Assessing hydrologic and salinity thresholds driving ecosystem transition at Alligator River National Wildlife Refuge

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Managing Forested Wetlands with Fire in a Changing Climate
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Outline

- Scientific interest/rationale
- Forested wetland C cycling monitoring at ARNWR
  - Rationale
  - Project description, methods and team
  - Comparison with LCP pine forests
  - Moving forward
- Effects of hydrology and salinity on ARNWR ecosystem transition
  - Rationale
  - Select ecosystems to monitor
  - Methods and timeline
- The future

Scientific interest

- Tree Physiology and Ecosystem Science Lab at NCSU
  - Forest ecophysiological responses to land use, management and environmental change

    -Integrate molecular-cellular-plant-ecosystem-landscape-regional scales through measurements and models
  - Investigations include:

    -Tree physiology and forest productivity

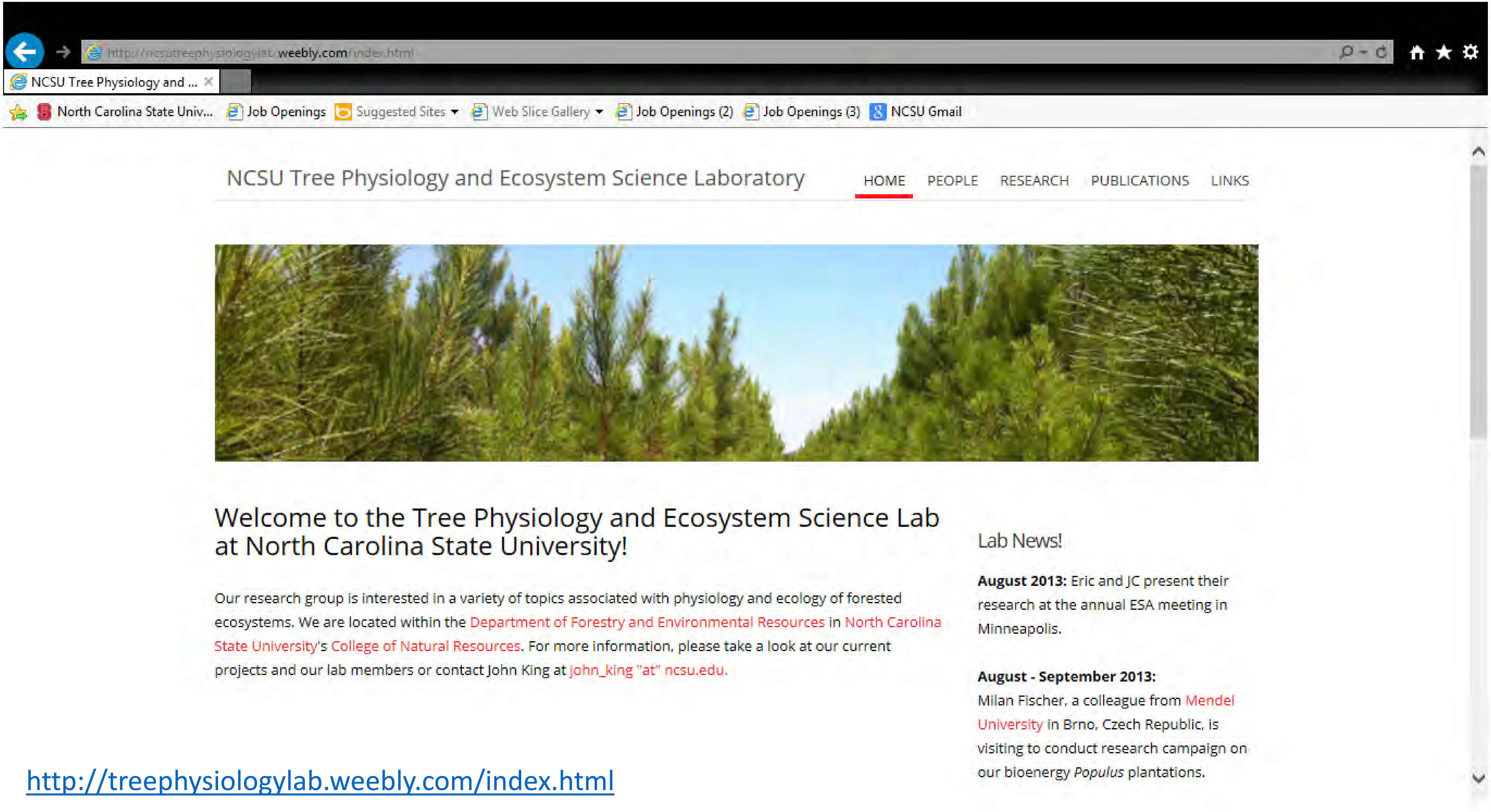
    -Land-atmosphere exchanges of carbon (C), water and energy

    -Carbon storage and cycling in plant biomass and soils

    -Water use (efficiency) of managed and natural ecosystems

    -Changes in availability of key limiting resources: nutrients, temperature, water, and light

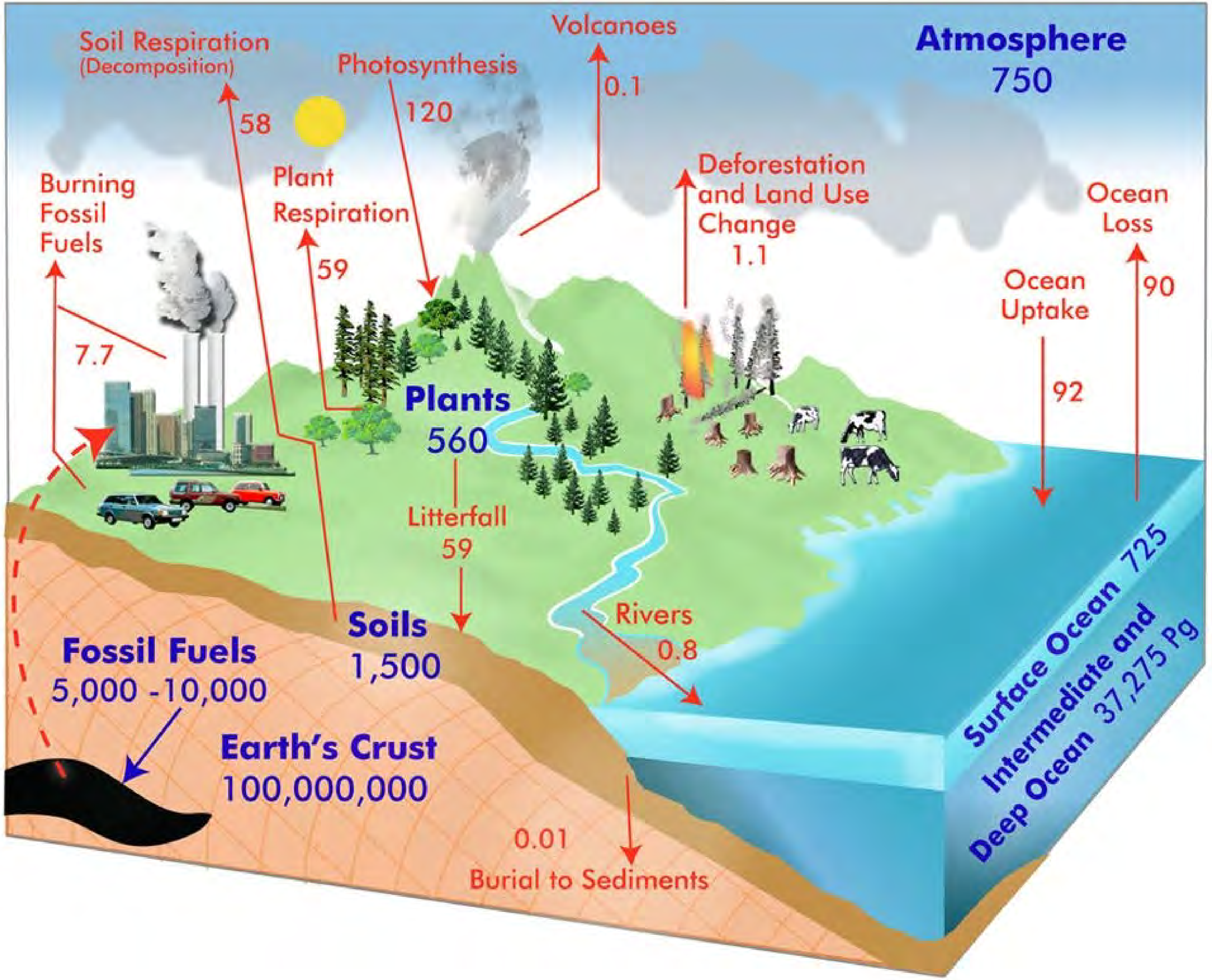
    -Feedback of tree responses to ecosystem function and biogeochemical cycling



