Error Analysis of Bathymetric Data Derived from IKONOS Imagery
Location: Tutuila Island, American Samoa

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Produced for: Pacific Islands Benthic Habitat Mapping Center (PIBHMC) / NOAA Fisheries' Coral Reef Ecosystem Division (CRED)

Analysis Overview

Bathymetric data were derived from IKONOS multispectral satellite imagery provided by the National Center for Coastal Monitoring and Assessment (NCCMA). The original imagery, purchased from Space Imaging, Inc. (now Geoeye, Inc.), was orthorectified to correct for detected geographic offsets. Five images, acquired on different dates, were analyzed to extend the spatial coverage of the final derived bathymetry product. The imagery was provided as IMG files named "otutu_msi_61091.img", "otutu_msi_60736.img", "otutu_msi_65904.img", "otutu_msi_65907.img" and "otutu_msi_65909.img". They will be referred to as Tut091, Tut736, Tut904, Tut907 and Tut909 in this analysis.

Processing steps were based on methods originating in Lyzenga 1985 with refinement as described in Hogrefe et al. 2008 and Hogrefe 2008 (http://dusk.geo.orst.edu/djl/theses/kyle/Cookbook_042108.pdf).

An overview of the processing steps as follows:

1) Data conversion from digital number to radiance values
2) Correction for atmosphere and water surface reflection
3) Linearization of spectral decay of as function of depth
4) Masking of data not applicable to depth derivation
5) Extraction of linearized spectral values and depth data
6) Performance of multiple linear regression to determine formula variables for depth derivation (and derivation of depth)
7) Integration of derived bathymetry with multibeam sonar bathymetry

This analysis focuses on the statistical accuracy of several products that result from step 6 to determine the most accurate data for integration with multibeam sonar bathymetry collected by PIBHMC/CRED. Once the multiple linear regression was performed in step 6, the resulting variables were plugged into the multivariate slope intercept formula (below) to derive bathymetry. These variables can be adjusted to increase the accuracy and coverage of the product. The two basic changes in derived bathymetry that can be accomplished by adjusting the original multiple linear regression (MLR) variables are:

1) Depths can be changed equally across the entire image by adjusting the Y intercept. Depths are increased when the Y intercept is decreased and depths are decreased when the Y intercept is increased.

2) The slope of the regression line (of the derived depths against sonar bathymetry) in the error analysis can be changed by adjusting the slope of the linearized blue and green spectral values. Thus, changing depths to varying degrees throughout the depth range.

These adjustments to the MLR variables allow for greater depth range and spatial coverage in the derived bathymetry. Depths derived in areas of very shallow water often have positive values which are then lost when the product is "trimmed" to include only depth (i.e. negative) values. I hypothesize that this effect is due to an inversion of the spectral relationship between the blue and green bands in these very shallow areas. Where depths are greater than ~3 meters, blue radiance values are always greater than green radiance values, however, where depths are less than ~3 meters the inverse is often true. This "shallow inversion" is not captured in the values extracted for the multiple linear regression that determines the variables for depth derivation. While this problem is reduced by adjusting the MLR variables, the adjustments also impact the statistical accuracy of the product.

This error analysis validates the choice of which product(s) to integrate by establishing the statistical accuracy of derived bathymetry from each image using the original variables and then documents the statistical differences as the variables are adjusted.

The formula used to derive bathymetry is a multivariate slope intercept formula as follows:
$\text{Depth} = Y_{int} + (m_{blue})(x_{blue}) + (m_{green})(x_{green})$
Where:
Y_{int} = Y intercept
m = slope
x = linearized spectral value

Part 1: Analysis of Derived Bathymetry using Extraction Points.

In processing step 5, ArcGIS point features are created to extract sonar depth and linearized spectral values for use in the step 6 regression analysis. Approximately 500 points are chosen per satellite image where pixels with clear spectral signal are concurrent with depths between the shallowest available and 25 meters. These same point features are used to extract derived depth values for comparison with sonar depth values in the following linear regression analyses. For image Tut091, 495 points were used; for image Tut736, 693 points were used; for image Tut904, 553 points were used; for image Tut907, 536 points were used and for image Tut909, 539 points were used.

Image Tut091

As shown in Figure 1, the R^2 value for the bathymetry derived using the original MLR values is 0.3011 while the slope of the regression line is also 0.3011. The R^2 value represents a decent grouping of the derived depth scatter plot around its regression line while the slope value indicates a reasonable correlation between derived and sonar depth, represented by the red plot. The resulting raster grid provides realistic bathymetric data and provides for good coverage into shallow areas. The aforementioned phenomenon of positive values in very shallow areas does lead to some data loss close to the island. The solution for expanding coverage in shallow areas is described below.

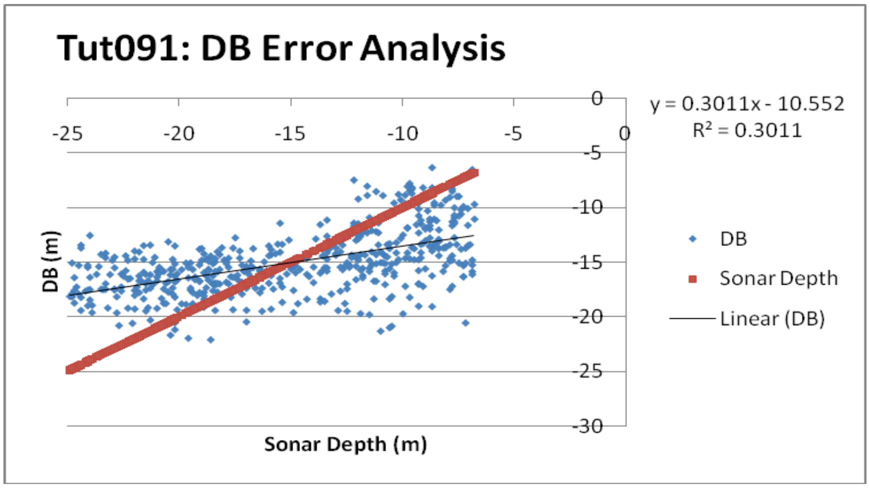

Figure 1. Error analysis of derived bathymetry from Tut091 using original MLR variables. Formula applied: Depth = 19.7602 - 1.6871 * X_{blue} + 12.3928 * X_{green}

In order to increase shallow coverage (0-5 m), new bathymetry was derived by decreasing the Y-intercept value. In order to increase the coverage to the desired extent, the Y-intercept value needed to be decreased by 12. This change to Y-intecept value would result in a 12m jump in depth value at the seam between datasets. To alleviate this problem, 3 new bathymetry products were derived by decreasing the Y-intercept value by 4 during each iteration (Figures 2 through 4). Each product was then mosaiced in sequence while giving priorty to the previously integrated grid.

Note that the spatial coverage gains made through these adjustments are not apparent in the following graphs, but they are implied by the decreasing Y-intercept values of the regression line of each subsequent error analysis. The coverage gains are readily apparent in the map images provided in the Tutuila deliverable package. Statistical assessments of the integrated product are detailed in Part 2.

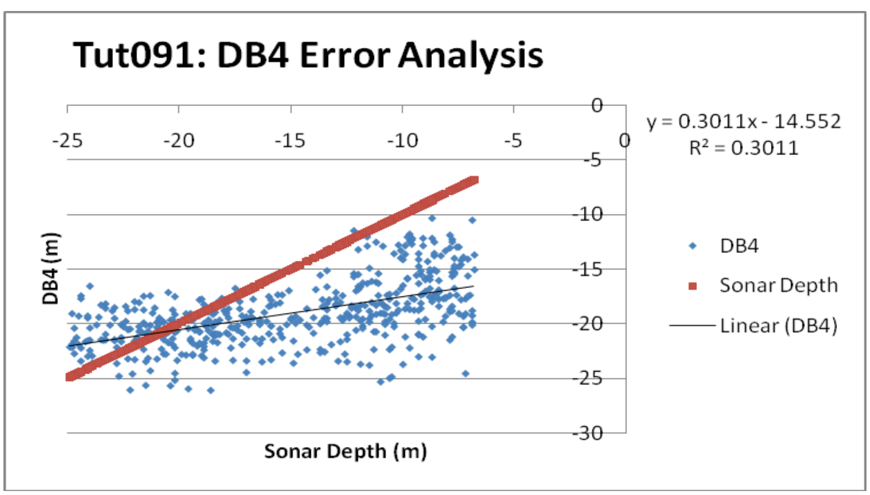

Figure 2. Error analysis of derived bathymetry from Tut091 using decreased Y-intercept value. Formula applied: Depth = 15.7602 - 1.6871 * X_{blue} + 12.3928 * X_{green}

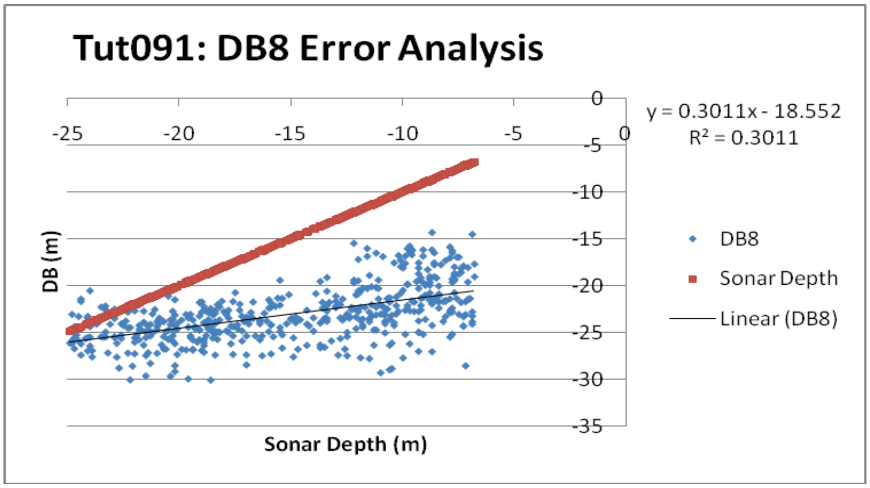

Figure 3. Error analysis of derived bathymetry from Tut091 using decreased Y-intercept value. Formula applied: Depth = 11.7602 - 1.6871 * X_{blue} + 12.3928 * X_{green}

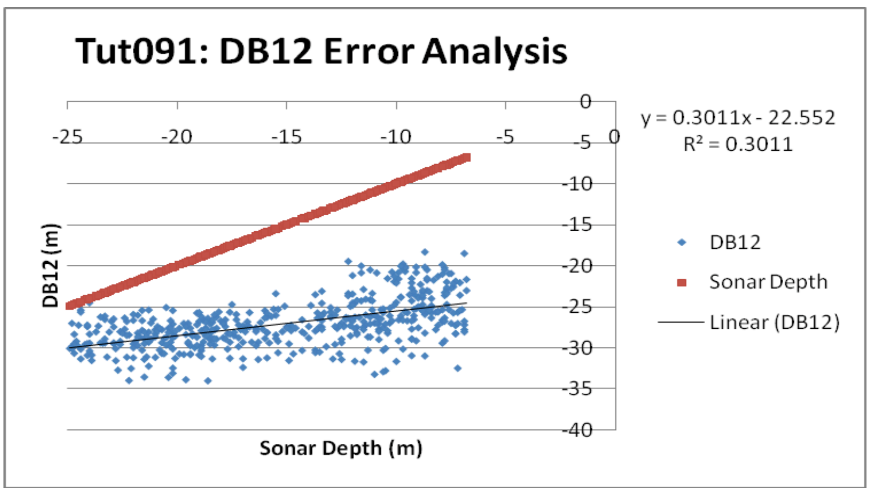

Figure 4. Error analysis of derived bathymetry from Tut091 using decreased Y-intercept value. Formula applied: Depth = 7.7602 - 1.6871 * X_{blue} + 12.3928 * X_{green}

Image Tut736

As shown in Figure 5, the R^2 value for the bathymetry derived using the original MLR values is 0.1811 while the slope of the regression line is also 0.1811. This R^2 value represents a fairly loose grouping of the derived depth scatter plot around its regression line and the slope value indicates some degree of correlation between derived and sonar depth, represented by the red plot. Though these statistical indices are fairly low (especially compared to previous products provided under this contract) the resulting raster grid still provides realistic bathymetric data with good terrain representation. The diminished statistical accuracy of this product is due to the high degree of sea surface reflection (glint) in this image coupled with the steep terrain around Tutuila. These factors make it difficult to accurately establish the differential decay rate between the blue and green bands.

