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General Locality:	CA, OR, WA Coastline

2015

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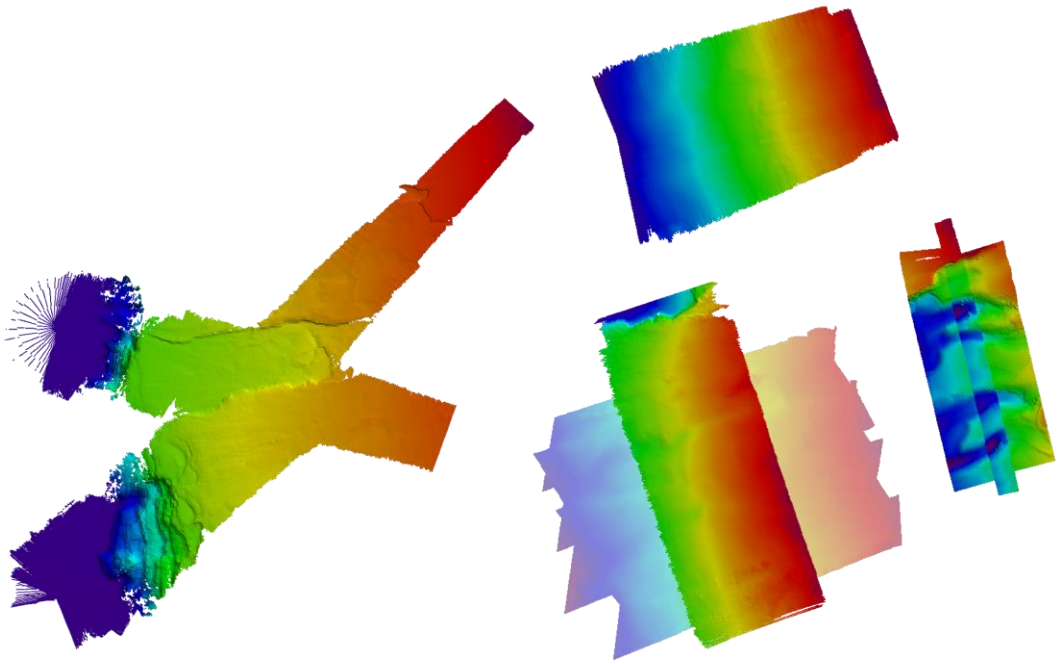
Date:

E/V Nautilus
EM302 Multibeam Echosounder
System Review
NA055
March 30 – April 5, 2015



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Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of UNH or NSF.

Cover image: Bathymetry of the calibration lines, reference surface, one accuracy cross line survey pass, and extinction survey passes at the continental shelf break off St. Petersburg, Florida. Data were processed with Caris HIPS 9.0 and are shown with individual color scales for contrast.

Introduction

The E/V *Nautilus* undertook an engineering shakedown leg (NA055) in order to perform an assessment of the vessel's Kongsberg EM302 multibeam echosounder. Data were collected along the continental shelf break (Figure 1) between St. Petersburg, Florida, and Gulfport, Mississippi, from March 30 to April 5, 2015. Paul Johnson and Kevin Jerram provided logistical and technical support for mission planning, data collection, and analysis. This report presents:

- an overview of the data collected and the processing methods applied to it
- an EM302 system accuracy assessment and swath coverage analysis
- a history of all changes made to the system configuration, starting from the initial install and up through the most recent calibration, prior to the start of the 2015 operational season
- vessel self noise as measured by the multibeam receiver at various speeds in calm water and headings relative to the swell
- EM302 transducer impedance data to document system transducer health.

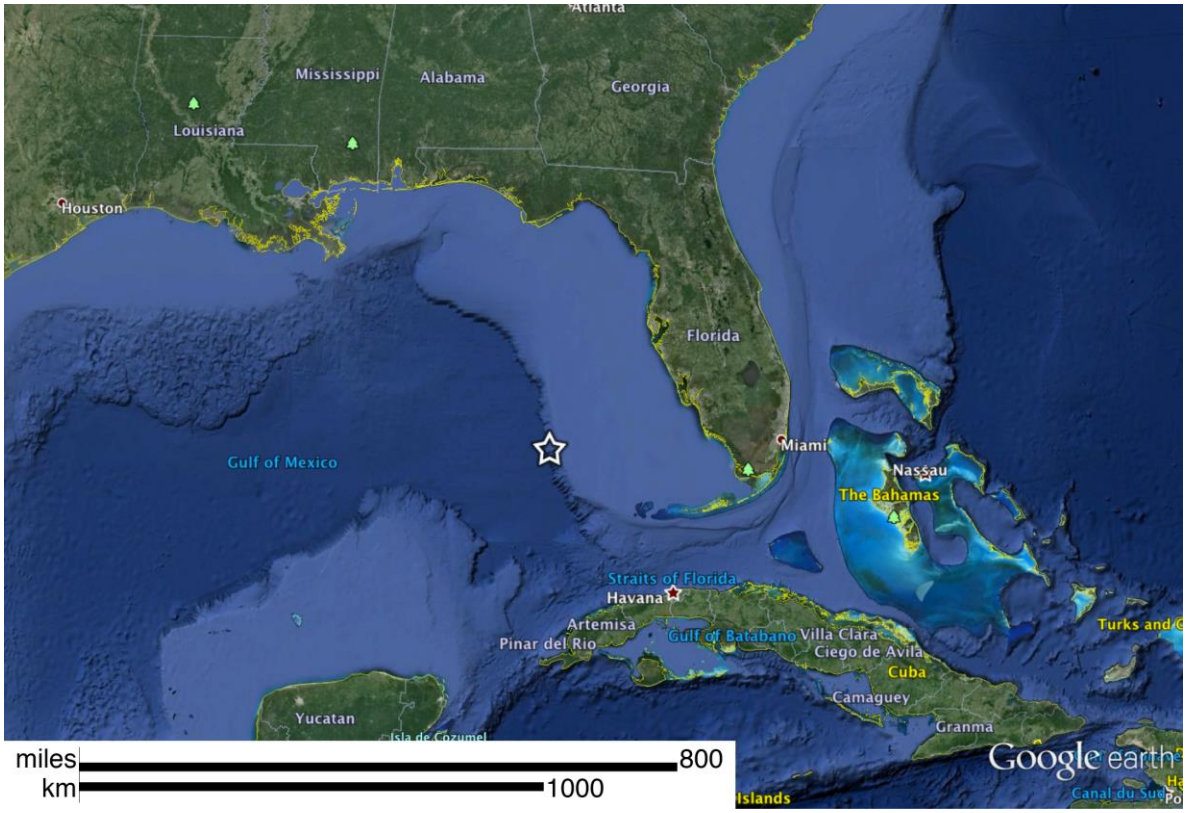

Figure 1. EM302 system testing was performed during NA055 at the continental shelf break off St. Petersburg, Florida, at the calibration site used during NA040 (star).

Cruise Participants

Danielle Altebrando
Steve Auscavitch
Alexandra Avila
Tim Brogdon
Dwight Coleman
Max Cremer
Ethan Gold
Kevin Jerram
Paul Johnson
Jordan Kirby
Dan Larsh
Dave LePage
Justin Lowe
Neal Miles
Mary Nichols
Mark O'Riordan
Al Santos
Will Sellers
Clara Smart
Scott Stamps
Ian Vaughn
Bob Waters
Jonathan Zand

Survey System Components

The mapping system consists of the following primary components:

1. Kongsberg Maritime EM302 multibeam echosounder (30 kHz), v1.3.1, s/n 110
2. Kongsberg Maritime Seafloor Information System (SIS), v4.1.3
3. Kongsberg Seatex Seapath 330+ vessel navigation system
    - Seapath 330+ GNSS antennae
    - MRU 5+, s/n C126NS2018
4. AML Oceanographic Micro-X surface sound speed sensor
5. Sippican expendable bathythermograph (XBT) profiling system

Activities

Cruise activities included a review of the survey system geometry, calibration for residual angular offsets of the motion sensor ('patch test'), accuracy evaluation with respect to the bathymetric reference surface created during NA040 (2014), ship speed self noise testing in calm seas, ship heading self noise testing relative to swell direction, and swath coverage/extinction evaluation on and off the continental shelf break. Ancillary activities included support for watchstander training, verification of the Knudsen subbottom profiler operation, and surveys of opportunity during transits.

Overview of System Geometry

In this report, we use the term 'system geometry' to mean the linear and angular offsets of the primary components of the multibeam mapping system, including the transmit array (TX), receive array (RX), and ship navigation sensor (MRU). These parameters are critical for data collection in an unbiased and repeatable manner. **Error! Reference source not found.** presents a chronological outline of documented modifications to system geometry.

Table 1. Documented modifications to system geometry.

Date	Cruise ID	Location	Event	References
2013 March		Istanbul, Turkey	Install EM302 MBES, Seatex Seapath 330+ MRU, AML Oceanographic surface sound speed sensor, Sippican XBT profile; establish vessel reference frame and survey sensor offsets	Kongsberg Maritime (KM) Harbor Acceptance Test (HAT) report, Parker Maritime survey report
2013 April	NA025	Toulon, France	EM302 sea acceptance trials; MRU angular offsets determined by patch test and applied in SIS	UNH/IFREMER Sea Acceptance Trials (SAT) report, Gates Acoustic Services report
2013 June	NA030	Gulf of Mexico	Original MRU 5+ unit replaced with spare by KM engineer at start of NA030	2014 EM302 Multibeam Echosounder System Review
2014 May	NA040	Gulf of Mexico	Original MRU 5+ unit reinstalled by KM engineer at start of NA040; EM302 system performance review; residual angular offsets determined by patch test and applied in SIS	2014 EM302 Multibeam Echosounder System Review
2015 April	NA055	Gulf of Mexico	EM302 system performance review; residual angular offsets determined by patch test and applied in SIS	2015 EM302 Multibeam Echosounder System Review (this document)

TX and RX Arrays

Linear and angular offsets of the TX and RX arrays were determined from a ship survey performed by Parker Maritime in Istanbul in March of 2013 (see Parker Maritime survey report and UNH/IFREMER Sea Acceptance Trial [SAT] report for details). Offsets of the hull-mounted arrays are not expected to have changed since the Parker survey. Accordingly, no array offset modifications are documented in this report.

MRU

All modifications to the system geometry since installation have involved the MRU. Prior to the 2013 season, linear and angular offsets of the original MRU were determined from the Parker Maritime survey and SAT patch test, respectively. The original MRU was deemed faulty and replaced by Kongsberg engineers before the start of NA030 in July 2013. A patch test was performed at the start of NA030 to determine angular offsets between the replacement MRU and the ship reference system, holding all other offsets constant. The NA030 patch test results for angular offsets were applied for the remainder of the 2013 multibeam mapping season. No changes to linear offsets were recorded, as they were expected be on the order of millimeters and would not have had an appreciable effect on the bathymetry (or, consequently, been resolvable through patch testing).

The original MRU removed prior to NA030 was serviced by Kongsberg, reinstalled at the start of the 2014 season, and then calibrated for angular offsets during the NA040 leg (see E/V Nautilus EM302 Multibeam System Review NA040 report for details). This MRU remained in place throughout the 2014 season. A review of the installation parameters in SIS at the start of NA055 confirmed that the NA040 calibration results were maintained without modification (accidental or otherwise) leading into the 2015 operating season. Residual angular offsets were determined through patch testing during NA055 and are documented in this report.

Calibration

A patch test was conducted at the start of NA055 to determine residual angular offsets of the MRU in the order of pitch, roll, and yaw. Data were collected in depths of 900-1250 m over seabed features near the continental shelf break southwest of St. Petersburg (**Error! Reference source not found.**). Descriptions of the rationale for calibration line planning are available in the *Cookbook for Caris HIPS 8.1 Patch Test with Kongsberg EM302*, which was developed with examples from NA040 (2014).

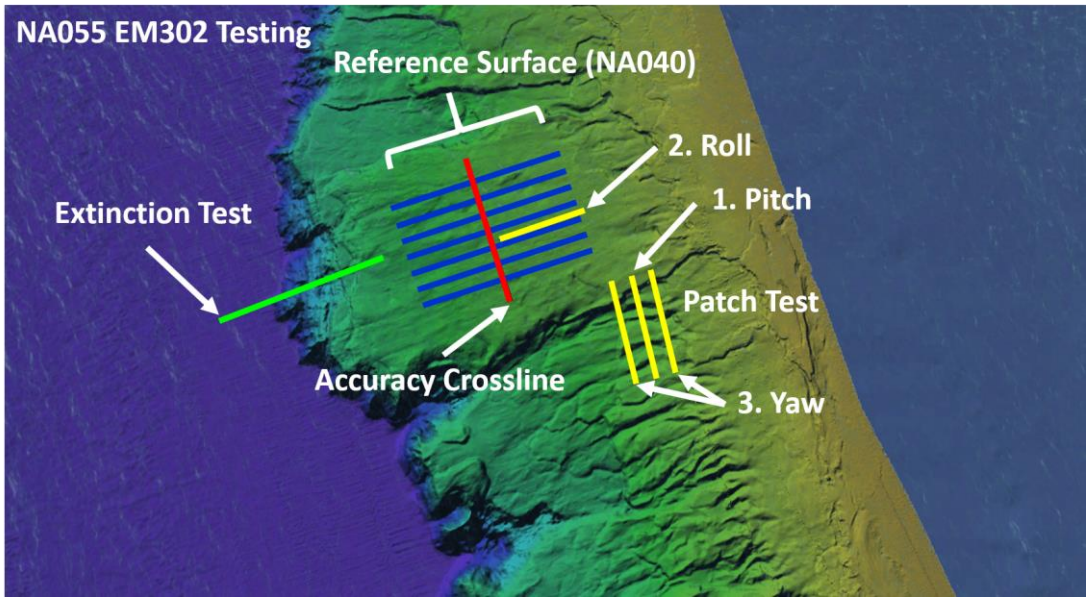

Figure 2. Layout of NA055 operational areas for EM302 evaluation (presented in Google Earth using historic multibeam echosounder data downloaded from the National Geophysical Data Center).

An XBT profile was acquired to 760 m depth prior to each set of the pitch, roll, and yaw calibration lines. All XBTs throughout NA055 were processed using WinMK and SVP Editor to remove spurious sound velocities, apply salinity data from the World Ocean Atlas, extend the cast to 12,000 m per SIS requirements, and load the resulting sound speed profile into SIS.

All calibration lines were collected at a vessel speed of 8 kts over ground (except one latency line collected at 12 kts) due to engine-related difficulties operating the vessel at slower speeds for extended periods. While this speed reduces the alongtrack sounding density compared to previous patch tests performed at 4-6 kts, the lengths of the calibration lines ensure sufficient data quantity for calibration purposes. To maximize ping rate and sounding density, the EM302 was configured as follows:

Depth mode:	AUTO	
Dual-swath mode:	enabled (dynamic)	
Transmit mode:	FM enabled (unchecked)	
Yaw stabilization:	enabled (rel. mean heading)	
Pitch stabilization:	enabled	
Beam spacing:	High density equidistant	
Swath width:	Pitch:	15°/15° port/stbd
	Roll:	70°/70° port/stbd
	Yaw:	15°/60° port/stbd and 60°/15° stbd/port

Calibration survey data were collected using the post-NA040 angular offsets as the initial starting point for real-time processing in SIS. Accordingly, the angular offsets determined from the NA055 calibration constituted 'residual' values to be summed with the NA040 values. Angular offsets were determined in the order of pitch first, roll second, and yaw third. To minimize coupling of angular offsets in the calibration results, each angular offset was updated in SIS after completion of its respective calibration procedure and before the start of survey data collection for the next offset calibration. Calibration tools in SIS, Caris HIPS 9.0, and a pre-release version of QPS Qimera hydrographic software packages were used separately to evaluate each set of calibration lines. Results from independent examinations of each tests dataset by Johnson and Jerram, using all three tools, were in excellent agreement.

Calibration Results

No clear trends requiring residual angular offsets were observable for the pitch or yaw datasets when evaluated using all three of the calibration tools. Accordingly, pitch and yaw were left unchanged from post-NA040 values in SIS. The roll calibration lines suggested a residual angular offset of -0.02° which was added to the post-NA040 value, applied in SIS, and verified by collection and examination of a second set of roll calibration lines with excellent results (zero residual evident). No evidence indicating latency in the system was observed at any point during NA055.

Figure 3 to 5 depict example transects using the Caris HIPS Subset Editor calibration tool for the pitch, roll, and yaw calibration data sets. The final value for each offset is based on examination of multiple transects in the Subset Editor calibration tool. The results, in agreement with results from the SIS and Qimera calibration tools, represent the residual angular offsets applied to the MRU Installation Parameters in SIS (Table 2).

Table 2. Summary of MRU angular offsets.

Angular Offset	Pre-NA055 Value	NA055 'Residual'	Post-NA055 Value
Pitch	-0.12°	+0.00°	-0.12°
Roll	+0.15°	-0.02°	+0.13°
Yaw	+0.11°	+0.00°	+0.11°

All MRU angular offsets entered into SIS after the NA055 calibration reflect the net totals resulting from the NA030, NA040, and NA055 calibrations. NA055 survey data for deepwater accuracy and extinction utilized these post-calibration values and appear to be free of offset-related artifacts.

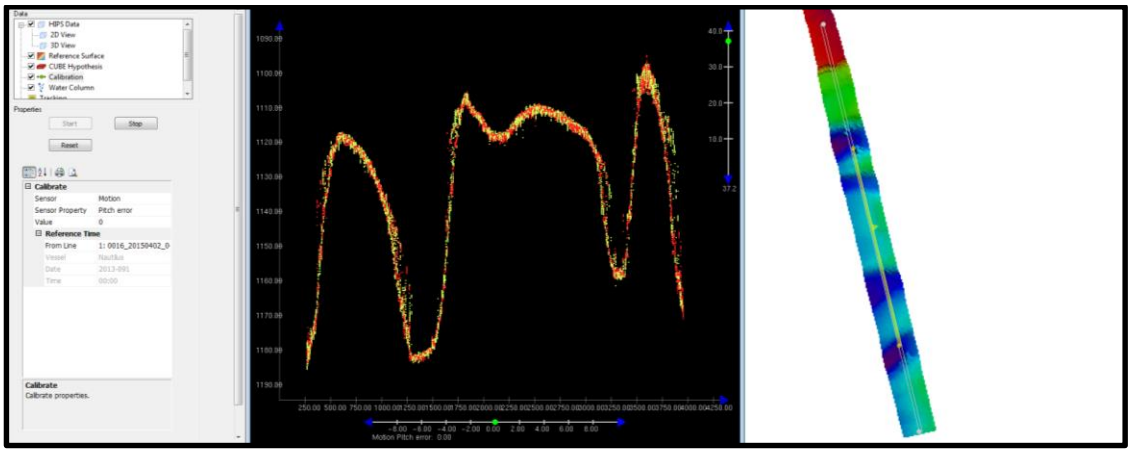

Figure 3. Example subset of pitch calibration data in Caris HIPS 9.0 yielding a residual MRU pitch offset of 0.00°. No change was made to the MRU pitch offset in SIS.

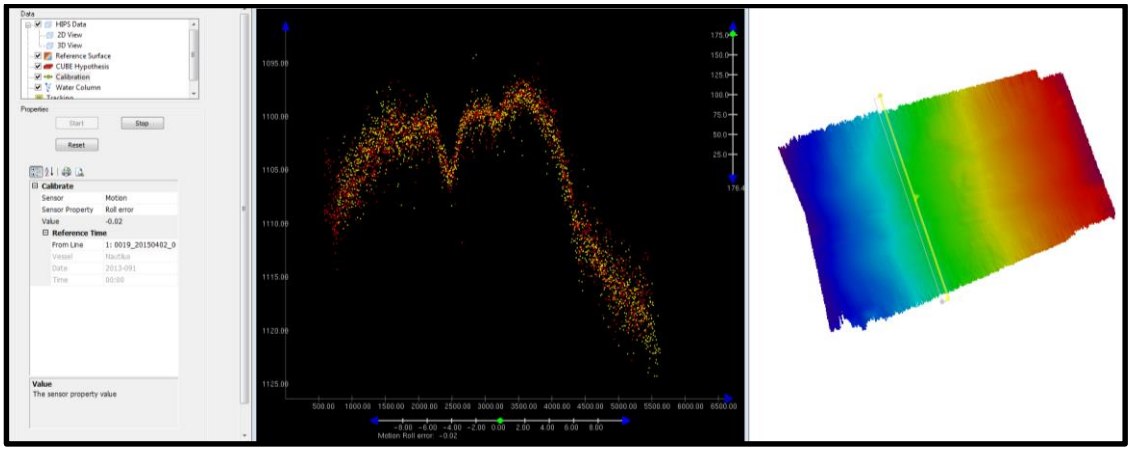

Figure 4. Example of subset of roll calibration data in Caris HIPS 9.0 yielding a residual MRU offset of -0.02°. This value was added to the existing MRU pitch offset before collecting yaw data and then validated during a second set of roll calibration lines.

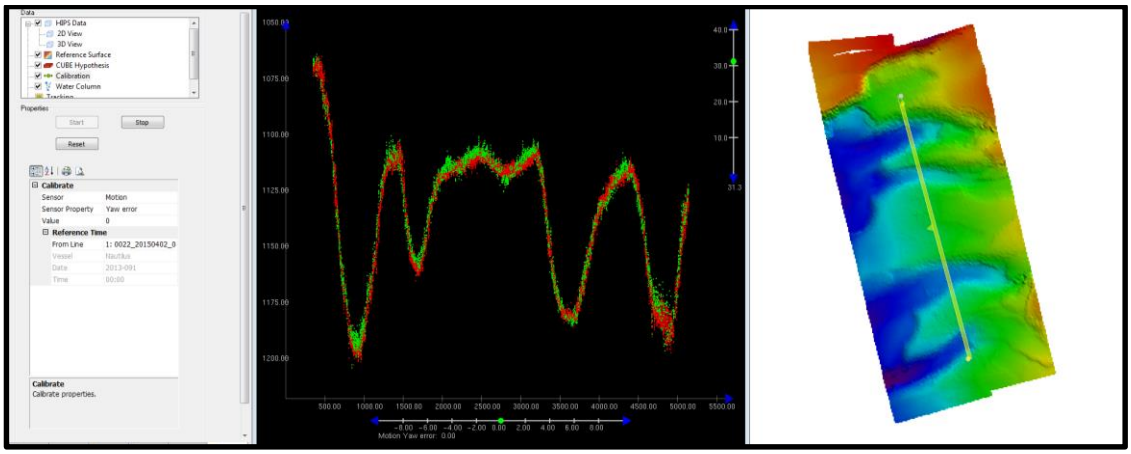

Figure 5. Example subset of yaw calibration data in Caris HIPS 9.0 yielding a residual MRU yaw offset of 0.00°. No change was made to the MRU yaw offset in SIS.

System Geometry and SIS Parameters (05 April 2015)

Table 3 includes the SIS configuration for the linear and angular offsets of the TX and RX arrays and the MRU at the end of the NA055 leg on April 5, 2015. Aside from applying the residual MRU roll angular offset determined from the NA055 patch test, no further modifications were expected or made to the SIS Installation Parameters (Figure *6*). Additional screenshots of SIS parameters are available in the Appendix C. These offsets represent the survey configuration which will be used at the start of the 2015 Nautilus operational season based on existing documentation and patch test results. All values are with respect to the Kongsberg (SIS) reference frame. These parameters are to be used until sensor locations or orientations are modified or it is determined that a new patch test should be undertaken.

Table 3. SIS PU parameters for linear and angular offsets at the end of NA055. Note that MRU linear offsets are not specified because navigation data from the Seapath 330+ navigation system are referenced to the center of the TX array, per Kongsberg convention for navigation input.

	X (m)	Y (m)	Z (m)	Roll (°)	Pitch (°)	Yaw (°)
Vessel Reference Origin	0.000	0.000	0.000	-	-	-
Navigation Reference Point	0.000	0.000	0.000	-	-	-
EM302 TX	+3.496	-0.137	+2.731	+0.61	+0.01	+0.22
EM302 RX	+1.516	+0.033	+2.732	+0.72	+0.32	+0.08
Seapath MRU	-	-	-	+0.13	-0.12	+0.11

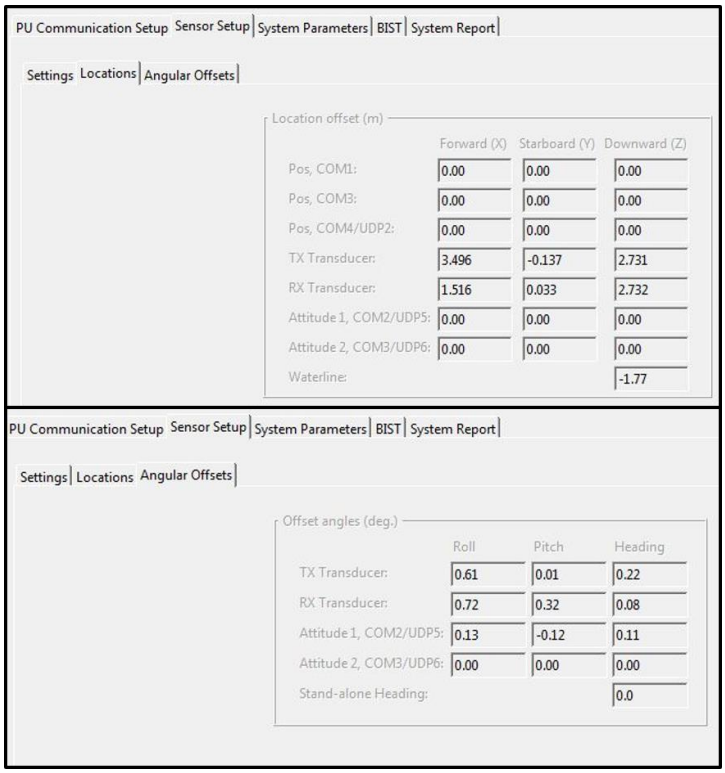

Figure 6. SIS screen captures of PU parameters for linear and angular offsets off system components after NA055.

Accuracy Assessment

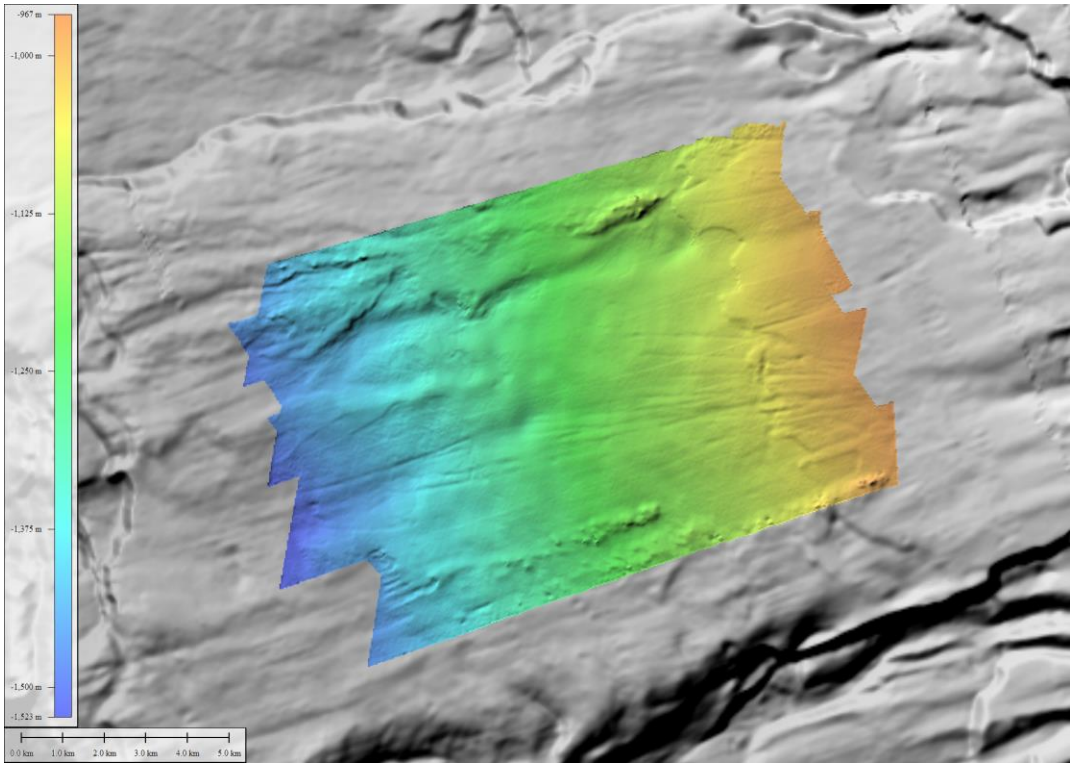

Figure 7 Overview of the reference surface created during NA040 (2014) and employed for deepwater accuracy evaluation during NA055 showing all data collected for the area.

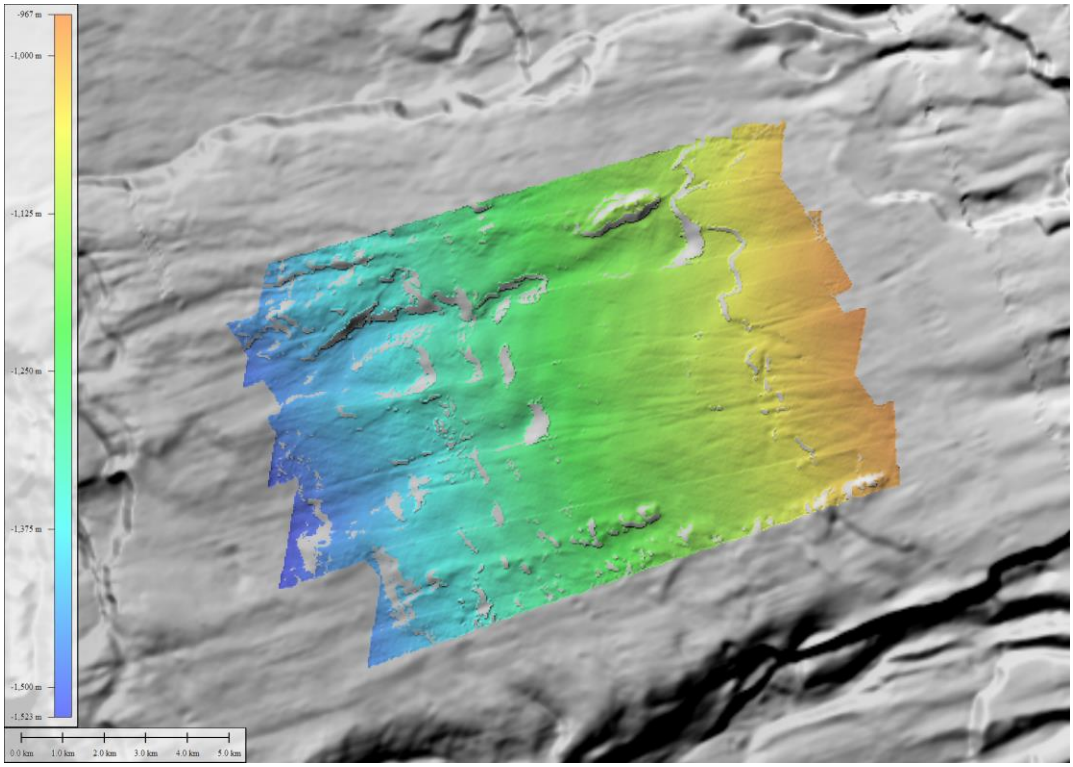

Figure 8. Reference surface with areas of slopes greater than 5° masked.

Reference surface lines collected during NA040 (2014) were reprocessed with Caris HIPS 9.0 and gridded at 30 m using the Combined Uncertainty and Bathymetry Estimator (CUBE) algorithm (Figure 7). A slope filter was then applied to the data to exclude areas having slopes greater than 5° from the cross line statistical analyses (Figure 8).

Cross lines were run using a variety of swath and transmit modes with vessel speeds of 8 kts and 10 kts during NA055 in the orthogonal direction (trending NW/SE) from the NA040 reference surface collection lines (trending SW/NE). As with patch test lines, engine constraints required a minimum vessel speed of 8 kts for first passes and 10 kts for all further surveying. Strong currents which had affected vessel operations during NA040 (e.g., requiring speed increases to reduce crabbing) were not a complicating factor during NA055.

Table 4 shows the Runtime Parameters settings for each of the cross lines over the reference surface. All tests were run in the DEEP ping mode, as the mean water depth in this area of 1250 m was too deep for the MEDIUM mode (which is best utilized in 250 – 750 m water depth) and too shallow for the VERY DEEP mode (which is best utilized in 3300 – 5000 m water depth). Accuracy data were collected over the reference surface for each setting on opposite headings at 8 and 10 kts to reduce potential biases resulting from the slope of the reference surface and cover the range of speeds expected for normal survey operations. Soundings from each of the cross line tests were compared on a beam-by-beam basis against the reference surface by sampling the

reference surface grid depth at the coincident point reported by each beam. A table of beam depth, beam angle, and reference surface depth was compiled using this cross line sampling method.

Table 4. SIS Runtime Parameters for each cross line over the reference surface. Note similarity to NA040 cross line settings, with the only difference being the order of CW and FM modes. Lines were run at 8 kts and 10 kts on opposite headings.

EM302 RUNTIME PARAMETERS	Cross Line Settings 1	Cross Line Settings 2	Cross Line Settings 3	Cross Line Settings 4
Sector Coverage				
Max. Angle (port)	70°	70°	70°	70°
Max. Angle (sbtd)	70°	70°	70°	70°
Max. Coverage (port)	5000 m	5000 m	5000 m	5000 m
Max. Coverage (stbd)	5000 m	5000 m	5000 m	5000 m
Ang. Coverage Mode	AUTO	AUTO	AUTO	AUTO
Beam Spacing	HD EQDST	HD EQDST	HD EQDST	HD EQDST
Depth Settings				
Force Depth	n/a	n/a	n/a	n/a
Min. Depth (m)	10	10	10	10
Max. Depth (m)	4000 m	4000 m	4000 m	4000 m
Dual Swath Mode	DYNAMIC	DYNAMIC	OFF	OFF
Ping Mode	DEEP	DEEP	DEEP	DEEP
FM Disable	Unchecked (FM)	Checked (CW)	Unchecked (FM)	Checked (CW)
Transmit Control				
Pitch Stabilization	ENABLED	ENABLED	ENABLED	ENABLED
Along Direction	0°	0°	0°	0°
Heading	0°	0°	0°	0°
Yaw Stab. Mode	REL. MEAN HDG.	REL. MEAN HDG.	REL. MEAN HDG.	REL. MEAN HDG.
Heading	0°	0°	0°	0°
Heading Filter	MEDIUM	MEDIUM	MEDIUM	MEDIUM

NOTE: Unchecked FM Disable means that FM is on.

Results from the cross line analyses were then tallied in 1° bins with the mean bias and standard deviation about the mean calculated for each bin. Figures 9-12 depict the beam-wise standard deviations (top) and biases (bottom) of all cross line soundings as percentages of water depths. Plots of these results for each vessel speed are included in the Appendix A.

