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The University of Texas at Austin
Jackson School of Geosciences
Bureau of Economic Geology

SMAP Cal/Val Workshop #9, October 22-23, 2018

In Situ Sensor Calibration and Validation at TxSON

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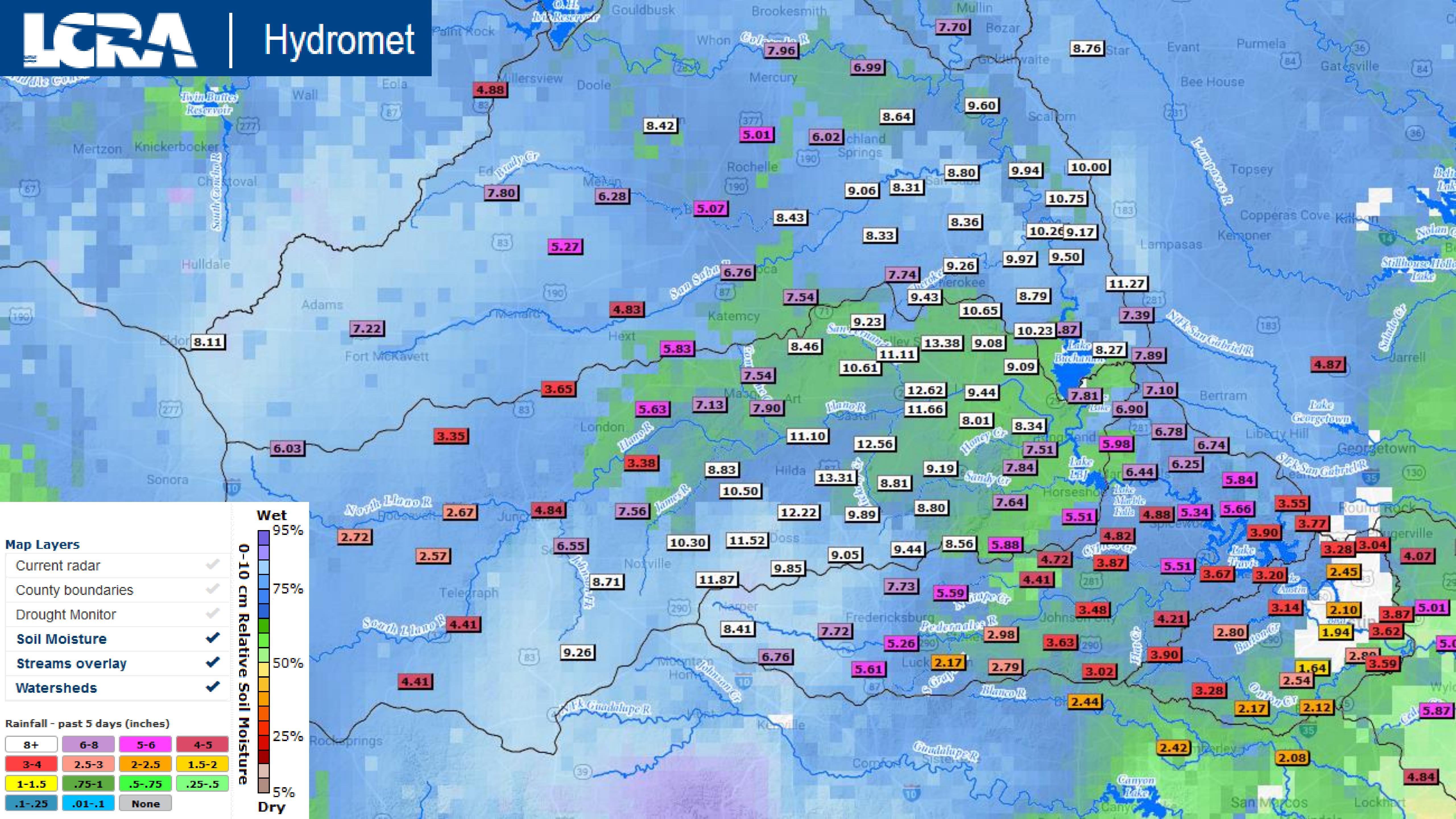

LCRA | Hydromet
Map Layers
Current radar
County boundaries
Drought Monitor
Soil Moisture
Streams overlay
Watersheds
Rainfall - past 5 days (inches)
8+
6-8
5-6
4-5
3-4
2.5-3
2-2.5
1.5-2
1-1.5
.75-1
.5-.75
.25-.5
.1-.25
.01-.1
None
0-10 cm Relative Soil Moisture
Wet
95%
75%
50%
25%
5%
Dry
Gouldbusk
Brookesmith
Mullin
Bozar
Whon
Mercury
Goldthwaite
Star
Evant
Purmela
Gatesville
Bee House
Millersview
Doole
Eola
Wall
Twin Buttes Reservoir
Mertzon
Knickerbocker
Christoval
Rochelle
Richland Springs
Scallorn
Topsey
Copperas Cove
Kempner
Lampasas
Hulldale
Adams
Menard
Katemcy
Cherokee
Hext
Eldorado
Fort McKavett
London
Mason
Art
Castell
Llano R
Hilda
Sonora
Junction
Noxville
Doss
Telegraph
Harper
Fredericksburg
Johnson City
Luckenbach
Mountain Home
Kerrville
Rocksprings
Comfort
Bertram
Liberty Hill
Georgetown
Jarrell
Round Rock
Pflugerville
Lake Buchanan
Lake LBJ
Lake Marble Falls
Lake Travis
Lake Austin
Lake Georgetown
Stillhouse Hollow Lake
Canyon Lake
San Marcos
Lockhart
Colorado R
San Saba R
Brady Cr
North Llano R
South Llano R
James R
Johnson Fk
Pedernales R
Blanco R
Guadalupe R
N Fk Guadalupe R
N Fk San Gabriel R
S Fk San Gabriel R
Lampasas R
Onion Cr
Barton Cr
Sandy Cr
Honey Cr
7.70
7.96
6.99
8.76
4.88
9.60
8.42
5.01
6.02
8.64
8.80
9.94
10.00
7.80
6.28
5.07
9.06
8.31
10.75
8.43
8.36
5.27
8.33
10.26
9.17
9.97
9.50
6.76
7.74
9.26
11.27
7.54
9.43
8.79
4.83
10.65
7.39
7.22
9.23
10.23
8.11
5.83
8.46
13.38
9.08
8.27
7.89
11.11
10.61
9.09
4.87
3.65
7.54
12.62
9.44
7.81
7.10
5.63
7.13
7.90
11.66
6.90
8.01
8.34
6.78
3.35
6.03
11.10
12.56
5.98
6.74
7.51
3.38
8.83
13.31
9.19
7.84
6.44
6.25
5.84
10.50
8.81
7.64
2.67
4.84
7.56
12.22
9.89
8.80
5.51
4.88
5.34
5.66
3.55
2.72
6.55
10.30
11.52
3.90
3.77
2.57
9.05
9.44
8.56
5.88
4.82
3.28
3.04
4.07
8.71
11.87
9.85
4.72
3.87
5.51
3.67
3.20
2.45
7.73
5.59
4.41
3.48
3.14
2.10
3.87
5.01
4.41
8.41
7.72
5.26
2.98
3.63
4.21
2.80
1.94
3.62
9.26
6.76
2.17
2.79
3.90
2.80
3.59
4.41
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3.28
2.17
2.12
5.87
2.44
2.42
2.08
4.84

Llano Floodi

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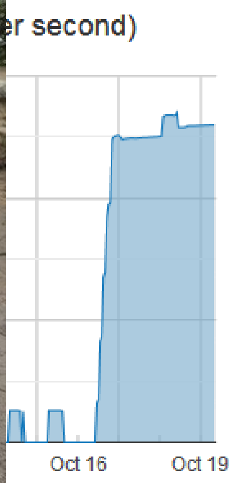

Current conditions across TxSON

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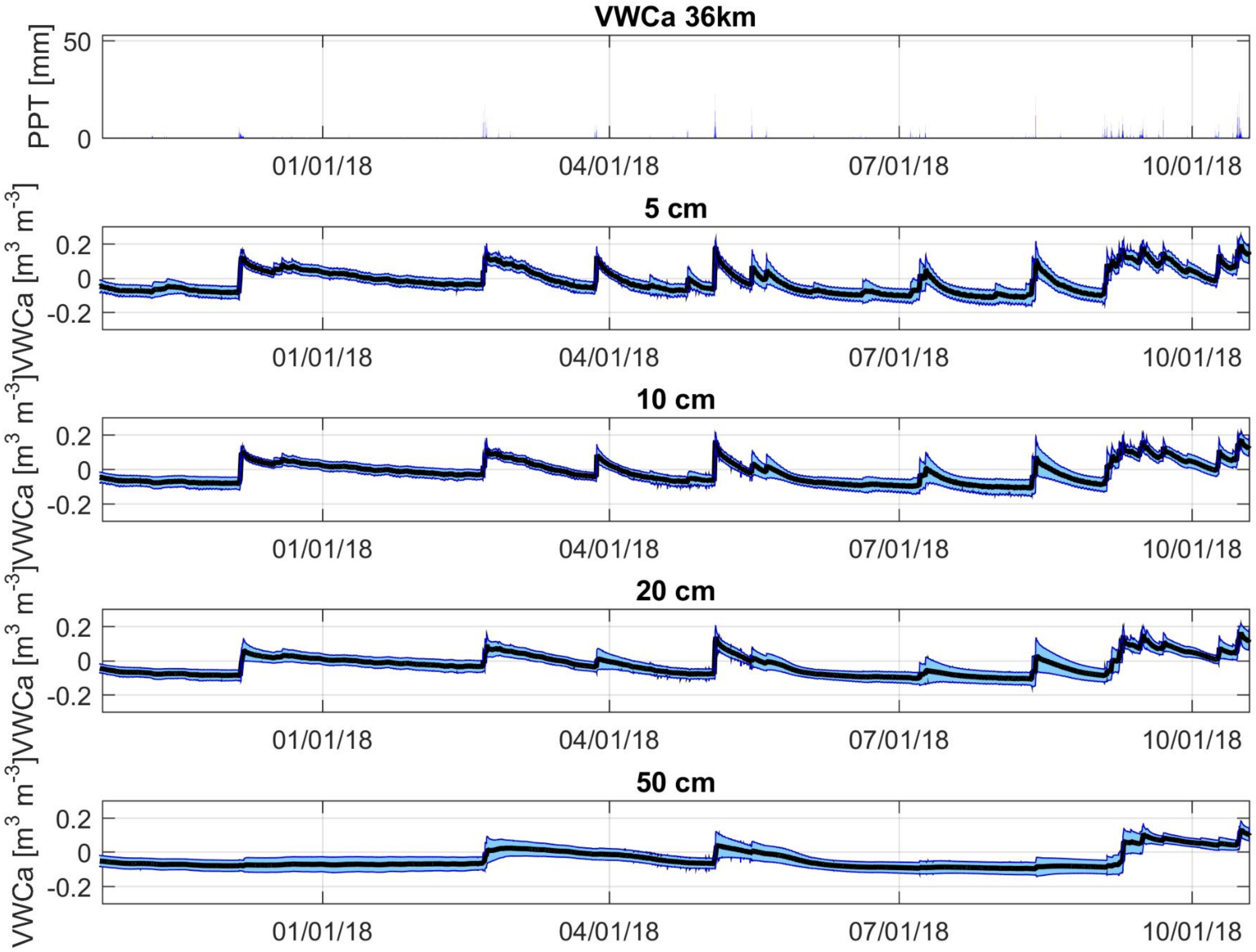

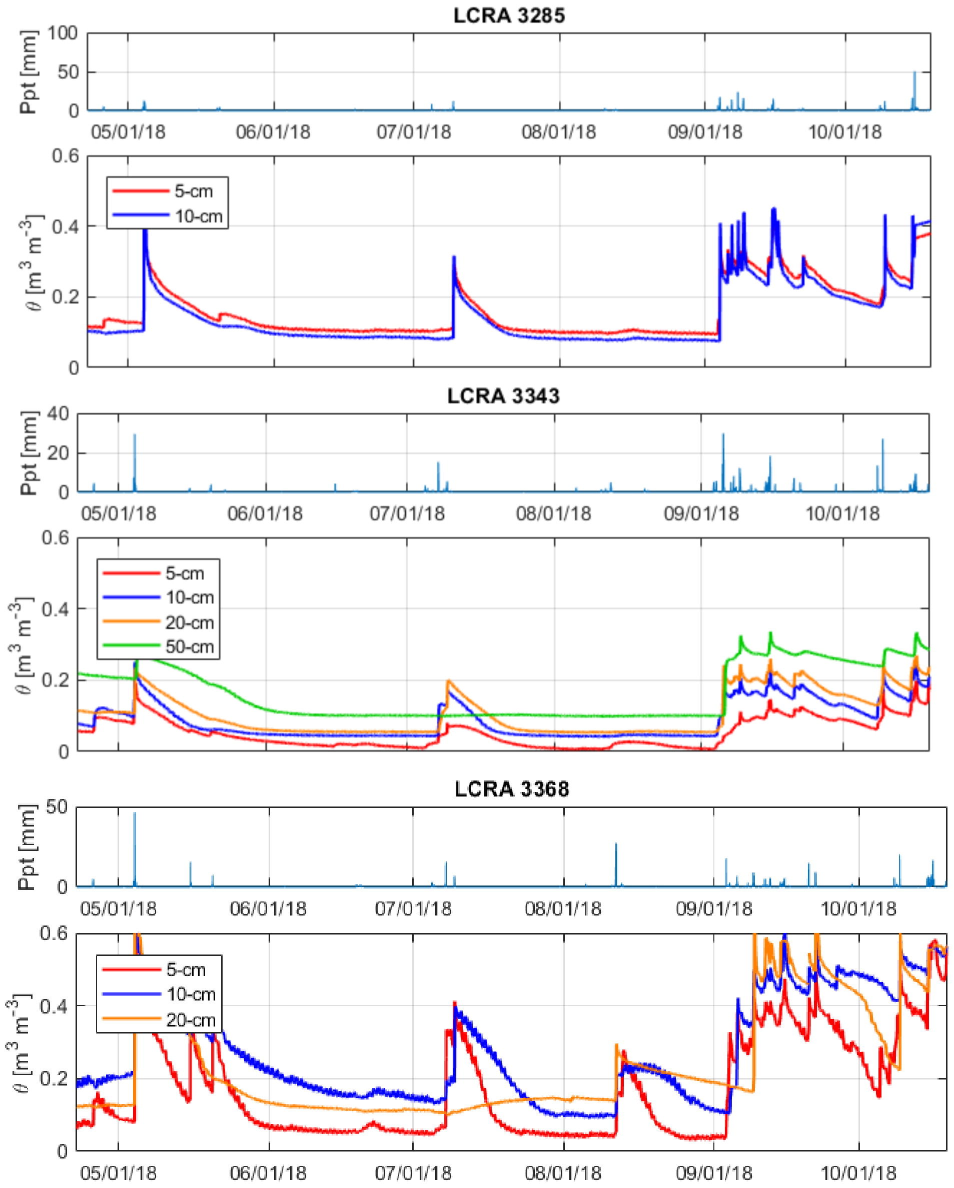

Texas Soil Observation Network (TxSON)

