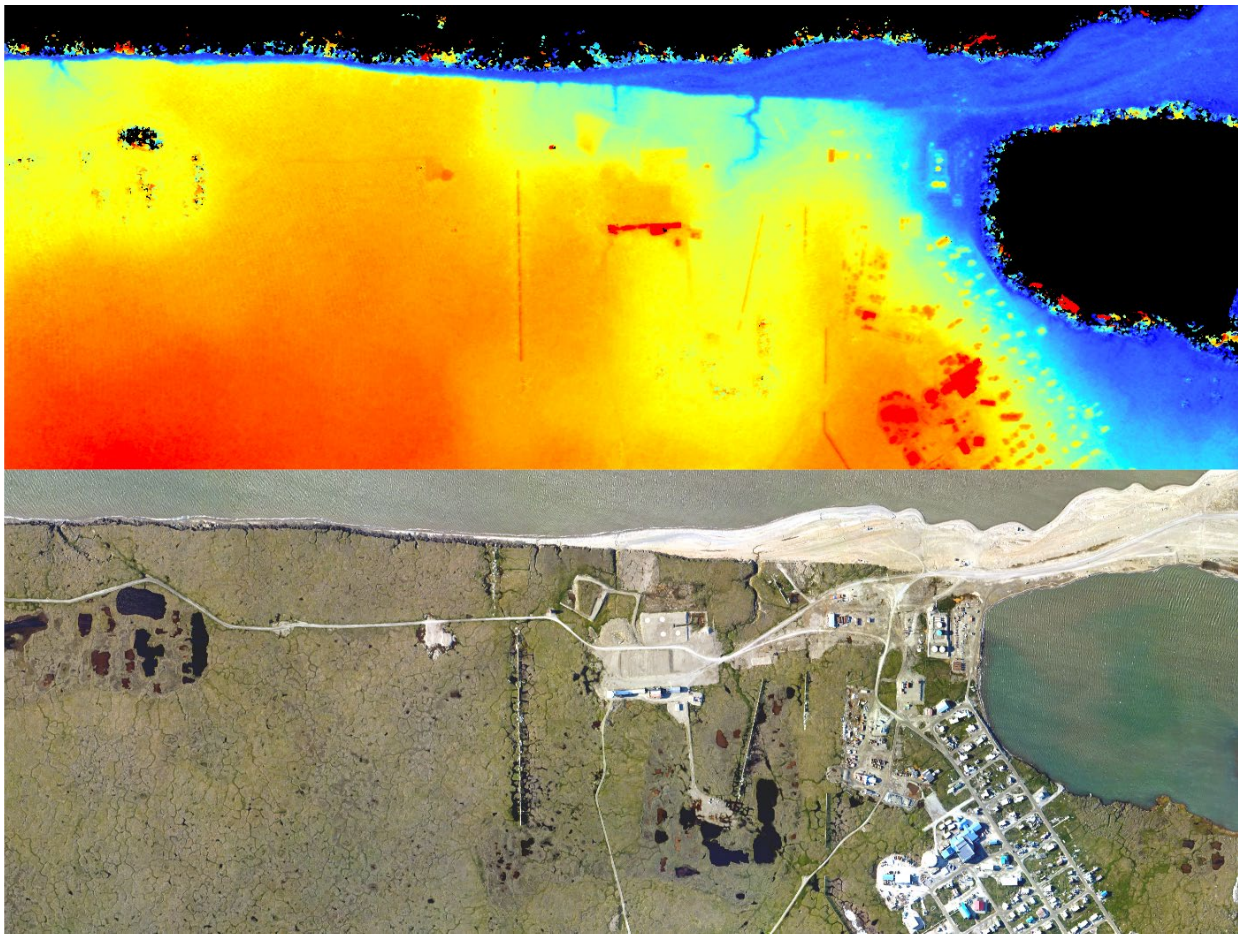
# PHOTOGRAMMETRIC DIGITAL SURFACE MODELS AND MOSAICED ORTHOIMAGERY FOR BARTER ISLAND, ALASKA

Stephen Escarzaga, Nicole E.M. Kinsman, and Jacquelyn R. Overbeck

**Raw Data File 2020-6**



Digital surface model (top) and orthoimage (bottom) of Kaktovik and surrounding area.