http://treephysiologylab.weebly.com/index.html

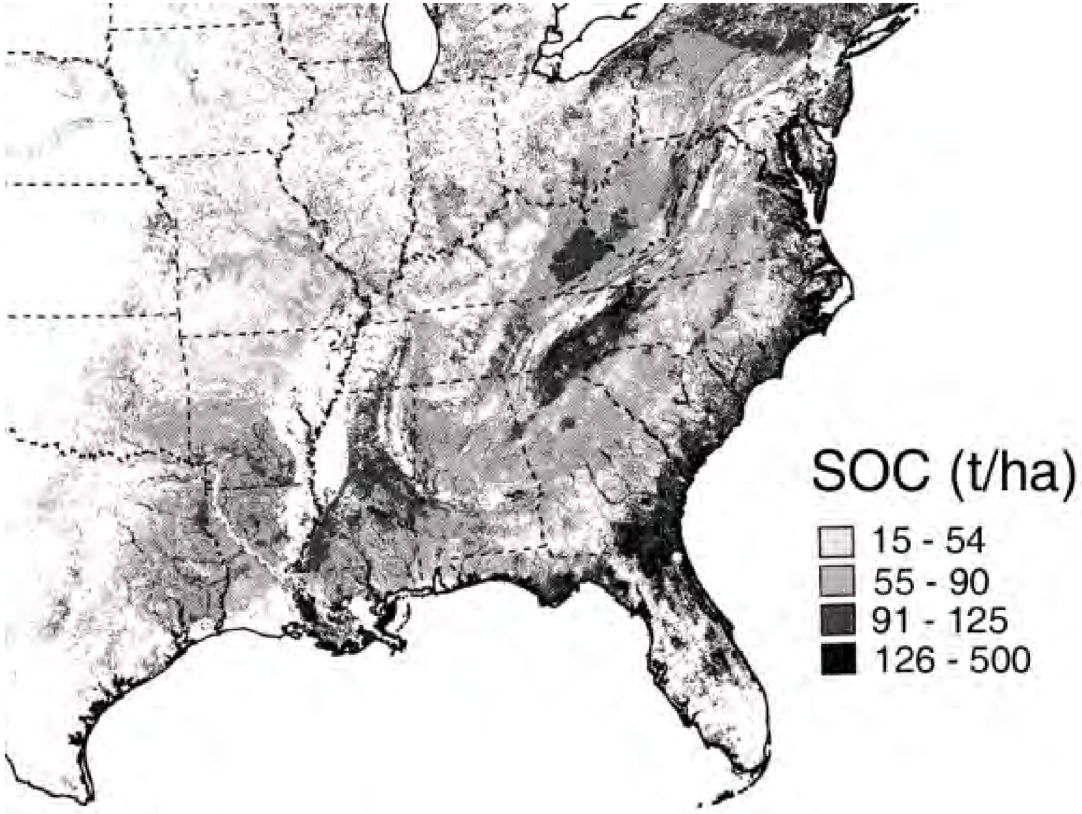
Rationale

- Wetland soils contain globally significant C reserves
  - o 2-3% of land area
  - o 18-30% of total global soil organic carbon
  - o Soil carbon residence time: ~500 years
- But poorly represented in global assessments of C cycling



From: NASA, 2010.

Soil organic C (SOC) is highest along the lower coastal plain

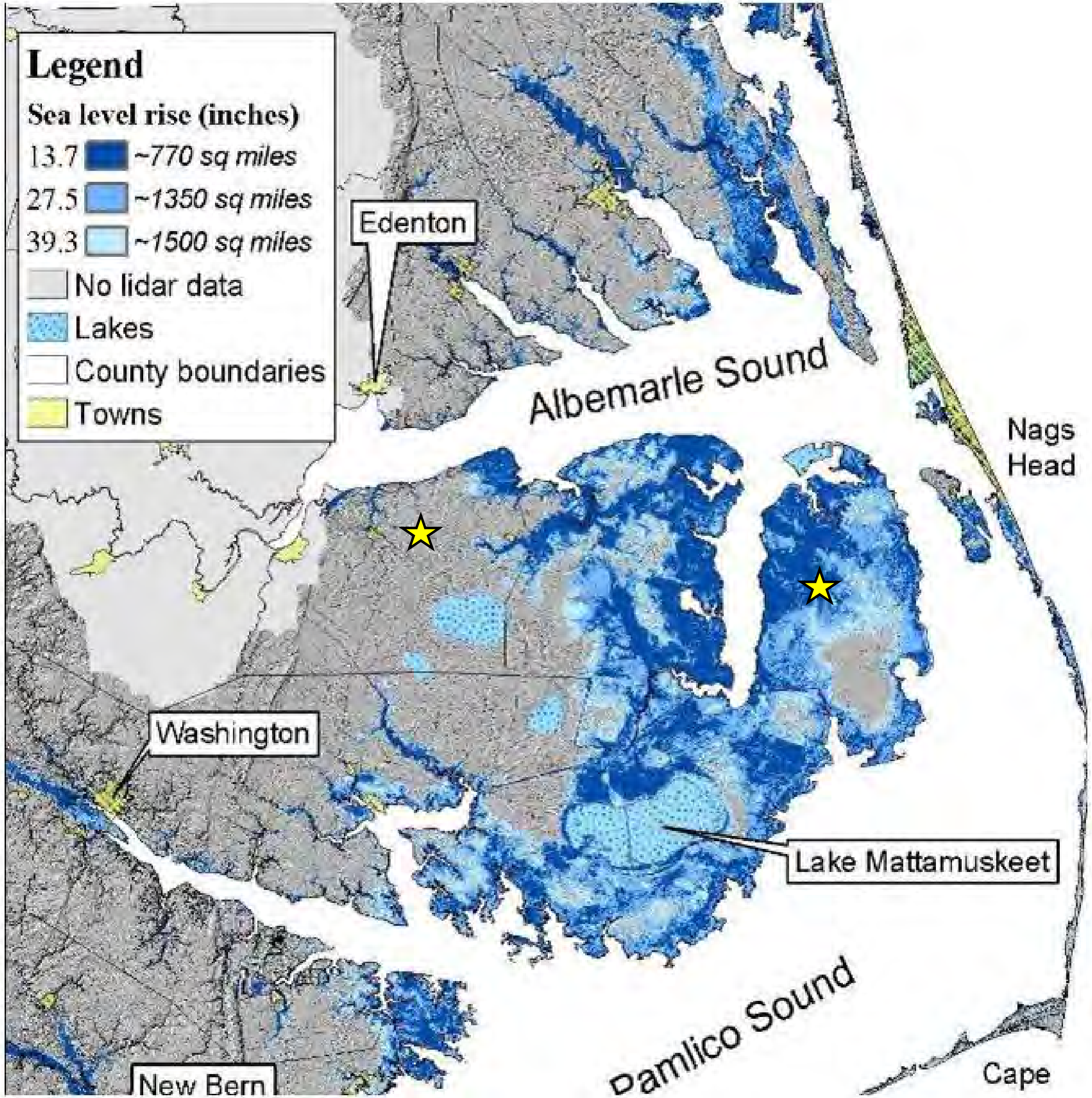


From: Johnson and Kern, 2003.

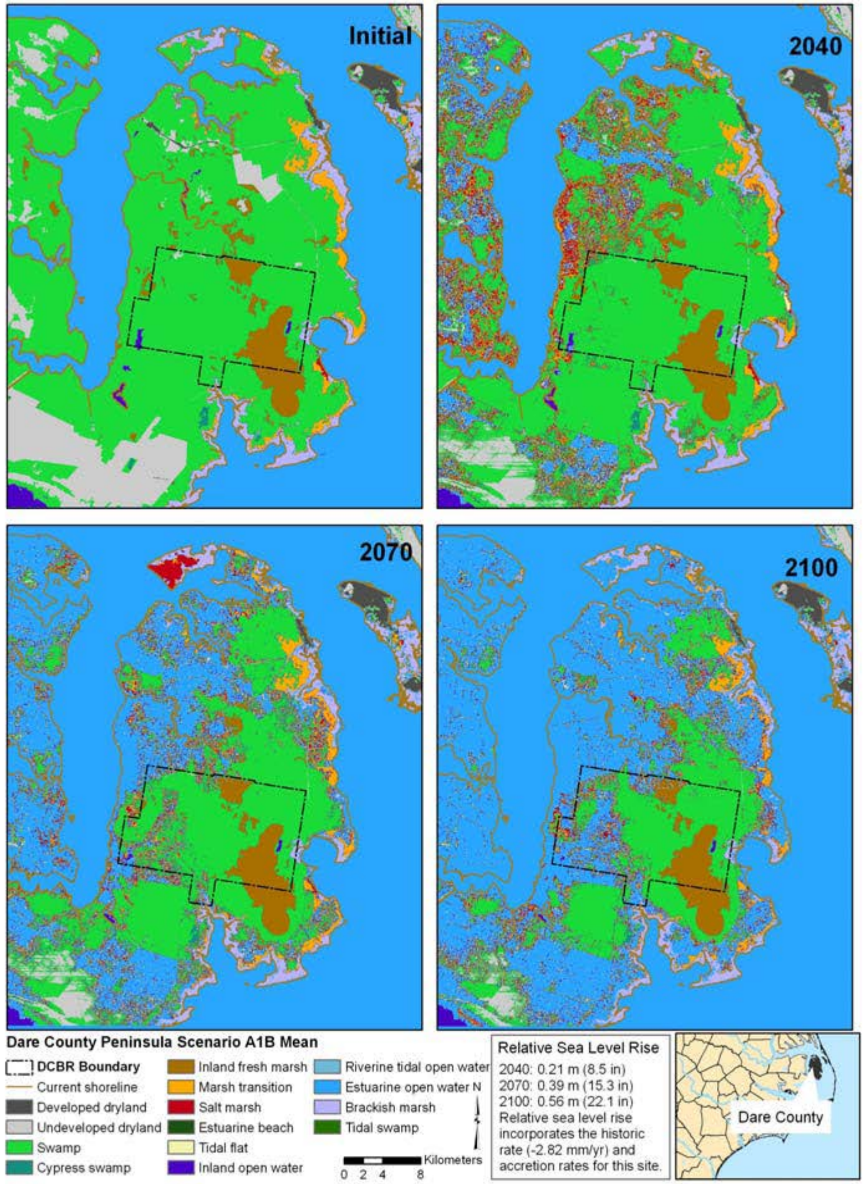
Table 1. Timberland biomass C densities for selected forest cover types of the eastern United States in 1997. From Heath et al. (2003).

