Future winters glimpsed in the Alps

January 2018 was an unusually warm and wet month across the Western Alps, with widespread landslides at low elevations and massive snowfall higher up. This extreme month yields lessons for how mountain communities can prepare for a warmer future.

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The weather of January 2018 was unusual — at the upper extreme of the historical distribution of storminess, temperature and precipitation measurements in the Western Alps — and broke many weather records. Not only was January 2018 unprecedentedly warm, it was also extremely wet, with unusual snowfall at higher elevations. As regional climate models predict substantial warming and, to a lesser extent, increased precipitation[1] across the European Alps, we argue that the extreme weather conditions and associate mass wasting observed during January 2018 could yield valuable insights into typical winter conditions to be expected by the end of the twenty-first century.

A January of extremes

In January 2018, measured air temperatures[2] at low elevations in large parts of France, Switzerland, Bavaria and Austria exceeded long-term means by 4–5 °C (Fig. 1a). The exceptionally warm temperatures in the lowlands were due to the Jetstream sitting farther to the south than usual in December 2017, thereby transporting warm and humid air masses to the Alps and generating strong winter storms.

Within the Alps, and especially at higher elevations, temperatures also exceeded long-term average values by 2–3 °C, although the influence of the Jetstream was less marked. The mild air masses also carried excessive humidity to the Alps that led to more than twice the usual precipitation over many regions, especially the Northern French and Western Swiss Alps (Fig. 1a). At lower elevations, this precipitation delivered multiple rain-on-snow episodes that induced flooding in smaller catchments and critical discharge levels in montane rivers north of the Alpine divide. In addition, water-saturated soils abetted the release of shallow landslides and debris flows in valleys where, historically, landslides and debris flows have been exceptionally rare.

Furthermore, the winter storms led to snow accumulations exceeding five metres at high elevations (Fig. 1b). These immense snow burdens pushed avalanche risk to extreme levels, threatening villages and communication routes, and leaving tourists stranded in mountain resorts. Several popular ski destinations — including Chamonix, Saas Fee, Val d'Isère and Zermatt — shut their ski runs and put helicopter shuttles in place to evacuate tourists from resorts during the major snowfall episodes.

It is noteworthy that, despite these recurrent, massive snowfall episodes, the ensuing snow avalanches neither caused major damage to mountain villages nor claimed lives in settlements. The number of avalanche deaths recorded in the French and Swiss Alps in January 2018 was considerably below average, and exclusively linked to outdoor leisure activities. As such, January 2018 stands in stark contrast to the situation in February 1999, when 74 people were killed inside houses or on roads by large and destructive avalanches in France, Switzerland and Austria[3]. Compared to 1999, individual snowfall episodes in 2018 were shorter and intervals between new snow accumulations were longer, such that snow cover could stabilize more effectively. But, more importantly, local authorities had learned from the 1999 disasters: dangerous slopes had been secured with avalanche barriers, snowdrift fences and road galleries; avalanche mining had been routinely used to unload snow from dangerous slopes; and local residents were evacuated from homes where avalanche risk was high.

Local residents and authorities were not as well prepared, however, for the widespread shallow landslides, debris flows and rain-on-snow floods in smaller, low-elevation catchments that occurred in January 2018. This can partly be explained by a lack of experience with comparable events during previous winter seasons. However, given that future climate warming could indeed promote landslides and debris flows even at high elevations and in winter[4], scientists and local authorities should take this recent extreme winter as a warning of what is to come and heed the lessons to be learned for future preparedness.

An analogue for future winters

The conditions during January 2018 may be anomalous in today's climate, but that is projected to change. When compared to localized climate model scenarios[5] for those stations with the longest historical records in Switzerland, the temperatures measured in January 2018 are projected to become commonplace at higher elevations by the end of the century (Fig. 1b). Climate warming in the European Alps will probably also be accompanied by changes in the seasonality of precipitation, with increased occurrences of extreme precipitation in the colder part of the year[1], even if the total precipitation may not be likely to reach January 2018 levels.

The events of January 2018 add to an active debate over the complex linkages between snow avalanche activity and climate warming[6]: despite extremely high temperatures, an exceptionally large number of high-magnitude, low-frequency avalanches were triggered. This observation is in line with existing studies showing that avalanche runout distances and avalanche type are more affected by climate warming than avalanche frequency[7]. Thus, January 2018 may provide a glimpse of avalanche activity in winters to come. Additionally, the succession of extreme snowfalls has also demonstrated that mountain populations and authorities have learnt their lessons from past avalanche disasters to effectively adapt.

In contrast, despite projections that rain-on-snow events and related floods are likely to increase by 2100 by almost 50% with temperatures 2–4 °C warmer than today[8], the events of January 2018 have demonstrated that communities throughout the European Alps are not yet ready to cope with increased winter landsliding and flooding. There is a clear need to better understand winter mass movements and flooding at lower elevations under warmer climates to improve residents' resilience to climate warming in the European Alps.

