NOAA QC Tools: Origin, Development, and Future

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Abstract

Advancing multibeam technology allows us to map the seafloor better than ever before, and we have plenty of stunning bathymetry to show for it. Yet the ever-increasing data volume presents some challenges during both quality review and in its generalization to nautical chart scale. Specific challenges and inefficiencies in these processes are addressed with NOAA QC tools, specifically: 1) "flier finder", which scans gridded bathymetry and flags anomalous data "fliers" for easy identification and removal, 2) feature scans, to ensure proper attribution and accurate representation within gridded bathymetry, and 3) an automated method of comparing survey soundings to those charted, as a formal means of chart comparison, identification of dangers to navigation, and also in the evaluation of a prospective chart sounding selection.

This paper discusses the QC tools listed above, with regards to: 1) their organic development within NOAA, to alleviate redundant, manually intensive tasks better suited for automation, 2) their implementation into the Rapid Survey Assessment (RSA) process of the NOAA Hydrographic Surveys Division (HSD), 3) their joint development with the Center for Coastal and Ocean Mapping & Joint Hydrographic Center (CCOM/JHC) through their integration within the HydrOffice research framework, and 4) future and ongoing improvements.

Proposed innovation includes flier identification through a multi-detector algorithm, a “smart” chart sounding selection, and a wide range of task-specific applications to facilitate all phases of ocean mapping.

Introduction

Whether onboard a survey vessel or inside a charting office, too often we allow conditions to persist that require personnel to complete monotonous, tedious tasks. Completing the same task over and over again is hardly the best use of their time, and furthermore, these tasks are ill-suited for a human, because by nature they will make a mistake. These tasks are better left to automation, while the human focuses on tasks they can do better than machines.

The existence of such monotonous tasks may be the result of software limitations. Manufacturers are only responsive to customers to a certain degree, and furthermore, very particular in-house requirements and best practices may never be commercialized. But software constraints need not be a limiting factor in a workflow—there are sufficient resources (in terms of both technology and personnel) to design whatever we wish.

Background

Hydrographic surveys are conducted by NOAA Ships and contractors, and their final survey products include gridded bathymetry, an S-57 feature file, and documentation, which are received by Hydrographic Branches (HB) onshore. The HB conducts a survey review, which verifies that the data meets NOAA specifications (2016) and at its conclusion marks an official acceptance of the data and transfer of ownership. After a successful review and acceptance, the HB begins the generalization of the high-resolution data to nautical chart scale, a process called chart compilation. The final product of chart compilation is an HCell, a preliminary chart product in S-57 format that encompasses the generalized survey data. The finished HCell is then transferred to the Marine Chart Division (MCD) for application to the charts.

During survey review and chart compilation at the HB, there are numerous tasks that are both manually intensive and time consuming. The reviewer often has a central conflict of ensuring data quality while also striving for timeliness in the ping-to-chart process. Because some of these tasks are also quite monotonous and tedious, there is a high likelihood of human error in the results. These challenges are exacerbated by the ever-increasing data volumes associated with hydrographic surveys.

In order to mitigate these challenges, tools were written in Python. First built in the Fall/Winter of 2014, the tools became known as QC (quality control) Tools, for their focus in assuring quality of hydrographic data during survey review, and of the HCell during chart compilation. In particular, they are designed to alleviate the manual burden associated with the tasks described above, while reducing human error. It is hoped that the result will be an improvement in accuracy of the final products, and decreased overall ping-to-chart times.

The general function of the QC Tools, shown in Figure 1, is to input the data exported from commercial processing software into Python, perform various algorithms, and then generate results. The results are then ingested back into the processing software via a drag and drop (if an accepted file type), or via a preexisting import utility for the software. The results of the algorithms are generally “flags” overlaid on the GIS that simply alert the user to locations that may require more attention (for example, potentially anomalous grid fliers, or incorrect feature attribution).

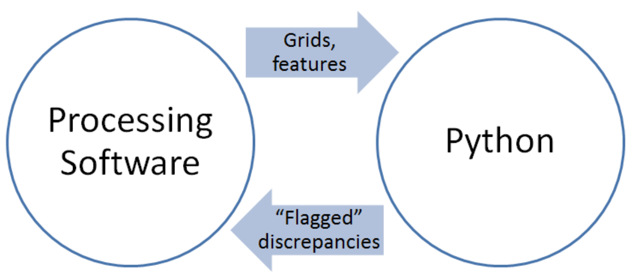

Figure 1. Grids and features are loaded into Python to perform algorithms customized to NOAA specifications and best practices. The outputs, areas of “flagged” discrepancies, are brought back into the processing software for examination.

This workflow has advantages because the algorithm independence from the processing software gives us complete freedom to customize them however we like, and to tailor their functionality to our exact specifications and best practices. Also, because the algorithm results are brought back into the processing software, this suggests that the functions themselves (if proven valuable enough) may eventually be incorporated into the commercial software, and circumventing the need to export to Python in this manner. Many popular GIS software already have embedded a Python interpreter, such that the grids and features could be passed directly as objects in memory.

The specific challenges, and algorithms designed to combat them in the current offerings of QC Tools, are described individually below, as well as additional considerations for the future.

Flier Finder

Challenge:

Figure 2 shows a 3D-view of gridded bathymetry with several anomalous grid data "fliers" amidst a dynamic, rocky seafloor.

