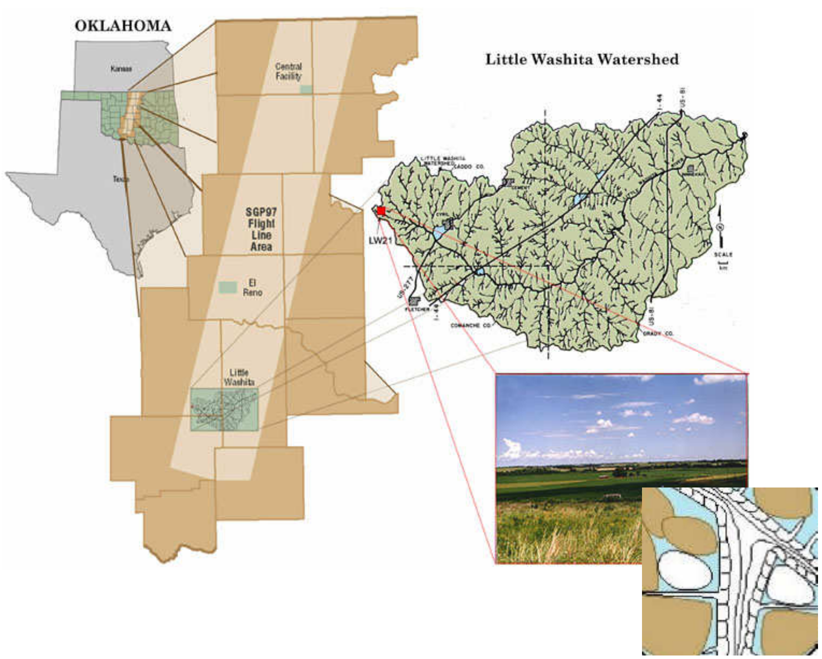
supported by:

Soil Moisture Physical Controls and Time Stability: Understanding Across Scales with Different Platforms, Process Modeling, and Parameter Estimation Techniques



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and Collaborators

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Overarching Objectives

- **Evaluate** the dominant physical controls (soil properties, vegetation types, topographic indexes, and precipitation intensity/duration) for soil moisture evolution and resultant vadose zone fluxes (evapotranspiration, infiltration, shallow ground water recharge) at different spatial scales (hill-slope, remote sensing footprint, landscape, watershed, region) in the selected hydro-climatic conditions.

- **Develop** aggregation/disaggregation rule(s) for determining scaled soil moisture and "effective" hydrologic parameters (related to the physical control representing the ensemble vadose zone flux behavior) at different spatial scales (hill-slope, remote sensing footprint, landscape, watershed, region) and platforms in the selected watersheds/hydro-climatic regions and test their mutual transferability for various applications.

Summary of Our Past/Ongoing/Planned Activities

- Field Campaigns (SGP97…, SMEX…, CLASIC…)
- Temporal Stability Studies
- Physical Controls for Soil Moisture
- Up/Downscaling Rules of Soil Moisture
- Land Surface Parameter Estimation / Scaling
- Multi-Scale Data Assimilation for Soil Moisture and Surface / Subsurface Hydrologic Fluxes

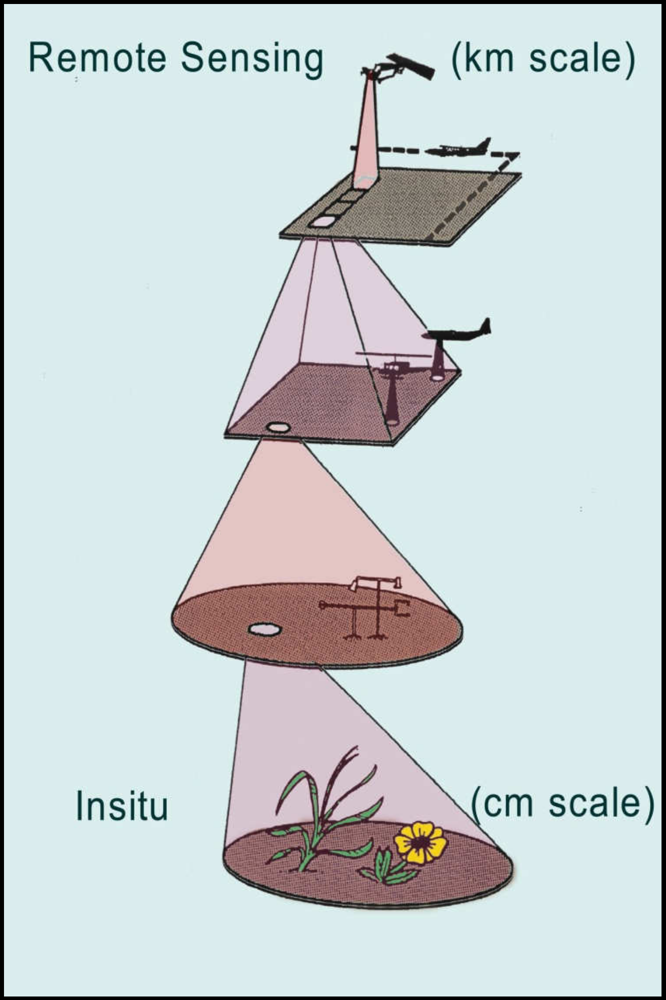
Soil Moisture / Brightness Temperature Measurement Platforms and Scales

