TCarta 10m Satellite Derived Bathymetry

Dominican Republic, Caribbean

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Prepared for:

THE NIPPON FOUNDATION-GEBCO SEABED 2030

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TCARTA

1. INTRODUCTION

In support of the Nippon Foundation-GEBCO Seabed 2030 Project (Seabed 2030) and the Hydrographic and Oceanographic Services of the Dominican Republic Navy to fill gaps in bathymetric data to enhance the understanding of the marine environments and support safe navigation, TCarta was contracted to produce 10m and 100m Satellite Derived Bathymetry (SDB) within an Area of Interest (AOI) in the waters around Dominican Republic, Caribbean.

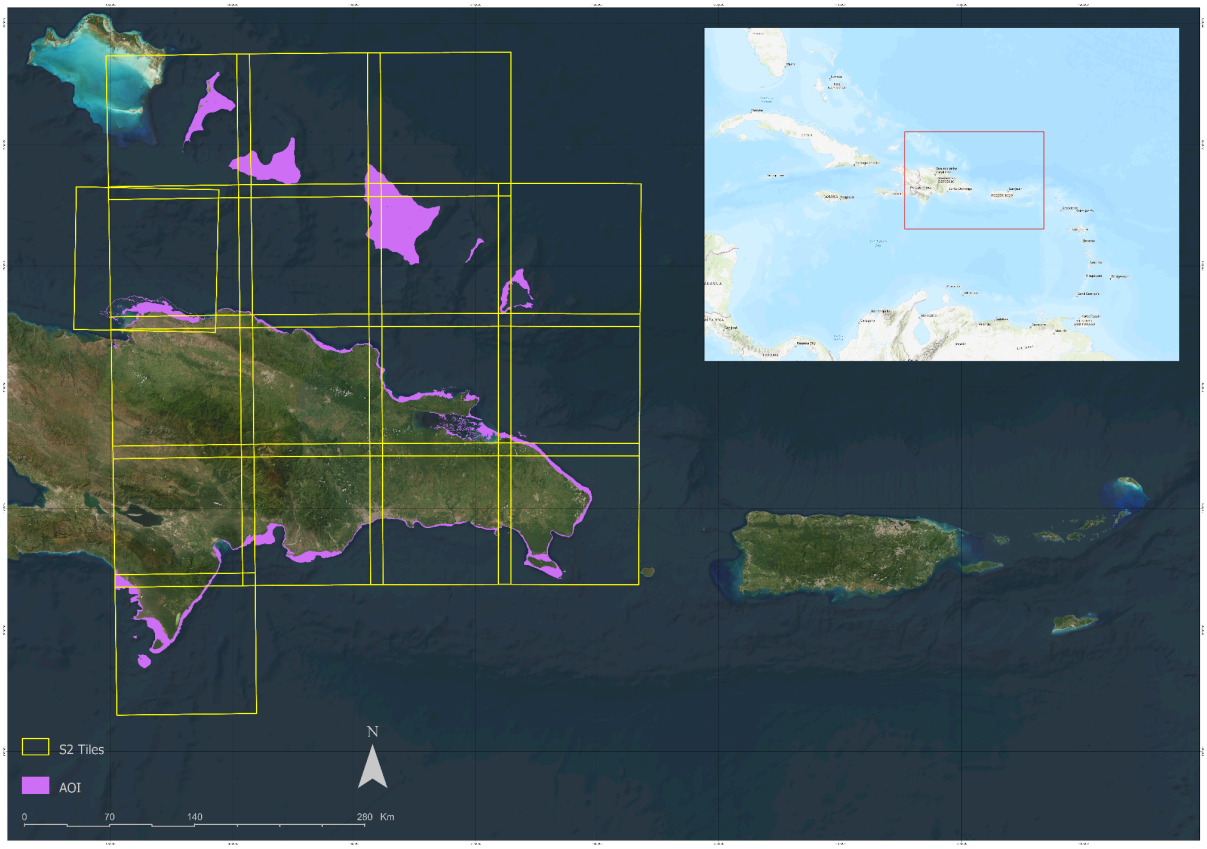


Figure 1: *Area of Interest for SDB production surrounding the Dominican Republic.*

The Dominican Republic occupies the eastern two-thirds of the Hispaniola island in the Caribbean, which it shares with Haiti. The country has a wide variety of terrain and vegetation, with alpine forest in the central mountains and deserts in the southwest. The southern coast features rocky cliffs and pebbled beaches, and a narrow, coastal plain widens to the southeast. Relative humidity remains uniform throughout the year (mean of 80 percent), and most of the rain falls during May through November with an annual mean rainfall of 1,390 millimeters.

The METOCEAN conditions within the AOI relevant to the production of SDB include tropical cyclones, northeast trade winds, easterly waves, and fronts that influence environmental conditions affecting Sentinel-2 A/B imagery acquisition. During mid-July through October hurricanes are a significant threat in the Dominican Republic, and a average of eight hurricanes per year strikes the Caribbean region. The implication of restricted months. Some areas may frequently be influenced by poor (turbid) water quality.

