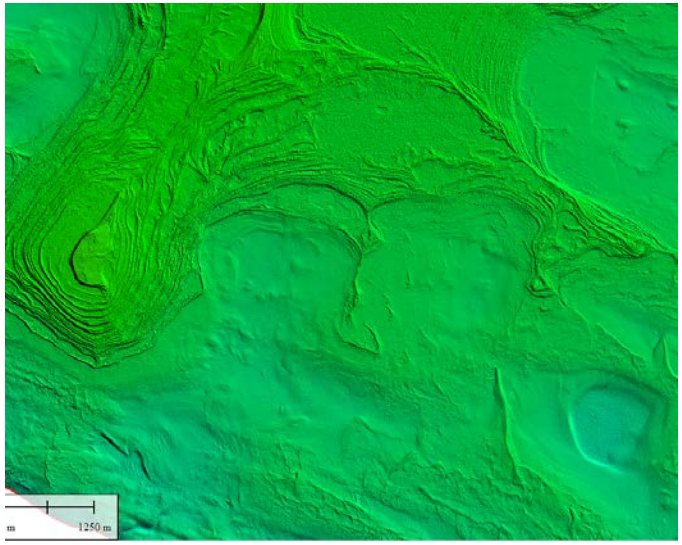
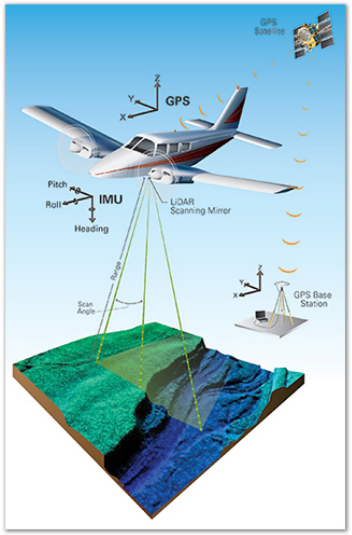
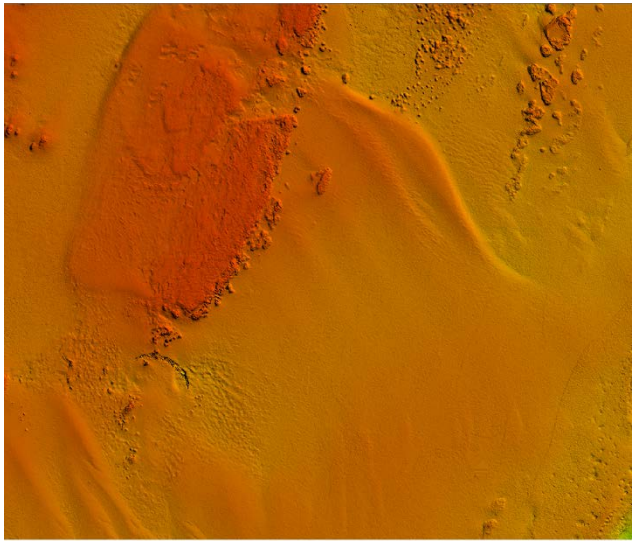




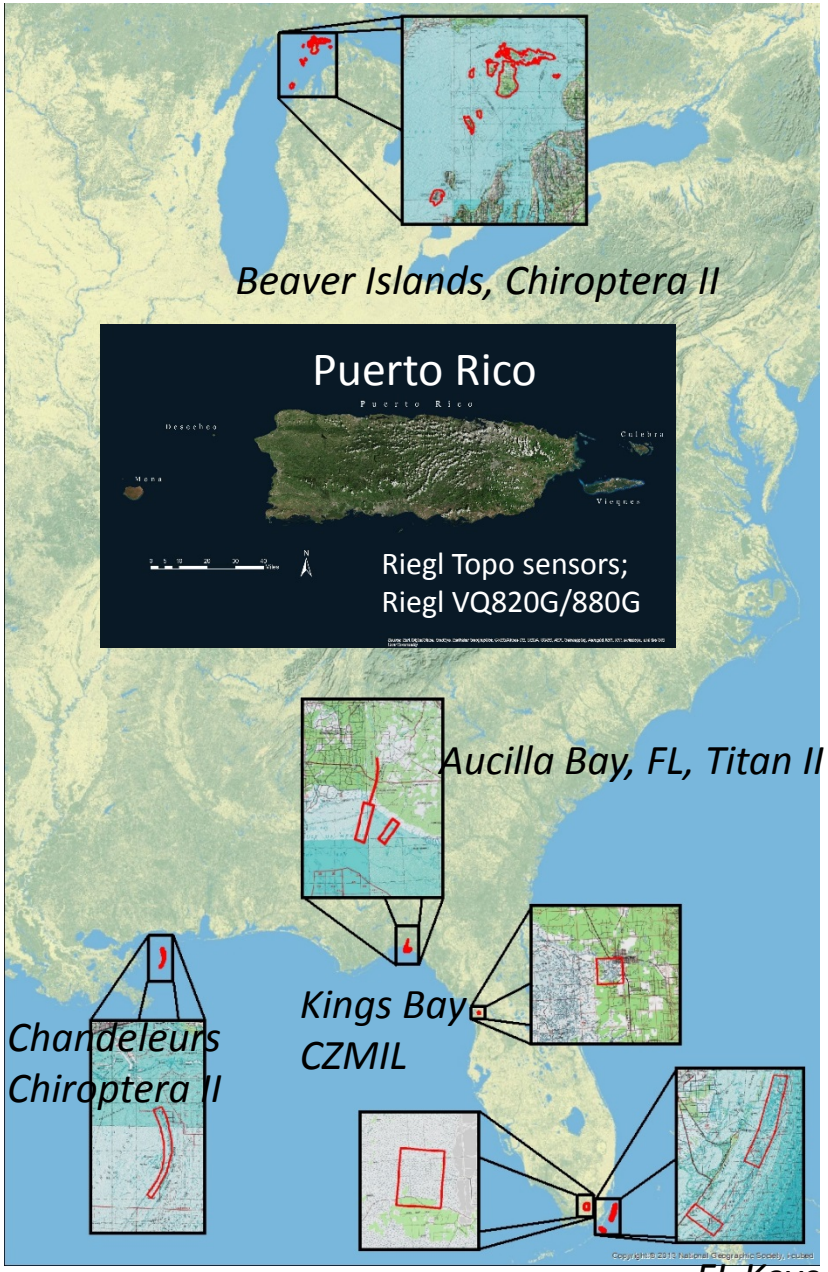


Recent Topobathy Lidar Projects – Puerto Rico, Beaver Islands, and beyond

Amar Nayegandhi, Dewberry

Recent Topobathy Projects by Dewberry

Client	Project Location	Sensor Used	Data Acquisition	Application
SWFWMD	Kings Bay / Three Sisters Springs, FL	CZMIL	April 2015	Florida Springs Initiative – protect and preserve natural springs
NOAA Office of Coastal Management	Beaver Islands Archipelago and South Manitou Island, Upper Lake Michigan	Chiroptera II	November 2015, completed May 2016	Sea Level Rise
USGS	Puerto Rico Topography and Topobathy	Riegl Q780 Riegl Q680 Riegl VQ820G	2014/15 (bathy) Jan – May 2016 (topo) – 81% complete	Mapping the entire island, including surrounding islands, for USGS 3DEP program.
NOAA NGS	Puerto Rico	VQ880G	Winter 2015/16	NGS Shoreline Mapping Program
USGS / NPS	Everglades NP	VQ880G Titan II	April / May 2016	Pilot study to determine the most appropriate sensor technology to use for mapping the Everglades
Florida DEP, Aucilla Research Institute	Aucilla and Ecofina Bay/River	Titan II	May 2016	Delineation of submerged river channels
USGS	Chandeleur Islands, Gulf of Mexico	Chiroptera II	June 2016	USGS Coastal Program research
USGS	Northern FL Reef Tract	Chiroptera II	June 2016	USGS Coastal Program research
USGS & NOAA (and USACE)	West coast El Nino project	Topo sensor – helicopter based	April-May 2016	El Nino research

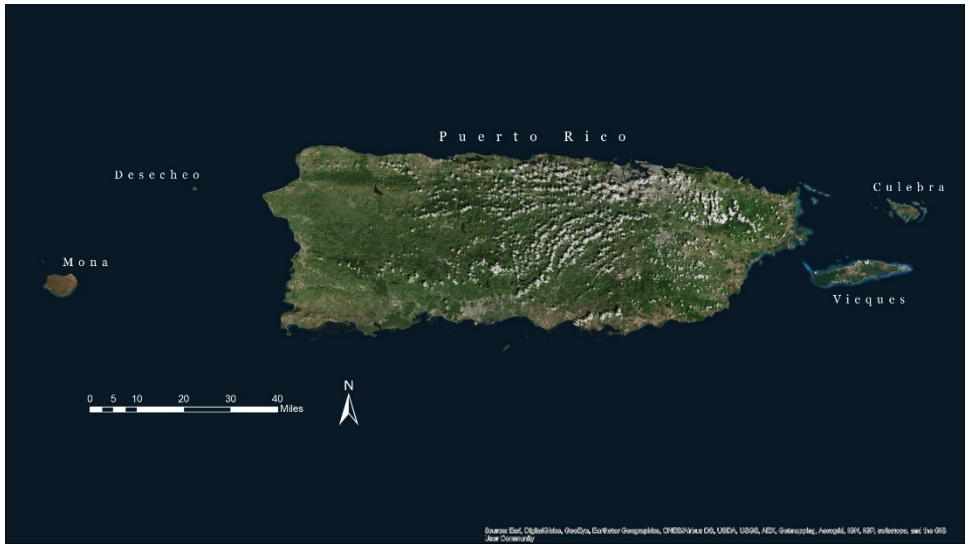


Sensor Selection Criteria

- Dewberry selects/recommends topobathy sensor technology based on a "horses for courses" approach.
  - Mostly British expression – comes from the horse racing world, where it is widely assumed that some horses race better on certain courses than on others
- Sensor selection is based on project requirements, intended application, cost, and client recommendation.
- Sensor agnostic / vendor neutral approach
- Work with sensor manufacturers, data acquisition partners, and client to acquire data.
- Will lease sensor/aircraft or subcontract as needed.

Dewberry

Puerto Rico Topographic/Topobathy Lidar Survey

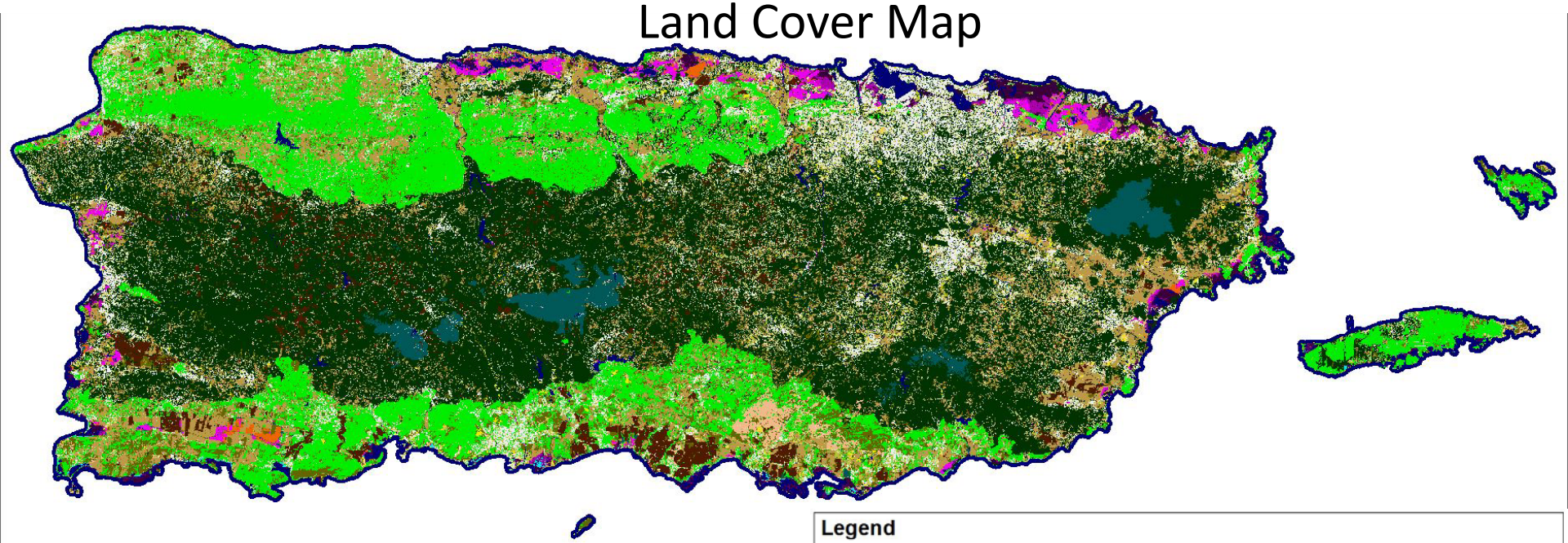


- Task awarded under USGS Geospatial Products and Services Contract - II
- Collaboration between USGS NGP and NOAA NGS

- Acquire and process topographic Lidar for entire island, including surrounding islands under the Commonwealth of Puerto Rico
- Process topobathy Lidar and created seamless data products for all data acquired by NOAA in 2014/15.

Dewberry's Experience in Puerto Rico

NOAA's Coastal Change Analysis Program – High Resolution Land Cover Map



Based on data acquired in 2010
Project completed in 2015

Puerto Rico Topobathy Lidar Survey

- Topobathy Lidar Survey
  - Data acquisition by NOAA National Geodetic Survey
  - 1,487 square miles
  - Penetration to ~12 meters
  - 3 Phase Acquisition by NOAA:
    - 2014 – Riegl VQ820G Oct/Nov 2014
    - 2015 – Riegl VQ820G April/May 2015
    - 2016 – Riegl VQ880G – March/April 2016
  - Dewberry has completed the processing of the 2014/2015 data under USGS GPSC Task Order.
  - 2016 data processing tasking by NOAA NGS (planned).

Puerto Rico Topographic Lidar Aerial Survey

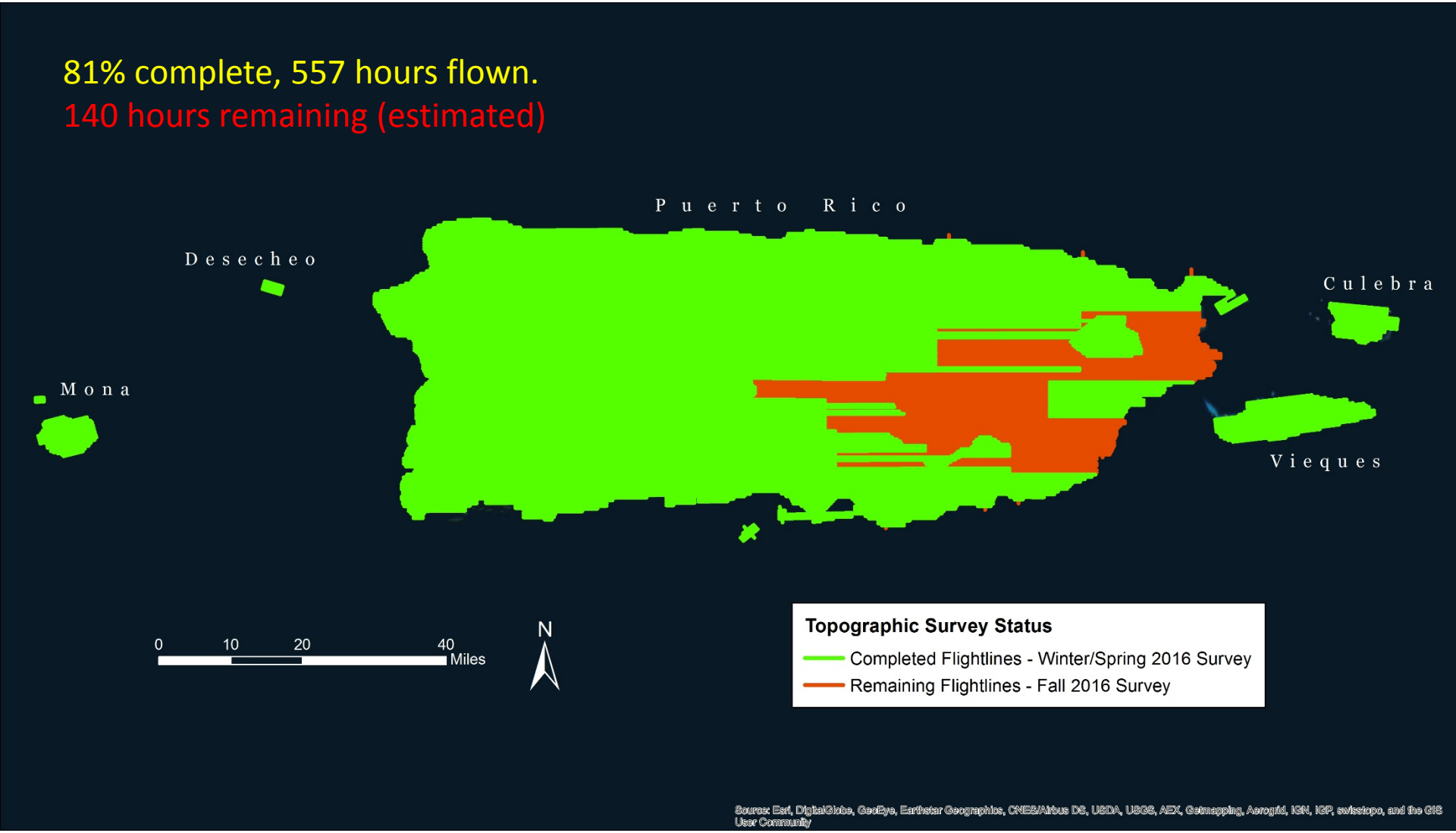
Task Order awarded under USGS GPSC II Contract

Aerial Survey

- 3,451 square miles – including Mona, Culebra, Vieques
- Mobilized - January 29, 2016
- Completed 81% of survey - May 16, 2016
- Remainder to be acquired Nov/Dec 2016.
- Persistent cloud cover in the southeast
- 557 total hours of flight time (including transit to location and daily transit time)
- 96 total days so far

Puerto Rico – Topographic Aerial Survey Status

81% complete, 557 hours flown.
140 hours remaining (estimated)