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

2020
STATE OF ALASKA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGICAL & GEOPHYSICAL SURVEYS

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# PHOTOGRAMMETRIC DIGITAL SURFACE MODELS AND MOSAICED ORTHOIMAGERY FOR BARTER ISLAND, ALASKA

Stephen Escarzaga[1], Nicole E.M. Kinsman[2], and Jacquelyn R. Overbeck[3]

## ABSTRACT

In 2017, the National Oceanic & Atmospheric Administration (NOAA), National Geodetic Survey, Remote Sensing Division (RSD) performed extensive aerial collection of imagery along Alaska's northeastern coastline in support of NOAA's Coastal Mapping Program. Data collected under this initiative are typically used to improve maritime chart products, serve as a baseline for shoreline change monitoring, and update the national shoreline database. This report summarizes photogrammetric digital surface models (DSMs) and an orthomosaic derived from this image dataset using Structure from Motion (SfM) techniques for the Barter Island area. Aerial images used to derive products described in this report were collected on July 19, 2017. Ground control points (GCPs) and checkpoints used for vertical correction and validation of this data were collected with Global Navigation Satellite System (GNSS) surveys by the U.S. Geological Survey (USGS) on September 4, 2014, and September 18, 2016. This data collection is being released as a Raw Data File with an open end-user license and includes the following for the Barter Island area: (1) orthomosaic raster, (2) DSM raster, (3) smoothed DSM raster, and (4) DSM hillshade.

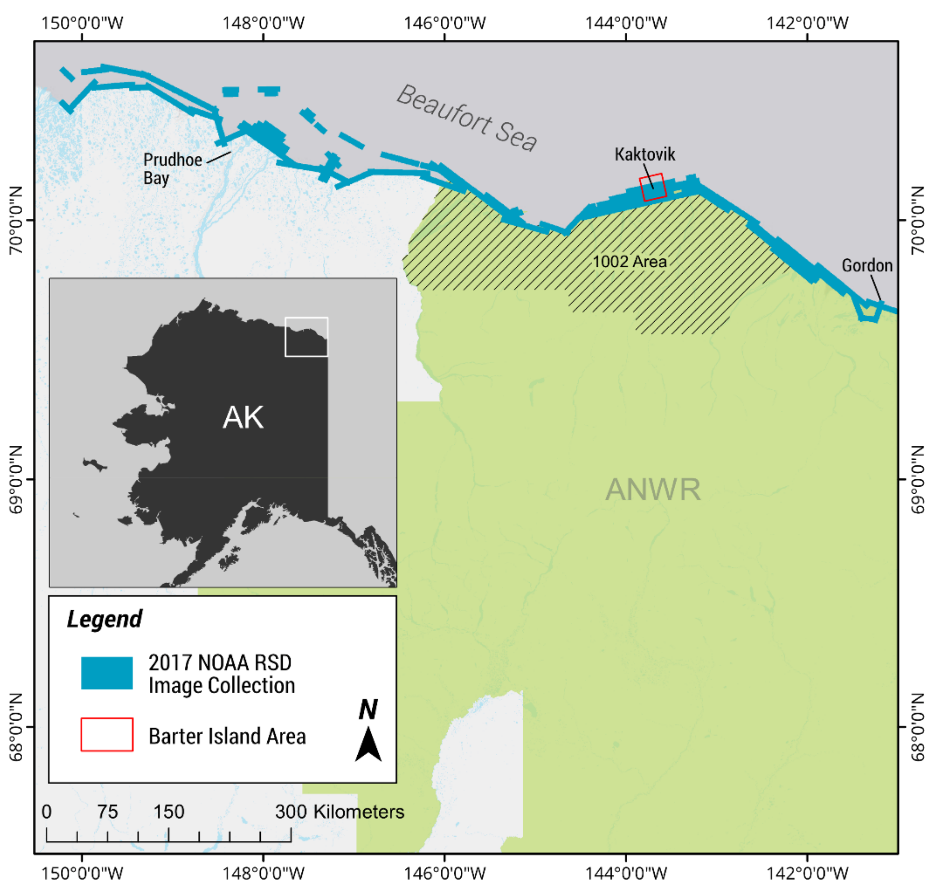


**Figure 1.** Overview of 2017 NOAA Remote Sensing Division image collections in northern Alaska and the Barter Island area of interest.