All optically shallow water within the AOI (Figure 1) was surveyed out to the extinction depth, with a final total surveyed area of 7,053.89 km^2.

2. SOURCE DATA

IMAGERY

The imagery processed to survey the AOI was sourced from the European Space Agency's Sentinel-2 (S2) satellite. Sentinel-2 data is sorted by a tile grid system around the world. 17 S2 tiles covered the AOI and were therefore selected for processing (Table 1).

In order to overcome the negative effects of local water column and atmospheric conditions, and to provide the most seamless survey possible, for each tile in the country main land, a multi-image approach was used to generate a radiometrically accurate composite image that is optimized to create the "best" pixels for SDB derivations, free of the typical artifacts found in a single image such as clouds, cloud shadows, waves, and turbidity. For offshore features, Mouchoir Bank, Silver Bank, and Navidad Bank a single image solution was proposed to overcome interstitial noise observed in these areas with multi-image approach. The parameters of these S2 imagery composites can be found in Table 1.

Table 1: *Imagery Composite Information*

S2 Tile ID	Image Solution
18QZH	Multi-image Composite
19QBA	Multi-image Composite
19QBB	Multi-image Composite
19QBC	Multi-image Composite
19QBD	Multi-image Composite
19QBV	Multi-image Composite

19QCA	Multi-image Composite
19QCB	Multi-image Composite
19QCC	Single Image
19QCD	Single Image
19QDA	Multi-image Composite
19QDB	Multi-image Composite
19QDC	Single Image
19QDD	Single Image
19QEA	Multi-image Composite
19QEB	Multi-image Composite
19QEC	Single Image

Source Sentinel-2 Level-1C imagery was selected programmatically via Google Earth Engine, with all contributing imagery collected no earlier than 2018. Prior to composite creation, all singular images underwent land masking using a NDWI threshold method, in addition to atmospheric correction using the MAIN atmospheric correction algorithm. Regarding with single image solution glint correction was performed utilizing the Hedley glint-correction method to reduce/mitigate the effects of specular reflection in multispectral imagery.

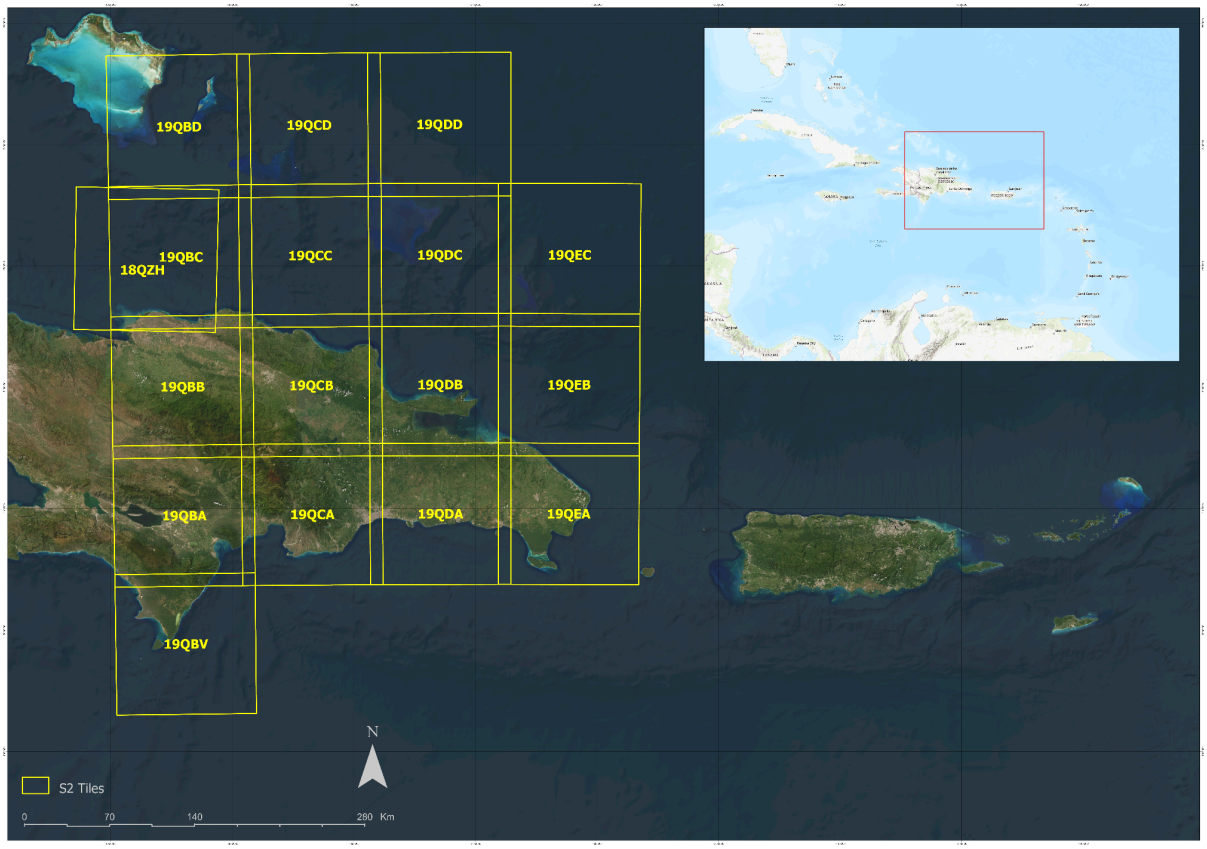


Figure 2: *Sentinel-2 Tiles selected.*

IN SITU

ICESat-2 data was utilized for SDB calibration and validation. TCarta supervised machine learning algorithms programmatically correlate these refracted/tide-corrected data with the seabed reflectance values within the extent of each candidate image, deriving values which model and extrapolate across the survey area.

