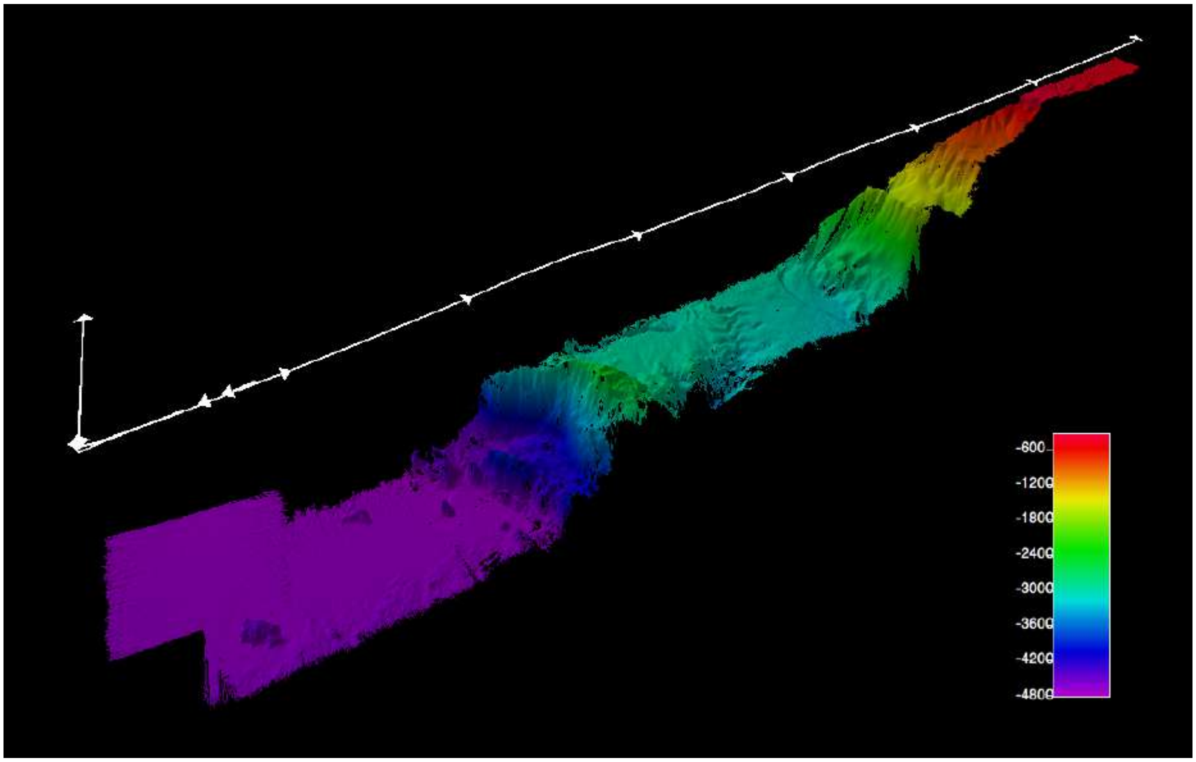
R/V Kilo Moana
EM122 Multibeam Echosounder Review
KM1514- August 9-13, 2015



Report prepared by:

Paul Johnson and Kevin Jerram
University of New Hampshire
Center for Coastal and Ocean Mapping/Joint Hydrographic Center
Durham, NH

Vicki Ferrini
Lamont-Doherty Earth Observatory
Columbia University
Palisades, NY

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Cover: Bathymetry from the EM122 accuracy and extinction testing collected southwest of Oahu. Data were processed with QPS Qimera and are shown for display purposes only.

Introduction

The R/V *Kilo Moana* undertook an engineering shakedown leg (KM1514) in order to assess acoustic noise issues documented during the KM1505 Quality Assessment Visit (QAT) conducted by the Multibeam Advisory Committee (MAC) in April, 2015 and documented in that report (see R/V *Kilo Moana*, EM122 and EM710 Multibeam Echosounder System Review, KM1505 April 28 – 30, 2015). Undertaking this assessment were Vicki Ferrini and Paul Johnson as the MAC Quality Assessment Team, Tim Gates and Marisa Yearta as the Noise Assessment Team, Scott Ferguson representing the University of Hawaii's Ocean Technology Group (OTG), and Chuck Hohing and Travis Eliasen representing Kongsberg Maritime.