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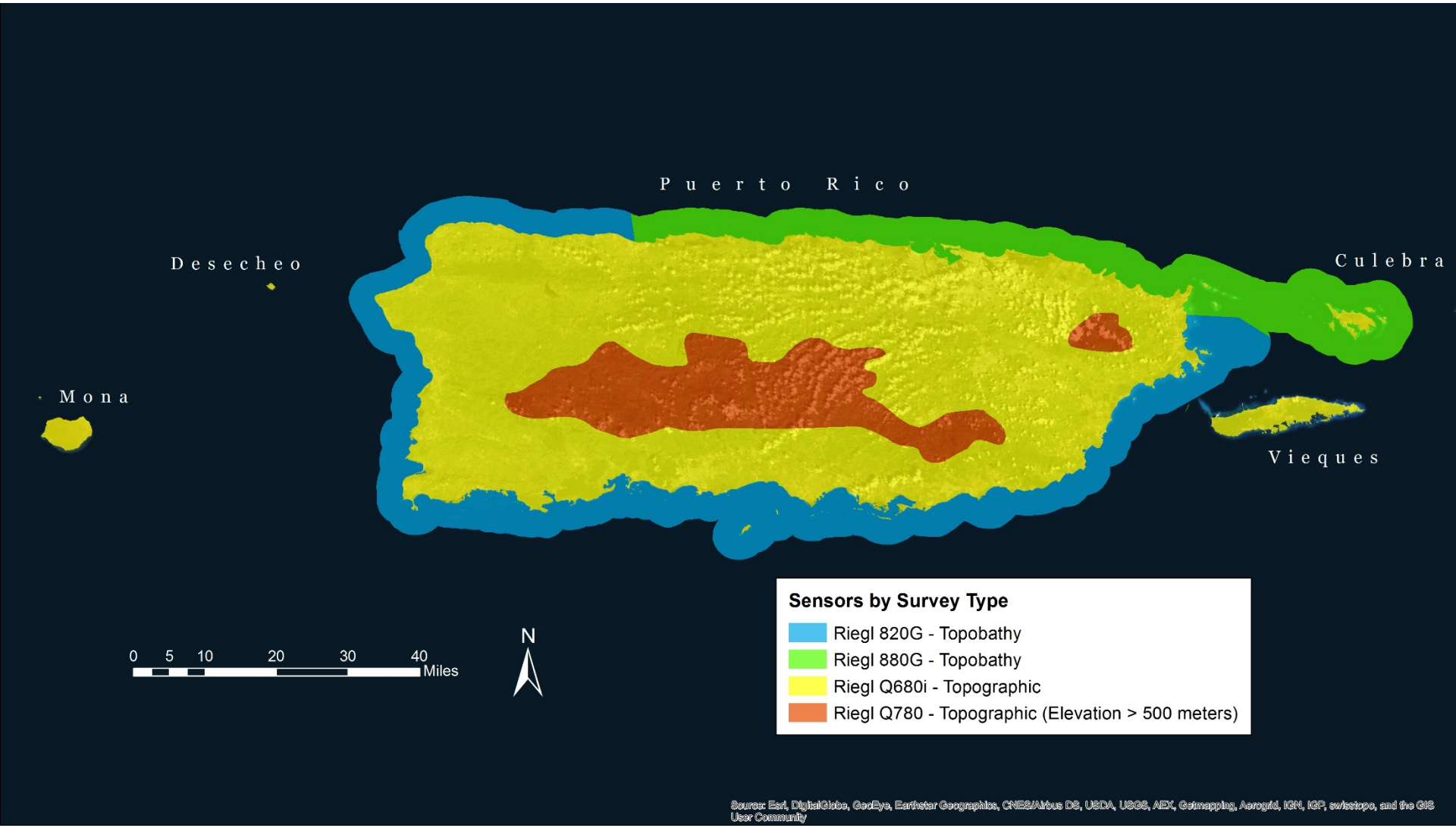
Puerto Rico Survey – Sensor Used



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Puerto Rico – Deliverables

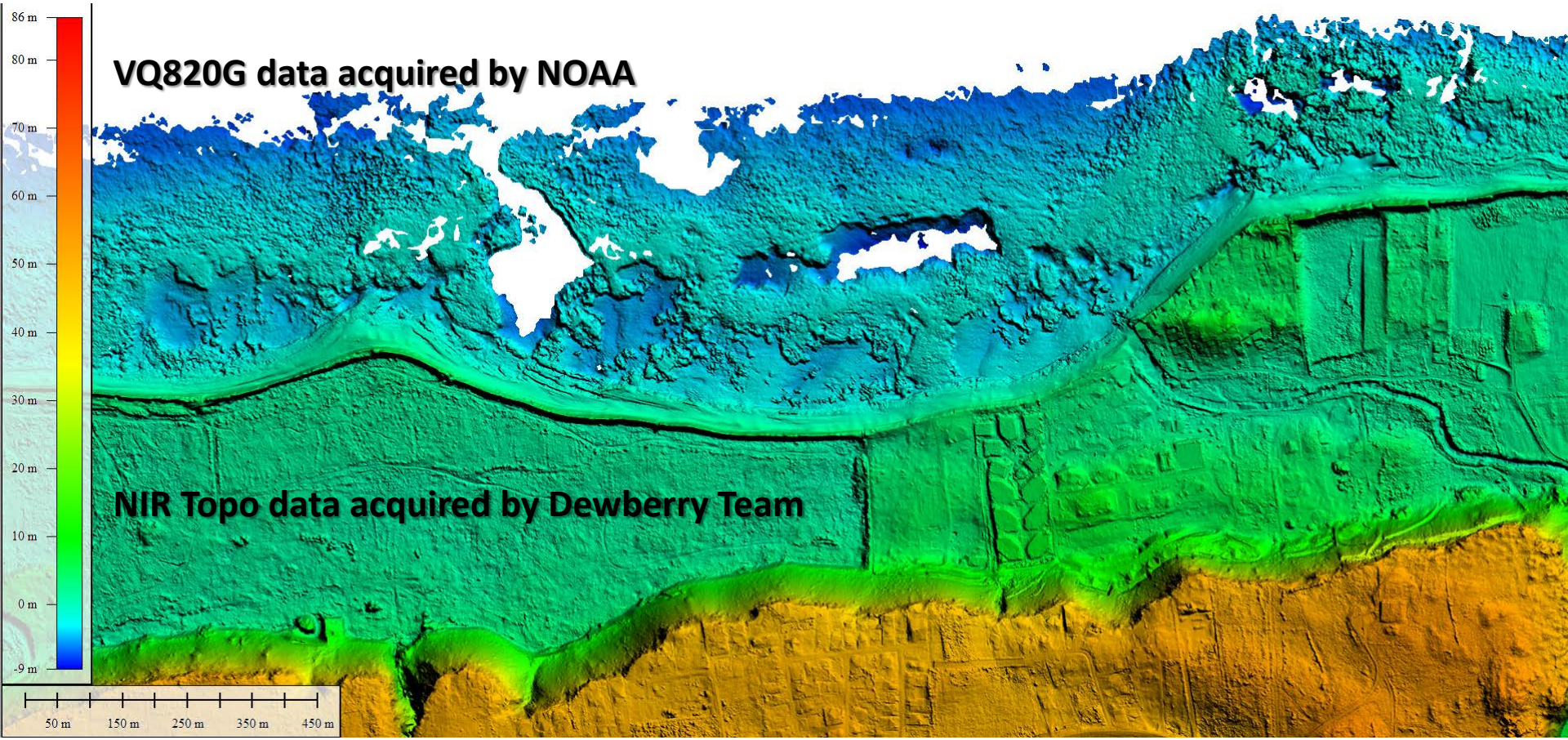
USGS

- Classified Topographic LAS v1.4
- Classified Topobathy LAS v1.2
- Hydroflattened “Topo” DEMs
- NOAA-acquired Topobathy DEMs
- *Merged Topographic/Topobathy DEM*

NOAA

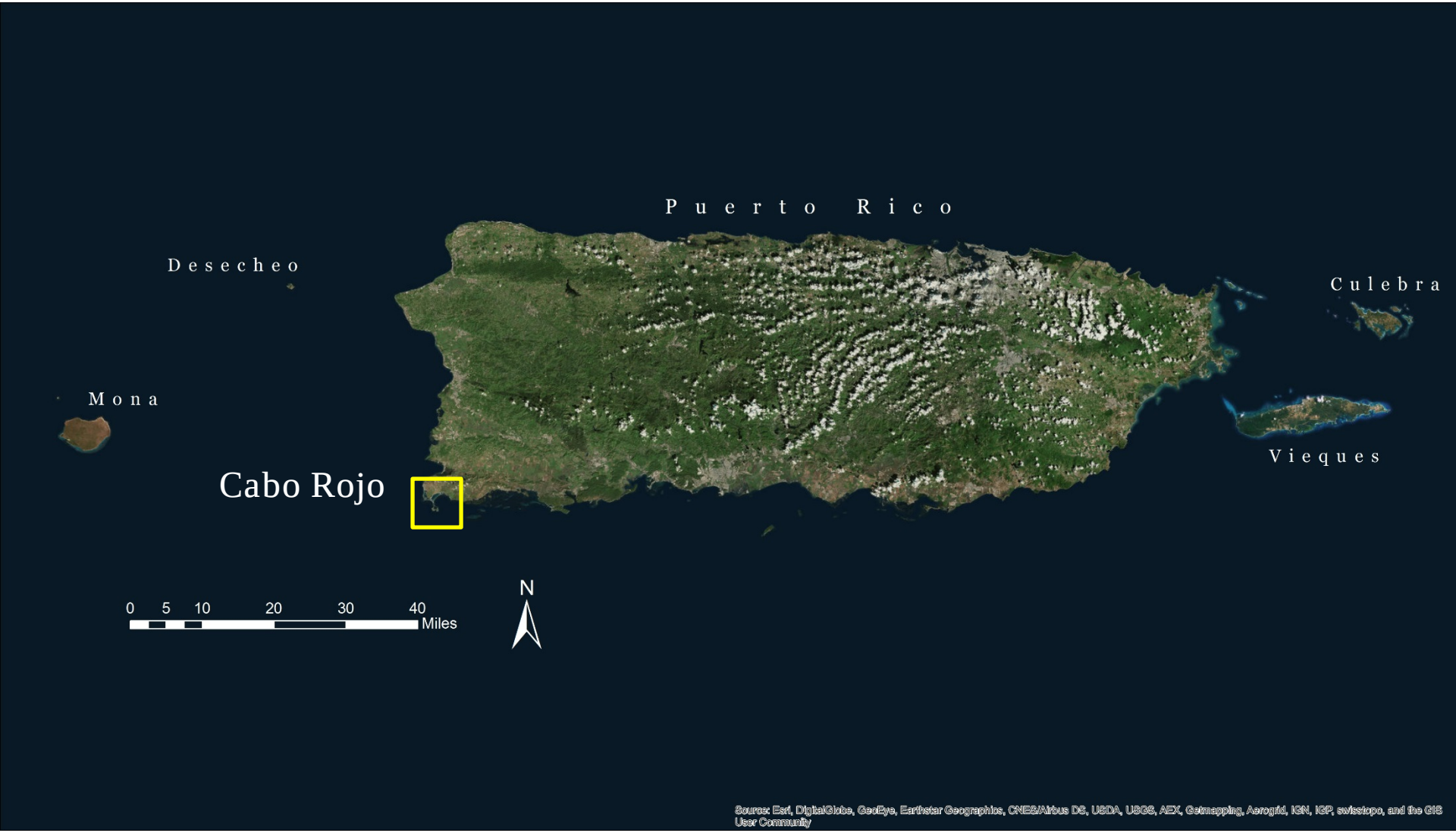
- Classified Topobathy LAS v1.2
- Topobathy DEMs
- *Merged Topographic/Topobathy DEM*
- Shoreline & Navigational Aid Shapefiles

Puerto Rico – Merged Topobathy DEM



Puerto Rico Topobathy Lidar Highlights

Puerto Rico Topobathy Lidar – Cabo Rojo



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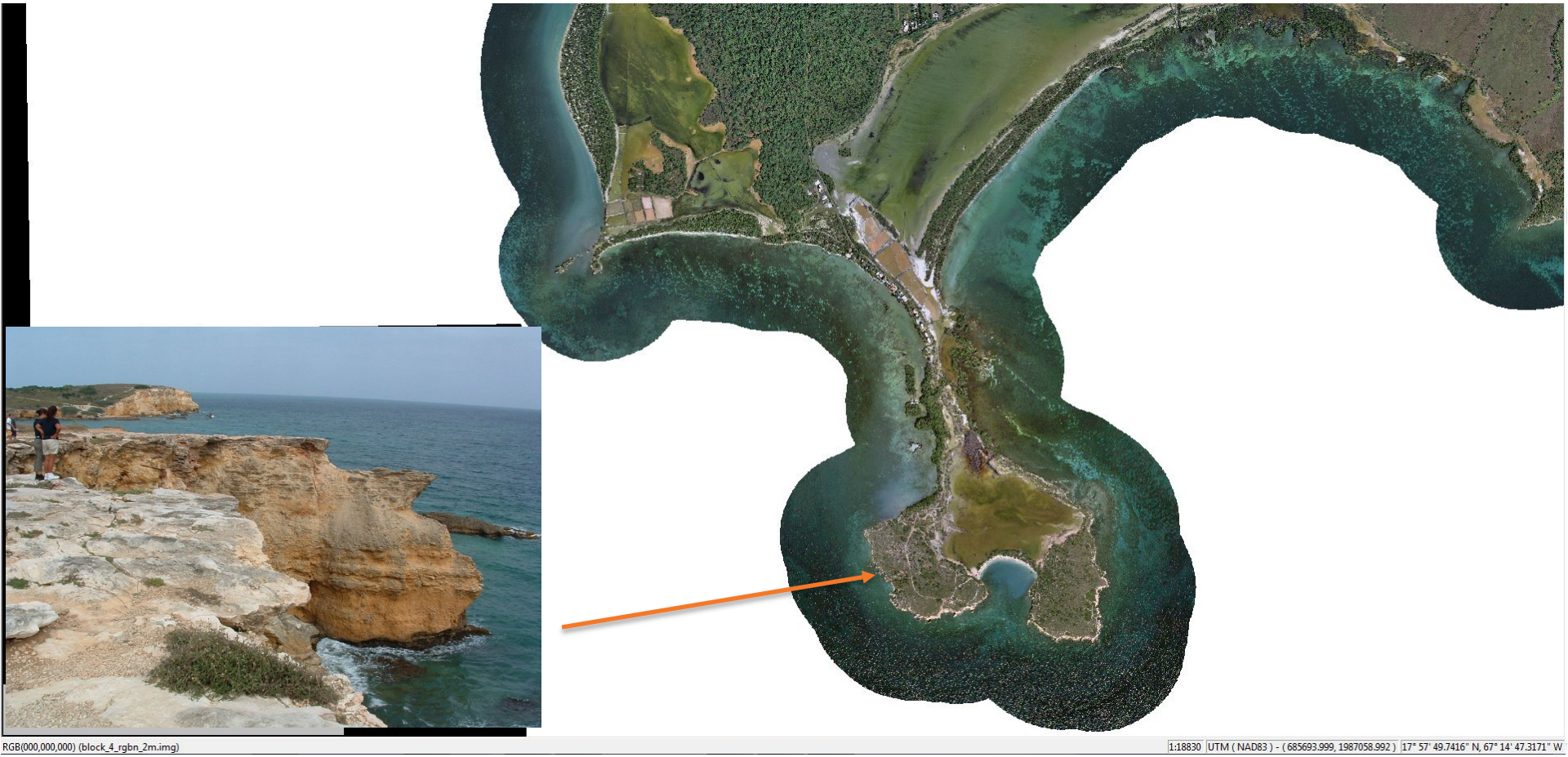
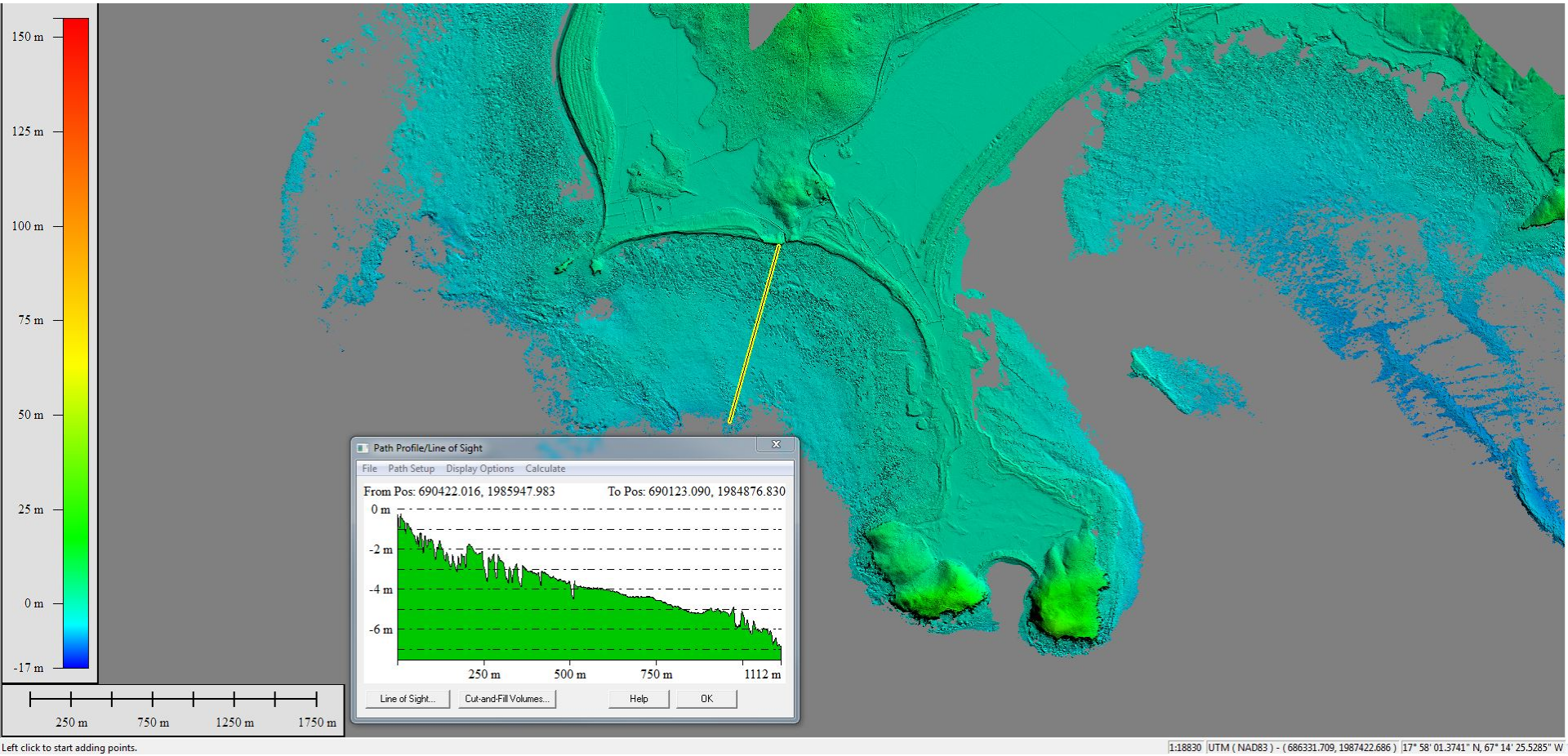
Puerto Rico Topobathy DEM – Cabo Rojo



