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Multibeam Advisory Committee (MAC) 2022 RVTEC Update

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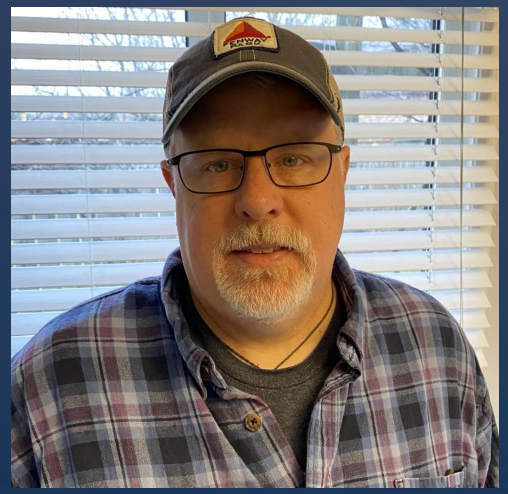

Paul Johnson

Data Manager (UNH)

Extended Continental Shelf, GEBCO, Seabed2030

Vicki Ferrini

Sr. Research Sci. and Assoc. Dir. DEI (LDEO) / Affiliate Assoc. Prof. (UNH)

GMRT, MGDS, Seabed2030, GEBCO, Explorers Club

Kevin Jerram

Mapping Specialist (UNH)

CCOM research, MAC field support

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The Multibeam Advisory Committee (MAC)

- Established 2011 with funding from NSF to ensure the consistent collection of high-quality multibeam data across the U.S. Academic Research Fleet (USARF)
  - ***Standardize*** *system performance testing*
  - ***Publish*** *performance and share best practices*
  - ***On-board & remote support*** *for ships*
- Technical Reports & Resources
  - Sea Acceptance / Quality Assurance / Noise Testing
  - Host Non-USARF reports
  - Assessment tools, survey guidance

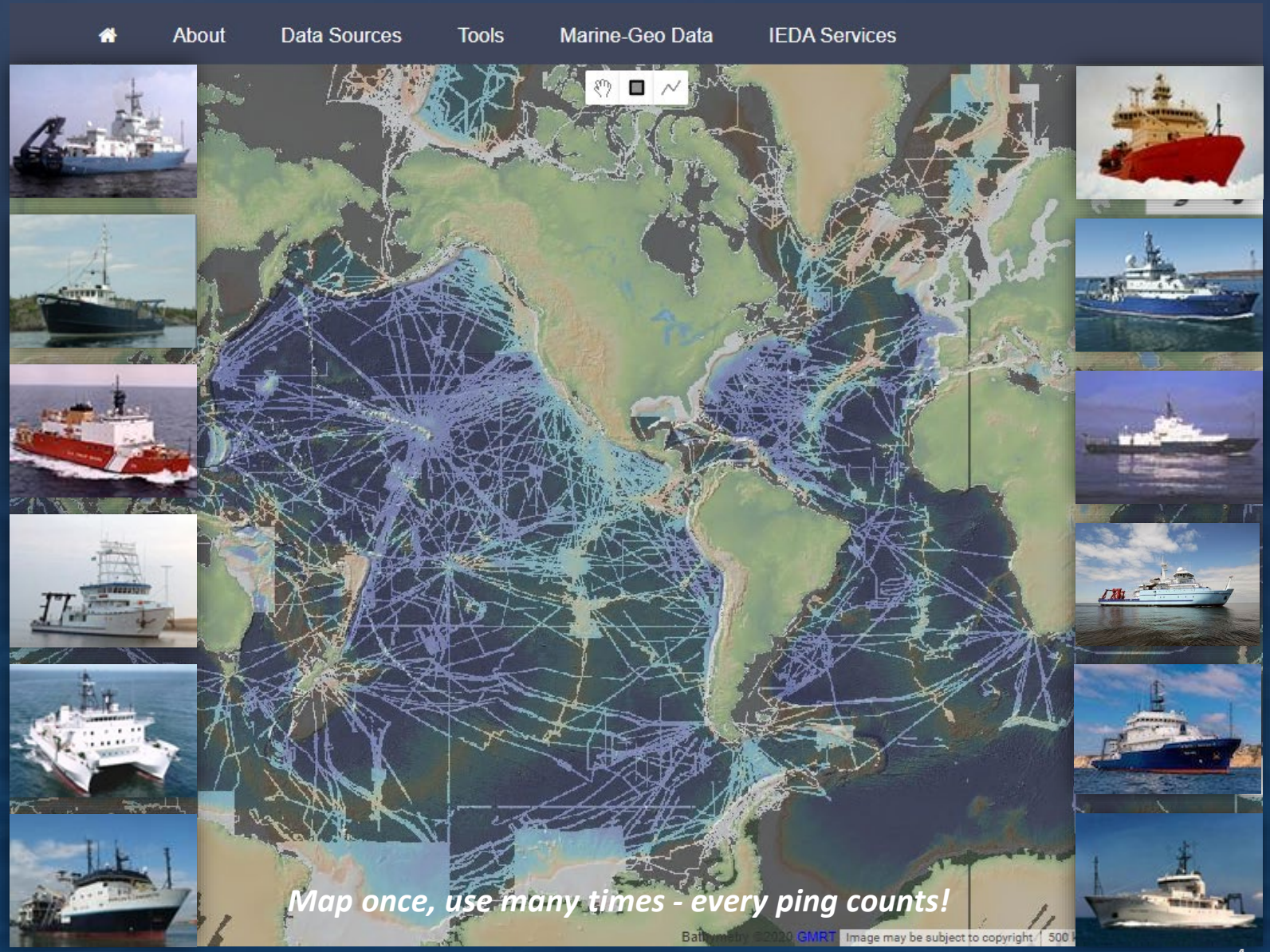
Website: mac.unols.org

Help desk: mac-help@unols.org

Wiki: github.com/oceanmapping/community/wik

Mapping Systems in the U.S. Academic Fleet

- USARF vessels with MBES
  - 11 Research Vessels
  - 1 USCG Icebreaker
- 15 Kongsberg systems
  - EM710 / EM712
  - EM302
  - EM122 / EM124
- 2 Reson shallow systems
- RCRVs under construction
  - EM304/EM2040



Kongsberg Systems in the U.S. Academic Fleet

Ship	**System(s)**	**Gondola**	**Arrays**	**Life Cycle**	**MAC Visits** (Most Recent)
Atlantis	**EM124**	Y	2021	Early	SAT* (2021), QAT* (2022)
Healy	*EM122*	N	2010	Late	ANT, QAT* (2022)
Kilo Moana	EM122 / EM710	N	2012	Late	ANT, QAT* (2022)
Marcus G. Langseth	EM122	Y	2007 (TX) / 2010 (RX)	Late	ANT, QAT* (2020)
Nathaniel B. Palmer	EM122	N	2015	Mid	SAT, ANT, QAT (2015)
Neil Armstrong	*EM122* / EM710	N	2016	Mid	SAT, QAT* (2020)
Roger Revelle	EM124 / EM712	Y	2020	Early	SAT*, QAT (2020)
Sikuliaq	*EM302* / EM710	N	2014	Mid	SAT, QAT* (2022)
Sally Ride	**EM124** / EM712	N	2016	Mid	SAT (2021), QAT (2021)
Thomas G. Thompson	*EM302*	*N*	2018	Mid	SAT, QAT* (2021)

*Indicates remote support

Underline = recent install (2021)

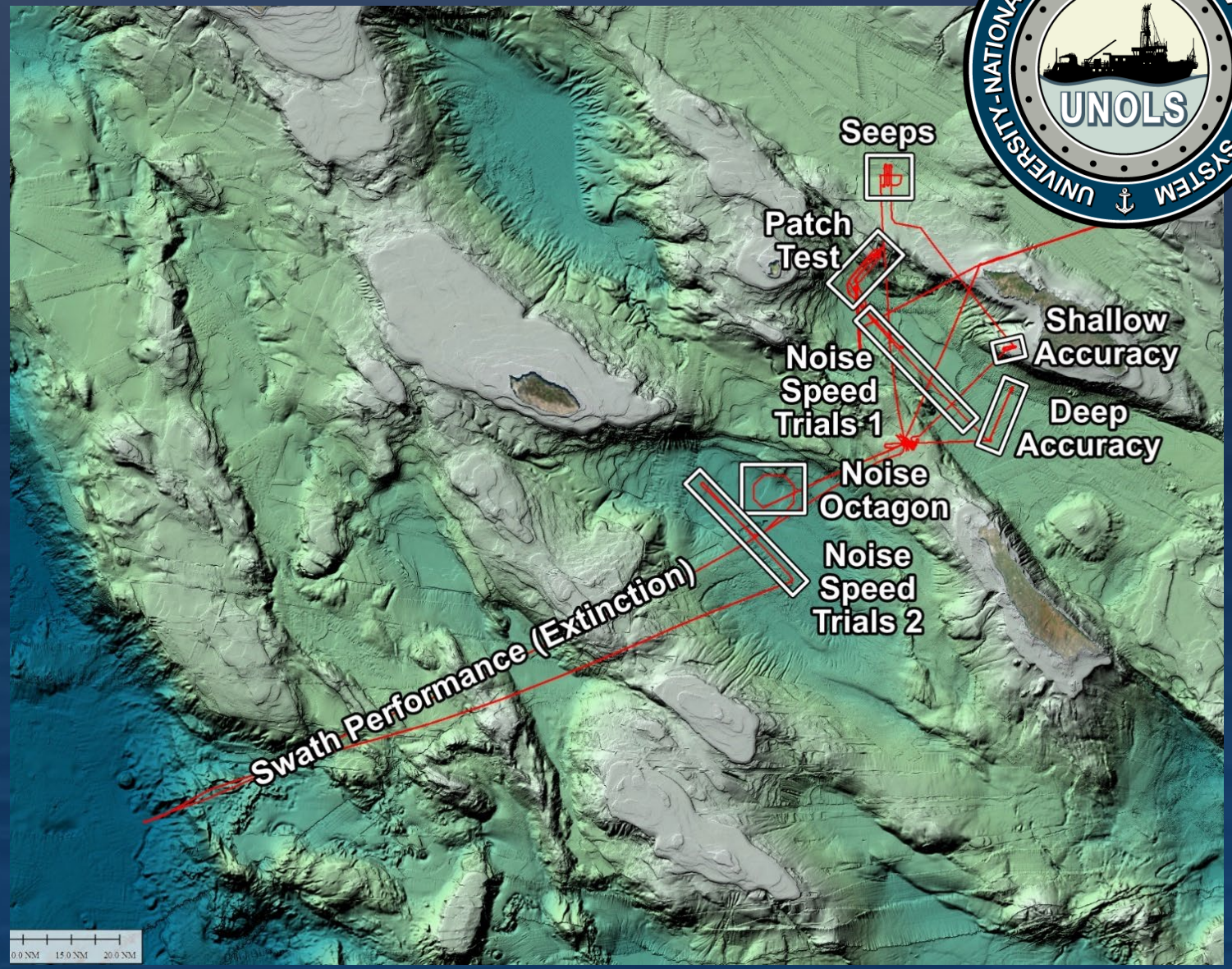
Italic = pending replacement (2023+)

Green = visited in last two years

System Performance Testing

SAT and QAT procedures include:

1. Geometry & Configuration
2. Calibration (‘patch test’)
3. RX noise testing
4. Swath accuracy
5. Swath coverage (extinction)
6. Impedance testing
7. Water column evaluation
8. BS normalization
9. Reporting



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SAT / QAT Checklist

Standardized procedures in order of priority

Collaborative planning → data collection → follow-up

Multibeam Advisory Committee
Mapping System SAT/QAT Checklist

Roger Revelle EM124 / EM71
San Diego, October 2020

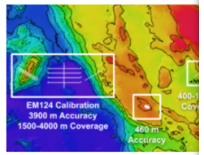
General

Shared documents for RR 2020 SAT plan

Revelle IMTEC survey docs

MAC geometry review

MAC assessment tools in development

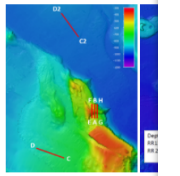


Notes for next planning call

1. Vessel offset review and SIS/Sea
2. Updated reference surface survey
   a. Added reference lines for
   b. Added 460 m site
3. Coverage line and transits may p
   different line)
4. Expectation for PHINs calibration
5. Marine forecast and early predicti
6. MAC: provide updated noise test
7. MAC: provide crossline settings
8. MAC: provide data trimming proc
   a. Tested with the latest SIS

MAC: Finalize/share setti
additional accuracy sites

Update 2020/10/08: Calib
crosslines over existing r
folder: https://drive.googl



SAT/QAT Procedures

1. System geometry revie
   a. Vessel survey rev
   b. Configuration revi
      each change) in t
      i. Multibeam
         1. Mu
         2. TX
         3. TX
         4. Po
         5. Po
      ii. Position/at
         1. Po
         2. GN
         3. Mo
         4. Mo
         5. Po

