New Topographic-Bathymetric Lidar Technology for Post-Sandy Mapping

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NOAA's National Geodetic Survey

Canadian Hydrographic Conference
April 14 - 17, 2014

National Oceanic and Atmospheric Administration

Background

- U.S. Department of Commerce
  - National Oceanic Atmospheric Administration (NOAA)
    - National Ocean Service
      - National Geodetic Survey
        - Remote Sensing Division
- Primary programs
  - Coastal Mapping Program
  - Aeronautical Survey Program
  - Emergency Response

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Hurricane Sandy

- Landfall- October 29, 2012
- Cost: est. $50B in damages
- Damage extends over significant portion of U.S. East Coast and on both sides of the land-water interface
  - Innovative remote sensing tools & techniques needed

Topo-Bathy Lidar

- Emerging class of lidar system: occupies middle ground between conventional topographic and bathymetric systems:
  - Shallow water
  - Narrow beam, low power, very high measurement rates
- Why of interest to NOAA?
  - Uniquely suited for shoreline mapping
    - Seamless, high-resolution data across backshore, intertidal, and nearshore marine zones
  - Fill in shallow water gap (shoreward of NALL line)
  - SLR analysis, inundation modeling
  - Habitat mapping
  - Riverine mapping
  - Coastal zone management, coastal science => ***IOCM!***

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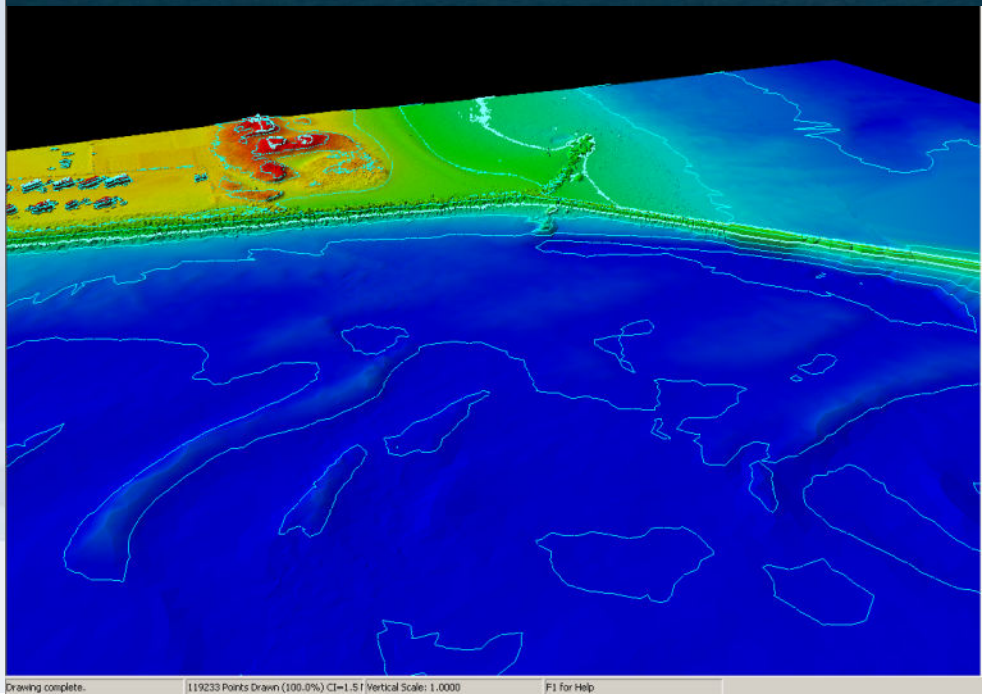
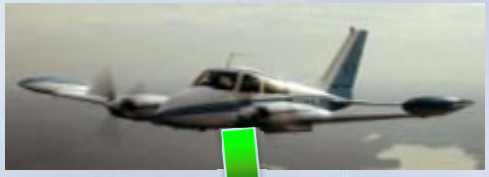
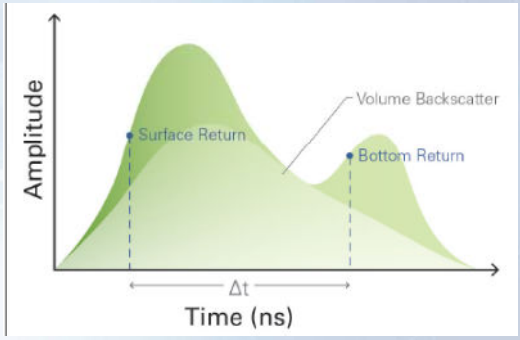


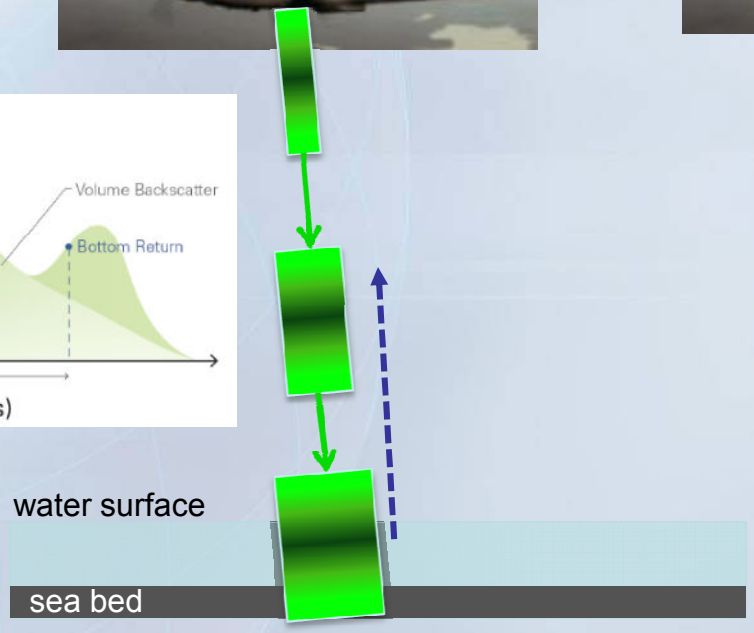
Design considerations for topo-bathy lidar:

Effect of pulse power and width on determining shallow submerged topography

Traditional bathymetric Lidar

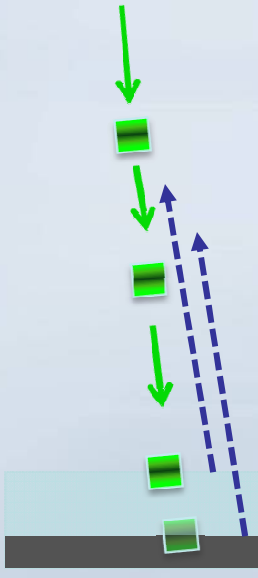


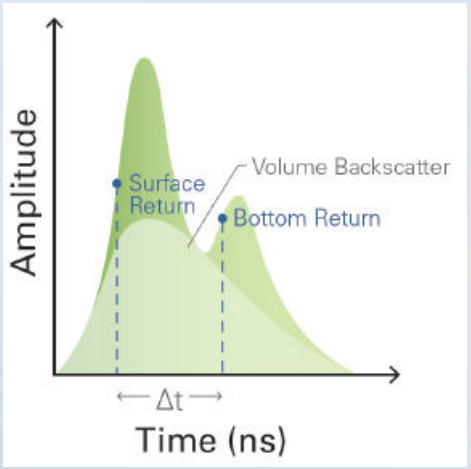




"long", "wide", high-power pulse: cannot (easily) differentiate between surface and bottom return

Topo-bathy Lidar





"short" pulse: surface and bottom return is separate or convolved

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Slide courtesy of Amar Nayegandhi, Dewberry

Current Commercial Bathy and Topo-bathy Systems*

	CZMIL	LADS Mk3	Hawkeye III	SHOALS 3000	Chiroptera	VQ-820-G
Manufacturer / Owner	Optech	Fugro	Leica - AHAB	Optech	Leica AHAB	Riegl
Mapping Environment	Topo-Bathy	Bathy	Topo-Bathy	Bathy	Topo-Bathy	Topo-Bathy
Country of origin	USA	Australia	Sweden	Canada	Sweden	Austria
Released / First known survey	2012	2011	2013	2010	2011	2011
Number of Lasers	2	1	3	2	2	1
Laser wavelength	532 nm (green) and 1064nm (IR)	532 nm (green)	532 nm (green) X 2 and 1064 nm (IR)	532 nm (green) and 1064 nm (IR)	532 nm (green) and 1064 nm (IR)	532 nm (green)
Pulse Width	short	long	long	long	short	short
Maximum Pulse Repetition Frequency (kHz)						
Land Topography	70 kHz	N/A	100 - 400 kHz	20 kHz	400 kHz	520 kHz
Shallow bathymetry	70 kHz	N/A	35 kHz	N/A	36 kHz	520 kHz
Deep bathymetry	10 kHz	1.5 kHz	10 kHz	3 kHz	N/A	N/A
Laser Energy per pulse at 532 nm (green)	3 mJ	7 mJ	3 mJ	4 mJ	0.1 mJ	0.02 mJ
Nominal Flying Height	400 m	400 - 700 m	250 - 500 m	300 - 400 m	250 - 600 m	600 m
Nominal Laser footprint @ water surface (@ 532 nm green) at nominal flying height	2 m	3 m	4 m (deep); 2 m (shallow)	2 m	1.5 m	0.6 m
Point density (points per square meter) at nominal flying height	0.25 to 1	0.25 to 0.025	13 (topo); 0.3 - 1.2 (bathy)	0.025 - 0.04	13 (topo); 1.2 (bathy)	6 - 10 (topo and bathy)
Typical maximum water depth (measured as Secchi depth)	2.5 - 3	2.5 - 3	2 - 2.5	2 - 2.5	1.0 - 2.0	1.0

http://www.lidarnews.com/PDF/LiDARMagazine_Quadros-BathymetricLiDARSensors_Vol3No6.pdf

***Not an exhaustive list**

Slide courtesy of Amar Nayegandhi, Dewberry

Riegl VQ-820-G

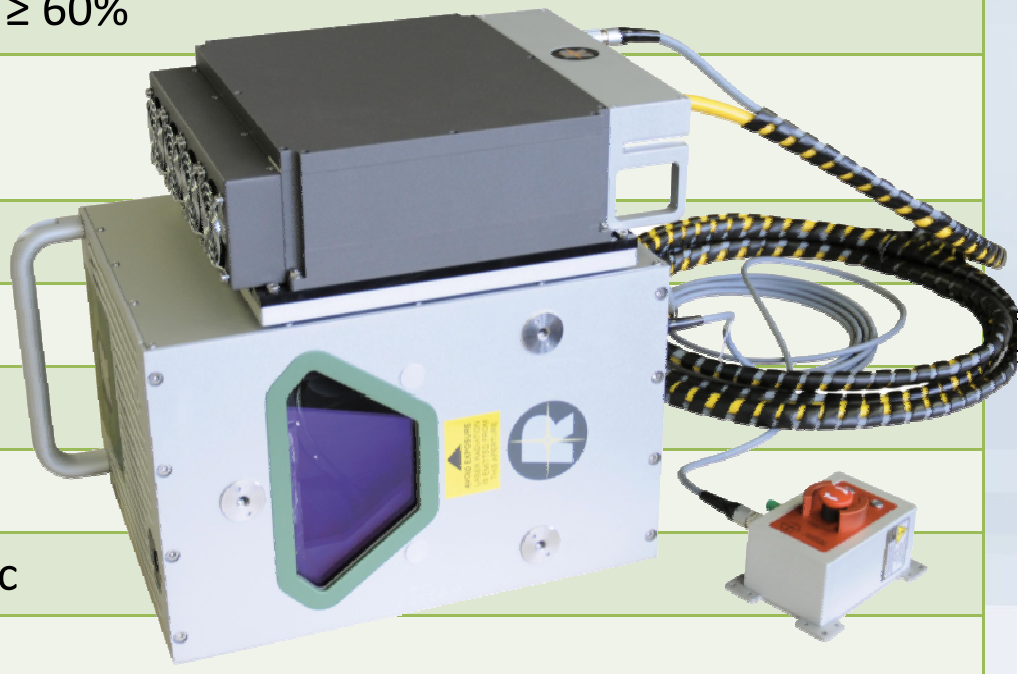
New commercial topo-bathy system:

- narrow laser beam
- high range resolution
- high measurement rate
- compact and lightweight design

Designed for:

- high-resolution mapping of shallow waters
- focus on min. depth capturing (shallow water)

Wavelength	532 nm (visible green)
Measurement range Topography	10 – 1500 m at ρ ≥ 20% 10 – 2500 m at ρ ≥ 60%
Measurement range Bathymetry	1 Secchi depth
Ranging accuracy	25 mm
Full scan angle	42°, 60°*
Beam divergence	1 mrad
Measurement rate	520 kHz
Scan rate	50 – 200 lines/sec
Laser safety	Laser Class 3B



June 2013 Data Acquisition

NOAA Hawker Beechcraft King Air 350ER

Furthest aft: Riegl VQ-820-G topo bathy lidar. Foreground: Applanix DSS DualCam digital aerial camera; twin Riegl IR lidars LMS-Q680i/Q780(1550nm and 1064nm)

Sept 2013 Data Acquisition

NOAA DeHavilland Twin Otter (DHC-6)

Left: Riegl LMS Q-680i, Right: Riegl VQ-820-G

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Acquisition: Sensor Suite

Topo-Bathy Lidar: VQ820G

- 532 nm laser
- 1 Secchi Depth System
- Effective Measurement Rate: 200,000 meas./sec.

