

DPH-9.1 Report on Overlap Consistency (interswath)

The USGS Lidar Base Specification Version 2.1 states: "Overlap consistency will be assessed at multiple locations within overlap in nonvegetated areas of only single returns and with slopes of less than 10 degrees. To the degree that the data allow, test areas should be located such that the full width of the overlap is represented. The overlap areas that will be tested are those between the following:

- adjacent, overlapping parallel swaths within a project,
- cross-tie swaths and a sample of intersecting project swaths in both flight directions; and
- adjacent, overlapping lifts.

Each overlap area will be evaluated using a signed difference raster with a cell size equal to the ANPS, rounded up to the next integer, then doubled (Cellsize=CEILING(ANPS)×2). The difference rasters will be statistically summarized to verify that RMSDz values do not exceed the limits set forth in table 2 for the QL of information that is being collected."

Table 2. Relative vertical accuracy for light detection and ranging swath data.

[QL, quality level; RMSD_z, root mean square difference in the z direction; m, meter; ≤, less than or equal to]

Quality level	Smooth surface repeatability, RMSD _z (m)	Swath overlap difference, RMSD _z (m)
QL0	≤0.03	≤0.04
QL1	≤0.06	≤0.08
QL2	≤0.06	≤0.08
QL3	≤0.12	≤0.16

The purpose of this section is to show two versions of a thematically rendered map of swath separation for all of the data processed.

For the first – known as a Measurable Flightline Separation Raster (FSR) - processing has been done to isolate measurements to clusters of single returns and is limited to areas of < 10 degree slope. The colors are gradated by the selected QL's swath overlap difference RMSDz limits. Only swath overlap areas are shown in the raster. The color is overlaid on a lidar intensity background to show land cover features. The swath overlap difference RMSDz values are reported on the pages following the raster graphic.

For the second raster – known as a Swath Separation Image and found at the end of this test section – there are no limitations on slope angles and return types are user defined. The colors are gradated by the selected QL's swath overlap difference RMSDz limits. Only swath overlap areas are shown in the RGB raster. The color is overlaid on a lidar intensity background to show land cover features.

