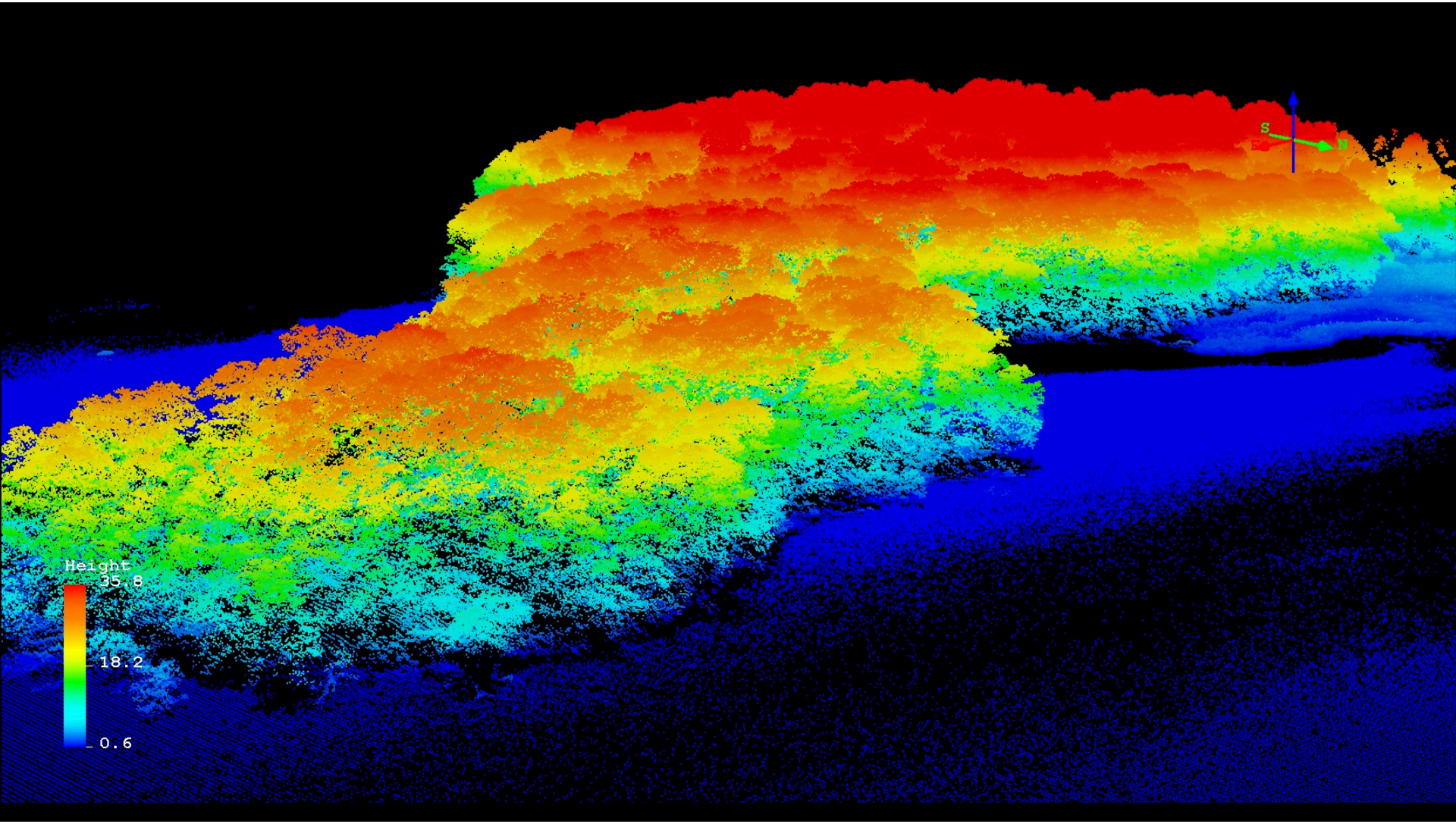
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

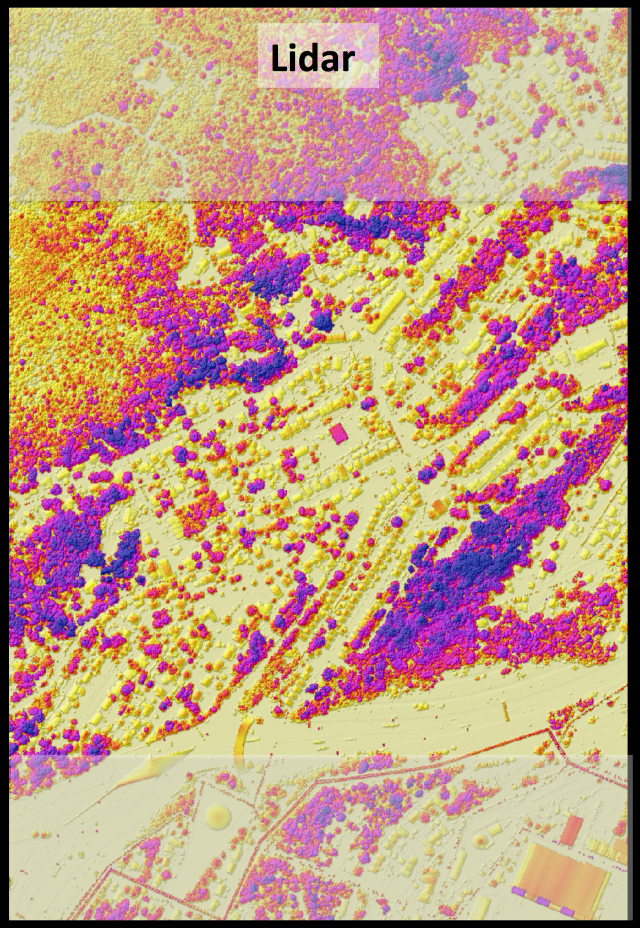
NASA Carbon Monitoring System

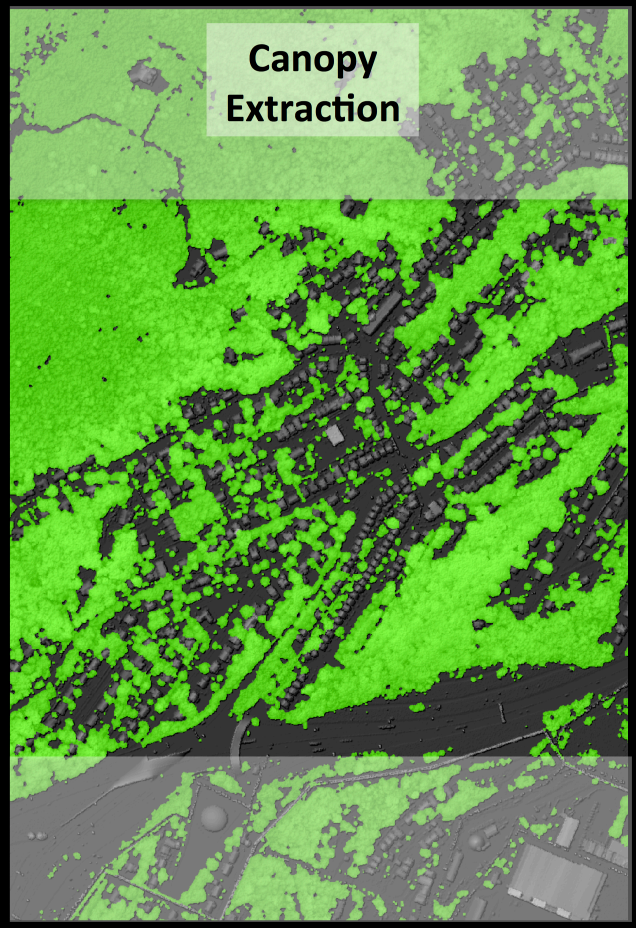
The goal for NASA's CMS project is to prototype the development of capabilities necessary to support stakeholder needs for Monitoring, Reporting, and Verification (MRV) of carbon stocks and fluxes.

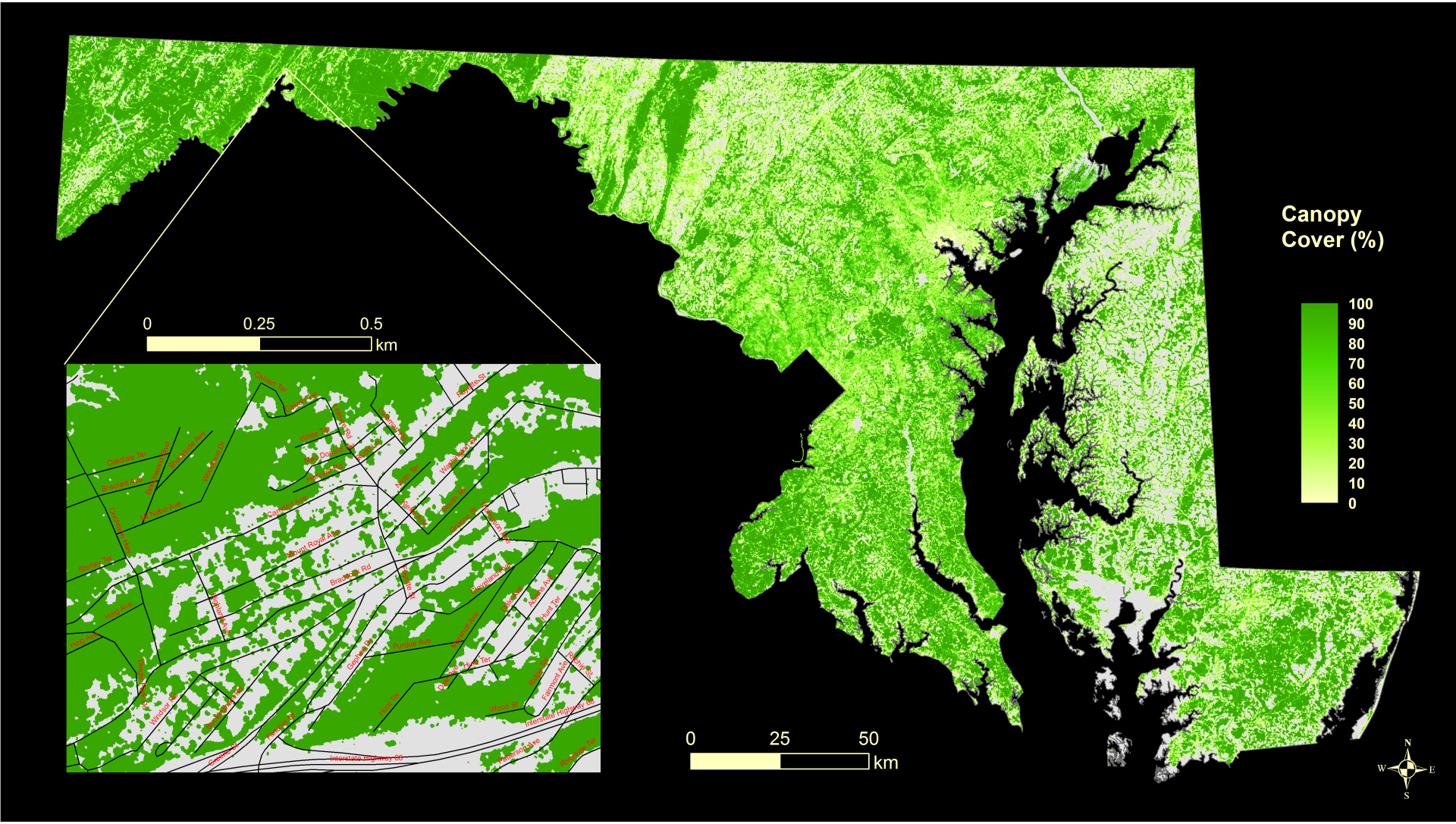
High resolution carbon monitoring and modeling prototype

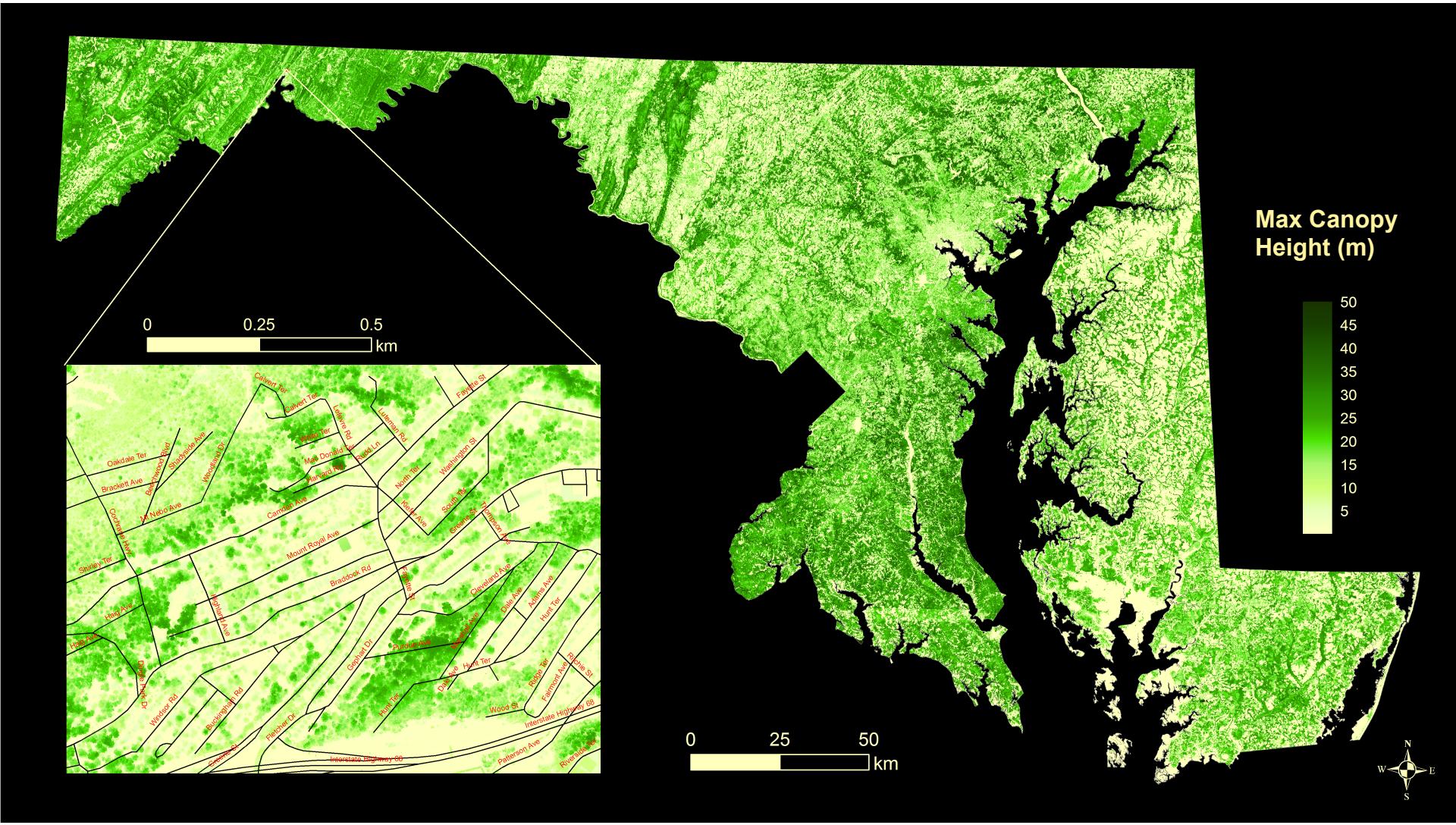

Height
35.8
18.2
0.6
S
N

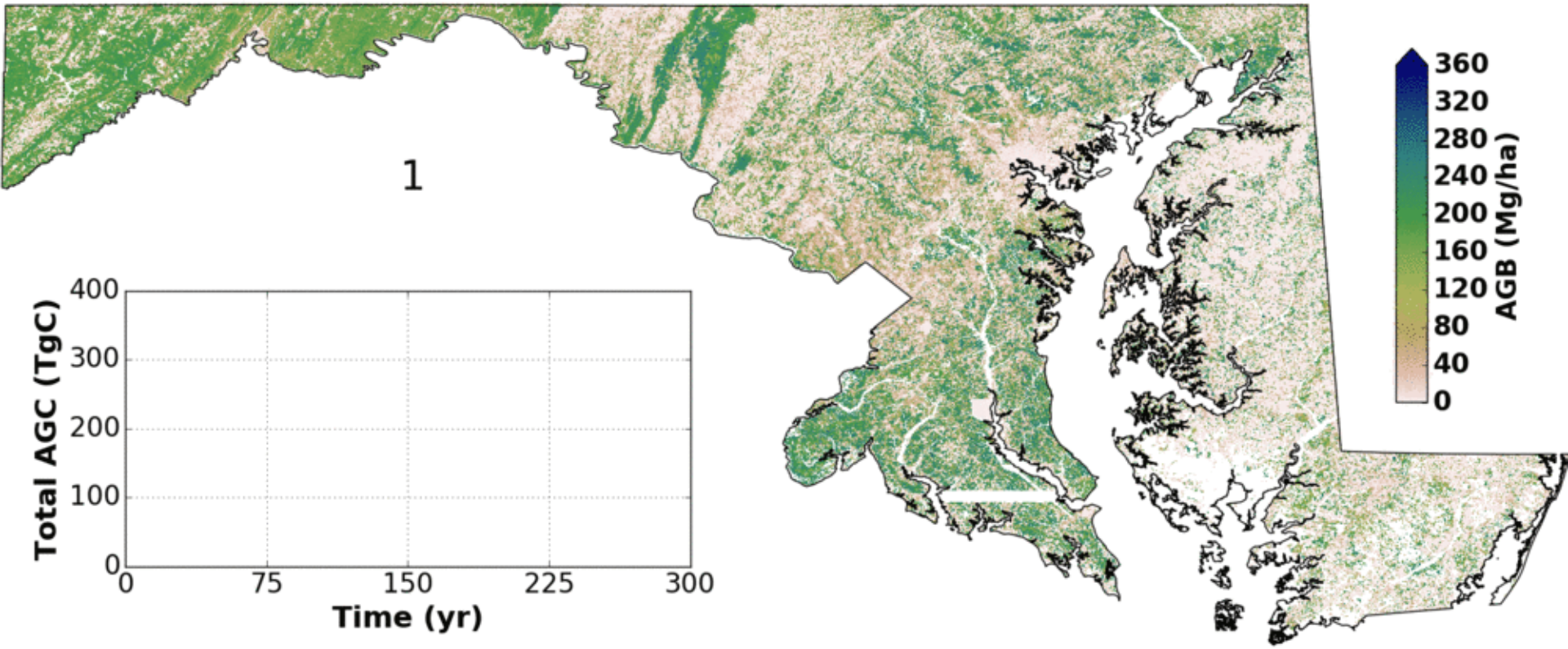
Canopy Cover Generation

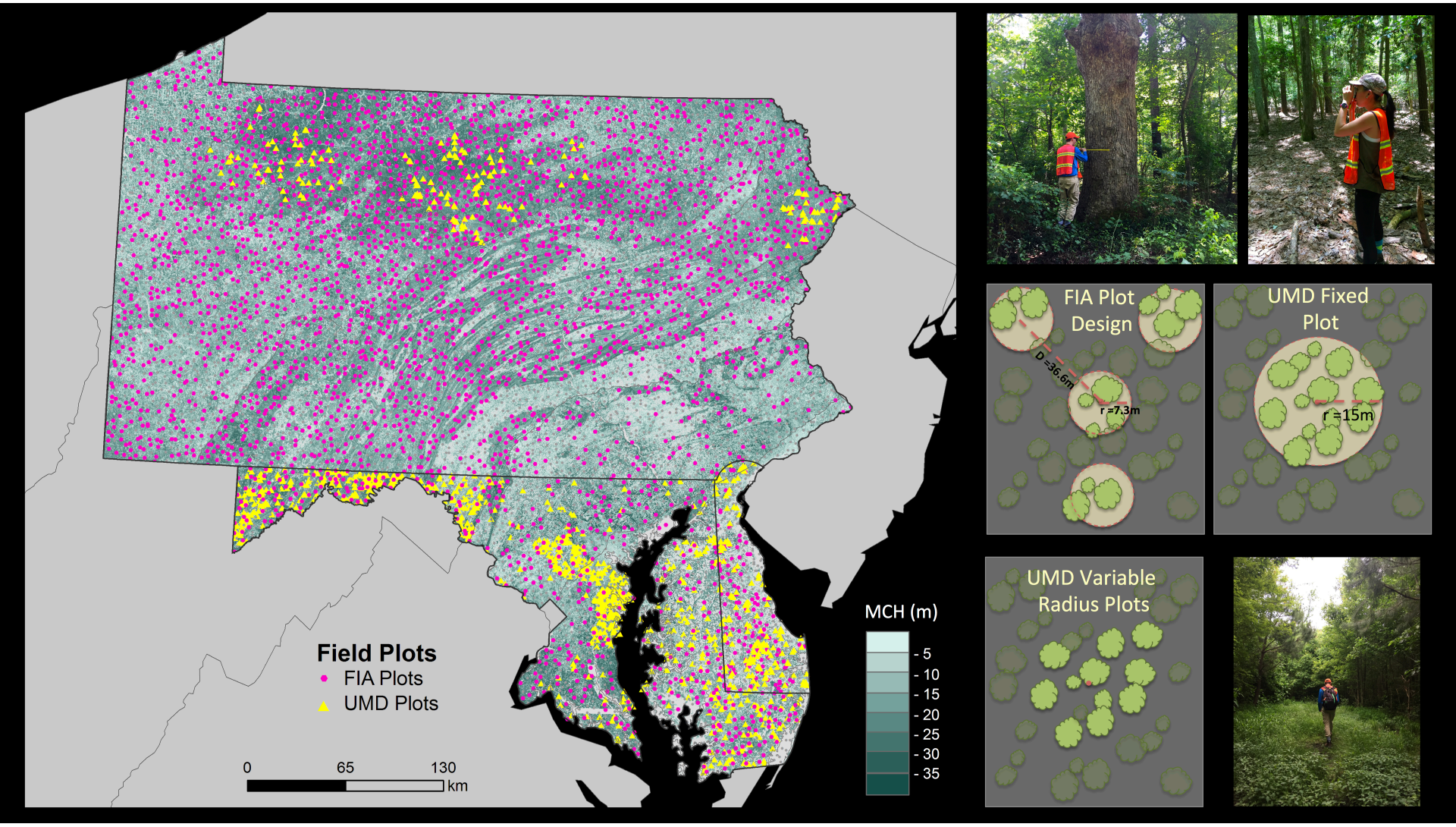


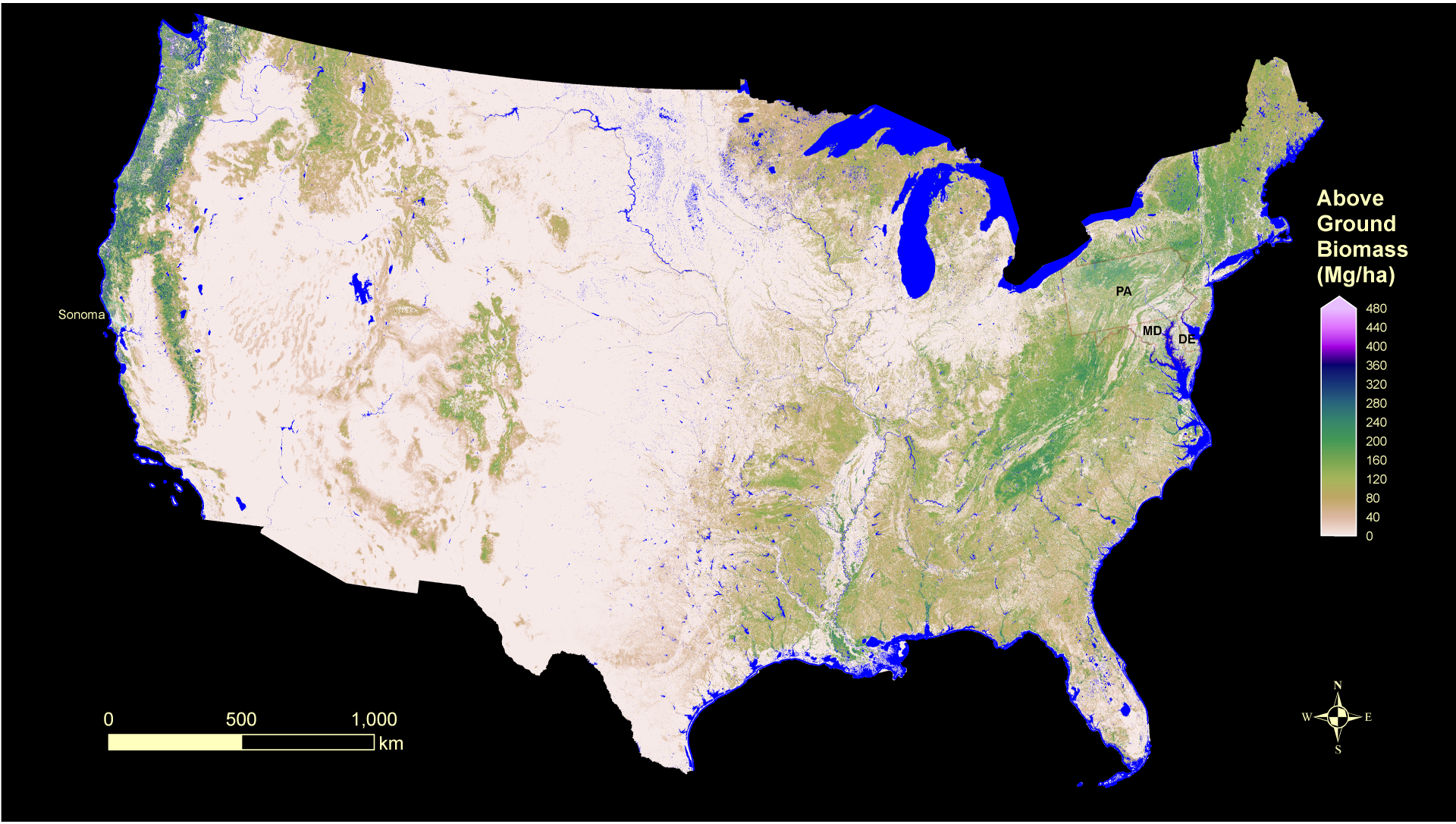



Canopy Cover (%)
100
90
80
70
60
50
40
30
20
10
0
0 25 50
km
0 0.25 0.5
km
N
W
E
S

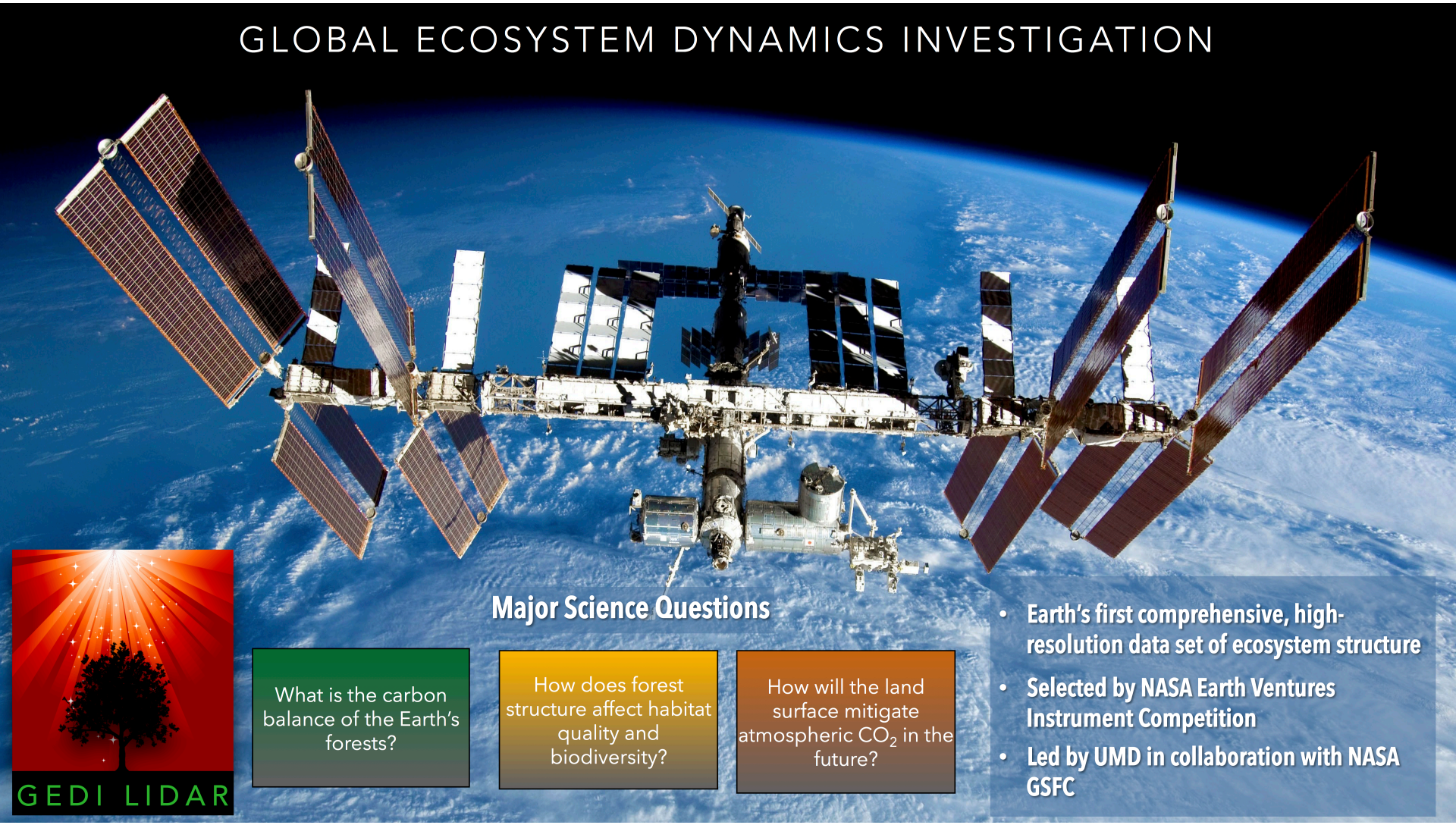

Max Canopy Height (m)
50
45
40
35
30
25
20
15
10
5
0
0.25
0.5
km
0
25
50
km
N
W
E
S
Calvert Ter
Calvert Ter
Lefevre Rd
Lutzman Ave
Fayette St
Oakdale Ter
Bracken Ave
Parkinwood Road
Shadyside Ave
Woodland Dr
Mc Donald Ter
Hazel Ln
Mallard Ln
North Ter
Washington St
South St
Mc Nabb Ave
Cedarcliffe Drive
Camden Ave
Hollis Ave
Glenmore Ave
Shirley Ter
Mount Royal Ave
Braddock Rd
Highland Ave
Cleveland Ave
Dale Ave
Adelina Ave
Hunt Ter
Corbett Dr
Dale Ave
Hunt Ter
Ridge Ter
Fairmont Ave
Ritchie St
Windsor Rd
Buckingham Rd
Fletcher Dr
Hunt Ter
Wood St
Interstate Highway 68
Interstate Highway 68
Patterson Ave
Riverside Ave


1
AGB (Mg/ha)
360
320
280
240
200
160
120
80
40
0
Total AGC (TgC)
400
300
200
100
0
0
75
150
225
300
Time (yr)


Field Plots
FIA Plots
UMD Plots
0
65
130
km
MCH (m)
- 5
- 10
- 15
- 20
- 25
- 30
- 35
FIA Plot Design
D =36.6m
r =7.3m
UMD Fixed Plot
r =15m
UMD Variable Radius Plots


Above Ground Biomass (Mg/ha)
480
440
400
360
320
280
240
200
160
120
80
40
0
Sonoma
PA
MD
DE
0
500
1,000
km
N
W
E
S

GLOBAL ECOSYSTEM DYNAMICS INVESTIGATION



GEDI LIDAR

Major Science Questions

- What is the carbon balance of the Earth's forests?
- How does forest structure affect habitat quality and biodiversity?
- How will the land surface mitigate atmospheric CO_2 in the future?

- **Earth's first comprehensive, high-resolution data set of ecosystem structure**
- **Selected by NASA Earth Ventures Instrument Competition**
- **Led by UMD in collaboration with NASA GSFC**

Acknowledgements

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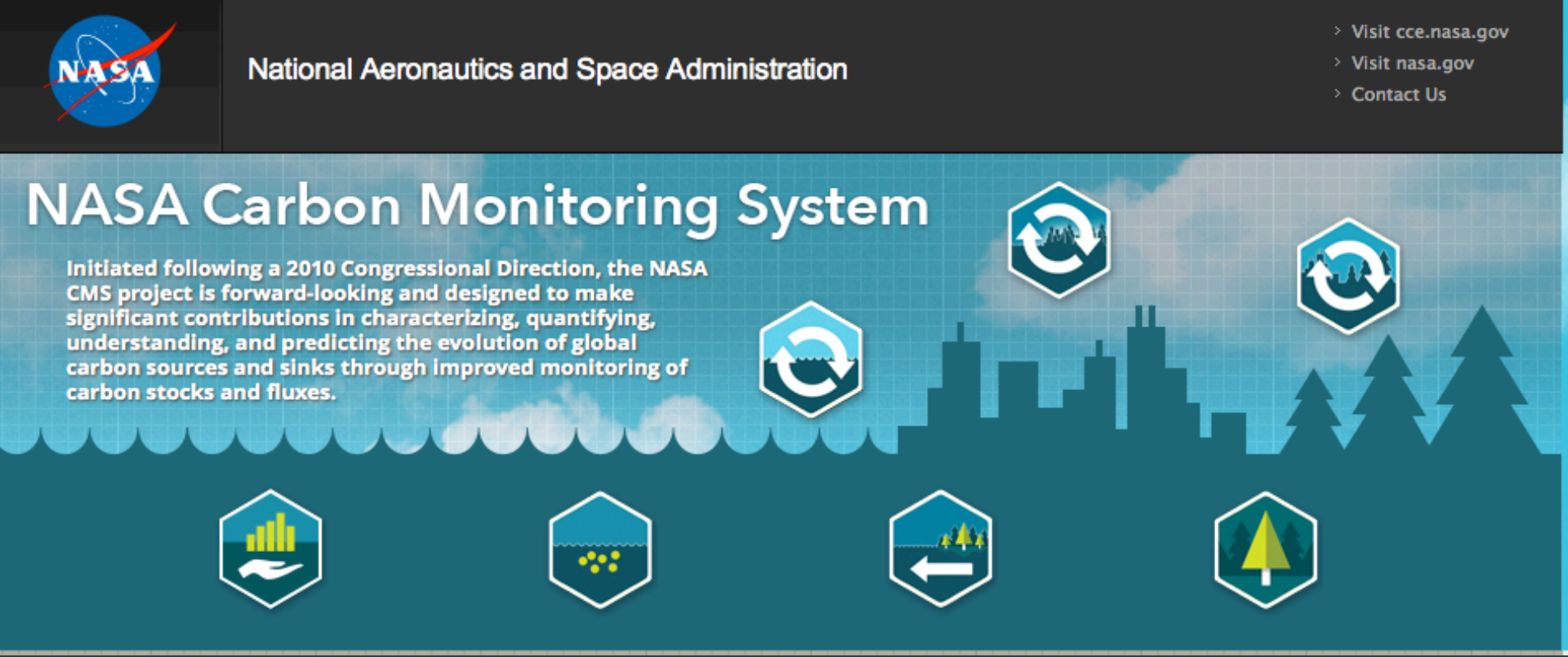
Laura Duncanson, NASA
Peter Griffith, NASA
David Lagomasino, NASA
David Stroud, NASA



CMS Applications Perspective and Expectations for the Tri State Region

Vanessa M. Escobar

CMS Applications PI

NASA CMS & USFS 2016 Applications Workshop & Tutorial – September 9th, 2016

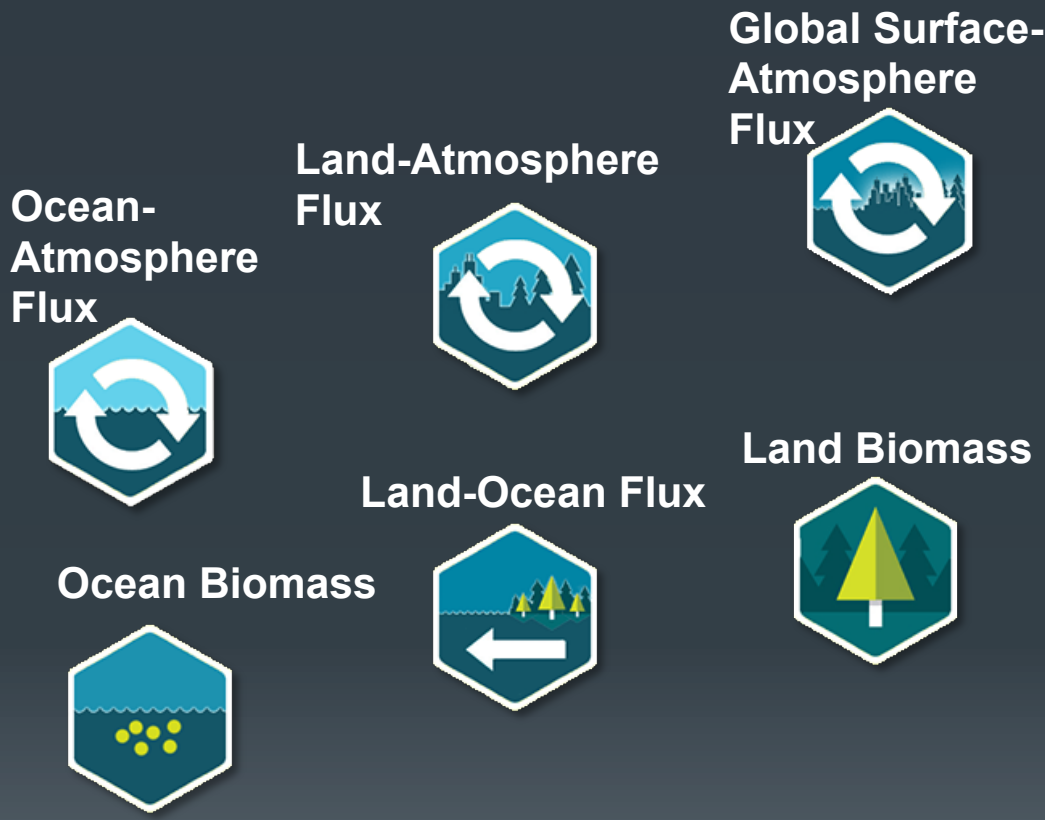
Goals of Workshop

- Understand stakeholders needs for carbon monitoring and MRV
- Understand how CMS can support climate change action plans & policies from the states of MD, DE, PA
- Identify way CMS state climate policies
- Demonstrate new NASA CMS capabilities and elicit feedback for the project

NASA's Carbon Monitoring System

- Initiated in 2010 by Congressional direction

- Designed to make significant contributions in characterizing, quantifying, understanding, and predicting the evolution of global carbon sources and sinks through improved monitoring of carbon stocks and fluxes.



George Hurtt, U Maryland
Science Team Leader

CMS Applications Team:
Vanessa Escobar, Lead
Edil Sepulveda Carlo, Coordinator
Sabrina Delgado Arias, Member

For more info, please visit:
http://www.carbon.nasa.gov

NASA CMS Objectives

- Use the full range of NASA satellite capabilities for supporting national and international policy, regulatory, and management activities.
- Prototype the development of carbon Monitoring Reporting and Verification [MRV] systems which can provide transparent data products achieving levels of precision and accuracy required by current carbon trading protocols.
- Harness unique capabilities and competitive peer review wherever possible.
- Rapidly inform and distribute products, both for evaluation and to inform near-term policy development and planning
- Engage with, and contribute to, related U.S. and international stakeholders and agencies

NASA CMS has

- 52 projects
- Over 116 products
- Each project has at least 1 stakeholder engaged
  - Modeling and analysis, decision support, research support, report/document reference, and policy support

- Applications in CMS
  - Decision Support
  - Stakeholder Engagement
  - MRV

CMS MD/PA/DE

Tri State Area Stakeholder Interests

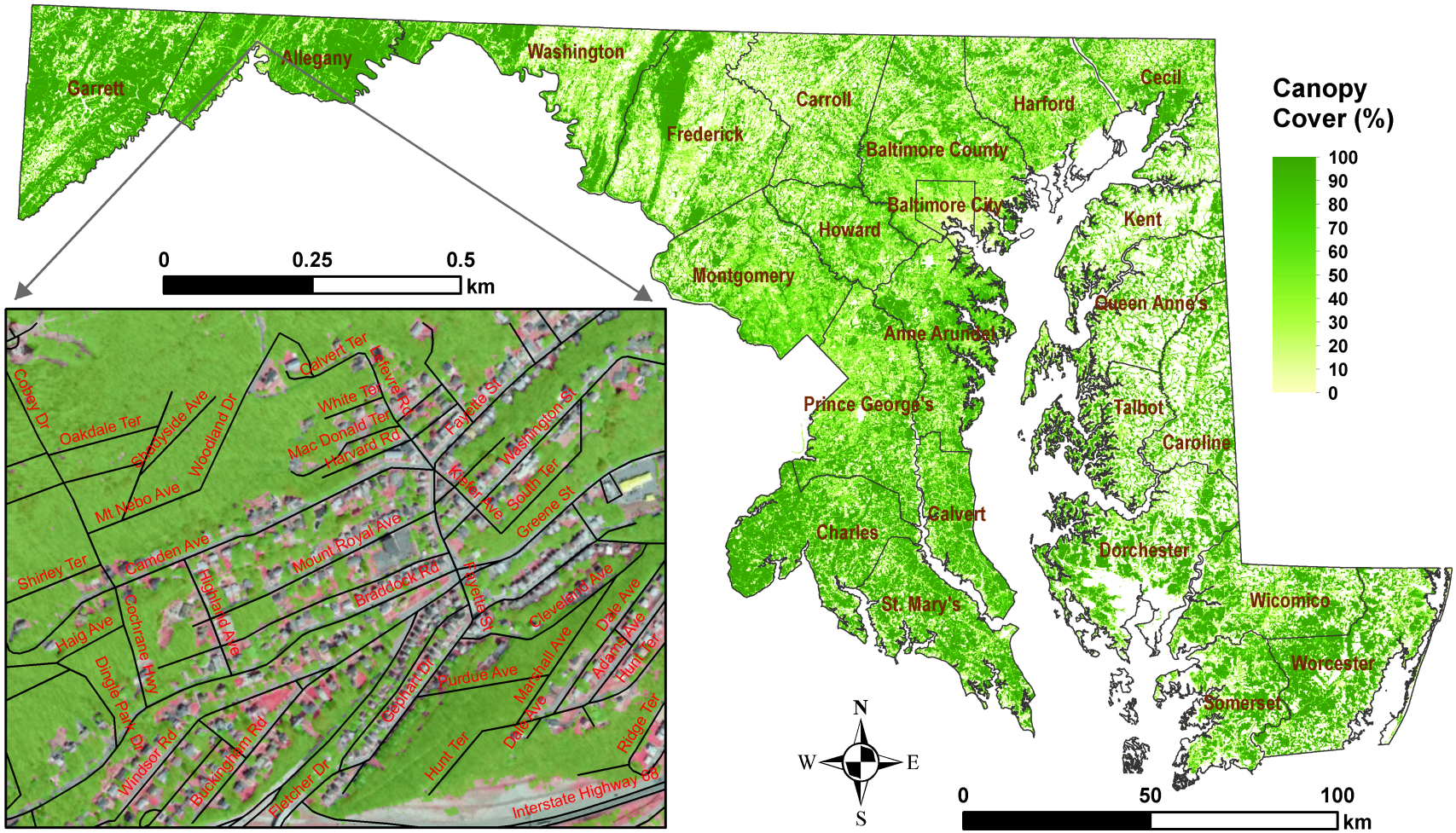
State	Data Need / Interest	Agency
Maryland	- canopy cover - tree species - precision streams - affordable updates to LiDAR coverage at regular intervals of 3 to 5 years	MD Forest Service
Maryland	- impervious surface assessments - wetland maps	MD DNR
Delaware	- sea-level change - blue carbon - wetland maps - carbon sequestration potential maps	DE DNREC
Delaware	- tree species classification for biodiversity and conservation purposes	DE Parks Department
Pennsylvania	- carbon sequestration potential - canopy changes monitoring - monitor changes in hydrology - LiDAR applications around natural gas developments	PA DCNR

Topics of Interest – State Needs

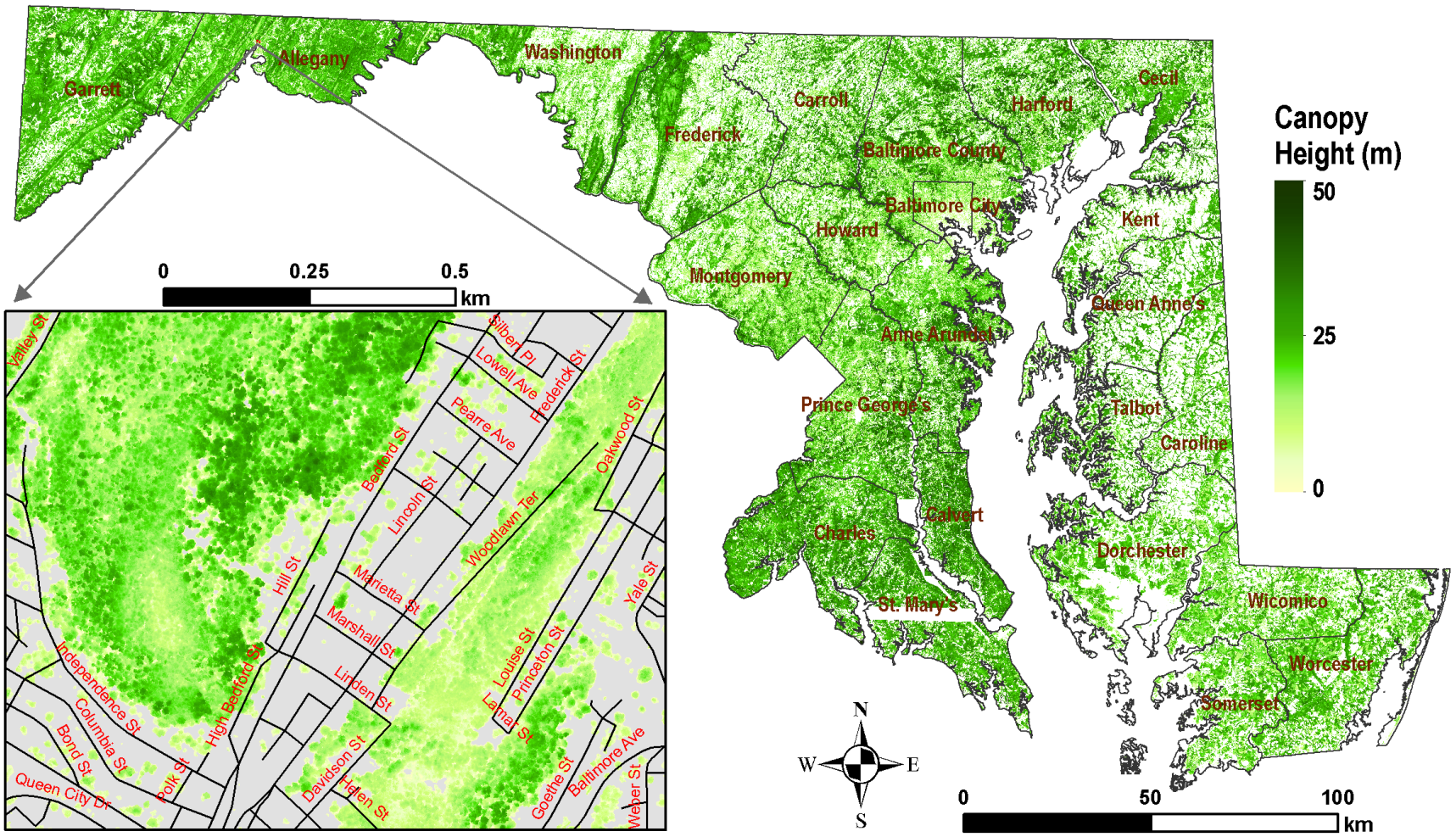
- What are the data needs for Forestry, Agriculture, Hydrology?
- Challenges and gaps with new data?
- Perspective on Statewide LiDAR data collection efforts, partnerships, specifications of collected data (resolution, etc.) and collection cycle interests
- Use of Lidar to monitor emissions reductions in the states
- CMS data synergies with PA and DE, leverage MD

Products for the states of Maryland, Delaware and Pennsylvania

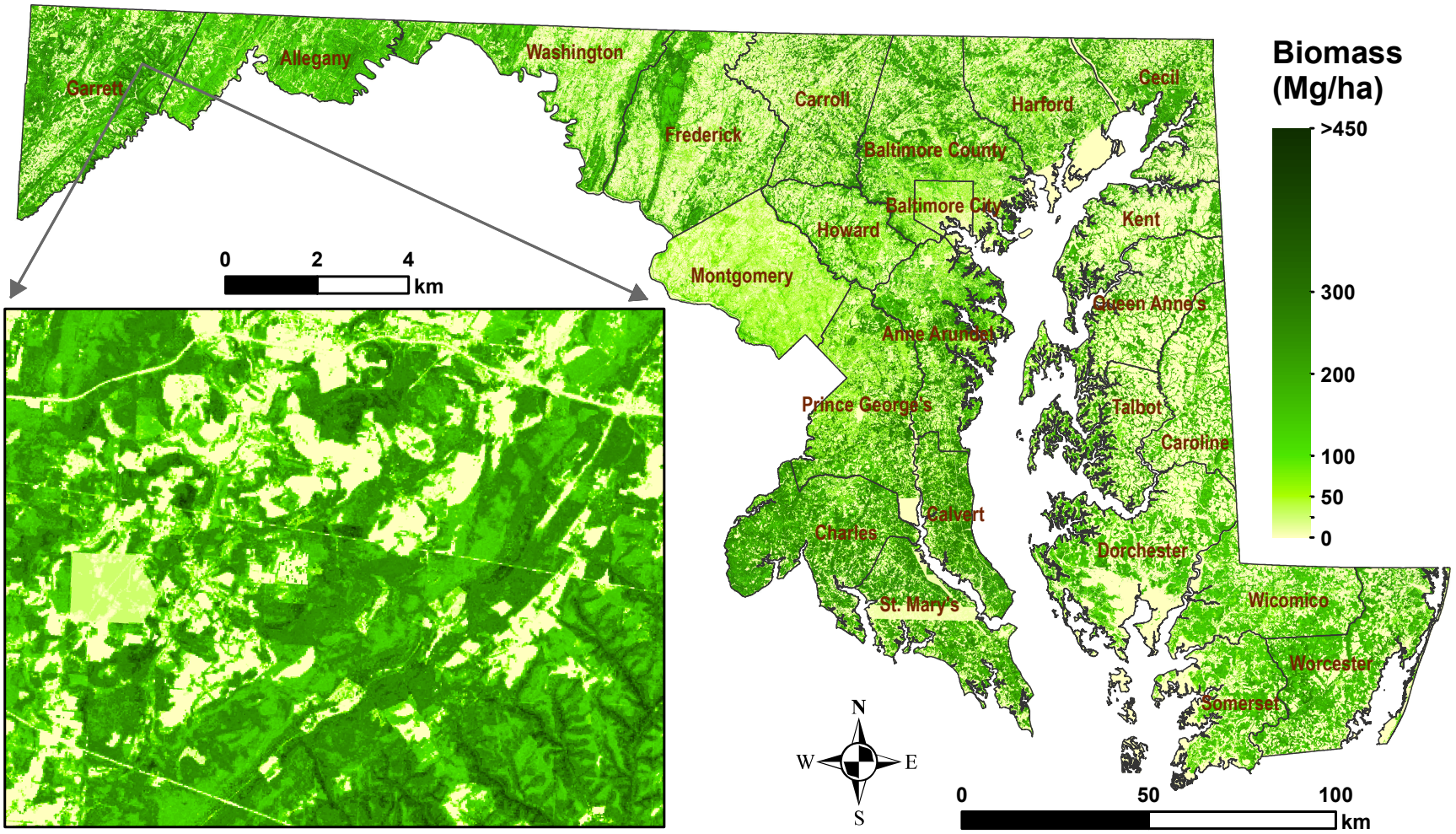
1. Tree Canopy Cover [1 m]



