EAARL Coastal Mapping Perspective

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U.S. Department of the Interior
U.S. Geological Survey

National Lidar Initiative Meeting
February 14-16, 2007

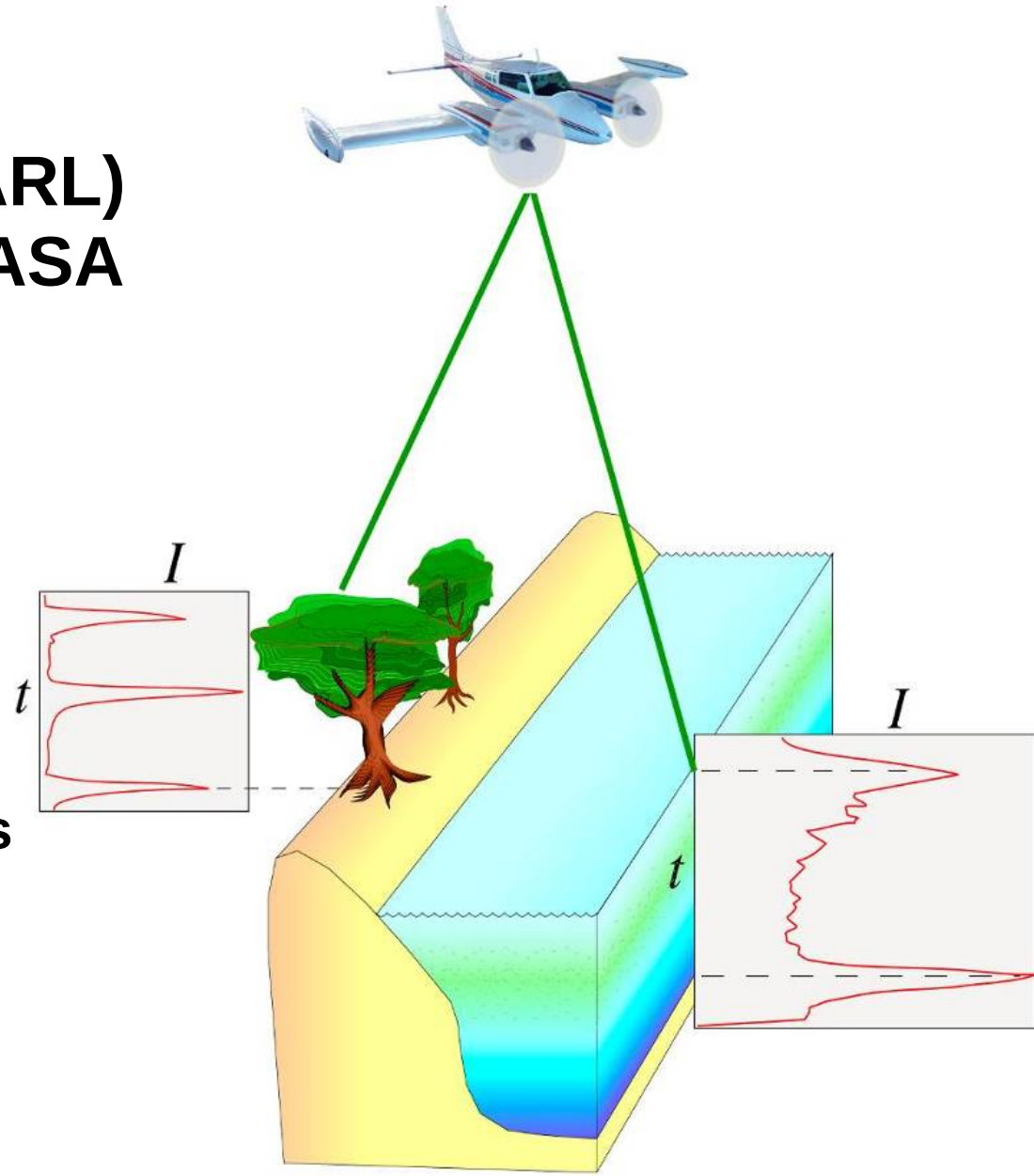
Outline

- NASA EAARL system principles and capabilities
- USGS Coastal projects using EAARL data
- Lidar data requirements for coastal and watershed studies

USGS

NASA Experimental Advanced Airborne Research Lidar (EAARL)
PI: Wayne Wright, NASA

- **Cross Environment Topo/Bathy Capabilities**
- **Small-footprint, waveform-resolving, green-wavelength lidar**
- **Detailed topography of Shallow Marine Substrates & Vegetated Canopies**
- **Digital multi-spectral imagery (RGB and CIR)**



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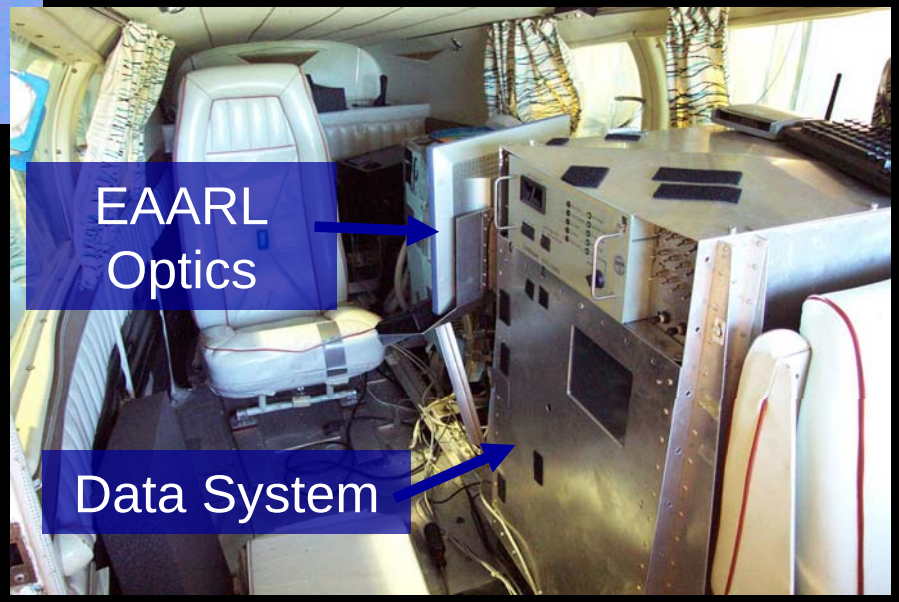
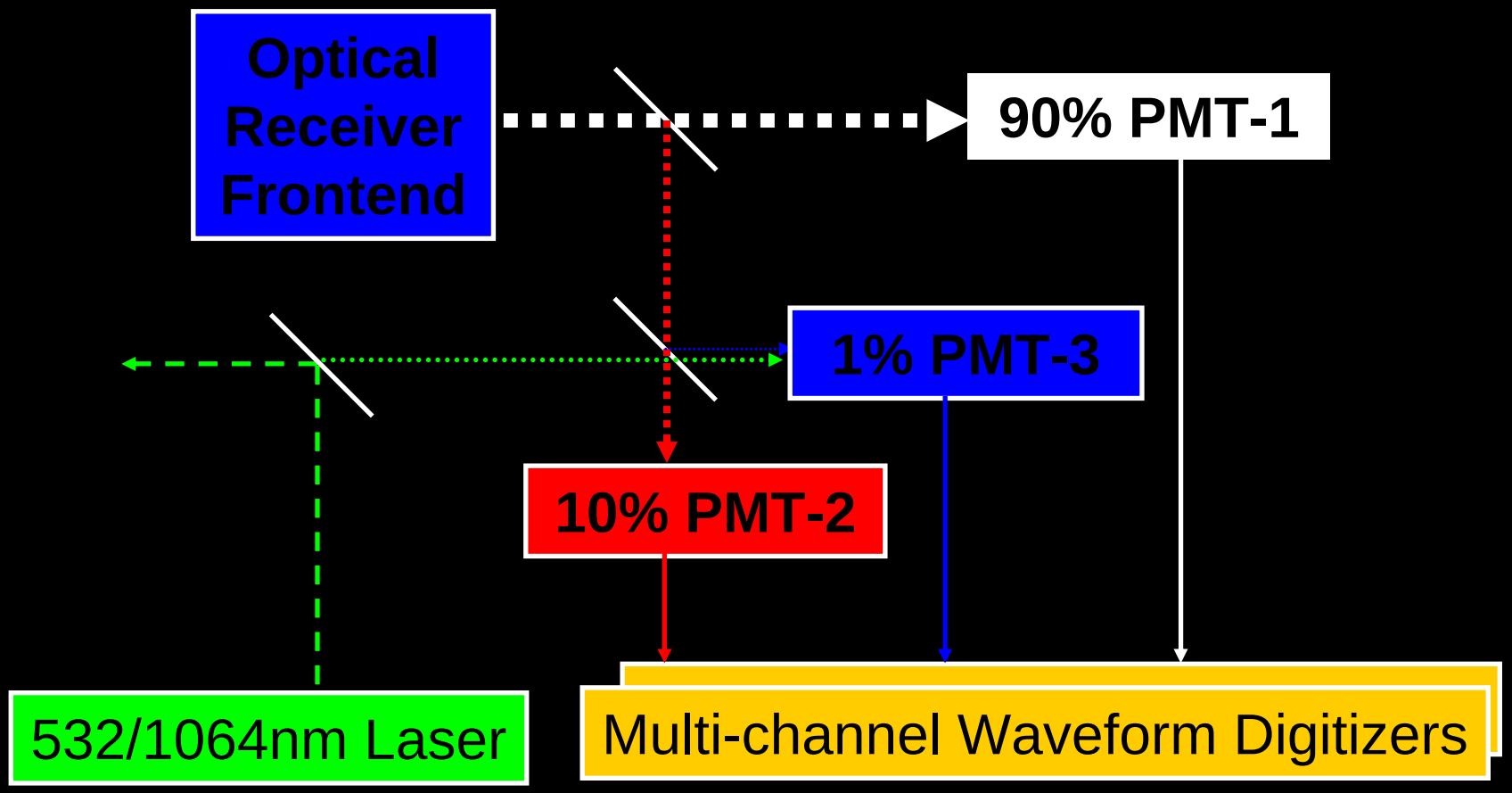
EAARL Specifications:

- **300 m operating altitude**
- **240 m wide swath**
- 120 points/swath
- 43-80 km^2/hour
- 2 m cross track sampling
- 2.5 m average along track spacing.
- **15-20 cm diameter illumination spot**
- 1 m diameter detection area
- **0-20 m water depth range (~ 1.5 x Secchi depth)**
- 20 Hz scan rate
- 250 lbs total weight
- 400 watts nominal @28vdc
- Variable PRF (Operating max. 3,000 Hz)
- 3 cm RMS nominal ranging accuracy.
- 1 m horizontal positioning
- **Digitizer sample interval 1 ns (15 cm in air, 11cm in water)**
- **Four waveform channels**
- **Co-registered digital camera**