MAC: Review survey/con

Detailed SAT and QAT reports for
Reports for similar testing aboard

Pre-SAT/QAT Planning

1. Vessel survey planning
   a. MAC guidelines for
      http://mac.unols.org
2. Initial system geometry r
   a. MAC and vessel pe
      interpretation of res
      configurations, mair
      sensor reference fra
   b. This is a fundament
      error; this process i
      guidelines noted ab
   c. The initial review of
      ambiguities with the

RR: Provide vessel survey(
and position/attitude systen

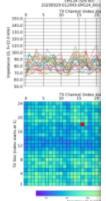
3. Develop test plan
   a. MAC and vessel pe
      desired ports of call
   b. MAC develops mor
   c. MAC and vessel pe
      SAT/QAT operation

RR: Use previously shared
Overview:
1. EM712
   a. Calibration (
   b. Shallow Acc
   c. Deep Accura
   d. Swath cover
2. EM124
   a. Calibration (
   b. Shallow Acc
   c. Deep Accura
   d. Swath cover

to confirm res
PHINS attitud
b. Access to Ko
the accuracy
c. If time allows
accuracy site

4. MAC will provide / is
   a. IMTEC surve
   b. Accuracy cro
   c. Survey line pl
      system to sat
   d. Coverage tes
   e. BIST plotter u

5. Initial dockside BIST
   a. Note SIS 5 bu
      update the pl
   b. EM124 TX Cl
      colorbar and



c. EM124 RX C
file… need to
Noise initial r

9. Seapath: antennas = RR-41 and RR-47

Vessel survey review (2020/10/12)

1. Initial offset review sheet with notes/questions from survey report (contact if you don't have access)
   https://drive.google.com/file/d/1Pypu0M4ONFozQ0eznyUZTcGTRpM_Rbkh/view?usp=sharing
2. Need to clarify in report / review sheet above:
   a. Antenna offsets for Seapath, PHINS, and any real time correction services
      i. Surveyed points
      ii. Phase centers
3. Report should be updated with following:
   a. Pictures/diagrams of all surveyed points
   b. Clarification of 'measured points' on Seapath MRU and PHINS IMU and sources for calculations of 'centers' for each
      i. Seapath MRU ref point is on bottom face of MRU housing
         1. Is MRU installed with +X axis toward the bow?
   c. Master ref plate angles are used for PHINS angles but not Seapath MRU angles; what was surveyed on MRU to produce angles?
   d. Clarification of array survey points: are results the center of the frames (i.e., after leveling), or on the center of the array face? Kongsberg requires center of array face for configuration
   e. Add labels for view direction and transducers for clarity in gondola diagram
   f. Report all angles in decimal degrees; keep descriptions of rotations
   g. Waterline estimate or Z values of draft marks in final reference frame for direct calculation of waterline underway and implementation in SIS

Notes from 2020/10/08 planning call

All: update these notes with any other thoughts/concerns/clarifications

1. Initial RX Noise BIST testing should be prioritized as soon as ship reaches 500+ m, ideally 1000+ m
   a. Machinery lineup is all new; initial testing is to confirm no limitations on data quality for calibration and accuracy testing, provide time for troubleshooting ahead of SAT items
   b. More detailed speed and heading noise tests can be conducted as sea state / other operations allow (ideally, calm for noise vs speed, 3-5+ ft swell for heading test)
2. Order of EM124 and EM712 calibrations is flexible, depending on weather windows, etc.
3. Follow-up needed:
   a. Is it correct to assume Seapath is the primary position, attitude, and attitude velocity feed to EM124/EM712, with PHINS strictly as a backup? If PHINS is working (received by SIS without errors) and logging in the .kmall files, then the calibration data will provide angular offsets for both Seapath and PHINS motion sensors in SIS. However, the cal and accuracy data will not be 100% representative for the PHINS performance because attitude velocity is still from the Seapath. If the PHINS is used in the future as the sole/primary feed, a calibration should be run

2

Post-SAT / Pre-SVC Review (Discussion)

These topics help to ensure an up-to-date understanding of the mapping system and adequate/complete plan for testing, taking into consideration any changes since the SAT or last QAT.

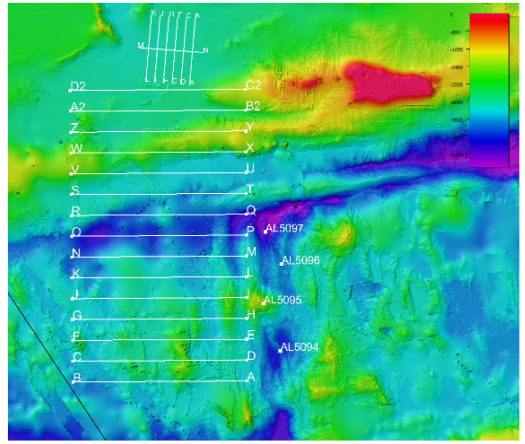
1. What has changed since the last MAC visit or review?
   a. Any sensors replaced, removed, and/or reinstalled?
   b. Any damage or repairs?
   c. Any upgrades to hardware or software?
2. Is there any new documentation?
   a. Updated survey of vessel a
   b. Updated guidance or servi
   c. Any performance notes fro
3. Is there any recent data that can b
   a. Ideally, these data would b
      profiling; data covering a w
      depth as an early indicator
   b. Any recent 'problem' datas
      as appropriate

Recommended/Prioritized P

1. **EM124 updates**
   a. Kongsberg has released s
      issues; ***the EM124 should***
      i. Download links and
      https://github.com/d
   b. Known issues with recent S
      i. https://github.com/d
   c. Related: Update to Sound
      i. https://www.hydroff
2. **Dockside testing and review**
   a. Prior to departure, the MA
      i. Seapath and EM12
      ii. line plan review wit
      iii. pre-cruise system t
3. **Antenna calibration**
   GNSS antenna baseline calibratio
   a. Seapath antenna calibratio
      i. Antenna calibration
      at least two hours p
      antenna baseline, a
      average baseline re
4. **DONE! Swath coverage testing**
   Swath coverage data are collected
   Additional time should be planned
   perpendicular to contours for estat
   potential complications (e.g., noise
   follow the MAC instructions for sw

   The 2021 SAT covered a limited d
   the utility of this dataset for covera
   the guidelines in the SAT report (re
   and verify proper automatic mode
   runtime parameters) is available

6. **DONE! RX noise testing (data collected 20 July 2022)**
   For Kongsberg systems, RX Noise and RX Spectrum Build-In Self-Test (BIST) testing assesses the vessel, machinery, and flow noise characteristics as perceived by each multibeam echosounder; data acquisition generally follows the MAC approach for routine noise testing.
   a. **Tested in 2021 (worthwhile to redo and compare to 2021 results)**
      i. **Noise vs. speed** testing is performed over a wide range of speeds in calm seas; with typical engine configurations online, the vessel starts drifting and increases speed in 1-2 kt increments up to maximum speed (~1-2 hours, depending on number of speed steps and time to settle at each speed)
      ii. This test should be repeated underway to ensure there have been no major changes to the vessel's noise environment since the SAT
      iii. **See 'Noise vs. Speed' section under RX Noise Logging**
   b. **Untested:**
      i. **Noise vs. heading** testing is performed at eight headings (separated by 45°) relative to the prevailing swell; these tests are conducted at typical speed and engine configuration for normal mapping operations (~2 hours, depending on sea state and time to settle at each heading)
      ii. This test requires deep water (>1000 m) and a slightly elevated sea state (3-5 ft or greater) to generate swell impact noise and bubble sweep, while remaining within the range of sea states where mapping ops would be expected/accepted
      iii. **See 'Noise vs. Azimuth' section under RX Noise Logging**
7. **PROPOSED: Overnight mapping / test survey in poorly mapped areas**



8.
   a. There are large unmapped tracts nearby that would provide a useful demonstration survey and contribute to the global grids (blurry areas with wild single beam artifacts)
   b. This can arguably be considered a both test survey and/or 'routine mapping' - so please check that it would not run afoul of your permits in Cayman waters
      i. Waypoint (B) remains just inside the Cayman EEZ; please double check on board
   c. The survey plan is meant for simplicity to pick up on any lines that are close to your dive sites
   d. Lines are 80 km long, or just over 5 hrs at 8 kts; it might be possible to run one pair of adjacent lines west and then east per night (speeding up to 10 kts if necessary)
   e. Line spacing is conservative (10000 m) for lots of overlap even in the shallowest parts; this also helps with refraction correction later down the pipeline (no processing expected on board)
   f. At least one XBT (or XCTD, XSV, or CTD - any real sound speed profile) should be collected throughout the survey each night, preferably near the middle of the survey area

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Vessel Offset Survey Reports

Data quality depends on correct configuration

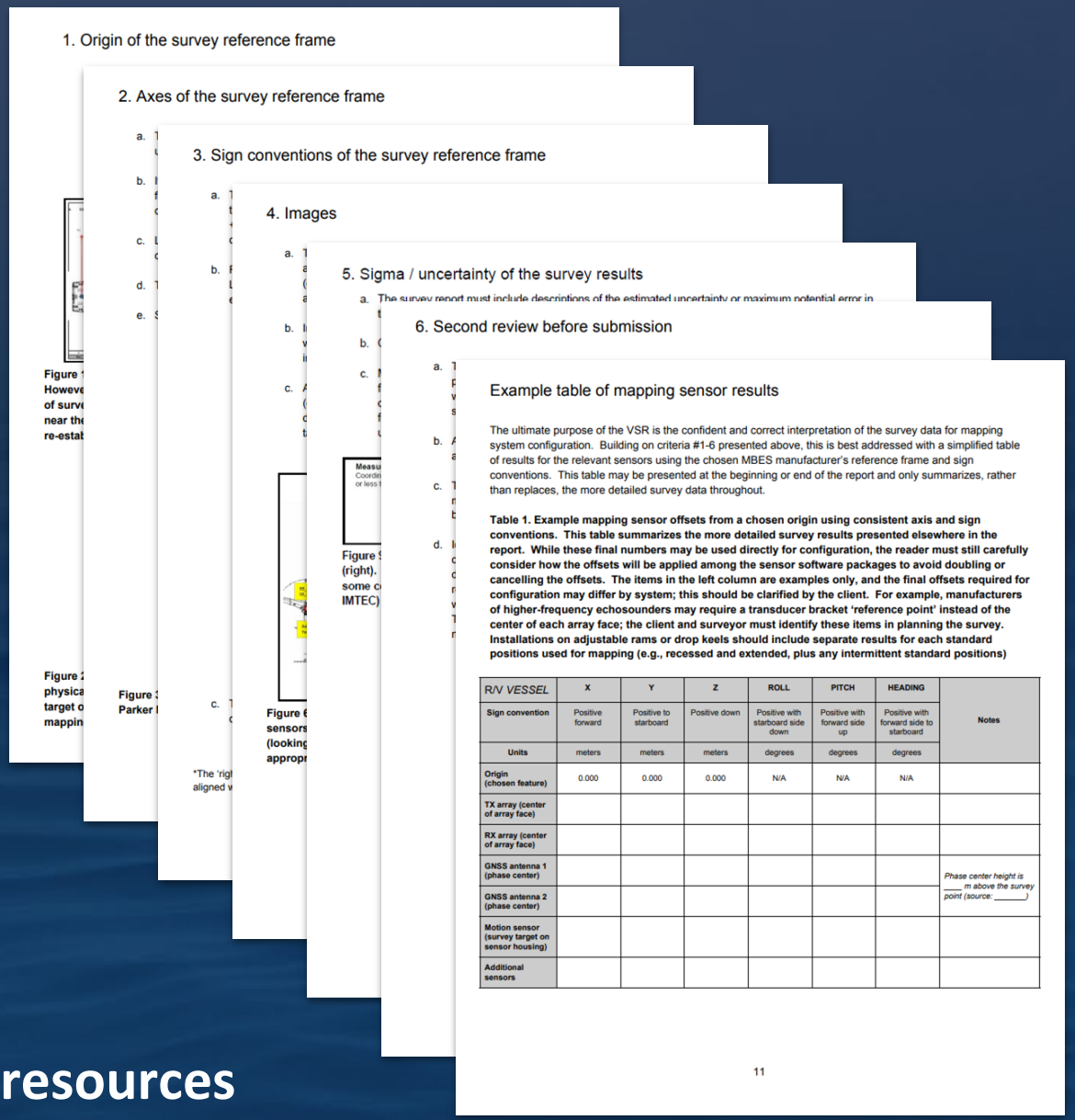
Vessel and sensor offsets must be clearly documented

Survey reports directly impact data quality for decades

Vessel / sensor offset survey reports **MUST** include:

1. **Origin** of survey reference frame
2. **Axes** of survey reference frame
3. **Sign conventions** of survey results
4. **Images** of surveyed points and sensors
5. **Sigma** / standard deviation or uncertainty
6. **Second review** before submission

Critical requirements for your surveyor!
Early discussion saves significant sea time!



