Soil Moisture Estimation Using Active DTS at MOISST Site

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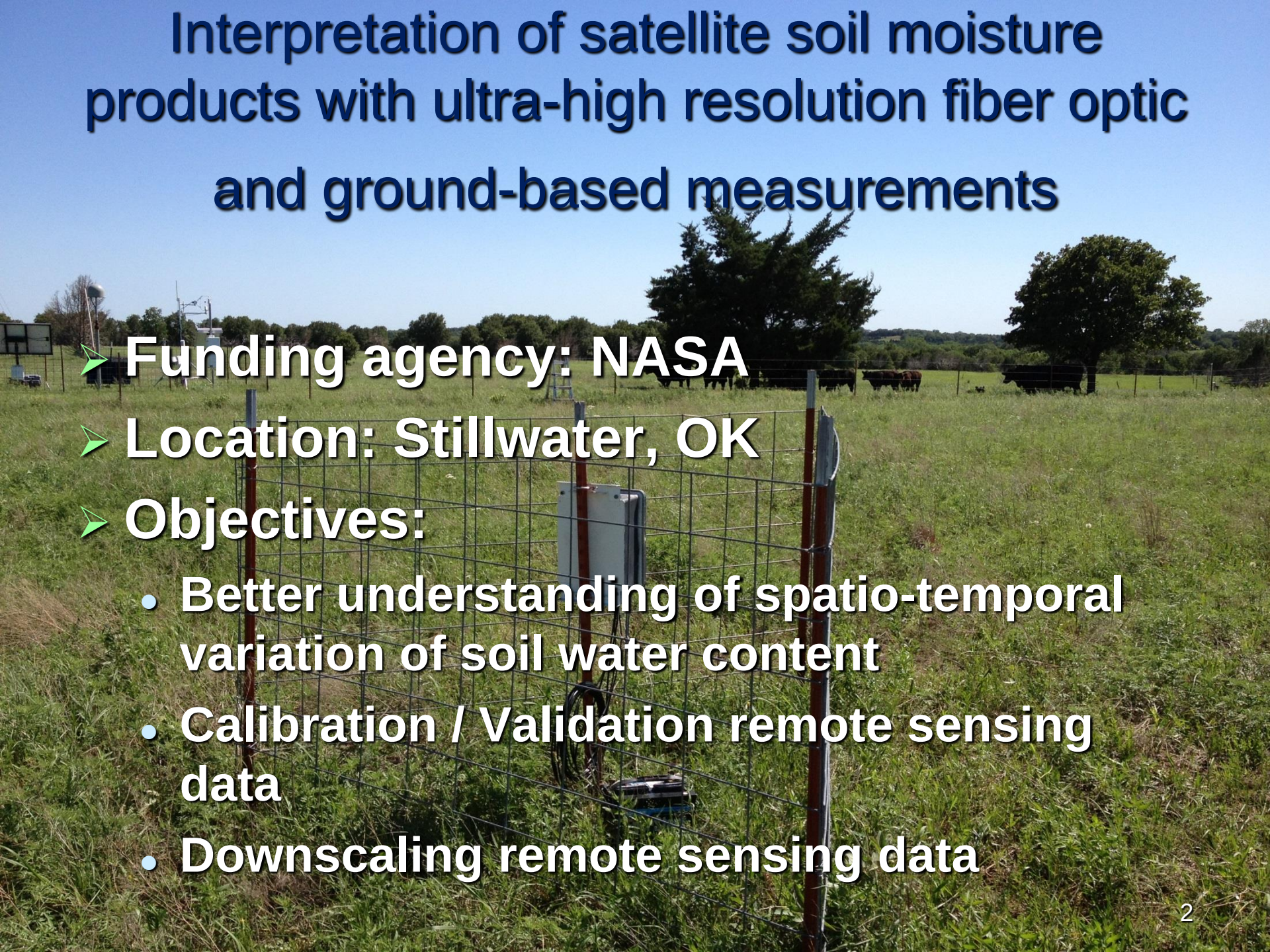
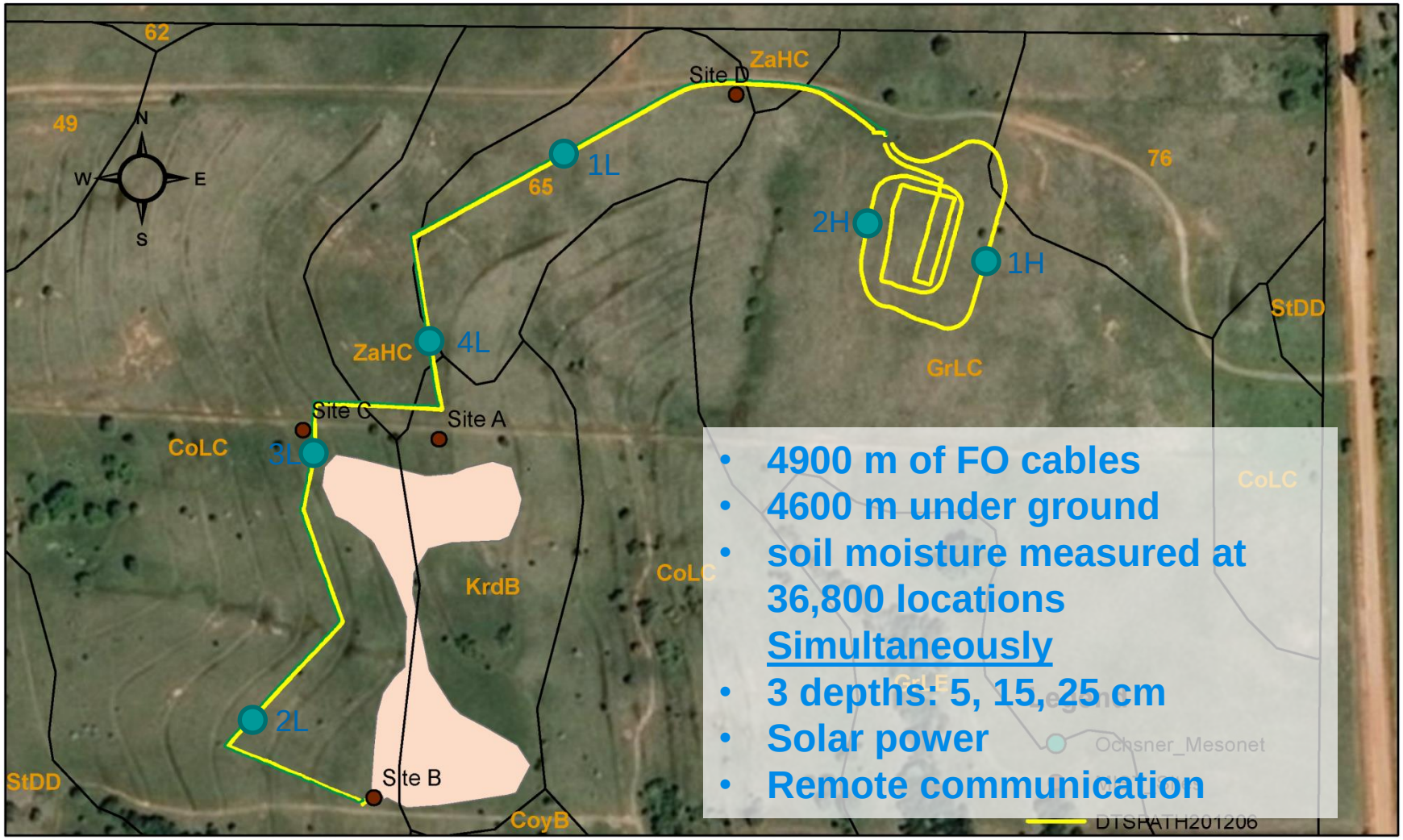
Interpretation of satellite soil moisture products with ultra-high resolution fiber optic and ground-based measurements



- Funding agency: NASA
- Location: Stillwater, OK
- Objectives:
  - Better understanding of spatio-temporal variation of soil water content
  - Calibration / Validation remote sensing data
  - Downscaling remote sensing data

Fiber Optics Cable Path



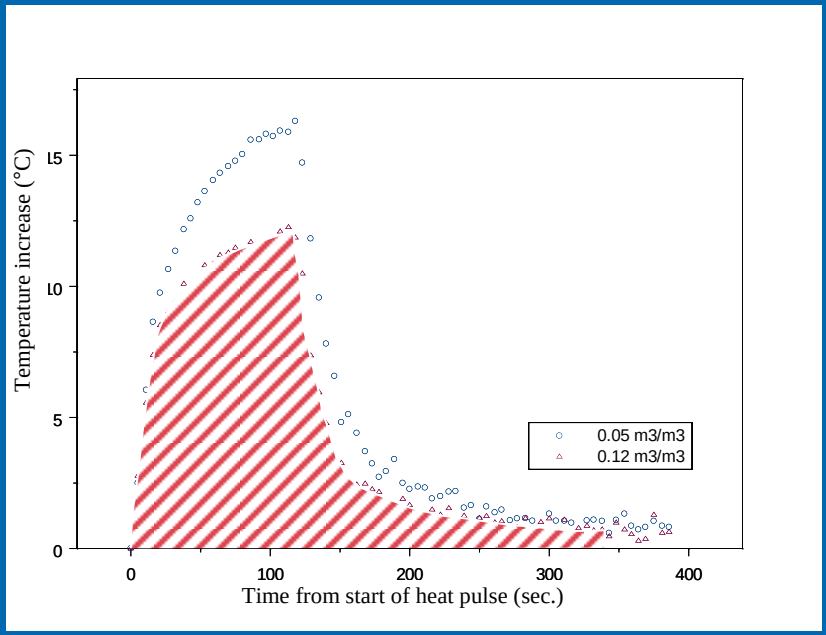
- 4900 m of FO cables
- 4600 m under ground
- soil moisture measured at 36,800 locations Simultaneously
- 3 depths: 5, 15, 25 cm
- Solar power
- Remote communication