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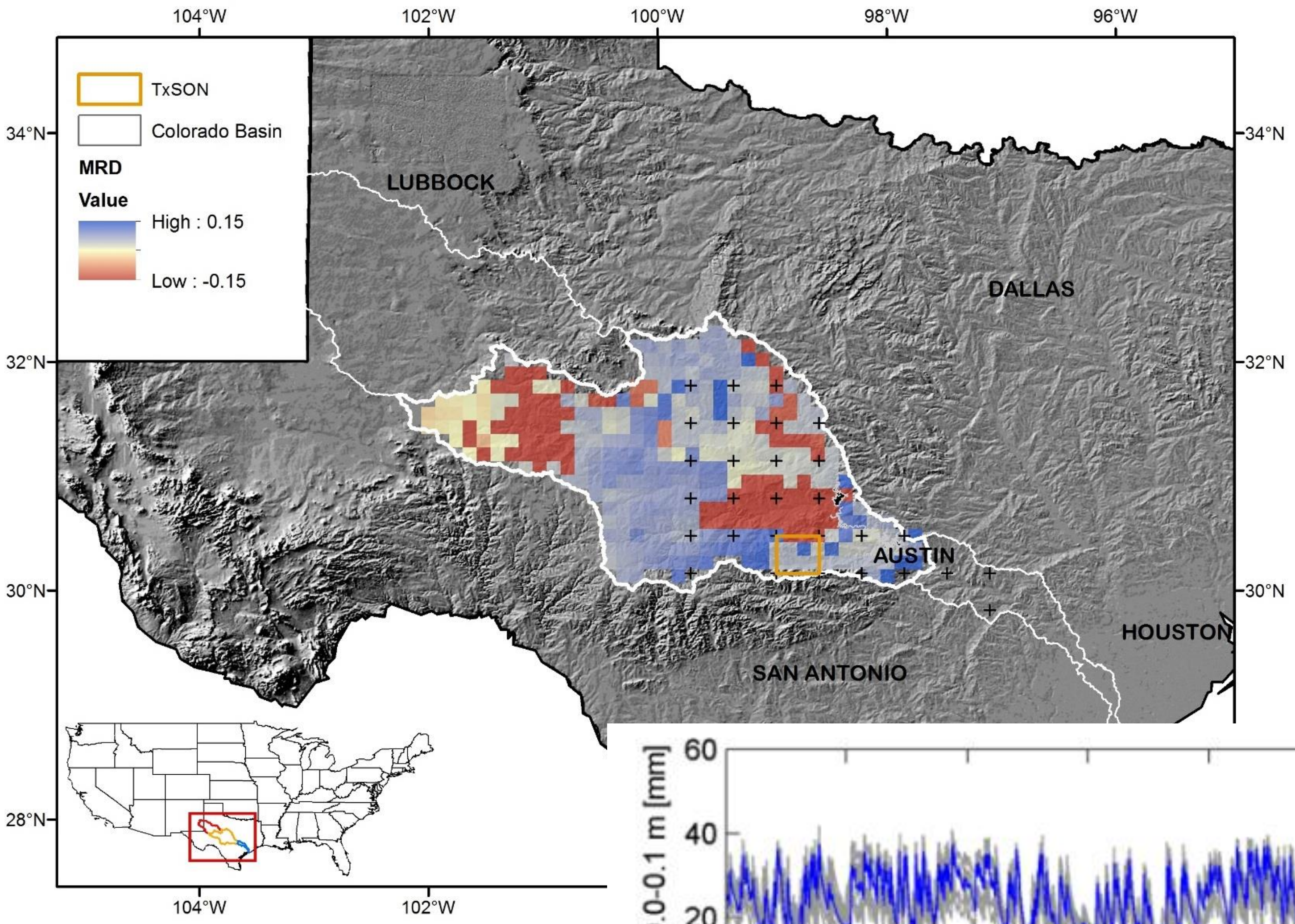
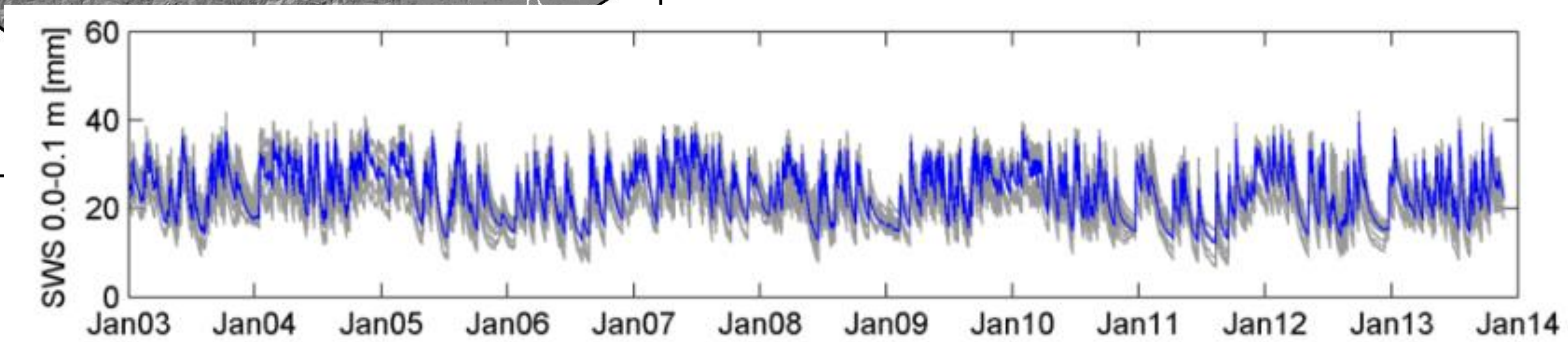
I. Where is it and why?
II. Sensor calibration and field performance
III. Upscaling functions and SMAP validation
IV. New 3 km dense grids

Where do we put it? CVS and EASE-2 Grid Selection



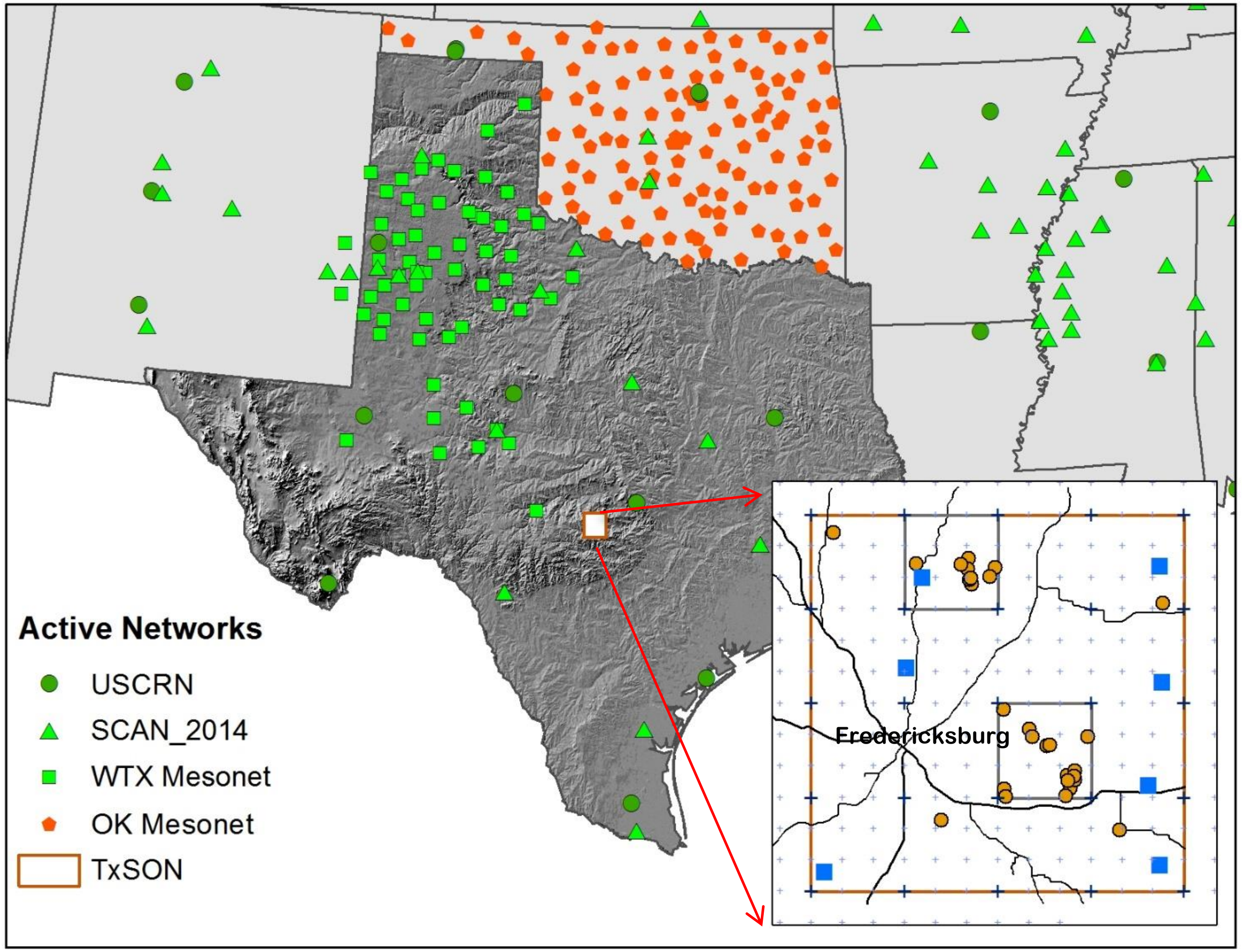


MRD using NLDAS within each HUC 8

- Cool = wet (+ 25%)
- Hot = drier (- 25%)
- **12090206** most stable within Highland Lakes bounds

SMAP Core Cal/Val Partner and the uRMSE of 0.04 $m^3\ m^{-3}$

- Verify and improve performance of the science algorithms
- Validate accuracies of the science data products



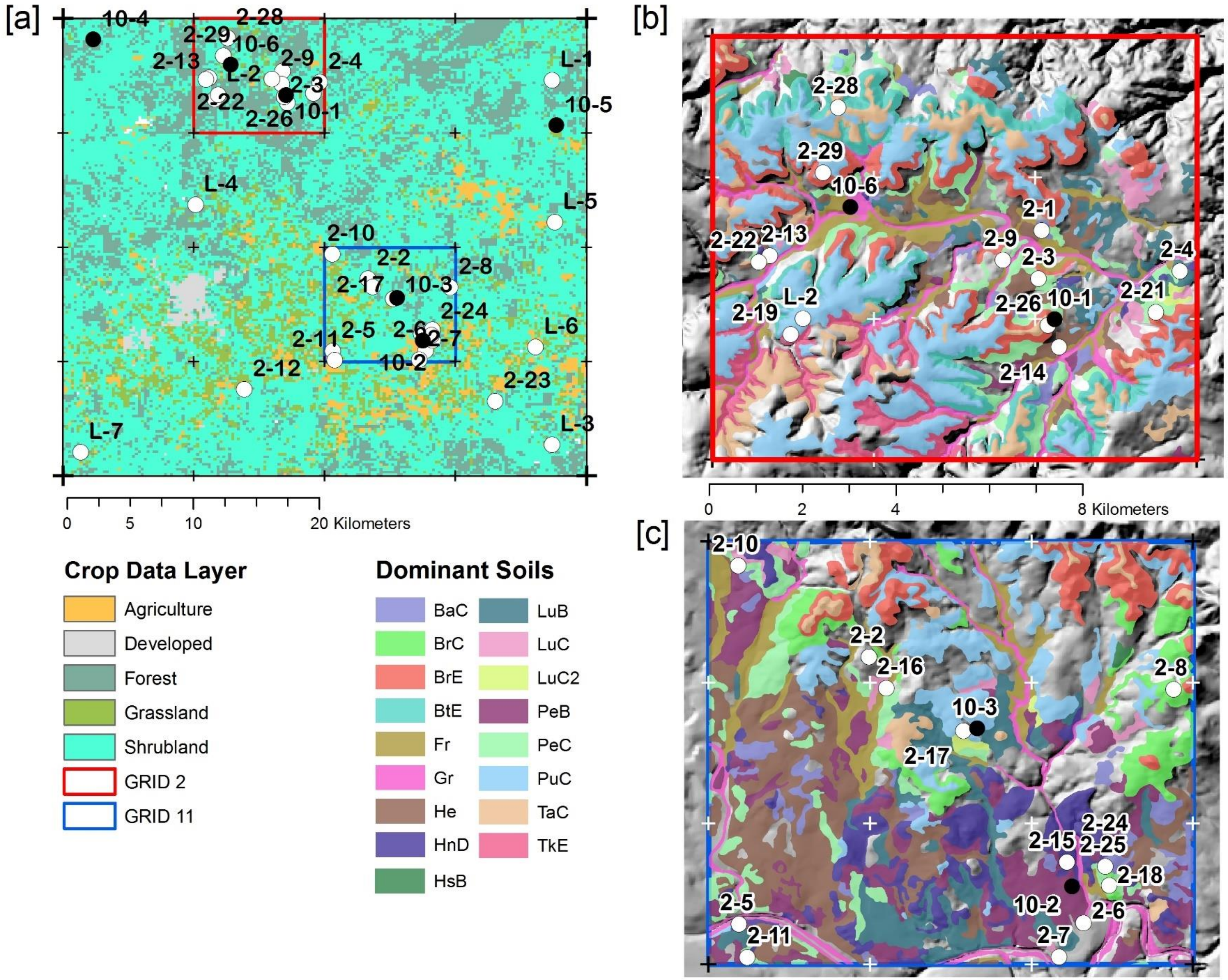
Mission goal must be met using replicated data at the appropriate scale

The Ideal Core Cal/Val Site:

- 5-cm soil moisture with replication (n > 3) at:
  - 36 km footprint (yellow)
  - 9 km (white)
  - 3 km
- Historical data
- In Situ data
  - Publically available
  - Real-time
- Nested within EASE-2
- Validation against gravimetric soil moisture data
- Upscaling routine
  - Spatial mean
  - Variably weighted method

Where is the ideal monitoring location?

