Satellite activities in NOAA:

Satellite-derived bathymetry (SDB)

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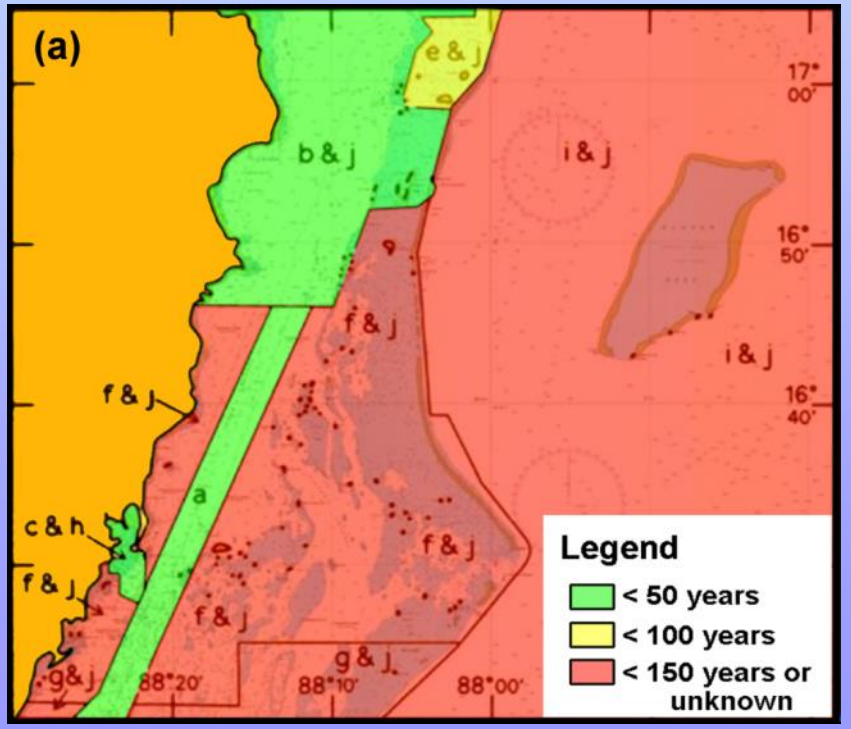
Motivation

National hydrographic offices need to periodically assess the adequacy of information on existing nautical charts for survey planning and prioritization.

One of the key factors is the adequacy of the charted bathymetry.

Hence, there is a need for low-cost, up-to-date reconnaissance surveys.



SDB Algorithms

Several approaches have been developed for SDB:

Analytical methods that are usually designed for a specific data set.

Optimization approach that assumes vertically invariant water column and bottom conditions that requires to fix all but one parameter. A sub-category of this approach is a ratio approach that derives bathymetry based on the log ratio (or ratio of logs) of two bands.

Look-up tables (LUT) that use a comparative method for bathymetry classification based on large database generated from radiative transfer models.

Note:

For an algorithm that can be used by the hydrographic community on a COTS GIS software, a ratio transform algorithm based from an optimization approach provides a robust solution that does not require to sample the environment or generate a database.

Historical Review

2003 – Stump's algorithm for SDB

2010 – Developing the SDB (Nigeria and Belize)

2012 – IHO-IOC Gebco Cook Book

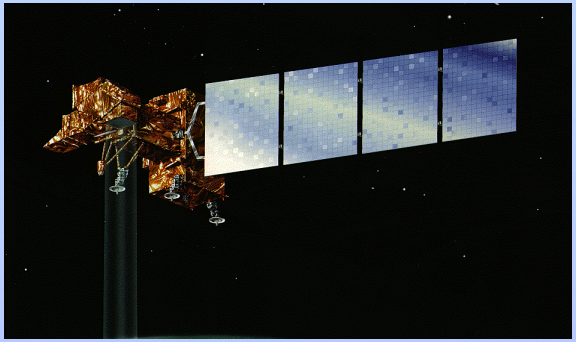
2013 – Integration of single-image SDB approach

2014/2015 – Development and integration on multi-image SDB approach

Activities within NOAA

- **Reconnaissance tool**
  - Chart adequacy and survey planning
  - Magenta line
- **Chart Adequacy**
  - Risk assessment (incorporated with AIS datasets)
  - Monitoring dynamic seafloor regions
- **Emergency response**
  - Sandy response efforts
- **International collaboration and outreach**
  - Gebco (cook book and short-term internships)
  - Haiti
  - Graduate programs (Brazil, Nigeria and Ghana)

Available resources



Landsat 7

Launch Date: 4/1999

Landsat 8 (LDCM)

Launch Date: 2/2013

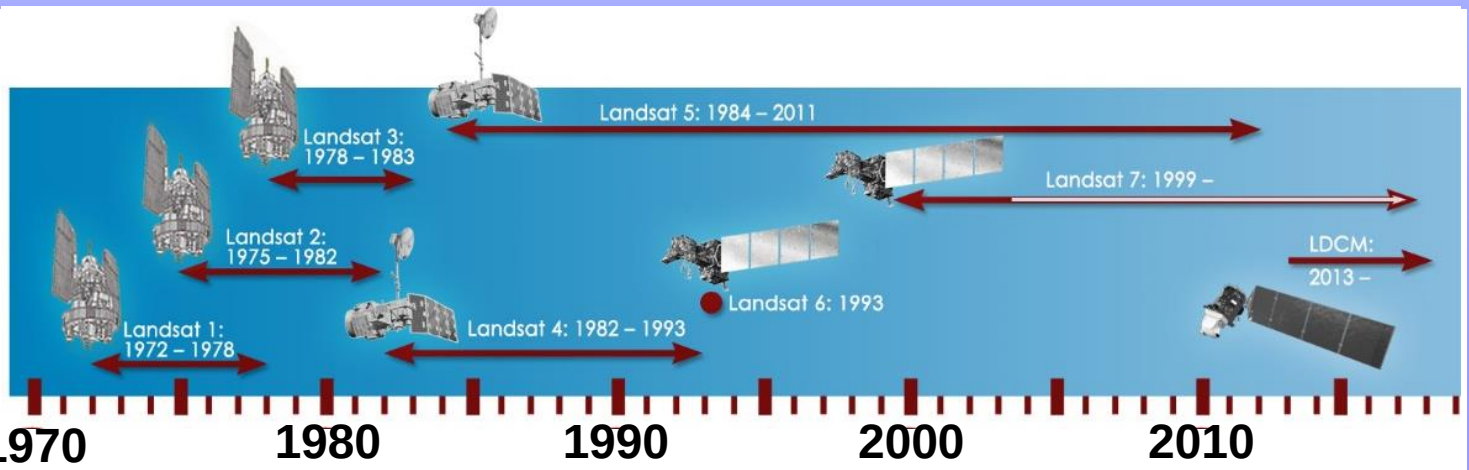
WorldView2

Launch Date: 10/2009

Organization: NASA/USGS program
Swath: 185km
Ground resolution: 28.5m

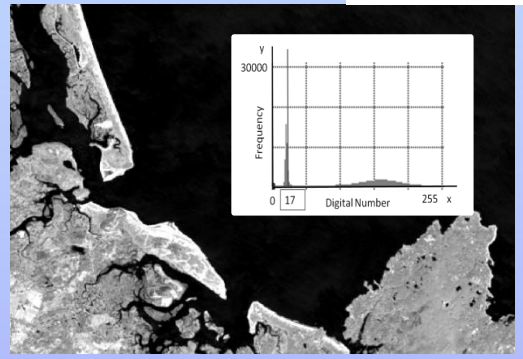
Company: DigitalGlobe
Swath: 18 km
Ground resolution: 2m

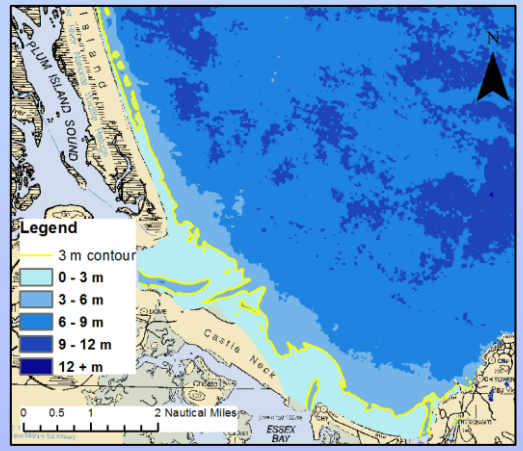
(Images from landsat.gsfc.nasa.gov and www.digitalglobe.com)



