Multibeam bathymetry data from 2015-2017 RAMP cruises (ASRAMP; HARAMP; MARAMP)

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**Study and report supported by JIMAR's Deep Sea Corals Program, and conducted by NOAA PIFSC scientists within the Ecospatial Information Team of the Ecosystem Sciences Division (ESD)*

Contents

File Directory

Raw Data:

- ASRAMP: \\PICMakai\Mapping\mapping\multibeam\Cruise\HA1501\SIS
- HARAMP: \\PICMakai\Mapping\mapping\multibeam\Cruise\HA1606\SIS
- MARAMP: \\PICMakai\Mapping\mapping\multibeam\Cruise\HA1701\SIS

Saber Files and tide/draft/SVP corrected *gsf. (ASRAMP only draft-corrected):

- ASRAMP: \\PICMakai\Mapping\mapping\multibeam\Cruise\HA1501\SABER
- HARAMP: \\PICMakai\Mapping\mapping\multibeam\Cruise\HA1606\SABER
- MARAMP: \\PICMakai\Mapping\mapping\multibeam\Cruise\HA1701\SABER

Post-Processing Logs:

- ASRAMP: \\PICMakai\Mapping\mapping\multibeam\Cruise\HA1501
- HARAMP: \\PICMakai\Mapping\mapping\multibeam\Cruise\HA1606
- MARAMP: \\PICMakai\Mapping\mapping\multibeam\Cruise\HA1701

Qimera Projects & *final processed data (*Howland, Baker, Guam only):

**gsf data within subdirectories of below (…Qimera\"project"\Export\)*
**Processed surfaces: (…Qimera\"project"\GridData\)*

- ASRAMP: \\PICMakai\Mapping\mapping\multibeam\Cruise\HA1501\Qimera
- HARAMP: \\PICMakai\Mapping\mapping\multibeam\Cruise\HA1606\Qimera
- MARAMP: \\PICMakai\Mapping\mapping\multibeam\Cruise\HA1701\Qimera

Newly created composite Digital Bathymetric Models (DBMs)

- Guam: \\PICMakai\Mapping\mapping\gis\Data\CNMI-Guam\Guam\Basemaps\Bathymetry\Multibeam
- Howland: \\PICMakai\Mapping\mapping\gis\Data\PRIAs\Howland\Basemaps\Bathymetry\Multibeam
- Baker: \\PICMakai\Mapping\mapping\gis\Data\PRIAs\Baker\Basemaps\Bathymetry\Multibeam

Cruise Metadata

- ASRAMP: https://inport.nmfs.noaa.gov/inport/item/47822
- HARAMP: https://inport.nmfs.noaa.gov/inport/item/37075
- MARAMP: https://inport.nmfs.noaa.gov/inport/item/47803

Product metadata

- Baker (ASRAMP): https://inport.nmfs.noaa.gov/inport/item/47744
- Howland (ASRAMP): https://inport.nmfs.noaa.gov/inport/item/47761
- Guam (MARAMP): https://inport.nmfs.noaa.gov/inport/item/47577

Reports:

- \\PICMakai\Mapping\mapping \Publications\Reports\2017 Deep Sea Corals
    - (includes processing summary report, and more technical processing crib-notes)
- *Useful report on acquisition/vessel:
    - \\PICMakai\Mapping\mapping\gis\Dove\Working\Reporting\Deep_Sea_Corals\Younkin_reports

Objectives and Summary

The overarching objective of this project has been to evaluate and post-process the multibeam echo-sounder (MBES) bathymetry data (EM3002D & EM300 sonars) acquired from the *R/V Hi'ialakai* during the 2015 ASRAMP (Pacific Remote Island Area - cruise ID: HA1501), 2016 HARAMP (NW Hawaiian Islands - cruise ID: HA1606), and 2017 MARAMP (Marianas – cruise ID: HA1701) cruises. It was intended that the final data would be incorporated (i.e. gap-filling) with existing, previously acquired bathymetry data in each region to create seamless products, and update the associated bathymetry data products to be published and archived online. It was understood at the outset however that the original acquisition of the ASRAMP and HARAMP bathymetry data (primarily the EM3002D data) was inhibited by several significant problems (e.g. sonar calibration/sea trials not implemented (therefore not detecting faulty sonar head & roll-bias), poor sound-velocity control of water column, potentially imprecise DGPS positioning), and thus the acquired data may suffer from several intrinsic issues (i.e. mapping extent, vertical control, positioning). Unfortunately several of these issues persisted through to the acquisition of the MARAMP data, as results from the sea trials conducted en route showed that previously-identified (and repaired) problems with the EM3002D hardware had not been resolved (see note below regarding MARAMP sea trials results).

This report chronicles how these issues, sourced from both sonar-system faults as well as acquisition errors, have resulted in bathymetry data of insufficient quality (accuracy and coverage) to be officially archived, or used to update existing data products. In particular, the high-resolution EM3002D data suffer from significant hardware-related problems. The medium-resolution EM300 data are largely not used because the newly acquired data do not fill existing data gaps. An exception to this is EM300 data acquired at Howland and Baker as part of ASRAMP, and EM300 data acquired at Guam (MARAMP). In these cases, the data have been processed as well as possible (e.g. considering availability of sound-velocity data), and mosaicked/synthesized together with existing PIBHMC bathymetry data products, and served these to the PIBHMC website (www.soest.hawaii.edu/pibhmc/cms/). Because of the variable issues affecting the acquired data across the three RAMP cruises, we are only archiving (www.ncei.noaa.gov) the processed MBES bathymetry data for these three islands.

The report describes issues specific to each RAMP cruise, and hopefully will help to enable improved data acquisition in the future (e.g. cruise planning, employing suitable expertise onboard, importance of timely sea trials/sonar calibration, importance of sound-velocity information, compatible acquisition and post-processing software).

The report is organized with separate sections for each mapping campaign, and is largely organized around figures, which are used to demonstrate geographic coverage (or lack thereof), and various data-quality issues. HARAMP data were analyzed first as they were anticipated to be of better quality than the ASRAMP data, and MARAMP data were not yet acquired. Because of this, there is considerably more context and detail given for the HARAMP sections in describing data quality, and resulting usefulness of the data. Many of the descriptions given in the HARAMP section (e.g. data deficiencies) also apply to ASRAMP and MARAMP data, but are not repeated for brevity. Further survey-specific issues for ASRAMP and MARAMP are mentioned briefly within each relevant section.

Results from MARAMP Sea Trials

****Near time of completing this report (05/18/2017), we received news that recent analysis of the EM3002D patch test data (acquired in 2017 - pre-MARAMP) by E. Younkin (OCS) and with feedback from Kongsberg, that the EM3002D is effectively not operational, citing a variety of issues from partly malfunctioning transducer head, faulty software and instrument components, and vertical and roll issues resulting from possible mounting/installation errors. From office-based post processing (D. Dove), it is also clear that some of these problems were active during HARAMP data acquisition, and originated between the previous 2015 ASRAMP cruise and the 2016 HARAMP cruise. Prior to ASRAMP the Hi'ialakai was successfully sea trialed and all instruments calibrated to quality standard by members of ESIT on January, 21, 2015. Unfortunately, because sea trials were not (e.g. patch test) conducted prior to HARAMP, these issues were not identified and rectified.*

Following recognition of some of the data issues during HARAMP (e.g. spurious data from starboard head), sonar system (hardware/software) checks and updates were conducted during post-HARAMP/pre-MARAMP dry-dock of the Hi'ialakai. Unfortunately, because parts were not available at the time, the starboard transducer was not repaired until just prior to the 2017 MARAMP (by working divers on the pier at Ford Island) survey, and sea trials had to be conducted en route. As stated at the outset of this note however, it is clear from the analysis of the pre-MARAMP sea-trials data that several issues (e.g. roll-bias) were not adequately fixed during the diver repairs in port.

ASRAMP

Data Provenance:

- **Survey Vessel: R/V NOAA Hi'ialakai (cruise ID: HA1501)**
- **Survey dates: Jan- Apr. 2015** (Johnston, Howland, Baker, Swains, Palmyra, Tutuila, Jarvis)
- **Instrumentation: Kongsberg EM3002D and EM300 sonars**

Methods

**Methods for processing ASRAMP data are consistent with those for HARAMP, so not repeated here. However, with only a couple of exceptions (i.e. EM300 data for Howland and Baker), newly acquired data did not fill geographic gaps in existing data products. Because of this, several steps were not completed for HARAMP as final data products were not required (i.e. tide-correction, spline filtering, *gsf export of cleaned data). For processing protocol associated with the EM300 data from Howland and Baker, please see the Island-specific sections below.*

Results ASRAMP (HA1501)

With the exception of EM300 data acquired at Howland and Baker, the remainder of the EM300 data, and all of the EM3002D data, are not being archived as final data products (or being used to update existing map products), as they do not cover significant gaps in existing bathymetry data. The source data have been documented in InPort and archived with NCEI.

Data Quality

ASRAMP bathymetry data have fewer sources of potential vertical error than HARAMP (e.g. roll-bias, faulty transducer head), because the systems were patch-tested in advance of the survey. That being said, there is little to no control on sound-velocity of the water column as no mapping CTD's were acquired during the course of the survey. Also, the data were acquired with a 'set-it and forget-it' approach as no dedicated hydrographic surveyors were onboard, and survey lines were not designed for optimal swath coverage (or data quality). One exception to this is at Tutuila (EM3002D). By in large, data were acquired at speeds too high for quality data recovery, therefore data dropouts, caused by heave and/or aeration under the hull (disrupting propagation of sound), are commonly observed.

There is also significant horizontal uncertainty (up to ~5-8m) in the ASRAMP data as the dGPS navigation system was not operating with full corrections. An example of this can be seen in the Tutuila data.

ASRAMP Gap Analysis

Medium-resolution EM300 data were acquired at all islands visited during ASRAMP, whereas high-resolution EM3002D data were only acquired at Tutuila, and a very small survey at Johnston.

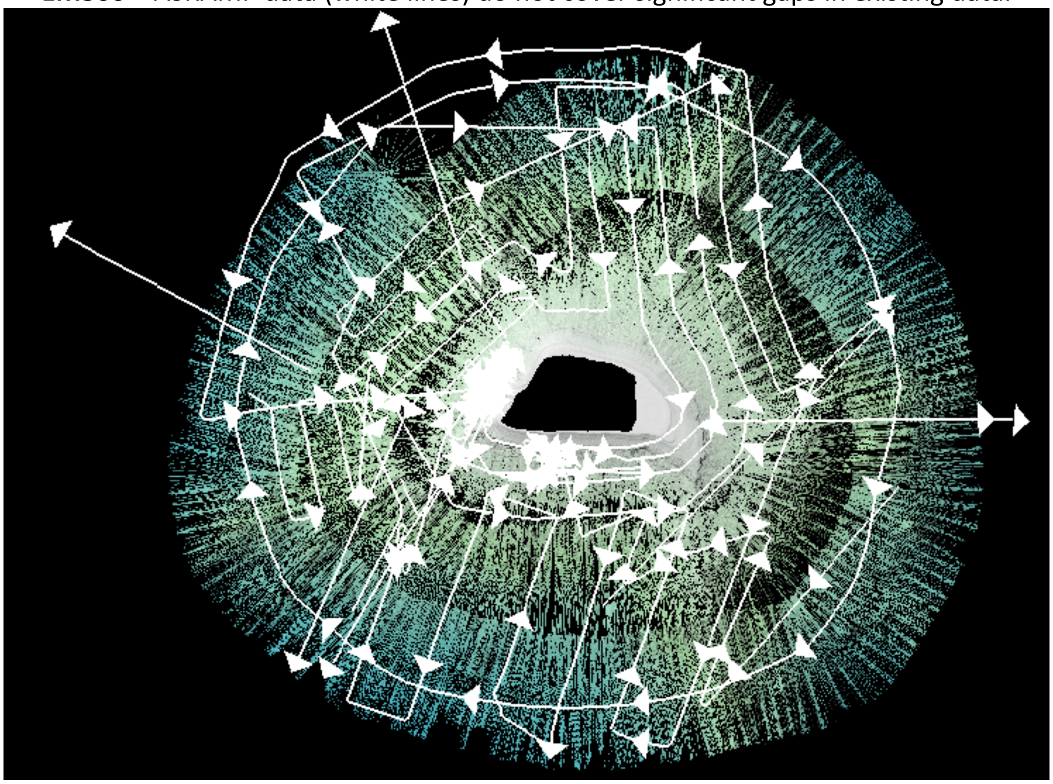
Below figures demonstrate how ASRAMP data, with the exception of EM300 data at Howland and Baker, do not cover significant gaps in existing data. In general, figures depict new data (tracklines and rainbow color-scale surfaces) overlying existing surfaces (white-blue color-scale).

Deliverables

Qimera projects have been created for each island, though because data at Jarvis, Tutuila, Palmyra, Swains, and Johnston do not cover previously un-surveyed seabed, MARAMP data have not been further processed, and will not be archived. For Howland and Baker, Qimera projects include processed data and new gridded surfaces. The new surfaces have been mosaicked together with existing PIBHMC data (methods below) to produce a new composite digital bathymetric model (DBM). This section, and the figures below are produced to chronical the issues surrounding data acquisition and data quality.

