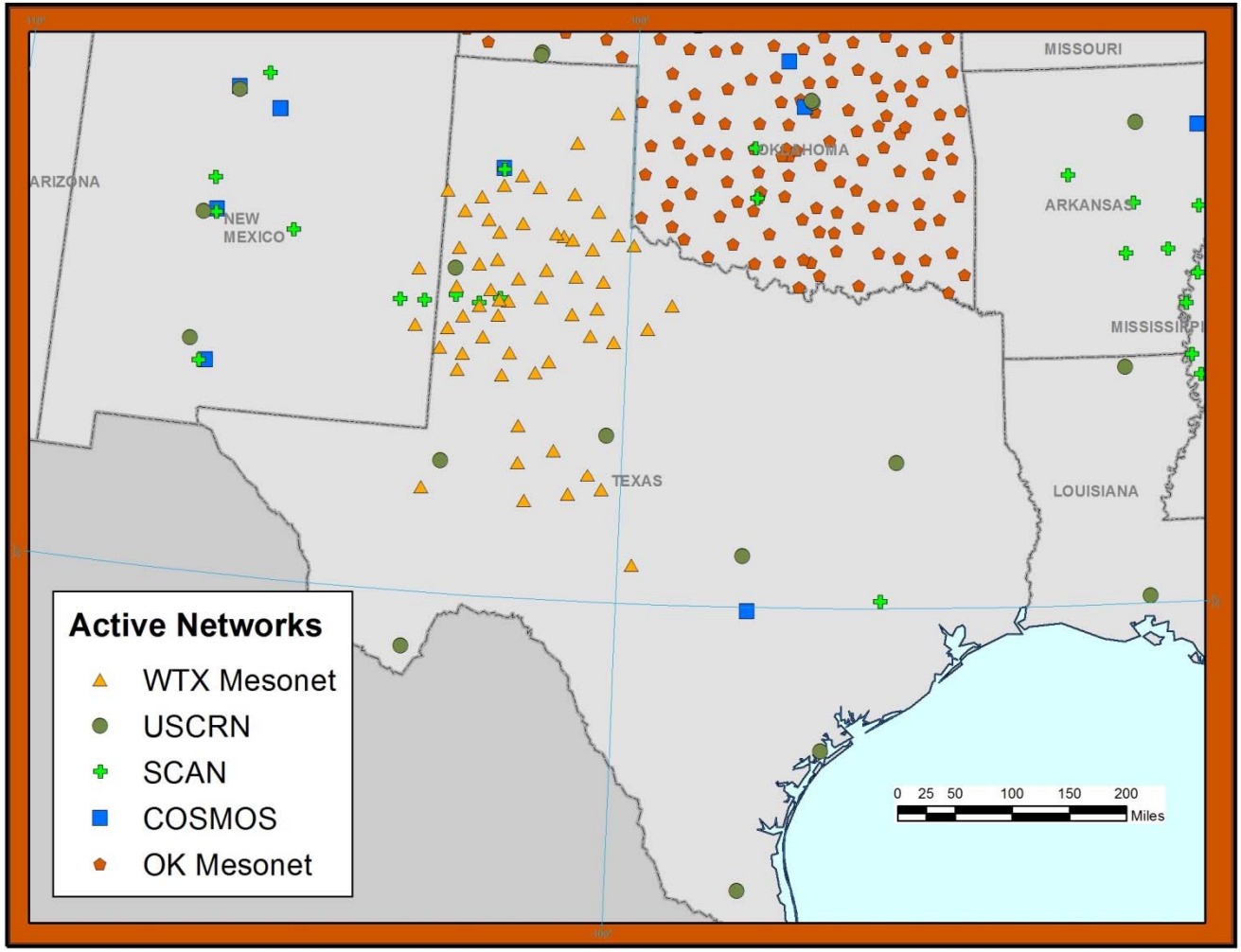


Validating Noah – monitoring soil moisture

- Large forcing errors correspond to large error in soil water storage for 0-10 cm
- Structural errors in model were as prevalent as poor observational data
- The models help validate the observations and vice-versa but perhaps neither is correct!
- Results nationally for 2012 soil moisture (0-10cm) ↓

