Glacier systems: comparative case studies

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Synopsis
The world’s ice is melting due to climate change. This is reflected in the retreat of most glaciers in recent decades.

Glaciers may be thought of as systems in which there is a balance between inputs of snow, and outputs from melting and evaporation. This balance determines whether glaciers are advancing, retreating, or are more or less stationary.

Local climatic conditions can mean that some glaciers go against the general trend, even within a region. Other factors that can produce unusual behaviour in glaciers are also involved.

Aside from the immediate impact of glaciers shrinking or disappearing, there are wider impacts on human behaviour. Glaciers are important sources of water, and feed a number of the world’s major rivers. Retreating glaciers can also point to the importance of taking action against climate change.

Key terms
- glacier budget
- accumulation
- ablation
- systems
- climate change/global warming

Learning objectives
After studying this GeoFile you should be able to:

- understand the concept of glacial budget
- explain how this influences the advance and retreat of glaciers and ice sheets.

The case studies apply the concept of budget to real glaciated areas and will help you to understand the factors that affect glacial advance and retreat.

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Glacier-like conditions on Ben Nevis

A BBC news report in August 2014 stated that hazards associated with arctic and alpine areas, but considered ‘extremely unusual’ in the UK during the summer, had been found on Ben Nevis:

- On the mountain’s north face, snowfields remained in many gullies and upper scree slopes.
- These snowfields included areas of compacted, dense, ice hard snow – névé.
- Névé is the first stage in the formation of glaciers.
- There were some sheets of snow weighing hundreds of tonnes.
- The snowfields also contained tunnels and fissures, known as bergschrunds.

‘Surprise! Glaciers appearing in Scotland’ (Figure 1). Such a headline would indeed be a surprise. Not only did glaciers disappear from Scotland at the end of the last ice age but we also live at a time when global climate change is leading to the almost worldwide retreat of glaciers and ice sheets (Figure 2).

Mountain glaciers are retreating in many parts of the world. One particular area scientists are concerned about is Alaska. There, the Columbia Glacier has retreated by 15km over the past 25 years. Many of the mountains in the area now have much less snow. It is believed the situation is so extreme in Alaska that of the 2,000 glaciers observed, 99% of them are retreating.

In Europe, the situation is worrying too. Europe’s glaciers are thought to have lost around a quarter of their mass in the last eight years.

To understand why glaciers and ice sheets are retreating around the world, although advancing in a few areas, it is helpful to understand the concept of glacier budget.

Glacier budget

The word ‘budget’ is usually used about money, meaning the balance between income and money that is spent. In systems terms, a budget is the balance between inputs and outputs. This is the same with glaciers and ice sheets. They are examples of open systems, with inputs and outputs of:

- energy – inputs from the sun and outputs of heat from movement and friction, and
- matter – inputs of snow and rock and outputs when melting occurs

Within the glacial system there are stores of matter (such as rock and ice) and processes occurring (like melting and evaporation) that change the inputs into outputs (Figure 3). This was covered very thoroughly in an earlier GeoFile (September 2010 number 622).

All glaciers and ice sheets are either growing or retreating, depending on the balance between accumulation (the gains in mass) and ablation (losses of mass).

Accumulation

Glaciers and ice sheets grow through precipitation. If inputs of snow are greater...
than losses through ablation, then a glacier will grow.

- Snow builds up and is compressed by the weight of fresher snow above.
- This compressed snow gradually turns into névé, ice that has been partially melted and refrozen and compacted.
- Névé has quite a lot of air contained within it, so it is granular.
- In time, more air is squeezed out and after about a year this changes to a more compressed form of ice called firn.
- Eventually hard ice forms. For this process to occur there needs to be a certain level of energy or insolation from the sun. If insolation is reduced, for example due to more cloud cover, then lower temperatures will encourage ice to develop. If there is a higher level of energy over a year then more melting and evaporation will occur, and a glacier will retreat (outputs will exceed inputs).

Most accumulation occurs towards the upper end of a glacier, where it is colder at higher altitudes and ice has a greater chance to develop. The part of a glacier that experiences net accumulation is called the accumulation zone (Figure 3).

A glacier is more than just ice and snow, however. Its mass is also made up from:

- rock debris that may fall onto it from valley sides as the result of weathering
- glaciers may also be added to by avalanches.