Space-borne

Air-borne

Ground-based

In situ



AMSR-E/ SMAP

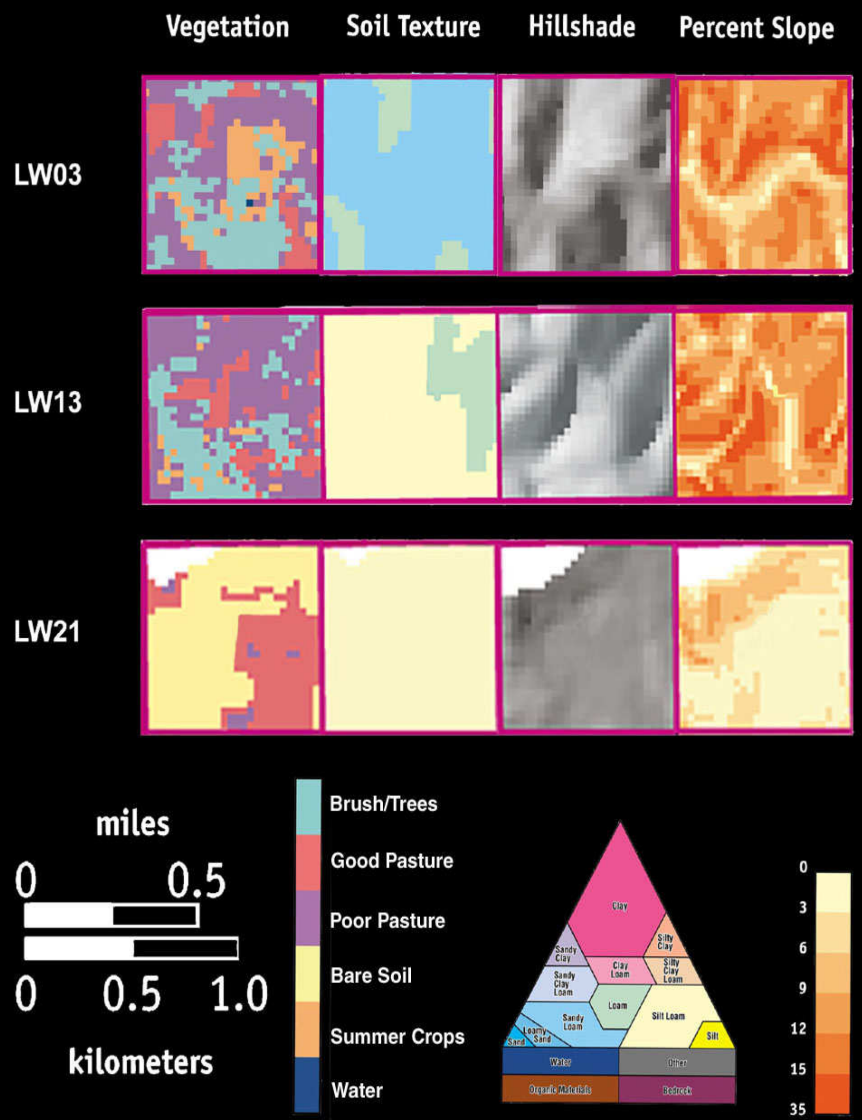
ESTAR/ PSR

TOWER/ Truck

TDR/ Gravimetric

Temporal Stability of Soil Moisture and Physical Controls at Different Scales

Vegetation Soil Slope

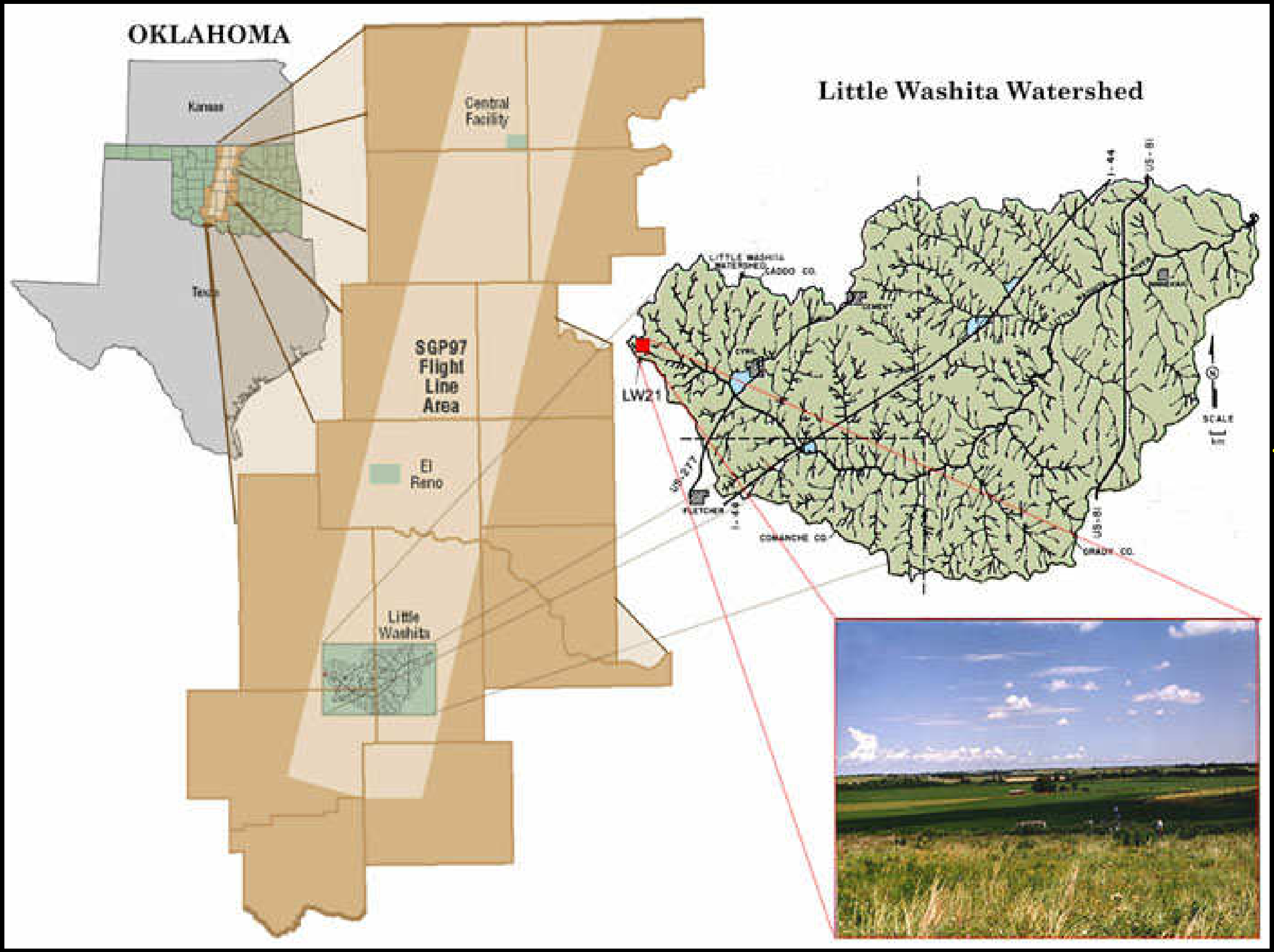


Soil Moisture and Physical Controls at Different Scales

Region

Watershed

Field

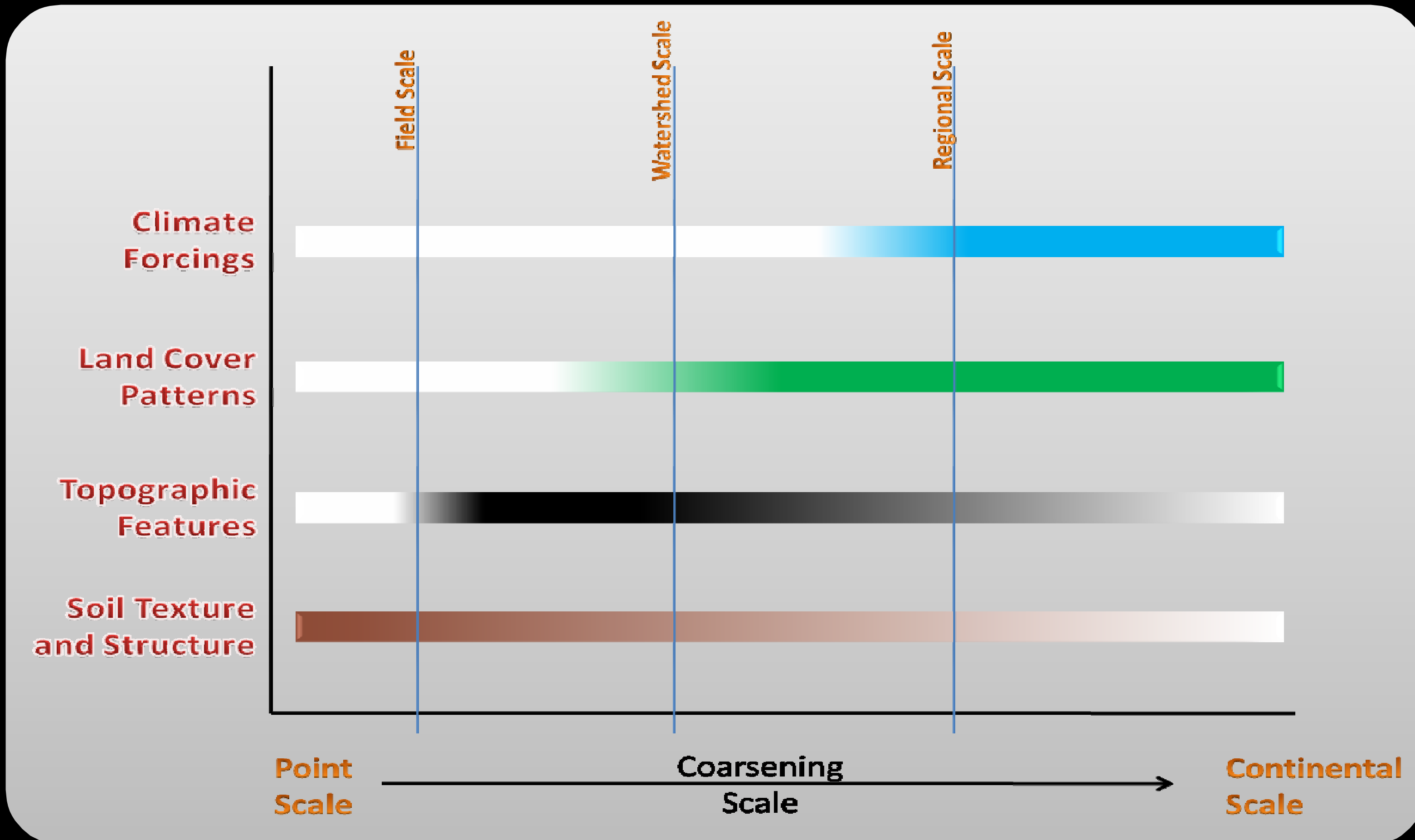


Vegetation/ Precipitation

Topography

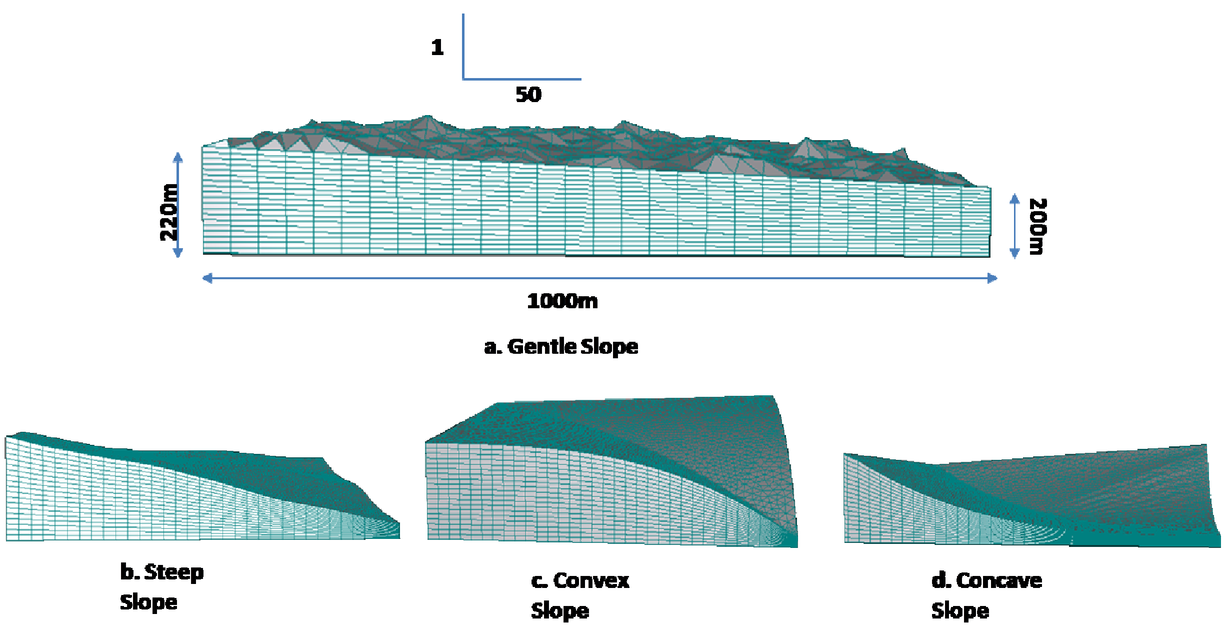
Soil

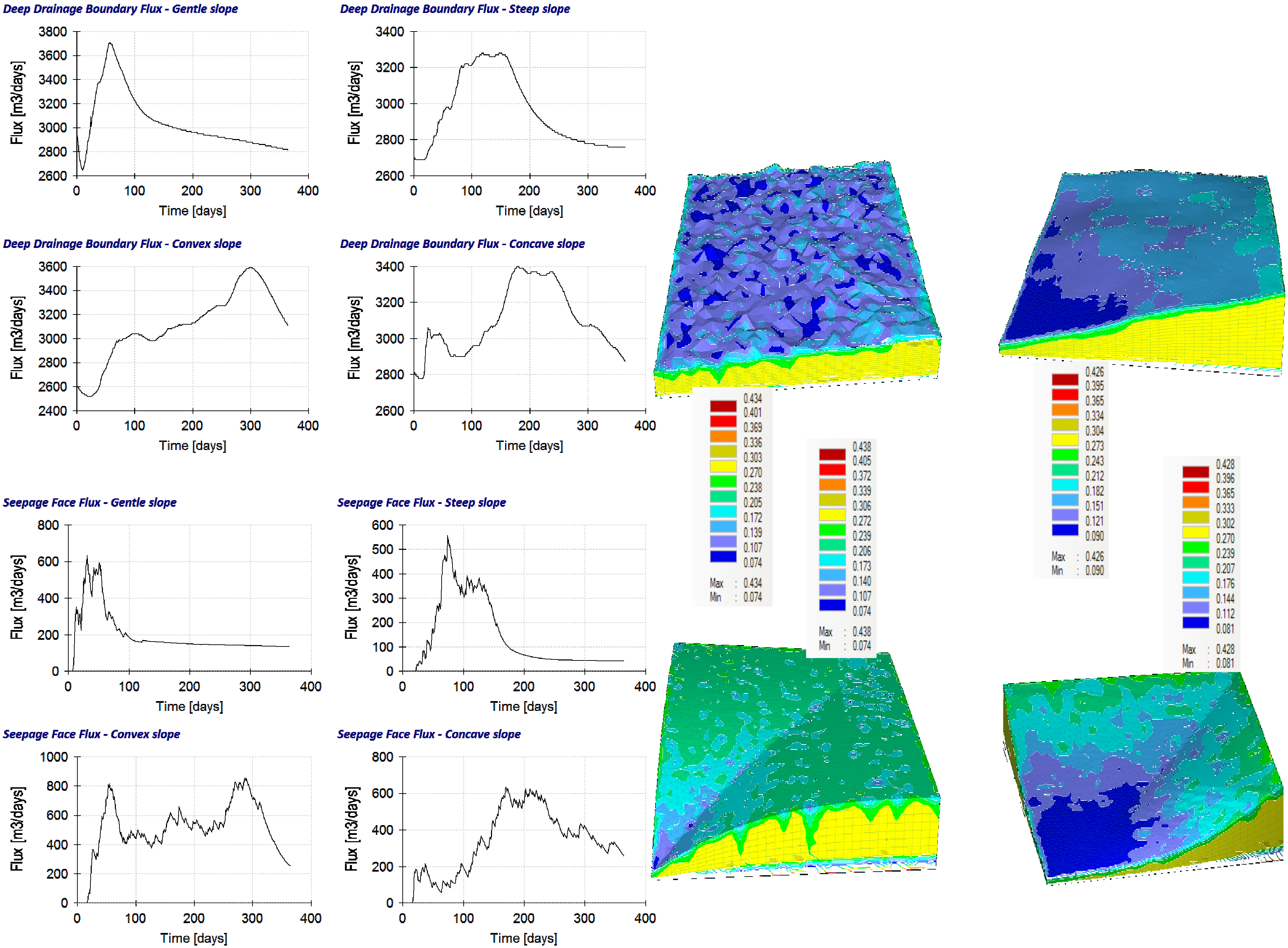
- Soil moisture variability is dominated by



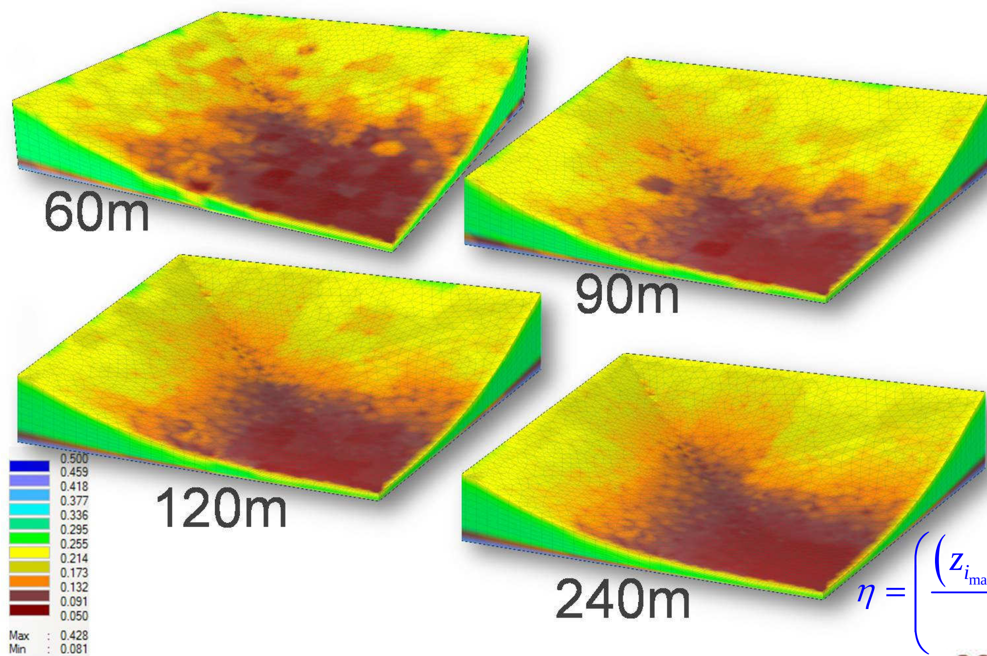
  – Modified sampling strategies to better assist development of algorithms for scaling of land surface parameters (e.g., soil hydraulic parameters) and soil moisture state is necessary