Single-image approach

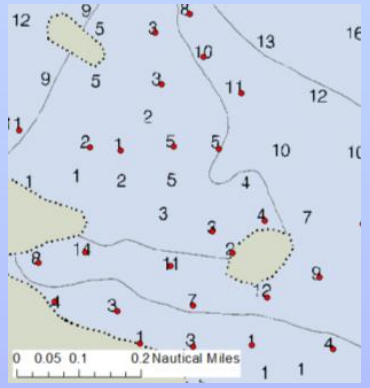
Identifying the land/water

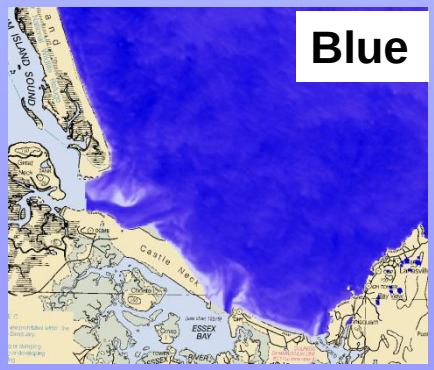


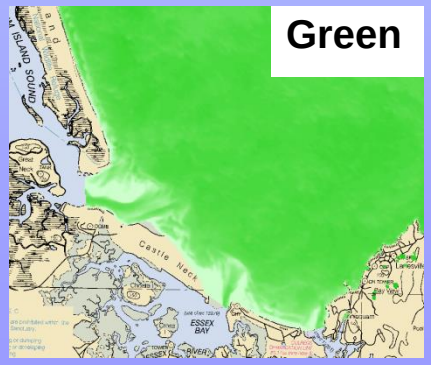


Satellite-derived bathymetry

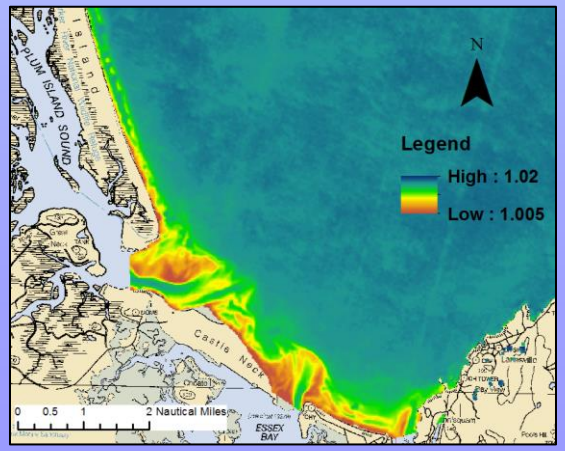
Referencing to chart datum





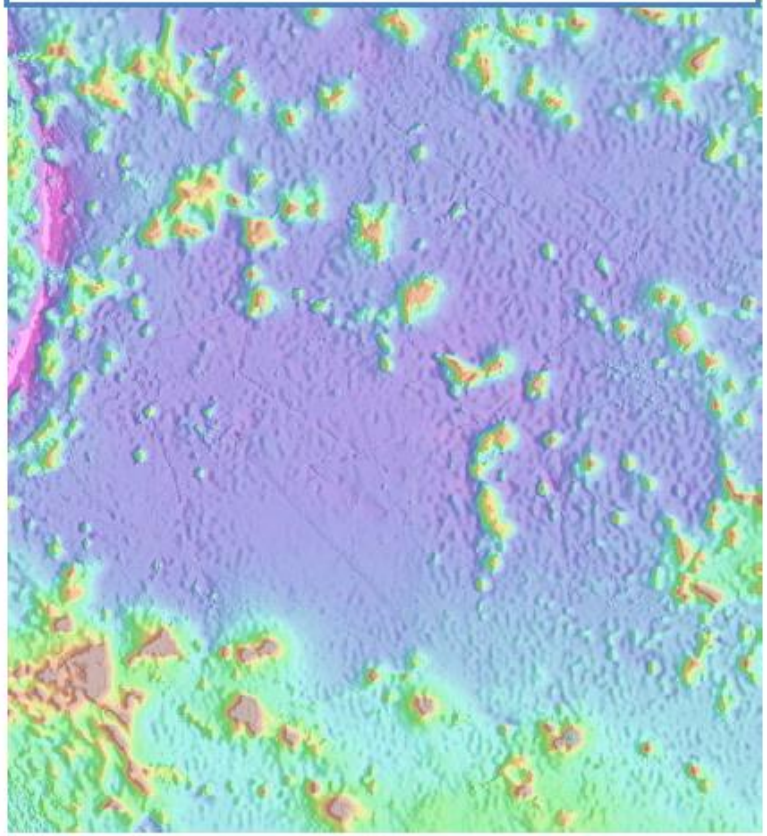


Masking the blue and green bands



Applying the algorithm

The IHO-IOC GEBCO Cook Book



February 2013

IHO Publication B-11
IOC Manuals and Guides, 63

Chapter 11.0 LANDSAT 7 Satellite-Derived Bathymetry

Contributed by S. Pe'eri, B. Madore and L. Alexander, Center for Coastal and Ocean Mapping, USA, C. Parrish and A. Armstrong, National Oceanic and Atmospheric Administration, USA, and C. Azuike, Nigerian Navy Hydrographic Office Lagos, Nigeria

Since the 1970's, satellite remote sensing has become increasingly recognized as a useful reconnaissance tool to map near-shore bathymetry, characterize a coastal area and to monitor seafloor changes that may have occurred since the last hydrographic survey was conducted. Satellites allow for the capturing of images over broad expanses of the Earth. The following procedure provides the user with an inexpensive and quick approach to derive bathymetry from satellite imagery. The data sources used in the procedure below are publicly-available imagery collected by LANDSAT 7 satellite using the Enhanced Thematic Mapper Plus (ETM+) instrument and chart soundings.

The key steps in the procedure include:

1. **Pre-processing** – Satellite imagery is downloaded based on the geographic location and environmental conditions (e.g., cloud coverage and sun glint) had to be used.
2. **Water separation** – Dry land and most of the clouds are removed.
3. **Spatial filtering** – 'Speckle noise' in the Landsat imagery is removed using spatial filtering.
4. **Applying the bathymetry algorithm** – The Stumpf et al. (2003) algorithm using the blue and green bands.
5. **Identifying the extinction depth** – The optic depth limit for inferring bathymetry (also known as, the extinction depth) is calculated.
6. **Vertical referencing** – A statistical analysis between the algorithm values to the chart soundings references the Digital Elevation Model (DEM) to the chart datum.

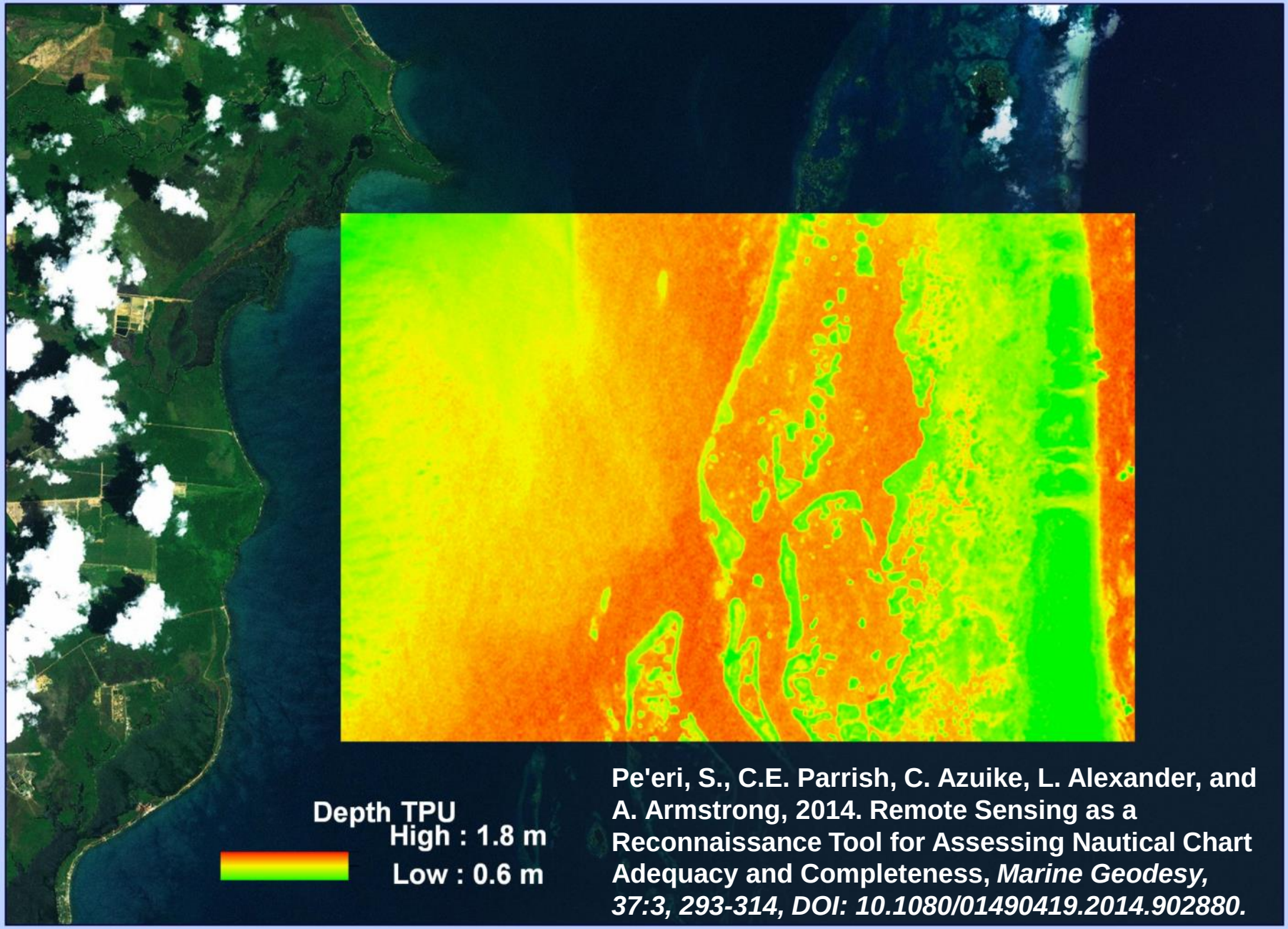
For more details on satellite-derived bathymetry and hydrographic applications, please refer to Pe'eri et al. (2013).

Pe'eri, S., C. Parrish, C. Azuike, L. Alexander and A. Armstrong, 2013. Satellite Remote Sensing as Reconnaissance Tool for Assessing Nautical Chart Adequacy and Completeness, *Marine Geodesy* (submitted).

Stumpf, R., K. Holderied and M. Sinclair, 2003, Determination of water depth with high-resolution satellite imagery over variable bottom types, *Limnology and Oceanography*, **48,** 547-556.

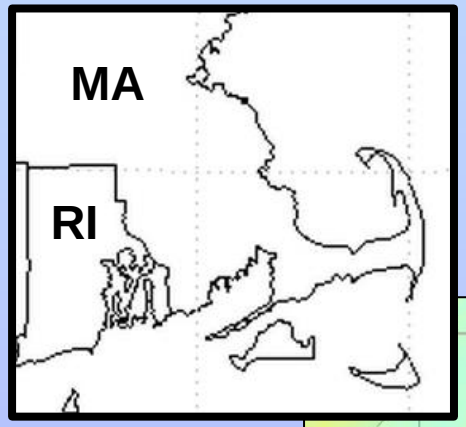
www.gebco.net/data_and_products/gebco_cook_book/

Uncertainty Surface for Belize Satellite-Derived Bathymetry

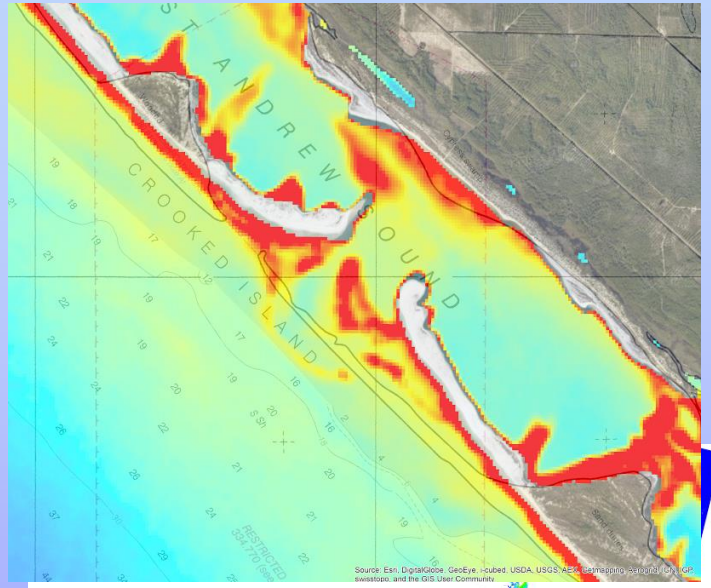


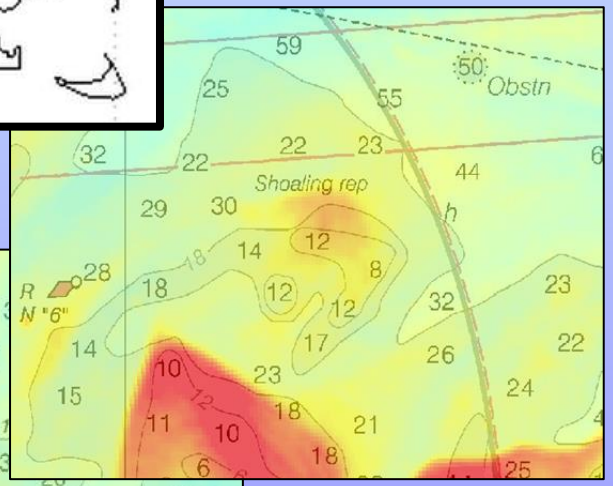
Pe'eri, S., C.E. Parrish, C. Azuike, L. Alexander, and A. Armstrong, 2014. Remote Sensing as a Reconnaissance Tool for Assessing Nautical Chart Adequacy and Completeness, *Marine Geodesy, 37:3, 293-314, DOI: 10.1080/01490419.2014.902880.*

