LiDAR for Wetland Mapping

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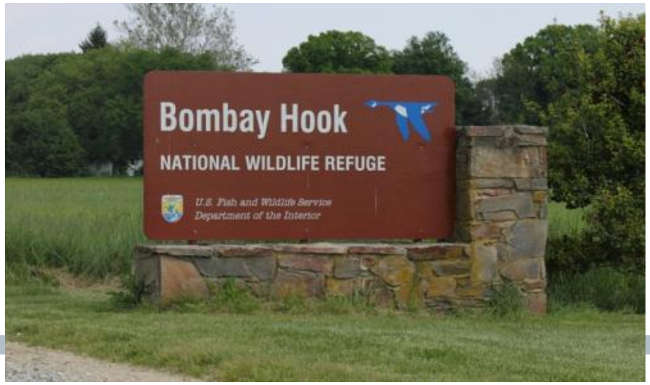
Case Study – LiDAR for wetland mapping?

- What information do LiDAR data provide to delineate wetland vegetation communities?
- Do LiDAR waveforms provide any additional information that can be useful in wetland vegetation classification?
- Can we determine invasive species such as "*Phragmites*" by fusing LiDAR and multispectral imagery?

Study Area – Bombay Hook National Wildlife Refuge



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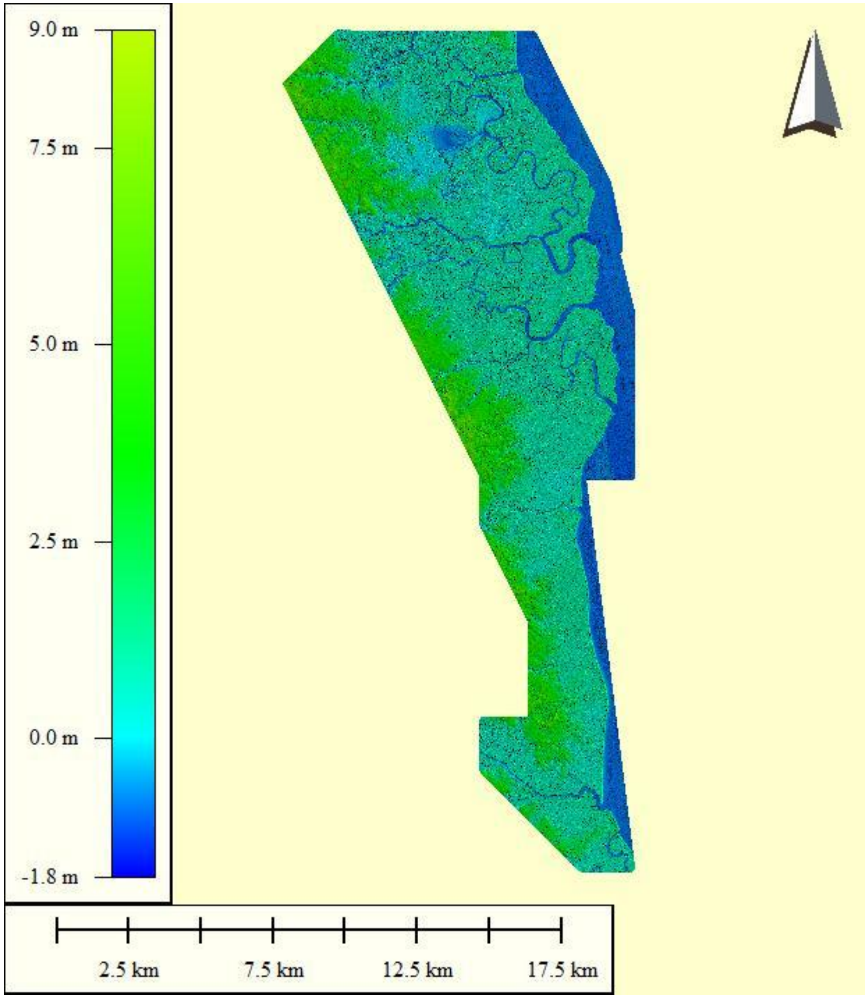
Discrete-return LiDAR data



- LiDAR survey conducted April 18 – 20, 2011 using Optech ALTM 3100 EA system

- NOAA CSC and Delaware Department of Natural Resources and Environmental Control

- Horizontal Datum: NAD83 (NSRS2007)
- Vertical Datum: NAVD88 (GEOID09)
- Coordinate System: Delaware State Plane

- Units: meters (Horizontal and Vertical)

- Accuracy: $RMSE_z$ = 0.07 m (FVA: 0.14m; CVA:0.11m)
- Resolution: NPS = 0.75 m

- All data collection shall be within a time window of tidal conditions at or below +0.50 ft MLLW

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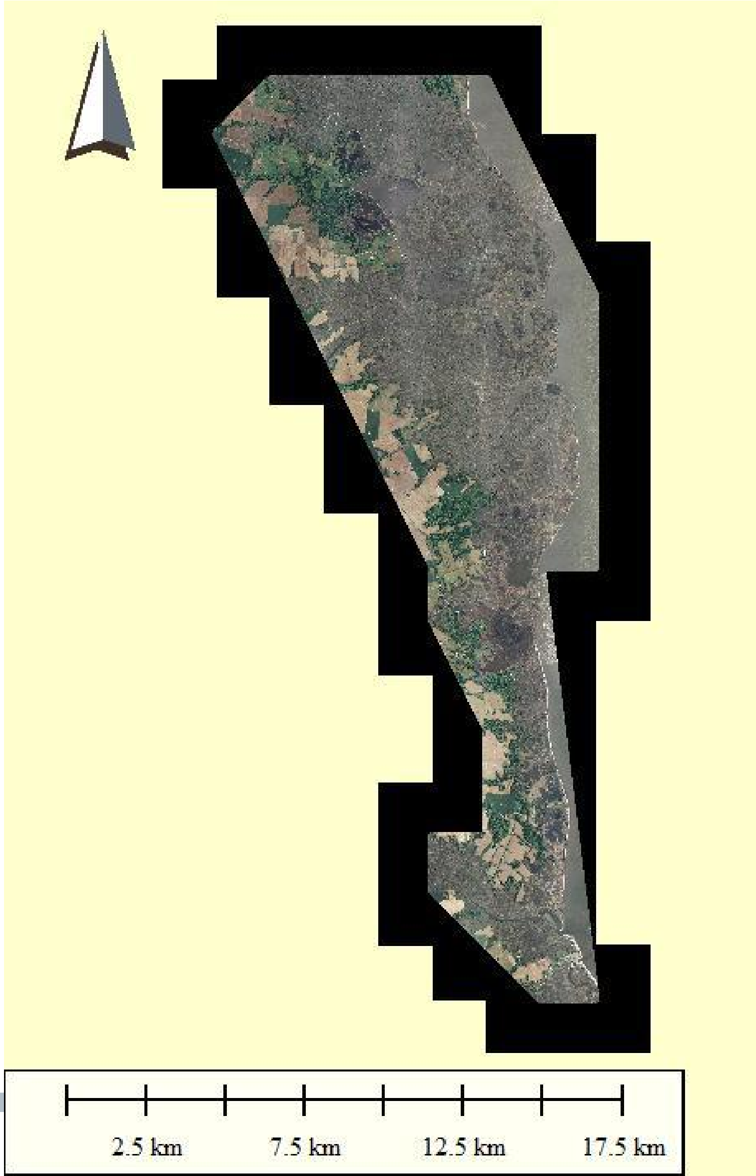
Multispectral Data



- Orthophoto survey conducted May 7, 2011
- 4 – band imagery (R,G,B, NIR)

- NOAA CSC and Delaware Department of Natural Resources and Environmental Control

- Horizontal Datum: NAD83 (NSRS2007)
- Vertical Datum: NAVD88 (GEOID09)
- Coordinate System: Delaware State Plane
- Units: meters

- $RMSE_r$ = 0.223 m
- Horizontal $Accuracy_r$ = 0.387 m (requirement: 2m)

- Resolution: 25 cm

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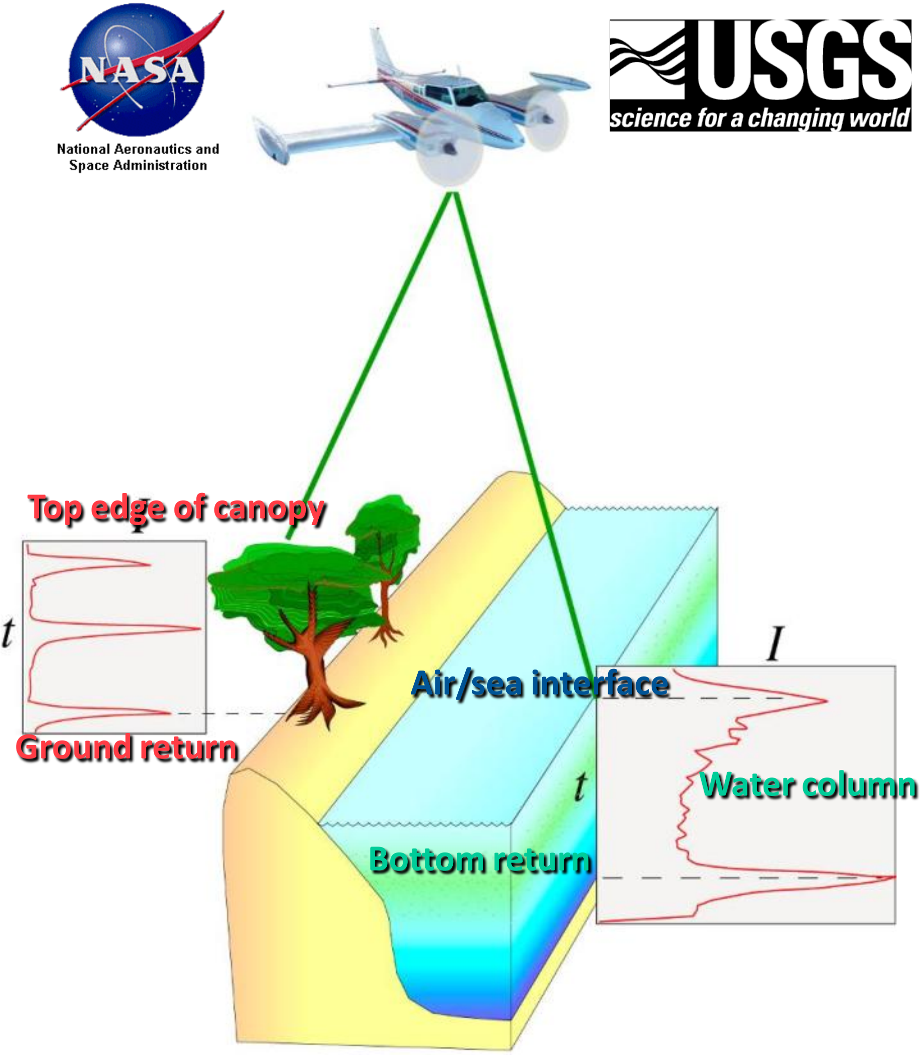
Green-waveform LiDAR data



