Bathymetric Lidar as a Tool for Mapping Bottom Materials in Coastal Environments

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Joint Airborne Lidar Bathymetry Technical Center of Expertise

Coastal GeoTools 2011

March 22, 2011

US Army Corps of Engineers
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Joint Airborne Lidar Bathymetry
Technical Center of eXpertise

Talk Overview

- JALBTCX and USACE NCMP
- 2008 NCMP Lake Superior Stamp Sands
- Methods
  - Bathymetric lidar-derived seafloor reflectance and texture-based image analysis
- Results
  - Nearest neighbor classification of bottom materials
- Looking ahead
- Summary

Joint Airborne Lidar Bathymetry Technical Center of eXpertise

- JALBTCX
  - Operations
    - USACE
    - Navy
  - Technology Evolution
    - Coastal Measurements & Data Usage
    - Sensors & Systems
    - NOAA

Director: Jennifer Wozencraft

Optech

itres

US Army Corps of Engineers MOBILE DISTRICT

U. S. Naval Research Laboratory Stennis Space Center, MS

EARTH SCIENCE APPLICATIONS DIRECTORATE John C. Stennis Space Center

Welcome to the US Army Corps of Engineers. Engineer Research and Development Center Waterways Experiment Station, Vicksburg, MS

Department of Marine Science of The University of Southern Mississippi

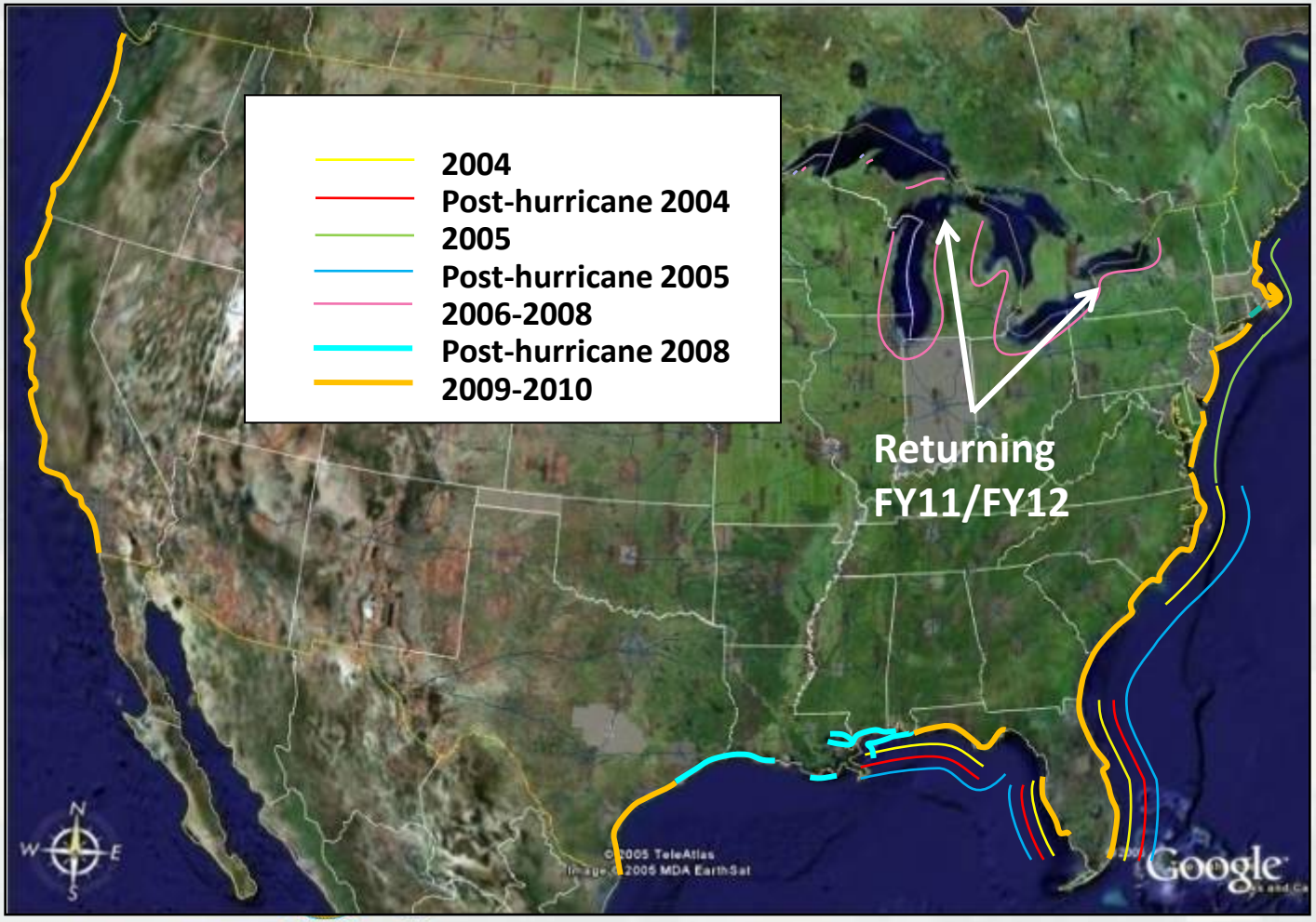
NAVAL OCEANOGRAPHIC OFFICE

NOAA Satellites and Information
National Environmental Satellite, Data, and Information Service

3001 the geospatial company

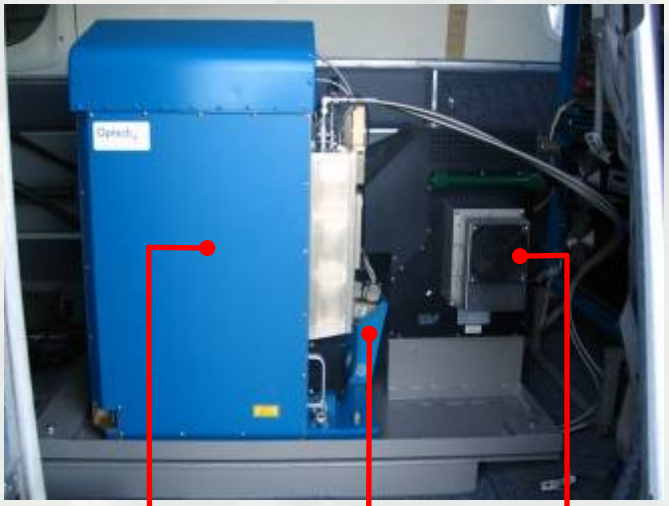
Bowhead

National Coastal Mapping Program



- Funded by USACE Headquarters
- Initiated FY2004
- Collect lidar elevation and imagery data in support of engineering and research
- Focus on sandy shorelines
- In-house and contract survey capability

USACE Survey Capability



Optech SHOALS-1000 Integrated Laser System

DuncanTech-4000 RGB camera

Itres CASI-1500 Hyperspectral Imager

Bottom Aircraft Port

<u>System II Specifications</u>

1,000 Hz Pulse Rate (hydro)

10,000 Hz Pulse Rate (topo)

1 Hz Digital camera (~20 cm pixel)

CASI-1500 Hyperspectral Imager

1500 cross-track pixels

380 – 1050 nm wavelength

1 m pixel w/ 36 spectral bands

CHARTS

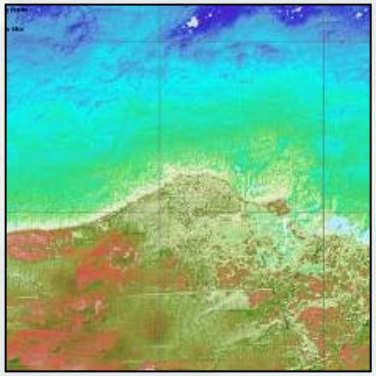
COMPACT HYDROGRAPHIC AIRBORNE RAPID TOTAL SURVEY

NCMP Product Evolution

2004

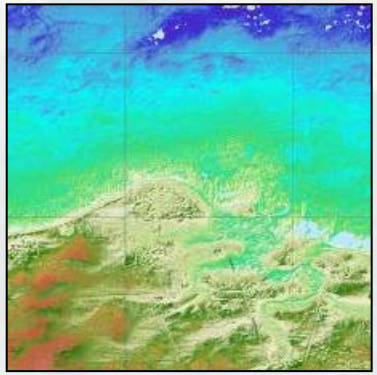
- ASCII xyz
- NAVD88 0 Shoreline
- RGB Mosaics

2005



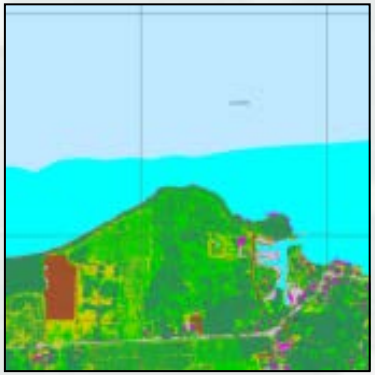
- Bathy/Topo DEM

2006



- LAS Format Topo
- Bare Earth DEM

2007-2009



- Hyperspectral Mosaics
- Laser Reflectance
- Land Cover Classification

Geographic Coordinates
NAVD88 Vertical Datum or IGLD85

More NCMP Information

Support for Physical and Environmental Studies:

- Landuse/Land Cover: Identification of physical and natural features in the landscape for resource management and coastal planning