Puerto Rico Topobathy DEM – Cabo Rojo



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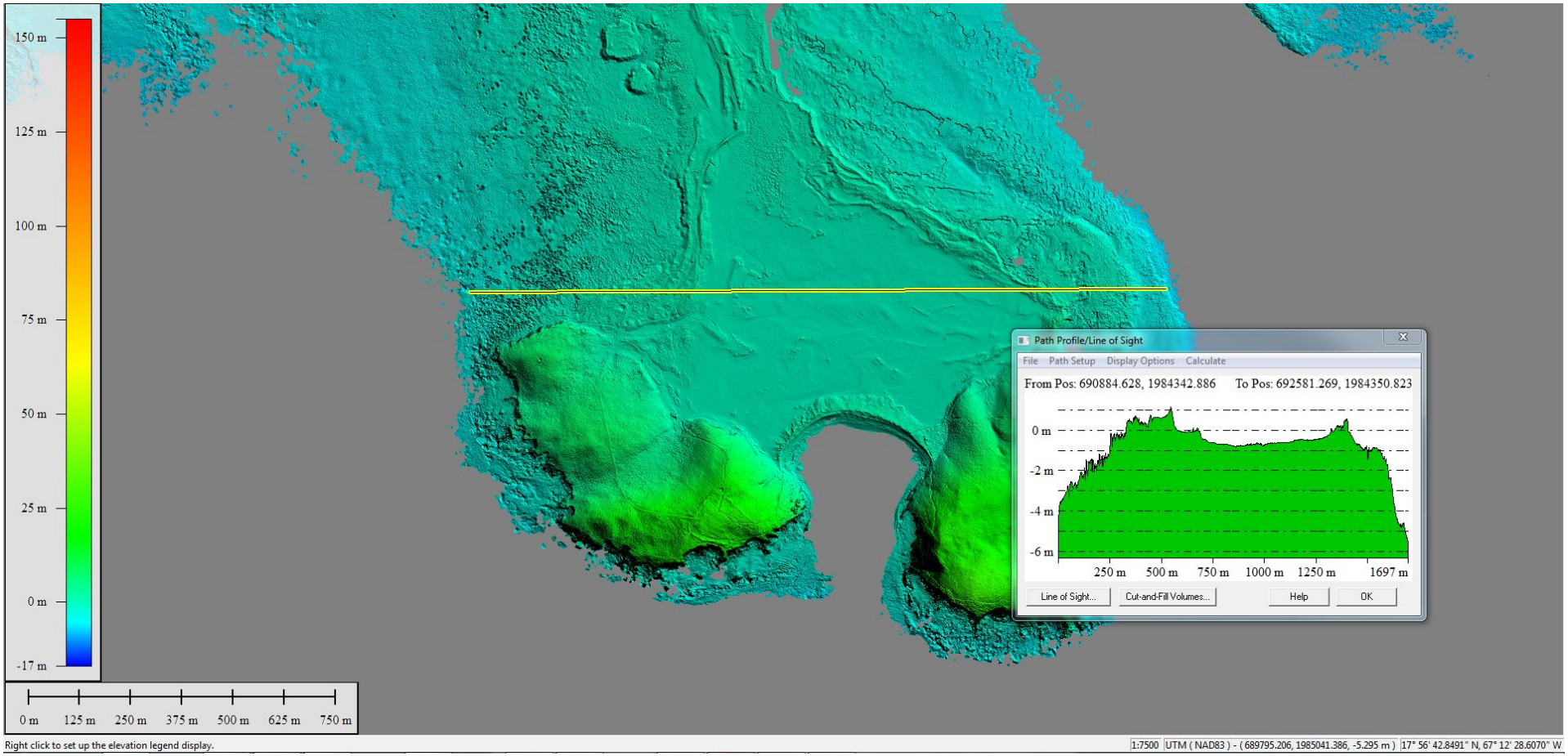
Puerto Rico Topobathy DEM – Cabo Rojo



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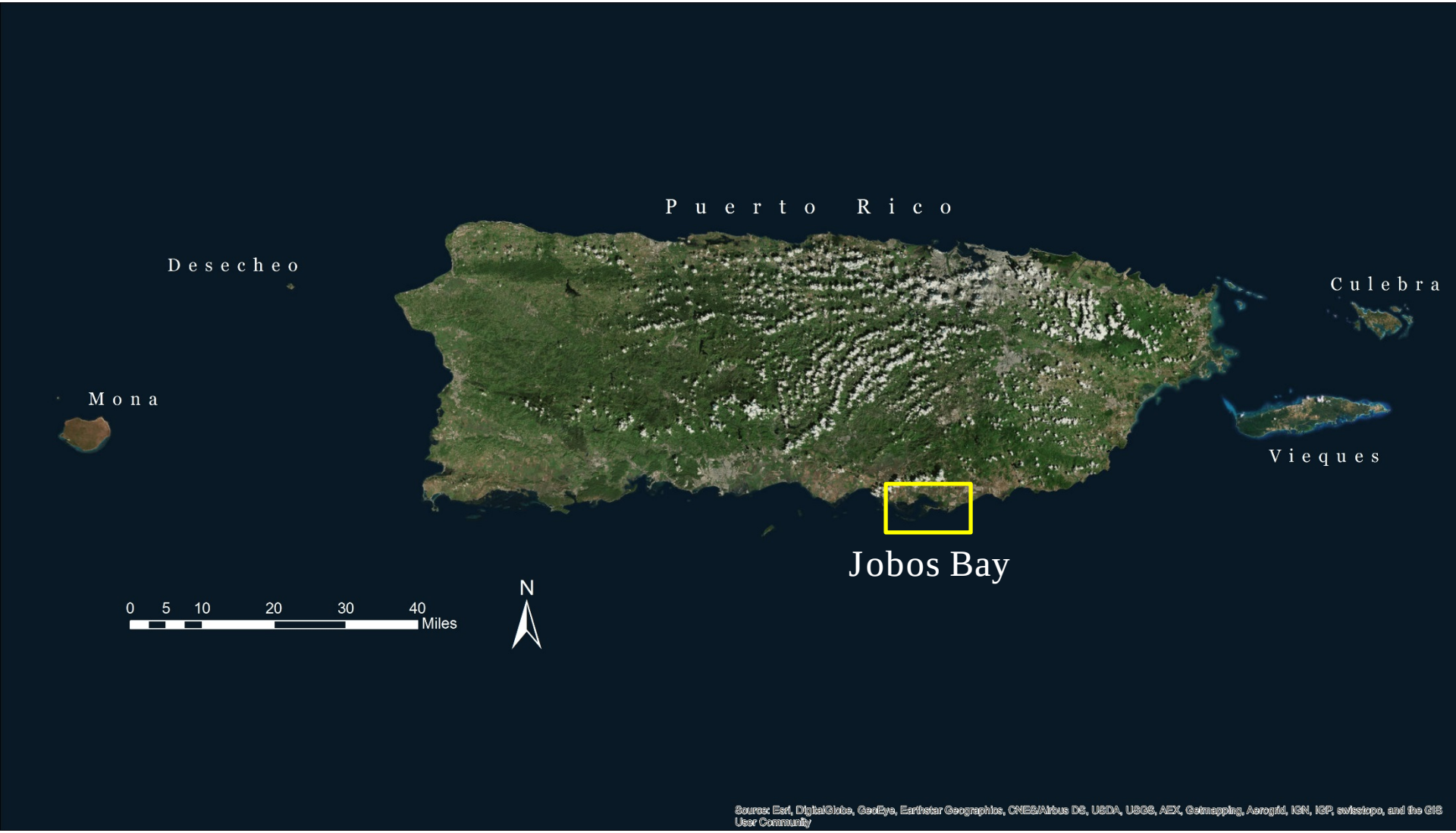
Puerto Rico Topobathy Lidar – Jobos Bay



Puerto Rico Topobathy Lidar – Jobos Bay

The bay is an intertidal tropical ecosystem dominated by seagrass beds, coral reefs, and mangrove

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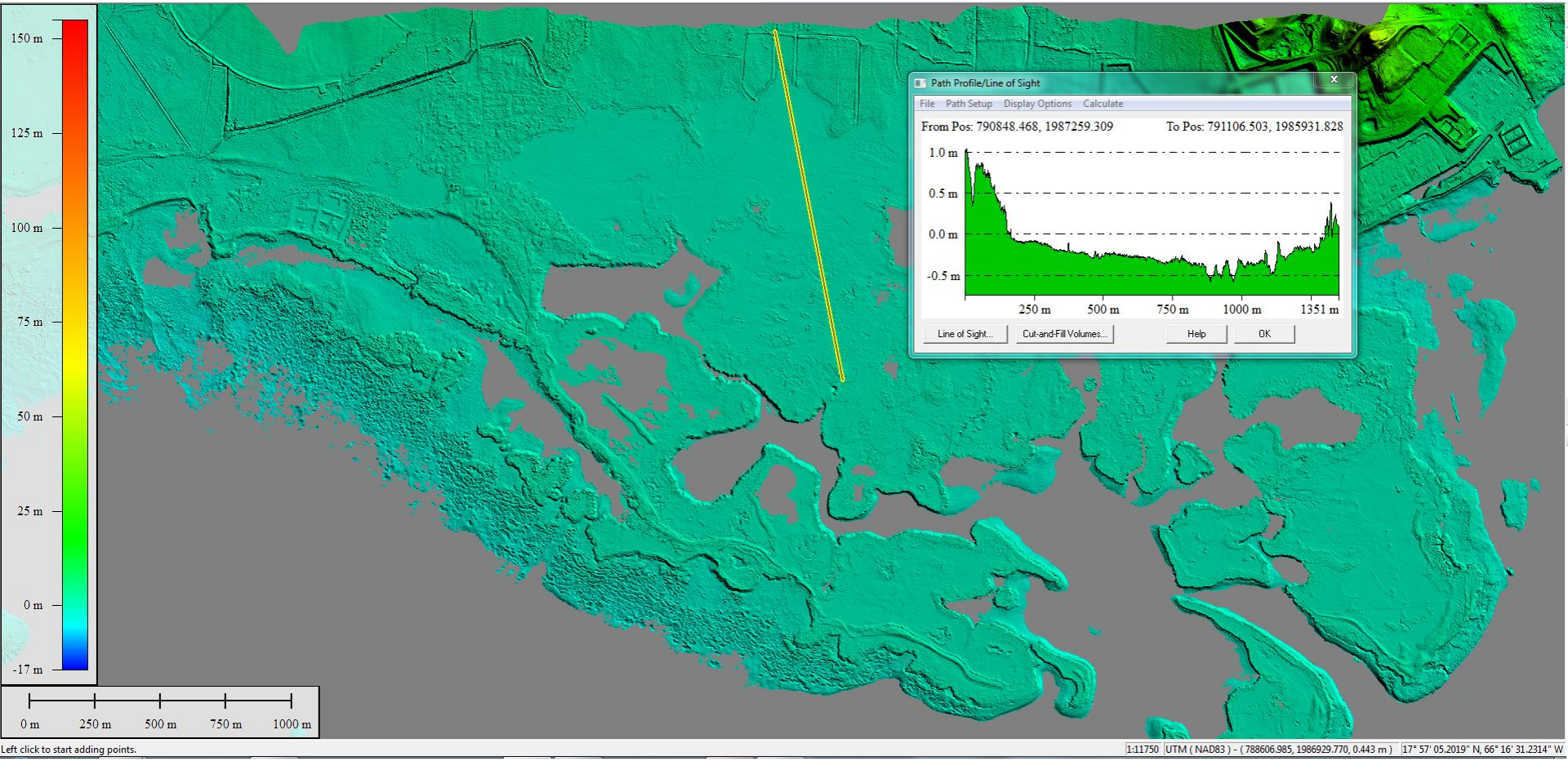
Puerto Rico Topobathy DEM – Jobos Bay



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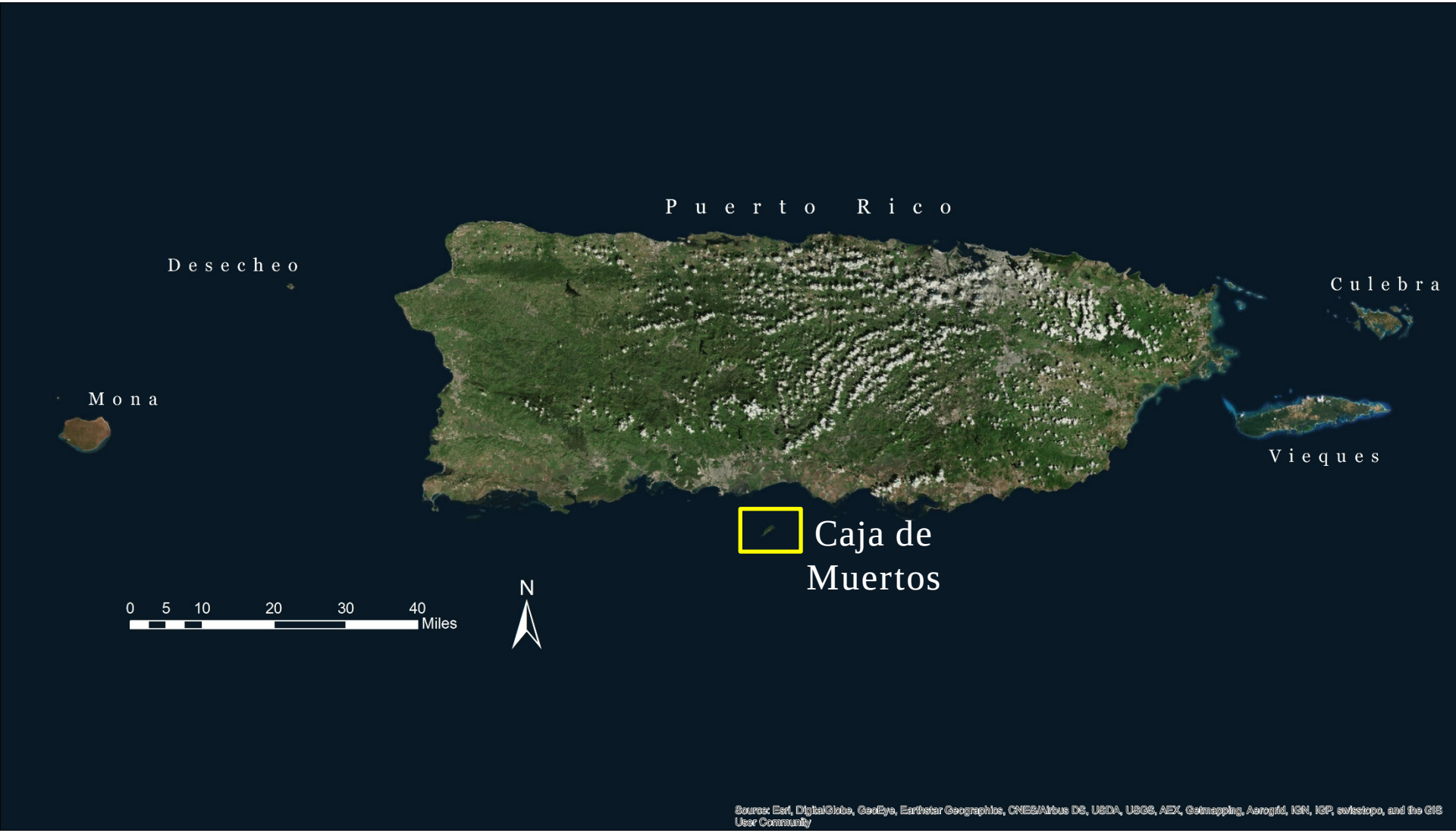
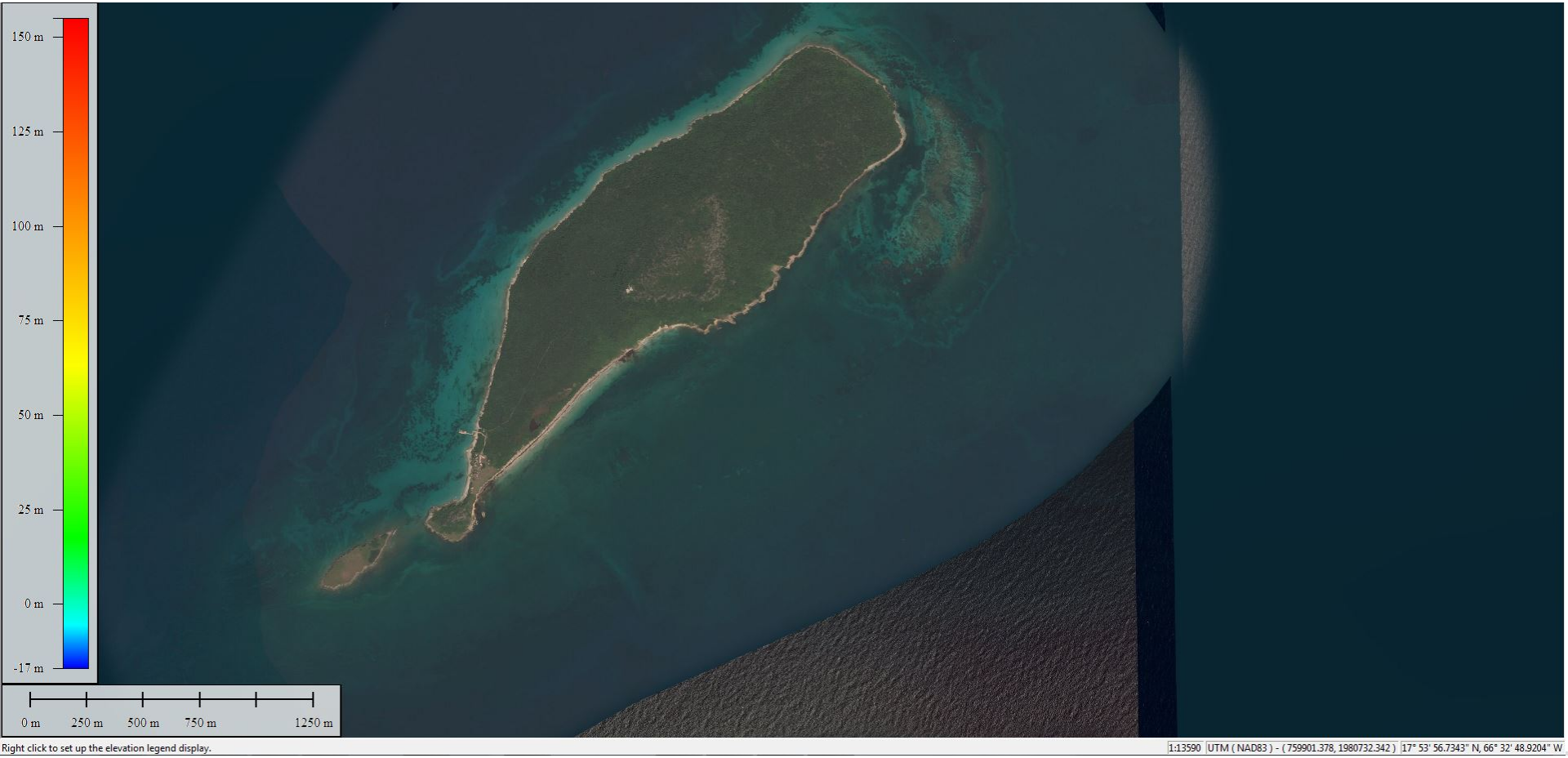
Puerto Rico Topobathy Lidar – Caja de Muertos