NASA's ICESat-2 satellite has the ability to penetrate the water column, allowing the extraction of shallow water bathymetry soundings from the ATL03 global geolocated photon data product. With an accuracy of about ~50 cm and an orbit cycle of 91 days, the ICESat-2 bathymetry soundings can be used to derive frequent and broader information on coastal bathymetry at a global scale.

3. METHODOLOGY

HORIZONTAL GEODETIC CONTROL

The original horizontal position of the bathymetry data is deemed as accurate as the position of the satellite imagery: The horizontal position of Sentinel-2 is reported at 12m (CE95). All positions are provided in geographic coordinates referenced to the WGS84 horizontal datum. No further adjustments or improvements were made to the source imagery.

Table 2: *Coordinate Reference System parameters.*

Coordinate Reference System Parameters	
Projection	WGS 1984 UTM Zone 19N
Central Meridian	-69.0
Scale Factor	0.9996
Grid Coordinates	Projected

VERTICAL CONTROL

Depths are calibrated to the ICESat-2 sounding depths, which are calibrated to Mean Sea Level (MSL). During ICESat-2 depth retrieval processing, the source data is converted from WGS84 ellipsoidal heights to orthometric heights, based on the EGM2008 geoid as provided by NASA in the ICESat-2 ATL03 data product.

SDB PROCESS

The bathymetric retrieval method is based on the physical relationship between satellite observed surface reflectance and properties of the water column such as depth and bottom reflectance. A machine learning, forest-based classification (FBC) model was utilized to derive water depths from multispectral satellite imagery. For this supervised machine learning method, the calibration depth dataset (ICESat-2) acts as the dependent variable, and each spectral band and every band-ratio permutation that exists for that satellite sensor are used as independent variables. The FBC method differentiates itself from the log-ratio method by incorporating information from all spectral bands, not just green and blue bands. Minimal training allows the algorithm to determine which spectral bands have the most statistical correlation with the trained model to determine the most accurate water depths.

POST-PROCESSING

The resulting SDB surface was manually inspected and cleaned through a 2D editor in ArcPro. Shallow water masks were created based on in situuting the in situ points as shallow water mask labels and user input of deep water polygons. A randon forest algorithm classifies pixels that belong to optically water or deep water. Analysts removed any depth artifacts such as shadows, turbidity, cloud remnants, and optically deep water by referencing the imagery, in-situ data, and any external references available.

4. RESULTS

BATHYMETRIC DATA

The resulting SDB surface covers 7,053.89 km^2, with a maximum depth of -30m and a minimum depth of -0.1m. Depths are adjusted to Mean Sea Level tide (MSL).

