

R/V *Atlantis*

EM124 & Seapath 380

Sea Acceptance Testing

July 18-21, 2021

AT-43-02-SVC

Multibeam Advisory Committee

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Executive Summary

1. The R/V *Atlantis* (AT) replaced its EM122 multibeam echosounder with an EM124 upgrade during the 2020-21 midlife refit period; a Seapath 380 position/attitude system was installed to replace the PHINS as the primary feed to the multibeam mapping system
2. A vessel survey was performed by IMTEC to establish the vessel-fit reference frame with a new origin; all antennas and arrays were surveyed and reported in the new vessel frame, adhering to Kongsberg axis and sign conventions; ***because the 2021 survey report also presents offsets translated into the ‘original’ coordinate system (see 2011-19 IMTEC surveys), users must be extremely careful to ensure consistent EM124 and Seapath configurations using the ‘new’ frame (see System Geometry section for details)***
3. The Multibeam Advisory Committee (MAC) was asked to assist with Sea Acceptance Testing (SAT) for the new EM124 during AT-43-02-SVC (Anacortes to San Francisco); due to scheduling constraints with other vessels, the MAC assisted remotely with WHOI and Kongsberg personnel for test planning, data collection, and analysis leading up to and throughout the SAT
4. Planning followed the standard MAC SAT checklist, starting with hardware health and noise testing with the new equipment; calibration, accuracy, and coverage test plans were developed using previously occupied sites off the coast of Washington (priority) with backup sites at Mendocino Ridge and off San Francisco
5. The EM124 SAT data collection window was limited to approximately two days; this report includes recommendations for additional data collection to more fully characterize baseline EM124 performance

Executive Summary

6. This report describes the procedures and results for mapping system geometry review, baseline hardware health monitoring, RX noise characterization over a wide range of speeds, geometric calibration ('patch test'), accuracy testing in two modes at a 2400 m reference site, and swath coverage assessment for the EM124 over a limited range of depths
7. Initial dockside hardware testing indicated acceptable impedance levels within factory tolerances; several RX channels showing high impedance levels were addressed during the SAT with cable extension repairs
8. Initial BIST results serve as a baseline for tracking hardware health over the service life of the EM124, using routine BISTS (e.g., start and end of every cruise) in between direct impedance measurements (e.g., 1-2 years)
9. The final EM124 and Seapath configurations reflect a well-integrated mapping system:
 - a. Patch test data clearly demonstrated the required adjustments in both SIS and Qimera assessments
 - b. Accuracy testing indicated expected performance across the swath in two modes
 - c. Swath coverage testing suggests the system achieved approximately the maximum swath width down to a depth of 1600 m (a 2° swath angle reduction from the user setting is being investigated by Kongsberg)
 - d. The current settings should be maintained until any mapping sensors are modified or another calibration becomes necessary for other reasons (e.g, seasonal readiness testing)
10. RX Noise testing indicated a relatively quiet vessel and normal trends of increasing 12-kHz noise levels with increasing speed perceived by the EM124

Executive Summary

10. RX Noise testing revealed high noise levels on RX Module 1 and several individual channels; these should be investigated with Kongsberg support to improve noise levels (and monitoring) over the EM124 service life
11. The MAC is available to assist with opportunistic testing for more complete SAT characterization of baseline EM124 performance at the start of its service life, as well as routine quality assurance testing (QAT) in the seasons ahead; priorities for ongoing SAT data collection during upcoming transits are:
 - a. Swath coverage testing with all other acoustic systems secured, crossing contours over a wide range of depths from the continental shelf to the abyssal plain
 - b. Accuracy testing in untested modes (e.g., Shallow, Medium, Very Deep) at appropriate sites; these tests can be planned individually according to available ship time and proximity to established reference sites (or survey of suitable new reference sites in the vessel's working areas) •
 - c. RX Noise testing with Kongsberg support to address the high levels on RX module 1 and other channels
 - d. RX Noise versus heading (relative to the prevailing seas) to identify preferred orientations for mapping
 - e. Routine quality assurance testing (QAT) in the season(s) ahead (e.g., noise and hardware monitoring)

Planning Overview

1. SAT items were planned off Washington to prioritize early testing of the EM124 at two sites used in 2016 for the R/V *Sally Ride* (<https://mac.unols.org/reports/2016-sally-ride-system-review>)
 - a. Opportunistic / transit coverage testing en route from the Strait of Juan de Fuca
 - b. Patch test with remote (MAC) and on-board (WHOI / Kongsberg) processing
 - c. 2400 m reference surface survey and accuracy test crosslines



Survey System Components

The primary mapping system components are:

1. Kongsberg Maritime EM124 multibeam echosounder (12 kHz, 1.0° TX x 1.0° RX), s/n 10025
2. Kongsberg Maritime Seafloor Information System (SIS), v5.6
3. Kongsberg Seapath 380 navigation system
 - a. NovaTel GNSS-850 antennas
 - b. Kongsberg Seatex MRU 5+
4. Sea-Bird SBE 45 TSG sensor for surface sound speed
5. Sippican XBT sound speed profiling system
6. No CTD was installed during the SAT

System Geometry Review

Overview: History

The term ‘system geometry’ means the linear and angular offsets of the primary components of the multibeam mapping systems, including the transmit arrays (TX), receive arrays (RX), GNSS antennas, and motion sensors (MRU/IMU). The following table provides an overview of the system geometry history.

Date	Location	Event	References
2011-2013	Jacksonville, FL	IMTEC surveys to establish vessel reference frame and offsets of EM122 arrays, PHINS MRU, GNSS and C-Nav antennas; offsets reported in Kongsberg axis conventions using multiple origins (noted in each report version); <i>this series of survey reports has been superceded by the 2021 survey</i>	2011-13 IMTEC survey reports through Rev. 4 provided by WHOI
2019-Jan	Vallejo, CA	IMTEC survey to re-establish 2011 reference frame and offsets of EM122 arrays, PHINS MRU, GNSS and C-Nav antennas, and Seapath demonstration unit (MRU and antennas); origin defined as intersection of forward perpendicular (FP) at Base Line (BL); EM122 patch tests with Seapath and PHINS at Mendocino Ridge	2019 IMTEC survey report and Seapath / PHINS test notes
2021-Jan-Mar	Anacortes, WA	IMTEC survey to establish vessel reference frame, EM124 arrays, Seapath MRU, GNSS antennas; offsets reported in Kongsberg convention with origin on centerline (CL) at Frame 60, 10 feet above Base Line (BL) ; this origin was used for 2021 Seapath and EM124 configuration; Seapath antenna calibration and EM124 patch test Note: the 2021 survey report includes a table using the 2011 reference frame; this is intended for configuration of other systems on board, and multibeam users must be careful to avoid mixing reference frames; the 2021 definition (on CL at Frame 60, 10' above BL) was used for Seapath and SIS configuration during this SAT	2021 IMTEC survey report (Rev. 2) provided by WHOI

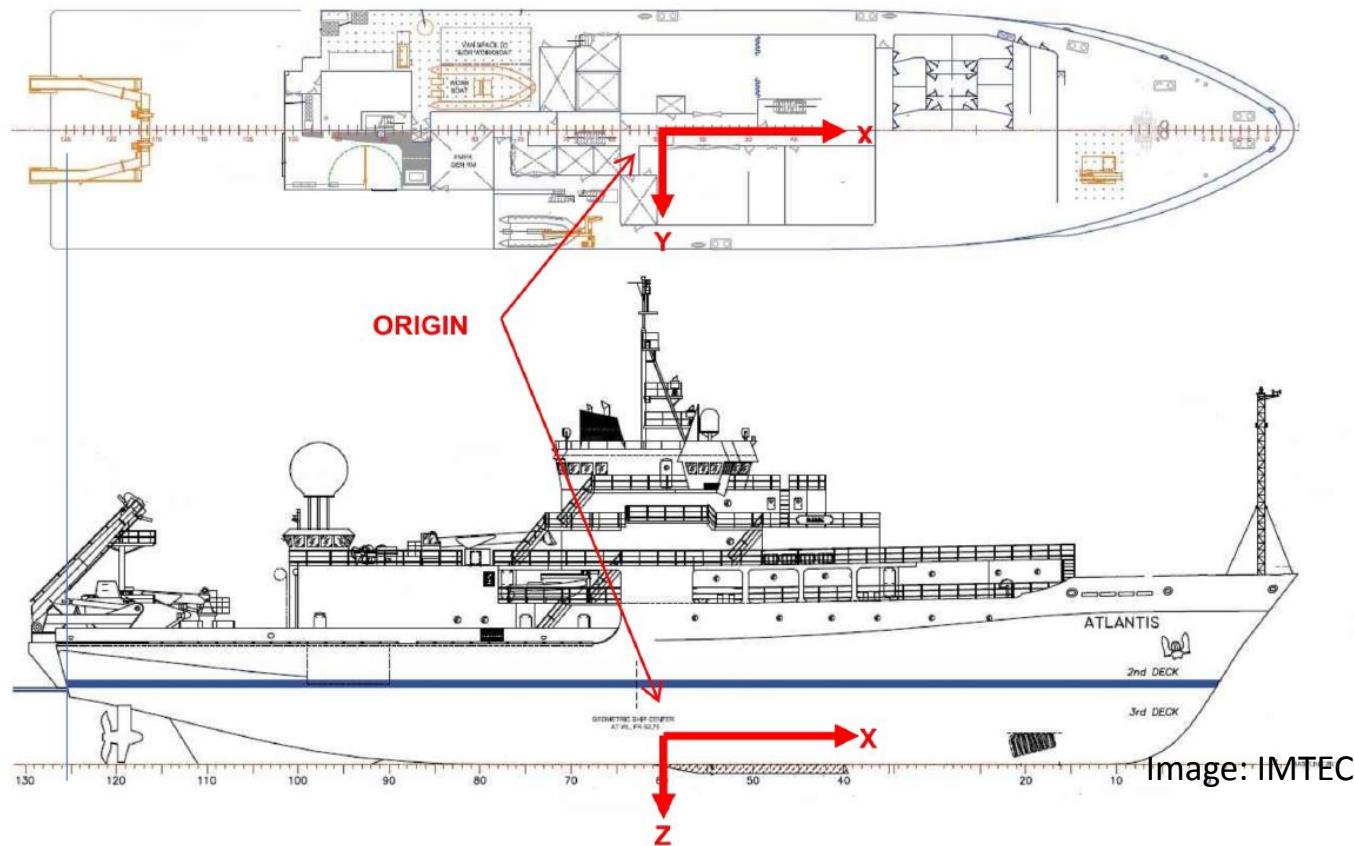
System Geometry Review

Overview: Vessel Survey

1. A survey of the vessel and mapping sensors was conducted by IMTEC and reported through Rev. 2 (11 June 2021), incorporating several rounds of feedback from WHOI, Kongsberg, and the MAC
2. The origin of the 2021 mapping system reference frame is defined as a point on the Centerline (CL) at Frame 60, 10 ft above the Baseline (BL); this origin differs from that used in previous surveys (e.g., the 2011 frame presented in the last table of Rev. 2), and users/readers must be careful to ensure consistency in configuration
3. The 2021 origin is used for all SIS and Seapath configuration; Seapath navigation input to SIS is provided / considered valid at the origin

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FIGURE 2



System Geometry Review

Vessel Survey

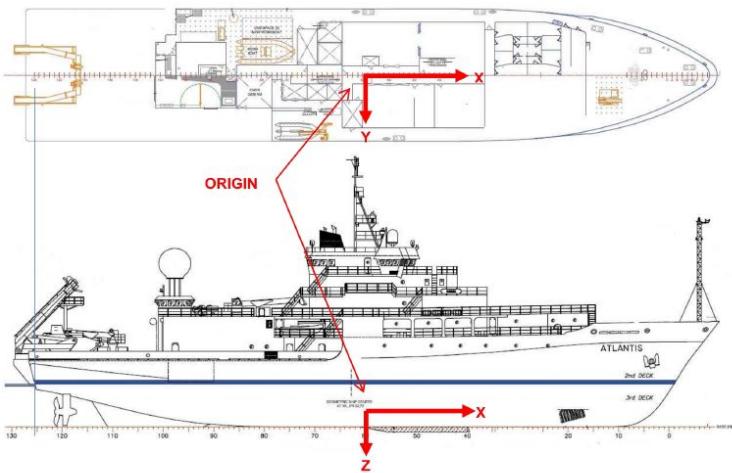


TABLE 2- ELEMENT COORDINATES 2021 SURVEY- METERS			
ELEMENT	X	Y	Z
RX124 EL	10.863	0.008	3.695
TX124 EL	6.399	-0.373	3.688
EK80-70	7.108	1.075	3.676
EK80-200	8.115	0.956	3.673
EK80-18	6.486	0.949	3.676
EK80-120	7.035	0.669	3.673
EK80-38	7.653	0.912	3.672
PHINS 1 CTR	9.527	0.471	0.205
PHINS 2 CTR	9.526	0.269	0.203
SEAPATH CTR	9.538	0.66	0.223
AUX 1 CTR	9.163	0.586	0.295
AUX 2 CTR	9.162	0.332	0.292
USBL Pole	3.387	-1.851	2.927

Rev-1 Note-SEAPATH and PHINS X,Y,Z given at Phase Center,
AUX X,Y,Z given at center on hippy plate

Rev-2 TABLE 3 ELEMENT INCLINATIONS						
ELEMENT	AZIMUTH	RÖTATION	PITCH	RÖTATION	Rev-2 ROLL	RÖTATION
124TX	0.0061	To Stbd	0.0553	Bow Up	-0.1940	Stbd Up
124RX	-0.0895	To Port	-0.1044	Bow Down	-0.0977	Stbd Up
New Hippy Plate	N/A	N/A	0.1440	Bow Up	0.6000	Stbd Down
SEAPATH MRU	0.2378	To Port	0.0456	Bow Up	0.3122	Stbd Down
Rev-1 EK80-18	-0.0530	To Port	0.2110	Bow Up	-0.3139	Stbd Up
Rev-1 EK80-38	-0.3032	To Port	0.0842	Bow Up	0.0272	Stbd Down
Rev-1 EK80-70	-0.5491	To Port	0.1694	Stbd Up	0.0428	Stbd Down
Rev-1 EK80-120	-0.5000	To Port	0.2285	Bow Up	-0.3038	Stbd Up
EK80-200	-0.0311	To Port	0.1859	Bow Up	-0.3222	Stbd Up

1. The 2021 IMTEC survey (Rev. 2) provided mapping sensor linear and angular offsets using the Kongsberg/Seapath axis and sign conventions
2. **Origin** is on CL at Frame 60, 10' above BL
3. **Linear offsets** reported in meters in 'right-handed' system
 - a. **+X** forward (agrees with KM/Seapath)
 - b. **+Y** to starboard (agrees with KM/Seapath)
 - c. **+Z** down (agrees with KM/Seapath)
4. **Angular offsets** reported in DDD with description of rotation direction
 - a. **+Roll** with starboard side down (agrees with KM/Seapath)
 - b. **+Pitch** with bow up (agrees with KM/Seapath)
 - c. **+Heading** with bow to stbd / compass (agrees with KM/Seapath)

Note during configuration: order of angular offsets (azimuth, pitch, roll) in report differs from Kongsberg SIS / Seapath order (roll, pitch, heading)

System Geometry Review

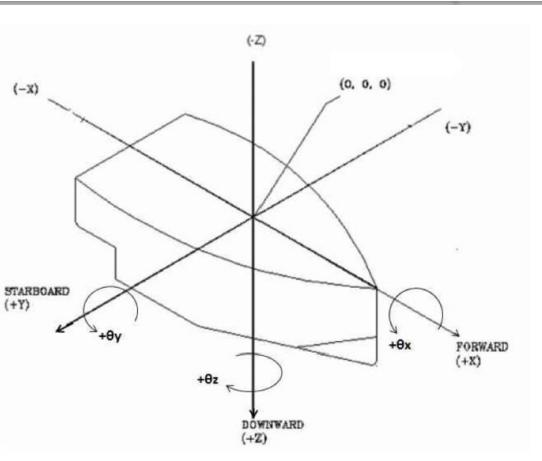
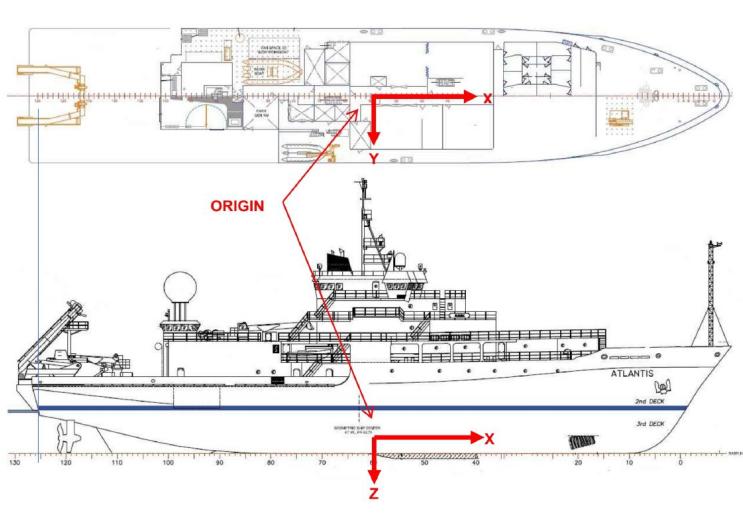
Coordinate Systems

IMTEC Convention

Source: 2021 IMTEC report Rev. 2 "B"

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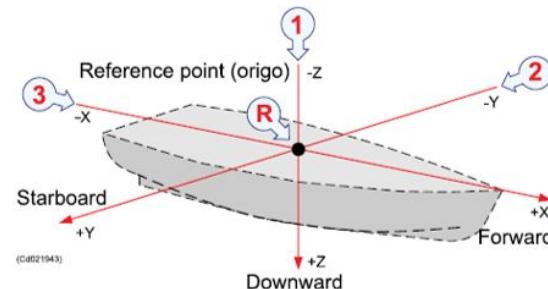
FIGURE 2



Kongsberg Maritime Convention

Source: Kongsberg EM302 Installation Manual

Figure 56 Reference points



Reference points must be established on the vessel at selected positions. These are needed during measurements of the sensor positions. Visual markings at these positions should be prepared and noted on the vessel drawings with XYZ coordinates in the vessel coordinate system.

Transducer heading

The heading of the transducers is measured as the average heading of the two fore-and-aft oriented sides of each transducer arrays. Thus, the heading of the transmit transducer is the heading along the keel, while the heading of the receiver array is the heading across the keel. For the receive transducer it may be better to measure the heading along the keel, and then subtract 90° to achieve the correct value. The measurement accuracy is required to be within one fifth of the beamwidth of the transmit transducer.

Note however that the measurement accuracy of the relative heading between the transmit and receive transducers must be better than 0.1°.

Transducer roll and pitch

Roll and pitch measurements are made according to standard conventions with positive pitch angle if the transmitter array's forward end is above the aft end (tilts up), and positive roll if the starboard side of the receiver array is lower than the port side.

Note that the roll and pitch angles to be measured are relative to the horizontal plane as defined by the vessel's coordinate system. I.e. for roll the angle that the transducer's y-axis have with respect to the horizontal and for pitch the angle that the transducers x-axis have with respect to the horizontal plane. The multibeam echo sounder converts the measured angles as entered into the installation menu to rotation angles before use i.e. do not do such a conversion before entering them into the system.

Seapath Convention

Source: Seapath 330 Manual

Figure 4 Definition of Origin on vessel and positive X, Y and Z axes directions

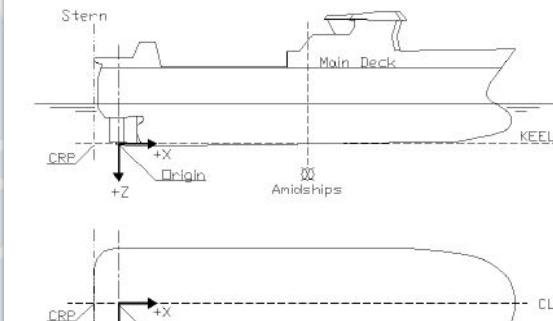
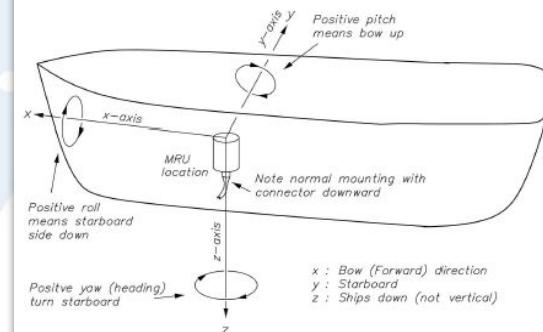


Figure 12 Default MRU mounting position



Positive (+) output signals from the MRU include:

- Positive pitch means bow up, or a clockwise rotation about the y-axis.
- Positive roll means starboard (right) side facing downward, or a clockwise rotation about the x-axis.
- Positive yaw (heading, azimuth) means a turn to starboard (right), or a clockwise rotation about the z-axis.

