Synergistic Linkage of CZOs to SMAP

Henry Lin (*Pennsylvania State Univ.) and *CZO Teams

SMAP Cal/Val Workshop, May 3-5, 2011, Oxnard, CA





NSF Critical Zone Observatories:

CZOs "*operate at the watershed scale and that will significantly advance our understanding of the integration and coupling of Earth surface processes as mediated by the presence and flux of fresh water.*"

http://www.nsf.gov/pubs/2006/nsf06588/nsf06588.pdf

3 CZOs (CA, CO, PA): 2007-2012
3 CZOs (AZ, DE, PR): 2009-2014

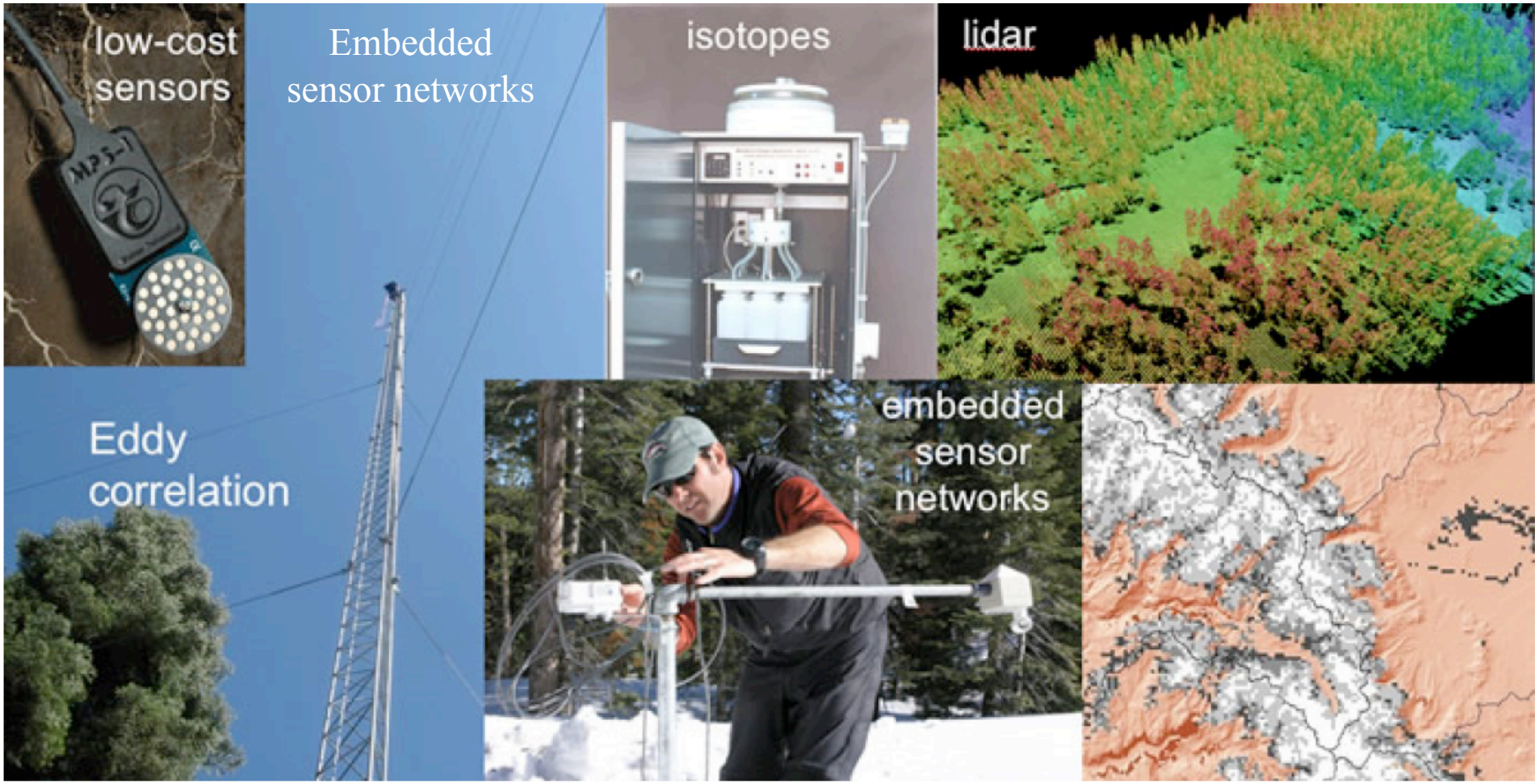


The National CZO Program is a community resource. It serves the international scientific community through research, infrastructure, data, and models. The interdisciplinary teams at each CZO work on site-specific science as well as cross-site science

GET CZO DATA

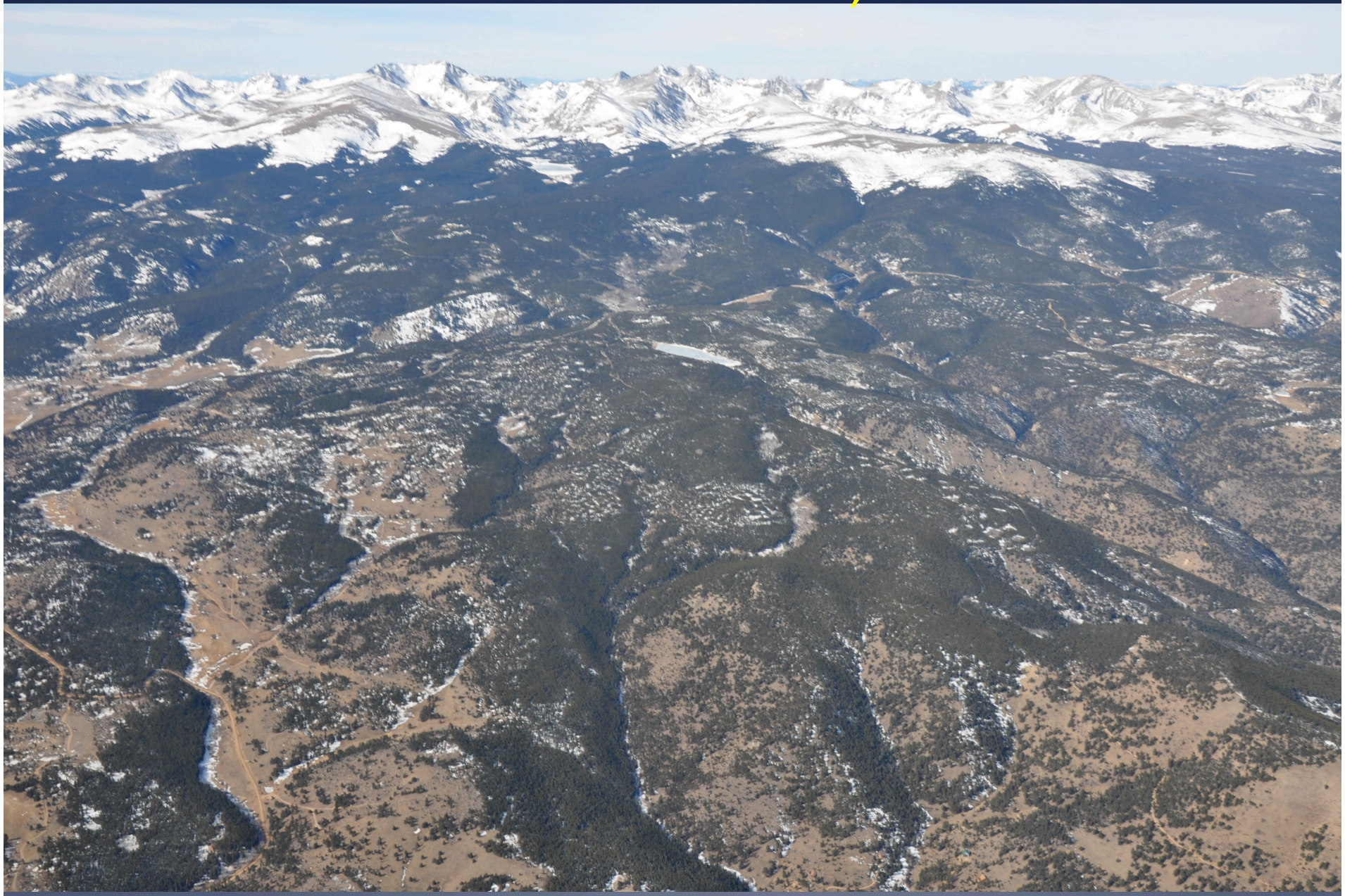
At present, CZO data can be accessed through online resources of the individual CZOs:
Boulder Creek | Christina River | Jemez - Catalina | Luquillo | Southern Sierra | Shale Hills

A national CZO portal is being developed for seamless access of data from all CZOs (see below text about CZO Central).

