Downscaling radiometer derived soil moisture
using
Radar
and
Visible/Near Infrared data

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Literature

Radar

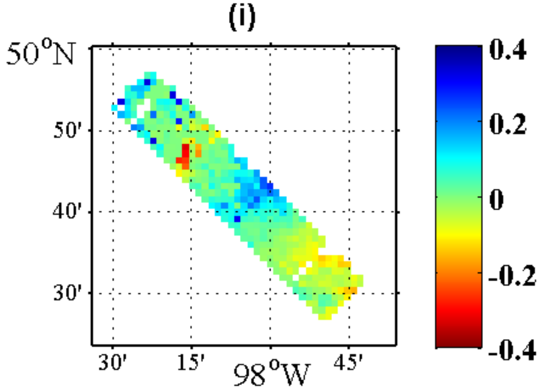
- Narayan, U., **Lakshmi, V**., and T. Jackson, High resolution change estimation of soil moisture using L-band radiometer and radar observations made during SMEX02 experiments, Vol. 44, No. 6, pp 1545-1554, *IEEE Transactions on Geoscience and Remote Sensing*, 2006

Vis/IR

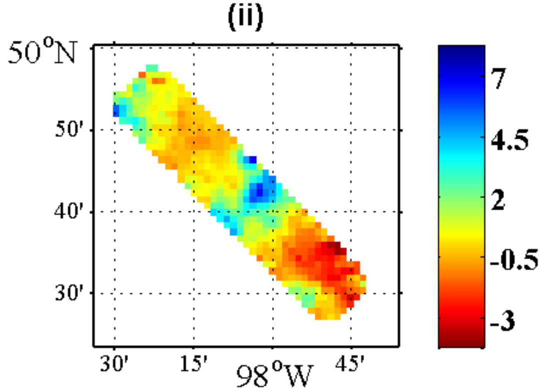
- Fang, B., **V. Lakshmi**, R. Bindlish, T. Jackson, M. Cosh and J. Basara, Passive Microwave Soil moisture downscaling using vegetation index and surface temperatures, *Vadose Zone Journal*, doi:10.2136/vzj2013.05.0089, 2013

Radar

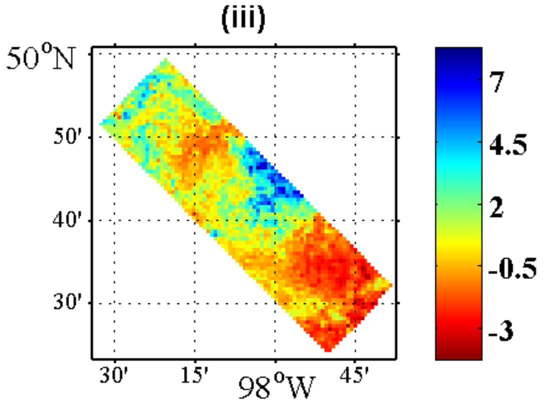
July 10 - 13



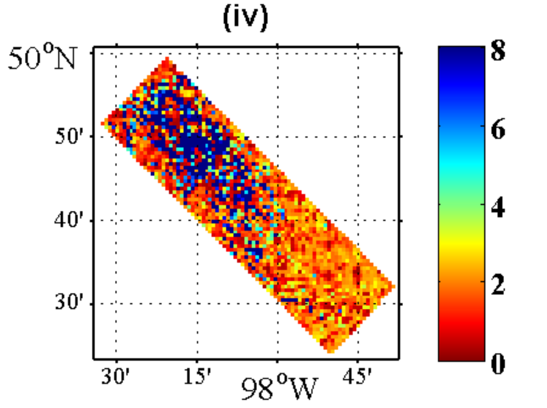
PALS Δθ (m³/m³,1500 m)



PALS Δσ (m³/m³,1500 m)



UAVSAR Δσ (m³/m³, 800 m)



Vegetation Water Content (kg/m², 800 m)

- PALS passive: 1K (bias); 0.2K (stability)
- PALS active: 2dB (bias); 0.2dB (stability)
- UAVSAR residual error by instrument: 3 dB for agricultural areas; 2.6 dB for forests

Change Estimation Approach

• Approximately linear dependence of radar backscatter change on soil moisture change[2]

$$\sigma^0_{pp} = C + Dm_v \qquad \textbf{(1)}$$

• Assume C does not change at the scale of few days, D depends on vegetation attenuation

$$\Delta\sigma^0_{pp} = D\Delta m_v \qquad \textbf{(2)}$$

• Relative sensitivity is a function of vegetation opacity only[1]

$$\frac{D}{D_0} = f(\tau) \qquad \textbf{(3)}$$

• Combining (2) and (3)

$$\Delta\sigma^0_{pp} = f(\tau)D_o\Delta m_v \qquad \textbf{(4)}$$

• Substituting and writing for m_v

$$\Delta m_v = \frac{\Delta\sigma^0}{S_0} \qquad \textbf{(5)}$$

• Expressing m_v change at a lower resolution (radiometer X), $S_0 = f(\tau)D_0$

$$\Delta m_{v,X} = \frac{1}{N}\sum m_{v,x} \qquad \textbf{(6)}$$

•Evaluation of S at lower resolution

$$S_0 = \frac{1}{N}\frac{\sum\Delta\sigma^0_x}{\Delta m_{v,X}} \qquad \textbf{(7)}$$

•For SMPVEX12, τ was unchanged within footprint, soil moisture change at the higher spatial resolution (radar x)

