

## Applications of low-cost, high-precision GNSS positioning for RPAS measurements in an inaccessible area

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The photogrammetric approach using remotely-piloted aircraft systems (RPAS, also known as UAS: unmanned aerial system or drone) for the acquisition of high-definition topographic data has become widely available in geosciences. However, the accuracy of such data needs careful assessments particularly for the change detection of landforms using multitemporal datasets. Although setting numerous and distributed ground control points (GCPs) in a target area is a promising solution to improve the accuracy of topographic data, limitations in the accessibility are often found for target areas including oceanic coasts and volcanoes. Here we demonstrate the way of improving the accuracy of topographic data derived from RPAS using an onboard global navigation satellite system (GNSS) receiver. The study area is a crater of an active volcano of Tateyama Midagahara in Toyama Prefecture, Japan. An L1 GNSS receiver (emlid Reach) with a small antenna, which is capable of kinematic corrections, was attached on the aircraft body of RPAS (DJI Phantom) and its precise positioning data were recorded and post-processed with the camera images. The geographical coordinates of several GCPs were separately measured using another GNSS with kinematic corrections, which are compared with those on the RPAS-derived topographic model. The onboard high-precision GNSS positioning data improved the accuracy of the photogrammetric data by one order of magnitude (decimeters to centimeters), enabling us to proceed to the widespread, accurate monitoring of topographic changes in the crater without GCPs.

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