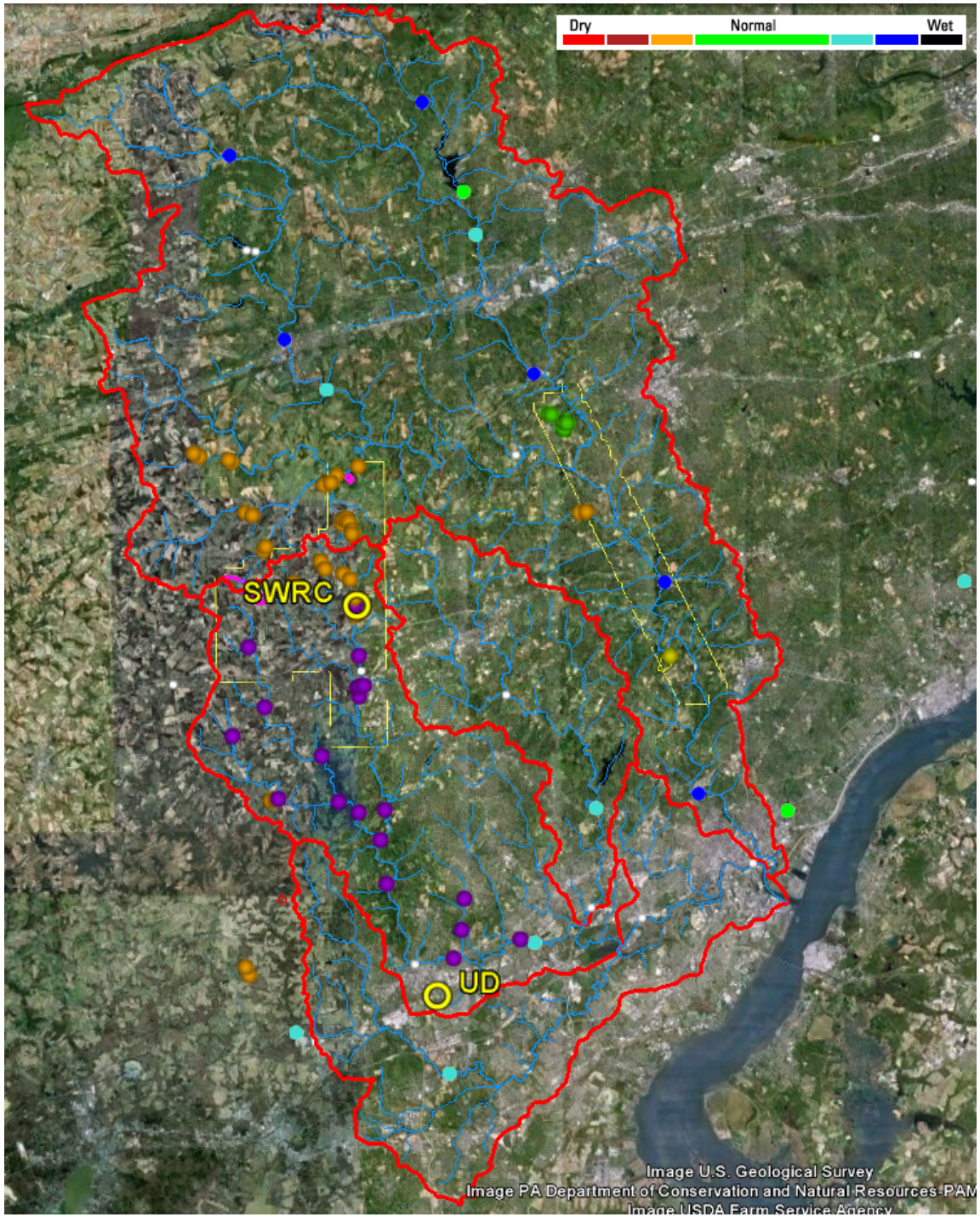


http://criticalzone.org/data.html

Boulder Creek CZO, CO



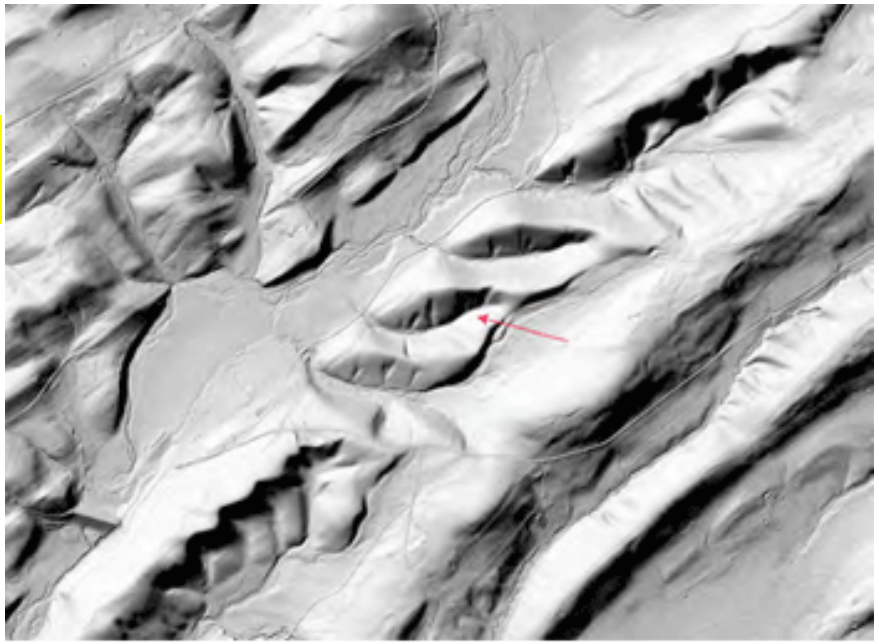
(Slide courtesy of Suzanne Anderson)



Christina River Basin CZO

- 3rd order White Clay Creek at SWRC, 800 ha
- 1st order forest, 24 ha
- 1st order row crop, ~40 ha
- 1st order construction, ~50 ha
- mouth White Clay Creek, 277 km^2
- mouth Brandywine Creek, 842 km^2

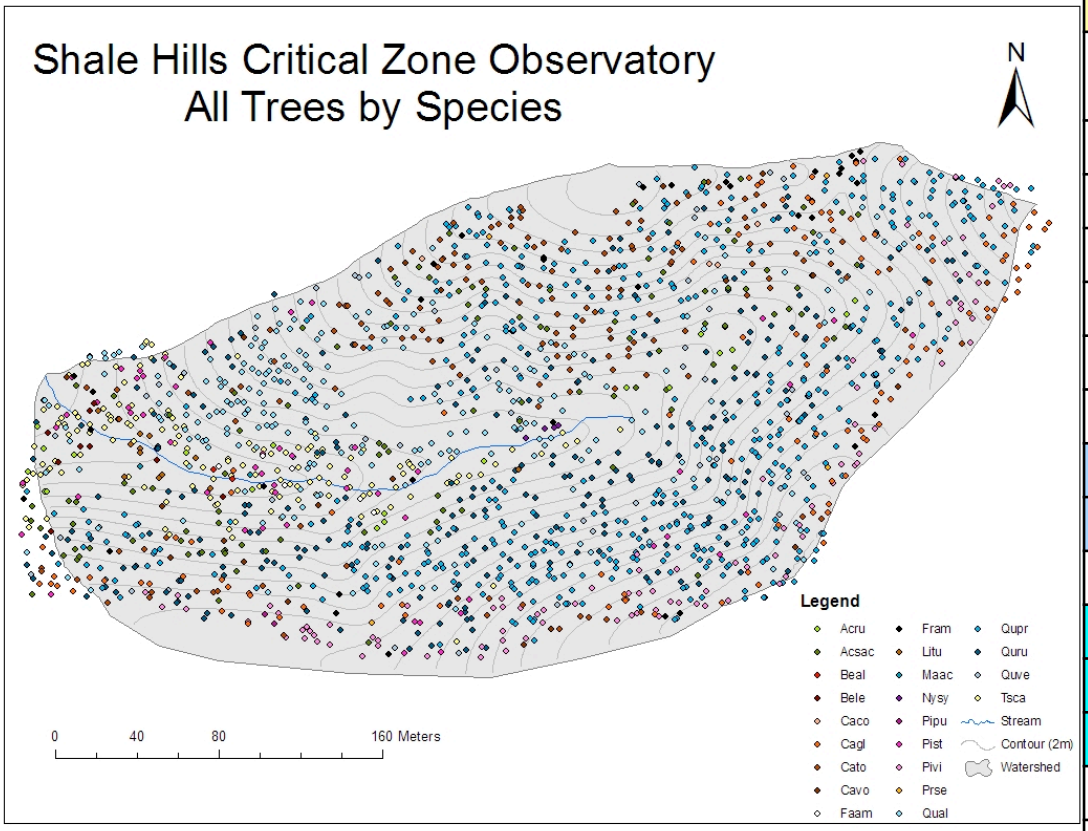
LIDAR Surveys at Each CZO



1. **Tree scale mapping (sub-m scale)**
   - Location of trees
   - DBH
   - Canopy Closure
   - Tree Height
   - LAI
   - Species Identification

2. **Bare Earth Ground Truth (Leaf off flight)**
   - Shale Hills Watershed (leveraged dataset)
   - Mid-Basin Stream Channel Ground Control Point (downstream)
   - Leading Ridge Watershed 1 Ground Control Point

Numbers of individual trees at the Shale Hills Catchment



Species Common Name	Number of Trees
Red maple	22
Sugar maple	122
Yellow birch	2
Sweet birch	10
American Hickory	3
Bitternut hickory	184
Pignut hickory	122
Shugbark hickory/ Mockernut hickory	26
Beech	7
White ash	36
Yellow-poplar	13
Cucumber tree	3
Blackgum	5
Table Mountain pine	2
Eastern white pine	59
Virginia pine	96
Black cherry	5
White oak	282
Chestnut oak	558
Red oak	287
Black oak	47
American basswood	3
Eastern hemlock	164
SUM	**2058**

