NASA EAARL System – Principles and Applications

Experimental Advanced Airborne Research Lidar

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USGS science for a changing world

Airborne Lidar Technology and Applications
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NASA

EAARL

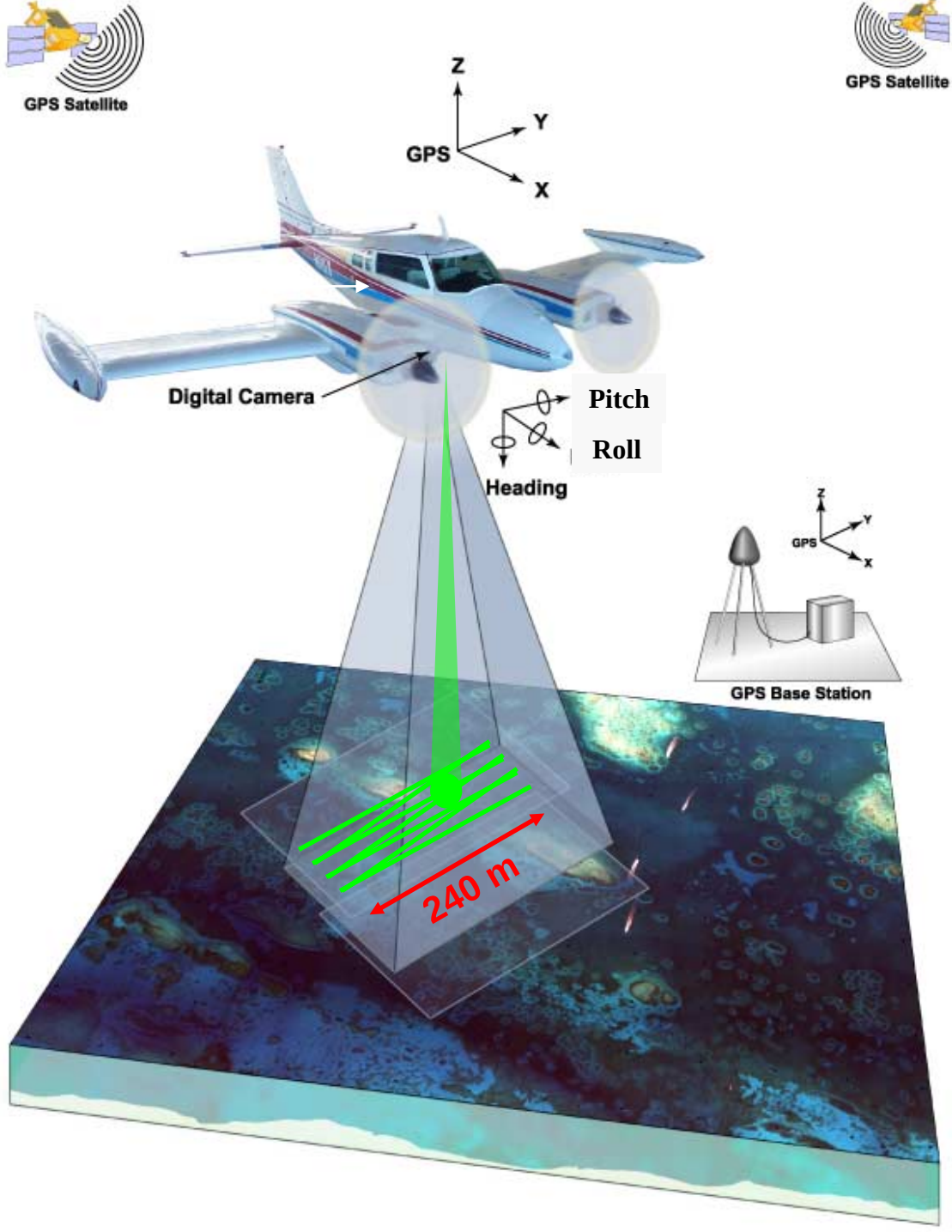
Return Waveforms
(15cm air
11cm water)

Raster scanning
(25 rasters/sec)

Small footprint
(15 cm)
Low power green
laser (70uj, 532 nm)

Adaptive pulse rate
optimization
(5000 Hz Peak)

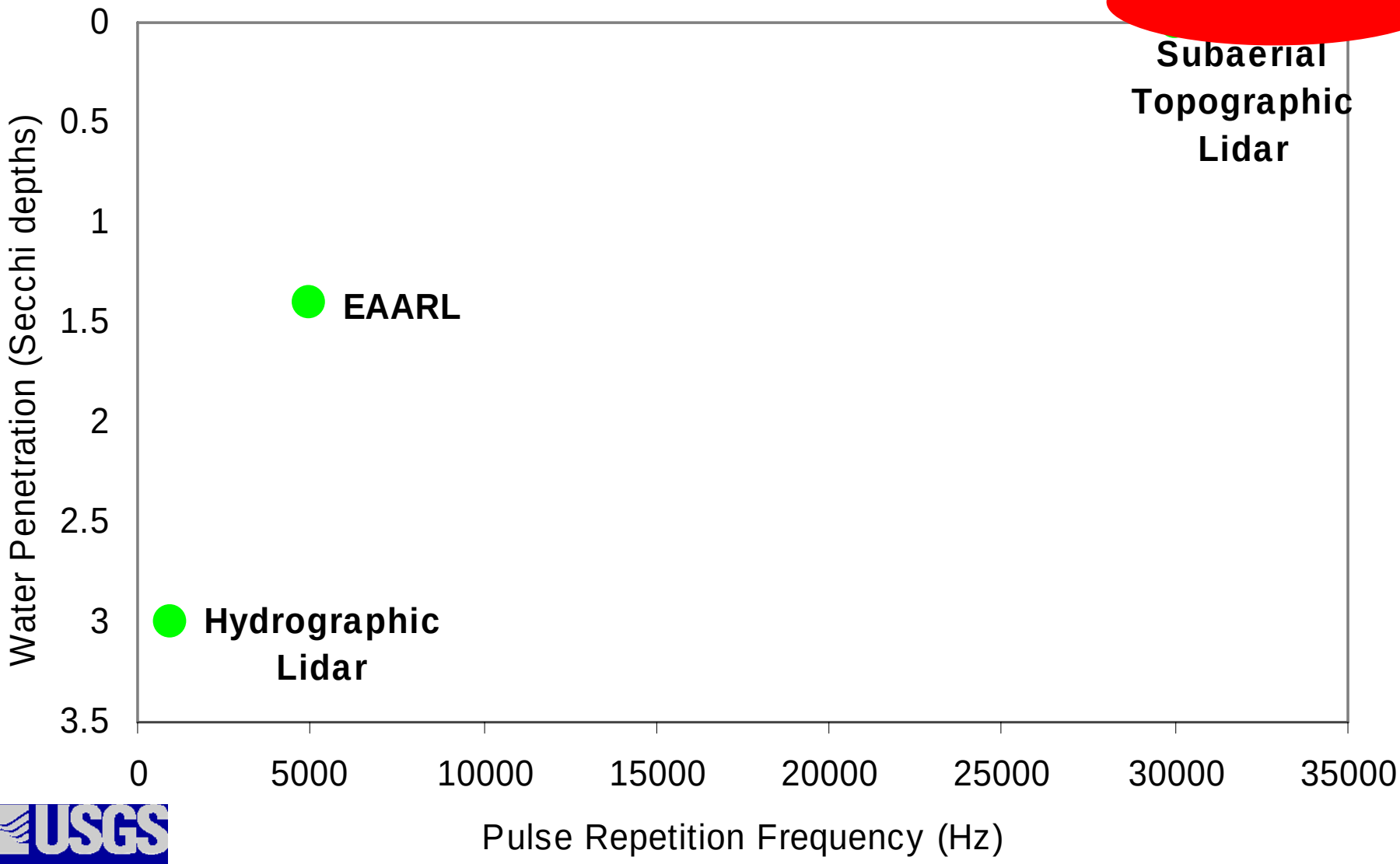
2 x 2.5m spacing



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 includes features of both topographic and hydrographic lidar systems



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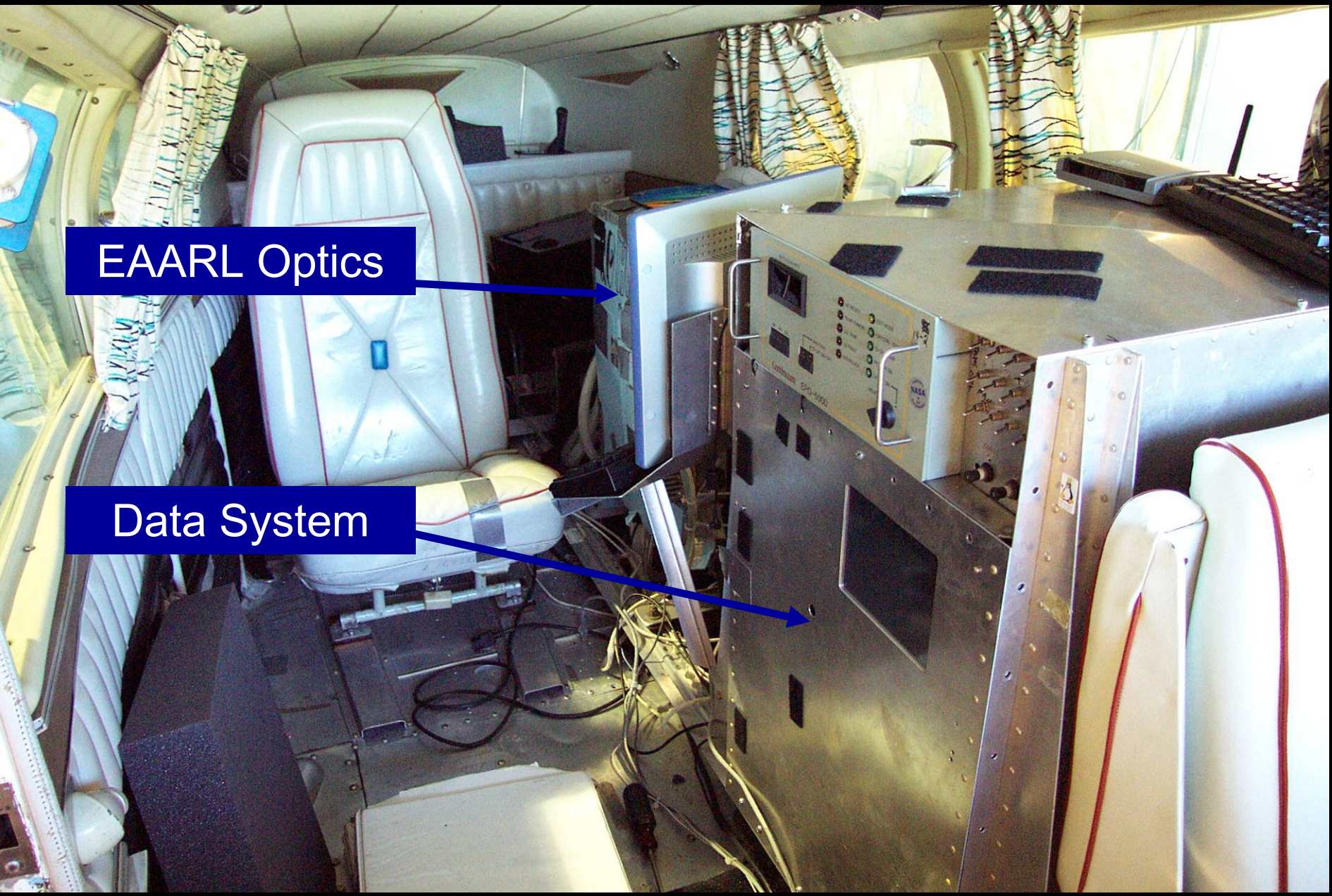
EAARL Operates From Commercially Available Light Aircraft


EAARL Optics
Data System

Basic System Modules

System Control & Pilot Guidance

System Control & Co-Pilot Guidance

GPS Base Station

IMU & Data System

GPS Attitude

GPS

Wireless Lan

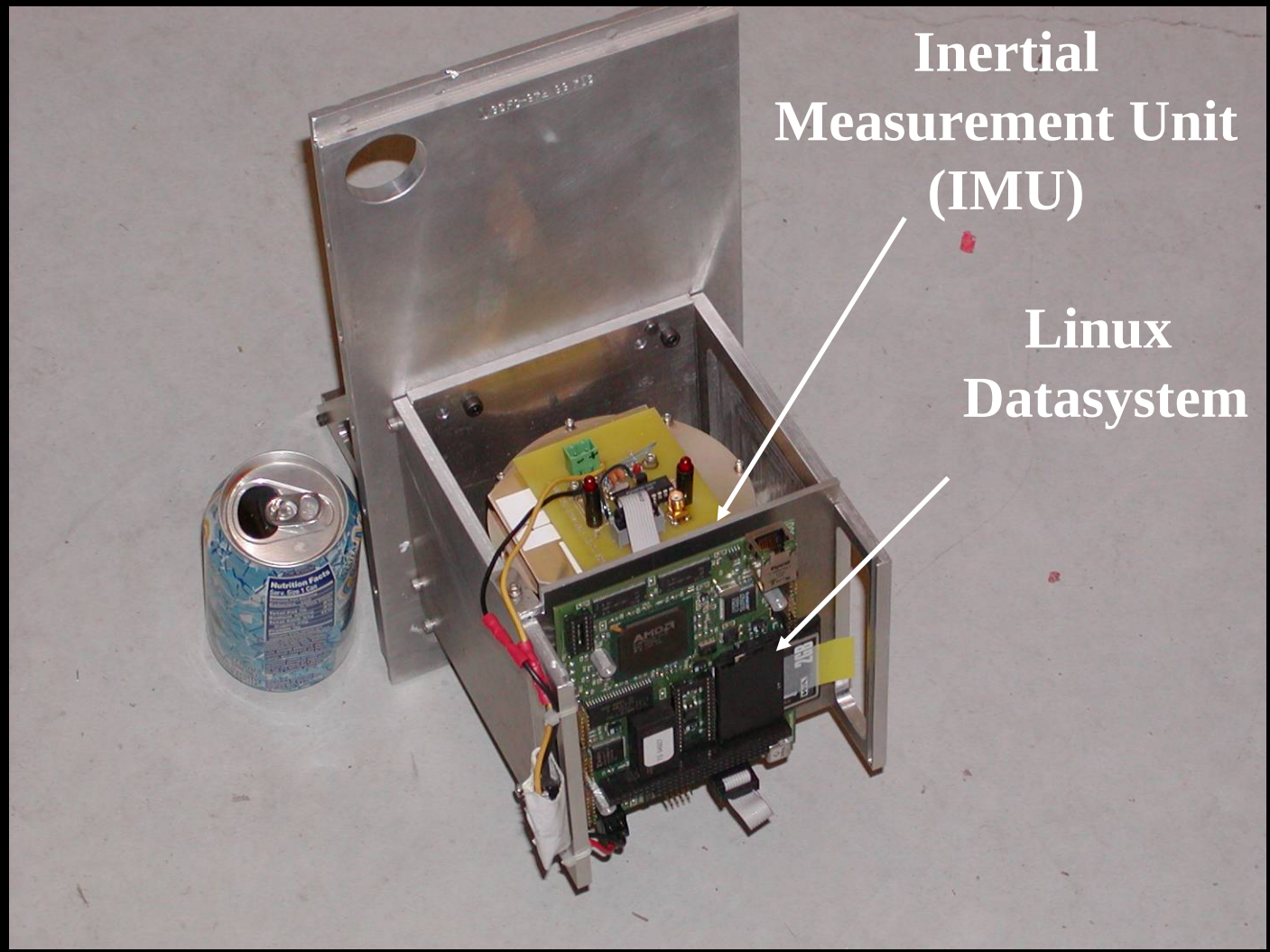
100mb Switched Ethernet LAN

Adaptive Waveform LIDAR System

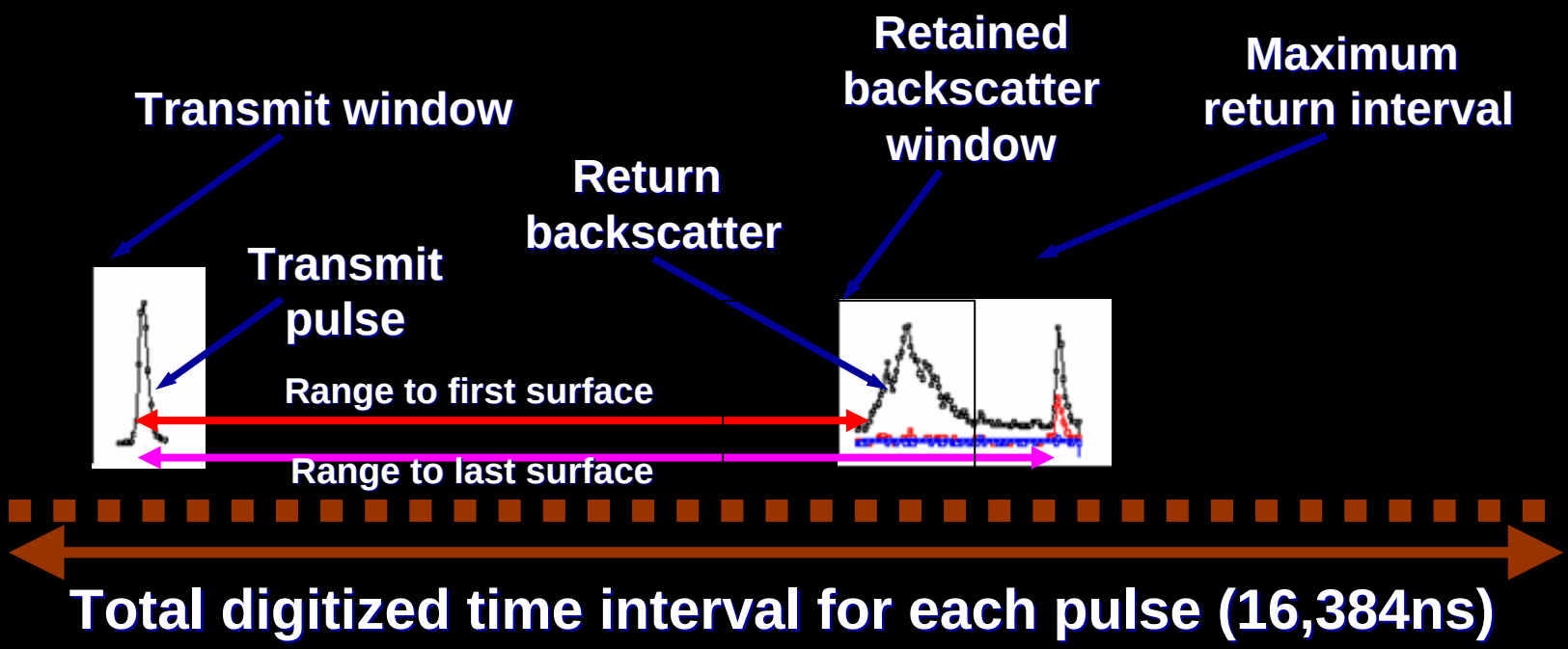
Hi-Res CIR Digital Camera (14cm pixel)