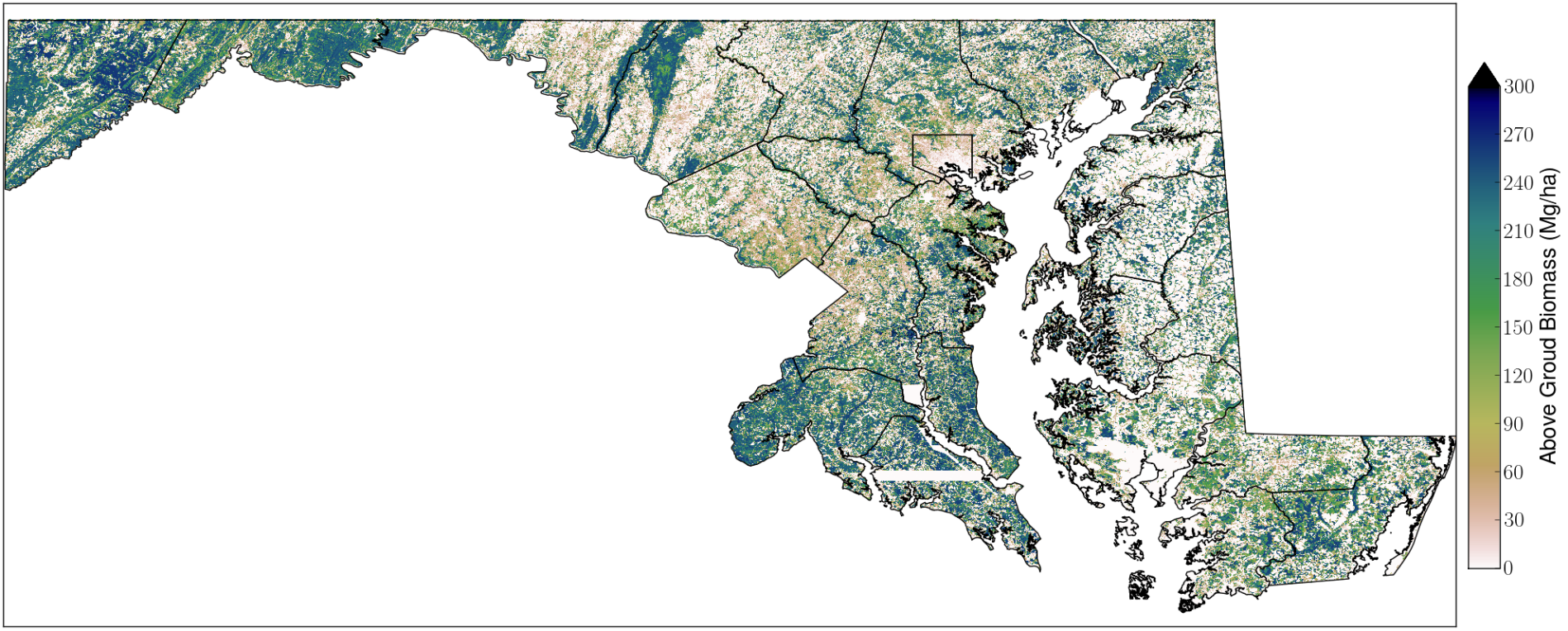
2. Canopy Height [1 m]



3. Empirical Biomass [30 m]



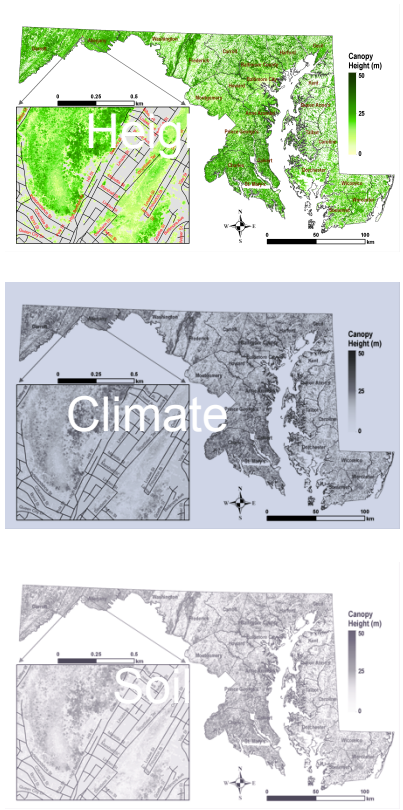
4. ED Model Biomass [90 m]



- High-resolution modeling computationally intensive
  - 72,000 for 0.5° x 0.5° global modeling
  - 7,900,000 for 90 m Maryland modeling
  - 2 days processing on medium-size super computer

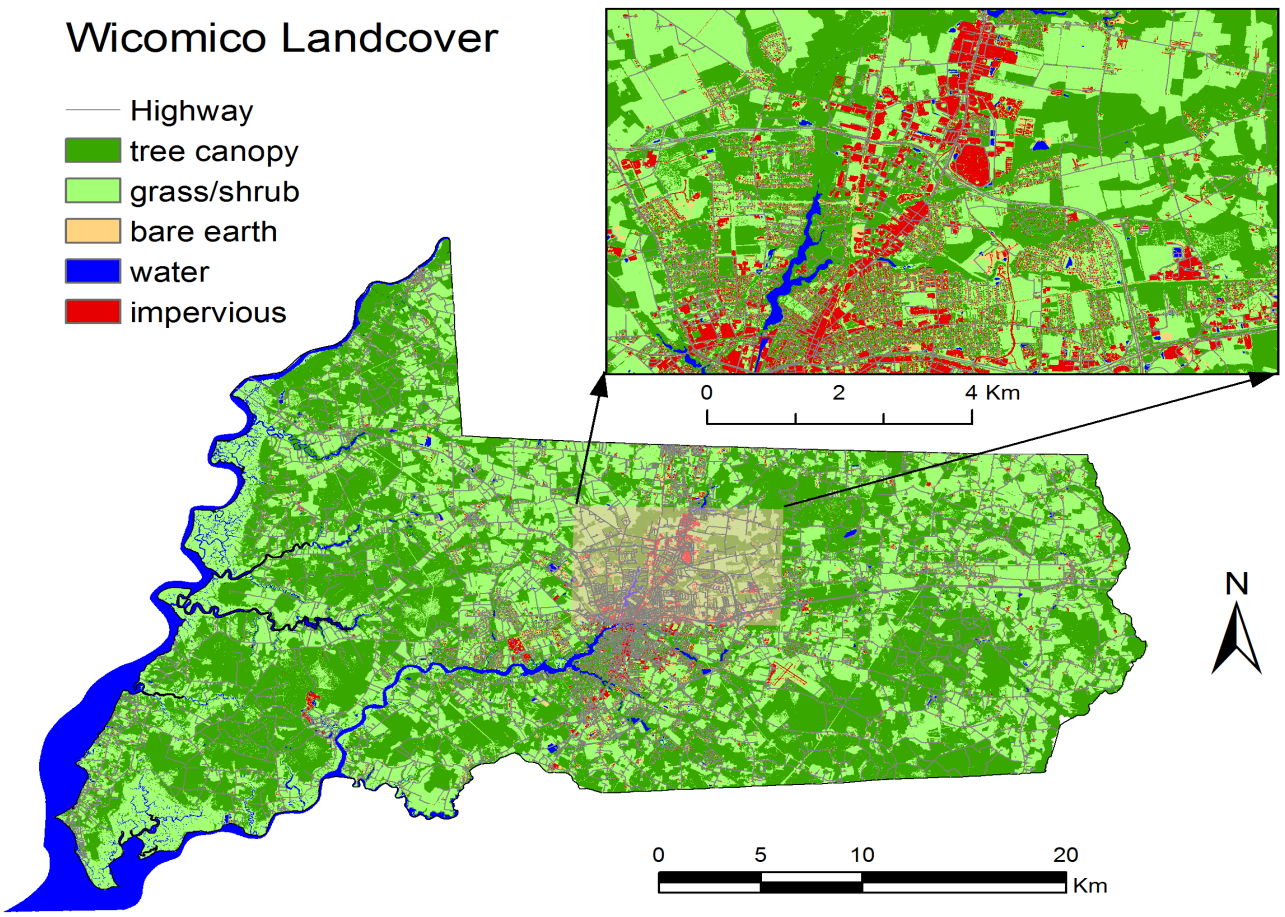
ED: Prognostic Ecosystem Modeling

- Height-structured ecosystem model
- Initialized with lidar height



Ecosystem
Demography
Model
(ED)

5. Impervious Cover Map-Wicomico County



- Map is a classified landcover map classfied using NAIP imagery and Lidar
- Following counties have impervious cover maps: Ann Arundel, Baltimore City, Baltimore County, Carroll, Harford, Howard, Montgomery, Prince George's, Wicomico
- 3 impervious classes are mapped: Building, roads and "other paved"

To map the remainder of the state funding is needed. CMS allows us leverage to make a new state wide map.

Completed CMS MD/PA/DE Products

- MARYLAND
  - For all counties and as state mosaic
    - 1-2 m forest/non-forest
    - 1-2 m canopy height
    - 30 m canopy cover
    - 30 m canopy height
    - 30 m aboveground biomass and biomass density
  - Carbon model products (all counties/state)
    - 90 m biomass
    - 90 m stand age
    - 90 m carbon sequestration potential
    - 90 m sequestration gap (potential – gap)
    - 90 m age gap (time to reach sequestration potential)
- DELAWARE
  - 1m land cover (including canopy cover)
- PENNSYLVANIA
  - 1m canopy cover
  - 1m land cover coming soon

Previous Stakeholder Engagement

- CMS & Maryland DNR Applications Workshop: Identifying the Benefits of Lidar for Maryland at the County Level
  - Identified the benefits for using Lidar at the county level in Maryland.
- CMS & Maryland DNR Applications Workshop: Economic Analysis of LiDAR Applications
  - Presented results from a CMS sponsored economic analysis that helps quantify the impact of Maryland DNR's Lawn to Woodland Initiative.
- Delaware Geographic Data Committee Meeting

&
Better Forest Management Decisions Using LiDAR Products

25
Thursday

About Our Speakers

Christine Conn is the Director of Integrated Policy and Review Unit at Maryland Department of Natural Resources (DNR). She focuses on developing land conservation priorities and scorecards through GreenPrint, communicating conservation and restoration priorities through GIS interactive mapping solutions and targeted outreach to local governments and sister state agencies, and developing approaches to more fully integrate ecosystem service values in decision frameworks.

Rob Feldt received a BS in Forestry from Virginia Tech in 2004 and a Master of Forestry in 2006. He has worked with the Maryland Forest Service since 2004 and has been working with its Forest Resource Planning section since 2008. Recent projects have involved writing an assessment of Maryland's forests, assisting the DNR Marcellus Shale review team on forestry issues, mapping riparian forest buffers, and various other mapping projects. He is currently serving as the Chair of the Maryland/Delaware Division of the Society of American Foresters and the Database Chair for the Maryland Tree Farm Committee.

About the Talk

APPLICATIONS: The LiDAR technology poses numerous opportunities for accurate and precise data collection that can help Maryland DNR set, progress, and evaluate its environmental policy goals. From shoreline mapping and change analysis to ecological restoration, we will discuss how the Maryland DNR seeks to incorporate Lidar data at its programmatic and policy-level decisions.

FOREST: The potential for LiDAR to influence forest management decisions is well known, but mostly utilized only locally. Recently acquired LiDAR products for the entire State of Maryland offer unprecedented accuracy and precision at the statewide level. We will discuss how these new data products can help us make forest management decisions, how we proceed in a tight budget environment, how LiDAR may help answer other natural resource problems, and what the future of LiDAR in natural resource management could look like.

Slides

PDF of slides – Maryland Department of Natural Resources (DNR) Applications Using LiDAR Data: The Big Picture

PDF of slides – Better Forest Management Decisions Using LiDAR Products

Recording

View Talk directly on YouTube

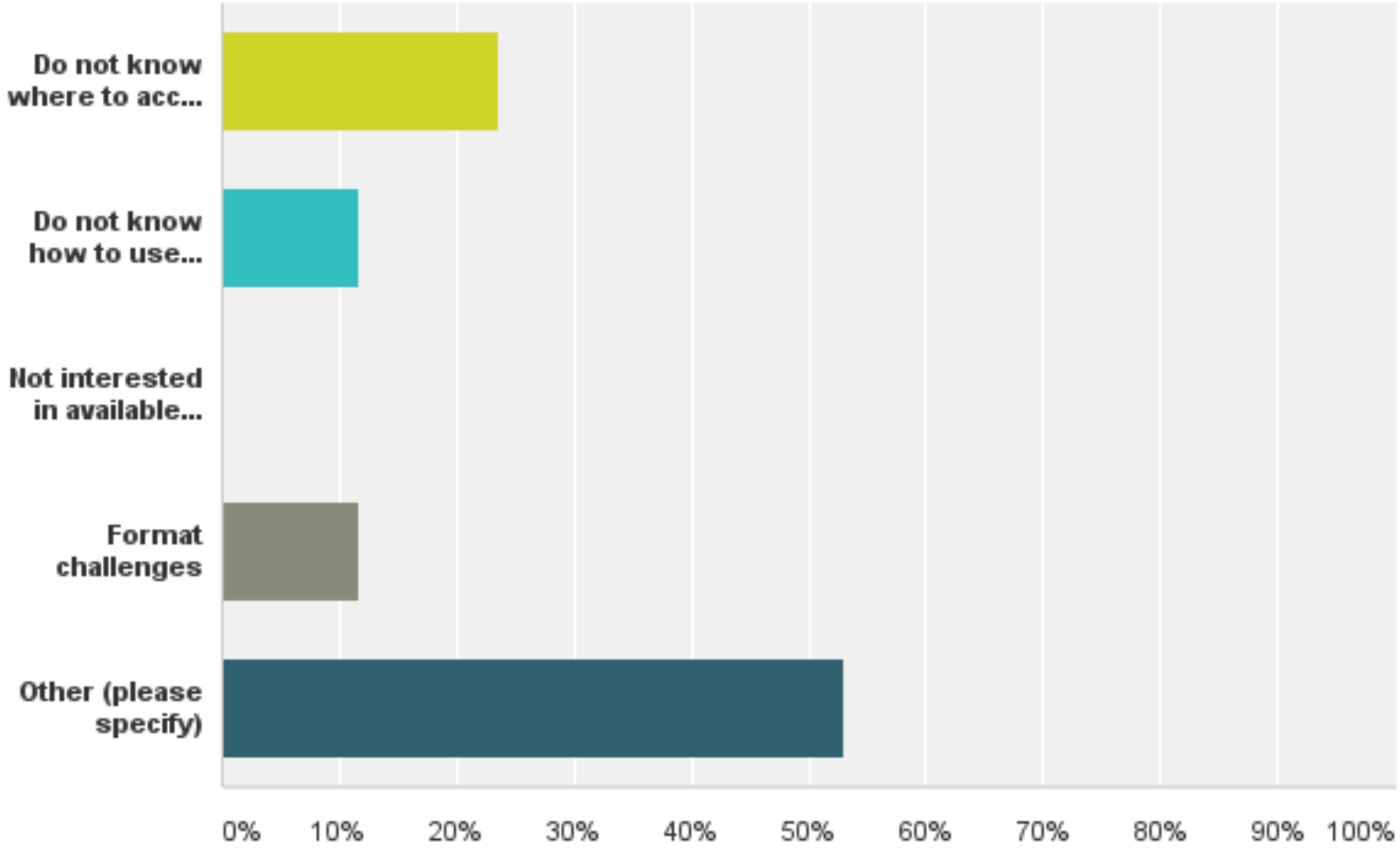
This talk was held at NASA Goddard Space Flight Center on September 25, 2014, as part of the Carbon Monitoring System Applications Policy Speaker Series.

MD Lidar Applications and User Survey

- Lidar products being used mostly by local government (counties) and some at state government
- Most users access the data products online – importance of MD iMAP and DE FirstMap
- Most common Lidar products accessed are 6-inch/pixel Orthos, 1-meter Bare Earth DEM, and 1-meter Canopy Cover Raster
- Some of the uses of the 1m canopy cover raster include: overlay analysis; assess properties for conservation; forest cover and biomass estimates; supplement field observations; and evaluate coastal forests.

Q9 What prevents you from accessing Maryland DNR lidar products?

Answered: 17 Skipped: 11



Future Work

- CMS and Lidar Applications and Use Survey for stakeholders in Delaware and Pennsylvania
- Report at the end of 2017 describing the uses and benefits of Lidar and CMS products for the Tri State Area state and local government agencies
- Explore the potential of expanding the project to other Northeast and Mid-Atlantic states
- Identify vehicle to fund continued use of Lidar (repeat every 5 years) for canopy height/cover and biomass

Workshop Outcome

- Expose stakeholders on how to use CMS data products, and on the value, applications and uses of LiDAR data
- Receive feedback and guidance on how agencies can use and apply CMS data products to achieve the goals of state climate action plans
- Develop a Tri State Working Group for updates on state needs and CMS products

Discussion Questions

- What is the status of the different state climate change action plans?
- What are the current mitigation strategies to achieve the proposed GHG reductions?
- What are specific **forestry programs and initiatives** that will contribute towards these mitigation targets?
- How can LiDAR and CMS data products contribute towards these state mitigation targets and forestry programs and initiatives?
  - Aboveground biomass maps – 30m Resolution
  - ED based maps of carbon sequestration potential – 90m Resolution
  - 1m canopy cover maps
  - Lidar Point Cloud
  - 1-meter Bare Earth DEM

Contact us!

- George Hurtt: gchurtt@umd.edu
- Vanessa Escobar: vanessa.esocbar@nasa.gov
- Katelyn Dolan: kdolan@umd.edu
- Edil Sepulveda Carlo: edil.sepulvedacarlo@nasa.gov
- Jarlath O'Neil Dunne: Jarlath.ONeil-Dunne@uvm.edu

Addressing Climate Change in Pennsylvania

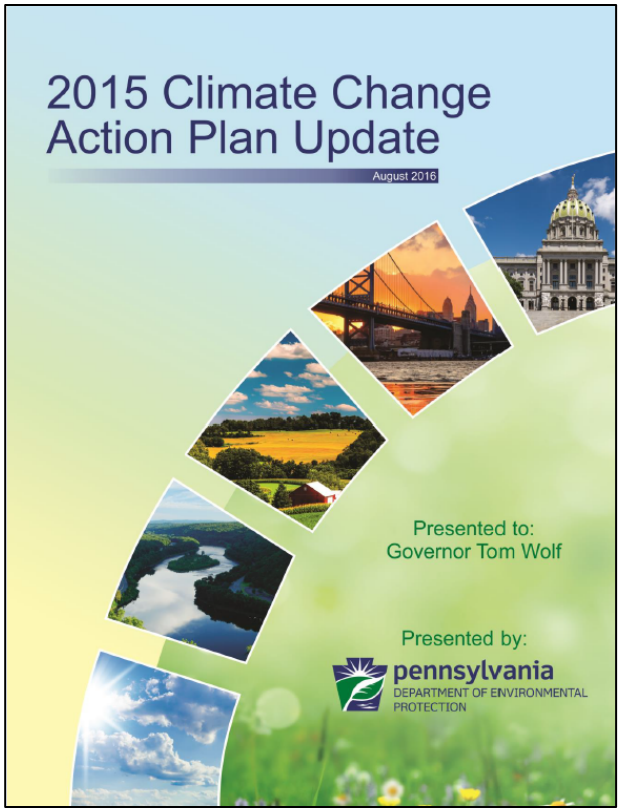
Greg Czarnecki
Climate Change & Research Coordinator

pennsylvania
DEPARTMENT OF CONSERVATION
AND NATURAL RESOURCES

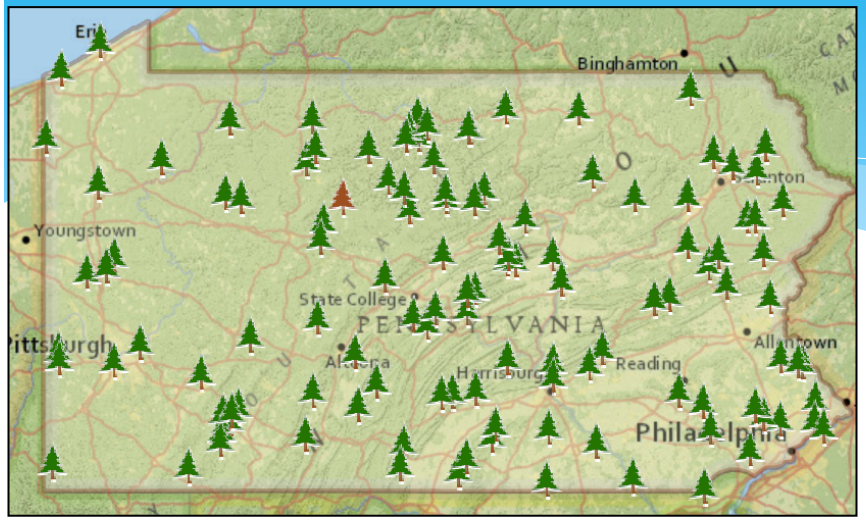
Pennsylvania Climate Change Act

Forestry Component

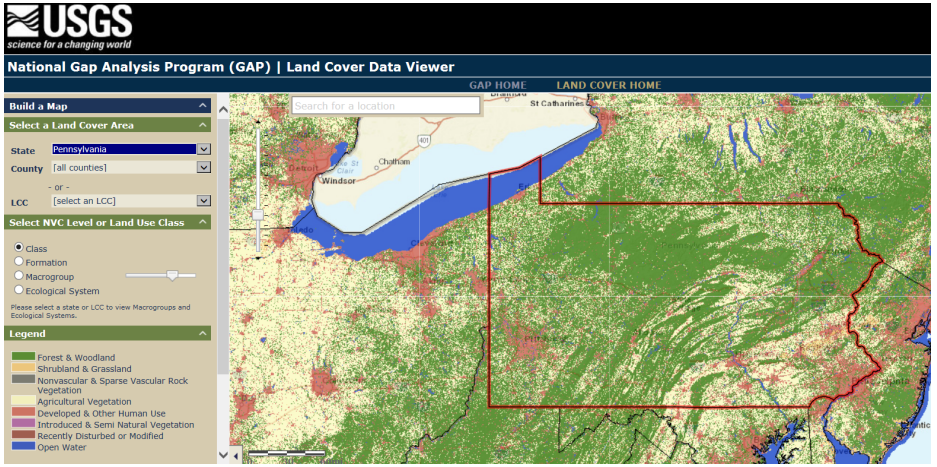
- Urban and community forest focus
- i-Tree Vue
- Goal: Maintain and/or increase urban tree cover

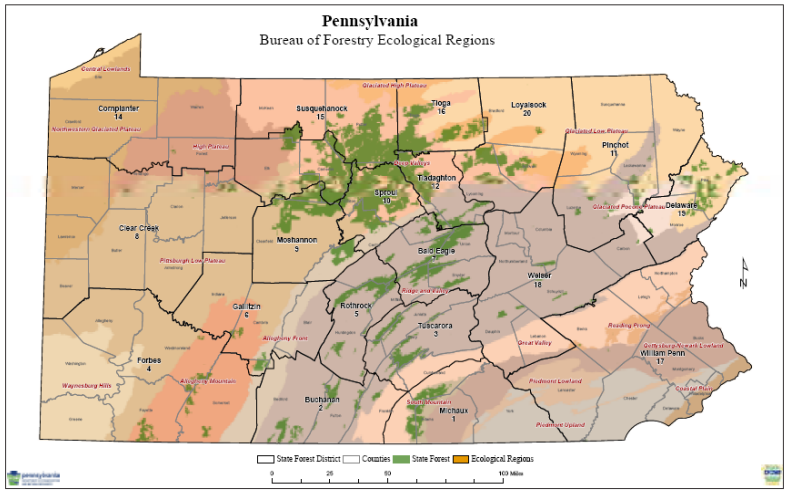


pennsylvania
DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES



120 State Parks

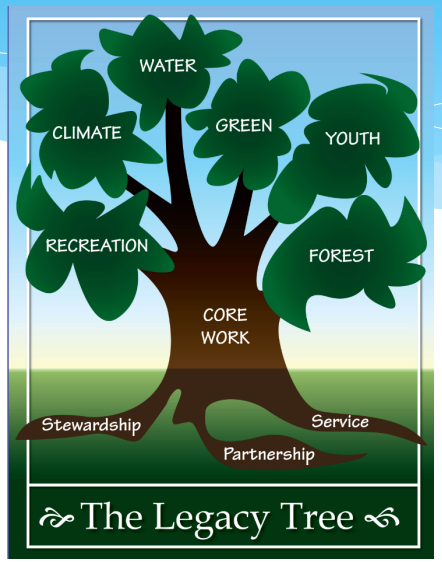


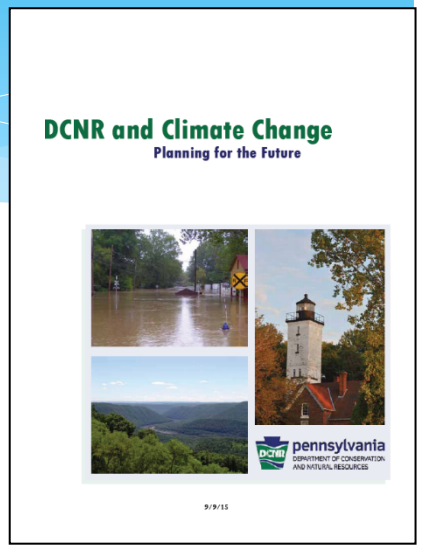


2.2 Million Acres of State Forest

DCNR's Climate Change Goals

- Maintain healthy, diverse forests that sequester an increasing amount of carbon
- Understand the current & developing impacts of climate change on DCNR's mission and lands
- Reduce our carbon footprint
- Identify vulnerabilities and implement a climate change adaptation plan





NIACS
Northern Institute of Applied Climate Science

NASA's Carbon Monitoring System & USDA Forest Service 2016 Applications Workshop & Tutorial: "*LiDAR and CMS Applications, Uses & Lessons Learned in the Tri-State Area of Maryland, Delaware and Pennsylvania*"

September 9, 2016

Shawn L. Lehman
PA DCNR Bureau of Forestry

CMS for Carbon Monitoring Needs

Current approach to forest carbon MRV in the state of Pennsylvania

2006

- Carbon sequestration estimates on SFL.
  - Calculated an estimate of above ground carbon in standard tons.
  - Calculated annual growth estimate for projecting future above ground carbon estimates.

Data Sources

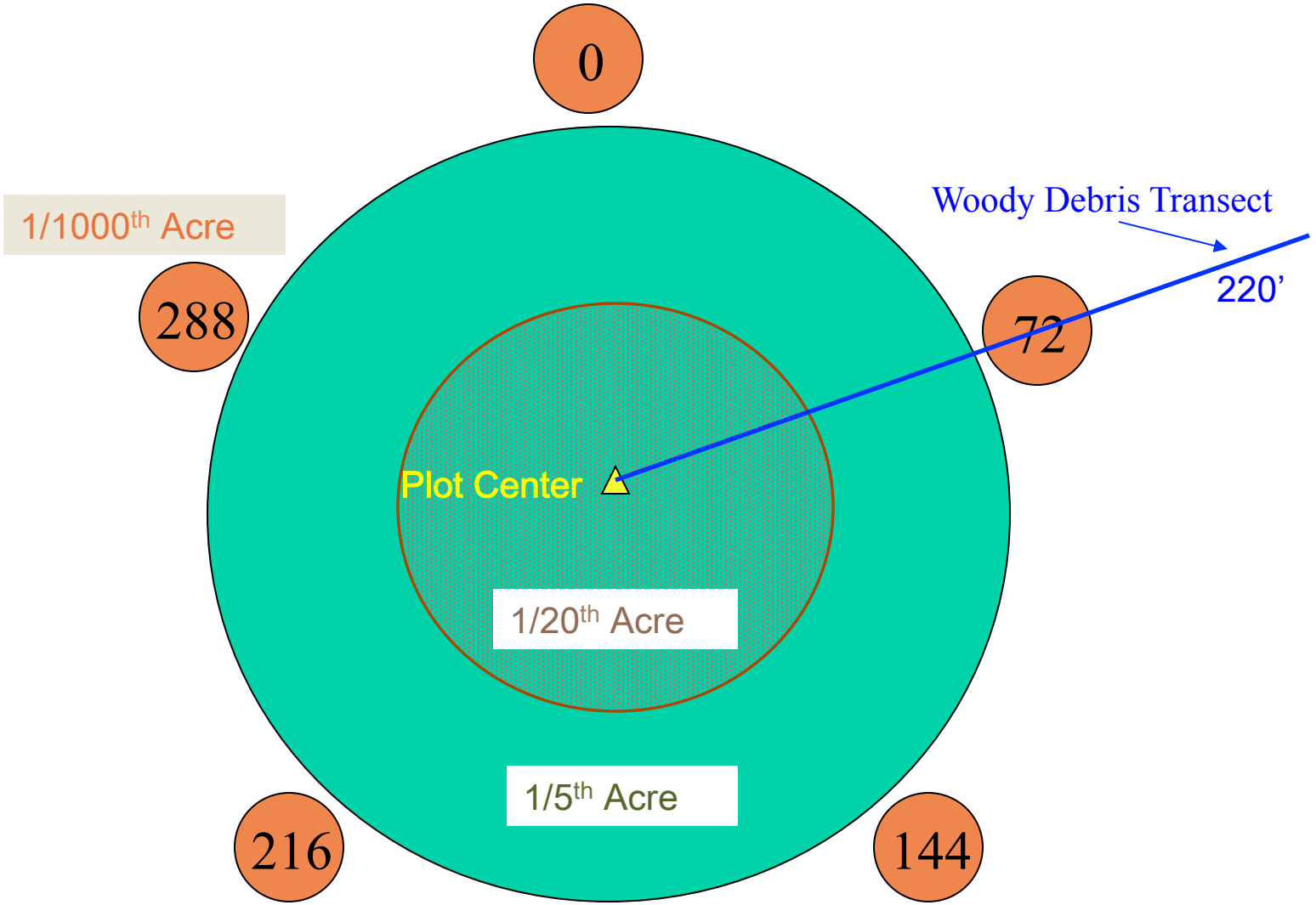
- BOF Forest Community Classifications
  - All SFL delineated into stands (>70,000)
    - Management Zone (7)
    - Forest Community
      - 24 Terrestrial
      - 12 Palustrine
      - Numerous woodland, herbaceous and non-forest types
    - Site Class (3)
    - Size/Stocking (8)
    - Commercial Availability (2)

M AH 2 2 C

Data Sources

- BOF Continuous Forest Inventory (CFI)
  - Cycle 1: 1997-2000
  - 790 inventory plots

CFI Plot Diagram



Data Sources

- BOF Continuous Forest Inventory (CFI)
  - Cycle 1: 1997-2000
  - 790 inventory plots

  - Cycle 2: 2003-2008, 1701
  - Cycle 3: 2009-2014, 1664
  - Cycle 4: 2015-2019, ~1500

Approach

1. Cross-walked BOF Forest Community Types to US Forest Service species groups.
2. Generated outputs for above ground biomass.
   - Jenkins, et al. coefficients (GTR-319).
   - Values summed by forest type.
   - Generated per acre biomass estimates by Forest Community.

Approach

3. Converted bone dry biomass estimates to carbon.
   - Multiply by 0.5.
   - UN IPCC and US 1605(b) guidelines.

Units Per Acre BOF Forest Community Type	Bone dry Biomass Metric Tonnes	Biomass 3% AG – Metric Units	Carbon Metric Tons	Carbon 3% AG - Metric	Bone dry Biomass Standard Tons	Biomass 3% AG – US Units	Carbon Standard Tons	Carbon 3% AG – US Units
AD - White Oak	90.66	2.72	45.33	1.36	99.91	3.00	49.95	1.50
AH - Oak Heath (Chestnut Oak)	76.25	2.29	38.13	1.14	84.03	2.52	42.01	1.26
AR - Red Oak	106.27	3.19	53.13	1.59	117.11	3.51	58.55	1.76
BB - Northern HW	105.05	3.15	52.52	1.58	115.76	3.47	57.88	1.74
BC - Black Cherry	109.40	3.28	54.70	1.64	120.56	3.62	60.28	1.81
CC - Red Maple	82.12	2.46	41.06	1.23	90.50	2.71	45.25	1.36
CS - Sugar Maple/ Basswood	89.63	2.69	44.82	1.34	98.78	2.96	49.39	1.48
DD - Aspen/Birch	92.59	2.78	46.30	1.39	102.04	3.06	51.02	1.53
EO - Pitch Pine/ Oak	55.62	1.67	27.81	0.83	61.30	1.84	30.65	0.92
FA - Dry White Pine/Oak	71.44	2.14	35.72	1.07	78.72	2.36	39.36	1.18
FB - Hemlock/ White Pine/NH	109.83	3.30	54.92	1.65	121.04	3.63	60.52	1.82
FF - Hemlock/White Pine	112.74	3.38	56.37	1.69	124.24	3.73	62.12	1.86
FM - Hemlock/Rich Mesic HW	75.61	2.27	37.80	1.13	83.32	2.50	41.66	1.25
FR - Hemlock/Red Oak	114.47	3.43	57.23	1.72	126.15	3.78	63.07	1.89
FT - Hemlock/Tulip	134.72	4.04	67.36	2.02	148.46	4.45	74.23	2.23
GB - Black Gum	51.60	1.55	25.80	0.77	56.86	1.71	28.43	0.85
MM - Mixed Mesophytic	118.37	3.55	59.18	1.78	130.44	3.91	65.22	1.96
O5 - Woodland	49.21	1.48	24.60	0.74	54.23	1.63	27.11	0.81
TM - Tulip/Beech/ Maple	109.45	3.28	54.72	1.64	120.61	3.62	60.30	1.81

Approach

4. Used current GIS layer of Forest Communities to generate an acreage estimate of each type.

Approach

5. Applied the per acre estimates of carbon by forest type to the acreage estimates of each Forest Community type.
   - Carbon estimate for SFL.
   - Total SFL system:
     - 95,784,212 metric tonnes
     - 105,512,461 standard tons

Approach

6. Calculate annual growth on SFL.
   - From CFI Cycle 1 inventory:
     - 3.4% annual growth.
     - 3,256,663 metric tonnes
     - 3,587,423 standard tons

Application

- Carbon sequestration projection estimates based on 2006 calculations with a 3.4% growth rate.

Projection Estimates

Year	Annual above ground sequestration (standard tons)	Above ground carbon (standard tons)
2006		105,512,461
2007	3,587,424	109,099,885
2008	3,709,396	112,809,281
2009	3,835,516	116,644,797
2010	3,965,923	120,610,720
2011	4,100,764	124,711,484
2012	4,240,190	128,951,675
2013	4,384,357	133,336,031
2014	4,533,425	137,869,457
2015	4,687,562	142,557,018
2016	4,846,939	147,403,957
2017	5,011,735	152,415,691
2018	5,182,134	157,597,825
2019	5,358,326	162,956,151
2020	5,540,509	168,496,660
2021	5,728,886	174,225,546

Citations

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CMS for Wetland Carbon Monitoring and Assessment in the state of Delaware

Kari St.Laurent, Ph.D.

Delaware National Estuarine Research Reserve

September 9th, 2016

DELAWARE COASTAL PROGRAMS

DCMP

National Estuarine Research Reserve System

Delaware Coastal Programs

The Delaware Coastal Programs (DCP) is a cooperative program between the State of Delaware and the National Oceanic and Atmospheric Administration (NOAA). The DCP helps manage Delaware's federal coastal zone and balance the use and protection of its resources through the combined efforts of the Delaware Coastal Management Program and Delaware National Estuarine Research Reserve.

DCMP

DELAWARE COASTAL MANAGEMENT PROGRAM

The Delaware Coastal Management Program

works to protect, develop, and where possible enhance the coastal resources of the State through the implementation of the federal consistency program, coastal and ocean resource planning, and by providing technical and financial assistance to address coastal management issues.

The Delaware National Estuarine Research Reserve serves to preserve and manage the natural resources within the Reserve as a place for research, provide education and outreach programs that promote better understanding of Delaware's estuarine and coastal areas, and promote informed coastal decision-making.

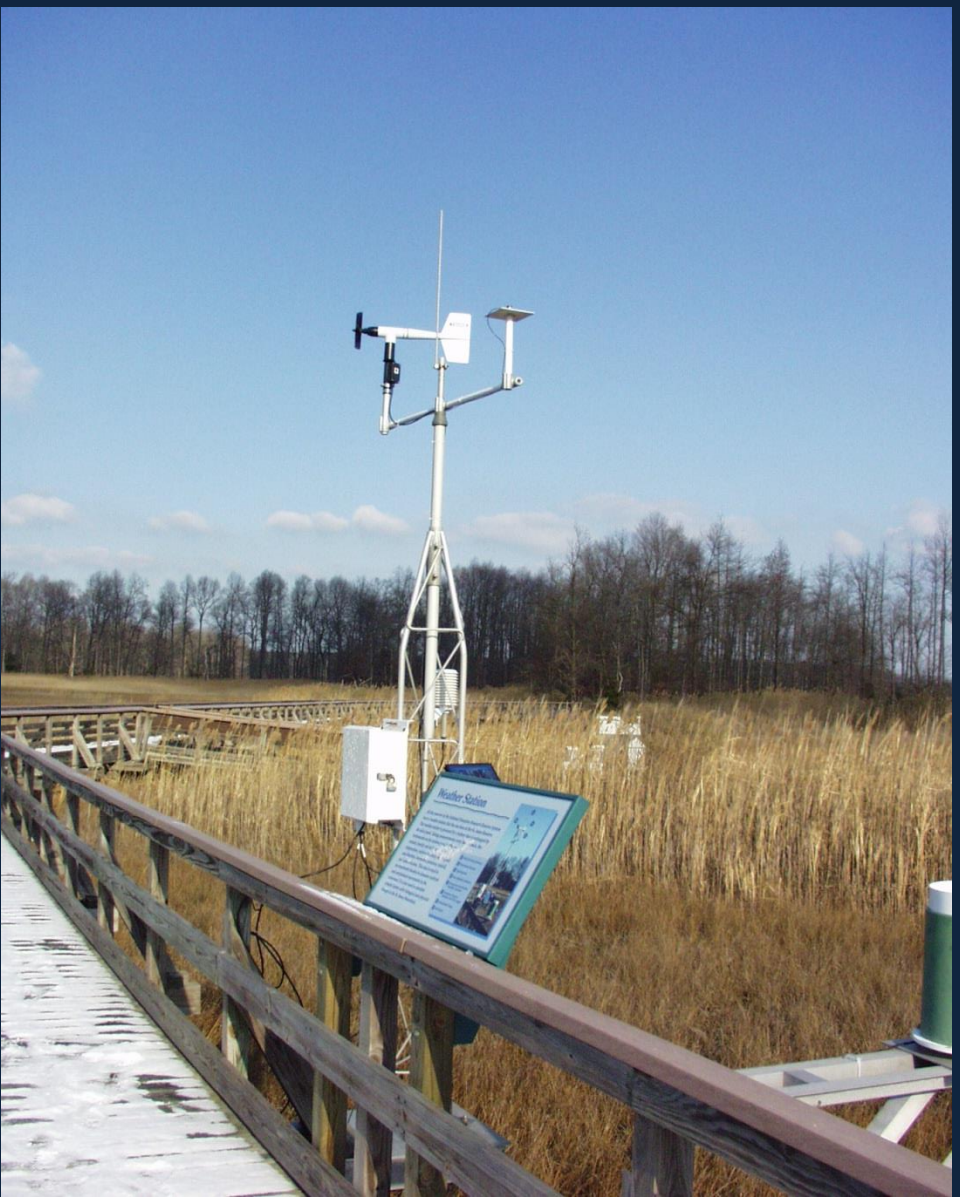
Delaware National Estuarine Research Reserve

5 Priority Research Areas

1) Habitat and ecosystem processes
2) Anthropogenic influences on estuaries
3) Habitat conservation and restoration
4) Species management
5) Social science and economics

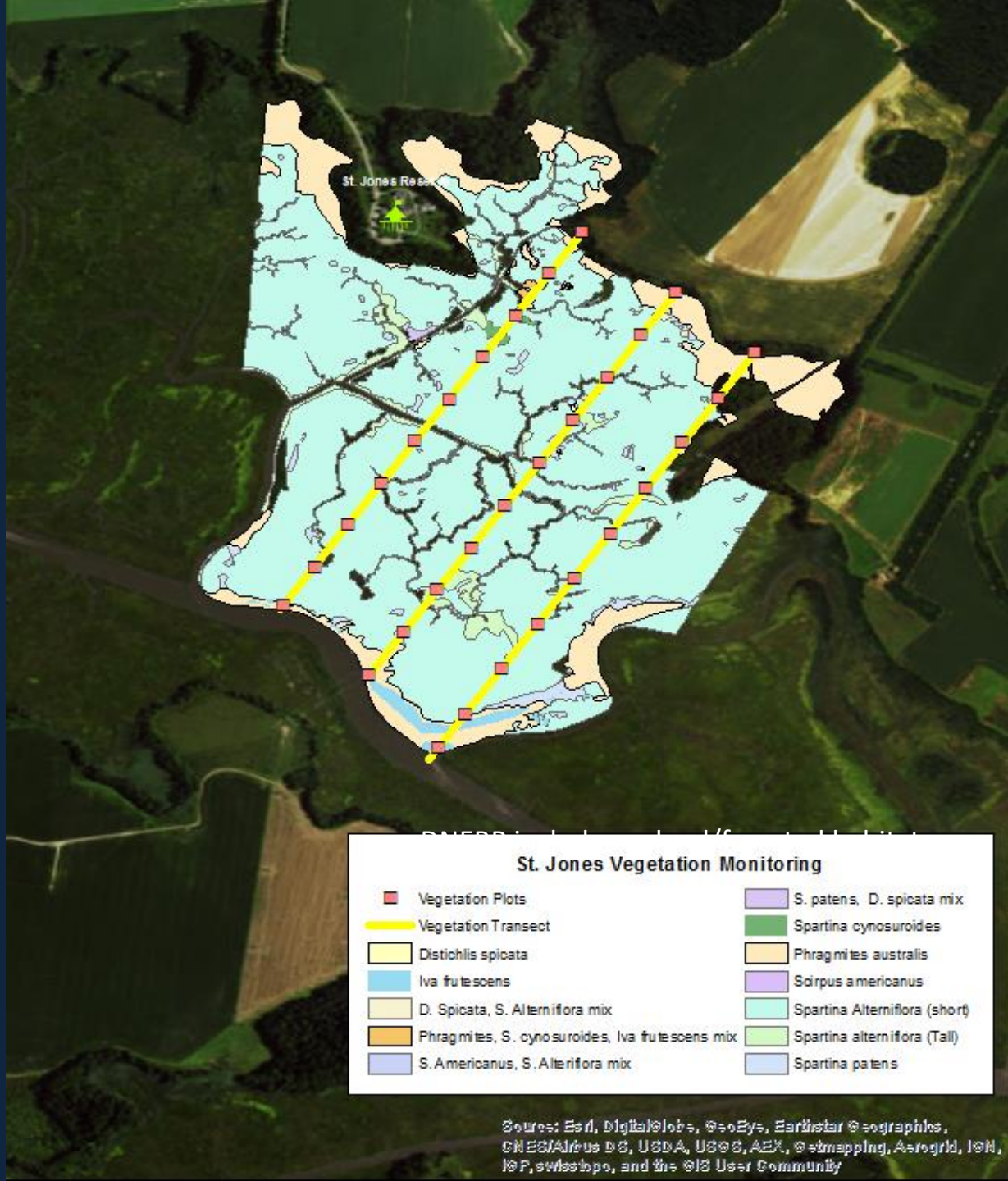
Provide defendable, data-driven research to inform decision-makers, land-managers, and individuals

Becoming a Sentinel Site to understand the effects of Climate Change



SSAM-1: What are the long-term changes to vegetation communities and sediment elevation resulting from changes in local water levels and inundation patterns?

-Abiotic parameters (met and WQ)
-Emergent tidal marsh vegetation monitoring
-Surface Elevation Changes (SETs)
-Vertical Reference System


St. Jones Reserve
St. Jones Vegetation Monitoring
Vegetation Plots
Vegetation Transect
Distichlis spicata
Iva frutescens
D. Spicata, S. Alterniflora mix
Phragmites, S. cynosuroides, Iva frutescens mix
S. Americanus, S. Alterniflora mix
S. patens, D. spicata mix
Spartina cynosuroides
Phragmites australis
Scirpus americanus
Spartina Alterniflora (short)
Spartina alterniflora (Tall)
Spartina patens
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Delaware National Estuarine Research Reserve:
Current Carbon Monitoring Efforts

- Conduct our own research
- Create data for management needs

- Support academic research
- Partner with NEP, NGOs, etc

- Education, outreach, enhance community resiliency

In progress: Spatial Variability in Carbon Storage Within and Across Marshes of the National Estuarine Research Reserve System (NERRS), USA: A Comparison of Methodologies and Coastal Regions

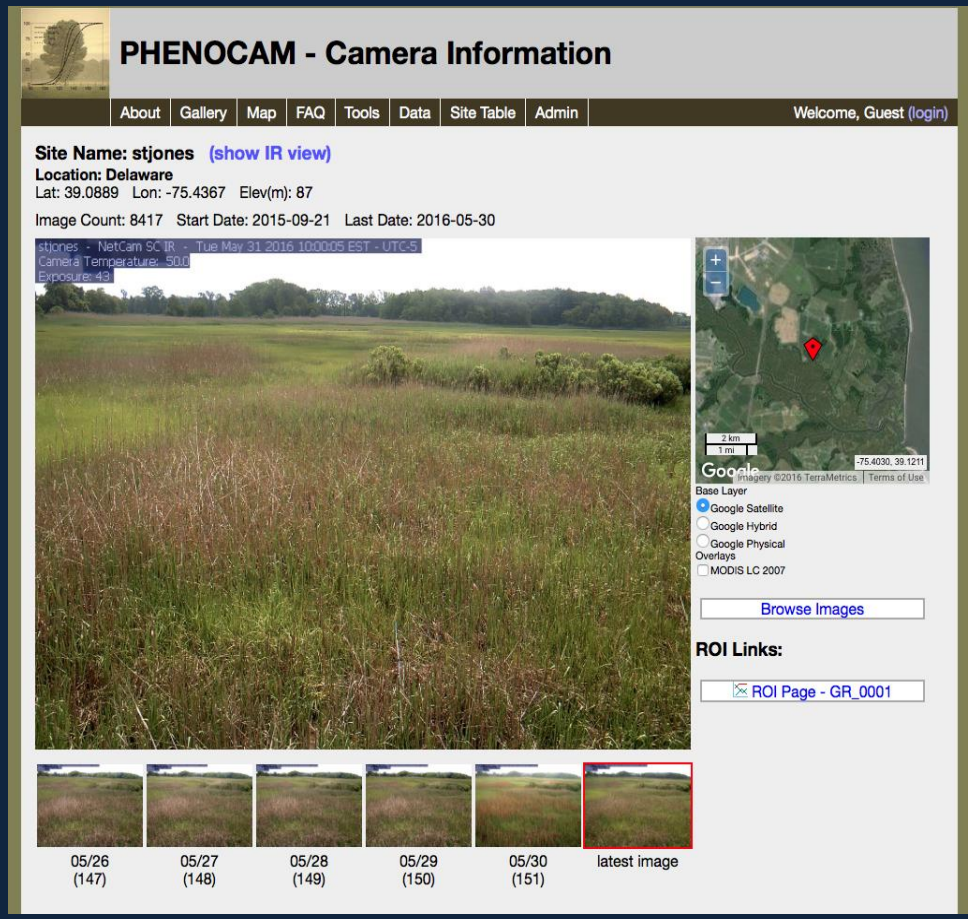
Goal: Quantify the marsh soil organic carbon content in 8 NERRs to better understand SOC variability in different marsh habitat types

In progress: Spatial Variability in Carbon Storage Within and Across Marshes of the National Estuarine Research Reserve System (NERRS), USA: A Comparison of Methodologies and Coastal Regions

- RC sector time: Blue Carbon (NASA carbon storage)
  - Led by Matt Ferner (SFB-NERR)

In Progress: A Framework for monitoring impacts of climate change on Blue Carbon in estuaries

- PI: Rodrigo Vargas and Angelia Seyfferth (UD)
- "Studying carbon dynamics in salt marshes using state-of-the-art approaches"



In progress: Effect of Hurricane Joaquin on the St. Jones Salt Marsh

Hypothesis: the salt marsh is very resilient.

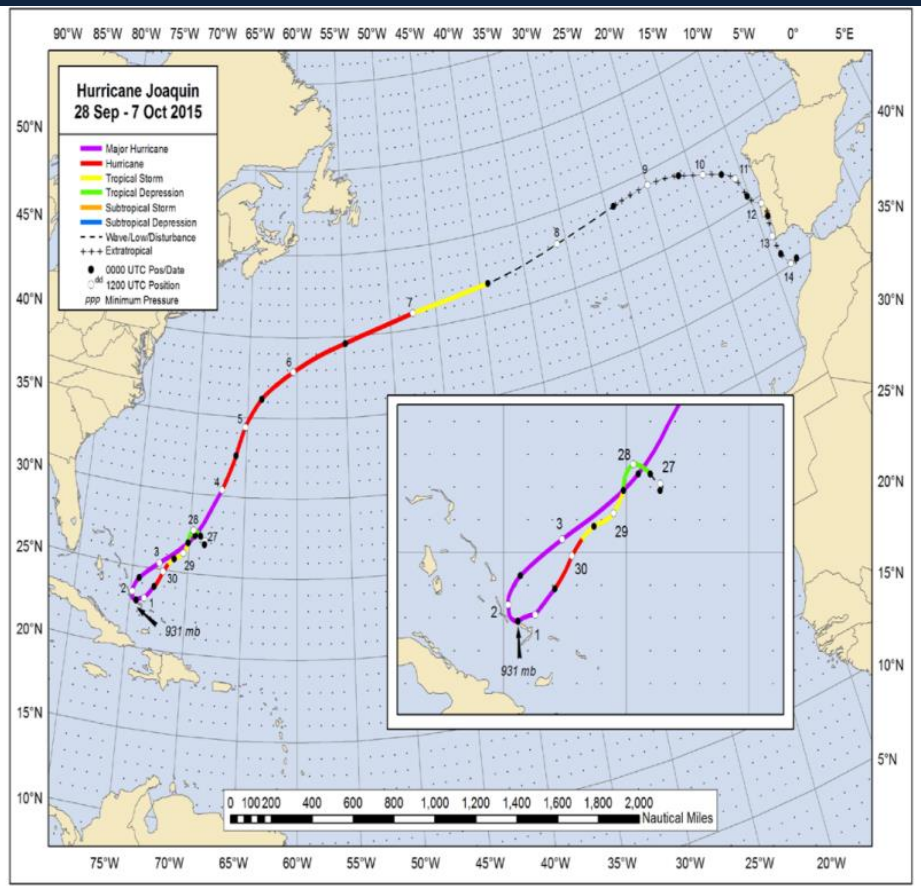
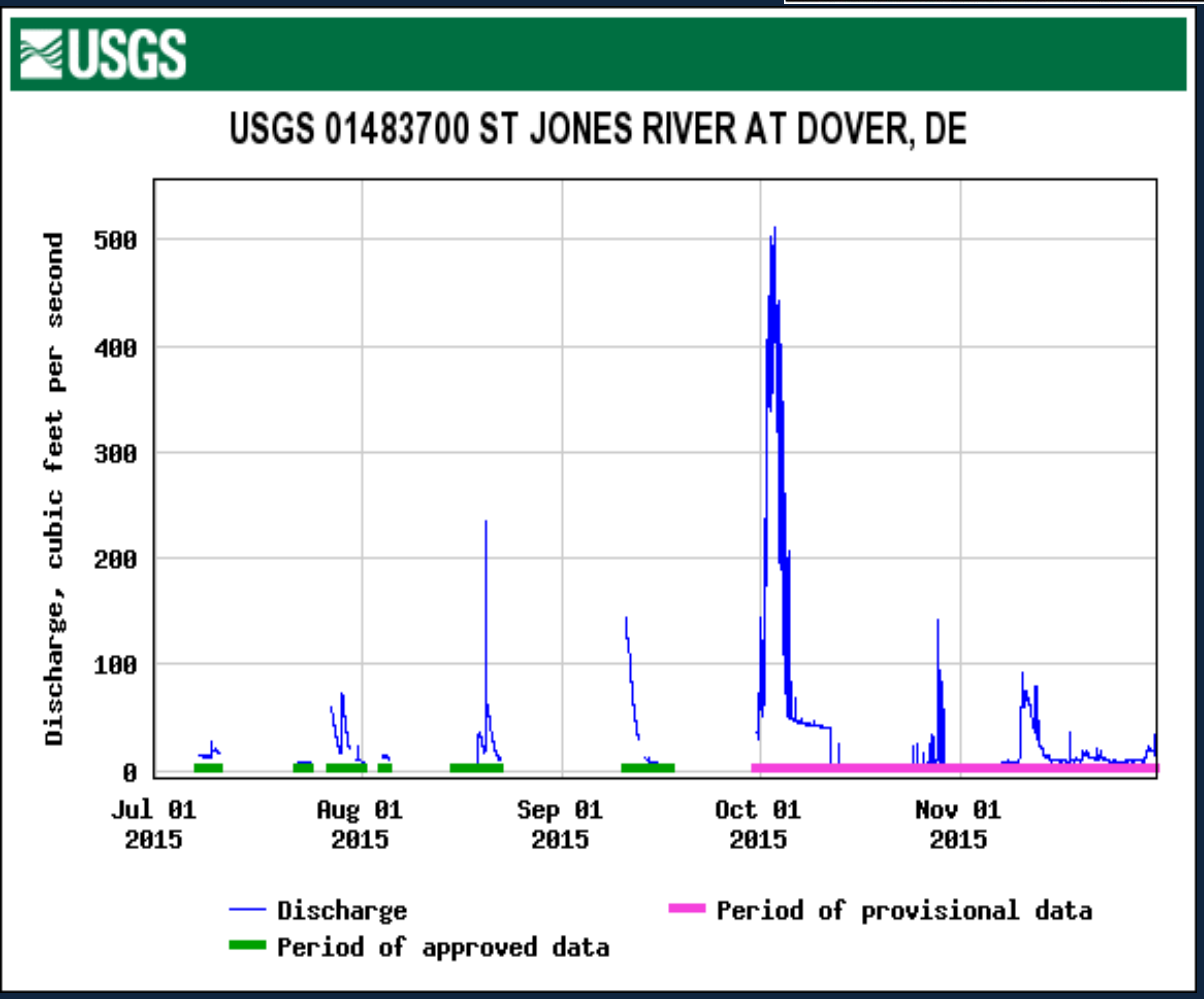


Figure 1. Best track positions for Hurricane Joaquin, 28 September – 7 October 2015. The track during the post-tropical stage is partially based on analyses from the NOAA Ocean Prediction Center.