System Geometry Review

TABLE 4 - ANTENNA COORDINATES (METERS)

ANTENNA	X	Y	Z
STBD MAST SPARE CTR	-0.585	3.329	-26.631
SEAPATH GPS FWD	-21.763	4.05	-13.803
SEAPATH GPS AFT	-24.986	1.517	-13.841
PORT SEANAV @ L1	-0.876	-2.942	-27.243
PORT SEANAV @ L2	-0.876	-2.942	-27.232

Rev-1 Note: SEAPATH GPS Fwd, Aft and Stbd Spare Elev given at the Center at Base,

NAV Engine Configuration

The screenshot shows a 3D model of a ship's hull with coordinate axes (X, Y, Z) and sensor locations. The top view shows the Keel and CL (Center Line). The bottom view shows the hull profile. On the left, a tree view lists categories like Vessel, Sensors (GNSS, DGNSS, MRU), Monitoring points, Communication interface, and Network. At the bottom, there are tabs for Antenna configuration (Type: NovAtel GNSS-850, Position [m]: X: -24.986, Y: 1.517, Z: -13.940), Antenna offset (Baseline length: 4.099 m, Heading offset: 321.844 °, Height difference: 0.038 m), and a Calibration wizard.

Seapath Antenna Lever Arms

1. IMTEC reported the threaded rod base positions; the phase center for each antenna was estimated by adding:
 - a. 47 mm height of the antenna reference point (ARP) above the base of the threaded rod
 - b. 51.7 mm phase center height above ARP (NovaTel spec)
 - c. Total height adjustment: 98.7 mm above IMTEC Z value
2. Antenna 1 (primary, port/aft) offsets were set to the phase center calculated as above
 - a. $X = -24.986 \text{ m}$
 - b. $Y = +1.517 \text{ m}$
 - c. $Z = -13.940 \text{ m}$ (phase center, 98.7 mm above reported Z)
3. Antenna 2 (secondary) offsets were determined from the dockside Seapath antenna calibration, treating the Antenna 1 position as fixed and updating the Antenna 2 position
 - a. $X = -21.763 \text{ m}$
 - b. $Y = -4.049 \text{ m}$
 - c. $Z = -13.902 \text{ m}$ (phase center, Seapath cal)

System Geometry Review

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NAV Engine Configuration

Connected to Seapath 380+

Seapath Antenna Lever Arms

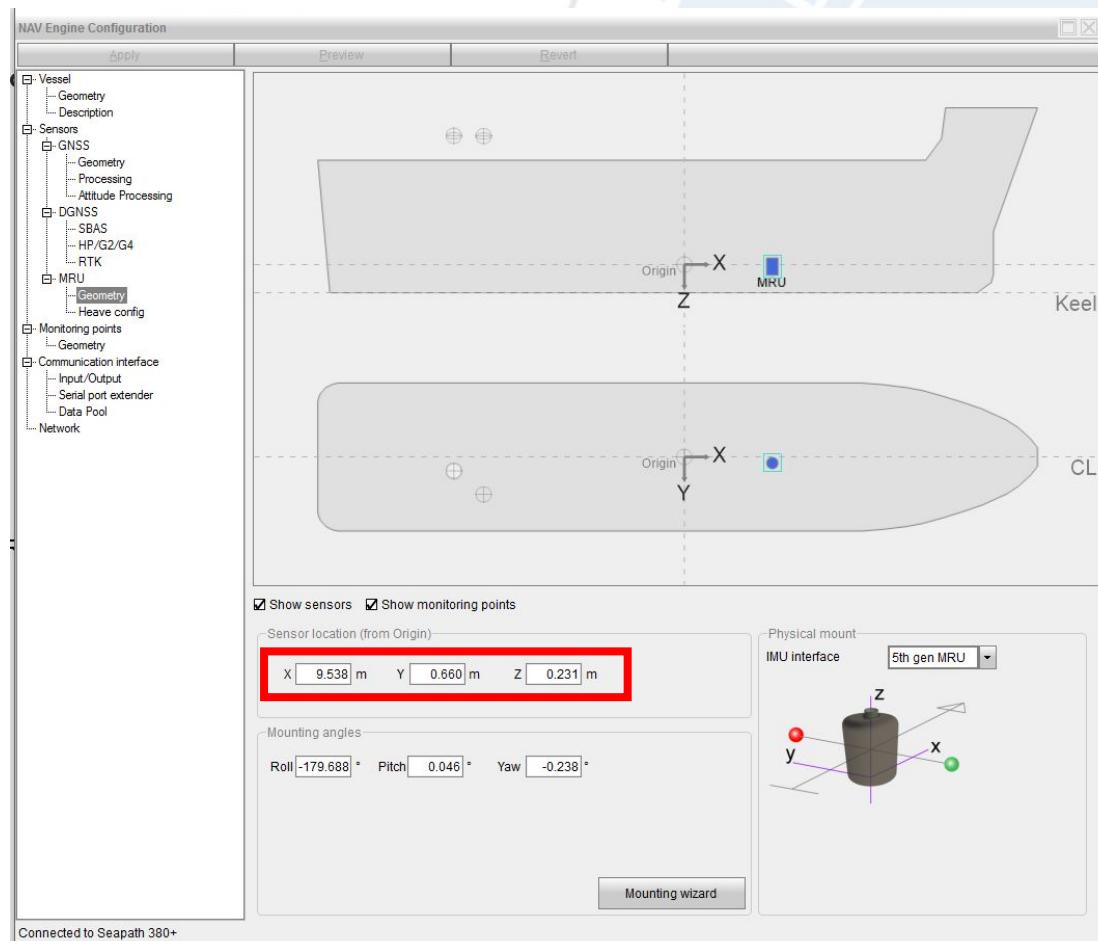
4. The resulting antenna baseline vector of $[+3.223, +2.533, +0.038]$ from the primary (port/aft) antenna places the secondary (stbd/fwd) 4.099 m from the primary, with a baseline orientation 38.16° to stbd of the alongship axis
5. Although this is an atypical orientation for the antennas, the Seapath calibration results agreed well with the IMTEC survey
6. There is a difference between the references (and perhaps the sign conventions) used for reporting the baseline orientation from the primary to secondary antenna:
 - a. 38.16° azimuth in the ‘compass’ convention (i.e., calculated from IMTEC offsets)
 - b. 321.84° azimuth in the Seapath configuration (i.e., $360^\circ - 38.16^\circ$, resulting from Seapath calibration)
7. Despite the difference how this baseline orientation is reported, the high level of X, Y, Z agreement between the IMTEC survey and Seapath calibration is reflected in the relatively small EM124 and heading patch test results

System Geometry Review

SEAPATH CTR	9.538	0.66	0.223
AUX 1 CTR	9.163	0.586	0.295
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USBL Pole	3.387	-1.851	2.927

Rev-1 Note-SEAPATH and PHINS X,Y,Z given at Phase Center,
AUX X,Y,Z given at center on hippy plate

+ 8 mm to MRU reference point



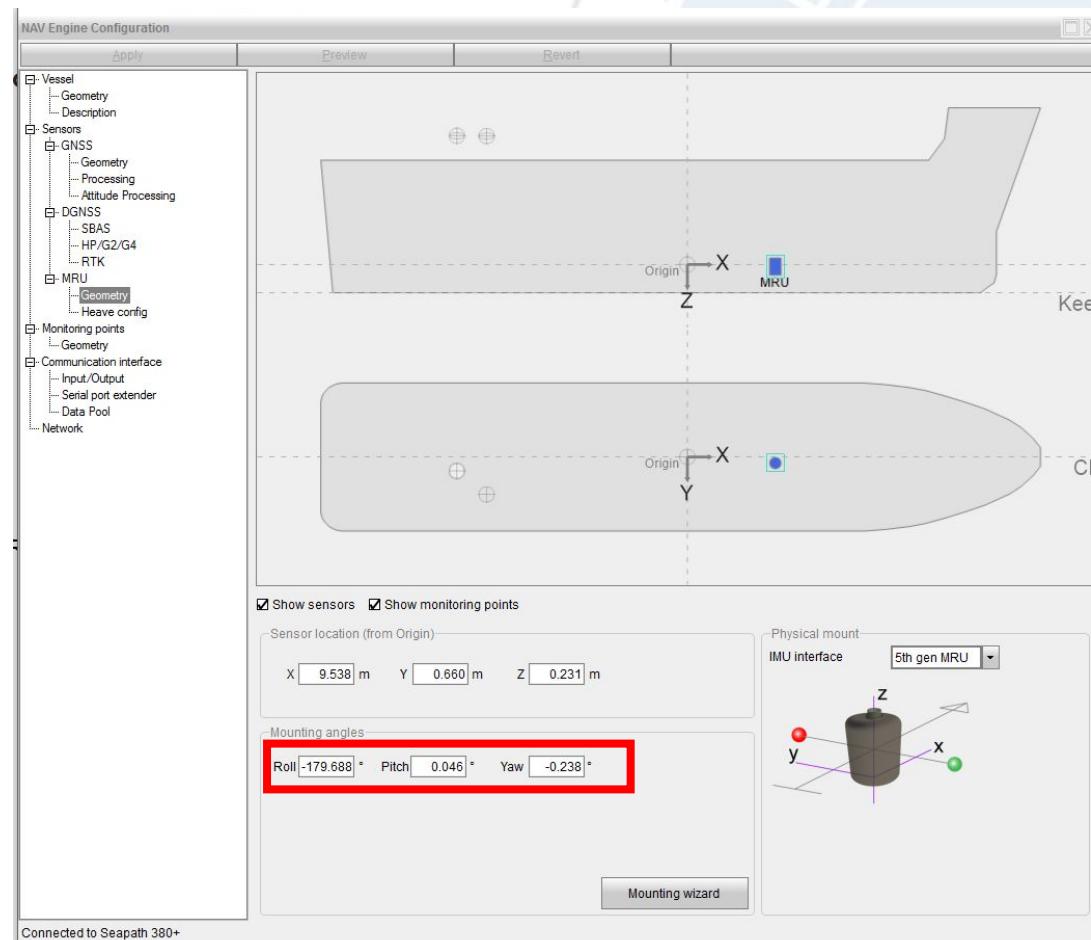
Seapath MRU-5 Lever Arms

1. The MRU reference point is 17 mm above the 'HIPPY Plate' (i.e., the bracket 'floor'; see Seapath MRU 5 bracket spec)
2. The IMTEC report Rev. 2 MRU height is ~25 mm above the HIPPY Plate to which the bracket is affixed; accordingly, the Seapath configuration was adjusted by 8 mm down (more positive) to match the MRU bracket spec ahead of the SAT; the IMTEC report should be updated accordingly in Rev. 3
3. The Seapath MRU was configured as follows for the SAT:
4. **MRU-5 linear offsets in Seapath:**
 - X: +9.538 m (IMTEC)
 - Y: +0.660 m (IMTEC)
 - Z: +0.231 m (8 mm down from IMTEC per bracket spec)
5. Seapath output is received by SIS as *Attitude 1* (post-SAT configuration) and expected to be valid at the origin
6. **Attitude 1 linear offsets in SIS:**
 - X: 0.000 m
 - Y: 0.000 m
 - Z: 0.000 m

System Geometry Review

Seapath MRU-5 Mounting Angles

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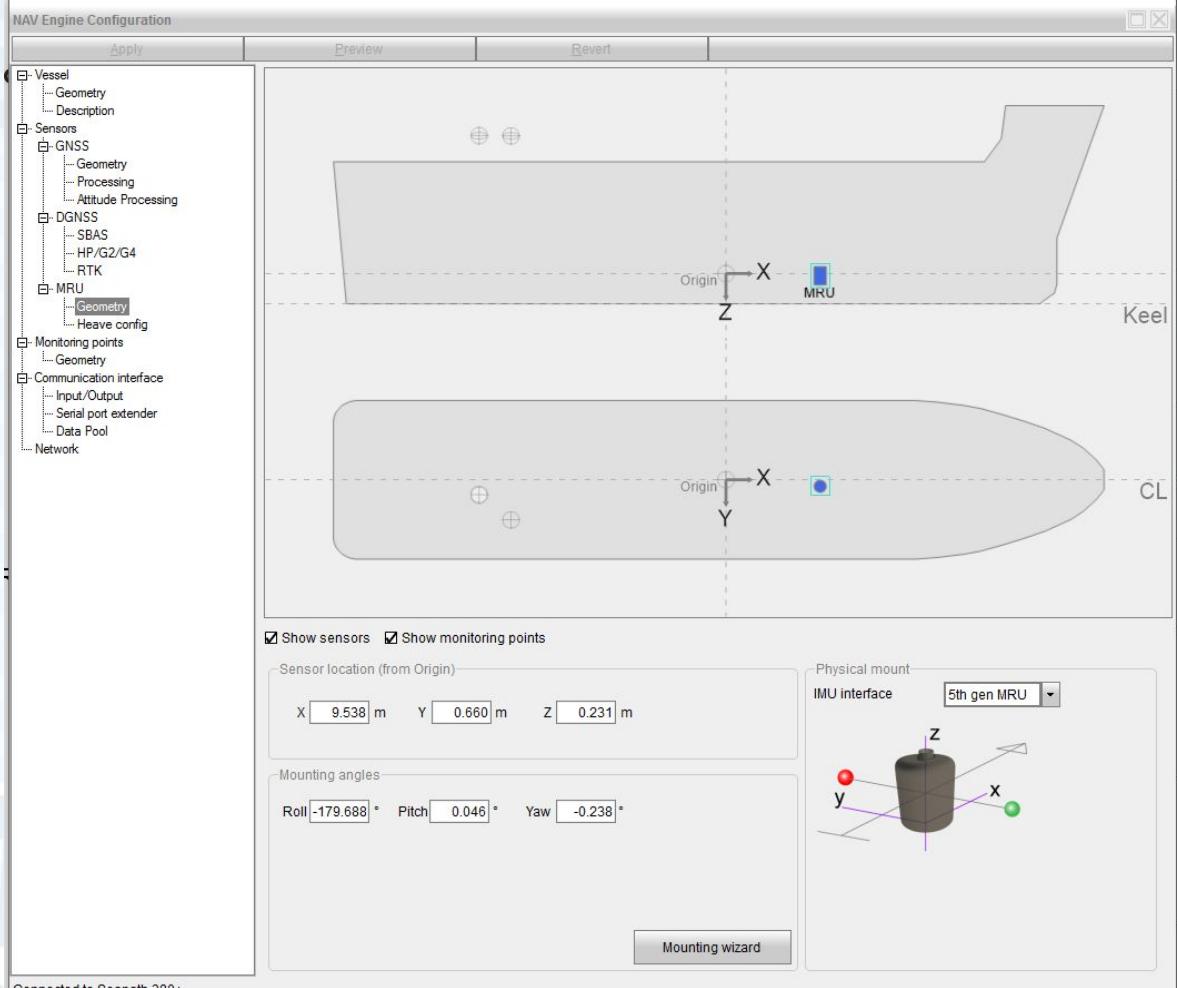
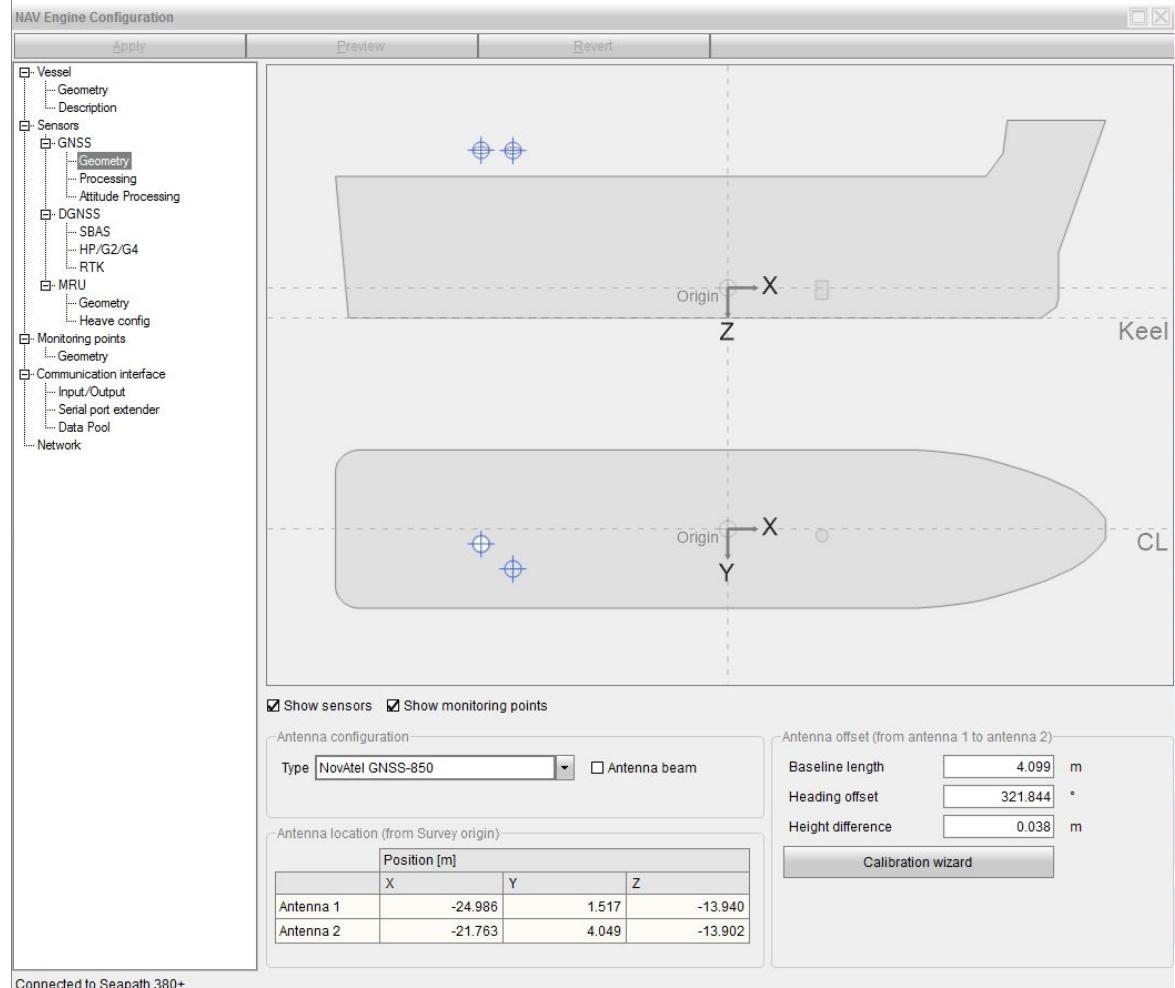


1. IMTEC reported installation angles for the MRU-5 using the Seapath sign convention (note order of columns for config.)
2. IMTEC angles were used directly for configuring the MRU orientation in the Seapath software, subtracting a 180° roll offset to accommodate the installation orientation (per the Seapath software MRU 'mounting wizard' on [-180° +180°])
3. **MRU-5 installation angles in Seapath:**
 - Roll: -179.688 (+0.312° IMTEC result - 180° offset)
 - Pitch: +0.046°
 - Heading: -0.238°
4. Initial *Attitude 2* installation angles were set to zero in SIS, then updated with the patch test results (see **Calibration** section notes on the post-SAT switch from *Attitude 2* to *1*)
5. MRU installation angles based on the IMTEC survey should remain unchanged in the Seapath software until the MRU is moved (and/or re-surveyed)

System Geometry Review

Seapath Configuration

The Seapath configuration is derived directly from the 2021 IMTEC survey and Seapath antenna calibration
Screenshots below show GNSS and MRU offsets as configured through the 2021 EM124 SAT



System Geometry Review

EM124 TX & RX Offsets

TABLE 2- ELEMENT COORDINATES 2021 SURVEY- METERS			
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TX124 EL	6.399	-0.373	3.688
EK80-70	7.108	1.075	3.676
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Rev-2 TABLE 3 ELEMENT INCLINATIONS						
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New Hippy Plate	N/A	N/A	0.1440	Bow Up	0.6000	Stbd Down
SEAPATH MRU	-0.2378	To Port	0.0456	Bow Up	0.3122	Stbd Down

Transducer setup

The screenshot shows the 'Transducer setup' section of the EM124_60 software. It includes icons for a wrench, gear, and key, and the text 'EM124_60'. Below this, there are two tables for TX and RX offsets.