RGB Digital Camera (.7m pixel)

EAARL IMU and Data System

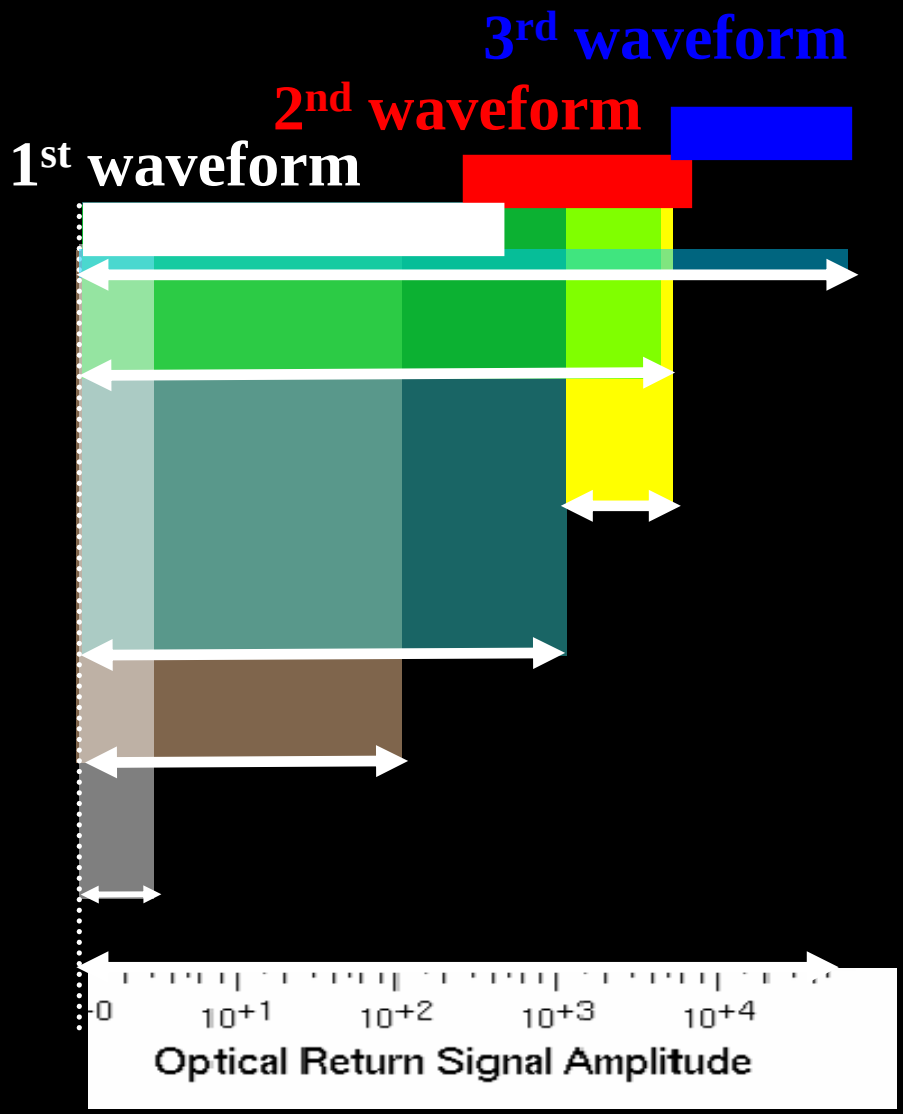


Time Resolved Digitized Waveform Lidar



- Four 8 bit 1 ns-resolution waveforms captured for each laser pulse
- 196 million samples/second
- Realtime signal detection and extraction

Backscattered Signal Distribution



Water surface Fresnel reflection

Submerged topo signals

Beach Sand

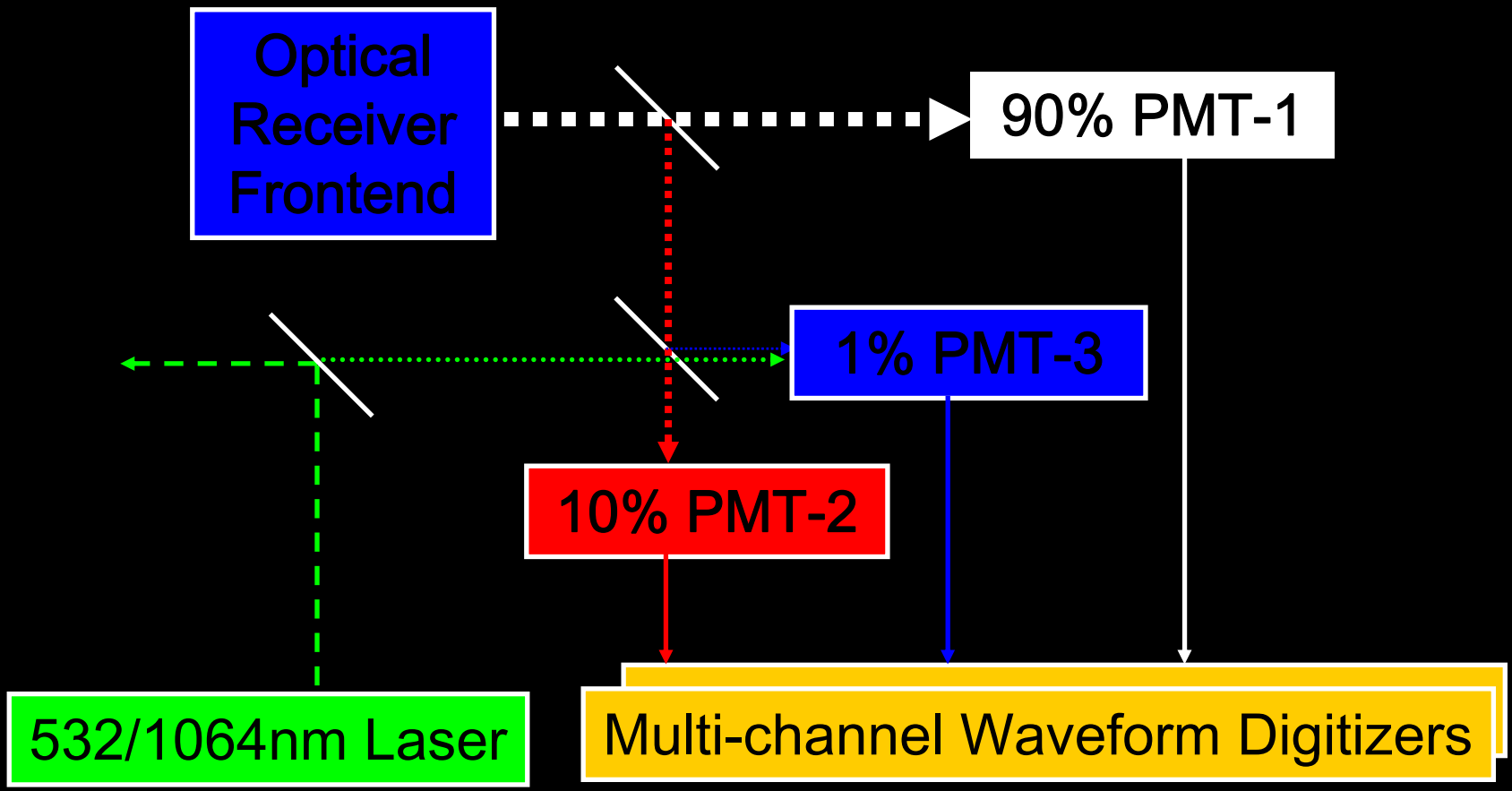
Subaerial Vegetation

Turbid Water column

Clear Water column

44 dB range (0-25,000)

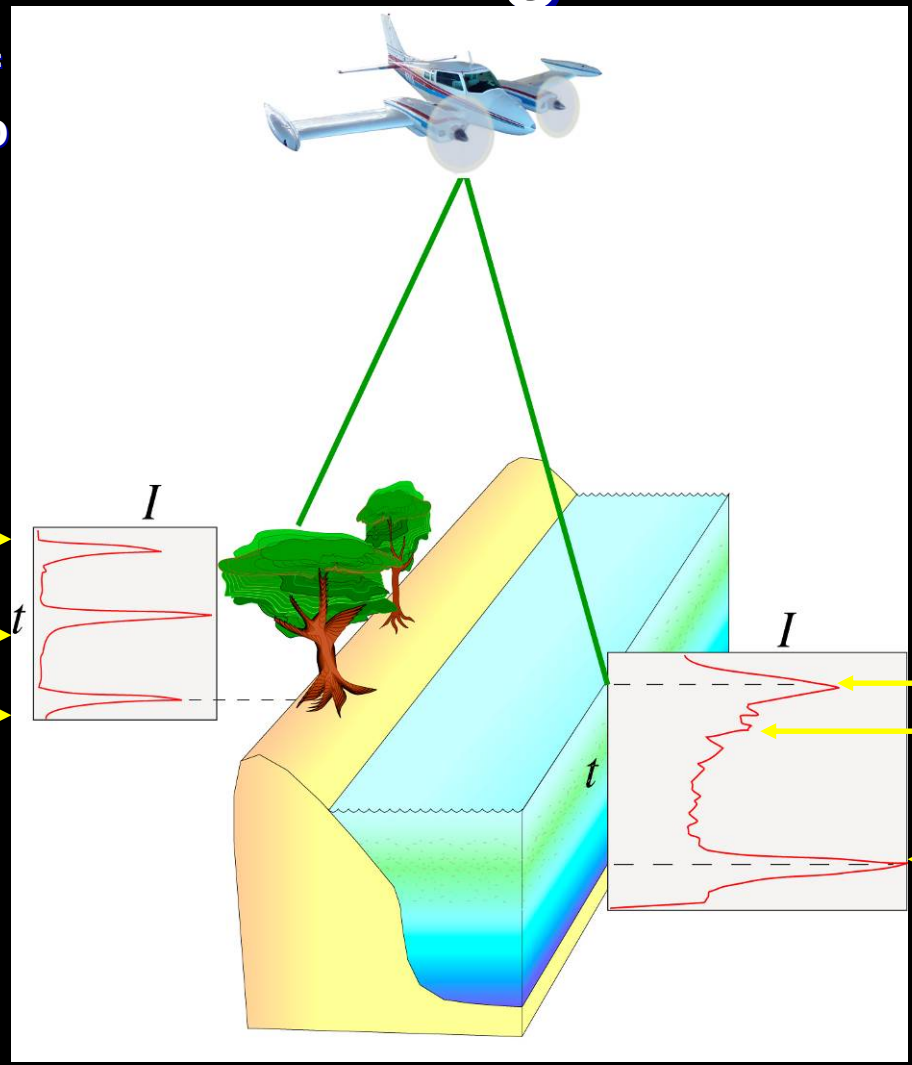
EAARL Laser Return Optics



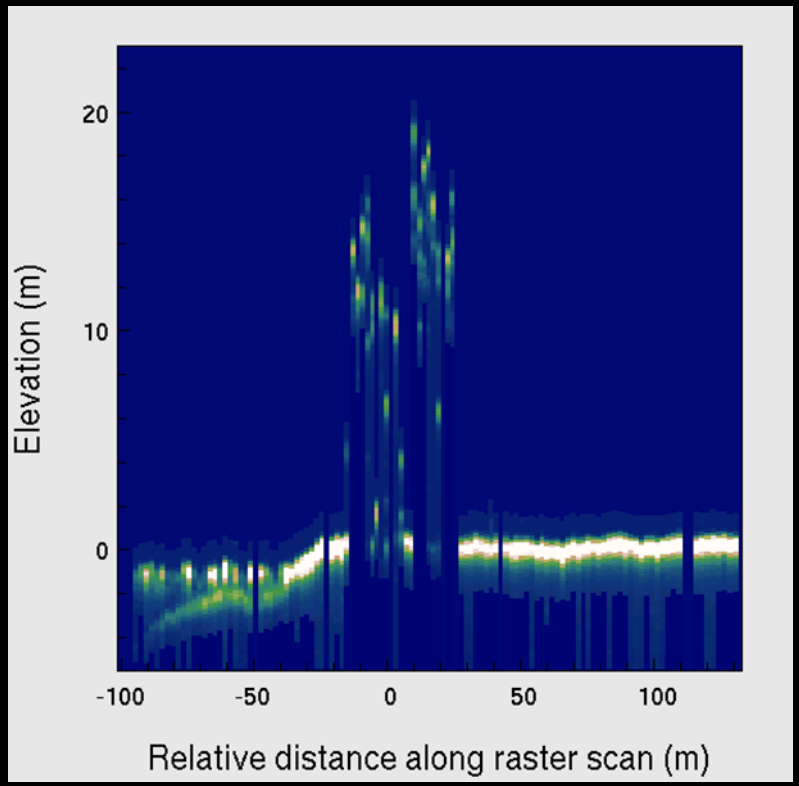
Unique capabilities of a green waveform-resolving lidar

A time sampling interval of 1 nanosecond translates to range digitization at these resolutions:

- **15 cm in air**
- **11 cm in water**

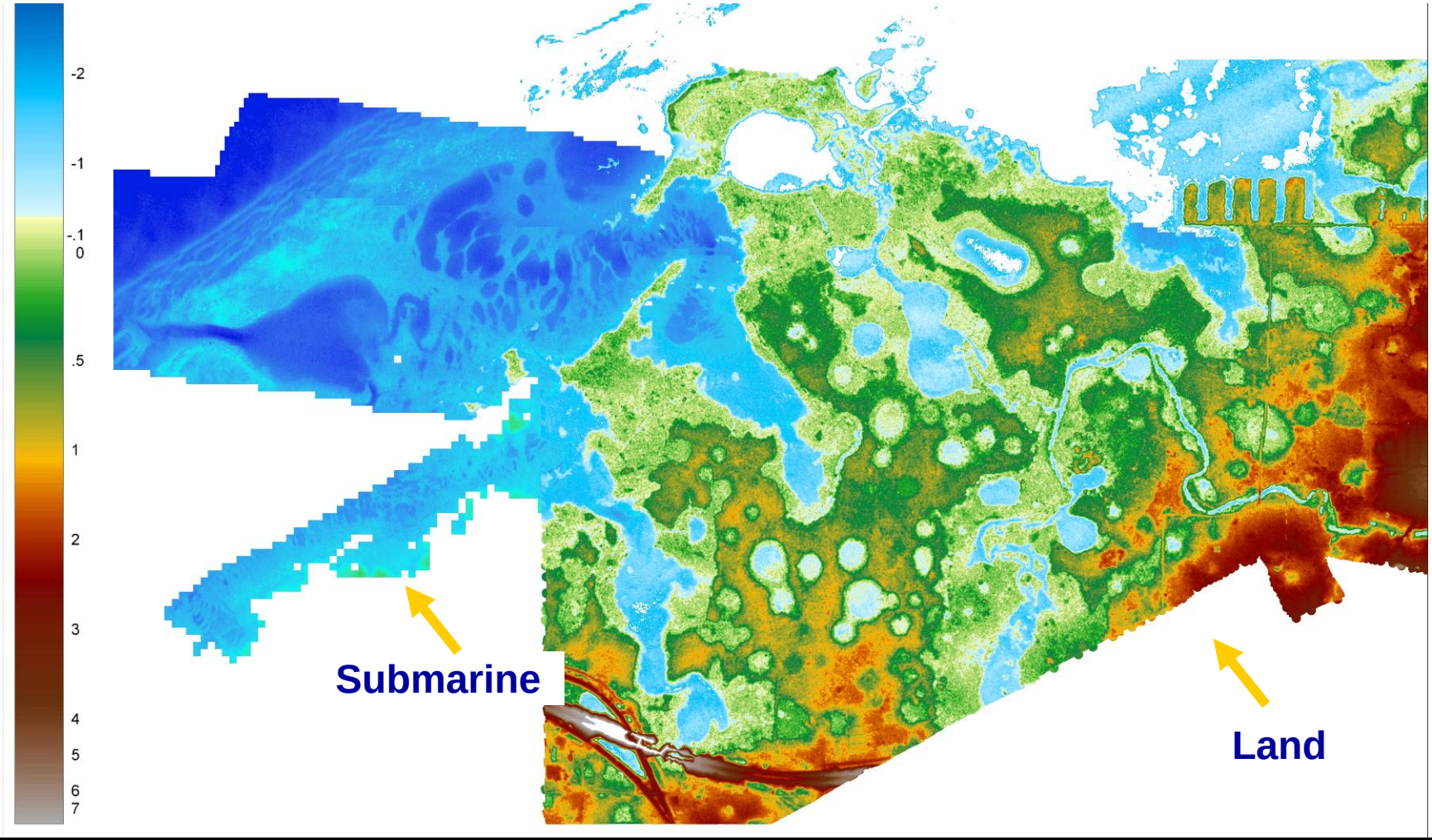


Here is an example of “cross environment” surveying:

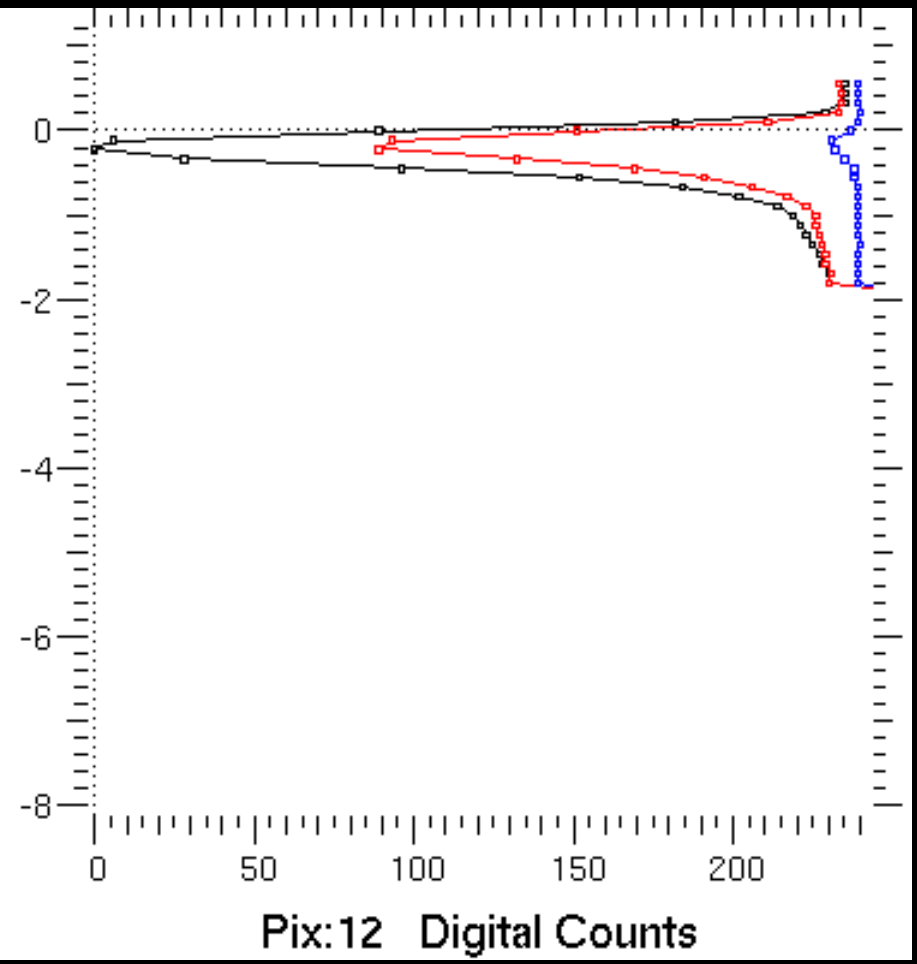


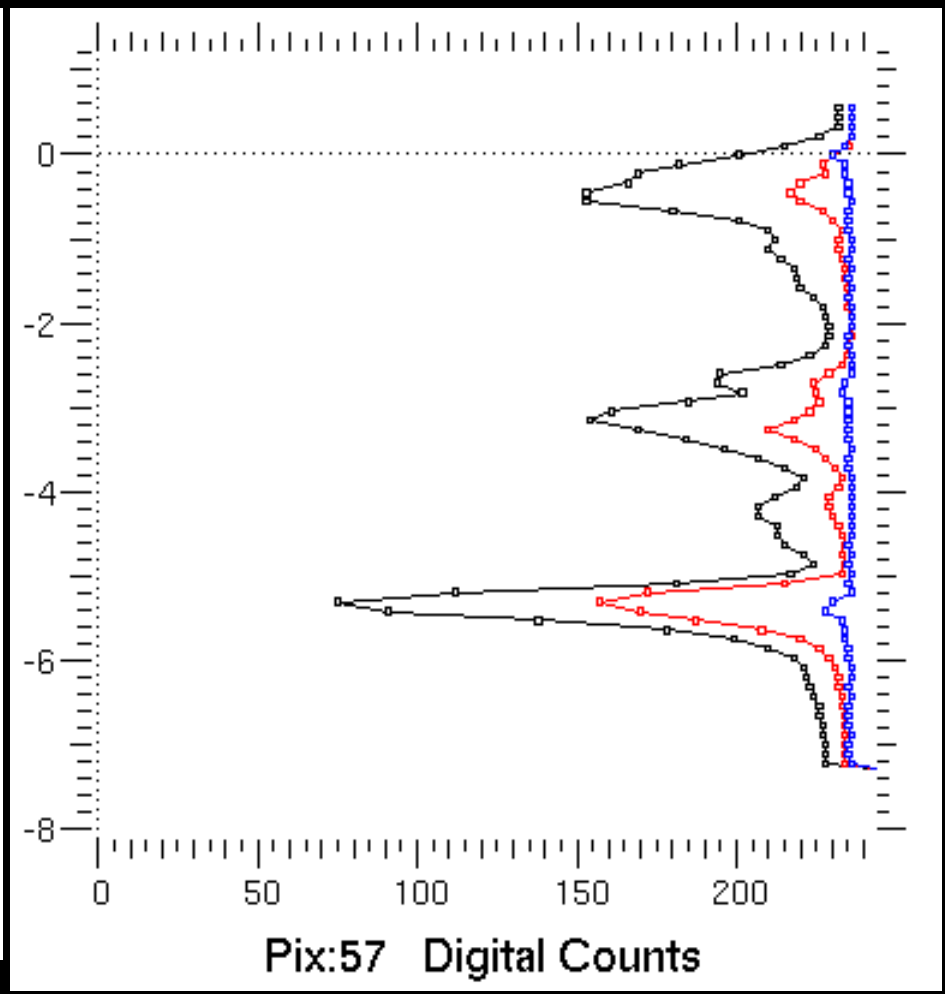
EAARL Raster, Tampa Bay, FL.

BASELINE TOPOGRAPHIC MAPPING
Terra Ceia, Tampa Bay

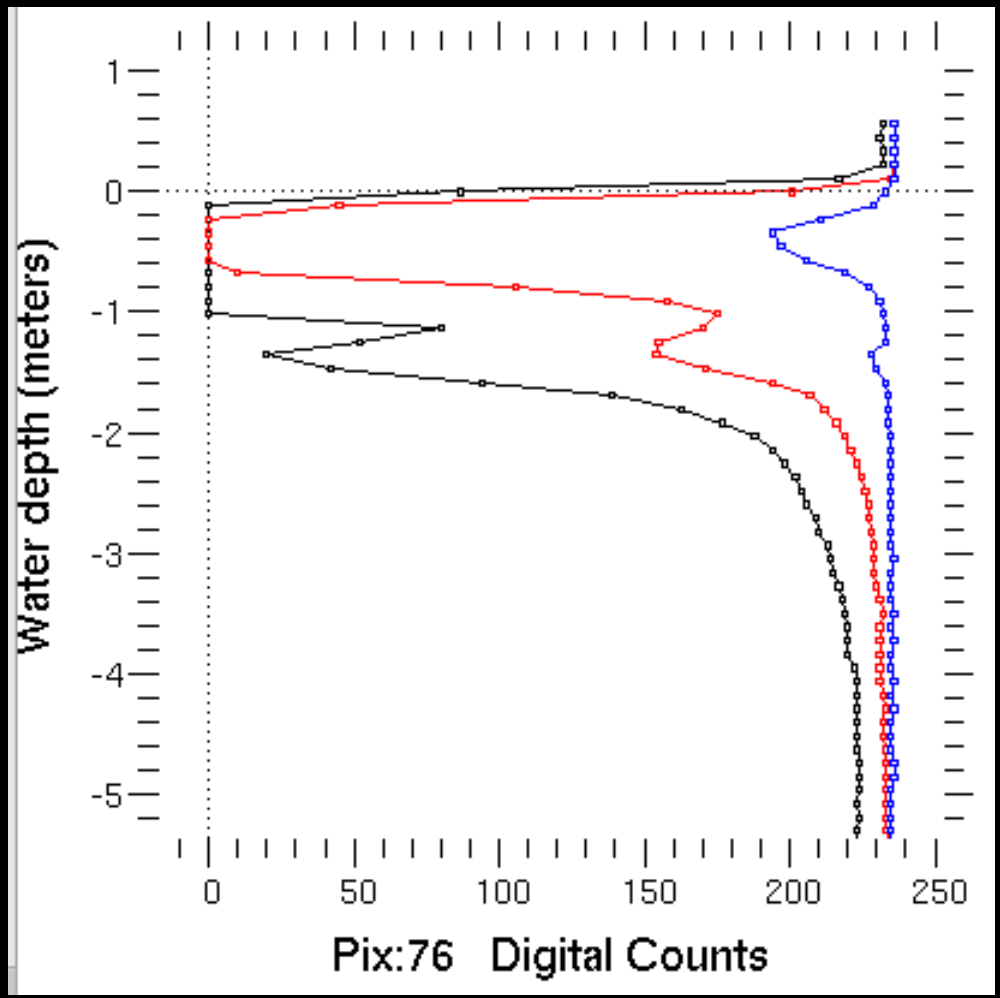


Adaptive Waveform Backscatter Signals



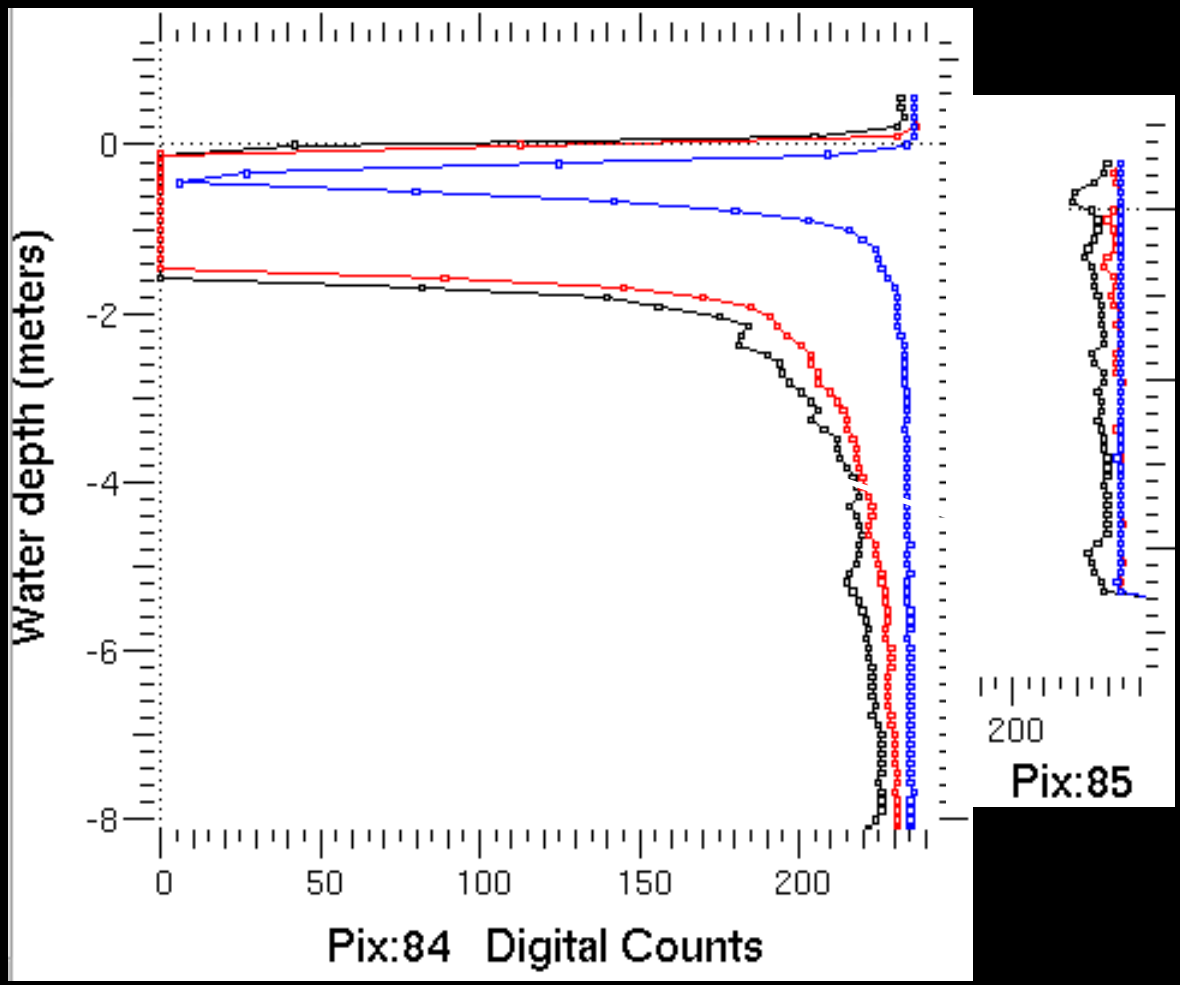


Strong Water Surface



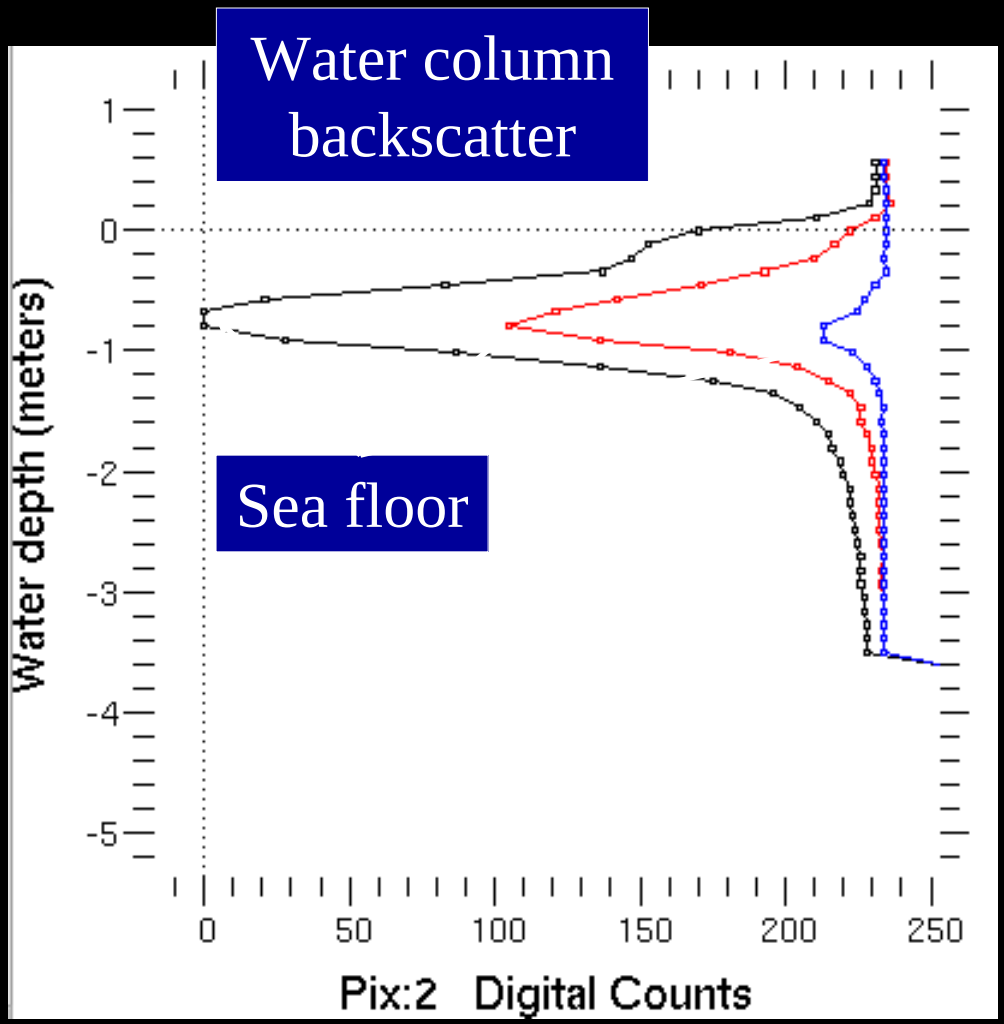
- Convolved weaker bottom signal in channels wf-1&wf-2
- Wf-1 & wf-2 off scale
- Wf-3 provides usable surface and bottom signal

Very Strong, and Very Weak Within 2m Horizontal



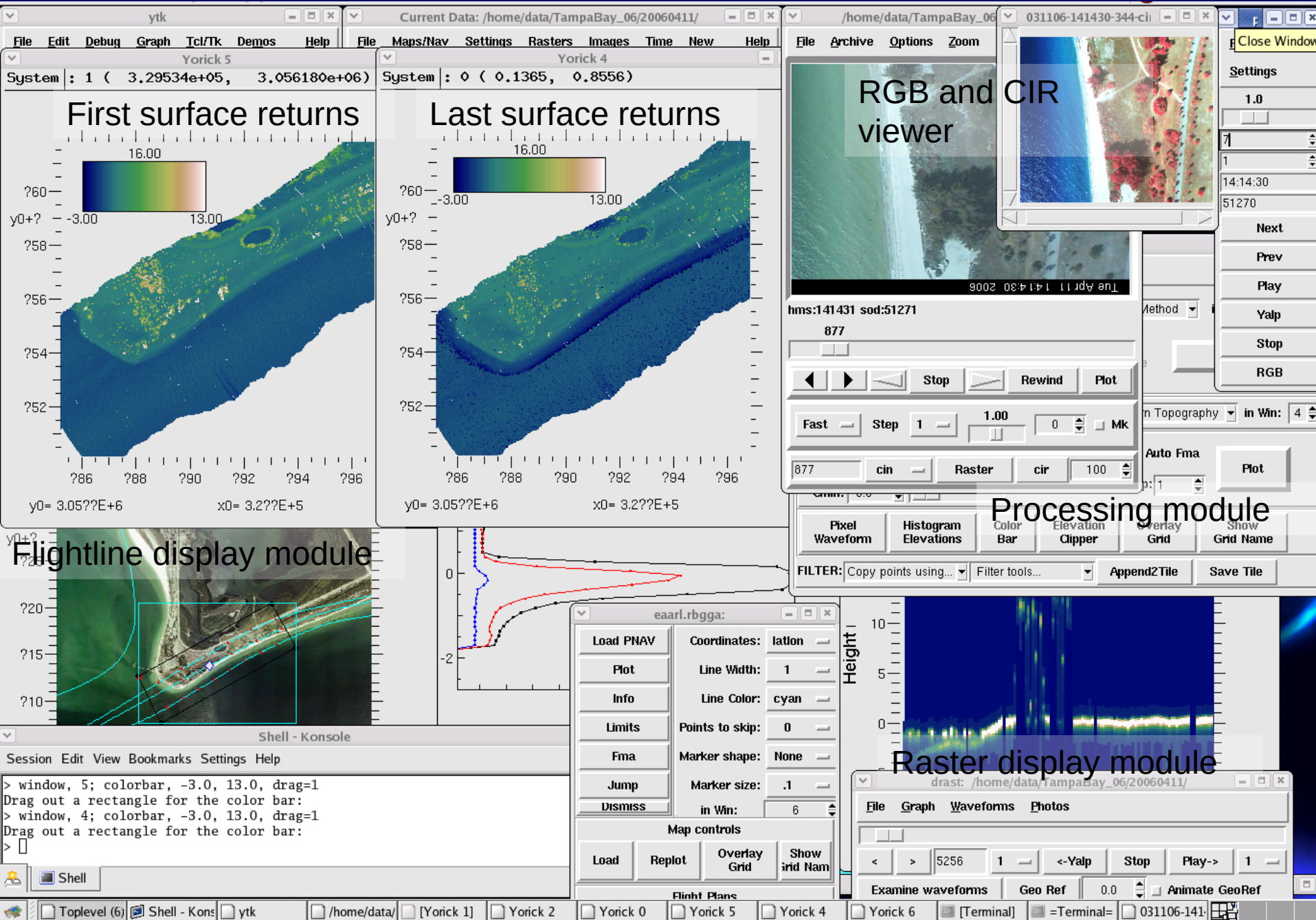
- Undistorted signal recovered from wf-3
- Wf-1 provides weak but usable bottom signal at 5m

Weak Surface/volume, Strong Bottom



- Convolved weak surface signal in wf-1 & wf-2
- Wf-1 provides usable surface and wf-3 provides usable sea floor signal

The Airborne Lidar Processing System (ALPS)