Accuracy Results – FM Dual-Swath

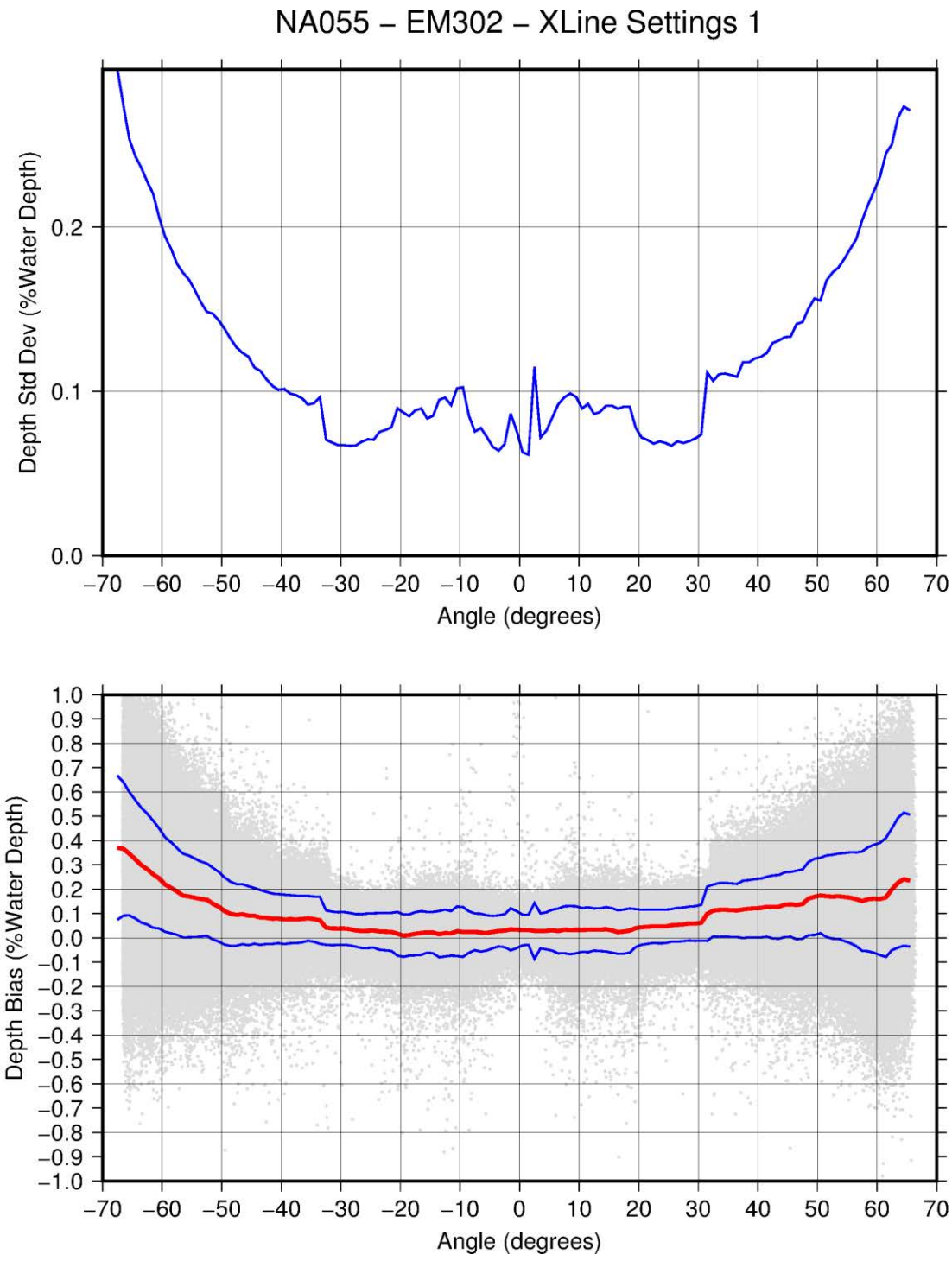

Figure 9. Depth standard deviations (top) and biases (bottom) as percentages of water depths for all cross line soundings collected at 8 kts and 10 kts using FM, dual-swath configuration (cross line settings 1). The bottom figure includes all raw soundings (grey points), the mean depth bias (red line), and the standard deviation of depth bias (blue lines) for each beam angle.

Accuracy Results – CW Dual-Swath

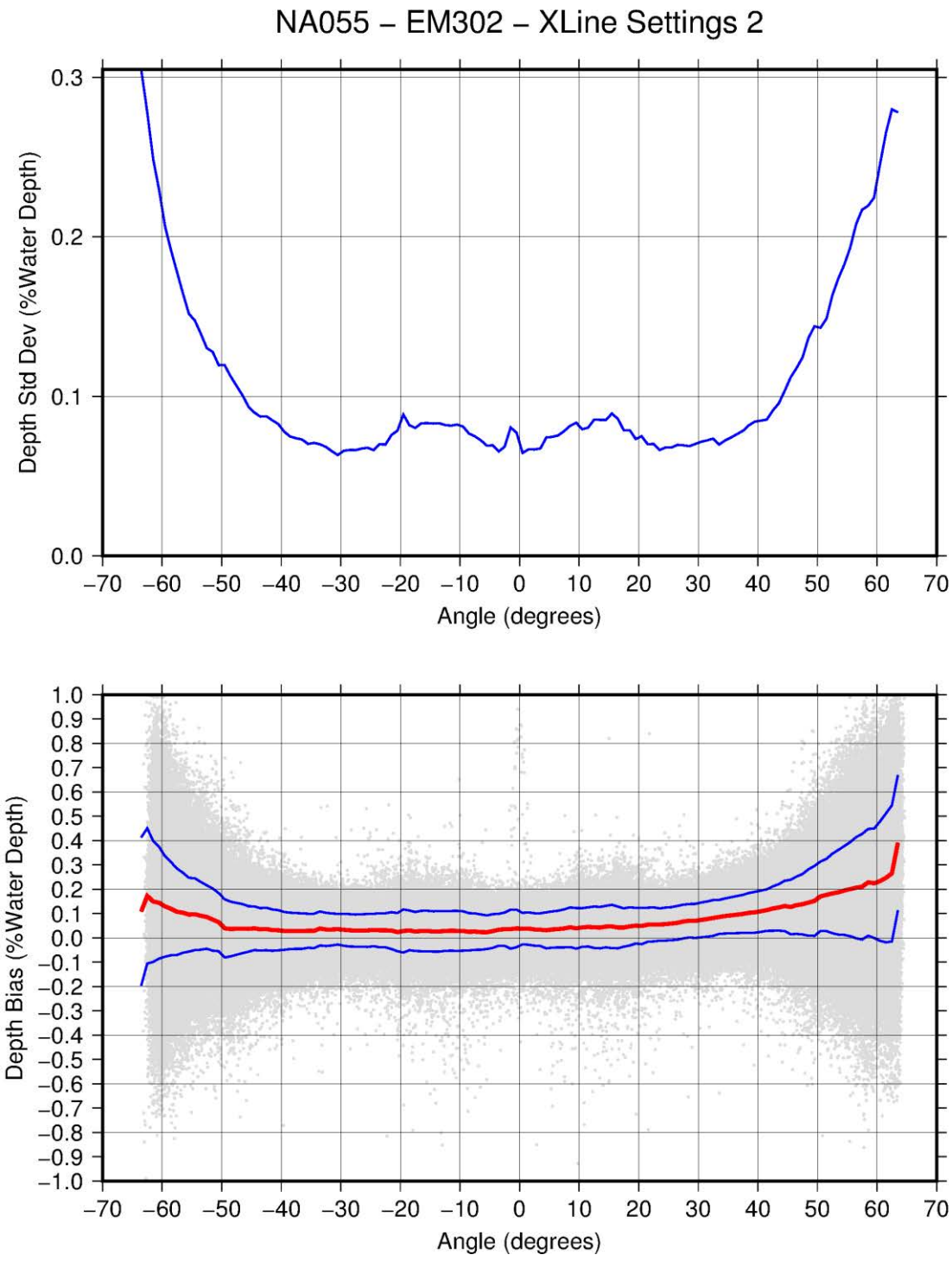

Figure 10. Depth standard deviations (top) and biases (bottom) as percentages of water depths for all cross line soundings collected at 8 kts and 10 kts using CW, dual-swath configuration (cross line settings 2). The bottom figure includes all raw soundings (grey points), the mean depth bias (red line), and the standard deviation of depth bias (blue lines) for each beam angle.

Accuracy Results – FM Single-Swath

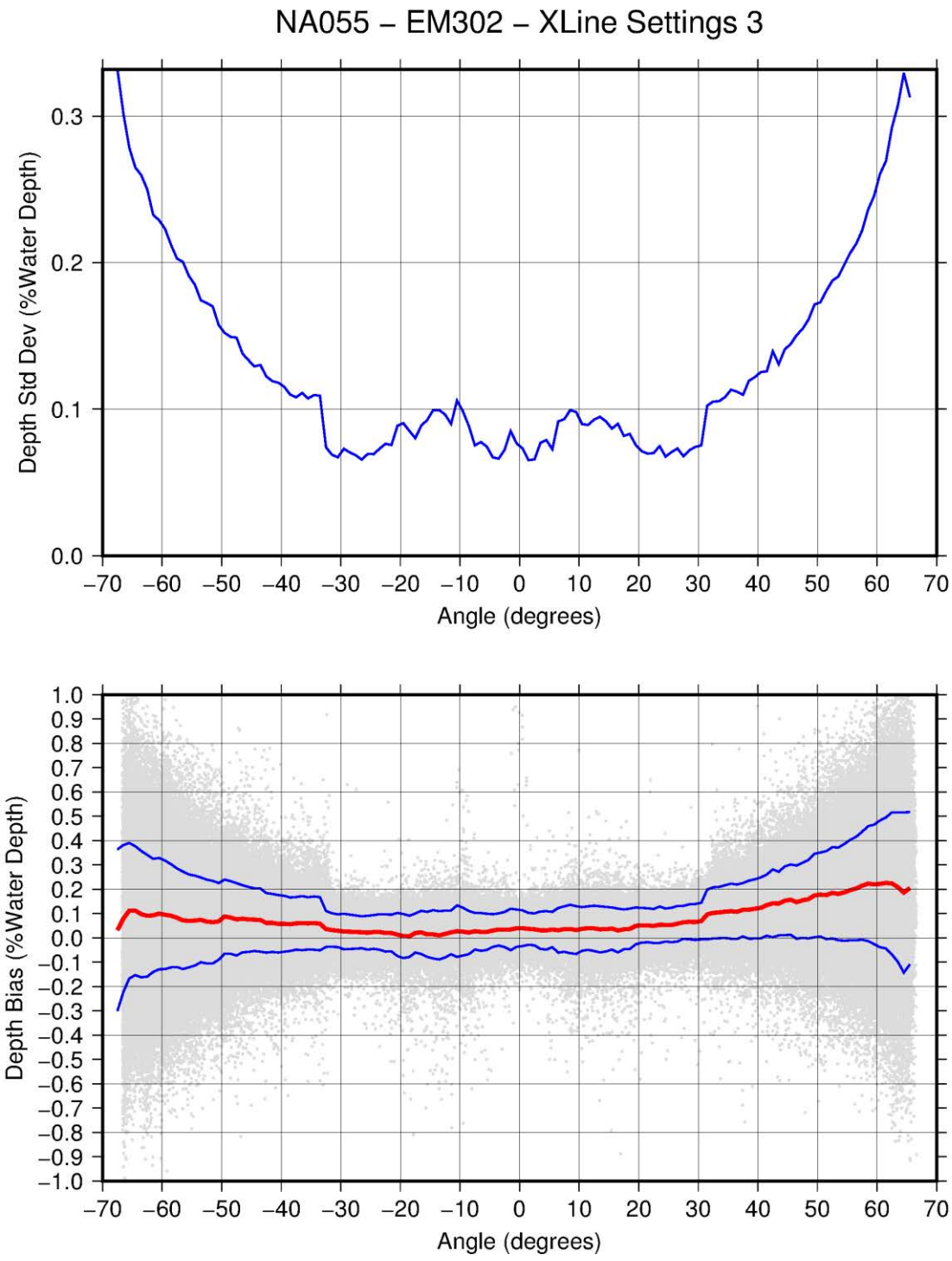

Figure 11. Depth standard deviations (top) and biases (bottom) as percentages of water depths for all cross line soundings collected at 8 kts and 10 kts using FM, single-swath configuration (cross line settings 3). The bottom figure includes all raw soundings (grey points), the mean depth bias (red line), and the standard deviation of depth bias (blue lines) for each beam angle.

Accuracy Results – CW Single-Swath

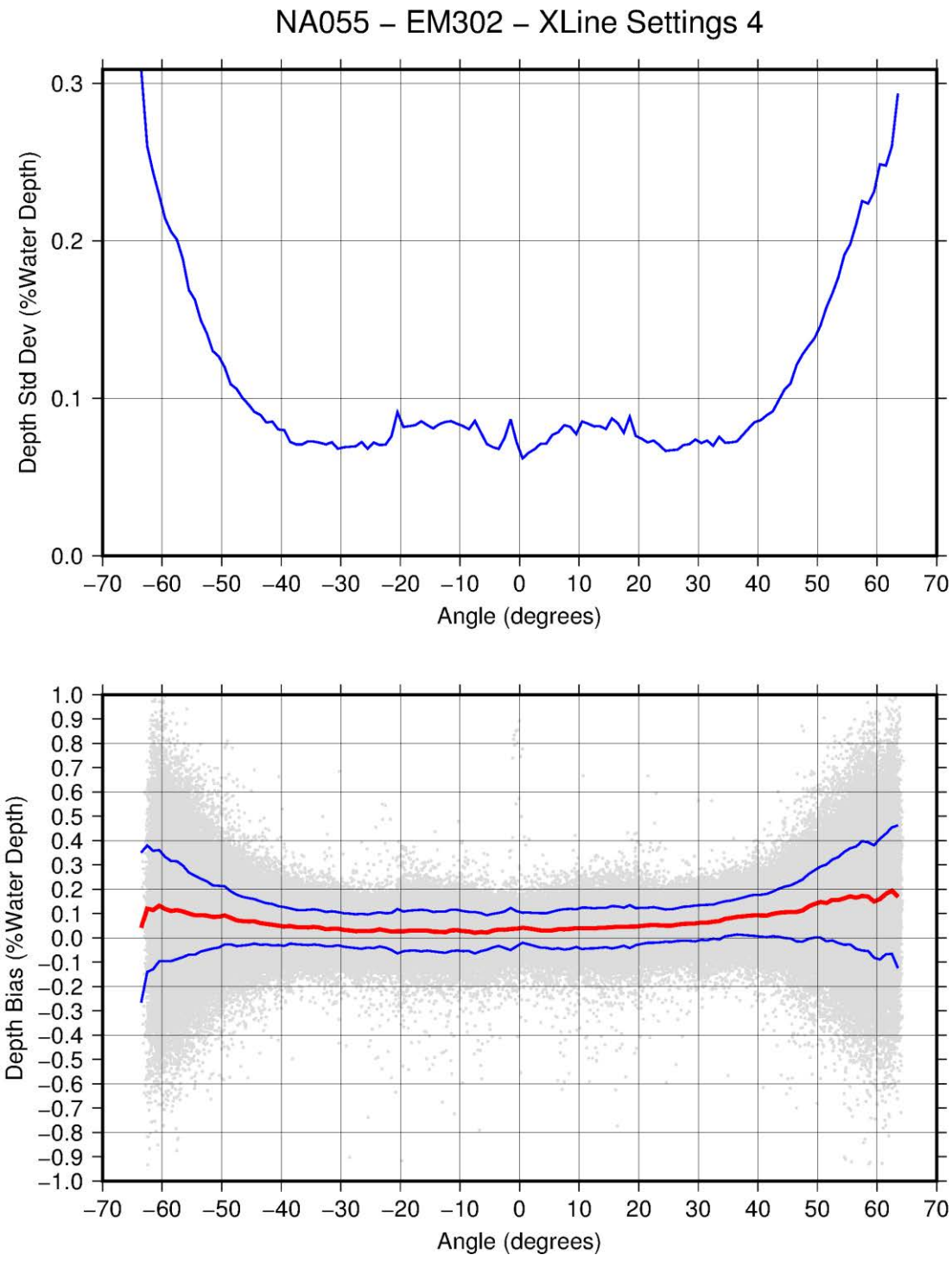

Figure 12. Depth standard deviations (top) and biases (bottom) as percentages of water depths for all cross line soundings collected at 8 kts and 10 kts using CW, single-swath configuration (cross line settings 4). The bottom figure includes all raw soundings (grey points), the mean depth bias (red line), and the standard deviation of depth bias (blue lines) for each beam angle.

Examining Figs. 9-12, it can be seen that the EM302 provides fairly unbiased soundings over the majority of the swath in all modes tested. As in the NA040 evaluation, and despite updating sound speed data with an XBT profile before every other cross line, a small non-linear refraction-like bias is apparent in the outermost sectors for almost all test cases. The refraction-like biases could be minimized with even more frequent collection of XBT profiles or the selection of an alternative area with a more stable water mass for data collection.

The observed mean biases and standard deviations are within the expected performance tolerances of the system as a whole, with no significant difference in performance compared to 2014. A majority of the swath shows beam-wise depth biases of less than 0.1% of water depth. The standard deviations about the mean bias are typically within +/-0.15% to +/-0.25% water depth (1-σ) across the majority of the swath with higher uncertainties at the limits of the swath, as expected and typical for these systems. Also, as expected, the CW modes perform more consistently across the entire swath than the FM modes, which tend to support longer ranges but exhibit noisiness at sector boundaries and increased vertical scatter in the outer swath.

Achieved Coverage

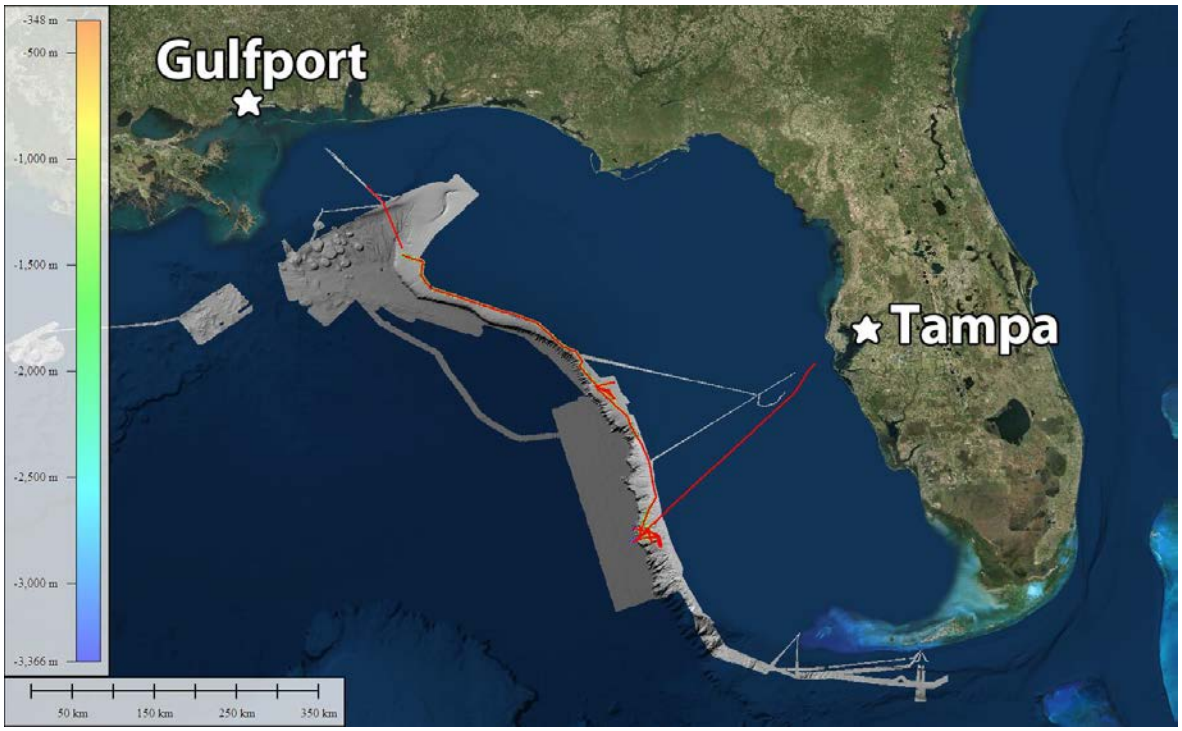

Figure 13. Red line shows the ship navigation extracted from the EM302 data included in the swath coverage calculation.

The swath coverage performance was evaluated by tracking the outermost port and starboard soundings from all data acquired during the patch test, reference surface collection, extinction test and parts of the transit to Gulfport (Figure 13). Figure 14 depicts the across-track coverage versus depth up to approximately 3350 m. Ideally, all data included in the swath coverage analysis should have been collected in automatic angular coverage mode, automatic depth mode,

and FM transmit mode in order to calculate the swath width as a function of depth using settings optimized by the EM302 for maximum coverage. However, as during NA040, other test activities were being undertaken during the cruise and the data utilized to produce the coverage plots were collected with many different Runtime Parameters, including limitations to the angular coverage (during patch testing only), changes to the depth mode, and both CW and FM transmit modes.

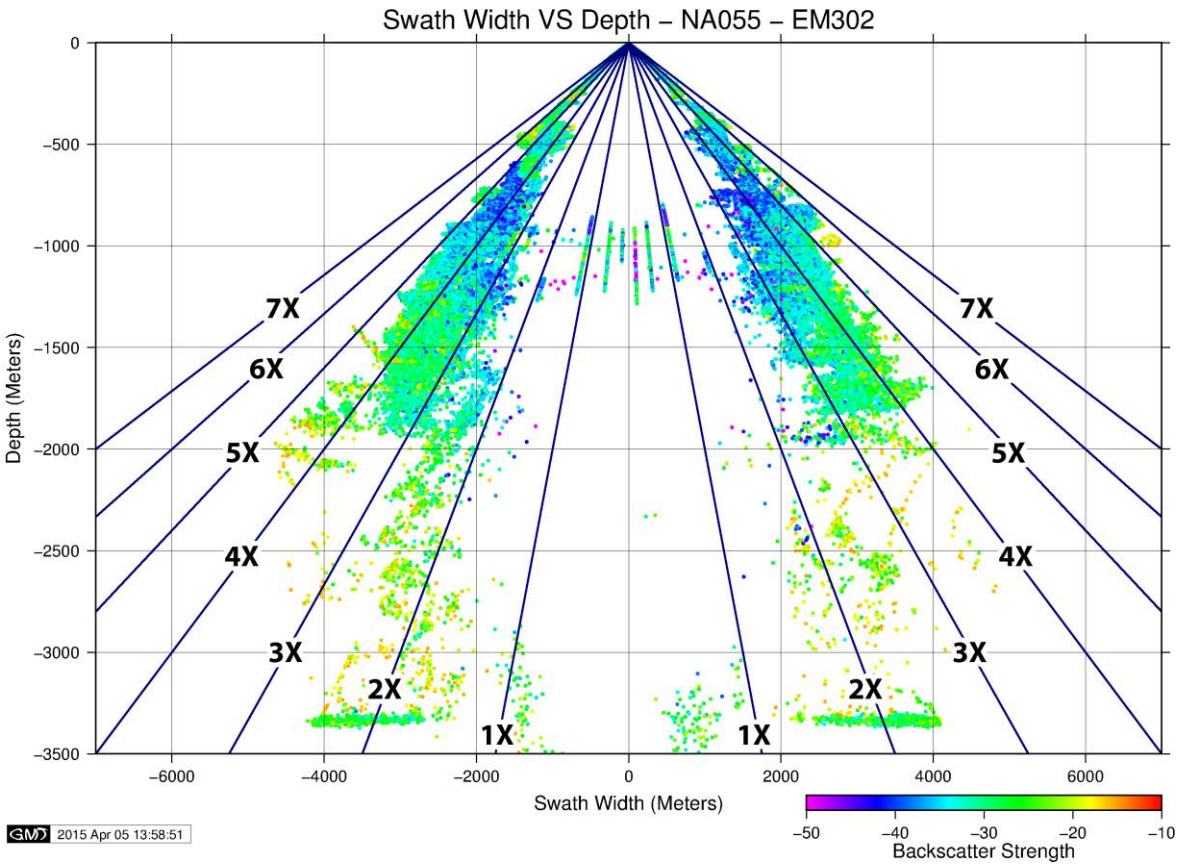

Figure 14. EM302 coverage evaluation plot showing outermost sounding coverage (i.e., swath width) versus depth. Colors of the points are based on the backscatter strengths of the contributing sounding.

Swath width compared favorably with NA040 results, providing across-track coverage of 6 times water depth in shallow waters up to 500 m depth and 5 to 4 times water depth to approximately 1500 m depth. At depths greater than 1500-1800 m, the system tracked consistently between 3 and 2.5 times water depth down to 3,350 m. Soundings deeper than 3,350 m in this plot are outliers and do not represent the observed maximum depth during testing. The coverage achieved up to 3,350 m depth is comparable to other EM302 installations and indicates that the system is performing well. Note that a major difference in Fig. 13 compared to NA040 (Fig. 10 in the 2014 report) is that outer beam soundings with backscattering strengths greater than -15 dB have been eliminated. These soundings likely fell on rugged features of the continental shelf break, such as canyon walls, facilitating stronger backscatter values and atypically wide across-track ranges.

Noise Level Assessment

To assess vessel noise at the transducers, measurements were made at the receiver while the vessel operated at a variety of speeds and headings relative to the swell. Speed-dependent self noise was measured at 2-10 kts while heading into a 1-m swell (Figure 15 and Figure 16) and then measured at 3-12 kts while heading with the swell (Figure 17 and Figure *18*). These plots clearly show significant and consistent elevated noise at 2-4 kts and 10-12 kts, with reduced noise at 6-8 kts. Engine constraints during NA055 frequently required speeds of 10 kts, presenting a concern for the elevated noise measured by the EM302. The self noise data suggest that surveys should be conducted at 6-8 kts, though a repeat noise test with test survey lines under identical conditions would be required to establish whether the vessel noise appreciably affects data quality and accuracy.

Self Noise Results – Speed – Into Swell

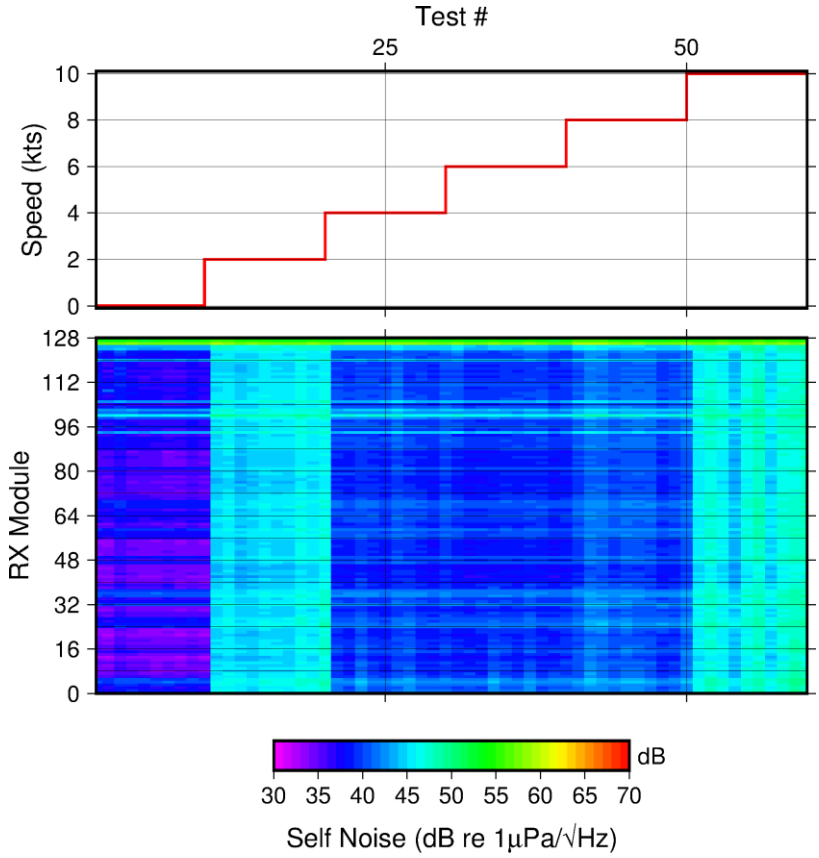

Figure 15. Receiver module self noise versus test number at vessel speeds of 0-10 kts while heading into a 1-m swell. Ten test measurements were made at each speed.

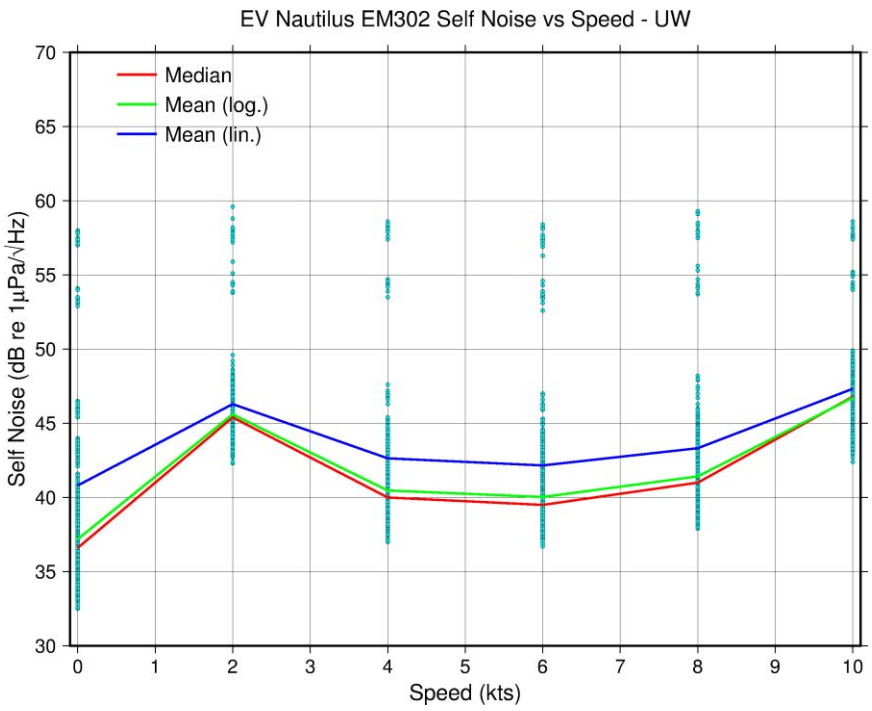

Figure 16. Receiver module self noise versus speed while heading into a 1-m swell.

Self Noise Results – Speed – With Swell

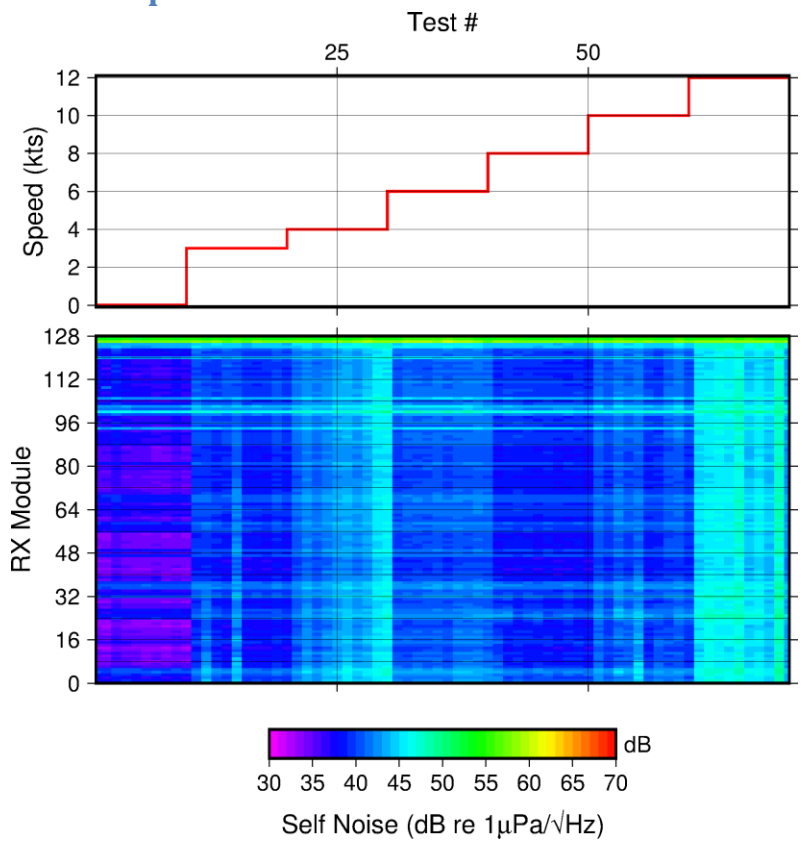

Figure 17. Receiver module self noise versus test number at vessel speeds of 0-10 kts while heading with a 1-m swell. Ten test measurements were made at each speed.

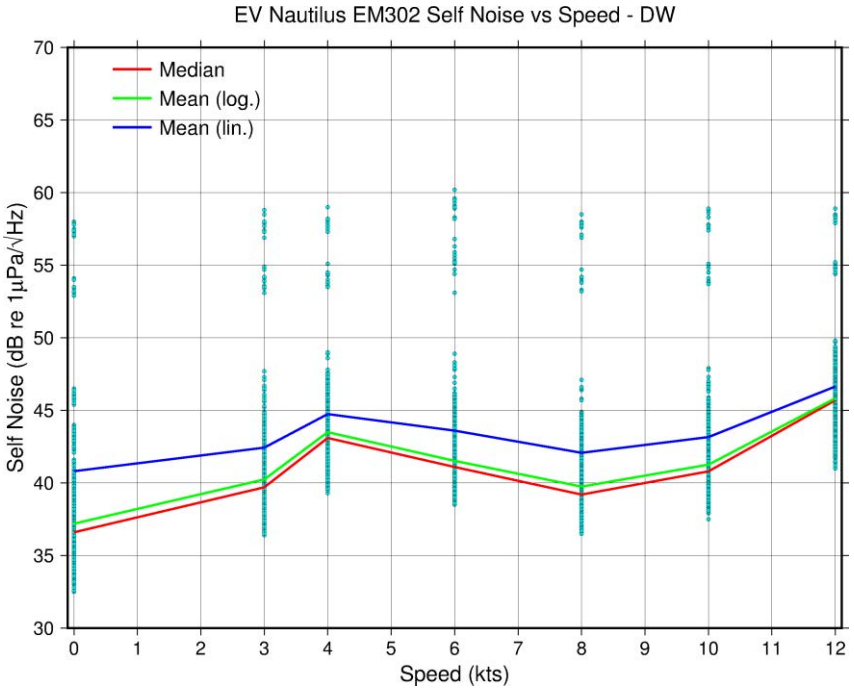

Figure 18. Receiver module self noise versus speed while heading with a 1-m swell.

Self Noise Azimuth Results

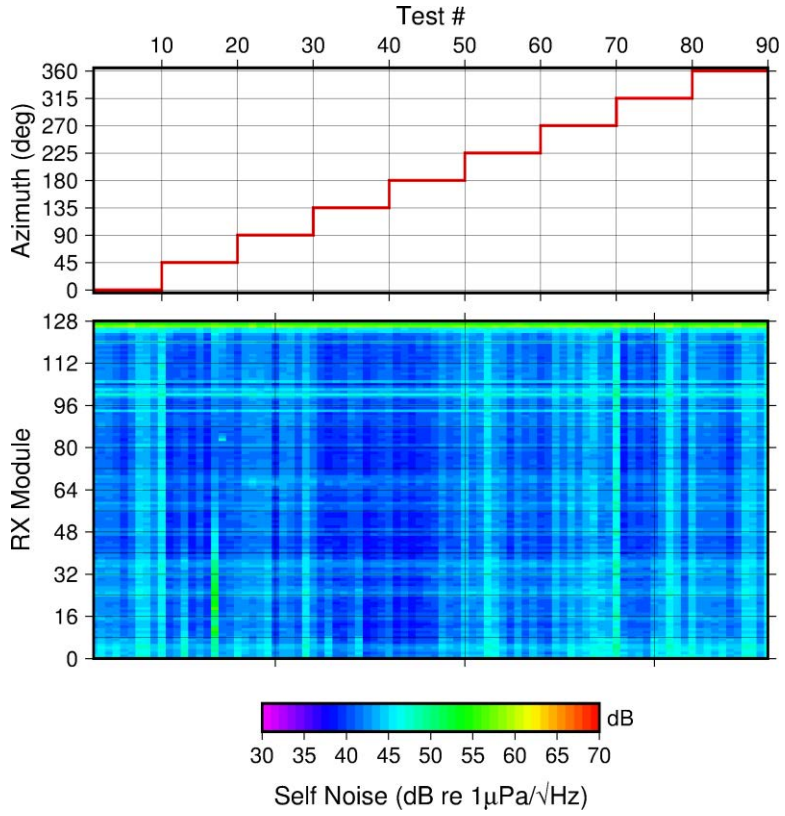

Figure 19. Receiver module self noise versus test number at vessel azimuth relative to the prevailing seas (2-m swell). Azimuth of 0° corresponds to vessel heading with the swell. Vessel speed was 10 kts for all tests and ten measurements were made at each heading.

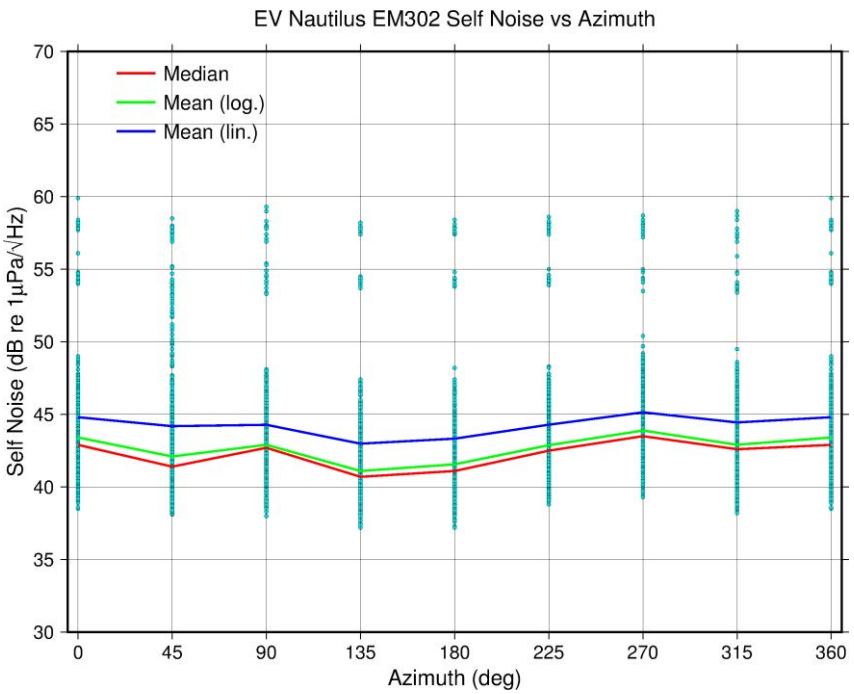

Figure 20. Receiver module self noise versus azimuth relative to a 2-m swell. Azimuth at 0° is with the swell directions, while azimuth 180° is into the seas.

