



Mapping and Monitoring of Wetland Dynamics for Improved Resilience and Delivery of Ecosystem Services in the Mid-Atlantic Region

I. Yeo^a, M. Lang^b, C. Huang^a, C. Jantz^c, V. Thomas^d, S. Prince^a, and M. Kearney^a

a Department of Geographical Sciences, University of Maryland ; **b** USDA Forest Service Northern Research Station; **c** Shippensburg University; **d** Virginia Tech

Presented at 2013 LCLUC Spring Science Team Meeting



Overview

- Project overview
 - Background
 - Research objectives and benefits
 - Study design and expected outcomes
- Research progress and outcomes
 - Summary of progress
 - Innovation in mapping technique
 - Vulnerability impact assessment
 - Ecosystem service assessment



Project Overview

- Background
- Research objectives and benefits
- Study design and expected outcomes





Background: Chesapeake Bay Watershed (CBW)

- The largest and most productive estuary in the US
- Extends ~ 165,759 km² and covers part of NY, PA, MD, DE, VA, WVA, and Washington DC.
- More than > 100,000 streams drain the coastal margin of the Bay and the Eastern shore of MD and VA.
- Has the highest land to water ratio (14:1) of any estuary in the world, undergoing a rapid population growth and land use changes.

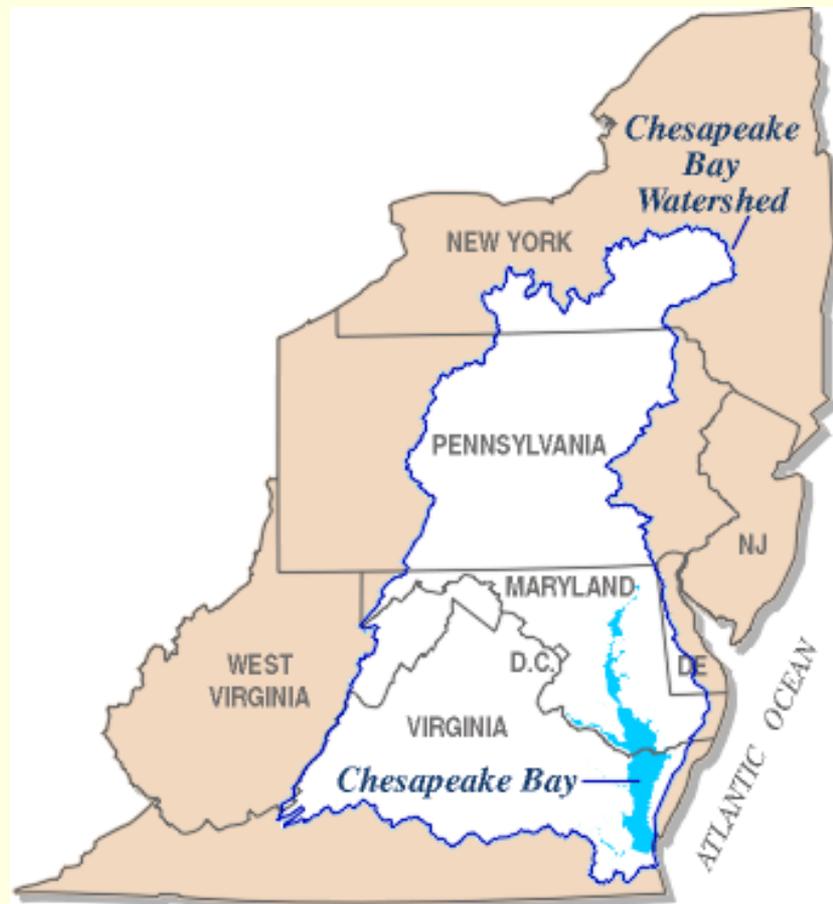
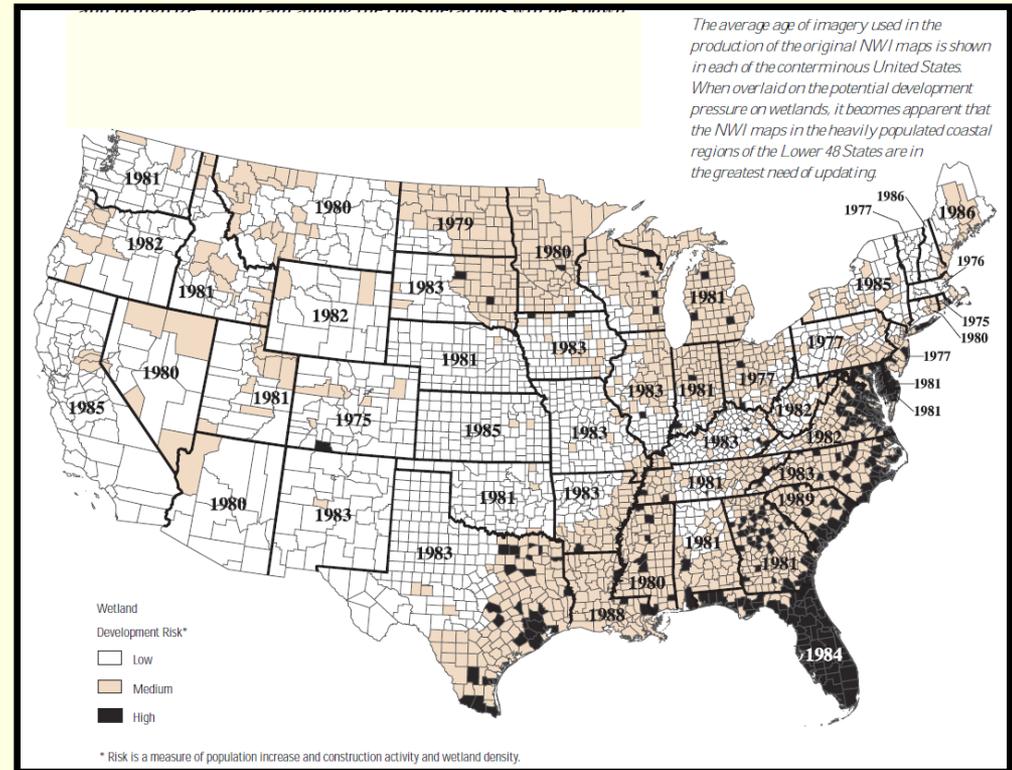


Figure 1. Chesapeake Bay watershed and surrounding area.



Background: Wetlands in the CBW

- The importance of wetland systems are recognized regionally, nationally, and internationally (RAMSAR site).
- The CBW has lost over 60% of its historic wetlands.
- It is predicted that existing wetlands are at high risk for future loss.



Risk Based on Historic Population/Construction Data and 1980s NWI Wetland Density