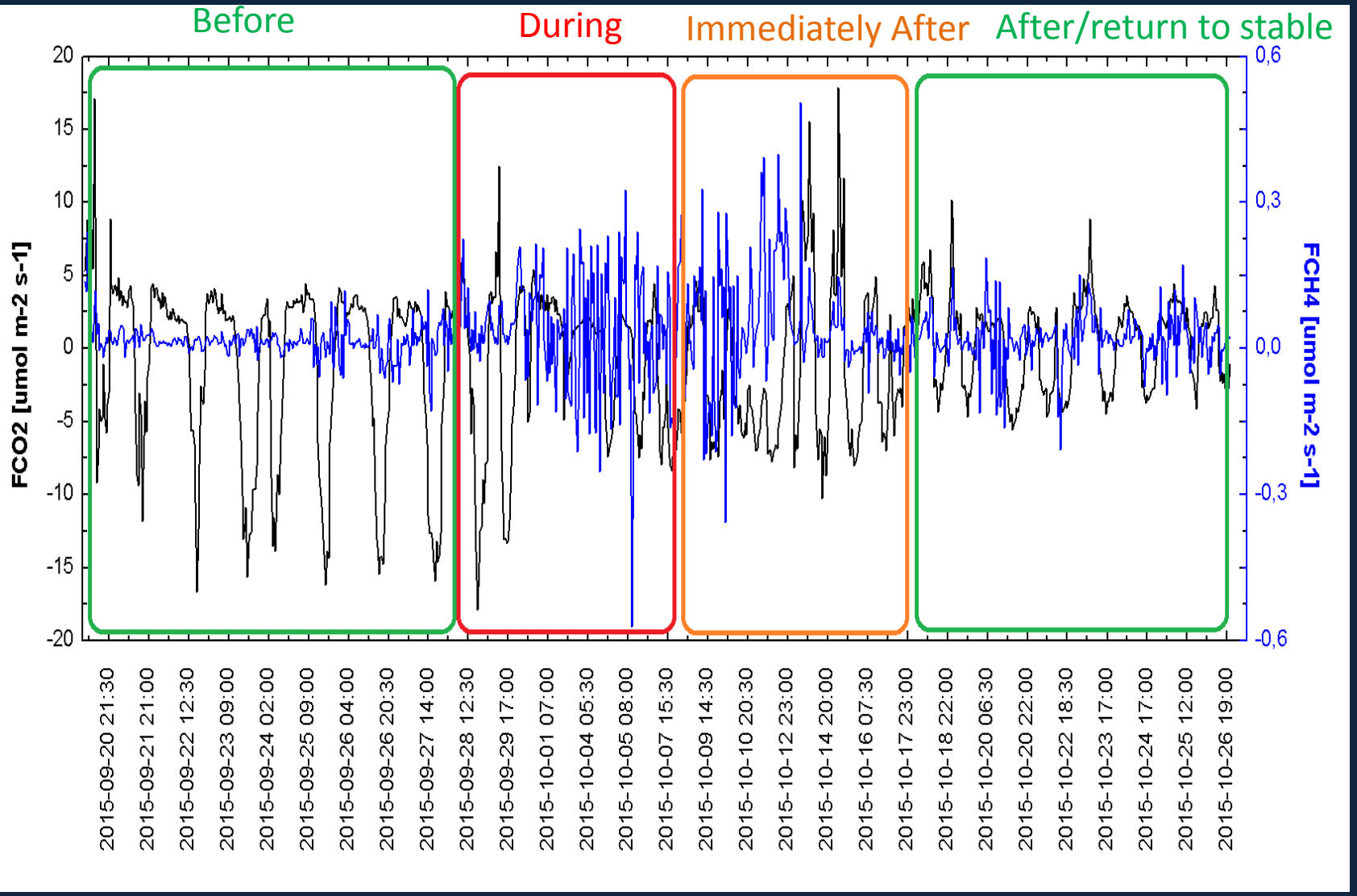
Hurricane Joaquin didn't affect directly, but it created a surge. It occured from 28 of September to 7 of October 2015 (Figure 1)

Research in preparation. Presentation prepared by Natalia Kowalska



Research in preparation.
Presentation prepared by
Natalia Kowalska

How did carbon dioxide and methane fluxe patterns respond to Hurricane Joaquin?



Research in preparation. Presentation prepared by Natalia Kowalska

Follow-up Study in Progress

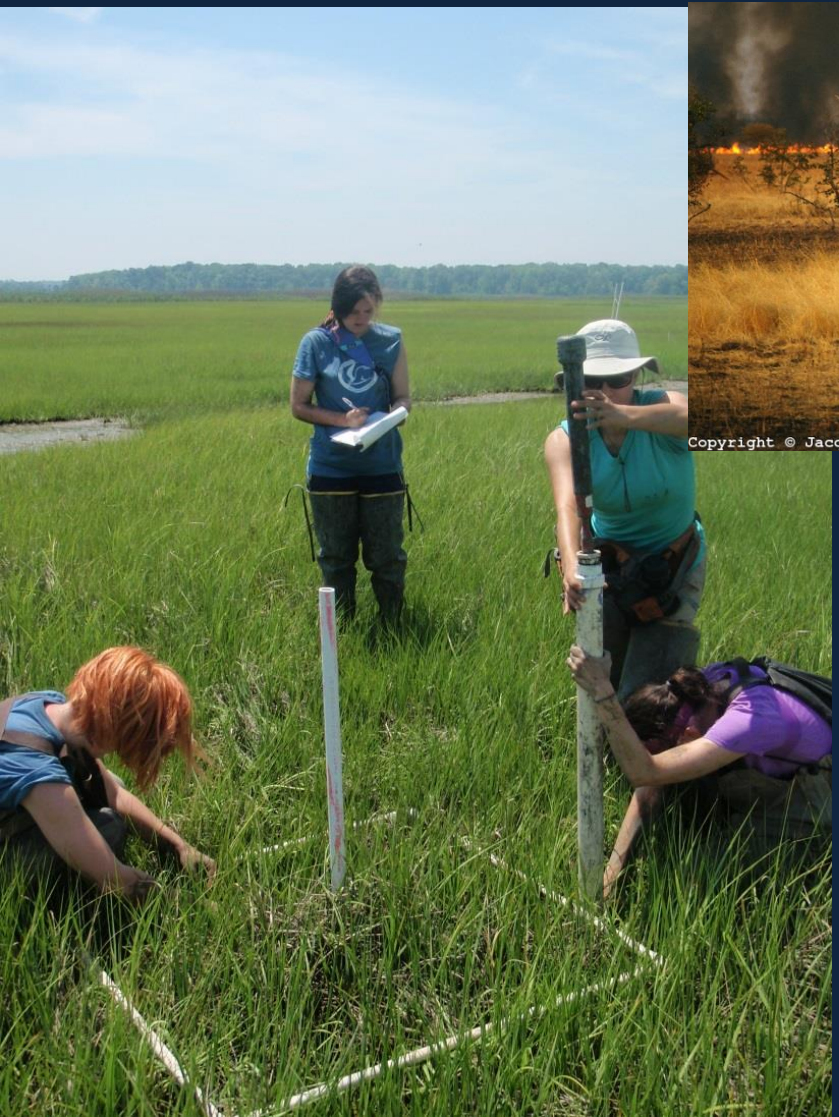
Other Projects to Highlight: Living Shoreline

"**Living Shorelines**: Coastal Resilience with a **Blue Carbon** Benefit"
(Atwood et al., 2015)

Research Questions
Data and analytical needs and gaps

- Quantify wetland carbon stocks and assess future changes
  - Help identify optimal land acquisitions
  - Identify ecosystem service changes
  - Ideal: Delaware-specific and updatable
- Close the blue carbon loop
  - What are the vertical and lateral C fluxes?
  - What are the spatiotemporal patterns?
  - Resiliency to large events (storms)?
- C-sequestration in different habitat types
  - Metabolic rate changes due to changes in redox conditions
  - Ecosystem service benefits of carbon storage (green vs gray)

Questions?
kari.stlaurent@state.de.us

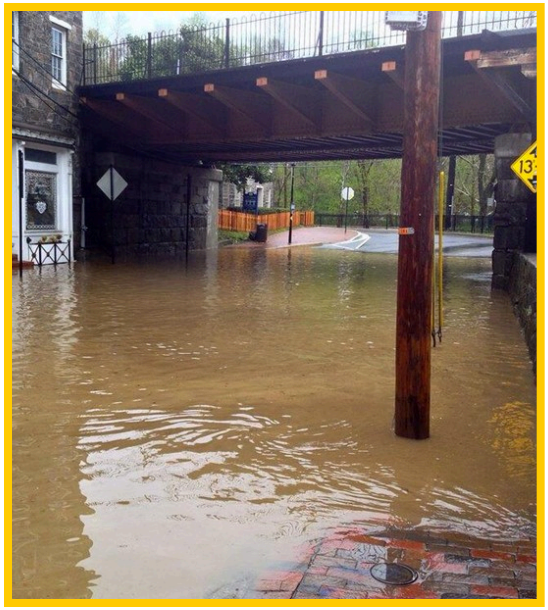


The Maryland Greenhouse Gas Emission Reduction Act

Elliott Campbell, PhD
Chesapeake and Coastal Service
Maryland Department of Natural Resources

Presentation Overview

- The Greenhouse Gas Emission Reduction Act (GGRA)
  - 2009 and 2016
- Forestry and Sequestration Sector
  - Specific Forestry Programs



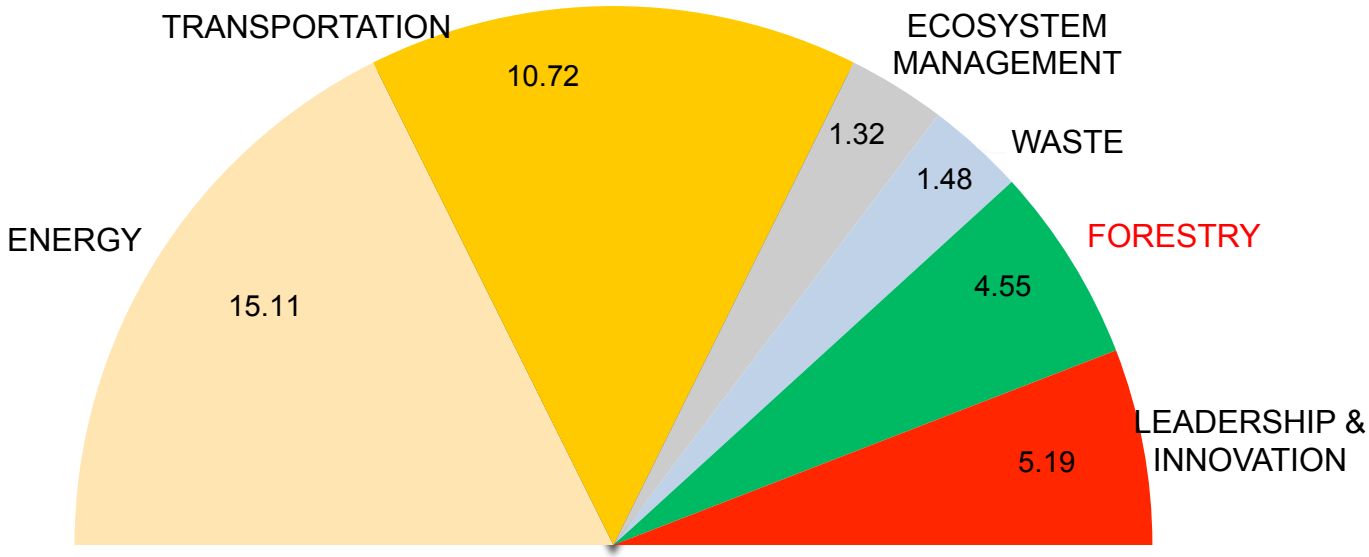
Greenhouse Gas Emission Reduction Act

- Originally adopted in 2009
- Administered by the Maryland Commission on Climate Change (MCCC)
- Required that Maryland develop and implement a plan to reduce greenhouse gas (GHG) emissions by 25% by 2020
- The law also requires that the plan support a healthy economy and create new jobs
- Required a status report/update from MDE in October of 2015
  - The update report summarized
    - Emission reductions
    - Economic benefits and jobs
    - How to move forward

GGRA 2020 Requirement
The Bottom Line

MARYLAND DEPARTMENT OF NATURAL RESOURCES

- The 25% by 2020 Reduction Requirement = 34.36 $MMtCO_2e$*
- Reductions expected by 2020 = 38.37 MMtCO2e



CO2 Emission Reductions by Sector (MMtCO2e)

* MMtCO2e = Million Metric Tons of Carbon Dioxide Equivalents

Economic Benefits and Jobs

- The 2015 GGRA Plan Update includes refined estimates of the economic benefits and job creation driven by the Plan
- Also includes real world examples of economic benefits and job creation
- Win, Win, Win programs are abundant – programs where we see reductions in GHG emissions, net economic benefits and additional new jobs

	2015 GGRA Update
Net Economic Benefit in 2020	$2.5 to $3.5 Billion in economic output
Jobs Created and Maintained in 2020	26,000 to 33,000 jobs

The GGRA of 2016

- Reauthorized and enhanced GGRA of 2016 signed into law on April 4, 2016
- Builds from the recommendations of the MCCC
- Core elements of new law
  - 40% reduction by 2030
  - Must support a healthy economy and create new jobs
  - Maintains structure and safeguards from 2009 law

GGRA - A Balanced Approach to Address Climate Change

- The law continues to include a balanced set of requirements and safeguards
  - GHG emission reductions, economic progress, new jobs and more…
- Key safeguards include:
  - Manufacturing sector not covered unless through a federal rule
  - Mid-Course status report from MDE on greenhouse gas (GHG) emission reductions, jobs and the economy
  - Mid-Course reaffirmation of goals by the General Assembly
    - … or the law sunsets

The Basic 40 by 30 Schedule

- 2016, 2017 and 2018 - MDE, other State agencies, MWG and stakeholders research and build the 40% by 2030 reduction plan
  - Stakeholder meetings across the State
- December 31, 2018 - Draft plan to Governor and General Assembly
- December 31, 2019 - Final plan to Governor and General Assembly
- October 1, 2022 - MDE owes mid-course status report
  - Emission reductions
  - Jobs, the economy … more
- October 1, 2022 – Manufacturing study due
- December 1, 2023 – Law terminates if not reauthorized

40 by 30 – What Do We Know?

- Many of the control programs in the current "25% by 2020" plan will continue to generate deeper reductions as they are implemented through 2030
  - Mobile source measures will be critical as federal rules kick in and fleets "turn over"
  - Energy sector reductions should also continue to increase
- Other factors should also be helpful in getting to 40 by 30
  - As we continue to improve reduction estimates, we may be able to use less cautious discount factors for projected benefits
    - We currently discount the credit for many measures by 30%
  - Natural gas and travel trends continue to be interesting

Transportation Sector

Key mobile source programs that will drive significant post-2020 reductions

State and Federal Mobile Source Programs
The Maryland Clean Cars Program
Federal Light Duty Fuel Economy (CAFÉ) Standards (2012 to 2016)
Federal Tier 3 Vehicle and Fuel Standards (2017 to 2025)
Federal Phase 1 Medium and Heavy Duty GHG Standards (2014 to 2018)
Federal Renewable Fuel Standards
Federal Phase 2 Medium and Heavy Duty GHG Standards (proposed)
Federal GHG Reductions from Aircraft (just starting)

Energy and Other Sectors

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Key Programs that will drive post-2020 reductions

Energy Sector
Regional Greenhouse Gas Initiative (RGGI)
Potential Clean Power Plan/CPP (inside Maryland and in states that Maryland imports energy from)
Empower Maryland/PSC 2015 Energy Efficiency Goals
Renewable Portfolio Standard

Other Sectors
Forestry and Sequestration
Building Codes and Trade Codes
Leadership by Example/Partnerships

Forestry and Sequestration Programs

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Total Forestry and Sequestration

- 4.55 MMtCO2e reduction (13% of total reduction by 2020)

Managing Forests to Capture Carbon

- 1.8 MMtCO2e reduction

Planting Forests in Maryland

- 1.79 MMtCO2e reduction

Other programs: biomass to energy, ecosystem markets, wetland and waterways restoration, increasing urban tree canopy, and Ag. Land conservation make up the remainder of GHG reduction

Managing Forests to Capture Carbon

- Public lands: acreage certified under FSC and SFI (211,000 acres, on track to meet goal of 50% of state owned forest land)
  - All state forest land and some Wildlife Management Areas (WMA's) currently dual certified
- Private Lands: acres undergoing forest management, Stewardship Plans (~18,000 acres per year)
  - Sediment Control (~ 11,000 acres per year)
  - Tree Planting (~ 1,500 acres per year)
  - Timber Stand Improvement (~ 4,500 acres per year)
  - Wildlife Habitat (~ 2,800 acres per year)
- Exceeding goal of providing sustainable forest management on 30,000 acres per year (currently averaging over 40,000)

Planting Forests in Maryland

- Current goal is establishing 30,000 acres of new forest land through afforestation or reforestation on public and private land
- Exceeded the goal in 2015 (33,000 cumulative acres of forest established)
- Currently on track for 47,000 new acres of forest by 2020

MDE Initial Projection

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… the challenge of 40 by 30

	Estimated Reductions Needed *Most Optimistic*	**Estimated Reductions Needed** *Least Optimistic*
Reductions needed by 2030 to achieve a 40% reduction (with different growth assumptions)	57 $MMtCO_2e$	61 $MMtCO_2e$
Rough, preliminary estimate of where we will be with 40 by 30 based upon programs that are in the works	**-2 $MMTCO_2e$ (surplus - more than 40 by 30)**	16 $MMtCO_2e$ (additional reductions needed)

$MMtCO_2e$ = Million Metric Tons of Carbon Dioxide Equivalent

Climate Commission Web Site

MARYLAND DEPARTMENT OF NATURAL RESOURCES

http://www.mde.state.md.us/programs/Marylander/Pages/mccc.aspx

- Also a direct link from MDE Home Page
- Membership
- Meetings
- Working Groups
- Commission documents
- Interesting articles and documents from external sources
- More

Questions?

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NATURAL RESOURCES

Other Critical Balancing Provisions

- Reauthorized GGRA maintains all of the key issues that are part of the balance that allowed the 2009 and 2016 legislation to pass with support from all interested parties
- For example, the 40 by 30 Plan must:
  - Produce a net economic benefit to the State's economy & a net increase in State jobs
  - Encourage new employment opportunities in the State related to energy conservation, alternative energy supply, and greenhouse gas emissions reduction technologies.
  - Ensure that the plan does not decrease the likelihood of reliable and affordable electric service and statewide fuel supplies

More Balance

- The 40 by 30 Plan must also:
  - Not disproportionately impact rural or low–income, low–to-moderate–income, or minority communities or any other particular class of electricity ratepayers
  - Not directly cause the loss of existing jobs in the manufacturing sector
  - Consider the impact on rural communities of any transportation related measures
  - Provide credit for voluntary action
  - Consider whether the measures would result in an increase in electricity costs to consumers in the State
  - Attract, expand and retain aviation services
  - Conserve, protect, and retain agriculture
  - Minimize leakage

MARYLAND DEPARTMENT OF NATURAL RESOURCES

Lessons Learned from Using LiDAR and CMS Products for Forest Planning and Management in Maryland

Jack Perdue, MD Forest Service

Mark Beals, MD Forest Service

NASA Carbon Monitoring System (CMS) Applications Workshop
Friday, September 9, 2016
U.S. Forest Service, Northern Research Station
Newtown Square, PA

The Maryland Forest Service

Mission: *Restore, manage, and protect Maryland's trees, forests, and forested ecosystems to sustain our natural resources and connect people to the land.*

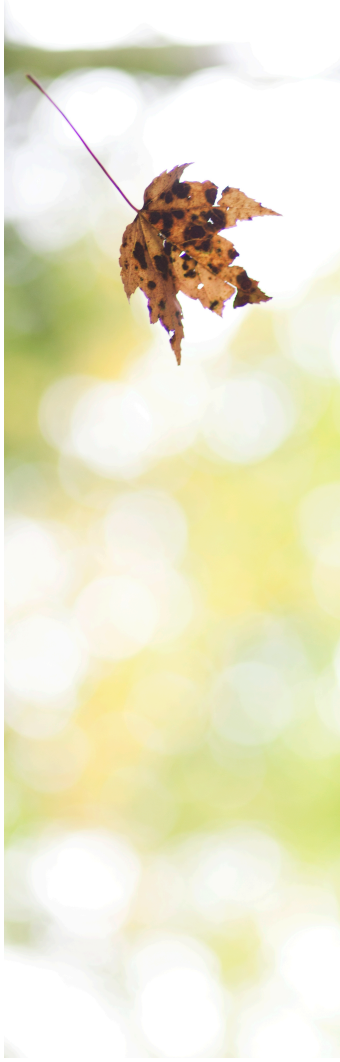
- 82 permanent employees
- Numerous Seasonal and Contractual employees annually
- Manage state forests
- Provide services to private landowners.
- Primary tool is legislation.

A Brief Introduction to Maryland Forests and Forestry

- In 2013, Maryland Forest Cover is estimated at 2,462,473 acres (Pennsylvania has about this much in public ownership alone).
- ~76% of Maryland Forests are privately owned.
- Most common forest type is Oak-Hickory.
- Lost about 300k to 350k acres (gross) of forest since 1970. (about the size of Worcester County, MD)

MD Forest Service: Forest Resource Planning

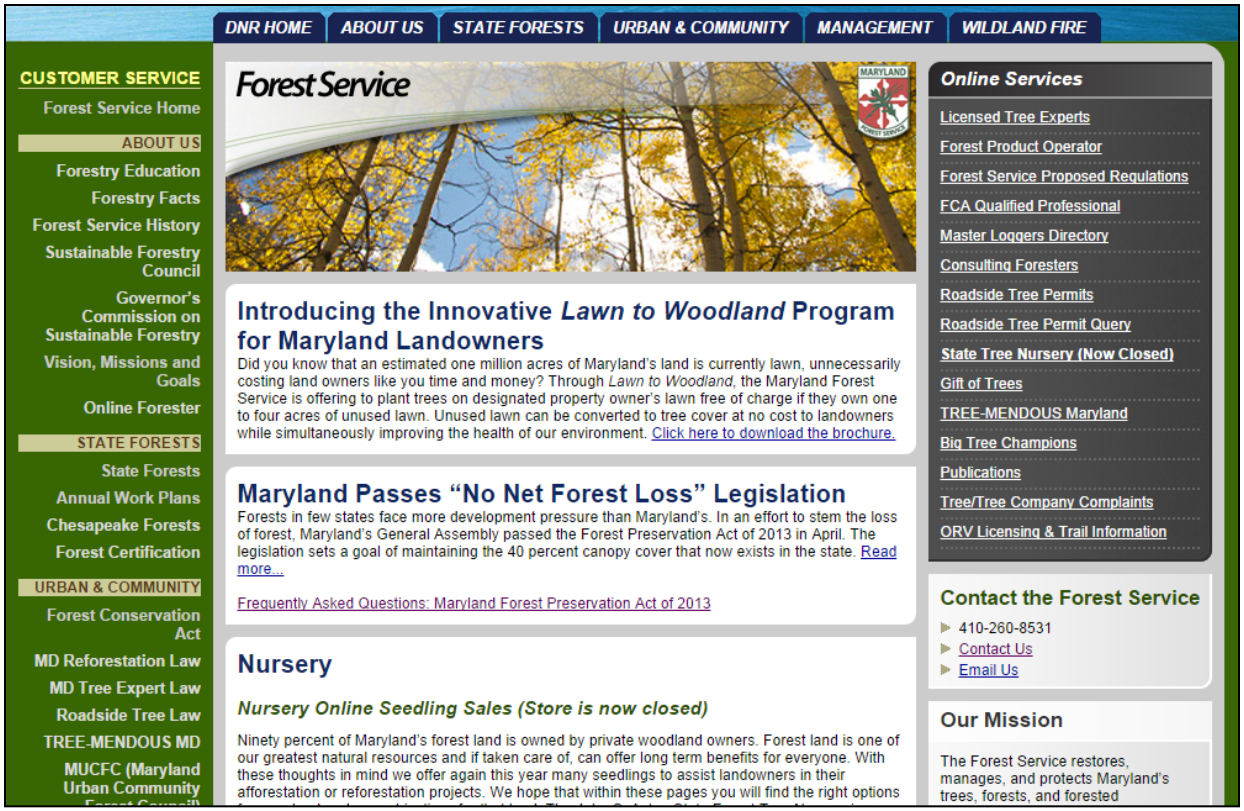
- Decision Support
  - Provide an assessment of Maryland's forests every 5 years.
  - Answer questions about Maryland's forests for Forestry decision makers: the State Forester, Governor's office, Legislature, Sustainable Forest Council, other agencies—often lots of literature review.
  - Assist with sustainable management of state forests.



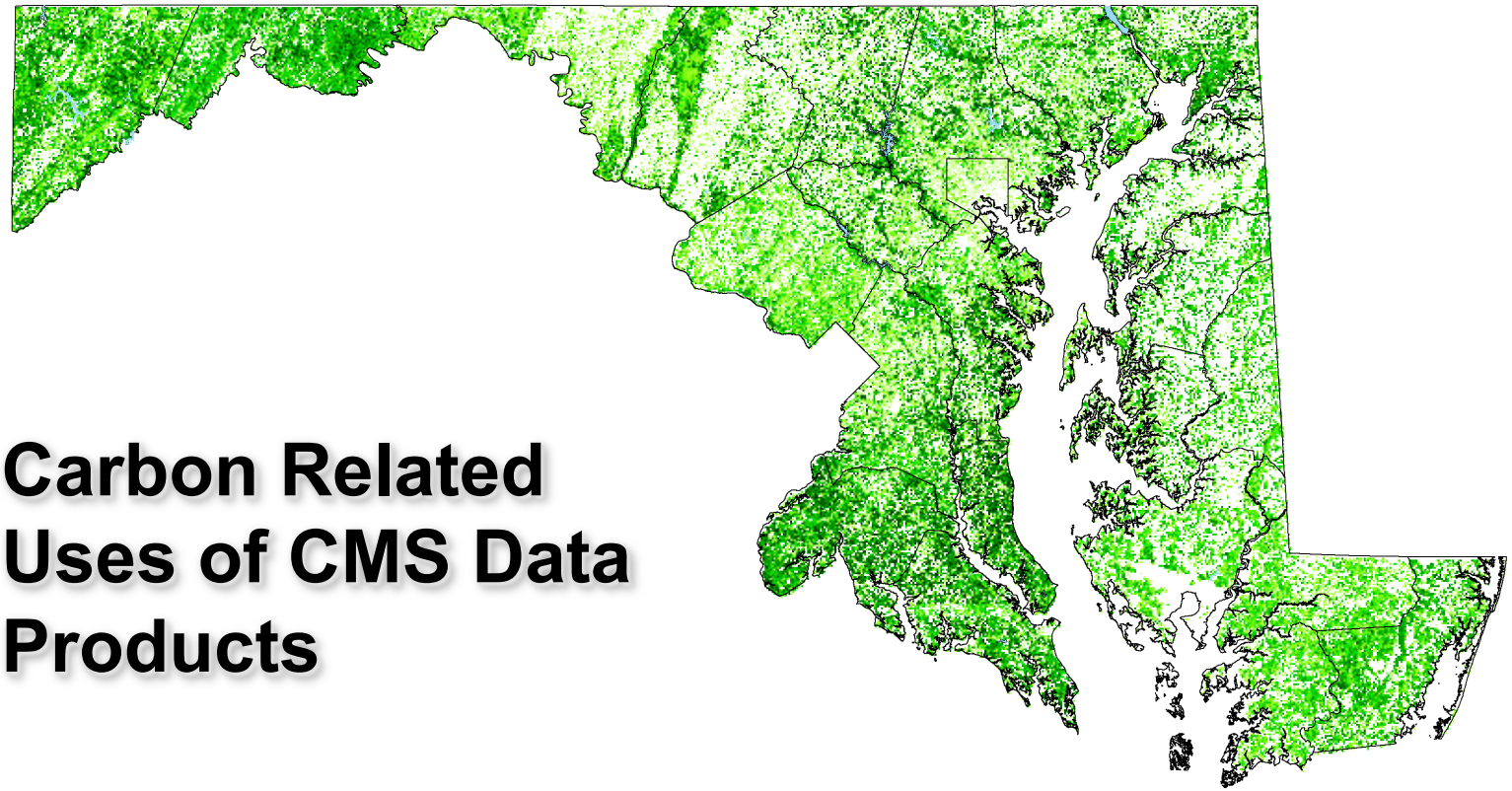
The Forest Preservation Act of 2013

Sets a goal of 40% canopy cover statewide.

How do we do this?

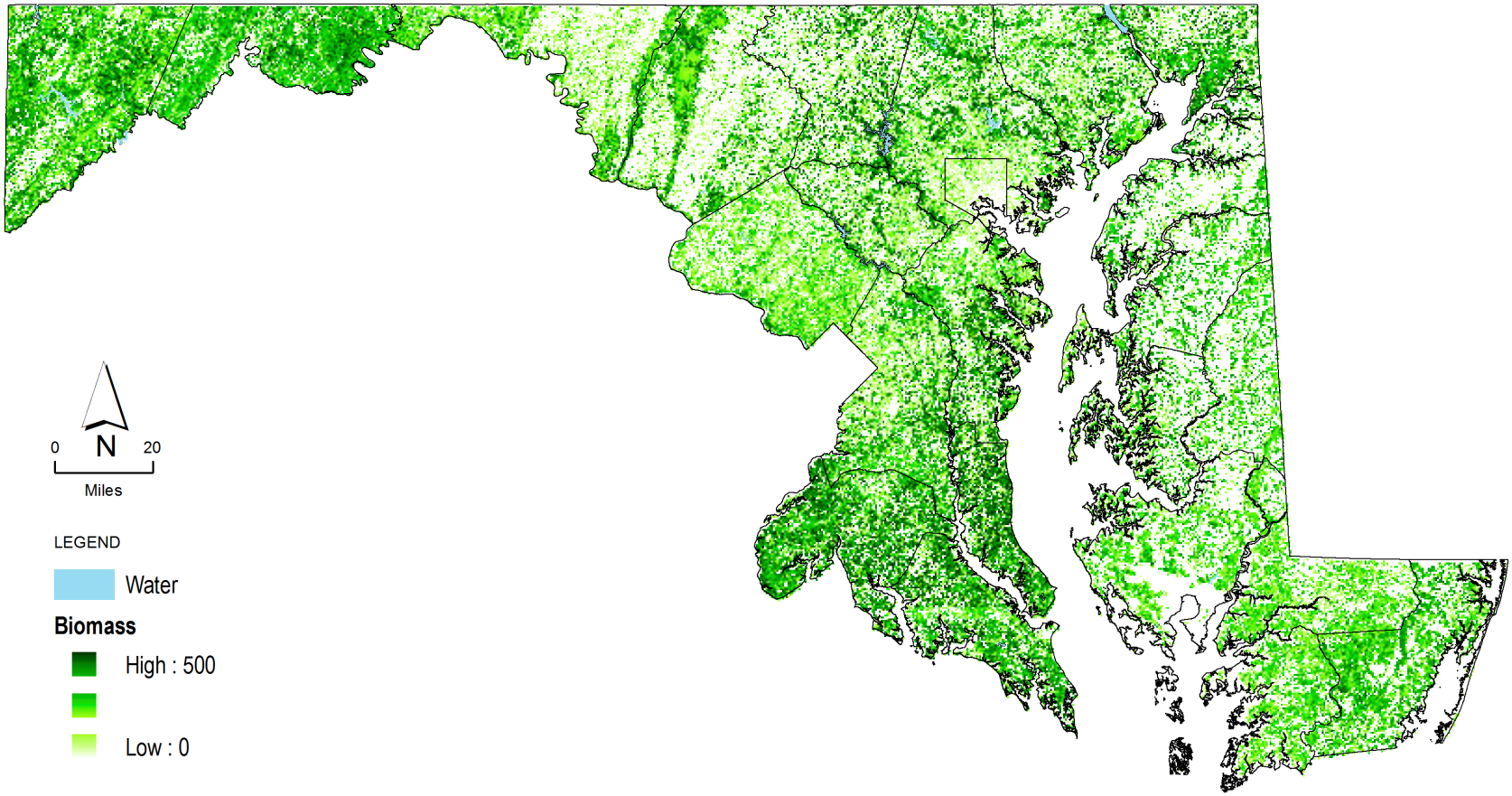


Carbon Related Uses of CMS Data Products



High Resolution Carbon Monitoring and Modeling: A NASA CMS Phase II Study

Lessons Learned from Using LiDAR and CMS Products for Forest Planning and Management in Maryland

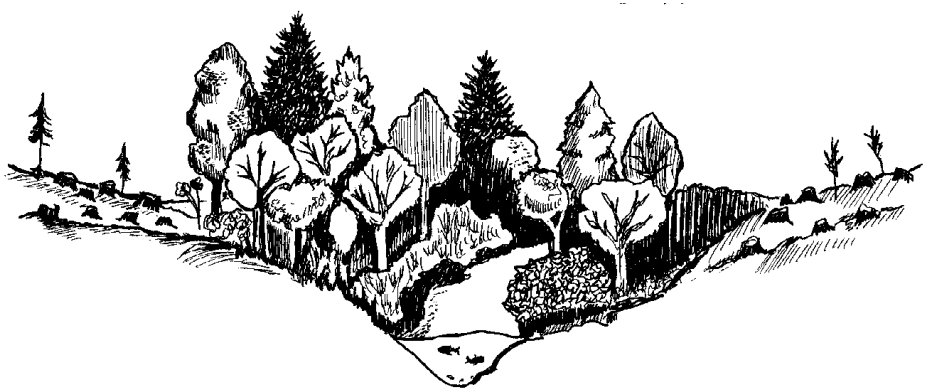


Carbon Related Uses of CMS Data Products

- FIA data for state estimates. CMS product for smaller areas.
- Unique opportunities to estimate biomass content of select areas—state forest/park, watershed, neighborhood, etc. Possible online tool as well.
- Important component in biomass energy project estimates—can help decision makers view it as a viable option. MFS discussion about an online tool.
- How much was lost from a mature forest that was cleared? What is the potential of nearby areas if planted?

James Stimpert

Non-Carbon Related Uses of CMS Data Products

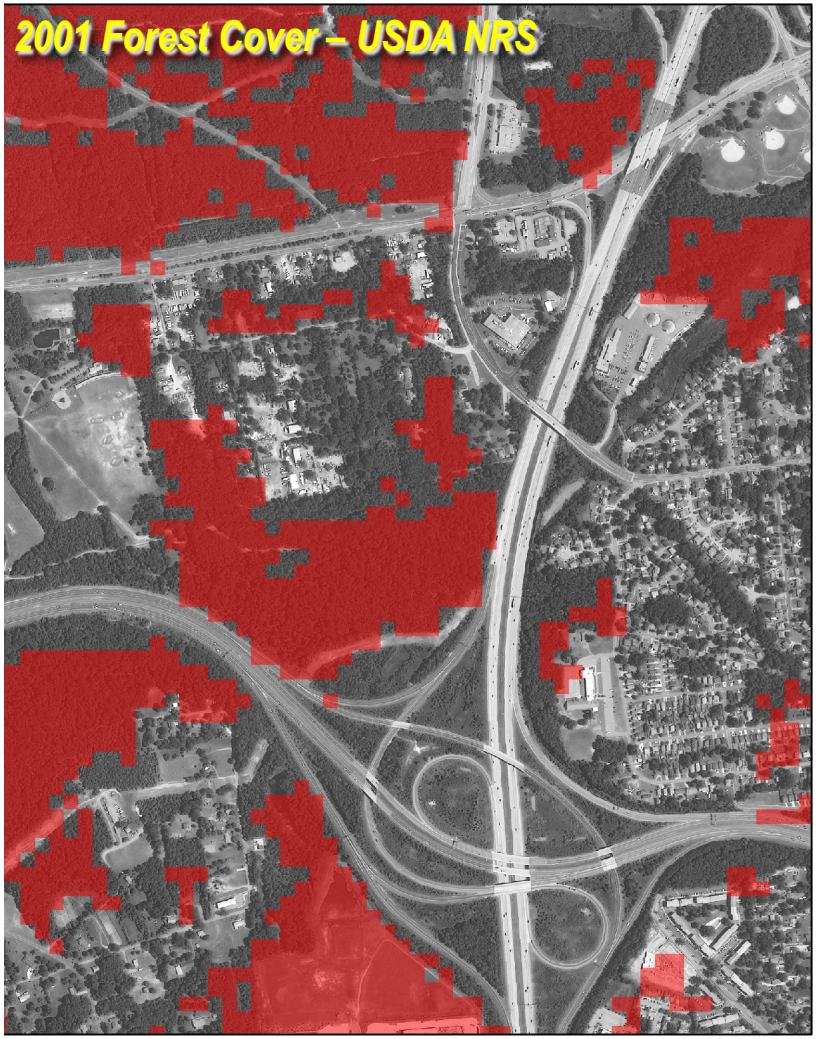


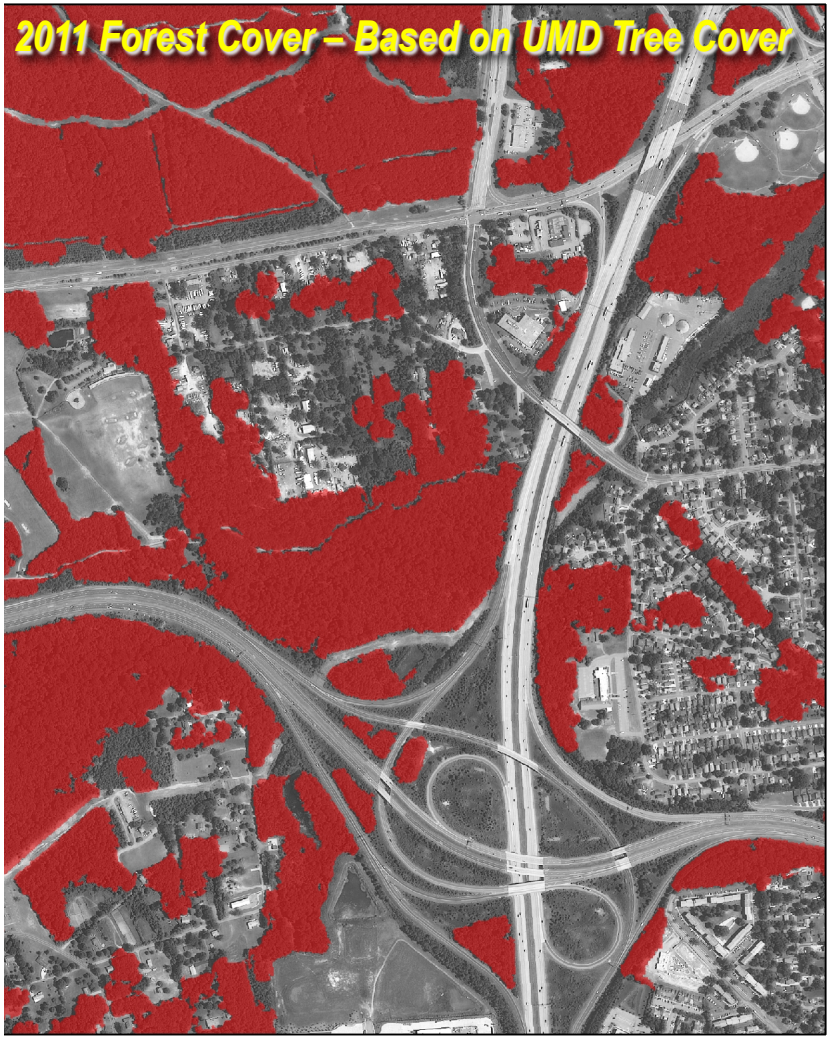
Bel Air, Maryland, 2011

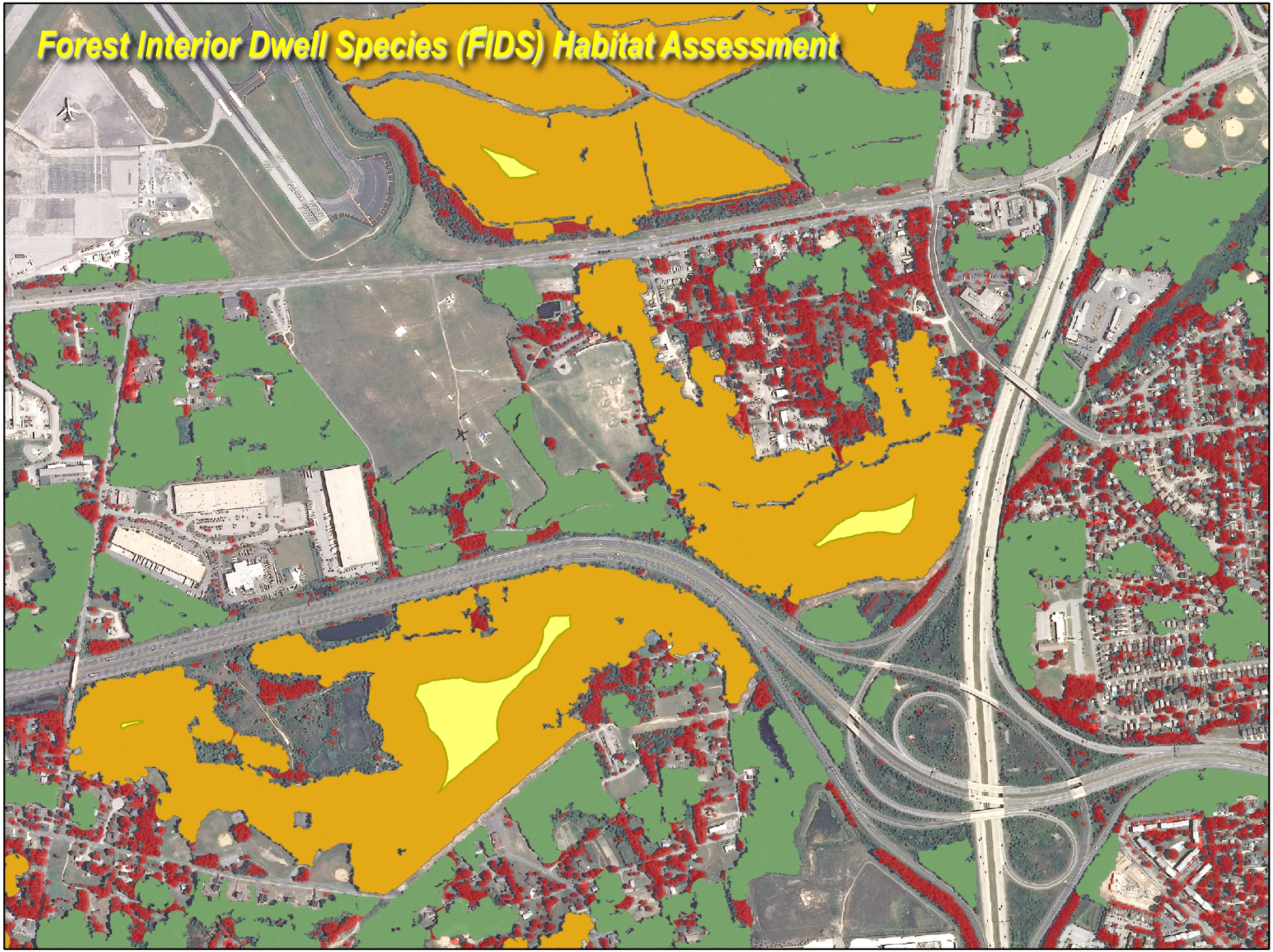
UMD delivered tree cover (red) – Harford County, MD - ca. 2011 LiDAR
data with 2011 National Agricultural Imagery Program (NAIP) Imagery

Significant Tree Cover Loss Analysis 2011 to 2013
Areas greater than 0.5 acres extracted

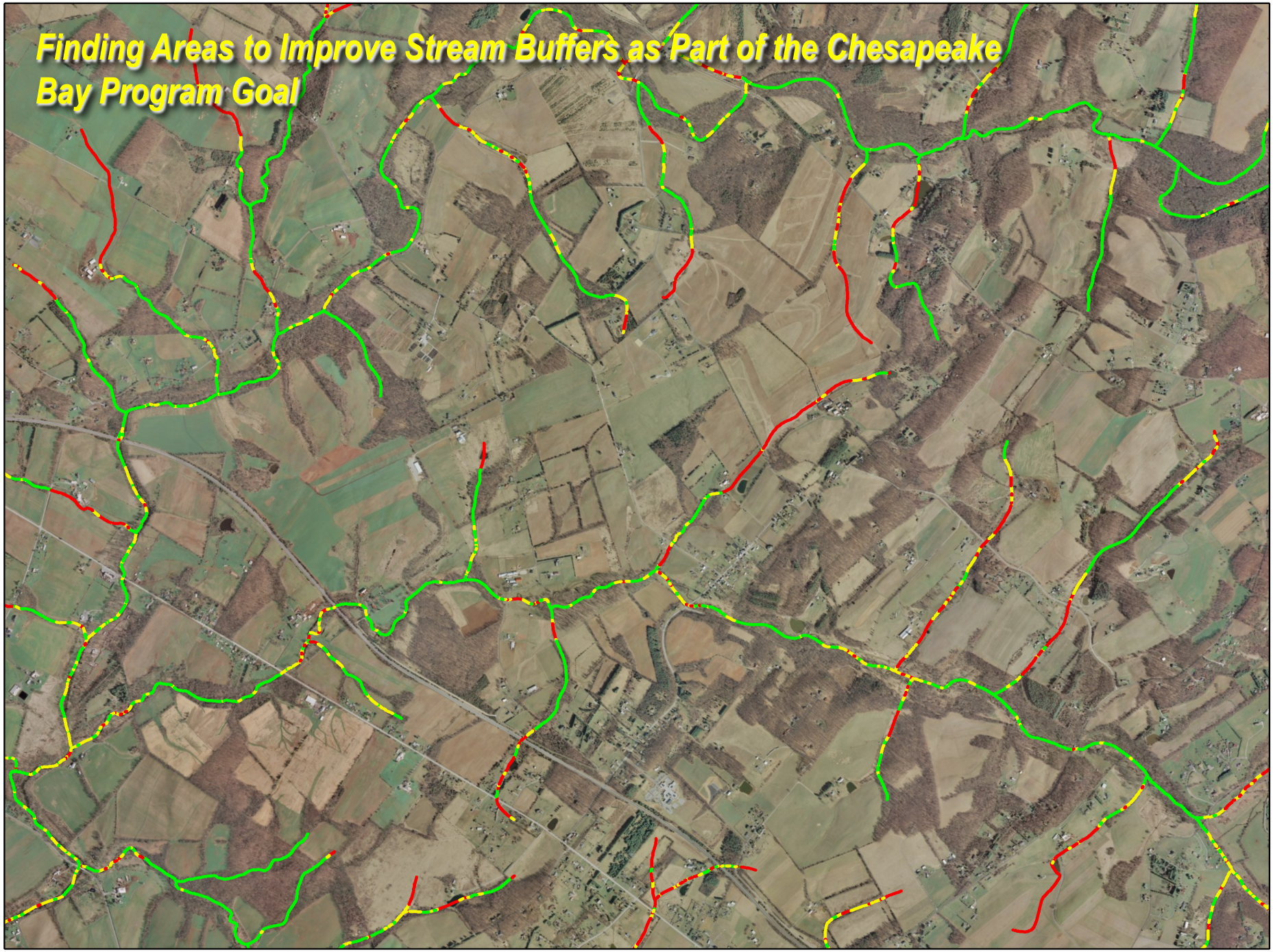
Lessons Learned from Using LiDAR and CMS Products for Forest Planning and Management in Maryland






Forest Interior Dwell Species (FIDS) Habitat Assessment

Tree Height From LiDAR for Habitat Location


Finding Areas to Improve Stream Buffers as Part of the Chesapeake Bay Program Goal

Future Carbon Science Information Should…

- Be provided at the state level—counties/municipalities can be extracted.
- Offer a good spatial scale: 1 meter seems to work well—<1 meter could be problematic. 30m probably "ok" for biomass.
- Be provided frequently: 1 year is ideal—everything else is probably "gravy". Example: Forest Disturbance Mapper data every 8 days, but resolution is coarse. Does increased frequency mean reduced resolution? What can we live with?
- Be tailored for trees. All the uses shown were from LiDAR collected for bare-earth applications. Can LiDAR be optimized for tree/tree canopy? Leaf-on "biomass" flights? LiDAR paired with multispectral camera? Etc.

