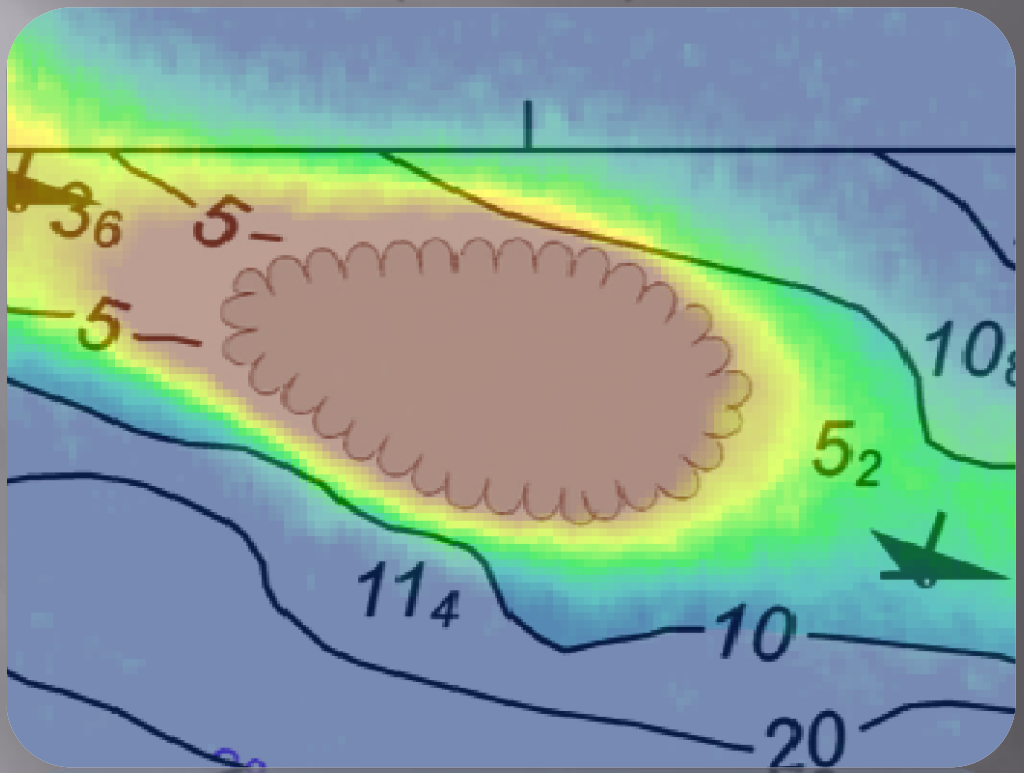
Satellite-derived bathymetry (SDB)



Prepared by Leland Snyder

14th MACHC – Sint Maarten

December 9-13, 2013

INTERNATIONAL HYDROGRAPHIC ORGANIZATION
MESO AMERICAN & CARIBBEAN SEA HYDROGRAPHIC COMMISSION

SATELLITE-DERIVED BATHYMETRY (SDB)

Outline:

- Introduction
- Technical overview
- Study and use case
- Future

Introduction

- ESRI International User Conference – July 2013
  - Overview meeting of SDB process
  - IHO, Academia, NOAA, UKHO, ESRI
  - University of New Hampshire, Center for Coastal and Ocean Mapping/Joint Hydrographic Center

- Presentation of work completed by Lt Cmdr Chuckwuma Azuike – Nigerian Navy
  - Canadian Hydro Conference 2012
  - Addressed C-55 using SDB

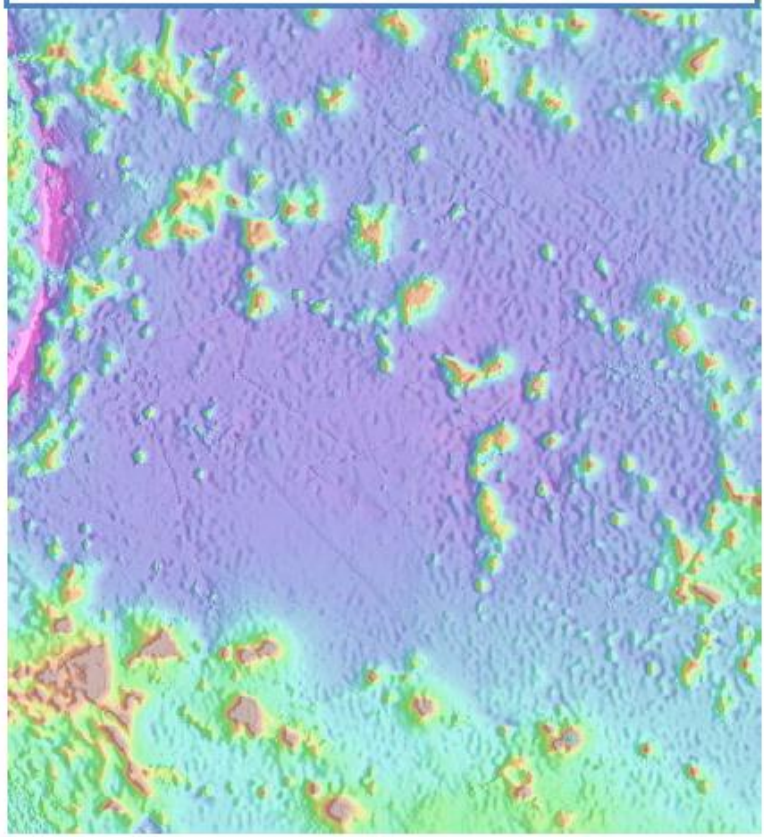
Introduction

- Further work completed by Ms. Eunice Nuerkie Tetteh – Ghana National Hydrographic Data Center

- GEBCO Cook Book

Release date	Change
November 2013	Chapter 11.0 updated: LANDSAT 8 Satellite-Derived Bathymetry (replaces previous version: LANDSAT 7 Satellite-Derived Bathymetry) Contributors: 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; C. Azuike, Nigerian Navy Hydrographic Office Lagos, Nigeria and Eunice N. Tetteh, Ghana National Oceanographic Data Centre, Ghana

The IHO-IOC GEBCO Cook Book



February 2013

IHO Publication B-11
IOC Manuals and Guides, 63

http://ibis.grdl.noaa.gov/SAT/GEBCO_Cookbook/index.php

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).

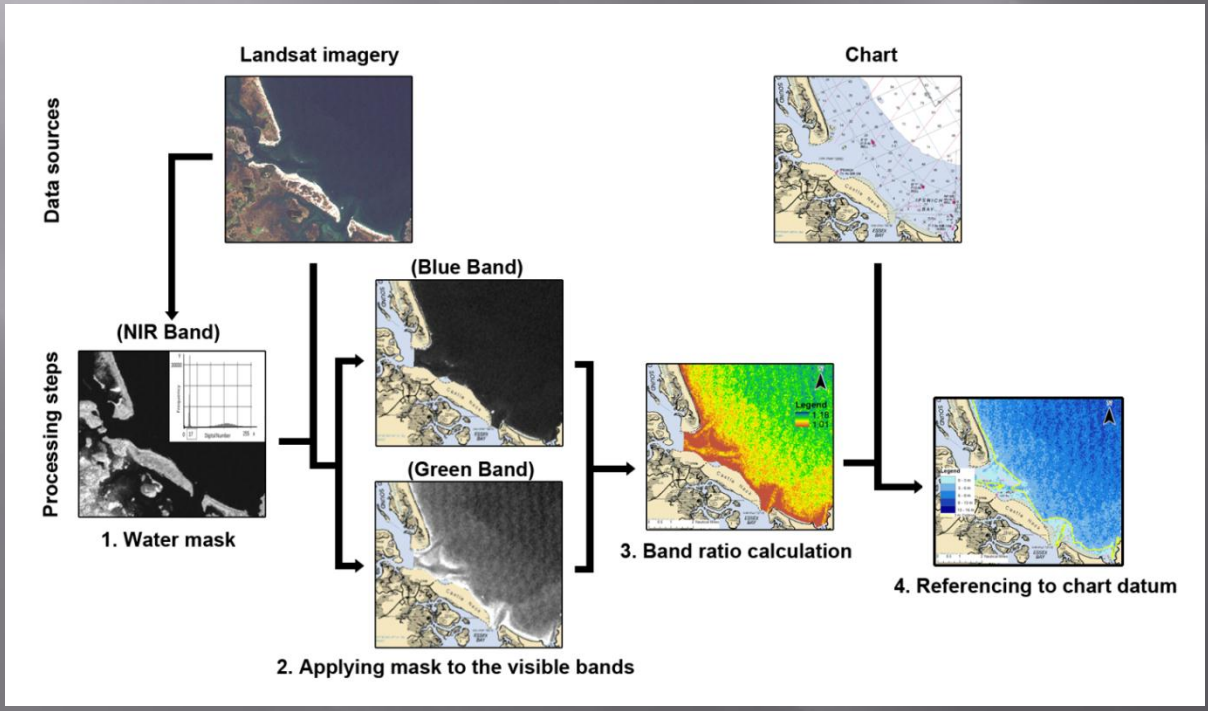
Pe'eri, S., C. Parrish, C. Azuike, L. Alexander and A. Armstrong, 2013. Satellite Remote Sensing as Reconnaissance Tool for Assessing Nautical Chart Adequacy and Completeness, *Marine Geodesy* (submitted).

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.

SDB: Overview

Approach taken:

- Optimization (*utilized by UKHO, SHOM, NOAA, and NGA*)
- Reconnaissance Evaluation of Chart Adequacy
- M_QUAL/CATZOC



NOAA/NOS/OCS/MCD

Stumpf et al. 2003

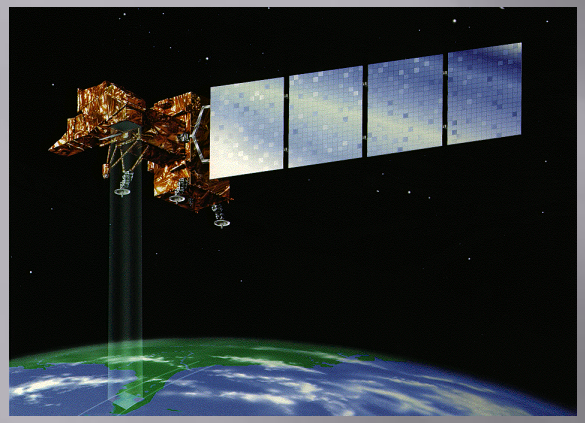
$$Z = m_0 \cdot \frac{\ln(L_{obs}(\lambda_i))}{\ln(L_{obs}(\lambda_j))} - m_1$$

$L_{obs}(\lambda_i)$, $L_{obs}(\lambda_j)$-radiance values

m_o- gain

m_1- offset

SDB: Available resources



Landsat 7

Launch Date: 4/1999

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

Landsat 8 (LDCM)