DPH-9.1 Report on Overlap Consistency (interswath) - Measurable FSR

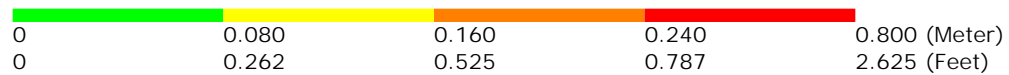
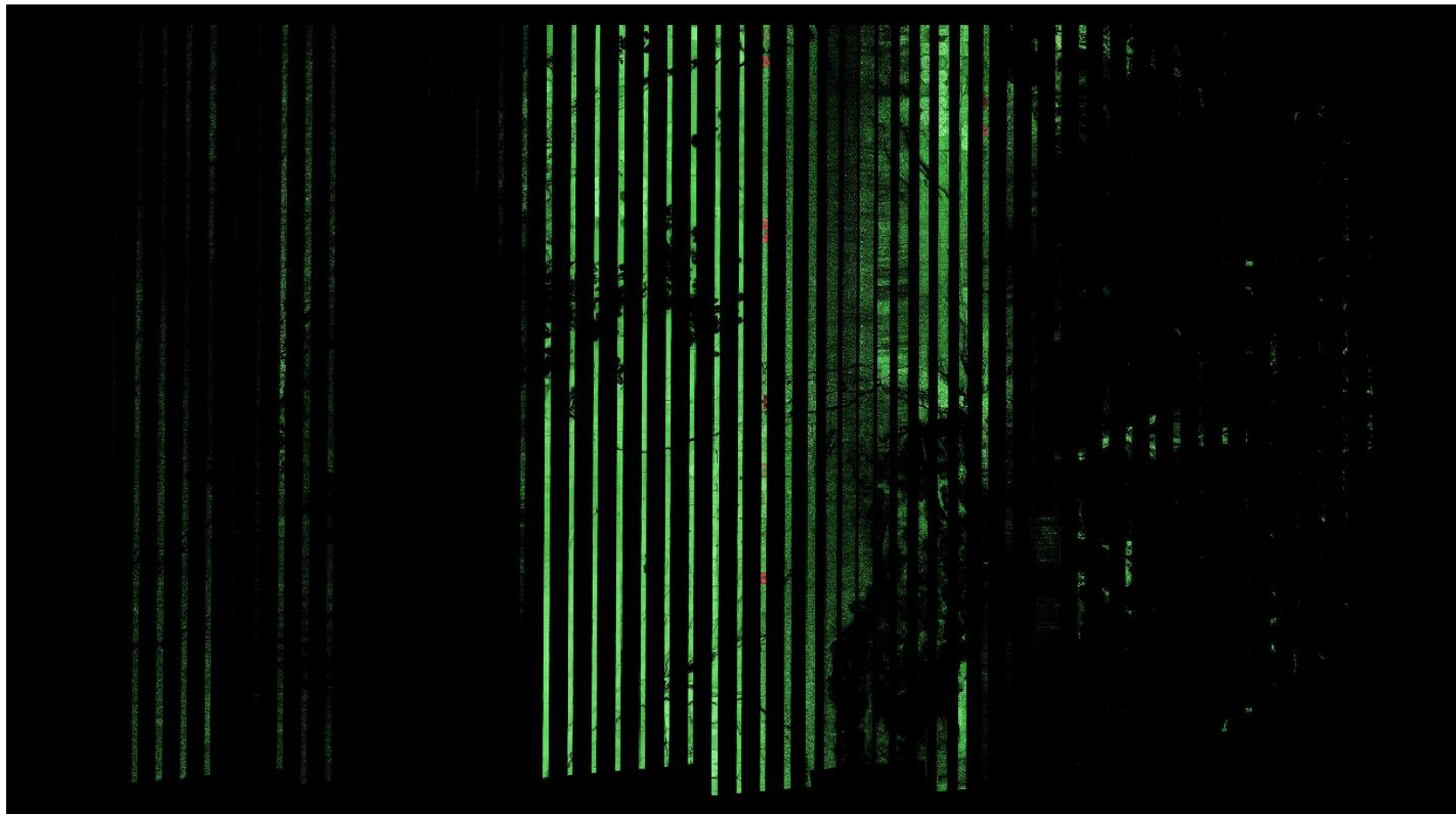
Description of the process that generates the Measurable Flightline Separation Raster (FSR):

- a. Boundaries are determined for all swath overlap areas.
- b. A TIN is created for each swath in an overlap area, and a Grid is overlaid on those TINs. Grid cell sizes are 3x the aggregate nominal pulse spacing (ANPS) as shown in Table 1 of the USGS Lidar Base Specification v 2.1. ANPS varies depending on the Quality Level of the data.
- c. The grid cells are populated with the vertical separation values between the underlying TINs as measured at the centroid of each grid cell. When three or more swaths coincide with a cell, the value is set to the difference between the maximum and minimum of all elevations. Only areas of slope < 10 degrees are measured. Points flagged as Withheld, and points classed as High or Low Noise, are excluded from this analysis.
- d. The Measurable FSR uses a pre-filtering algorithm that selects only clusters of single returns for use in the RMSDz analysis. The algorithm's purpose is to find areas for measurement that are in the open, away from roof edges, trees, etc. - it is not designed to find ground below vegetation canopy. By using only clusters of single returns (at a minimum distance from any multiple returns) and ignoring cells with NODATA values, reliable RMSDz values are produced. These values are listed for each swath overlap area in the RMSDz table immediately following the raster page.
- e. A vertical separation cut-off is used to remove values that are not appropriate for separation measurements (e.g., trees, moving objects, etc.). This cut-off is set to 10 times the color gradation interval value.
- f. The same RMSDz calculation is then run on the final vertical separation grid. A single, aggregate RMSDz is calculated from this larger, all-encompassing grid, and the final thematic raster is generated from the grid.

DPH-9.1 Report on Overlap Consistency (interswath) - Measurable

[Data Source - Y:\Mapping\Projects\65220595_CO_SanLuisJuanMiguel\Production\Final_Client_Deliverables\Block1_Surdex\point_cloud\Swaths](#)

[Result Path - D:\00_San_Miguel\San_Luis_Juan_Miguel_B1A_QC\DPH_9_1\FlightlineSeparation_SingleFile_Measurable_TIN.jp2](#)



A maximum vertical separation cutoff has been applied to this graphic for the purpose of masking out disruptive features that do not show calibration issues between swaths (e.g., trees, moving cars, etc.).