Topo Lidar: Q680i

- 1550 nm laser
- Effective Measurement Rate: 266,000 meas./sec.

Applanix Digital Sensor System: DSS 439

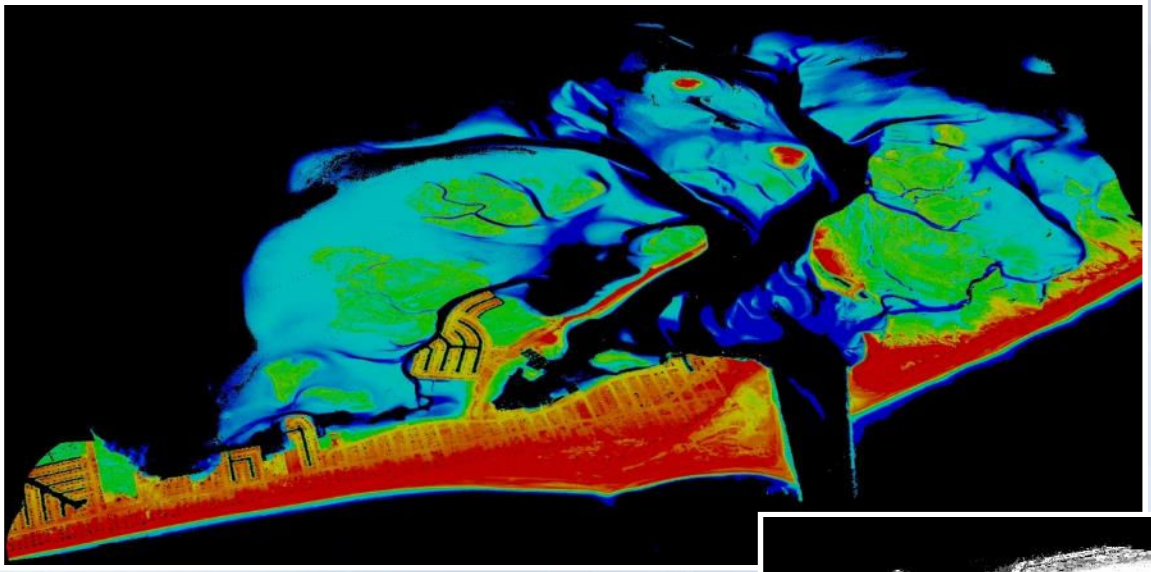
- 39 Mega Pixels
- True Color: Red/Green/Blue

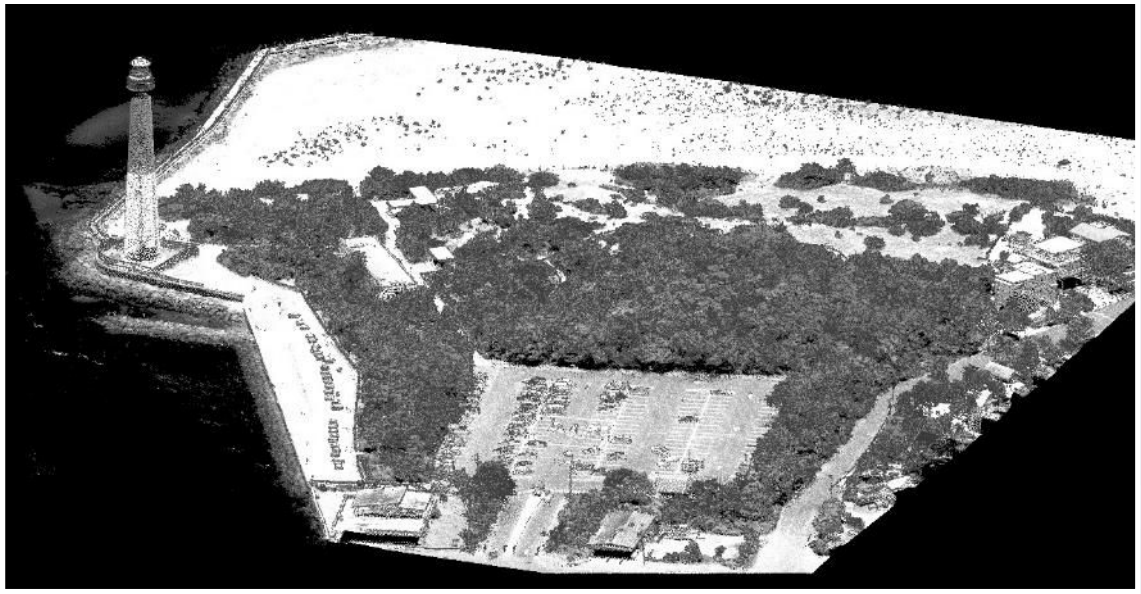
Acquisition: Operations

Topo-Bathy Lidar: VQ820G

- ***AGL: 1000 feet***
  - Nominal Point Density: 18 pt/m²
  - Swath Width: 234 meters
- ***AGL: 2000 feet***
  - Nominal Point Density: 9 pt/m²
  - Swath Width: 468 meters
- ***Operational Parameters:***
  - 50% sidelap of swaths
  - 42° Field of View

Barnegat Inlet, NJ





Barnegat Bay, NJ

September 2013

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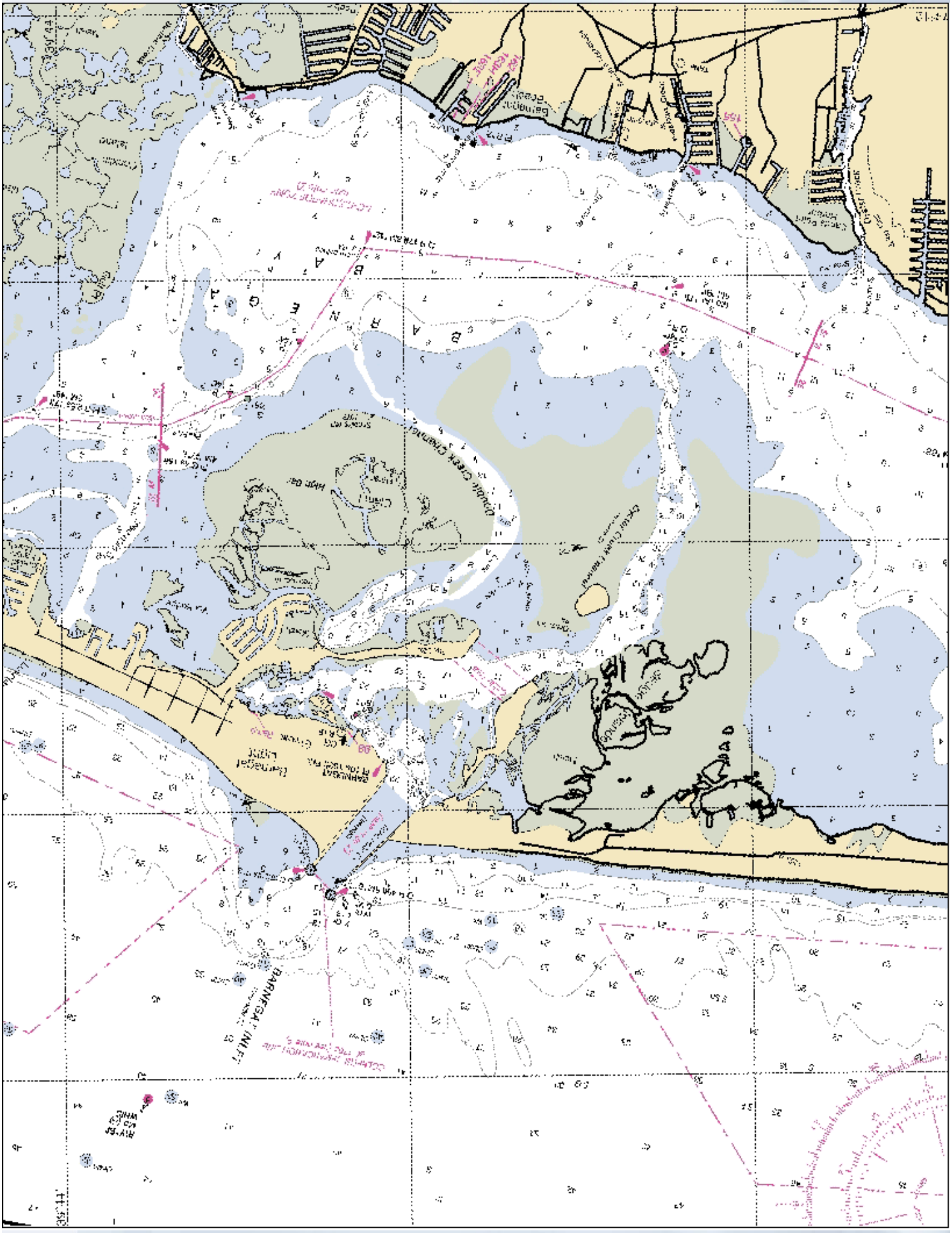


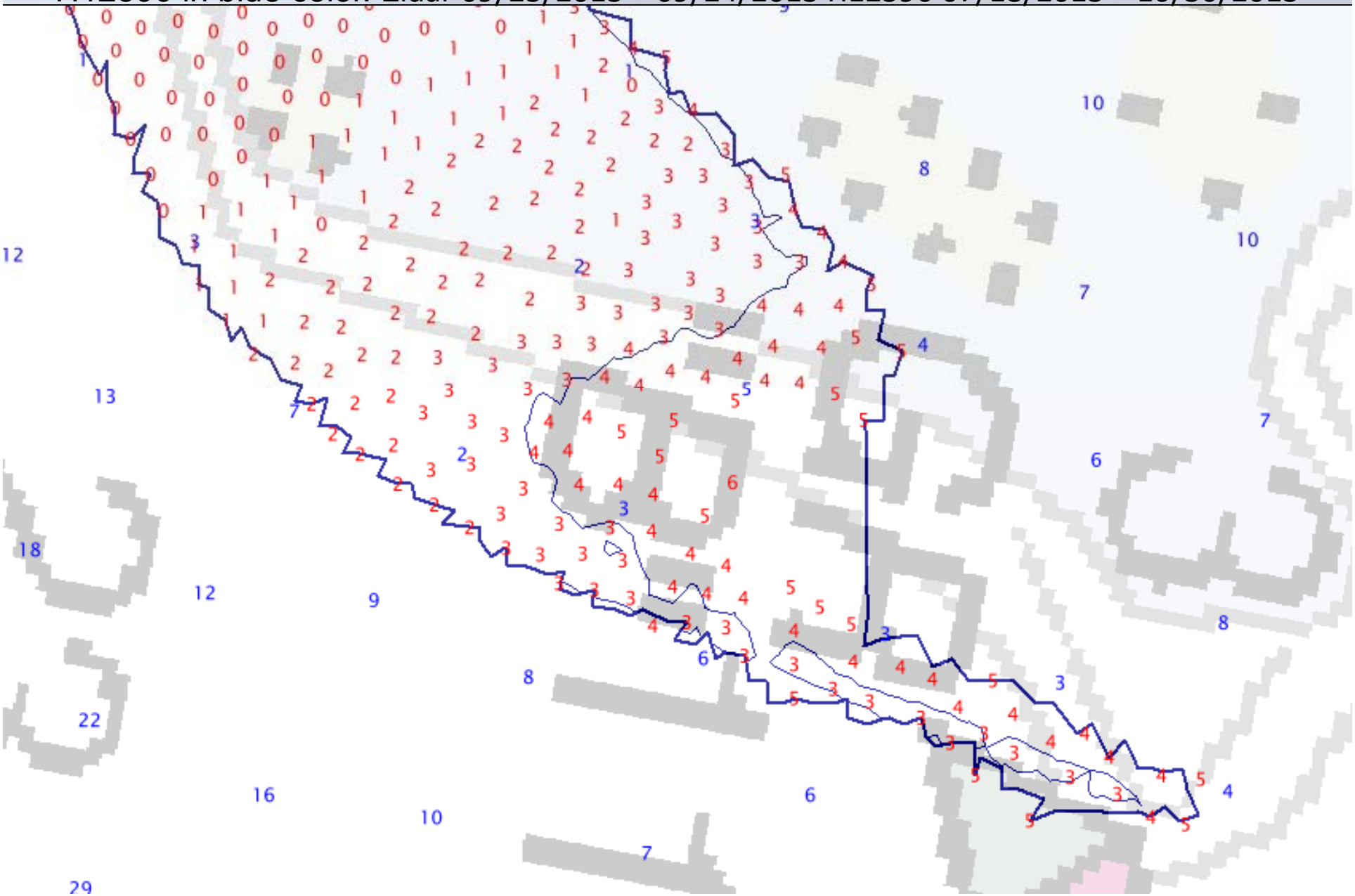
Project Statistics and Accuracy Assessment

- **Total # of Lidar Returns: 1,130,349,822**
- *Bathymetric Points: 508,802,577 (some of these might be water column noise, etc.)*

