

# Analysis of Multibeam Crosschecks Using Automated Methods

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## Abstract

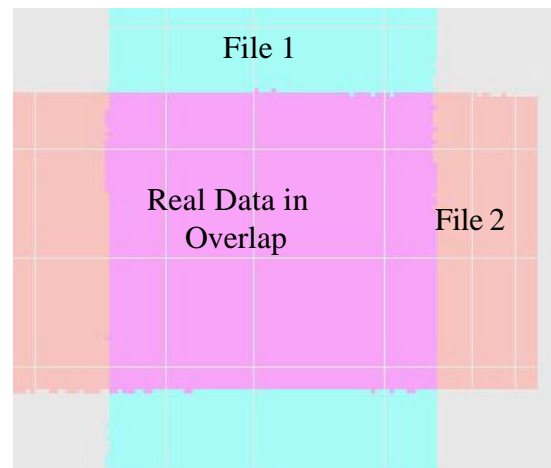
The widespread use of multibeam sonar systems has brought to the forefront many developments to handle the tremendous amounts of data collected. One of the valuable quality assurance tools available for hydrographic data is that of analyzing depths where two tracklines cross. In contrast to the single-beam echosounding case, where crossing tracks result in single overlapping footprints, multibeam sonar crossing tracks involve the analysis of a multitude of redundant data points. The earliest (pre-GPS) multibeam crossing track analysis tools were used to improve georeferencing, shifting tracks to achieve spatial correlation at all intersections. Now, with georeferencing handled by GPS and other sensors, crossing track comparisons are important quality management tools. This paper describes an automated means of evaluating data quality from multiple multibeam crosschecks.

The current tools available at the Naval Oceanographic Office require executing a string of six programs to evaluate a single crosscheck. A typical survey area has hundreds of crossings when crosscheck lines are run at 10 times the development line spacing. Software was written that ingests a set of multibeam trackline files in Generic Sensor Format (gsf), determines the intersections and automatically grids and analyzes the crossing data. Two crosscheck analyses are performed. The first analysis determines a single quality indicator for each crosscheck, based on statistics run for residual depth differences of gridded data. This quality indicator is compared against a threshold, and the results are displayed. The user can easily determine any unexpected quality trends in the data. A trackline file whose quality indicators exceed the threshold for multiple crosschecks merits further investigation and analysis.

The second analysis compares each crosscheck beam by beam. This analysis is based on the increase in depth uncertainty with increasing beam angle, which is characteristic of multibeam sonar, primarily due to roll and sound-speed profile uncertainties. For each crosscheck, a profile of the depth discrepancies is generated between the center (nadir) beam data from one trackline compared to the entire ping from the other trackline and vice versa. The results identify whether or not the overall comparison from the first analysis is driven by beam-dependent uncertainties.

## Introduction

The Naval Oceanographic Office (NAVOCEANO) has collected multibeam data since 1967. And just as with single-beam depth data, crosscheck lines are run to compare the depth differences at the crossings. The comparison of a common area of seafloor covered by more than one dataset is known as a crosscheck as depicted in Figure 1. Some errors are evidenced by a series of high residuals along any given trackline. In the past, for single-beam surveys, the method was to plot out soundings and eyeball whether they appeared to be within an acceptable limit. No digital means of evaluating crosschecks were used, although now software such as Hypack does do single-beam comparisons. Single-beam crosschecks provide a single residual value at the crossing, which often requires that true measurements be interpolated to the crossing location. (If an inclusive geographic box is used around the crossing, multiple depths from the single-beam could be used, but some gridding



**Figure 1. Multibeam crosscheck. Files 1 (blue) and 2 (orange) both have real data in the pink grid cells. Data is gridded at footprint size for each file and compared.**

would be needed so that collocated data could be compared, and statistics could then be applied to aid in the analysis.) After crosscheck analysis, a determination is made as to whether the data along the errant track with high residuals can be corrected or should be thrown out and the data re-acquired.

For most NAVOCEANO surveys today, the primary bathymetric data collected is multibeam (MB), and even with the few digital tools available for crosscheck analysis, the process is tedious. But even prior to the recent digital MB editing methods now available, crosschecks were still run. In the past, for non-hydrographic deep-water surveys, NAVOCEANO would typically run multibeam crosschecks at a crossing of opportunity or an occasional figure-4 pattern at the start or end of a survey line. With this few number of crosschecks, it was reasonable to analyze each one, even by hand. The manual method was to first scale off the crosscheck geographic center and determine the data time frame on each of the survey lines. Then a strip plot was made for each swath at an exaggerated scale and overlain on the navigation plotted at the same scale. The strips were then shifted and rotated so that it could be seen whether there existed any skew in the mismatched contours (indicating a roll bias error), or if navigation shifts were required. Later, once digital techniques were used, data could be gridded and several tools became available to analyze crosscheck data similar to the method described above. The digital method uses data that is gridded with a cell size close to footprint width and allows a set of residual values to be calculated from the collocated grid cells. Statistics can then be employed in addition to matching up the contours. But even with digital methods, the process is tedious. A string of at least six programs must be run to evaluate a single crosscheck in NAVOCEANO's suite of MB processing software. This becomes extremely impractical for a hydrographic survey where crosscheck lines are run at 10 to 12 times the development line spacing. This generates hundreds of crosschecks for which quantitative analysis is not being done because of the time consuming method now in use.