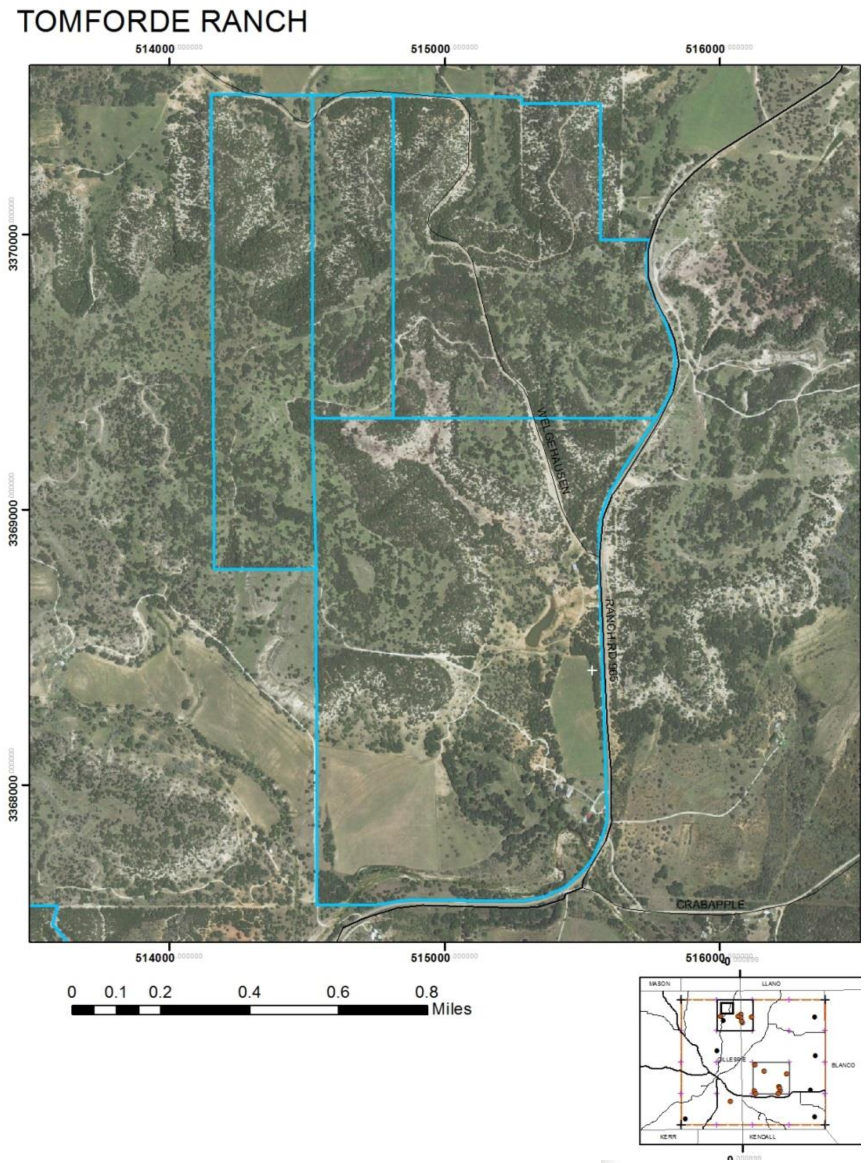
- Land Use
  - (Cedar) forest dominates north
  - Grasslands dominate south
  - Shrublands everywhere
- Topography
  - Rugged stair-step topography in north
  - Much flatter in the south
- Soils (SSURGO)
  - Shallow clay-rich soils in to north
  - Deep sandy soils along Pedernales (south)
- But ultimately it is Land Accessibility
  - What is available?

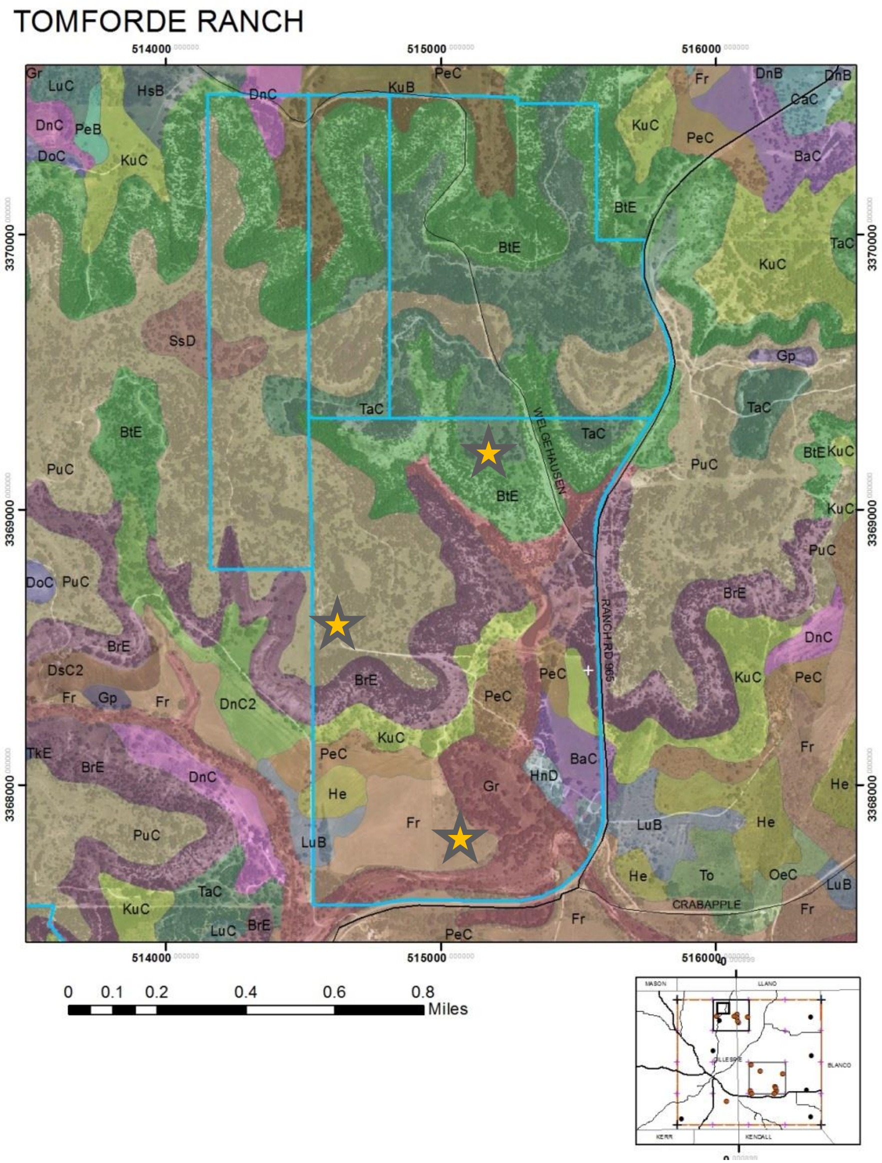


Site selection based on map unit %coverages (SSURGO)

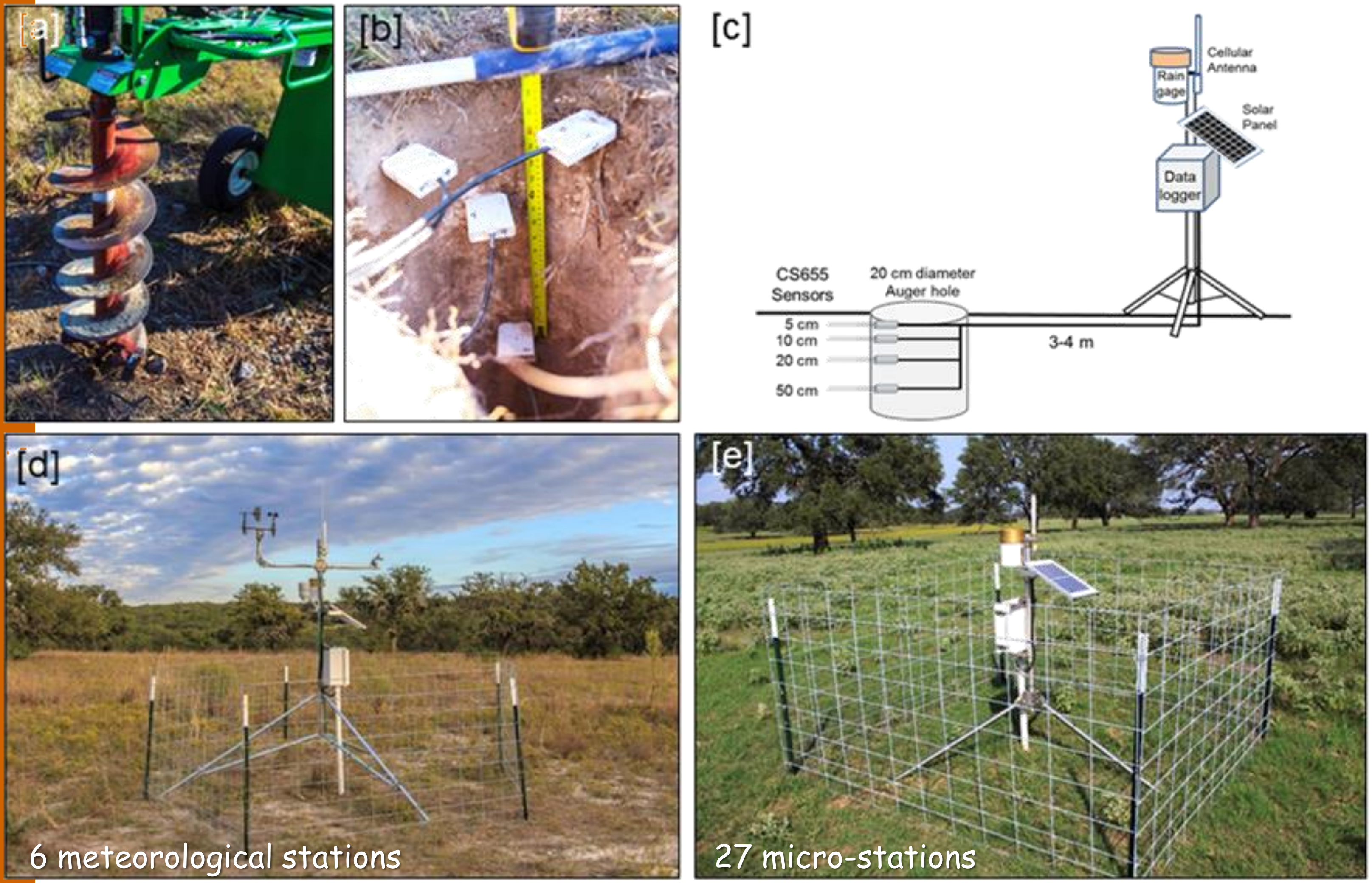
MUSYM	MUKEY	SAND	SILT	CLAY	Dep2Res	%Area	%Grid11	%Grid2	Logger_ID
BrC/BrE/BtE	Brackett soils	38.8	36.7	24.5	36	9.8	10.0	15.1	CR200_8, CR200_18, CR200_21, CR200_26, CR1000_5, LCRA_1, LCRA_3, LCRA_7
TaC, TkE	Tarrant soils	22.1	27.9	50.0	30	9.1	1.9	6.3	CR200_28, CR1000_4
PuC	Purves soils	28.7	29.4	41.9	36	8.2	8.5	18.0	CR200_17, CR200_19, CR200_29, LCRA_2, LCRA_5
PeB/PeC	Pedernales fine sandy loam	55.7	12.5	31.8		7.2	15.4	5.1	CR200_10, CR200_11, CR1000_2
DoC/DsC2	Doss silty clay	7.4	**48.6**	44.0	48	6.8	5.4	1.4	CR200_23
LuB/LuC	Luckenbach clay loam	33.8	32.8	33.4		5.8	8.2	5.0	CR200_2, CR200_4, CR200_13
He	Heaton loamy fine sand	85.9	**6.6**	7.5		5.7	13.3	3.1	CR200_3, CR200_14, CR200_22
DnC	Denton silty clay	**5.8**	48.3	45.9	97	4.9	3.7	3.5	
SpC/SsD	Tarpley clay	18.5	24.9	**56.6**	36	4.7	0.3	4.7	
Gr, Fr, Gp	Boerne and Oakalla soils	43.0	39.5	17.5		8.1	10.0	9.3	CR200_12, CR200_16, CR1000_6, LCRA_6
HnD	Hensley loam	29.1	30.8	40.1	46	2.9	7.5	0.3	CR200_5, CR200_15, CR200_24, LCRA_4
KuB/KuC	Krum silty clay	7.0	47.5	45.6		2.7	4.4	6.8	CR1000_1, CR1000_3
BfB/BaC	Bastrop loamy fine sand	83.4	7.5	9.1		2.2	3.1	1.2	CR200_1, CR200_7, CR200_25
TpB	Topia clay	18.5	25.8	55.7	81	1.8	0.6	1.4	
DeC	Loneoak fine sand	**89.3**	6.9	**3.8**	142	1.2	0.2	1.1	CR200_9
LlC	Ligon soils	30.6	33.0	36.4	46	1.2	0.0	3.1	
HsB	Hensley soils	29.1	30.8	40.1	46	1.1	0.1	0.2	
To	Tobosa clay	22.1	27.9	50.0		1.0	0.5	0.4	CR200_6
					%TOTAL:	**84.3**	**93.2**	**85.8**	

