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Land and Sea Shaping the World
Terre et Mer Façonnant le Monde

Uncertainty Estimates in Satellite Derived Bathymetry

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#chcnsc2018

Introduction and Overview

1. TCarta
2. Satellite Derived Bathymetry Overview
3. Satellite Derived Bathymetry Limitations
4. IHO Standards
5. Satellite Derived Bathymetry Uncertainty
6. Future Developments

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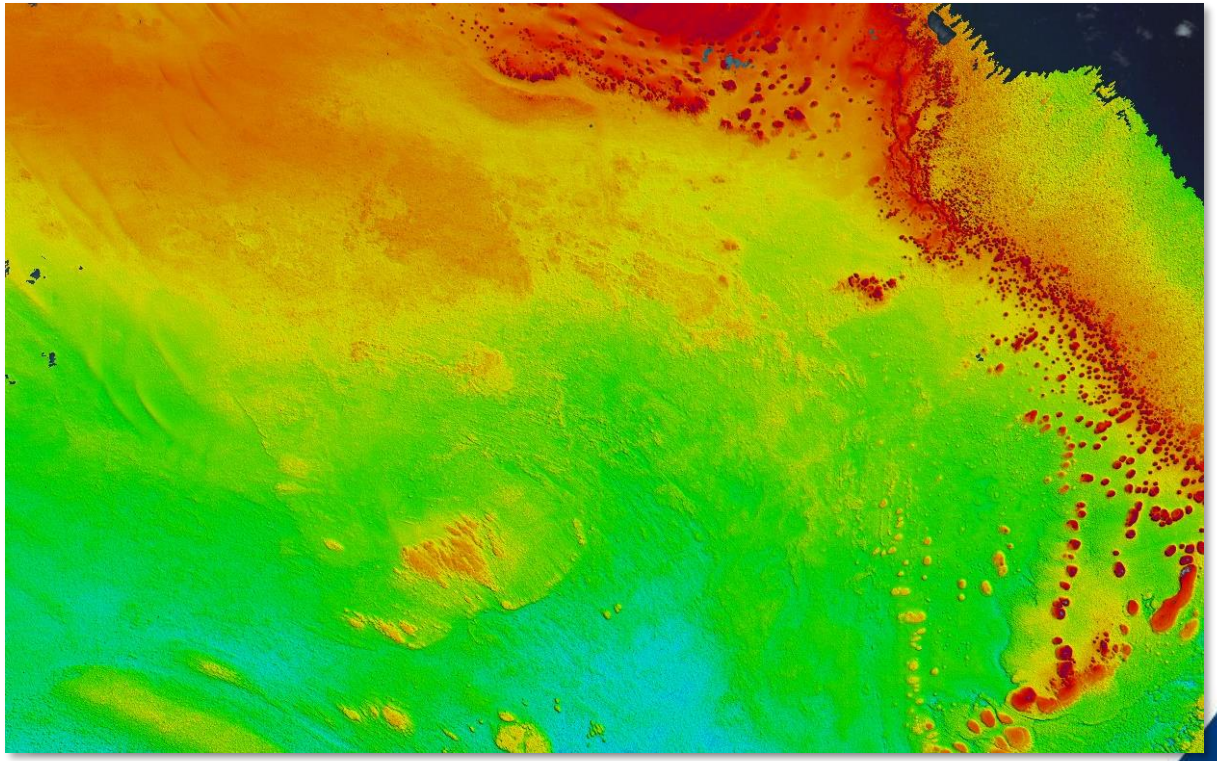
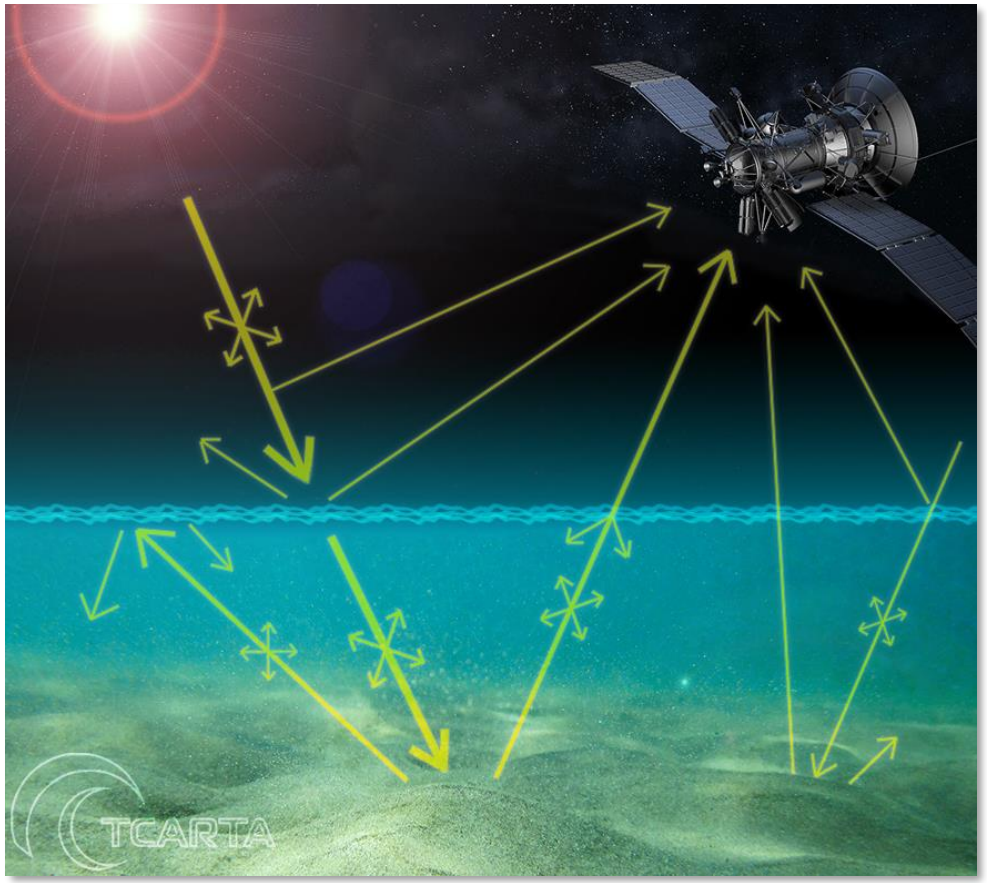
- Satellite Derived Bathymetry
- Global GIS Bathymetry Package
- Topo Bathymetry Model
- Vector Shoreline Products
- Marine Basemap
- Remote Sensing