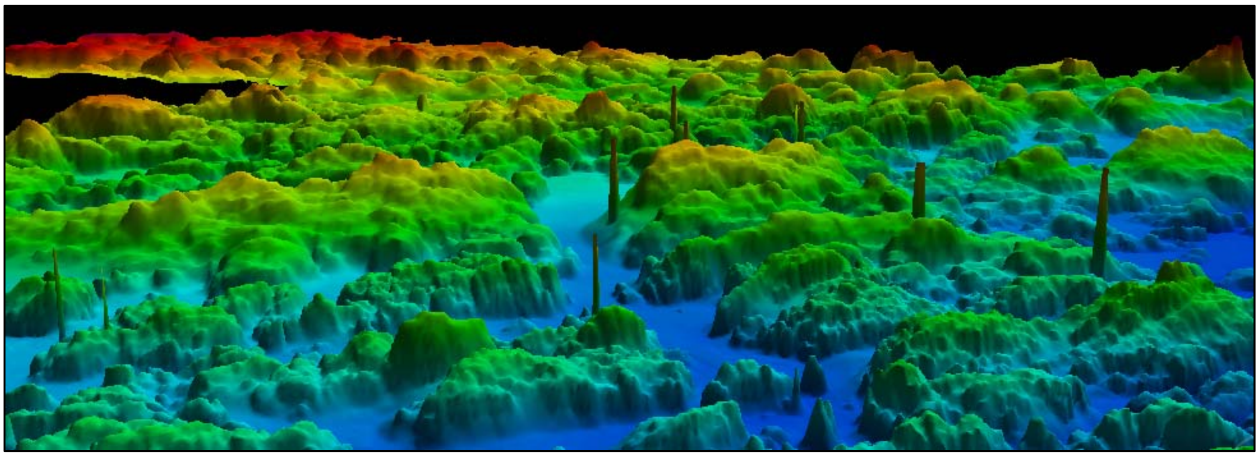

Figure 2. A 3D-view of gridded bathymetry shows a rocky seafloor and several data "fliers".

3D-views with vertical exaggeration, like that shown in Figure 1, may be quite effective in identifying fliers, as are shoal-biased sounding selections, and simply panning around the grid with various statistical layers displayed to search for anomalies. But none of these traditional methods of flier detection are foolproof, and they may actually be insufficient. In 2015, it was reported that nearly 25% of the surveys received by the NOAA Hydrographic Surveys Division (HSD) are affected by fliers (Gonsalves, 2015). This is very troublesome, because the occurrence of fliers requires the recreation of final survey products, which requires significant time and effort for the HB. But also problematic is that the authenticity of the original field submission is lost, meaning that the remainder of the survey review will focus on products created by the HB, and not those that were submitted. This can have potentially serious implications, especially with contractors.

The high percentage of flier occurrences may be because scanning the grid for anomalous data is largely a manual process, and the human reviewer likely will not find the single needle that resides in the haystack. The task may be facilitated by some degree of automation, to decrease the likelihood of "misses" attributed to human error.

Algorithm:

The first evolution of flier finder is very simple. The grid is scanned from west to east. Any depth changes across adjacent nodes greater than a user defined height are flagged. This in itself is effective. The process has further evolved to reduce the occurrence of "false flags", for example, those depth changes that occur as part of a slope. This was accomplished by requiring a pairing of both a rise and fall (for a potential shoal flier), or fall and rise (for a potential deep flier), within 3 nodes of the other, in order to register a flag, as shown in Figure 3. Figure 4 shows output of flier finder atop a grid in both plan view and 3D view.

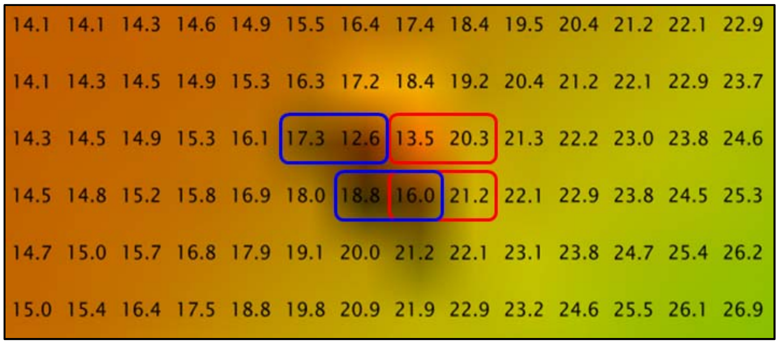

Figure 3. An anomalous grid data "flier" exists on a slope (grid node depths given in meters). Flier finder, using a 1m search height, requires a pairing of a "rise" (blue) to occur within 3 grid nodes of a "fall" (red) in order to register a flag, so none of the depth changes across the slope are flagged.

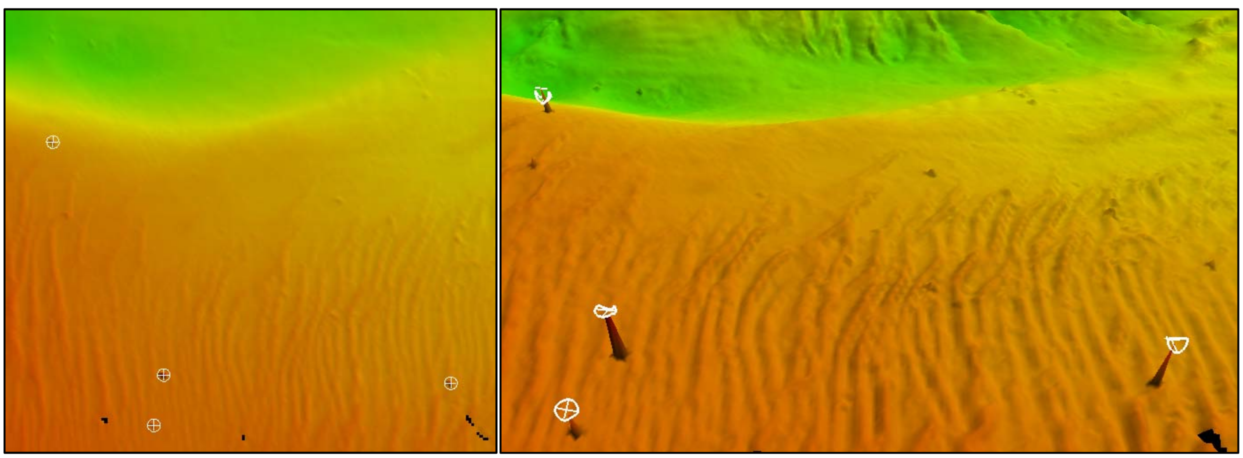

Figure 4. The output of flier finder atop the surface in plan view (left), and in 3D view (right), where the grid fliers are much more apparent. At the very least, the flier finder output is a GIS layer marking their precise location, to facilitate quick detection and removal.