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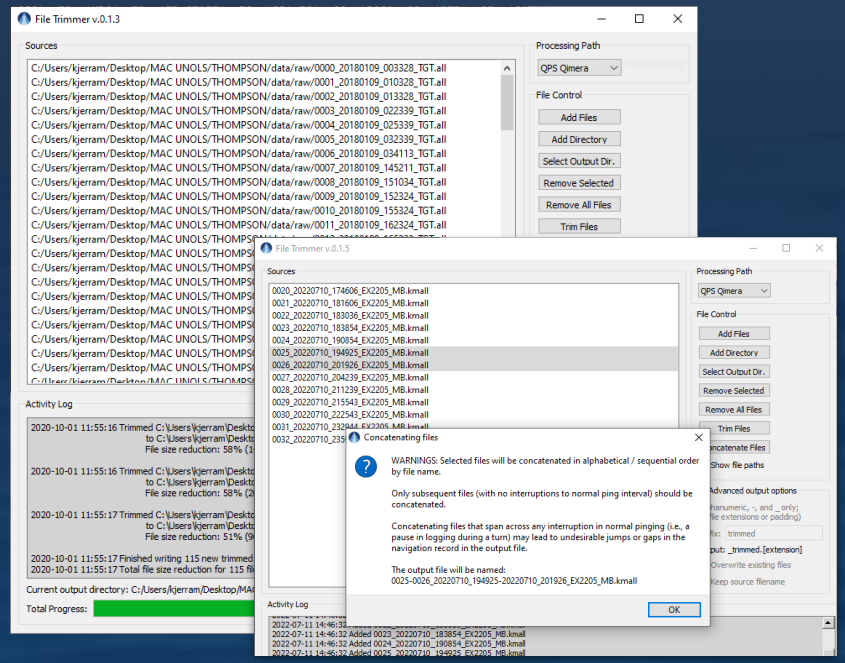
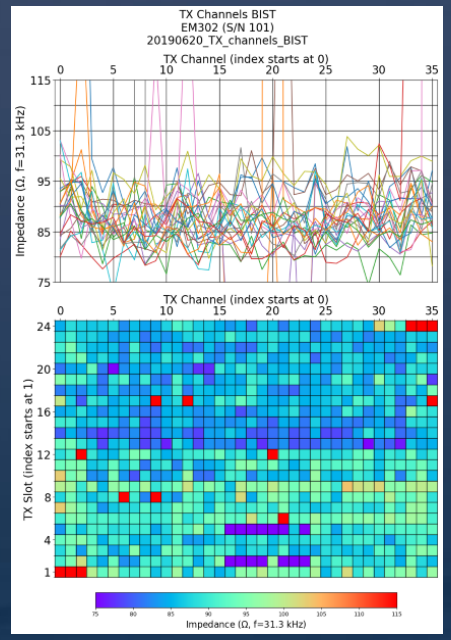
Assessment Tools

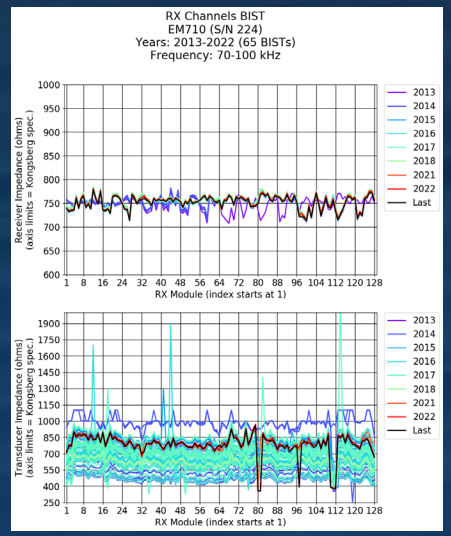
1. **File Trimmer**
2. **BIST Plotter**
3. Swath Coverage Plotter
4. Swath Accuracy Plotter



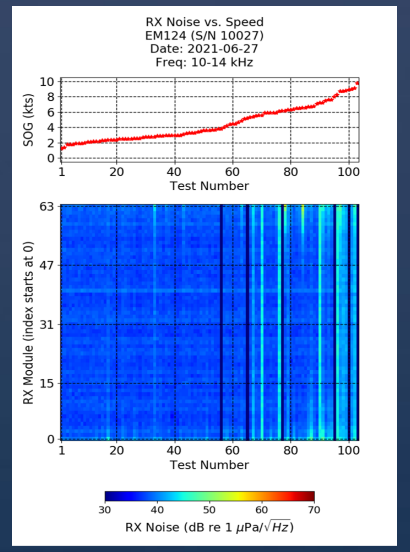
Reduce file size for translate to shore
Concatenate split files for special proc.

TX/RX Impedance History

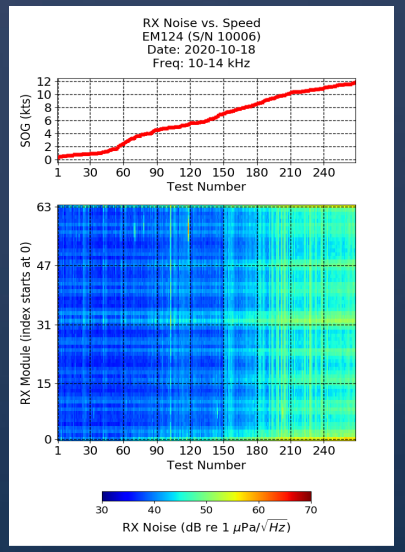




Vessel 1

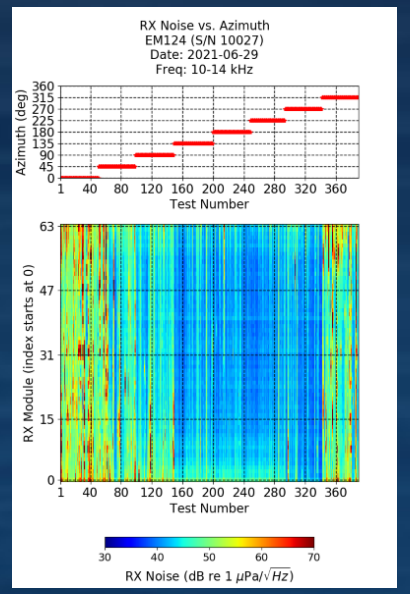


Vessel 2

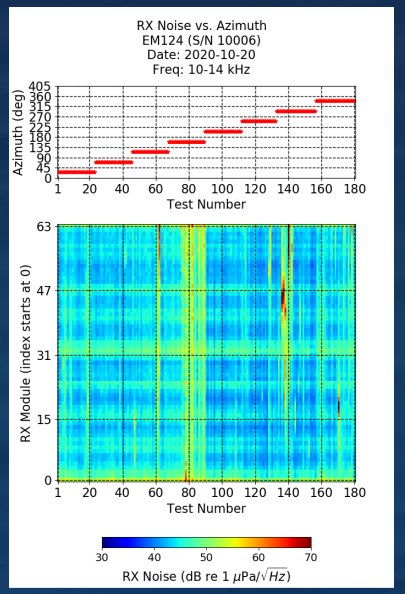


Noise vs. Speed

Vessel 1



Vessel 2



Noise vs. Azimuth (0° = into the swell)

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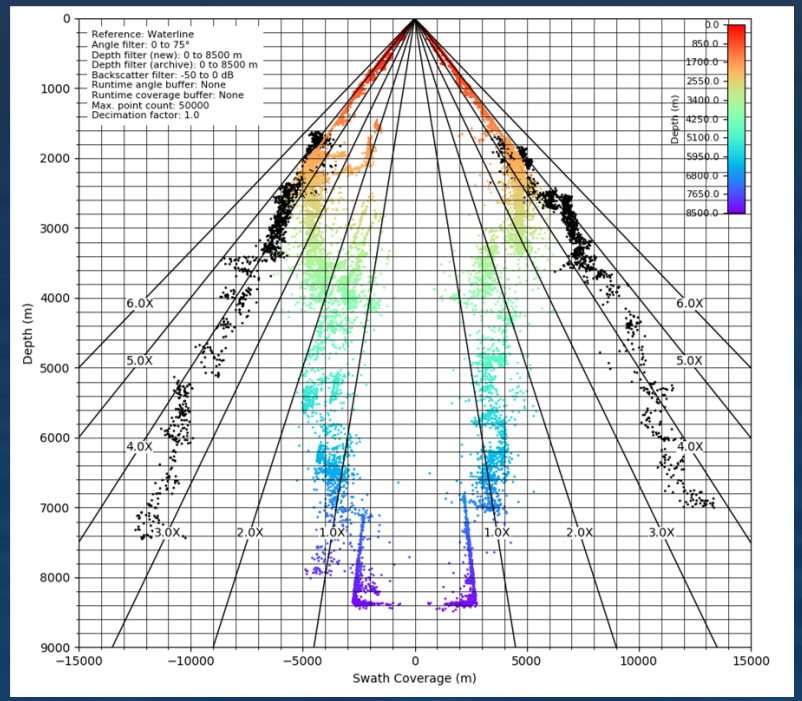
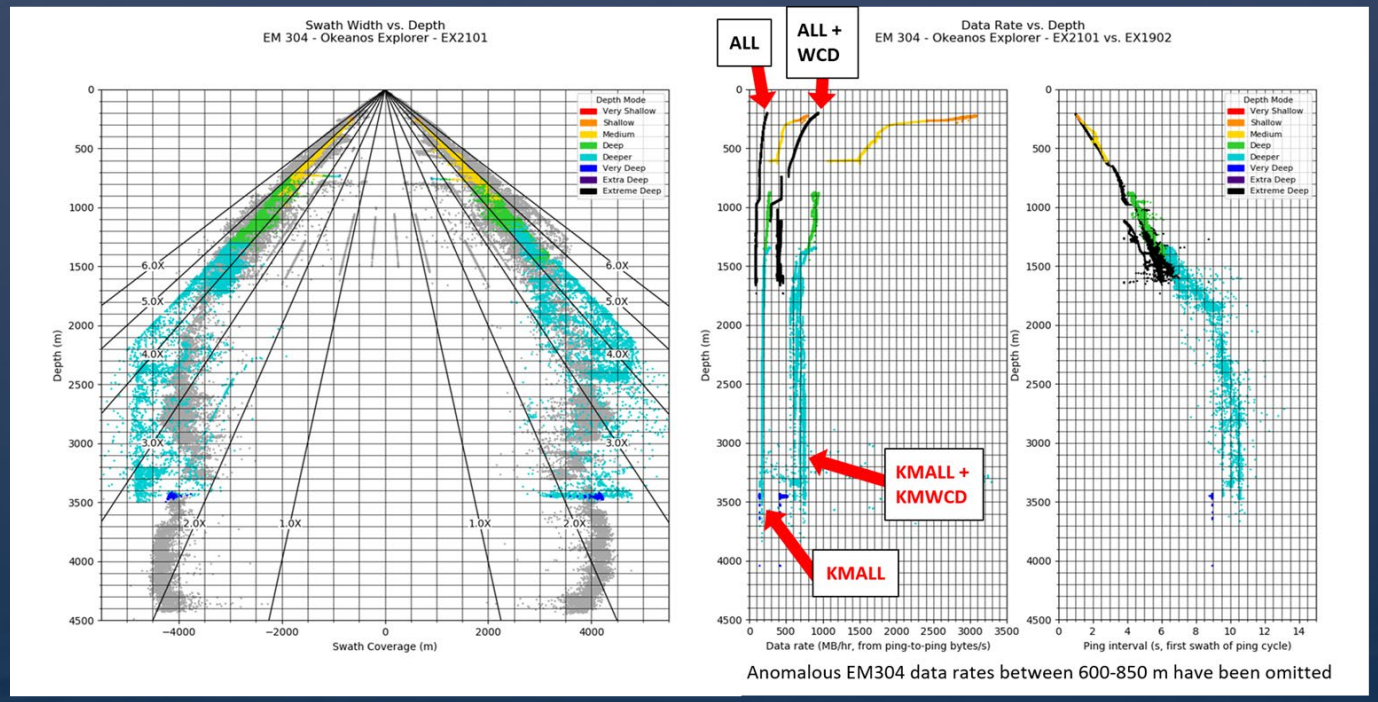
Assessment Tools