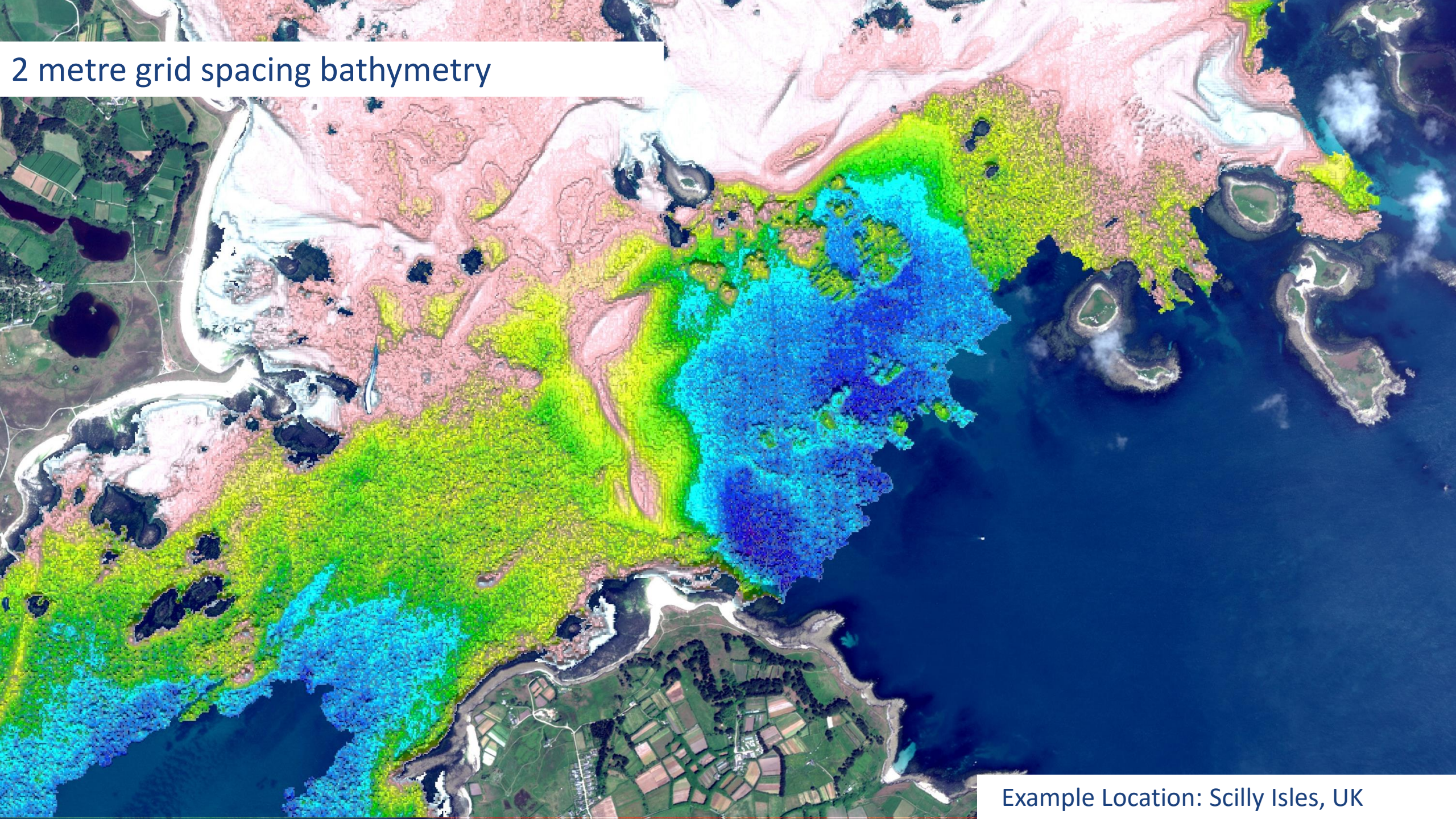
2m spacing Satellite Derived Bathymetry: British Virgin Islands

What is Satellite Derived Bathymetry (SDB)?

- Depths extracted by analyzing the **multispectral bands** available within satellite images;
- **Passive system** using only reflected sunlight;
- No indication of **depth quality**; this is something that TCarta provide as part of our product offering;
- TCarta produces SDB at **2m density** with an uncertainty estimate for each depth.



2 metre grid spacing bathymetry



Example Location: Scilly Isles, UK

Applying Satellite Derived Bathymetry

Engineering and Environment

- Ports
- Construction
- Dredging
- Aquaculture
- Pipelines
- Modelling

Government and Defence

- Navigation
- Fisheries
- Military
- Transport
- Urban Planning

Energy and Renewables

- Seismic operations
- Environmental impact assessments
- Pipeline routing
- Monitoring
- Exploration

