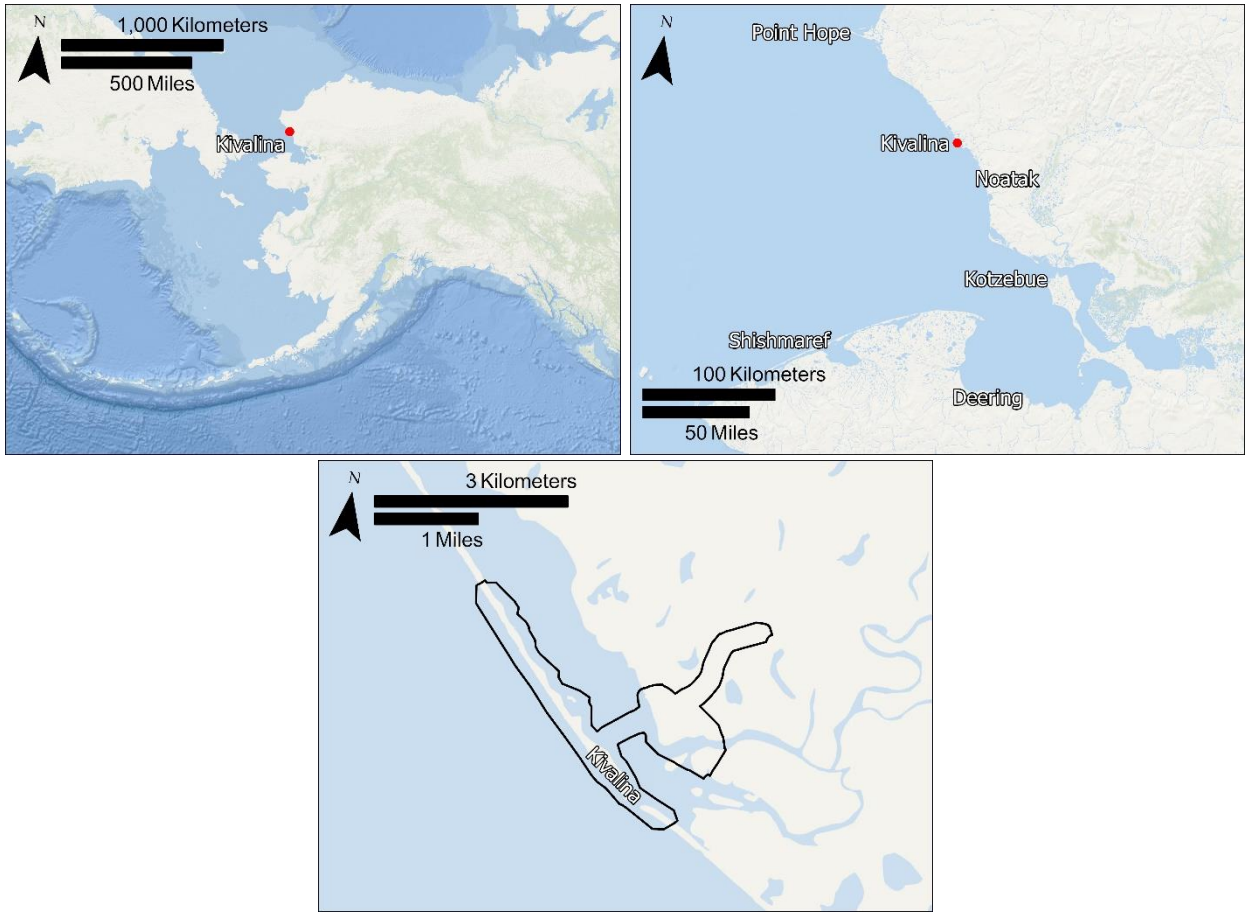
PHOTOGRAMMETRY-DERIVED ORTHOIMAGERY AND ELEVATION DATA FOR KIVALINA, ALASKA, COLLECTED AUGUST 21 AND 23, 2023

Keith C. Horen and Nora M. Nieminski

Raw Data File 2024-19



Location maps showing the survey area.

This report has not been reviewed for technical content or
for conformity to the editorial standards of DGGS.