Forest type	Live biomass (t C ha^{-1})	Dead bimss (t C ha^{-1})	SOC (t C ha^{-1})	Total forest (t C ha^{-1})	Regional (10^9 t C)
Loblolly-shortleaf	50.4	21.3	91.7	163.4	3.48
Oak-pine	56.9	26.5	82.3	165.7	2.28
Longleaf-slash	43.6	19.1	136.3	199.0	1.06
Oak-gum-cypress	81.1	26.5	152.2	259.7	3.18

NC has ~5,200 km^2 < 1 m elevation and the sea is rising…

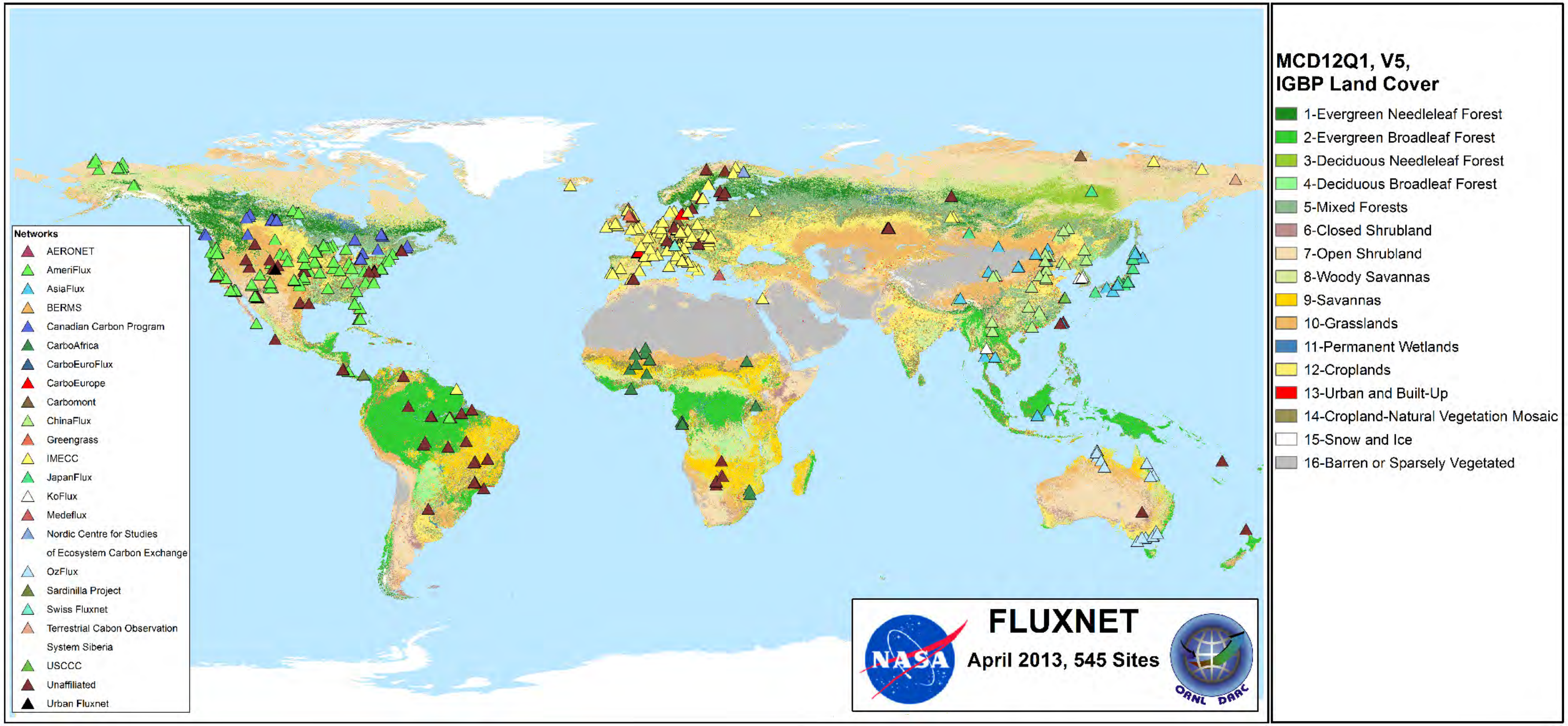


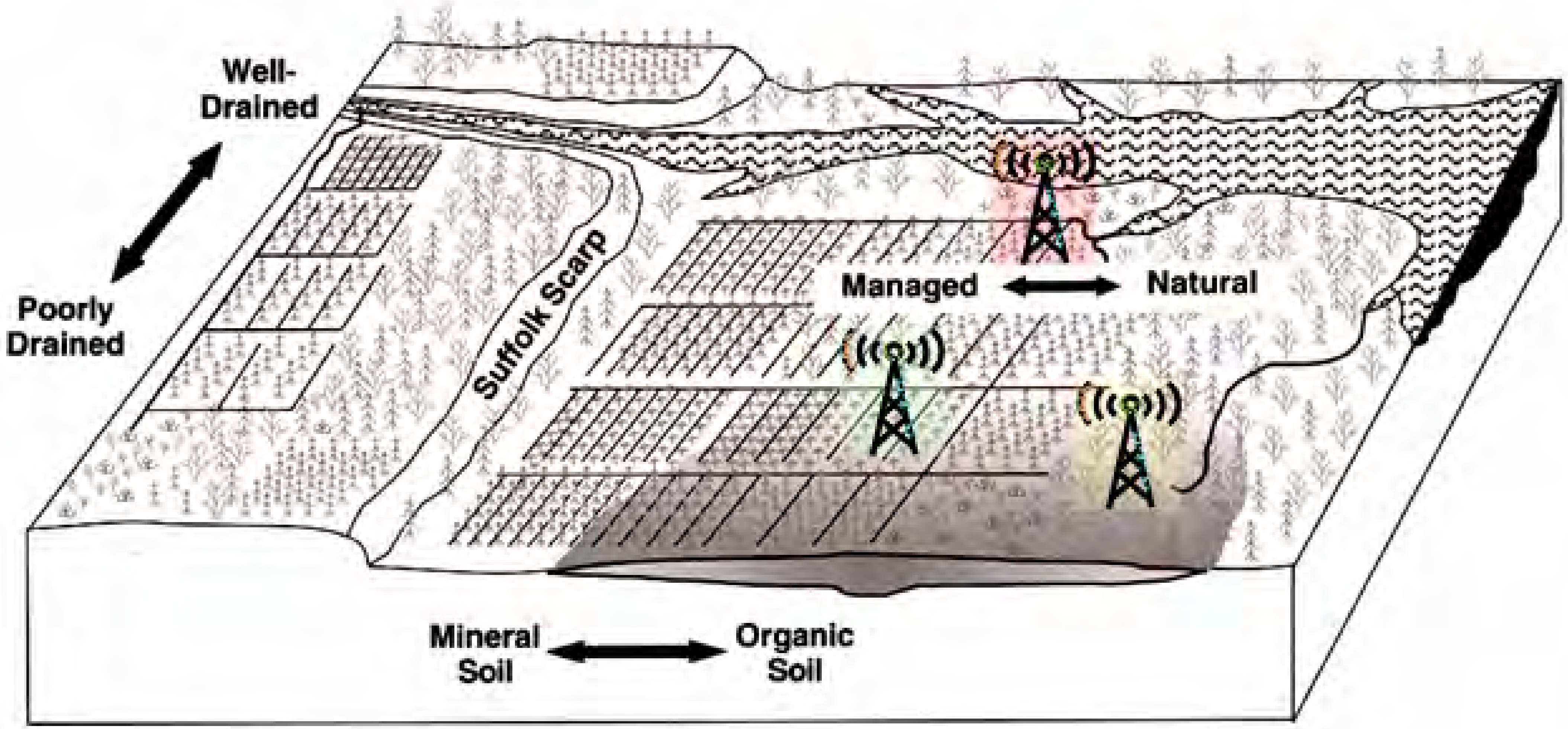
From: USFWS ARNWR, 2005.



