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Error-reducing Structure-from-Motion derived Digital Elevation Models in data-scarce environments

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High-accuracy Digital Elevation Models (DEMs) improve the quality of flood risk assessments and many other environmental applications, yet these products are often unavailable in developing countries due to high survey costs. Structure-from-Motion (SfM) photogrammetry combined with Unmanned Aerial Vehicles (UAVs) has been proven as an effective and low-cost technique that enables a wide audience to construct local-scale DEMs. However, the deviation from strict survey designs and guidelines regarding the number and distribution of Ground Control Points (GCPs) can result in linear and doming errors. Two surveys that suffer from these errors have been supplied for error-reduction, but both areas did not have an available high-accuracy DEM or could afford an additional differential Global Navigation Satellite System (dGNSS) ground survey to extract control points from to use in relative georeferencing approach. Little attention has been given to error-reduction using global open-access elevation data, such as: The TerraSAR-X add-on for Digital Elevation Measurements (TanDEM-X) 90; the Ice, Cloud and land Elevation Satellite-2 (ICESat-2); and Hydroweb.

The aim of this study was to improve and validate the two DEMs using control point extraction from the above data and analyze the validation results to determine the impact on error-reduction using regression analyses between the vertical error and distance from nearest control point. The outcomes shows that the ICESat-2 and Hydroweb can support surveys in absence of dGNSS GCPs with similar impact but cannot replace the necessity of dGNSS measurements in georeferencing and validation. These findings suggests that survey guidelines can be maintained with global open-access elevation data, but the effectiveness depends on both the number, distribution and estimated accuracy. Doming errors can be prevented by correct camera lens calibration, which depends on stable lens conditions or a stratified distribution of high-accuracy reference data. The validation of the SfM DEM in data-scarce areas proves difficult due to the lack of an independent validation dataset, but the Copernicus GLO-30 can give a quantification and show the spatial variability of the error. This study highlights the increasing accuracy of global open-access elevation data and shows that these databases allow the user to easily acquire more and independent data for georeferencing and validation, but the RSME is unable to be accurately reduced to sub-meter.