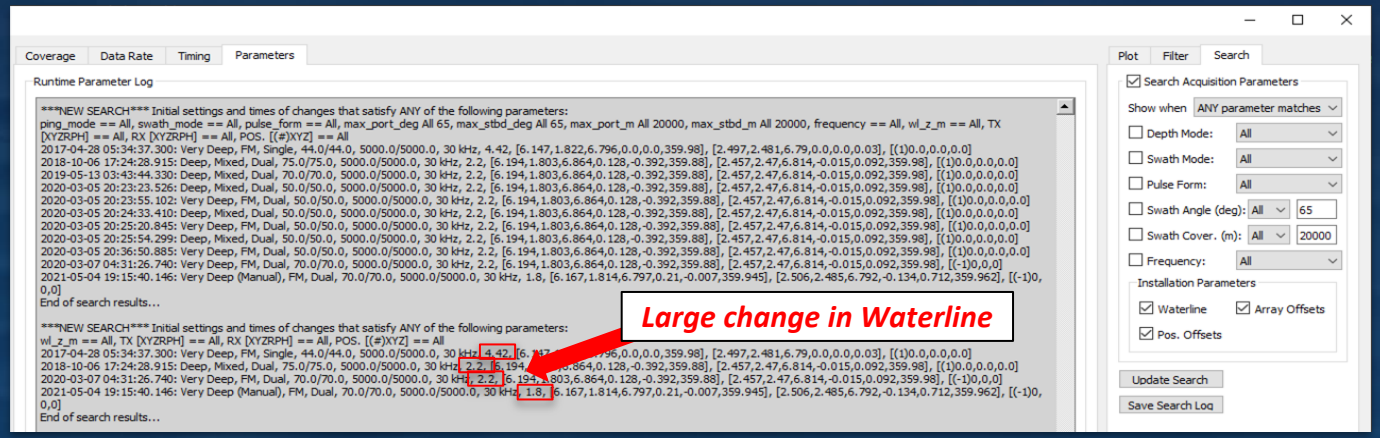
1. File Trimmer
2. BIST Plotter
3. **Swath Coverage Plotter**
4. Swath Accuracy Plotter

EM304 MKII vs. EM124 over Puerto Rico Trench





Swath coverage and data rates vs. depth



Runtime / Installation Parameter tracking

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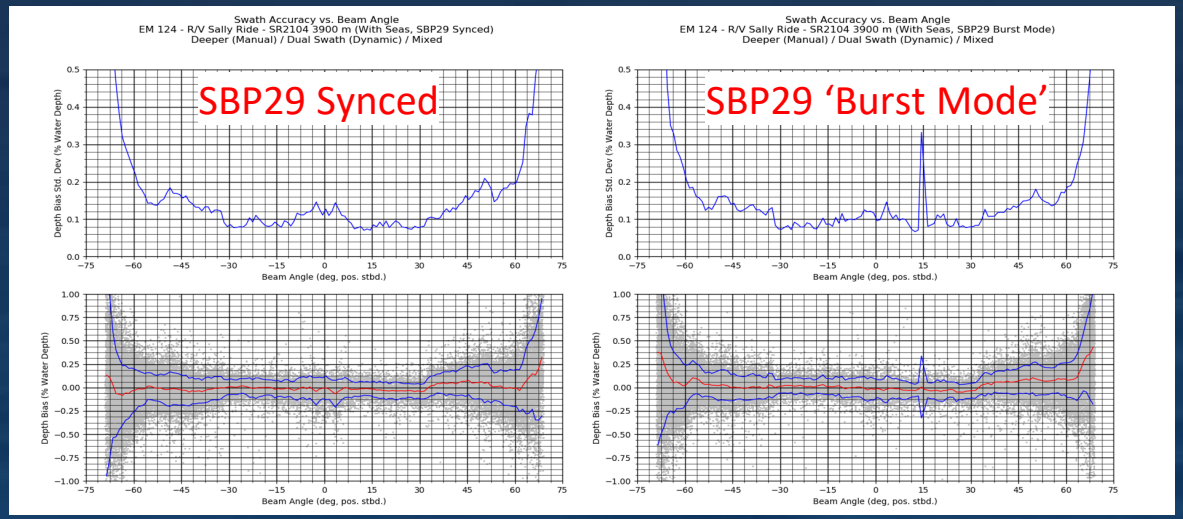
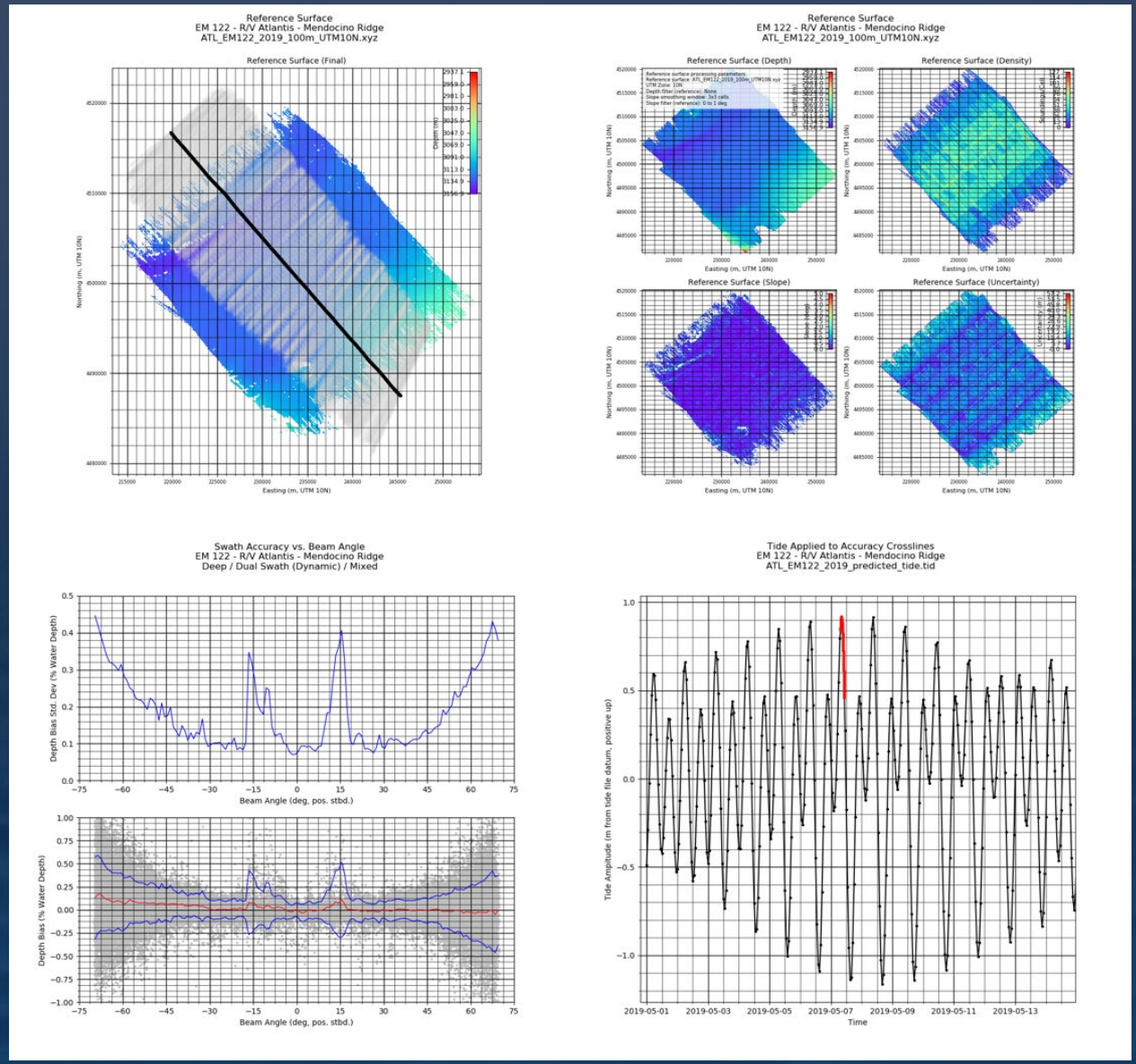
Assessment Tools

1. File Trimmer
2. BIST Plotter
3. Swath Coverage Plotter
4. **Swath Accuracy Plotter**

Swath accuracy vs. synchronization mode with other systems

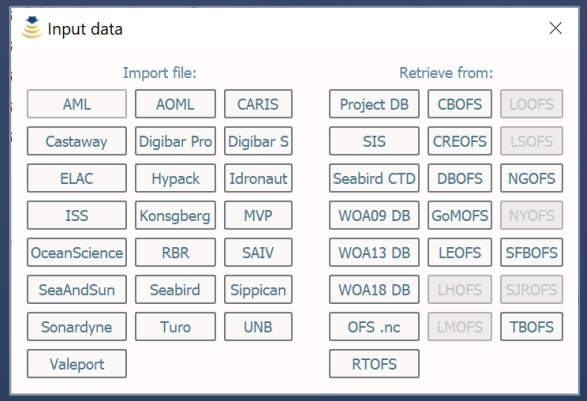


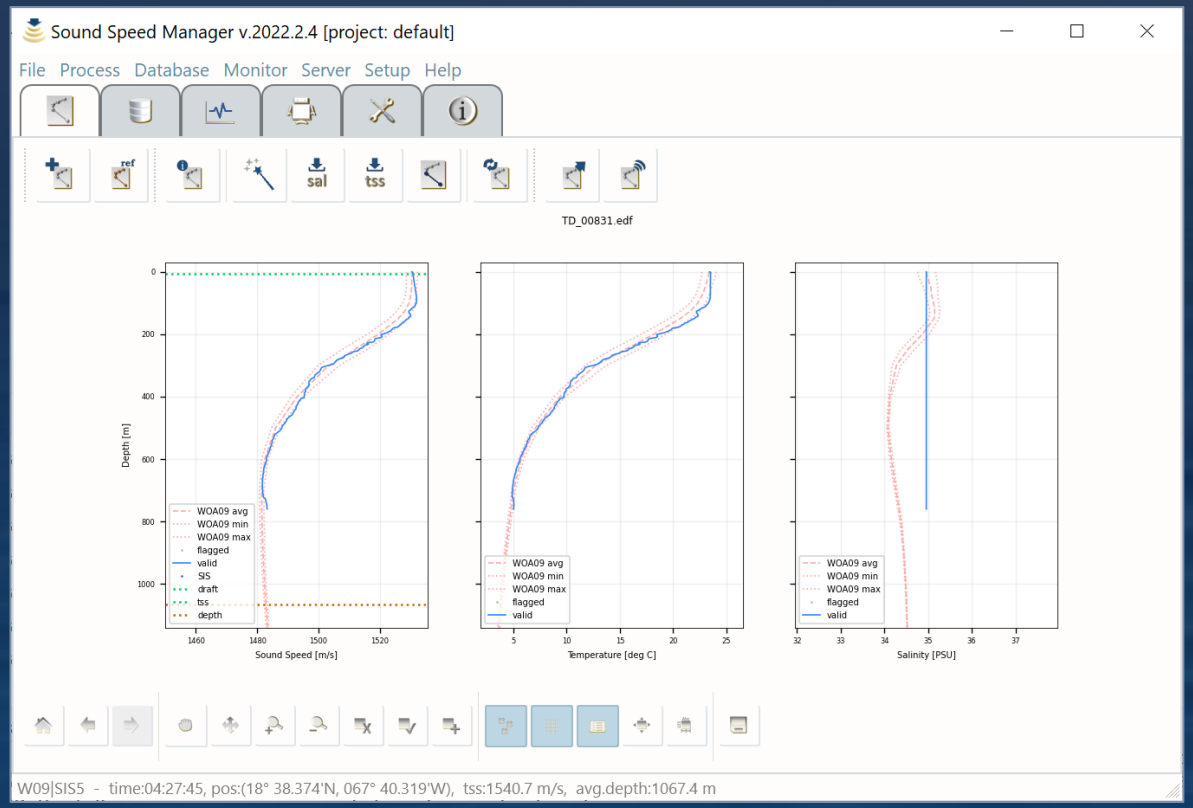


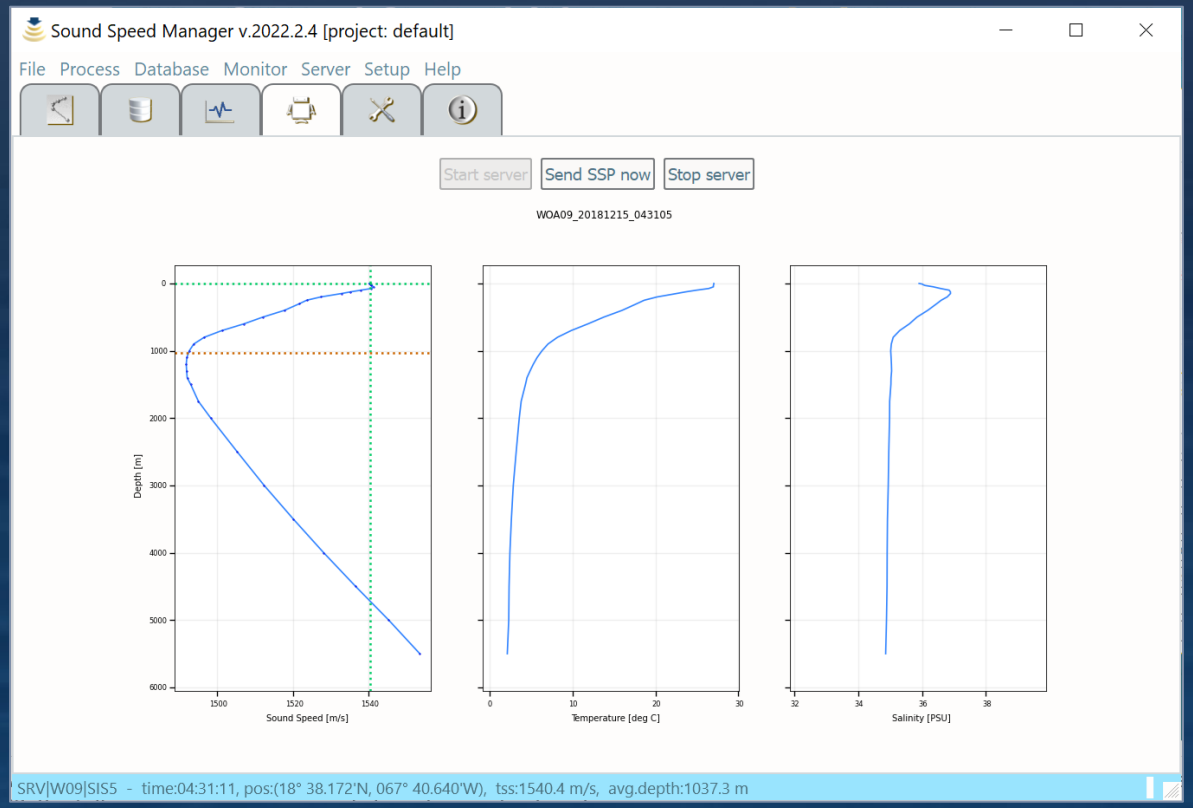
Swath accuracy testing with ref. surface and tide options