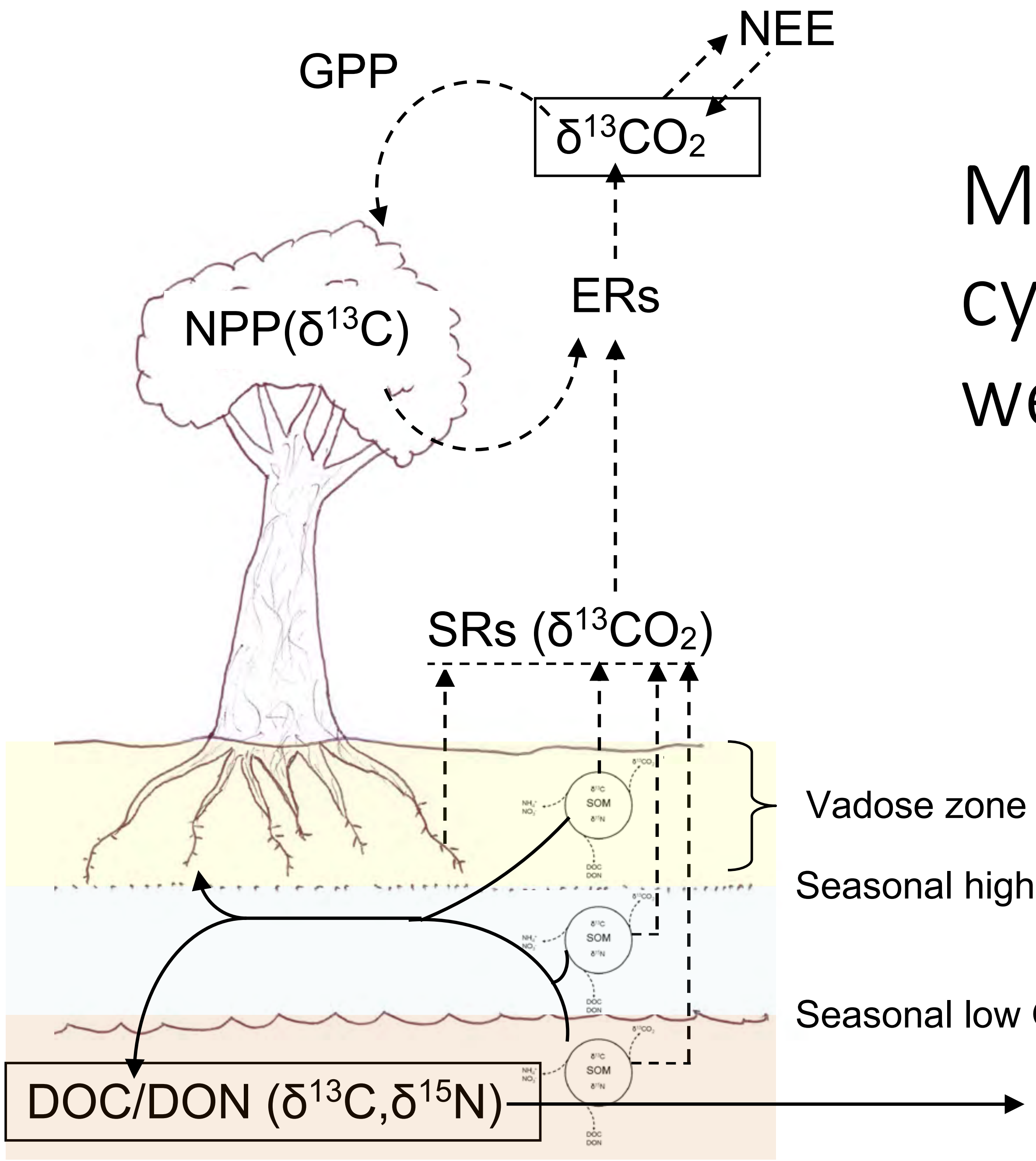
Source: DOD, 2010.

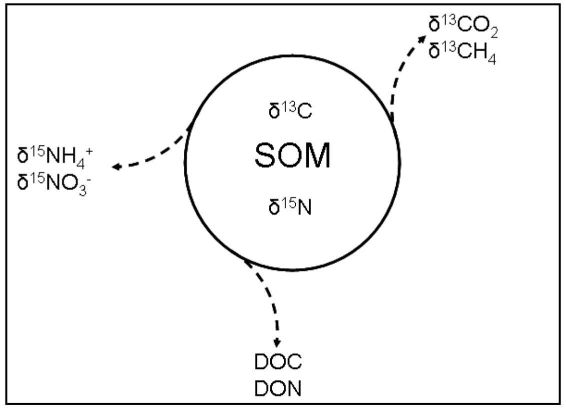
Our site at ARNWR is part of a global C monitoring network: “Long-term climate change observatory”



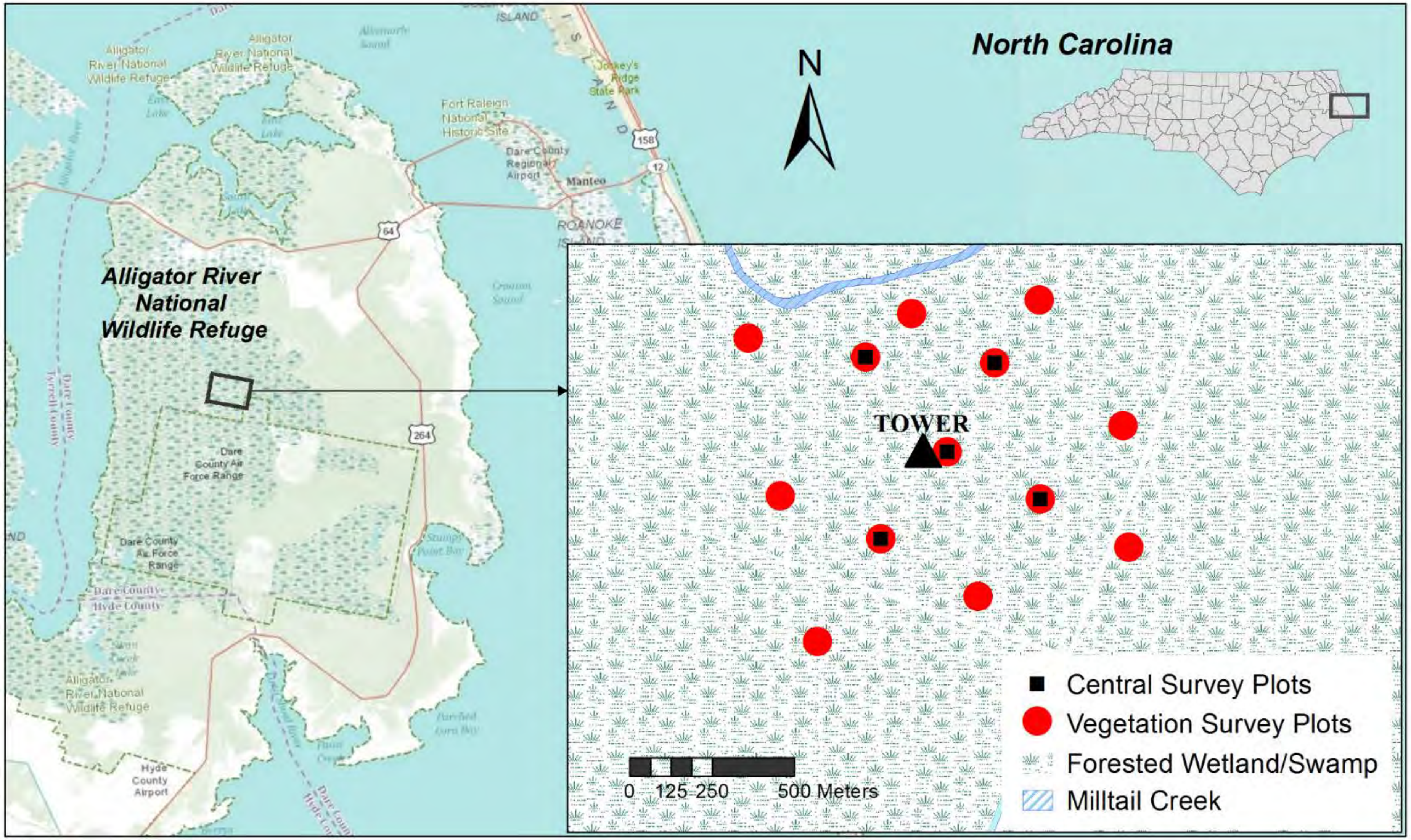

Well-
Drained
Poorly
Drained
Suffolk Scarp
Managed
Natural
Mineral
Soil
Organic
Soil

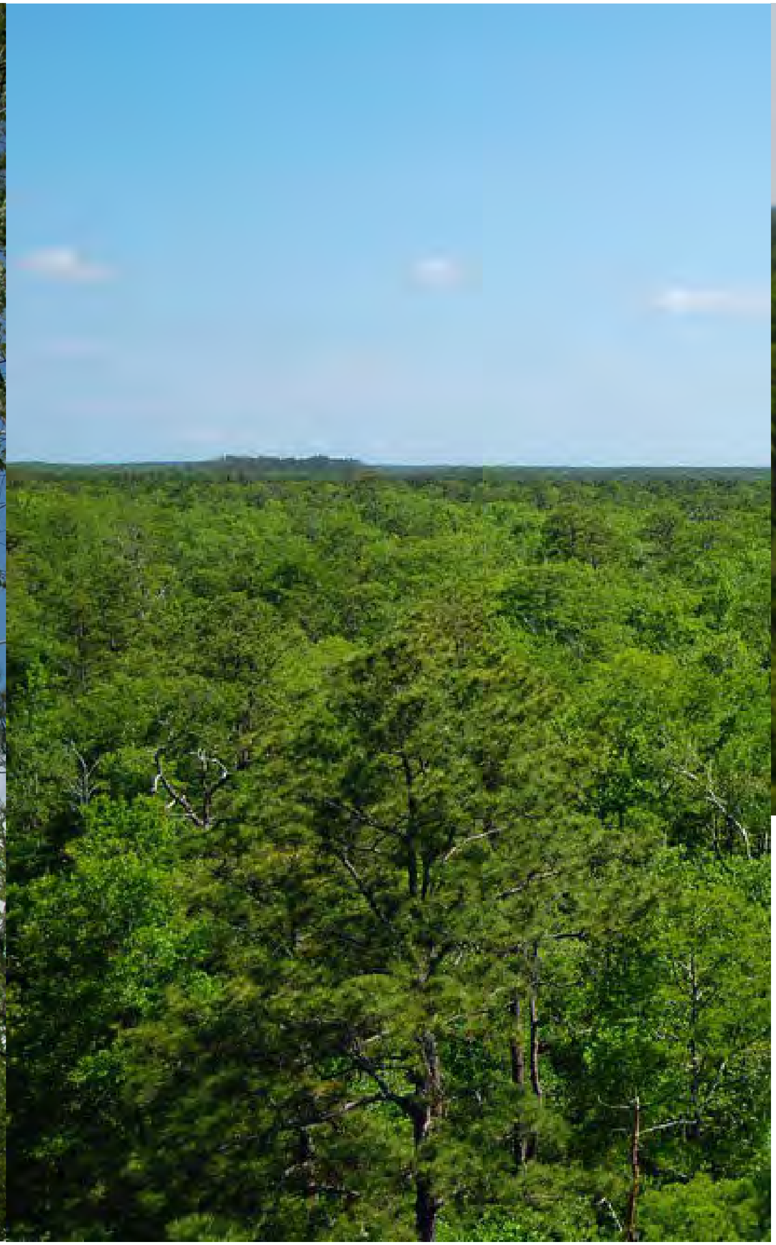
Monitoring C cycling in forested wetlands





