Lidar-derived Digital Elevation Models for Coastal Pohnpei, FSM

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Summary

This dataset includes a 10-m resolution digital terrain model (DTM) of much of the island of Pohnpei, the largest and highest of the islands in the Federated States of Micronesia (FSM). The vegetation-free DTM was generated by rasterizing the ground-classified points of a point cloud collected during an airborne lidar survey. The instrument was a RIEGL LMS-Q680i, and the aircraft was a Britten-Norman Islander. Additional data include a digital surface model (DSM) comprising elevation measurements associated with the first returns, that is, the highest points in the point cloud data set, which in most parts of the surveyed area will pertain to the forest canopy; a pulse density map, in which each cell of the raster contains a value equal to the number of laser pulses fired by the lidar instrument that were recorded to have fallen within the corresponding 10 m2; and a ground point density map, in which each cell holds the number of points classified as ground. The survey flights took place in July 2023 and February and March 2024. The data are provided in GeoTIFF format.

There are four data files in GeoTIFF format with this dataset.

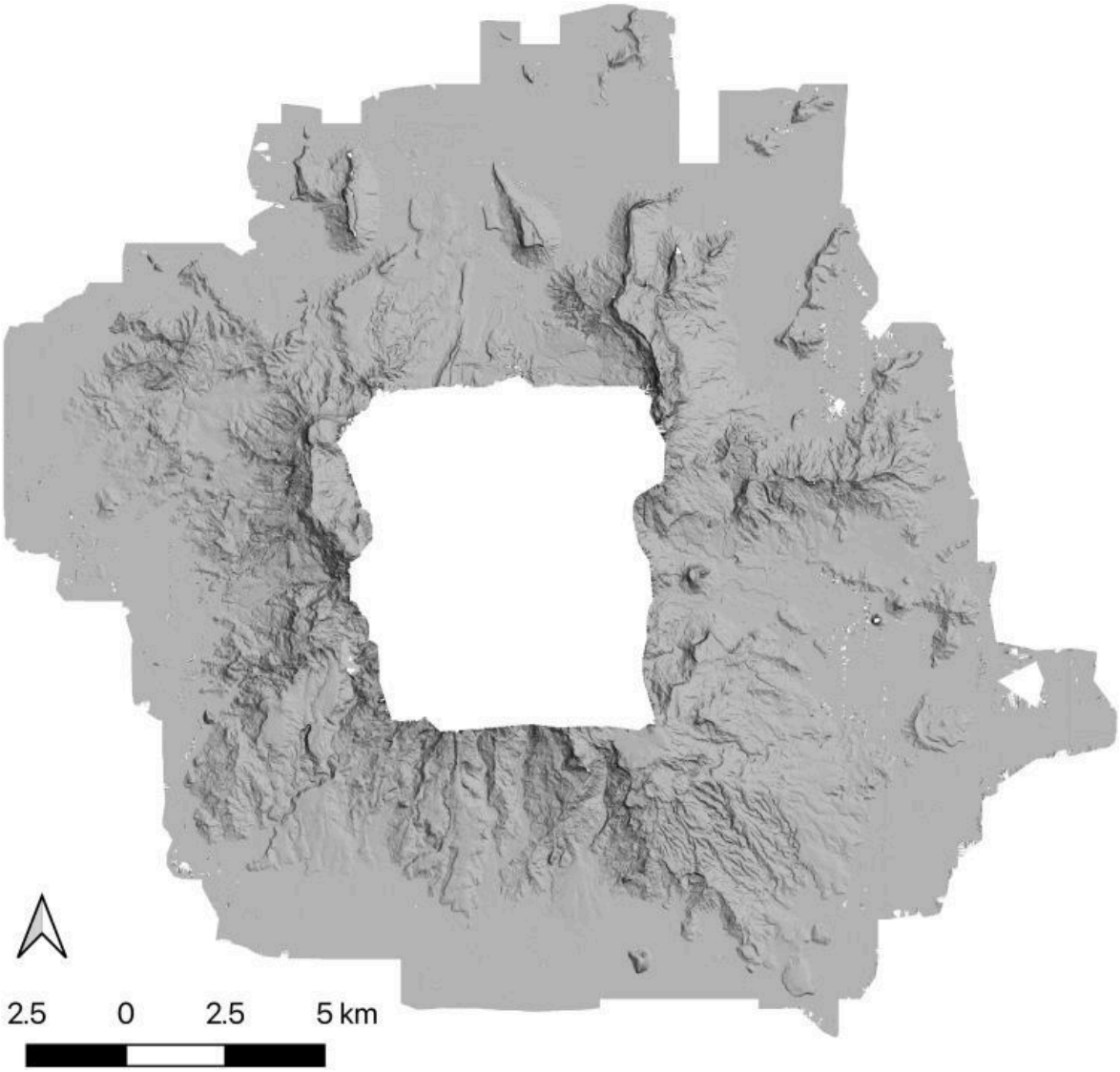


Figure 1. A grayscale multidirectional hillshade image of the 10-m digital terrain model (DTM) for the island of Pohnpei, Federated States of Micronesia (FSM), derived from the July 2023 and February and March 2024 airborne lidar acquisitions. Missing values (outside of the data collection area or removed from the DTM) are not shown.