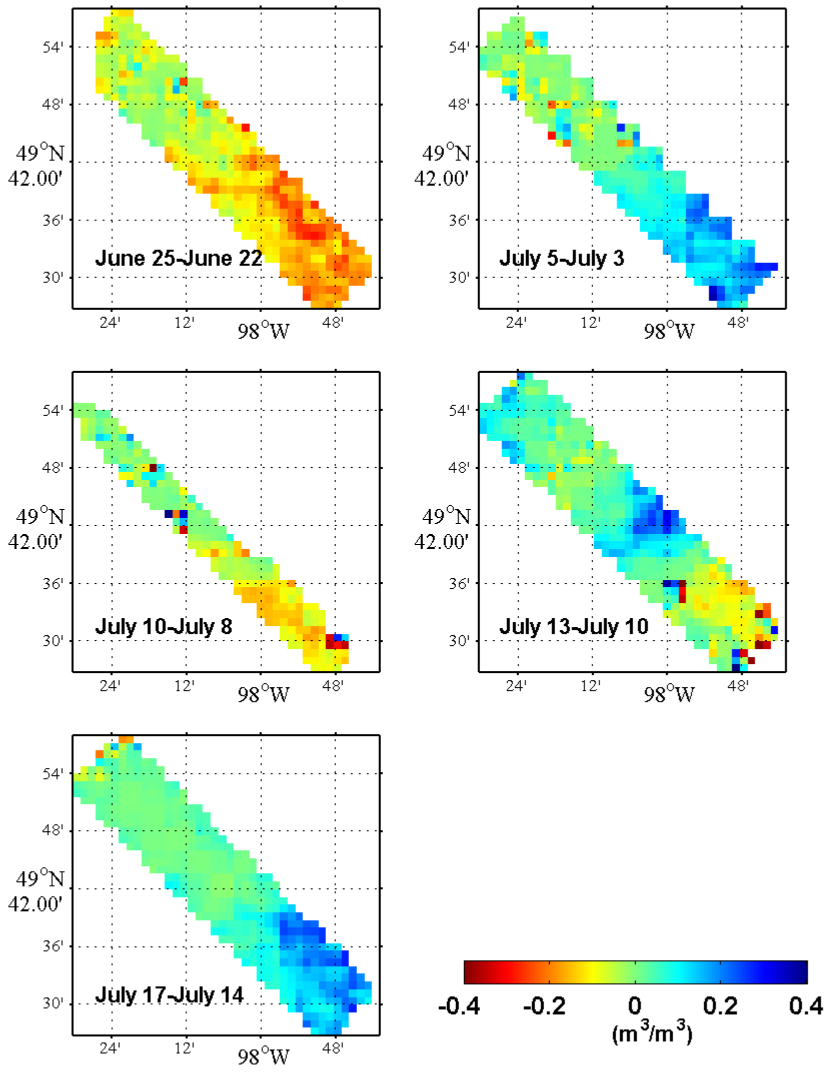
$$\Delta m_{v,x} = \frac{\Delta\sigma^0_x}{S_0} \qquad \textbf{(8)}$$

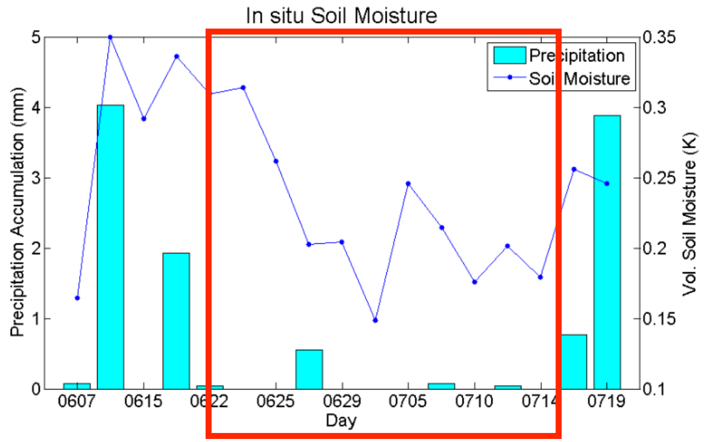
(1) Du, Y., F.T. Ulaby, and M.C. Dobson, *Sensitivity to soil moisture by active and passive microwave sensors.* IEEE Transactions on Geoscience and Remote Sensing, 2000. **38**(1): p. 105-114.

(2) Njoku, E.G., W.J. Wilson, S.H. Yueh, S.J. Dinardo, F.K. Li, T.J. Jackson, V. Lakshmi, and J. Bolten, *Observations of soil moisture using a passive and active low-frequency microwave airborne sensor during SGP99.* IEEE Transactions on Geoscience and Remote Sensing, 2002. **40**(12): p. 2659-2673.

Disaggregated Soil Moisture

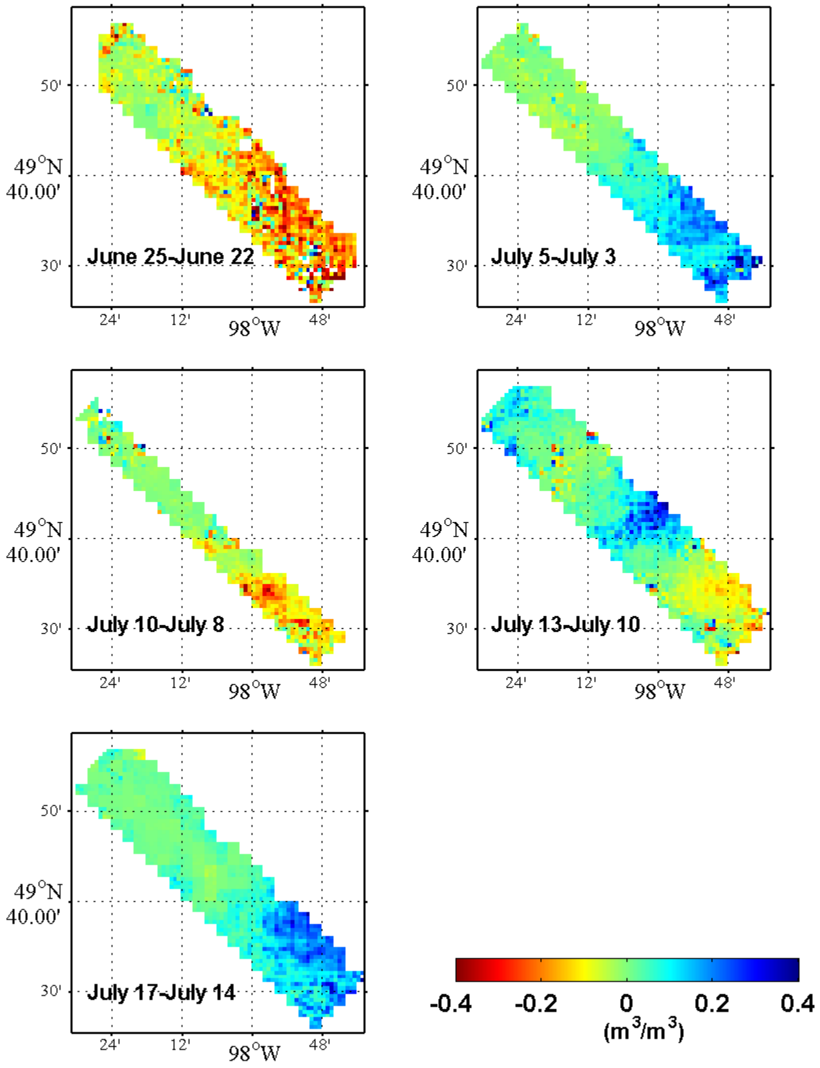
PALS (1500 m)