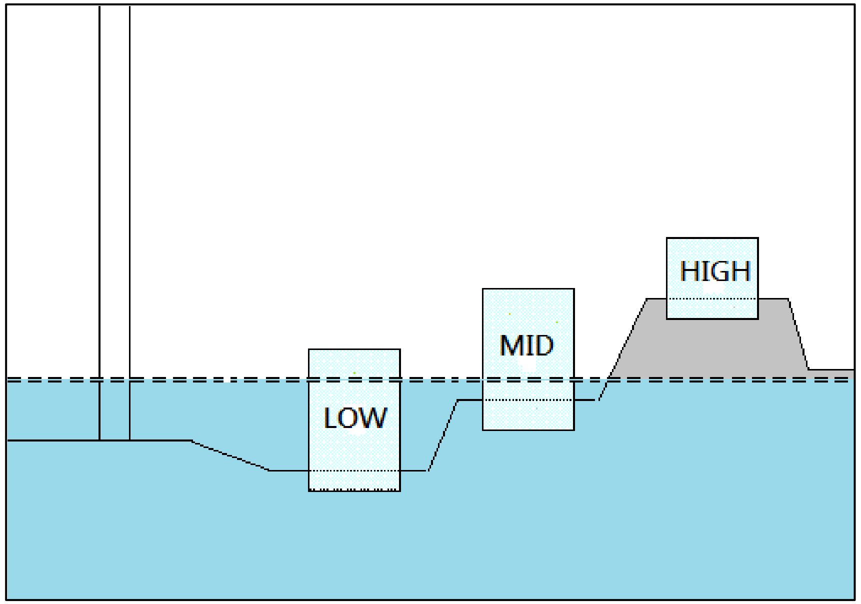
Field site next to Milltail Creek, DCBR

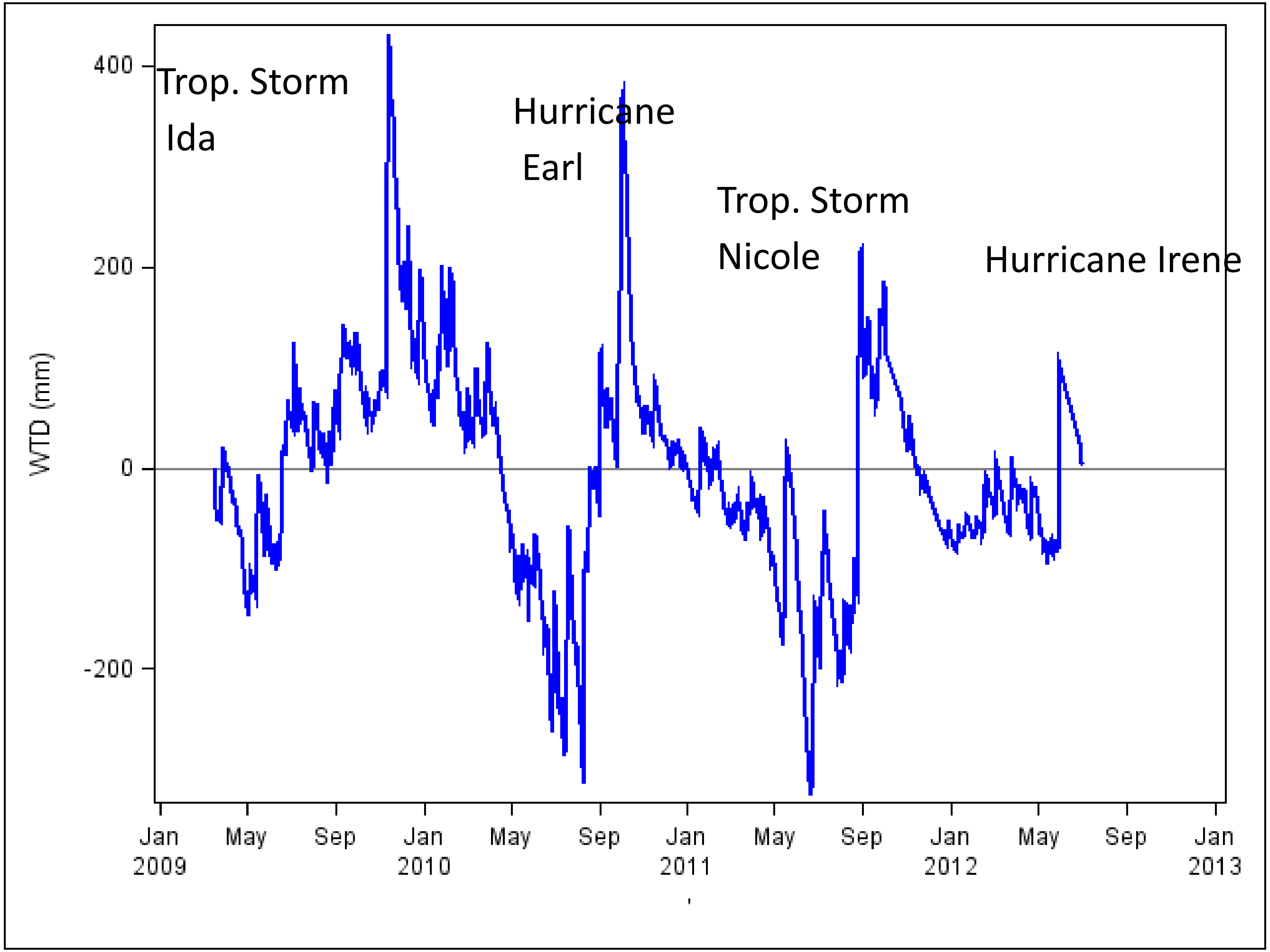



Eddy covariance
“flux” tower

Highly variable micro-topography





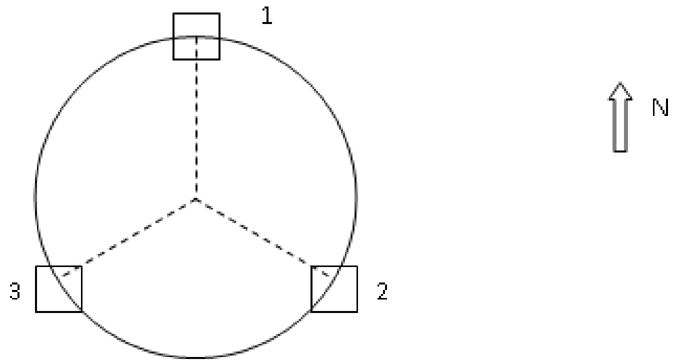
Constantly fluctuating water table

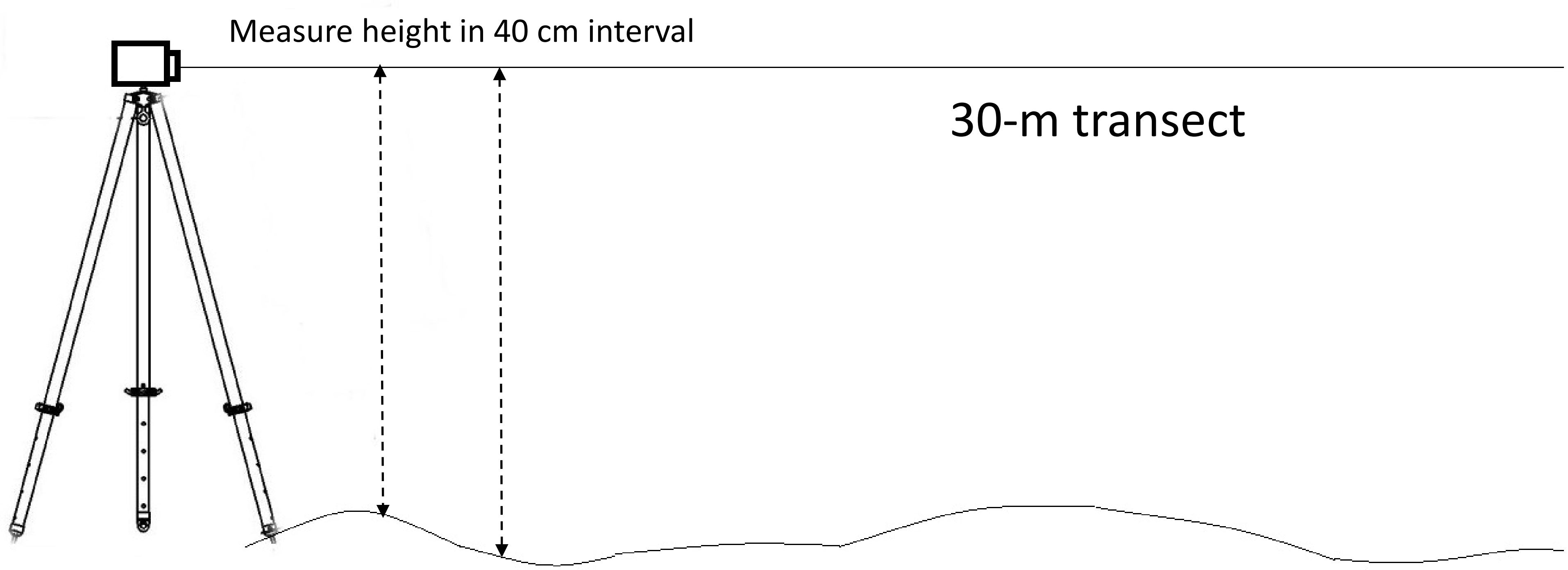

One storm + one
$50,000 instrument =
one $10,000 repair bill


Microtopography survey

At 5 survey plots

All the heights were normalized relative to the groundwater probe location at micrometeorology station.