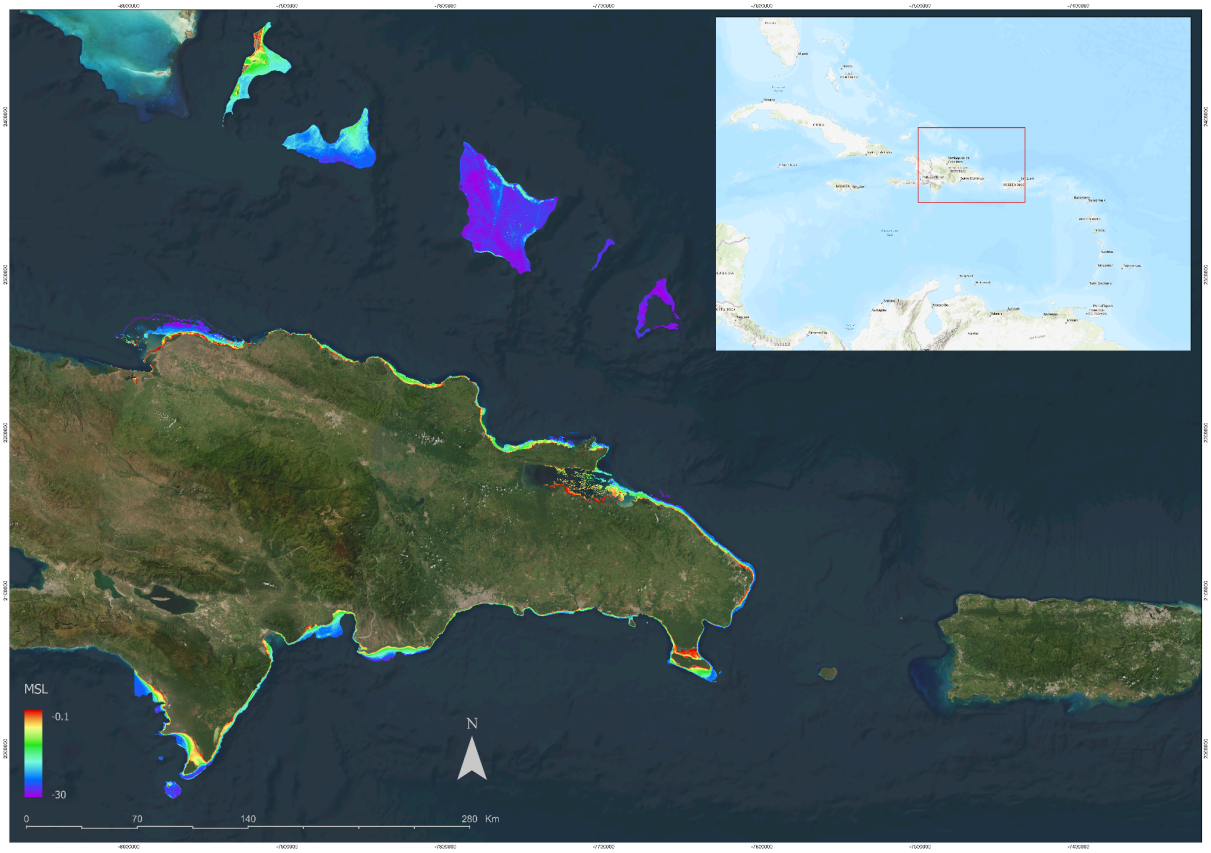


***Figure 4**. Produced SDB in Dominican Republic*

VALIDATION METHOD

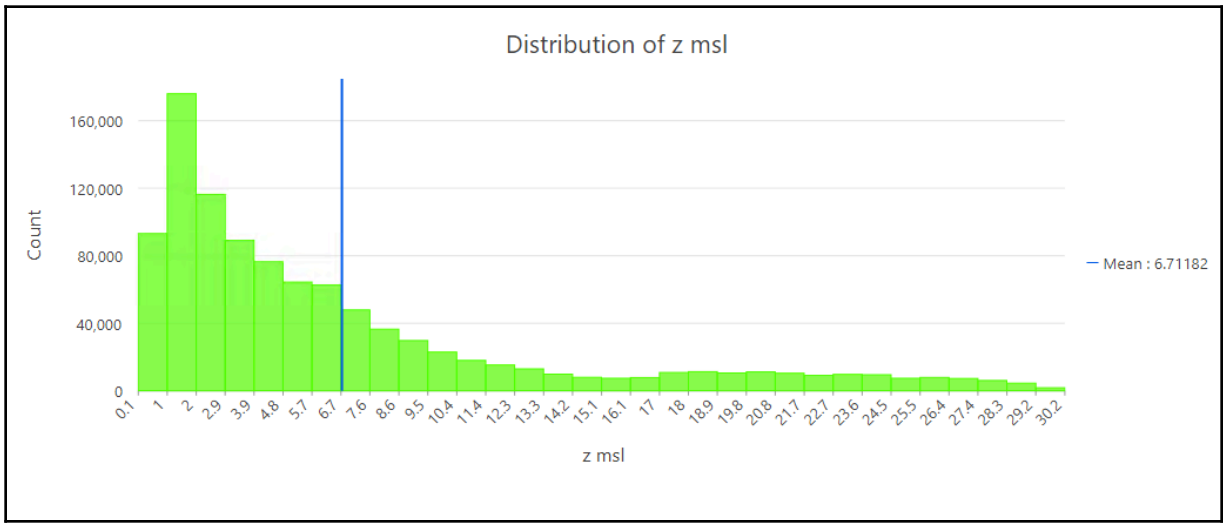
Each SDB surface was evaluated individually with the ICESat-2 data to assess the data accuracy of each iteration of SDB processing for each image. The ICESat-2 validation dataset data is a random selection of depth bins that was not included in the ICESat-2 calibration dataset. Statistical comparison of ICESat-2 bathymetric depths with SDB surfaces were divided into depth bins with ranges: above 0-0m, 0-2m, 2-5m, 5-10m, 10-20m,and 20-30m to provide more discretized comparisons. Statistics were calculated for each SDB surface individually using Mean Error (ME), Mean Absolute Error (MAE), Mean Square Error (MSE), Root Mean Square Error (RMSE), and Mean Absolute Percentage Error (MAPE). Statistical analysis of the Baffin Island SDB compared to ICESat-2 is presented in Table 3.

