IfSAR Quality Assurance (QA) Report

QA Report for Intermap Cells 333, 334, 335, 347, 348, 349, 361, 362, and 375

Produced for U.S. Geologic Survey

USGS Contract: G16PC00020

Task Order: 140G0219F0031

Report Date: April 29, 2020

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Contents

Executive Summary

The following Interferometric Synthetic Aperture Radar (IfSAR) quality assurance report documents Dewberry's review of IfSAR data and associated products for Intermap's Kodiak and St. Lawrence Lot 6 Option 1 cells of the Alaska Statewide Digital Mapping Initiative (SDMI). This dataset consists of nine 1° x 1° cells: 333, 334, 335, 347, 348, 349, 361, 362, and 375. The average area per cell within the Kodiak and St. Lawrence Lot 6 Option 1 datasets is approximately 1,714 square kilometers. Each full cell contains 16 USGS 15' tiles and 4 NGA 30' tiles. All cells in Kodiak and St. Lawrence Lot 6 Option 1 are partial tiles due to their island locations. Each 15' USGS tile contains a Digital Terrain Model (DTM) and Digital Surface Model (DSM) with 5 meter post spacing, an Ortho-rectified Radar Image (ORI) with 0.625 meter pixel size, a hydrology layer, void areas, void fill sources, a slope mask, associated metadata, and Quality Report. Each 30' tile for the National Geospatial-Intelligence Agency (NGA) contains a re-sampled DTM with .4 x .8 arc/second post spacing, associated metadata files, and Quality Report. The figure below shows the location of the nine cells *(Figure 1)*.

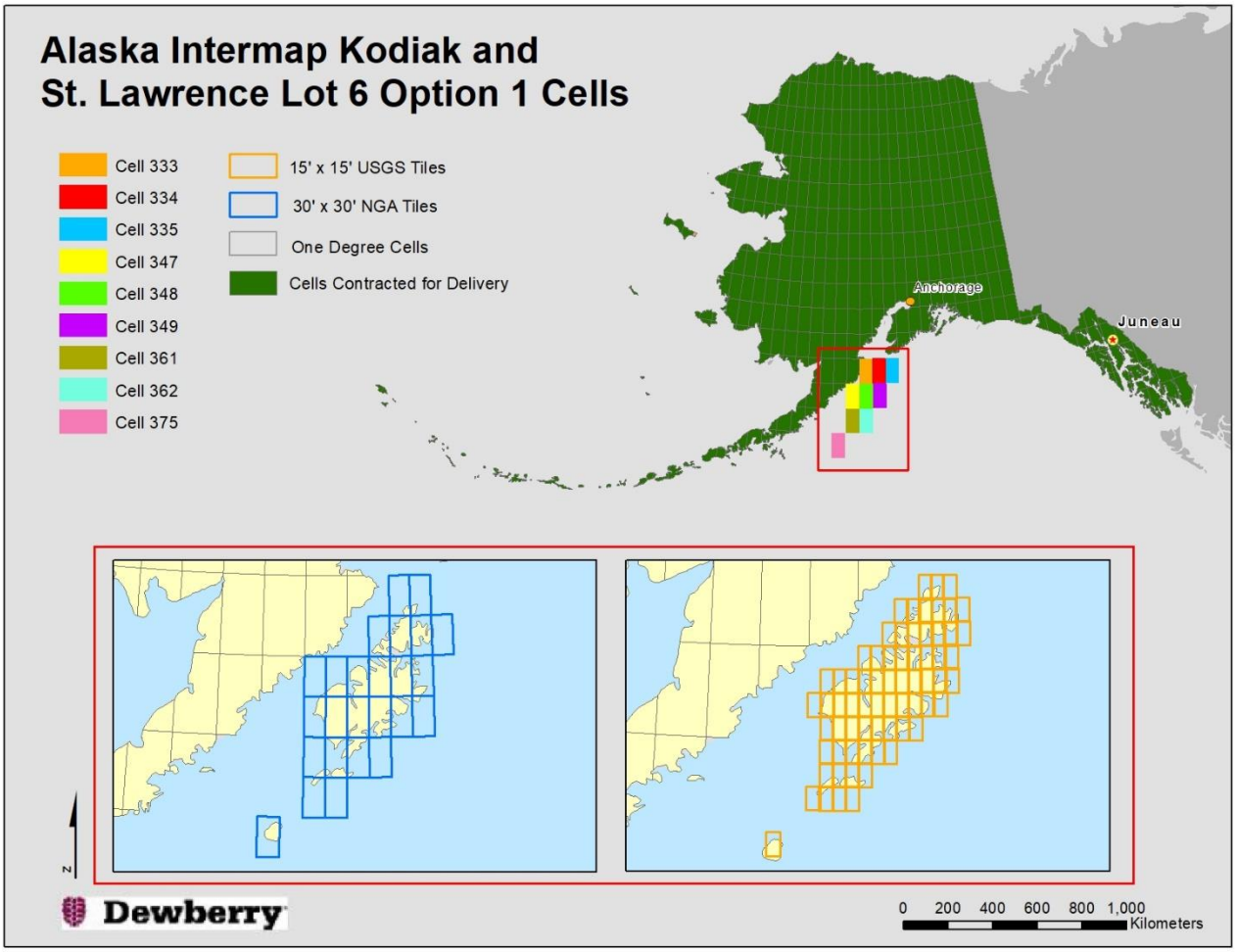

Figure *1* - Location of Cells 333, 334, 335, 347, 348, 349, 361, 362, and 375.

Contract:	Production Contractor:	Delivery #:	Dewberry Recommendation:
Alaska Statewide Digital Mapping Initiative IfSAR QA Contract	Intermap	Kodiak and St. Lawrence Lot 6 Option 1, Delivery 2	It is Dewberry's recommendation that the data be accepted.
Data History: ❑ Delivery 2 of Kodiak and St. Lawrence Lot 6 Option 1 - Cells 333, 334, 335, 347, 348, 349, 361, 362, and 375. ❑ Delivery 1 of Kodiak and St. Lawrence Lot 6 Option 1 - Cells 333, 334, 335, 347, 348, 349, 361, 362, and 375.			

The IfSAR data and derived products were processed through Dewberry's comprehensive quantitative/qualitative review. This multipart analysis determines the degree to which the data met expectations for completeness, relative accuracy, and conformity to specific project requirements for each data product. Examples of the data are documented in the report.

All data for the Alaska SDMI Kodiak and St. Lawrence Lot 6 Option 1 cells were thoroughly examined by Dewberry for completeness and conformity to project specifications. Surveyed checkpoints were used to independently assess the vertical accuracy of the DTM data, as well as to determine how well Intermap's STAR X-band Ifsar system is at mapping the extremely vegetated island topography located within the Kodiak and St. Lawrence Lot 6 Option 1 cells. Though the DTM data did not pass vertical accuracy in the first delivery when checkpoints located under dense vegetation were incorporated, Intermap re-processed the DTMs in the second delivery and the accuracy results under tree canopy are much improved, with results right at accuracy thresholds for open, non-vegetated and 0-10 degree sloped terrain. DTM data passes vertical accuracy when checkpoints located under tree canopy are removed from the accuracy testing. This smaller, non-vegetated, sample of checkpoints is more in line with locations surveyed in the rest of the State for accuracy. Please see the DTM Quantitative Review section of this report for more information.

Thirteen locations were identified in the first delivery for piers flattened in the DSMs, or piers excluded in the hydro mask and not properly flattened in the DTMs. The piers were correctly included in the hydro mask (flattened in the DTMs) and modeled properly in the DSMs by Intermap in the second delivery. All DTMs and DSMs for Kodiak and St. Lawrence Lot 6 Option 1 conform to project specifications.

The ORI data were reviewed for completeness as well as used to verify that the hydrologic layer for each tile meets project specifications. No survey checkpoints were located at locations that were photo-identifiable within the ORIs so the horizontal accuracy of the ORI data was not tested. All ORI data for the Kodiak and St. Lawrence Lot 6 Option 1 cells conform to project specifications.

Shapefiles were delivered for hydrology, void areas, void fill sources, and slopes. Hydrology was collected to project specifications and used to enforce both the DSMs and DTMs. The void areas and void fill sources were used during the completeness review for the DTMs, DSMs, and ORIs. Acquiring data from multiple look angles reduced the number of voids within the Kodiak and St. Lawrence Lot 6 Option 1 cells, but voids are present in every cell. The majority of voids within the Kodiak and St. Lawrence Lot 6 Option 1 data have been filled using data from the National

Elevation Dataset (NED). The slope layer categorizes the entire cell into the following: 0°-10°, 10°-20°, 20°-30°, and >30°. This layer was used during the general QC as well as during the vertical accuracy testing to ensure only surveyed checkpoints located in the 0°-10° category were used for the final statistics and calculations. Several issues were identified in the hydro mask of the first delivery where potential land features were either excluded or included within the hydro mask. These areas were all addressed by Intermap in the second delivery. All quality masks for the Kodiak and St. Lawrence Lot 6 Option 1 cells conform to specifications.

The 15' USGS tiles were re-sampled into 30' NGA tiles with .4 x .8 arc/second posting. These DTMs follow HRTe3 data guidelines and specifications. The HRTe3 NGA data for the Kodiak and St. Lawrence Lot 6 Option 1 cells conform to project specifications.

Metadata was delivered for each DSM, DTM, ORI, and NGA 30' DTM in XML, HTML, and TXT format. There were no MetaParser errors and all metadata files were verified to contain sufficient content. A Certified ISO 9001 quality report is delivered for each 15' tile and each 30' tile. Ancillary data including a swath locator diagram, USGS 15' tile grid, and NGA 30' tile grid are delivered with the data. Metadata for the Kodiak and St. Lawrence Lot 6 Option 1 data meet project specifications.