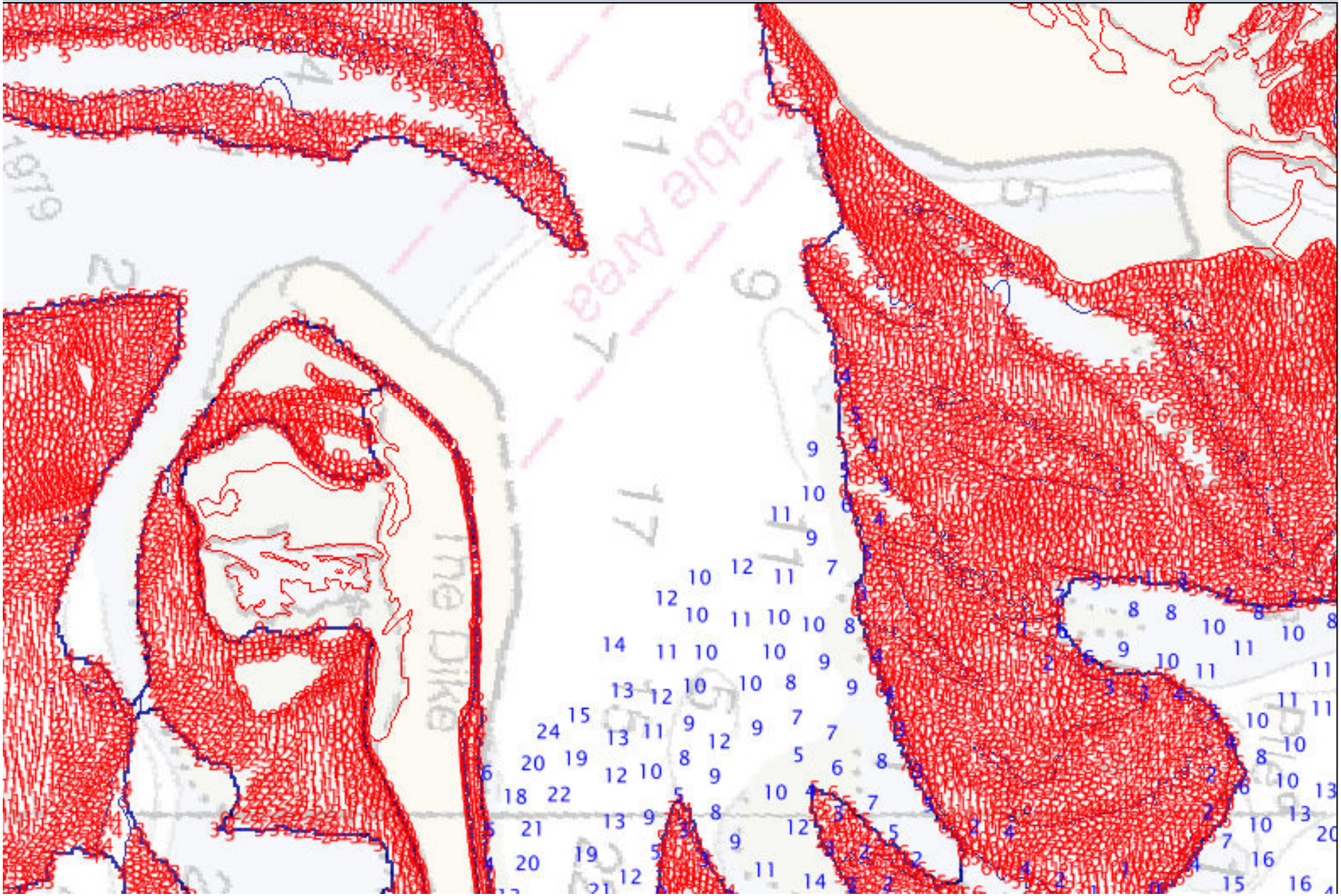
- **Accuracy Assessment** (meters) based on 27 GPS Control Points

  - Average dz: -0.001
  - Minimum dz: -0.039
  - Maximum dz: +0.056
  - Average magnitude: 0.023
  - Root mean square: 0.027
  - Std. Deviation: 0.028

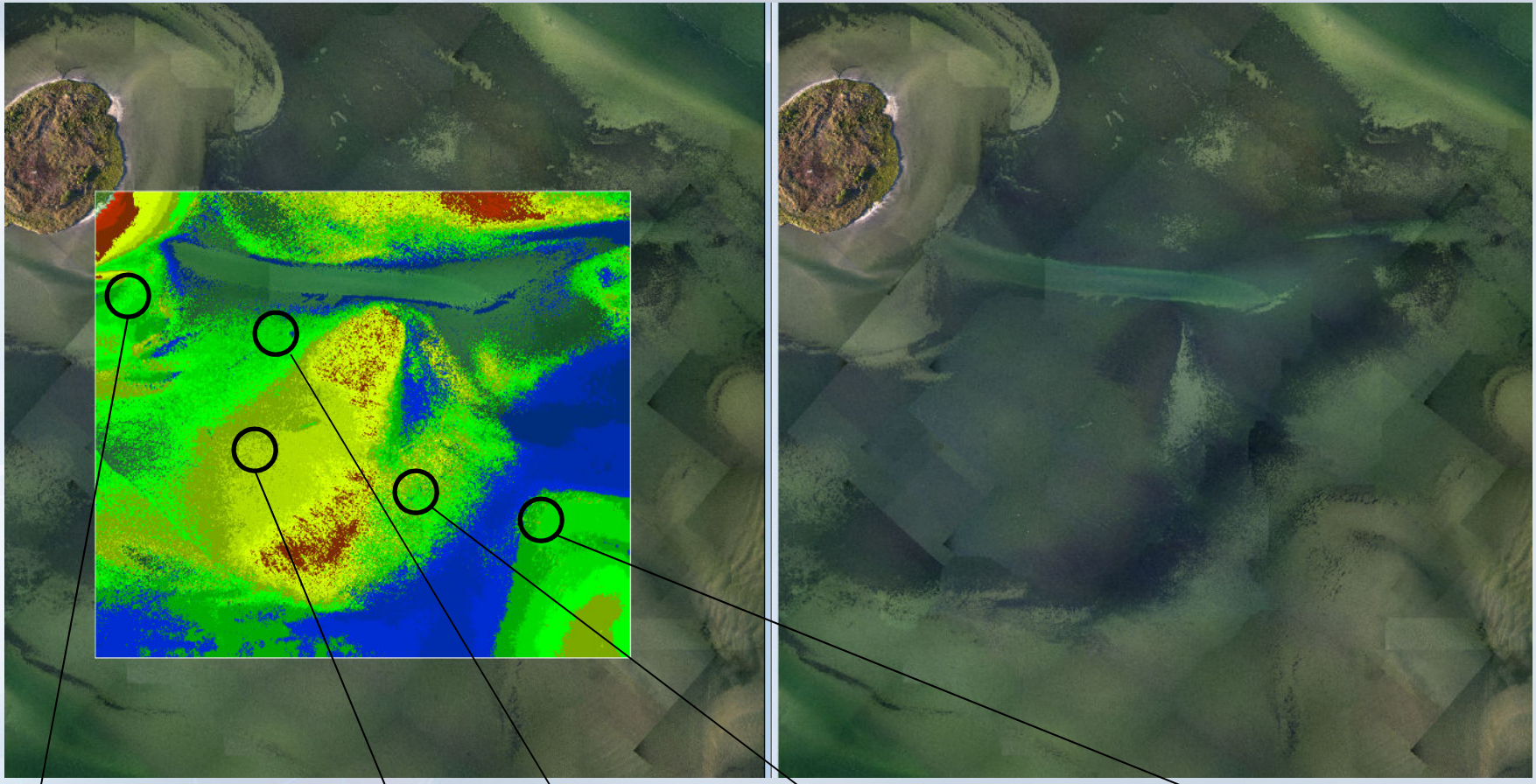
Areas of common overlap of W00279 (lidar survey) and H12596 (hydrographic survey) are in harmony, with occasional exceptions. W279 soundings are in red color, with H12596 in blue color. Lidar 09/23/2013 – 09/24/2013 H12596 07/18/2013 – 10/30/2013



Limitation of LIDAR coverage of chart update based upon water depth and the inshore limit of the hydro survey



Barnegat Inlet Point Density



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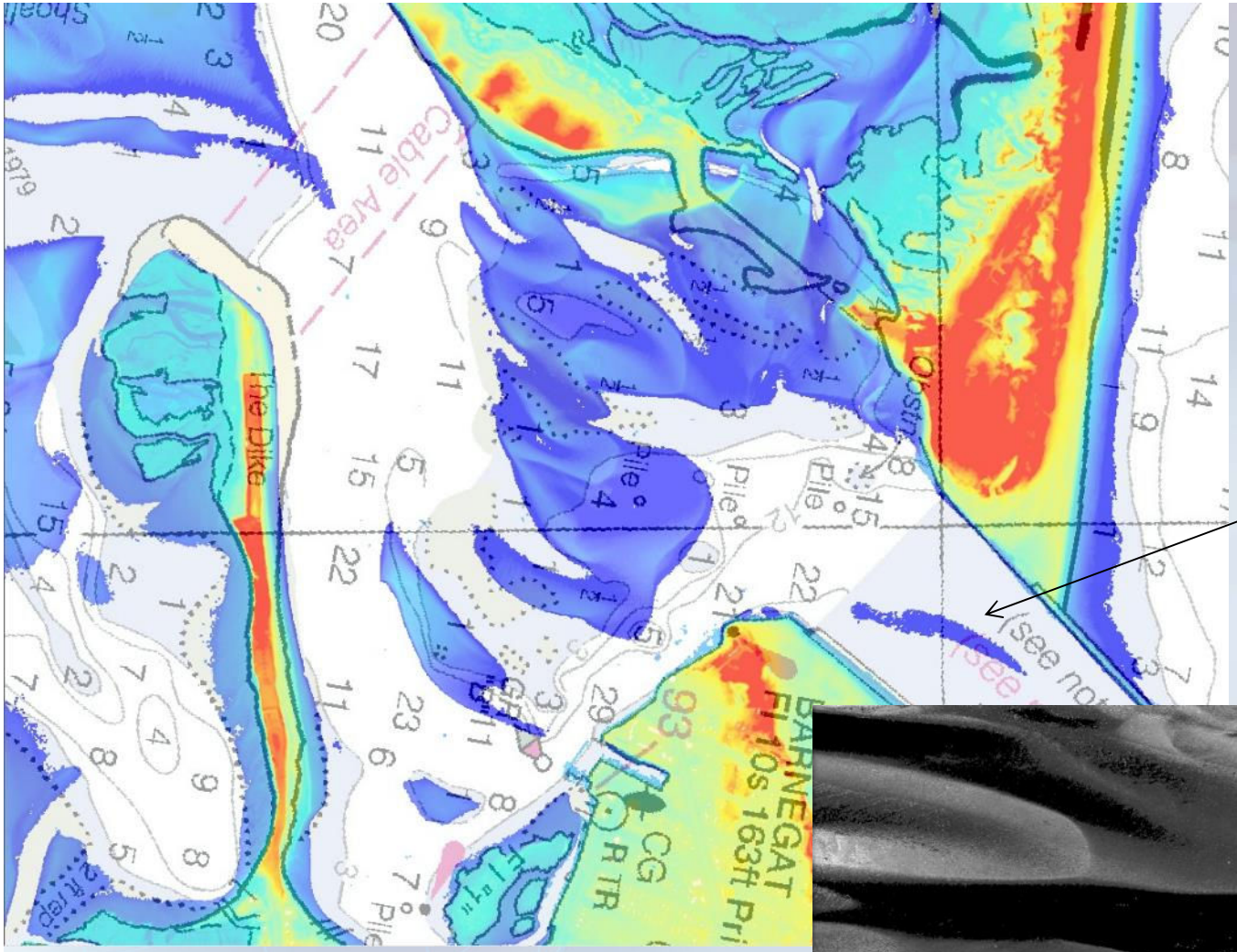
Barnegat Inlet Entrance Shoals



