GeoAcoustics GeoSwath Plus
Data Processing with CARIS HIPS 8.1
in Support of Sandy Supplemental Research

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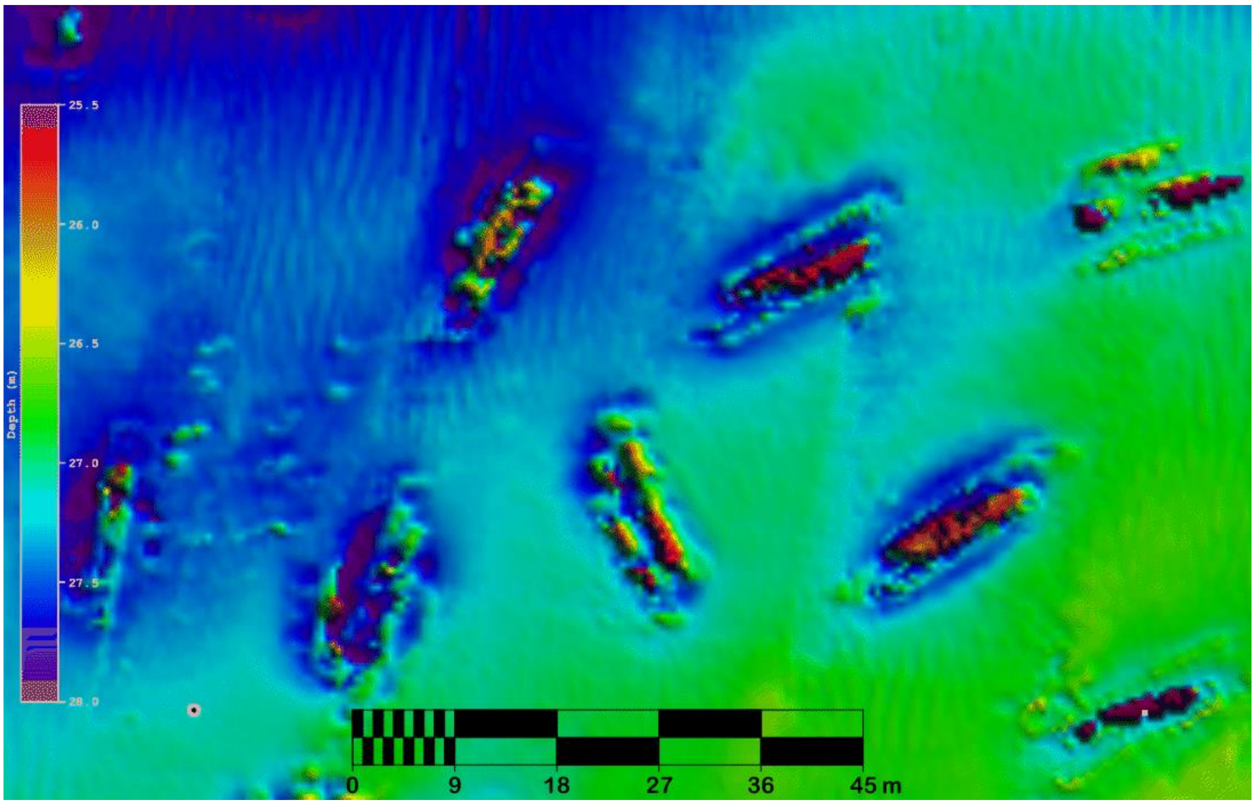


Sunken subway cars and sediment waveforms are readily apparent in this GeoAcoustics GeoSwath Plus survey conducted by AUV over Redbird Reef off the coast of Delaware. Data were gridded at 50 cm using the CUBE algorithm in CARIS HIPS 8.1 without manual editing. Depth scale is 25.5 m (purple) to 28.0 m (dark blue).

PURPOSE

Phase-measuring bathymetric sidescan (PMBS) echosounders, such as the GeoAcoustics GeoSwath Plus, offer potential increases in swath width and sounding density in shallow waters compared to multibeam echosounders. These advantages are balanced by the drawbacks of increased volume and 'noisiness' of PMBS data, which have traditionally presented challenges in post-processing but may now be accommodated using existing multibeam workflows in modern software.

CARIS HIPS 8.1 is a commercial off-the-shelf software package employing the Combined Uncertainty and Bathymetry Estimator (CUBE) algorithm to effectively handle large PMBS datasets and produce bathymetric surfaces requiring only minor manual editing. This document is intended to supplement the CARIS HIPS 8.1 multibeam workflow [Help → User Guides → User Guide (workflow)] by providing additional information specific to the processing of GeoAcoustics GeoSwath Plus PMBS data. Unless specified herein, the CARIS User Guide should be consulted for the orders and details of data processing steps.

This guide does not represent an endorsement of any particular echosounder or software package.