Wetland Mapping Background

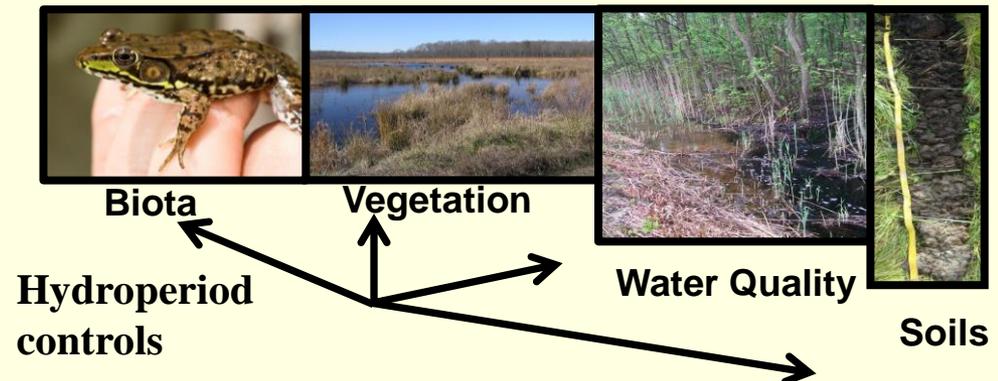
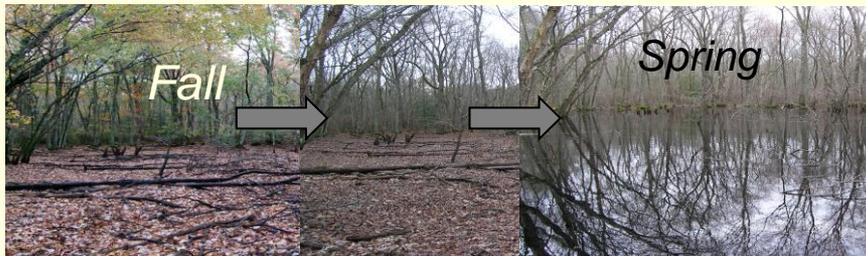
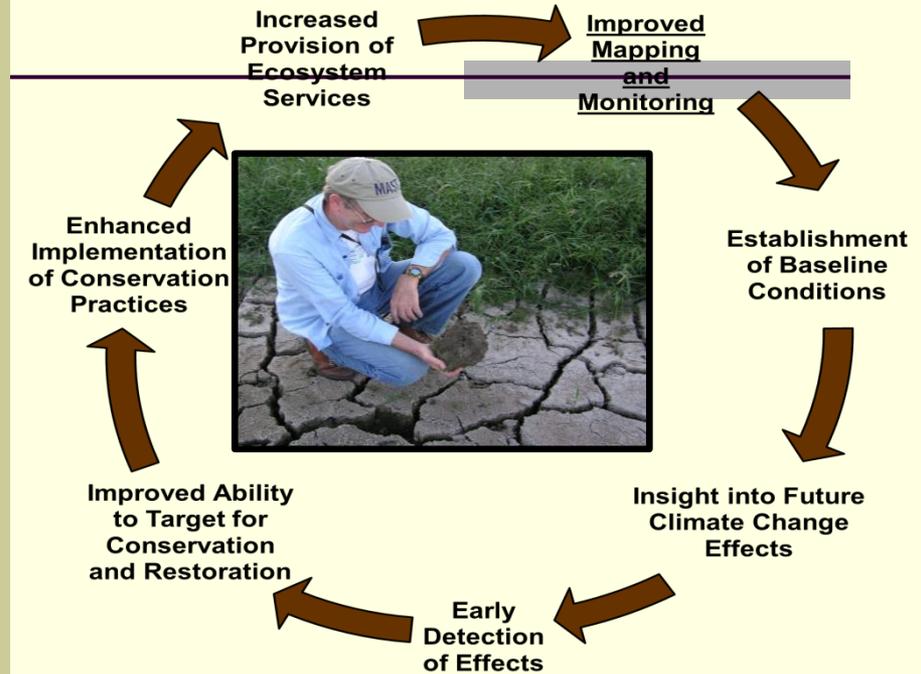
- Fundamental wetland data are lacking to assess the effects of LCLUC on regional-scale wetland distribution, extent, and function.
- Available wetland maps are dated and do not represent wetland dynamics.
 - Water levels in wetlands can vary highly, in response to climate condition.
 - Rapid changes in land cover further confound wetland mapping in developing areas.
- Forest wetland maps are inaccurate, especially at moderate spatial resolutions.
 - The vast majority of wetlands in the CBW are forested.
 - Forested wetlands continue to sustain high levels of loss.
- Improved mapping of forested wetlands and wetland change is needed to assess current impacts and vulnerabilities of wetlands to climate and land cover change and to develop adaptation strategies.

Research Benefits & Innovation

Accurate, dynamic wetland maps can improve society's resilience to increasing urbanization, population growth, and climate change through

- early detection
- improved understanding of climate change and LCLUC effects
- enhanced management of wetlands to target desired ecosystem services

Wetland hydroperiod (duration and frequency of flooding and soil saturation at a specified depth) is the most important abiotic factor controlling wetland extent and function





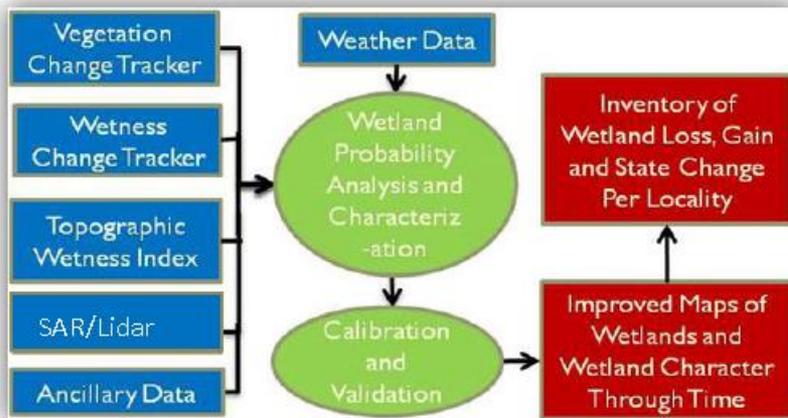
Research Objectives

1. Develop ***improved wetland mapping and change detection*** using remote-sensing data from **multiple, complementary sensors** at various temporal and spatial scales;
2. Study ***the socioeconomic, policy, and physical drivers of wetland change*** affecting wetland extent and function **from regional to local scales**;
3. Assess ***the impacts of multiple environmental stressors*** (particularly the anthropogenic ones);
4. Quantify ***vulnerability of wetlands and wetland ecosystem services*** under **multiple climate and land use change scenarios**.

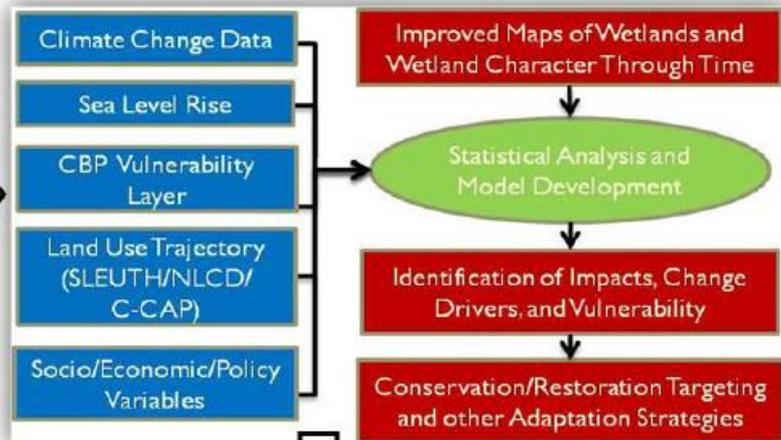


The overall research design and outcomes

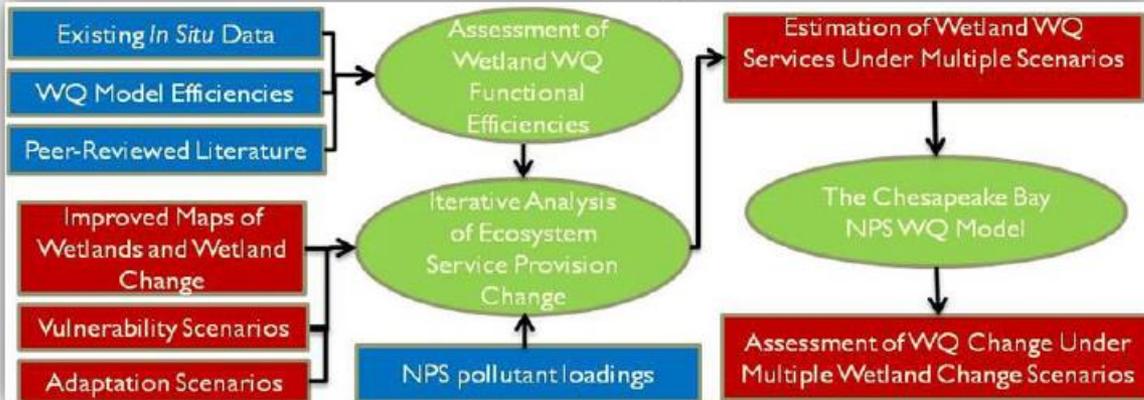
(Part 1) Geospatial Analysis (obj 1)



(Part 2) Impacts and Vulnerability Assessment (obj 2&3)



Note: Blue boxes indicate input data, green ovals indicate analytical processing, and red boxes indicate final products.



(Part 3) Ecosystem Service Assessment (obj4)

