How Can Brown Dog Support Critical Zone Observatory Study?

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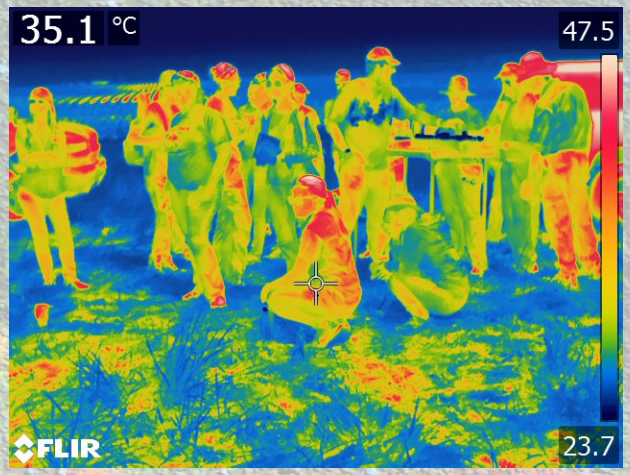
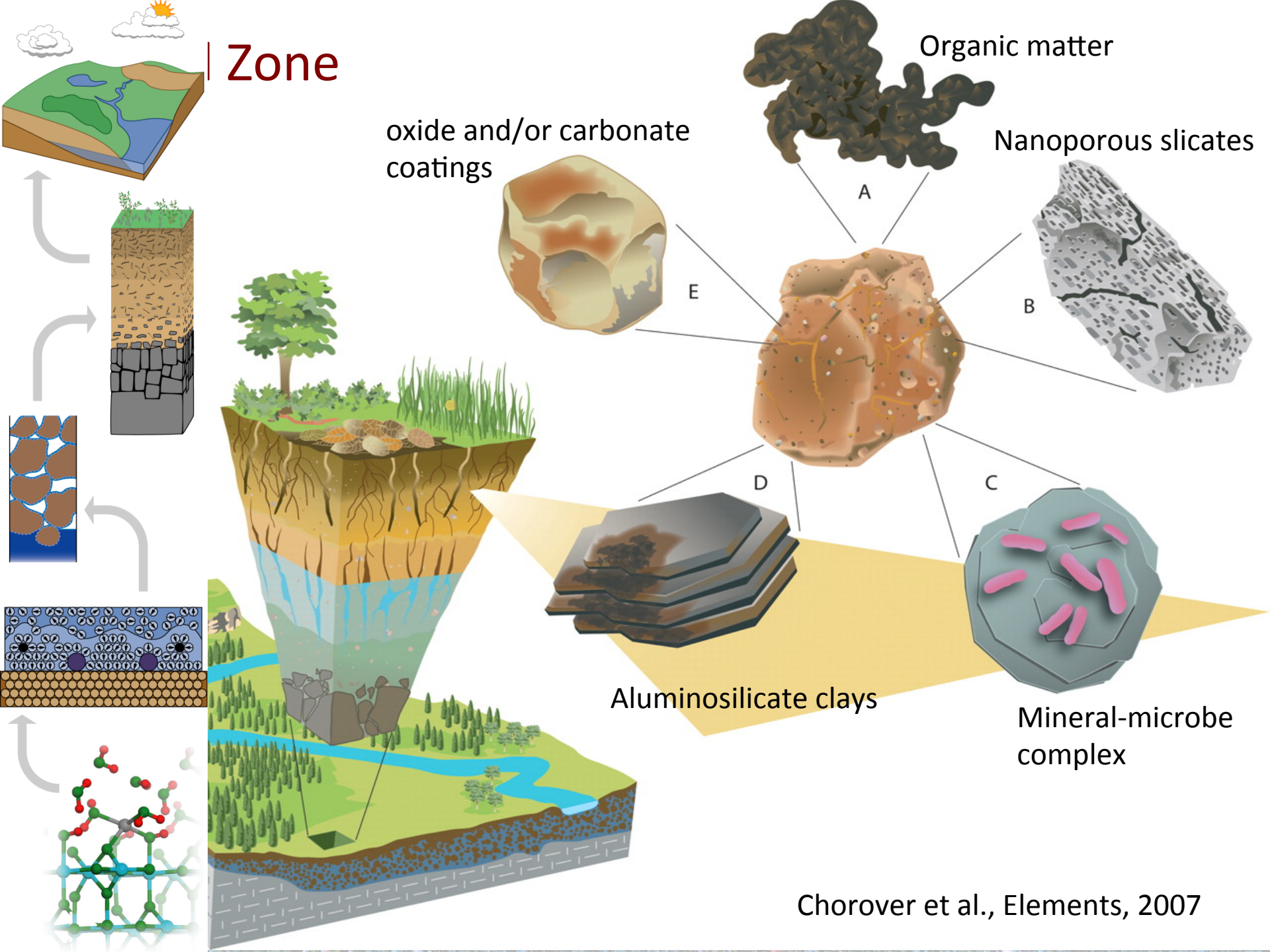
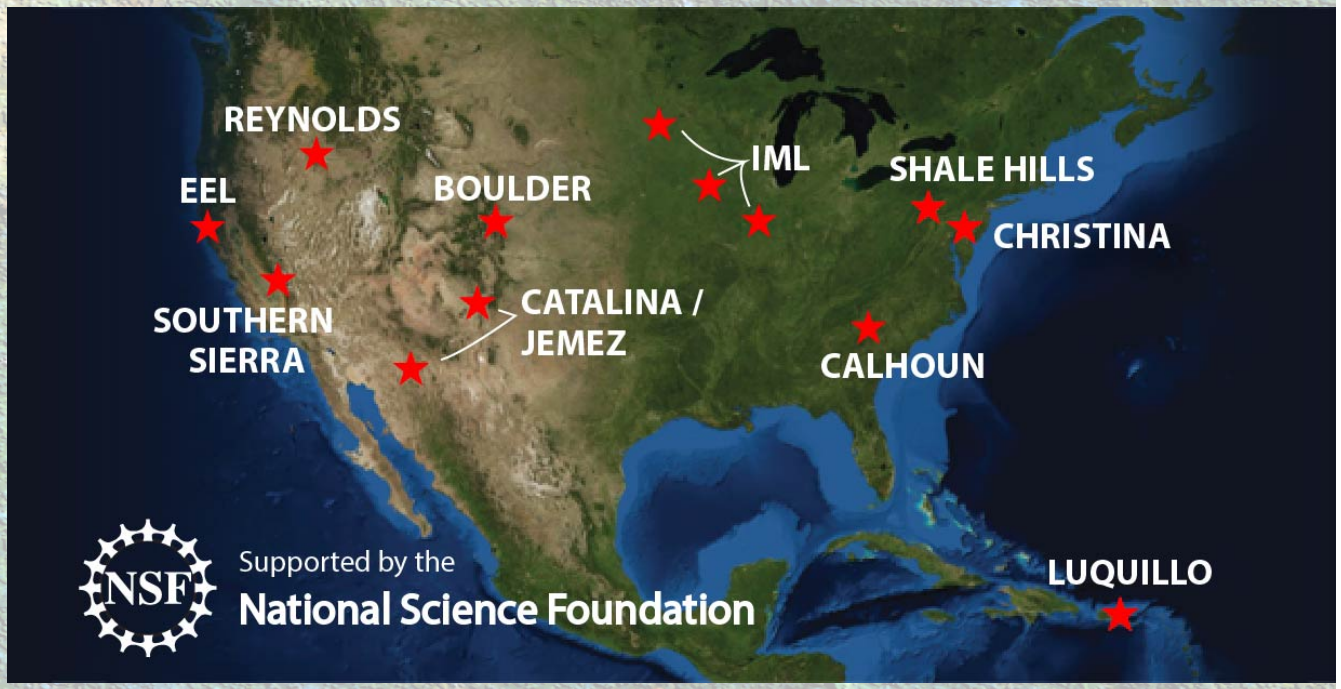


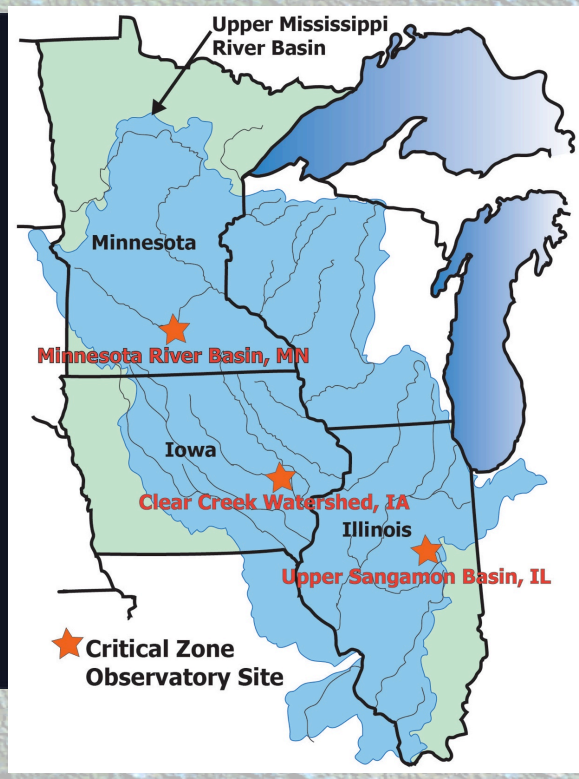
Zone



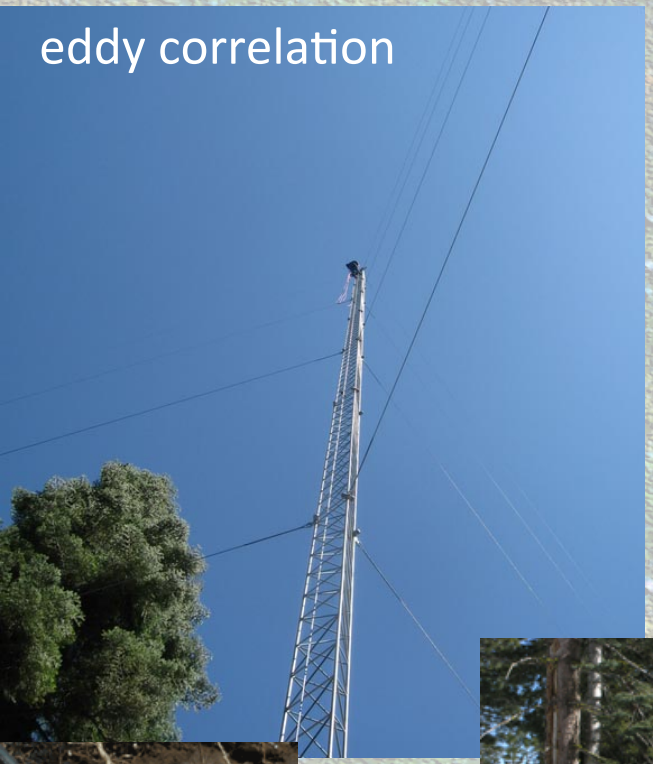
Chorover et al., Elements, 2007

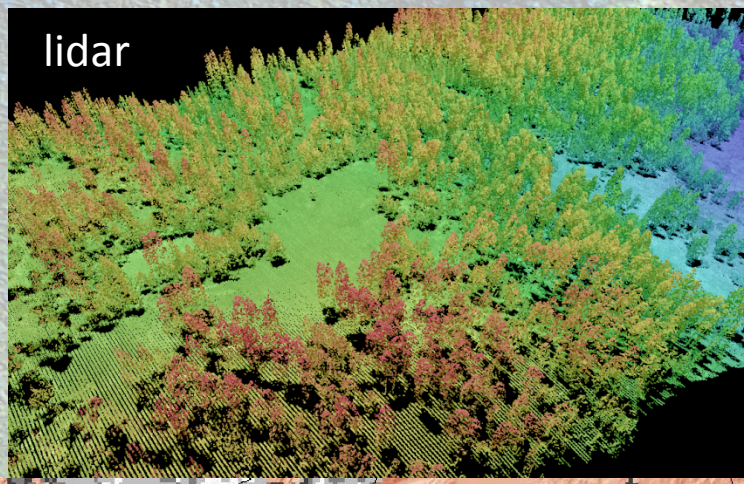
Critical Zone Observatories Network (2013)

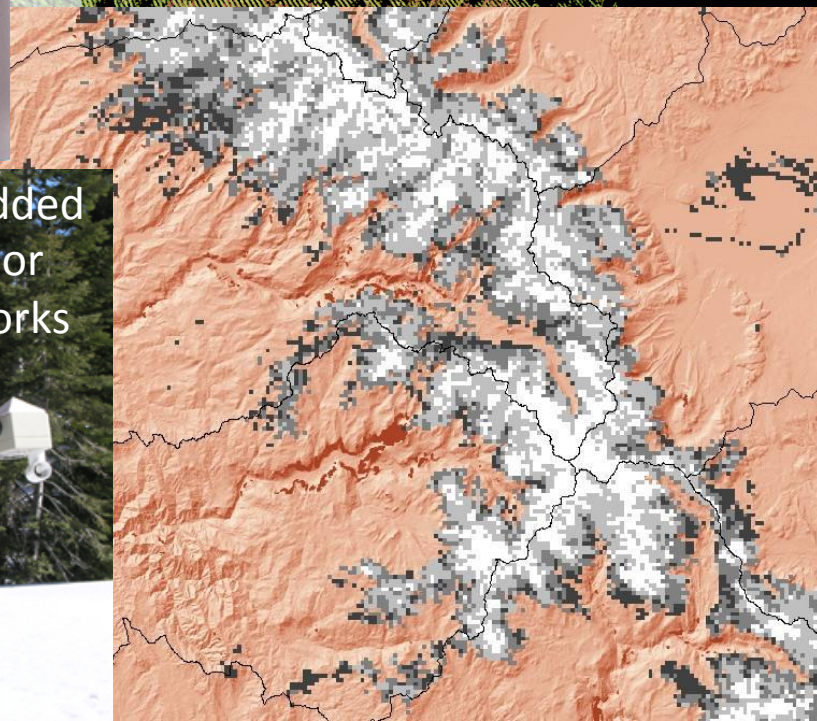




CZOs provide a new generation of integrated measurements







Core Data Measurements

Climatology / Meteorology
Temperature
Precipitation
Snowfall
Snow depth
Relative humidity
Barometric pressure
Dew point
Wind speed
Wind direction
Cloudiness
Incoming shortwave radiation
Latent/ Sensible heat flux

Management
Tile Flow
Flashiness Index
Grass: Crop
Land Use Diversity
STIRs

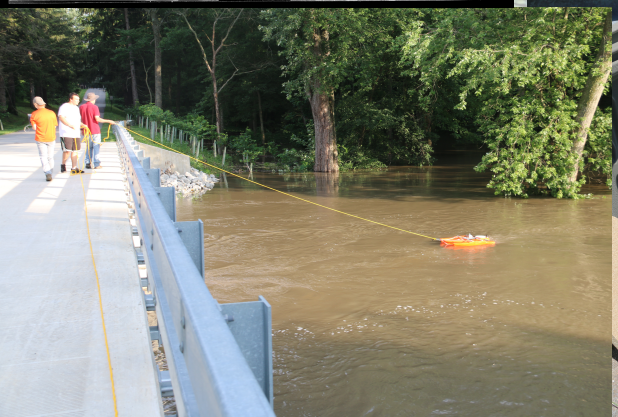
Geomorphology
Lidar
Erosion Rates
Soil Science / Pedology
Soil taxonomy
Parent lithology
Depth to bedrock
Soil temperature
Soil moisture/ Volumetric water content
Water/ Matric potential
Bulk electrical conductivity