✓ Land Cover

✓ Change Detection/ Monitoring

✓ Post-storm Analysis

2009 Orleans Ave. Canal, LA

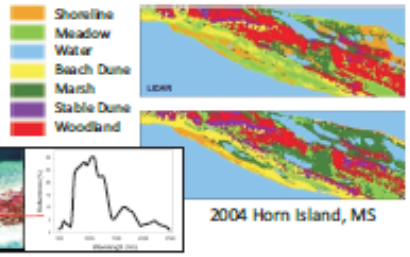
17th St. Canal

- Habitat/Species Composition: Discrimination of habitats for ecosystem restoration and monitoring (e.g. coastal wetlands); Identification of vegetation species for environmental assessment (e.g. invasive, threatened, and endangered species)

✓ Habitat Maps

✓ Wetlands Identification

✓ Ecosystem Restoration/ Monitoring

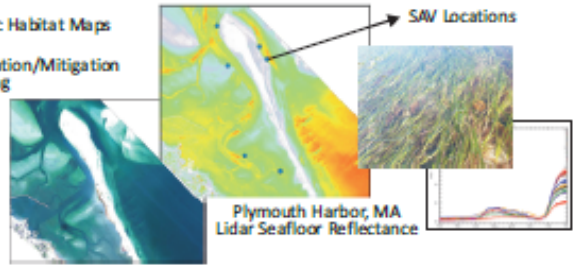


2004 Horn Island, MS

- Benthic Habitat Characterization: Mapping of the seafloor and benthic habitats, such as Submersed Aquatic Vegetation (SAV) and oyster reefs

✓ Benthic Habitat Maps

✓ Restoration/Mitigation Planning



Plymouth Harbor, MA
Lidar Seafloor Reflectance

Support for Coastal Engineering Projects:

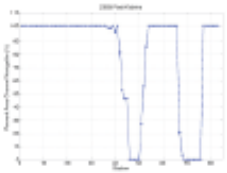
- Shore Protection: Quantification of volumetric change associated with geomorphic features, such as dune peak and shoreline, for efficient monitoring of project performance
- Navigation: Identification of inlet bathymetric features (ebb shoal, channel) for navigable conditions; Delineation of navigation structures

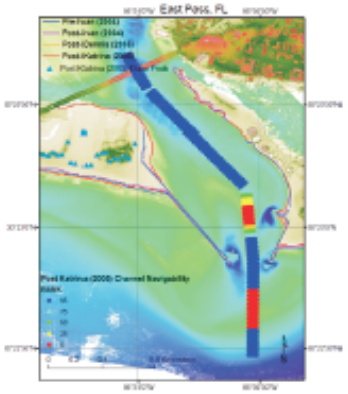
✓ Shoreline Change

✓ Dune Peak

✓ Navigable Channel Conditions

✓ Shore Protection and Navigation Project Monitoring



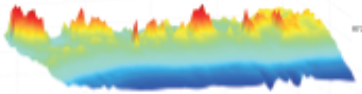


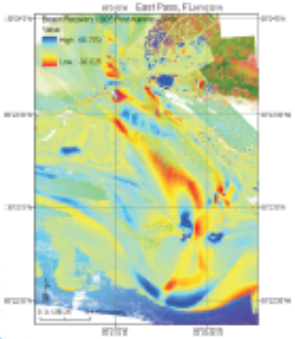
- Storm Damage Assessment: Quantification of pre/post storm elevation change for recovery efforts

✓ Elevation Change

✓ Post-storm Recovery

✓ Coastal Vulnerability Assessment





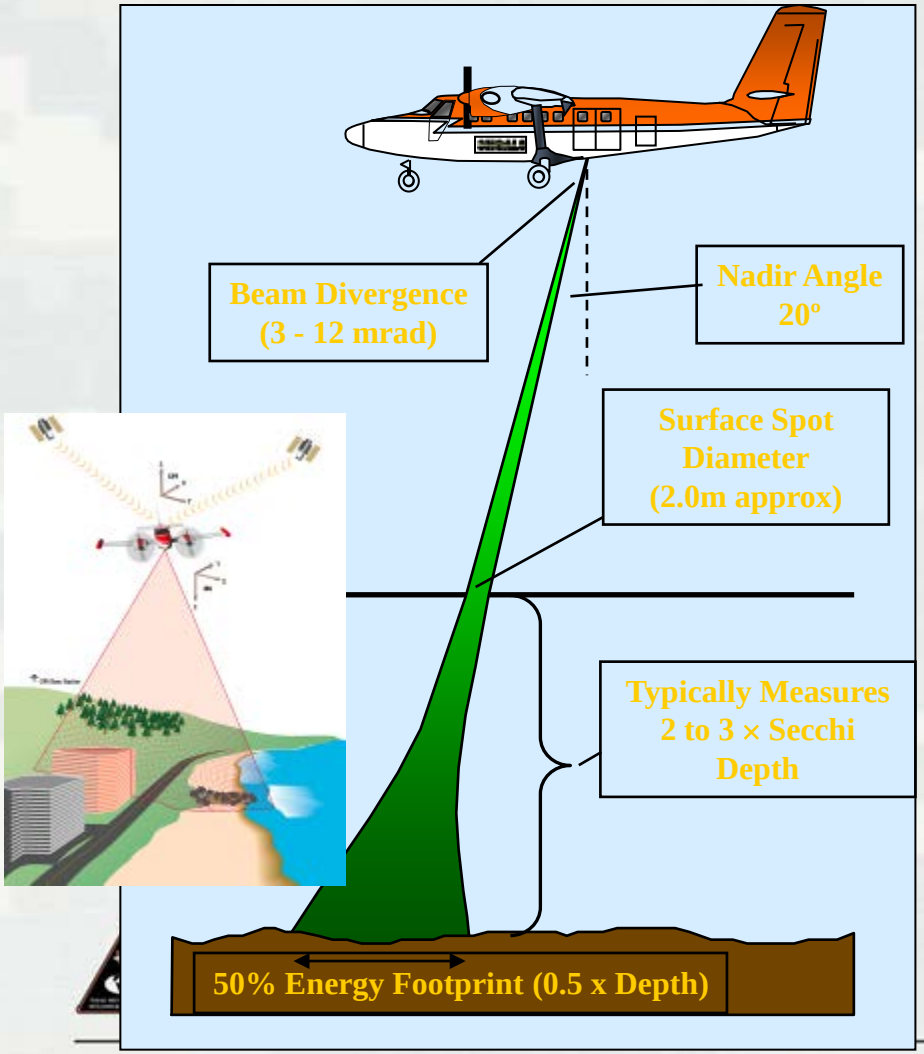
Post-storm Recovery
Elevation Change
(blue = accretion, red = erosion)

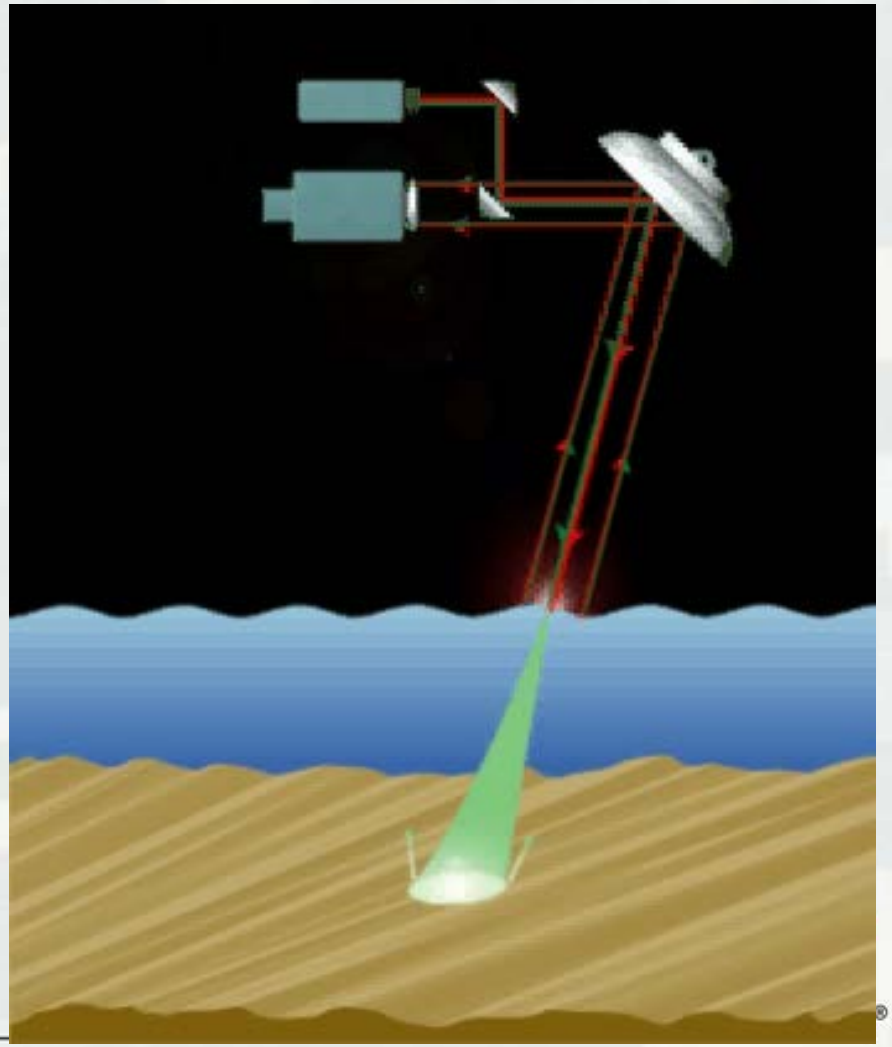
http://www.jalbtcx.org

Bathymetric Lidar for Seafloor Characterization

- Maps depicting distribution of bottom materials are important to dredging, regional sediment management and environmental applications.
- Operates over a range of depths 0-60 m, depending on water clarity.
- Cost-effective coverage over large areas in a short time period.
- Multiple sensors mounted in the aircraft offer opportunities for data fusion and improved accuracy.