Conditions developed sufficiently on the last day of NA055 to produce a 2-m swell from the northeast (045°) and facilitate measurement of azimuthal noise relative to prevailing seas. Receiver noise was measured in eight directions separated by 45°, starting with the swell, while the vessel transited at 10 kts (Figure 19 and Figure 20).

The results of noise testing relative to sea direction show the unexpected results of reduced noise heading into the swell and increased noise heading with the swell. Though primary swell direction was from 045° (relative to true north), other swell patterns were observed from a variety of directions which may complicate this analysis.

Transducer and System Health

A full Built-In Self Test (BIST) diagnostic routine was run prior to departure as well as when underway. Among other tests, the BIST provides the ability to perform impedance measurements of the transmitter and receiver arrays. These test results may be used as proxies the health of transducer elements, as these components of the mapping system have been known to degrade with time. It is important to note that the BIST impedance measurements do not provide a full characterization of transducer properties as a function of frequency. However, BISTs provide useful information for monitoring overall transducer health and should be run on a routine basis.

The EM302 receiver and receiver transducer impedances, as measured through the BIST routines, were compared to measurements made throughout the 2013 and 2014 seasons, as well as those conducted during previous system acceptance tests. NA055 BIST results were found to be within the nominal acceptable range expected by the manufacturer (Figure *21* and Figure *22*). All but one transmitter impedance value fell within normal ranges (Figure 23). This figures shows that

channel 15 in TX slot 12 reported a high impedance in 2014 and 2015, however, this is not expected to significantly impact transmitter performance.

Impedance Results – Receiver

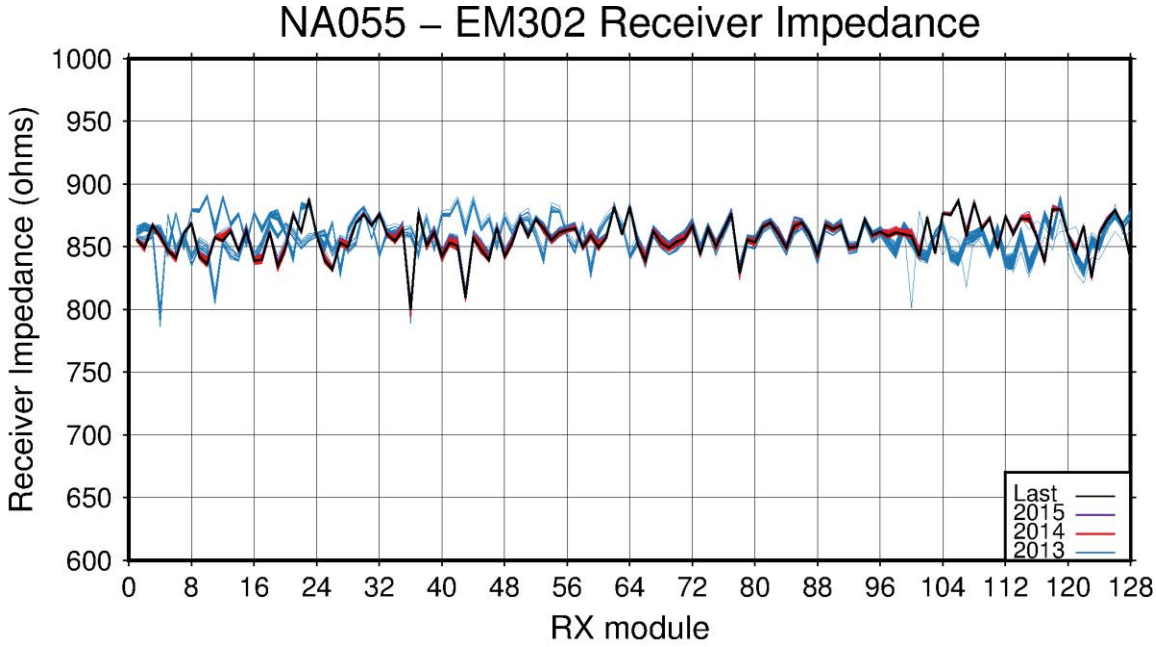

Figure 21. EM302 receiver impedance measurements. Historic measurements are colored and measurements from this evaluation in black. The impedance range on the Y-axis represents the range defined by Kongsberg within which the system will pass a BIST test.

Impedance Results – Receiver Transducer

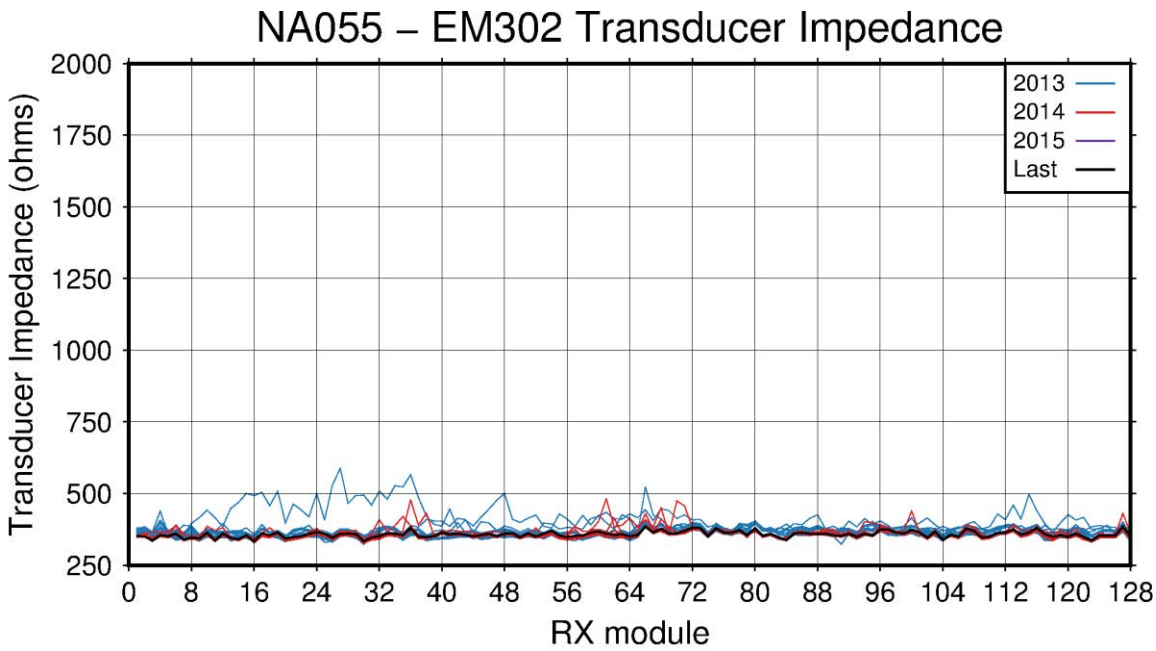

Figure 22. EM302 receiver transducer impedance measurements. Historic measurements are colored in black. The impedance range on the Y-axis represents the range defined by Kongsberg within which the system will pass a BIST test.

Impedance Results – Transmitter

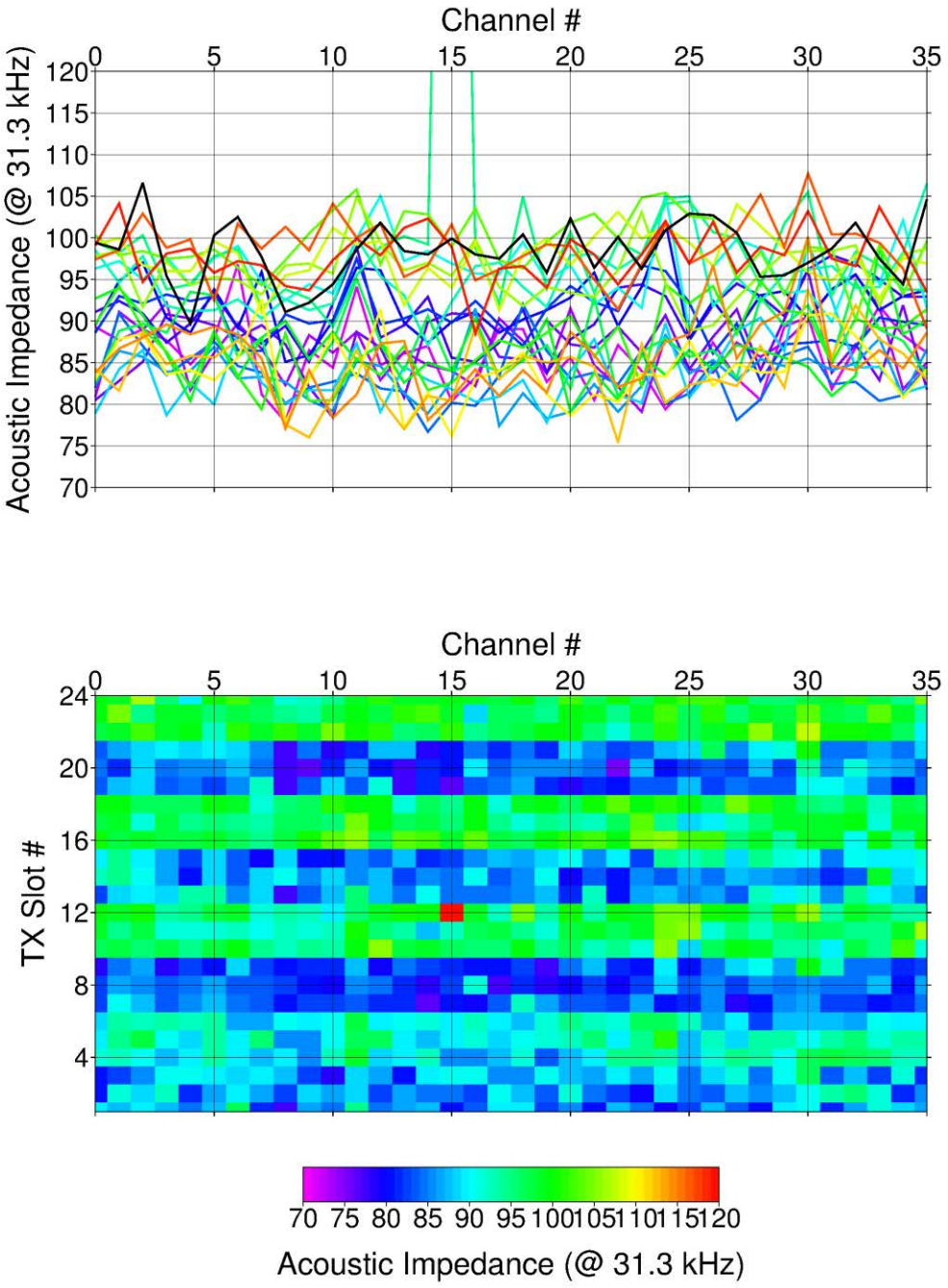

Figure 23. EM302 transmitter acoustic impedances as observed during NA055. Individual colors in the top figure correspond to individual slots across all channels. Slot 12, channel 15 exhibited high impedance in 2014 and 2015, shown by the turquoise line with a spike in the top figure and red square in the bottom figure. There has been no noticeable change in transmitter acoustic impedance between 2014 and 2015.

Summary and Recommendations

- Heading into the 2015 operating season, the EM302 and associated sensors aboard E/V Nautilus are working well compared to previous evaluations and to other EM302 systems examined recently. The patch test showed no pitch or yaw bias and only a very slight residual angular offset for roll, indicating no major changes to the system geometry.

- Sensor positions and SIS Installation Parameters should not be changed. A PU Parameters file containing all SIS Installation Parameters and Runtime Parameters were written to disk on the primary acquisition machine (and stored on the shiphouse share) at the end of NA055. If any problems or questions arise with any parameters, this file should be reloaded to restore a functional configuration for SIS. Johnson and Jerram have a copy of this file and can provide it if required.

- The onboard technical staff have collected routine BIST results throughout the previous year. This practice provides excellent information for tracking system health and should be continued moving forward.

- System operation from the data lab has greatly simplified multibeam operations during engineering shakedown legs. If possible, additional headset/microphone stations at other desks would provide further flexibility.

- Ethan Gold documented that the ethernet cables between the switch and TX boards in the TRU cabinet are extremely sensitive to vibration and deformation, resulting in lost connectivity to individual boards. Due to the high vibration environment, this could result in component failure during startup or survey. This occurred once during NA055 and resolved with adjustment of the ethernet cables and a restart of the TRU.

- The 2013 SAT report included several recommendations to address installation and operation concerns specific to E/V Nautilus (e.g., power supply issues) and to avoid problems commonly experienced aboard other similarly equipped research vessels (e.g., accidental motion sensor alteration). Many of these recommendations have been implemented over the 2013 and 2014 seasons, while a few remain relevant as of NA055 and are listed below.

    - A removable protective structure, such as a cage-like cover, should be built around the MRU to help prevent accidental impact damage. This structure should be large enough to prevent workers in the TRU room from stepping on the MRU plate, provide secure routing for the cable, and ensure ample air flow for cooling.

    - Ensure cables behind the MRU are supported and not in contact with any other apparatus in the TRU room.

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- Beaudoin, J. (2012b). “R/V Kilo Moana Multibeam Echosounder System Review”. Multibeam Advisory Committee, Sea Acceptance Team. Report, 27 pp. Available online at: http://mac.unols.org/sites/mac.unols.org/files/20120701_Kilo_Moana_SAT_ report-final_0.pdf

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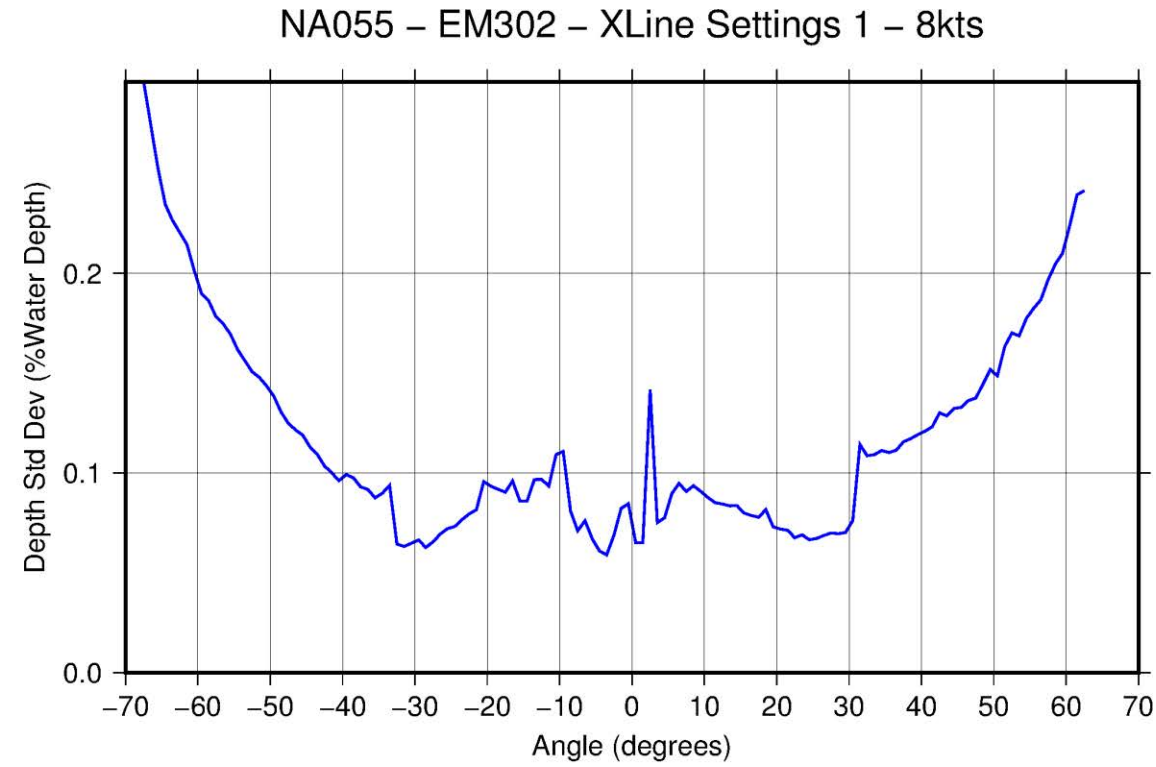
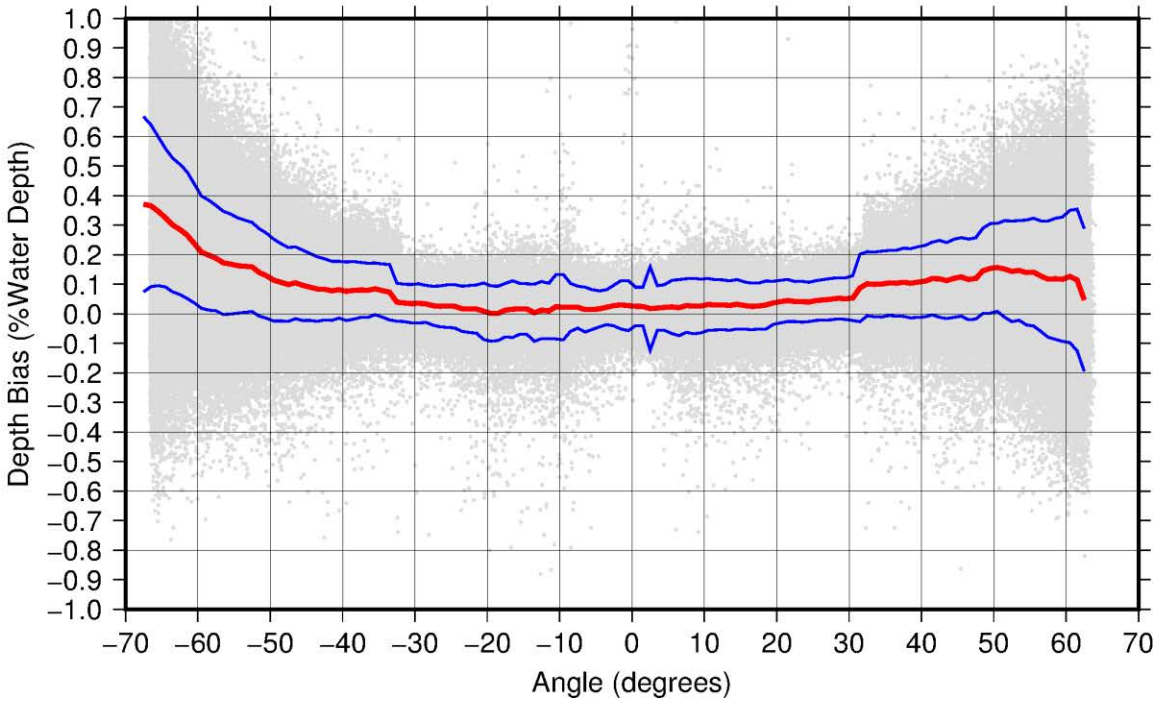
- Johnson, P., and Jerram, K. (2014). “E/V Nautilus EM302 Multibeam Echosounder System Review”

- Kongsberg (2000). “Backscattering and Seabed Image Reflectivity”. EM Technical Note, Kongsberg Maritime, Horten Norway, 5 pp.

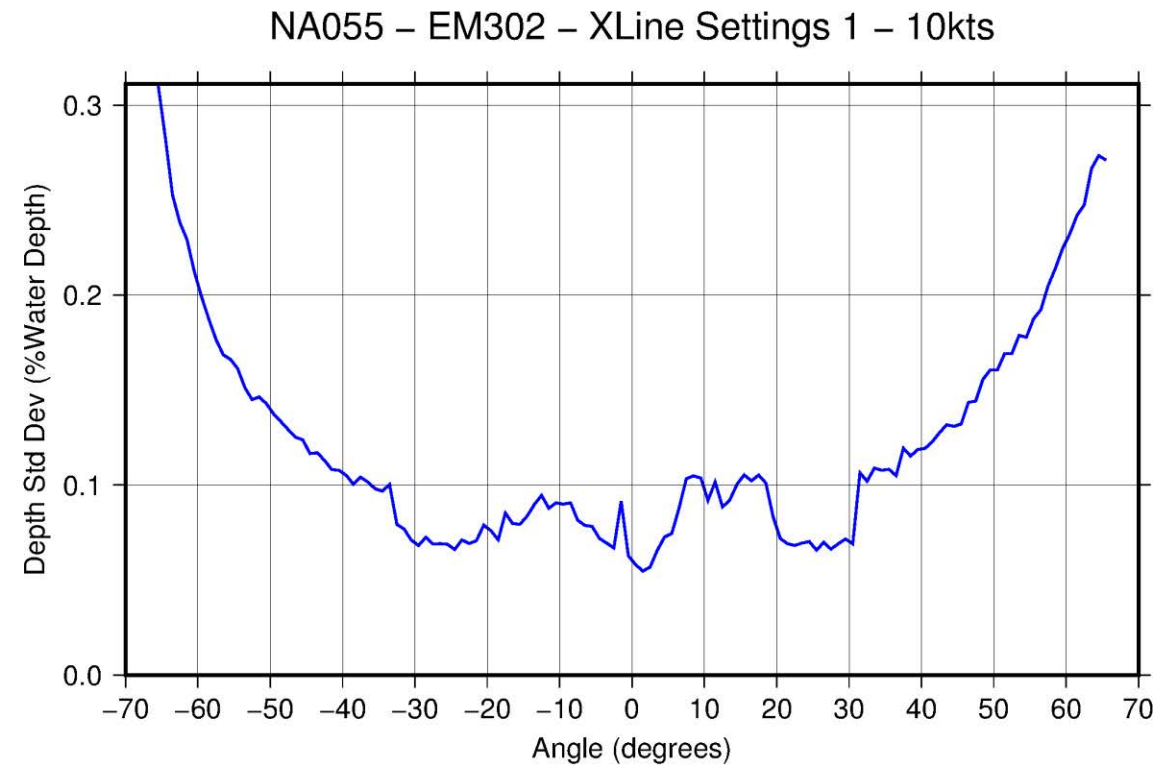
Appendix A – Accuracy Testing

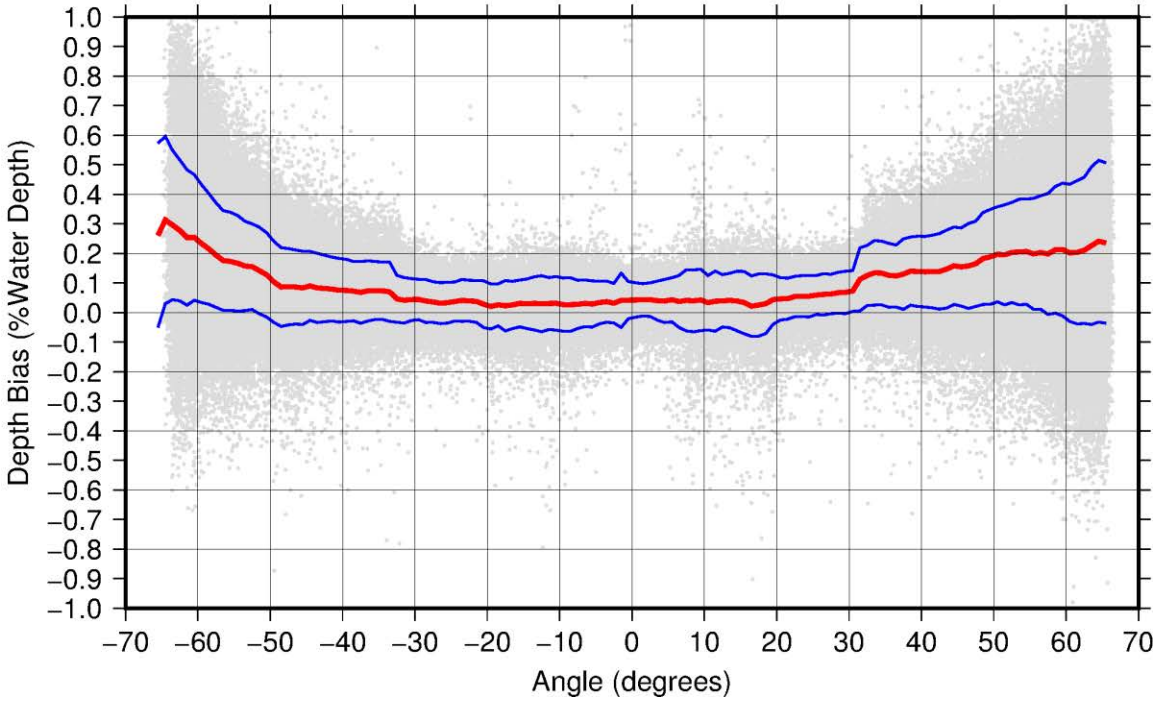
Accuracy Results – FM Dual-Swath (8 kts)



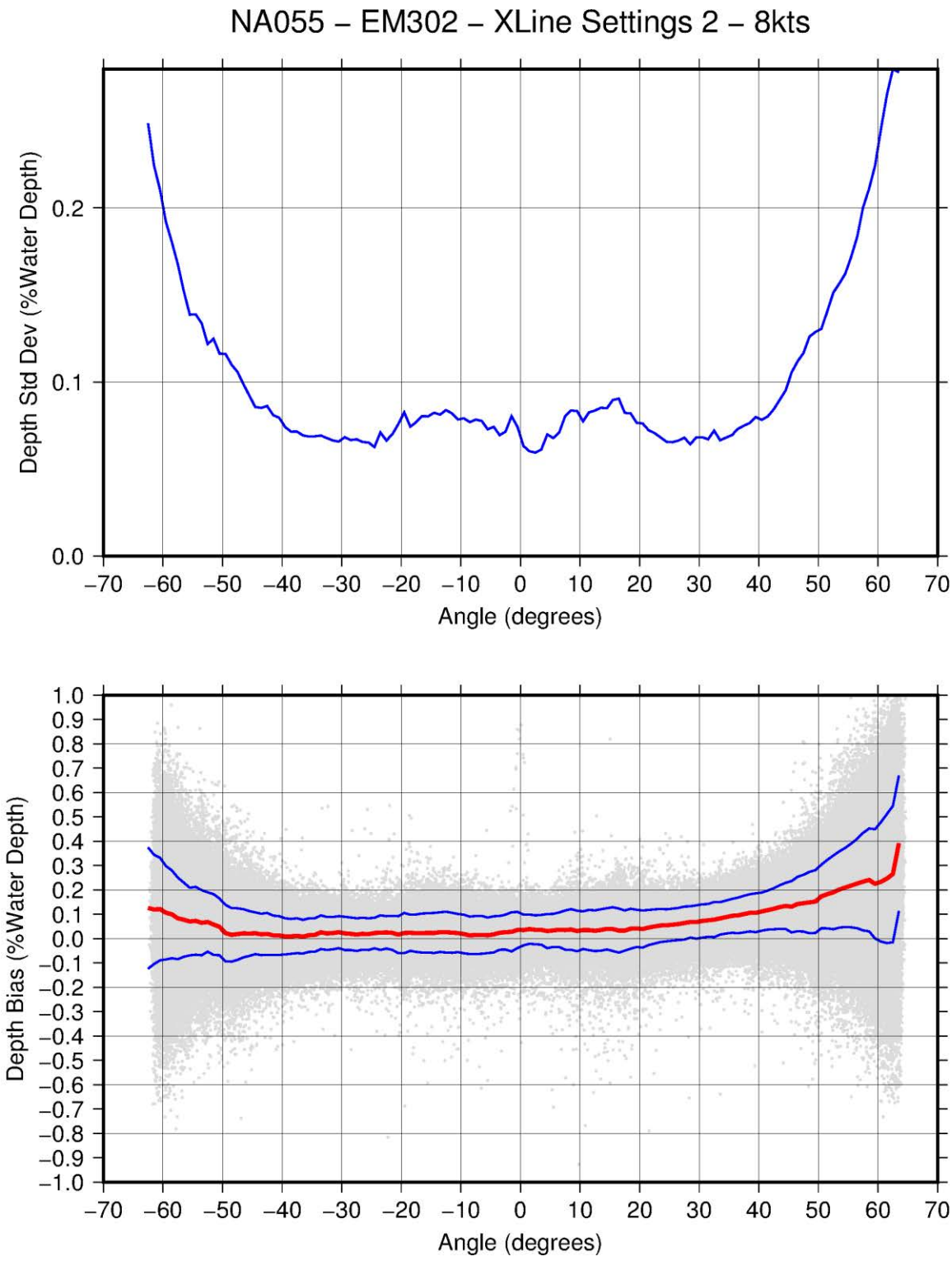


Accuracy Results – FM Dual-Swath (10 kts)

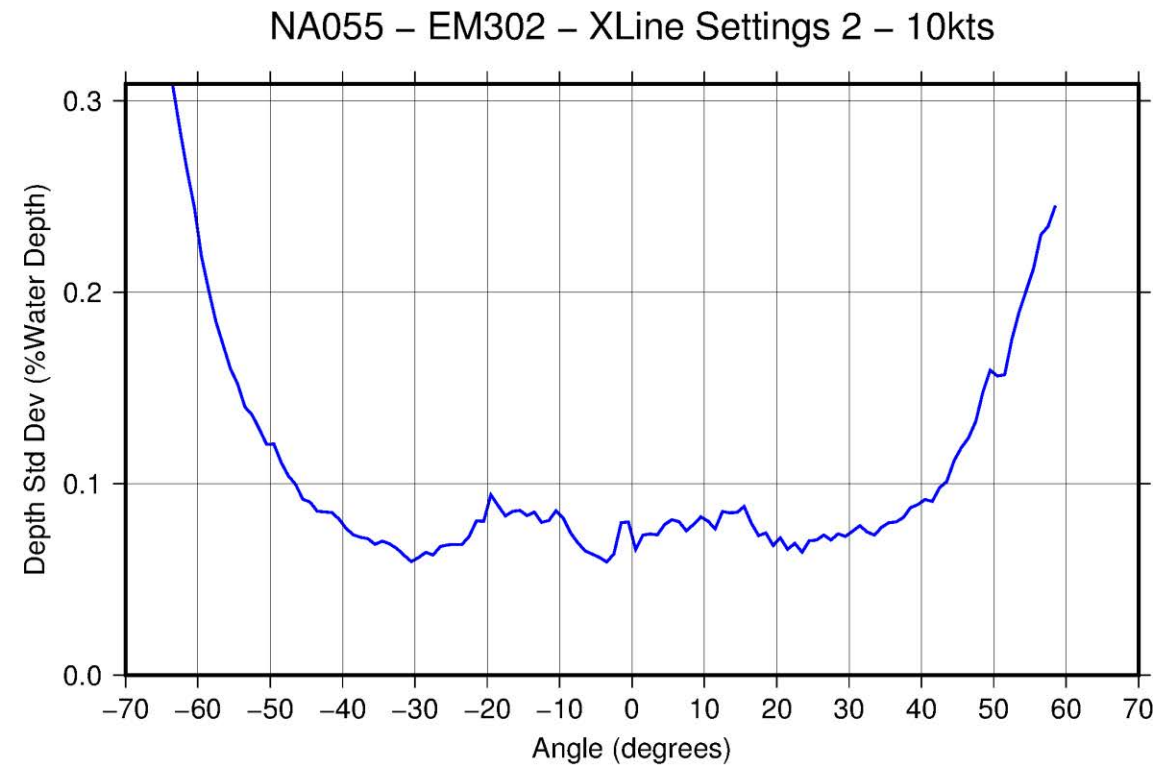


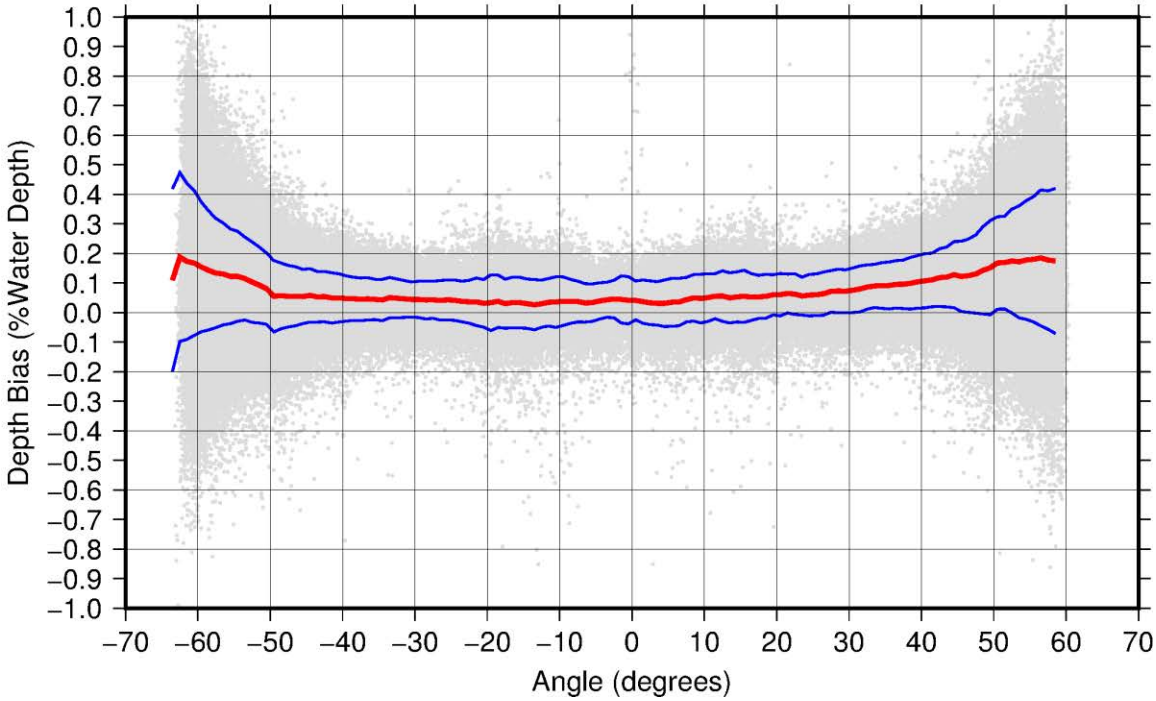


Accuracy Results – CW Dual-Swath (8 kts)