GEOACOUSTICS DATA EXAMPLES

This processing guide mentions examples of GeoAcoustics sonar data collected at Redbird Reef off the coast of Delaware. The Redbird Reef site was impacted by Super Storm Sandy and is considered relevant to the Sandy Supplemental research proposal submitted by the University of New Hampshire Center for Coastal and Ocean Mapping (UNH CCOM). Data were collected with a 500-kHz GeoSwath Plus PMBS installed aboard the 'Dora' Gavia autonomous underwater vehicle (AUV) operated by the University of Delaware and UNH CCOM. Because GeoAcoustics data may be collected from a variety of platforms and vehicles, parameters specific to the Gavia AUV described here may or may not apply to processing of data collected from other vessels. These parameters include, but are not limited to, sensor offsets in the vessel configuration file and sources for navigation, draft, tide, and attitude data.

VESSEL CONFIGURATION FILE

GENERAL

CARIS requires a HIPS Vessel File (HVF) describing the positions (and angles, as appropriate) of all sensors from which data must be integrated. HVF definition is the first step in any CARIS project, unless an HVF applicable for the survey is already available. Note that the HVF was called a Vessel Configuration File (VCF) in a previous version of HIPS, and 'VCF' is still referenced occasionally in the CARIS help documentation.

Correct definition of the HVF is of critical importance for GeoSwath Plus data because these systems utilize two transducer arrays which are treated independently in CARIS. CARIS identifies the port and starboard transducers as numbers 1 and 2, respectively.

The CARIS HVF coordinate system is X positive to starboard, Y positive forward, and Z positive downward. Rotation about these axes follows the right-hand rule: pitch (about the X axis) is positive with the bow up, roll (about the Y axis) is positive with the port side up, and yaw or azimuth (about the Z axis) is positive with bow rotation to starboard (compass convention). Note that these sensor installation attitude sign conventions may differ from those applied for attitude of the entire vessel reference frame, such as in vessel attitude data recorded by an onboard motion sensor.

Setup Depending on Sound Velocity Correction

GeoSwath Plus sounding data in RDF format include transducer-relative angles and ranges without refraction correction. Refraction correction is performed in the HIPS workflow through the Sound Velocity Correction (SVC) step. While not strictly required by the HIPS workflow for other applications, SVC must be performed for GeoSwath Plus data to properly account for transducer installation angles. The SVC step must be completed even if no refraction correction is desired.

The installation angles for the port and starboard receive arrays must be entered in the SVP1 and SVP2 fields, respectively; these values should match the TPU Trans Roll and Trans Roll 2 offsets. For example, GeoSwath Plus transducer installation roll angles are nominally 60° to either side from the vertical axis. Under the CARIS sensor installation roll sign convention, these installation angles should be entered as +60° for SVP 1 Roll (port) and -60° for SVP 2 Roll (starboard).

Modifications to these installation angles (e.g., transducer angular offset calibration results) may be applied in the Transducer 1 and Transducer 2 fields of the HVF in a manner that is consistent with this CARIS sign convention.

The Transducer 2 entry includes a field for 'beams.' Because swaths containing more than 2000 samples (referred to as 'beams' in this context only) are automatically decimated by CARIS, this field may be set to an arbitrary number (i.e., 2001).

Changes to the HVF

It is important to carefully manage the vessel configuration file. With care paid to the dates for each entry, multiple sets of setting can be specified in a single file to provide a running history of changes. Alternatively, separate vessel configuration files may be used, though this may require separate CARIS projects for each survey.

