Characterizing Disaster Impact Using Lidar and AVIRIS: 2011 Mississippi Flood Study

UNIVERSITY OF ILLINOIS AT URBANA-CHAMP

NSF

Characterizing Disaster Impact Using Lidar and AVIRIS: 2011 Mississippi Flood Study

Praveen Kumar[1], Debsunder Dutta[1], Allison Goodwell[1], Zhenduo Zhu[1], Jonathan Greenburg[2], Marcelo Garcia[1], Bruce Rhoads[2], Gary Parker[1], David Berretta[3], Robert Holmes[4], Robert Darmody [5], James E Garvey [6], Robert Jacobson[4]

[1]Department of Civil & Env. Eng., Univ. of Illinois

[2]Department of Geography, Univ. of Illinois

[3]US Army Corps of Engineers, Memphis

[4]USGS

[5]Natural Resource and Env. Science, Univ. of Illinois

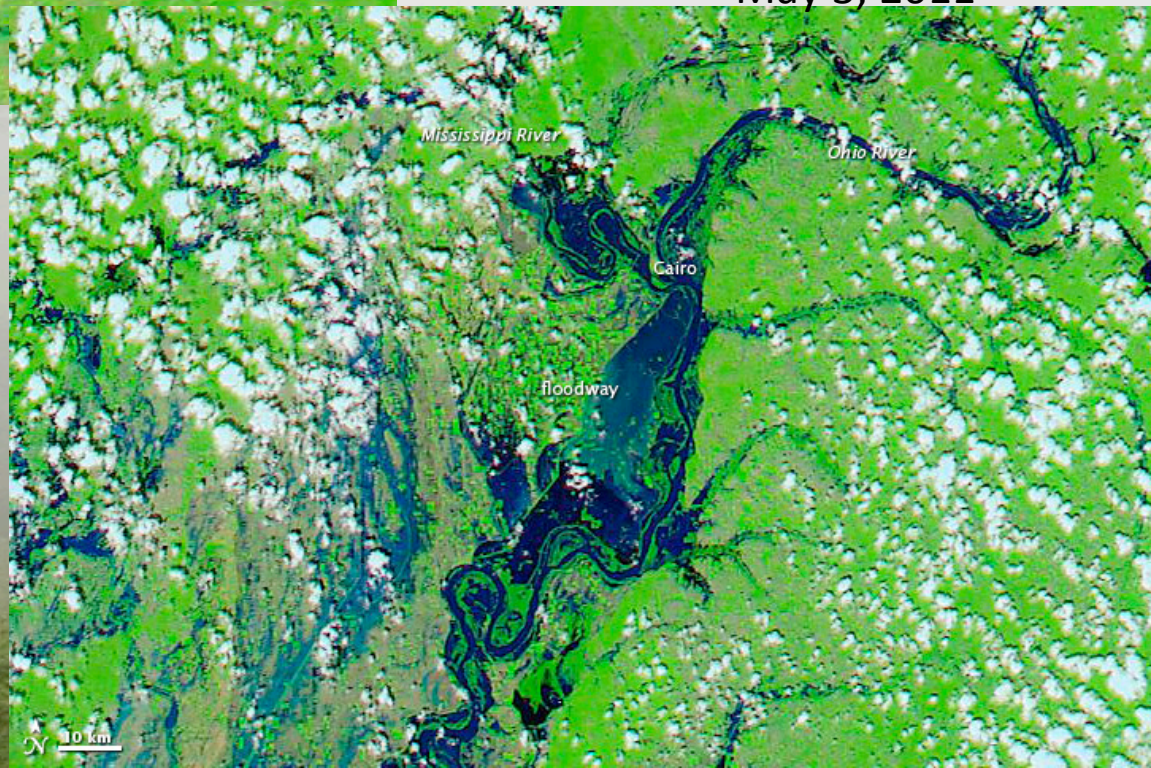
[6]Department of Zoology, Southern Illinois Univ.

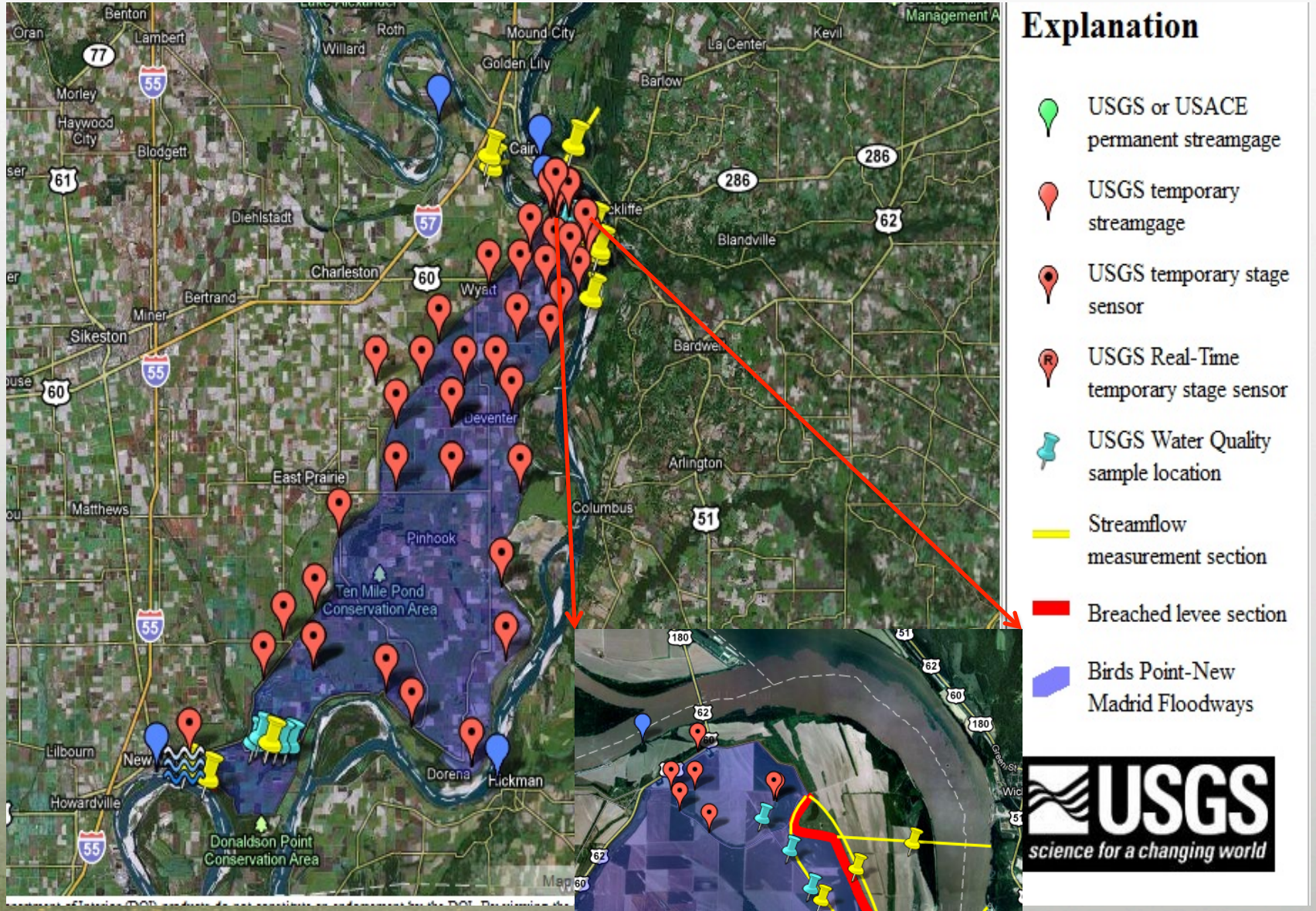
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

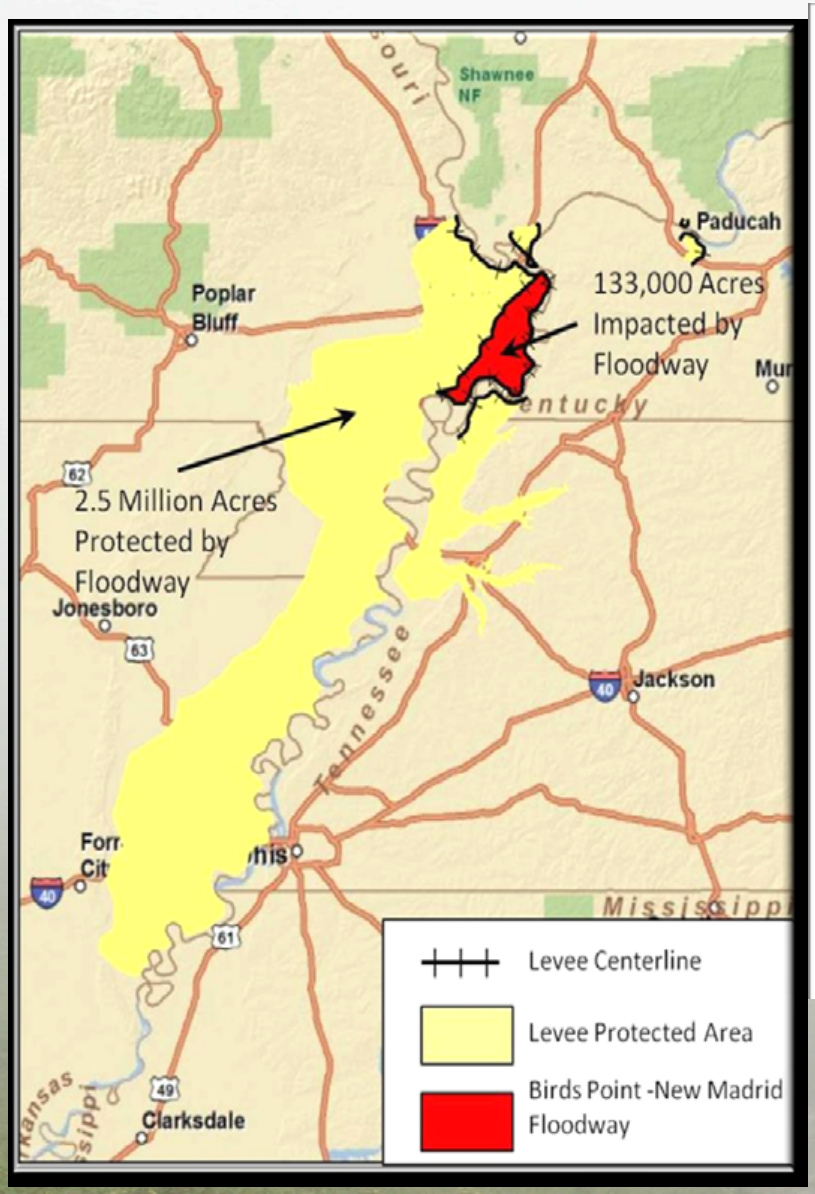
illinois.edu

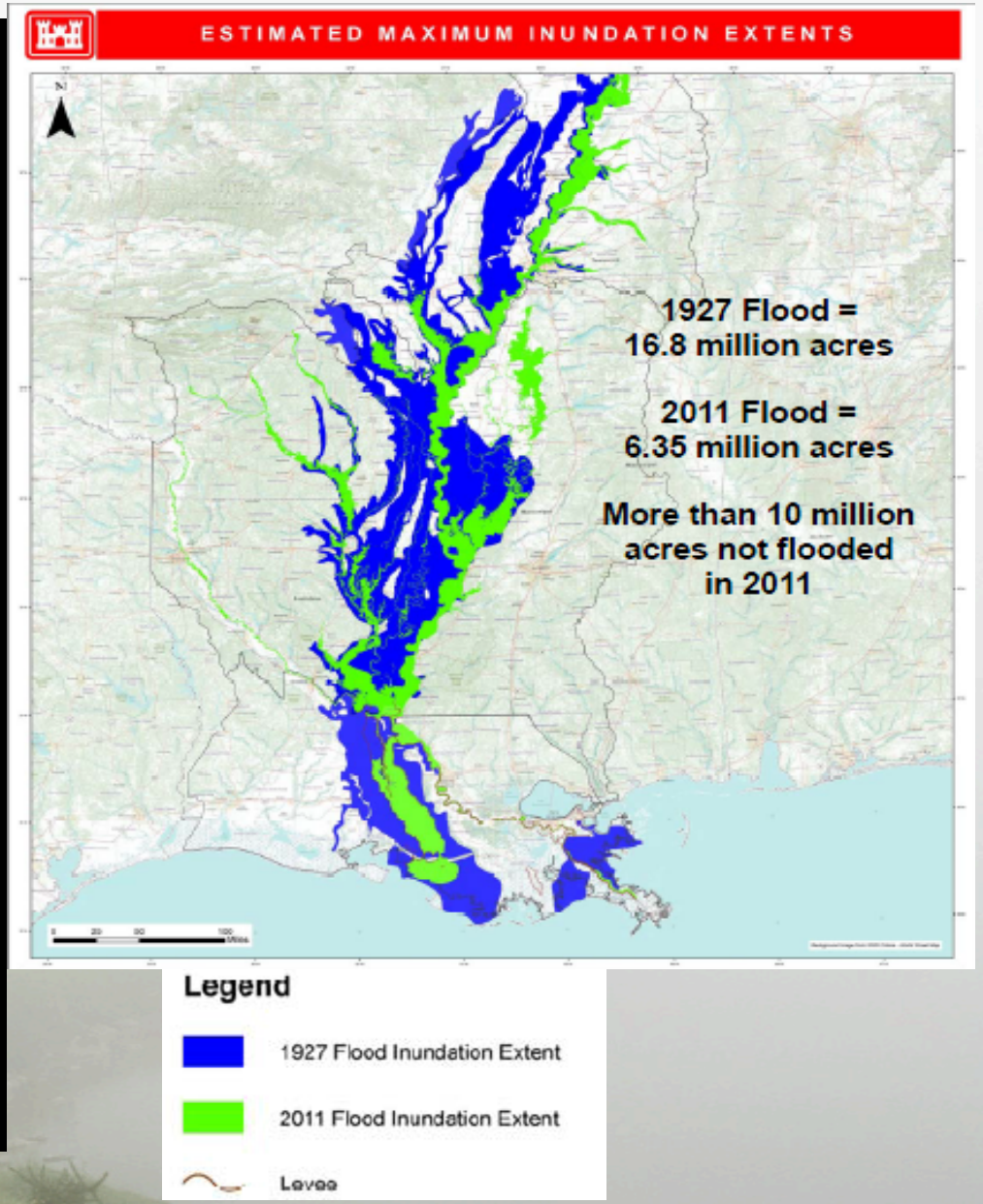
Apr 29, 2011

May 3, 2011

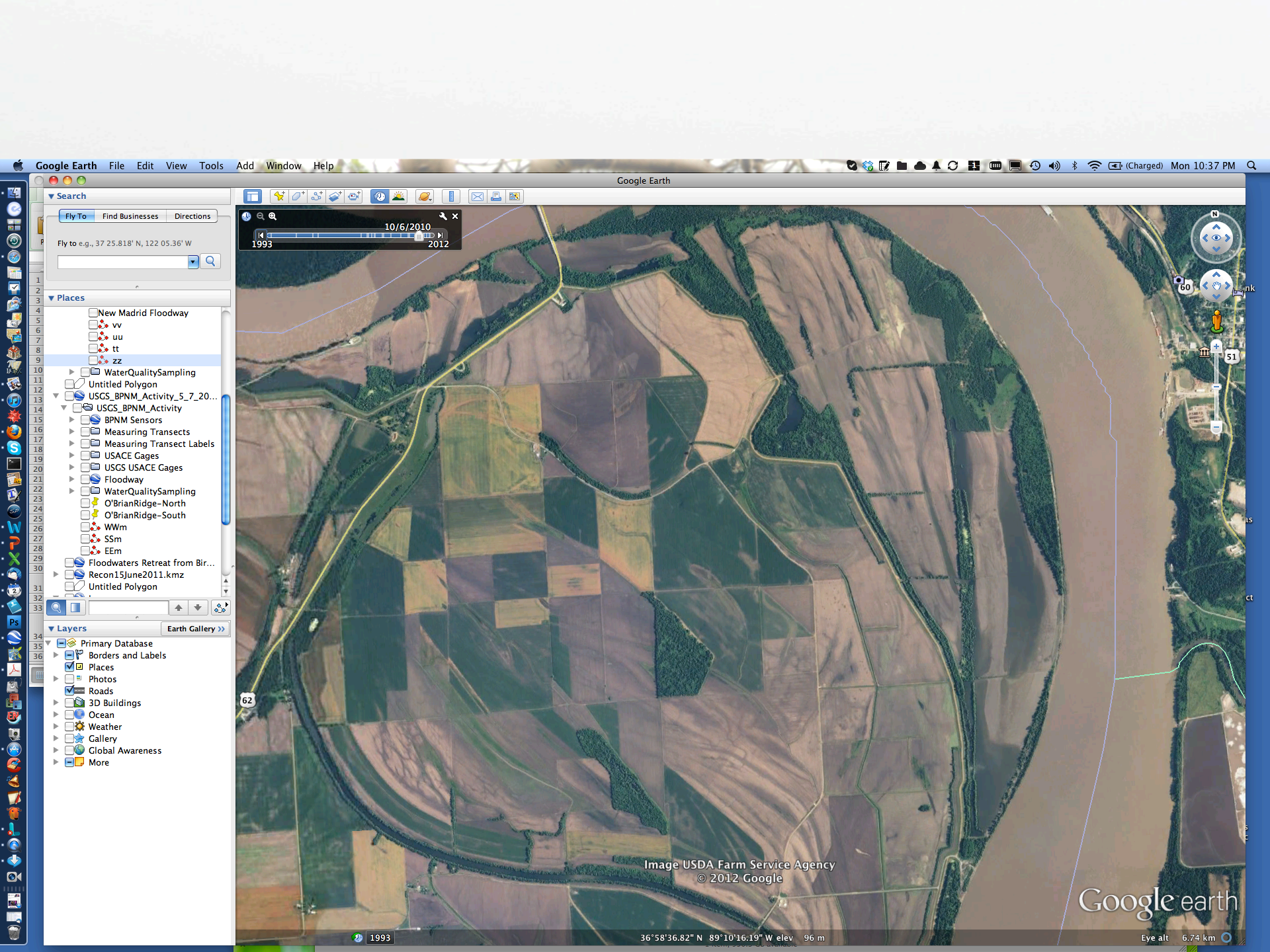



Explanation
USGS or USACE permanent streamgage
USGS temporary streamgage
USGS temporary stage sensor
USGS Real-Time temporary stage sensor
USGS Water Quality sample location
Streamflow measurement section
Breached levee section
Birds Point-New Madrid Floodways
USGS
science for a changing world
Benton
Lambert
Morley
Haywood City
Blodgett
Willard
Roth
Mound City
Golden Lily
La Center
Kevil
Barlow
Diehlstadt
Charleston
Bertrand
Miner
Sikeston
Wyatt
Blandville
Bardwell
Arlington
Columbus
East Prairie
Matthews
Pinhook
Ten Mile Pond Conservation Area
Lilbourn
New
Howardville
Dorena
Hickman
Donaldson Point Conservation Area
Management A
77
55
61
57
60
286
62
51
180