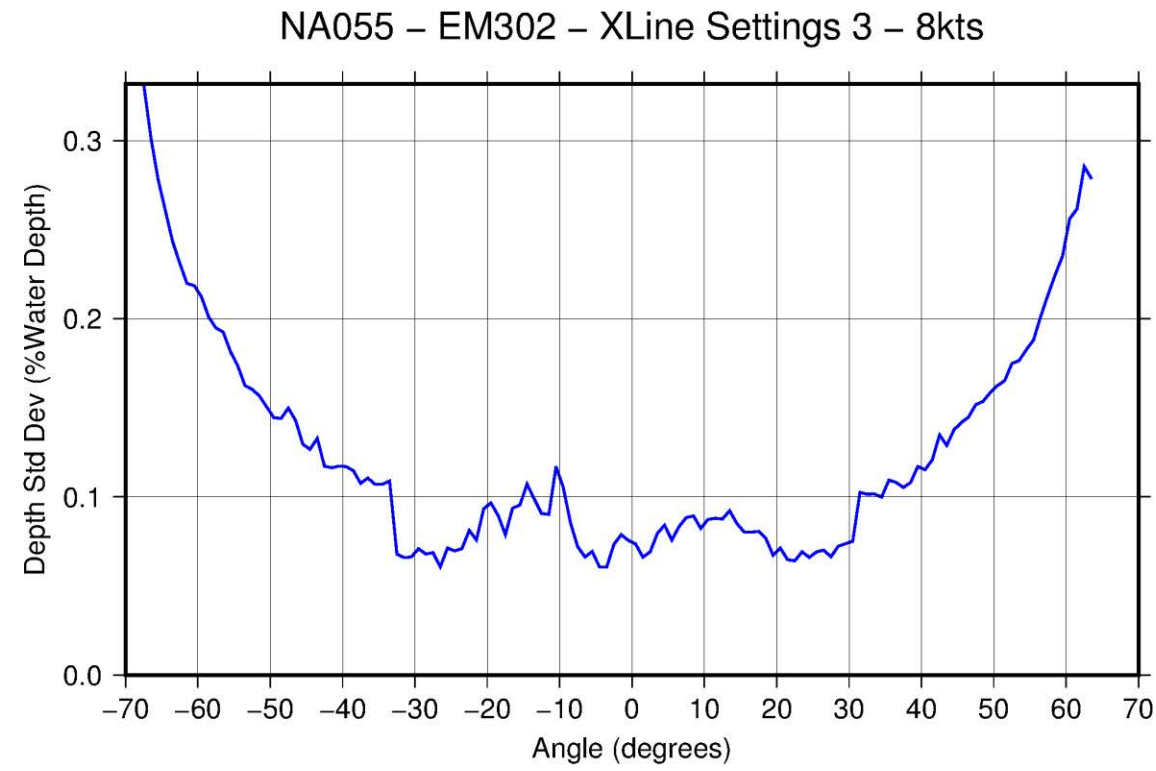


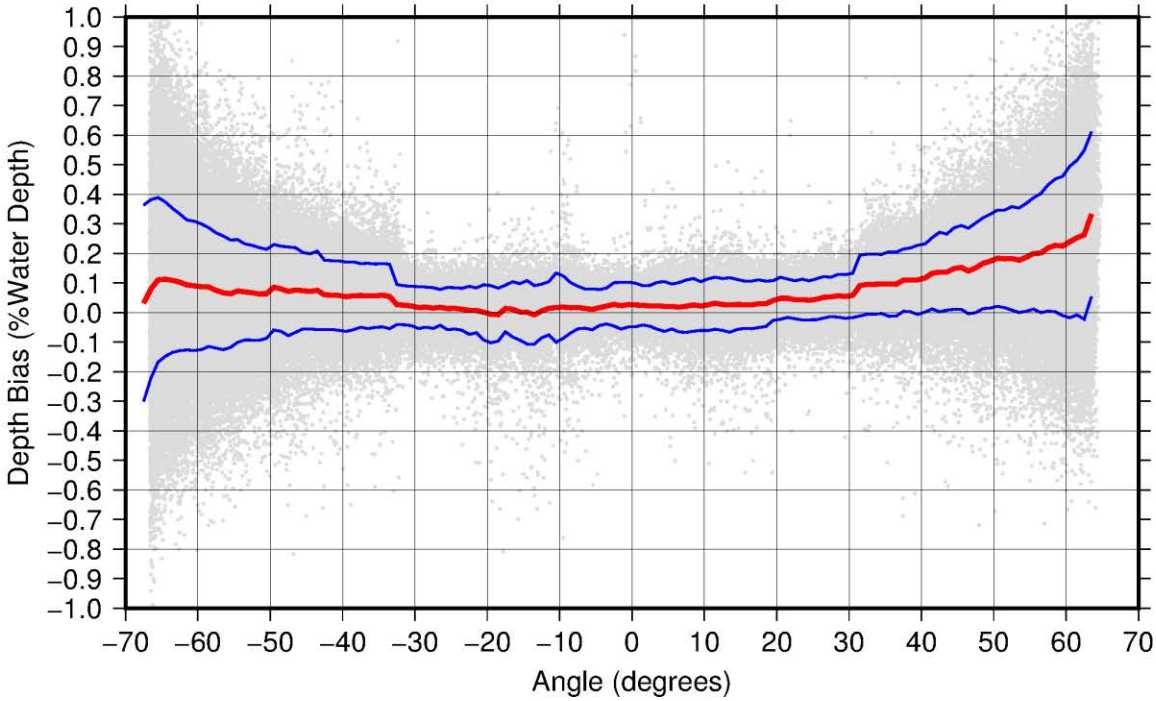
Accuracy Results – CW Dual-Swath (10 kts)



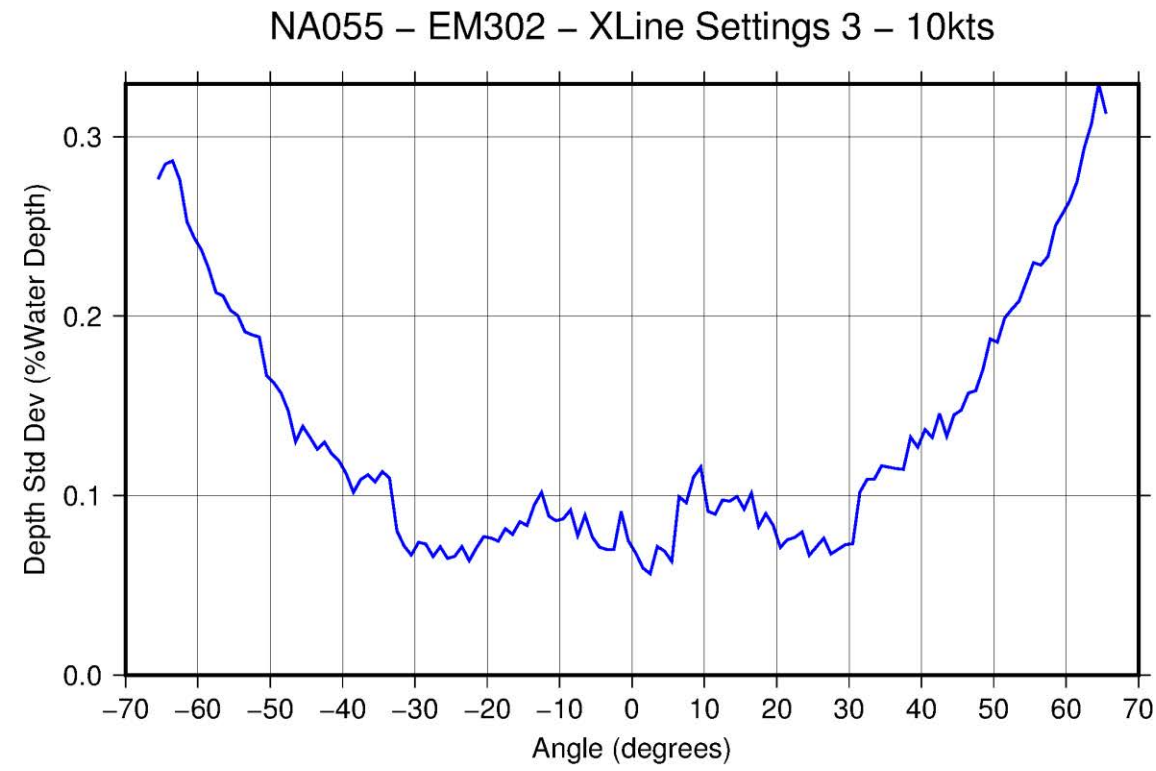


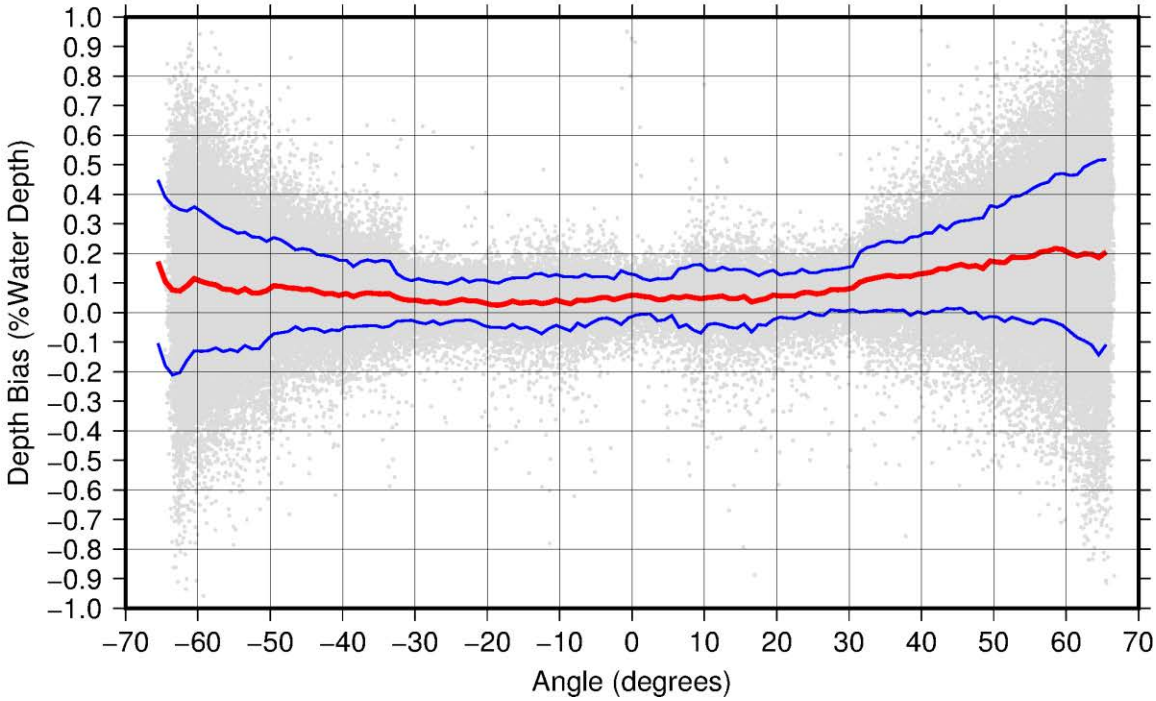
Accuracy Results – FM Single-Swath (8 kts)



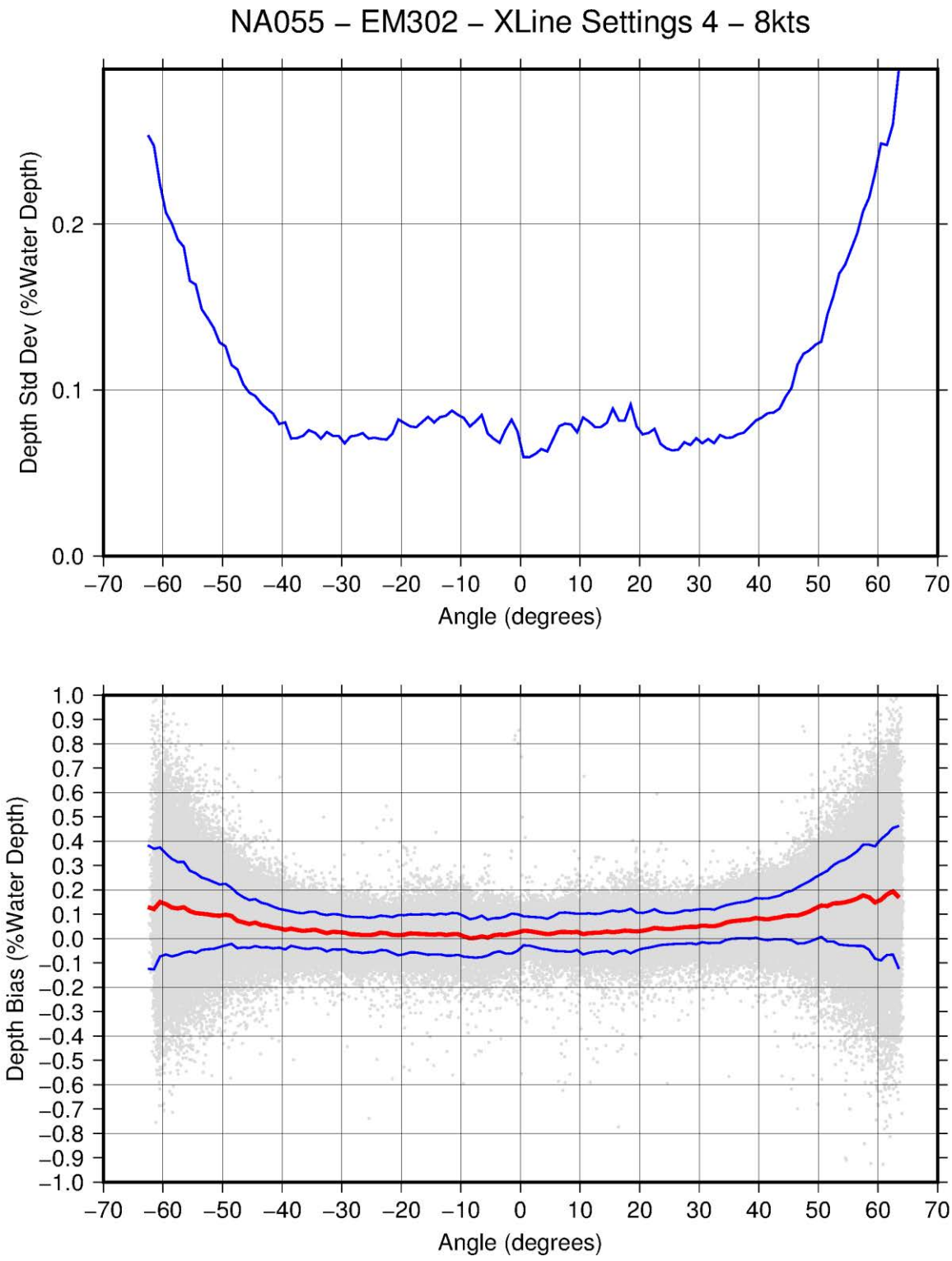


Accuracy Results – FM Single-Swath (10 kts)

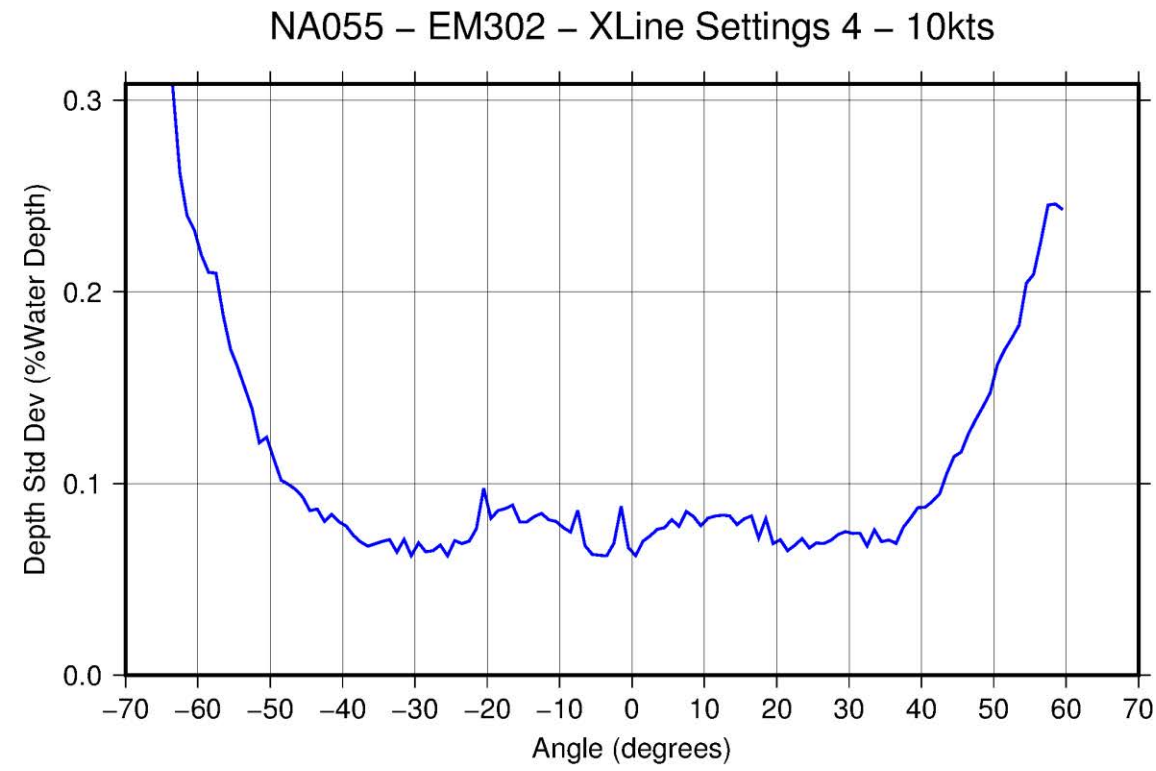


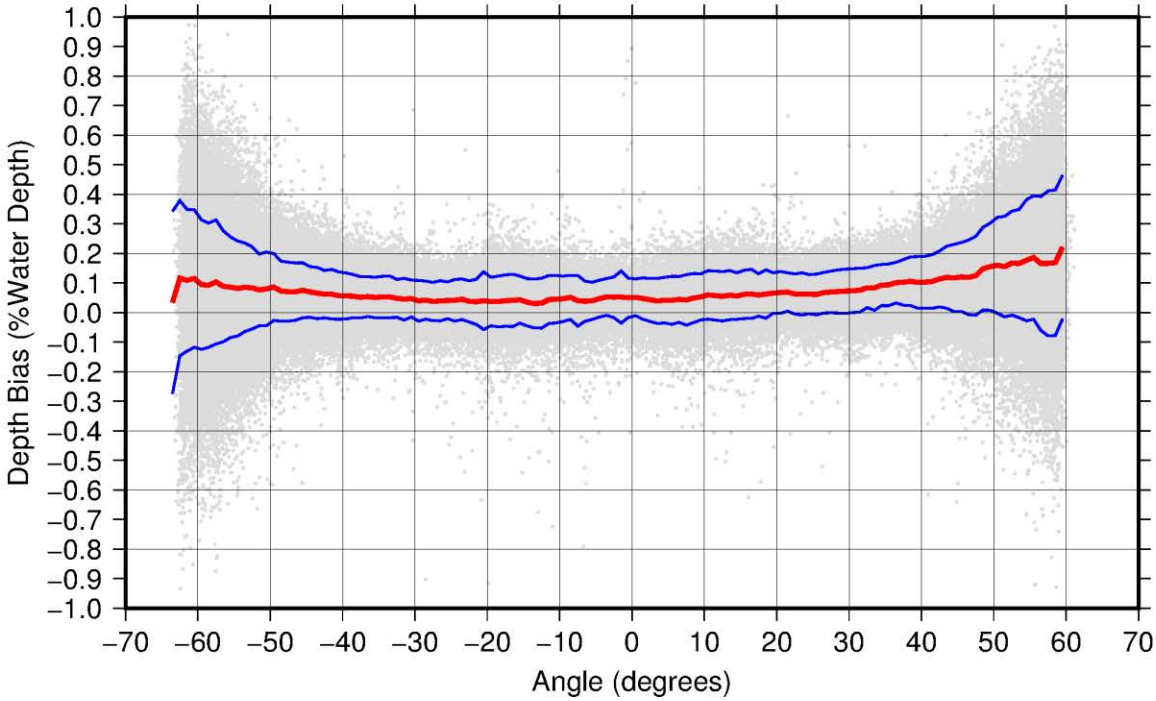


Accuracy Results – CW Single-Swath (8 kts)



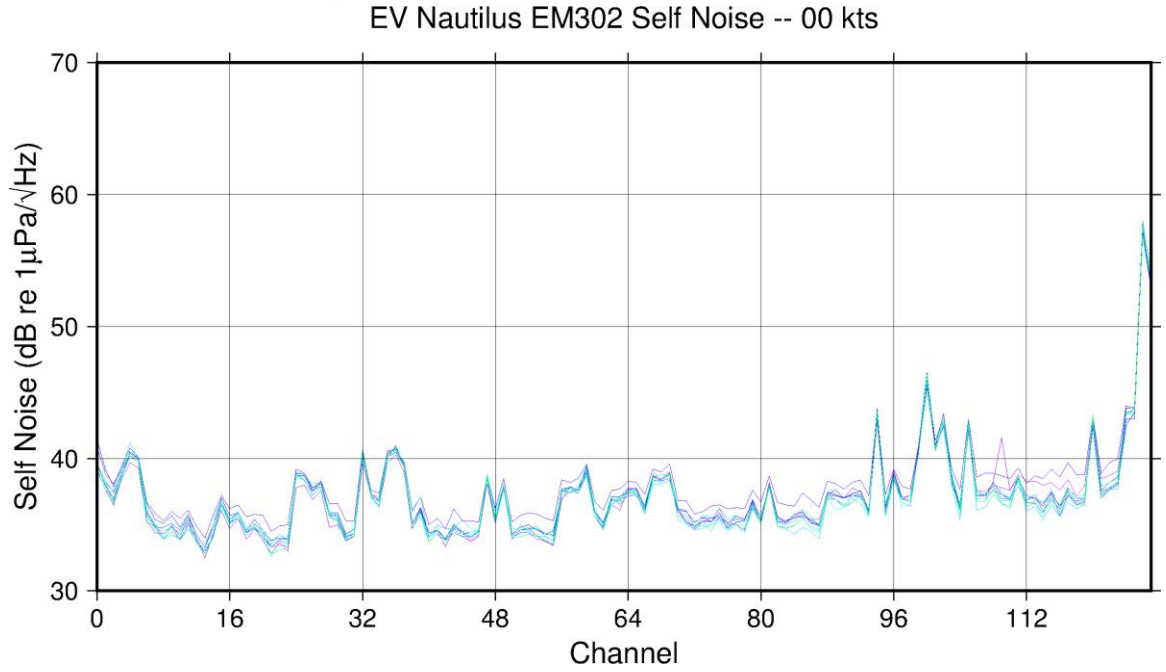
Accuracy Results – CW Single-Swath (10 kts)

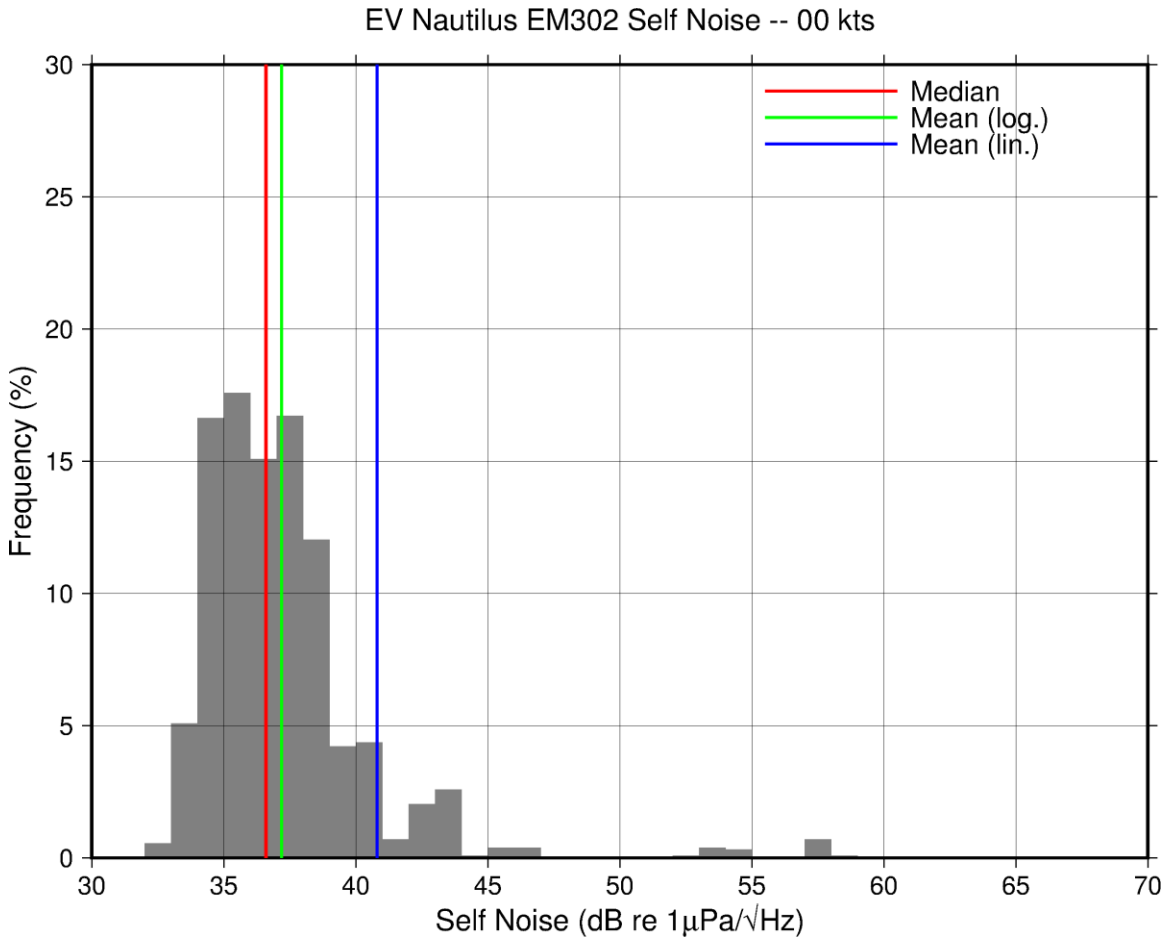




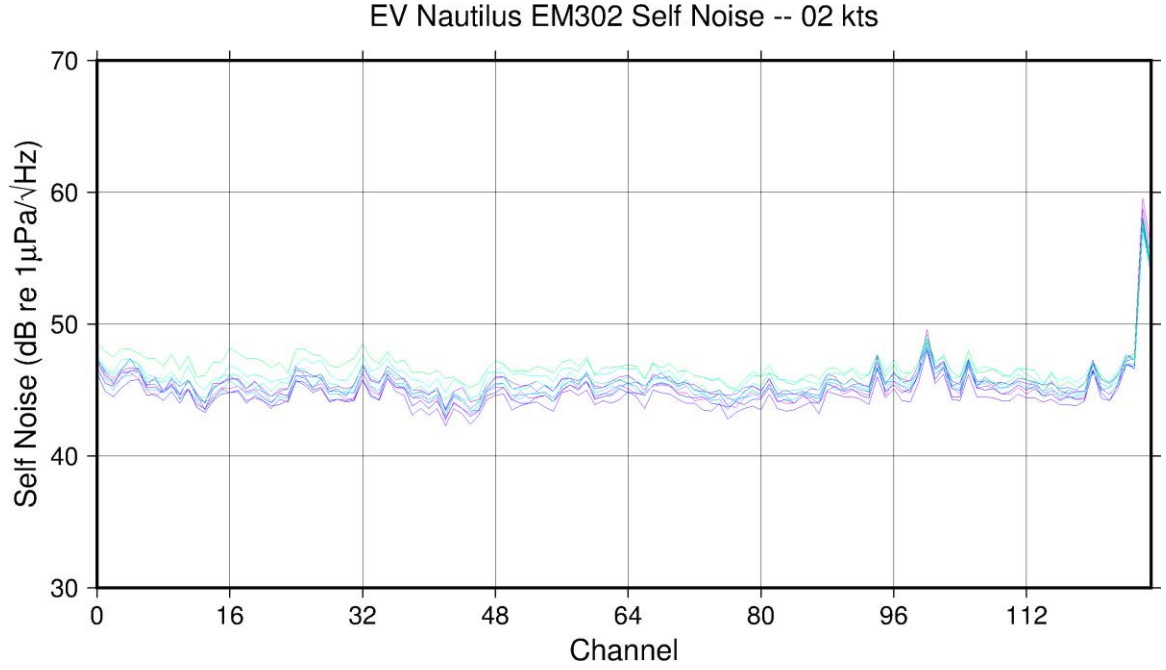
Appendix B – Noise Testing

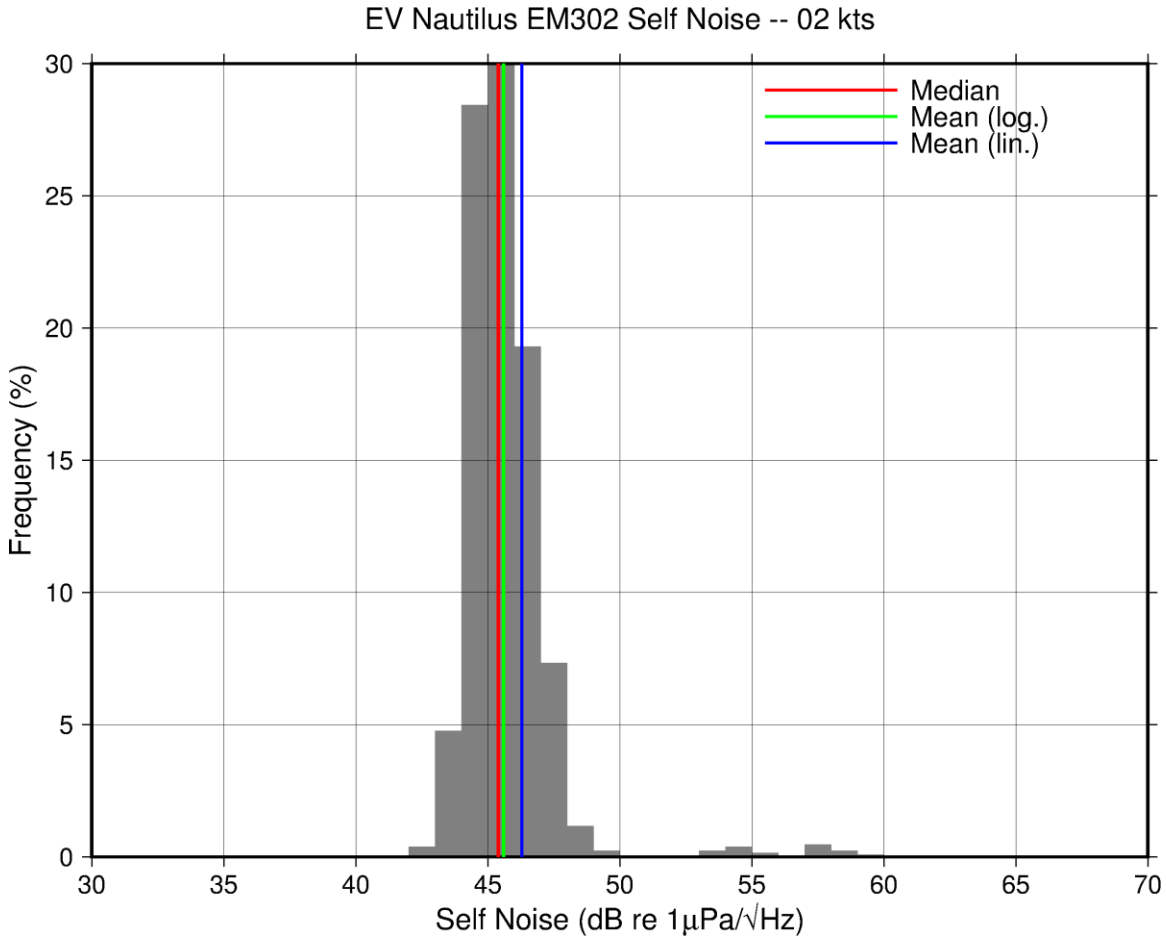
Self Noise Results – Speed – Drifting (0 kts)



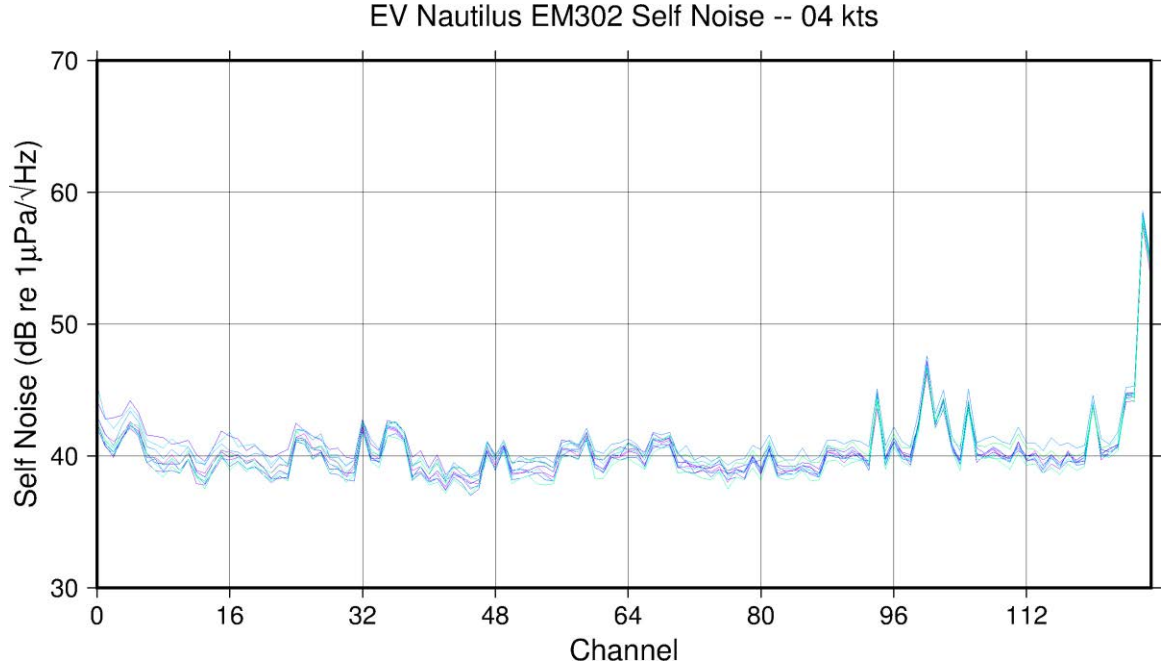


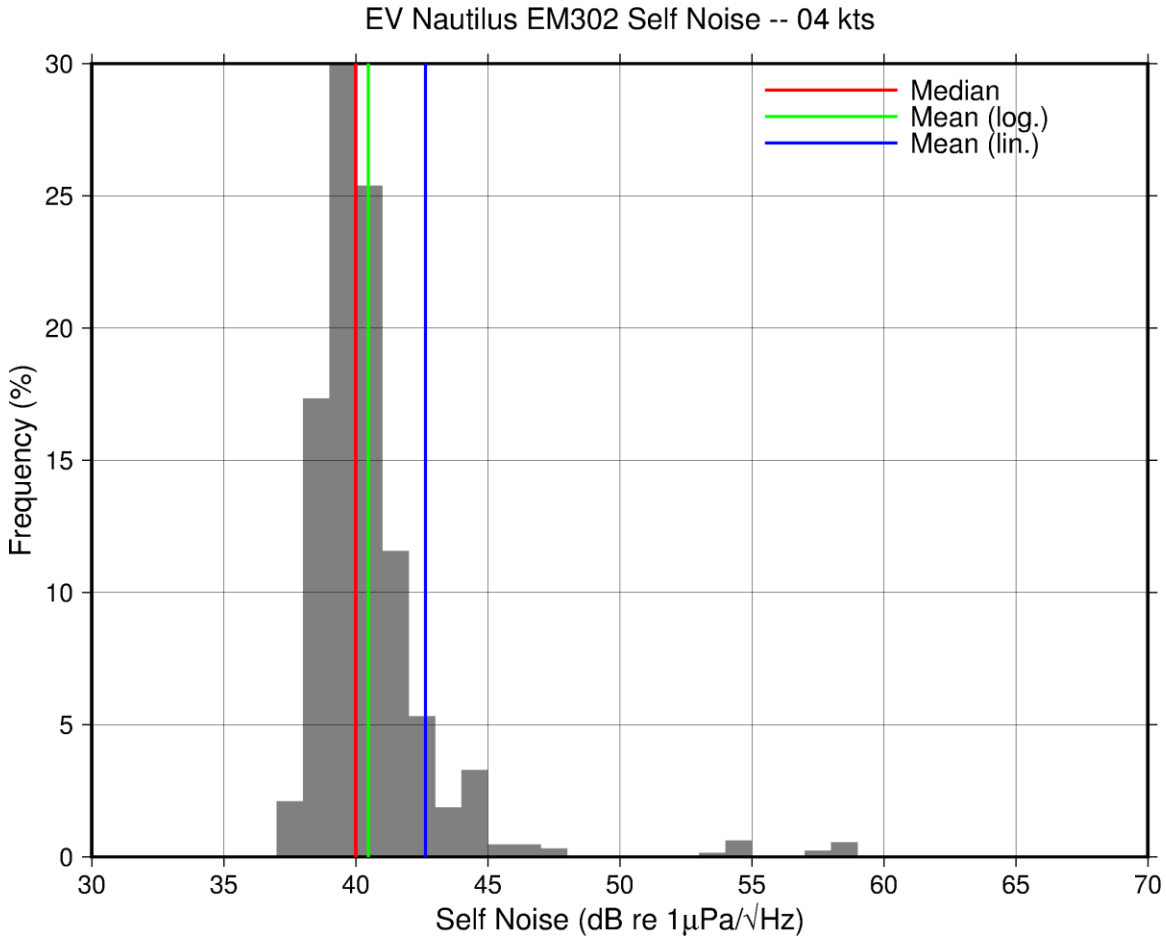
Self Noise Results – Speed – Into Seas (2 kts)