3 stations: targeting Tarrant (TaC), Oakalla (Fr), and Purves (PuC)





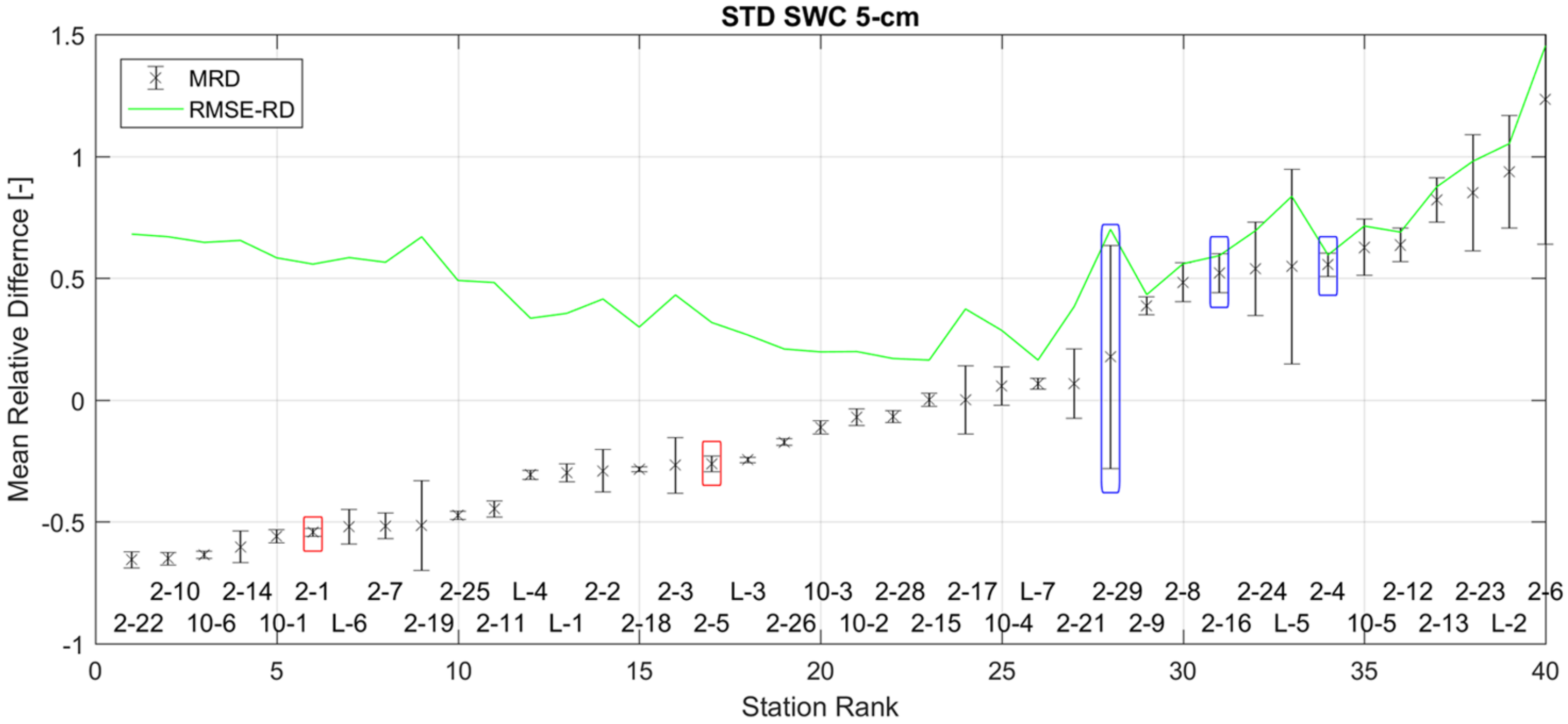
Site installation – soil micro-station at TxSON CVS



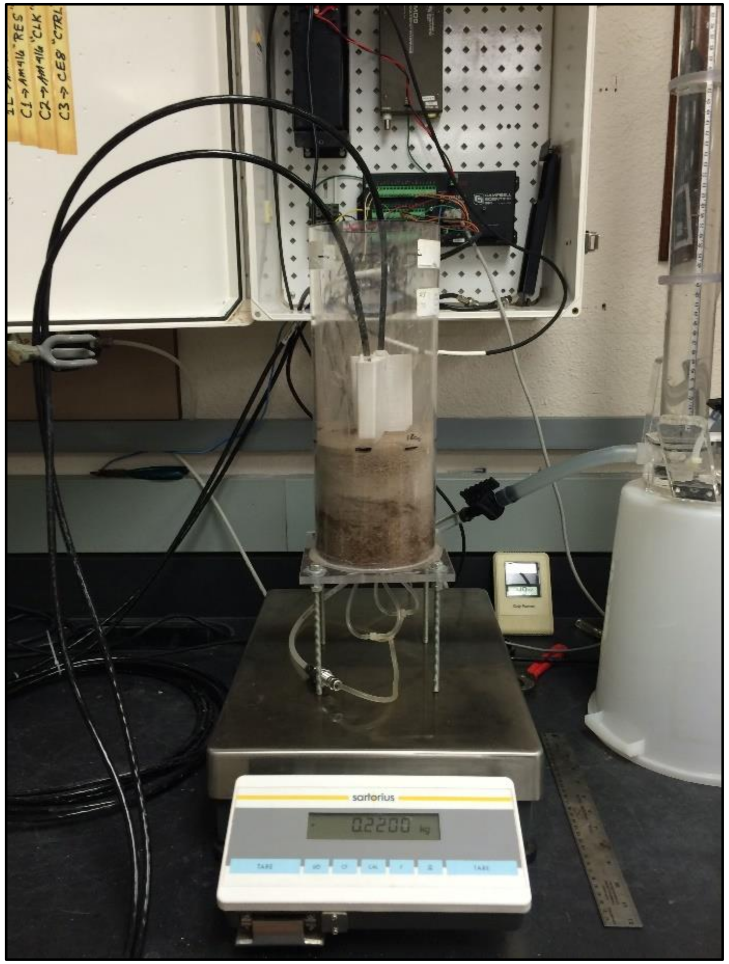
CS-655 Sensor (12-cm rods)

- Operate at 100 kHz
- High EC (<8 dS/m)
- θ, EC, and T (SDI-12)
- 5, 10, 20, and 50 cm depths
- 5 min sampling intervals
- Averaged hourly
- Updated hourly
- Post-processed at midnight

CS-655 Lab calibrations – downward infiltration

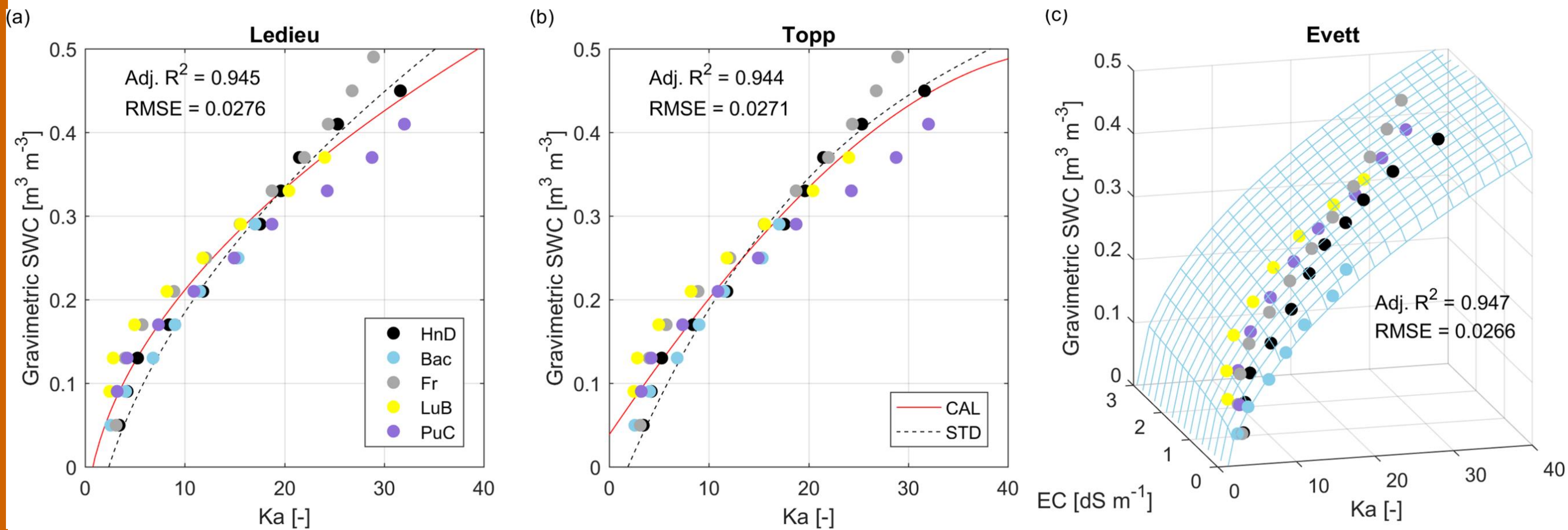


- Five soils: ranked low (CR200_1, fine sand) to high (CR200_29, high EC clay); CR200_5 ~ mean
- Low permittivity (<10) highly sensitive to measured EC
- All soils show a significant deviation from standard Topp Eq. (i.e. factory calibration)



Caldwell et al. (2018), Vadose Zone J., doi:10.2136/vzj2017.12.0214

CS-655 Lab calibrations – downward infiltration



$$SWC = C_0 + C_1\sqrt{Ka}$$

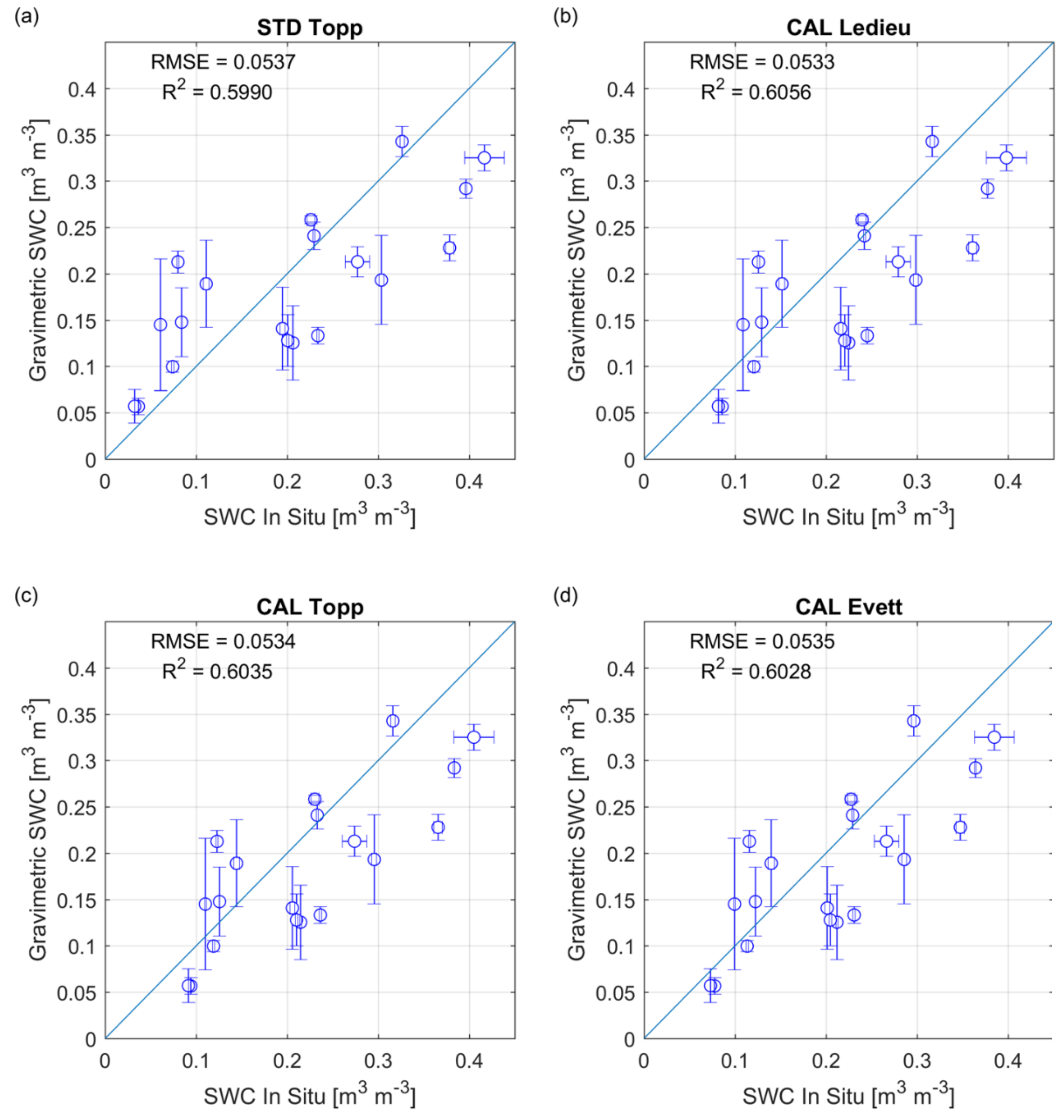
$$SWC = C_0 + C_1 Ka + C_2 Ka^2 + C_3 Ka^3$$