	Forward, X / Roll	Starboard, Y / Pitch	Downward, Z / Heading
TX 1 Location offset (XYZ)	6.399	-0.373	3.688
TX 1 Angular offset (Roll/Pitch/Heading)	-0.194	0.055	0.006
	TX 1 Location offset (XYZ)	TX 1 Angular offset (Roll/Pitch/Heading)	TX 1 BS offset
RX 1 Location offset (XYZ)	10.863	0.008	3.695
RX 1 Angular offset (Roll/Pitch/Heading)	-0.098	-0.104	359.911
RX 1 BS offset	0.00		

At the bottom left, it says 'Water line vertical location' and at the bottom right is '-2.00'.

- Linear offsets for the Kongsberg EM124 array face centers were provided by IMTEC using the Kongsberg sign conventions with origin at the reference plate
- Angular offsets for the arrays were provided using the Kongsberg sign conventions
- Note different orders of TX and RX array rows and angle offset columns when reviewing SIS configuration**
- EM124 SIS Installation Parameters were configured using the IMTEC results as follows :

EM124 TX Transducer

X: +6.399 m Roll: -0.194°
Y: -0.373 m Pitch: +0.055°
Z: +3.688 m Heading: +0.006°

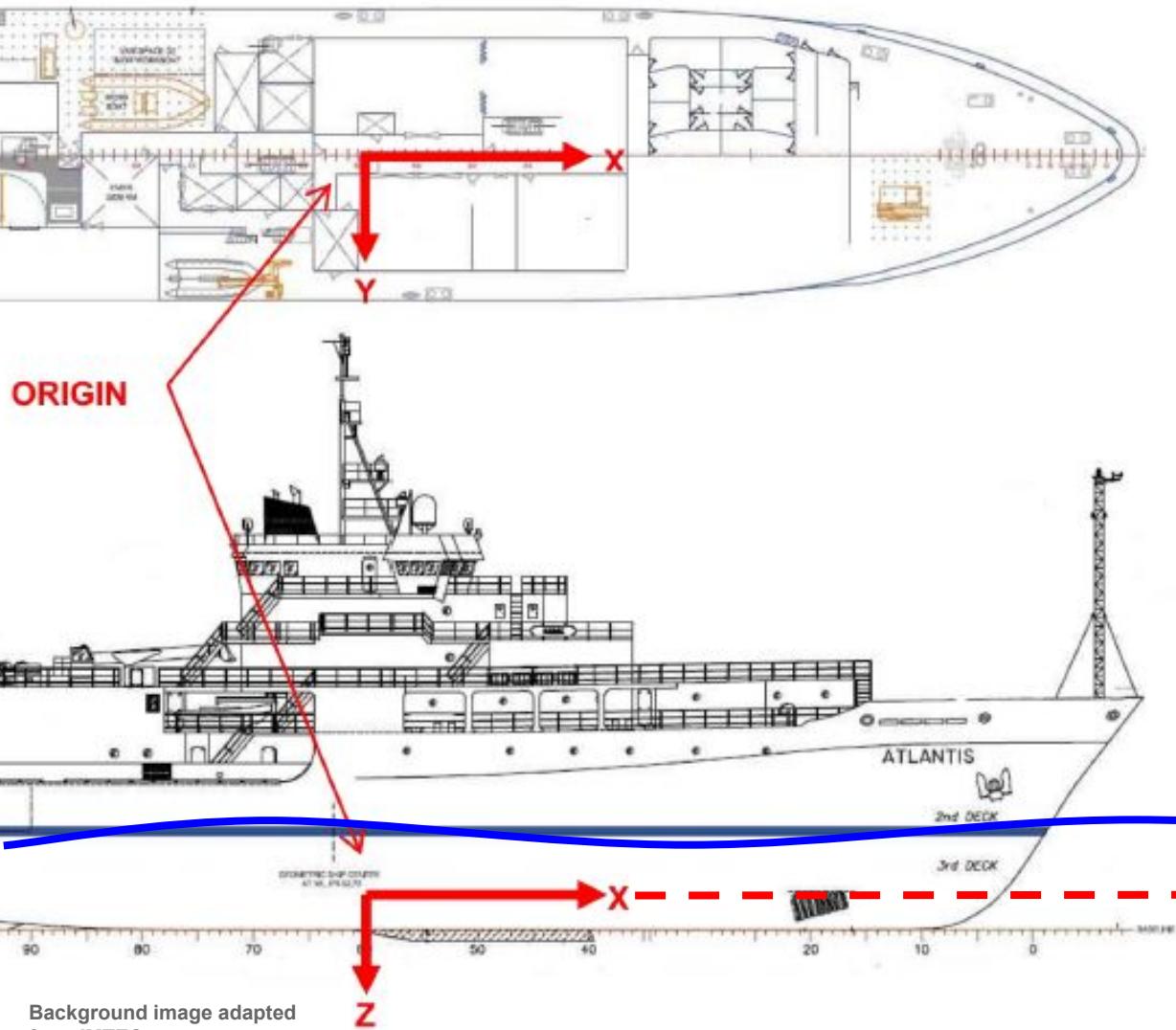
EM124 RX Transducer

X: +10.863 m Roll: -0.098°
Y: +0.008 m Pitch: -0.104°
Z: +3.695 m Heading: +359.911°

System Geometry Review

Waterline

FIGURE 2



1. SIS and EK80 software require the water level in meters, positive down from the mapping system origin
2. Waterline was estimated by WHOI and Kongsberg technicians at 2.00 m above the origin
3. EM124 waterline configuration was updated to -2.00 m ahead of AT-43-02
4. Assuming no change in draft reference (i.e., EM124 array depth), the new WL value of -3.35 from the current origin agrees within 0.20 m of the old WL value of -5.27 m from the 2011 origin at the FP/CL/keel

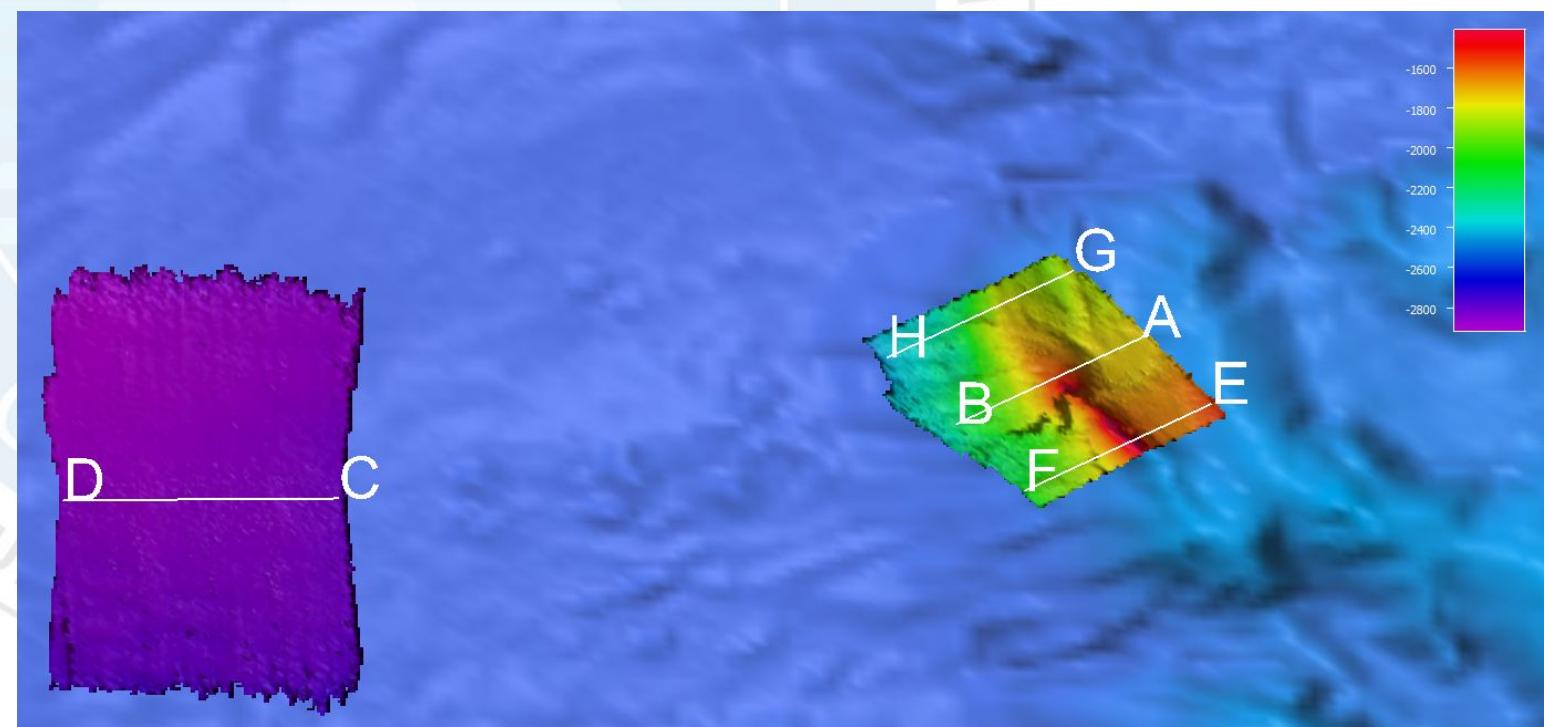
SIS / EK Waterline = -2.00 m (+down from origin)

EM124 Calibration

Planning

1. EM124 patch test plans were developed at a site off Washington state used previously for EM122 testing aboard R/V *Sally Ride* (2016) and USCGC *Healy* (2017, 2020-21)

EM122/4 off Washington	Waypoint	Decimal Degrees		Degrees Decimal Minutes			
		Lat.	Lon.	Lat. Deg.	Lat. Min.	Lon. Deg.	Lon. Min.
Pitch	A	48.072776	-126.418400	48	4.367	-126	25.104
	B	48.057382	-126.451455	48	3.443	-126	27.087
Roll	C	48.044200	-126.561085	48	2.652	-126	33.665
	D	48.043854	-126.610035	48	2.631	-126	36.602
Heading 1	E	48.060957	-126.406157	48	3.657	-126	24.369
	F	48.045566	-126.439207	48	2.734	-126	26.352
Heading 2	G	48.084594	-126.430650	48	5.076	-126	25.839
	H	48.069196	-126.463708	48	4.152	-126	27.822



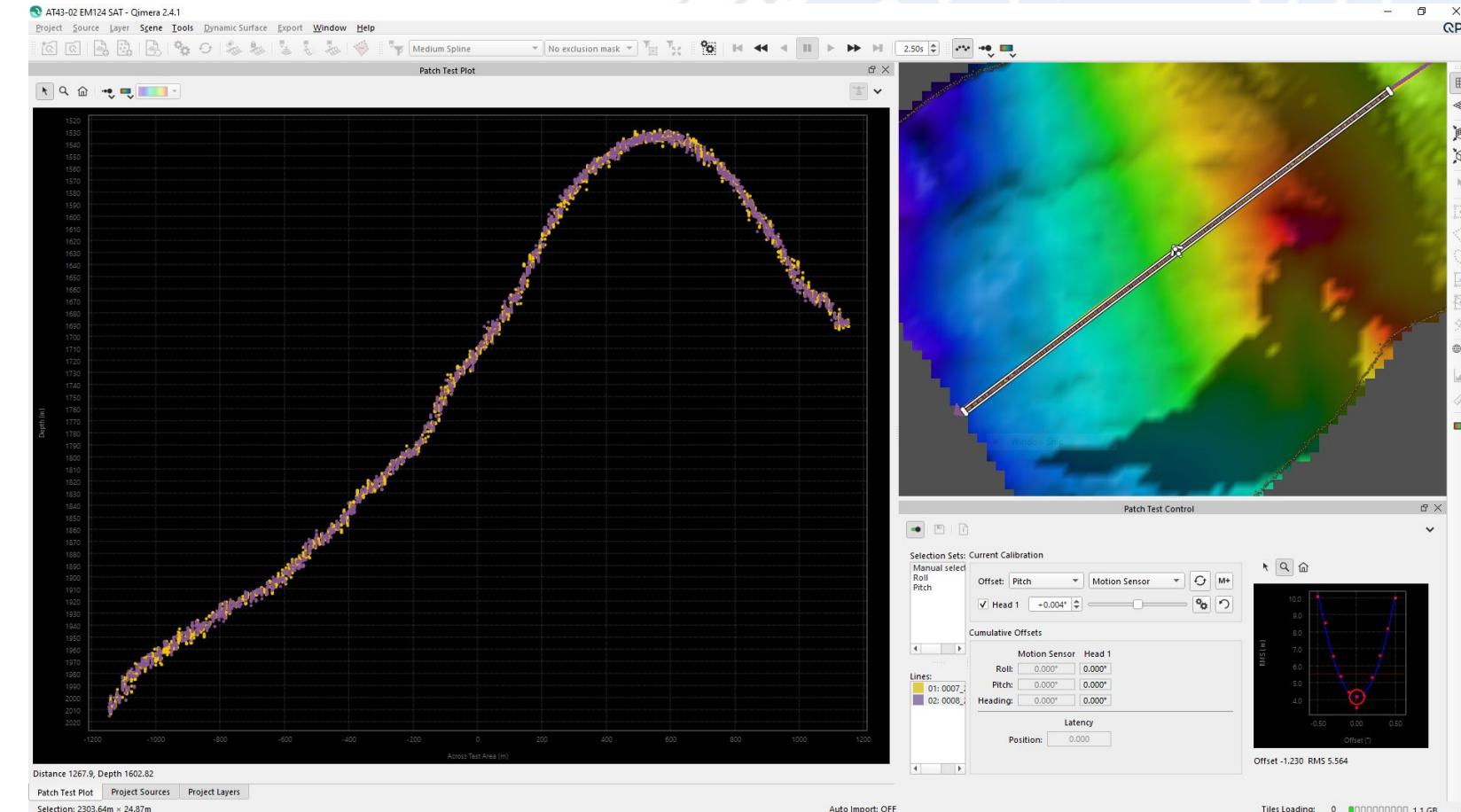
EM124 Calibration

Data Collection and Processing

1. Sound speed profiles were acquired with the CTD and XBTs, processed in Sound Speed Manager, and applied in SIS prior to and throughout the patch test procedure
2. Calibration data were examined by KM, WHOI, and MAC personnel in SIS and Qimera to arrive at initial offsets for *Attitude 2* (Seapath input to SIS during the SAT; now configured on *Attitude 1*)
3. Results showed very clearly in SIS and Qimera and agreed across multiple assessments within $\pm 0.01^\circ$ for pitch and roll and within $\pm 0.05^\circ$ for heading; in consideration of other ship scheduling needs, only the pitch and roll verification lines were run (and showed no need for further adjustment) prior to accuracy testing
4. During Qimera analysis, files were processed with nearest-in-time sound speed scheduling, edited to remove outlier soundings, and then scrutinized with the patch test tool using a combination of
 - a. visual assessment and adjustment of the biases across a wide variety of data subsets
 - b. 'Autosolver' method to confirm minimum RMS differences between suitable subsets
5. Whenever possible, the result of each calibration step was updated in the *SIS Installation Parameters* prior to data collection of the subsequent test (e.g., applying the pitch result before roll calibration); this was not always possible due to data transfer speeds under the initial satellite configuration
6. Final results applied in the EM124 should remain unchanged until sensors are modified, routine assessment, or the need for additional patch testing is indicated by bathymetric artifacts

EM124 Calibration

Results: Pitch (Seapath)



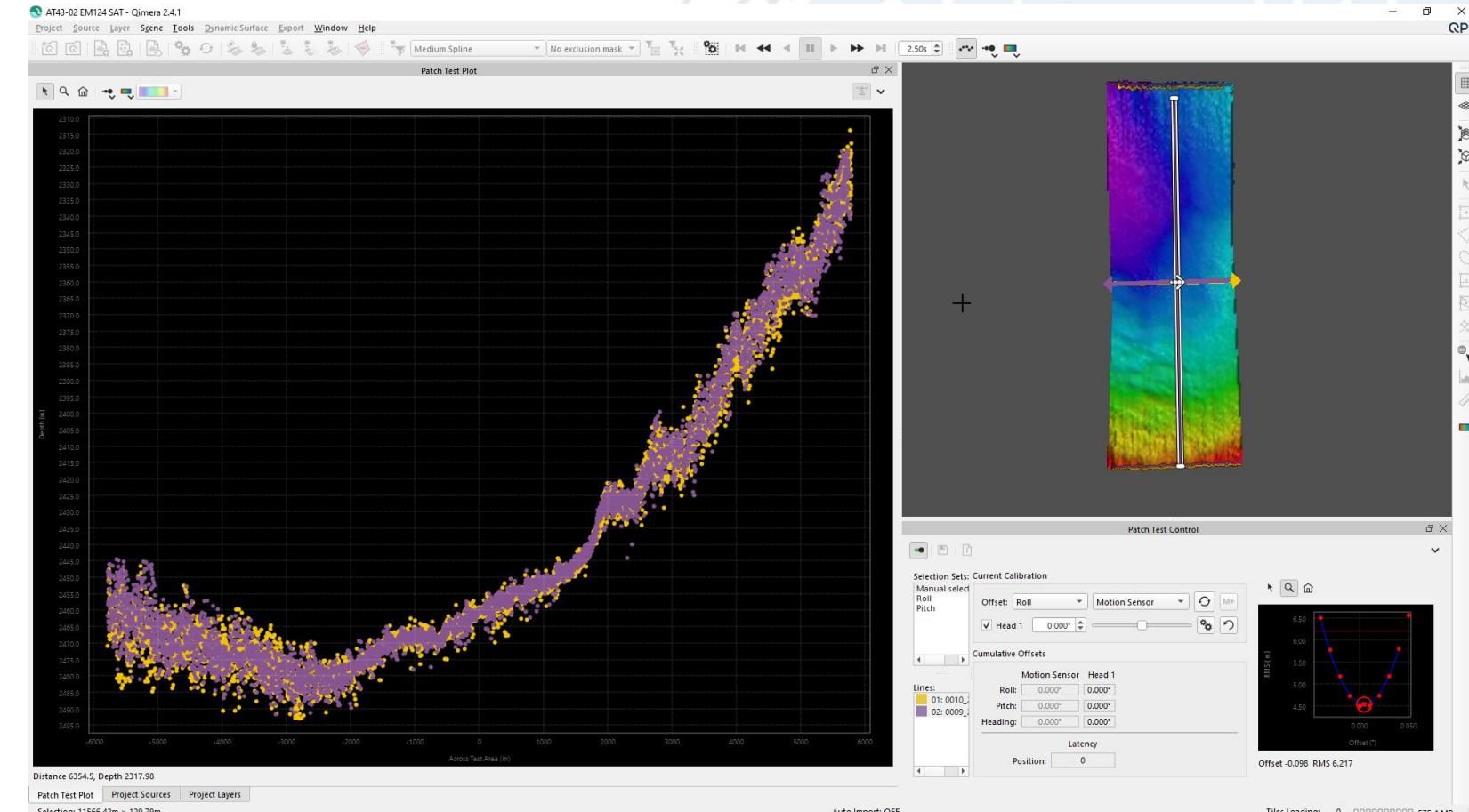
Pitch verification lines shown at left in the Qimera Patch Test Tool

Files: 0-1, 7-8

1. Attitude 2 initial setting: 0.00°
2. Calibration adjustment: -0.17°
3. Verification adjustment: 0.00°
4. **Final pitch offset: -0.17° in SIS**

EM124 Calibration

Results: Roll (Seapath)