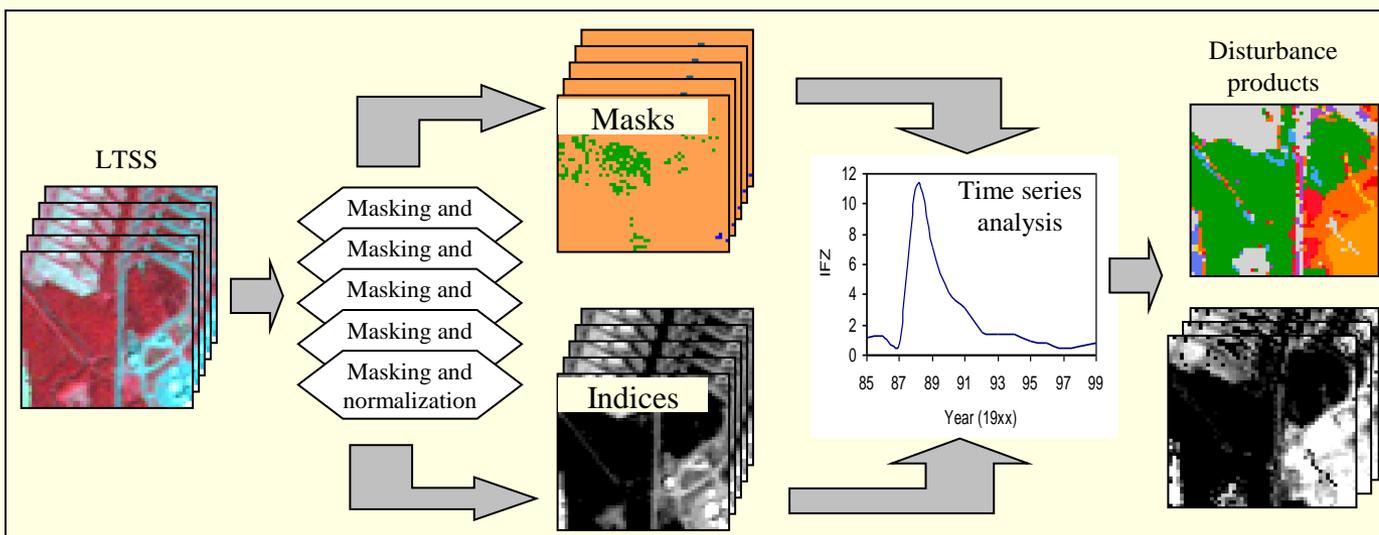


Project benefits

- Improved, consistent, recent wetland maps for CBW – readily operational technique
- Enhanced understanding of change drivers = greater conservation of wetlands and ecosystem services
- Near time tracking of wetland loss to enhance regulatory abilities
- Targeting for restoration and conservation
- Improved parameterization of the Bay Model
- Support for Ecosystem Markets
- Greater understanding of climate change impacts

Developing Technologies & Techniques

- Landsat historic record (1972-Present)
 - Advanced geometric and radiometric correction
- Knowledge from North American Forest Dynamics Project: Vegetation Change Tracker (Co-I Huang)

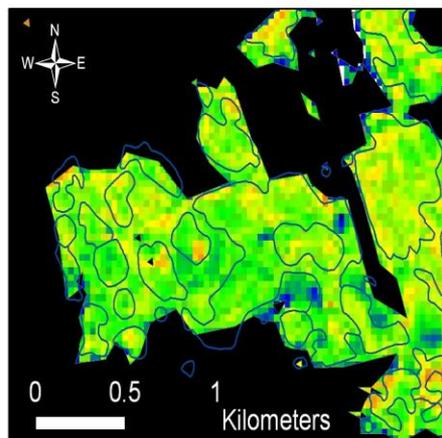


Yearly Information on Vegetation Change from 1972 - Present

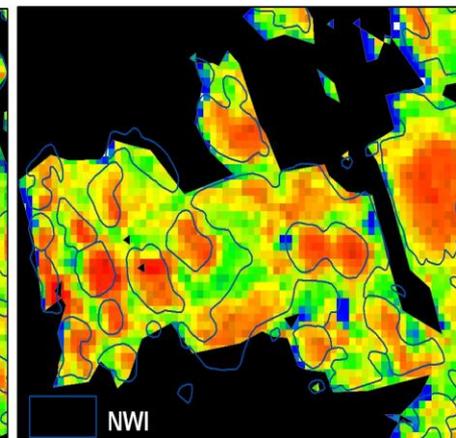


Developing Technologies & Techniques

- Wetness Change Tracker!
- Monitoring **hydroperiod** in response to weather and land cover change
- DEM based topographic wetness indices complement optical data
- Implications for climate change

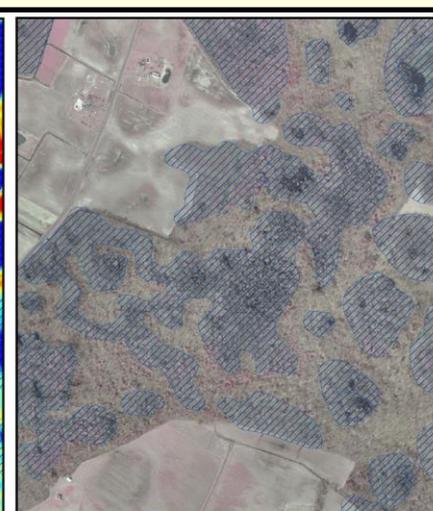
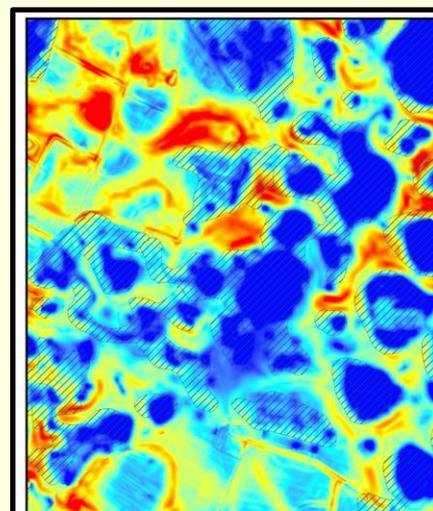
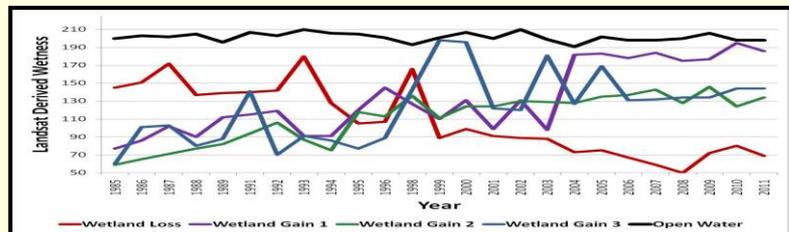


March 2009

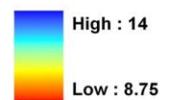


March 2010

Monitoring the Connection between Weather and Hydroperiod with Landsat Based Wetness Trends through Time



Wetness Index



350

Meters



Note that different trends in wetland gains are probably due to natural versus human based drivers and differences amongst human based restoration implementation practices.



Progress and findings

(including achievement by Co-Is and collaborators)

■ Publication related to the project (component 1&3)

Yeo, I., Y. Peng, M. Lang, and C., Huang, 2013 Mapping forested wetlands and their change dynamics in response to variable weather conditions, *Remote Sensing of Environment*, (to be submitted) (1)

Yeo, I., M. Lang, and E. Vermote. 2012, Assessing suspended sediment removal efficiency of wetlands using multitemporal remote sensing data, *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing* (under review after revision) (3)

Lang, M, G. McCarty, R. Oesterling and I. Yeo. 2012, Topographic indices for improved mapping of forest wetlands, *Wetlands*, 33(1): 141-155, DOI: 10.1007/s13157-012-0359-8 (1)

■ Educational outcome (component 2 & 3)

Stubbs, Q. A Spatial-Temporal Analysis of Wetland Loss and Vulnerability on the Delmarva Peninsula: 30 Years of Impact from Physical and Anthropocentric Drivers (Ph.D. Proposal defended 2013)

Lee, S. Assessing the water quality benefits of wetland systems in agricultural watersheds: integrated approach of field observation and numerical modeling (Ph.D. student, UMD)

Butler, K. Improving information about wetland change using remote sensing data analyses (Master's thesis completed Spring 2012).

Dylan Summers, Using Outlier Detection Analysis and Land Cover Datasets to Assess Wetland Change in the Chesapeake Bay Watershed, 2012 SESYNC Social-Environmental Sustainability and Internship Program (Undergraduate intern, Dartmouth University)

Dung Tran, Wetland change analysis using regional land cover products (Undergraduate intern, Geographical Sciences, UMD)

■ Collaboration, public outreach, and information sharing (component 1, 2, 3)

Invited talk, Designing sustainable coastal habitats, 2013 Scientific and Technical Advisory Committee (STAC) Chesapeake Research Consortium Responsive Workshop, April 16, 2013 (1,2)

Working group meeting with wetland specialists, land use modelers, and Chesapeake Bay Watershed Modelers in the Chesapeake Bay Program (EPA, USGS, USFS) (Sept, 2012) (1,2,3)

Technical meeting wetland data provider, including federal agencies (USFS, NOAA) and private sector (MDA Federal) (1)

Lang, M, I. Yeo, and C. Huang, Mapping and Monitoring of wetland dynamics for improved resilience and delivery of ecosystem services. Invited Presentation at the Annual Meeting of Mid-Atlantic Wetland Workgroup (April 18, 2011) (1,2,3)