NASA DTS MOISST Project

Installation

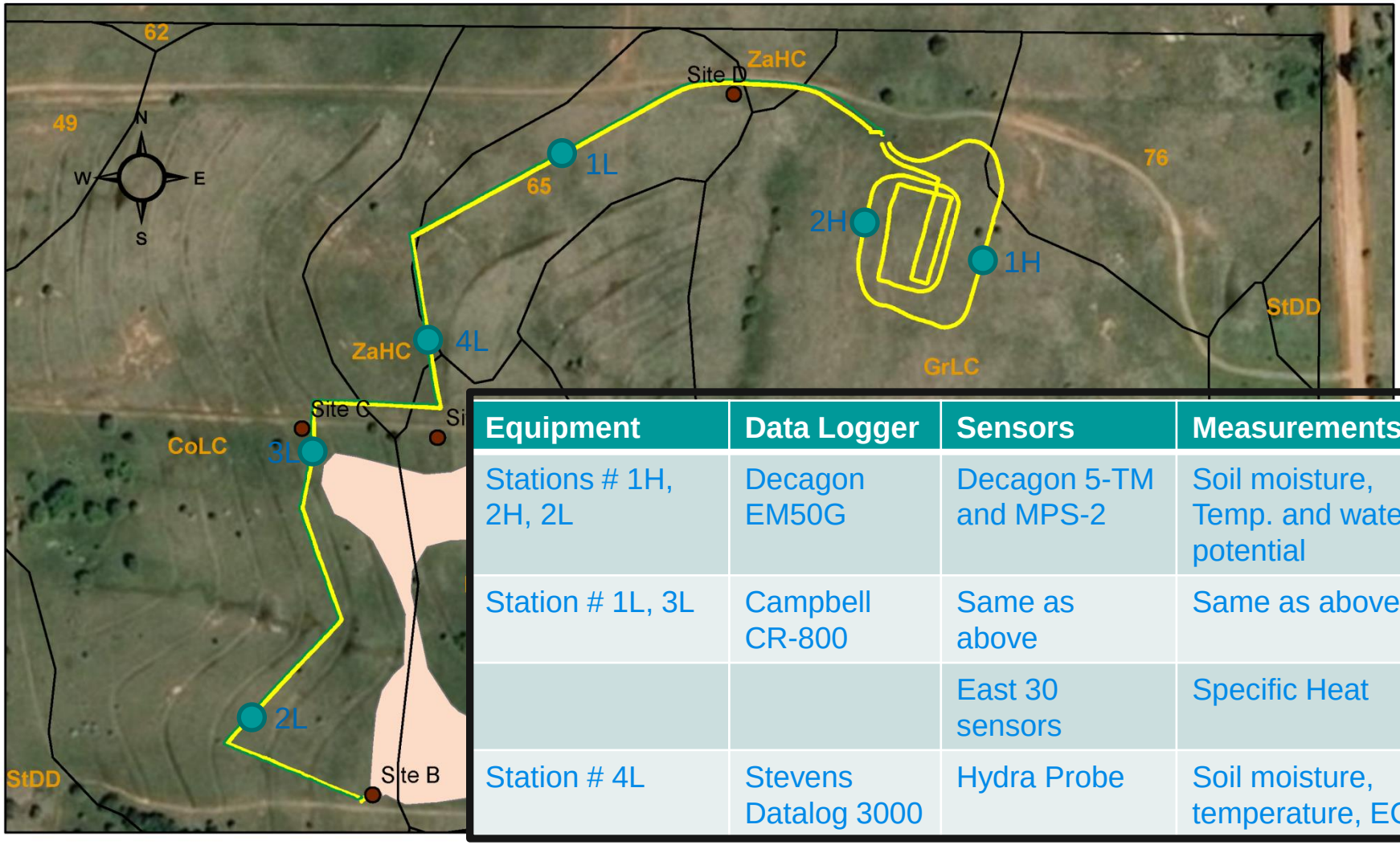
Heat Pulse Interpretation: **The Integral Method**

$$T_{cum} = \int_{t_0}^{t_j} \Delta T \, dt$$



T_{cum}	is the cumulative temperature increase
t_0	is the time to start of a heat pulse
t_j	is the total time of integration
ΔT	is the temperature increase over ambient temperature.

Fiber Optics Cable Path



Equipment	Data Logger	Sensors	Measurements
Stations # 1H, 2H, 2L	Decagon EM50G	Decagon 5-TM and MPS-2	Soil moisture, Temp. and water potential
Station # 1L, 3L	Campbell CR-800	Same as above	Same as above
		East 30 sensors	Specific Heat
Station # 4L	Stevens Datalog 3000	Hydra Probe	Soil moisture, temperature, EC

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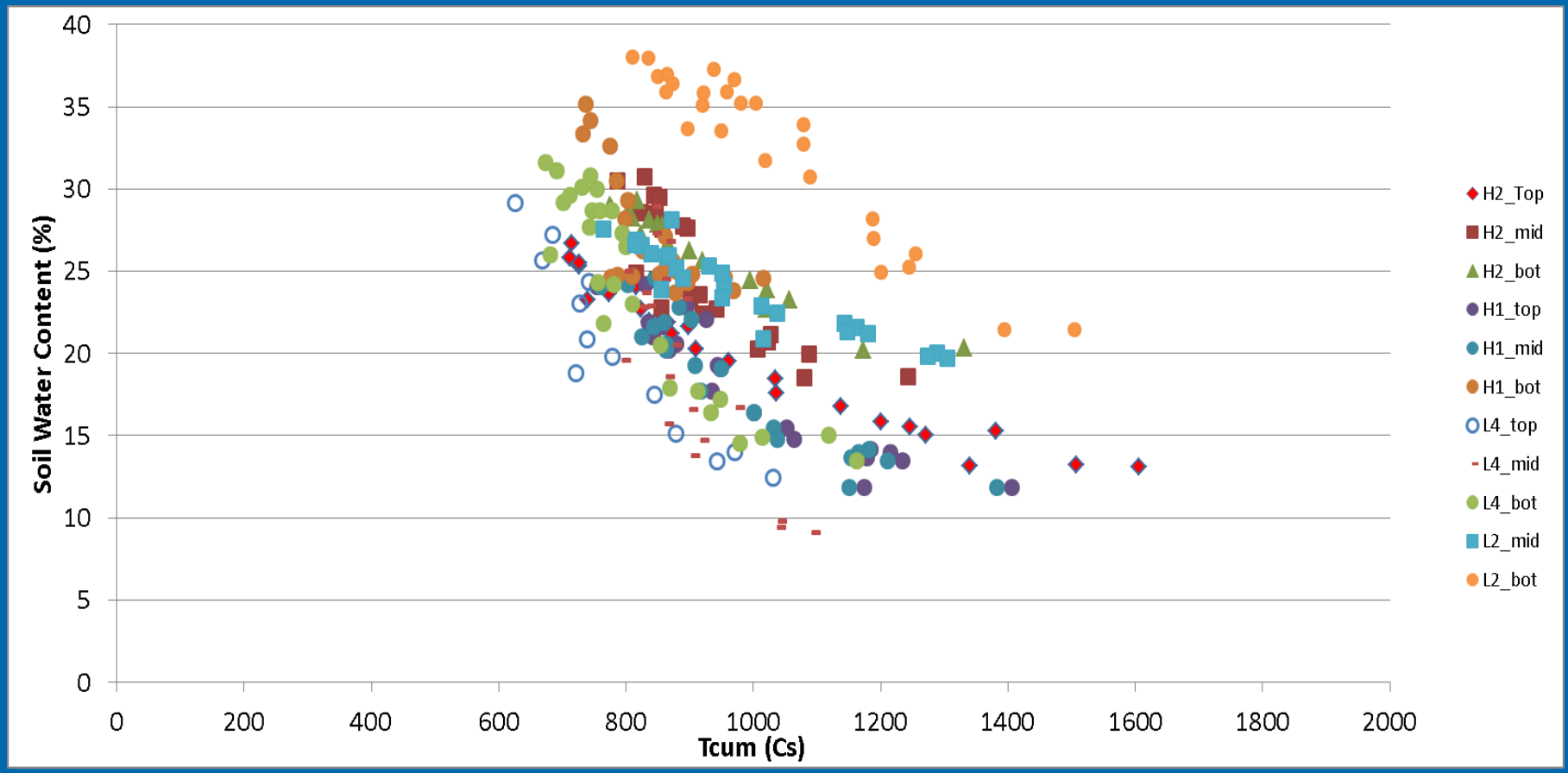
Comparing DTS to point measurements



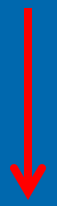
- Spatial variability of soil's thermal properties
- Each soil has separate calibration cure but following a general form

