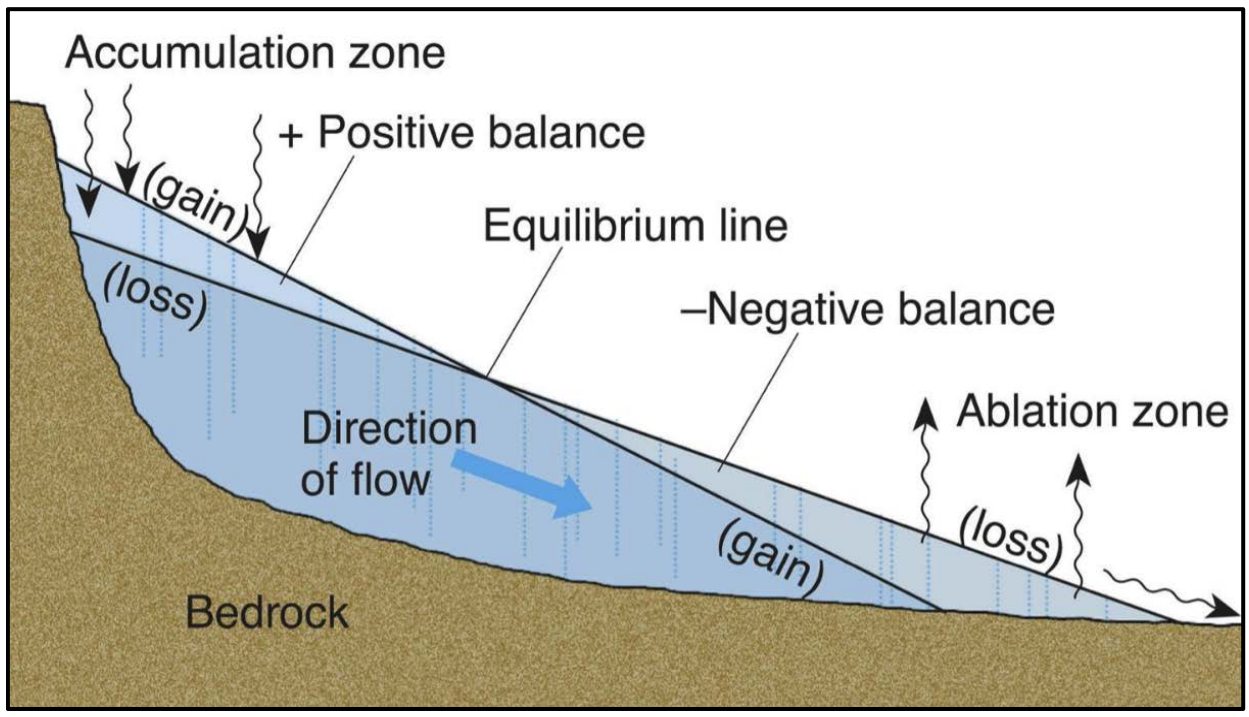
Resource B:

