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Evaluating the performance of UAV photogrammetry with PPK positioning in topographic reconstruction and change-detection

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Unmanned aerial vehicles (UAVs) are being increasingly used to provide high resolution imagery which, through photogrammetric method Structure-from-Motion (SfM), can be used for high resolution topographic reconstruction. PPK (Post-Processing Kinematic) positioning solution offers the potential of accurate image georeferencing without ground control points (GCPs). By integrating consumer-grade cameras and an onboard RTK/PPK GNSS receiver, we managed to have a low-cost and effective approach involving topographic change-detection. Here, we evaluated the positional accuracy and reproducibility of DSMs generated from PPK-SfM workflow with two camera setups by conducting multiple UAV surveys over a test field. Our results showed that the PPK solution has the same accuracy (mean: ca. 0.01 m, RMSE: ca. 0.03 m) as the more traditional georeferencing method based on ground control points. Furthermore, our results indicated that camera properties (i.e. focal length, resolution, sensor quality) have a large impact on the accuracy: a DSLR camera (Canon EOS), with 0.63 cm px-1 GSD, had 0.011 m planimetric error and 0.012 m altimetric error; while a cheap and light Action camera (GoPro) with 3.11 cm px-1 GSD had 0.019 m planimetric error and 0.024 m altimetric error at the same flight height. The repeatability of DSM construction was assessed by a DoD (DEMs of Difference) analysis. The LoD95% and LoDmin were ca. $\pm$0.08 m and ca. $\pm$0.04 m for the DSLR camera and ca. $\pm$0.16 m and ca. $\pm$0.08 m for the action camera (for a flight altitude of 45 m). The level of detection substantially improved when reducing the UAV flight altitude. We found that tie point density greatly controlled the error of the topography reconstruction for the DSLR camera. By exploiting the relation between error and tie point density, we demonstrated that a spatially explicit DoD threshold, according to the local surface condition, can greatly improve surface change detection. Volume estimation was conducted over the plowing area and obtained comparable results from DSLR and action camera datasets. Overall, the application of a PPK-UAV workflow provides a high-precision and high-efficiency solution in surveying and geomorphological applications.