Jarvis

- **EM300** – ASRAMP data (white lines) do not cover significant gaps in existing data.



- **EM3002D** – No EM3002 data were acquired at Jarvis.

Howland

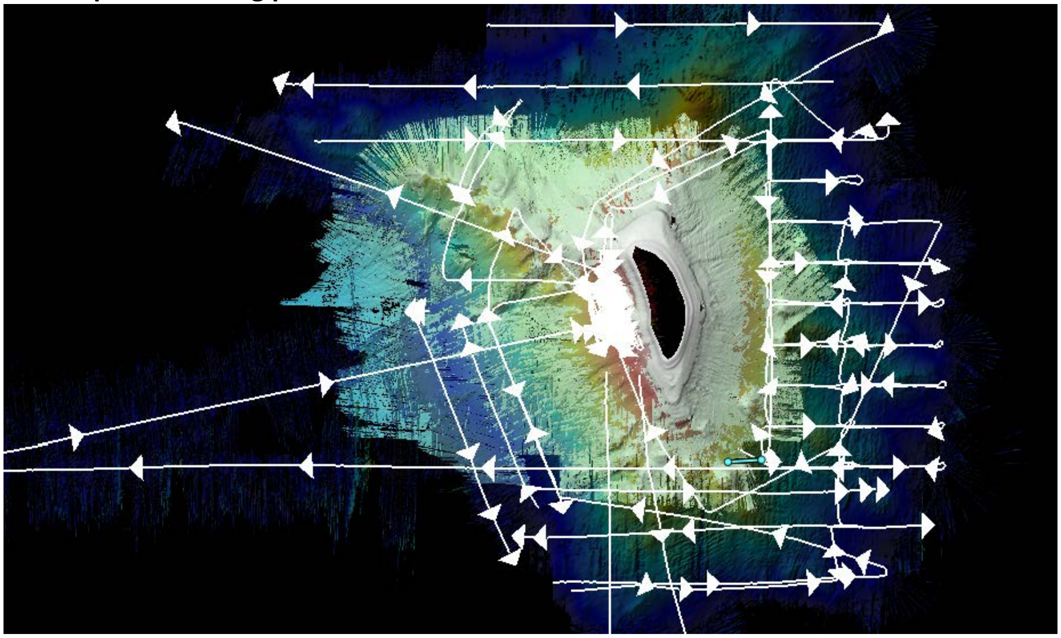
EM300 data acquired during ASRAMP are being used to update existing bathymetric products, as they cover areas not previously surveyed. Unfortunately, no sound velocity data were acquired during the survey, so there are vertical errors (averaging ~5-10m) between the new data and previously acquired surfaces. However, because the EM300 survey depths up to nearly 4,000 m, these vertical errors are considered acceptable to update the surface. Attempts were made to use other SVP sources to improve vertical fit, but these were not effective. These included: i) using SVP data acquired from previous cruises (as was effective at Guam (MARAMP)), and ii) derive synthetic SVP data from World Ocean Atlas (using velocipy).

Because of variable vertical errors averaging ± 5-10 m from lack of SVP constraint, it was considered that vertical effects from tides (up to ±0.5m) would be negligible, and hence tidal corrections were not applied to the data.

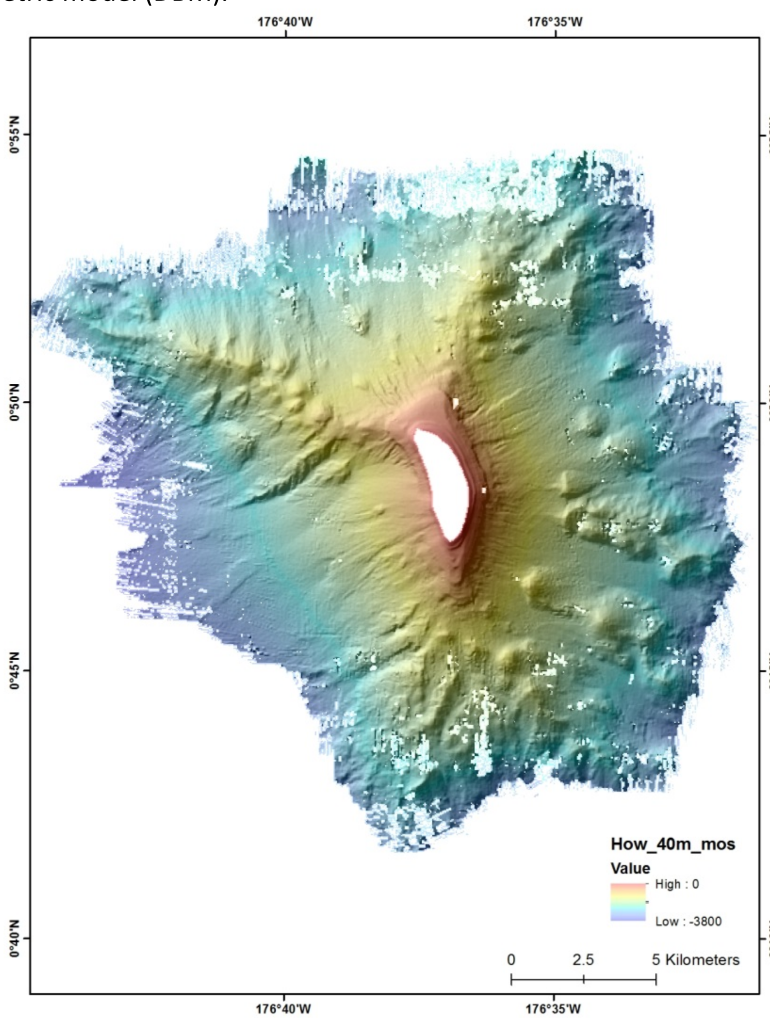
Following draft and offset corrections in SABER, the data were cleaned using QPS Qimera. All data were first cleaned using a medium tension spline filter, then Dynamic Surfaces were hand edited using the 2D Slice function to remove remaining spurious data points. The cleaned surface (40m resolution) was then exported to floating point geotif, where in ArcGIS this was mosaicked (‘Mosaic to new Raster’) with the existing 40m bathymetry surface. The new mosaic surface is being uploaded to the PIBHMC website.

Notably, there are further bathymetric data at Howland very recently acquired by NOAA *Okeanos Explorer*. Unfortunately, the processed data are not yet released to combine with the ASRAMP data, but these data will be included when they become available.

- **EM300 – Data acquired during ASRAMP cover areas not previously surveyed. As such these data are being used to update existing products**



- **Updated DBM –** Processed Howland EM300 data mosaicked with existing surface to create updated 40m digital bathymetric model (DBM).



- **EM3002D -** *No EM3002D data acquired at Howland.

Baker

EM300 data acquired during ASRAMP are being used to update existing bathymetric products, as they cover areas not previously surveyed. Unfortunately, no sound velocity data were acquired during the survey, so there are vertical errors (averaging ~5-10m) between the new data and previously acquired surfaces. However, because the EM300 survey depths up to over 3,000 m, these vertical errors are considered acceptable to update the surface. Attempts were made to use other SVP sources to improve vertical fit, but these were not effective. These included: i) using SVP data acquired from previous cruises (as was effective at Guam (MARAMP)), and ii) derive synthetic SVP data from World Ocean Atlas (using velocipy).

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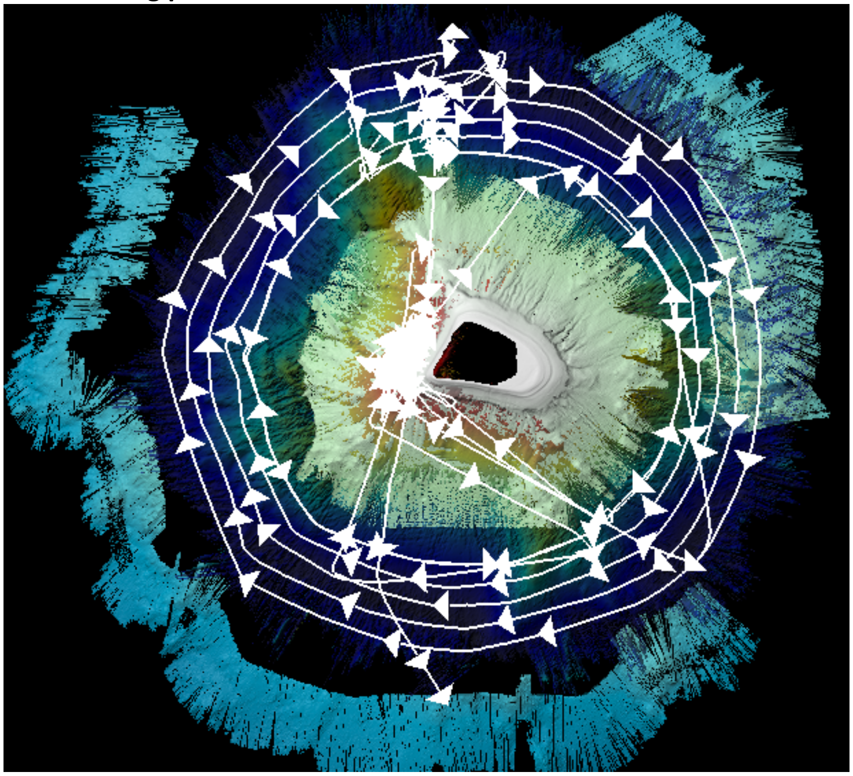
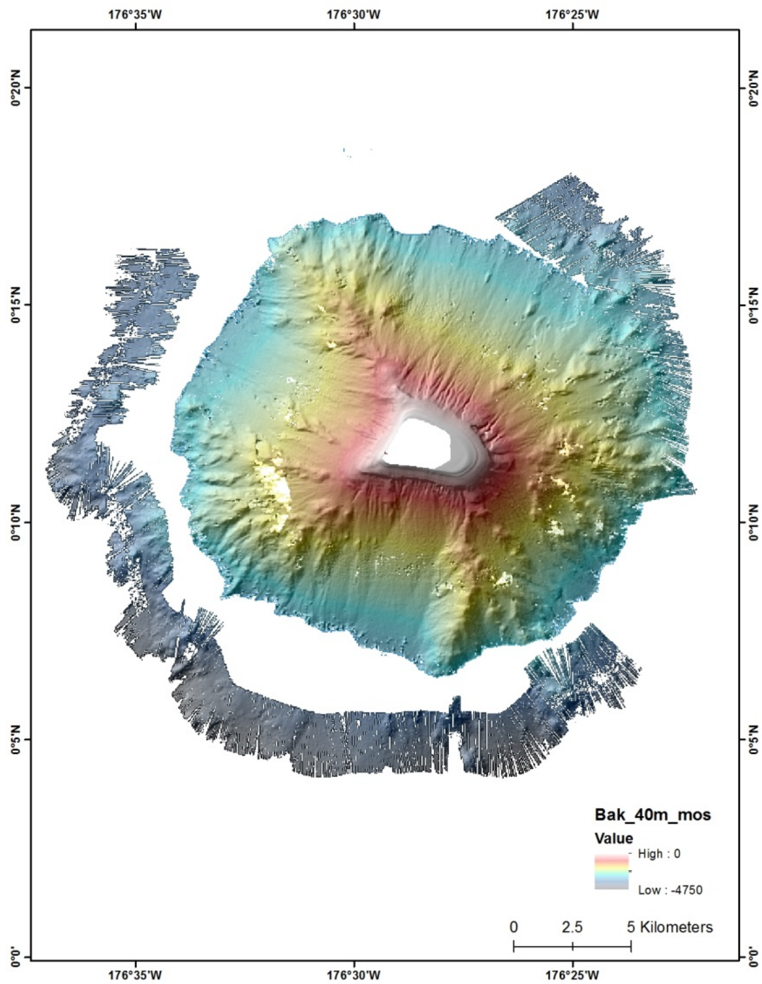
Notably, there are further bathymetric data at Baker very recently acquired by NOAA *Okeanos Explorer*. Unfortunately, the processed data are not yet released to combine with the ASRAMP data, but these data will be included when they become available.