Flier finder represents a proactive way in which reviewers can hunt down anomalous data fliers. There is assurance that any flier which meets the search height parameter *will* be flagged, which can be very gratifying. However, there are certain seafloors that may be too dynamic to use flier finder. The presence of "false flags" may be too great, such that the burden of false flags to sift through outweighs their benefit.

Future considerations:

Reducing instances of "false flags" may be accomplished through more robust scanning; for example, in four directions, rather than just one. Currently the depth layer scanning happens in the west-east direction. One could also search for rise and fall pairings in the north-south, northwest-southeast, and northeast-southwest directions, effectively using all the adjacent grid nodes around each initial pairing. This would raise confidence in an existing flag. An example of the more robust scanning is shown in Figure 5.

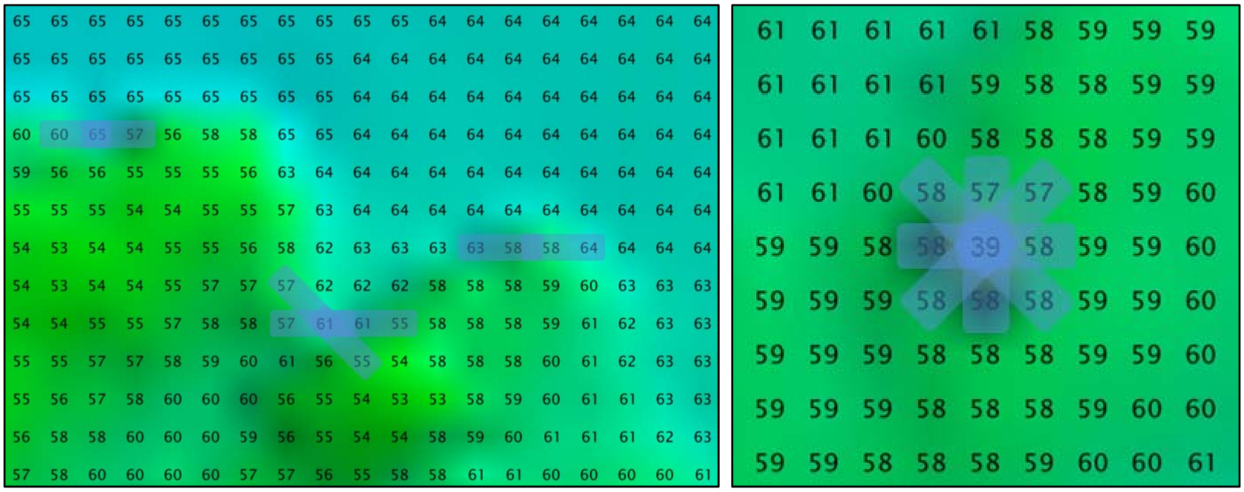

Figure 5. "False flags", using a 4 meter height search, at the edges of rock outcroppings (left), and a "true flag" that marks an anomalous grid data flier (right). Of the 4 directions available for scanning, the false flags only reveal 4 meter rise and fall pairings in the west-east direction, and one instance of a northwest-southeast pairing. Conversely, the true flag has 4 meter rise and fall pairings in all 4 directions, and so suggests much higher confidence that it is truly a flier.

Other ways to further distinguish real fliers, while reducing instances of false flags, are to use the magnitude of the rise and fall pairings, and the statistical layers of the grid. The left side of Figure 5 shows two deeps and one shoal that met the current criteria for flagging. The magnitudes of the fall and rise pairings are between 4 and 6 meters. In comparison, the real flier shown on the right side of Figure 5 is a shoal flier with a rise and fall magnitude of 19m.

Generally, CUBE (Combined Uncertainty and Bathymetry Estimator) grids are used in flier finder, as these are the final gridded product most commonly received at HSD. As such, the statistical layers of hypothesis count and hypothesis strength in the CUBE grid (Calder and Mayer, 2003) may be used in the flier search criteria, in addition to standard deviation and uncertainty.

By using the three additional criteria discussed above, flags could be weighted by confidence. For example, more robust scanning provides the rise and fall pairings found in 1 (lowest confidence) to 4 directions (highest confidence). All flags could be attributed by the magnitude of the rise and fall pairings. Lastly, those flags could be further attributed by the grid statistics of the corresponding grid node, which adds further weight.

The software implementation may have a slider bar that toggles through flier confidence. Set to highest confidence only shows those flags with 4 directions, highest magnitude, and most exclusive grid statistics. Conversely, the lowest confidence setting on the slider bar is least exclusive, and reveals all flags without additional filtering. This is depicted in Figure 6.

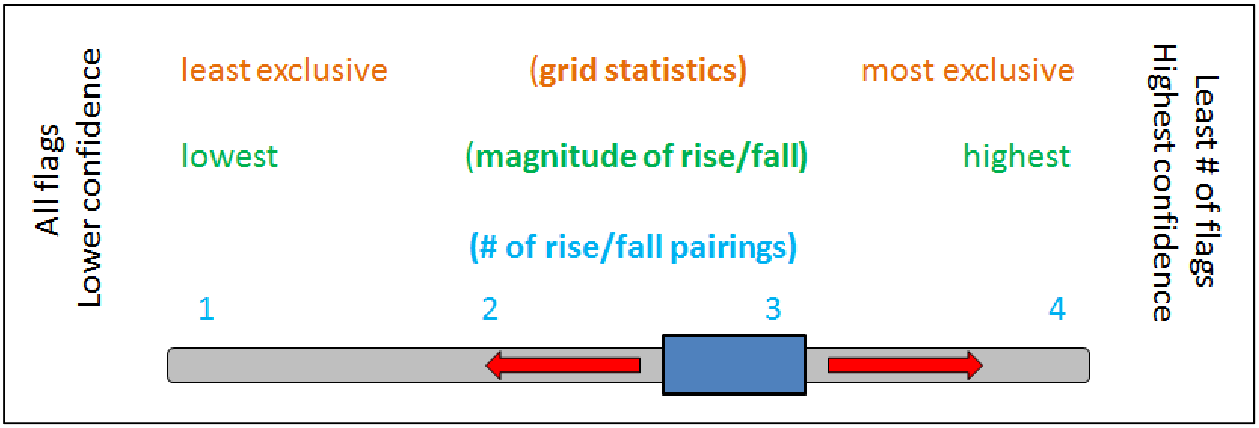

Figure 6. The proposed slider bar, with a least exclusive setting (left side) to see all flags, most exclusive setting (right side), to see only those flags with the highest confidence of anomalous grid data detection, and settings in between.