- One Example - When upscaling to large extents
  - hill-slope scales and beyond
  - topography plays a significant role, can no longer be ignored
  - lateral flows occur within the vadose zone; surface run-off/run-on also occurs





Deep Drainage Boundary Flux - Gentle slope
Deep Drainage Boundary Flux - Steep slope
Deep Drainage Boundary Flux - Convex slope
Deep Drainage Boundary Flux - Concave slope
Seepage Face Flux - Gentle slope
Seepage Face Flux - Steep slope
Seepage Face Flux - Convex slope
Seepage Face Flux - Concave slope
Flux [m3/days]
Time [days]
Max : 0.434
Min : 0.074
Max : 0.438
Min : 0.074
Max : 0.426
Min : 0.090
Max : 0.428
Min : 0.081

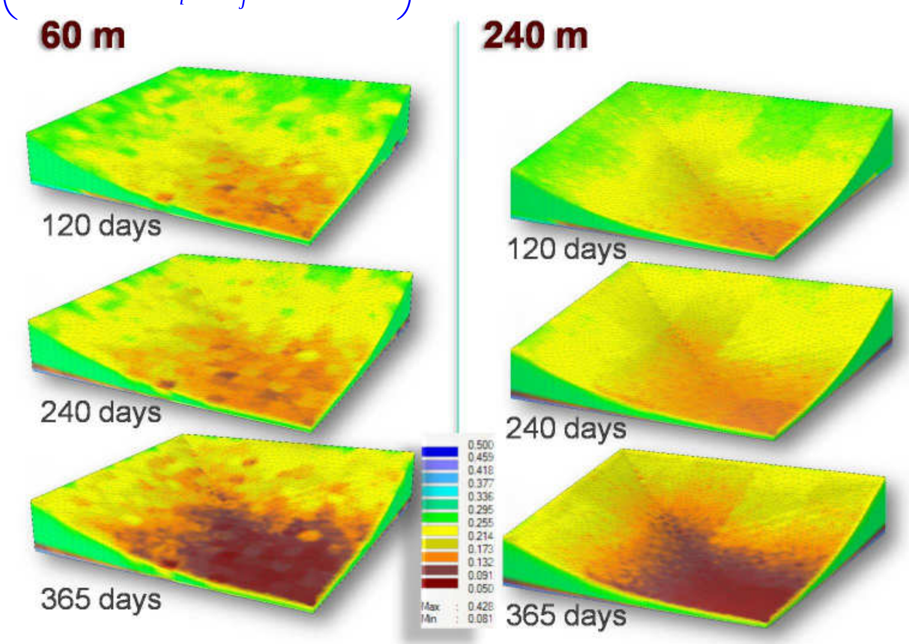


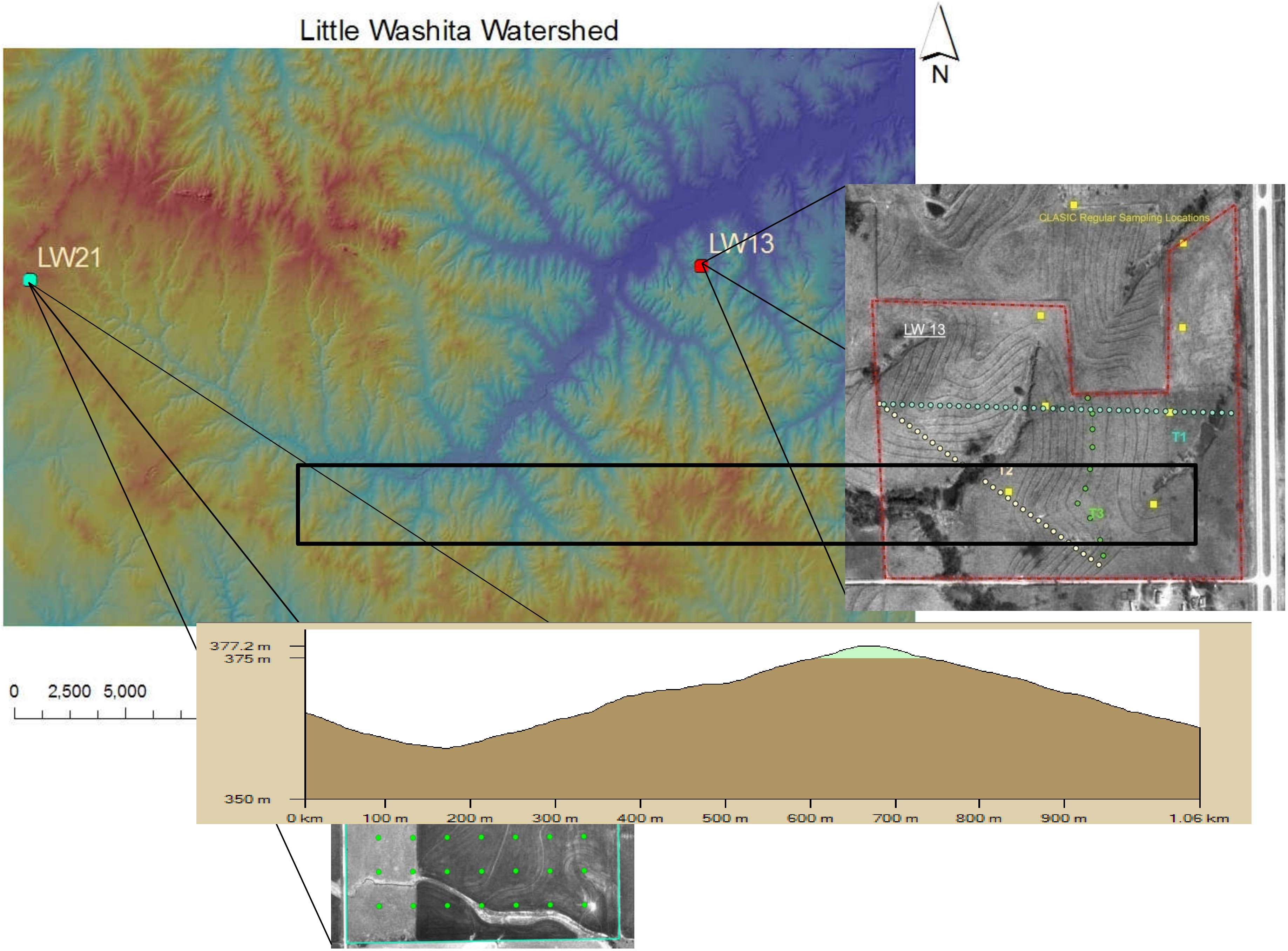
Soil Moisture states at end of simulation at different resolutions

$$Sup(p_i, p_j) = e^{\eta (p_i - p_j)^2}$$

$$\eta = \left(\frac{\left(z_{i_{max}} - z_{i_{min}}\right) - \left(z_{j_{max}} - z_{j_{min}}\right)}{z_i - z_j} \right)^2 * \frac{\sqrt[2]{(x_i - x_j)^2 + (y_i - y_j)^2 + (z_i - z_j)^2}}{S}$$