Launch Date: 2/2013

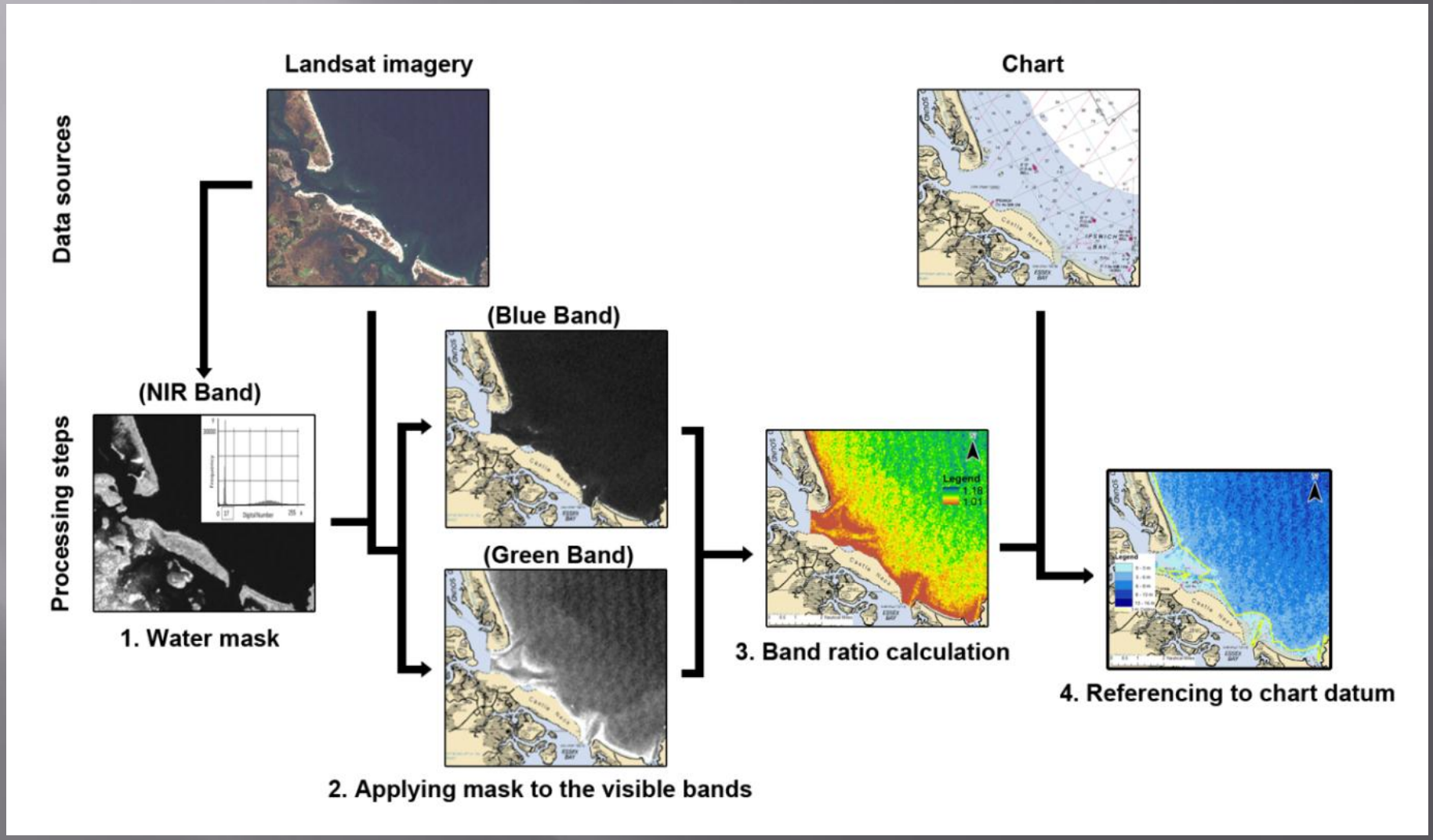
WorldView2

Launch Date: 10/2009

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

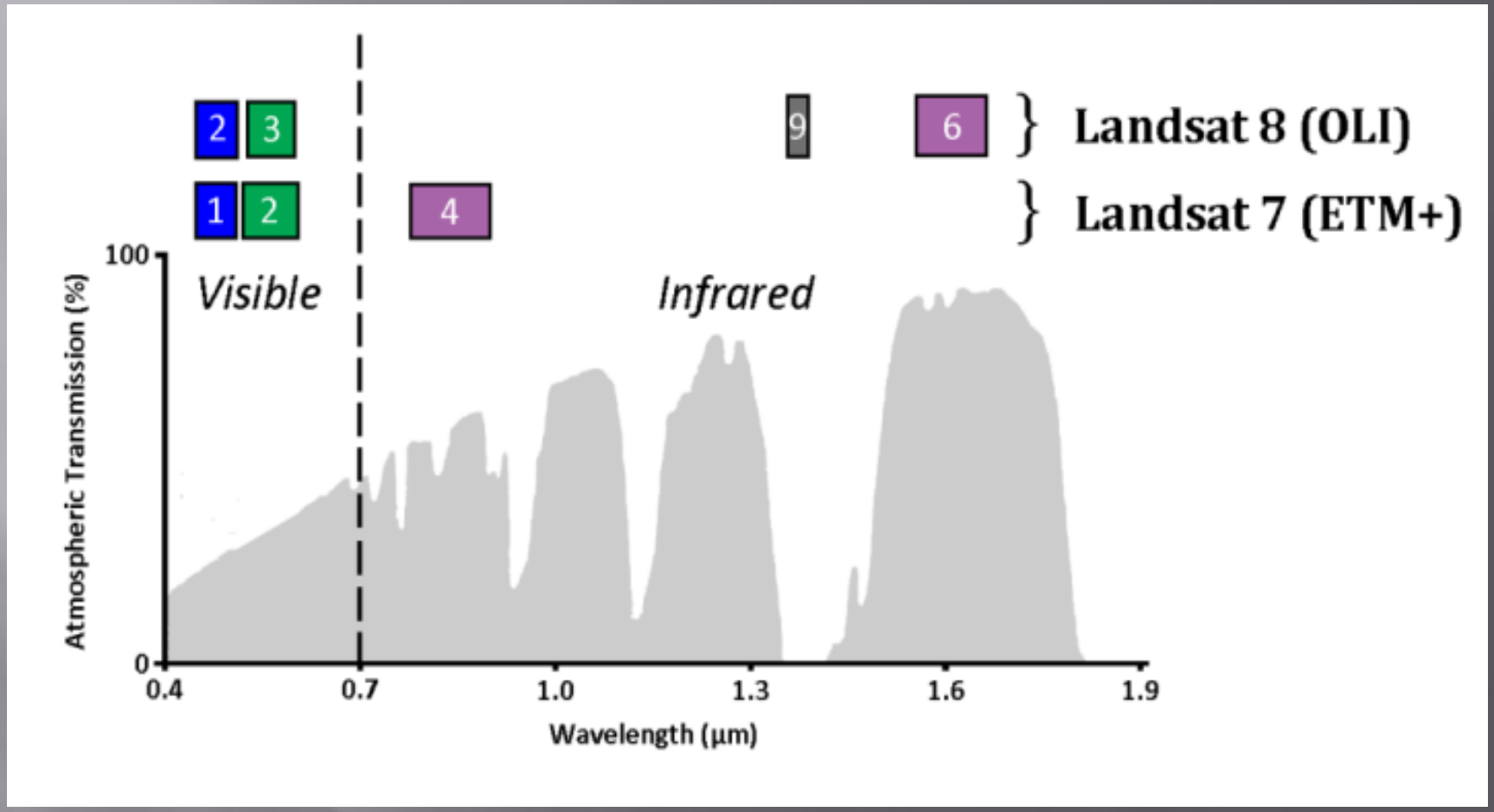
(Images from landsat.gsfc.nasa.gov and www.digitalglobe.com)

The procedure



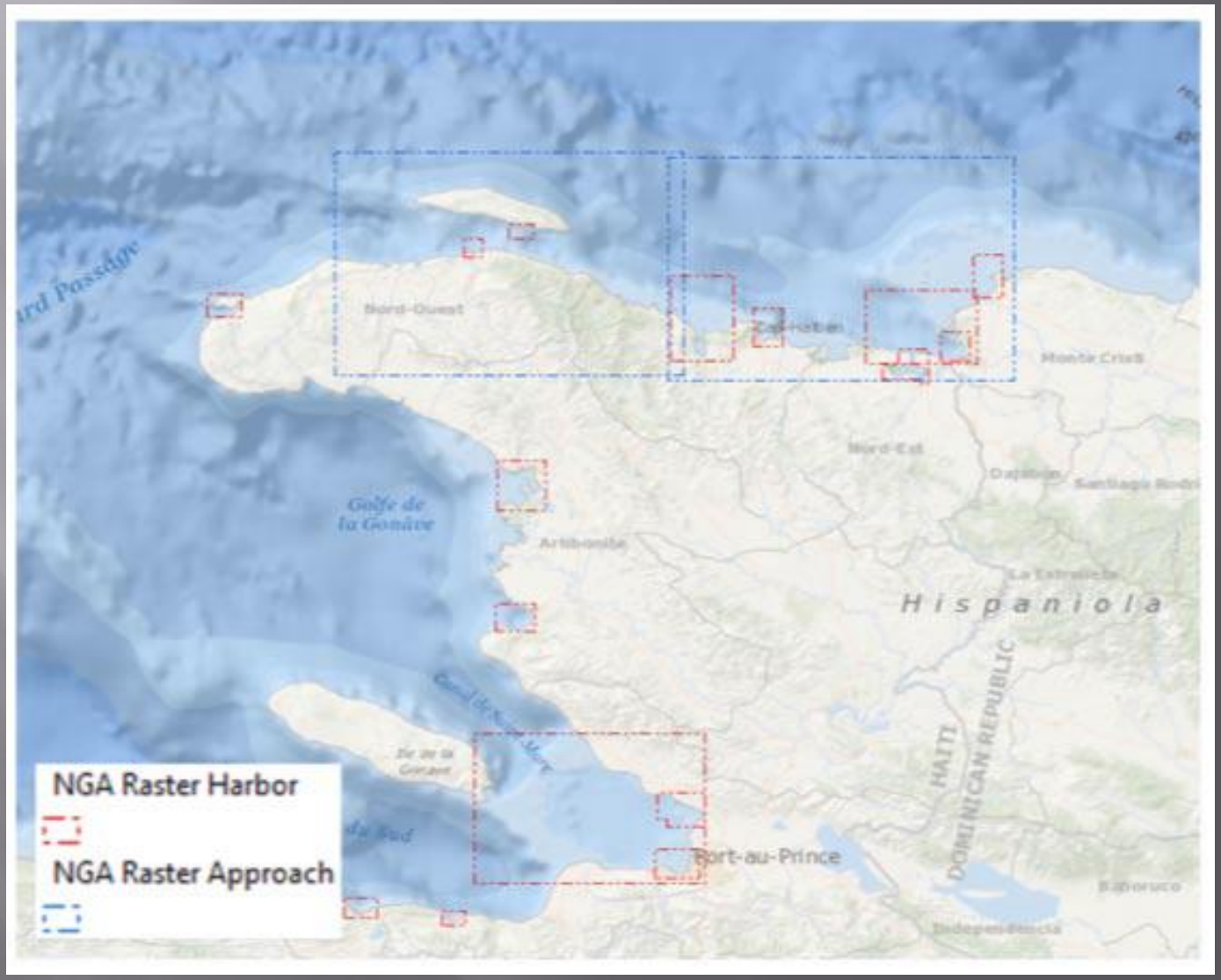
The procedure

- Pre-processing
- Water separation
- Spatial filtering
- Glint/cloud correction
- Applying the bathymetry algorithm
- Identifying the extinction depth
- Vertical referencing

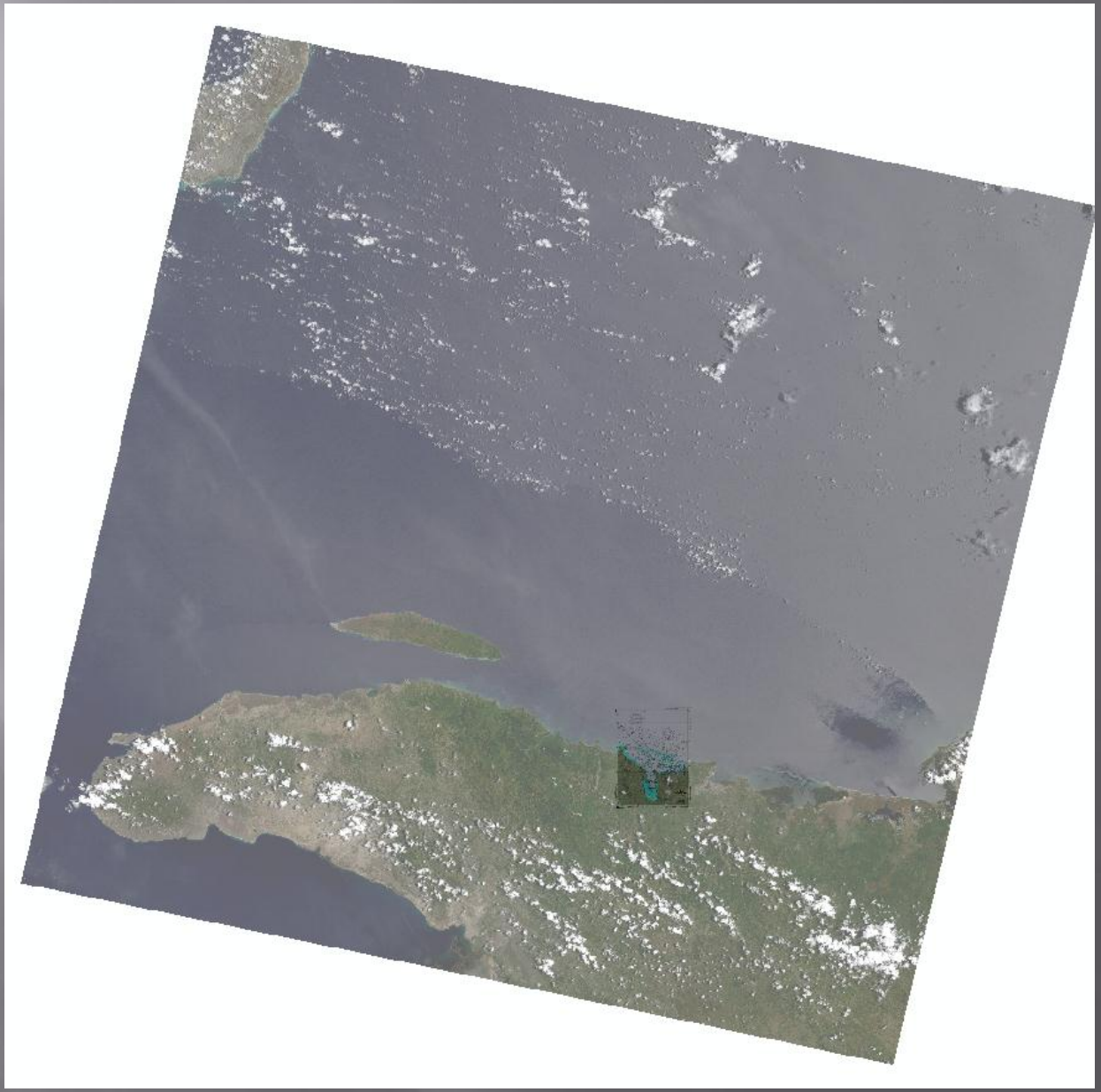


Bands of Landsat 7 and 8 imagery used in the SDB procedure.