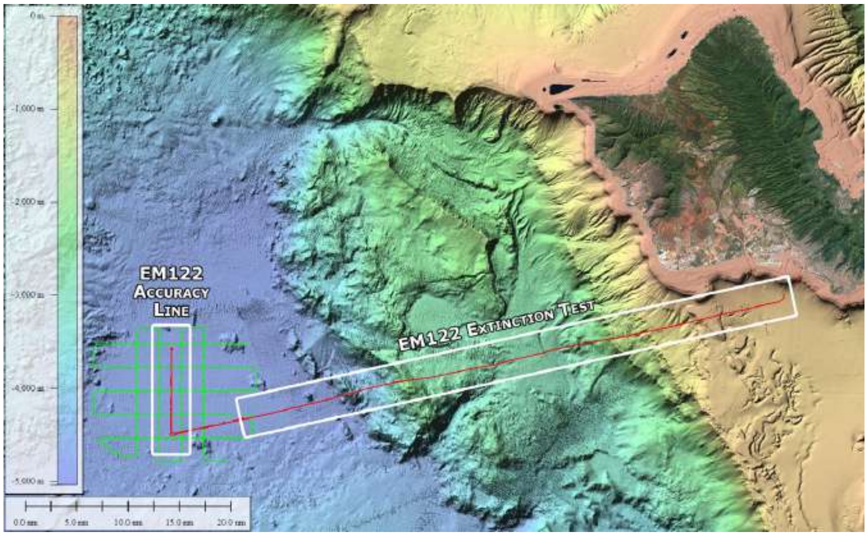

Figure 1. Red line shows the ship track for the 2015 EM122 multibeam system testing. Green track lines are ship tracks for the 2012 shipboard acceptance tests.

Following the KM1505 leg, it was realized by the *Kilo Moana*'s engineers and OTG personnel that mounts for the ship's generators had been changed and apparently installed incorrectly during the spring's 2015 shipyard period. During the early part of the summer of 2015 these mounts were correctly reinstalled and then tuned to minimize transmission of generator vibration to the hull. With this in mind, the above personnel set out to 1.) verify that the ship's self noise had returned to its previously monitored levels as documented in 2012, and 2.) assess the swath bathymetry coverage and accuracy of the *Kilo Moana*'s EM122. For this leg, data to assess both these conditions were collected southwest of Honolulu from August 9-13, 2015 (Figure 1). This report presents:

- a brief description of the testing undertaken during KM1514
- swath coverage / extinction data for the EM122 MBES
- accuracy results for the EM122

Detailed results and discussion of the acoustic noise testing can be found in the *Kilo Moana* 2015 Acoustic Test Report submitted by Gates Acoustic to the MAC and will not be discussed in this report.

Survey System Components

The R/V *Kilo Moana*'s mapping systems consist of the following primary components:

EM122

1. Kongsberg Maritime EM122 multibeam echosounder (12 kHz), v1.3.2, s/n 109
2. Kongsberg Maritime Seafloor Information System (SIS), v4.1.3

EM710

3. Kongsberg Maritime EM710 multibeam echosounder (70-100 kHz), v2.5.3, s/n 219
4. Kongsberg Maritime Seafloor Information System (SIS), v4.1.5

MRU

5. Applanix POS/MV-320 v4 MRU, s/n 2319
6. Trimble BD950 GPS receivers

Sound Speed

7. AML Oceanographic surface sound speed sensor
8. Sippican expendable bathythermograph (XBT) profiling system

KM1514 Activities

The KM1514 leg had three main goals: 1.) testing of the University of Hawaii's Deep Ocean Exploration and Research remotely operated vehicle, Lu'ukai, 2.) determining the R/V *Kilo Moana*'s self noise and comparing it to previously collected data, and 3.) testing of the depth accuracy and swath capability of the *Kilo Moana*'s Kongsberg EM122 multibeam echosounder. Unfortunately, all of the above activities required separate scheduling of ship time due to due to different mission profiles. For instance, the ROV testing required the use of the ship's bow thruster (thus creating a very noisy and stationary environment unsuitable for multibeam testing), while the multibeam could not be transmitting during vessel noise testing (which relies upon the Built-In System Testing capability of the EM122). Finally, the EM122 depth accuracy and swath capability testing naturally required the ship to move over the seafloor while pinging. Because of this, ROV operations (not discussed in this report) were conducted during daylight hours and the acoustic noise assessment and the multibeam testing were conducted at night.

Initial testing during KM1514 were focused on quantifying the *Kilo Moana*'s acoustic self noise signature. The testing process and results are well documented in the Gates report. In brief, after rigorous testing of multiple modes of operation it was revealed that one channel on the pre-amplifier board was causing an increase in noise across the entire array. Mark Rognstad, of the University of Hawaii, was able to disable this single channel and thereby lower the apparent received noise levels down to levels similar to those observed in 2012. However, further testing and inspection of the multibeam sonar data revealed that, despite the reduction in the apparent ship's acoustic/electrical noise levels, the quality of the multibeam bathymetry data was still compromised.

After multiple rounds of further systems checks, including board swaps, power supply swaps, and frankly a lot of head scratching by the entire team present, it was discovered that the quality of the swath data was improved significantly when the RX array was switched from a 2° to a 4° RX beamwidth configuration. This switch is made using Kongsberg software to utilize half of the array for receiver beamforming process. This discovery induced further testing, including pulling the RX cables leading from the RX module to the pre-amplifier so that the system could utilize only 4 of the 8 RX array modules at a time (making it a 4° system at the hardware level, rather than through the software). This modification yielded the same results as the software test, so the team then cycled through different groupings of RX modules by advancing down the array 1 module at a time. These tests revealed that the 6th module in the RX array, which had been swapped in the spring 2015 shipyard period by Kongsberg due to historically higher noise levels, was actually wired with reverse phase. Amazingly, a wiring diagram for the RX module cable was discovered near the Pre-Amplifier box on the ship and a jumper was constructed to correct the wiring and therefore improve the quality of the swath data.