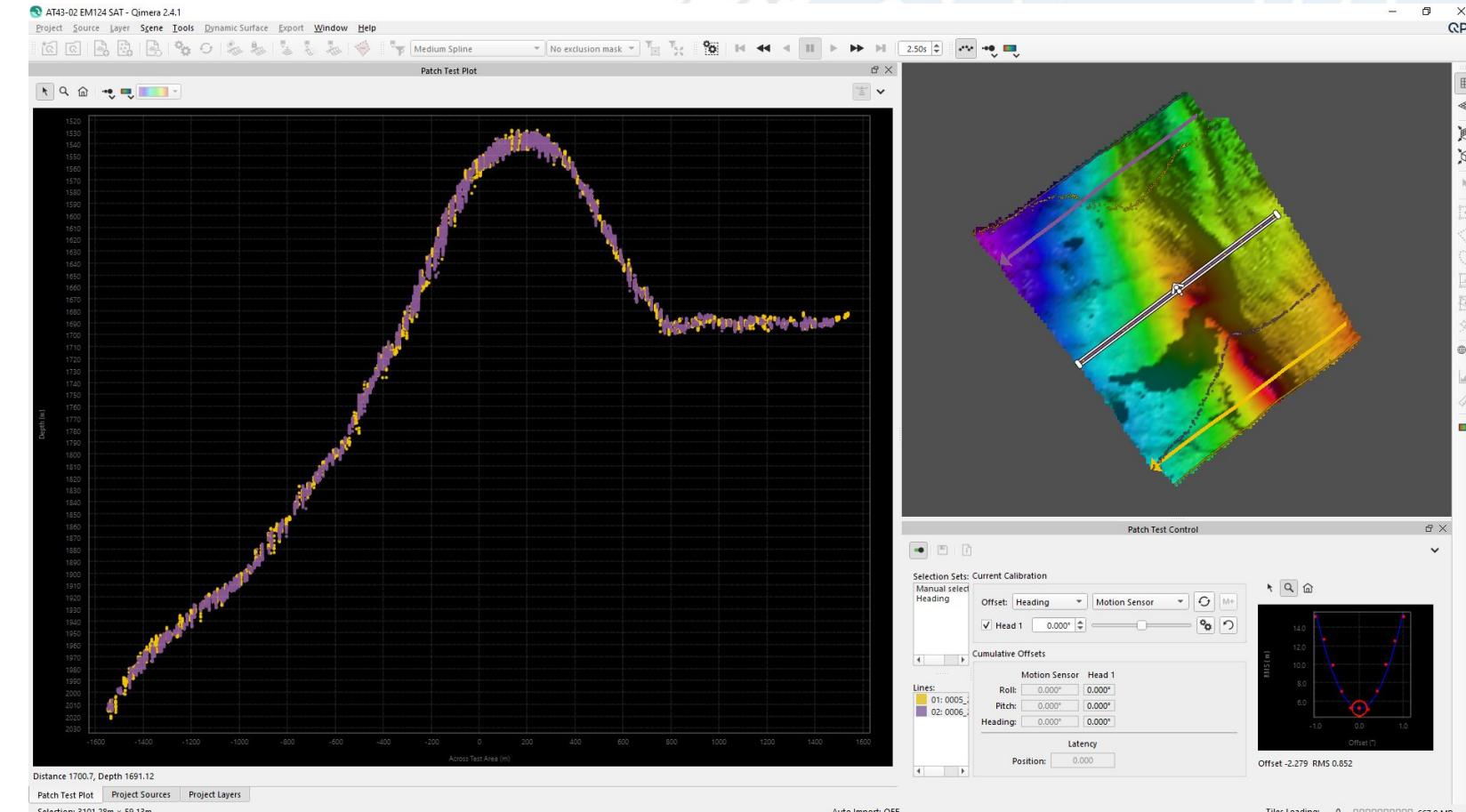
Roll verification lines shown at left in the Qimera Patch Test Tool

Files: 3-4, 9-10

1. Attitude 2 initial setting: 0.00°
2. Calibration adjustment: -0.11°
3. Verification adjustment: 0.00°
4. **Final roll offset: -0.11° in SIS**

EM124 Calibration

Results: Heading (Seapath)



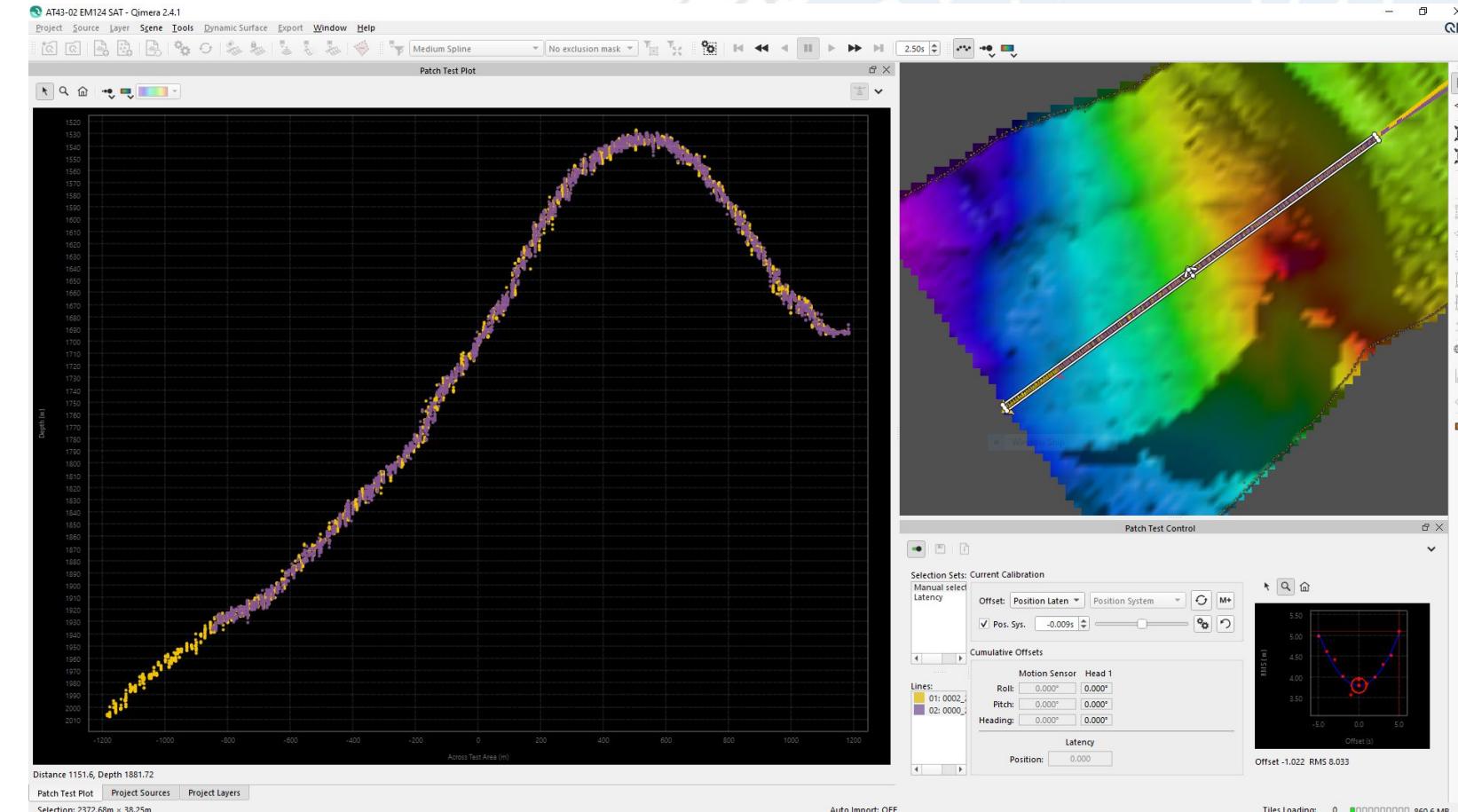
Heading calibration lines shown at left in the Qimera Patch Test Tool

Files: 5-6

1. Attitude 2 initial setting: 0.00°
2. Calibration adjustment: -0.05°
3. Verification adjustment: N/A
4. **Final hdg. offset: -0.05° in SIS**

EM124 Calibration

Results: Latency Check (Seapath)



Latency check lines shown at left in the Qimera Patch Test Tool

One 6-kt pitch calibration line was compared with a 10-kt repeat pass

There was no obvious EM124 positioning latency in deep water under the final configuration

It is not clear that a test in this water depth would be conclusive for small latency; however, there were no obvious position or attitude latency issues observed during AT-43-02

EM124 Calibration

POST-CALIBRATION (EM124)

Sensor setup

EM124_60

Position system 1	Position system name	Serial port 1
Position system 2	Position system name	No
Position system 3	Position system name	No
Attitude system 1	Attitude system name	Net port 1

Name: Attitude system name

Forward, X / Roll	Starboard, Y / Pitch	Downward, Z / Heading
Location offset (XYZ) 0.000	0.000	0.000
Angular offset (RPH) -0.110	-0.170	-0.050

Attitude delay (s)
0.000

Roll reference plane
Rotation

Format
KM Binary

Input
Net port 1

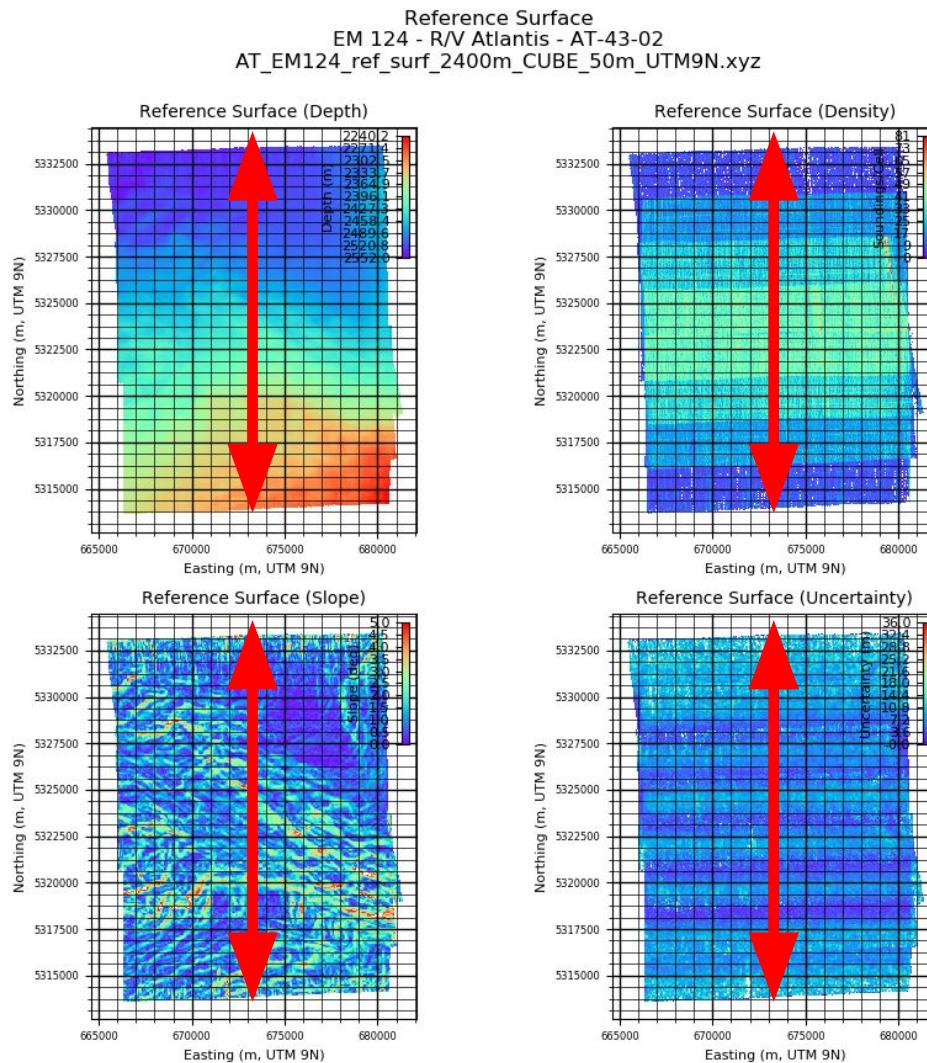
Ethernet adapter:
Main net

Port:
3001

Post-Calibration Configuration

1. The adjustments made during AT-43-02 were small and fell within the typical range, suggesting acceptable vessel survey results and consistent sensor integration
2. Following the SAT, Seapath attitude and attitude velocity feeds to SIS were reconfigured as a single KM Binary feed on *Attitude 1* (left)
3. This configuration is becoming more widely adopted and is reflected in the updated screenshot at left; *Attitude 2* offsets applied during the SAT were reset to zero after the SAT, as this input is no longer used
4. The *Installation Parameters: Angular Offsets* shown at left should be maintained until any modification is made to the EM124 or Seapath, or another calibration becomes necessary for other reasons

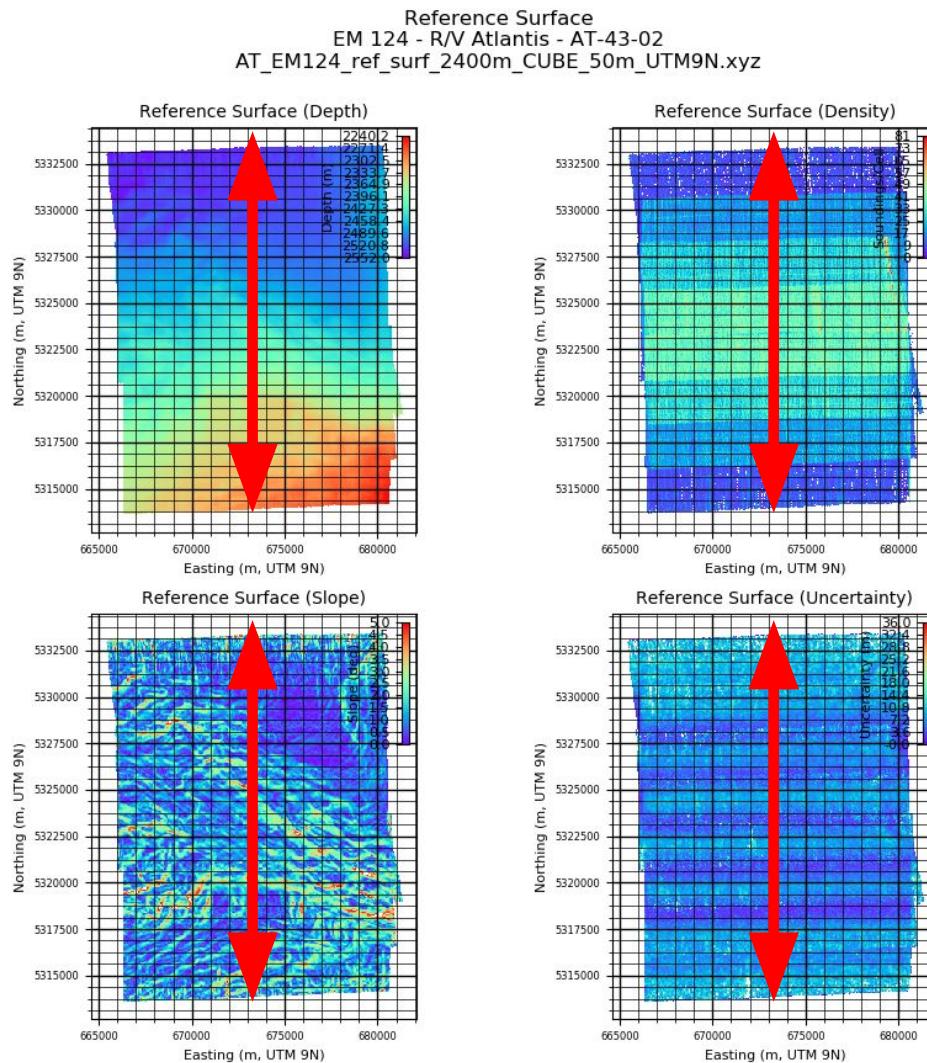
Accuracy Testing



Testing Procedure

1. Swath accuracy was assessed by conducting a reference survey and running crosslines (e.g., red lines, left) at a 2400 m site used previously by the R/V *Sally Ride* (2016) and USCGC Healy (2021)
2. Due to scheduling constraints, the reference surface lines were reduced from 8X water depth (planned) to 6X water depth (surveyed); crosslines were oriented to maximize coverage across the reference surface and were consequently limited to 70° to fit on the reduced surface
3. Crosslines were oriented orthogonal to the reference surface survey lines in order to reduce any potential coupling of echosounder biases across the swath
4. Sound speed profiles were collected throughout the survey and crosslines and applied during data collection and processing
5. Reference survey and crossline speeds were 8-9 kts

Accuracy Testing

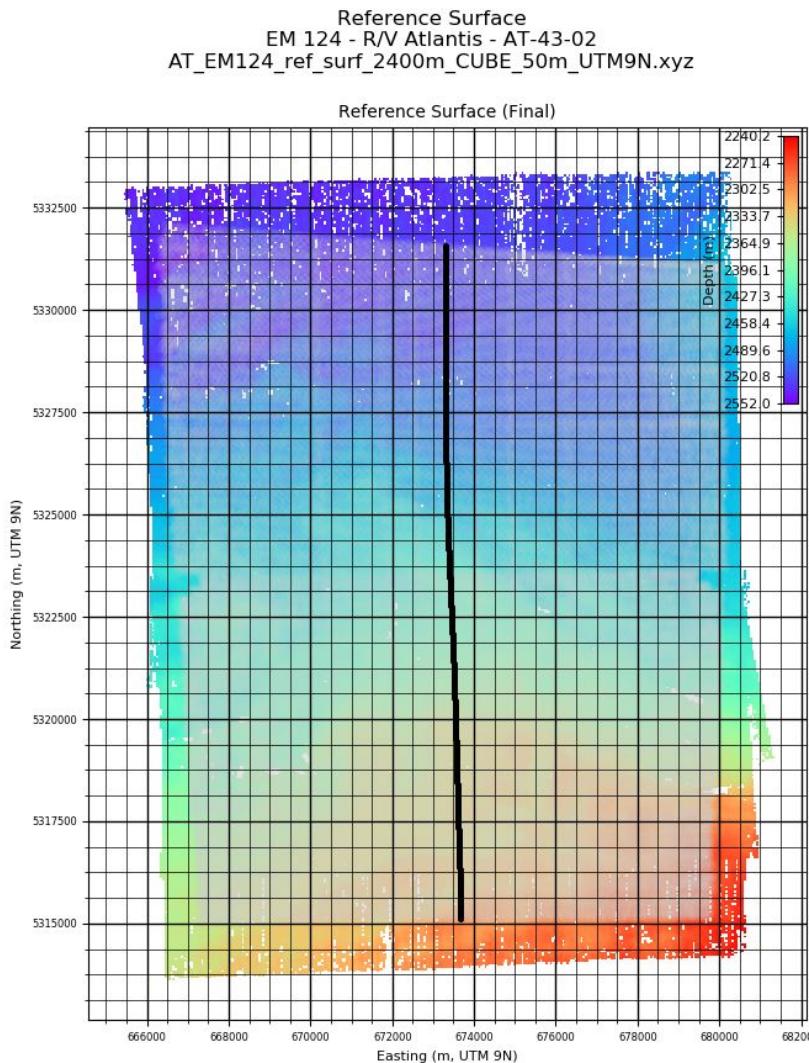


Testing Procedure

6. TPXO (<https://tpxows.azurewebsites.net/>) estimated tide corrections were applied for the reference surface and crosslines
7. The reference surface was gridded with the CUBE algorithm in QPS Qimera at 50 m resolution, then filtered by slope, sounding density, and uncertainty in the MAC Accuracy Plotter app
8. Only reference surface cells meeting the slope, density, uncertainty criteria outlined below were used for analyses of crossline data (e.g., filtered 2400 m reference surface shown at left)

Reference Surfaces	EM124 Washington
Nominal depth (m)	2400
Grid size (m)	50
Min. soundings/cell	5
Max. slope (deg)	5
Max. uncertainty (m)	15
Max. diff. from ref. (m)	NA