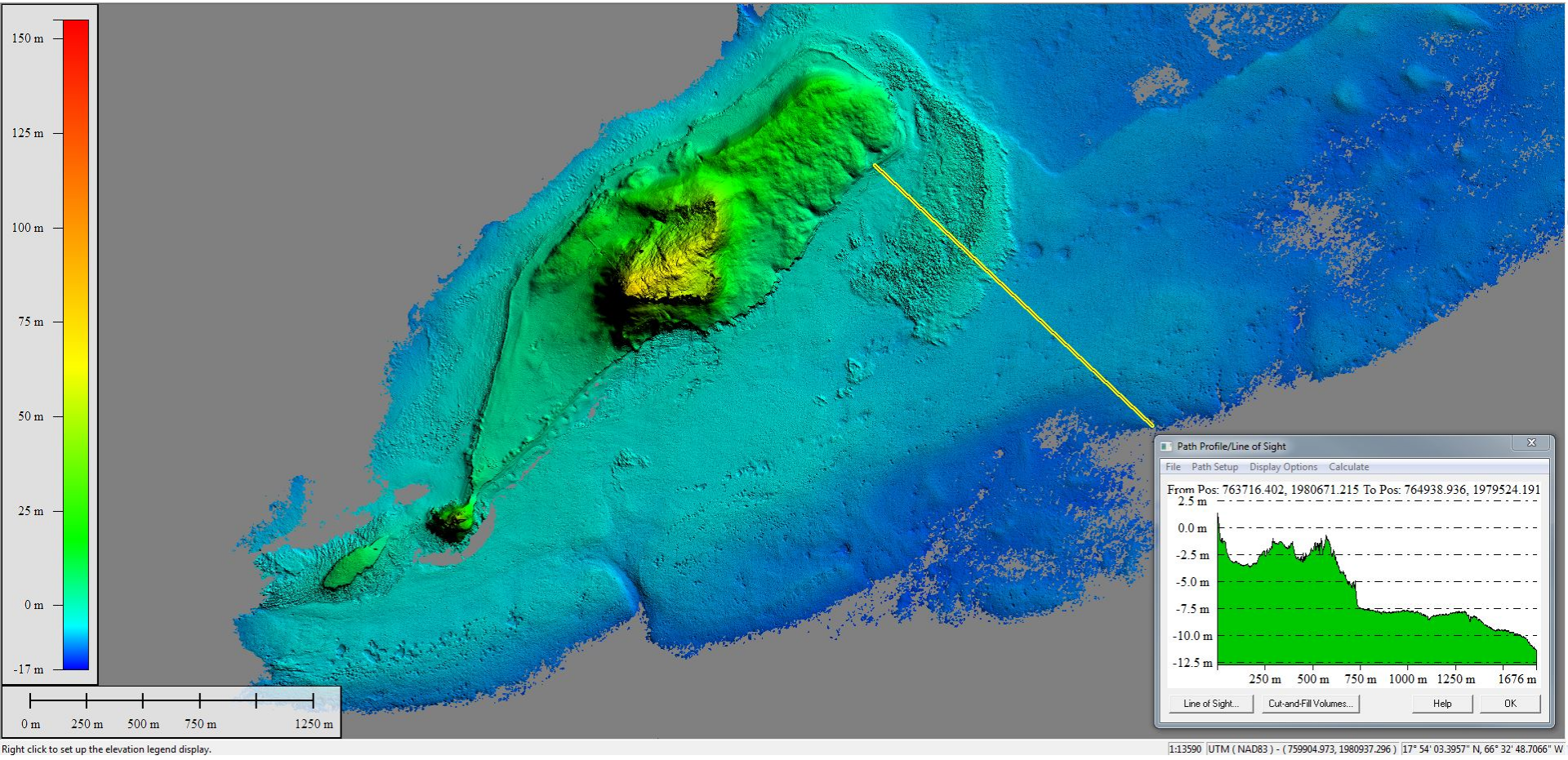


Dewberry

Puerto Rico Topobathy Lidar – Caja de Muertos



Puerto Rico Topobathy Lidar – Caja de Muertos



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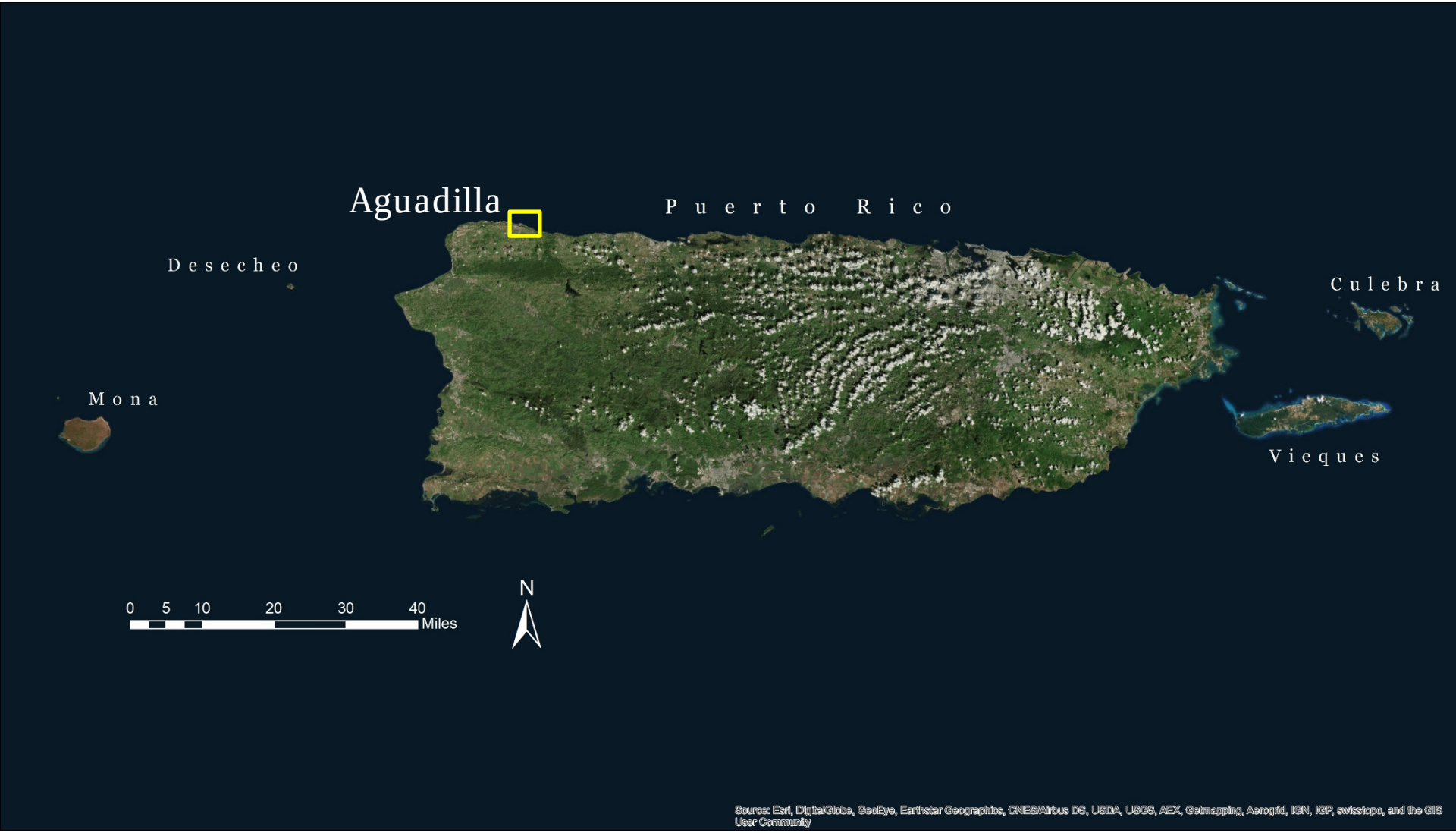
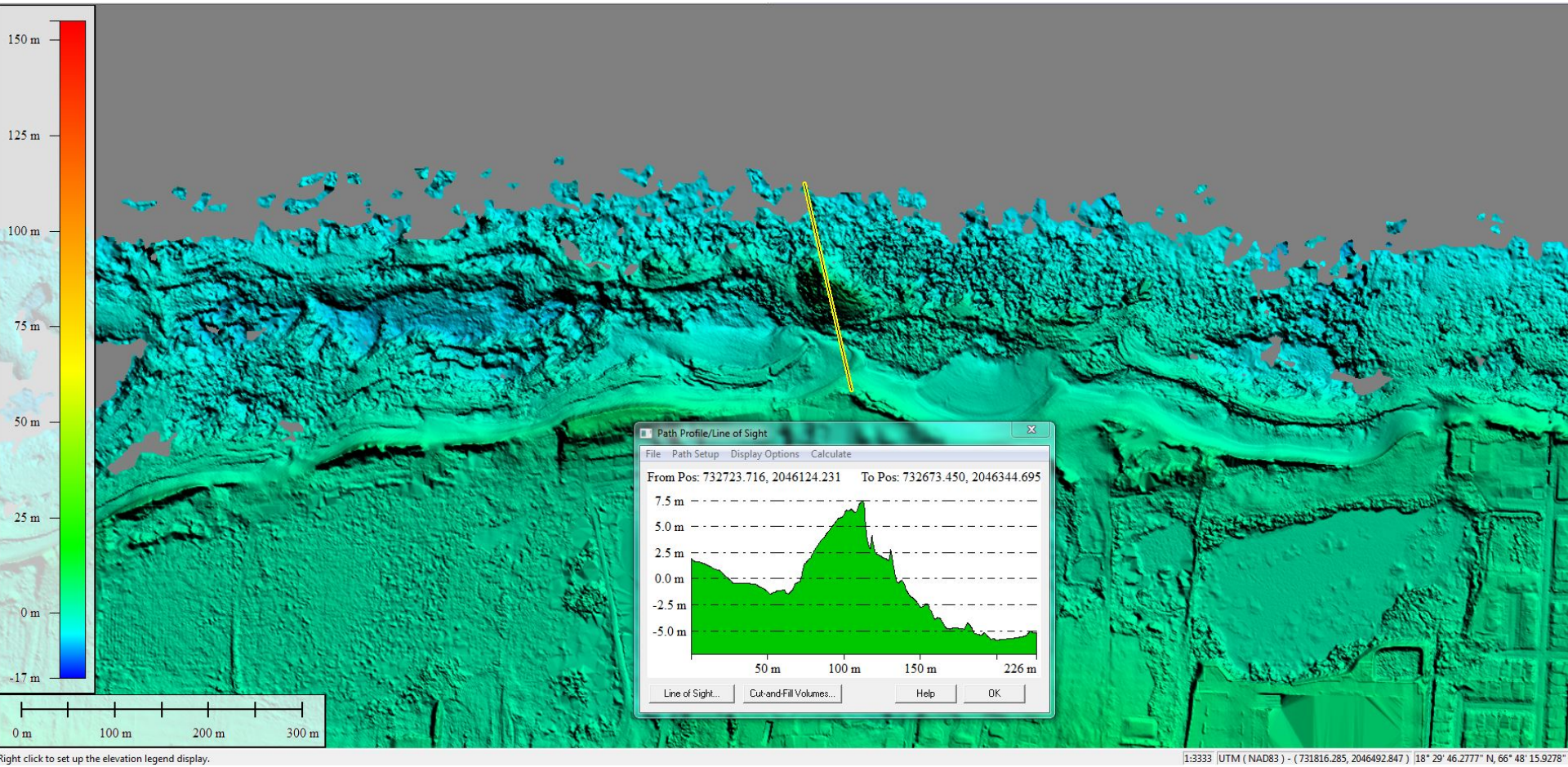
Puerto Rico Topobathy Lidar – Aguadilla