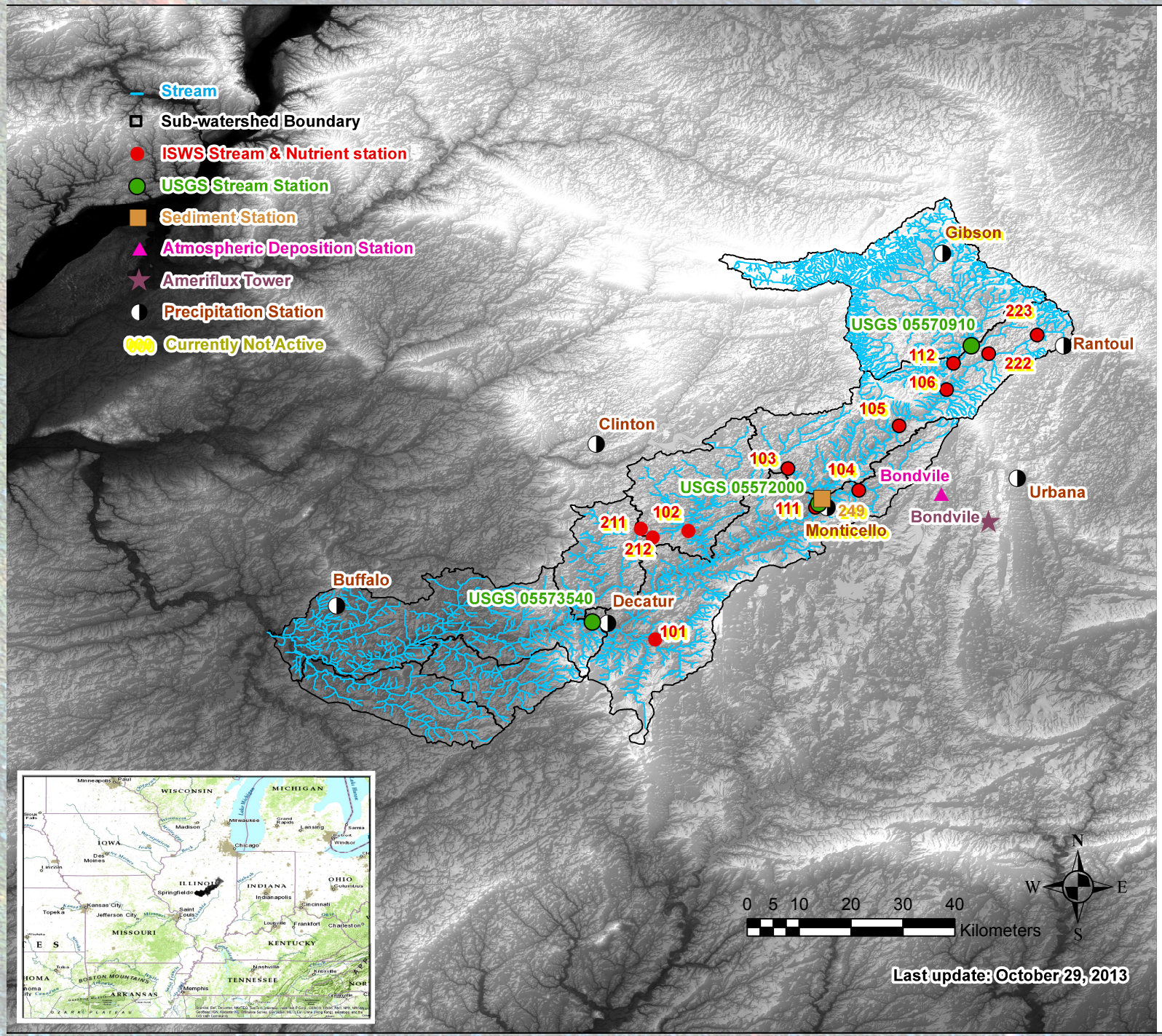
Hydrology
Stage, Discharge
Well water levels
Well water temperature
Water Chemistry
Stream water TSS
Stream water POC, PON, nutrient loads
Stream water DO
Stream water specific conductance
Stream water temperature
Stream water pH

Biogeochemistry
%C, C mass
%N, N mass
C:N
Soil CO_2
Eddy Covariance/ NEE
Biology/ Ecology
LAI
GPP

Data Heterogeneity

Josh Peschel

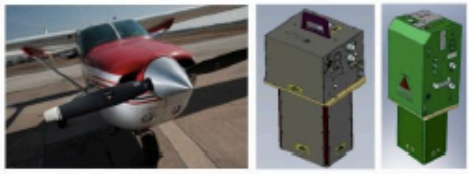



Stream
Sub-watershed Boundary
ISWS Stream & Nutrient station
USGS Stream Station
Sediment Station
Atmospheric Deposition Station
Ameriflux Tower
Precipitation Station
000 Currently Not Active
Gibson
USGS 05570910
223
Rantoul
112
222
106
105
Clinton
103
104
Bondvile
Urbana
USGS 05572000
111
249
Monticello
Bondvile
211
102
212
Buffalo
USGS 05573540
Decatur
101
0 5 10 20 30 40
Kilometers
N
W
E
S
Last update: October 29, 2013

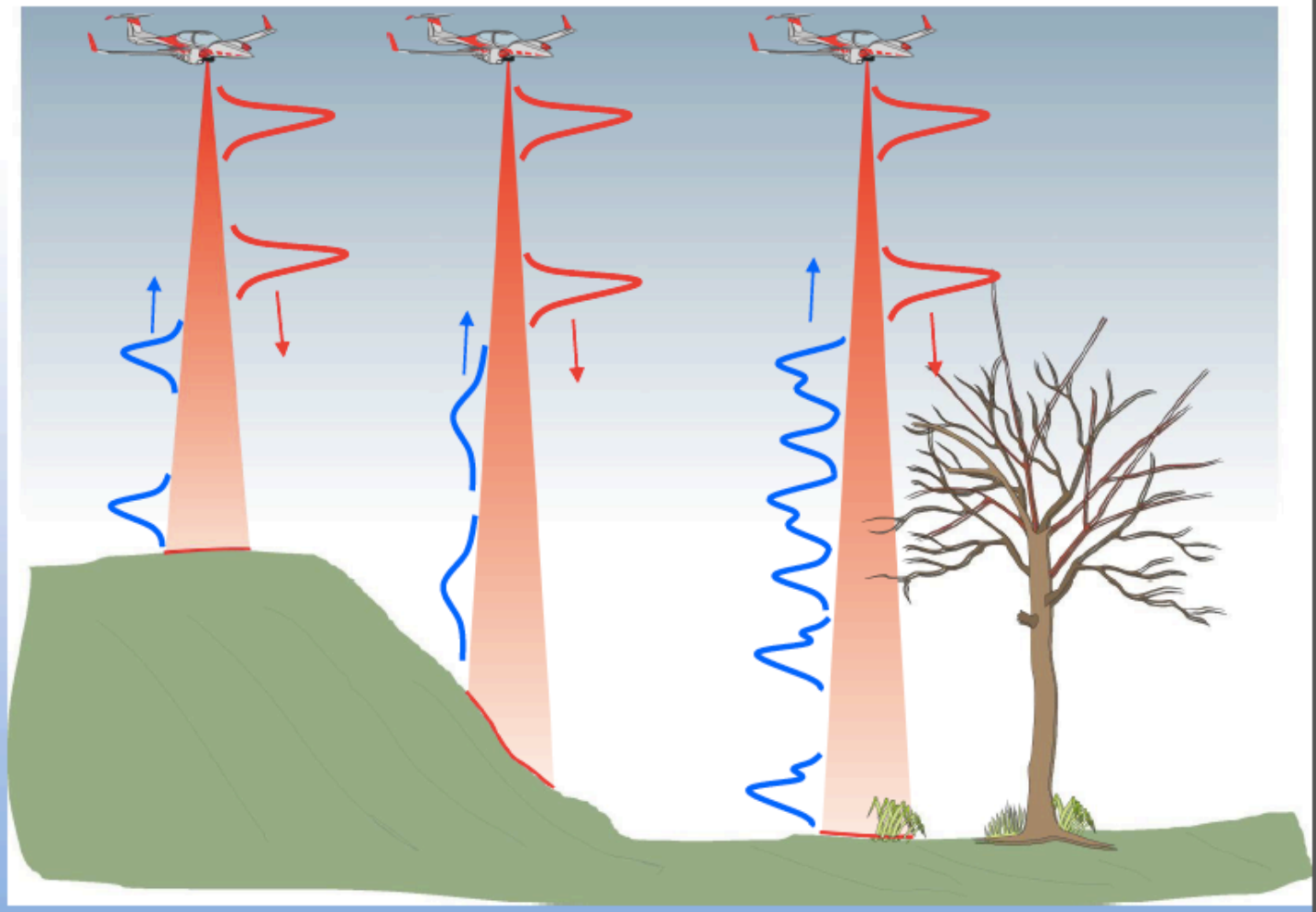
LiDAR Topography Data

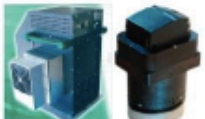
Red: Open Topography
Yellow: Community Contributed

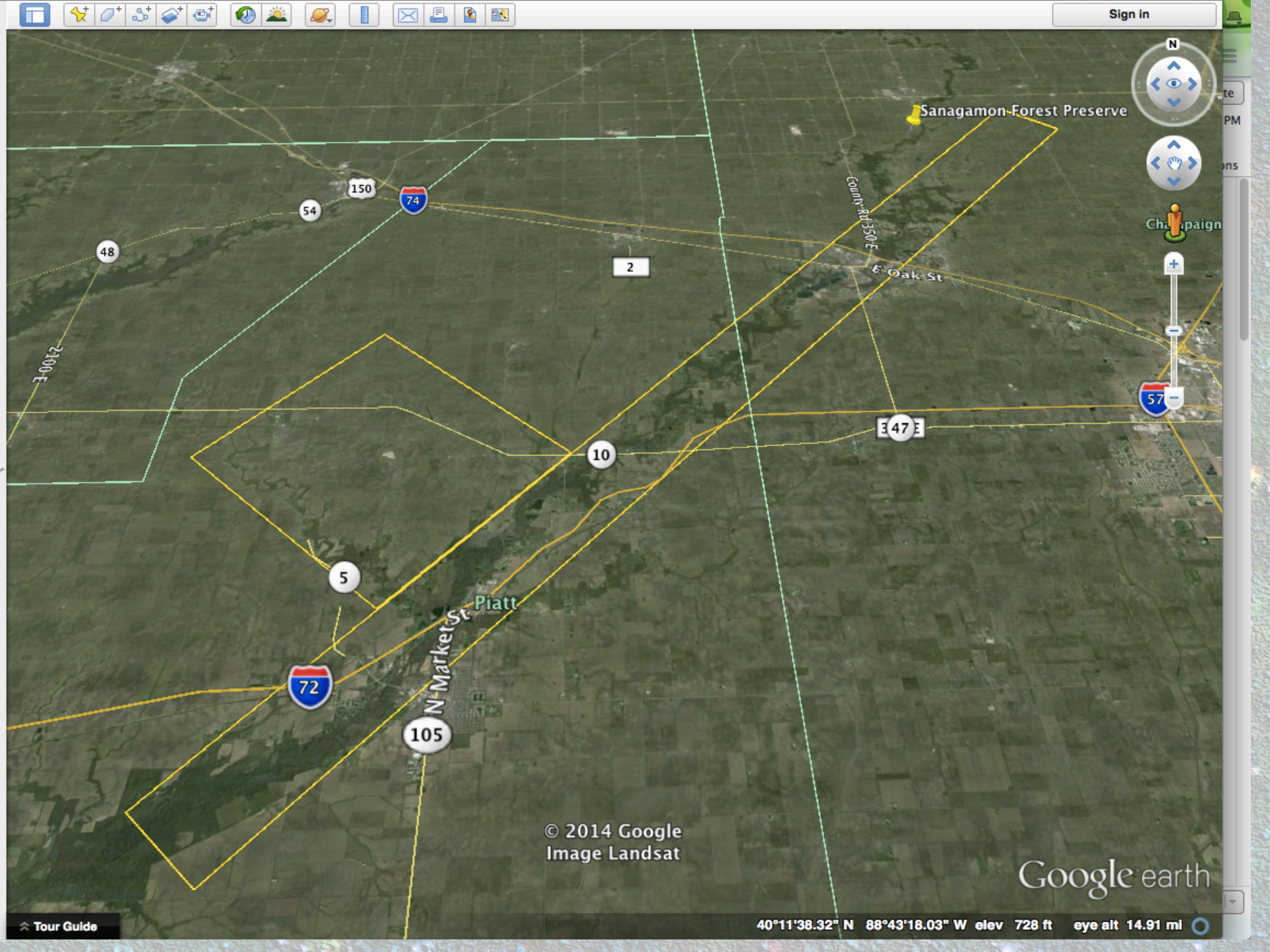
http://opentopo.sdsc.edu/gridsphere/gridsphere?cid=datasets