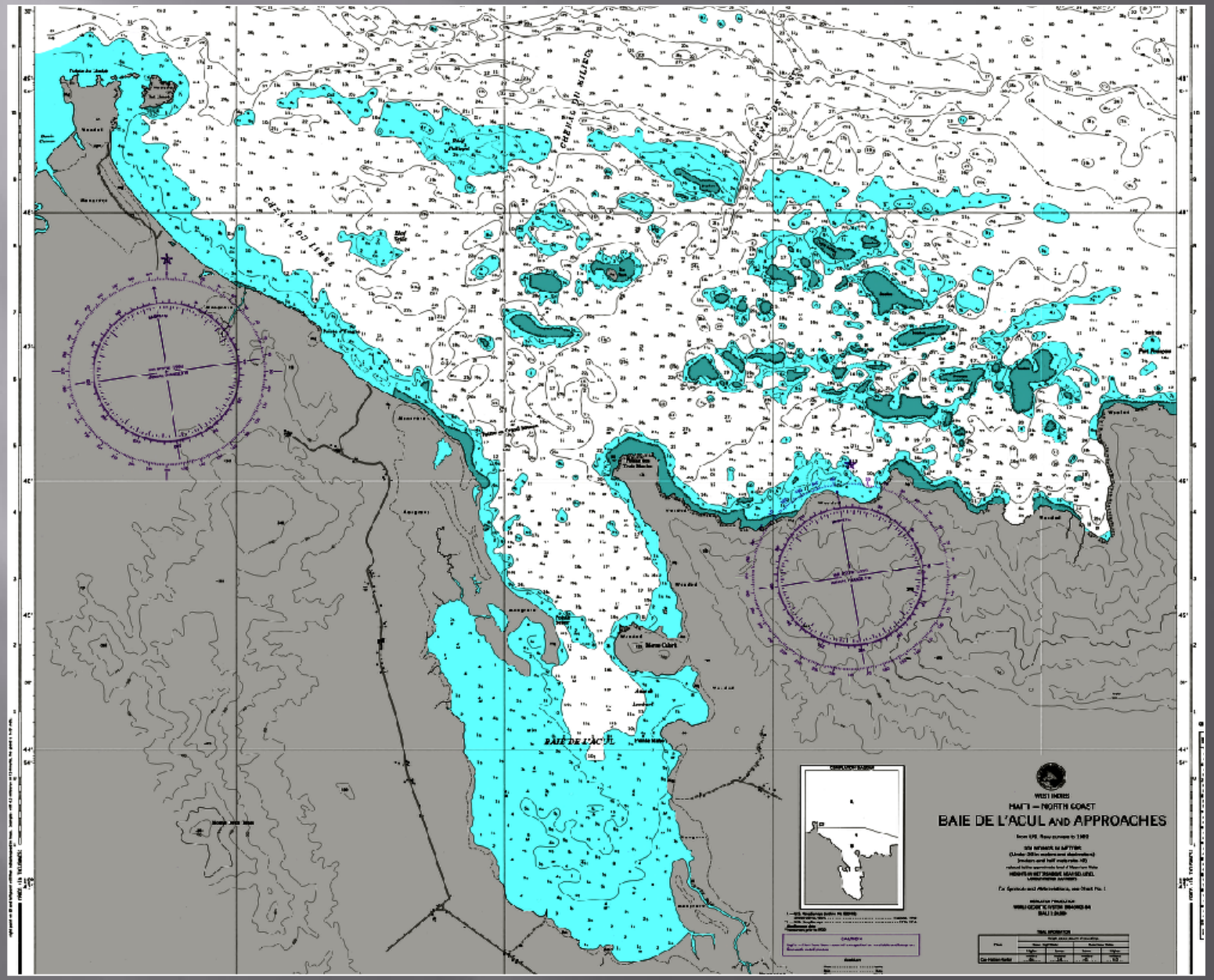
Study Area - Haiti

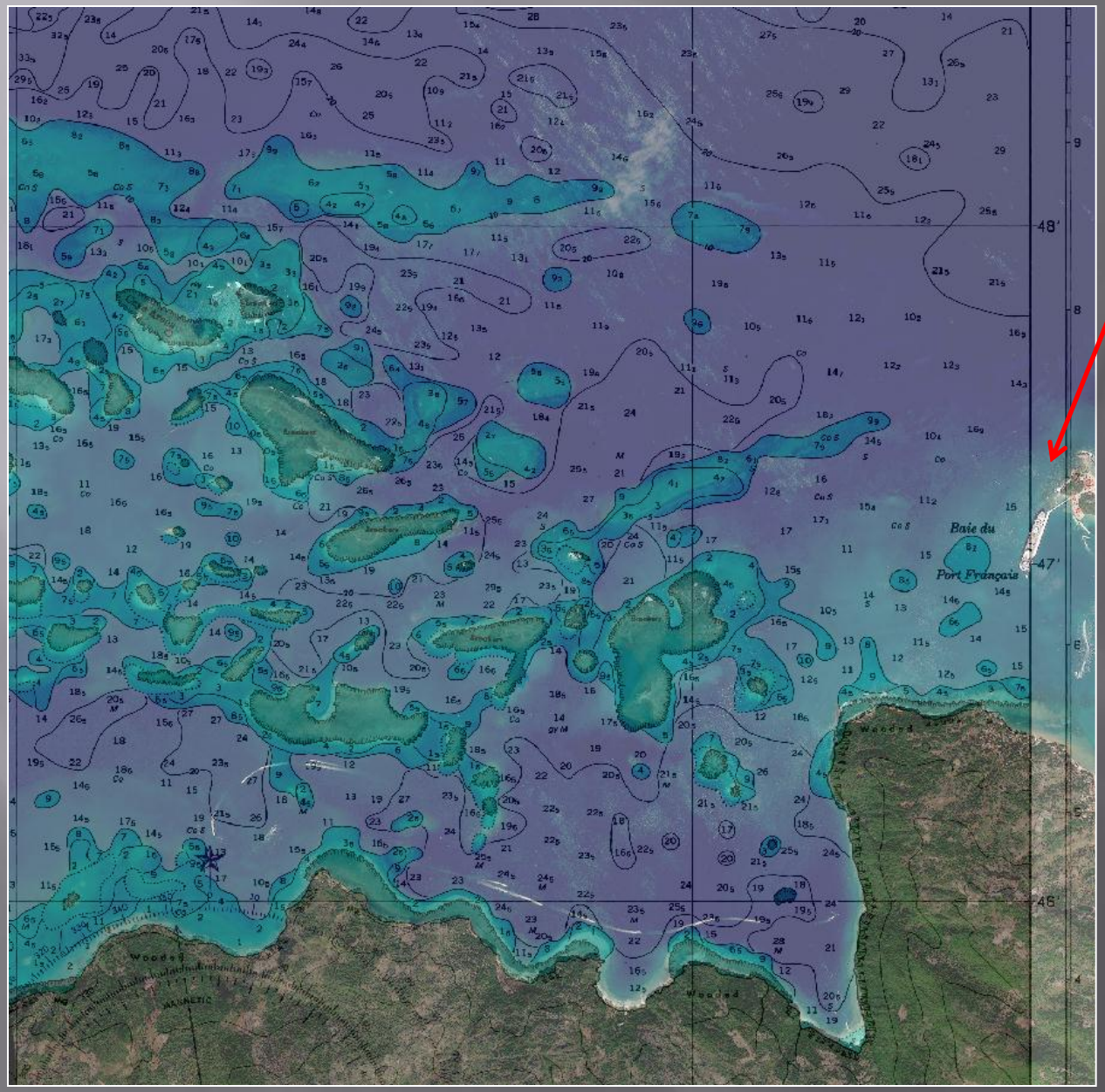


Landsat 8, Northern Coast Haiti



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



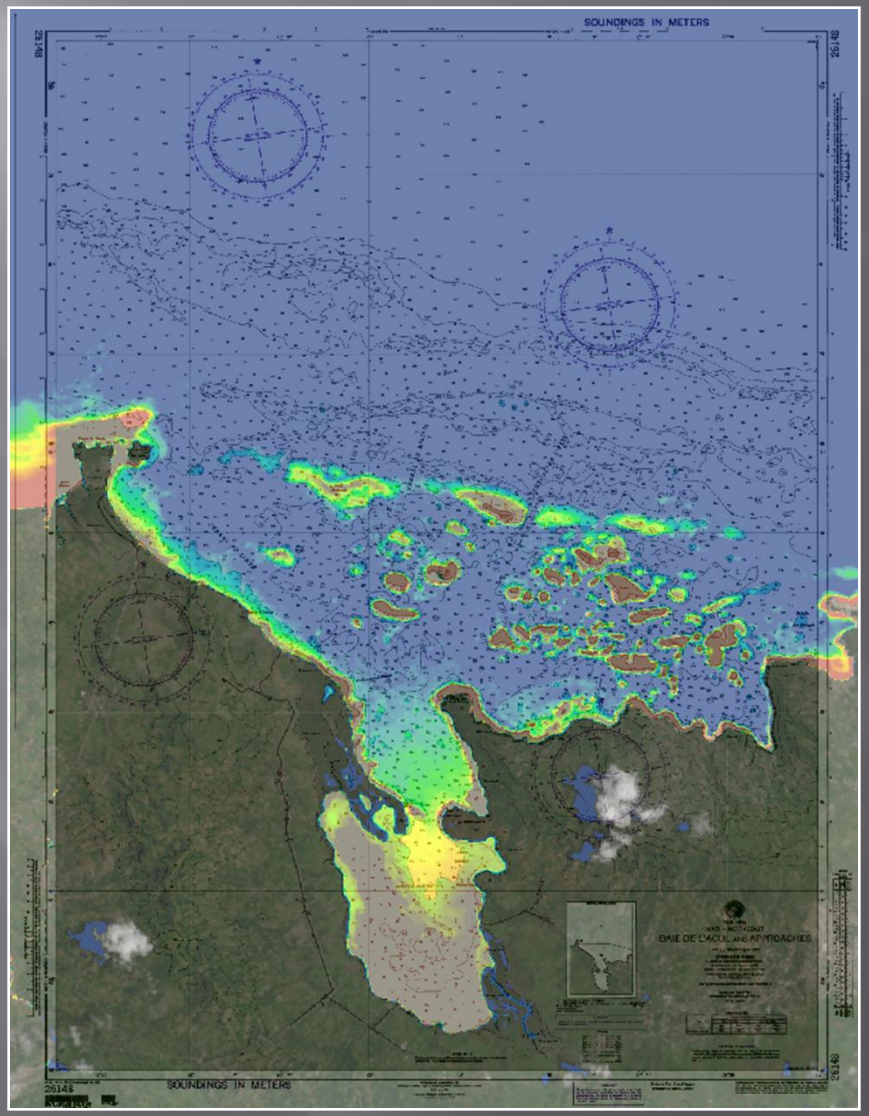


Labadee, Haiti
Royal Caribbean

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

Depth (m)

