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Comparing and integrating multiple data source for 3D surface reconstruction of Alpine Glaciers

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Alpine glaciers are generally undergoing a fast and complex process leading to the reduction of the ice mass. Monitoring this process from a quantitative and qualitative point-of-view is of great importance for understanding the related dynamics and to apply proper numerical models.
While the analysis of archive maps, medium resolution satellite images and DEM's may provide an overview of the long-term processes, the application of close-range sensing techniques offers the unprecedented opportunity to operate a 4D reconstruction of the glacier geometry. Terrestrial sensors technologies (Long and Very-long Range TLS and SfM Photogrammetry) integrated to UAV Photogrammetry may offer a complete view of the dynamical evolution of a glacier, reaching a high spatial and temporal resolution. Up until today, not many cases exist where a long-term archive of 4D high-resolution data has been established, limiting the chance to understand and to model the undergoing physical processes.
The goal of the research presented here is to collect a set of multi-temporal data sets of the lower part of the Forni Glacier, in the National Stelvio Park, Italy. The first data acquisition campaign was carried out during August 2016, to be followed on yearly regular-basis. This will give the researchers the opportunity to analyse 4D data describing in detail the disruption of the glacier and its dramatic retreat. These data sets could be compared to DEM's acquired in the past by using UAV-Photogrammetry (2014) and traditional stereo-photogrammetry (2007). In addition, the presence of additional hydrological and meteorological data can be exploited in the analyses.
The first data acquisition campaign has also given the opportunity to investigate the data acquisition methodology. The UAV flight has revealed to output a complete overview of the glacier surface in terms of DEM and orthophoto. Thanks to the photogrammetric process and the use of seven GNSS-GCPs, a high resolution has been obtained (about 102 pts/m2). The presence of vertical and sub-vertical surfaces has motivated the use of terrestrial sensors. The integration of sensors from ground and from drones has allowed to better describe some local physical processes (i.e. opening of crevasses, ice tunnelling, local collapses) that are giving an impressive contribution to the loss of ice bulk. This processes require a detail 3D modelling to be investigated, calling for the use of sensors able to reconstruct also the vertical and sub-vertical faces, thus using a ground-based standpoint. To this purpose, the adoption of SfM-Photogrammetry has yielded results comparable to the ones achieved using a long-range TLS Riegl LMS-Z420i, which can be assumed as benchmarking for accuracy assessment, but being more cumbersome and difficult to be operated in the glacier area. The measurement of GCPs for the terrestrial photogrammetric project reveal to be a complex task, involving the need of a total station. For this reason, the integration of GNSS and cameras will be developed for the future measurement sessions. The effect of block geometry on the final output has also been investigated for SfM-Photogrammetry, considering the severe limitations implied in the Alpine environment.