- **EM300 - Data acquired during ASRAMP cover areas not previously surveyed. As such these data are being used to update existing products**



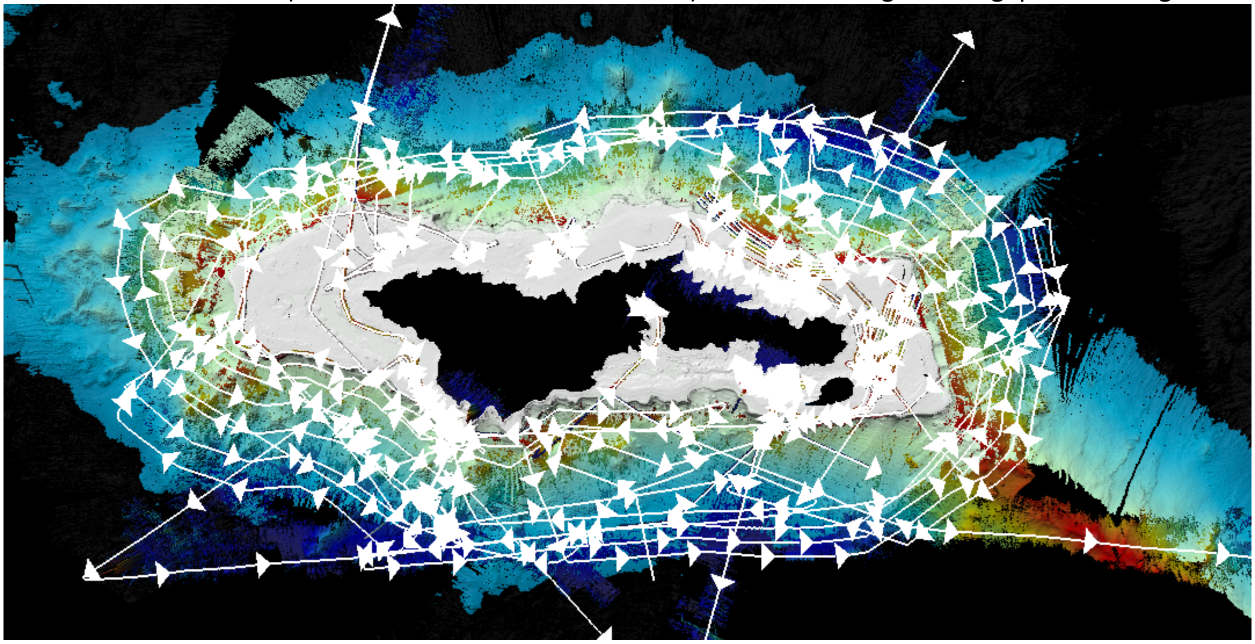
- **Updated DBM –** Processed Baker EM300 data mosaicked with existing surface to create updated 40m digital bathymetric model (DBM).



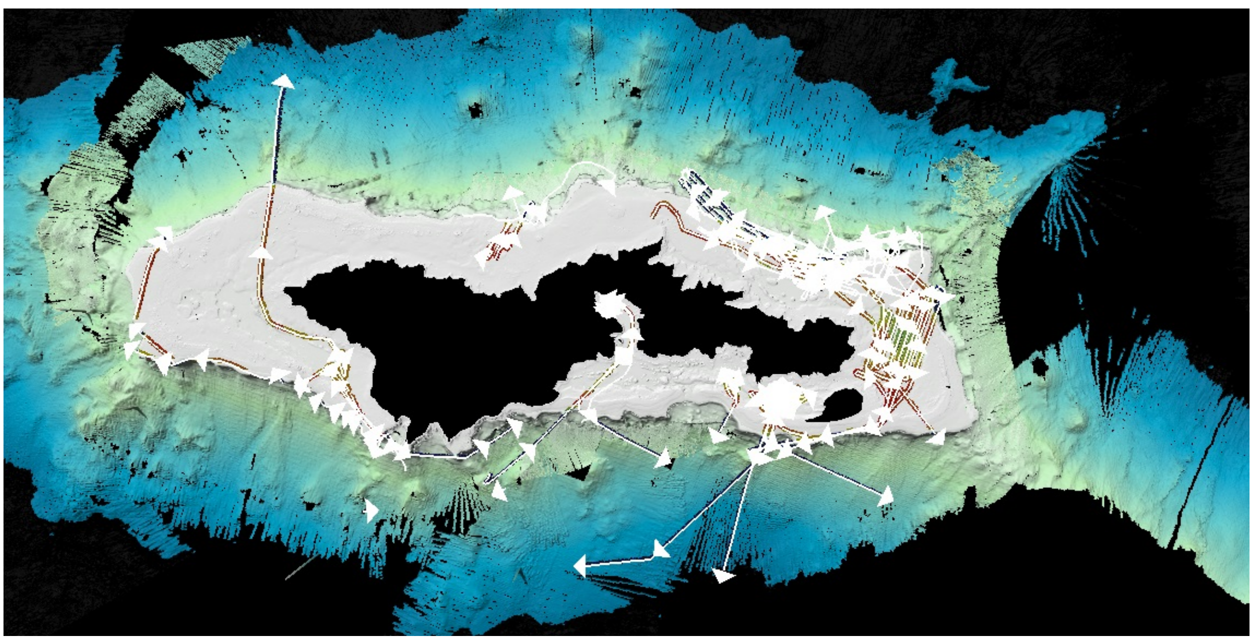
- **EM3002D -** *No EM3002D data acquired at Baker.

Tutuila

- **EM300**- ASRAMP data (white lines & rainbow color-scale) do not cover significant gaps in existing data.

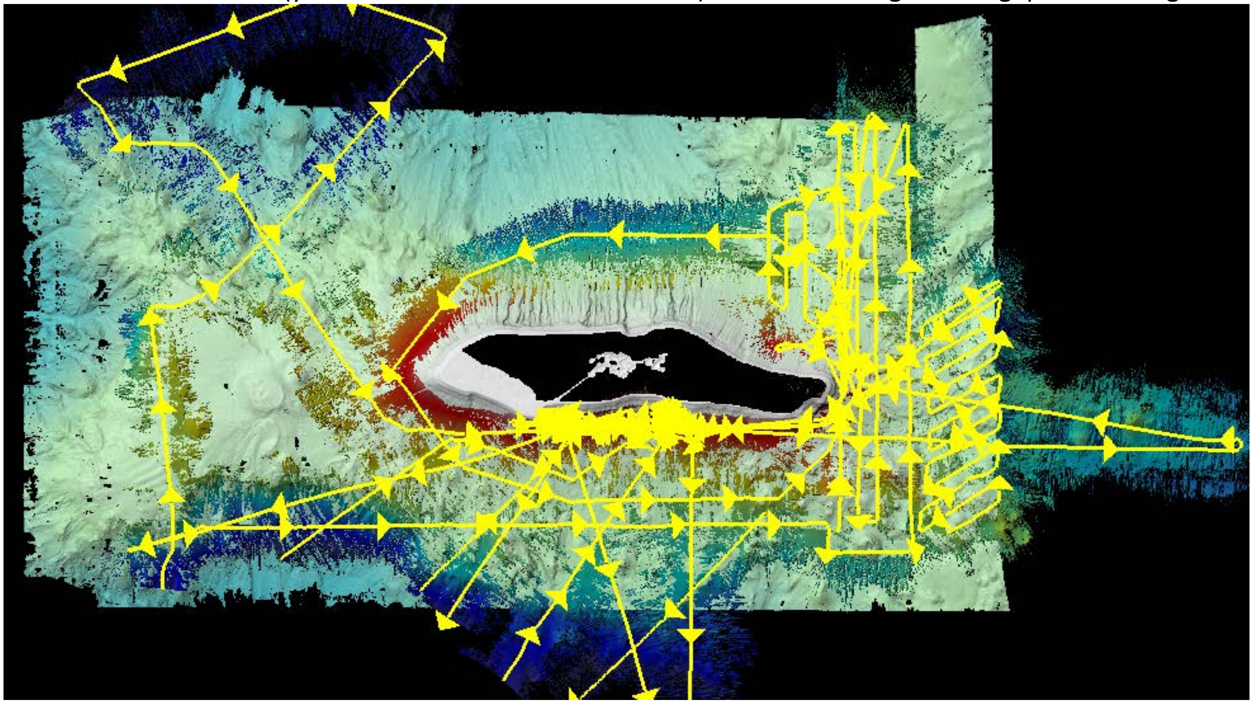


- **EM3002D** - ASRAMP data (white lines & rainbow color-scale) do not cover significant gaps in existing data.



Palmyra

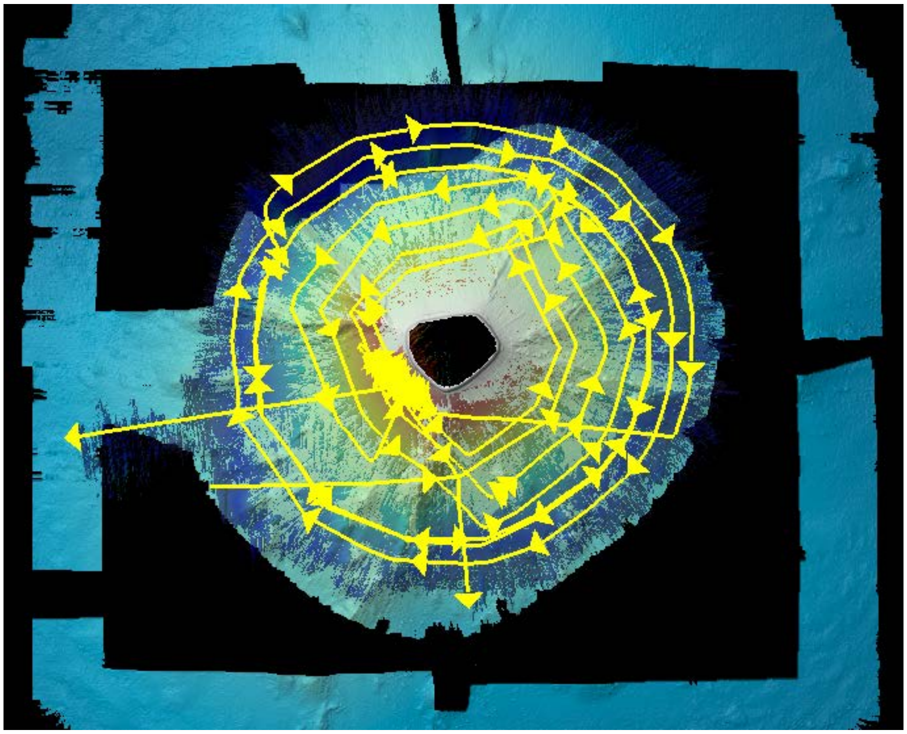
- **EM300** - ASRAMP data (yellow lines & rainbow color-scale) do not cover significant gaps in existing data.



- **EM3002D** – *No EM3002D data acquired at Palmyra.

Swains

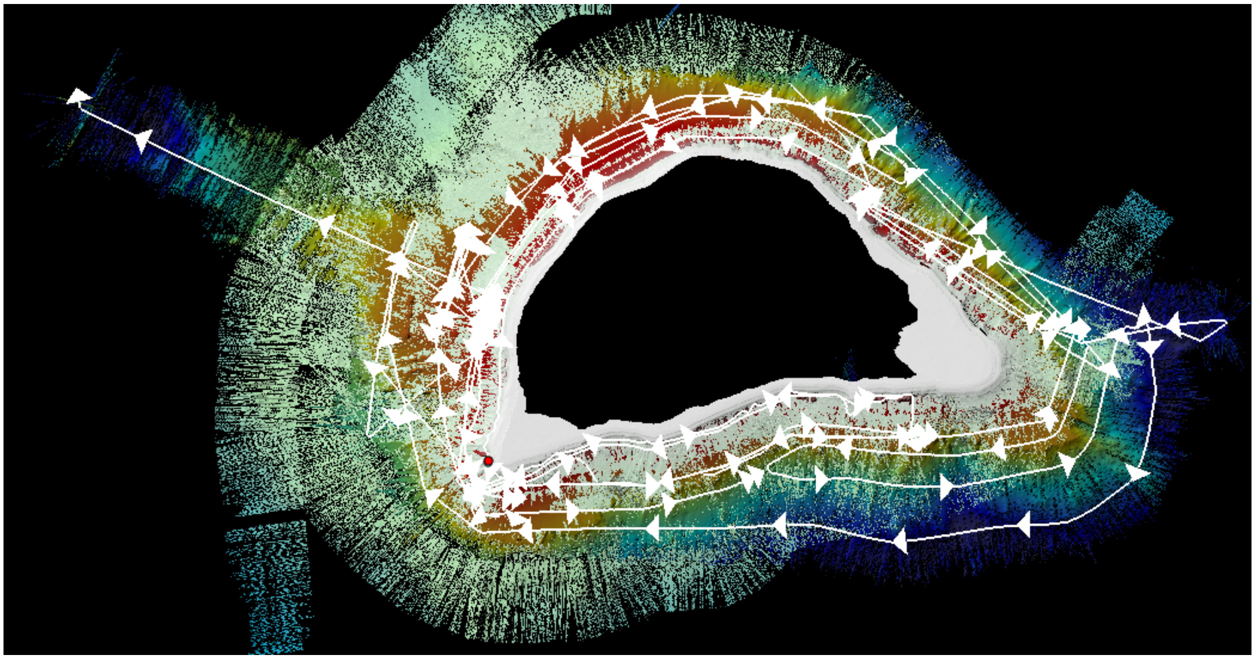
- **EM300 –** ASRAMP data (yellow lines & rainbow color-scale) do not cover significant gaps in existing data.