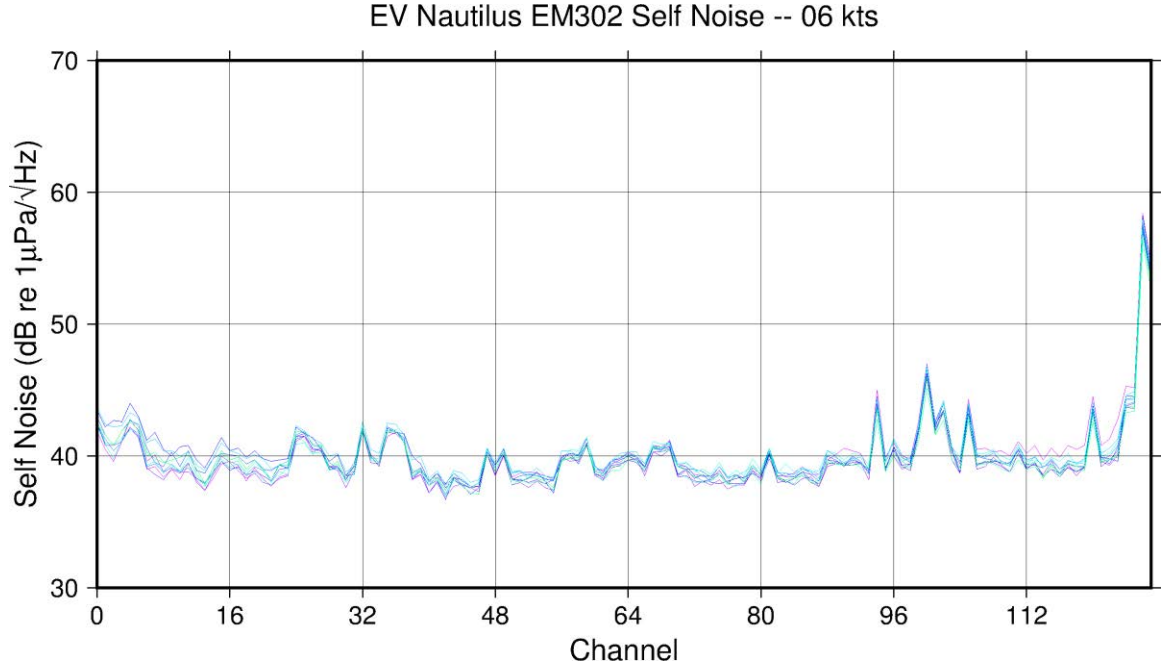


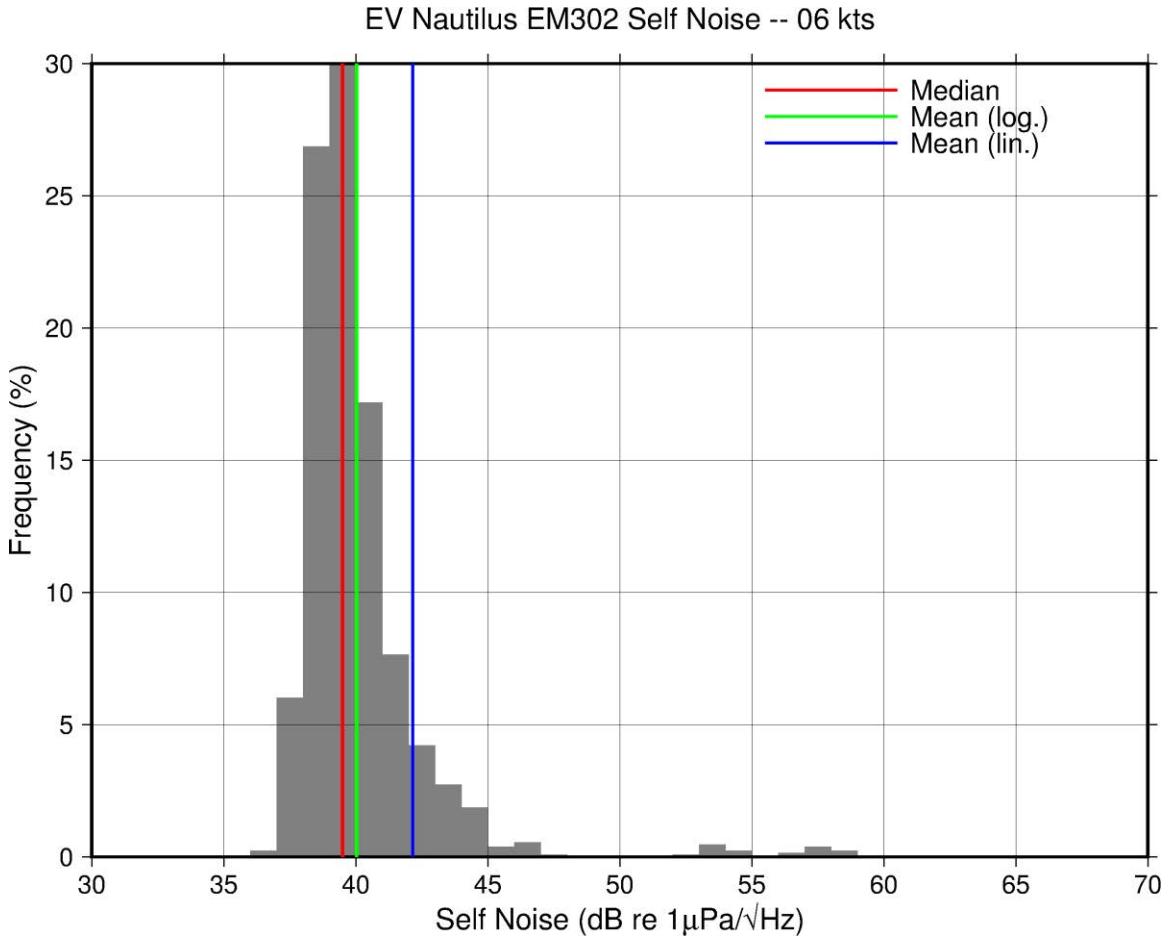
Self Noise Results – Speed – Into Seas (4 kts)



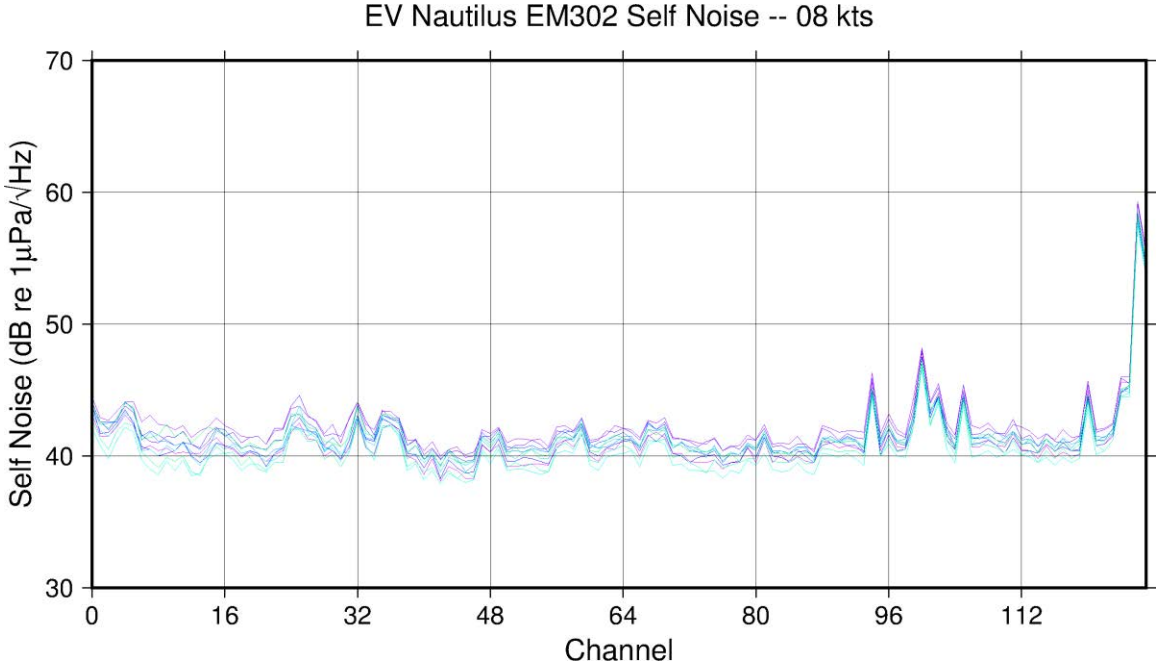


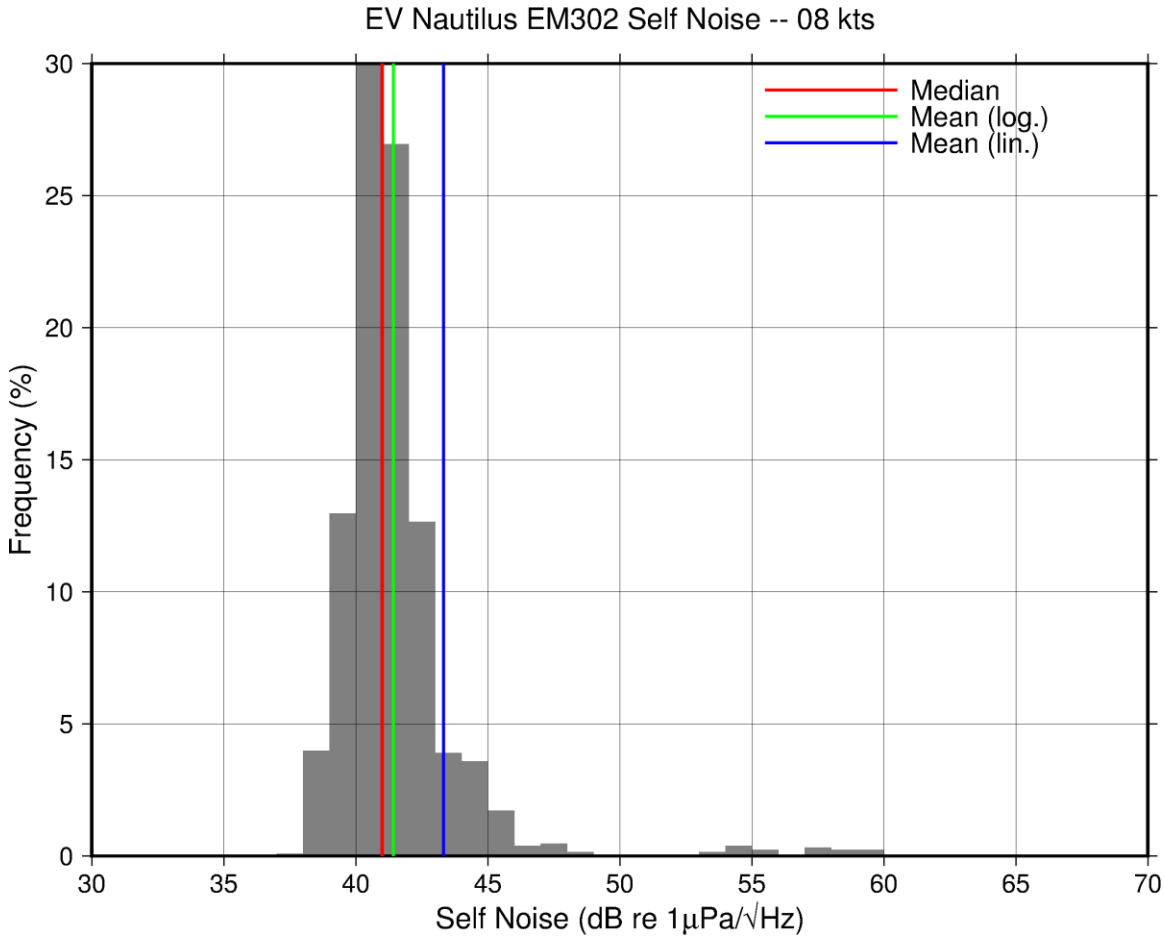
Self Noise Results – Speed – Into Seas (6 kts)



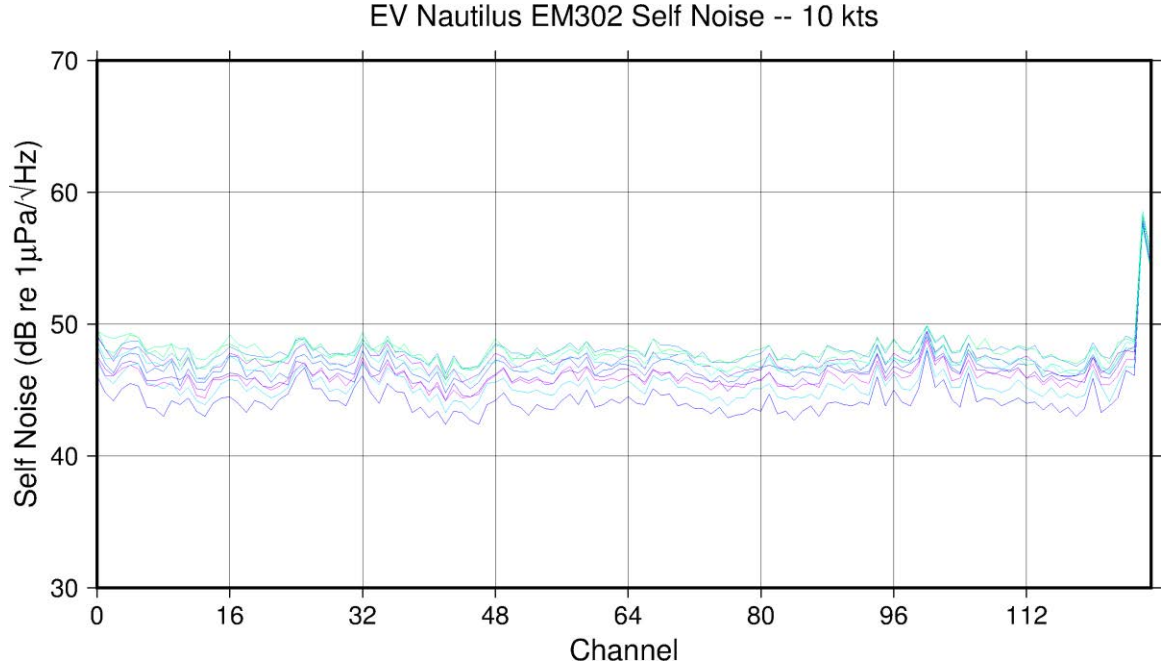


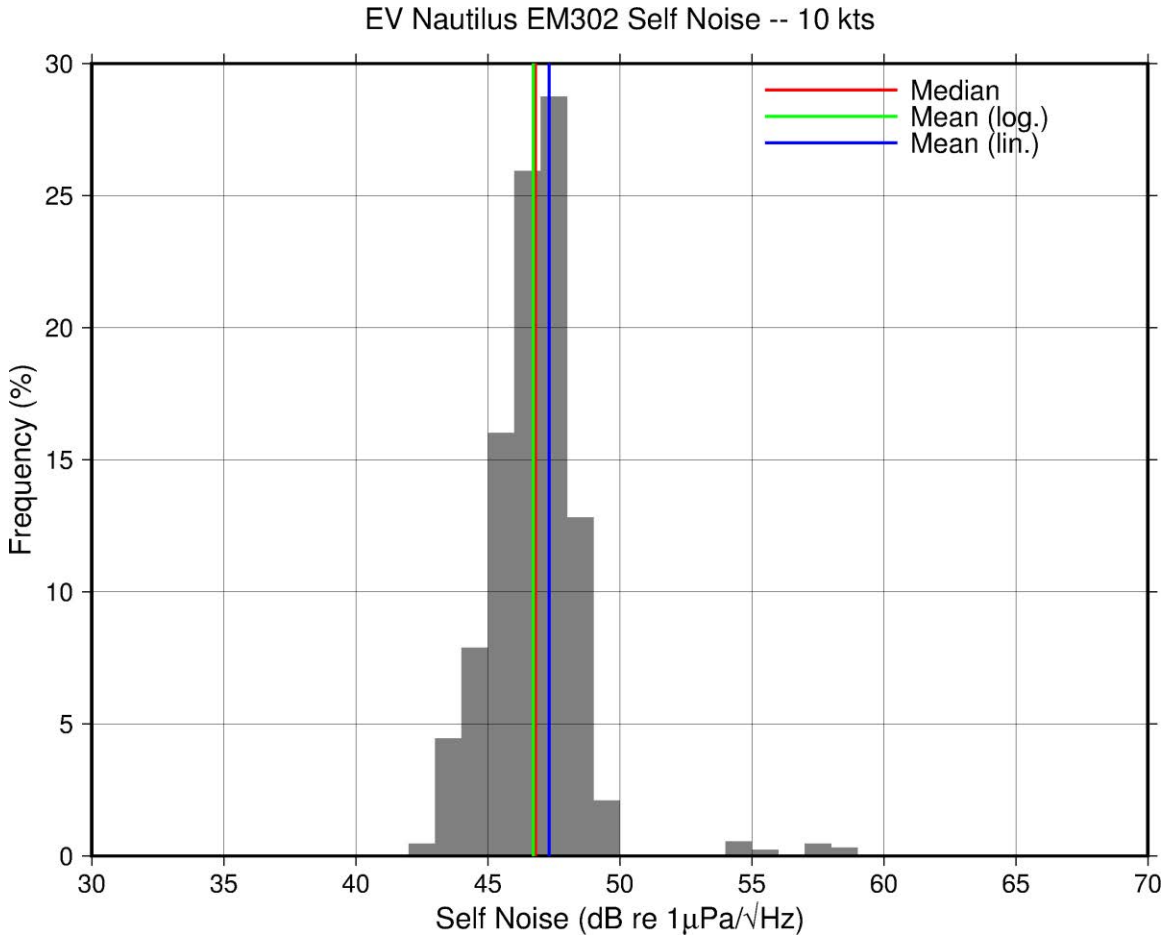
Self Noise Results – Speed – Into Seas (8 kts)



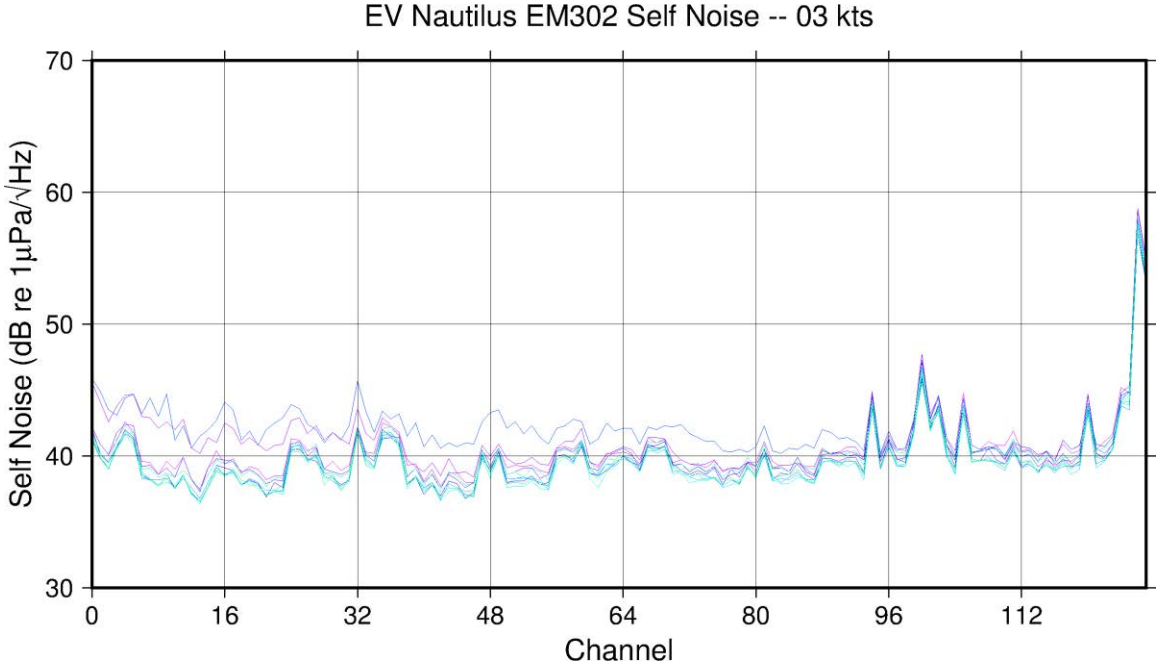


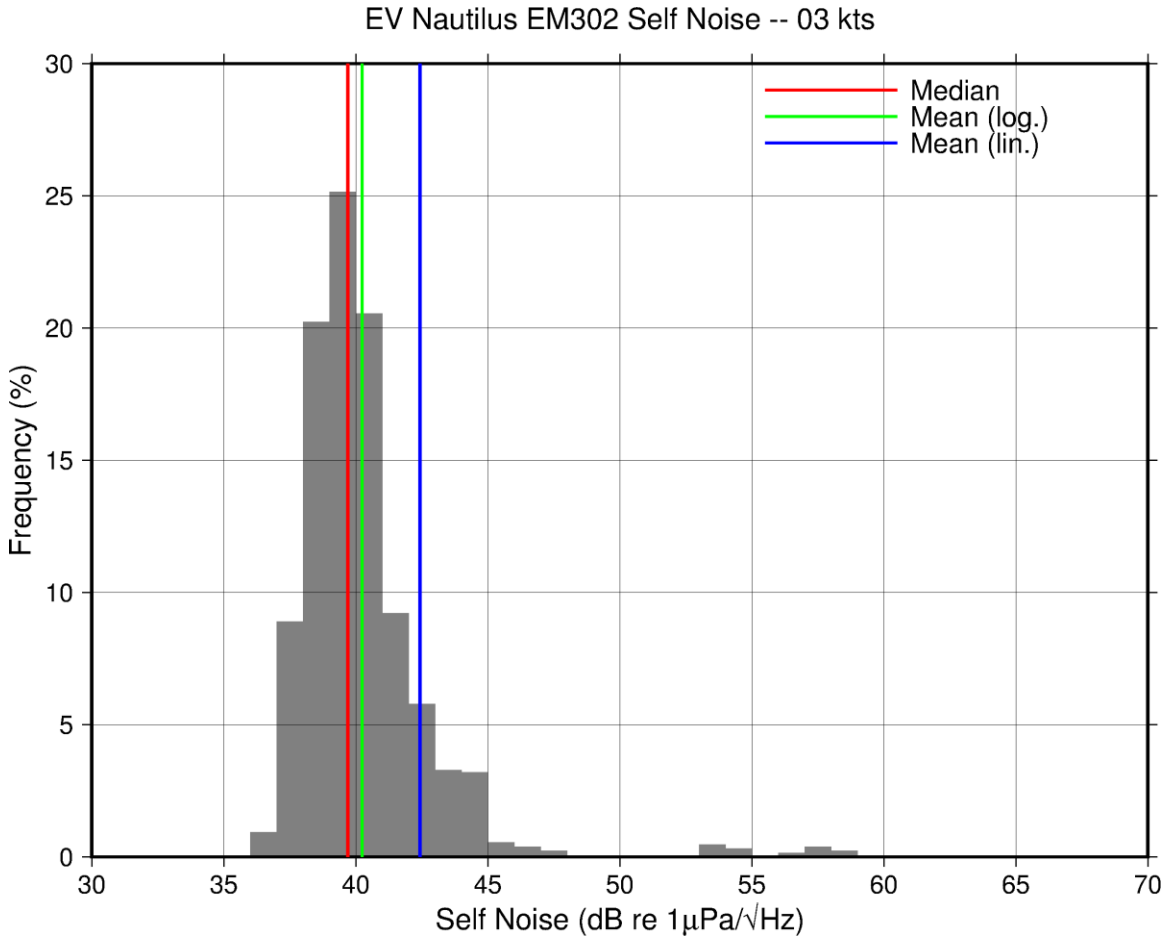
Self Noise Results – Speed – Into Seas (10 kts)



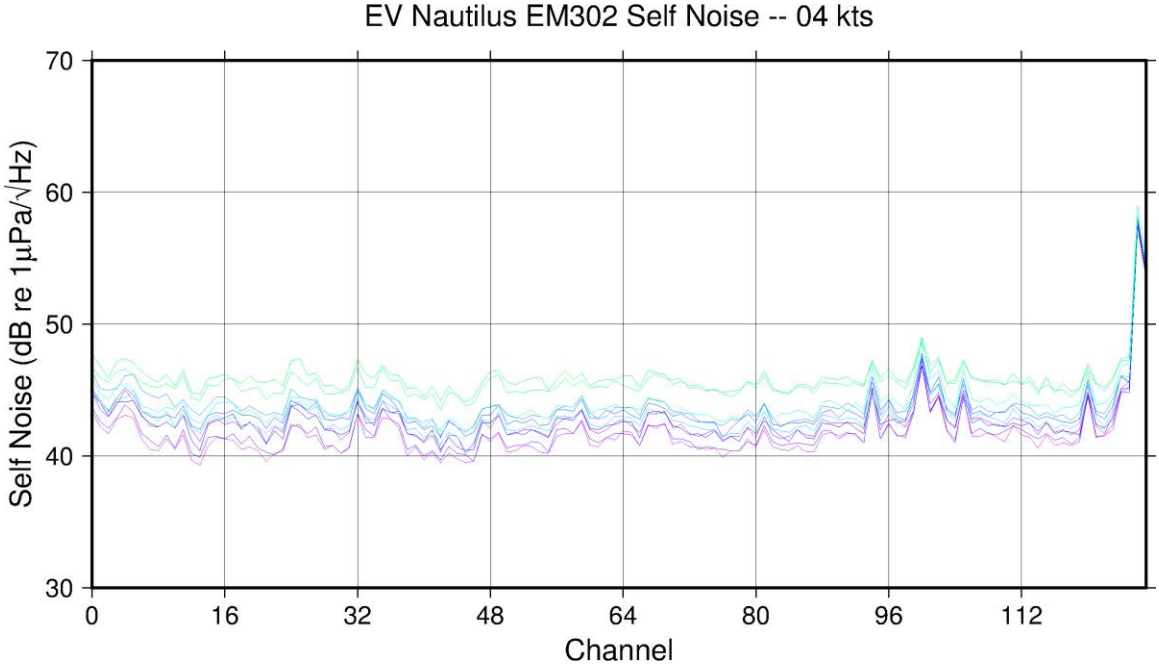


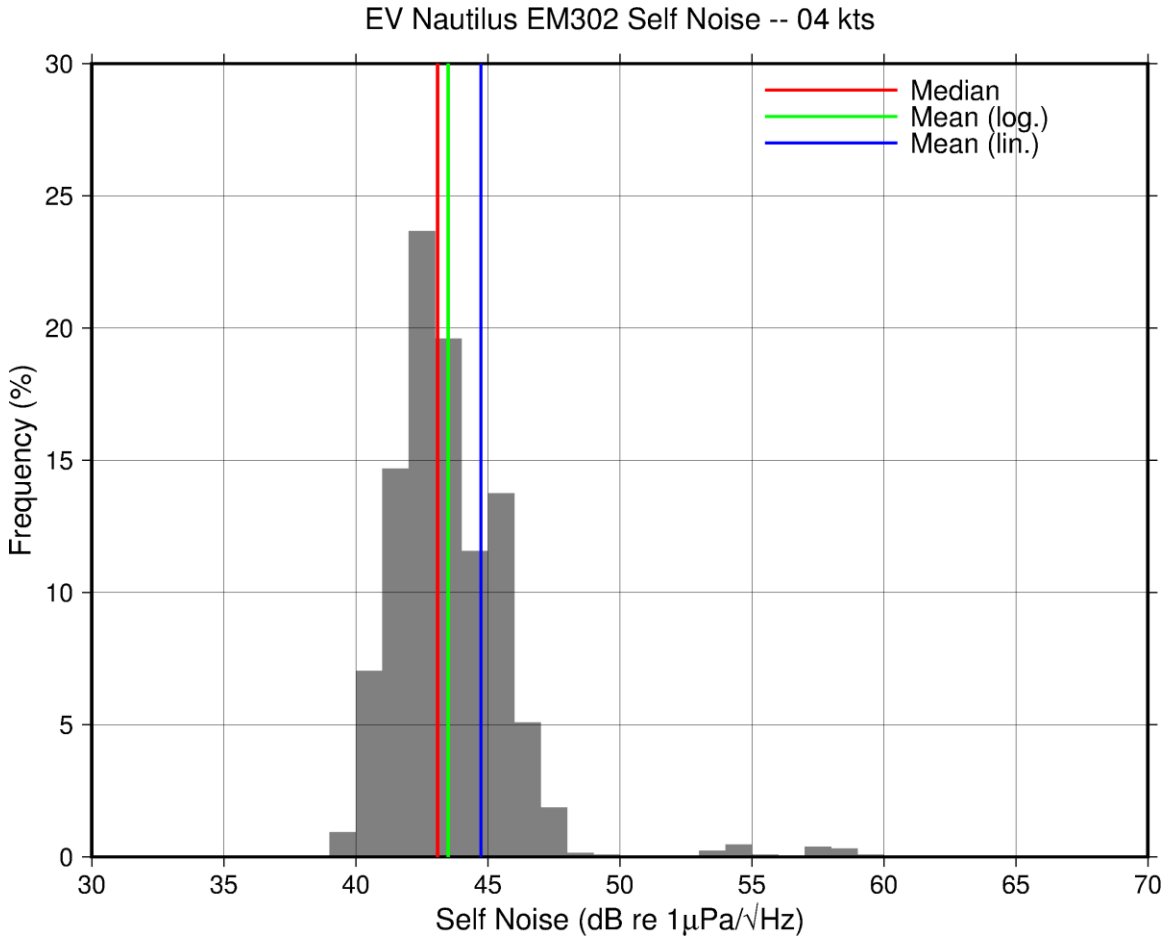
Self Noise Results – Speed – With Seas (3 kts)



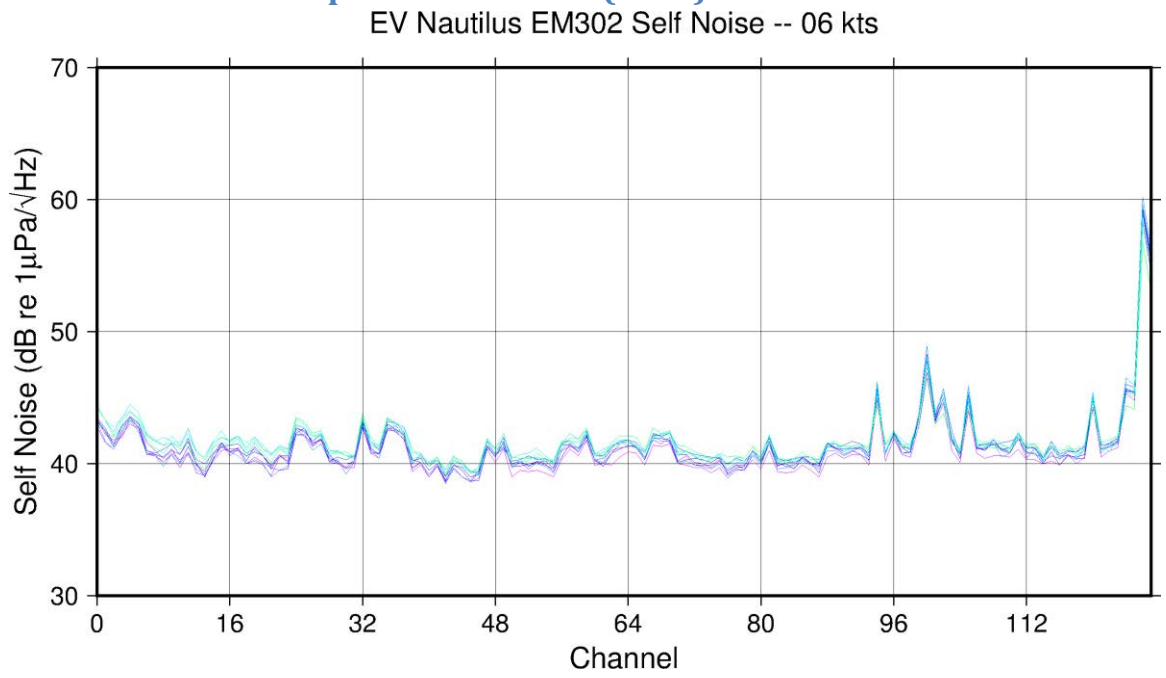


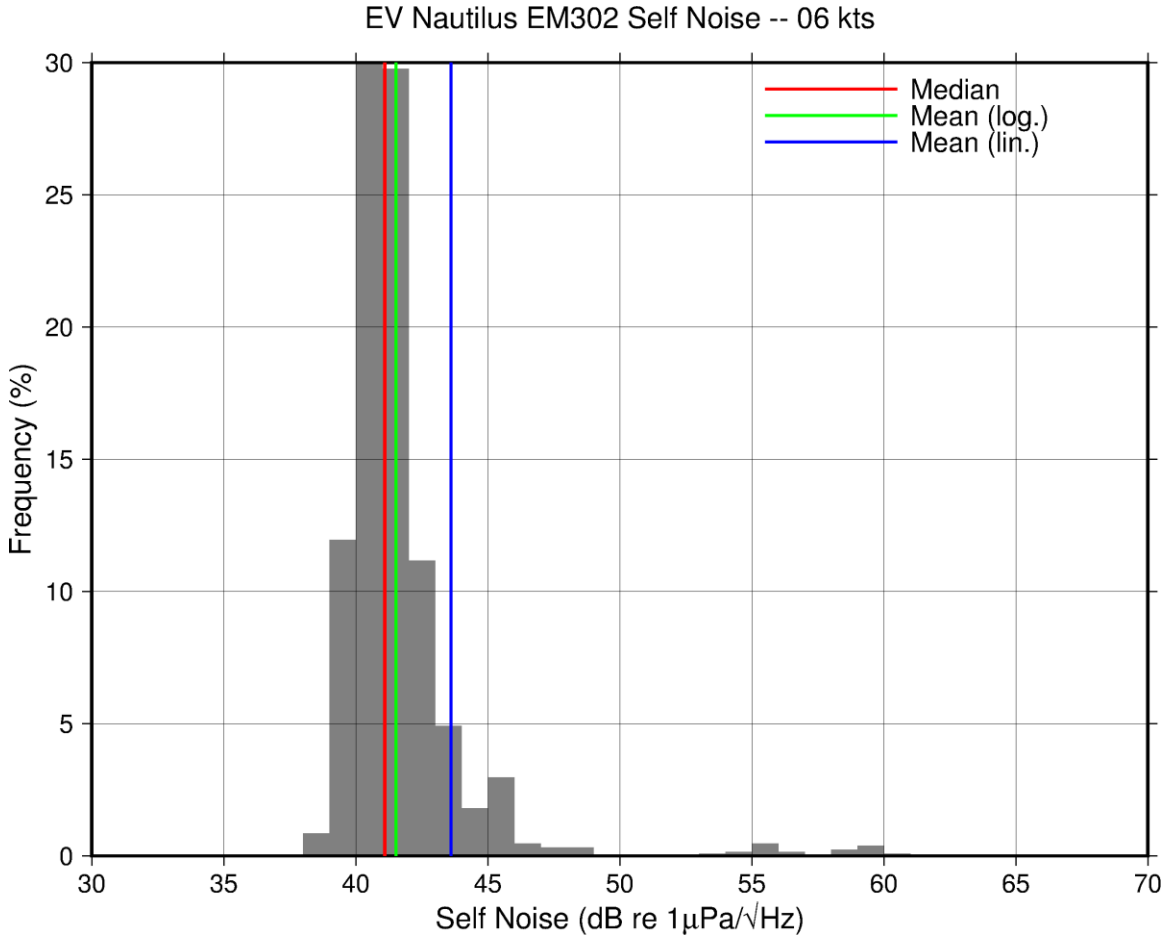
Self Noise Results – Speed – With Seas (4 kts)