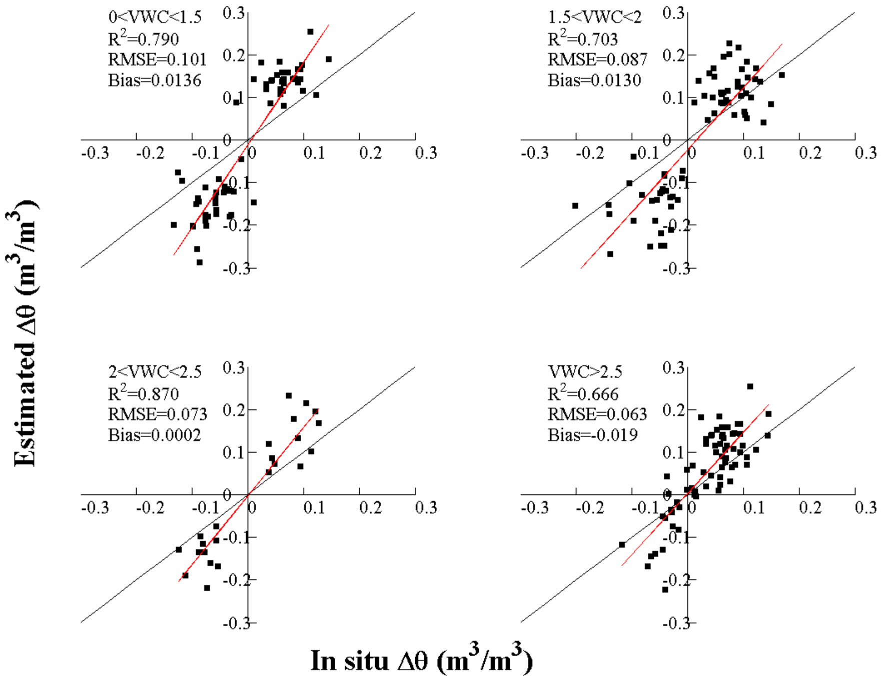
Box shows covered time period

UAVSAR (800 m)