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## DATA ACQUISITION

NOAA RSD collected aerial imagery over the Barter Island area on July 19, 2017, from a Beechcraft King Air 350CER aircraft flying at a nominal altitude of ~2,286 m above ground level (AGL), resulting in an average 26 cm ground sampling distance (GSD) in the images. While many areas surveyed under the NOAA NGS Coastal Mapping Program are done with single flight lines, RSD planned the Barter Island survey to include multiple parallel lines providing ~30 percent image sidelap; images were captured every ~8 to 9 seconds, producing ~60 percent image endlap. In addition to nadir scenes, RSD also collected oblique images with two additional cameras in the fore and aft positions mounted at ~33° and ~36° view angles, respectively. For the nadir, fore, and aft aircraft ports, Applanix DSS SN580 cameras with focal lengths of 51.542 mm, 60.202 mm, and 60.292 mm (respectively) collected 80.2 (nadir) and 39 (oblique) megapixel images in RAW format (table 1). Image capture between cameras was synchronized with each other and to an on-board Applanix POS/AV410 Global Navigation Satellite System (GNSS) and Inertial Measure Unit (IMU) system. The AeroAntenna GNSS antenna was mounted approximately 1.1 m above the camera ports.

**Table 1.** Camera system and image specifications for data used in product creation.

| | Camera Model | Resolution (pixels) | File Type | Focal Length | Pixel Size | Coordinate Reference System | Associated Metadata |
|---|---|---|---|---|---|---|---|
| **Nadir** | Applanix DSS SN580 | 10329 x 7760 | JPEG | 51.542 mm | 5.2x5.2 µm | WGS84/UTM 7N/ Orthometric (EGM96) | latitude, longitude, height & omega, phi, kappa |
| **Fore Oblique (33°)** | Applanix DSS SN580 | 7212 x 5480 | JPEG | 60.202 mm | 6.8x6.8 µm | WGS84/UTM 7N/ Orthometric (EGM96) | latitude, longitude, height & omega, phi, kappa |
| **Aft Oblique (37°)** | Applanix DSS SN580 | 7212 x 5480 | JPEG | 60.295 mm | 6.8x6.8 µm | WGS84/UTM 7N/ Orthometric (EGM96) | latitude, longitude, height & omega, phi, kappa |

## DATA PROCESSING

Airborne GNSS and IMU data were processed using Applanix's PosPac MMS 8.0 commercial software by technicians and cartographers within RSD. Due to the remoteness of the survey area, a satellite-derived, real-time extended positioning method with no static base station was used for post-processing. Total Propagated Uncertainty for the resultant positional data is 66 cm. GPS data were adjusted to the World Geodetic System 1984 (WGS84) reference frame (mapping epoch of 2017.542466), and heights referenced to the Earth Gravitational Model of 1996 (EGM96) (table 1).

Photos were individually processed along with dark current images to remove inherent sensor noise. Raw images from the sensor (.RAW format) were processed to JPEG format to accommodate the transfer and subsequent SfM processing of this data. Batch color correction of oblique JPEGs was then conducted in Adobe Photoshop to more closely match the color profile of nadir images.

Positional (latitude, longitude, height) and rotational (phi, kappa, omega) data from the on-board GPS/IMU system were supplied in additional metadata files, each pertaining to a specific camera location and rotation in space and time. These data fields were programmatically copied from the metadata documents into one camera external orientation file used in SfM processing within Agisoft Metashape Professional. Orthometric camera heights in the external orientation file were converted to ellipsoidal heights (WGS84) using NOAA's VDatum conversion tool. A total of 144 images were used in the SfM processing (50 nadir and 94 oblique), in which computer vision algorithms create a three-dimensional terrain model from overlapping sections of image data. The final orthomosaic is a result of orthometric correction of the images using this terrain model and a subsequent mosaicking of these orthoimages. Figure 2 summarizes the data preprocessing and SfM procedure/parameters used to create these final products.

## DATA PRODUCTS

The data products for the Barter Island project area include the following: (1) orthomosaic raster, (2) DSM raster, (3) smoothed DSM raster, and (4) DSM hillshade raster. These data are stored in the WGS84 (mapping epoch of 2017.542466) reference frame, projected in Universal Transverse Mercator (UTM) Zone 7 North, with heights referenced to the ellipsoid (WGS84).