The flexibility offered by such an implementation will allow the user to toggle the output based on the seafloor topography. The most innocuous of fliers on a generally flat seafloor could be located using the least exclusive setting (all the way to the left), while excessive false flags can be minimized greatly on the most dynamic seafloors using the most exclusive setting (all the way to the right), and settings in between used as needed or at the discretion of the user.

Rather than user-defined search height criteria, another option would be to have a depth-dependent search height, perhaps based on the NOAA and IHO allowable error formula, available via a checkbox.

These additional options for the user increases the flexibility of flier finder, and proactive flier “hunting” in this manner, tailored to best fit the bathymetry, may offer a better chance of identifying and removing anomalous grid data, for both field personnel and reviewers.

Grid to Feature Check

Challenge:

Another time consuming, manually intensive process is that of feature management. Survey deliverables require each feature to be represented in S-57 format, with both mandatory and prohibited attributes (NOAA, 2016). Furthermore, each feature that is attributed with a surveyed least depth must also be properly represented in the corresponding gridded bathymetry.

NOAA routine receives surveys with hundreds, and sometimes thousands, of features, and the processes necessary for their review are entirely manual. Not surprisingly, feature review is generally the most time consuming part of the review, and it is another common source of error. In 2015, errors associated with features, in either their agreement to the grid, or in their attribution, were found up to 13% and 25% of the time, respectively, for surveys received by HSD (Gonsalves, 2015). Once again, the process of feature verification is ripe for automation to some degree, to expedite the process, and at the very least to ensure no errors remain at the conclusion of the review.

Algorithm:

With the grid loaded into Python, it is convenient to also load an S-57 feature file, to ensure there is parity amongst these important deliverables. The S-57 attribute, VALSOU (value of sounding), is a user entry that denotes the depth of a feature (e.g. wreck, rock or obstruction) and this value must match the depth of a corresponding grid node. Though there is some leeway in the horizontal position, it is an HB best practice for the corresponding grid node to be the closest node to the feature. Figure 7 provides a demonstration.

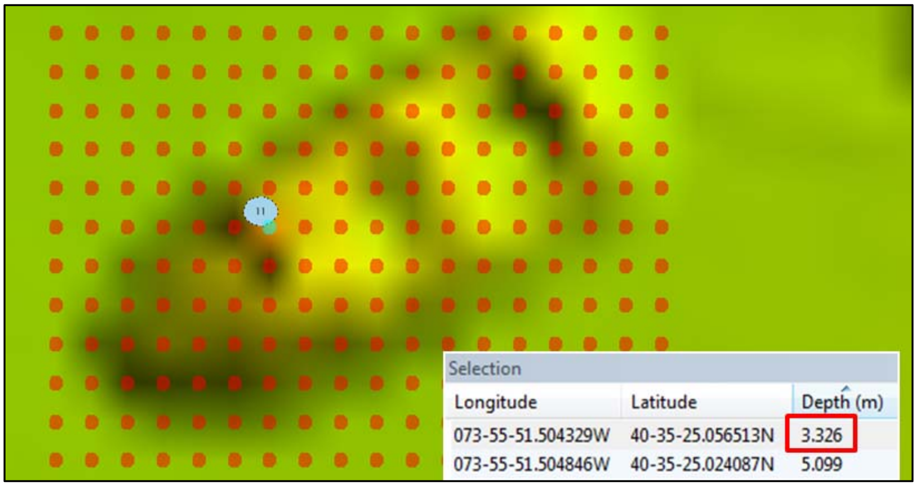

Figure 7. A wreck as portrayed in the gridded bathymetry and as an S-57 feature. The least depth of the wreck should be attributed to the S-57 feature VALSOU (value of sounding), shown here in feet, and this should match the depth value of the nearest grid node, shown here in meters. Often times, this agreement is found to be lacking.

The grid to feature check in the QC Tools automatically scans all features with a VALSOU and compares them to a grid to ensure agreement, and any discrepancies are flagged. Then, with all the features still loaded into memory, there is good opportunity to scan them to ensure mandatory attributes are populated, prohibited attributes are not, and once more flag any discrepancies. The requirements for this attribution are given in the Hydrographic Surveys Specifications and Deliverables manual (NOAA, 2016).

Future considerations:

A further improvement to feature management is to include soundings in the agreement check. As stated previously, the S-57 VALSOU must match the grid, but both of these must agree with the chosen least depth sounding of the feature in question. This three-way agreement is critical, and is likely attained at some point during the preparation of survey deliverables. But additional processing, or otherwise manipulation of the data, later breaks this agreement, and most software offers no linkage between these three important elements to alert the user that parity is lost.

Triangle Rule

Challenge:

The challenge of a chart sounding selection, and to a greater extent, chart compilation, is first illustrated through mere data volume. The components extracted for chart compilation are usually not larger than 4MB, which is a small fraction of a percentage of the original survey data that is often several hundred GBs. From the high-resolution data, composed of hundreds of millions of soundings, a handful of soundings, contours, and features are extracted to create the chart update product. Of these components, the chart sounding selection is by far the most subjective and time-consuming part of chart compilation. An example is shown in Figure 8.