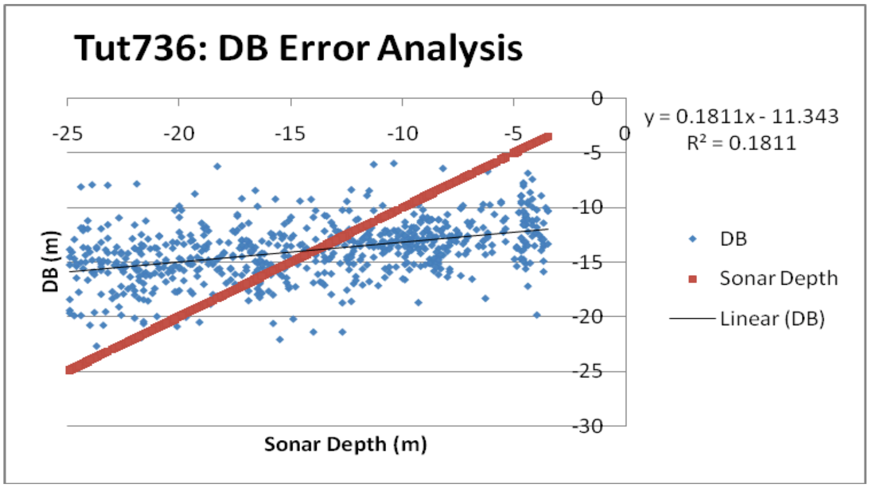

Figure 5. Error analysis of derived bathymetry from Tut736 using original MLR variables**.**
Formula applied: Depth = -4.3919 - 8.6422 * X_{blue} + 12.2726 * X_{green}

In order to increase shallow coverage (0-5 m), new bathymetry was derived by decreasing the Y-intercept value. In order to increase the coverage to the desired extent, the Y-intercept value only needed to be decreased by 4, which resulted in only a small seam between datsets, so that only one additional product was derived. This new product was then mosaiced to the original while giving priorty to the original grid.

Note that the spatial coverage gain made through this adjustment is not apparent in the following graph, but they are implied by the decreased Y-intercept value of the regression line. However, the coverage gains are readily apparent in the map images provided in the Tutuila deliverable package. Statistical assessments of the integrated product are detailed in Part 2.

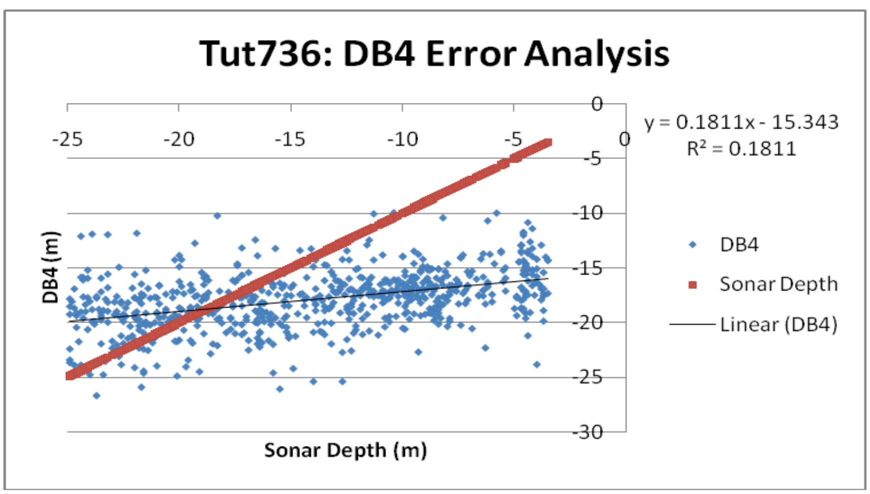

Figure 6. Error analysis of derived bathymetry from Tut736 using reduced Y-intercept values**.**
Formula applied: Depth = -8.3919 - 8.6422 * X_{blue} + 12.2726 * X_{green}

Image Tut904

As shown in Figure 7, the R^2 value for the bathymetry derived using the original MLR values is 0.3122 while the slope of the regression line is also 0.3122. This R^2 value represents a decent grouping of the derived depth scatter plot around its regression line while the slope value indicates reasonable correlation between derived and sonar depth, represented by the red plot. The resulting raster grid provides realistic bathymetric data with good terrain representation, but its shortcoming is the aforementioned phenomenon of positive values in very shallow areas leading to limited coverage. The solution for expanding coverage in shallow areas is described below.

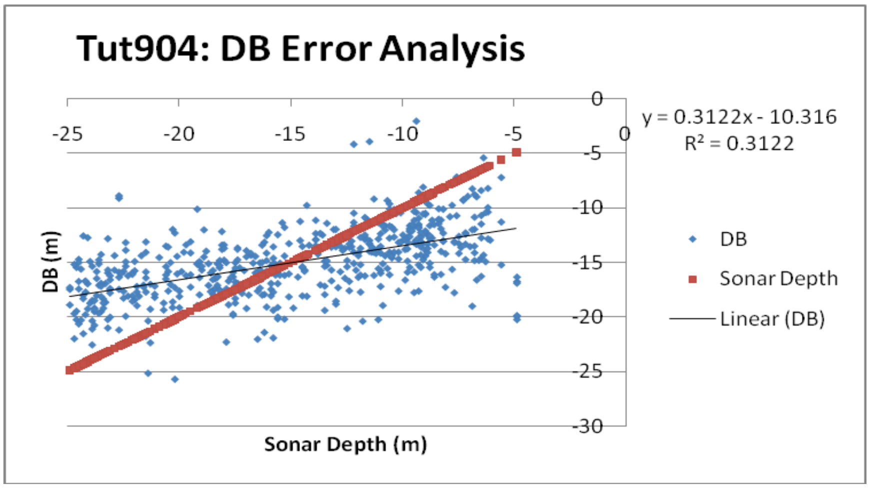

Figure 7. Error analysis of derived bathymetry from Tut904 using original MLR variables**.**
Formula applied: Depth = 2.8541 - 18.3048 * X_{blue} + 25.7446 * X_{green}

In order to increase shallow coverage (0-5 m), new bathymetry was derived by decreasing the Y-intercept value. In order to increase the coverage to the desired extent, the Y-intercept value needed to be decreased by 12. This change to Y-intecept value would result in a 12 m jump in depth value at the seam between datasets. To alleviate this problem while maintaining the integrity of the terrain representation, 3 new bathymetry products were derived by decreasing the Y-intercept value by 4 during each iteration (Figures 8 through 10). Each product was then mosaiced in sequence while giving priorty to the previously integrated grid. Thus, maintaining statistical accuracy while providing increased coverage in shallow areas.

Note that the spatial coverage gains made through these adjustments are not apparent in the following graphs, but they are implied by the decreasing Y-intercept values of the regression line of each subsequent error analysis. The coverage gains are readily apparent in the map images provided in the Tutuila deliverable package. Statistical assessments of the integrated products are detailed in Part 2.

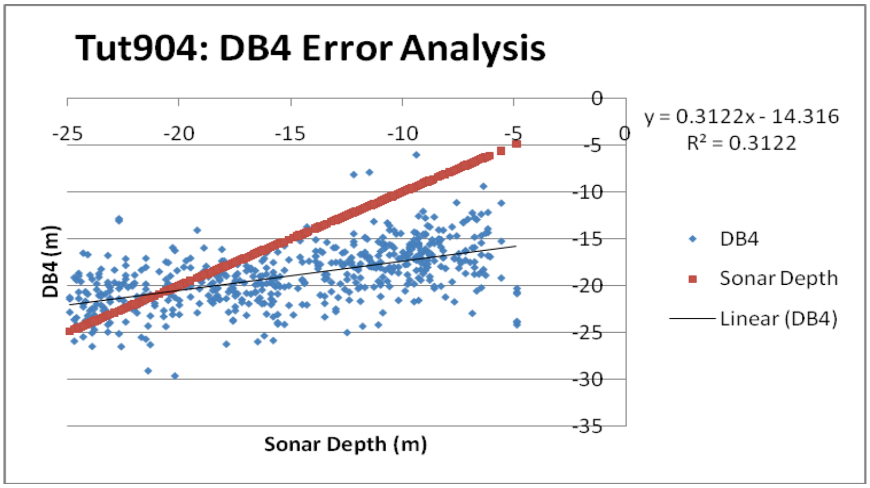

Figure 8. Error analysis of derived bathymetry from Tut904 using decreased Y-intercept value. Formula applied: Depth = -1.1459 - 18.3048 * X_{blue} + 25.7446 * X_{green}

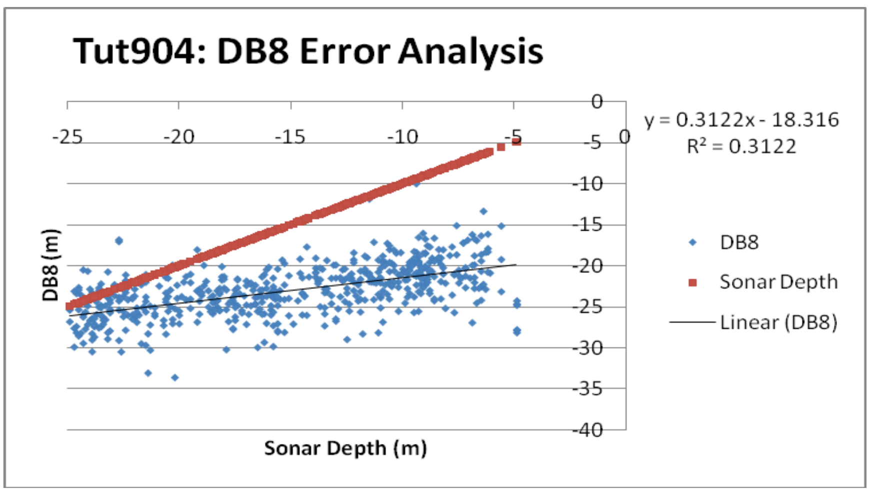

Figure 9. Error analysis of derived bathymetry from Tut904 using decreased Y-intercept value. Formula applied: Depth = -5.1459 - 18.3048 * X_{blue} + 25.7446 * X_{green}

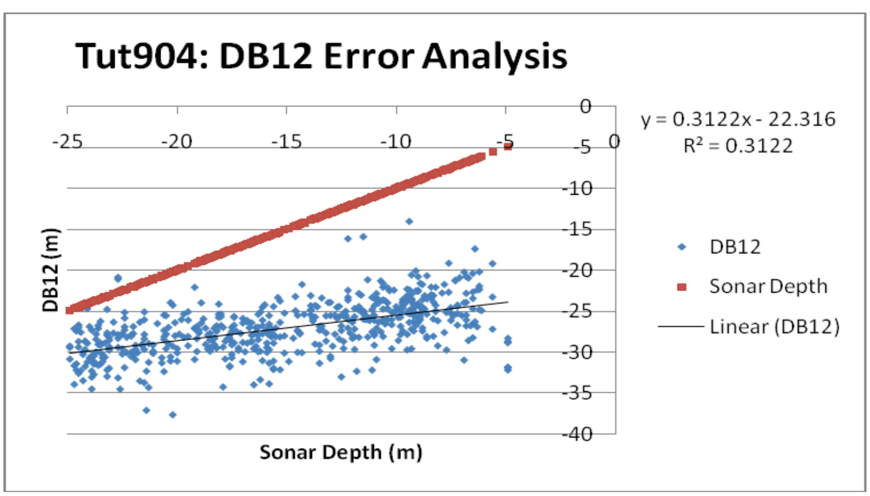

Figure 10. Error analysis of derived bathymetry from Tut904 using decreased Y-intercept value. Formula applied: Depth = -9.1459 - 18.3048 * X_{blue} + 25.7446 * X_{green}

Image Tut907

As shown in Figure 11, the R^2 value for the bathymetry derived using the original MLR values is 0.3192 while the slope of the regression line is also 0.3192. This R^2 value represents a good grouping of the derived depth scatter plot around its regression line while the slope value indicates reasonable correlation between derived and sonar depth, represented by the red plot. The resulting raster grid provides realistic bathymetric data with good terrain representation, but its shortcoming is the aforementioned phenomenon of positive values in very shallow areas leading to limited coverage.

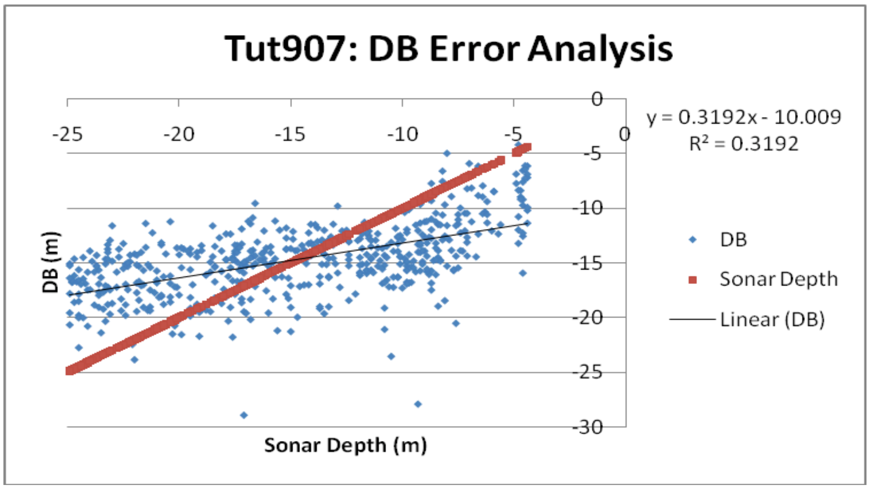

Figure 11. Error analysis of derived bathymetry from Tut907 using original MLR variables**.** Formula applied: Depth = -5.4039 - 13.7452 * X_{blue} + 18.3747 * X_{green}

In order to increase shallow coverage (0-5 m), new bathymetry was derived by decreasing the Y-intercept value. In order to increase the coverage to the desired extent, the Y-intercept value needed to be decreased by 8. This change to Y-intecept value would result in a 8m jump in depth value at the seam between datasets. To alleviate this problem while maintaining the integrity of the terrain representation, 2 new bathymetry products were derived by decreasing the Y-intercept value by 4 during each iteration (Figures 12 and 13). The products were then mosaiced in sequence while giving priorty to the previously integrated grid. Thus, maintaining statistical accuracy while providing increased coverage in shallow areas.