Soil Moisture states at different resolutions and times

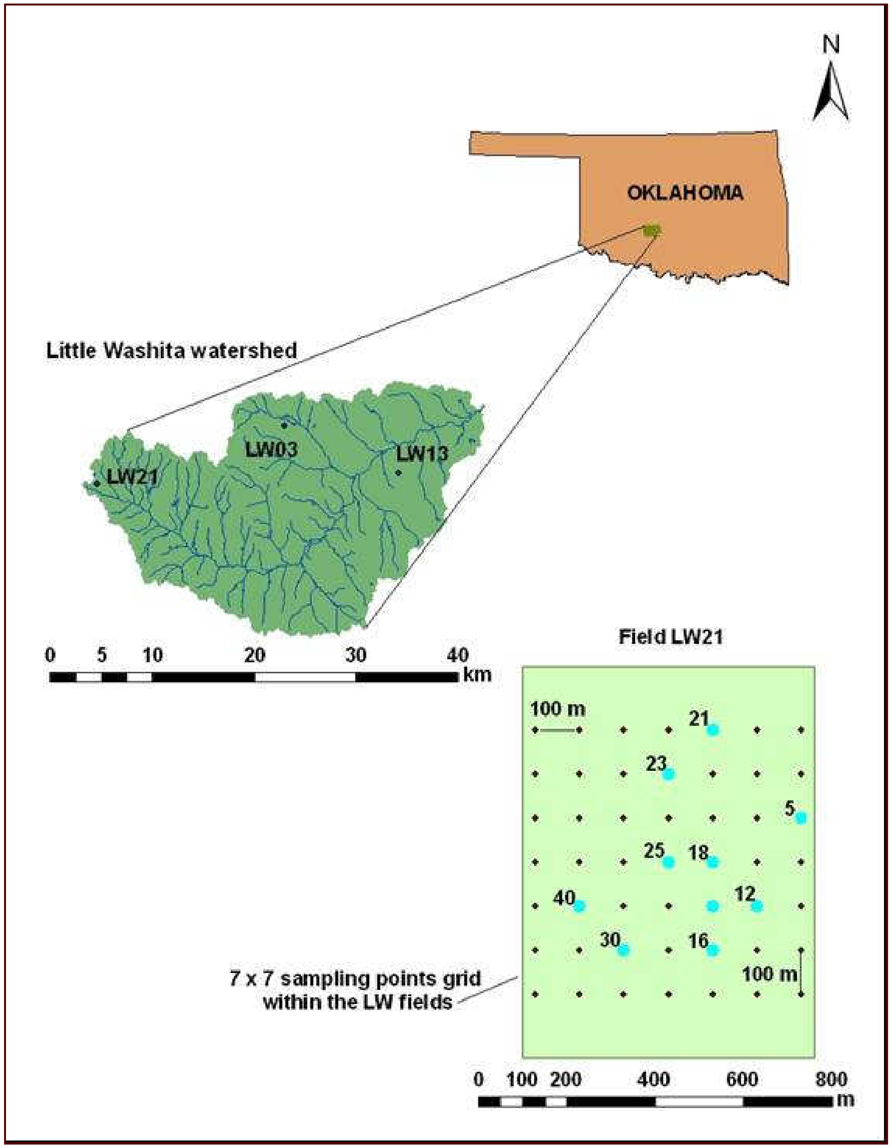


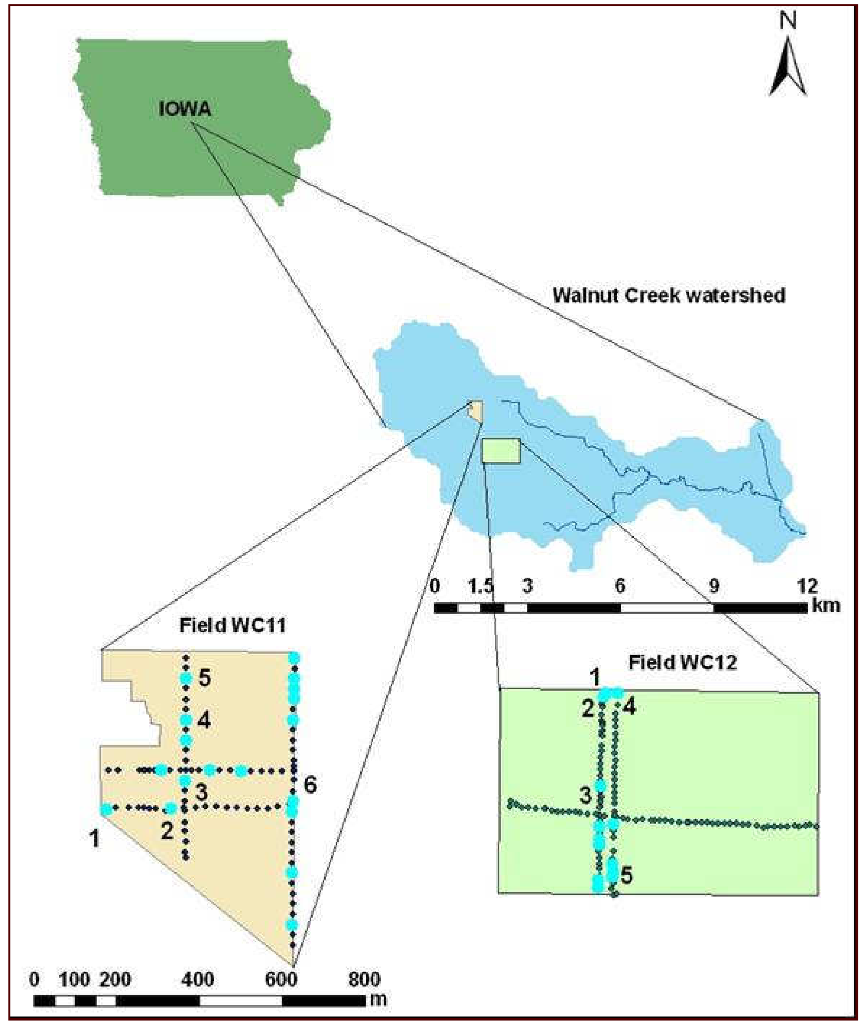

Little Washita Watershed
N
LW21
LW13
CLASIC Regular Sampling Locations
LW 13
T1
T2
T3
0 2,500 5,000
377.2 m
375 m
350 m
0 km
100 m
200 m
300 m
400 m
500 m
600 m
700 m
800 m
900 m
1.06 km

- The *validation* problem necessitates identification of 'time stable' locations within a field/footprint that can estimate the field/footprint mean soil moisture and can maintain being stable over a long period of time

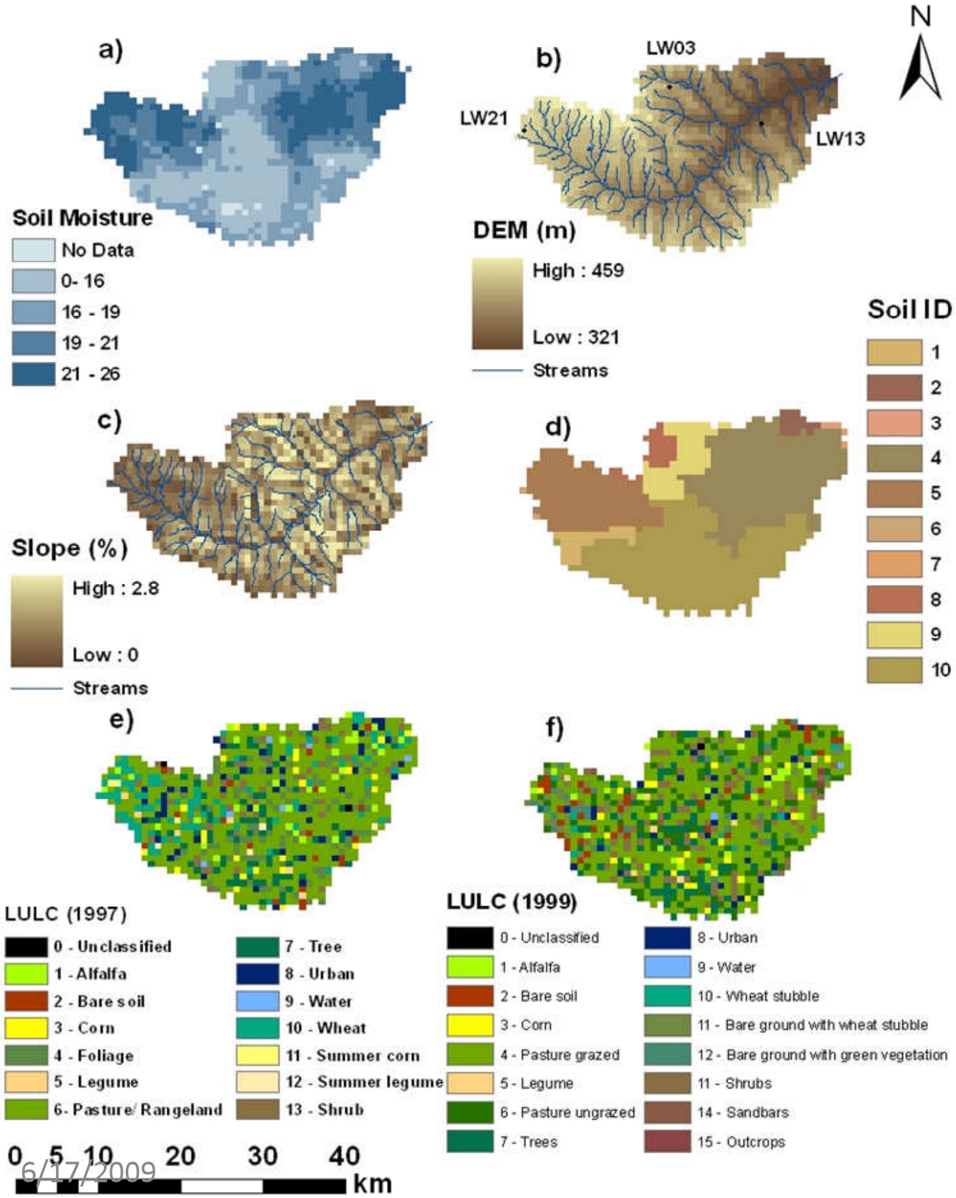
- *Advantages* of TS locations
  - reduce the number of *in-situ* sampling points in designing hydrology experiments for RS validation
  - downscaling the RS soil moisture products
  - determining physical controls affecting soil moisture spatio-temporal variability at different scales

Study Areas


N
OKLAHOMA
Little Washita watershed
LW03
LW13
LW21
0 5 10 20 30 40
km
Field LW21
100 m
21
23
5
25
18
40
12
30
16
100 m
7 x 7 sampling points grid
within the LW fields
0 100 200 400 600 800
m


N
IOWA
Walnut Creek watershed
0 1.5 3 6 9 12
km
Field WC11
5
4
3
6
1
2
Field WC12
1
2
4
3
5
0 100 200 400 600 800
m

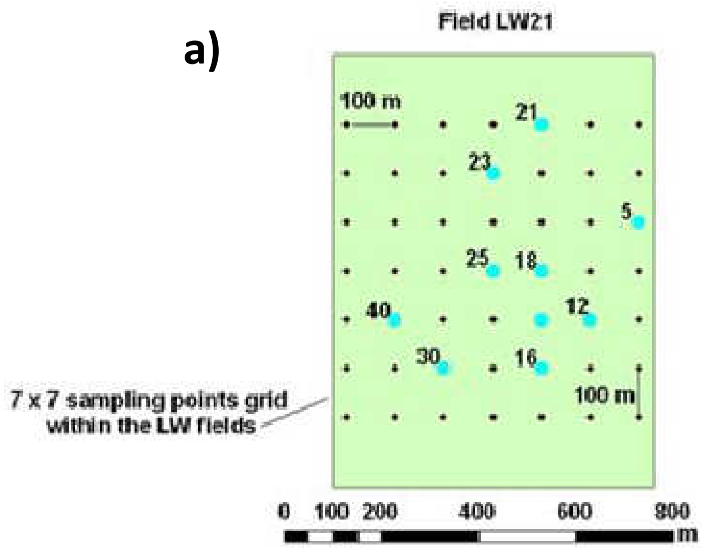
Physical attributes (LW watershed, OK)



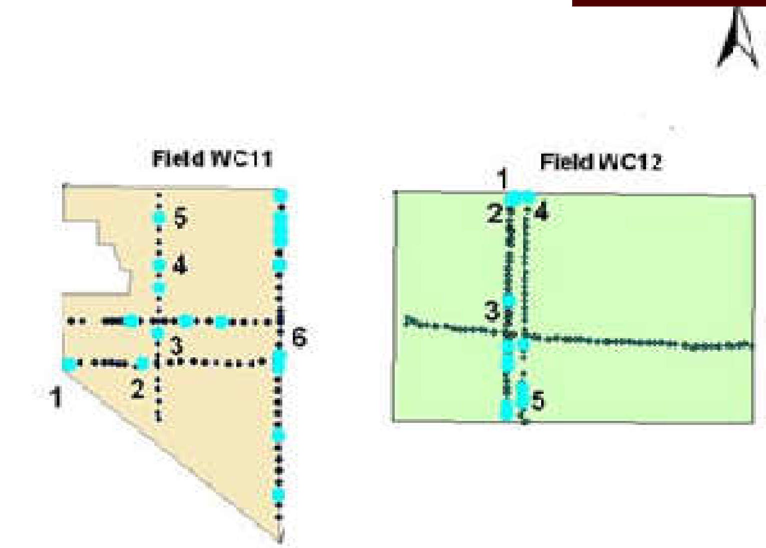
Soil ID	Sand (%)	Silt (%)	Clay (%)
1	**41**	**45**	**15**
2	23	63	14
3	18	69	13
4	**37**	**47**	**15**
5	21	66	13
6	58	32	10
7	30	50	20
8	79	15	6
9	**60**	**31**	**10**
10	56	32	12

Results (Field-scale)

a)



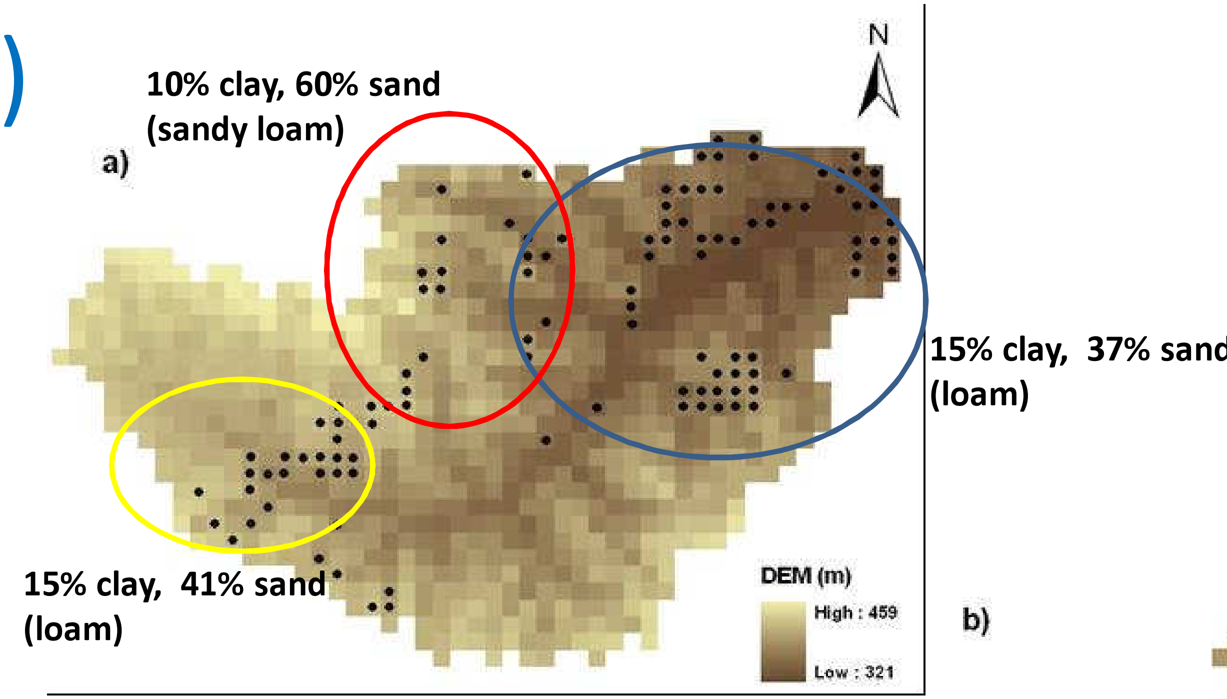
b)