- Acquired by NASA (now USGS) Experimental Advanced Airborne Research LiDAR (EAARL)
- Acquisition dates: February – April, 2004
- Granted access to “raw” data by USGS
- EAARL is a topo-bathy green-only LiDAR
- Uses a very short laser pulse (1.6 ns FWHM)

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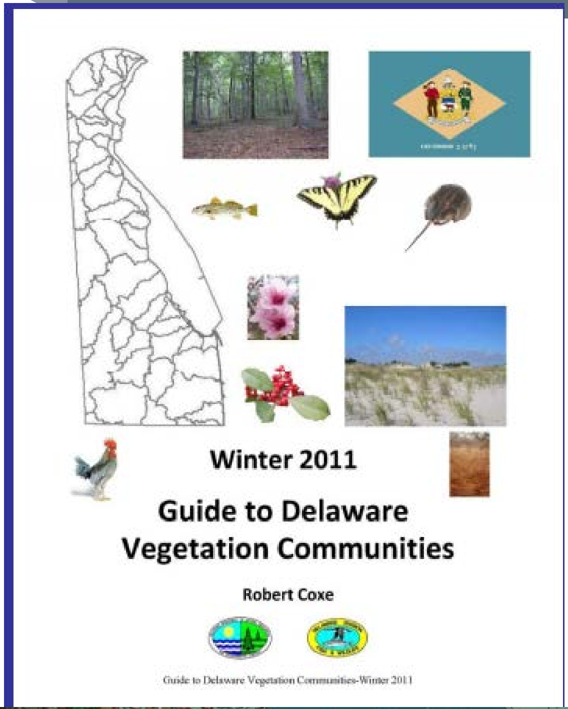
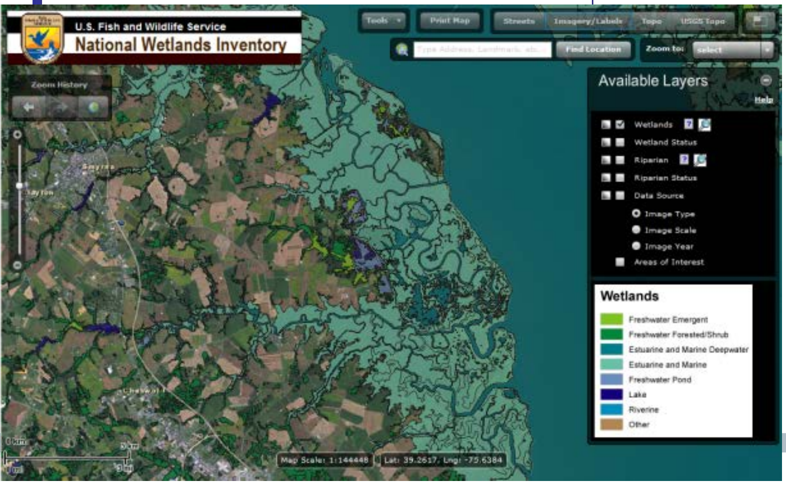
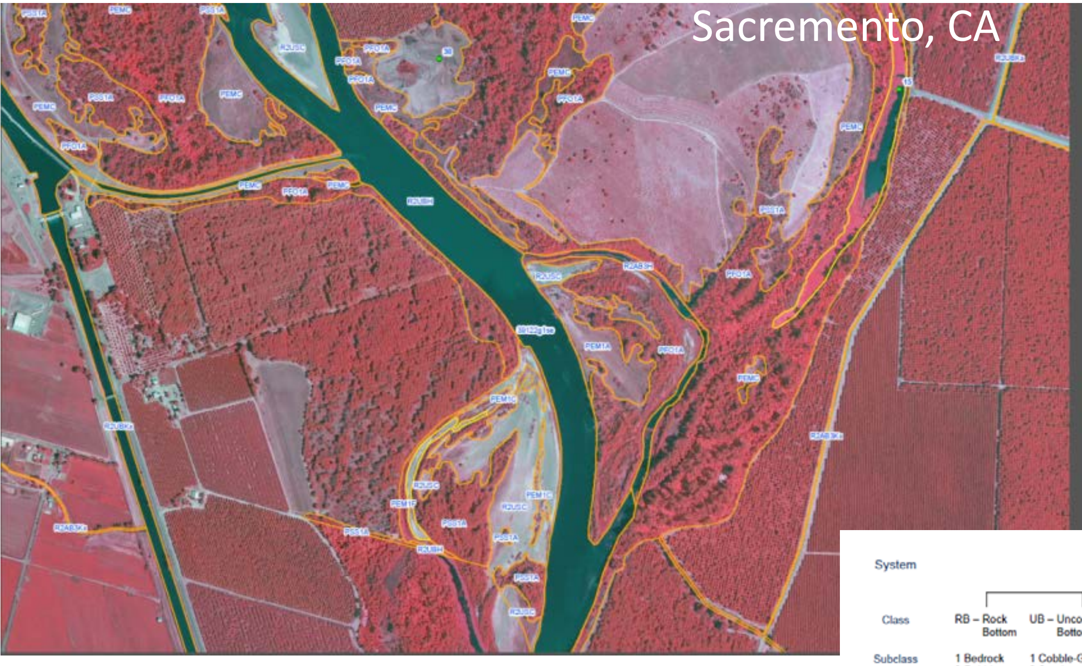
Ancillary Data





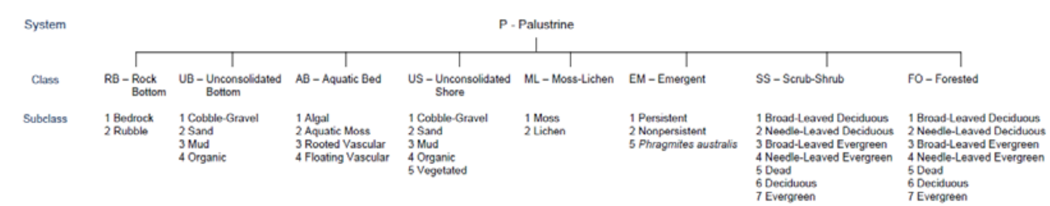
- USGS – National Vegetation Classification System (NVCS) statewide classification map (courtesy Robert Coxe – Ecologist at Delaware Natural Heritage and Endangered Species Program)
- Based on 2002 ortho imagery
- National Wetlands Inventory (available online)

Motivation



Do LiDAR data provide more information to help in Photo Interpretation

Dewberry's natural resource scientists provide wetland delineation, mitigation planning, water resources services to many state and federal clients

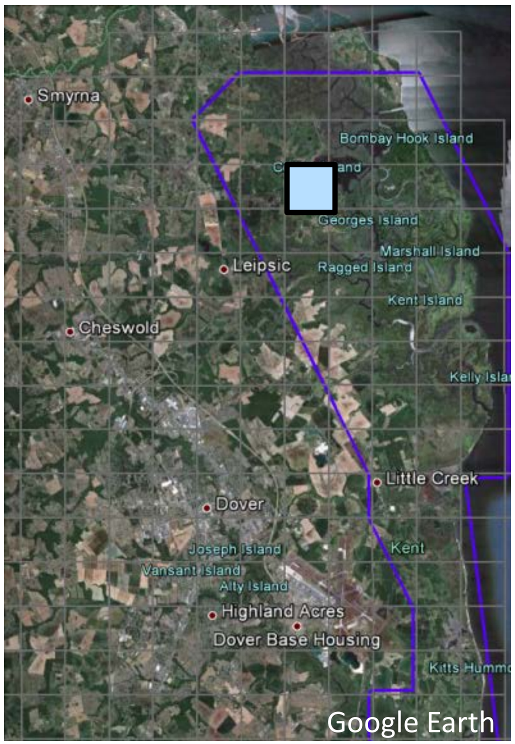


MODIFIERS

In order to more adequately describe the wetland and deepwater habitats, one or more of the water regime, water chemistry, soil, or special modifiers may be applied at the class or lower level in the hierarchy. The farmed modifier may also be applied to the ecological system.

Water Regime			Special Modifiers	Water Chemistry			Soil
Nontidal	**Saltwater Tidal**	**Freshwater Tidal**		**Coastal Halinity**	**Inland Salinity**	**pH Modifiers for all Fresh Water**	
A Temporarily Flooded	L Subtidal	S Temporarily Flooded-Tidal	b Beaver	1 Hyperhaline	7 Hypersaline	a Acid	g Organic
B Saturated	M Irregularly Exposed	R Seasonally Flooded-Tidal	d Partly Drained/Ditched	2 Euhaline	8 Eusaline	t Circumneutral	n Mineral
C Seasonally Flooded	N Regularly Flooded	T Semipermanently Flooded-Tidal	f Farmed	3 Mixohaline (Brackish)	9 Mixosaline	l Alkaline	
E Seasonally Flooded/ Saturated	P Irregularly Flooded	V Permanently Flooded-Tidal	h Diked/Impounded	4 Polyhaline	0 Fresh		
F Semipermanently Flooded			r Artificial	5 Mesohaline			
G Intermittently Exposed			s Spoil	6 Oligohaline			
H Permanently Flooded			x Excavated	0 Fresh			
J Intermittently Flooded							
K Artificially Flooded							

