Chapter 14
Glacial and Periglacial Landscapes

Elemental Geosystems 5e

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Glacial and Periglacial Landscapes

- Rivers of Ice
- Glacial Processes
- Glacial Landforms
- **Periglacial Landscapes**
- **The Pleistocene Ice Age Epoch**
- **Deciphering Past Climates: Paleoclimatology**
- **Arctic and Antarctic Regions**

Periglacial Landscapes

- Geography of Permafrost
  - Continuous and discontinuous zones
  - Behavior of permafrost
- Ground Ice and Frozen Ground Phenomena
  - Frost-action processes
  - Hillslope processes
- Humans and Periglacial Landscapes

Permafrost Distribution

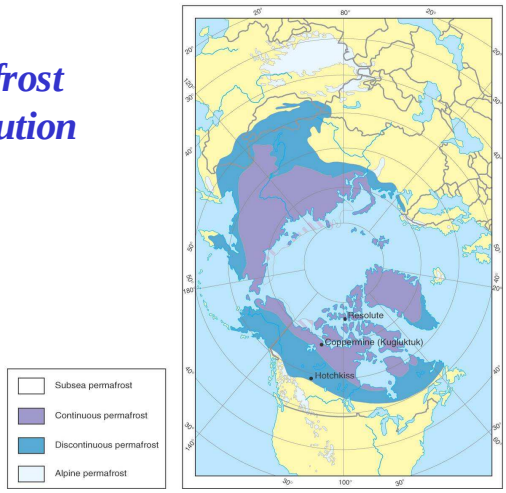


Figure 14.16

Periglacial Environments

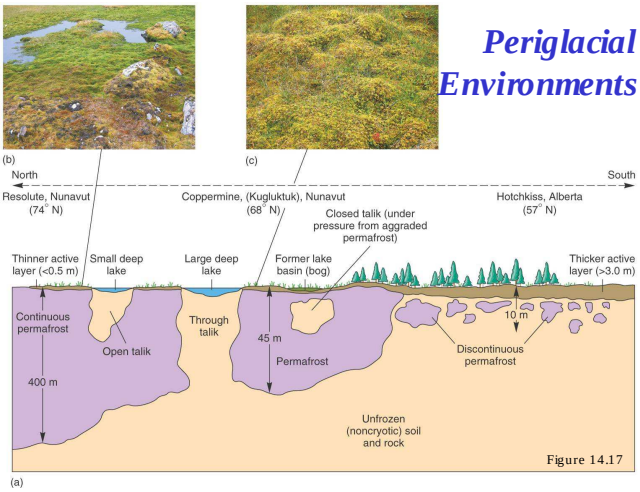


Figure 14.17

Ice Wedge

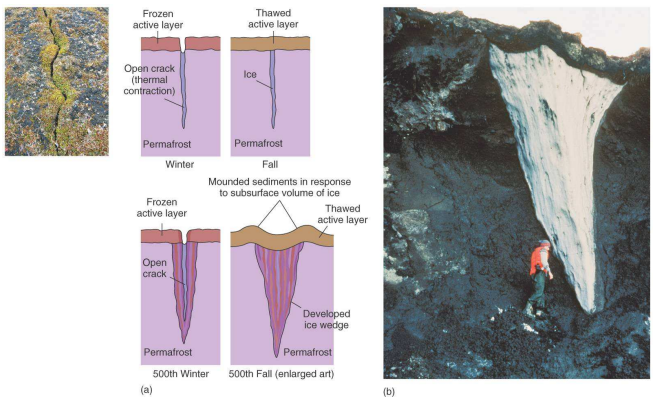


Figure 14.18

Patterned Ground

Figure 14.19

Gelifluction Lobes

Figure 14.20

Permafrost Melting

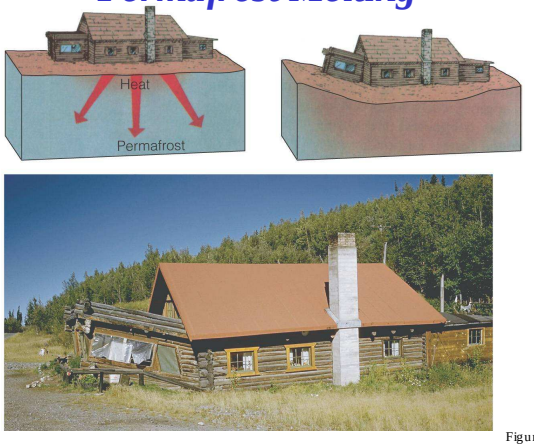


Figure 14.21

Permafrost Structures

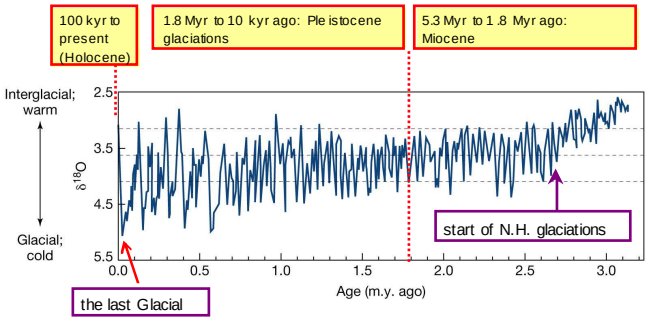
Figure 14.22

1. Past Changes in the Cryosphere
   A. Pleistocene glaciations
   B. Abrupt Climate Changes
   C. Recent Cryosphere Changes
2. Future Cryosphere Changes

A. Glacial-interglacial cycles