Note that the spatial coverage gains made through these adjustments are not apparent in the following graphs, but they are implied by the decreasing Y-intercept values of the regression line of each subsequent error analysis. The coverage gains are readily apparent in the map images provided in the Tutuila deliverable package. Statistical assessments of the integrated products are detailed in Part 2.

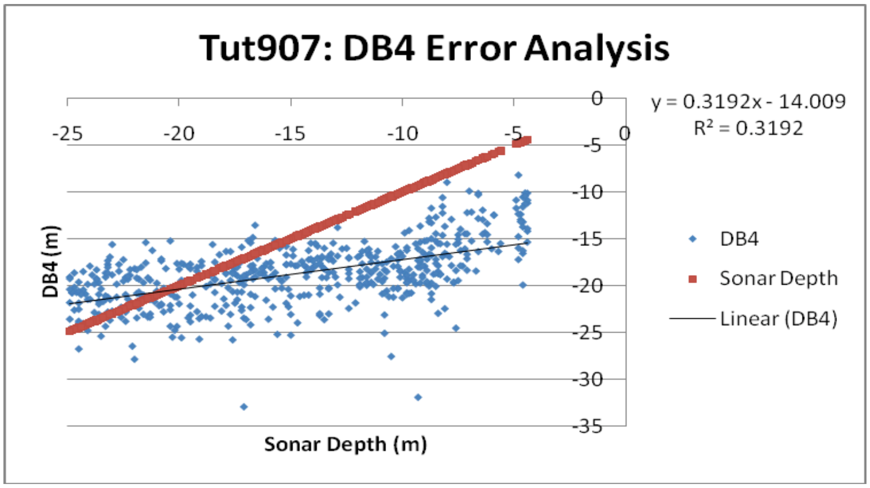

Figure 12. Error analysis of derived bathymetry from Tut907 using decreased Y-intercept value. Formula applied: Depth = -9.4039 - 13.7452 * X_{blue} + 18.3747 * X_{green}

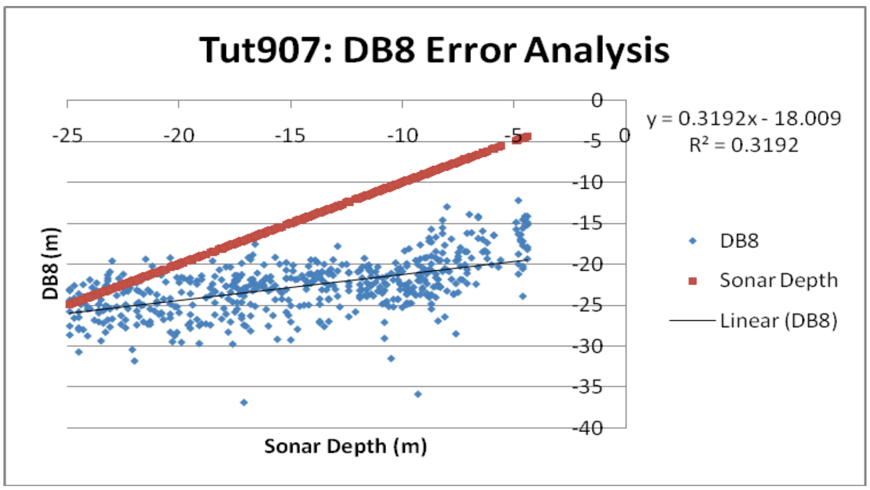

Figure 13. Error analysis of derived bathymetry from Tut907 using decreased Y-intercept value. Formula applied: Depth = -13.4039 - 13.7452 * X_{blue} + 18.3747 * X_{green}

Image Tut909

As shown in Figure 14, the R^2 value for the bathymetry derived using the original MLR values is 0.5295 while the slope of the regression line is 0.4842. This R^2 value represents a good grouping of the derived depth scatter plot around its regression line while the slope value indicates good correlation between derived and sonar depth, represented by the red plot. The resulting raster grid provides realistic bathymetric data with excellent terrain representation, but its shortcoming is the aforementioned phenomenon of positive values in very shallow areas leading to limited coverage.

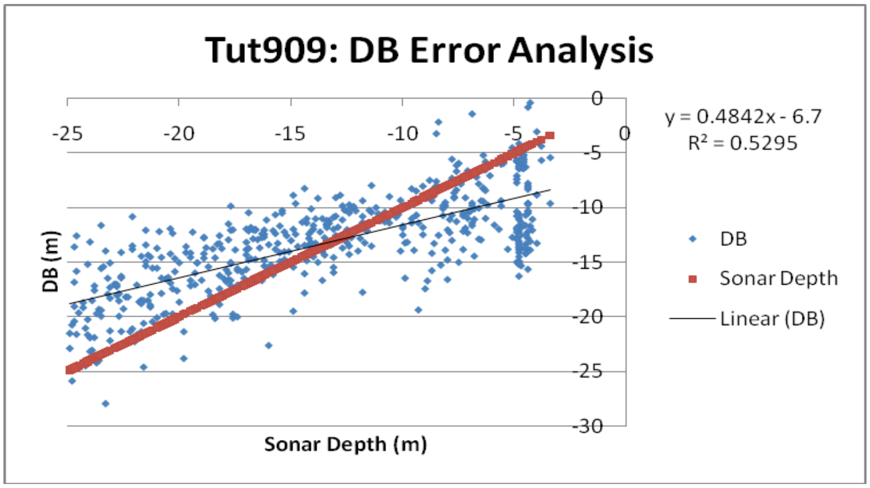

Figure 14. Error analysis of derived bathymetry from Tut909 using original MLR variables**.**
Formula applied: Depth = 17.1093 - 1.2295 * X_{blue} + 11.0006 * X_{green}

In order to increase shallow coverage (0-5 m), new bathymetry was derived by decreasing the Y-intercept value. In order to increase the coverage to the desired extent, the Y-intercept value needed to be decreased by 12. This change to Y-intecept value would result in a 12m jump in depth value at the seam between datasets. To alleviate this problem, 3 new bathymetry products were derived by decreasing the Y-intercept value by 4 during each iteration (Figures 15 through 17). Each product was then mosaiced in sequence while giving priorty to the previously integrated grid.

Note that the spatial coverage gains made through these adjustments are not apparent in the following graphs, but they are implied by the decreasing Y-intercept values of the regression line of each subsequent error analysis. The coverage gains are readily apparent in the map images provided in the Tutuila deliverable package. Statistical assessments of the integrated product are detailed in Part 2.

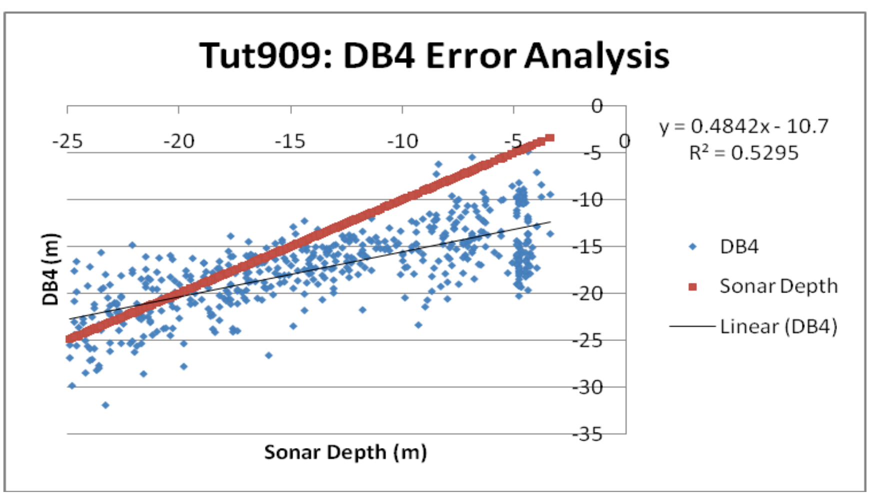

Figure 15. Error analysis of derived bathymetry from Tut909 using decreased Y-intercept value**.**
Formula applied: Depth = 13.1093 - 1.2295 * X_{blue} + 11.0006 * X_{green}

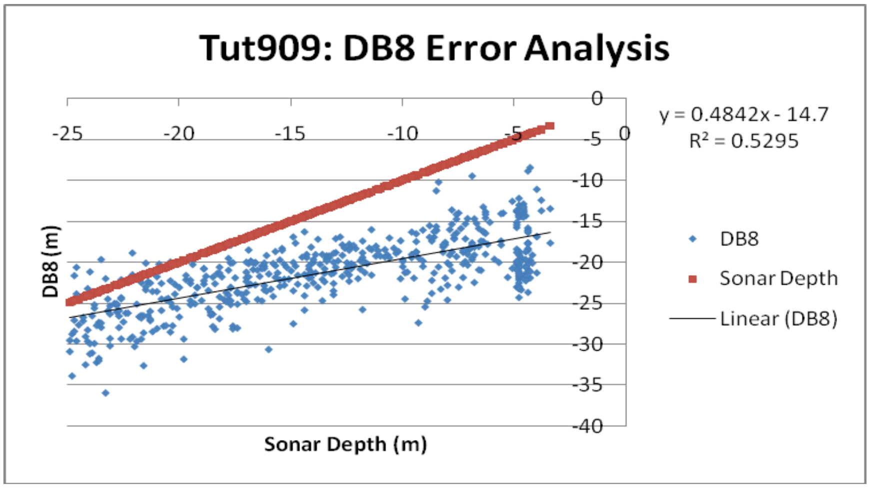

Figure 16. Error analysis of derived bathymetry from Tut909 using decreased Y-intercept value**.**
Formula applied: Depth = 9.1093 - 1.2295 * X_{blue} + 11.0006 * X_{green}

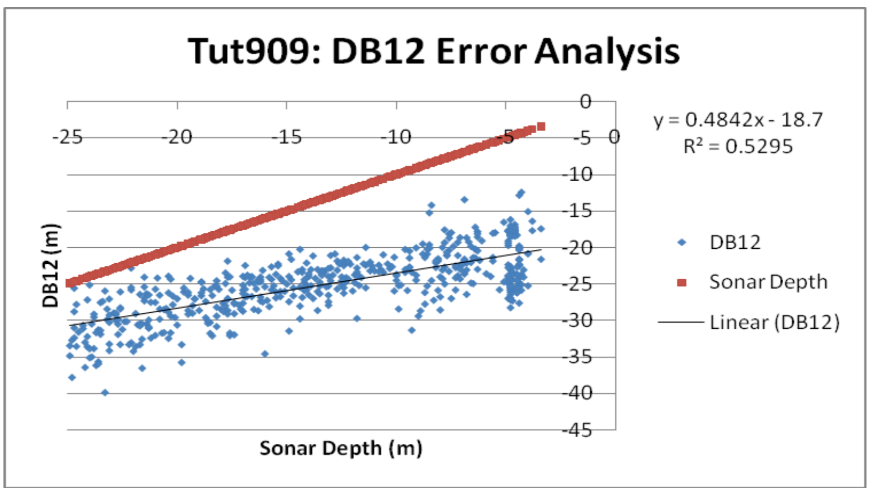

Figure 17. Error analysis of derived bathymetry from Tut909 using decreased Y-intercept value**.**
Formula applied: Depth = 5.1093 - 1.2295 * X_{blue} + 11.0006 * X_{green}

Part 2: Analysis of Derived Bathymetry where Derived Depth Concurs with Multibeam Sonar Depths of less than 20 m.

The following analyses are a comprehensive statistical review of the derived bathymetry grids from each image as they are combined to form the integrated derived bathymetry mosaic, Tut_DBall. An analysis of this final derived bathymetry grid, which is subsequently integrated with multibeam bathymetry into the product Tut_DBMB, is also included.