$$SWC = C_0 + C_1\sqrt{Ka} + C_2\sqrt{EC}$$

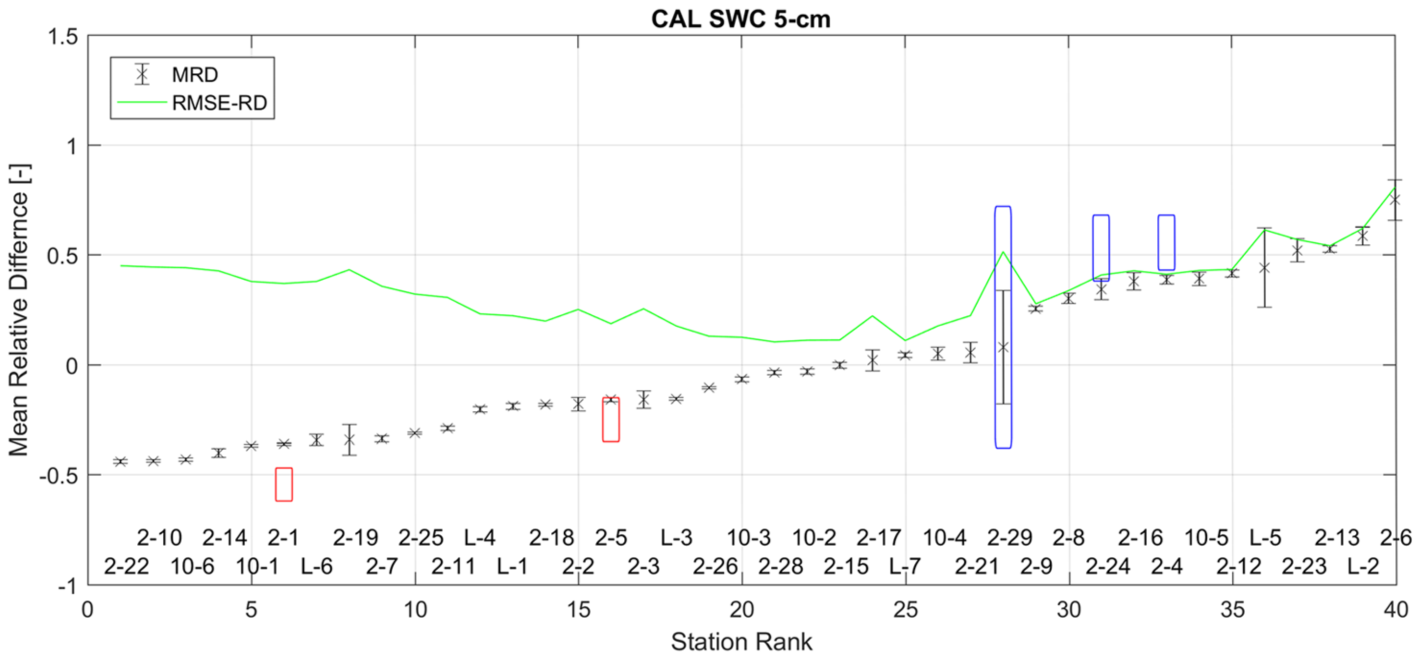
$C_0 = -5.30x10^{-3}$ $C_2 = 5.5x10^{-4}$

$C_1 = 2.92x10^{-2}$ $C_3 = 4.3x10^{-6}$

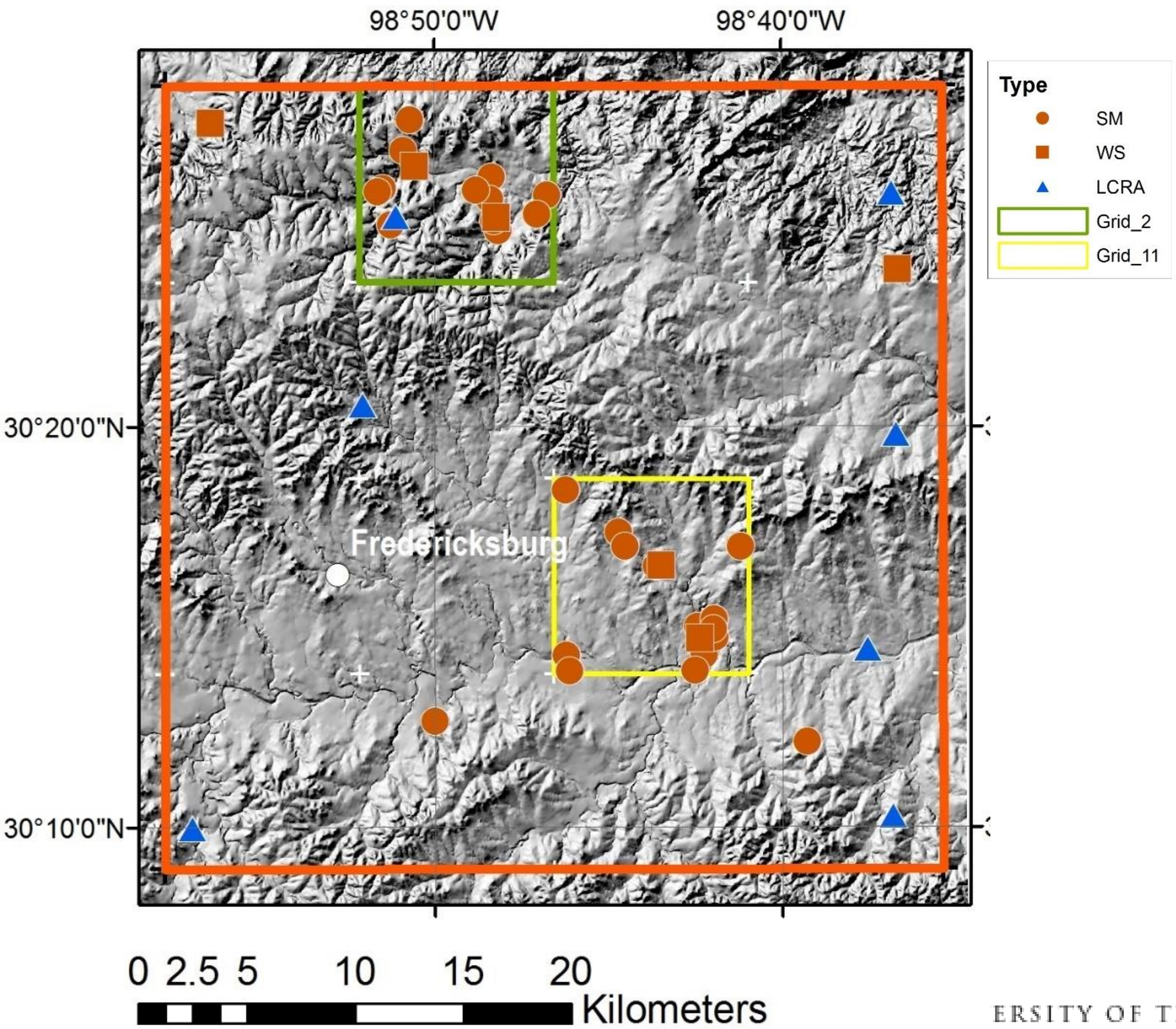
CS-655 Lab calibrations results and field validation



- Standardized Topp Eq.
  - Bias low Ka<15
  - High bias Ka > 15
- Lab-based calibration
  - Reduced RMSE from 0.07 to <0.03
  - No advantage of site-specific
- Spatial variability exceeds sensor calibration
- Global SWC-Ka-EC (Evett) implementation
  - Arithmetic mean similar
  - Network variance reduced 50%