DELIVERABLES SUMMARY FOR INTERMAP CELLS 333, 334, 335, 347, 348, 349, 361, 362, AND 375

Deliverable	Applicable Acceptance Criteria	Dewberry Recommendation
DSM/DTM USGS 15' tiles	**11, 2, 3, 4, 5, 6, 7, 8, 12, 13, 17, 18, 19, 21, 22, 23, 24, 25, and 26**	☑ Accept ☐ Accept with Comments ☐ Return for Corrections ☐ Reject
ORIs	**2, 5, 6, 8, 11, 17, 25, and 26**	☑ Accept ☐ Accept with Comments ☐ Return for Corrections ☐ Reject
Re-Sampled NGA 30' tiles	**4, 5, 6, 7, 8, 14, 17, 23, 25, and 26**	☑ Accept ☐ Accept with Comments ☐ Return for Corrections ☐ Reject

Quality Masks	**5, 6, 8, 15, 17, 25 and 26**	☑ Accept ☐ Accept with Comments ☐ Return for Corrections ☐ Reject
Metadata	**17 and 20**	☑ Accept ☐ Accept with Comments ☐ Return for Corrections ☐ Reject
Certified ISO 9001 Quality Report	**16 and 17**	☑ Accept ☐ Accept with Comments ☐ Return for Corrections ☐ Reject
Ancillary Data	**5, 6, 8, and 27**	☑ Accept ☐ Accept with Comments ☐ Return for Corrections ☐ Reject

The applicable acceptance criteria refer to the numbered criteria found in "Appendix A-Acceptance Criteria." The acceptance criteria were also outlined in the final Quality Plan created by Dewberry.

Approved by: David F Maune _____ Date: 4/29/2020
(sign & stamp)

American Society for Photogrammetry and Remote Sensing
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Overview

The goal of the USGS Alaska DEM Task Order is to evaluate mid-accuracy elevation datasets and associated deliverables created from IfSAR technology. As part of the Kodiak and St. Lawrence task order, Intermap acquired and fully processed IfSAR data for 15 1° x 1° cells, or approximately 20,380 square kilometers. This report addresses Lot 6 Option 1, nine 1° x 1° cells, or approximately 15,424 square kilometers. Per each complete cell, Intermap delivered 16 USGS 15' tiles that include a DSM, DTM, ORI, slope mask, hydrology mask, void areas, void fill sources, metadata, and Quality Report. The USGS DTM datasets are created with 5 meter post spacing and are re-sampled into four 30' datasets per each cell with .4 x .8 arc/second spacing for the NGA. These 30' tiles follow HRTe3 product guidelines.

Dewberry's role is to provide Quality Assurance (QA) of the IfSAR data and supplemental deliverables provided by Intermap that includes completeness checks, vertical and horizontal accuracy testing, and a qualitative review of the bare earth surfaces. Each product is reviewed independently and against the other products to verify the degree to which the data meets expectations.

DSM AND DTM ANALYSIS FOR THE USGS 15' TILES

The IfSAR DSM and DTM data are reviewed on project and tile levels to determine the accuracy of the data and conformity to project requirements. The DTM surface is compared with surveyed checkpoints to determine vertical accuracy. The elevation dataset properties are analyzed to determine formatting and completeness. The quality of the elevation datasets is assessed with visual micro and macro checks.

DTM QUANTITATIVE REVIEW

One of the first steps in assessing the quality of the IfSAR is a vertical analysis of the bare earth DTMs in comparison with surveyed checkpoints. An independent survey was conducted by JOA Surveys, LLC. JOA Surveys acquired 30 total checkpoints in the nine cells delivered as Kodiak and St. Lawrence Lot 6 Option 1. Kodiak Island was originally going to be mapped with Fugro's GeoSAR system, which uses both X-band and P-band radar, so that the P-band could be leveraged for vegetation penetration. However, Fugo's GeoSAR system was decommissioned before Kodiak Island could be acquired. In order to determine how well Intermap's STAR X-band Ifsar system is at mapping the extremely vegetated island topography located within the Kodiak and St. Lawrence Lot 6 Option 1 cells, Dewberry asked JOA Surveys to survey a sample of the checkpoints for this lot under tree canopy. It was fully expected the accuracy results of these checkpoints located in dense vegetation would be poorer than previously seen as these checkpoints were located in "worst-case scenario locations." The 15 checkpoints surveyed under tree canopy are labelled "tree" in their point id's. The remaining 15, non-vegetated checkpoints were surveyed in a manner more in line with locations surveyed in the rest of the State for accuracy.

Initially, the DTM data did not pass vertical accuracy when checkpoints located under dense vegetation were incorporated (RMSEz of 3.210 m and ACCURACYz of 6.292 m). Intermap re-processed the DTMs in the second delivery and the accuracy results under tree canopy are much improved, though still slightly outside of the project RMSEz specification by 2.8 cm (RMSEz of 1.878 m and ACCURACYz of 3.681 m). As vegetated checkpoints are not surveyed as part of the "normal" accuracy assessment and only non-vegetated points in sloped terrain of 0-10 degrees are included, this 2.8 cm excess of the specification is acceptable. It would be more appropriate to assess the vegetated checkpoints using a method similar to Vegetated Vertical Accuracy (VVA) outlined in the ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014), where VVA is tested using the 95th percentile method and max VVA thresholds are equal to 3 * RMSEz. Using this method, we could expect vegetated points in 0-10 degree sloped terrain to test at or better than 5.55 m (1.85 m * 3). The 14 checkpoints located in vegetated, 0-10 degree sloped terrain were tested to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 1.85 m RMSEz Vertical Accuracy Class. Actual VVA accuracy was found to be +/- 4.427 m at the 95th percentile. And DTM data fully pass vertical accuracy when checkpoints located under tree canopy are removed from the accuracy testing, per normal procedures. Due to the limited number of checkpoints within a single cell, the entire nine cell block was tested as one comprehensive project area.

Thirty (30) JOA survey checkpoints were located within the Kodiak and St. Lawrence Lot 6 Option 1 cells, fifteen (15) were surveyed under dense tree canopy, and fifteen (15) were surveyed under typical, non-vegetated, conditions. Dewberry buffered all potential checkpoints by the radial RMSE value of 8.035 meters. Only checkpoints whose entire buffered area were completely within the slope category of 0°-10° were used to calculate the vertical accuracy. Twenty eight (28) checkpoints were located on terrain with a slope of 0°-10° and were used to calculate vertical accuracy statistics for cells 333, 334, 335, 347, 348, 349, 361, 362, and 375. Two (2) checkpoints were located on terrain outside of the slope category of 0°-10°.

Survey Vertical Accuracy Checkpoints

The following table lists all survey checkpoints located within cells 333, 334, 335, 347, 348, 349, 361, 362, and 375. Checkpoints surveyed under tree canopy are labelled with "tree" at the end of the point id. Checkpoints without the "tree" label were surveyed under normal, non-vegetated, conditions. These checkpoints were used to test the vertical accuracy of Kodiak and St. Lawrence Lot 6 Option 1 cells.

Point ID	NAD83 (CORS96) Alaska Albers		NAVD88 (Geoid09)
	Easting X (m)	Northing Y (m)	Elevation (m)
333_07tree	40736.856	898639.108	33.839
333_09tree	40799.356	898710.418	34.901
333-4	57811.201	894230.247	3.742
334_10tree	108522.908	910298.02	7.847
334_11tree	108570.791	910310.976	7.996
334_12tree	108576.068	910257.755	8.521
334-1a	85112.125	904895.817	12.481
334-1b	85095.319	905077.85	10.504
334-2	88808.165	937330.751	5.305
347-1	-26470.19	840145.568	40.293
347-3	-13883.602	795151.118	2.365
348-1	43669.433	801432.41	17.052
348-2	1295.731	836851.029	19.467
348_01tree	50500.263	818338.361	5.455
348_02tree	50481.363	818368.147	6.252
348_03tree	50476.489	818399.301	6.25
348_04tree	57680.135	874004.921	119.282
348_05tree	57710.509	874010.098	120.603
348_06tree	57743.368	873984.464	121.808
349_30	86170.677	862237.074	759.084
349_13tree	97393.231	871621.951	39.435
349_14tree	97376.14	871629.177	40.571
349_15tree	97388.289	871659.092	41.752
349-1	92443.934	827004.558	23.915
349-2	88932.706	859846.421	8.814
361-1	-10745.132	770500.459	11.382

362-2	6828.408	773406.675	4.126
375_BBBG99	-108978.839	646195.659	12.346
333_08tree	40775.87	898768.136	34.707
349_40	84322.831	867476.201	733.666

Table 1: Survey checkpoints located within cells 333, 334, 335, 347, 348, 349, 361, 362, and 375. Checkpoints surveyed under tree canopy are labelled with "tree" at the end of the point id. Checkpoints without the "tree" label were surveyed under normal, non-vegetated, conditions.

