Changing Landscapes:
Glaciated Landscapes

Climate change and its impacts

What you need to know

- Causes of climate change through the Quaternary Ice Age including glacials, interglacials and stadial periods and thresholds for change
- Causes of changes in the glacier budget through historical time including the Little Ice Age
- Past distribution of valley glaciers and ice sheets during the Quaternary Ice Age
- Present day distribution of ice masses including valley glaciers and ice sheets

Research task

How and why climate has changed throughout the Quaternary Period, and its impacts on the distribution of ice masses (valley glaciers and ice sheets)

To include the following:

- What is meant by these terms: glacial, interglacial and stadial period
- The cycles of changing temperature during the Quaternary Ice Age: time scales, UK names for the different episodes, amount and rates of temperature change
- <u>Brief</u> details about the causes of these cycles – and the thresholds for change
- Causes of changes in the glacier budget through <u>historical</u> time including the Little Ice Age
- The changing distribution and extent of ice masses during the Quaternary up to the present day – this should include details at the global, European and UK scales

Resources – useful starting points

Quaternary Ice Age – Wikipedia (naturally) has some useful starting points

GCSE level details about Milankovitch cycles:

http://geography.about.com/od/learnabouttheearth/a/milankovitch.htm)

Pleistocene Ice Age – Wikipedia.

Historical climate change (Holocene Climate Change): http://www.atmo.arizona.edu/students/courselinks/fall12/atmo336/lectures/sec5/holocene.html

Royal Geographical Society (changes in ice sheets during the quaternary): http://www.rgs.org/OurWork/Schools/Teaching+resources/Key+Stage+3+resources/Glaciation+and+geological+timescales/Ice+Ages+and+geological+timescales.htm – which provides teaching resources, not all of which are useful as they are worksheets for use in the classroom, but it does have two PowerPoint slideshows…which have lots of useful info including maps of glacial extent, though seem to be mainly about the Last Glacial Maximum (LGM - Late Devensian, c.18k years ago).

Research task

What is meant by :

- **Glacial**
  - an interval of time (thousands of years) within an ice age that is marked by colder temperatures and glacier advances. (W) A period in the earth's history when polar and mountain ice sheets were unusually extensive across the earth's surface.
- **Interglacial**
  - periods of warmer climate between glacial periods. (W)
- **Stadial period**
  - a period of colder climate during an interglacial (e.g. Loch Lomond re-advance c. 11-10ka)

Research task

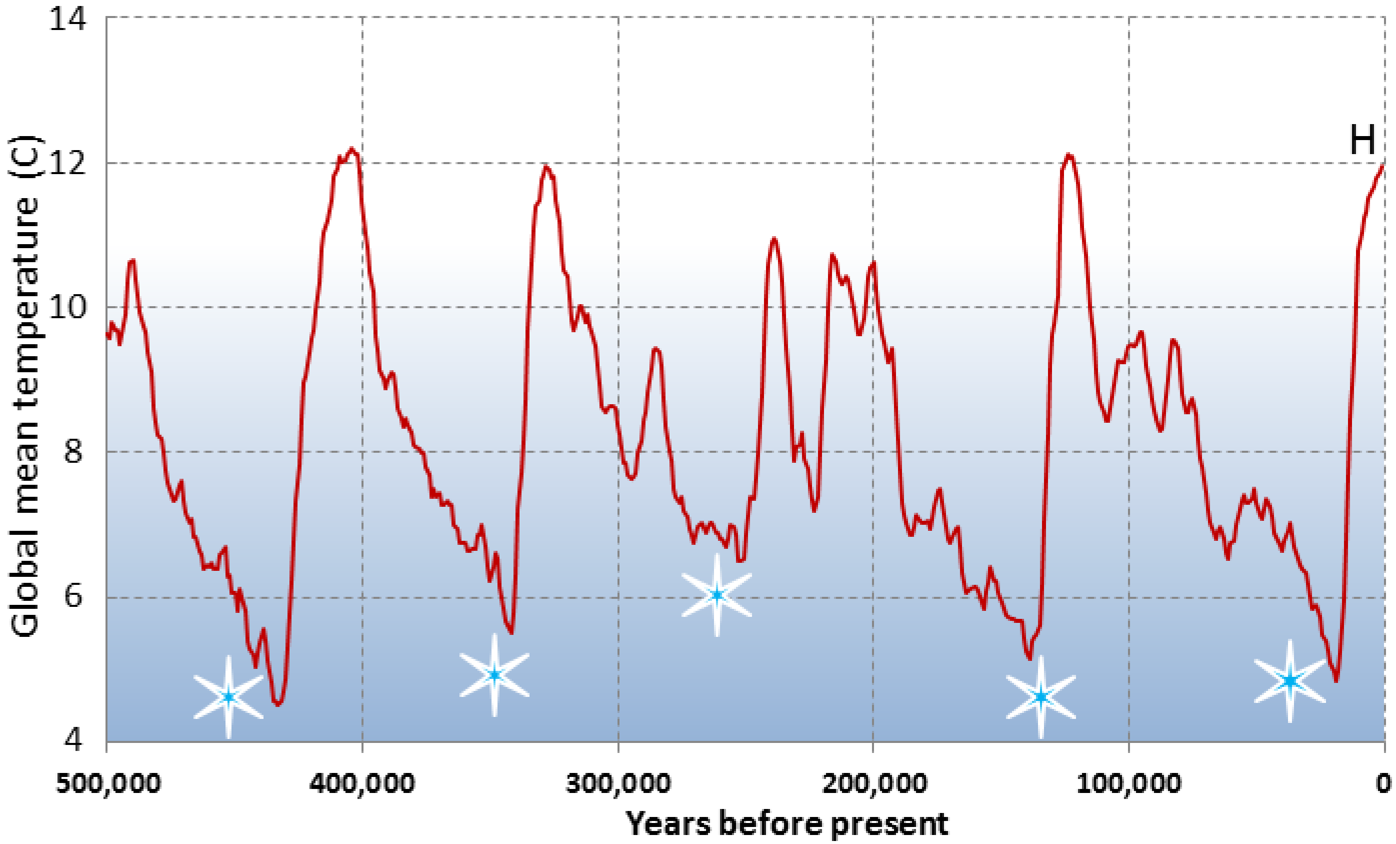
The cycles of changing temperature during the Quaternary Ice Age: time scales, UK names for the different episodes, amount and rates of temperature change

