Ice Cap Glaciers in the Arctic Region

John Evans Glacier, Ellesmere Island (Robert Bingham, U. Aberdeen)
• Iceland
• Svalbard
• Ellesmere and Baffin Islands
• Severny and Anzhu Islands

Topics:
• Temperate vs non-temperate glaciers
• Tidewater glaciers
• Jökulhlaups
• Sandurs
• Surge behaviour
Ice cap

• An ice cap is a relatively flat glacier (often occupying an upland area) that is less than 50,000 km$^2$ in area (<225 x 225 km)

• This is not an ice-cap!

• Many Arctic land masses north of 70° have ice caps

• Ice caps have outlet glaciers
Temperate vs non-temperate glaciers

• A temperate glacier is at its melting point, throughout its thickness, for most of the year
• A polar glacier is below its freezing point, from surface to base, through most of the year
• A sub-polar or polythermal glacier is intermediate between these extremes, with both temperate and polar ice depending on the ice thickness and the elevation
• Temperate glaciers are common in areas where there is a lot of precipitation, so that while it might not be that cold, there is plenty of snow accumulation in winter
• Iceland and Svalbard have temperate glaciers, largely because of their proximity to the Gulf Stream
Tidewater glaciers

• A tidewater glacier reaches the ocean, and therefore exists in an area that either has a great deal of precipitation (as snow) or is very cold

• Iceland does not have tidewater glaciers, but the other Arctic ice-caps do
Jökulhlaup

- A jökulhlaup is a large outburst of water that was stored either beneath, on or in front of a glacier
- Iceland is famous for jökulhlaups, most of which are related to subglacial melting by volcanism, but any glacial outburst flood is a jökulhlaup
Sandur

- A glacial outwash plain composed of sand and gravel – mostly as braided deposits
- Some sandurs are strongly affected by jökulhlaups
Surge glaciers

• Most glaciers move relatively steadily
• Some glaciers surge dramatically on time scales of months to years (with years to centuries of relative quiescence)
• Surging can be facilitated by changes in water flow (as we saw in Greenland), by temperature changes, or because of failure of the bed material
• Many of the Svalbard glaciers show surge behaviour
The largest ice cap on Iceland is Vatnajökull, with an area of 8,160 km^2. It reaches a thickness of >1,000 m.
Two different types of sub-glacial lakes. The one on the left is relatively stable. The one on the right is unstable.

H. Björnsson, 2002
Ice-surface subsidence above sub-glacial lakes that have been drained by jökulhlaups.
The Skeidara´ sandur (outwash plain) from Vatnajokull to the coast. Dykes control the river on the left hand side. The bridge across the river is 900 m long.

H. Björnsson, 2002
Major jökulhlaup outflows often produce large-scale cross beds, either normal, or reverse like these (because of standing waves). Vatnajökull

Russell, et al., 2006, Geomorphology 75, 33–64
The lake level of Grímsvötn 1930–2000. The lake level ascends until a jökulhlaup takes place. In 1996 the lake rose to the level required for floating of the ice dam. The average interval is about 4 years, although many are around 6 years.
Figure 1: Schematic representation of the glacial lake outburst flood scenario. The graph shows the elevation (m a.s.l.) versus distance (km) with key features labeled:

- Ice dam
- Lake water level
- Water
- Bedrock
- Ice

The graph illustrates the distribution of water and ice at different elevations along the distance axis, highlighting the critical points of interest in the scenario.

H. Björnsson, 2002
Jökulhlaup cascading off the margins of the Eyjafjallajökull volcano, Iceland, on 14th April 2010

Ice-cap and outlet glaciers on Svalbard
Surge Glaciers

• ~1% of glaciers on earth show surge behaviour (13 to 90% of Svalbard Glaciers)
• Glacier becomes decoupled from its base
• On Svalbard most surge glaciers are in areas where the bed is soft sedimentary rock (and therefore the till is soft and clay-rich)
• Base temperature also appears to be an important factor

Usherbreen started to surge in 1978, and the front has advanced 1.5 km and covered an area of 4.5 km². During the first two years the front advanced more than 1 m/d, and the front was still advancing 0.15-0.20m/d in 1985, seven years after the start. The mean gradient of the lower 7km decreased from 3.3 grad. to 1.8 grad. during the surge. The volume of ice transported down the glacier from higher to lower parts during the surge was 815 x 10hm³, which is almost 20% of the total glacier volume.

Old ice-cored ridges in front of the glacier were reactivated, and the whole ridge system was pushed forward, in the summer of 1985 at a speed of about 0.05 m/d. Parts of the ridge system were moved 200 m during this surge. New ridges were developed on the flat sandur in front of the old ridge system. This demonstrates that the glacier advanced further than in any previous surge.

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Fig. 2. The front of Usherbreen after the surge in August 1985. Photo direction is south–north. Note the steep front and the folded moraine ridge systems.
Murray et al, 1998, J. Glaciology, V. 44

Bakaninbreen
Bakaninbreen (B) before (1970) the 1985 to 1990 surge

Bakaninbreen after (1990) the 1985 to 1990 surge
In the surge area (upglacier from the surge front) the ice-sheet base is warm (at the freezing point). Downglacier from the surge front the basal ice is cold.

Mechanism

• The Bakaninbreen surge (1985-1990) took place in an area with a warm base
• The front of the surge was at the warm-cold boundary, and that boundary moved ahead during the surge (because the melting front moved)
• Part of the movement in the warm-cold boundary was due to heat created by sliding
• Eventually the movement stopped because there wasn’t enough heat to warm any more of the base

In late March 1991, Skeiðarárjökull began to surge. The surge motion was not measured but deduced from the formation of abundant new crevasses, which was monitored from the air. Crevasses initially formed 10 km up-glacier from the terminus and propagated up- and down-glacier.

The area affected by increased sliding, producing crevasses, continued to expand up-glacier until the end of October. It ultimately extended some 45 km upwards from the front to within 5 km of the centre of the ice dam containing the Grímsvötn lake.

In early May, a 50-m-high surge front reached the eastern part of the terminus and, after having advanced 450 m, stopped in mid-July.

In mid-September drainage began from Grímsvötn lake. The discharge of the lake water increased approximately exponentially and then fell rapidly; this may be explained as drainage through a single tunnel from the lake. The drainage, however, failed to develop into a normal outburst flood and terminated when less than a quarter of the lake volume had drained.

In late September, the western half of the terminus started to advance, and moved forward about 1,000m before halting in early November.

Bjornsson, 1998
(non-surge)
Nauthagajökull

Múlajökull
(surge type)

Johnson et al., 2010, Geology, V. 38
Figure 5. Drumlins from Figure 1 superimposed on 1995 air photo, showing that most drumlins are located below deep longitudinal crevasses or crevasse swarms near glacier margin.