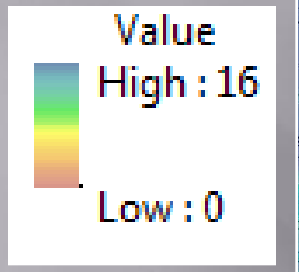
Value
High : 16
Low : 0

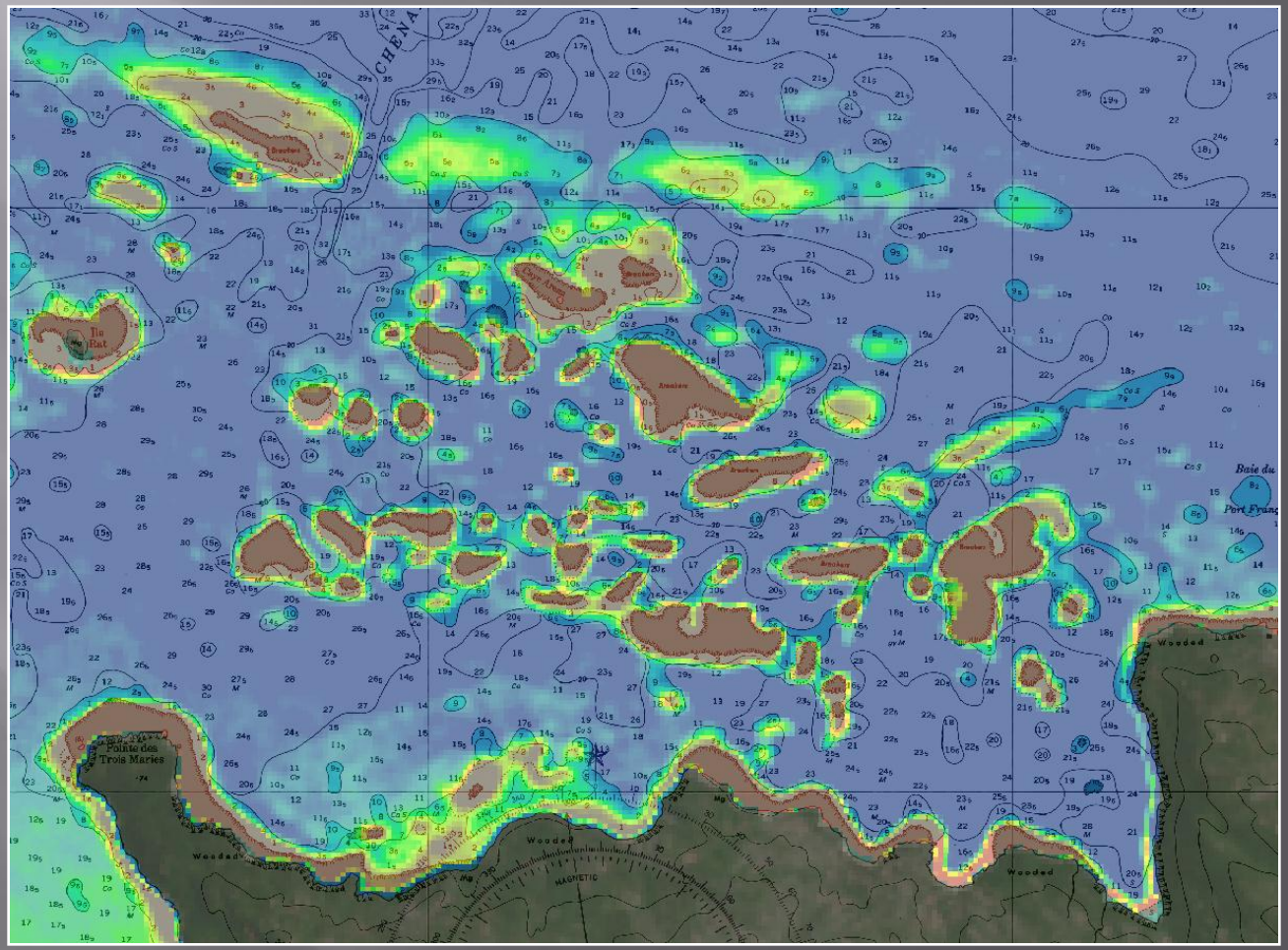


Landsat 8

Results

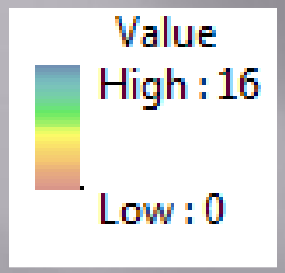
Depth (m)





Landsat 8

Depth (m)


Value
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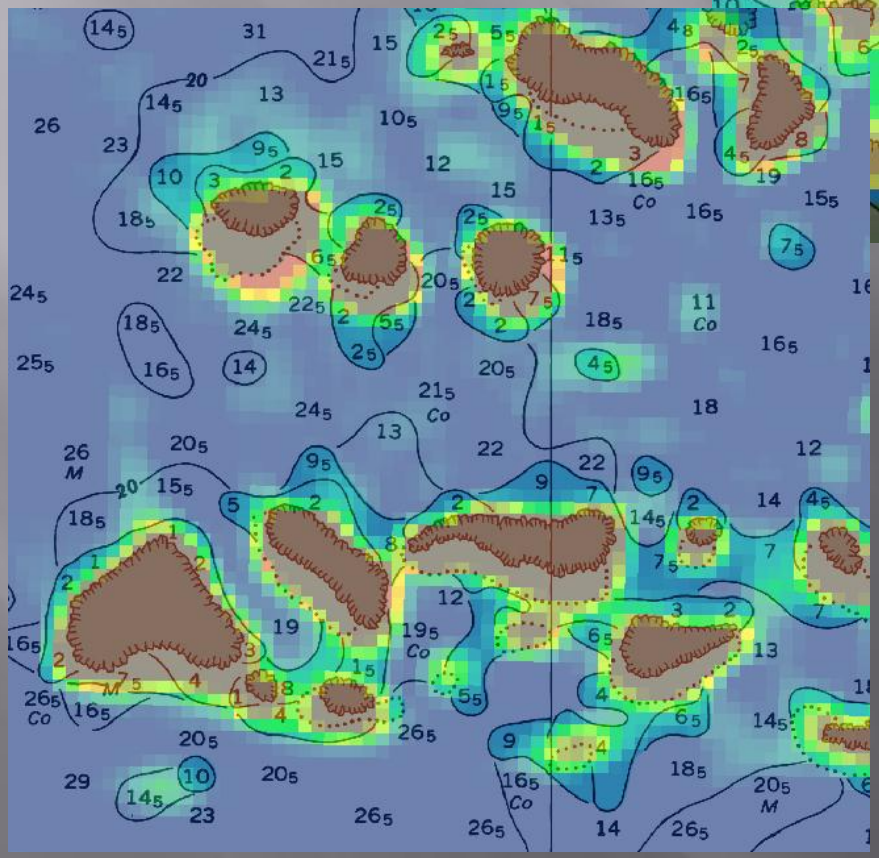
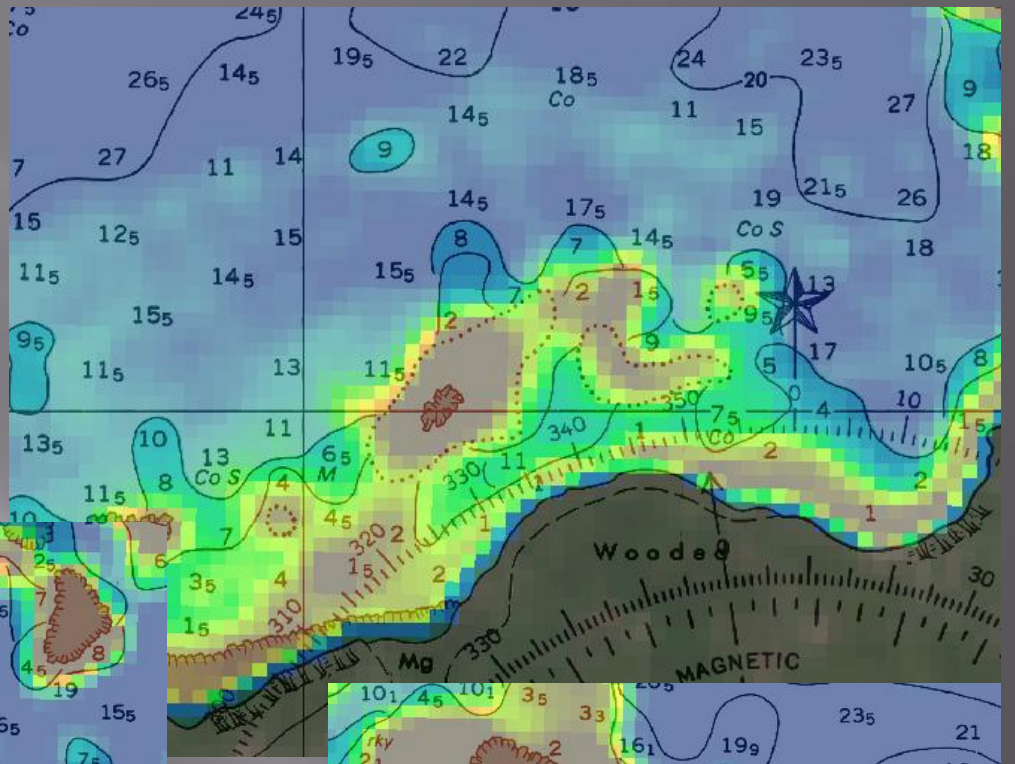
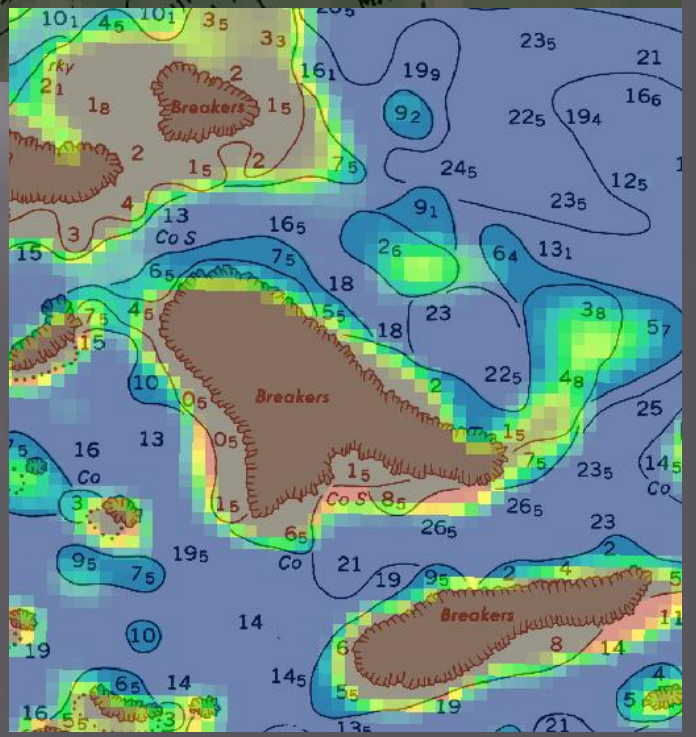
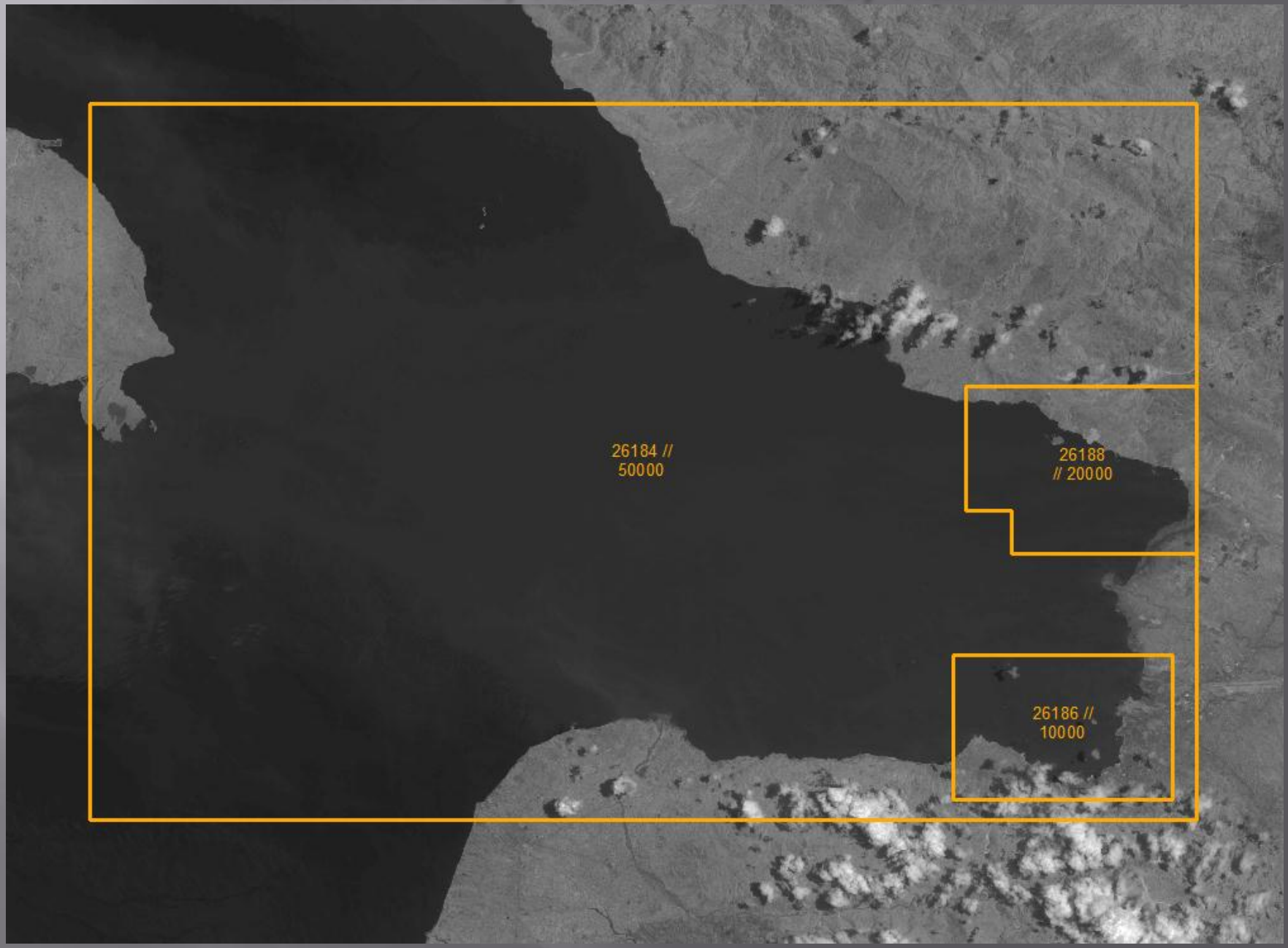
Low : 0