Accuracy Testing



Testing Procedure

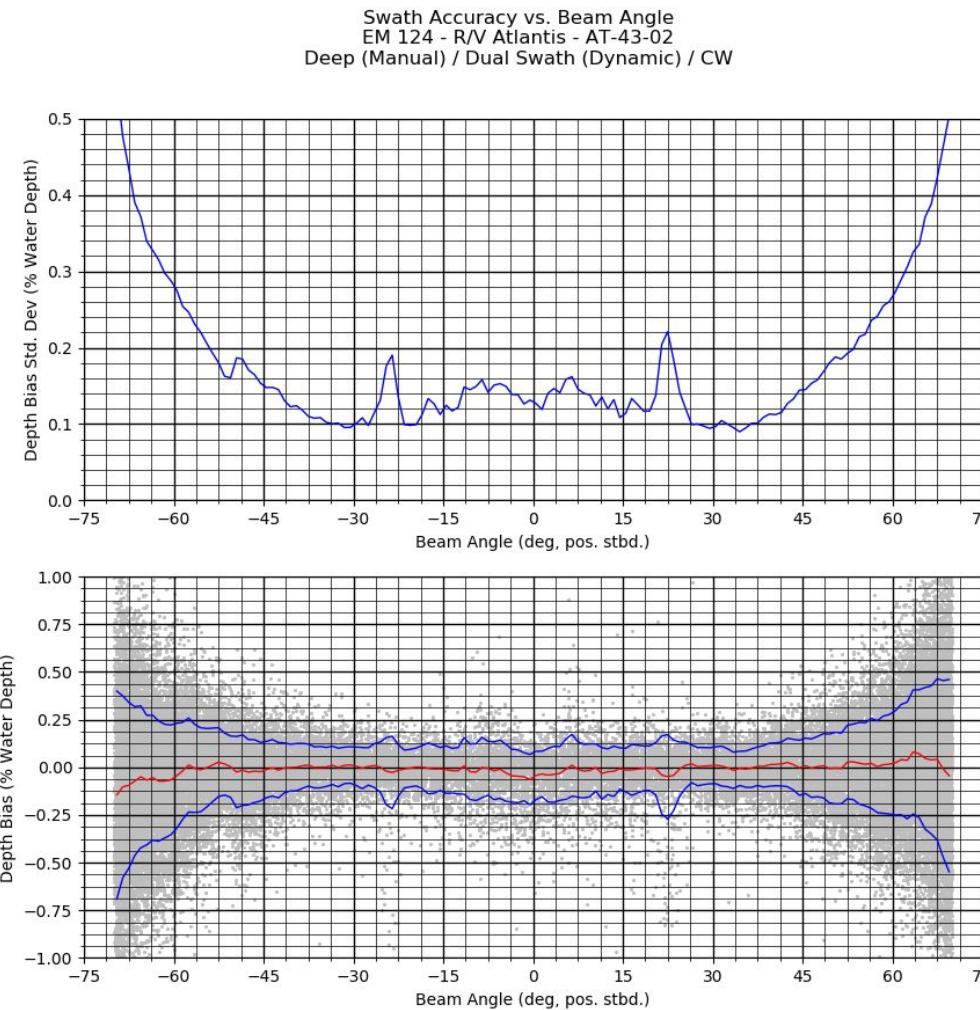
9. Examples of the reference surface filter results and the final grid used for comparison are shown at left on this and preceding slides
10. Crossline soundings (e.g., gray points at left; track line in black) were corrected for tide; no additional filtering was applied to the crosslines aside from +/-70° swath angle limits in the plotter
11. Sounding depths were compared to reference grid depths (interpolated onto the sounding horizontal position); mean depth bias and depth bias standard deviations as a percentage of water depth were then computed in 1° angular bins across the swath for each configuration (shown in following slides)
12. Two crosslines were acquired in modes appropriate for this depth:

Crossline Setting	Depth Mode	Swath Mode	Pulse Form	Yaw Stabilization ¹	Crossline Orientation
1	Deep	Dual	CW	RMH	Northbound
2	Deeper	Dual	CW	RMH	Southbound

¹RMH = Relative Mean Heading

Left: Reference surface after filtering and crossline coverage with trackline

EM124 Accuracy Testing 2400 m Accuracy: Results

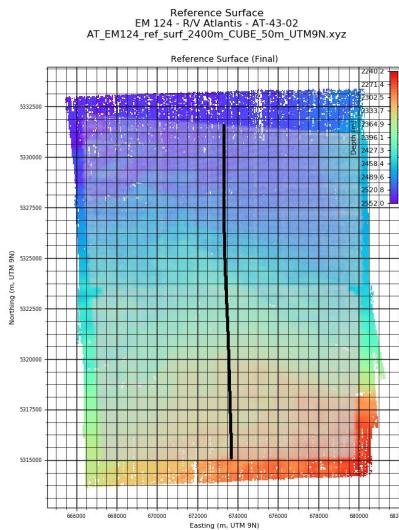


Example of swath accuracy as a percentage of water depth

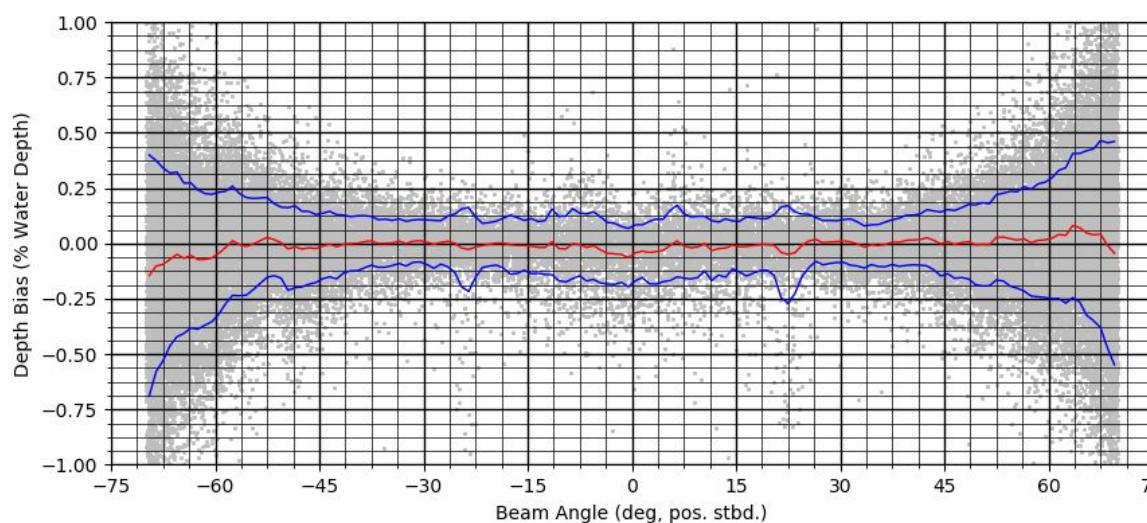
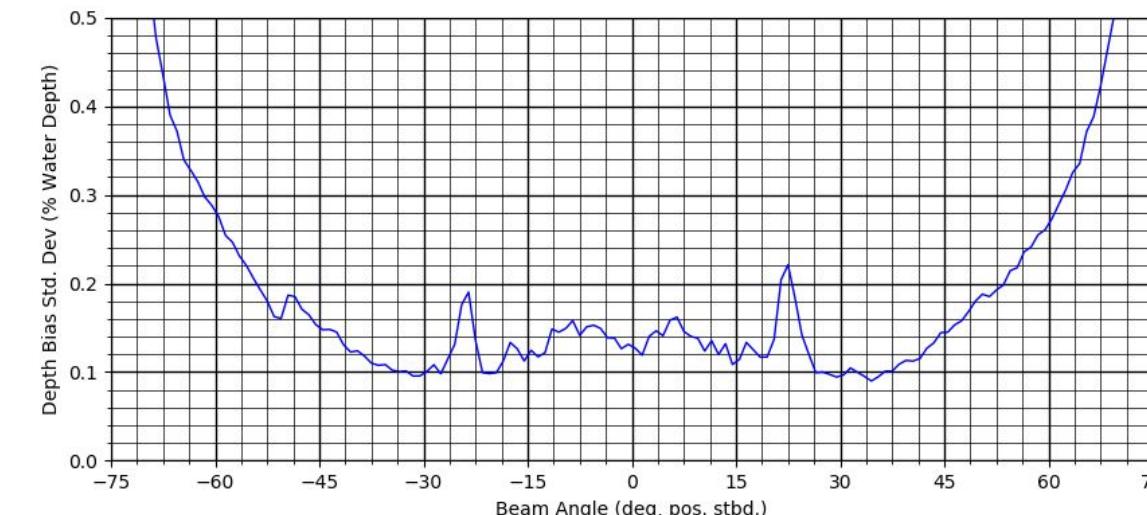
Results for each setting are presented in the following slides

1. The EM124 accuracy results at the 2400 m site indicate generally expected performance, with no significant impacts of sea state, refraction, or tide
2. The observed trends in standard deviations generally fall below 0.3 %WD out to 60° on each side; the raw data appeared to be relatively 'clean' and did not require any crossline filtering
3. A small roll bias is evident in the northbound pass (crossline 2, Deeper mode); this is attributed to a varying sound speed environment at the site, as this roll bias is not clear on the first crossline and the averages of multiple subsets of roll calibration data indicate no consistent, appreciable roll bias

EM124 Accuracy Testing 2400 m: Deep/Dual/CW/RMH

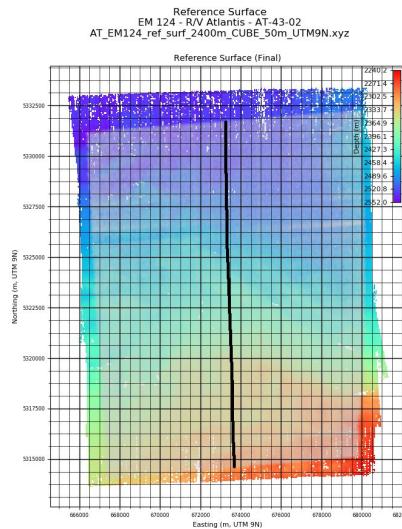


Swath Accuracy vs. Beam Angle
EM 124 - R/V Atlantis - AT-43-02
Deep (Manual) / Dual Swath (Dynamic) / CW

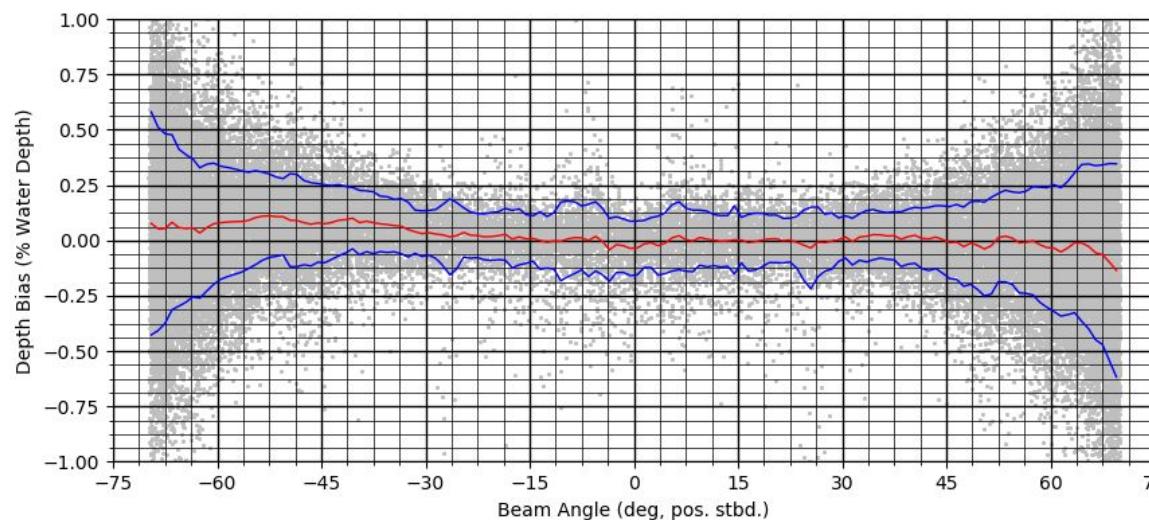
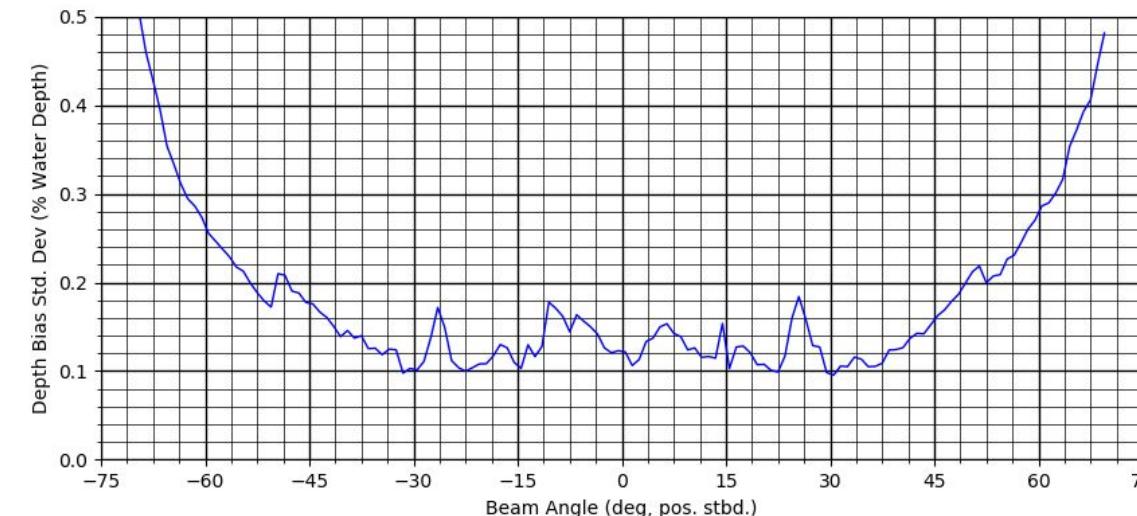


2021-07-19:
SAT survey files 10-12
No crossline filtering applied
TPXO tide adjustment applied

EM124 Accuracy Testing 2400 m: Deeper/Dual/CW/RMH



Swath Accuracy vs. Beam Angle
EM 124 - R/V Atlantis - AT-43-02
Deeper (Manual) / Dual Swath (Dynamic) / Mixed



Red: Mean Depth Diff. Blue: Depth Diff. Std. Dev.

2021-07-19:

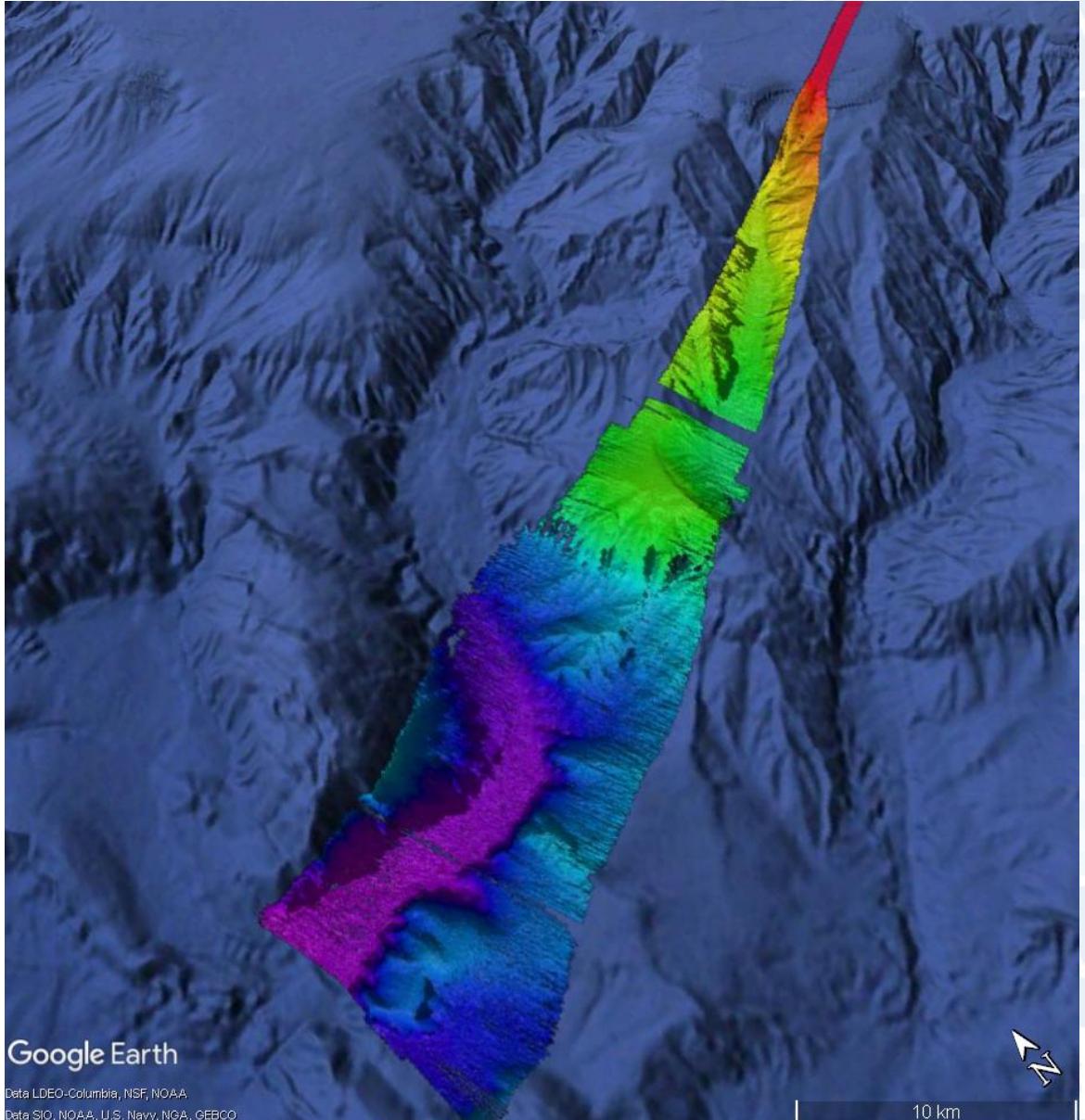
SAT survey files 13-15

No crossline filtering applied

TPXO tide adjustment applied

Swath Coverage Assessment

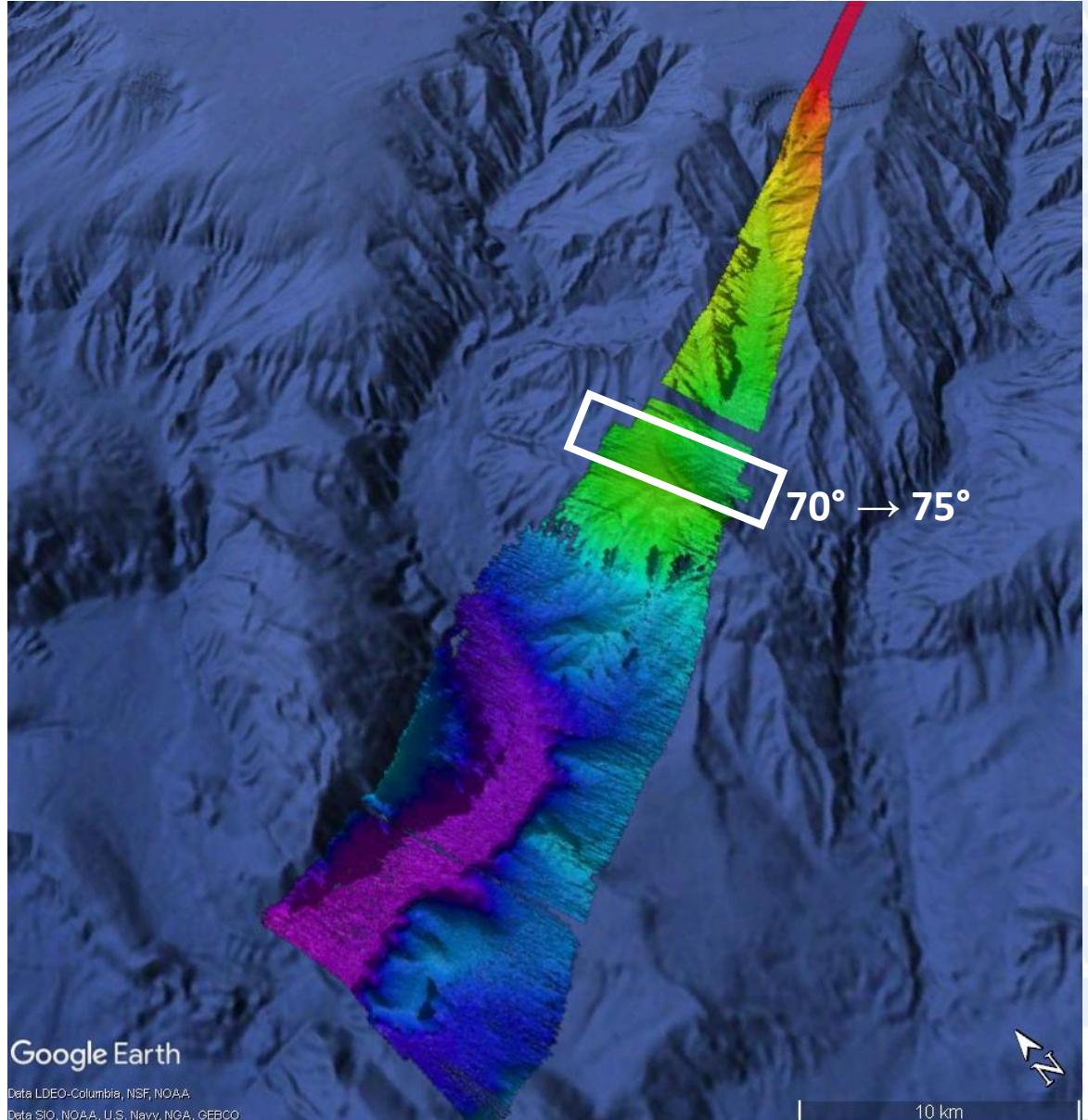
Overview



1. Due to scheduling and location constraints, swath coverage testing was incorporated into the transit off the shelf toward the patch test site
2. The following plots show the coverage achieved in the available transit data (as of writing) for reference only, and not as a full assessment of swath coverage
3. **Additional data collection is recommended with:**
 - a. Automatic depth mode
 - b. Maximum swath angles ($\pm 75^\circ$)
 - c. FM enabled and Dual Swath (Dynamic)
 - d. All other sonars secured
 - e. Typical mapping speeds (e.g., 8-10 kts)
 - f. A wide range of depths (especially 1500-5000 m)
 - g. Crossing contours as perpendicularly as possible