Lessons Learned from Using LiDAR and CMS Products for Forest Planning and Management in Maryland

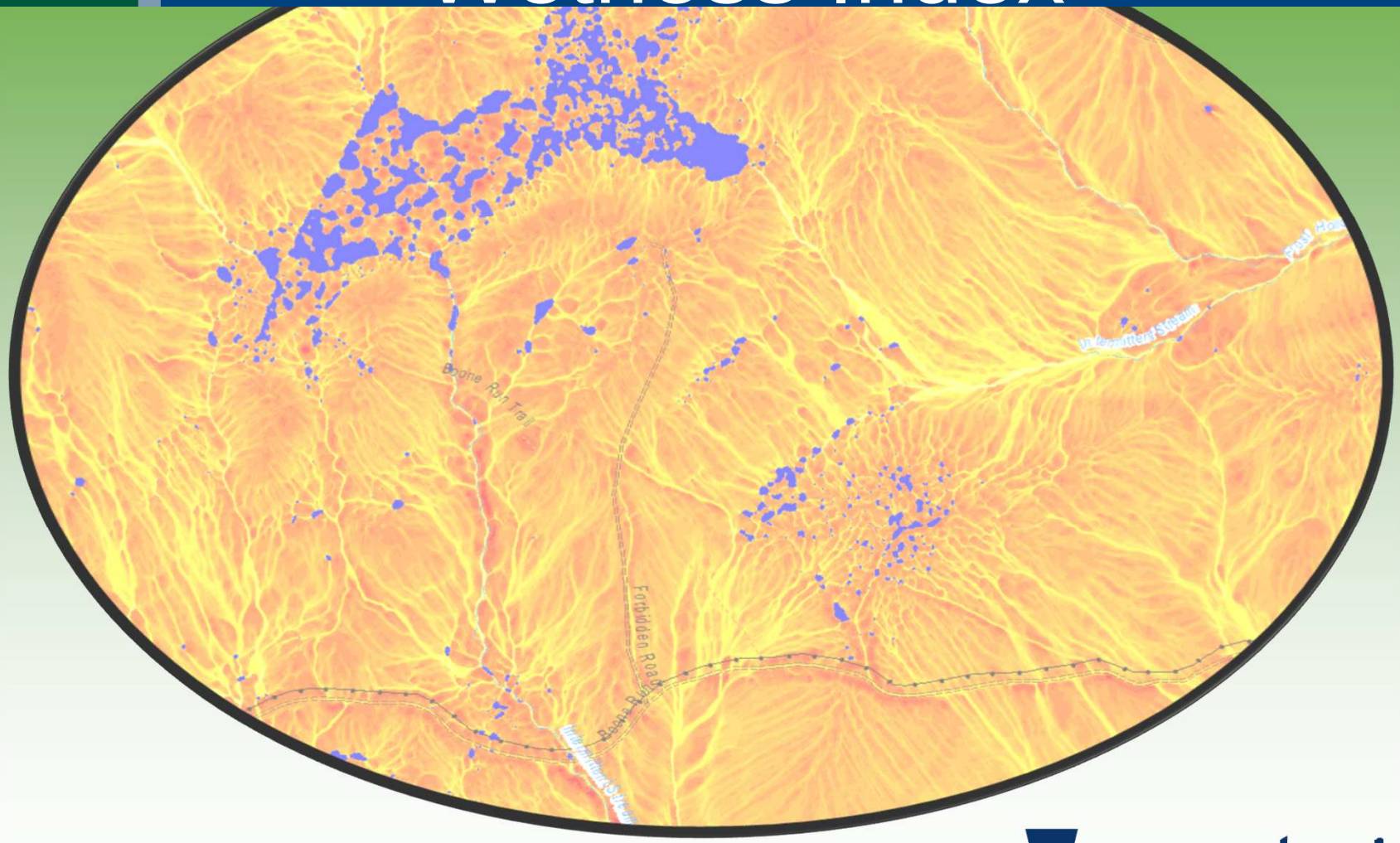
Robert Feldt - Maryland Forest Service, Forest Resource Planning

580 Taylor Avenue, E-1, Annapolis, MD 21401, 410-260-8529

rob.feldt@maryland.gov

Eric Reed

Lidar Derived Topographic Wetness Index



www.dcnr.pa.gov

pennsylvania
DEPARTMENT OF CONSERVATION
AND NATURAL RESOURCES

PA DCNR Shale-Gas Monitoring Program

- Overall, approximately 1.5 million acres of land administered by the PA DCNR Bureau of Forestry are underlain by Marcellus Shale
  - Approximately 258,000 acres are leased for development
  - Approximately 294,000 acres have severed subsurface ownership

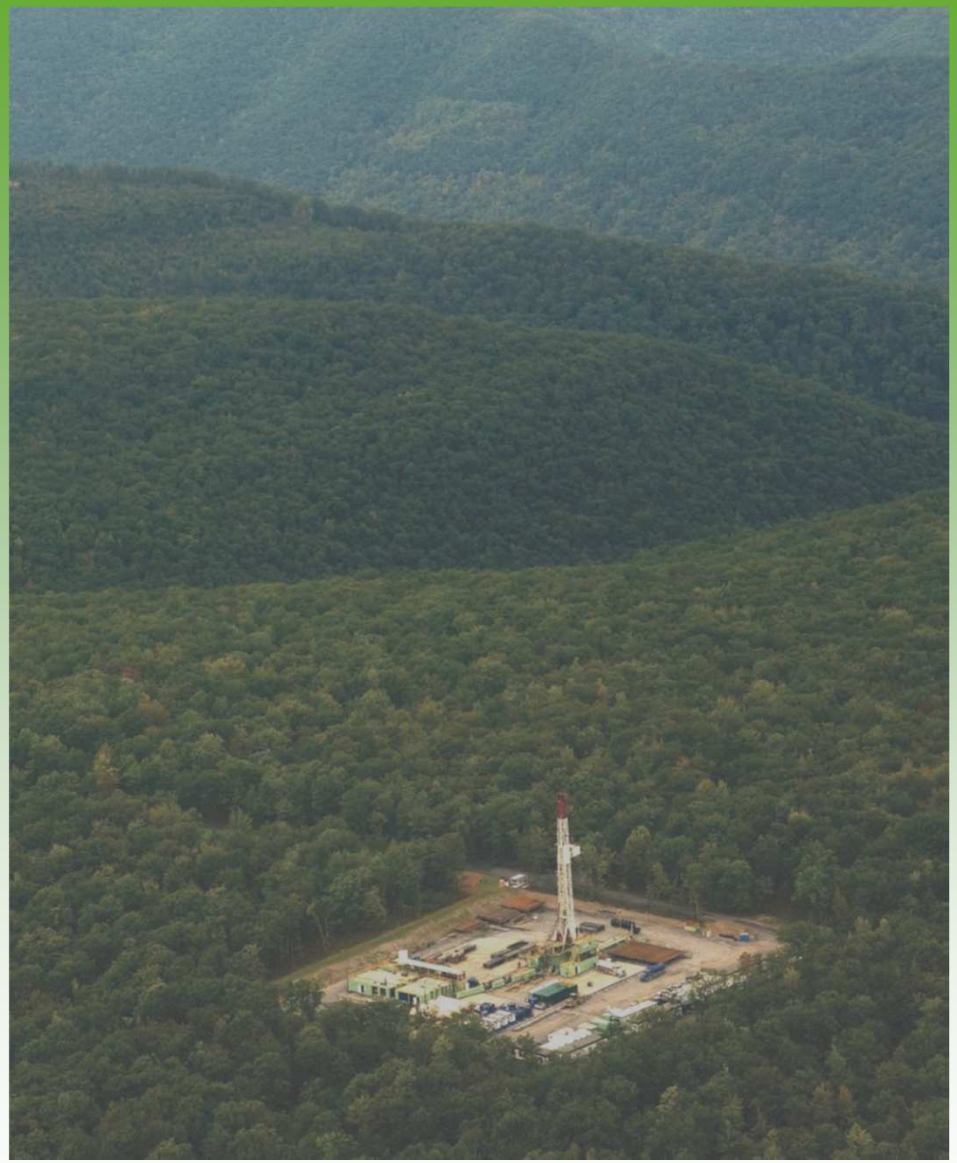


photo courtesy of Martha Rial

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Monitoring Program Continued..

- 3 Prong Approach
  - Group of specialists which devote the majority of their time to shale-gas monitoring and a field crew.
  - All program areas and field staff observe.
  - Partnerships with outside groups
    - Includes research where issues go beyond definition or scope of monitoring.
    - Ideally, research feeds back into improving the monitoring program or best practices.

Shale-Gas Monitoring and Carbon

- Would not have to reach too far to start tying shale-gas development to issues related to carbon but the Shale-Gas Monitoring Program has not ventured into that realm.
- We have leased and severed subsurface rights lands that are developed in accordance with current laws and regulations. **How can we monitor what is going on and improve how we manage the development that occurs?**

Research Utilizing Lidar

- Dr. Patrick Drohan at PSU has partnered with us to look at localized hydrologic effects of shale-gas development.
  - Includes fine tuning a model for calculating topographic wetness index.
  - Topographic Wetness Index (Compound Topographic Index) is a steady-state wetness index.
  - Predicts likelihood of wetness relative to surrounding topography.

Topographic Wetness index

- Dr. Drohan's research has not been incorporated into our Monitoring Program yet. The "fine tuned" topographic wetness index has become a tool in our review process for development proposals.
  - Good at estimating where water concentrates and potential drainage problems.
  - Indicates where there may be existing drainage problems.

The Script

- February 2015- Several folks from the Bureau of Forestry met with Dr. Drohan for a “knowledge transfer” session.
- This got us up and running but our TWI raster didn’t look as pretty as rasters generated by the SRBC
- April 2016- Contacted Jeff Zimmerman with the SRBC. He provided step by step instruction on how they calculate TWI.

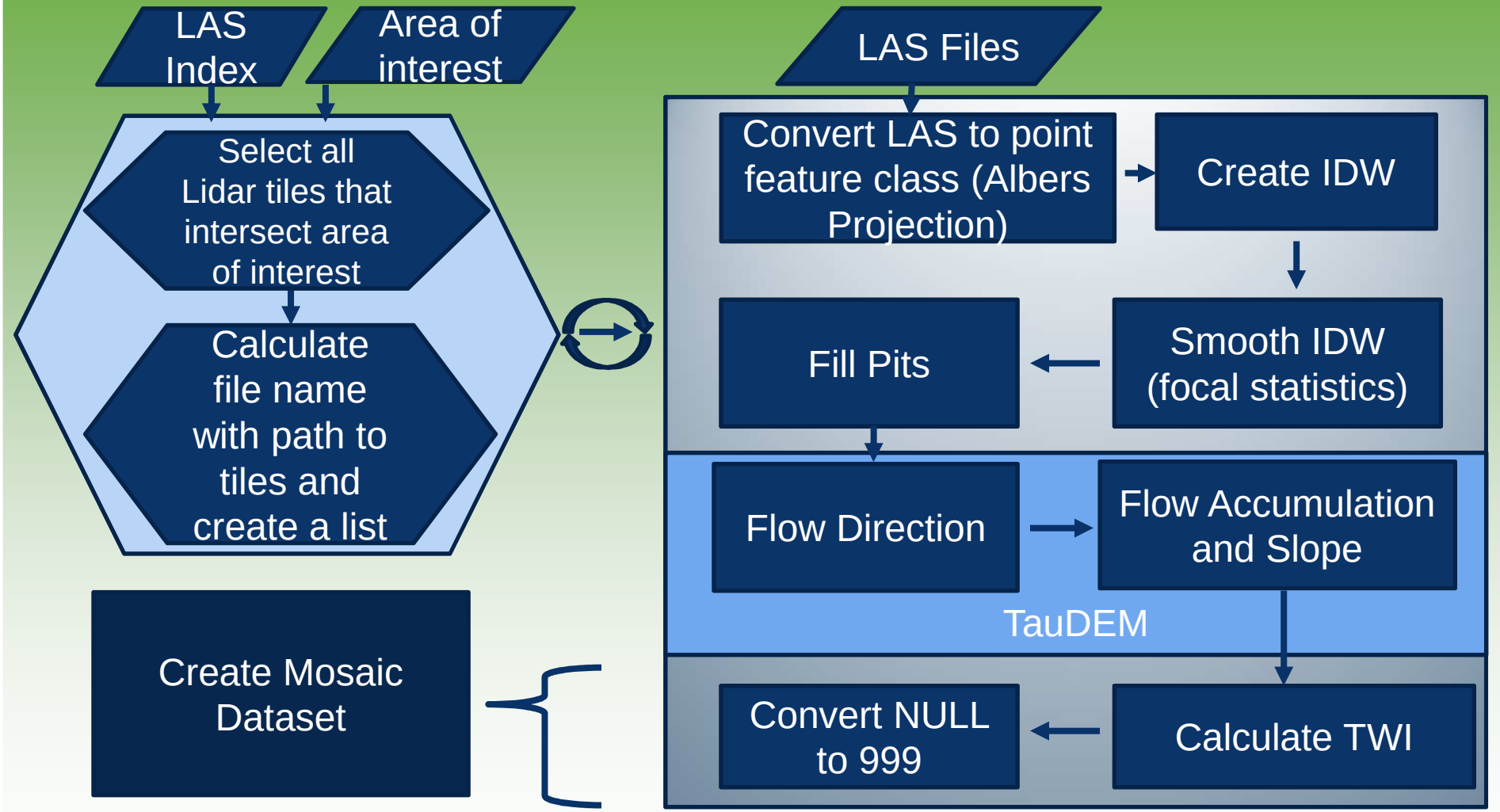
The Script, continued…

- The formula for TWI is very simple- TWI=ln(Upstream contributing area/tan(slope)
- But there are numerous ways to prepare the data.
- PSU-
  - Use Inverse Distance Weighting to generate the DEM.
  - Use multi-directional flow when calculating upstream contributing area
- SRBC-
  - Smooth the data

The Script, continued…

- Original efforts tried to calculate values on a tract basis (6 acres to 40,000).
  - Script choked on some of the tracts due to hardware and software limitations.
- Finally decided to calculate TWI for each Lidar tile and mosaic results together.
- Calculated TWI for all “Core Gas” Districts

Workflow



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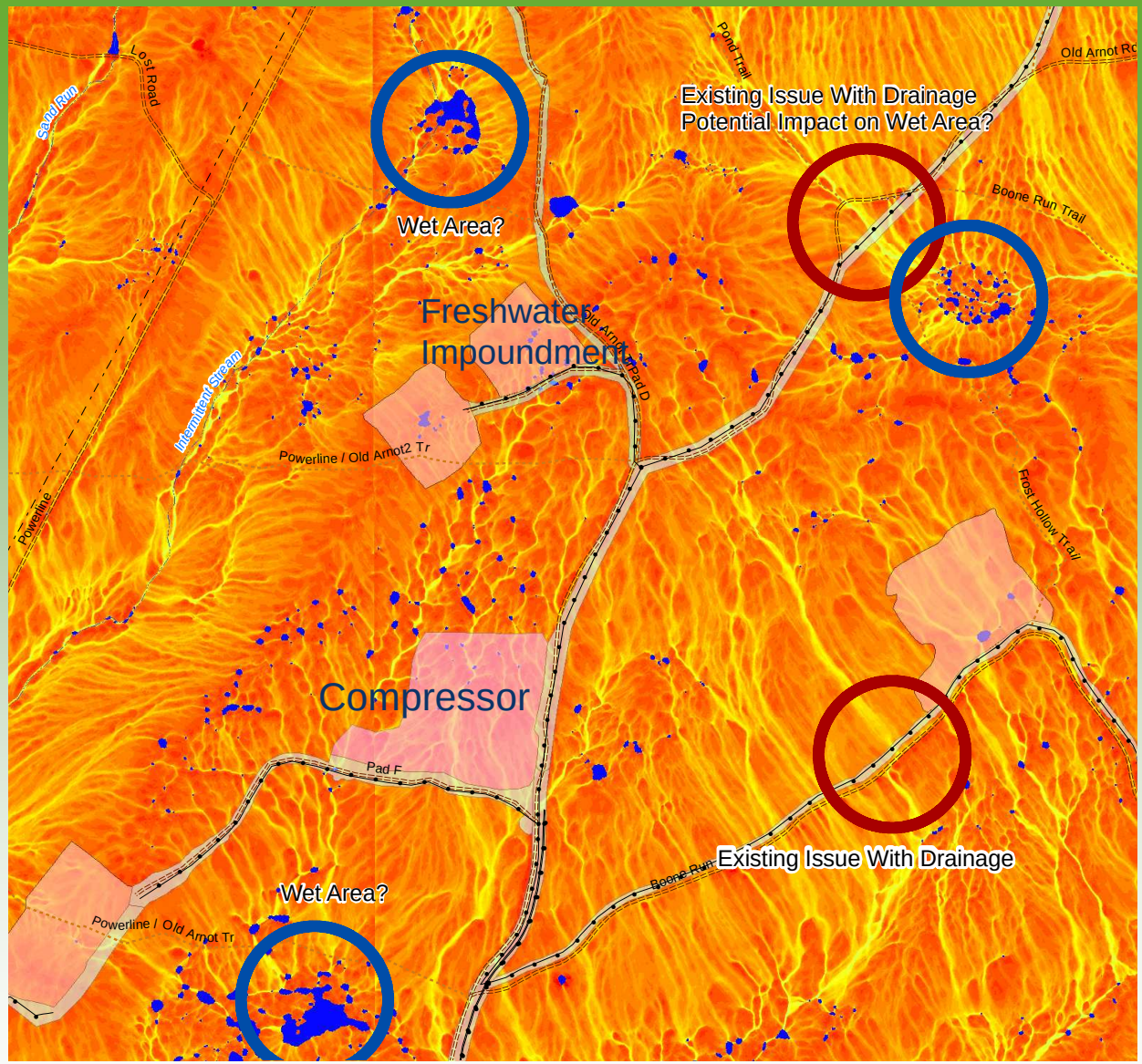
Visually Identifying Potential Issues With Topographic Wetness Index Only

- Will Compressor site impact wet area (potential wetland) to the south? Not likely
- Does the proposal correct existing drainage issues?
- Will the use of the road in North East corner impact wet area?



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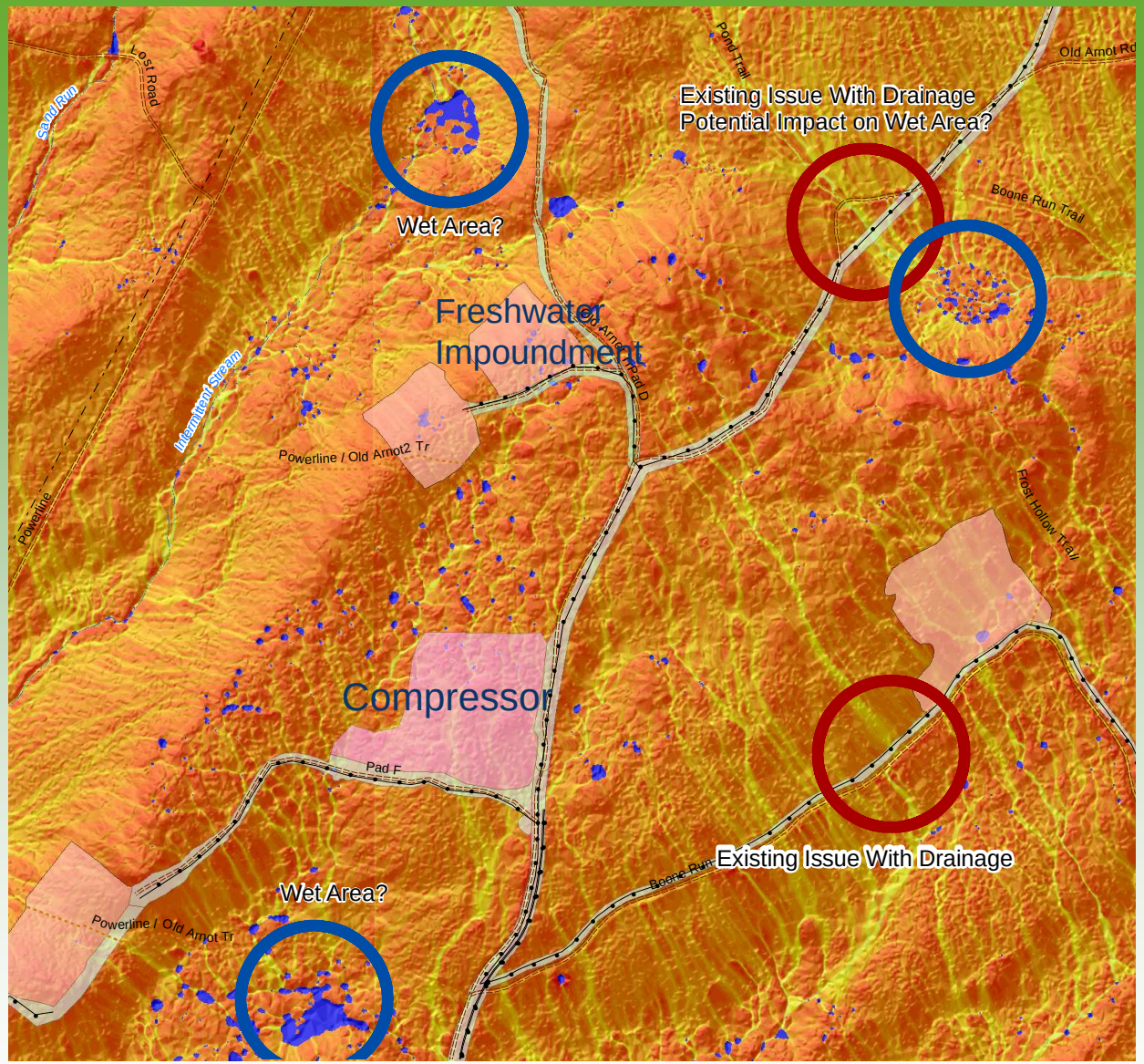
10X Lidar Derived Hillshade Over Topographic Wetness Index



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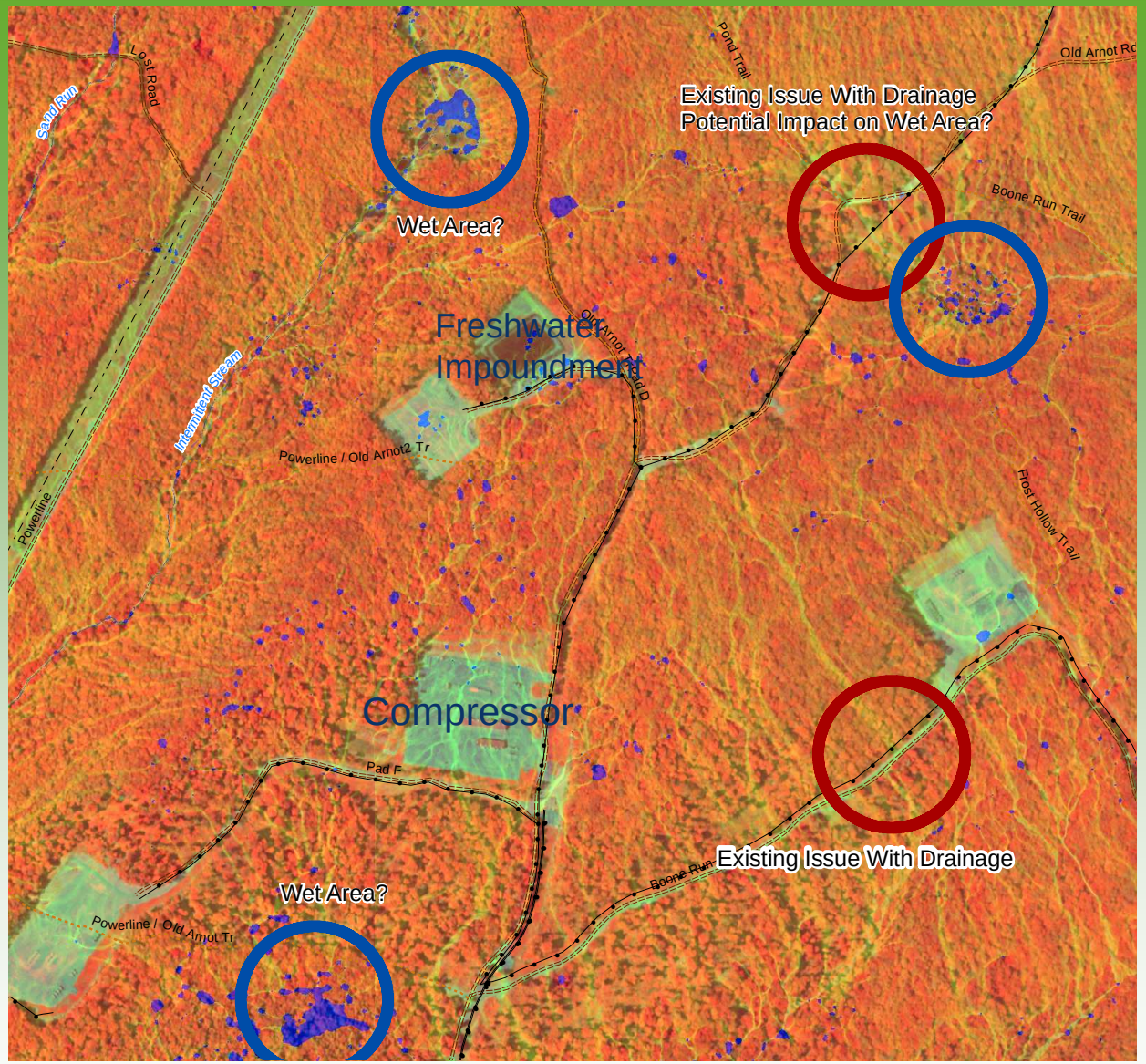
2015 NAIP Near Infrared Imagery Over Topographic Wetness Index



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Goals

- Manage what we have been charged with the best we can.
  - Adaptive Management-
    - Utilize monitoring and research to improve on the ground management.
    - Minimize environmental impact.
    - Manage for multiple values.
    - Adjust monitoring and management as new information becomes available.
  - Efficiency
    - Imagery and Lidar products help us identify where we should begin focusing our attention in the field.
    - Provides data that would otherwise have to be collected in the field.

Room for Improvement

- Edges of Lidar tiles do not always flow well from one to another.
- Figure out best compromise between appearance of results and accuracy on the ground.
- Improve display of results.
- Other, slower methods are available to fill pits that would avoid having to deal with null values.
- Natural Capital Project's Invest program and pygeoprocessing show promise for handling large datasets.

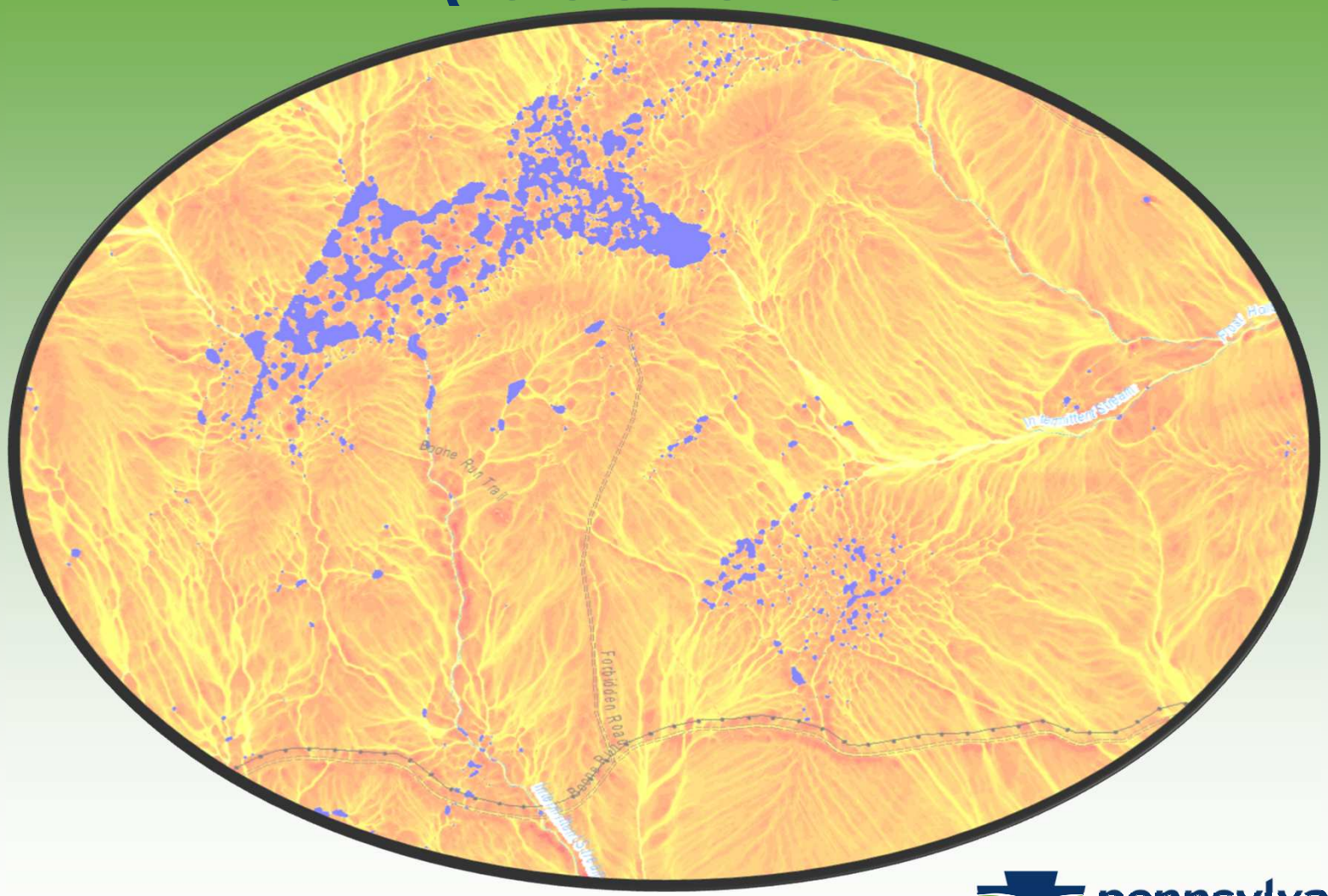
Potential Carbon Application

- May 2010- State Key Laboratory of Resources and Environmental Information System, the Chinese Academy of Sciences and the University of Wisconsin-Madison published a paper that indicated multi-flow direction Topographic Wetness Index has a strong correlation to soil organic matter. May be useful in mapping SOM.
- Potential tool in measuring below ground organic carbon.

Credits

- Patrick Drohan, Ph.D. Associate Professor of Pedology, Pennsylvania State University
- Jeff Zimmerman Jr. GIS Developer, Susquehanna River Basin Commission
- David Tarboton, Utah State University, TuadDEM
- ESRI

Questions?



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LiDAR-Based Sea Level Rise Mapping for the state of Delaware

Naomi S. Bates

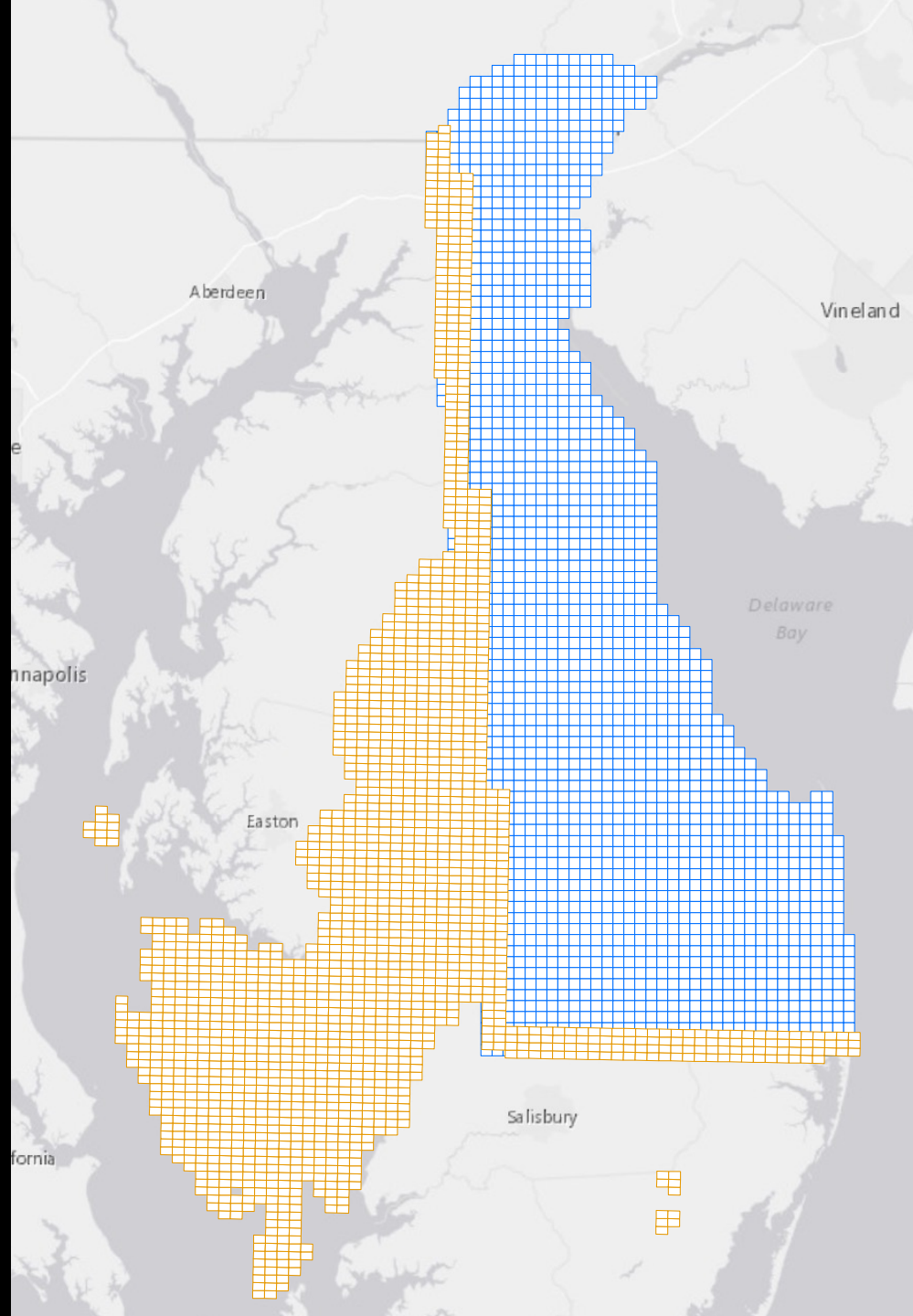
Delaware Geological Survey

September 9, 2016

UNIVERSITY OF DELAWARE

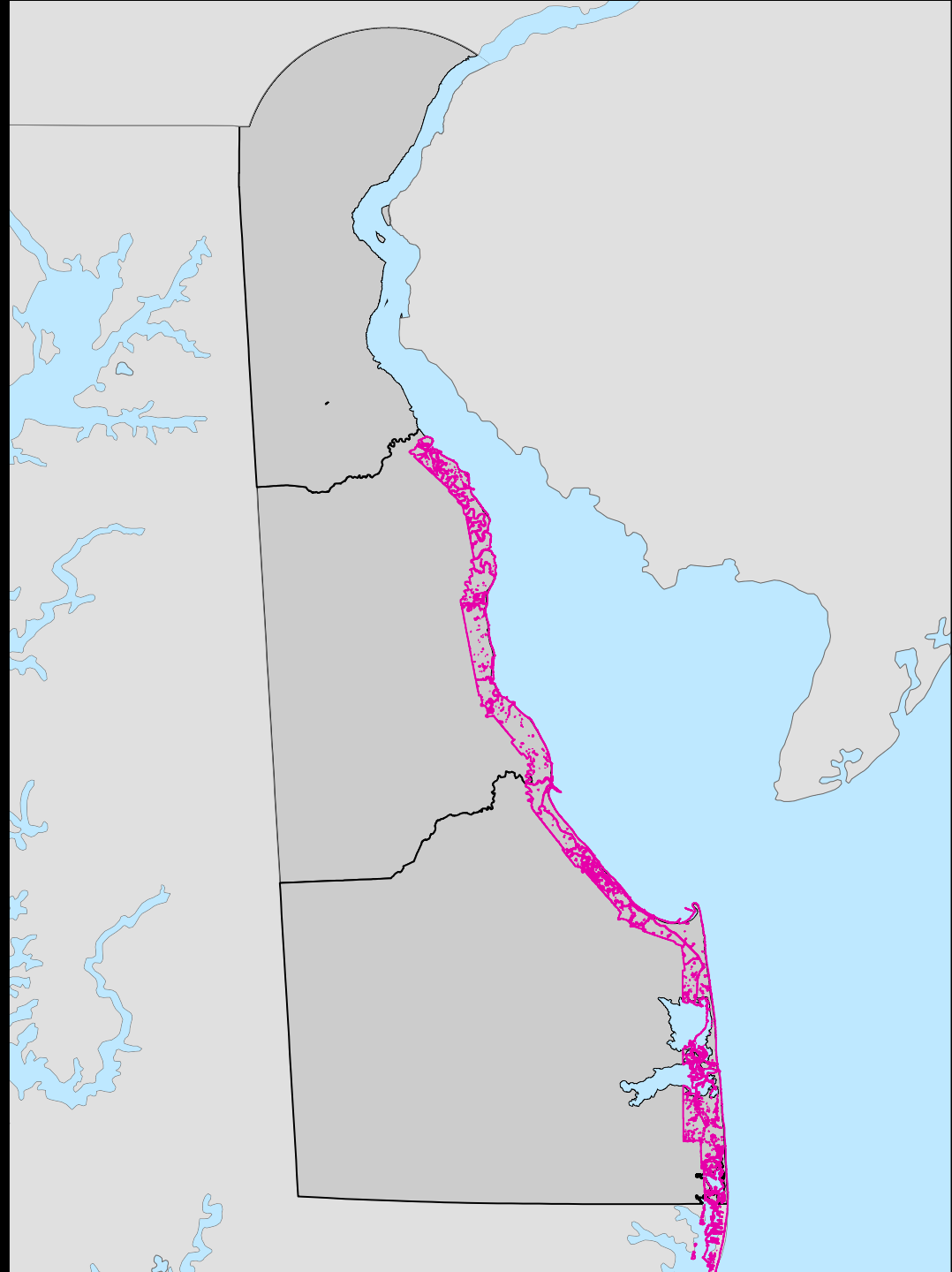
2014 Topographic (NIR) LiDAR

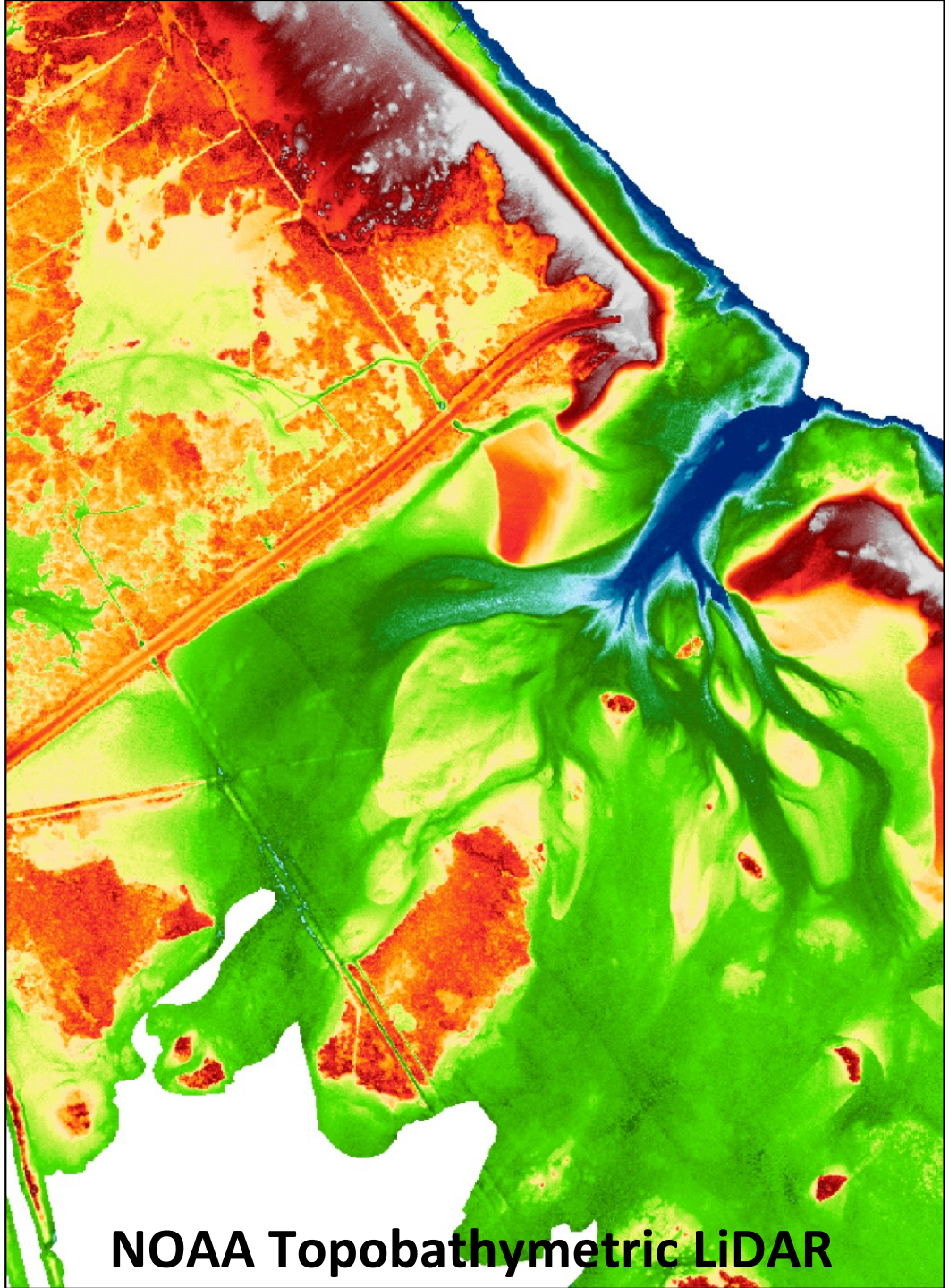
- Entire state of DE and part of MD (3000+ square miles)
- Funded through the Hurricane Sandy Supplemental Fund
  - USGS, DGS, DNREC, and DelDOT
- Quality Level 2 or better (>2 pts/m^2)
- December 2013 – April 2014
- Not tide coordinated
- Reported RMSEz open terrain: 6.3 cm
- Deliverables
  - classified point cloud
  - 1-m hydro-flattened DEM
  - intensity images
  - breaklines used for hydro-flattened



NOAA/NGS LiDAR

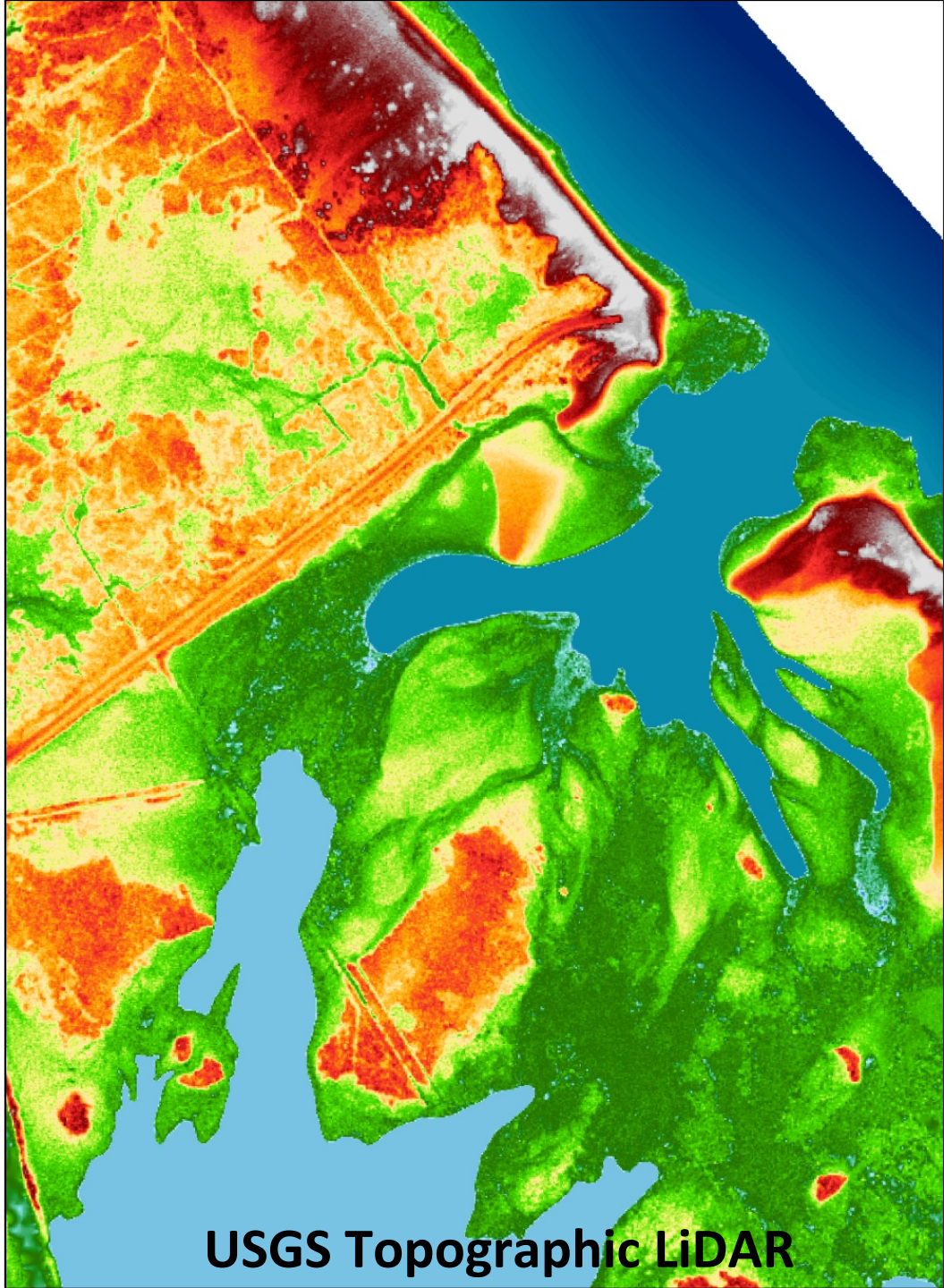
- NOAA Topobathymetric Lidar
- Green LiDAR (532 nm)
- Tide coordinated +/- 2 hrs
- NOAA ~300-m swath along coast of Sussex and Kent Counties
- 2775 miles^2 of Atlantic Coast from New York to South Carolina
- January – May 2014
- No hydro-flattening
- Average point density: 5-8 pts/m^2 (for ground/ bathy)
- Reported RMSEz open terrain: 6.2 cm
- Deliverables: classified point cloud, 1-m DEM

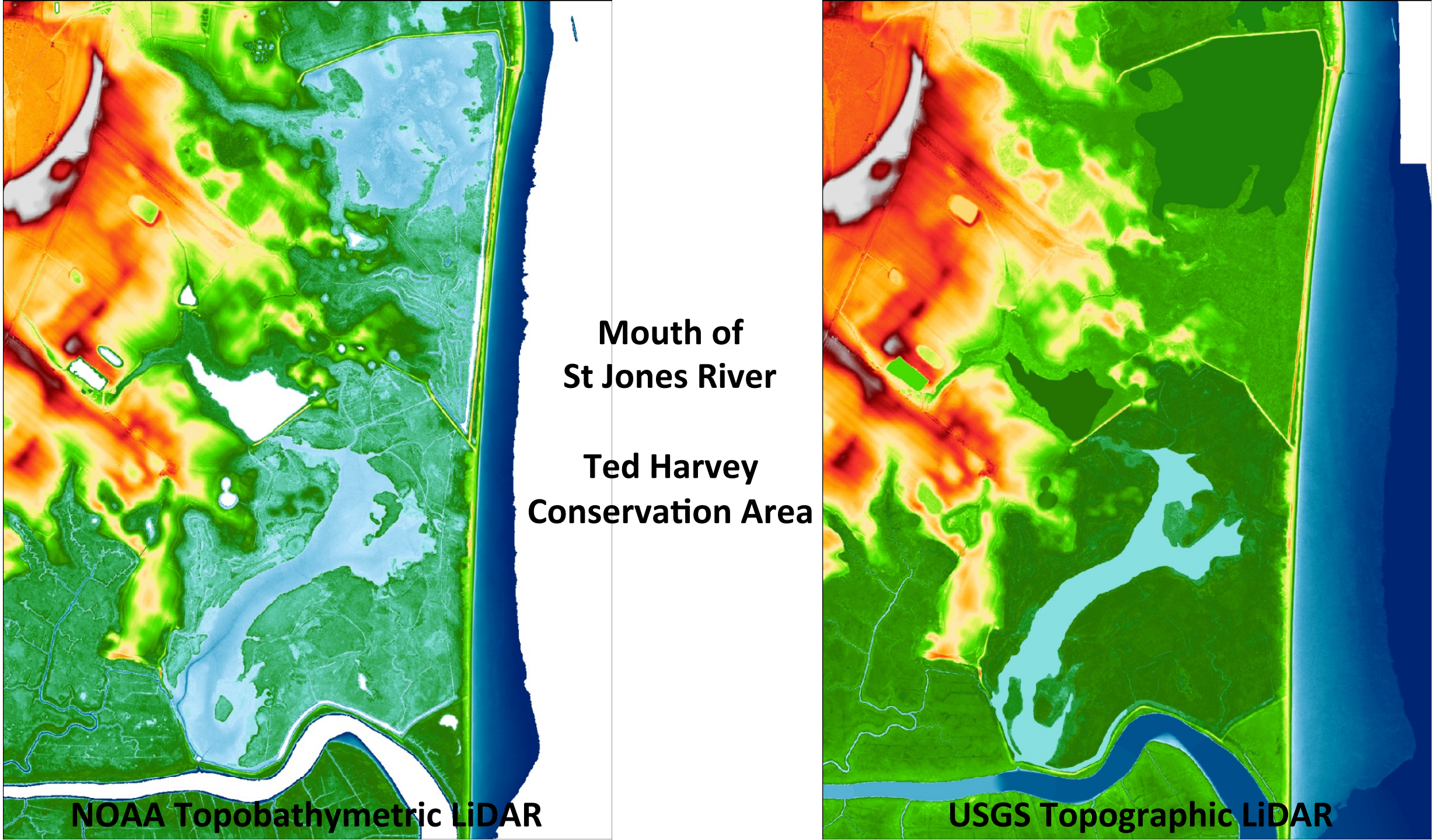


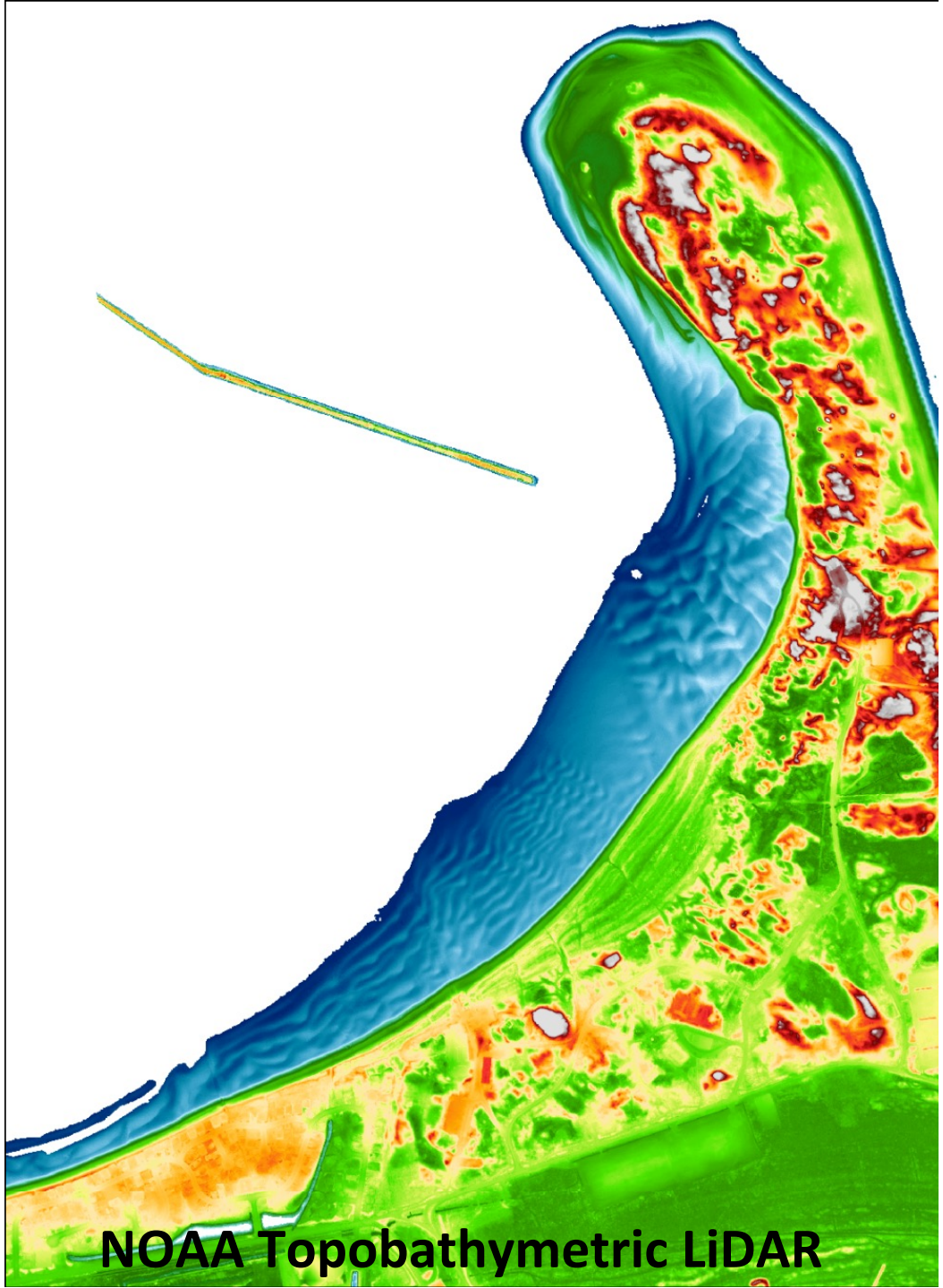


Prime Hook

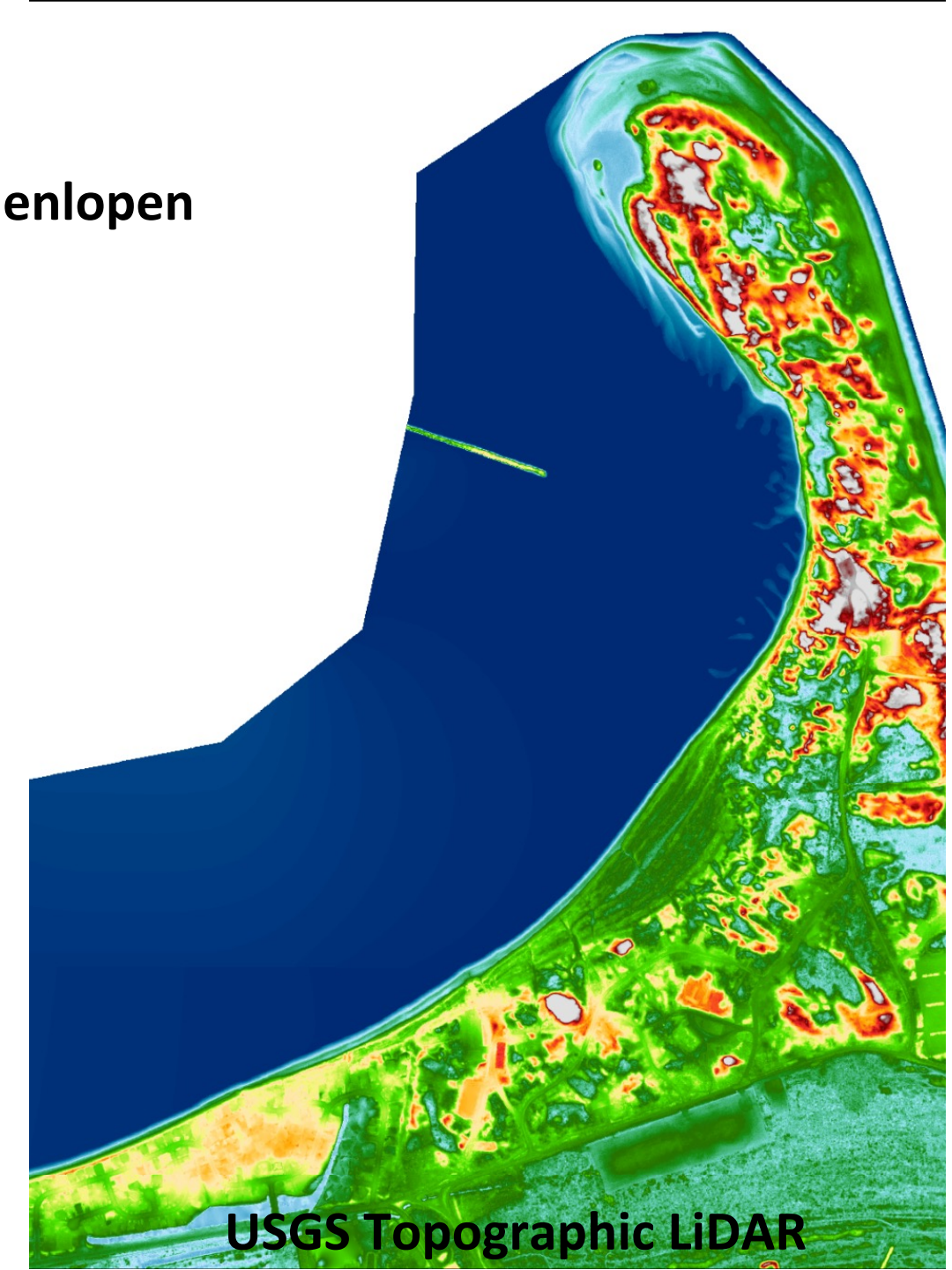
Fowler Beach




Mouth of
St Jones River
Ted Harvey
Conservation Area
NOAA Topobathymetric LiDAR
USGS Topographic LiDAR