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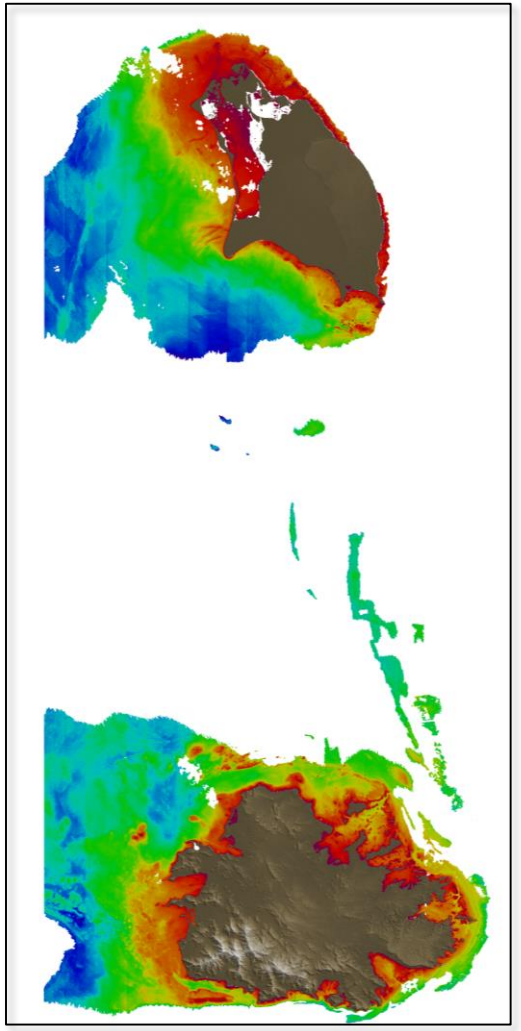
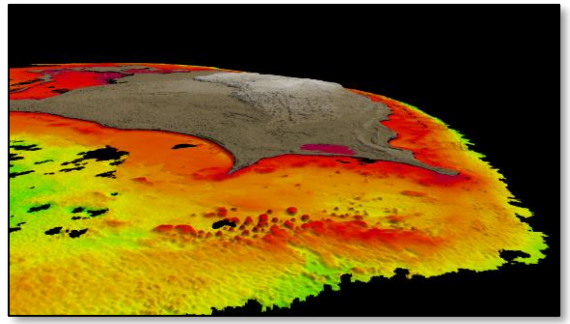
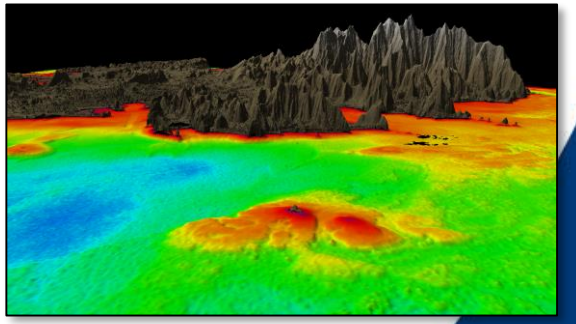
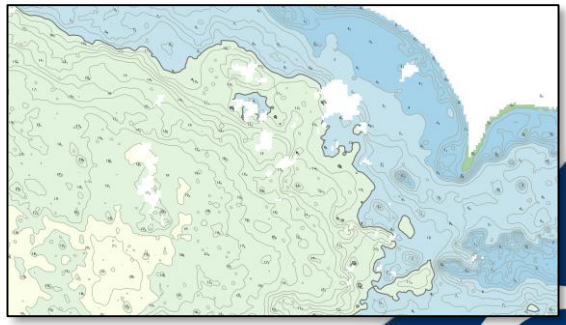
Application Example – Change Detection, Antigua & Barbuda

- Pre and Post **Hurricane Irma**, part of disaster relief;
- **UK government** tender;
- Part of the **Commonwealth Marine Economies (CME)** Program;
- **2m SDB** + Seamless 0.5m land model;
- Derived from **8-band** DigitalGlobe imagery.









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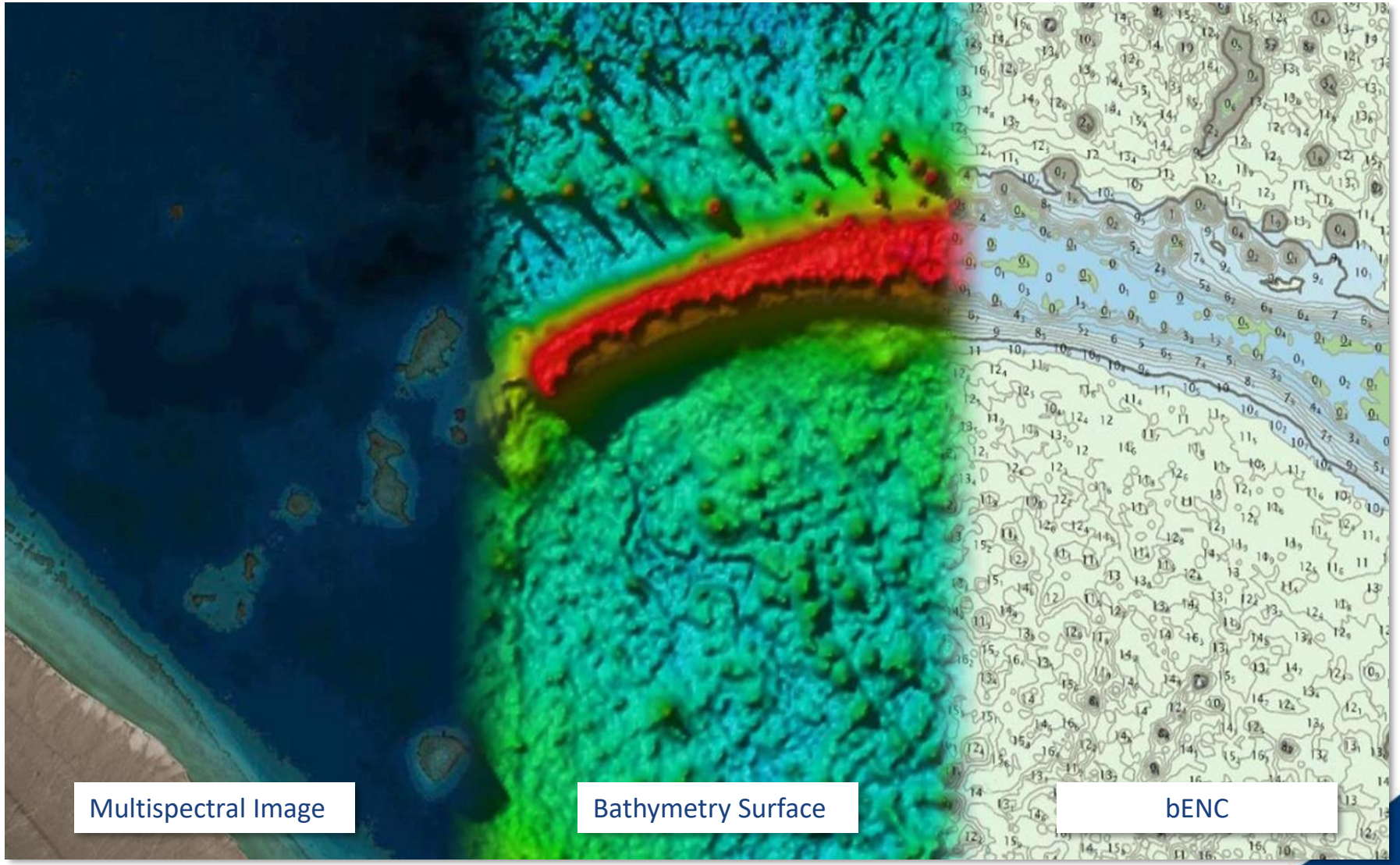
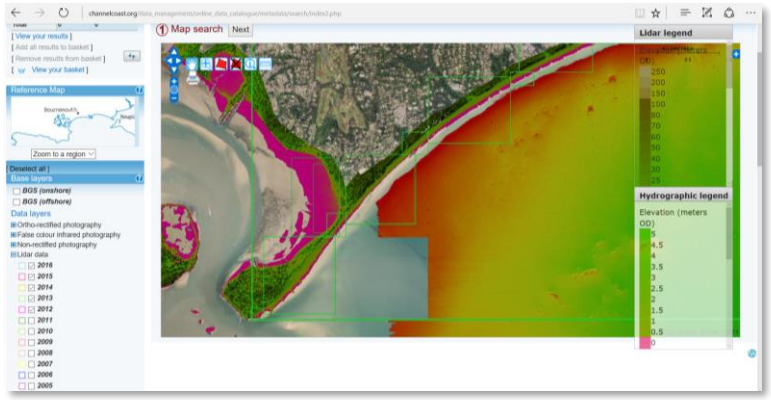
Application Example – Additional Intelligence, Red Sea