Focus Area 1 – Bombay Hook National Wildlife Refuge



Estuarine and Marine Deepwater

Estuarine and Marine Wetland

Freshwater Emergent Wetland

Freshwater Forested/Shrub Wetland

Freshwater Pond

Lake

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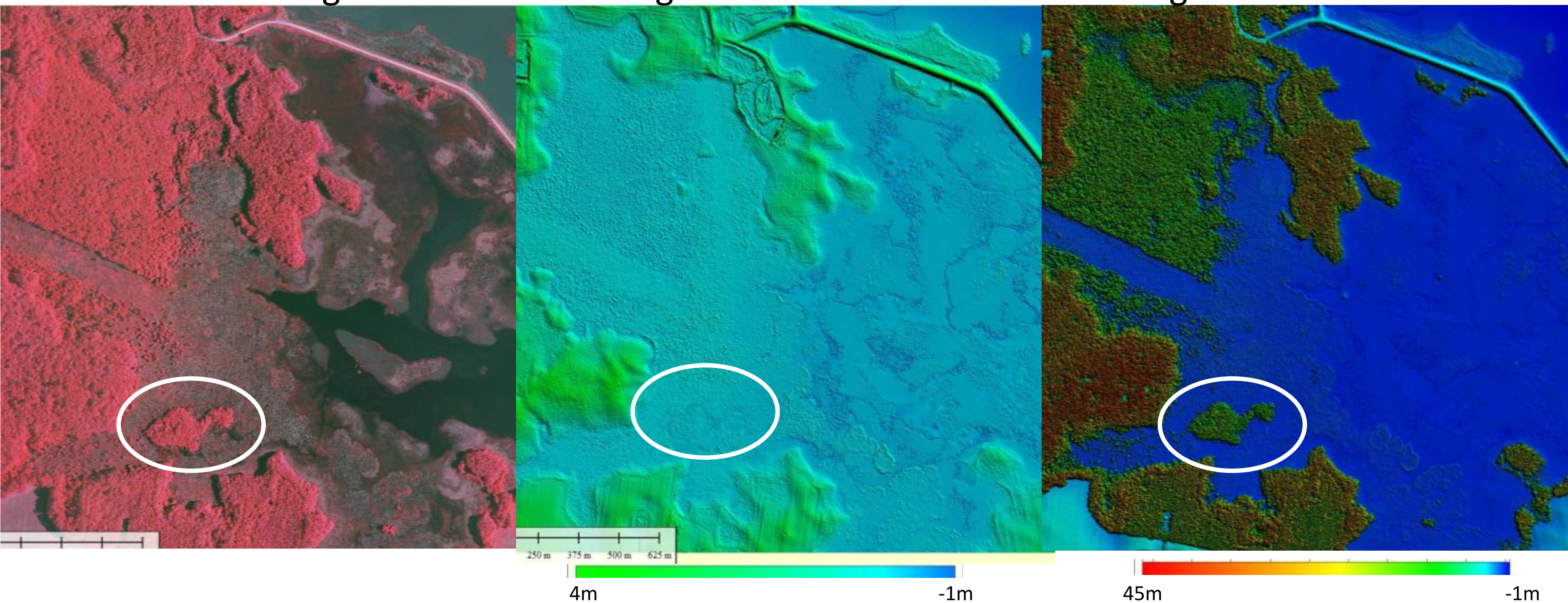
Using DEM and DSM for Wetland classification

CIR Image | Digital Elevation Model | Digital Surface Model



- From an NWI perspective, DEMs can help differentiate between Wetland and Upland Forest.
- Canopy Height or DSM is a always a useful metric for vegetation classification

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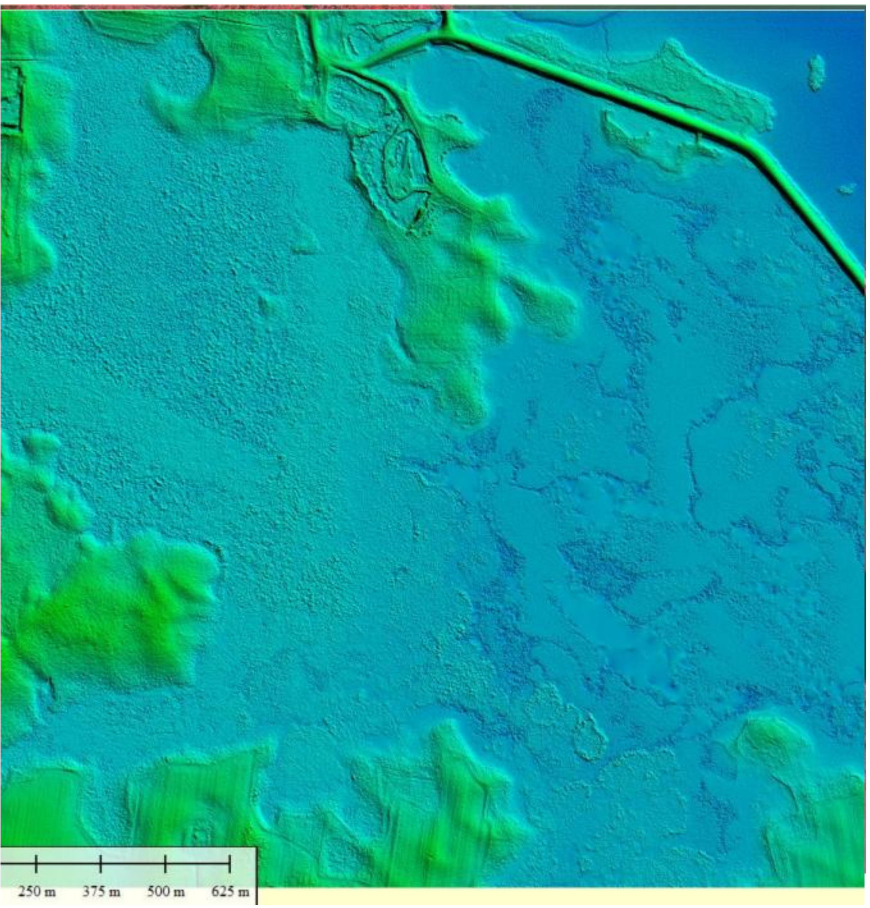
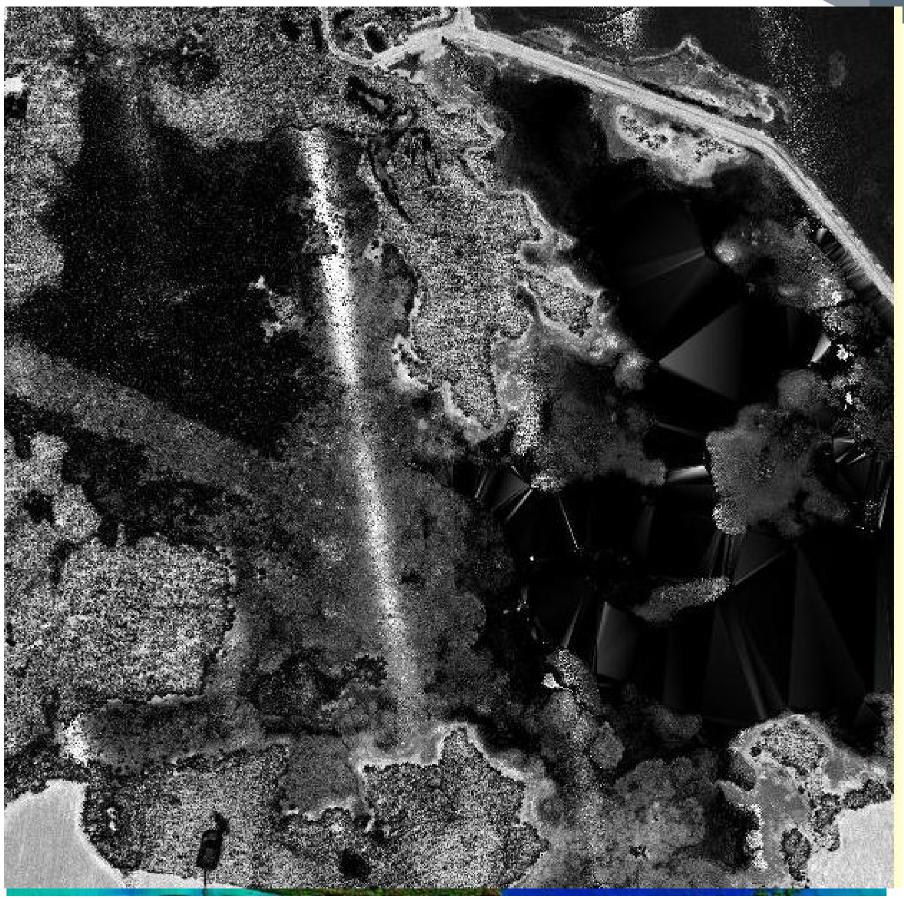
Using LiDAR Intensity Images for wetland classification



Bare-Earth DEM



Bare-Earth Intensity Image

LiDAR for wetland mapping?

- What information do LiDAR data provide to delineate wetland vegetation communities?
- Do LiDAR waveforms provide any additional information that can be useful in wetland vegetation classification?
- Can we determine invasive species such as "*Phragmites*" by fusing LiDAR and multispectral imagery?