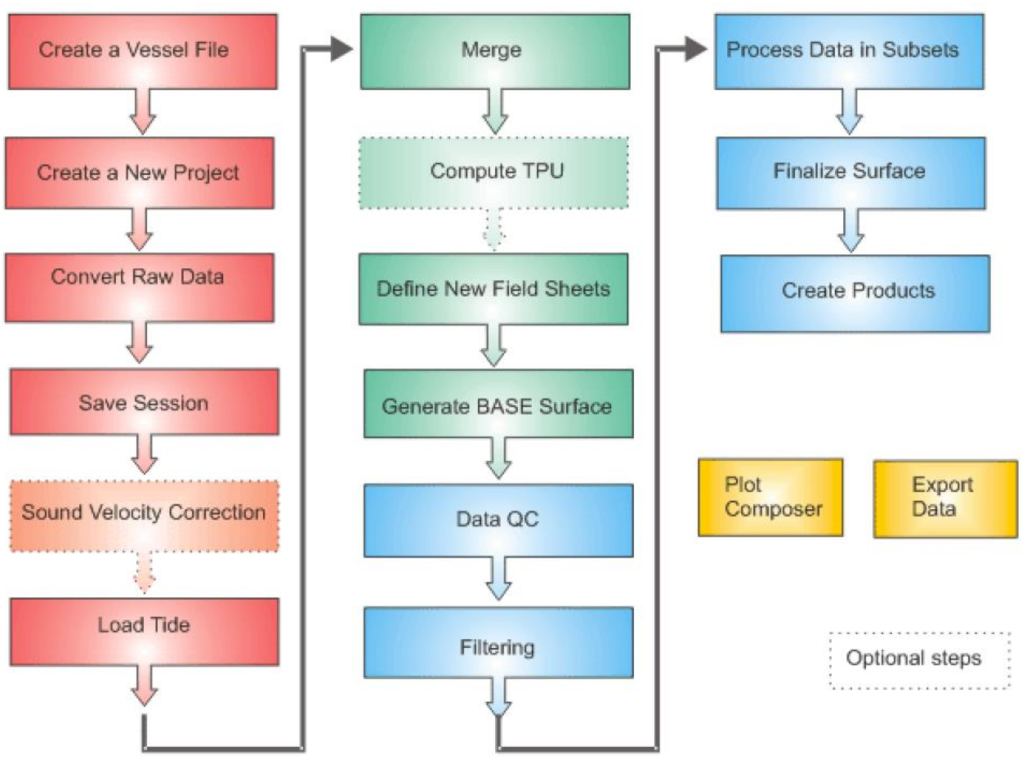
Some changes to the vessel configuration file require data to be reimported (attitude sensor latency, for example) whereas other changes do not (TPU parameters, for example). When in doubt, it is safest to reimport the data after any vessel file changes.

WARNING

Overlapping sensors (i.e., Transducer 1 and SVP 1 for GeoSwath Plus systems) may not be distinguishable in the CARIS Vessel Editor 3D view because the markers are the same size. Activation/deactivation may help distinguish overlapping markers, but may also lead to loss of entries in the vessel file. Be careful to keep at least one sensor active at all times or an error may result which removes all entries. Finally, be sure to activate all sensors required for the particular survey configuration and verify all offsets before saving the HVF and processing survey data.

DATA PROCESSING WORKFLOW

The steps outlined below follow the CARIS HIPS 8.1 general workflow (p. 18-20, User Guide) for multibeam data with additional information as appropriate for processing GeoAcoustics GeoSwath Plus PMBS data.



Data processing workflow as depicted in the CARIS HIPS and SIPS 8.1 User Guide, page 18.

1. Create or Copy an HIPS Vessel File (HVF)

a. If an HVF exists for the data collected, it must be copied to *HDCS_Data/VesselConfig/* before it will be selectable during project creation. In some installations of CARIS, the *HDCS_Data/VesselConfig/* directory is not created by default; the user must navigate to the CARIS root directory and create it.

b. If no HVF exists, the user should consult the CARIS User Guide ‘Create a New HVF’ section and *Vessel Configuration File* above.

c. WARNING: Dates in the HVF must precede the data to be processed. Otherwise, the data import process will fail.

2. Create a New Project

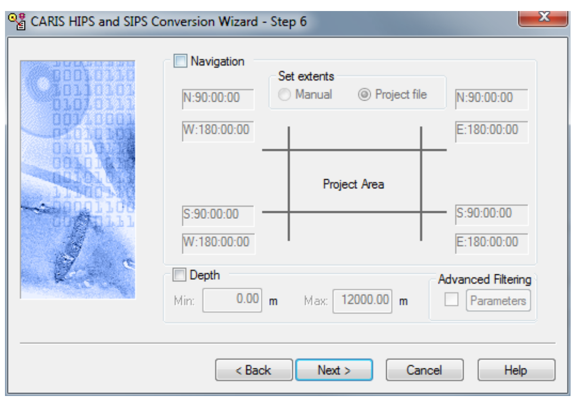
a. Establish the project-vessel-day directory structure.

3. Convert Raw Data

a. Using the Conversion Wizard, select *GeoAcoustics* for the data format

b. Filtering during import is an effective option for reducing outliers in PMBS data if the ranges of depths is known. Note that depth filters applied during data conversion are relative to the transducer and not relative to total water depth.

c. Select Navigation and/or Depth filters, if desired. Advanced Filtering during data conversion is not available for GeoSwath Plus data in CARIS HIPS 8.1.



d. In CCOM experience, additional filtering options during data conversion Step 7 have been used effectively for removing outliers. For example, using GeoSwath Plus data collected with the Gavia AUV, import filter parameters which appeared to reasonably reduce outer swath noise are as follows:

i. Amplitude Filtering: 10%

1. NOTE: CARIS determines the minimum and maximum amplitudes of soundings in a ping, then filters soundings with amplitudes below the selected percentage of that range. This filter setting does not

correspond to the percentage of soundings to be filtered. For example, an amplitude filter level of 50% applied to one GeoSwath Plus file rejected 96% of soundings; 10% and 1 % filter levels rejected 50% and 21% of soundings, respectively.