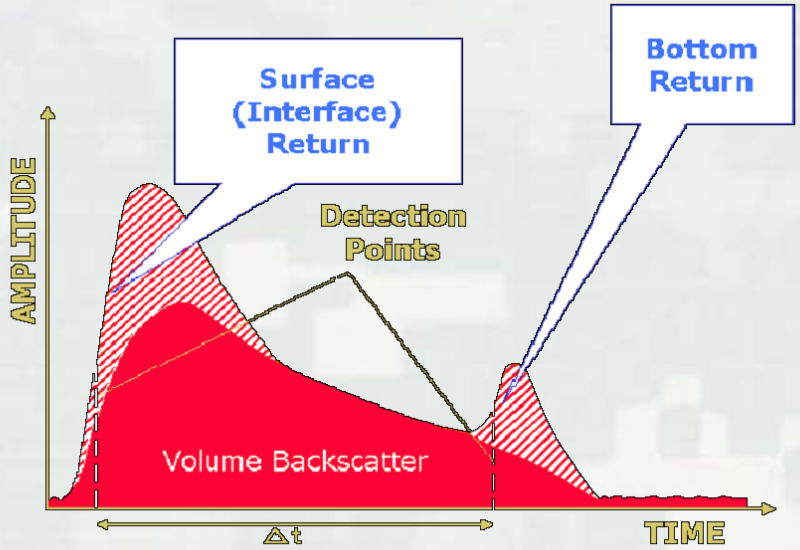
Bathymetric Lidar Principals

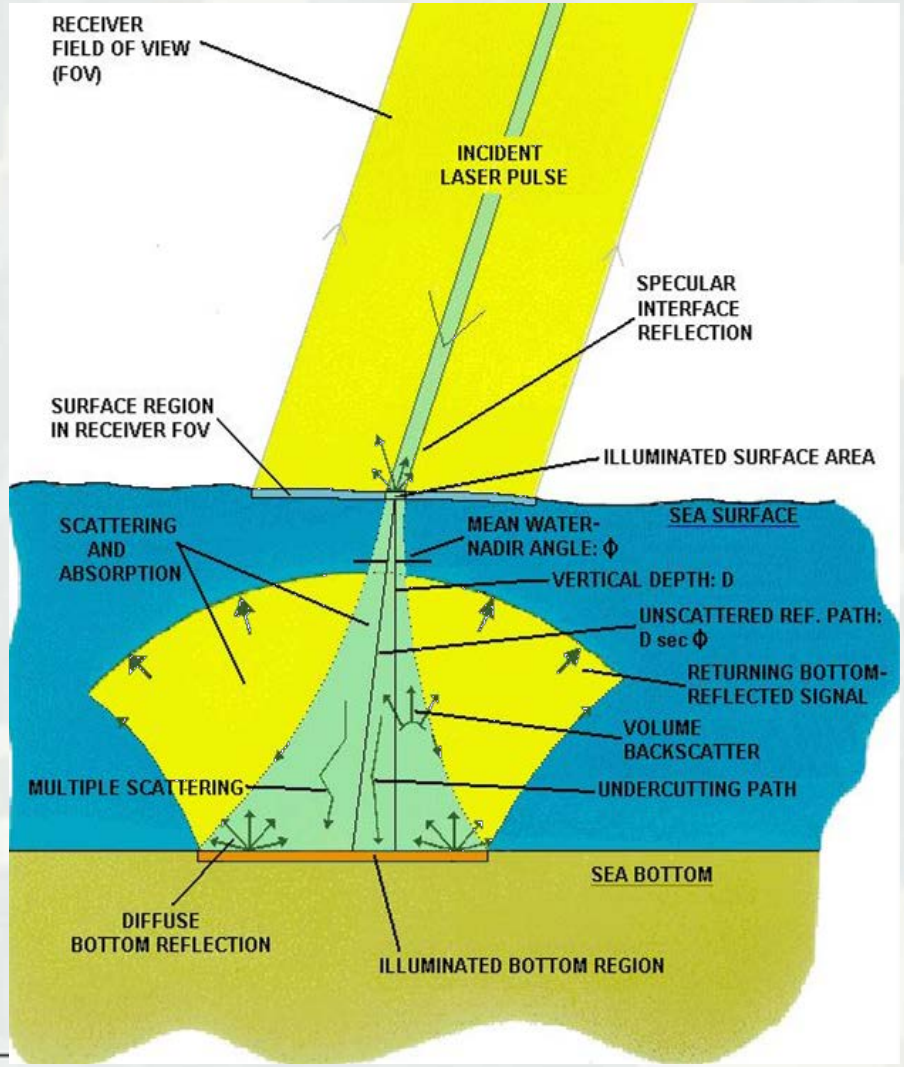




Bathymetric Lidar Principals

Lidar Waveform



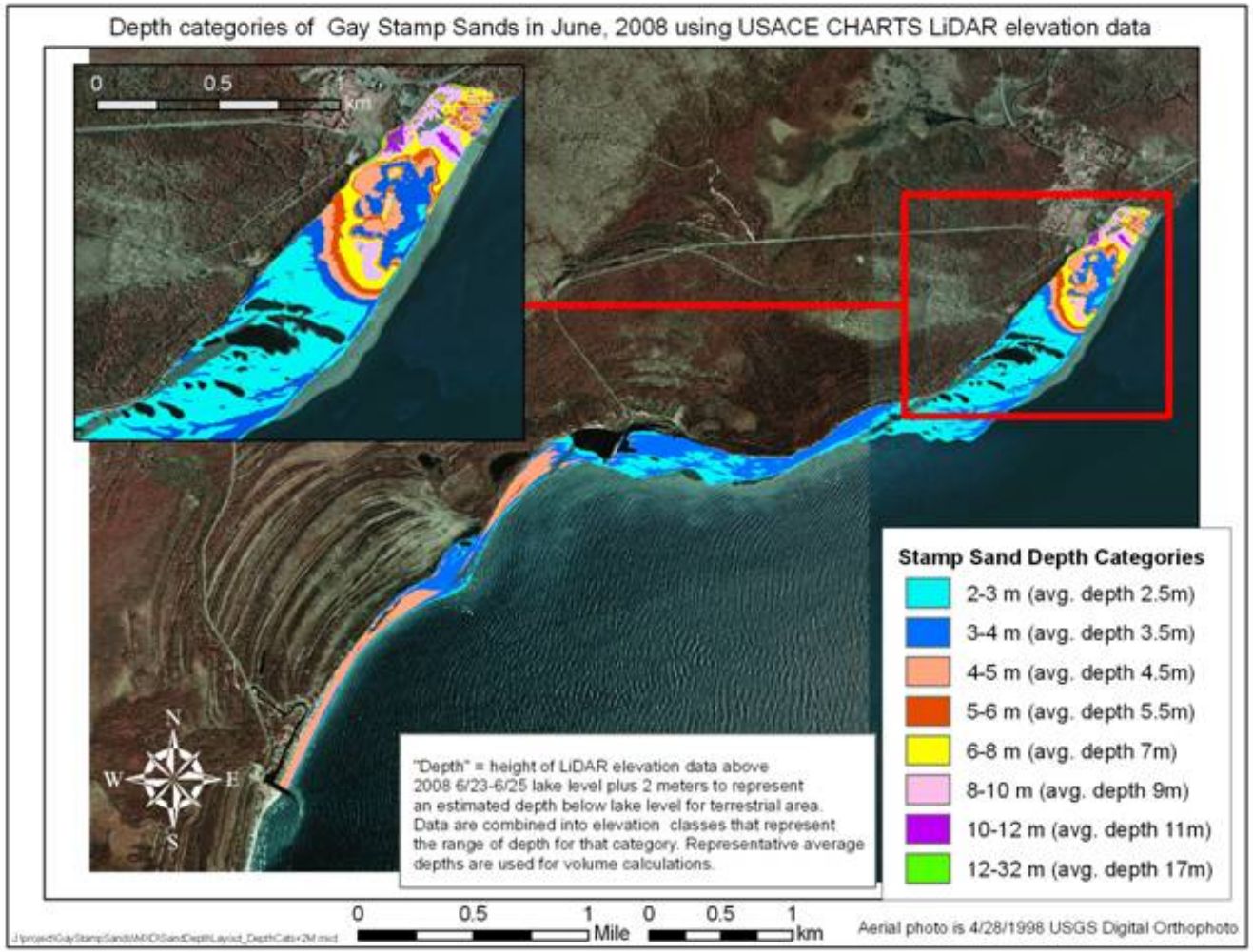


Study Site

2008 NCMP Lake Superior Stamp Sands

Estimating Volumetric Losses

- 250,000+ metric tons eroded into bay
- 21,000 metric tons eroded in last 10 years alone