After the Part 1 analyses were conducted, the derived bathymetry raster grids were prepared for integration with multibeam bathymetry by applying masks to exclude:

1) Derived depths of greater than 25 meters or less than 0 meters
2) Values derived from island areas and areas of cloud cover
3) Depths derived in areas deeper that 25 meters as indicated by the multibeam sonar bathymetry

All remaining values were considered to be potentially valid derived depths; however, derived data deeper than 20 m are seldom used because the multibeam data usually reaches shallower depths. Therefore, the following error analyses utilize the derived and sonar depth values of each grid cell where derived data overlaps with multibeam sonar data of 20 m or less. Microsoft Excel was used for these analyses.

Helpful notes:

Figures 18 through 21 analyze the same products as Figures 1 through 4: bathymetry derived from image Tut091 using original MLR variables, and then with progressively reduced Y-intercept values.

Figures 24 and 25 analyze the same products as Figures 5 and 6: bathymetry derived from image Tut736 using original MLR variables, and then with reduced Y-intercept values.

Figures 28 through 31 analyze the same products as Figures 7 through 10: bathymetry derived from image Tut904 using original MLR variables, and then with progressively reduced Y-intercept values.

Figures 34 through 36 analyze the same products as Figures 11 through 13: bathymetry derived from image Tut907 using original MLR variables, and then with progressively reduced Y-intercept values.

Figures 39 through 42 analyze the same products as Figures 14 through 17: bathymetry derived from image Tut904 using original MLR variables, and then with progressively reduced Y-intercept values.

Image Tut091

For the derived bathymetry products from image Tut091 presented in Figures 18 through 21, the R^2 values for the derived products are comparable to those from Part 1 despite the potential for greater variability in departure from the mean value when all derived depth less than 20 m are considered. Also notice that both statistical measures are reduced only slightly as “the tide is brought in” by reducing the Y-intercept. Review of the map images clearly demonstrates the increase in coverage.

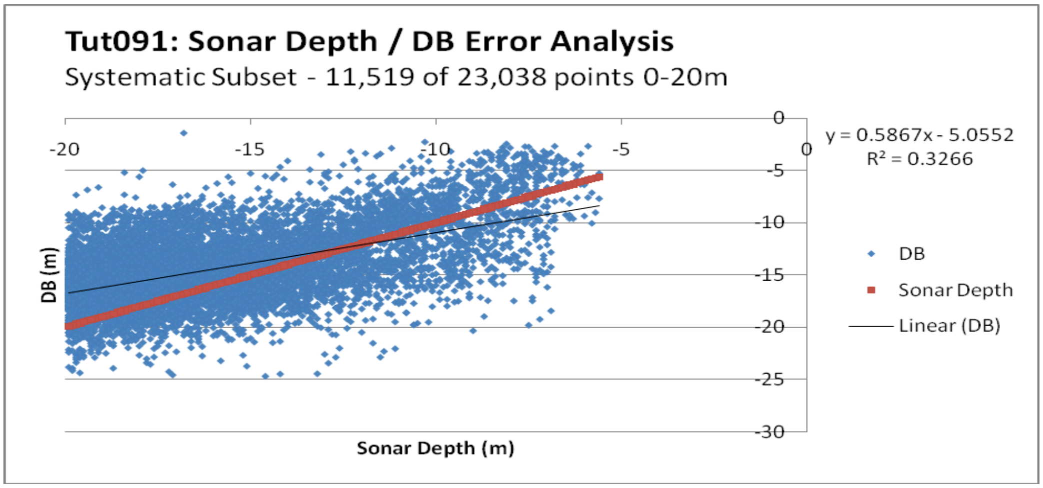

Figure 18. Comprehensive error analysis of derived bathymetry from Tut091 using original MLR variables**.** Formula applied: Depth = 19.7602 - 1.6871 * X_{blue} + 12.3928 * X_{green}

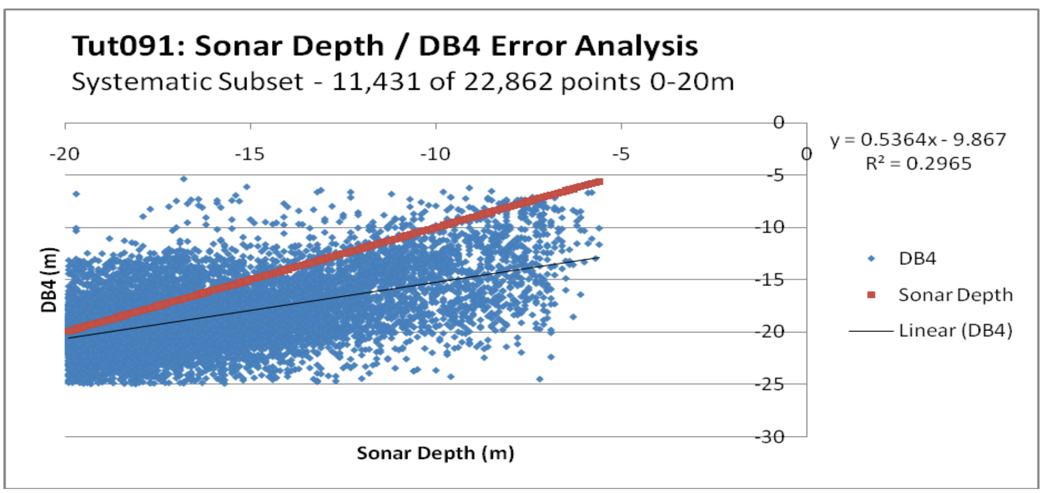

Figure 19. Comprehensive error analysis of derived bathymetry from Tut091 using decreased Y-intercept value**.** Formula applied: Depth = 15.7602 - 1.6871 * X_{blue} + 12.3928 * X_{green}

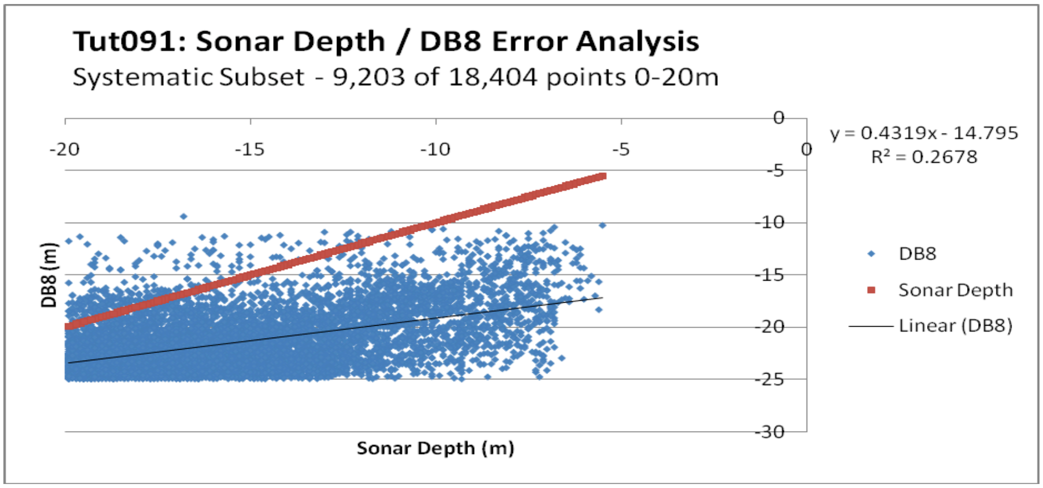

Figure 20. Comprehensive error analysis of derived bathymetry from Tut091 using decreased Y-intercept value. Formula applied: Depth = 11.7602 - 1.6871 * X_{blue} + 12.3928 * X_{green}

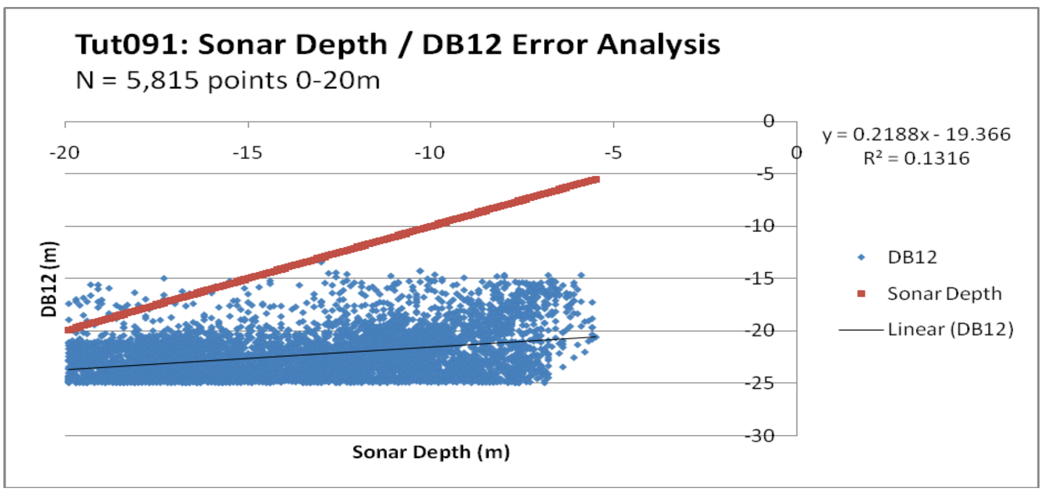

Figure 21. Comprehensive error analysis of derived bathymetry from Tut091 using decreased Y-intercept value. Formula applied: Depth = 7.7602 - 1.6871 * X_{blue} + 12.3928 * X_{green}

Once each of the just analyzed products were mosaiced using the sequential integration method described in Part 1, both a systematic and a sectional analysis were conducted. Figure 22 shows a statistical result similar to that of each individual product indicating minimal impact from the integration process. Figure 23 is from an area in the southern portion of the image where there is less cloud cover and associated haze. The increased R^2 (0.3579) and slope (0.6235) values in figure 23 indicate that some of the bathymetry derived from image Tut091 has a much higher statistical accuracy than would be indicated by the systematic sample.

As demonstrated by the map provided in the deliverable package (Tut091_DBall) and these figures, this process allowed for greatly expanded spatial coverage while maintaining the integrity of the product's terrain representation as well as its statistical accuracy. This mosaic is suitable for integration into the final product for Tutuila.

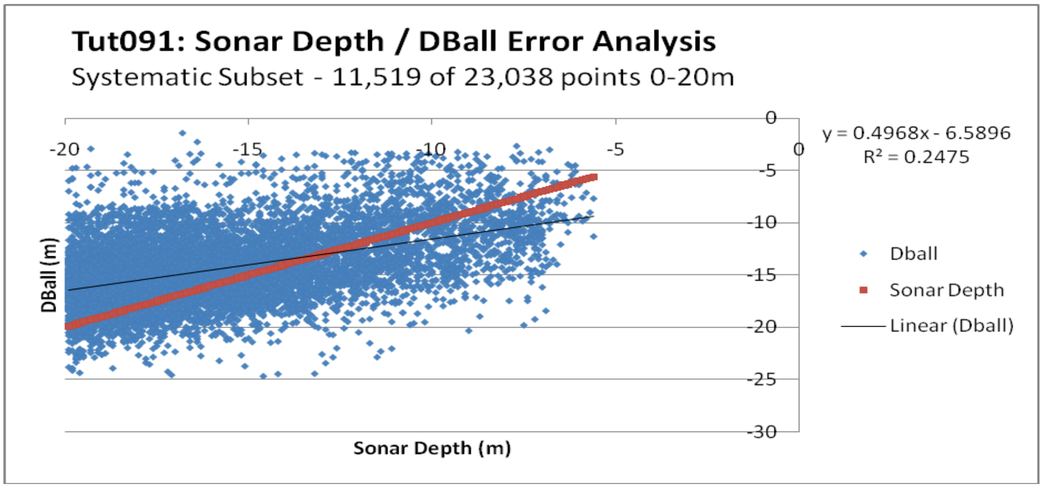

Figure 22. Comprehensive error analysis: mosaic of derived bathymetry products DB, DB4, DB8, and DB12 – Systematic Subset.

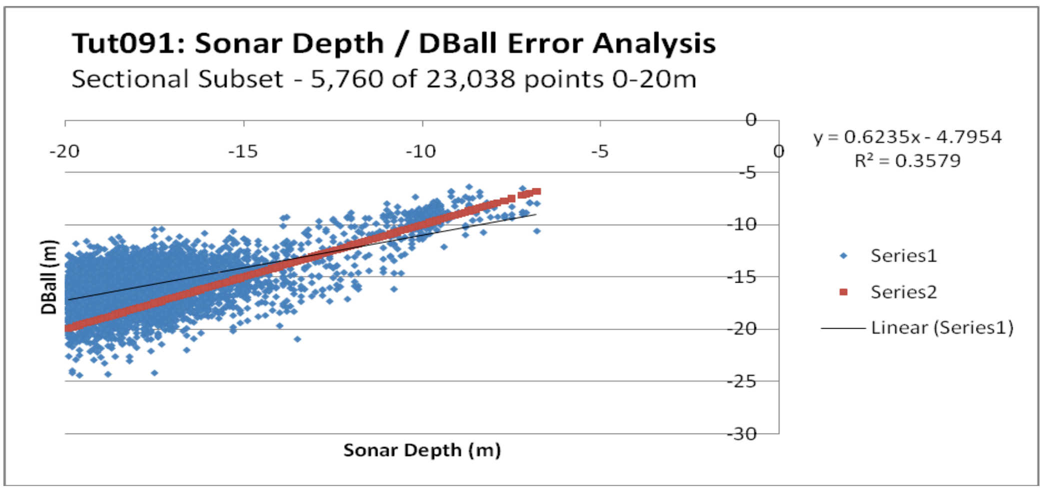

Figure 23. Comprehensive error analysis: mosaic of derived bathymetry products DB, DB4, DB8, and DB12 – Sectional Subset.