Microtopography survey

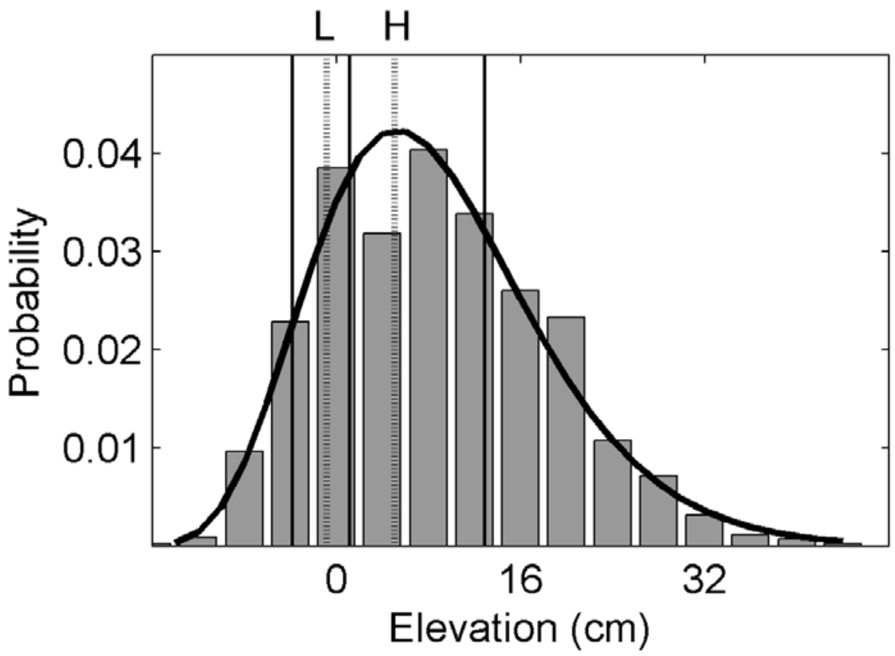
- **Gamma distribution**

▪ Site average elevation: 8.7 cm

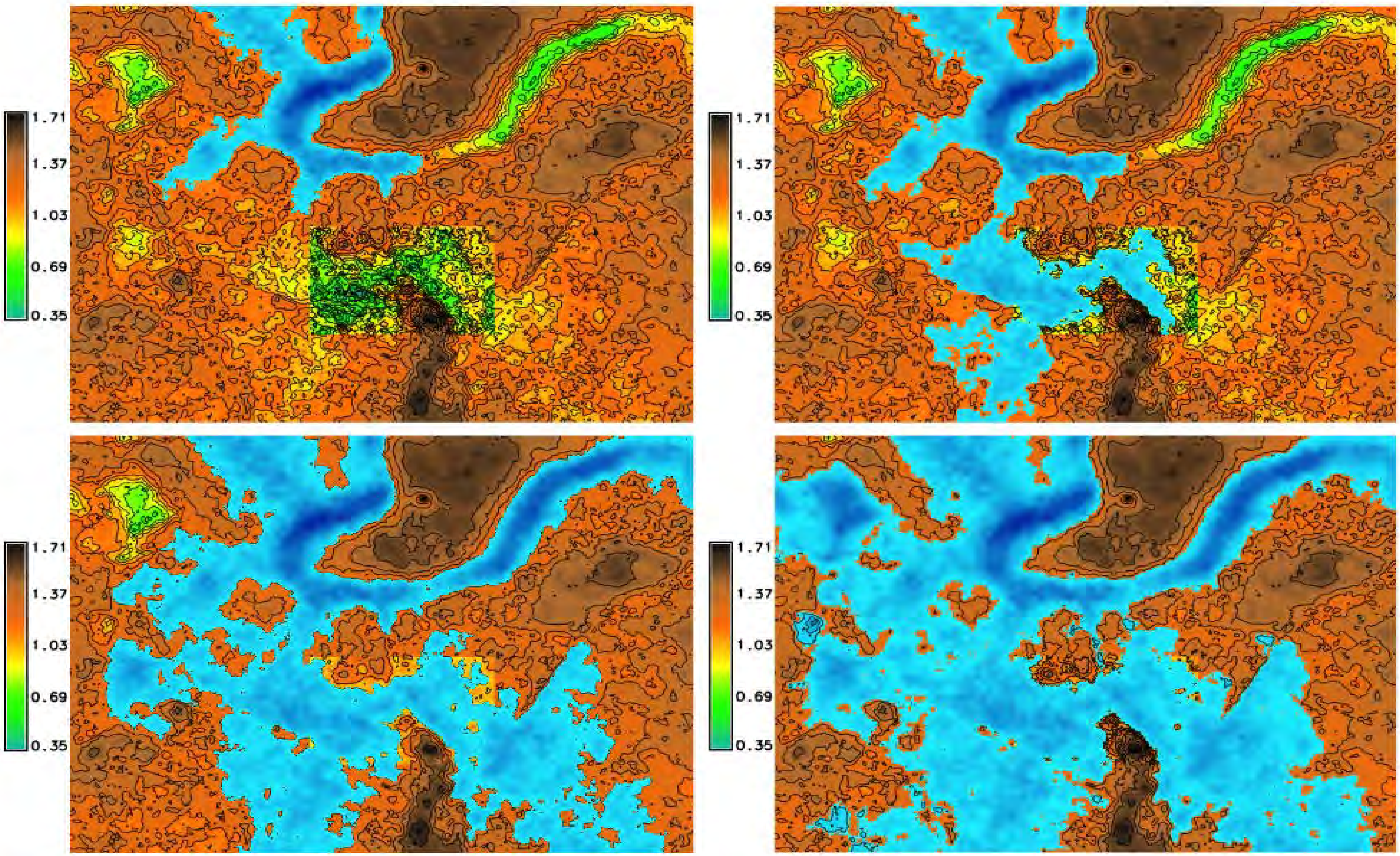
Used to separate flooded and non-flooded conditions in the ecosystem scale.

▪ 60% HIGH, 23% MID, 17% LOW

Used to upscale soil respiration.



Simulated flood using DEM



Annual allometric estimation of over story tree and under story biomass and NPP

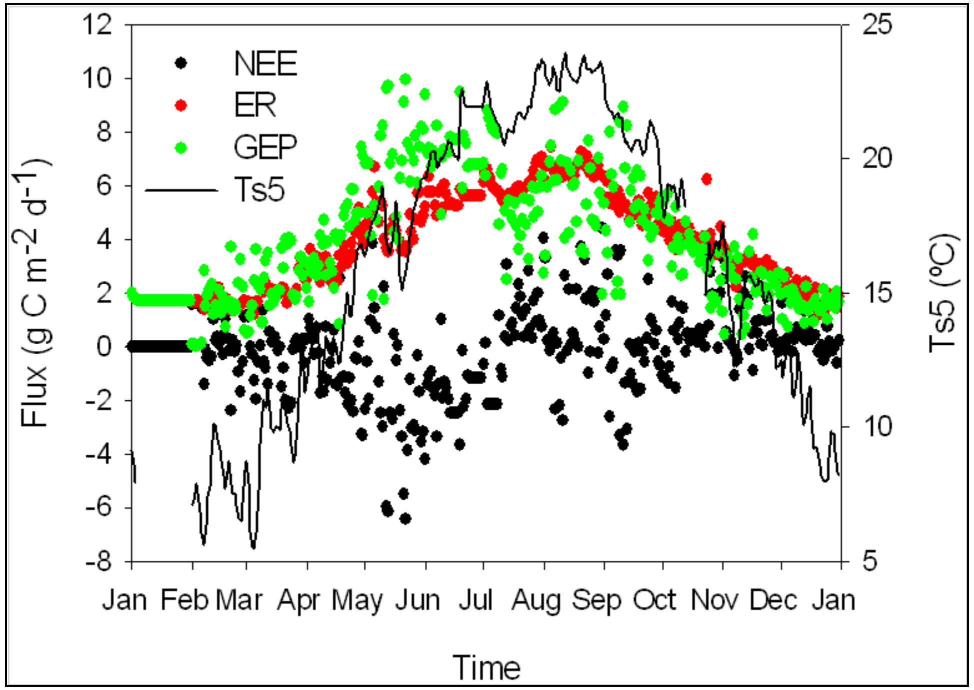

Decomposition of coarse woody debris (R_{CWD})

- Four decay classes (1-4)

Decay class 2

Decay class 3

Pools	Live Woody	Coarse Woody Debris	
2009 (Mg C ha^{-1})	22.5±8.5	n/a	
2010 (Mg C ha^{-1})	22.7±8.5	1.63±1.04	
Fluxes	**GEP**	**ER**	**SR**
2009 (g C m^{-2} yr^{-1})	1453	1397	440±275



These forested wetlands are a small but consistent C sink: 60 - 100 g C m^{-2} y^{-1}

Mid-rotation loblolly pine tower:

Mean annual GEP - 2695 (g C m^{-2} y^{-1})

Mean annual ER - 2085

Mean annual SR - 1150

Mean annual NEE - 610

Rh > litter fall by 109 g C m^{-2} y^{-1}

Table 2. Comparison of the unmanaged forested-wetland at Alligator River NWR to the intensively managed (drained, fertilized, thinned) loblolly pine plantations on former forested-wetland sites.