Mississippi River Commission 2011 MR&T Flood Report


Google Earth File Edit View Tools Add Window Help
Mon 10:37 PM
Google Earth
Search
Fly To
Find Businesses
Directions
Fly to e.g., 37 25.818' N, 122 05.36' W
Places
New Madrid Floodway
vv
uu
tt
zz
WaterQualitySampling
Untitled Polygon
USGS_BPNM_Activity_5_7_20...
USGS_BPNM_Activity
BPNM Sensors
Measuring Transects
Measuring Transect Labels
USACE Gages
USGS USACE Gages
Floodway
WaterQualitySampling
O'BrianRidge-North
O'BrianRidge-South
WWm
SSm
EEm
Floodwaters Retreat from Bir...
Recon15June2011.kmz
Untitled Polygon
Layers
Earth Gallery
Primary Database
Borders and Labels
Places
Photos
Roads
3D Buildings
Ocean
Weather
Gallery
Global Awareness
More
10/6/2010
1993
2012
Image USDA Farm Service Agency
© 2012 Google
Google earth
1993
36°58'36.82" N 89°10'16.19" W elev 96 m
Eye alt 6.74 km

Google Earth File Edit View Tools Add Window Help

Google Earth

Search

Fly To | Find Businesses | Directions

Fly to e.g., 37 25.818' N, 122 05.36' W

Places

- New Madrid Floodway
- vv
- uu
- tt
- zz
- WaterQualitySampling
- Untitled Polygon
- USGS_BPNM_Activity_5_7_20...
- USGS_BPNM_Activity
  - BPNM Sensors
  - Measuring Transects
  - Measuring Transect Labels
  - USACE Gages
  - USGS USACE Gages
  - Floodway
  - WaterQualitySampling
  - O'BrianRidge-North
  - O'BrianRidge-South
  - WWm
  - SSm
  - EEm
- Floodwaters Retreat from Bir...
- Recon15June2011.kmz
- Untitled Polygon

Layers | Earth Gallery

- Primary Database
  - Borders and Labels
  - Places
  - Photos
  - Roads
  - 3D Buildings
  - Ocean
  - Weather
  - Gallery
  - Global Awareness
  - More

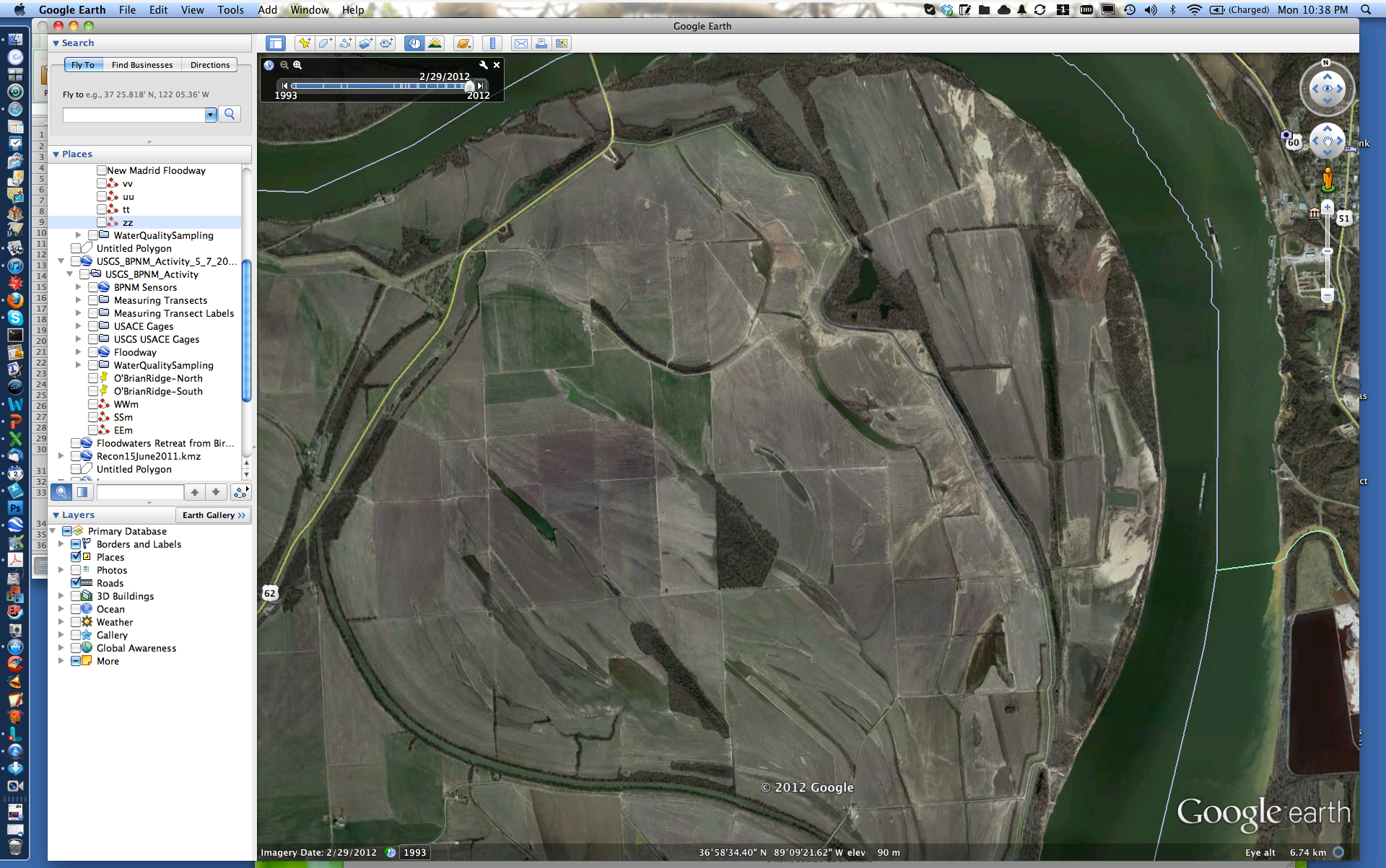
5/7/2011

62 60 51

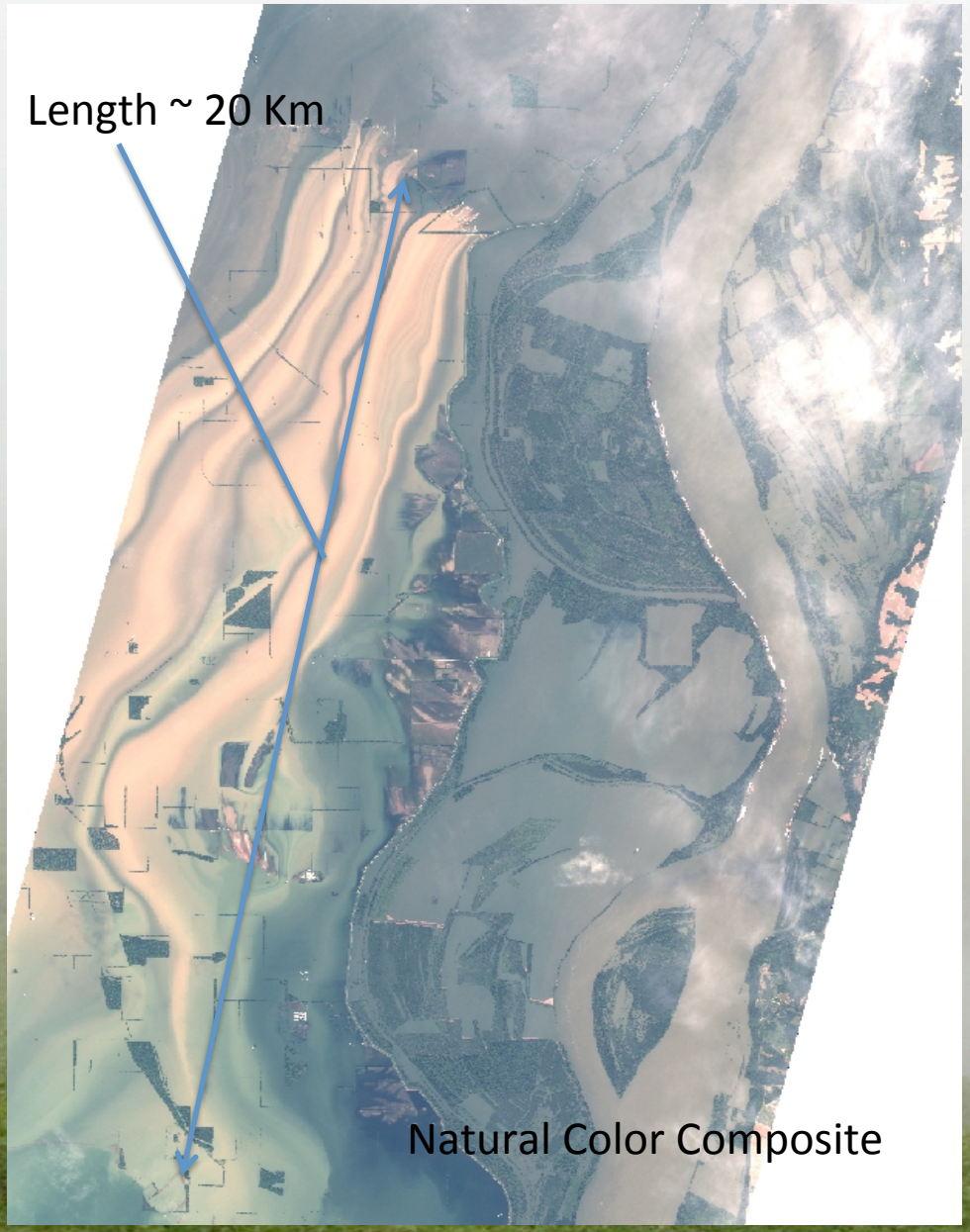
© 2012 Google
Image © 2012 GeoEye

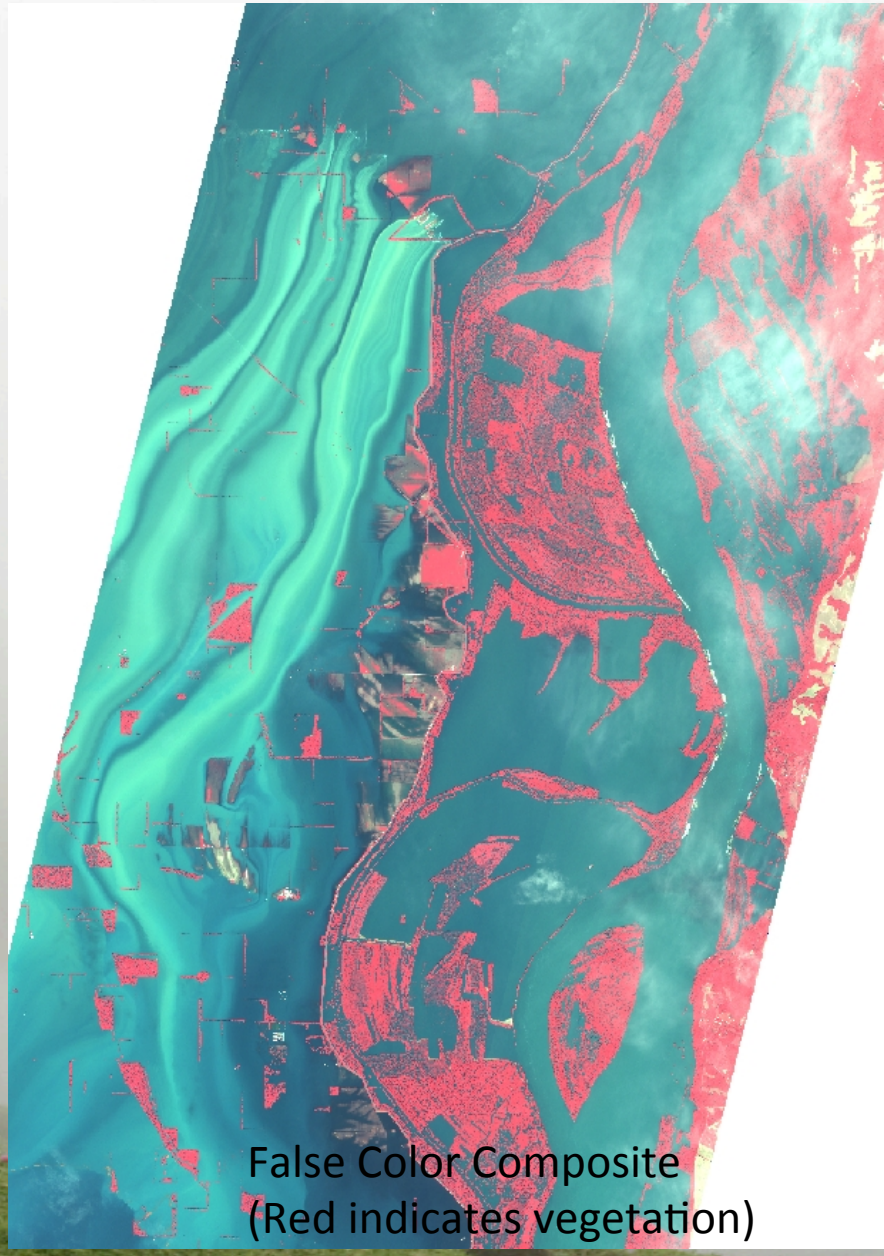
Google earth

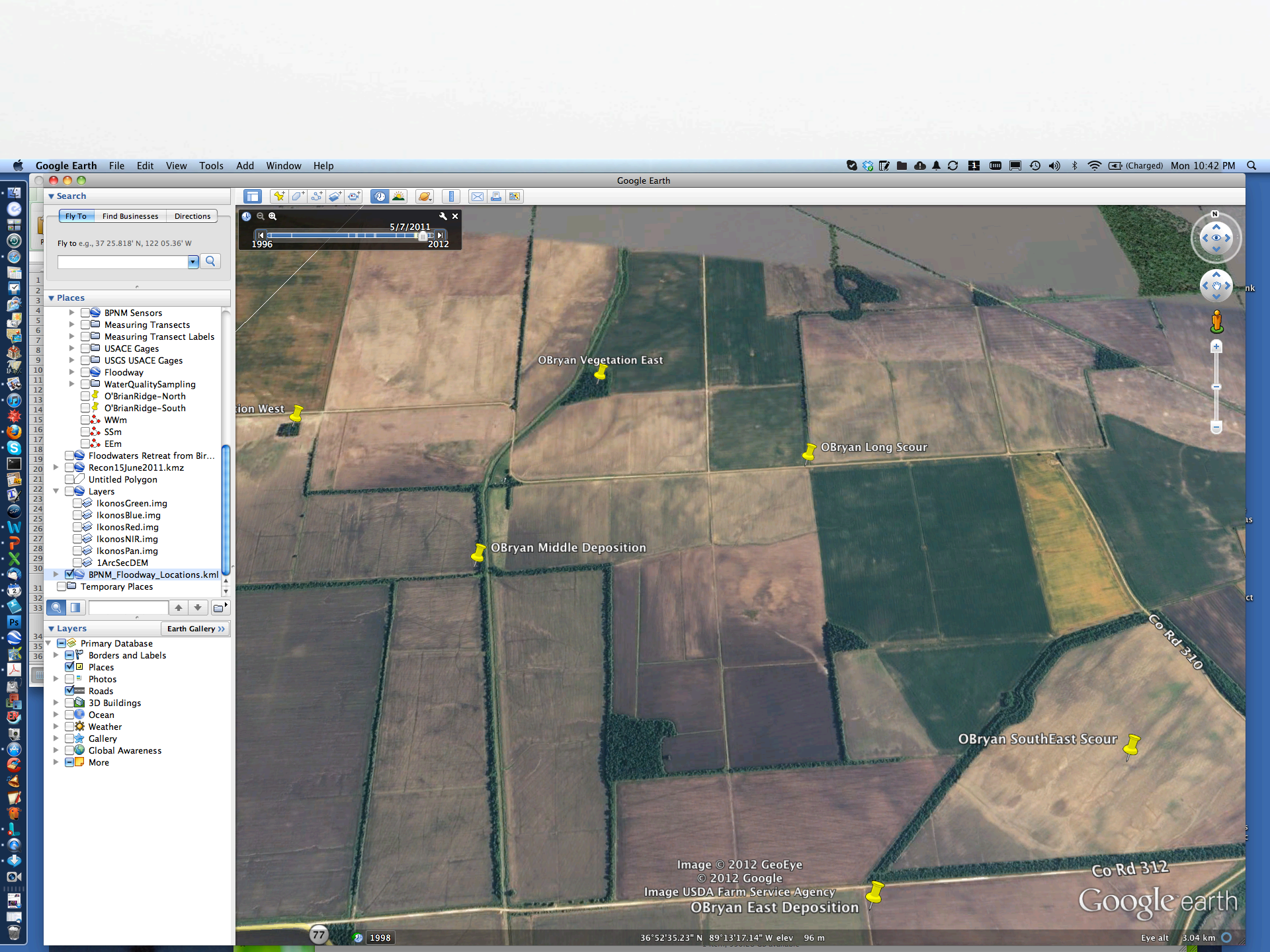
Imagery Date: 5/7/2011 1993 36°57'26.81" N 89°09'19.25" W elev 96 m Eye alt 6.74 km

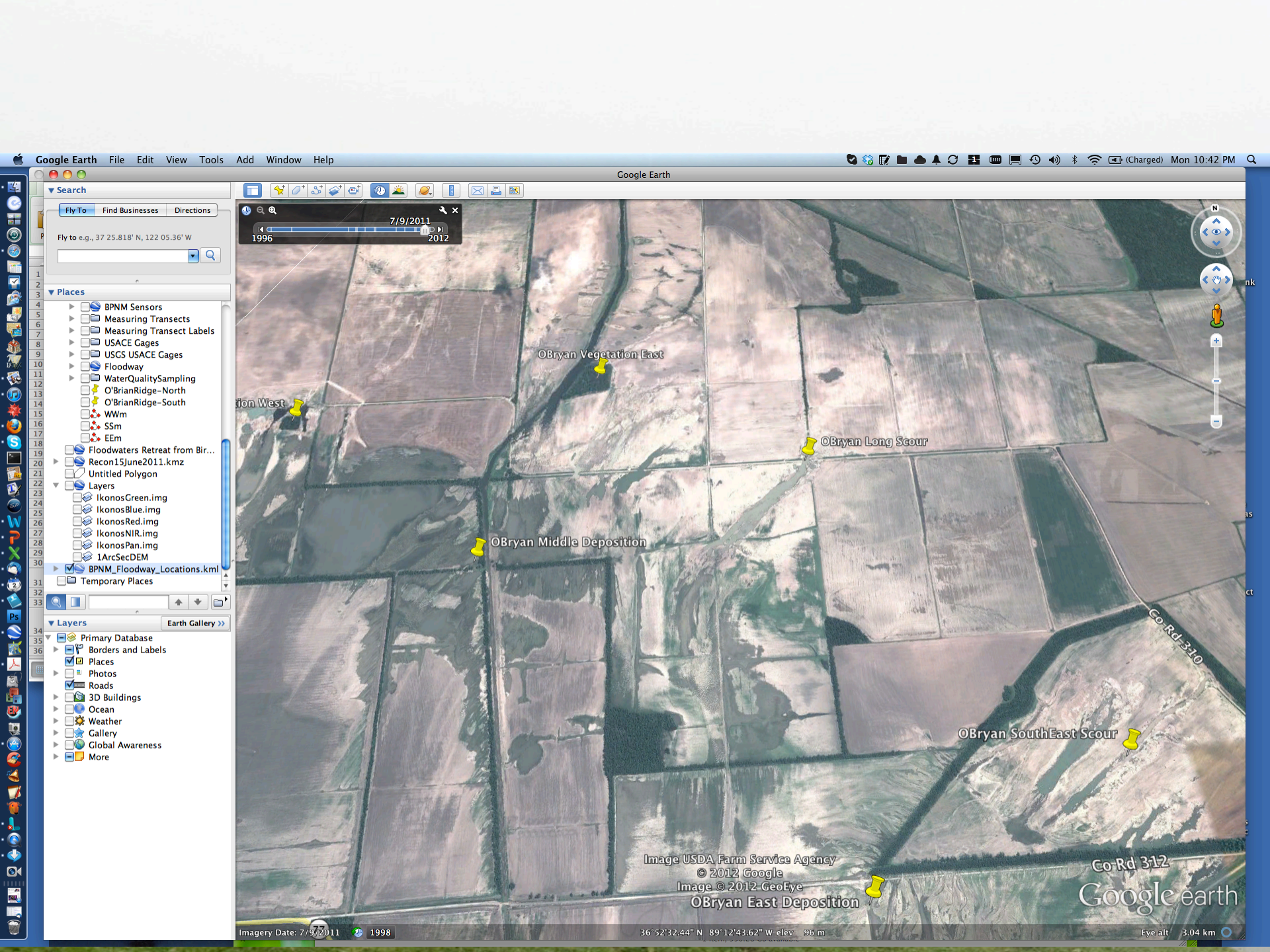

Google Earth File Edit View Tools Add Window Help
Mon 10:38 PM
Google Earth
Search
Fly To
Find Businesses
Directions
Fly to e.g., 37 25.818' N, 122 05.36' W
Places
New Madrid Floodway
vv
uu
tt
zz
WaterQualitySampling
Untitled Polygon
USGS_BPNM_Activity_5_7_20...
USGS_BPNM_Activity
BPNM Sensors
Measuring Transects
Measuring Transect Labels
USACE Gages
USGS USACE Gages
Floodway
WaterQualitySampling
O'BrianRidge-North
O'BrianRidge-South
WWm
SSm
EEm
Floodwaters Retreat from Bir...
Recon15June2011.kmz
Untitled Polygon
Layers
Earth Gallery
Primary Database
Borders and Labels
Places
Photos
Roads
3D Buildings
Ocean
Weather
Gallery
Global Awareness
More
2/29/2012
1993
2012
60
51
62
© 2012 Google
Google earth
Imagery Date: 2/29/2012
1993
36°58'34.40" N 89°09'21.62" W elev 90 m
Eye alt 6.74 km