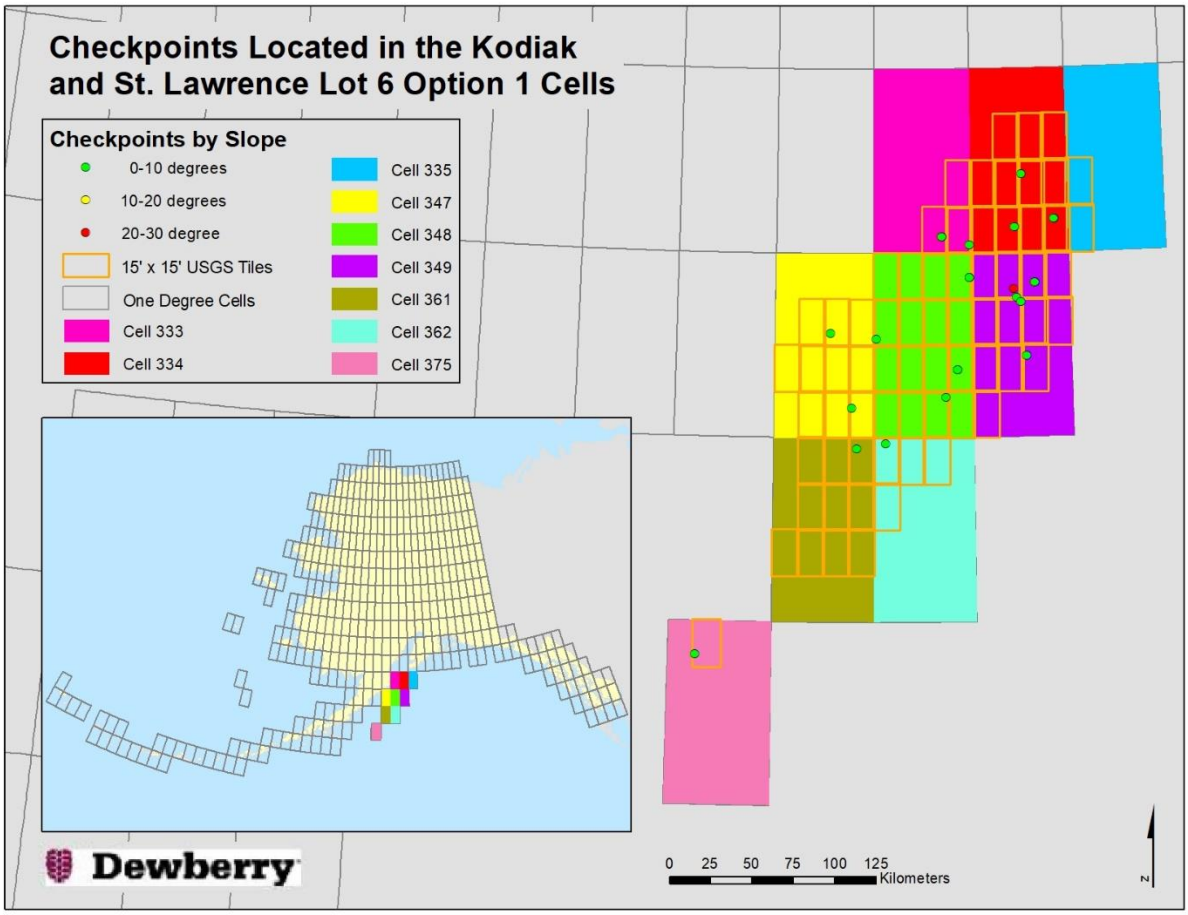

Figure 2 – Checkpoints displayed by slope.

The vertical accuracy assessment compares the measured survey checkpoint elevations with the elevations of the bare-earth raster, or DTM. The X/Y locations of the survey checkpoints are overlaid on the DTM and the elevation of the pixel at the checkpoint X/Y location is extracted and recorded. These extracted Z values are then compared with the survey checkpoint Z values and this difference represents the amount of error between the measurements. Once all the Z values are recorded, the Root Mean Square Error (RMSE) is calculated. The RMSE equals the square root of the average of the set of squared differences between the dataset coordinate values and the coordinate values from the survey checkpoints. The data for this project must meet 20 foot contour accuracy or the National Standard for Spatial Data Accuracy (NSSDA) equivalent using $Accuracy_z$ at the 95% confidence level, which is 3.63 meters. $Accuracy_z$ is equal to RMSEz x 1.9600.

Vertical Accuracy Results

Table 2 lists the RMSE and Accuracy$_z$ specifications for each slope category. From its initial technical proposal, Intermap indicated that it would make a best effort to meet specifications in areas of slope greater than 10 degrees, but can only commit to reach vertical accuracy specifications for un-obstructed areas with slopes less than 10 degrees where standard GCP layout can be established. For this reason Dewberry computed accuracy statistics separately for the mandatory slope category of 0 to 10 degrees.

Table 3 outlines the calculated RMSEz, vertical accuracy, and associated statistics for all checkpoints located within the 0°-10° slope category, including the checkpoints surveyed under tree canopy. Note: The 2.8 cm excess of the RMSEz specification is acceptable as vegetated checkpoints are not surveyed as part of the "normal" accuracy assessment; only non-vegetated points in sloped terrain of 0-10 degrees are typically included (see the beginning of the DTM Quantitative Review section for more information).

Table 4 outlines the calculated RMSEz, vertical accuracy, and associated statistics for just those checkpoints surveyed under typical, non-vegetated conditions. DTM data passes vertical accuracy when checkpoints located under tree canopy are removed from the accuracy testing, per normal procedures. This smaller, non-vegetated, sample of checkpoints is more in line with locations surveyed in the rest of the State for accuracy.

Table 5 outlines the 95th percentile and associated statistics for just those checkpoints surveyed in vegetated, 0-10 degree slope, as this would be a more appropriate method for assessing vegetated checkpoints.

Two checkpoints in the Kodiak and St. Lawrence Lot 6 Option 1 cells are located in slope categories other than 0°-10. Table 6 outlines the vertical accuracy statistics for all checkpoints in all slope categories for Kodiak and St. Lawrence Lot 6 Option 1.

Slope Category	RMSE Specifications (m)	Accuracy$_z$ Specifications (m)
0-10	1.85	3.63
10-20	3.71	7.27
20-30	5.56	10.90
>30	7.41	14.52

Table 2 — RMSE and Accuracy specifications by slope. Only data located in 0-10 degree sloped terrain are required to meet accuracy specifications.

100 % of Totals	# of Points	RMSE Spec=1.85 m	Accuracy$_z$ (RMSEz x 1.9600) Spec=3.63 m	Mean (m)	Median (m)	Skew	Std Dev (m)	Min (m)	Max (m)
Slope 0-10	28	1.878	3.681	0.320	-0.075	1.041	1.885	-2.732	6.071

Table 3 - The table shows the calculated RMSEz values and vertical accuracy for all 0-10 degree slope checkpoints located within the Kodiak and St. Lawrence Lot 6 Option 1 cells, including those surveyed under tree canopy.

100 % of Totals	# of Points	RMSE Spec=1.85 m	Accuracy$_z$ (RMSEz x 1.9600) Spec=3.63 m	Mean (m)	Median (m)	Skew	Std Dev (m)	Min (m)	Max (m)
Slope 0-10	14	0.531	1.041	-0.048	-0.131	0.449	0.549	-1.050	0.960

Table 4 - The table shows the calculated RMSEz values and vertical accuracy for 0-10 degree slope checkpoints located within the Kodiak and St. Lawrence Lot 6 Option 1 cells that were surveyed under typical, non-vegetated, conditions. These checkpoints are required to meet vertical accuracy specifications.

100 % of Totals	# of Points	RMSE Spec=1.85 m	95th Percentile Target=5.55 m	Mean (m)	Median (m)	Skew	Std Dev (m)	Min (m)	Max (m)
Slope 0-10	14	N/A	4.427	0.687	0.922	0.412	2.605	-2.732	6.071

Table 5 - The table shows the calculated 95th percentile for vegetated, 0-10 degree slope checkpoints located within the Kodiak and St. Lawrence Lot 6 Option 1 cells that were surveyed under tree canopy.

100 % of Totals	# of Points	RMSE Spec (0-10 degree)=1.85 m	Accuracy$_z$ (RMSEz x 1.9600) Spec (0-10 degree)=3.63 m	Mean (m)	Median (m)	Skew	Std Dev (m)	Min (m)	Max (m)
Slope 0-10	28	1.878	3.681	0.320	-0.075	1.041	1.885	-2.732	6.071
Slope 10-20	1	13.923	27.290	13.923	13.923	N/A	N/A	13.923	13.923
Slope 20-30	1	3.867	7.579	-3.867	-3.867	N/A	N/A	-3.867	-3.867

Table 6 - The table shows the calculated RMSEz values and vertical accuracy for checkpoints in all slope categories located within the Kodiak and St. Lawrence Lot 6 Option 1 cells; only non-vegetated checkpoints in slope category 0-10 degrees (Table 4) are required to meet vertical accuracy specifications.

DSM/DTM OVERVIEW

Dewberry received 16 DTM USGS 15' tiles and 16 DSM USGS 15' tiles for each complete cell. All raster elevation datasets were checked to ensure correct file type, tile size, cell size, pixel type, and assigned NoData values. All properties were correct and are as follows:

- File type: 32 bit GeoTIFF
- Tile size: 15', extents match USGS tile grid extents
- Cell/Pixel size: 5 meters
- Pixel type: Floating point
- NoData Value: -10000

All raster elevation datasets were checked to ensure they have the correct spatial reference information and is as follows:

- Horizontal Datum: NAD83 CORS96 Epoch 2003.00
- Projection: Alaska Albers

- Horizontal Units: Meters

While raster datasets do not store vertical spatial reference information, the vertical units were verified as meters during the quantitative vertical accuracy testing. All raster elevation datasets were verified to be named correctly with a deliverable product identifier (DSM/DTM) preceding the hemisphere, degree, minute referencing the southwest corner of each tile and "P" at the end of the tile name for files with voids.

DSM/DTM QUALITATIVE REVIEW

The goal of Dewberry's qualitative review is to assess the continuity and the level of cleanliness of the bare earth product. Each IfSAR tile is expected to meet the following acceptance criteria:

- The DTM represents the bare-earth surface and is mostly void of vegetation, buildings, and other elevated features;
- Both DSMs and DTMs show a consistent surface with no gross anomalies that affect the usability of the surfaces due to interruptions in elevation values or continuity.
- No obvious anomalies due to sensor malfunction or systematic processing artifacts are present (data voids, spikes, divots, ridges between flight lines or tiles, etc);
- The surfaces are hydro-flattened appropriately according to project specifications.

Dewberry analysts performed a visual inspection of 100% of the DTM and DSM data at a micro scale. The DTMs were reviewed to ensure all issues that might impact future modeling or analyses using the bare-earth surfaces were identified. DSMs were reviewed to ensure complete coverage, that there were no corrupt tiles, and that gross anomalies were not present. The DSMs were also used as supplemental data during the qualitative review of the DTMs, ORIs, and quality masks. Both the DSMs and DTMs were reviewed in Global Mapper and with the use of hillshades in ArcGIS. Hillshades apply shaded relief to raster datasets that enables the analyst to view the elevation datasets as if they were 3D.