**Ablation**

Ablation is the other side of a glacier’s budget. It refers to the loss of mass from a glacier or ice sheet; this is due to melting and evaporation. Ablation tends to be greatest in the lower section of a glacier (Figure 3). Temperatures are higher at lower altitudes, so more melting and evaporation occur.

Glaciers and ice sheets that flow into a lake or the sea often lose large masses of ice that break off to form icebergs. This is a process called calving; there are some impressive videos showing this process.

The part of a glacier that experiences net ablation – where losses to melting and evaporation exceed accumulation – is called the ablation zone.

We can now look at specific areas of the world and see how the idea of glacial budget can be applied to real glaciers and ice sheets.

**Why are most ice sheets and glaciers retreating?**

The behaviour of glaciers is very complex, and melt rates can be influenced strongly by many factors.

Ice in glaciers and ice sheets can range from a few

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**Case studies**

**Glacial retreat in the French Alps: the Mer de Glace**

According to recent research, glaciers in the French Alps have lost about a quarter of their area since the 1970s. In the late 1960s/early 1970s, the ice fields on Mont Blanc and the surrounding mountains of the European range covered some 375 sq km; by the late 2000s, this area had fallen to about 275 sq km.

This represents an average loss of some 26% over the last 40 years. The retreat of glaciers in the French Alps has not been uniform. The greatest losses have been in the southern parts of the Alps. In the Belledonne Massif (Massif is a French word for a large area of mountains), for example, the...
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Glaciers have almost completely disappeared. In the Ecrins Massif, the rate of glacier retreat is almost three times greater than in the Mont Blanc area. Broadly, the rate of glacier retreat is less significant in the northern Alps than the southern Alps.

- The southern mountains are at a lower altitude and so are warmer.
- There is more precipitation and cloud cover in the north.
- In other words the inputs of mass are greater in the north, and there is also less of the sun’s energy or insolation reaching the ice, so retreat is slower.

**Mer de Glace**
- The Mer de Glace (‘sea of ice’) (Figure 4), on the northern side of Mt Blanc, is the largest glacier in the western French Alps.
- This glacier is gradually thinning and retreating.

- A report published in 2012 indicated that a third of the thinning in the lower section of the glacier was due to reduced flow from higher up the glacier, and the remaining third was due to ablation of the glacier snout.
- A recent study in 2014 suggested that a minimum retreat of 1200m is likely by 2040.

You should be able to find some impressive vertical photographs on the internet showing stages in the retreat of this glacier.

**Glaciers in the Himalayas**
Like many other mountainous regions in the world, glaciers are retreating...
Glaciers are very sensitive to changes in temperature, so studying them can help us understand how the earth’s climate is changing. Since the early 20th century, most glaciers have been retreating; in fact, several have disappeared entirely. Many scientists attribute this glacial retreat to the Industrial Revolution, which accelerated in the mid-19th century, and ongoing climate change since that time.

**Conclusion**

Figures from the World Glacier Monitoring Service suggest that the earth’s glaciers are melting so fast that many will disappear by the end of the 21st century. The retreat of glaciers and ice sheets will have many geographical consequences, many not fully understood.

- While summer melting of ice increases, this can add to flooding.
- Glacial meltwater provides water for agriculture and communities in otherwise dry areas of the world like Pakistan near the Himalayas.
- The loss of ice changes the earth’s albedo (reflectivity of the surface), with consequences for local and global weather patterns and climate. The lower the reflectivity of the surface, the greater the impact on global warming.
- Glacier and ice sheet retreat continues to be monitored and studied and provides useful evidence of climate change. They point to the need to change the way we live to reduce human impact on the earth’s climate.
Focus questions

1. Explain how glaciers operate as a system.
2. How do the following factors influence why glaciers are retreating in some parts of the world yet advancing in others? Use located examples in your answer.
   - Altitude
   - Solar energy (insolation)
   - Climate change
   - Rock debris – ash from a volcanic eruption – on the surface of a glacier.
3. Carry out some research on the human and natural consequences of glaciers and ice sheets retreating.
   Consider:
   - Where in the world will the greatest impact of climate change and melting glaciers be felt?
   - What is the global threat of glaciers melting?
   - Who is most at risk from glaciers melting and sea levels rising?

Learning checkpoint

1. What is meant by the term ‘glacier budget’?

2. Why are most glaciers in the world retreating?

3. List some of the factors that influence the advance and retreat of glaciers.

4. Should we be concerned that glaciers around the world are retreating? Why?