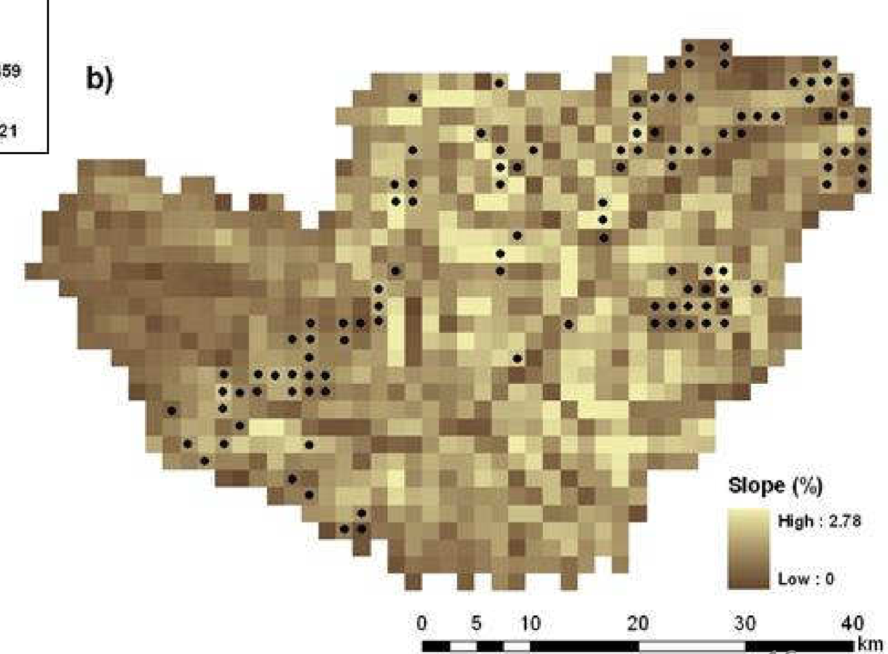


- ❖ 10 of the 14 TS locations (~ 71%) from SGP97 were TS during CLASIC 2007 within ± 10% VSM
- ❖ WC11 has higher TS characteristics & lower temporal variability than WC12 field in a 3-year period
- ❖ In WC11, 18 of the 32 TS locations (~ 56%) from SMEX02 exhibited TS features during SMEX05 within ± 10% VSM
- ❖ 6 of 18 repeated TS locations (~ 33%) captured the field mean within ± 5% VSM, during both SMEX02 and SMEX05, in WC11 field
- ❖ In WC12, 14 of the 64 TS points from SMEX02 were TS during SMEX05 within ± 10% VSM
- ❖ 36% of these repeated 14 TS points (i.e., 5 out of 14) captured the field mean within ± 5% VSM

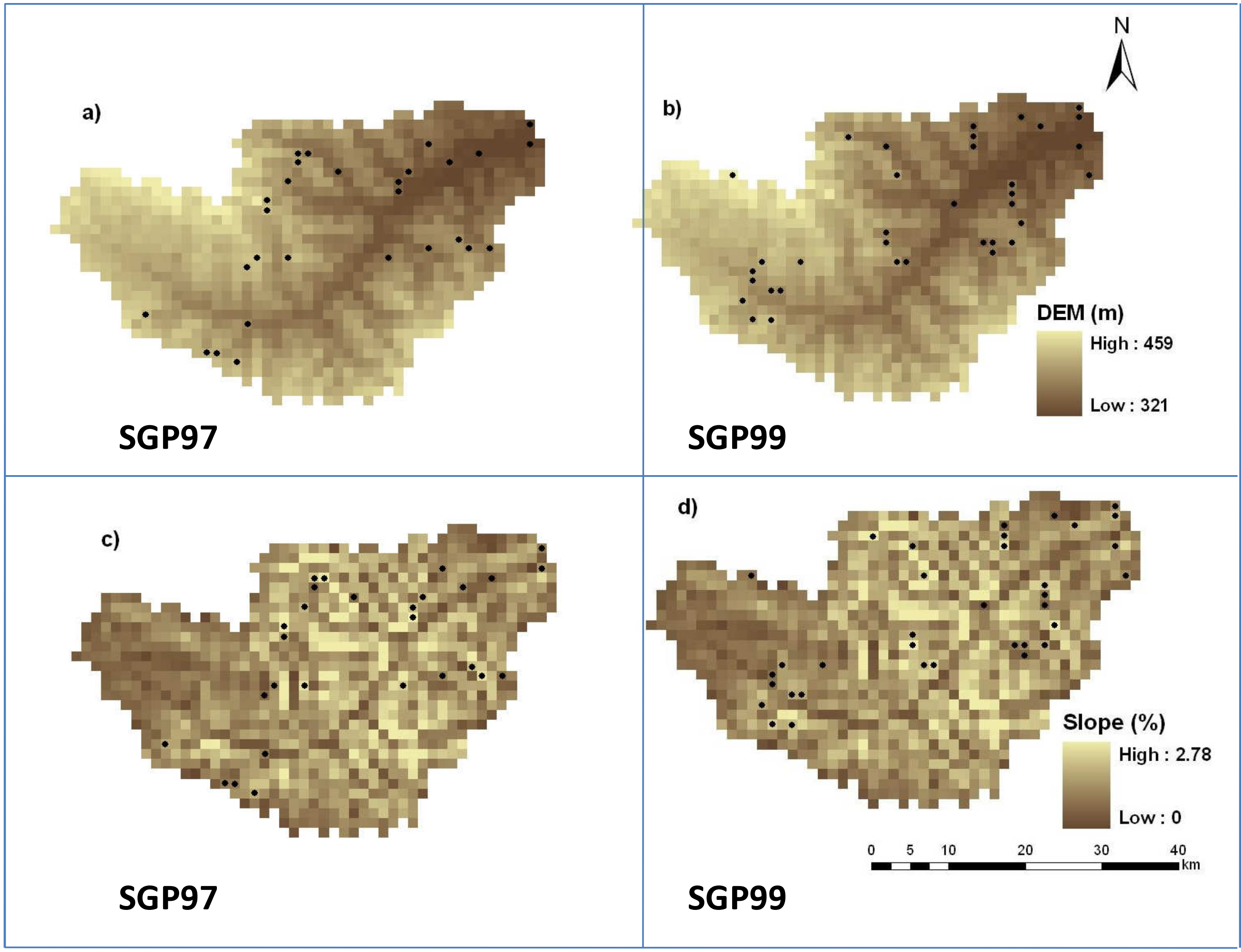
Results (Watershed-scale)

a)





TS footprints (ESTAR) within ± 10% VSM during SGP97 & SGP99 in LW watershed, OK.



TS footprints (ESTAR) within ± 1 % VSM during SGP97 & SGP99.