With completion of engineering trouble shooting, the final modes of acoustic noise testing were performed to check for any residual noise with the fully functional array. Following this, the ship was given over to the Quality Assurance Team for the final few hours of the KM1514 leg for a quick run on the deep water reference surface area, before the ship had to transit back to Honolulu Harbor.

EM122 Accuracy Testing

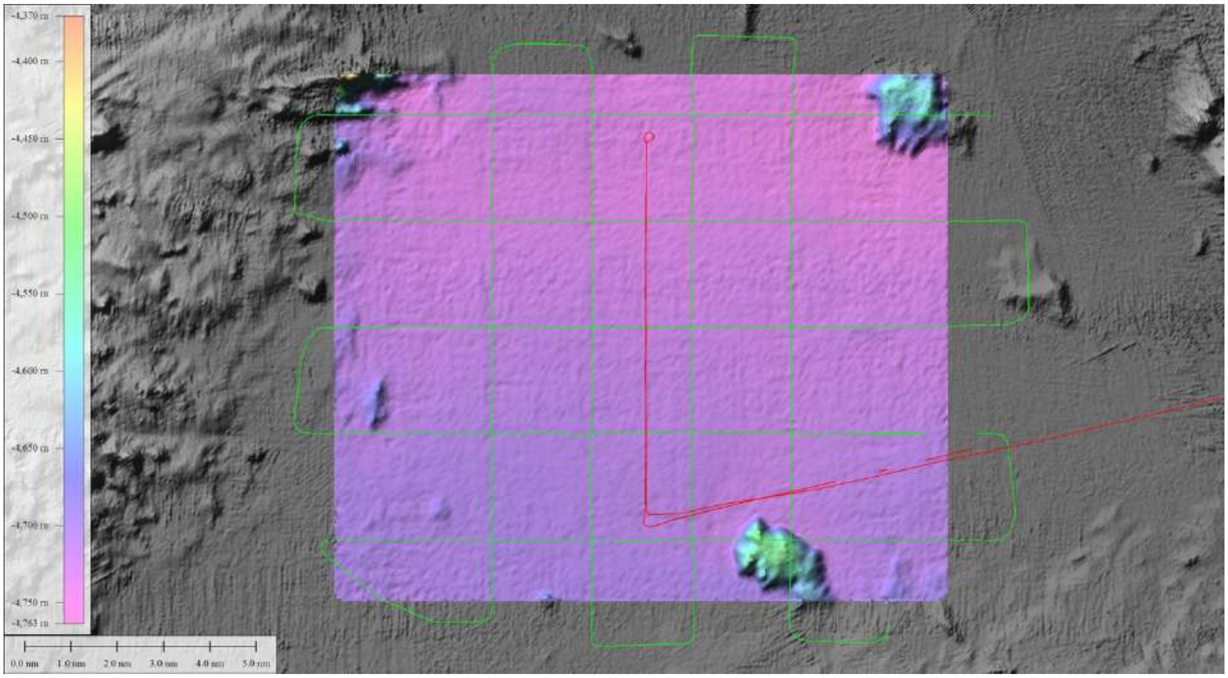

Figure 2. The deep water reference site collected during the 2012 EM122 Shipboard Acceptance Test. Reference surface data

were gridded at 100 meters. The colored EM122 surface, shown here, is overlain on background bathymetry (SOEST Main Hawaiian Island Multibeam Synthesis) gridded at 50 m.

Overview

Accuracy testing was conducted for the EM122 over a deep water reference surface with nominal depths of 4700 meters (Figure 2). This reference surface was constructed using data collected during 2012 EM122 Shipboard Acceptance Test on the R/V *Kilo Moana*. All soundings in the reference surfaces and accuracy cross lines were corrected for tide using the Oregon State University global tide model (http://volkov.oce.orst.edu/tides/otps.html). Furthermore, bathymetric slopes were computed for the reference surfaces and used as a mask to exclude areas of significant topography (>5°) from the crossline analysis (Figure 3). Prior to collection of the cross lines, it was verified that the EM122 was the only acoustic system running at the time.