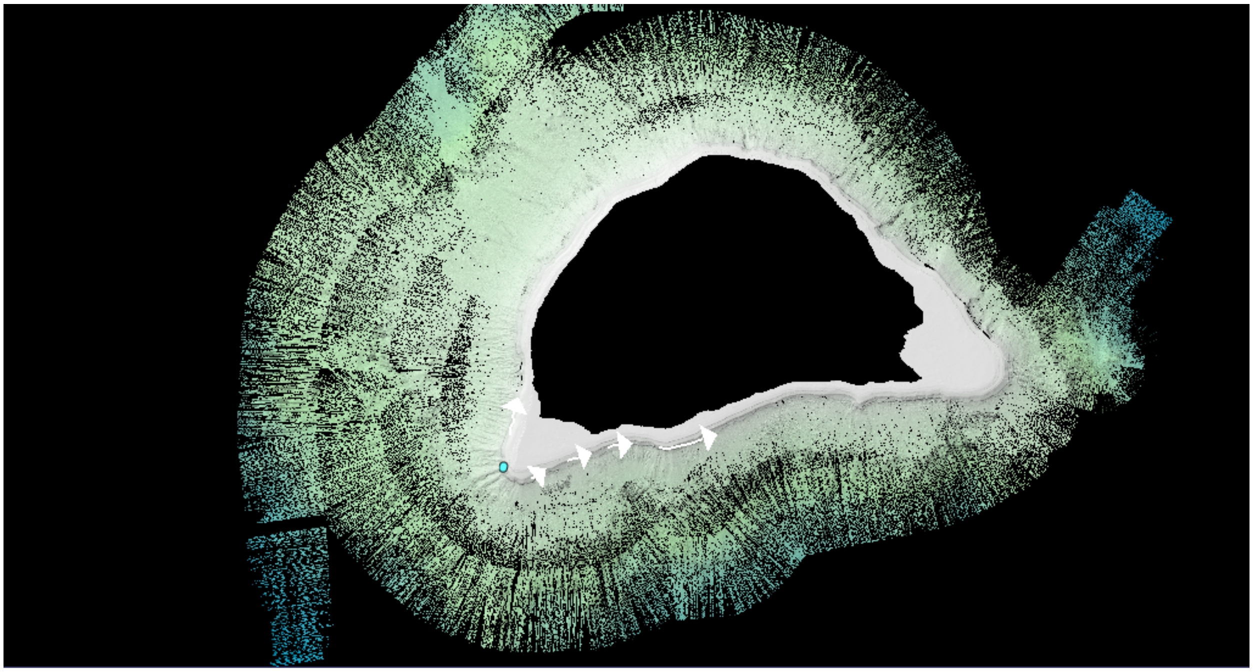
- **EM3002D -** *No EM3002D data acquired at Swains.

Johnston

- **EM300** - ASRAMP data (white lines & rainbow color-scale) do not cover significant gaps in existing data.



- **EM3002D**- ASRAMP data (white lines) do not cover significant gaps in existing data.



HARAMP – MBES bathymetry Processing Summary (EM3002D & EM300 sonars)

Data Provenance:

- **Survey Vessel: R/V NOAA Hi'ialakai (cruise ID: HA1606)**
- **Survey dates (location): Sept. 2016** (French Frigate Shoals, Pearl and Hermes, Lisianski, and Kure islands)
- **Instrumentation: Kongsberg EM3002D and EM300 sonars**

Objectives - Delivery

After processing the HARAMP bathymetry data (both EM30002D and EM300), and integrating these data together with pre-existing data, it has been decided (together with Ecospatial Information -team colleagues within the Coral Reef Ecosystem Program (CREP)) that these data will not be used to update formal products because of the data issues listed within the Introduction (i.e. mapping extent, vertical control, positioning). This section summarizes the processing and data evaluation that led to this decision. Deliverables from this work include this report, processed data * Generic Sensor Format (gsf) products (with and without SVP applied), as well as QPS Qimera projects for each data, with all new and previously acquired bathymetry data for each island surveyed (i.e. French Frigate Shoals, Pearl and Hermes, Lisianski, and Kure). *Importantly, despite that these data are not being used to update formal bathymetric grids, the data are of potential use towards separate scientific objectives (e.g. time-series analysis). Hopefully further value can be extracted from the data in the future.*

Methods

Scientific software employed in the post-processing of the MBES data include: LEIDOS SABER, QPS Qimera (*'clean' version*), QPS DMagic, Pydro-Velocipy, SEABIRD SBE DataProcessing, ArcGIS. The processing routine was made somewhat more complex due to lack of funding to acquire 'full' version of QPS's Qimera, which would have removed requirement to apply a number of data corrections externally with SABER and Pydro-Velocipy. **More detailed crib notes on the processing protocol is held by the Ecospatial Information team ('Processing HARAMP MBES data.docx'). A post-processing log is also available ('HA_1606_post-processing_log.xlsx').*

Basic processing workflow:

- Load raw bathymetry data (*.all) into SABER software run on the remote 'Anaxi' Linux server; data are converted to *gsf;
- Using observed tide data available from NOAA COOPS (https://tidesandcurrents.noaa.gov/waterlevels.html?id=1612340), apply the tides (in SABER) to the bathymetry data using the 'zonal tide' method (geographically-zoned predicted time and range corrections). The tide zones in the NW Hawaiian Islands were also made available by NOAA COOPSs.
    - After detecting that there remained significant vertical errors in the bathymetry data (when compared to overlapping areas with existing bathymetric surface based on multiple cruises), it was discovered that the ship's draft (~3 m) had not been applied during acquisition, thus draft also was applied to data in SABER.
- As observed sound-velocity profiles (SVP) were at first not available (these are typically acquired and converted during acquisition from CTD casts), we experimented with applying synthetic SVPs based on modelled predictions from the World Ocean Atlas (WOA). This process was facilitated by NOAA's Velocipy software, as part of the Pydro package provided by Erik Younkin from Office of Coast Survey.

- Once we acquired relevant software (SBE-Data Processing), observed SVP information was extracted from the ~daily CTD data that was acquired during the survey. Relevant SVP profiles were then applied to the data in SABER.

- Processed *gsf files were then imported into QPS Qimera bathymetry processing software to produce gridded surfaces, and compared with previously acquired data (i.e. 5m, 20m, and 50m surfaces available through PIBHMC website, and the NW Hawaiian multibeam synthesis compiled by John Smith at UH). Both data with draft+tides+SVP corrections, and just draft+tide corrections have been preserved, as we don't have sufficient constraint on sound velocity for consistently effective vertical-correction.
- In part because the HARAMP data aren't being used to update the existing grids, and because of the efficacy of the automated filters within Qimera, no individual 'ping' editing is being conducted. Instead we're producing 'spline-filtered' versions of the draft-tide, and draft-tide-svp *gsf files. The spline filtering removes most spurious data points.

Results - EM3002D

Data Quality

Inherent problems with HARAMP data across multiple islands; justification for not employing these data to update existing bathymetry compilations. Examples of this are shown in Figs. 1-13, which are organized by island.

- Insignificant gap filling: One sonar-head (starboard side) was dysfunctional during the majority of HARAMP cruise, immediately reducing potential coverage by 50% (e.g. Fig. 13). This is compounded on some islands (e.g. Kure, Pearl & Hermes) by the fact that beam-angle ('coverage') setting during acquisition was manually set too low (too narrow), so the resulting swath-width was further decreased (e.g. Figs. 9,10). For example on Pearl & Hermes, in waters of 60m depth, swath-width is only 70-80m. On a properly functioning/calibrated system, swath width is typically 4-5x water depth (e.g. ~250m). Ultimately, the insignificant coverage by the HARAMP mapping is largest influence on not using these data for updating existing bathymetry surfaces.

- Insufficient constraint of water column sound velocity (resulting in inconsistent vertical error): Accurately characterizing the velocity of the water column is fundamental towards accurate mapping of the seabed using sonars. As is a common practice, the surveyors on board the *Hi'ialakai* deployed CTD casts in order to calculate SVP for mapping purposes. This is particularly important in shallow water up to 100m. Unfortunately, only ~1 CTD/day was acquired, when typically these would be acquired every ~4hrs, or when velocity errors are apparent on acquisition displays. Further to this, SVP was not calculated/extracted offshore, and it took some time for those of us in the office to acquire the software to undertake this work.
  - Synthetic SVP: In the meantime, we experimented with applying synthetic (modelled) sound velocity information using the Velocipy software. Unfortunately this was not effective in a consistent way. While the synthetic profiles improved vertical fit in some locations, it amplified errors in others.
  - Observed SVP: Once observed SVP profiles were extracted from CTD data, these profiles were used to correct *gsf files. On the whole this improves vertical fit, but there remain inconsistencies (Figs. 8,13). With larger errors at depth, this indicates we still don't have adequate SVP constraint (insufficient CTD casts). Beyond this, there remains a consistent error

away from nadir that suggests potential system offset/mounting-angle issues (e.g. roll bias), but we can't confirm this until results from patch-test have been analyzed by colleagues at Coast Survey (i.e. Erik Younkin). ***See "Results from MARAMP Sea Trials" note on page 4

- Roll-bias: While it is difficult to discriminate this element at times due to the inconsistent effect of poorly constrained SVP (above), roll-bias resulting from uncalibrated source compounds the vertical error throughout the HARAMP EM3002D survey data (Fig. 11). This error persisted through the HARAMP survey because sea trials (patch test) were not conducted following dry-dock and prior to the HARAMP survey (discussed above). Apart from the identification of roll-bias during post-processing of the data, this error has been confirmed by the very-recent analysis of patch-test data (post-dating the HARAMP survey) by Erik Younkin at OCS.
- Potential navigation errors (Kure?): Beyond the sources of vertical error described above, at the outset of the project there was also concern about potential horizontal error as well, resulting from a suspected undocumented move of a dGPS antenna onboard the *Hi'ialakai* prior to the survey (2014). Due in part to the small footprint of the data (explained above), it has been difficult to verify this in the acquired data. On exception to this is in the Kure data, where imaging of a sediment wave field appears to be offset (~3-5m) from previous surveys (Fig. 3).

Data Deliverables

- EM3002D: Spline filtered versions of processed *gsf data (draft+tide) with and without SVP correction.
- EM300: Spline filtered versions of processed *gsf data (draft-corrected, but no tides) without SVP correction

Results - EM300 data

EM300 data were only acquired at Kure and Pearl and Hermes atolls. The EM300 data are inhibited by the same issues as described for the EM3002D (e.g. insufficient gap filling, poor constraint on SVP), with the exceptions that the transducer appears to be properly functioning, and there are no apparent roll-bias issues. Poor control of SVP though, has, if anything, a greater impact on the deeper EM300 data. While the swath width of the EM300 is as expected (~4 x water depth), the primary reason these data are also not being used to update the existing surfaces published online or being preserved in national archives is that they simply do not cover sufficiently large areas, and fill existing data gaps (e.g. Kure, and Pearl and Hermes).

Data examples (by island)

*Kure Atoll- (**EM3002D**)*

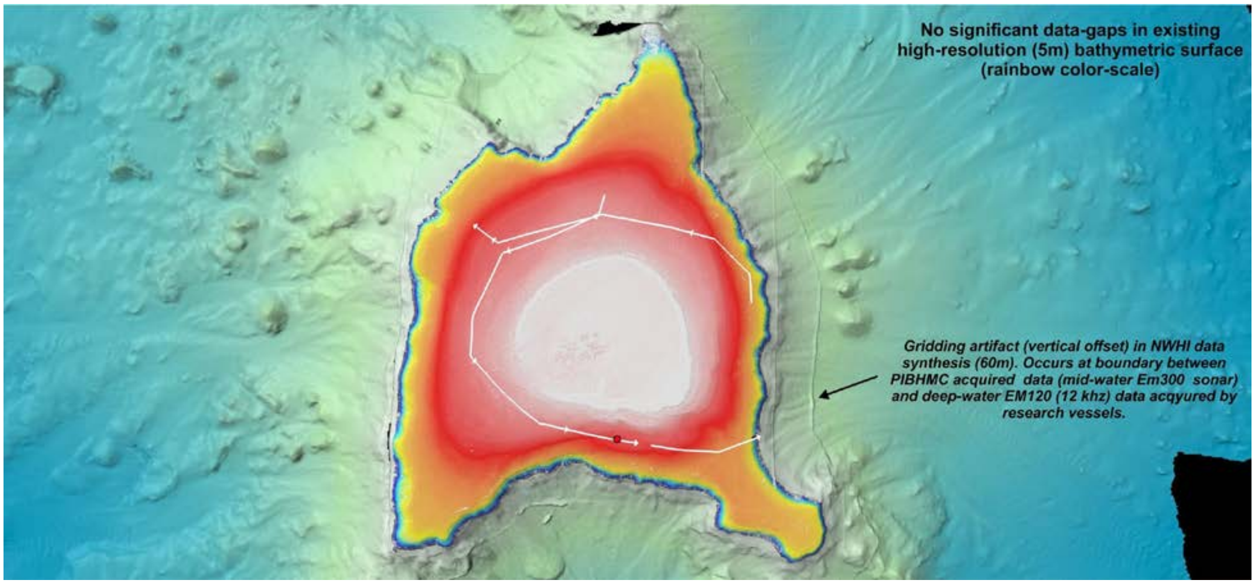


Figure 1: **Kure Atoll- HARAMP EM3002D survey line/coverage (white arrows) overlain on high-resolution 5m PIBHMC data (rainbow color-scale), which are in turn overlain on the coarser resolution (60m) SOEST UH NWHI synthesis (blue color-scale) (http://www.pacioos.hawaii.edu/metadata/hurl_bathy_60m_nwhi.html). Note absence of gaps in high-res data in shallow Kure shelf.**