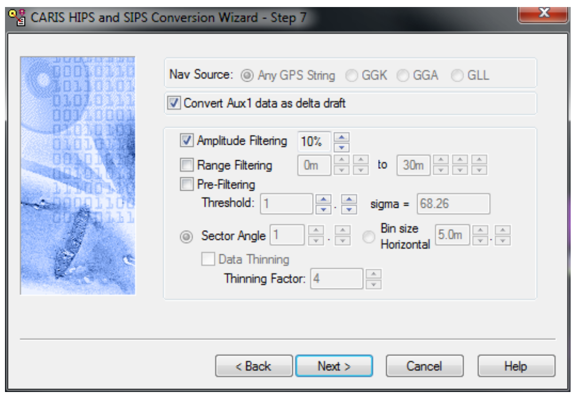
ii. Range Filtering: not selected

iii. Pre-Filtering Threshold: not selected

1. NOTE: This option does not appear to result in any filtering of raw data in HIPS 8.1

iv. Data Thinning: not selected

1. NOTE: A thinning method is automatically applied to swaths containing more than 2000 soundings or 'beams'



e. See **Help → Help Topics → HIPS and SIPS Workflow → Convert Data → Select Filters → Advanced Filtering** for more information.

f. NOTE: Screenshots in the Help documents do not always match CARIS 8.1 windows.

4. Open Converted Files

5. Save Session

6. Load Delayed Heave (Optional)

a. Load post-processed heave data, if available, to reduce heave uncertainty.

b. This step is optional and no delayed heave is loaded in this example.

7. Load Delta Draft (Optional)

a. Load delta draft to provide additional correction for the vertical position of the vessel reference frame relative to the water surface.

b. This step is optional and may not be necessary for all data collection methods, such as from a surface vessel with reliable vertical position data.

c. In this example, loading a delta draft file is necessary because significant surface swell yielded artifacts in the pressure sensor record. The delta draft file is created outside of CARIS.

8. Load Tides

a. Loading tide data is a necessary step in the CARIS HIPS 8.1 workflow.

b. Select either a tide file (.tid) or a tide zone definition file (.zdf).

c. A zero-tide file (zerotide.tid) is available under HDCS_Data\Tide and may be applied when tidal amplitudes are negligible. Note that the dates in the tide file must cover the data time range. The default zerotide.tid may be modified with any text editor to accommodate the data time range.

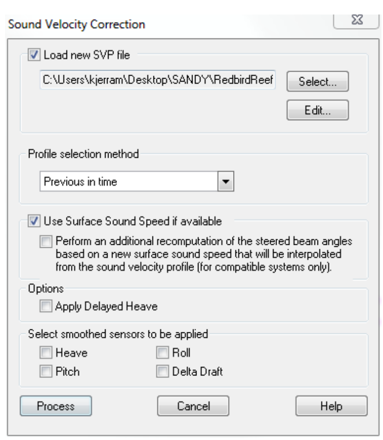
9. Sound Velocity Correction

a. Sound Velocity Correction (SVC) is typically performed to address refraction artifacts in multibeam or PMBS data. While not mandatory for all data types, this step is required when processing GeoAcoustics data to properly apply the transducer installation angles recorded in the SVP 1 and SVP 2 fields of the HVF.

b. If no sound speed profiles are available or desired for refraction correction, a uniform (isovelocity) profile may be created with a text editor outside of CARIS and loaded to satisfy the SVC requirement for transducer installation angles.

c. The option ‘Use Surface Sound Speed if available’ should be checked.

d. The option ‘Perform an additional recomputation of the steered beam angles…’ should be checked if the surface sound speed data are not available or the sound speed profiles selected are believed to be more reliable.



10. **Merge**

a. The Merge process is required.

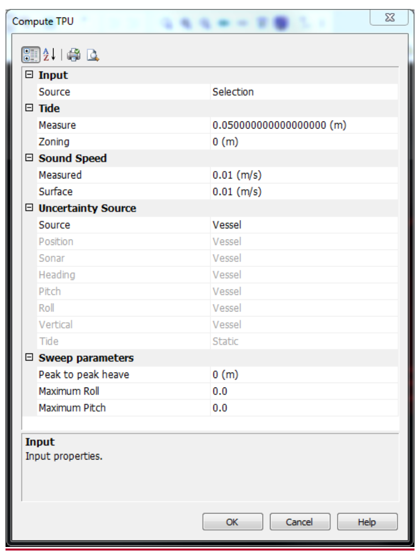
b. After merging, the raw data have been converted to HIPS format with corrections for vessel draft, attitude, tides, and refraction (including transducer installation angles) and are now ready for calculation of total propagated uncertainty and incorporation into a gridded surface.