Radar Shadow and Layover

Two conditions that usually occur with IfSAR data is layover and shadow. Layover occurs when the terrain angle is greater than a line perpendicular to the look angle and causes radar signals from the top of the feature to reach the antennae before signals from the bottom of the feature. This causes the feature to "layover" toward the IfSAR sensor. As described in Intermap's Product Handbook, the previously compressed regions are stretched during the production process to better represent the terrain. This may cause areas of layover to appear blurred as areas of higher terrain have been "pulled" back to their correct position. If there is no valid elevation in regions of layover, these areas are filled through interpolation or ancillary data and will be represented with a void mask. However, many of these layover areas contain valid elevation information due to overlapping data from other swaths or flight lines. An example is shown below.

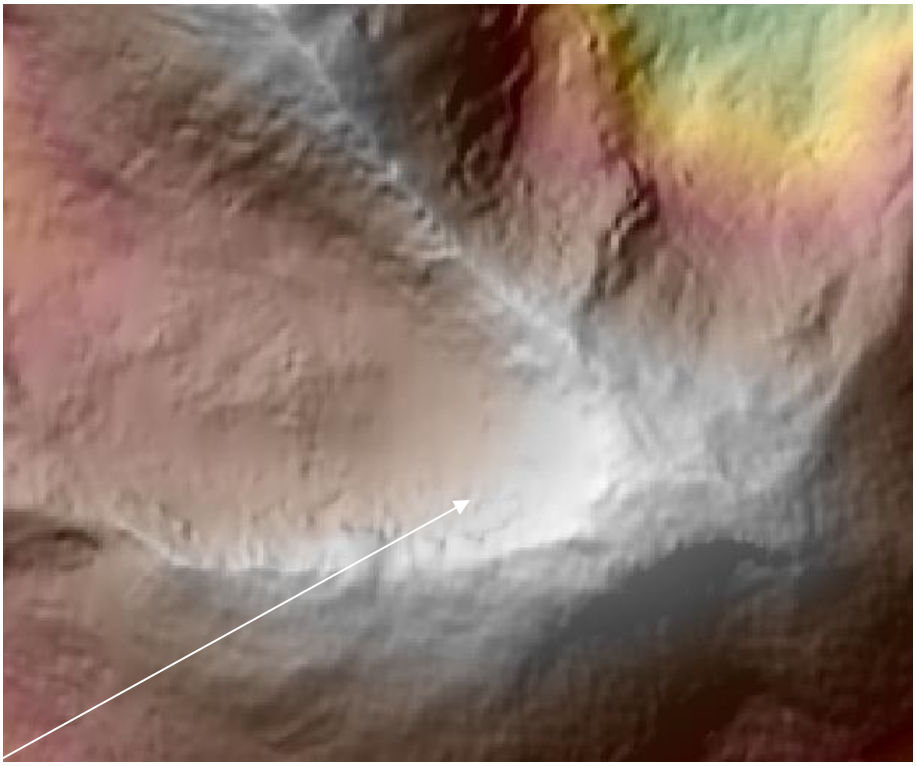

Figure 3- Tiles N5715W15330P and N5715W15345P from cell 348. Some areas of layover may appear 'blurred', but valid elevations exist in these areas.

Radar shadow occurs when the radar signal cannot reach a portion of terrain because it is obscured by other parts of the terrain (such as the side of a mountain facing away from the IfSAR sensor). Both layover and shadow can prohibit the mapping of elevation data and result in voids. In an effort to reduce voids, Intermap acquired multiple look angles in areas of steep terrain by flying additional flight lines or swaths. The amount of void areas is well within project specifications with no 15' tile exceeding the 5% void area limit. No cell within Kodiak and St. Lawrence Lot 6 Option 1 cells had void areas greater than 0.98%. The majority of voids located within the Kodiak and St. Lawrence Lot 6 Option 1 cells used the NED as the fill source. The interpolation used to fill some void areas cause a loss of definition in the surface. This is expected and generally occurs in areas of very steep terrain, in the >30° slope category. An example is shown below.

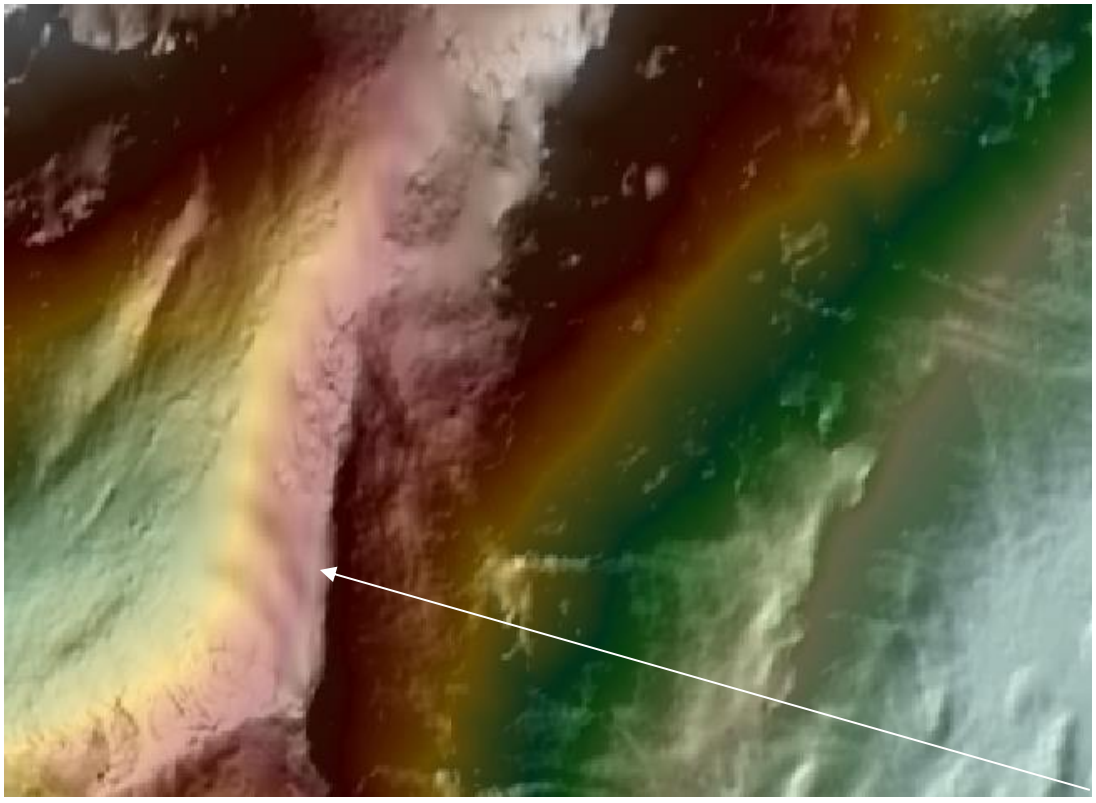

Figure 4 - Tile N5715W15330P from cell 348. Loss of surface definition is generally present in areas of steep terrain where interpolation methods were used to fill void areas.

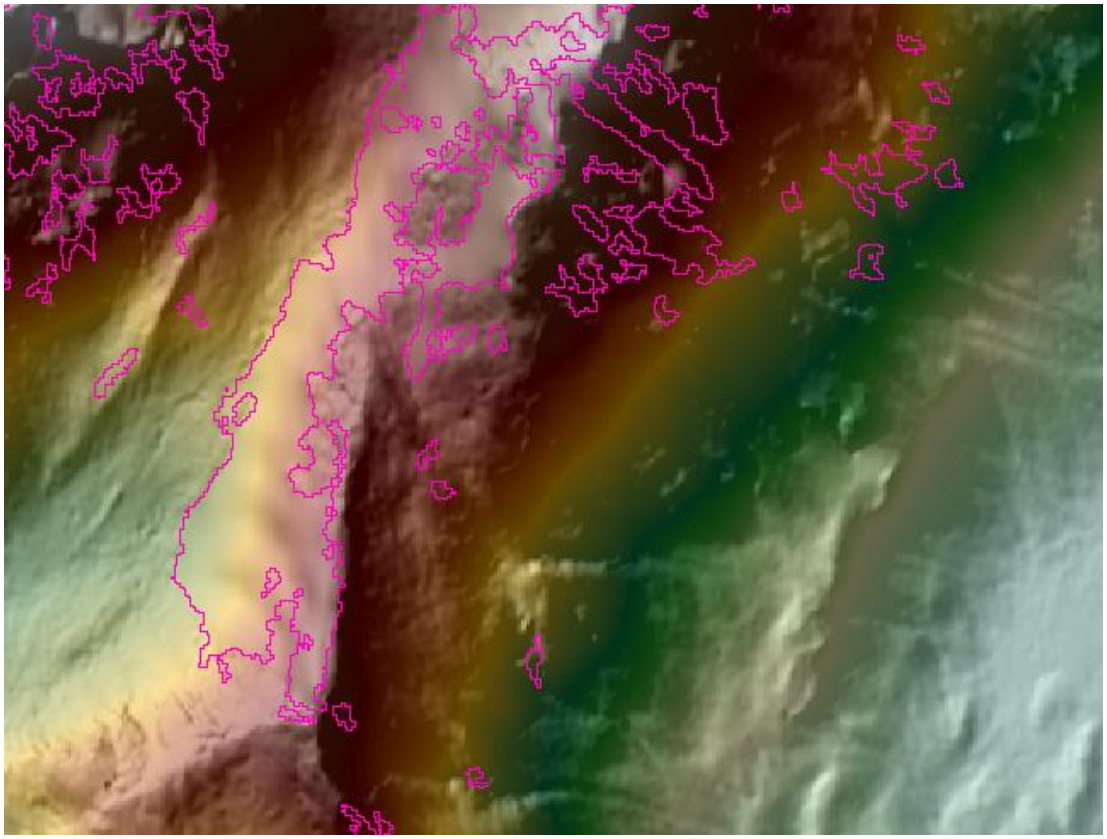

Figure 5 - Tile N5715W15330P from cell 348. Void areas are identified with a void mask (in pink). No individual cell in either Kodiak and St. Lawrence Lot 6 Option 1 cells had void areas greater than 0.98% of the cell area.