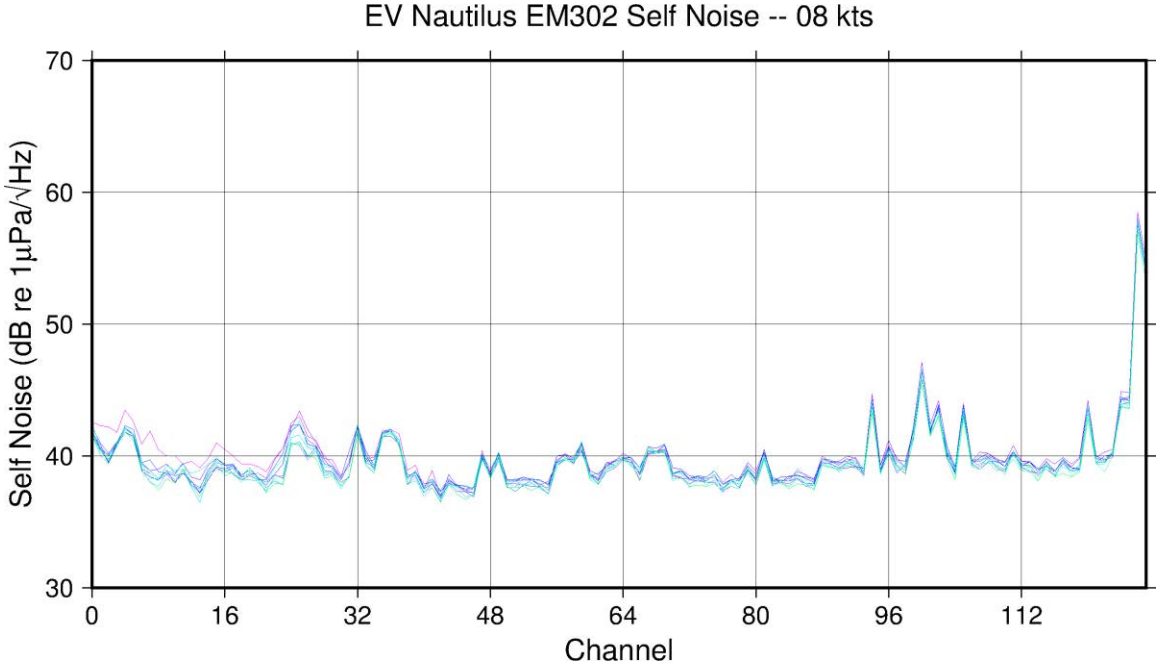


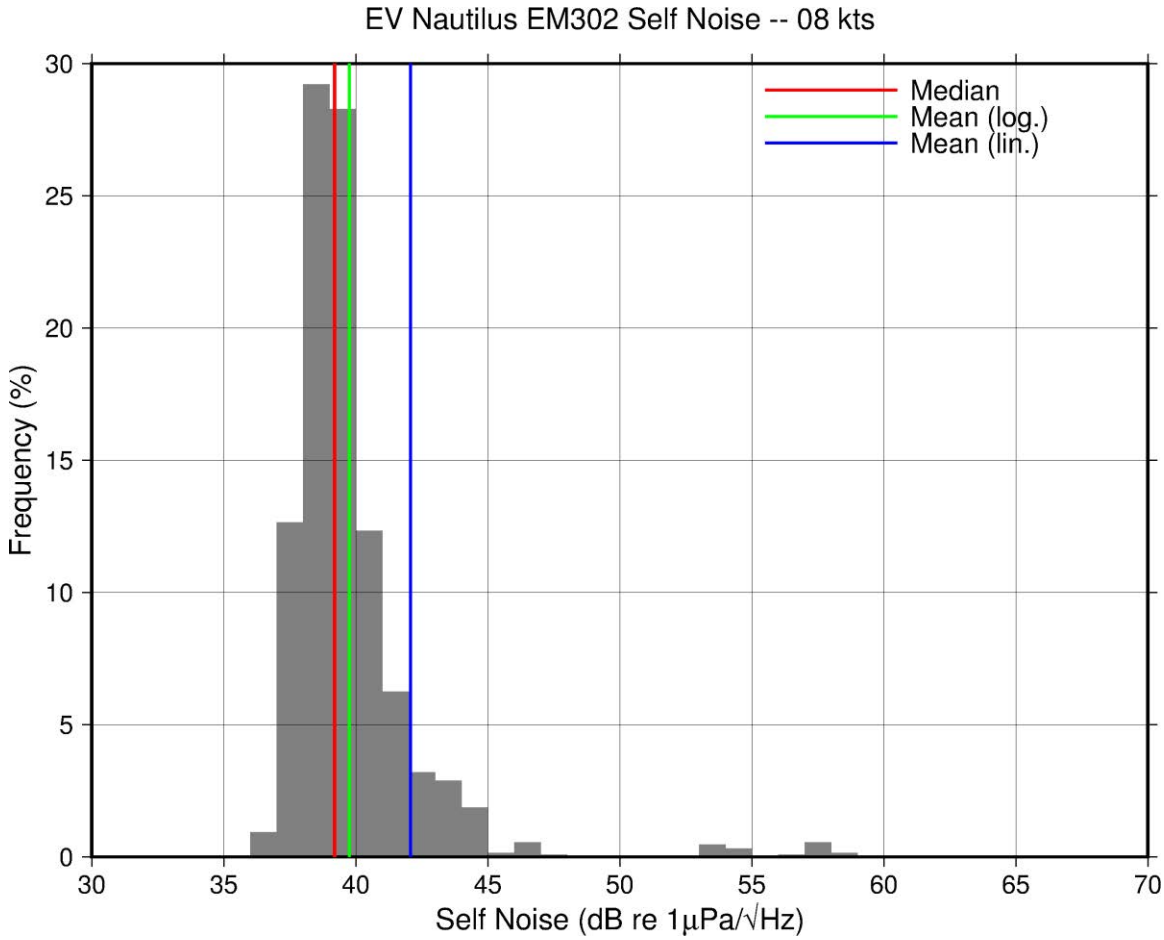
Self Noise Results – Speed – With Seas (6 kts)



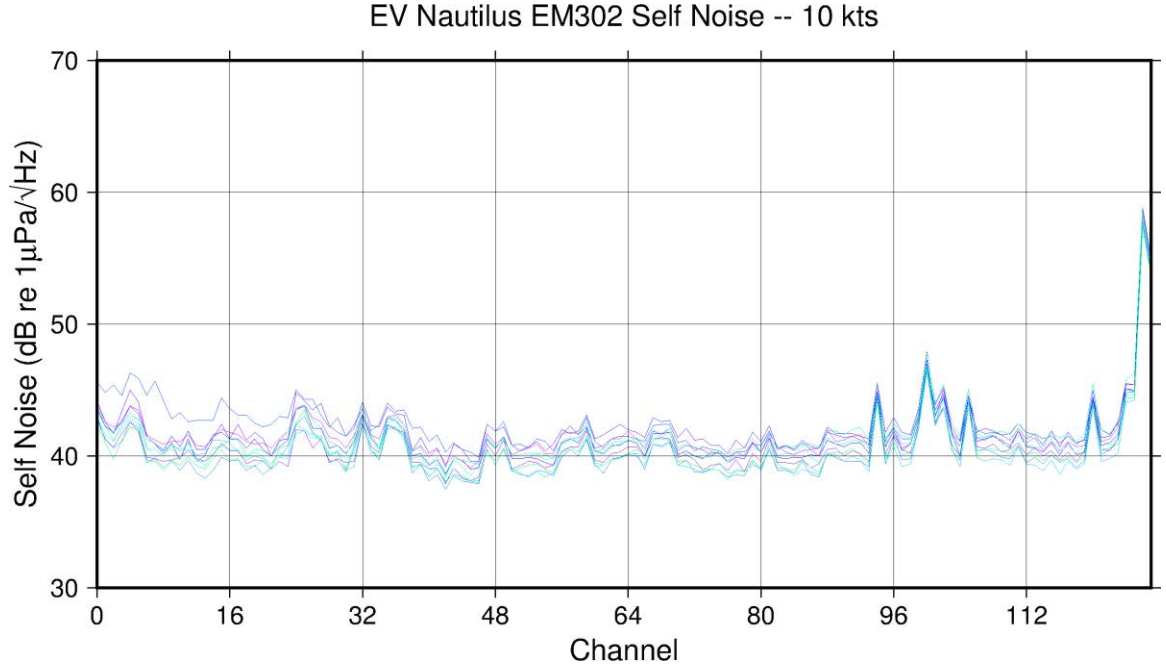


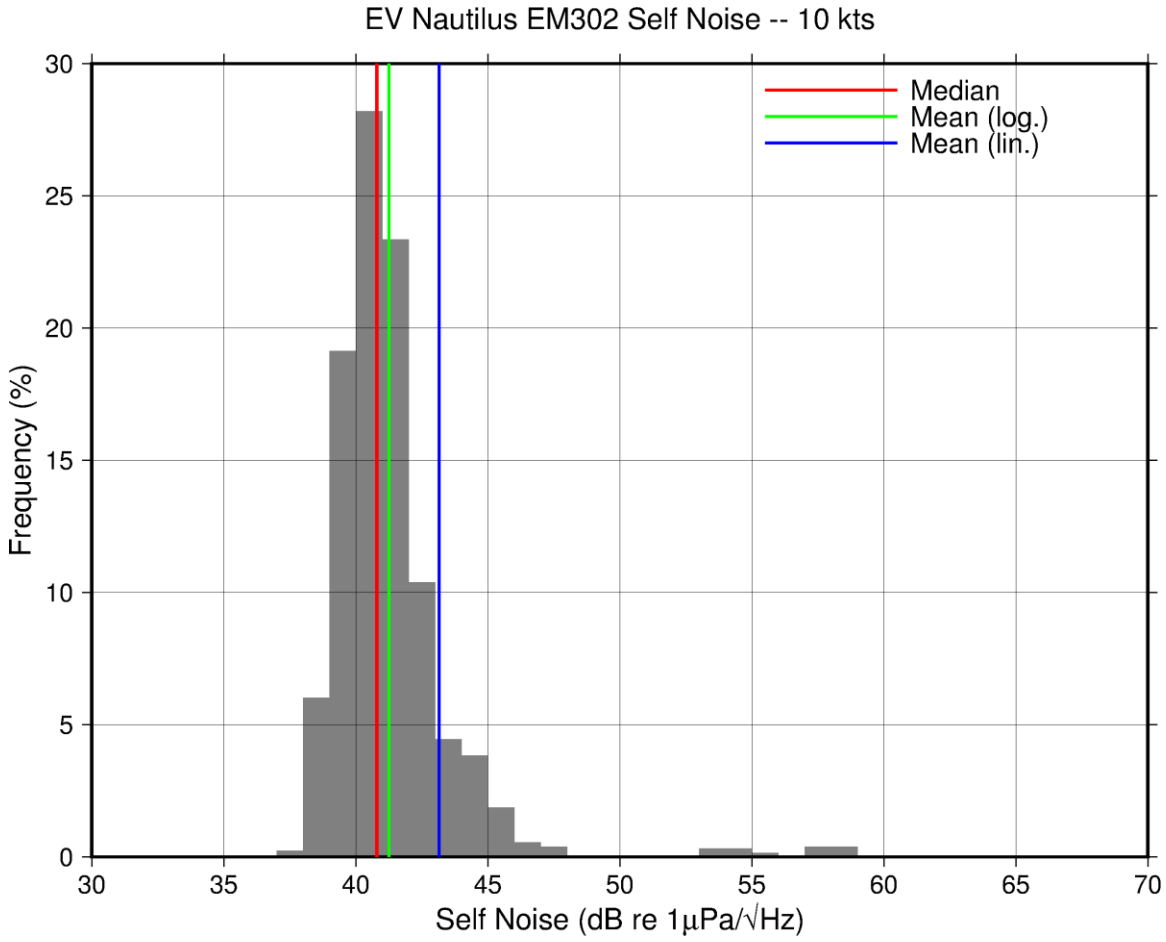
Self Noise Results – Speed – With Seas (8 kts)



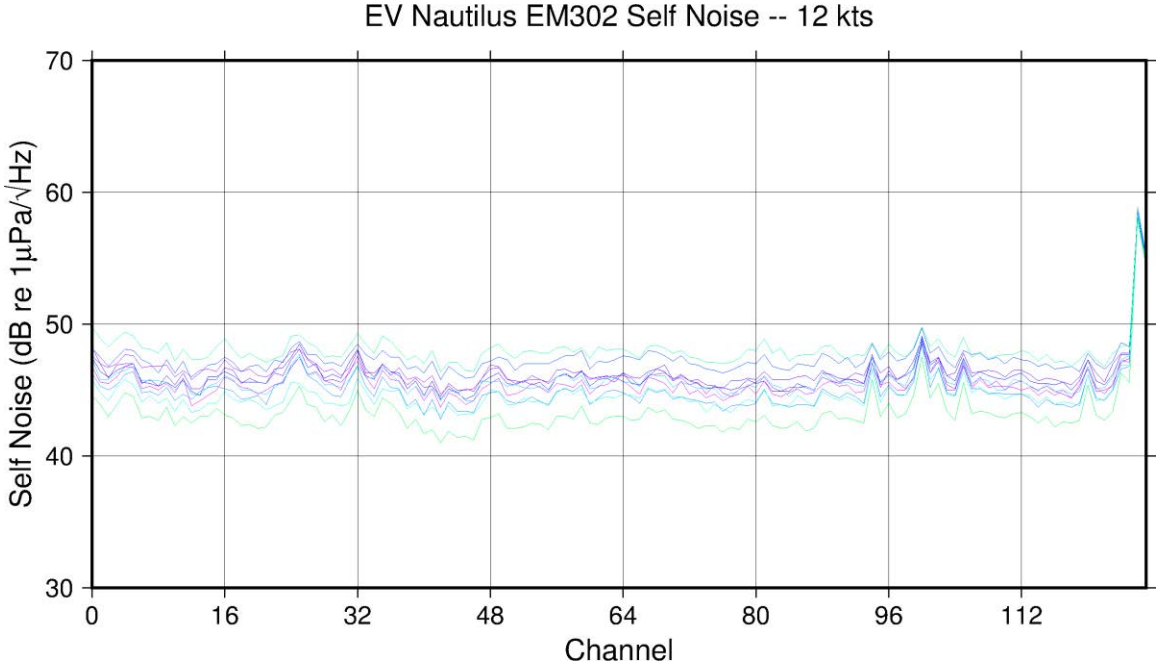


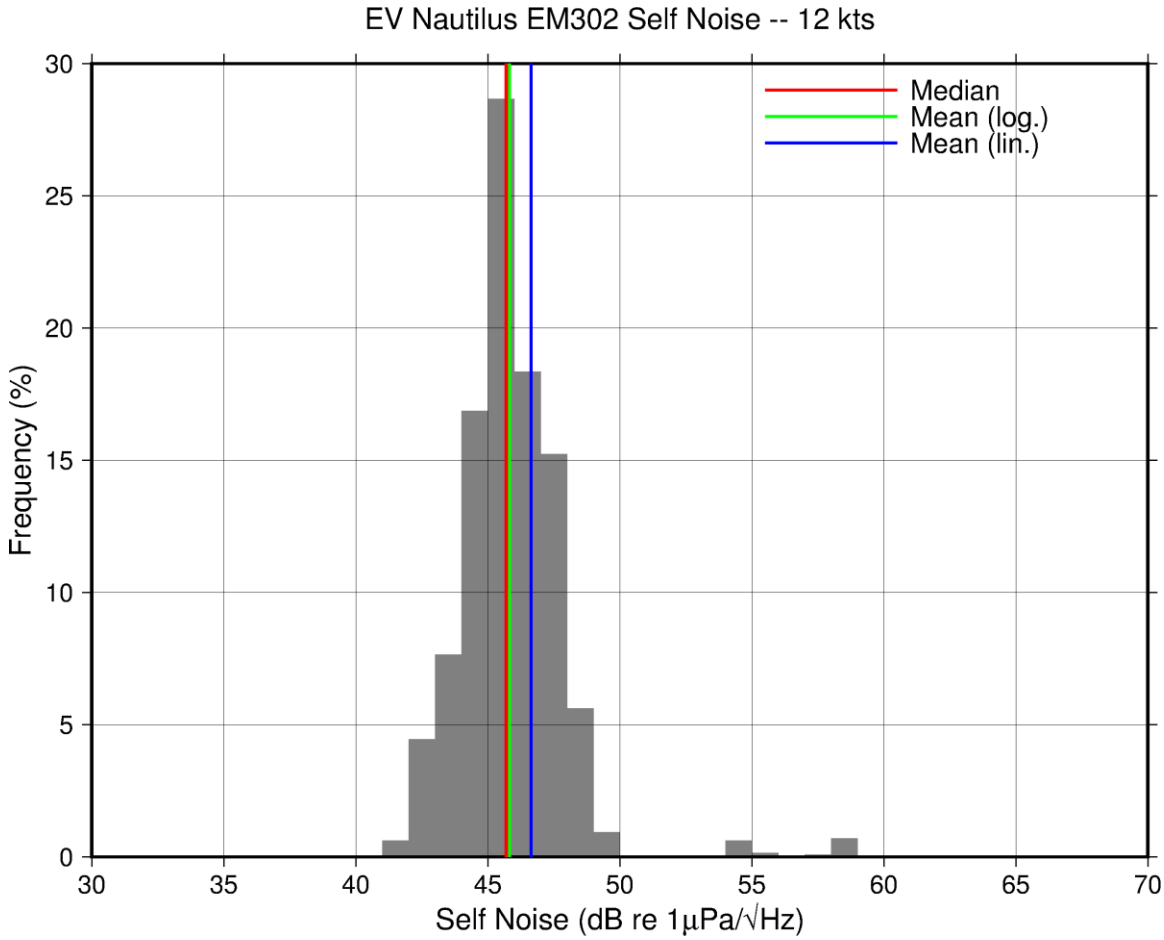
Self Noise Results – Speed – With Seas (10 kts)



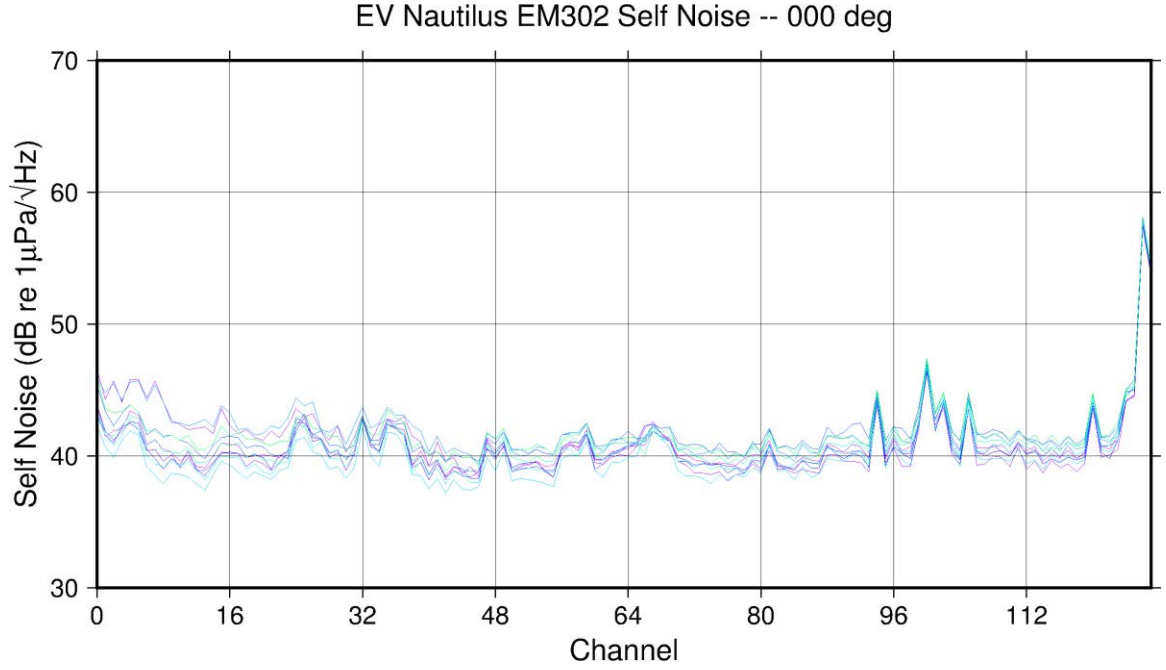


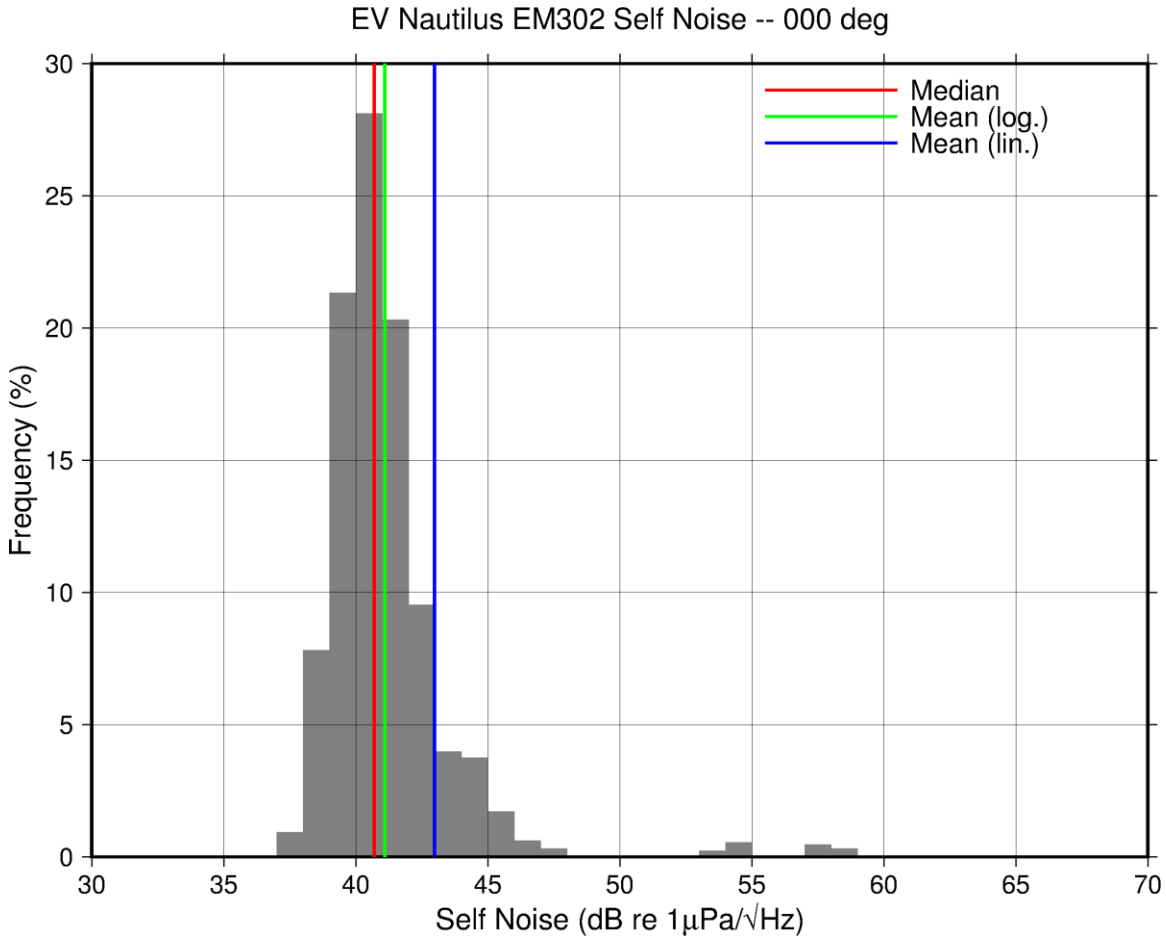
Self Noise Results – Speed – With Seas (12 kts)



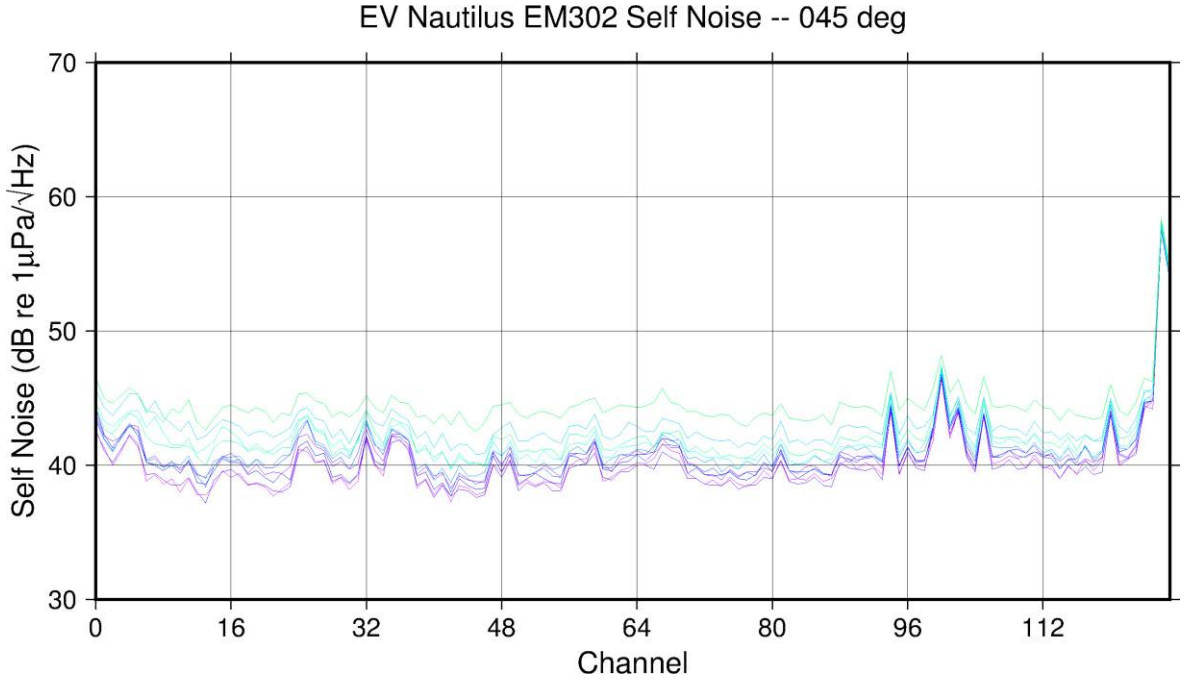


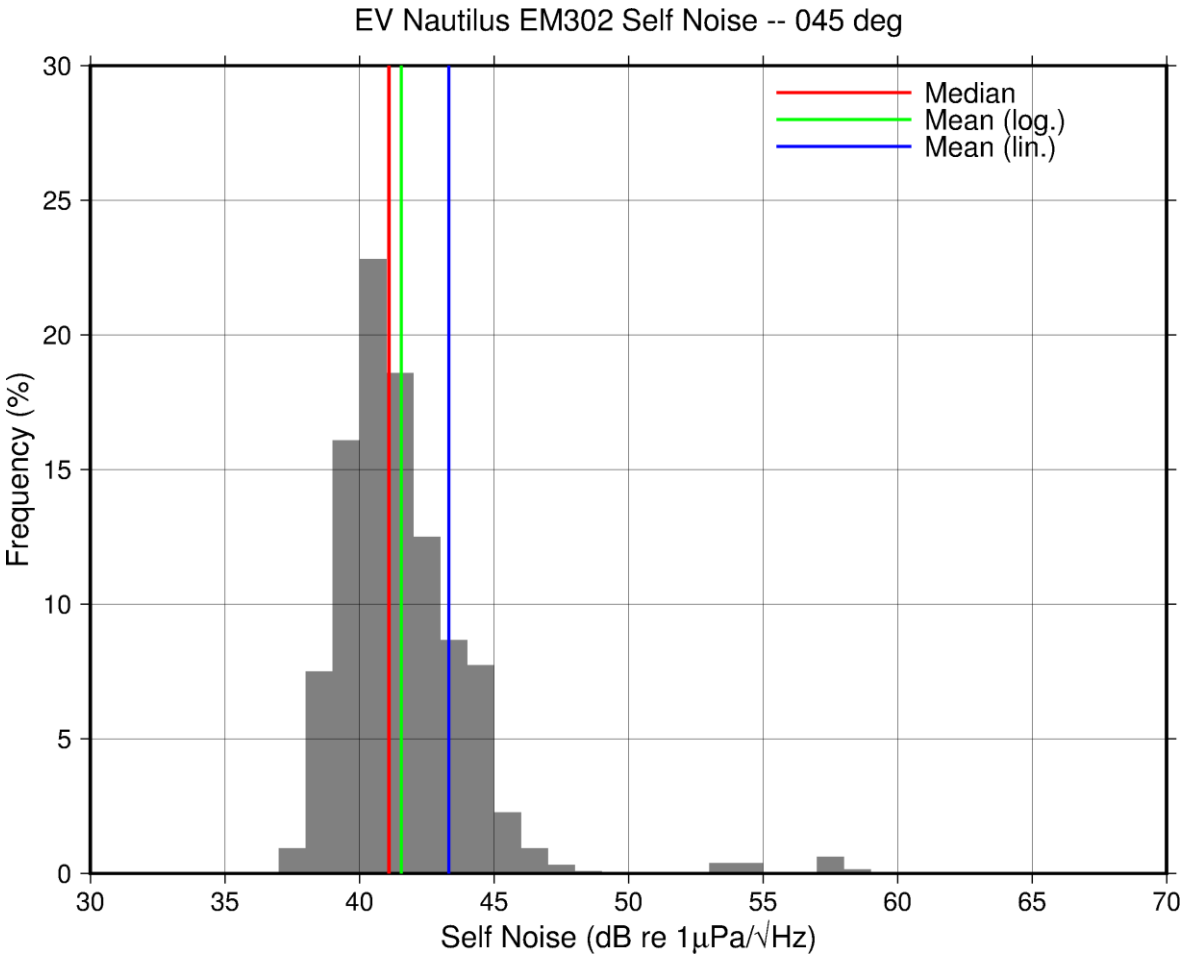
Self Noise Results – Swell – 000° (With Swell)