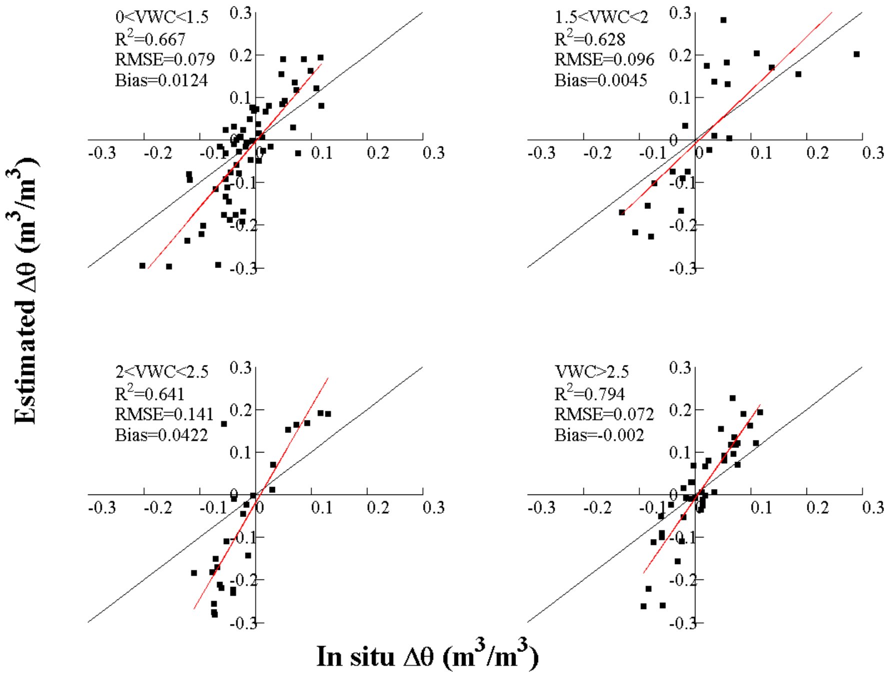


Overall Estimated Δ vs. In Situ Δ

PALS



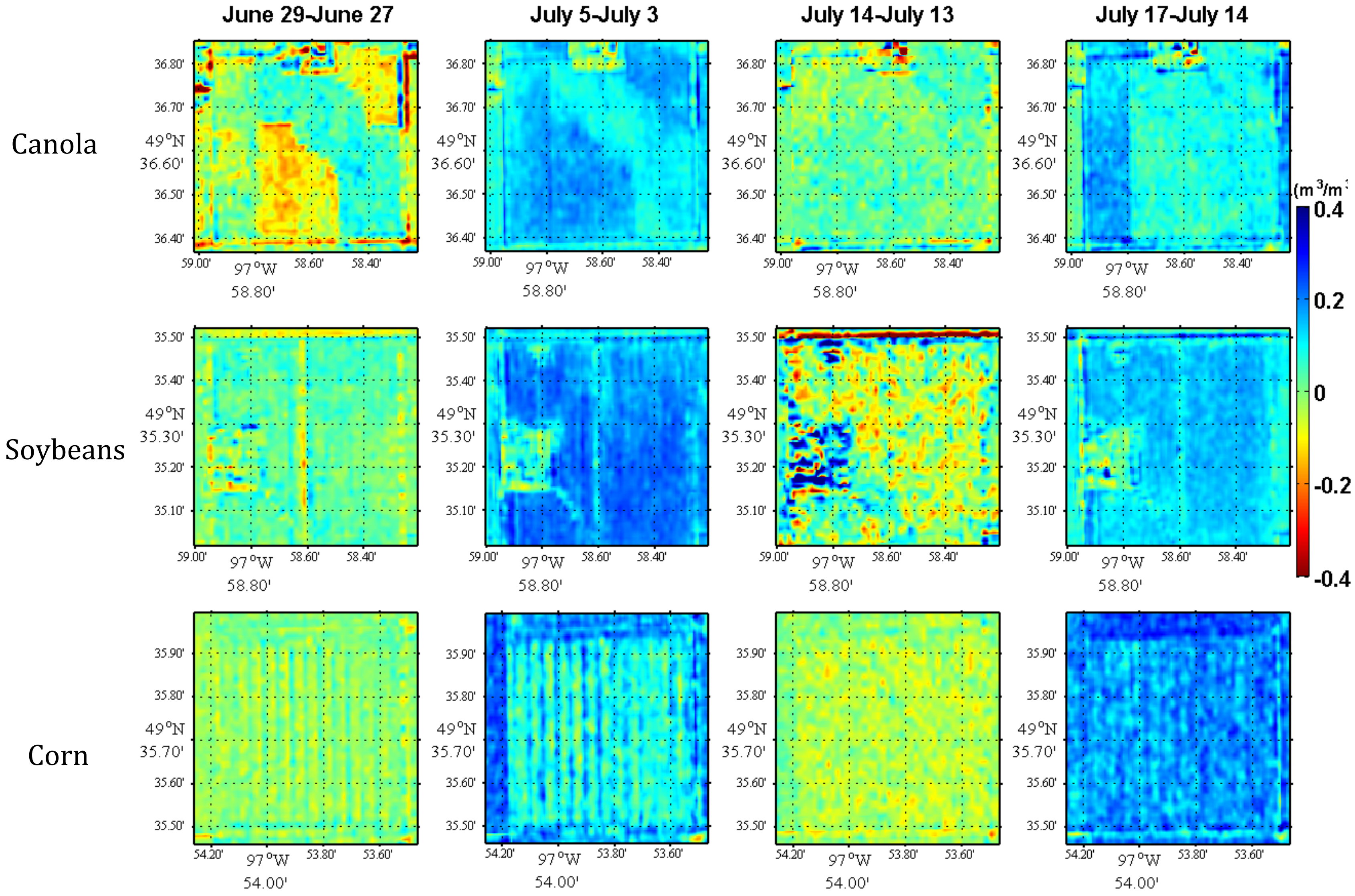
UAVSAR

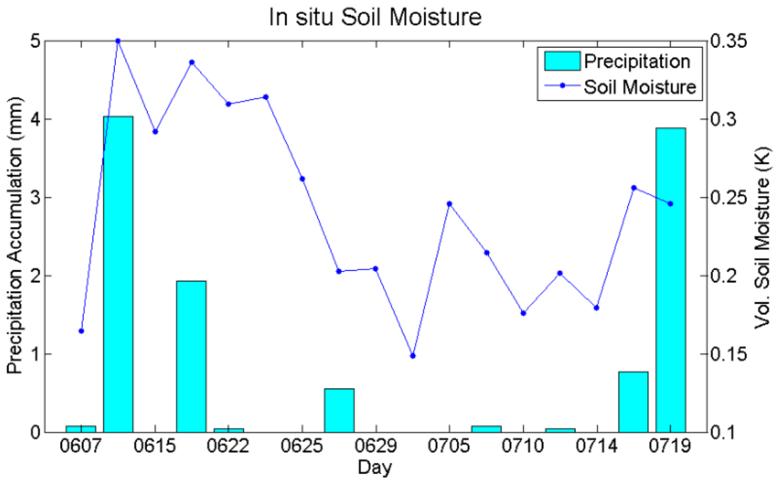


	Number of Points	R^2	Slope	RMSE (m^3/m^3)	Bias (m^3/m^3)
0<VWC<1.5	64	0.79	1.939	0.101	0.014
1.5<VWC<2	68	0.703	1.458	0.087	0.013
2<VWC<2.5	23	0.87	1.607	0.073	<0.001
VWC>2.5	48	0.666	1.432	0.063	-0.019

	Number of Points	R^2	Slope	RMSE (m^3/m^3)	Bias (m^3/m^3)
0<VWC<1.3	60	0.667	1.542	0.079	0.012
1.3<VWC<1.8	22	0.628	1.257	0.096	0.005
1.8<VWC<2.2	27	0.641	2.257	0.141	0.042
VWC>2.2	40	0.794	1.89	0.072	-0.002

Disaggregated UAVSAR $\Delta\theta$ At 5M Resolution (m^3/m^3)

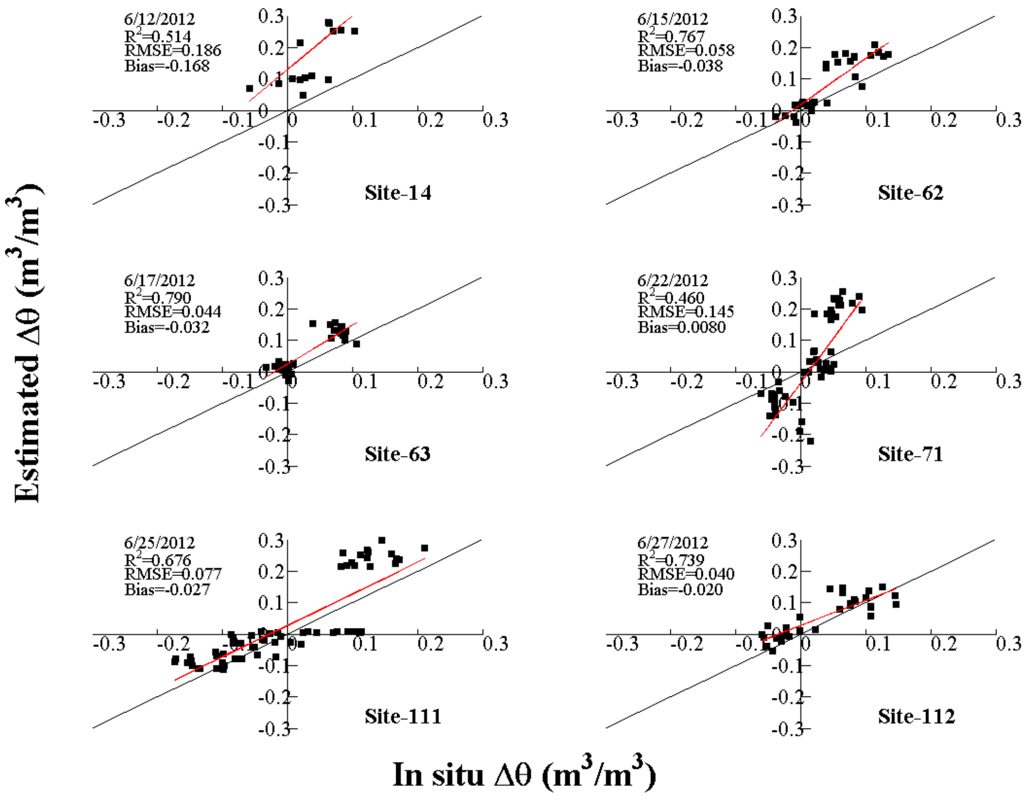




The 5m UAVSAR displays the crop features such as rows and smaller features of wetting and drying

Validation of Disaggregated UAVSAR Δθ (5m)