IKONOS (05-12-2011)






Google Earth File Edit View Tools Add Window Help
Mon 10:42 PM
Google Earth
Search
Fly To
Find Businesses
Directions
Fly to e.g., 37 25.818' N, 122 05.36' W
Places
BPNM Sensors
Measuring Transects
Measuring Transect Labels
USACE Gages
USGS USACE Gages
Floodway
WaterQualitySampling
O'BrianRidge-North
O'BrianRidge-South
WWm
SSm
EEm
Floodwaters Retreat from Bir...
Recon15June2011.kmz
Untitled Polygon
Layers
IkonosGreen.img
IkonosBlue.img
IkonosRed.img
IkonosNIR.img
IkonosPan.img
1ArcSecDEM
BPNM_Floodway_Locations.kml
Temporary Places
Layers
Earth Gallery
Primary Database
Borders and Labels
Places
Photos
Roads
3D Buildings
Ocean
Weather
Gallery
Global Awareness
More
5/7/2011
1996
2012
OBryan Vegetation East
ion West
OBryan Long Scour
OBryan Middle Deposition
Co Rd 310
OBryan SouthEast Scour
Image © 2012 GeoEye
© 2012 Google
Image USDA Farm Service Agency
OBryan East Deposition
Co Rd 312
Google earth
77
1998
36°52'35.23" N 89°13'17.14" W elev 96 m
Eye alt 3.04 km


Google Earth File Edit View Tools Add Window Help
(Charged) Mon 10:42 PM
Google Earth
Search
Fly To
Find Businesses
Directions
Fly to e.g., 37 25.818' N, 122 05.36' W
Places
BPNM Sensors
Measuring Transects
Measuring Transect Labels
USACE Gages
USGS USACE Gages
Floodway
WaterQualitySampling
O'BrianRidge-North
O'BrianRidge-South
WWm
SSm
EEm
Floodwaters Retreat from Bir...
Recon15June2011.kmz
Untitled Polygon
Layers
IkonosGreen.img
IkonosBlue.img
IkonosRed.img
IkonosNIR.img
IkonosPan.img
1ArcSecDEM
BPNM_Floodway_Locations.kml
Temporary Places
Layers
Earth Gallery
Primary Database
Borders and Labels
Places
Photos
Roads
3D Buildings
Ocean
Weather
Gallery
Global Awareness
More
7/9/2011
1996
2012
OBryan Vegetation East
OBryan Long Scour
OBryan Middle Deposition
OBryan SouthEast Scour
OBryan East Deposition
Co Rd 310
Co Rd 312
Image USDA Farm Service Agency
© 2012 Google
Image © 2012 GeoEye
Google earth
Imagery Date: 7/9/2011
1998
36°52'32.44" N 89°12'43.62" W elev 96 m
Eye alt 3.04 km

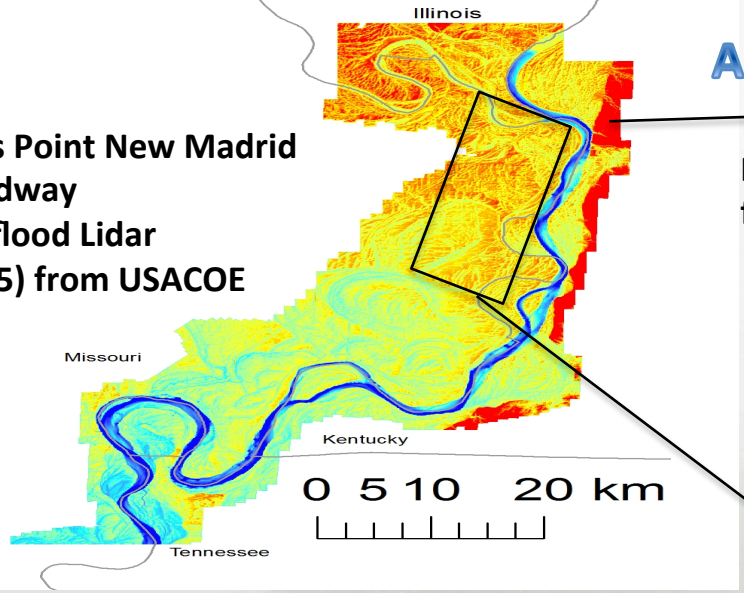
Photos of BPNM Floodway scouring and deposition, 15th June 2011

Problem Statement

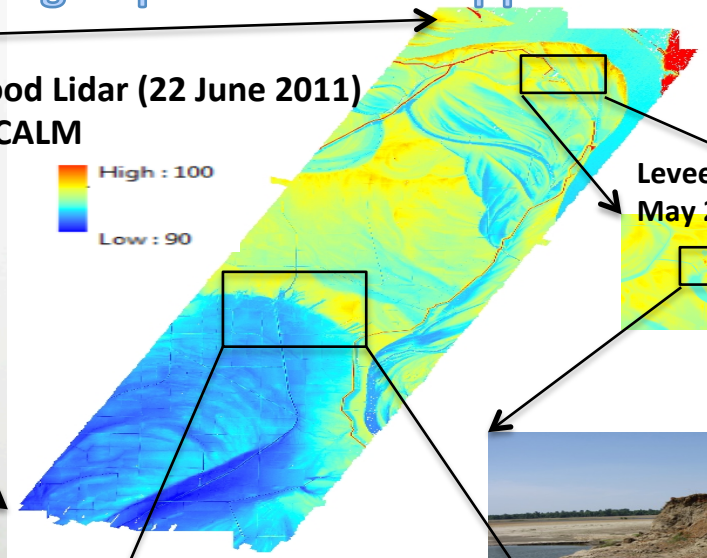
- How can we assess the impact of the flood (disaster) at such large spatial scales?
- What are the challenges and what methodological advances are required?
  - Classification
  - Identification
- How can the estimates be scaled for satellite (HyspIRI) based assessment?
- How can this data be used for modeling and prediction?

Assessing Impact of Mississippi Flood 2011

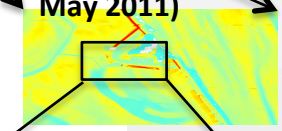
Birds Point New Madrid Floodway
Pre-flood Lidar (2005) from USACOE



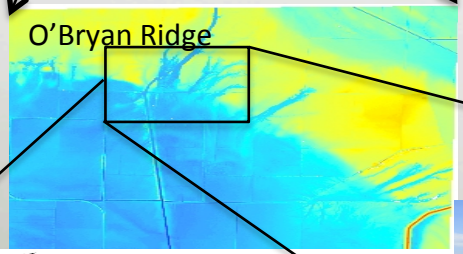
Post-flood Lidar (22 June 2011) from NCALM



Levee Breach (2 May 2011)

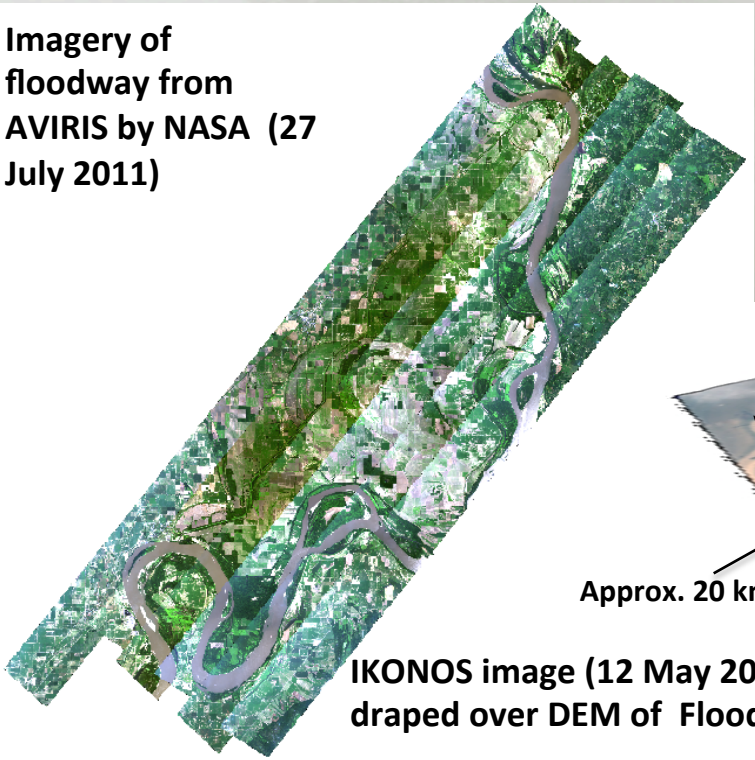


Breached levee (pictured 15 June 2011)

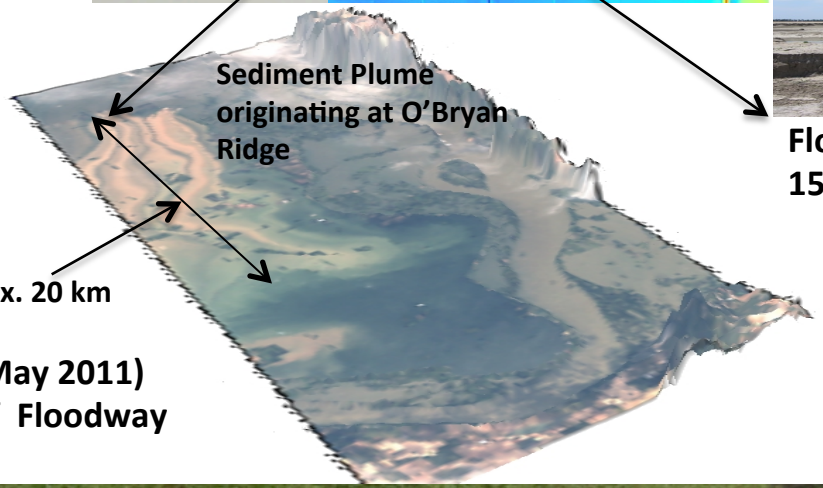


Flood scour (pictured 15 June 2011)

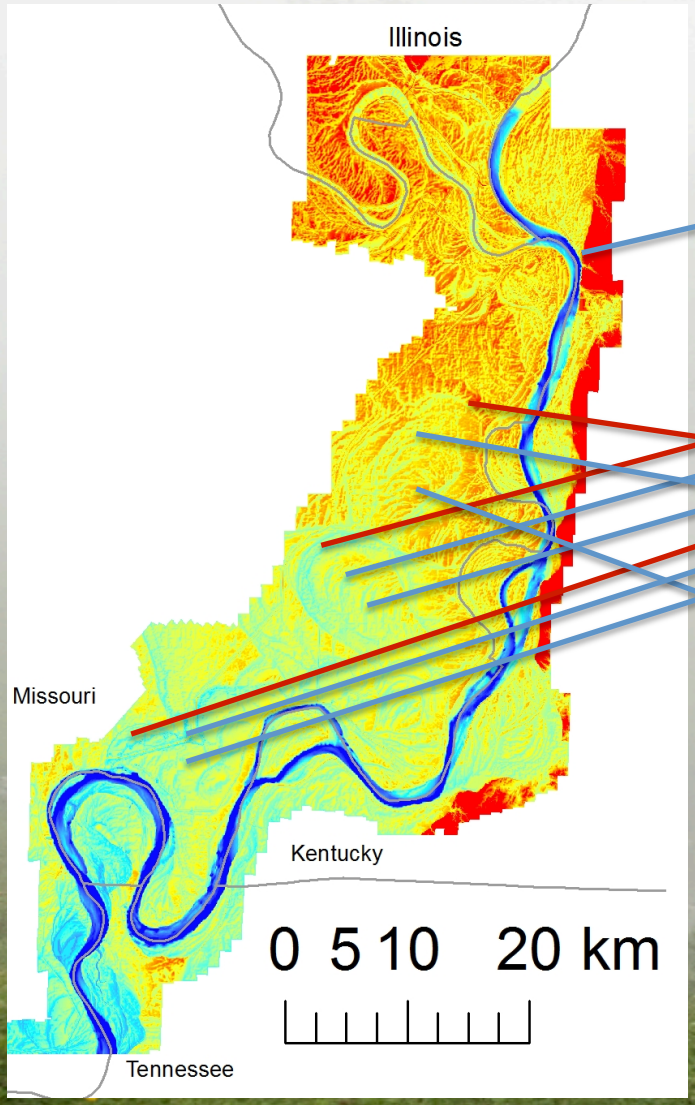
Imagery of floodway from AVIRIS by NASA (27 July 2011)



IKONOS image (12 May 2011) draped over DEM of Floodway



Mississippi River Time Line



Today
100 years ago
500 years ago

1000 years ago

2000 years ago

4000 years ago

6000 years ago

Vegetation and Moisture Indices

- Normalized Difference Vegetation Index (NDVI)
  - $NDVI = NIR - Red / NIR + Red$
  - Values between +1 and -1
  - Range for green vegetation is 0.2 to 0.8
- Water Band Index (WBI)
  - $WBI = 900 / 970$
  - As water content increases the strength of absorption around 970 nm increases relative to 900 nm.
  - Green vegetation ranges from 0.8 to 1.2.

References

Penuelas, J., I. Filella, C. Biel, L. Serrano, and R. Save, 1995. *The Reflectance at the 950-970 Region as an Indicator of Plant Water Status*. International Journal of Remote Sensing 14:1887-1905.

Sellers, P.J., 1985. *Canopy Reflectance, Photosynthesis and Transpiration*. International Journal of Remote Sensing 6:1335-1372.

Vegetation and Moisture Indices

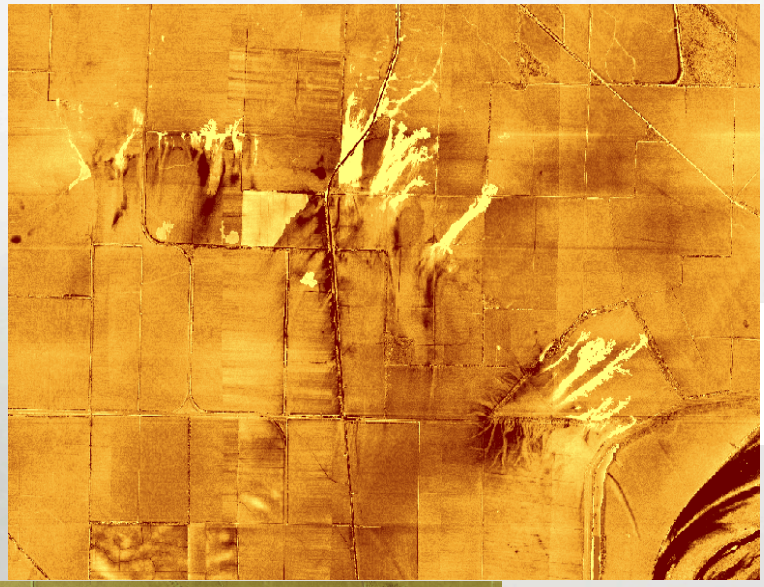
- Moisture Stress Index (MSI)
  - As water content increases the strength of absorption around 1599 nm increases but that of 819 nm is unaffected.
  - Ranges from 0 to more than 3
  - Green vegetation ranges from 0.4 to 2.
- Normalized Difference Nitrogen Index (NDNI)
  - Reflectance around 1510 nm dependent on Nitrogen content as well as foliar biomass
  - Reflectance around 1680 nm dependent on foliar biomass only.
  - Green vegetation ranges from 0.02 to 0.1.

References

Hunt Jr., E.R. and B.N. Rock, 1989. *Detection of Changes in Leaf Water Content Using Near- And Middle-Infrared Reflectances*. Remote Sensing of Environment 30:43-54.

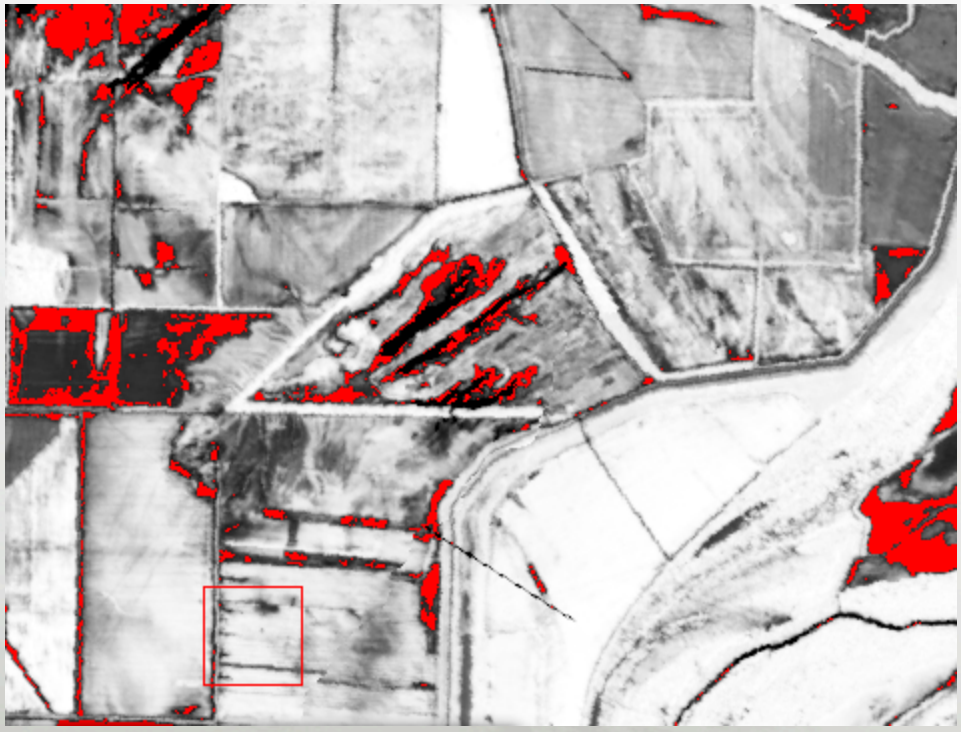
Serrano, L., J. Penuelas, and S.L. Ustin, 2002. *Remote Sensing of Nitrogen and Lignin in Mediterranean Vegetation from AVIRIS Data: Decomposing Biochemical from Structural Signals*. Remote Sensing of Environment 81:355-364.