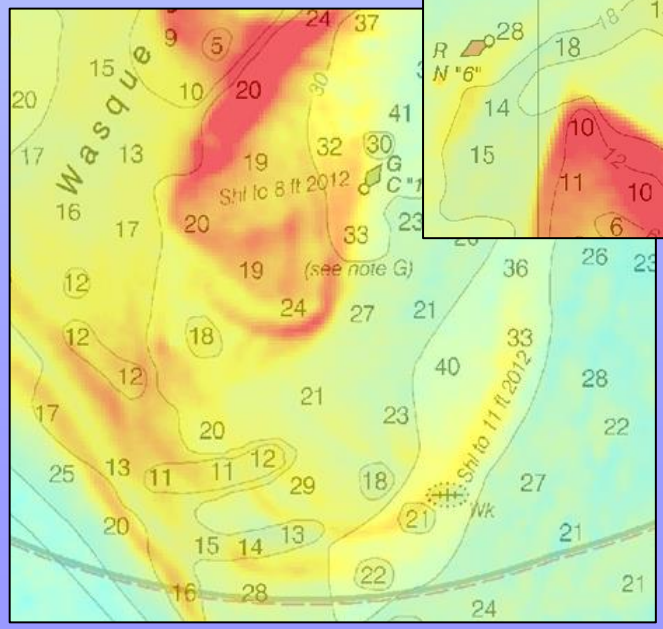
Reconnaissance tool
Chart Adequacy

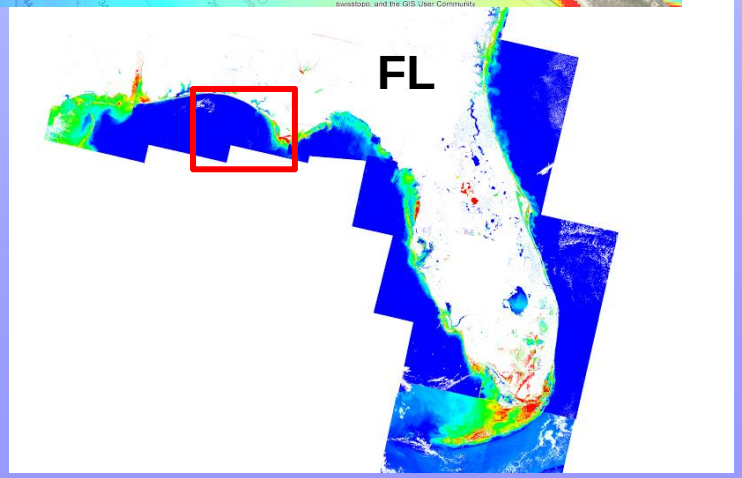


Will be presented at US Hydro 2015 Thursday 11:30 am

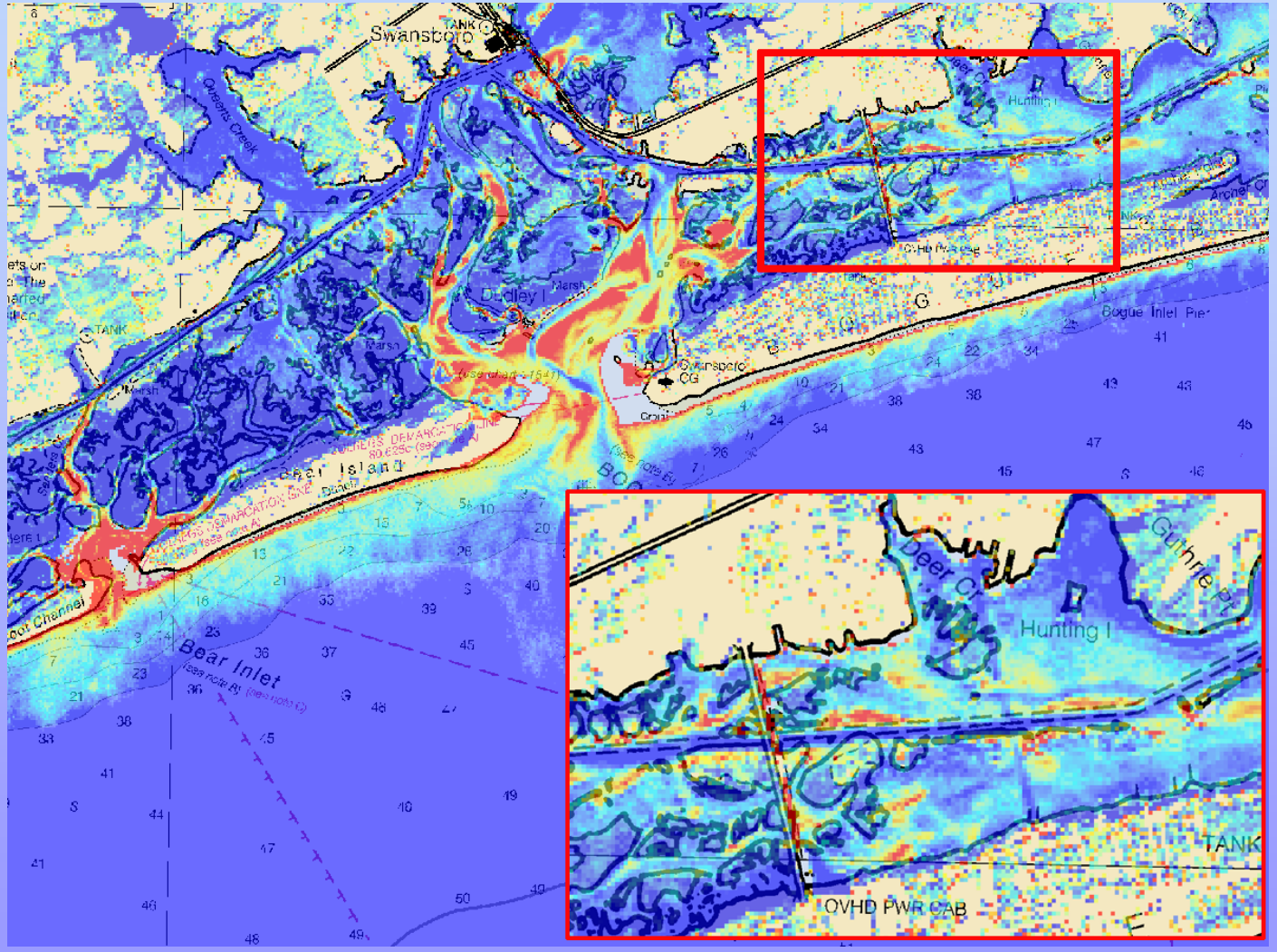








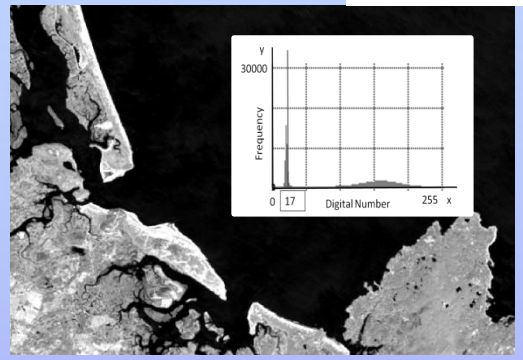
Reconnaissance tool
Magenta Line

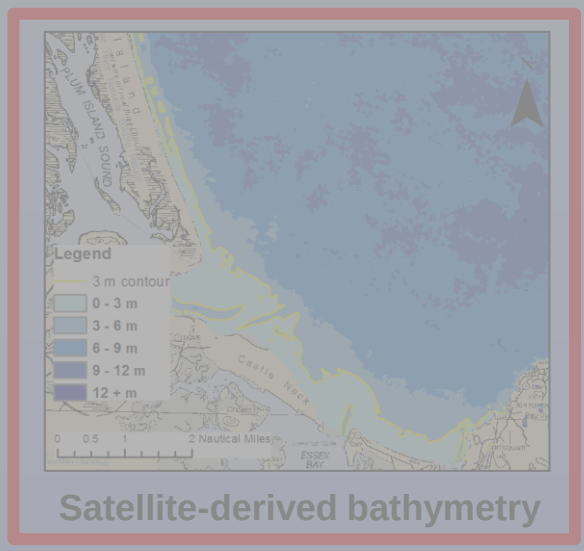


SDB (Landsat 8) over Bogue Inlet, North Carolina.

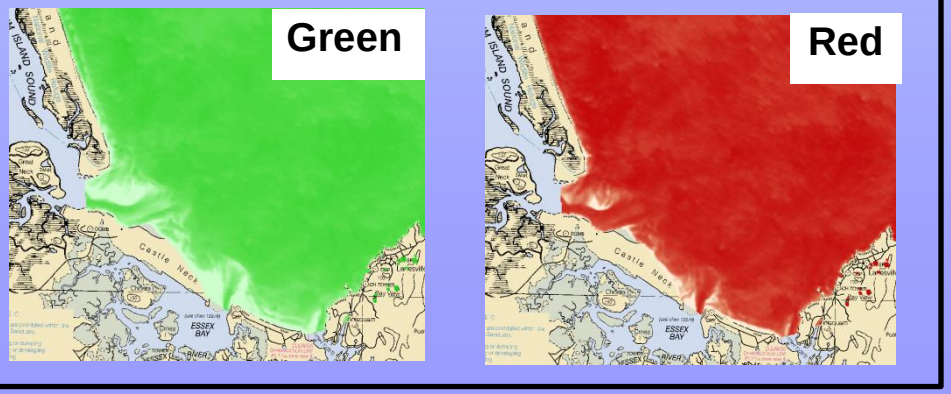
SDB in turbid waters

Identifying the land/water

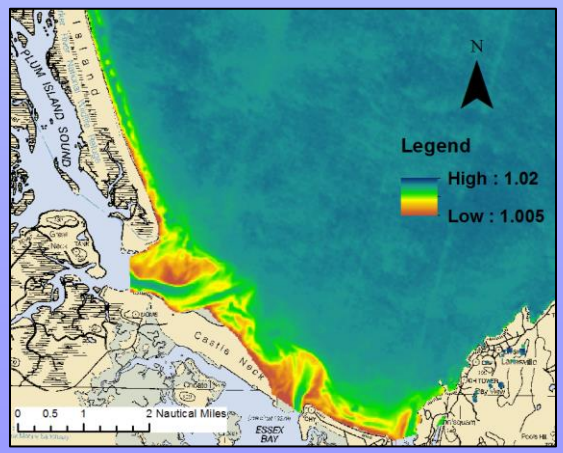




Referencing to chart datum



Masking the blue and green bands

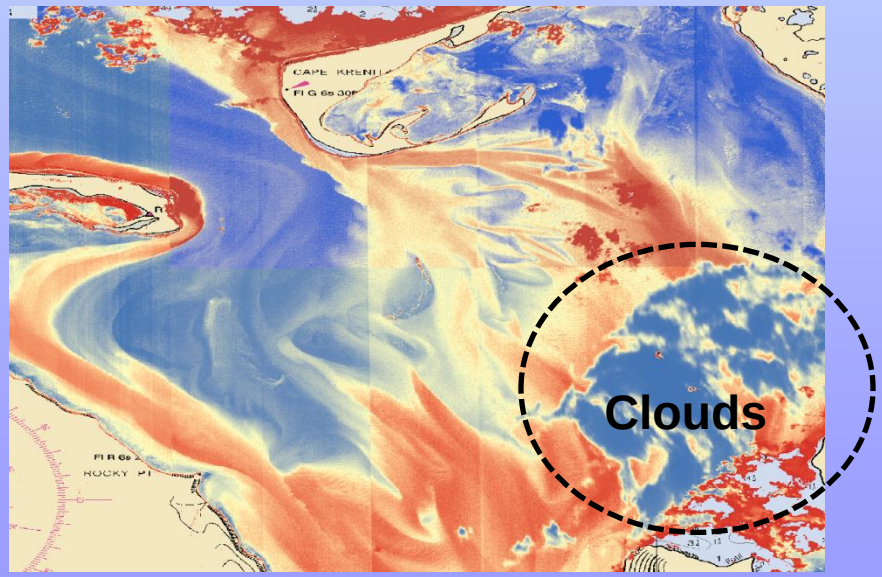


Applying the algorithm

Bechevin Bay, AK

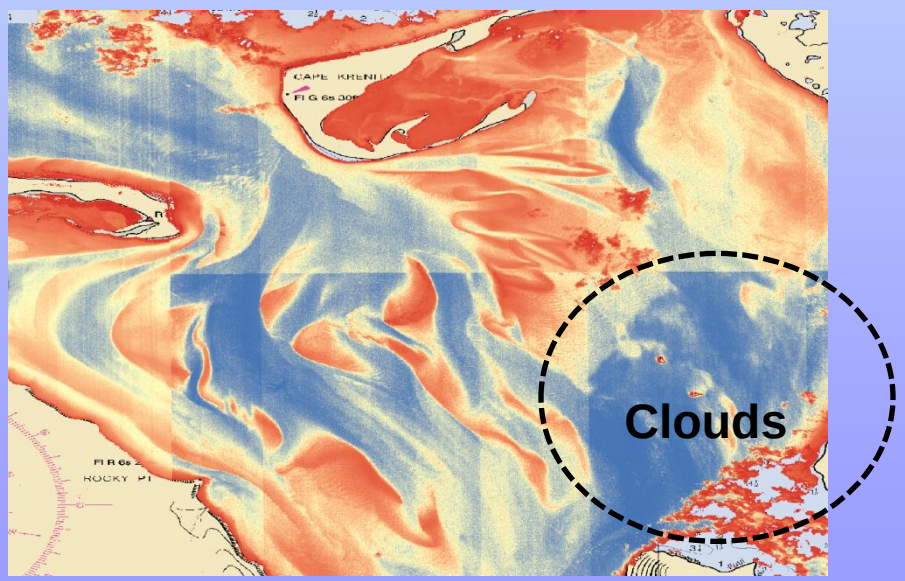
Satellite-derived bathymetry (WV-2) from March 2013 over Bechevin Bay, AK.