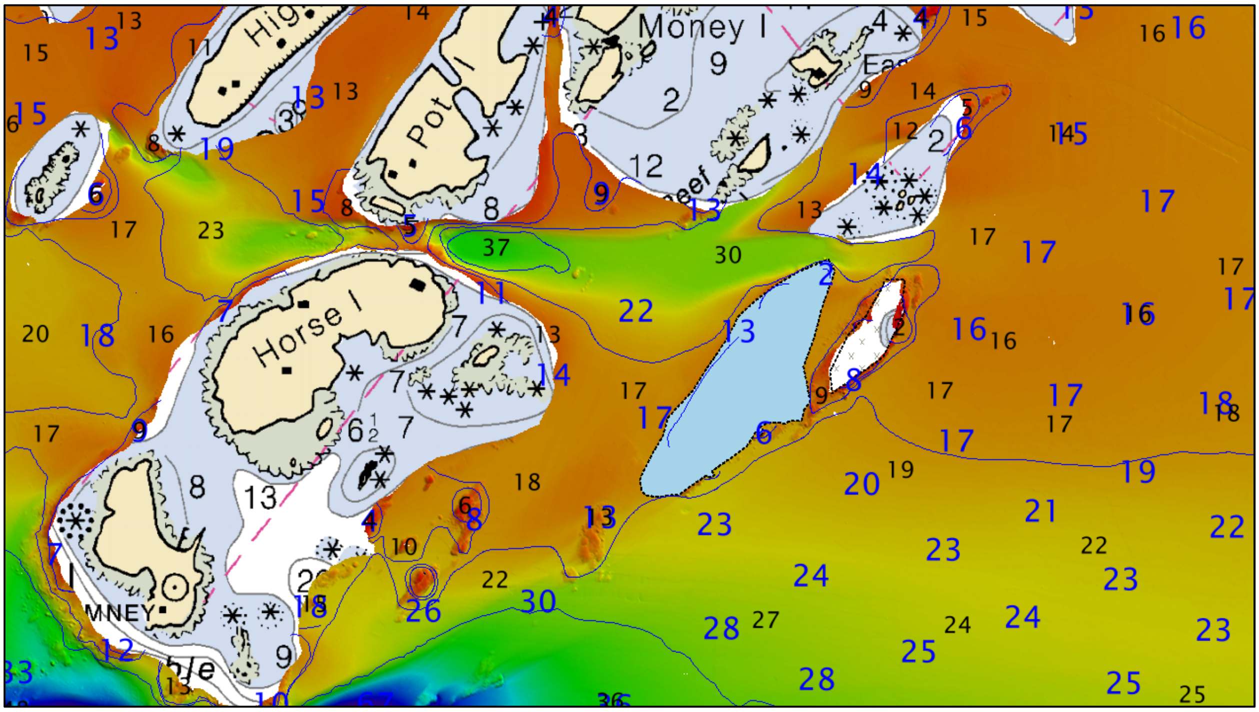

Figure 8. From the high-resolution bathymetry, an initial automated shoal-biased sounding selection (blue font) must then have significant manual intervention prior to the finalized selection (black font). For example, efforts are made to show navigationally-significant deeps, to remove unnecessary soundings off chart text, contours, and features, and to decrease sounding density in deeper water. Also, the finalized selection must interface well with the un-surveyed parts of the chart. The background is raster chart 12373, and all soundings are in feet.

A shoal-biased sounding selection can be generated automatically based on a user-defined radius, but this is merely a starting point in determining the sounding selection used to update a nautical chart (Owens and Brennan, 2012). Numerous modifications to the selection then must be performed manually. In addition to shoals and hazards, charted soundings must also define deeps, to indicate safe navigation channels and potential anchorage areas. Furthermore, a shoal-biased sounding selection will naturally select shoal non-skin of the earth features (wrecks, rocks, and obstructions), which is not allowed given that the sounding must not occupy the same space as the cartographic feature (Owens and Brennan, 2012). Selected soundings must also interface well with junctions and un-surveyed parts of the chart. Sounding density may need to be increased in shallows, or decreased in deeper parts. Lastly, attempts are made to avoid unnecessary sounding selections atop contours, text, or other chart marginalia, none of which automated selections take into account.

Algorithm:

Once the cartographer has performed all of the manual adjustments described above, the resulting sounding selection must be validated to ensure all shoals and hazards are still properly represented, in order to uphold safety of navigation. The triangle rule, a longtime HB best practice, is often used to perform this task. Note that it does not alleviate the subjectivity associated with the selection; rather it is used to help ensure its validity. The triangle rule stems from the basic rationale that one can interpolate on a chart a depth that exists between two charted depths. For example, one could reasonably expect the depths between charted 16 and 25 foot depths to be somewhere between 16 and 25 feet. It may be deeper than 25 feet, but it should never be shoal of 16 feet. The triangle rule is illustrated in Figure 9.