DPH-9.1 Report on Overlap Consistency (interswath) - continued

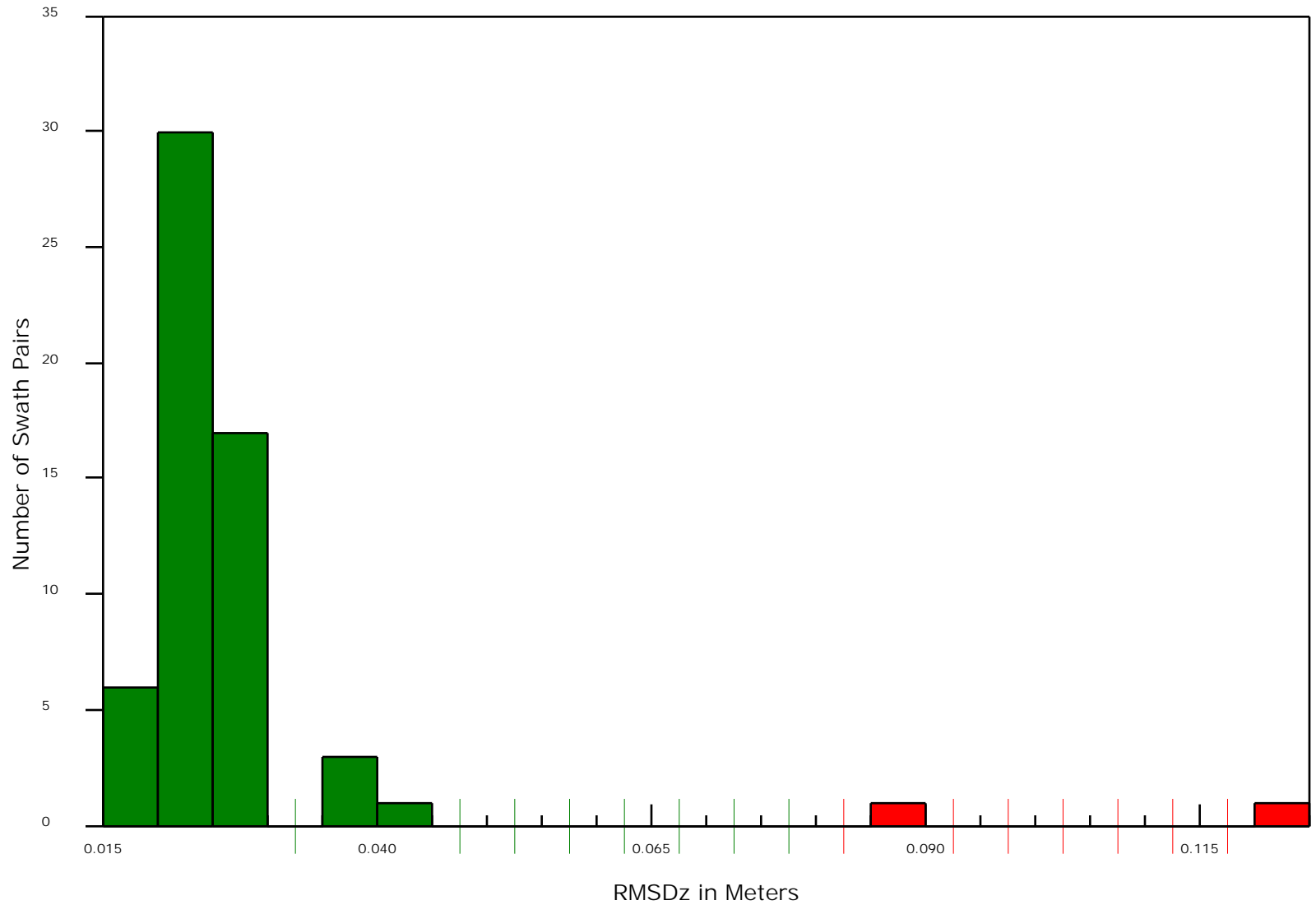
Adjacent Flight Line 1	Adjacent Flight Line 2	Area 1 (square Meter)	Area 2 (square Meter)	Overlap Area (square Meter)	RMSDz (Meter/Feet)
00233	00187	158999257.258	158649121.960	16225629.935	0.088 / 0.288
00189	00110	80135882.203	78423869.702	14880993.877	0.125 / 0.410
00065	00233	80118835.260	79652867.830	23313169.158	0.029 / 0.094
00065	00146	80173420.345	79513255.381	29456434.696	0.026 / 0.086
00186	00051	14639418.114	14557215.560	3068871.531	0.027 / 0.090
00186	00018	79687822.282	78975050.177	16296342.465	0.040 / 0.131
00186	00156	79588257.316	79416788.931	16366788.774	0.026 / 0.084
00238	00144	75947690.719	76138047.756	13412678.611	0.027 / 0.087
00238	00114	76045212.627	76431145.677	14012745.925	0.022 / 0.073
00064	00172	78729615.817	77913289.039	14815961.666	0.019 / 0.064
00064	00110	78591865.325	78520705.174	13649608.324	0.021 / 0.070
00173	00171	76937054.904	76836059.361	13440800.959	0.020 / 0.067
00173	00099	77038754.753	77277906.599	13757079.974	0.023 / 0.075
00169	00049	79271817.940	79128608.464	15655303.732	0.020 / 0.067
00169	00166	79371795.528	77819300.637	15687073.490	0.029 / 0.096
00051	00120	14467193.528	14360273.828	2863541.028	0.041 / 0.133
00051	00018	29126968.656	30186824.808	14236491.617	0.026 / 0.084
00022	00172	151177645.850	151346323.456	13215810.341	0.020 / 0.066
00022	00188	75677220.378	75882508.059	13812981.433	0.020 / 0.065
00210	00041	78315305.349	78121525.678	15468603.828	0.026 / 0.086
00210	00124	78453644.187	78531460.960	15464478.044	0.020 / 0.065
00192	00203	66866759.998	67824741.524	13573341.565	0.027 / 0.089
00192	00198	67963233.461	47676914.103	10948829.348	0.025 / 0.083
00049	00151	78986243.400	78881671.930	15533446.706	0.019 / 0.063
00024	00225	78526734.967	79295063.764	15576120.285	0.020 / 0.066
00024	00177	77744512.429	77911243.158	15346399.040	0.021 / 0.070
00166	00032	77602665.993	17301418.424	13950603.999	0.022 / 0.073
00125	00203	69536791.718	68696701.910	13605575.711	0.037 / 0.123
00125	00072	70423646.420	71631758.652	14122986.661	0.023 / 0.075
00120	00187	79417719.205	79240247.098	15872941.261	0.027 / 0.090
00120	00018	79262075.845	79102324.565	15373512.852	0.030 / 0.098
00185	00196	76198301.382	76383063.196	13916990.361	0.021 / 0.071