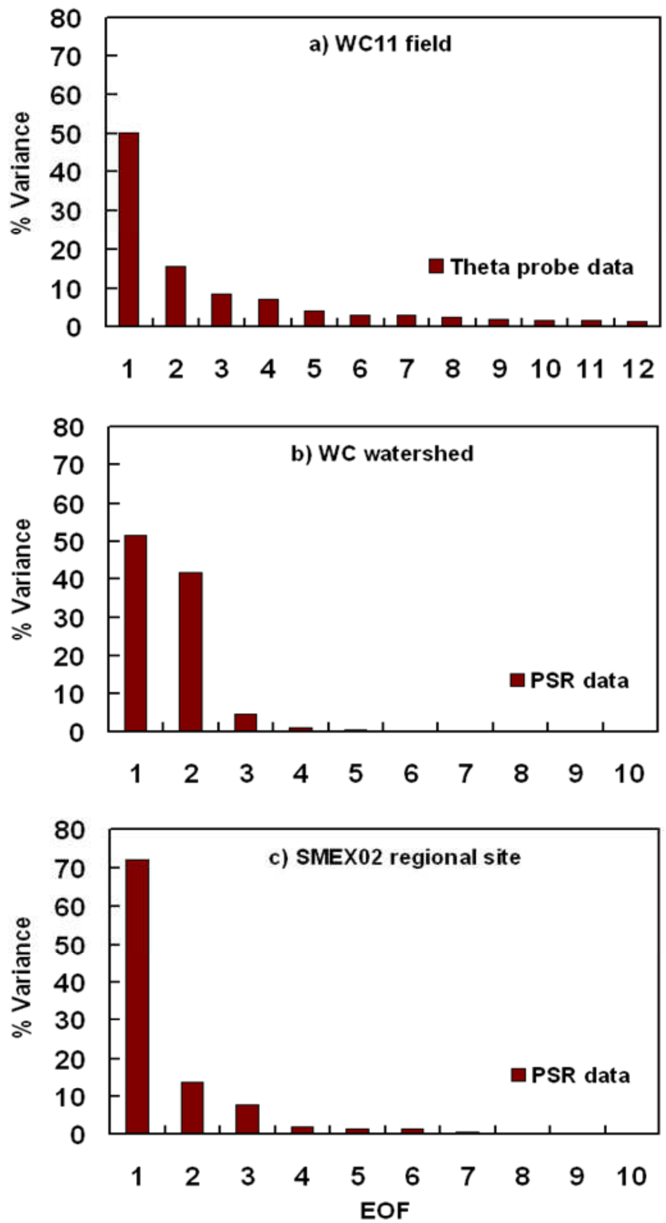
EOF Analyses

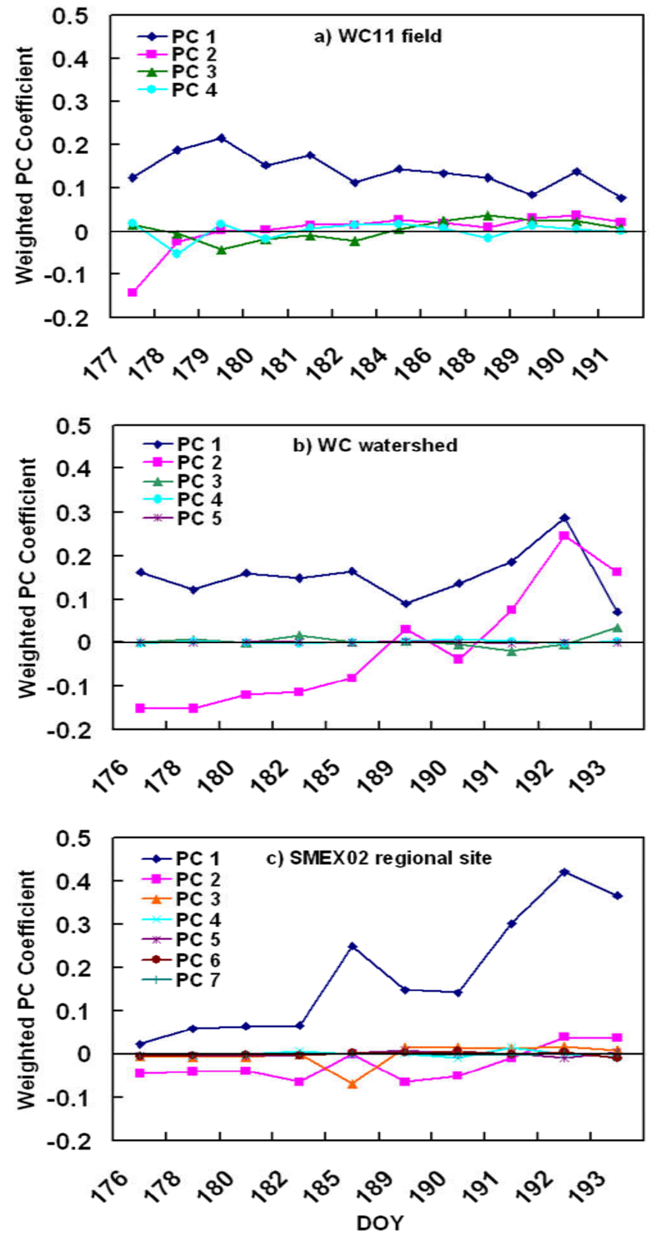
TEXAS A&M UNIVERSITY

Field-scale

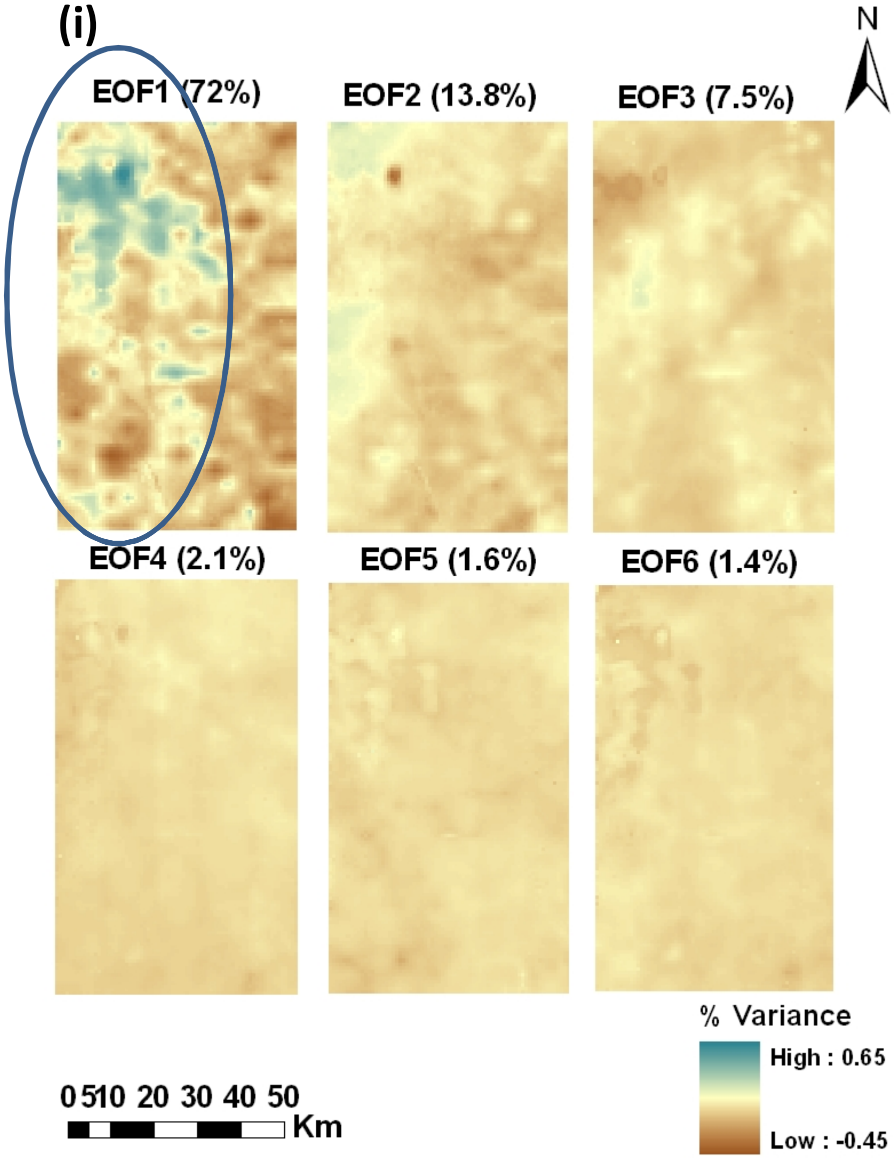
Watershed-scale

Regional-scale



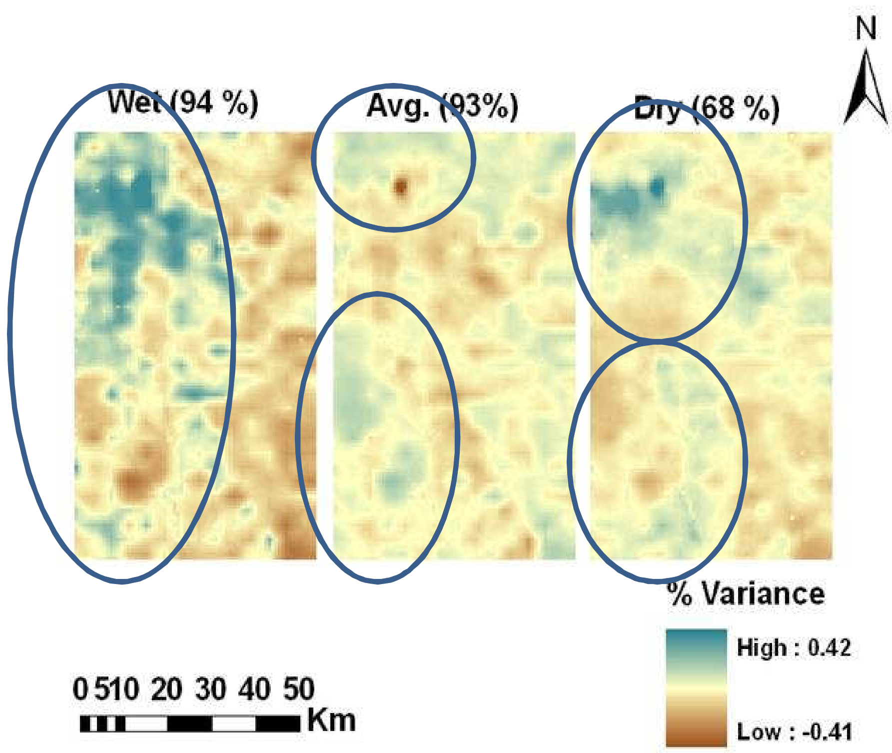


(i)



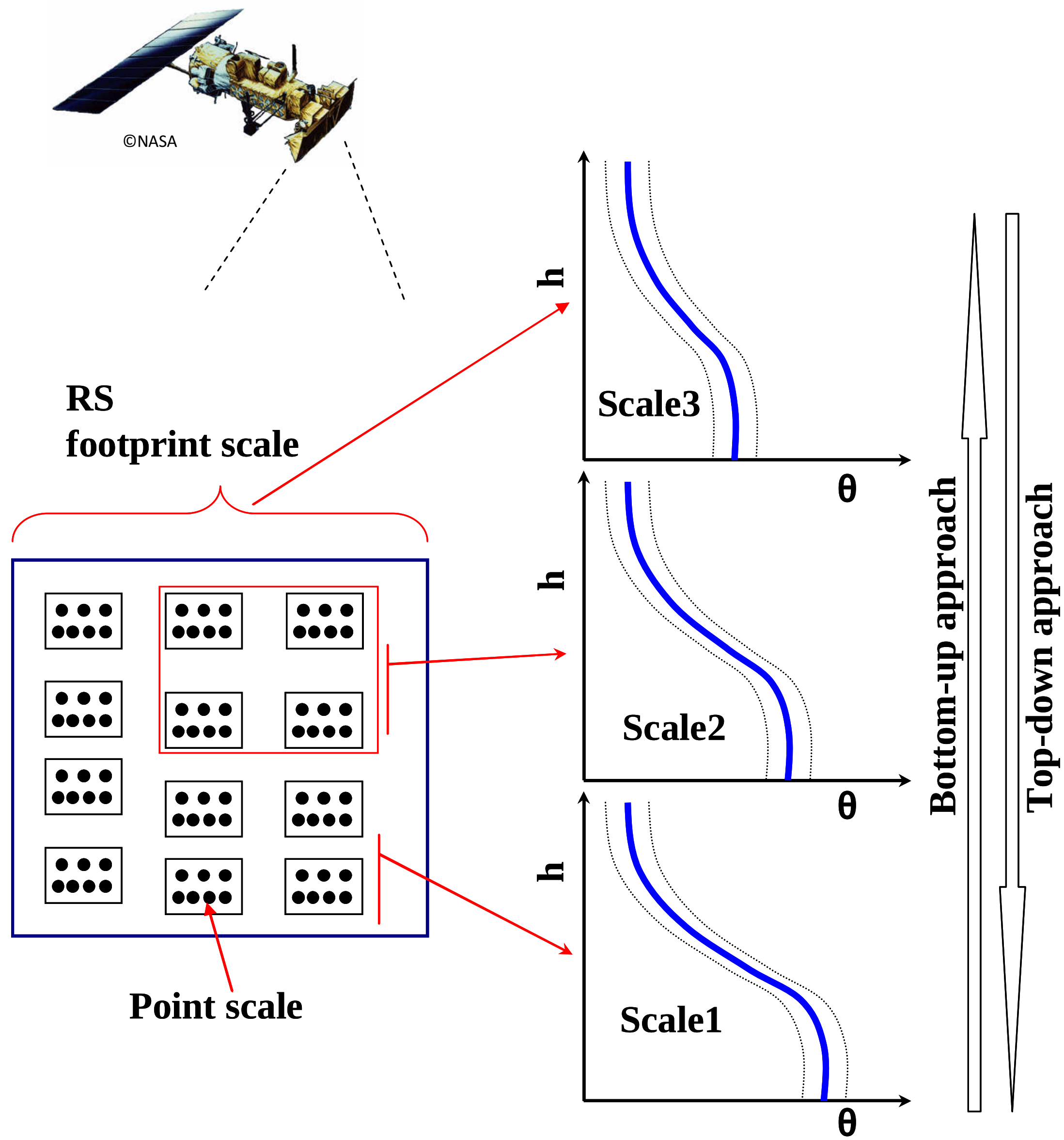
N
EOF1 (72%)
EOF2 (13.8%)
EOF3 (7.5%)
EOF4 (2.1%)
EOF5 (1.6%)
EOF6 (1.4%)
% Variance
High : 0.65
Low : -0.45
0 5 10 20 30 40 50
Km

(ii)



N
Wet (94 %)
Avg. (93%)
Dry (68 %)
% Variance
High : 0.42
Low : -0.41
0 5 10 20 30 40 50
Km

Soil Hydraulic Function Scaling Hypothesis

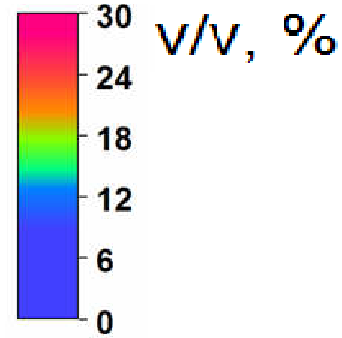


Using the information content of the soil moisture data collected at that particular SCALE, we can <u>estimate</u> the scale dependent soil hydraulic properties