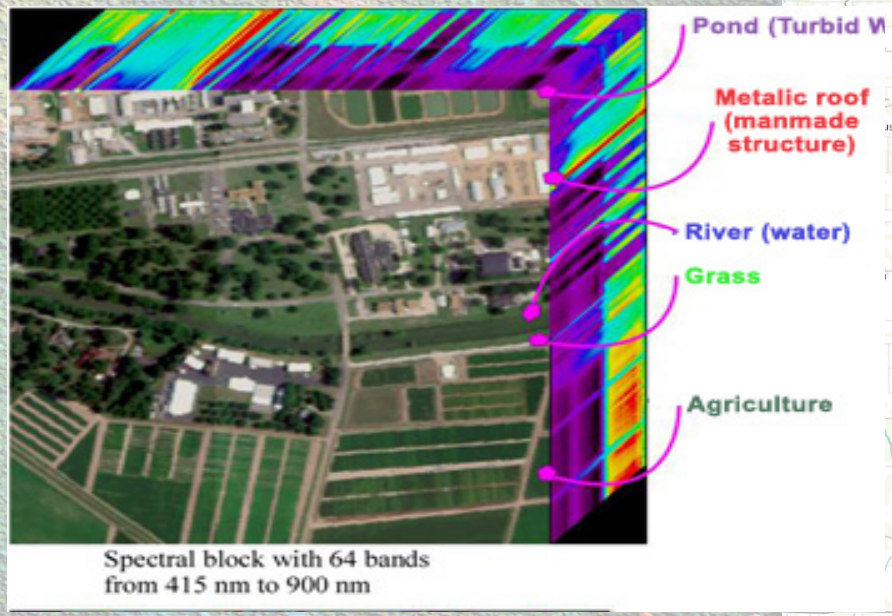
Full Waveform Data Acquisition





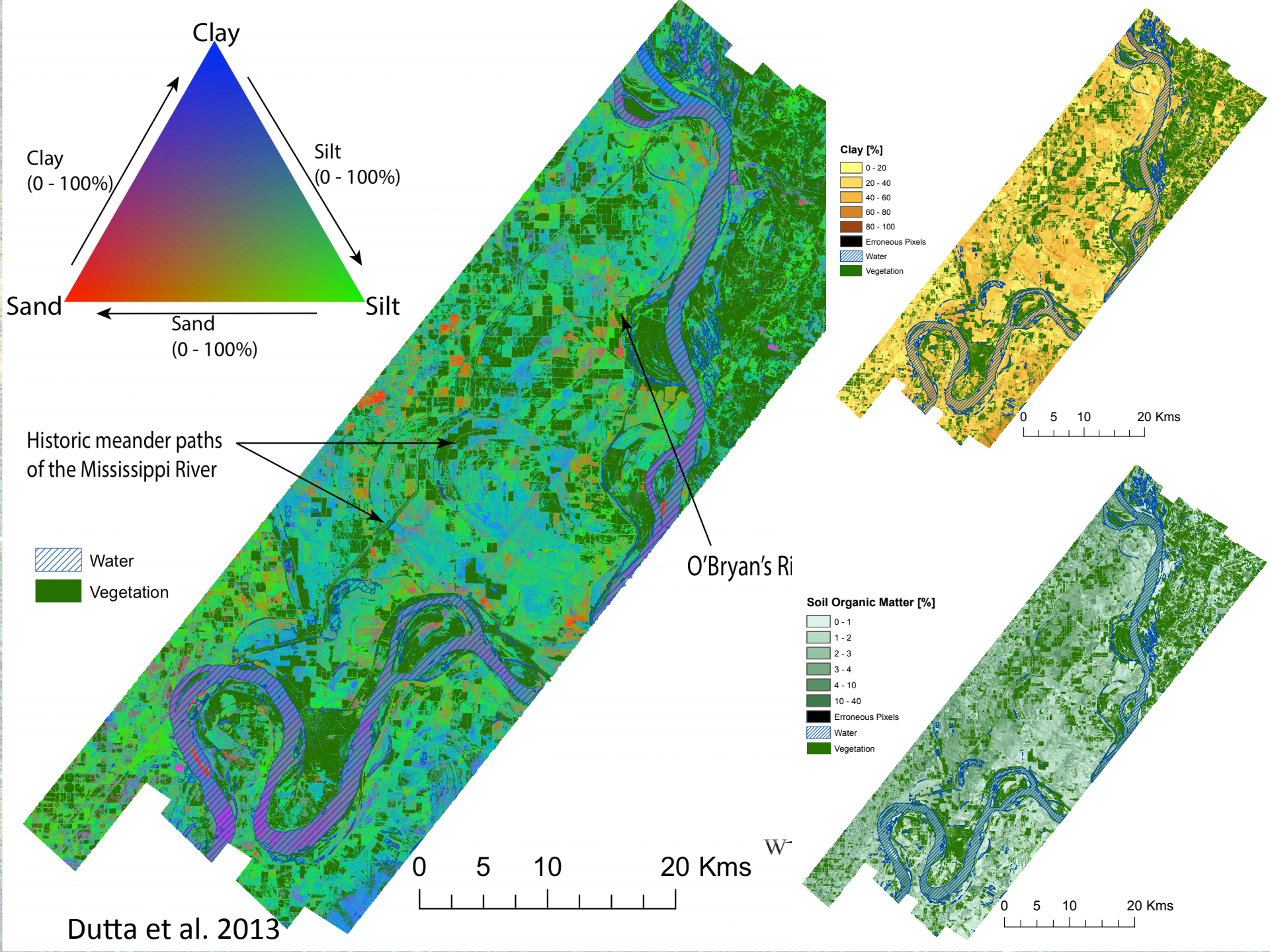

Sign in
Sanagamon Forest Preserve
150
74
54
48
2
County Rd 350 E
E Oak St
2100 E
57
47
10
5
Piatt
N Market St
72
105
© 2014 Google
Image Landsat
Google earth
Tour Guide
40°11'38.32" N 88°43'18.03" W elev 728 ft eye alt 14.91 mi

How can we achieve LiDAR scale or finer resolution observation for soil related variables?



Spectral block with 64 bands from 415 nm to 900 nm

Dutta et al. 2013


Clay
Clay
(0 - 100%)
Silt
(0 - 100%)
Sand
Silt
Sand
(0 - 100%)
Historic meander paths
of the Mississippi River
Water
Vegetation
O'Bryan's Ri
0 5 10 20 Kms
Clay [%]
0 - 20
20 - 40
40 - 60
60 - 80
80 - 100
Erroneous Pixels
Water
Vegetation
0 5 10 20 Kms
Soil Organic Matter [%]
0 - 1
1 - 2
2 - 3
3 - 4
4 - 10
10 - 40
Erroneous Pixels
Water
Vegetation
0 5 10 20 Kms
Dutta et al. 2013

Aspirations from BrownDog

- **"Unstructured" data** is viewed broadly as comprising of a collection of heterogeneous data with formats that reflect temporal and disciplinary legacies, data from emerging low cost open hardware based sensors and embedded sensor networks that lack well defined metadata, and sensor characteristics, as well as data that are available as maps, images and text.

Aspirations from BrownDog

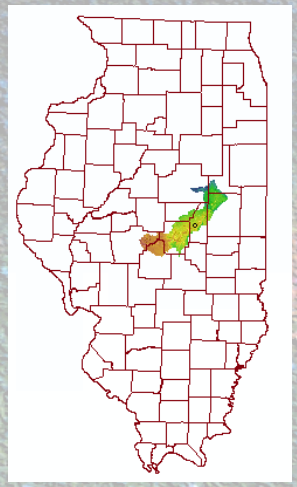
- **Develop capability to "integrate" heterogeneous data** that reflect the formats used in different disciplines, to address well-defined scientific questions pertaining to CZ. Such integration may range from overlays in common geographical formats to more formal integration in a geodatabase.
- **Develop example applications of analysis and modeling** that exploit the integrated data. These applications will in turn inform the data integration that is needed.
- **Guide the translation of the above technologies** for general-purpose use for broader adoption by the CZ community.

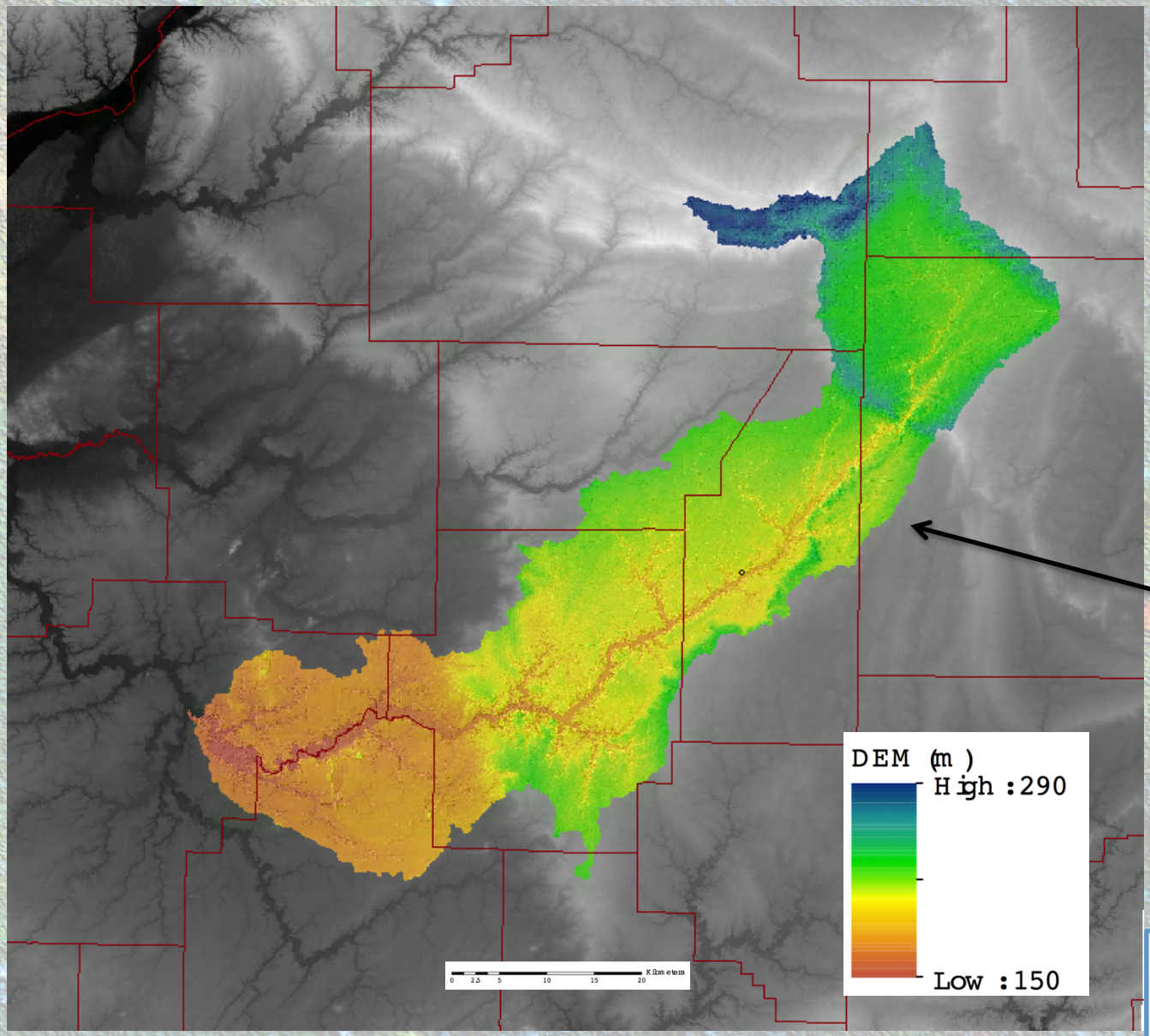
LiDAR Data Studies

- Identify geomorphic features in:
  - Low gradient streams and landscapes
  - Human modified landscapes
- Initial focus on terraces, floodplains, stream cross-section
  - Help understand equilibrium or disturbance impacts

<u>This presentation</u>: focus on methods for extraction of useful information from LiDAR data

Upper Sangamon River Basin (USRB)





Basin Area:
3731.5 km^2

Data source: Illinois State Geological Survey

LiDAR
High Resolution Digital Elevation Model (DEM)

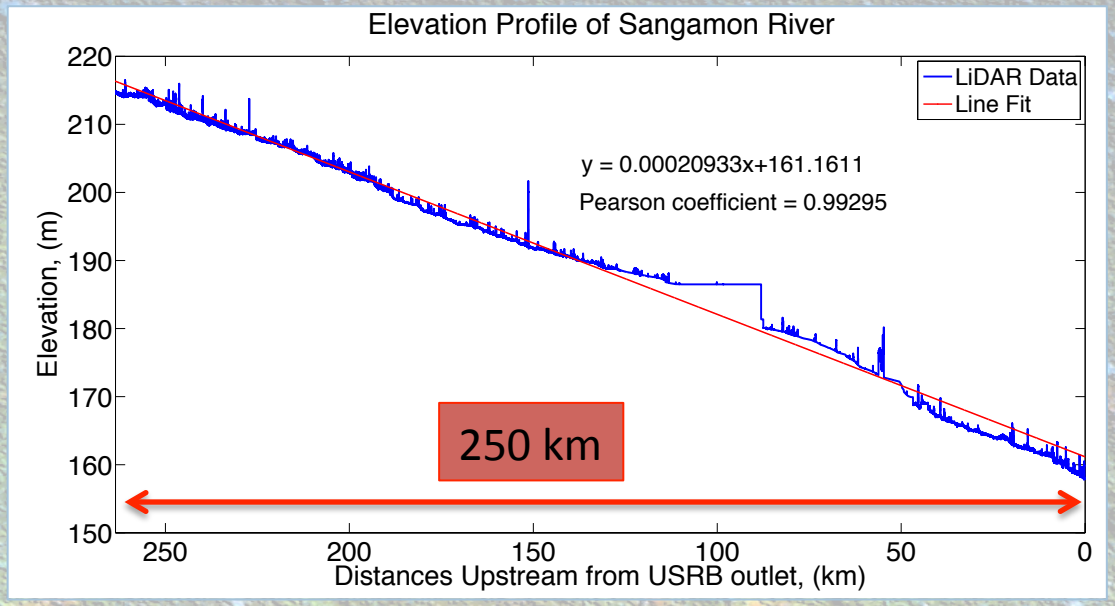
DTM:
digital terrain models (represent only the ground surface)
a 'bare earth' point cloud

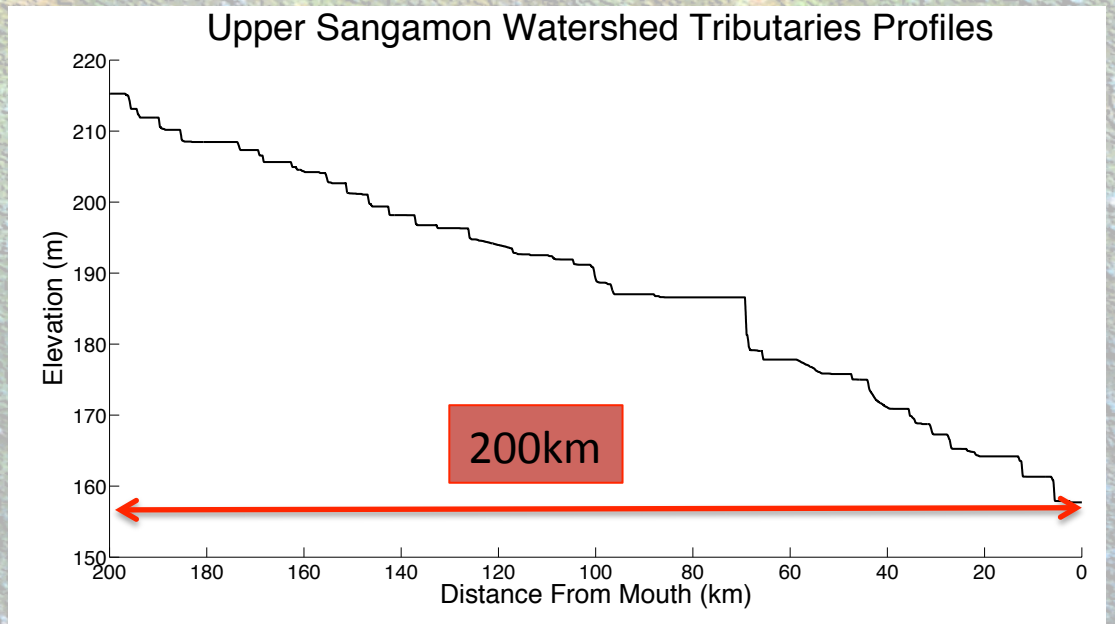
DSM:
digital surface model

LiDAR data advantages

LiDAR (1.2 m DEM) v.s. 30 m DEM

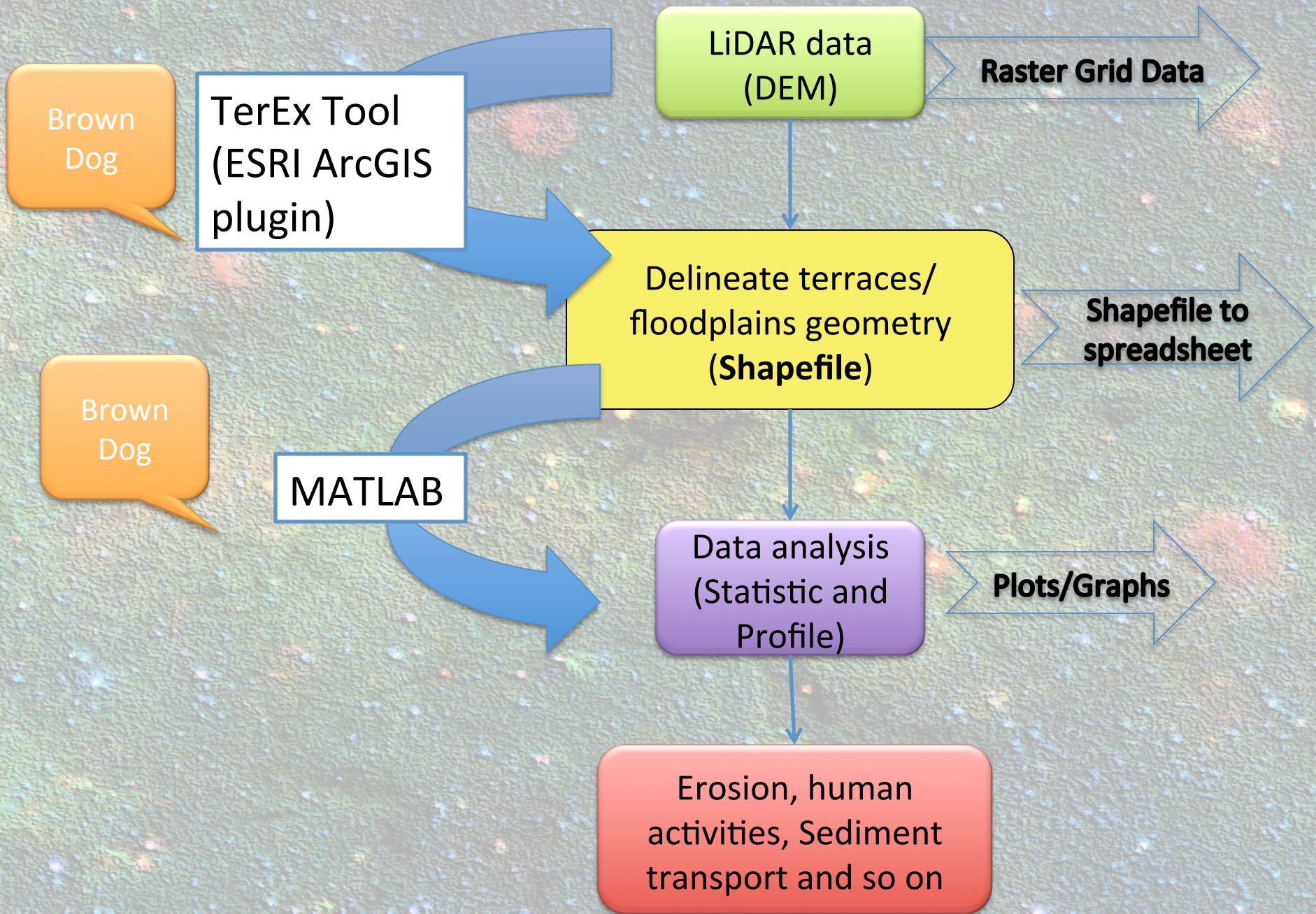
- Longer stream profiles (25%)
- More obvious concave and convex curves