Blue/green algorithm



Direct measurement of the bathymetry

Green/red algorithm

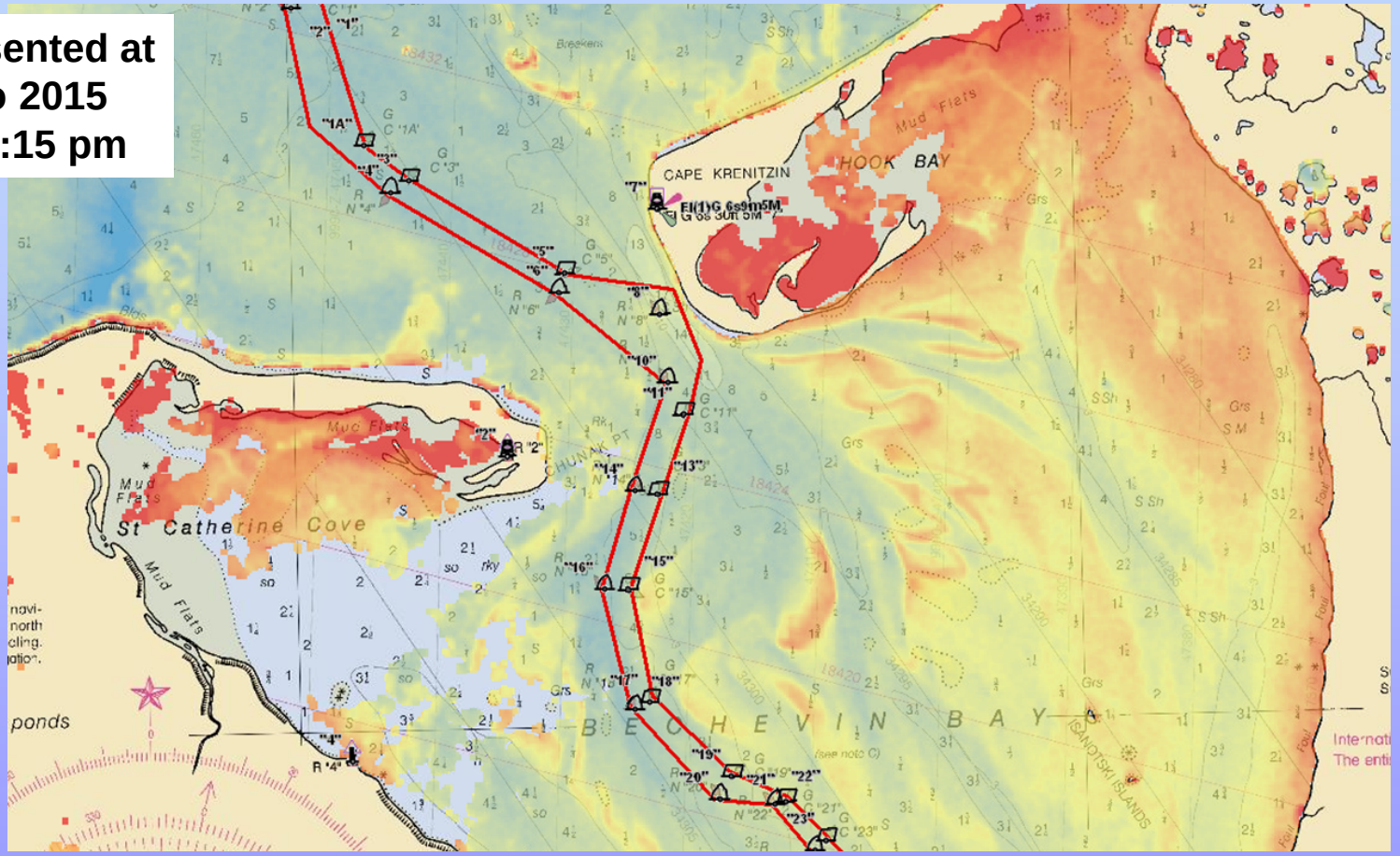


Mapping of the turbidity

Reconnaissance tool

Chart adequacy and survey planning

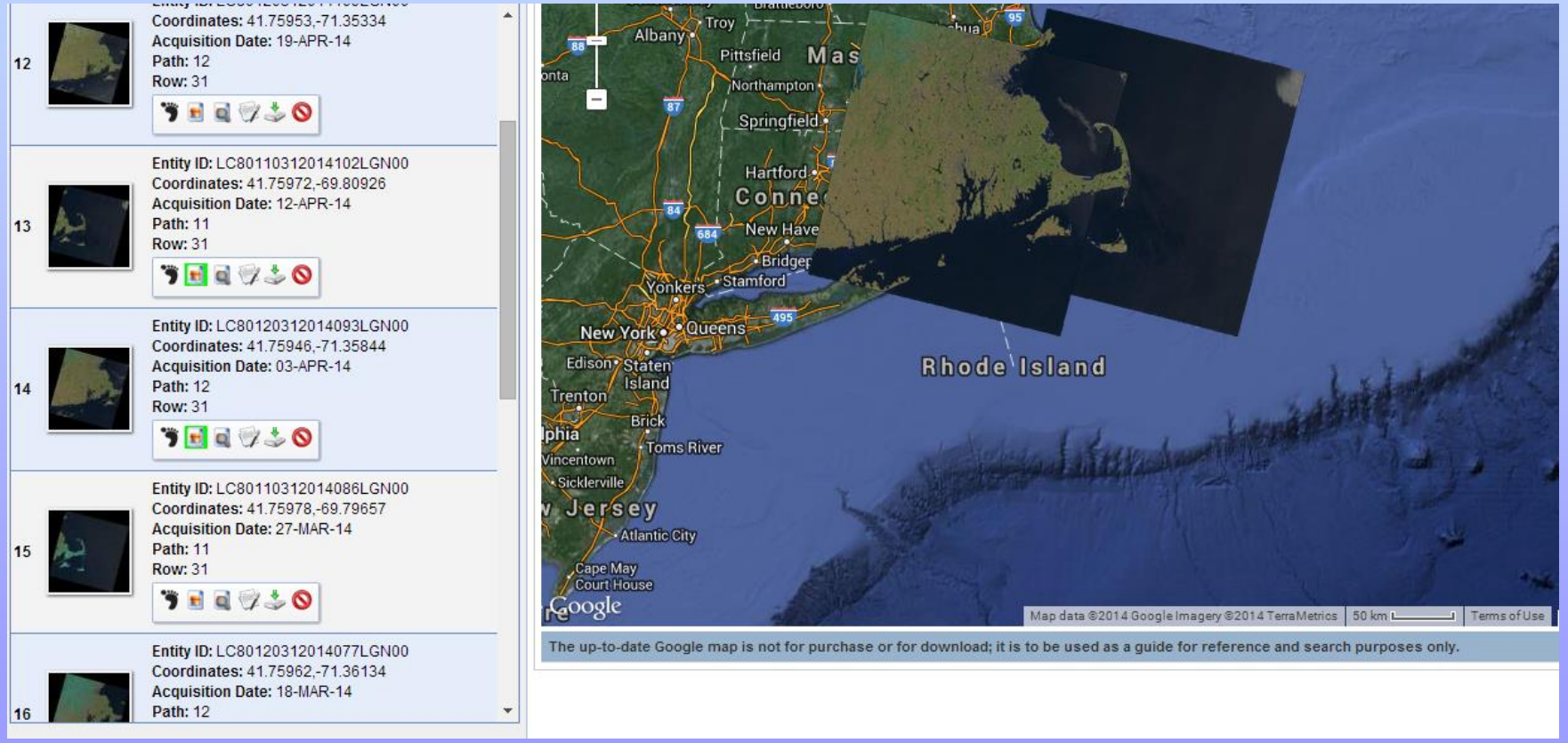
Will be presented at US Hydro 2015 Tuesday 2:15 pm



Satellite-derived bathymetry (Landsat 8) from March 2014 over Bechevin Bay, Alaska. The bathymetry is overlaid on a NOAA chart and the channel (red outline) from 2013 is depicted using USGC's aid-to-navigation (ATONs).

SDB multiple-image approach

What can be done with multiple images over the same area during a given period of time?



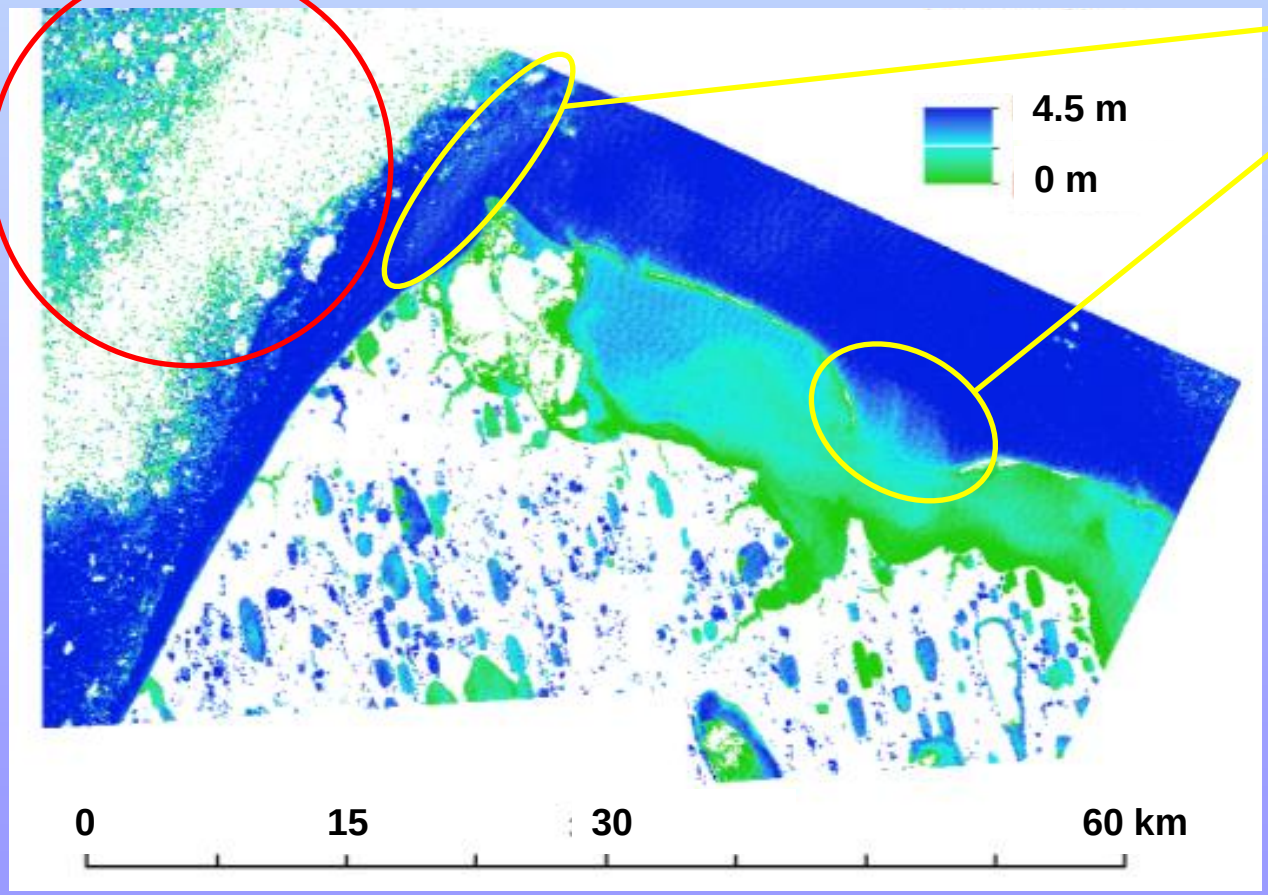
(EarthExplorer.USGS.gov)