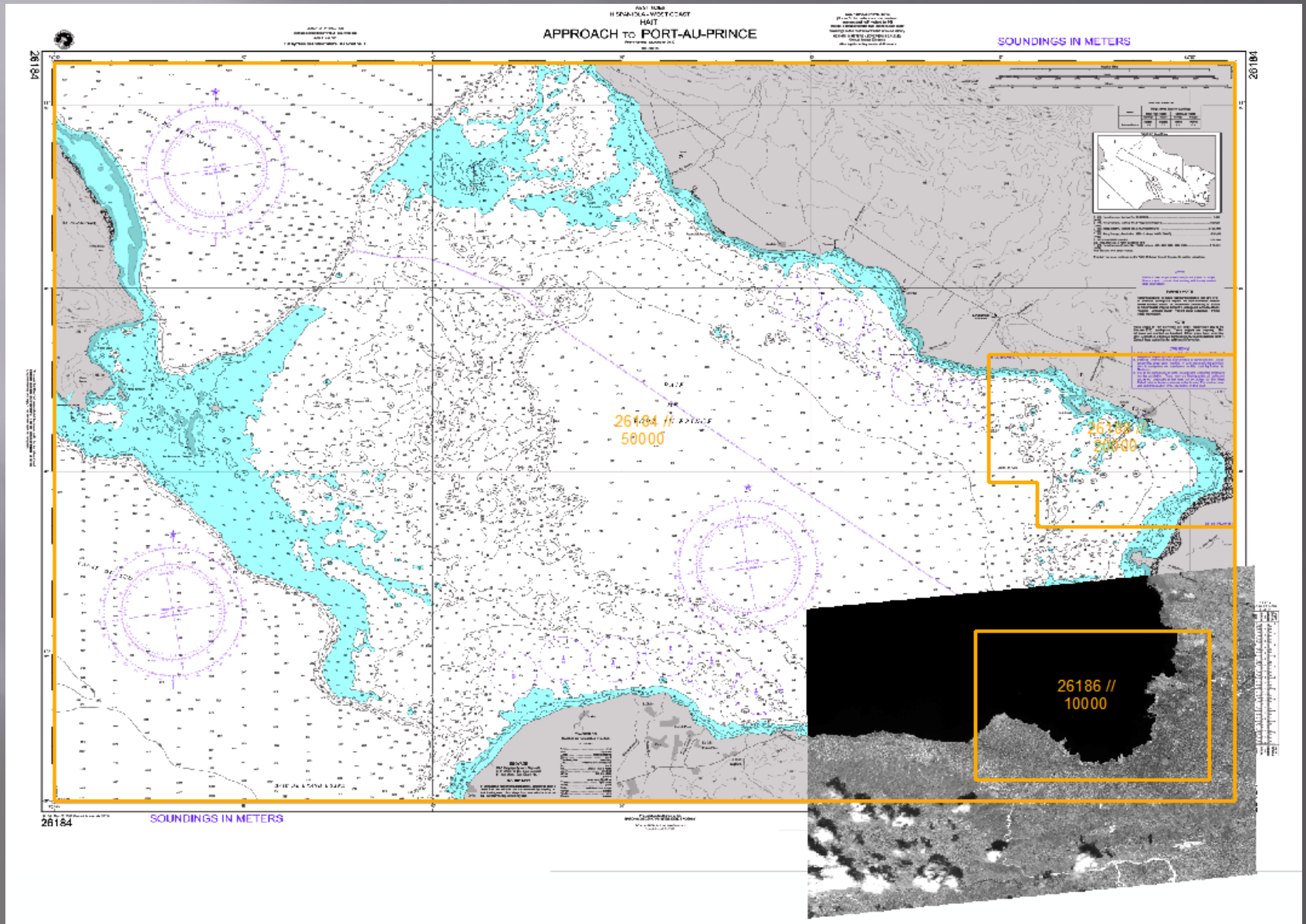

Wooded
MAGNETIC


Breakers
Breakers
Breakers

Landsat 8, Port-au-Prince, Haiti

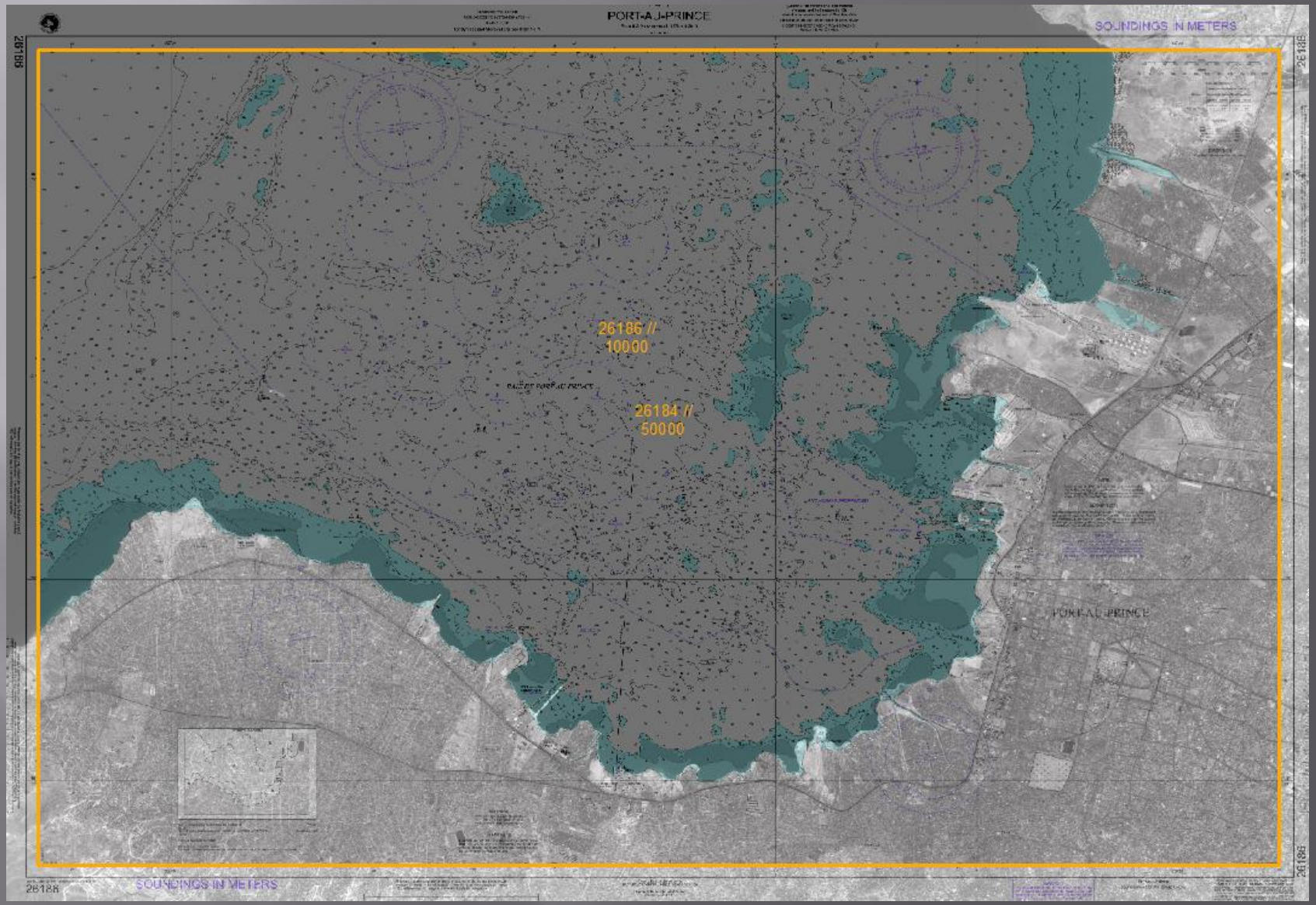


Worldview 2
Small Scale Port-au-Prince
1:50,000



Stacked Worldview 2 and Landsat 8
Small Scale Port-au-Prince
1:50,000

Worldview 2
Large Scale Port-au-Prince
1:10,000



26186, 1:10,000
Port-au-Prince

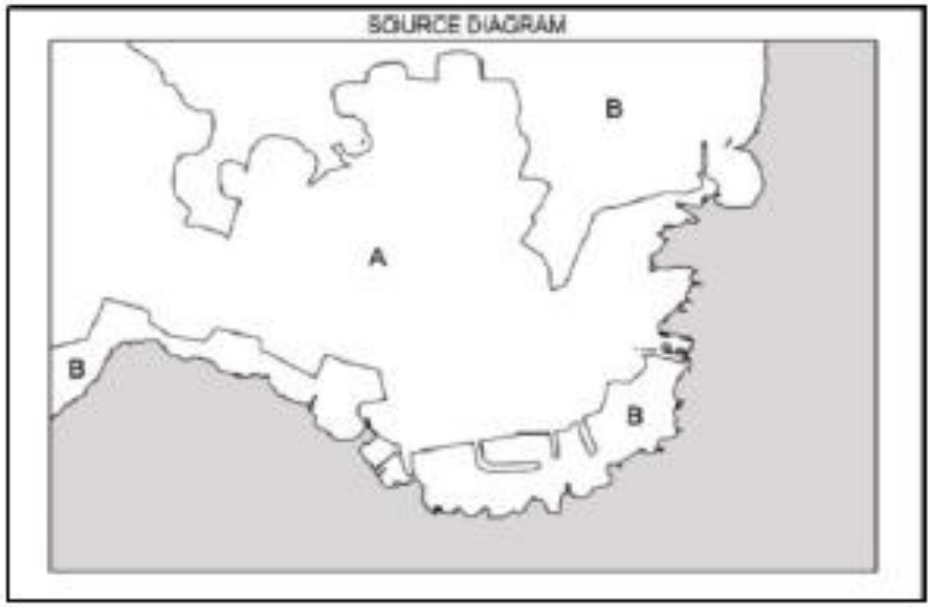
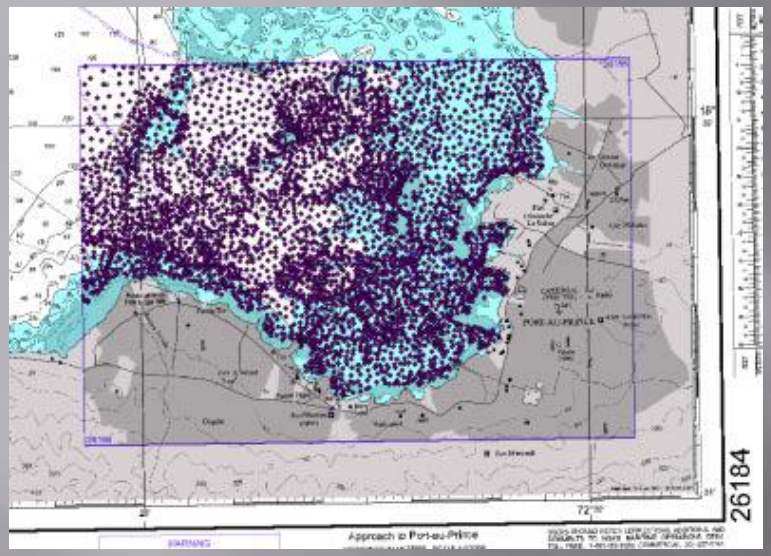
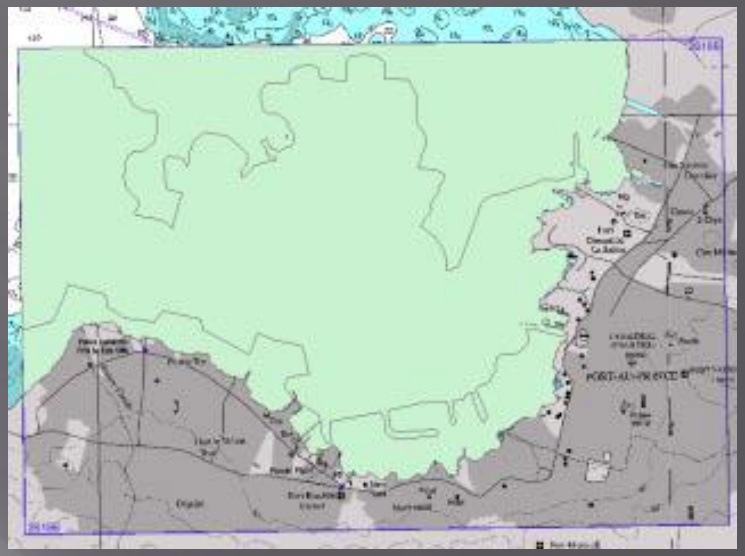
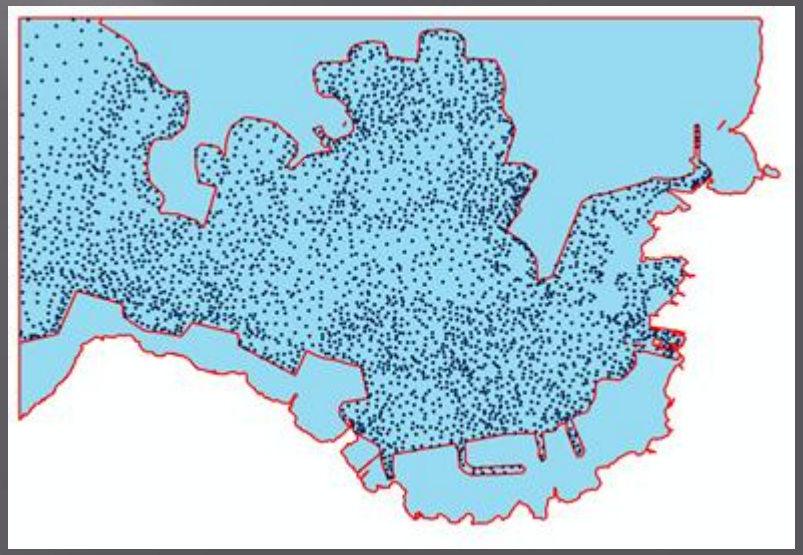


Figure 6. Source diagram of NGA Chart 26186: (Area A) U.S. Navy Survey from 2010 (Survey scale 1:1,000), (Area B) U.S. Navy Survey from 1978 (Survey scale 1:5,000 -1:10,000).