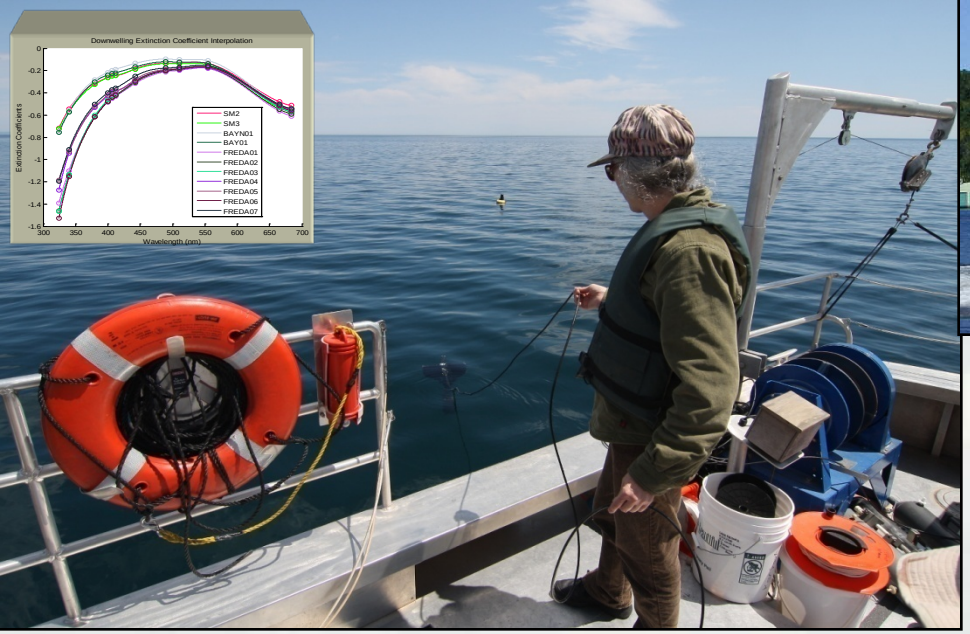


Slide courtesy of ERDC, MTU and MTRI

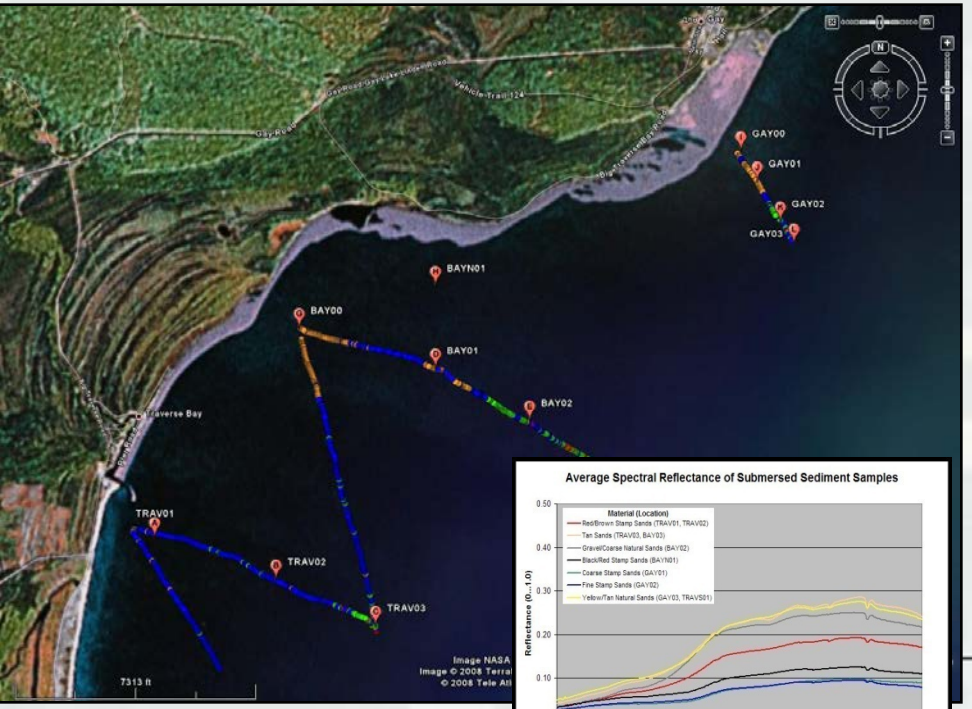
Airborne Data Collection

2008 NCMP Lake Superior Stamp Sands

- June 23-27, 2008
- 90 km^2



Simultaneous Ground Truth Data Collection:



- **Sediment grabs – visual and spectral characterization**
- **Up- and down-welling spectral radiance profiles**
- **Hydroacoustic bathymetry and bottom typing**

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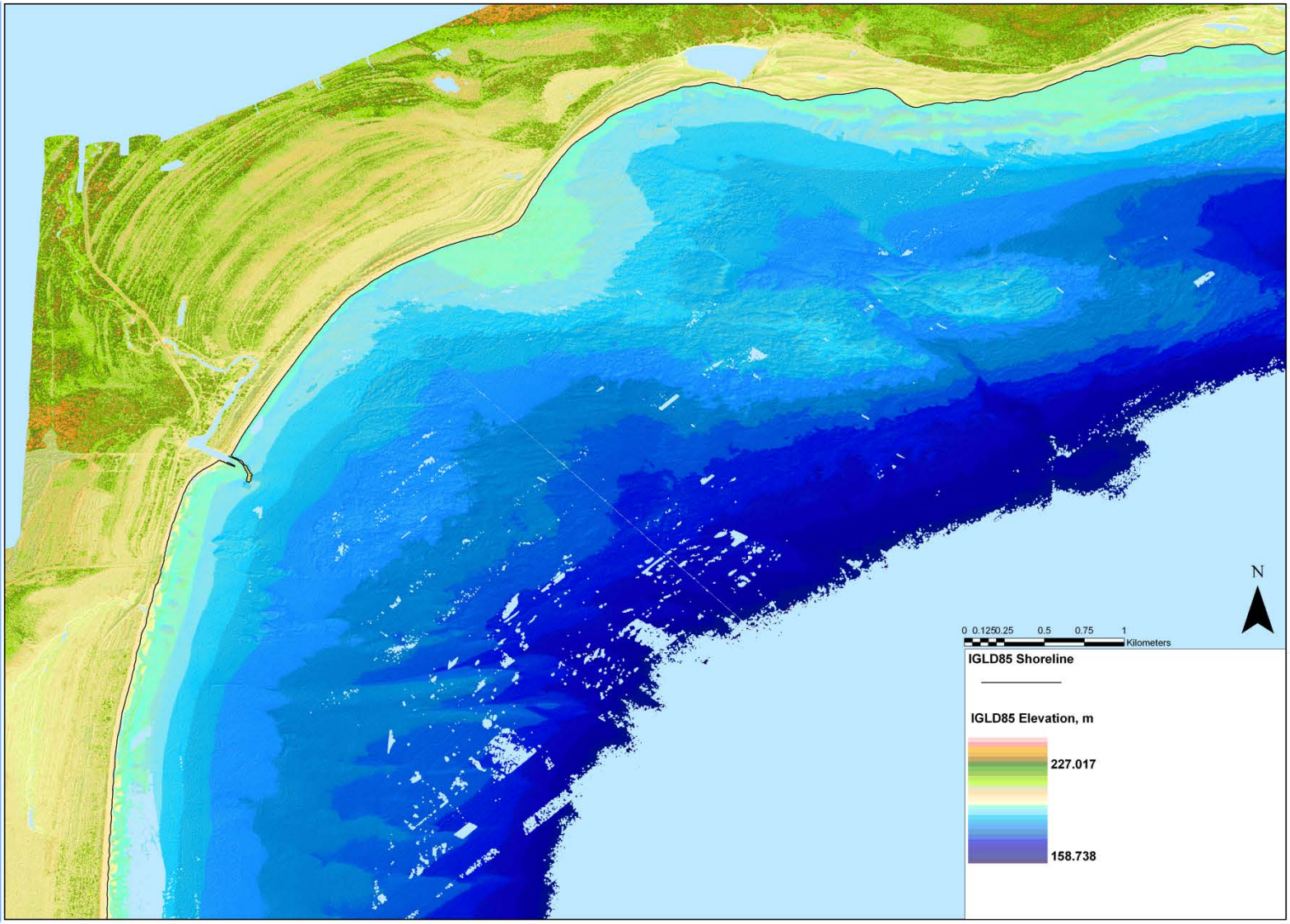
Slide courtesy of ERDC, MTU and MTRI