NDVI

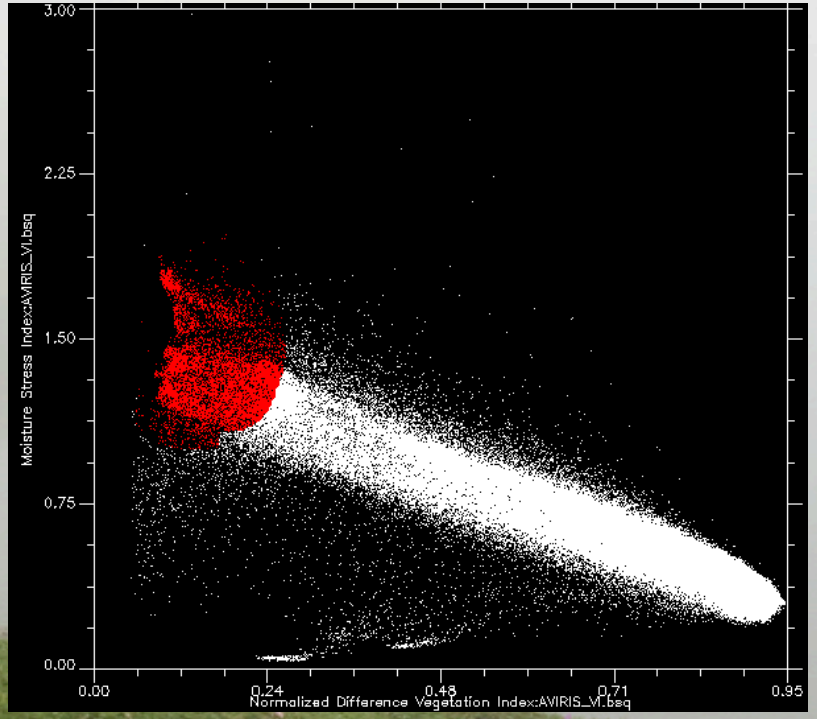


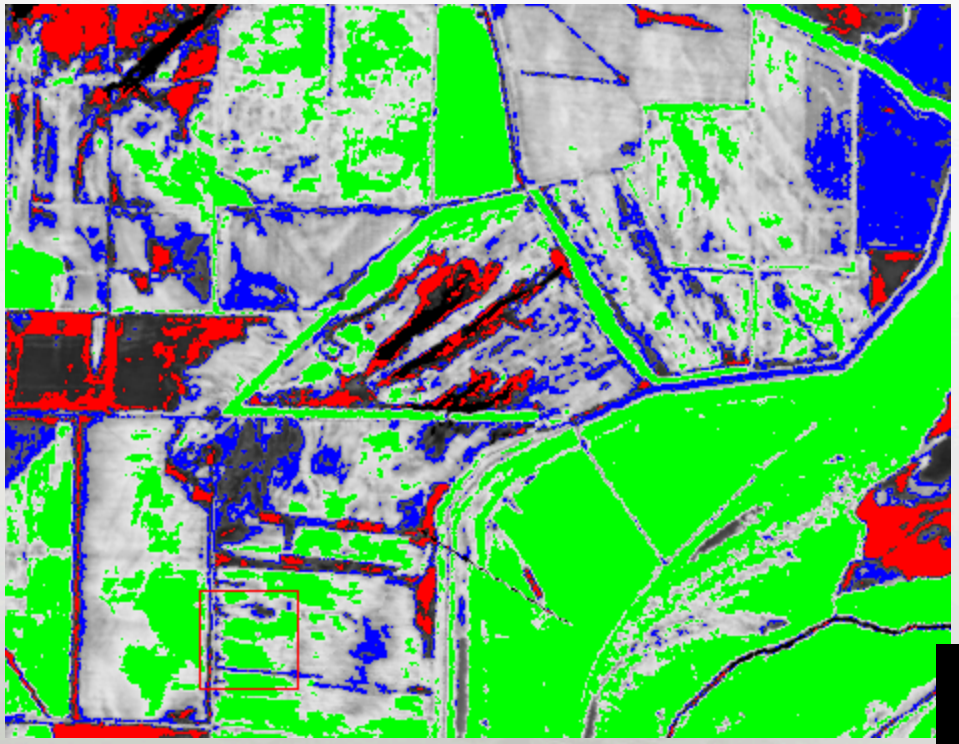
LiDAR (differenced)

LiDAR superimposed on NDVI Image

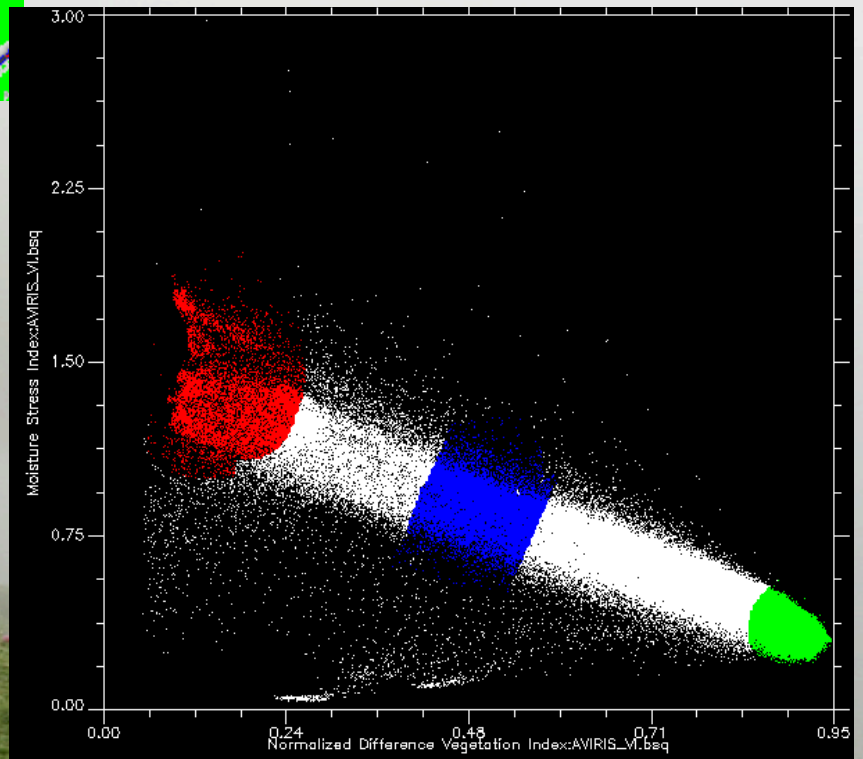


Zones of high scouring show strong signals of High moisture stress and low NDVI values

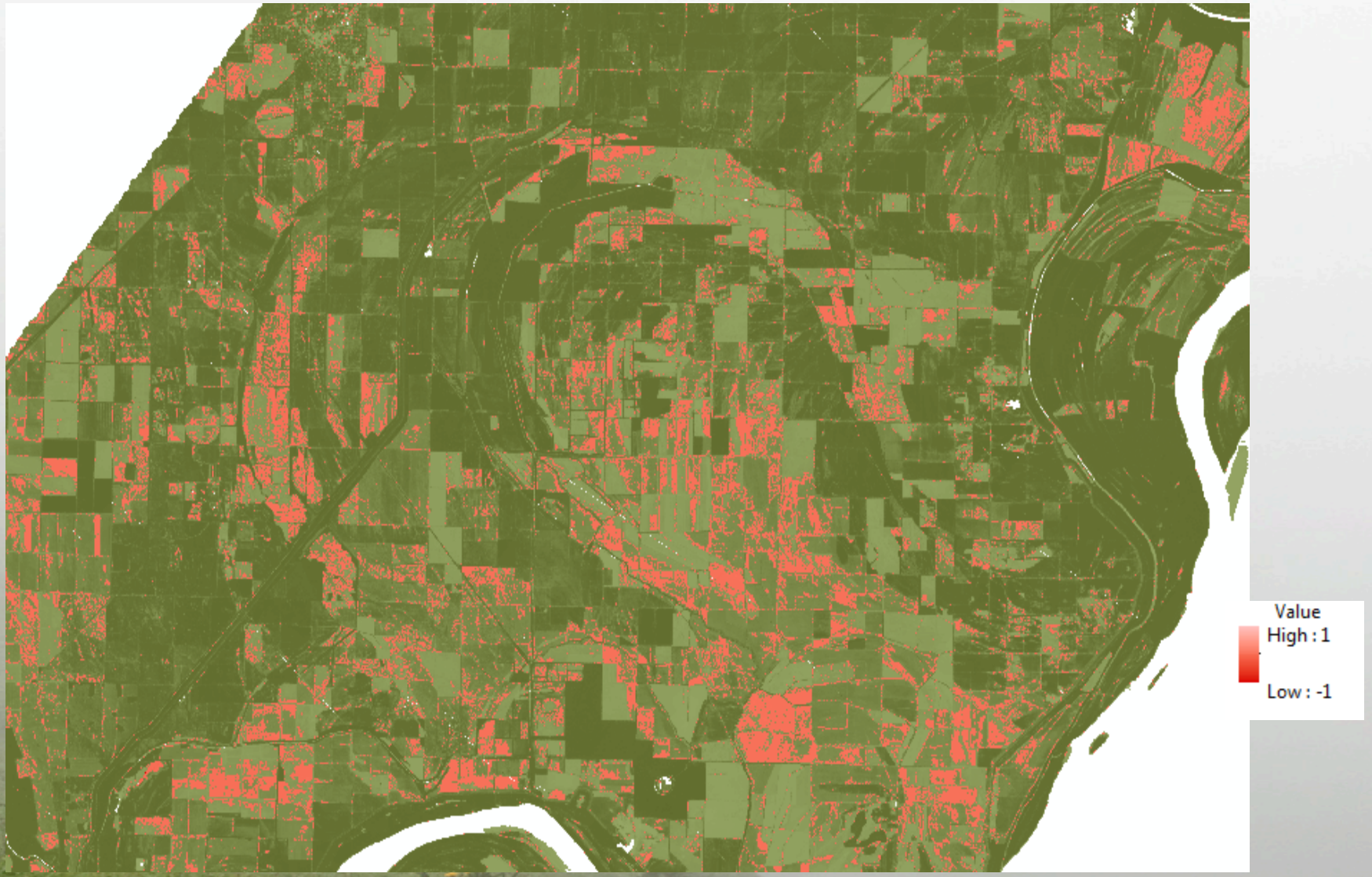




Zones of very High NDVI and low moisture stresses are the Forest Regions



NDNI



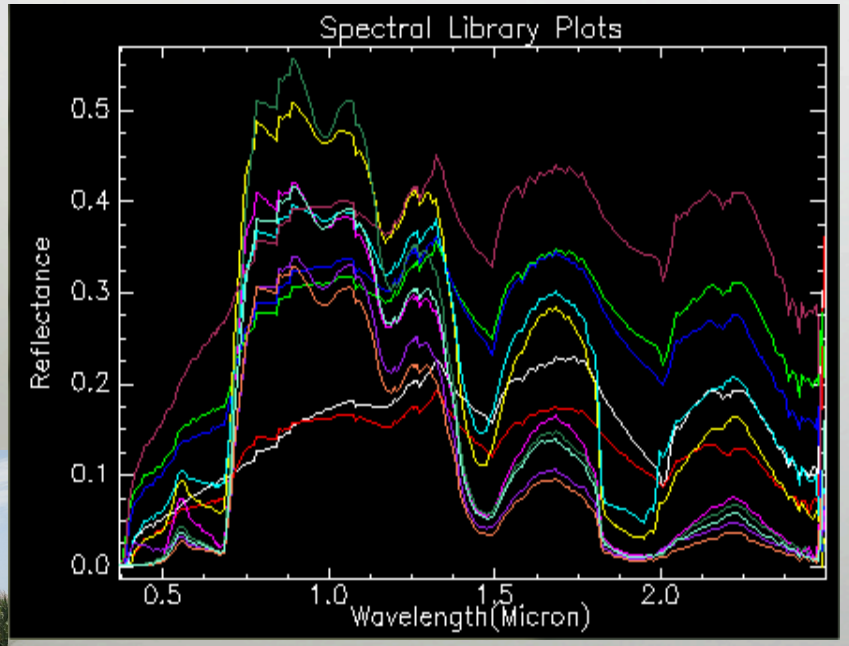
NDNI Values superimposed on NDVI map

Spectral Angle Mapper (SAM) Classification using Endmember Collected from Data Combined with USGS Library

- The USGS digital spectral library 06a has 1365 spectral signatures (0.2 – 150 micron):
  - Minerals
  - Soils, Rocks, and Mixtures (except those with vegetation)
  - Coatings
  - Liquids, Liquid Mixtures, Water, Other Volatiles, and Frozen Volatiles
  - Artificial (Man Made) Including Manufactured Chemicals
  - Plants, Vegetation Communities, Mixtures with Vegetation, and Microorganisms

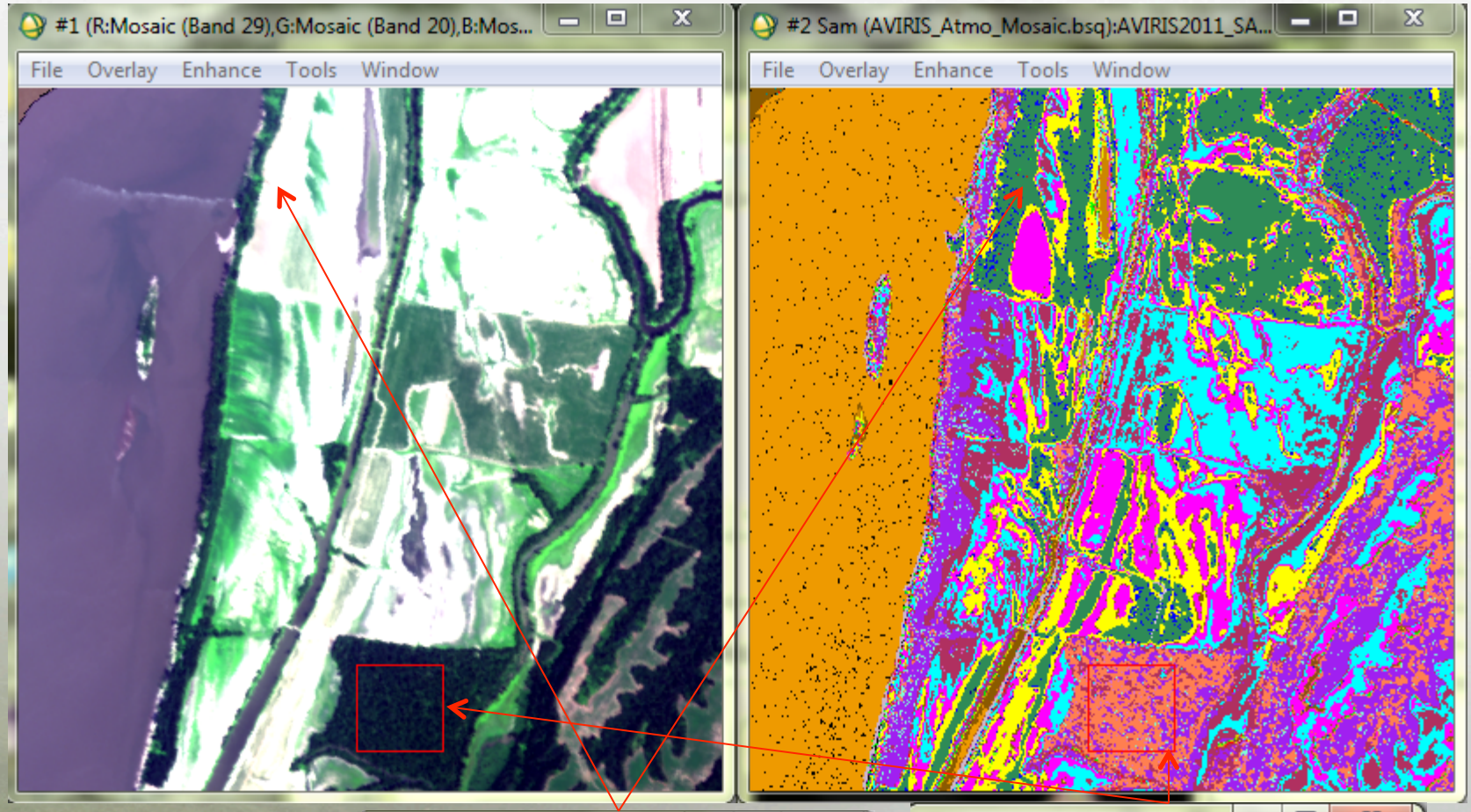
- These have been convolved to the AVIRIS wavelength range (0.4 – 2.5 micron).

- A number of endmember spectra of trees, bare soils, small plants and corn have also been collected from the calibrated image and used for classification.