Sound Speed Manager

1. Added **World Ocean Atlas 2018**
2. Enhanced ***Server Mode***
3. Additional format support
4. Quick turnaround for new versions







NOAA: B. Gallagher, C. Zhang

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MAC Activities Since RVTEC 2021

Remote* and on-board support:

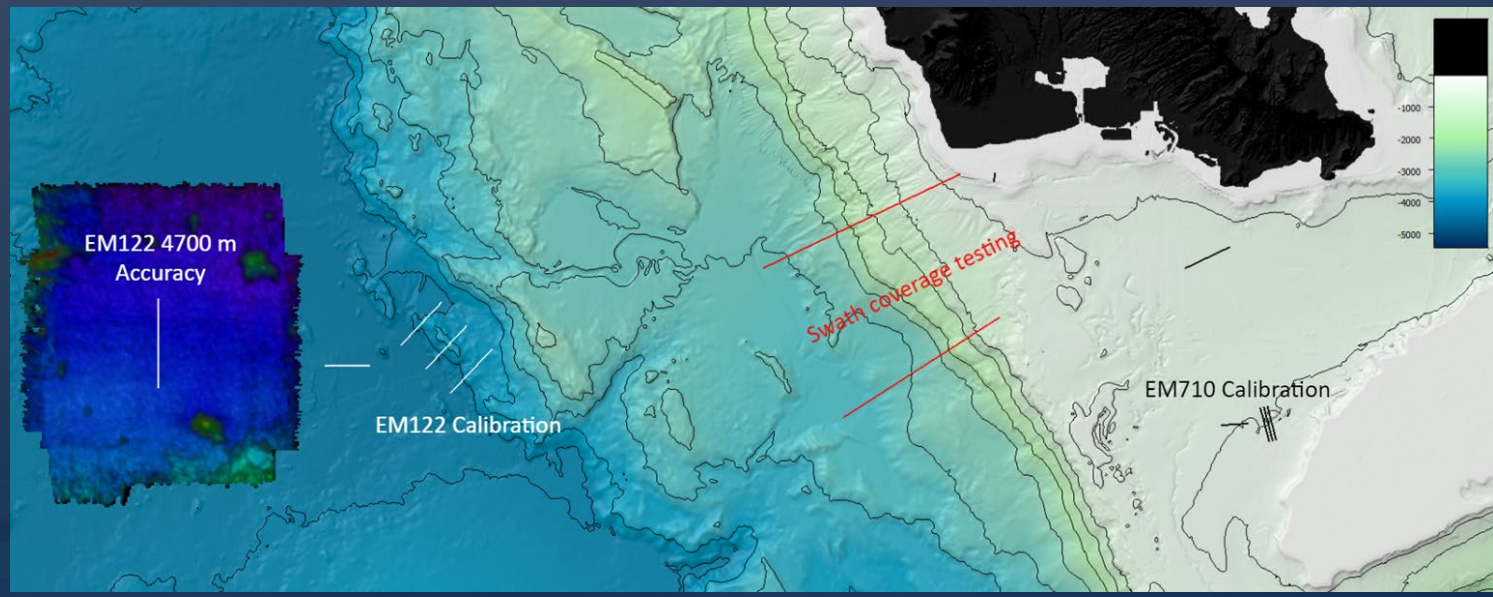
- *Atlantis* (post-SAT*)
- *Healy* (QAT*)
- *Kilo Moana* (QAT*)
- *Sikuliaq* (QAT*)

Related projects:

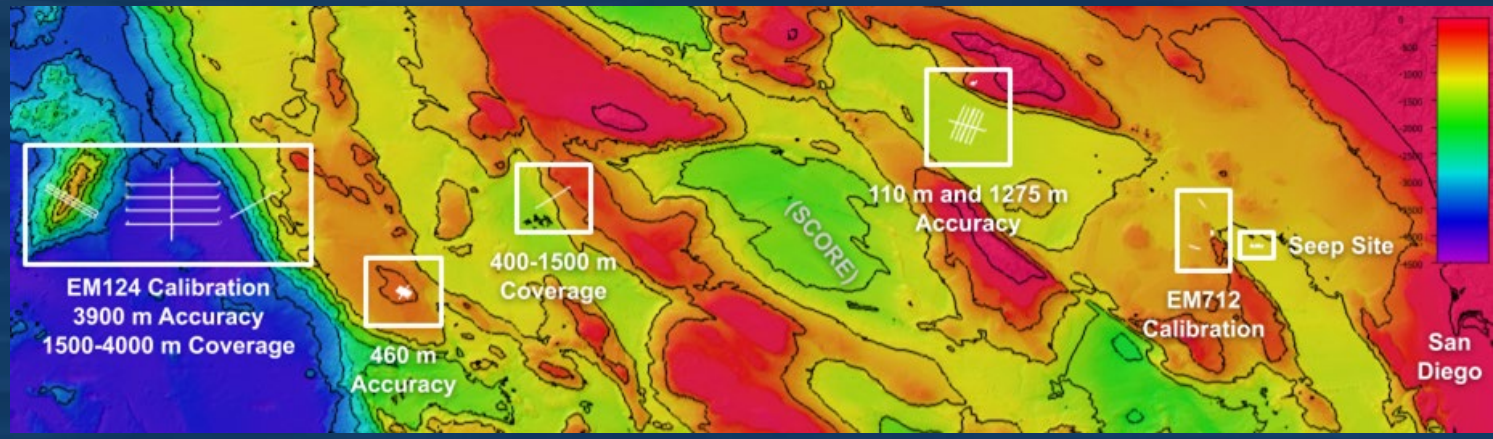
- Assessment tools
- SAT/QAT site database
- GMRT tiling package

Non-MAC testing / field work:

- *OceanXplorer* (QAT)
- iXBlue *DriX* (NA142)
- *Nautilus* (QAT)
- Saildrone *Surveyor* (various)
- *Okeanos Explorer* (various)



THANK YOU to technicians and managers for making remote support possible



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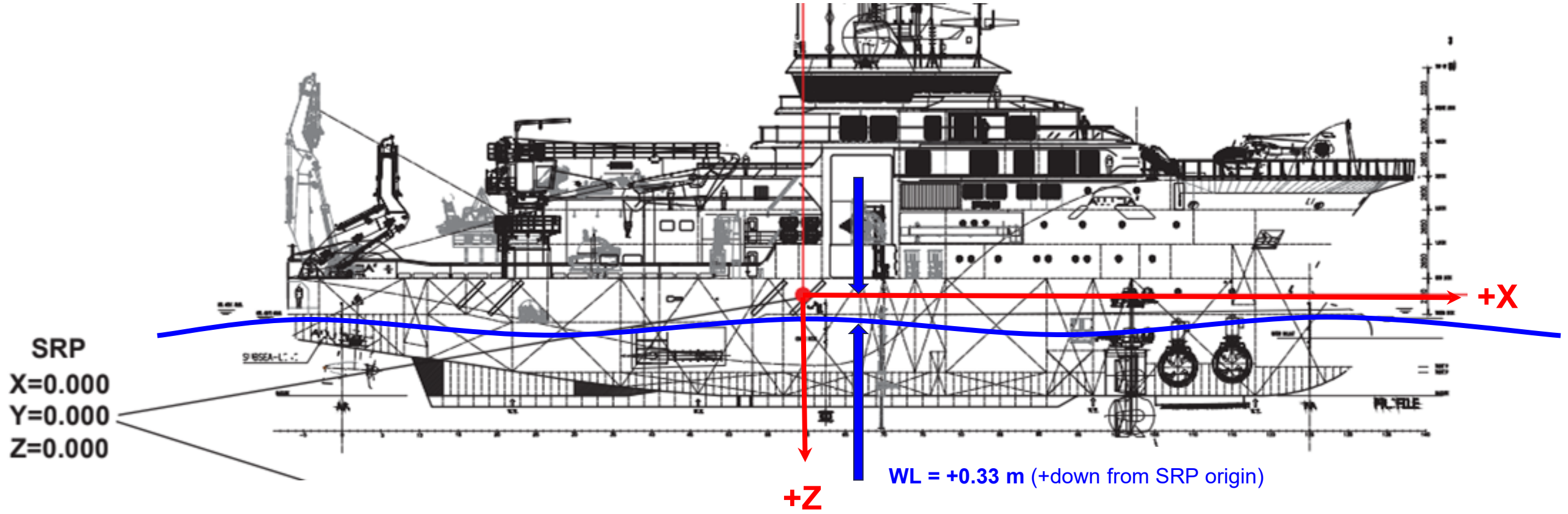
Takeaways from the Field 2021-22

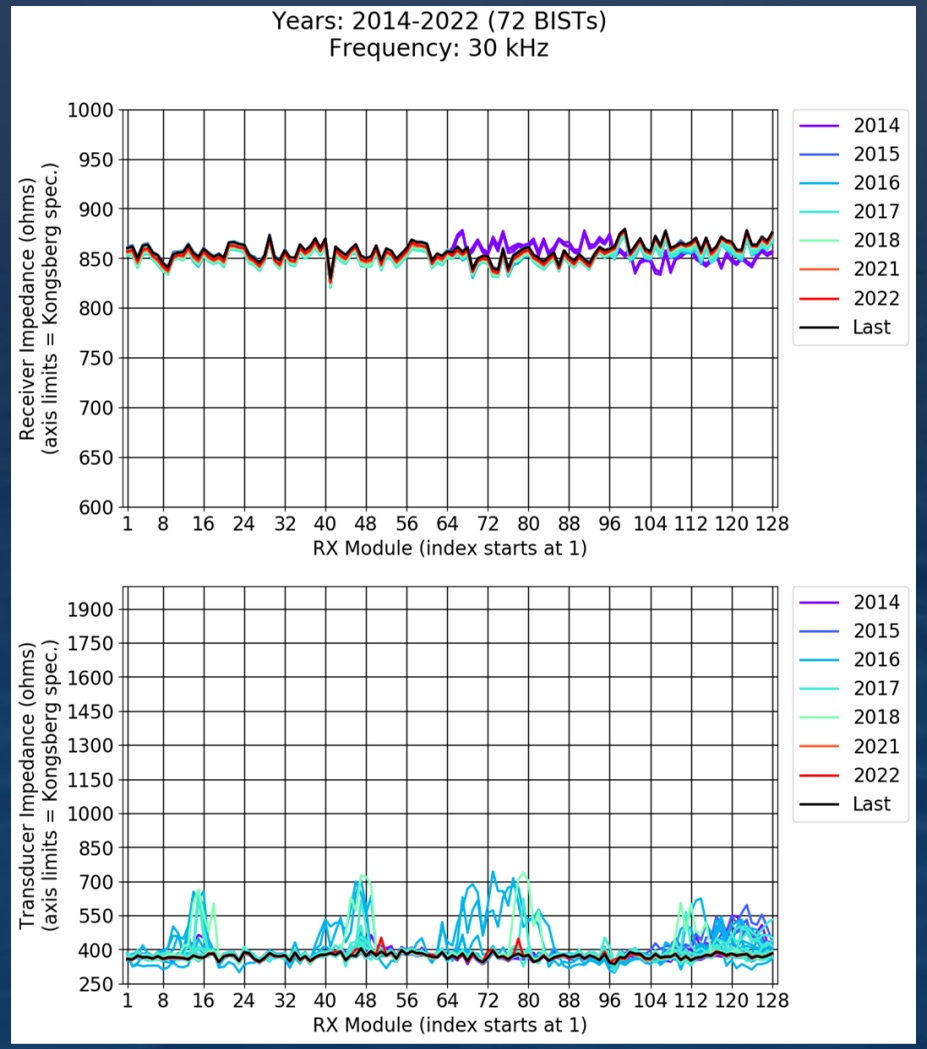
- Even the **best** survey reports can still be interpreted incorrectly
- **Waterline** remains a window of opportunity for large, persistent errors