11. **Compute Total Propagated Uncertainty (TPU)**

a. This step is required for creating a BASE surface using the Combined Uncertainty and Bathymetry Estimator (CUBE) algorithm in CARIS HIPS 8.1.

b. NOTE: As of writing, CARIS HIPS 8.1 does not incorporate an echosounder uncertainty model for GeoAcoustics systems. Thus, TPU relies primarily on parameters specified in the HVF and other uncertainty sources specified in this processing step. An uncertainty model for this system is expected to be implemented in a future release.

c. Enter uncertainty values as appropriate for the data sources and click **OK**.



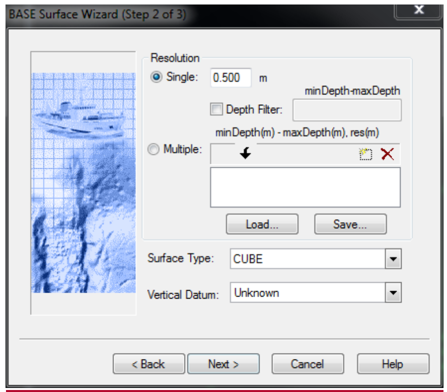
12. **Create a Field Sheet**

a. This step is required for creating a BASE surface in CARIS HIPS 8.1.

13. **Create a CUBE surface**

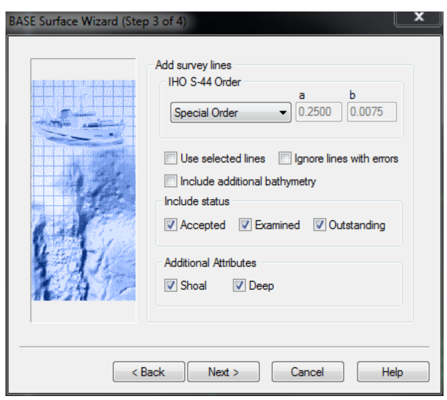
a. The CUBE algorithm is readily applied to PMBS data following the CARIS workflow. In CCOM experience, CUBE processing has handled large PMBS datasets and effectively rejected outliers to develop reasonable hypotheses for bathymetric surfaces. As with multibeam datasets, manual inspection and additional sounding rejection or hypothesis selection may be necessary.

b. Depth filters may be selected during surface creation. Note that depth filter values are water depth rather than relative to the transducer (as with filters applied during data conversion).



a. Select the desired IHO specification. CUBE determines the range inside which soundings will contribute to a grid node by the criteria specified in the IHO specifications. For this example, data density is assumed to be sufficient to support Special Order.

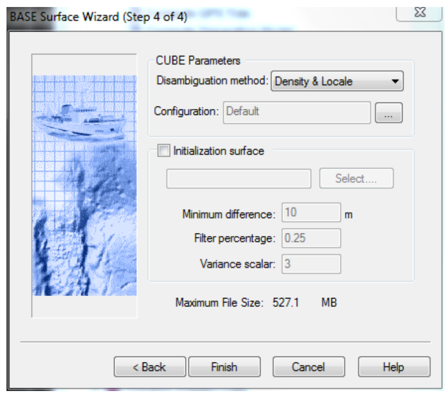
b. Select the 'Shoal' and 'Deep' options to create additional layers showing the shoal and deep hypotheses, which may assist in data cleaning.