EAARL Operates From Commercially Available Light Aircraft

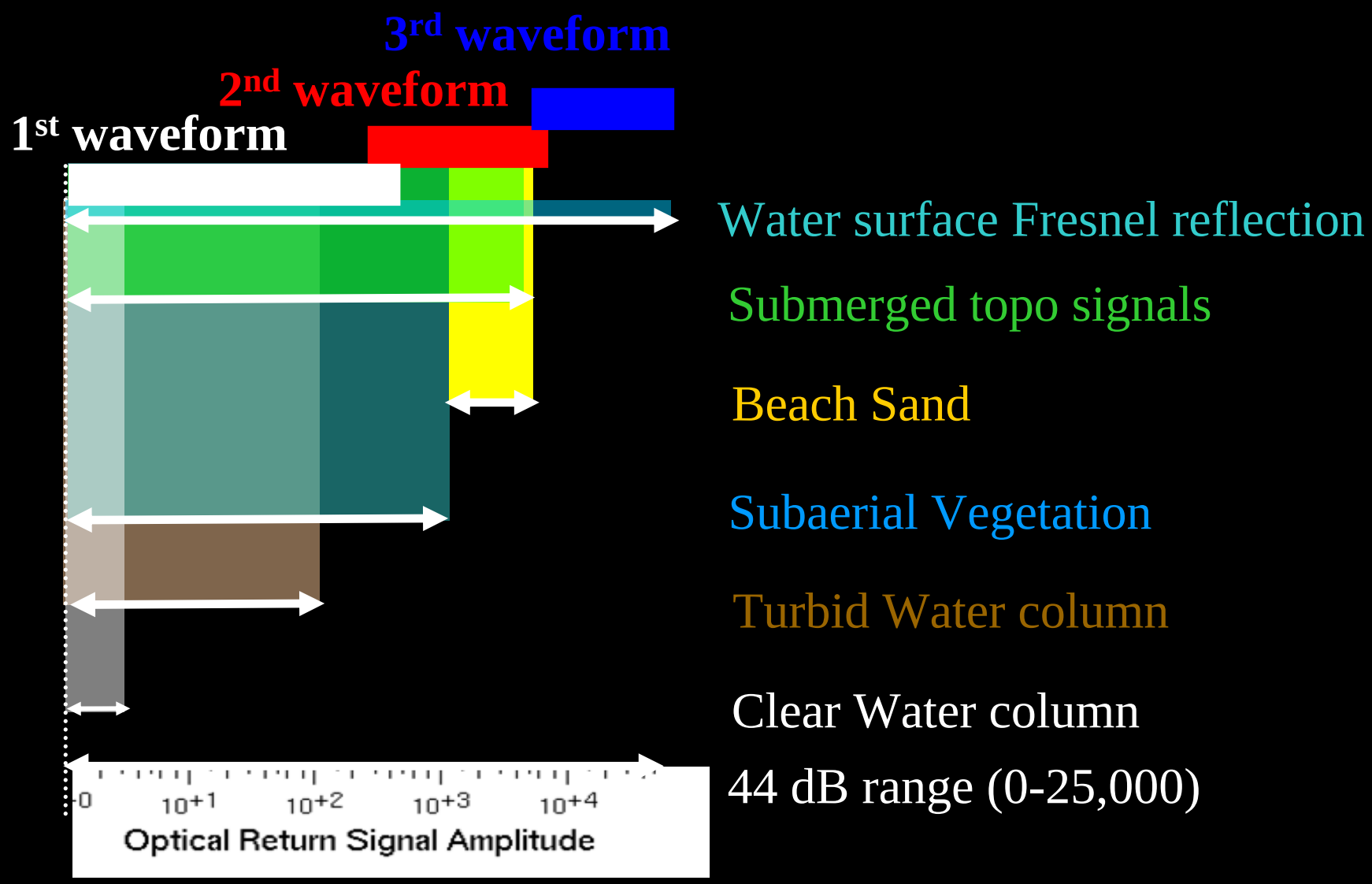


EAARL Laser Return Optics

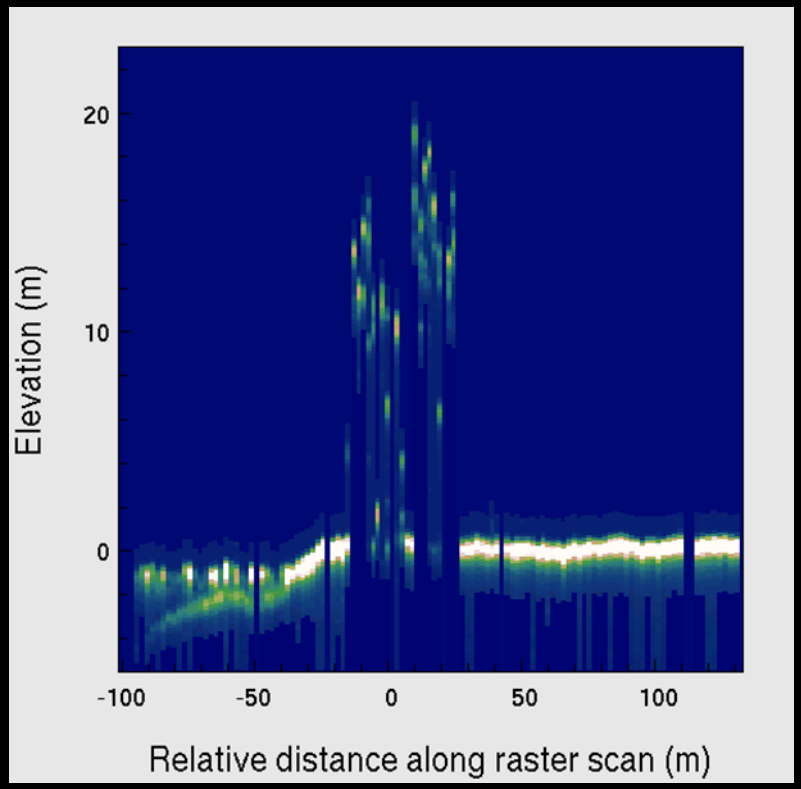


196 million samples digitized per second

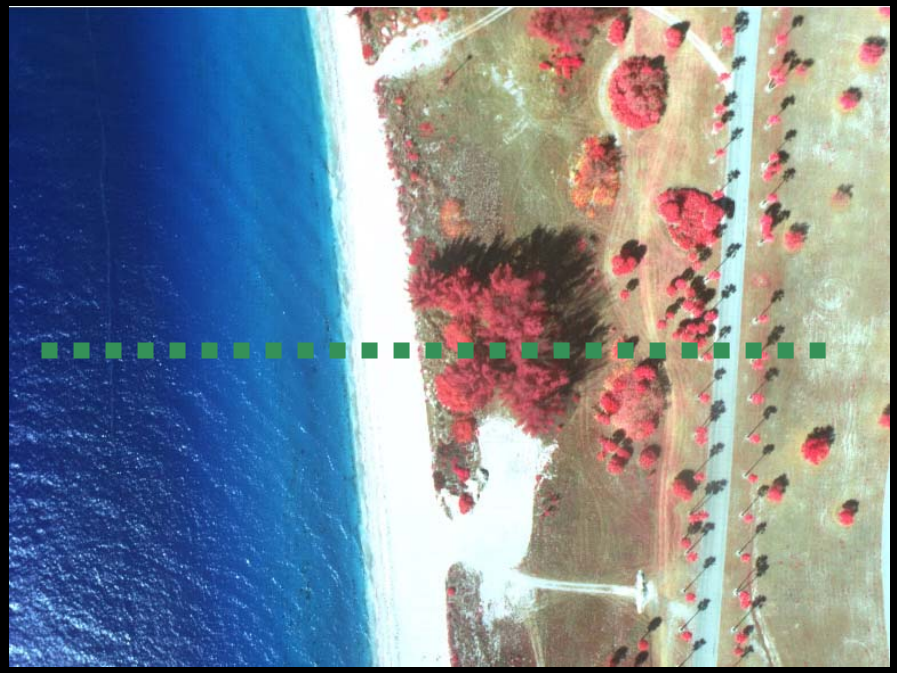
Backscattered Signal Distribution



Cross environment surveying using EAARL



Lidar backscatter along scan



Color Infrared (CIR) Image co-registered with lidar

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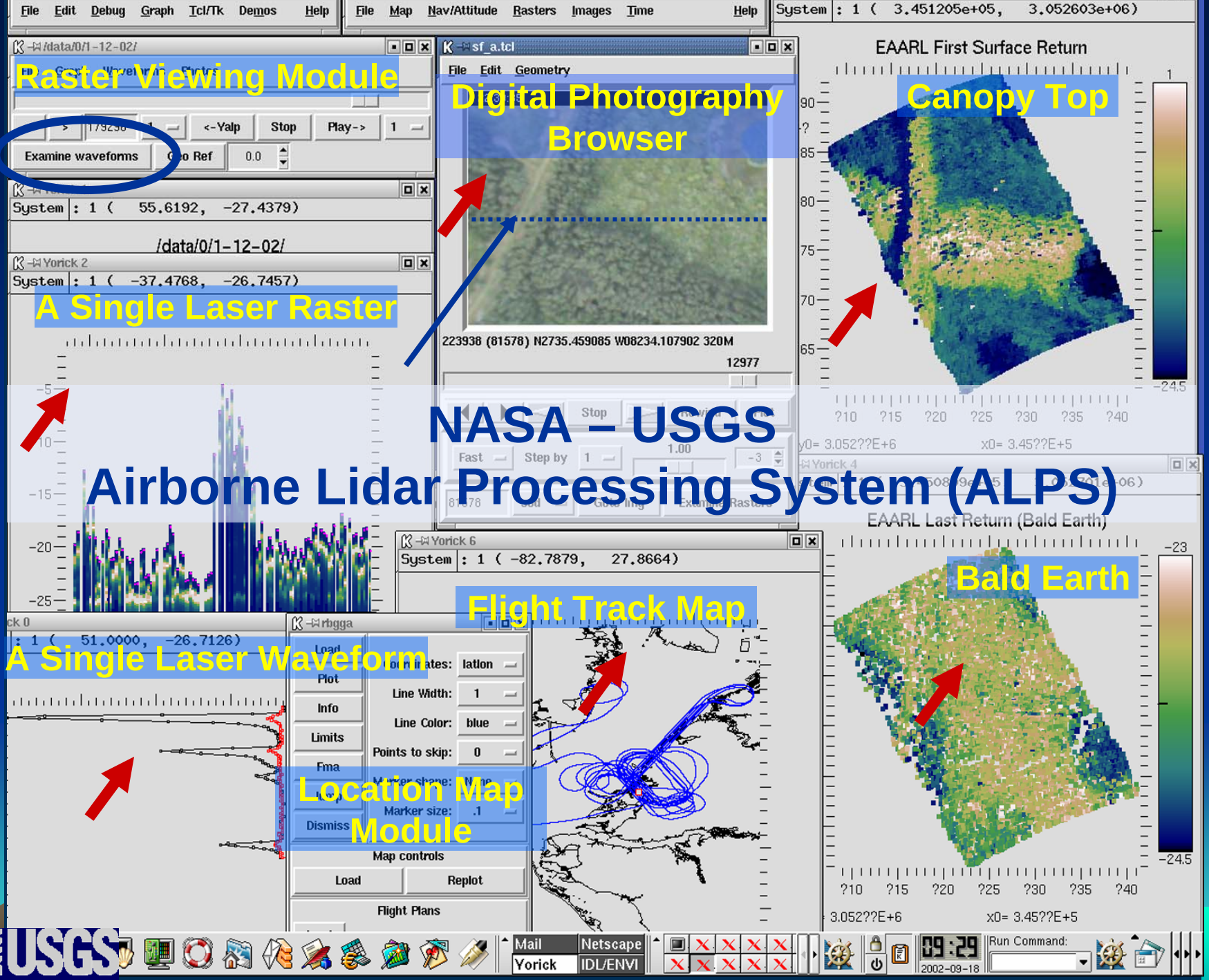
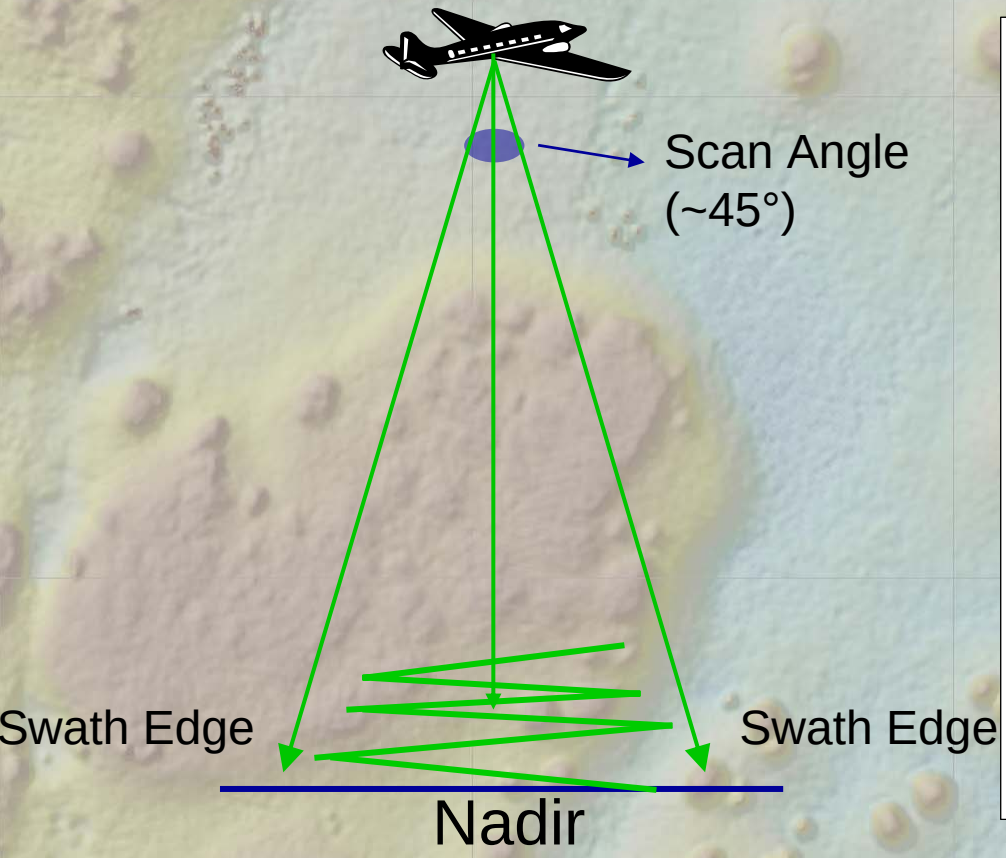
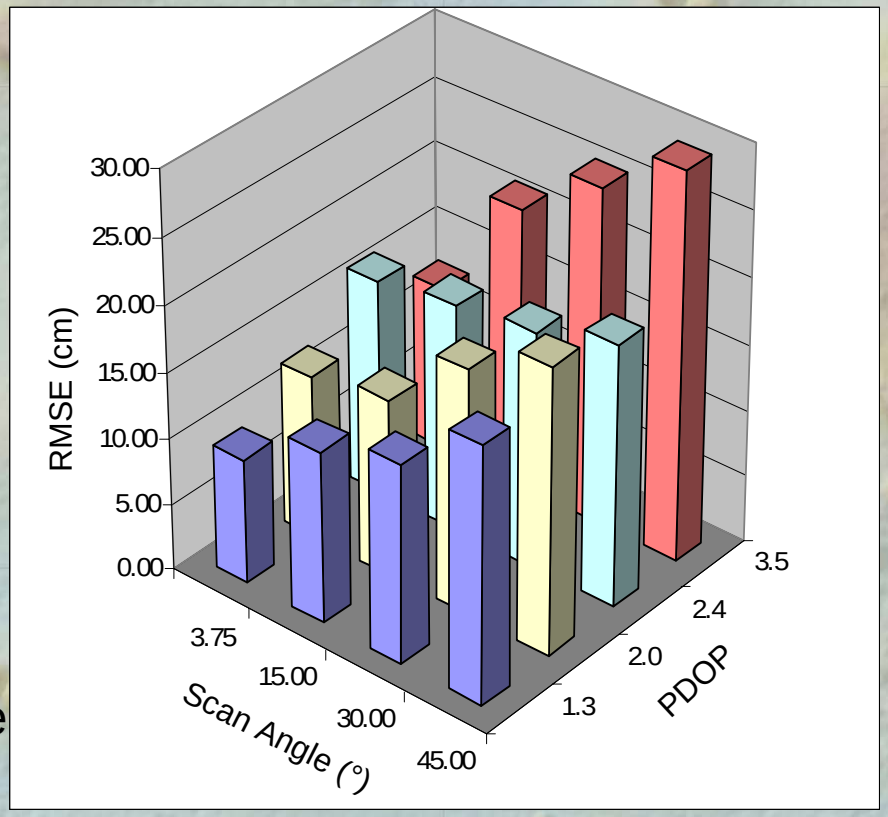
Tampa Bay, FL