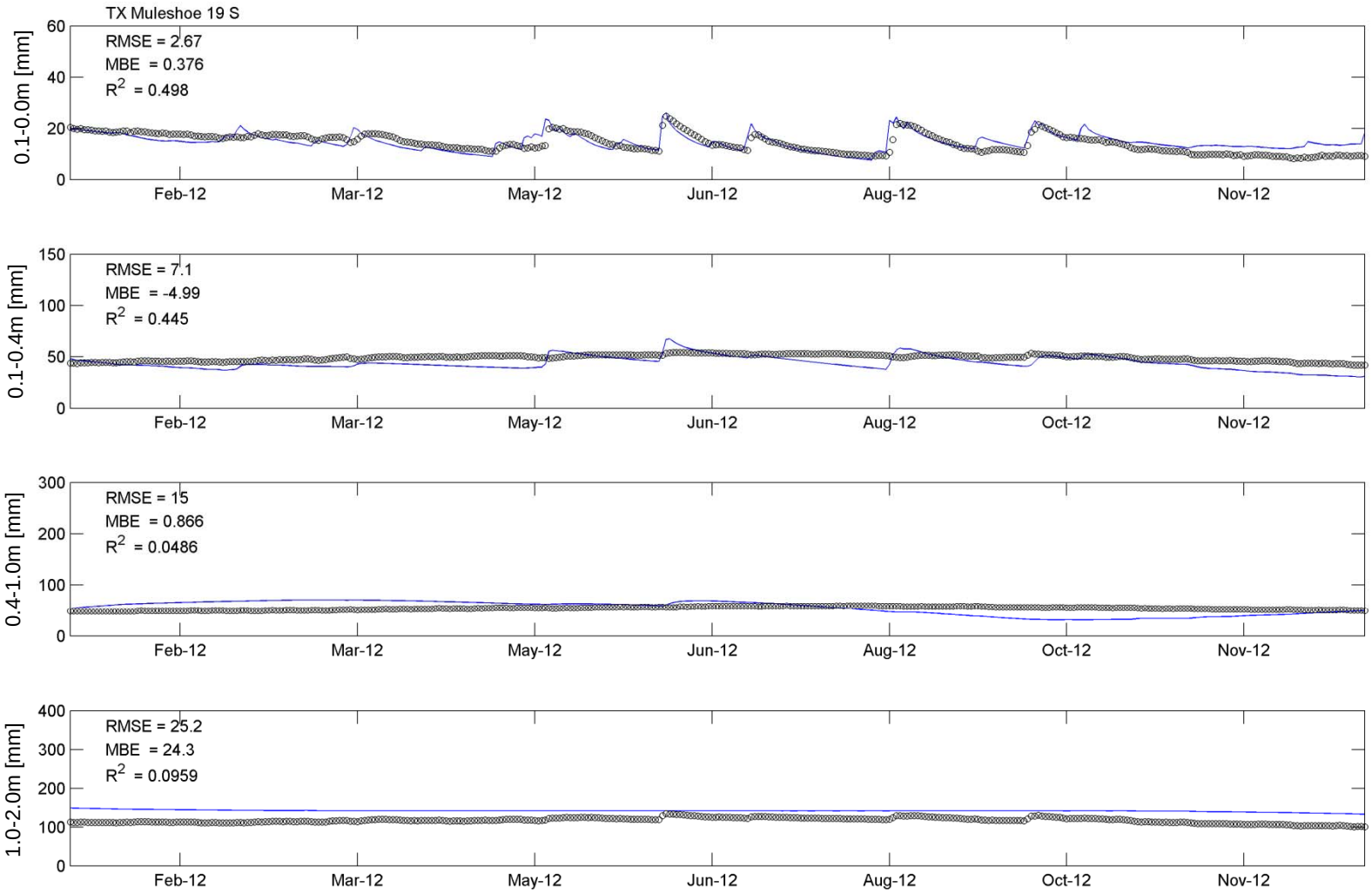
Network	N	RMSE (mm)	MBE (mm)	R^2
SCAN	163	14.9	-13.5	0.38 ± 0.02
USCRN	111	8.2	-3.7	0.53 ± 0.20
COSMOS	62	9.7	-0.3	0.53 ± 0.21

