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The Implementation of UAS-Photogrammetry in Extreme Altitude Tropical Glacier Surveying – A Field Study in the Bolivian Andes

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Runoff from tropical snow covers and glaciers, 95% of which are situated in the Andes Mountains, provides water to the surrounding ecosystems as well as millions of people. Feeding hydropower plants, agriculture and drinking water reservoirs, meltwater is a critical resource. Hence, accurate monitoring and modelling of surface mass balance are crucial steps in understanding and predicting ongoing changes in water availability.
Combining UAS surveying and structure-from-motion (SfM) photogrammetry is a cost-effective method of producing highly accurate, high-resolution geodata, particularly under conditions preventing terrestrial or manned aerial data acquisition. While there have been several studies on tropical glaciers using satellite and manned aerial imagery, the achieved resolution and reference accuracy is considerably lower than that which can be accomplished by current UAS-based workflows. Due to the often difficult-to-traverse terrain, extreme altitudes and changing weather conditions, UAS-photogrammetry also has considerable advantages over terrestrial methods involving more strenuous field work.
As a feasibility study for an upcoming project, we used a small UAS equipped with a manual shutter RGB-camera, as well as automated, GNSS-equipped markers to investigate two Bolivian glaciers: Llojeta (19K | 575150E | 8225000S), part of the central Cordillera Real, and Quimsa Cruz (19K | 671850E | 8124700S) in the southern Cordillera Oriental were surveyed at flight altitudes of 5500 m and 5370 m MSL, respectively, and 110 m AGL, resulting in a ground sample distance (GSD, i.e. pixel size) of 3 cm. Moreover, we conducted a test flight at a maximum altitude of 6100 m MSL in the Cordillera Occidental, on the slopes of Mount Acotango (19K | 494960E | 7967460S).
Using SfM algorithms, we computed georeferenced dense point clouds of both glaciers from the gathered imagery and marker data, subsequently generating full resolution digital surface models (DSMs) and orthomosaic maps covering the investigation areas of 62 ha and 42 ha, respectively. Despite high reflection and comparably low visual structure on the snow caps, we found the high- resolution imagery allowed for better tie point allocation throughout those uniformly reflective areas, resulting in a more consistent camera alignment compared to lower resolution images.
While high-andean terrain provides unique challenges for UAS surveying, we found it to be well suited for data acquisition on tropical glaciers at altitudes up to 6100 m MSL. High flexibility in mission parameterization and timing, as well as financial feasibility facilitates mission planning and realization, enabling surveyors to gather data during the critical time frame of optimal snow melt. These, along with considerably higher spatial and temporal resolution, are major methodical benefits that cannot be accomplished with other imaging methods. UAV technology is also capable of performing in these extreme environments, though further improvement is necessary to allow for higher payloads (e.g. UAS-LiDAR), extended flight time and climbing range, as well as and flight automation in areas with insufficient available data for flight planning.