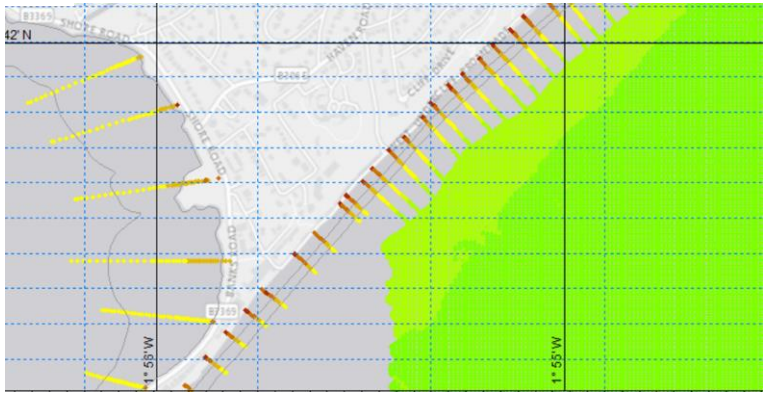


Application Example – Filling the data gap, UK

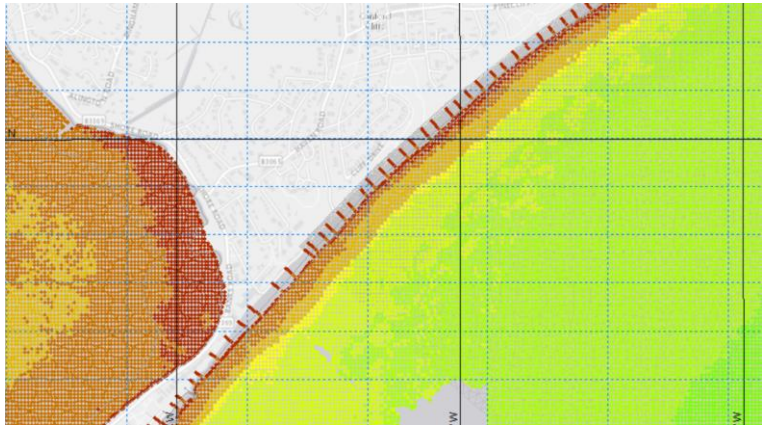
1. Freely available data:



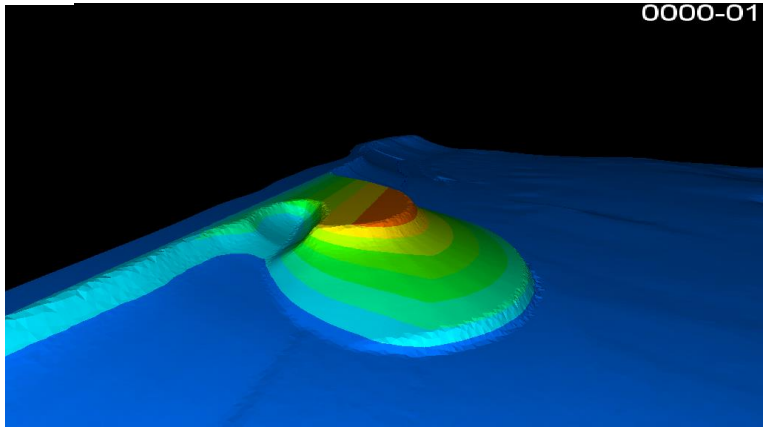
2. Freely available data close up – the white ribbon:



3. Satellite derived bathymetry data infill:

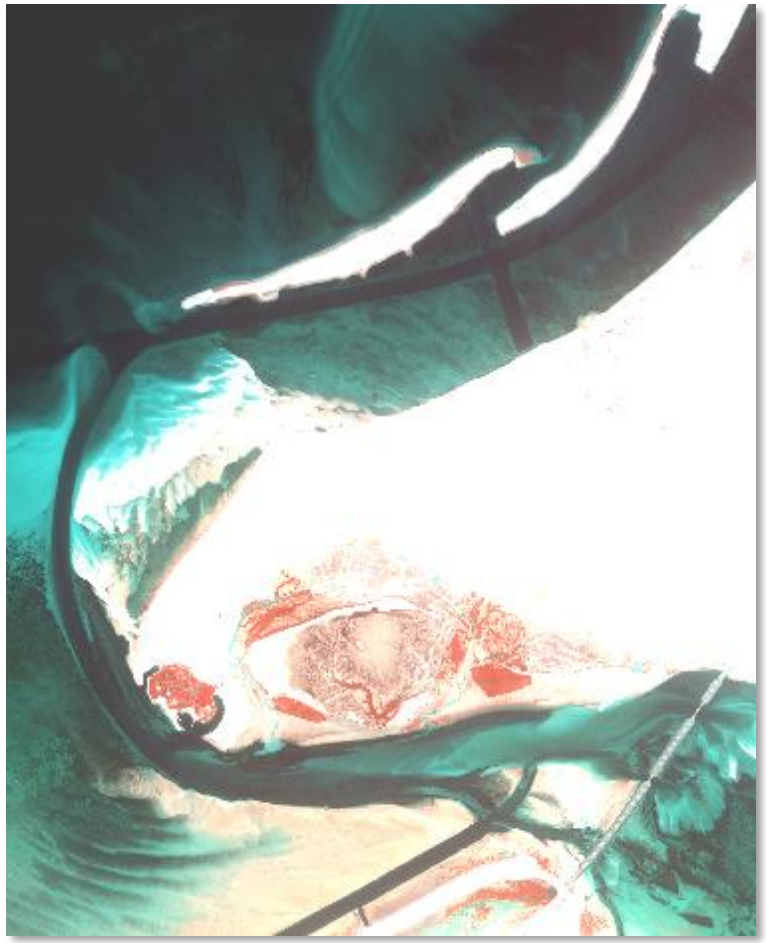


4. Improved morphological modelling:



Satellite Derived Bathymetry: Limitations

- Very dependent on **water clarity**;
- **20m depth** limit (30m in ideal conditions), and potentially <5m in poor conditions (possibly both exist on same satellite image!);
- **Tide** needs to be predicted or modelled in some way meaning uncertainties;
- **Ground truth data** is needed to limit uncertainties; difficult in areas where SDB is attractive.