Global CZOs

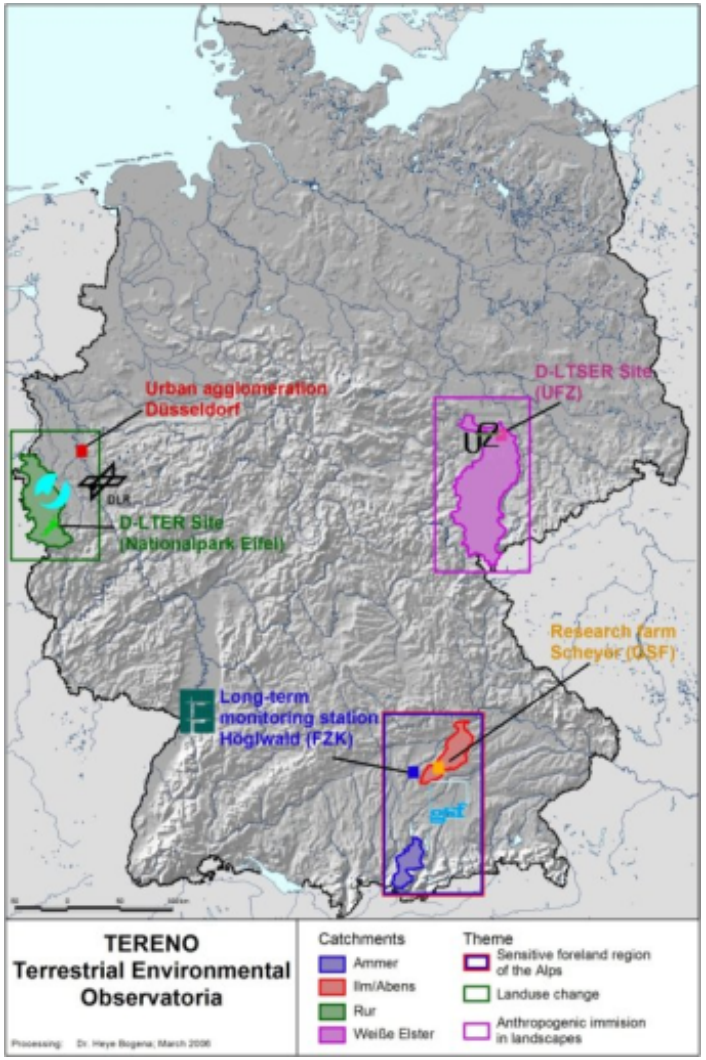
SOILTREC



Four SoilTrEC CZOs:

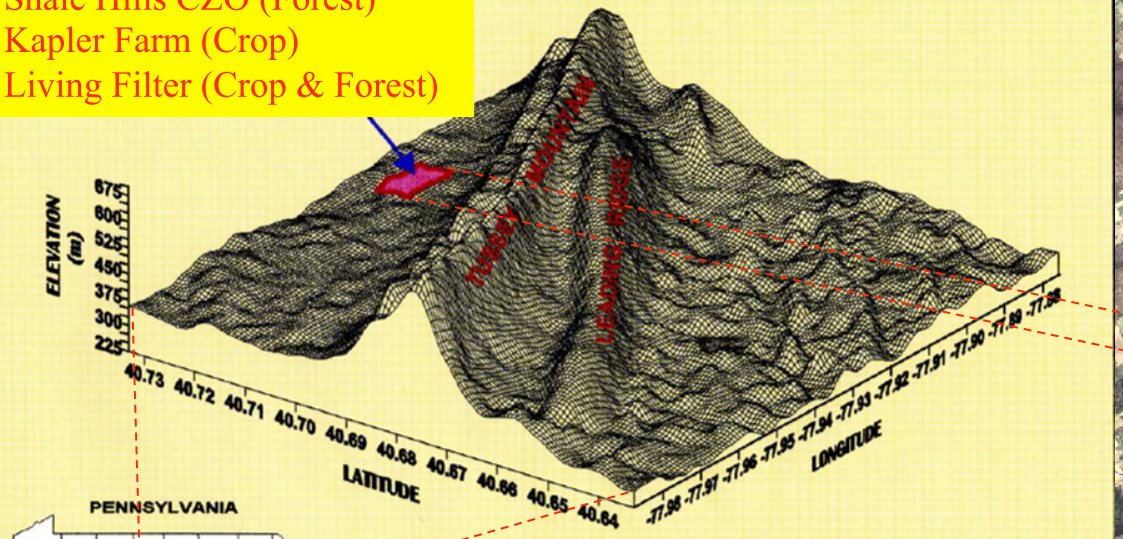
- Fuchsenbigl, Austria
- Koiliaris River Basin, Crete, Greece
- Damma Glacier, Canton Uri, Switzerland
- Kladska Lake, Chatteau, Mt. Lysina, Czech Republic

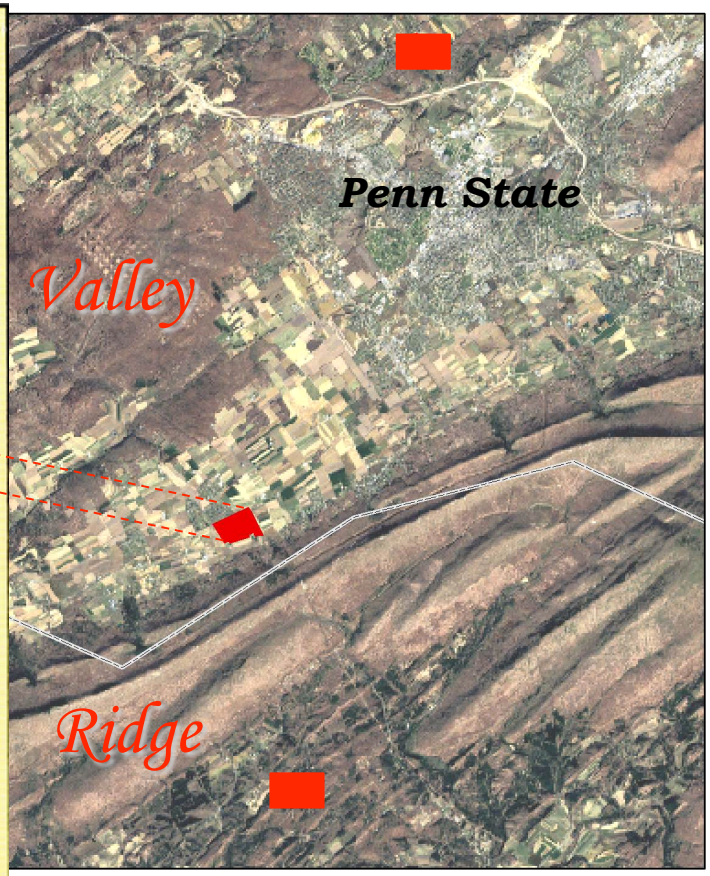
Australia, China, …



Three Hydropedologic Observatories at Penn State :

- Shale Hills CZO (Forest)
- Kapler Farm (Crop)
- Living Filter (Crop & Forest)