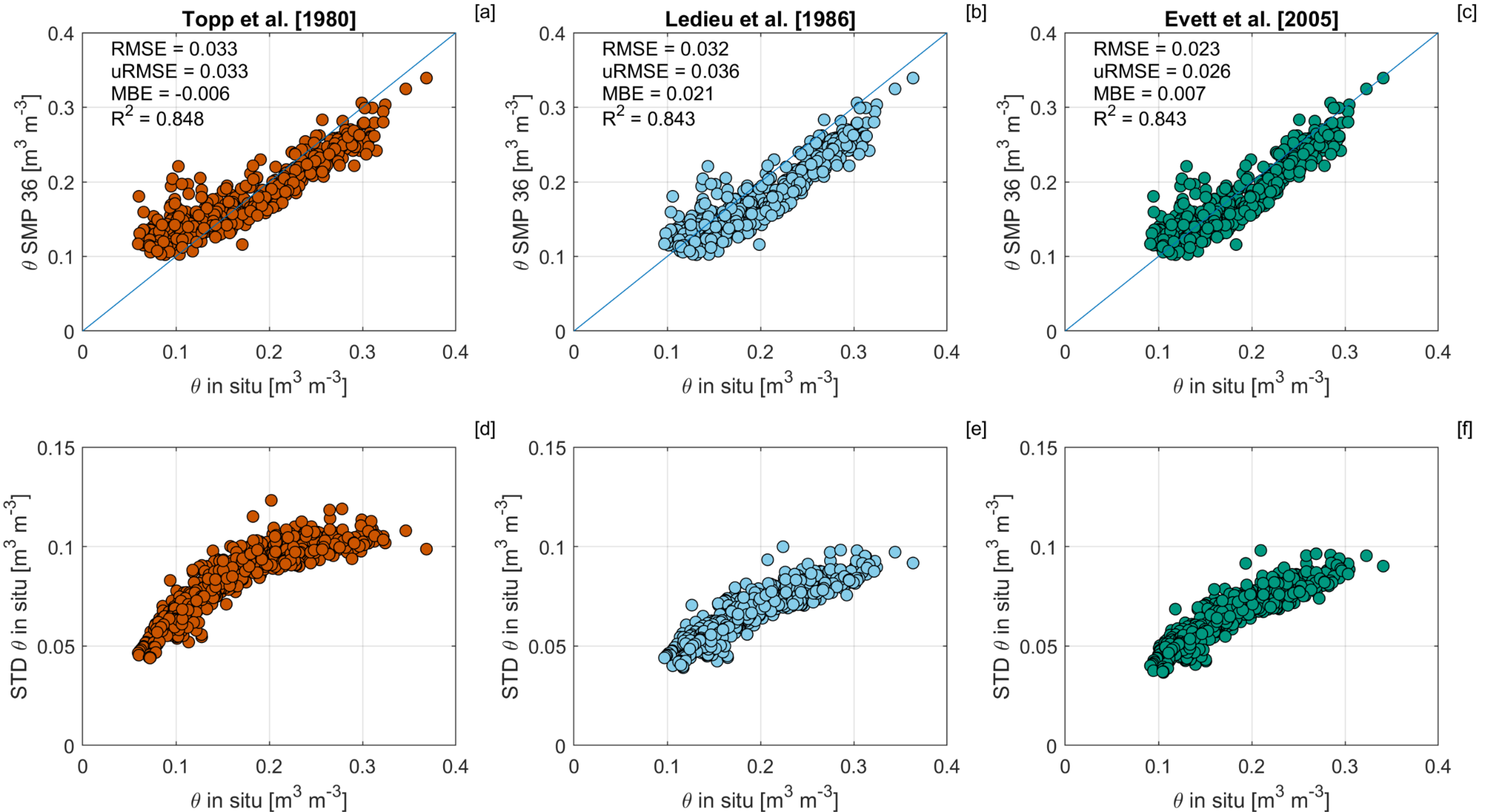


TxSON CVS – Fredericksburg, TX

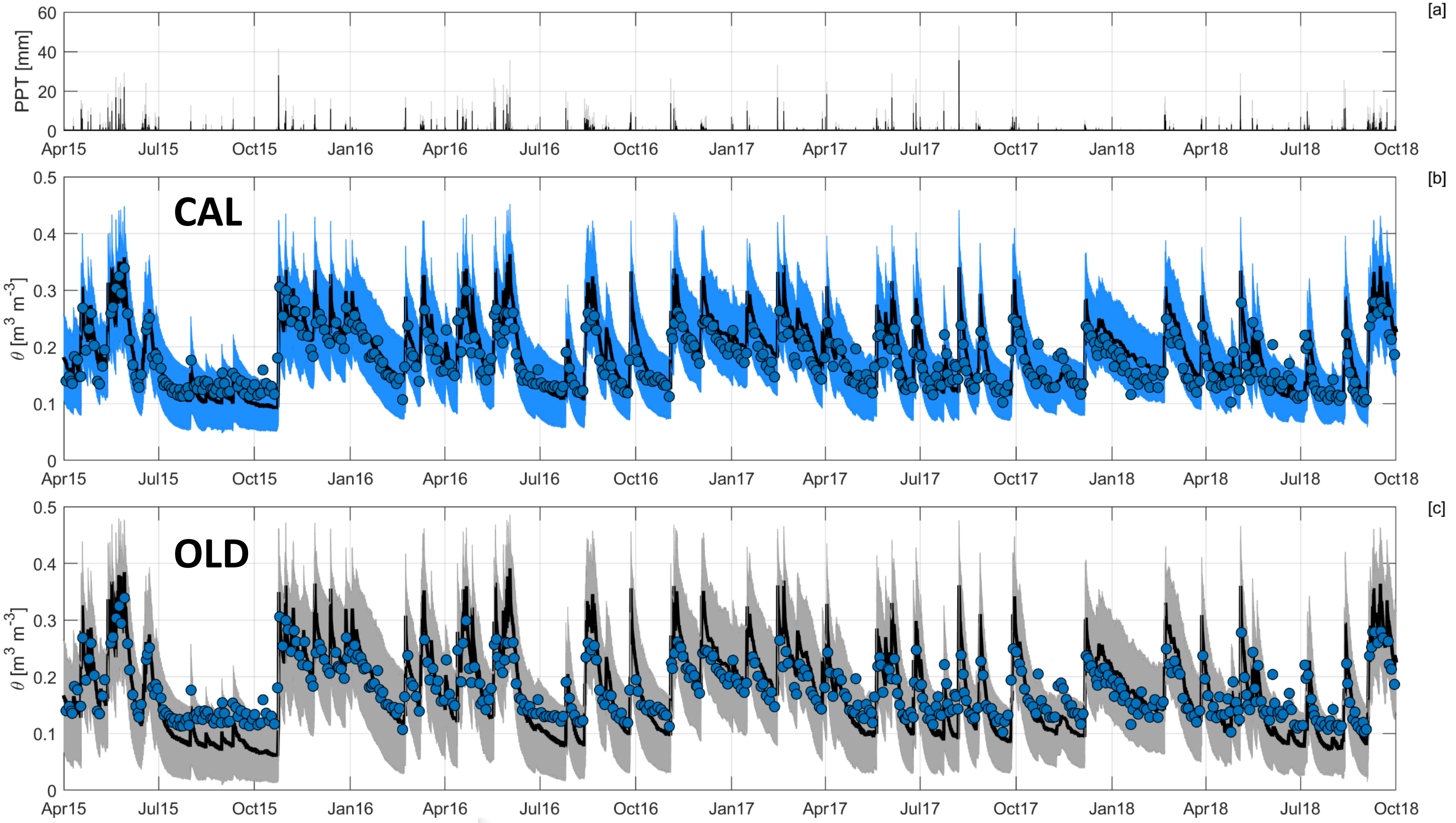


- 40 Station on real-time data collection
  - 27 Micro-stations
  - 6 Weather Stations
  - 7 Partner Stations (LCRA)
- Reporting Sensors by Depth
  - 39 (40) @ 5 cm
  - 38 (39) @ 10 cm
  - 37 (38) @ 20 cm
  - 28 (29) @ 50 cm
- Station per EASE-2 grid: 40 station @ 36 km
  - 9 km, **Grid_2**: 15 stations (2 WS)
  - 9 km, **Grid_11**: 15 station (2 WS)
  - 3 km (n = 3): 2 in Grid_11, 1 in Grid_2
- Upscaling routines (36 and 9 km)
  - Arithmetic mean
  - Voronoi (e.g. Thiessen) spatially weighted
  - Inverse distance, radial (1 km) power function

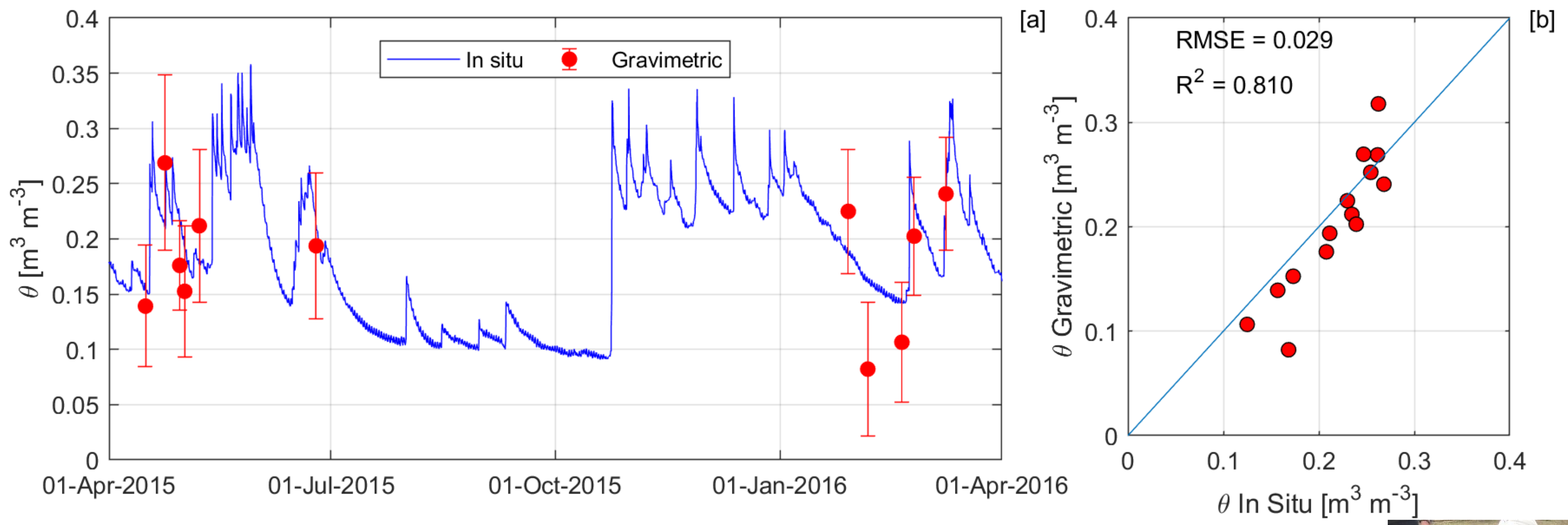
Impact of global sensor calibration functions on SMAP metrics



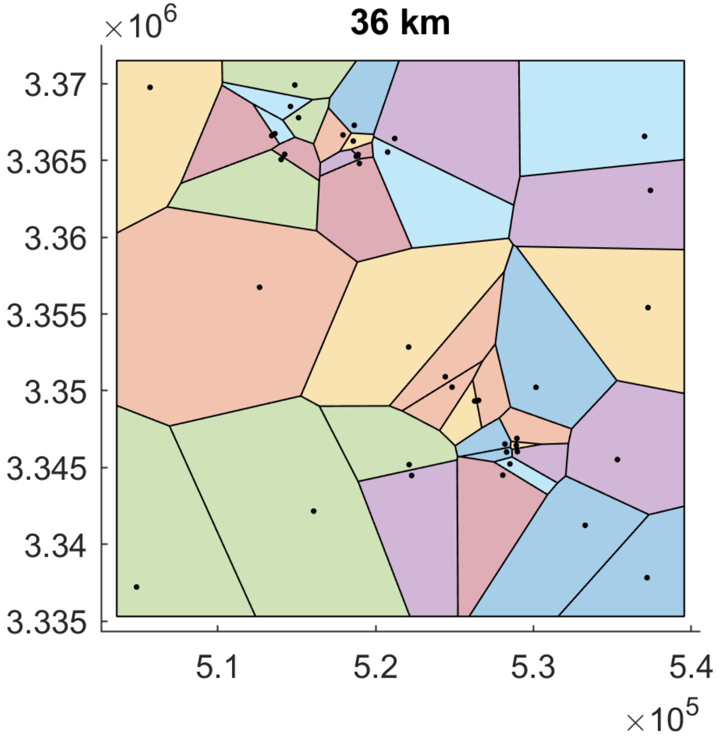
Impact of global sensor calibration functions on SMAP metrics

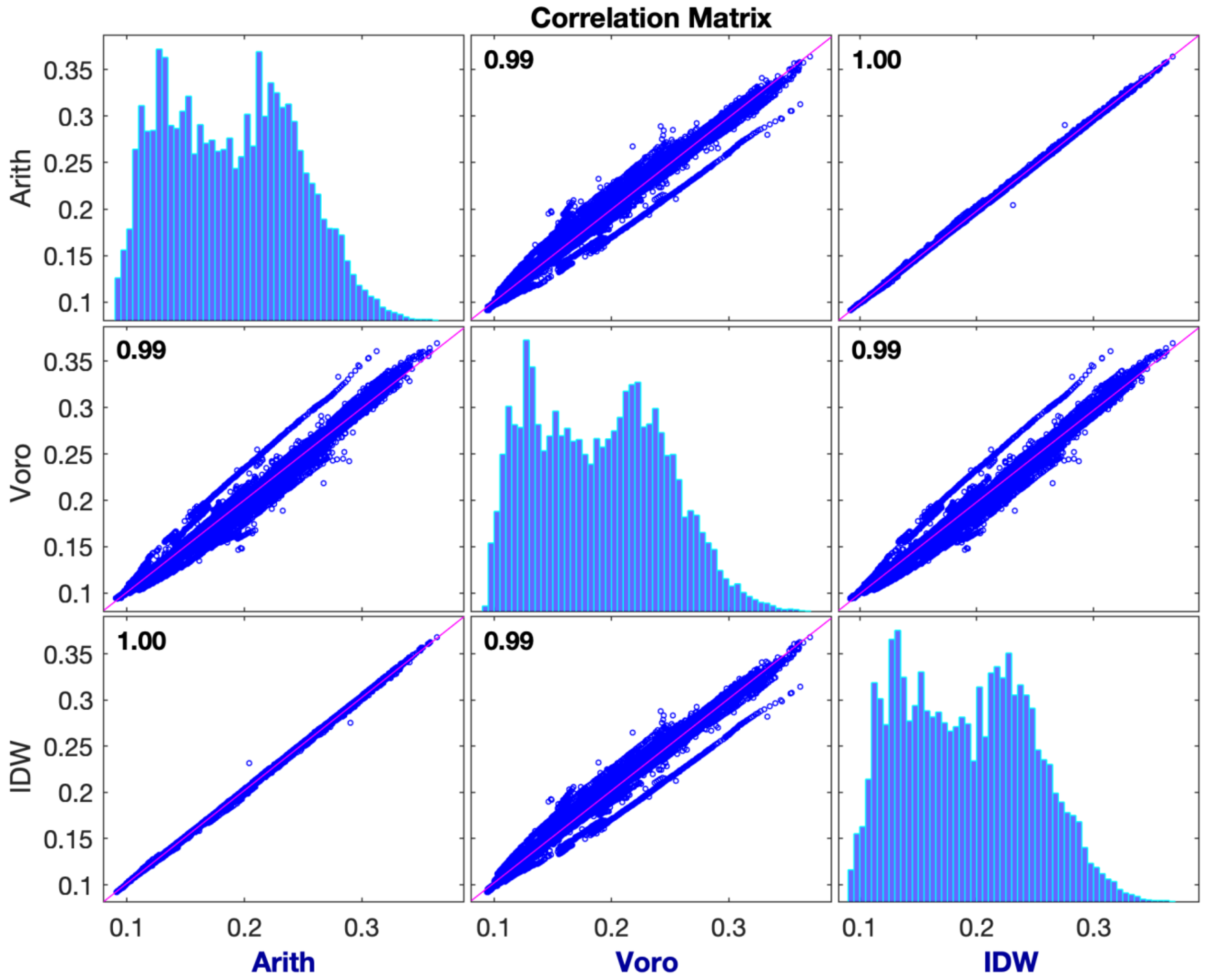


Field campaign – gravimetric sampling vs Evett SWC



Upscaling functions – arithmetic, Voronoi, IDW





- Arithmetic mean, Voronoi, and inverse (radial) distance
- Strongly correlated
- Minimal impact on SMAP metrics