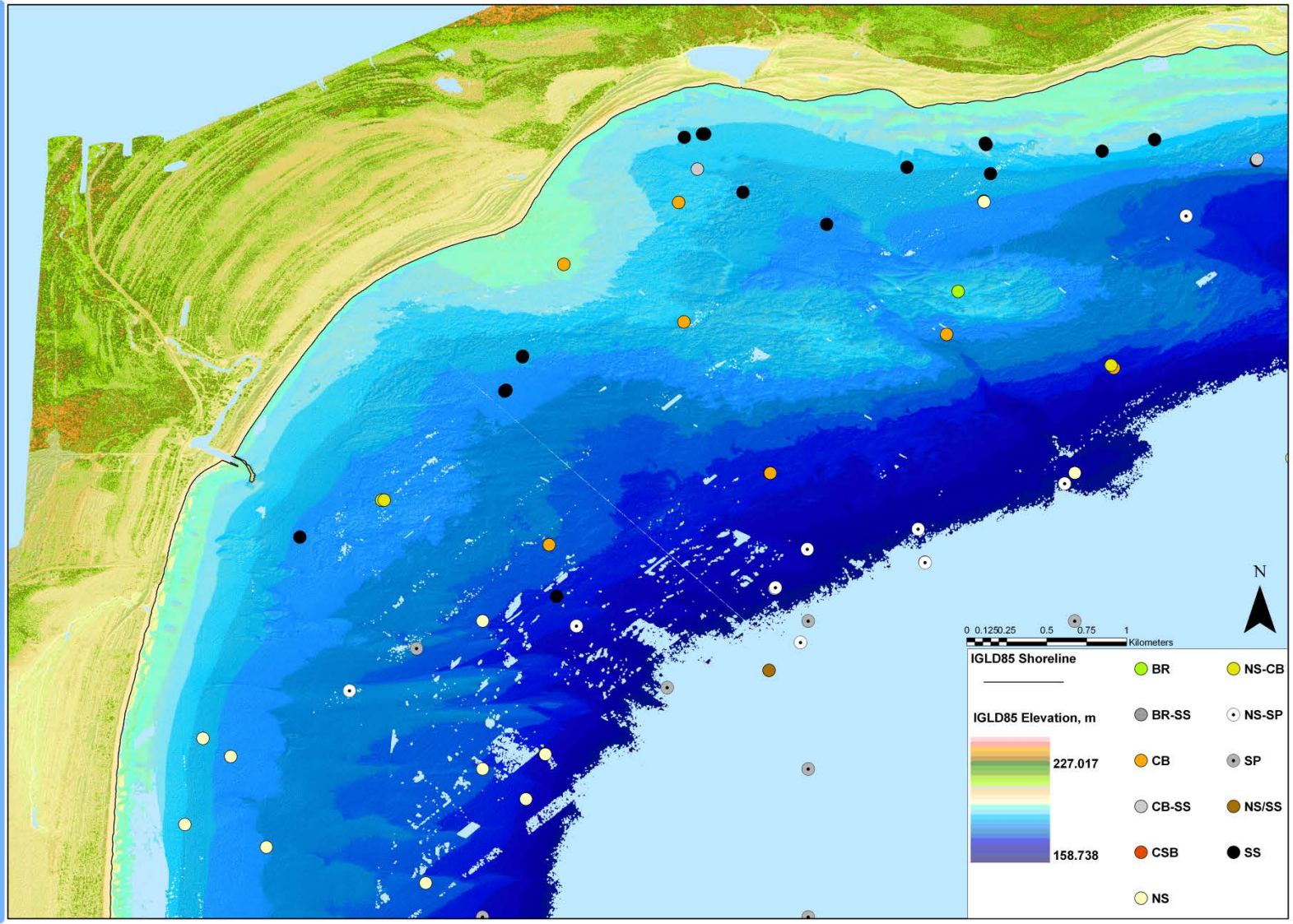
Lidar Elevation

2008 NCMP Lake Superior Stamp Sands



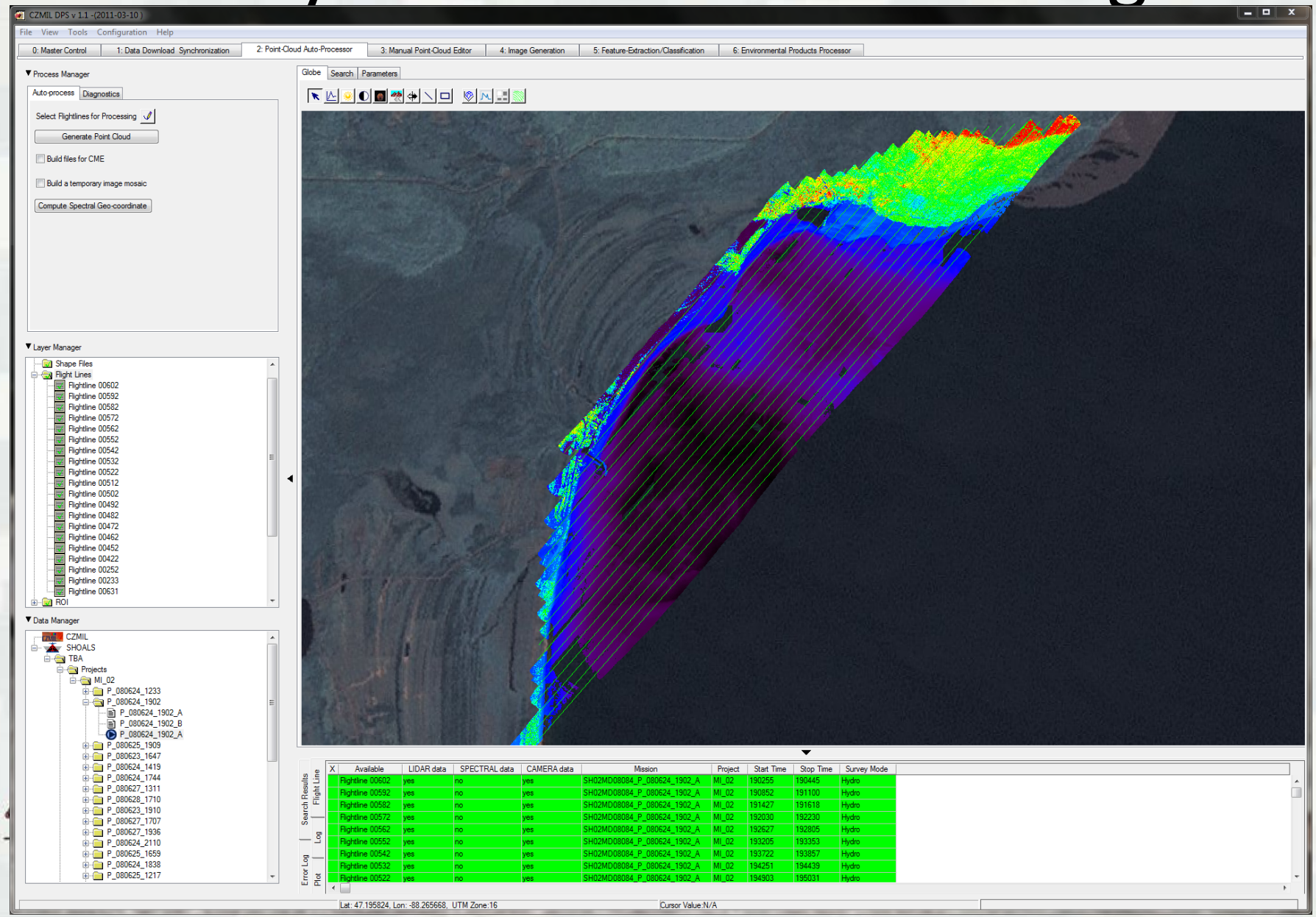
Sediment Grab Locations

2008 NCMP Lake Superior Stamp Sands

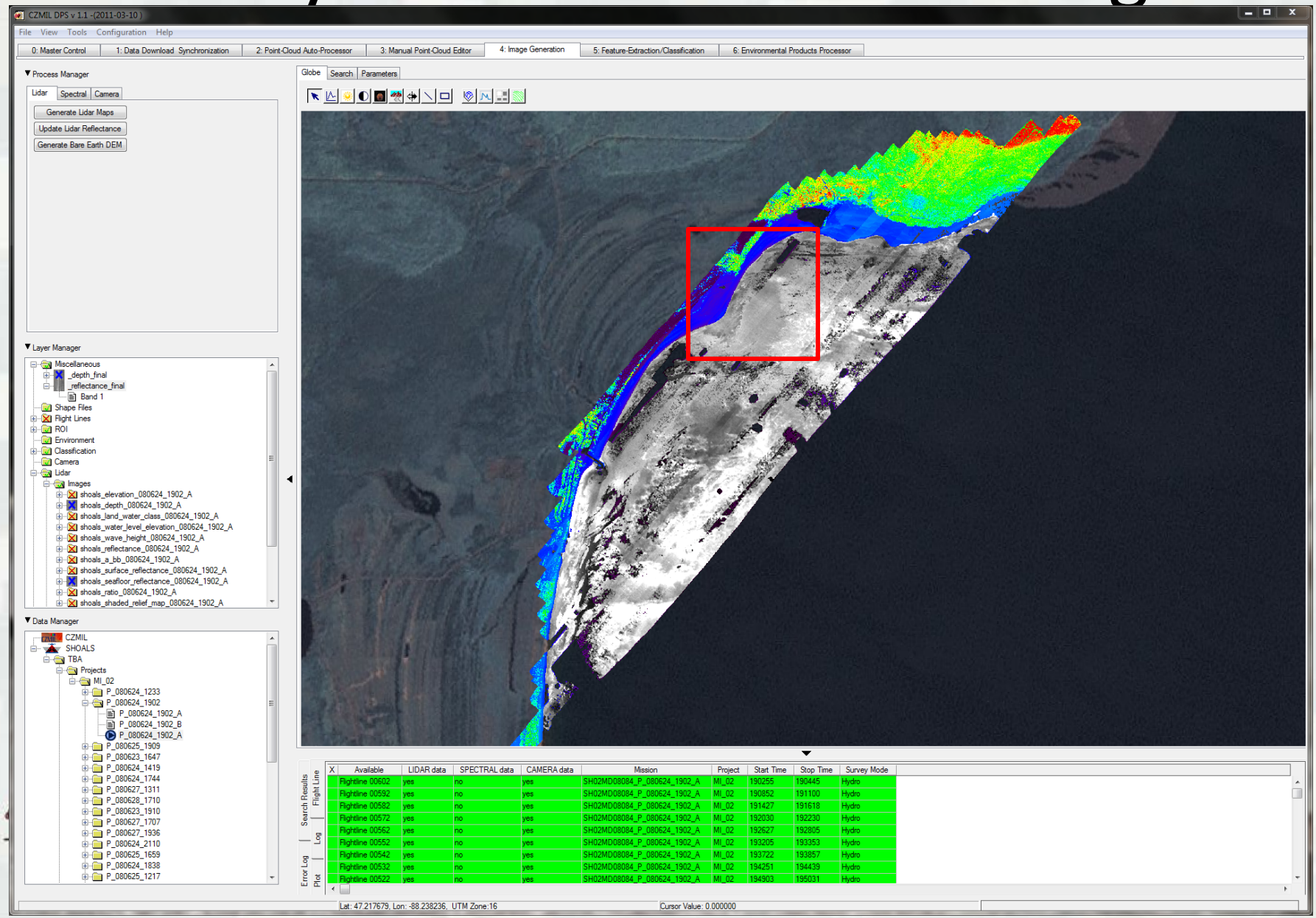


Sediment grab data courtesy of Colin Brooks, MTRI