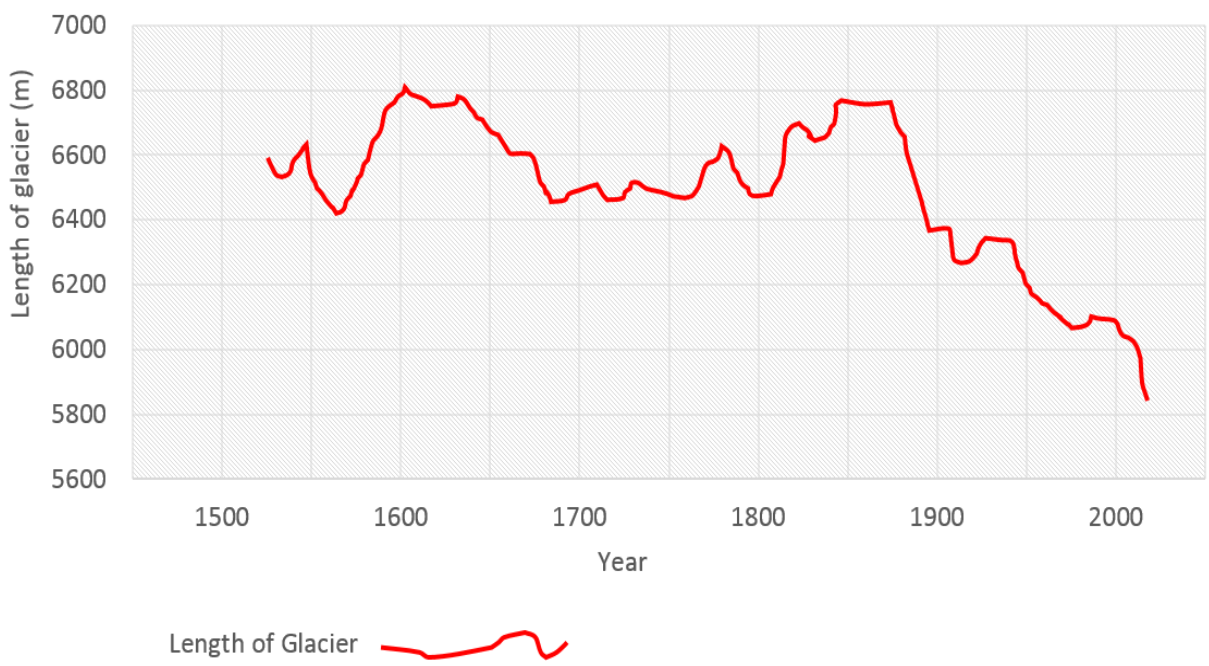
Resource B1:

A mass balance diagram for a valley glacier:



Resource B2:

A graph showing the changing length of the Upper Grindelwald glacier:



Resource B4: Valley Glaciers

The polar ice caps are not the only places where permanent ice exists. In high altitude areas, glaciers can form wherever it is cold and shaded enough that more mass of snow falls over the winter than the mass of ice which melts in the summer (accumulation of snow exceeds ablation of ice). Over time, the snow which builds up in these areas compacts under the weight of snow on top of it, and the surface of it melts and freezes diurnally (through a 24 hour period). This squeezes the air out of it and turns it first into 'firn' (sometimes called névé) and then genuine ice.

The area in which a glacier forms is called a cirque – often described as an 'armchair-shaped' geological feature. When the mass of snow and ice is sufficiently thick, it begins to move due to a combination of slope, gravity and pressure which melts the base of the ice allowing it to slide - such glaciers are thus called 'warm based'. On steeper slopes, this basal sliding can occur with as little as 15m depth of snow/ice. Ice more than 50m thick also experiences 'plastic flow' where ice near the surface moves faster than ice deep down in the glacier. The ice moves out of the cirque and down the valley, picking up weathered rocks from the landscape and scouring the bedrock with them (abrasion) to widen and flatten the valley bottom from the typical 'V-shape' of a river valley into a 'U- shape'. The cirque glacier is called a 'valley glacier' once it extends below the lip of the cirque where it began.

Because glacial mass is affected by long-term climatic changes (e.g., precipitation, mean temperature, and cloud cover) glacial mass changes are considered among the most sensitive indicators of climate change and are also a major source of variations in sea level. Glaciers are almost always melting near their snout, called the 'ablation zone', and gaining mass of snow in their 'accumulation zone' at the head of the glacier in the cirque. The altitude on the glacier where there is no net change in the volume of snow and ice is called the 'equilibrium line'. If a glacier overall has a negative mass balance (more melting than accumulation), the equilibrium line will be rising in altitude over time, even as the glacier potentially flows faster due to more melt water under the ice reducing friction. Glaciers typically move at 1m per day, but can surge 30x faster than this or more, if lots of snow is accumulating at the top, and vigorous melting is happening nearer the snout.

Resource B3:

Photos of the end of the Upper Grindelwald glacier on the same day of the year during:

i) Summer 2010

ii) Summer 2013