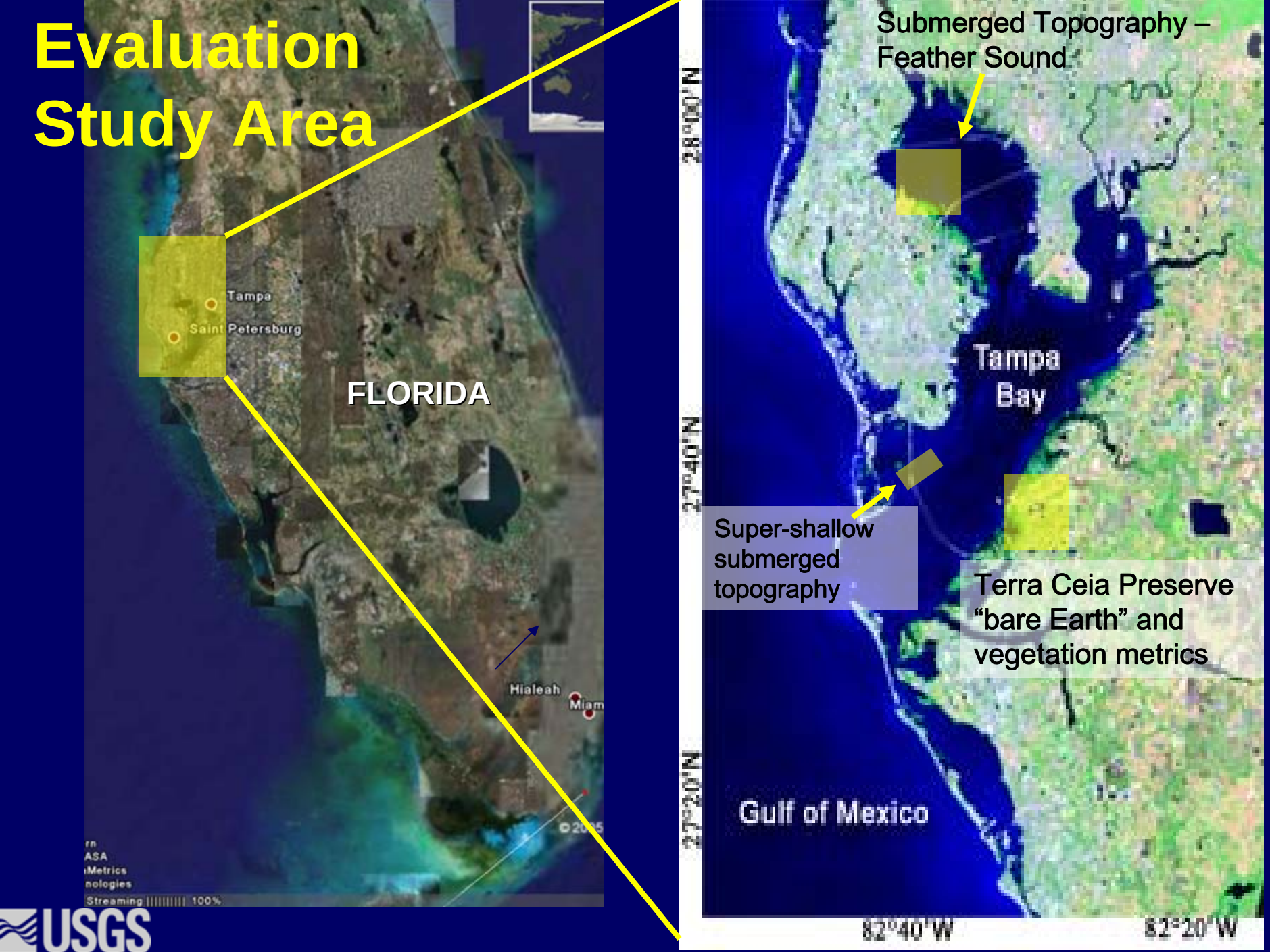


NASA EAARL Projects

- 100 missions completed last 36 months
- 2 billion waveforms collected
- 2 million geolocated digital photos
- Coral reef mapping
  - Florida Keys, Dry Tortugas, Puerto Rico, St. Croix, St. John
- Alluvial river mapping
  - Platte River, Ne
- Coastal Bays
  - Tampa Bay, Ft. Myers bay
  - Sea grass
- Coastal Erosion
  - NE barrier islands
  - Hurricane impact response
- Vernal Ponds
  - Delaware Wtr Gap, Pa
- Vegetation and Bare Earth mapping
  - Phragmites – De.
  - Mangroves – PR, Fla.
  - Tropical forests UVI, PR
  - Coastal veg – ASIS, DE
- Horseshoe crab habitat mapping - DE

Evaluation of Submerged and Sub-aerial Topography

Evaluation Study Area



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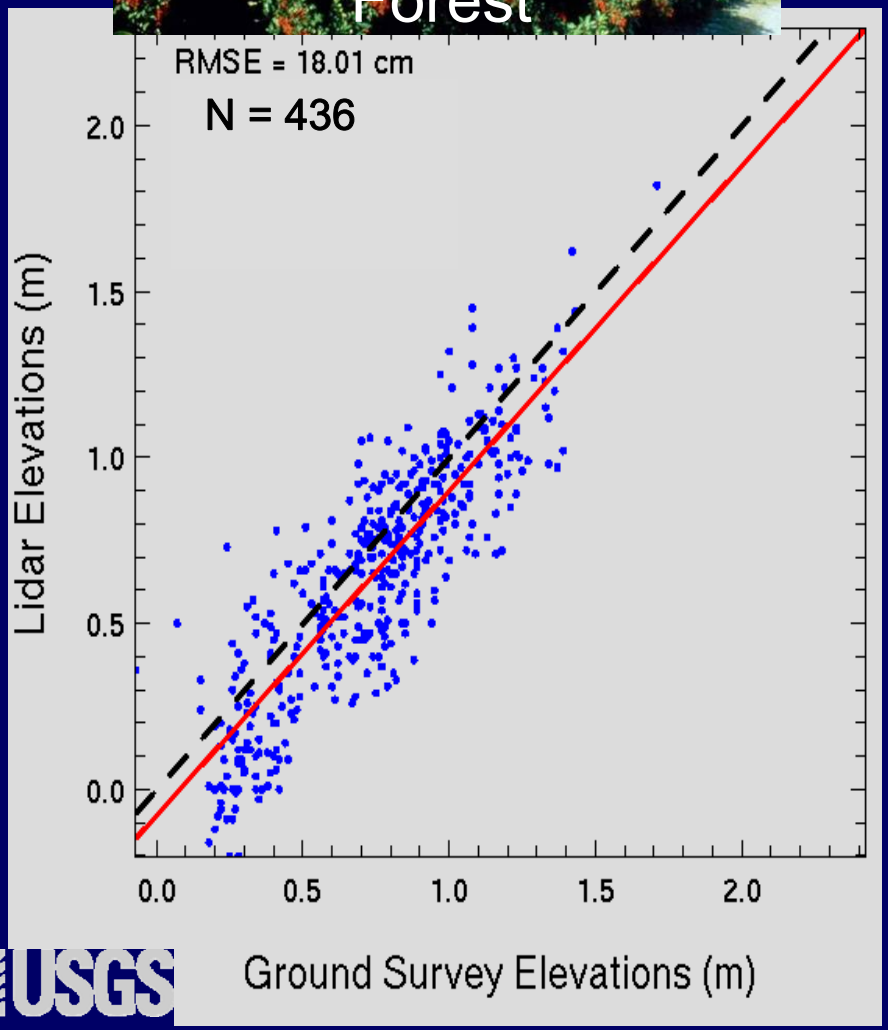
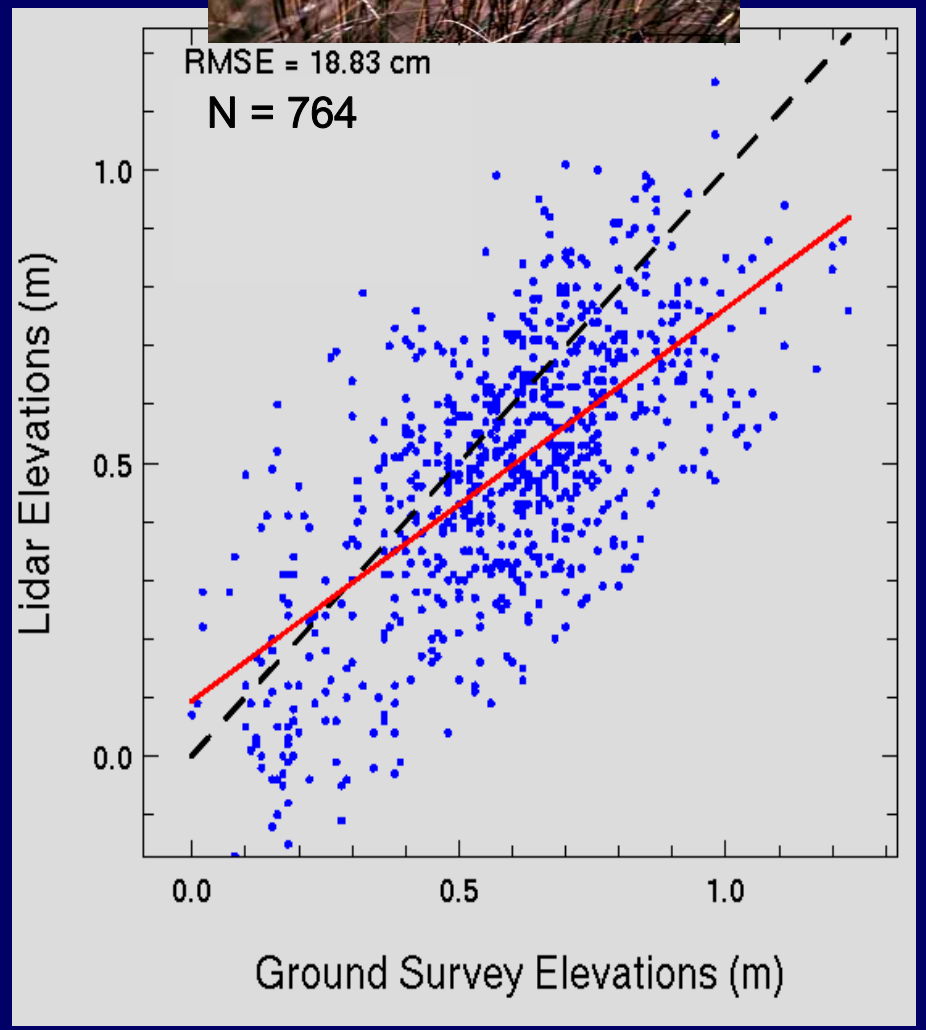
Correspondence Plots

Bare Earth Topography





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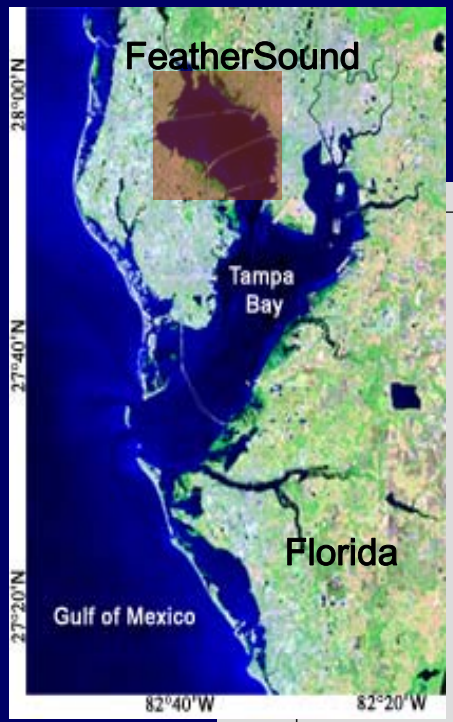
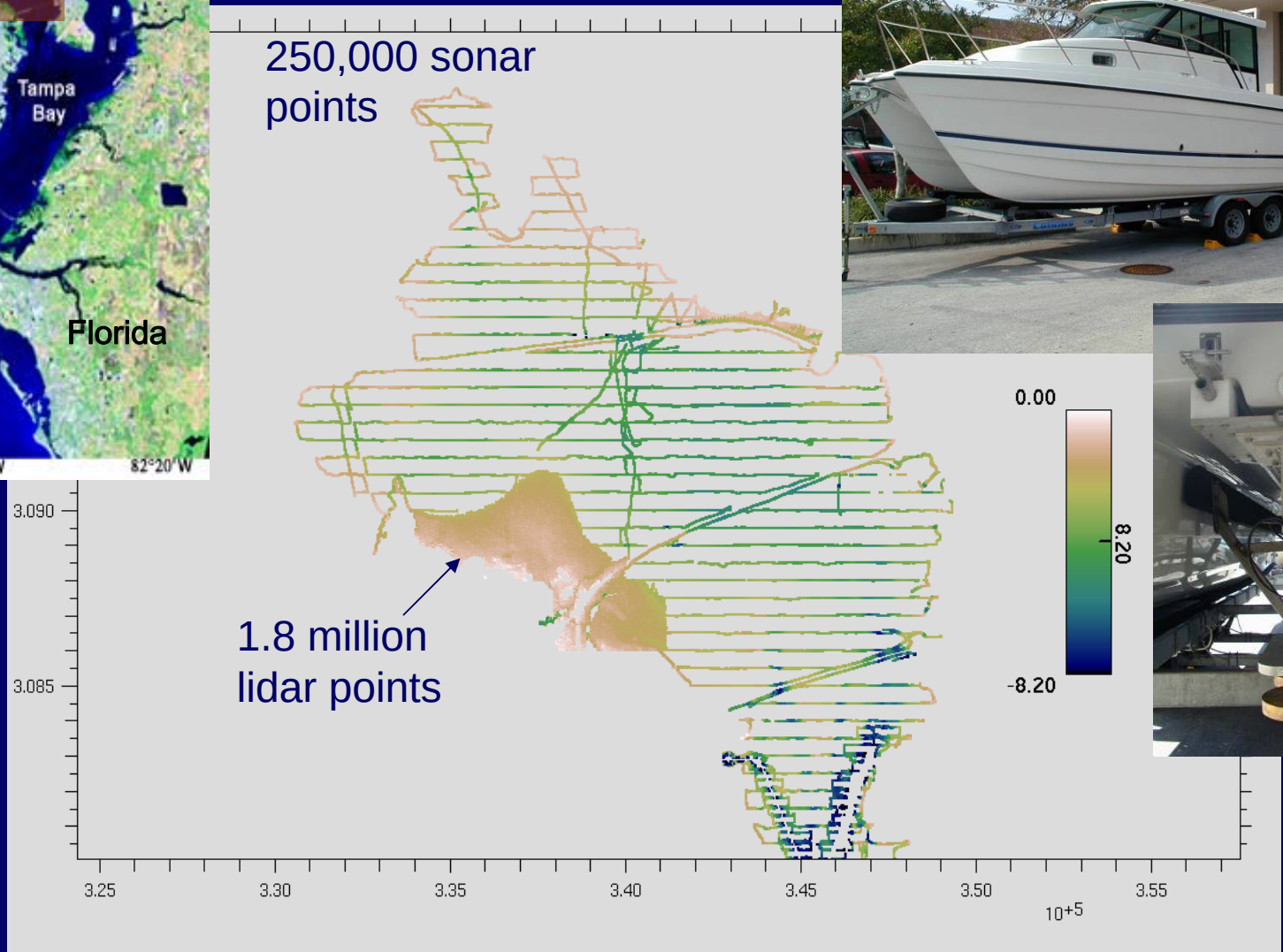
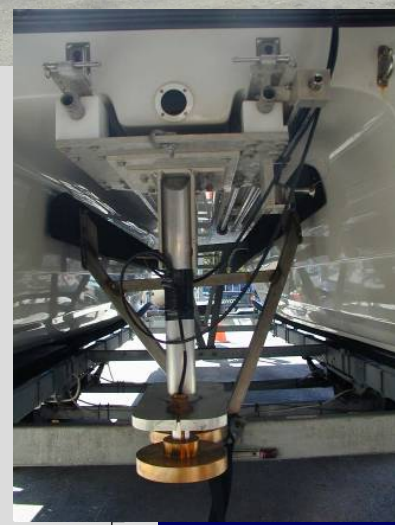
Evaluating submerged topography at Feather Sound using a boat-based sonar system



250,000 sonar points

1.8 million lidar points





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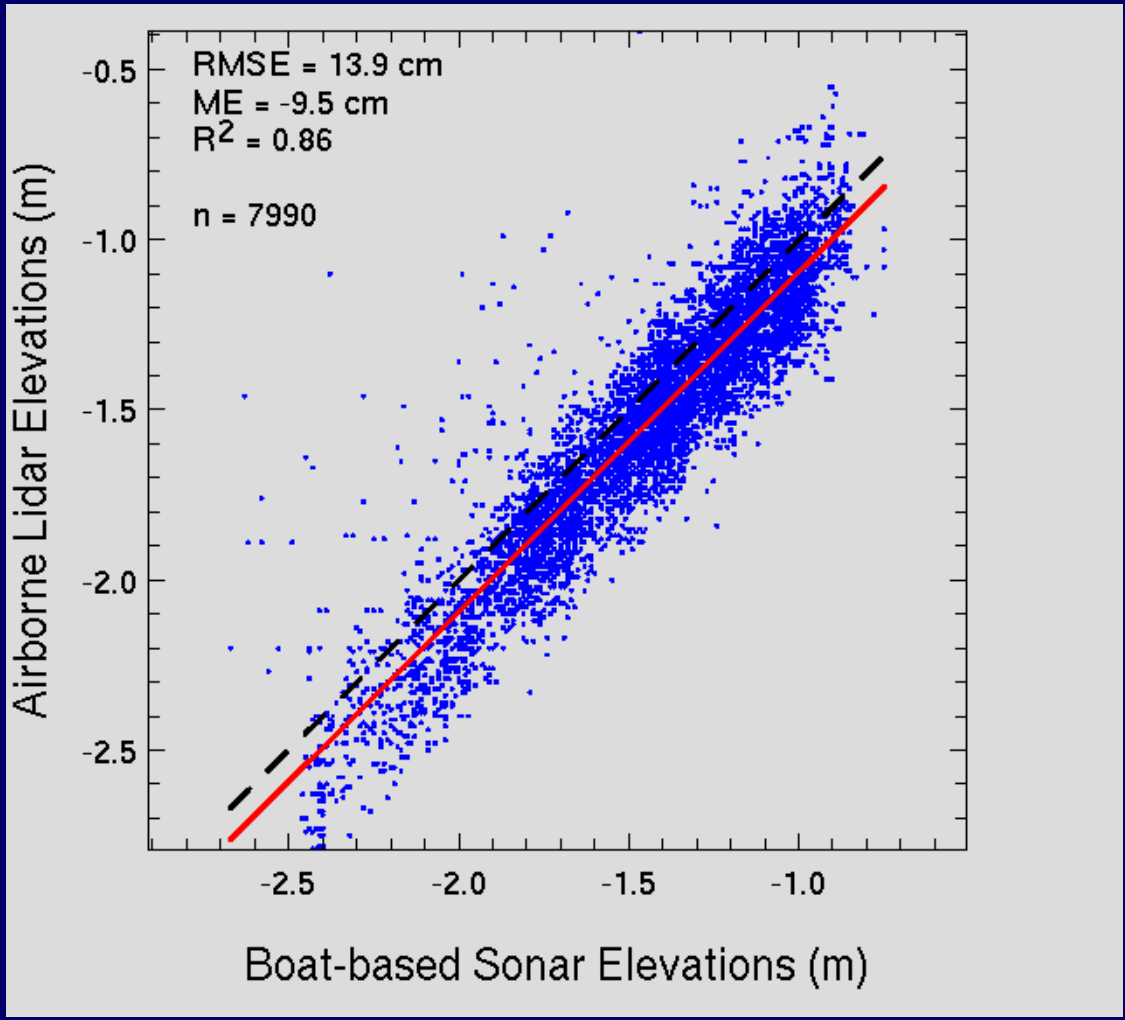
Lidar – Sonar comparison

Correspondence Plot



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Evaluating “super shallow” submerged topography using GPS total station in Tampa Bay