### Orthomosaic

The orthomosaic is a 3-band, 8-bit unsigned integer raster file (red/green/blue; file format GeoTIFF) with a GSD of 26 cm (fig. 3A). NoData values for each band have been set to 0. The file employs Lempel-Ziv-Welch (LZW) compression and total uncompressed file size is 3.19 GB.

### Digital Surface Model (DSM)

The DSM is a 1-band, 32-bit floating point integer raster file (file format GeoTIFF) with a GSD of 53 cm. DSM raster cell values represent elevation values at any given point. NoData values have been set to -3.40282346639e+038. The uncompressed file size is 2.16 GB.

### Smoothed Digital Surface Model (DSM)

The smoothed DSM is a 1-band, 32-bit floating point integer raster file (file format GeoTIFF) with a GSD of 53 cm. This DSM was created from a smoothed 3D mesh, rather than a dense point cloud. 3D mesh creation and subsequent smoothing was done in Agisoft Metashape. Smoothing here removes much of the inherent low-noise in surface features that exist in the normal DSM (fig. 4). DSM raster cell values represent elevation values at any given point. NoData values have been set to -3.40282346639e+038. The uncompressed file size is 1.42 GB.

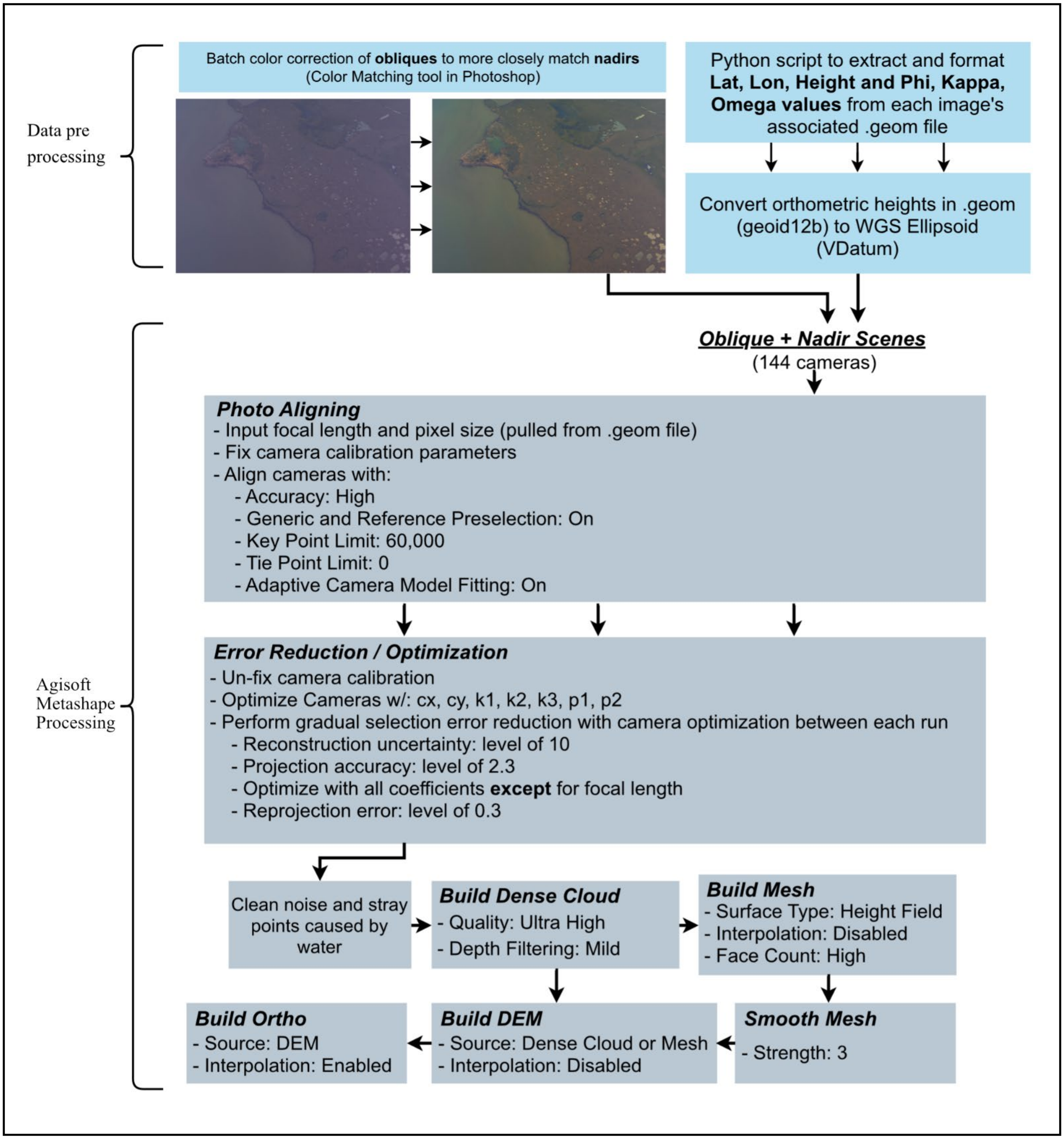


**Figure 2.** Diagram detailing the steps and parameters used within the SfM processing procedure.

## DSM Hillshade

The DSM hillshade is a 3-band, 8-bit unsigned integer raster file (red/green/blue; file format GeoTIFF) with a GSD of 53 cm (fig. 3B). It represents hillshading of the unsmoothed DSM raster. NoData values have been set to 255. The file employs LZW compression. The hillshade was produced using the Image Analysis tools within ArcGIS Desktop (ArcMap 10.4). The uncompressed file size is 1.62 GB.

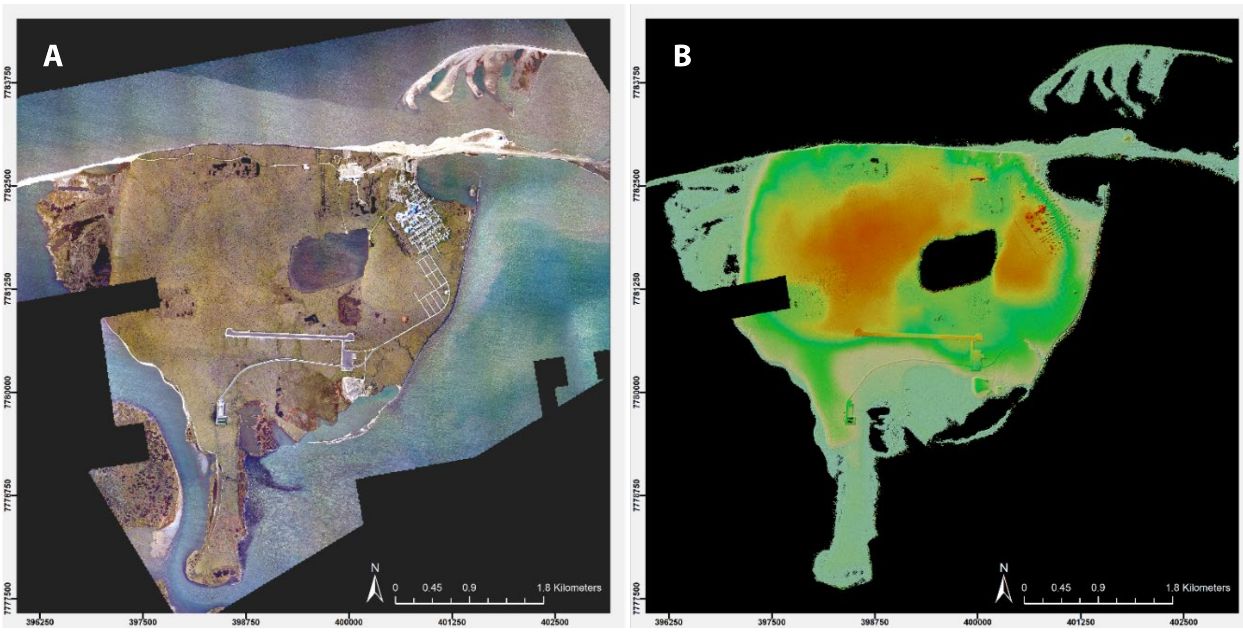


**Figure 3. A.** RGB orthomosaic of Barter Island included in this data release. **B.** DSM hillshade of Barter Island included in this data release.

## DATA QUALITY

The original airborne imaging survey design for this dataset was optimized to support orthomosaic production and subsequent 2D feature extraction (e.g., shoreline position). The planned image endlap and sidelap (60 percent and 30 percent, respectively) is on the extreme low end for SfM production and is more characteristic of traditional photogrammetric applications.