Citation

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1. Dataset Overview

This dataset includes a 10-m resolution digital terrain model (DTM) of much of the island of Pohnpei, the largest and highest of the islands in the Federated States of Micronesia (FSM). The vegetation-free DTM was generated by rasterizing the ground-classified points of a point cloud collected during an airborne lidar survey. The instrument was a RIEGL LMS-Q680i, and the aircraft was a Britten-Norman Islander. Additional data include a digital surface model (DSM) comprising elevation measurements associated with the first returns, that is, the highest points in the point cloud data set, which in most parts of the surveyed area will pertain to the forest canopy; a pulse density map, in which each cell of the raster contains a value equal to the number of laser pulses fired by the lidar instrument that were recorded to have fallen within the corresponding 10 m2; and a ground point density map, in which each cell holds the number of points classified as ground. The survey flights took place in July 2023 and February and March 2024.

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2. Data Characteristics

Spatial Coverage: Pohnpei, Federated States of Micronesia (FSM)

Spatial Resolution: 10 m

Temporal Coverage: 2023-07-01 to 2024-03-31

Temporal Resolution: One time estimate.

Study Area: Latitude and longitude are given in decimal degrees.

Site	Westernmost Longitude	Easternmost Longitude	Northernmost Latitude	Southernmost Latitude
Pohnpei, Micronesia	158.1112	158.3651	7.01234	6.77703

Data File Information

This dataset includes four files in GeoTIFF (.tif) format described in Table 1.

Table 1. Data files and descriptions

Filename	Description
dsm_denoised_thresholded_ellip_p2r_10m.tif	Digital Surface Model that contains elevation including vegetation. The elevation values pertain to the highest elevation recorded by the lidar sensor in the area defined by each cell. "p2r" refers to the points-to-raster algorithm that was used, also with the lidR R package, to derive the DSM from the classified and de-noised point cloud.
dtm_denoised_thresholded_ellip_kriging_10m.tif	Digital Terrain Model that contains ground surface elevation not including vegetation as modeled using the "kriging" algorithm and the lidar ground-classified points of the cloud.
ground_point_density_denoised_10m.tif	Ground point density: Each cell contains a value equal to the number of points, in the original point cloud, that were classified as ground and that fall within the corresponding 10 m^2 cell.
pulse_density_denoised_10m.tif	Pulse density: Each cell contains a value equal to the number of laser pulses fired by the lidar instrument falling within it.

The "denoised" and "thresholded" components of the file names indicate that the data were derived from a version of the lidar point cloud that was cleaned of noise using a statistical outlier removal protocol, and that implausibly high and low values were removed from the rasterized product. The "ellip" signifies that the elevation measurements assigned to the raster cells are referenced to the WGS84 ellipsoid.

Data file properties:

- Coordinate reference system: WGS84 / UTM zone 57N (EPSG 32657).
- The vertical reference of the DTM and DSM is the WGS84 ellipsoid.
- Spatial resolution: 10 m

- No data value: -9999, corresponds to areas where no data were collected, or where collected data points were, upon evaluation, considered implausible and removed (see “Data acquisition, materials and methods”).

3. Application and Derivation

Lidar-derived digital elevation models (DEMs), a class of data products that includes the DTM and the DSM, have many uses, from generating canopy height models to modeling landslide risk. The DTM may be broadly useful, applicable to virtually any project to which an accurate, precise, and relatively high-resolution model of Pohnpei’s topography (except in the island’s center, where data was impossible, during these surveys, to collect) might be relevant.

Foreseeable potential applications include the two noted above, as well as studies of relative sea level change, legal and administrative activities on Pohnpei, calibration or validation of datasets gathered by satellite-borne instruments (in a region in which data of this kind is relatively sparse), and studies of anthropogenic land-use and landscape change. The latter two applications are the ones most relevant to the purposes for which the dataset was acquired. The intended purpose of sharing the pulse and ground point density files is to equip the dataset user with measurements to evaluate the precision of the DTM and the DSM.

4. Quality Assessment

Ten ground control points were acquired with GNSS survey equipment. The GNSS base station was placed at the Kolonia airport, and its location was referenced to that of the Continuously Operating Reference Station (CORS) maintained within the yard of the National Oceanic and Atmospheric Administration (NOAA) offices in Kolonia (the antenna of this CORS is atop a concrete pillar, such that the antenna itself is 1.59 meters above the surrounding ground; see SONEL 2025). The CORS was also used as a control point (11 such points total). After post-processing with NovAtel’s GrafNet software (Hexagon AB 2025), a comparison of the coordinates of the ground control points with the corresponding locations in the DTM yielded a mean error of 0.0333 m (with a standard deviation of 0.0438 m) and a root mean square error (RMSE) of 0.0437 m. The mean vertical difference between the DTM and the ground control points is 0.0135 m.