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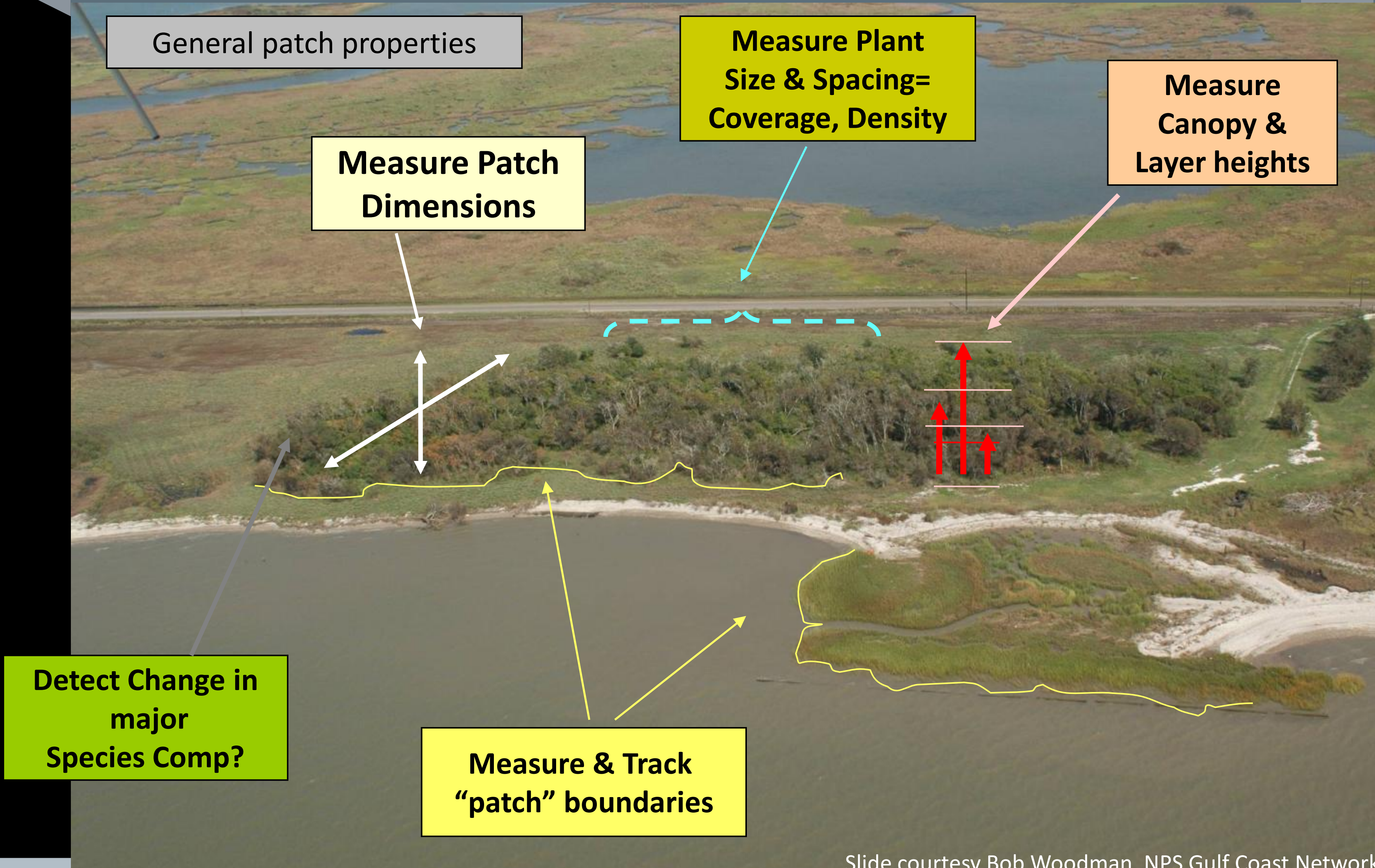
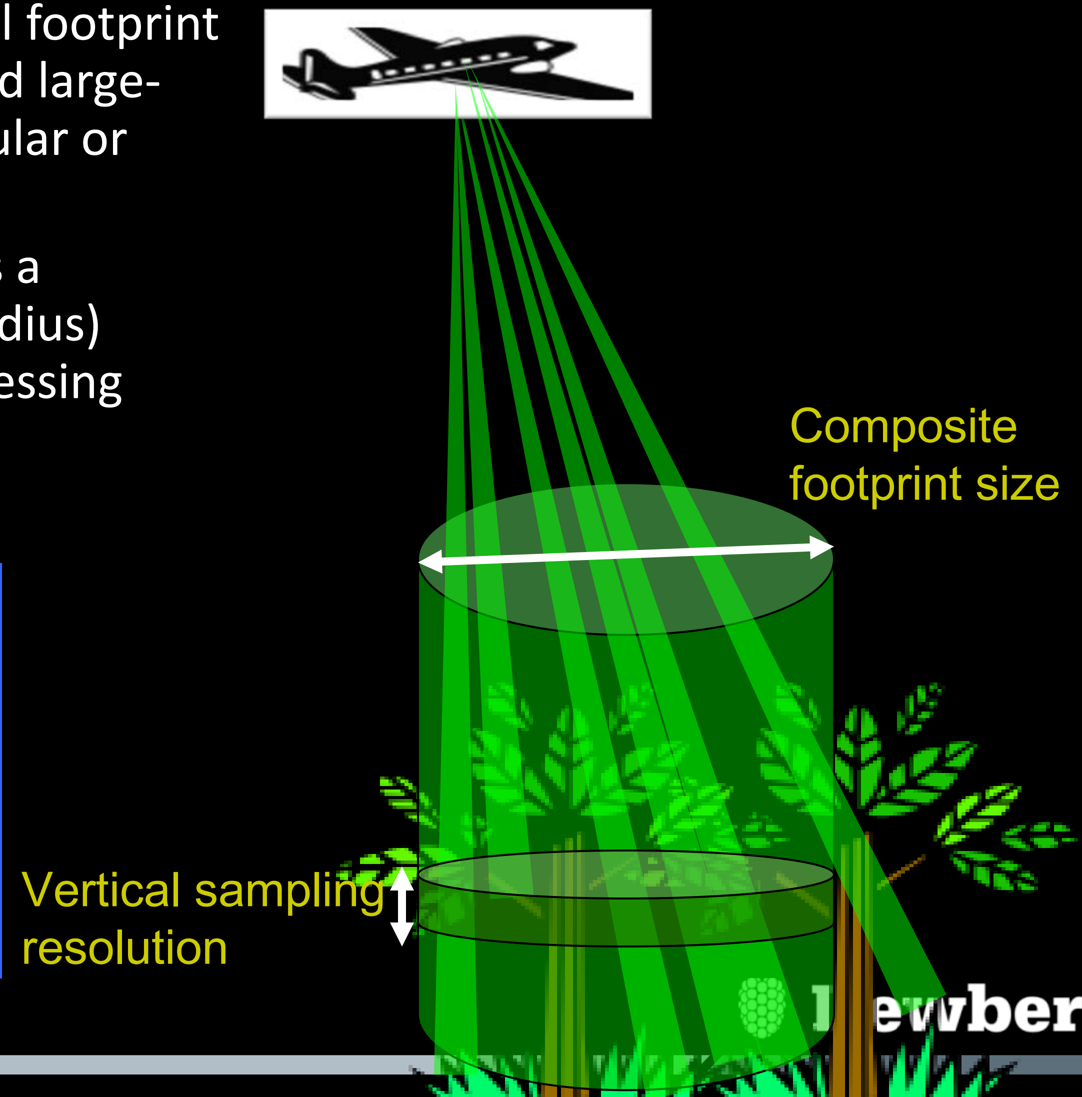
Background: Waveform Lidar can measure these attributes…



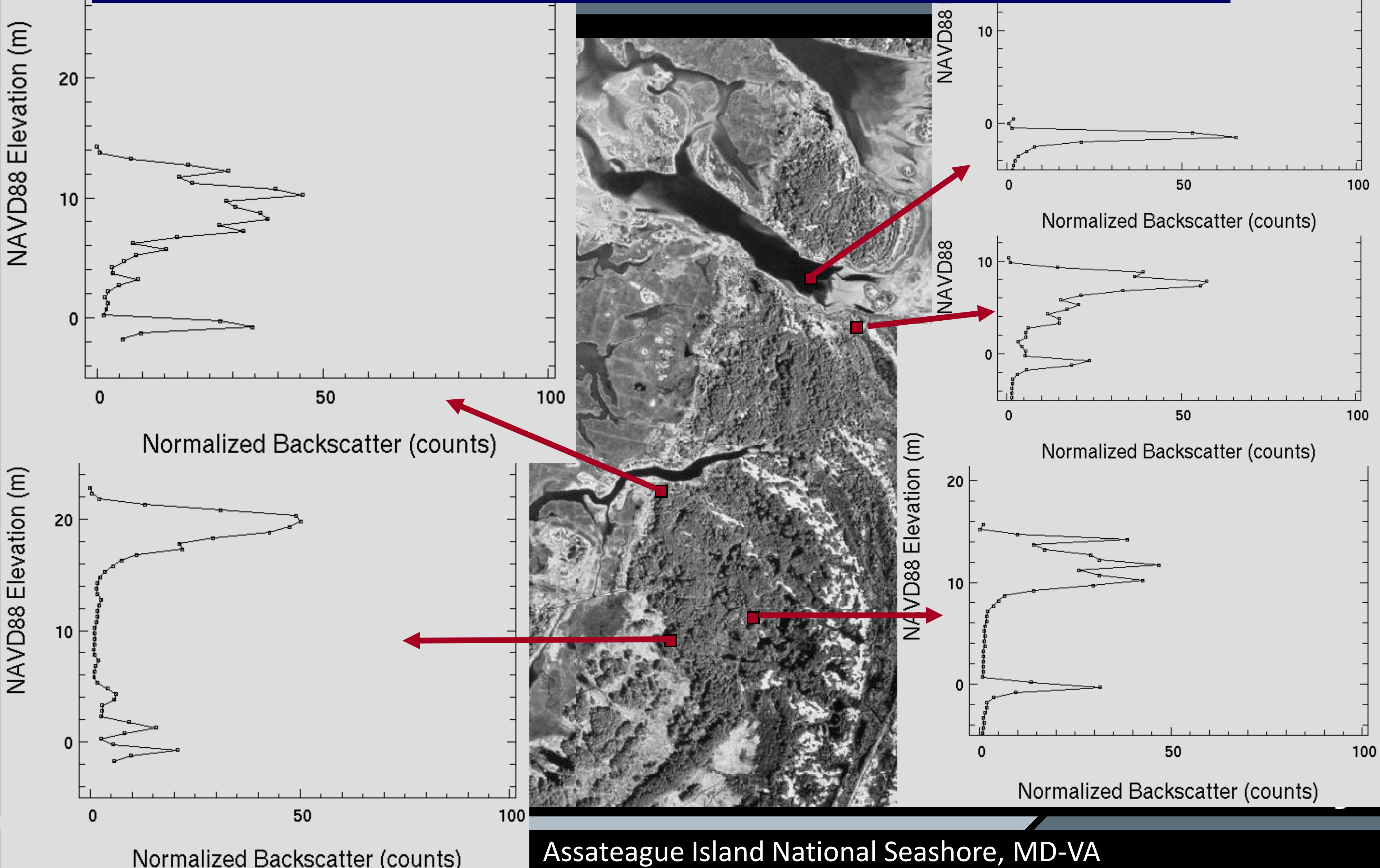
Background: Technique to derive vegetation canopy characteristics using small-footprint waveform lidar

- Integrating individual small footprint waveforms to a synthesized large-footprint within a rectangular or circular cone
- Composite footprint size is a variable (5x5 m or 10 m radius) defined in post-flight processing software



From: Nayegandhi, A., Brock, J.C., Wright, C.W., Oconnell, M.O., 2006. Evaluating a small-footprint, waveform-resolving lidar over coastal vegetation communities. Photogrammetric Engineering and Remote Sensing 2006-12:1408-1417.