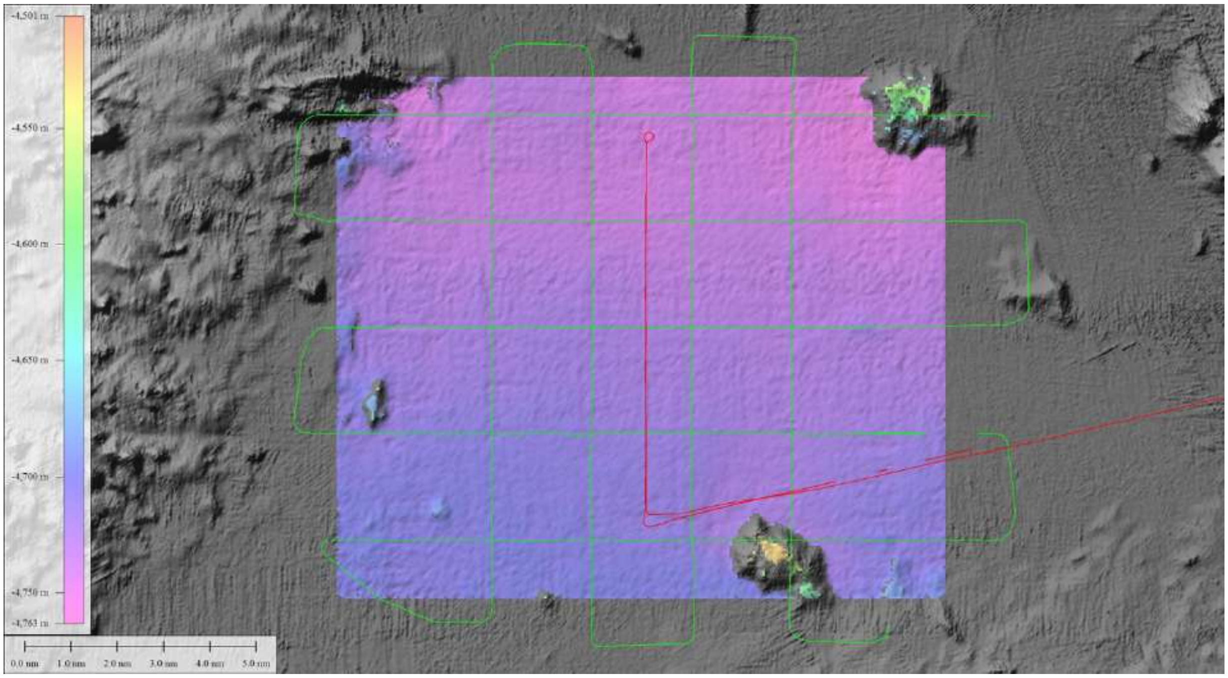

Figure 3. The deep water reference site data with slopes over 5° masked. Cross line analysis was run on the north-south oriented red lines.

The cross line was run in a North/South direction, but was situated to avoid overlapping nadir of the crossline with nadir of the reference surface lines. This precaution was taken to reduce any effects of compounding or canceling biases across the swath. To reduce refraction artifacts, an XBT profile was collected prior to the start of acquisition of the cross line, then processed with SVP Editor, and loaded into SIS. Unfortunately, due to engine issues on the R/V *Kilo Moana* causing alarms at slower speeds and in certain engine configurations, we had to run with both port and starboard engines running. This allowed a minimum speed of 8-9 kts instead of the desired speed of 6 kts running with only the starboard engines engaged; the slower configuration would normally be preferred because it is the quietest mode of operations for multibeam collection and would increase alongtrack sounding density.

Major outliers (such as bottom detections at constant range across the swath due to interference) were removed from the accuracy analysis, as these would clearly be edited during normal bathymetric processing. Mean depth bias and depth bias standard deviations as a percentage of water depth were then computed in 1° angular bins across the swath.

EM122 Accuracy Testing Results

Only one cross line (north and south) in only one operation mode (Table 1) was run for the EM122, as there was very limited time available for testing prior to departure from the deep water accuracy site for port. The mean bias across the swath (Figure 4, bottom) is approximately zero, with the port side value trending deeper and the starboard side trending shallower, possibly indicating a slight roll bias in the system. The depth standard deviation (Figure 4, top) generally shows a similar pattern to that seen during the 2012 shipboard acceptance test (Figure 5, top) with outer portions of the swath (> 45°) trending from 0.1 to 0.4% WD, with most of the inner portion of the swath falling below 0.1% WD.

Table 1. EM122 deep water accuracy cross line settings.

SONAR RUN TIME PARAMETERS

Sector Coverage	**Cross Lines Settings 1**
Max angle (port)	70
Max angle (sbtd)	70
Angular Coverage Mode	Auto
Beam Spacing	HIDENS EQDIST

Depth Settings	**Cross Lines Settings 1**
Force Depth	n/a
Min depth (m)	4500
Max depth (m)	5000
Dual swath mode	DYNAMINC
Ping mode	DEEP
FM disable	Unchecked (FM)

Transmit Control	**Cross Lines Settings 1**
Pitch stabilization	ENABLED
Along direction	0
Auto Tilt	OFF
Yaw stab. Mode	REL. MEAN HDG
heading	n/a
heading filter	MEDIUM
Min Swath Dist	0
Enable Scanning	Off

What is a little troubling with the 2015 data is that several regions of the inner swath standard deviation exceed 0.1% WD. In 2012 (Figure 5, top), it can be seen that the entire inner portion of the swath is close to 0.05% WD, while the KM1514 data (Figure 4, top) plot shows that the inner region is not nearly as accurate, with multiple spikes present and some exceeding 0.1% WD. Potential complicating factors for this assessment are the higher speed (8+ kts in 2015 and 6 kts in 2012) and less desirable engine configurations (port and starboard generators in 2015 versus starboard only in 2012) during the KM1514 accuracy data collection. This is a potential data quality issue that should be reevaluated when time is available through additional passes over the reference surface in different engine configurations.

