Satellite Computed Bathymetry Assessment- SCuBA

One of the National Geospatial-Intelligence Agency's (NGA) and the National Oceanic and Atmospheric Administration's (NOAA) missions is to ensure the safety of navigation on the seas by maintaining the most current information and the highest quality services for U.S. and global transport networks. To achieve this mission, we need accurate coastal bathymetry over diverse environmental conditions. The SCuBA program focused on providing critical information to improve existing bathymetry resources and techniques with two specific objectives. The first objective was to validate National Aeronautics and Space Administration's (NASA) Ice, Cloud and land Elevation SATellite-2 (ICESat-2), an Earth observing, space-based light detection and ranging (LiDAR) capability, as a useful bathymetry tool for nearshore bathymetry information in differing environmental conditions. Upon validating the ICESat-2 bathymetry retrievals relative to sea floor type, water clarity, and water surface dynamics, the next objective is to use ICESat-2 as a calibration tool to improve existing Satellite Derived Bathymetry (SDB) coastal bathymetry products with poor coastal depth information but superior spatial coverage. Current resources that monitor coastal bathymetry can have large vertical depth errors (up to 50 percent) in the nearshore region; however, derived results from ICESat-2 shows promising results for improving the accuracy of the bathymetry information in the nearshore region.

Project Overview

One of NGA's and NOAA's primary missions is to provide safety of navigation information. However, coastal depth information is still lacking in some regions—specifically, remote regions. In fact, it has been reported that 80 percent of the entire seafloor has not been mapped. Traditionally, airborne LiDARs and survey boats are used to map the seafloor, but in remote areas, we have to rely on satellite capabilities, which currently lack the vertical accuracy desired to support safety of navigation in shallow water.

In 2018, NASA launched a space-based LiDAR system called ICESat-2 that has global coverage and a polar orbit originally designed to monitor the ice elevation in polar regions. Remarkably, because it has a green laser beam, ICESat-2 also happens to collect bathymetry information. ICESat-2 (nasa.gov)

With algorithm development provided by University of Texas (UT) Austin, NGA Research and Development (R&D) leveraged the ICESat-2 platform to generate SCuBA, an automated depth retrieval

algorithm for accurate, global, refraction-corrected underwater depths from 0 m to 30 m, detailed in Figure 1 of the documentation. The key benefit of this product is the vertical depth accuracy of depth retrievals, which is ideal for a calibration tool. NGA and NOAA National Geodetic Survey (NGS), partnered to make this product available to the public for all US territories.