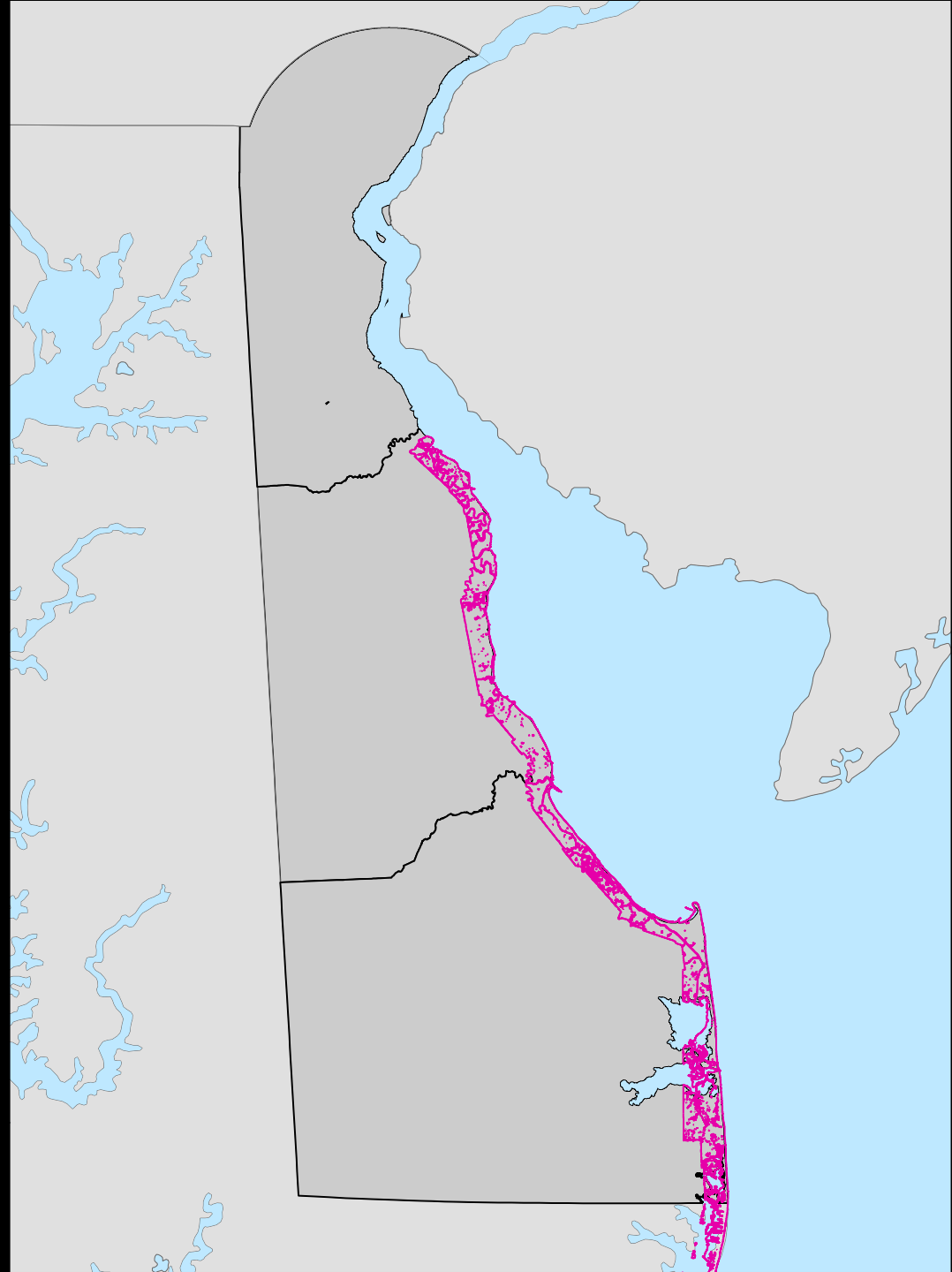


Cap Henlopen



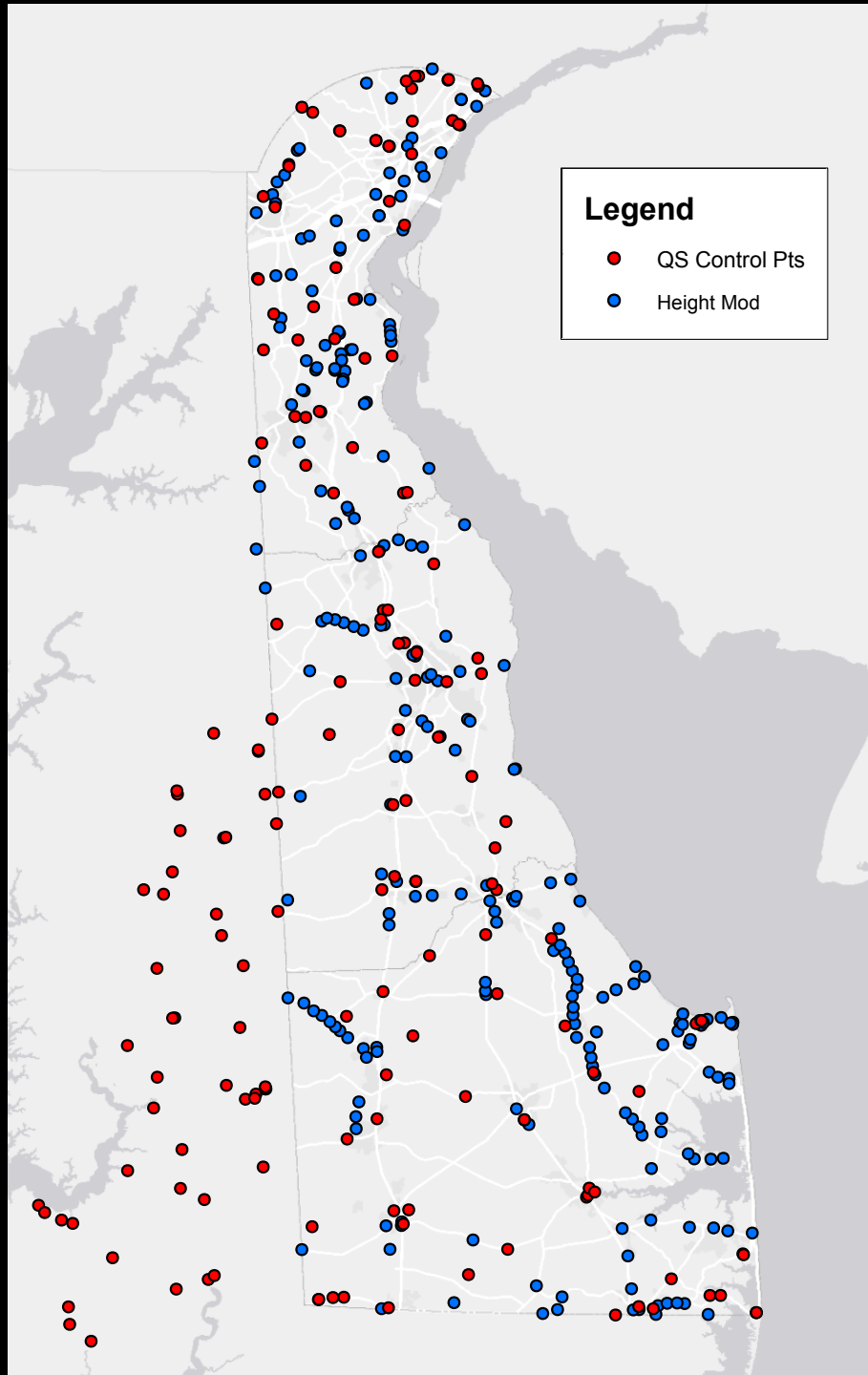
USGS and NOAA LiDAR

- NOAA Topobathymetric LiDAR of limited spatial extent
- Focus on USGS topographic LiDAR for many applications

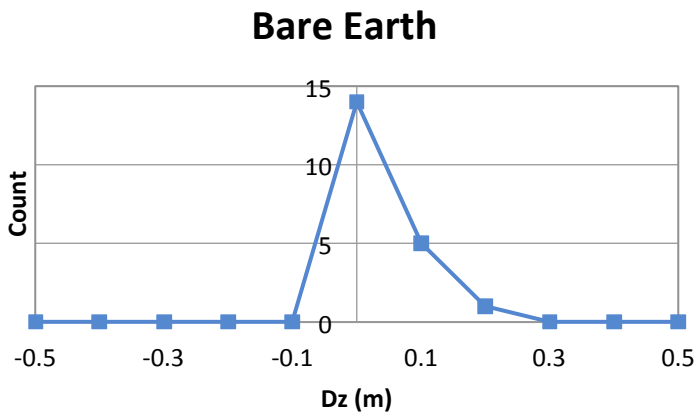


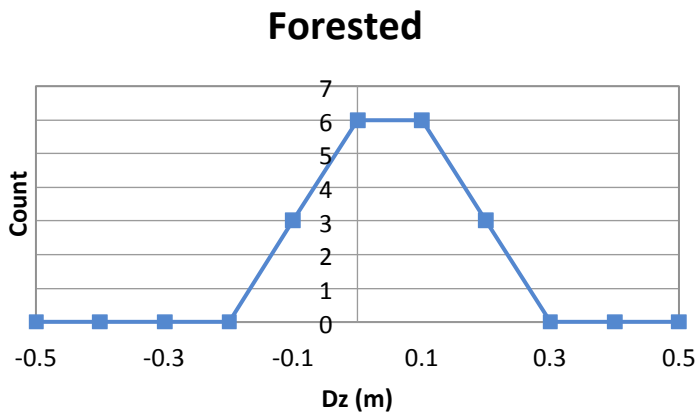
QA/QC

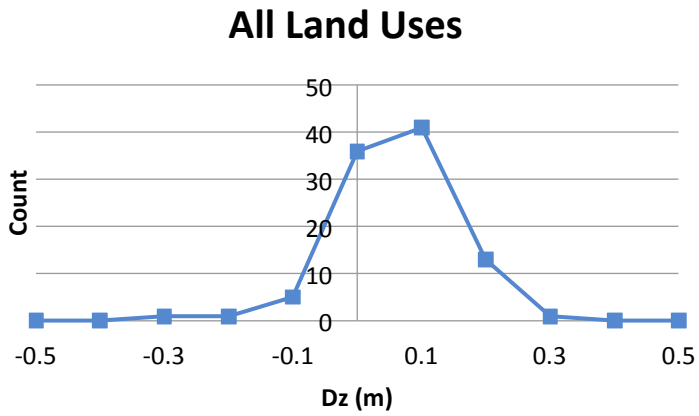
- Replicated Quantum Spatial's analysis
  - Control points (177 total, 118 in Delaware)
- Additional control points
  - Updated when Delaware Height Modernization data becomes available (~240 points; DNREC Coastal Programs)
- Examining QA/QC in the context of Land Use

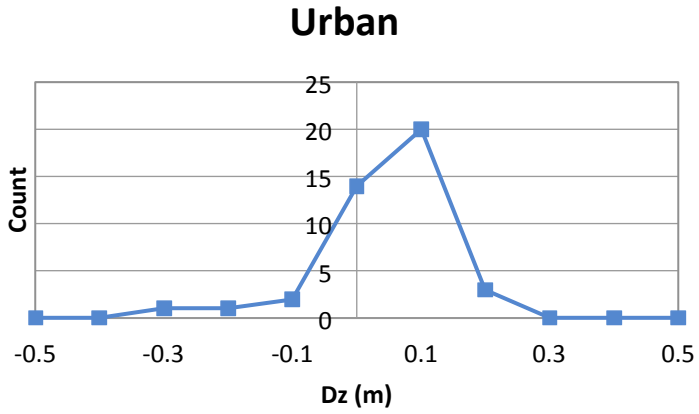


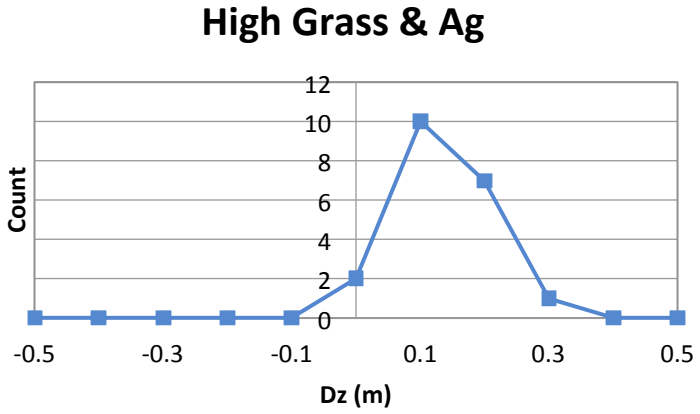
Distribution of Errors
Quantum Spatial Control Points











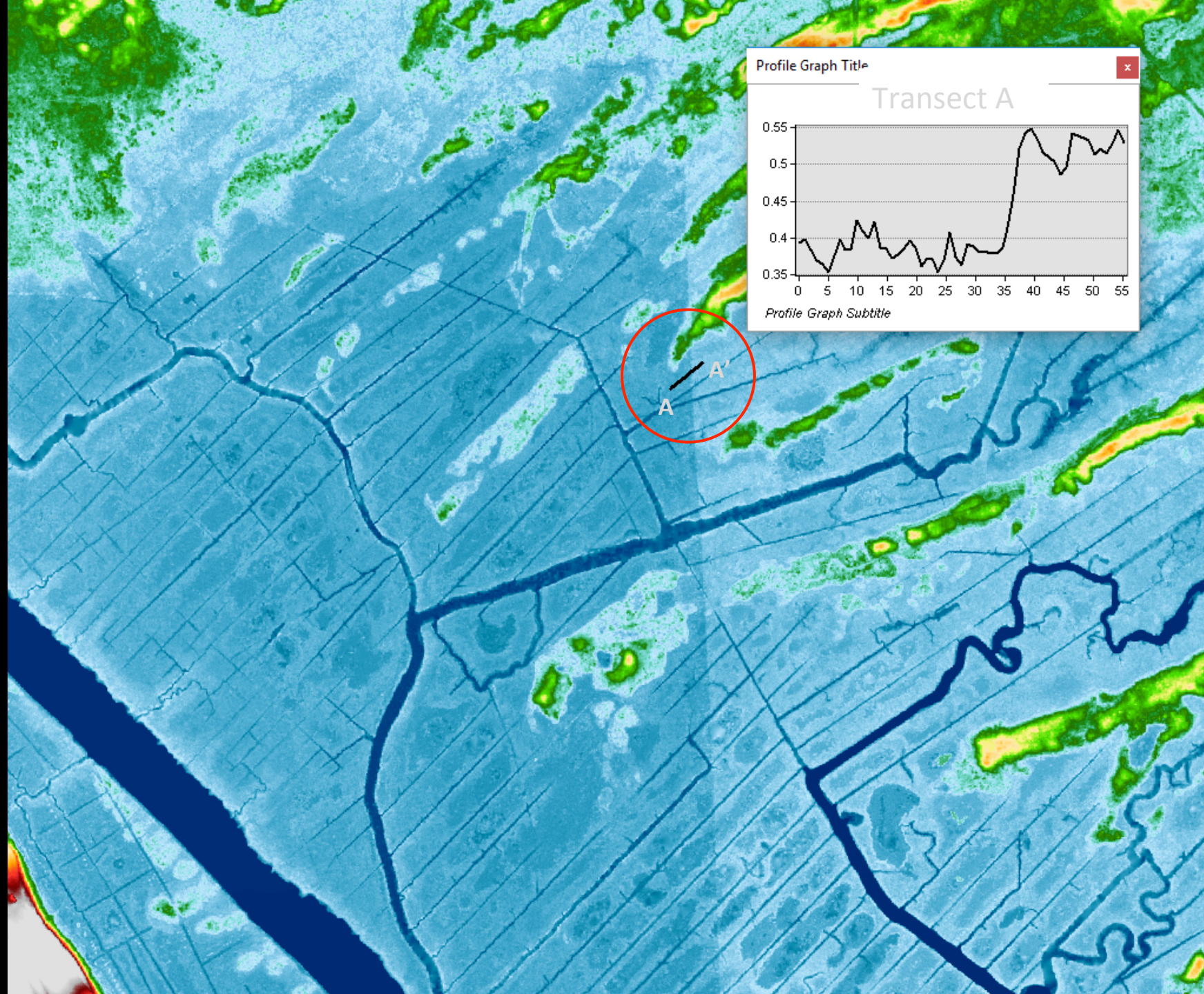
(Dz = LiDAR – actual)

Striping

- Difference grid (USGS - NOAA)
  - Red = USGS Higher
  - Green = NOAA Higher
- Striping from flight lines in both datasets

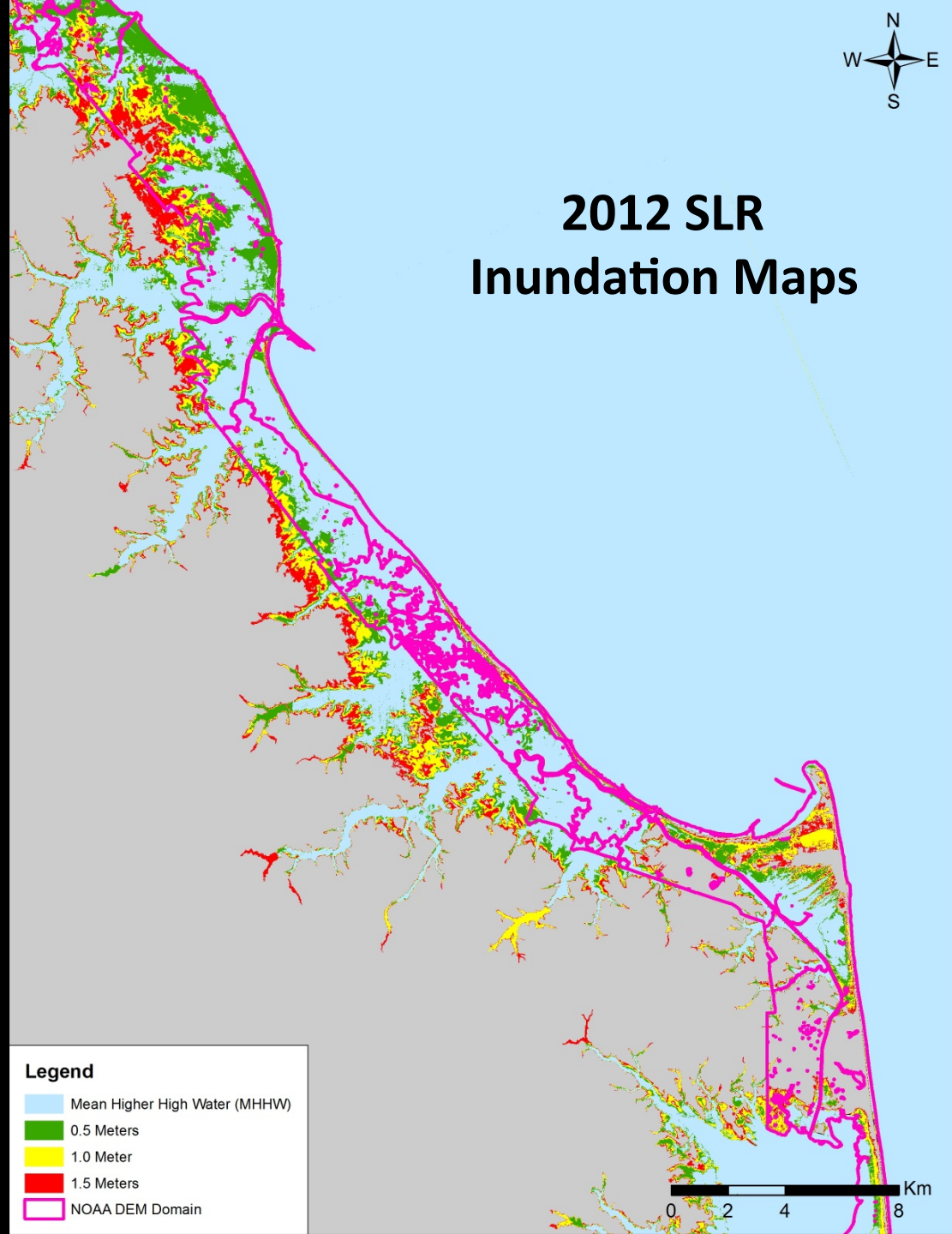
USGS DEM Striping

- Differences are within specifications
- Be aware of the data biases and limitations when using

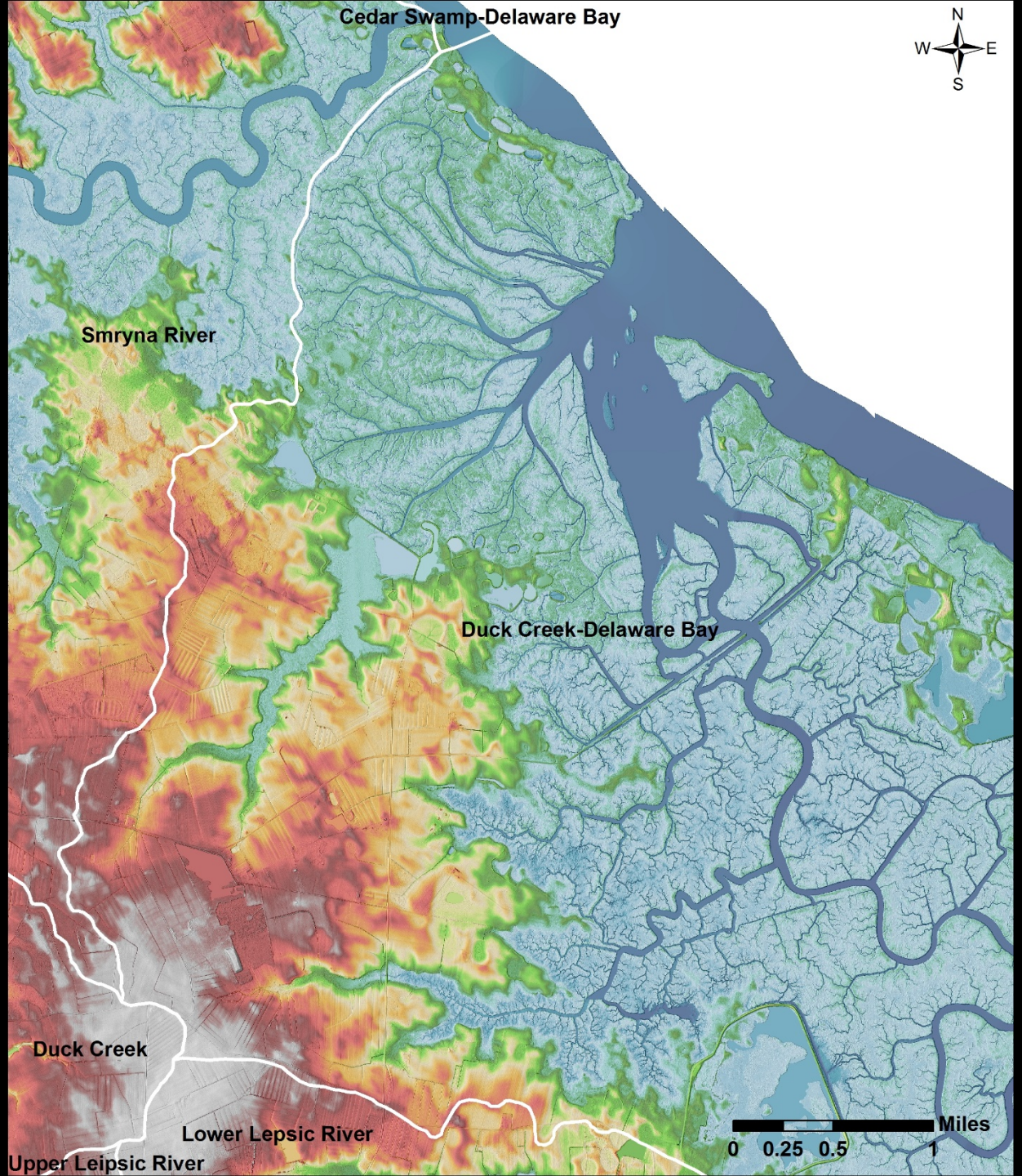


Sea-Level Rise Inundation

- 2016 Delaware SLR Technical Committee
- Delaware Geological Survey
  - Coordinating for DNREC
- Review sea-level rise research
  - update planning scenarios/inundation maps
- 2014 LiDAR-based DEM
  - bathtub-model SLR coastal inundation maps
- Sea-Level Rise planning scenarios,
  - Mean Higher-High Water (MHHW) to 7 ft above MHHW, in 1 foot increments
  - advise long-range planning of infrastructure, facilities, land management, land-use, and capital spending

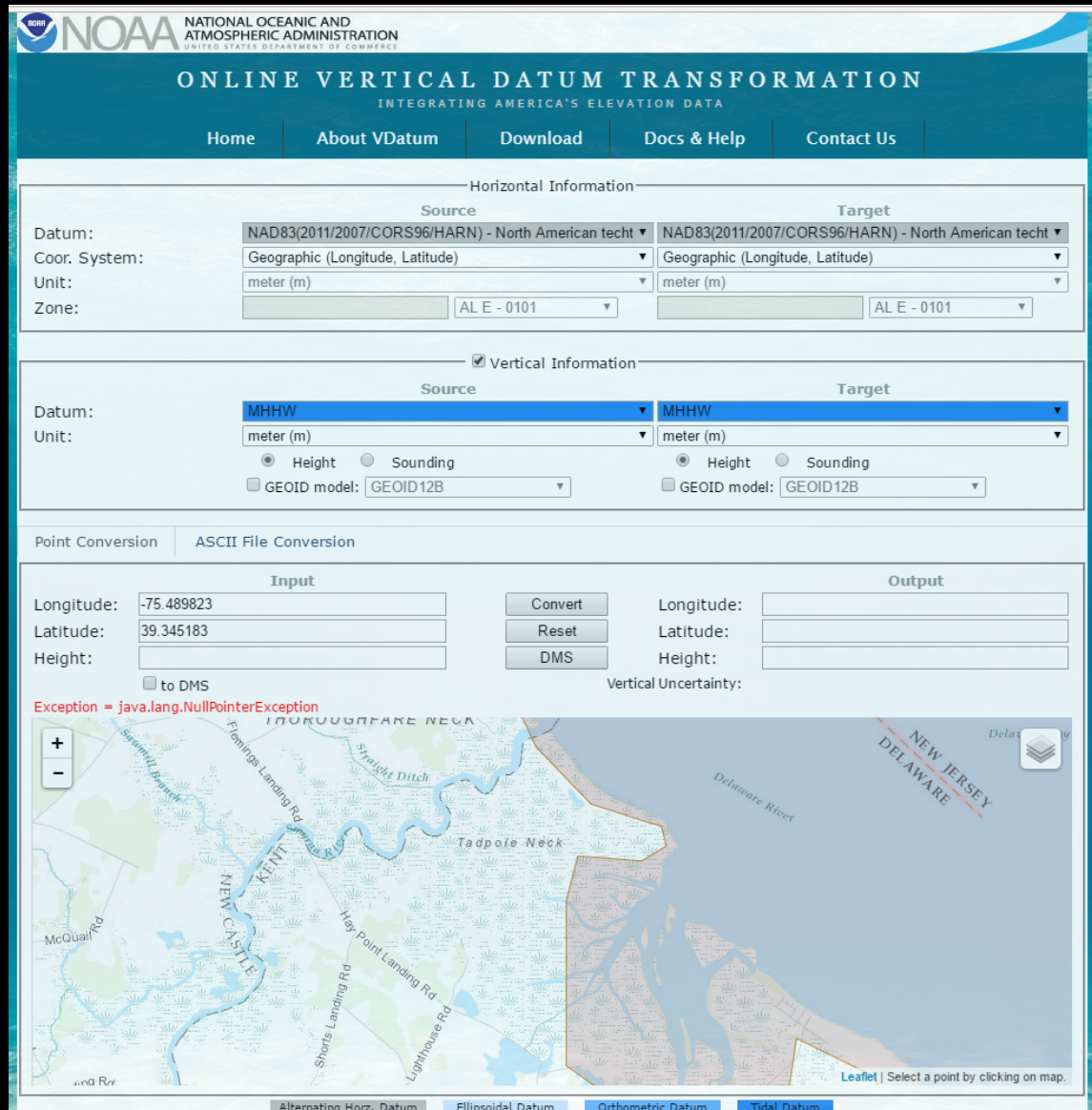


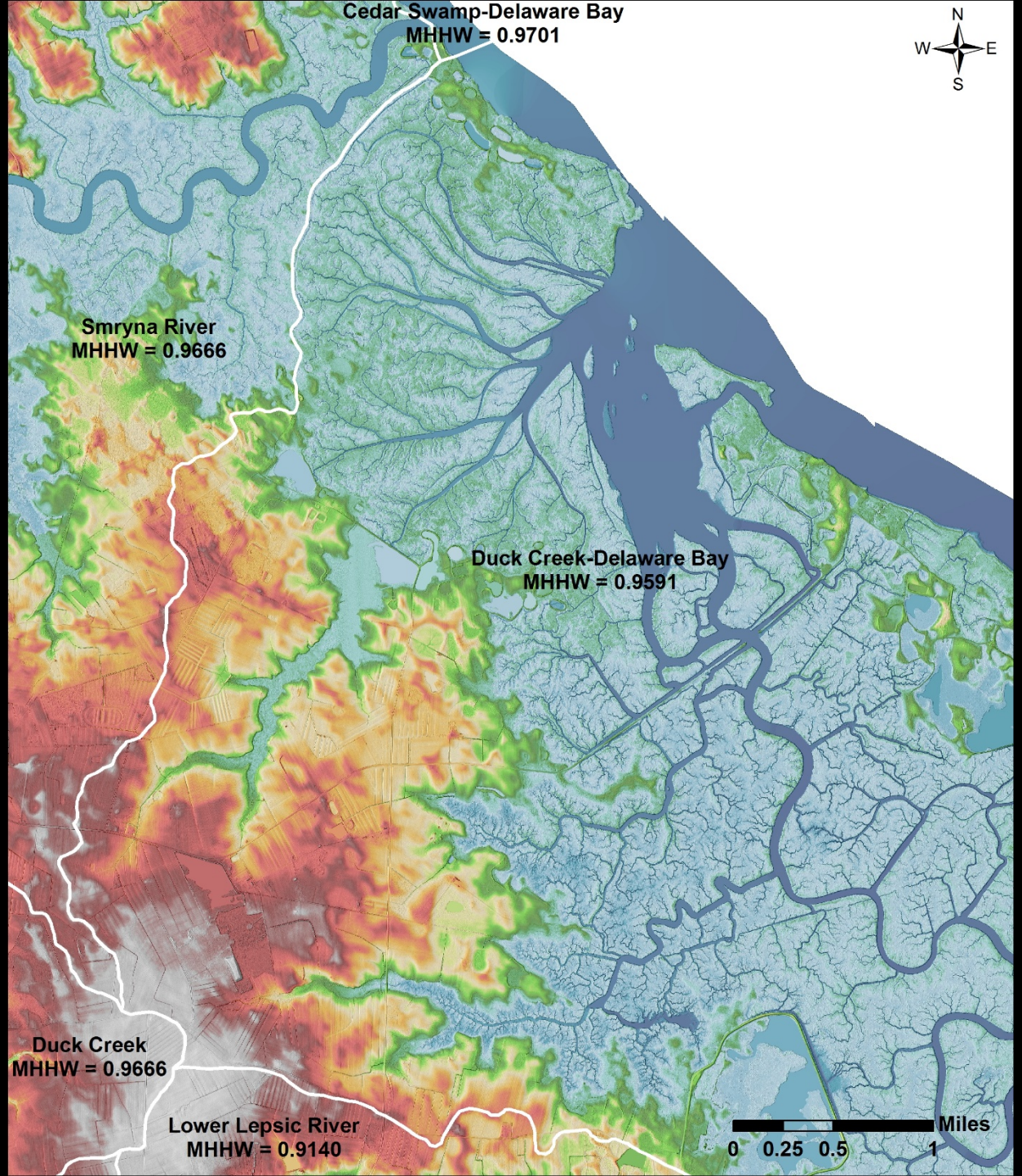
Start with hydro-flattened DEM with a few manual corrections

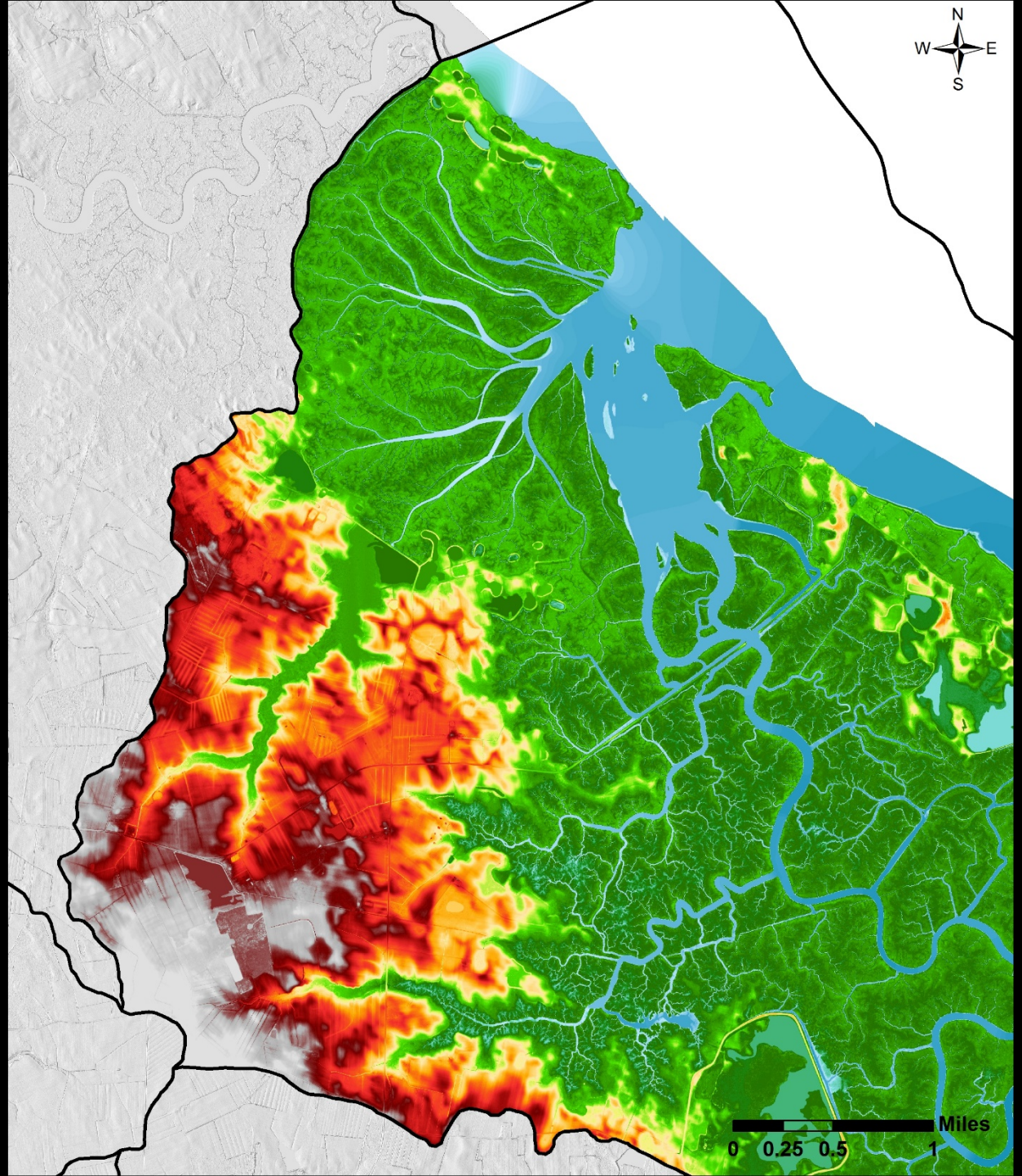


MHHW for Each Watershed

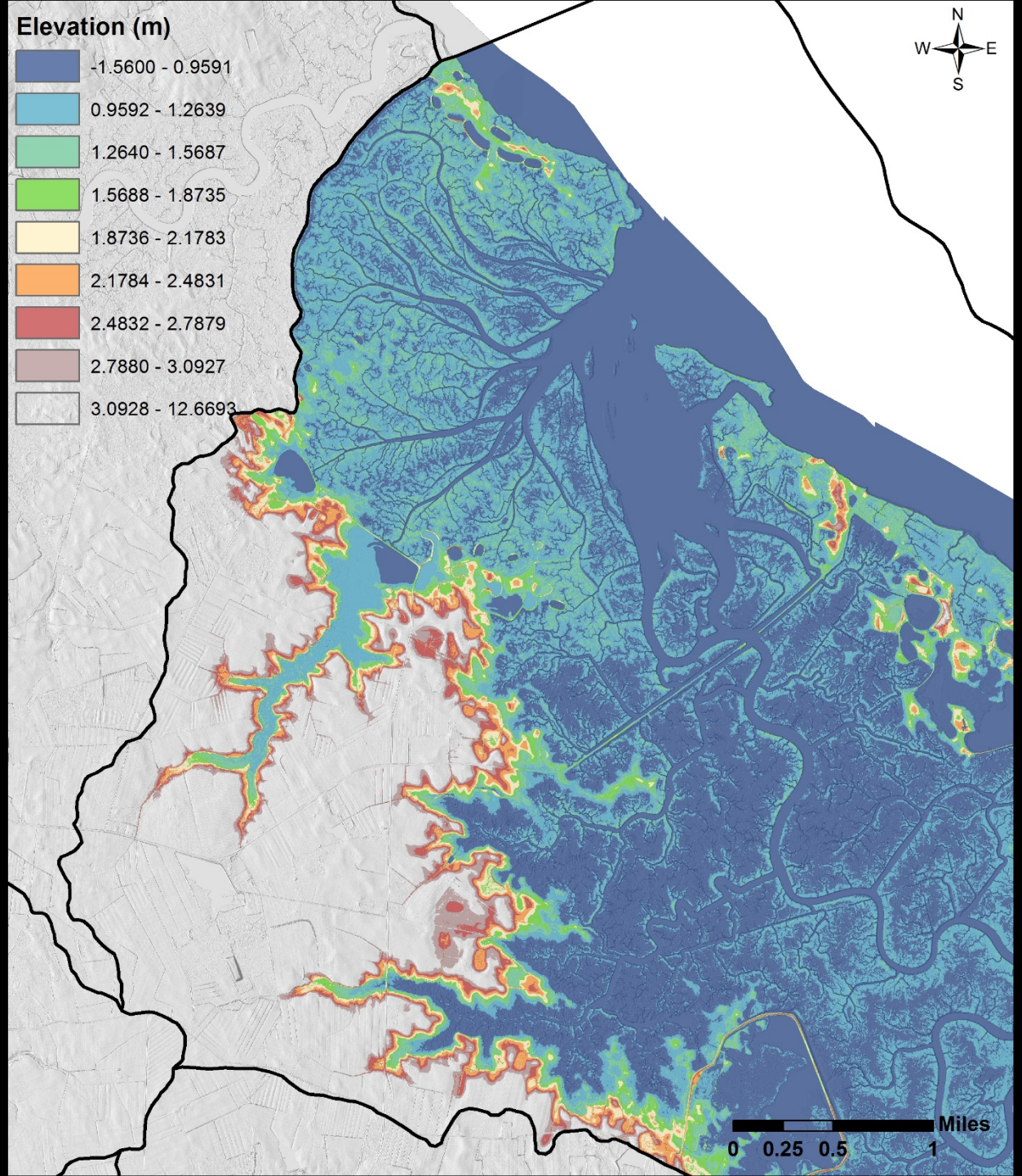
- Used NOAA's VDatum tool to determine MHHW at the mouth of each coastal watershed

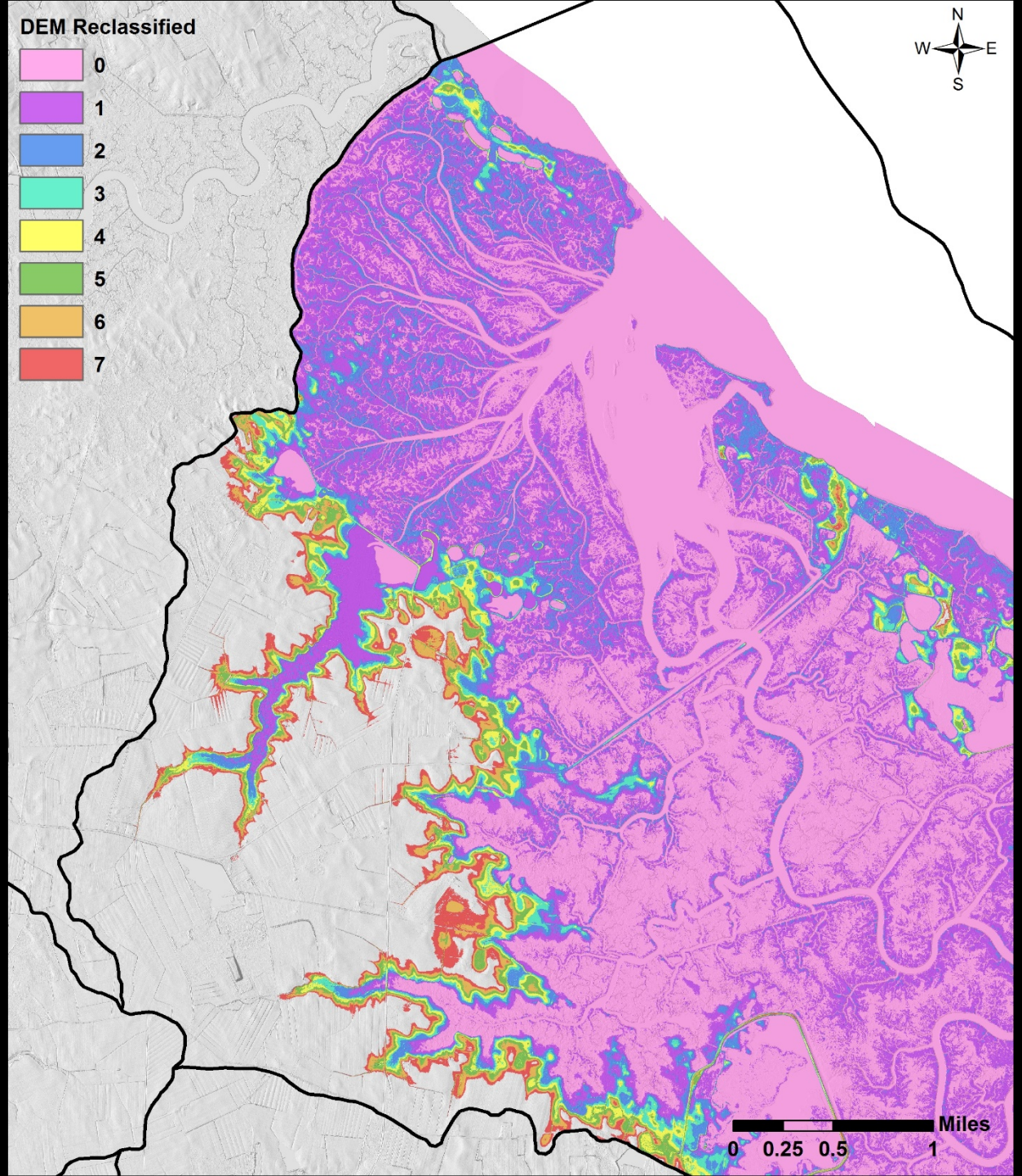


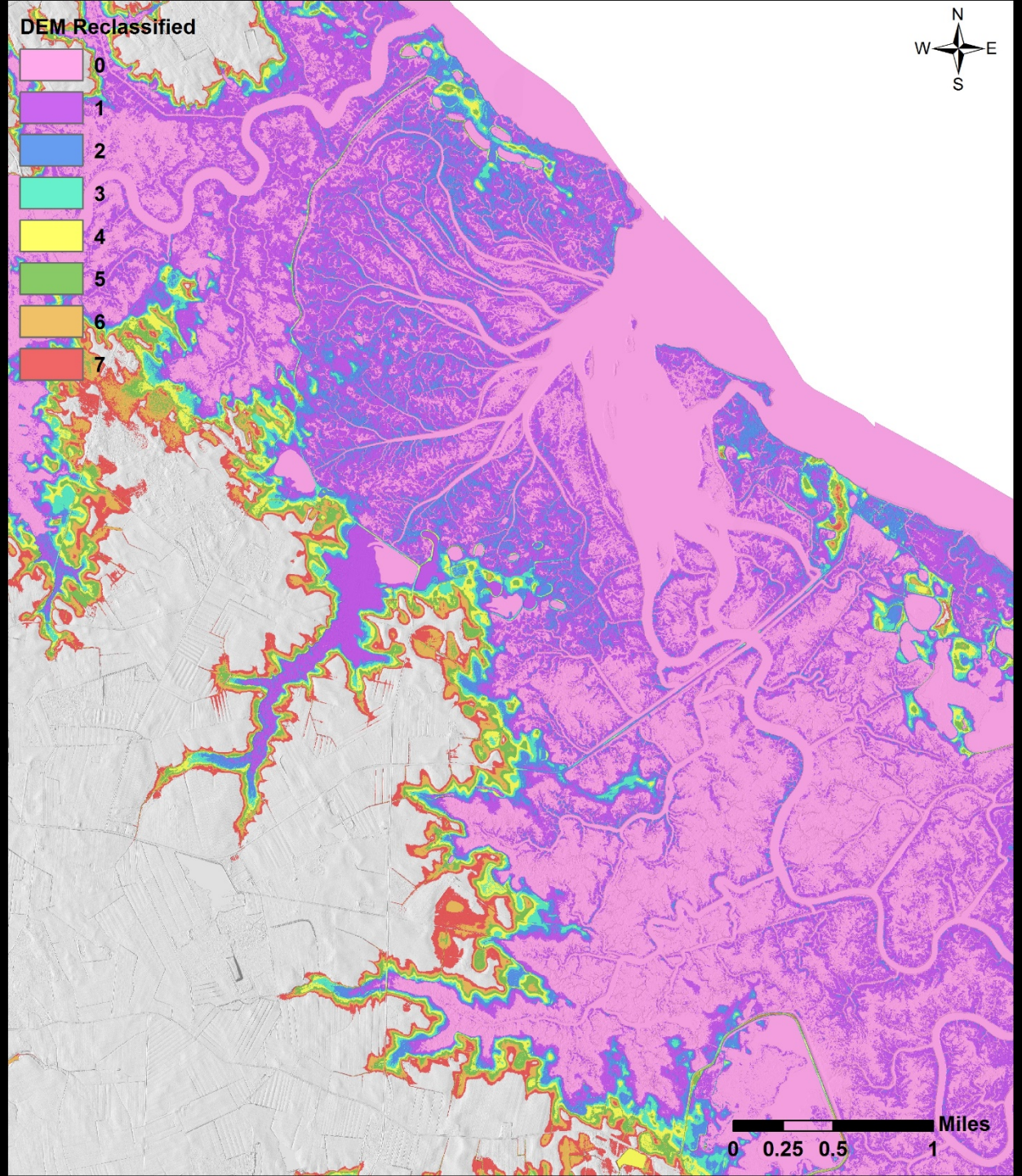

Cedar Swamp-Delaware Bay
MHHW = 0.9701
N
W
E
S
Smryna River
MHHW = 0.9666
Duck Creek-Delaware Bay
MHHW = 0.9591
Duck Creek
MHHW = 0.9666
Lower Lepsic River
MHHW = 0.9140
Miles
0 0.25 0.5 1


N
W
E
S
Miles
0 0.25 0.5 1

SLR Scenarios	ft	m	DuckCr
MHHW	0	0	0.9591
1ft	1	0.3048	1.2639
2ft	2	0.6096	1.5687
3ft	3	0.9144	1.8735
4ft	4	1.2192	2.1783
5ft	5	1.5240	2.4831
6ft	6	1.8288	2.7879
7ft	7	2.1336	3.0927




DEM Reclassified
0
1
2
3
4
5
6
7
N
W
E
S
Miles
0
0.25
0.5
1


DEM Reclassified
0
1
2
3
4
5
6
7
N
W
E
S
Miles
0
0.25
0.5
1

Scenario:

SLR = 2ft

Scenario:

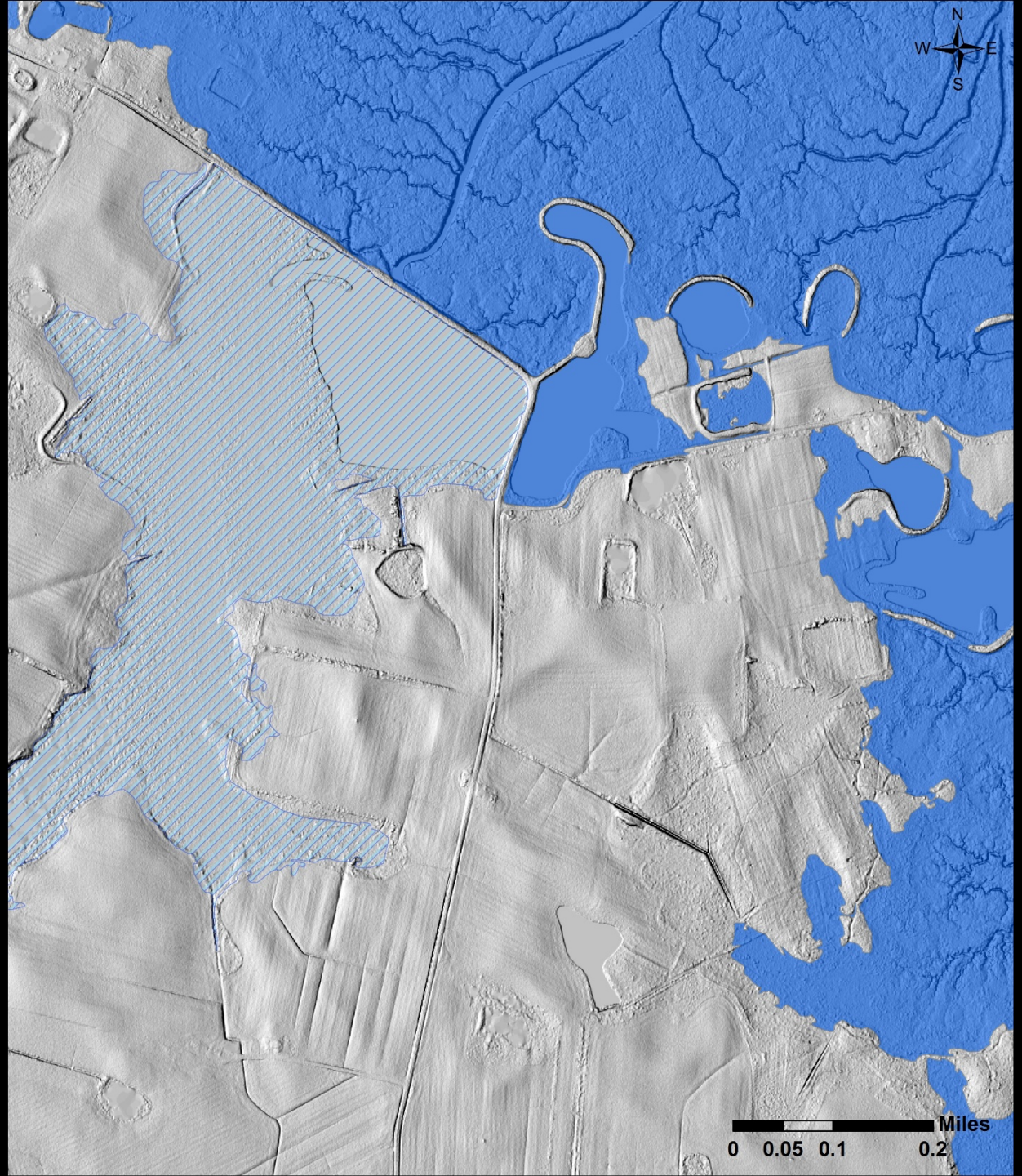
SLR = 2ft

Scenario:

SLR = 2ft

Scenario:

SLR = 2ft

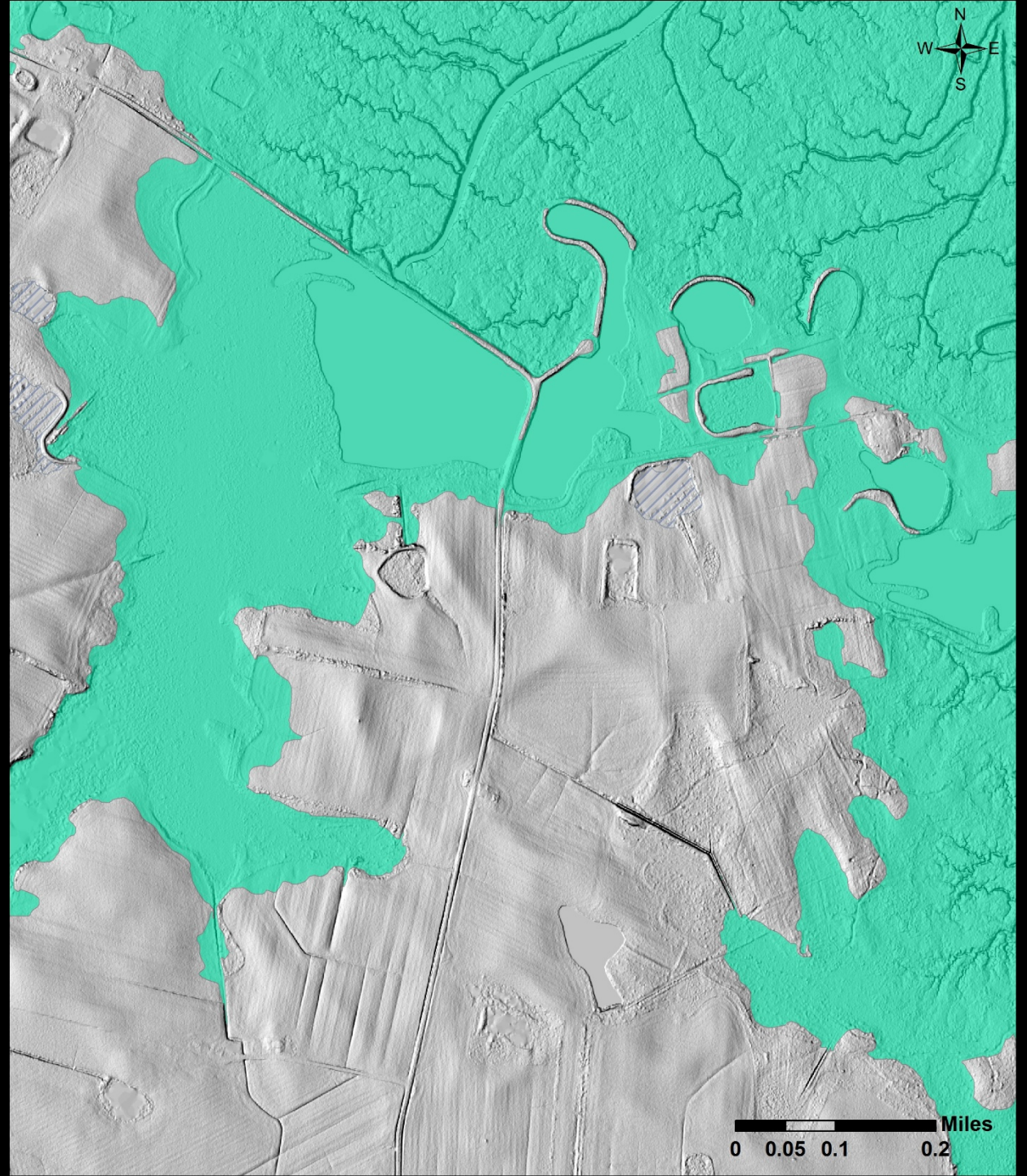


Scenario:

SLR = 3ft

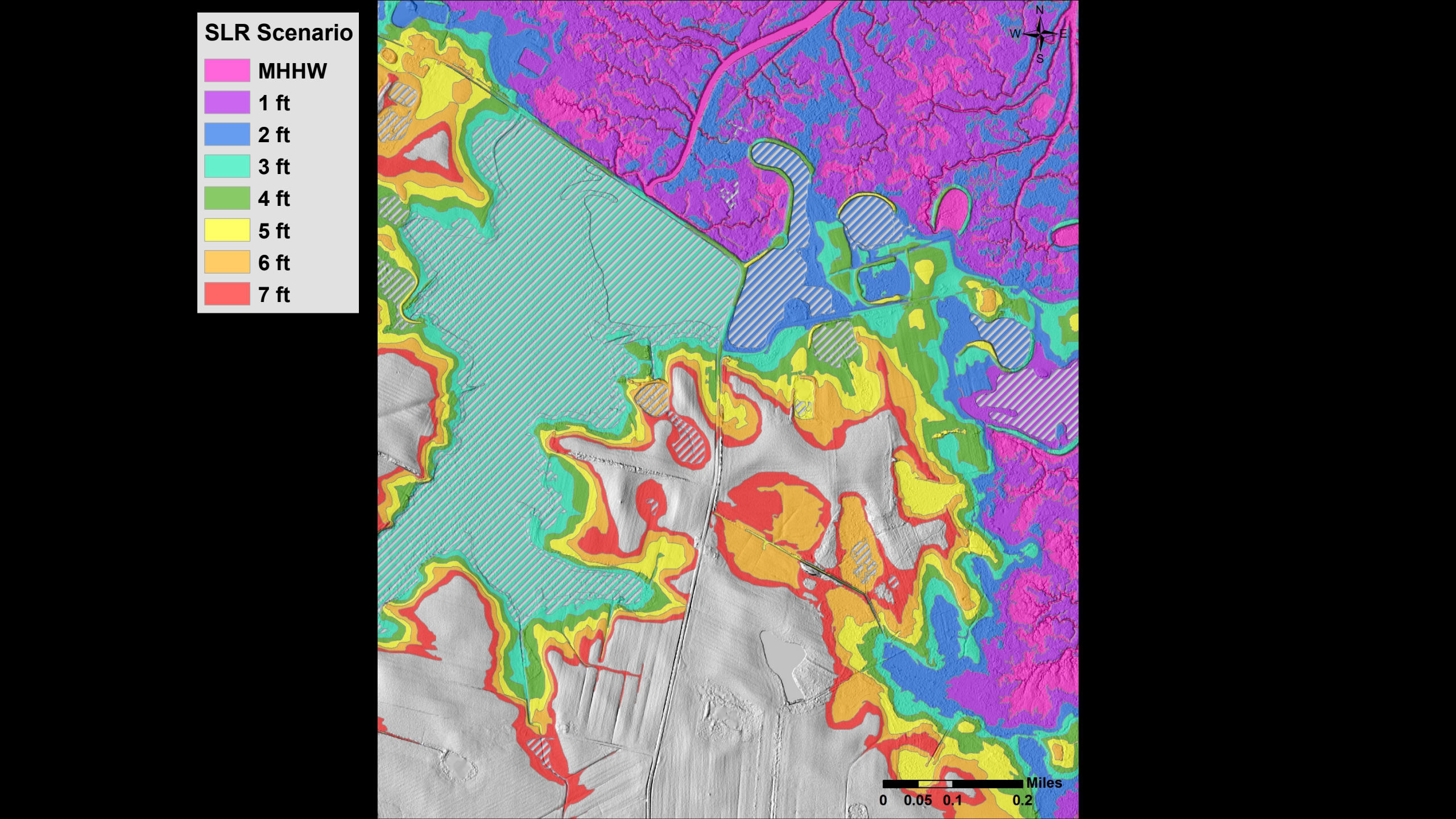
Scenario:

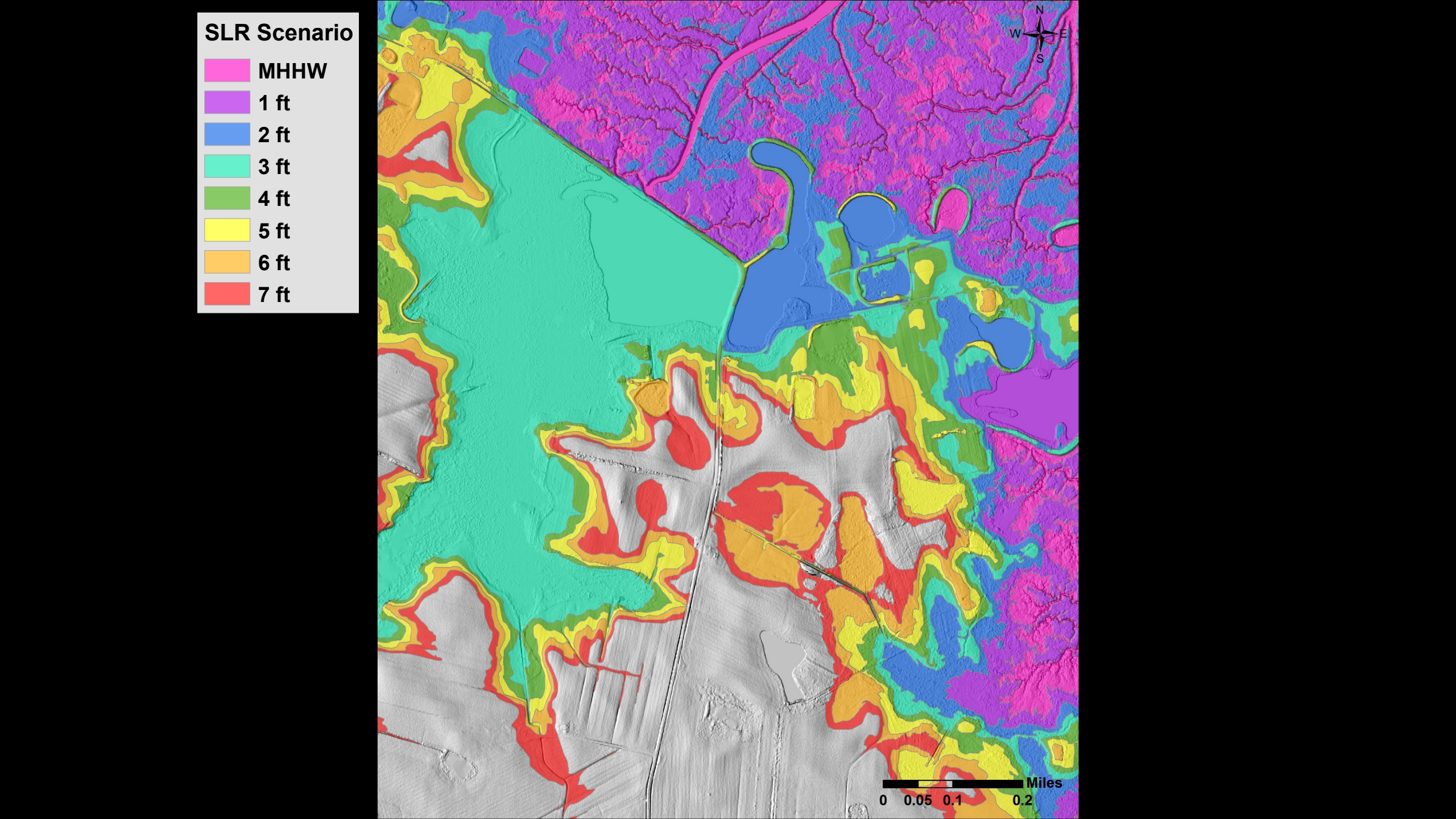
SLR = 3ft



Scenario:

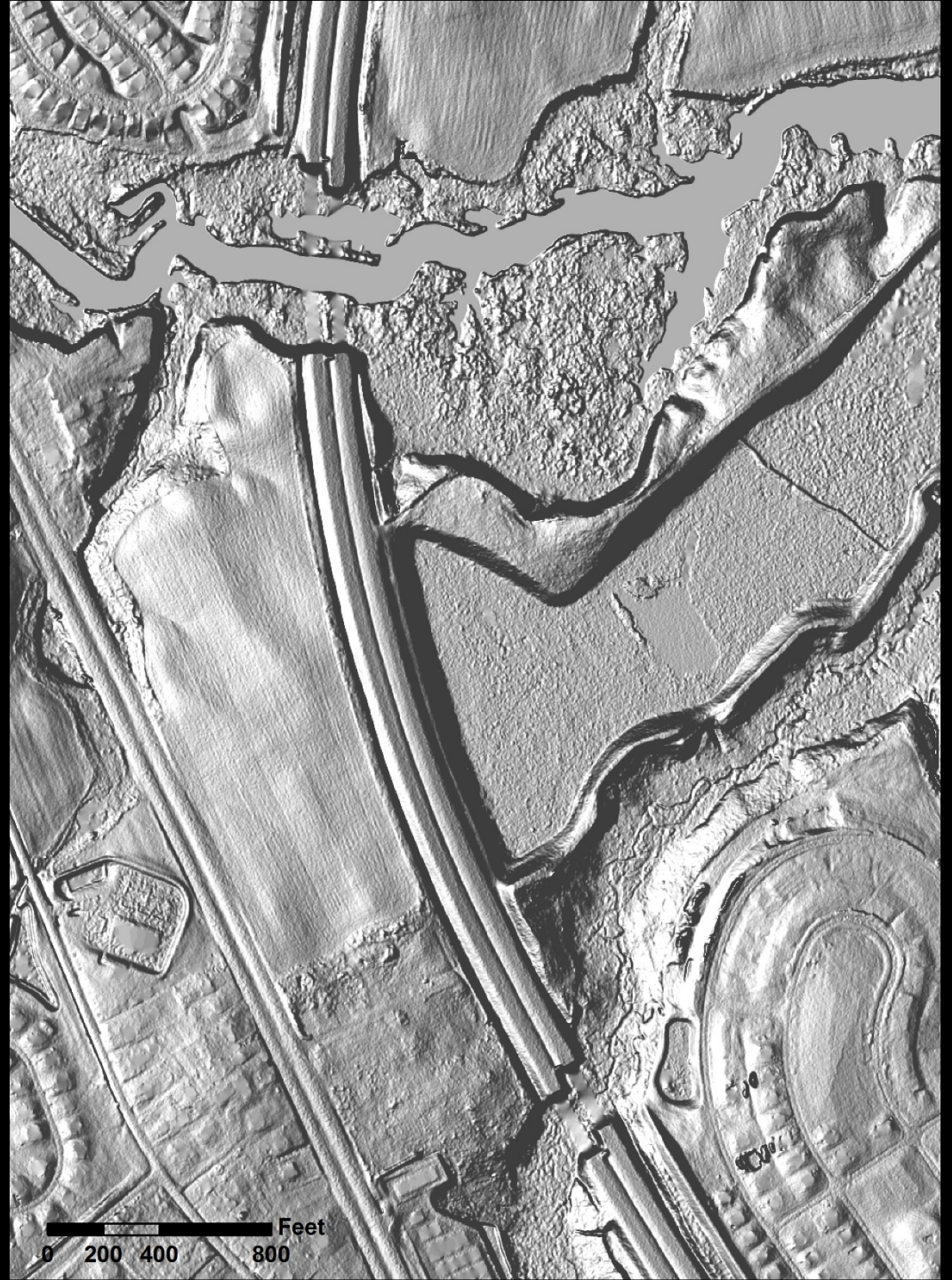
SLR = 7ft

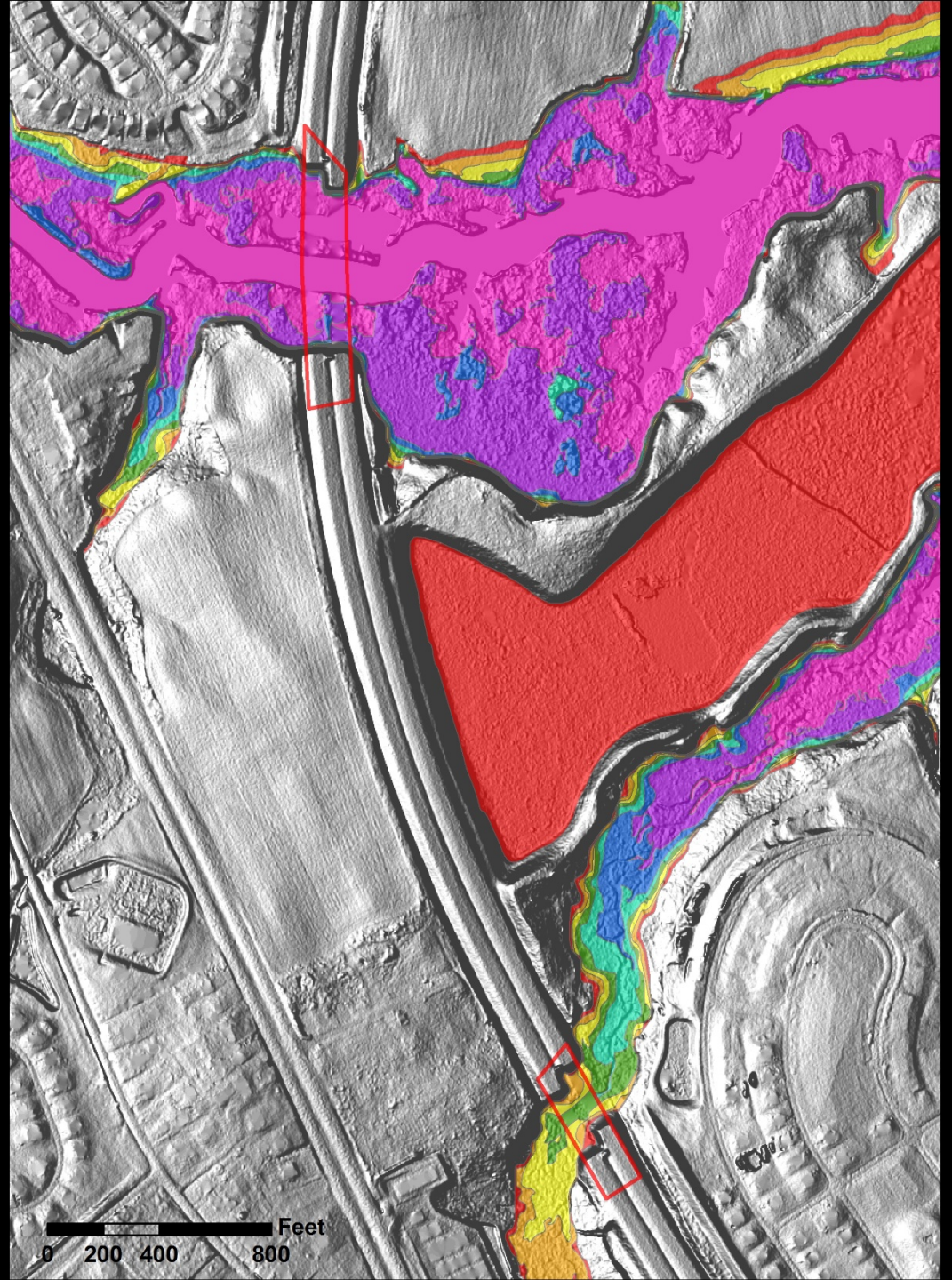

SLR Scenario
MHHW
1 ft
2 ft
3 ft
4 ft
5 ft
6 ft
7 ft
N
W
E
S
Miles
0
0.05
0.1
0.2

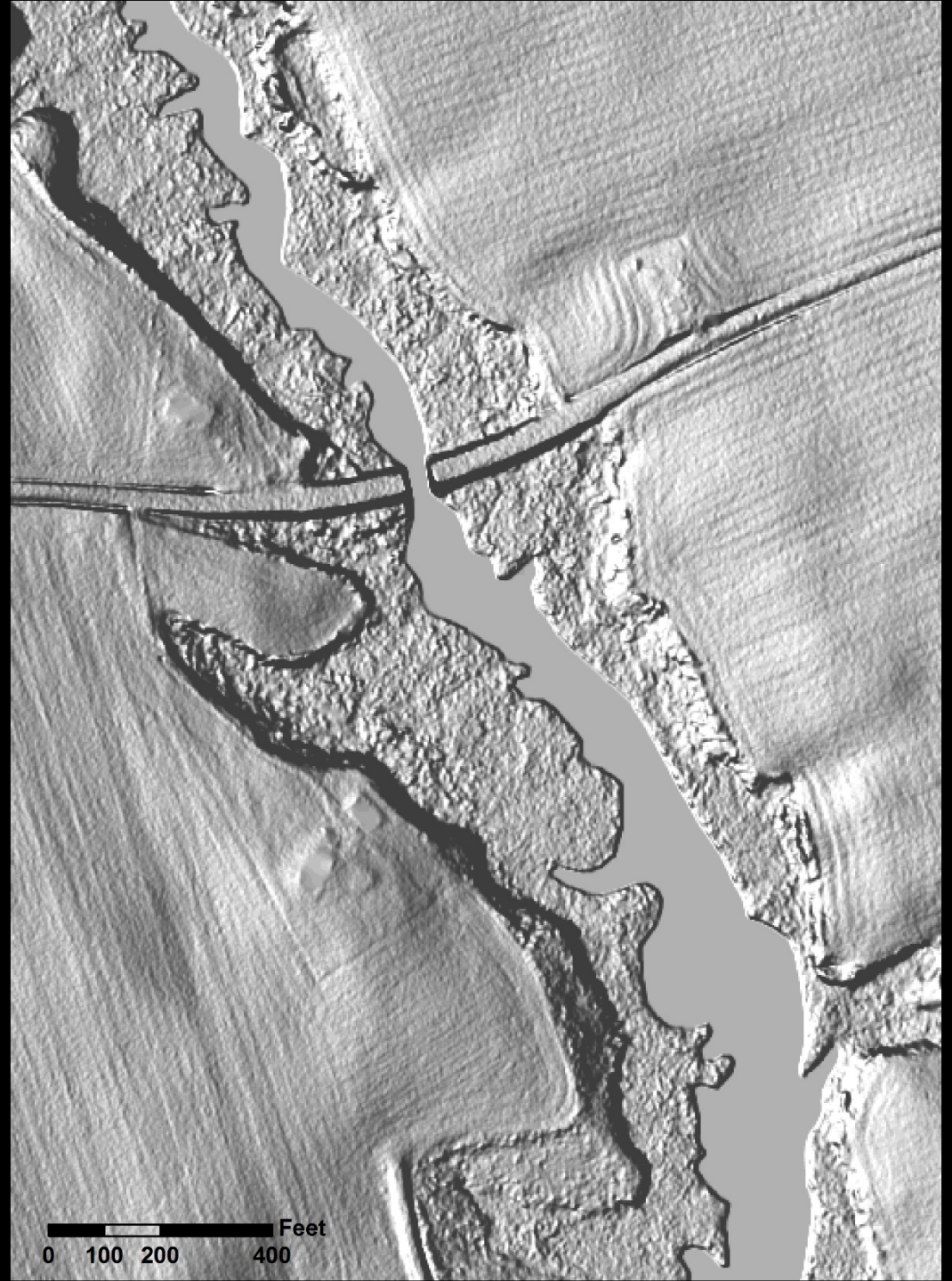

SLR Scenario
MHHW
1 ft
2 ft
3 ft
4 ft
5 ft
6 ft
7 ft
N
W
E
S
Miles
0
0.05
0.1
0.2

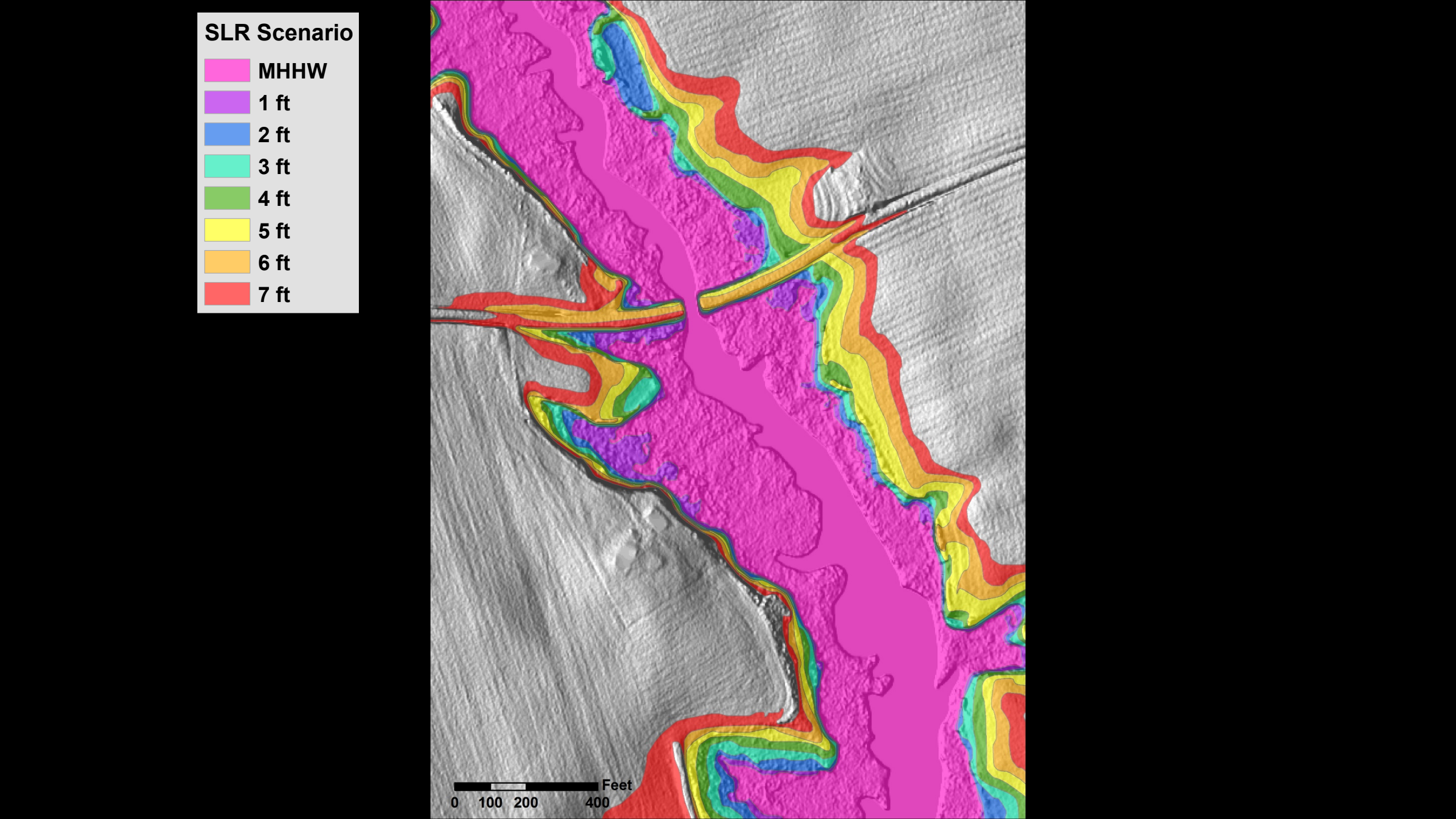
Elevated Roadways

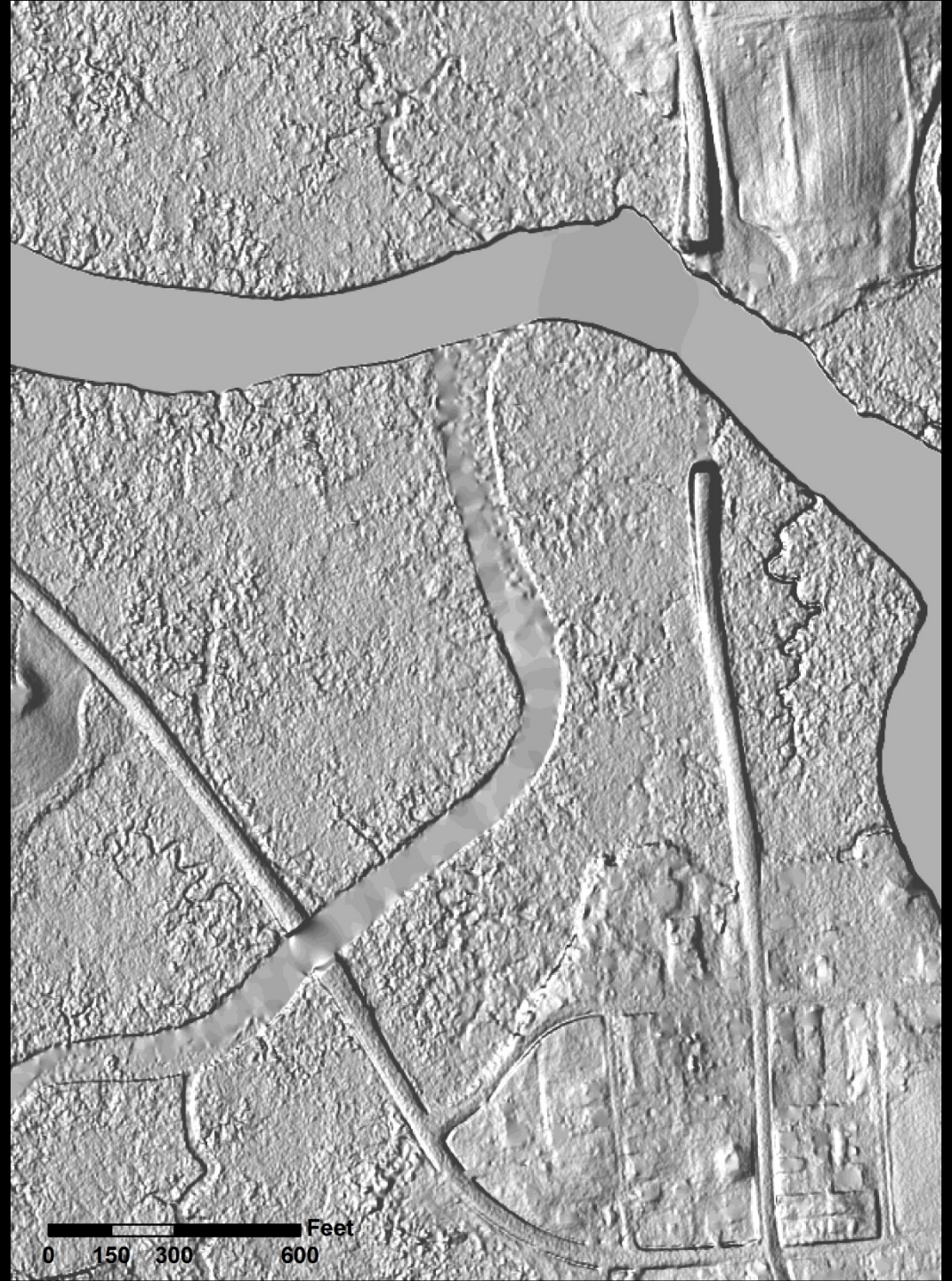
- Elevated Roadways often removed from Bare Earth DEM
- Important to know how these roadways affected by SLR
- Manually adjust SLR maps

