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# The current deglaciation of the Ortles-Cevedale massif (Eastern Italian Alps): impacts, controls and degree of imbalance

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The Ortles-Cevedale is the largest glacierized mountain group of the Italian Alps hosting 112 ice bodies, with a total area of 76.8 km$^2$. Since the 1980's, this massif is undergoing a rapid deglaciation, as most of the mountain ranges in the European Alps. The aims of this work were: i) to quantify area and volume change of the Ortles-Cevedale glacier system from the 1980s to the 2000s; ii) to improve the knowledge of factors controlling the spatial variability of the deglaciation; and iii) to assess the degree of imbalance of individual glaciers with respect to the present climate conditions.

Two inventories were created, based on Landsat5 TM scenes of 20-09-1987 and 31-08-2009. Contrast-enhanced composites (bands TM5, TM4 and TM3), aerial photos and field surveys (for the most recent period) were used to correct the automatic delineation of glaciers derived from a hard classification based on a threshold applied to a TM3/TM5 ratio image. Since Landsat scenes were acquired at the end of the ablation seasons and fresh snow was absent, the accumulation areas could be roughly determined by mapping the snow covered area. This region was identified from the difference in reflectance between snow and ice in the near infrared band of Landsat (TM4), and mapped after correcting topographic effects to determine surface reflectance. The area-averaged geodetic mass budget was then calculated for the individual glaciers by differencing two Digital Terrain Models (2000s minus 1980s, derived from LiDAR and aerial photogrammetry) and combining the result with the glacier outlines. Afterwards, we examined the mass balance data using statistical analyses (Correlation matrices, Principal Component Analysis, Cluster Analysis). This allowed us highlighting clusters of glaciers, which exhibit a similar behavior, identify the outlayers and the relative influence of the factors controlling spatial variability of the mass losses. Finally, we assessed the degree of imbalance of individual glaciers by comparing the current Accumulation Area Ratios (AAR) with the balanced-budget AAR (AAR0), the latter also accounting for the debris cover of glaciers.

We found that the total area loss of the Ortles-Cevedale glaciers from 1987 to 2009 amounts to 23.5 km$^2$, i.e. 23.4% of the initial area. On the other hand, the AAR of the entire glacier system was 0.3 in both investigated years. The overall debris cover increased from 10.5% to 16.3%. The geodetic mass balance rate was -0.7 m w.e. y$^{-1}$(as an average on 112 ice bodies), ranging from -0.1 to -1.7 m w.e. y$^{-1}$. We also found that the main controls of the differing change of single glaciers are related to their hypsometry (elevation range and slope), AAR, feeding source and debris cover. Interestingly, a significant correlation was found between AAR, AAR0 and debris cover. This information was used to assess and visualize the needed additional reduction of individual glaciers to reach equilibrium with the current size of their accumulation areas. This amounts on average to a further reduction of $\sim$40% of the current areal extent of glaciers.