In-Situ Distributed Calibration

- **Thermal conductivity air<<water<soil solid**

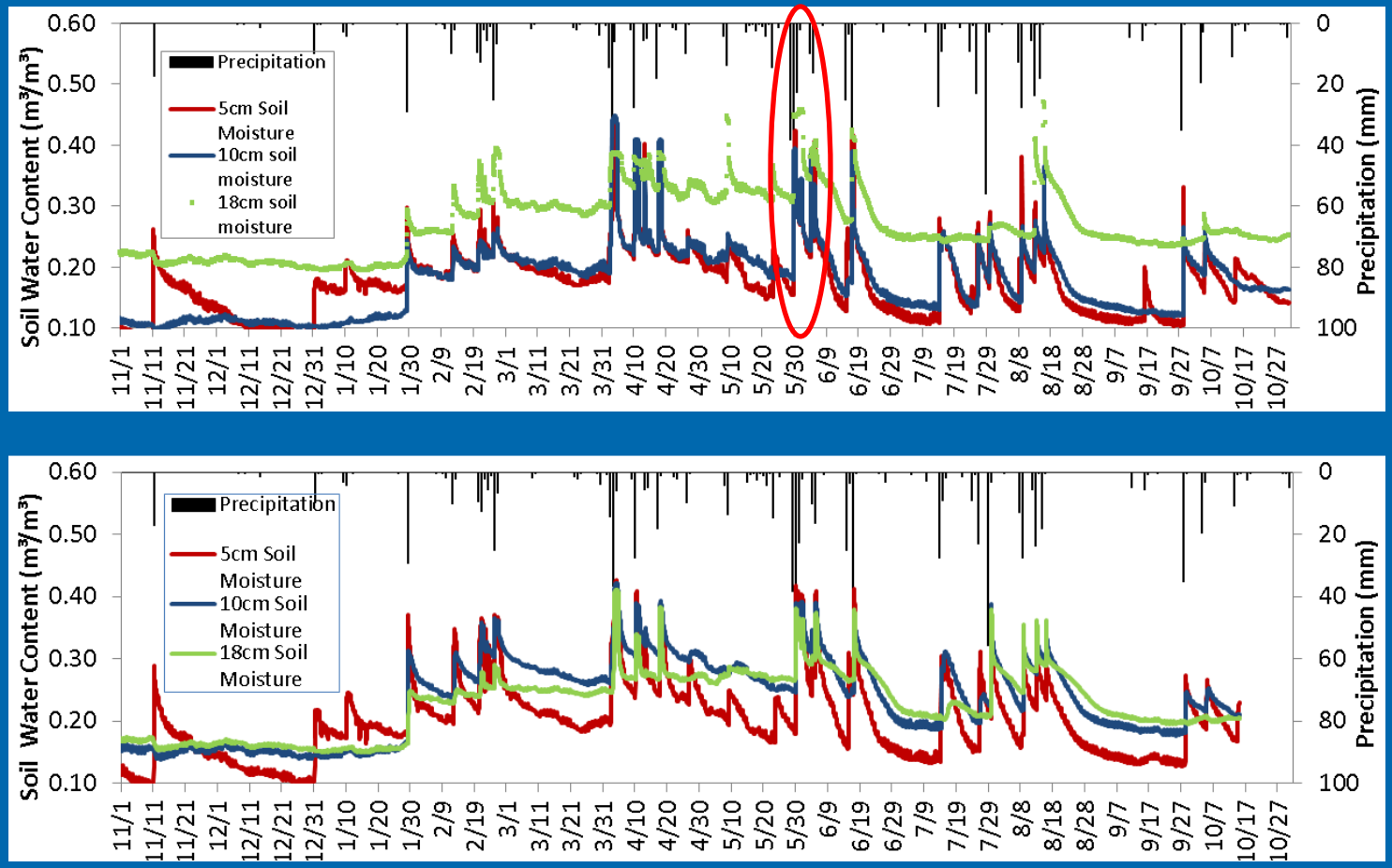
Mineral soil with higher porosity has lower thermal conductivity

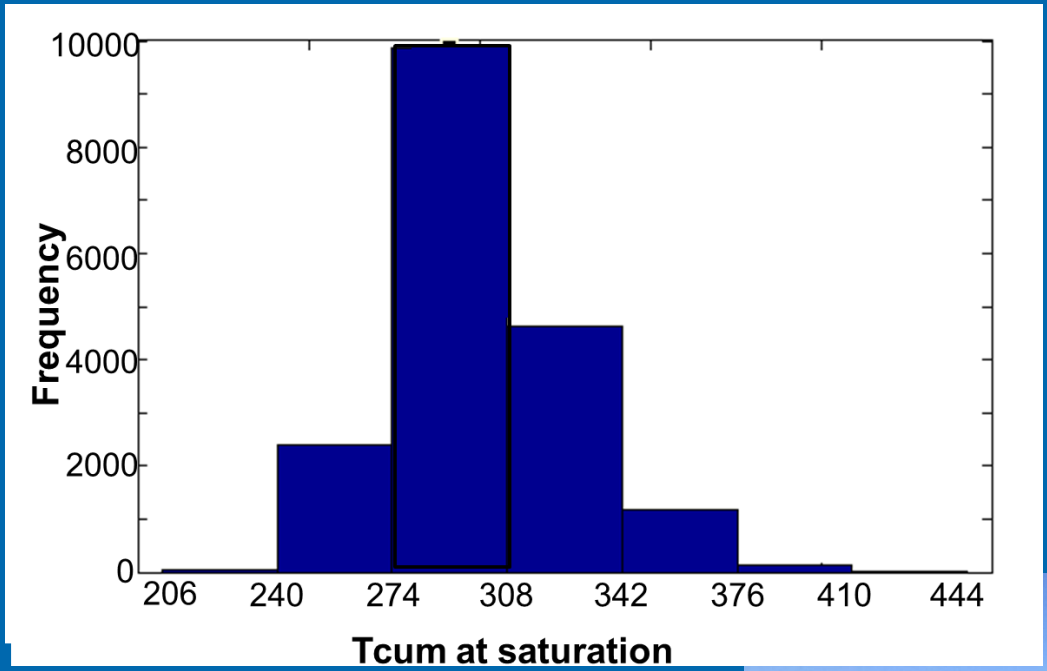
- ***Tcum*** **is ∝ (thermal conductivity)$^{-1}$**



Use *Tcum* at saturation to group soils with similar thermal behavior

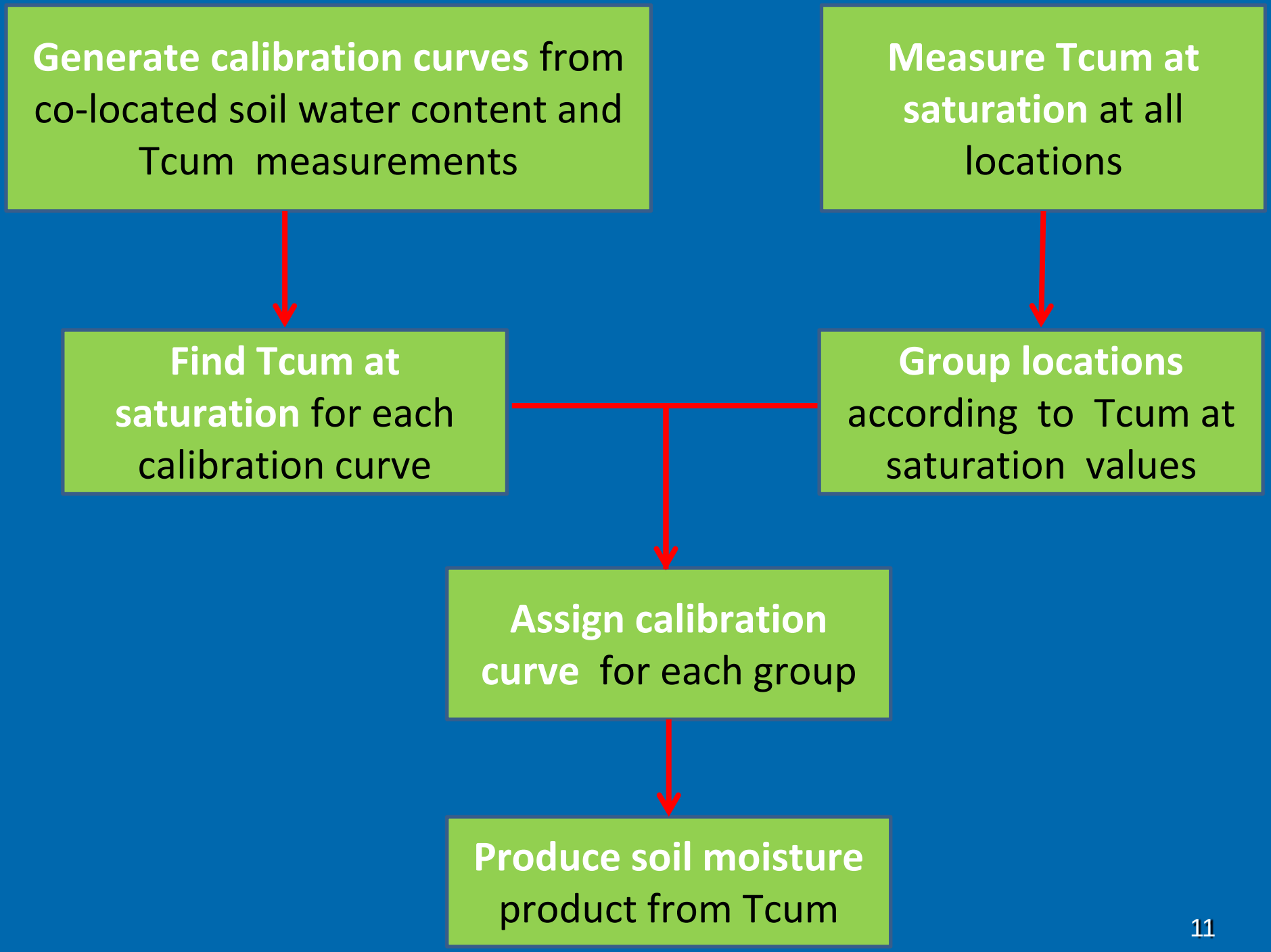
Precipitation recorded at the site and Soil Water Contents measured at Stations 1H and 2H