Software was recently developed at NAVOCEANO to tie this string of programs together and perform automated processing of MB crosschecks. This necessitates calculating if and where two lines cross, a necessary pre-processing step for automation. The automated method reads in a list of multibeam files, determines their intersections, and performs all the gridding and calculating of statistics automatically. The results should be plotted in a meaningful way, allowing the user to analyze hundreds of crosschecks at once. Without automated crosscheck analysis of some sort, ship time is wasted when crosschecks go unevaluated. Discussed below are two types of analyses performed, the steps that are needed to perform automated crosscheck analysis, and a sample test area where an analysis is performed.

## **Twofold Crosscheck Analysis**

There are two aspects to the crosscheck analysis—an area view and a beam by beam analysis, both of which are based on the calculation of depth residuals. Depth residuals are depth differences between two data files at the same location. The first approach is to compare collocated grid cells to obtain a batch of depth residuals from which statistics are calculated, and a single quality indicator is obtained for the crosscheck as a whole. The second approach is a ping method, where a residual is calculated for each beam in a ping that is compared to collocated near-nadir data of the crossing file.

### **Area Method**

In the area approach, a single quality indicator for each crosscheck is output to a format that can be plotted. The quality indicator is a calculated or empirical value used to compare statistical measures against the allowable error. The allowable error, or threshold, is calculated from the IHO SP-44, Table 2 formulas when given the order and the average depth of the survey. The residual between the quality indicator and the threshold is not to be perceived as an absolute error in the depths. The quality indicator is simply a metric employed to give some indication of the relative differences between crosschecks, and the IHO specification used is a yardstick. Errors associated with the depth and position of an individual sonar beam must include positioning system error, depth measurement error, the uncertainty associated with the ray path model, accuracy of the vessel heading, system pointing errors due to transducer misalignment, vessel motion sensor (roll, pitch, heave) accuracy, and time latency. Crosscheck discrepancies would be somewhat absolute, reflecting all error sources if a data file were compared to ground truth data. However, it must be kept in mind that some errors pervasive in both files will be masked in a comparison. Therefore, data files collected and processed independently add to the value of the crosscheck analysis.

The quality indicator is compared to the threshold and the plot color or symbol for those that exceed the threshold is changed. A plot is generated of all the quality indicators, and from this plot the user can easily determine any bad quality trends in the data (Figure 5). A data track file with multiple quality indicators that exceed the threshold becomes suspect.

## Ping Method

The nadir depths are considered to have the least amount of uncertainty, so they can be used as the reference depth. The beam-by-beam, or ping-based, approach is the second aspect of the crosscheck analysis and compares across-track data to nadir depths. This can aid the user in determining why the quality indicator was above the threshold value. At each crossing, the across-track beams within a ping from one file are compared to only the center beam, or near-nadir grid cell data from the other file. Comparing the actual ping data to gridded data is simply one method of finding collocated depths for comparison. Other algorithms for comparing a ping or several pings from one file to nadir depths of the other file may be used. The beam-by-beam comparison results are written to a file from which a profile of crosstrack residuals can be plotted. The characteristic shape of the profiles can aid the user in determining exactly what the problems might be with the data files at the crossings. Figures 1 and 2 are illustrations of these two methods where Figure 2 shows the area-based approach and Figure 3 illustrates the ping-based approach. Each red arrow represents a calculated depth residual value.

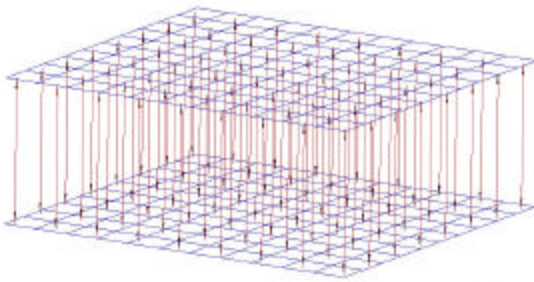


Figure 2. Area comparison approach. Each red arrow is a residual value. A single quality statistic is calculated from the residuals of collocated grid cells.

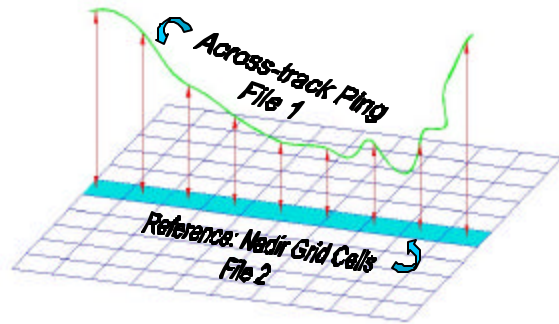


Figure 3. Ping comparison approach. A residual is found between an actual ping and nadir grid cells.

