

Frequently Asked Questions

FAQ 4.2 | Are Glaciers in Mountain Regions Disappearing?

In many mountain ranges around the world, glaciers are disappearing in response to the atmospheric temperature increases of past decades. Disappearing glaciers have been reported in the Canadian Arctic and Rocky Mountains; the Andes; Patagonia; the European Alps; the Tien Shan; tropical mountains in South America, Africa and Asia and elsewhere. In these regions, more than 600 glaciers have disappeared over the past decades. Even if there is no further warming, many more glaciers will disappear. It is also likely that some mountain ranges will lose most, if not all, of their glaciers.

In all mountain regions where glaciers exist today, glacier volume has decreased considerably over the past 150 years. Over that time, many small glaciers have disappeared. With some local exceptions, glacier shrinkage (area and volume reduction) was globally widespread already and particularly strong during the 1940s and since the 1980s. However, there were also phases of relative stability during the 1890s, 1920s and 1970s, as indicated by long-term measurements of length changes and by modelling of mass balance. Conventional *in situ* measurements—and increasingly, airborne and satellite measurements—offer robust evidence in most glacierized regions that the rate of reduction in glacier area was higher over the past two decades than previously, and that glaciers continue to shrink. In a few regions, however, individual glaciers are behaving differently and have advanced while most others were in retreat (e.g., on the coasts of New Zealand, Norway and Southern Patagonia (Chile), or in the Karakoram range in Asia). In general, these advances are the result of special topographic and/or climate conditions (e.g., increased precipitation).

It can take several decades for a glacier to adjust its extent to an instantaneous change in climate, so most glaciers are currently larger than they would be if they were in balance with current climate. Because the time required for the adjustment increases with glacier size, larger glaciers will continue to shrink over the next few decades, even if temperatures stabilise. Smaller glaciers will also continue to shrink, but they will adjust their extent faster and many will ultimately disappear entirely.

Many factors influence the future development of each glacier, and whether it will disappear: for instance, its size, slope, elevation range, distribution of area with elevation, and its surface characteristics (e.g., the amount of debris cover). These factors vary substantially from region to region, and also between neighbouring glaciers. External factors, such as the surrounding topography and the climatic regime, are also important for future glacier evolution. Over shorter time scales (one or two decades), each glacier responds to climate change individually and differently in detail.

Over periods longer than about 50 years, the response is more coherent and less dependent on local environmental details, which means that long-term trends in glacier development can be well modelled. Such models are built on an understanding of basic physical principles. For example, an increase in local mean air temperature, with no change in precipitation, will cause an upward shift of the equilibrium line altitude (ELA; see Glossary) by about 150 m for each degree Celsius of atmospheric warming. Such an upward shift and its consequences for glaciers of different size and elevation range are illustrated in FAQ 4.2, Figure 1.

Initially, all glaciers have an accumulation area (white) above and an ablation area (light blue) below the ELA (FAQ 4.2, Figure 1a). As the ELA shifts upwards, the accumulation area shrinks and the ablation area expands, thus increasing the area over which ice is lost through melt (FAQ 4.2, Figure 1b). This imbalance results in an overall loss of ice. After several years, the glacier front retreats, and the ablation area shrinks until the glacier has adjusted its extent to the new climate (FAQ 4.2, Figure 1c). Where climate change is sufficiently strong to raise the ELA permanently above the glacier's highest point (FAQ 4.2, Figure 1b, right) the glacier will eventually disappear entirely (FAQ 4.2, Figure 1c, right). Higher glaciers, which retain their accumulation areas, will shrink but not disappear (FAQ 4.2, Figure 1c, left and middle). A large valley glacier might lose much of its tongue, probably leaving a lake in its place (FAQ 4.2, Figure 1c, left). Besides air temperature, changes in the quantity and seasonality of precipitation influence the shift of the ELA as well. Glacier dynamics (e.g., flow speed) also plays a role, but is not considered in this simplified scheme.

Many observations have confirmed that different glacier types do respond differently to recent climate change. For example, the flat, low-lying tongues of large valley glaciers (such as in Alaska, Canada or the Alps) currently show the strongest mass losses, largely independent of aspect, shading or debris cover. This type of glacier is slow in