Hydro-Flattening

All features that were collected as part of the hydrologic mask have been flattened in both the DTMs and DSMs. All waterbody and linear hydrographic features that are flattened in the DTMs and DSMs are at an elevation that is either just at or below the surrounding terrain. An example is shown below.

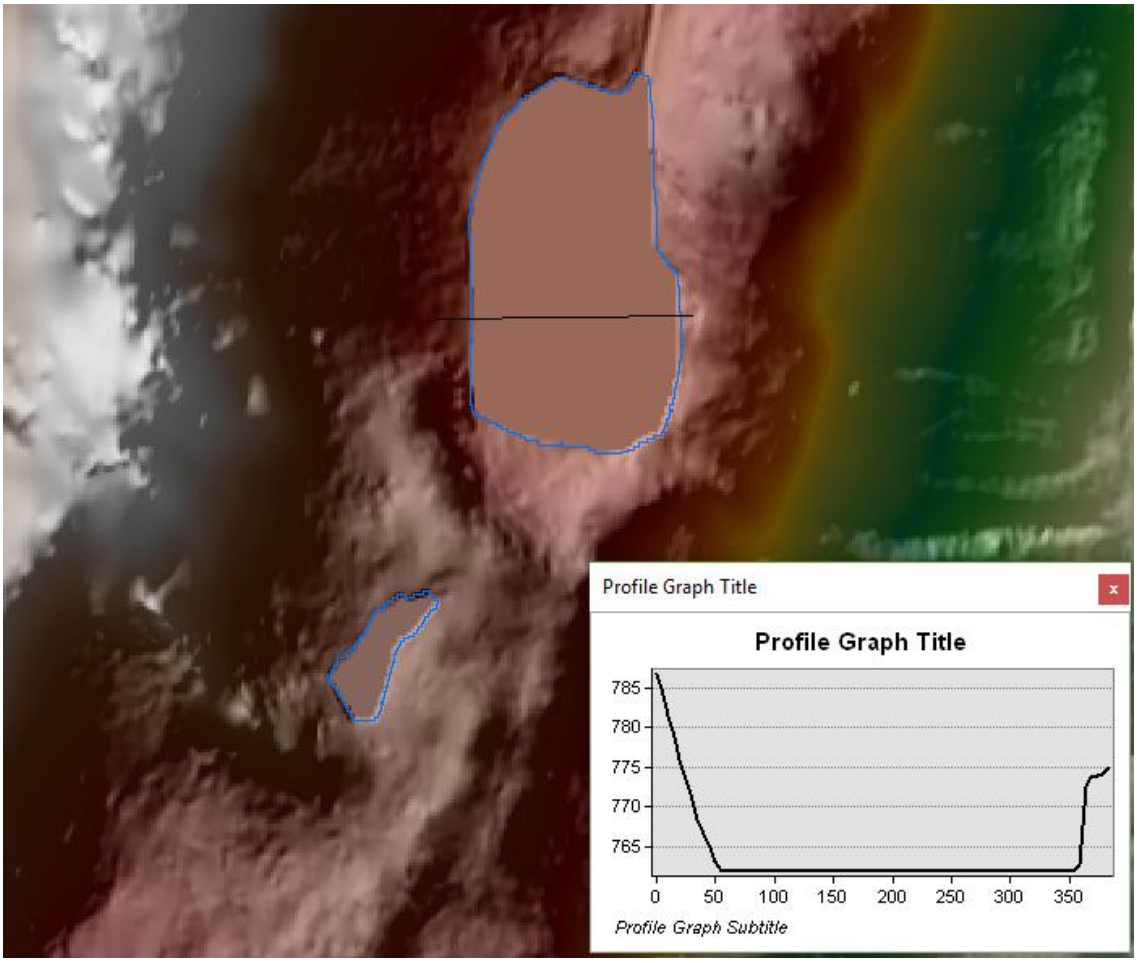

Figure 6 – Tile N5730W15300P from cell 349. All features captured as part of the hydrologic mask are flattened in both the DSMs and DTMs.

Piers and Docks

Piers, docks, and bridges should be fully modeled in the DSMs, but hydro-flattened in the DTMs. The hydro mask should match the DTMs to represent all areas hydro-flattened in the DTMs. In the first delivery, thirteen (13) areas were identified where docks or piers were either not modeled properly in the DSMs or were excluded in the hydro mask, causing the feature to not be flattened or modeled properly in the corresponding DTM and DSM. All piers/docks were addressed by Intermap in the second delivery and are modeled properly in the DTMs and DSMs. Examples are shown below.

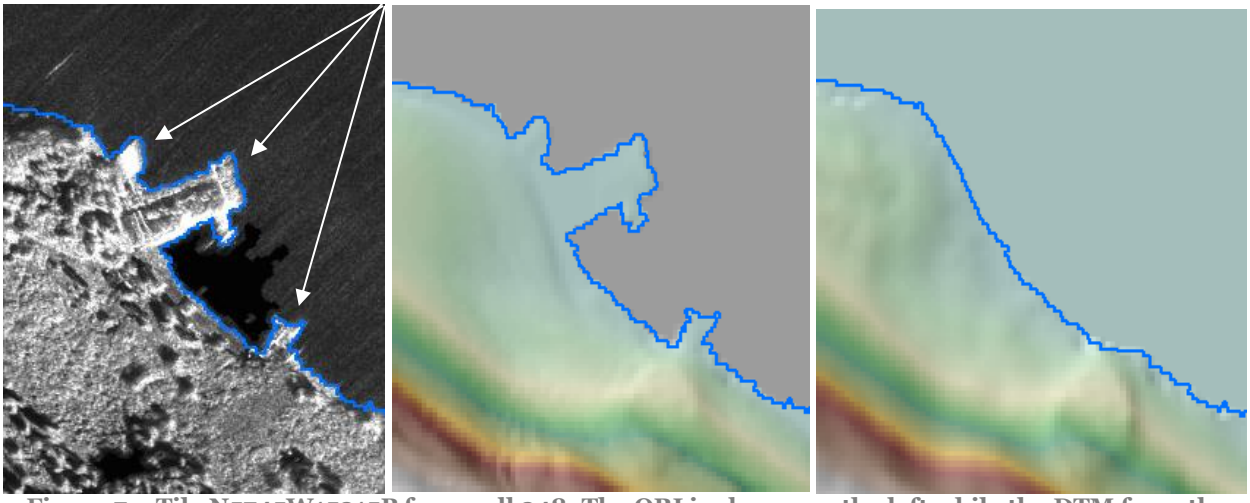

Figure 7 – Tile N5745W15315P from cell 348. The ORI is shown on the left while the DTM from the first delivery is shown in the middle image. The hydro mask (blue) and DTM required adjustments so the piers/docks were hydro-flattened in the DTM. Both the hydro mask and DTM were updated in the second delivery (right image) so the piers/docks are properly hydro-flattened.

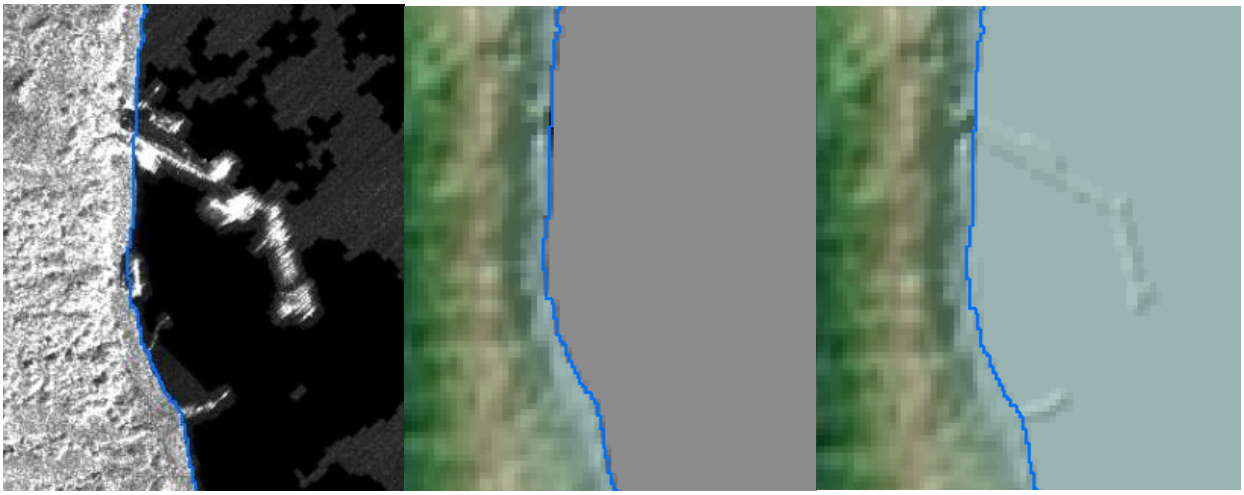

Figure 8 – Tile N5700W15415P from cell 347. The ORI is shown on the left while the DSM from the first delivery is shown in the middle image. Several piers/docks were properly hydro-flattened in the DTMs, however, they were not modeled in the DSMs. In the second delivery (right image), the piers/docks were modeled properly in the DSMs.

Relative Accuracy of Adjoining Cells

Dewberry tested the relative accuracy of all adjoining cells in this delivery by subtracting one cell from another for every cell edge that overlapped with another cell. Elevations for adjoining cells must match within the combined nominal RMSEz value for both datasets, which is 3.756 m for the Kodiak and St. Lawrence Lot 6 Option 1 cells. All overlapping edges between cells 333, 334, 335, 347, 348, 349, 361, 362, and 375 exactly matched with no elevation differences between overlapping pixels.