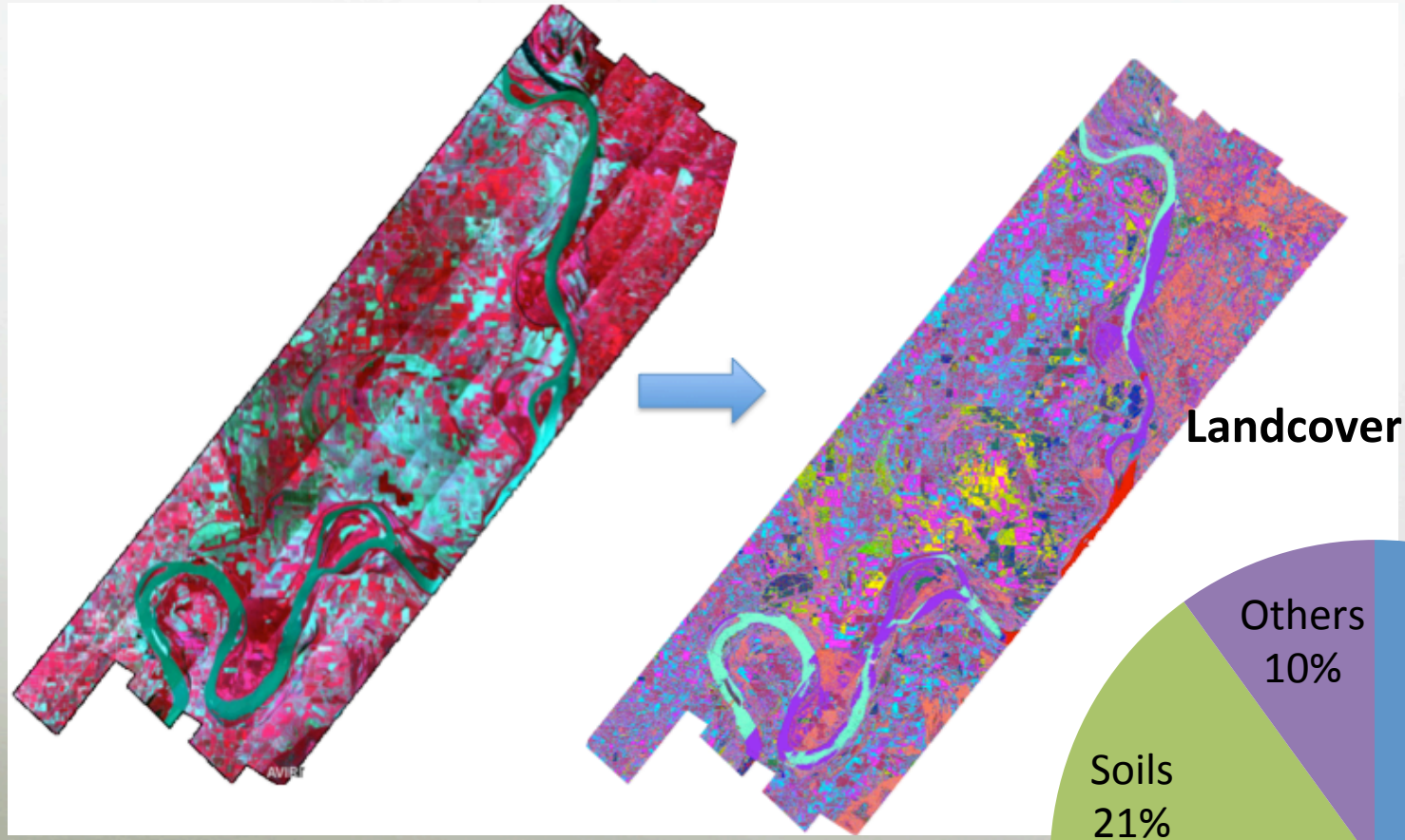


Spectral Plots from Endmember Collection

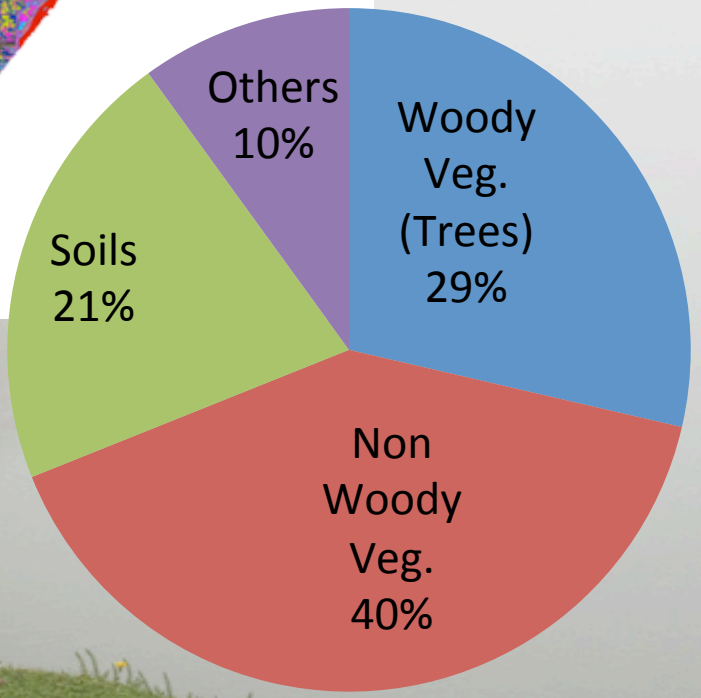
Ground Truthing



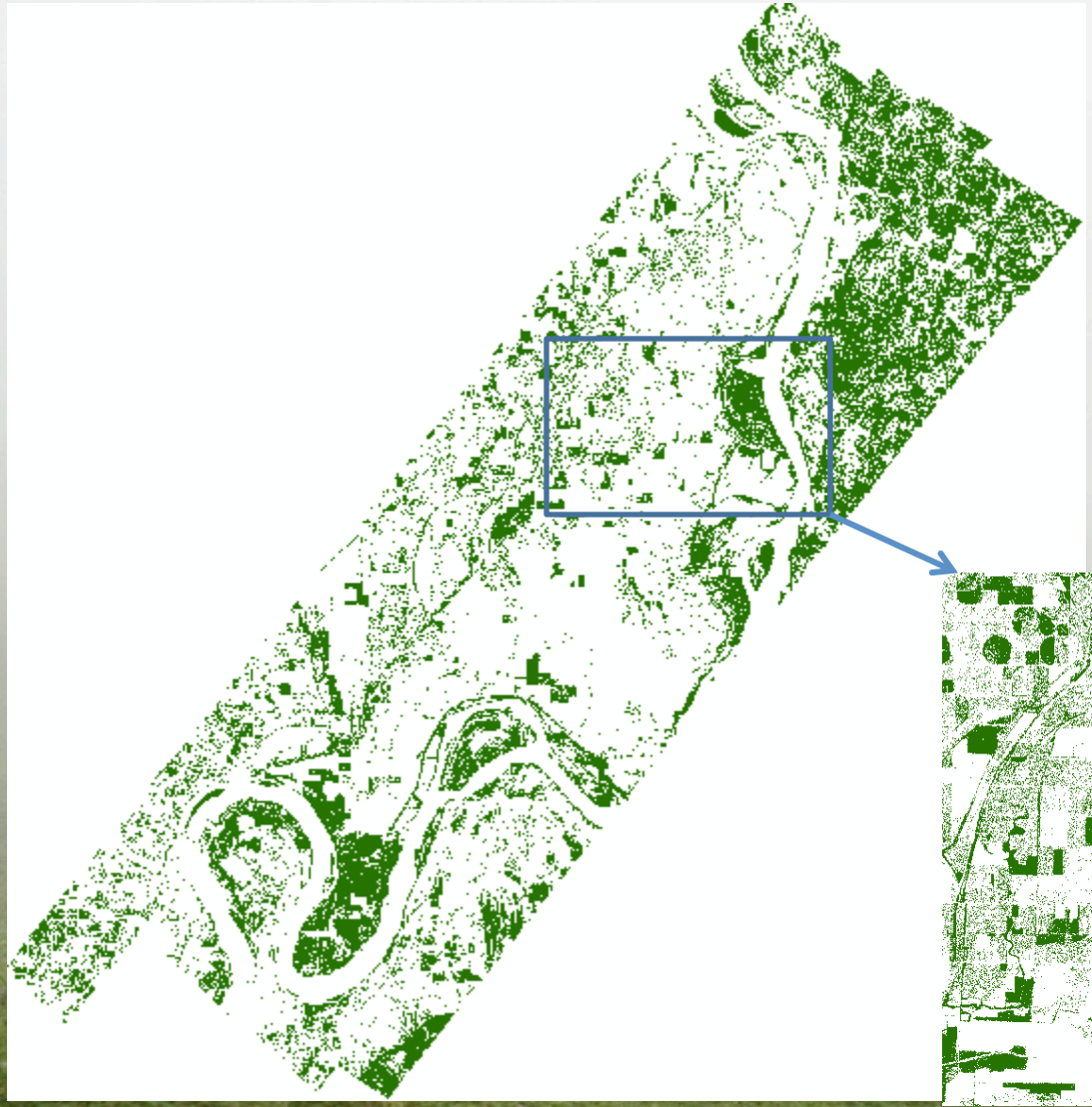
Inspection of the True Color Composite Image with Classified (1377 samples) show that the classification is consistent

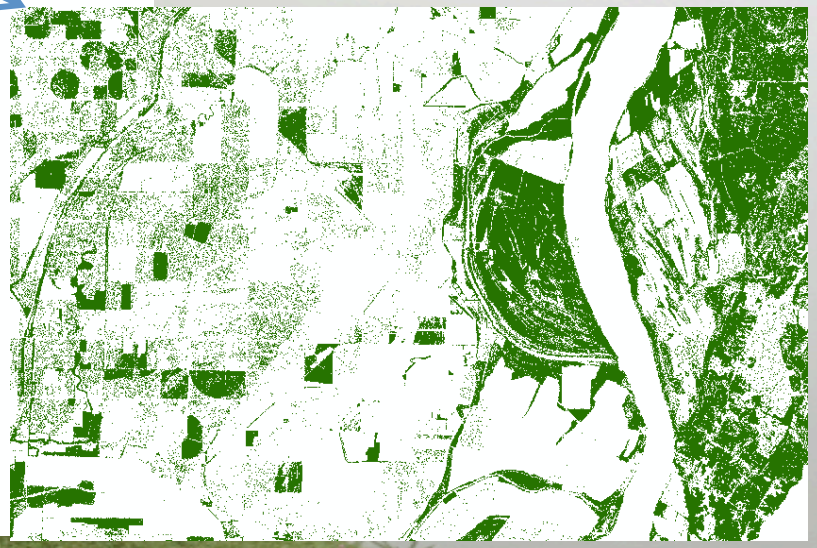


Landcover Classes



Trees

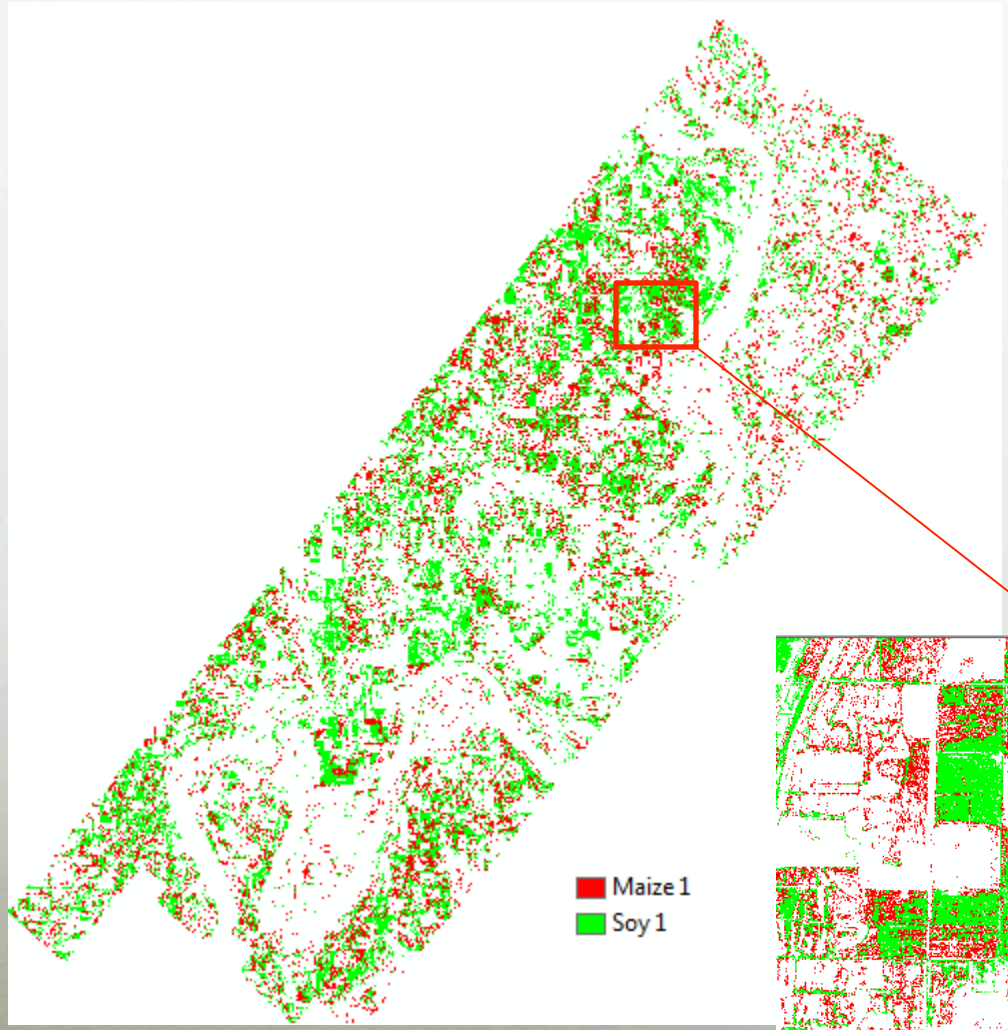


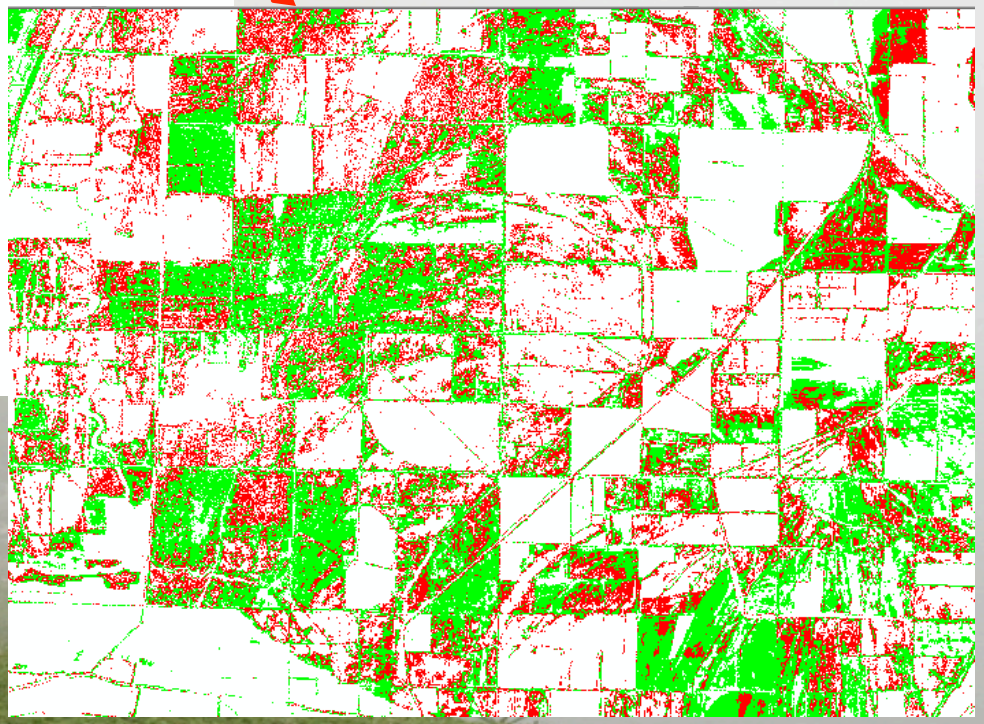


The tree classification seems almost accurate with large groups occurring in the bends and meanders and mostly in the northeast part.

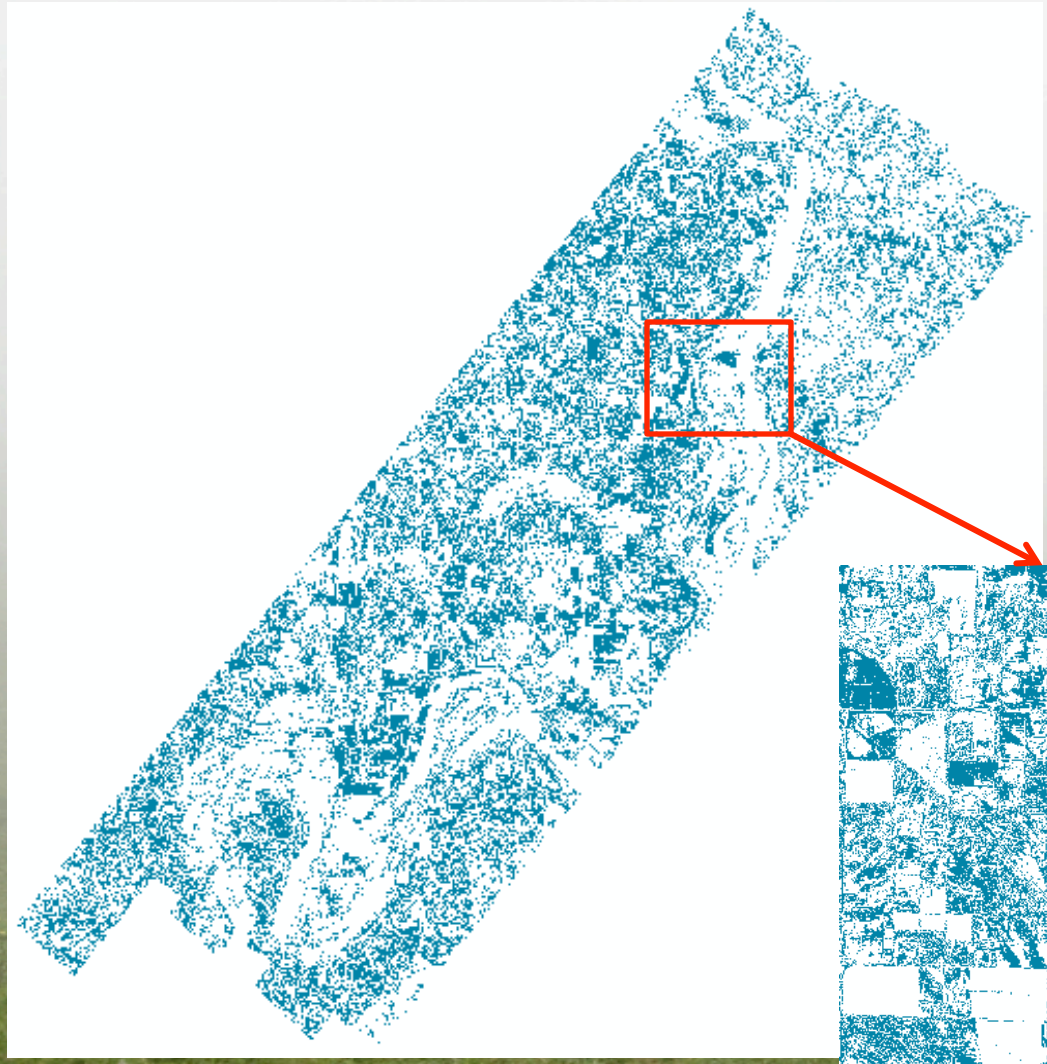
The total fraction of tree cover is 28.63%

Corn and Soy Classifications

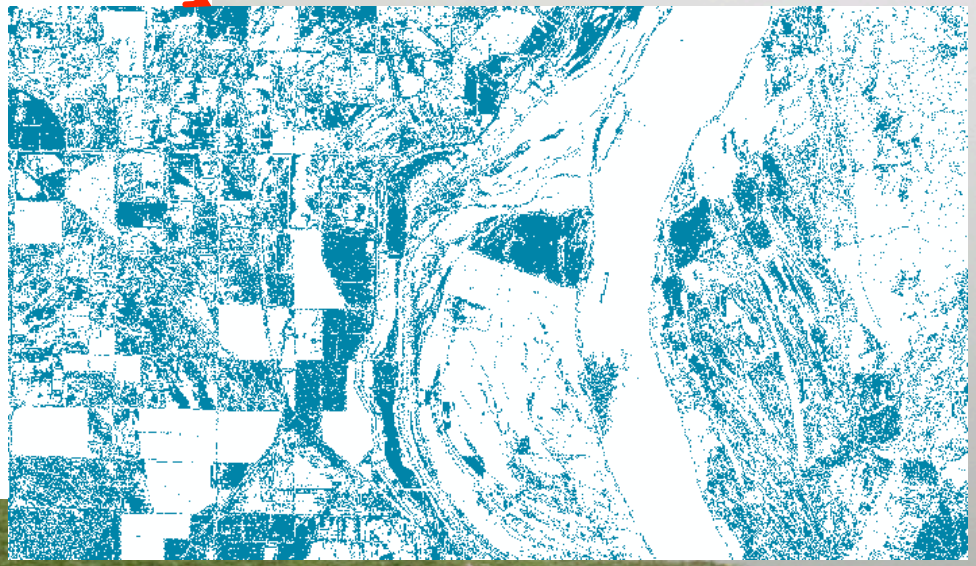




Herbs and Small Plants



This class is composed of herbs and groups of small plants and hedges and bushes that are probably a few centimeters tall, they have the maximum percentage of land cover and it is about 33.71%