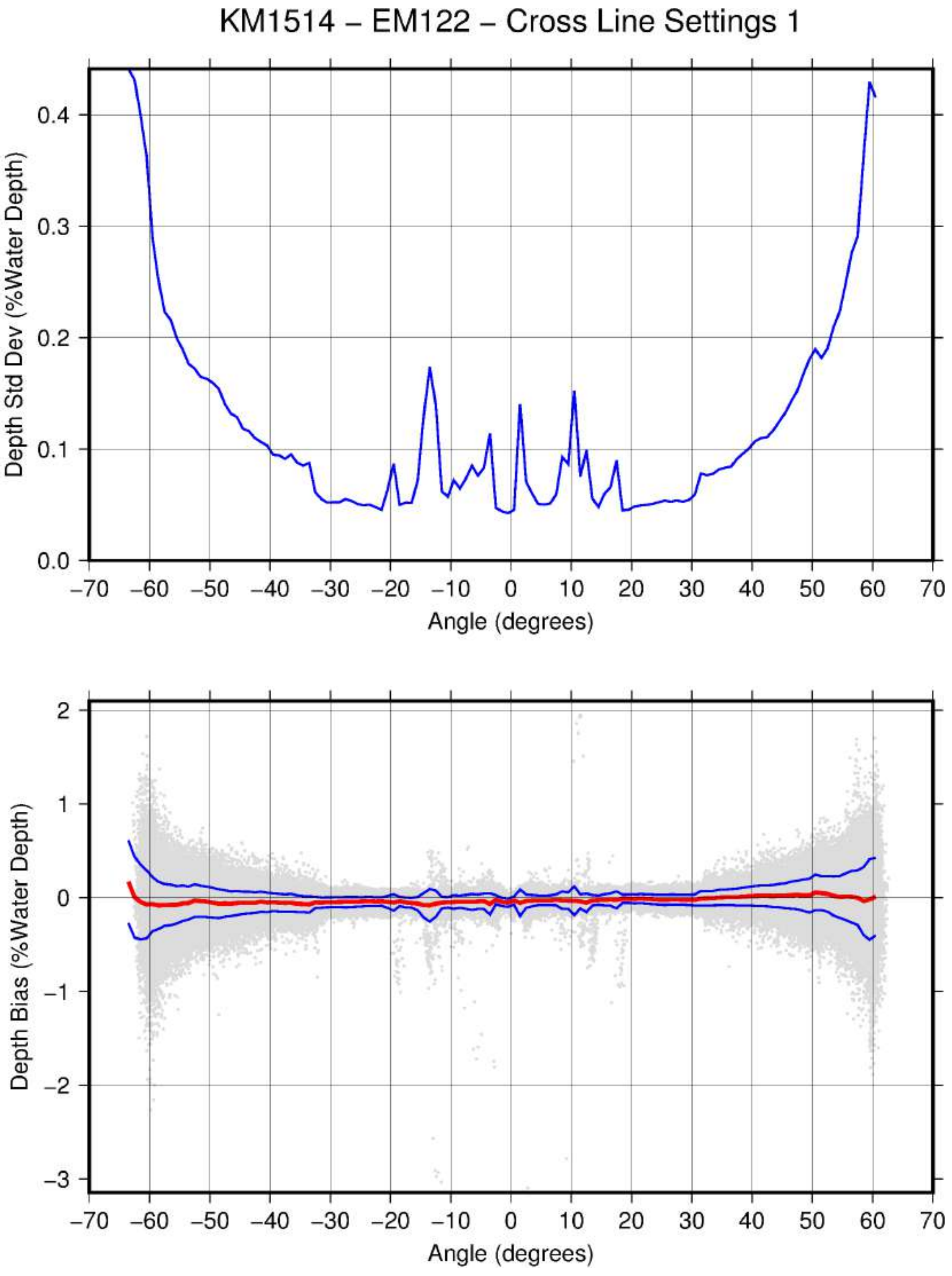

Figure 4. EM122 deep water accuracy results (Deep, Dynamic, FM) from KM1514. Top: depth bias standard deviation as a percentage of water depth. Bottom: mean depth bias (red) as a percentage of water depth +/- one standard deviation (blue).

