

MARTA CHIARLE¹, CRISTINA VIANI^{2*}, GIOVANNI MORTARA¹,
PHILIP DELINE³, ANDREA TAMBURINI⁴ & GUIDO NIGRELLI¹

LARGE GLACIER FAILURES IN THE ITALIAN ALPS OVER THE LAST 90 YEARS

ABSTRACT: CHIARLE M., VIANI C., MORTARA G., DELINE P., TAMBURINI A. & NIGRELLI G., *Large glacier failures in the Italian Alps over the last 90 years.* (IT ISSN 0391-9838, 2022).

Ice failures are among the least known and least studied mass movements, both because large events are quite rare, and because they usually develop in remote and little-frequented areas. However, the unprecedented transformation of glaciers due to climate change, on the one hand, and the growing human pressure on high-elevation environments, on the other, nowadays require a more careful and in-depth consideration of these hazardous processes, such as tragically highlighted by the collapse of the Marmolada Glacier (Italy) on July 3, 2022. In this context, a review of existing documentation on past glacier failures is essential to learn about their spatio-temporal distribution, the characteristics of the glaciers where the failures occurred and flow properties. In turn, these findings are fundamental to inform the assessment of current and future hazards. The present work contributes to the topic by documenting, cataloguing, and analysing the glacier failures larger than 10,000 m³ that occurred in the Italian Alps in the period 1930-2022. Sixty-eight glacier failures are documented, which affected 29 glaciers distributed throughout the Italian Alps. The volumes of glacier failures are mostly between 10,000 and 50,000 m³ (1.1 × 10⁶ m³ in one case). The events occurred mainly in summer, with a frequency peak in August. The H/L ratio, i.e. the ratio between the vertical (H) and horizontal (L) distances covered by the process, indicator of the mobility of the detached mass, is between 0.33 and 0.80. Although glacier failures can occur during both glacial advance and retreat, we found a sharp increase in the number of documented cases since the

1990s. We are aware that, due to the difficulty of finding information, the dataset provided in this work is only partially representative of the glacier failures that occurred in the Italian Alps in the period considered: nevertheless, it is a useful starting point for studies aimed at assessing hazards related to glacier failure, and for risk mitigation. Given the speed and intensity with which glaciers and their surrounding environments are evolving in response to climate change, their continuous observation is essential, as is the systematic documentation of glacier failure events. Remote sensing data and tools can nowadays facilitate glacier monitoring and the documentation of ice failures: however, field data such as those collected during the annual glaciological surveys of the Italian Glaciological Committee (CGI) remain fundamental for the validation of remote sensing data and numerical models.

KEY WORDS: Glacier failure, Italian Alps, Climate change, Hazard assessment.

RIASSUNTO: CHIARLE M., VIANI C., MORTARA G., DELINE P., TAMBURINI A. & NIGRELLI G., *Crolli di ghiaccio di grandi dimensioni nelle Alpi Italiane nel corso degli ultimi 90 anni.* (IT ISSN 0391-9838, 2022).

I crolli di ghiaccio sono tra i processi d'instabilità naturale meno conosciuti e studiati, sia perché eventi di grandi dimensioni sono piuttosto rari, sia perché coinvolgono per lo più aree remote e scarsamente frequentate. Tuttavia, le rapide e profonde trasformazioni dei ghiacciai in atto per effetto dei cambiamenti climatici, da una parte, e la crescente frequentazione e pressione antropica sugli ambienti di alta quota, dall'altra, richiedono oggi una più attenta e approfondita considerazione di questi fenomeni, la cui pericolosità è stata tragicamente evidenziata dal crollo occorso al Ghiacciaio della Marmolada il 3 luglio 2022. In questo contesto, particolarmente importante risulta la documentazione di eventi di instabilità avvenuti in passato, al fine di disporre di informazioni su distribuzione spatio-temporale degli eventi, caratteristiche dei ghiacciai soggetti a crollo e della dinamica dei fenomeni che si originano, dati indispensabili per la valutazione della pericolosità attuale e di scenari futuri. Il presente lavoro intende dare un contributo in questo senso attraverso la documentazione, schedatura e analisi di eventi di crollo di ghiaccio di volume > 10.000 m³ occorsi nelle Alpi Italiane tra il 1930 e il 2022. Sono stati così documentati 68 eventi che hanno coinvolto 29 ghiacciai distribuiti sull'intero arco alpino. Si tratta per lo più di crolli di dimensioni comprese tra 10.000 e 50.000 m³ (ma in un caso è stato raggiunto il valore di 1.1 × 10⁶ m³), avvenuti per lo più in estate, con un picco nel mese di agosto. Il rapporto H/L, cioè il rapporto tra dislivello (H) e distanza orizzon-

¹ Italian National Research Council, Research Institute for Geo-Hydrological Protection (CNR-IRPI).

² Department of Earth Sciences, University of Torino.

³ EDYTEM, Université Savoie Mont Blanc, CNRS.

⁴ IMAGEO srl.

* Corresponding author: C. Viani (cristina.viani@unito.it)

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