From the days of July 5-July 3, July 8-July 5, July 10-July 8, Jul 13-July 10



Site	Type	Number	R^2	Slope	RMSE (m^3/m^3)	Bias (m^3/m^3)
Site-14	Soybeans	22	0.514	1.171	0.186	-0.168
Site-62	Canola	31	0.767	1.471	0.058	-0.038
Site-63	Soybeans	32	0.79	1.24	0.044	-0.032
Site-71	Corn	51	0.46	2.82	0.145	0.008
Site-111	Soybeans	64	0.676	0.998	0.077	-0.027
Site-112	Soybeans	32	0.739	0.802	0.04	-0.02

Site	UAVSAR θ (m^3/m^3)	In Situ θ (m^3/m^3)	Difference θ (m^3/m^3)
Site-14	**0.113**	0.049	0.064
Site-62	**0.081**	0.052	0.029
Site-63	**0.061**	0.049	0.012
Site-71	**0.169**	0.038	0.131
Site-111	**0.128**	0.106	0.022
Site-112	**0.062**	0.062	<0.001

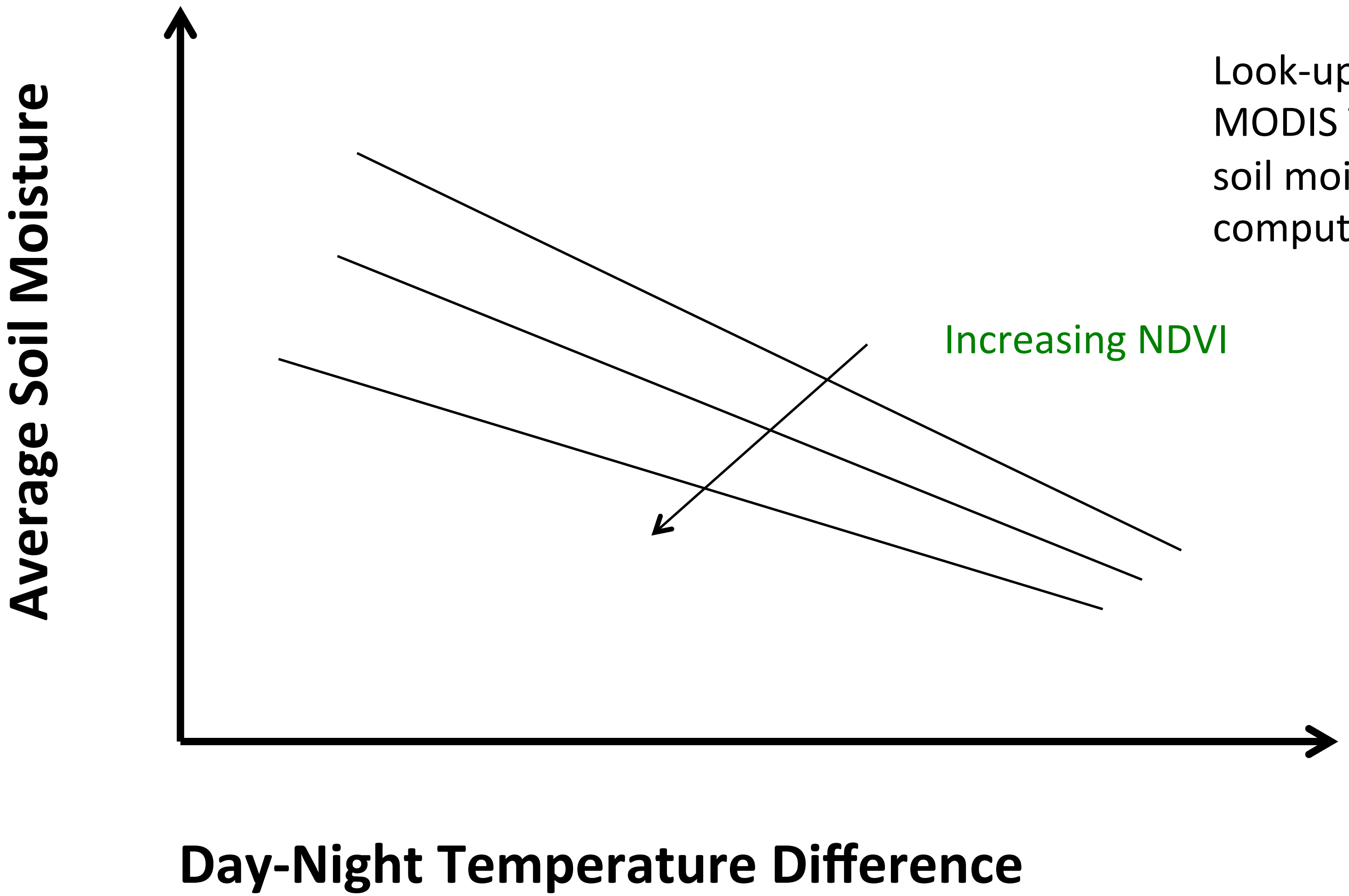
Summary - Radar

- Downscaling using PALS radar and UAVSAR both result in good results. The exception is the method – as PALS radiometer and radar have same spatial resolution (1500m), there was an up-scaling of the radiometer (to 4500m) followed by downscaling (to 1500m). In the case of UAVSAR (field scale 800m) no such exercise was conducted.
- The 5m UAVSAR was used to downscale to specific points in each field and this illustrates the higher spatial resolution: UAVSAR can pick out crop rows
- Crop type does not influence the downscaling results.

Visible/Near Infrared

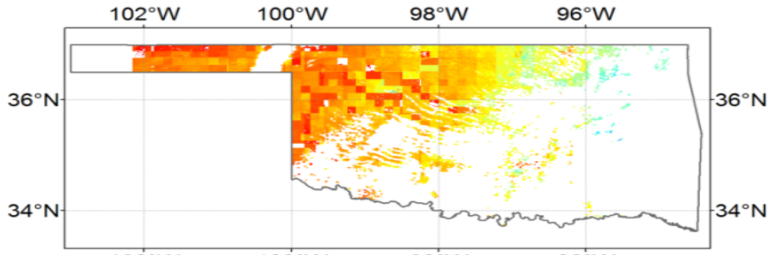
There also exists a simple method based on thermal inertia using vegetation surface temperature from MODIS to downscale AMSR-E derived soil moisture from 0.25^o to 1km