Certain areas of the DTM have a stretched or fractured appearance. This results from a density of ground points that is too low to model the ground surface at 10-meter resolution. This effect corresponds to occasions on which the orientation of the sensor was off-nadir to an unusual degree (that is, when the airplane was turning), such that the area directly under the sensor was not receiving the density of laser pulses that would have resulted had the sensor been pointing straight down. Comparing these areas of the DTM with their corresponding locations in the ground point density raster revealed that they are derived from relatively low densities of ground points. These stretched- or fractured-looking areas are best regarded with skepticism in relation to their accuracy.

Some parts of the surveyed region received many more laser pulses per unit of area than did others, partly because some areas were scanned more than once. Areas of the DTM and the DSM derived from greater densities of pulses and resulting points can be considered more precise than areas derived from lower densities. The pulse and ground point density rasters are included in this dataset so that users will be able to evaluate for themselves whether the elevation models, or spatial subsets of them, are sufficiently precise for their applications.

5. Data Acquisition, Materials, and Methods

This dataset includes a 10-m resolution digital terrain model (DTM) of much of the island of Pohnpei, including most of the islets in Pohnpei's lagoon, without vegetation. The DTM was generated by rasterizing the ground-classified points of a point cloud collected during an airborne lidar survey. The instrument was a RIEGL LMS-Q680i, and the aircraft was a Britten-Norman Islander. Survey flights began in July 2023 and were interrupted by weather. Flights resumed in February 2024 and continued into March 2024. The goal was to survey as much of the island as possible. The island's mountainous interior remained cloudy throughout the survey periods, resulting in a data gap in the surveyed area's center (Figure 1). The dataset provided covers approximately 294 km^2 of Pohnpei's 356 km^2 of land area, including the extensive coastal mangrove forests. The lidar data were collected with the goals of documenting archaeological features and of comparing the airborne lidar results with datasets collected by the Global Ecosystem Dynamics Investigation (GEDI; GEDI Ecosystem Lidar, 2025) instrument and the Ice, Cloud and land Elevation Satellite-2’s (ICESat-2’s) Advanced Topographic Laser Altimeter System (ATLAS; Markus et al. 2017).

The point cloud was classified with the software TerraScan (for a general description of the type of algorithm involved, see Fernandez-Diaz et al. 2014: pp. 9980–9983; see also Axelsson, 2000); subsets of the point cloud were rasterized with an R script using the lidR package (Roussel and Auty. 2024; Roussel et al., 2020). The vegetation-free ground elevation model is referred to as a DTM. A digital surface model (DSM) is provided comprising elevation measurements associated with the first returns—that is, the highest points—in the point cloud data set, which in most parts of the surveyed area will pertain to the forest canopy; a pulse density map, in which each raster cell holds the number of lidar pulses fired at the corresponding area; and a ground point density map, in which each cell holds the number of points classified as ground.

The instrument was mounted on a piece of plywood that extended through a doorway on the aircraft's port side (the door was temporarily removed). Flight lines were planned such that adjacent swaths would overlap by 50%. The island's terrain, however, is in many places very irregular, and maintaining a constant altitude was difficult. Flying a straight line in the fixed-wing platform was also a challenge, especially with the interference of wind. Flight altitude was generally approximately 600 m, although the platform's true altitude over the terrain was highly variable. The pulse repetition rate (PRR) was 133 kHz (though at short intervals during the survey, when the terrain dropped such that the absolute altitude suddenly increased, the PRR was lowered toward 100 kHz to minimize the potential for ambiguities resulting from multiple pulses being simultaneously in the air; this adjustment was precautionary rather than necessary, since the LMS-Q680i is designed to allow for post-mission correction of such ambiguities with RIEGL software.

Implausible-seeming values were removed in several ways. First, data were de-noised with a simple removal of statistical outliers: For each point in the point cloud, the mean and standard deviation of the distances between that point and its 10 nearest neighbors were calculated. Any of those neighboring points farther than the mean plus five times the standard deviation of the distances were classified as noise.

Even after the application of this de-noising algorithm, some points were implausibly high. They were removed by normalizing the point cloud—that is, setting the elevation of the terrain as the vertical reference for point elevation values—and removing points at or above 50 m, a threshold higher than any vegetation on Pohnpei can be expected to reach.

Having generated the rasterized DTM and DSM, values were removed that were impossibly low by converting from ellipsoidal to orthometric heights and setting a lower bound at -3. From the DTM, implausibly high values were removed by computing the difference between it and the Shuttle Radar Topography Mission's (SRTM's) global 1-arc-second elevation product (U.S. Geological Survey, 2014), then removing all DTM values that were 20 m or higher than the SRTM elevations. The DTM and DSM elevations were converted back to ellipsoidal heights before archiving. The code that performed the de-noising, thresholding, and generation of the raster files is available in https://github.com/jacomer2113/Pohn_lidar_CNN/.

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