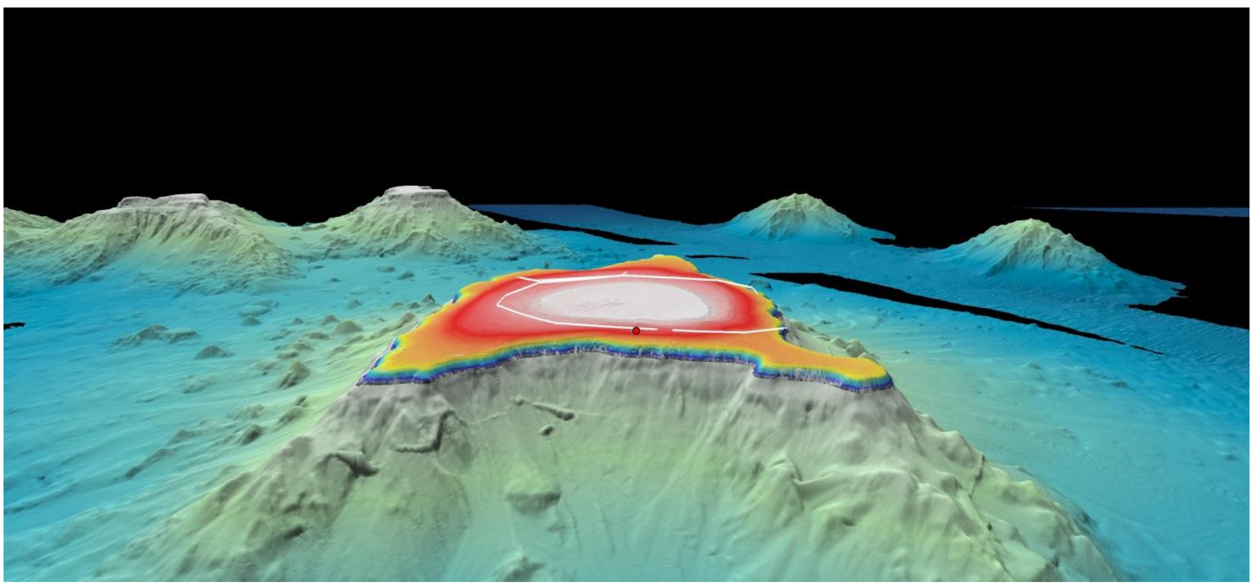


Figure 2: Kure - 3D perspective of area shown in Fig. 1 to illustrate that high-resolution EM3002D (5m) bathymetry don't extend beyond 300-400m deep. Abyssal plain at base of seamounts is ~4,000-5,000 m depth. Red dot shows location of Fig. 3.

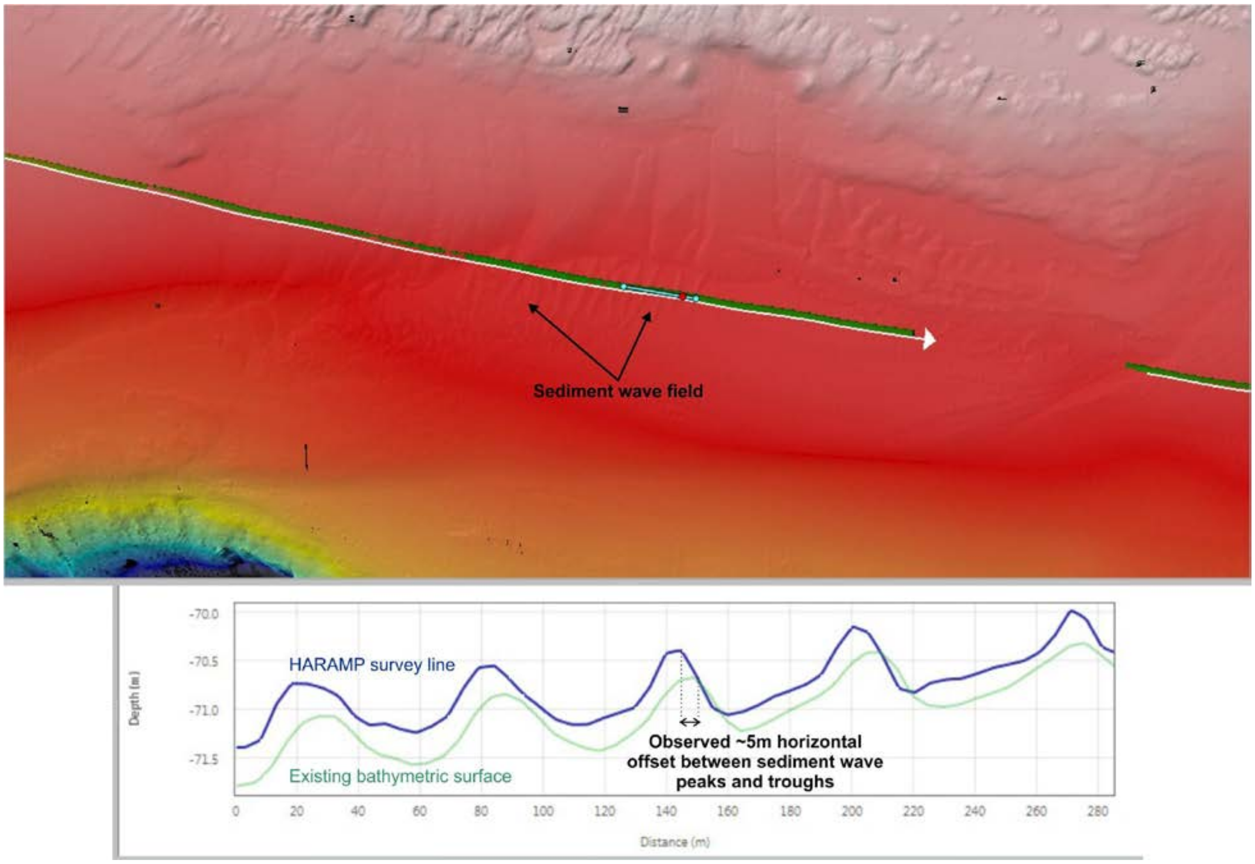


Figure 3: Kure - Potential positioning error – horizontal offset. Selected profile (light blue) south of Kure Atoll reveals potential horizontal offset between HARAMP EM3002D survey-line, and previously compiled bathymetric grid. Note ~3-5m horizontal mismatch in bottom-right cross-section. For location see red dot on Figs. 1 & 2. This horizontal error is suspected to have originated from an un-recorded moving of one of the vessel \DGPS antennae in advance (2014) of the survey.

*Kure Atoll - **(<u>EM300</u>)***

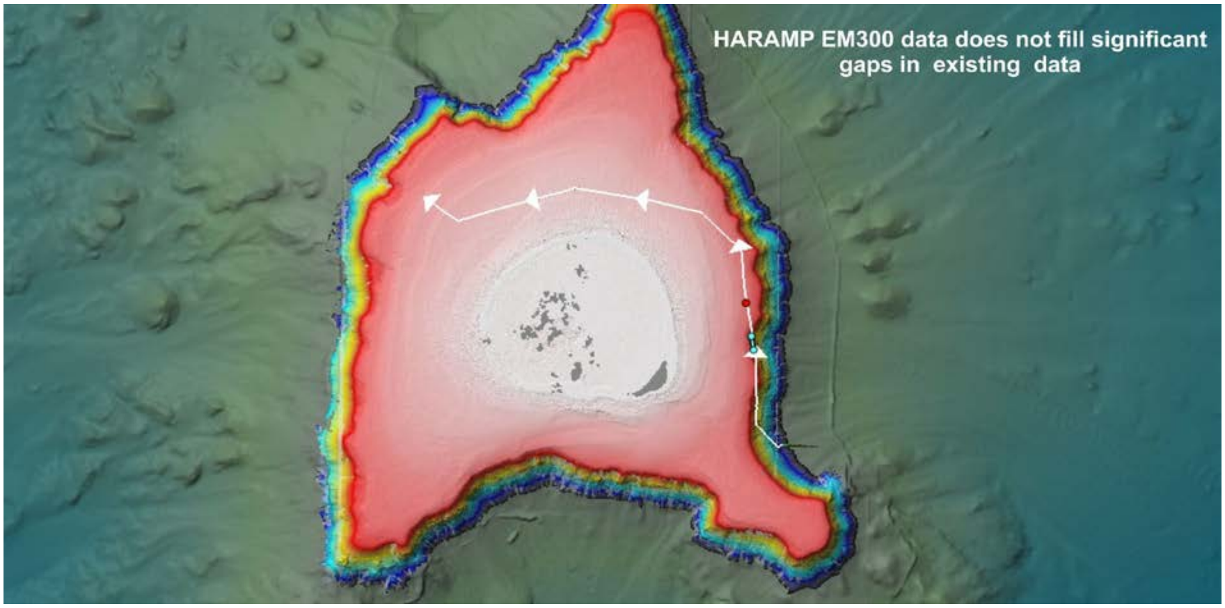


Figure 4: Kure- HARAMP EM300 survey line/coverage (white arrows) overlain on 40m resolution PIBHMC data (rainbow color-scale), which are in turn overlain on the coarser resolution (60m) NWHI synthesis (blue color-scale). Note that the HARAMP data do not fill any significant gaps in the existing data.

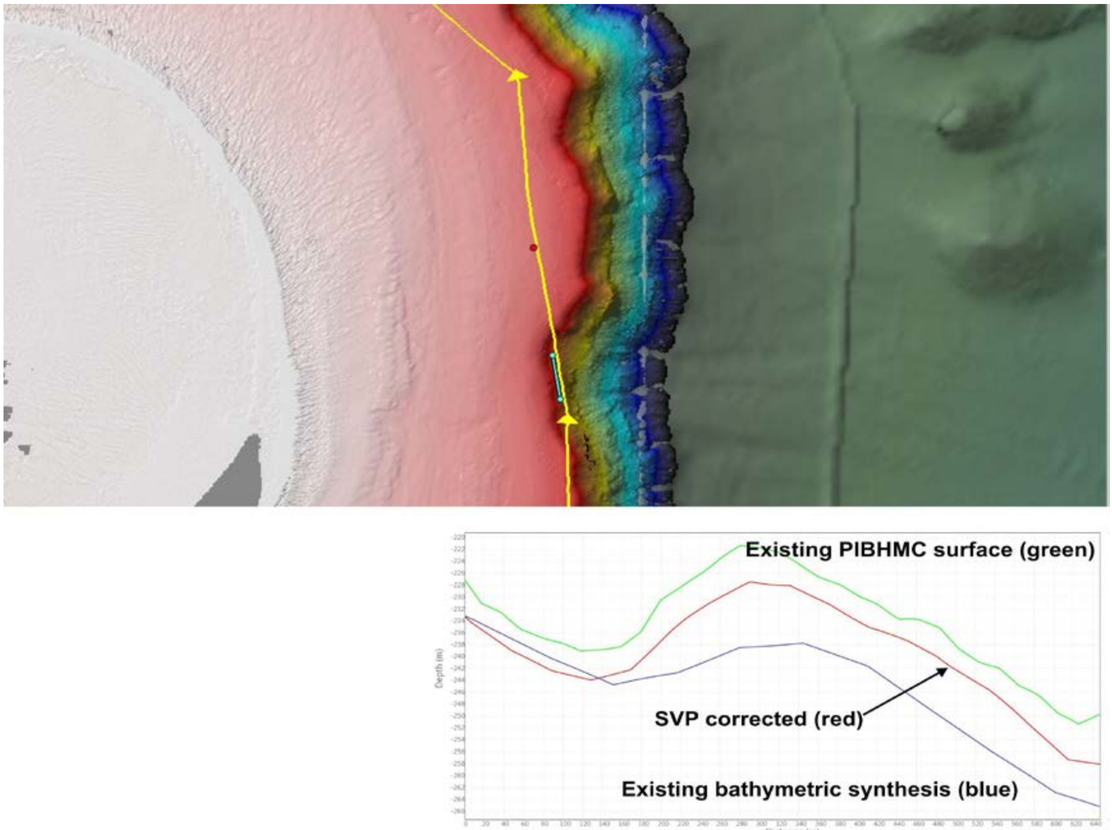


Figure 5: Kure – Better quality EM300 bathymetry were acquired on the eastern margin, and vertically position between two existing data products: 1) PIBHMC 40m grid based on previously acquired EM300 data, and 2) SOEST (UH) NWHI's bathymetry synthesis based on 12kHz bathymetry acquired from various research vessels. This however also illustrates the challenge in determining which vertical levels are 'correct' when testing various Draft/SVP/Tide corrections.