Dewberry

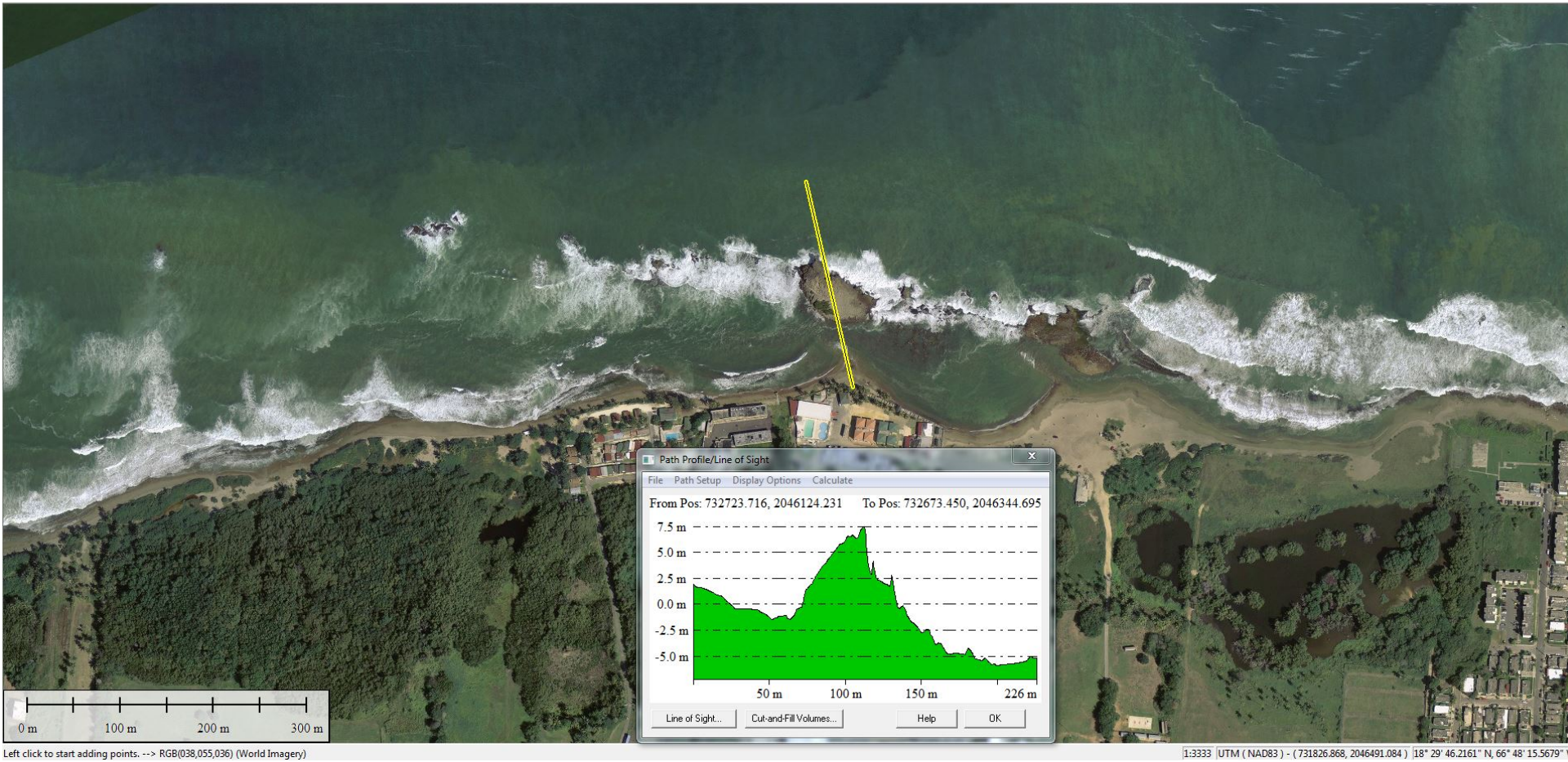
Puerto Rico Topobathy Lidar – Aguadilla

Puerto Rico Topobathy DEM – Aguadilla



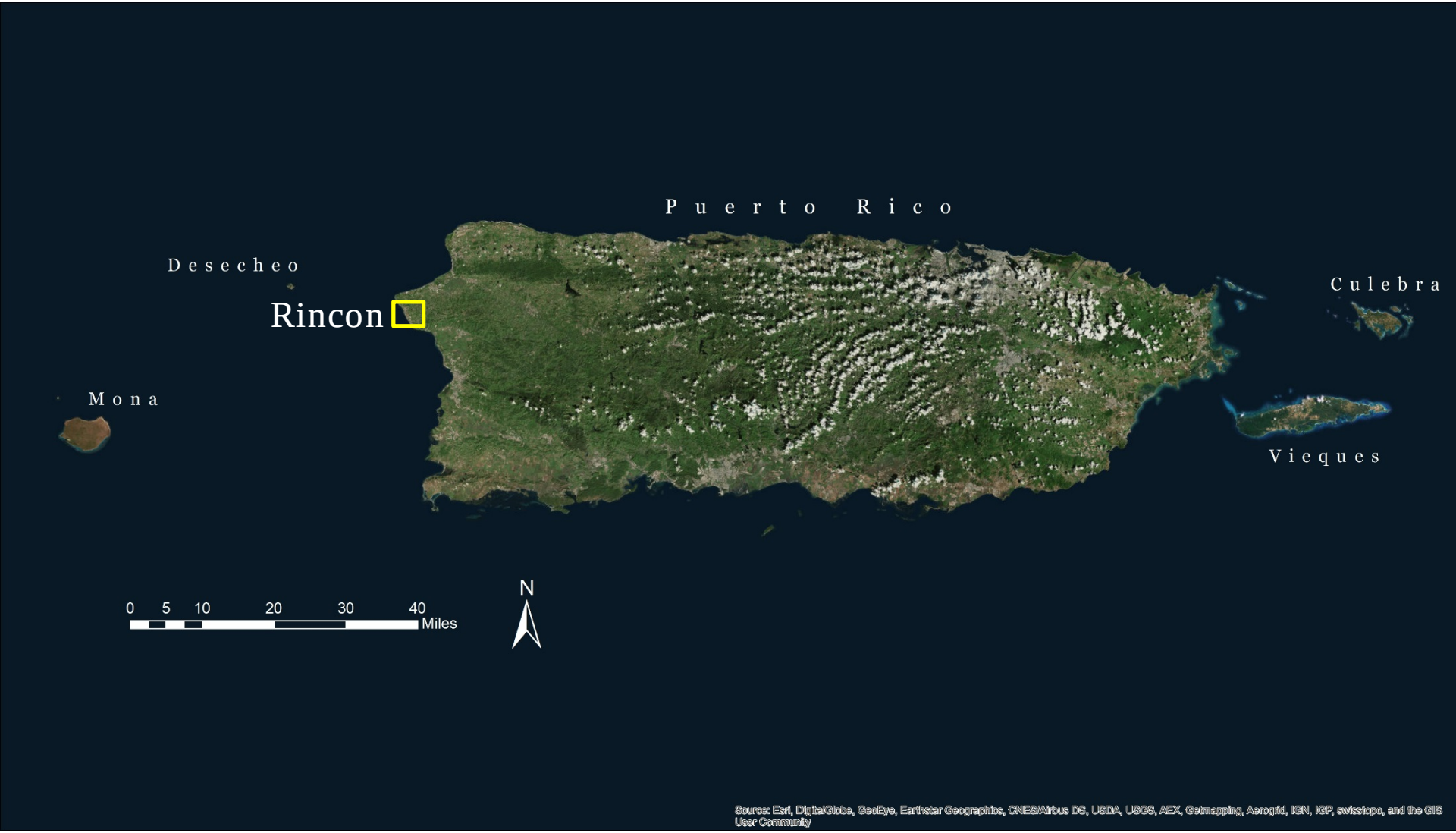
Dewberry

Puerto Rico Topobathy Lidar – Aguadilla

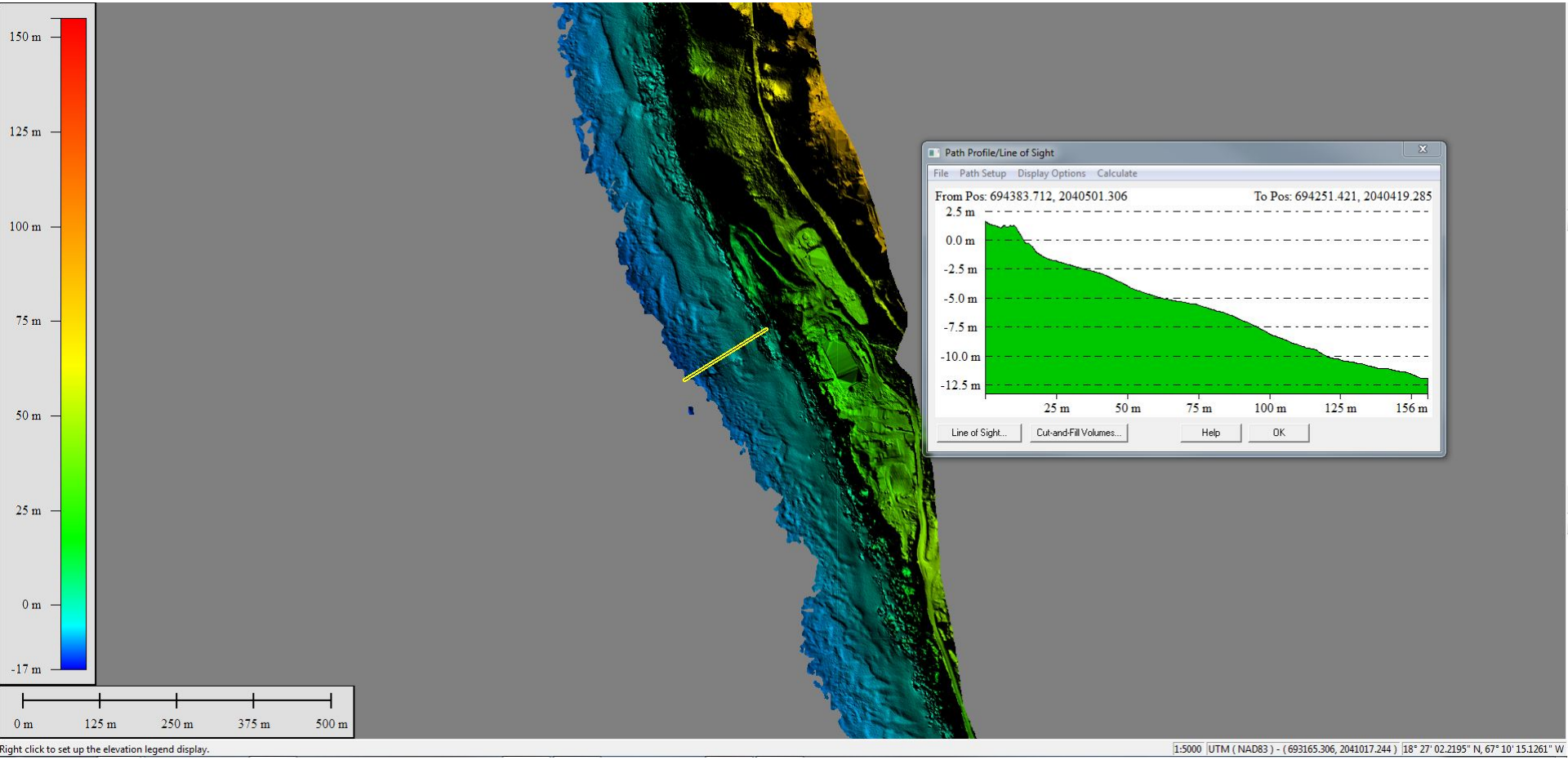


Dewberry

Puerto Rico Topobathy Lidar – Rincon

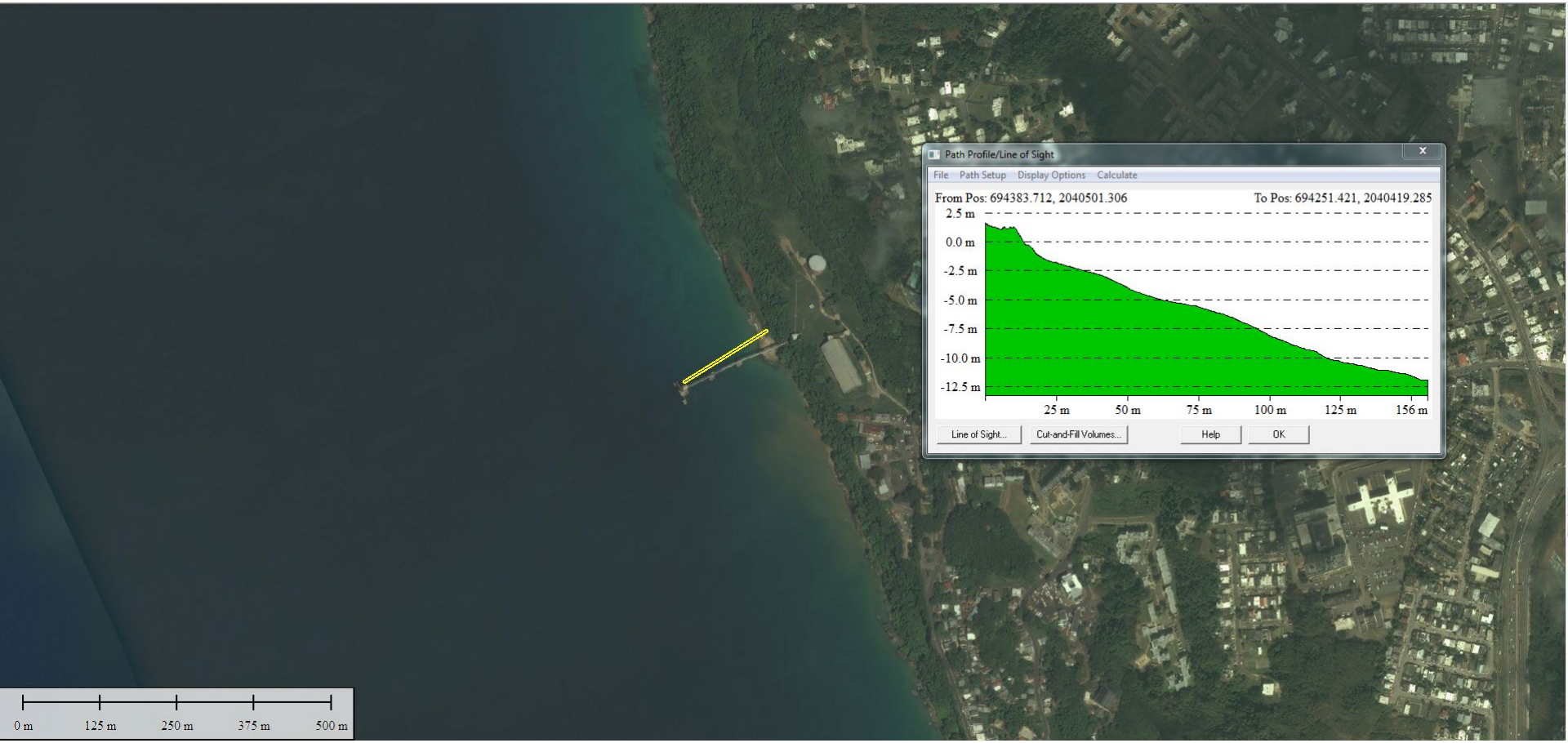


Puerto Rico Topobathy DEM – Rincon



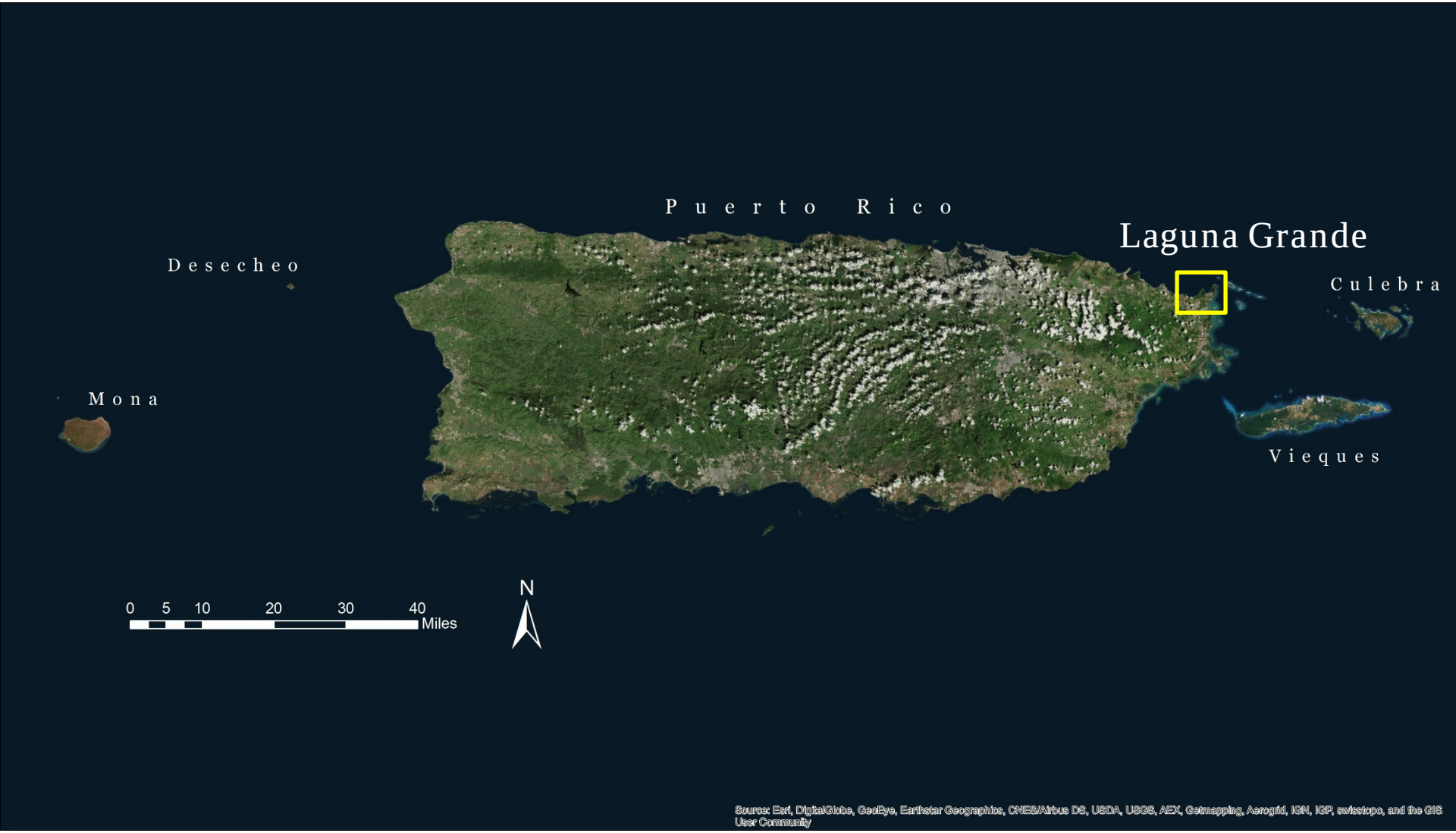
Dewberry

Puerto Rico Topobathy Lidar – Rincon

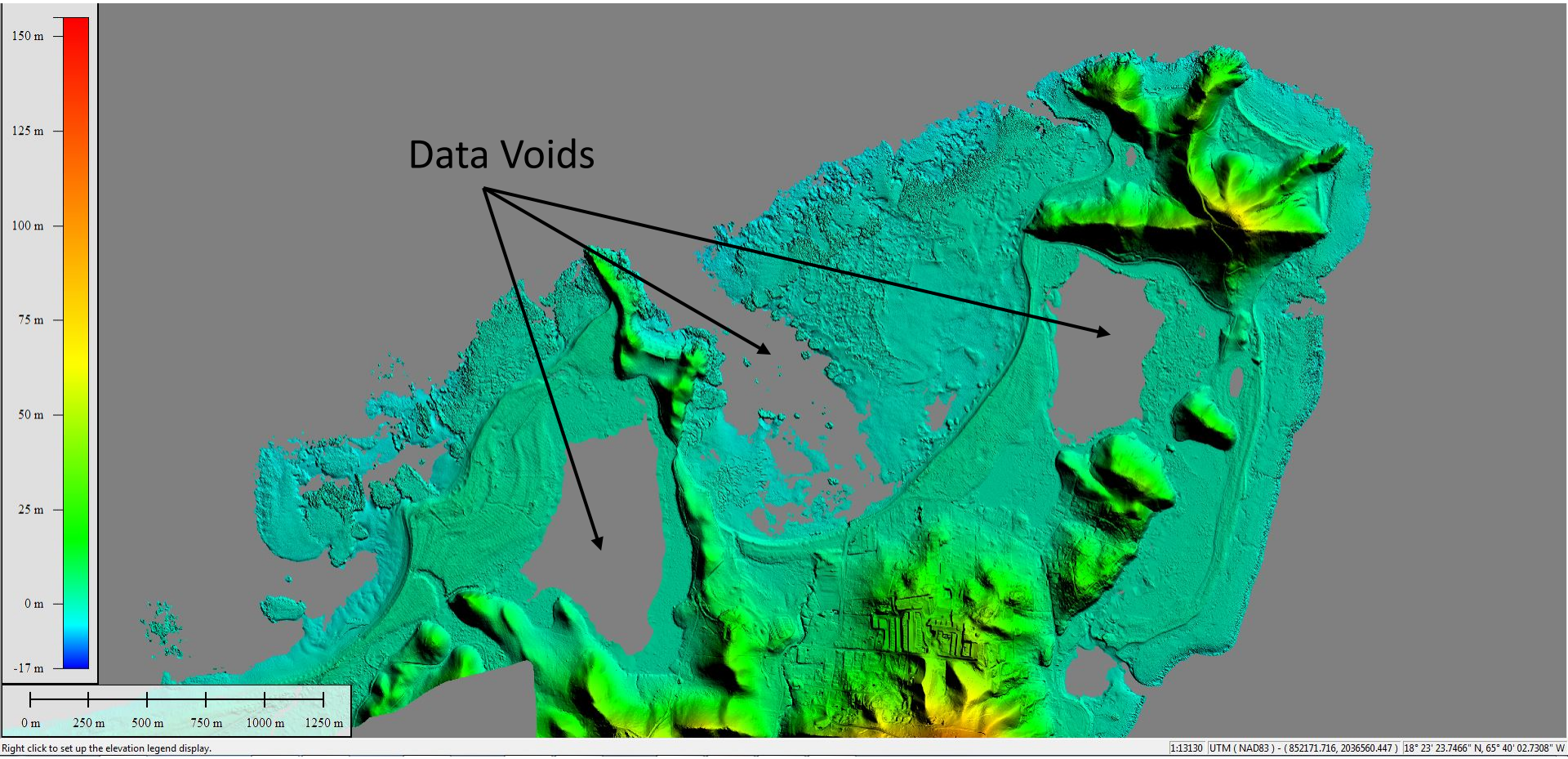


Dewberry

Puerto Rico Topobathy Lidar – Laguna Grande



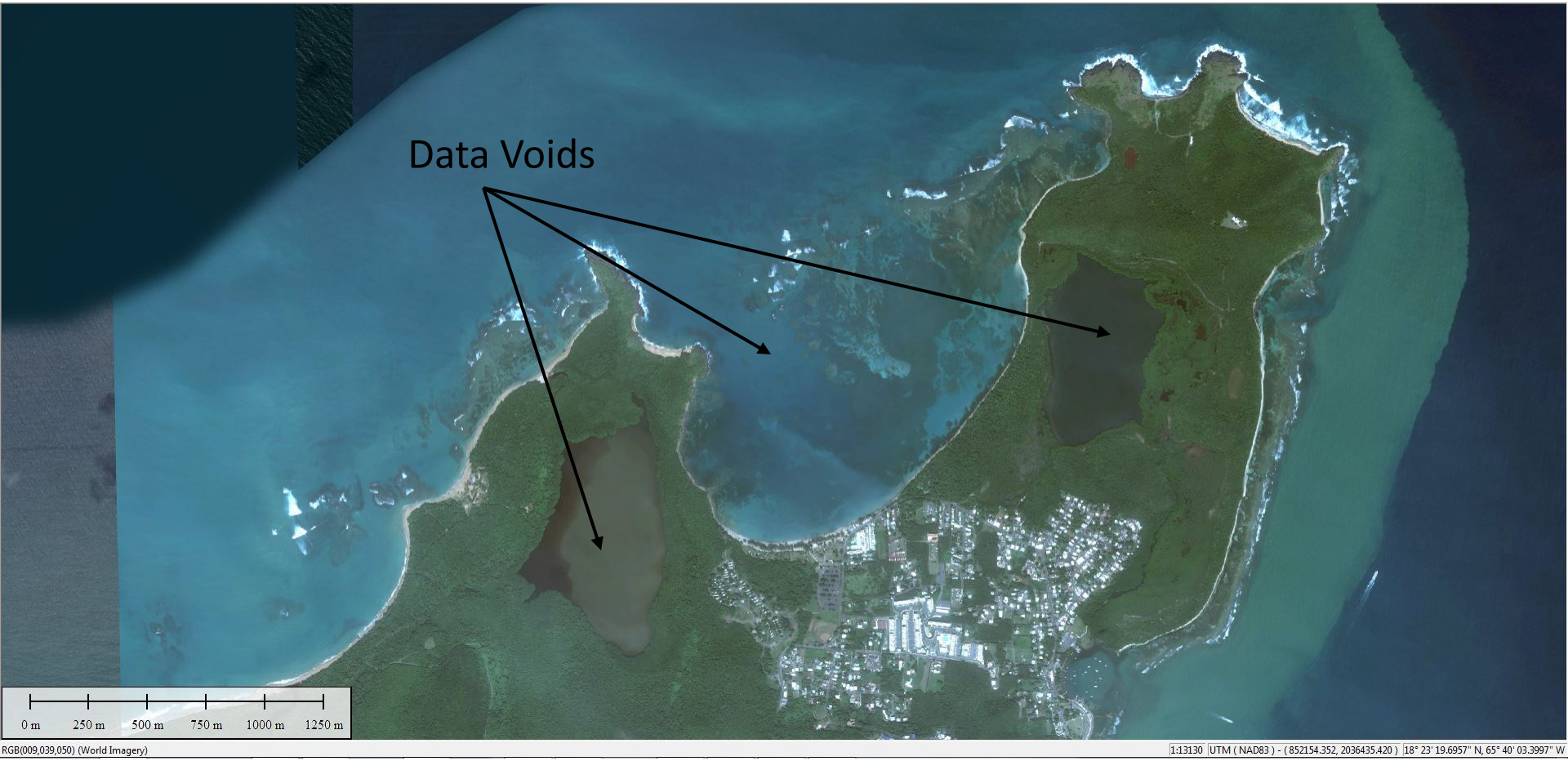
Puerto Rico Topobathy Lidar Data Voids
Laguna Grande