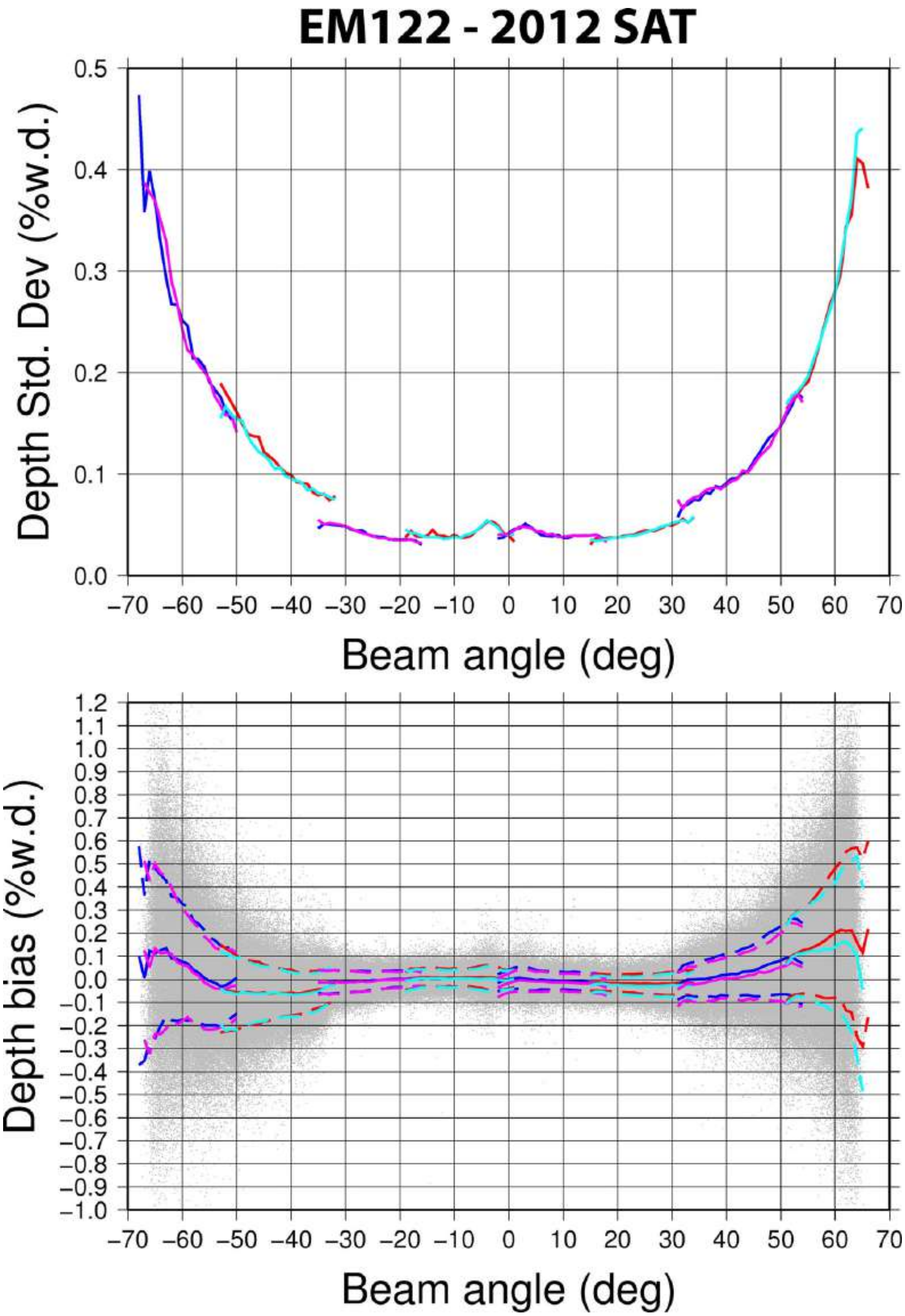

Figure 5 EM122 deep water accuracy results (Deep, Dynamic, FM) from the 2012 R/V Kilo Moana shipboard acceptance test. Top: depth bias standard deviation as a percentage of water depth. Bottom: mean depth bias (solid middle line) as a percentage of water depth +/- one standard deviation (dashed lines).

