Hindu Kush-Himalayan Glaciers

Frequently asked questions

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FOR MOUNTAINS AND PEOPLE

What is a glacier?

- A glacier is a large body of ice, in which ice from a higher elevation is transported to a lower elevation. The body of ice must be at least 30 metres thick for this to take place. The movement of the ice is always from the upper part of the glacier towards the lower end (the snout), regardless of whether the glacier is advancing or retreating.

What is moraine?

- The glacier may also transport stones, rocks, and boulders inside or on top of the ice. These will eventually be deposited as 'moraine' at the edge of the glacier, on the side and at the front, forming moraine ridges. A terminal moraine ridge is formed when a glacier ends at about the same position over an extended period of time.

Why does a glacier transport ice?

- A glacier can be divided into an accumulation zone and an ablation zone. In the accumulation zone, in the upper part of the glacier, more snow falls than melts during the course of a year. The result is a net gain (income) in the form of snow. In the ablation zone, in the lower part of the glacier, more ice and snow melts than accumulates during the course of a year. The result is a net loss of snow and ice. The lost ice in the ablation zone is replaced by ice from the accumulation zone through transport of ice from the upper part to the lower part with the help of gravity. The accumulation is determined by deposition from snowfall, and snow and ice avalanches onto the glacier surface. The ablation is determined by the air temperature and solar radiation (heat from the sun) causing melting. Accumulation normally increases with increasing altitude, while melting increases with decreasing altitude.
- The altitude where accumulation equals ablation is called the equilibrium line altitude (ELA). The ELA for a particular glacier can only be found by measurement of accumulation and ablation. When, as often, this information is not available, the zero degree isotherm (ZDI) can be used to give an approximate indication of the ELA. The ZDI is the altitude at which the annual maximum temperature is at or below 0°C in a free atmosphere. The ELA is approximately located at the same altitude as the permanent snowline, the altitude where snow can be found at any time of the year.

What is the mass balance?

- The glacier mass balance is the difference between the total accumulation of snow on the glacier and the total ablation of ice and snow calculated over a year. The glacier mass balance can be positive or negative (or zero). If the accumulation is substantially higher than the ablation over a number of years, then the glacier will grow in mass. If the ablation is substantially larger than the accumulation over a number of years, the glacier will reduce its mass.

Why do glaciers 'grow' and 'shrink'?

- A glacier is a form of storage. For storage to be in an equilibrium state the input (precipitation/snowfall) at the accumulation zone and output (melting) at the ablation zone should be equal. In other words the mass balance is zero. This balance can be changed as a result of changes in the input (more or less snowfall) and/or changes in the amount of melting (due to warming). Changes in snowfall can result because of changes in the overall annual precipitation, and/or changes in the timing of the precipitation (eg, more falling in the summer as rain). Changes in melting can occur as a result of increased average annual air temperatures, and/or changes in the solar radiation. Melting will be affected if the glacier is covered by moraine, dust, or soot particles (eg, a thin layer of soot on the glacier surface that increases heating, or a thick layer of debris on the surface that acts as an insulator).

What is glacial retreat and glacial advance?

- A glacier is said to retreat or advance when the position of the end (terminus or snout) of the glacier changes, advancing down the slope or retreating higher up the slope.

Does glacial advance or glacial retreat mean that a glacier has more or less ice?

- In general, a change in the position of a glacier snout is a good indication of change taking place in the total amount of ice in the glacier, but the relationship is not direct; the position of the snout is only an indicator, it does not give exact information about changes (or otherwise) in the amount of ice in the glacier.

What factors affect the length of the glacier?

- If the glacier mass is accumulating faster than it is melting, in other words if the glacier mass balance is positive over a number of years, it will normally result in the glacier snout advancing. Similarly, if the glacier mass balance is negative over a number of years, it will normally result in the glacier snout retreating.
- The position of the snout is also influenced by other factors, particularly the bottom topography under the glacier ice, and whether the glacier is covered by moraine or not. For example, a glacier with a negative mass balance can lose ice through decrease of ice thickness without the position of the snout changing.
- Some glaciers show a so-called surging behaviour. Such glaciers do not have a straight relationship between the mass balance and the snout position. They may have a stagnant snout position over many years, followed by a very extensive and rapid advance, which in turn is replaced by a (rapid) retreat.
- Some glaciers may advance simply because more of the ice mass moves downslope, without any change, or even with a reduction, in the total ice mass. The change is thought to be due to increased elasticity resulting from an increased internal temperature of the ice (similar to heating thick sugar syrup). The glacier then becomes longer but thinner.