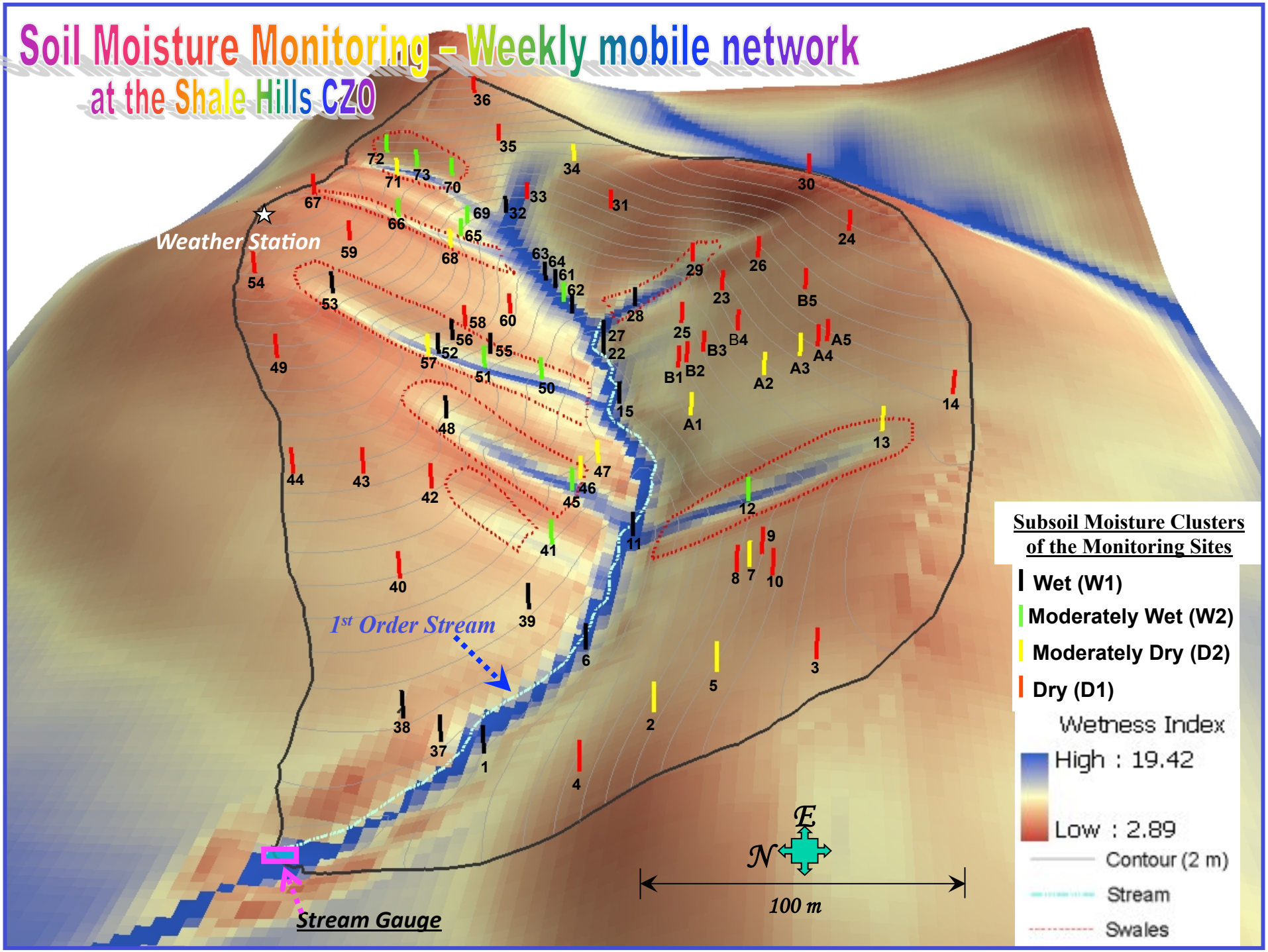


0 1.5 3 6 9 12 15








Soil Moisture Monitoring – Weekly mobile network
at the Shale Hills CZO
Weather Station
1st Order Stream
Stream Gauge
100 m
N
E
Subsoil Moisture Clusters of the Monitoring Sites
Wet (W1)
Moderately Wet (W2)
Moderately Dry (D2)
Dry (D1)
Wetness Index
High : 19.42
Low : 2.89
Contour (2 m)
Stream
Swales



Instrument Installation Scheme at the Shale Hills

Well

A Horizon

Bt1 Horizon

Bt2 Horizon

C Horizon

2” Schedule 40 PVC

Thermocouples

Bentonite

Sand

10 cm

20 cm

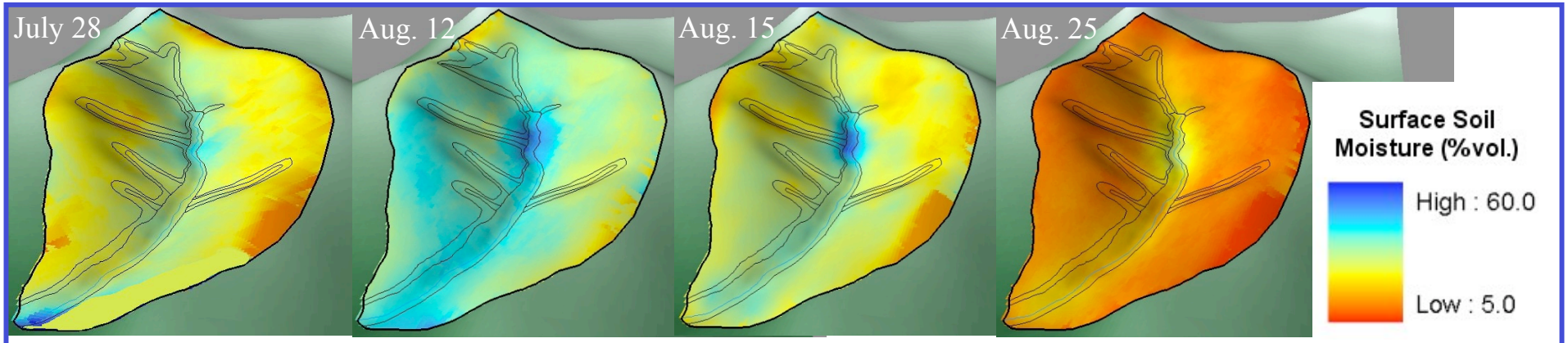
60 cm

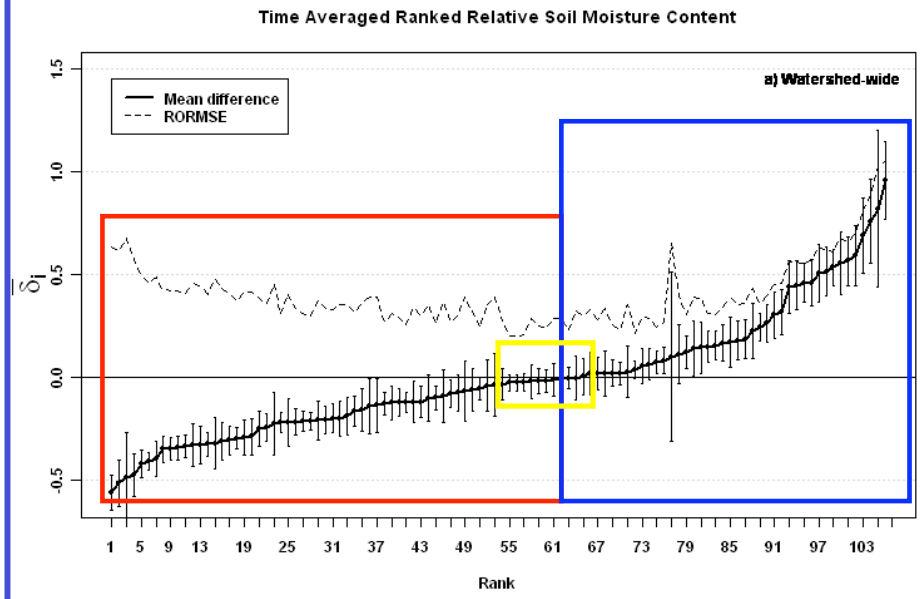
100 cm

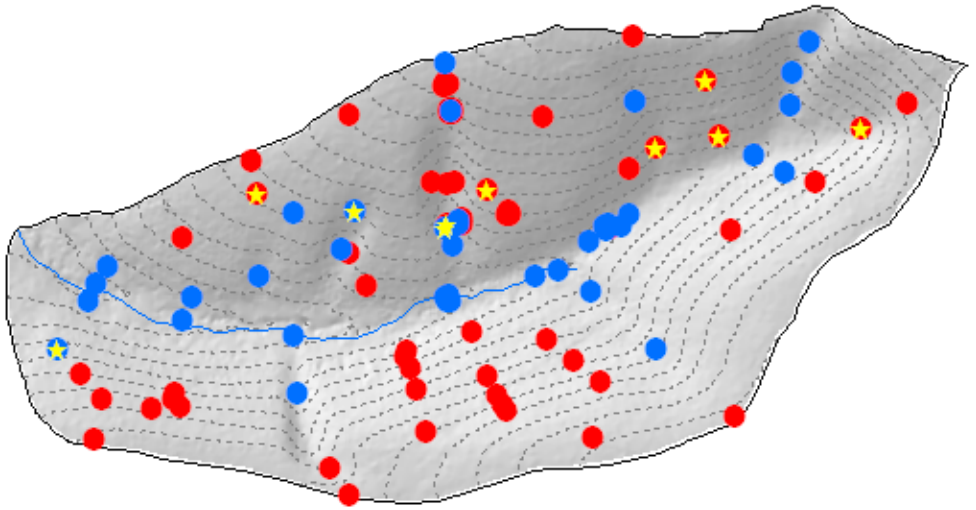
Portable Soil Moisture Profiling Probe (TDR)