Raster Viewing Module
Digital Photography Browser
Canopy Top
A Single Laser Raster
NASA – USGS
Airborne Lidar Processing System (ALPS)
Flight Track Map
Bald Earth
A Single Laser Waveform
Location Map Module
EAARL First Surface Return
EAARL Last Return (Bald Earth)
/data/0/1-12-02/
Examine waveforms
Stop
Play->
<-Yalp
System : 1 (55.6192, -27.4379)
System : 1 (-37.4768, -26.7457)
System : 1 (-82.7879, 27.8664)
System : 1 (51.0000, -26.7126)
System : 1 (3.451205e+05, 3.052603e+06)
223938 (81578) N2735.459085 W08234.107902 320M
Line Width:
Line Color:
Points to skip:
Marker size:
Map controls
Load
Replot
Flight Plans
Dismiss
Info
Limits
Plot
Mail
Netscape
Yorick
IDL/ENVI
09:29
2002-09-18
Run Command:

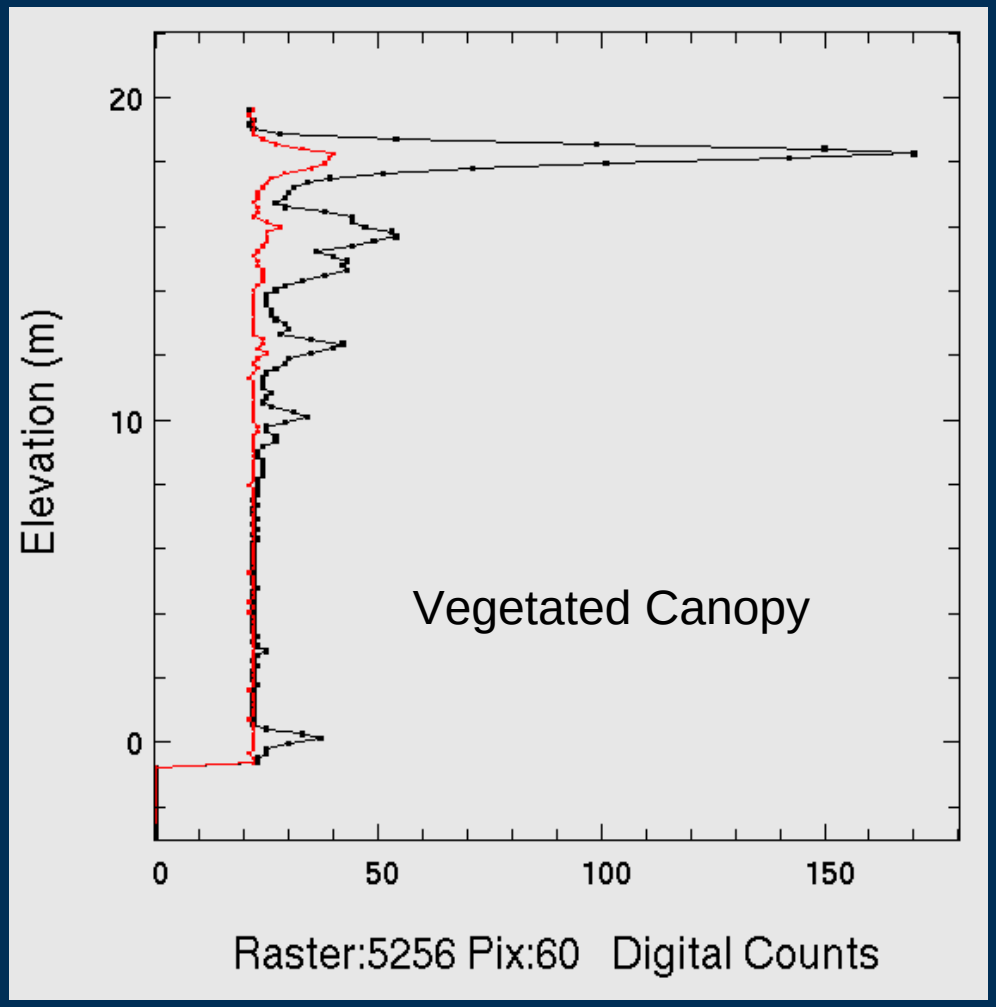
Effect of GPS and Scan angle on vertical accuracy

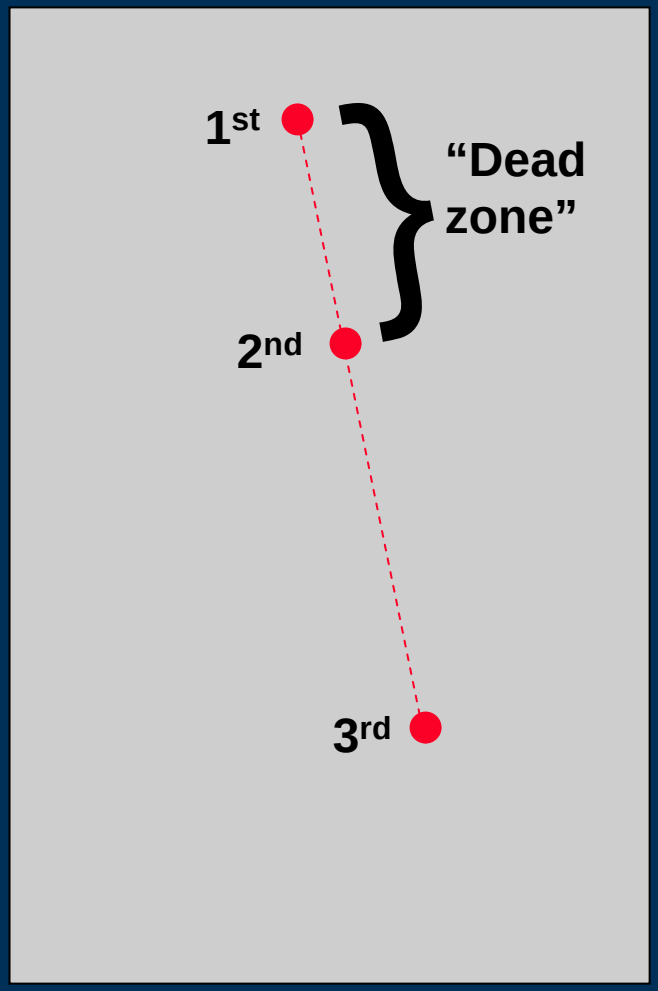




Terra Ceia, Tampa Bay, Florida

Waveform-digitizing vs. Discrete-return





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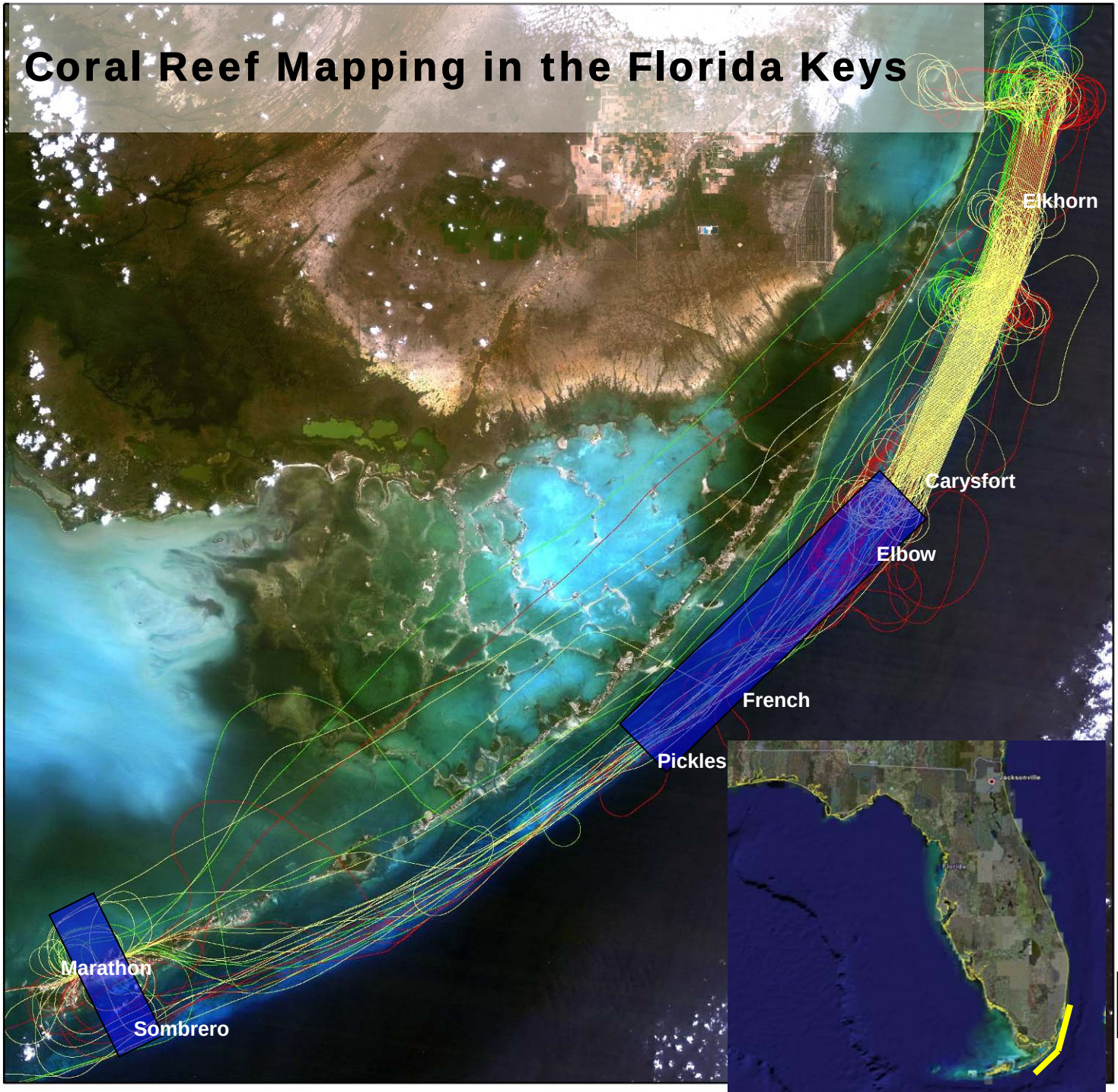
USGS Coastal Projects using EAARL data

- Advanced Remote Sensing Methods for Coastal Science and Management
- Decision Support for Coastal Parks, Sanctuaries, and Preserves
- Coral Reef Program
- National Assessment of Coastal Change Hazards

