Multi-scale Soil Moisture Model Calibration and Validation:

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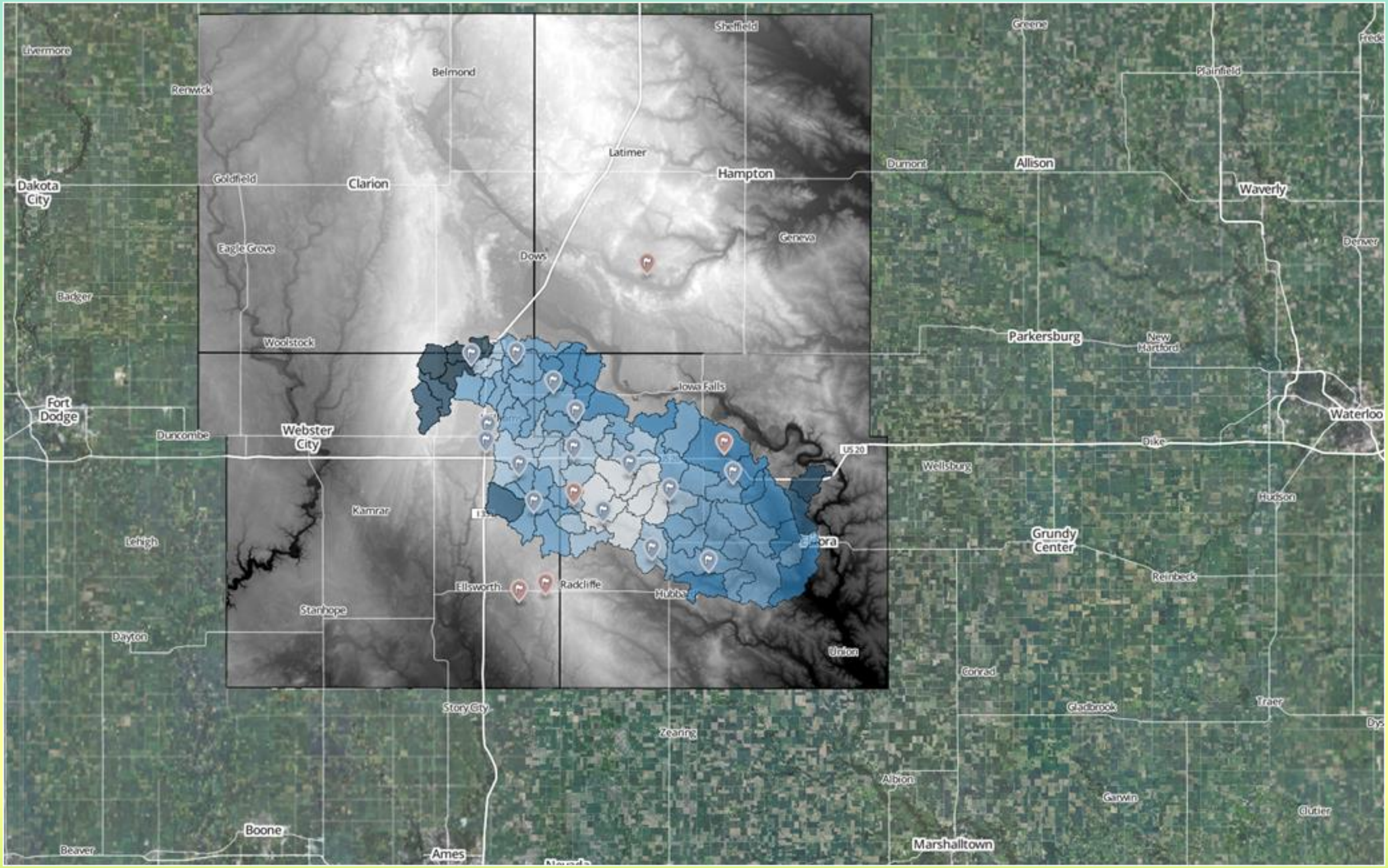
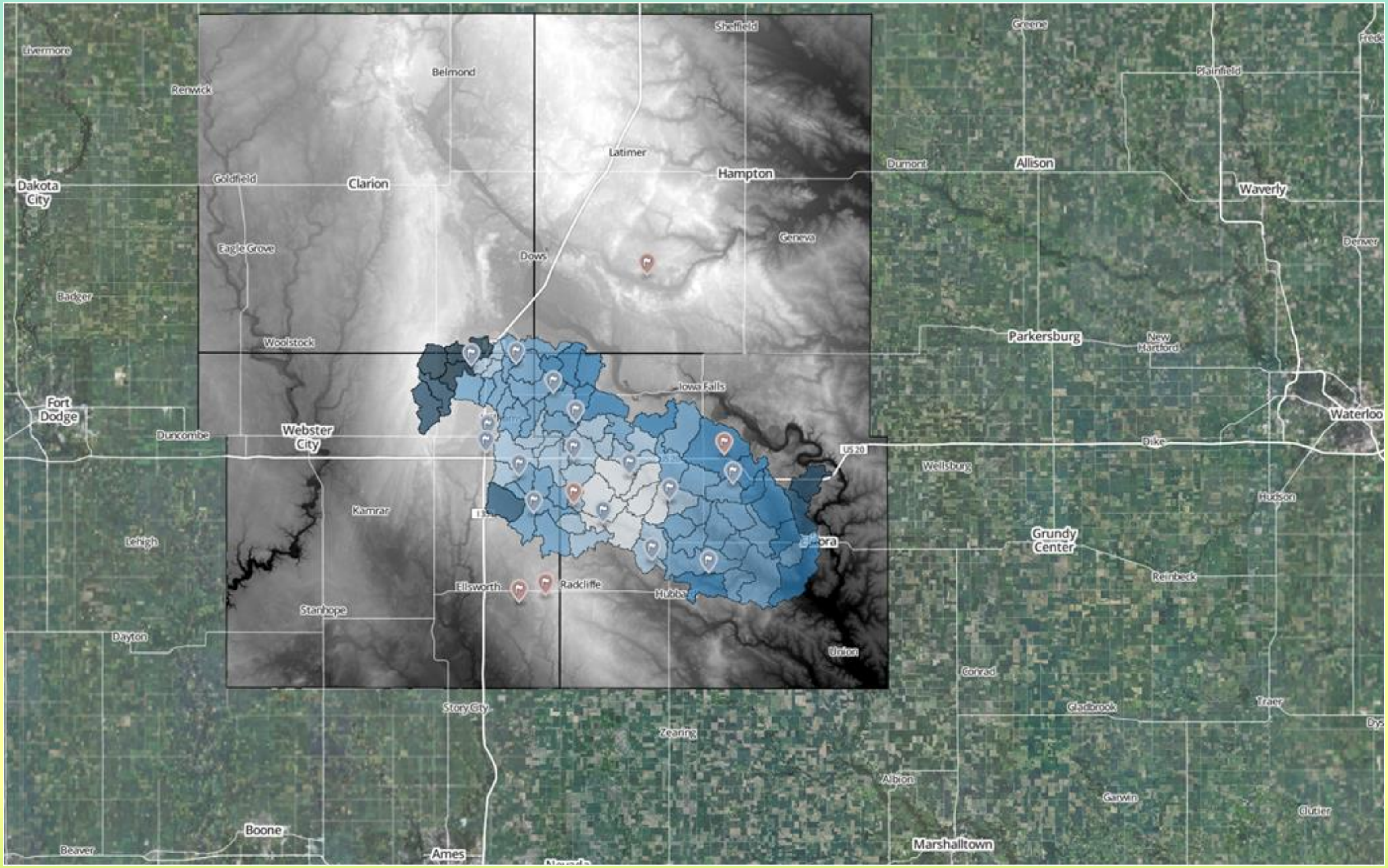