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Adjacent Flight Line 1	Adjacent Flight Line 2	Area 1 (square Meter)	Area 2 (square Meter)	Overlap Area (square Meter)	RMSDz (Meter/Feet)
00185	00188	76103365.864	75980341.116	13497021.617	0.020 / 0.067
00113	00043	75389337.705	76182650.374	15033173.424	0.024 / 0.079
00113	00219	74079982.924	74029961.605	14727167.881	0.024 / 0.079
00043	00161	76314071.064	77018121.568	15604642.331	0.027 / 0.089
00229	00164	77399630.615	77123343.617	30593632.283	0.024 / 0.077
00229	00101	77456450.317	77568793.391	35186287.897	0.021 / 0.068
00015	00198	17697701.064	83803228.582	4724450.373	0.023 / 0.075
00041	00177	78018231.020	77997786.278	15351099.417	0.022 / 0.071
00021	00196	76480424.656	76483520.005	13412336.785	0.020 / 0.067
00021	00171	76569457.967	76738914.472	14033732.986	0.021 / 0.070
00146	00158	78730014.084	78256529.573	25840969.725	0.026 / 0.086
00124	00151	78626545.865	78790035.066	15526597.221	0.021 / 0.069
00158	00164	77223689.646	77055131.388	24575649.617	0.025 / 0.081
00225	00117	79197902.641	78995988.599	15687962.048	0.021 / 0.070
00107	00031	77755454.168	77701215.829	29703084.613	0.022 / 0.073
00107	00075	78090207.292	79482139.844	21845892.821	0.020 / 0.065
00235	00179	76560021.335	76886169.745	14161508.249	0.019 / 0.064
00235	00114	76471530.094	76533486.768	13526478.253	0.023 / 0.074
00189	00075	80046296.909	79572502.726	15922331.452	0.022 / 0.071
00014	00156	79171196.111	79335833.235	18264860.997	0.024 / 0.080
00014	00161	79021679.697	78419727.882	17028057.191	0.021 / 0.069
00144	00099	77360662.385	77370659.461	14226775.830	0.027 / 0.089
00117	00216	78903195.844	77053240.021	14986078.030	0.027 / 0.087
00179	00216	76981900.150	76956688.521	13463056.040	0.036 / 0.119
00031	00101	77655165.431	77615057.627	33655460.040	0.020 / 0.067
00219	00082	73935640.654	73175606.949	14586743.948	0.027 / 0.089
00082	00072	71810545.024	71772217.549	14168587.216	0.022 / 0.071
Aggregate					0.038 / 0.123