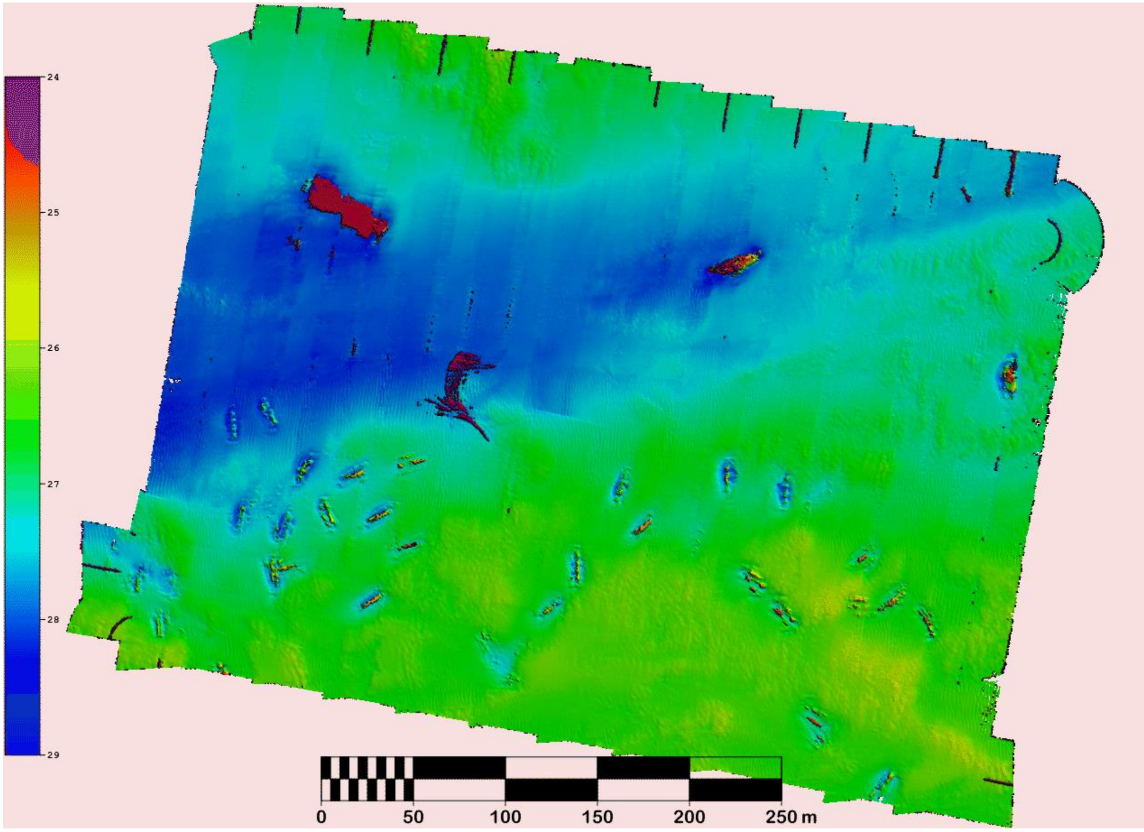
c. CUBE generates multiple hypotheses depending on agreement among soundings contributing to a grid node, then applies a disambiguation algorithm to determine which hypothesis is the most likely to be acceptable for each node. CUBE makes this determination based on the number of soundings contributing to the hypotheses (density), the nearness of the hypotheses to those in adjacent grid nodes (locale), or a blending of the two methods. The blended option 'Density and Locale' is typically selected for most CUBE surfaces.

d. Uncheck 'Initialization surface' unless using an existing CUBE surface for disambiguation and/or additional filtering.

e. CUBE offers Advanced Options to optimize its operation or meet additional criteria. These options can be found under the **Configuration** ellipsis [...]. These parameters are typically left unchanged for routine CUBE processing.



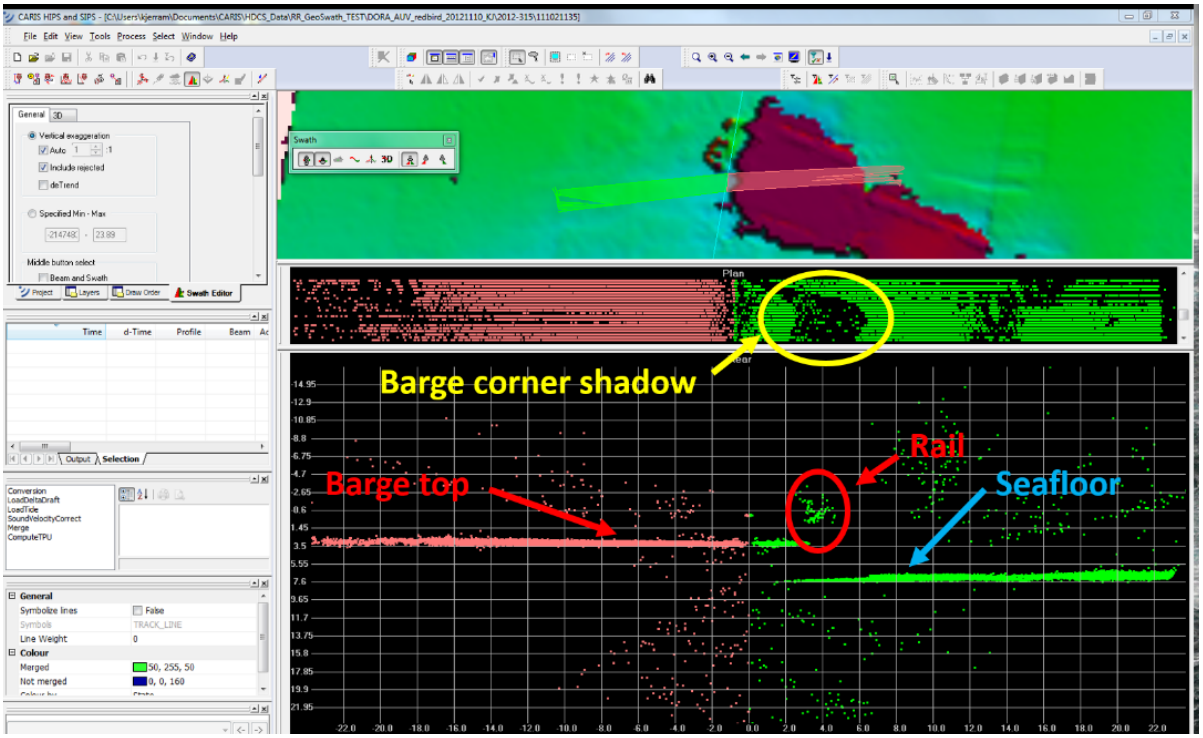
f. Click **Finish** to begin computing the CUBE surface.