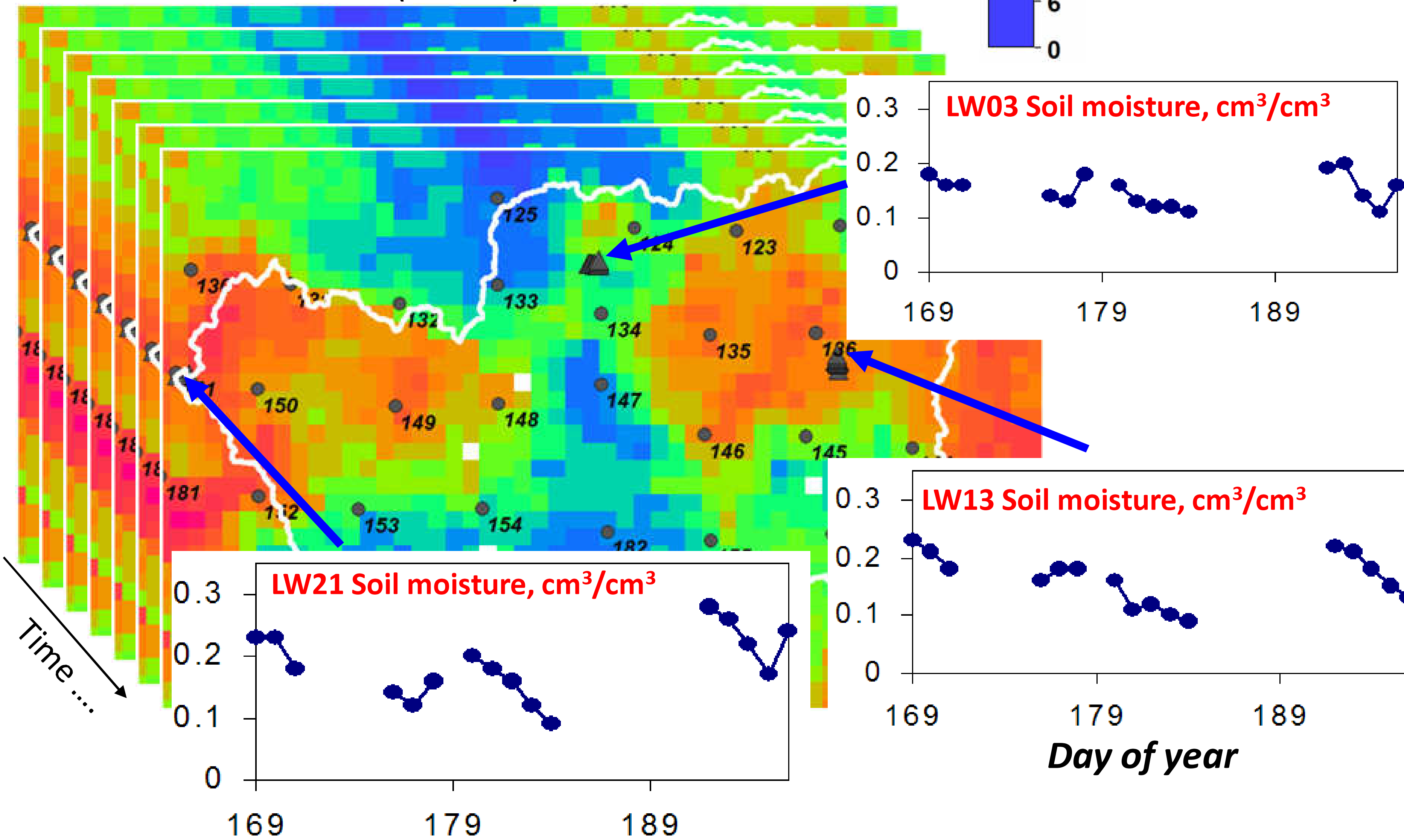
$$S_e = \frac{\theta(h)-\theta_{res}}{\theta_{sat}-\theta_{res}} = \left[\frac{1}{1+|\alpha h|^n}\right]^m$$

$$K(h)=K_{sat}S_e^{\lambda}\left[1-\left(1-S_e^{1/m}\right)^m\right]^2$$

Remote sensing data

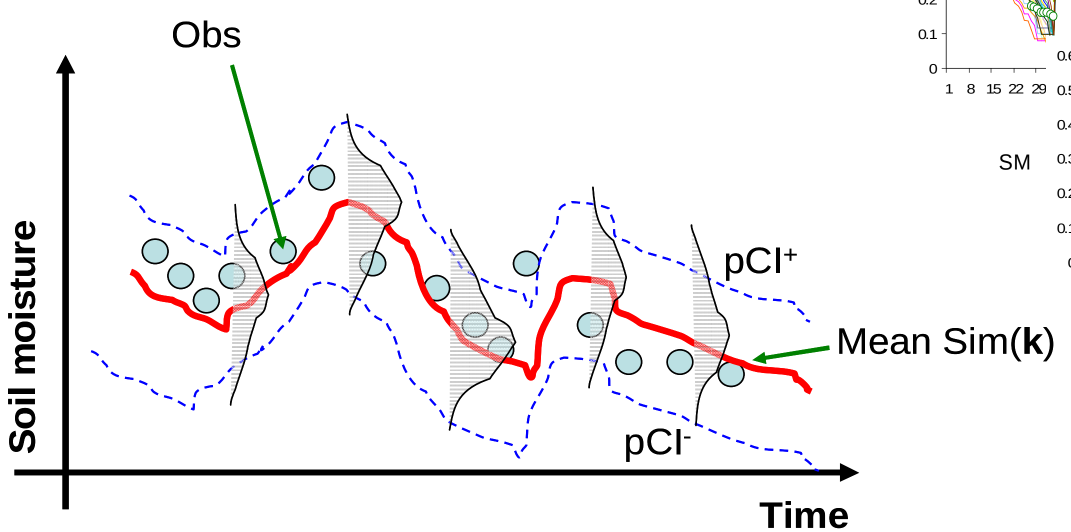


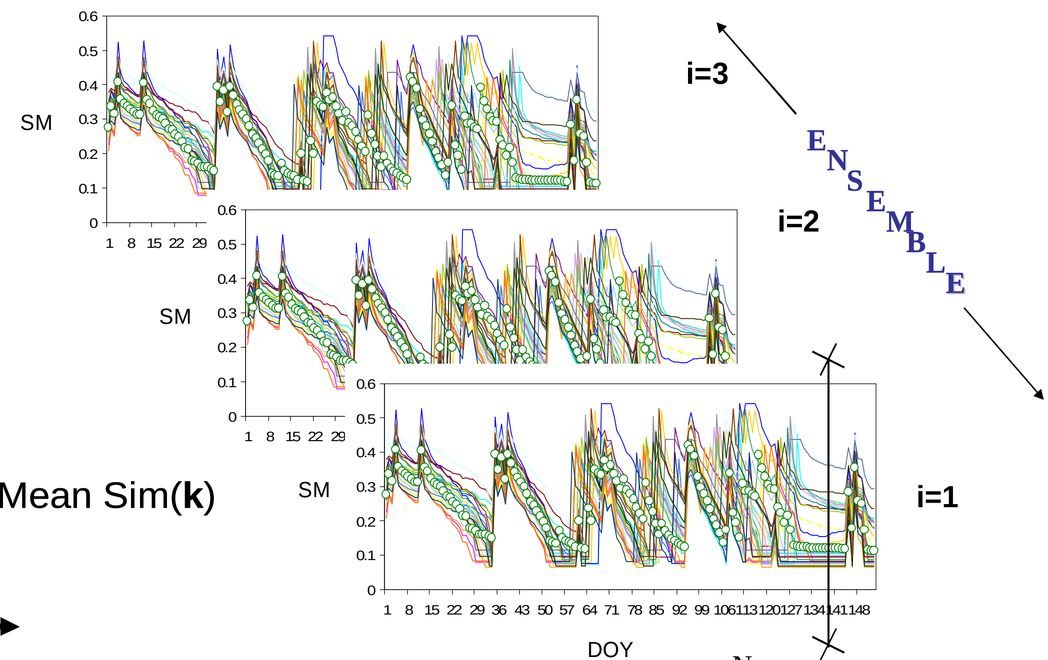
- Airborne: **ESTAR** (SGP97)



1. Noisy Monte Carlo Genetic Algorithm

Inverse Problem Formulation





$$\sum_{r=1}^{N_{resample}} \mathrm{Sim}(\mathbf{k}^r)_{ti}$$

$$\mathrm{Obj}(\mathbf{k})_i = \mathrm{Min}\left(\frac{1}{T}\sum_{t=1}^{T}\left|\frac{1}{N_{resample}}\left(\sum_{r=1}^{N_{resample}} \mathrm{Sim}(\mathbf{k}^r)_{ti}\right) - \mathrm{Obs}_t\right|\right) \quad \forall i$$

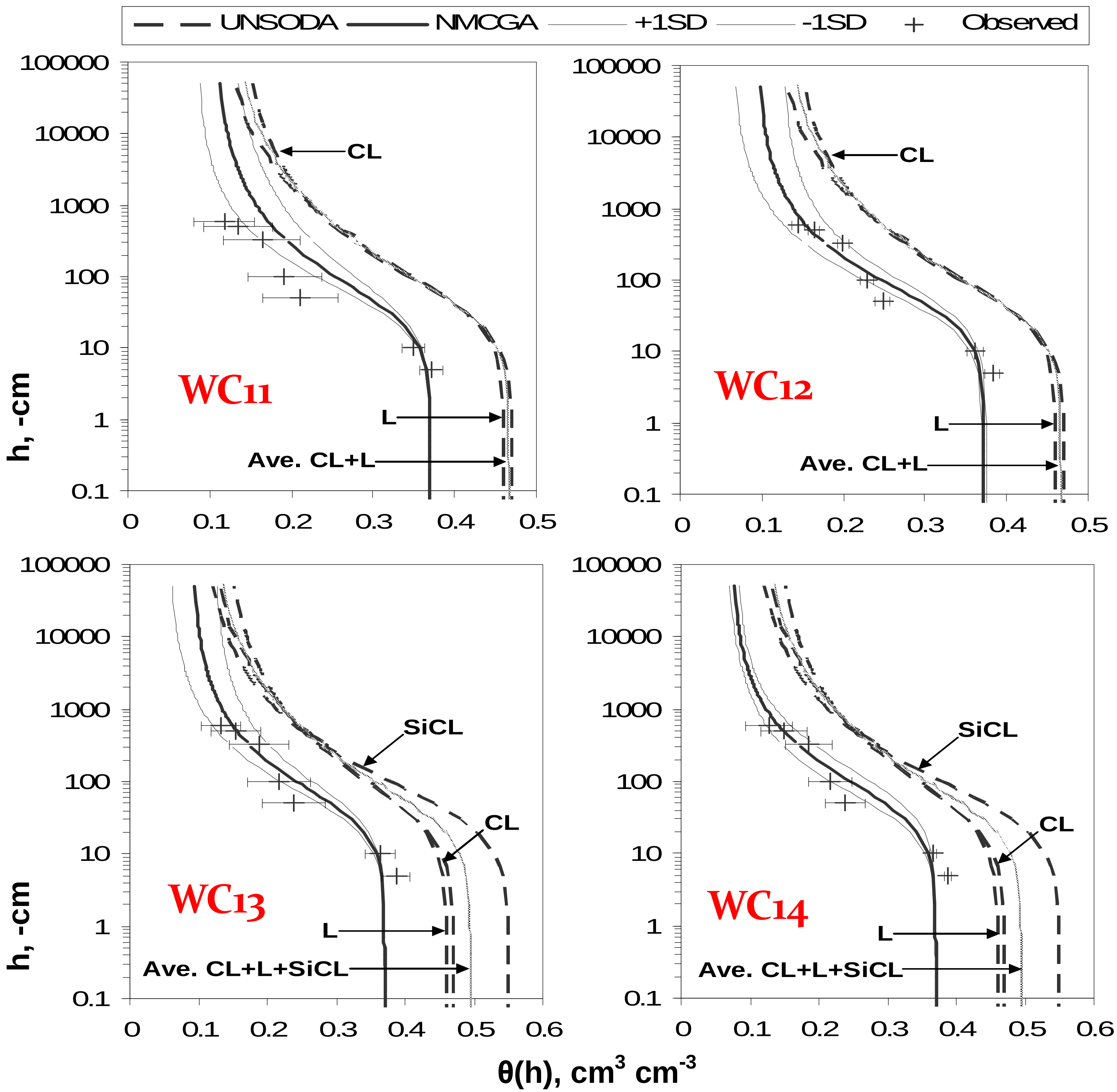
$$\mathrm{Constr}(\mathbf{k})_{ti} = \left(\mathrm{Obs}_t < \mathrm{PCI}^+\left(\mathrm{Sim}(\mathbf{k}^r)\right)_{ti}\right) \mathbf{AND} \left(\mathrm{Obs}_t > \mathrm{PCI}^-\left(\mathrm{Sim}(\mathbf{k}^r)\right)_{ti}\right)$$