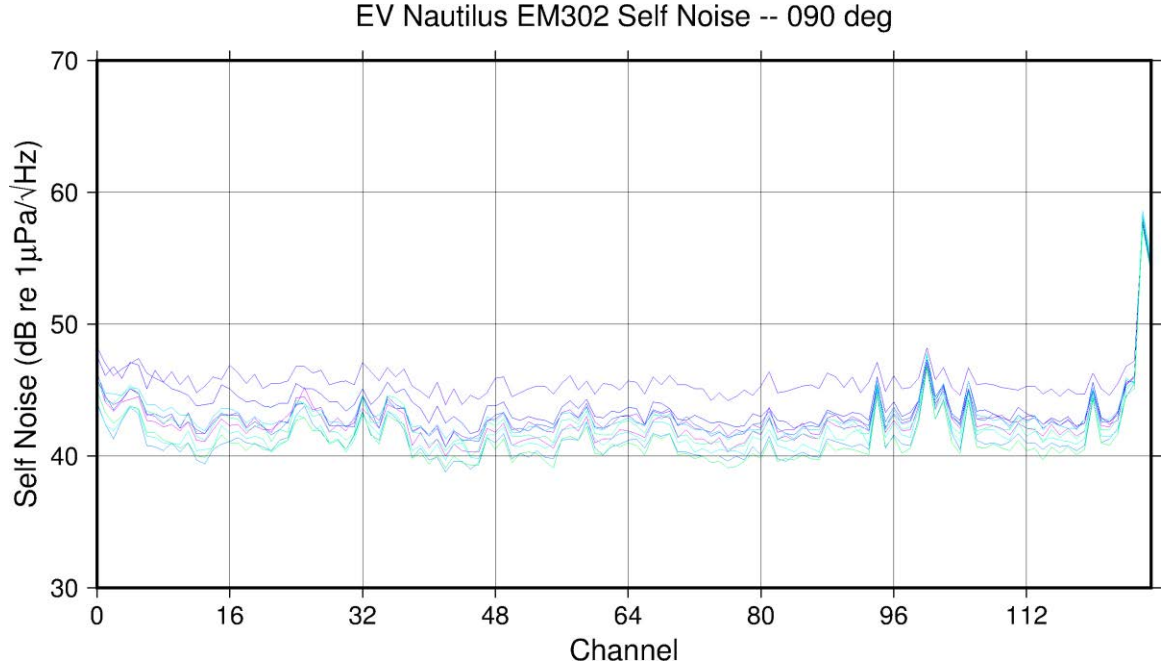


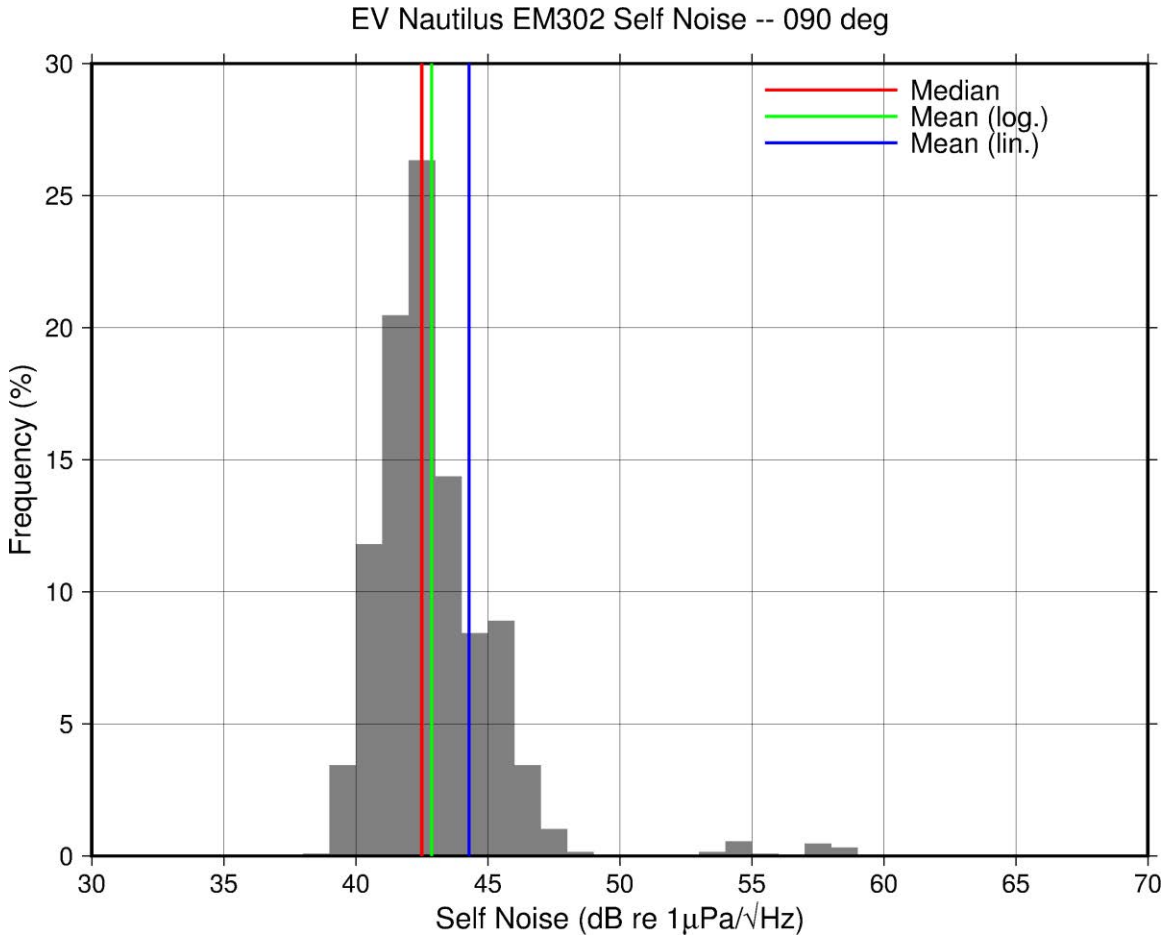
Self Noise Results – Swell – 045°



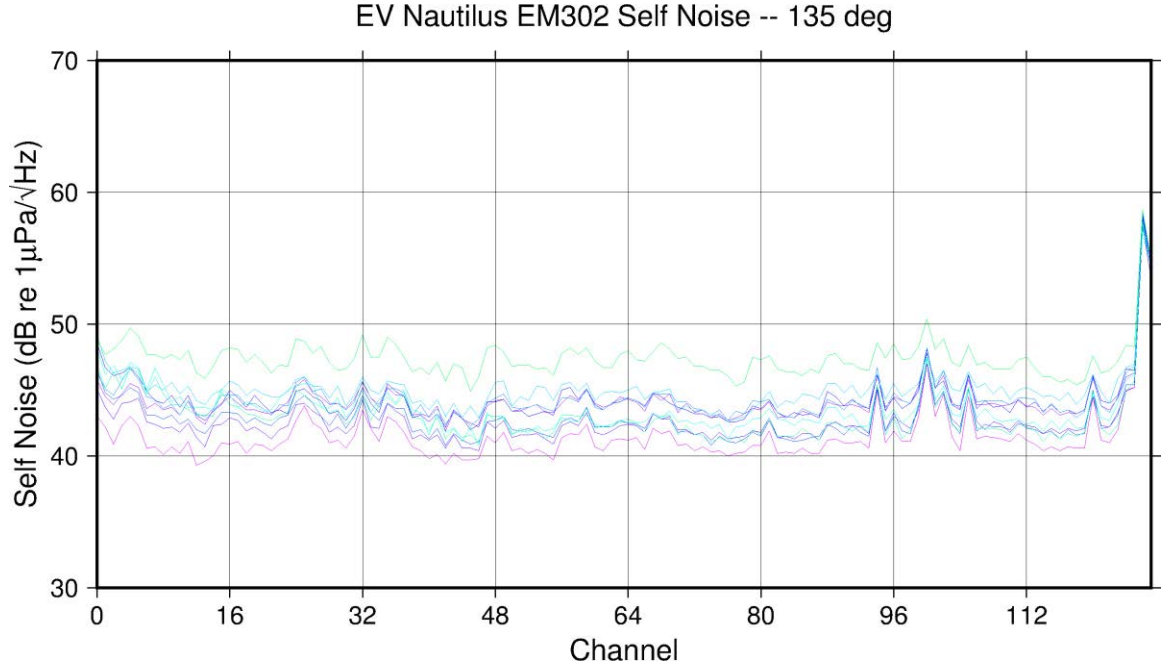


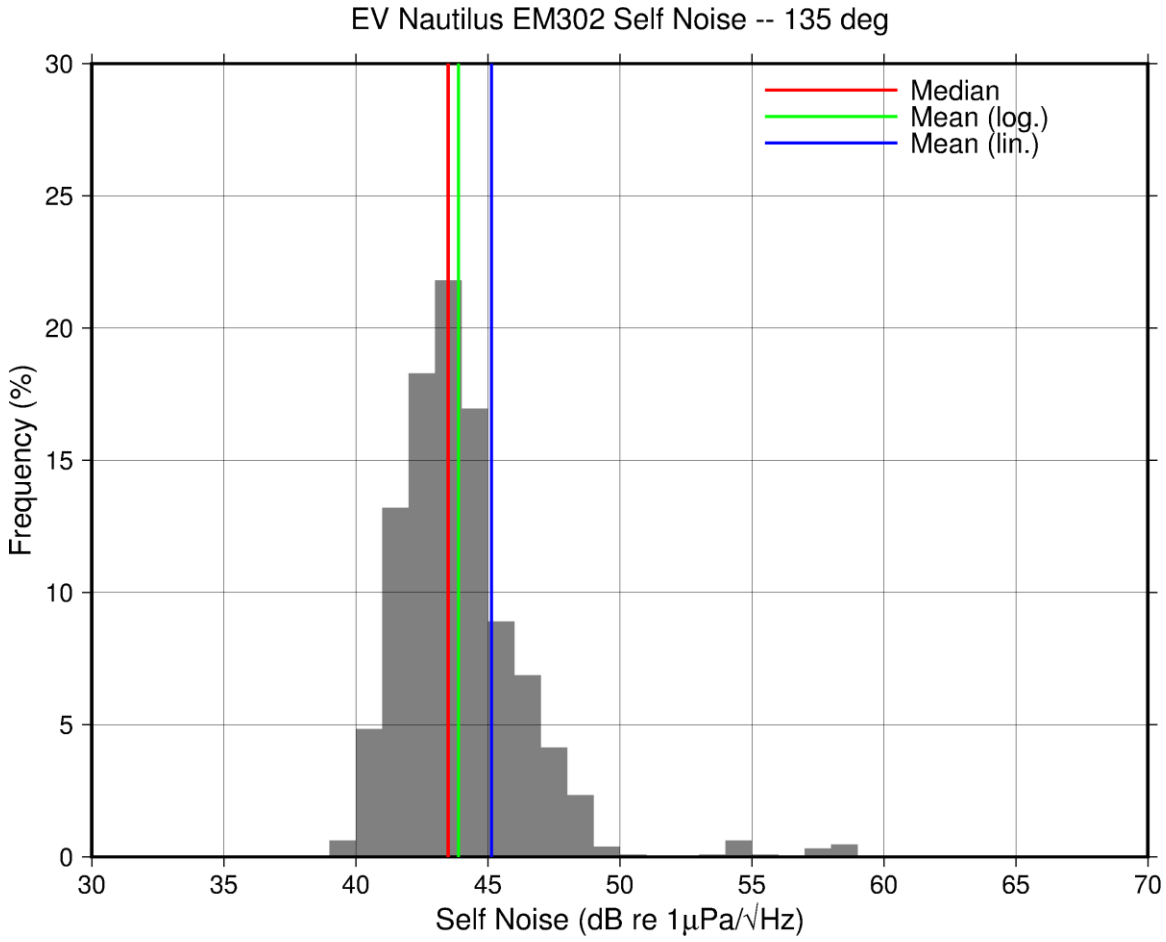
Self Noise Results – Swell – 090°



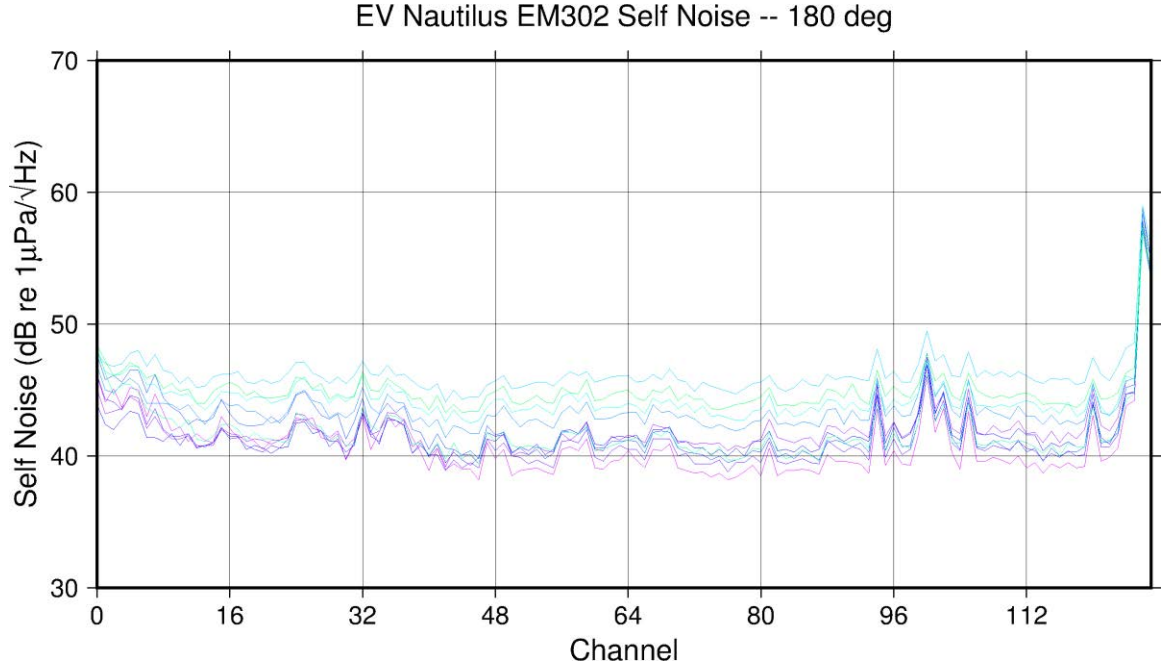


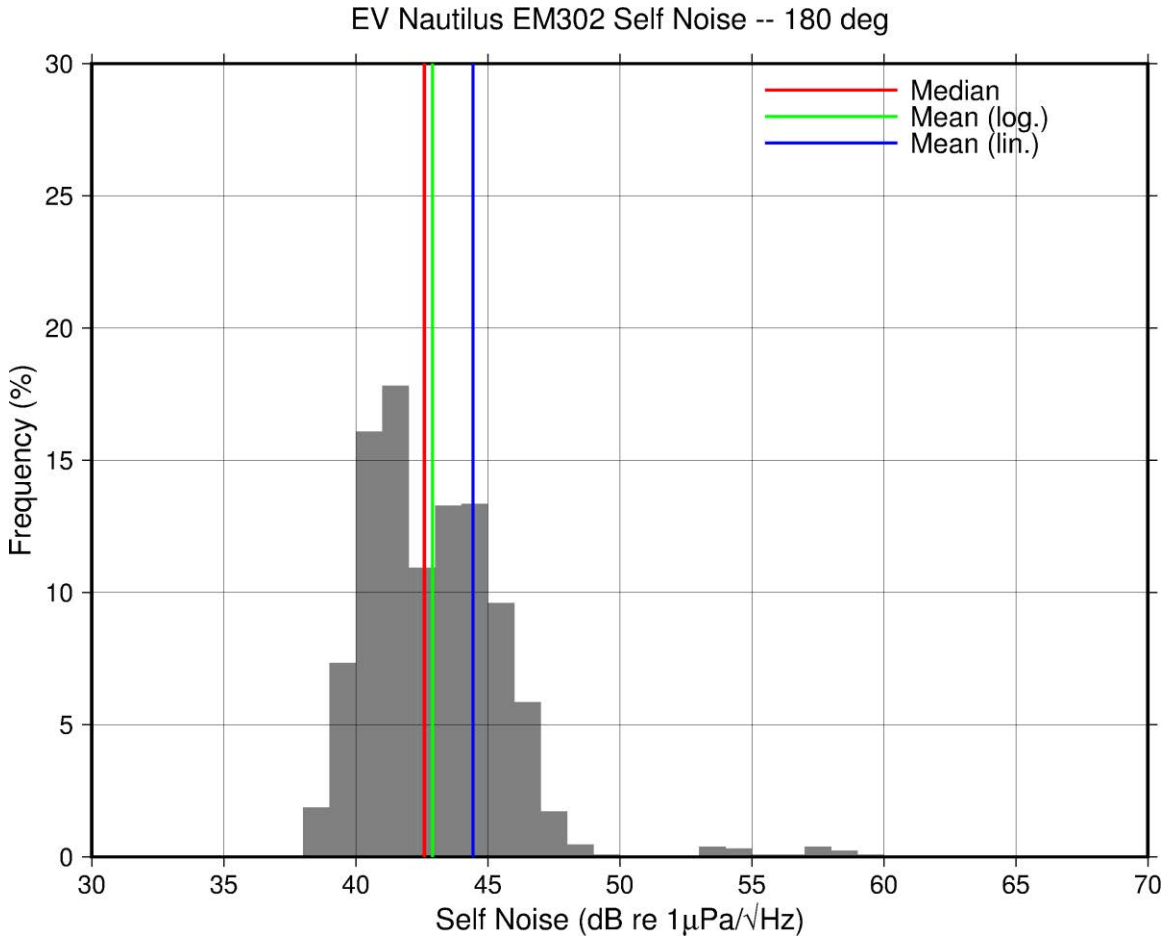
Self Noise Results – Swell – 135°



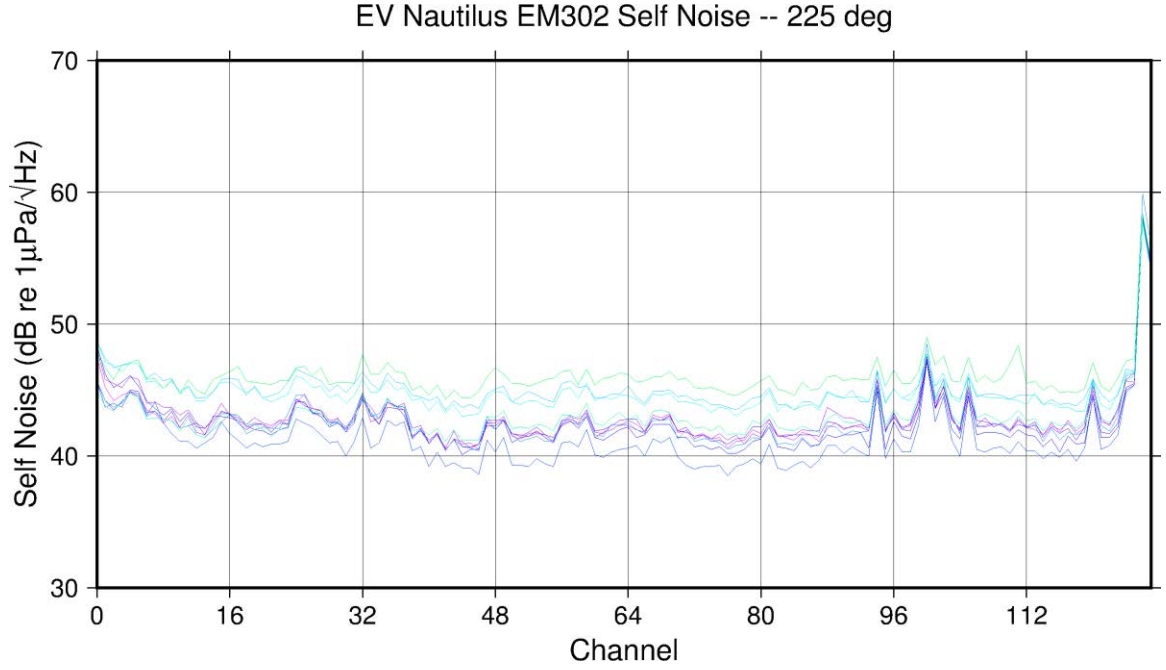


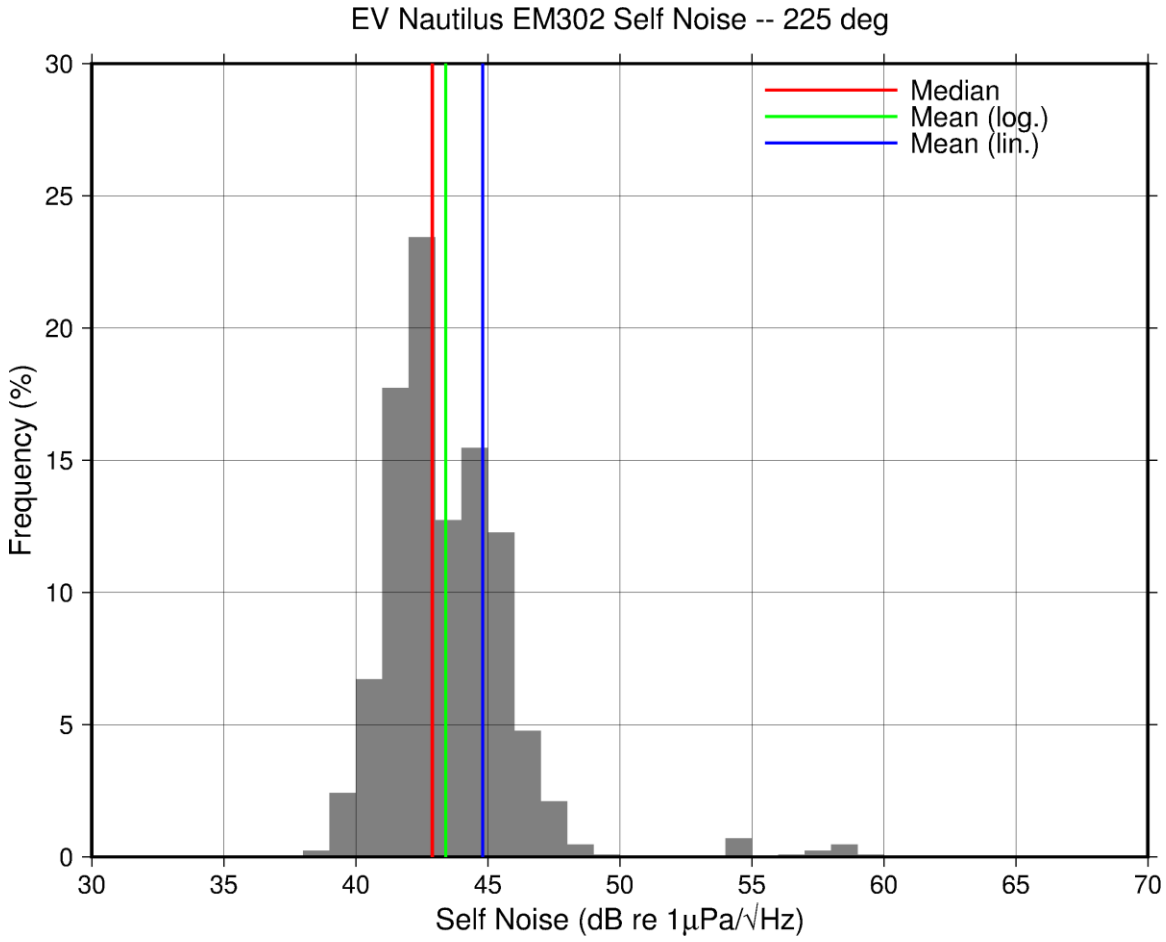
Self Noise Results – Swell – 180° (Into Swell)



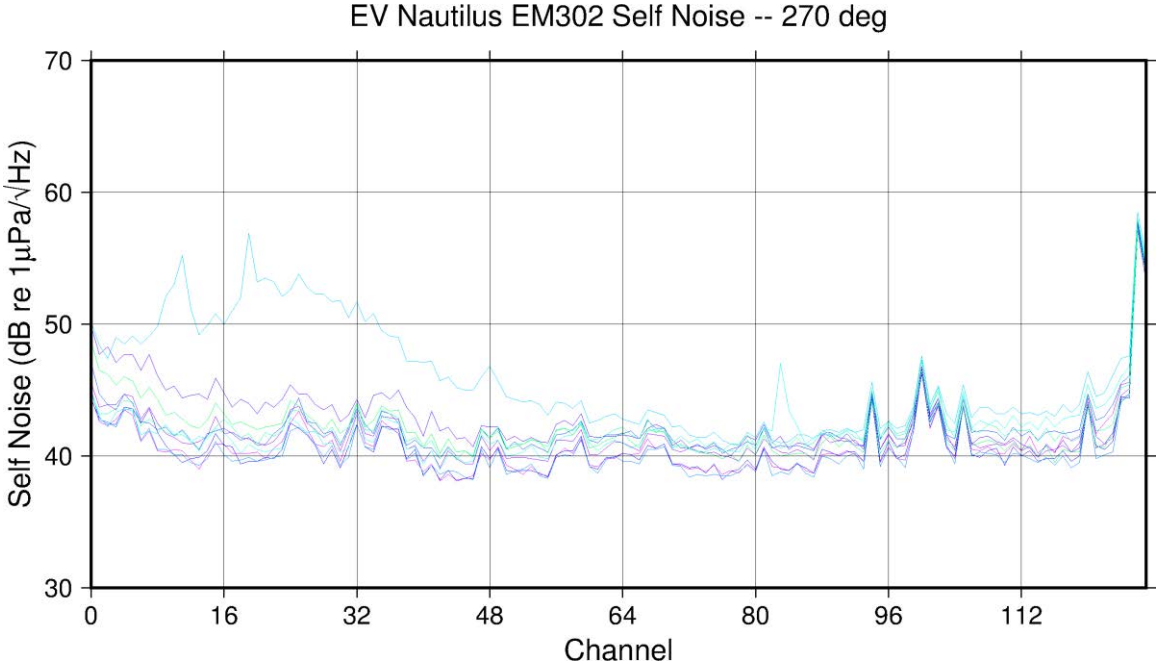


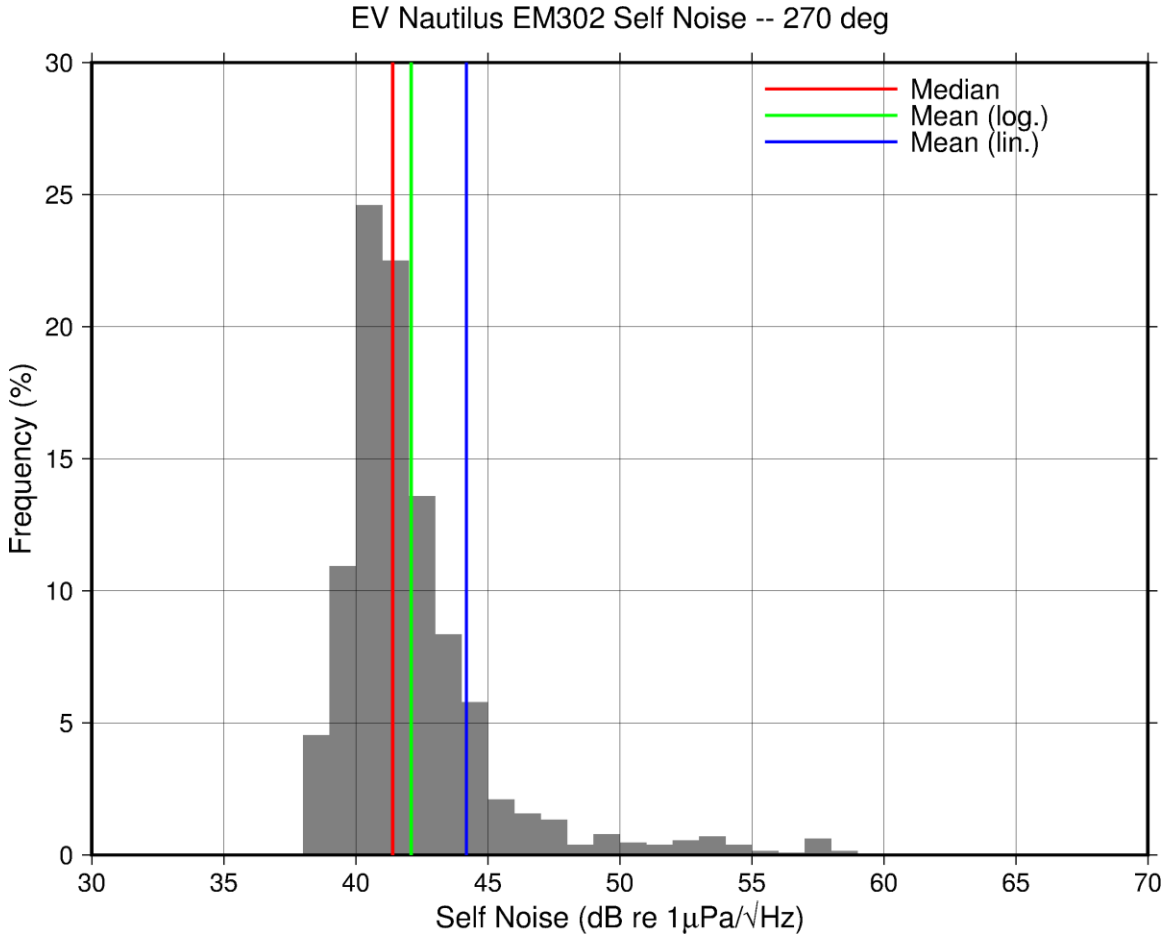
Self Noise Results – Swell – 225°



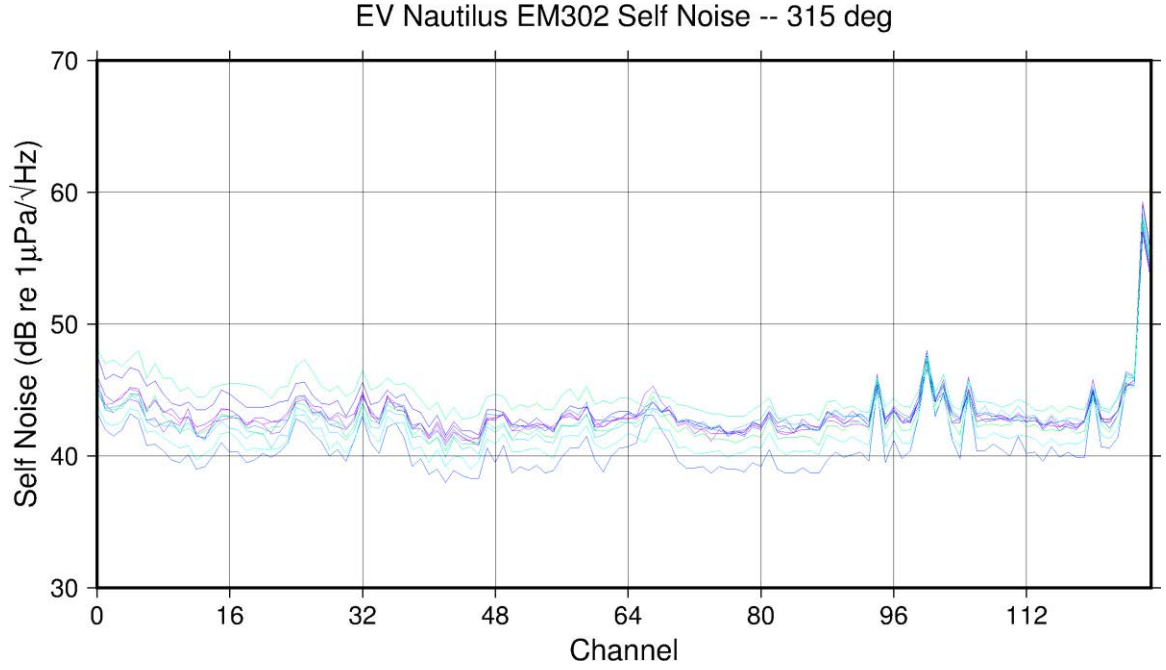


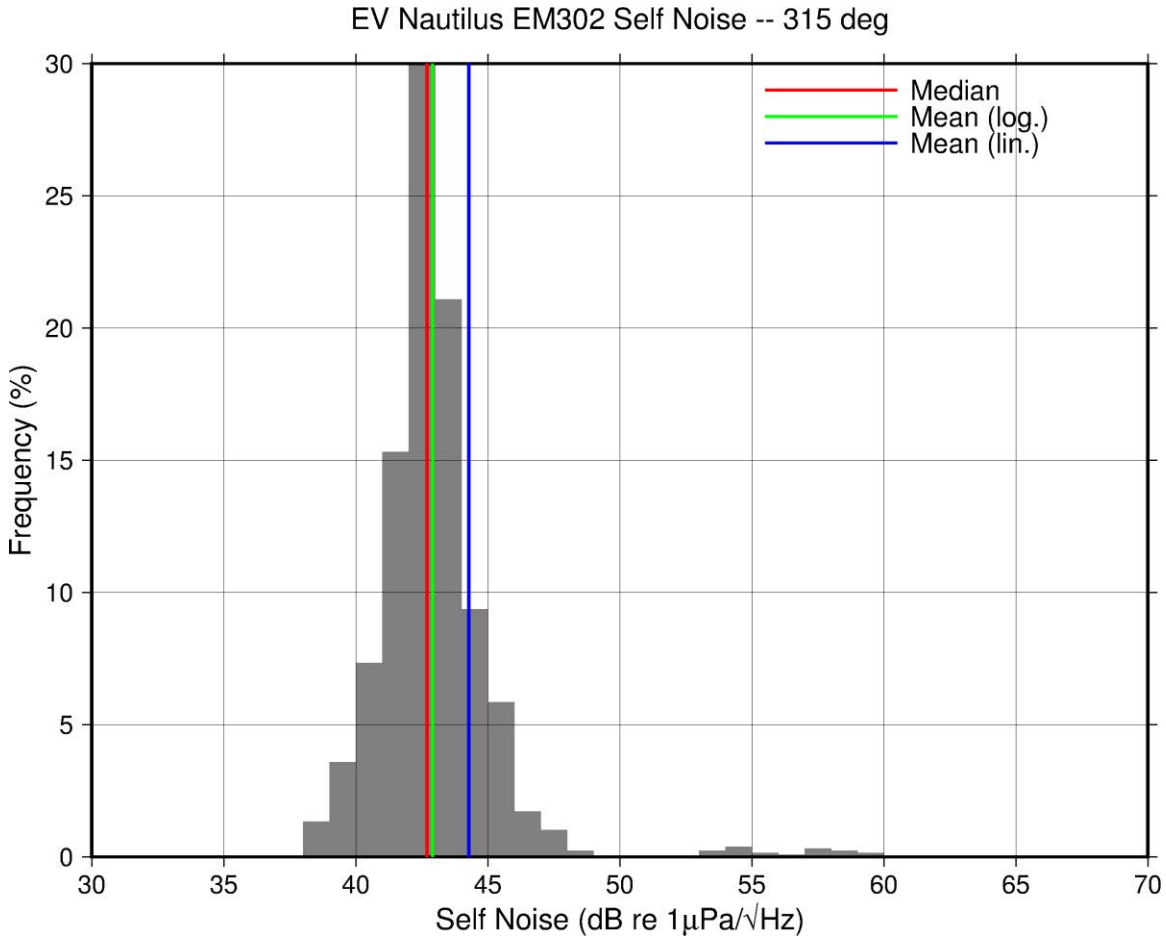
Self Noise Results – Swell – 270°





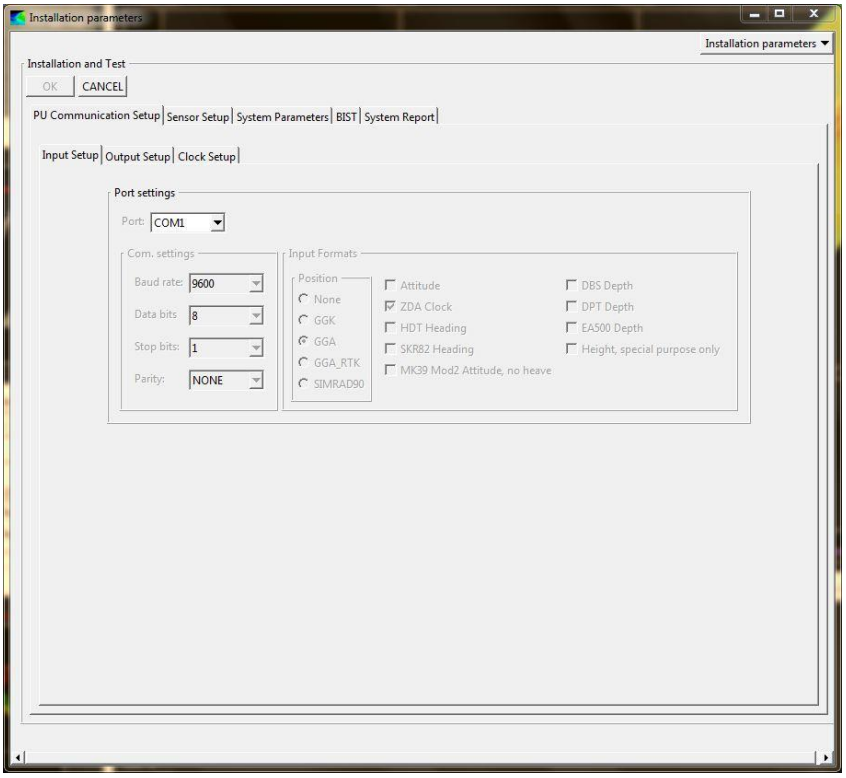
Self Noise Results – Swell – 315°

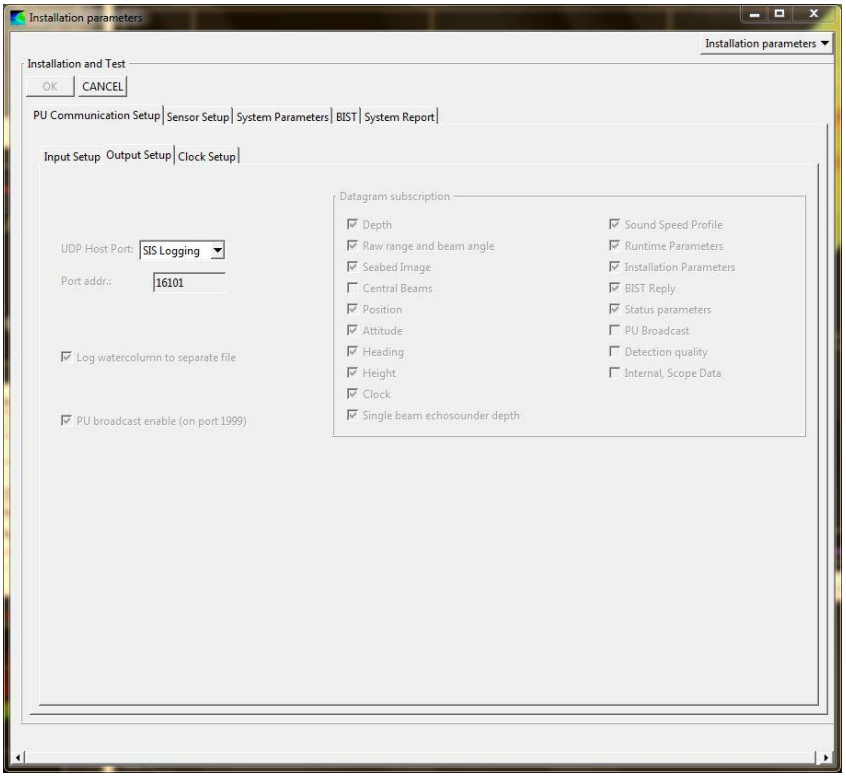


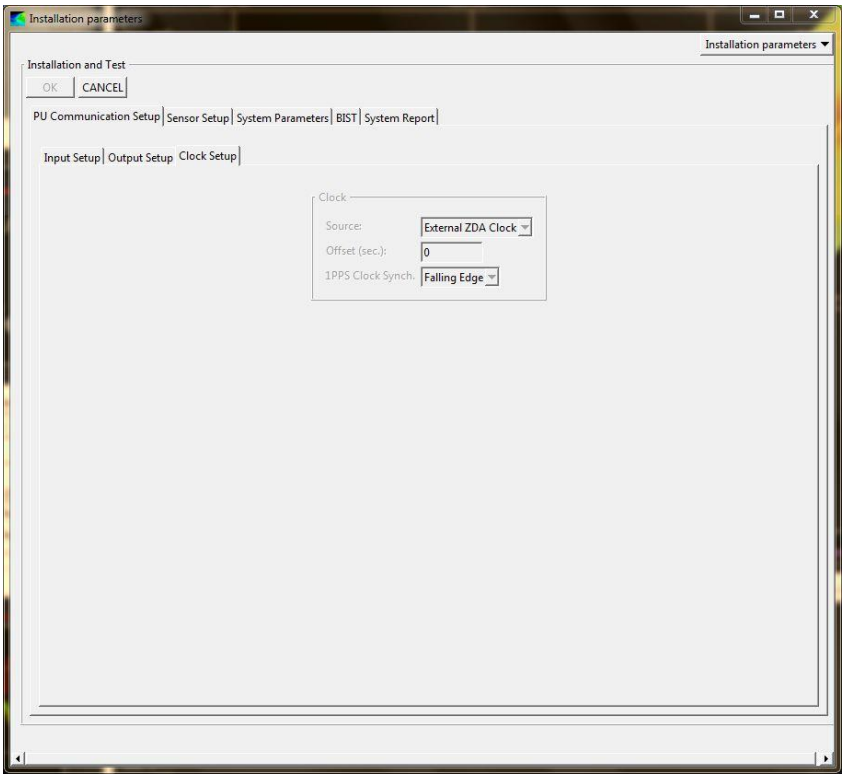


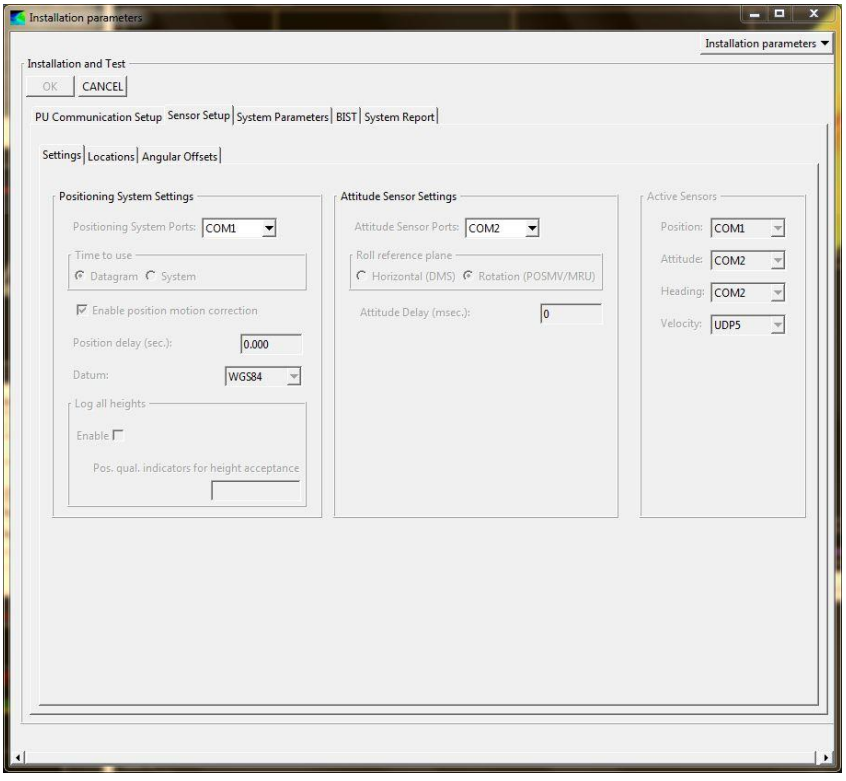
Appendix C - SIS Screenshots

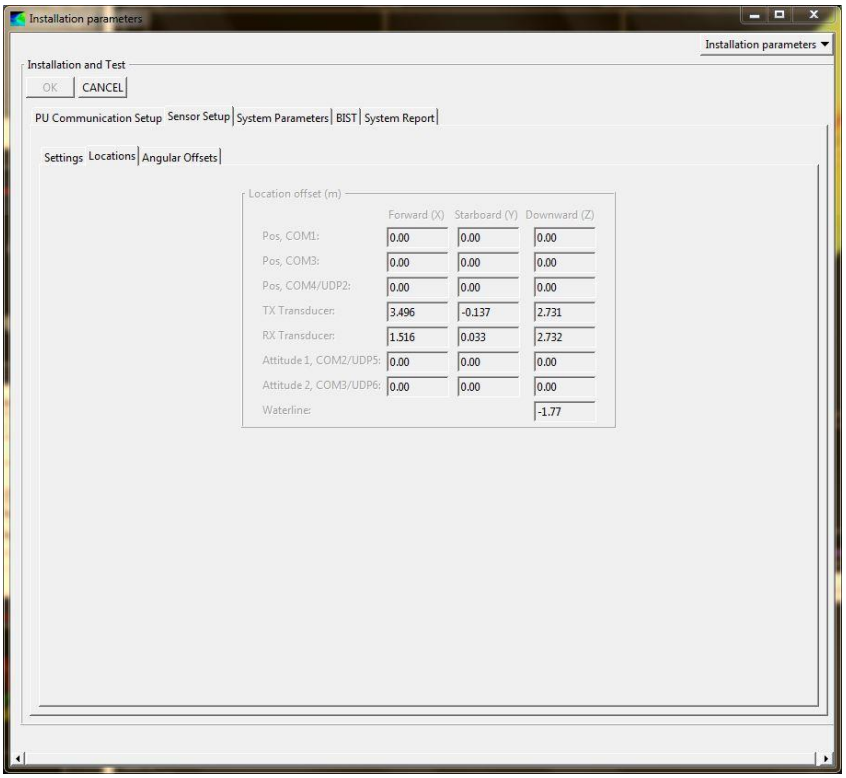
SIS Screenshots – PU Parameters (05 April 2014)