USGS

Coral Reef Mapping in the Florida Keys



NASA EAARL Flightlines over the Northern Florida Reef Tract

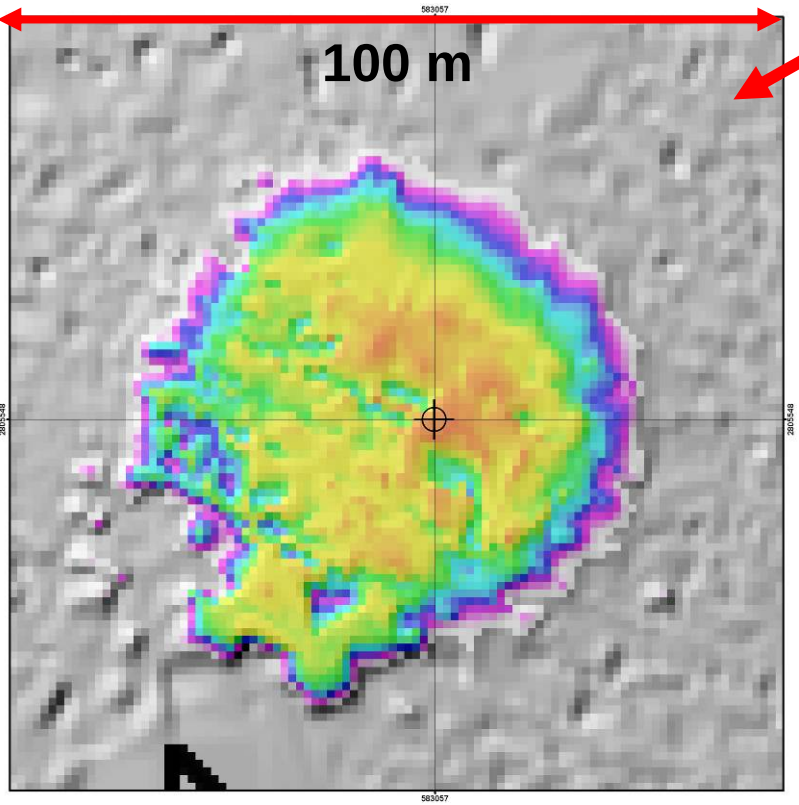
Acquisition Dates

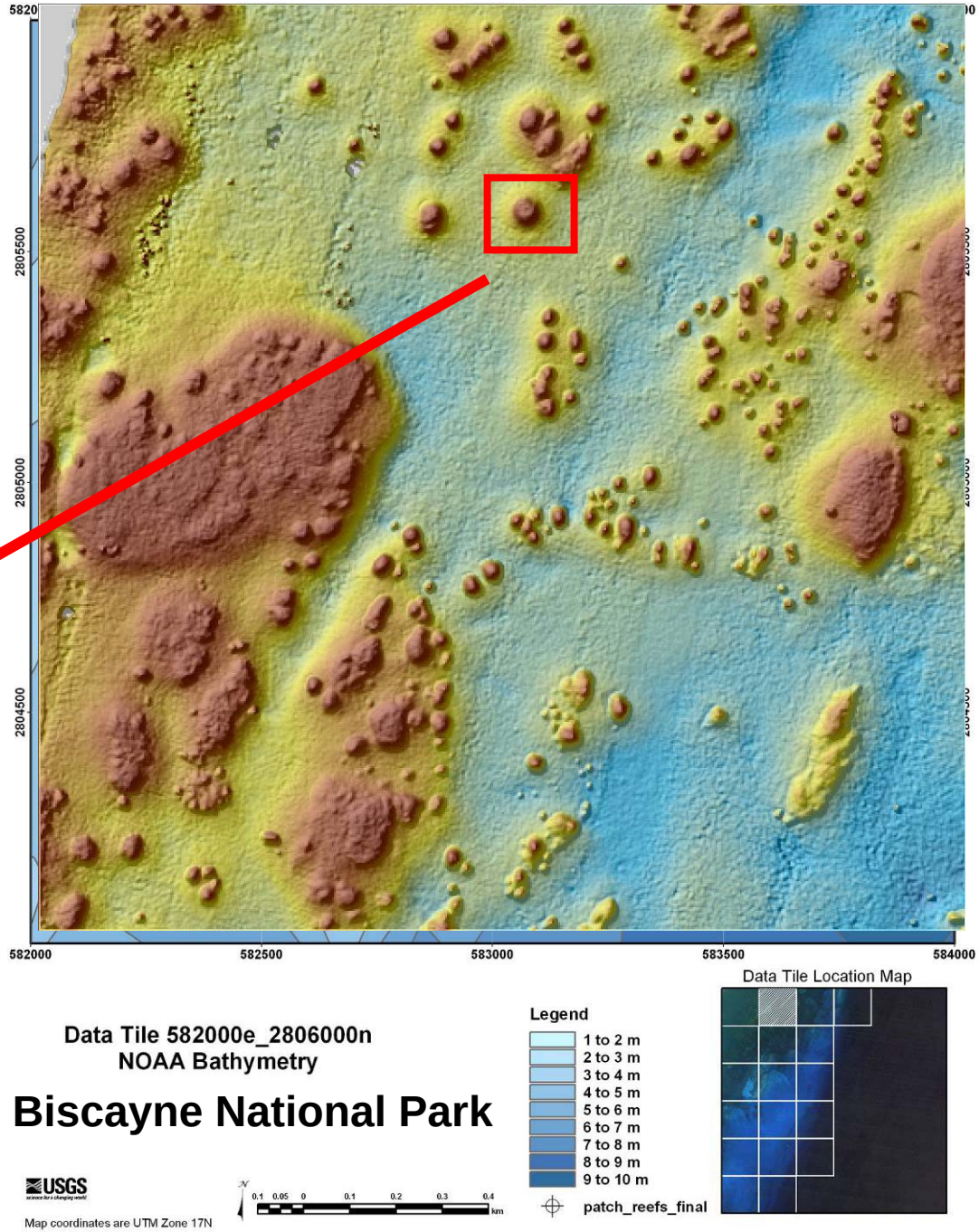
- Aug. 2-8, 2002
- July 10-14, 2001
- Sep. 4-7, 2001
- Apr 17-20 2006

6 3 0 6 12 18 Km

NASA EAARL Submarine Topography Map:

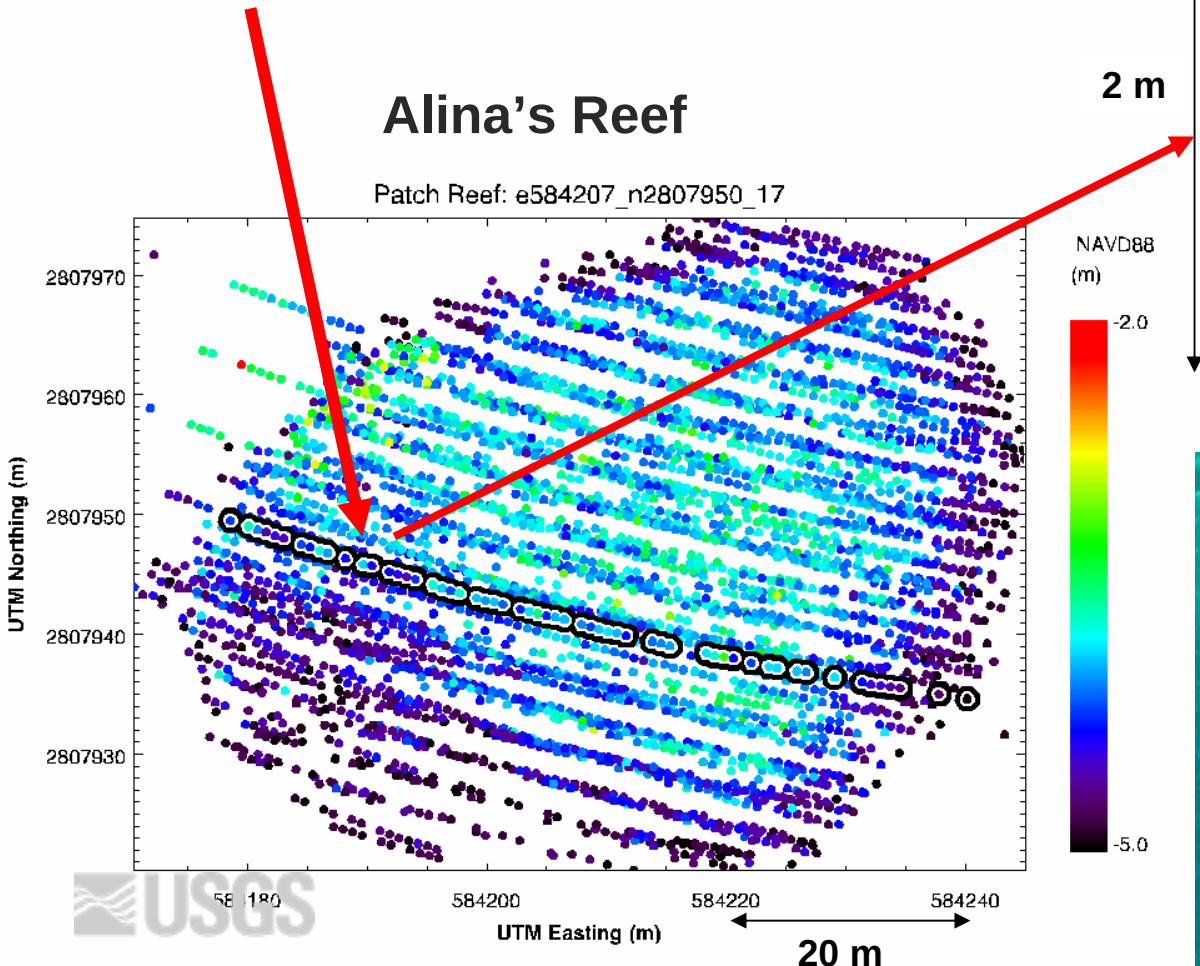
- 2 km by 2 km map region
- 1.0 m image resolution
- Color-coded for elevation