Great Britain	Inter/Glacial	Period (ka)	Epoch
Flandrian	interglacial	present – 12	Holocene
Devensian	glacial period	12 – 71	Pleistocene
Ipswichian	interglacial	115 – 130	
Wolstonian	glacial period	130 – 200	
Hoxnian	interglacial(s)	374 – 424	
Anglian	glacial period(s)	424 – 478	

Wikipedia

Research task

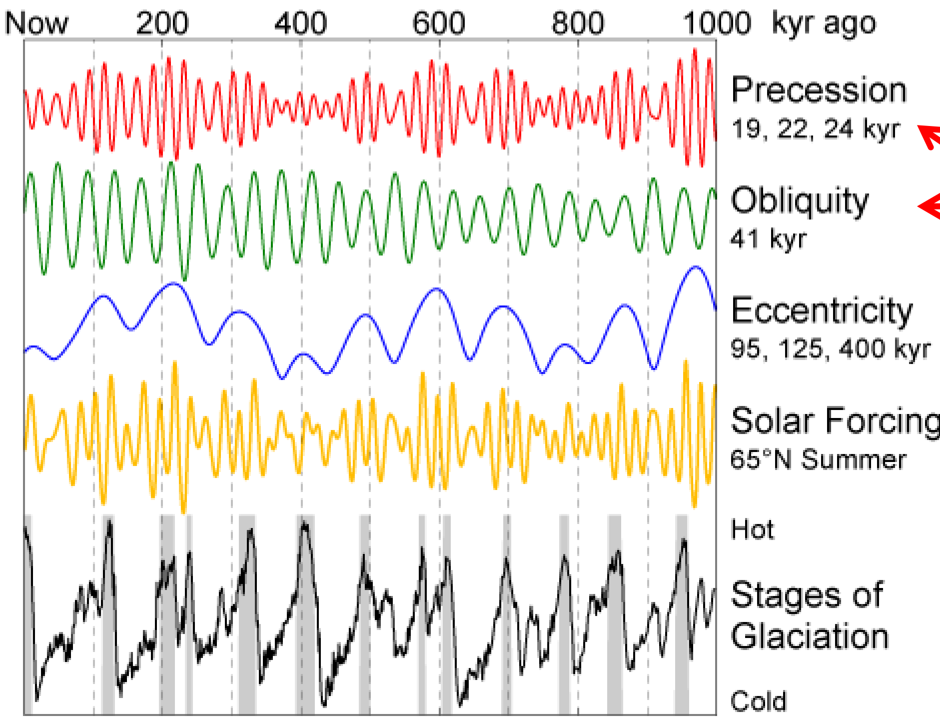
The cycles of changing temperature during the Quaternary Ice Age: time scales, UK names for the different episodes, amount and rates of temperature change



https://opentextbc.ca/geology/chapter/16-1-glacial-periods-in-earths-history/

Research task

<u>Brief</u> details about the causes of these cycles – and the thresholds for change



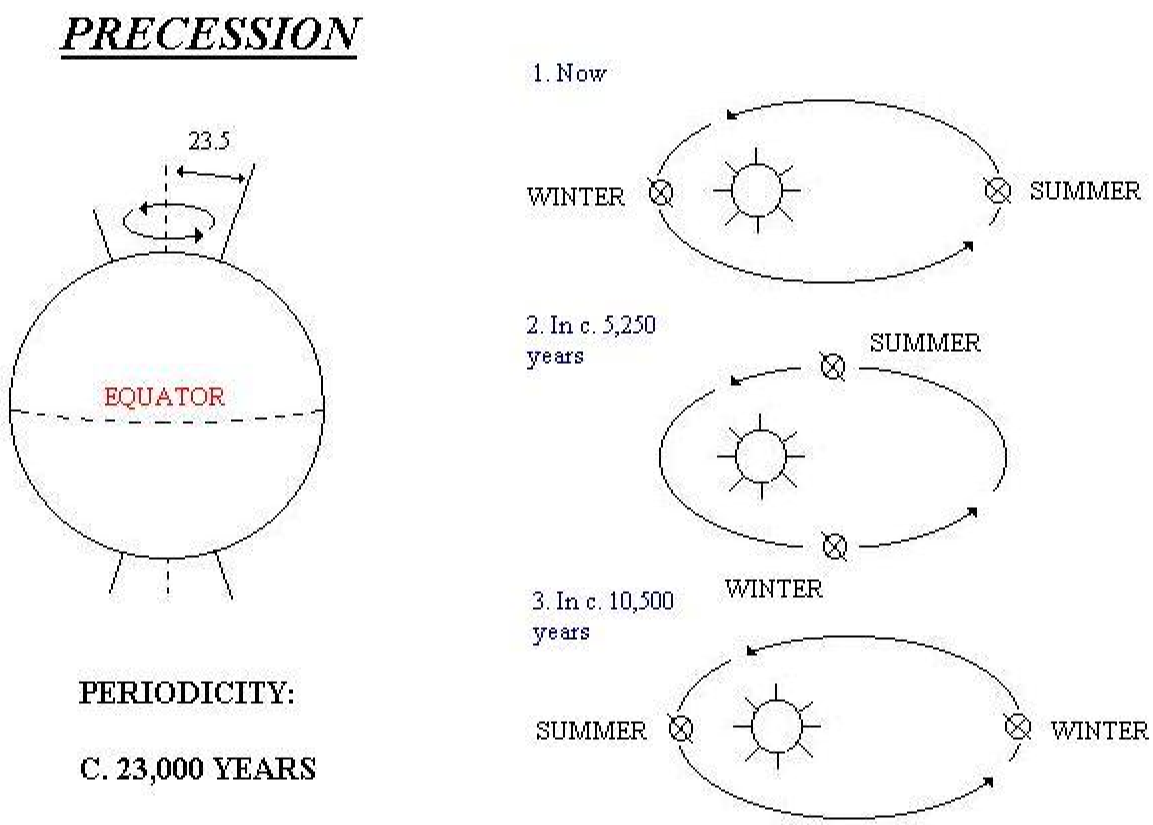
Milankovitch cycles

The amount of solar radiation reaching Earth – heated debate about impact, though!