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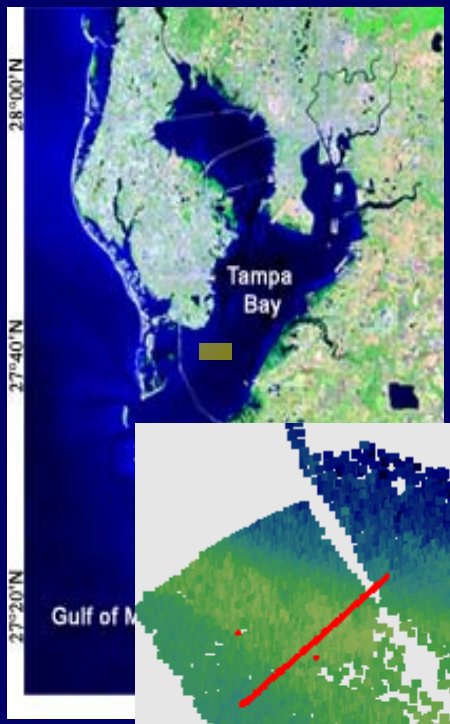
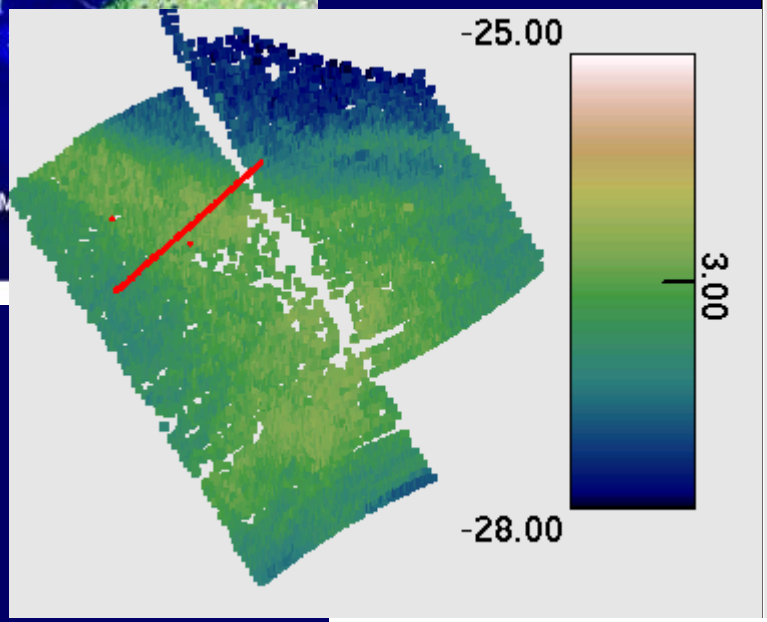
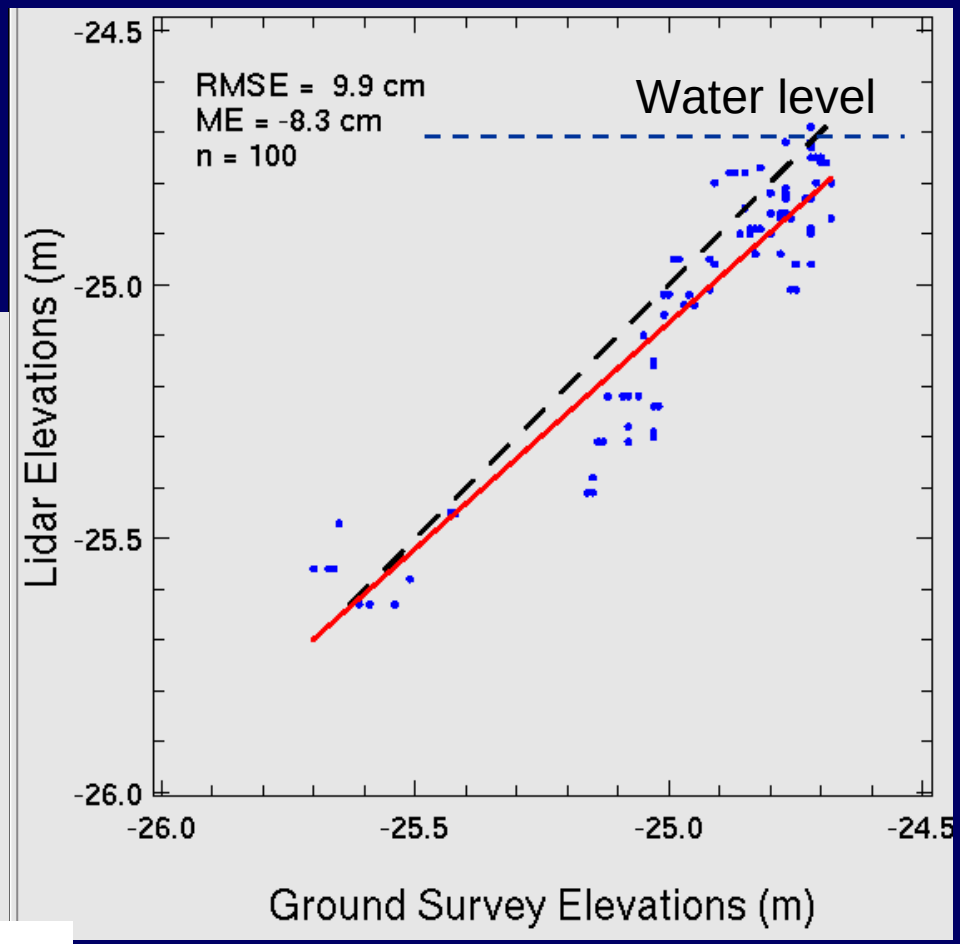
Evaluating “super shallow” submerged topography using GPS total station in Tampa Bay





Ground surveyed points

Correspondence Plot



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Braided River Channels

COMPLEX SURFACES

- **Sandbed –dynamic – avian habitat**
- **Bare and vegetated (sandbars / islands)**
- **Forested floodplains and riparian areas**

SURVEYING TECHNIQUES

- **Boat w/ echo-sounder – too shallow**
- **Wading w/ RTK GPS - accurate but time consuming**
- **Remote Sensing ? Lidar?**

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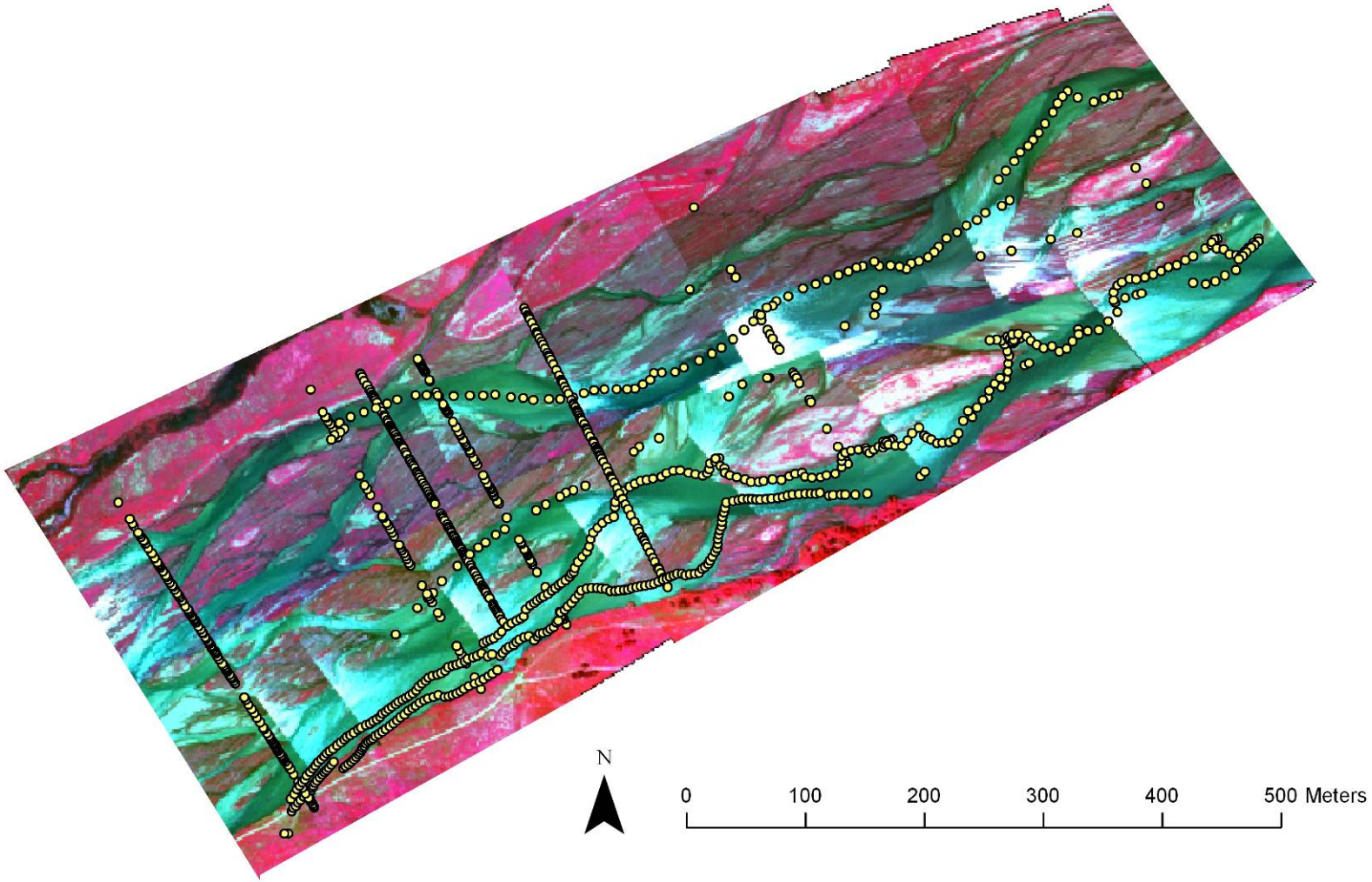
Images and Analyses courtesy Paul Kinzel, USGS

NASA

Rowe Sanctuary (6-15-05) - RTK-GPS Ground Survey Points



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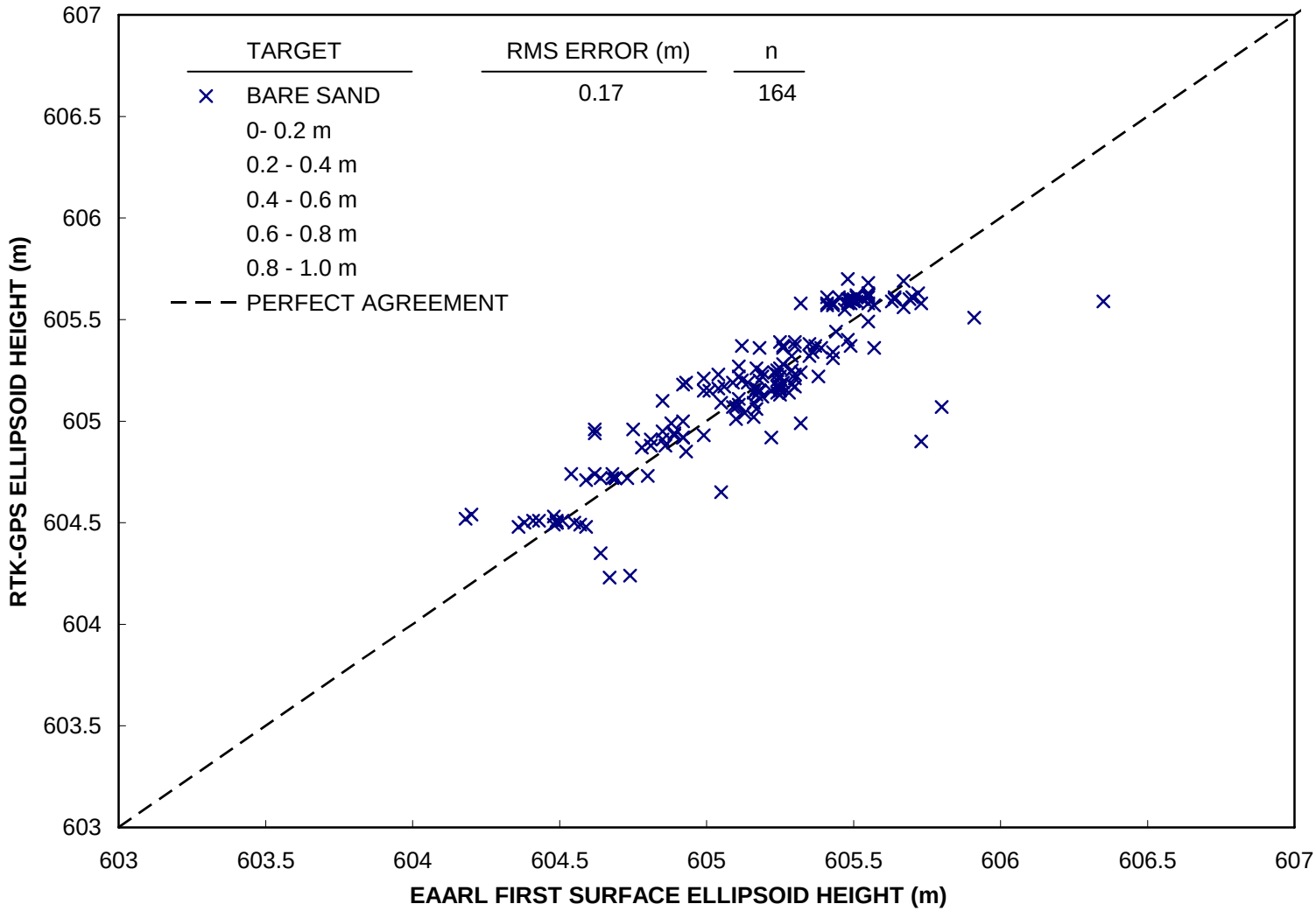
GROUND-TRUTH COMPARISON



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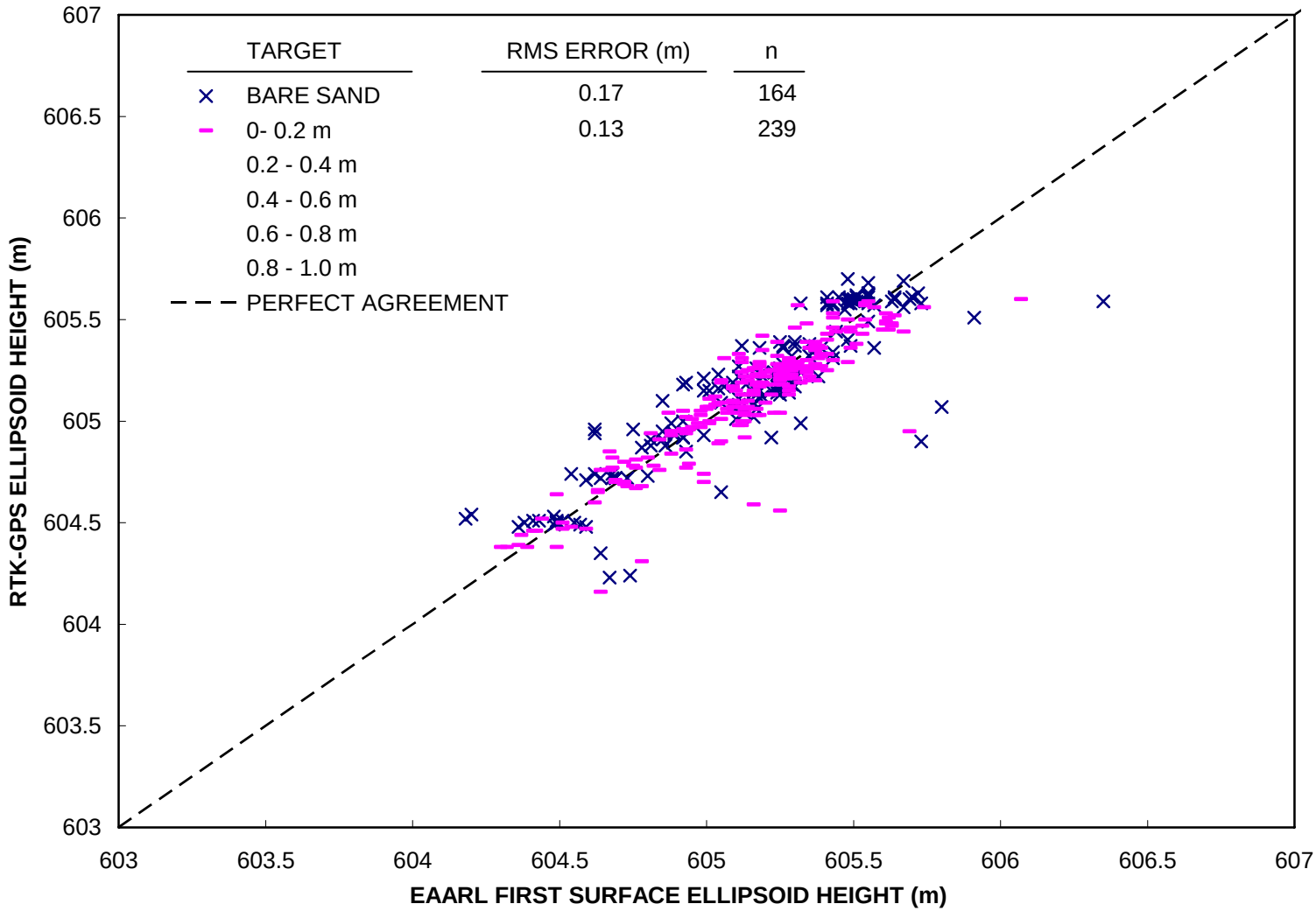
GROUND-TRUTH COMPARISON