*Pearl and Hermes Atoll (PHR) - **(EM3002D)***

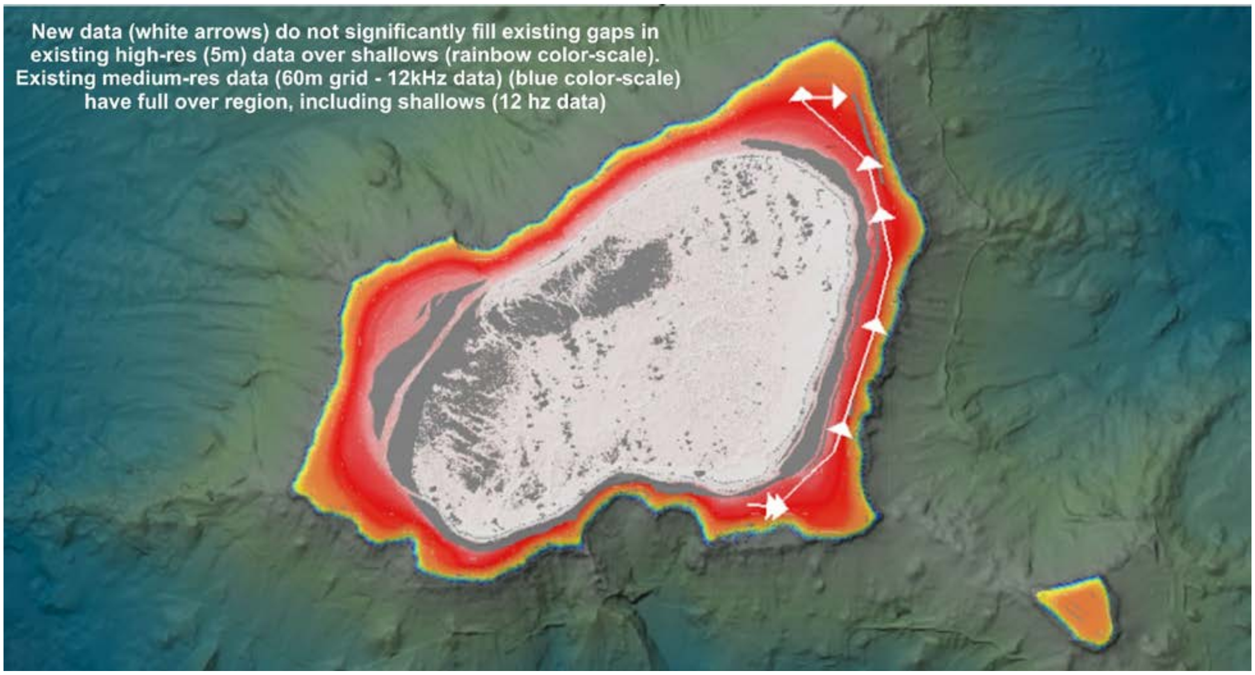


Figure 6: Pearl and Hermes Atoll - HARAMP EM3002D survey lines (white arrows) overlain on high-resolution 5m PIBHMC data (rainbow color-scale), which are in turn overlain on the coarser resolution (60m) NWHI synthesis (blue color-scale). Note gaps in high-resolution data (300 kHz system) over shallow reef, but that these areas are covered by the 60m grid (12 kHz systems).

Pearl and Hermes Atoll (PHR) ***- (EM300)***

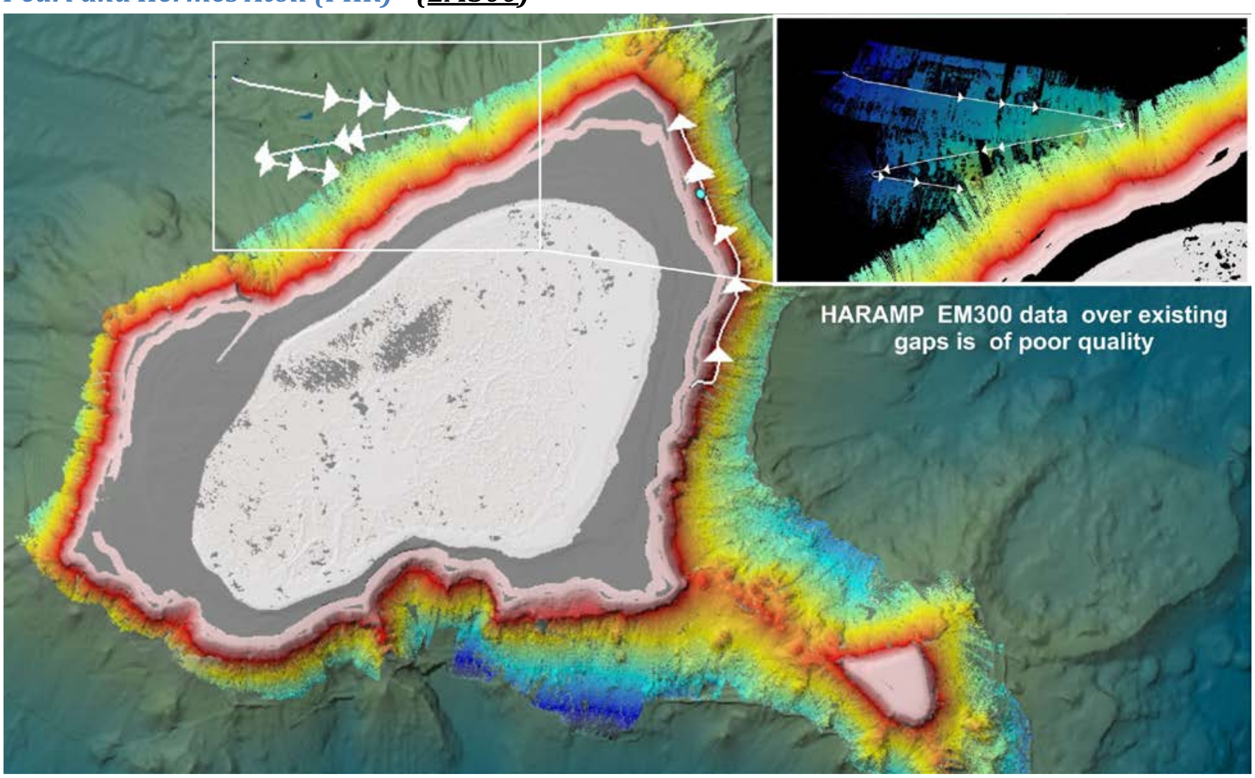


Figure 7: Pearl and Hermes Atoll– Figure illustrates that where HARAMP EM300 data cover regions not previously mapped with medium-resolution data (i.e. PIBHMC 40m grid), the new data are not of sufficient quality to be used (top-right inset).

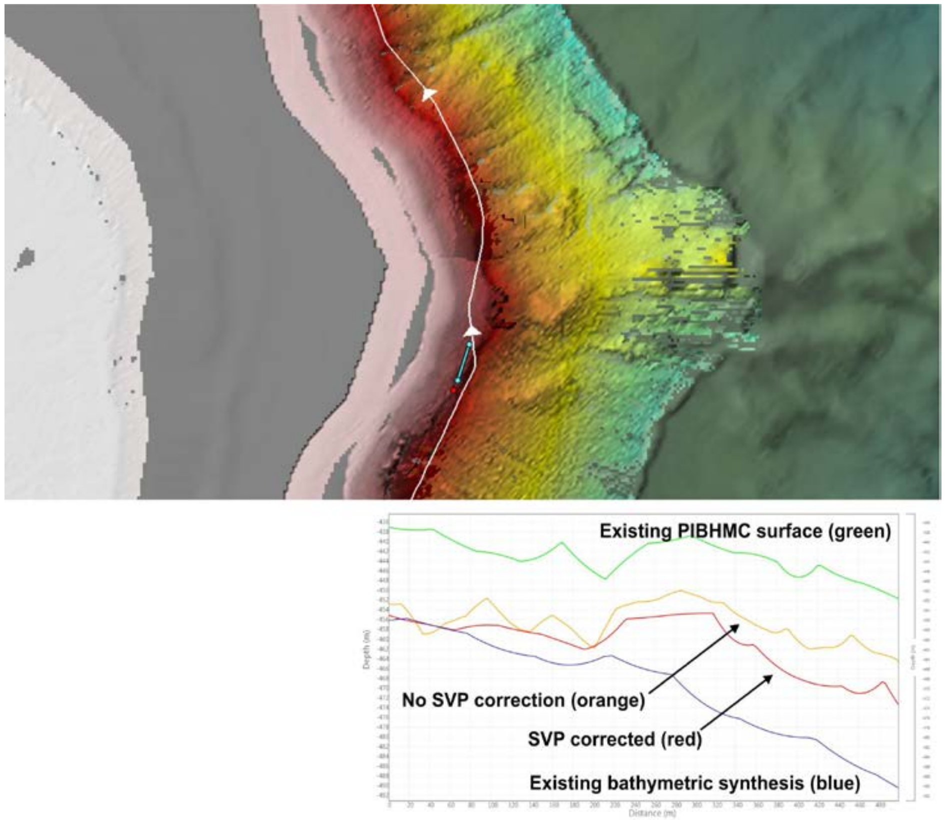


Figure 8: Eastern margin of Pearl and Hermes Atoll. Figure illustrates challenges in determining 'correct' vertical reference as both the SVP corrected, and uncorrected HARAMP EM300 data fall between previously compiled surfaces: 1) PIBHMC 40m grid based on previously acquired EM300 data, and 2) SOEST's (UH) NWHI bathymetry synthesis, which also includes 12kHz bathymetry acquired from various research vessels.

Lisianski Island (LIS) - (EM3002D)

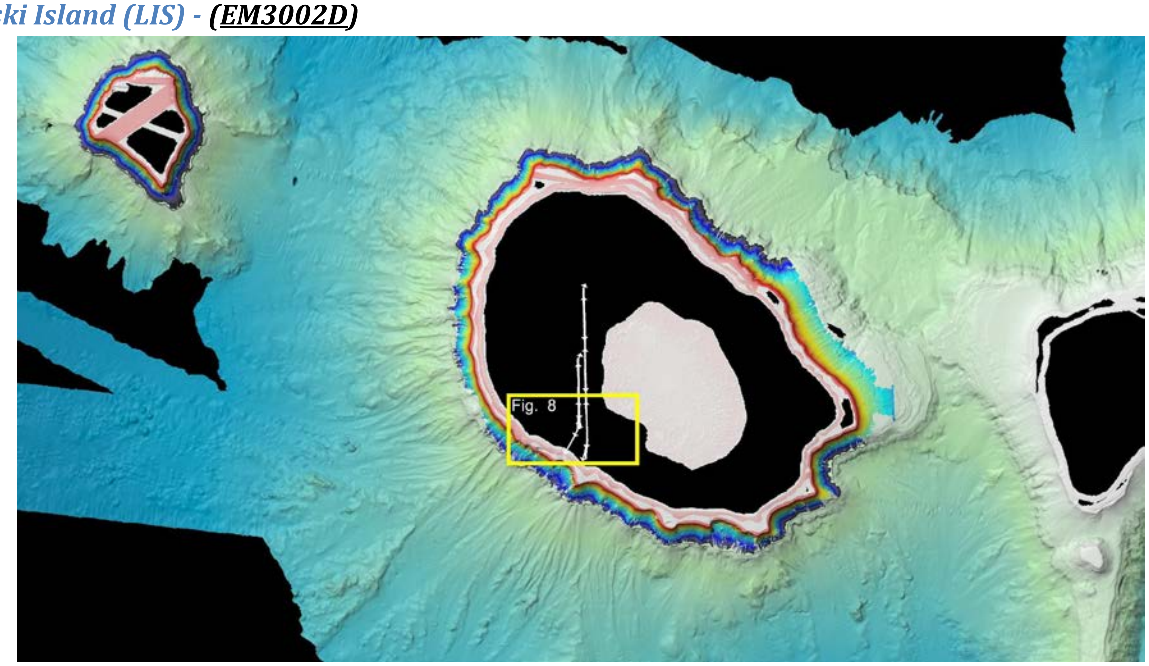


Figure 9: Lisianski Island- EM3002D survey line/coverage (white arrows) overlain on high-res 5m PIBHMC data (rainbow color-scale), which is in turn overlain on the coarser resolution (60m SOEST (UH) NWHI's synthesis; blue color-scale). Note that data gaps remain in shallow water, but the limited coverage by HARAMP data and poor data quality are judged insufficient to be used to fill these gaps (see Fig. 10).