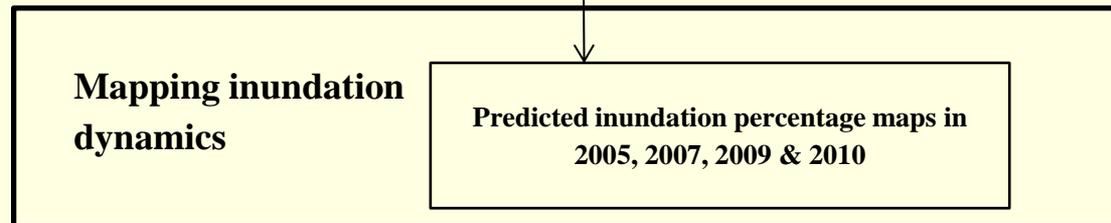
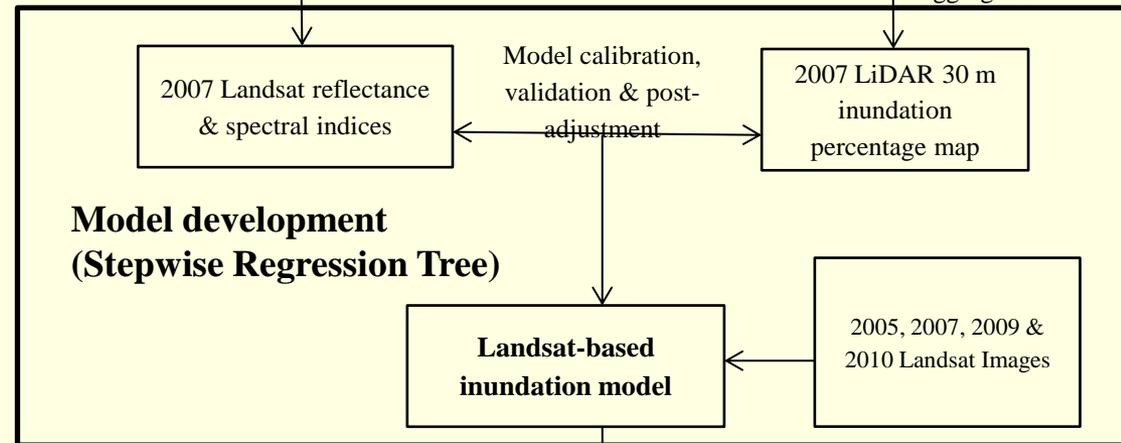
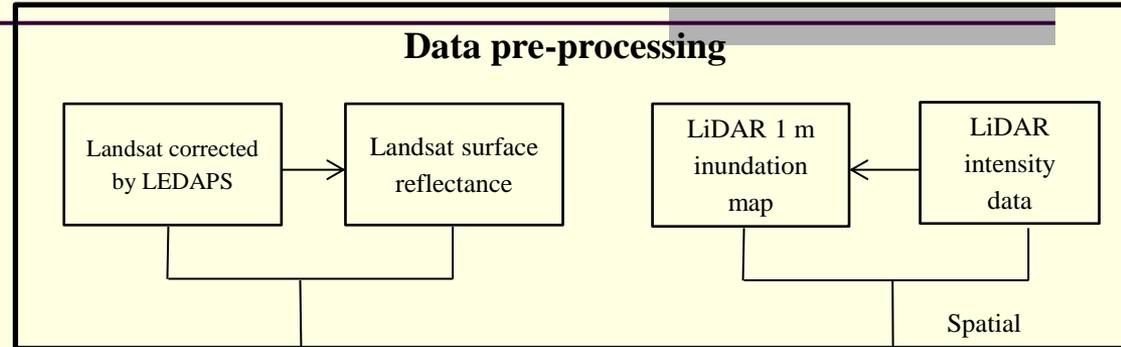
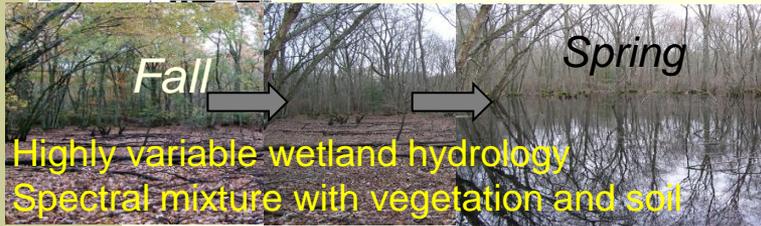
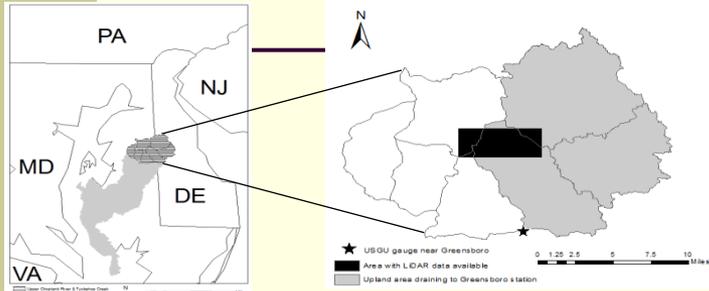
Progress and findings

- Innovation in mapping technique
- Vulnerability Impact Assessment – regional approach and case study
- Ecosystem service assessment – integrated approach (literature review, numerical modeling, and parameterization of existing model)



1. Innovative Mapping Technique

Mapping forested wetlands and their change dynamics in response to variable weather conditions (Landsat based approach) (1)

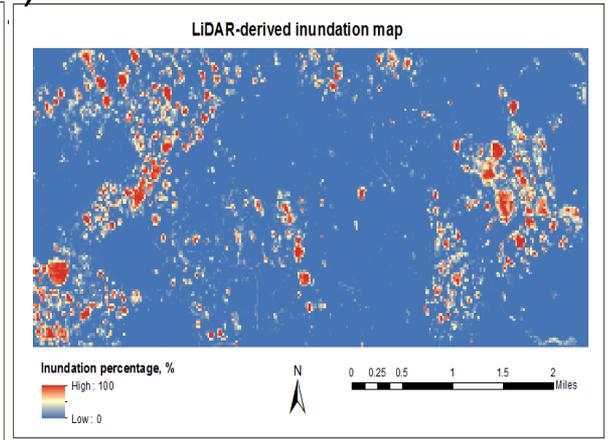
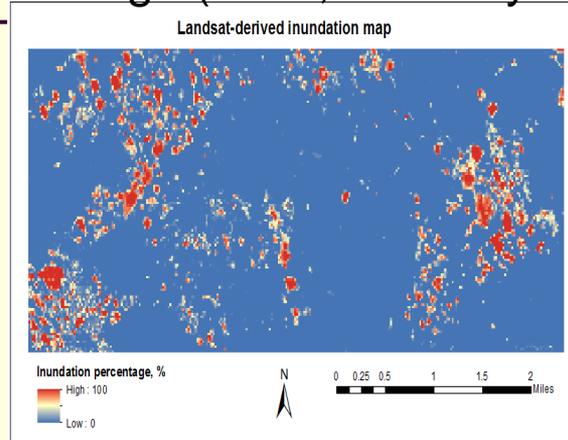
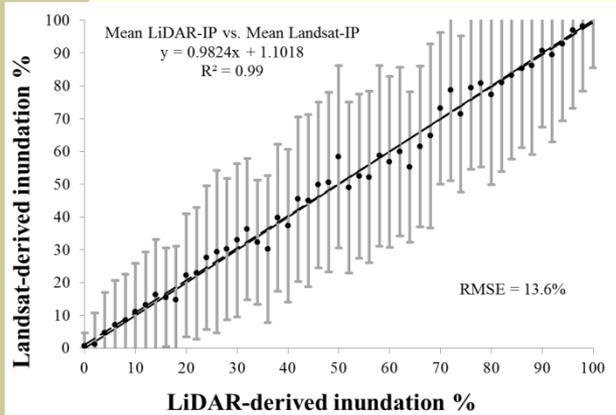


Spectral Index	Formula	Reference
NDVI	$(\text{Band 4} - \text{Band 3}) / (\text{Band 4} + \text{Band 3})$	Rouse et al., 1974
NDWI-1	$(\text{Band 4} - \text{Band 5}) / (\text{Band 4} + \text{Band 5})$	Gao, 1996
NDWI-2	$(\text{Band 3} - \text{Band 5}) / (\text{Band 3} + \text{Band 5})$	Rogers & Kearney, 2004
TCWGD	TCW - TCG	In this study
TCA	Arctan (TCG / TCB)	Powell et al., 2010
IVR	Band 5 / Band 2	Ozesmi & Bauer, 2002
IR	$(\text{Band 5} - \text{Band 7}) / (\text{Band 5} + \text{Band 7})$	Ruan et al., 2007