The unsmoothed DSM included here contains inherent low noise in surface values (on the order of 25 to 30 cm) throughout areas presumed to be flat. This noise is most likely a product of the collection parameters and use of compressed JPEGs as opposed to TIFFs. Figure 4 shows a comparison of surface elevation profiles between the smooth and unsmoothed DSMs along a section of the graded-gravel airport runway. Other DSM anomalies include concentric rings in surface elevation (an SfM processing artifact most likely caused by sub-optimal image overlap), and high noise in surface elevation over areas of water caused by the SfM algorithm's inability to match features between image pairs where water is present (fig. 5).

Ground control points (GCPs) were supplied by the U.S. Geological Survey (USGS) Pacific Coastal & Marine Science Center from field reconnaissance on September 4, 2014, and September 18, 2016, with an

Ashtech Z-Extreme GNSS system. A subset of 200 GCPs were used to evaluate these photogrammetric products, with 100 used to determine a mean vertical offset (as control) and 100 to determine residual error after vertical transformation (as checkpoints). Of this subset, only two GCPs were photo-identifiable. A well-distributed network of photo-identifiable GCPs is typically used to determine the horizontal accuracy of orthomosaics and co-located DSMs. Due to the lack of photo-identifiable GCPs in this porject, no horizontal transformation has been applied to the data. However, in the two locations where these GCPs do exist, the orthomosaic showed an estimated 20 cm and 25 cm offset in the easting direction.

Vertical accuracy was determined for both the smoothed and unsmoothed DSMs. Accuracies were determined by calculating the mean vertical offset between DSMs and 100 GCPs, reducing this mean offset to zero by applying a vertical transformation and then determining a vertical Root Mean Square Error (RMSEz) for the transformed surfaces using the 100 checkpoints. Table 2 shows a summary of DSM accuracy statistics. The unsmoothed DSM had a mean vertical offset of +5 cm, and the final unsmoothed DSM had an RSMEz of 13.7 cm with +/- one standard deviation of 11.3 cm; 95 percent of checkpoints fell within 26 cm. The smoothed DSM had a mean vertical offset of +8 cm and the final smoothed DSM had an RMSEz of 13.3 cm with +/- one standard deviation of 8.5 cm; 95 percent of checkpoints fell within 28 cm.