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PHOTOGRAMMETRY-DERIVED ORTHOIMAGERY AND ELEVATION DATA FOR KIVALINA, ALASKA, COLLECTED AUGUST 21 AND 23, 2023

Keith C. Horen[1] and Nora M. Nieminski[1]

INTRODUCTION

The Alaska Division of Geological & Geophysical Surveys (DGGS) collected low-altitude aerial images from an unmanned aerial vehicle (UAV) in the community of Kivalina, Alaska, on August 21 and 23, 2023. We used Structure-from-Motion (SfM) photogrammetry to produce a digital surface model (DSM) and orthorectified imagery (fig. 1). The orthoimage and elevation data are useful for assessing riverine hazards and changes over time. These products are released as a Raw Data File with an open end-user license. All files can be downloaded from https://doi.org/10.14509/31287 or elevation.alaska.gov.

LIST OF DELIVERABLES

- Orthoimagery
- Digital Surface Model (DSM)
- Metadata

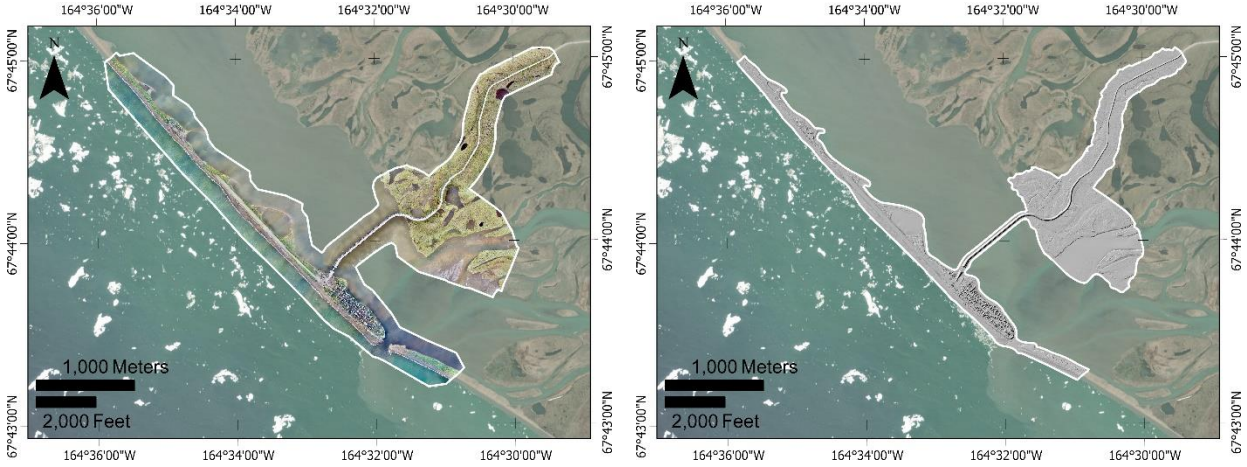

Figure 1. Extent of orthoimage (left) and digital surface model (DSM) (right) for Kivalina, Alaska.

METHODS

Aerial Photogrammetric Survey Details

DGGS conducted flights on August 21, 2023, from approximately 7:30 PM to 9:15 PM AKDT and August 23, 2023, from 11:00 AM to 1:15 PM AKDT using a DJI Phantom 4 RTK UAV with a FC6310R camera model (8.8 mm lens) to collect 3,370 20-megapixel JPEG photographs (5,472 x 3,648 pixels per image). The operator returned the UAV five times to change batteries during each period of operation. DGGS flew the aerial survey with 75 percent sidelap and 75

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percent frontlap, 110 m above ground-level at 9.5 m/s, with nadir orientation stabilized using a three-axis gimbal. This resulted in images covering 4.331 km^2 with a ground sampling distance (GSD) of 0.018 m. The weather throughout the survey was mostly cloudy with light wind. No abnormalities were observed during the flights.

Ground Survey Details

On August 21 and 23, 2023, DGGS temporarily installed a Trimble R10 receiver sampling at 5 Hz as a Global Navigation Satellite System (GNSS) base station over a found, R&M Consultants, Inc., aluminum cap benchmark stamped "RM2 ADL 420984". This provided real-time kinematic (RTK) corrections to the ground rover, a Trimble R8s GNSS receiver. DGGS measured the location of 31 photo-identifiable ground control points (GCPs) with the ground rover (fig. 2).