A Temperature Record of the Past 3 Million Years can be extracted from ocean sediment cores.

deep-sea record of $\delta^{18}O$ (a measure of glacial ice volume) of seawater during the last 3 million years, as told by 2 bottom foram species in mid-latitude North Atlantic



Astronomical Factors

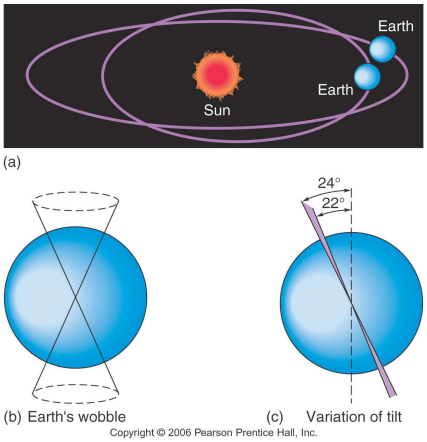
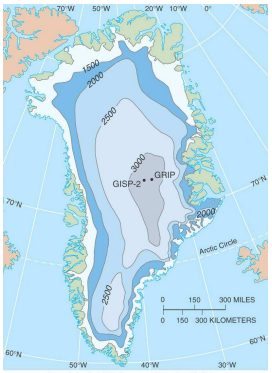
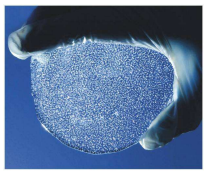


Figure 14.27

Greenland and Dome C Ice Cores



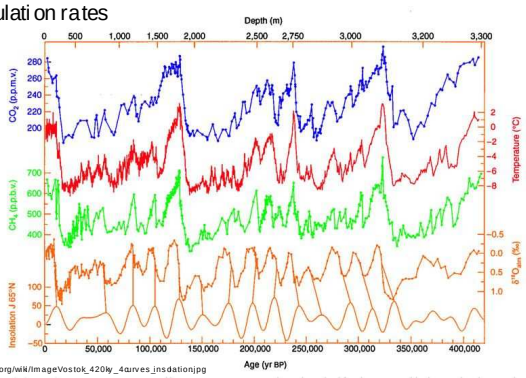
FigureFS 14.1.1



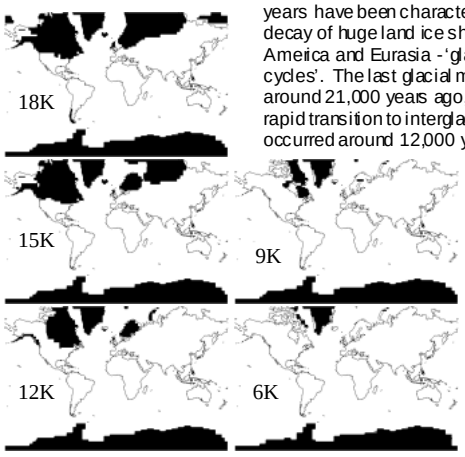
FigureFS 14.1.3

Ice cores give a record of past climates

- isotopes of water give a proxy for temperature
- CO_2, CH_4, dust, sea salt, other gases
- accumulation rates



http://commons.wikimedia.org/wiki/ImageVostok_420ky_4curves_insdationjpg



Climate change over the last half million years have been characterized by growth and decay of huge land ice sheets over North America and Eurasia - 'glacial-interglacial cycles'. The last glacial maximum was around 21,000 years ago, and a relatively rapid transition to interglacial conditions occurred around 12,000 years ago.

The maps show ice coverage from 18,000 years ago to 6,000 years ago. (source: NOAA Paleoclimatology program)

During the cold periods, glaciers covered large portions of the Northern Hemisphere.