What determines the rate of retreat (or advance) of a glacier?

- In most cases, the rate at which a glacier retreats or advances depends on the rate at which the mass balance (total amount of ice) changes and the size and geometry of the glacier. However, there is a time lag between the change in the glacier mass balance, and the change in its snout position. In other words, the position of the snout may not change for some time after the glacier starts to accumulate or lose ice.
- The time that a glacier takes to respond to climatic perturbation causing changes in glacial fluctuation (heating, cooling, changes in precipitation) is called the response time. Larger glaciers have a larger response time or longer time lag; smaller glaciers respond more quickly. For large glaciers, the time lag may be in the range of decades, while for small glaciers it may be a few years.
- The extent of deglaciation (loss of ice) and rate of retreat of a glacier is strongly influenced by the altitude. A glacier accumulates ice above the equilibrium line altitude (ELA) and loses ice mass below this altitude. Glaciers that have most of their accumulation area at high altitude are retreating less rapidly than those at lower altitude.

Are glaciers good indicators of climate change

- Changes in climate include rising (or lowering) temperatures leading to increased or reduced melting, and changes in the amount and timing of precipitation (snowfall), leading to changes in the amount of accumulation.
- In general, changes in the position of the glacier snout, are a good indicator of the mass balance, and thereby of the climate. However, the snout position is only a general indicator. Fluctuation in a glacier terminus is an indirect, delayed, and filtered signal of climate change. Measurements of the mass balance are needed in order to identify any actual changes in the amount of ice in the glacier. Mass balance is a direct and undelayed signal of climate change.
- The snout position of glaciers subject to surging may not be in phase with the mass balance, and thereby climatic shifts, and should not be used as a climate indicator. Some glaciers in Pakistan may be subject to surging phenomena.
- Observations of a single glacier or group of glaciers in a single small region should not be used to make generalised statements about climate change.

The Hindu Kush-Himalayan Glaciers

Are the Hindu Kush-Himalayan glaciers retreating?

- The majority of observations on glacier fluctuation indicate that the Hindu Kush-Himalayan glaciers are retreating substantially, especially in China, India, Nepal, and Pakistan. The glaciers in the Karakorum range are also in a general state of retreat, although some of these glaciers may be advancing.
- The glacier observations in the Himalayan region are mainly based on observations of changes in terminus position (from satellite images and some ground-based observations). In most Himalayan glaciers, the retreat can be seen clearly using the position of the Little Ice Age moraine ridges as a baseline.
- Mass balance measurements are the only way to determine whether a glacier is really losing volume. Unfortunately mass balance measurements in the Himalayas are rare and intermittent. Until mass balance measurements are available for a variety of glaciers at different altitudes and in different parts of the extended Himalayan ranges (east to west) it will be difficult to make a detailed or accurate scientific assessment of the extent and rate of deglaciation, or of the associated climate change factors.

What is the rate of glacier retreat in the Hindu Kush-Himalayas?

- In general, glaciers have been retreating worldwide since the end of the Little Ice Age (approximately 1850). The rate of glacial retreat has increased since the latter half of the 1900s as a result of a rise in global temperatures (generally thought to be the result of human activity).
- In the Himalayas, this has meant a substantial reduction in the size of glaciers with a retreat rate more rapid than the global average. Reported rates of retreat include 160 m per year on average from 1988 to 1993 for the Luggye glacier in Bhutan; and 35 m per year on average from 1984 to 1998 increasing to 60 m per year between 1988 and1993 for the Raphstreng glacier in Bhutan. The valley glaciers on the right flank of the Poiqu Basin on the eastern slope of the Xixiabangma mountains in China retreated at a rate of 45-68m per year over the last twenty-five years with a 100m shift upslope in the elevation of the termini.
- The retreat rate is determined by the size and geometry of each glacier, the altitude of the glacier, and the local climatic conditions. There cannot be one representative rate for the whole region and it is not useful to try to establish a range of retreat rates or average retreat rate.

Is the rate of glacier retreat slowing down?