## The Quality Indicator

Figures 2 and 3 illustrate two different series of depth residuals used to perform the crosscheck analysis. In the area-based approach (Figure 2), each grid cell comparison will generate a single residual depth value. Statistics are calculated on the entire lot of residuals for each crosscheck. Many different statistics can be generated, but it is necessary to provide a single value at each crossing which will give some indication of the quality of data at that intersection. Table 1 gives a sample of statistical information from which a single value should be selected for what is to be used as the quality indicator. The question to answer is what statistic should be used as the quality indicator? Should it be the mean depth difference, the standard deviation (STDDEV), normalized STD (STD as % of depth), root

Table 1: Area Method. Statistics are generated from thousands of collocated grid cells. Crosscheck number, file names, the value at which 95% of the data is below, root mean square (RMS), standard deviation (STDDEV), and more are shown for several crosschecks in the test are.

CC	FILE1	FILE2	95%	RMS	R95	MEAN DEPTH DIFF	MEAN DEPTH	STDDEV	STD As %DEPTH	QUALITY INDICATOR
1	037d14	037d34	2.252	2.02	3.96	2.018	65.86	0.145	0.22	2.25
2	037d14	037d38	2.208	1.99	3.9	1.985	65.8	0.138	0.21	2.21
3	037d14	037d52	2.033	1.8	3.54	1.798	65.17	0.156	0.239	2.03
4	037d14	056d17	19.742	10.28	20.15	-0.473	65.63	10.27	15.649	19.74
19	037d27	056d17	21.621	10.49	20.56	-2.316	63.78	10.231	16.041	21.62
20	037d27	056d19	3.824	1.61	3.16	0.859	63.77	1.363	2.137	3.82
21	037d31	037d34	0.4	0.19	0.38	-0.077	63.74	0.177	0.278	0.4
22	037d31	037d38	0.44	0.22	0.43	-0.14	63.71	0.172	0.269	0.44
23	037d31	037d52	0.576	0.32	0.62	-0.26	63.41	0.179	0.282	0.58
24	037d31	056d17	21.918	10.5	20.58	-2.335	63.76	10.239	16.059	21.92
25	037d31	056d19	3.883	1.62	3.17	0.886	63.76	1.354	2.123	3.88

mean square (RMS), or some other number? Some statistics can reveal trends in the data. The standard deviation shows the distribution about the mean, but what if the mean is biased? In that case, a low STDDEV would not reflect this bias.

It can be shown that a constant offset, which may occur with an erroneous tide corrector, can result in a large mean depth difference but a very low standard deviation value since all residuals are close to the mean. This is the case for crosscheck 1 and all crosschecks with data file 037d14 (Table 1) where the mean depth difference is high (2.02 m) but the STDDEV is low (.145 m). Conversely, a crosscheck with data file 056d17, which has a large (5°) roll bias error, has a relatively low mean depth difference but a very high STDDEV as seen in Table 1 for CC 4. For CC 4, the mean depth difference is -.473 m but the STDDEV is 10.27 m. The same holds true for those crosschecks that include data file 056d19, which contains a large sound speed error. The quality indicator must somehow encapsulate all types of errors.

The RMS looks like a promising calculated statistic, since not only are high STDDEVs included, but also any bias is reflected. The region included in one RMS contains only 68 percent of the residual population (1 sigma), and the calculated value for the 95 percent region (2 sigma), the R95 value or  $1.96 \times \text{RMS}$ , is of more interest. In hydrography, the specifications are related to the 95 percent confidence region, and that is the value sought. An alternative approach to calculating the R95 value takes advantage of the fact that there is such an abundance of depth residuals at each crossing with the data gridded at footprint size. With a large number of data points (thousands), it is reasonable to

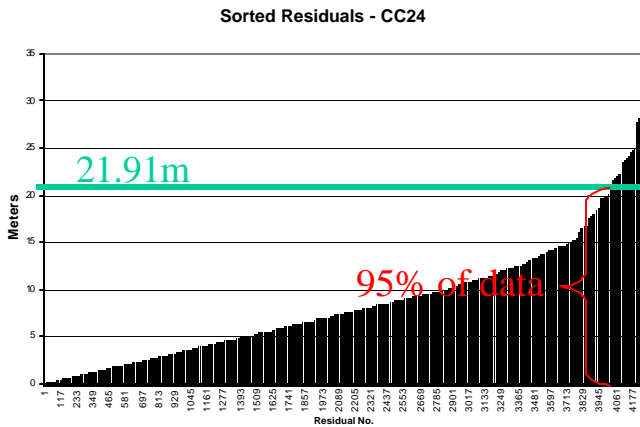


Figure 4. Sorted residual values for crosscheck #24 showing the value of 21.91 m that occurs at the bound of the 95 percent region.

