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Glacier change monitoring using optical satellite imagery: the case of Forni Glacier

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Glaciers are one of the most important indicators of climate change. Monitoring their evolution is, therefore, crucial for safeguarding the Earth's ecosystem. In this study, exploiting photogrammetric optical satellite processing techniques, we used image pairs from Ikonos-2 and Plèiades-HR satellites to generate Digital Surface Models (DSMs) of Forni Glacier (Ortles–Cevedale group, Italy) and compute its morphological variations between 2009 and 2016. In addition, we used DSMs generated from Unmanned Aerial Vehicle (UAV) acquisitions collected during summer campaigns from 2014 to 2021 for comparison with very high-resolution DSMs on the terminal portion of the glacier including its tongue, which is also the area more affected by morphological changes. To evaluate the glacier height loss, DSMs co-registration was applied to remove DSM biases due to inconsistencies in the georeferencing of the different satellite image pairs. For this purpose, we used the 2016 UAV DSM as a reference, and we co-registered all the optical DSMs to the 2016 UAV DSM using the Nuth and Kaab algorithm. The DSM height differences after co-registration highlighted a final accuracy of one meter. Since optical satellite data have the advantage of providing information on very large areas, we analysed glacier change not only on small areas of Forni Glacier tongue but also on larger regions including parts of the entire glacial apparatus to depict the evolution of the glacier at different altitudes. Results from optical DSMs were consistent with the average annual variation of the glacier suggested by UAV DSMs analysis, confirming an average 5.00 m/y loss on the Forni tongue during 2014-2016. Furthermore, based on both UAV and optical data, melting trends have highlighted how climate change is causing an acceleration in the melting process, with values averaging 3.3 m/y in the period 2009-2013, 3.8 m/y in 2009-2016 and 4.7 m/y in 2009-2021. With reference to the optical data only, we observed that the intensity of melting varied at different altitudes, with 10 m of maximum variation above 3000 m, and 30 m between 2600-3000 m during 2009-2016. Our results suggested that despite the limitations related to weather conditions (e.g. cloud coverage) and time revisit, high-resolution optical satellite imagery can certainly be used to estimate relevant morphological variations of glaciers in the order of meter/years, offering the opportunity of monitoring large-scale areas.