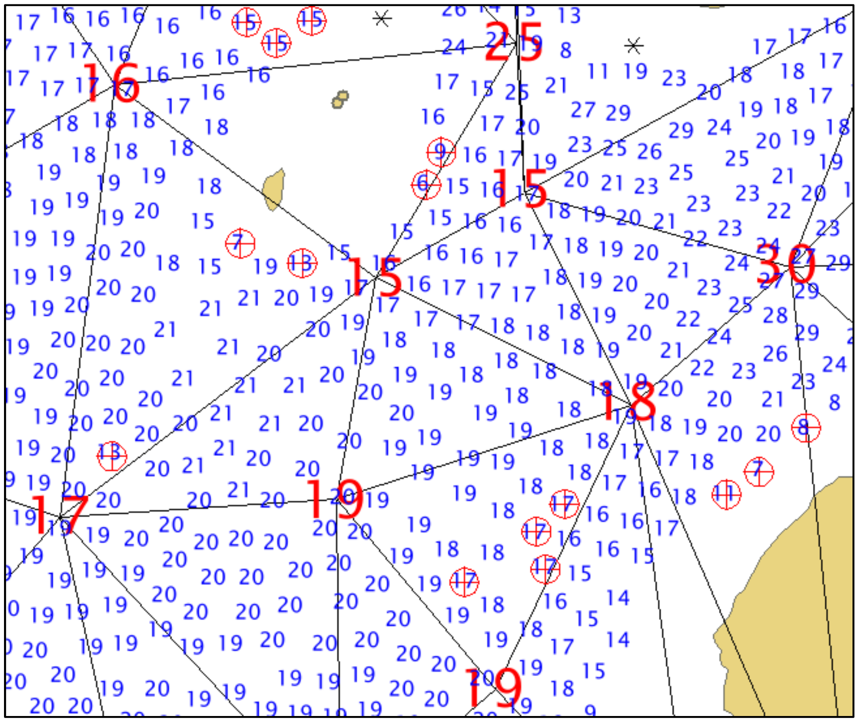

Figure 9. A triangulated irregular network (TIN) is created from a prospective chart sounding selection. The survey soundings are categorized into the triangles of the TIN, and we should generally expect that no single survey sounding is shoal of the three chart soundings that compose the vertices of the triangle it falls within. If so, then these are flagged (red targets). Of course, there are exceptions, given that contours represent depths in addition to soundings, but still, this is an effective QC Tool. In the above example, the flagged soundings near land are likely not problematic (given they will be encompassed by contours near land and away from vessel traffic), however, the westernmost flag (the 13 foot sounding) is a significant shoal that must be represented in the charted soundings. Furthermore, the encroaching 18 foot contour in the south likely should be highlighted with one of the flagged 17 foot soundings.

The triangle rule should be performed as needed throughout the HCell compilation process, but certainly toward the end, as a final check to ensure all shoals are accounted for, either by sounding, contour, or as a feature.

This same method can be used during survey acquisition with *existing* chart soundings, rather than a prospective chart sounding during compilation. This methodology represents an automated scan for previously unknown or uncharted shoals and dangers to navigation. Note that there are similar methods of comparing survey data to an ENC, however, these generally rely on a grid derived from the ENC soundings and does not allow features to be included in the comparison, which may be essential. The QC Tools represent a certain advantage in that they flag particular soundings (rather than grid nodes), and furthermore, allow for features to be included in the comparisons, which can yield results much easier to interpret.

Future considerations:

While the triangle rule is an effective means of quality control for a prospective chart sounding selection, it does not mitigate the highly manual and time consuming process of generating the actual selection. As described earlier, an initial shoal-biased sounding selection begins the process, but this requires significant manual intervention thereafter.

An automated “smart” sounding selection would greatly increase efficiency and timeliness in chart compilation by removing an intensely manual process. This smart sounding selection would ensure the following (Owens and Brennan, 2012):

1) Soundings not unnecessarily propagate on features, contours, and other predetermined objects, while still ensuring least depths and critical shoals are represented,
2) Supporting soundings are selected adjacent to features and contours,
3) Isolated deep soundings in areas of navigational significance,
4) Sounding de-confliction with chart interface and junction surveys, and
5) In general, increased sounding density with shallower depths and with increased degree of slope.

HCell Validation

Challenge:

The composition of our chart update product requires a very particular set of S-57 features, and associated attribution, that is described in the current HCell Specification (2015). Note that the required attribution is quite different from the hydrographic specifications (NOAA, 2016), so with a multitude of features, there is considerable effort required to update the attribution. Finally, there are methods to validate the preliminary chart update product product using commercial software, to ensure proper attributions, geometry, topology, and so forth. However, these methods are designed toward ENC validation, and not an HCell, so much of the output from these processes is inapplicable.

Algorithm:

With the features loaded into memory, they are scanned to ensure adherence to HCell Specifications (2015), which dictates mandatory S-57 attributes to be populated, prohibited S-57 attributes to be empty, and even a logic check to safeguard against certain unallowable combinations of attributes. Other checks are performed, which are either a listed specification or a best practices. For example, each charted sounding, wreck, rock, or obstruction in the HCell must have a correlating survey sounding. However, a charted sounding may not reside on a feature, which is a topographic violation. An additional check ensures no object redundancy amongst any sounding or feature. All discrepancies are flagged to alert the user.

Future considerations:

Currently, the validation function only utilizes those features with point geometry, while existing software programs that utilize all geometries do not evaluate the HB chart update product, but rather a full ENC. Thus, either the output is incomplete (not factoring in all geometries and objects), or much of it is inapplicable (tailored to a different product). An ideal solution would be for either the existing software to incorporate our HCell into their validation process, or to further advance the HCell validation routine of the QC Tools to incorporate all geometries.

The need for a viable HCell validation technique is even more pressing, considering the HCell prototype specifications (2014), or the potential for the HB to upload the relevant chart update information directly to the NIS (Nautical Information Systems) database. Either solution will require the generation of both contours and depth areas to occur at the HB. Thus, improved methods of contour generation to meet our charting requirements are a high priority, considering the manual burden associated with hand-drawing that is currently necessary. In addition, it may be necessary to merge updated contours and depth areas with those objects in the corresponding ENC, a process that has proved very manually intensive, and problematic in terms of ensuring correct alignment and topology (Owens, 2016). Direct reading and writing of ENC and survey-derived S-57 objects, and better tailoring the functionality, output, and the validation to our specifications would greatly facilitate the proposed workflow.

For these reasons, and given the current limited support of S-57 format in the available open-source geospatial libraries (i.e., GDAL), the incubation of two correlated libraries for accessing data in the ISO 8211/IHO S57 standards have started. The ENC X application has been developing in parallel with these libraries. The aim of this tool is to ease the exploration of the content of ISO 8211-based formats, at multiple levels of abstraction from the physical content to the Product Specification level.

Implementation

The flier finder and grid to feature check algorithms were packaged together, along with a function to export seabed areas in a required text format for the National Centers for Environmental Information (Ferguson, 2013). Because each tool is geared toward survey acceptance review (SAR), the package was called “SARScan”, although the functions are also useful for field parties during and after data acquisition. The triangle rule and HCell validation functions were packaged together under the name “HCellScan”, because of their use during chart compilation. Both SARScan and HCellScan were distributed to NOAA Ships and HBs on an informal basis, for testing purposes, as part of a proof-of-concept phase.