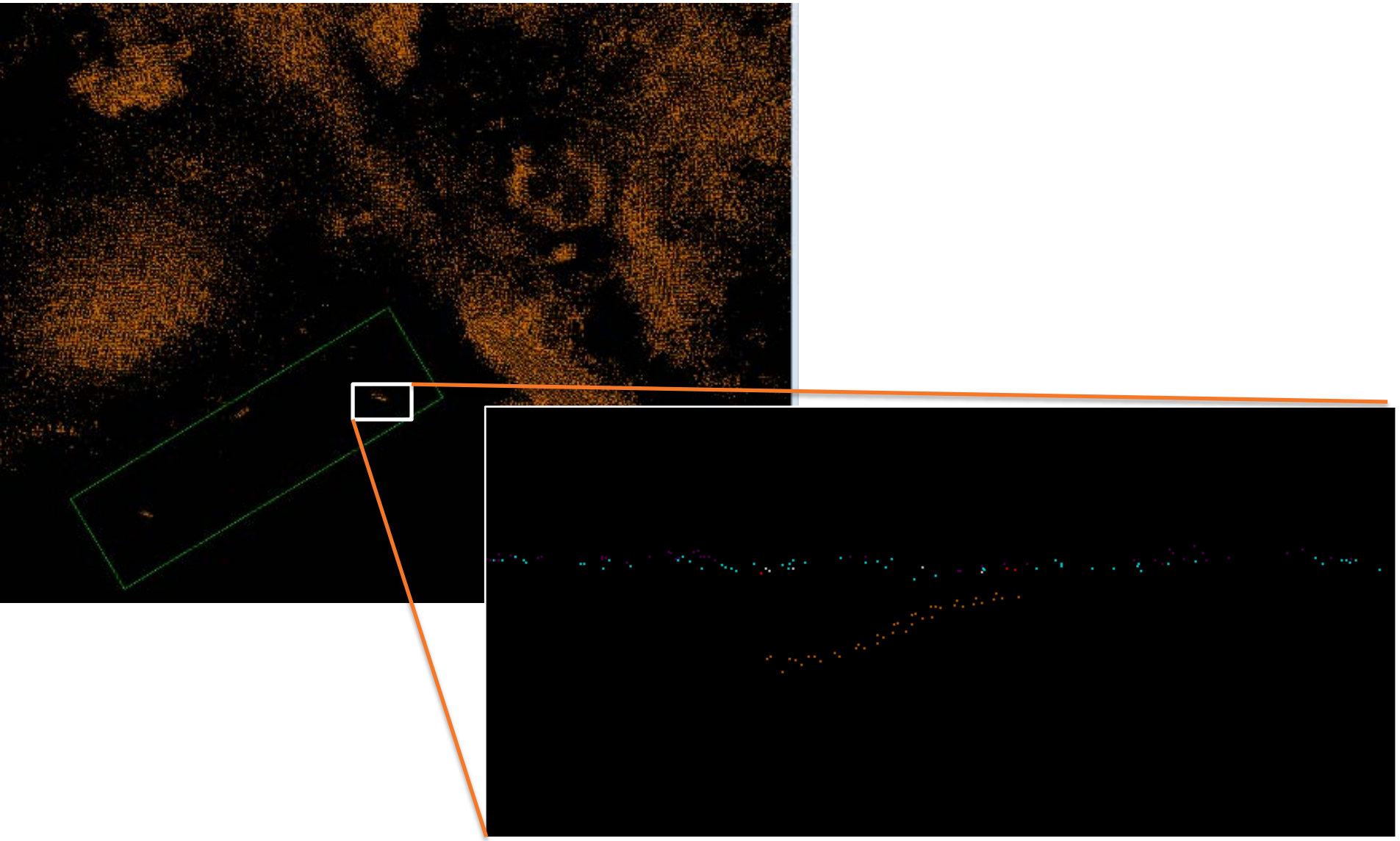
Bio-luminescent Bay

Dewberry

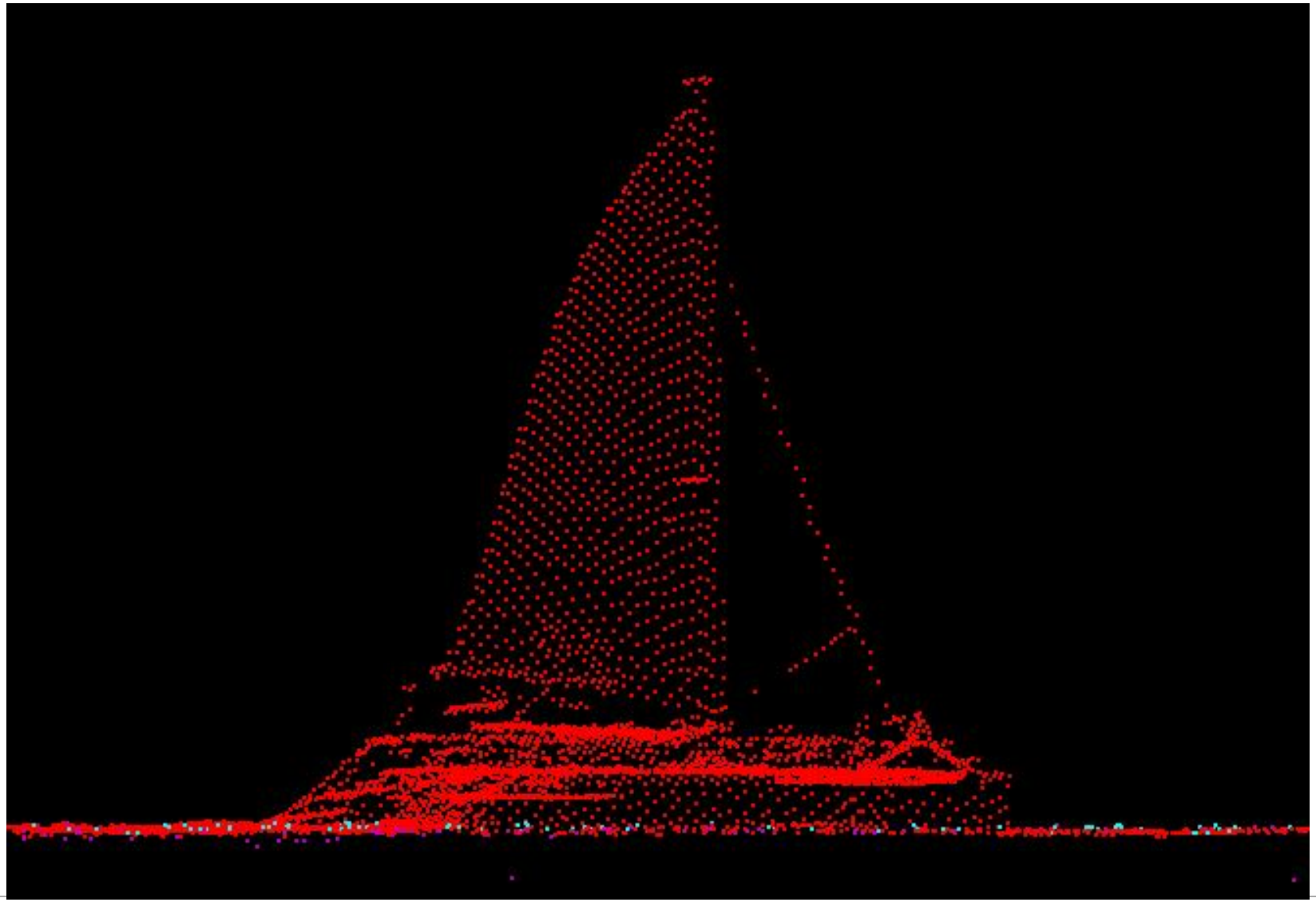
Puerto Rico Topobathy Lidar Data Voids
Laguna Grande



Puerto Rico Topobathy Lidar – Are these dolphins?



Puerto Rico Topobathy Lidar – Sailboat



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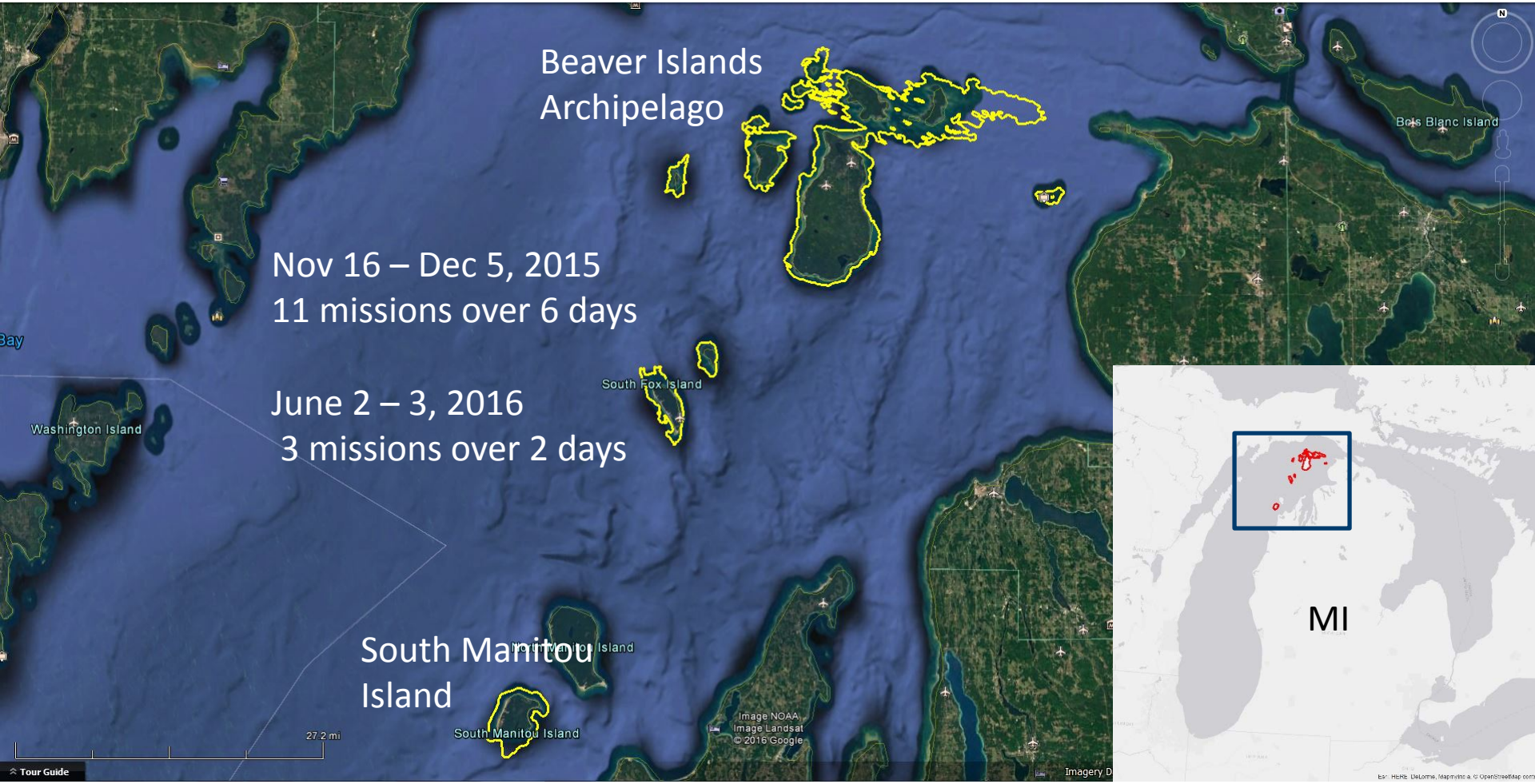
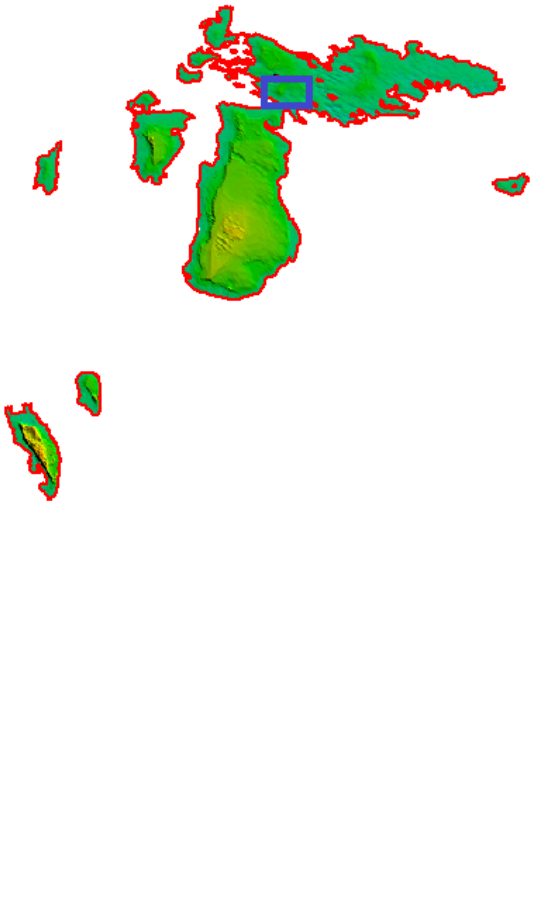
Beaver Islands Archipelago & South Manitou Island Topobathy Lidar Survey

Beaver Islands Archipelago & South Manitou Island

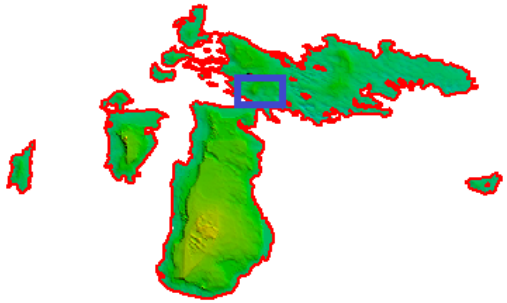


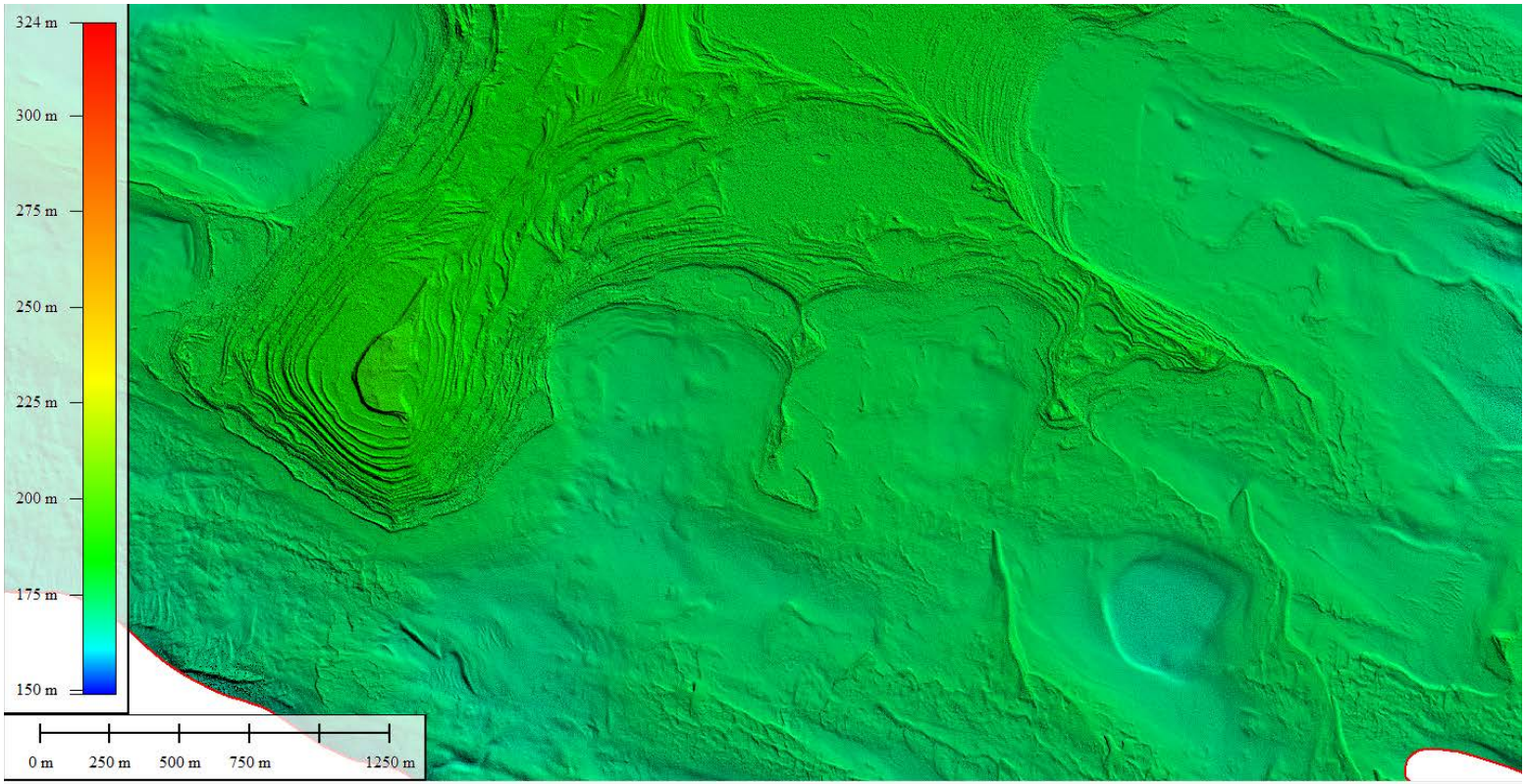
Data Coverage

- Depths to ~ 8 m
- Full coverage within AOI
- Final data products will delivered to NOAA by July 29th.



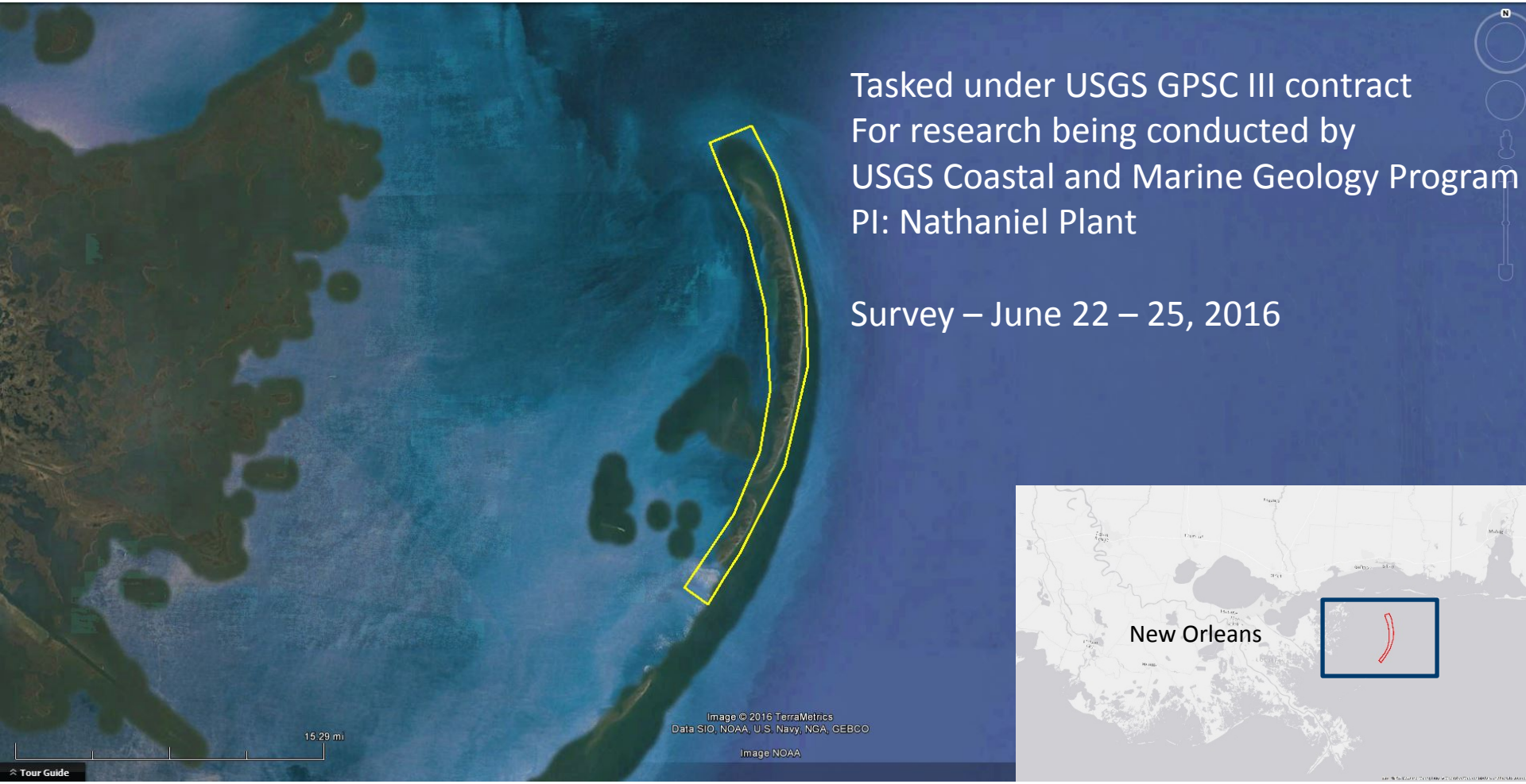
Beaver Islands Archipelago & South Manitou Island DEM