EM122 Achieved Coverage

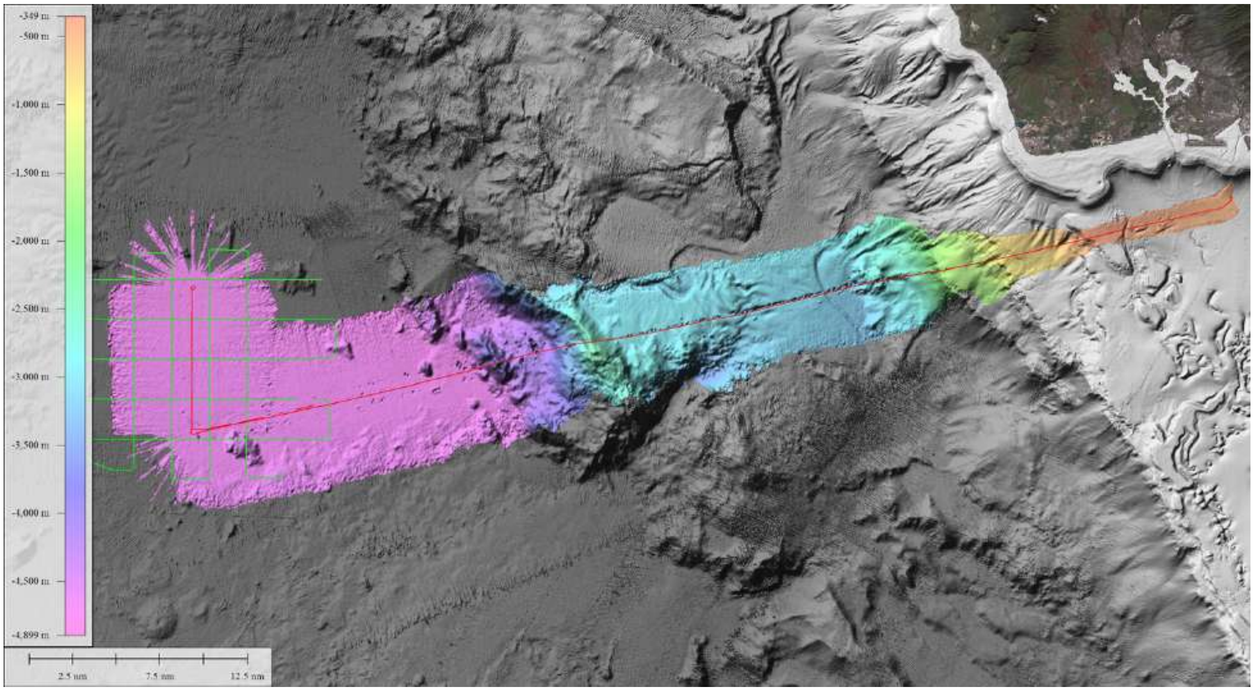

Figure 6. EM122 accuracy test and transit line data used for the swath coverage assessment. Colored bathymetry indicates data used for swath coverage assessment.

The EM122 swath coverage performance was evaluated by tracking the outermost port and starboard soundings from all data acquired from the accuracy test site and during the transit to Honolulu Harbor (Figure 6). Figure 7 depicts the across-track coverage versus depth for depths between ~300 m and ~4700 m. Ideally, all data included in the swath coverage analysis should have been collected in automatic angular coverage mode, automatic depth mode, FM transmit mode, at 6 kts speed, and perpendicular to the slope of the seafloor in order to calculate the maximum swath width as a function of depth. However, as much of the data covering a majority of the depth range were collected during the final hours of the cruise on a transit back to Honolulu Harbor, the speed was higher than desired (8+ kts) and the ship track was at an oblique angle to the seafloor slopes. Thus, the data collected may not fully represent the maximum swath width achievable.

A swath width of 4 times water depth was observed during KM1514 at the maximum depth mapped of ~4700 m (Figure 7), which is very close to that seen during the 2012 SAT (Figure 8). In shallower depths, the KM1514 data seems to show similar trends as the 2012 SAT for swath width as a function of depth, with overall swath width increasing to 5 to 6 X water depth in shallower waters. Ideally, we would have more data to better define this swath coverage curve, but the limited data from KM1514 suggest no major changes in swath width performance between 2012 and 2015.