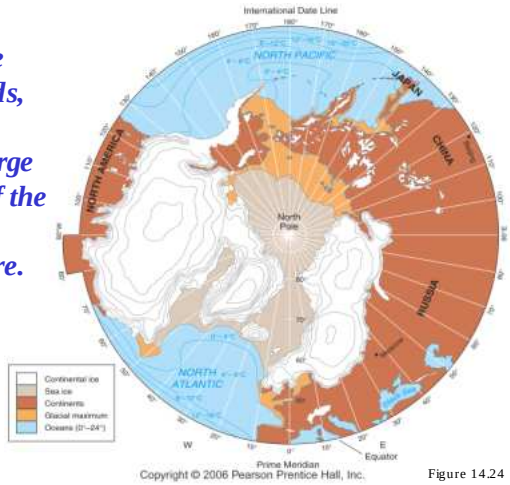
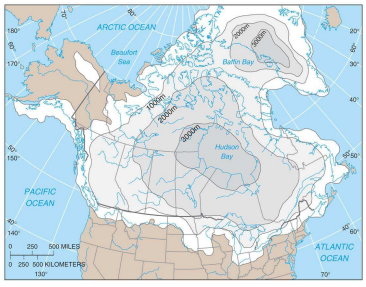


Figure 14.24

The Pleistocene Glaciation had its maximum about 20,000 years ago. Most of the Laurentide ice sheet was gone by 10,000 years ago.



18,000 years ago

9500 years ago

Figure 14.24

Lakes formed (now they are "paleolakes") because the rainfall was higher and temperatures were colder (less evaporation).

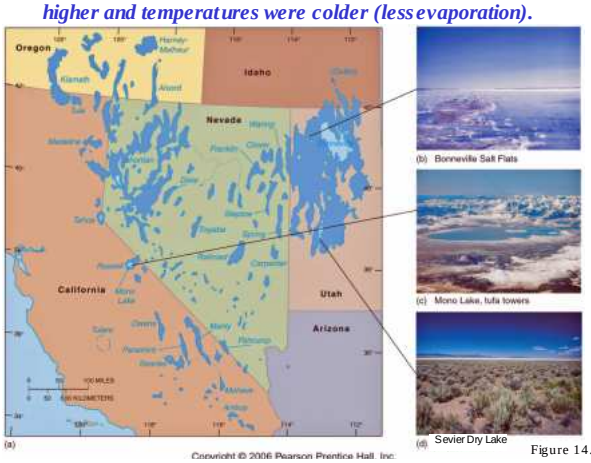
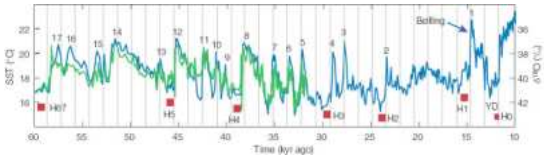


Figure 14.25

Lake Missoula was dammed by the ice sheet and occasionally broke through the dam, causing giant outburst floods which carved big channels in eastern Washington State.

B. **Abrupt climate changes** during the last glacial period

Within the last glacial period, climate change has been characterized by abrupt climate changes on roughly 1500 year intervals - the so-called Dansgaard-Oeschger (D/O) cycles. The cycles are characterized by rapid warming followed by a gradual cooling. Several of the D/O events are terminated by Heinrich events, which are characterized by massive outbreaks of icebergs from the Hudson strait into the north Atlantic



Temperature reconstructions from ocean sediments and Greenland ice. Proxy data from the subtropical Atlantic86 (green) and from the Greenland ice core GISP2 (ref. 87; blue) show several Dansgaard–Oeschger (D/O) warm events (numbered). The timing of Heinrich events is marked in red. Grey lines at intervals of 1,470 years illustrate the tendency of D/O events to occur with this spacing, or multiples thereof.

Greenland Ice Core Record

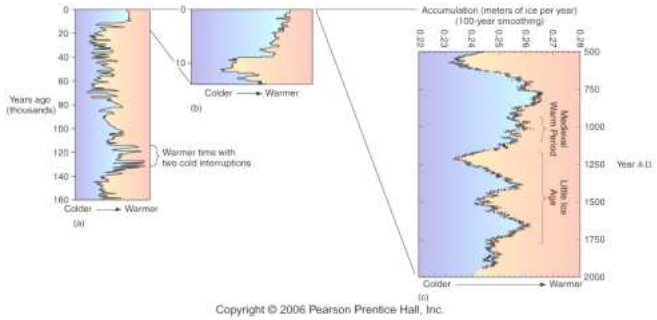
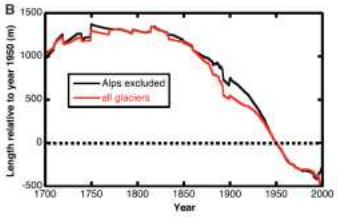