Chandeleur Islands & Florida Keys Upper Reef Tract Topobathy Lidar Survey

Chandeleur Islands

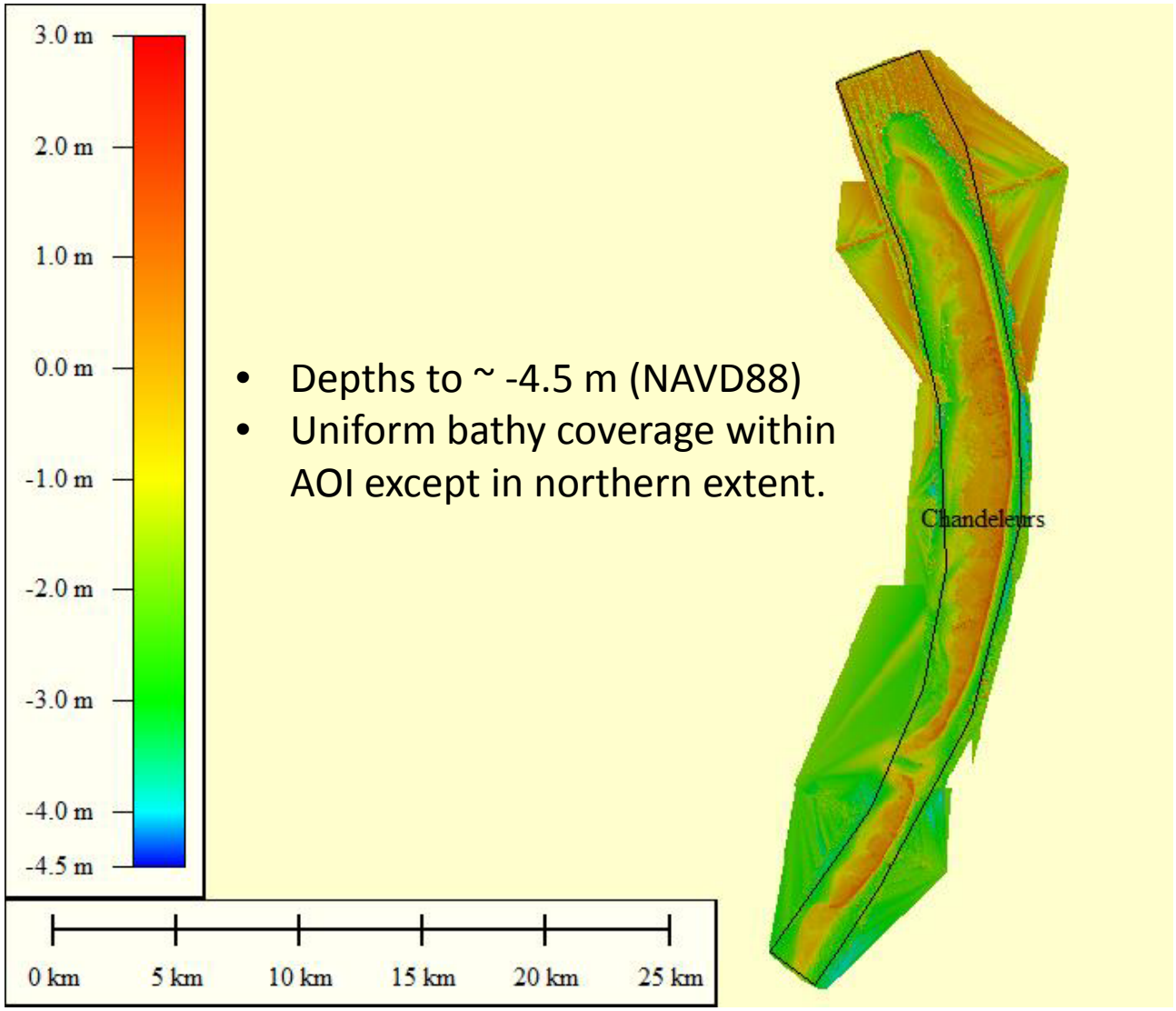


Tasked under USGS GPSC III contract
For research being conducted by
USGS Coastal and Marine Geology Program
PI: Nathaniel Plant

Survey – June 22 – 25, 2016

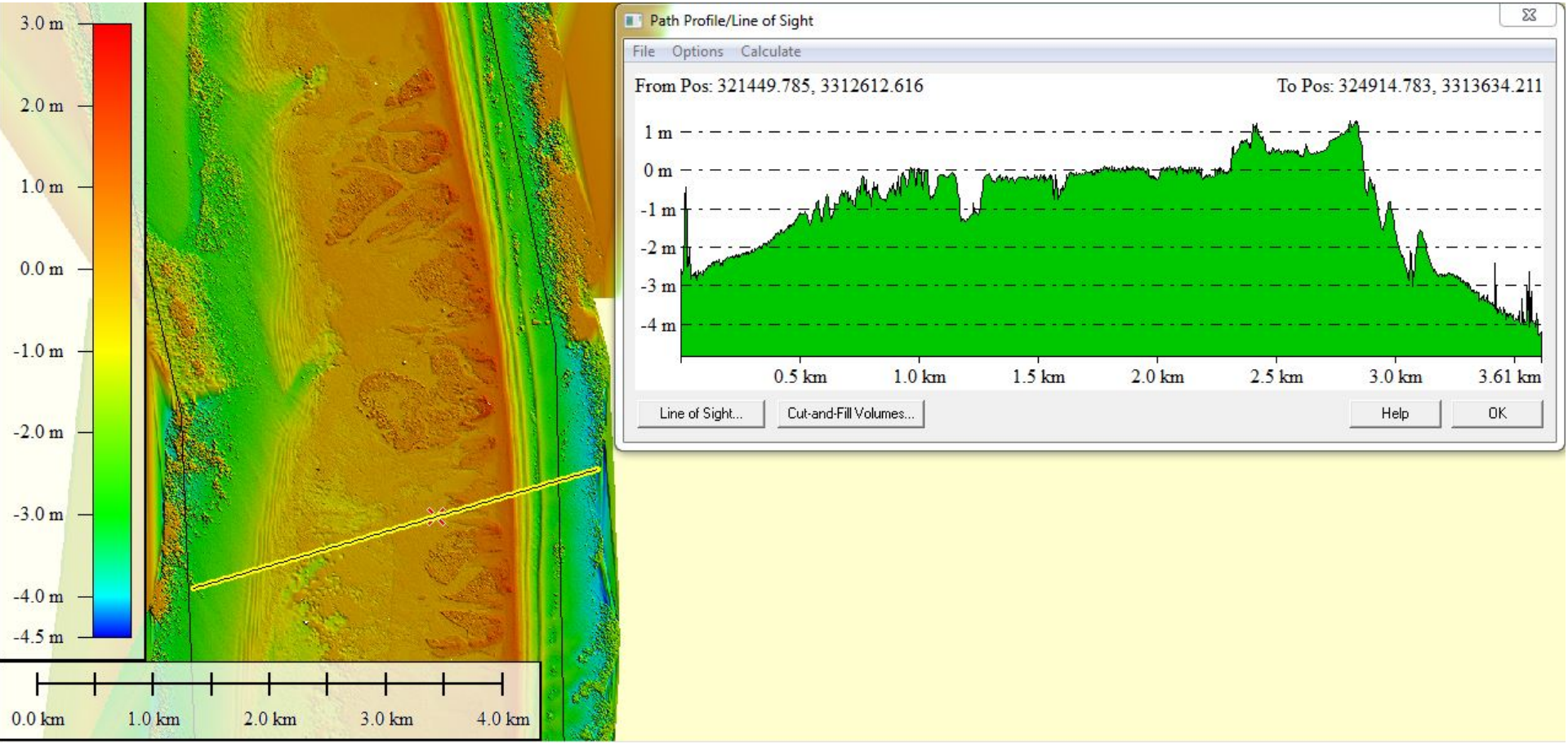
Dewberry

Preliminary Images – Chandeleur Islands

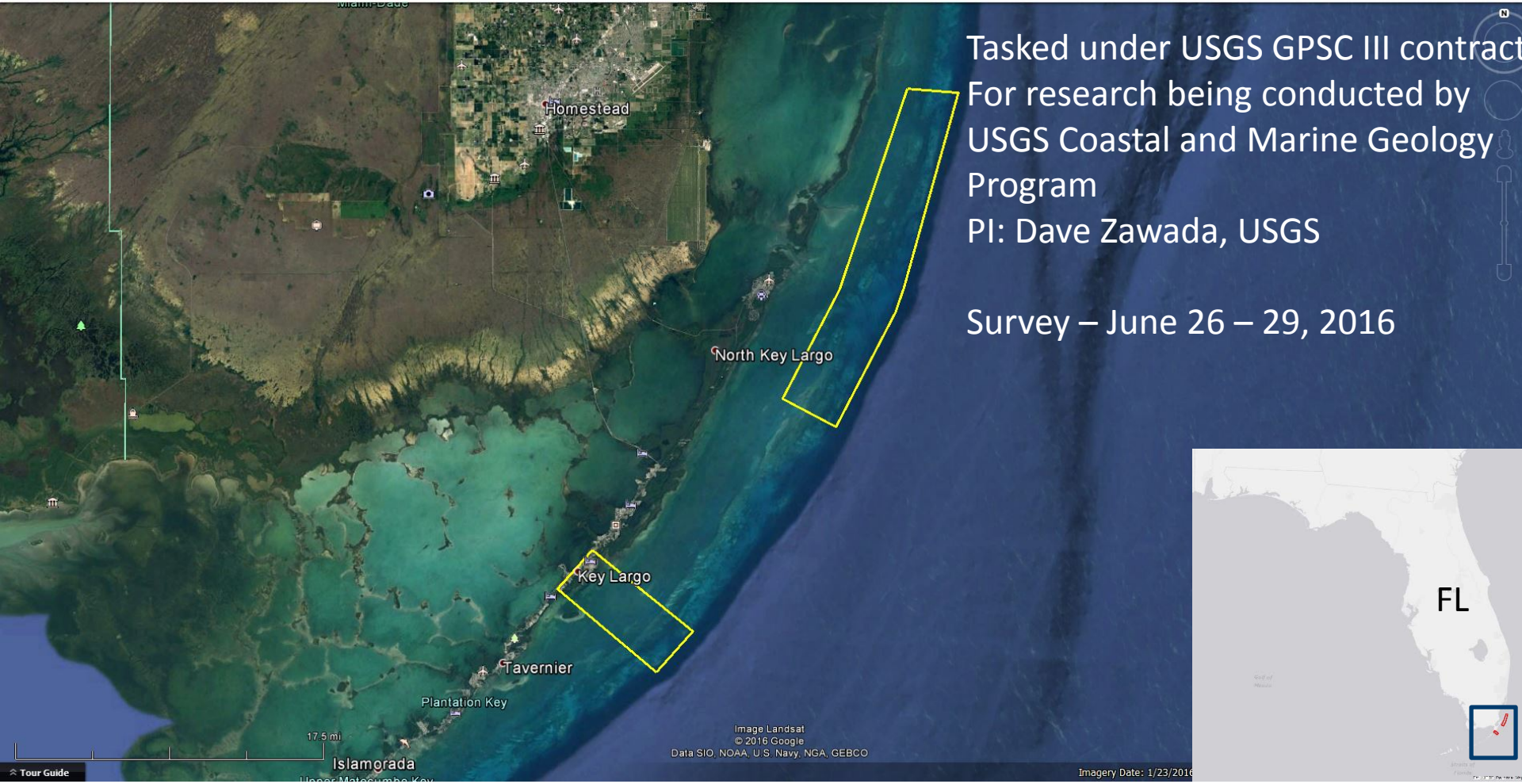


- Depths to ~ -4.5 m (NAVD88)
- Uniform bathy coverage within AOI except in northern extent.

Preliminary Images – Chandeleur Islands



Florida Keys Upper Reef Tract

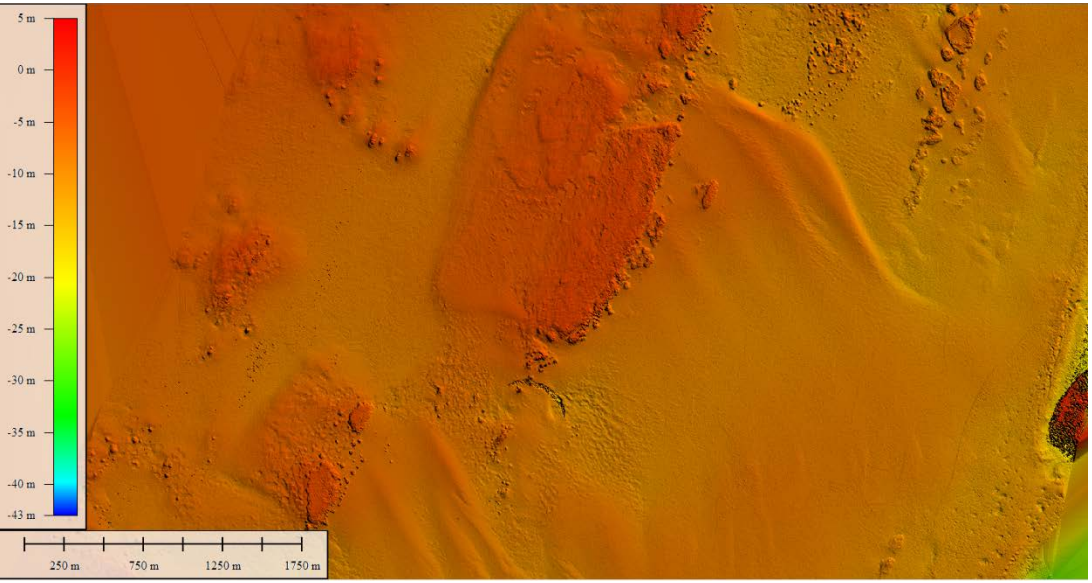


Tasked under USGS GPSC III contract
For research being conducted by USGS Coastal and Marine Geology Program
PI: Dave Zawada, USGS

Survey – June 26 – 29, 2016

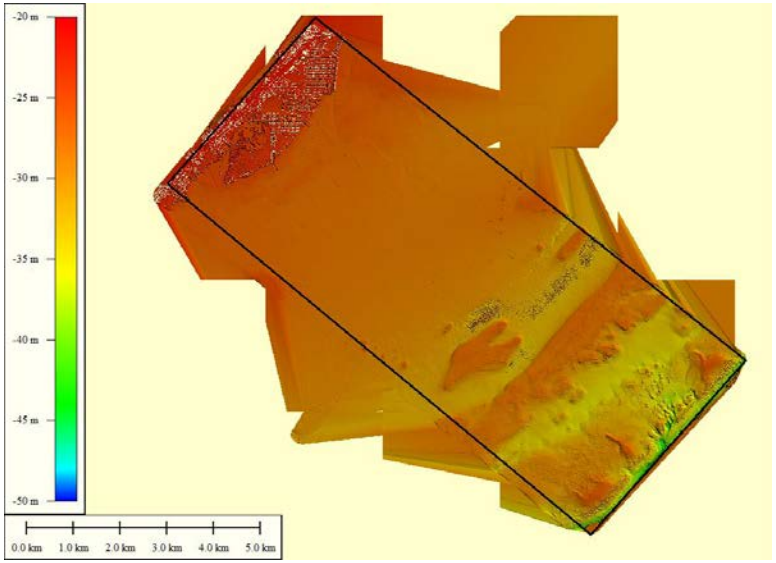
Dewberry

Florida Keys Upper Reef Tract Preliminary DEM



Northern block. Data referenced to NAVD88 orthometric elevations.

Southern portion. Data referenced to NAD83 ellipsoid elevations. Depths up to 25 m.



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FL Everglades NP LiDAR Pilot 2016

Dewberry is currently performing a pilot project for USGS and NPS for the collection of lidar over Everglades National Park.

The pilot project will be evaluated for use in supporting critical environmental management objectives to include response to sea level rise, increased predictive capability of hydrologic models and improved modeling and understanding of the unique Everglades.

The project will also support a scientific study underway to model marl prairie habitat for the Cape Sable Seaside Sparrow, an endangered non-migratory song bird residing solely in the Everglades.

Cape Sable Seaside Sparrow

FL Everglades NP LiDAR Pilot 2016

USGS QUALITY LEVEL 1

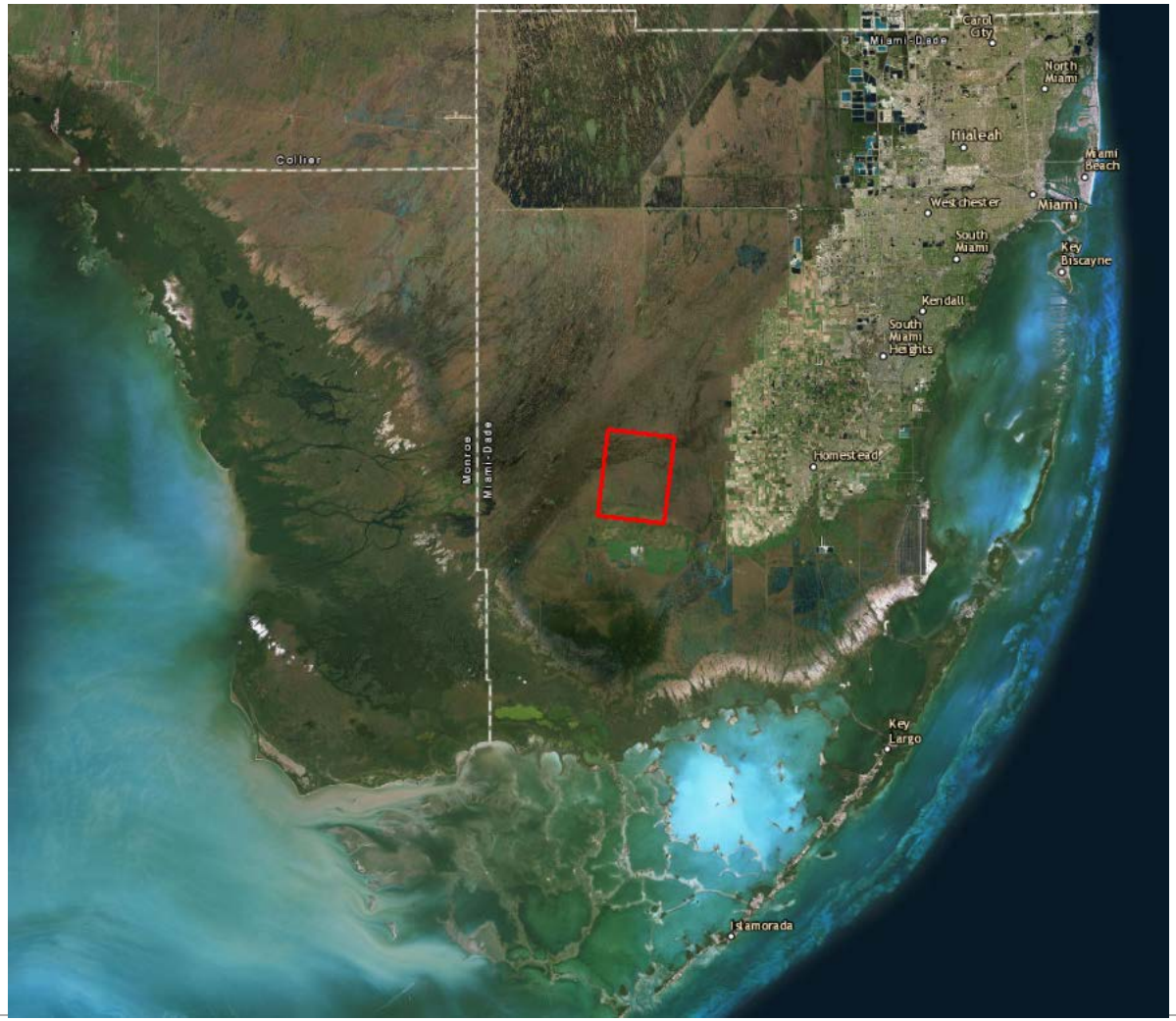
SPECIFICATIONS:

Aggregate Nominal Pulse Spacing (ANPS) shall be no greater than 0.35 meters (QL1). (8ppsm)

- $RMSE_Z \leq 10$ cm (non-vegetated, Swath, DEM))
- NVA ≤ 19.6 cm 95% Confidence Level (Swath, DEM)
- VVA ≤ 29.4 cm 95^{th} Percentile (DEM)

FL Everglades NP LiDAR Pilot 2016

Pilot Boundary



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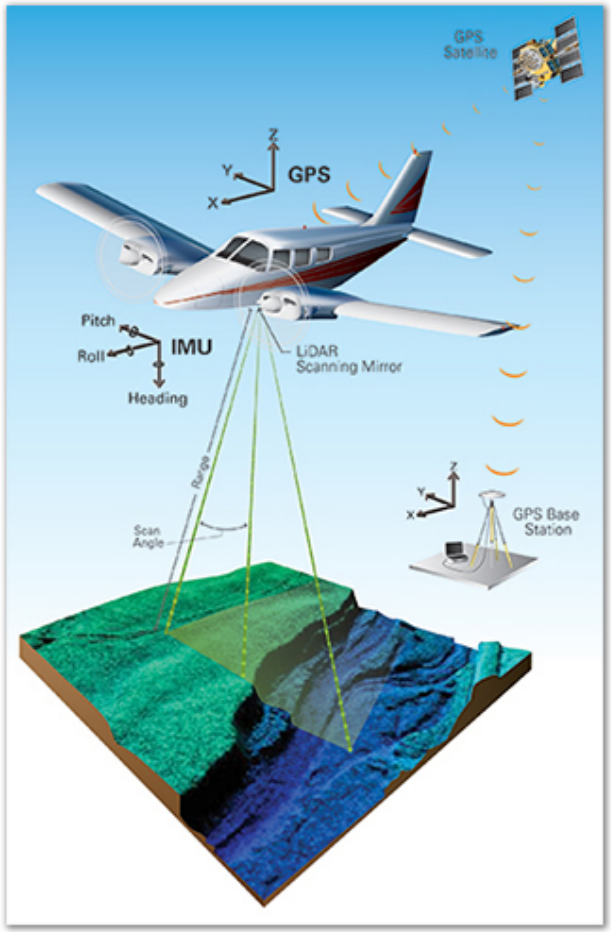
FL Everglades NP LiDAR Pilot 2016

Dewberry designed the pilot project to test various lidar sensors flown at different altitudes. This will ensure that we deploy the best solution for lidar mapping within the Everglades going forward.