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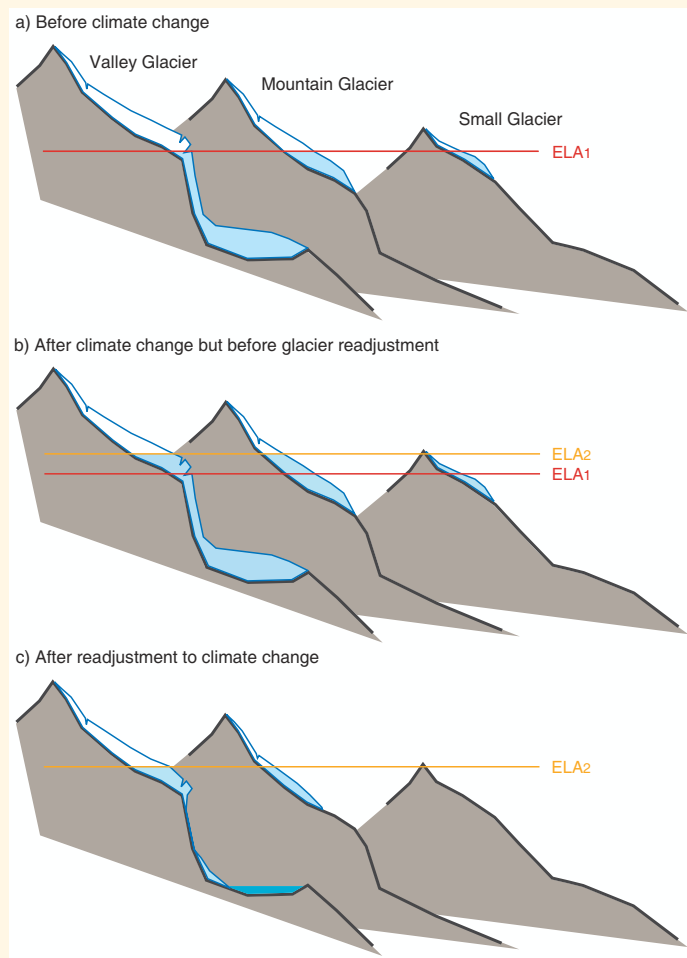
FAQ 4.2 (continued)

adjusting its extent to new climatic conditions and reacts mainly by thinning without substantial terminus retreat. In contrast, smaller mountain glaciers, with fairly constant slopes, adjust more quickly to the new climate by changing the size of their ablation area more rapidly (FAQ 4.2, Figure 1c, middle).

The long-term response of most glacier types can be determined very well with the approach illustrated in FAQ 4.2, Figure 1. However, modelling short-term glacier response, or the long-term response of more complex glacier types (e.g., those that are heavily debris-covered, fed by avalanche snow, have a disconnected accumulation area, are of surging type, or calve into water), is difficult. These cases require detailed knowledge of other glacier characteristics, such as mass balance, ice thickness distribution, and internal hydraulics. For the majority of glaciers worldwide, such data are unavailable, and their response to climate change can thus only be approximated with the simplified scheme shown in FAQ 4.2, Figure 1.

The Karakoram–Himalaya mountain range, for instance, has a large variety of glacier types and climatic conditions, and glacier characteristics are still only poorly known. This makes determining their future evolution particularly uncertain. However, gaps in knowledge are expected to decrease substantially in coming years, thanks to increased use of satellite data (e.g., to compile glacier inventories or derive flow velocities) and extension of the ground-based measurement network.

In summary, the fate of glaciers will be variable, depending on both their specific characteristics and future climate conditions. More glaciers will disappear; others will lose most of their low-lying portions and others might not change substantially. Where the ELA is already above the highest elevation on a particular glacier, that glacier is destined to disappear entirely unless climate cools. Similarly, all glaciers will disappear in those regions where the ELA rises above their highest elevation in the future.



FAQ 4.2, Figure 1 | Schematic of three types of glaciers located at different elevations, and their response to an upward shift of the equilibrium line altitude (ELA). (a) For a given climate, the ELA has a specific altitude (ELA1), and all glaciers have a specific size. (b) Due to a temperature increase, the ELA shifts upwards to a new altitude (ELA2), initially resulting in reduced accumulation and larger ablation areas for all glaciers. (c) After glacier size has adjusted to the new ELA, the valley glacier (left) has lost its tongue and the small glacier (right) has disappeared entirely.

a discussion of the improvements in techniques of measurement and understanding of the change made since AR4 (e.g., Lemke et al., 2007; Cazenave et al., 2009; Chen et al., 2011).

4.4.2.1 Techniques

The three broad techniques for measuring ice-sheet mass balance are the mass budget method, repeated altimetry and measurement of

temporal variations in the Earth's gravity field. Each method has been applied to both ice sheets by multiple groups, and over time scales ranging from multiple years to decades (Figures 4.13 and 4.14). The peripheral glaciers, surrounding but not strictly a part of the ice sheets, are not treated in the same manner by each technique. Peripheral glaciers are generally excluded from estimates using the mass budget method, they are sometimes, but not always, included in altimetric estimates, and they are almost always included in gravity estimates.