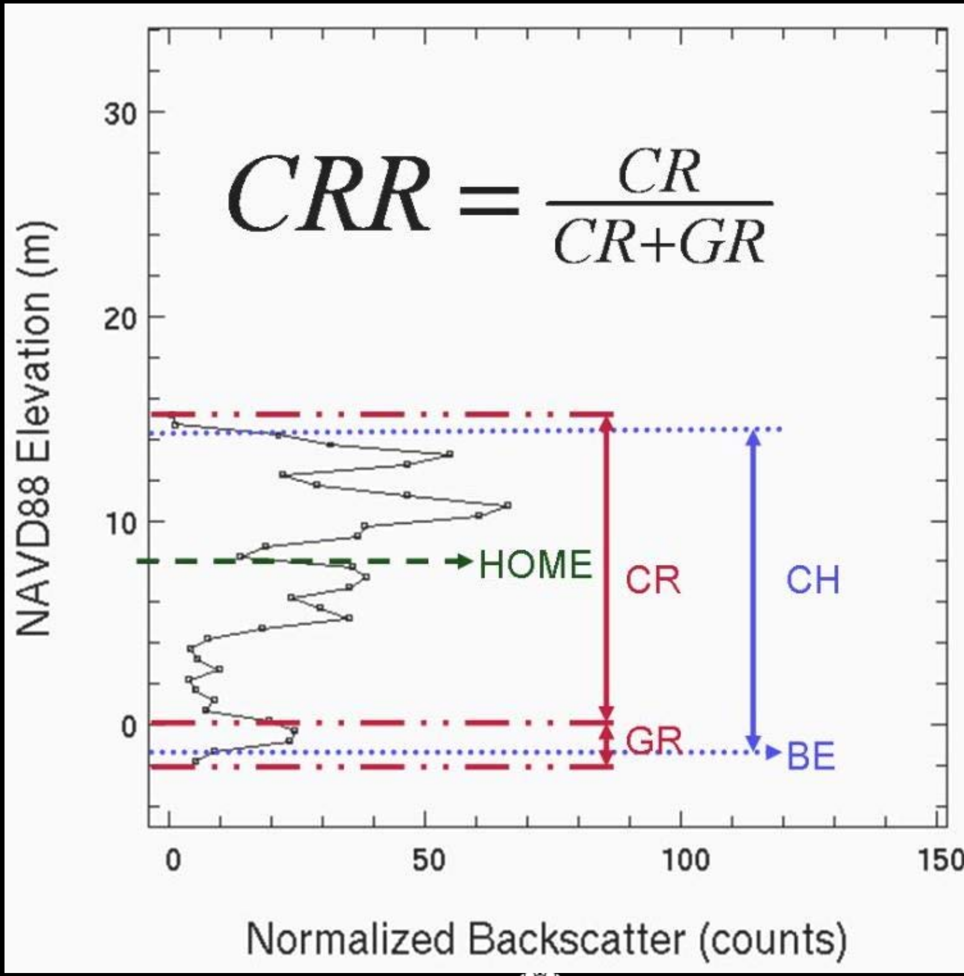
Example Composite Waveforms from the EAARL system in vegetated environments



Assateague Island National Seashore, MD-VA

Vegetation metrics derived from waveform LiDAR

- **BE** = Bare Earth - is derived from individual small footprints;
- **CH** = Canopy heights - is the distance from the first return to the ground
- **CRR** = Relative Canopy Cover - is the sum of the waveform returns reflected off the canopy (CR) divided by the sum of all returns (CR and the ground GR). CRR is a relative measure of canopy closure.
- **HOME** = The height of median energy - is the median height of the entire signal. HOME is predicted to be sensitive to changes in both the vertical arrangements of the canopy and the degree of canopy openness. HOME has been found to be a good predictor of biomass and structural attributes in tropical forests (Drake et. al 2002).

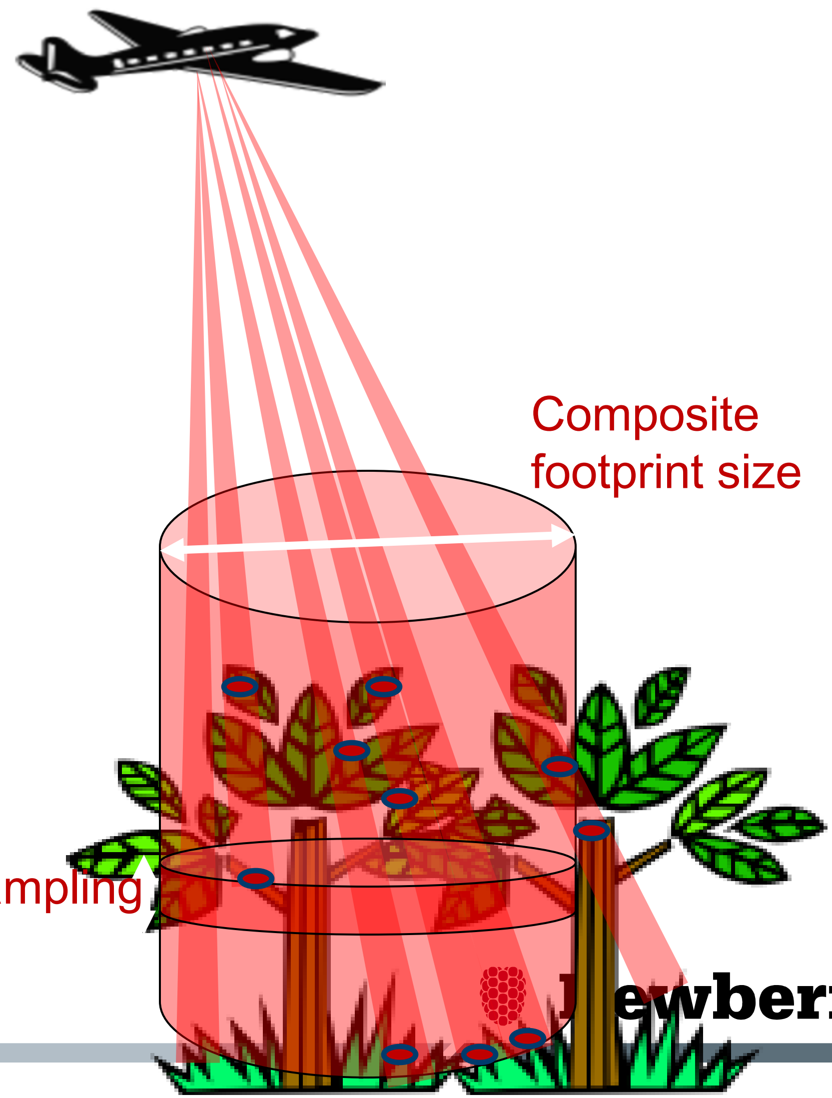


Creating Pseudo Waveforms from discrete return data

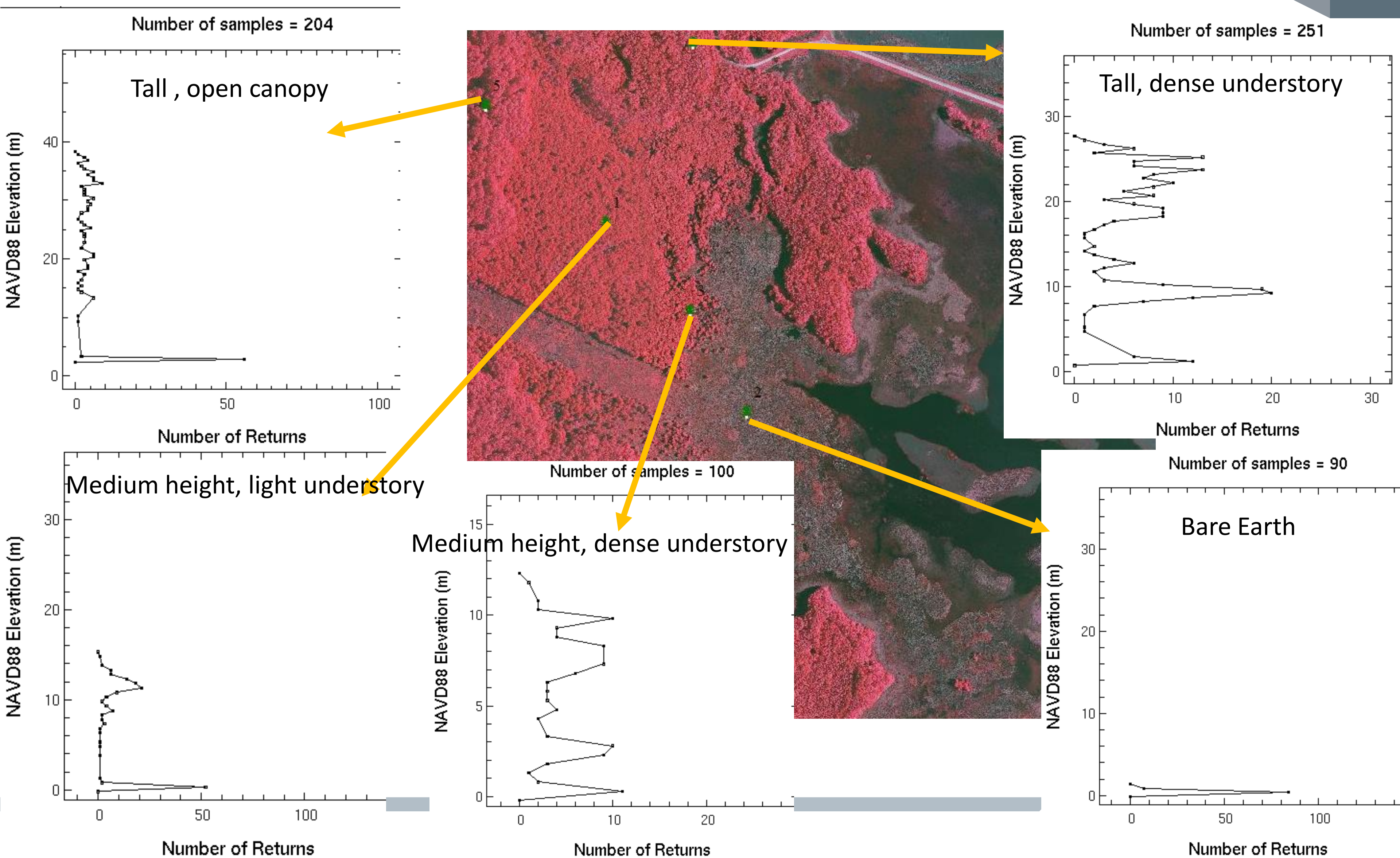
- All waveforms within each composite footprint were collected and binned based on height above ground (50 cm vertical sampling resolution)

- Each vertical bin was assigned a value based on:

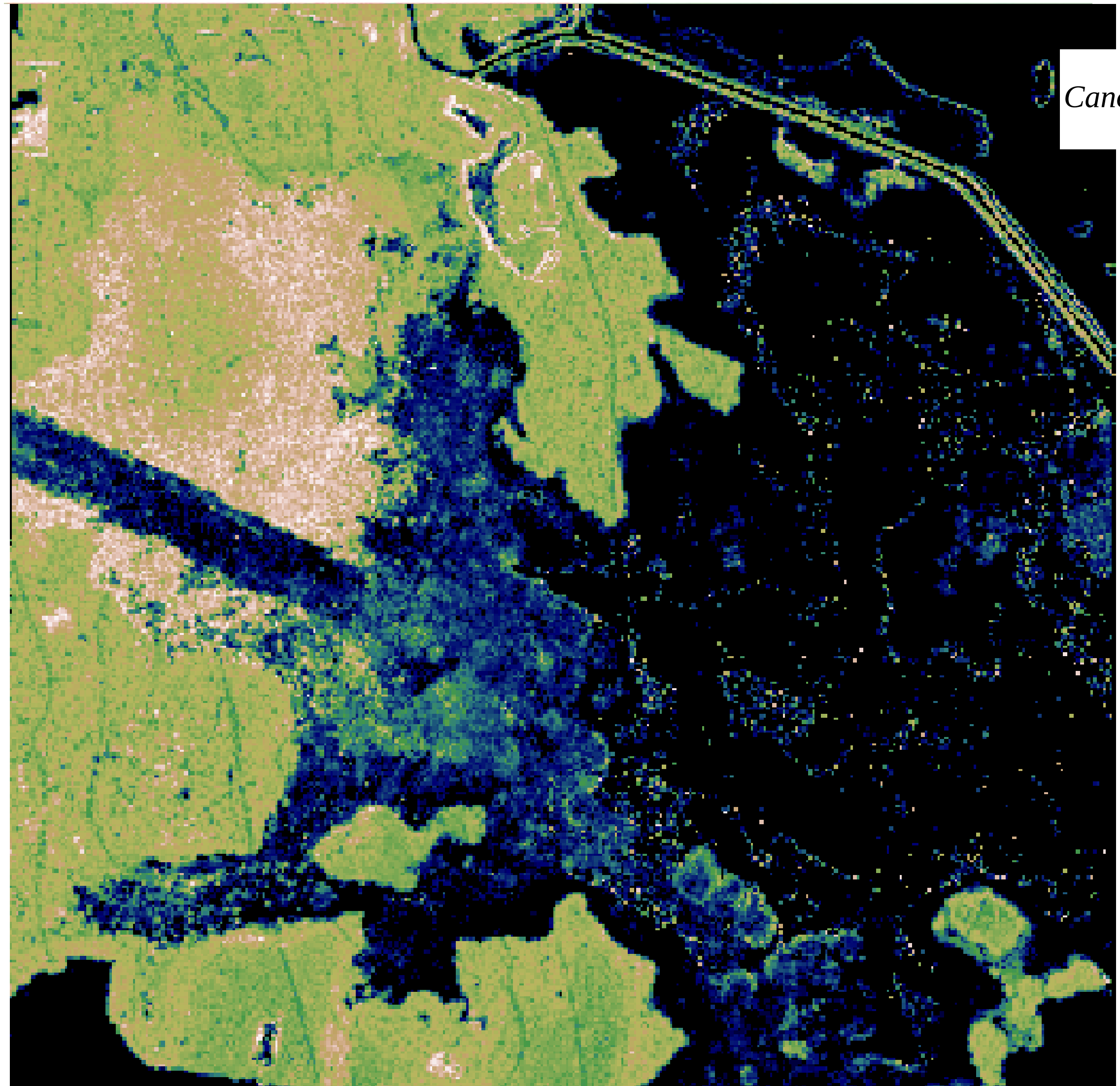
  Total number of returns in the bin
  (height frequency distribution)
  for Frequency Wave (FW)



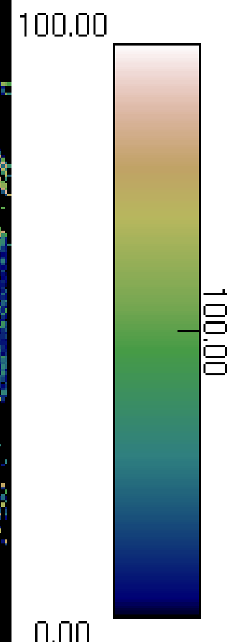
Pseudo composite waveforms –Frequency Wave (FW)



Canopy Cover estimate: “Frequency Wave” Composite



$$CanopyCover = \frac{\sum NumberOf\ ReturnsAboveGroud}{\sum NumberOf\ ReturnsInCompositeFootprint}$$



Canopy Cover
(Number of Returns)

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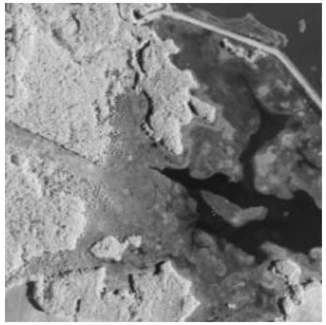
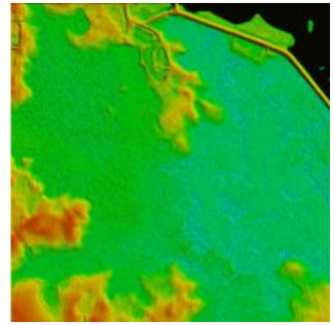
Using LiDAR and multispectral imagery for classifying wetland communities

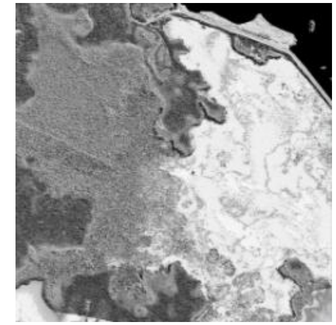
RGB (3 bands)



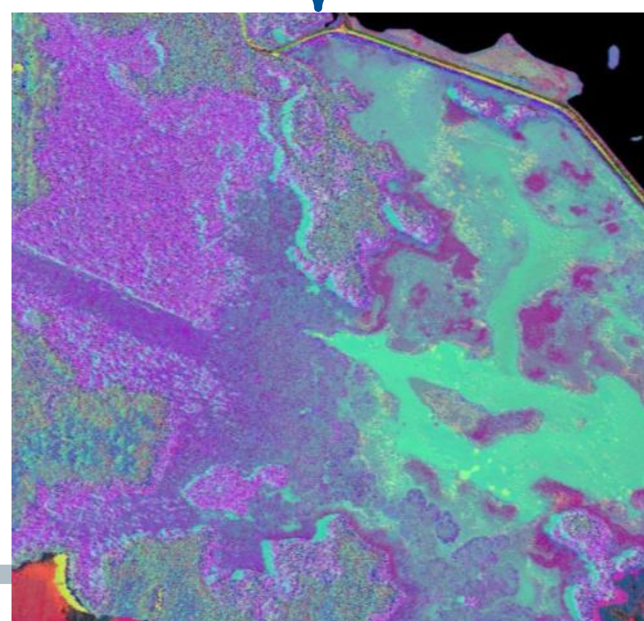
NIR (1 band)



DEM (stretched)



Canopy Height (stretched)



- Principle Component Analysis
- (3 bands)

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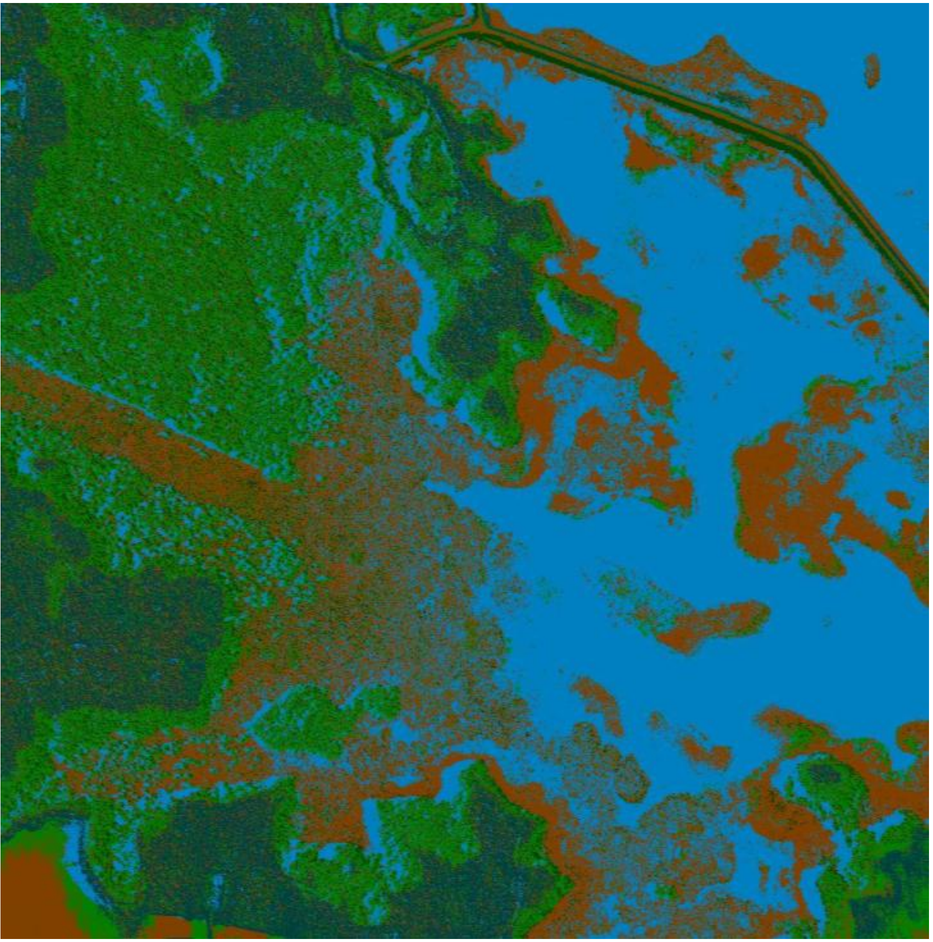
Unsupervised Classification (isodata)