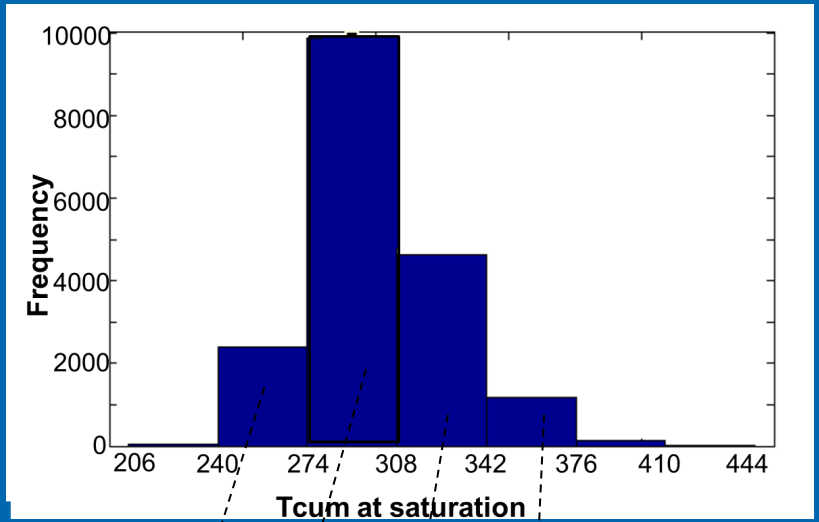


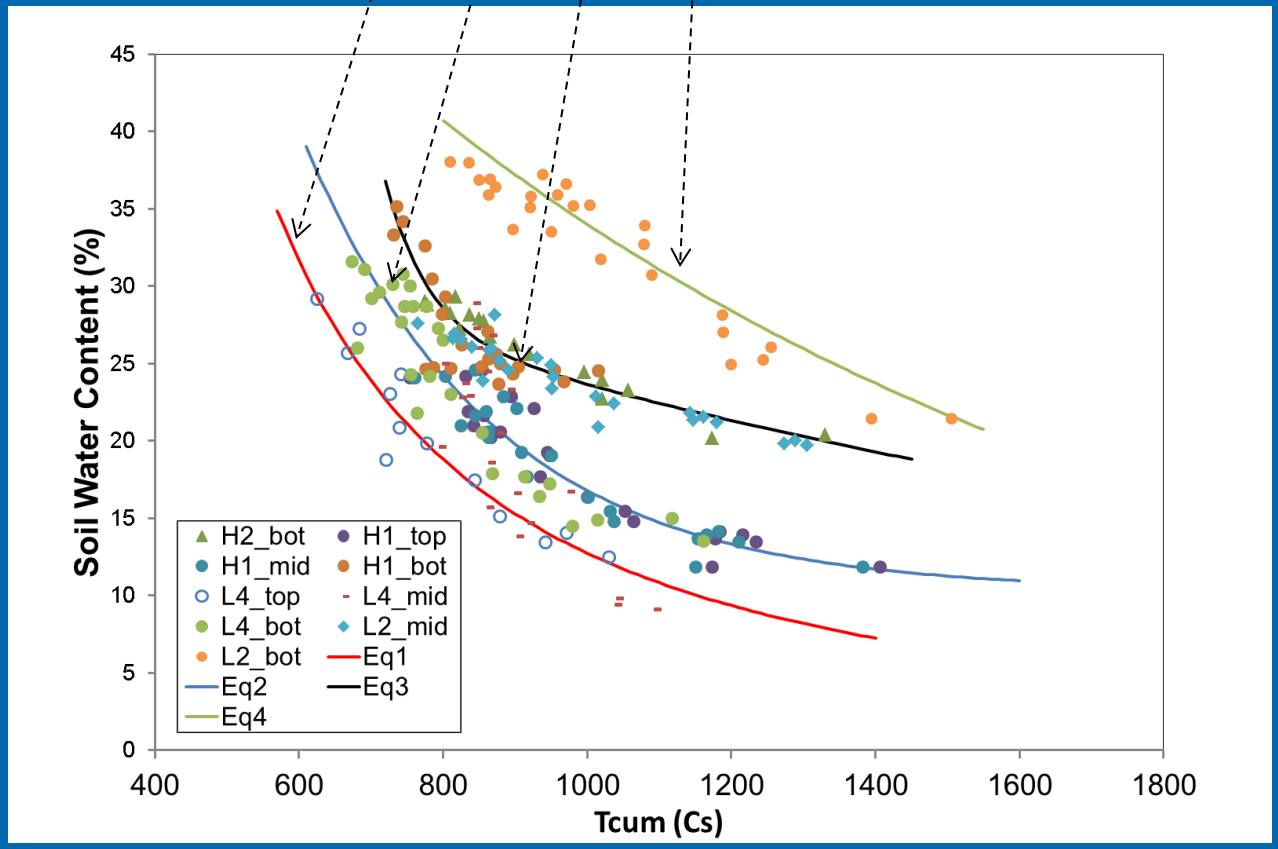


Histogram of Tcum on June 1, 2013

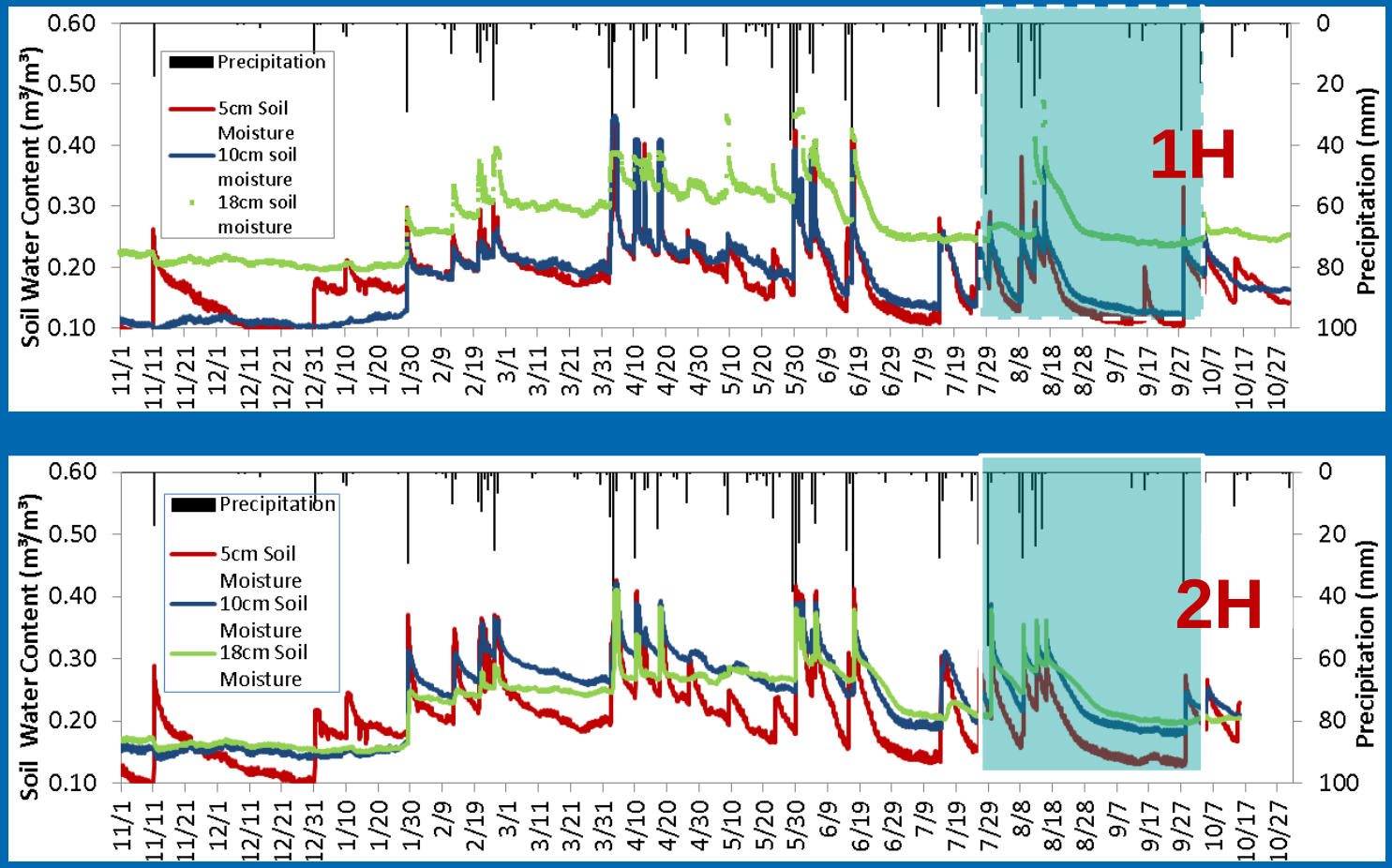
Saturated soil after heavy rainfall

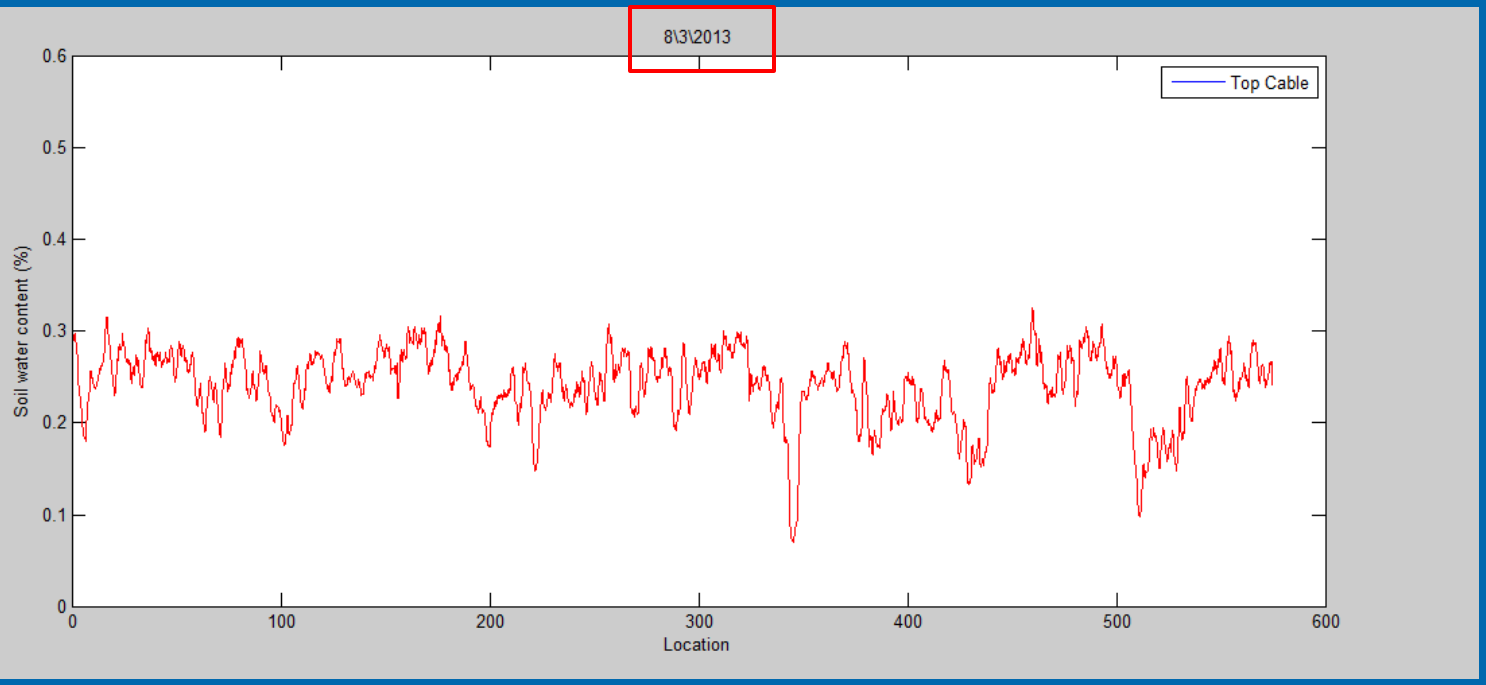

Generate calibration curves from co-located soil water content and Tcum measurements
Measure Tcum at saturation at all locations
Find Tcum at saturation for each calibration curve
Group locations according to Tcum at saturation values
Assign calibration curve for each group
Produce soil moisture product from Tcum