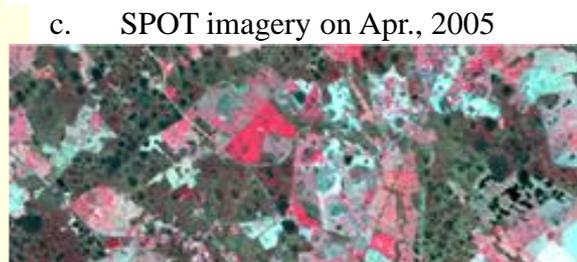
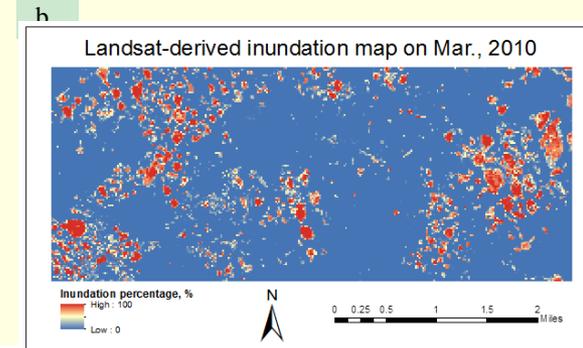
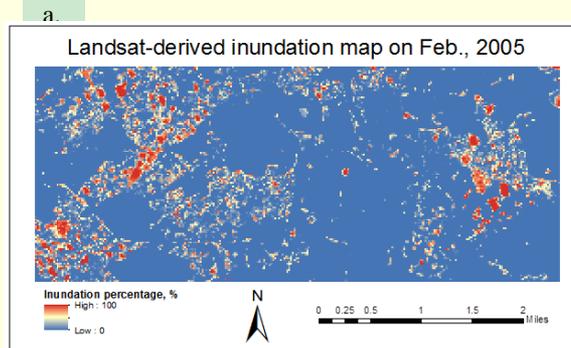
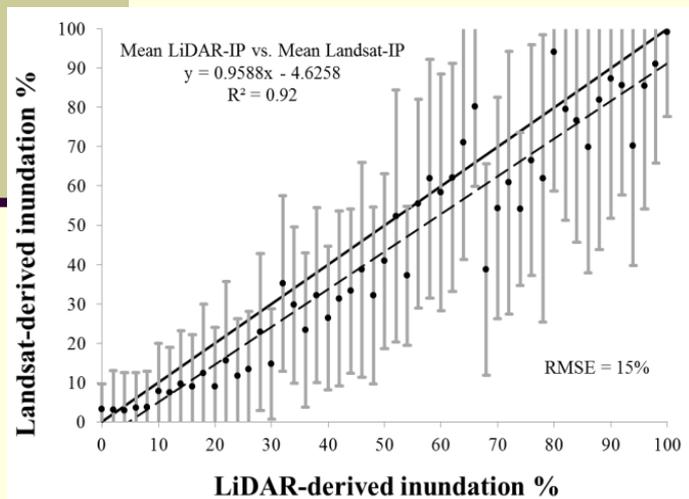
1. Innovative Mapping Technique

Mapping forested wetlands and their change dynamics in response to variable weather conditions (Landsat based approach) (3)

(1) Results from reference image (2007, normal year)



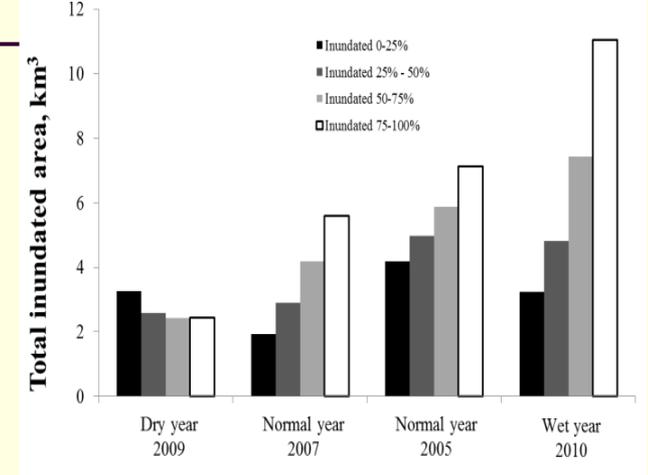
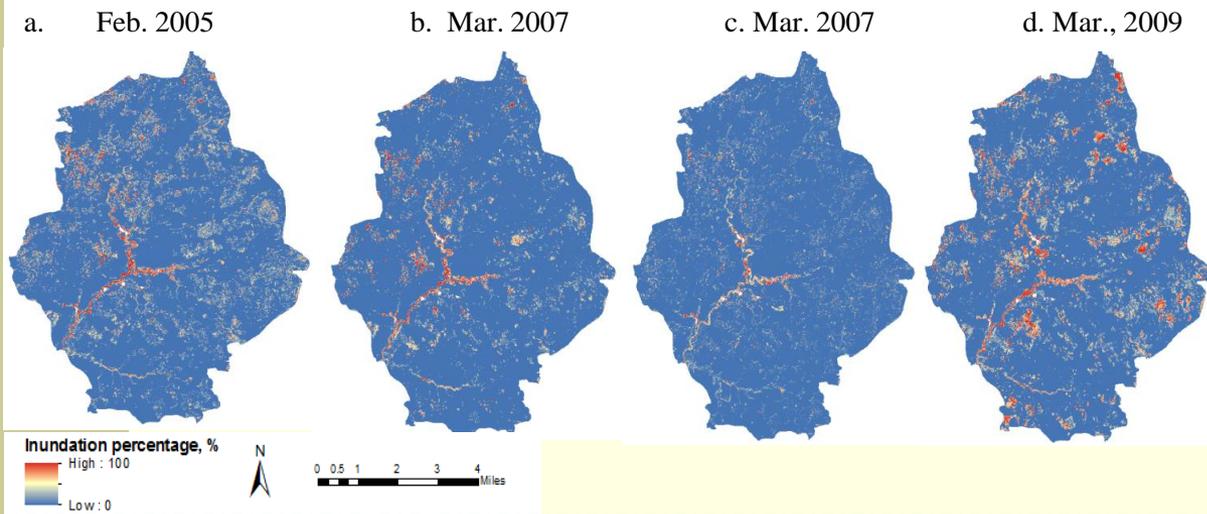
(2) Results from other target years (2005, 2009, 2010)



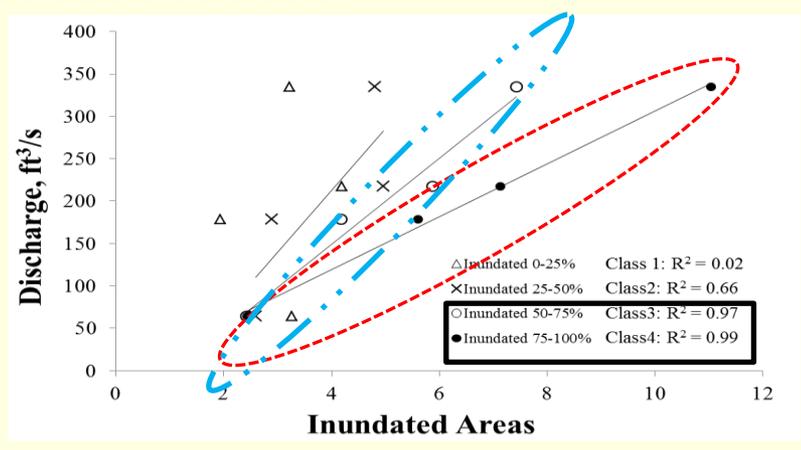
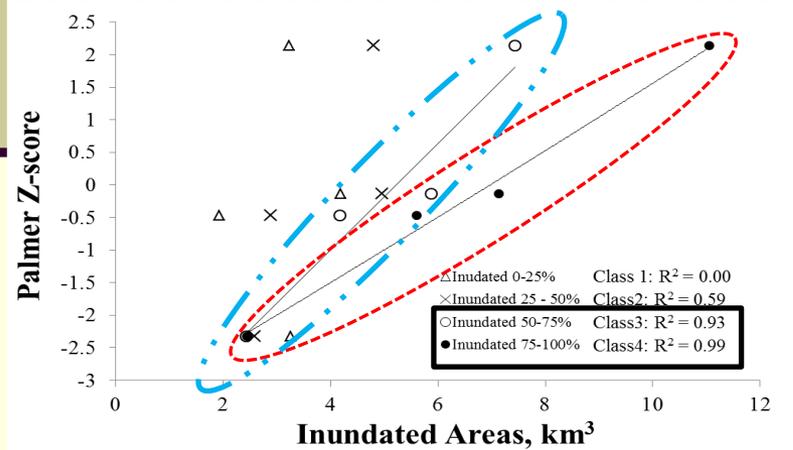
Subpixel Inundation Percent (2009)

1. Innovative Mapping Technique

Mapping forested wetlands and their change dynamics in response to variable weather conditions (Landsat based approach) (3)



