Validation of DEM data derived from World View 3 stereo imagery for low elevation Majuro Atoll, Marshall Islands

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ABSTRACT

The availability of surface elevation data for the Marshall Islands has been identified as a “massive” data gap for conducting vulnerability assessments and the subsequent development of climate change adaption strategies. Specifically, digital elevation model (DEM) data are needed to support modeling efforts to assess vulnerabilities to extreme tide events, storm surge wave events, and unusual swell conditions. The only data currently available for the entire Majuro Atoll are the National Geospatial-Intelligence Agency (NGA) digital terrain elevation data (DTED) which have a 30 m spatial and 5.0 m vertical resolution. Due to the low elevation profile (< 3.0 m), small land mass (< 10 km^2), and narrow geographic profile (0.5 km wide) of Majuro Atoll, high spatial (1.0 m) and vertical (< 0.5 m) resolution DEMs are required to support inundation vulnerability modeling efforts. The cost effective application of new higher resolution World View 3 (WV3) stereo satellite imagery with a nominal spatial resolution of 0.31 m will be used to create high resolution elevation data. DEM specification objectives are an absolute vertical 90% linear error (LE90) of approximately 0.35 m. To validate the adherence to required DEM specifications, a statistically robust reference database was needed.

METHODS

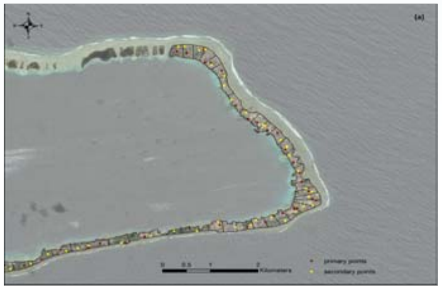
An *in situ* ground survey will be initiated to provide elevation data for use as both ground control points (GCPs) to support photogrammetric model calibration and to provide reference data for subsequent validation of high resolution DEM products. The reference database will consists of surveyed elevation points across Majuro Atoll from the Peace Park located approximately 2.5 km west of Amata Kabua International Airport, extending to the east including the downtown area, and to the north terminating the high tide mark in Rita (Figure 1). To provide a statistically robust reference database, a statistical sampling frame was first developed incorporating a systematic unaligned design to provide relatively equally distributed randomly selected points. Next, random points were generated for each segment including both primary and secondary points. All points were then plotted over the WV2 imagery and assessed for potential collectability. Problematic points (i.e., landing on structures, dense vegetation, etc.) were eliminated and a final Excel database of sampling coordinates (n=120), including both primary (n=60) and secondary (n=60) points, was created to support the field survey data collection effort.

Data analysis included the development of a water-land boundary coverage to first delineate the study area using WV2 imagery collected during a high tide event, to coincide with the normal high water mark (March 4, 2014). A shapefile of the study area was then generated using heads-up digitizing to create the land-water intersection polygon. Next, the equal-area sampling frames were generated by first calculating the total land area of the study area shapefile (Figure 2), then divided by 60 to derive the aerial extent for individual segments. Due to the extremely irregular and narrow shape of the study area, a grid mythology initially used to delineate equal area segments proved ineffective as a majority of the grid pixels fell along the water-land boundary and required removal. To overcome this problem, individual polygons were delineated using manual digitizing in ArcMap to create 60 equal area (6.75 ha) polygons. Primary and secondary *in situ* sampling points were then randomly generated for each sampling frame segment (Figure 3a).

DISCUSSION

For quality assurance (QA) purposes, all randomly generated points were then examined in order to determine potential collectability. If the point landed on or near the coastline or on a building, it was deemed uncollectable and was replaced by the next point until two collectable points were identified. Sampling point collectability was first assessed using visual interpretation of high resolution WV2 natural color (Figure 3b) and near infrared (Figure 3c) imagery with the random sampling points displayed. A secondary QA was performed by a resident of the study area, who was able to identify unstable land areas that necessitated additional sampling point replacement.

A total of 44 segments had a primary point eliminated because they were determined to be non-collectable and were replaced by a secondary point. Likewise, 33 segments had both the primary and secondary point eliminated as non-collectable and were replaced by a third or higher point. One segment had 23 random points that were non-collectable with the 24th designated as the primary collection point. The generation of numerous replacement points was a clear reflection of the irregular shape, geology, and urban density of the study area. Accordingly, the systematic unaligned design provided a relatively equally distributed sampling segments for the generation of random sampling points that often required multiple iterations. The reference database was developed to support a statistically robust assessment of the DEM data being developed for Majuro Atoll.



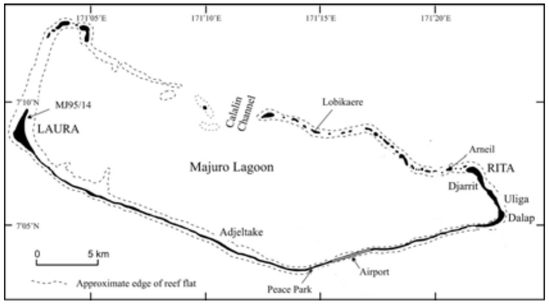


Figure 1. Majuro Atoll location map provided by the Office of Planning and Statistics, Republic of the Marshall Islands (1989).

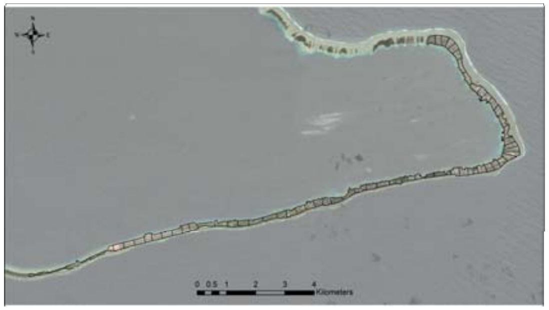


Figure 2. A total of 60 equal area segments were derived for the eastern portion of Majuro Atoll.

Figure 3a-c. For each equal area segment (6.75 ha) a total of two primary and two alternate random sampling points were selected (a). Primary sampling points were evaluated for survey data collectability using both natural (b) and CIR (c) imagery backdrops. If a primary sampling point was deemed to be not collectable, secondary points were evaluates and selected to replace primary points as needed.

DISCLAIMER - Although this work was reviewed by EPA and approved for publication, it may not necessarily reflect official Agency policy.