$$\forall\, t \text{ (where } t \leq T\text{)}, \forall\, i$$

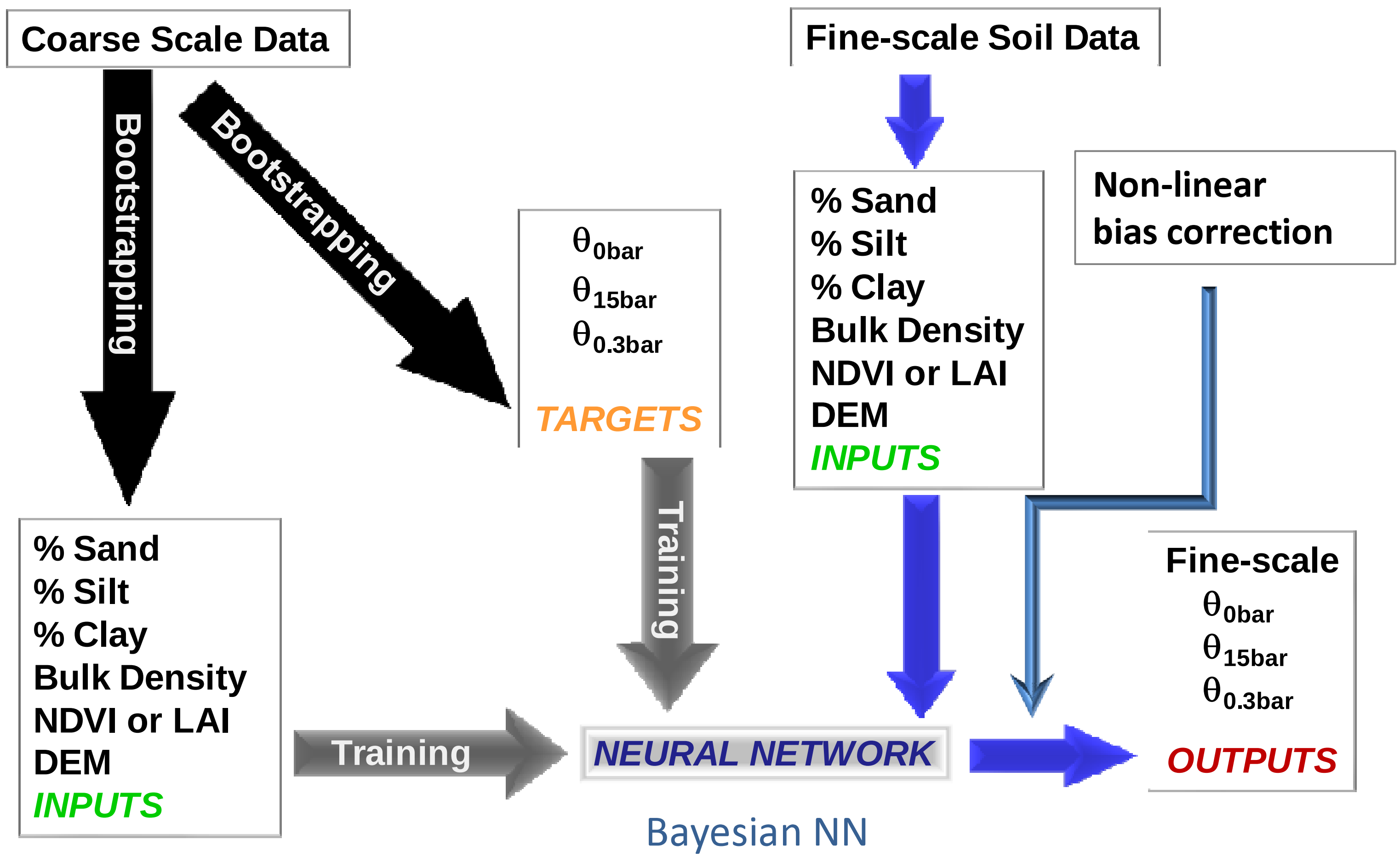
k={α, n, θ_{res}, θ_{sat}, K_{sat}, λ}
(stochastic variables)

Ines and Mohanty, 2008 WRR

Air-borne RS scale (Polarimetric Scanning Radiometer: PSR)

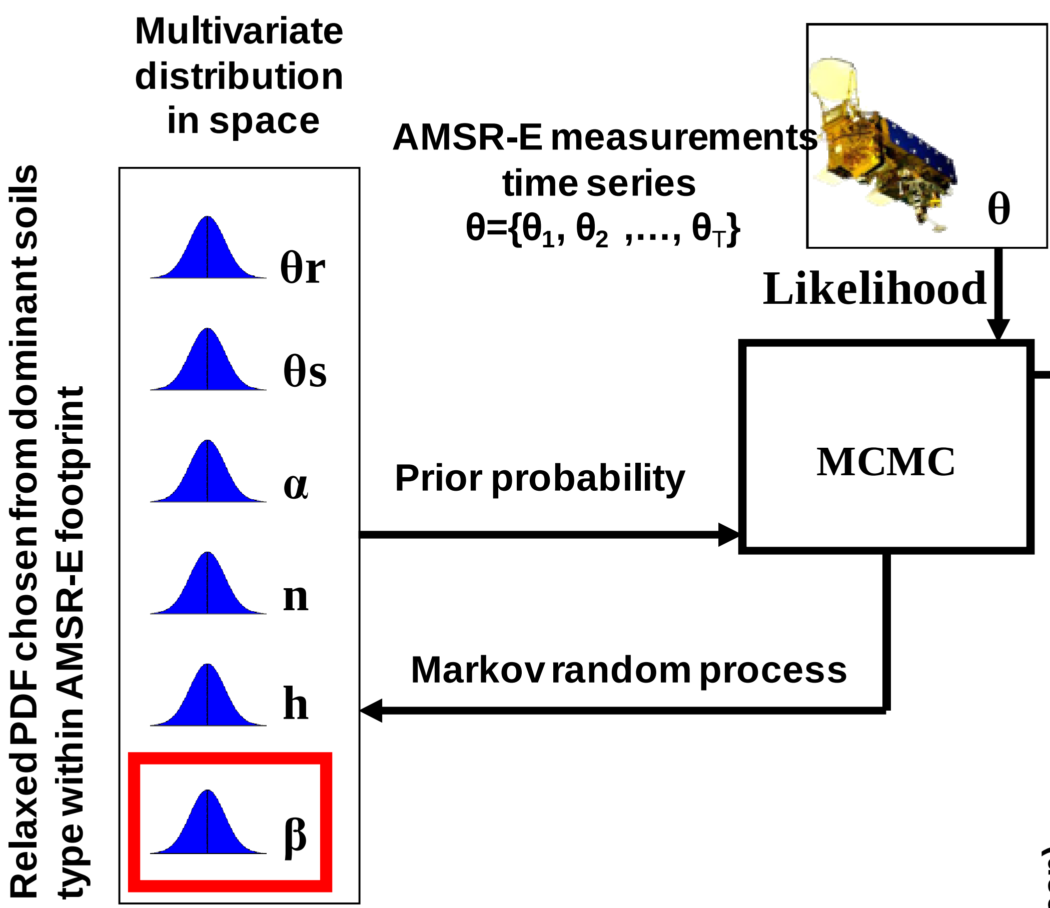


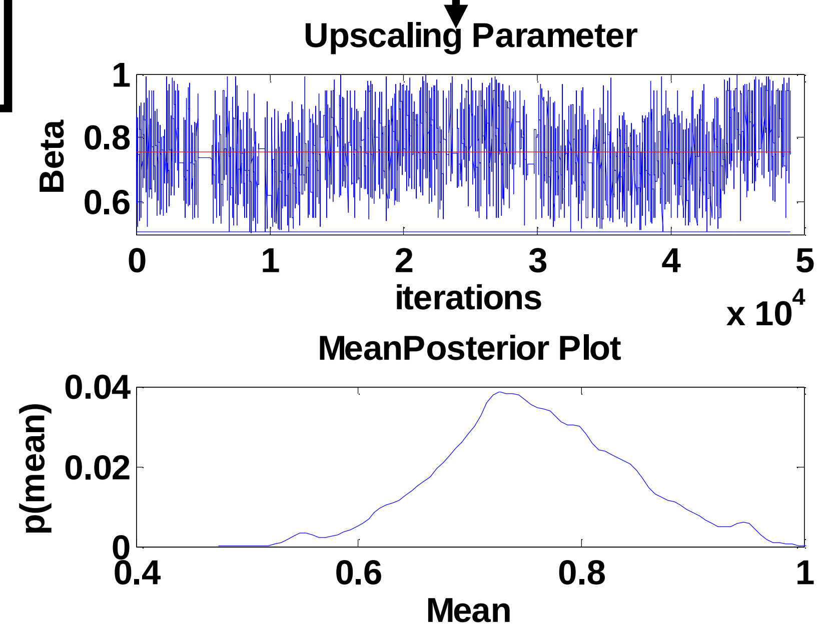
2. Pedo-Topo-Vegetation-Transfer Function



Jana et al., 2008 WRR

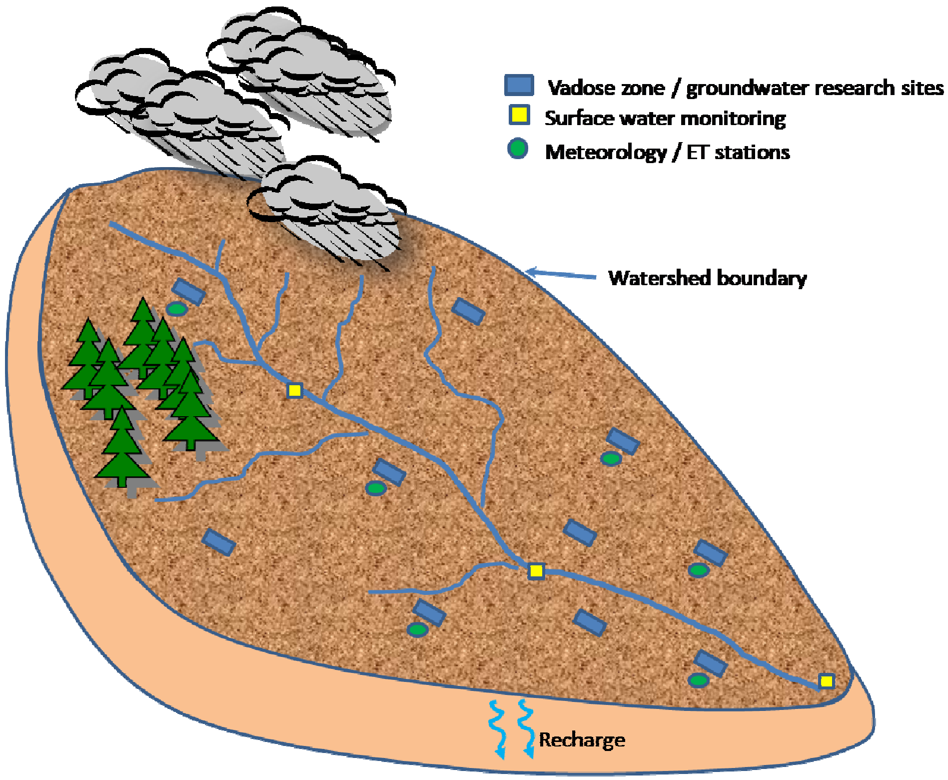
3. Markov Chain Monte Carlo approach





Schematic of parameter estimation

Das et al., 2008 WRR



- New sampling strategies to be developed based on the dominant physical controls and TS concepts at different scales

- Nested sampling to capture variations in scale, soil type, topography, land cover, and hydroclimate is necessary