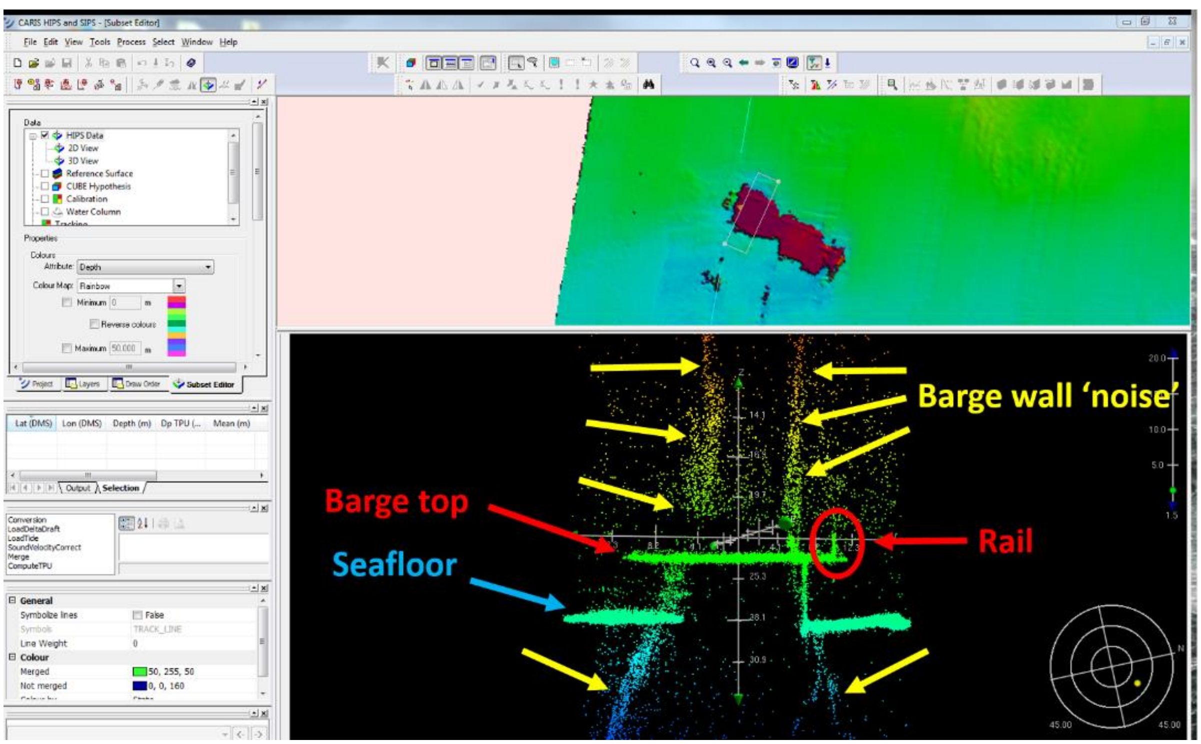
An example of GeoSwath Plus PMBS bathymetry data collected at Redbird Reef and gridded at 50 cm resolution using the CUBE implementation in CARIS HIPS 8.1, as outlined in the workflow in this document. The scattered features are submerged railway cars (lower image) and a barge (upper left of image). The color scale is 24 m (purple) to 29 m (dark blue). No manual inspection or rejection of soundings has been performed. The most obvious artifacts include outer swath errors during turns (upper right and left of center) and seabed penetration near nadir (along most lines). Additionally, a small transducer installation roll angle adjustment may be necessary, as evidenced by the slight discrepancies between outer swaths on reciprocal headings in flat regions (blue and light blue, left of center).

14. Data inspection and product creation

a. While PMBS data are likely to appear both higher in density and 'noisier' than multibeam data, inspection of the surface and removal of outliers are accomplished using the same tools. Swath Editor and Subset Editor may be used for inspecting and editing the surface prior to final product creation. Examples of a barge and associated noise along its edges as seen in both editors are included below.