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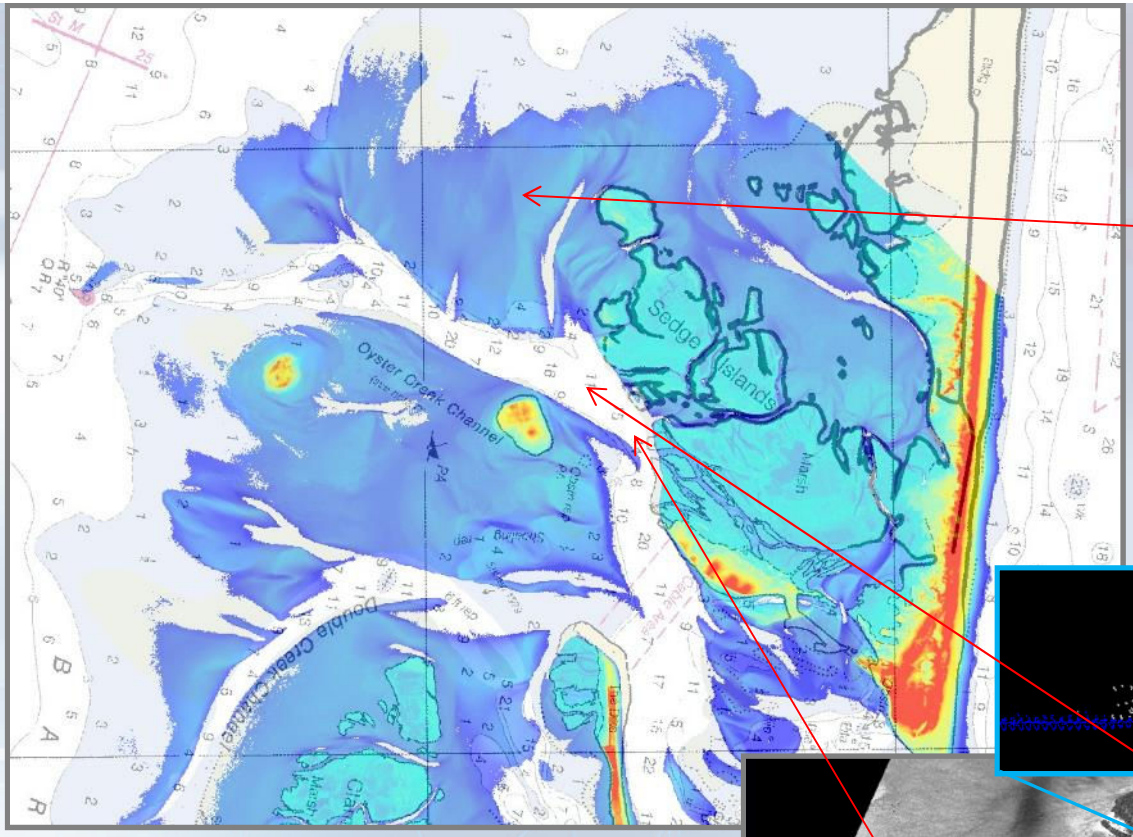
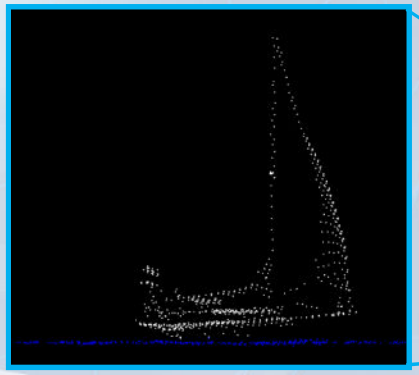
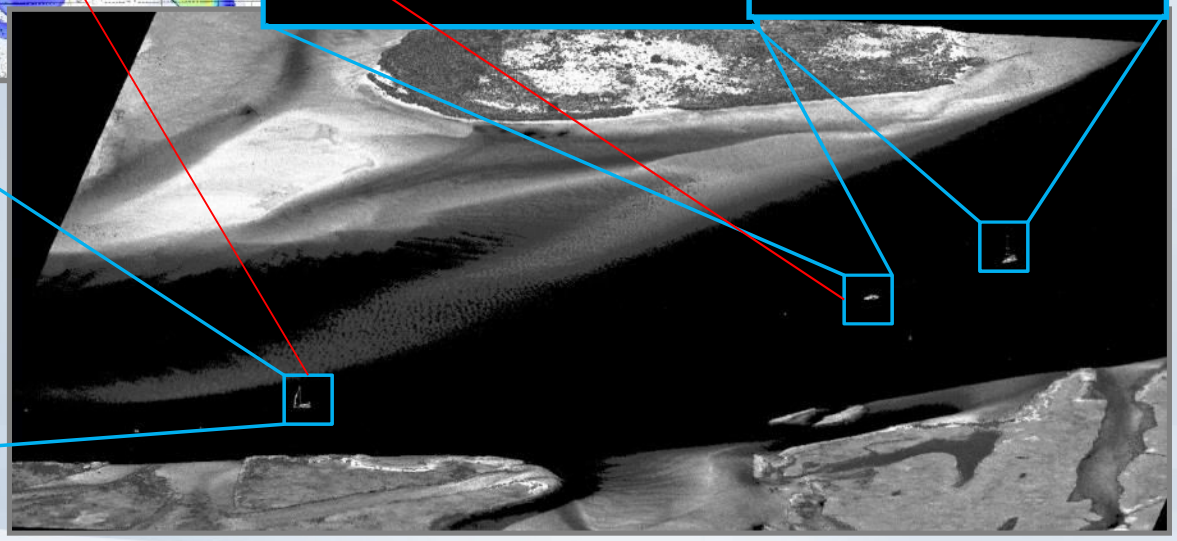
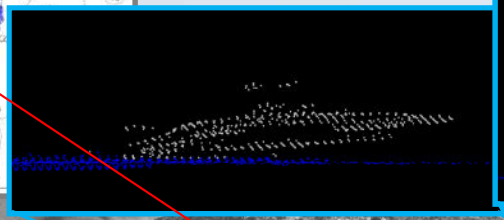
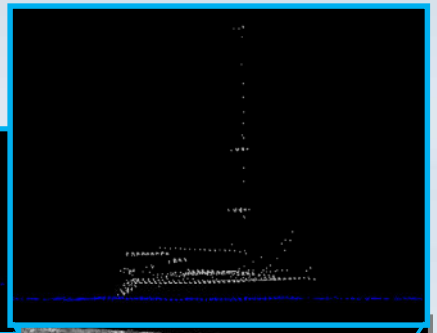
Uncharted Shallows











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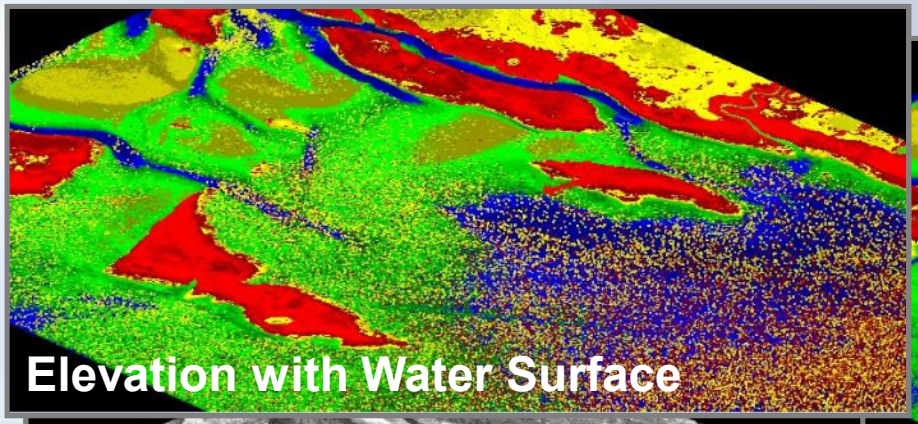
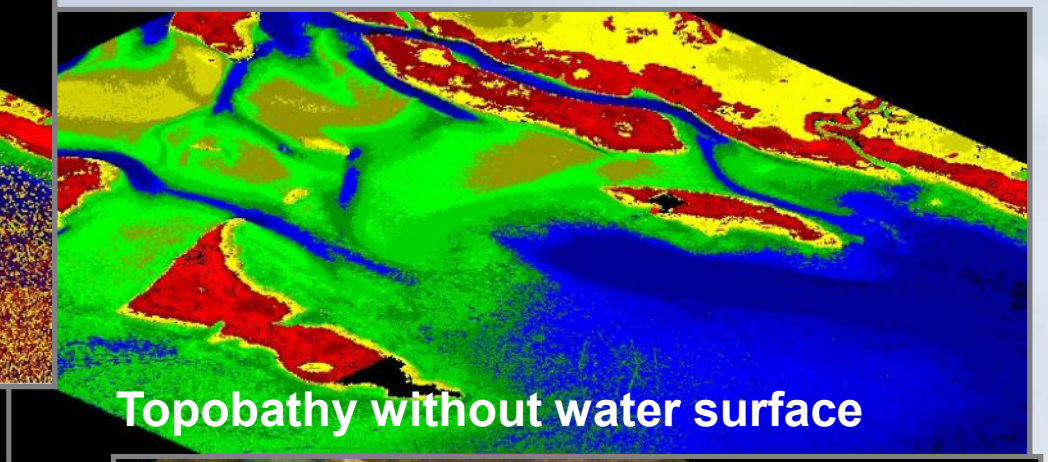
Point Cloud Derivatives





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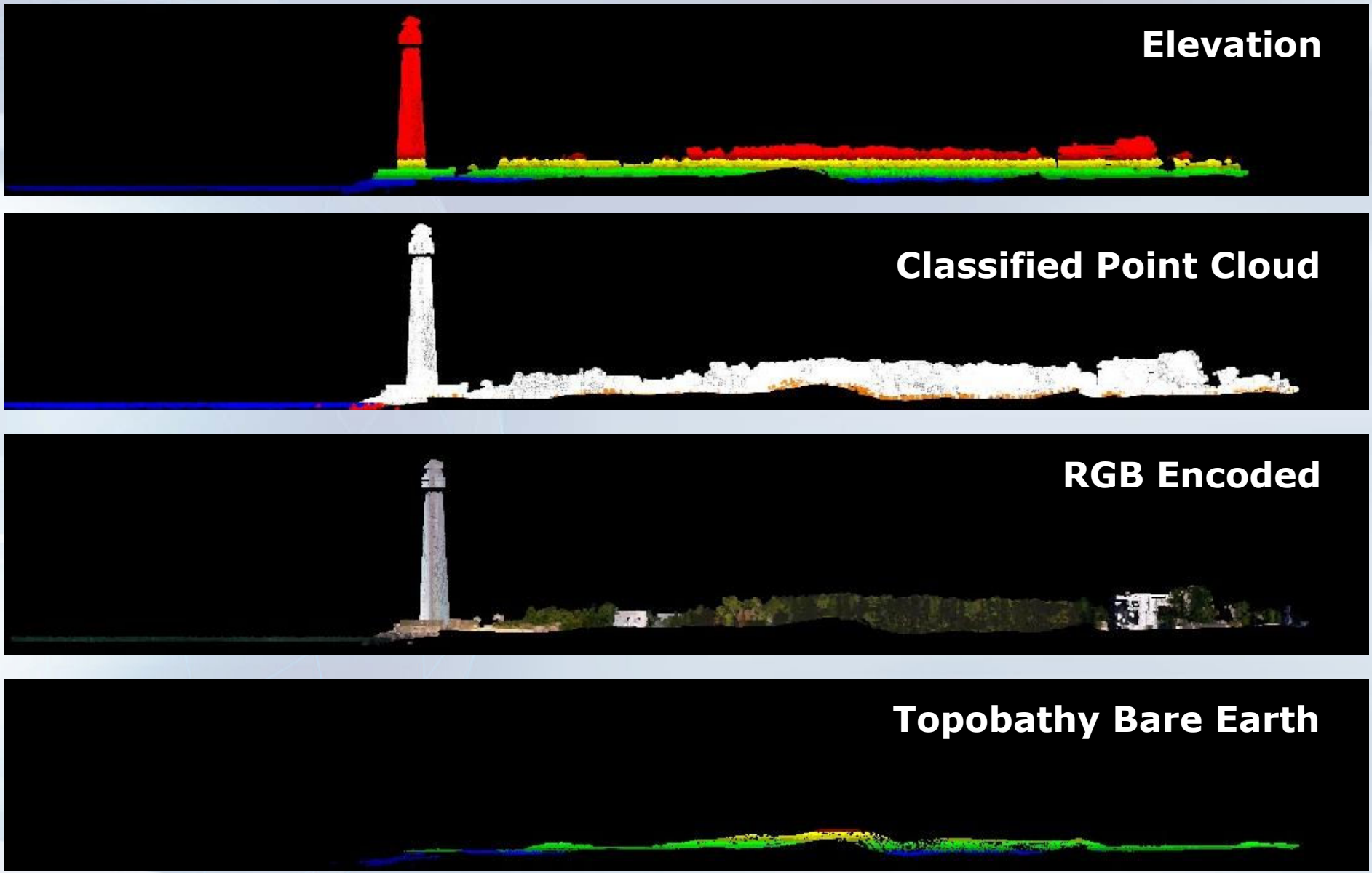