Chart Adequacy

Arctic

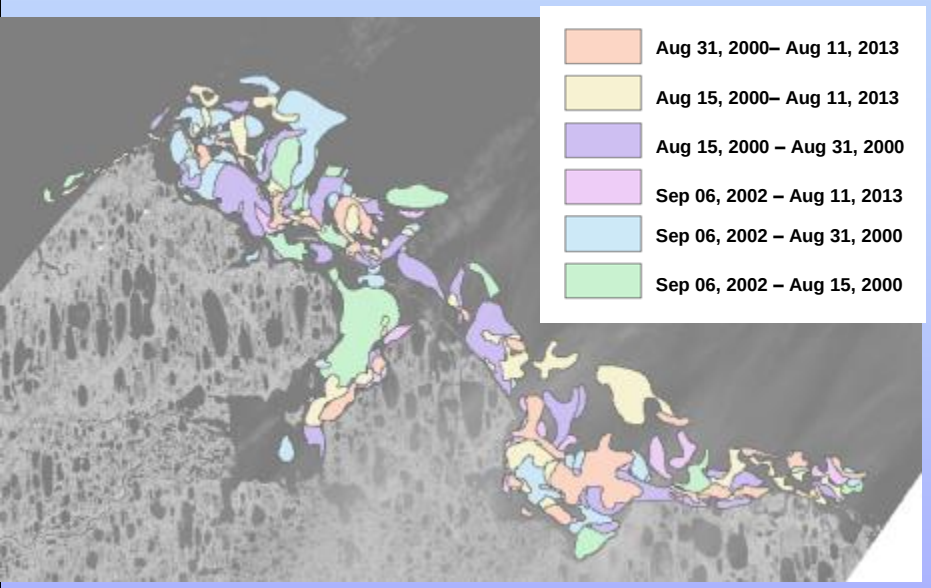
Single-image approach

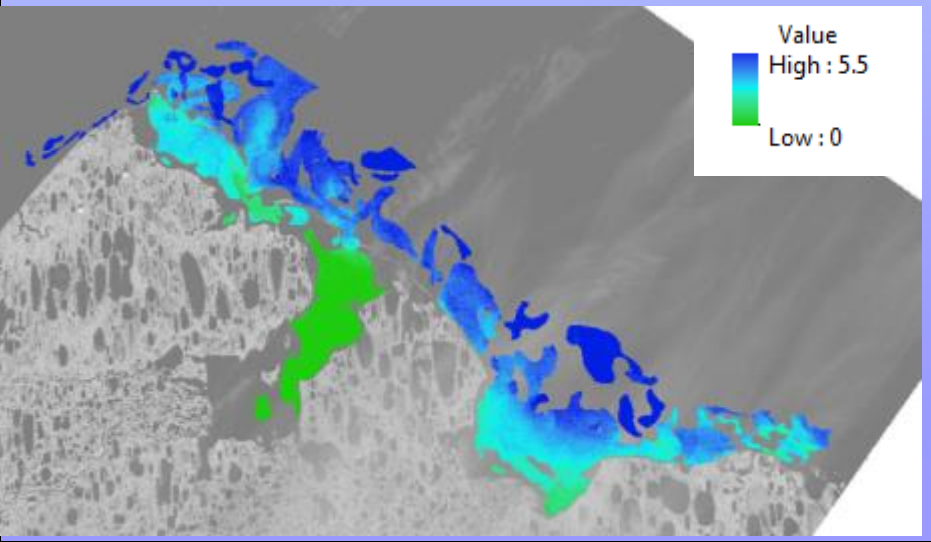
(Acquisition date : July 18, 2002)



Extinction depth: 4.5 m (15 ft)

Chart Adequacy
Arctic





Multiple-image procedure

…

(I'll be happy to explain the full procedure workflow offline).

…

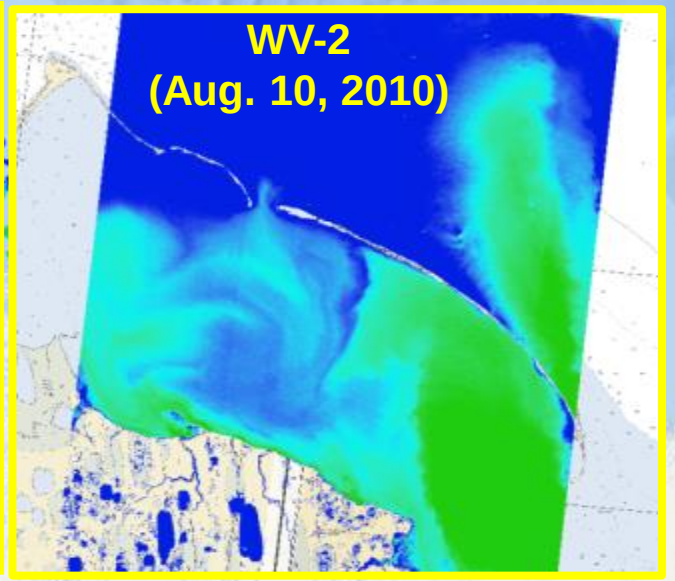
Six dataset were produced from the four available images (three pairs). All the dataset were merged into one dataset.

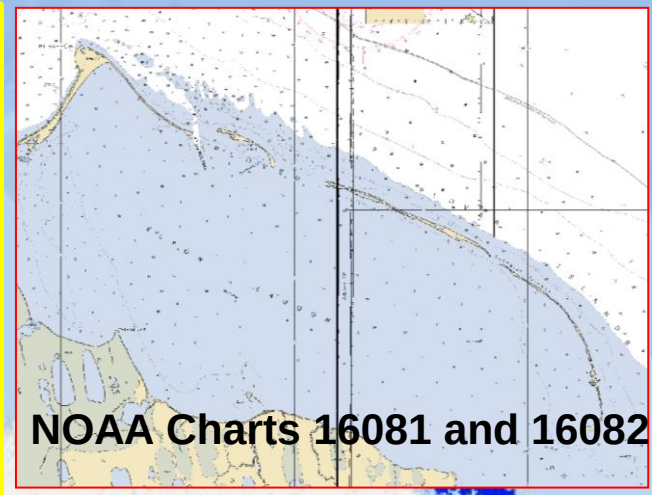
The data set was referenced to the chart datum.

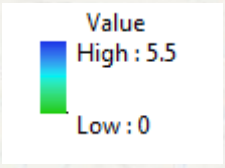
Chart Adequacy
Arctic

Final result

Presented at
CHC 2014



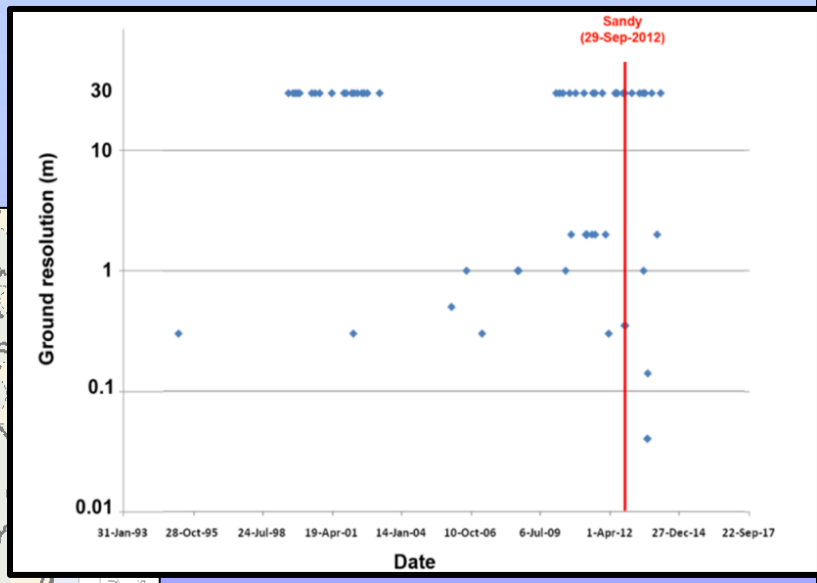


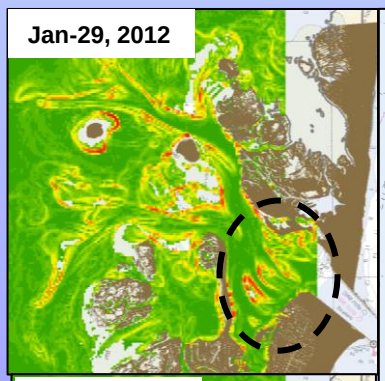


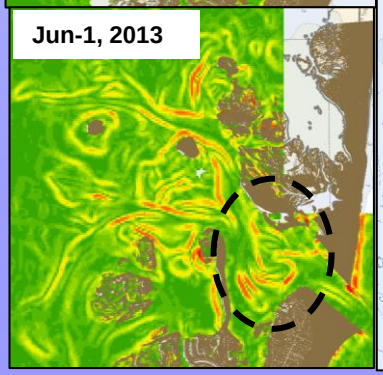
Bathymetry derived from Landsat 7 and Landsat 8 imagery over the Arctic north slope

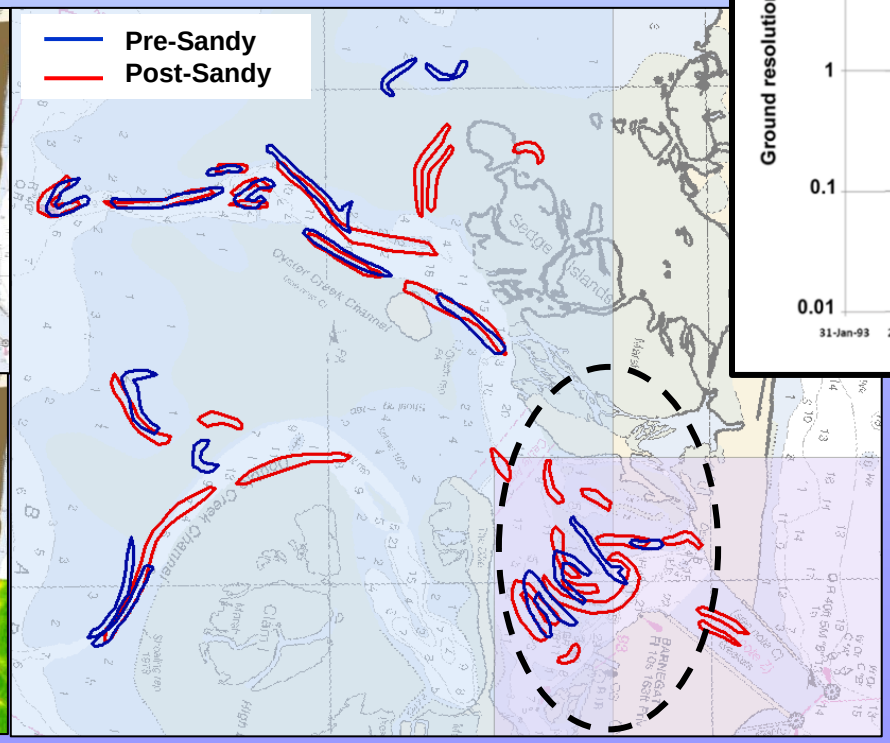
Emergency Response
Superstorm Sandy

Flood-tidal delta at Barnegat Inlet, looking south. An oblique aerial image acquired at low tide on Aug. 26, 1997 (Department of Environmental Protection, State of New Jersey 2000).