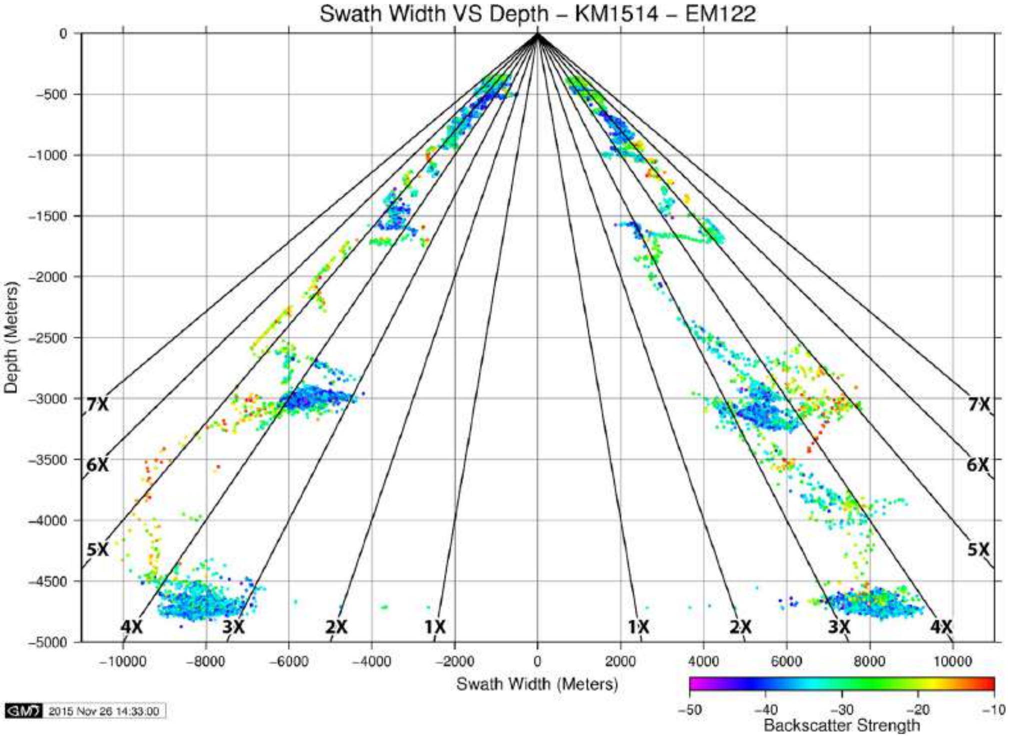

Figure 7. EM122 coverage achieved during KM1514. Data points are the outermost port and starboard soundings from each ping. Colors of the points are based on the backscatter strengths of the contributing soundings.

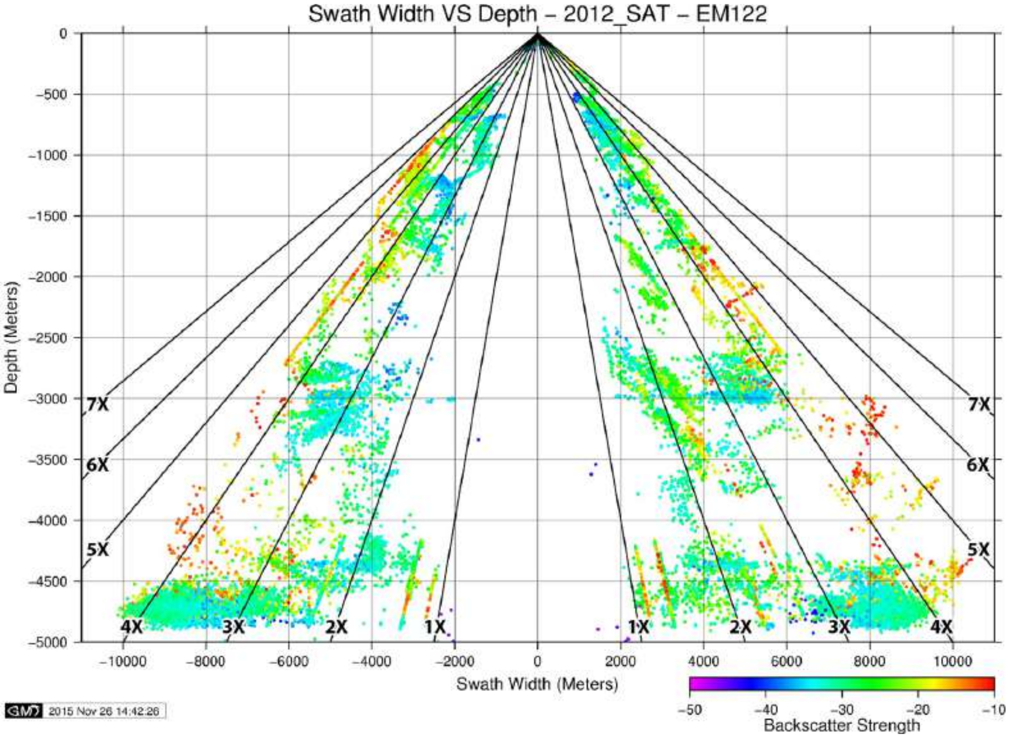

Figure 8. Swath coverage achieved during the 2012 SAT conducted over similar survey areas.

Conclusions and Recommendations

1. Having the “A” team (Acoustic Noise Team, Quality Assurance Team, Kongsberg Maritime, and UH Ocean Technology Group) aboard to troubleshoot the EM122 multibeam problems worked great. Without this multidisciplinary and talented group, it is probable that the issue might not have been resolved without additional ship time.

2. The EM122 accuracy assessment shows what appears to be a less accurate/noisier inner swath than that observed in 2012. Complicating this assessment, the tests were run at higher speeds and with a different engine configuration compared to 2012, due to the limited available time and engine issues during KM1514. To truly compare the two accuracy datasets, additional runs should be undertaken at 6 kts with a starboard engine configuration.

3. The assessment of swath width as a function of depth shows similar swath width at the reference surface site (~4700m) as seen in 2012. The transit line from the reference site back to Honolulu Harbor crosses the seafloor slopes at oblique angles and was run at higher than desired speeds due to time constraints. In light of these factors, there appear to be no major changes in swath width from the 2012 SAT to KM1514.

4. It was noticed that there were many nadir “punch-through” artifacts seen during the transit back to Honolulu Harbor. This was a very limited sampling interval, and there was no attempt to steer the beams in order to see if this could be minimized. A mapping cruise is currently underway and the MAC will be contact with the scientists aboard to see if this has been an issue.