An Ideal Location:

Three Types of Similarity…



Hydro-climatic (47km x 40km)

Edaphic (clay loam with tile drains)

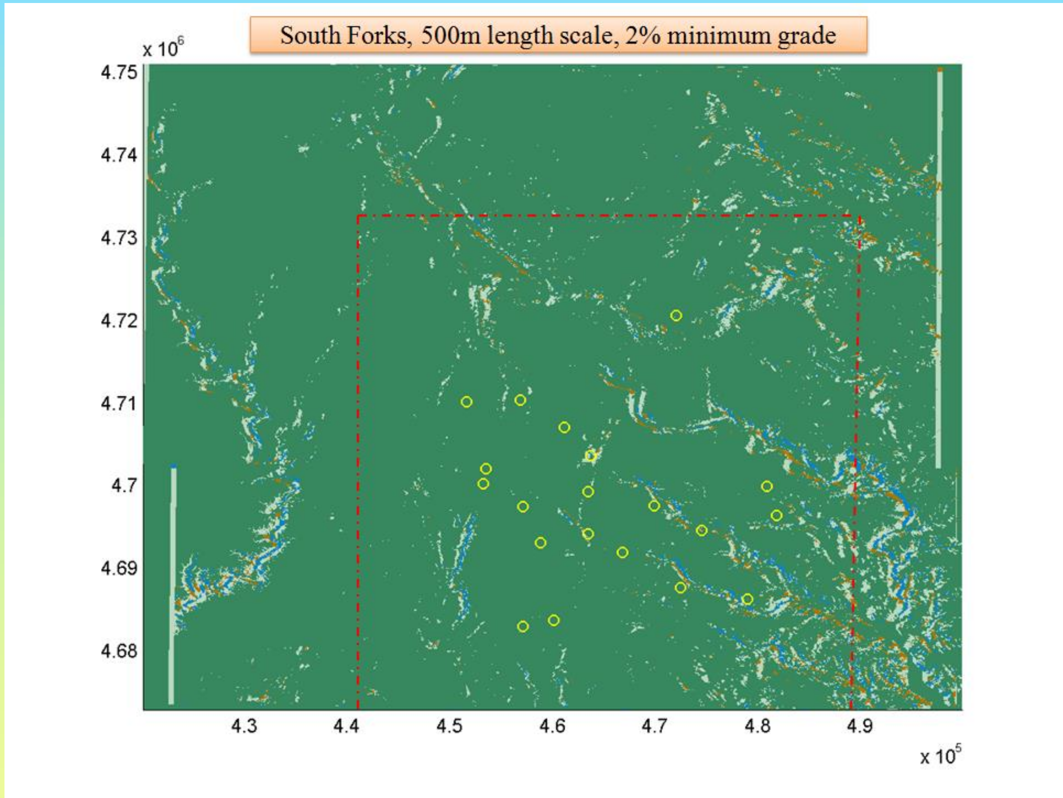
Topography (…continued…)