Data Processing

Base positions were corrected using Online Positioning User Service (OPUS) solutions (table 1), which were used to update the UAV and ground rover positions with post-processed kinematic (PPK) adjustments.

UAV positions were updated in RTKLIB (Version 2.4.3) software with the following settings applied: L1+L2 frequencies forward and backward filtered; a 10-degree elevation mask; receiver dynamics disabled; broadcast ionosphere and Saastamoinen troposphere corrections; a minimum fixed-ambiguity ratio of three; and L1/L2 code/carrier-phase error ratios of 100/100. During post-processing, DGGS applied International GNSS Service (IGS) precise orbits and final clock solutions retrieved from the Crustal Dynamics Data Information System (CDDIS) found at urs.earthdata.nasa.gov. Final corrected data were exported as time-stamped position files in WGS84 horizontal coordinate system with ellipsoidal heights and paired to corresponding photographs using an Aerotas P4RTK PPK Adjustments (Version 1) macro-enabled Microsoft Excel file.

Ground rover positions were updated using PPK corrections in Trimble Business Center (Version 5.51) software using default settings. Final corrected data were exported as comma-delimited text files in WGS84 horizontal coordinate system with ellipsoidal heights.

DGGS used Agisoft Metashape Professional (Version 1.8.3 build 14331) software for photogrammetric processing following the steps and settings outlined in Over and others (2021). During processing, DGGS used 16 GCPs for photograph alignment and lens distortion parameter optimization (fig. 2, table 2), leaving 15 GCPs as horizontal and vertical check points (fig. 2, table 3). A confidence filter was applied to the resulting dense point cloud, eliminating all points derived from fewer than three discrete camera positions. Additional noise was removed from the dense point cloud through visual inspection.

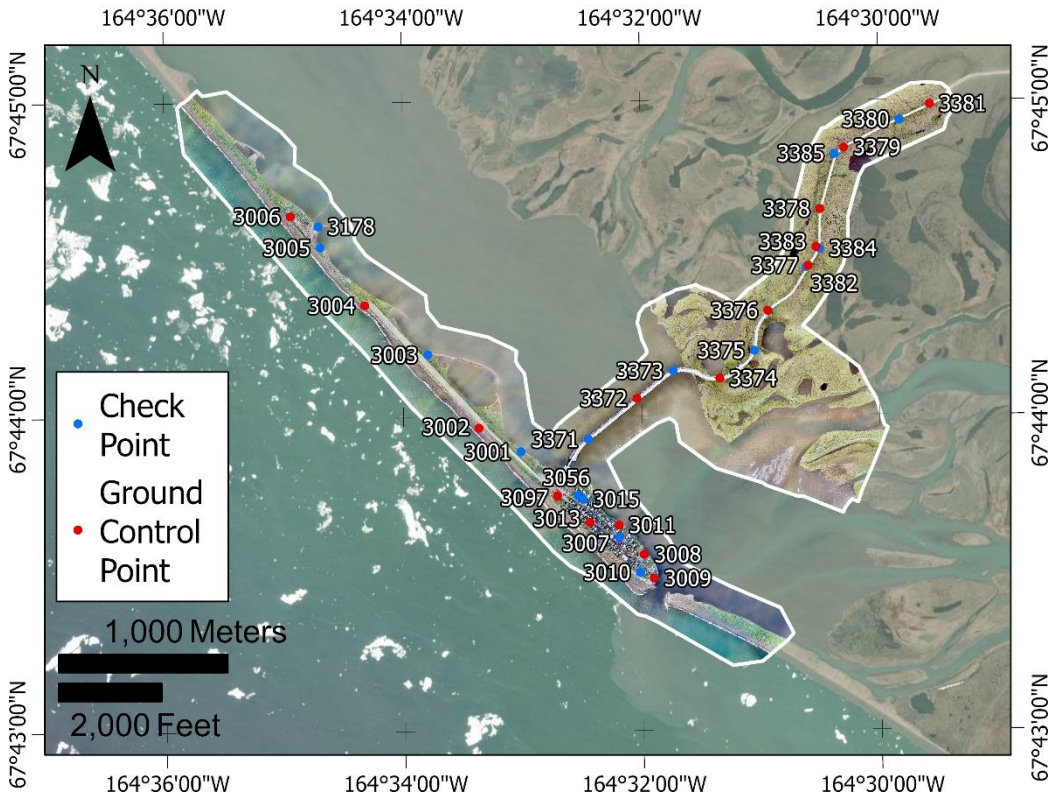

Figure 2. Location of photo-identifiable ground control points (GCP; red) and check points (CHK; blue).