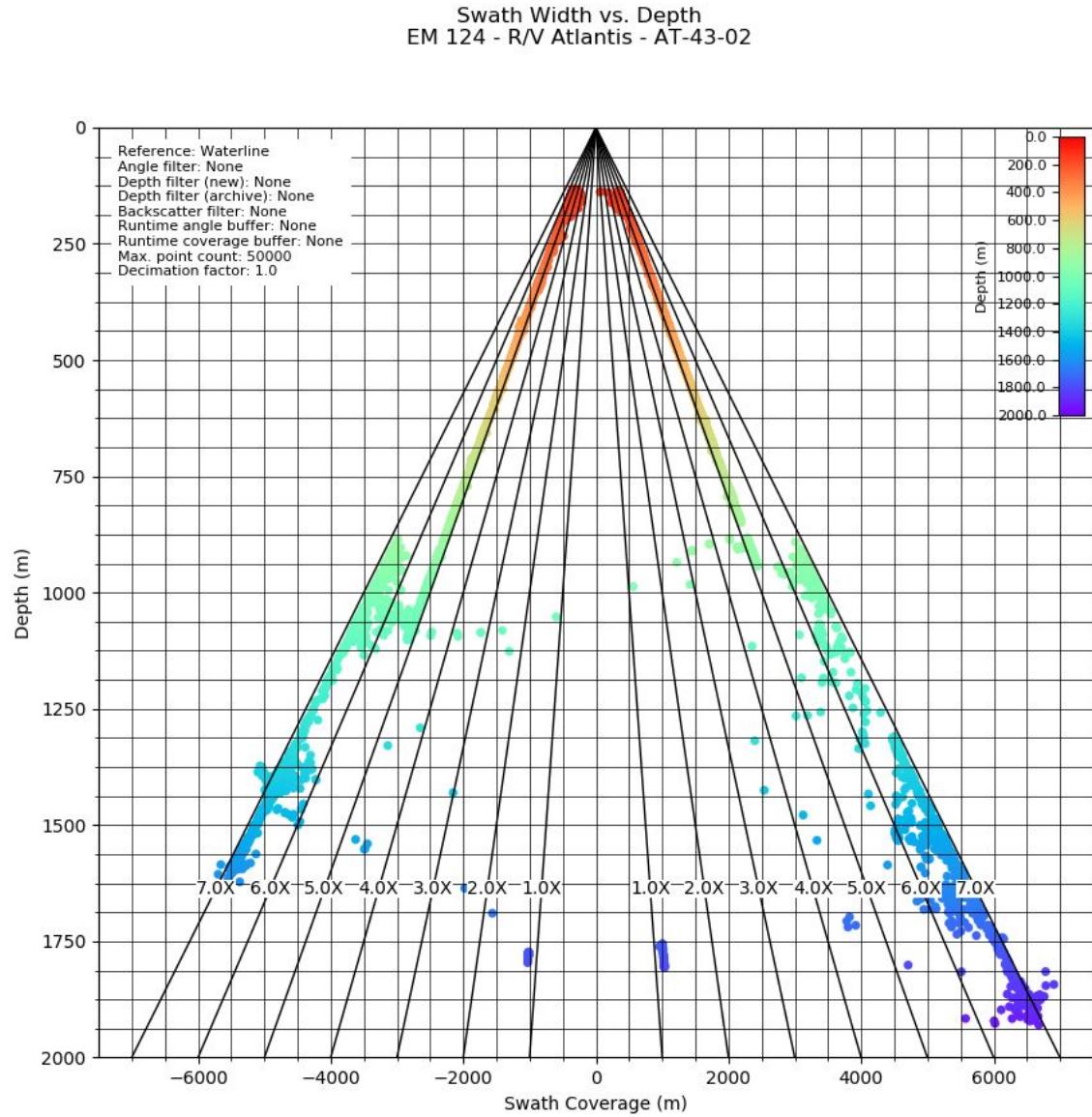
Swath Coverage Assessment

Overview



4. Transit files 13-20 on 2021-07-18 are the most suitable available for coverage assessment, with some considerations for the following factors:
 - a. **Speed:** these files were acquired at a transit speed of 11 kts, which may create a higher noise environment and reduce swath coverage compared to lower speeds
 - b. **Terrain:** the shelf break in this region consists largely of canyons with rugged and steep terrain; these slopes may improve or degrade coverage
 - c. **Angles:** SIS swath angle limits were set to 70° and 75° throughout the transit (see transition at left and between 900-1100 m depths in plots)
 - d. **SIS:** currently, SIS appears to ‘trim’ the swath by 2° on each side, resulting in narrower coverage than the desired maximum; this may be related to an effort to reduce ‘noisy’ data in the outer swath and is being investigated by Kongsberg
 - e. **Modes:** only Shallow, Medium, and Deep modes with all CW pulse forms are represented in these tests; Deeper (CW/FM mix), Very Deep (FM), and Extra Deep (FM) should be tested for baseline performance

Swath Coverage Assessment



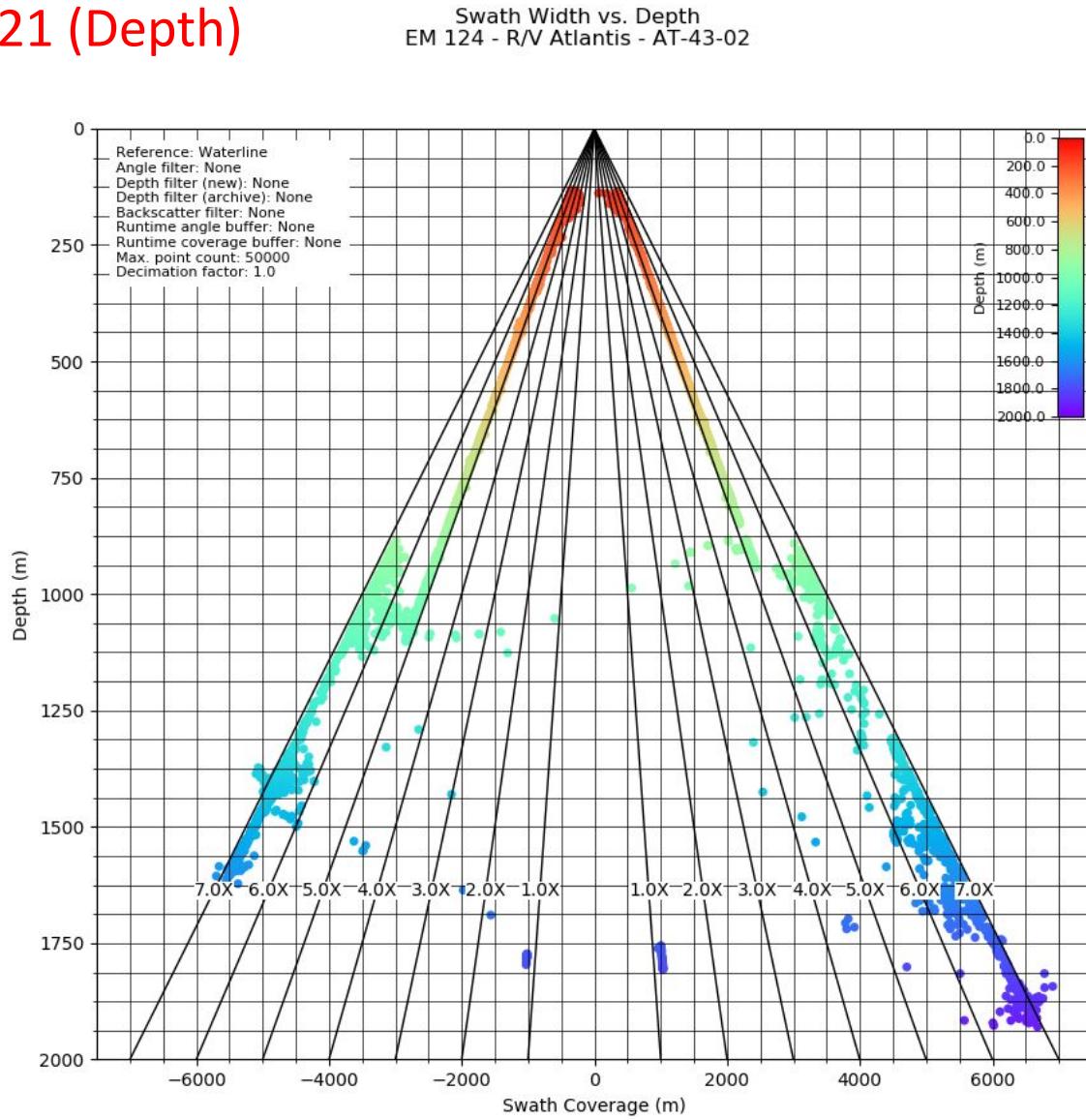
Results

1. Across-swath distance from nadir was calculated for the outermost port and starboard 'valid' sounding for each ping and then plotted against depth to evaluate trends in the achieved swath width versus depth
2. The following slides present the achieved swath coverage versus depth, colored by a variety of parameters to illustrate performance in these modes
3. Despite the SIS swath angle reductions of 2° on each side, the EM124 typically achieved $72\text{-}73^\circ$ coverage on each side (total $\sim 7X$ water depth) down to 1600 m depth after the angles were opened up to $\pm 75^\circ$
4. The transit coverage data showed the expected depth mode transition behavior over the range of 200-1600 m
5. Acknowledging the calm sea state, the relatively low occurrence of outliers suggests consistent coverage with minimal interference, as well as effective exclusion of outliers seen in the outermost few degrees aboard other EM systems during recent SATs

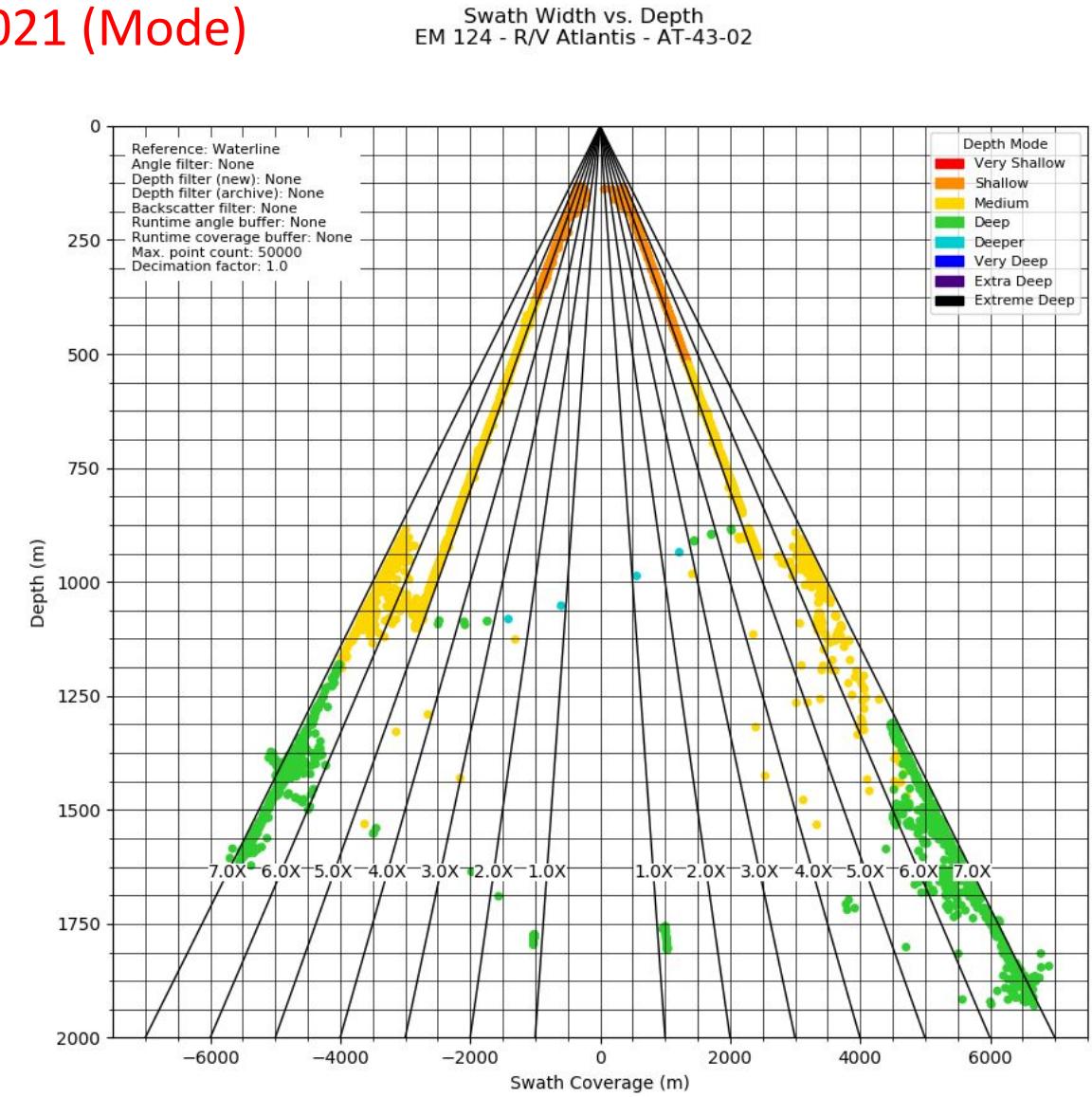
EM124 Swath Coverage

Results

2021 (Depth)



2021 (Mode)

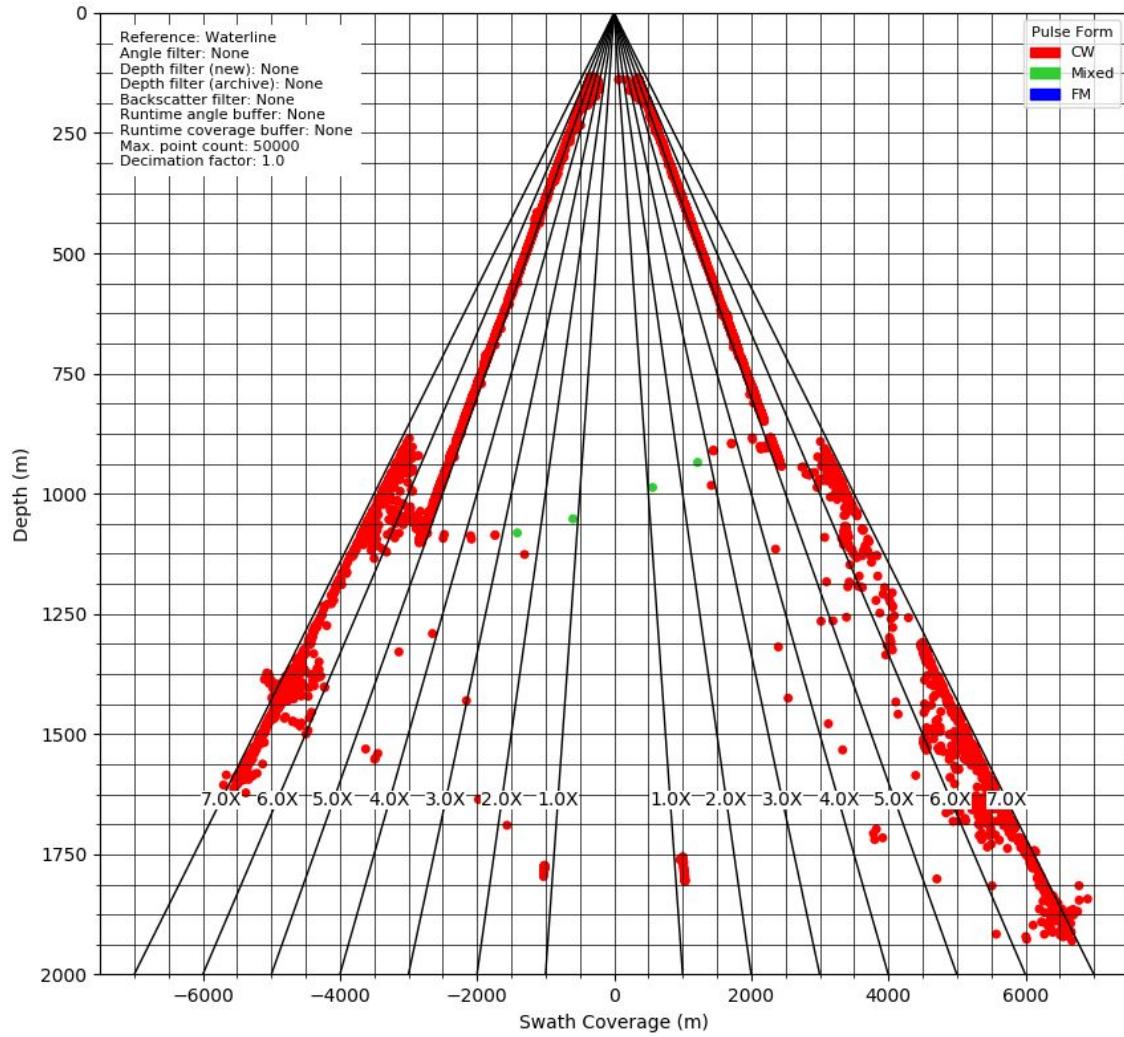


EM124 Swath Coverage

Results

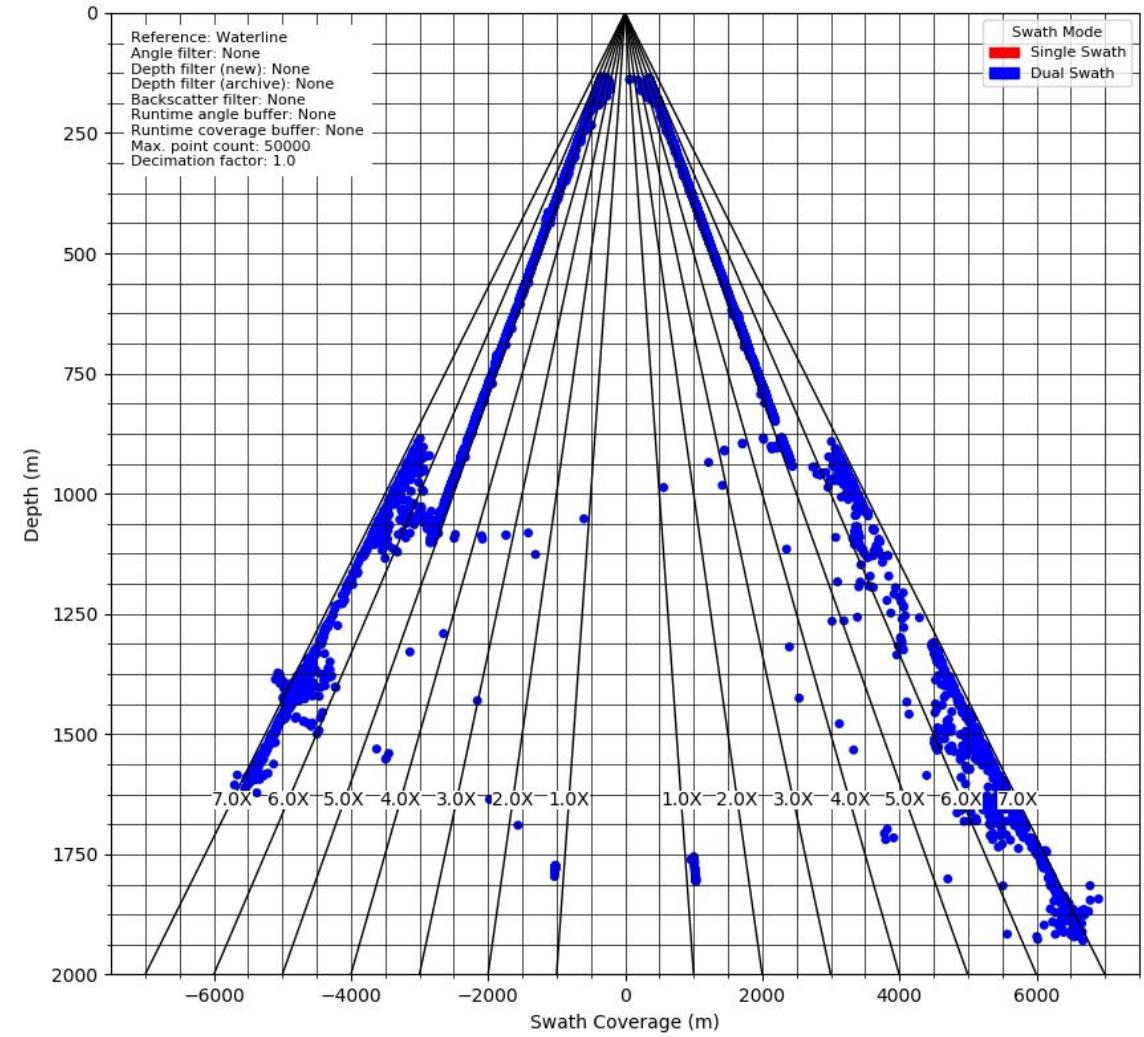
2021 (Pulse Form)