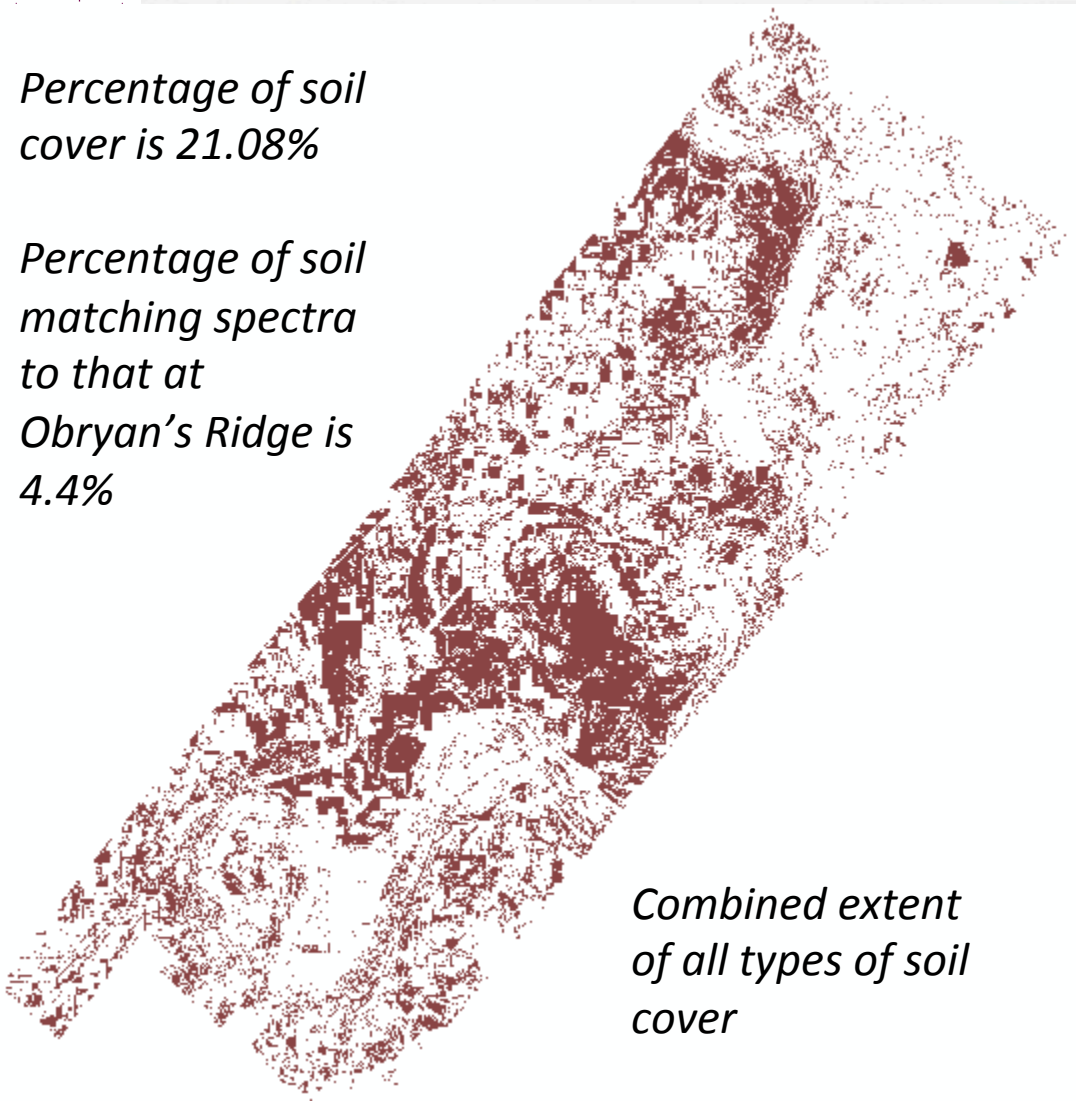


Soils

Percentage of soil cover is 21.08%

Percentage of soil matching spectra to that at Obryan's Ridge is 4.4%

Soil Spectra matching that at O'Bryan's Ridge

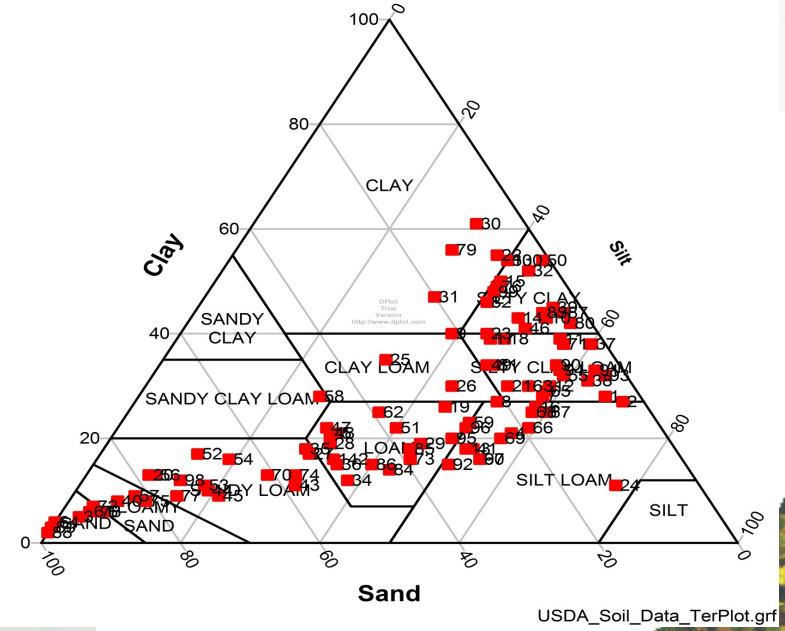


Combined extent of all types of soil cover

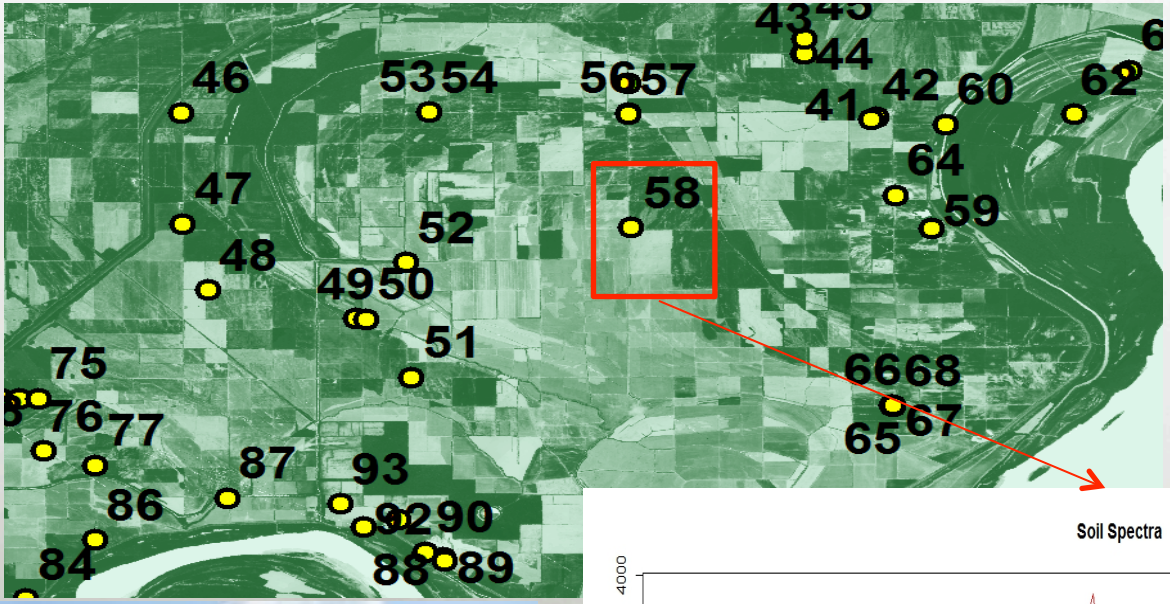
Soil Sample Data

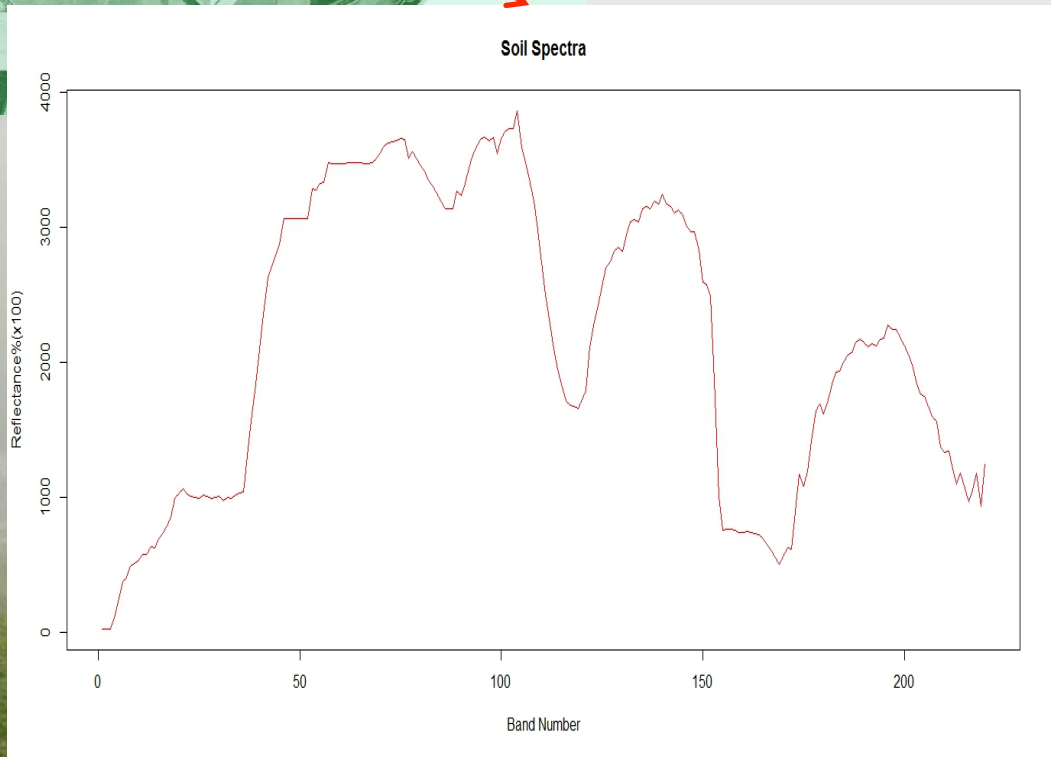
- Soil grab sample from the floodway from about 130 locations were collected around the same date of the AVIRIS flights (27th July 2011).
- Results from the textural and chemical analysis of the samples are available.
- Physical textural analysis results include the *percent sand, silt, clay, moisture content* etc.
- Chemical analysis results include pH, SOM, S, P, Na, Ca, Mg, K, B, Mn, Cu, Zn, Al, other bases, base saturation and soluble salts.

Pictures of some of the sites from which grab samples are extracted


Clay
Silt
Sand
CLAY
SANDY CLAY
CLAY LOAM
SANDY CLAY LOAM
SILT LOAM
SILT
SAND
LOAMY SAND
USDA_Soil_Data_TerPlot.grf

Extracting the Soil Spectra from AVIRIS Data





$$Percent_{sand/silt/clay} = A_0 + A(\alpha_1 f_1 + \alpha_2 f_2 + ... + \alpha_n f_n)$$

$$A_0 = Intercept$$

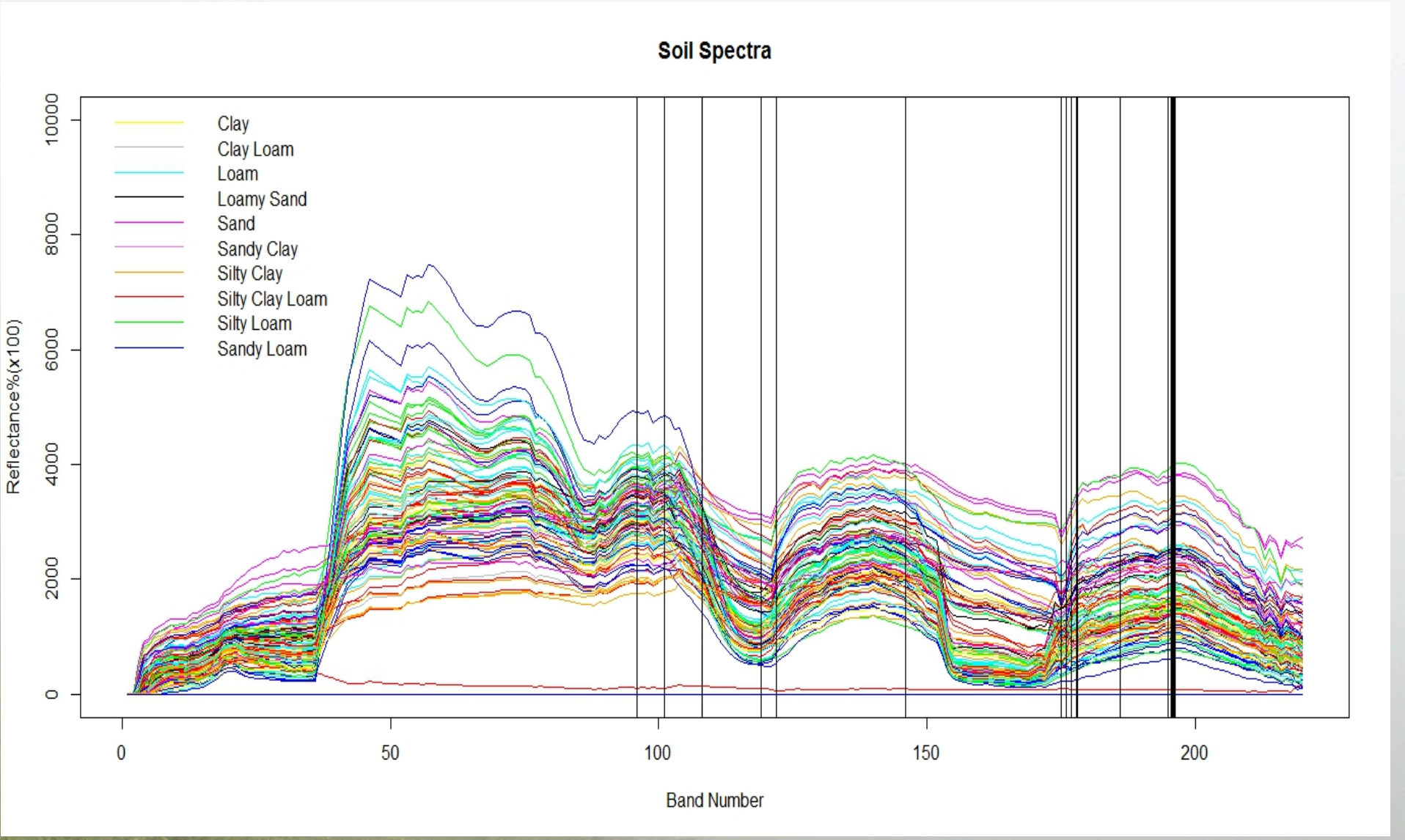
$$\alpha_k = \frac{a_k}{A}$$

$$A = \Sigma_{i=1}^{k} |a_k|$$

Value of Alpha k	Sand	Silt	Clay
(Intercept)	0.104	0.507	0.414
band.96	0.001	0.024	-0.028
band.101	0.006	-0.031	0.022
band.108	-0.003	0.011	-0.003
band.119	0.037	-0.042	-0.031
band.122	-0.096	0.103	0.072
band.146	0.014	-0.031	0.008
band.175	-0.013	-0.005	0.030
band.176	0.033	-0.010	-0.051
band.177	-0.138	0.112	0.139
band.178	0.134	-0.117	-0.124
band.186	0.005	-0.024	0.022
band.195	0.270	-0.240	-0.262
band.196	-0.252	0.251	0.207

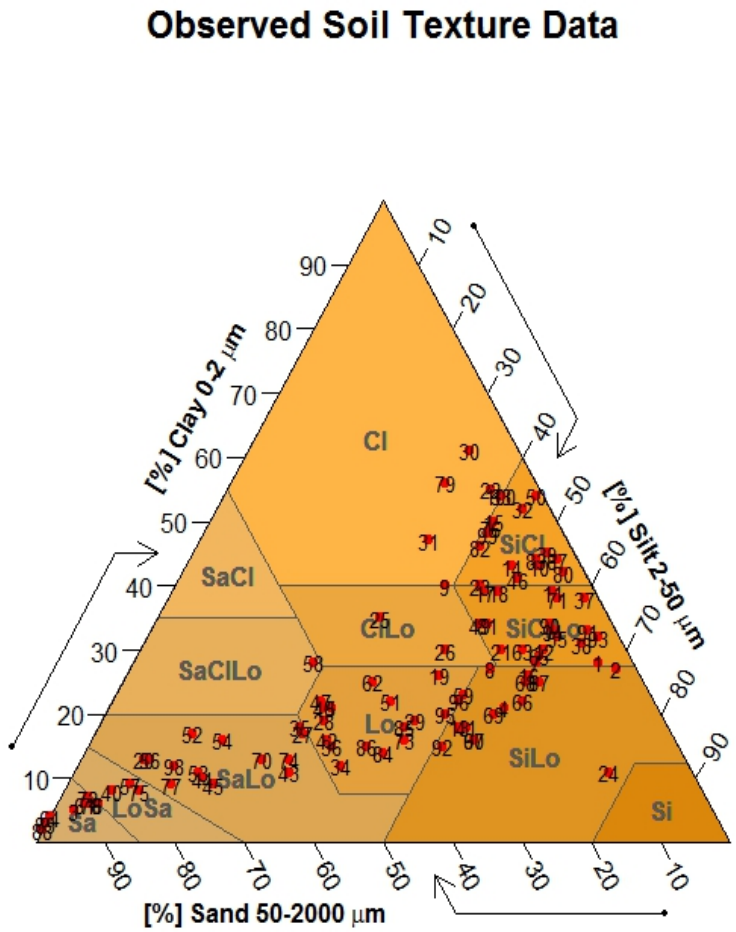
Only One Set of Equations shown here say for Sand, we can similarly write it for Silt and Clay

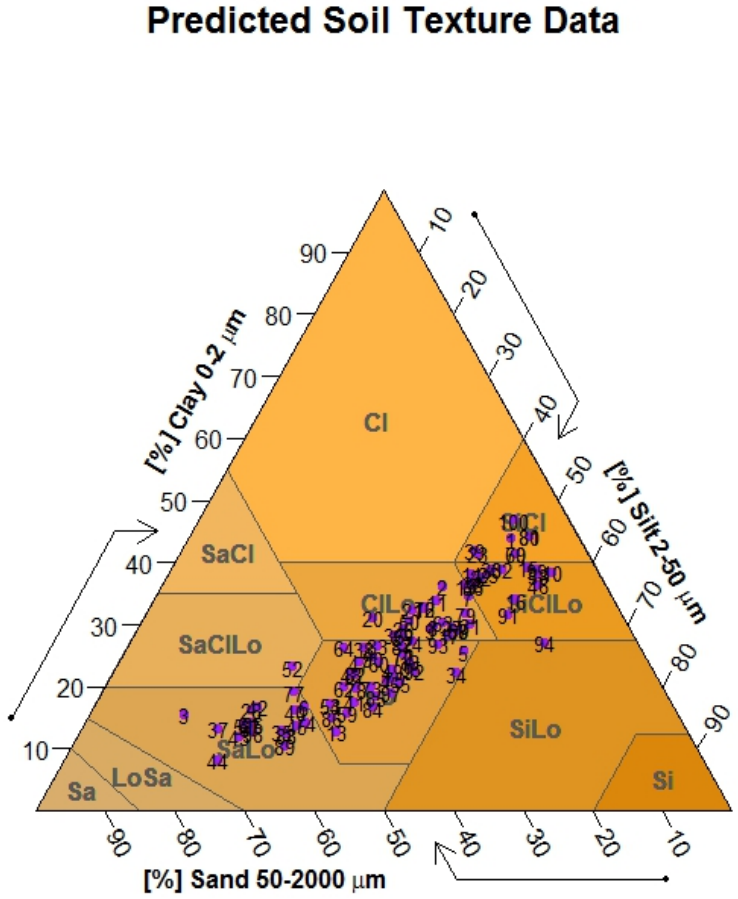
There are two distinct set of bands which emerge clearly out of the analysis showing strong gradient type influences and which are found to be physically meaningful also