Robert A. Rohde from publicly available data, and is incorporated into the Global Warming Art project. Wikipedia

Research task

<u>Brief</u> details about the causes of these cycles – and the thresholds for change



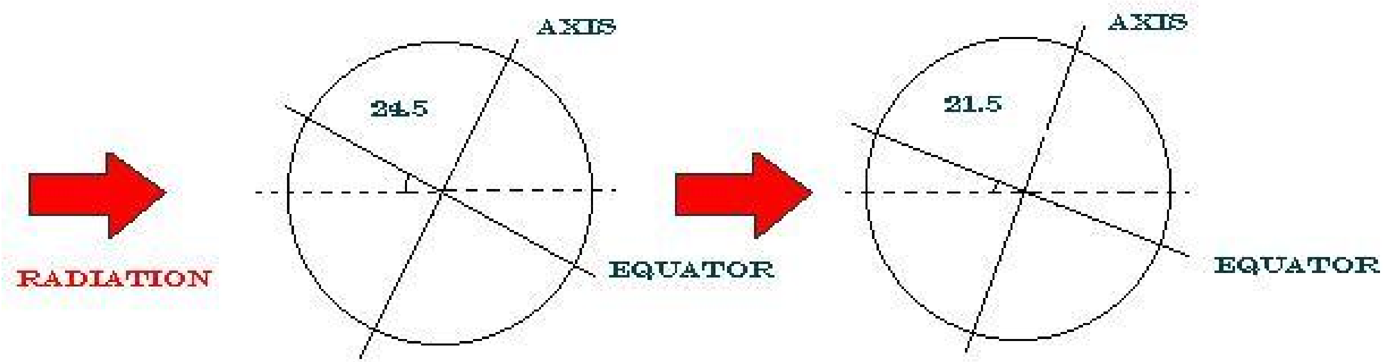
Due to this wobble a climatically significant alteration must take place. When the axis is tilted towards Vega the positions of the Northern Hemisphere winter and summer solstices will coincide with the aphelion and perihelion, respectively. This means that the Northern Hemisphere will experience winter when the Earth is furthest from the Sun and summer when the Earth is closest to the Sun. This coincidence will result in greater seasonal contrasts. At present, the Earth is at perihelion very close to the winter solstice.

http://www.indiana.edu/~geol105/images/gaia_chapter_4/milankovitch.htm

Research task

<u>Brief</u> details about the causes of these cycles – and the thresholds for change

AXIAL TILT (aka obliquity)



PERIODICITY:

41,000 YEARS

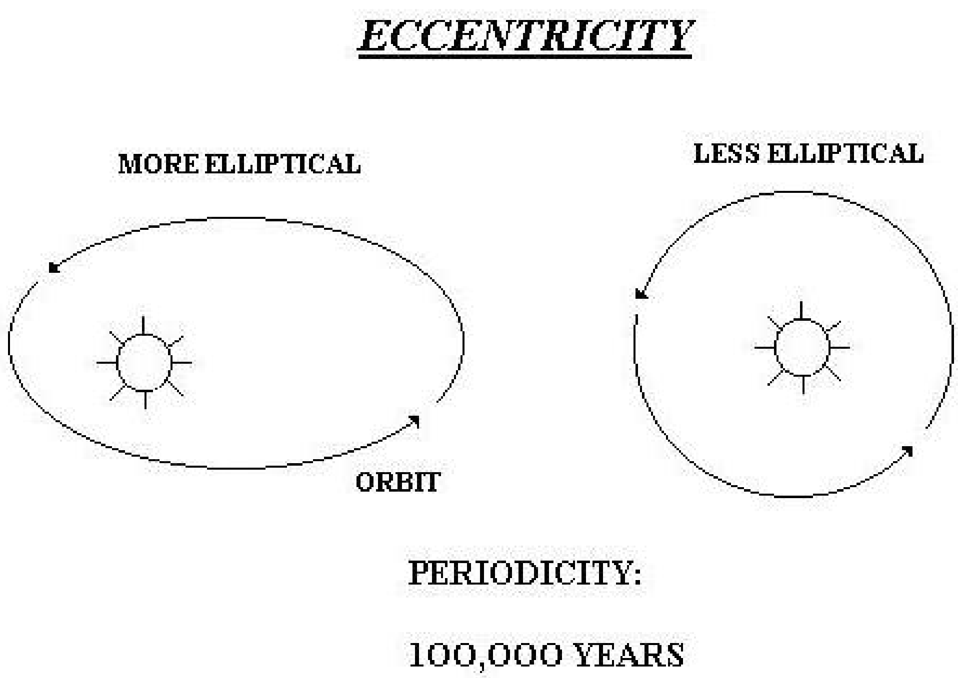
Today the Earth's axial tilt is about 23.5 degrees, which largely accounts for our seasons. Because of the periodic variations of this angle the severity of the Earth's seasons changes. With less axial tilt the Sun's solar radiation is more evenly distributed between winter and summer. However, less tilt also increases the difference in radiation receipts between the equatorial and polar regions.

One hypothesis for Earth's reaction to a smaller degree of axial tilt is that it would promote the growth of ice sheets. This response would be due to a warmer winter, in which warmer air would be able to hold more moisture, and subsequently produce a greater amount of snowfall. In addition, summer temperatures would be cooler, resulting in less melting of the winter's accumulation. At present, axial tilt is in the middle of its range.

http://www.indiana.edu/~geol105/images/gaia_chapter_4/milankovitch.htm

Research task

Brief details about the causes of these cycles – and the thresholds for change



Today a difference of only about 3 percent occurs between aphelion (farthest point) and perihelion (closest point). This 3 percent difference in distance means that Earth experiences a 6 percent increase in received solar energy in January than in July. This 6 percent range of variability is not always the case, however. When the Earth's orbit is most elliptical the amount of solar energy received at the perihelion would be in the range of 20 to 30 percent more than at aphelion. Most certainly these continually altering amounts of received solar energy around the globe result in prominent changes in the Earth's climate and glacial regimes. At present the orbital eccentricity is nearly at the minimum of its cycle.

http://www.indiana.edu/~geol105/images/gaia_chapter_4/milankovitch.htm

Research task

<u>Brief</u> details about the causes of these cycles – and the thresholds for change