8-band, stretched image

IHO: S-44

Reference	Order	Special	1a	1b	2
Chapter 1	**Description of areas.**	Areas where under-keel clearance is critical	Areas shallower than 100 metres where under-keel clearance is less critical but *features* of concern to surface shipping may exist.	Areas shallower than 100 metres where under-keel clearance is not considered to be an issue for the type of surface shipping expected to transit the area.	Areas generally deeper than 100 metres where a general description of the sea floor is considered adequate.
Chapter 2	**Maximum allowable THU 95% *Confidence level***	2 metres	5 metres + 5% of depth	5 metres + 5% of depth	20 metres + 10% of depth
Para 3.2 and note 1	**Maximum allowable TVU 95% *Confidence level***	a = 0.25 metre b = 0.0075	a = 0.5 metre b = 0.013	a = 0.5 metre b = 0.013	a = 1.0 metre b = 0.023
Glossary and note 2	***Full Sea floor Search***	Required	Required	Not required	Not required
Para 2.1 Para 3.4 Para 3.5 and note 3	***Feature Detection***	Cubic *features* > 1 metre	Cubic *features* > 2 metres, in depths up to 40 metres; 10% of depth beyond 40 metres	Not Applicable	Not Applicable
Para 3.6 and note 4	**Recommended maximum Line Spacing**	Not defined as *full sea floor search* is required	Not defined as *full sea floor search* is required	3 x average depth or 25 metres, whichever is greater For bathymetric lidar a spot spacing of 5 x 5 metres	4 x average depth
Chapter 2 and note 5	**Positioning of fixed aids to navigation and topography significant to navigation. (95% *Confidence level*)**	2 metres	2 metres	2 metres	5 metres
Chapter 2 and note 5	**Positioning of the Coastline and topography less significant to navigation (95% *Confidence level*)**	10 metres	20 metres	20 metres	20 metres
Chapter 2 and note 5	**Mean position of floating aids to navigation (95% *Confidence level*)**	10 metres	10 metres	10 metres	20 metres

Standard to 1m
Good to 6m

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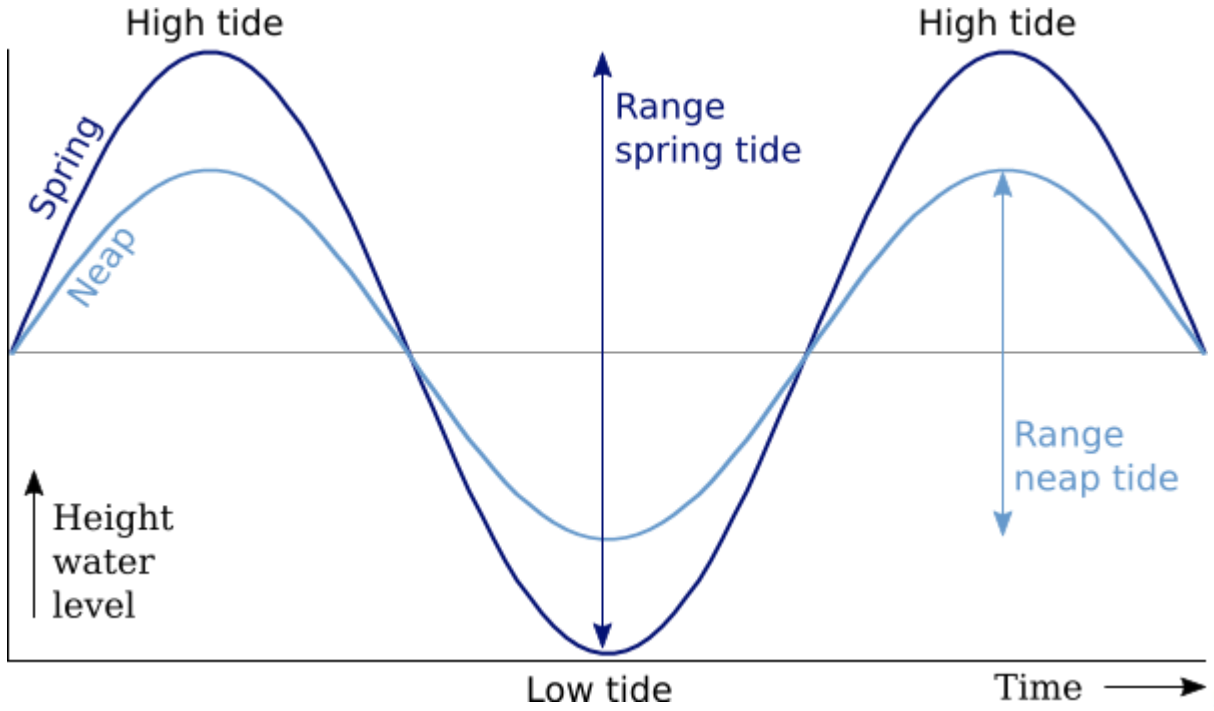
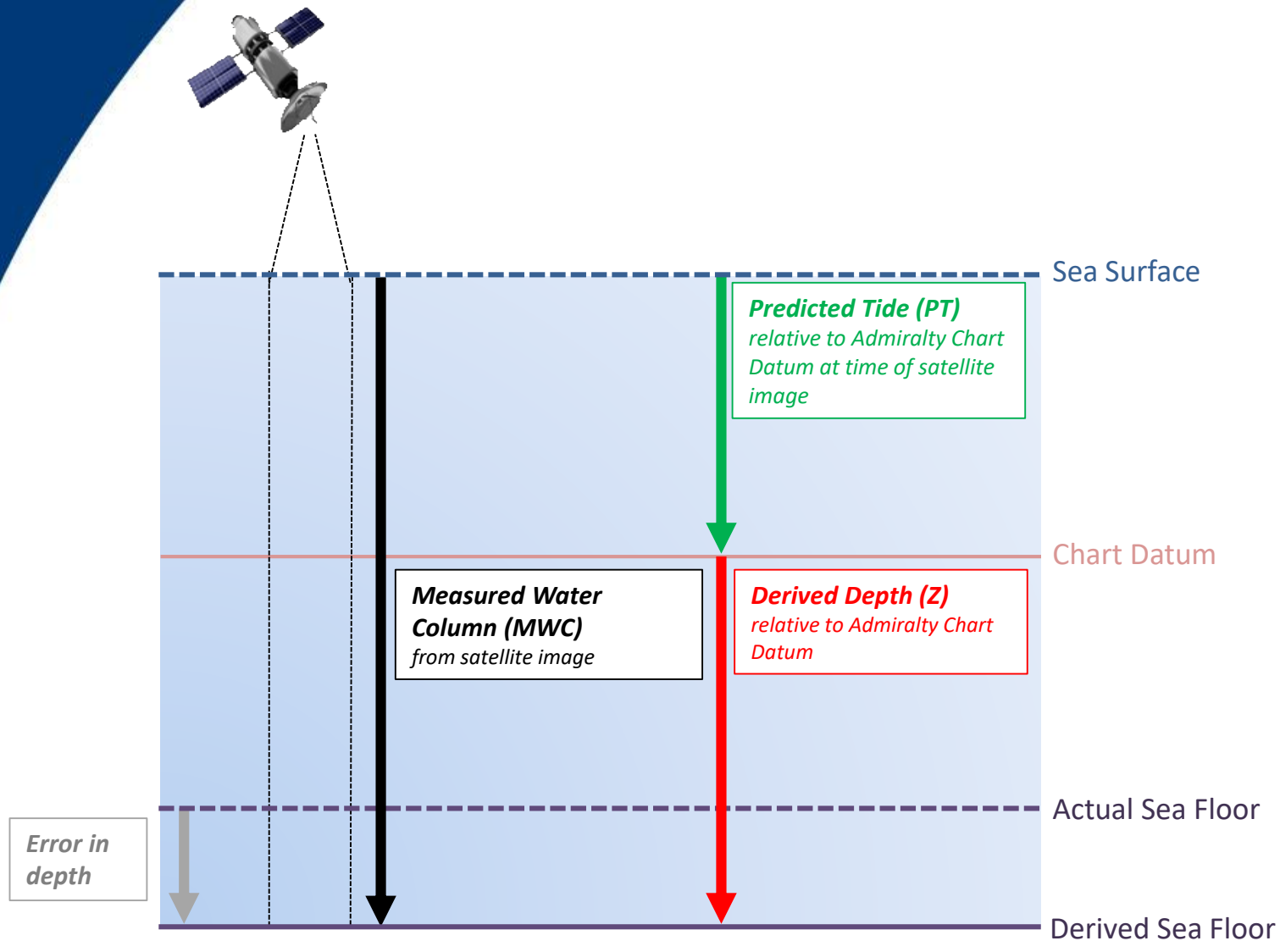
Satellite Derived Bathymetry: Tide