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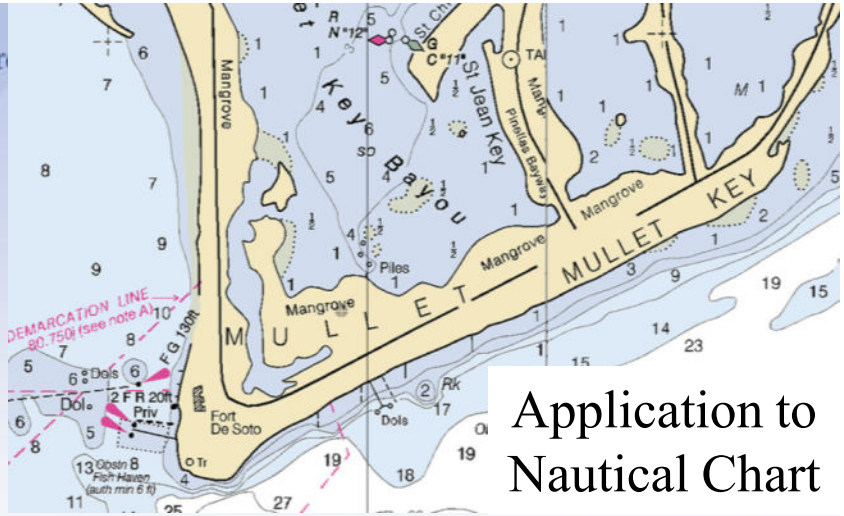
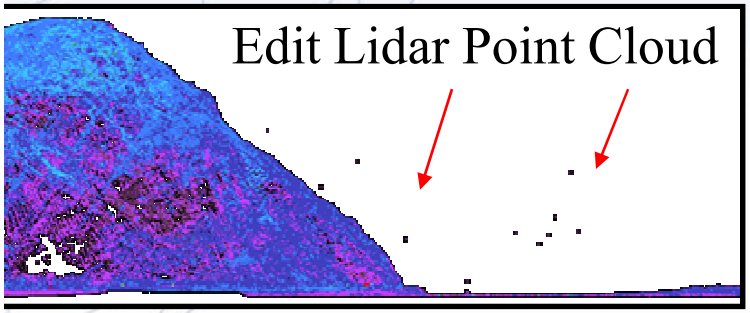
Positioning America for the Futur

Acquire coastal lidar and process to point cloud



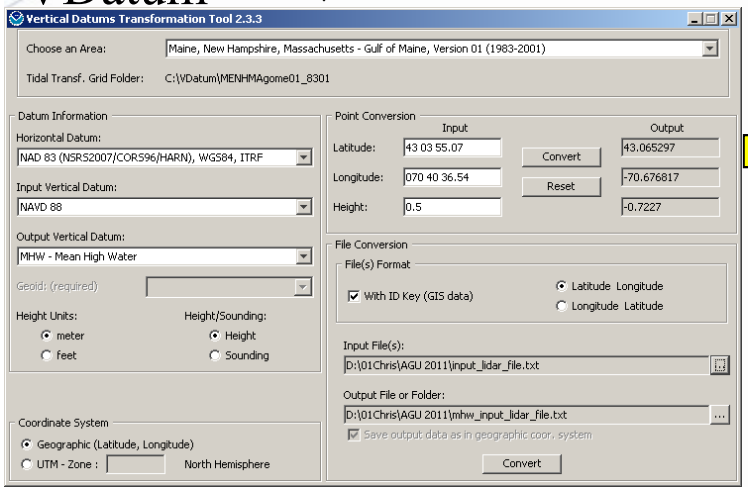
Application to Nautical Chart

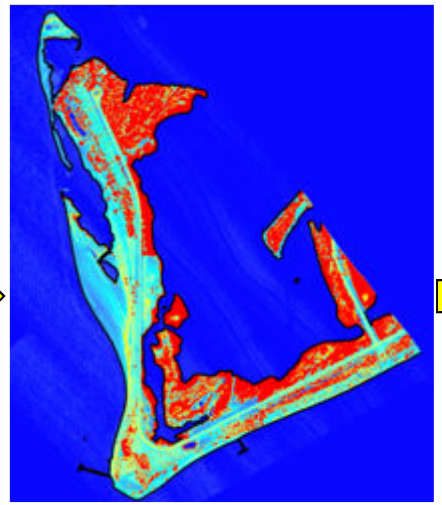


Edit Lidar Point Cloud

Lidar Shoreline Mapping Process

VDatum





Contour Shoreline from DEM

Editing, Attribution, and QA/QC

NOAA National Shoreline Products

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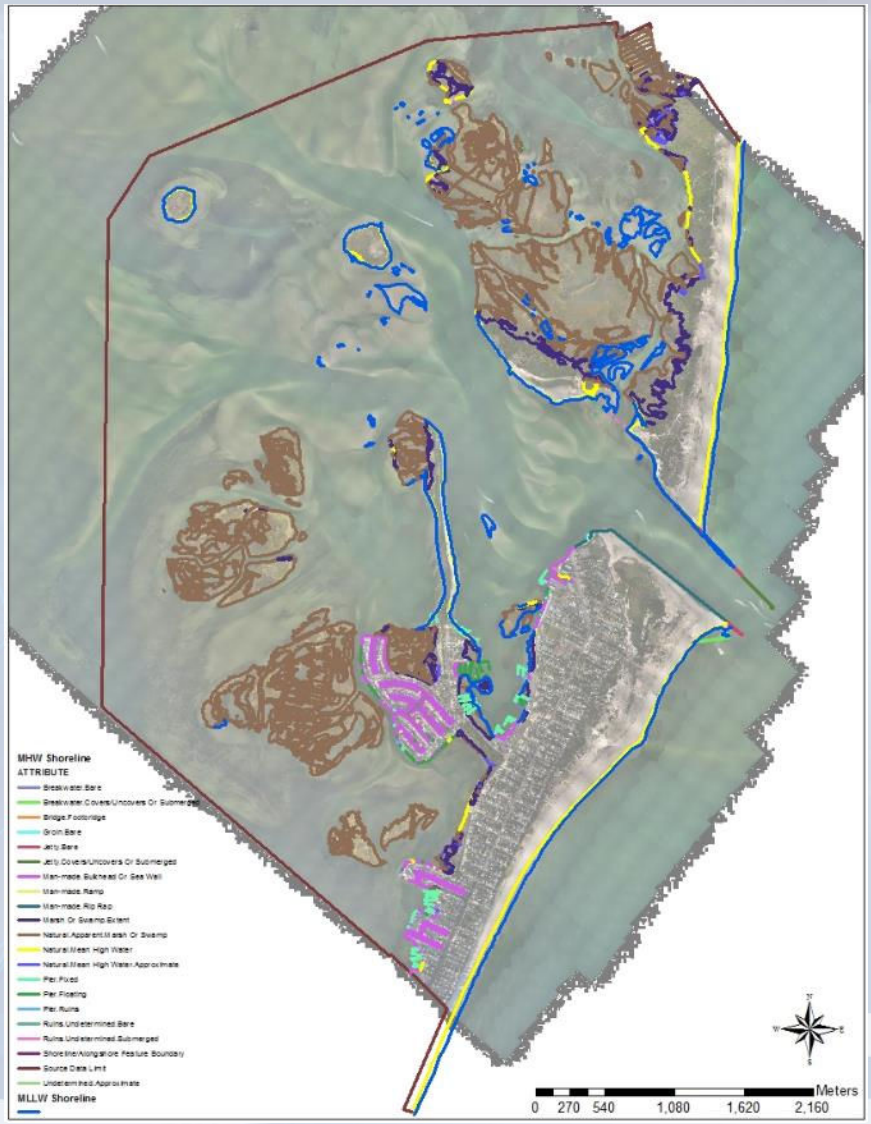
Final Geographic Cell (GC) for Barnegat Inlet



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SOW for Contract Topo-Bathy Lidar in Sandy-Impact Region:

- Contracted imagery and topo-bathy lidar acquisition to support update of the National Shoreline in Sandy region
  - Additional uses: mapping, charting, geodesy services, marine debris surveys
- Deliverables (partial list):
  - Merged, cleaned topo-bathy point clouds in LAS 1.2 format
  - Topo-bathy DEMs
  - GeoTiff RGB/NIR ortho-mosaics

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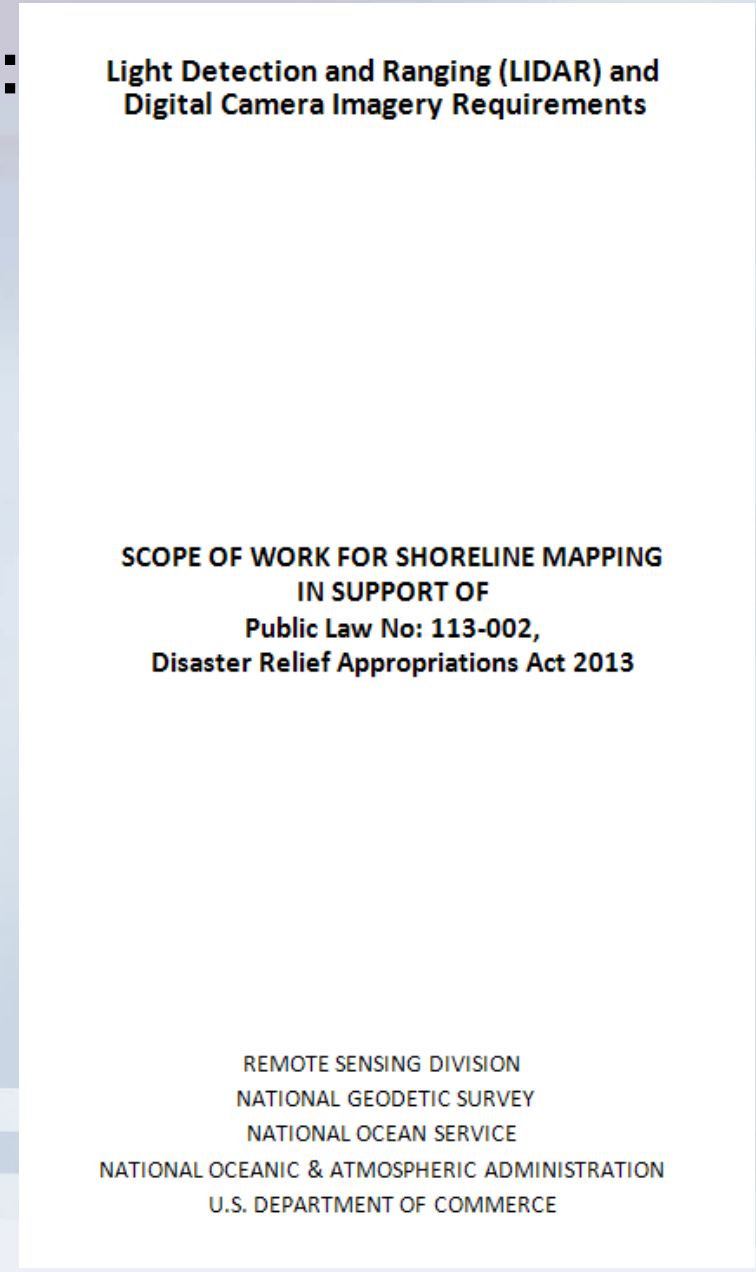


Light Detection and Ranging (LIDAR) and Digital Camera Imagery Requirements

SCOPE OF WORK FOR SHORELINE MAPPING IN SUPPORT OF Public Law No: 113-002, Disaster Relief Appropriations Act 2013

REMOTE SENSING DIVISION
NATIONAL GEODETIC SURVEY
NATIONAL OCEAN SERVICE
NATIONAL OCEANIC & ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

Project Area

- Supplemental Sandy Topobathy LiDAR and Imagery Task for the NOAA NGS Shoreline Mapping Program
- Dewberry tasked as prime contractor under the NOAA CGSC II contract
- Subcontractors – Quantum Spatial (LiDAR and Imagery), Woolpert (Imagery)
- Project is currently underway (acquisition began Nov 21, 2013).
- 3 aircraft with topobathy LiDAR being deployed
- Current acquisition status: 89% complete
  - Block 1 – 100% complete
  - Block 2 – 96% complete
  - Block 3 – 69% complete

PRELIMINARY

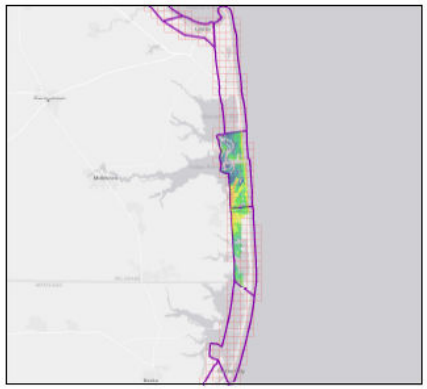
NOAA Sandy Coverage 12/21/2013
Block 80 Lines 1636-1657