Average soil moisture versus day-night temperature difference

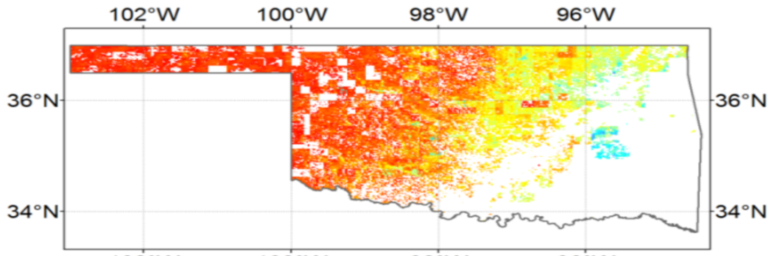


Look-up tables are created using MODIS Ts, NDVI and N/GLDAS soil moisture making this method computationally efficient

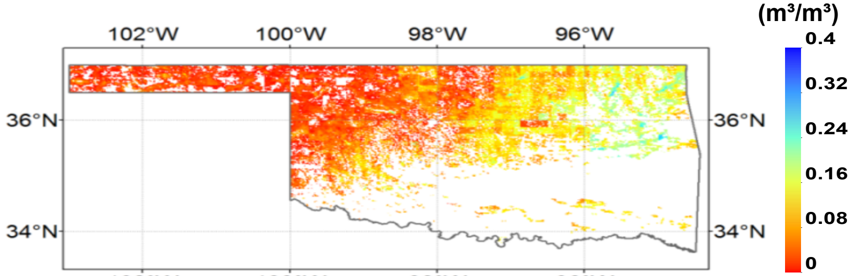
1KM, AMSR-E AND NLDAS SOIL MOISTURE FOR OKLAHOMA