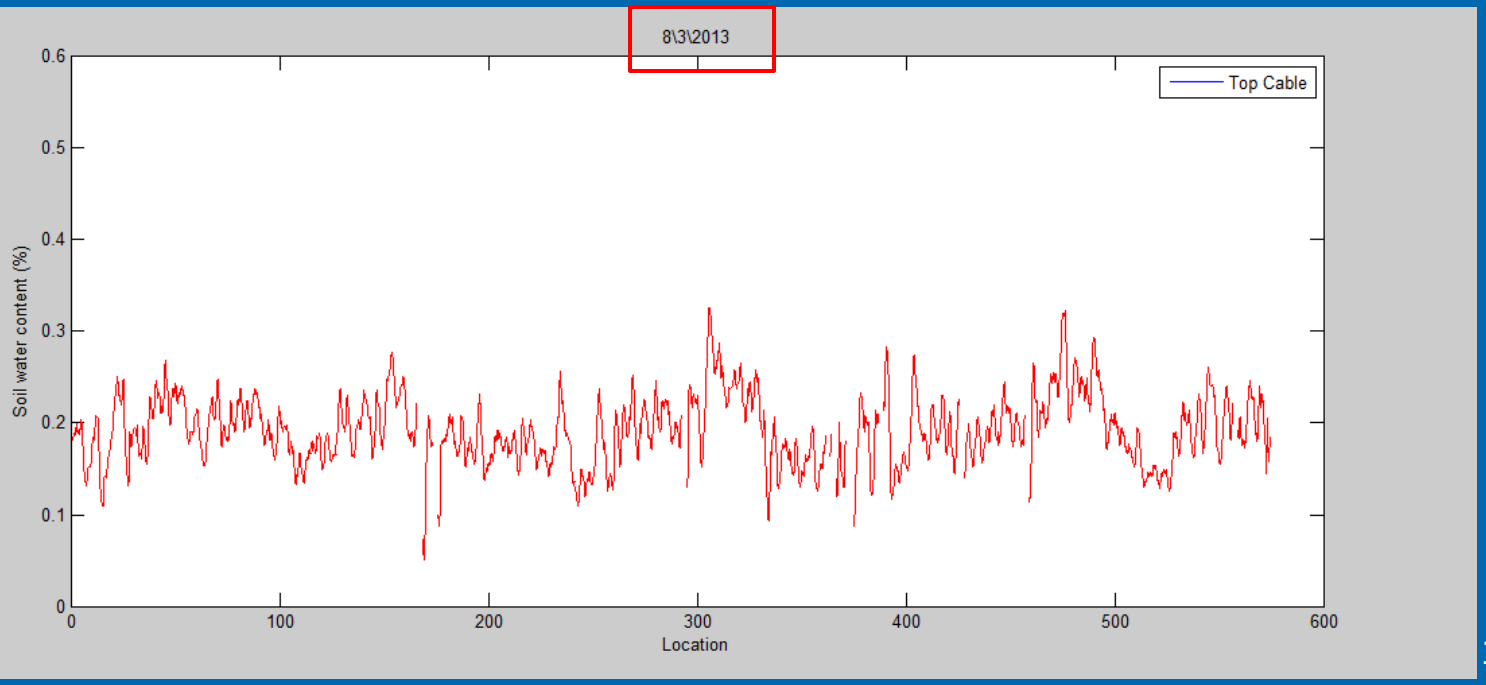

10000
8000
6000
4000
2000
0
Frequency
206
240
274
308
342
376
410
444
Tcum at saturation


45
40
35
30
25
20
15
10
5
0
Soil Water Content (%)
400
600
800
1000
1200
1400
1600
1800
Tcum (Cs)
H2_bot
H1_top
H1_mid
H1_bot
L4_top
L4_mid
L4_bot
L2_mid
L2_bot
Eq1
Eq2
Eq3
Eq4

Precipitation recorded at the site and Soil Water Contents measured at Stations 1H and 2H




8\3\2013
Top Cable
Soil water content (%)
Location
0
0.1
0.2
0.3
0.4
0.5
0.6
0
100
200
300
400
500
600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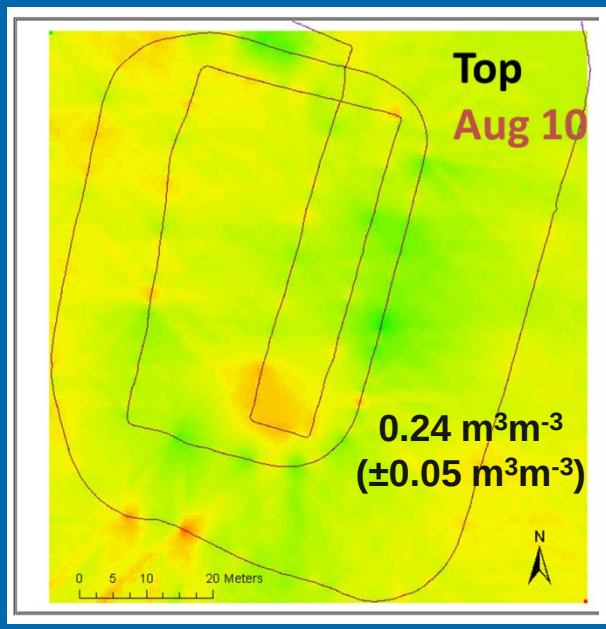
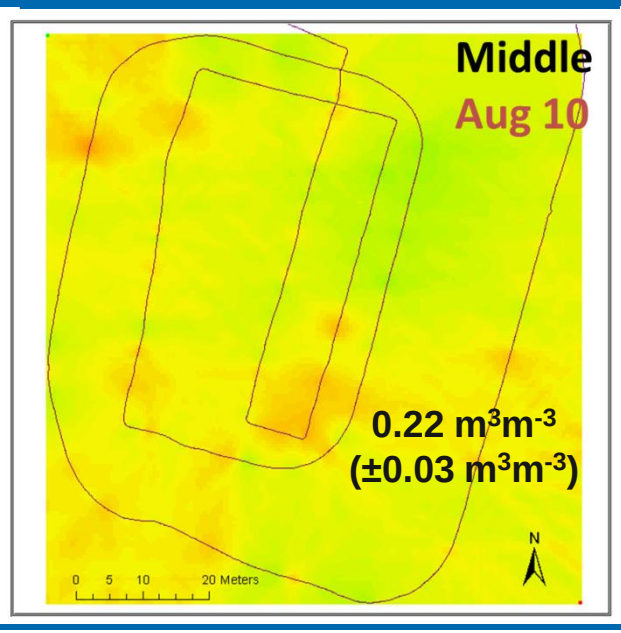
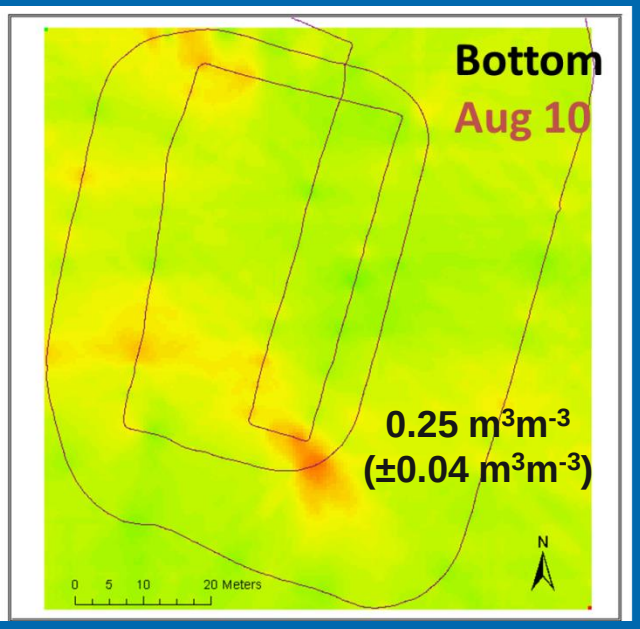
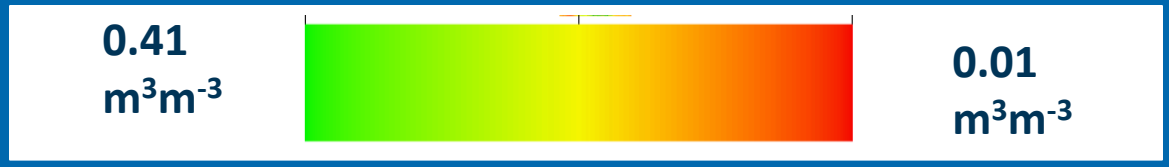
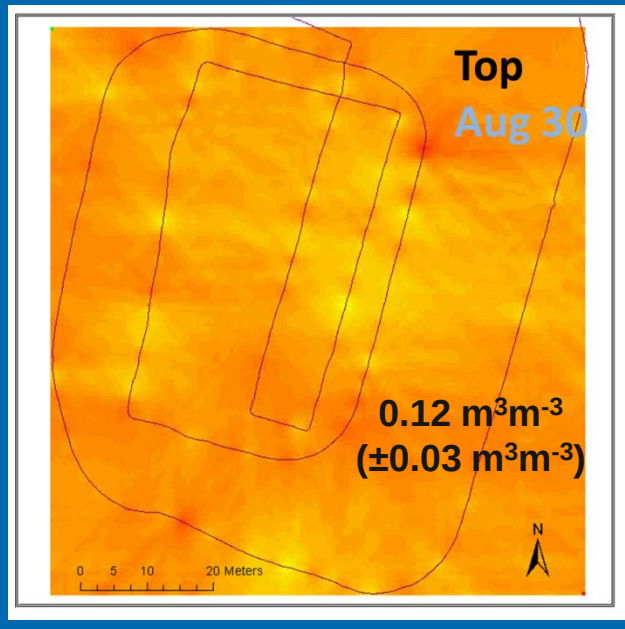
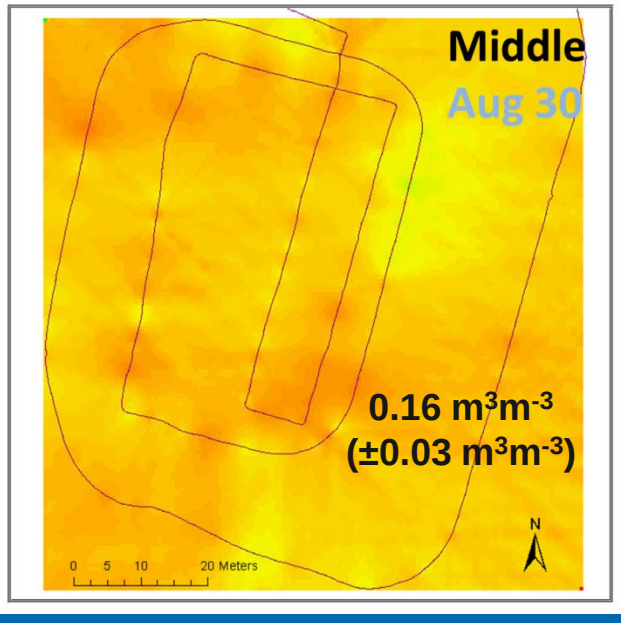