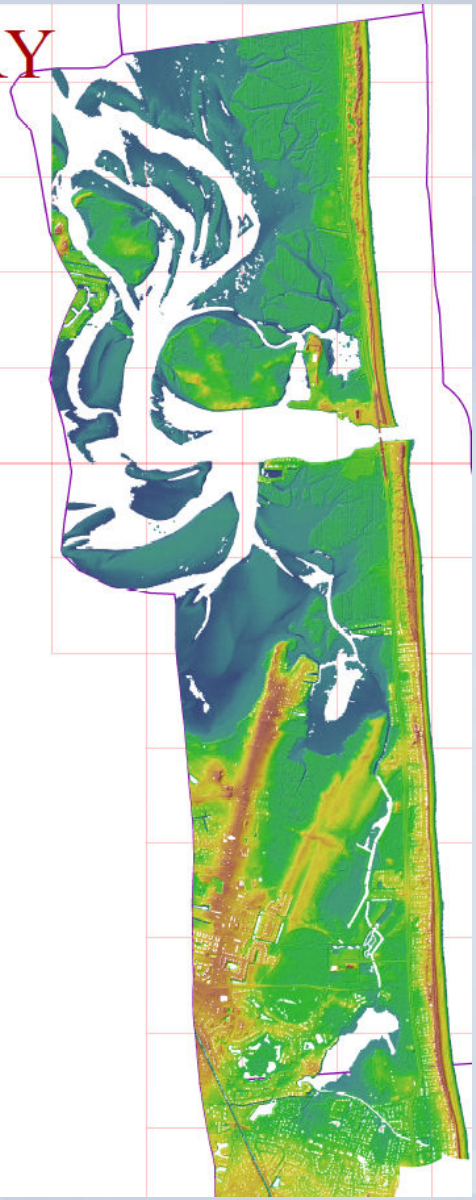
NOAA Sandy Flight Blocks

Tile Index

N

0 0.5 1 2 Miles





PRELIMINARY

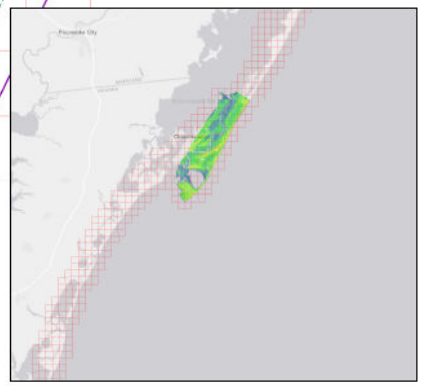
NOAA Sandy Coverage 12/16/2013

NOAA Sandy Flight Blocks

Tile Index

N

0 0.5 1 2 Miles



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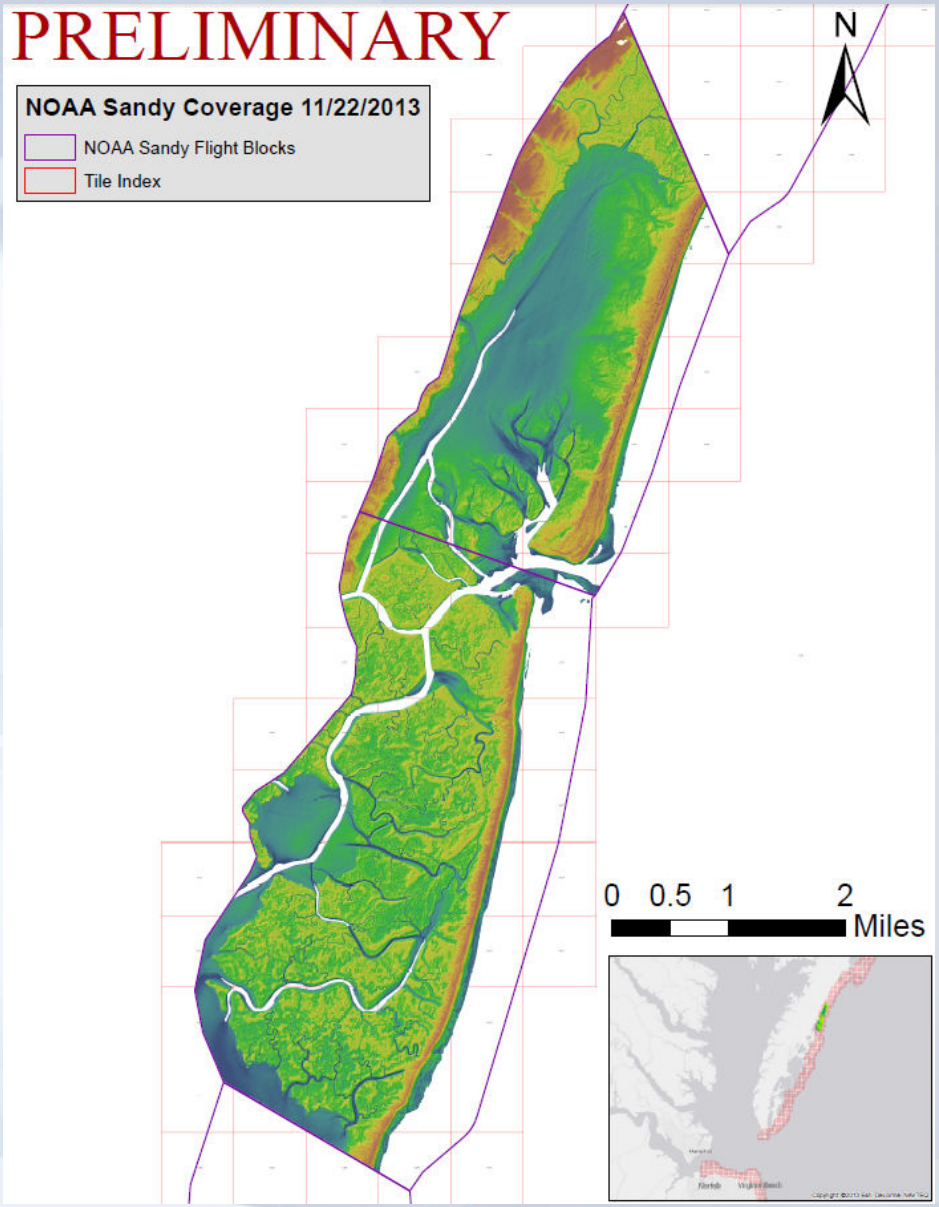
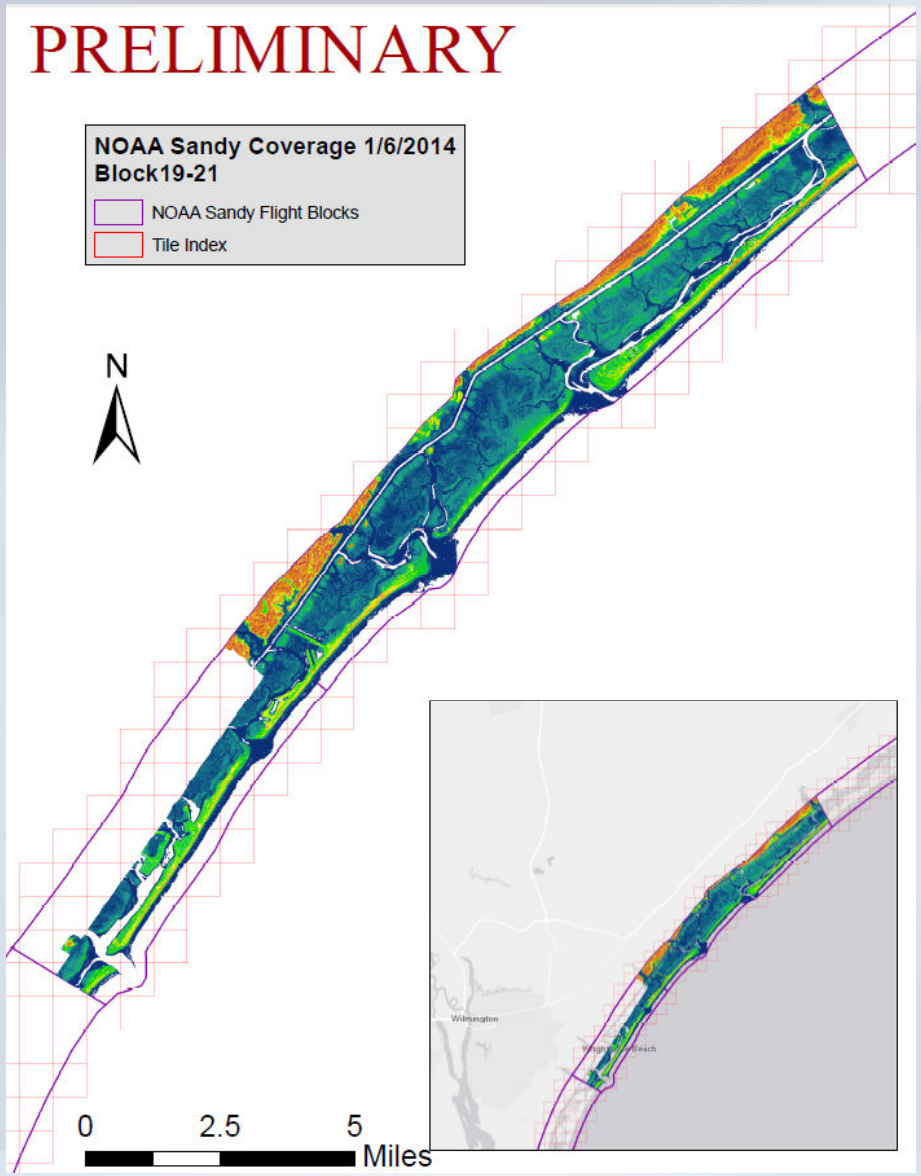
PRELIMINARY



PRELIMINARY



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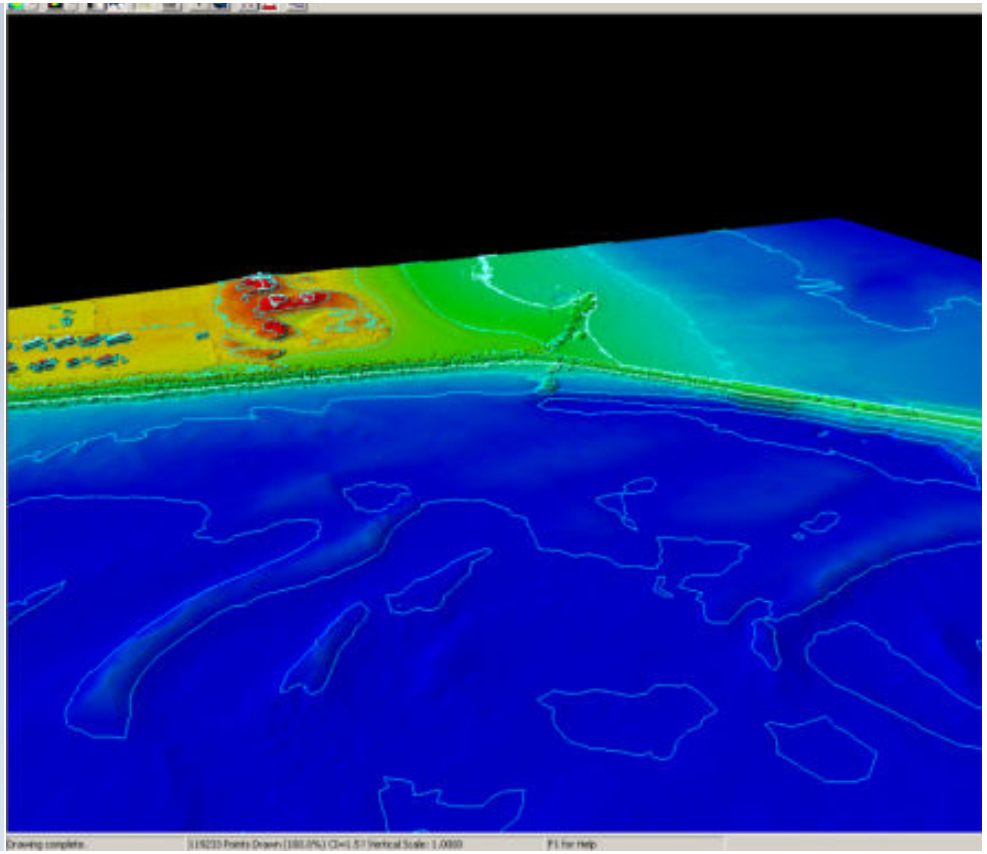
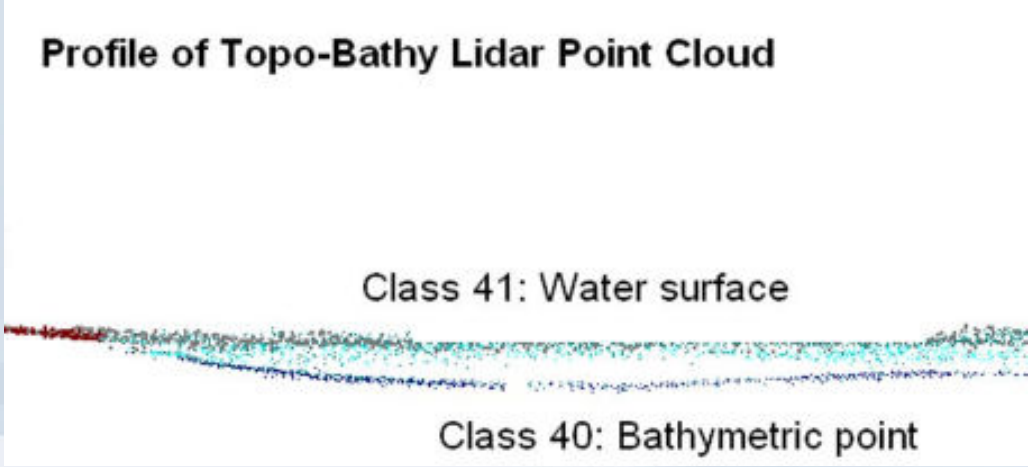
LAS 1.4: Topo-Bathy Domain Profile

- New point classes:
  - Bathymetric point (e.g., seafloor ,riverbed; AKA - submerged topography)
  - Water surface (observed)
  - Water surface (derived)
  - Submerged object
  - IHO S-57 object
  - Bottom-not-found depth
- New attributes:
  - (pseudo)-reflectance
  - XYZ Uncertainty
  - Water column optical depth
  - Figure of Merit
  - Flags





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Qunitero, R., 2013. New LAS Enhancements Support Topographic-Bathymetric Lidar, *LiDAR Magazine*, Vol. 3, No. 6