- Some observations suggest that the retreat rate of individual glaciers has slowed down recently. This does not necessarily mean a slowing in rate of change of air temperature. Various factors can play a role. For example:
  - The retreat rate depends on the ice thickness, determined by the bottom topography. If the terminus retreats into an area with thicker ice, the retreat rate (as seen in the snout position) may decrease although the rate of loss of ice mass may be the same.
  - The retreat of the glacier is a response to negative mass balance over a number of years. As the glacier reduces its volume it will approach a new state where accumulation and ablation is similar, i.e. a new steady state position where the glacier is in balance with the climate. When this state is approached (smaller difference between accumulation and ablation) the retreat rate will slow down.

Will the Himalayan glaciers vanish in the next 30-40 years?

- By the end of the century, smaller glaciers below 5000m will probably disappear and larger glaciers will be reduced in mass, manifesting in a reduction in glacier length (retreating snout) and thickness (lowering of ice surface). The reason for this can be summarised as follows: the average position of the zero degree isotherm (ZDI) in the Himalayan ranges is thought to be around 5400 metres above sea level (masl). In other words, above this altitude, the free air temperature never rises above zero. The ZDI is an approximate indicator of the level above which glaciers accumulate ice. The accumulation zones of most Himalayan glaciers extend much higher than this elevation. As overall temperatures rise, the position of the ZDI will also move to higher altitude. For example, a 4°C rise in temperature would cause the ZDI to rise by about 650m to 6050 masl. (Temperatures in the Indian subcontinent are predicted to rise by between 3.5 and 5.5°C by 2100.) Even at this level, many of the Himalayan glaciers will still lie above the ZDI and will continue to exist. Equally, large glaciers will retreat more slowly than small glaciers and even at lower elevations will take longer to disappear completely.

- The potential impact of changed precipitation patterns on the glaciers is still poorly understood. Climate change models suggest that there will be changes in both geographical, seasonal, and intensity distribution of rain (and snow) fall. But the specific projections are inconsistent and no general conclusions can be drawn.

Does deglaciation mean less water available?

- The Himalayan glaciers provide the headwaters of ten major rivers in Asia. The glaciers store the water from the time of precipitation in the form of ice and release it slowly over time. The glacier contribution to river flow is most important in the dry season when there is no rainfall and in areas of generally low precipitation. The amount of meltwater depends on the mass of ice available for melting. In the early stages of deglaciation, more ice will melt and there will be more water in the rivers. As the glaciers reach a new equilibrium with a smaller overall mass, melting will be reduced. The timing and quantity of these changes is highly uncertain and needs more research. Changes in water availability will be most important in those river basins where the contribution of meltwater runoff is significant.
- Changes in precipitation from snowfall to rainfall (as temperature increases) do not mean that there will be changes in overall (annual) water availability, rather that water previously stored in the form of ice and snow and slowly released over time, will flow directly into the rivers at the time of rainfall. This means more water in the rivers in the rainy season and less in the dry season, which translates into more floods and more droughts, and the need to find alternative forms of water storage. This will have most impact in the upstream areas of rivers where meltwater plays a greater role.

What do the Himalayan glaciers tell us about climate change

- The overall changes in the Himalayan glaciers, with loss of small glaciers and retreat of others, are consistent with an increase in average temperatures, and possibly change in precipitation patterns. Observations of a single glacier (whether small or large) cannot be used to extrapolate any general statements on climate change as there are too many site specific factors that can affect the behaviour of a specific glacier. It is important to compare and summarise observations from a number of glaciers in different areas, of different size, and at different altitudes to draw clear scientifically justified conclusions about the changes that are occurring. Direct measurements of Himalayan glaciers are few and far between, and generally restricted to the more accessible glaciers. Remote observations (from satellites) only show approximate indicators like glacier length and no comparative images are available for historical periods. A much increased level of scientific observation will be needed before the changes in the Himalayan glaciers can be accurately recorded and reliable predictions made. Statements based on individual glacier behaviour may have contributed to recent contradictory interpretations that have appeared in the media.

Summary

- The general behaviour of the Himalayan glaciers is clear – overall they are currently in a state of rapid and substantial retreat. A few glaciers may be acting differently as a result of their different individual physical 'character'.
- The rapid loss of glacier mass is resulting in more meltwater being added to the Himalayan rivers. As the glaciers approach a new (smaller size) steady state, this additional meltwater contribution will cease.
- The total runoff in the Himalayan rivers is dependent on i) melting snow, ii) melting ice, and iii) the volume and nature of rainfall. All three factors are of importance and interpretations on changes in water runoff has to take all three components into account.

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