Table 3: *Statistical report on SDB surface accuracy compared to ICESat-2 Soundings.*

Interval	ME	MAE	MSE	RMSE	MAPE
0.12m - 30m	0.023	0.449	0.624	0.79	11.171
0m - 1m	-0.11	0.22	0.174	0.417	23.748
1m - 5m	-0.016	0.316	0.265	0.515	13.672
5m - 10m	0.091	0.457	0.517	0.719	7.301
10m - 15m	0.042	0.572	0.91	0.954	4.973
15m - 20m	-0.07	0.809	1.761	1.327	4.834
20m - 30m	0.219	1.091	2.507	1.583	4.726

Table 4: *Number of ICESat-2 soundings used for calibration/validation of RF SDB.*

Total Soundings Count during calibration	
Total Soundings Count	756,550
Depth Range (MSL)	0.09m to -30.1m
Total Soundings Count within AOI	
Total Soundings Count	1,012,129
Depth Range (MSL)	0.09m - 30.2m
Depth distribution of ICESat-2 soundings in Dominican Republic	



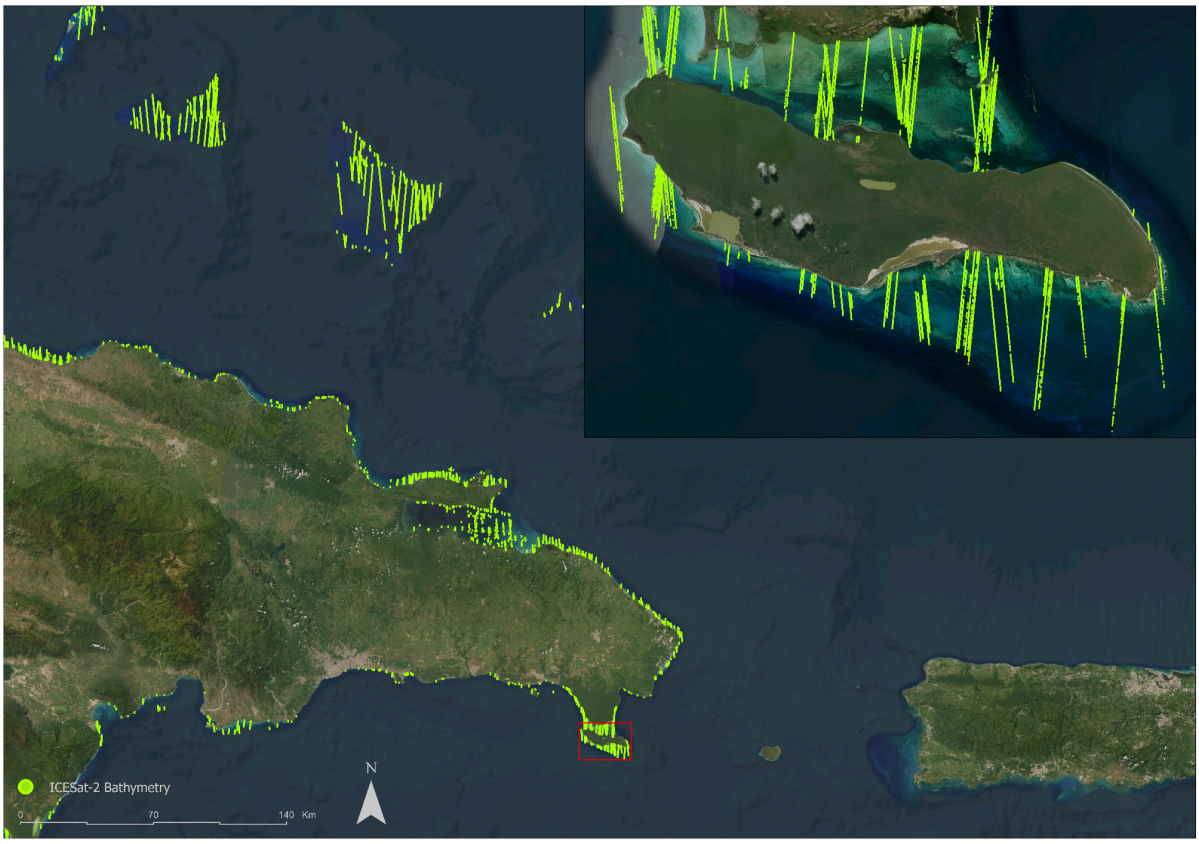


***Figure 5**. Overview of ICESat-2 Soundings in Dominican Republic.*

Data Gaps

The images included in this report capture the gaps caused by turbidity regimes.