(A) Inundation percentage maps for the catchment

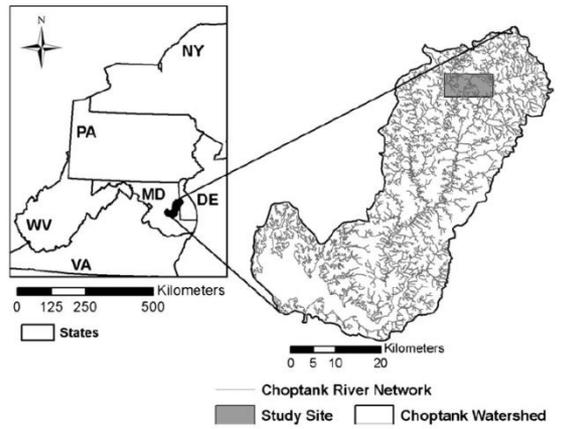


(B) Total inundated area vs. the Palmer seasonal drought index

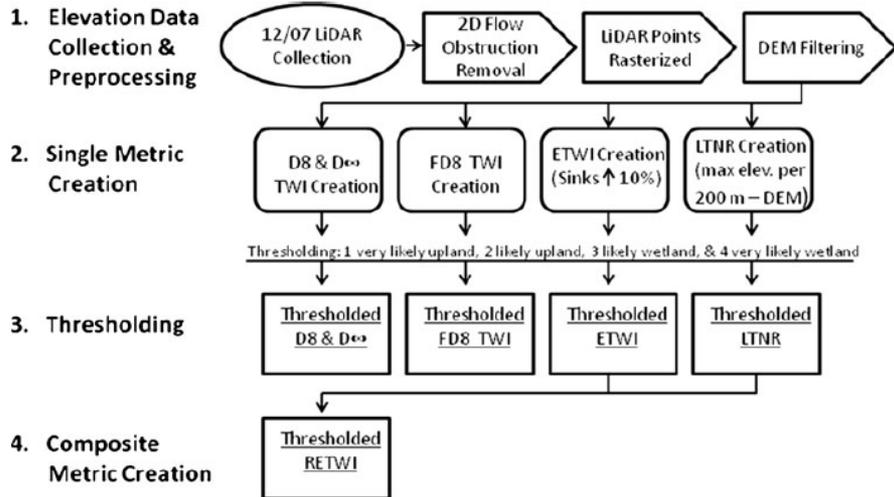
(C) Total inundated area vs. Stream discharge data

1. Innovative Mapping Technique

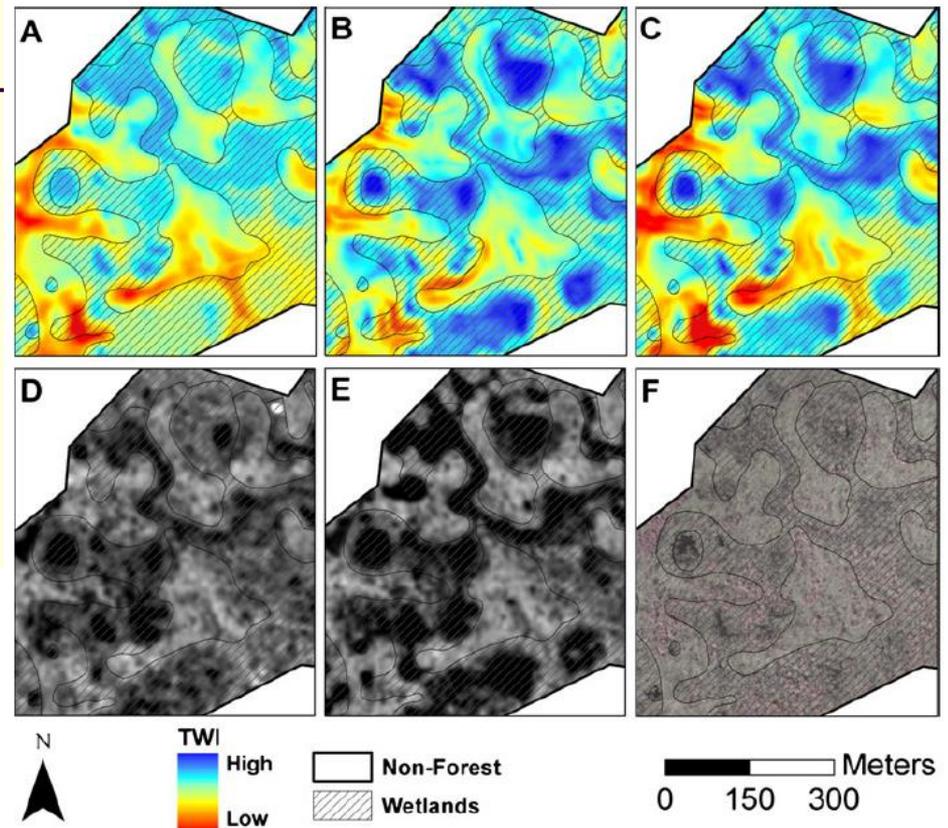
Topographic metrics for improved mapping of forested wetlands
(LiDAR-based approach) (1)



(A) Study site



(B) The overall design of the methodology

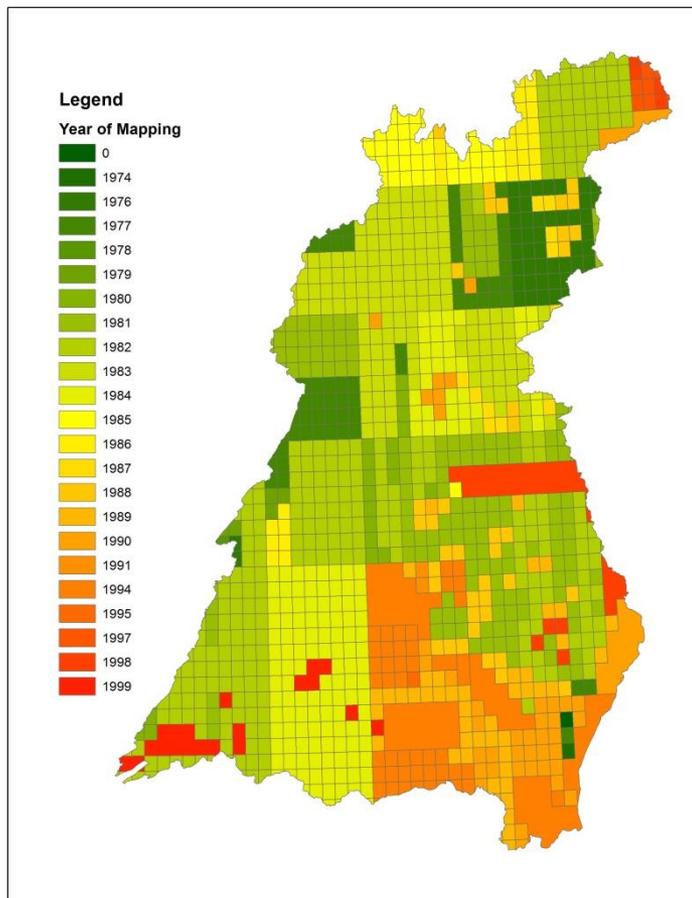


(C) Topographic index vs. products and forested wetlands

(a) the local terrain normalized relief; (b) enhanced topographic wetness index (ETWI); (c) the relief enhance topographic wetness index; (d) LiDAR intensity during a dry spring (e) LiDAR intensity during average spring; (f) false color near infrared aerial photograph (collected coincident to e)