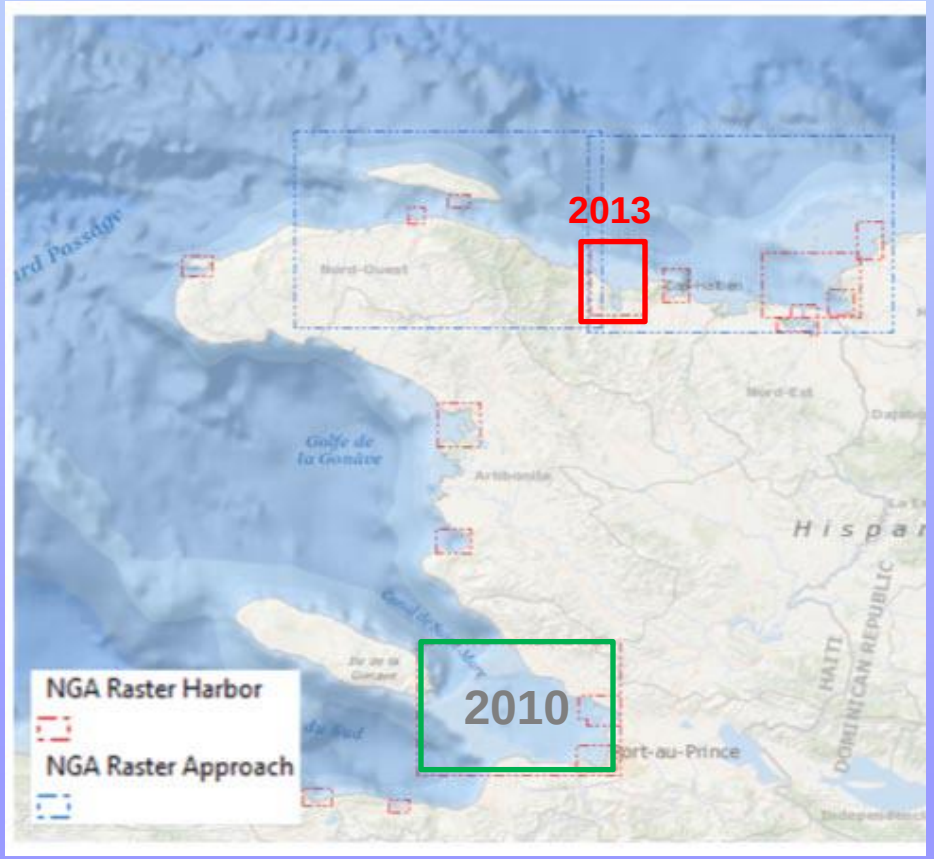


Will be presented at US Hydro 2015 Tuesday 2:00 pm

International collaboration

Haiti

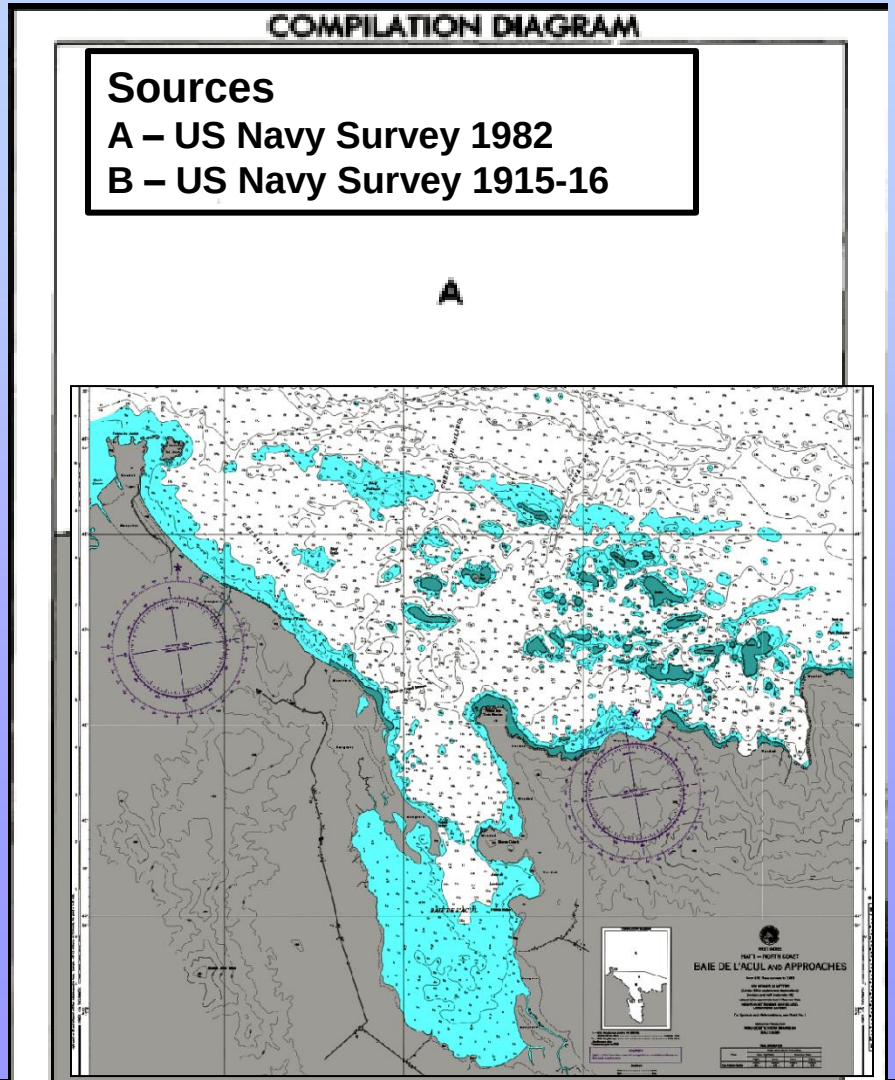
NOAA-NGA's 2013 efforts supporting the Service Maritime et de Navigation d'Haiti (SEMANAH).

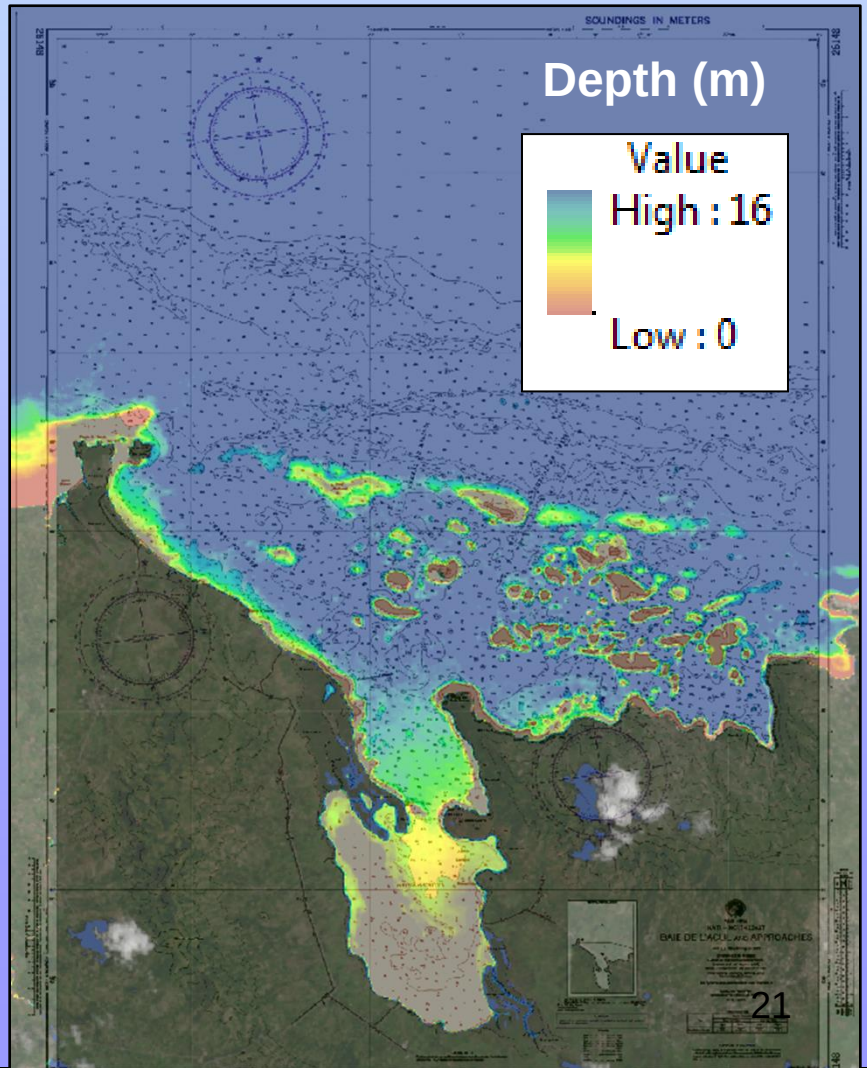


International collaboration

Haiti

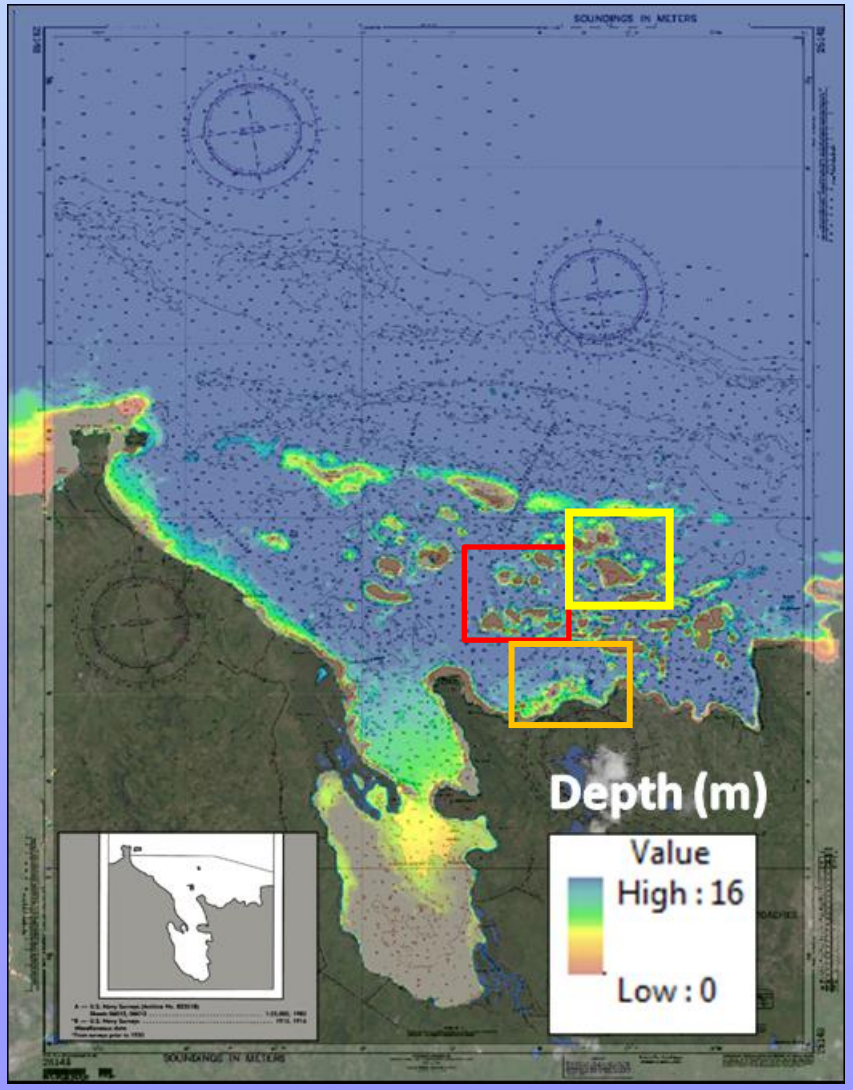
NGA Chart 26148, Baie de L'Acul and Approaches, 1:20,000