Nested Piezometers with Thermocouples

Nested Tensiometers

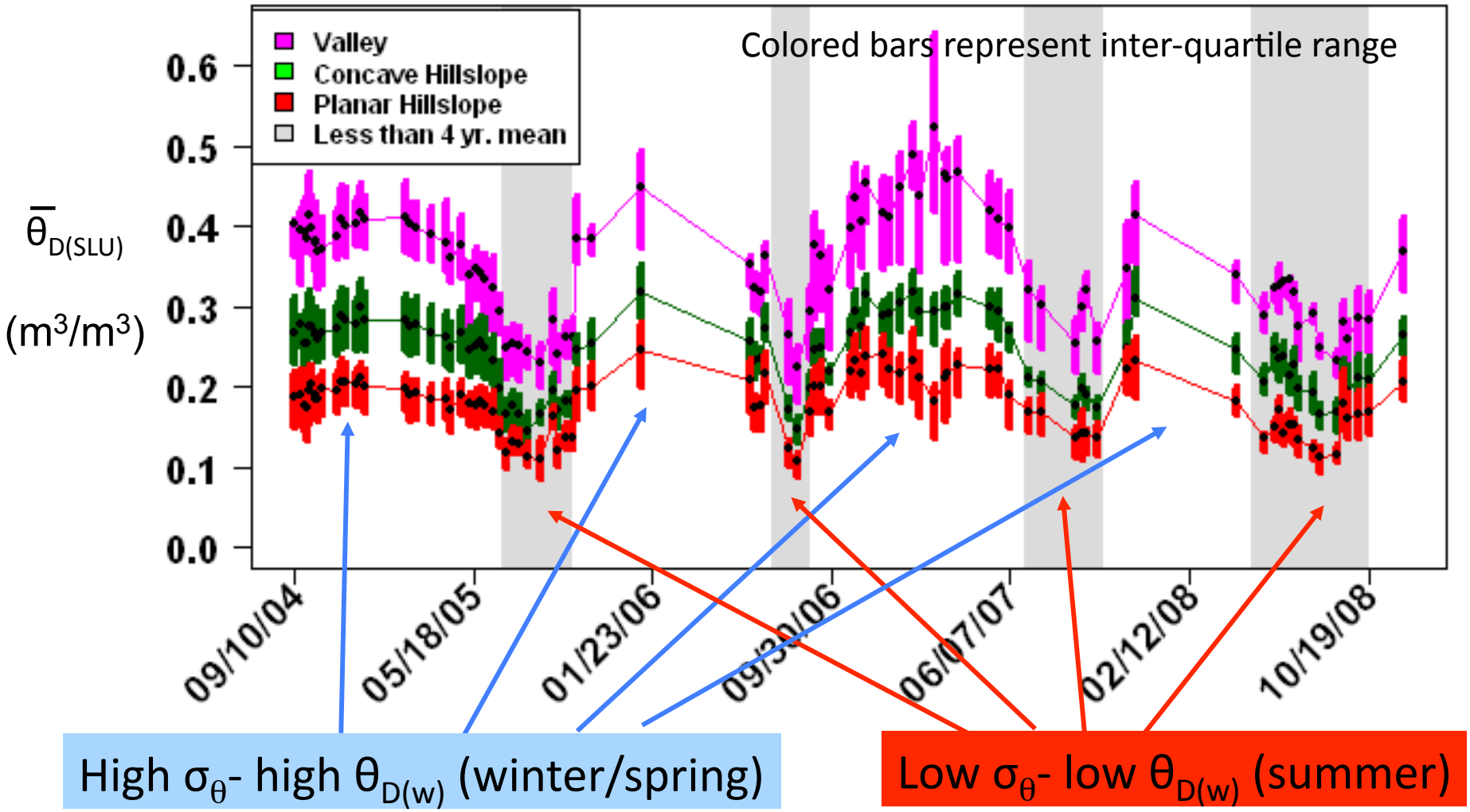




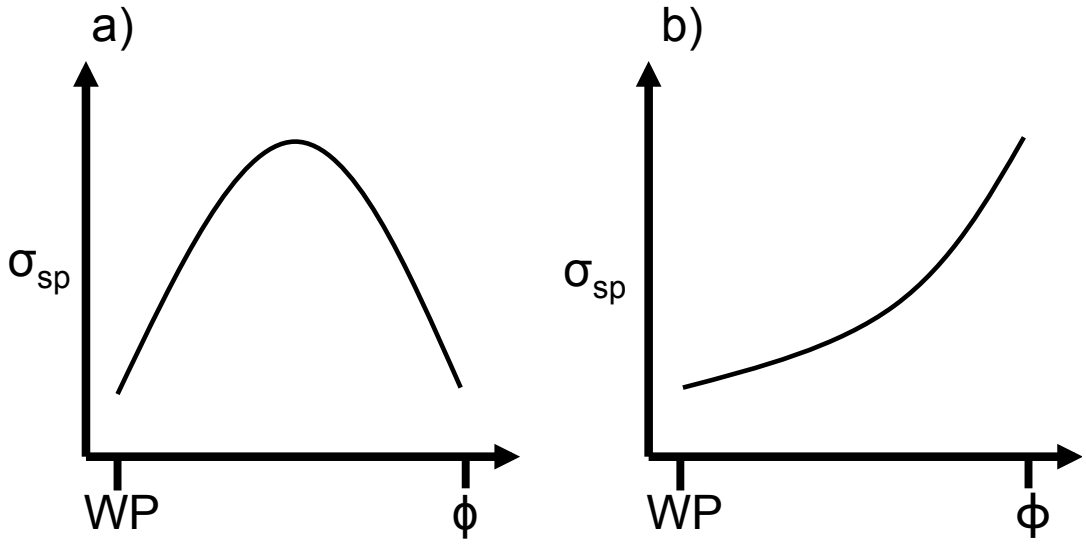


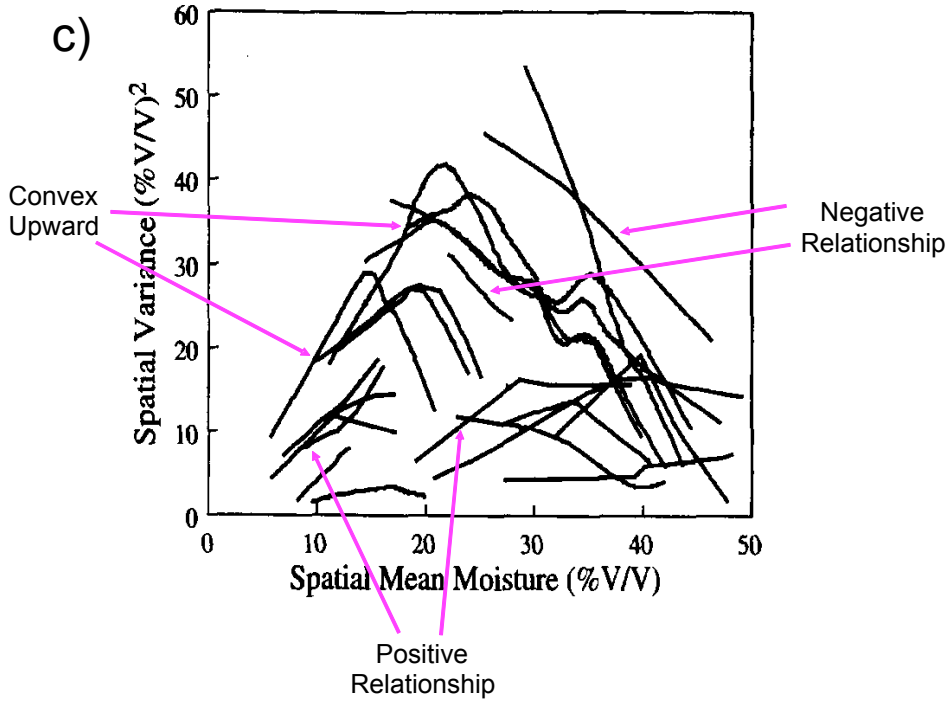
- 106 total monitoring locations
- 2004 – Present (~weekly)