2. Vulnerability Impact Assessment:

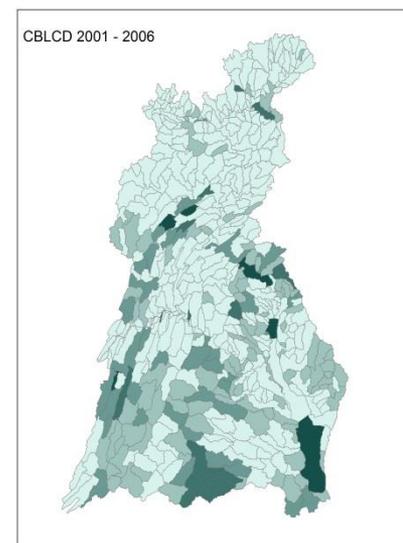
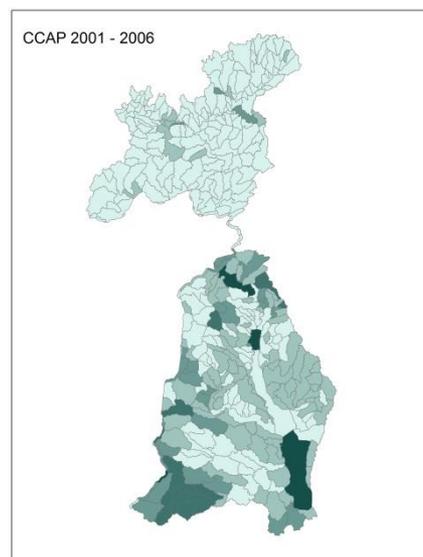
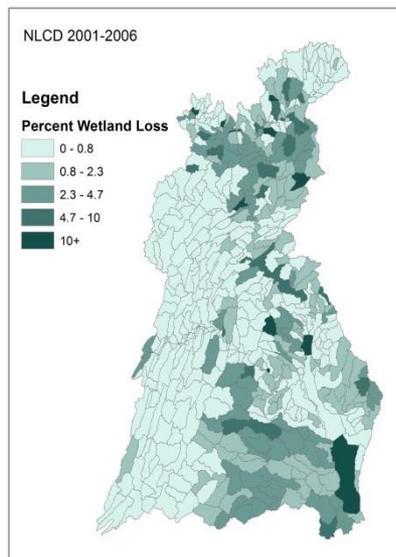
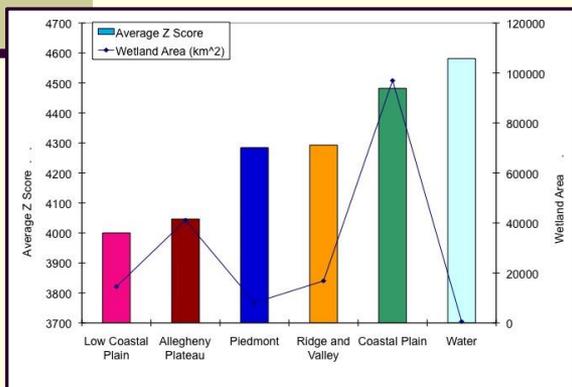
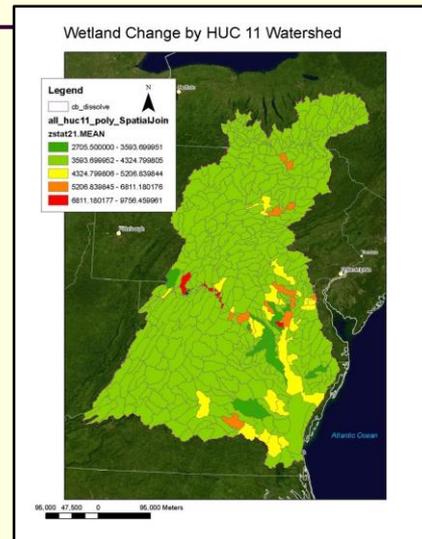
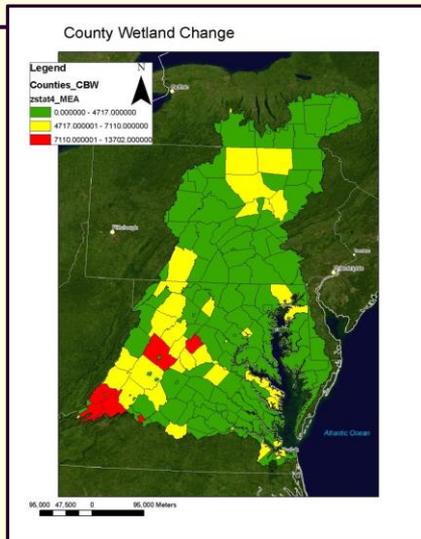
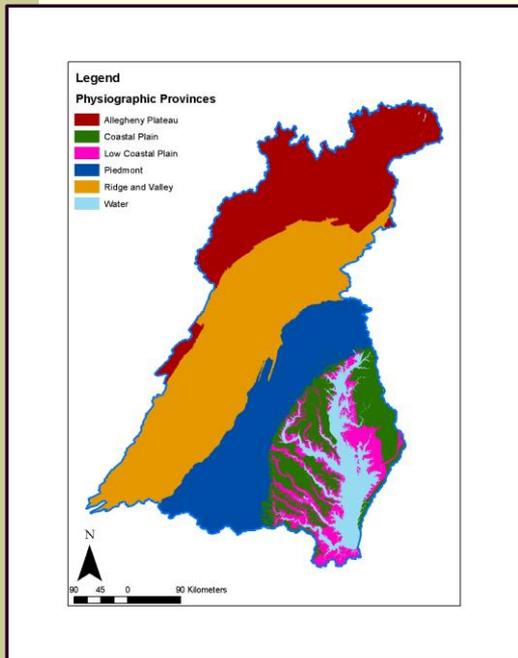
Wetland changes and their potential drivers – regional assessment using existing dataset (1)



(a) Year of Mapping - NWI Map

- Each Dataset covers a range of different time periods, both yearly and seasonally.
 - NWI – 1977 to 1998
 - NLCD – 1992 (unusable for wetlands), 2001, 2006
 - CCAP – 1992 (DE, MD, VA) 1996, 2001, 2006
 - CBLCD – 2001 baseline, 2006, 1992 and 1984 retroactively
 - Outlier detection method (NWI, 2002) - Nielsen, E. M., S. D. Prince & G.T. Koeln (2008)
- Study differences in land use classification methods and their accuracy involved with each products (e.g., NLCD – a minimum mapping unit, CBLCD - correction of coastal emergent wetlands)
- Identify the amount, location, and potential drivers of wetland changes at multiple spatial scales
- Identify the most vulnerable/stressed places (“hotspot”) for wetland changes (loss/gain)

2. Vulnerability Impact Assessment: Wetland changes and their potential drivers – regional assessment using existing dataset (2)



2. Vulnerability Impact Assessment:

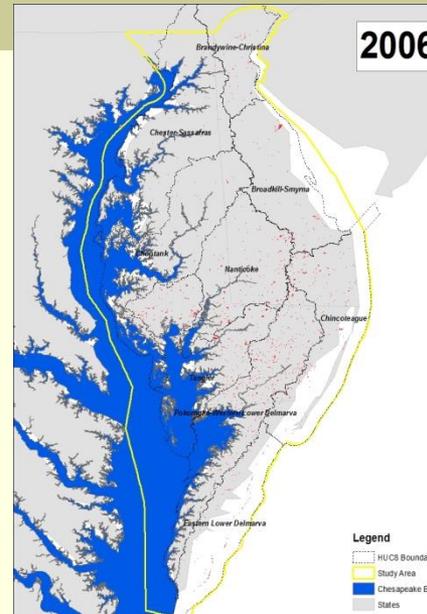
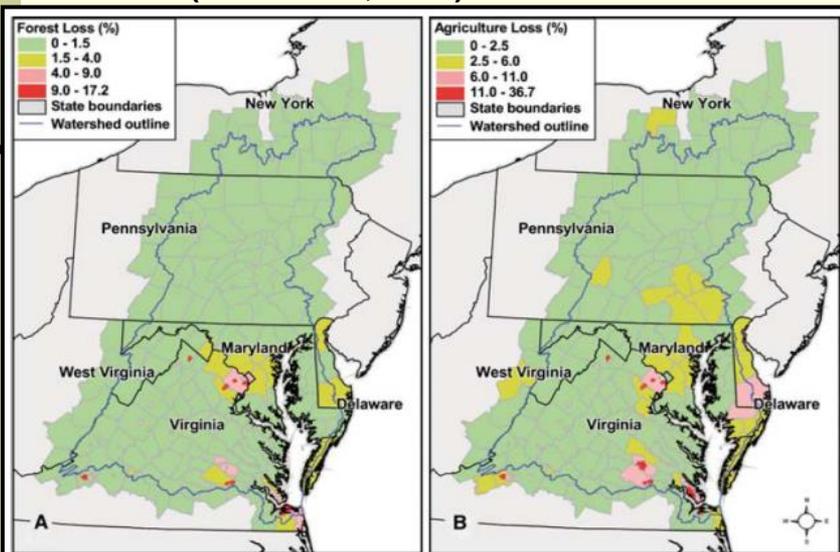
Wetland changes and their potential drivers – regional assessment using existing dataset: Delmarva Peninsula (3)

(a) Study site

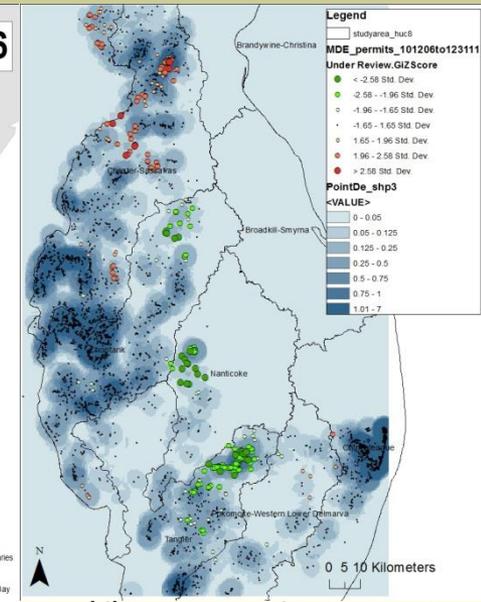


- What is the quantity of the wetland change over the last 30 years on the Delmarva Peninsula measured by existing geospatial data sets?
- What physical and anthropocentric drivers of land use and land cover change are correlated with wetland loss on the Delmarva Peninsula?
- **What information do the spatial and temporal distribution of wetland permits and wetland loss patterns provide regarding the influence of wetland change drivers and the impacts of the wetland permitting system?**
- What wetlands, watersheds, and counties are most vulnerable to wetland loss due to physical, socioeconomic and policy drivers of wetland change?