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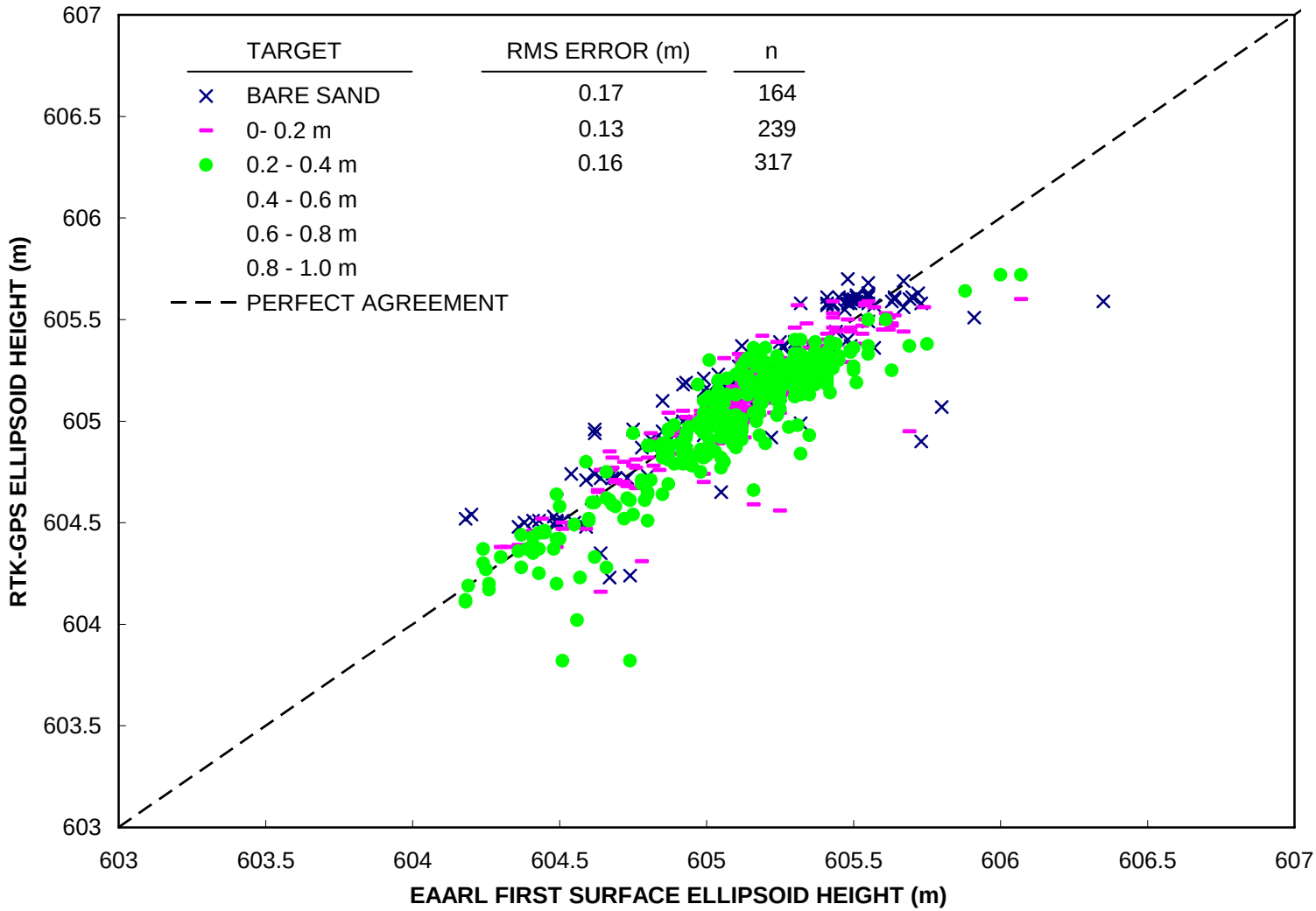

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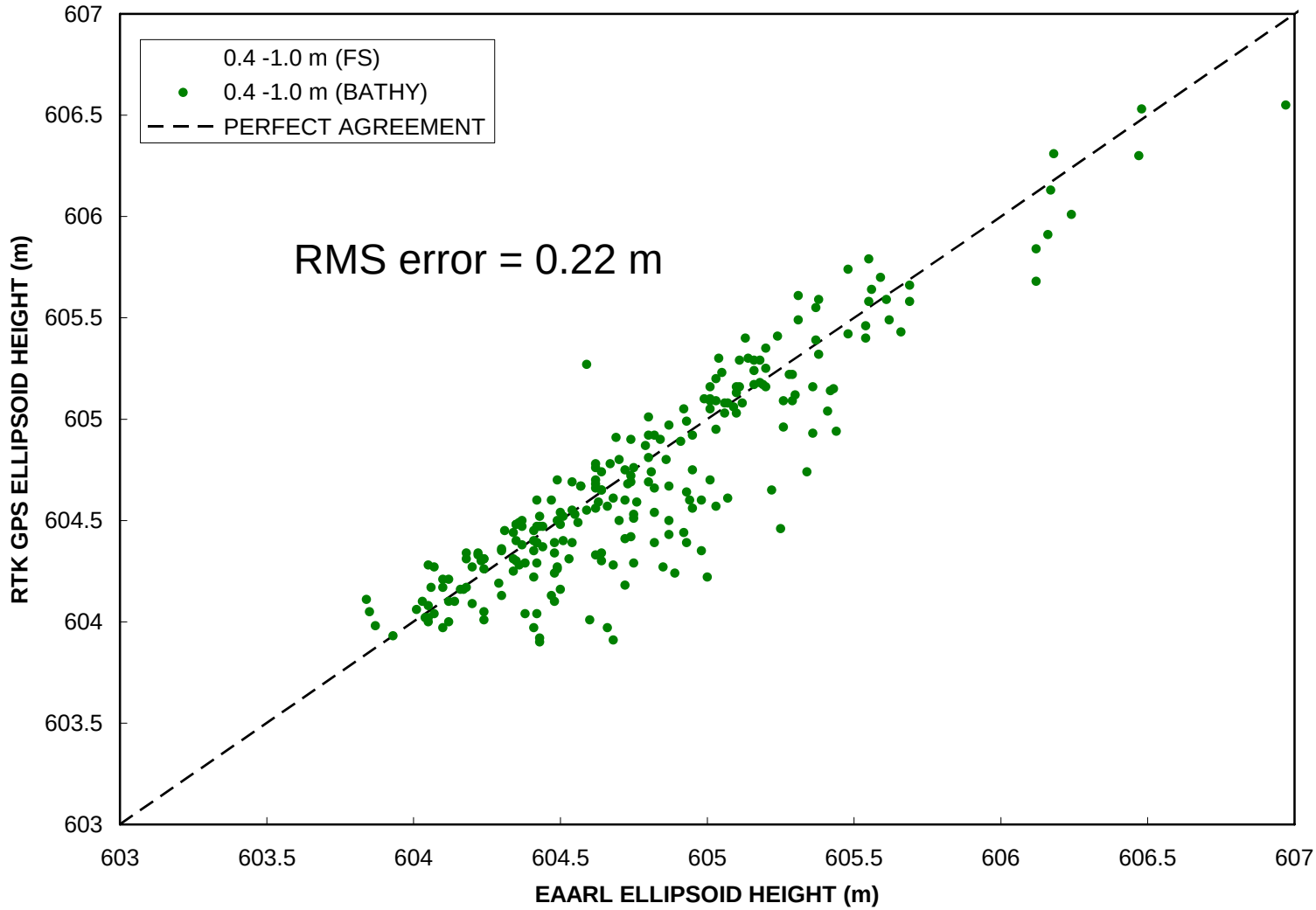
GROUND-TRUTH COMPARISON



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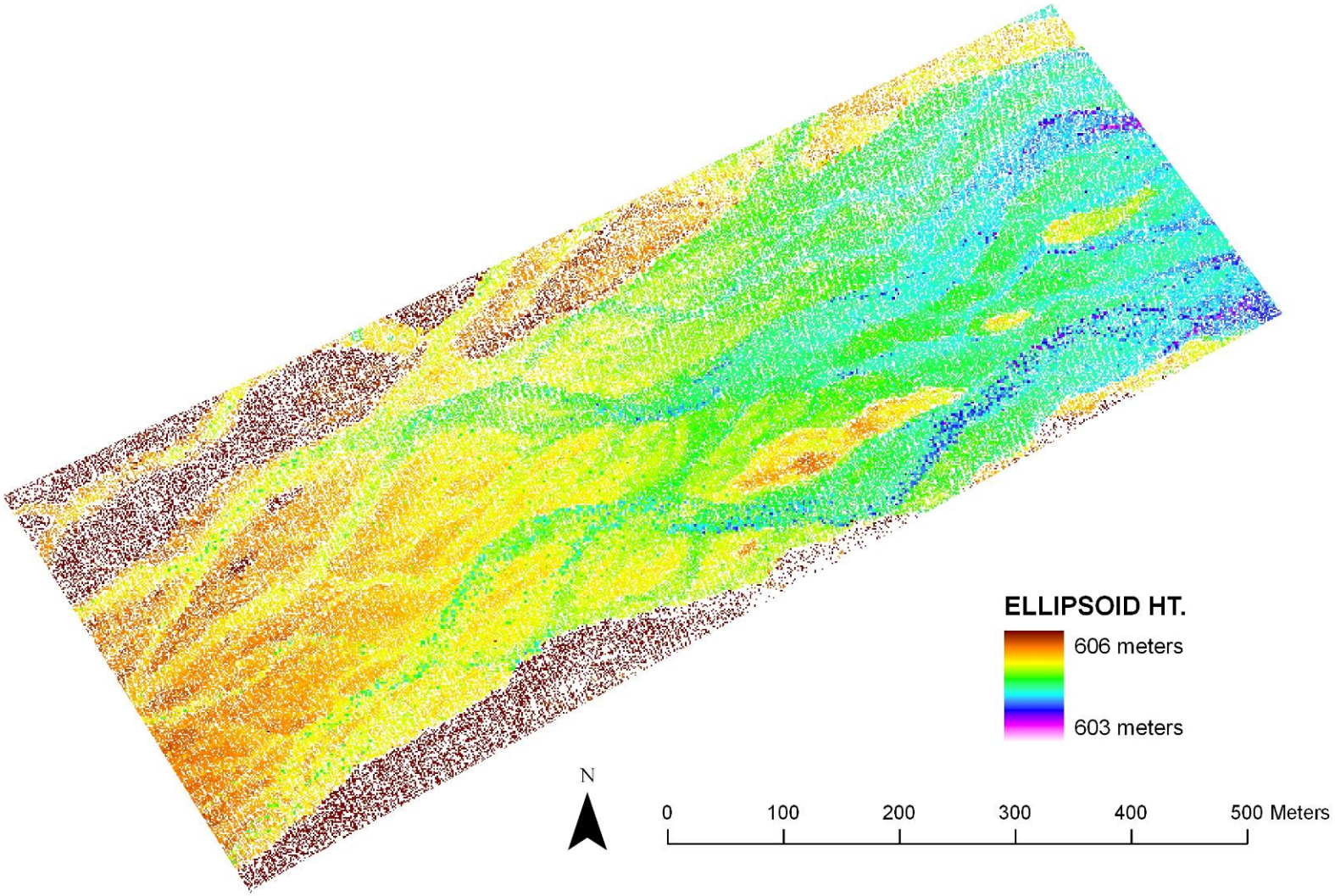
Bare Earth and Bathy Ellipsoid Height Map



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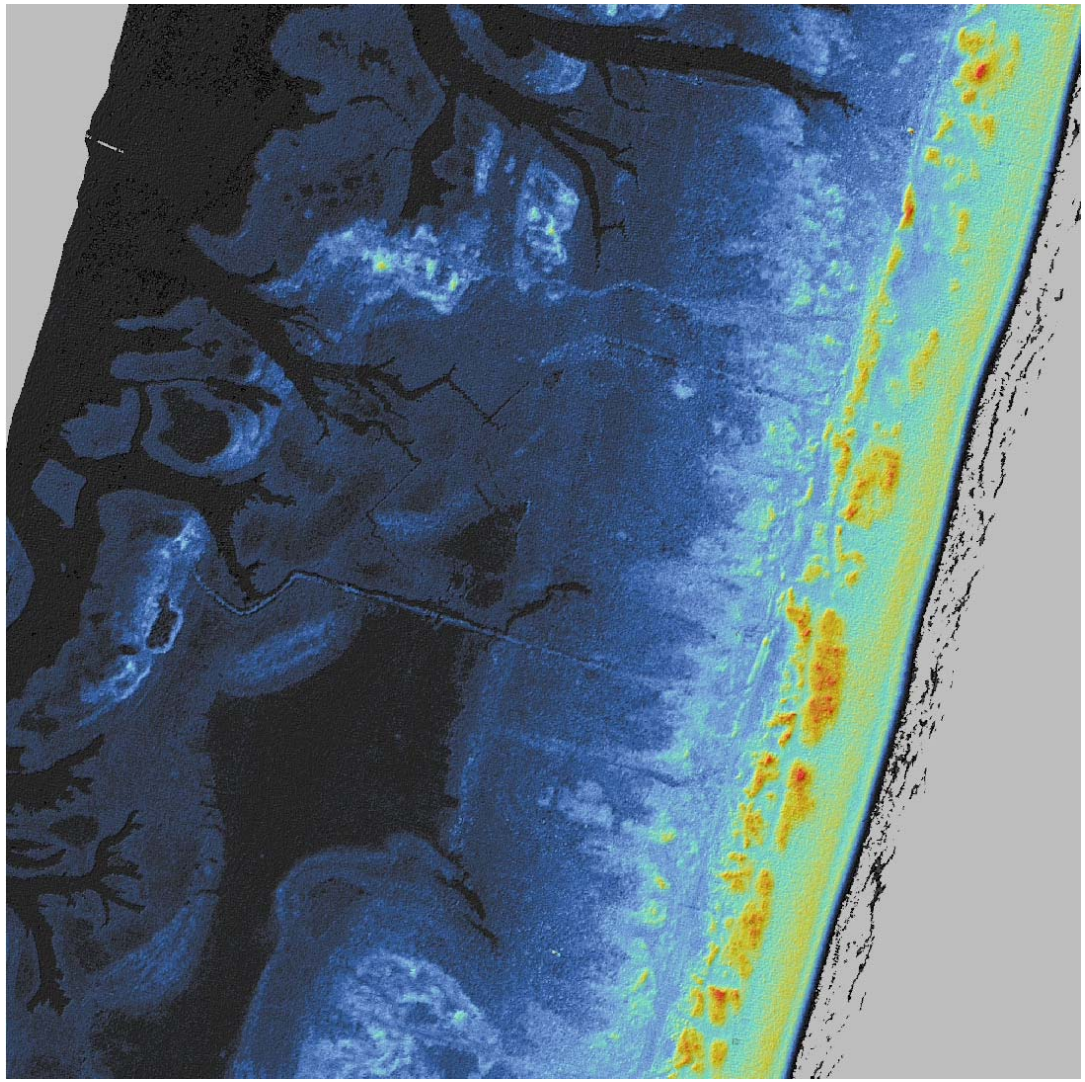
Sample EAARL Lidar Data Products