Monitoring soil moisture in Texas

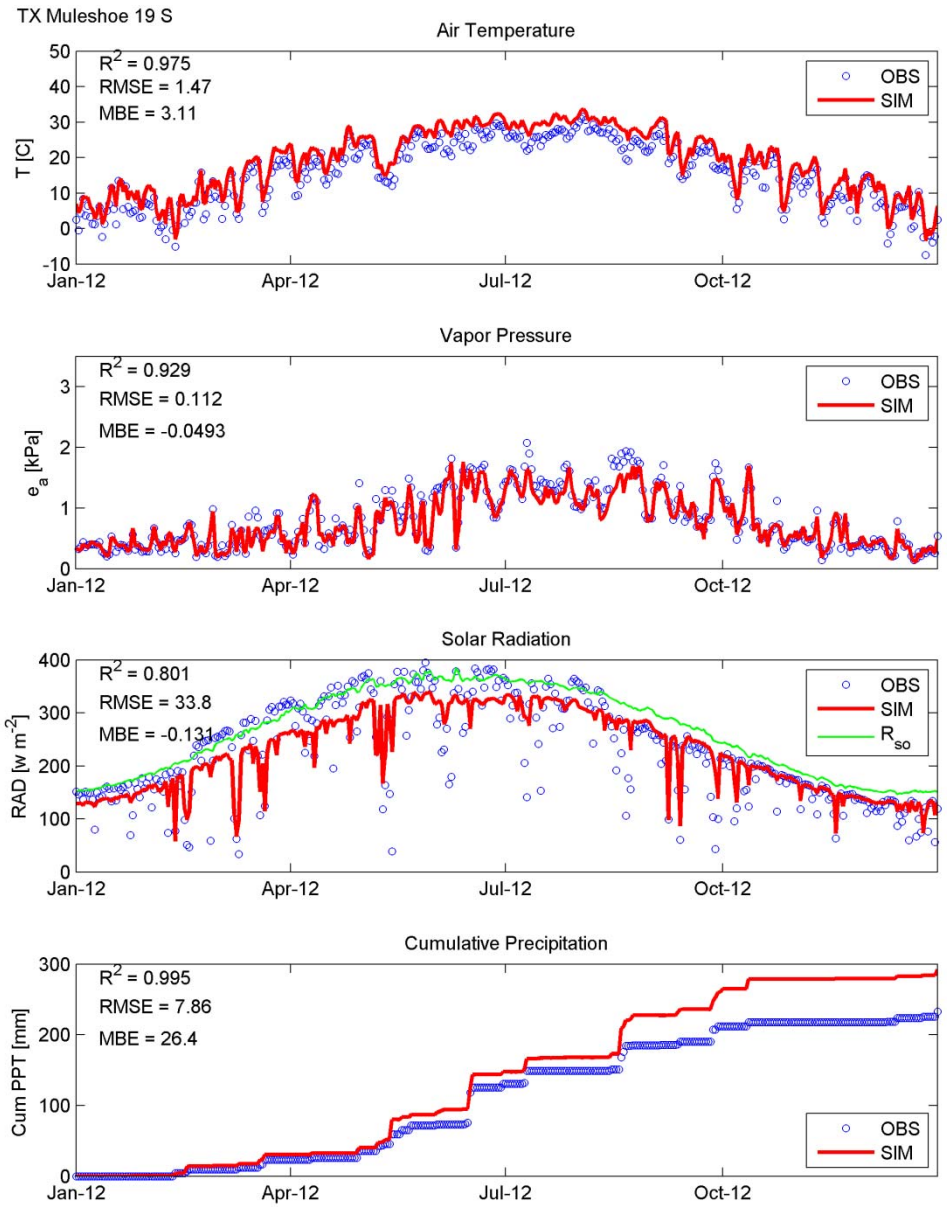


Soil moisture data is sparse across much of Texas

Validating Noah – USCRN Muleshoe (TX)



Validating forcings – USCRN Daily: Muleshoe



Bureau of Economic Geology

Concluding remarks: Droughts will occur…will Texas be ready?

- Soil moisture storage is a huge, unknown component of the Texas water balance
- The 2011 drought resulted in a soil-water deficit of 14-83 km^3 (11-67 MAF) in discrepancy between models
- Or 20-119 mm of precipitation over Texas
- How much precipitation over our largest basins?

Rio Grande	35 mm	Brazos	63 mm
Colorado	49 mm	Red	48 mm
Trinity	105 mm	Nueces	81 mm

We can reduce this uncertainty

Concluding remarks:
Droughts will occur…will Texas be ready?

- Model output, alone, is insufficient for the defense of water allocations and drought declarations
- We need to account for all of our water
- Data collected at the appropriate location and scale can dramatically reduces our uncertainty in the Texas water balance
- Better data yields substantial benefits:
  - **Total water accounting to assist water managers**
  - **Crop forecasts to support farmers**
  - **Flood and fire forecasting to aid emergency response**

International soil moisture networks

Country	Network	Sensor	Sites	Year
Australia	CosmOz	Cosmos	10	2012
Australia	OzNet	CS-615	38	2012
Denmark	HOBE	Decagon 5TE	30	2009
Umbria	Umbria	EnviroScan	13	2002
China: Tibetan Plateau	DAM	?	69	?
Spain	REMEDHUS	Hydra Probe	24	2005

- Soil moisture is being operationalized
- International Soil Moisture Network (http://ismn.geo.tuwien.ac.at/ismn/)
- SMOS and SMAP (2014) Satellite calibration/validation mission