Bathymetric Lidar Processing

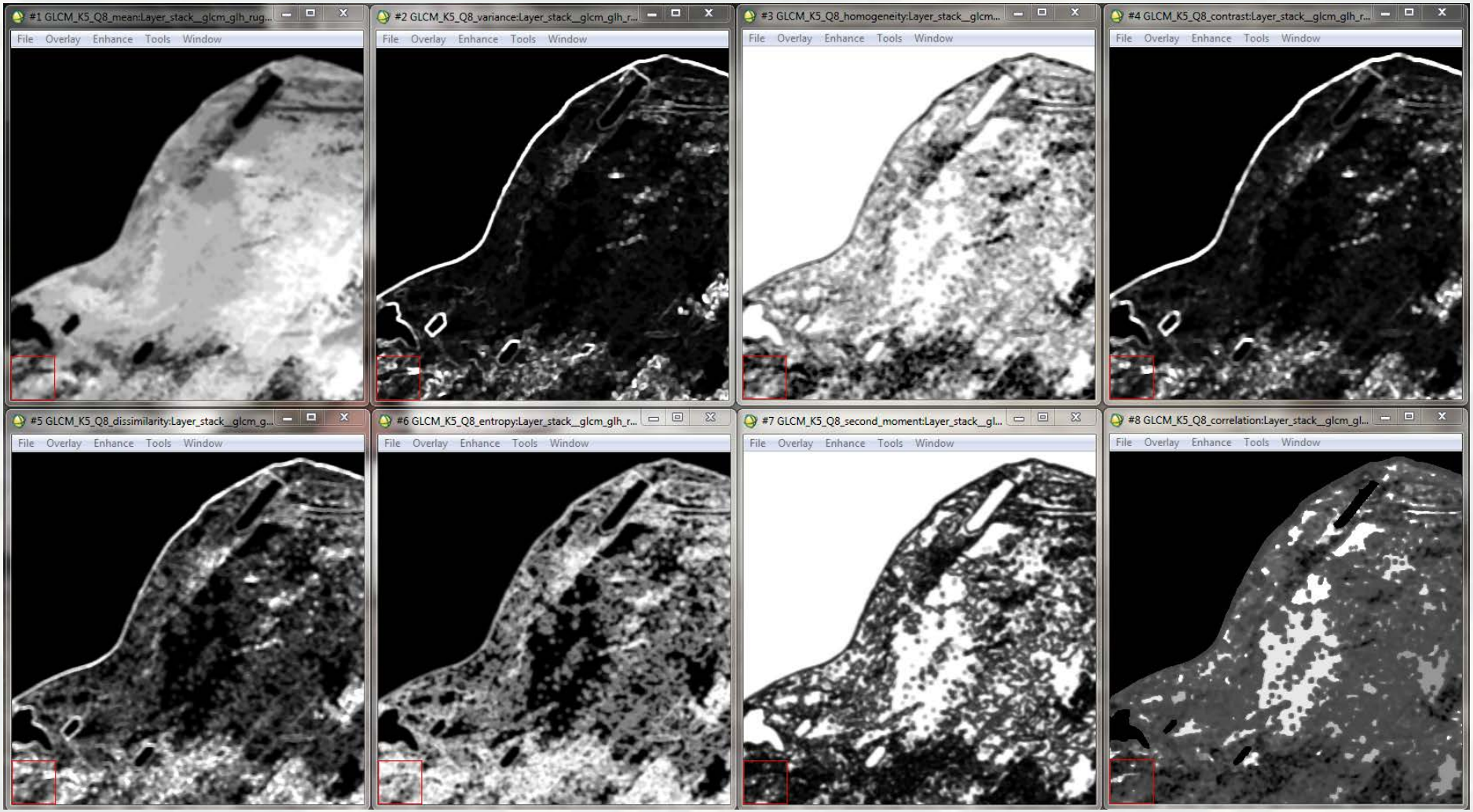


Bathymetric Lidar Processing

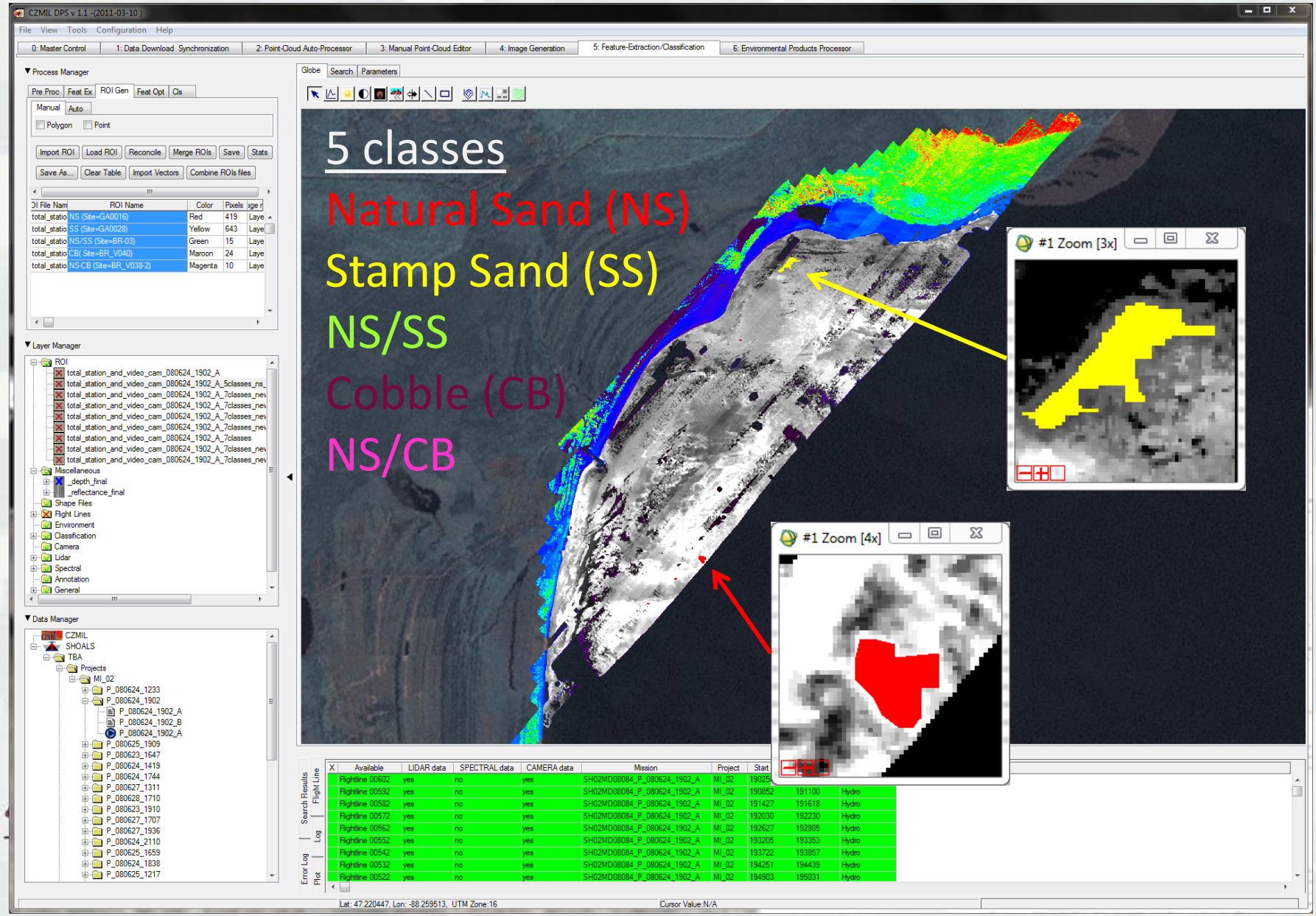


Feature Extraction

Computation of GLCM, GLH, Rugosity and Wavelets



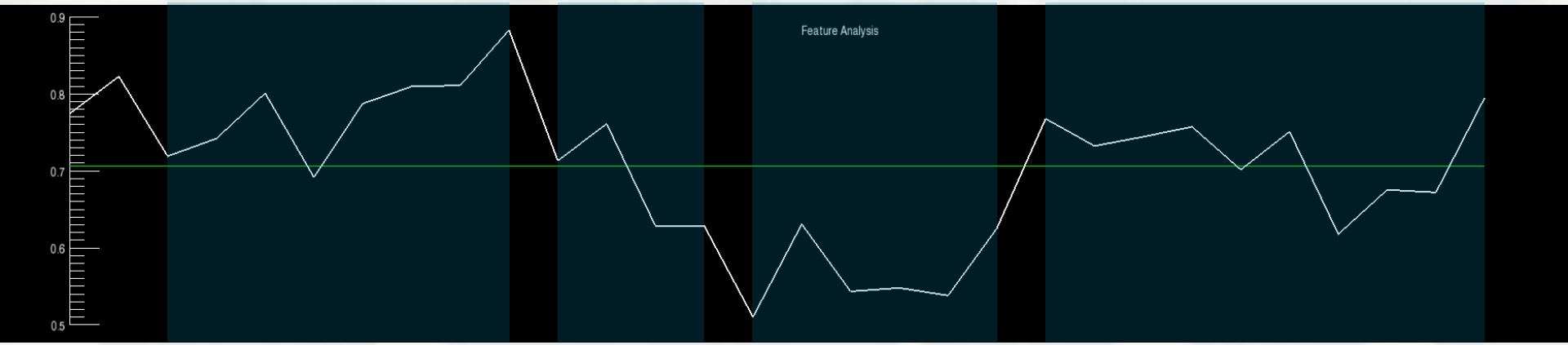