In Closing

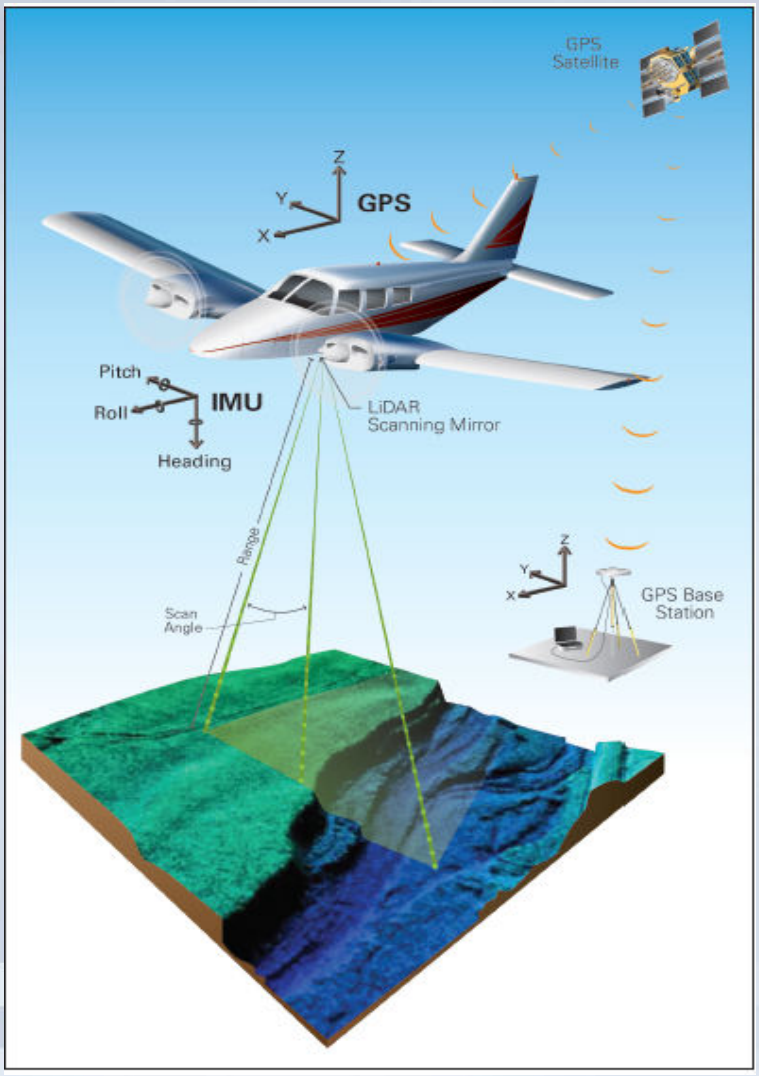
Topobathy Lidar is proving to be a valuable tool to meet NOAA's requirements

- **IOCM multi-use**
  - **Shoreline mapping**
  - **Charting**
    - **Fill in data gap ("white ribbon") along coast**
  - **SLR inundation modeling**
  - **Benthic habitat mapping**
  - **Coastal zone management, coastal science**
- **Potential for increased efficiencies in operations**
  - **Initial airborne Lidar survey to then support hydrographic operations**
- **Opportunity for both the Terrestrial and Bathymetric communities to incorporate the data for their needs**
  - **Software on both sides needs to ingest LAS 1.4 – Littoral processing**
  - **Orthoimagery also needs to be easily ingestible especially in bathymetric processing workflows.**

Backup Slides

Airborne Topo-bathy Lidar

- New generation of systems designed:
  - Very high-res, seamless data in littoral zone
    - Multiple pts/m^2
- IOCM multi-use
  - Shoreline mapping
  - Charting
    - Fill in data gap (“white ribbon”) along coast
  - SLR inundation modeling
  - Benthic habitat mapping
  - Coastal zone management, coastal science



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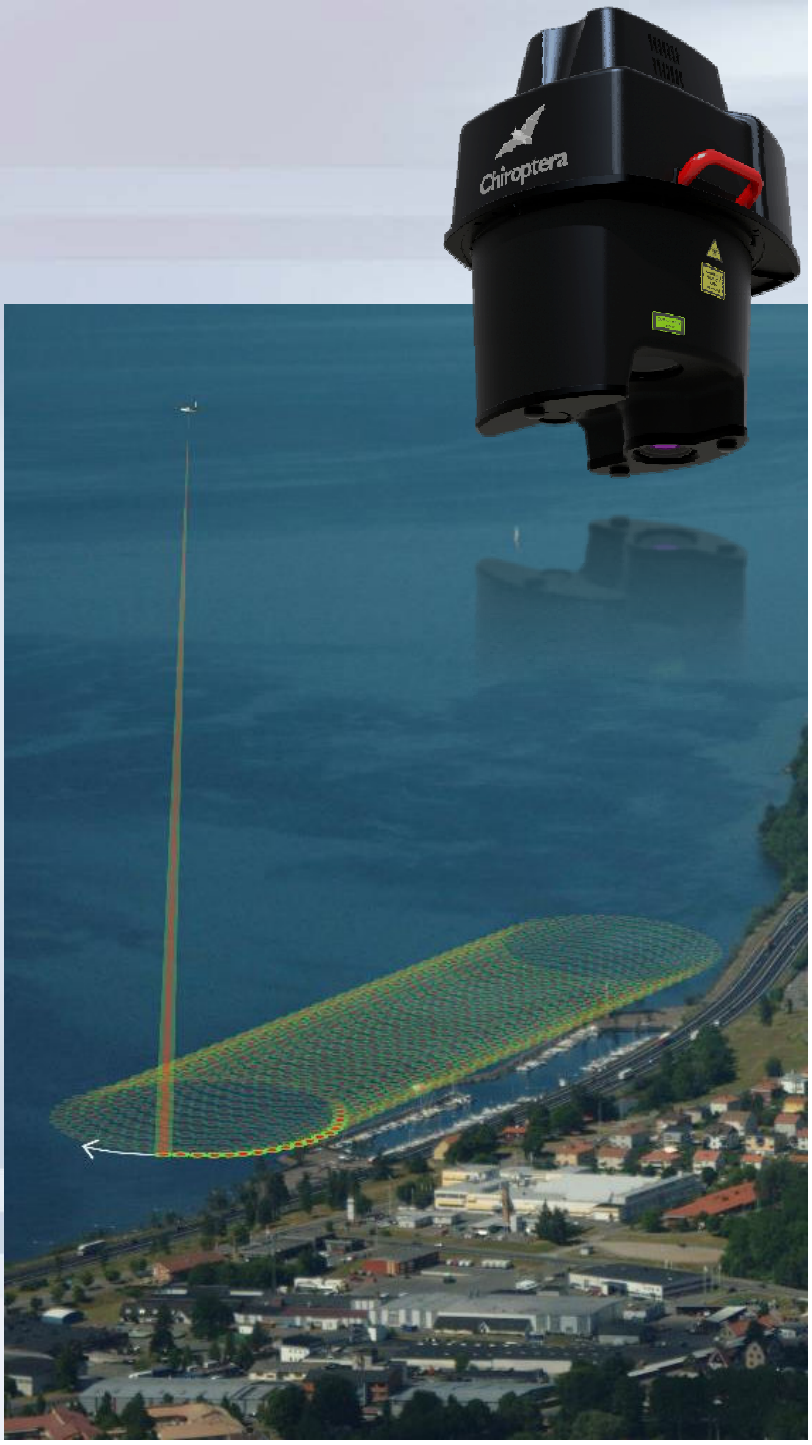
Slide courtesy of Amar Nayegandhi, Dewberry

AHAB Chiroptera

- Topo up to 400 KHz
- Bathymetric survey 35 KHz
- Depth penetration adapted to bathymetric needs
  - Full coverage to $K_d x D_{max} > 2$
- High energy laser and fast sytem response time
  - Excellent target detection and shallow water capability
  - Oblique scanner principle
  - Automatic water refraction correction



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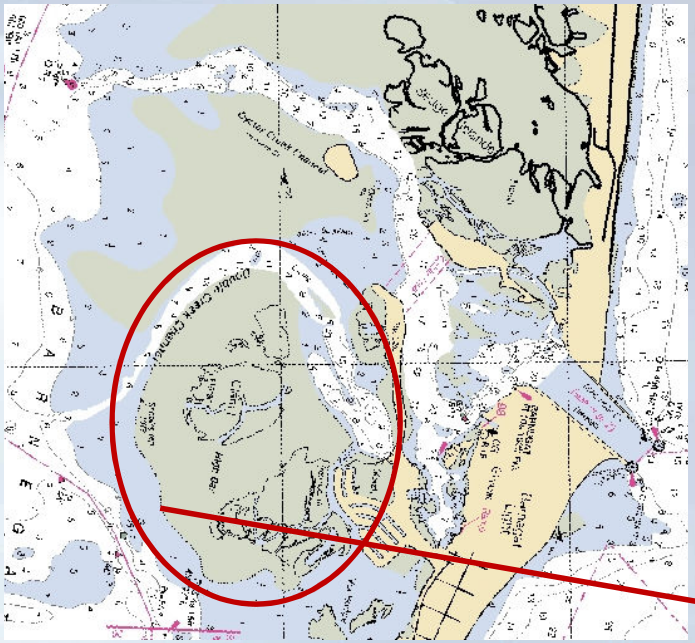
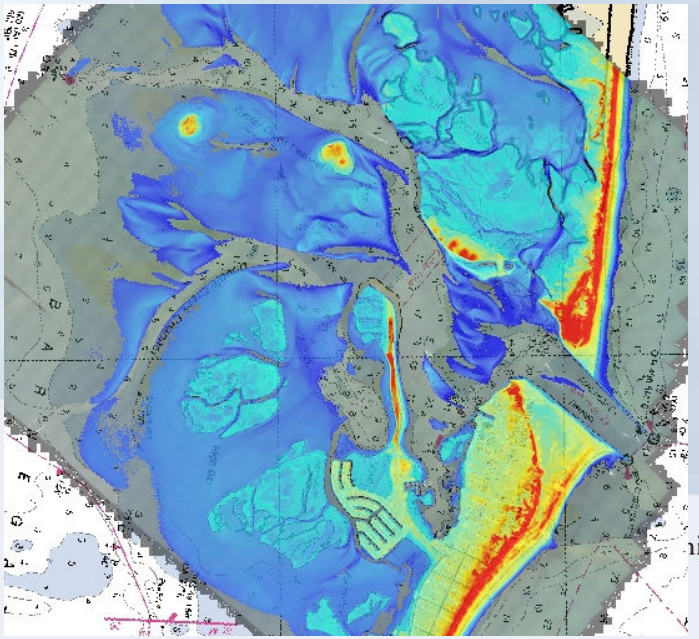
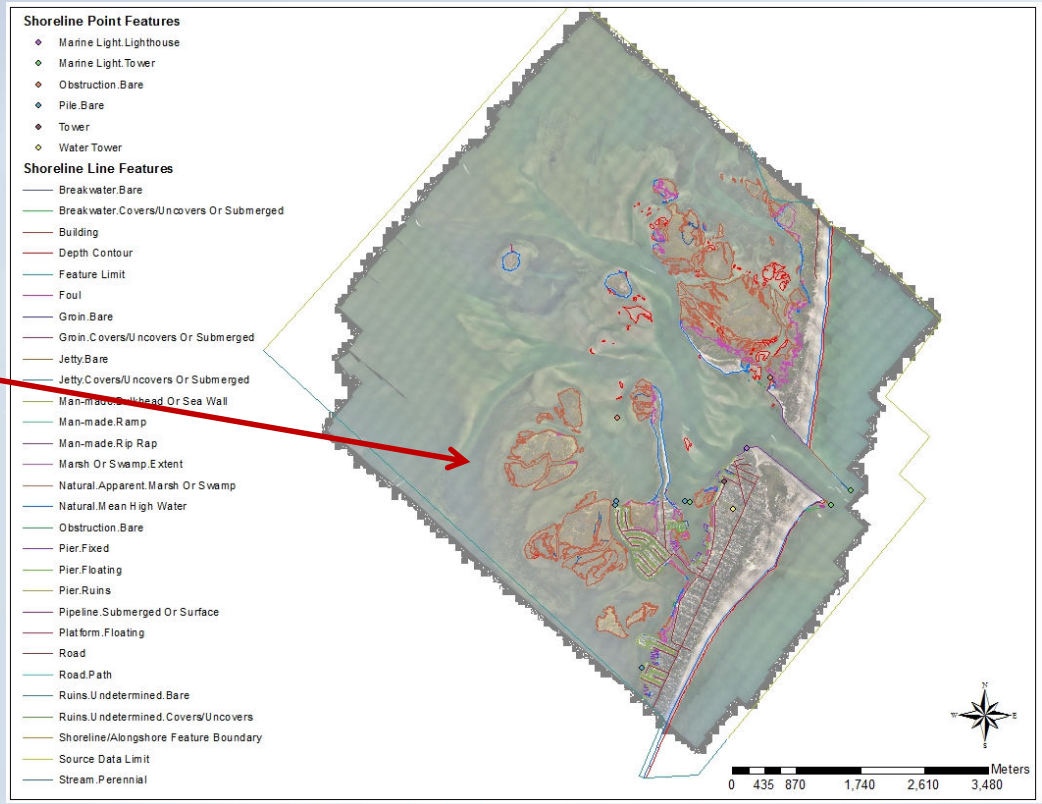
Images courtesy of Anders Ekelund, AHAB