IMAGERY PRODUCTS

Orthoimagery

The orthoimage is a three-band (red, green, blue), eight-bit unsigned GeoTIFF file derived from a color-adjusted mosaic of 3,119 aerial photographs with a GSD of 0.018 m per pixel; the "No Data" value is set to 0.

Digital Surface Model

The DSM represents surface elevations including the height of vegetation, buildings, and other man-made features derived from the dense point cloud. The DSM is a single-band, 32-bit floating point GeoTIFF file with a GSD of 0.037 m; the "No Data" value is set to $-3.4028235 \times 10^{38}$.

ACCURACY REPORT

Coordinate System and Datum

All data were processed in the WGS84 horizontal coordinate system and WGS84 ellipsoid vertical datum. All data were reprojected using Esri ArcGIS Pro (Version 3.2.1) software and are delivered in NAD83 (2011) UTM Zone 3 North horizontal coordinate system and NAVD88 (GEOID12B) vertical datum.

Horizontal Accuracy

DGGS quantified the horizontal accuracy of the GNSS position data using the latitudinal and longitudinal peak-to-peak errors provided by OPUS (table 1). Consistent with OPUS shared

solution requirements (NOAA, 2022), DGGS considers high-quality GNSS solutions to have latitudinal and longitudinal errors less than or equal to 0.04 m.

We quantified the horizontal accuracy of the DSM and orthoimage by comparing the known locations of 15 photo-identifiable check points measured with GNSS against their modeled locations in the photogrammetric products (fig. 2, table 3). These are independent checkpoints not used during processing. X and Y errors are calculated as the root-mean-square (RMS) error of offsets, 0.046 m and 0.035 m, respectively (table 3). The total horizontal error is the root-sum-square error of X and Y RMS errors, 0.058 m (table 3).

Vertical Accuracy

DGGS quantified the vertical accuracy of the GNSS position data using the combined ellipsoidal height peak-to-peak errors provided by OPUS and orthometric height RMS error provided by NOAA's Vertical Datum Transformation software (NOAA, 2016; table 1). Consistent with OPUS shared solution requirements (NOAA, 2022), DGGS considers high-quality GNSS solutions to have vertical errors less than or equal to 0.08 m.

We quantified the vertical accuracy of the DSM using the same 15 check points used to quantify the horizontal accuracy (fig. 2, table 3). The RMS error of Z offsets is 0.064 m (table 3). The total RMS error of the DSM (X, Y, and Z) is 0.086 m (table 3).

Table 1. Base station coordinates and GNSS errors.

NAD83 (2011) Easting	NAD83 (2011) Northing	NAVD88 Elevation	GNSS X Error (m)	GNSS Y Error (m)	GNSS Z Error (m)
519265.293	7512860.285	6.662	0.006	0.007	0.073

Table 2. Ground control point coordinates and offsets from orthoimagery and DSM.

Point	Easting	Northing	Elevation	X Offset (m)	Y Offset (m)	Z Offset (m)	GNSS X/Y Error (m)	GNSS Z Error (m)
3002	518770.681	7513134.487	3.816	0.025	0.022	-0.015	0.006	0.011
3004	518093.574	7513856.770	4.517	-0.026	0.017	0.061	0.008	0.013
3006	517652.464	7514382.335	4.295	-0.082	0.023	-0.075	0.008	0.012
3008	519749.114	7512389.681	3.597	0.048	-0.005	0.022	0.007	0.010
3009	519808.403	7512248.697	4.084	0.054	0.012	-0.021	0.007	0.011
3011	519599.473	7512562.328	2.642	0.053	0.002	0.041	0.007	0.009
3013	519427.569	7512578.361	4.721	0.007	0.012	-0.064	0.008	0.012
3097	519234.947	7512735.525	4.654	0.022	0.024	-0.098	0.005	0.007
3372	519704.348	7513311.405	5.340	-0.054	-0.025	0.081	0.006	0.008
3374	520195.156	7513429.547	4.959	0.047	-0.048	0.120	0.006	0.009
3376	520478.091	7513830.484	4.973	-0.010	-0.017	-0.061	0.005	0.009