Top
Aug 10
0.24 m³m⁻³
(±0.05 m³m⁻³)
N
0 5 10 20 Meters

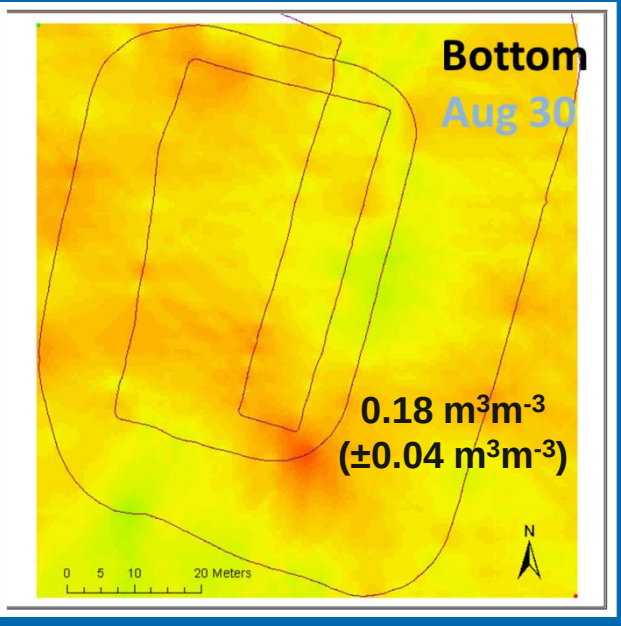

Middle
Aug 10
0.22 m³m⁻³
(±0.03 m³m⁻³)
N
0 5 10 20 Meters


Bottom
Aug 10
0.25 m³m⁻³
(±0.04 m³m⁻³)
N
0 5 10 20 Meters


0.41
m³m⁻³
0.01
m³m⁻³


Top
Aug 30
0.12 m³m⁻³
(±0.03 m³m⁻³)
N
0 5 10 20 Meters


Middle
Aug 30
0.16 m³m⁻³
(±0.03 m³m⁻³)
N
0 5 10 20 Meters


Bottom
Aug 30
0.18 m³m⁻³
(±0.04 m³m⁻³)
N
0 5 10 20 Meters

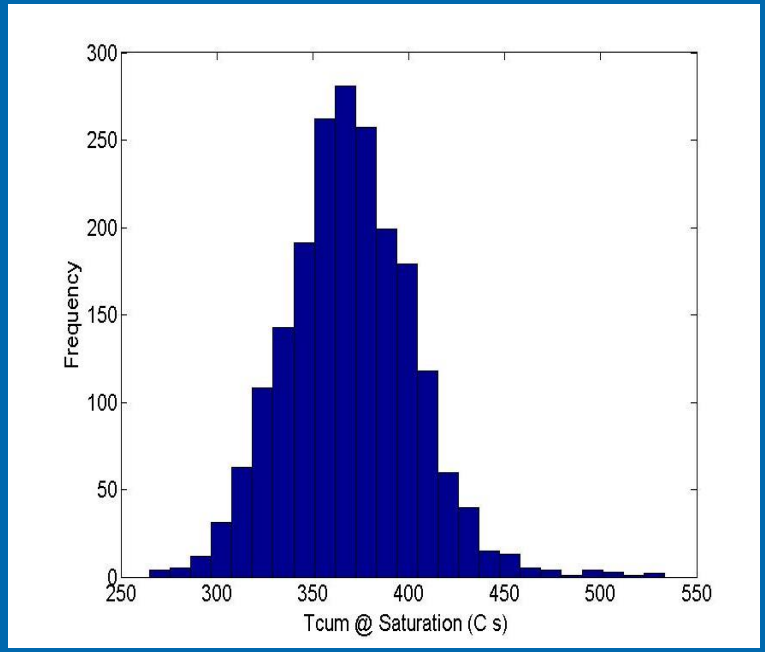
Challenges

- Logistic challenges:
  - Batteries failure
  - Power controller
  - Remote communication
  - DTS
- Data analysis: 5 Gb/hour
- Calibration/validation

Future work: Increasing Calibration Accuracy

Generate distributed calibration curves:

- Thermal response curve generated from non disturbed samples
- Strategic detailed surveying of soil water content and soil thermal properties
- Vegetation and topography indices



Future work

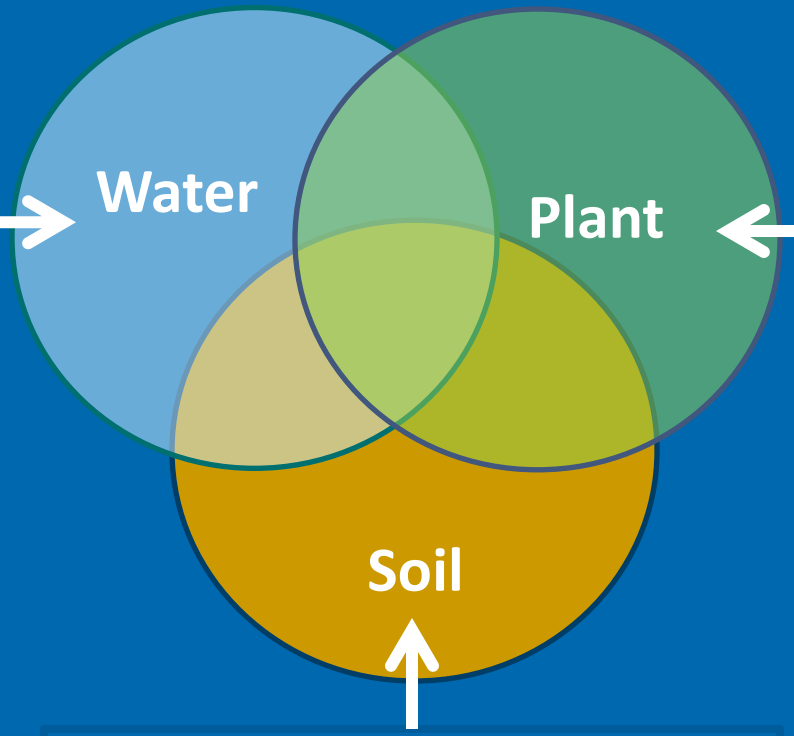
- Publishing all data online
- Validation campaigns:
  - Strategic point measurements in August and September/October
- LIDAR mapping of topography and vegetation height: Water-Soil-Plant Interaction

LIDAR mapping of Topograhy and Vegetation

- Water-Soil-Plant interaction across 0.1 m to 1000 m scales:
  - Effect of surface topography (slope and surface storage/accumulation)
  - Spatial variability of soil physical properties (from DTS thermal properties)
  - Can we use vegetation height as indicator for soil water availability?
- Upscaling DTS measurements to represent entire field (region?): using topography and vegetation as indicators

Water-Soil-Plant Interaction

- Precipitation data
- DTS soil moisture measurements
- Soil moisture from point measurements