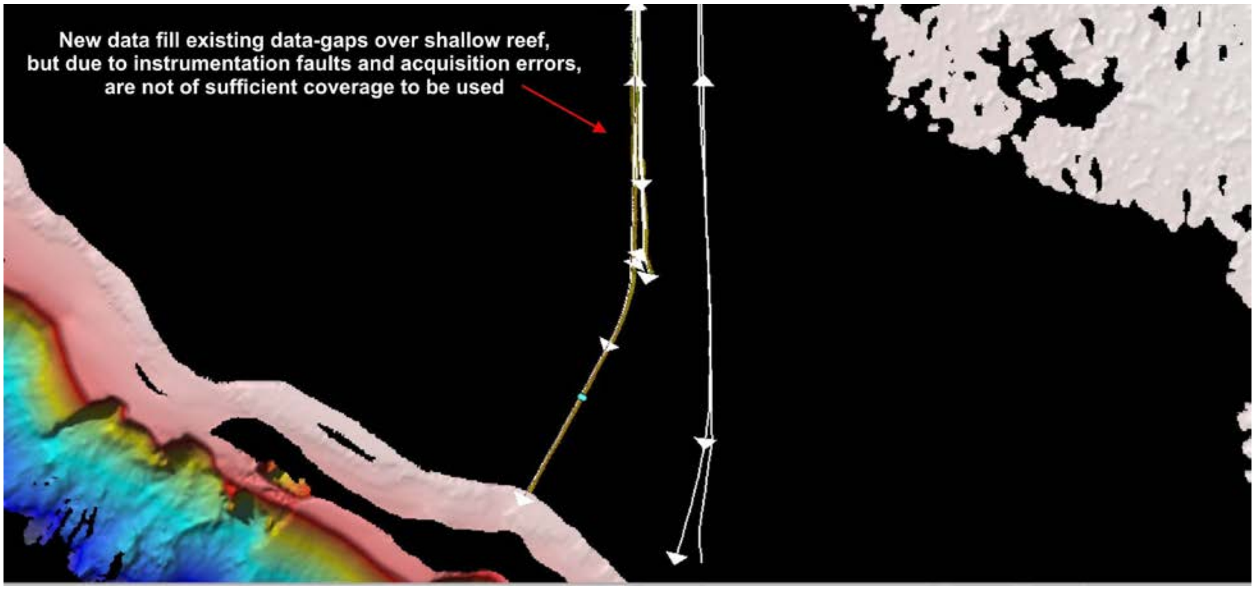


Figure 10: Lisianski Island – Figure demonstrates how limited swath width (only ~40m here, due to faulty transducer, as well as beam angle set too low/narrow) negates usefulness of the HARAMP data even where there are gaps in pre-existing data. Because the data cover such small areas, and due to inherent vertical error issues with data, the EM3002 data are not being used to update existing surfaces.

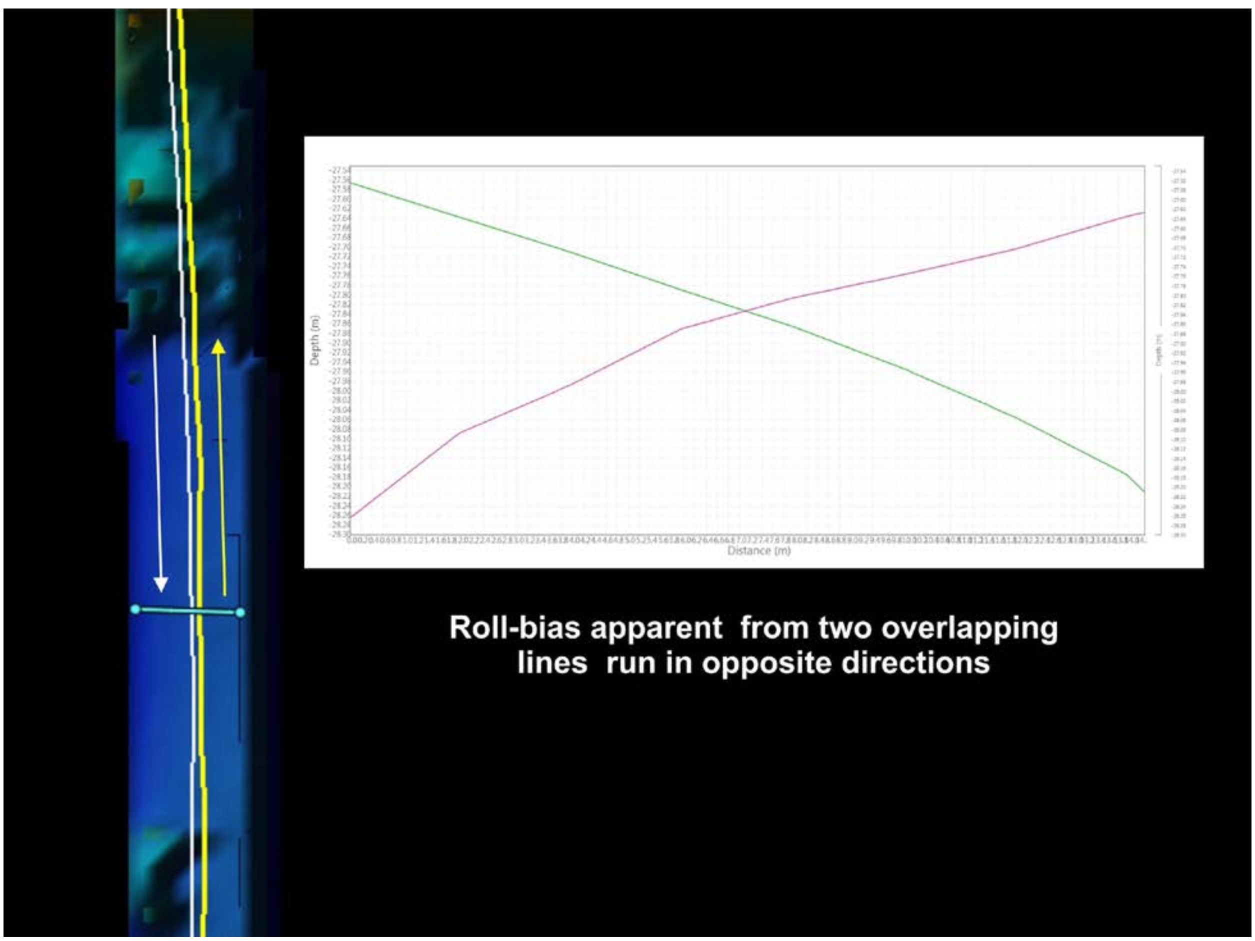


Figure 11: Lisianski Island- Demonstration of unaccounted-for roll-bias in the HARAMP data. Profile shows two surfaces associated with two separate lines of opposite heading, resulting in vertical uncertainty up to 2m. This effort is amplified in deeper water with wider swath widths.

*French Frigate Shoals (FFS) - **(EM3002D)***

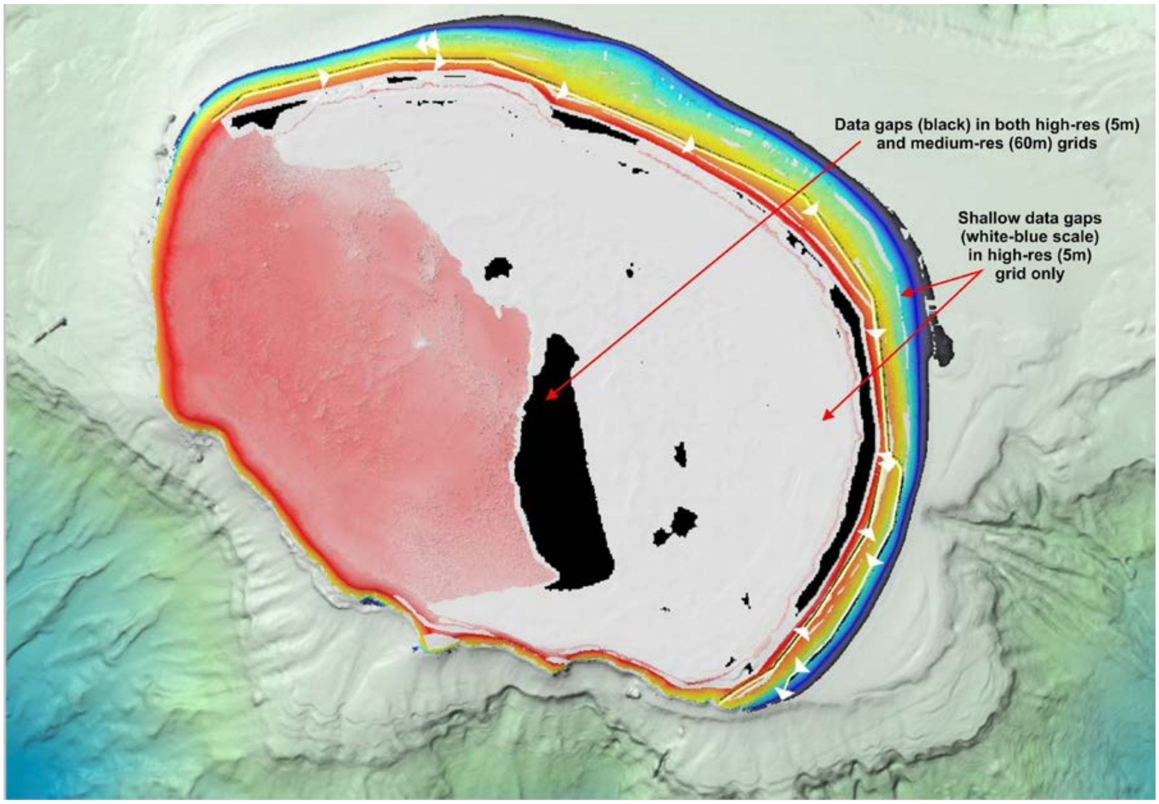


Figure 12: French Frigate Shoals - HARAMP EM3002D survey line/coverage (white arrows) overlain on high-res 5m PIBHMC data (rainbow color-scale), which is in turn overlain on the coarser resolution (60m) NWHI synthesis (blue color-scale). New HARAMP data do not significantly fill existing gaps in the existing high-resolution grid.

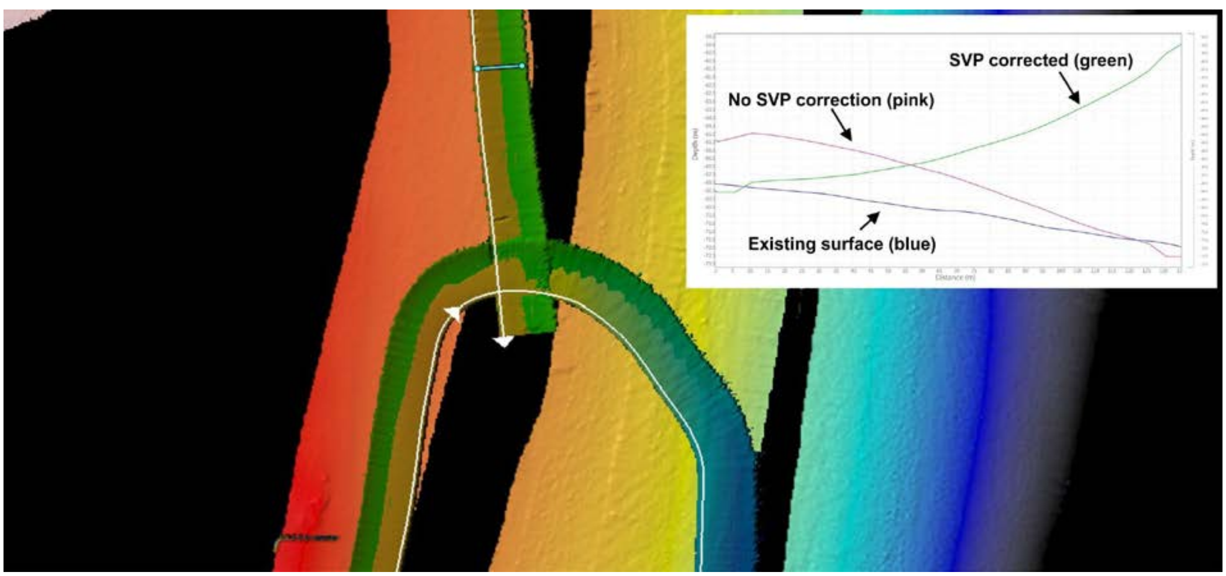


Figure 13: French Frigate Shoals - Inset profile (top-right) illustrates significant vertical errors in new HARAMP data. Data window includes new HARAMP data (green-blue) overlain on existing high-resolution 5m surface (rainbow color-scale). Location of profile shown in light blue. Within the profile (top-right), the existing high-res surface is shown by blue line, together with two versions of the new HARAMP EM3002D data: with (green) and without (pink) correction based on observed sound-velocity profile (SVP). Note that both surfaces fail to accurately trace the existing surface, which results from two separate sources of uncertainty/error: 1) roll-bias (uncalibrated system), and 2) poor constraint on sound-velocity of water column (insufficient CTD casts during acquisition). Such errors are ubiquitous throughout HARAMP data, but are difficult to correct in a consistent way as sound velocity of water column is highly variable.

MARAMP

Data Provenance:

- **Survey Vessel: R/V NOAA Hi'ialakai (cruise ID: HA1701)**
- **Survey dates (location): May, 2017** (Guam, Aguijan)
- **Instrumentation: Kongsberg EM300 sonar**

Methods

**Methods for processing MARAMP data are consistent with those for HARAMP, so details not repeated here. Importantly, due to analysis of patch-test data from MARAMP, the EM3002 instrument is effectively inoperable due to the large number of issues causing poor/limited data acquisition (e.g. defective starboard head). The EM3002 data are therefore not presented for MARAMP.*

It is worth noting that useful sound velocity information (extracted from mapping CTD casts) was acquired during the hydrographic survey at Aguijan, and a couple days after the initial survey at Guam. This has enabled relatively good vertical control on the resulting bathymetric surfaces, and good fit with existing, partially overlapping data, particularly at Aguijan (see examples below).

While the EM300 data are of good quality at Aguijan, they do not cover existing gaps and hence are not used to update existing data products. We are, however, updating data products with the newly acquired data at Guam, despite that they do not cover a very large area.