MLLW Shoreline Changes



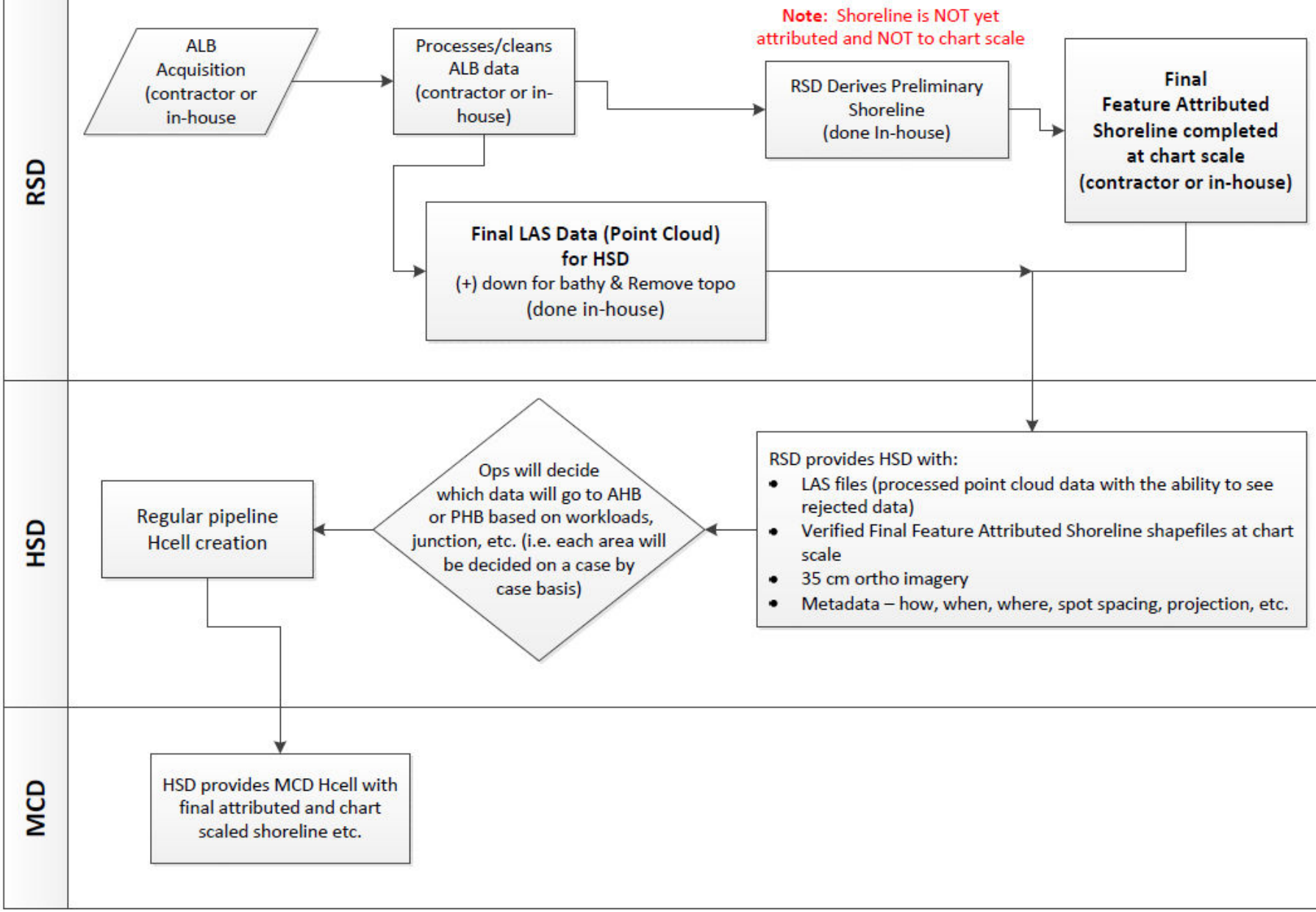




Derived MLLW Shoreline distance to MHW shoreline less than threshold needed to be depicted on Nautical Chart.

RSD In-house & Contract ALB to HSD & MCD

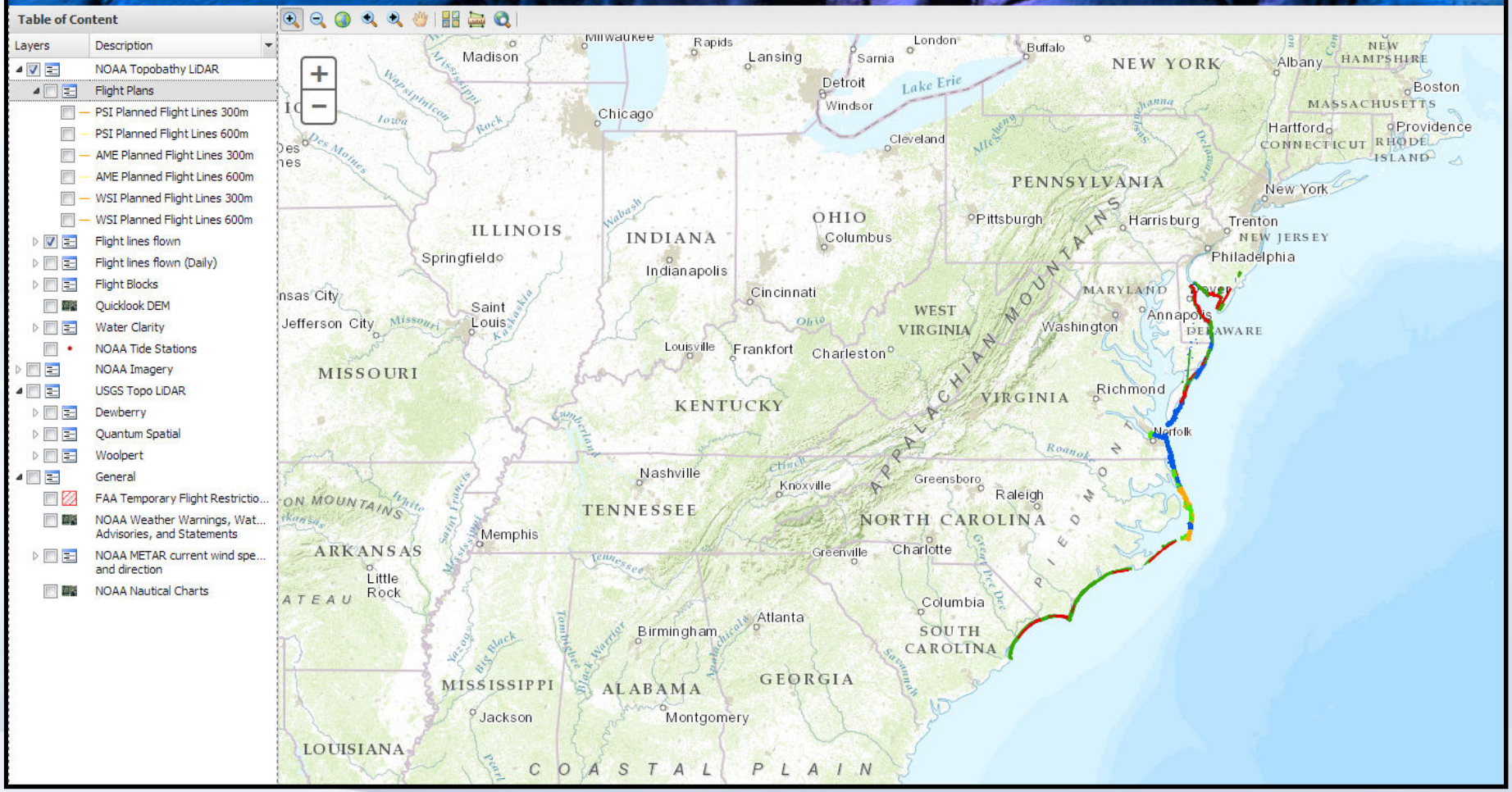
DRAFT



Supplemental Sandy LiDAR and Imagery Acquisition for NOAA and USGS

In support of: NOAA Coastal Geospatial and Services Contract, NOAA Shoreline Mapping Program, USGS Geospatial Products and Services Contract

Dewberry



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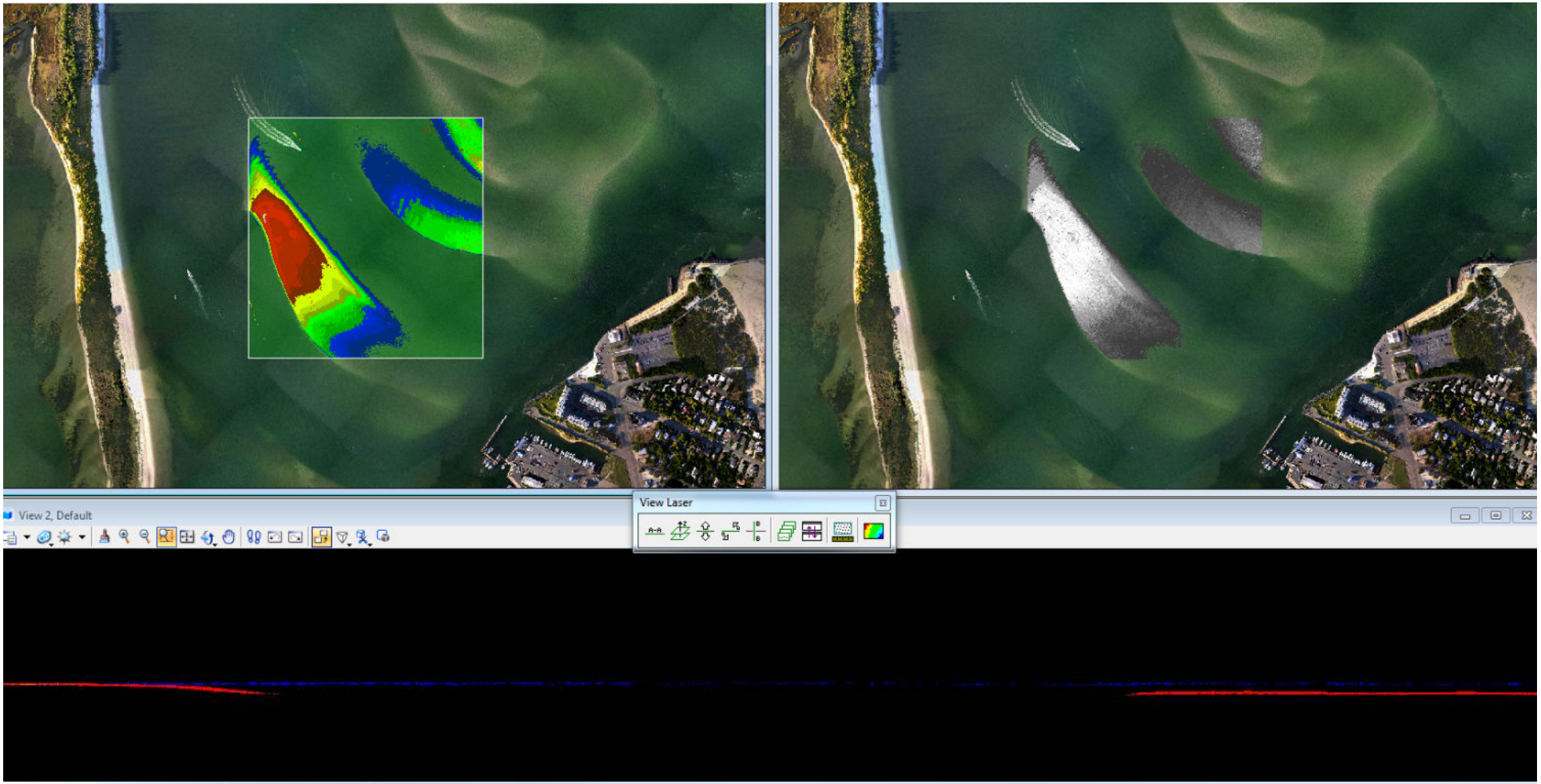
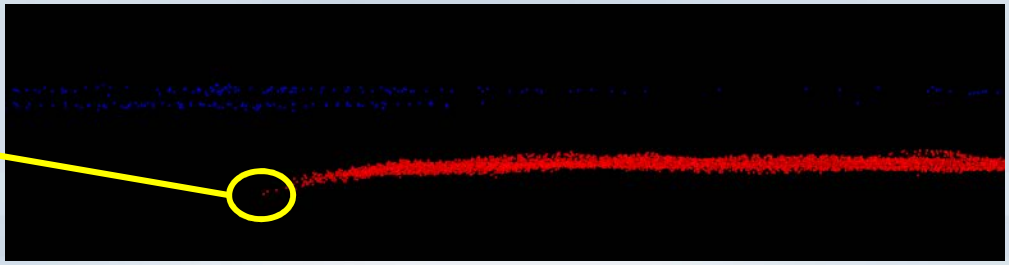


Depth of 1.5m
relative to MLLW



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