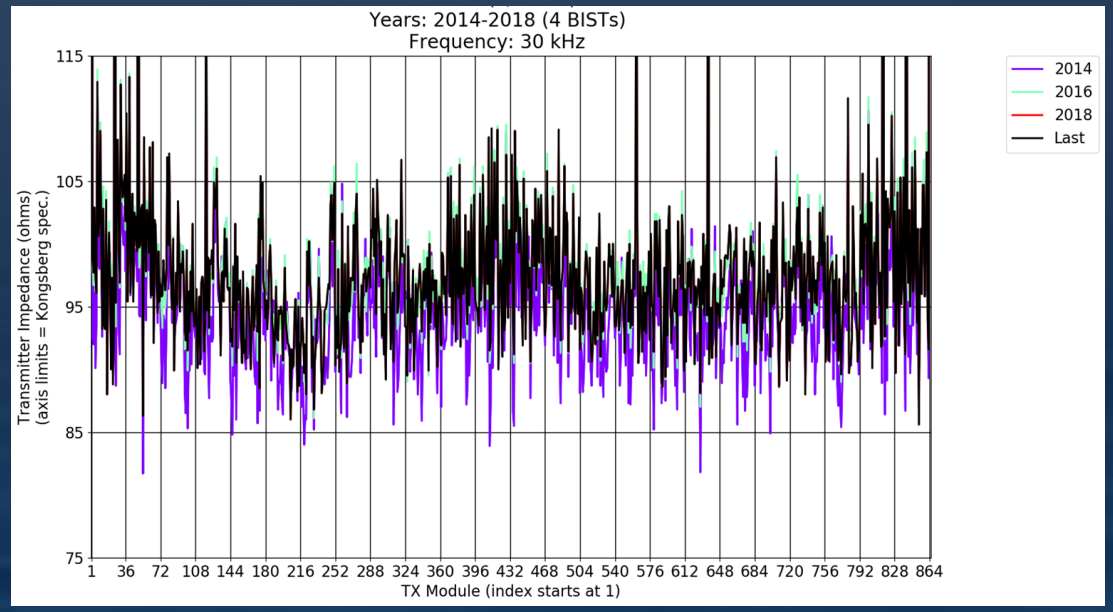


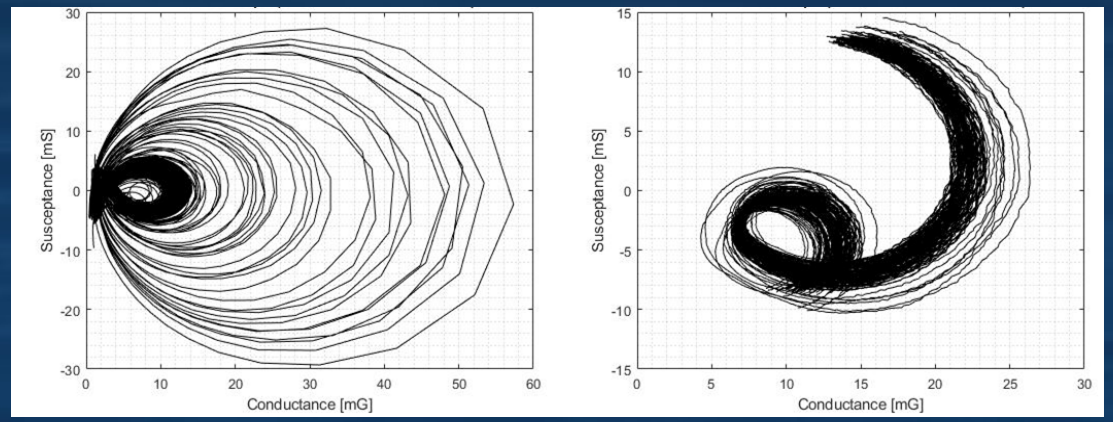
Background image adapted from ANKO

Takeaways from the Field 2021-22

- Routine BIST monitoring is extremely useful for tracking **general system health**
- **Direct impedance analysis** is critical; some element-level trends not reflected in BISTs

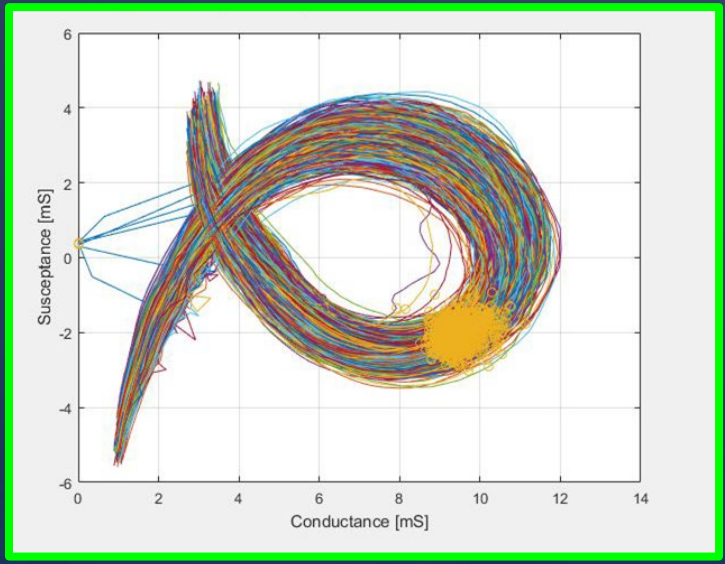




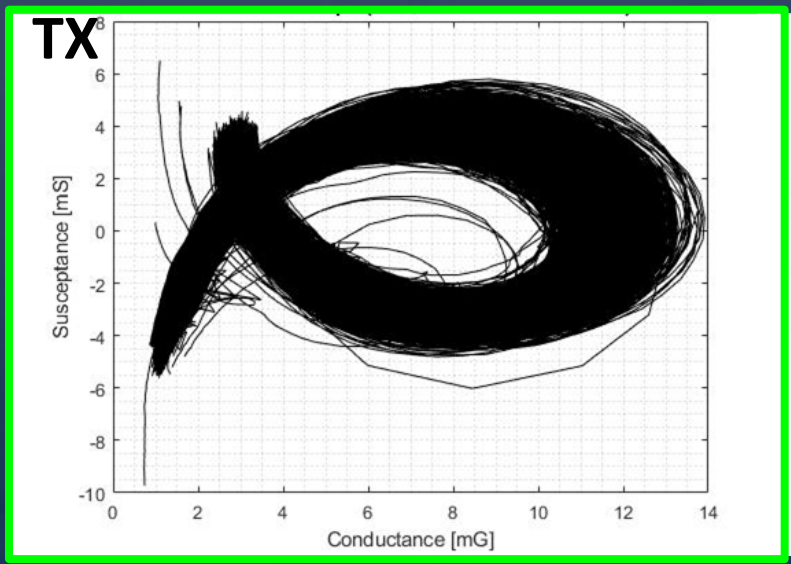


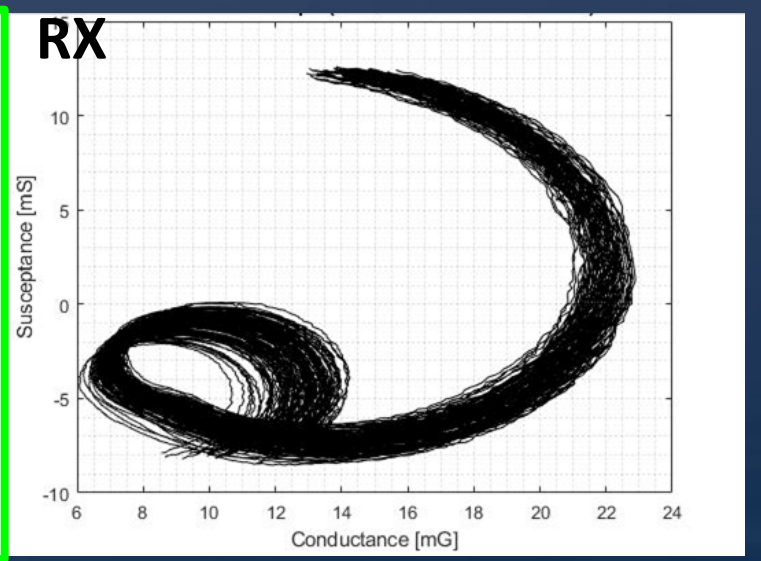
Takeaways from the Field 2021-22

‘Healthy’ EM302 TX (**Kongsberg**)

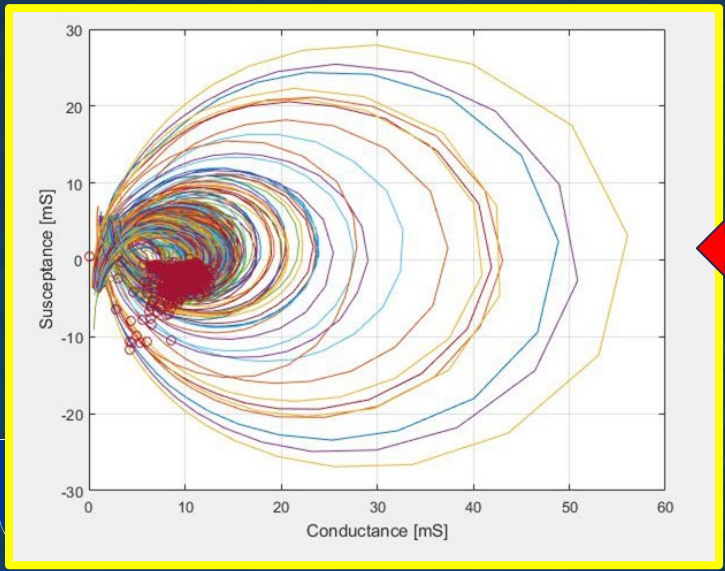


UNOLS EM302 (2020, 6 yrs)

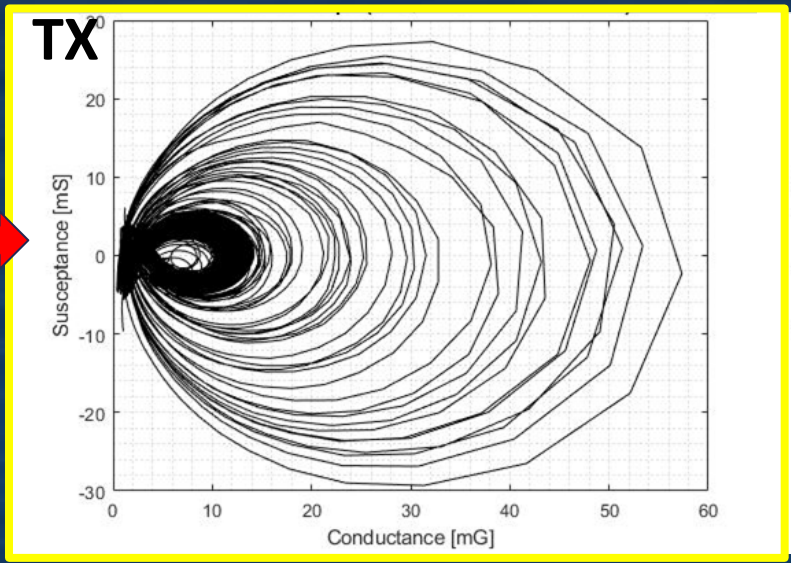


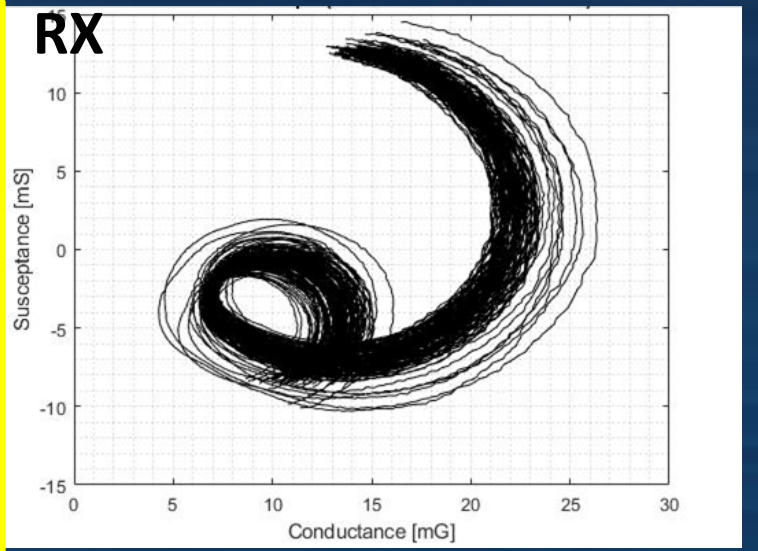


‘Failing’ EM302 TX (**NOAA**, 12 yrs)