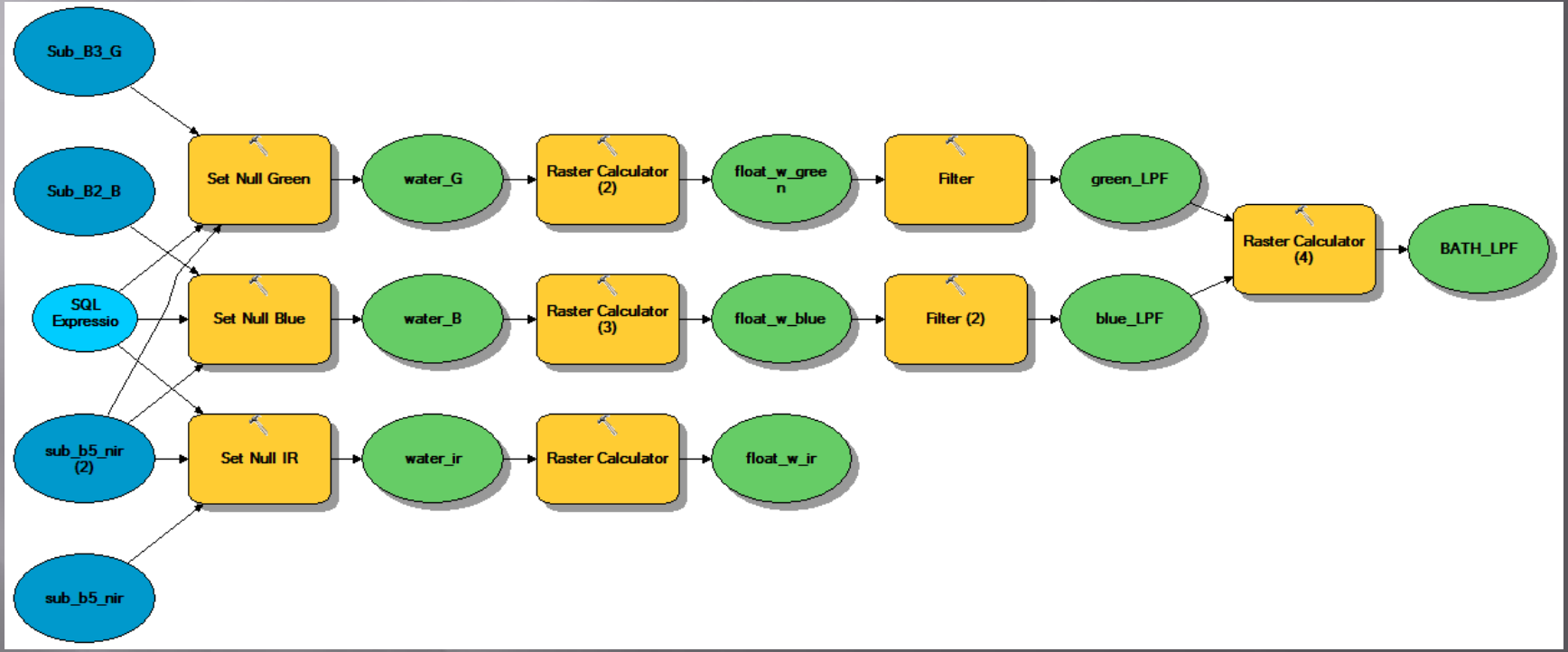
Using ENC Point Cloud



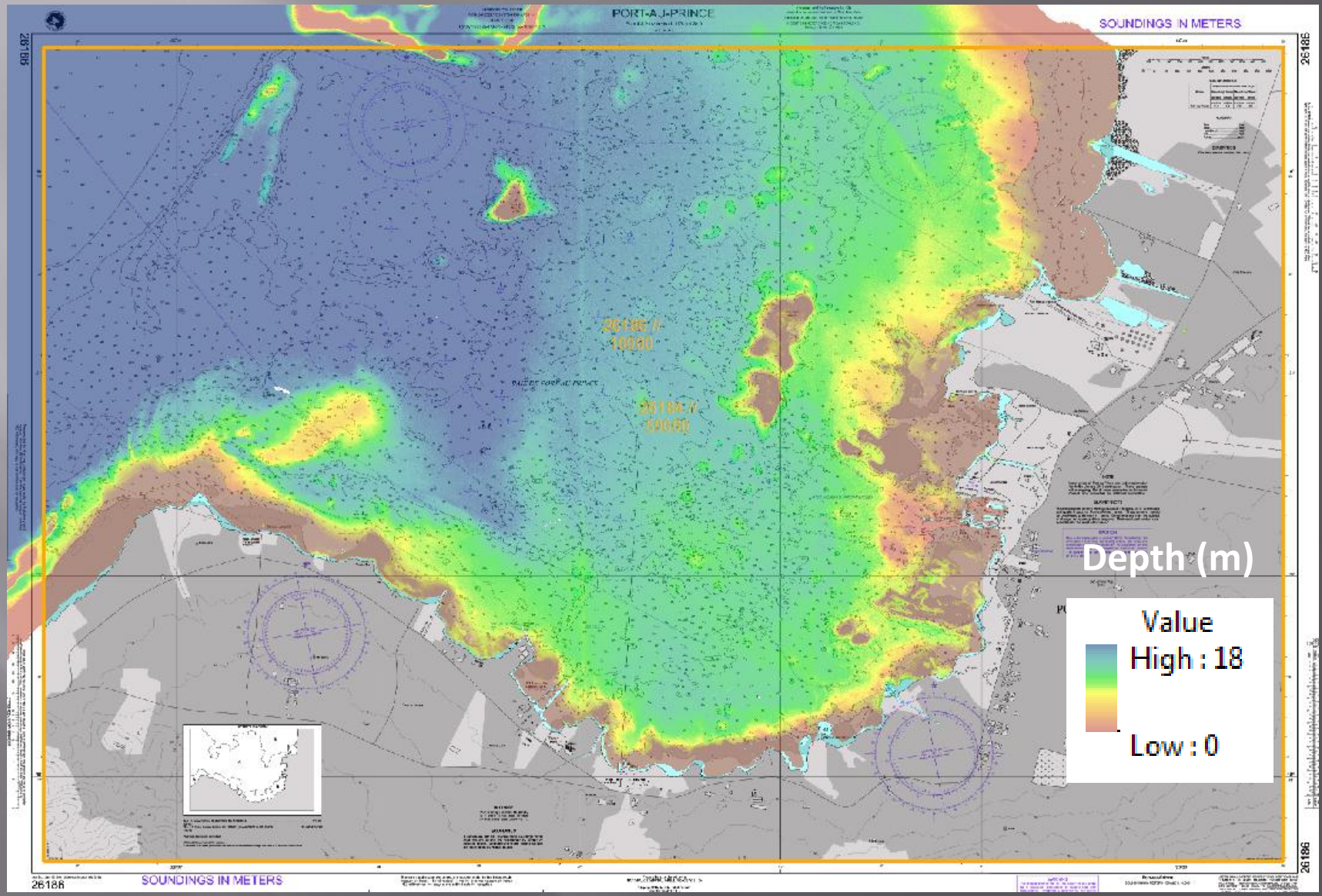




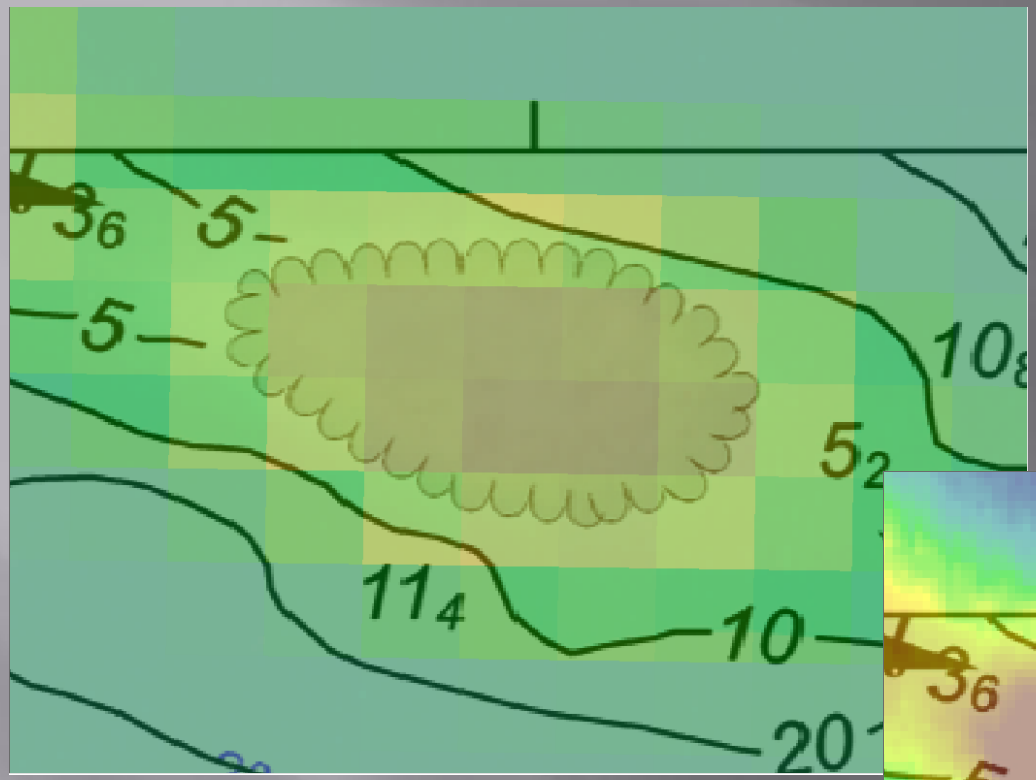
Automation through Modeling

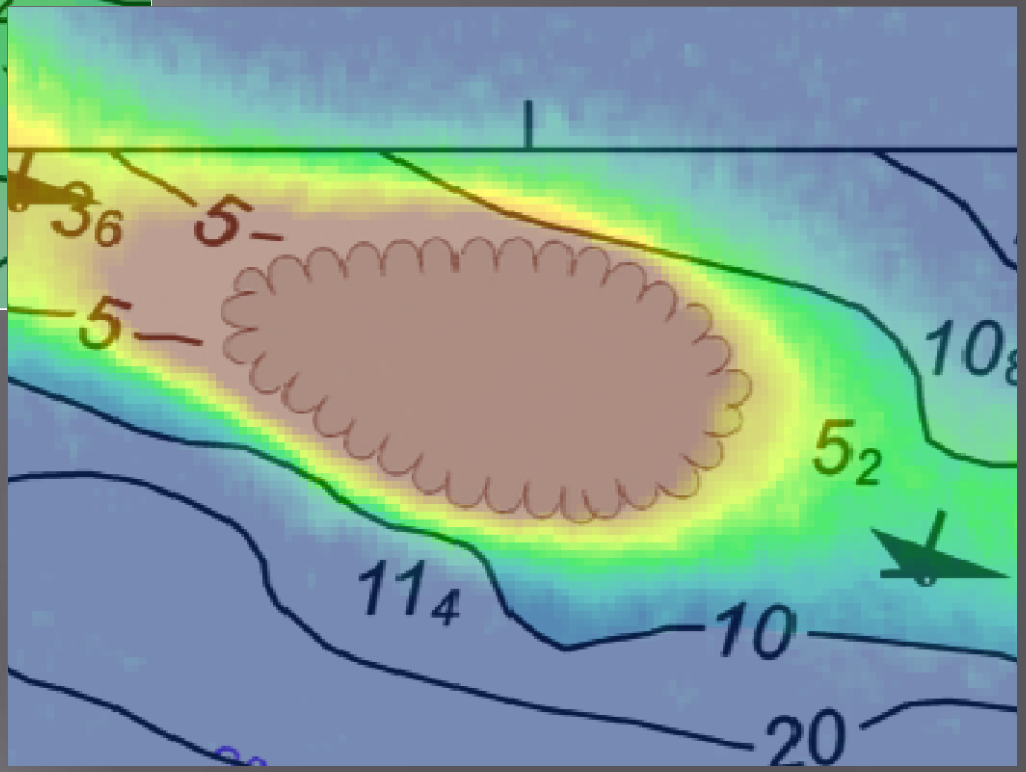


Worldview 2 Results



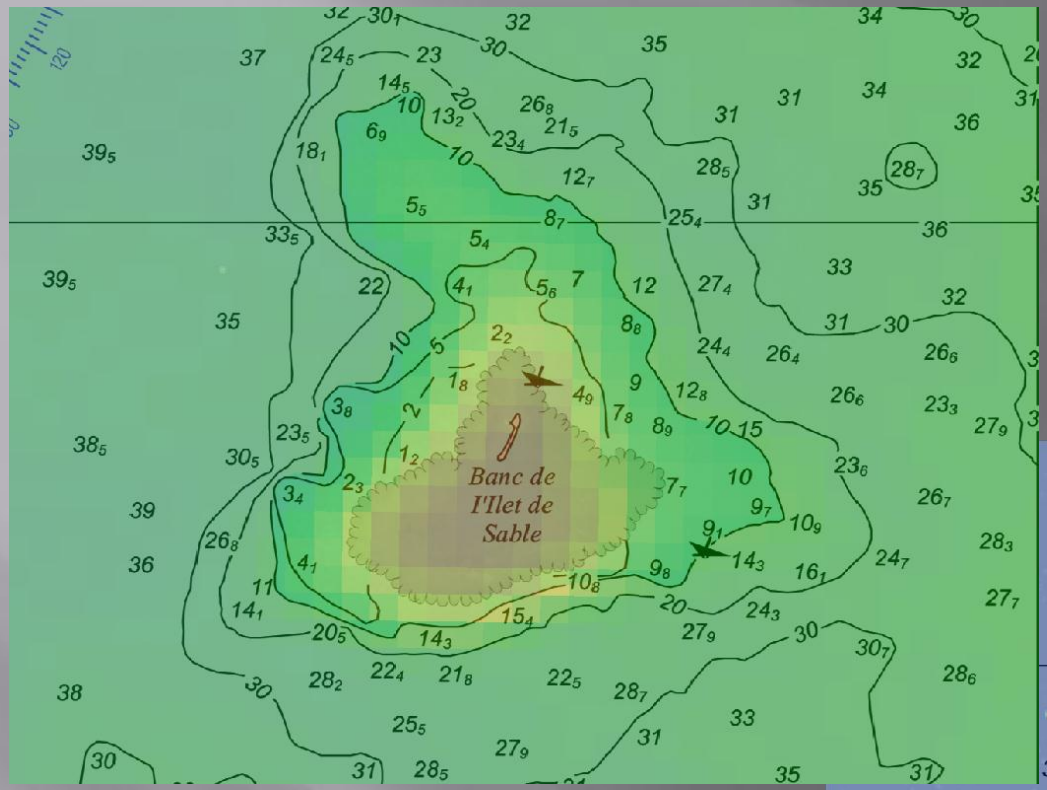
Landsat 8 vs Worldview 2

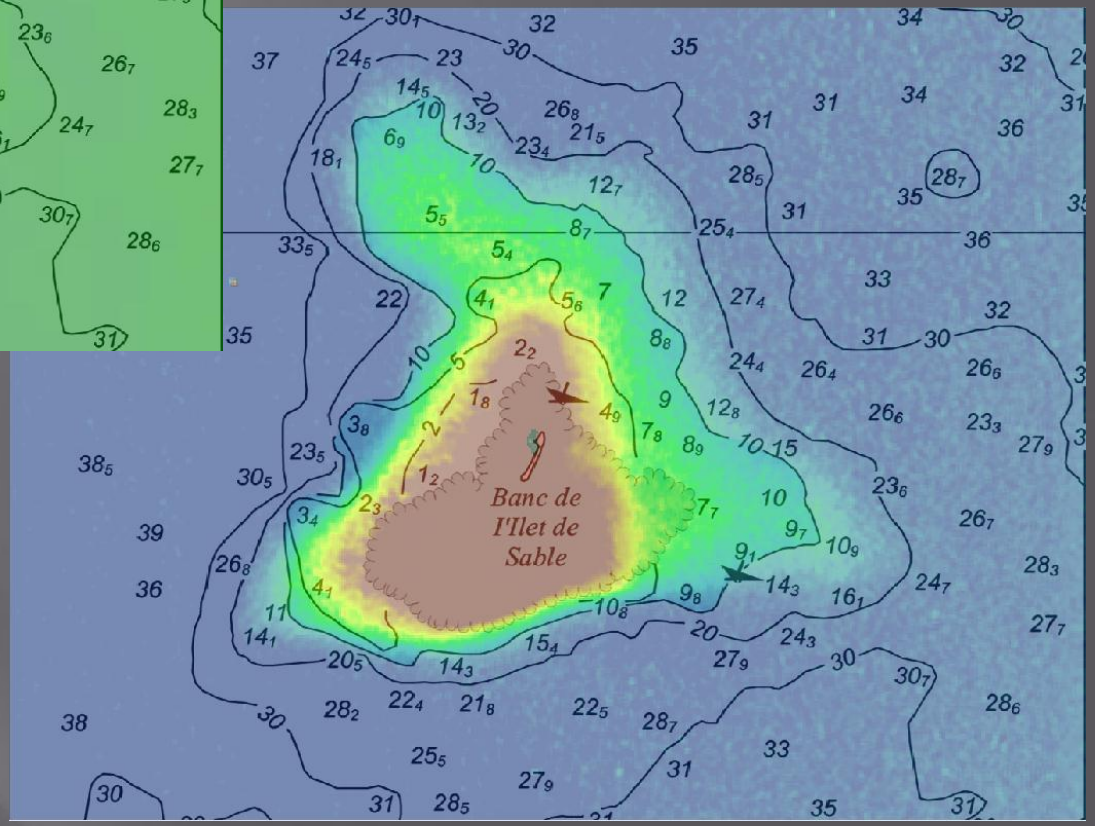




30m vs 2.4m

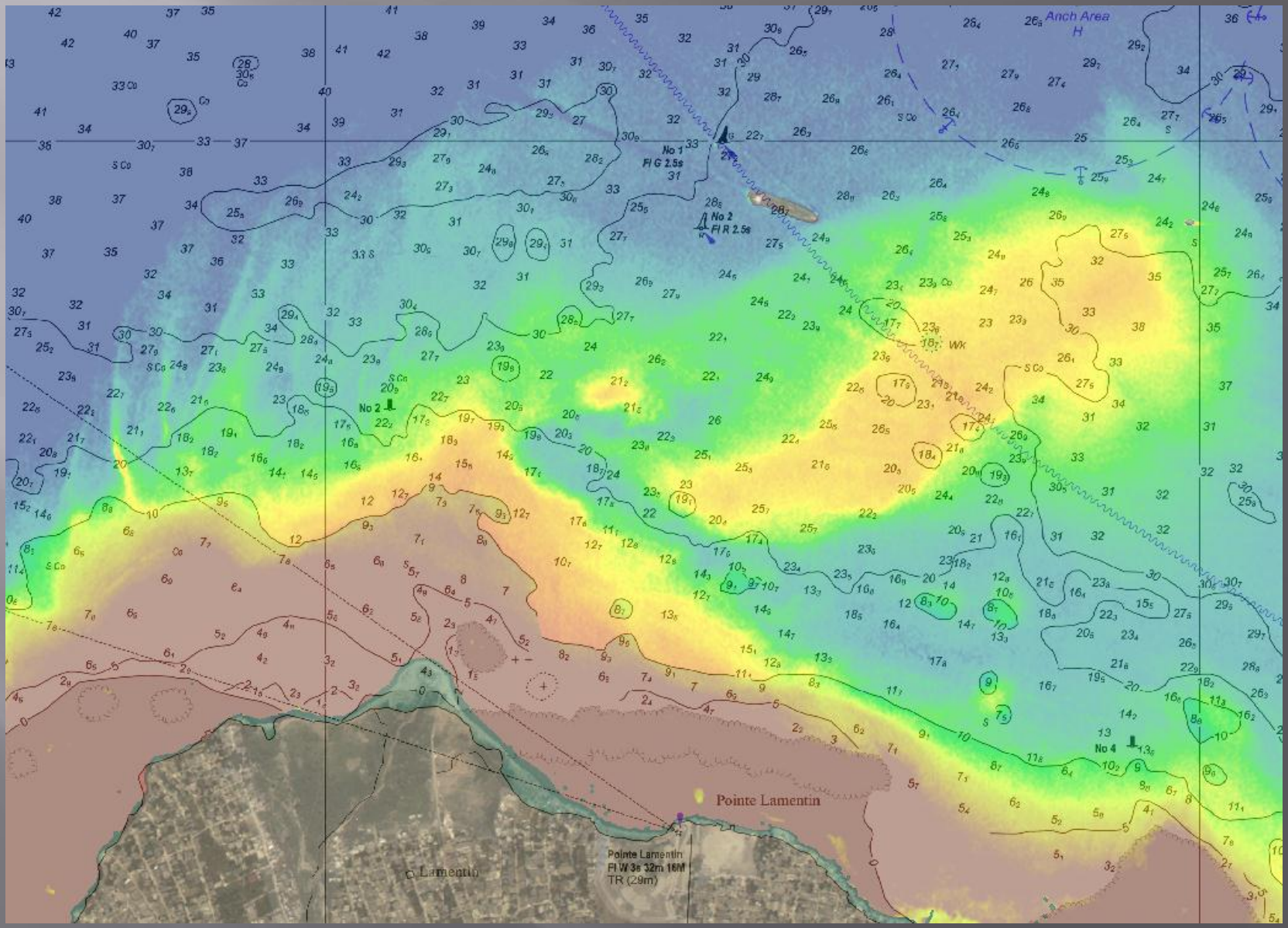
Landsat 8 vs Worldview 2



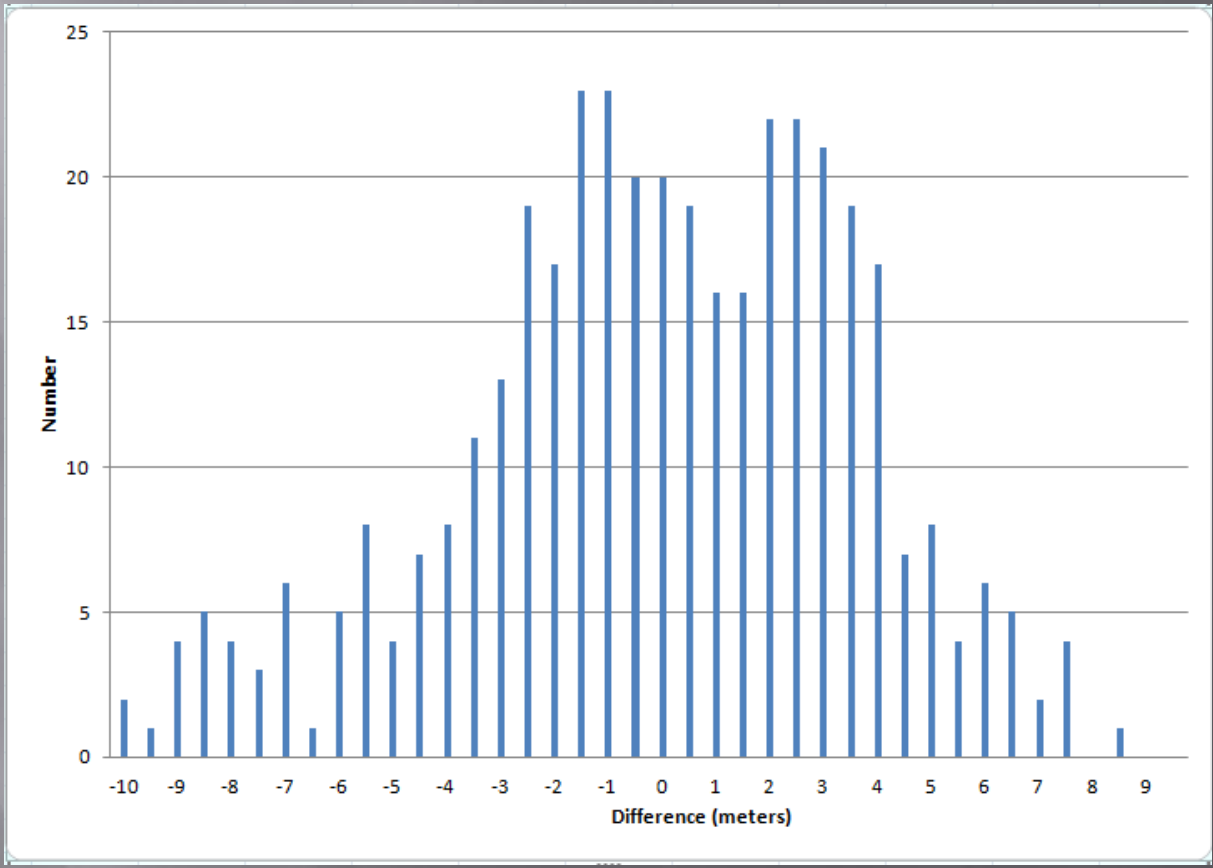


30m vs 2.4m

Sediment Plume

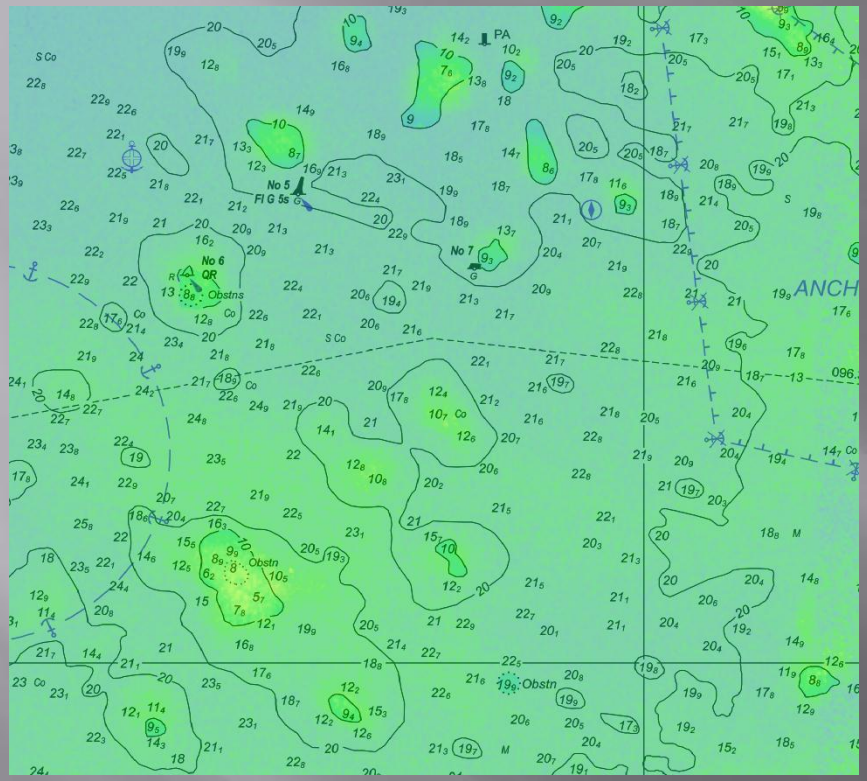


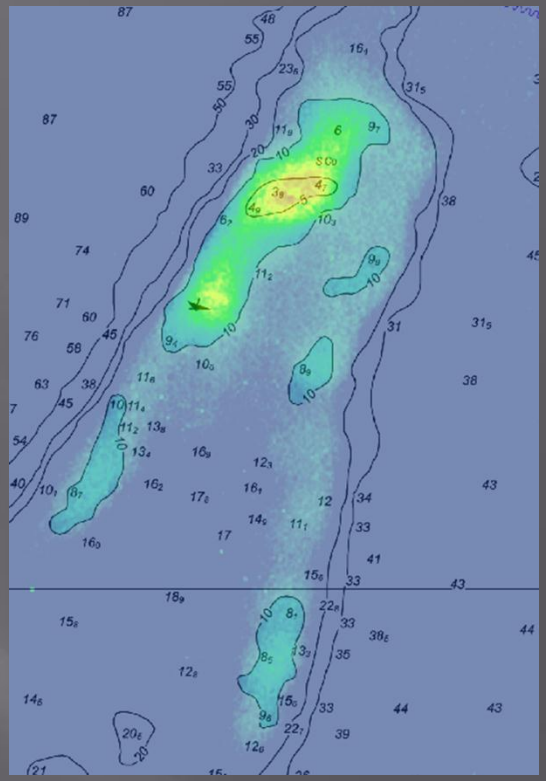
Results