DTM Elevations Higher Than DSM Elevations

In February of 2018, users of the Alaska IfSAR data contacted USGS after observing areas in the data where DSM elevations were lower than the DTM elevations. As DSMs are a reflective surface and the DTM is a bare earth surface, users may assume DSM elevations will always be higher than or equal to (in non-vegetated, bare earth terrain) DTM elevations but never lower than DTM elevations. However, this assumption is not correct with IfSAR data. As described and explained by Intermap, the delivered DSM is the surface "as-sensed" by the IfSAR and contains undulating noise of approximately 30 cm in height. The DTM is then created from the DSM surface using specific algorithms and edit rules which seek to preserve terrain features while reducing the radar noise in the data. This processing both raises and lowers the DTM data (noise divots or valleys are raised and noise spikes or hills are lowered). Areas in the DTM which are raised all have the potential to have final elevations higher than the original, un-edited DSM surface. Intermap's Product Handbook (page 156), excerpt shown below, details this known phenomenon and when the DTM is further edited to reduce how much higher it is compared to the DSM.

Feature:	DTM is high (above the DSM)
Definition:	Expectations for the DTM are that the elevations will be lower than the DSM in obstructed areas and approximately equal to the DSM in unobstructed areas. In some cases, the DTM creation process will violate this condition, causing localized areas of DTM above DSM. This can be caused by several factors, including: DSM noise that is represented as a smoothed surface in the DTM Areas of natural rapid elevation change in the DSM, such as: pits, forest edges, cliff bottoms, embankment bottoms, unedited bridges bottoms, and cuttings through trees or ground, valleys, ridge bottoms, dam bottoms, weir bottoms, and forest clearings Areas of unnatural rapid elevation change in the DSM due to radar or processing artifacts, such as: parking lots or other unedited road features (due to low radar signal return), and depressed edges behind buildings, trees, or similar objects Depending on the amount the DTM is above the DSM and where this occurs, some of these deviations will be corrected and some will be retained. DTM high errors will be fixed according to automatic QC tool parameters and the DTM-above-DSM tool. This rule applies in areas in which the Forest edit rule is not utilized.
DTM Edit Rule:	Areas of DTM above DSM shall be edited if they meet the following criteria: Where there is an automatic QC Tool error on a 2000 square meters area of bare ground with valid DSM elevations Where the difference between the DTM and DSM is greater than 4m over an area of 2000 square meters Where there is an automatic QC Tool error on any SLD, provided the DSM elevations are valid Edits will be performed until these criteria (elevation difference and/or size) are no longer met. Areas of DTM above DSM may remain after editing.

Feature:	Bare ground
Definition:	Unobstructed terrain.
DTM Edit Rule:	The elevations of unobstructed terrain will be smoothed to remove radar noise. A conservative smoothing algorithm balances the need to preserve terrain features in the DTM while reducing the amount of noise in the data. The smoothing process both lowers and raises individual posts.

DSM Edit Rule:	Elevations will remain as sensed by the radar.
Obstruction Rule:	N/A
Ancillary Data Usage:	Ancillary data will be used to improve interpretation.

Table 7-Excerpt from Intermap's Product Handbook detailing the known phenomenon of DTM elevations being higher than DSM elevations and rules for when the DTM is further edited to reduce this phenomenon.

For Intermap's Kodiak and St. Lawrence Lot 6 Option 1 (cells 333, 334, 335, 347, 348, 349, 361, 362, and 375), Dewberry subtracted the DTM surface from the DSM surface. There are locations across the cells where DTM elevations are slightly higher than the DSM elevations. However, the overwhelming majority of locations where the DTM is higher than the DSM have differences less than 50 cm (see image below). Additionally, while speckled throughout the cells, the areas of higher DTM elevations are not contiguous and represent Intermap's explanation of undulating radar noise. The few locations where DTM elevations are higher than DSM elevations by more than 50 cm generally occur in very steep terrain, in interpolated areas identified by the void mask, and along steep hydrographic embankments.

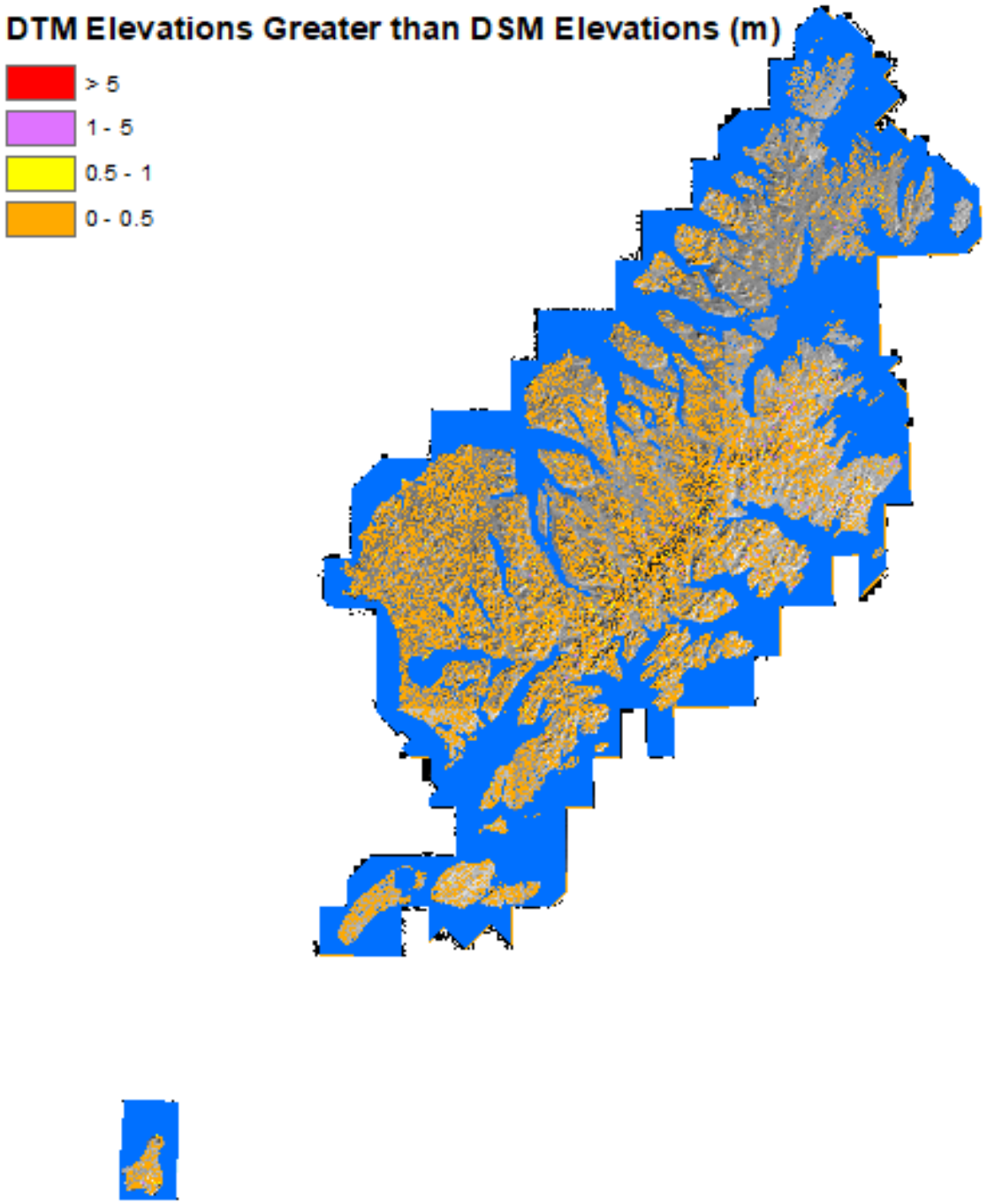

Figure 9 - DSM/DTM difference rasters for Kodiak and St. Lawrence Lot 6 Option 1, cells 333, 334, 335, 347, 348, 349, 361, 362, and 375 are overlaid on ORIs, showing locations where the DTM elevations are higher than DSM elevations at the same xy location (5 m raster pixel). There are locations speckled throughout these cells where DTM elevations are higher than DSM elevations; this is a known and expected phenomenon with this IfSAR technology. The vast majority of areas where the DTM is higher in elevation than the DSM are by 50 cm or less.

DSM/DTM RECOMMENDATION

Dewberry recommends that the 15' USGS DSM and DTM data delivered for Intermap's Kodiak and St. Lawrence Lot 6 Option 1 (cells 333, 334, 335, 347, 348, 349, 361, 362, and 375) be accepted. No qualitative issues were identified in the DSMs or DTMs and the DTM data passes vertical accuracy requirements when checkpoints located under tree canopy are removed from the accuracy testing, per normal accuracy testing procedures. Assessing the vegetated checkpoints using the more appropriate 95th percentile method yields acceptable results.

Ortho-Rectified Radar Images (ORI)

The ORIs are verified for complete coverage and are used as reference information when reviewing the DSM/DTM data and quality masks. ORIs are used extensively to check for the completeness of the hydrology mask. ORIs will also be used for horizontal accuracy testing of the dataset.

ORI OVERVIEW

Dewberry received 16 full, complete ORIs that matched in extents to the USGS 15' tiles for every complete cell. Partial cells may have contained fewer tiles. All ORIs were checked to ensure correct file type, cell size, pixel type, tile size, and extents. All properties were correct and are as follows:

- File type: 8 bit GeoTIFF
- Tile size: 15', extents match USGS tile grid extents
- Cell/Pixel size: 0.625 meters
- Pixel type: Integer

All ORIs were checked to ensure they have the correct spatial reference information and is as follows:

- Horizontal Datum: NAD83 CORS96 Epoch 2003.00
- Projection: Alaska Albers
- Horizontal Units: Meters

Intermap assigns voids within project boundaries a value of 1. All ORIs were verified to be named correctly with a deliverable product identifier (ORI) preceding the hemisphere, degree, minute referencing the southwest corner of each tile and "P" at the end of the tile name for files with voids.