In 2015, data mining of recent and past survey acceptance reviews suggested that data quality might actually be waning (Gonsalves, 2015). Furthermore, it was shown that the need for rework and reprocessing at the HBs dramatically increases survey review and acceptance times (Evans, 2015). Thus, one of the eventual outcomes of these discussions was the Rapid Survey Assessment (RSA), an HSD initiative to quickly identify significant deficiencies in survey deliverables. Because the newly developed QC Tools incorporate automation and promote accuracy and timeliness, they were a further catalyst for the RSA, and the two were merged together.

The RSA was signed into policy (Berkowitz, 2015), and incoming surveys to the HBs were evaluated by this process as soon as possible after arrival. Surveys that fail the RSA are returned to the field for rework. There is advantage in that significant deficiencies are found (and corrected) immediately, while data is still fresh in mind and fresh on data drives, rather than after sitting in a queue for several weeks, or even months, while ships move and personnel rotate.

Surveys that pass the RSA then transition to the survey acceptance review queue, and when the review process commences there is greater confidence in data quality and that no time-consuming rework will be necessary.

The next year saw a 30% rejection rate by RSA in the surveys received at HSD (Evans and Jaskoski, 2016), meaning the surveys were returned to the field for rework. As for the ensuing survey acceptance reviews (after RSA), the sample size was deemed too small to determine whether or not the RSA process is beneficial to timeliness of the overall process. RSA benefits and drawbacks will be further discussed and reevaluated at future meetings and workshops.

Also in 2015 began extensive collaboration with the Center for Coastal and Ocean Mapping and Joint Hydrographic Center (CCOM/JHC), which resulted in significant improvement in the usability and organization of the QC Tools, to further their potential and expand their reach via implementation in the CCOM/JHC initiative, HydrOffice, a free and open source research software environment with applications to facilitate all phases of ocean mapping. There was also collaboration with NOAA Hydrographic Systems and Technology Branch (HSTB) to implement the QC Tools in Pydro, which greatly facilitated accessibility and distribution to NOAA users.

The improvements to the QC Tools upon incorporation into HydrOffice were significant, and include a user interface with updated functionality, message window, direct link to the software manual, and an improved overall aesthetic. For SARScan specifically, separate office and field profiles are available, to allow for customization of the algorithm settings and parameters for the field during acquisition, or in the office during review. The tool is also made more efficient by direct reading of the CARIS (CARIS Spatial Archive) and BAG (Bathymetric Attributed Grid) formats, rather than ASCII-exported grids, which eliminates unnecessary steps. Many of these improvements are shown in Figure 10.

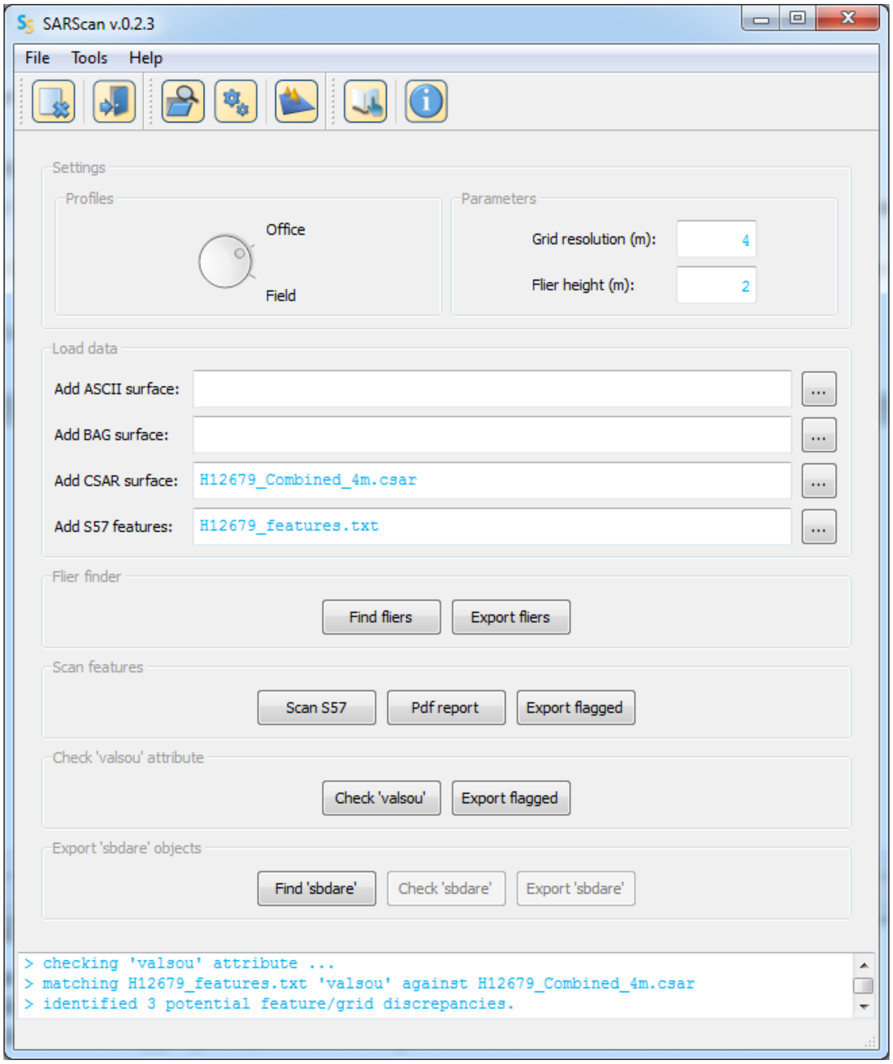

Figure 10. The SARScan interface, a part of the QC Tools segment of HydrOffice. A profile knob can tune the algorithms to specific user profiles. Grid resolution and desired flier search height are set in the parameters. Grids (ASCII, BAG, or CSAR) are loaded and scanned for fliers. Features (ASCII) are loaded and scanned to ensure agreement to the grid and that attribution is set per required specifications.