simply sort the absolute value of the residuals to find the region within which 95 percent of the residuals fall. This is an empirical method of obtaining the quality indicator, and all types of error mentioned above will be represented in this value. Figure 4 is a plot of the sorted residual values for CC 24 and shows that 95 percent of the residuals lie below 21.91 m. Table 1 indicates that for this particular crosscheck, the mean depth difference was only -2.335m but the STDDEV as a percent of depth (STD normalized) is 16.059 m, and the R95 is 20.58 m. It appears that the calculated R95 and the empirical 95 percent value give approximately the same result, and either method to obtain this statistic could be used.

## The Area Plot of Quality Indicators

The quality indicator is calculated for each intersection, and then these values are geographically located on hardcopy or screen plots. The quality indicators less than the computed threshold are plotted with a different color or symbol. This makes along-track analysis easy. A problem trackline is highlighted with a series of high quality indicator values. Data files suitable for plotting are generated. Gnuplot scripts can be created for a quick, easy plotting routine that renders to the screen when the gnuplot program is invoked. (This is UNIX freeware and well worth becoming familiar with. [Hint: Start with man pages in UNIX by typing "man gnuplot". Or use the online help for gnuplot by executing the gnuplot shell and typing in help: Ex. \$gnuplot help.] )

In Figure 5, test data (See Figures 6 and 7.) is plotted where the red, underlined numbers indicate crosschecks whose quality indicator was greater than the

quality threshold. The quality indicator must somehow encapsulate all types of errors.

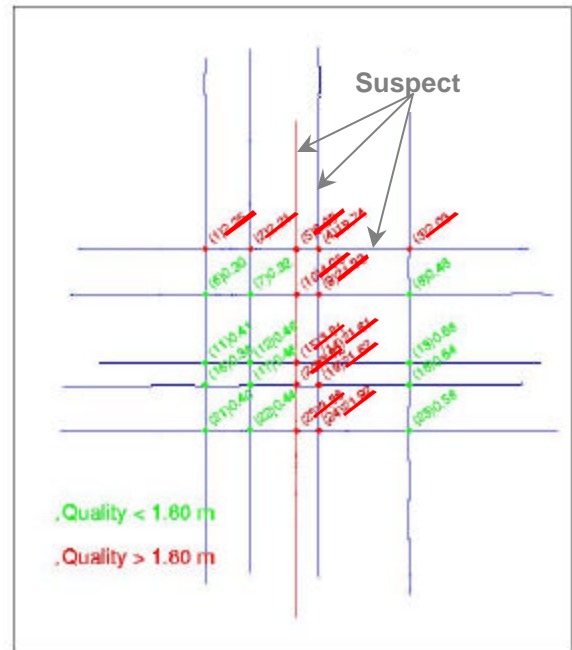


Figure 5. Area plot of quality indicator calculated from thousands of residuals at each crossing. Red underlined values failed when compared to the quality threshold; green passed.

calculated threshold value (1.8 m). The plot shows that the northernmost east-west running line and the middle two NS running lines are suspect and require further investigation.

### Ping Profiles and Correlated Errors – Test Area

The ping comparison is used to evaluate the type of errors that may be present in the data. That knowledge may help rectify data errors before the next line of survey data is collected. A beam-by-beam profile plot is generated for each crosscheck to analyze visually what the crosscheck errors may be attributed to. Plotting depth residual against beam number creates a profile plot (Figures 8, 10, 12 and 14). Although statistics are not used in the ping method, a profile plot reveals much about the source of depth discrepancies, which is discussed below.

Following is a series of ping profiles that exhibit some of the common errors found in test data, which can give a quality indicator that exceeds the threshold. First, a "good" crosscheck is shown followed by typical profiles for constant offset (water level), sound speed or roll bias errors. Each profile is a plot of residual differences between the near-nadir data of one file against the collocated across-track ping of the other file. Figures 6 and 7 show a sample dataset corresponding to the area plot in Figure 5. The MB editor side view of the data is shown in Figure 6, where the red file has a constant 2 m offset caused by a bad tide correction. The dark blue file has a sound speed problem, and the pink file has an incorrect roll bias. Residual profile plots for crosschecks involving these data files are shown following the example of a "good" crosscheck. Figure 7 shows a 3D view of the same data.