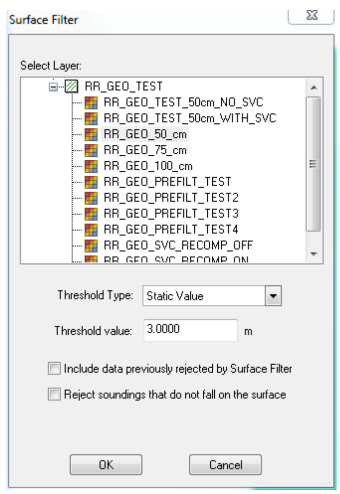
Example of the barge top, rail, and seafloor in Swath Editor. The edge of the barge passes to starboard of the GeoSwath Plus, creating a 'shadow' region of low sounding density on the seafloor.



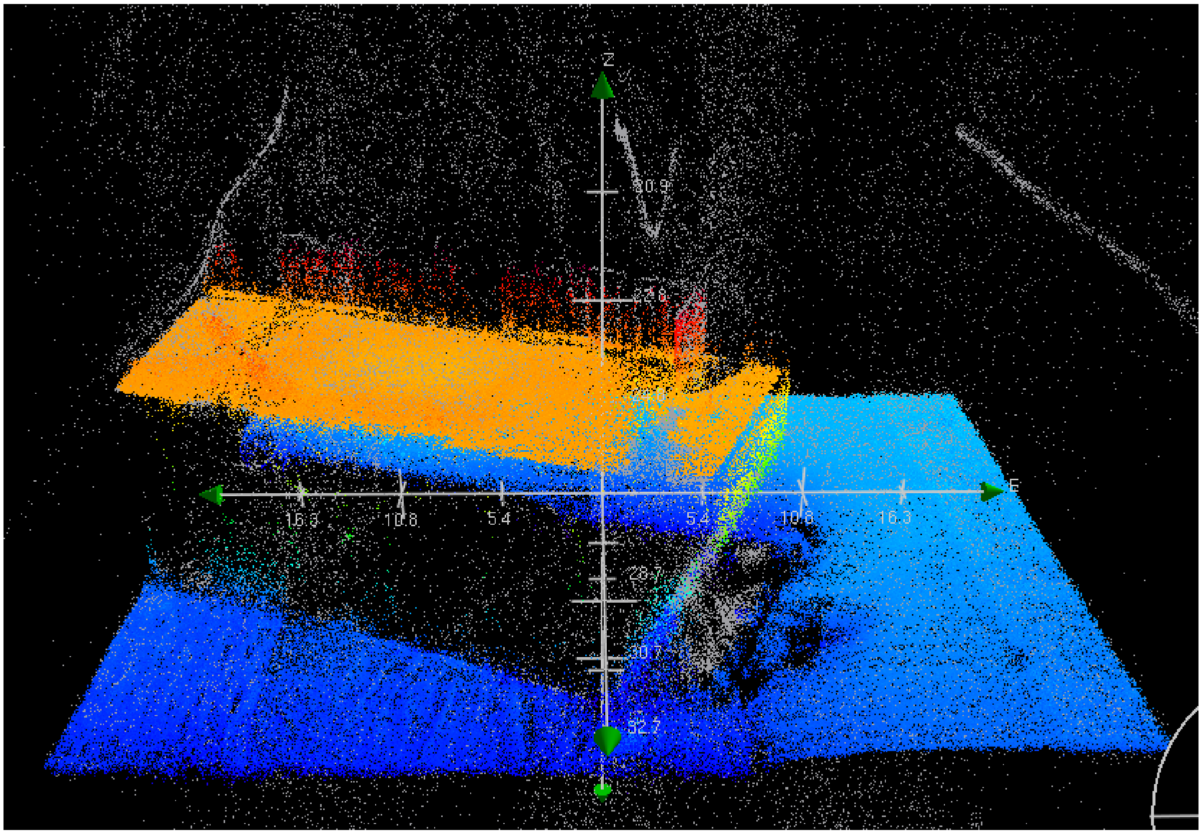
Example of the barge top, rail, and seafloor in Subset Editor. The large vertical arcs of soundings correspond to acoustic returns from the barge walls at similar ranges having inaccurate target angles.

b. In CCOM experience, Surface Filtering has also been effective for removing noise in GeoSwath Plus data by excluding soundings beyond a selectable threshold from a CUBE surface.

c. Select all lines to be cleaned and click **Tools → Apply Filters → Surface Filter**. Select the CUBE surface to be used as a reference and the threshold to apply (depth difference, standard deviation, etc.). In this example, soundings in a grid cell are rejected if they fall more than three standard deviations from the CUBE surface gridded at 50 cm.



d. An example of a barge and railing after Surface Filtering is shown below.



In this example of GeoAcoustics GeoSwath Plus data collected at the Redbird Reef site off the Delaware coast, a combination of the CUBE processing and subsequent surface filtering is used to reject the majority of noisy soundings while retaining a sunken barge and preserving a railing along its top edge. Coherent lines of noise in the top of this image result from the transmit pulse and therefore depict the approximate path of the AUV used for data collection.