The Pleistocene

The Last Glacial Maximum (LGM) of the late Pleistocene is a period when large areas of the high and mid-latitudes were covered by continental-scale ice sheets. After 18ka BP the ice sheets started to melt, and this process continued into the early part of the Holocene. The climates of this time have been reconstructed using a number of proxy records, including oxygen isotopes from ice cores (eg Grootes et al. 1993), foraminifera from marine cores (eg Dowsett 1991) and mollusk records from thick terrestrial loess deposits (eg Keen 1995). From these, it is clear that climate change during the LGM in the period leading up to the Holocene was rapid and significant (Alley et al. 2003). The largest shift in temperature at this time occurred during the Younger Dryas stadial between 11.6 to 12.9 ka BP; the start of which was recorded by a reduction in Greenland temperatures of 15°C (Alley et al. 1993). At the end of the Younger Dryas temperatures rose as sharply, with most of the temperature change occurring over a decade or less. The likely cause of this cooling event appears to be rapid drainage of glacier-dammed lakes into the North Atlantic from the St Lawrence, which caused a rapid shutdown in the THC (Broecker 1997; 1998),

https://www.actuaries.org.uk/documents/predicting-future-climate-change-lessons-palaeoclimatology

Research task

Causes of changes in the glacier budget through historical time including the Little Ice Age

Historical times??

Summary of distinct climatic periods during the Holocene epoch

Period	Name	Climate conditions
14,000 years ago	Holocene warming	Slow warming from the last ice age; large ice melt
10,000 - 8500 BC	Younger-Dryas	Rapid cooling, prolonged cold period, then Rapid warming
5000 - 3000 BC	Climatic optimum	Warm conditions; temperatures were perhaps 1 to 2 degrees Celsius warmer than they are today. Great ancient civilizations began and flourished.
3000 - 2000 BC		Cooling trend; drops in sea level and the emergence of many islands.
2000 - 1500 BC		Short warming trend
1500 - 750 BC		Colder temperatures and renewed ice growth, sea level drop of between 2 to 3 meters below present day levels.
750 BC - 150 BC		Slight warming not as warm as the Climatic Optimum.
150 BC - 900 AD		Cooling trend; Nile River (829 AD) and Black Sea (800-801 AD) froze
1100 - 1300 AD	Little Climatic Optimum or Medieval Optimum	Warm; warmest climate since the Climatic Optimum, Vikings established settlements on Greenland and Iceland.
1300 - 1550 AD		Cool and more extreme weather; abandonment of settlements in the Southwest United States,
1550 to 1850 AD	Little Ice Age	Coldest temperatures since the beginning of the Holocene. Populations die from crop failure and famine in Europe.
1850 AD - present	Contemporary climate	Warming trend

http://www.atmo.arizona.edu/students/courselinks/fall12/atmo336/lectures/sec5/holocene.html

Little Ice Age

During the Medieval Warm Period (1100-1300 AD), global average temperatures were only 1°C (or less) warmer than in 1900, but in Europe:

- The Vikings established a colony on Greenland
- Farming was productive on Greenland (has not been productive again since that time)
- At end of period, the Viking colony was lost to sea ice expansion
- Grape vines were grown in England
- Wheat was grown in Norway (64° North latitude)

During the Little Ice Age (1550-1850 AD), global average temperatures were only 1°C (or less) cooler than in 1900, but in Europe:

- Re-advance of glaciers down mountains (valley houses in Swiss Alps were covered)
- Canals in Holland froze for three months straight. This rarely occurred before or after this period.
- Agricultural productivity dropped significantly, even becoming impossible in parts of northern Europe.

http://www.atmo.arizona.edu/students/courselinks/fall12/atmo336/lectures/sec5/holocene.html

Little Ice Age

“The Little Ice Age was a period of regionally cold conditions between roughly AD 1300 and 1850. The term “Little Ice Age” is somewhat questionable, because there was no single, well-defined period of prolonged cold. There were two phases of the Little Ice Age, the first beginning around 1290 and continuing until the late 1400s. There was a slightly warmer period in the 1500s, after which the climate deteriorated substantially, with the coldest period between 1645 and 1715 . During this coldest phase of the Little Ice Age there are indications that average winter temperatures in Europe and North America were as much as 2°C lower than at present.

There is substantial historical evidence for the Little Ice Age. The Baltic Sea froze over, as did many of the rivers and lakes in Europe. Pack ice expanded far south into the Atlantic making shipping to Iceland and Greenland impossible for months on end. Winters were bitterly cold and summers were often cool and wet. These conditions led to widespread crop failure, famine, and population decline. The tree line and snowline dropped and glaciers advanced, overrunning towns and farms in the process. There were increased levels of social unrest as large portions of the population were reduced to starvation and poverty.

Tax records in Scandinavia show many farms were destroyed by advancing ice of glaciers and by melt water streams. Travellers in Scotland reported permanent snow cover over the Cairngorm Mountains in Scotland at an altitude of about 1200 metres. In the Alps, the glaciers advanced and threatened to bulldoze towns. Ice-dammed lakes burst periodically, destroying hundreds of buildings and killing many people. ”

https://www.eh-resources.org/little-ice-age/

Little Ice Age

Figure 1 A portrait of the Argentiere glacier in the French Alps from an etching made between 1850 and 1860 just prior to its dramatic withdrawal, and a modern photograph of the glacier from a similar vantage point taken in 1966. (Reproduced by permission of Doubleday and Company, Inc., from Le Roy Ladurie, E, 1971 (Plates XXI and XXII))

https://www.actuaries.org.uk/documents/predicting-future-climate-change-lessons-palaeoclimatology

Little Ice Age

“The exact cause of the Little Ice Age is unknown, but there is a striking coincidence in the sunspot cycle and the timing of the Little Ice Age. During the Little Ice Age, there is a minimum in sunspots, indicating an inactive and possibly cooler sun. This absence of sunspots is called the Maunder Minimum.

The Maunder Minimum occurred during the coldest period of the Little Ice Age between 1645 and 1715 AD, when the number of sunspots was very low. The lack of sunspots meant that solar radiation was probably lower at this time, but models and temperature reconstructions suggest this would have reduced average global temperatures by 0.4ºC at most, which does not explain the regional cooling of the climate in Europe and North America.