Point	Easting	Northing	Elevation	X Offset (m)	Y Offset (m)	Z Offset (m)	GNSS X/Y Error (m)	GNSS Z Error (m)
3377	520716.999	7514097.510	4.668	-0.020	-0.013	-0.085	0.006	0.009
3378	520786.394	7514432.548	4.376	-0.018	0.018	0.050	0.006	0.010
3379	520927.703	7514794.935	4.354	-0.030	-0.005	0.078	0.007	0.010
3381	521434.902	7515053.474	5.025	0.023	-0.100	-0.249	0.006	0.010
3383	520763.449	7514209.060	3.013	-0.044	-0.030	-0.055	0.006	0.010
			Mean	0.000	-0.007	-0.017	0.007	0.010
			Standard Deviation	0.042	0.033	0.092	0.001	0.002
			Range	0.136	0.124	0.368	0.003	0.006
			Root Mean Square Error	0.040	0.032	0.089	0.001	0.002
			Total Error	**0.051**		**0.103**	**0.002**	
				(XY)		**(XYZ)**	**(XYZ)**	

Table 3. Check point coordinates and offsets from orthoimagery and DSM.

Point	Easting	Northing	Elevation	X Offset (m)	Y Offset (m)	Z Offset (m)	GNSS X/Y Error (m)	GNSS Z Error (m)
3001	519018.354	7512995.119	3.661	0.059	0.040	-0.051	0.006	0.011
3003	518466.677	7513566.261	2.249	-0.019	0.045	0.016	0.007	0.012
3005	517828.901	7514198.429	2.331	-0.059	0.033	0.006	0.009	0.013
3007	519598.856	7512490.602	4.055	0.045	0.052	-0.003	0.004	0.007
3010	519724.320	7512283.460	4.637	0.084	0.016	-0.073	0.008	0.012
3015	519384.802	7512715.726	3.448	0.039	0.014	-0.006	0.008	0.013
3056	519355.746	7512738.320	3.550	0.020	-0.027	0.007	0.005	0.009
3178	517817.099	7514323.675	2.299	-0.073	0.039	-0.046	0.007	0.010
3371	519417.160	7513068.370	5.349	-0.030	0.022	0.094	0.005	0.008
3373	519918.563	7513473.361	5.444	0.010	-0.030	-0.057	0.006	0.009
3375	520398.825	7513595.318	5.153	-0.003	-0.048	-0.085	0.006	0.009
3380	521253.929	7514960.364	4.346	0.014	-0.046	0.136	0.006	0.010
3382	520704.857	7514088.085	2.738	-0.065	-0.024	-0.053	0.006	0.010
3384	520786.311	7514198.076	2.850	-0.045	0.003	-0.034	0.007	0.013
3385	520871.350	7514758.560	3.359	0.000	0.009	0.085	0.006	0.013
			Mean	-0.002	0.007	-0.004	0.006	0.011
			Standard Deviation	0.047	0.034	0.065	0.001	0.002
			Range	0.157	0.100	0.221	0.005	0.006
			Root Mean Square Error	0.046	0.035	0.064	0.001	0.002
			Total Error	**0.058**		**0.086**	**0.002**	
				(XY)		**(XYZ)**	**(XYZ)**	

Data Consistency and Completeness

DGGS visually inspected the orthoimage for data errors such as shifts, seamline mismatches, and water noise overlapping land. Visual errors common to these SfM photogrammetry products include discontinuous powerlines and distortion near high-angle features like buildings, as well as water boundaries. Highly reflective objects such as water bodies, metal roofs, and white paint may cause overexposure, leading to spurious elevation points. There were no significantly erroneous areas that required repair.

ACKNOWLEDGMENTS

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