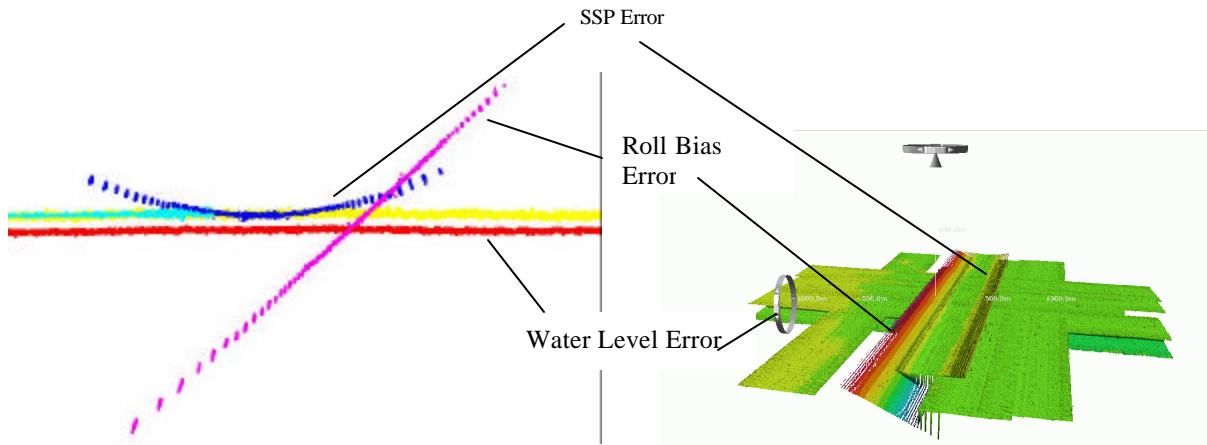


Figure 6. Profile of multibeam data with errors. The red file has a constant offset, pink is a file with an erroneous roll bias, and the dark blue is a file with an incorrect sound speed profile applied.

Figure 7. 3D view of sample data from Figure 6.

### Data Errors Determined from Crosscheck Analysis

In the series of plots that follow, a profile plot of the beam-by-beam residual data and a histogram are plotted. The profile plot shows the characteristic shape for some common some multibeam data errors. Three error sources are discussed, constant offset, sound speed and roll bias errors. The profile plot takes advantage of the fact that near-nadir data has the least amount of error in a multibeam dataset. As such, near-nadir data is used as a reference to compare to the opposing file and is labeled "Ref" in the plot legends. Even if MB data has errors, the nadir data will still be fairly good. When near-nadir data from a file with errors is compared to good data, errors will not be obvious. For this reason, a profile plot is generated for two directions. One direction compares across-track ping data from File 1 to near-nadir reference data and from File 2, as depicted in Figure 3. The second profile compares the entire ping from File 2 to near-nadir reference data of File 1. For each profile plot an accompanying histogram, or frequency plot is shown of residuals from the grid file comparison from the area method. The histogram also exhibits characteristics that correspond to its type of data error and can be useful supporting evidence.

## A "Good" Crosscheck

For a “good” crosscheck, one whose quality indicator is well below the allowable threshold, residuals are negligible and the residual profile plot is fairly flat, oscillating slightly about zero. Figure 8 shows the profile plot of a good crosscheck. Two profiles are shown, one set of residuals from each direction as described above. Figure 9 shows the histogram, or frequency distribution of a good crosscheck. Note that for a good crosscheck, the residual data is distributed narrowly and symmetrically about zero.

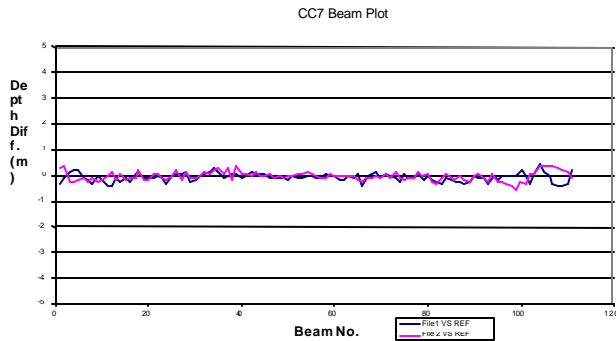


Figure 8. Ping approach. Residual profile of a “good” crosscheck. Two profiles show the residual values from both directions. The blue shows one direction and the pink shows the other.

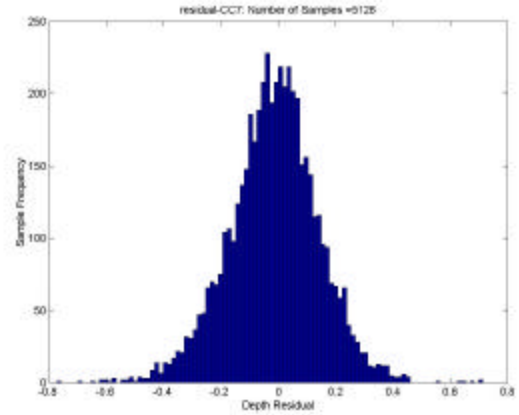


Figure 9. Area Approach. Histogram of grid comparison residuals. A "good" crosscheck shows residuals are distributed symmetrically and narrowly about zero.