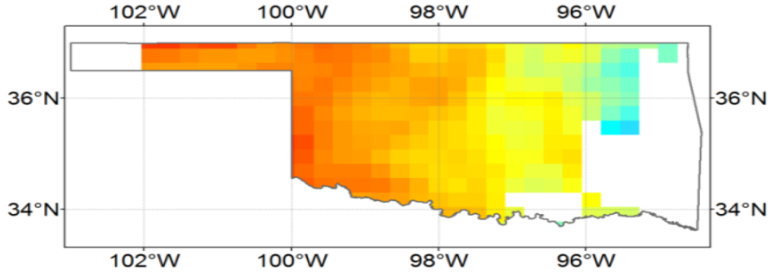
1 km θ^{av} from May 22, 2004



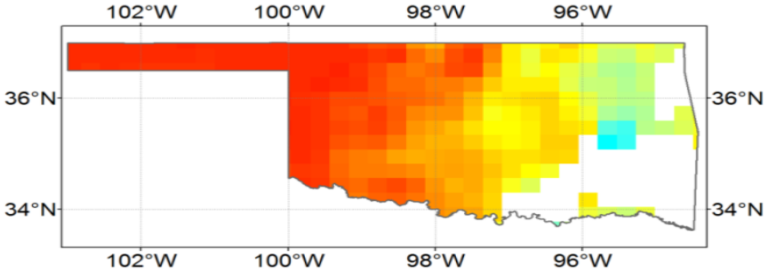
1 km θ^{av} from July 17, 2005



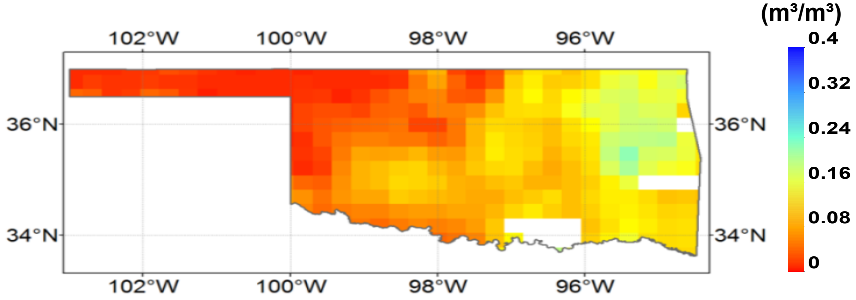
1 km θ^{av} from August 9, 2005



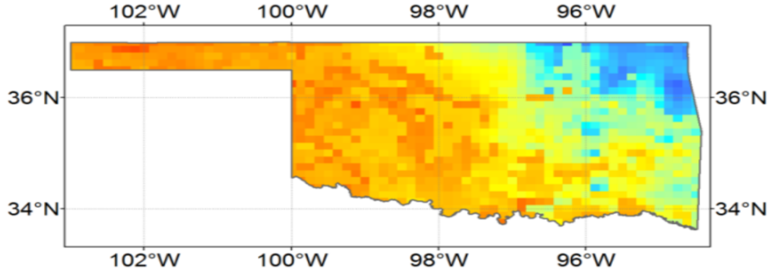
AMSR-E θ^{av} from May 22, 2004



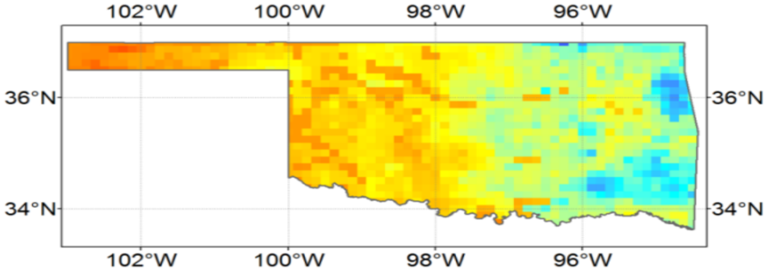
AMSR-E θ^{av} from July 17, 2005



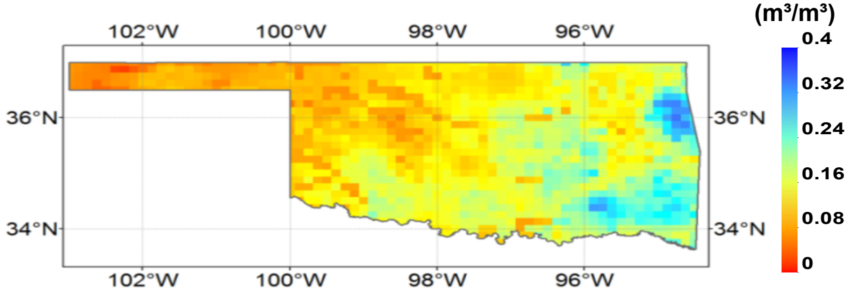
AMSR-E θ^{av} from August 9, 2005



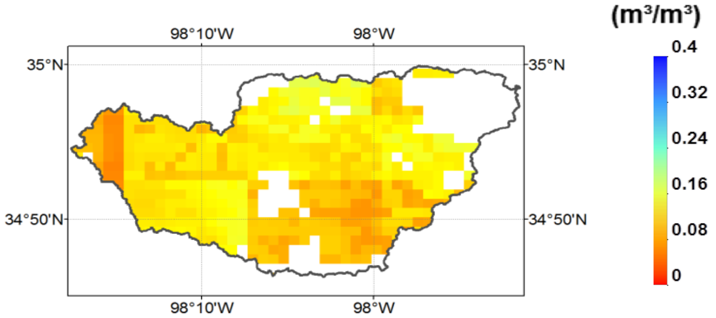
NLDAS θ^{av} from May 22, 2004



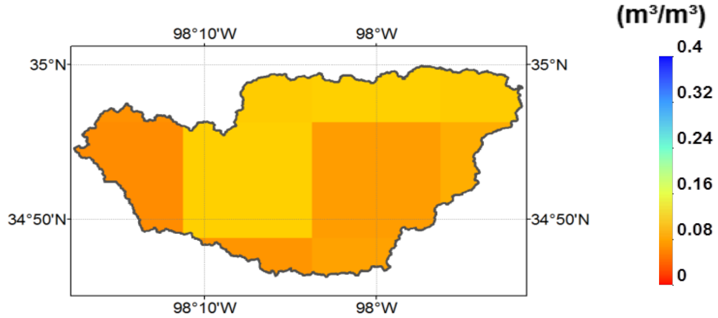
NLDAS θ^{av} from July 17, 2005



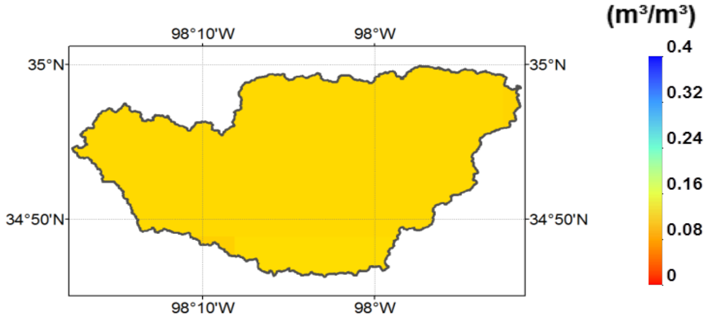
NLDAS θ^{av} from August 9, 2005



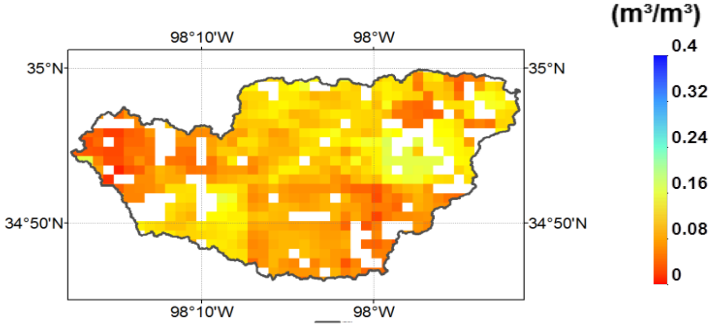
θ_{1km} from May 22, 2004



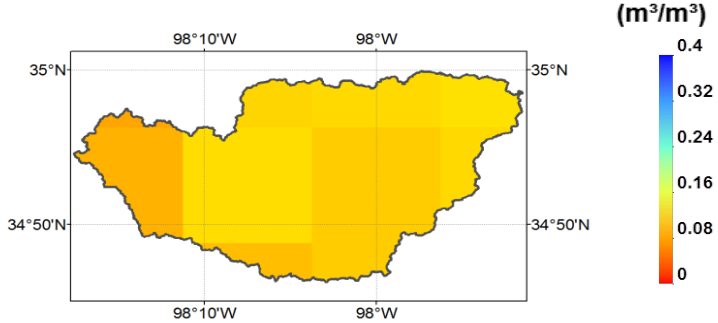
θ_{NLDAS} from May 22, 2004



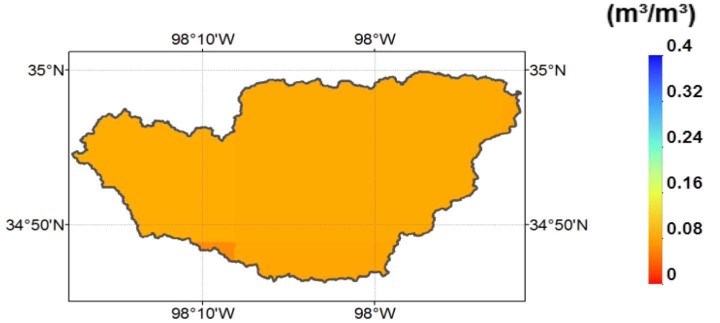
$\theta_{AMSR\text{-}E}$ from May 22, 2004



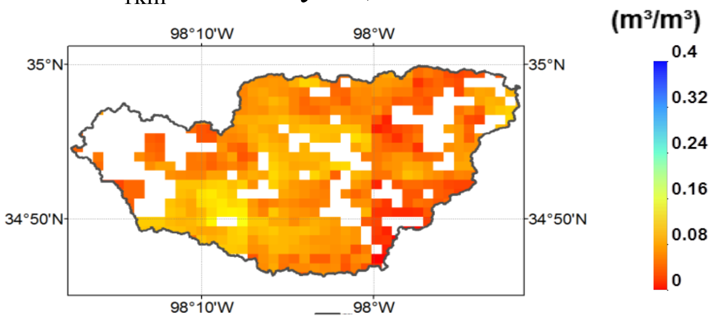
θ_{1km} from July 17, 2005



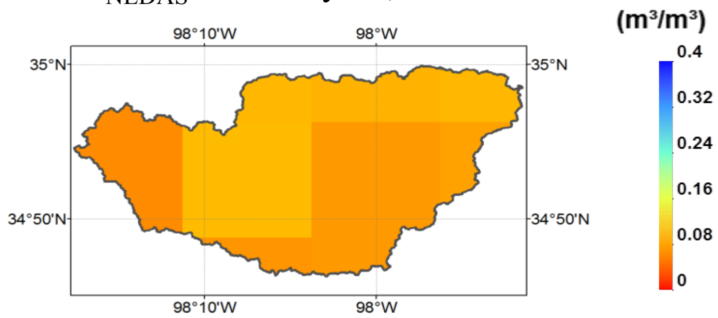
θ_{NLDAS} from July 17, 2005



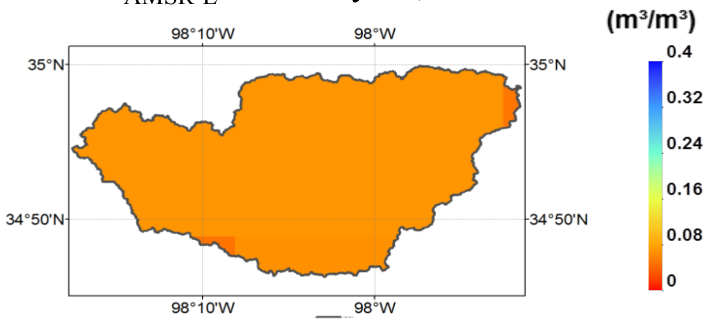
$\theta_{AMSR\text{-}E}$ from July 17, 2005