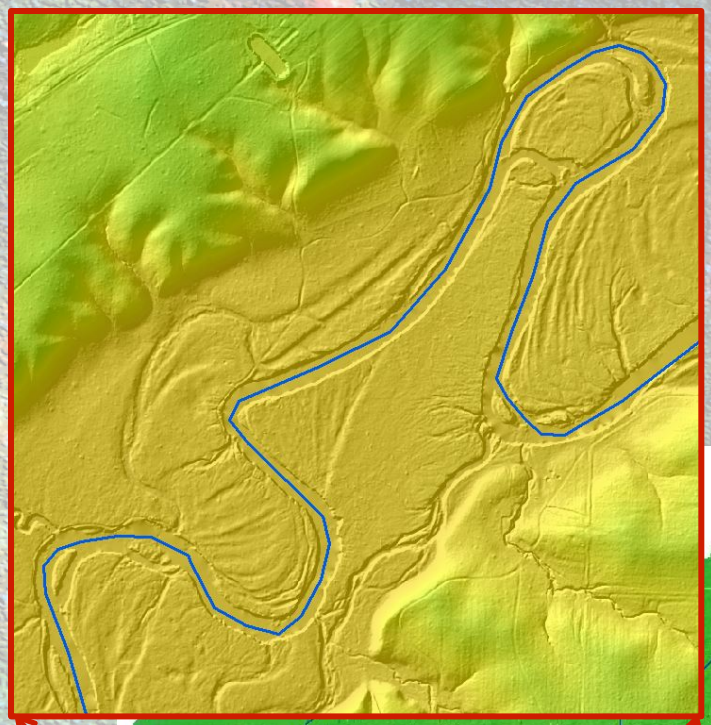
Terraces/Floodplain Study

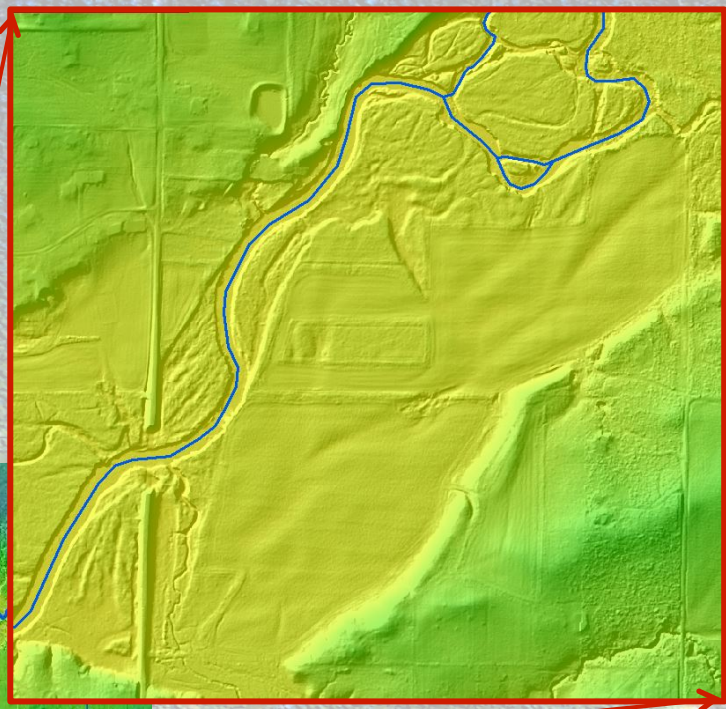
Analysis 1

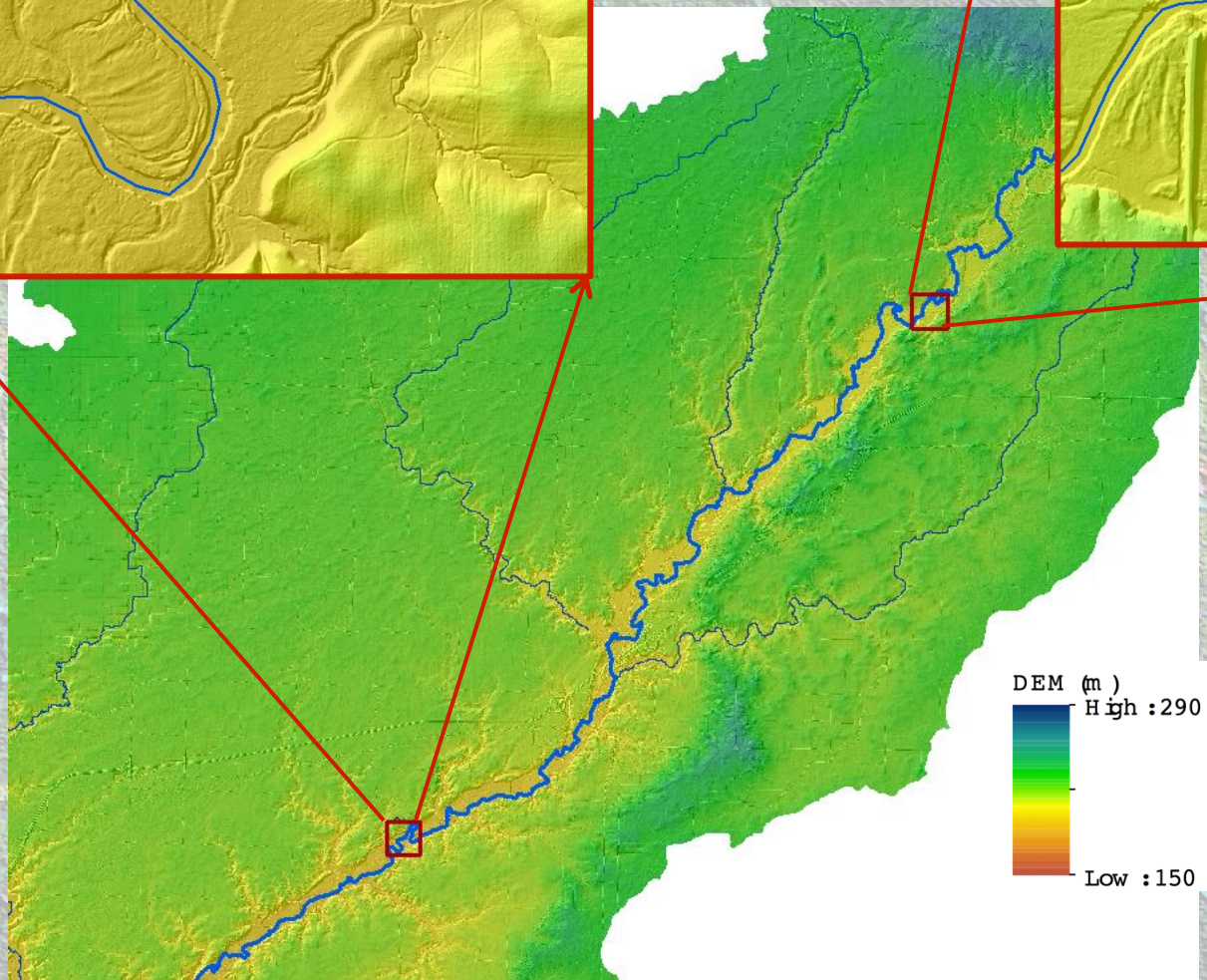


Analysis 1

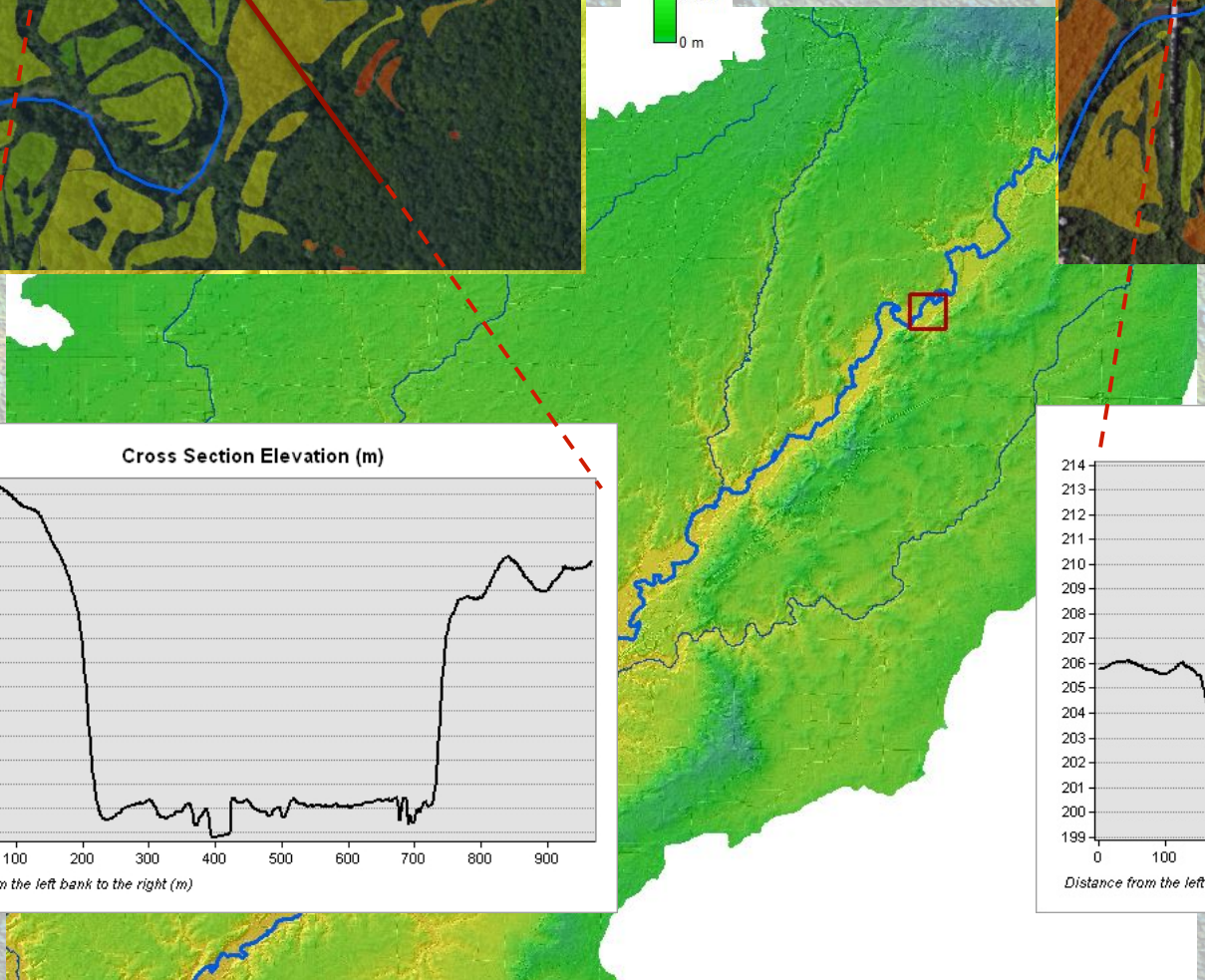
TerEx Tool

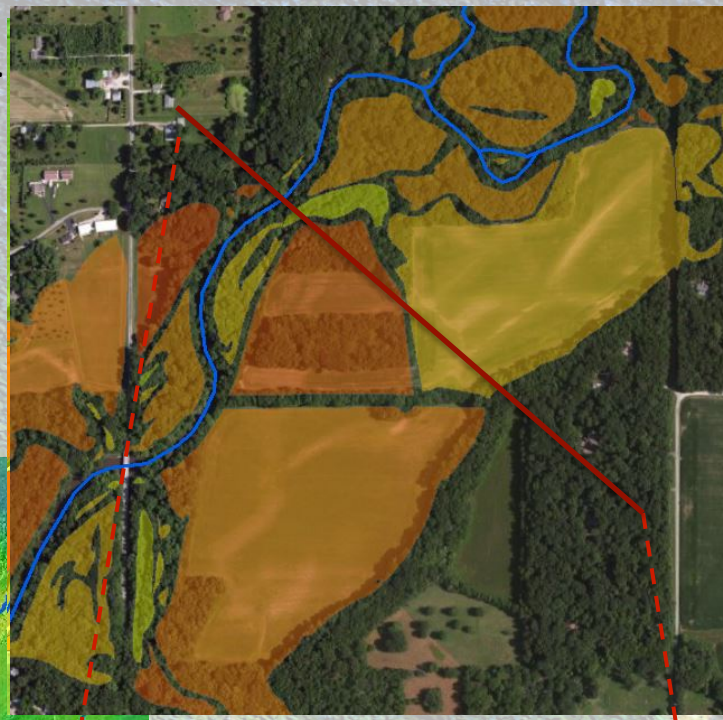


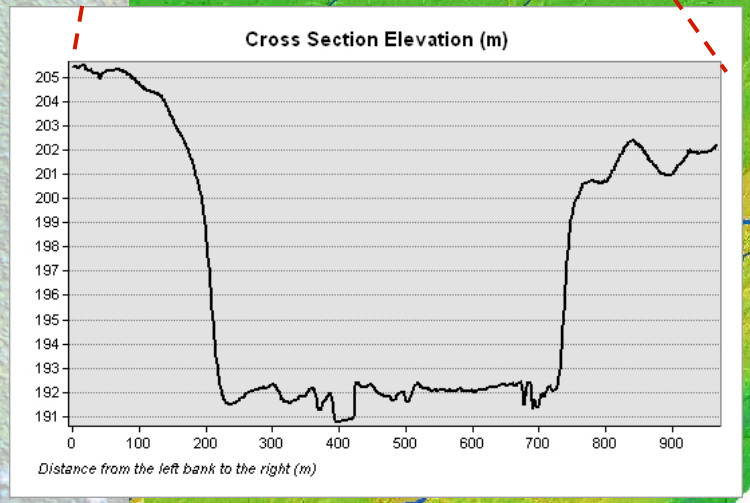


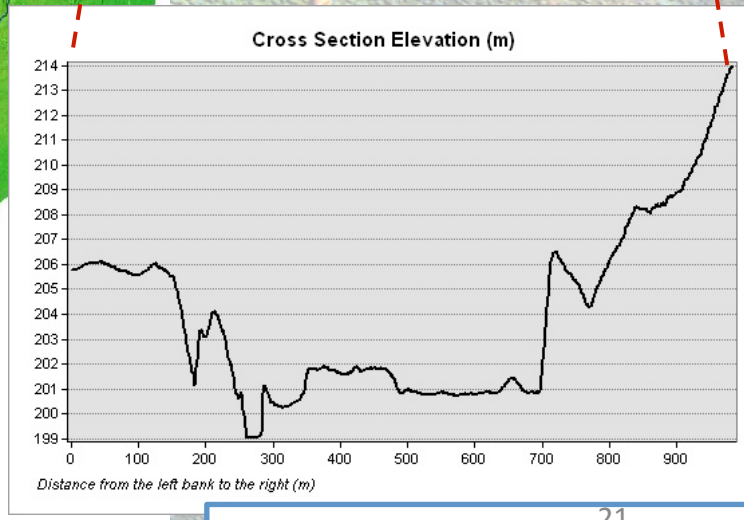


Terraces/floodplain Elev.