Figure 14.26

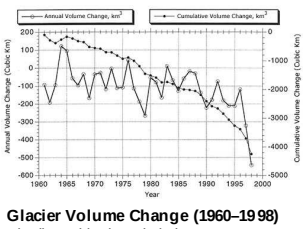
C. Recent Glacier Changes

169 representative glaciers have receded in the last 200 years



Glacier Length Changes

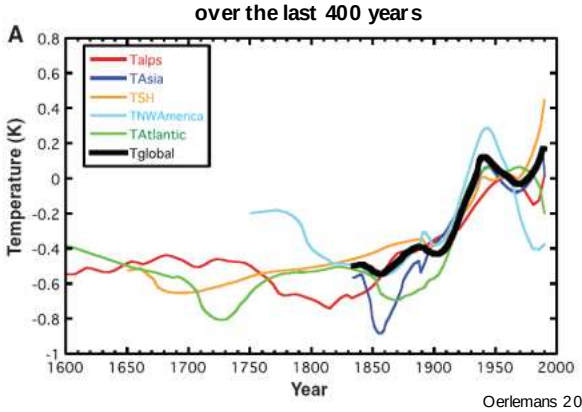
Oerlemans (2005) found that glaciers worldwide (excluding Greenland and Antarctica) have been retreating since the end of the Little Ice Age in ~1850. He used that fact and a simple model to predict what temperature change would have been required to produce the length changes. That reconstruction is shown on the next slide.



Glacier Volume Change (1960–1998)

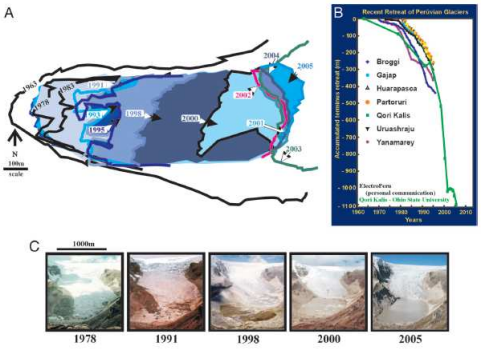
The line with closed circles represents the total change in glacial mass worldwide over a 28-year time period. To interpret this line, consult the scale on the right side of the graph, which shows change in cubic kilometers. Glaciers worldwide have been shrinking. *Source:* Institute of Arctic and Alpine Research, University of Colorado, Boulder

Glaciers record a temperature increase over the last 400 years



Oerlemans 2005

Tropical glaciers in retreat: Qori Kalis and other Andean Glaciers



Lonnie G. Thompson *et al*. 2006 PNAS

Cryosphere and Climate

1. Past Changes in the Cryosphere
   A. Pleistocene glaciations
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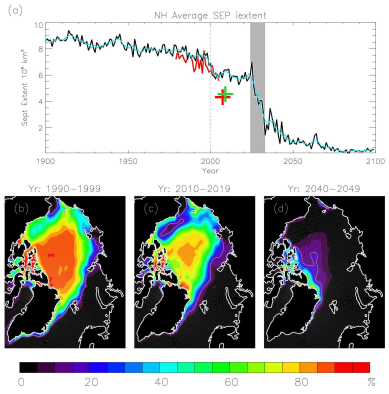
   C. Recent Cryosphere Changes
2. Future Cryosphere Changes

Future changes to the cryosphere will have profound implications for climate and human societies.

- Snow cover is projected to contract
- Widespread increases in thaw depth most permafrost regions
- Sea ice is projected to shrink in both the Arctic and Antarctic
- In some projections, Arctic late-summer sea ice disappears almost entirely by the latter part of the 21st century. September is shown at right (spatial extent in units of 10^6 km^2), CCSM3 in black and blue, observations in red.



Text from IPCC

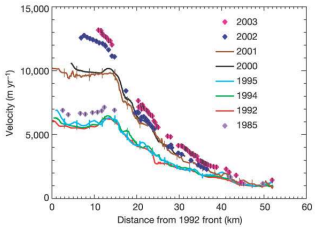
http://www.realclimate.org/index.php/archives/2007/01/arctic-sea-ice-decline-in-the-21st-century/

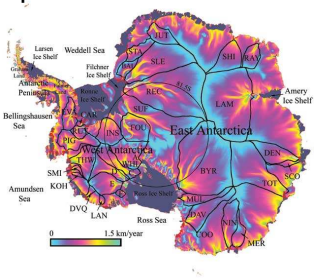
Future Glacier Changes: Potential Impact of Ice Sheet Instabilities

Dynamic ice flow adjustments have not been included in the 2007 IPCC analysis because they are not well-understood. They have been observed in the last few years.

WAIS susceptible to collapse because it's bed is below sea level (5 m sea level equivalent)

EAIS less susceptible because it's bed is above sea level (~60 m s.l.e.)





The velocity of Jacobshavn Isbrae in Greenland doubled in a 5 year period. Thought to be due to increased levels of meltwater percolating to the bed of the glacier and lubricating it.

Joughin et al, Nature 2004

http://www.lolfunny.com/page/2/