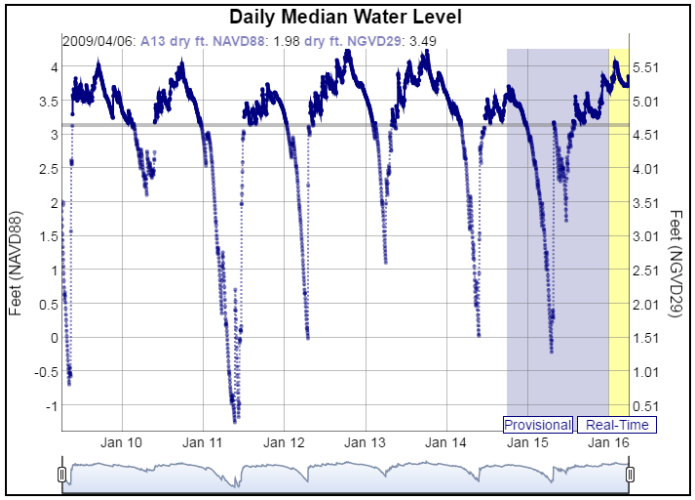


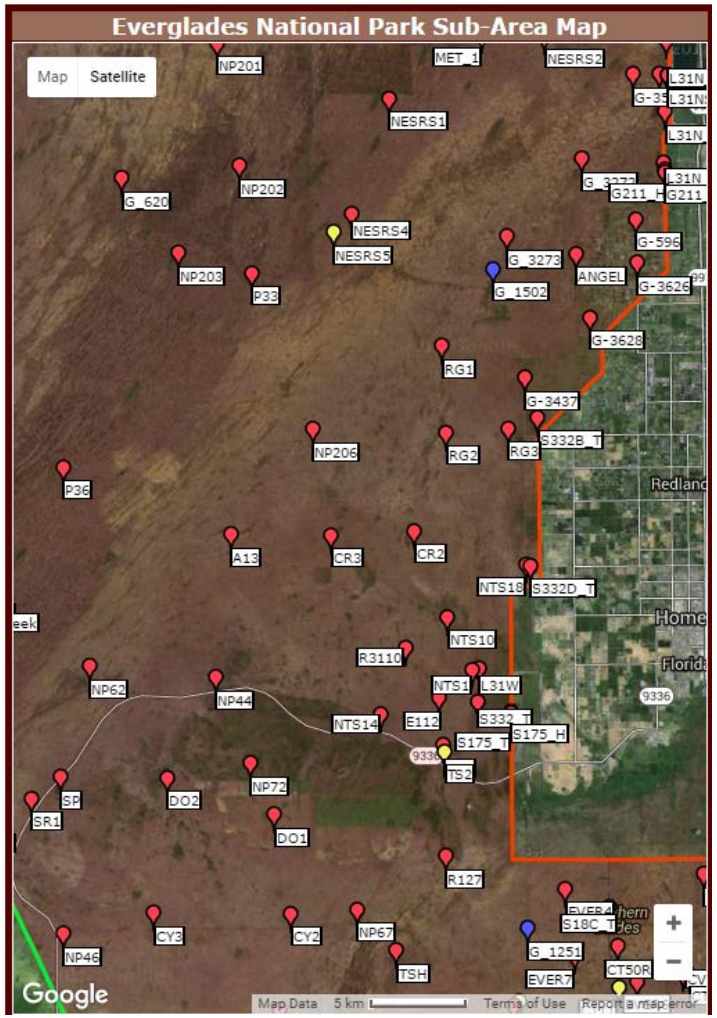
Dewberry

FL Everglades NP LiDAR Pilot 2016 – Current Status

LIDAR ACQUISITION – Conditions Monitoring

We monitored water gauges to pinpoint the lowest water levels likely to occur during the lidar acquisition window.





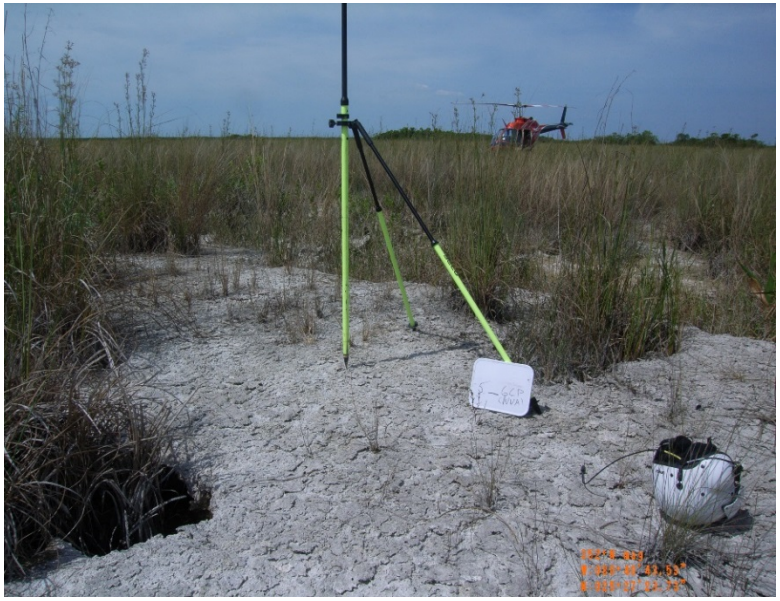
Everglades Depth Estimation Network (EDEN)

Dewberry

FL Everglades NP LiDAR Pilot 2016 – Current Status

Ground surveying for check points and ground control points was completed

- Dewberry (Keith Patterson, Ryan Ligon) completed the survey.
- NPS assisted with helicopter support in order to survey inaccessible points.



Dewberry

FL Everglades NP LiDAR Pilot 2016 – Current Status

TWO INDEPENDENT LIDAR ACQUISITIONS WERE COMPLETED

NOAA NGS completed lidar collection on May 5, 2016.

- Flown using a de Havilland Twin Otter aircraft.

Riegl VQ-880-G lidar sensor

- Combined Topo-Bathymetric airborne laser scanning system
- Full waveform sensor
- Narrow-beam green laser
- Integrated infrared laser
- Collected 6 inch GSD imagery as well as lidar
- Altitude = 1300 feet
- Point Density = 9 ppsm

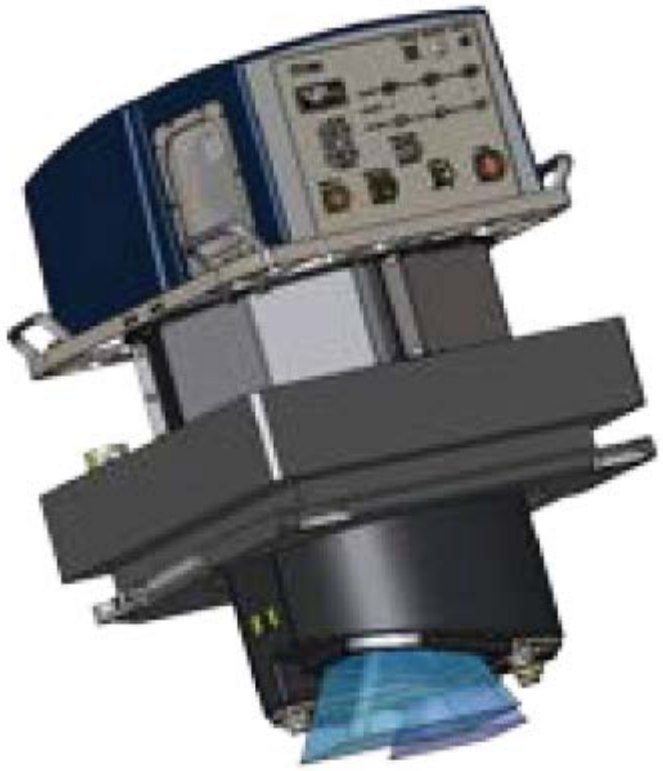
Dewberry

FL Everglades NP LiDAR Pilot 2016 – Current Status

TWO INDEPENDENT LIDAR ACQUISITIONS WERE COMPLETED

Dewberry leased the aircraft and sensor to complete lidar collection on June 15 -17, 2016.

- Flown using a Piper Navajo aircraft.



Teledyne Optech Titan lidar sensor

- Combined Topo-Bathymetric airborne laser scanning system
- Three independent channels – one for each wavelength.
  - 532nm –visible (green)
  - 1064nm -NIR
  - 1550nm -IR
- Altitude 1: 400 m AGL 10 ppsm per channel
- Altitude 2: 1000 m AGL 6 ppsm per channel

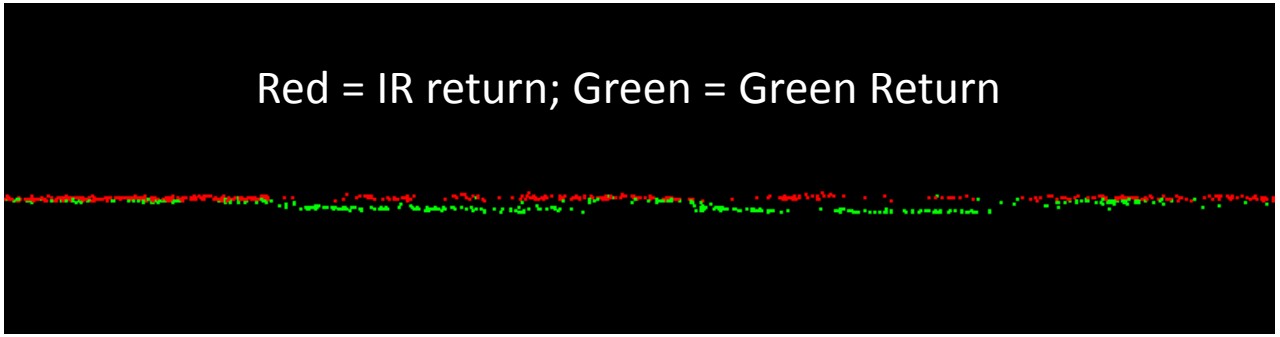
FL Everglades NP LiDAR Pilot 2016 – Current Status

Dewberry just received NOAA's Riegl 880-G data

The NOAA data passed pre-classification (preliminary) accuracy assessment using surveyed check points.

100 % of Totals	# of Points	RMSEz (m) NVA Spec=0.100 m	NVA- Non-vegetated Vertical Accuracy ((RMSEz x 1.9600) Spec=0.196 m
NVA	32	0.077	0.152

Processing and analysis is continuing.



Dewberry

FL Everglades NP LiDAR Pilot 2016 – Current Status

The pilot project lidar data and derivative products will be processed and analyzed with the goal of identifying the most cost-effective and scientifically sound approach to lidar collection for Everglades National Park.

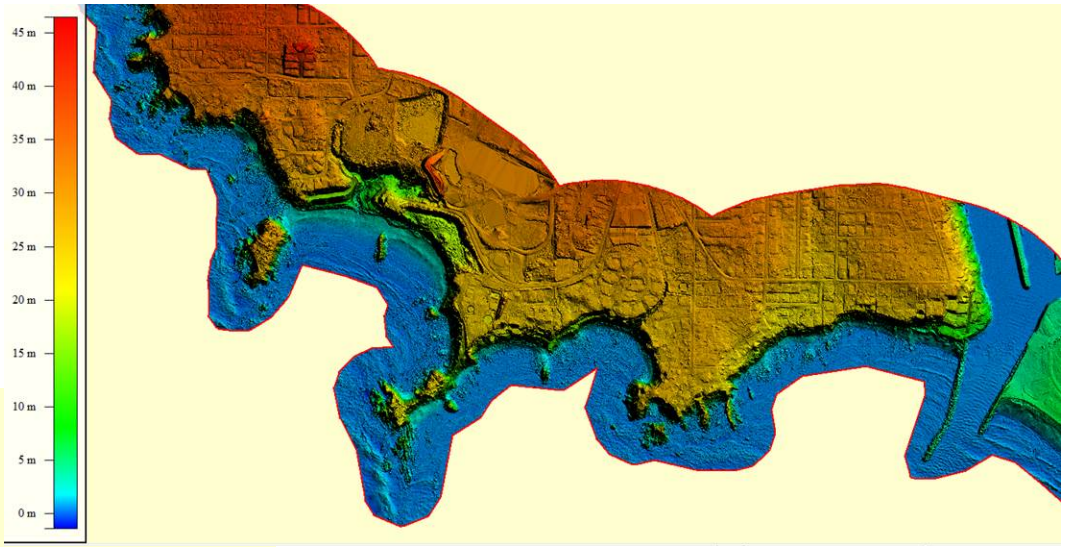
All draft deliverables, including a project report, are due to USGS by 8/31/2016.

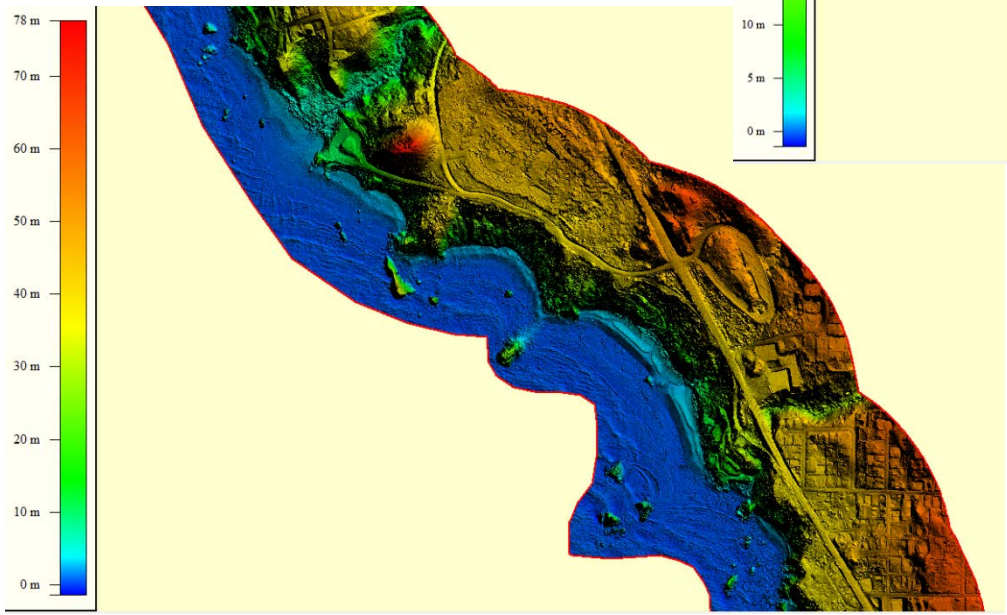
El Niño Study for NOAA Office for Coastal Management & USGS Coastal Program

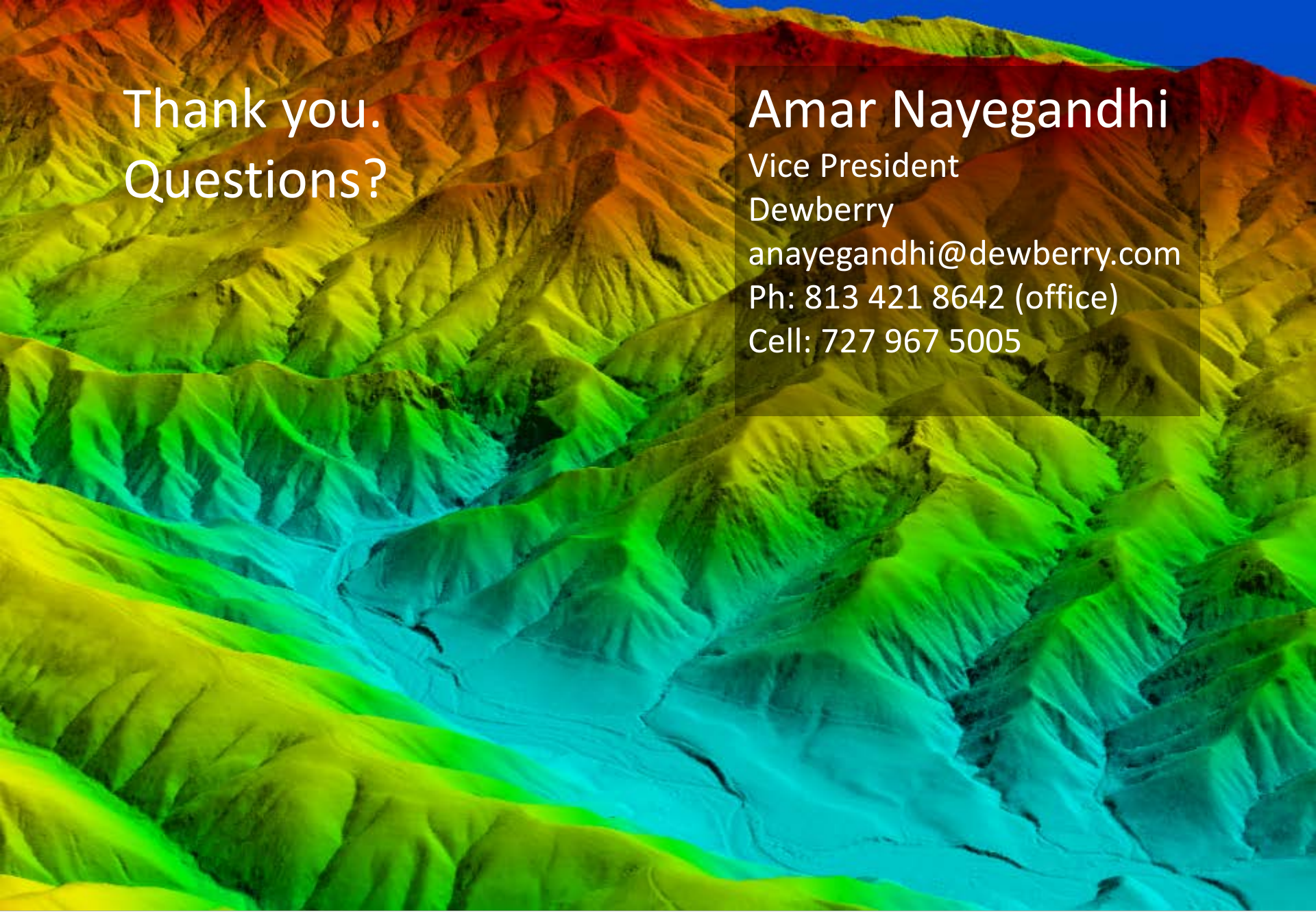
- Two Task Orders – USGS GPSC III and NOAA CGSC II
- Complete west coastline of US was mapped with QL1 LiDAR (> 8 ppsm) – Approx. 1,700 line miles
- 486 sq. miles with an additional 44 sq. miles to acquire harbor data for the USACE
- Mapped from low water line, 500 meters inland
- Collected at low tide
- Flights started Apr. 2nd, 2016 and were completed on May 20th, 2016 – 48 days on site
- Complete coastline collected in 113 flight hours

El Nino Study – Sample Images

DEM from Pilot Area in Oregon







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