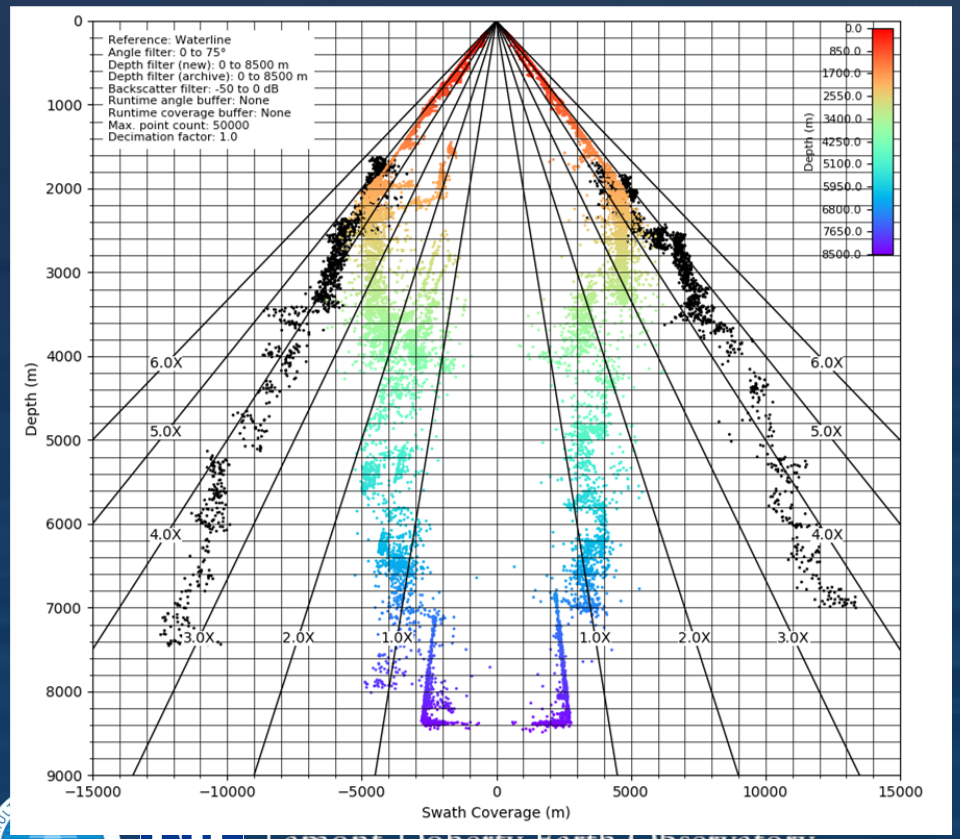
UNOLS EM302 (2022, 8 yrs)

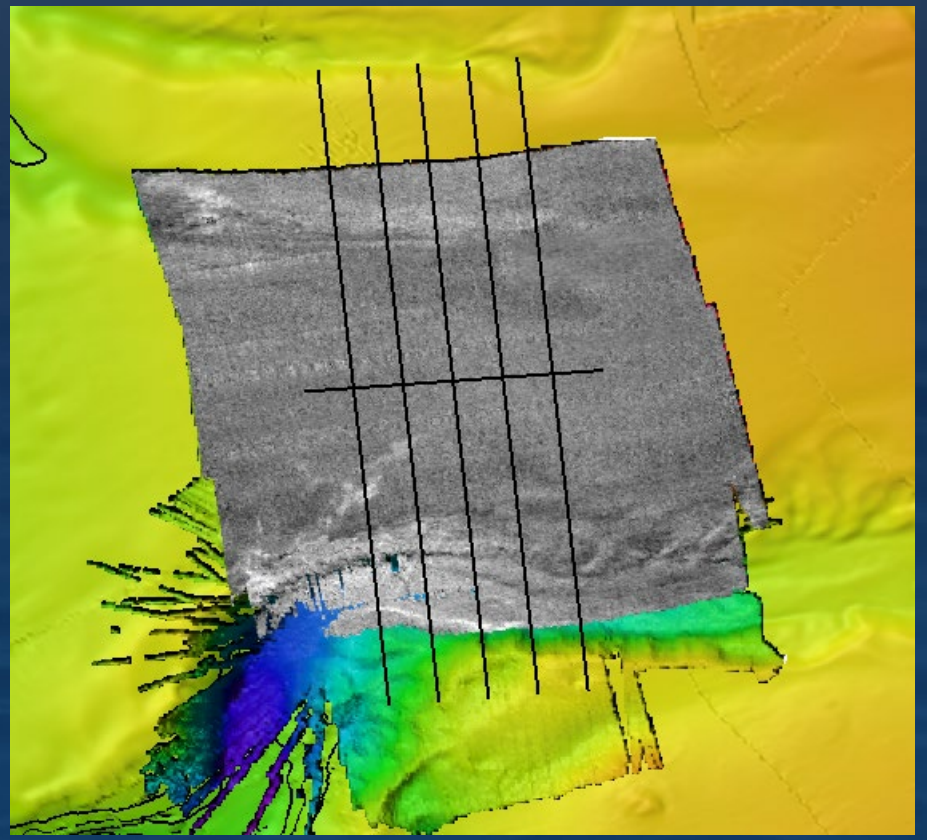


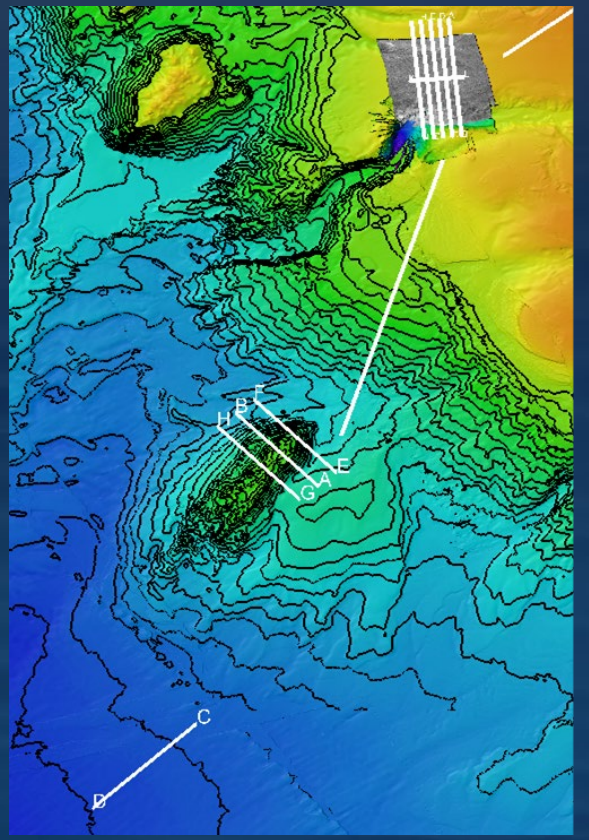


Takeaways from the Field 2021-22

- Value in using same test areas for yearly assessments and ‘apples to apples’ comparisons
- Test plans can be opportunistic and flexible, with limits
  - SAT/QAT steps can be readily dovetailed with other activities
  - Advance planning means efficient use of ship time, proven sites, and personnel

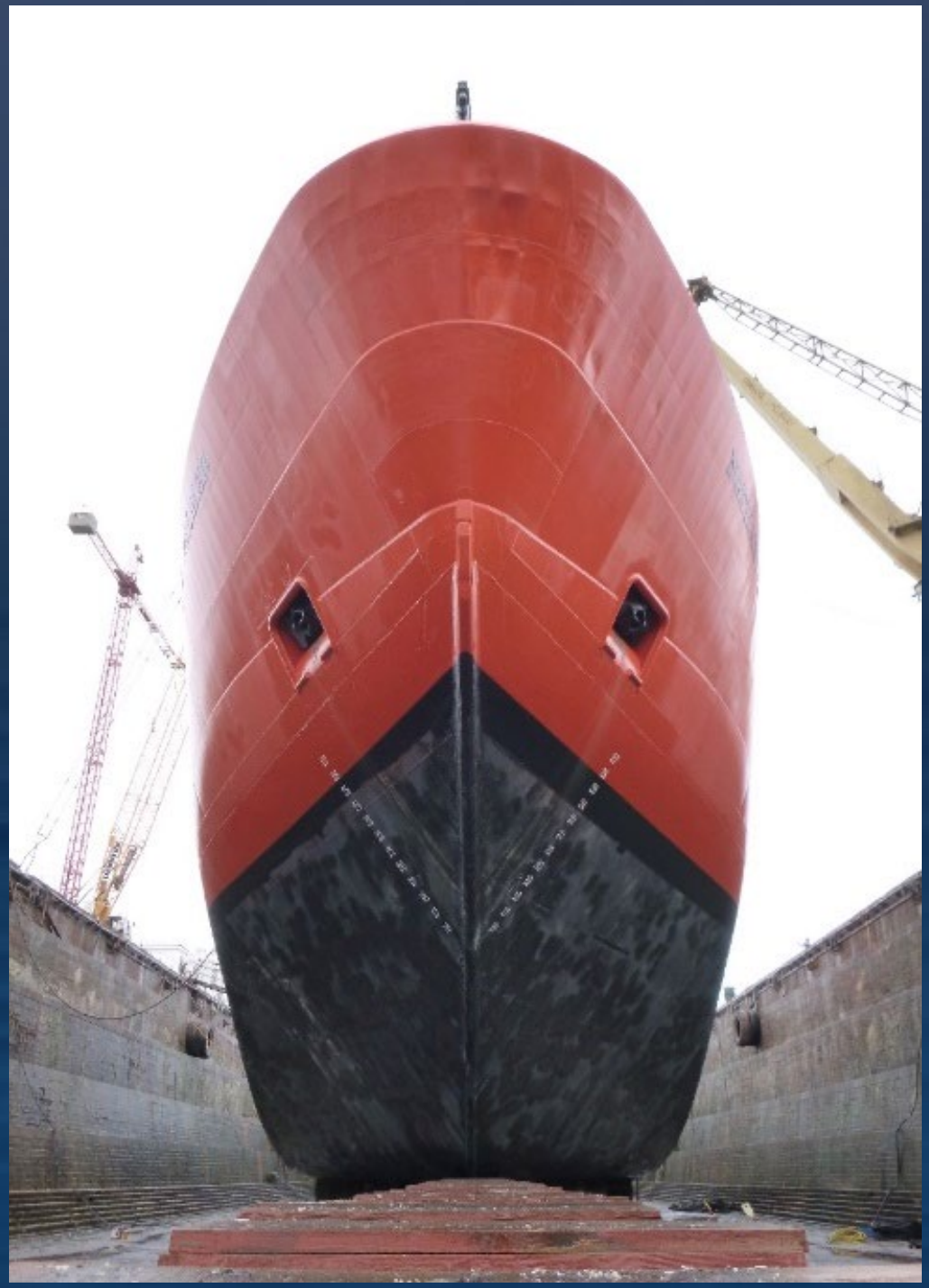






What's Next?