Swath Width vs. Depth
EM 124 - R/V Atlantis - AT-43-02



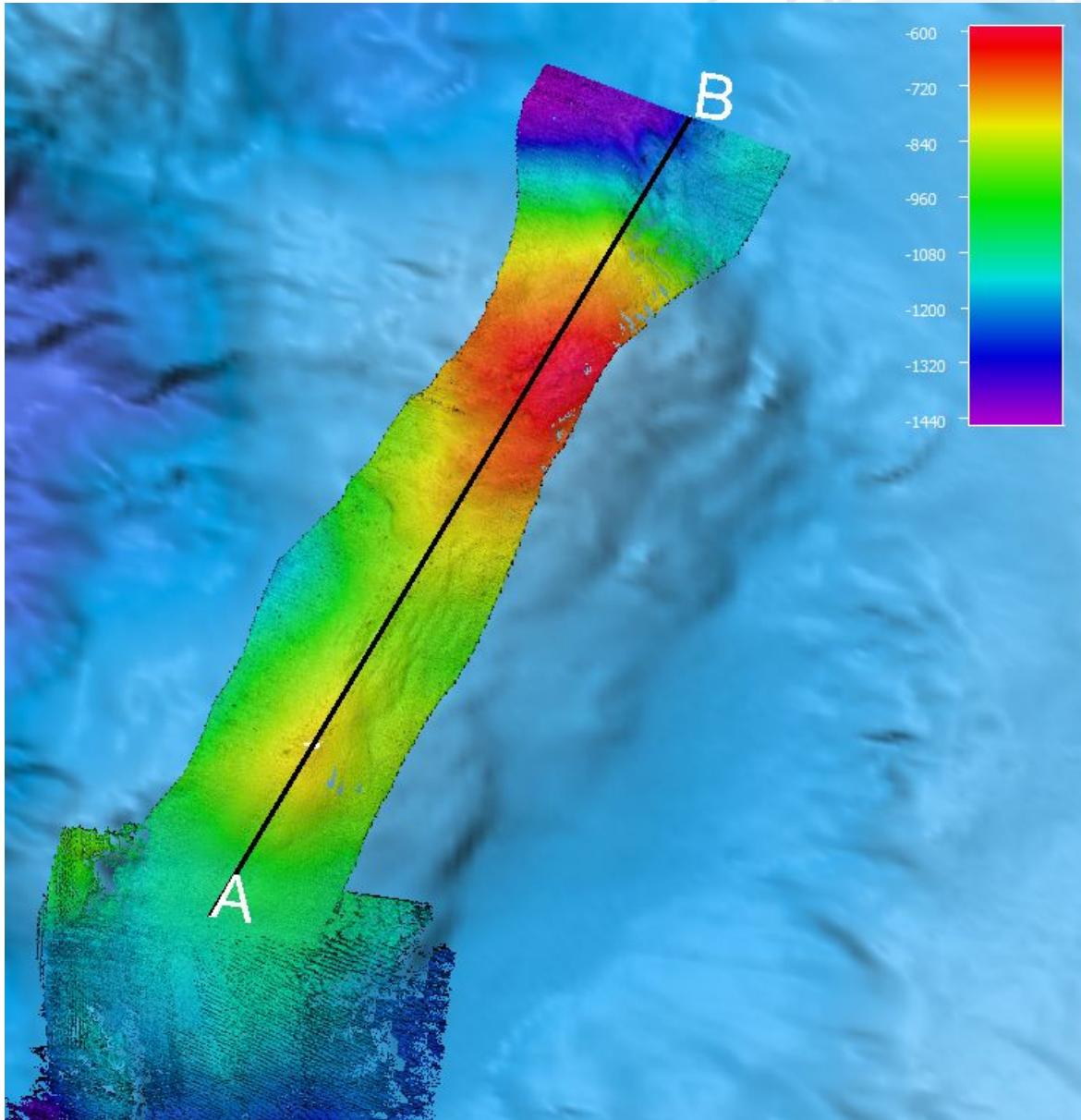
2021 (Swath Mode)

Swath Width vs. Depth
EM 124 - R/V Atlantis - AT-43-02



Midwater Target Detection

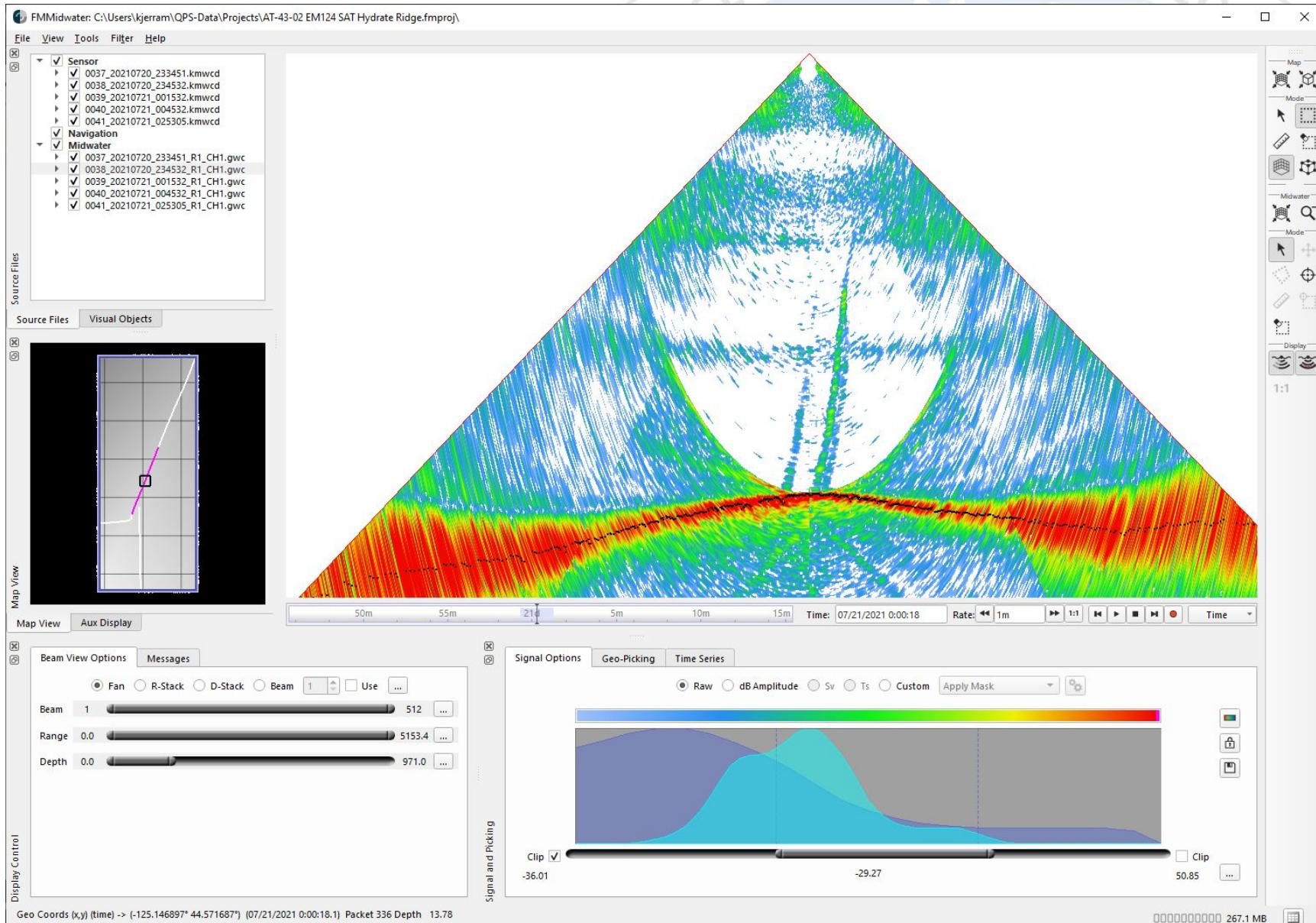
Overview



1. Following the priority SAT tasks, an opportunity arose during the transit to San Francisco to run a short survey over known seep sites at Hydrate Ridge
2. Two passes were made along the central axis of the ridge (left) with EM124 operation on A→B and EK80 operation on B→A
3. The EM124 clearly detected a cluster of seep sources at one site on the northbound pass (following slides)
4. File 0038 was processed in QPS FM Midwater v7.9.4 to extract high-amplitude targets and attempt to exclude seafloor returns and other ‘noise’
5. These examples demonstrate detection of midwater features of interest; it is likely the imagery could be improved by addressing higher noise levels on RX module 1 and reducing speed below 10 kts
6. Likewise, more advanced processing would better characterize these plumes (e.g., tracking in scattering layers where they are visible to the human eye but excluded by simple filtering in these examples)

Midwater Target Detection

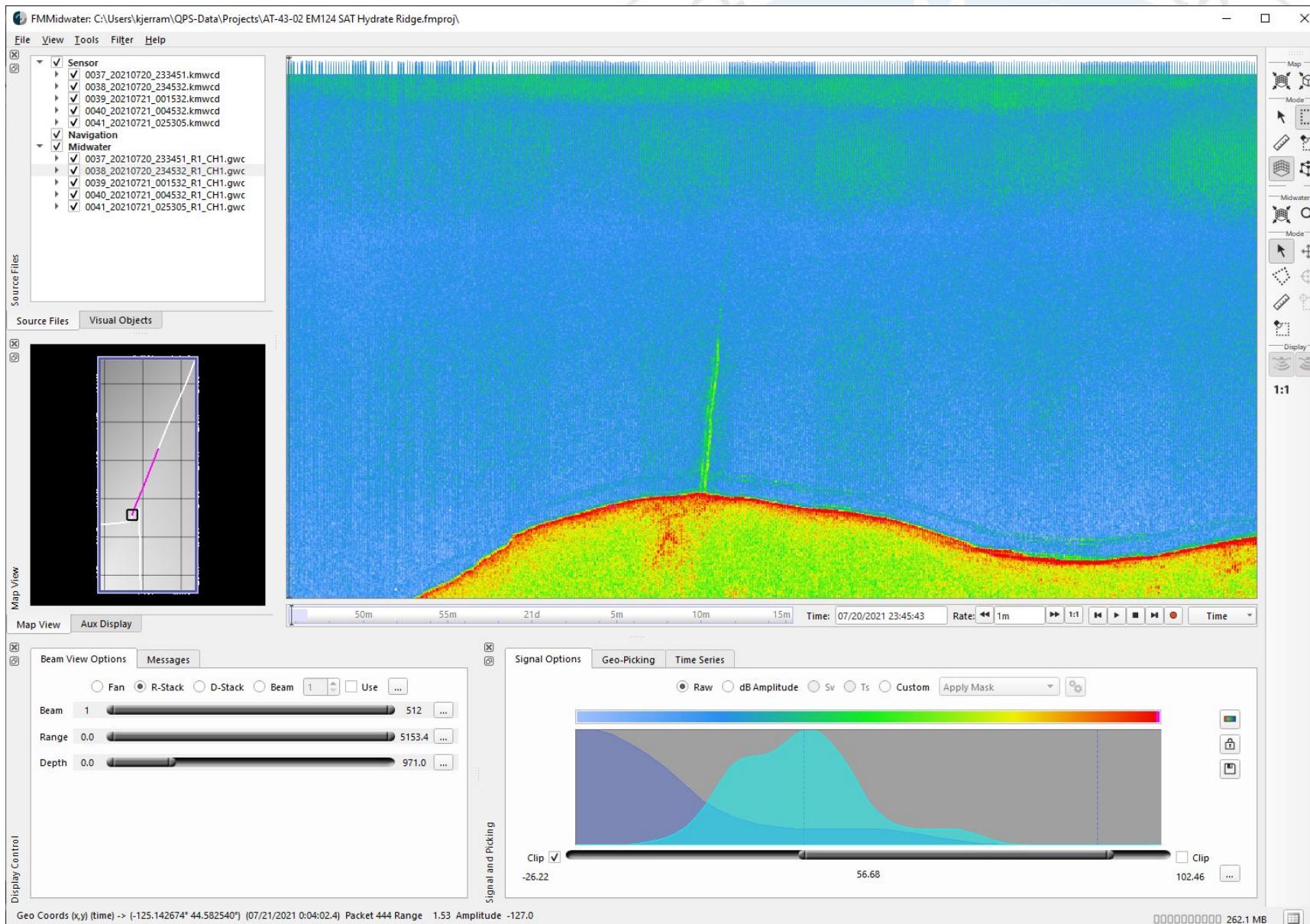
FM Midwater Examples



1. An example ‘fan’ view of one EM124 swath in file 0038 is shown in FM Midwater (v7.9.4)
2. These bubble plumes were detected in ~20 consecutive swaths as they rose from ~780 m and became indistinguishable at ~250 m
3. his ‘disappearance’ is likely due to changes in bubble size that reduce scattering strength (especially away from resonance) ~12 kHz, as well as masking by other midwater targets (e.g., plankton) in the deep scattering layer

Midwater Target Detection

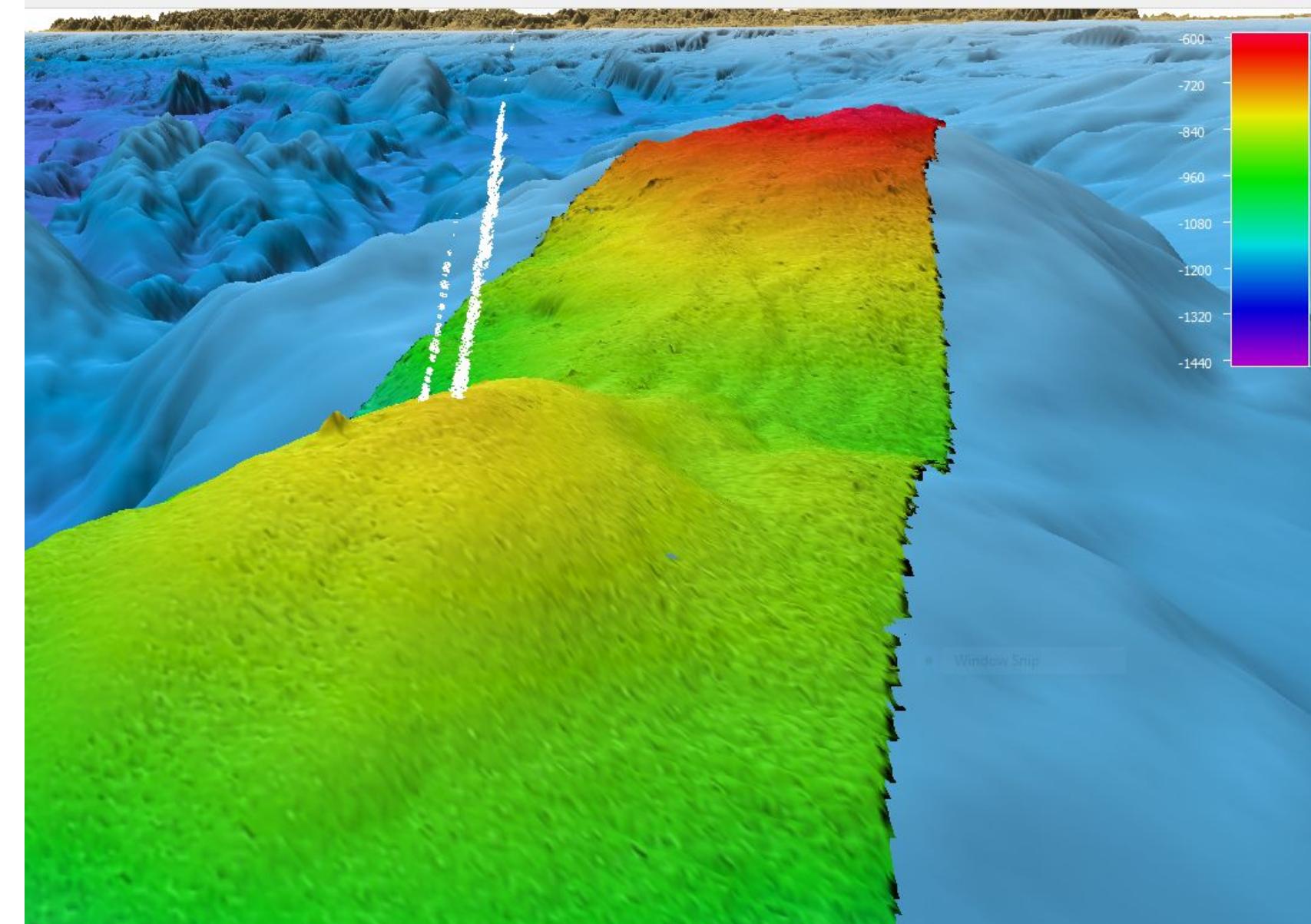
FM Midwater Examples



4. 'Range-stacked' view of file 0038
5. This view presents a 'side view' of the water column data (stacked by either range or depth) for relatively simple visual detection of midwater targets that persist across multiple swaths
6. In this example, the several closely spaced plumes from multiple vents are 'leaning over' due to currents
7. Note that the color scale in this example obscures some of the upper portions of the plumes that are visible in the 'fan view'

Midwater Target Detection

FM Midwater Examples



8. Midwater targets extracted from .kmwcd files in FM Midwater (filtered by range, depth, beam, and amplitude) are exported to SD format and presented with bathymetry from the associated .kmall files
9. Background bathymetry from the Global Multi-Resolution Topography compilation
10. (www.gmrt.org/GMRTMapTool)

RX Noise BIST Assessment

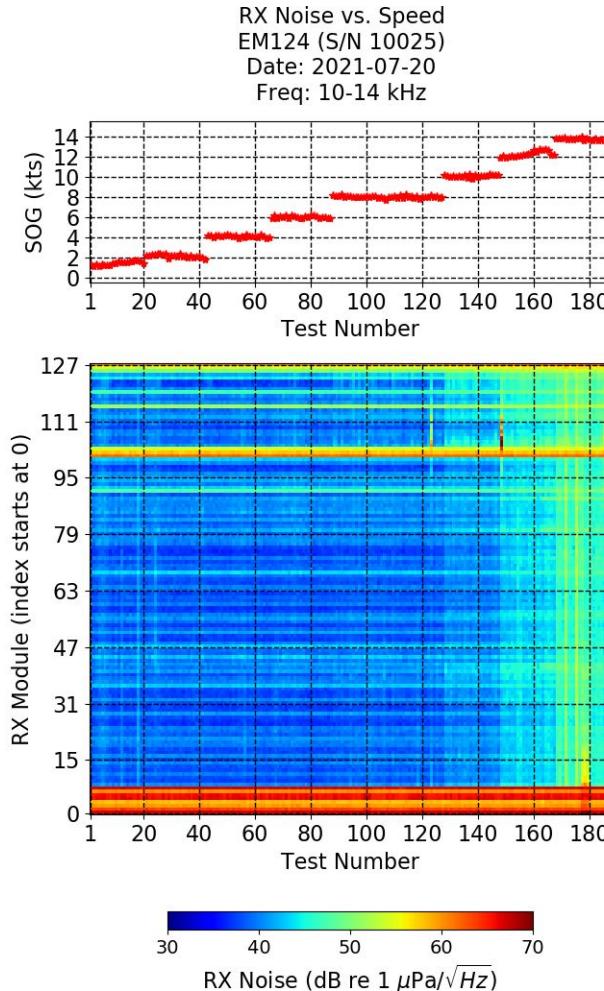
Noise Level vs. Speed and Azimuth

1. Major limitations of multibeam performance can stem from elevated noise levels due to hull design, engines and other machinery, sea state, biofouling, electrical interference, etc.
2. To characterize the vessel's noise environment as perceived by the EM124, a series of RX Noise Level Built-In Self-Tests (BISTs) were planned under two scenarios:
 - a. Noise vs. speed while the vessel slowly accelerating and decelerating over a range of 0-11 kts
 - b. Noise vs. azimuth relative to the prevailing seas, collected on headings in 45° increments
 - i. 0° = into the seas; 45° = on port bow; 90° = on port beam; 135° = on port qtr; etc.
3. As sea conditions were generally calm during the EM124 SAT window, only the RX Noise vs. speed testing was completed; noise testing vs. azimuth in a more elevated sea state can be conducted opportunistically as conditions allow during upcoming transits