What does explain a drop of up to 2 degrees C in winter temperatures? The North Atlantic is one of the most climatically unstable regions in the world. This is caused by a complex interaction between the atmosphere and the ocean. The main feature of this is the North Atlantic Oscillation (NAO), a seesaw of atmospheric pressure between a persistent high over the Azores and an equally persistent low over Iceland. Sometimes the pressure cells weaken and that has severe consequences for the weather in Europe.

When the Azores high pressure grows stronger than usual and the Icelandic low becomes deeper than normal, this results in warm and wet winters in Europe and in cold and dry winters in northern Canada and Greenland. This also means that the North Atlantic Storm track move north, directing more frequent and severe stroms over northern Europe. This situation is called a Positive NAO Index.

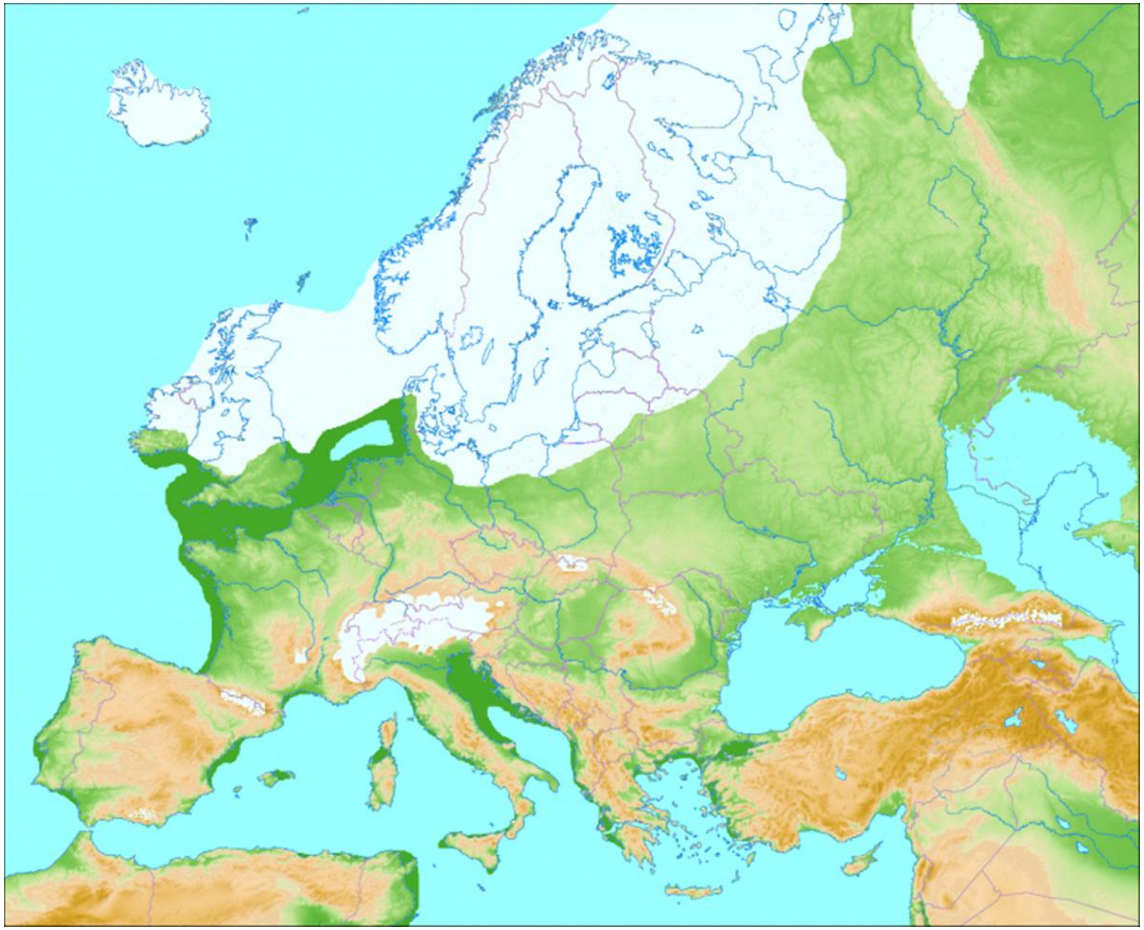
When both pressure systems are weak, cold air can reach Northern Europe more easily during the winter months resulting in cold winters and the North Atlantic strom track is pushed south, causing wet weather in the Mediterranean. This situation is called a Negative NAO Index.

It is now thought that during the Little Ice Age NAO Index was more persistent in a negative mode. For this reason the regional variability during the Little Ice Age can be understood in terms of changes in atmospheric circulation patterns in the North Atlantic region.”

https://www.eh-resources.org/little-ice-age/

Research task

The changing distribution and extent of ice masses during the Quaternary up to the present day – this should include details at the global, European and UK scales



Ice cover in Northern Europe during the Late Glacial Maximum – LGM (c.20ka)
https://www.qra.org.uk/what-is-the-quaternary/