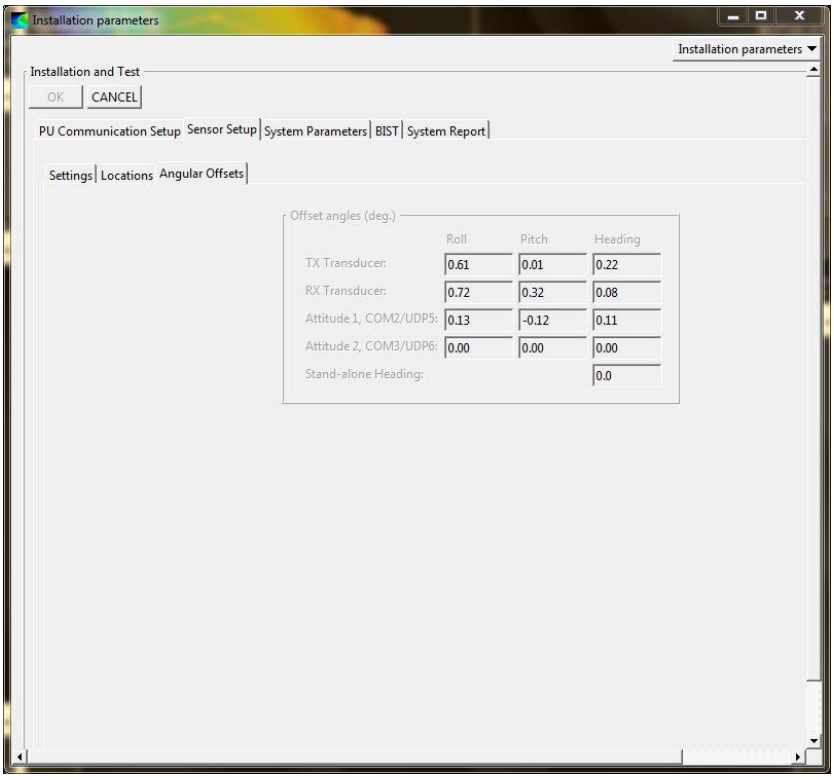


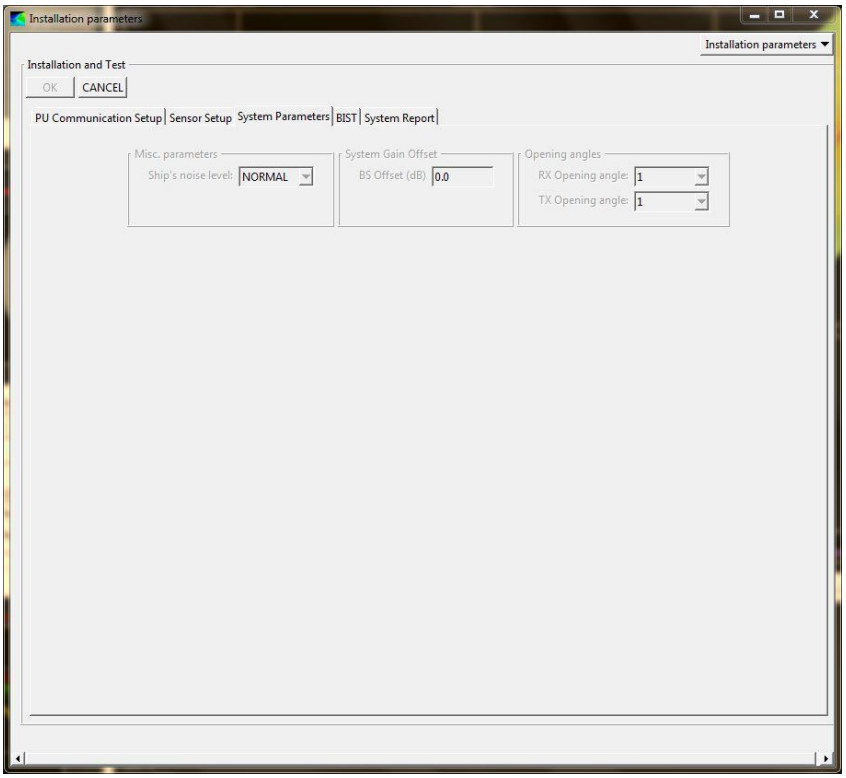


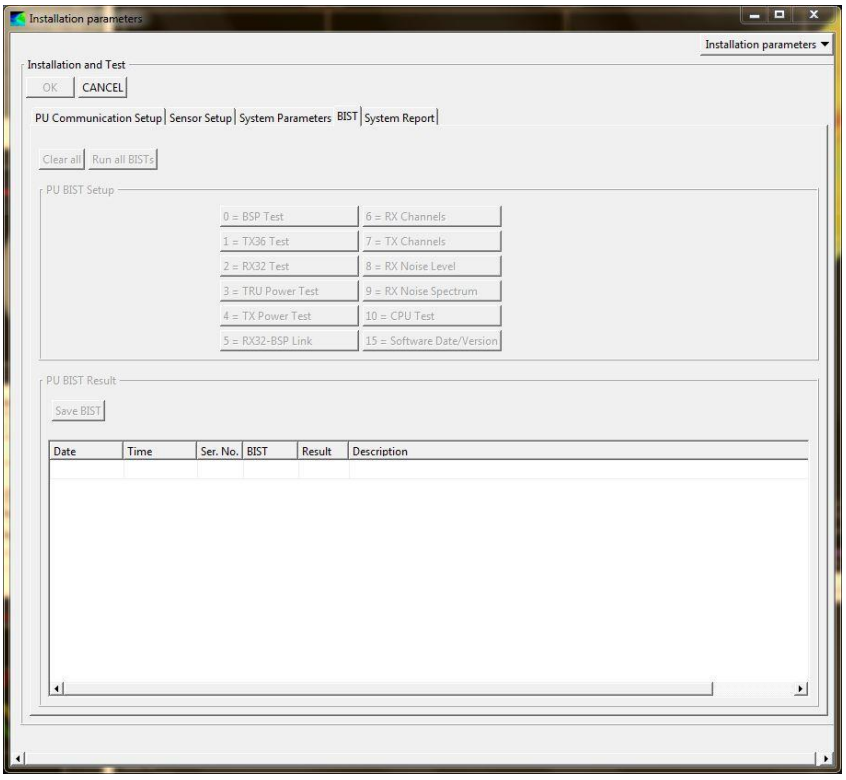

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Input Setup
Output Setup
Clock Setup
Clock
Source:
External ZDA Clock
Offset (sec.):
0
1PPS Clock Synch.
Falling Edge

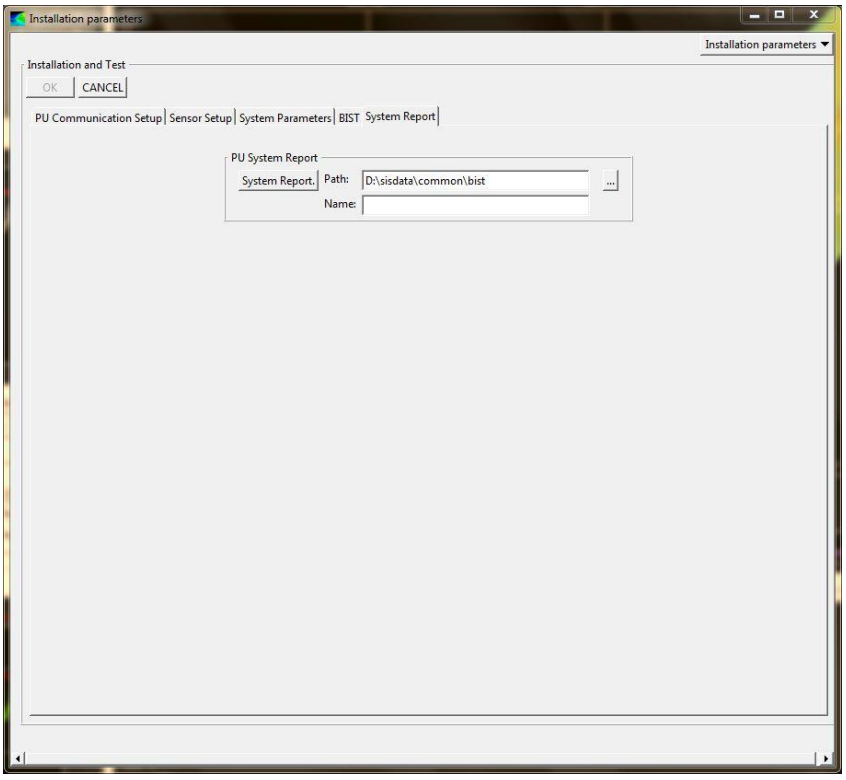

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Settings
Locations
Angular Offsets
Positioning System Settings
Positioning System Ports:
COM1
Time to use
Datagram
System
Enable position motion correction
Position delay (sec.):
0.000
Datum:
WGS84
Log all heights
Enable
Pos. qual. indicators for height acceptance
Attitude Sensor Settings
Attitude Sensor Ports:
COM2
Roll reference plane
Horizontal (DMS)
Rotation (POSMV/MRU)
Attitude Delay (msec.):
0
Active Sensors
Position:
COM1
Attitude:
COM2
Heading:
COM2
Velocity:
UDP5


Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Settings
Locations
Angular Offsets
Location offset (m)
Forward (X)
Starboard (Y)
Downward (Z)
Pos, COM1: 0.00 0.00 0.00
Pos, COM3: 0.00 0.00 0.00
Pos, COM4/UDP2: 0.00 0.00 0.00
TX Transducer: 3.496 -0.137 2.731
RX Transducer: 1.516 0.033 2.732
Attitude 1, COM2/UDP5: 0.00 0.00 0.00
Attitude 2, COM3/UDP6: 0.00 0.00 0.00
Waterline: -1.77

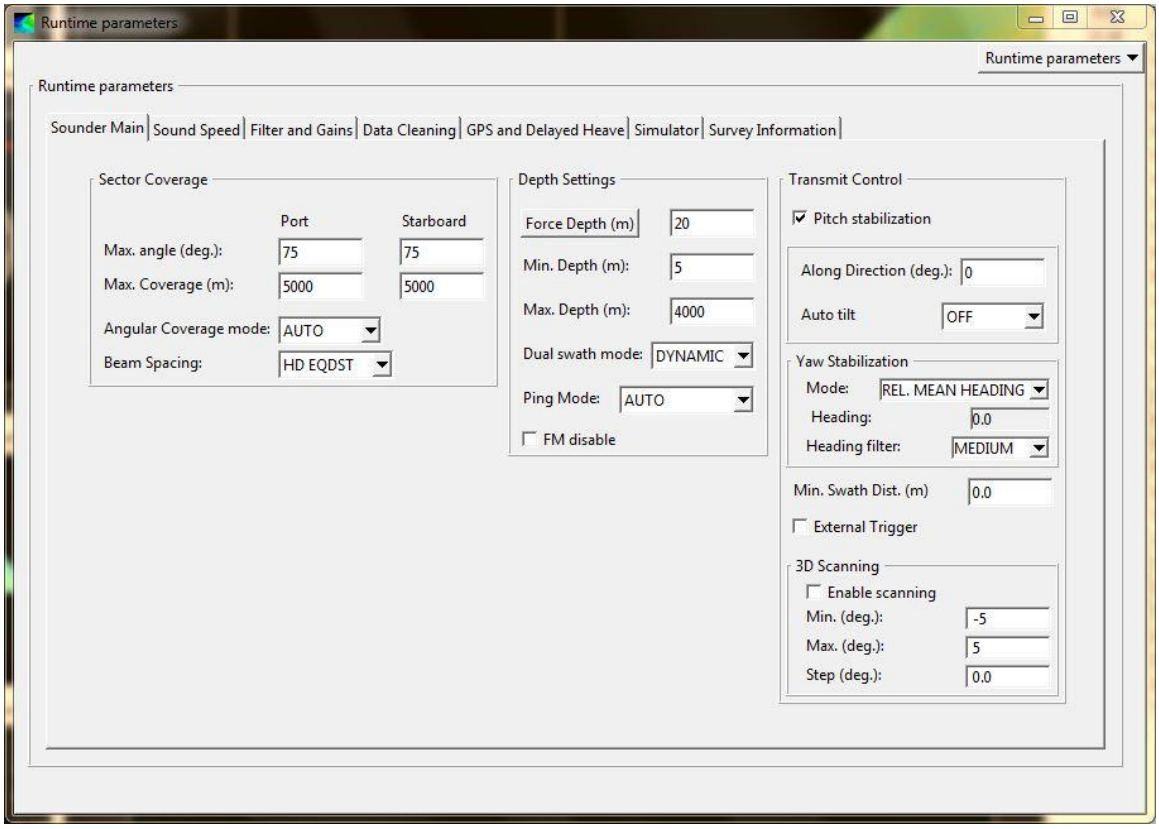

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Settings
Locations
Angular Offsets
Offset angles (deg.)
Roll
Pitch
Heading
TX Transducer: 0.61 0.01 0.22
RX Transducer: 0.72 0.32 0.08
Attitude 1, COM2/UDP5: 0.13 -0.12 0.11
Attitude 2, COM3/UDP6: 0.00 0.00 0.00
Stand-alone Heading: 0.0

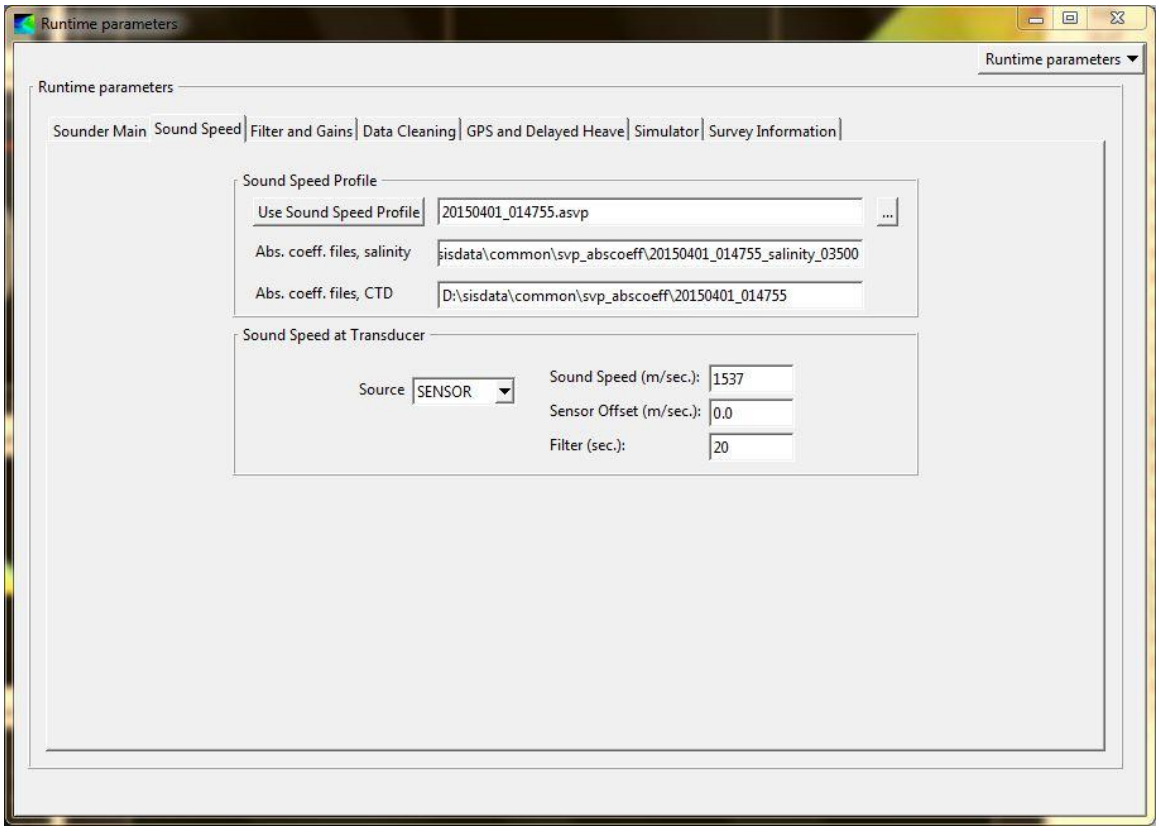

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Misc. parameters
Ship's noise level:
NORMAL
System Gain Offset
BS Offset (dB)
0.0
Opening angles
RX Opening angle:
1
TX Opening angle:
1

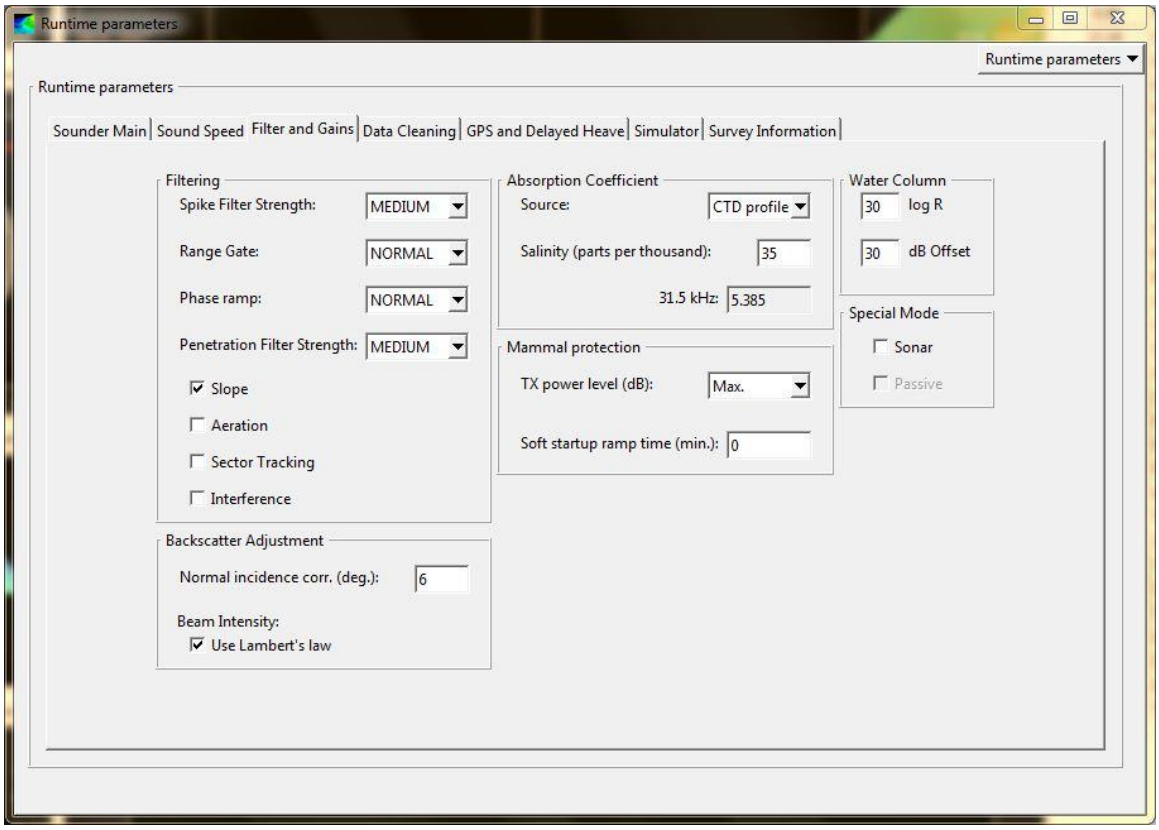

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Clear all
Run all BISTs
PU BIST Setup
0 = BSP Test
1 = TX36 Test
2 = RX32 Test
3 = TRU Power Test
4 = TX Power Test
5 = RX32-BSP Link
6 = RX Channels
7 = TX Channels
8 = RX Noise Level
9 = RX Noise Spectrum
10 = CPU Test
15 = Software Date/Version
PU BIST Result
Save BIST
Date
Time
Ser. No.
BIST
Result
Description

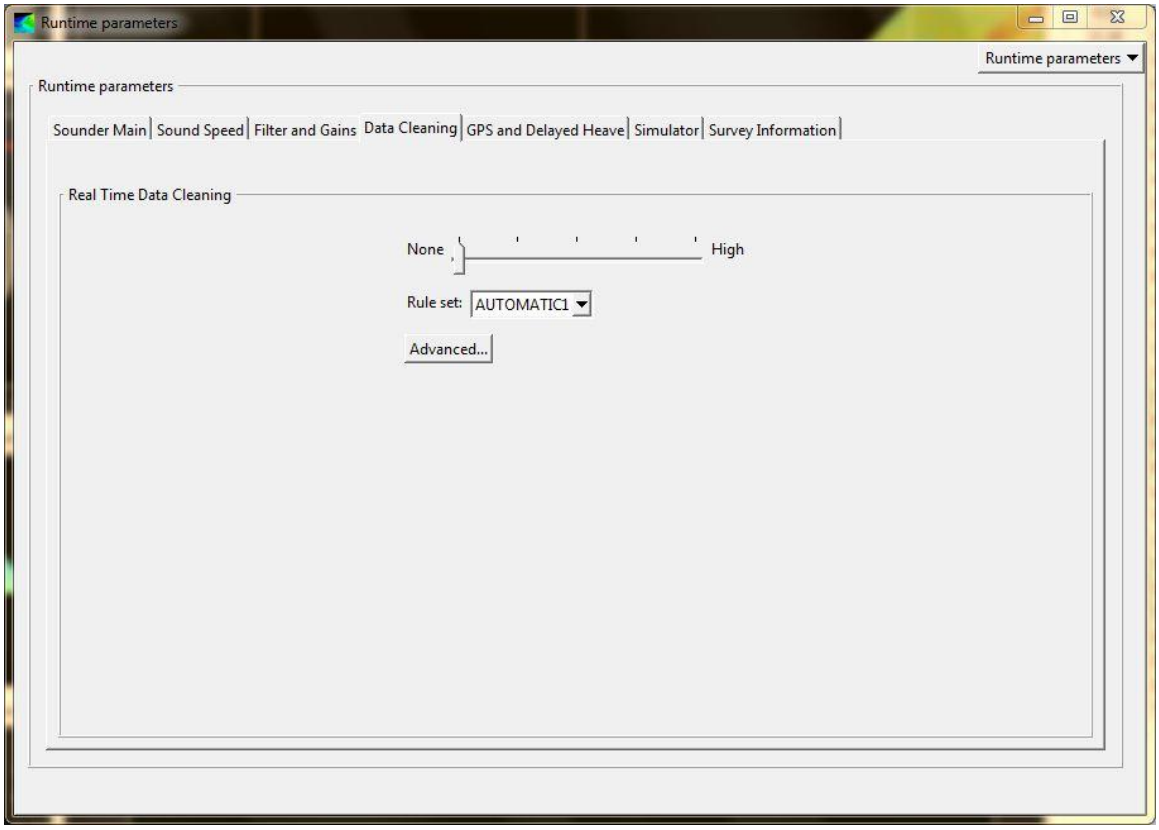

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
PU System Report
System Report.
Path:
D:\sisdata\common\bist
...
Name:

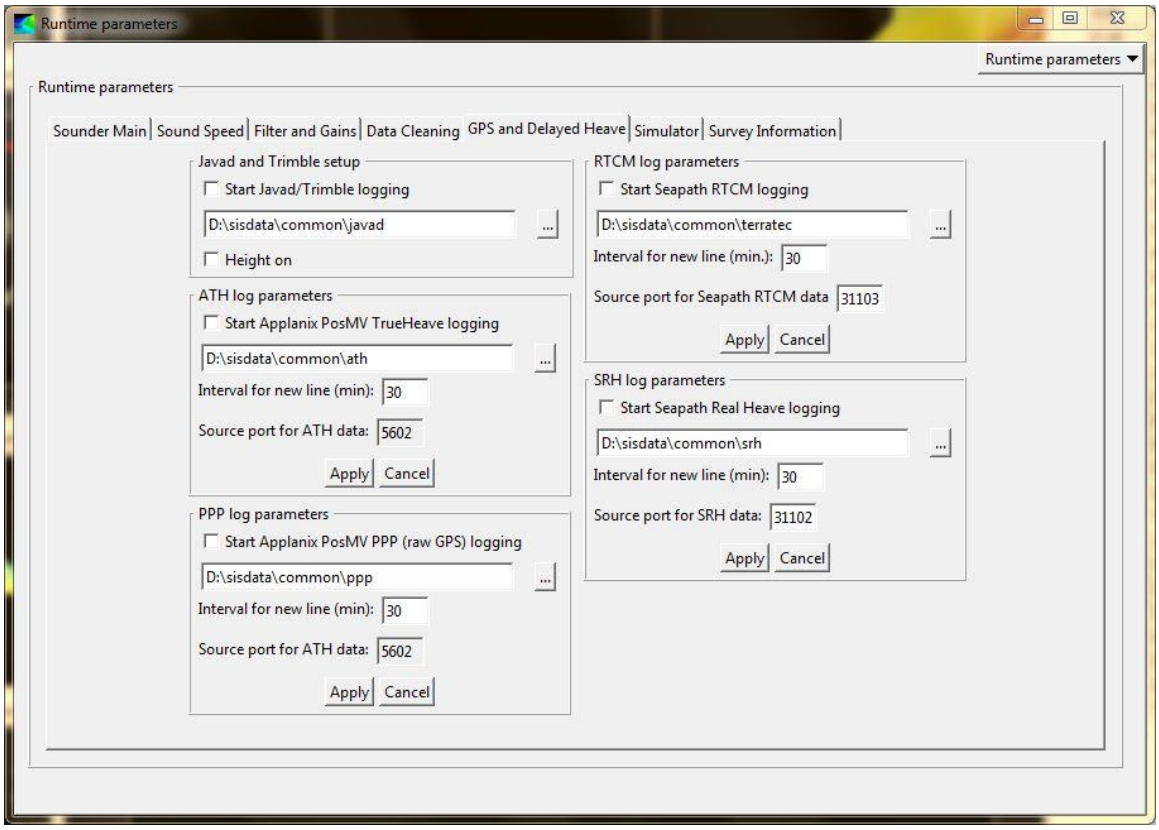
SIS Screenshots – Runtime Parameters

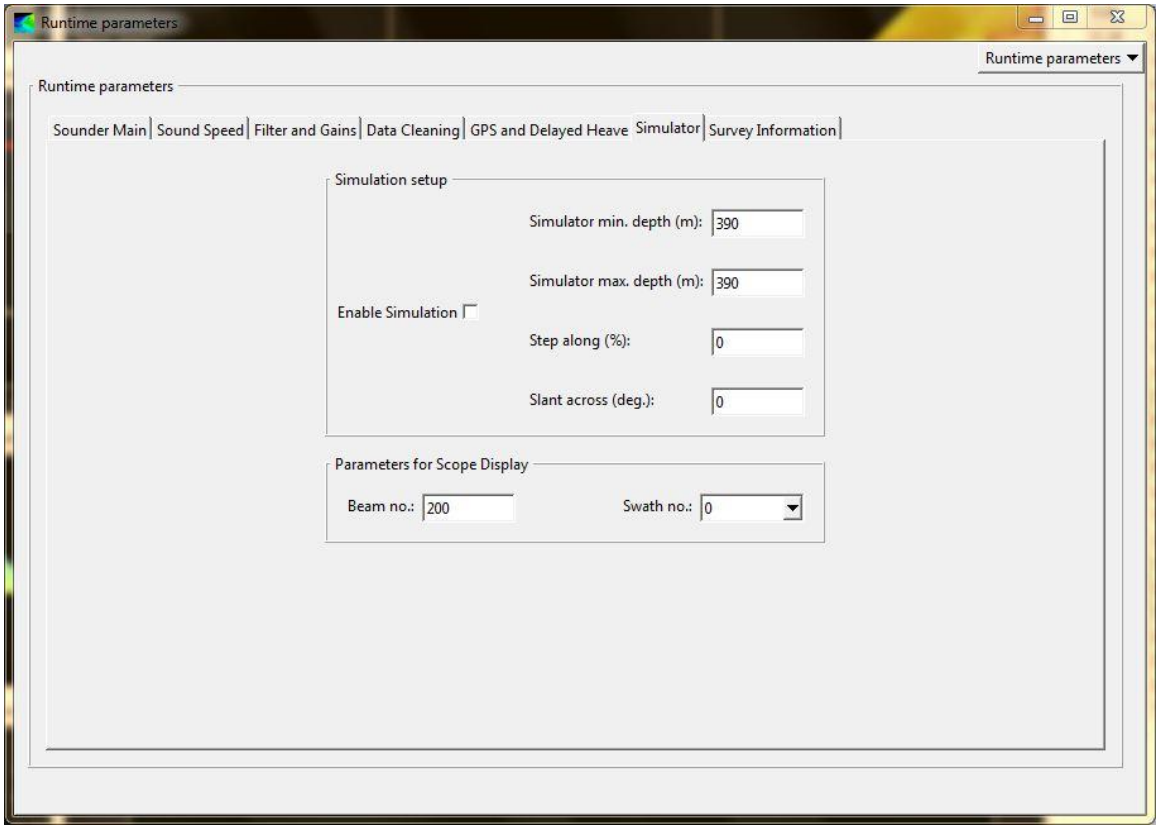


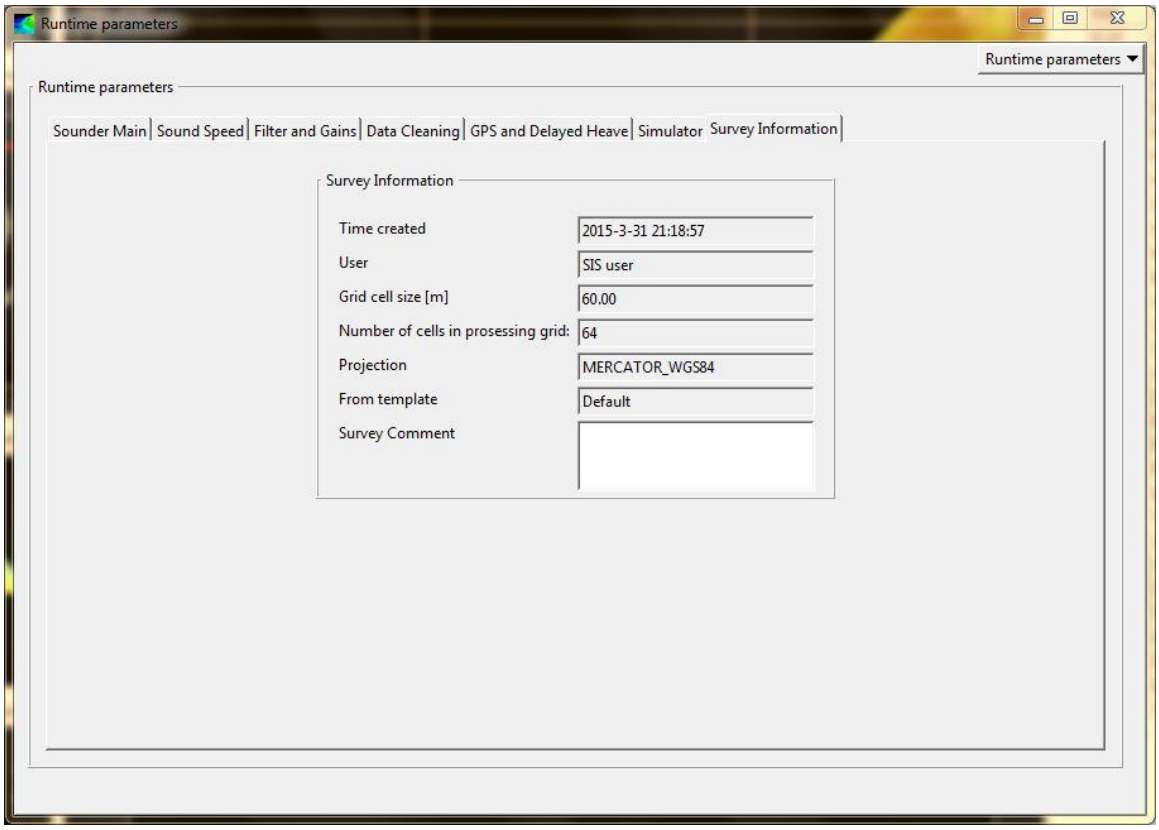



Runtime parameters
Runtime parameters
Runtime parameters
Sounder Main
Sound Speed
Filter and Gains
Data Cleaning
GPS and Delayed Heave
Simulator
Survey Information
Filtering
Spike Filter Strength:
MEDIUM
Range Gate:
NORMAL
Phase ramp:
NORMAL
Penetration Filter Strength:
MEDIUM
Slope
Aeration
Sector Tracking
Interference
Backscatter Adjustment
Normal incidence corr. (deg.):
6
Beam Intensity:
Use Lambert's law
Absorption Coefficient
Source:
CTD profile
Salinity (parts per thousand):
35
31.5 kHz:
5.385
Mammal protection
TX power level (dB):
Max.
Soft startup ramp time (min.):
0
Water Column
30
log R
30
dB Offset
Special Mode
Sonar
Passive


Runtime parameters
Runtime parameters
Runtime parameters
Sounder Main
Sound Speed
Filter and Gains
Data Cleaning
GPS and Delayed Heave
Simulator
Survey Information
Real Time Data Cleaning
None
High
Rule set:
AUTOMATIC1
Advanced...


Runtime parameters
Runtime parameters
Runtime parameters
Sounder Main
Sound Speed
Filter and Gains
Data Cleaning
GPS and Delayed Heave
Simulator
Survey Information
Javad and Trimble setup
Start Javad/Trimble logging
D:\sisdata\common\javad
Height on
ATH log parameters
Start Applanix PosMV TrueHeave logging
D:\sisdata\common\ath
Interval for new line (min): 30
Source port for ATH data: 5602
Apply
Cancel
PPP log parameters
Start Applanix PosMV PPP (raw GPS) logging
D:\sisdata\common\ppp
Interval for new line (min): 30
Source port for ATH data: 5602
Apply
Cancel
RTCM log parameters
Start Seapath RTCM logging
D:\sisdata\common\terratec
Interval for new line (min.): 30
Source port for Seapath RTCM data 31103
Apply
Cancel
SRH log parameters
Start Seapath Real Heave logging
D:\sisdata\common\srh
Interval for new line (min): 30
Source port for SRH data: 31102
Apply
Cancel


Runtime parameters
Runtime parameters
Runtime parameters
Sounder Main
Sound Speed
Filter and Gains
Data Cleaning
GPS and Delayed Heave
Simulator
Survey Information
Simulation setup
Simulator min. depth (m): 390
Simulator max. depth (m): 390
Enable Simulation
Step along (%): 0
Slant across (deg.): 0
Parameters for Scope Display
Beam no.: 200
Swath no.: 0


Runtime parameters
Runtime parameters
Runtime parameters
Sounder Main
Sound Speed
Filter and Gains
Data Cleaning
GPS and Delayed Heave
Simulator
Survey Information
Survey Information
Time created
2015-3-31 21:18:57
User
SIS user
Grid cell size [m]
60.00
Number of cells in prosessing grid:
64
Projection
MERCATOR_WGS84
From template
Default
Survey Comment