TxSON: SMAP/Sentinel Validation at 3 km

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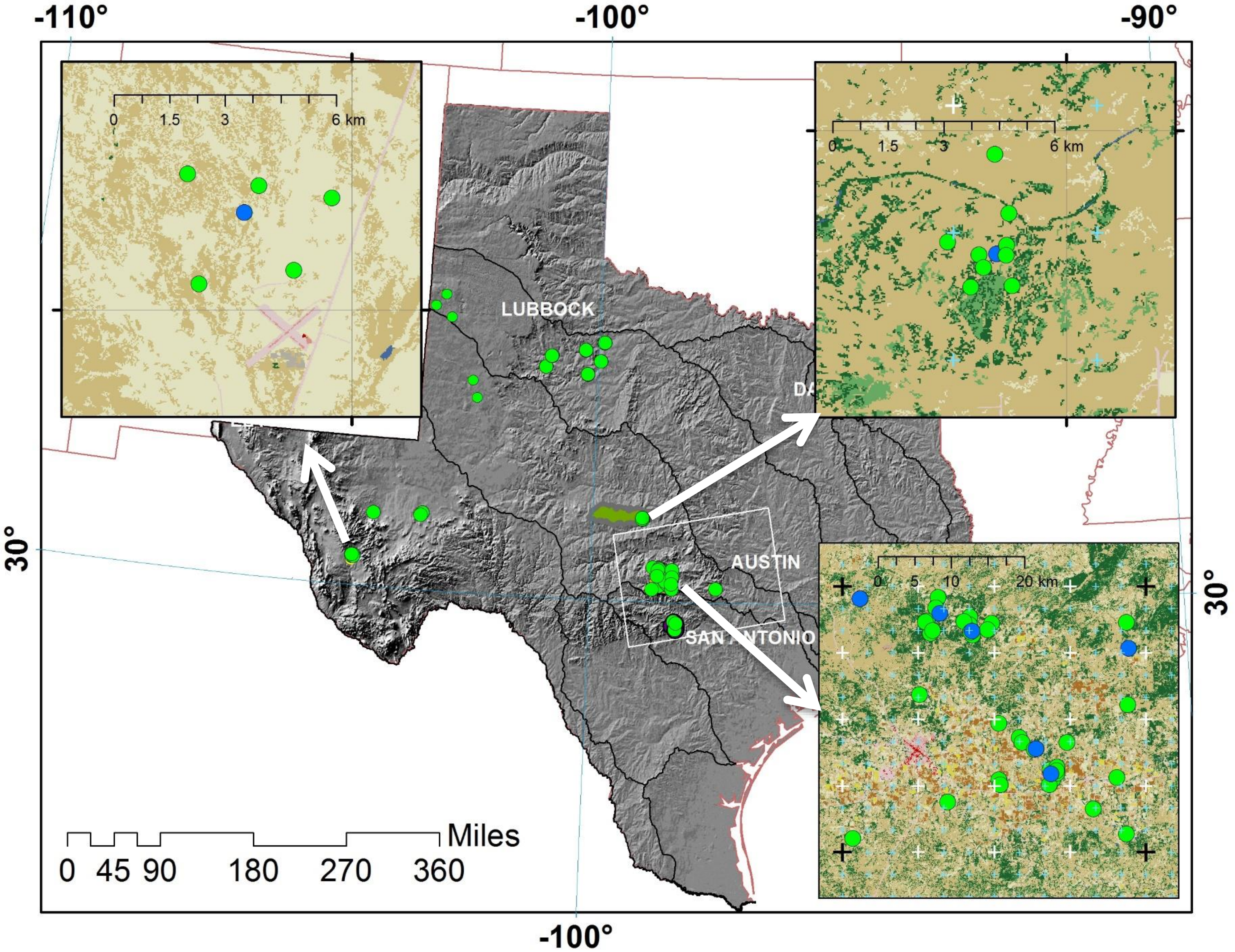
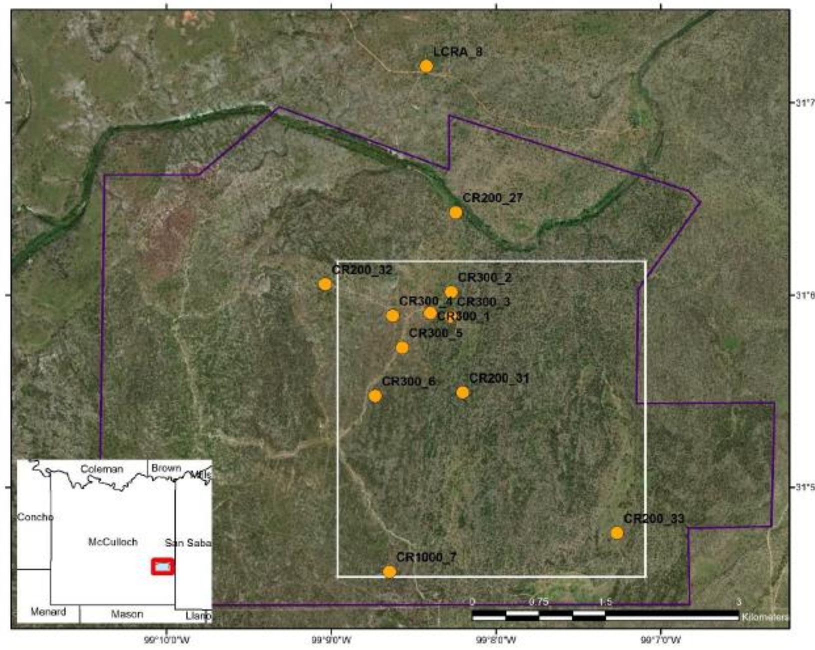
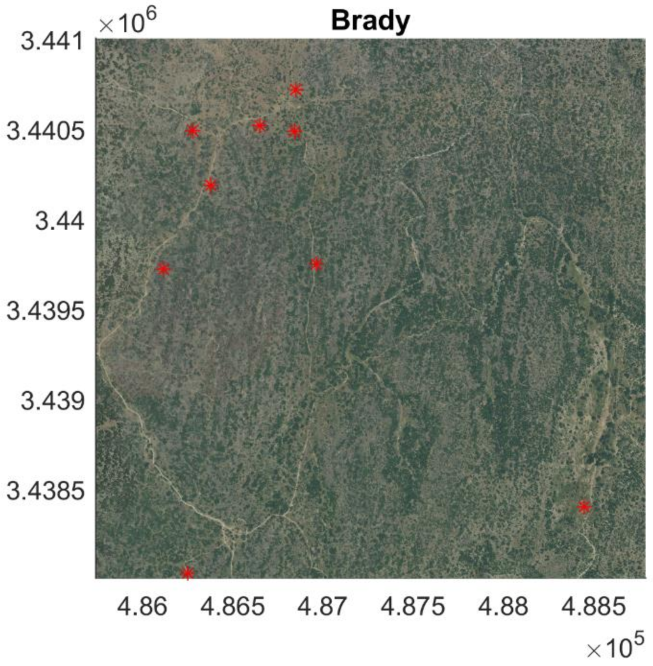
- In past 4 years, installed 70+ remote stations
- 2 dense, 3 km soil moisture networks 2017
- Intensively covering 30° latitude (E-W precipitation gradient)
- Intensively covering 100° longitude (N-S temperature gradient)

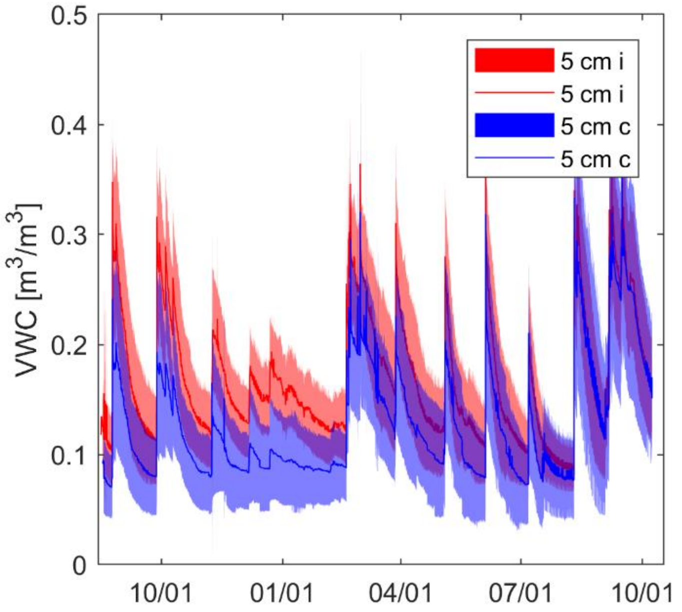


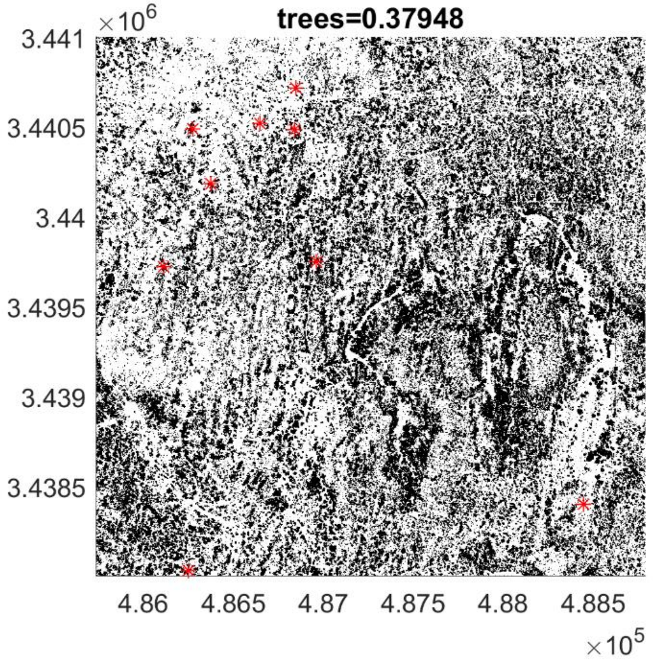
TxSON: Brady 3 km

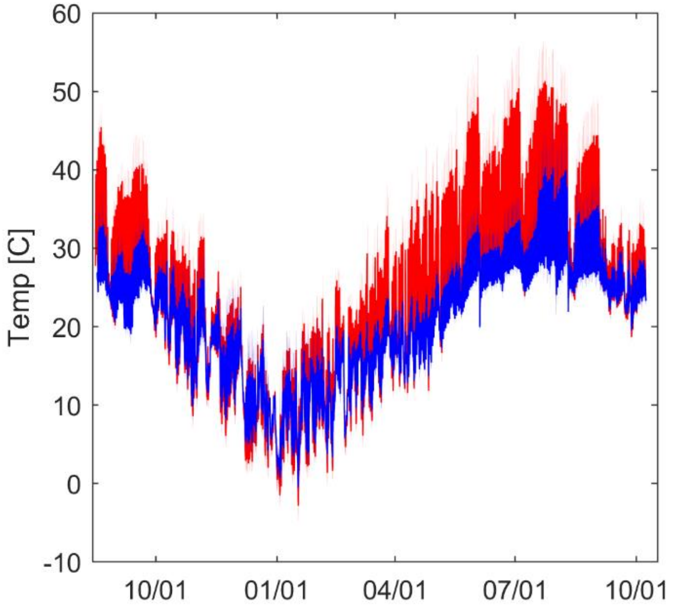
- TDR-315 and CS-655
- Paired measurements
  - Bare soil interspaces
  - Under Juniper canopy
- NAIP classify c:i ratio
  - 8:11 @ 5 cm
  - 5:7 @ 10 cm
  - 2:3 @ 20cm