## Constant Offset

A constant offset will contribute to a high mean depth difference between the two files, but the STDDEV will be very low since all residuals are almost the same. This is why the quality indicator must reflect both the high mean depth difference and the low STDDEV. Figure 10 shows a profile from a crosscheck where one of the files has an erroneous 2-meter tide correction. Note that a constant offset is seen in both profiles. From one direction, the offset is positive, and the offset is negative from the other direction. The histogram of this crosscheck (Figure 11) shows a narrow bell shape but centered on the mean residual of 2 m.

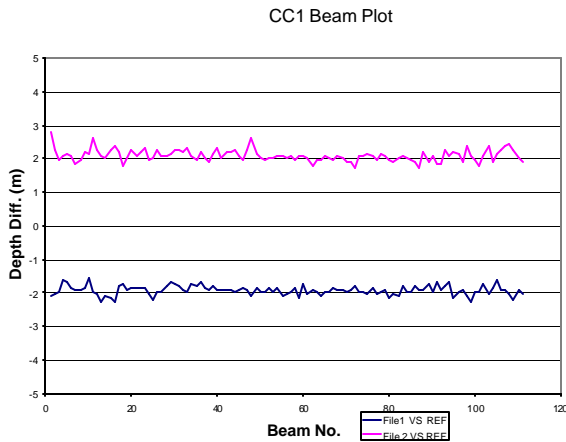


Figure 10. Residual profile with constant offset. The plot from either direction will show the error.

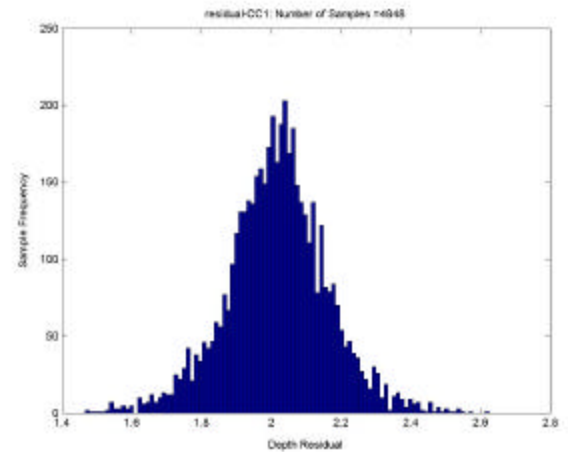


Figure 21. Histogram with a constant offset exhibits symmetrical, but offset distribution.

## Sound Speed Error

A sound speed error will result in depth errors that increase outward from the center beam, causing either a "smile" or a "frown" in the ping residual profile. The beam-by-beam residual plot, or profile, for a crosscheck where File 2 has sound speed errors can be seen in Figure 12. The typical smile artifact is shown but only when the across-track ping from the file with errors is compared to good near-nadir data as a reference (File 2 VS Ref). From the other direction, even with sound speed error, File 2 near-nadir data has little error. The blue profile (File 1 VS Ref) in Figure 12 compares the entire ping from the file with no error to the nadir data of the erroneous file. This, in effect, compares good data to good data, so the sound speed error will not be obvious in the blue profile (File 1 VS Ref).

The corresponding histogram of the grid cell residuals (Figure 13) shows a highly skewed distribution to the positive side. Sound speed errors causing the outer beam residuals to curve down would have resulted in the histogram being skewed to the negative.

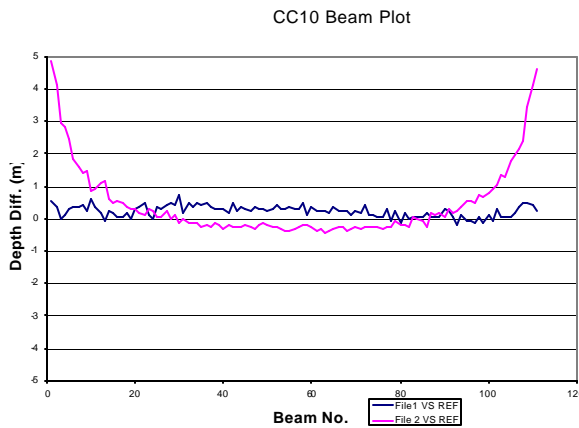


Figure 12. Crosscheck with sound speed errors in one of the files. Only the pink profile shows the sound speed error. The error is masked from the other direction.

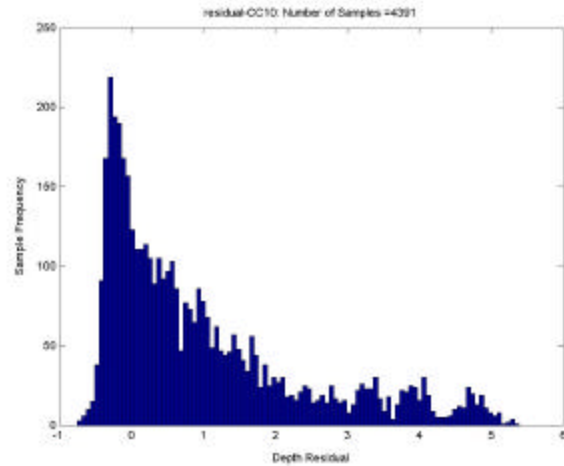


Figure 13. Histogram grid cell-by-cell comparison residuals for data with sound speed errors.