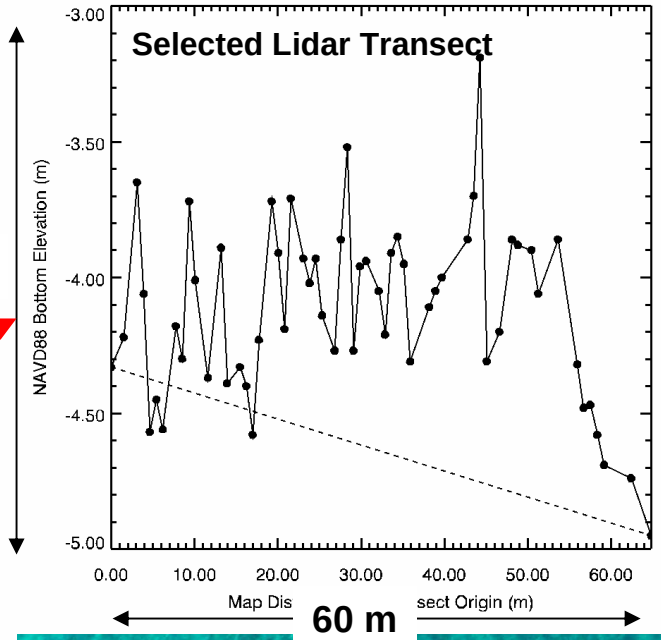




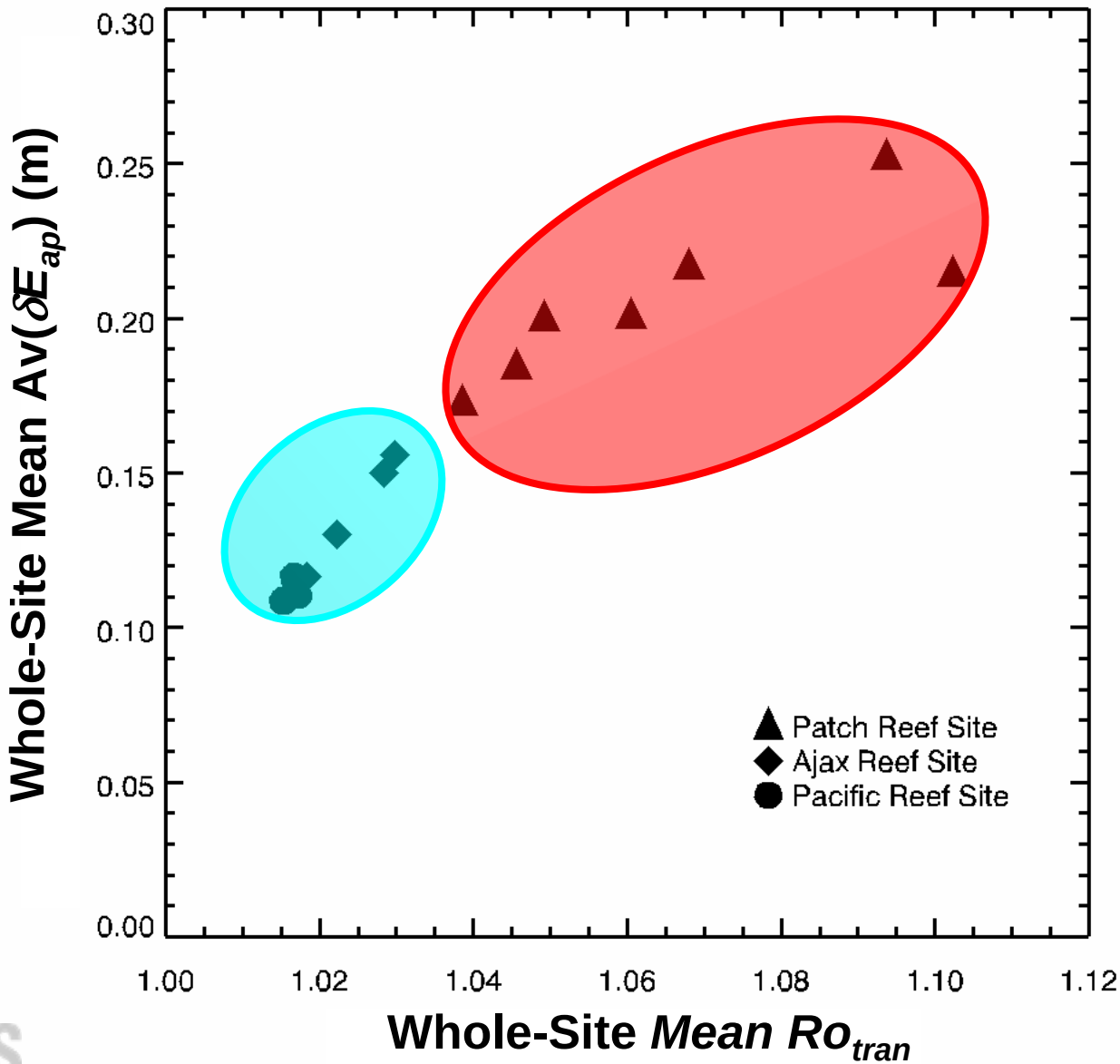
EAARL-Based Optical Indices of Topographic Variability Were Evaluated at 15 Patch and Bank Reef Sites

The analysis used large populations of topographic transects derived from closely spaced laser spot reflections along lidar raster scans





Patch Reefs vs. Bank Reefs



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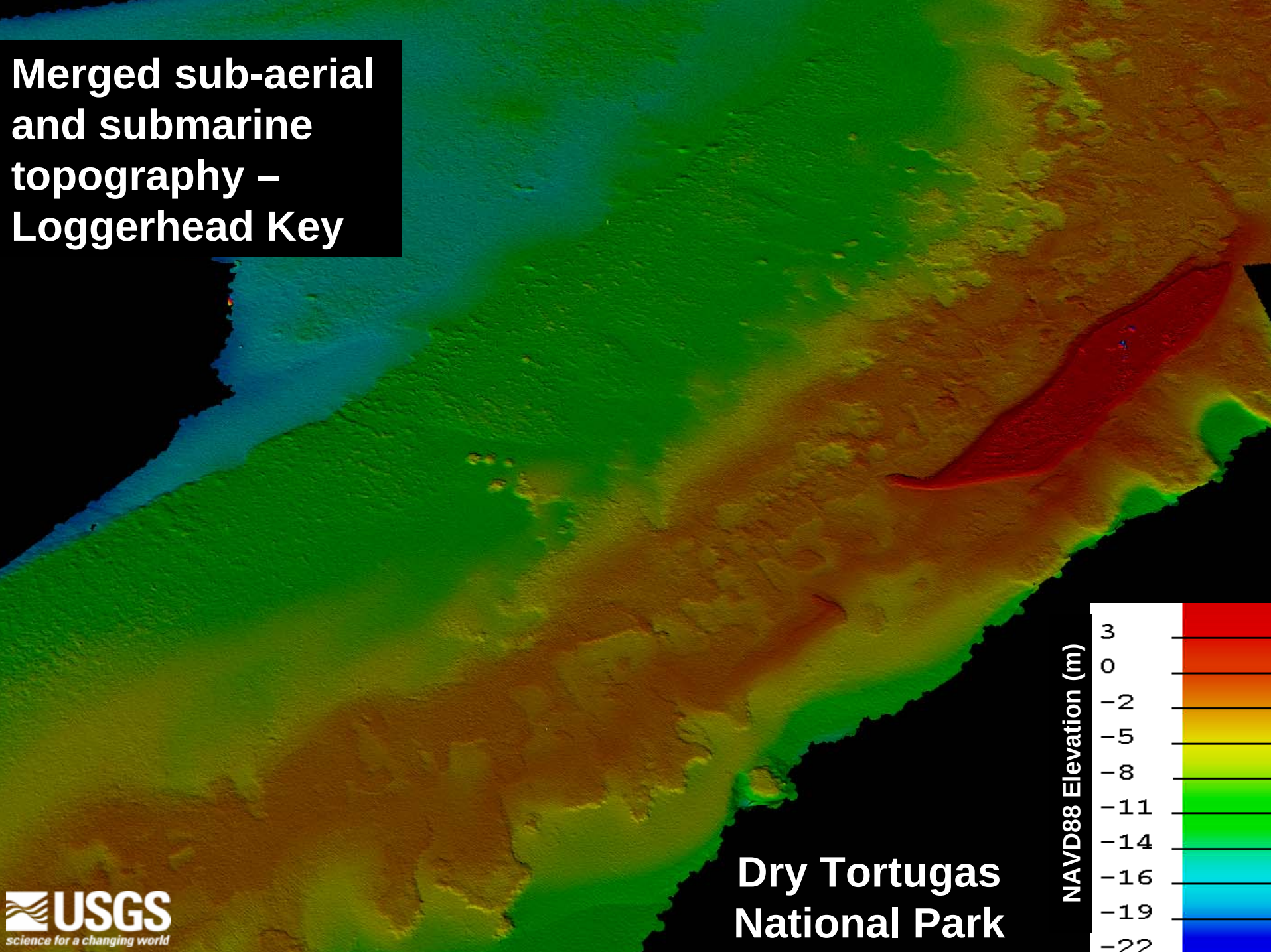
Merged sub-aerial and submarine topography – Loggerhead Key



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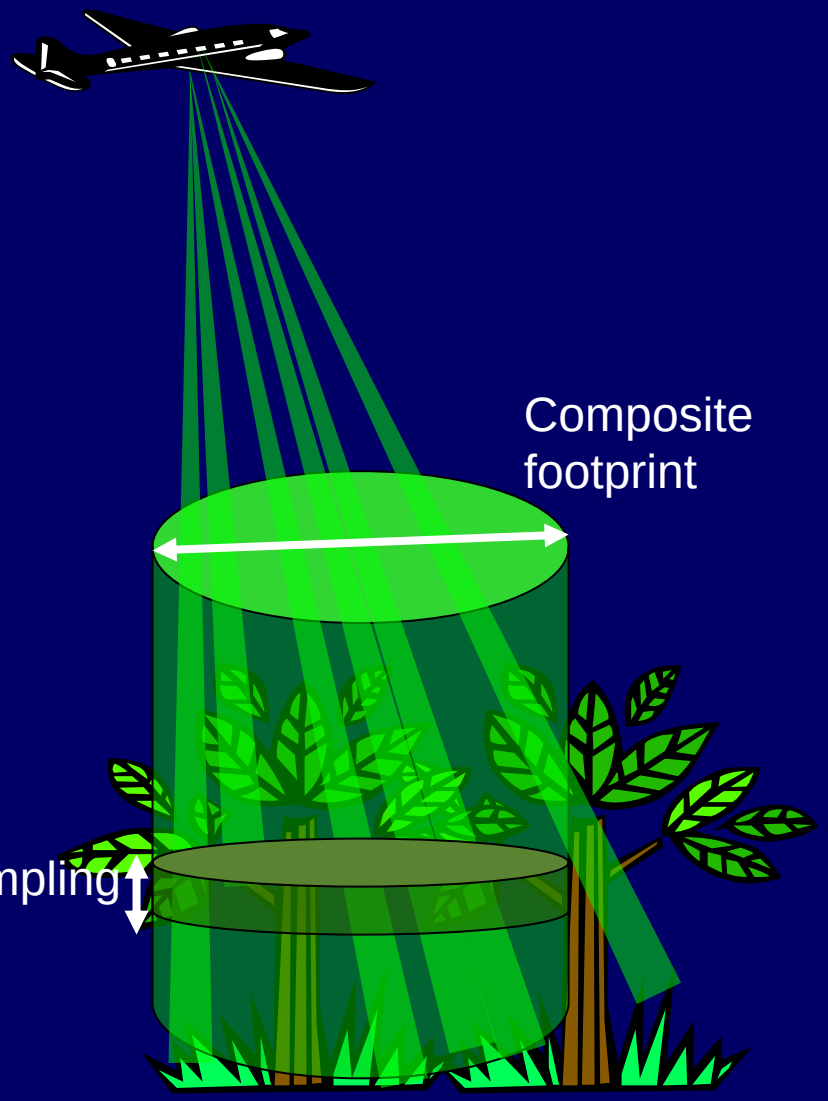
Deriving vegetation canopy characteristics

- 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
- There is a sampling bias inherent to small footprint lidar systems.



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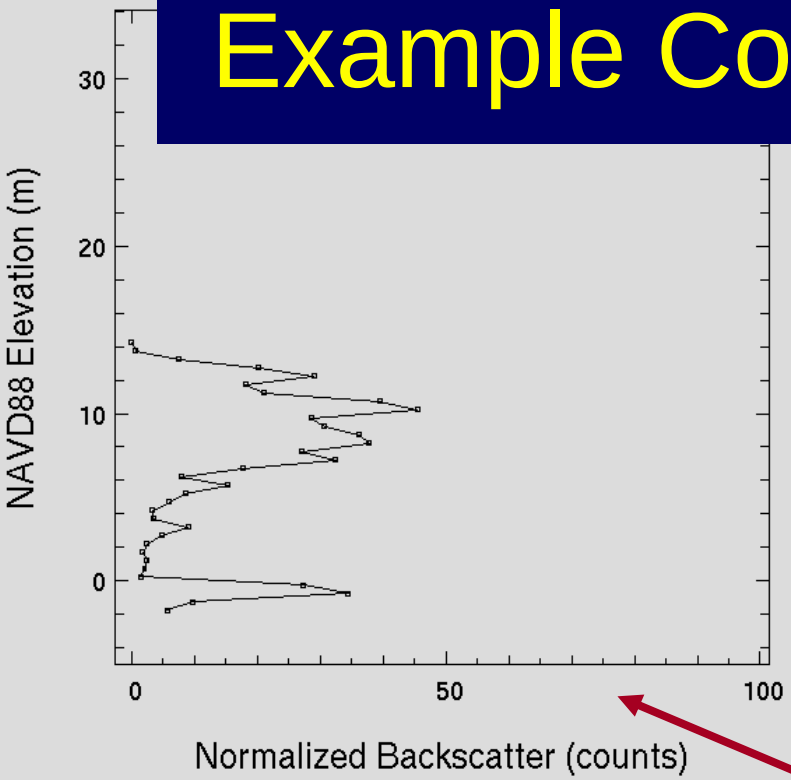
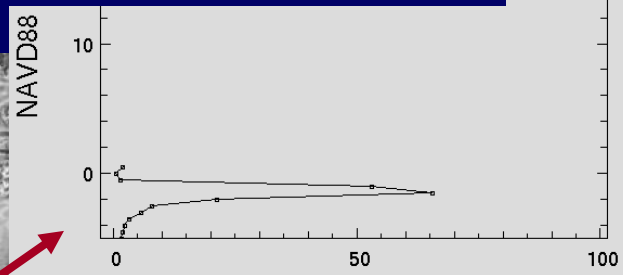
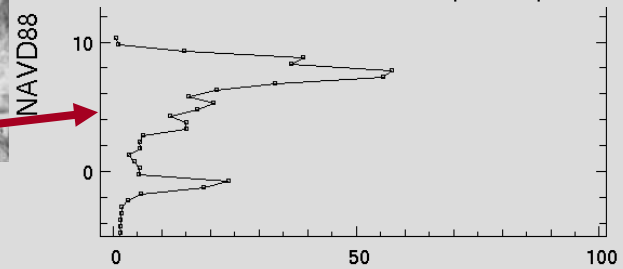
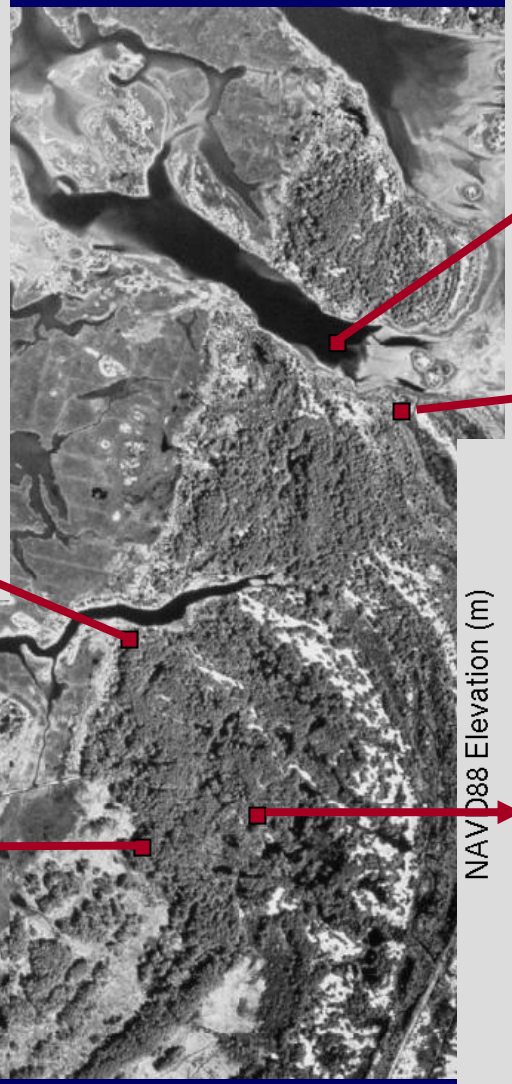
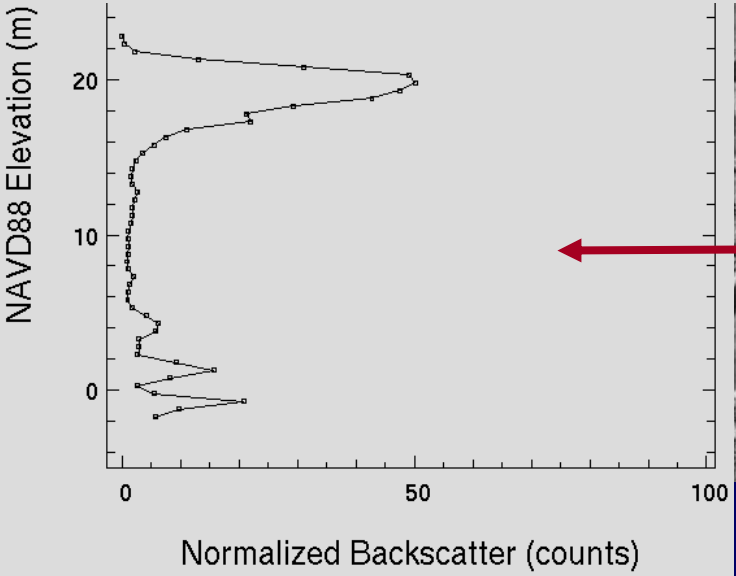
Example Composite Waveforms