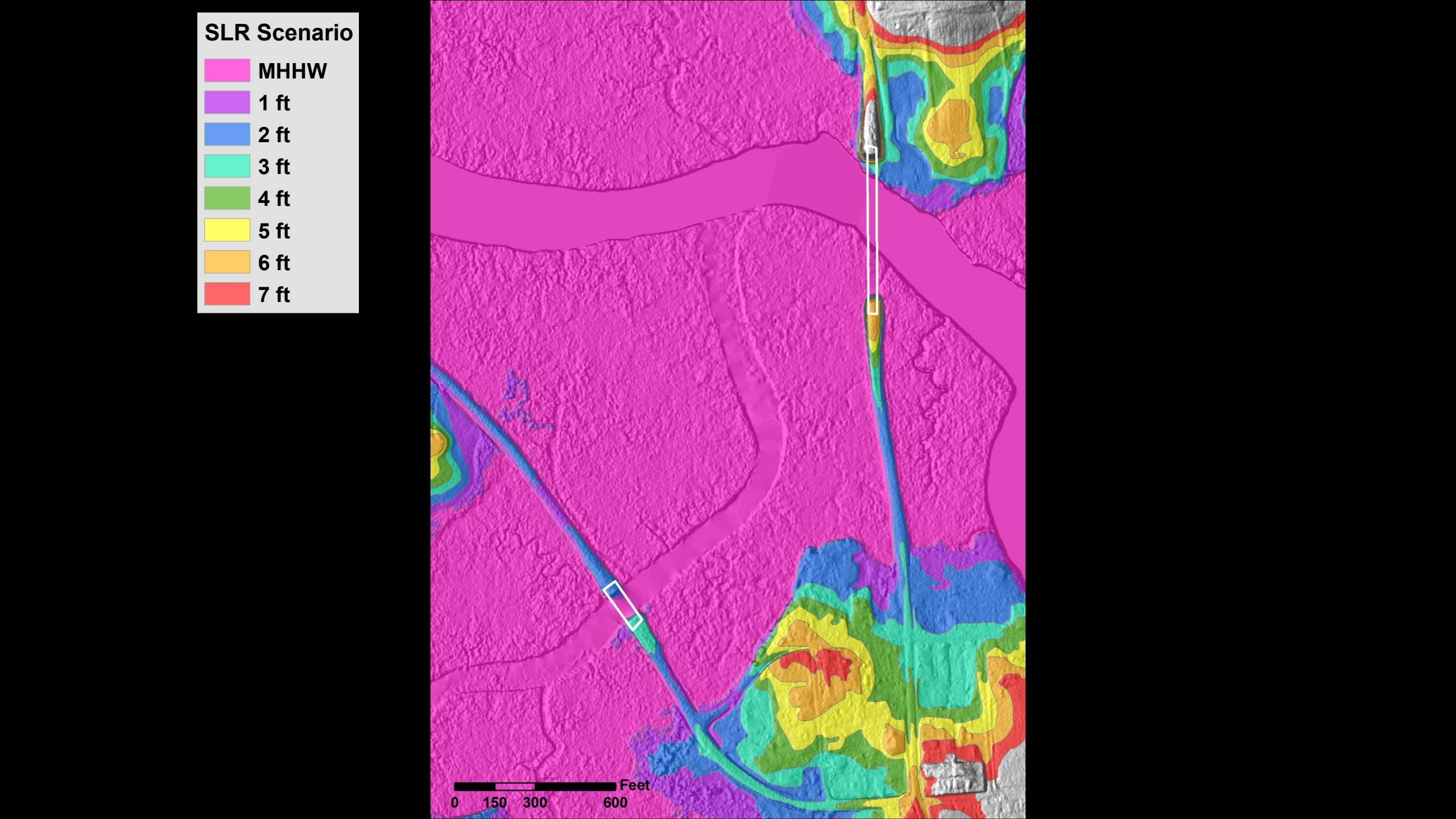



SLR Scenario
MHHW
1 ft
2 ft
3 ft
4 ft
5 ft
6 ft
7 ft
Feet
0 200 400 800

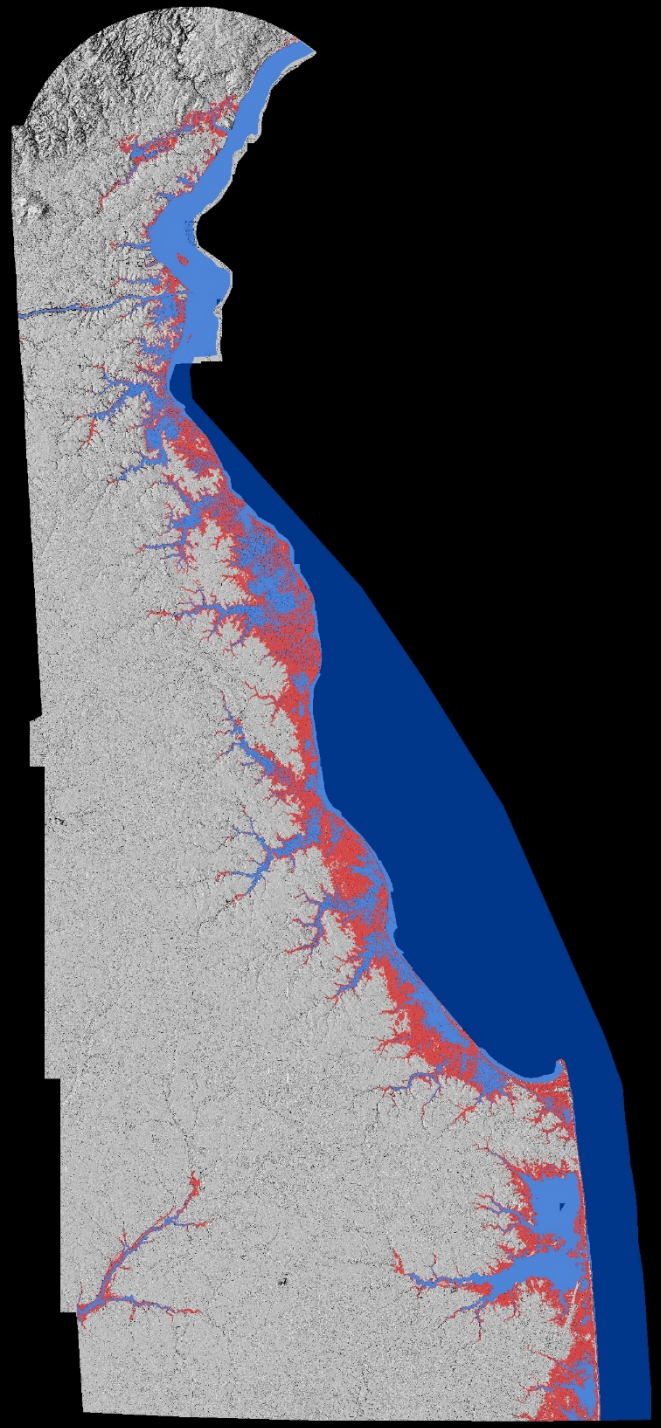

Feet
0 100 200 400


SLR Scenario
MHHW
1 ft
2 ft
3 ft
4 ft
5 ft
6 ft
7 ft
0
100
200
400
Feet

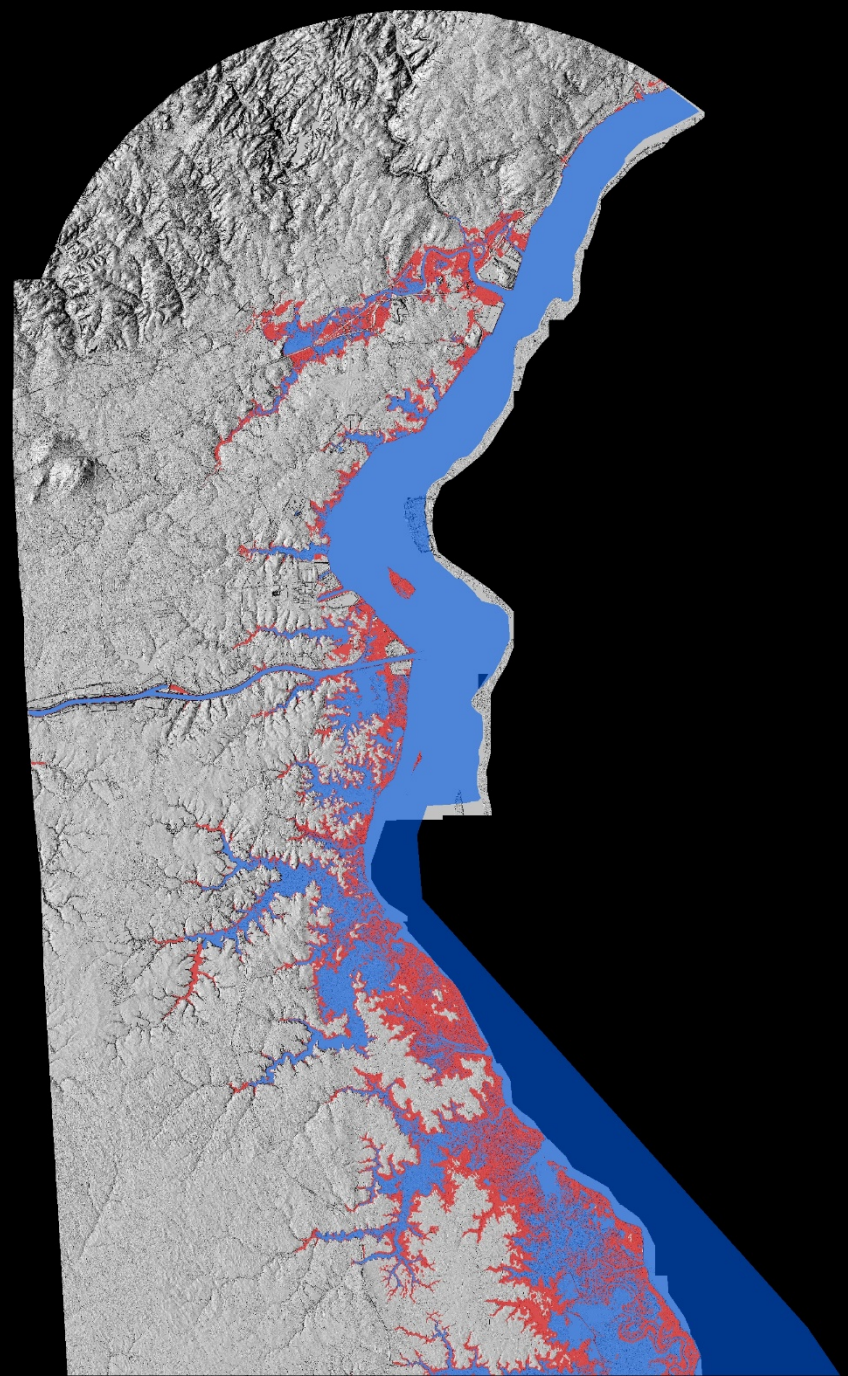

Feet
0 150 300 600


SLR Scenario
MHHW
1 ft
2 ft
3 ft
4 ft
5 ft
6 ft
7 ft
0
150
300
600
Feet

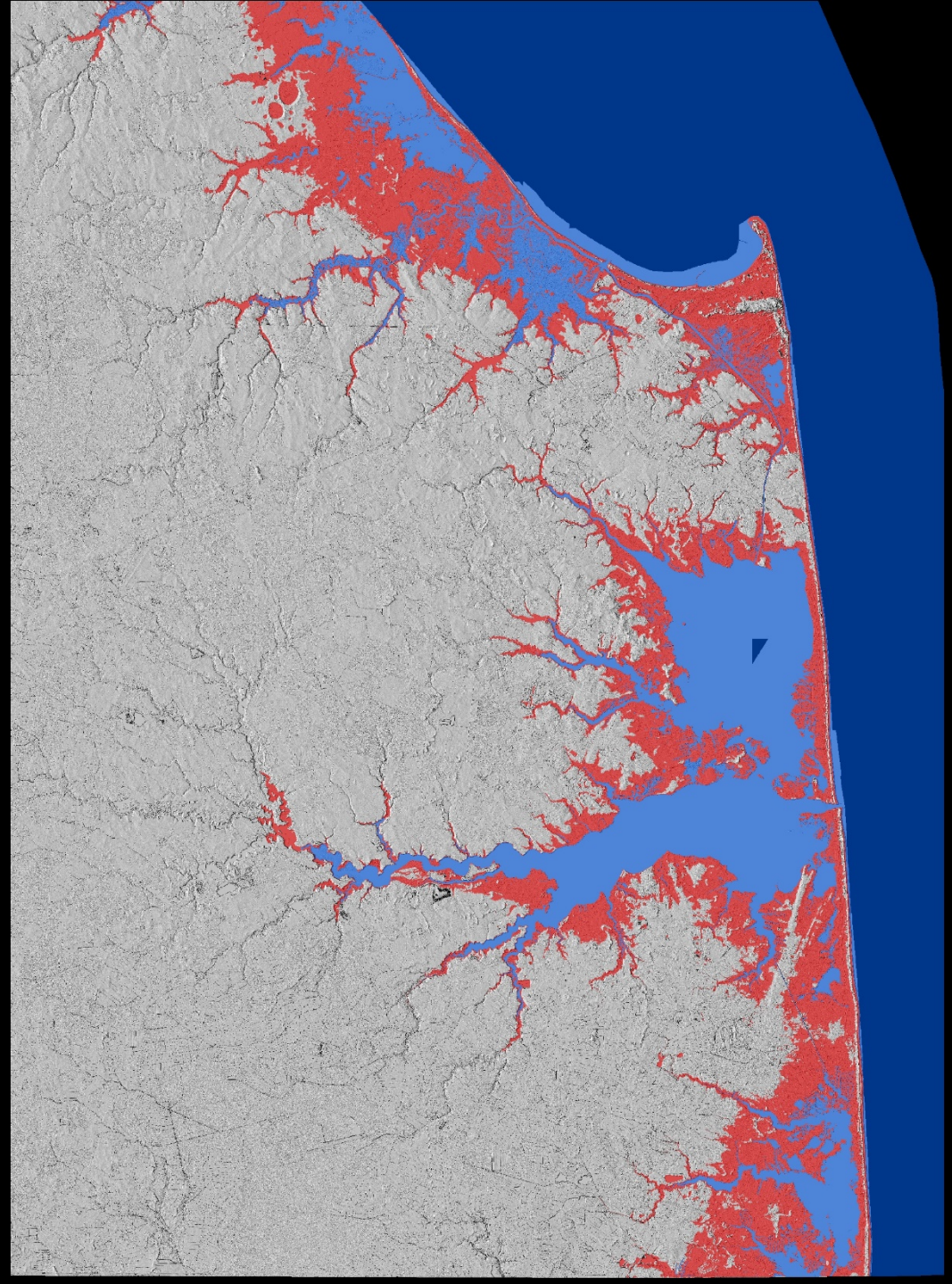
MHHW and 7-ft SLR Scenarios



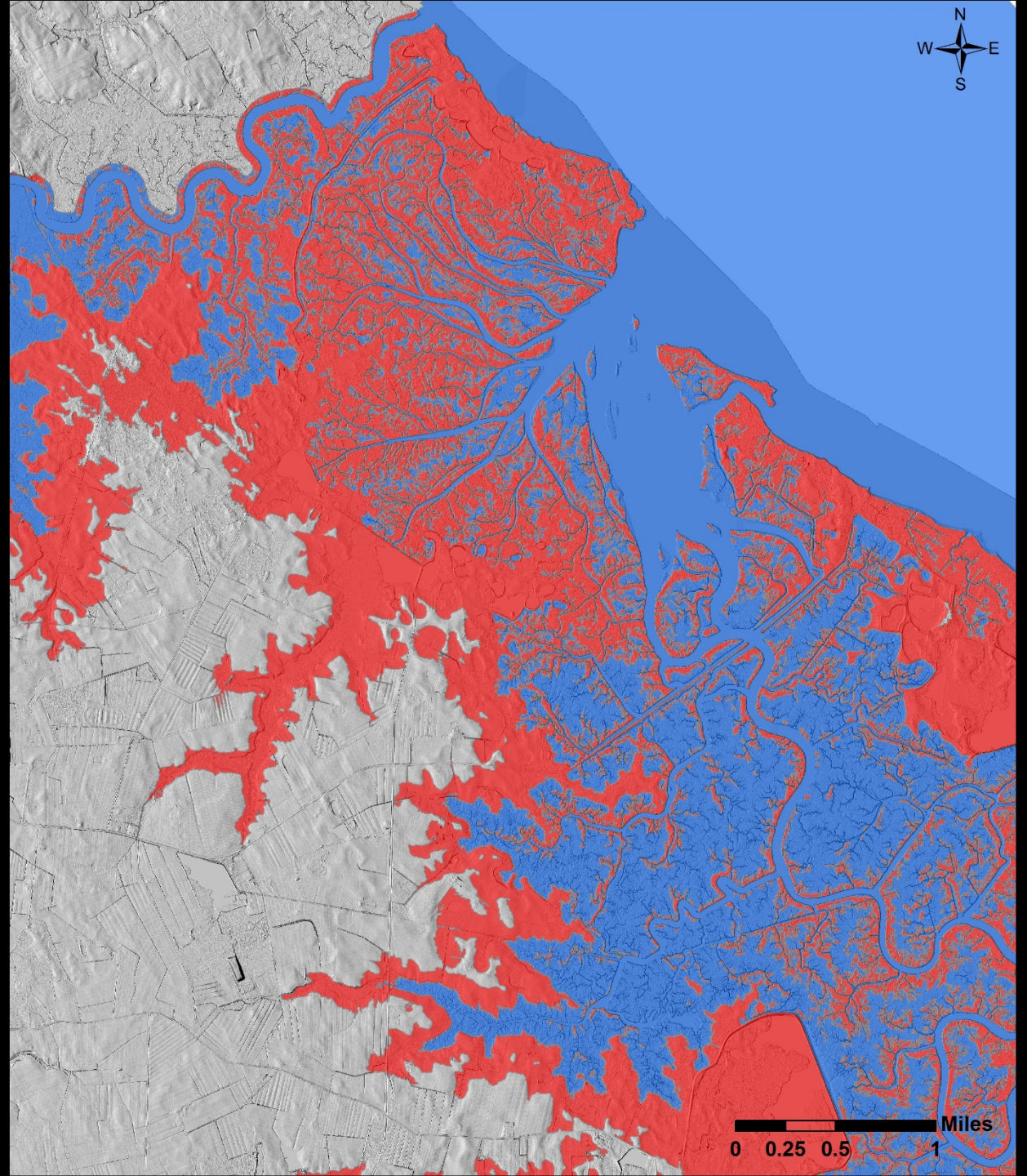
MHHW and 7-ft SLR Scenarios



MHHW and 7-ft SLR Scenarios



MHHW and 7-ft SLR Scenarios



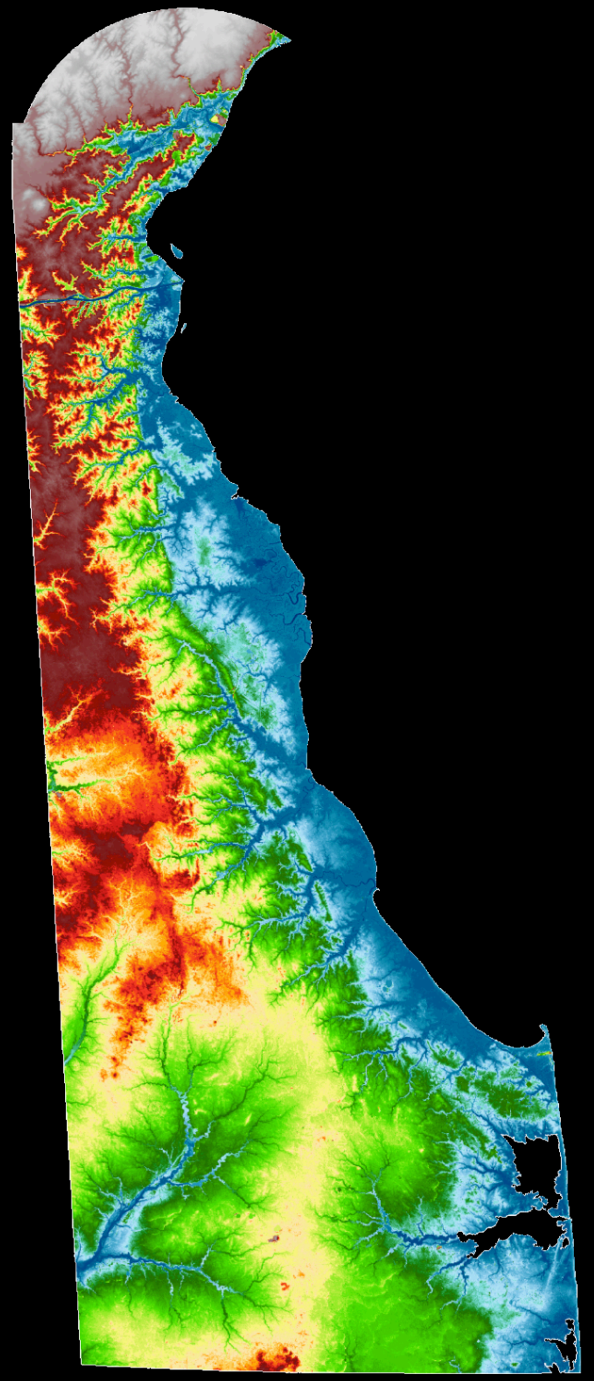
LiDAR Derivatives

- Hillshade
- Aspect
- Slope

1-ft Contours

- Smooth for cartographic purposes
- More exact for site-level assessments

Derived products for specific applications



7x7 Focal Statistics smoothing will be used to produce cartographic contours

N
W
E
S
Feet
0
250
500
1,000

N
W
E
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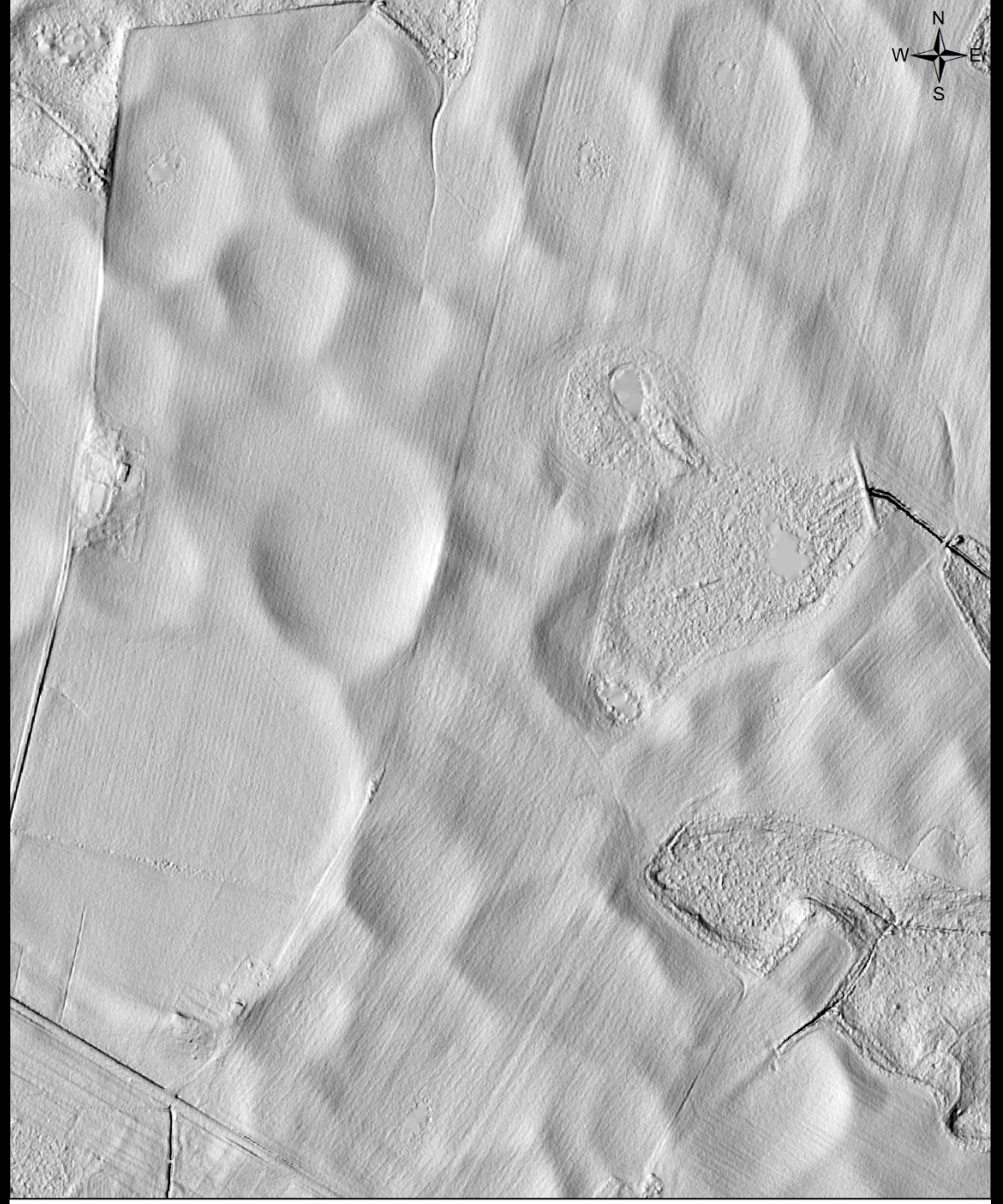
Feet
0
250
500
1,000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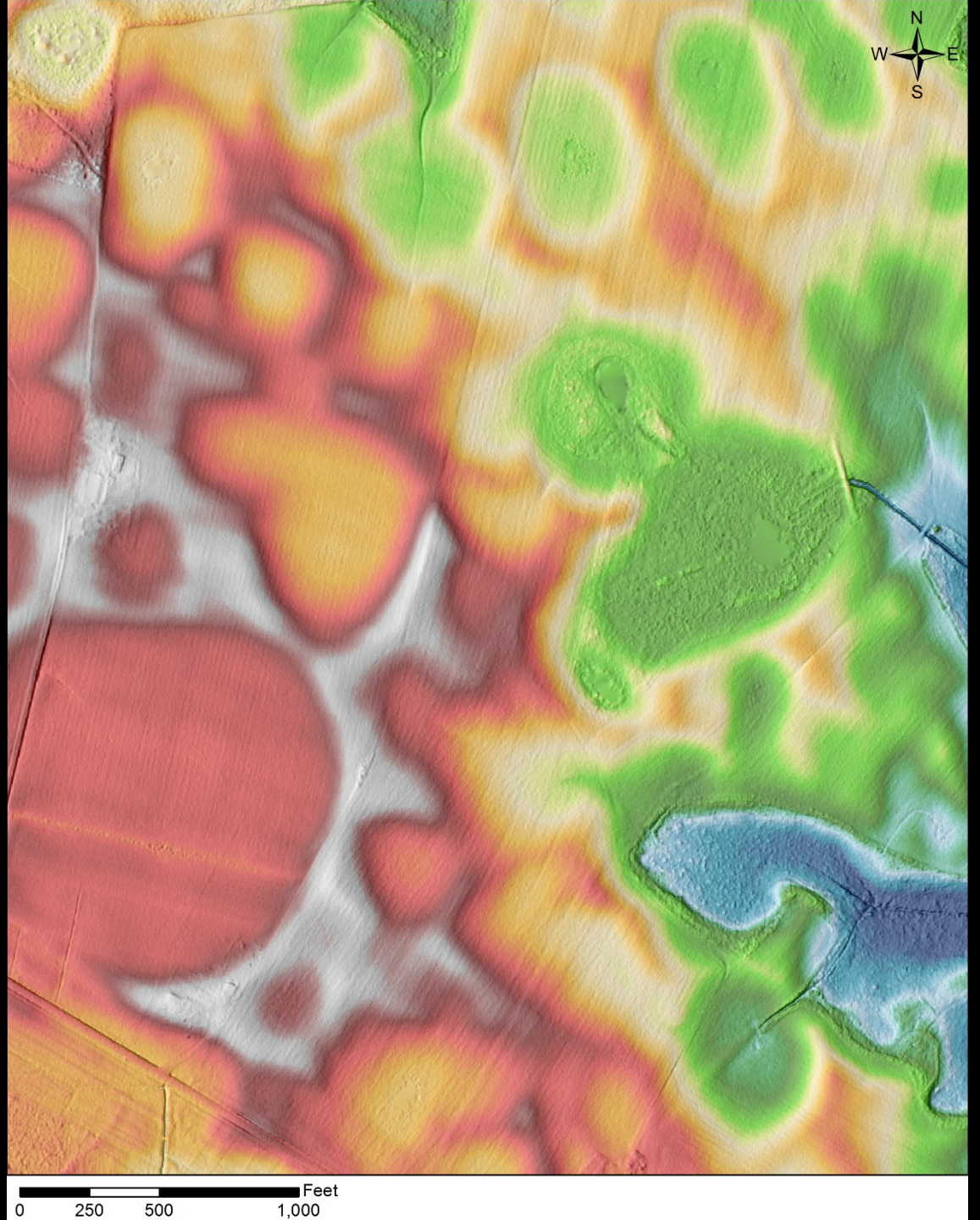
N
W
E
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Feet
0
250
500
1,000

Additional Applications

- Streamlines
- Wetted stream area
- Shoreline
- Vegetation
  - Urban tree canopy
  - Reforestation
  - Biomass
- Habitat analysis
  - Old growth forest
  - Habitat connectivity
- Supplement Survey Data
- Buildings
- Storm Surge Modeling
- Land cover!

Questions?

Naomi S. Bates
Delaware Geological Survey
nsbates@udel.edu

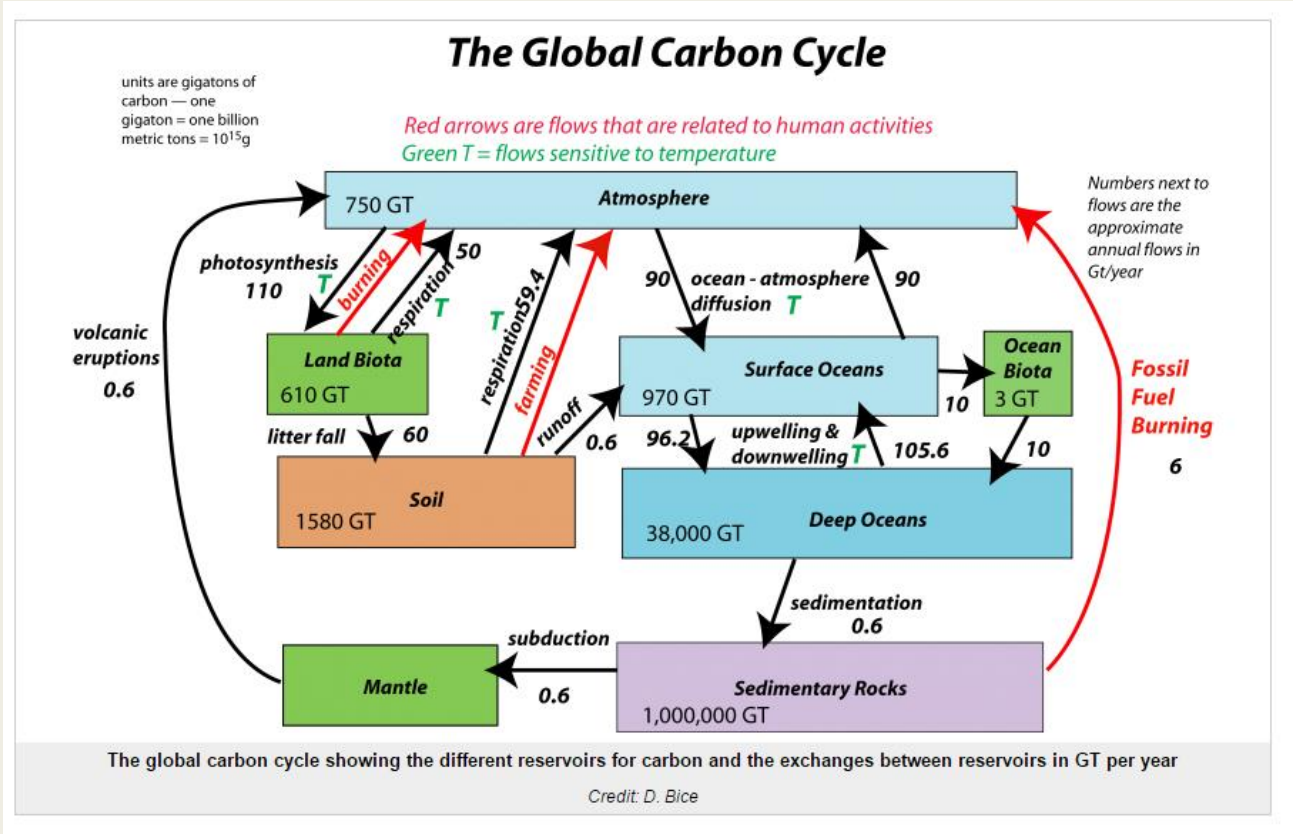
LIDAR APPLICATIONS FOR FINE TUNING FOREST INVENTORY ESTIMATES IN THE NONFOREST AND UNDERSTORY CARBON POOLS

Kristofer Johnson

Sep 8, 2016

Background

- Assumption that global climate change is linked to the global carbon cycle.
- To study and understand the global carbon cycle, estimates of global carbon pools are needed
- The aboveground terrestrial carbon pool is of particular interest because it is large, dynamic, and we are able to manage it somewhat.
- Many ecosystem models, including Earth System Models (ESM's), compare/calibrate with field-based estimates to gain confidence in their results.



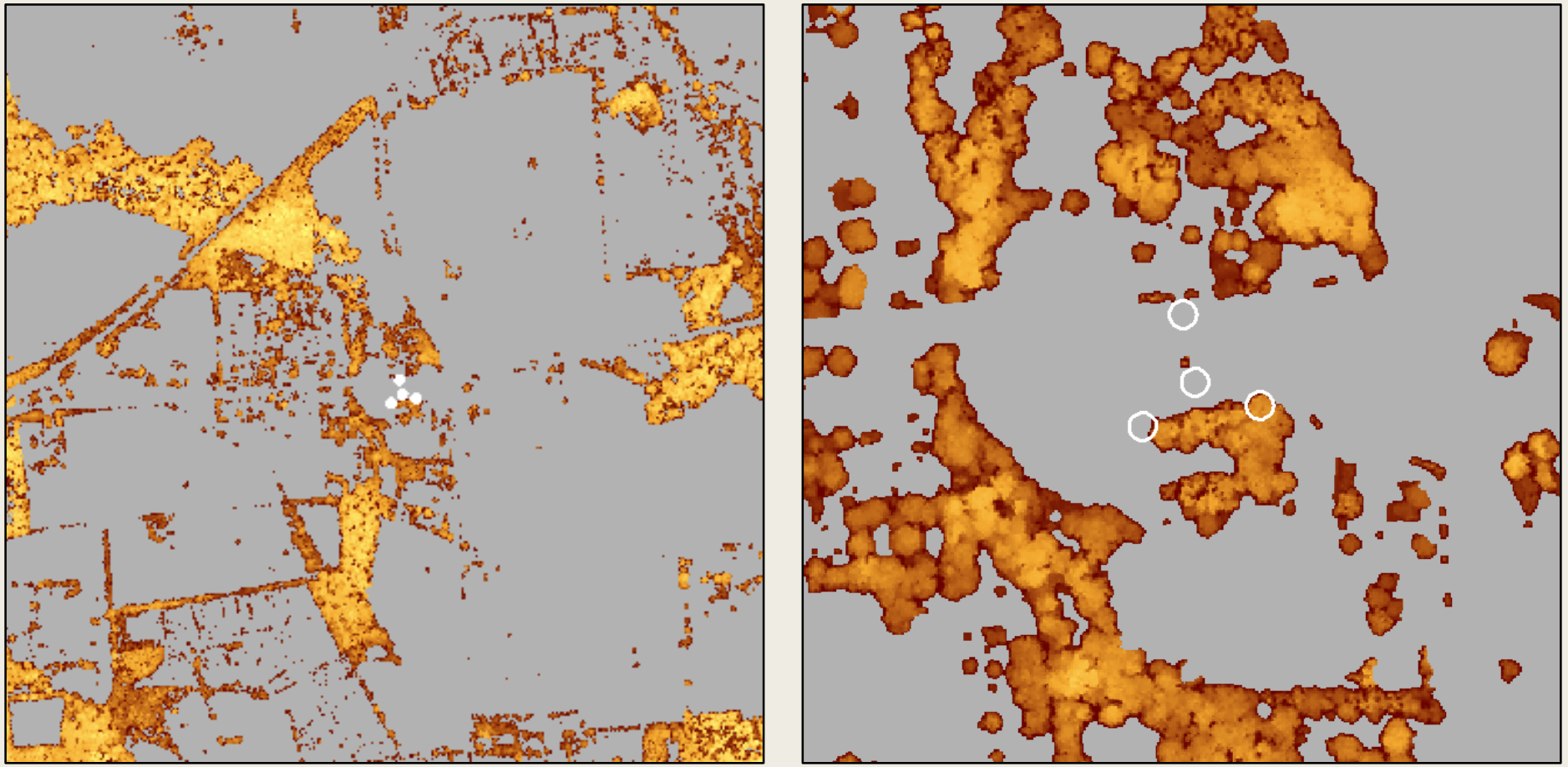
The global carbon cycle showing the different reservoirs for carbon and the exchanges between reservoirs in GT per year

Credit: D. Bice

Forest Inventory and Analysis (FIA)

- FIA provides estimates of aboveground carbon in landscapes defined as “Forest” in the United States.
  - *Systematic, spatially unbiased estimates over large areas (e.g. 10,000 km2)*
  - *Quality controlled*
  - *Well documented protocols*
- Currently, the U.S. reports terrestrial carbon estimates from it’s inventory, not maps.
- Although FIA plots extend throughout the U.S., ***plots defined as “Nonforest” are not visited***.

- forest (or forest land): ***land that is at least 10 percent stocked by forest trees*** of any size, or land formerly having such tree cover, and ***not currently developed for a nonforest use***. ***The minimum area for classification as forest land is one acre***. Roadside, stream-side, and shelterbelt strips of timber must be at least 120 feet wide to qualify as forest land. Unimproved roads and trails, streams and other bodies of water, or natural clearings in forested areas are classified as forest, if less than 120 feet in width or one acre in size. Grazed woodlands, reverting fields, and pastures that are not actively maintained are included if the above qualifications are satisfied. Forest land includes three subcategories: timberland, reserved forest land, and other forest land.
- nonforest land: land that does not support, or has never supported, forests, and lands formerly forested where use for timber management is precluded by ***development for other uses***. Includes areas used for ***crops, improved pasture, residential areas, city parks, improved roads of any width and adjoining rights-of-way, power line clearings of any width,*** and noncensus water. If intermingled in forest areas, unimproved roads and nonforest strips must be more than 120 feet wide, and clearings, etc., more than 1 acre in size, to qualify as nonforest land.
  - *Bechtold and Patterson, 2005*



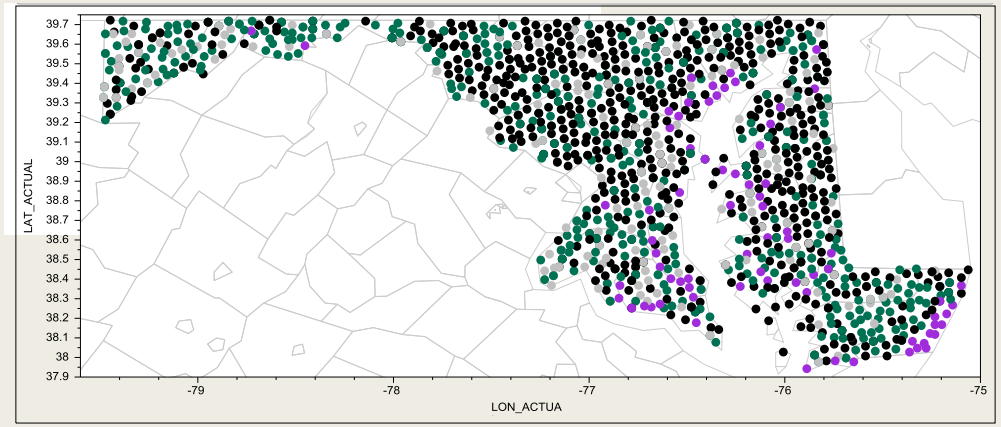
- Useful:
  - *Total Aboveground Carbon = "Forest" Aboveground Tree Carbon*
- More useful:
  - *Total Aboveground Carbon = "Forest"* ***and "Nonforest"*** *Tree Carbon*
- Still more useful:
  - *Total Aboveground Carbon = "Forest" and "Nonforest" Tree* ***and Understory Carbon***
- FIA does not sample Nonforest and Understory carbon pools because of extra costs, creating a data gap.

- LiDAR may be used to FILL THE GAP, i.e. estimate aboveground carbon where field crews do not go, including:
  - *Nonforest plots.*
  - *Nonsampled plots. Plots where access was denied permission by private landowners or dangerous sampling conditions*
- Additionally, LiDAR may improve estimates of other aboveground carbon pools not directly measured by field crews:
  - *Understory Vegetation*
  - *Soils, Litter? Using DTM information?*

Filling the Nonforest Gap in Maryland

METHOD

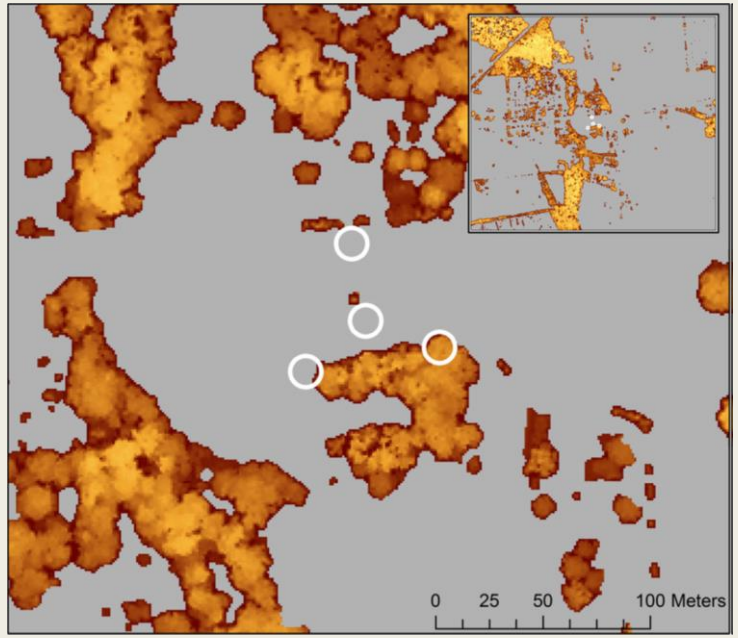
- Maryland FIA plots:
  - *2179 subplots, or 49%, were “Nonforest”*
  - *453 subplots or 10% “Nonsampled”*
- Determine the Nonforest plots where LiDAR indicates tree biomass may occur
- From this subset, investigate which plots are most likely to truly have tree biomass.
  - *Use 1m Landcover maps and Imagery (e.g. Google Maps)*
  - *Subjective*
- Result: 1088 subplots, or 24%, were determined to have biomass



Develop equation that predicts aboveground tree carbon

- Use “Forest” tree carbon
- Relate to mean subplot LIDAR height
- TOFsubplotbiomass (kg) = 0 + 167.95*Hsubplot (m)

  (r2 = 0.25, RMSE = 1753 kg, P < 0.0001, n = 704)



Validate with independent field data

- 33 actual Nonforest FIA plots were visited and measured

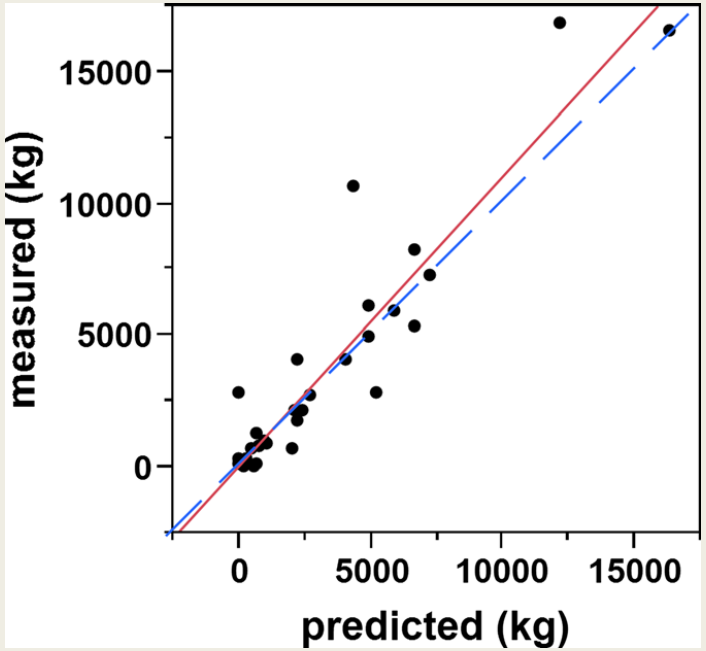


Table 1 Biomass of trees outside forest (TOF) estimates for three counties

	TOF biomass, Tg		% increase	
County	Predicted (95 % CI)	Measured (95 % CI)	Predicted	Measured
Allegany	0.56 (0.39, 0.74)	0.52 (0.36, 0.69)	5.7	5.3
Baltimore	3.30 (2.15, 4.46)	3.51 (2.27, 4.74)	26.8	28.4
Dorchester	0.57 (0.34, 0.80)	0.60 (0.35, 0.84)	6.7	7.0

Predicted estimates represent those predicted from LIDAR using Eq. 1. Measured estimates represent a ground inventory of all trees in FIA plots, both forest and nonforest. The % increase is the increase of total biomass in a county when TOF biomass is added to the traditionally reported FIA estimate. All estimates and 95 % confidence intervals were calculated using the EVALIDATOR tool

Researchers map Maryland's forest carbon

UM team uses satellites, planes, footwork to tally climate impact

Katie Kranich and David Bruhn, both 24, are researchers doing a forest inventory project. (Barbara Haddock Taylor, Baltimore Sun / November 7, 2012)

By Timothy B. Wheeler, The Baltimore Sun

3:49 p.m. EST, December 21, 2012

Total Biomass Results

- In some counties, Nonforest didn't matter
- En others, >45% difference when Nonforest was added
- Overall, there was a 15% increase in biomass for the whole state.

Table 2 The traditionally reported county and state FIA estimates, the predicted biomass of TOF, and the total tree biomass estimates in Tg biomass

County/state	FIA traditional, Tg	TOF biomass, Tg	Total tree biomass (FIA + TOF), Tg	Increase, %	TOF, Mg/ha
Worcester	9.14 (5.45, 12.83)	0.05 (0.04, 0.06)	9.19 (5.5, 12.9)	0.6	0.3
Somerset	4.03 (1.73, 6.33)	0.04 (0.03, 0.05)	4.07 (1.77, 6.39)	1.0	0.5
Wicomico	7.16 (3.78, 10.54)	0.36 (0.31, 0.41)	7.52 (4.12, 11.07)	5.1	3.6
Allegany	9.88 (6.73, 13.02)	0.56 (0.48, 0.65)	10.44 (7.13, 13.76)	5.7	4.8
Caroline	3.21 (0.88, 5.53)	0.18 (0.14, 0.22)	3.39 (1.05, 5.84)	5.7	2.0
Dorchester	8.5 (4.84, 12.17)	0.57 (0.49, 0.65)	9.07 (5.36, 12.98)	6.7	3.3
Kent	3.78 (1.06, 6.49)	0.31 (0.25, 0.37)	4.09 (1.35, 7.03)	8.2	4.3
Charles	12.72 (8.24, 17.21)	1.08 (0.97, 1.18)	13.8 (9.24, 18.66)	8.5	8.8
Washington	8.26 (4.46, 12.07)	0.78 (0.71, 0.86)	9.05 (5.21, 13.21)	9.5	6.4
St. Mary's	8.25 (4.12, 12.38)	0.81 (0.71, 0.92)	9.06 (4.85, 13.59)	9.8	7.4
Queen Anne's	4.55 (1.48, 7.62)	0.5 (0.43, 0.58)	5.06 (1.91, 8.47)	11.1	4.7
Garrett	14.35 (10.19, 18.51)	1.62 (1.49, 1.74)	15.97 (11.76, 20.6)	11.3	9.8
Montgomery	6.63 (2.97, 10.28)	0.76 (0.71, 0.81)	7.38 (3.68, 11.46)	11.4	6.0
Frederick	10.87 (6.51, 15.23)	1.38 (1.3, 1.47)	12.25 (7.73, 17.16)	12.7	7.6
Baltimore	12.34 (7.31, 17.37)	3.3 (3.09, 3.52)	15.64 (10.16, 22.02)	26.8	19.9
Pr. George's	8.57 (4.4, 12.75)	2.32 (2.14, 2.49)	10.89 (6.51, 16.2)	27.1	18.5
Talbot	2.09 (0.4, 3.78)	0.58 (0.45, 0.71)	2.67 (0.81, 4.83)	27.6	6.7
Calvert	6.31 (2.13, 10.48)	1.79 (1.42, 2.16)	8.1 (3.42, 13.46)	28.4	28.2
Cecil	4.9 (2, 7.79)	1.39 (1.28, 1.5)	6.28 (3.14, 10)	28.4	13.3
Harford	7.12 (3.22, 11.01)	2.25 (2.03, 2.46)	9.36 (5.17, 14.49)	31.5	18.6
Anne Arundel	3.23 (0.94, 5.52)	1.15 (1.04, 1.27)	4.38 (1.96, 7.49)	35.6	11.3
Howard	4.81 (1.49, 8.14)	2.24 (1.95, 2.53)	7.05 (3.27, 11.93)	46.5	32.6
Carroll	3.18 (0.84, 5.53)	1.5 (1.36, 1.63)	4.68 (2.08, 8.13)	47.0	13.3
Maryland	163.88 (153.75, 174)	25.52 (25.46, 25.58)	189.39 (179.47, 201.1)	15.6	25.9

All estimates were calculated using the EVALIDATOR tool. The % increase refers to the increase in biomass from the traditional FIA estimate. TOF biomass density in Mg/ha is the TOF biomass divided by the county area reported by FIA

Results

- Patterns – there was more missing Nonforest biomass in áreas closer to I-95 and heavy residential areas

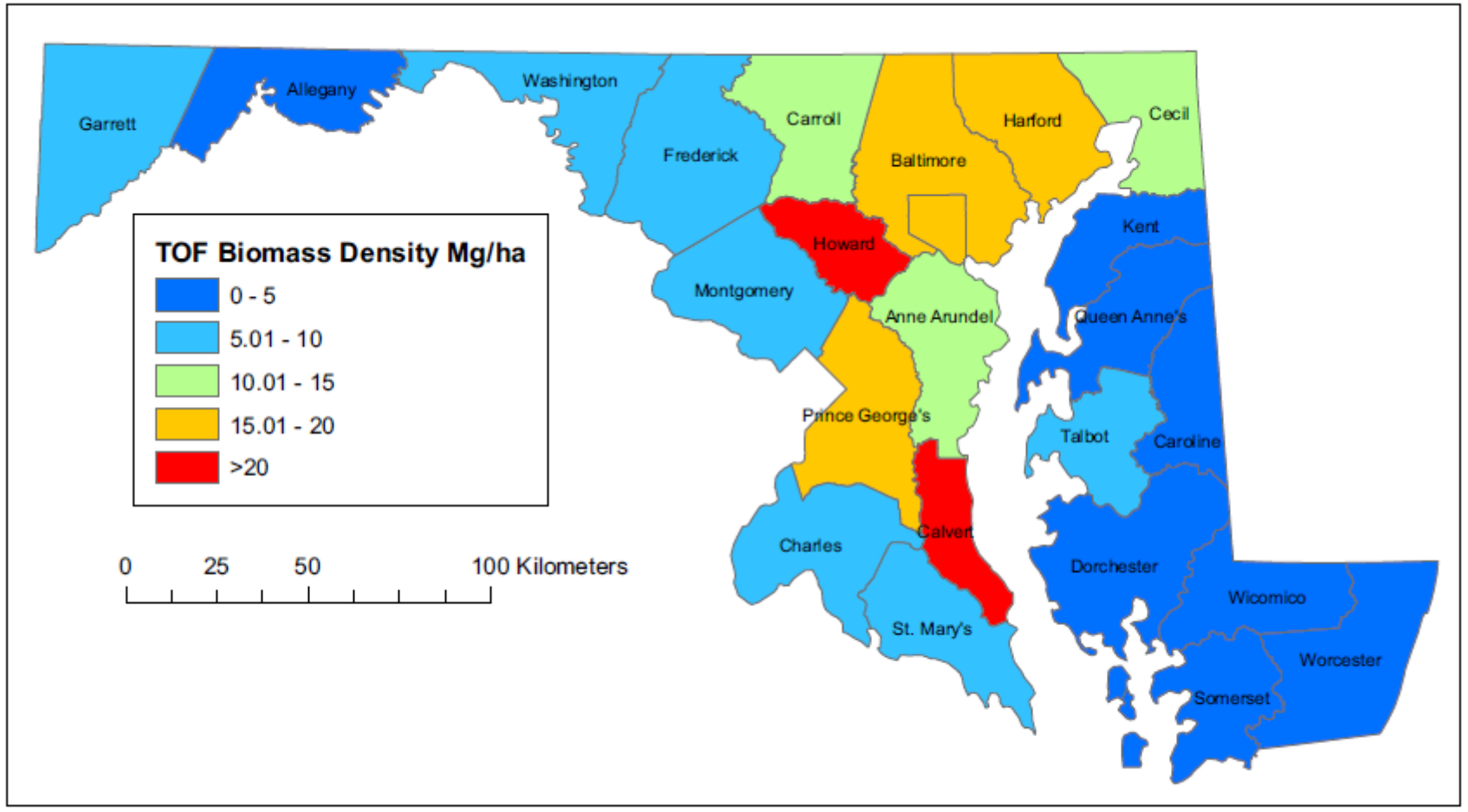
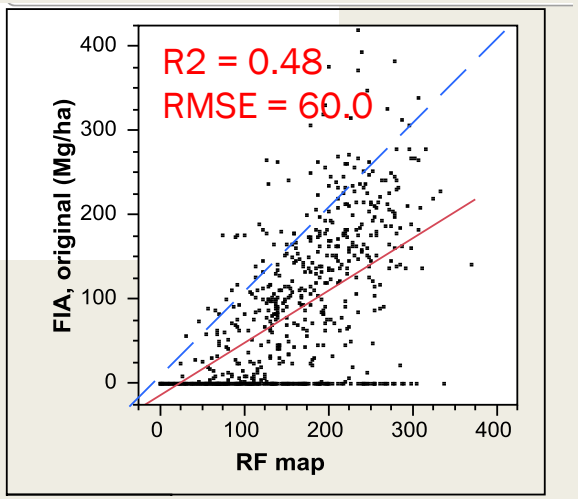


Fig. 3 The biomass density of TOF by county in Maryland. Higher densities generally correspond to counties closer to Interstate 95, which divides the Howard and Anne Arundel counties

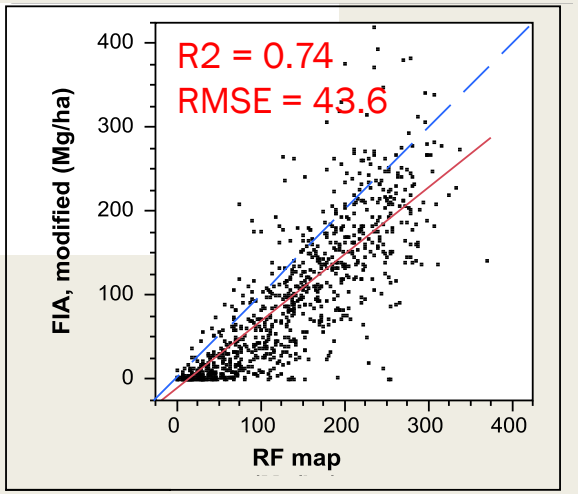
Comparison with CMS biomass maps

Plot Level

FIA Original

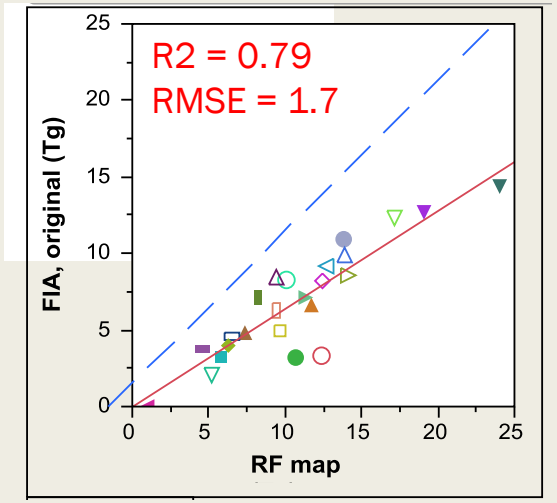


FIA Modified

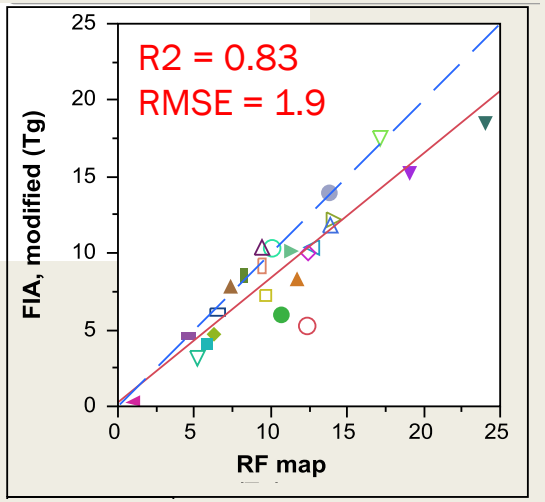


County Level

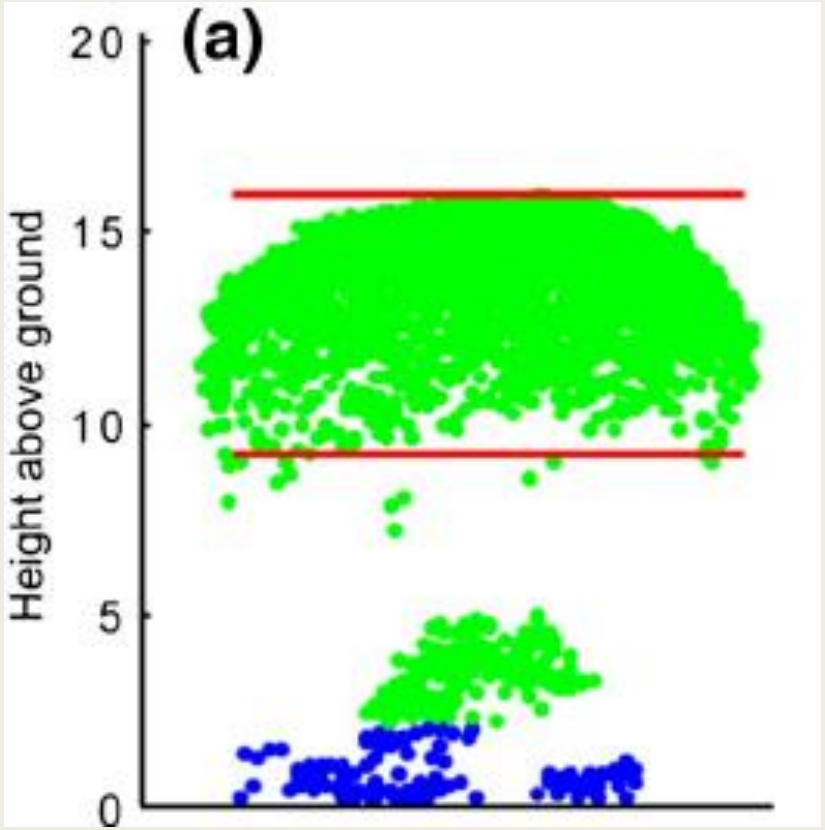
FIA Original



FIA Modified

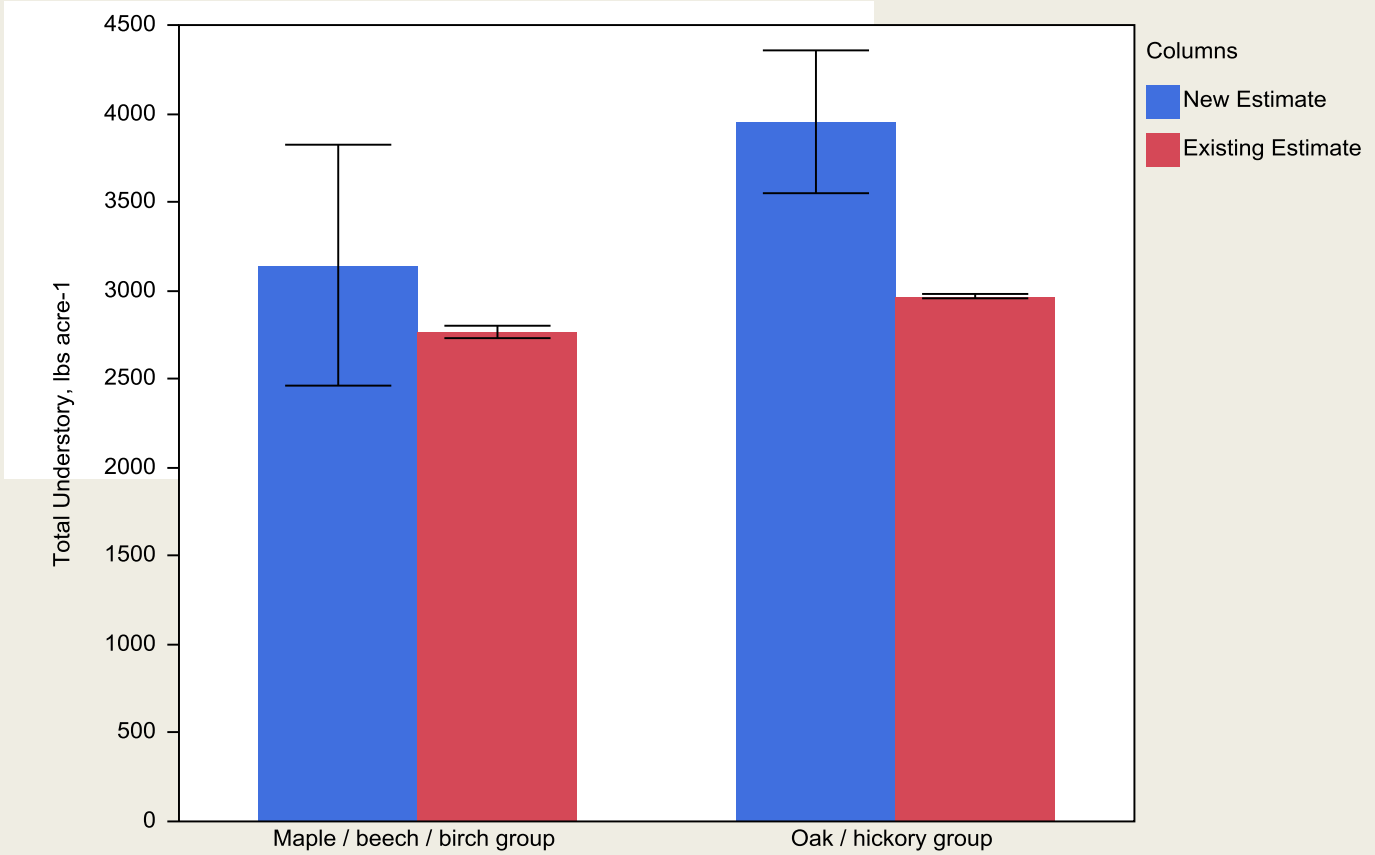


Understory Carbon



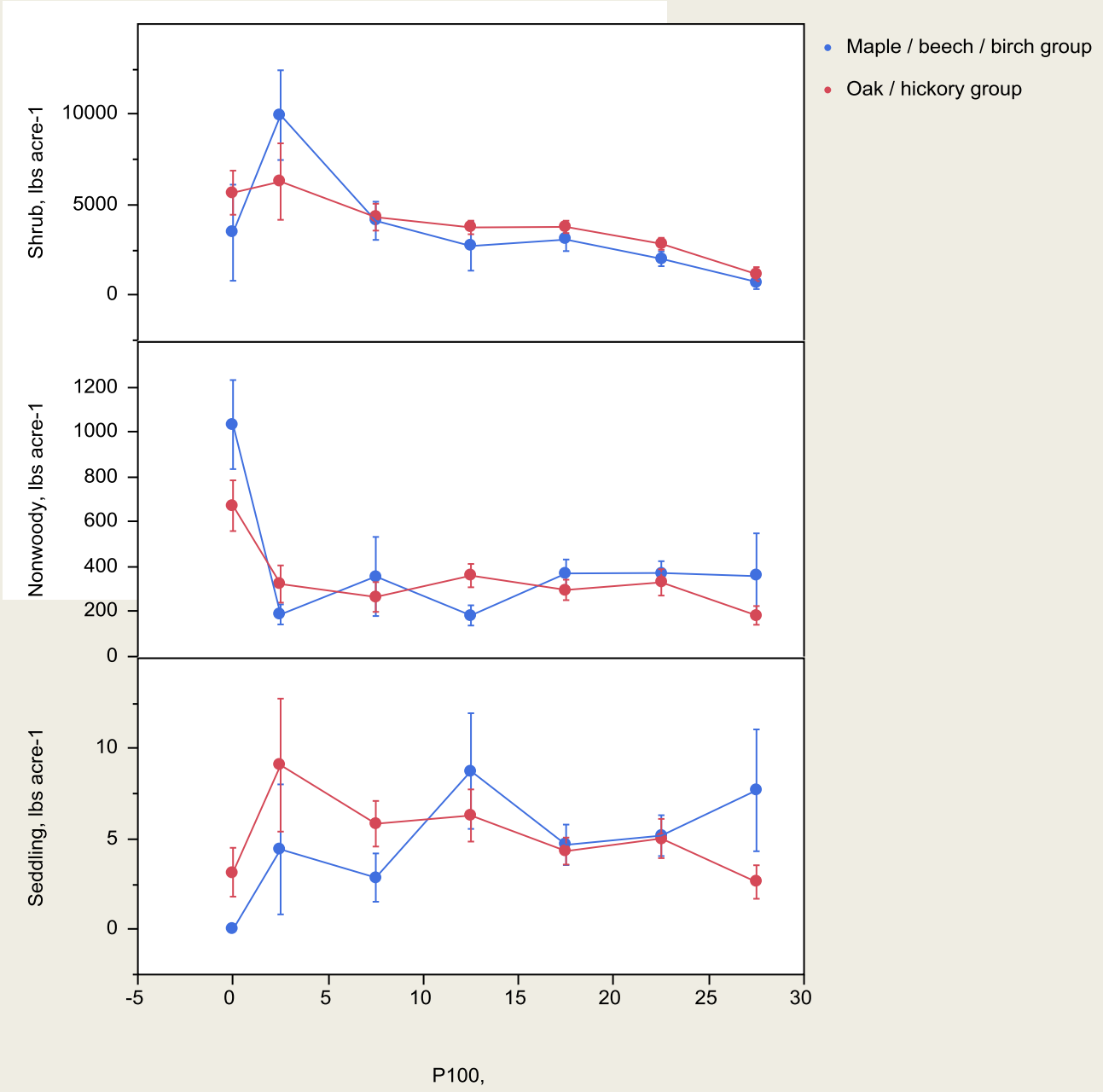
Alonzo, Michael, et al. "Mapping urban forest leaf area index with airborne lidar using penetration metrics and allometry." Remote Sensing of Environment 162 (2015): 141-153.

Understory Carbon Models from P2 to P3 Plots



LIDAR for Understory Carbon

- PA, MD, DE
- Understory Components:
  - *Shrub*
  - *Nonwoody (herbaceous)*
  - *Seedling*

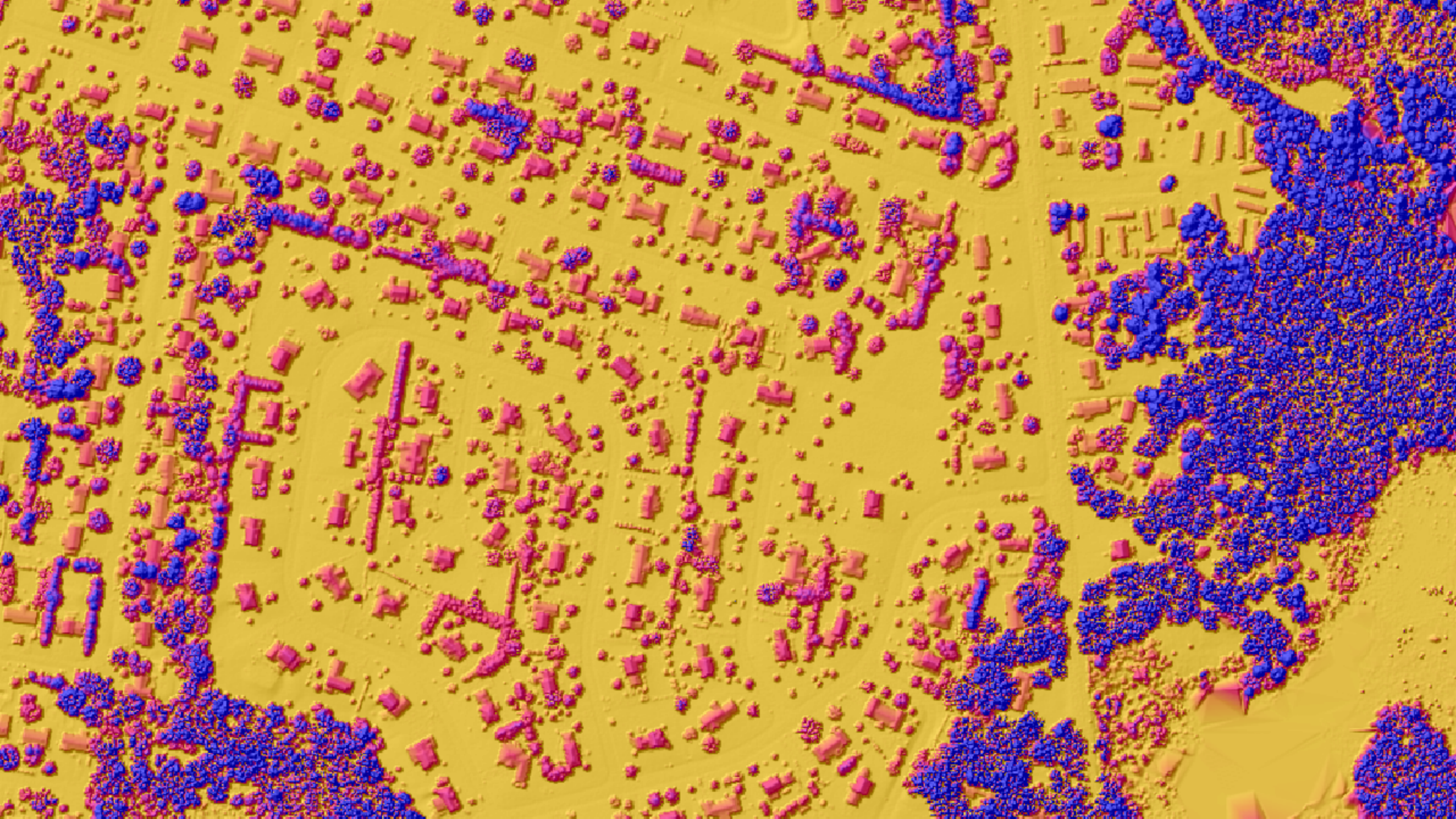


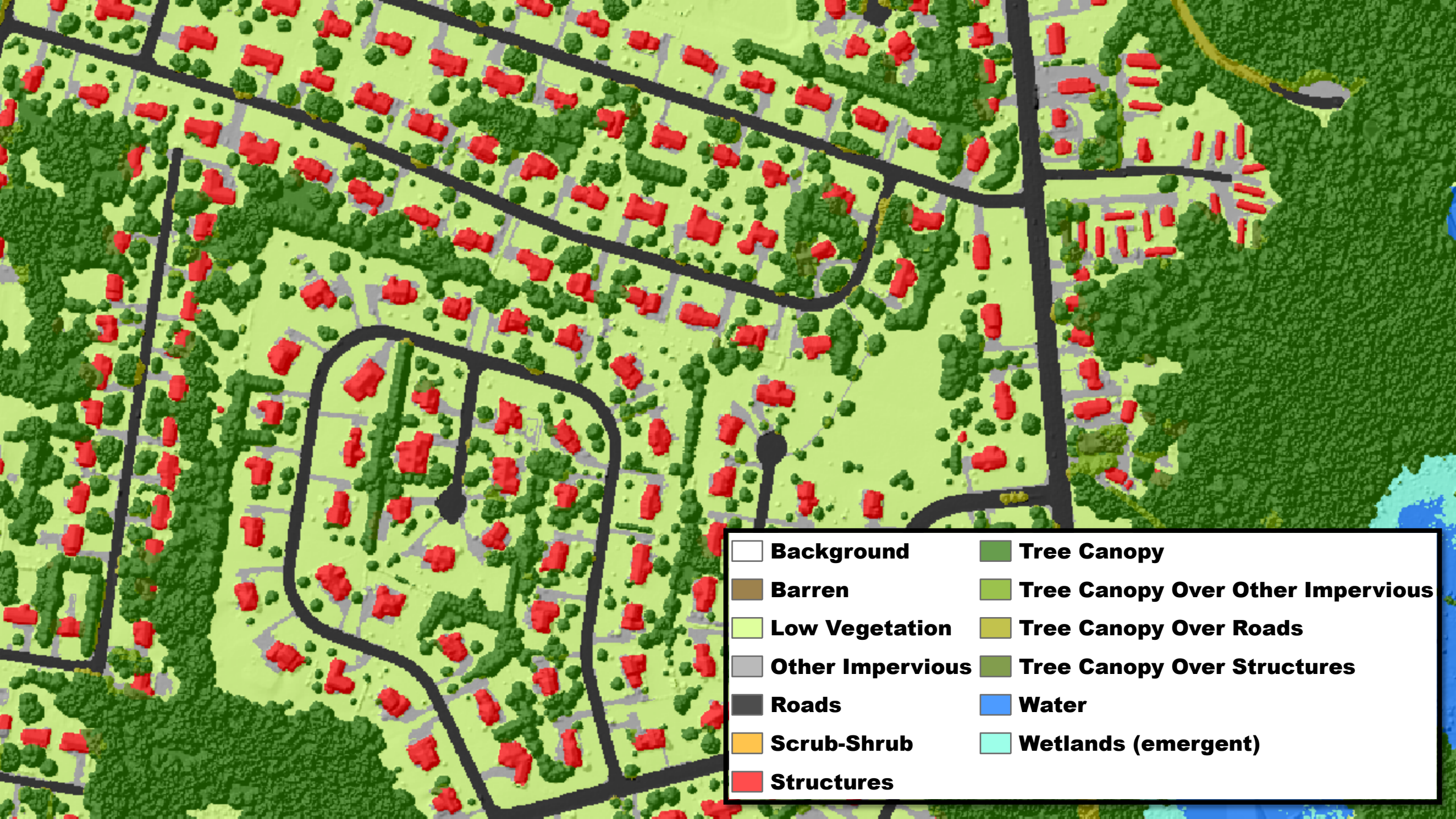
Conclusions

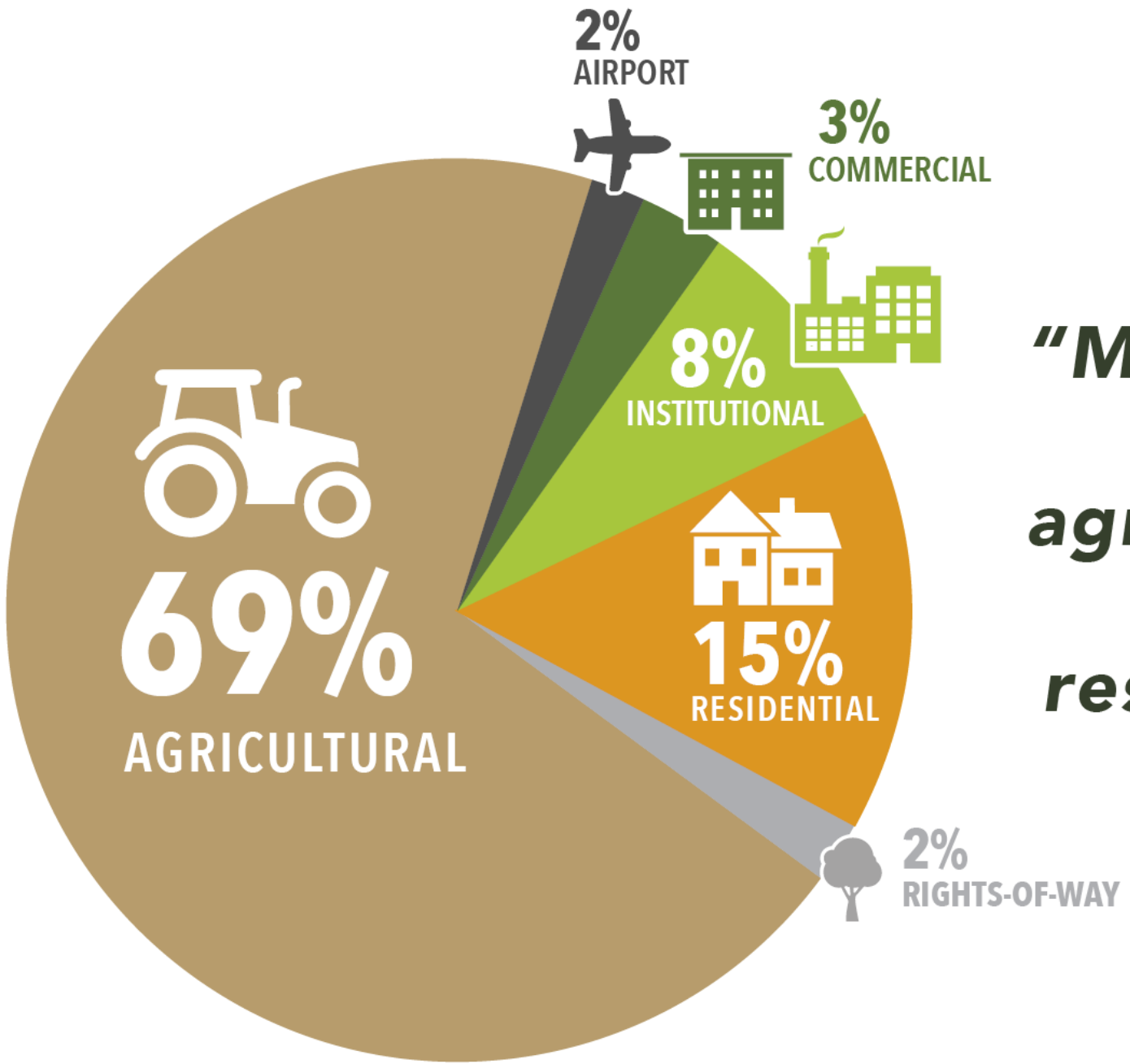
- Forest Inventories can be augmented/enhanced with lidar.
- Enhanced inventories provide more useful data for spatial/process model calibration and validation
- Lidar metrics appear to be related understory dynamics.