- RCRV SAT planning in progress
- Late-life cycle systems
  - EOL testing / replacement planning
- Who is planning what (and when)?
  - Adding navigation/attitude systems?
  - Most recent patch test?
  - Any new noise issues?
  - Available to help plan SAT/QATs
- Ocean Mapping Community Wiki
  - Share your (extremely valuable) experience



Ocean Mapping Community Wiki

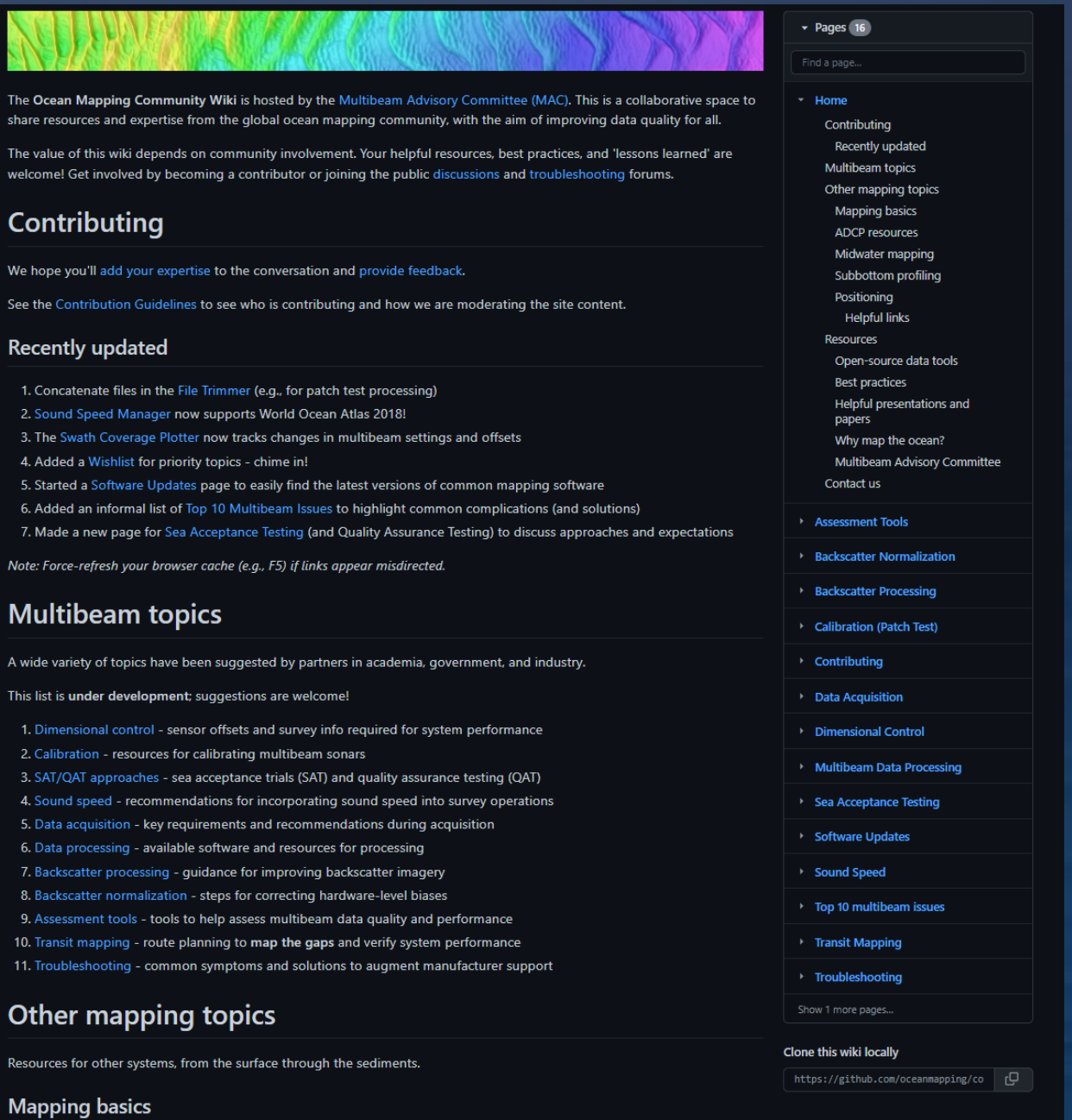
github.com/oceanmapping/community/wiki

What it IS (or aims to be)

1. Public resource with context
   a. Admins from MAC, NOAA, Saildrone
2. Easily updated and expanded
3. Platform for discussion / troubleshooting
4. Backed up with examples and references
5. Welcoming, accessible, and respectful

What it is NOT (or shouldn't be)

1. SOP repository (see Ocean Best Practices)
2. Replacement for manufacturer guidance
3. Promotional, preferential, or judgmental



The **Ocean Mapping Community Wiki** is hosted by the Multibeam Advisory Committee (MAC). This is a collaborative space to share resources and expertise from the global ocean mapping community, with the aim of improving data quality for all.

The value of this wiki depends on community involvement. Your helpful resources, best practices, and 'lessons learned' are welcome! Get involved by becoming a contributor or joining the public discussions and troubleshooting forums.

Contributing

We hope you'll add your expertise to the conversation and provide feedback.

See the Contribution Guidelines to see who is contributing and how we are moderating the site content.

Recently updated

1. Concatenate files in the File Trimmer (e.g., for patch test processing)
2. Sound Speed Manager now supports World Ocean Atlas 2018!
3. The Swath Coverage Plotter now tracks changes in multibeam settings and offsets
4. Added a Wishlist for priority topics - chime in!
5. Started a Software Updates page to easily find the latest versions of common mapping software
6. Added an informal list of Top 10 Multibeam Issues to highlight common complications (and solutions)
7. Made a new page for Sea Acceptance Testing (and Quality Assurance Testing) to discuss approaches and expectations

Note: Force-refresh your browser cache (e.g., F5) if links appear misdirected.

Multibeam topics

A wide variety of topics have been suggested by partners in academia, government, and industry.

This list is **under development**; suggestions are welcome!

1. Dimensional control - sensor offsets and survey info required for system performance
2. Calibration - resources for calibrating multibeam sonars
3. SAT/QAT approaches - sea acceptance trials (SAT) and quality assurance testing (QAT)
4. Sound speed - recommendations for incorporating sound speed into survey operations
5. Data acquisition - key requirements and recommendations during acquisition
6. Data processing - available software and resources for processing
7. Backscatter processing - guidance for improving backscatter imagery
8. Backscatter normalization - steps for correcting hardware-level biases
9. Assessment tools - tools to help assess multibeam data quality and performance
10. Transit mapping - route planning to **map the gaps** and verify system performance
11. Troubleshooting - common symptoms and solutions to augment manufacturer support

Other mapping topics

Resources for other systems, from the surface through the sediments.

Mapping basics

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Find a page...

- Home
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- Sound Speed
- Top 10 multibeam issues
- Transit Mapping
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Show 1 more pages...

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Lamont-Doherty Earth Observatory
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Ocean Mapping Community Wiki

github.com/oceanmapping/community/wiki

omcadmin@ccom.unh.edu or mac-help@unols.org

Assessment Tools

kjerram edited this page 13 days ago · 24 revisions

Overview

Multibeam assessment tools developed by the MAC include:

1. Swath Coverage Plotter
2. Swath Accuracy Plotter
3. BIST Plotter
4. File Trimmer

The tools are available as standalone Python apps on the multibeam_tools_distribution repository.

These tools are intended to give users the same plotting and reporting functions used by the MAC for routine performance testing (e.g., sea acceptance trials and quality assurance testing). Currently, only Kongsberg data formats are supported.

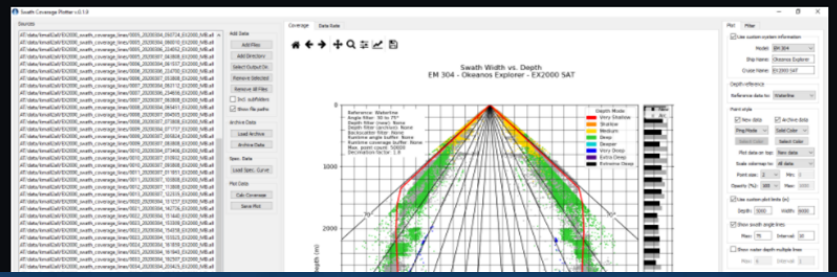
Hint: Most of the app features include tooltips; just hover over a button, list, or checkbox to get more information!

Instructions for data acquisition and processing are presented in the following sections. Suggestions are welcome for improving the workflow in each application.

The source code is available on the multibeam_tools repository.

Swath Coverage Plotter

The swath coverage plotter extracts the outermost soundings (flagged 'valid') and plots these with a variety of filtering and plotting options. Currently only .all and .kmall are supported.



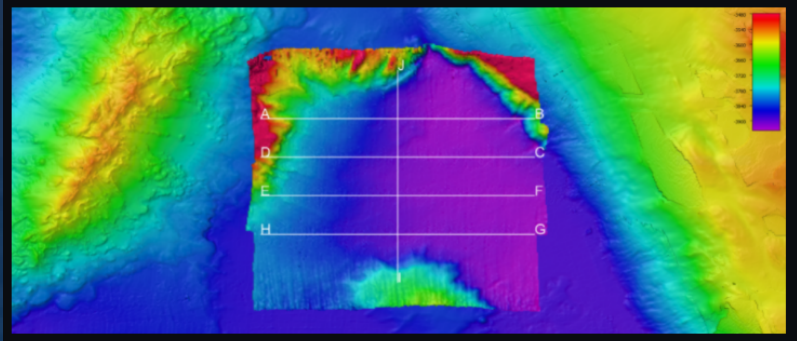
Reference survey acquisition

The reference survey should be planned over relatively flat, benign, homogenous seafloor with slopes no greater than a few degrees. Because the selected depths will likely be used for testing several different modes, the area may also be suitable for backscatter normalization across those modes [wiki development: add link to BS normalization section when complete].

The reference survey lines are planned with a few key considerations:

1. Orientation orthogonal to the crossline (or as a 'grid' if time allows)
   i. This reduces alignment of any swath biases in the reference grid with the crosslines
2. Narrow spacing (e.g., 1 WD) to achieve very high sounding density
3. Length sufficient to cover the full crossline swath width (e.g., 6-8 WD, with buffer for ship handling)
4. Number of reference lines to accommodate desired crossline length
   i. Typically 6-10 reference lines at 1 WD spacing, depending on depth, to yield several hundred crossline pings

Small regions of steeper slopes may be filtered during processing, if present (e.g., the 3900 m reference site off San Diego, below). Likewise, the number of lines may be adjusted to fit the terrain and the schedule.

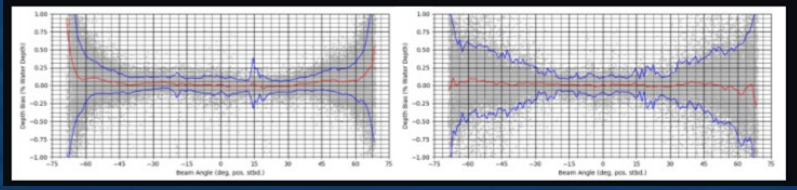


Crossline data acquisition

The primary crossline setting of interest should be the same used for the reference survey; ideally, this is a setting that would be selected automatically by the multibeam system for this depth. This provides a consistent comparison between the 'trusted' bathymetry created from a dense survey and the single-pass crossline(s) for the mode that is intended for this terrain.

As discussed in the planning constraints, there may be several modes of interest that have been grouped for this reference surface depth. Additional crosslines are added as needed and allowed by the ship schedule.

Crosslines are typically run in 'pairs' on opposite headings for each mode to assess any heading-dependent impacts, such as sea state (example below shows accuracy heading with seas and into seas shown on top and bottom, respectively). When seas are calm, this approach also supports deep roll verification using pairs of lines with the same mode and settings on opposite headings over the flat terrain.



Top 10 multibeam issues

kjerram edited this page 20 days ago · 5 revisions

Edit | New Page

The MAC, technicians, and colleagues encounter several common factors that limit data quality across a wide variety of platforms.

Top 10 common issues

In no particular order, here are ten common complications to consider when planning, collecting, and processing multibeam data:

1. **Inaccurate vessel offsets** (or incorrect interpretation)
   i. Data quality depends fundamentally on sensor configuration; see Dimensional Control
2. **Inadequate sound speed profiling** and/or mismatches at the transducer
   i. See Sound Speed and SmartMap
3. **Higher noise levels** due to biofouling on the arrays and hull
   i. Run pre- and post-shipyard RX Noise tests to examine this
   ii. For Kongsberg systems, see the Transducer Cleaning, Fairing, and Painting Procedure
4. **Inappropriate runtime parameters**
   i. The depth gates mean business!
5. **Infrequent calibrations**
   i. Routine patch testing can rule out some biases
6. **Interference** from other acoustic or electronic systems
   i. Is that 12 kHz bridge fathometer *really* secured?
   ii. Synchronize your scientific echosounders!
7. **Sea state**, aeration, and bubble sweep along the hull
   i. Work is underway to adjust ping cycles around washdown events
   ii. Meanwhile, testing RX Noise vs. swell direction can help to identify quieter/better survey orientations for each particular vessel
   iii. Mapping is often the 'back up plan' when other work is on hold due to sea state!
8. **Waterline errors**
   i. Like other sensor offsets, this *directly affects* the reported depth
   ii. Waterline impacts refraction correction by changing the 'starting point' in the sound speed profile
   iii. The value depends on the manufacturer's conventions and **is not always equivalent to the draft**
9. **Infrequent operation**
   i. It takes longer to identify issues when the systems are not operated routinely
   ii. When issues do arise, they are under more 'critical' circumstances and become 'emergencies'
   iii. Opportunistic testing and transit mapping helps to maintain operator familiarity and catch problems early
10. **Outdated software and firmware**
    i. Over the 10+ year hardware lifespan, manufacturers routinely release software and firmware updates to fix real issues with operation
    ii. While some of these might be simple user interface updates, some address fundamental errors in TX or RX processes
    iii. Keeping systems up to date can improve data quality (e.g., reduce outliers, provide new warnings to users) and protect hardware health (e.g., adjust duty cycles or power limits)

Uncommon multibeam issues

Here are a few examples of issues that severely impacted data quality and took a while to sort out, partially because they may are not common problems.

1. Transducer anti-fouling paint (over-application)

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- Backscatter Processing
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- Multibeam Data Processing
- Sound Speed
- Top 10 multibeam issues
  - Top 10 common issues
  - Uncommon multibeam issues
- Transit Mapping
- Troubleshooting
- Water Column Mapping

+ Add a custom sidebar

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MAC Breakout Session
Thursday at 3:00 PM

mac.unols.org

mac-help@unols.org

Lamont-Doherty Earth Observatory
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