Image Tut736

For the derived bathymetry products from image Tut736 presented in Figures 24 and 25 the R^2 values for the derived products are reduced significantly (from Part 1) due to a greater variability in departure from the mean value when all derived depth less than 20 m are considered. This is due to the inherent variability in the derived depth data when considering over 10,000 data points and the severe glint in the original image.

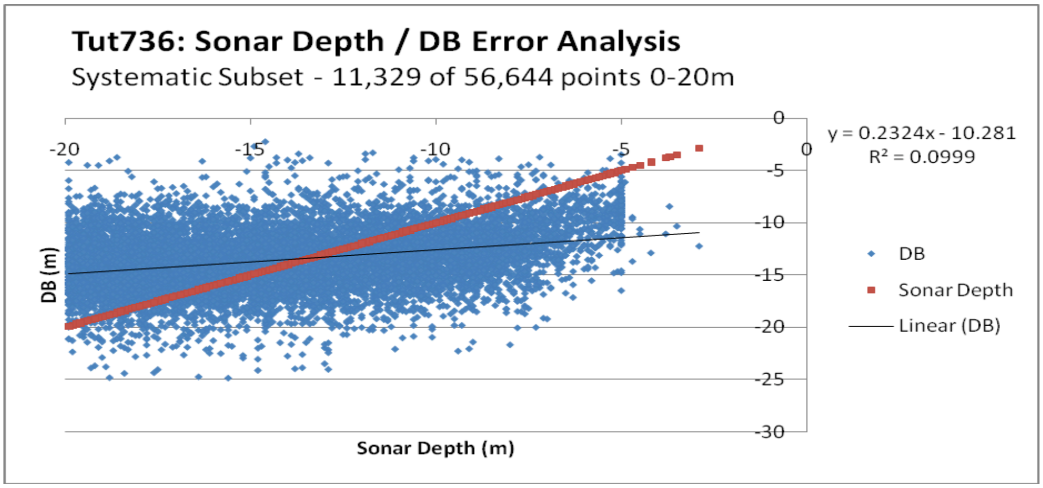

Figure 24. Comprehensive error analysis of derived bathymetry from Tut736 using original MLR variables. Formula applied: Depth = -4.3919 - 8.6422 * X_{blue} + 12.2726 * X_{green}

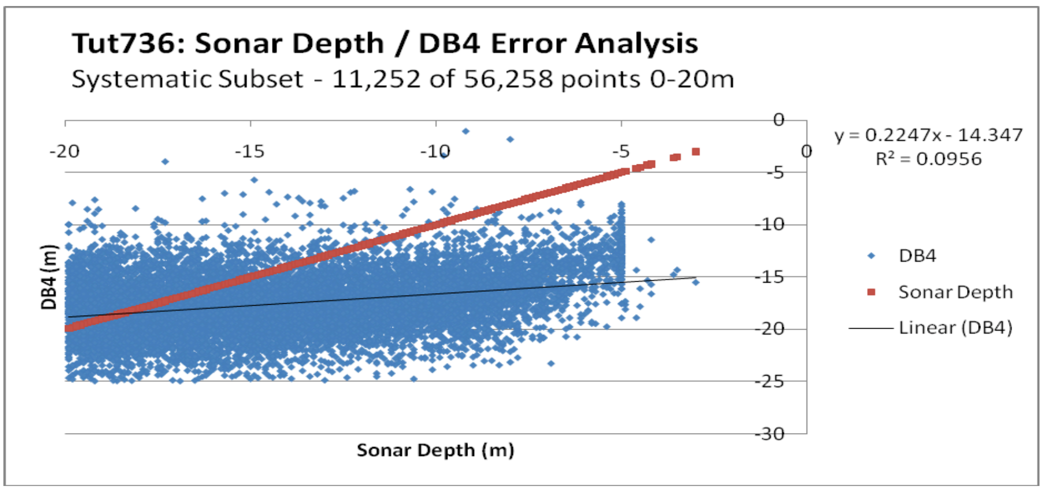

Figure 25. Comprehensive error analysis of derived bathymetry from Tut736 using reduced Y-intercept values. Formula applied: Depth = -8.3919 - 8.6422 * X_{blue} + 12.2726 * X_{green}

Once each of the just analyzed products were mosaiced using the sequential integration method described in Part 1, both a systematic and a sectional analysis were conducted. Figure 26 shows a statistical result similar to that of each individual product indicating minimal impact from the integration process. Figure 27 is from an area in the southern portion of the image. The increased R^2 value (0.142) in figure 23 indicates that some of the bathymetry derived from image Tut736 has a higher statistical accuracy than would be indicated by the systematic sample.

As demonstrated by the map provided in the deliverable package (Tut736_DBall) and these figures, this process allowed for greatly expanded spatial coverage while maintaining the integrity of the product's terrain representation as well as its statistical accuracy. This mosaic is suitable for integration into the final product for Tutuila.

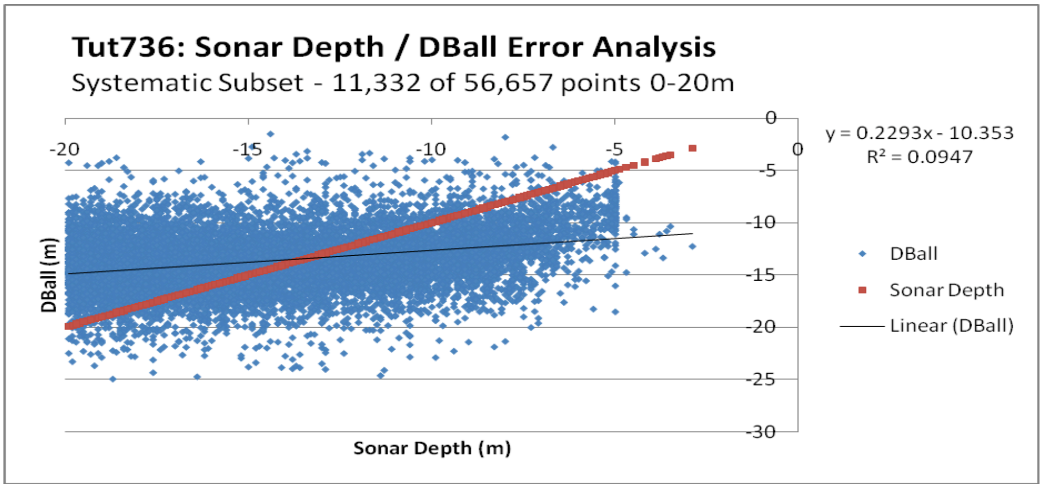

Figure 26. Comprehensive error analysis: mosaic of derived bathymetry products DB and DB4 – Systematic Subset.

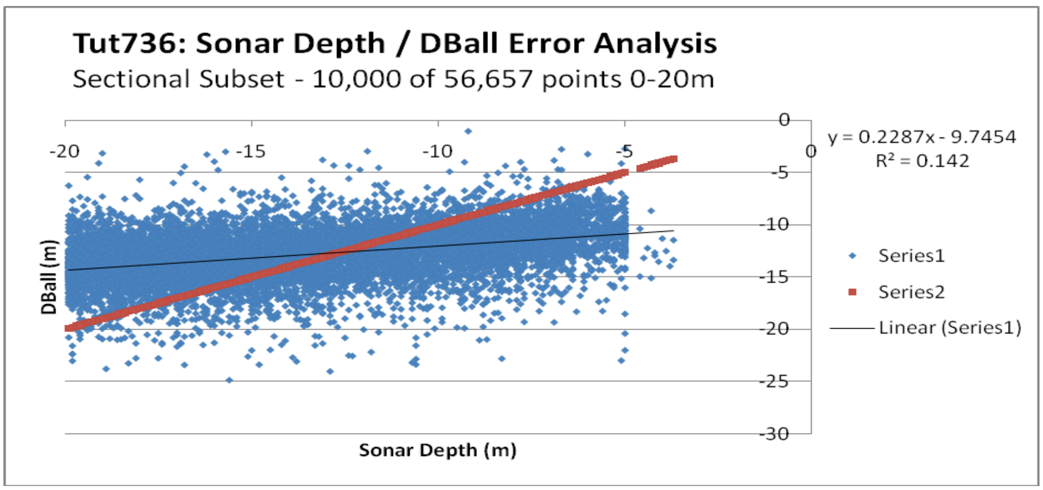

Figure 27. Comprehensive error analysis: mosaic of derived bathymetry products DB and DB4 – Sectional Subset.

Image Tut904

For the derived bathymetry products from image Tut904 presented in Figures 28 through 31, the R^2 values are reduced significantly (from Part 1) due to a greater variability in departure from the mean value when all derived depth less than 20 m are considered. This is due to the inherent variability in the derived depth data when considering over 10,000 data points and the severe glint in the original image. Also notice that both statistical measures are reduced only slightly as “the tide is brought in” by reducing the Y-intercept. Review of the map images clearly demonstrates the increase in coverage.

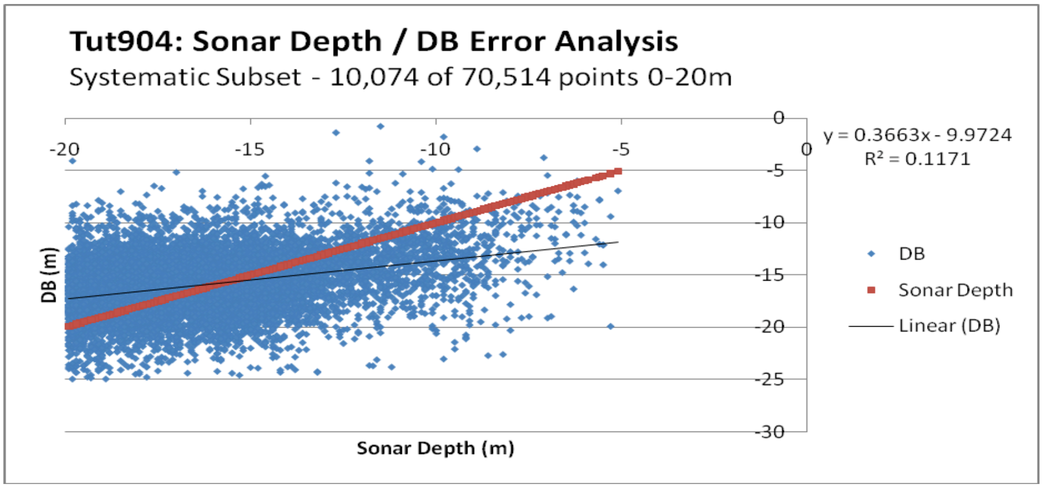

Figure 28. Comprehensive error analysis of derived bathymetry from Tut904 using original MLR variables. Formula applied: Depth = 2.8541 - 18.3048 * X_{blue} + 25.7446 * X_{green}

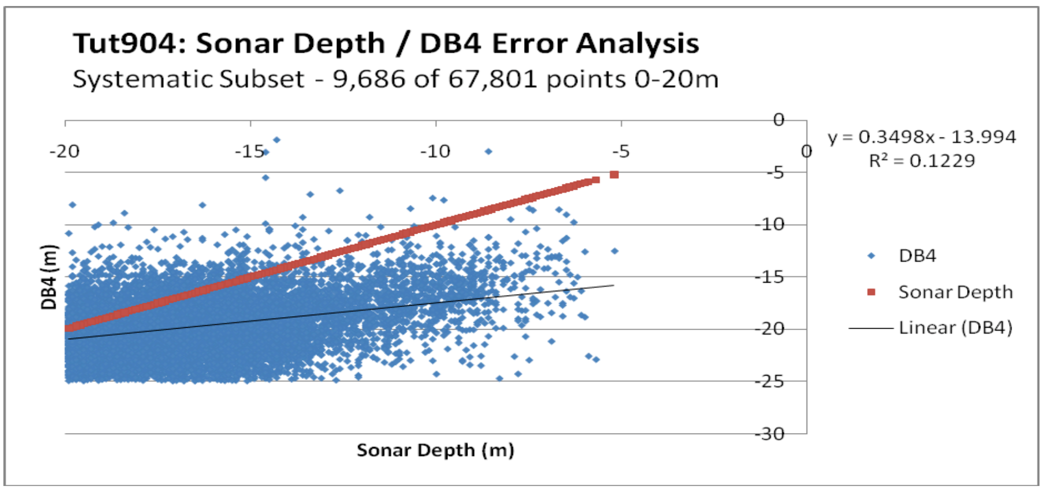

Figure 29. Comprehensive error analysis of derived bathymetry from Tut904 using decreased Y-intercept value. Formula applied: Depth = -1.1459 - 18.3048 * X_{blue} + 25.7446 * X_{green}