ROI Selection



Feature Optimization

Identify features most useful to classification

GLCM GLH Rugosity Wavelets



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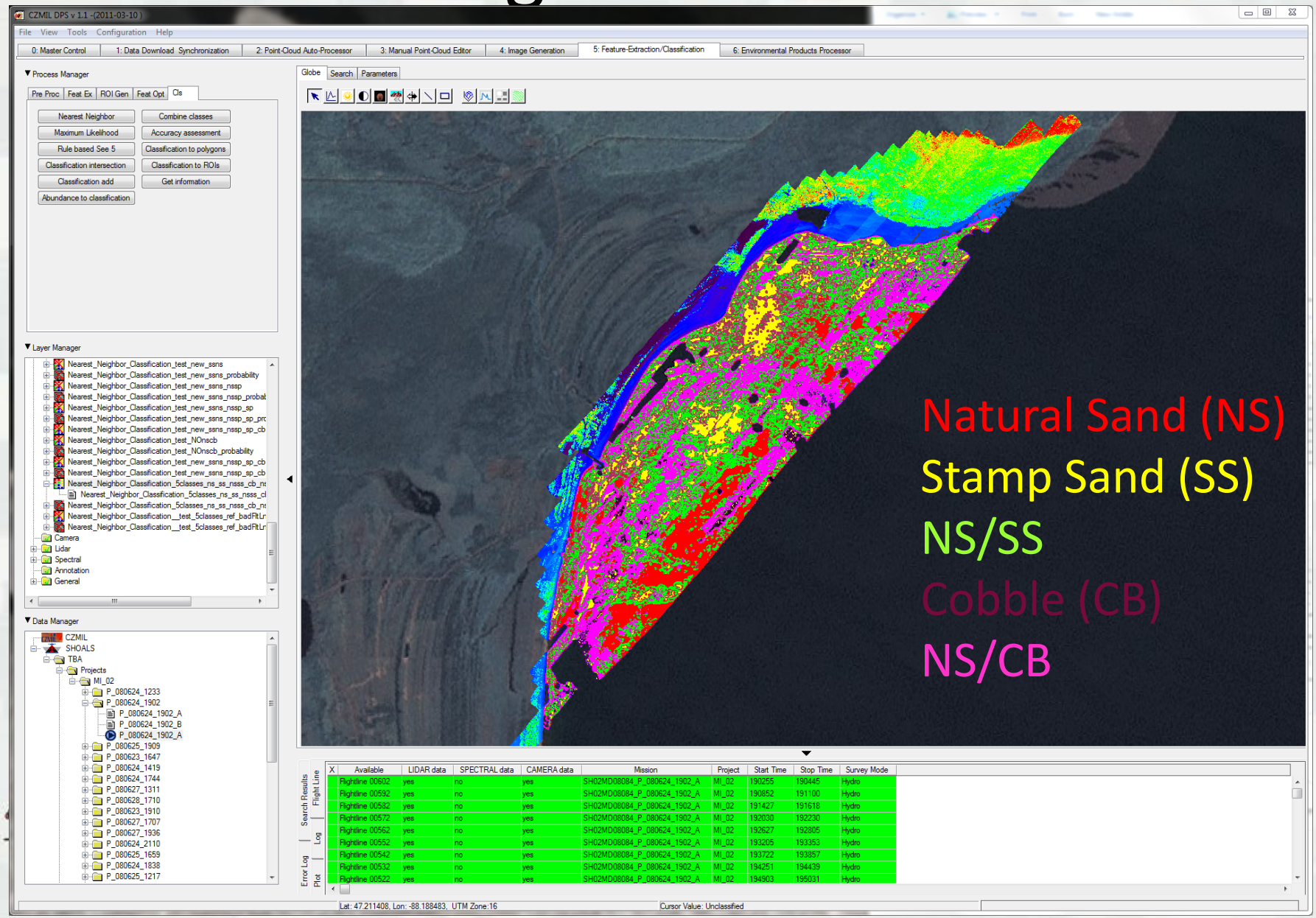
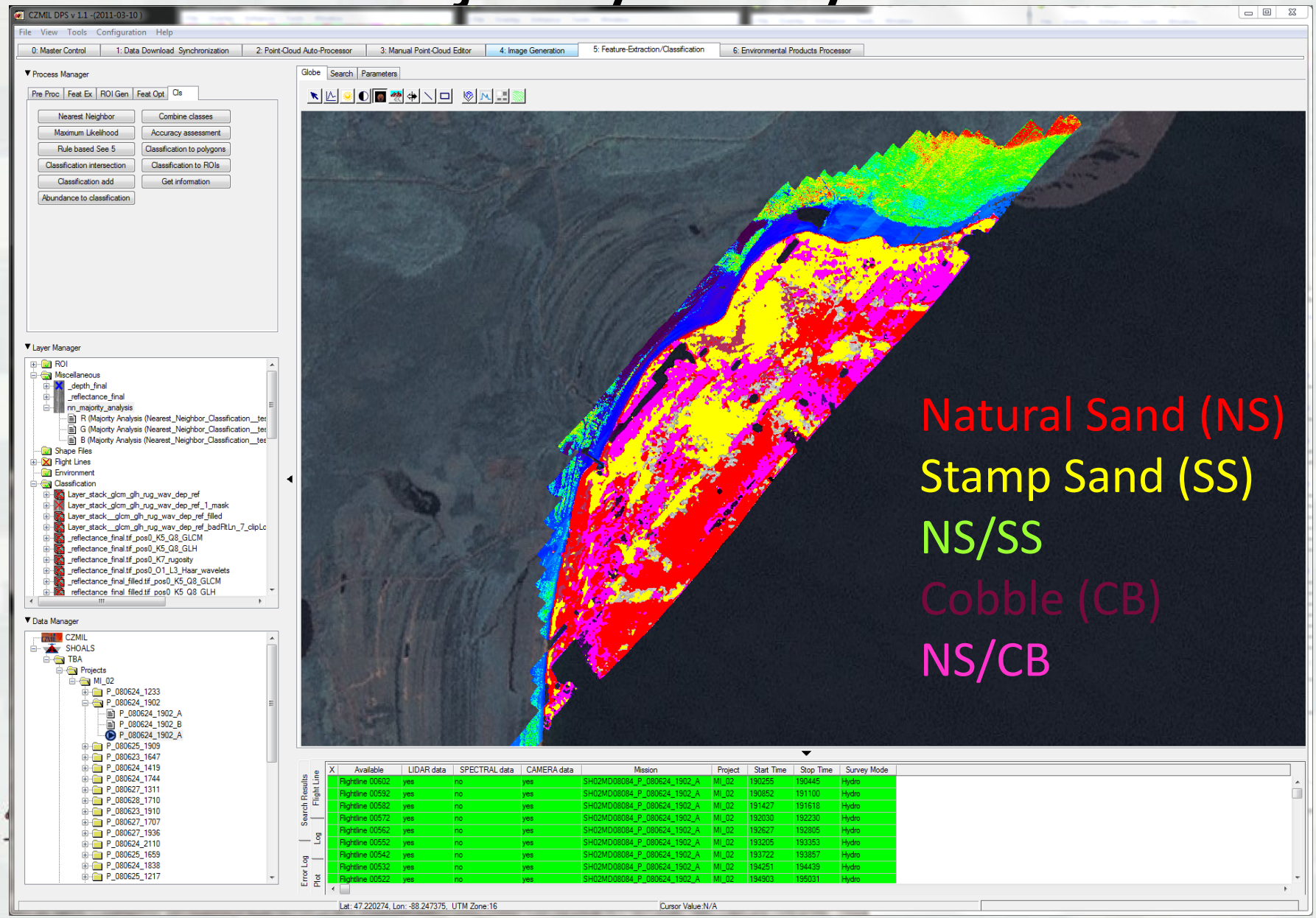
Nearest Neighbor Classification