	Alligator River forested wetland 2009, 2010, 2011	Mature loblolly pine[&] (US-NC2)	Young loblolly pine[&] (US-NC1)
NEE (g C m^{-2} yr^{-1})	+45, -113, +45	-360 … -1200	-253 … +837
ER (g C m^{-2} yr^{-1})	1397, 1681, 1204	1872 …2121	1638…2126
GEP (g C m^{-2} yr^{-1})	1167, 1797, 1275	2482 … 2911	1289 … 2205
SR (g C m^{-2} yr^{-1})	~794	1100 … 1331	965 … 1727
SR:ER	~0.48	0.62	0.59-0.81
NPP (g C m^{-2} yr^{-1}) AR not adjusted for mortality yet	0 … 300	967 … 1549	10 … 725
ET (mm yr^{-1})	791, 983, 927	927 … 1011	637 … 886
LAI (m^2 m^{-2})	2.5	4.5	
GEP:LAI	~565-611	~577	Variable from year to year

Assessing transition thresholds at ARNWR

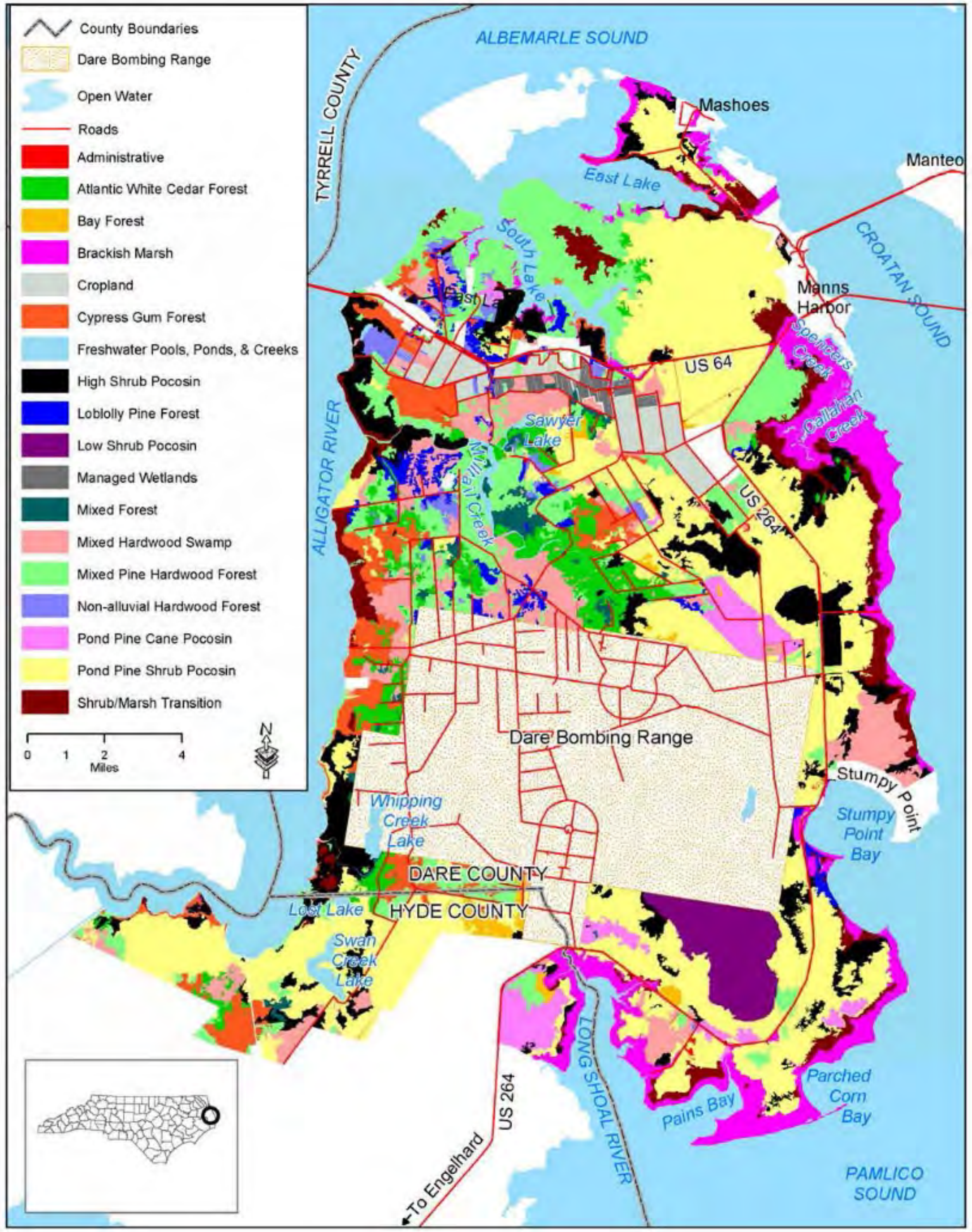
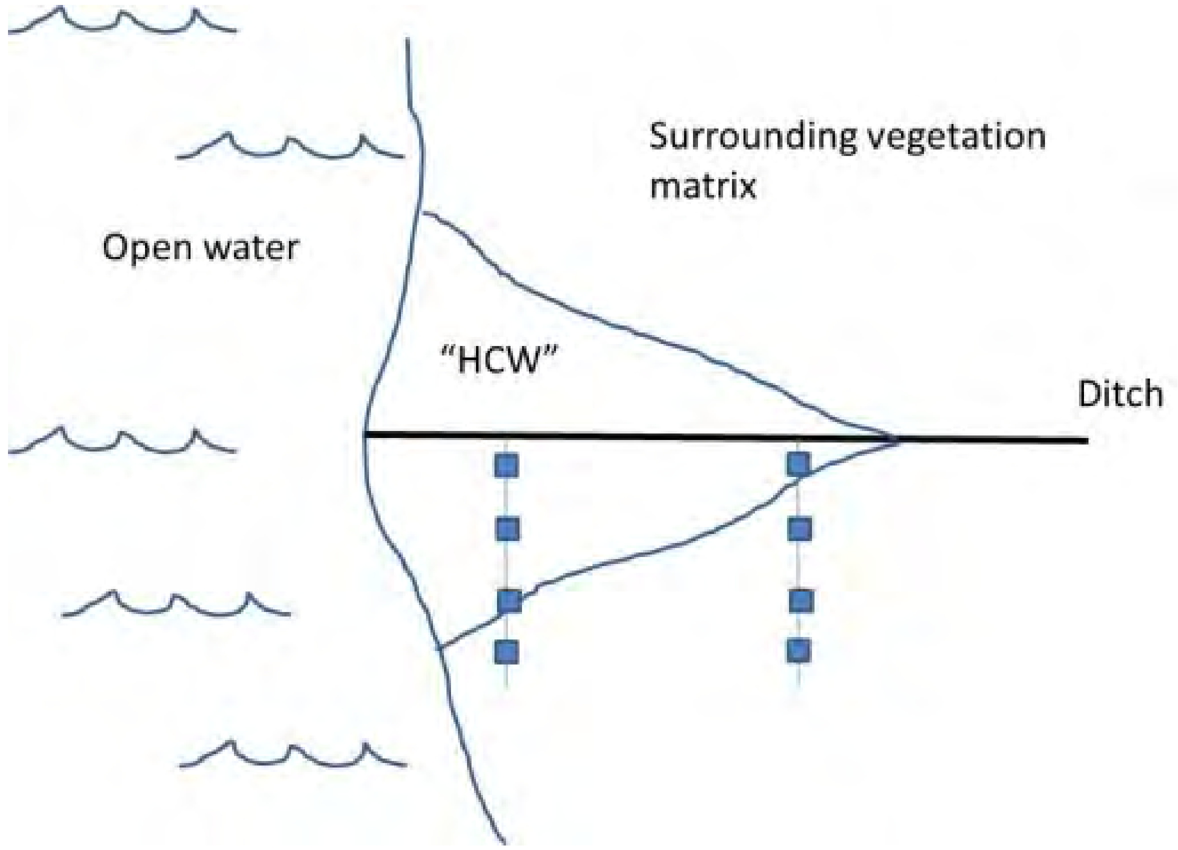


Table 2. Major ecosystem types to be monitored at the ARNWR Climate Change Observatory Ecosystem Transition transects.