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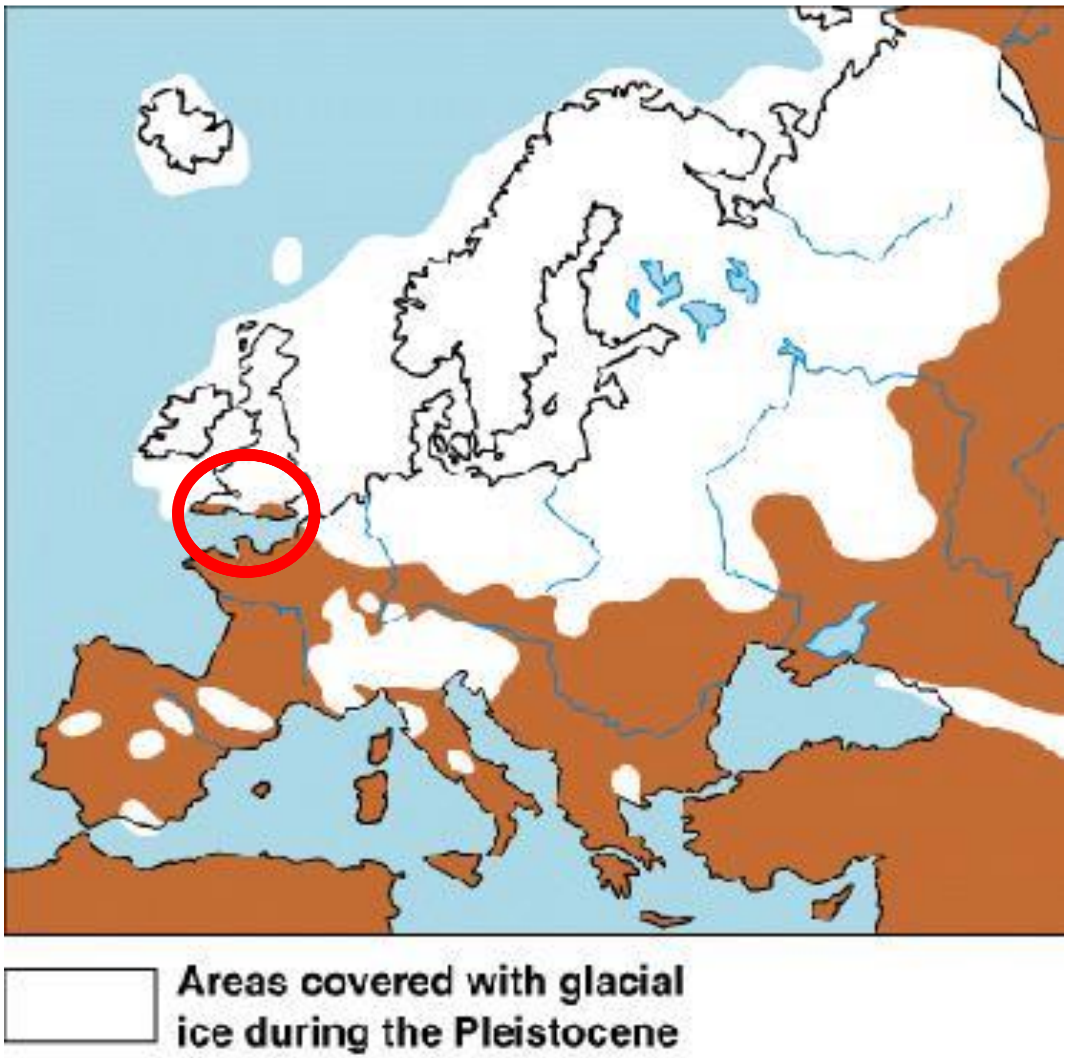


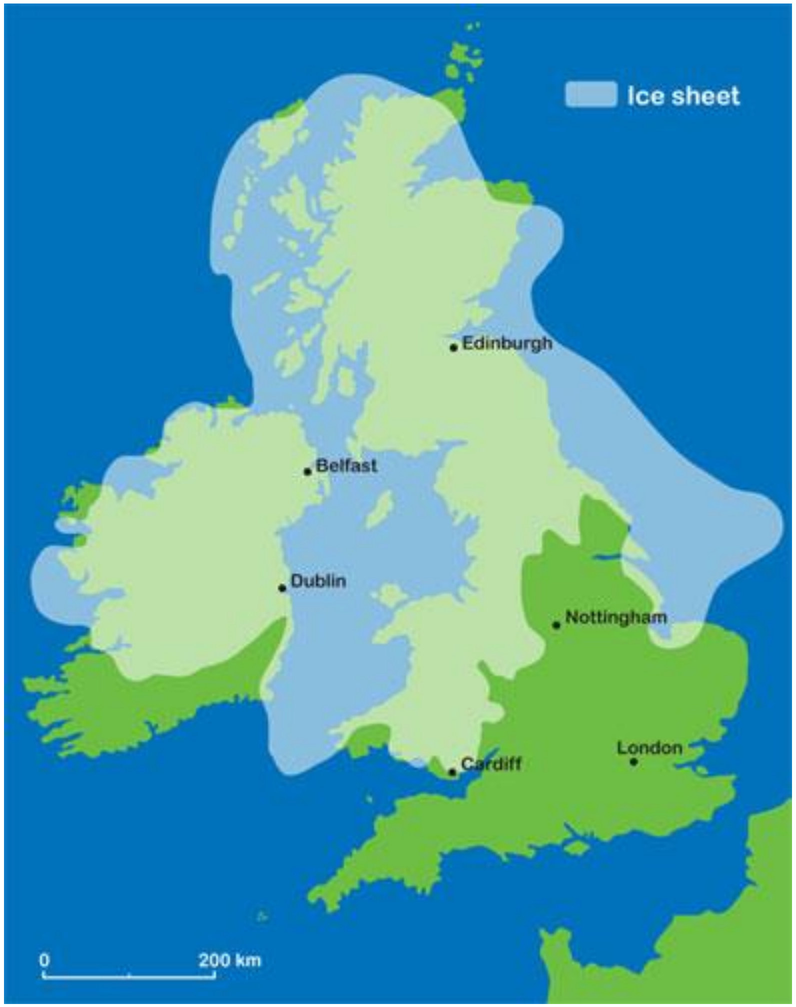
Ice cover over Northern Europe during the LGM (c.20ka)

http://onlinelibrary.wiley.com/higheredbcs/legacy/college/levin/0471697435/chap_tut/chaps/chapter15-05.html

CAREFUL!

Research task

The changing distribution and extent of ice masses during the Quaternary up to the present day – this should include details at the global, European and UK scales



Ice cover over the UK during the LGM (c.20ka)

http://www.bgs.ac.uk/discoveringGeology/geologyOfBritain/iceAge/home.html?src=topNav