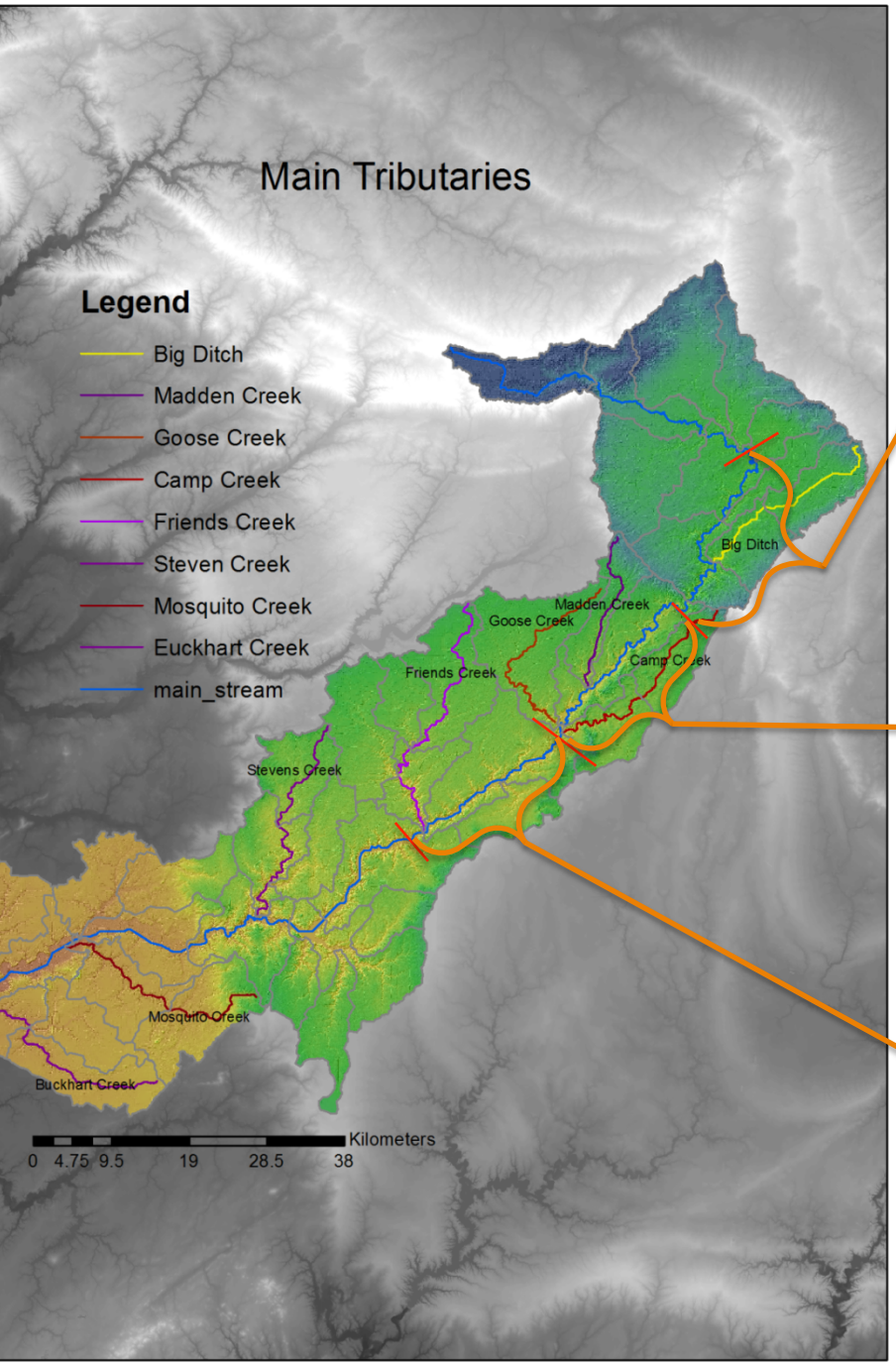


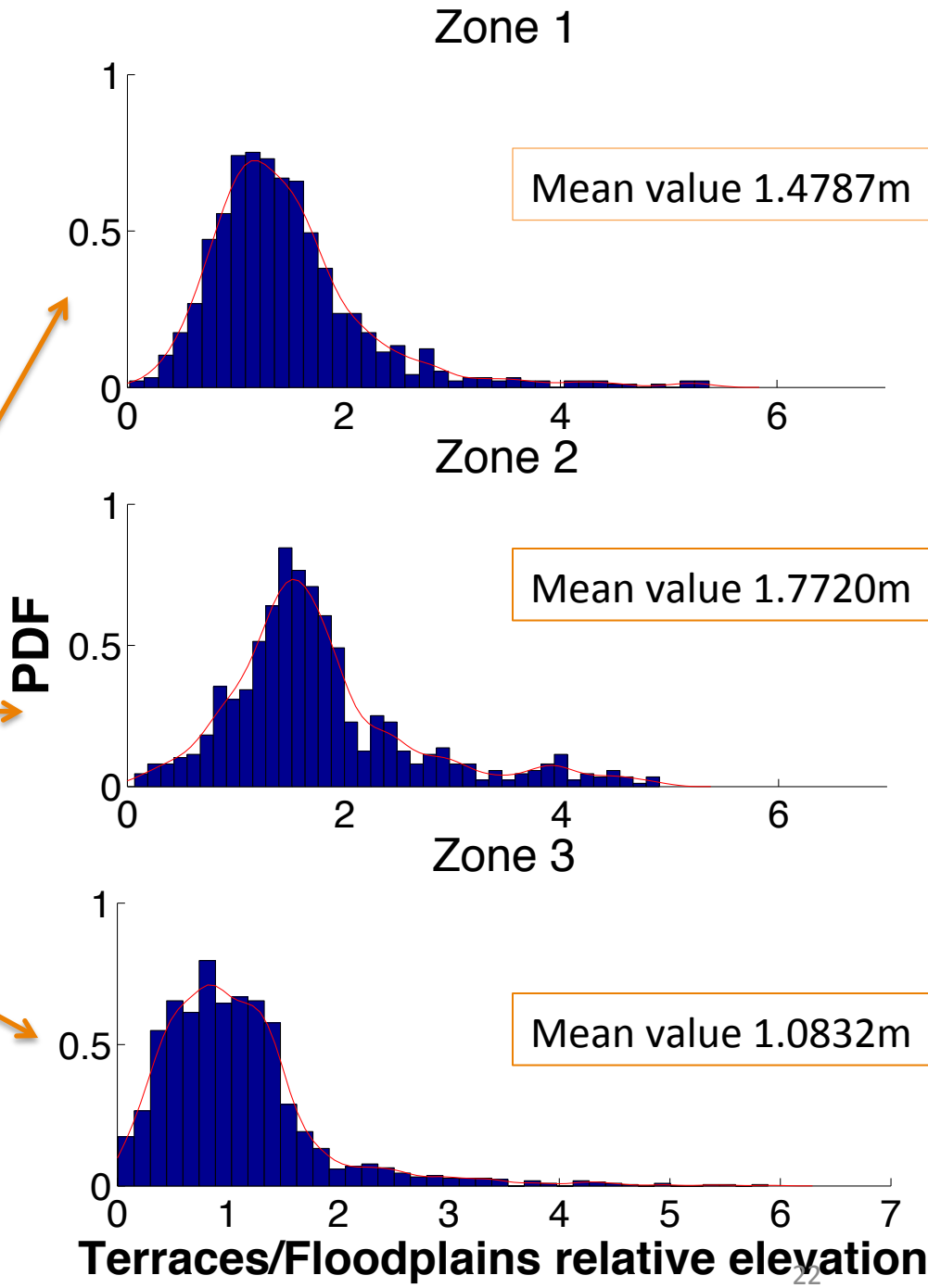




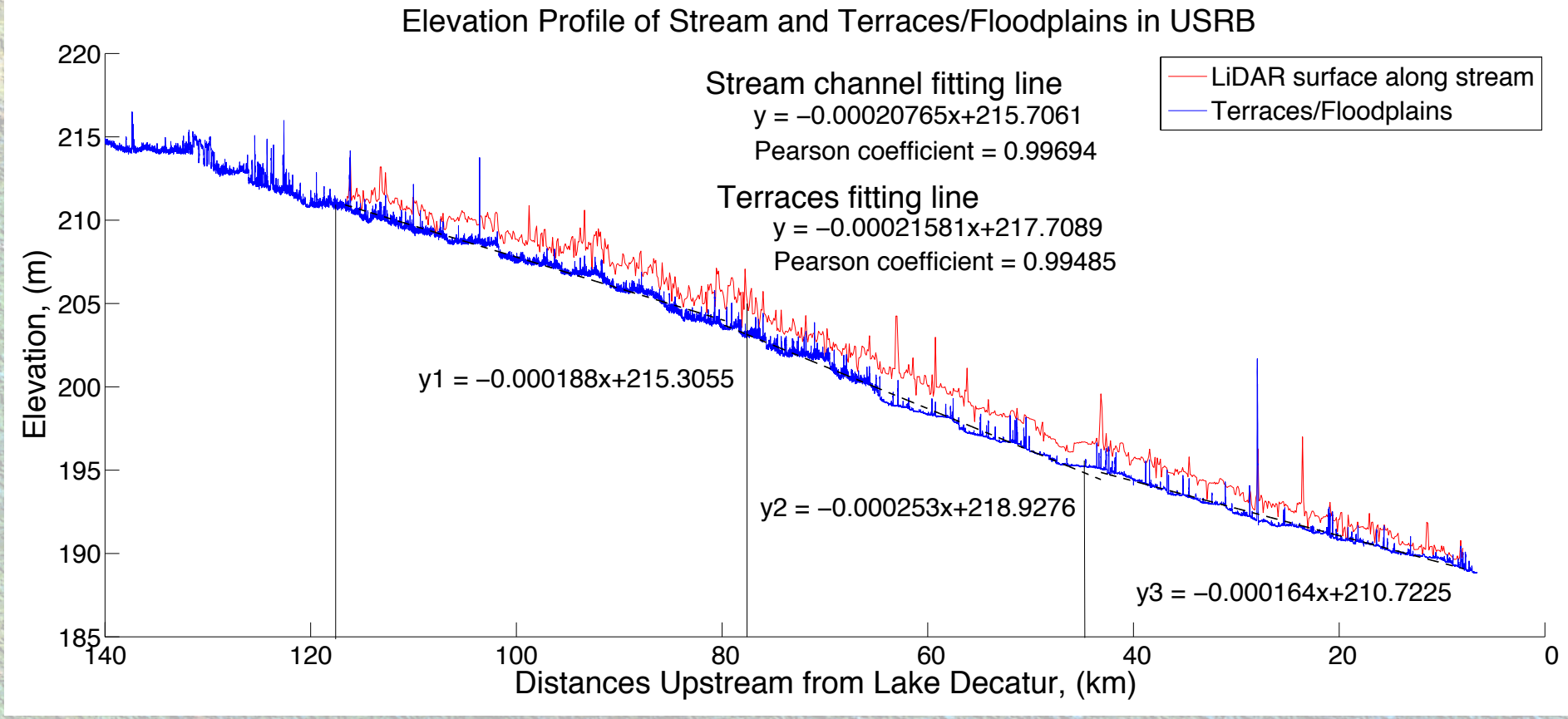


Belmont Lab Resources


Main Tributaries
Legend
Big Ditch
Madden Creek
Goose Creek
Camp Creek
Friends Creek
Steven Creek
Mosquito Creek
Euckhart Creek
main_stream
Big Ditch
Madden Creek
Goose Creek
Friends Creek
Camp Creek
Stevens Creek
Mosquito Creek
Buckhart Creek
Kilometers
0 4.75 9.5 19 28.5 38

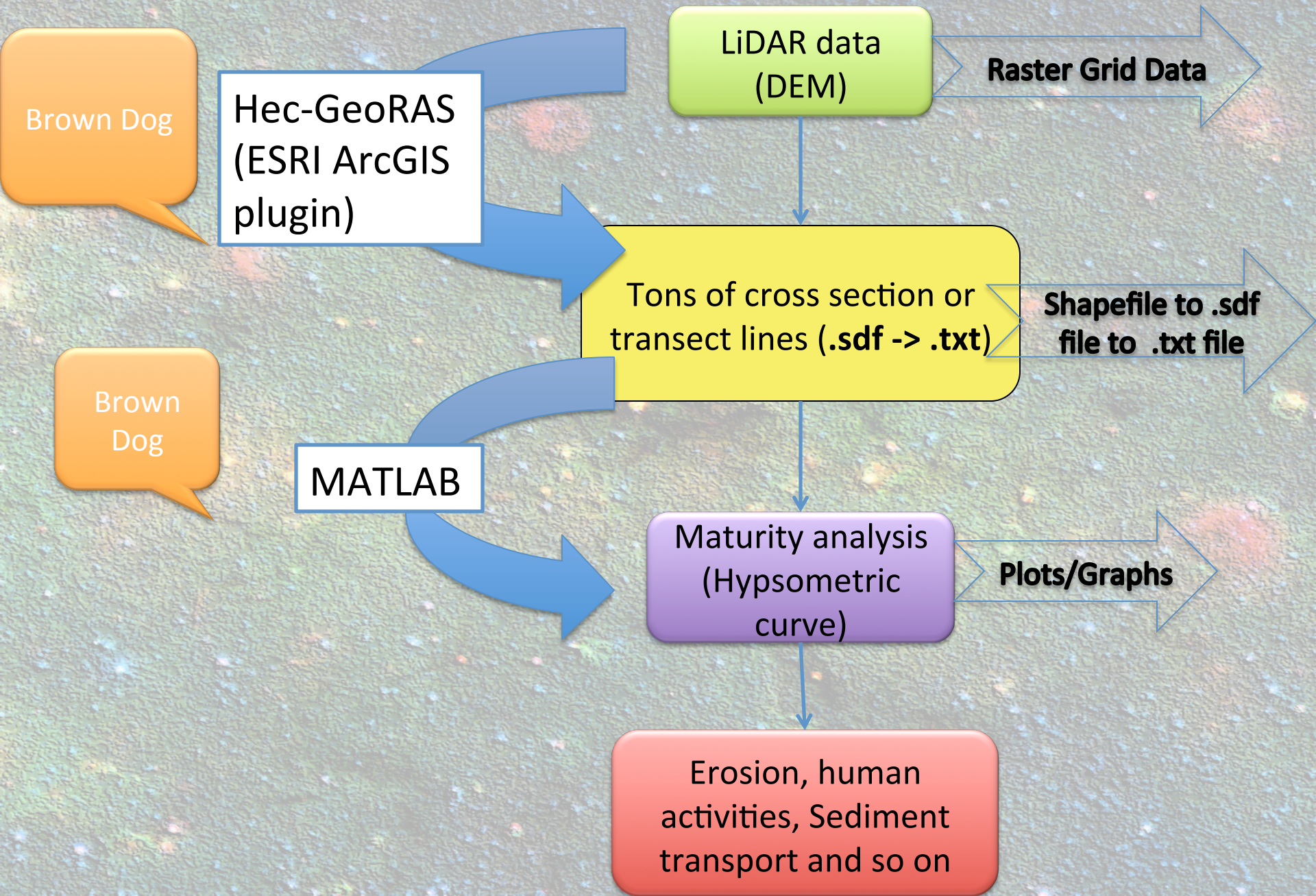

Zone 1
Mean value 1.4787m
Zone 2
Mean value 1.7720m
Zone 3
Mean value 1.0832m
PDF
Terraces/Floodplains relative elevation