(b) Forest and Agricultural Conversion in the CBW between 1990 and 2000 (Jantz et al., 2005)



(c) Wetland Loss (In Red) between 1992-2006 (CCAP)



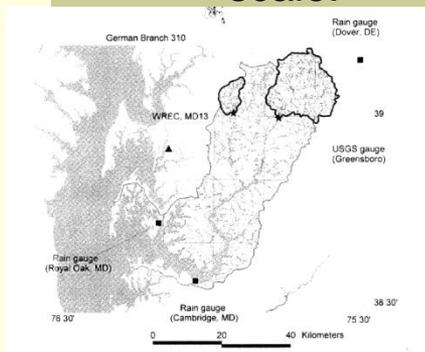
(d) Hot Spot and Point Density of Wetland Permits issued by the State of MD. MDE



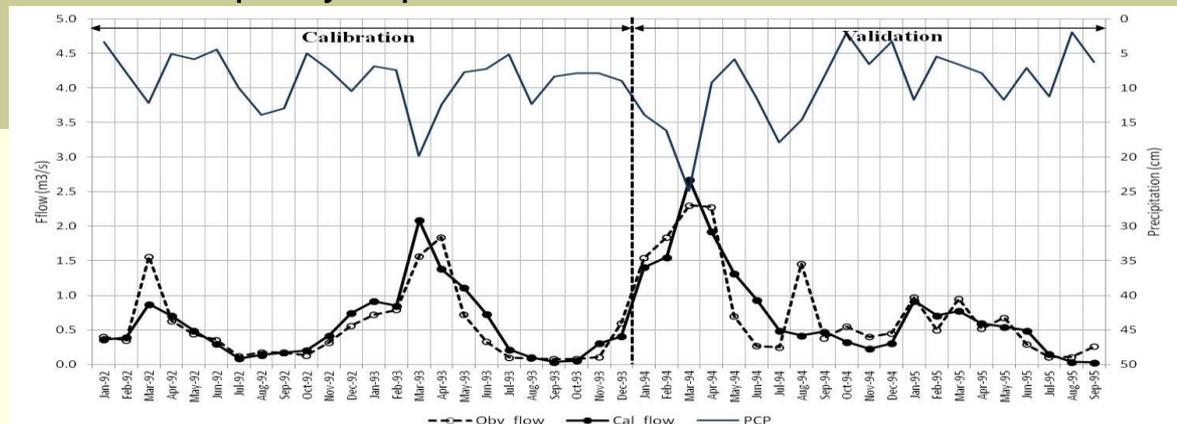
3. Ecosystem Service Assessment

Wetland function: Integrated approach (1)

- 1. Regional Assessment for the CBW:** use of regional models and existing dataset and literature to assess the ability of wetlands to improve water quality
 - Currently, regional water quality models (SPARROW, Chesapeake Bay Watershed Model) for the CBW do not simulate wetland processes.
 - Wetland function is based on the removal efficiency and it only applies to a specific type of wetlands (e.g., constructed wetlands).
 - We are in the process of compiling literature and field data to evaluate the range of nutrient removal efficiency of wetlands, key functional drivers affecting the removal efficiencies, and their applicability for the CBW
- 2. Simulation based approach at the local watershed: Choptank Watershed**
 - We are evaluating the effectiveness and accuracy of watershed process model (Soil and Water Assessment Tool, SWAT) to simulate natural wetland processes and its water quality improvement benefits at the watershed scale.



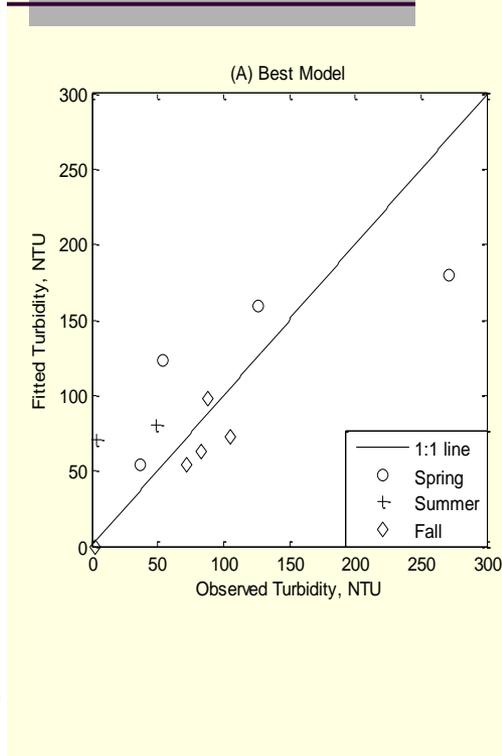
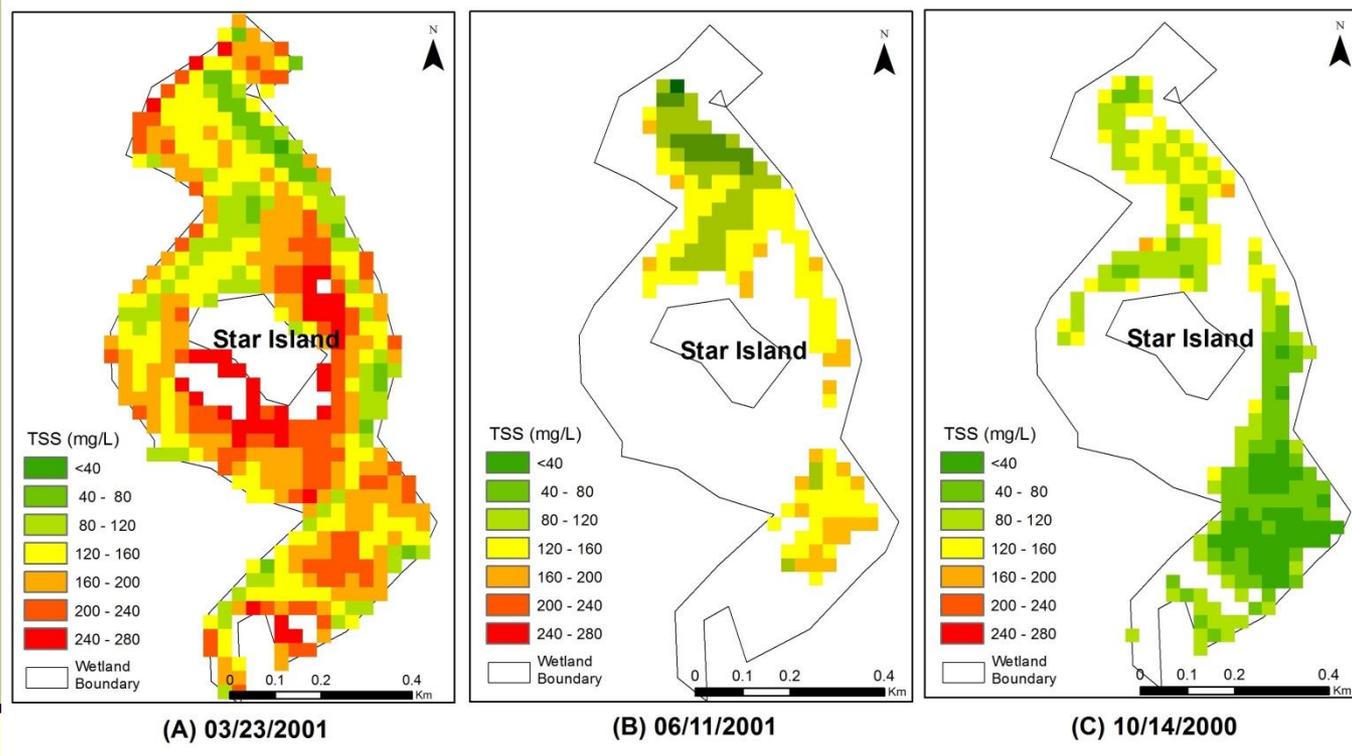
(A) Study site



(B) Calibration and validation of SWAT model

3. Ecosystem Service Assessment

Wetland function: Improved understanding of suspended sediment transport process using multi-temporal Landsat data (2)



We used historical water quality data, continuous *in situ* water quality monitoring data, and multi-temporal Landsat data

- study the distribution of total suspended sediments (TSS) in a freshwater coastal wetland and compare it with the removal efficiency estimated based on field studies.
- identify key physical drivers affecting the transport processes of suspended sediments



Thank you!

For additional information please contact In-Young at iyeo@umd.edu