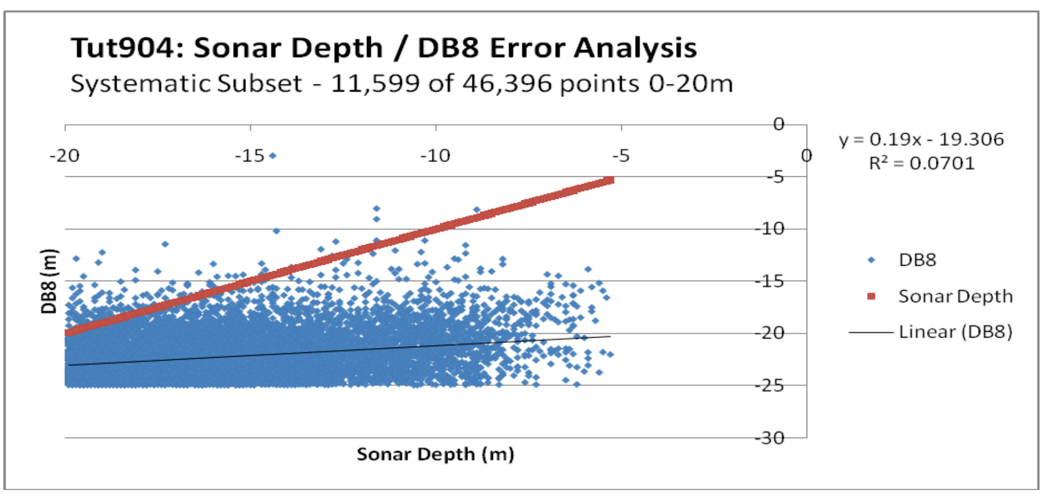

Figure 30. Comprehensive error analysis of derived bathymetry from Tut904 using decreased Y-intercept value. Formula applied: Depth = -5.1459 - 18.3048 * X_{blue} + 25.7446 * X_{green}

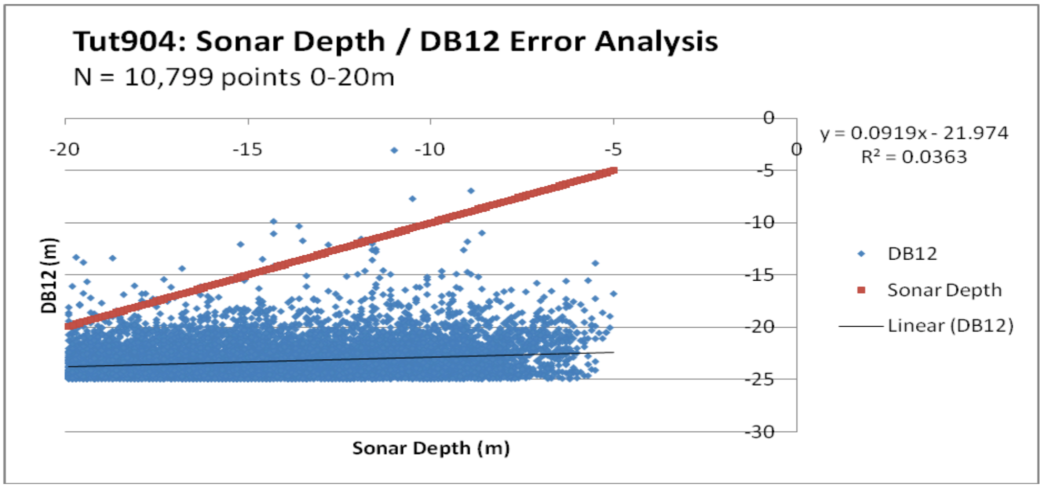

Figure 31. Comprehensive error analysis of derived bathymetry from Tut904 using decreased Y-intercept value**.** Formula applied: Depth = -9.1459 - 18.3048 * X_{blue} + 25.7446 * X_{green}

Once each of the just analyzed products were mosaiced using the sequential integration method described in Part 1, both a systematic and a sectional analysis were conducted. Figure 32 shows a statistical result that is similar to the best interim products. Figure 33 shows increased R^2 (0.4881) value indicating the potential for increased accuracy in some areas of the product.

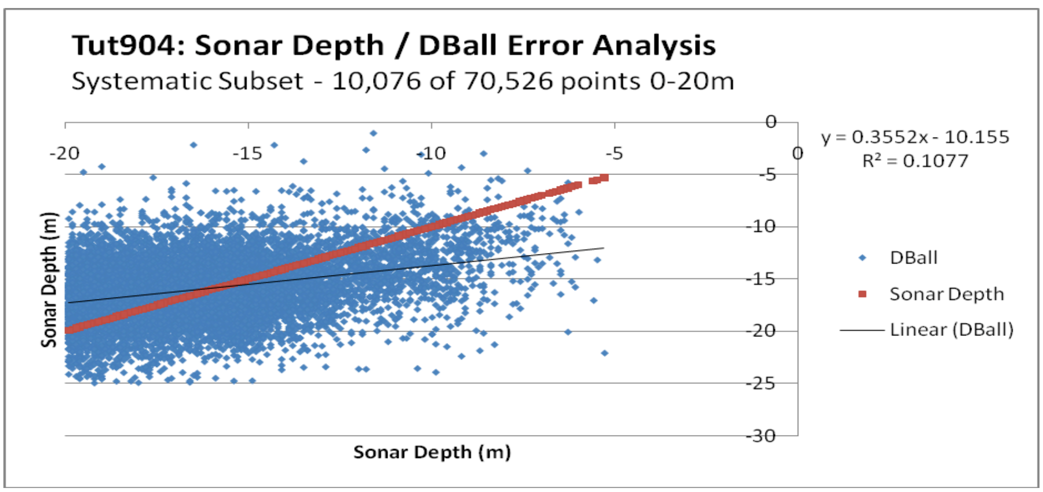

Figure 32. Comprehensive error analysis: mosaic of derived bathymetry products DB, DB4, DB8, and DB12 – Systematic Subset.

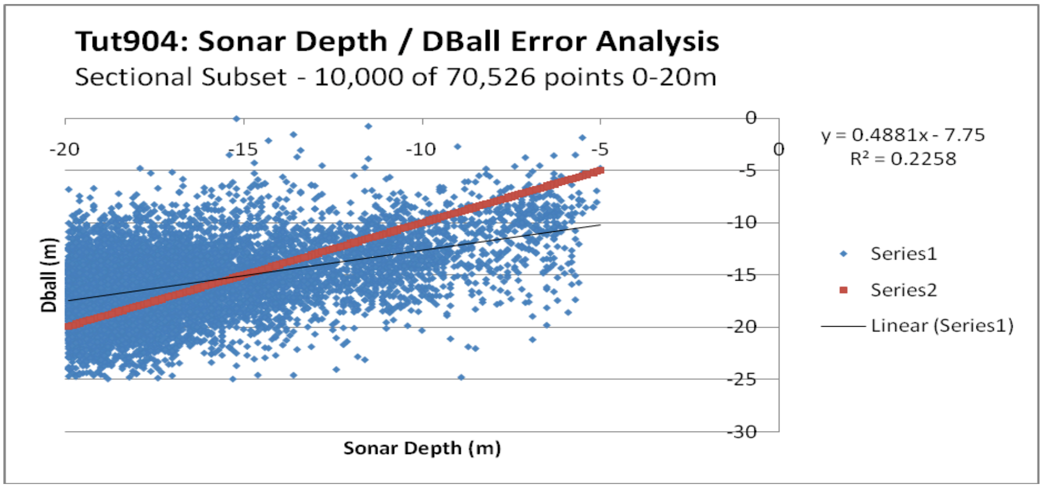

Figure 33. Comprehensive error analysis: mosaic of derived bathymetry products DB, DB4, DB8, and DB12 – Sectional Subset.

As demonstrated by the map provided in the deliverable package (Tut904_DBall) and these figures, this process allowed for greatly expanded spatial coverage while maintaining the integrity of the product's terrain representation as well as its statistical accuracy. This mosaic is suitable for integration into the final product for Tutuila.

Image Tut907

For the derived bathymetry products from image Tut907 presented in Figures 34 through 36, the R^2 values for DB and DB4 are reduced only moderately (from Part 1) even though there is potential for greater variability in departure from the mean value when all derived depth less than 20 m are considered. This is due to the inherent variability in the derived depth data when considering over 10,000 data points and the severe glint in the original image. Review of the map images clearly demonstrates the increase in coverage.

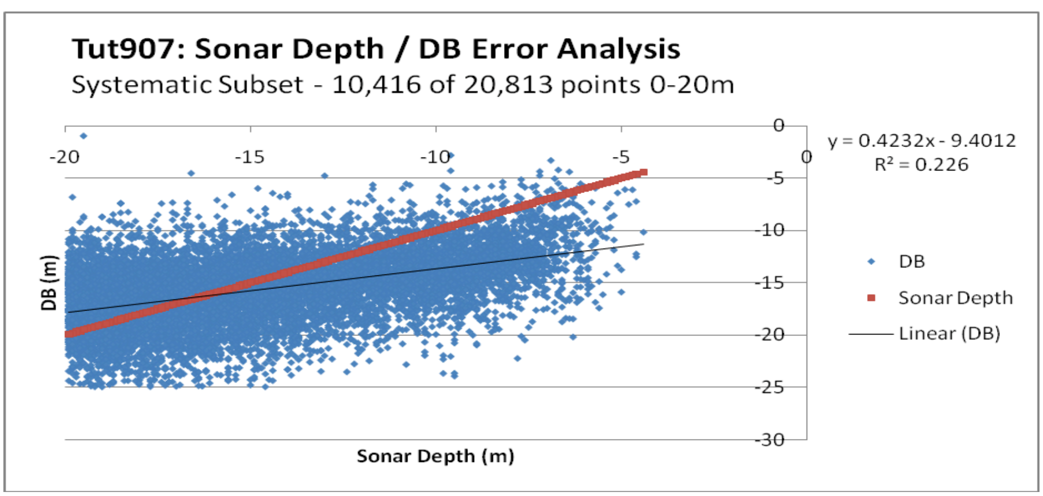

Figure 34. Comprehensive error analysis of derived bathymetry from Tut907 using original MLR variables. Formula applied: Depth = -5.4039 - 13.7452 * X_{blue} + 18.3747 * X_{green}

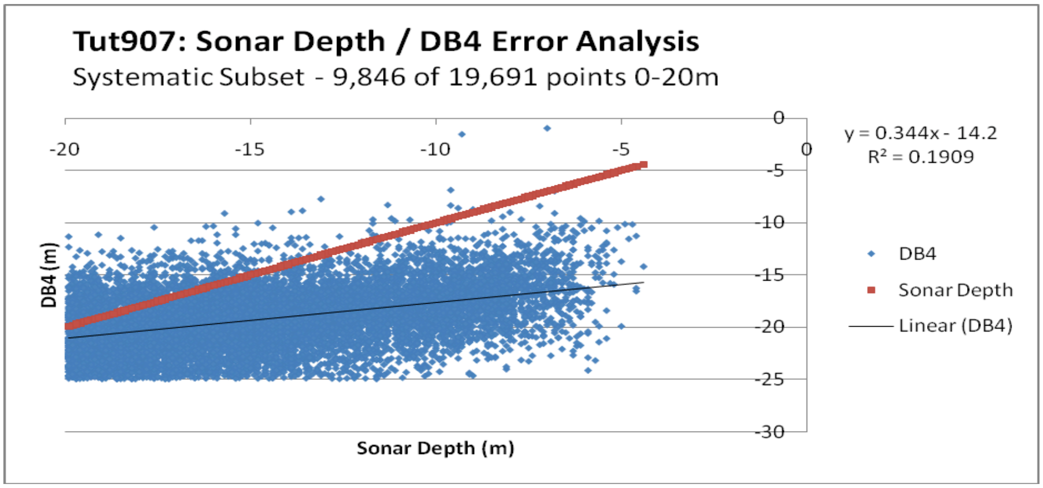

Figure 35. Comprehensive error analysis of derived bathymetry from Tut907 using decreased Y-intercept value**.** Formula applied: Depth = -9.4039 - 13.7452 * X_{blue} + 18.3747 * X_{green}

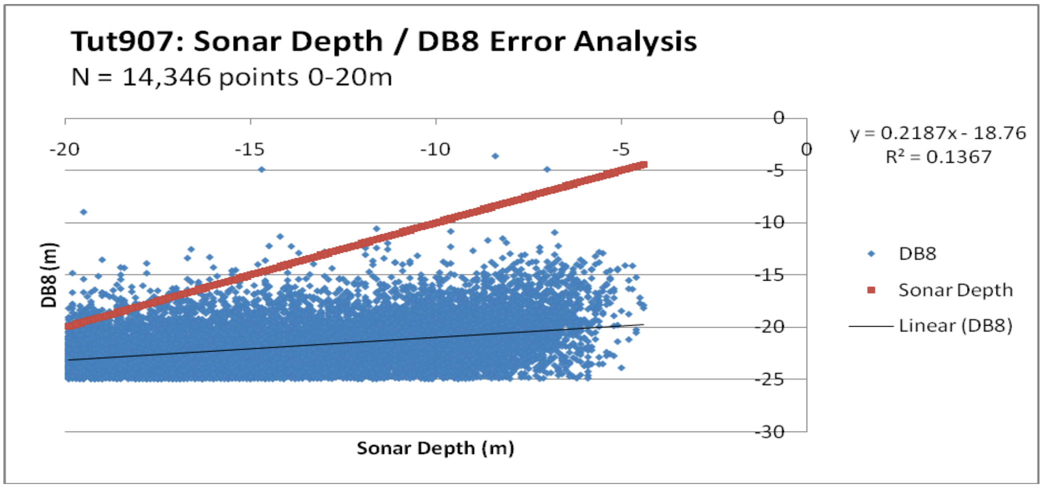

Figure 36. Comprehensive error analysis of derived bathymetry from Tut907 using decreased Y-intercept value**.** Formula applied: Depth = -13.4039 - 13.7452 * X_{blue} + 18.3747 * X_{green}

Once each of the just analyzed products were mosaiced using the sequential integration method described in Part 1, both a systematic and a sectional analysis were conducted. Figure 37 shows a statistical result similar to that of the best interim product indicating minimal impact from the integration process. The comparable R^2 and slope values in figure 38 indicate that the bathymetry derived from image Tut907 has a consistent statistical accuracy across the image.