DPH-9.1 Report on Overlap Consistency (interswath) - continued

The purpose of this page is to show a frequency distribution chart of RMSDz values.



DPH-9.1 USGS Swath Separation Image

Image creation:

- a. All returns shall be used to create the images.
- b. All point classes and flags shall be enabled when creating the images and points flagged as withheld or classified as noise shall be excluded.
- c. Elevation values and differences shall not be subjected to a threshold or otherwise clipped so all differences are represented.
- d. The images will be derived from TINs to reduce the number of false difference values on slopes; however, other algorithms are acceptable.
- e. The images shall consist of a 50 percent transparent RGB layer overlaying the lidar intensity image.
- f. The images shall use at least three color levels wherever two or more swaths overlap within a pixel.
- g. Where two or more swaths overlap within a pixel (based on point source ID),
 - i. pixel color shall be based on vertical difference of swaths using the following breaks (based on multiples of the Swath Overlap Difference for the QL):
 1. 0-8 cm: GREEN;
 2. 8-16 cm: YELLOW;
 3. > 16 cm or > last additional color ramp bin value: RED (for example, addition of ORANGE pixels for the range of 16-24 cm would require red pixels to represent > 24 cm).
 - ii. color choice of green, yellow, and red is suggested but not required.
- h. Where swaths do not overlap, pixel values shall be intensity alone.

Image file formats and version control:

- a. Swath difference image format may be delivered as GeoTIFF or JPEG (with world file) by tile or as a single compressed JPEG 2000 (JP2) image mosaic.
- b. The point cloud geometry and intensity data delivered shall be identical to the point cloud geometry and intensity data used to create the difference images. Changes in the point cloud geometry or intensity requires recreation of the difference images.

Spatial extent and coordinate reference system:

- a. Spatial resolution (pixel dimension) of the images shall be between 2 and 4 times the Nominal Pulse Spacing (2-4 x NPS) in the project's linear unit (meters or feet).
- b. The difference images must be representative of the associated data delivery.
- c. The images shall be in the same CRS as the point cloud data to ensure alignment with the point cloud.

Description of the process that generates the Swath Separation Image:

- a. Boundaries are determined for all swath overlap areas.
- b. A Grid is created for each overlap area. Grid cell sizes are 3x the aggregate nominal pulse spacing (ANPS) as shown in Table 1 of the USGS Lidar Base Specification v 2.1. ANPS varies depending on the Quality Level of the data. The grid cells are then populated with the maximum vertical separation values of the underlying points. Points flagged as Withheld, and points classed as High or Low Noise, are excluded from this analysis.
- c. No vertical separation cut-off is used for this raster.
- d. The final thematic raster is generated from the grid cell values. For QL1 and QL2, a green cell indicates an elevation difference of 8 cm or less, yellow indicates greater than 8 cm but LTE 16 cm, orange indicates greater than 16 cm but LTE 24 cm, and red is any value greater than 24 cm.

DPH-9.1 USGS Swath Separation Image - continued

[Data Source - Y:\Mapping\Projects\65220595_CO_SanLuisJuanMiguel\Production\Final_Client_Deliverables\Block1_Surdex\point_cloud\Swaths](#)

[Result Path - D:\00_San_Miguel\San_Luis_Juan_Miguel_B1A_QC\DPH_9_1\SSI_GRID.jp2](#)