ORI QUANTITATIVE REVIEW

During the 2010 data collection, Dewberry instructed JOA Surveys to collect some accuracy checkpoints at steel towers with the intent that Dewberry would attempt to photo-identify these towers on the ORI images, and compare the ORI X/Y location of the photo-identifiable features to the surveyed X/Y location to produce horizontal accuracy results. The RMSE equals the square root of the average of the set of squared differences between the coordinate values measured by Dewberry and the coordinate values from the survey checkpoints. The data for this project must meet the National Standard for Spatial Data Accuracy (NSSDA) 1:24,000-scale equivalent using $Accuracy_r$, which is 13.9 meters at the 95% confidence level. $Accuracy_r$ is equal to RMSEr x 1.7308. Dewberry was able to photo-identify several steel towers in both Fugro Earth Data, Inc (FEDI) and Intermap 2010 data and the resulting horizontal accuracy statistics showed the 2010 data passed horizontal accuracy specifications. However, the steel towers

interfered with the radar signals and caused some issues with the vertical accuracy testing and results. Rather than "throwing away" expensive checkpoints in the vertical accuracy testing, Dewberry has tasked JOA Surveys with only collecting checkpoints in open, flat areas for all subsequent data, giving priority to vertical accuracy testing over horizontal accuracy testing.

No checkpoints in the Kodiak and St. Lawrence Lot 6 Option 1 cells were photo-identifiable; horizontal accuracy could not be tested.

ORI RECOMMENDATION

It is Dewberry's recommendation that the ORIs for Intermap's Kodiak and St. Lawrence Lot 6 Option 1 (cells 333, 334, 335, 347, 348, 349, 361, 362, and 375) be accepted. While horizontal accuracy could not be tested, the ORIs meet all other project specifications.

Quality Masks

Dewberry reviewed the quality masks delivered for the Kodiak and St. Lawrence Lot 6 Option 1 data. Quality masks identifying hydrology, void areas, void fill sources, and slope categories were delivered for each 15' USGS tile. These quality masks were reviewed by themselves and in conjunction with other deliverables, such as DTMs or ORIs, to fully assess all aspects of the data.

QUALITY MASK OVERVIEW

Dewberry verified complete quality masks, including hydrology, void areas, void fill sources, and slope categories, were delivered for each 15' tile. The quality masks were verified to be in the correct shapefile format and to have the correct spatial projection information, shown below:

- Horizontal Datum: NAD83 CORS96 Epoch 2003.00
- Projection: Alaska Albers
- Horizontal Units: Meters

All quality masks were verified to be named correctly with a deliverable product identifier (fill_source/hydro/void/slope) preceding the hemisphere, degree, minute referencing the southwest corner of each tile and "P" at the end of the tile name for files with voids.

QUALITY MASK QUALITATIVE REVIEW

Each quality mask was viewed in an ESRI environment with other Kodiak and St. Lawrence Lot 6 Option 1 deliverables to check relative accuracies of deliverables in comparison with each other. Quality masks were also used as supplemental information during the review of the DSM and DTM surfaces.

The slope quality mask was used to identify each surveyed checkpoint as being located within one of the project specified slope categories: 0°-10°, 10°-20°, 20°-30°, and >30°. JOA Surveys also provided images of each surveyed checkpoint. These images were reviewed to ensure no gross differences existed between survey photos and Intermap's slope mask. The slope mask was utilized during vertical accuracy testing as only terrain located within the 0°-10° slope category is required to meet vertical accuracy specifications.

The void and void fill source masks were used during the DSM and DTM review to ensure areas lacking definition or shape were due to void areas filled by interpolation. An example of this was provided in Figures 4 and 5. As stated in the DSM/DTM section, the percentage of void areas in the Kodiak and St. Lawrence Lot 6 Option 1 dataset was well within project specifications with no cell having void areas greater than 0.98% of the cell area.

Hydrologic features meeting project requirements must be included in the hydrologic quality mask and these features must be flattened in the DTM. Intermap collects hydrographic features to their NextMap USA standards, resulting in the collection of much smaller features than required by project standards. The hydro mask was reviewed against the ORIs to check for completeness and consistency of capture. Several issues were identified with the hydro mask in the first delivery. They were addressed or explained by Intermap in the second delivery and are discussed below.

Eleven (11) areas were identified in the first delivery that required further investigation by Intermap to determine if valid land features were included in the hydro mask and flattened in the DTMs/DSMs. Intermap addressed the issues in the second delivery. An example is shown below.

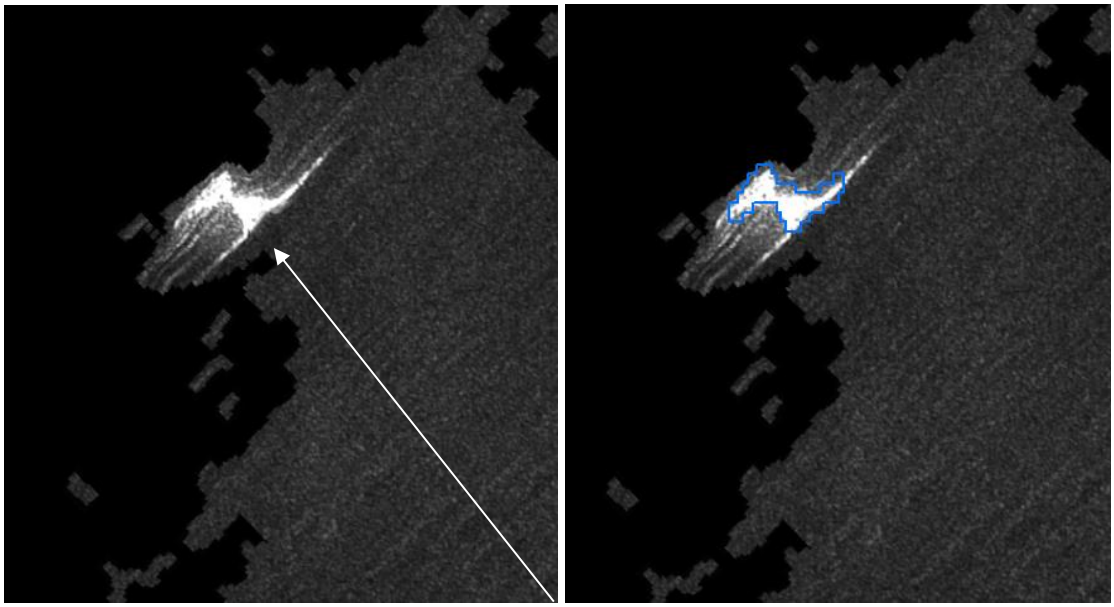

Figure 10 – Tile n5715w15445P from cell 347. Valid land features were included in the hydro mask and flattened in the DTMs/DSM in the first delivery (left image). Intermap excluded these land features from the hydro mask and modeled them properly in the DTM and DSM in the second delivery (right image).

Twenty six (26) issues were identified in the first delivery where small islands collected in the hydro mask required further verification. These features show no valid land in the corresponding ORIs. Intermap reviewed the features and found no valid land. The hydro mask, DTMs, and DSMs were adjusted in the second delivery to address the small polygons. An example is shown below.

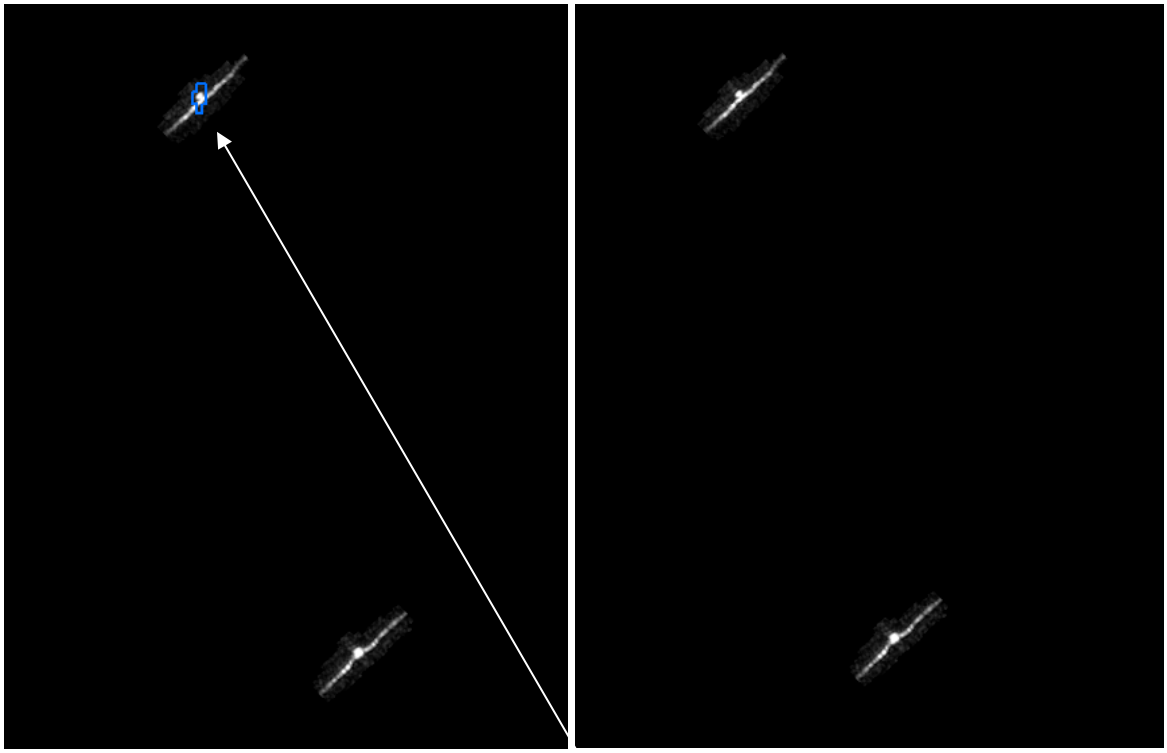

Figure 11 – Tiles n5800w15245P from cell 334. In the first delivery, small islands were collected in the hydro mask that required further verification to determine if there was valid land in these locations (left image). Intermap determined the small islands were not valid and the hydro mask was adjusted in the second delivery (right image)

QUALITY MASK RECOMMENDATION

It is Dewberry's recommendation that the hydro quality mask for Intermap's Kodiak and St. Lawrence Lot 6 Option 1 now be accepted. Several issues were identified in the first delivery, including potential land features either included or excluded from the hydro mask, and required review. All issues were addressed in the second delivery and all other quality masks, including slope, fill source, and void quality masks for Intermap's Kodiak and St. Lawrence Lot 6 Option 1 (cells 333, 334, 335, 347, 348, 349, 361, 362, and 375) were found to meet project requirements.