HydrOffice

HydrOffice is a CCOM/JHC initiative to develop a research software environment with applications to facilitate all phases of the ping-to-chart process. The environment lowers the barrier to creating ocean mapping apps, by easing the configuration management and leveraging existing infrastructure well-suited and modularly packaged to easily facilitate additional hydro-solutions. As free and open source software, the apps are available for use, and for contribution, to students, NOAA, and industry partners. The overall goal is to speed up both algorithm testing and Research-to-Operation (R2O).

Rather than a monolithic code structure required to solve each problem, HydrOffice has several small issue-specific applications (Hydro-solutions) that share a common base code. At the same time, several hydrographic-specific libraries have been developing. Built on top of the popular Python scientific stack, they all have a modular design to make them readily available for other applications. This structure makes it rather easy to add more solutions and encourages contribution. HydrOffice apps, those currently available and in development, are shown in Figure 11, which is followed by a short description of each app.

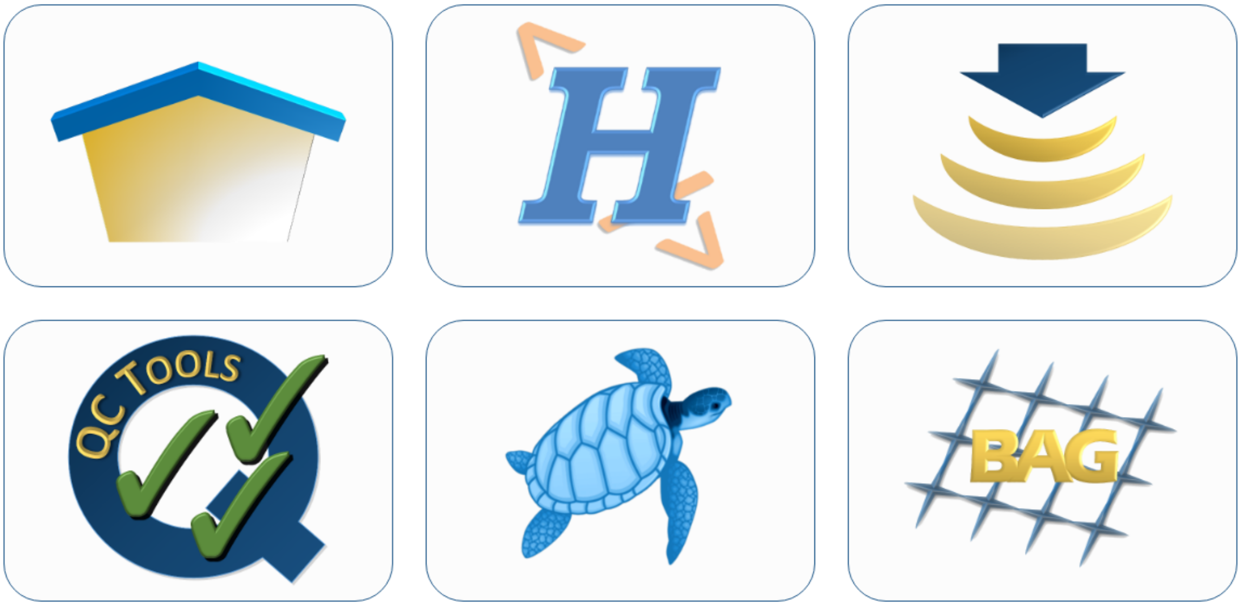

Figure 11. HydrOffice apps, clockwise from the top left, are the HydrOffice Managed Environment application (HOME); the Hydrographic Universal Data Description Language (HUDDL); Sound Speed Manager; the Bathymetric Attributed Grid (BAG) library and explorer; Oceano acoustic backscatter library; and the QC Tools.

- The HOME app simplifies the download and update of HydrOffice packages, and also grants access to a collection of tools to ease the creation of new HydrOffice libraries and applications.
- HUDDL is designed to simplify and standardize the description of hydrographic data files (Calder and Masetti, 2015).
- Sound Speed Manager is an application and sound speed library built to bridge the gap between sound speed profilers and multibeam echo-sounders. Originally created by Dr. Jonathan Beaudoin, many new functionalities have recently been added.
- The BAG library provides access to BAG-specific features, as well as a collection of tools to verify and manipulate BAG data files.
- Oceano is a library to process acoustic backscatter, with two main components: ARES to create acoustic reflectivity surfaces, and ARCH for seafloor characterization.
- QC Tools, to facilitate hydrographic survey review and nautical chart compilation, currently include SARScan, HCellScan, and ENC X.

The individual HydrOffice apps are also provided as "frozen", standalone click-and-play solutions that do not require the installation of a Python environment on the user machine. Some are currently available for download, while others are coming at the end of the incubation phase, on the HydrOffice website (https://www.hydroffice.org/), along with additional information and links that further describe the HydrOffice project.

Summary

It is an ongoing challenge to balance innovative survey review and generalization processes with ever-advancing multibeam technology and increasing data volumes. When lacking, poor practices might develop, such as those that are manually intensive, monotonous, or otherwise better for a machine to complete. Numerous such challenges have been noted in current practices, and they are met with QC Tools, an implementation of innovative ideas for better and more efficient survey review and generalization processes. With further development through the CCOM/JCH initiative, HydrOffice, the QC Tools are now in use at NOAA, as part of the Rapid Survey Assessment and available through HSTB Pydro.

HydrOffice lowers the barrier to innovation and implementation for field personnel by facilitating an effective means of development, organization, and distribution. Being part of the HydrOffice framework, QC Tools (and many more helpful applications) are available as free and open source software to the hydrographic community. Their joint development has highlighted relevant advantages by merging together technical knowledge and applied research, which both facilitates and shortens considerably the time between research and operations.

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Brian Calder is an Associate Research Professor and Associate Director at CCOM (UNH, USA). He has a Ph.D. in Electrical and Electronic Engineering, completing his thesis on Bayesian methods in SSS processing (1997). He is currently focusing on statistically robust automated data processing approaches and tracing uncertainty in hydrographic data.

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