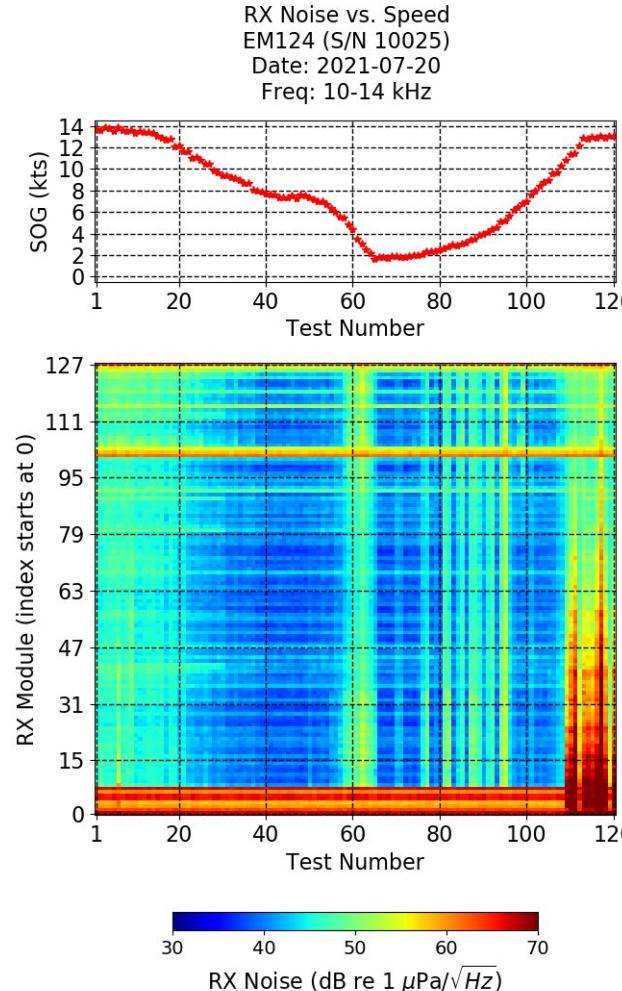
RX Noise BIST Assessment

Noise Level vs. Speed

Steady State Speeds



Slowly Changing Speed

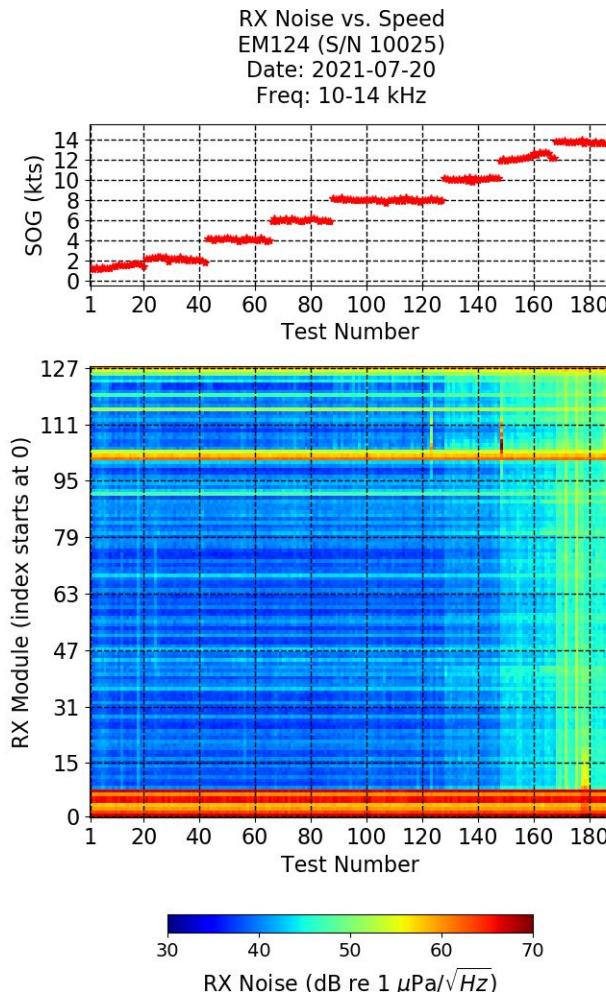


1. RX Noise vs. speed tests were conducted in two approaches:
 - a. Left: Discrete speeds with continuous BIST logging for a fixed time at each
 - b. Right: Coasting down and then ramping up to transit speed with continuous BIST logging
2. These tests show similar noise trends with speed (e.g., a sharp increase above 11 kts)
3. The plot at right illustrates the very high levels associated with transient machinery loads, such as accelerations and decelerations (e.g., steeper slopes in the speed log line up with higher RX amplitudes)

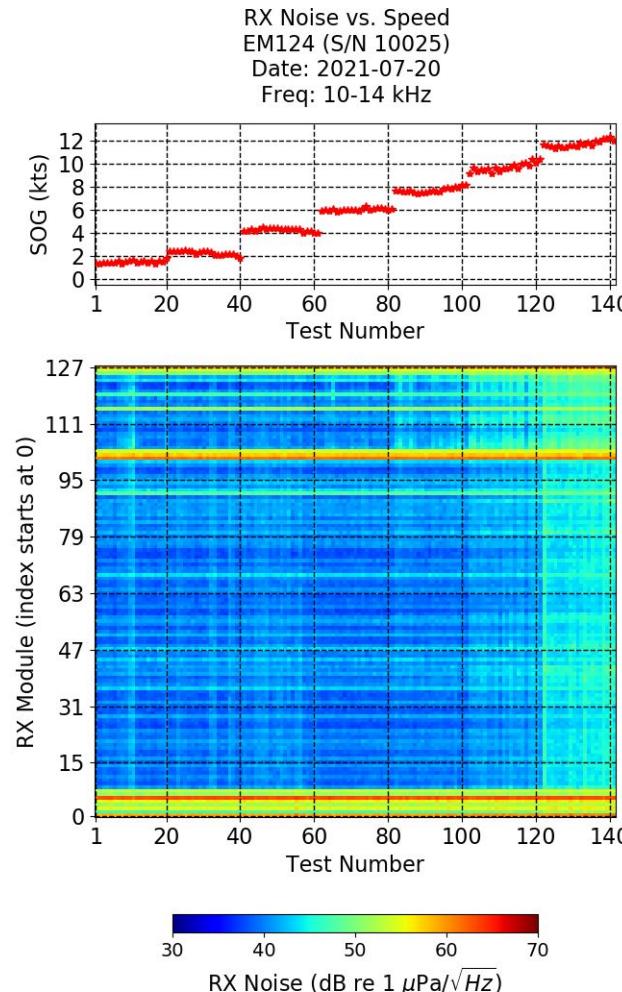
RX Noise BIST Assessment

Noise Level vs. Speed: Round 2

Pre-Cable Swap



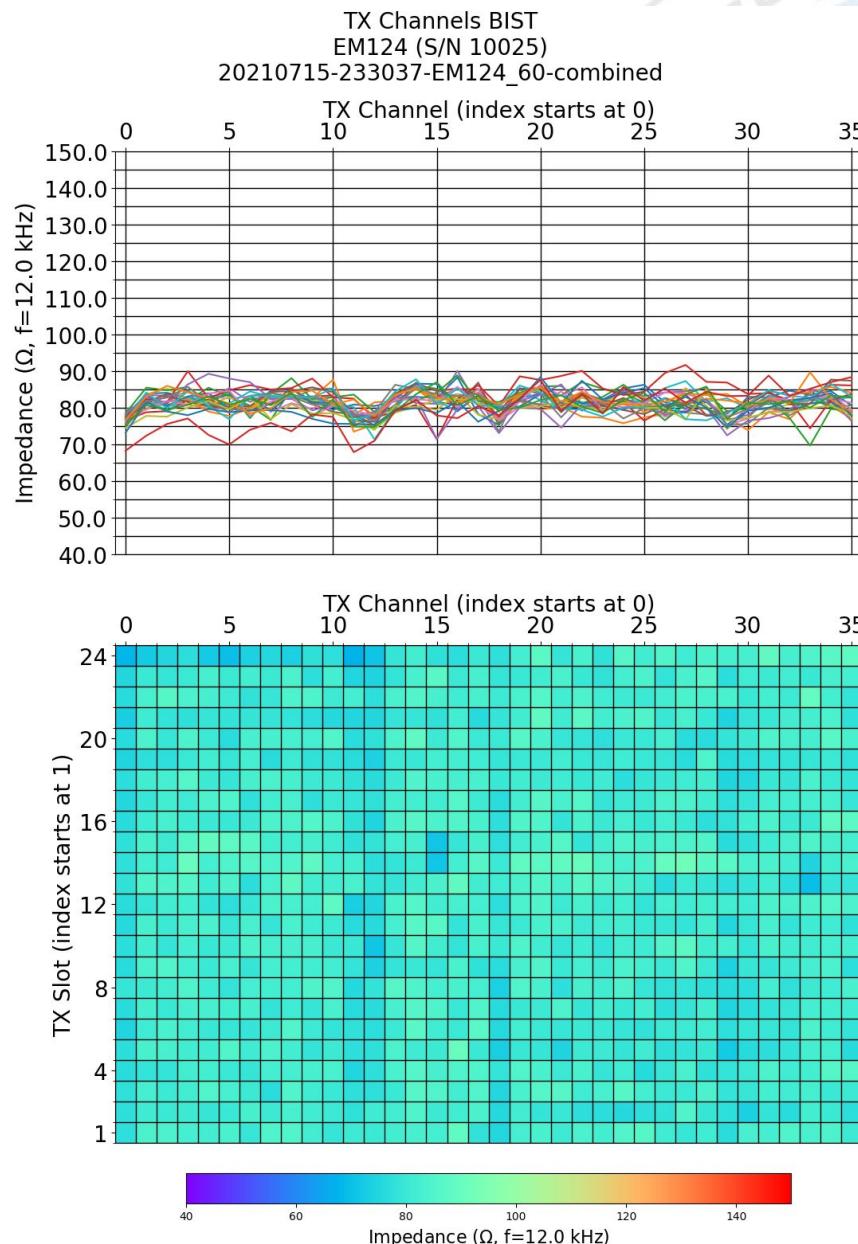
Post-Cable Swap



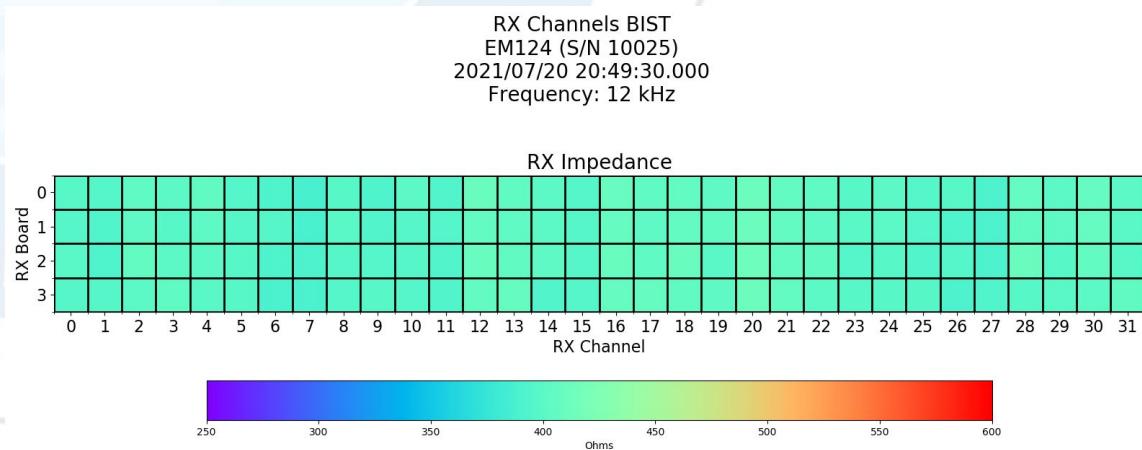
4. An extension cable on RX module 1 was replaced after initial RX Noise vs. Speed tests (left) showed very high levels for ch. 0-7
5. The second RX Noise vs. speed tests (right) show that the cable swap reduced levels by ~10 dB on this module; however, these results still show much higher mean amplitudes after the swap
6. These tests show consistently high levels for several RX channels (e.g., 6, 102-104)
7. It is strongly recommended that WHOI work with Kongsberg to address the root causes of higher levels on specific RX channels and RX module 1 to reduce the noise floor, improve SNR for RX beamforming, and aid routine noise monitoring throughout the service life of the new EM124
8. A *post-SAT RX Noise BIST collected dockside at WHOI on 2021-08-14 was inconclusive, as the high background noise levels in the harbor obscured any trend for RX module 1*

EM124 Hardware Health

TX/RX Channels



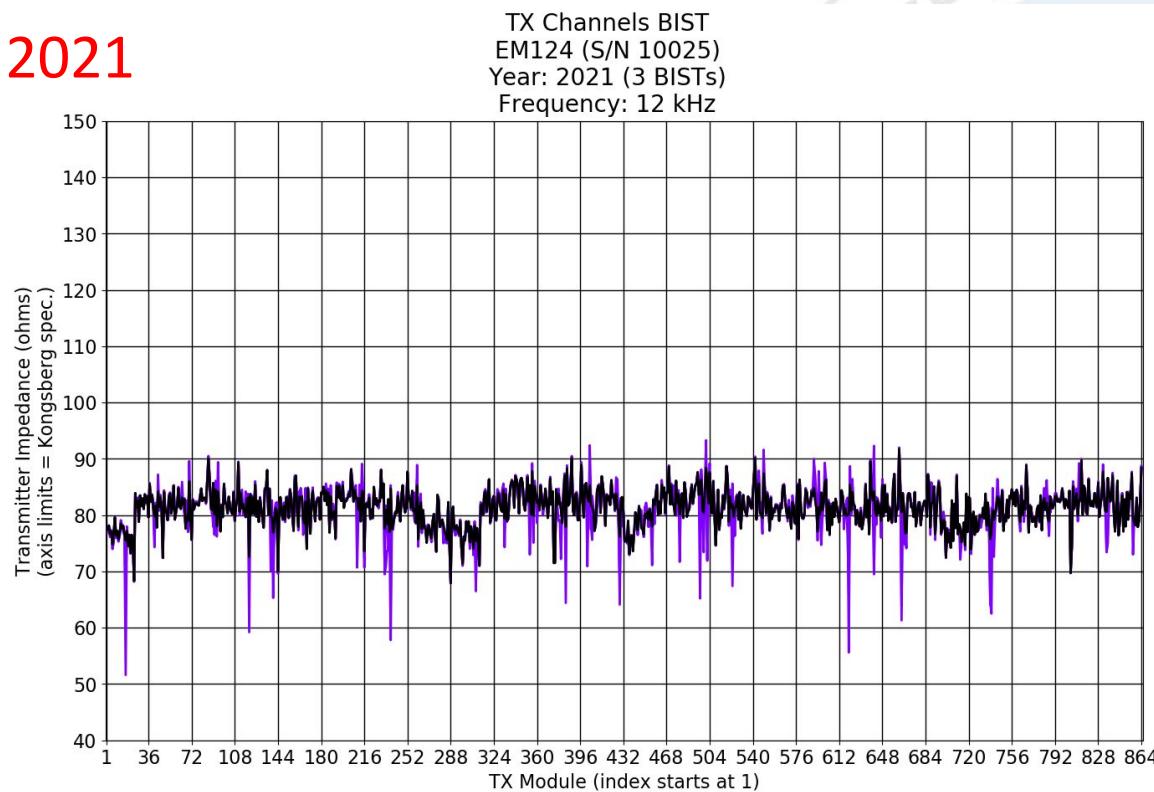
1. EM124 Built-In Self-Tests (BISTs) were collected during the HAT and SAT portions of AT43-02, including TX and RX Channels data that are useful as proxies for hardware health
2. The color scale on each plot is based on the acceptable impedance range to pass a BIST, as defined by Kongsberg
3. TX and RX Channels BISTs should be performed routinely (e.g., BISTs at the start and end of each mapping mission), between direct impedance measurements, to monitor for channel failures or general shifts over time
4. All EM124 TX and RX elements appear to be within factory limits; high Z results for specific RX channels during the SAT (see history plot, next) were resolved with targeted cable repair/replacement



EM124 Hardware Health

TX/RX Channels Baseline

2021



2021

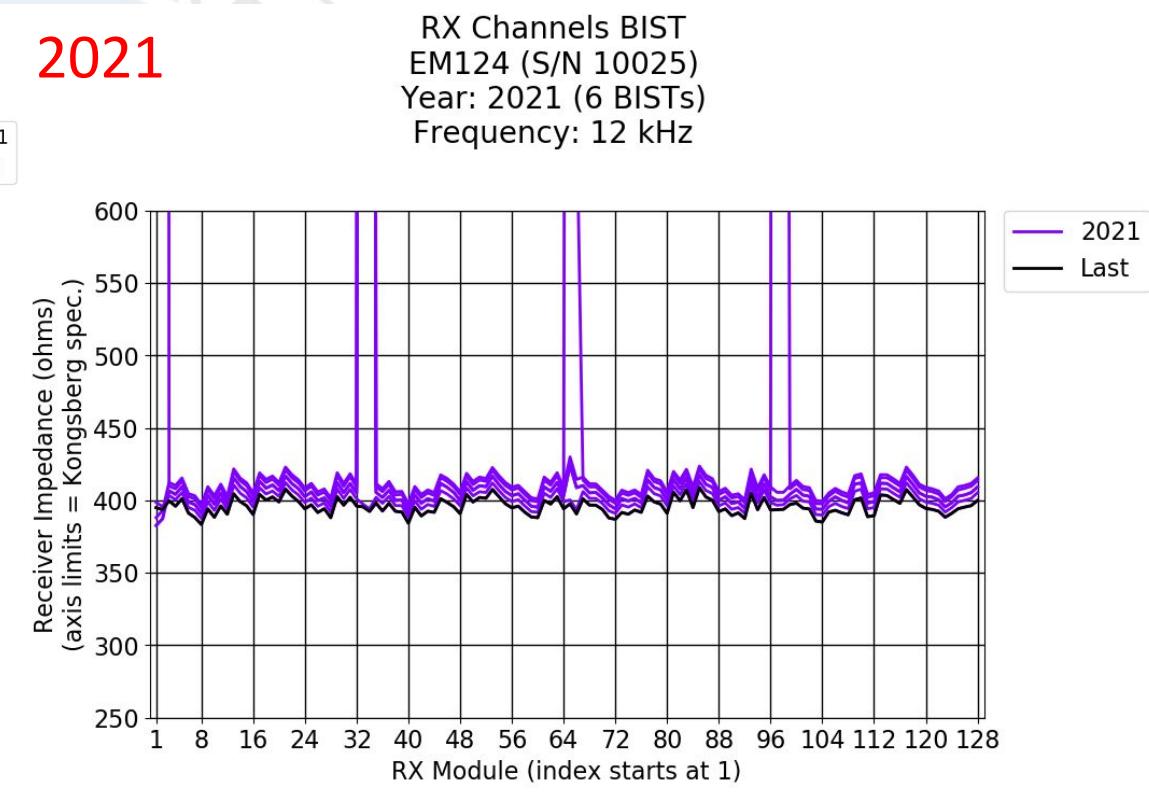




photo: WHOI

**Configuration appendices
available separately**