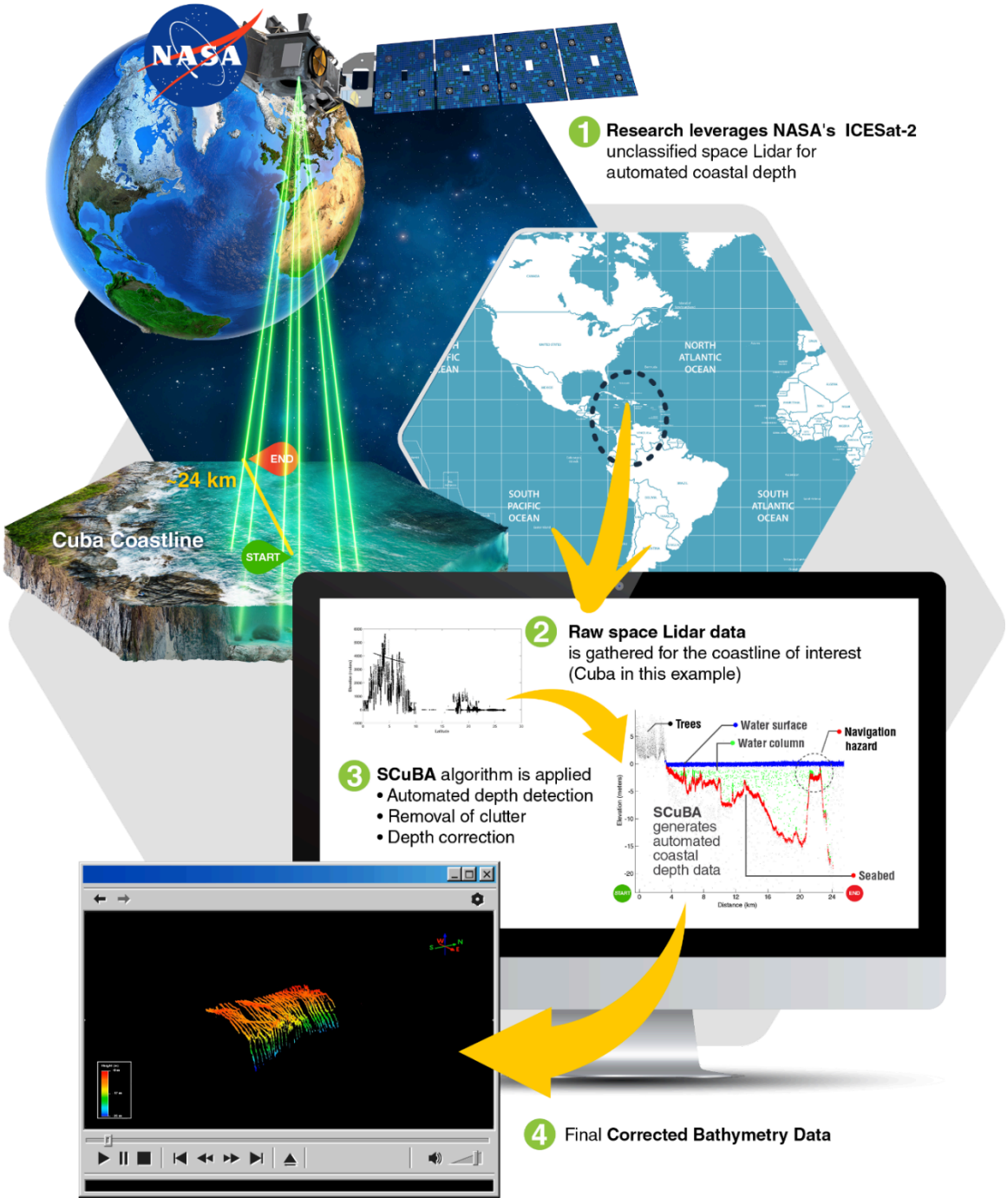

Figure 1. Depiction of how SCuBA works

How It Works

- ICESat-2 collects over a given region.
- The SCuBA algorithm automatically detects coastal underwater depths, removes the clutter, and applies a depth correction from refraction (bending of light) underwater.
- SCuBA products provide classification of water surface (refraction corrected) and underwater detected seabed (red line depth correction applied).

Results: Researchers compared the SCuBA-derived bathymetry retrievals to airborne LiDAR measurements from NOAA to validate SCuBA's accuracy of depth retrievals. Table 1 shows four locations with different water clarities (known as kd values), which reveal that the Outer Banks of North Carolina have the lowest clarity (most turbid) water conditions. We found a root mean square error (RMSE) ranging from approximately 30 cm to 1 m, depending on the water clarity.

Table 1. kd Values for Outer Banks, North Carolina

Region	Avg Refracted RMSE (m)	Avg kd490 Value for ICESat-2 Tracks
St. Thomas	0.65	0.05
Florida Keys	0.28	0.97
Outer Banks NC	0.83	0.78
Greater Alaska	0.97	0.72

How to download a specific region

The data files are zipped in a 900km X 400km grid and can be identified using the US_SCuBA_Processing_Legend_UTMtoState.docx .

On the NOAA NODD (NOAA Open Data Dissemination (NODD) | National Oceanic and Atmospheric Administration) site the files are hosted as "SCuBA_17R_FL_YYYY.zip"

In this zip file example SCuBA_17R_FL_YYYY.zip, the UTM code is 17R. The two state letter corresponds to Florida and is also added in the filename.

SCuBA_17R_FL_YYYY.zip

The year the data was collected will follow the location as YYYY.

How to use the data

Each folder provides the date and time stamp that ICESat-2 collected over a given region. For example

ATL03_20220104013002_01951407_006_01

_ is the raw photon product used to derive SCuBA

_is the YYYYMMDD of the collection from ICESat-2 and to follow the timestamp

_is the version of the ATL03 data release that was used in the SCuBA derivation

Within the folder, detailed in Table 2, there are files labeled gt1-3l and gt1-3r, which refers to the six laser beams on ICESat-2 ordered in three pairs of left (l) and right (r) beams and weak and strong beams. Note that left and right does not translate to weak and strong as left and right change depending on whether collection is north to south.

Researchers should start identifying what track or beams cover the area of interest. This can be done by using the *.kml files

After researchers identify the beams and tracks that cover the area, they can quickly screen the data for bathymetry data with the .png images of the algorithm outputs or move on to using a .xyz or .las file to view the outputs directly in a software application for point clouds. Note that classification labels exist in the ***all.xyz and ***.las files in which the water surface= 41 and the seafloor=40. This allows the user to filter the data on either value.

Also note that the ****Z_GEOID.xyz data is available to use and only includes the identified seafloor and no water surface. This data is the bathymetry-labeled photons for which heights have been corrected relative to the geoid.

All bathymetry products are refracted corrected.

Table 2. ICESat-2 Data Files

Outputs	File types	Description
Data Files water surface =41 and seafloor=40	SCUBA_{gtx}_{granule_name}.las	Contains photon information for sea surface and bathymetry photons
Recommended Data Files water surface =41 and seafloor=40	SCUBA_{gtx}_{granule_name}_Z_All.xyz	Contains photon information for sea surface and bathymetry photons Column names: Index, Time, Longitude, Latitude, Z_GEOID, Z_Ellipsoid, Z_Local, X_UTM, Y_UTM, Label, Sea_surf_confidence, bathymetry_confidence
Seafloor only data files	SCUBA_{gtx}_{granule_name}_Z_Geoid.xyz SCUBA_{gtx}_{granule_name}_Z_Geoid.txt	A XYZ file (no header) that only contains bathymetry labeled photons whose heights have been corrected relative to the geoid. No column names The header for this file is contained in the accompanying SCUBA_{gtx}_{granule_name}_Z_Geoid.txt file. - A txt file that only contains the header information for the SCUBA_{gtx}_{granule_name}_Z_Geoid.xyz file.
Track location – Google earth friendly	SCUBA_{gtx}_{granule_name}.kml	A kml file that samples points along the granule for later viewing in GIS software.
Quick look plots	SCUBA_{granule_name}_{gtx}_segs_{#n_of_#total_segs}_FINAL.png	- A png file of the classified points and noise points for each processed segment. Legend: grey - unclassified point blues - sea surface greens - bathymetry red - refraction corrected bathymetry