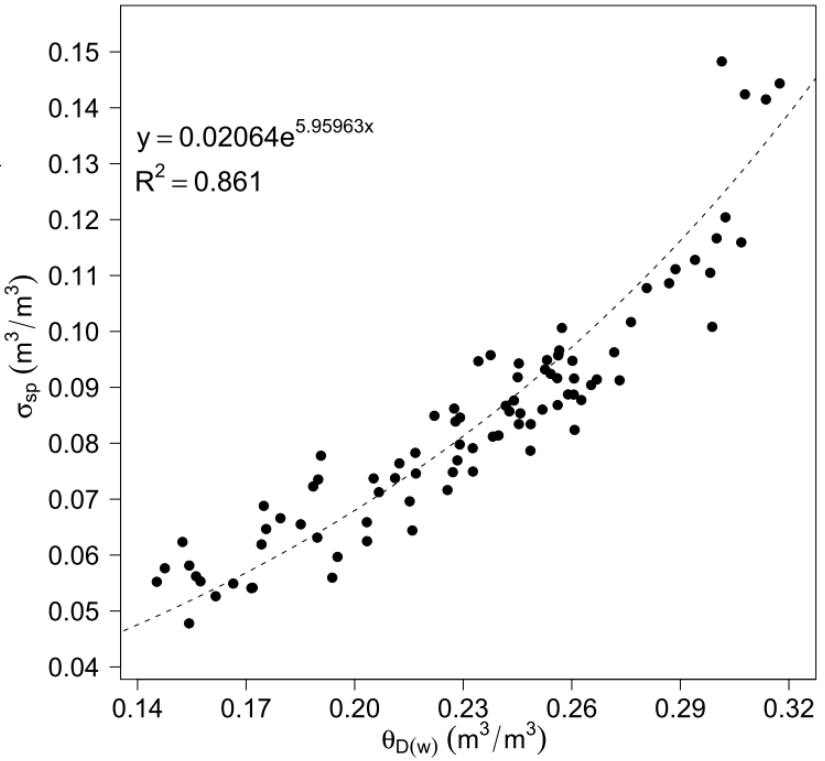
Changing controls of soil moisture



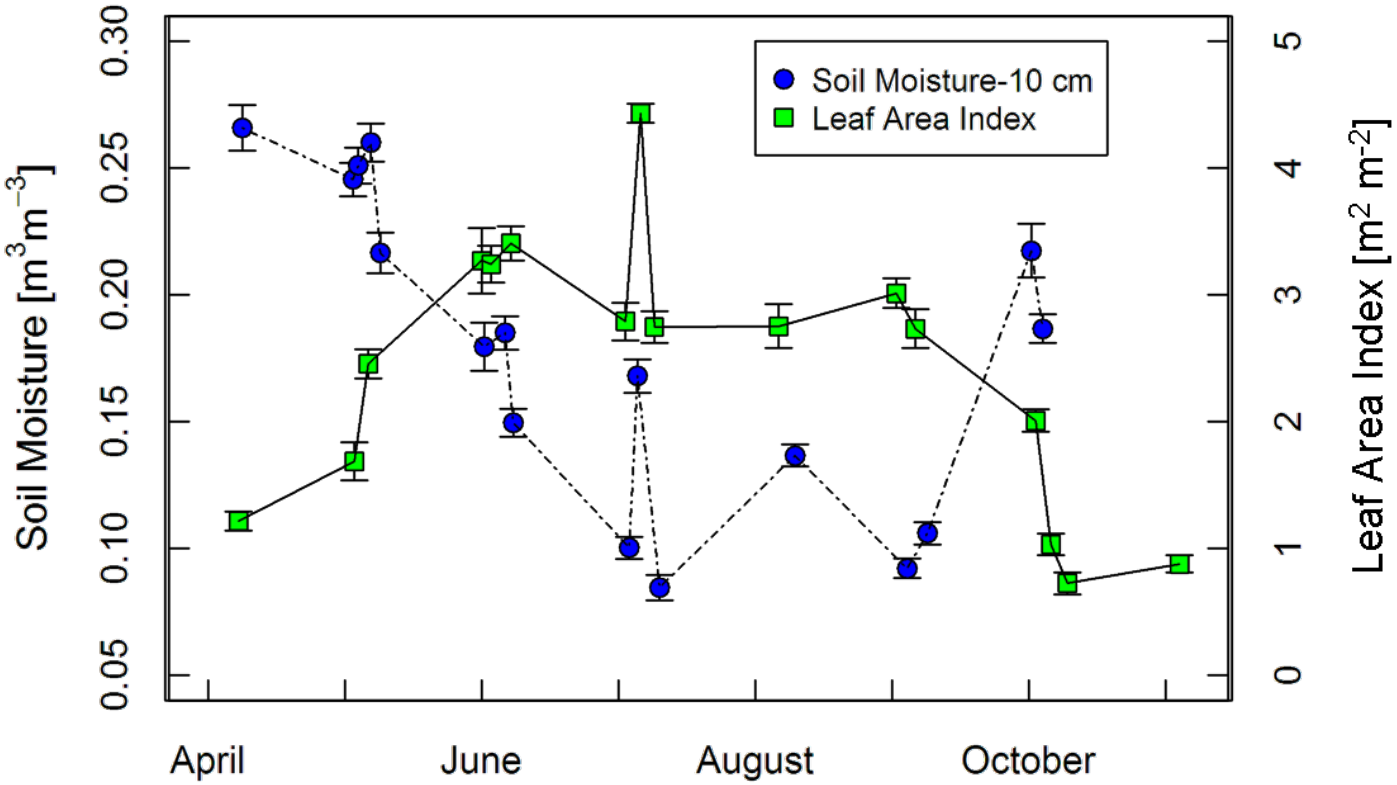
Valley θ > Concave Hillslope θ > Planar Hillslope θ


a)
σ_{sp}
WP
ϕ
b)
σ_{sp}
WP
ϕ


c)
Spatial Variance (%V/V)^2
Spatial Mean Moisture (%V/V)
Convex Upward
Negative Relationship
Positive Relationship

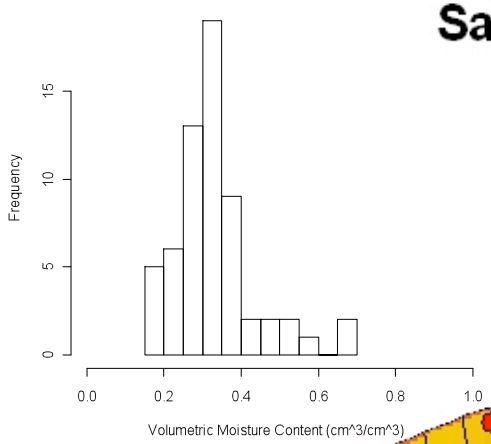

$y = 0.02064e^{5.95963x}$
$R^2 = 0.861$
σ_{sp} (m^3/m^3)
$\theta_{D(w)}$ (m^3/m^3)

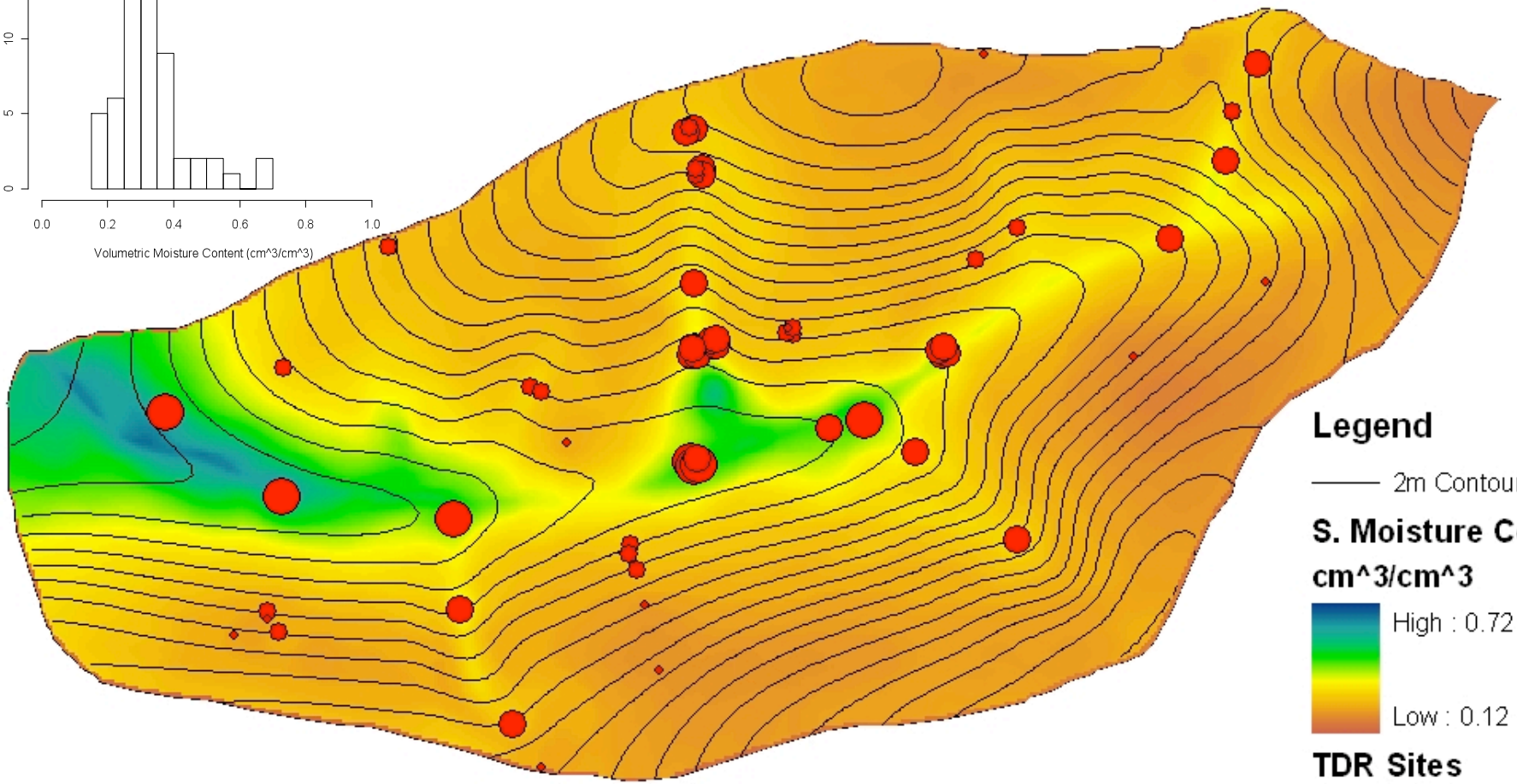
LAI and soil moisture display inverse relationship during growing season

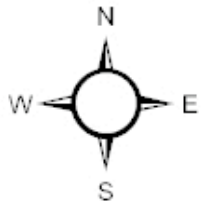


Soil moisture decreases from leaf onset to leaf maturity and then increases from maturity to leaf senescence.