The graph shows a preliminary statistical analysis of the results of the bathymetry. The X-axis has the difference values between the bathymetry and chart values. The Y-axis shows the number of occurrences of the binned value. The more values around 0 represent a good result.

Results





Final results and statistics will be made available through a NOAA Technical Memorandum to be released within the next few months.

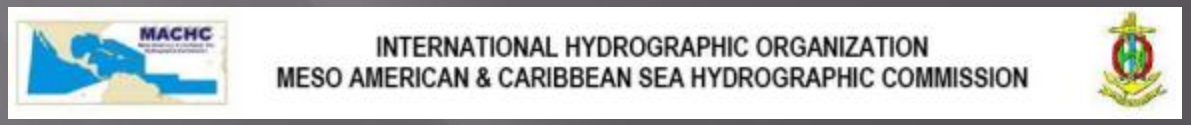
Additional thanks to:

Rear Admiral Gerd Glang, Director, Office of Coast Survey
Katie Ries, Deputy, Office of Coast Survey
Captain Shep Smith, Chief, Marine Chart Division
John Nyberg, Deputy, Marine Chart Division

James Rogers, National Geospatial Intelligence Agency

Service Hydrographique et Océanographique de Haiti

International Hydrographic Organization



Possibilities?

Inexpensive evaluation of Nautical Products:

- Reconnaissance
- Planning with other information, i.e. AIS, rocks, obstructions, etc.
- Change analysis

Layers for inclusion:

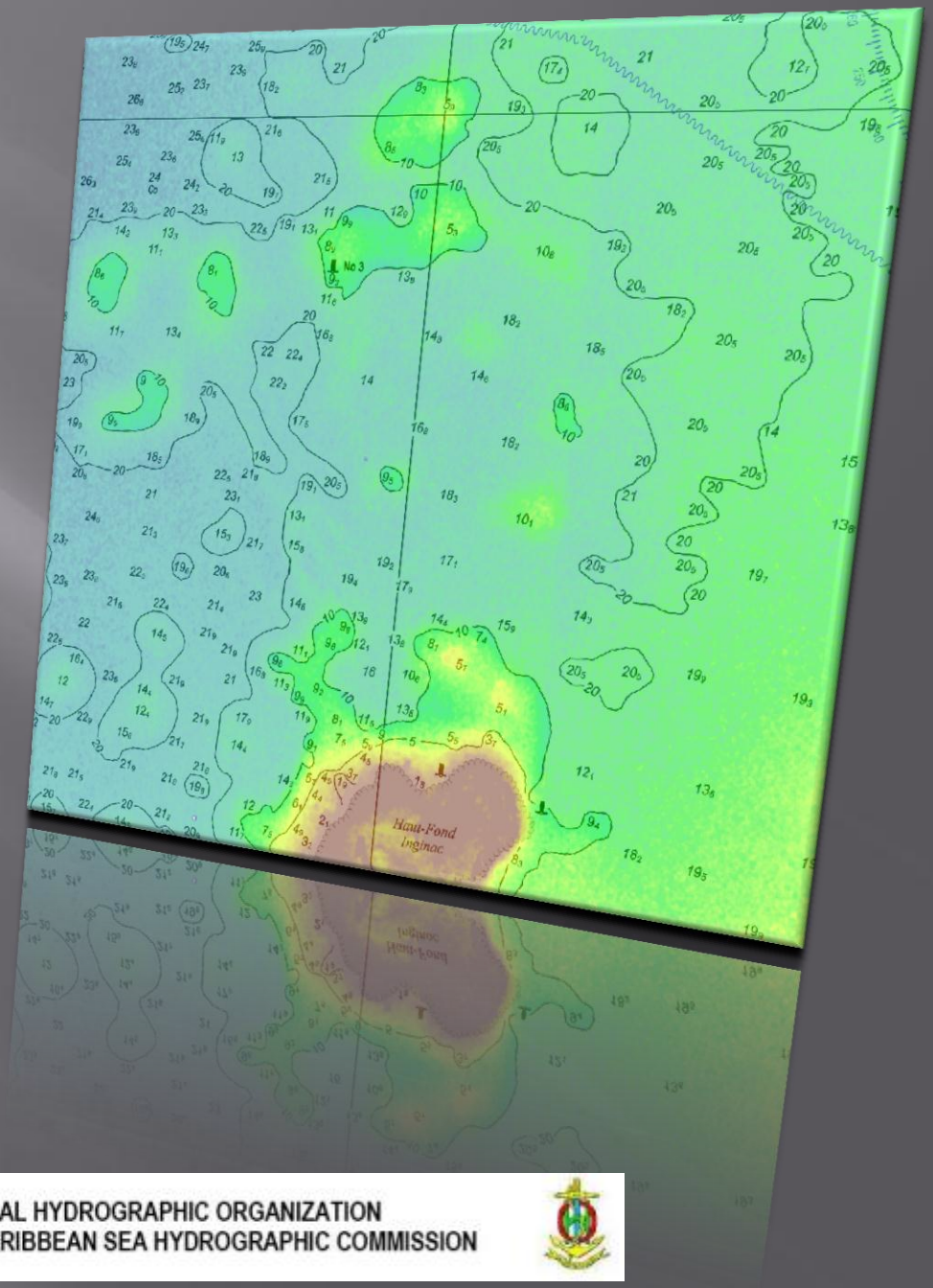
- ArcGIS Online
- ArcGIS Server
- CARIS Spatial Fusion
- Desktop clients

To support or compliment:

- IHO
- Member States/Regional Hydrographic Commissions
- MEIP
- MICC

Questions…

Comments…

Concerns…

Thank you to Dr. Shachak Pe'eri for technical assistance and guidance