Topographic Similarity: A flat landscape

- Examine points 500m to the north, south, east and west of point (x,y)

- Determine if those points are 10m above or below the elevation of point (x,y)

- Use these four relative points to determine classification.



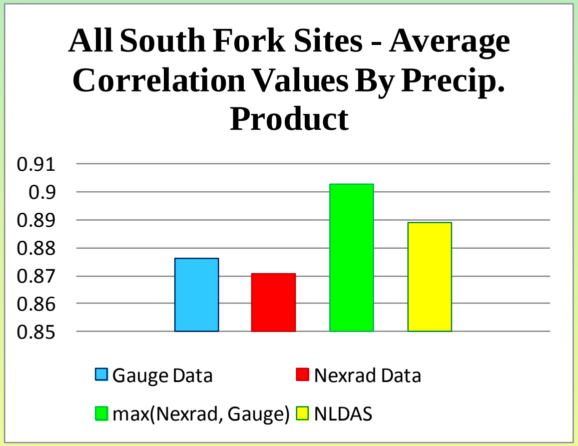
South Forks watershed topographical classification: Precipitation sensors labeled in yellow.

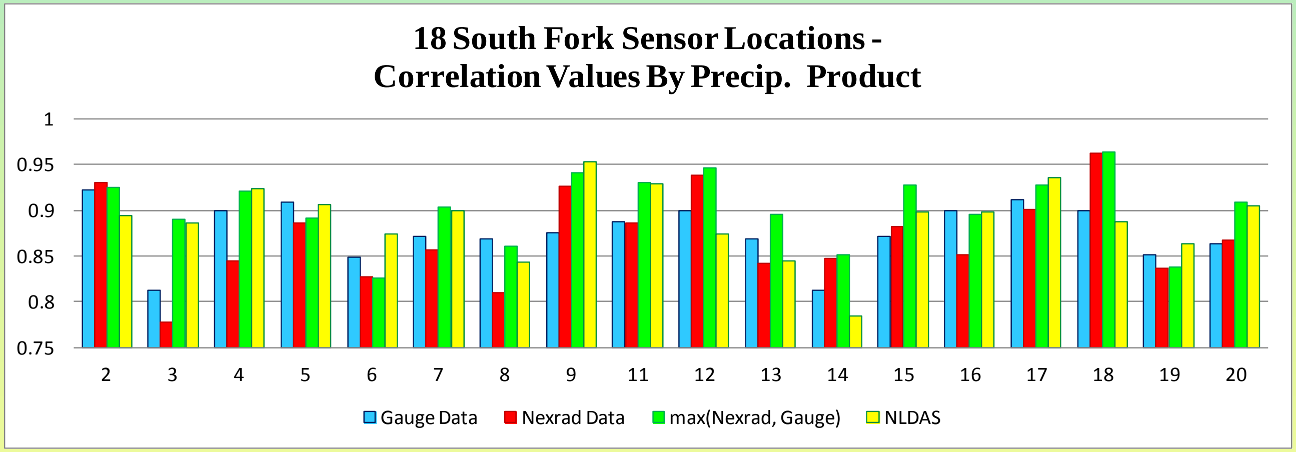
The area in question, bounded by the dashed-red line above, is topographically classified as:

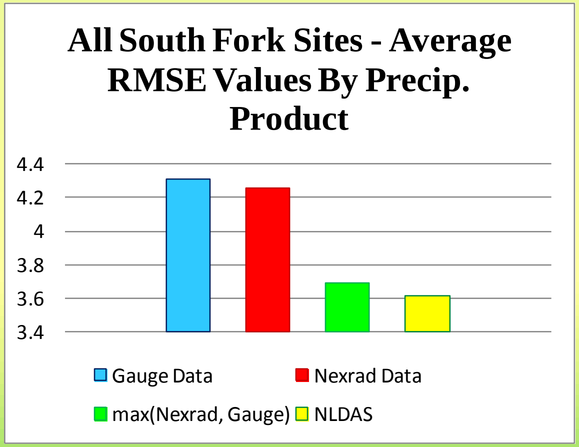
Pits : 1.18%,
Slopes: 4.08%,
Flats: 93.82%,
Peaks: 1.05%