Saturated Moisture Content at 20 cm Depth







$$\theta = \theta_r + \frac{(\theta_s - \theta_r)}{[1 + (\alpha\psi)^n]^m}$$

Legend

2m Contours

S. Moisture Content

cm^3/cm^3

High : 0.72

Low : 0.12

TDR Sites

Sat Moisture Value

0.17 - 0.23

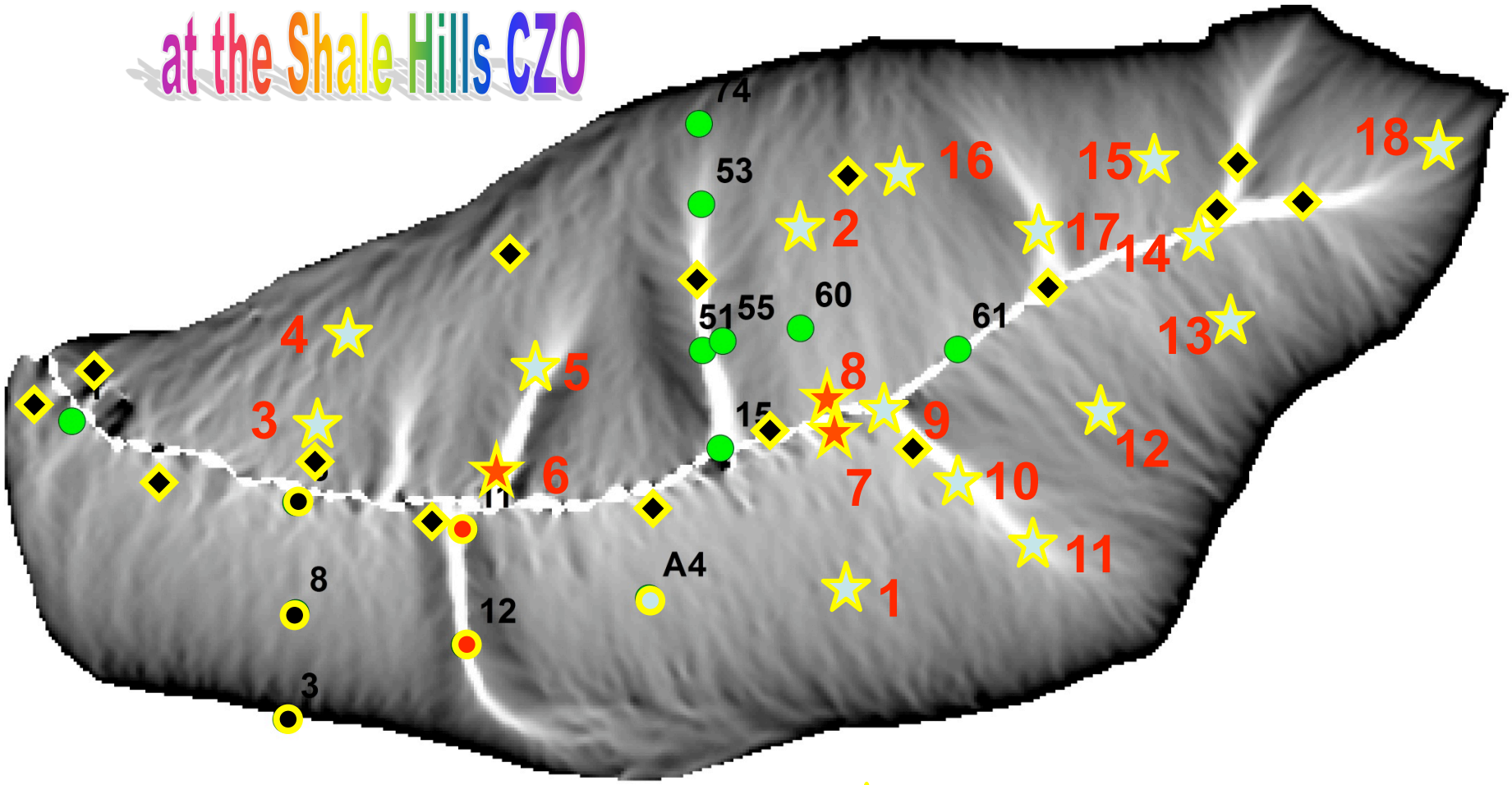
0.24 - 0.31

0.32 - 0.43

0.44 - 0.65

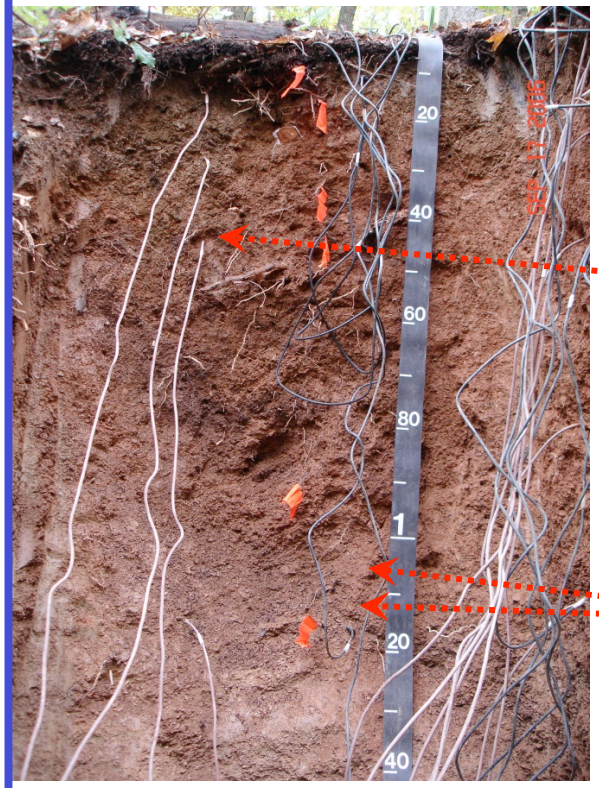
Real Time Moisture Monitoring

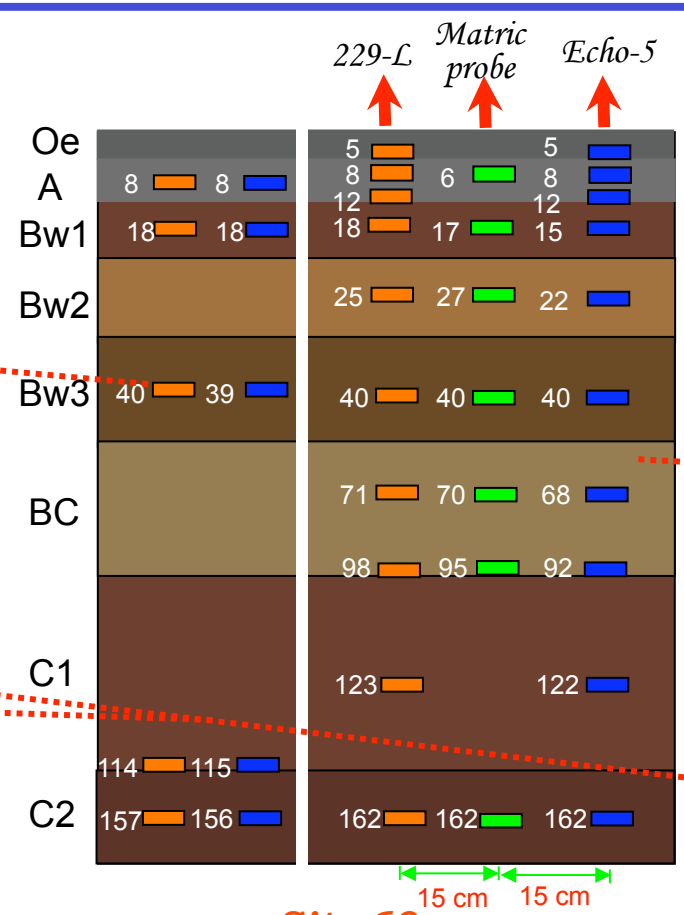
Soil Moisture Monitoring - Real-time sensor network at the Shale Hills CZO



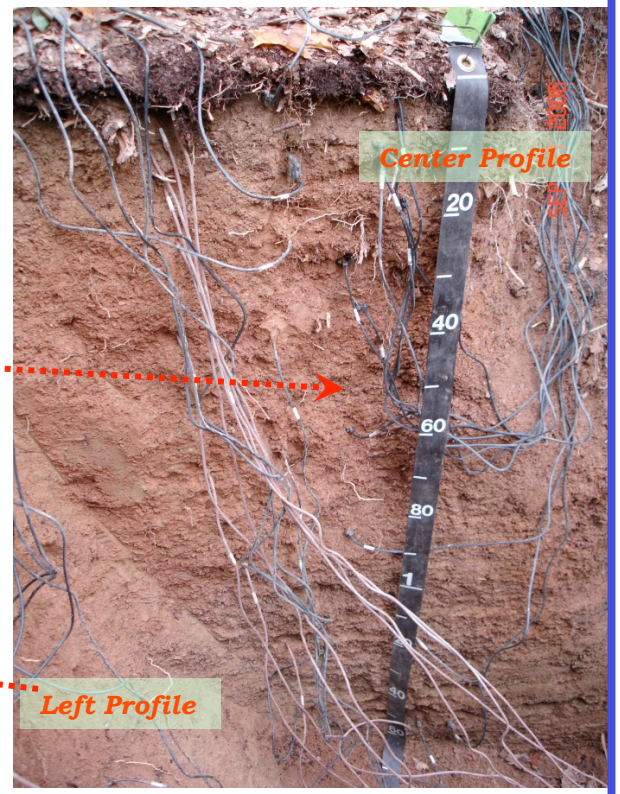
- Original Super Sites
- Stevens, 5TE & MPS on CR1000
- 5TE & MPS on EM50
- 5TE on EM50
- 3 5TM + 2 MPS + EM50
- 5TE, MPS and Stevens on CR1000
- 2-3 5TE on EKO

Site 51 Left Profile





Site 51 Center Profile



Site 74



Site 60



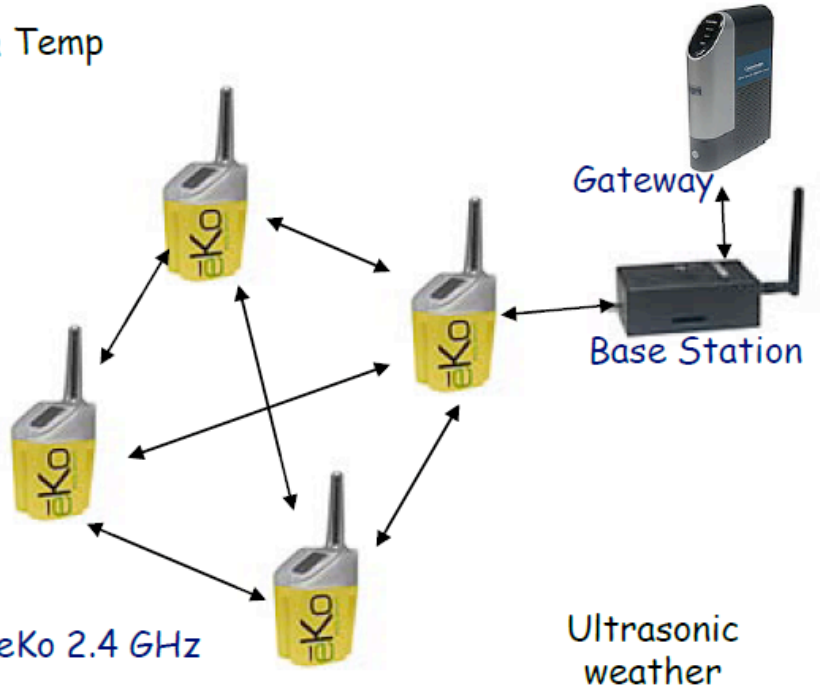
Site 15



Wireless Sensor Network



RH & Temp



Ultrasonic weather station

Soil Moisture
Soil Temp
Elec. Conduct.
Matric Poten.