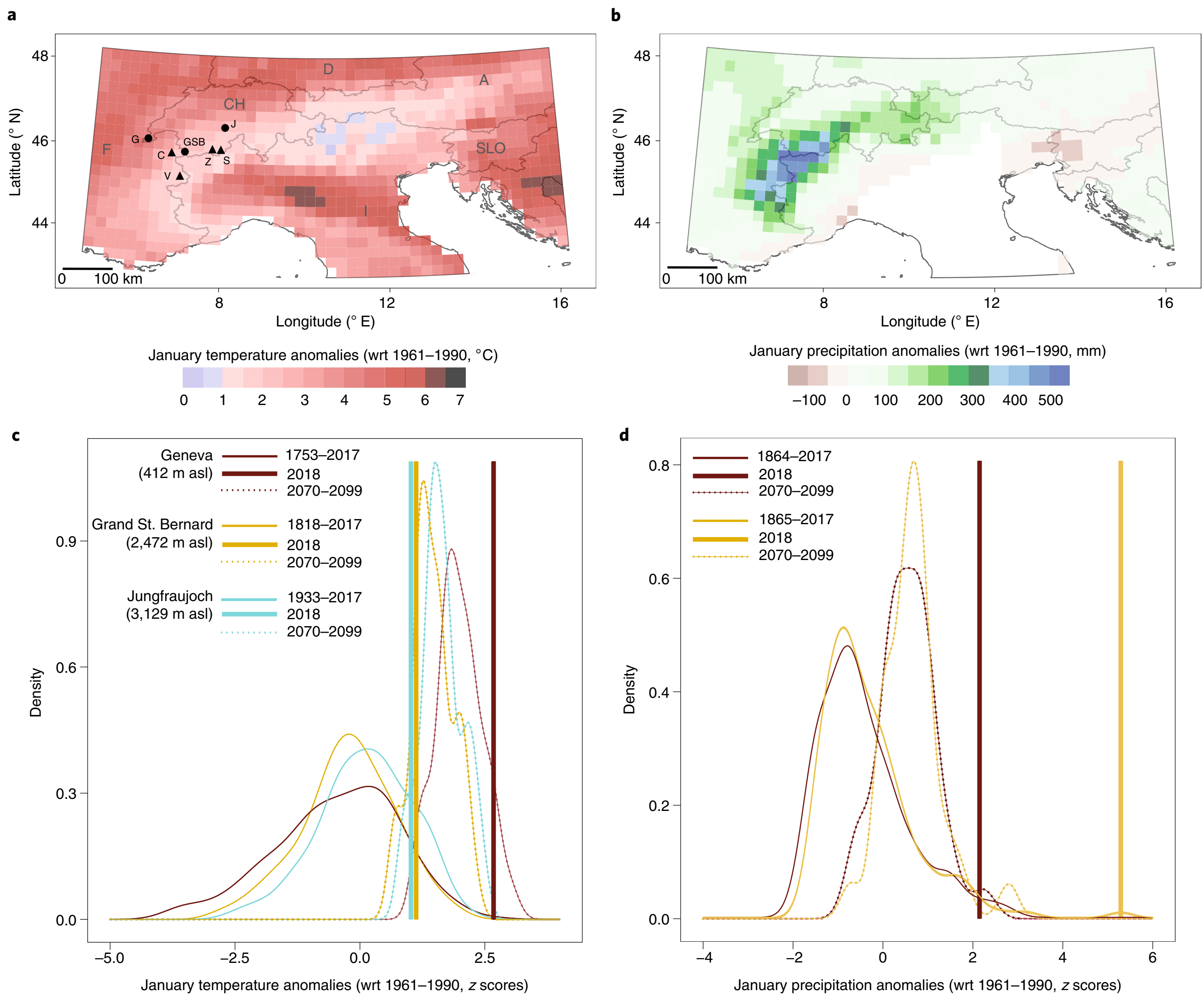

Fig. 1 | Temperature and precipitation anomalies measured across the European Alps in January 2018. a, Temperature anomalies (0.25 × 0.25 °C) obtained from the daily, high-resolution E-OBS dataset. **b**, Precipitation anomalies from the E-OBS dataset as compared to 1961–1990 values. **c**,**d**, Temperature anomalies (**c**) and precipitation anomalies (**d**) for January 2018 as compared to the distribution of previous January anomalies measured at the meteorological stations of Geneva, Grand St. Bernard and Jungfraujoch, and future January anomalies projected by climate models to the end of the twenty-first century. A, Austria; CH, Switzerland; D, Germany; F, France; I, Italy; SLO, Slovenia; C, Chamonix; G, Geneva; GSB, Grand St. Bernard; J, Jungfraujoch; S, Saas Fee; V, Val d'Isère; Z, Zermatt; wrt, with respect to; asl, above sea level.

In many mountain areas across the world, increasing air temperature has resulted in a reduced frequency of snowfall, as well as an increasing proportion of rain. These trends are projected to continue[6], with more rain-on snow events very likely to lead to changes in snow avalanche activity and character[9,10], as well as winter landsliding. The projected changes to mountain environments[6], combined with socio-economic, cultural and political developments, will probably produce conditions and mass wasting without historical precedent[4]. With the exposure of people and assets in high mountain regions to such natural hazards expected to increase in the future, the lessons learned from the extreme month of January 2018 can help authorities beyond the European Alps plan for the emerging risks. ❐

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Published online: 02 July 2018
https://doi.org/10.1038/s41561-018-0177-6

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Acknowledgements

This Comment greatly benefitted from meteorological records and monthly bulletins made available online by MeteoSwiss, ZAMG (Austria) and Météo France. Gridded daily change signals for temperature and precipitation in Switzerland (CH2011-PLUS) data for the period 2070–2099 were obtained from the Center for Climate Systems Modelling (C2SM) at ETH Zurich. The authors also acknowledge the E-OBS dataset from the EU-FP6 project ENSEMBLES (http://ensembles-eu.metoffice.com) and the data providers in the ECA&D project (http://www.ecad.eu).