Deliverables

Qimera projects have been created for each island, though because data at Aguijan do not cover previously un-surveyed seabed, MARAMP data have not been further processed, and will not be archived. For Guam, Qimera project includes processed data and new gridded surfaces. The new surfaces have been mosaicked together with existing PIBHMC data (methods below) to produce a new composite digital bathymetric model (DBM). Processed *gsf files are being archived.

Guam

While covering a relatively small area, newly acquired EM300 data from the NE coast of Guam do cover previously un-surveyed seabed, and the data are considered of sufficient quality to be used to update existing products. While a mapping CTD was deployed at Guam, previously acquired (HI0702) SVP data have been used to correct vertical levels of the MARAMP data. This was done because the MARAMP HA1701 CTD casts only reached ~170m in a survey area that reaches ~800m. Although this SVP information improved the vertical accuracy of the data, sound velocity information acquired to full ocean depths in 2007 (HI0702) was found to be more effective at matching existing surfaces (where overlapping), and hence were used in final processing. There are still variable vertical mismatches between the existing PIBHMC surface and the MARAMP data, up to 10m at greater depths, but largely the fit is good, and it is noted that similar discrepancies exist between PIBHMC surveys acquired over different years and between different instruments (e.g. 5m vs 60m grids from EM3002 & EM300 surveys respectively.

Following draft/offset and sound-velocity corrections in SABER, the data were cleaned using QPS Qimera. All data were first cleaned using a medium tension spline filter, then Dynamic Surfaces were hand edited using the 2D Slice function to remove remaining spurious data points. The cleaned surface (60m resolution) was then exported to floating point geotif, where in ArcGIS this was mosaicked (‘Mosaic to new Raster’) with the existing 60m bathymetry surface. The new mosaic surface is being uploaded to the PIBHMC website.

- **EM300**- MARAMP data (yellow lines & rainbow color-scale) cover previously un-surveyed areas and are being used to update existing products.

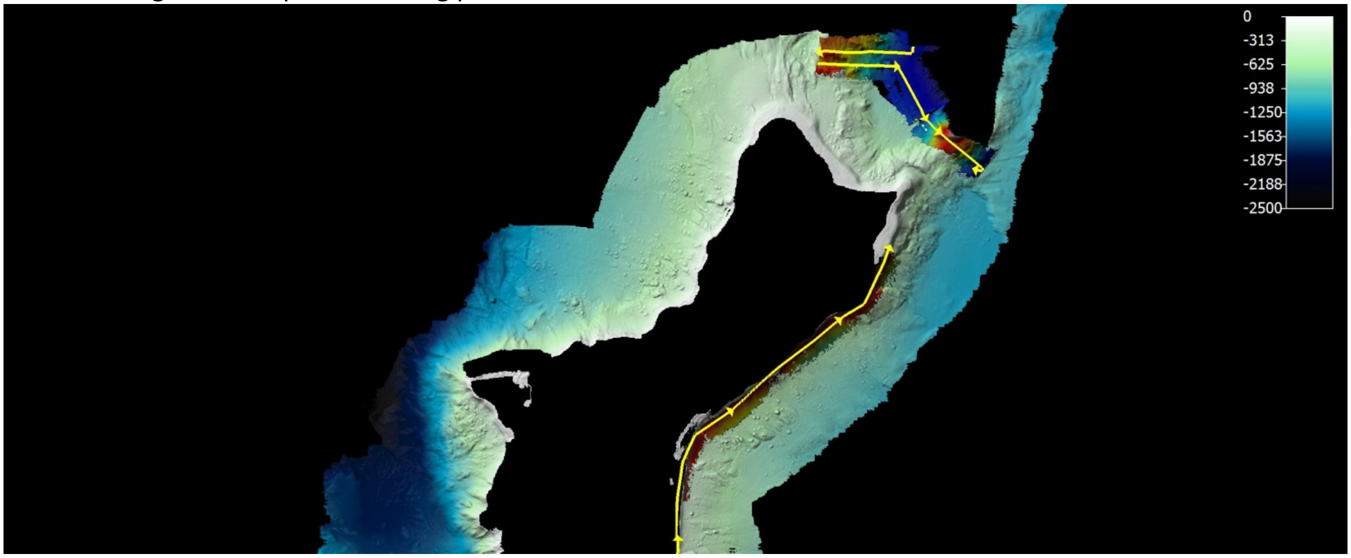


Figure 14: New RAMP data (rainbow color-scale) adjacent to existing PIBHMC surface.

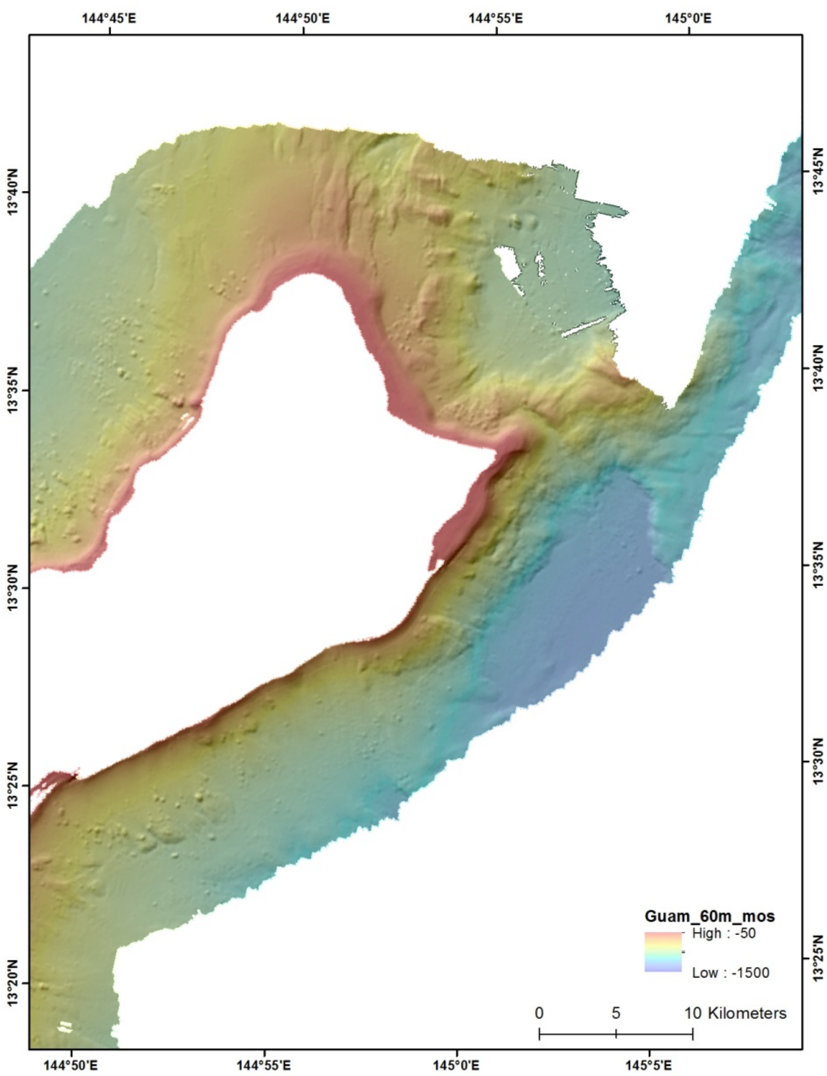


Figure 15: Composite Digital Bathymetric Surface of merged PIBHMC data with newly processed RAMP data.

Aguijan

*The EM300 survey at Aguijan provided good data, which results from extensive data being acquired with good constraint on sound velocity. Mapping CTDs were acquired during the survey, with resulting sound-velocity profiles being read into the MBES acquisition. **This is the first time this protocol (the correct protocol) was achieved over this and the two previous RAMP missions, but still demonstrates that high-quality and useful MBES data can be acquired from *Hi'ialaki.***

However, as the EM300 data do not cover previously un-surveyed areas, the new data have not been used to update existing products.

- **EM300**- MARAMP data (white lines & rainbow color-scale) do not cover significant gaps in existing data.

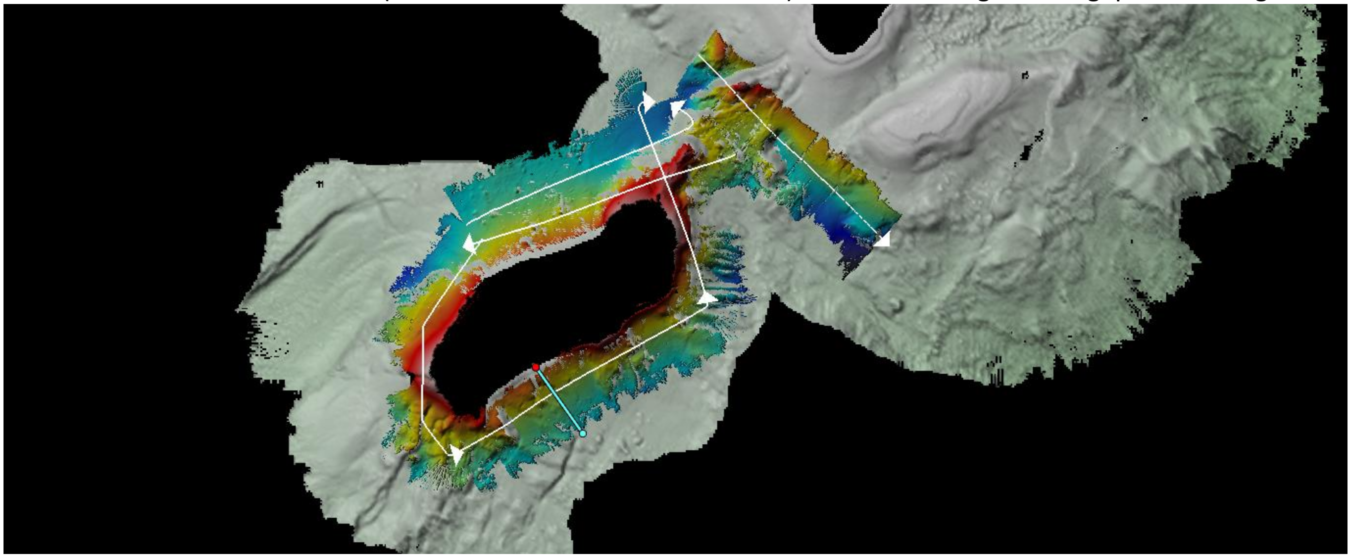


Figure 16. MARAMP EM300 data over existing 60m grid. Note location of profile related to figure below.

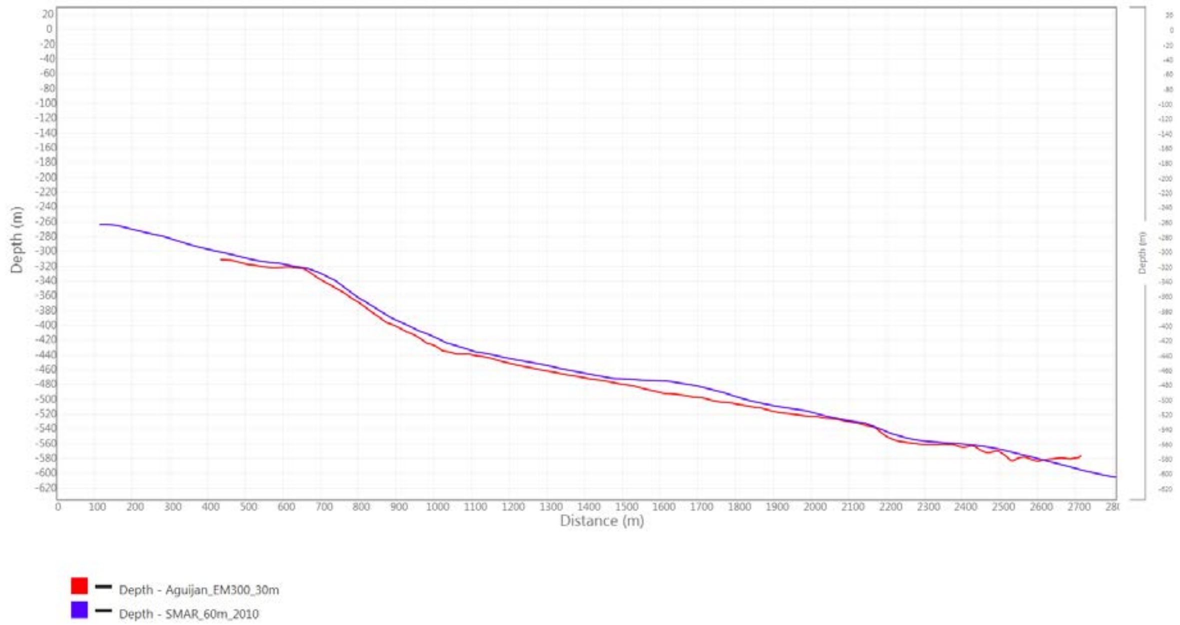


Figure 17. Good overall fit resulting from correct incorporation of sound velocity information. MARMAMP EM300 data shown in red, compared with existing 60m grid in blue. Note location of profile in above figure.