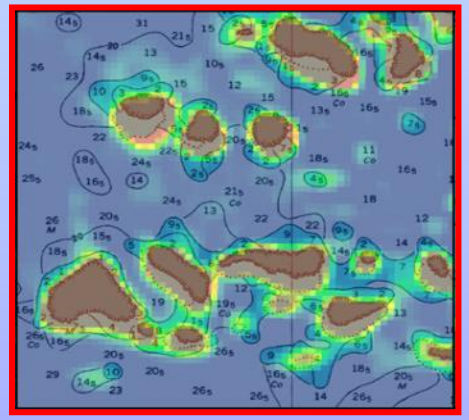


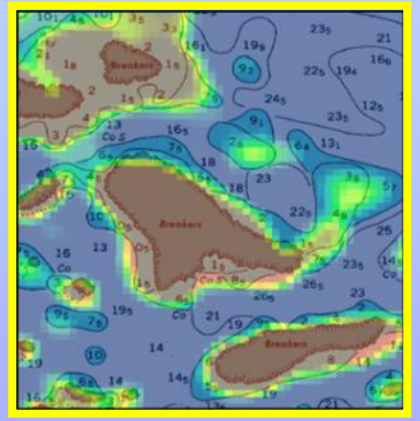
International collaboration

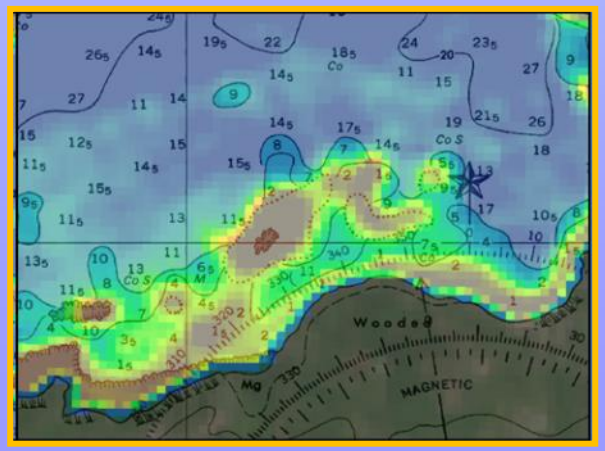
Haiti



Satellite derived bathymetry over NGA Chart (26148)
Baie de L'Acul and Approaches
(Scale:1:20,000)



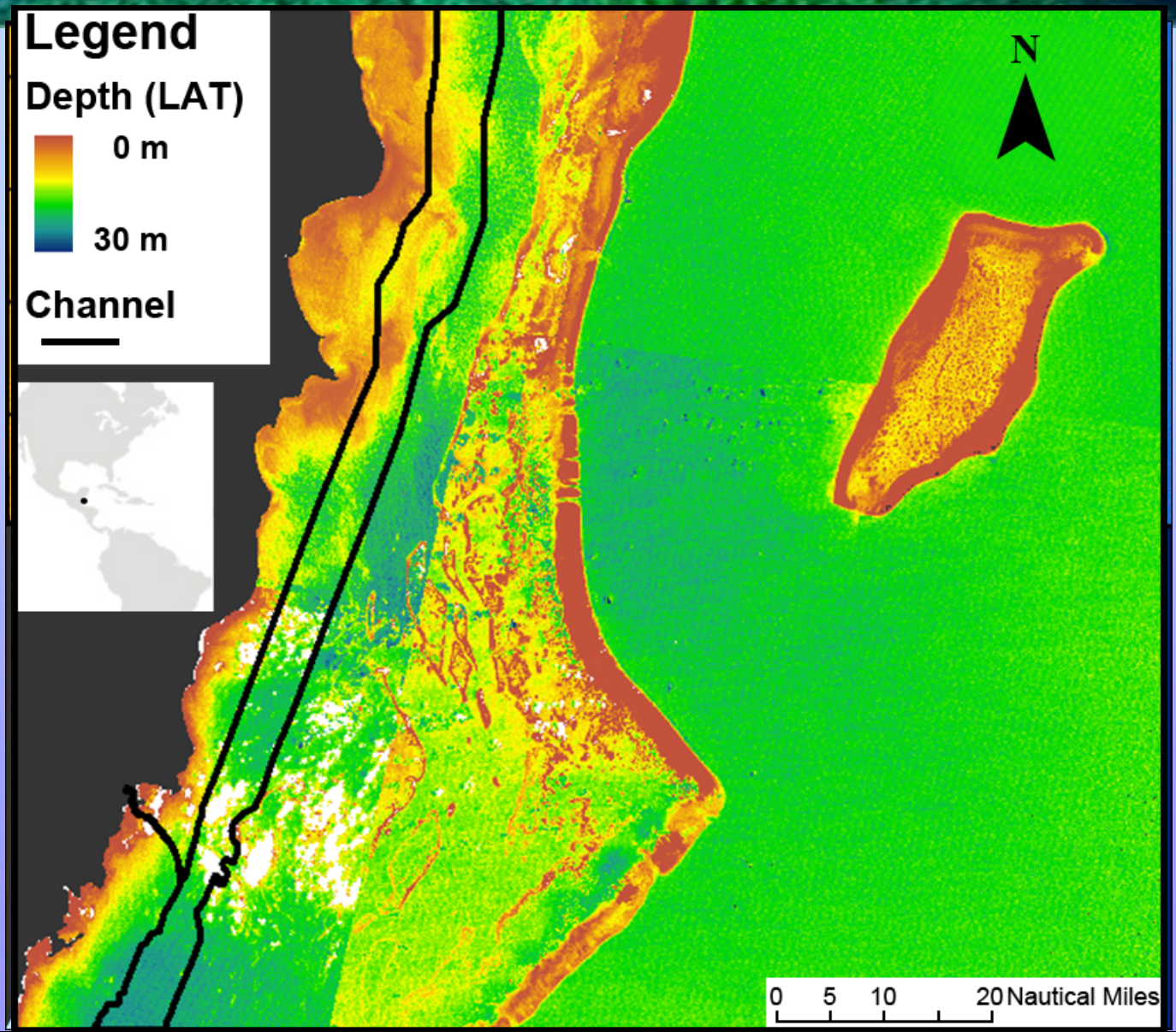




Landsat 8

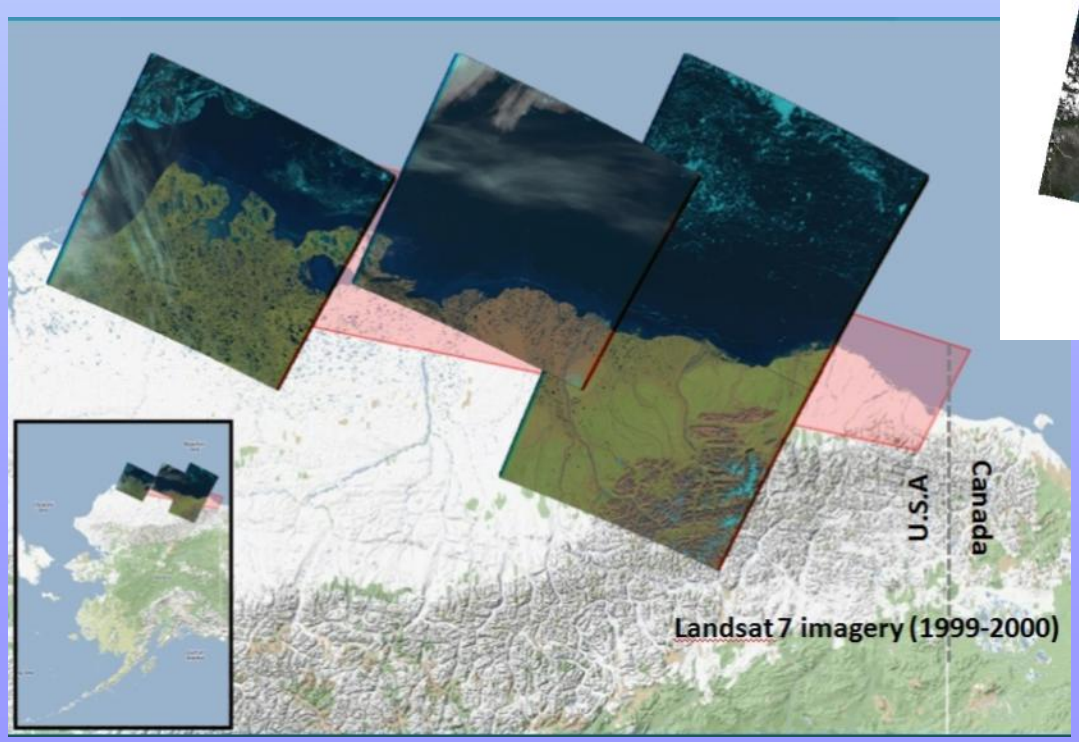
International collaboration

Big Creek, Belize



Discussion: Swath coverage

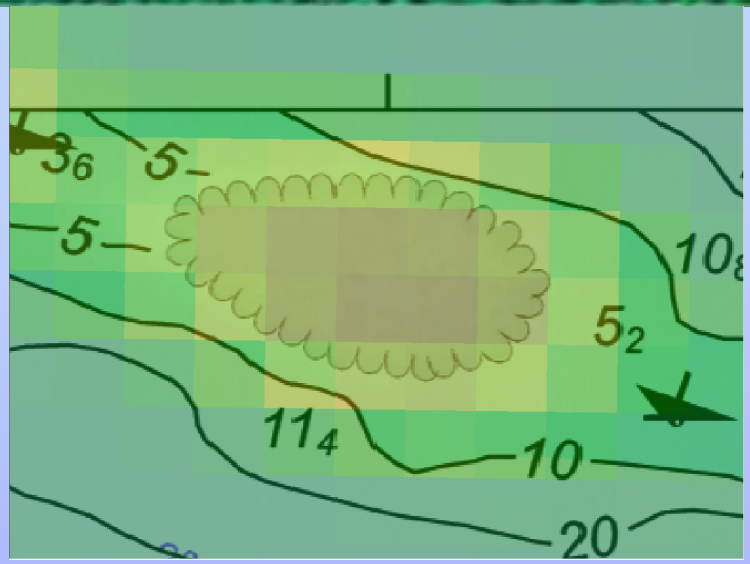
Four Landsat 7 images (RGB) covering most of the US Arctic North Slope.