LiDAR – Multispectral
“fused” classification

CIR Image

5 classes

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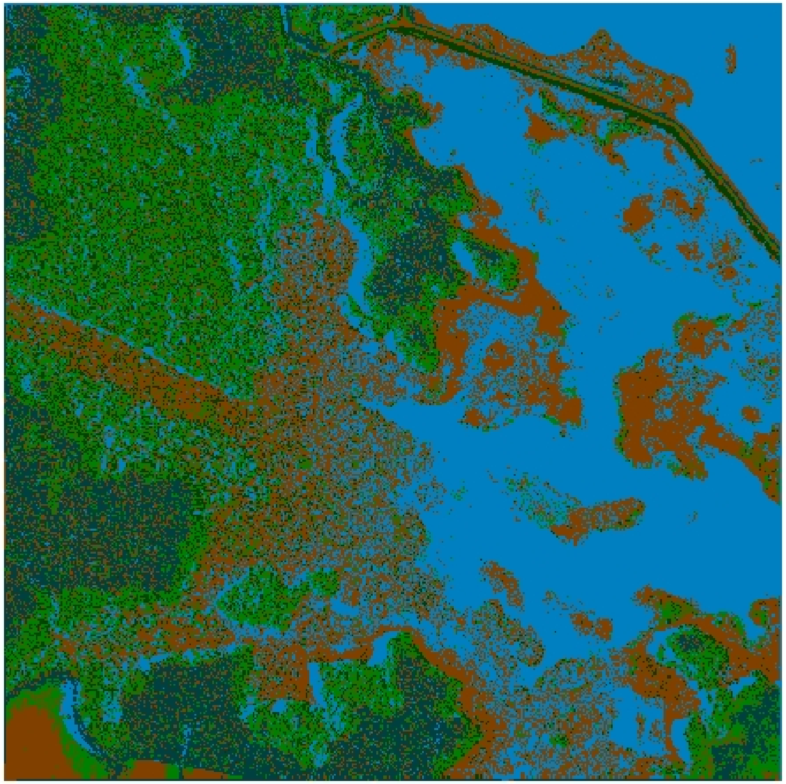
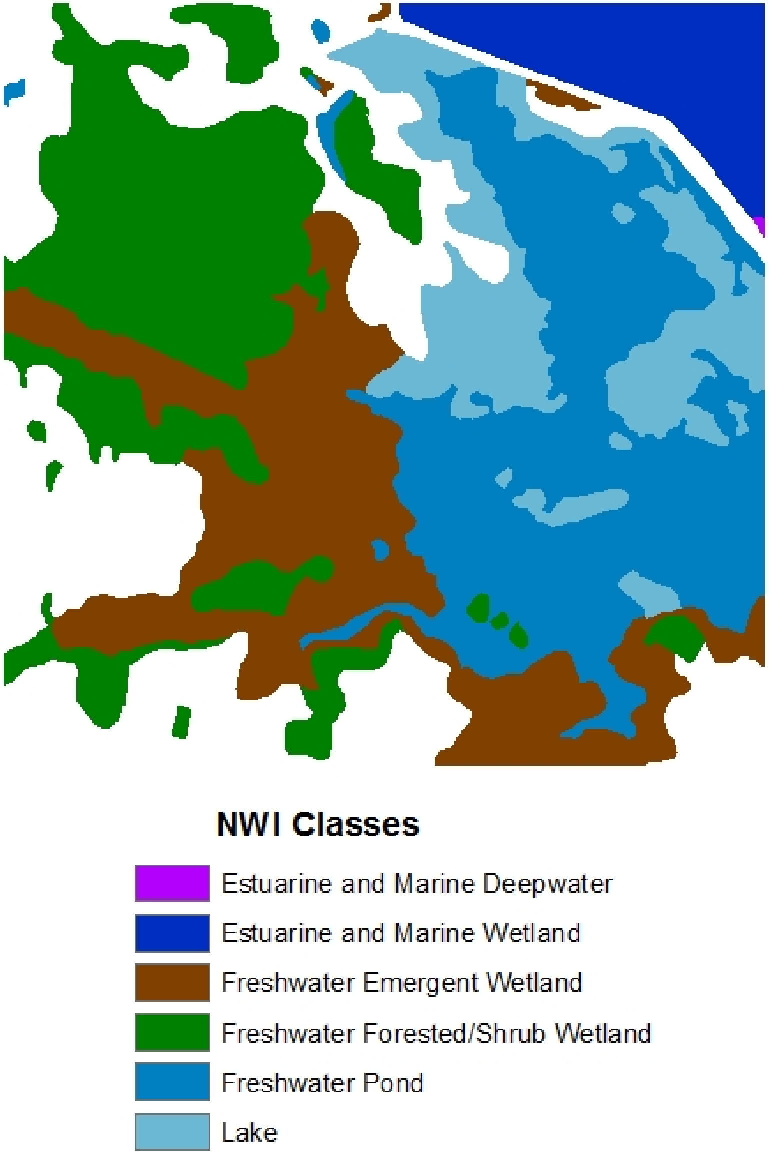
Unsupervised Classification



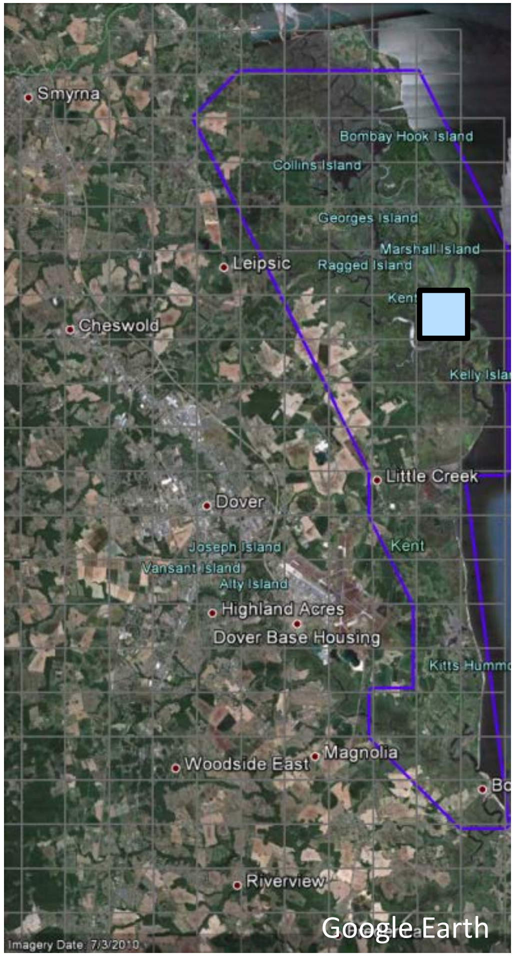
LiDAR – Multispectral
“fused” classification

5 classes

National Wetland Inventory Classification



Focus Area 2 – Bombay Hook National Wildlife Refuge



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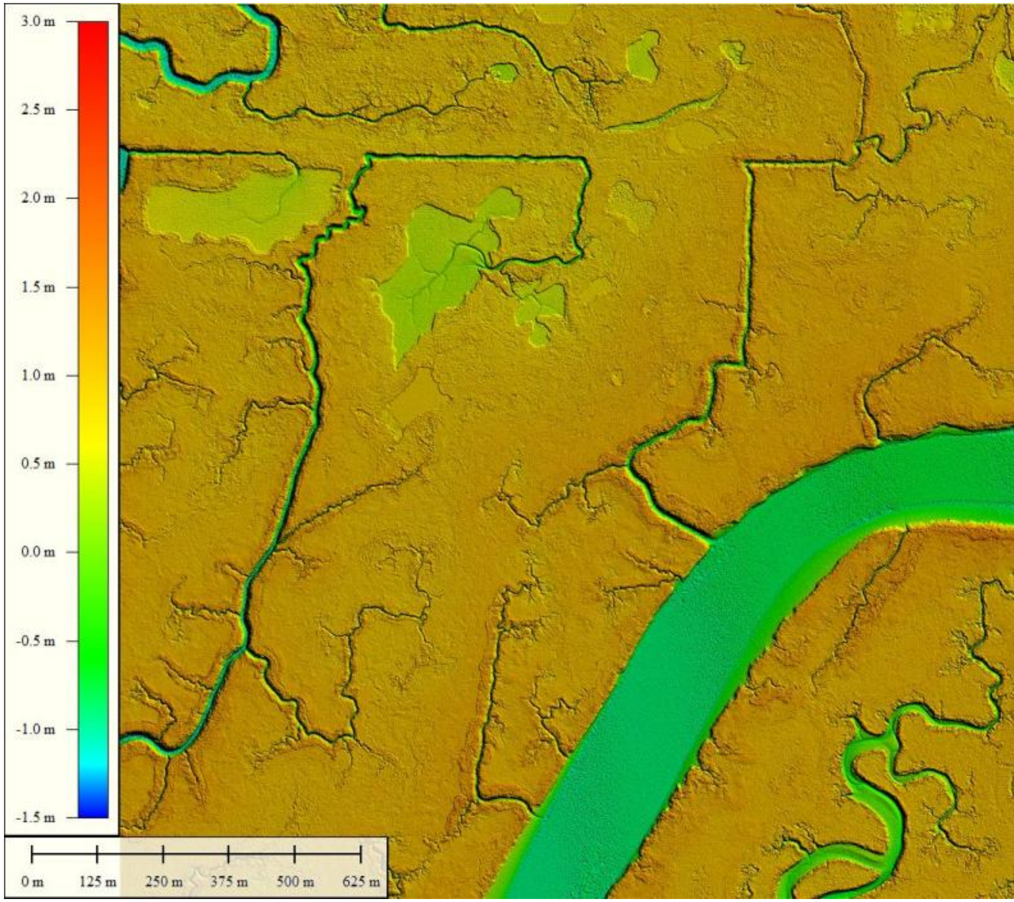
Area 2 – Exotic Vegetation (*Phragmites Australis*)

- *Phragmites* invasions may threaten wildlife because they alter the structure and function (wildlife support) of relatively diverse *Spartina* marshes. This is a problem on many of the eastern coastal National Fish and Wildlife Refuges.

Can we identify *Phragmites* from CIR imagery and discrete-return data?