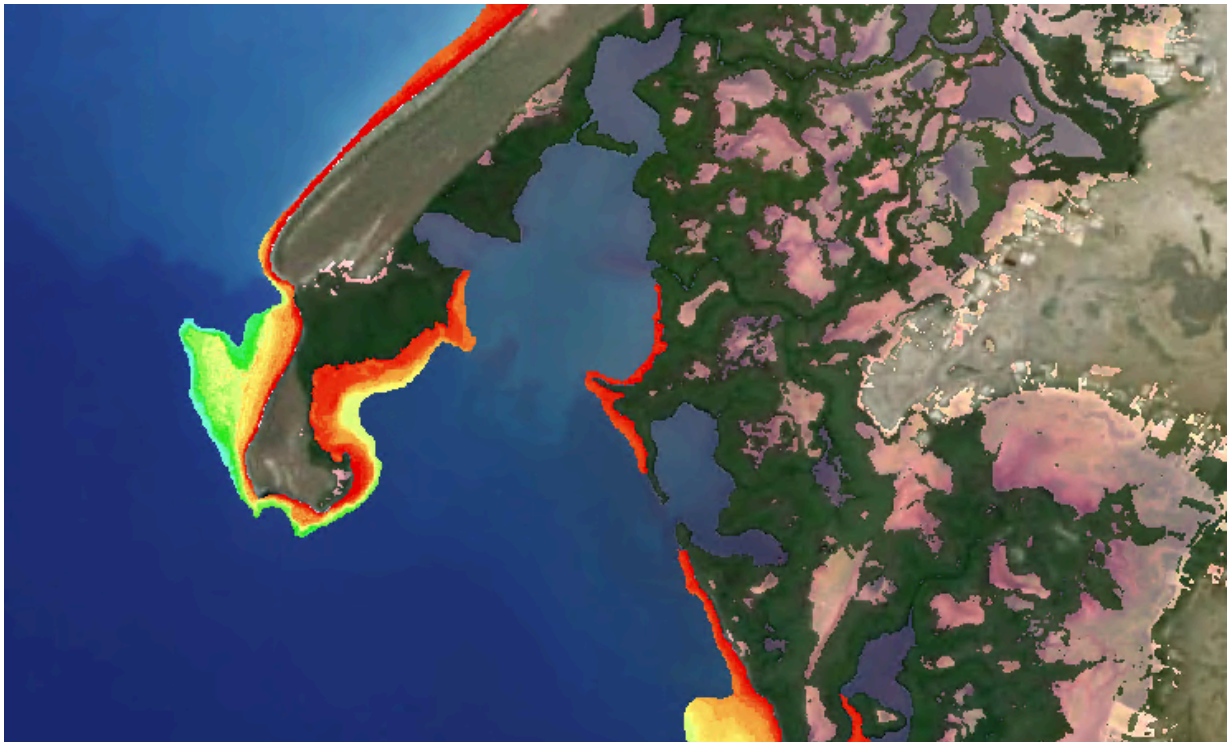


***Figure 6**. Turbidity regime in imagery 19QBB western coast of the AOI*

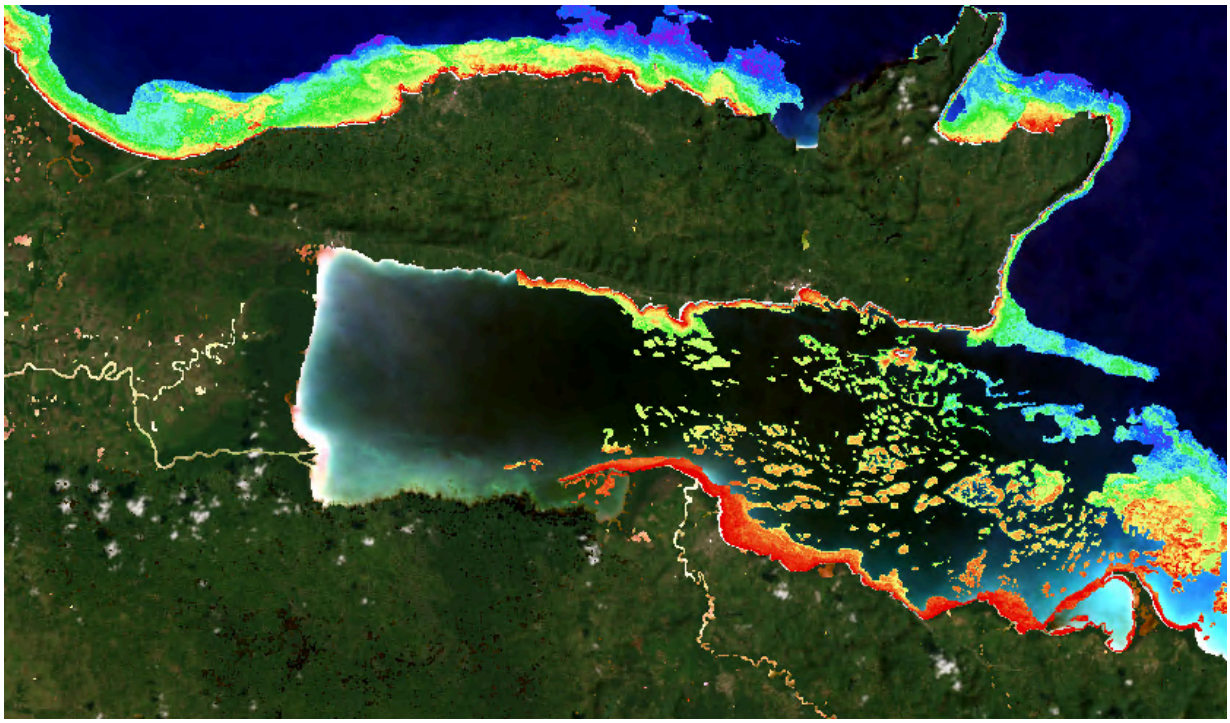


***Figure 7**. Turbidity regimes in imagery 19QDB in Bahia de Samana*

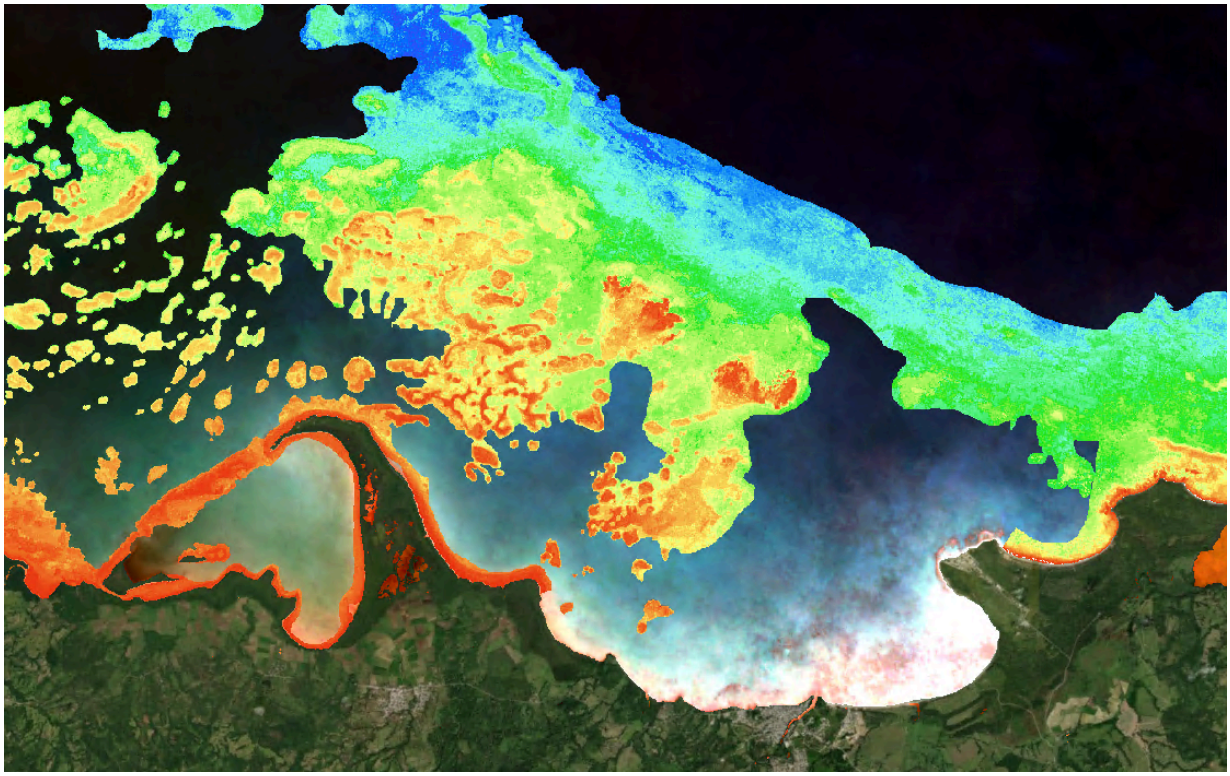


***Figure 8**. Turbidity regimes in imagery 19QDB*

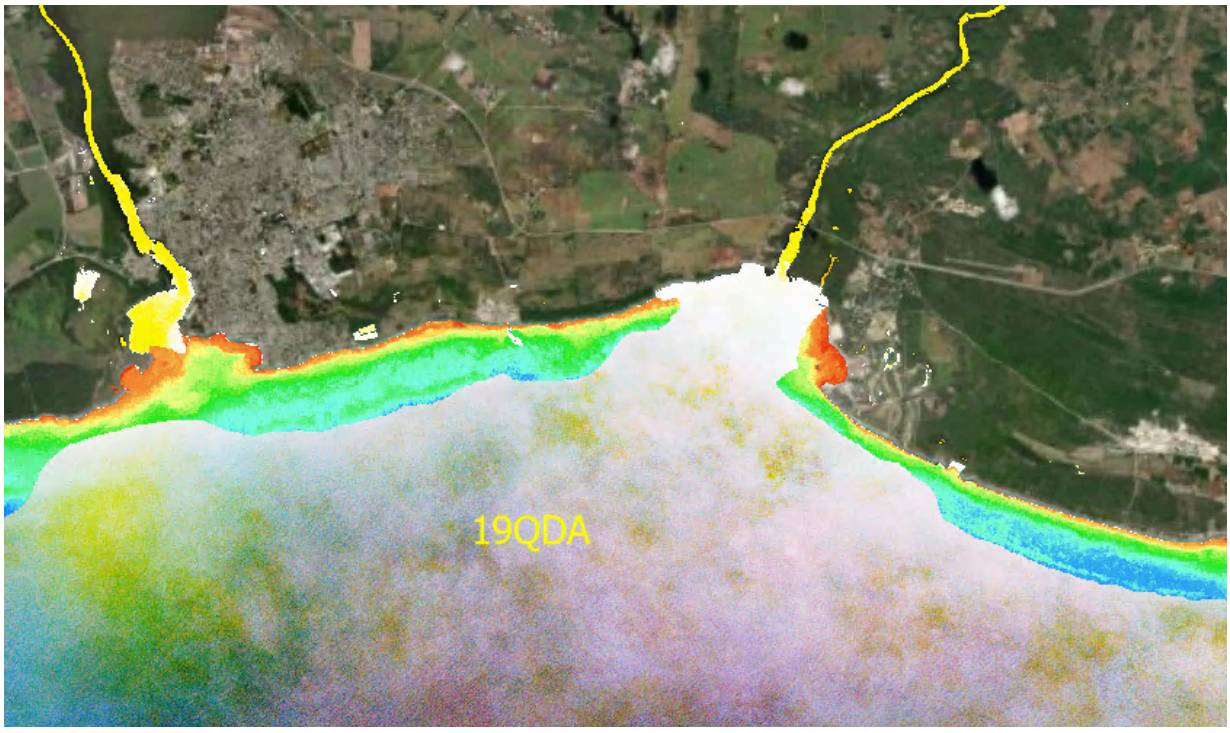


***Figure 9**. Turbidity regime in imagery 19QDA southeast shore of the AOI*

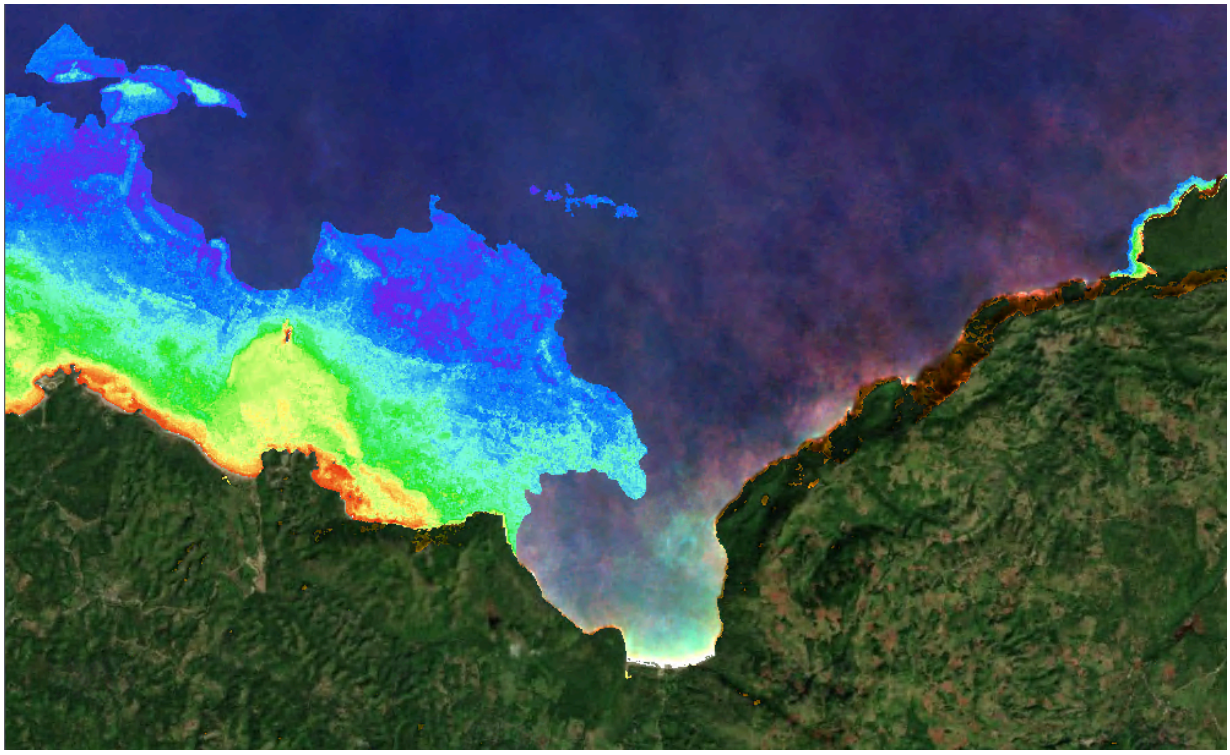


***Figure 10**. Turbidity regime in imagery 19QDB.*

CATZOC Zones

Category Zone of Confidence (CATZOC) is used to represent the level of accuracy or confidence in geodetic measurements. The large majority of data produced in the Dominican Republic falls into zones A2 and C. Within the provided CATZOC GeoTIFF, the following look-up table should be referenced:

***Table 5:** CATZOC GeoTIFF Look-up Table*

ZOC	GeoTIFF Coded Value
A2	1
C	2
D	3

Figure 11. *Example of CATZOC map in Dominican Republic mostly A2 zones and some B zones.*

5. CLAIMS & LIABILITY

Due to the impossibility of guaranteeing where every shoal is located, TCarta accepts no liability for any damages, or claims made as a result of using the Satellite Derived Bathymetry or derivatives of it, for navigational purposes.

6. DELIVERABLES

All deliverables have been provided in accordance with the UKHO Hydrographic Survey Specification (Satellite Derived Bathymetry), where applicable.

Seabed2030_Dominican_Republic_100m_SDB.zip

01_Reports

- **Survey Report**
  Dominican_Republic_Sept2024_SurveyReport.pdf

02_SDB

- **Single Band 100 m SDB Surface**
  Dominican_Republic_Sept2024_SDB_WGS84_UTM19N_MSL_100m.tif