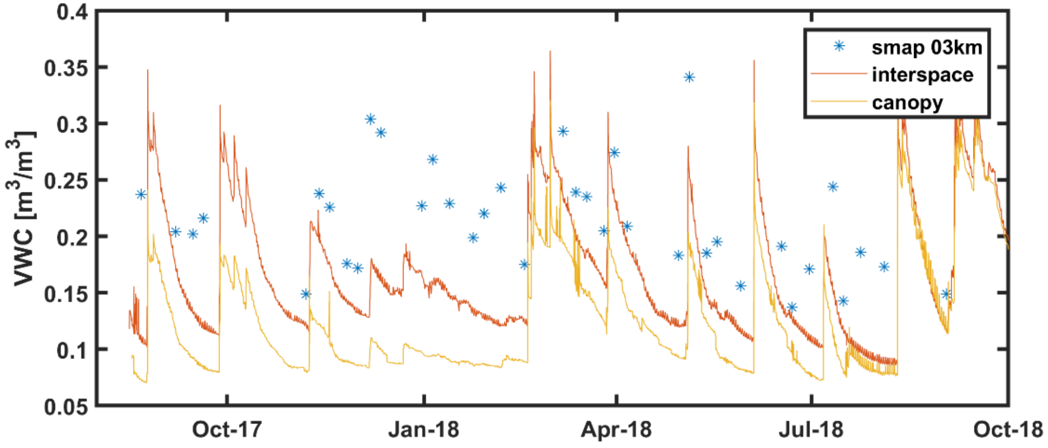


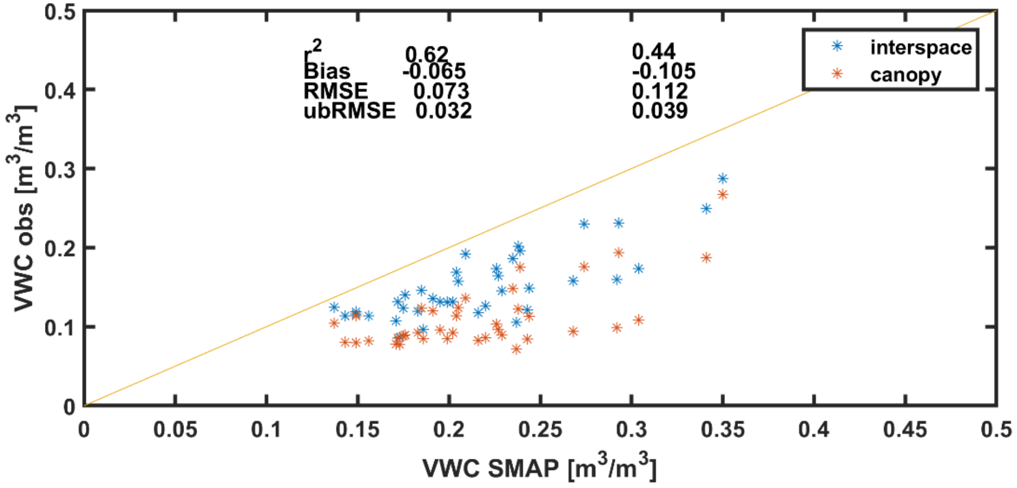


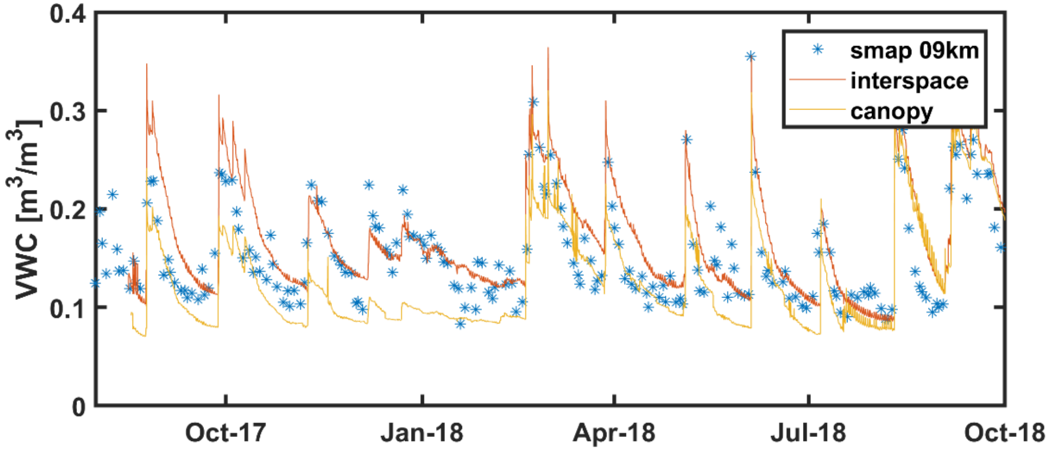


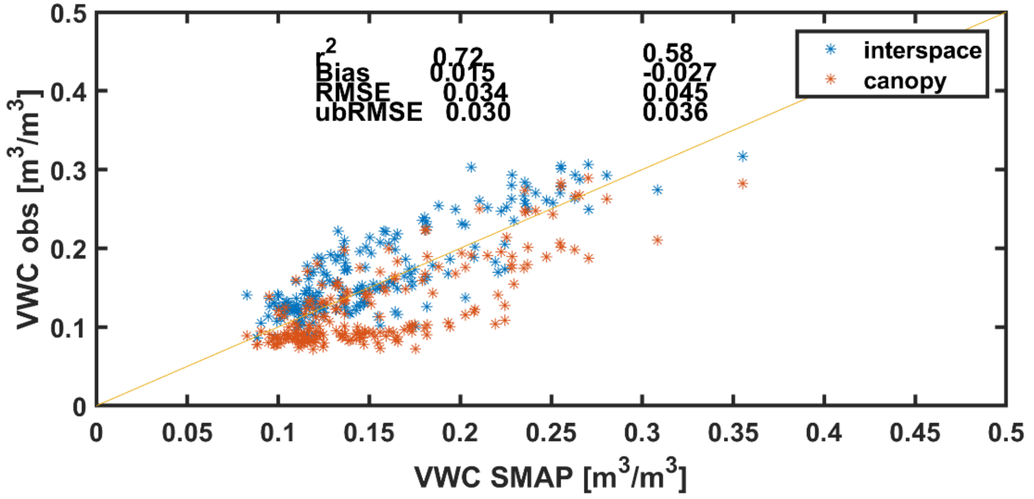


TxSON: Brady 3 km



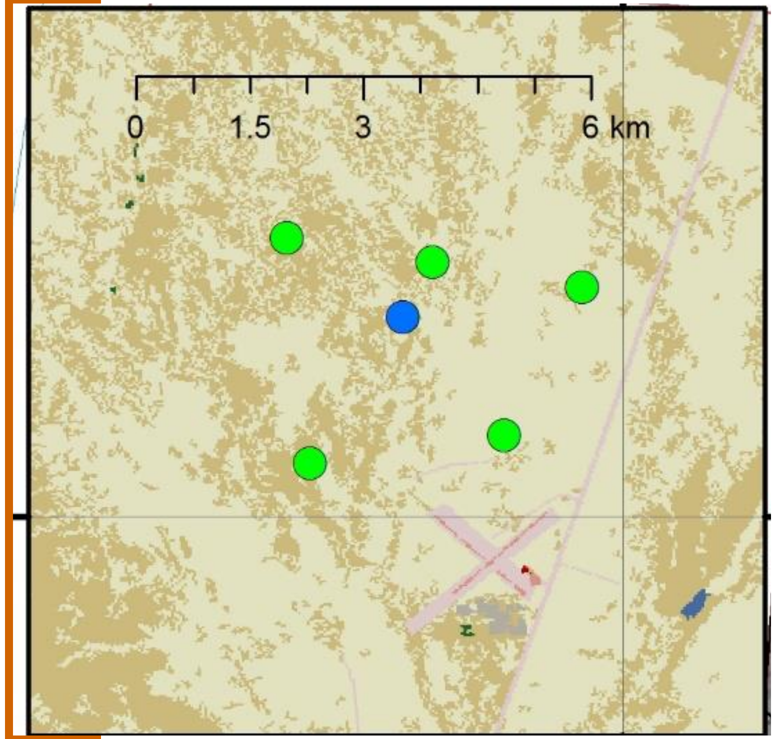


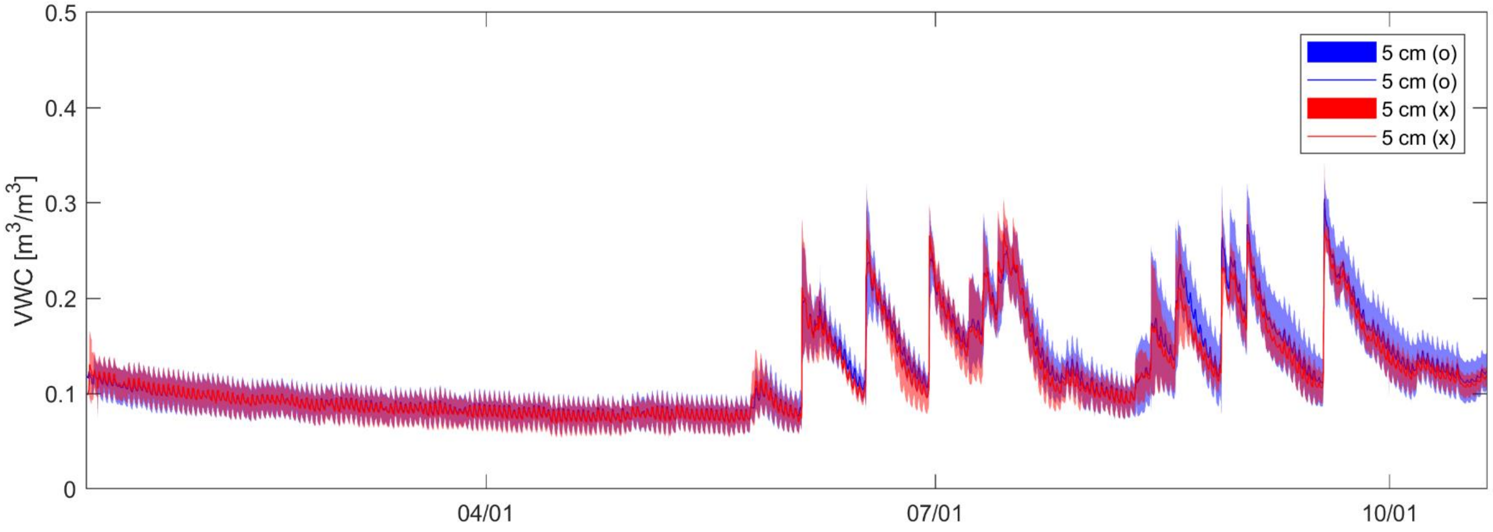


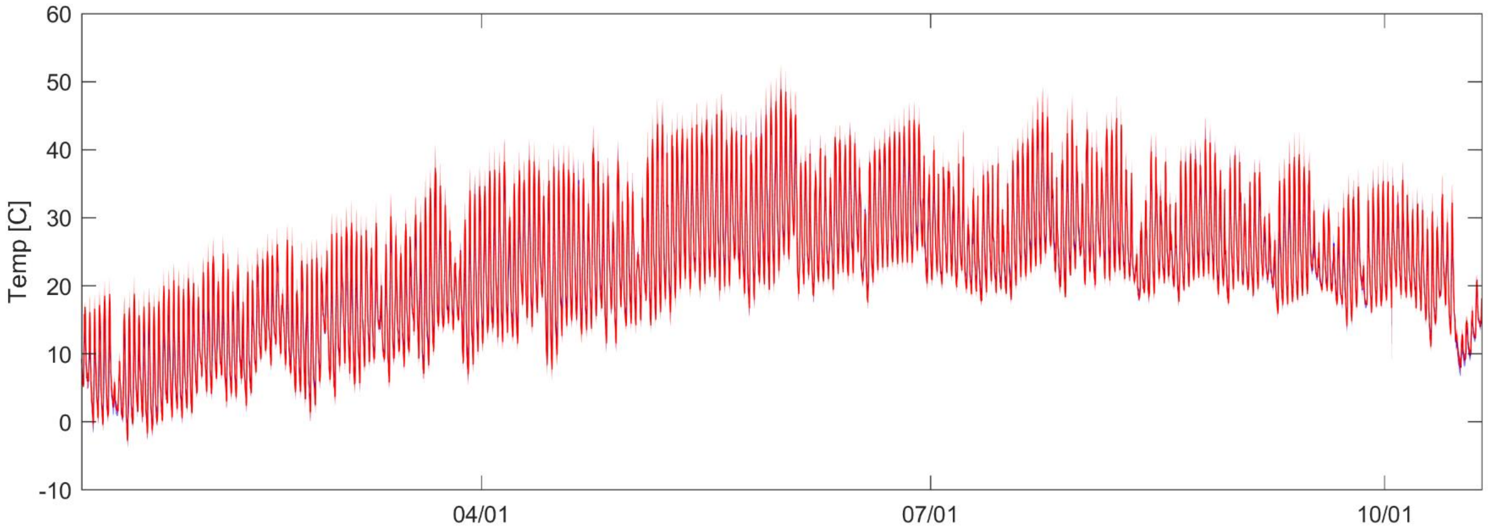


TxSON: Marfa 3 km (Mimms Unit)

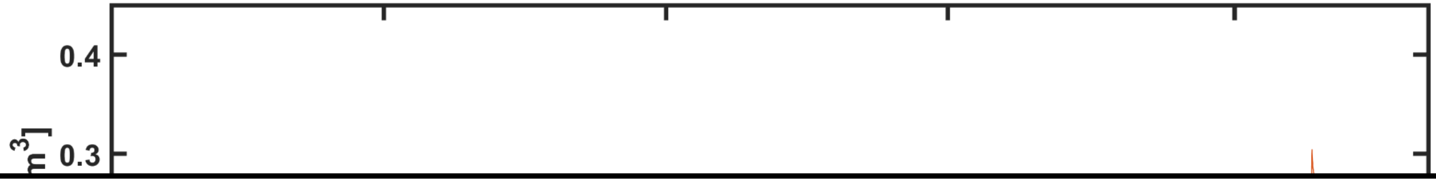
- CS-655 via spread spectrum radios
- Paired treatments
  - High intensity, short duration, n = 3
  - Standard density, cont. duration, n = 3
  - Exclosures (no grazing), n = 6





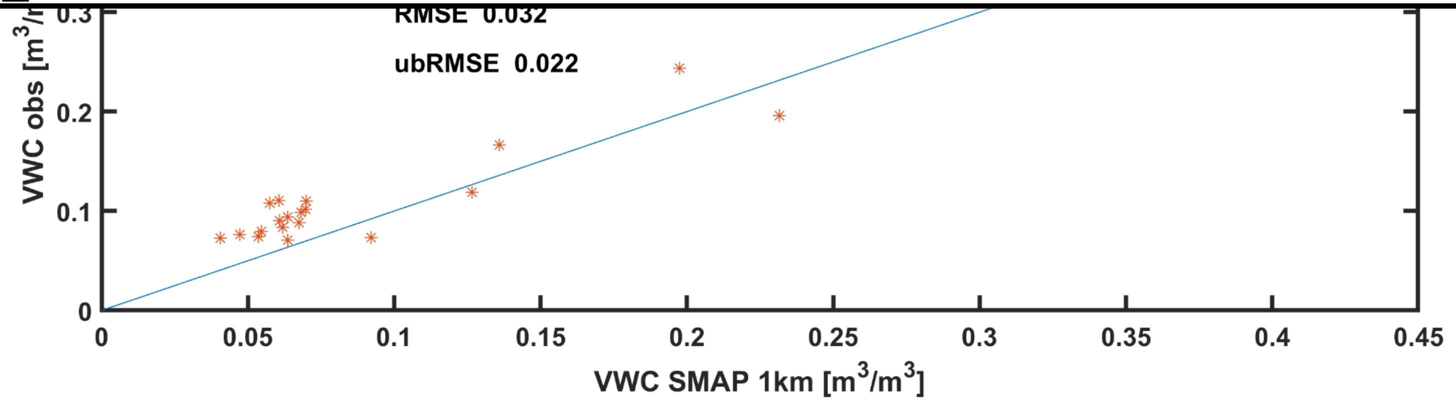


TxSON: Marfa 3 km (Mimms Unit)



1km

	r^2		bias		rmse		ubRMSE	
	open	Excl.	open	Excl.	open	Excl.	open	Excl.
300_7	0.739	0.787	0.020	0.010	0.035	0.027	0.029	0.025
300_8	0.821	0.766	0.017	0.012	0.029	0.030	0.024	0.028
300_9	0.712	0.668	0.010	0.038	0.023	0.043	0.021	0.021
300_10	0.309	0.271	0.041	0.031	0.060	0.055	0.044	0.045
300_11	0.868	0.852	0.047	0.027	0.051	0.035	0.021	0.023
300_12	0.810	0.792	0.000	0.007	0.023	0.025	0.023	0.024



Why is TxSON performing so well?

- Stratified vs. random site selection?
- Replication and upscaling functions?
- Nearly constant vegetation climatology?
- Sensor calibrations?
- Wet/dry cycles?

TxSON has taught us about TX rangelands:

- SMAP 0-5 cm SWC is robust, but
  - need to go deeper
  - need finer resolution, ideally 1 km
  - more frequent measurements
- Networks can feed into operations in real-time:
  - Partnerships between NASA, feds, universities and stakeholders work best when you have a common goal
  - Providing antecedent conditions
  - Drought mitigation requirements
  - Fire potential
  - http://coastal.beg.utexas.edu/soilmoisture/#/

LCRA ENERGY • WATER • COMMUNITY SERVICES
G. Rollie White Trust
JPL Jet Propulsion Laboratory
EDWARDS AQUIFER AUTHORITY
TEXAS PARKS & WILDLIFE
Dixon Water Foundation
The Nature Conservancy

Harris County Flood Control District

- March 2017: added CS655 sensors Harris County Flood Warning System
- Not many Hydromet stations around any native soil
- Two soils near K100_1185 Cypress Creek @ Sharp Road
  - Gessner (Ge) fine sandy loam
  - Katy* (Kf) fine sandy loam
- Installed sensors at 5, 20, and 40 cm
- Calibrated in Katy soil
- Recently added two more station, east of Houston

In cooperation with HCFCD staff Jeremy Justice, Mark Moore, Jim Greeson

Hurricane Harvey