Jarlath O'Neil-Dunne
University of Vermont

CMS High-Resolution Land Cover




Background
Barren
Low Vegetation
Other Impervious
Roads
Scrub-Shrub
Structures
Tree Canopy
Tree Canopy Over Other Impervious
Tree Canopy Over Roads
Tree Canopy Over Structures
Water
Wetlands (emergent)



"Majority of trees outside of agricultural areas are on residential land."

"Residential has the most area for establishing new tree canopy"*

ACRES

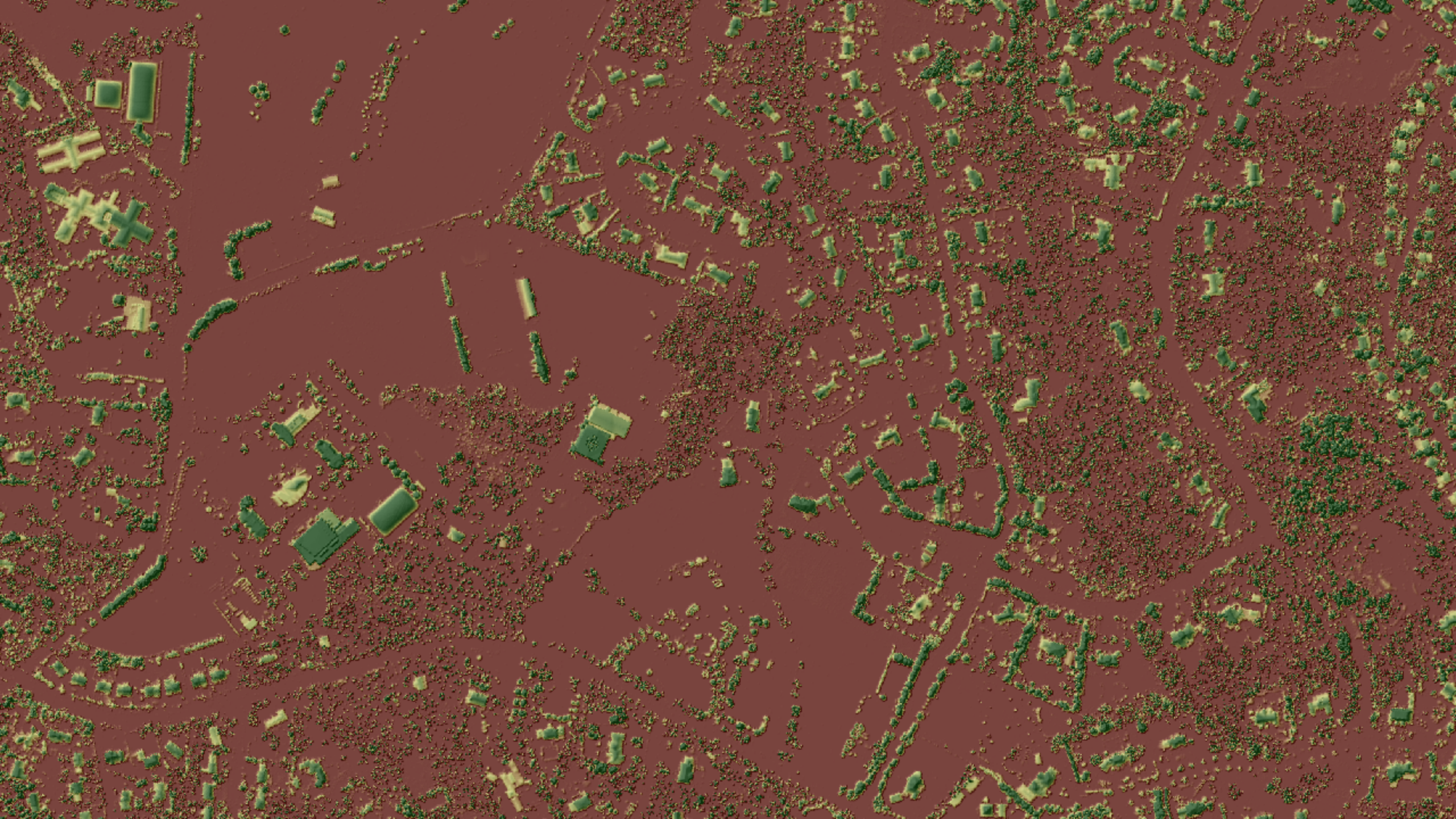
14515 RESIDENTIAL

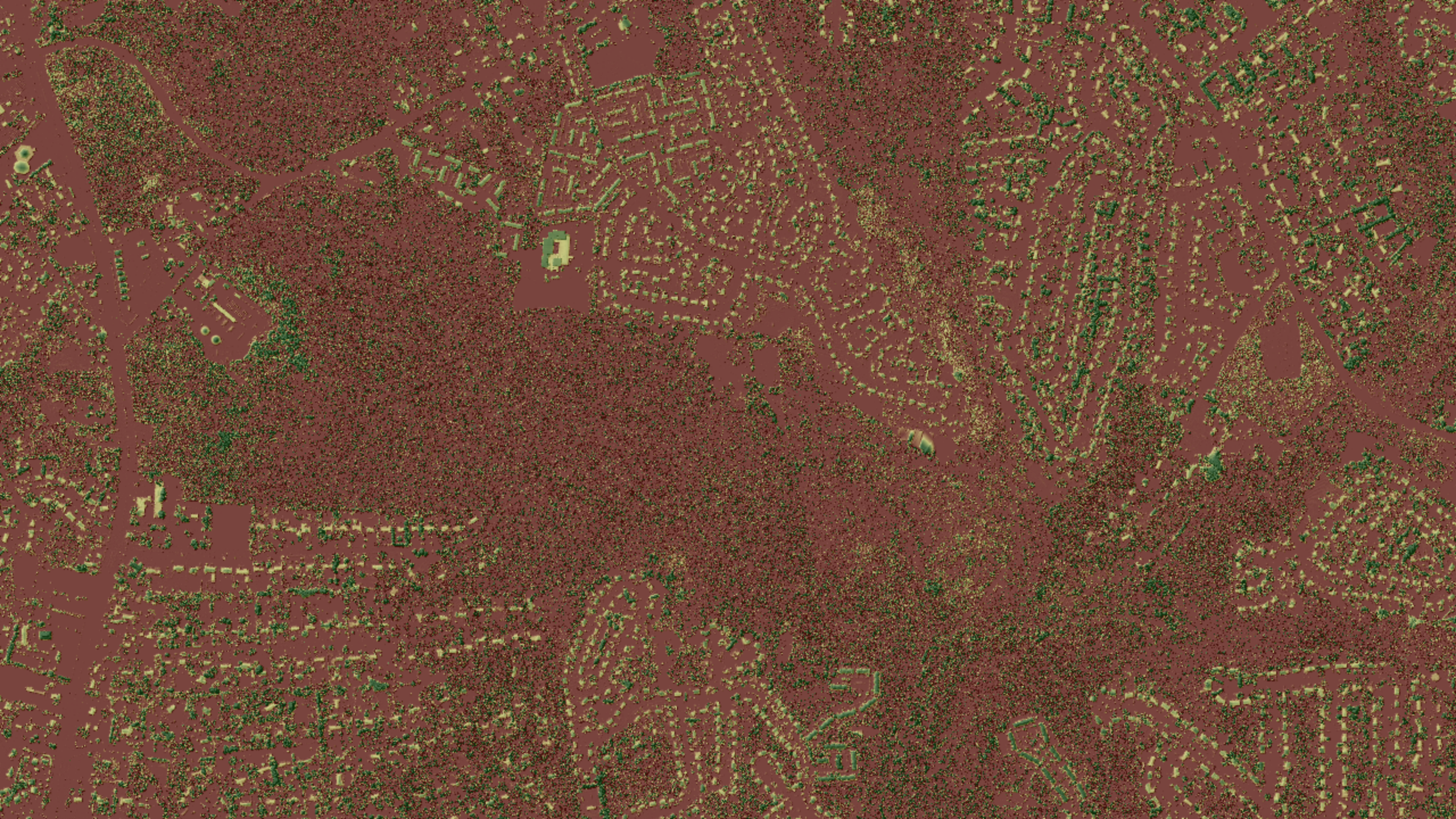
6806 COMMERCIAL

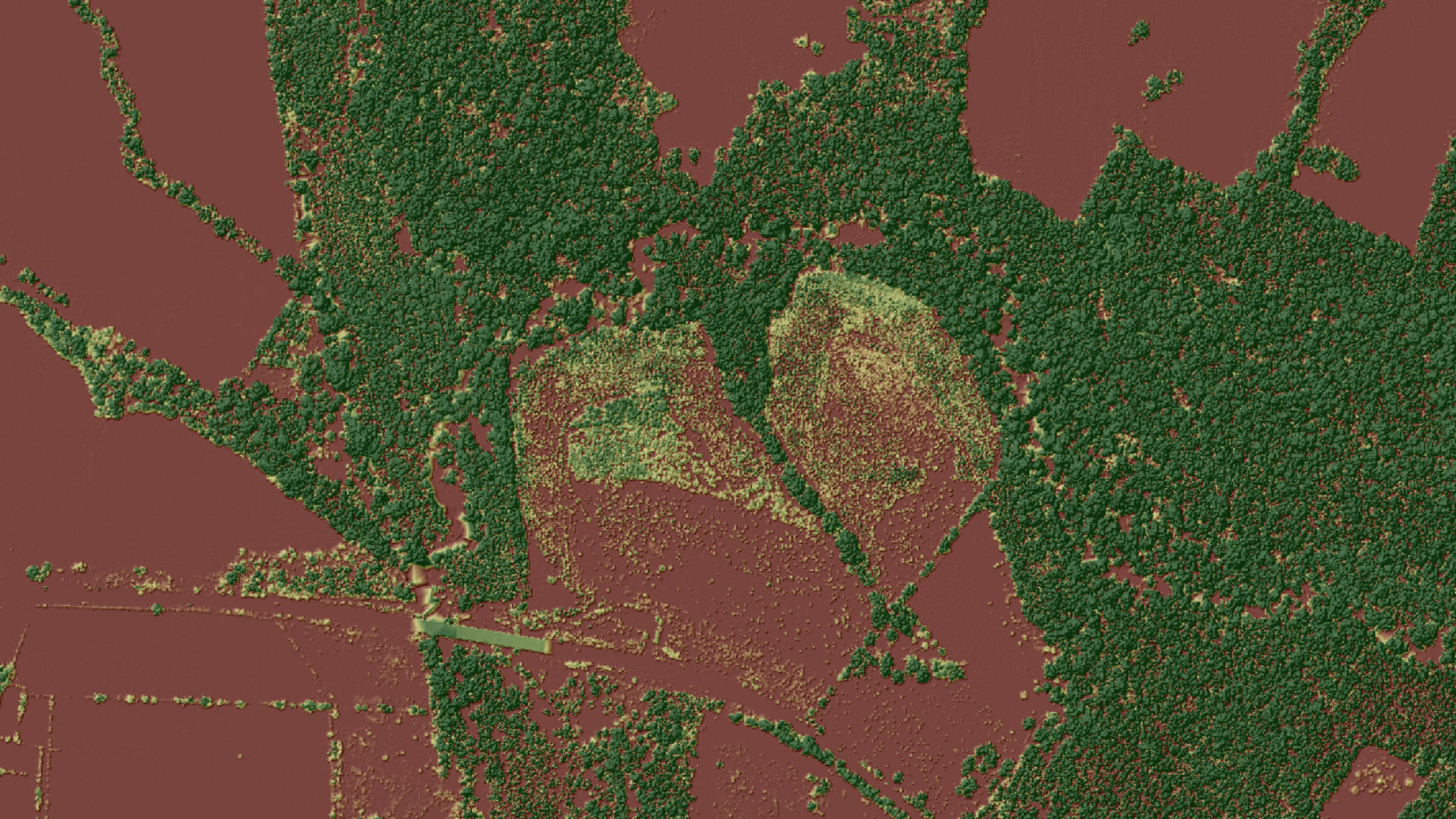
5490 INSTITUTIONAL

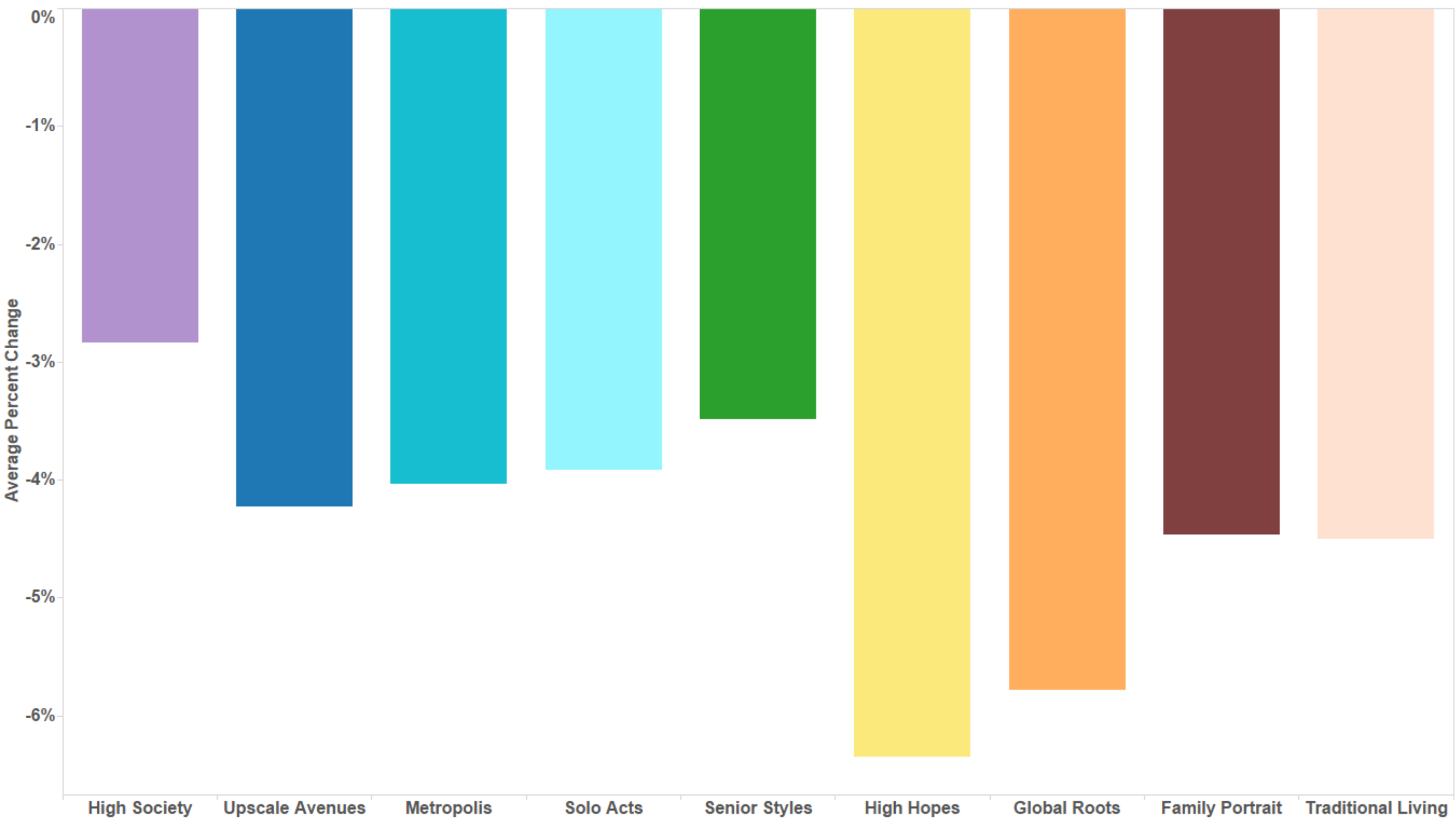
4347 AIRPORT

3681 RIGHTS-OF-WAY








0%
-1%
-2%
-3%
-4%
-5%
-6%
Average Percent Change
High Society
Upscale Avenues
Metropolis
Solo Acts
Senior Styles
High Hopes
Global Roots
Family Portrait
Traditional Living

High-Resolution Carbon Monitoring and Modeling: Continuing Prototype Development and Deployment

George Hurtt, UMD
Ralph Dubayah, UMD
Richard Birdsey, USFS
Kristopher Johnson, USFS
Phil DeCola, Sigma Space
Vanessa Escobar, GSFC
Edil Sepulveda, GSFC

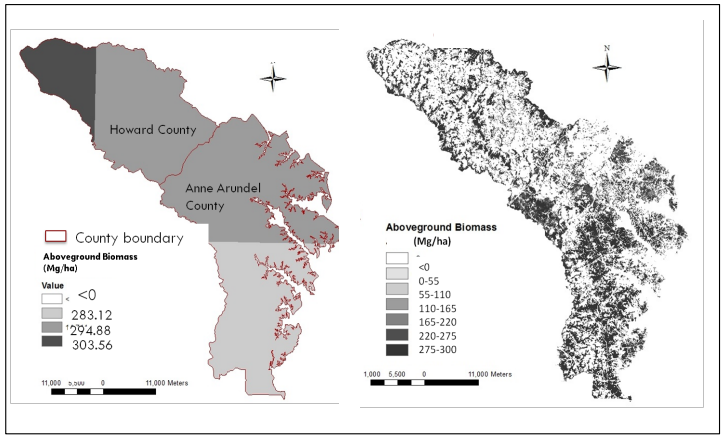
Katelyn Dolan, UMD kdolan@umd.edu
Wenli Huang, UMD
Andrew Finley, MSU
Steve Flanagan, UMD
Jarlath O-Neil-Dunne, UVT
Stuart Sheppard, UMD
Maosheng Zhao, UMD

USFS regional Office, PA
September 9th, 2016

DEPARTMENT *of* GEOGRAPHICAL SCIENCES

UNIVERSITY OF MARYLAND

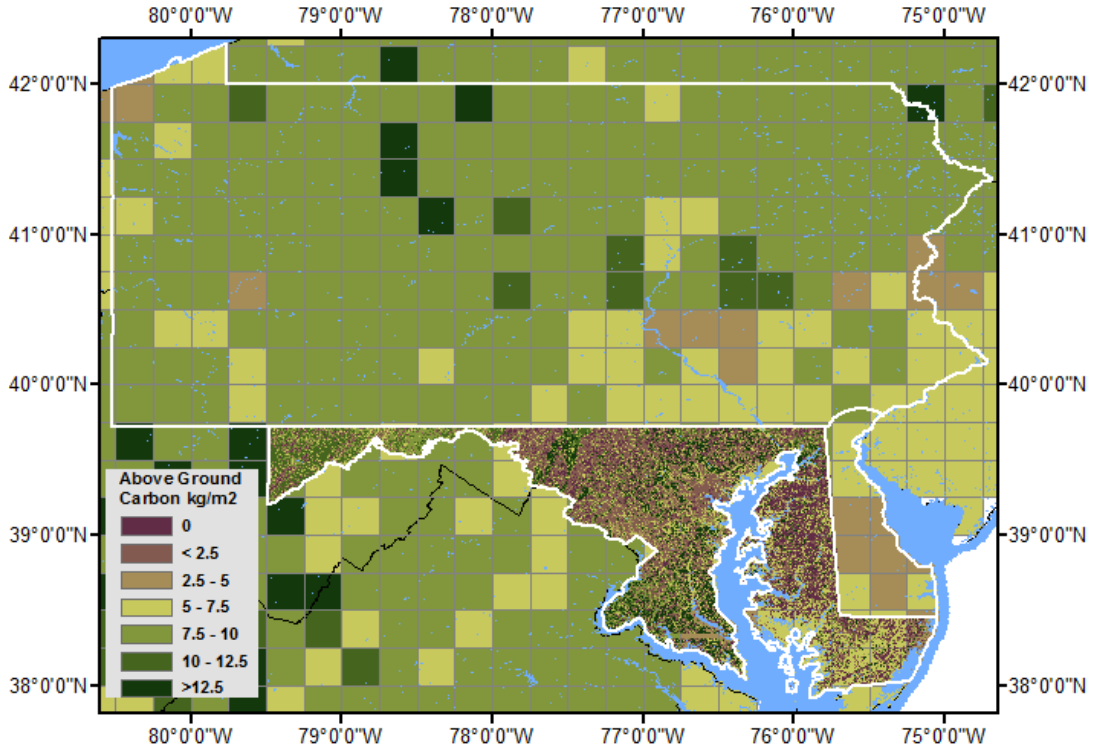
High-Resolution Carbon Monitoring and Modeling Development



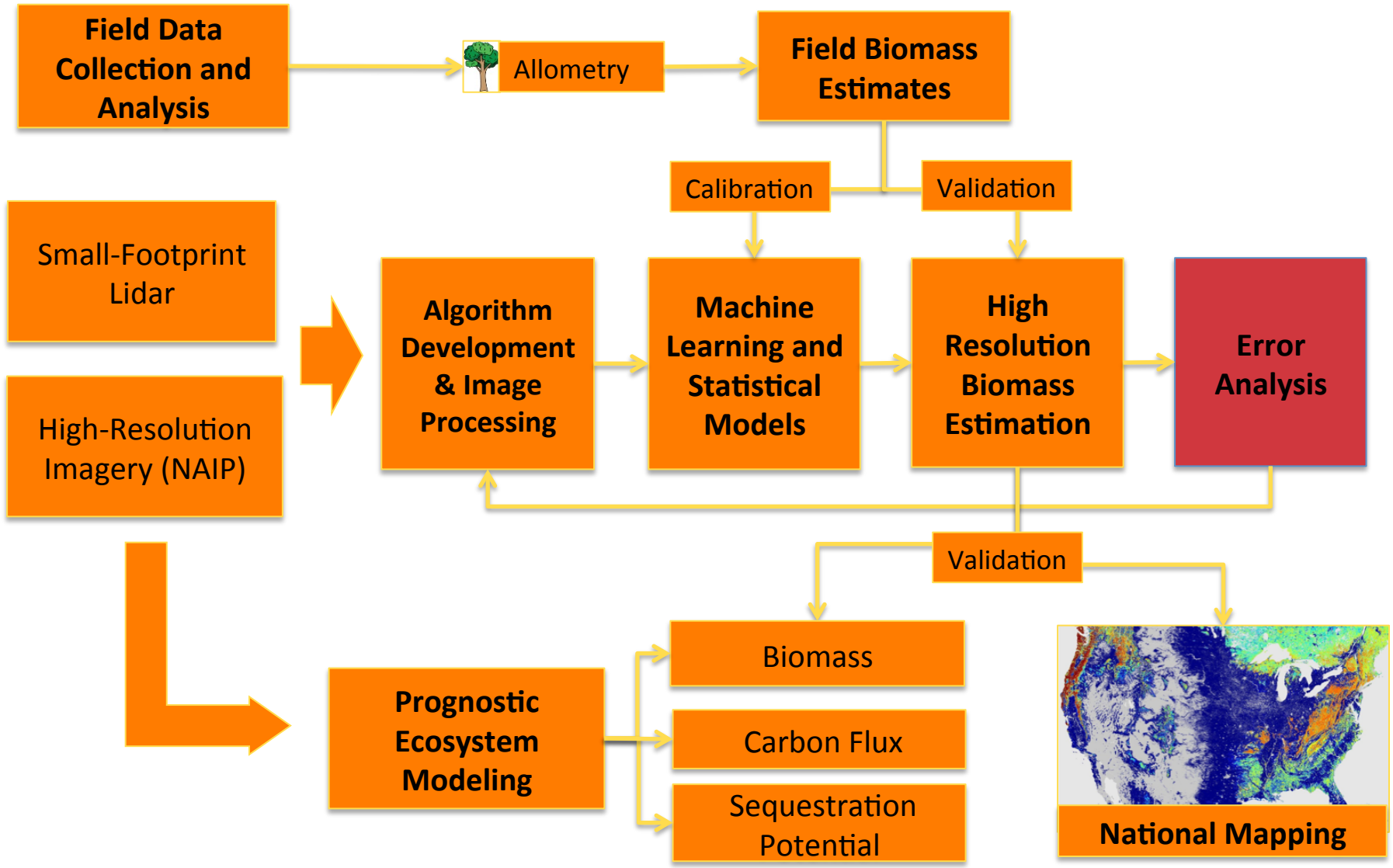
Phase 1: 2,181 km2

Phase 2: 32,133 km2

Phase 3: 157,868 km2



Biomass Mapping and Modeling



Biomass Mapping And Modeling Products

High Resolution Currently Available Technology (COT) Inputs

NAIP
National Agriculture Imagery Program 1m 4 band imagery

Lidar
Discrete, LAS Point Clouds, County and State acquisitions

1m Tree canopy

1m nDSM
Normalized Digital Surface Model

Algorithm Development & Image Processing

1m Tree Height

Vegetation Structure metrics
Over 35 metrics:
Max Height
Height Distributions
Mean Canopy Height

Percent Forest Cover (90m)

Mean Canopy Height (90m)

Soil Type and Depth SURGO

Climate

Mechanistic & Prognostic Ecosystem Model
Ecosystem Demography (ED) Model

FIA Field Plots
US Forest Service Forest Inventory and Analysis

Calibration

Field Biomass Estimation

UMD supplementary Field Plots
Variable and Fixed plots to represent ~30m biomass

Validations/ Uncertainty

Machine Learning and Statistical Models

High Resolution Biomass Estimation

Field Based Above Ground Tree Biomass (AGB) Maps (30m)

Field Based AGB uncertainty Maps (30m)

Above Ground Biomass

Carbon Sequestration Potential

Sequestration gap

Years to reach CSP

Political Boundaries

National Land Cover Data (NLCD)

USFS Eco-Providences

National Biomass Product Comparison

Scenario & Application Development

Product Access and Tools

State GIS outreach:

MD imap
DE Firstmap
PA Pennsylvania Spatial Data Access (PASDA)

Example Maryland iMAP website: Geodata.md.gov
Biota/MD_Biomass (30m)
Biota/MD_CanopyCover (30m)
Biota/MD_CanopyHeight (30m)

Data visualization, exploration and reporting

http://carbonmonitoring.umd.edu/data.html (MD)
Under Development…CMSAppName /ourecosystems.umd

Currently available on ORNL DAAC

National data archive - http://daac.ornl.gov

Input Datasets
- **Maryland_CanopyHeight_30m**
- **Maryland_PercentTreeCover_30m**

Field Based Biomass Product
- **Maryland_Biomass_RF_High_30m**
- **Maryland_Biomass_QRF_High_30m**
- **Maryland_Biomass_QRF_Low_30m**

Supporting Layers
- **Maryland_LidarYear_30m**
- **Maryland_MissingLidarMask_30m**

(includes full meta data)

Dubayah, R.O., A. Swatantran, W. Huang, L. Duncanson, K. Johnson, H. Tang, J.O. Dunne, and G.C. Hurtt. 2016. CMS: LiDAR-derived Aboveground Biomass, Canopy Height and Cover for Maryland, 2011. ORNL DAAC, Oak Ridge, Tennessee, USA. http://dx.doi.org/10.3334/ORNLDAAC/1320

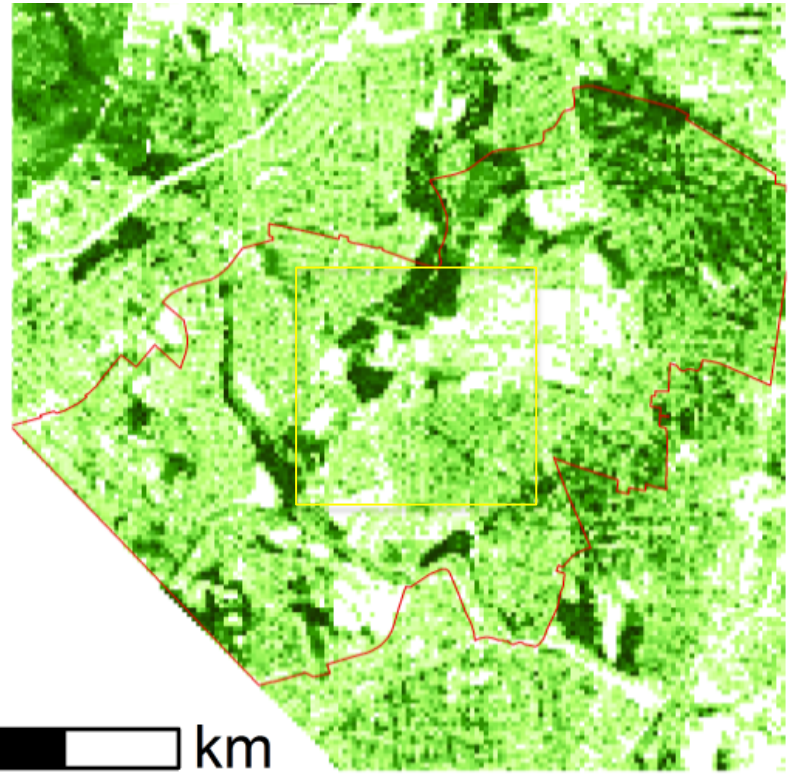
Questions about project outputs Contact us:
Katelyn Dolan, Ph.D. - CMS Project Scientist
Kdolan@umd.edu

- Various data and products from CMS projects
  - Orthophoto: NAIP (National Agriculture Imagery Program)
  - Lidar: point clouds; derived DEM and DSM;
  - Data products
    - nDSM (Normalized Digital Surface Model), CHM (Canopy Height Model)
    - Land/canopy cover and land/canopy cover change (select counties)
    - Forest biomass/carbon current, flux, and sequestration potential

NAIP IMAGERY

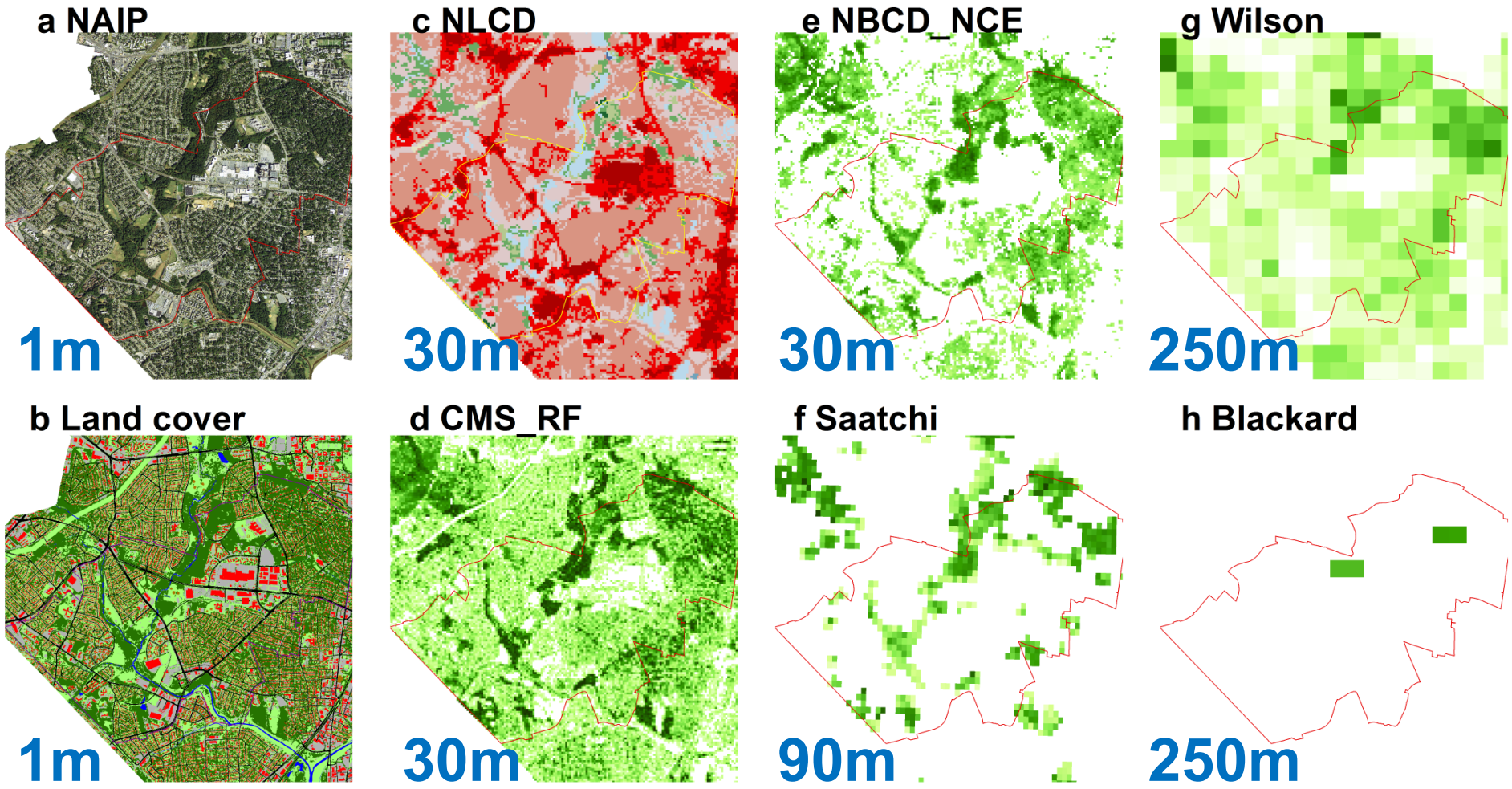
1M LAND COVER

30M BIOMASS



Example - University Park, MD

Comparison to National Products



(Huang et al., 2015)

Local Discrepancies in Continental Scale Biomass Maps

Objective: improve the understanding of local-scale map discrepancies and their impacts on carbon monitoring.

Method: compare a recent lidar-derived biomass map (CMS_RF) with four national biomass maps at pixel-, county-, and state-level.

Results: spatial patterns are broadly consistent, but there are large differences at fine scales (48.5-92.7 Mg ha^{-1}), and 30-80 Tg in forested and 40-50 Tg in non-forested areas at state-level).

Conclusions: net underestimation over high biomass forests and non-forested areas, local discrepancies could impact carbon accounting at all scales.

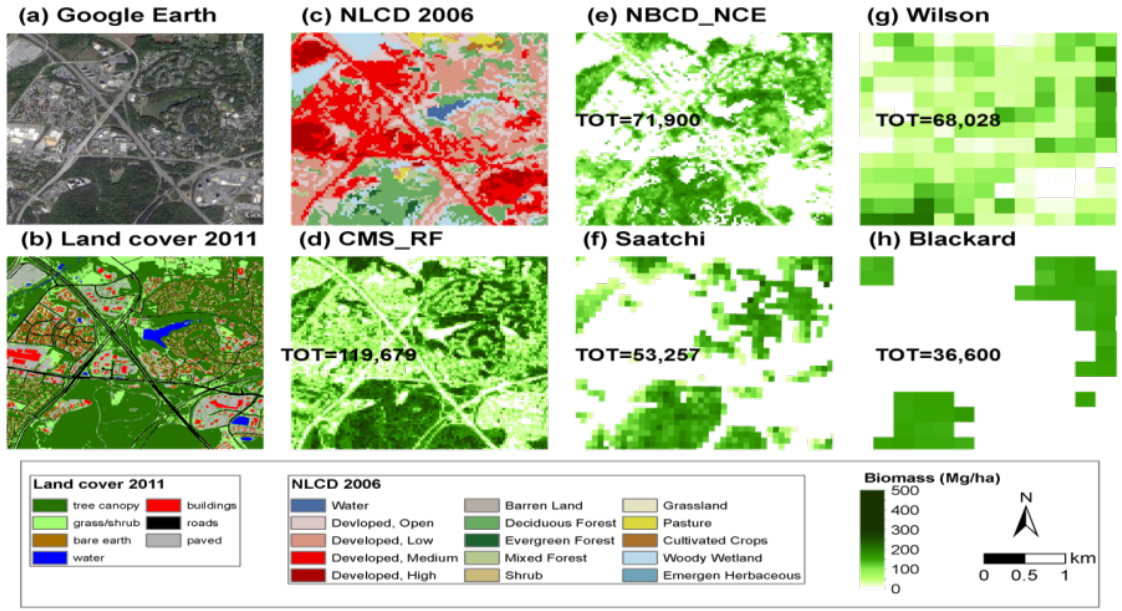


Fig. 1 Discrepancies in spatial distribution of biomass density at fine-scale.

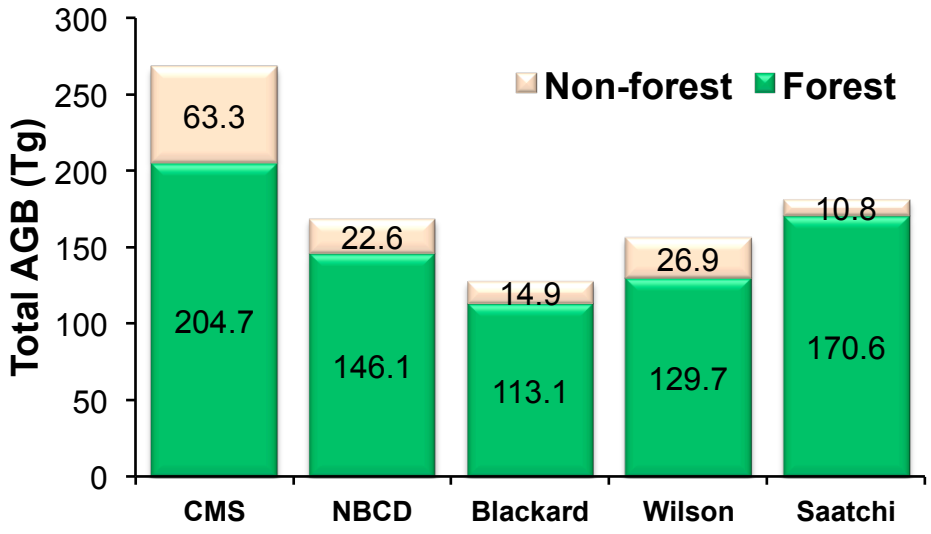
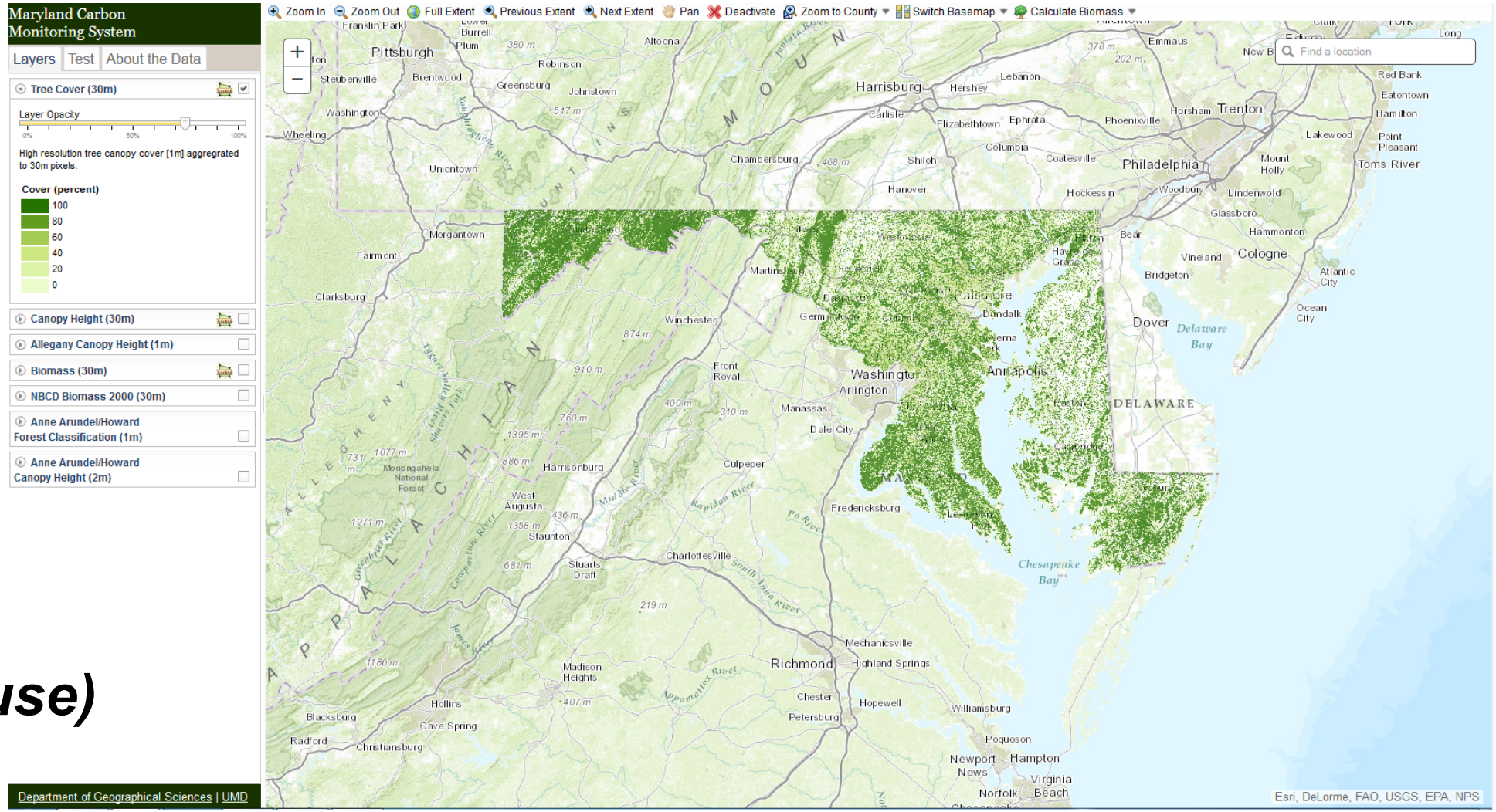


Fig. 2 Total biomass at the state level.

(Huang et al., 2015)

Maryland Carbon Monitoring System

ABOUT | PEOPLE | PUBLICATIONS | DATA | MAP | LINKS



Interactive Map (built in-house)

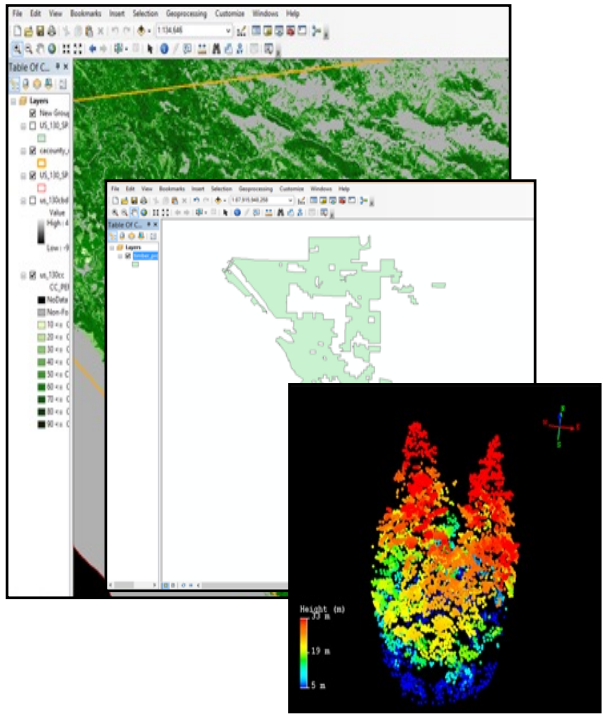
http://carbonmonitoring.umd.edu/map.html

Development of MRV Platform

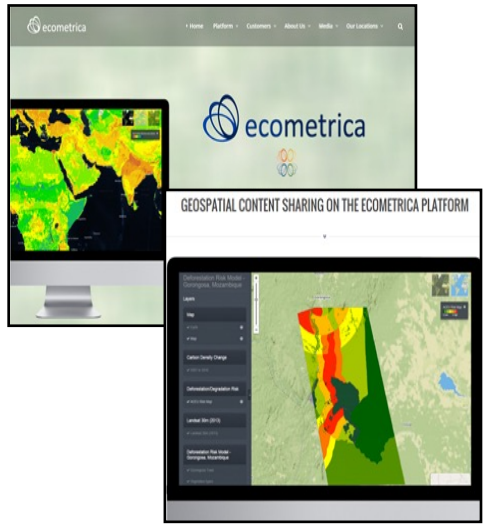
Implemented as a geospatial platform

– Entirely cloud-based

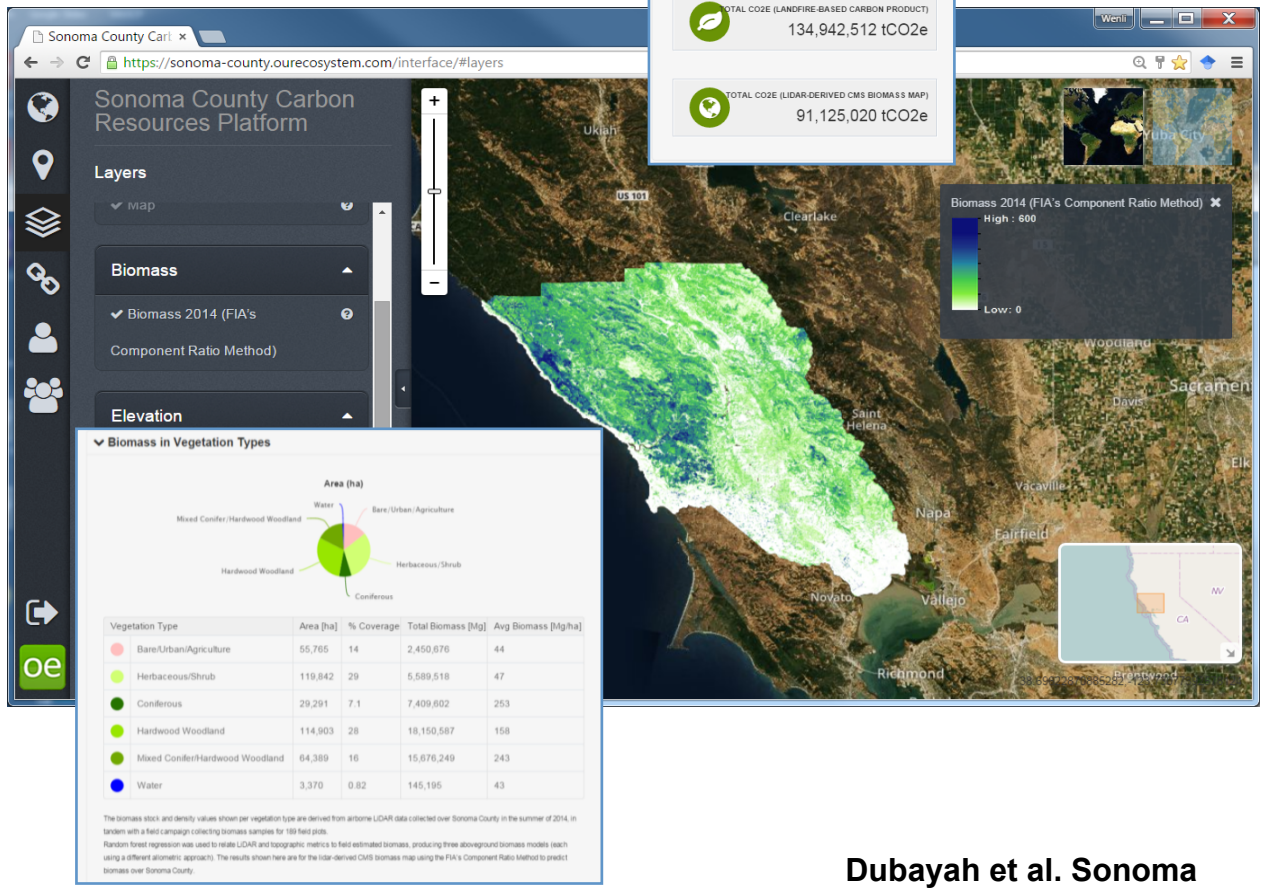
Project Level Content



Analysis & Reporting Tools



Geospatial Platform



Dubayah et al. Sonoma