θ_{1km} from August 2, 2005

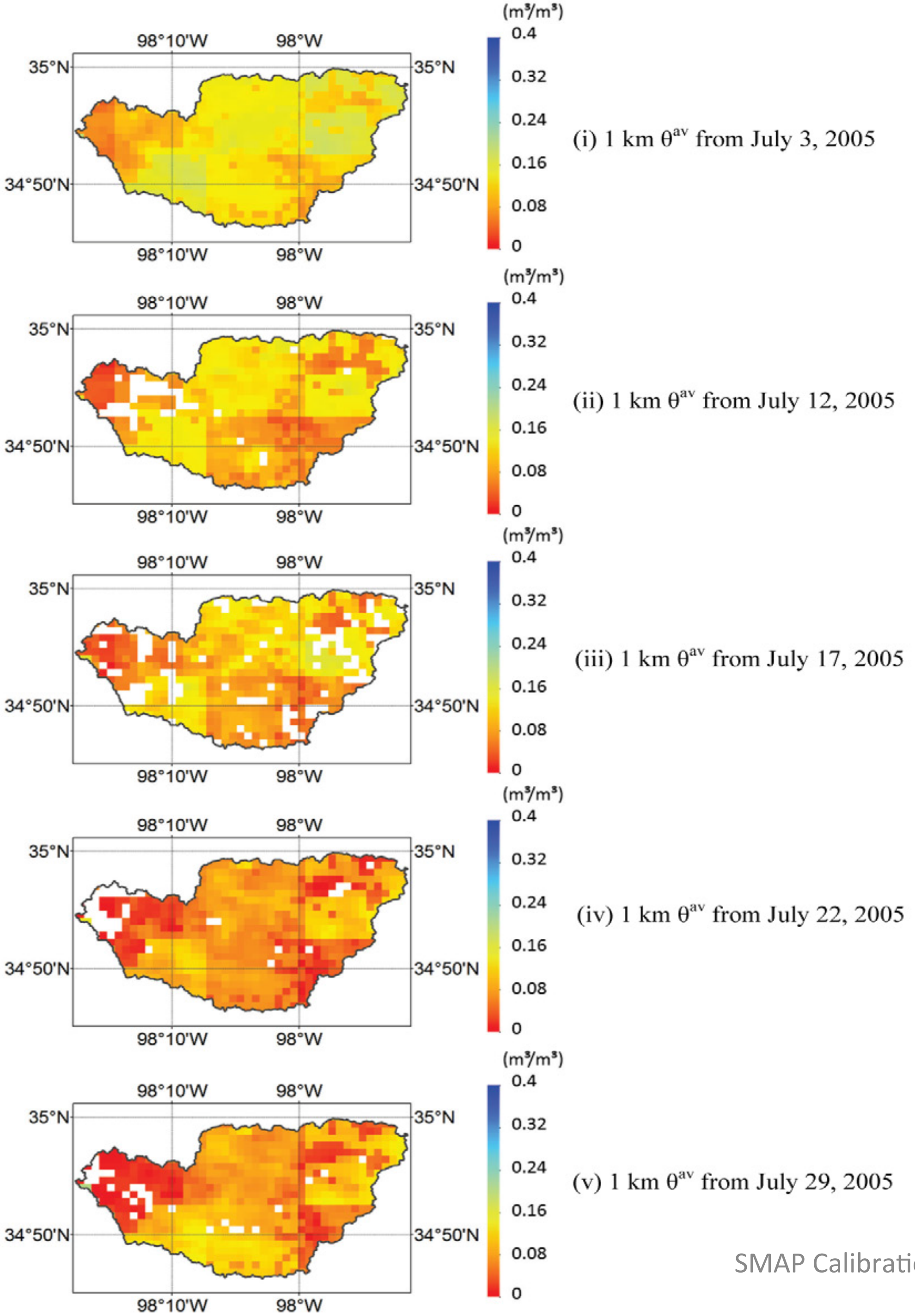


θ_{NLDAS} from August 2, 2005



$\theta_{AMSR\text{-}E}$ from August 2, 2005

1KM, AMSR-E AND NLDAS SOIL MOISTURE FOR LITTLE WASHITA



Dry down at catchment scale

Maps are produced using 0.25° satellite soil moisture that is downscaled to 1km spatial resolution using the physical relationship between vegetation and surface temperature over a 20 year period.

This method is validated using an in-situ observational network

Fang, B., V. Lakshmi, R. Bindlish, T. Jackson, M. Cosh and J. Basara, Passive Microwave Soil moisture downscaling using vegetation index and surface temperatures, Vadose Zone Journal, doi:10.2136/vzj2013.05.0089, 2013

VALIDATION WITH LITTLE WASHITA MICRONET OBSERVATIONS

Day	Dataset	Slope	RMSE (m^3/m^3)	Unbiased RMSE (m^3/m^3)	Spatial Standard Deviation (m^3/m^3)	Number of Points
May 2004	1km Downscaled	0.316	0.06	0.024	0.017	73
	AMSR-E	0.057	0.053	0.021	0.001	
	NLDAS	0.138	0.049	0.026	0.01	
	Micronet				0.027	
July 2005	1km Downscaled	0.1	0.058	0.03	0.029	68
	AMSR-E	0.062	0.038	0.03	0.004	
	NLDAS	0.068	0.051	0.032	0.002	
	Micronet				0.028	
Total	1km Downscaled	0.208	0.059	0.027	0.023	141
	AMSR-E	0.06	0.046	0.026	0.003	
	NLDAS	0.103	0.05	0.029	0.006	
	Micronet				0.028	

If needed…

- We can harness the power of MODIS [Surface Temperature and NDVI] to downscale the SMAP Radiometer derived soil moisture
- This will be limited by cloud cover and very high vegetation regions
- Look up tables can be refined using a suite of models. Regional models with higher spatial resolution can help to improve downscaled resolution/accuracy

Thank you