## Roll Bias Errors

Files that exhibit roll bias errors will have a too-low residual in the outer beams on one side of center and a too-high residual on the other side when compared to good data. Figure 14 shows good data from File 1 compared to

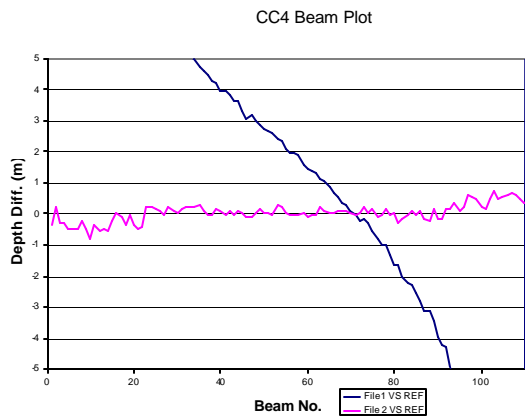


Figure 14. Profile plot of roll bias error. The highly slanted blue line depicts the error, but is masked the pink line from the other direction.

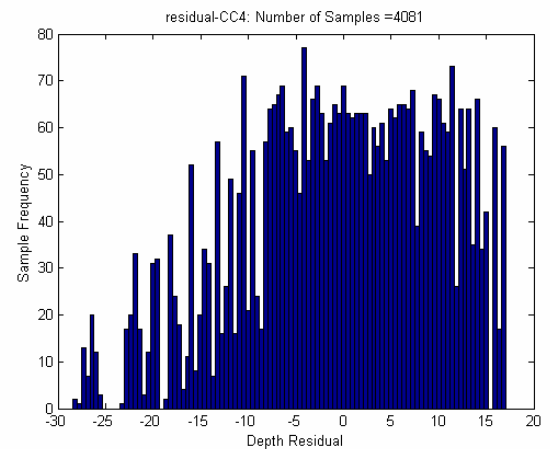


Figure 35. Histogram of crosscheck with roll bias error in one of the files.

erroneous data in File 2 that has a 5° roll bias error. This causes the mean depth difference statistic to average out but the STDDEV values will be very high (CC 4 in Table 1). The quality indicator is high, mirroring the R95 value, as in all the crosschecks. Figure 14 shows that the blue profile (File 1 VS Ref) is characteristic of what can be expected with roll bias errors, but only in that direction. As seen in the previous example of sound speed error, the analysis is directional. In the other direction, even though File 2 has a large error, the near-nadir depths have relatively little error so the profile in that direction does not exhibit characteristics of roll bias error. In that case, data from the good file (File 2) is compared to nadir depths of the erroneous File 1 (Figure 14, File 2 VS Ref) and the roll bias errors are not obvious. The typical histogram for a roll bias error is shown in Figure 15. The distribution in this case is spread out and asymmetrical.

## Steps for MB Crosscheck Analysis

Several issues must be kept in mind when designing an automated process for MB crosscheck analysis. First, the data quantities for multibeam are huge and the number of crossings is numerous. Even using automated means does not afford the luxury of reading through all the data points looking for data matched geographically. The task to determine whether lines potentially cross and where must be done with minimal processing overhead. For this reason, a few restrictions will be placed on the input data. The metadata, or header record in the data files must be accessed for a first-cut attempt to determine if and where the lines cross. In the case of the gsf files that NAVOCEANO uses, the summary record is used to obtain the minimum and maximum geographic bounds. Minimum and maximum boundaries can be combined for two possible solutions to obtain the line azimuth. Since the azimuth could be one of two choices, the azimuth must be supplied. This can come out of the data file with a bit of added programming sophistication or the user can supply this information when inputting the file names. The survey line must also hold its heading during the entire trackline run. It is much more complicated if the data contains turns, and it is recommended to run a preprocessing routine that will separate the data into line segments between major heading changes.

There are several steps that will lead to plots of crosscheck data that can be used to make decisions. Irrespective of the software used, the following steps will have to be done:

- **Calculate threshold.** From the order of the survey and average depth, the acceptable error limit must be calculated for a comparison of the quality indicator.
- **Determine if the tracklines cross.** When doing manual crosscheck analysis, tracklines are plotted out and the filenames that correspond to crossing tracks are found. Digital methods can be done using geometry as long as the track lines are relatively straight, the data collected in the turns is removed, and the azimuth is known (which can also be done with software). The tracklines can then be treated as line segments, and the geometry is fairly simple to determine whether they cross.
- **Determine where the crosscheck is centered.** Once the tracklines are roughly known to cross, a more accurate crosscheck center must be obtained. This center, along with the swath width, will control the size of the gridded files. Therefore, the calculated center should be as close to the actual center as possible without taking too much processing to find. The user can supply a box width to search, and the program can find where actual data crosses into the box. Once those locations are found, another geometric computation using line segments can be done to get a much closer estimate of what the crosscheck center is.
- **Determine a sufficient sized geographic box for crosscheck grids.** Using the system type, mode and swath width, all of which should be available in the data file, the size and geographic bounds of the actual collocated grid files can be determined. The smallest possible grid files are desirable since tight grid spacing (footprint size) will create large files.
- **Grid both data files.** Both data files are then gridded using the approximate beam footprint for the grid cell size and the bounds determined in the step above.
- **Calculate residuals for collocated grid cells.** The two grid files are then compared cell by cell, and depth residuals are obtained.
- **Determine the quality indicator.** From the many residuals at each crossing, determine a single value to be used as a quality indicator that will be compared to the threshold value. Use a calculated value for the RMS at the 95 percent region ( $RMS \cdot 1.96$ ), or sort the residuals' absolute values and pick the value coincident with the 95 percent region boundary.

- **Plot the quality indicators.** The quality indicators are plotted with some color or symbolic distinction between those that pass and those that fail when compared to the threshold value. This culmination of the area approach will allow the surveyor to see trends in the data that warrant further investigation.
- **Create ping profiles.** For each crosscheck, create a set of residuals, which is a comparison of center beam data of one file to across-track data of the other. An actual ping closest to the crosscheck center is selected from File 1 by the program and this ping is compared to the closest grid cells of file 2, which should contain almost entirely center beam data. This is repeated for the same crosscheck by using an actual ping from File 2 and gridded center beam data from File 1. The residuals are then plotted against the beam number. From these plots, the user may be able to see what the problems are.

## The Future of Crosscheck Analysis

As previously stated, this method has been implemented at NAVOCEANO using gsf files as input with good results in several test areas. No further resources will be put toward further development in that implementation. Instead, it is logical that this is implemented under the Pure File Magic (PFM) data structure that is the backbone of the Integrated Visualization Systems (IVS)-created Fledermaus program. NAVOCEANO has a Cooperative Research and Development Agreement (CRADA) with IVS for the development of Fledermaus. Ongoing discussions and requirements of them have prompted the creation of a crosscheck module for Fledermaus. That implementation is the objective of future and ongoing development and testing. The functionality of the Fledermaus crosscheck module was initially written to use crosscheck data to do an uncertainty assessment of interpolated data between survey lines. This compares real data to interpolated data. At some upper limit of uncertainty, a decision would be made to fill in between survey lines or not. In this case, IHO SP-44, Table 3 (the table for Bathymetric Model Accuracy, or interpolated data) should be used for comparing real data to interpolated data. But similar comparisons and plotting distinctions must be done for this interpolated data analysis as well as for the real data comparisons that this paper is about. The real data comparisons are still under development in the Fledermaus implementation.

Another CRADA is in place with Science Applications International Corporation (SAIC) for development of their product Survey Analysis and Area-Based Editor (SABER) package which is the post processing tool of the SAIC Integrated Survey System (ISS2000). A demonstration by Shannon Byrne of SAIC in March of 2002 showed the crosscheck capability of SABER. An overlapping area where lines cross can be selected, and statistics can be run. The drawback is that, although the interface is onscreen, only a single crosscheck is analyzed at a time.

Irrespective of the software used for automated crosscheck analysis, for real data comparisons, the two types of crosscheck analysis, area-based and ping-based, should be done. NAVOCEANO favors the implementation in Fledermaus and/or SABER, which is logical since the CRADAs cover the development cost and both processing packages have become an integral tool for multibeam processing.

## Conclusions

Data redundancy is perhaps the most valuable quality assurance tool and running crosscheck lines provides just such a dataset. However, if these data go unevaluated, collection of redundant data, or crosschecks is a waste of ship time. Hundreds of crosschecks are collected in a survey area and an automated tool must be implemented to handle analysis of these data. Analysis includes the ability to see trends in the trackline data and determine possible causes for discrepancies between redundant data segments.

Automated processing reads in a list of file names, determines if and where any two of the files cross, and proceeds with a twofold analysis. The first area-based approach will determine a single statistical quality indicator from the depth residuals between collocated grid files for each crosscheck, measure this quality indicator against the maximum allowable error or threshold, and flag the crossings that fail the comparison. The user can then investigate the source of high residual values with the ping approach. The ping approach generates a profile of the beam-by-beam depth residuals when comparing an across-track ping from one file at the crosscheck center to the along-track center beam data from the second file. This allows the users to determine if the uncertainties are constant, possibly related to the water level, or whether sound speed or roll bias problems have corrupted the data. The data can either be corrected with current available post processing tools, or the data is thrown out and re-acquired. System corrections can be made prior to the collection of subsequent survey data. This fulfills the intent and value of spending ship time to collect crosscheck data.

## References

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