The Band Positions of the selected variables shown with a relative weighting of the coefficients, the bands are representative of some specific signature found in minerals

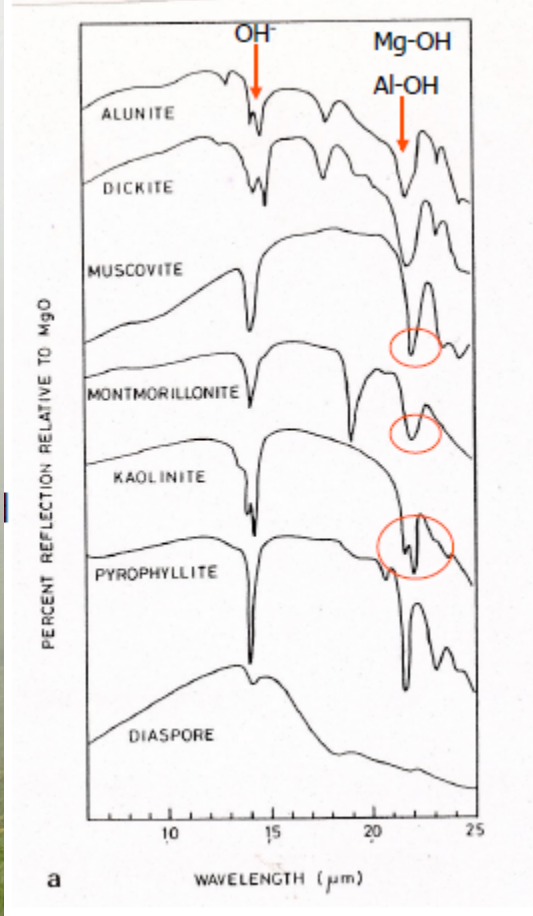
Observed and Predicted Classes

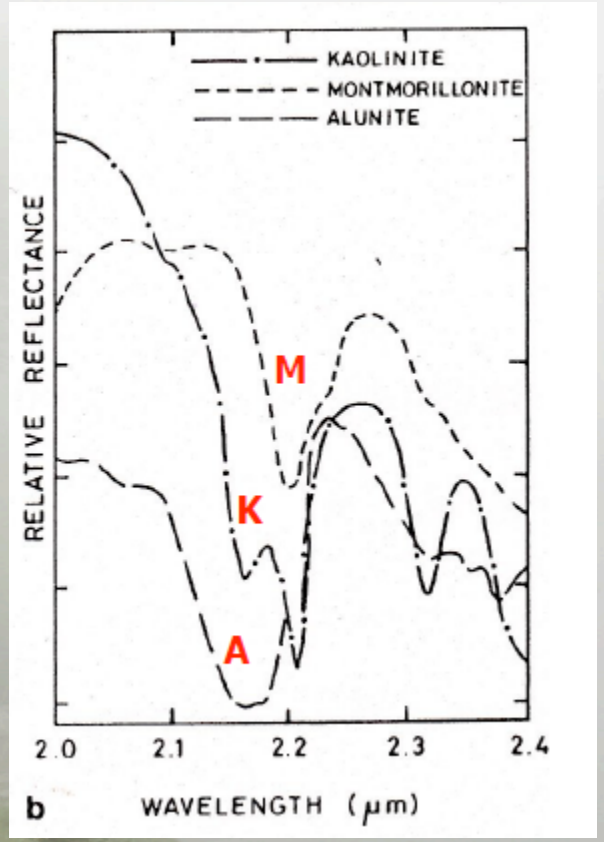




Physical Significance of Results

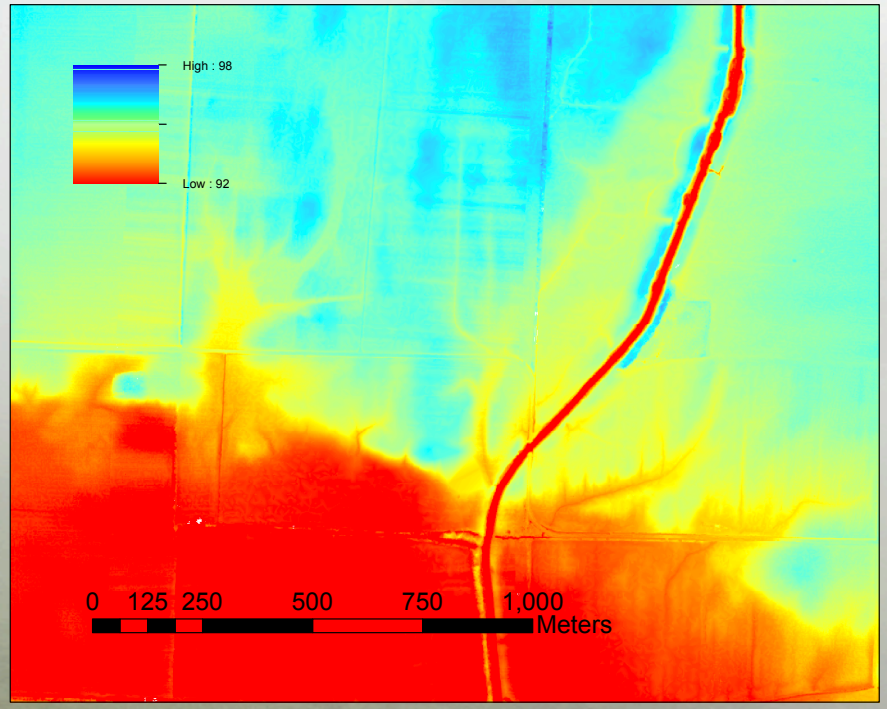
- Silt-granular between sand and clay and mineral origin is quartz and feldspar
- Clay-minerals are kaolin group(kaolinite, dickite etc), montmorillonite, smectite etc
- Sand-most common constituent is silica and quartz.



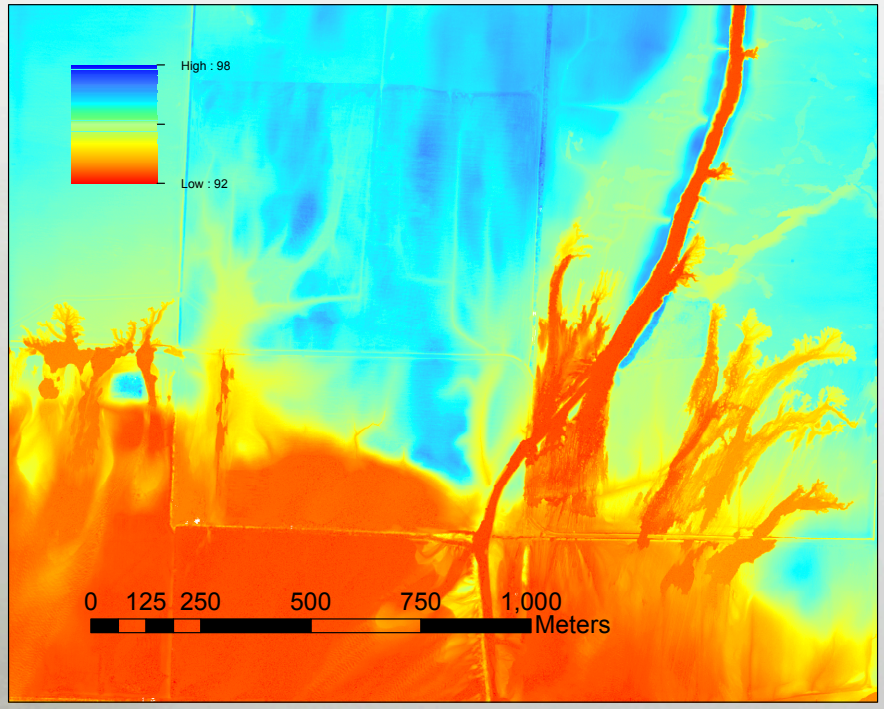


Spectral Features of clay in SWIR region

Modeling Study

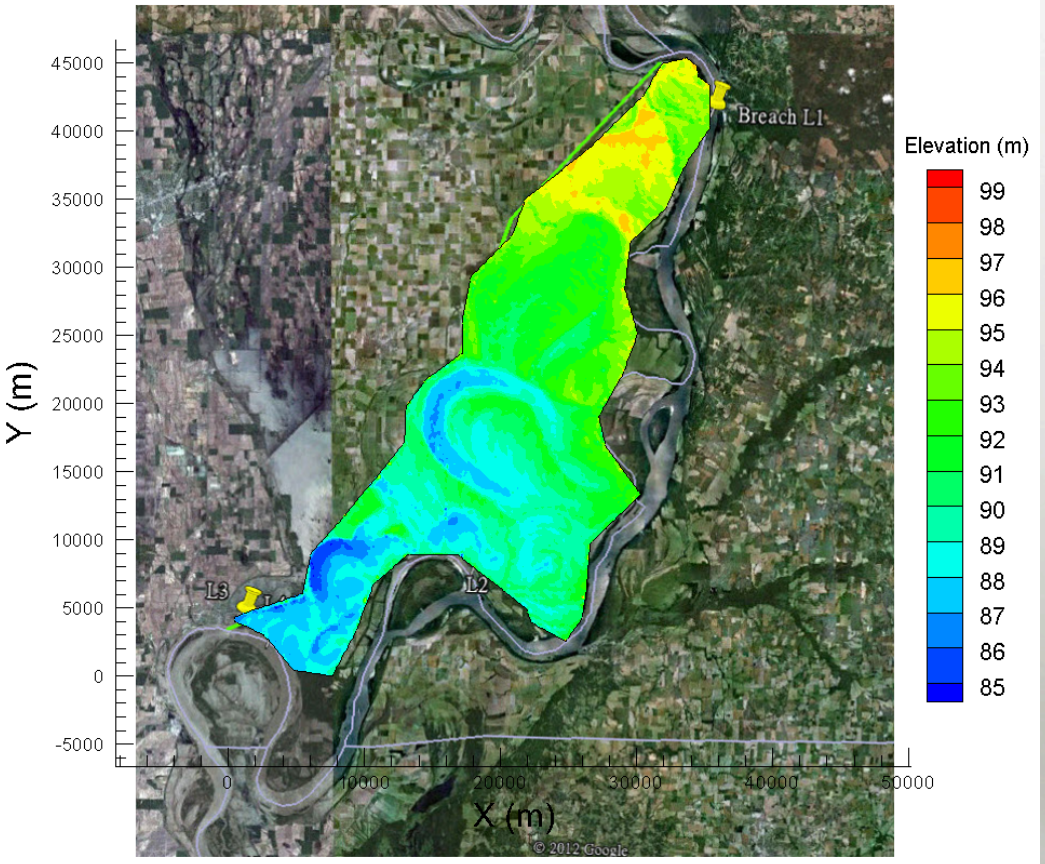


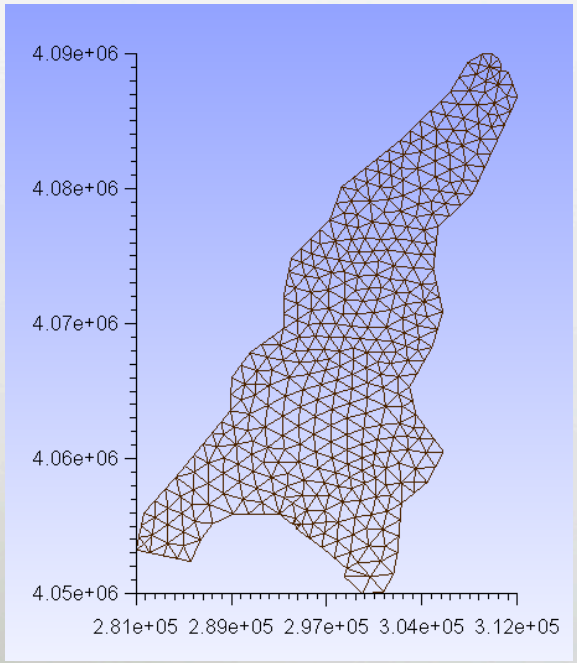
O'Bryan Ridge 2005 Lidar DEM (blue indicates higher elevation)



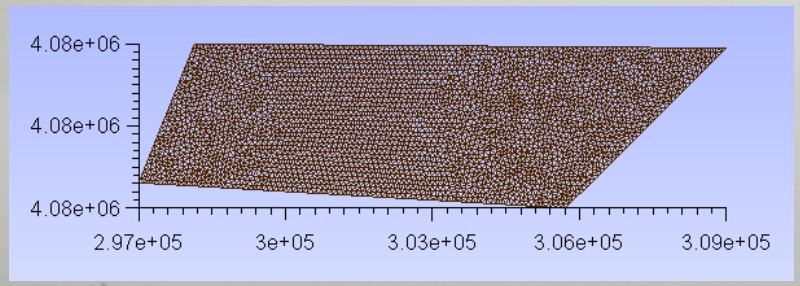
O'Bryan Ridge 2011 Lidar DEM: scours up to 600 m long, 200 m wide, 3 m deep