Leaf Wetness



Snow Depth



Groundwater Level







Hydropedograph

Input Data

File path and file name (include extension)

C:\Data\Shale Hills\60_SM.csv

Browse

Number of Probes

5

Column of Time Data

1

Data Locations

Probe Number

1

cm

Probe Depth

10

[10 20 30 40 50]

Probe Column

C1

[2 3 4 5 6]

Submit

Reset Depths and Columns

Analysis Modules

Summary Figures

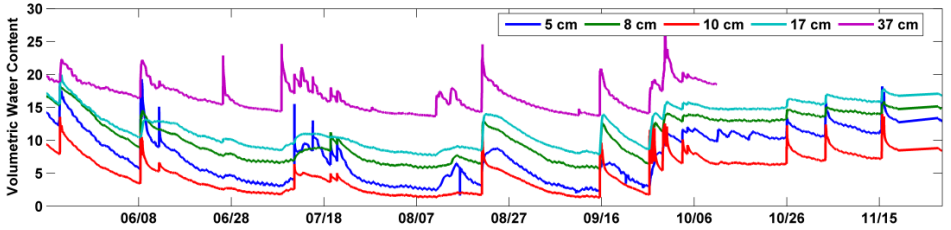
Preferential Flow

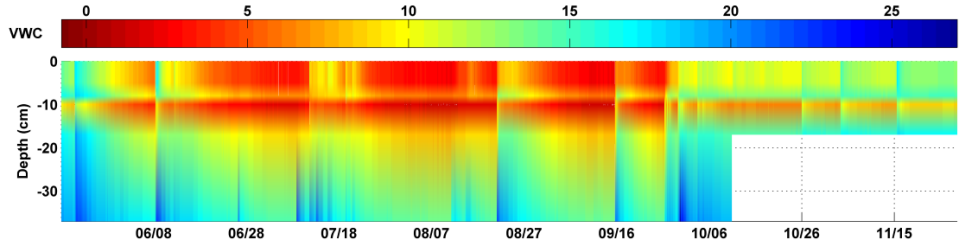
Moisture Release

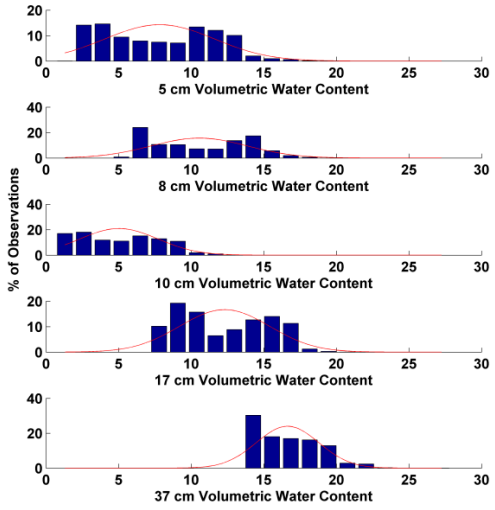
Recession Analysis

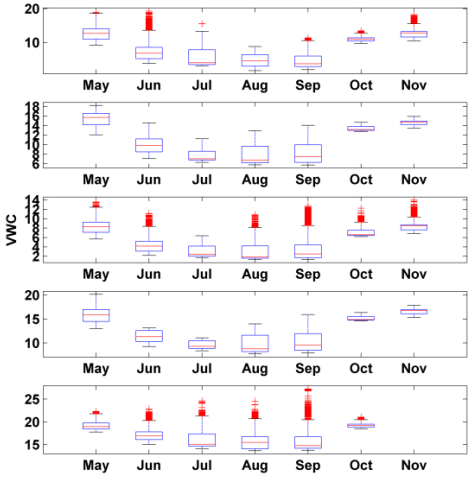
Soil Physical Properties

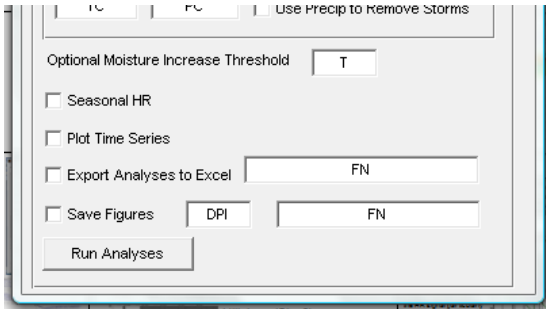
Hydraulic Redistribution

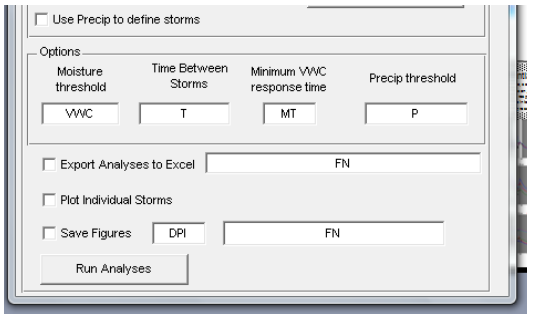












Spatial Extent

Relatively flat field

Hilly landscape

Watershed

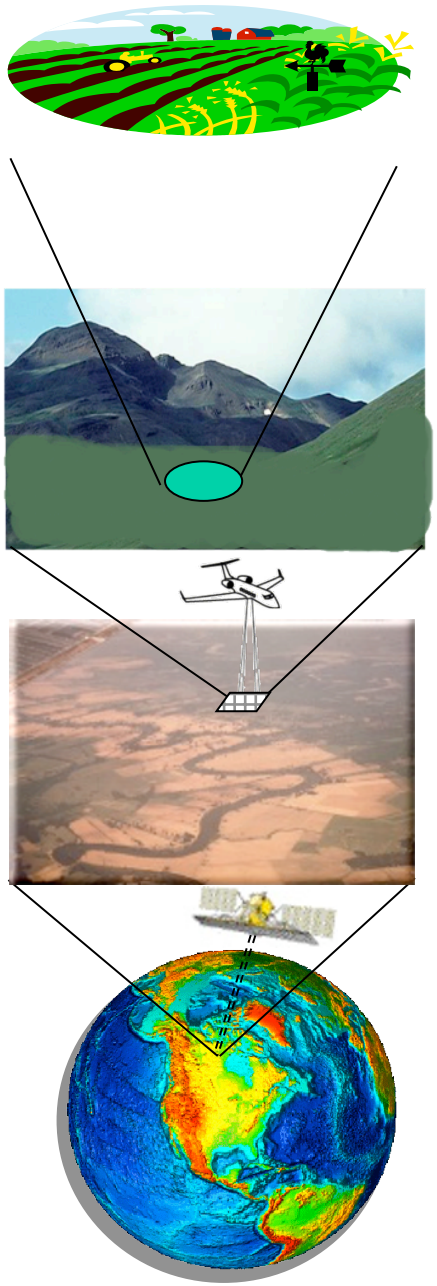
Region/Nation/ Globe

a)

b)

c)

d)



Spatial Model

Standard Geostatistics

Hierarchical Linear Model

Spatial Bayesian Hierarchical Model

Prior Model
$\pi(\boldsymbol{\theta})$

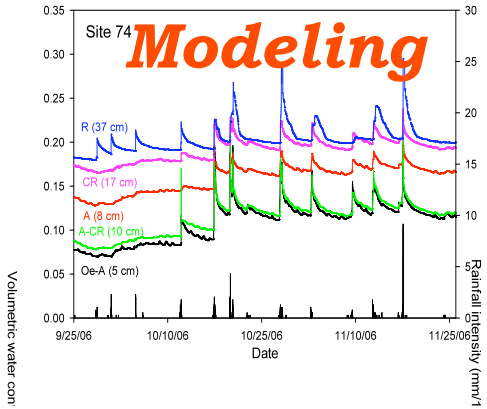
Process Model
$f(\boldsymbol{Y} \mid \boldsymbol{\theta})$

Data Model
$g(\boldsymbol{Z} \mid \boldsymbol{Y}, \boldsymbol{\theta})$



Iterative loop of *mapping*, *monitoring*, *modeling* (3M) may be developed into an integrated and evolutionary approach to address the complexity and dynamics of the Critical Zone across scales and geographic regions





Model guidance to site selection

Model inputs and validation

(Lin, HESS, 2010)

Key Issues

1. Linking surface to subsurface
2. Linking point to area
3. Linking status to process