As demonstrated by the map provided in the deliverable package (Tut907_DBall) and these figures, this process allowed for expanded spatial coverage while maintaining the integrity of the product's terrain representation as well as its statistical accuracy. This mosaic is suitable for integration into the final product for Tutuila.

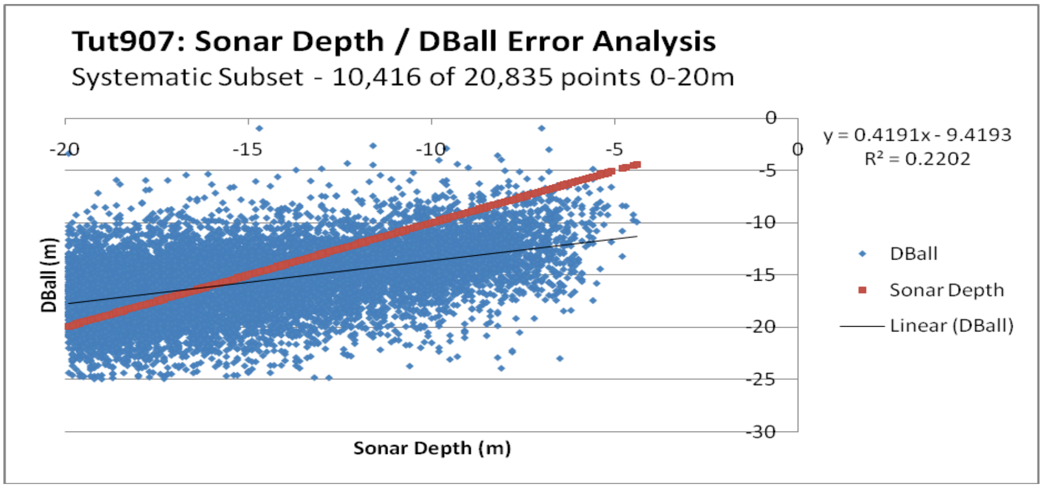

Figure 37. Comprehensive error analysis: mosaic of derived bathymetry products DB, DB4 and DB8 – Systematic Subset.

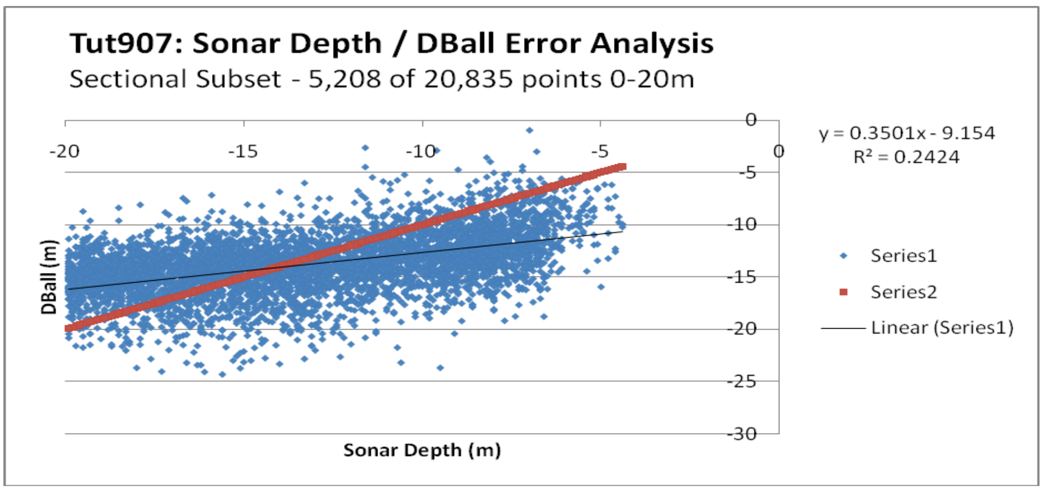

Figure 38. Comprehensive error analysis: mosaic of derived bathymetry products DB, DB4 and DB8 – Sectional Subset.

Image Tut909

For the derived bathymetry products from image Tut909 presented in Figures 39 through 42, the R^2 and slope values for the derived products are reduced significantly (compared to those from Part 1) due to the greater variability in departure from the mean value when all derived depth less than 20 m are considered. This is the result of the severe sun glint in the original image. However, notice that both statistical measures are reduced only slightly as “the tide is brought in” by reducing the Y-intercept. Review of the map images clearly demonstrates the increase in coverage.

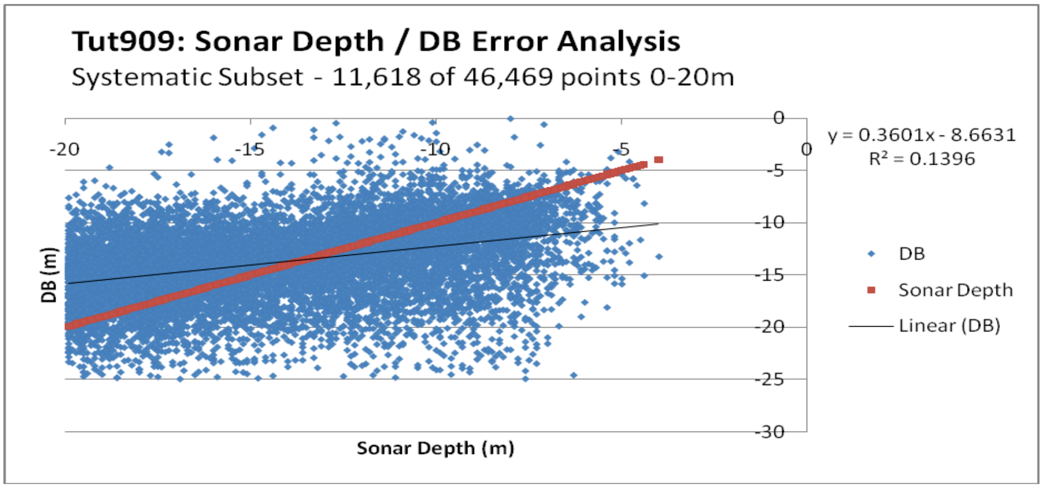

Figure 39. Comprehensive error analysis of derived bathymetry from Tut909 using original MLR variables**.** Formula applied: Depth = 17.1093 - 1.2295 * X_{blue} + 11.0006 * X_{green}

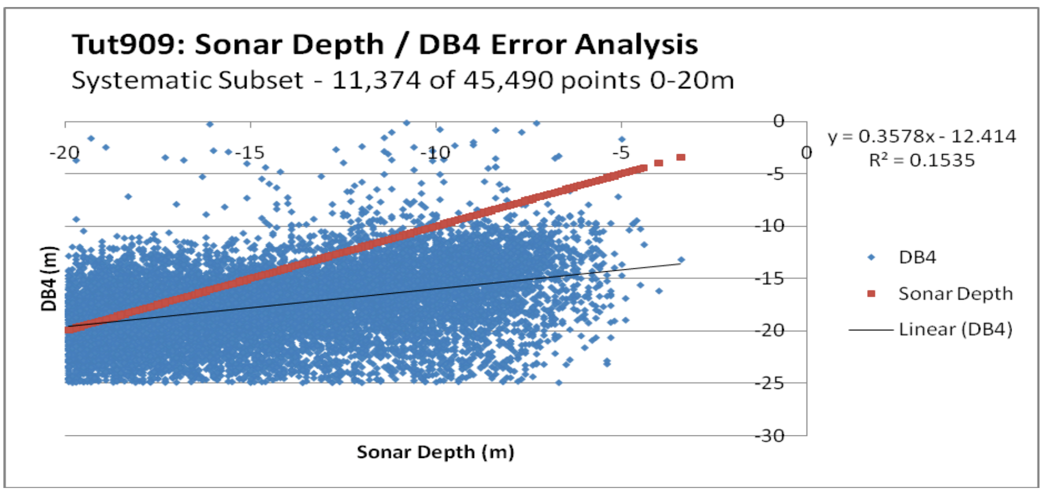

Figure 40. Comprehensive error analysis of derived bathymetry from Tut909 using decreased Y-intercept value**.** Formula applied: Depth = 13.1093 - 1.2295 * X_{blue} + 11.0006 * X_{green}

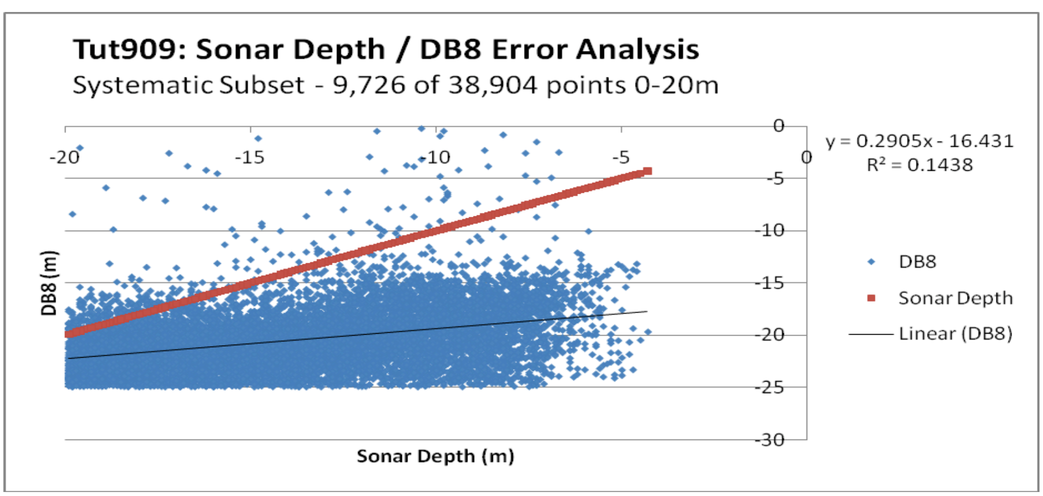

Figure 41. Comprehensive error analysis of derived bathymetry from Tut909 using decreased Y-intercept value**.** Formula applied: Depth = 9.1093 - 1.2295 * X_{blue} + 11.0006 * X_{green}

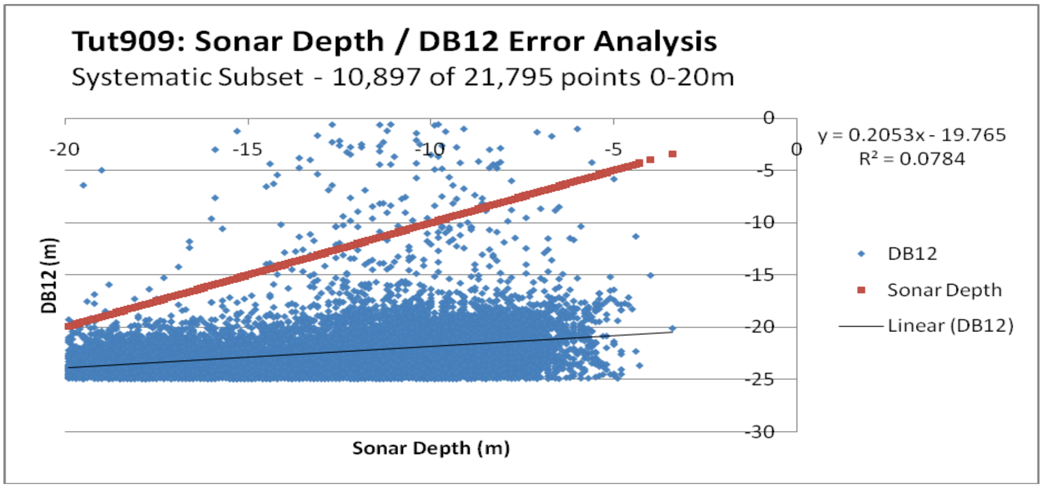

Figure 42. Comprehensive error analysis of derived bathymetry from Tut909 using decreased Y-intercept value**.** Formula applied: Depth = 5.1093 - 1.2295 * X_{blue} + 11.0006 * X_{green}

Once each of the just analyzed products were mosaiced using the sequential integration method described in Part 1, both a systematic and a sectional analysis were conducted. Figure 43 shows a statistical result similar to that of each individual product indicating minimal impact from the integration process. The increased R^2 and slope values in figure 44 indicate that some of the bathymetry derived from image Tut909 has a higher statistical accuracy than would be indicated by the systematic sample.