Stream Elevation Profile with Averaged Terraces/Floodplains Elevation



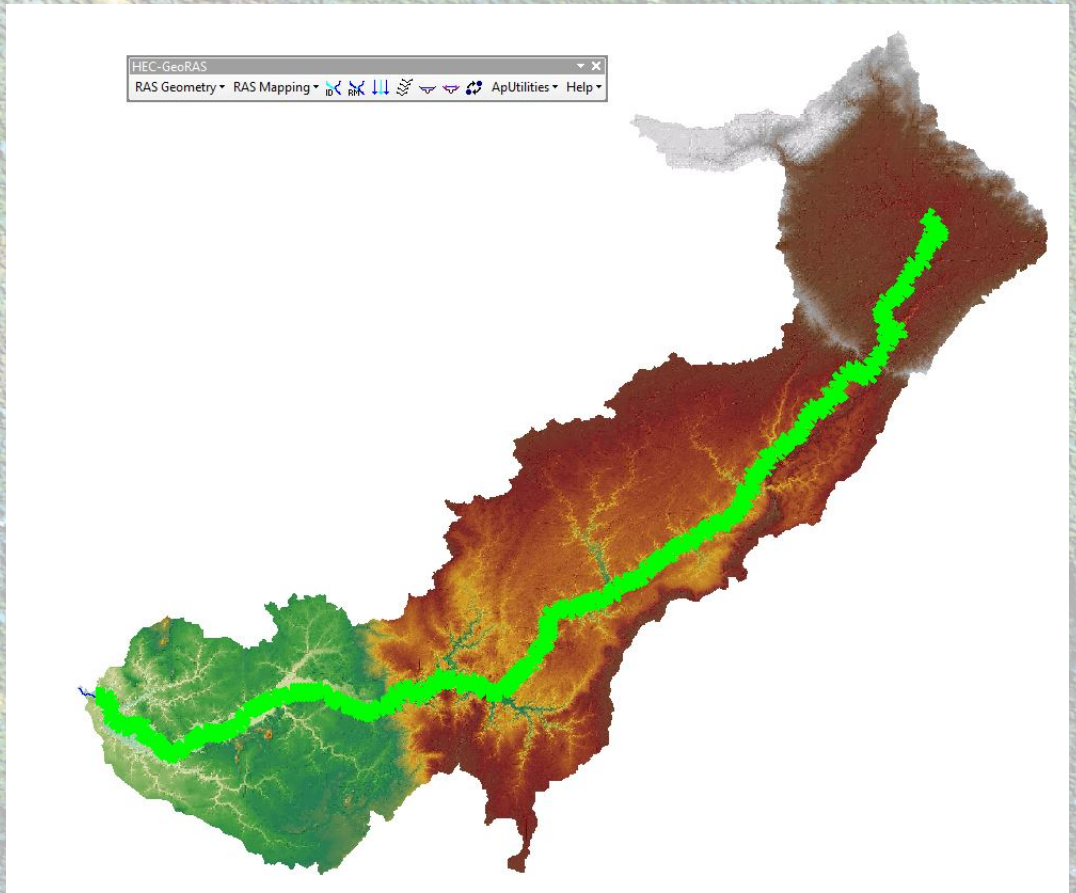
Hypsometric Curve Study

Analysis 2



Cross Section Gathering

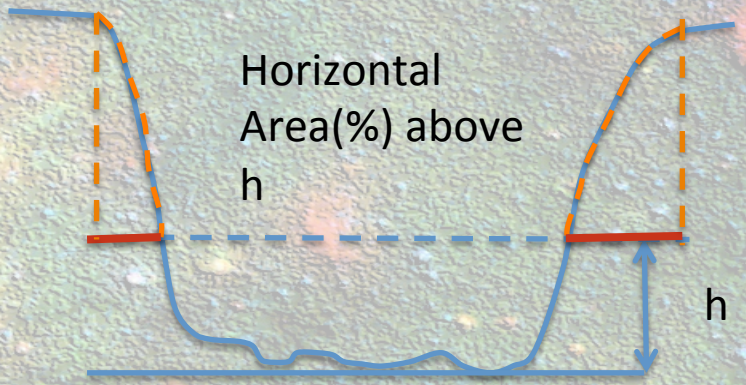
- Hec-GeoRAS
  - Cross section interval is 200m, width is 1km -- 2km

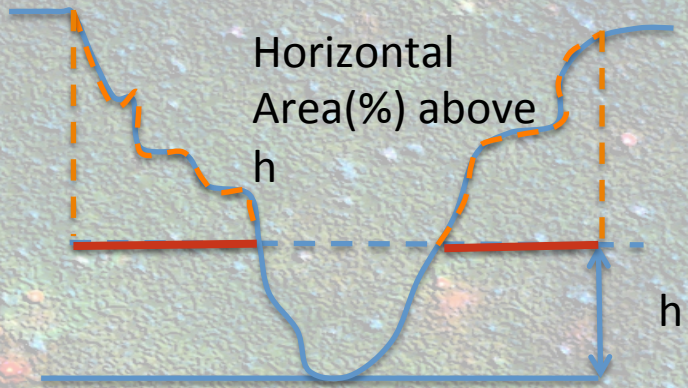


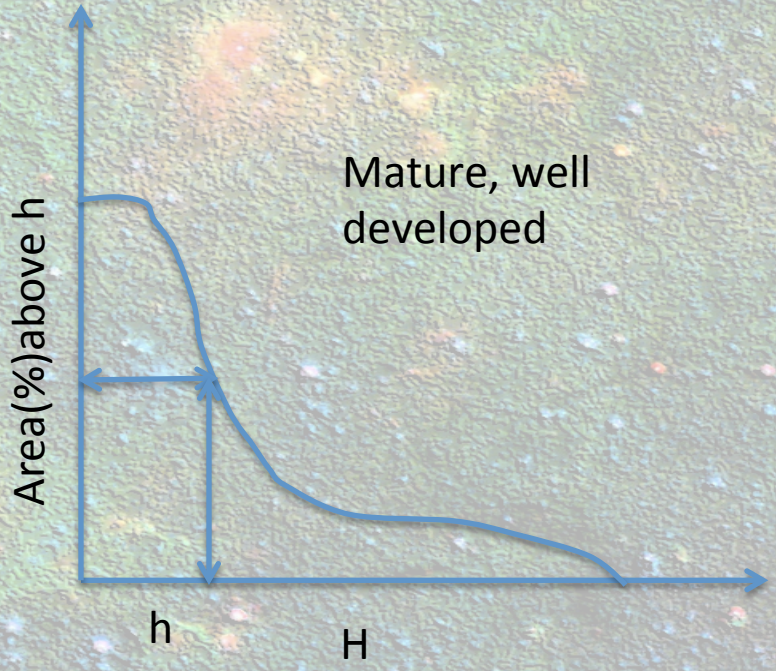
Disadvantages

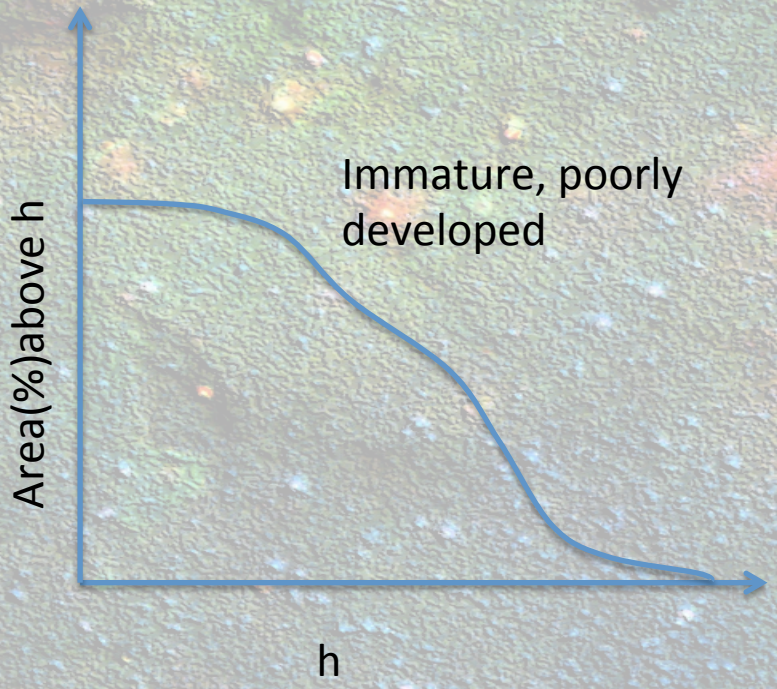
- Can not generate more than 2000 cross section lines at the same time.

‘Hypsometric’ Curve

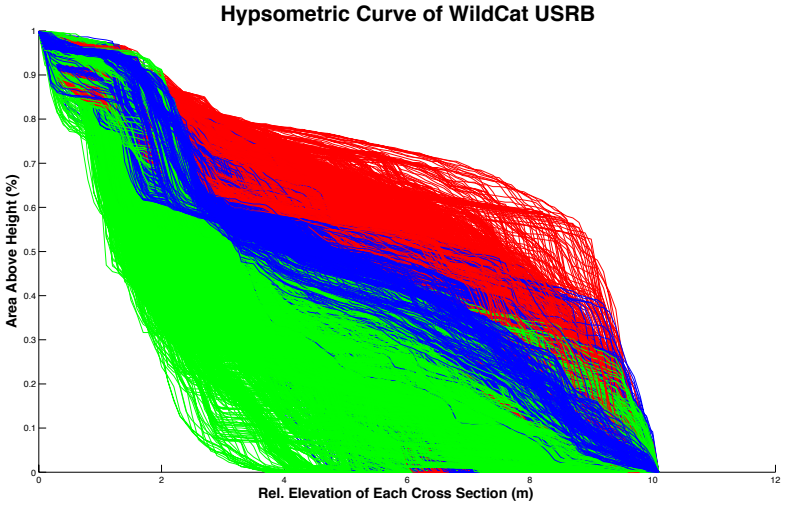


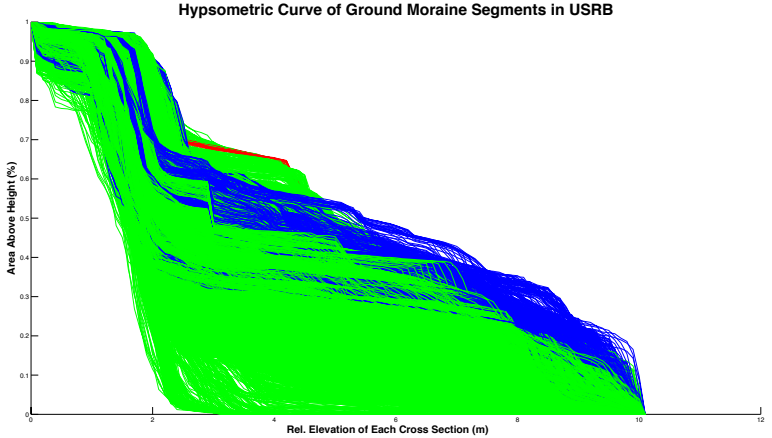


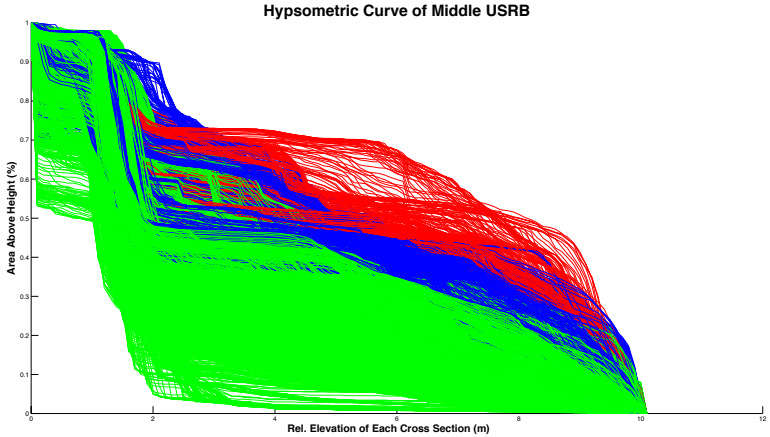


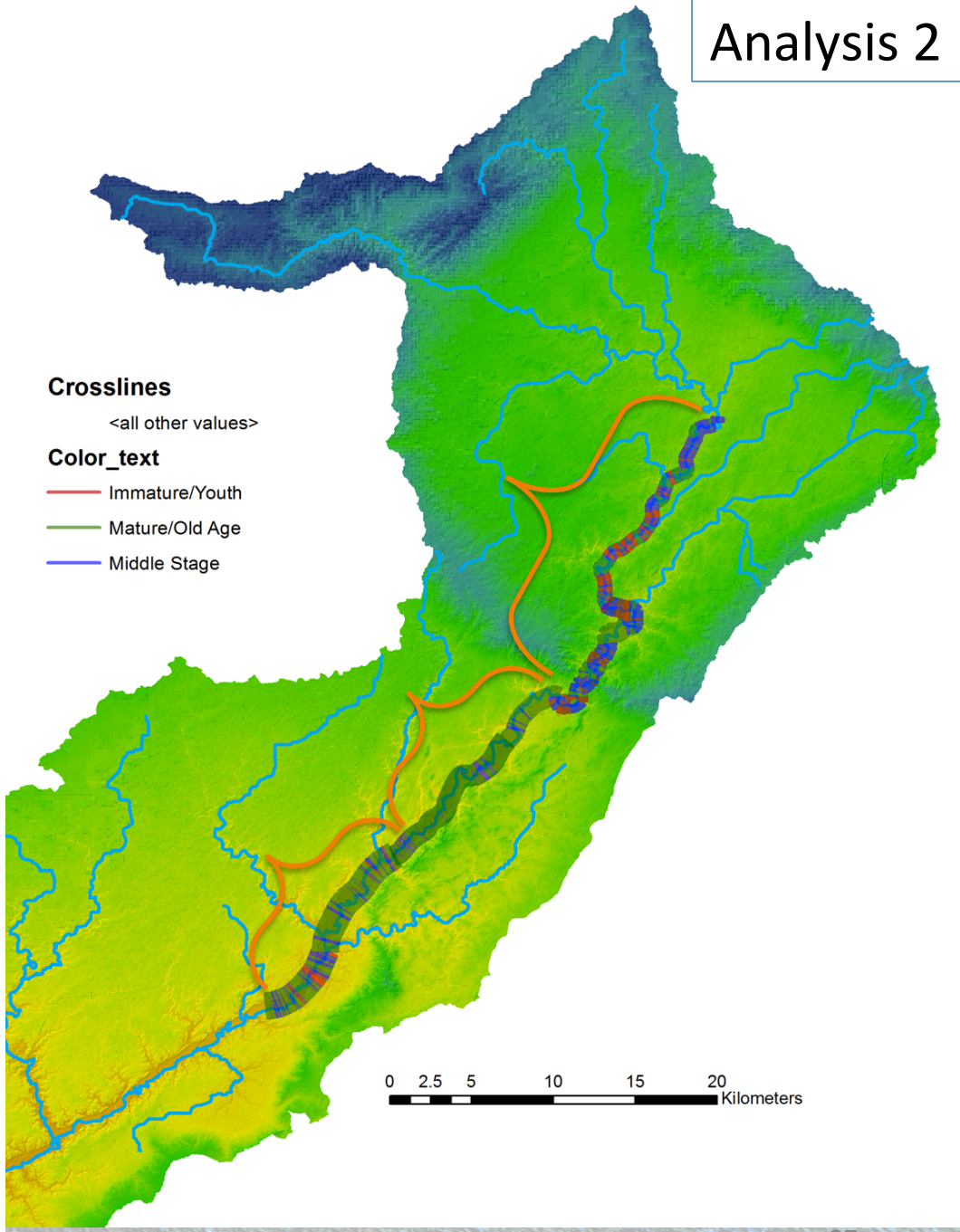


Analysis 2


Hypsometric Curve of WildCat USRB
Area Above Height (%)
Rel. Elevation of Each Cross Section (m)