- Vegetation Height from LIDAR
- Vegetation color from UAV

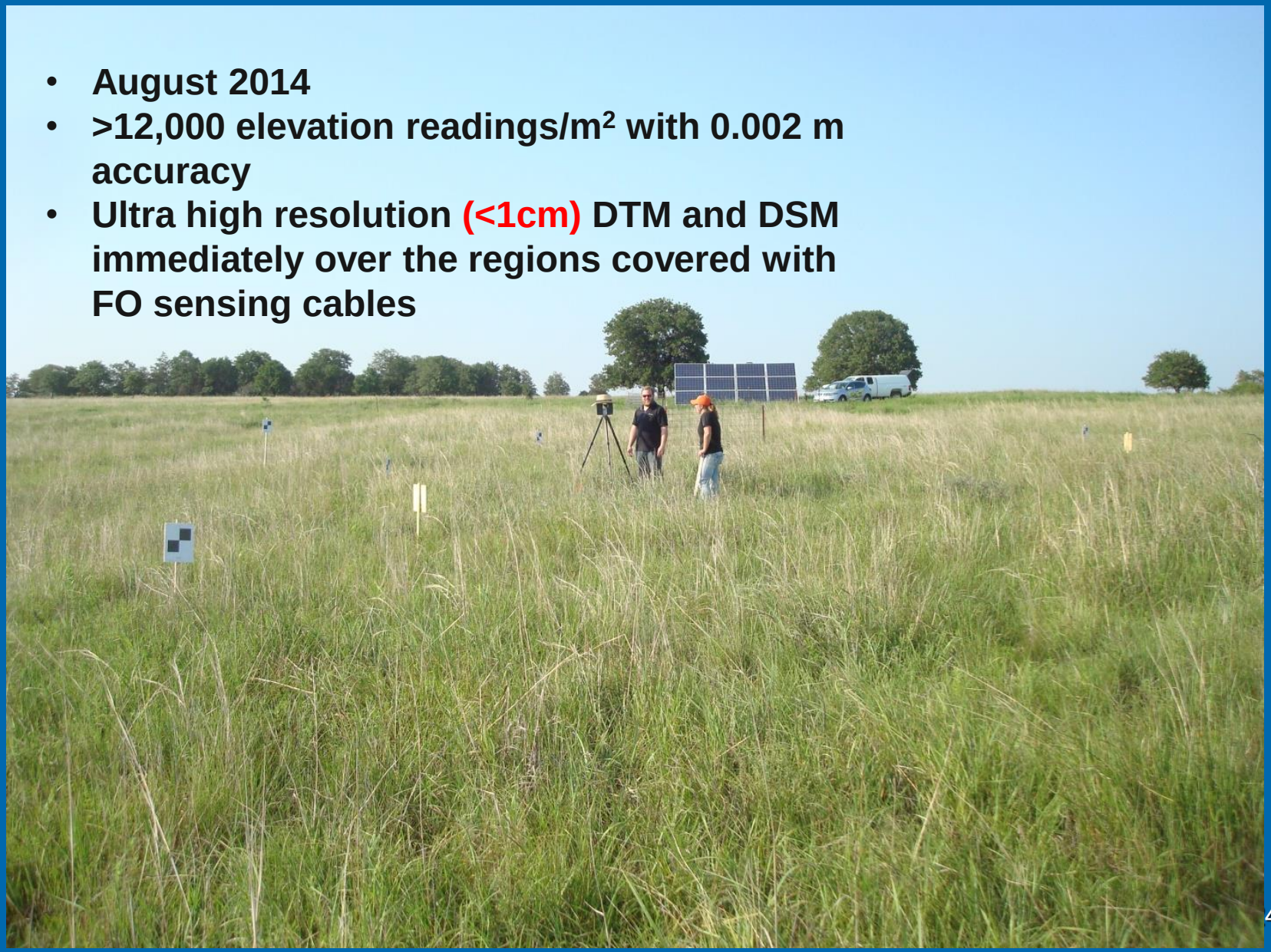
- Soil surface topography 0.1m to 1000 m from LIDAR
- Soil physical properties from DTS thermal response at saturation
- Soil texture from EMI?


1 to 1000 m scale

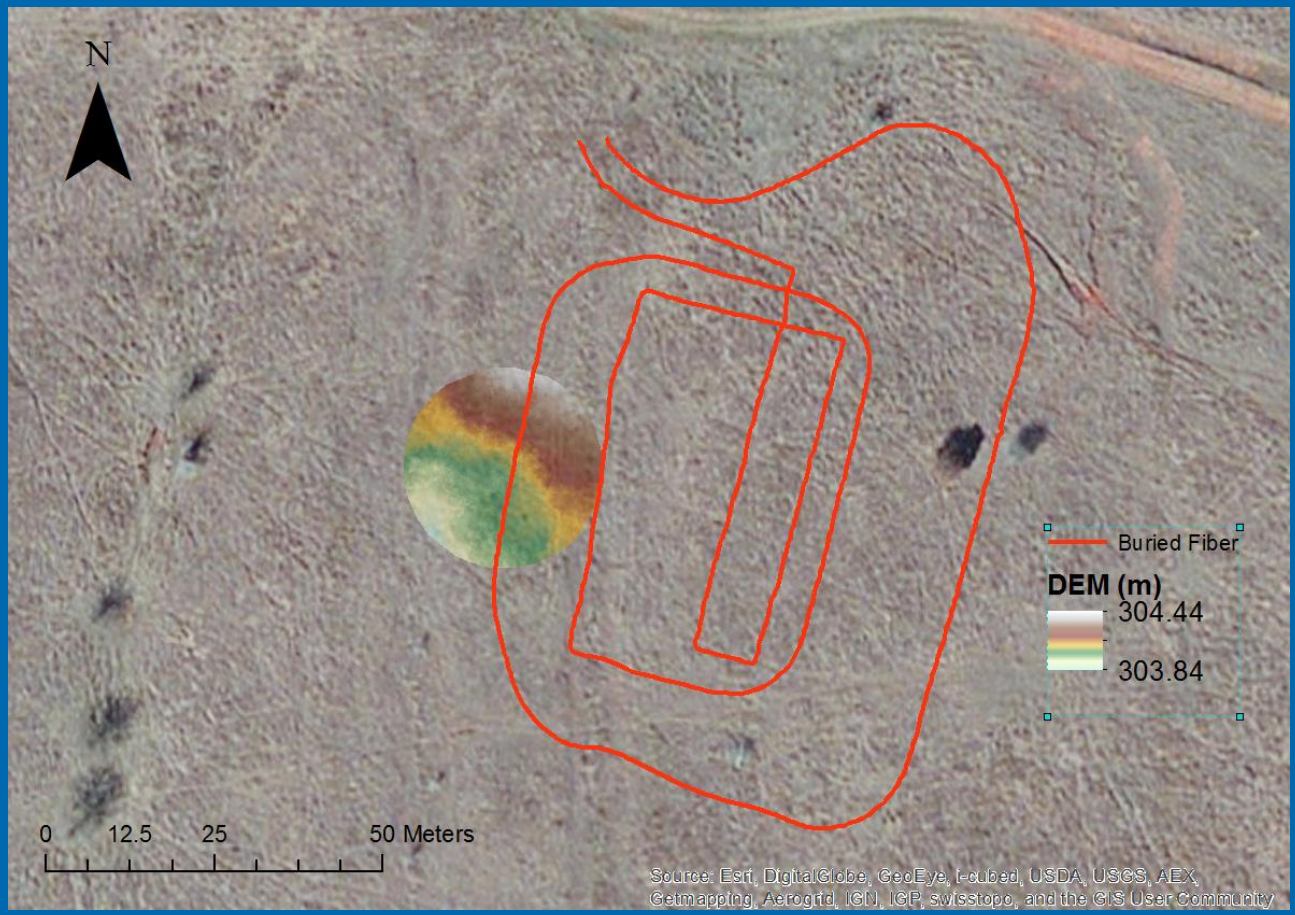

<1 m scale

Terrestrial LIDAR

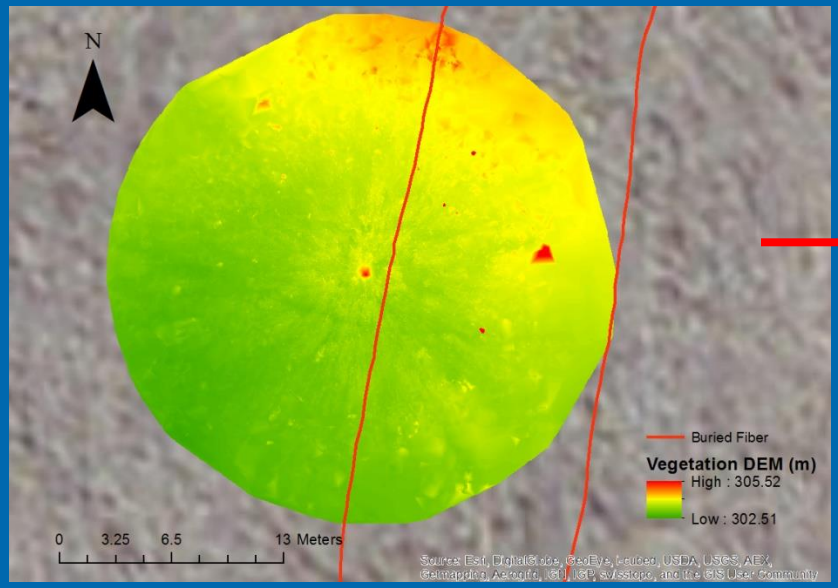
- **August 2014**
- **>12,000 elevation readings/m^2 with 0.002 m accuracy**
- **Ultra high resolution (<1cm) DTM and DSM immediately over the regions covered with FO sensing cables**