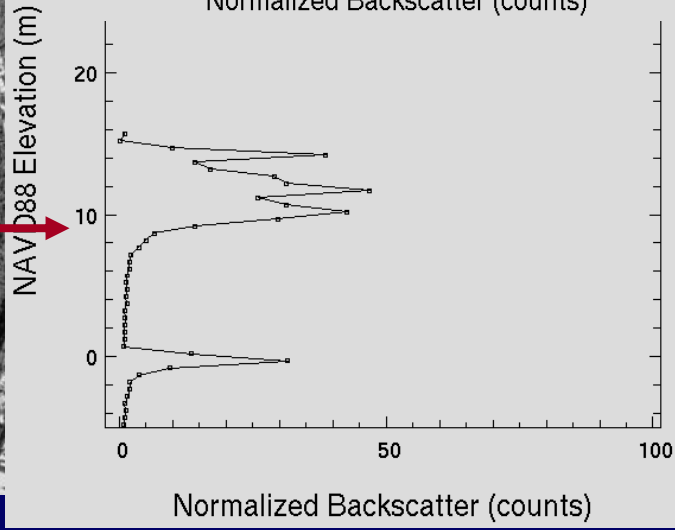








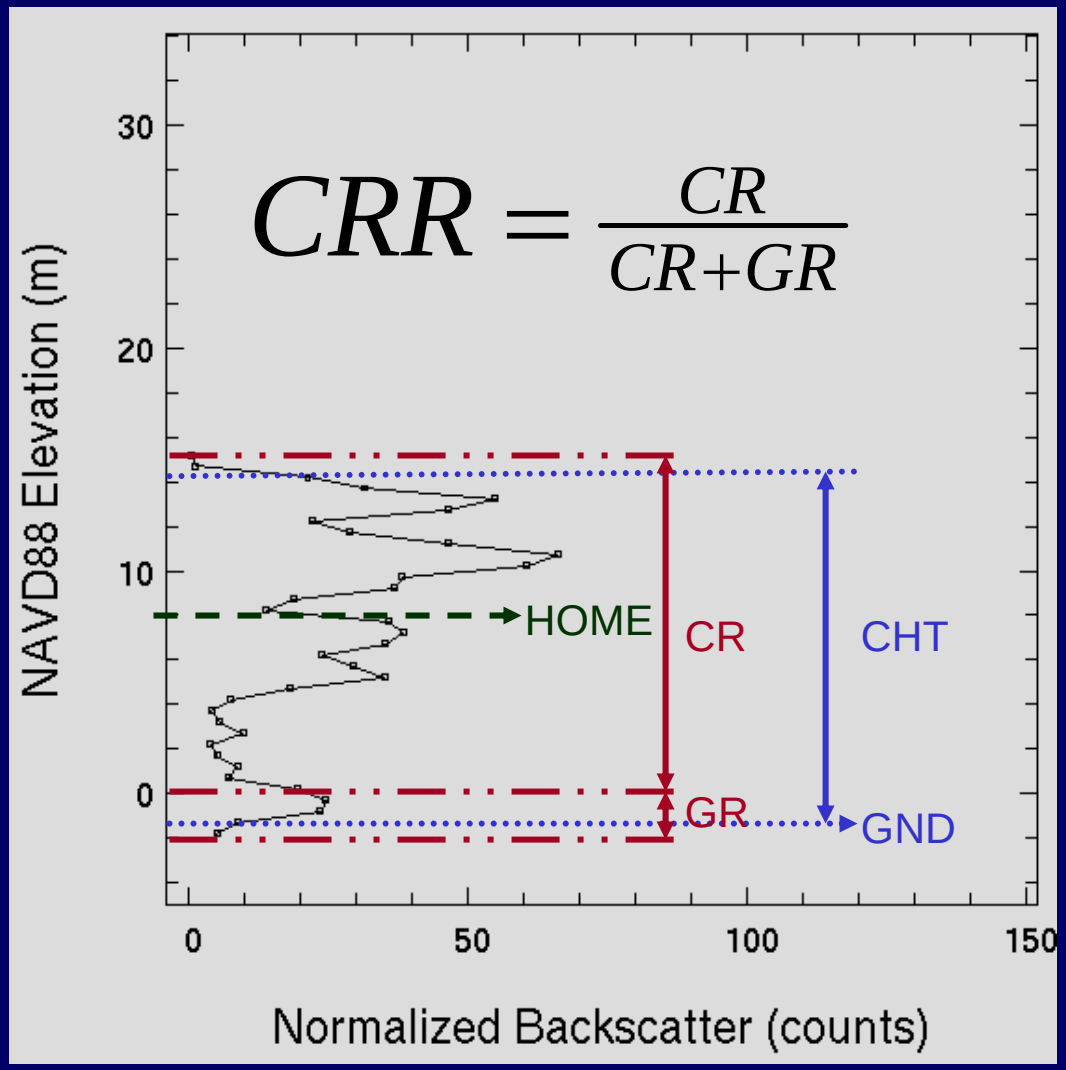




Assateague Island National Seashore, MD

Deriving Vegetation Metrics

- Canopy Height (CHT)
- Bare Earth (GND)
- Relative canopy cover (CRR)
- Height of Median Energy (HOME)



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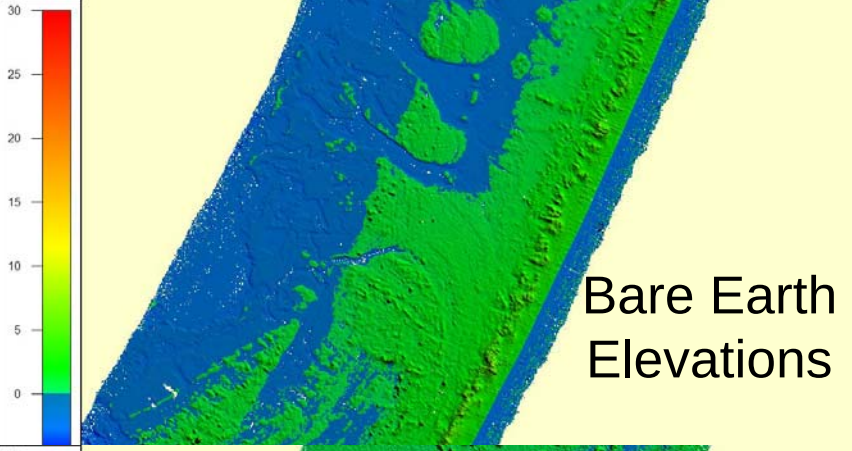
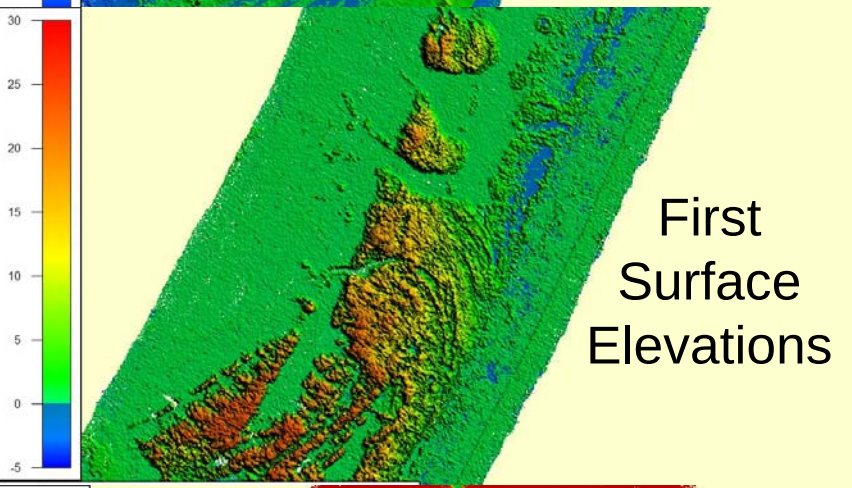
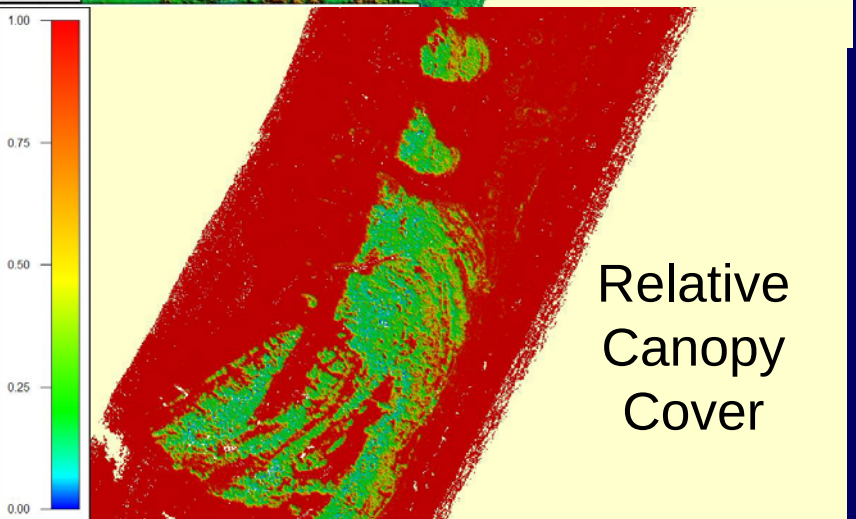
Vegetation classification using Lidar