CIR Imagery



DSM (LiDAR)

- Identifying Phragmites

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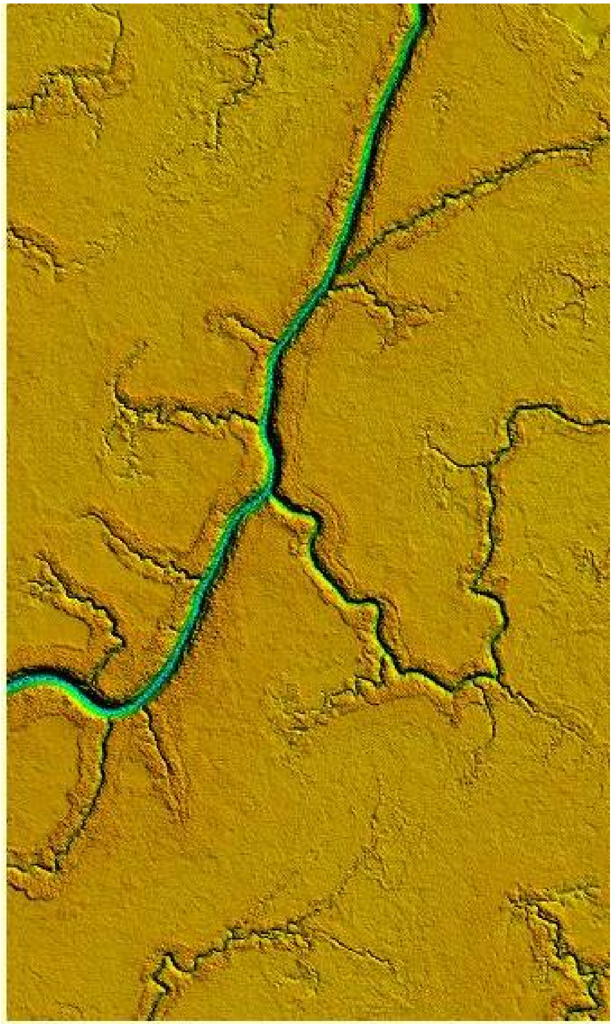
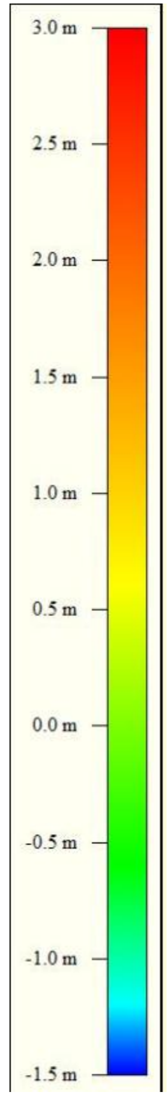
Can we detect *Phragmites* from EAARL waveform data?

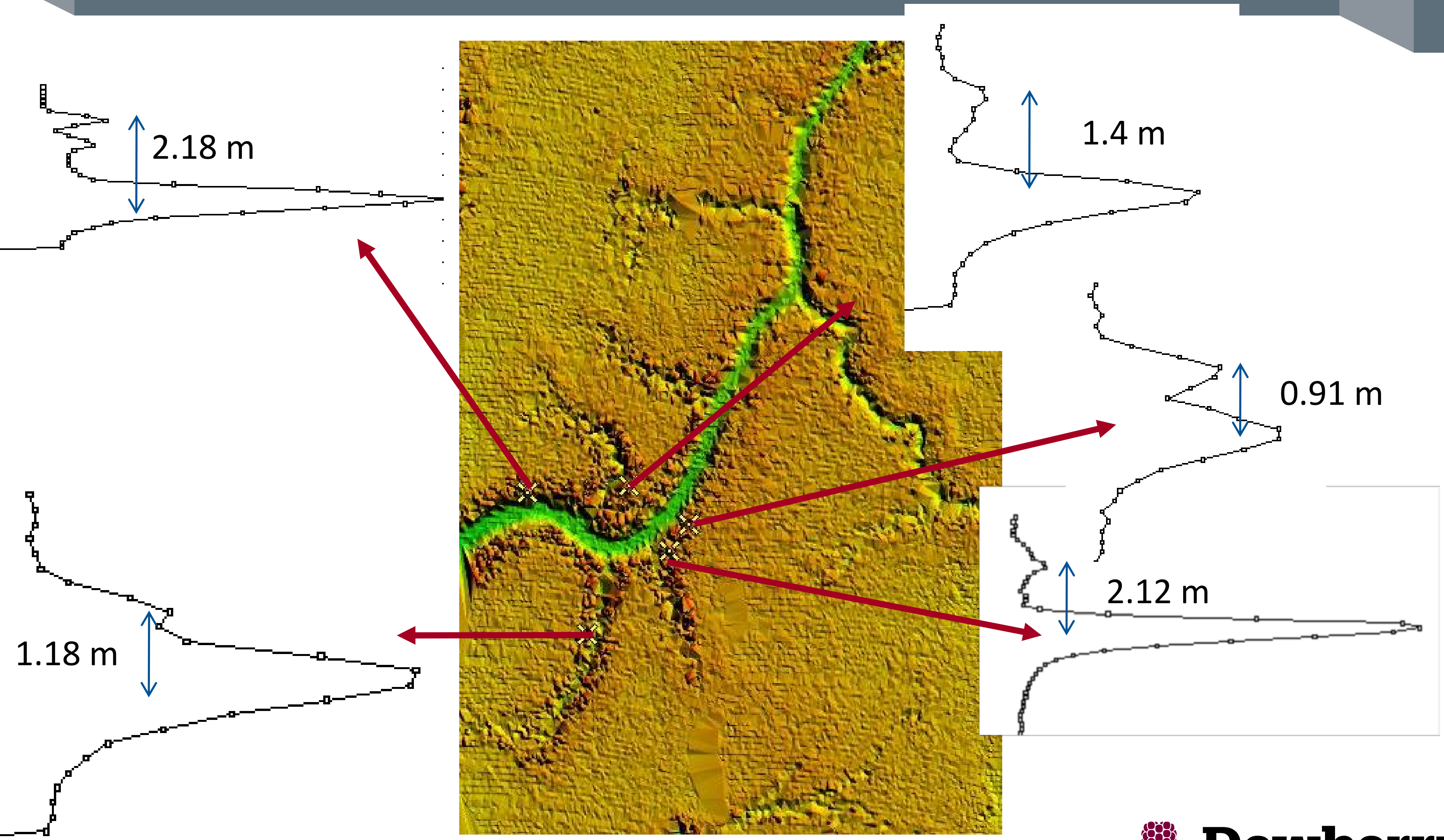


DSM – Discrete Return (2011)



EAARL DSM (from waveforms) - 2004

EAARL waveforms from *Phragmites*



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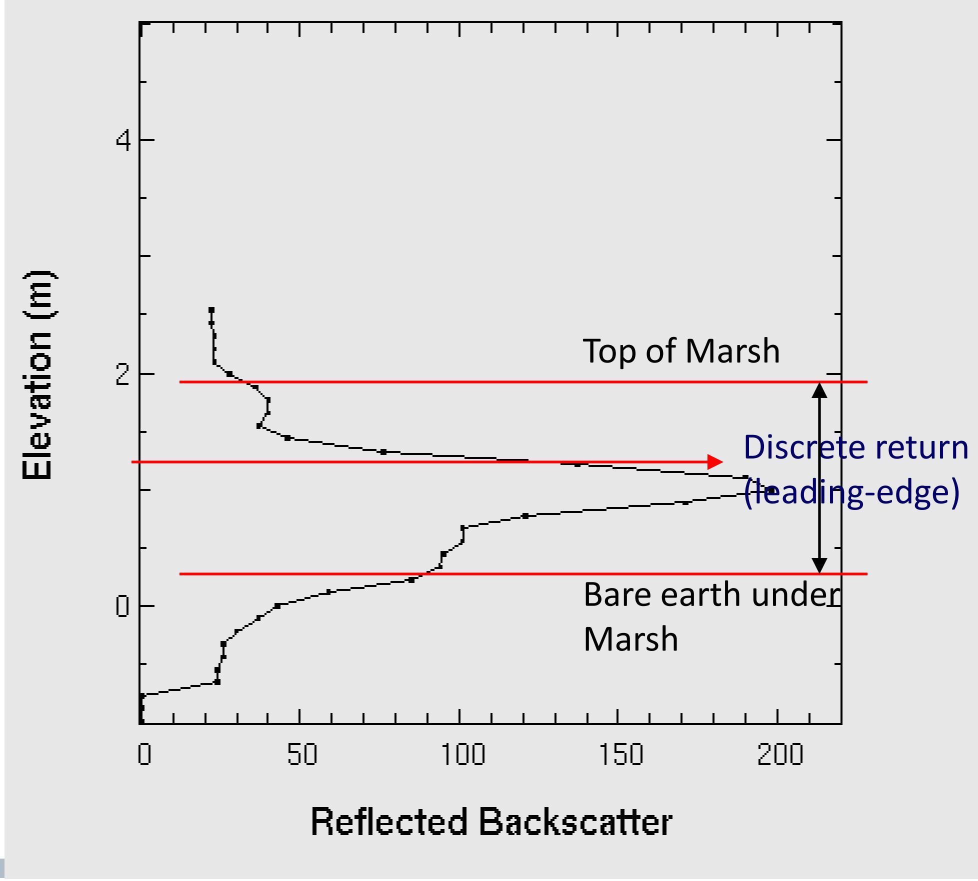
Can waveforms improve measurement of marsh heights?

- Pulse width, bandwidth, and response of detector play a key role

Waveforms allow various ranging methods to be used in post-flight processing software



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LiDAR for wetland mapping?

- What information do LiDAR data provide to delineate wetland vegetation communities?
  - DSM, DEM, Bare Earth Intensity, and Canopy Height Models can be used to aid Photo Interpretation and serve as input models in automated classification routines

- Do LiDAR waveforms provide any additional information that can be useful in wetland vegetation classification?
  - Waveforms enable measurement of the 3-D structure and function of vegetation communities
  - Pseudo Waveforms from discrete return data can provide estimate of canopy cover (Frequency wave)

- Can we determine invasive species such as "*Phragmites*" by fusing LiDAR and multispectral imagery?
  - CIR Imagery shows a "white tinge" indicating possible presence of *Phragmites*
  - Waveform LiDAR from a short laser pulse can detect the height of *Phragmites*.

Advantages of waveform LiDAR

- “unlimited” returns for each laser pulse
- Better ground topography
- Improved multiple-target resolution
- Improved detection of discontinuities and breaklines
- Ability to use post-processing methods to retrieve (more) information from data
- At a minimum, waveform data when decimated to discrete data can provide more than 3-4 returns per laser pulse

Use of LiDAR in wetland mapping

- Wetlands develop in areas of low topographic relief
  - Accurate topography from LiDAR (esp. waveform LiDAR)
- Hydrology and Hydraulic Modeling
  - Delineate drainages and water levels
  - Understand water flow paths
- Habitat mapping
  - Topography may be an important factor in soil type, soil moisture content, water salinity
  - LiDAR is very useful tool for vegetation monitoring / habitat assessment
- LiDAR can provide a synoptic/comprehensive view of the geomorphology and its relationship to land use, land cover, and cultural features.
- Use of topo-bathymetric LiDAR **may** provide seamless topography across land/water interface.

Thank you.

Questions?

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