Ecosystem	Dominant species	Location	Soils	Environment
Brackish marsh	*Juncus roemerianus* *Spartina patens* *Phragmites australis*	Shoreline	Anaerobic muck	Brackish Saline
Freshwater marsh	*Typha sp.*	Very near shore	Organic muck	Freshwater
Low shrub pocosin	*Ilex glabra* *Lyonia lucida* *Cyrrila racemiflora*	Near shore	Organic muck	Freshwater
Pond Pine pocosin	*Pinus serotina* *Magnolia virginiana* *Persea borbonia*	Near shore	Organic muck or histic-mineral	Freshwater
Mixed pine-hardwoods	*Pinus taeda* *Quercus rubra* *Liquidambar styraciflua*	Interior	Mineral or histic-mineral	Freshwater
Forested wetland	*Taxodium* sp. *Nyssa* sp. *Acer rubrum*	Interior (flux tower) Riparian	Organic muck	Freshwater

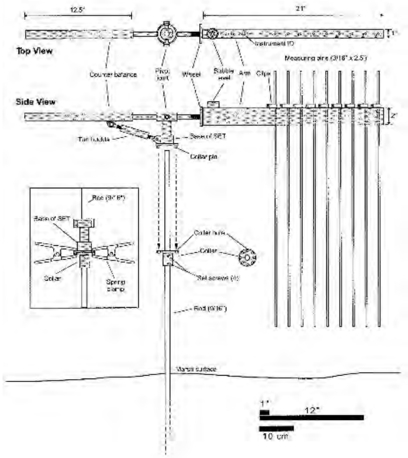
Habitat change wedge (a la Dennis Stewart)



Determine thresholds of hydroperiod and salinity leading to ecosystem transition

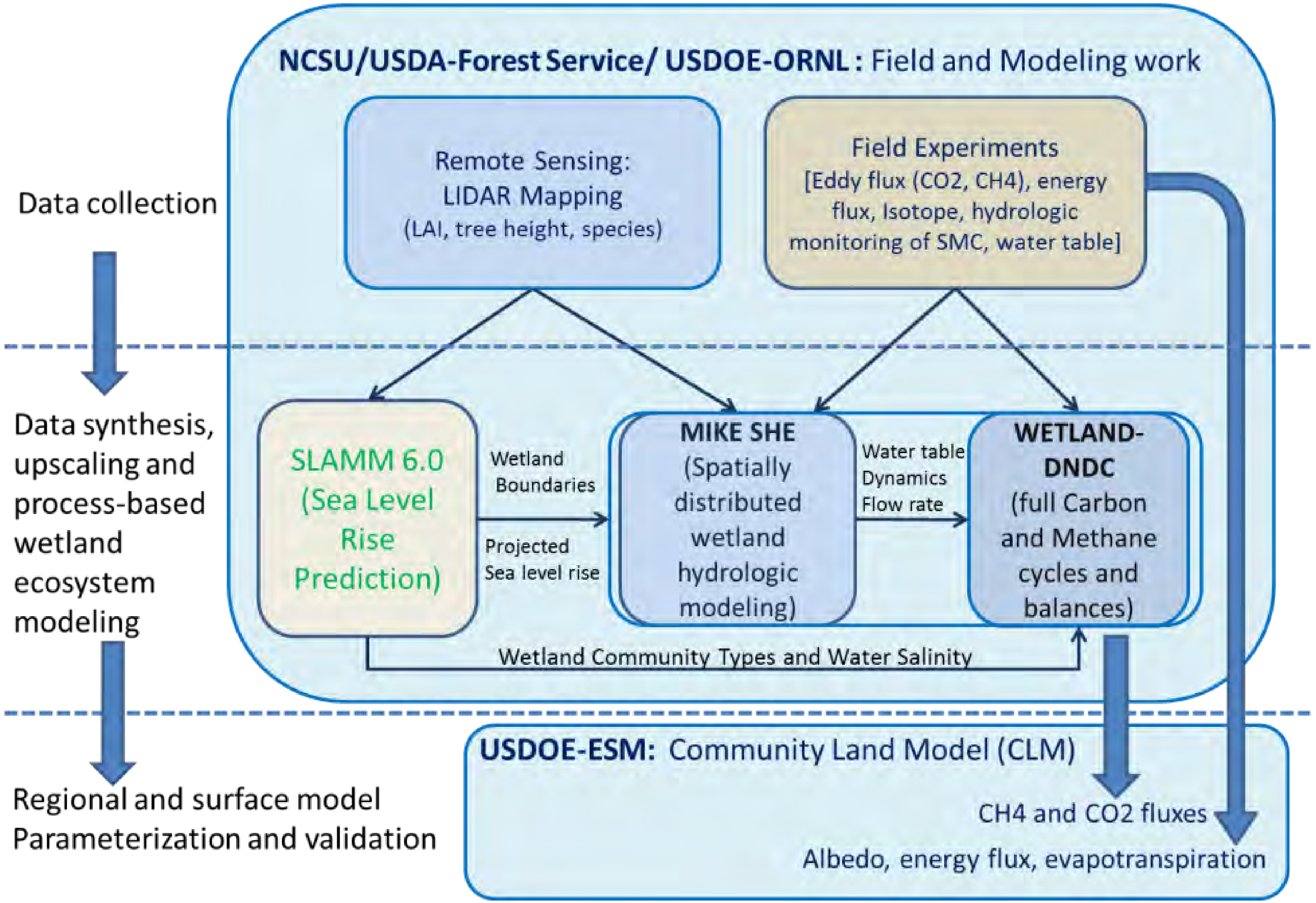
Measurements

- Species composition
- Above- and belowground plant biomass and C
- Physiological performance: photosynthesis, stomatal conductance, transpiration, chlorophyll flourescence
- Soil organic carbon content, density fractionation, isotopic signature
- Ground water table dynamics
- Soil water content and salinity
- Marsh soil accretion/loss



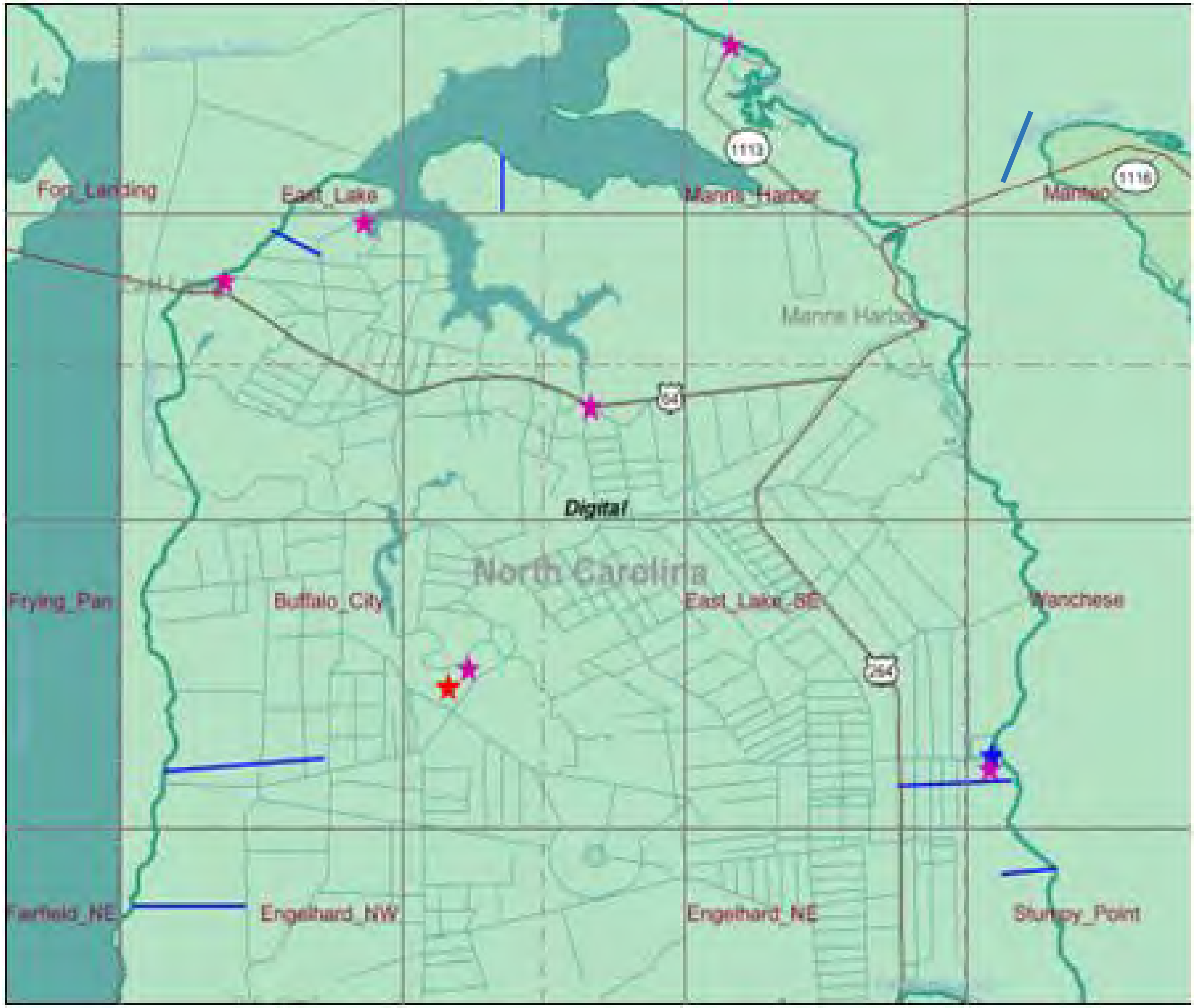
The Future

- Incorporate fire?
- Ecosystem to landscape scale model development and linkage
- Expansion of eddy covariance studies across the Refuge
- Team building and collaboration
- Public interface



NCSU/USDA-Forest Service/ USDOE-ORNL : Field and Modeling work
Data collection
Remote Sensing: LIDAR Mapping (LAI, tree height, species)
Field Experiments [Eddy flux (CO2, CH4), energy flux, Isotope, hydrologic monitoring of SMC, water table]
Data synthesis, upscaling and process-based wetland ecosystem modeling
SLAMM 6.0 (Sea Level Rise Prediction)
Wetland Boundaries
Projected Sea level rise
MIKE SHE (Spatially distributed wetland hydrologic modeling)
Water table Dynamics Flow rate
WETLAND-DNDC (full Carbon and Methane cycles and balances)
Wetland Community Types and Water Salinity
Regional and surface model Parameterization and validation
USDOE-ESM: Community Land Model (CLM)
CH4 and CO2 fluxes
Albedo, energy flux, evapotranspiration

Public outreach



*Workshop at ARNWR HQ

-Present summary of scientific understanding of climate change and SLR

-Describe research projects at ARNWR and elsewhere

*Climate change driving tour at Refuge

-Visit ecosystem transition sites

-Posters/photos of before and after

*Open discussion and solicitation of perspectives from public

Acknowledgements

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