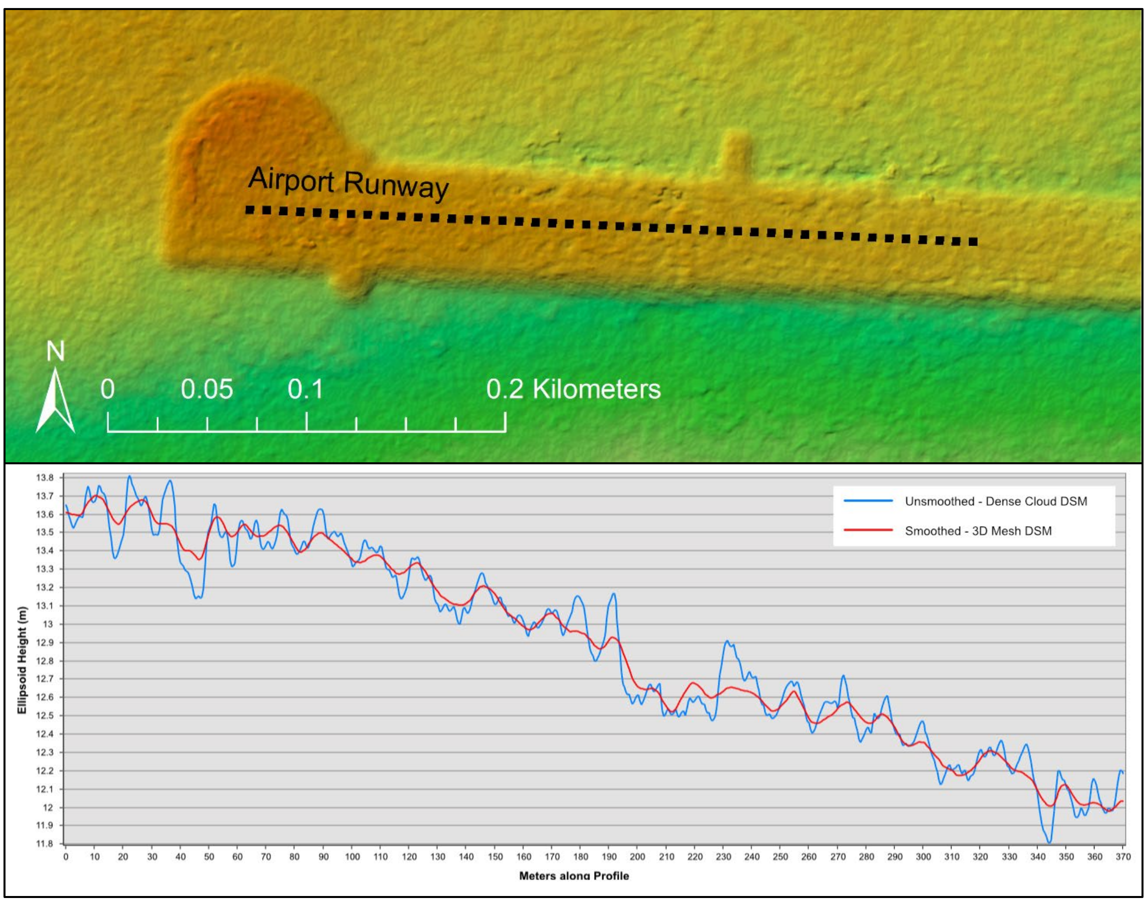


**Figure 4.** (Top) Map showing the hillshade DSM with elevation profile location (dashed black line). (Bottom) Elevation profile showing the unsmoothed DSM (blue) and smoothed DSM (red).

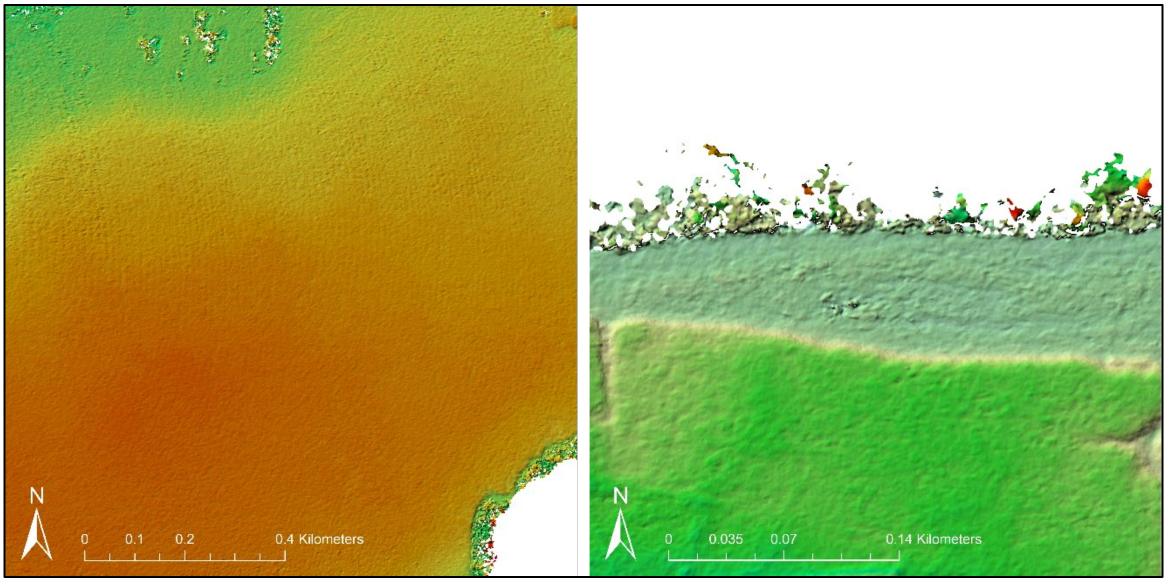


**Figure 5.** Maps of processing artifacts. (Left) Hillshade DSM showing an example of concentric ring features. (Right) Hillshade DSM showing high noise over water at the coast in northern portion of image.

**Table 2.** Summary statistics for vertical accuracies of unsmoothed and smoothed DSMs.

| | Number of GCPs/Checkpoints | Mean Vertical Offset | Final RMSEz | Standard Deviation / 95$^{th}$ Percentile |
|---|---|---|---|---|
| **Unsmoothed DSM** | 103/32 | 5 cm | 13.7 cm | 11.3 cm / 26 cm |
| **Smoothed DSM** | 103/32 | 8.5 cm | 13.3 cm | 8.5 cm / 28 cm |

## ACKNOWLEDGMENTS

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