Modeling Landscape Changes



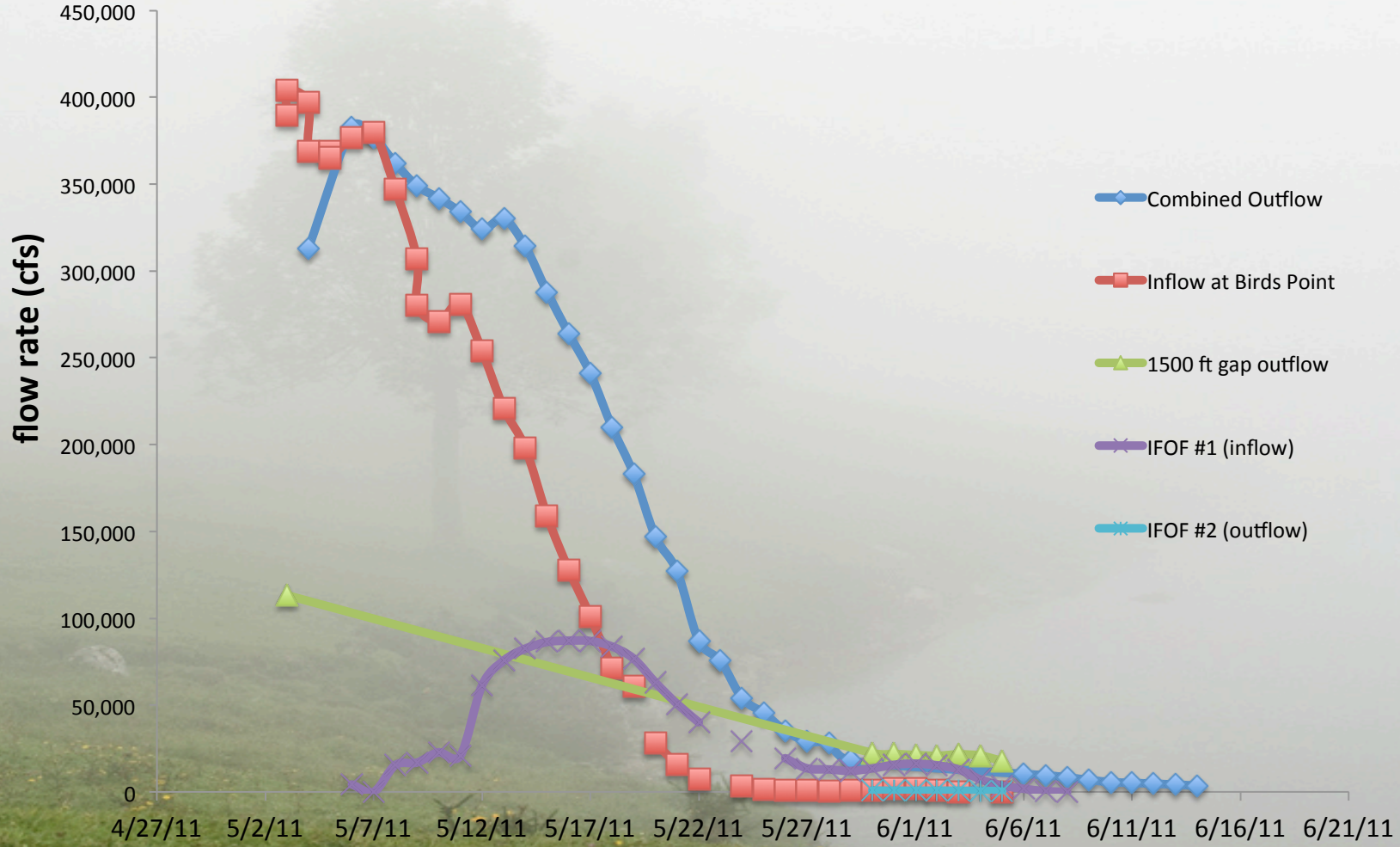


BPNM 1000 m mesh

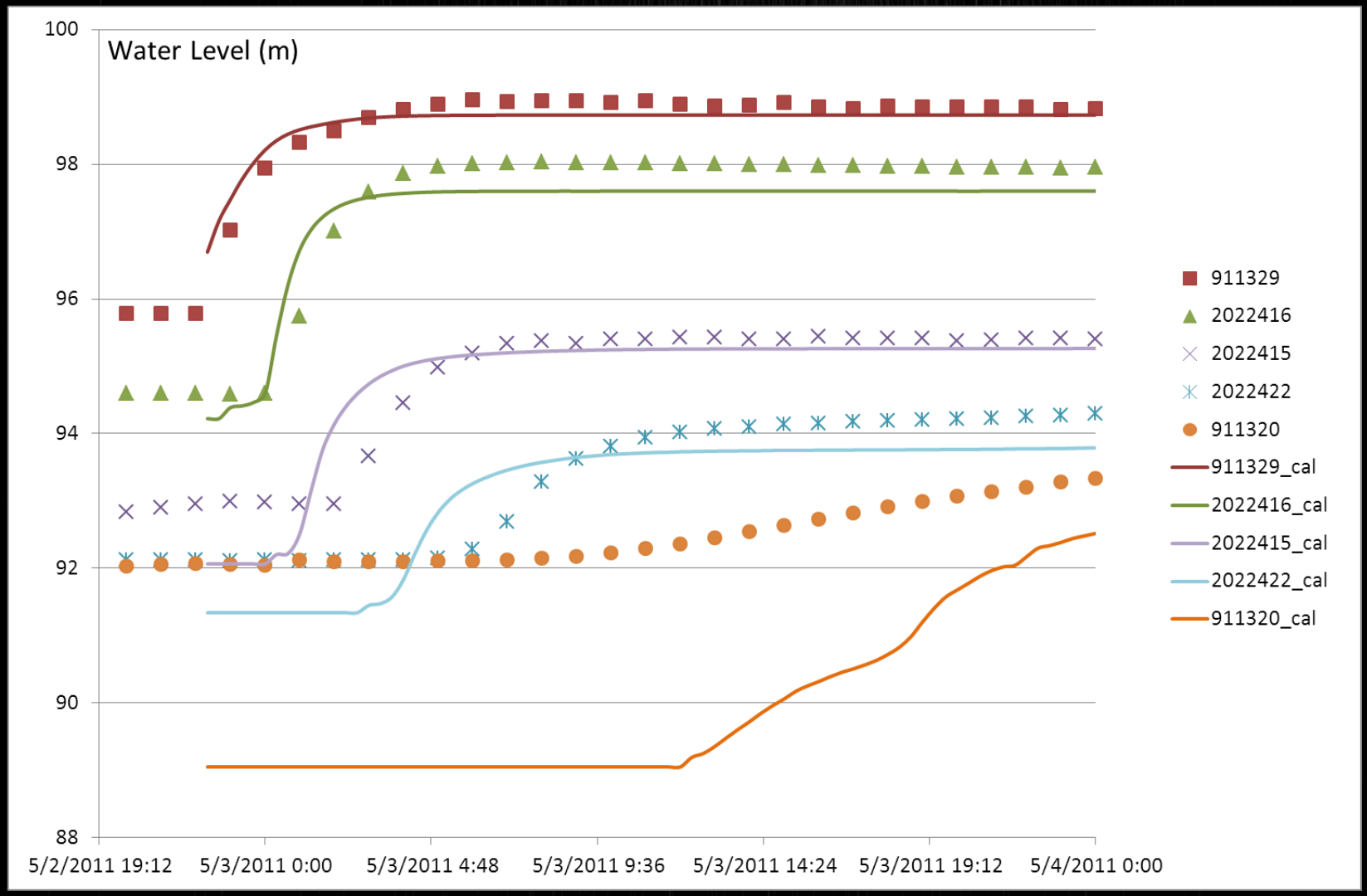


O'Bryan Ridge 100 m mesh

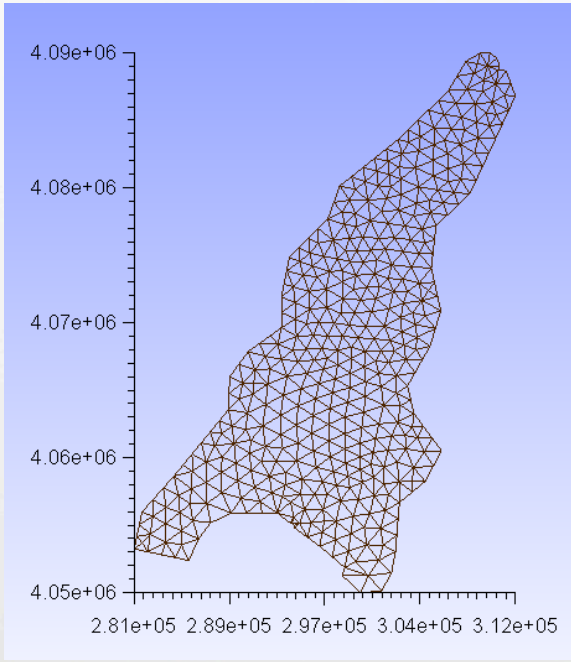
Flow Data from USGS



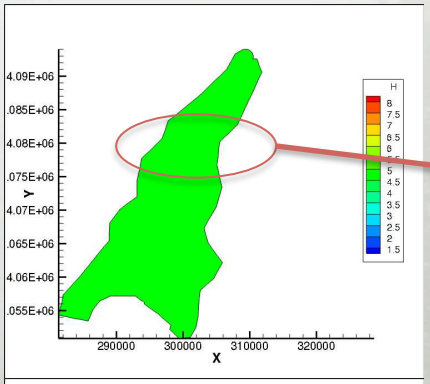
Results

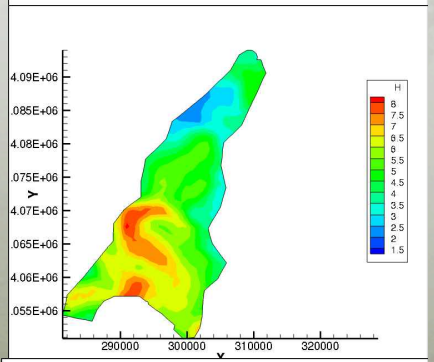

Water Level (m)
100
98
96
94
92
90
88
5/2/2011 19:12
5/3/2011 0:00
5/3/2011 4:48
5/3/2011 9:36
5/3/2011 14:24
5/3/2011 19:12
5/4/2011 0:00
911329
2022416
2022415
2022422
911320
911329_cal
2022416_cal
2022415_cal
2022422_cal
911320_cal

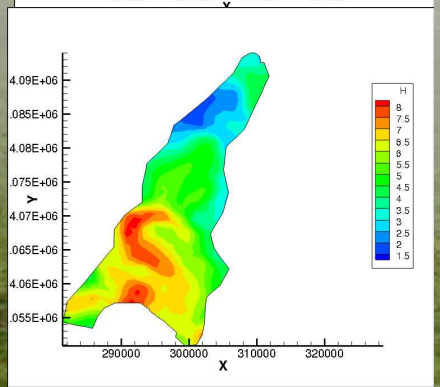
BPNM – OBryan Ridge Nesting



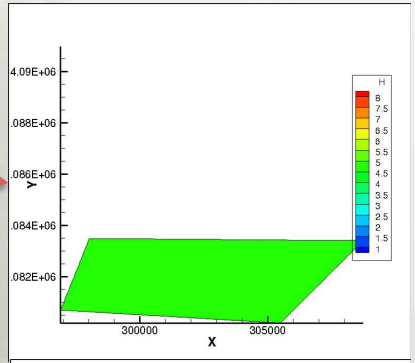
1000 m cells

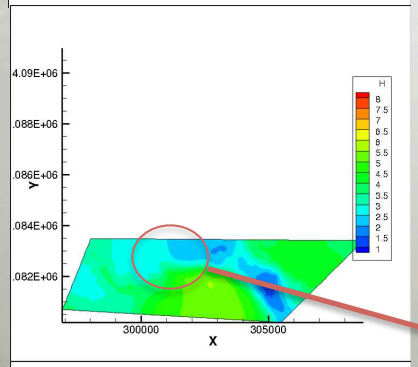


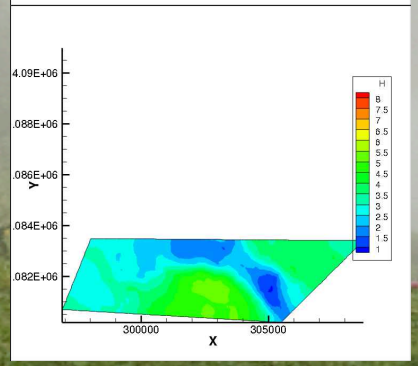




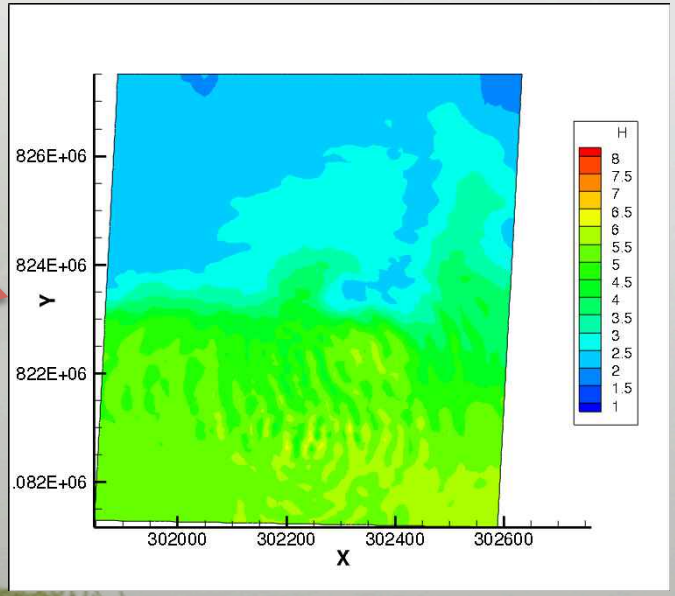
100 m cells



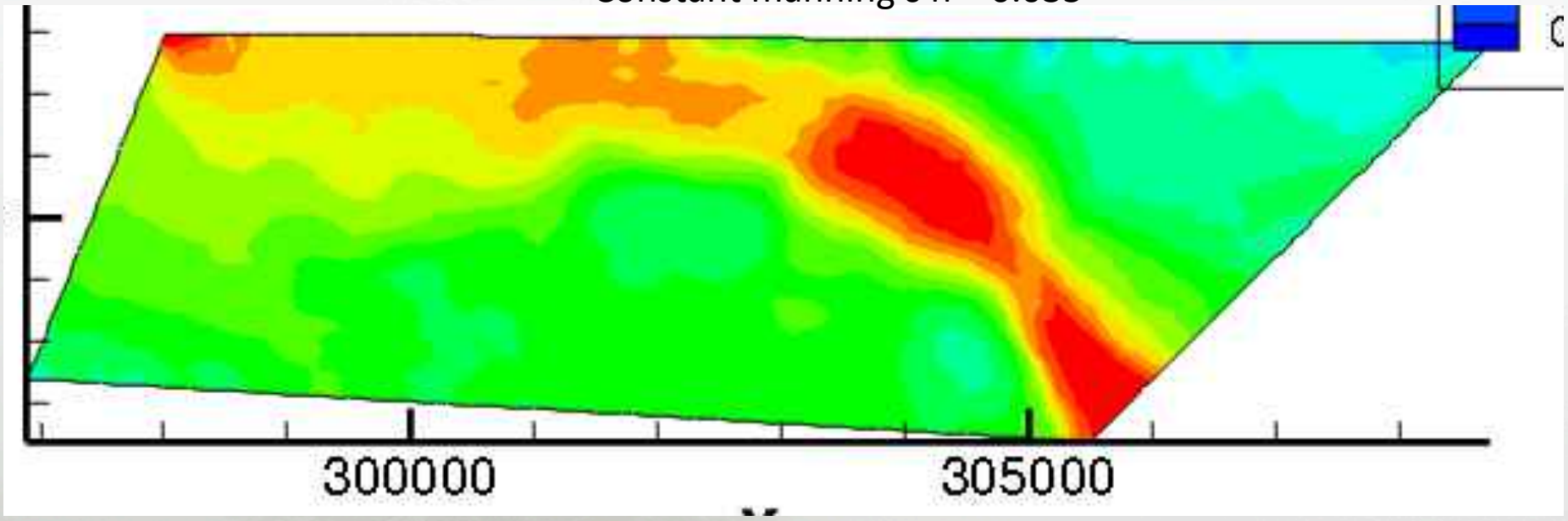




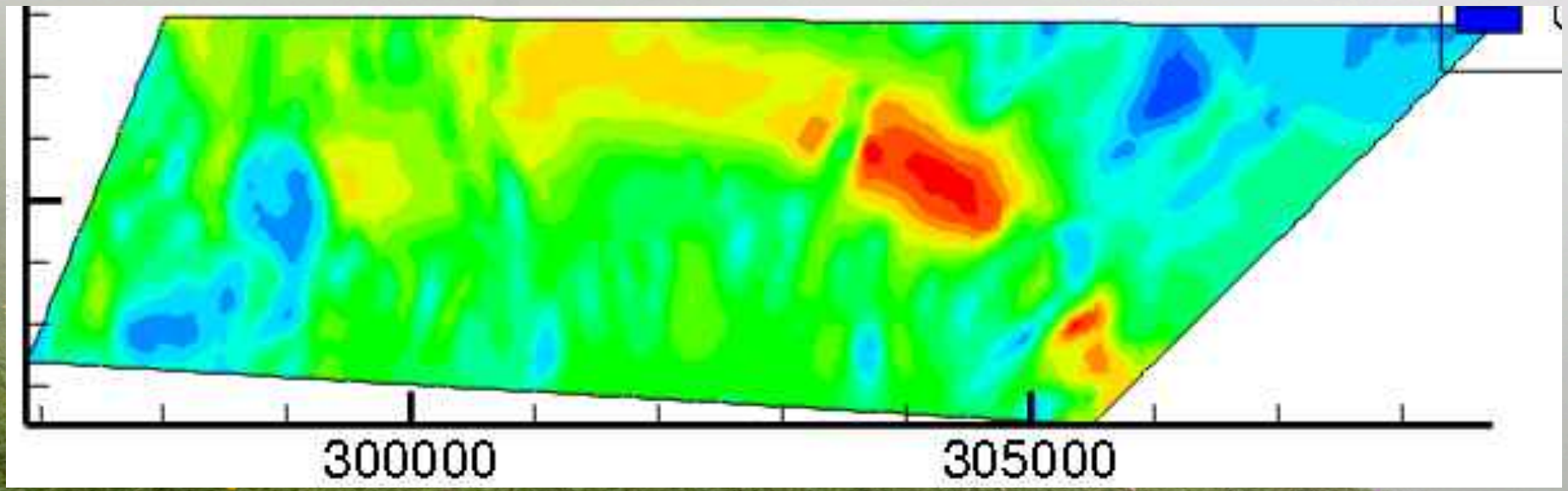
10 m cells

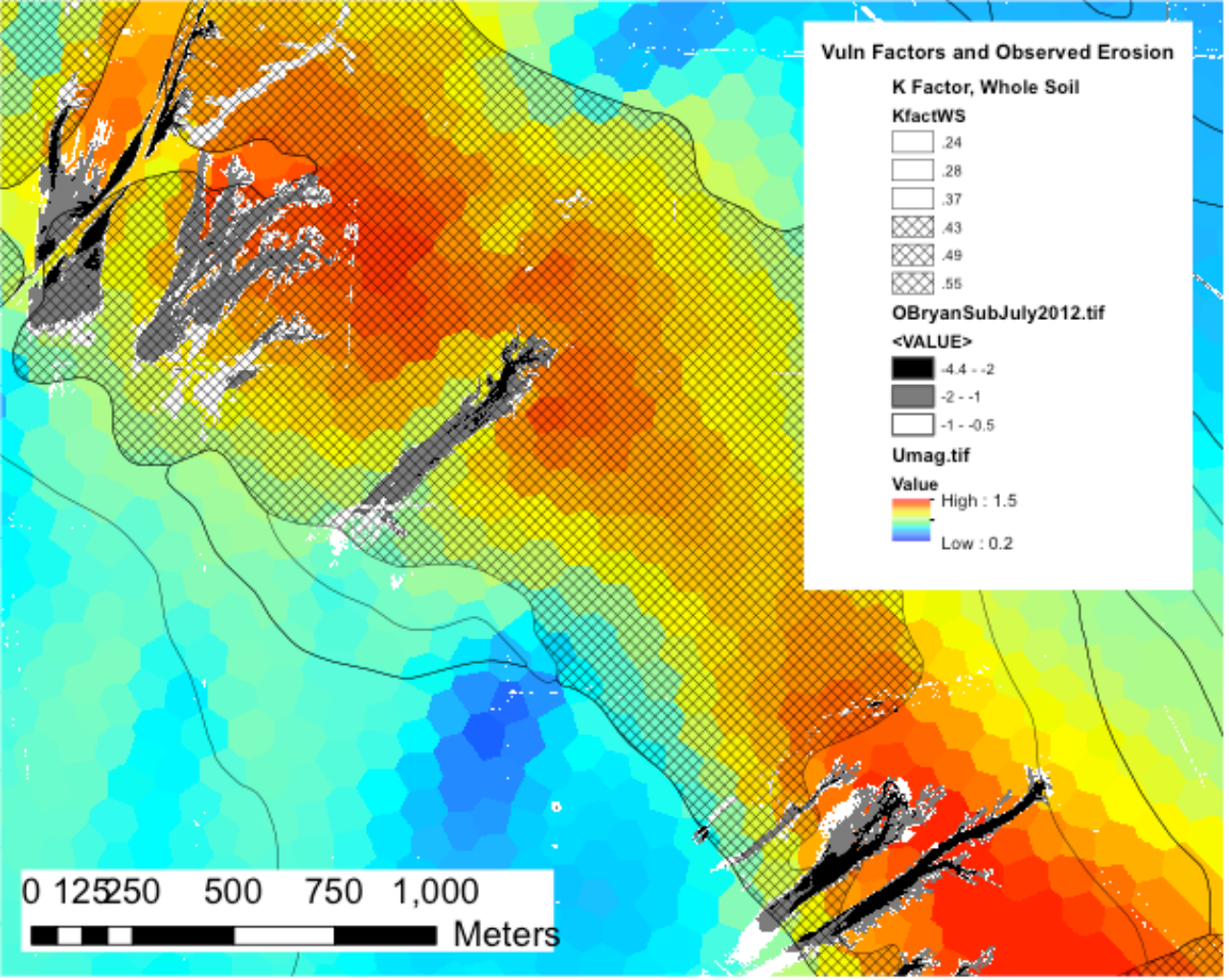


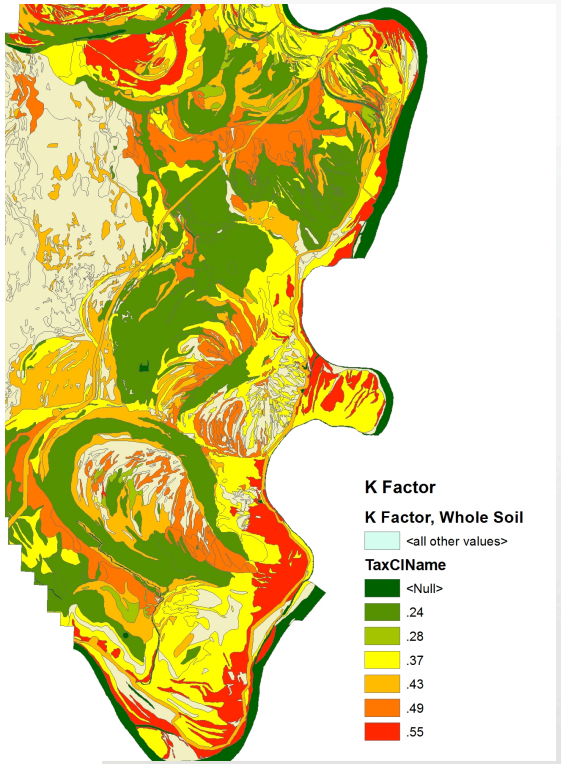
Constant manning's n = 0.035



Mannings N based on AVIRIS tree vs no-tree classification (max = .2 min = .035)







Soil Erosion Factor Map from Web Soil Survey

Vulnerability Factors (Flow Speed from HydroSed2D modeling and K Factor from USDA Web Soil Survey) overlaid by observed erosion at O'Bryan Ridge. Regions of high vulnerability are expected to have high exposure (high flow), high sensitivity, and low adaptive capacity (not shown). Observed erosion generally matches well with highly vulnerable areas.

Conclusions

- Accurate identification of land cover classes and more precise vegetation species and soil types is possible. This helps in modeling flow over the landscape accurately.
- Some of the historic meanders of Mississippi were highlighted in indices and classifications from the AVIRIS data showing evolutionary history between topography and vegetation dynamics.
- Simple statistical models can be used to model and interpret soil properties
- Sophisticated statistical models may be able be used for the exploration and study of various physical and chemical properties using imaging spectroscopy data.

Thanks!

Questions?