As demonstrated by the map provided in the deliverable package (Tut909_DBall) and these figures, this process allowed for greatly expanded spatial coverage while maintaining the integrity of the product's terrain representation as well as its statistical accuracy. This mosaic is suitable for integration into the final product for Tutuila.

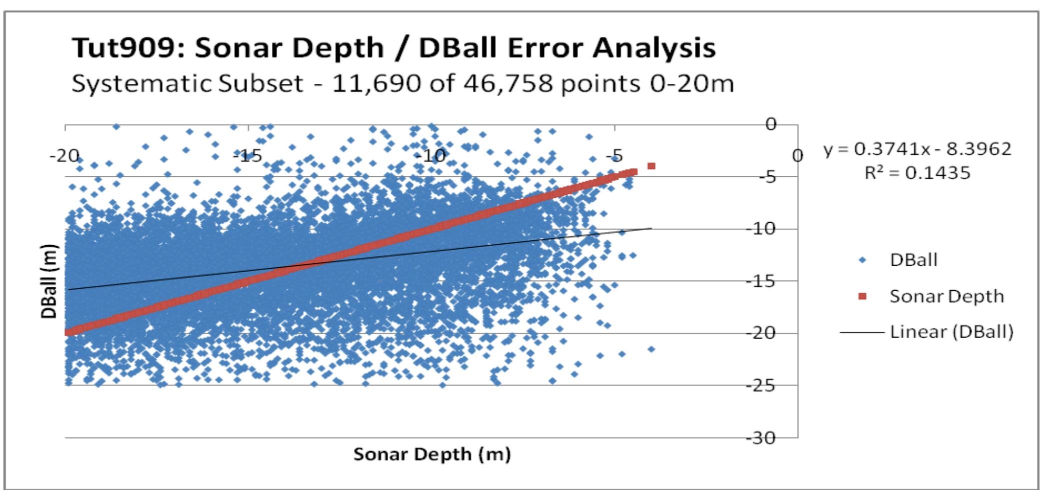

Figure 43. Comprehensive error analysis: mosaic of derived bathymetry products DB, DB4, DB8 and DB12 – Systematic Subset.

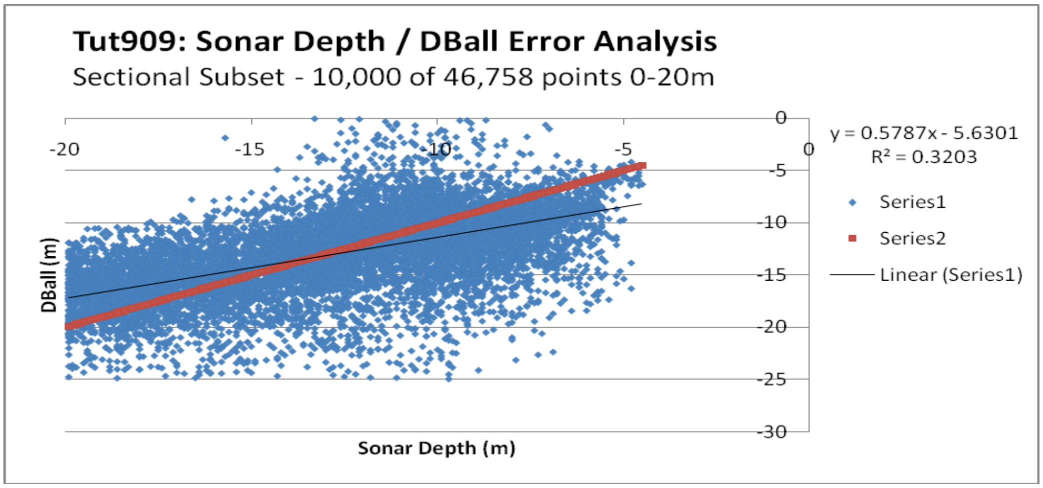

Figure 44. Comprehensive error analysis: mosaic of derived bathymetry products DB, DB4, DB8 and DB12 – Sectional Subset.

Final Mosaics of Derived Bathymetry from all Images

In order to achieve the greatest spatial coverage possible, the derived bathymetry from each image was mosaiced in a final integration. During this integration (product Tut_DBall) the trimmed data from each image was mosaiced giving the product with the best statistical accuracy priority.

The statistical analysis in Figures 45 and 46 demonstrates the accuracy of the Tut_DBall product with a systematic and a sectional sample, respectively.

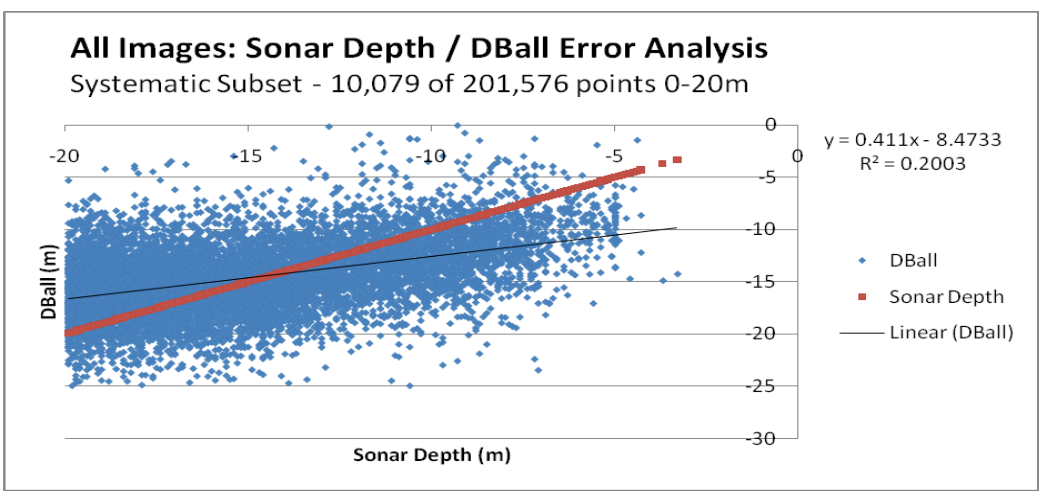

Figure 45. Comprehensive error analysis 0 – 20 m: integration of derived bathymetry from all images – systematic sample.

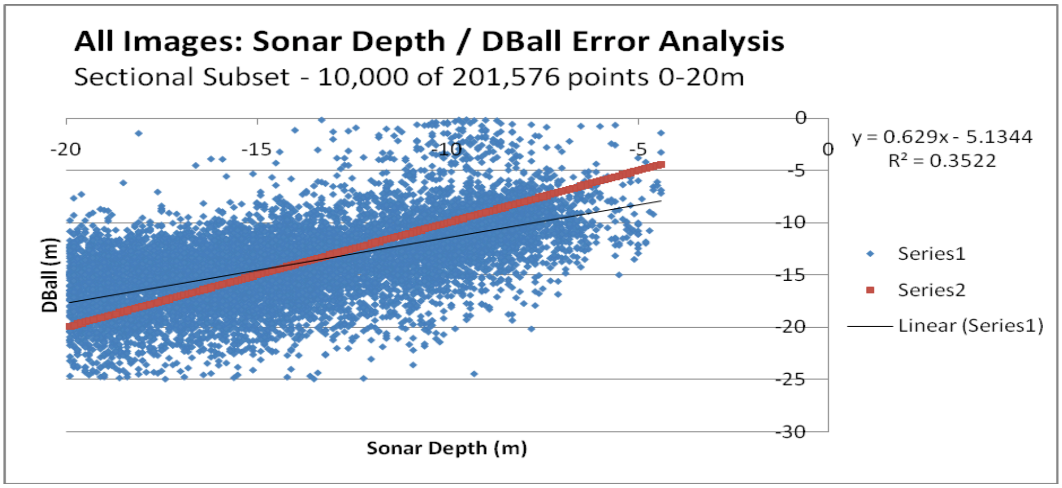

Figure 46. Comprehensive error analysis 0 – 20 m: integration of derived bathymetry from all images – sectional sample.

Because the final mosiac actually includes some data up to 25m of depth in regions around the island where multibeam data did not have full coverage, an assessment of derived depth up to 25 m is included. All data derived deeper than 25 m was trimmed from the final product. The statistical analysis in Figures 47 and 48 demonstrates the accuracy of the Tut_DBall product with a systematic and a sectional sample, respectively. The sectional sample covers the same geographic area as the sectional sample covering depth less than 20 meters.

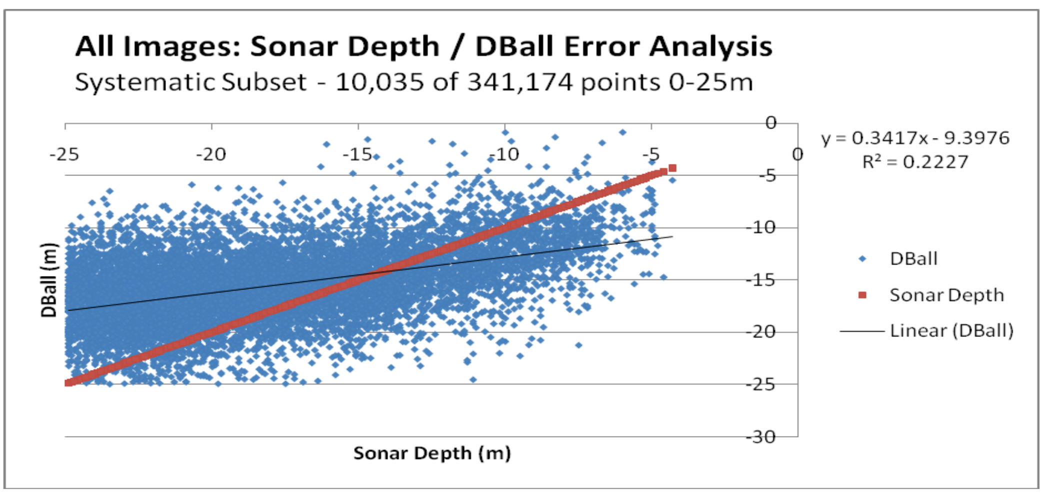

Figure 47. Comprehensive error analysis 0 – 25 m: integration of derived bathymetry from all images – systematic sample.

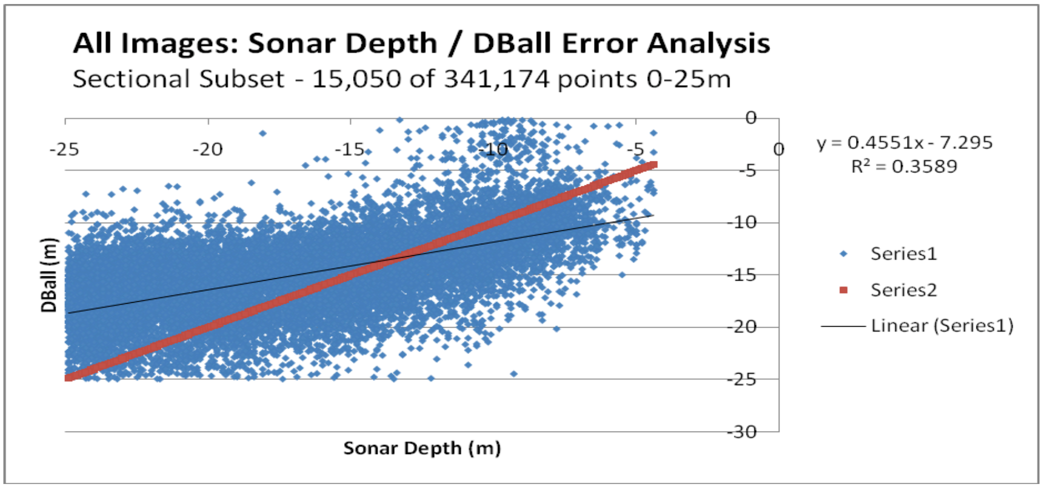

Figure 48. Comprehensive error analysis 0 – 25 m: integration of derived bathymetry from all images – sectional sample.