Re-sampled NGA 30' Tiles to HRTe3 Data Specifications

The USGS DTM 15' tiles with 5 meter post spacing were re-sampled into 30' tiles with .4 x .8 arc/second post spacing, 2251 columns and 4501 rows. These re-sampled tiles follow HRTe3 data product guidelines.

HRTE3 DATA OVERVIEW

Dewberry received 4 DTM NGA 30' tiles per complete cell. All 30' raster elevation datasets were checked to ensure correct file type, tile size, cell size, pixel type, assigned NoData values, number of rows, and number of columns. All properties were correct and are as follows:

- File type: 16 bit GeoTIFF

- Tile size: 30 x 30'
- Cell/Pixel size: .4 x .8 arc/second
- Pixel type: Integer
- NoData Value: -32767
- Number of columns and rows: 2251 x 4501

All raster elevation datasets were checked to ensure they have the correct spatial reference information and is as follows:

- Horizontal Datum: NAD83 CORS96 Epoch 2003.00 (Geographic)
- Horizontal Units: Degrees

All raster elevation datasets were verified to be named correctly with the hemisphere, degree, minute referencing the southwest corner of each tile and "P" at the end of the tile name for files with voids.

HRTE3 DATA QUALITATIVE REVIEW

The HRTe3 30' tiles are re-sampled from the 15' USGS DTM tiles. As such, the tiles were reviewed in Global Mapper at a macro level for complete coverage, no corrupt files, and no anomalies that were not present in the 15' tiles but may have been introduced during the re-sampling. Void areas are not to be filled with interpolation methods in the HRTe3 data. Voids have been correctly left as is and assigned the correct NoData value of -32767.

SPIKES/WELLS

The HRTe3 files were reviewed in Quick Terrain Modeler software. This software allows the user to view the data in 3D and to tilt it about its z-axis to more readily identify spikes or wells that are present in the data. Additionally, this software produces statistics from the elevation data that can help identify outliers that are spikes or wells that need to be corrected. No spikes or wells were identified in the HRTe3 data.

HRTE3 RECOMMENDATION

Dewberry recommends that the HRTe3 data for Kodiak and St. Lawrence Lot 6 Option 1 (cells 333, 334, 335, 347, 348, 349, 361, 362, and 375) be accepted. The HRTe3 data meets all product guidelines and specifications outlined for this project.

Metadata

Metadata was delivered in XML, HTML, and TXT format for every DSM, DTM, and ORI file. Metadata was also delivered in all three formats for each NGA 30' DTM. All metadata files were named correctly to match the data product they described. No errors were returned from the USGS MetaParser tool. All metadata was verified to contain sufficient content with no issues noted.

A certified ISO 9001 quality report is delivered for each 15' tile and each 30' tile. The quality report identifies data delivery quality checklists performed by Intermap, accuracy testing and void analyses performed by Intermap, an overview of Intermap's quality control process, and ground control and navigation processing methods that Intermap used for this project.

Ancillary files including a swath locator shapefile, tile grid of the USGS 15' cells, tile grid of the NGA 30' cells, and project area shapefiles are included with the delivery. The flight dates, flight direction, GPS week, beginning GPS time, and ending GPS time are provided for each swath in the swath locator shapefile.

METADATA RECOMMENDATION

It is Dewberry's recommendation that all ancillary files, quality reports, 15' metadata files and 30' metadata files for Intermap's Kodiak and St. Lawrence Lot 6 Option 1 (cells 333, 334, 335, 347, 348, 349, 361, 362, and 375) be accepted.

Other Comments

All data was provided in the correct structure in that all data associated with a particular 15' or 30' tile is organized into a single directory. The ancillary data folder is correctly located at the same level as the highest-level directory in the directory structure.

Recommendations Summary

The following represents a summary of Dewberry's recommendations for Intermap's Kodiak and St. Lawrence Lot 6 Option 1 cells. These recommendations can be found throughout the various sections of this report but are summarized here for convenience.

DSM/DTM:

1. No issues to be addressed.

ORI:

1. No issues to be addressed.

QUALITY MASKS:

1. No issues to be addressed.

NGA 30' TILES:

1. No issues to be addressed.

METADATA:

1. No issues to be addressed.

APPENDIX A – ACCEPTANCE CRITERIA

Criteria	Tested Characteristic	Measure of Acceptability
IFSAR ACCURACY ACCEPTANCE CRITERIA		
1.	Vertical Accuracy	Data within a Slope Range of 0°-10° must meet an ACCURACYz of 3.63 meters Or 20 ft equivalent contour accuracy (RMSEz of 1.85 meters)
2.	Horizontal Accuracy	$RMSE_{xy}$ ≤ 5.682 meters, RMSEr ≤ 8.035 meters, ACCURACYr 13.9 meters
GEOGRAPHIC COVERAGE AND CONTINUITY ACCEPTANCE CRITERIA		
3.	Coverage	Voids should be less than 5% of a single 15'x15' tile. Voids should be less than 3% of entire project area. Percentages pertain to void areas prior to filling or interpolation.
SPATIAL REFERENCE FRAMEWORK		
4.	Vertical Datum	NAVD 88, processed with Geoid09
5.	Horizontal Datum	NAD 83, GRS80
6.	Projection	Alaska Albers (Geographic for HRTe3 Data)
7.	Vertical Units	Meters (orthometric heights to the centimeter precision)
8.	Horizontal Units	Meters (decimal degrees for HRTe3 Data)
DELIVERABLES		
9.	Flight Plan	Flight plan should include but is not limited to: planned swaths, potential base station locations, horizontal and vertical accuracy of base stations, projected maximum baseline length for airborne trajectories, prior calibration reports, process to perform daily calibration checks, flight acquisition, actual flight lines, any problems encountered during acquisition, etc.
10.	Report of Survey	Text report that describes survey methods; x,y,z results; contractor's accuracy assessments, including internal consistency and absolute accuracy; file formats; file naming schemes; tiling schemes., *.pdf, .doc, or .odt format*. The survey data and report shall be delivered on the same media as the actual data and shall include the checkpoints used for quality control.
11.	Ortho Rectified Radar Images (ORIs)	Single band 8 bit GeoTIFF with 5 meter pixels or better (Intermap is delivering .625 m ORI pixels)
12.	Digital Surface Models (DSMs)	32 bit GeoTIFF 15'x 15' tiles with 5 meter post spacing
13.	Digital Terrain Models (DTMs)	32 bit GeoTIFF 15'x 15' tiles with 5 meter post spacing
14.	HRTe3 data product	Re-Sampled DTM data in 30' x 30' tiles, .4 arc/second post spacing (.4 x .8 arc/second above 50N), signed 16 bit GeoTIFF with whole integers.
15.	Quality/Slope Mask	Four separate Shapefiles with polygons identifying slope accuracies, hydrology, nulls or void data, void fill sources, and areas of interpolation.
16.	Certified ISO 9001 Data Quality Report	Report for each 15'x15' tile in PDF format.
17.	File naming convention	Tiles are named by referencing the southwest corner of each tile in the form of hDDMMhDDDMM (hemisphere, degree, minute). Any cell that contain voids will have "P" in the file name (hDDMMhDDDMMP). An identifier of ori, dsm, or dtm shall be added to the beginning of each file name.

Criteria	Tested Characteristic	Measure of Acceptability
18.	DTM Hydro-Enforcement	Hydrographic features that meet or exceed requirements outlined in SOW should be flattened and/or monotonic
19.	DTM Artifacts	DTM shall represent the bare earth ground surface and should not have excessive vegetation, buildings, tiling artifacts, gaps or artificial smoothing at tile boundaries.
20.	Formal metadata	FGDC compliant metadata that is free of MetaParser (MP) errors, contains items outlined in SOW and is delivered per 15'x15' tile in XML, HTML, and TXT formats for each tile.
21.	Inconsistent Post-Processing, Editing	No gross vertical offsets caused by editing, processing or calibration errors
22.	Over-Smoothing	Smoothing techniques shall not remove topographic features necessary to define drainage structures or tops of mountains.
23.	Spike/Well Threshold	No spike or well shall exist that is greater than 10 meters.
24.	Overlap Area along the 147th Meridian	Data delivered from each producer (FEDI and Intermap) within the overlap area will be compared to surveyed checkpoints to determine an absolute accuracy within the 350 meters of overlap. Data from each producer will be compared against each other to produce accuracy statistics relative to each other.

USABILITY ACCEPTANCE CRITERIA

25.	Internal file formats	Files shall have consistent internal formats
26.	File Sizes	Files shall not exceed 200MB when zipped except for ORIs which may be larger due to Intermap's .625 meter pixel ORI resolution.
27.	Ancillary geographic feature data	Ancillary geographic feature data represented as vector data types, such as the swath locator diagram, grid of the quarter-quadrangle tiles and project area, shall have complete and correct associated projection files.