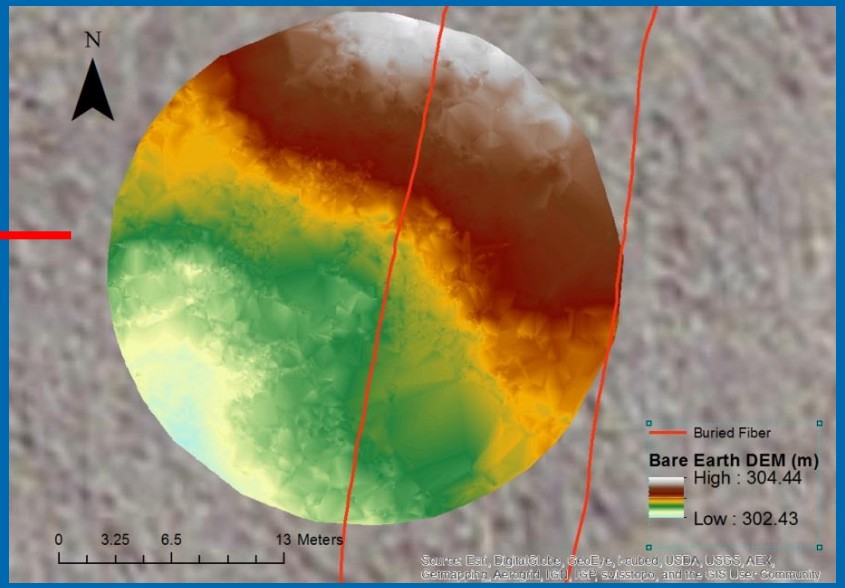
Quick peek at the results

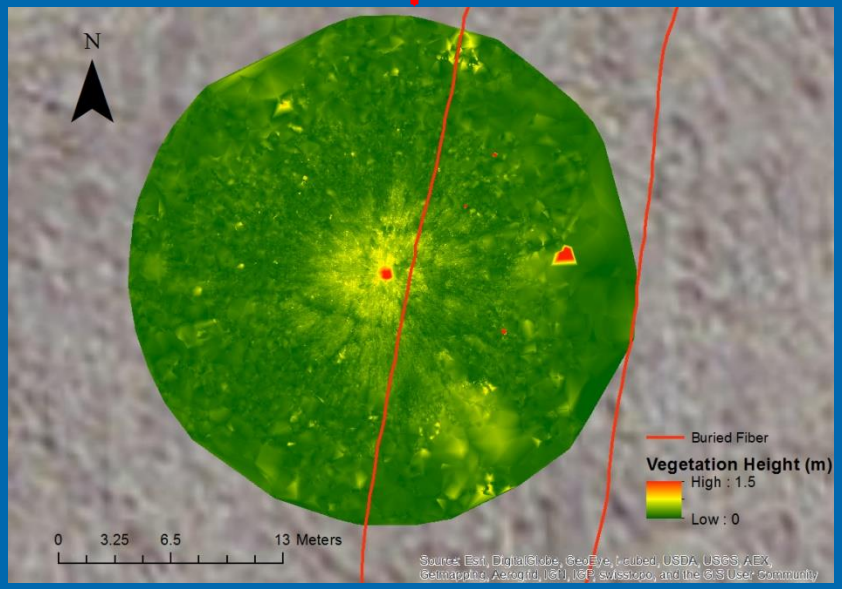


Vegetation Elevation



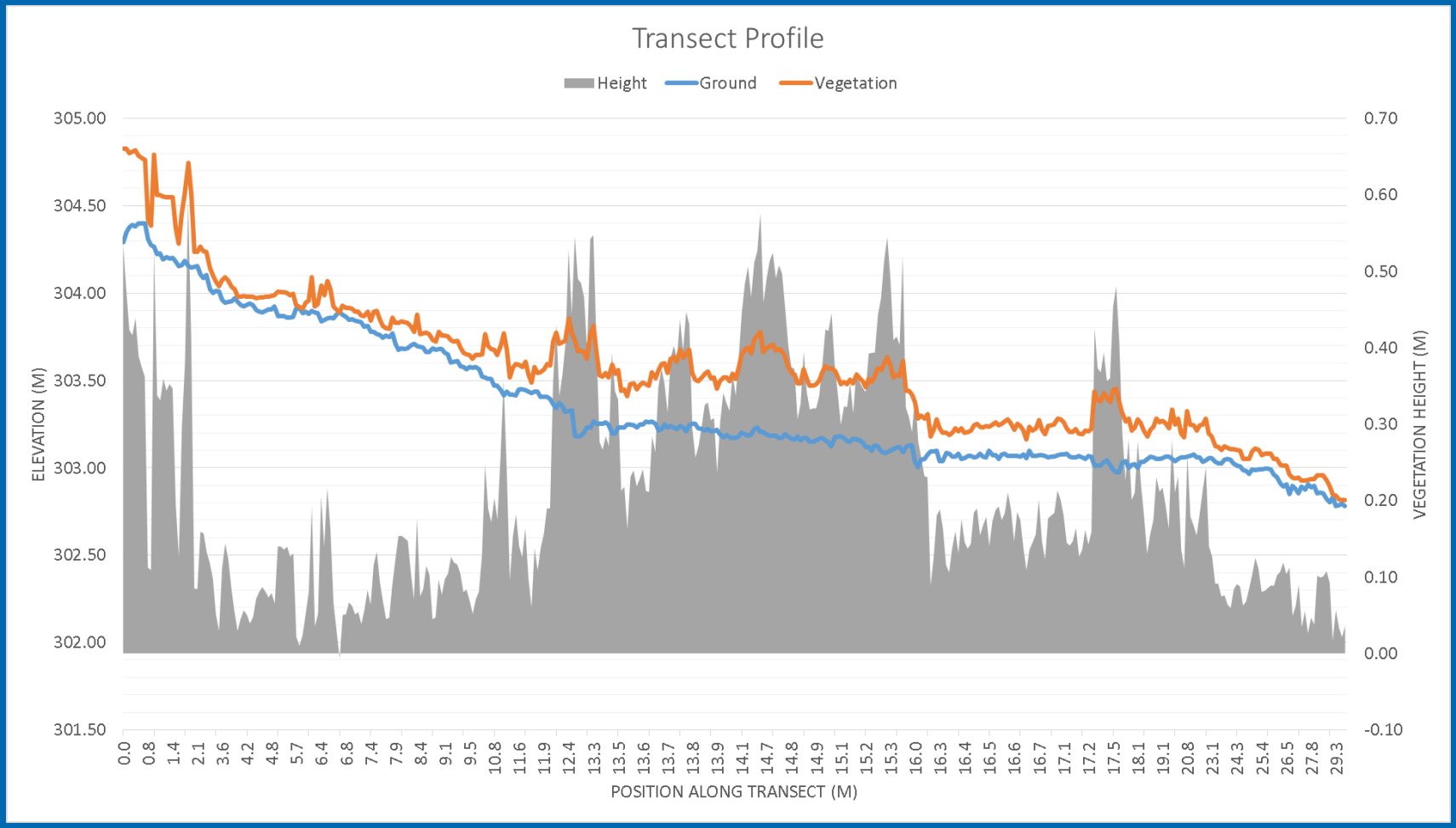
Bare Earth Elevation

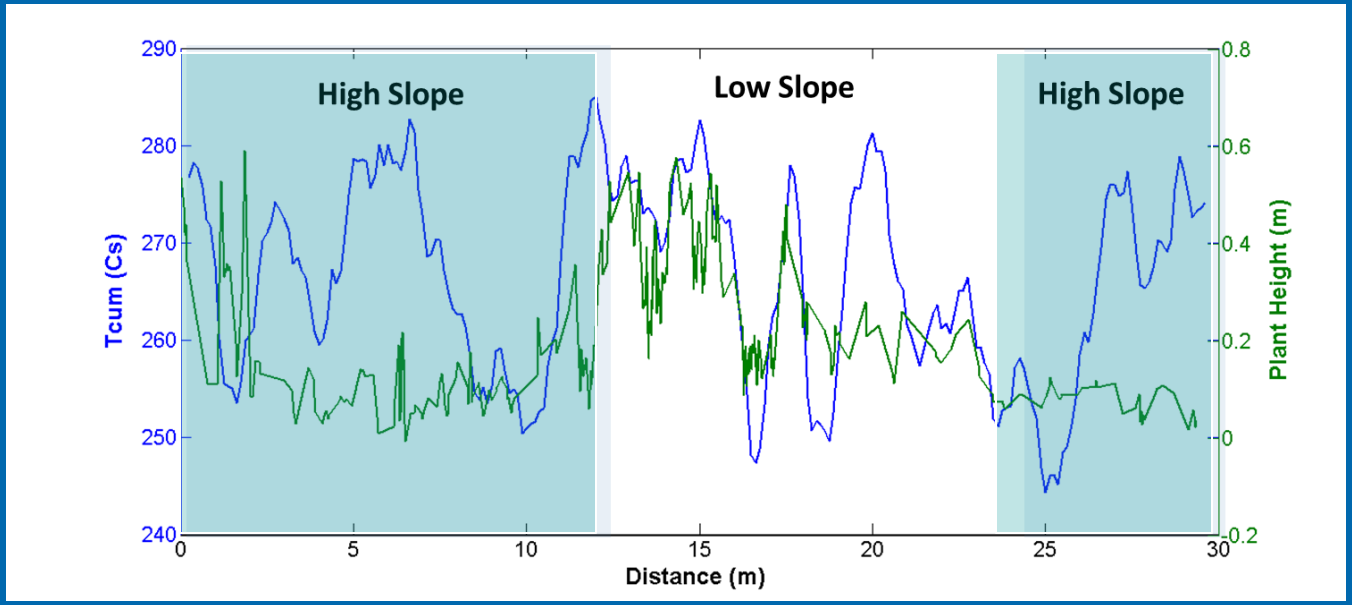




Vegetation Height

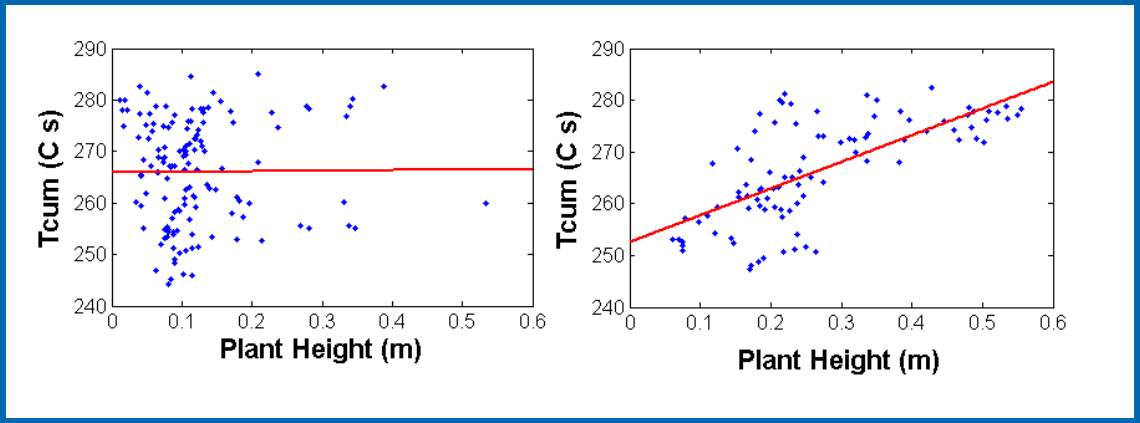
Ground elevation, plant elevation, and plant height along the fiber optic cable pass





High Slope

Low Slope



Summary

- Active DTS Soil Moisture product available in the summer
- Distributed calibration
- Dynamic calibration: Increased accuracy with more data integrated
- High resolution LIDAR micro-topography and vegetation height maps:
  - Improving the accuracy of DTS products
  - Effects of micro-topography on Hydrologic processes in the field
  - Upscaling DTS soil moisture

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- Special thanks to Tyson and his team