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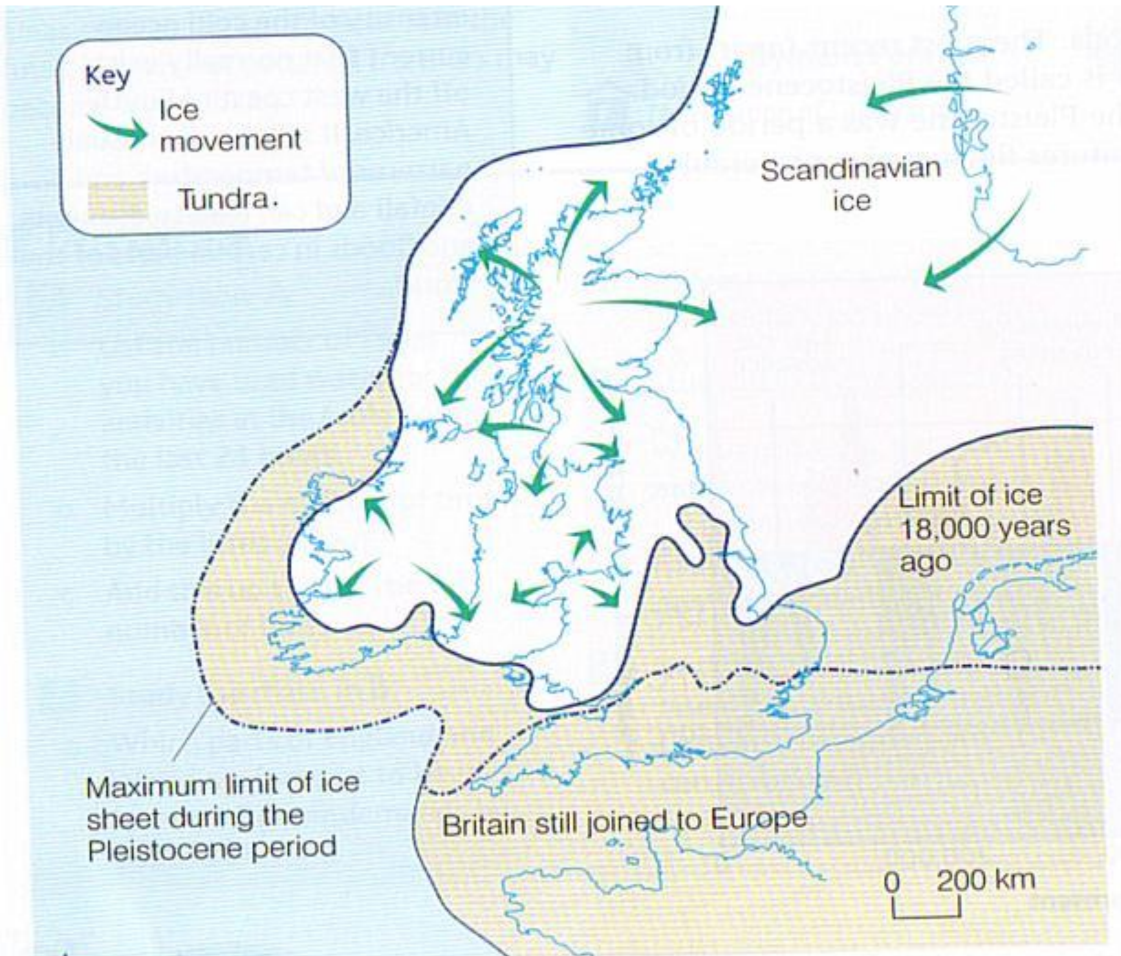


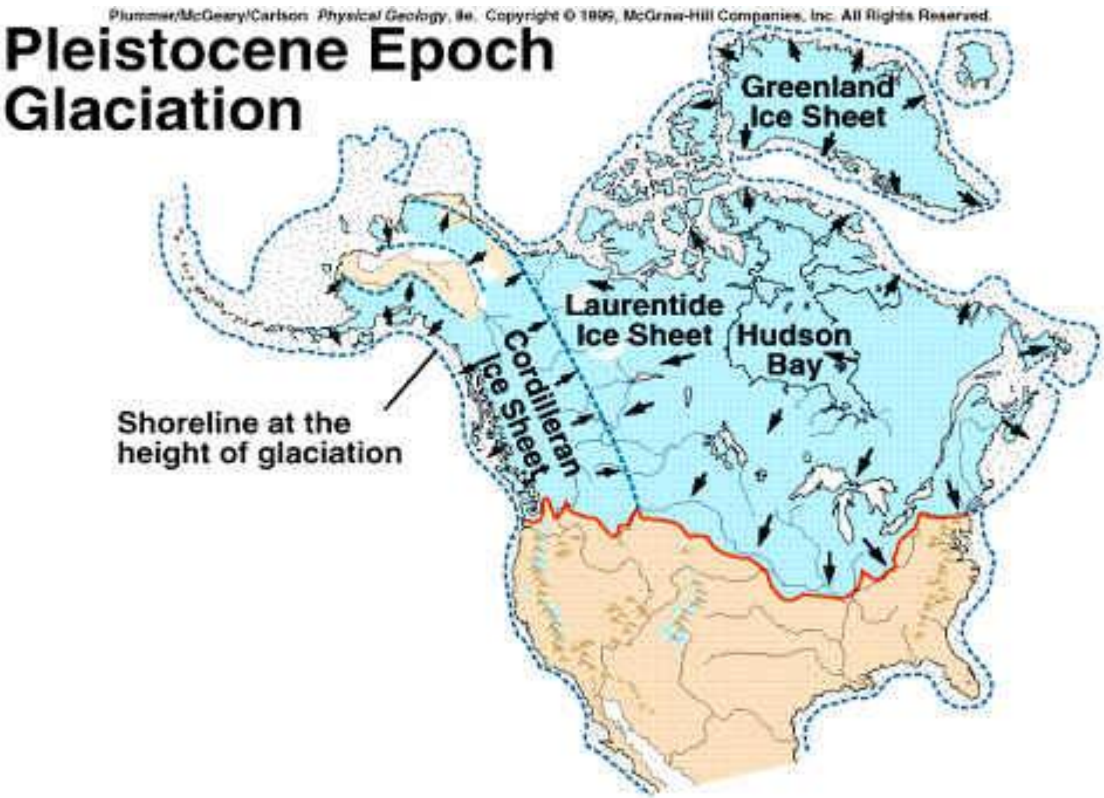
Ice coverage over the British Isles 18,000 years ago

Changing ice cover over the UK

https://onlinegeography.wikispaces.com/file/view/UK_ice_extent.jpg/80871801/616x543/UK_ice_extent.jpg

Research task

The changing distribution and extent of ice masses during the Quaternary up to the present day – this should include details at the global, European and UK scales