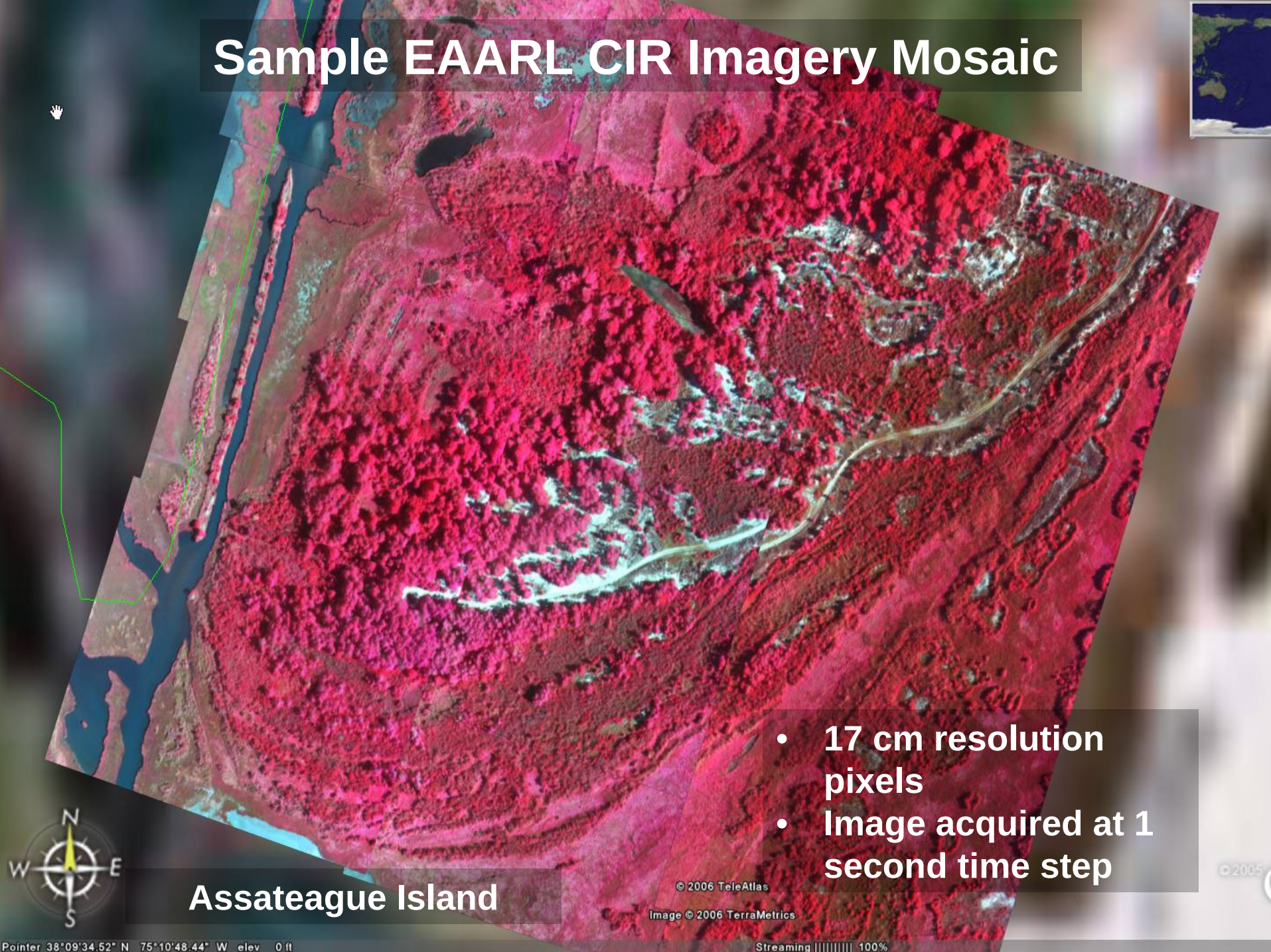
EAARL Derived Lidar DEM Products

- *Canopy Topography*
- *Bare Earth Topography*



August 2004 EAARL survey
Assateague Island NS

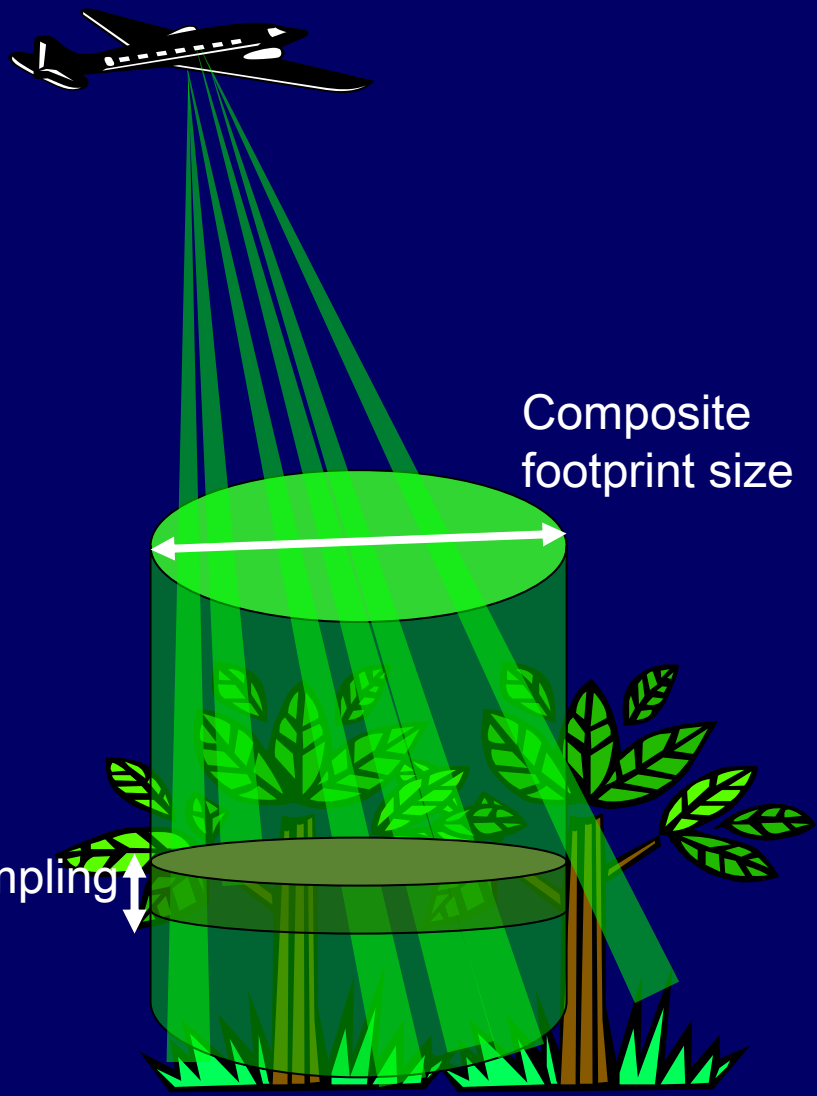
Sample EAARL CIR Imagery Mosaic



- 17 cm resolution pixels
- Image acquired at 1 second time step

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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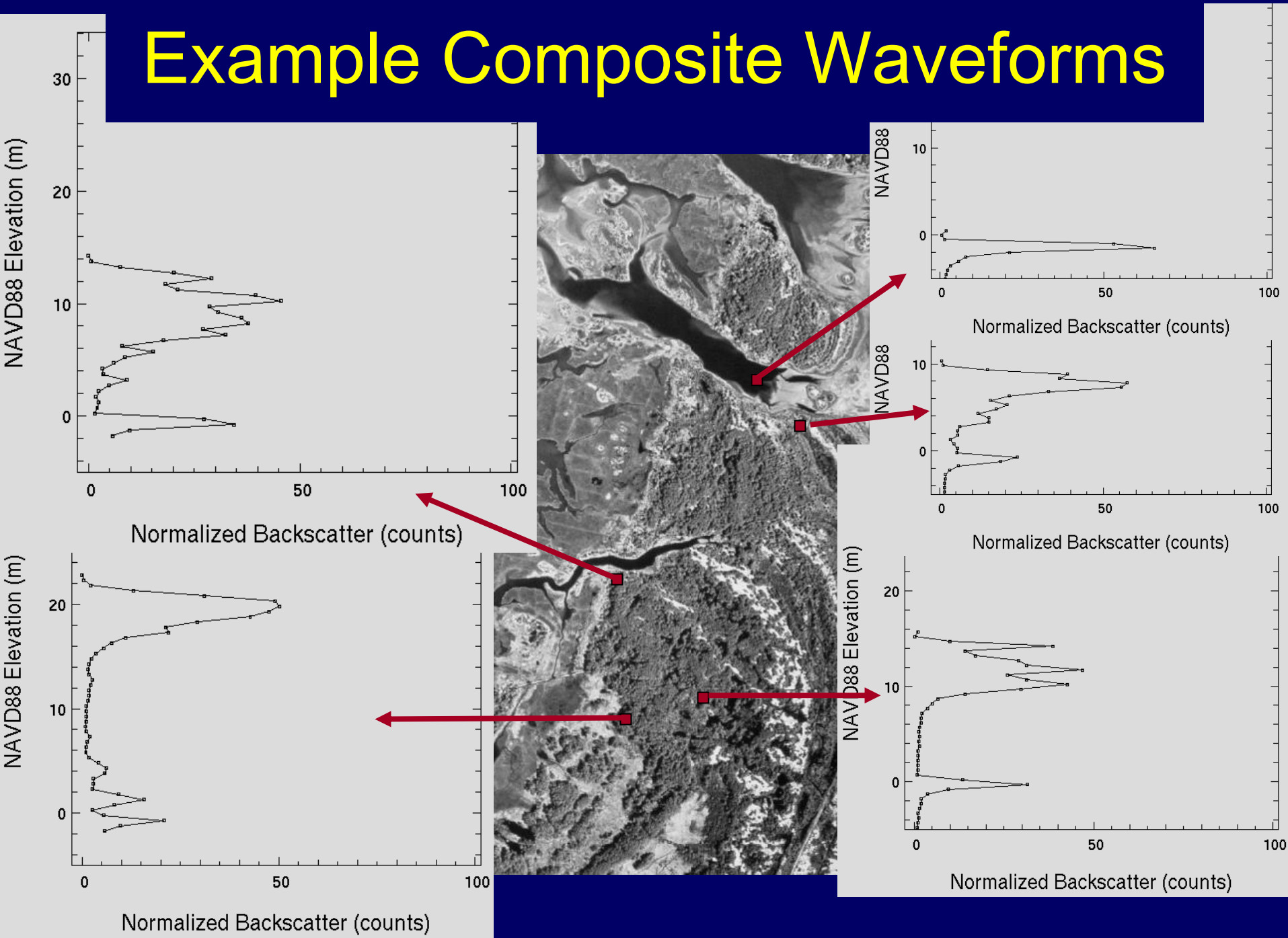
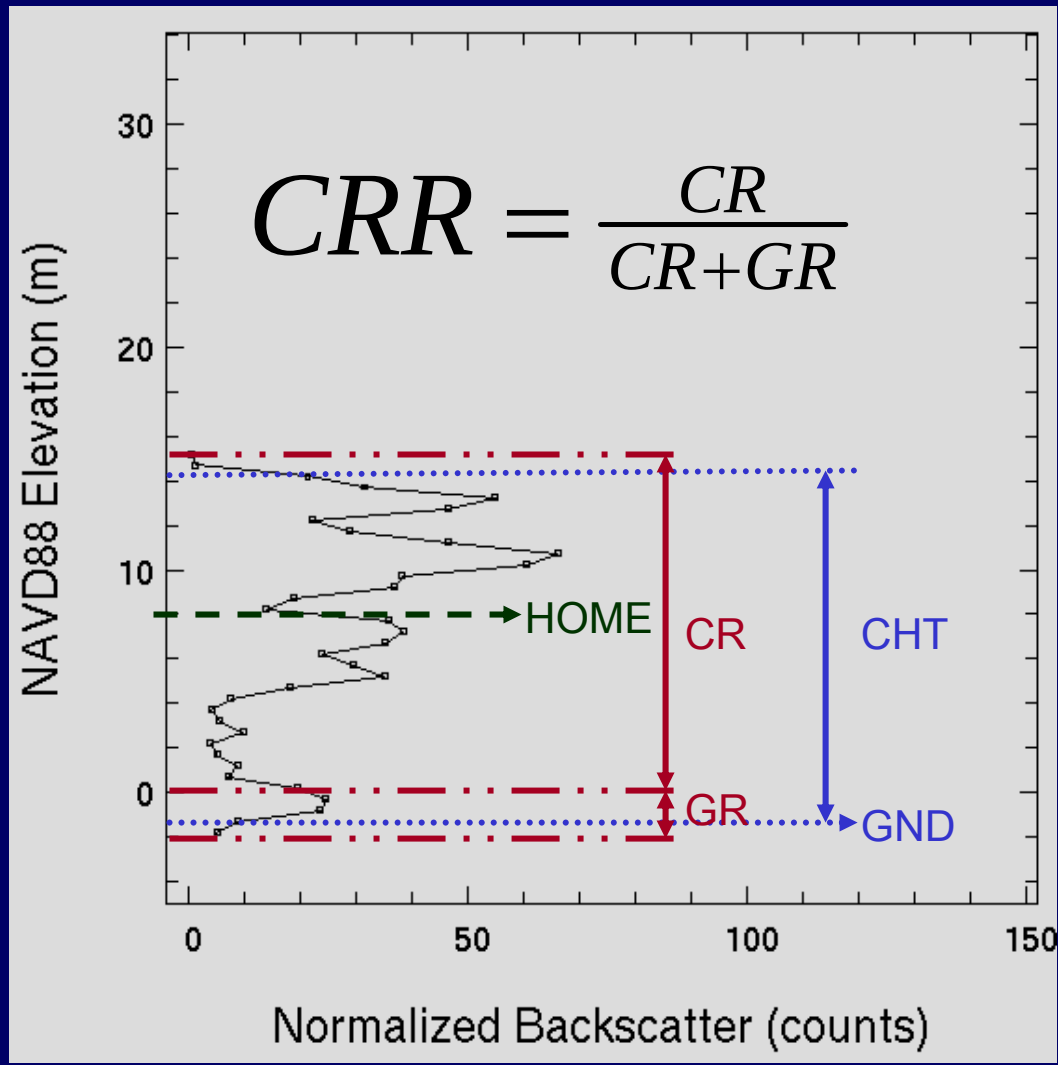
Example Composite Waveforms



Deriving Vegetation Metrics

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



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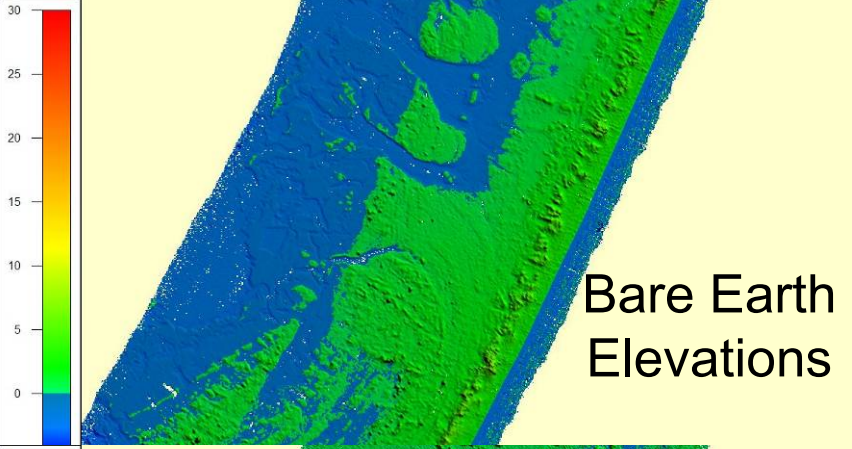
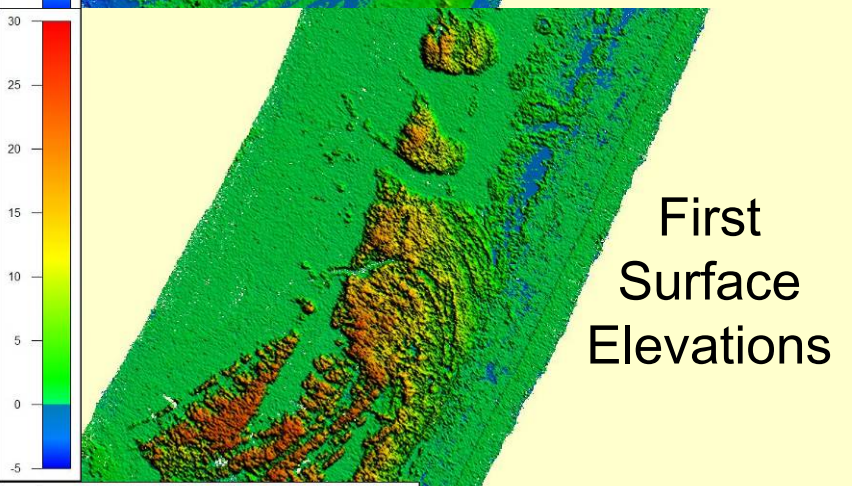
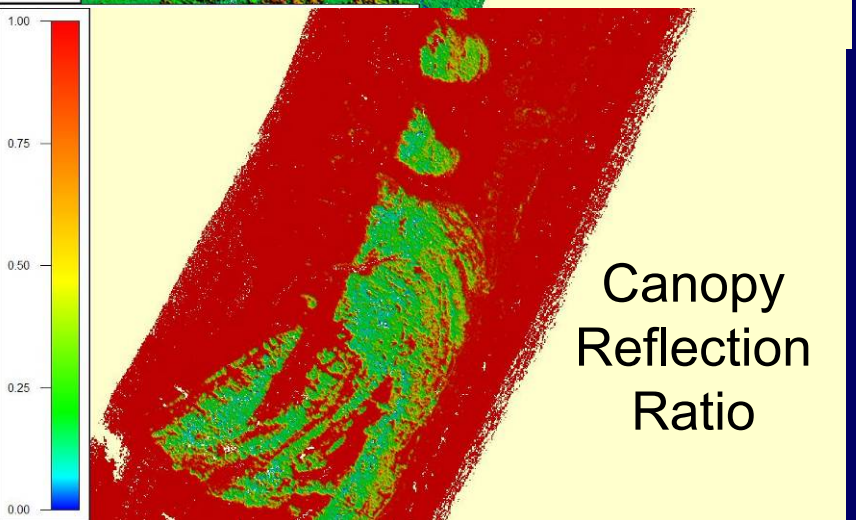
Vegetation classification using Lidar



Bare Earth Elevations



First Surface Elevations



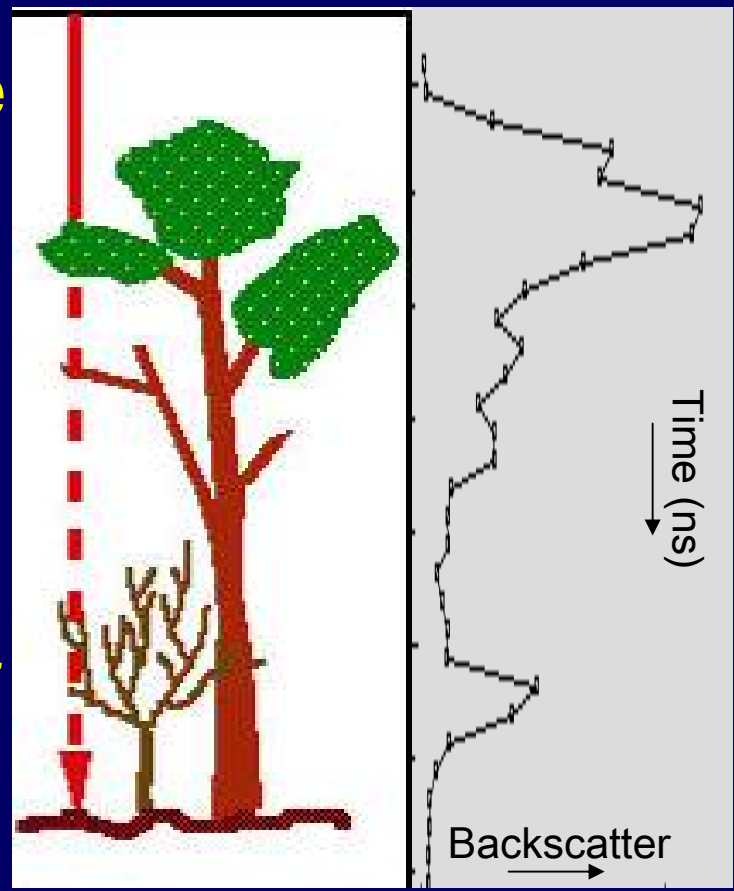
Canopy Reflection Ratio

Unsupervised classification in GIS software

Classification map

Lidar vegetation metric applications…

- "Objective" monitoring tool
- Metrics can be used to estimate several forest inventory parameters (biomass, canopy cover, basal area, stem density)
- Vertical distribution of canopy biomass
- Determine spatial distribution of community types
- Use in conjunction with aerial photographs



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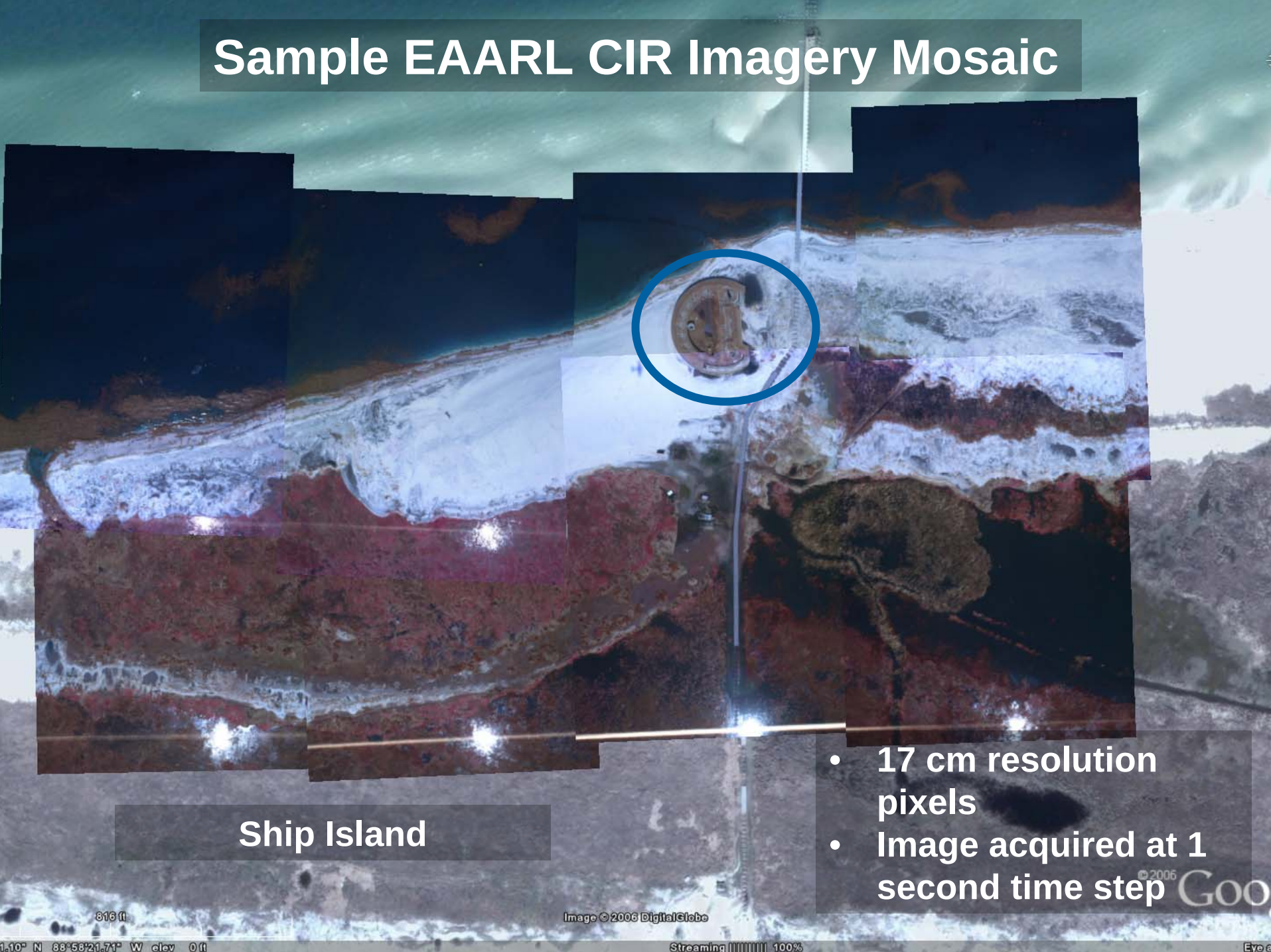
Existing EAARL data at NGOM