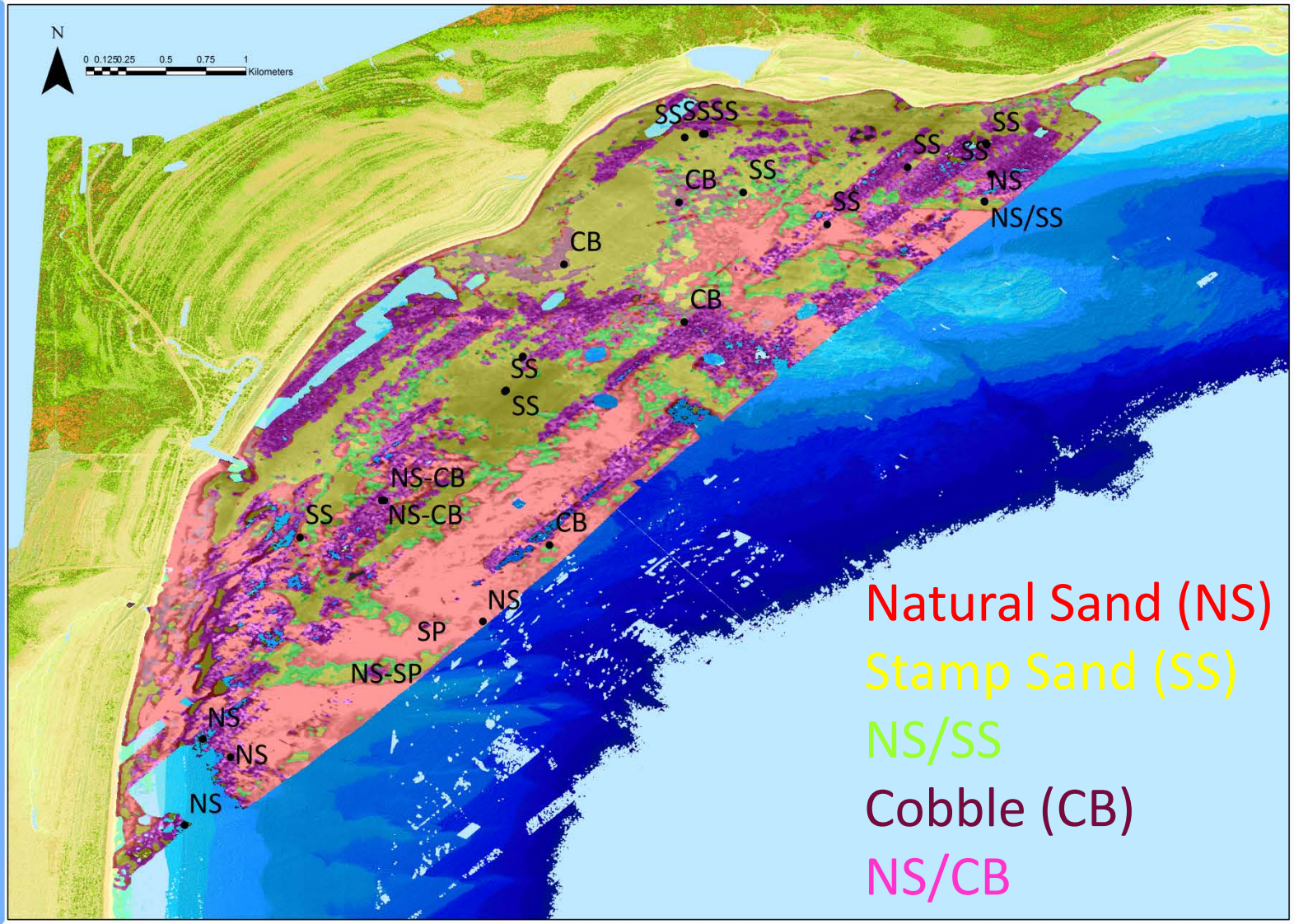


Majority Analysis



Qualitative Assessment

2008 NCMP Lake Superior Stamp Sands



Looking Ahead …

- ROI refinement
- Process additional mission datasets
- Compare results to MSS-based classifications

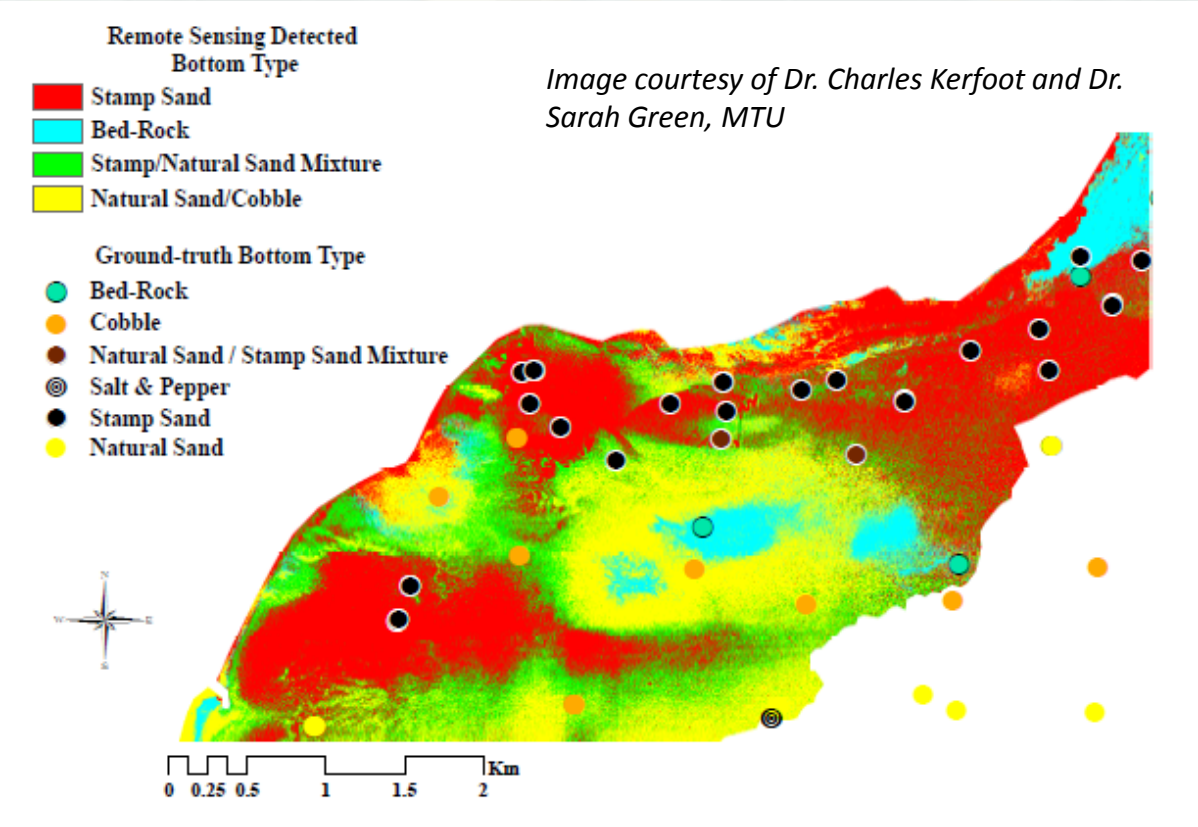


Image courtesy of Dr. Charles Kerfoot and Dr. Sarah Green, MTU

Summary

- JALBTCX performs operations, R&D in airborne bathymetric lidar and complementary technologies in support of navigation, coastal engineering and environmental monitoring requirements of USACE.
- Bathymetric lidar-derived depth and reflectance images combined with texture-based image analysis and limited ground truth supports the identification and mapping of bottom materials over large spatial extents.
- Lidar-only identification of bottom materials has the potential to improve classification accuracies.

Stay Tuned!

Talks Thursday @ 11:00 am

- H01: ***USACE Coastal Change Analysis in Response to the November 2009 Mid-Atlantic Nor'easter***, Lauren Dunkin
- H05: ***Hyperspectral and Lidar Fusion for Land Cover Classification and Change Assessment***, Chris Macon
- H06: ***Geospatial Data Fusion for Coastal Environmental Applications***, Molly Reif

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Thanks!

Special thanks to:

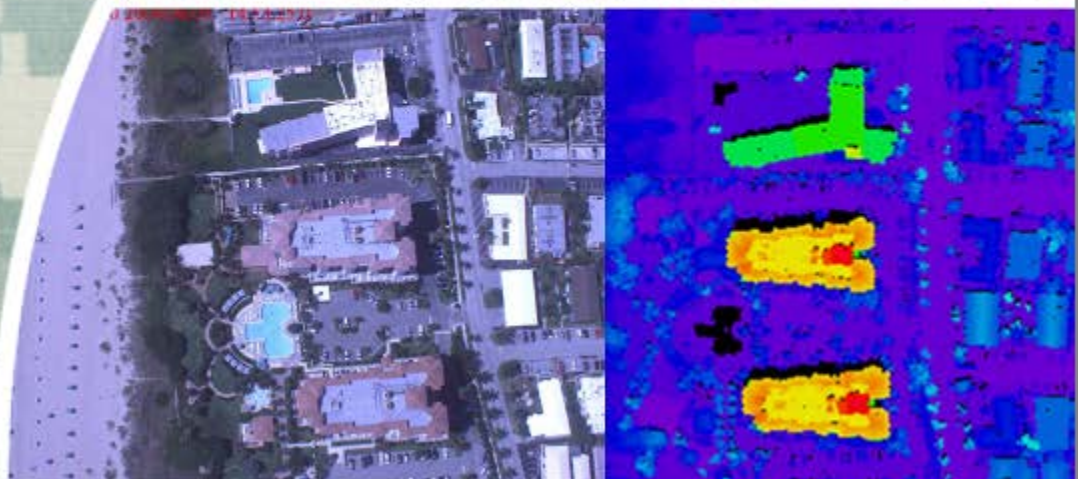
JY Park and Vinod Ramnath, Optech International Inc.

Chris Macon and Molly Reif, JALBTCX

Bruce Sabol, USACE ERDC-EL

Dr. W. Charles Kerfoot and Foad Yousef, MTU

Colin Brooks, MTRI



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