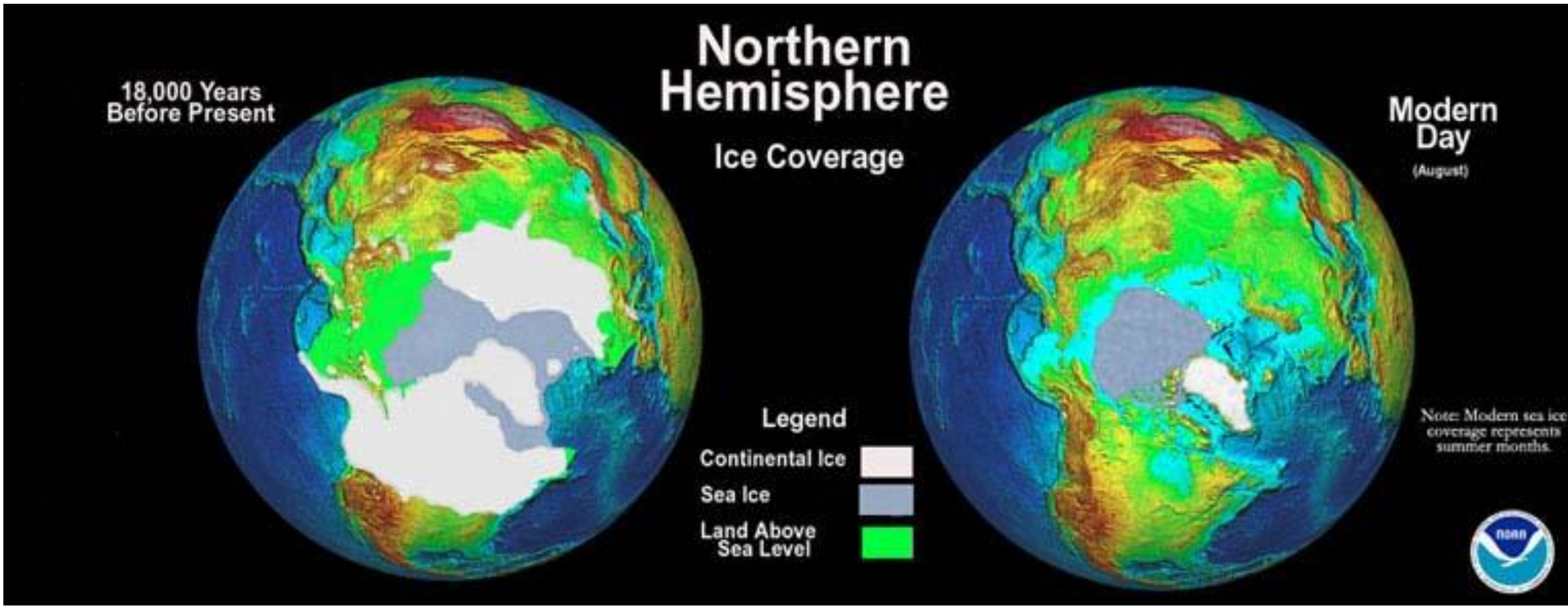


Ice cover over North America during the LGM (c.20ka)

http://www.personal.kent.edu/~sclement/dynamics/glaciers/glaciers.htm

Research task

The changing distribution and extent of ice masses during the Quaternary up to the present day – this should include details at the global, European and UK scales

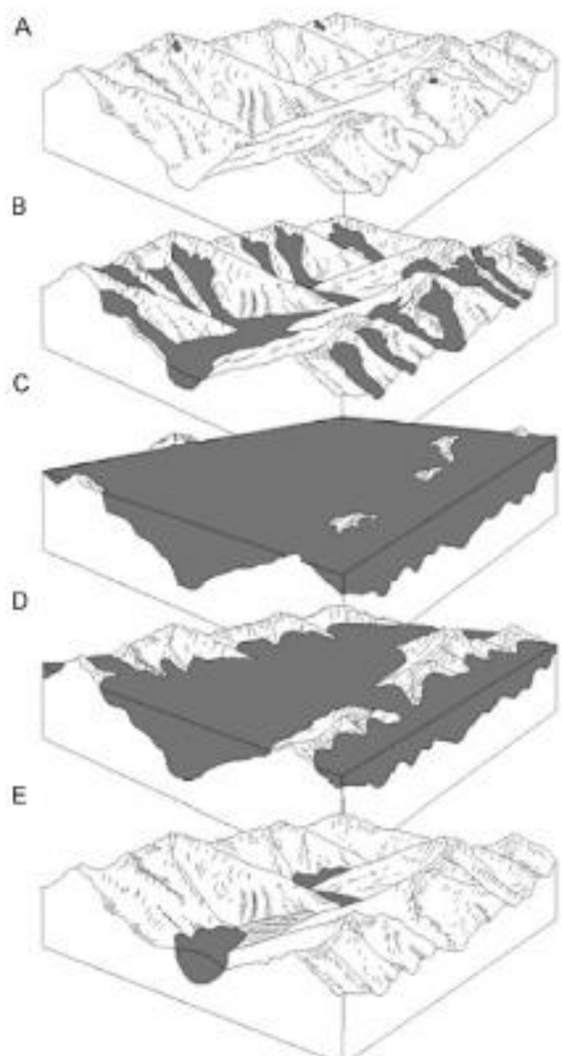


Ice cover in the Northern Hemisphere during the LGM (18ka)

http://www.atmo.arizona.edu/students/courselinks/fall12/atmo336/lectures/sec5/pleistocene.html

Research task

The changing distribution and extent of ice masses during the Quaternary up to the present day – this should include details at the global, European and UK scales



Growth and decay of the cordilleran ice sheet

https://books.google.co.uk/books?id=pUjRgq7zyVcC&pg=PA564&lpg=PA564&dq=growth+and+decay+of+valley+glaciers&source=bl&ots=Io1CMIUv5j&sig=--pyTb4C2TlfdRsYmw2YLIFgvGM&hl=en&sa=X&ved=0ahUKEwjj043V0LzPAhUFVT4KHQdrBL4Q6AEIQzAI#v=onepage&q=growth%20and%20decay%20of%20valley%20glaciers&f=false

FIGURE 44.3 Schematic diagram showing growth and decay of the Cordilleran ice sheet. (A). Mountain area at the beginning of a glaciation. (B). Development of a network of valley glaciers. (C). Coalescence of valley and piedmont lobes to form an ice sheet. (D) Decay of ice sheet by downwasting; upland areas are deglaciated before adjacent valleys. (E). Residual dead ice masses confined to valleys. (Modified from Clague, 1989, fig. 1.13).