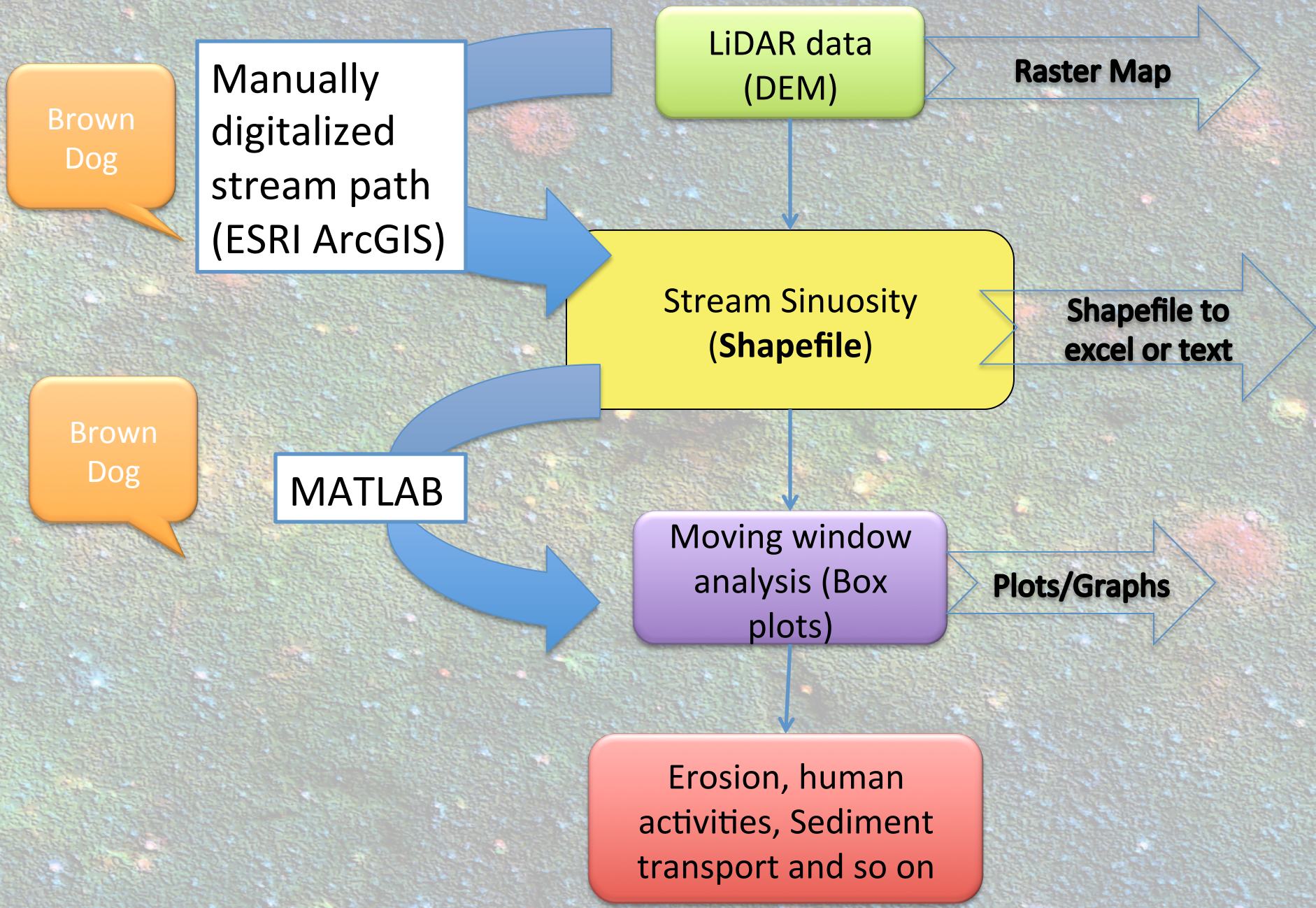

Hypsometric Curve of Ground Moraine Segments in USRB
Area Above Height (%)
Rel. Elevation of Each Cross Section (m)


Hypsometric Curve of Middle USRB
Area Above Height (%)
Rel. Elevation of Each Cross Section (m)


Crosslines
<all other values>
Color_text
Immature/Youth
Mature/Old Age
Middle Stage
0 2.5 5 10 15 20
Kilometers

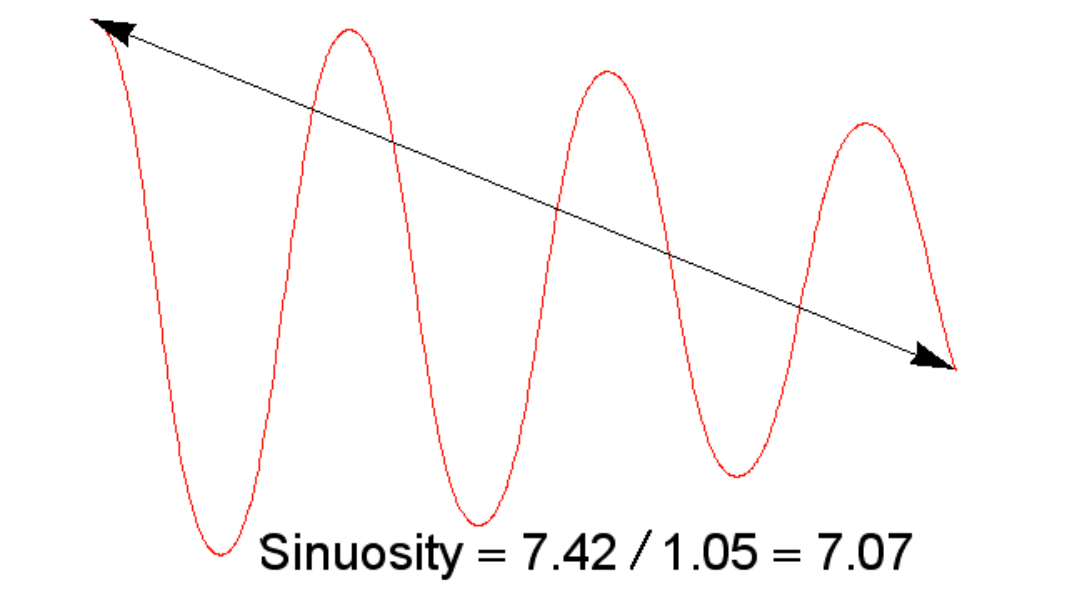
Channel Sinuosity Study

Analysis 3



Sinuosity Concept

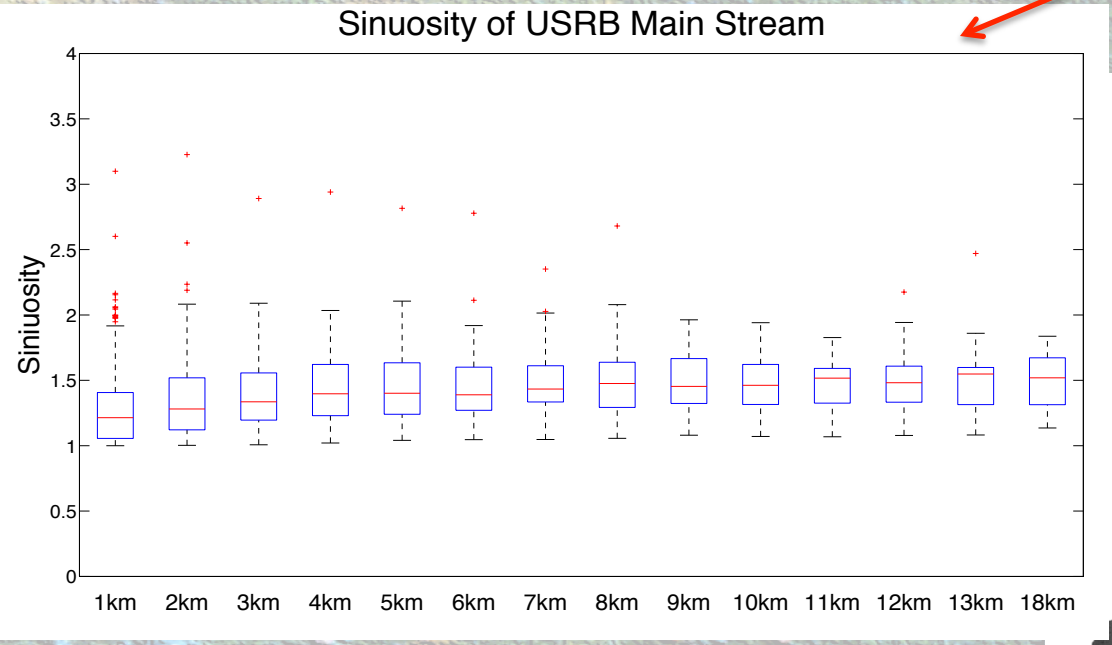
$$\frac{\text{Actual channel length}}{\text{Straight line distance}}$$

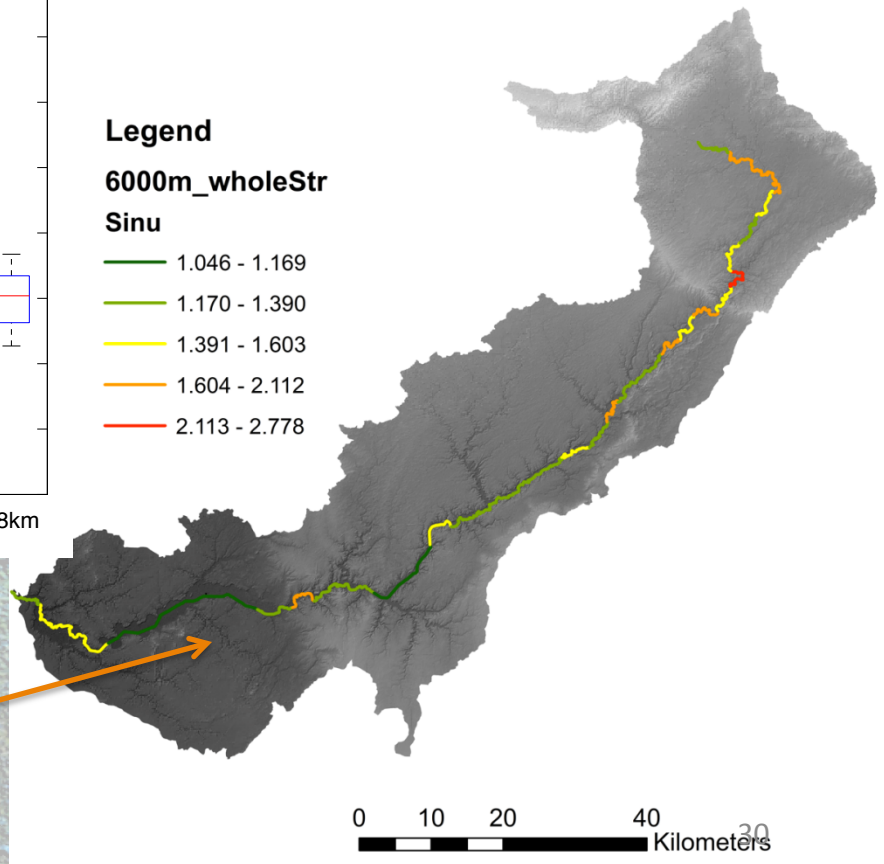


Sinuosity in Upper Sangamon River Watershed

- Total Length (length chosen for sinuosity)
  - 216km
- General Sinuosity
  - 1.87

Moving window to compute sinuosity based on different space intervals





Space interval: 6000m as an example

Uncurated data process

- Aerial photos
  - Thousands of photos from 1993yr to 2012yr
- Format
  - Geotiff and .sid file
- Target
  - With help from Brown Dog
  - Detect the streams' migration, modification or extension

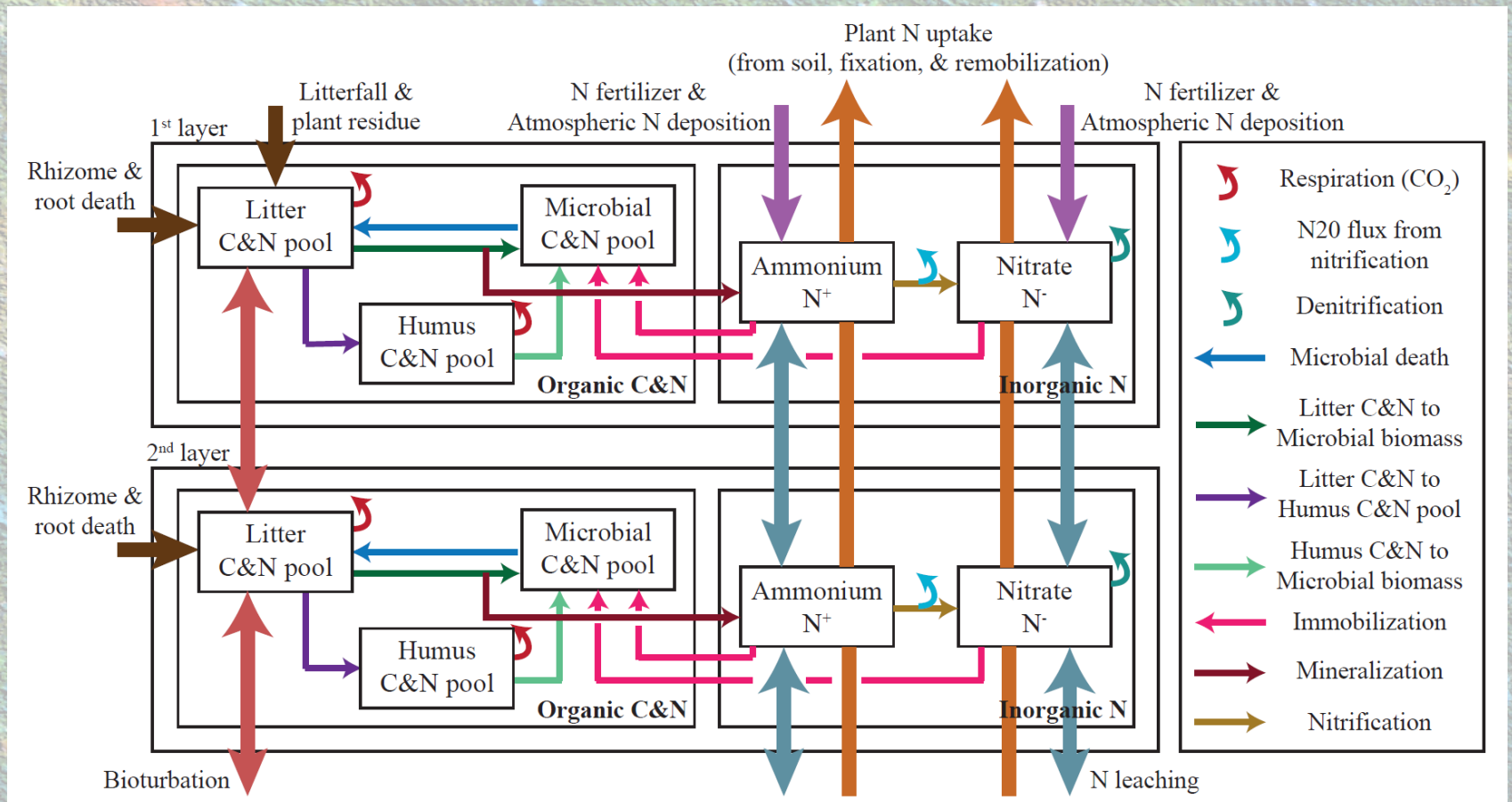
Brown Dog can help to:

- Replace existing tools with servers which can increase the processing speed
- Create a better tool on servers
  - Expand data process limitation
  - Show more intelligent way of extracting raster data

Nutrient modeling

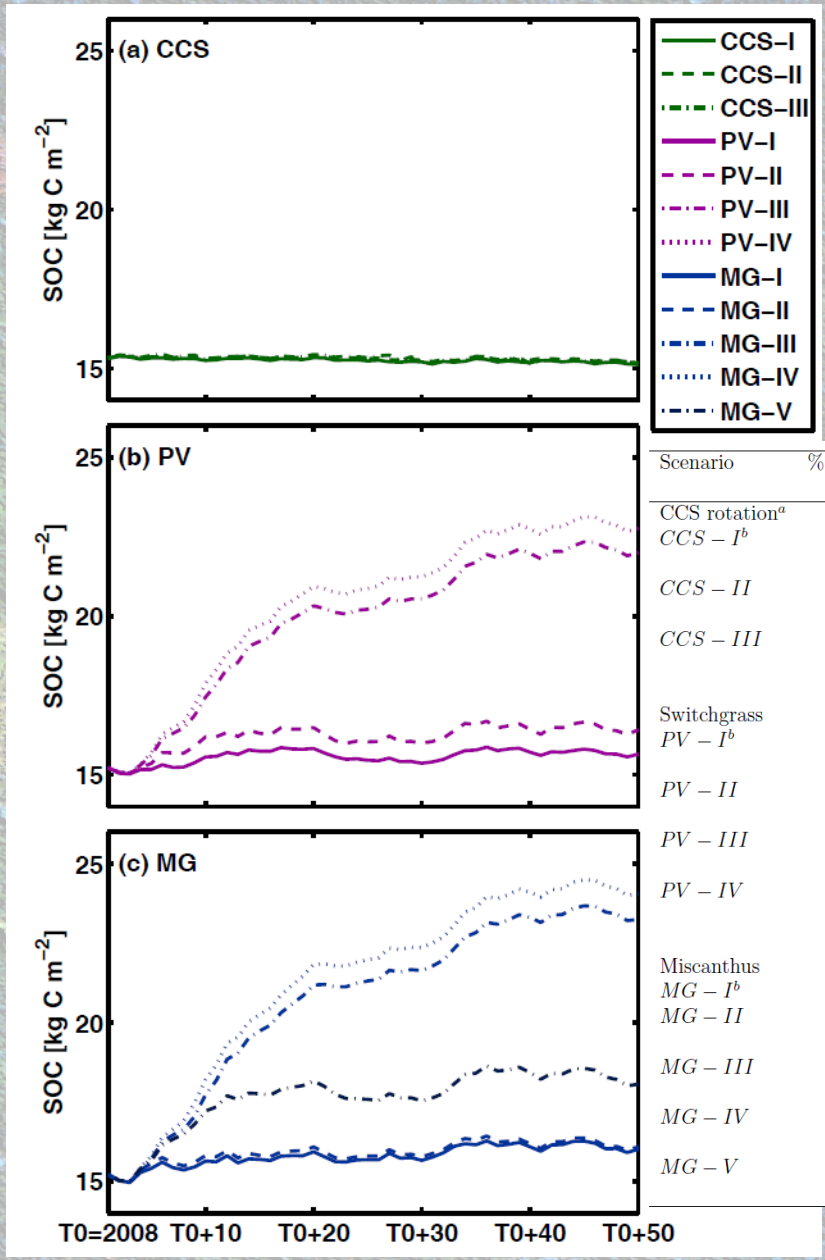
Multi-layer soil nutrient model

- **Soil carbon and nitrogen dynamics**
  - Soil carbon and nitrogen dynamics controlled by soil microbial organisms.



Bioenergy crops

- Threshold effect on soil carbon accumulation
- Due to high above-ground C:N ratio in bioenergy crop at harvest
- Result in substantial atmospheric CO_2 sequestration



Scenario	% of above-ground biomass inputs at harvest
CCS rotation[a]	
$CCS - I^b$	C: 50%; S: 100% (185 kg C m^{-2} yr^{-1})
$CCS - II$	C: 75%; S: 100% (269 kg C m^{-2} yr^{-1})
$CCS - III$	C: 100%; S: 100% (354 kg C m^{-2} yr^{-1})
Switchgrass	
$PV - I^b$	2% (17 kg C m^{-2} yr^{-1})
$PV - II$	20% (165 kg C m^{-2} yr^{-1})
$PV - III$	25% (206 kg C m^{-2} yr^{-1})
$PV - IV$	30% (248 kg C m^{-2} yr^{-1})
Miscanthus	
$MG - I^b$	0%
$MG - II$	10% (87 kg C m^{-2} yr^{-1})
$MG - III$	15% (130 kg C m^{-2} yr^{-1})
$MG - IV$	20% (174 kg C m^{-2} yr^{-1})
$MG - V$	15% (130 kg C m^{-2} yr^{-1})

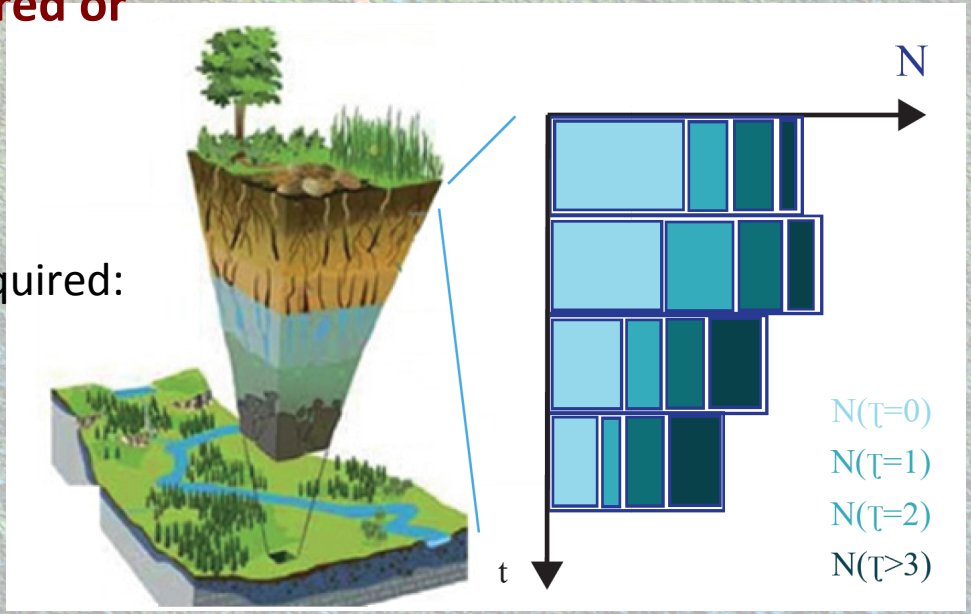
Source: Woo et al., 2014 (under review)

Nitrogen Age

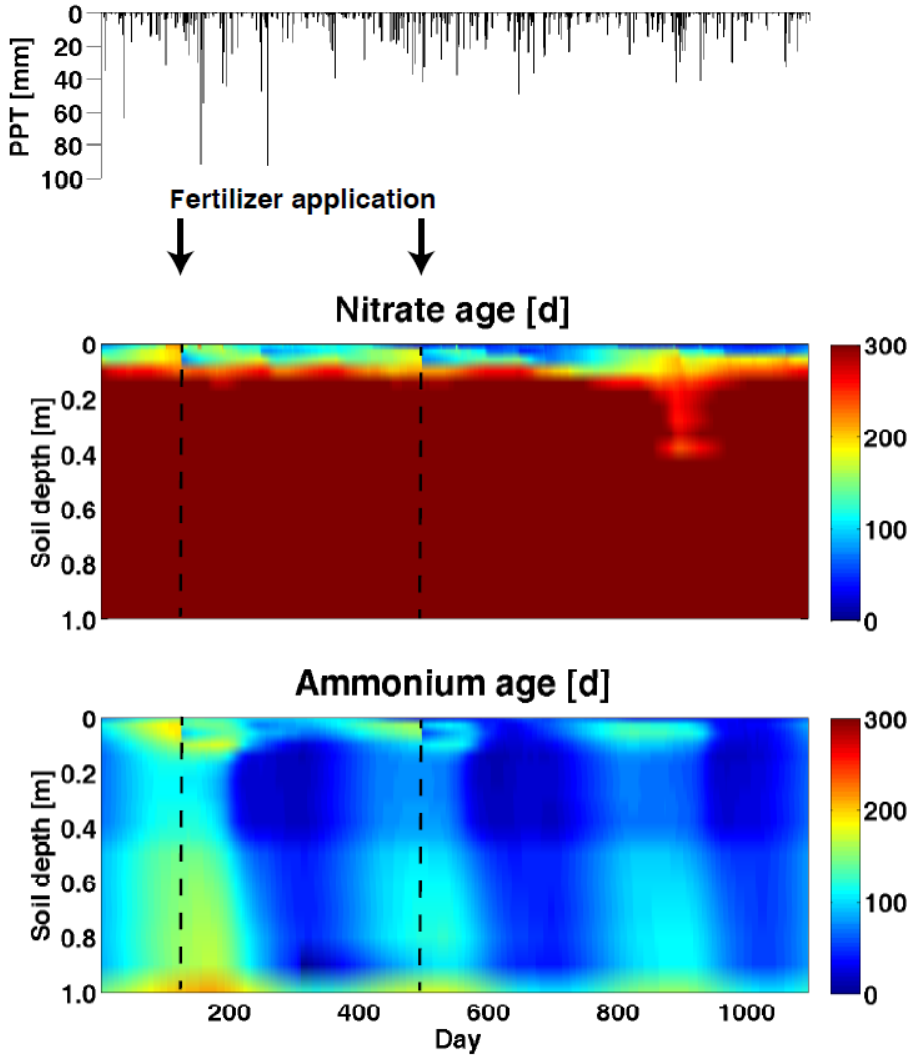
- **Age**:
  - "Time elapsed since the particle under consideration left the region in which its age is prescribed to zero'' (Deleersnijder et al., 2001)

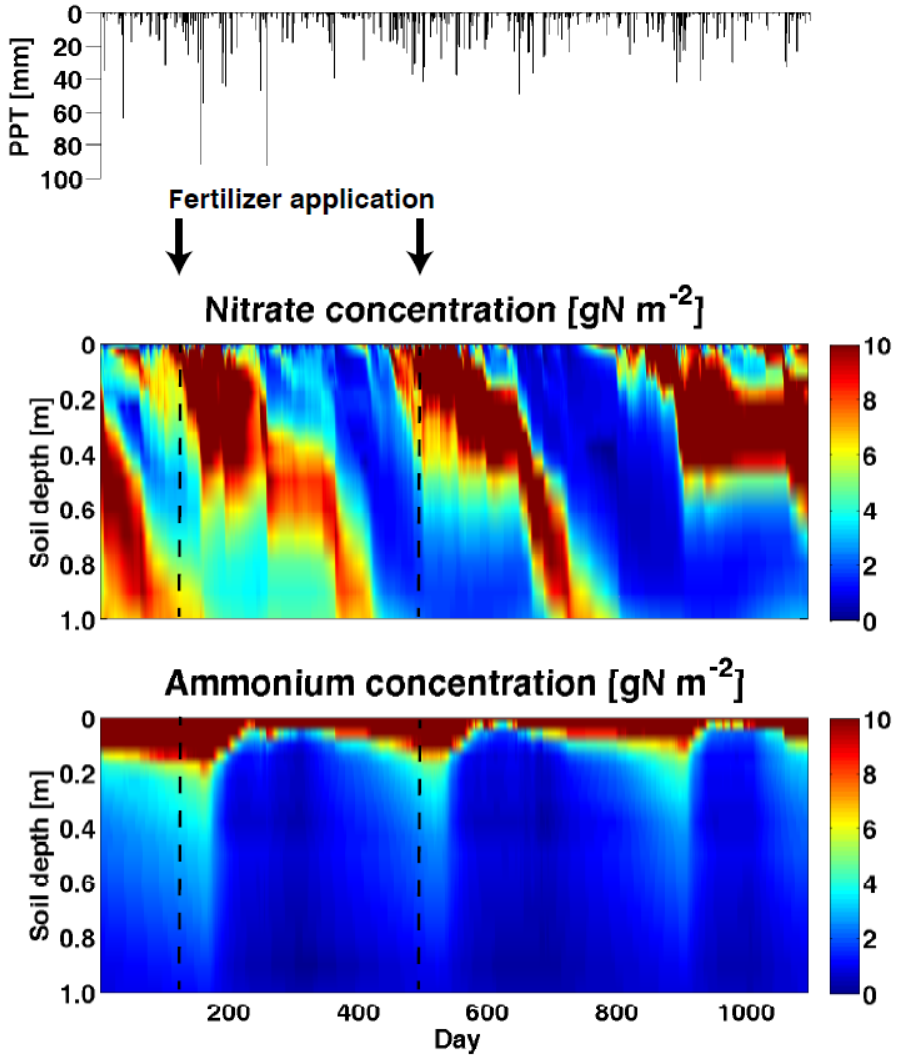
Difficult to achieve deep insight with a simple analysis of available measured or simulated variables

- Specific interpretation methods required: analysis of elapsed time



Nitrogen Age & Concentration





List

- Data
  - LiDAR data (1.2 meter DEM)
  - 30 meter DEM
  - Point, line and polygon shapefiles
  - Aerial photos
  - Weather data
  - Soil nutrient data
  - Text
  - Excel
  - .MAT
  - .CVS
  - .SDF

- Tools
  - ESRI ArcGIS
    - TerEx Tool
    - Hec-GeoRAS
    - Stream profiler
    - ArcHydro
  - C++
  - MATLAB
  - CUDA
  - VMT (Velocity-mapping-tool)

Summary and Conclusions

- IMLCZO offers unique and compelling opportunities for development of BrownDog technologies
- BrownDog technologies can significantly expand the science of IMLCZO and CZOs broadly

Partnership between CZO, BrownDog, SEAD & EarthCube: All benefit

Questions?