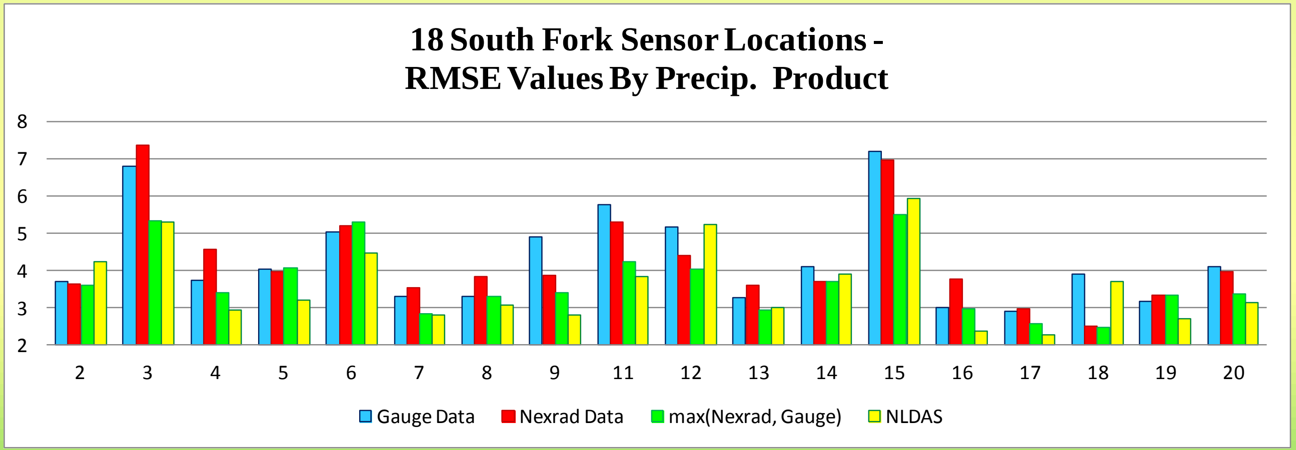
Choosing the Best Precipitation Product:

The case for NLDAS data









A Point-Model for Estimating Soil Moisture:
The Diagnostic Soil Moisture Equation

Θ = f(~~Hydro-climate~~, ~~Soil Texture~~, ~~Topography~~, Precipitation)

Calibrate model at each gauge → Validate parameters at other locations → Apply model at each 500m x 500m square

Diagnostic soil moisture equation (Pan et al, 2003; Pan, 2012)

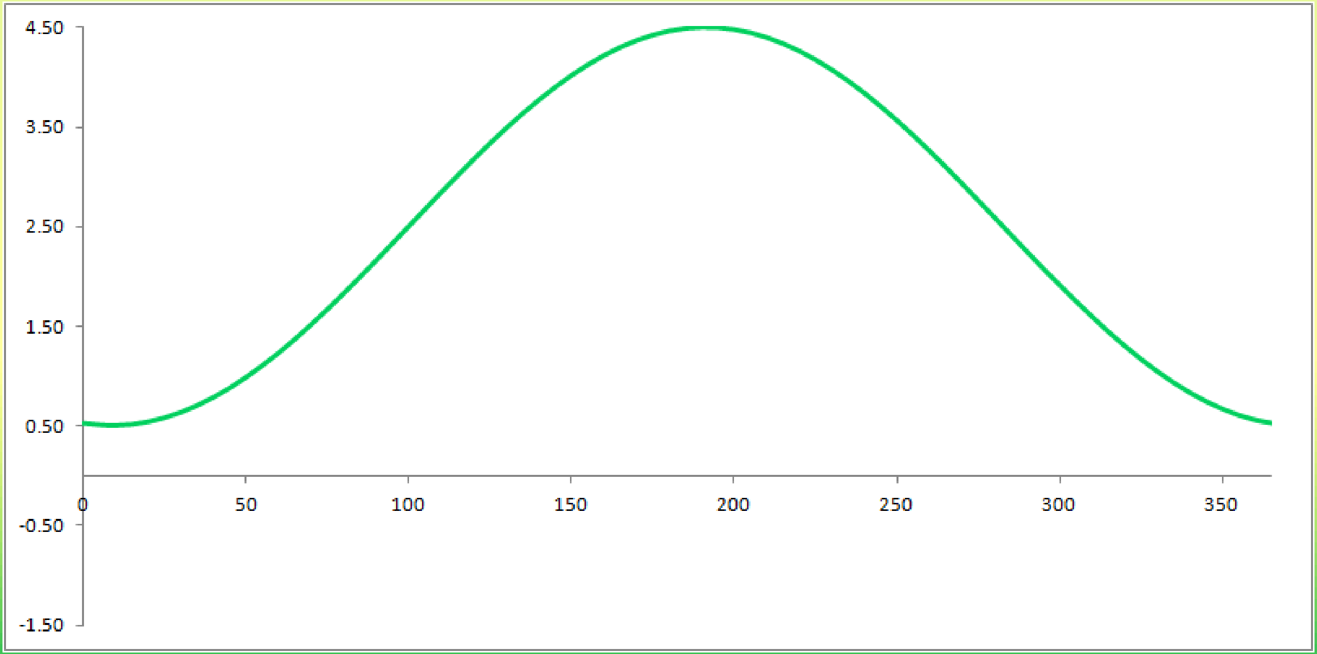
A Point-Model for Estimating Soil Moisture:

The Diagnostic Soil Moisture Equation

$$\theta_{estimated} = \theta_{re} + (\phi_e - \theta_{re})\left(1 - e^{-c_4\beta}\right)$$

$$\beta = \sum_{i=2}^{i=n-1}\left[\frac{P_i}{\eta_i}\left(1 - e^{-\frac{\eta_i}{z}}\right)e^{-\sum_{j=1}^{j=i-1}\left(\frac{\eta_j}{z}\right)}\right] + \frac{P_1}{\eta_1}\left(1 - e^{-\frac{\eta_1}{z}}\right)$$

“Loss” function for soil moisture



Diagnostic Soil Moisture Equation:
6 Parameters are required

Once these first three parameters are fit via a genetic algorithm, three final parameters are fit via a 2nd genetic algorithm based on observed soil moisture values and the chosen loss function.

{v, α, h, Θ_{re} , Φ_{e} , C_4}

$$\theta_{estimated} = \theta_{re} + (\phi_e - \theta_{re})\left(1 - e^{-c_4\beta}\right)$$

Residual Soil Moisture

Effective Porosity

Soil Drainage Constant

The Approach:
Transforming a point model into an area estimate

Calibrate the model at each site usage gauged soil moisture and NLDAS precip.

Sensor #	Original RMSE	Closest Sensor	RMSE (Using NLDAS data)
2	3.617	3	6.541
3	4.961	2	7.091
4	2.732	7	6.301
5	3.200	6	4.379
6	4.570	5	5.197
7	2.878	8	4.682
8	3.257	7	5.036
9	3.070	8	6.524
11	3.793	13	5.543
12	5.626	14	7.164
13	2.908	11	5.14
14	3.832	12	5.895
15	6.384	20	7.723
16	2.286	18	2.919
17	1.592	6	3.709
18	3.318	16	4.278
19	2.211	7	3.649
20	2.964	15	5.659
MEAN	**3.511**	**---**	**5.413**

Area estimates require using a model at a different site than the one for which it was calibrated.

In this case, at each site, we choose the calibrated parameters from the nearest (but not the same) sensor.

*Sensors 1 and 10 are removed due to flooding / gopher damage.

The Approach:

Transforming a point model into an area estimate

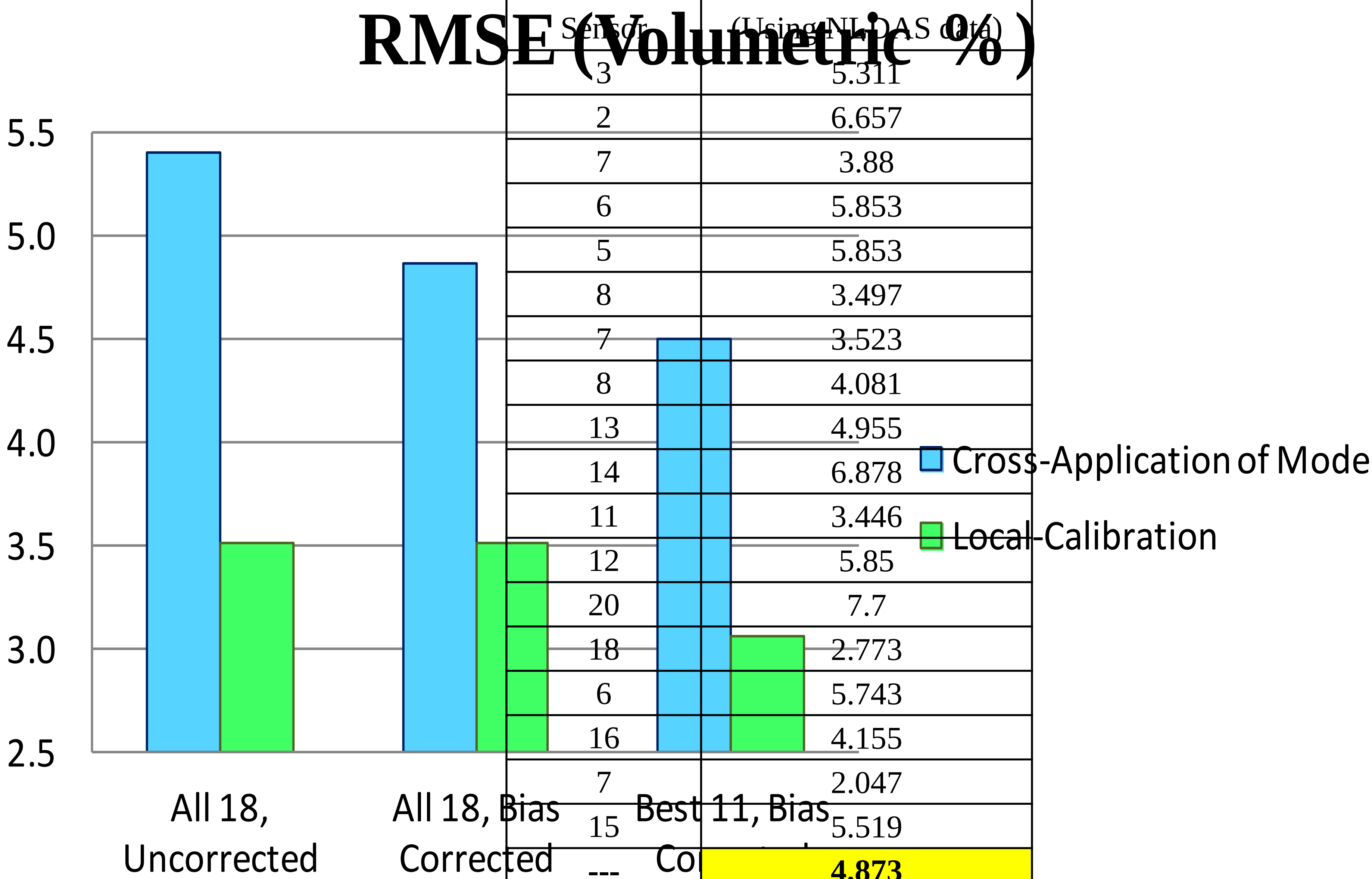
Sensor #	Original RMSE	Closest Sensor	RMSE (Using NLDAS data)	RMSE, Bias Corrected (Using NLDAS data)
2	3.617	3	6.541	5.311
3	4.961	2	7.091	6.657
4	2.732	7	6.301	3.88
5	3.200	6	4.379	5.853
6	4.570	5	5.197	5.853
7	2.878	8	4.682	3.497
8	3.257	7	5.036	3.523
9	3.070	8	6.524	4.081
11	3.793	13	5.543	4.955
12	5.626	14	7.164	6.878
13	2.908	11	5.14	3.446
14	3.832	12	5.895	5.85
15	6.384	20	7.723	7.7
16	2.286	18	2.919	2.773
17	1.592	6	3.709	5.743
18	3.318	16	4.278	4.155
19	2.211	7	3.649	2.047
20	2.964	15	5.659	5.519
MEAN	**3.511**	**----**	**5.413**	

Sensors are not identical in calibration – in some cases a sensor is simply a few percent wetter or drier than another over the course of the season.

In this case, we correct for this bias, *then* cross-apply the parameters from the closest sensor.

The Approach:

Transforming a point model into an area estimate



Closest Sensor	RMSE, Bias Corrected (Using NLDAS data)
3	5.311
2	6.657
7	3.88
6	5.853
5	5.853
8	3.497
7	3.523
8	4.081
13	4.955
14	6.878
11	3.446
12	5.85
20	7.7
18	2.773
6	5.743
16	4.155
7	2.047
15	5.519
---	**4.873**

The Approach:
Transforming a point model into an area estimate

For every location (*x*,*y*), at time *t*, estimate the quantity of soil moisture as:

$$\theta_{x,y,t} = \sum_{i=1}^{n} \left[\theta_{i,t^*,s} - \theta_{i,t,m}\left(P_{x_i,y_i,t}\right) + \theta_{i,t^*,m}\left(P_{x,y,t^*}\right)\right] \frac{\frac{1}{\left(d_{x_i,y_i}\right)^2}}{\sum_{j=1}^{n} \frac{1}{\left(d_{x_j,y_j}\right)^2}}$$

Estimate of soil moisture at point (*x*,*y*) at time *t*.

Sensor (*s*) observation for gauge (*i*) at the last time at which a valid reading appeared (*t**).

Modeled (*m*) estimate at gauge (*i*) at time (*t*) as a function of…

…precipitation (*P*) at (*x*,*y*) coordinates of gauge (*i*), at time (*t*).