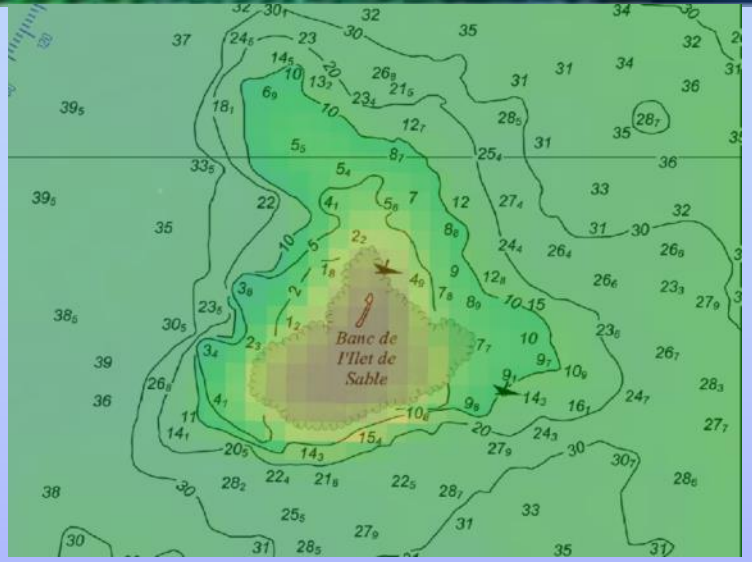


Landsat 8 versus WV-2 coverage over Port-au-Prince, Haiti. A WV-2 image (IR band) overlaid on NGS Chart 26184 (1:50,000). The NGA chart is overlaid on a Landsat 8 image (RGB image).

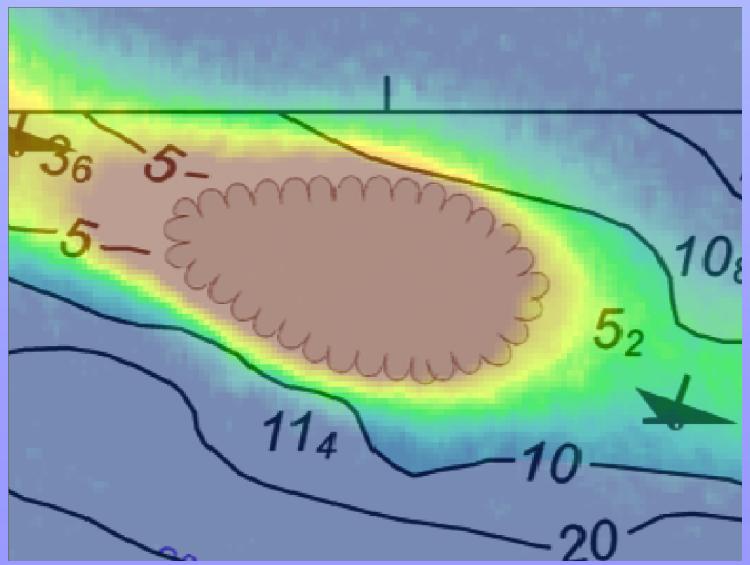
Discussion: Resolution

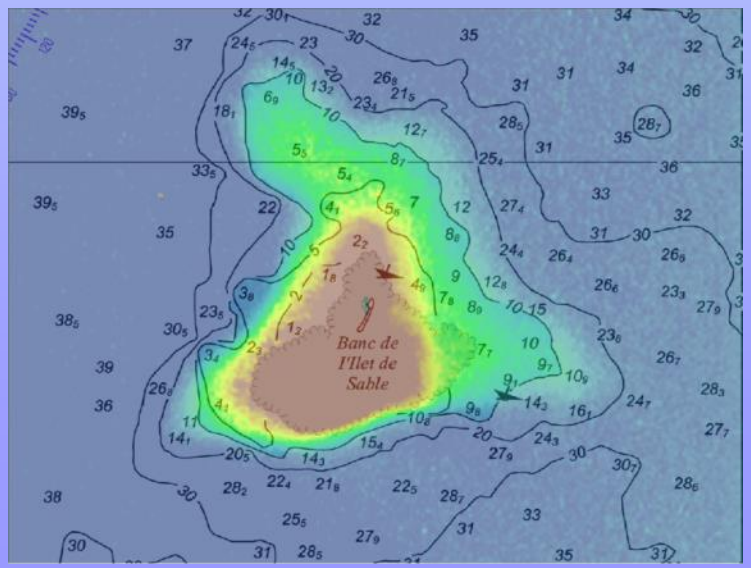
Landsat 8 (28.5 m)





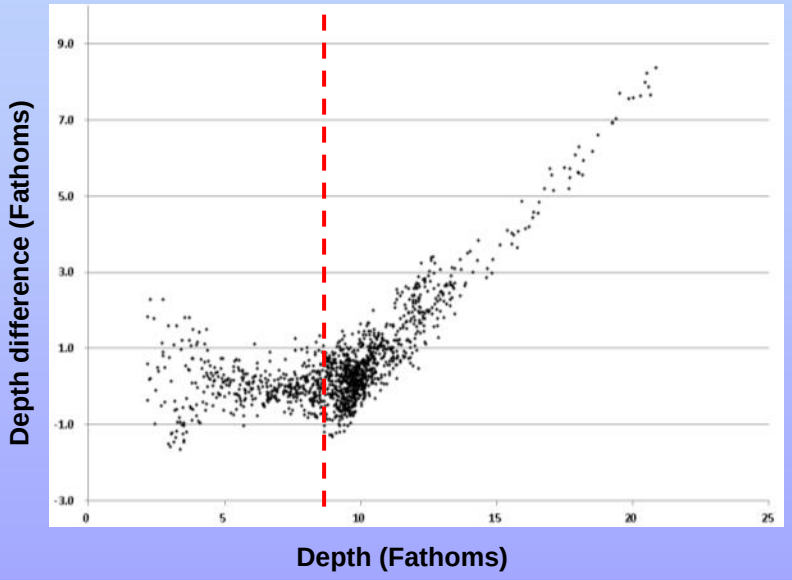
Worldview 2 (2 m)



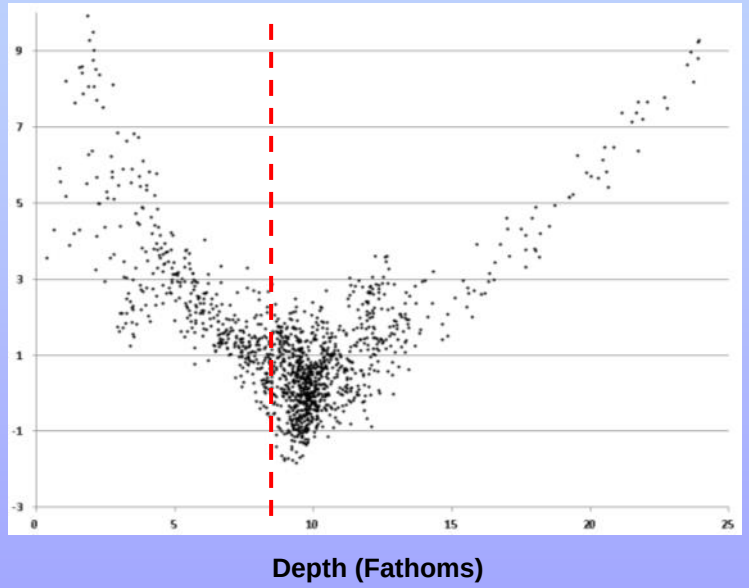


Discussion: reference sources

Elevation difference over Buck Island study site between satellite-derived bathymetry (Landsat 7) and the lidar reference bathymetry (LADS MK-II)

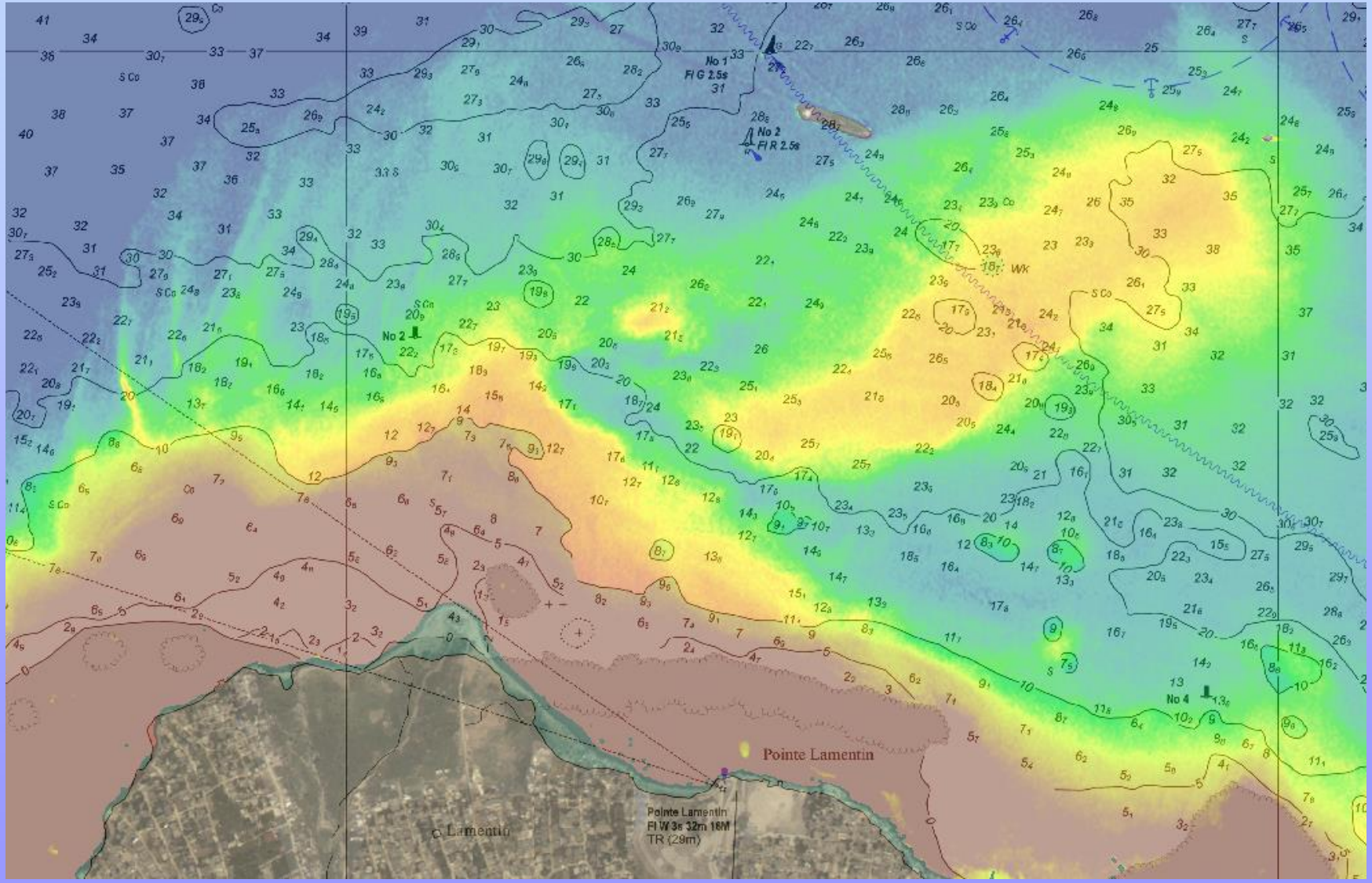


Referencing to chart datum using lidar



Referencing to chart datum using chart soundings

Discussion: Turbidity



Summary

- Landsat imagery is publically-available and free.
- Procedures for different hydrographic applications are being developed (some are already available).
- In addition to work conducted at NOAA the procedure can have a broader impact.

Thanks

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OCS/HSD

OCS/MCD

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NGS/RSD