Gulf Islands National Seashore (Sept 2005)

Chandeleur Islands (Sept 05, Mar 06, Sept 06)

Jean Laffitte National Park (Sept 06)

Sample EAARL CIR Imagery Mosaic

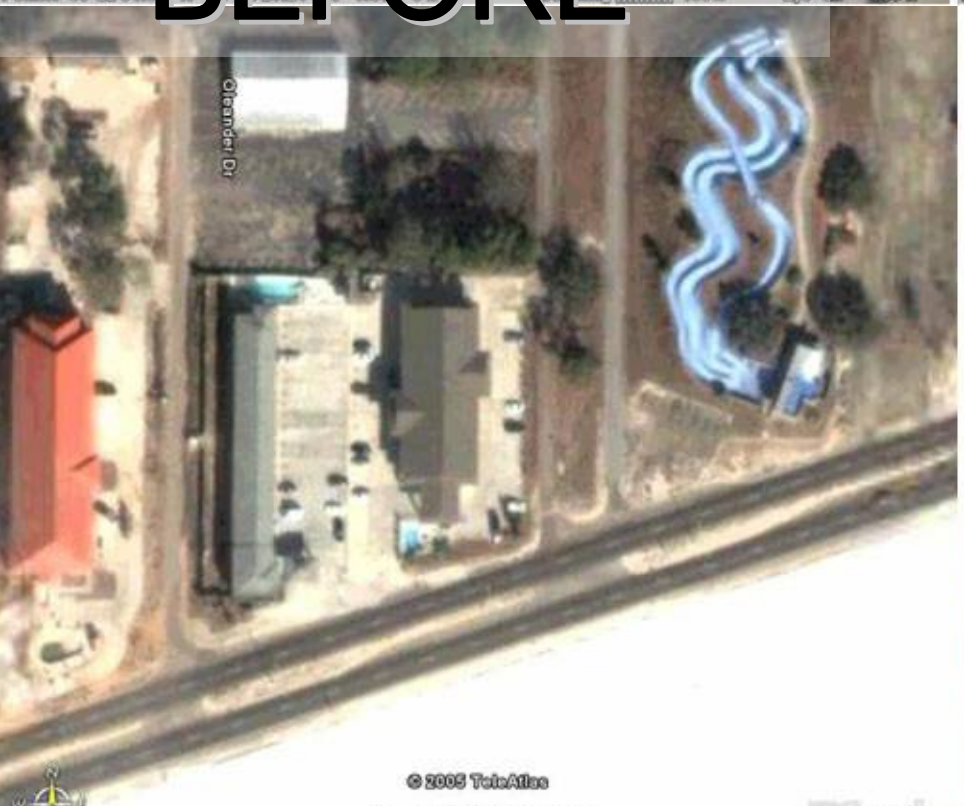


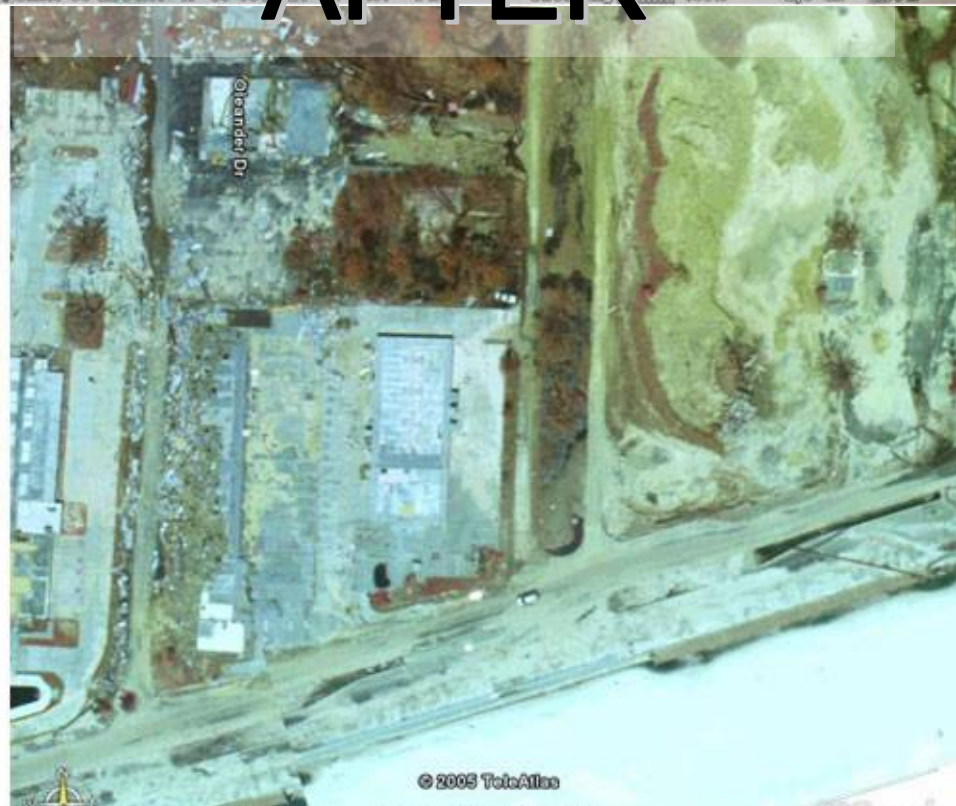
- 17 cm resolution pixels
- Image acquired at 1 second time step


Sample EAARL CIR Imagery
Fort Massachusetts at Ship Island
95 ft
Image © 2006 DigitalGlobe
Pointer 30°12'44.37" N 88°58'18.81" W elev 0 ft
Streaming 100%


Google Earth imagery
Nixon St
Midway Ave
Oak Ave
90
© 2005 TeleAtlas
BEFORE

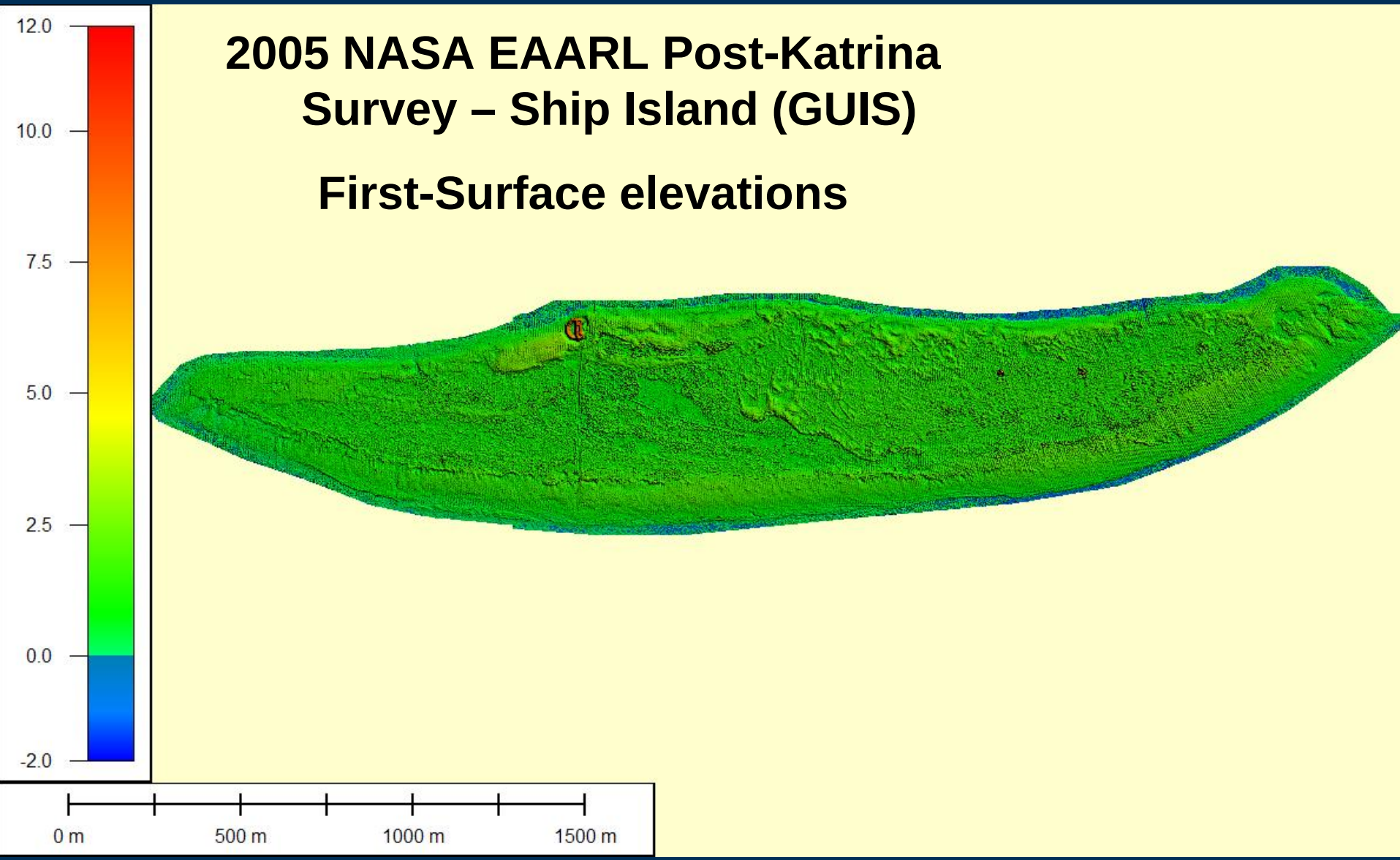

EAARL CIR Imagery
Nixon St
Midway Ave
Oak Ave
90
© 2005 TeleAtlas
AFTER


Oleander Dr
© 2005 TeleAtlas


Oleander Dr
© 2005 TeleAtlas

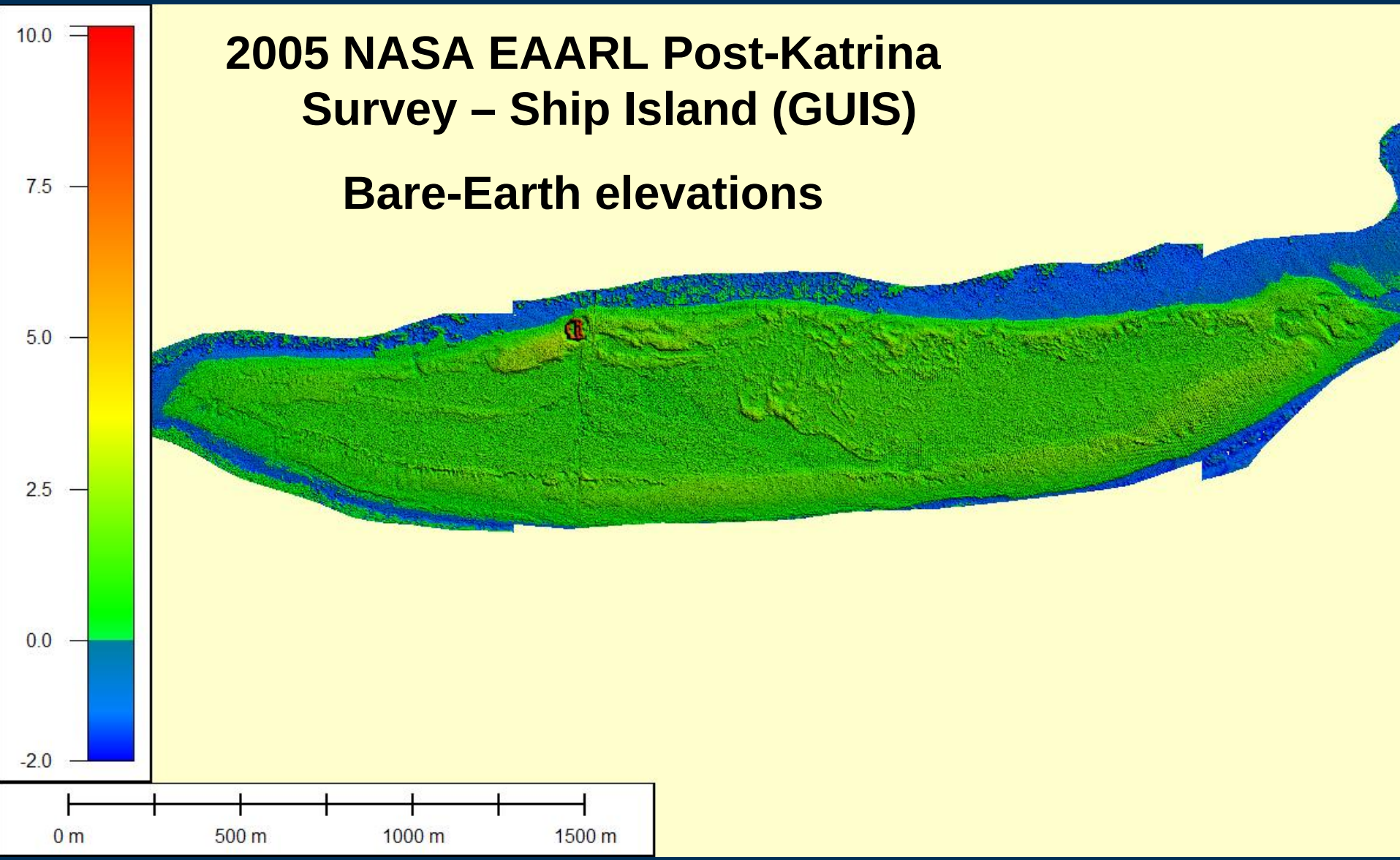
2005 NASA EAARL Post-Katrina Survey – Ship Island (GUIS)

First-Surface elevations

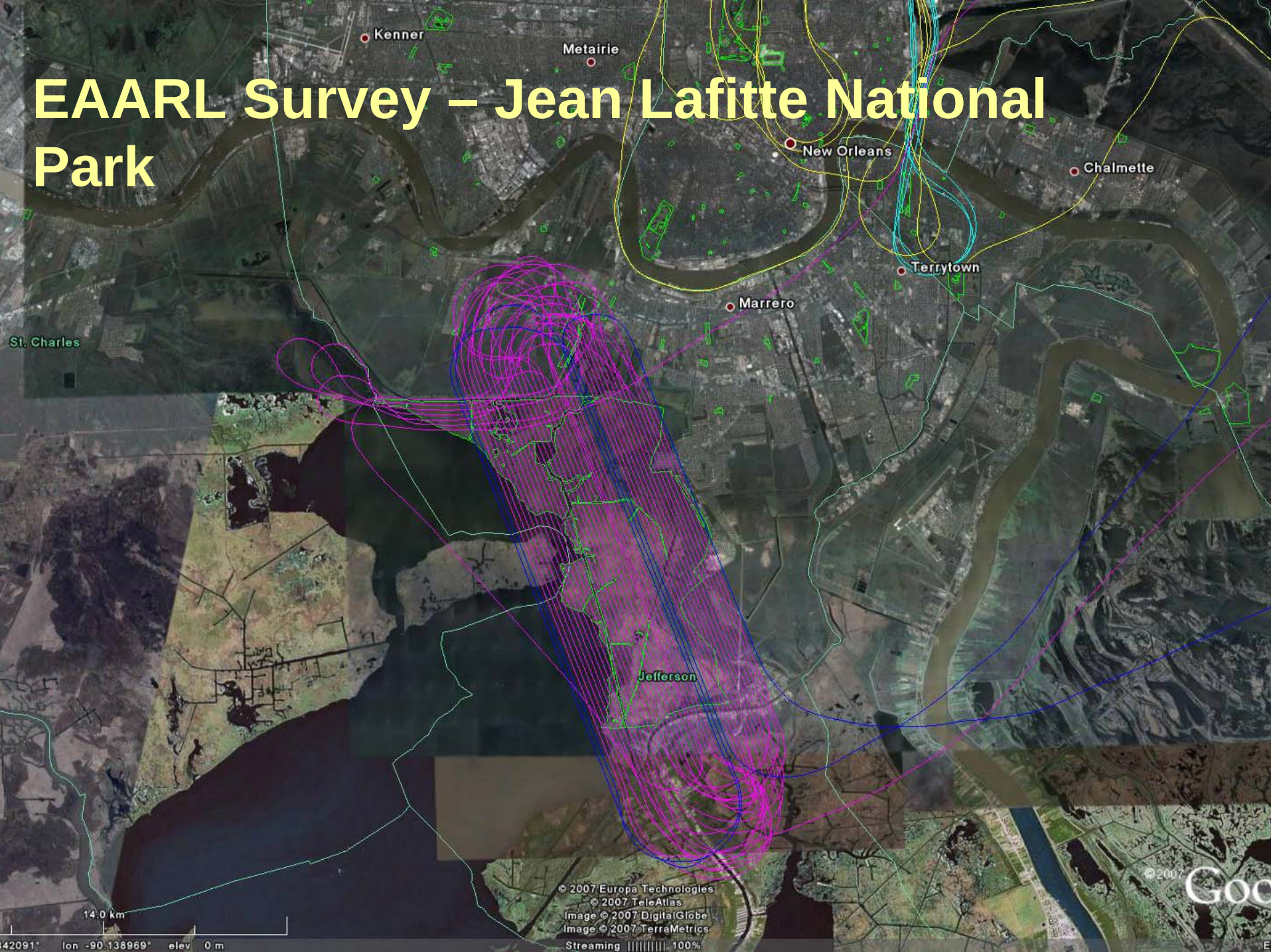


2005 NASA EAARL Post-Katrina Survey – Ship Island (GUIS)

Bare-Earth elevations



EAARL Survey – Jean Lafitte National Park



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

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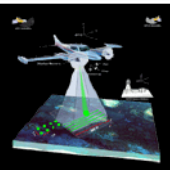

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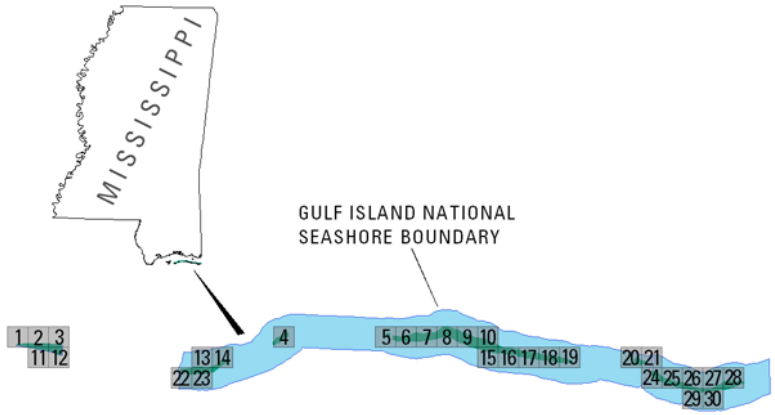
- Metadata
- Collaborators

Gulf Islands National Seashore, Mississippi

John C. Brock, C. Wayne Wright, Matt Patterson,
Amar Nayegandhi, and Iris Wilson

This DVD contains 30 LIDAR-derived first return topography maps and GIS files for Gulf Islands National Seashore. Click on a tile number (1-30) in the map below to view the corresponding map in PDF format.



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