Modeled (*m*) estimate at gauge (*i*) at time (*t**) as a function of…

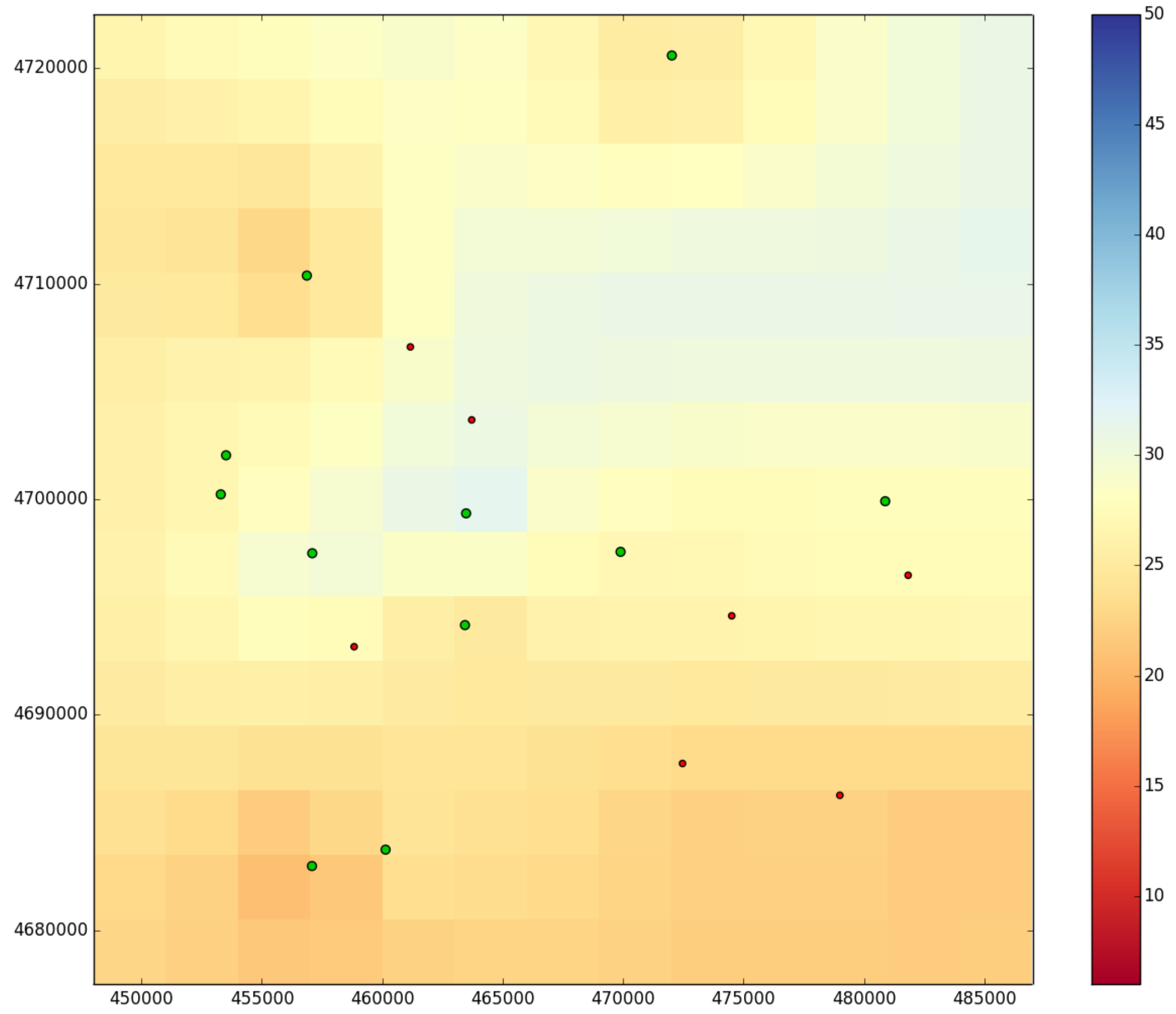
…precipitation (*P*) at (*x*,*y*) coordinates for which an estimate is needed, at time (*t**)

Distance (*d*) from point (*x*,*y*) to gauge (*i*) or (*j*)

The Approach:

Aggregating to obtain estimates for 3,000m x 3,000m squares

Applying the equation over every 500m x 500m square



Growing Season 2013:

An animation

SF_3000m_all3_every4_Summer2013.exe

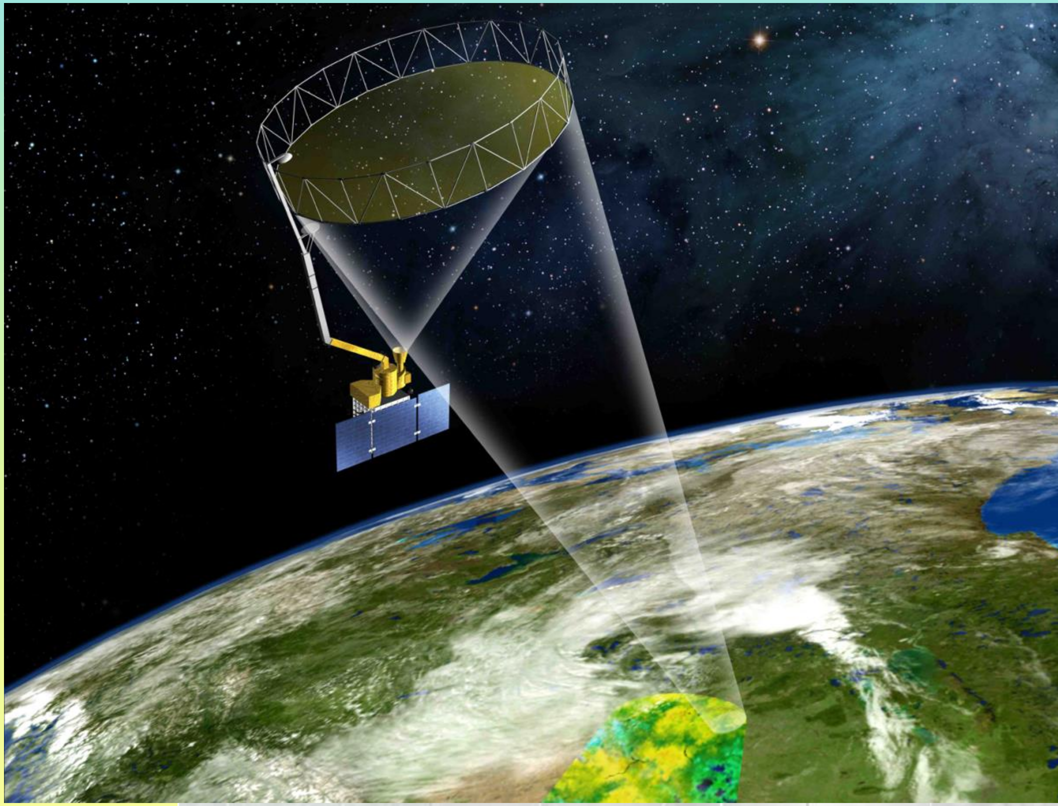
Conclusions & Future Work:

Extending the approach – Non-uniform watersheds

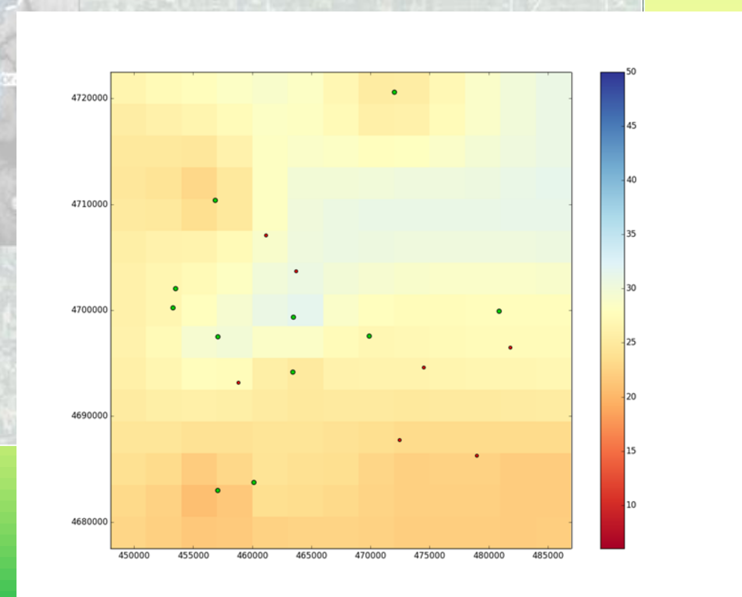
$$\theta_{x,y,t} = \sum_{\mathrm{i=1}}^{\mathrm{n}} \left[\theta_{i,t^*,s} - \theta_{i,t,m}\left(P_{x_i,y_i,t}\right) + \theta_{i,t^*,m}\left(P_{x,y,t^*}\right)\right] \frac{\frac{1}{\left(d_{x_i,y_i}\right)^2}}{\sum_{\mathrm{j=1}}^{\mathrm{n}} \frac{1}{\left(d_{x_j,y_j}\right)^2}}$$

Rather than summing over *all* gauges, we can choose only those gauges deemed ‘similar’ in terms of soil and topography.

Conclusions & Future Work:
Extending the approach – SMAP



…and can be deployed to validate the estimates from SMAP.



Estimates made at 3km scale will be aggregated to obtain a 36km, *in situ* product...

Acknowledgements

This work was supported by NASA Terrestrial Hydrology Program, the Global precipitation mission, and USDA-ARS