- Adjust ground truth to reflect the **height of tide** when satellite image was taken;
- Tide is needed to **reduce SDB** depths to required vertical datum (LAT);
- Tidal predictions are based on **UKHO's Total Tide** stations adjusted to location of image by local co-tidal chart;
- Tide at the satellite image is checked for consistency from surrounding stations. Even if agreement, the **min vertical uncertainty is set at 0.3m** to account for prediction.



Satellite Derived Bathymetry: Uncertainty



Tidal Uncertainty (TU)

- PT is based on an average of predictions at multiple local tide stations;
- TU allows for this average, assigning a value based on the difference between the local tide station predictions;
- TU is always minimum 0.3 metres

MWC Uncertainty (MWCU)

- During MWC production a quality indicator places outputs into 3 bands; Good; Moderate; and Unusable;
- Good depths are assigned a MWCU of 10% of MWC;
- Moderate depths are assigned a MWCU of 20% of MWC;
- Unusable depths are discarded.

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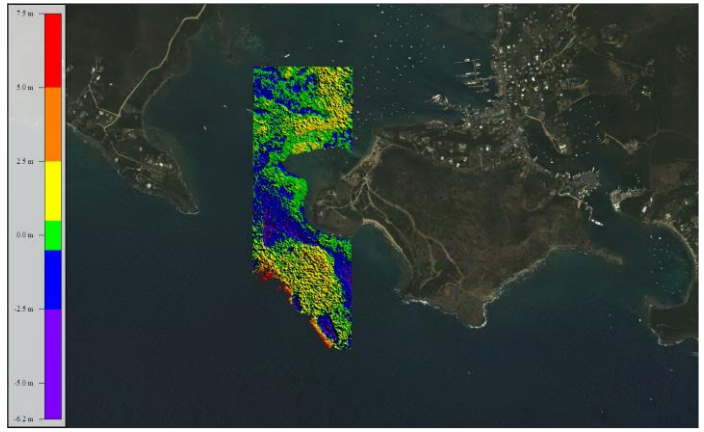
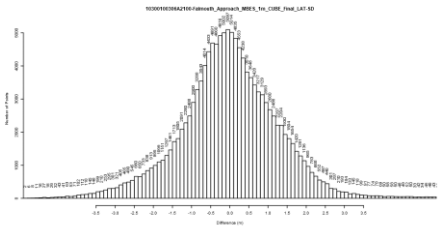
Satellite Derived Bathymetry: Uncertainty

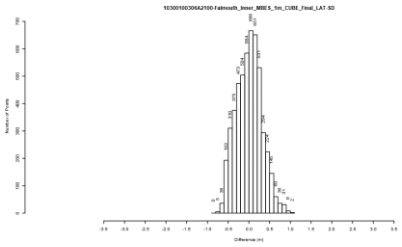
Ground Truth data comparison:



Comparison:

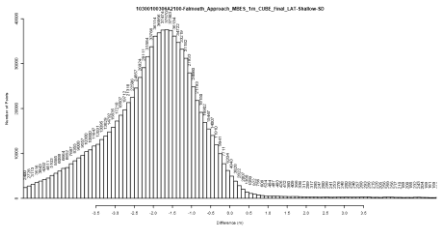


Sign	Count	Percentage
-1	67260	50.42
1	66150	49.58

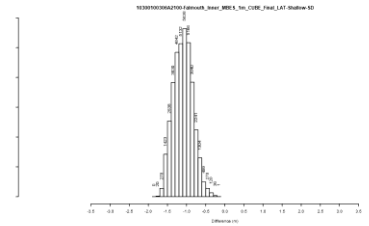


Sign	Count	Percentage
-1	2480	48.36
1	2648	51.64

Shallow Comparison:
(12% +0.75m)

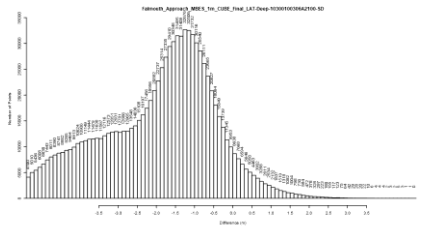


Sign	Count	Percentage
-1	950150	96.42
1	35261	3.58

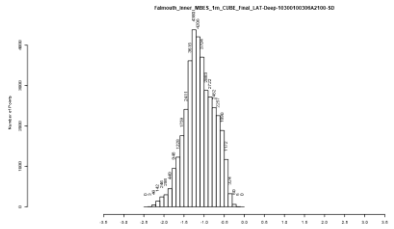


Sign	Count	Percentage
-1	37194	100

Deep Comparison:
(12% -0.75m)

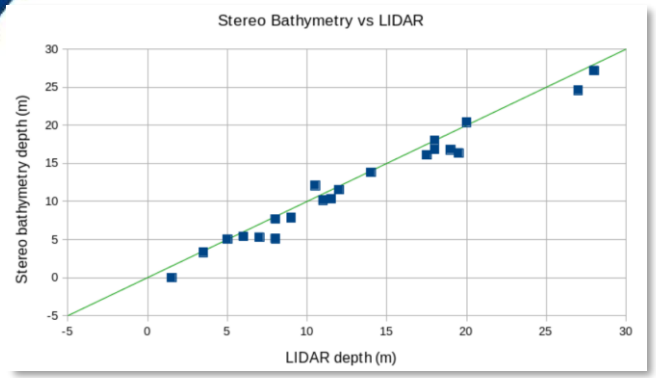


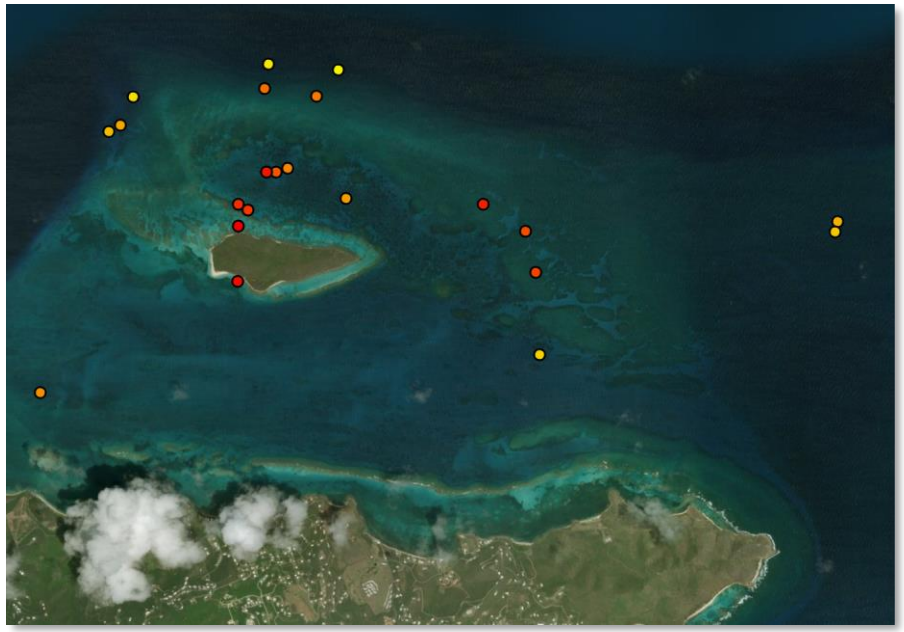
Sign	Count	Percentage
-1	921202	93.48
1	64214	6.52