Bare Earth Elevations

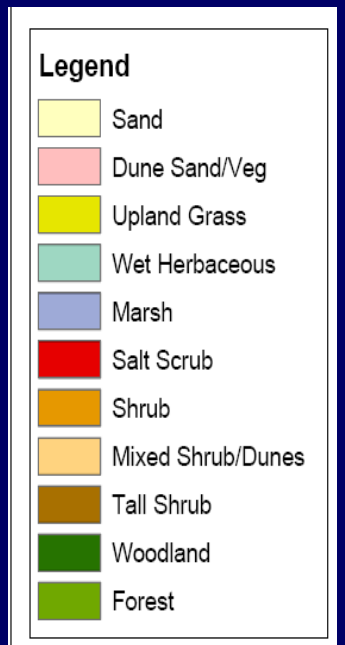


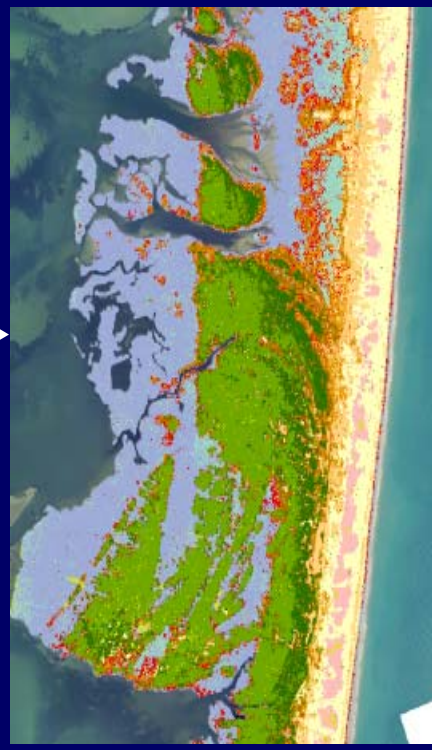
First Surface Elevations



Relative Canopy Cover

Unsupervised classification in GIS software





Classification map

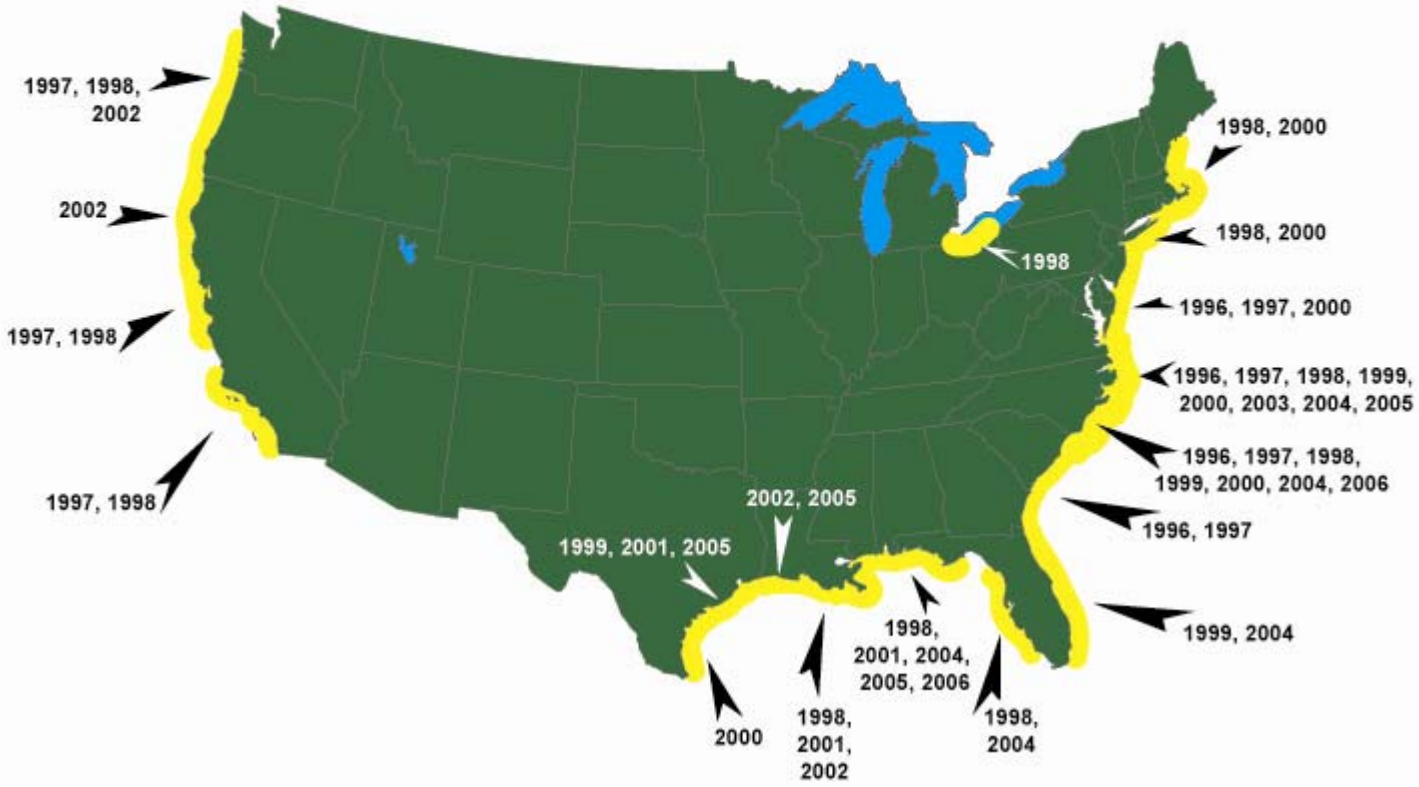
National Assessment of Coastal Change Hazards

Develop a predictive understanding of the coast's vulnerability to extreme storms and hurricanes.

1. Quantify the longshore-variable response of beaches to storms.
2. Identify the processes responsible for the observed patterns of change.
3. Develop and test a model for predicting the likely impact of an approaching storm.

USGS

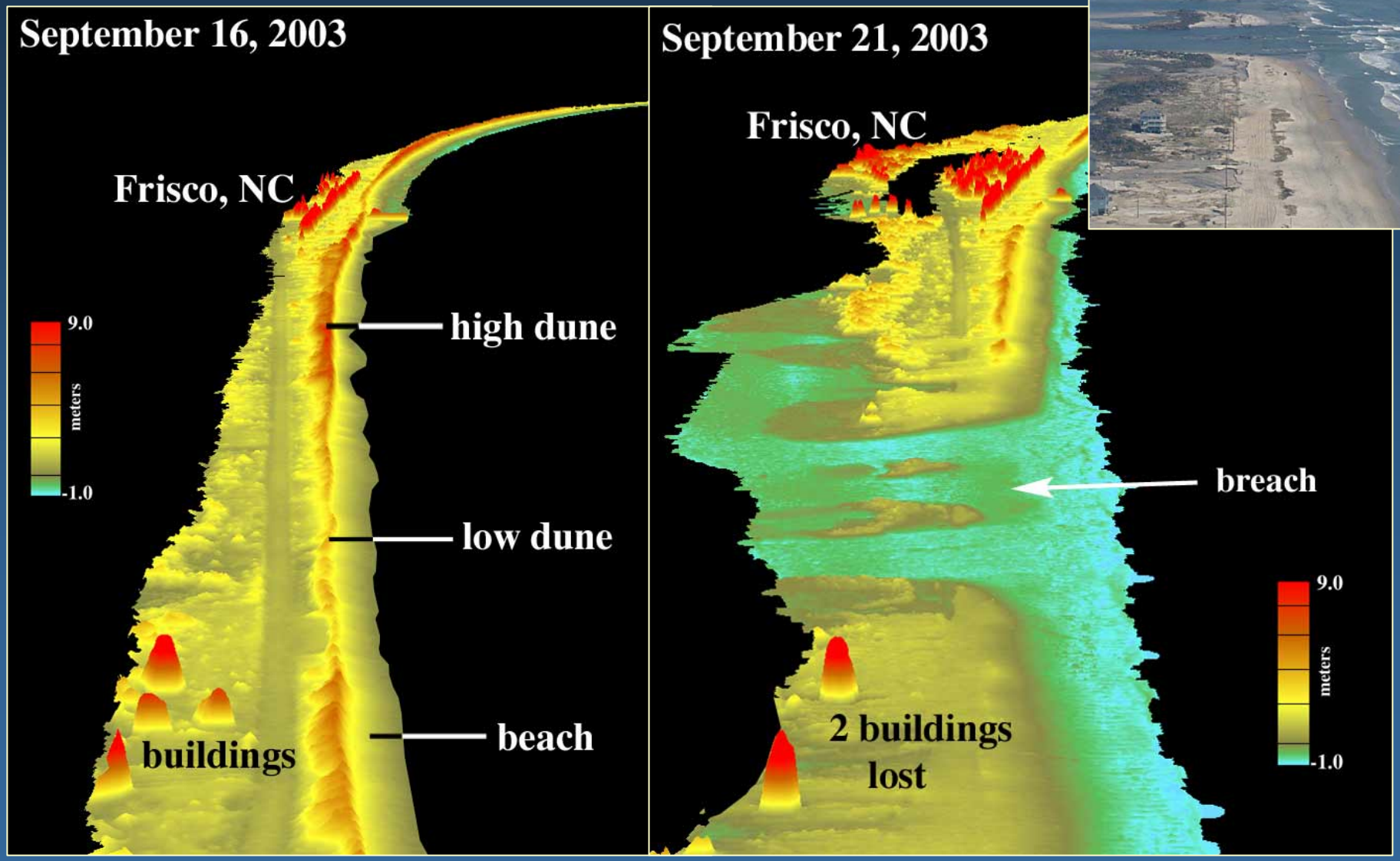
National Coastal Lidar Coverage: USGS, NASA, USACE, NOAA, TBEG



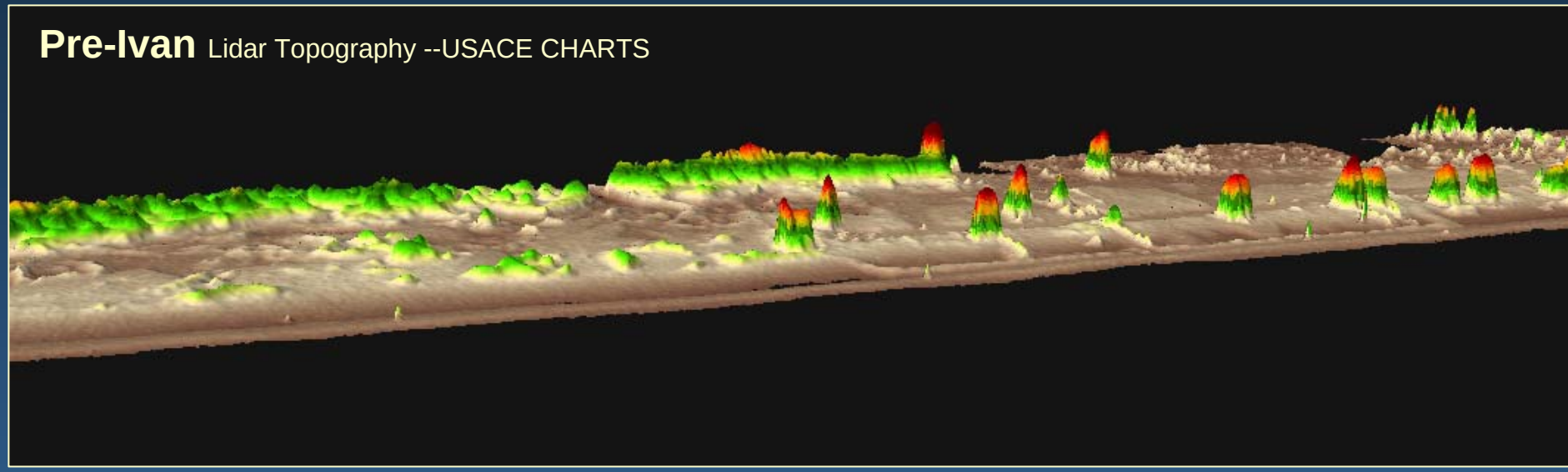
USGS

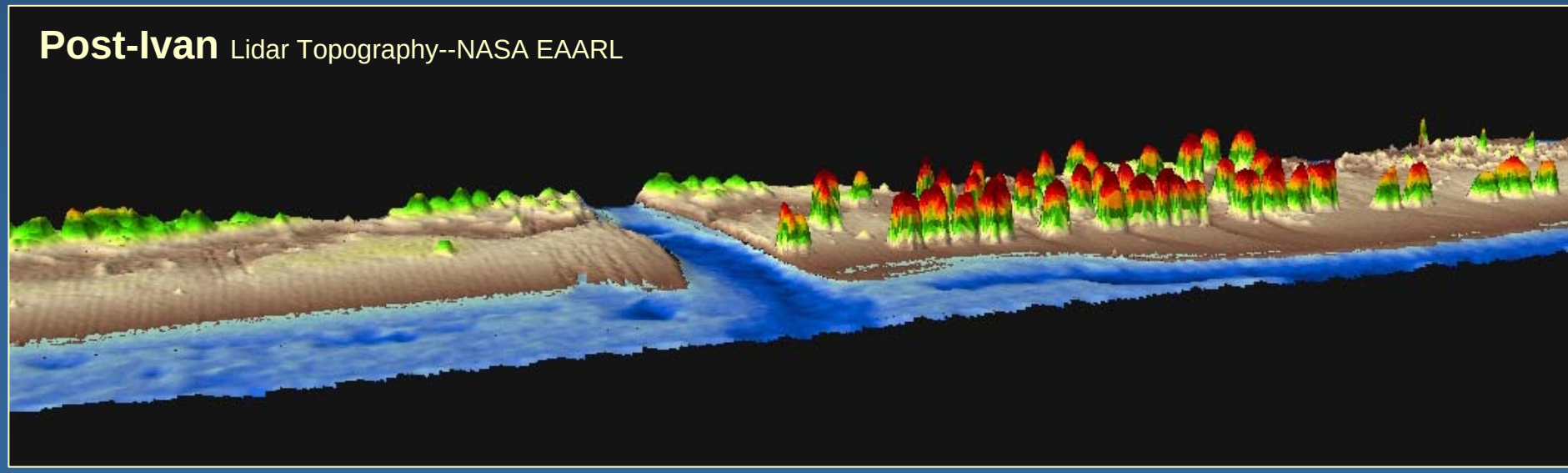
Hurricane Isabel

Island breach in Hatteras, NC



Can we predict which areas are most vulnerable to extreme coastal change?

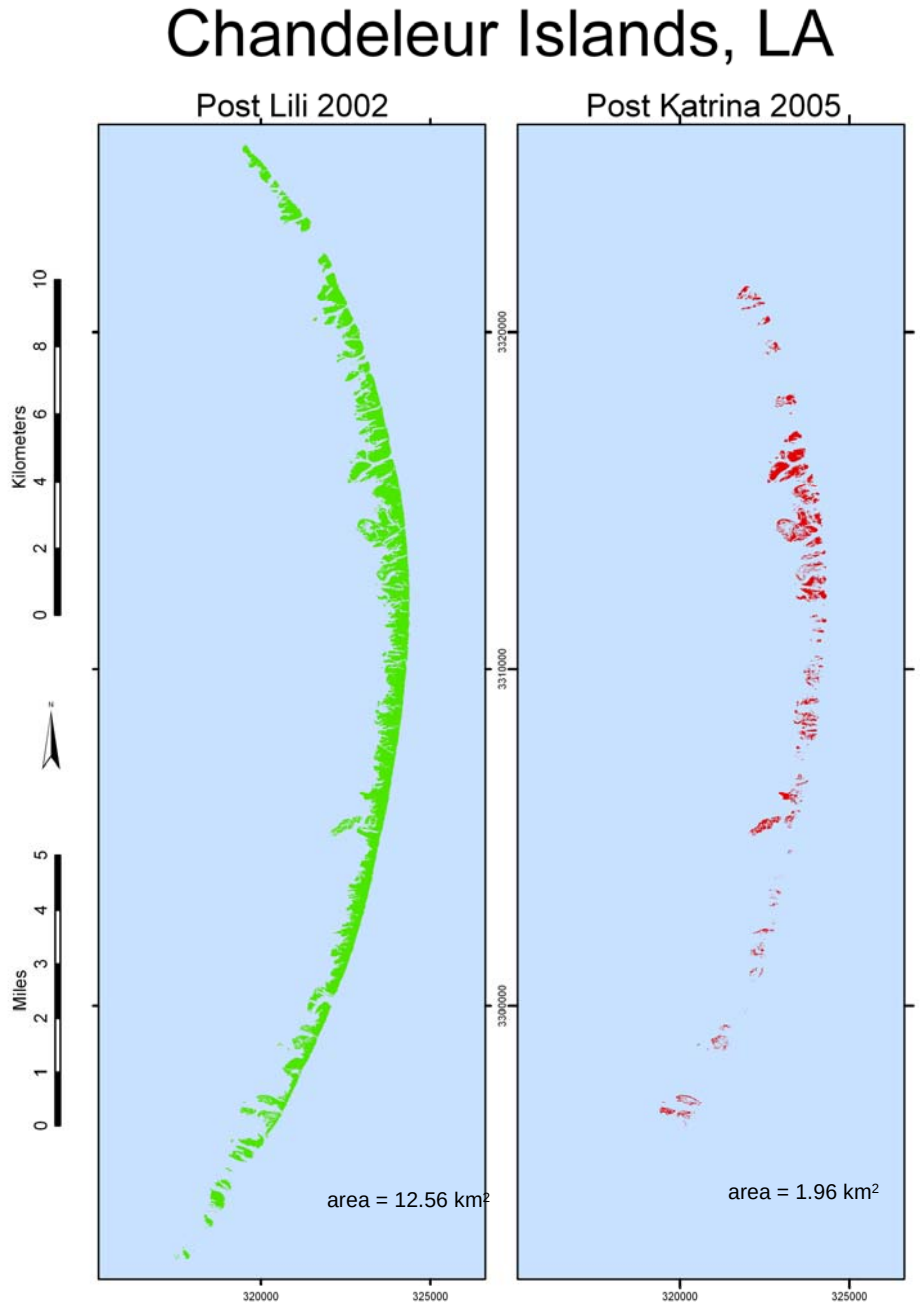




Island Area and Volume (% change)

$\Delta A = -84.4\%$

$\Delta V = -91.7\%$



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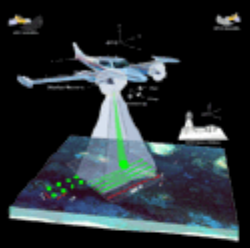
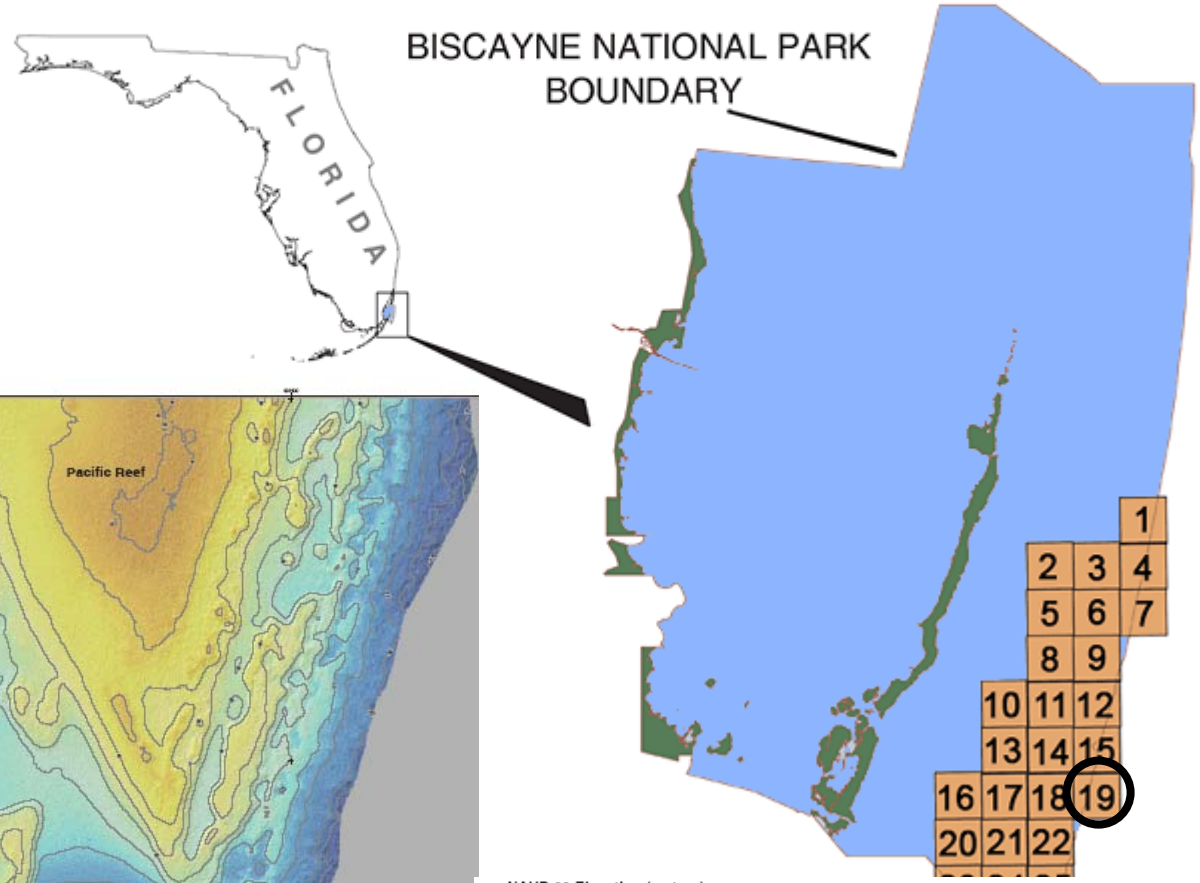
USGS Coastal Project: Decision Support for Coastal Parks, Sanctuaries, and Preserves

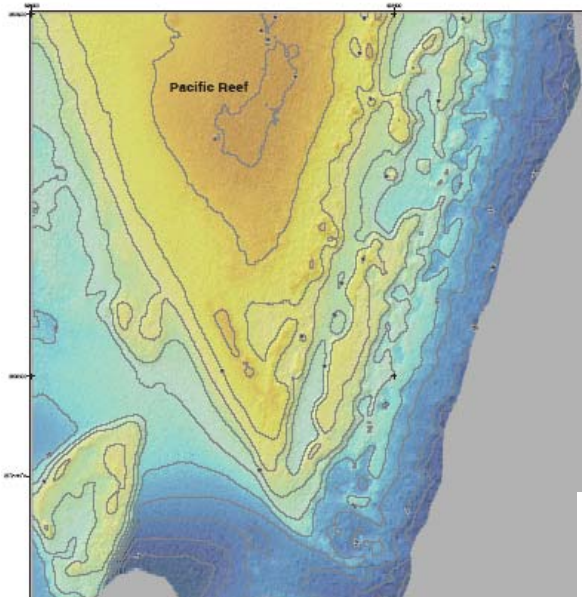
- Enable the systematic publication of detailed submarine and sub-aerial topographic maps
- Assist the Parks in working with lidar data

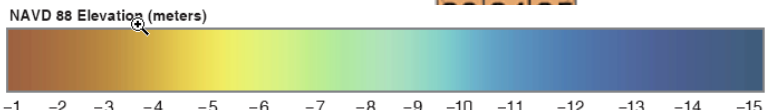


Biscayne National Park

Click on the tile number to view the corresponding map in PDF format







USGS-NPS-NASA EAARL Topography - Dry Tortugas National Park

United States Geological Survey Open File Report OF-2006-1244

John C. Brock[1], C.W. Wright[2], Matt Patterson[3], Amar Nayegandhi[4], and Judd Patterson[3]

This lidar-derived submarine topography map was produced as a collaborative effort between the U.S. Geological Survey (USGS) Coastal and Marine Geology Program, National Park Service (NPS) South Florida/Caribbean Network Inventory and Monitoring Program, and the National Aeronautics and Space Administration (NASA) Wallops Flight Facility. One objective of this research is to create techniques to survey coral reefs for the purposes of habitat mapping, ecological monitoring, change detection, and event assessment (for example: bleaching, hurricanes, disease outbreaks). As part of this project, data from an innovative instrument under development at the NASA Wallops Flight Facility, the NASA Experimental Airborne Advanced Research Lidar (EAARL) are being used. This sensor has the potential to make significant contributions in this realm for measuring water depth and conducting cross-environment surveys. High spectral resolution, water-column correction, and low costs were found to be key factors in providing accurate and affordable imagery to managers of coastal tropical habitats.

Metadata
FAQ

[1] U.S. Geological Survey, Florida Integrated Science Center, St. Petersburg, FL
[2] NASA Wallops Flight Facility, Wallops Island, VA
[3] NPS South Florida Caribbean Network Inventory and Monitoring Program, Miami, FL
[4] ETI Professionals Inc. U.S. Geological Survey, Florida Integrated Science Center, St. Petersburg, FL

Disclaimer

Visualizing and disseminating data in Google Earth

Coastal mapping perspective… more questions

- Should lidar bathymetry mapping be part of the National Lidar Initiative?
  - If so, how deep or offshore should we map?

- Accuracy: Flat, dynamic terrains need higher accuracy than sloping, static terrains.

- Repeatability: Should repeat surveys in coastal zones be done at higher temporal frequency (5 yr time scale?)

Coastal mapping perspective… more questions

- Waveform-digitizing vs. multiple return data? (“dead zone” effect)
- Better understanding of lidar error sources:
  - GPS, IMU, ranging, filtering, datum conversion
- Definition of “raw” data availability?
- Focus on data dissemination and visualization
  - Google Earth or similar application

THANK YOU.

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http://coastal.er.usgs.gov/remote-sensing/

http://lidar.cr.usgs.gov/eaarl/

http://inst.wff.nasa.gov/eaarl/