Sign	Count	Percentage
-1	37200	100

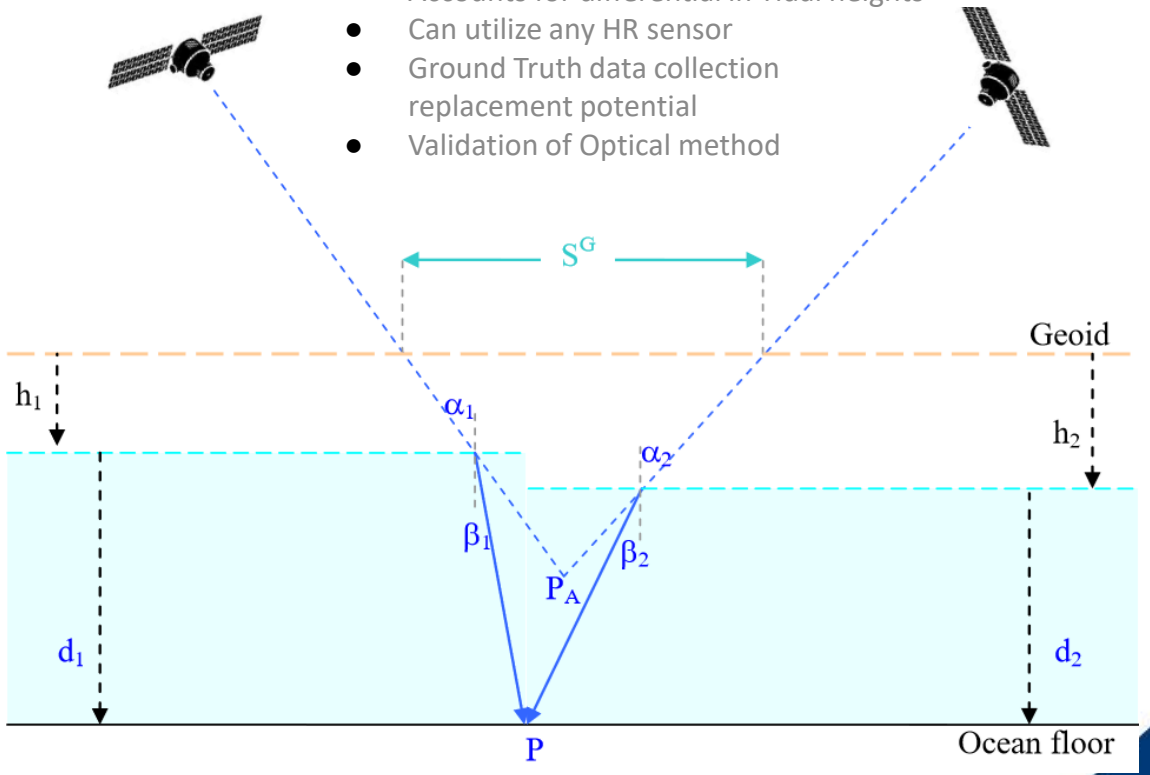
Future Developments: Stereo Bathymetry





Advantages of Technique:

- Object based extraction, independent of seabed type
- Accounts for differential in Tidal heights
- Can utilize any HR sensor
- Ground Truth data collection replacement potential
- Validation of Optical method



St. Croix - SPB accurate to within 4.66% of LiDAR Survey

DigitalGlobe

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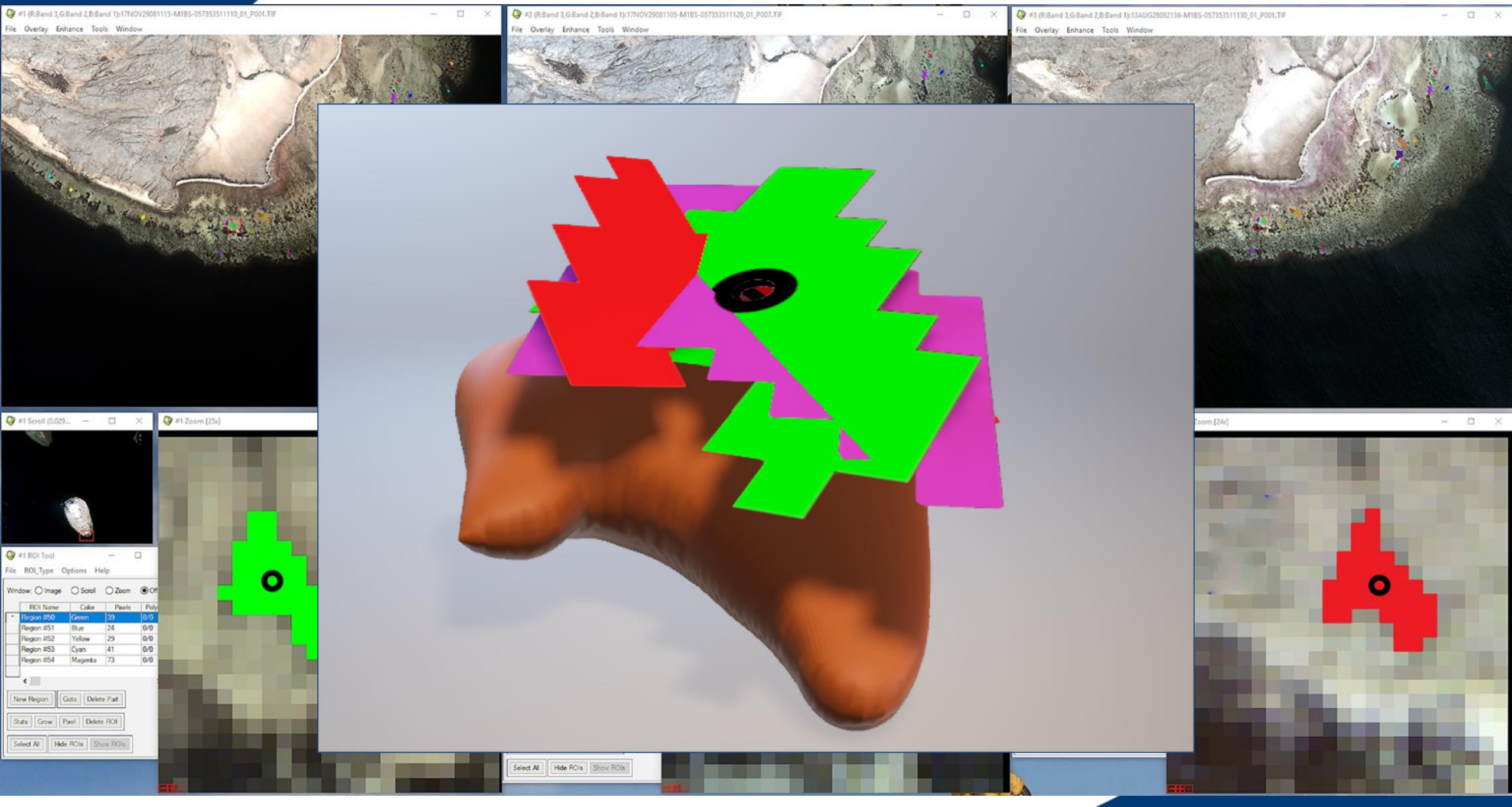
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File Overlay Enhance Tools Window
#2 (R:Band 3,G:Band 2,B:Band 1):17NOV29081105-M1BS-057353511120_01_P007.TIF
File Overlay Enhance Tools Window
#3 (R:Band 3,G:Band 2,B:Band 1):13AUG28082136-M1BS-057353511130_01_P001.TIF
File Overlay Enhance Tools Window
#1 Scroll (0.029...
#1 Zoom [25x]
#1 ROI Tool
File ROI_Type Options Help
Window: Image Scroll Zoom Off
ROI Name Color Pixels Poly
Region #50 Green 39 0/0
Region #51 Blue 24 0/0
Region #52 Yellow 29 0/0
Region #53 Cyan 41 0/0
Region #54 Magenta 73 0/0
New Region Goto Delete Part
Stats Grow Pixel Delete ROI
Select All Hide ROIs Show ROIs
Zoom [24x]
Select All Hide ROIs Show ROIs

Conclusions

1. Satellite Derived Bathymetry is a **useful tool**, but not in all situations;
2. Satellite Derived Bathymetry must be used with **caution** and the pitfalls must be known;
3. Uncertainty can only be measured when you have something to measure it and **check against**.

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Questions?

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