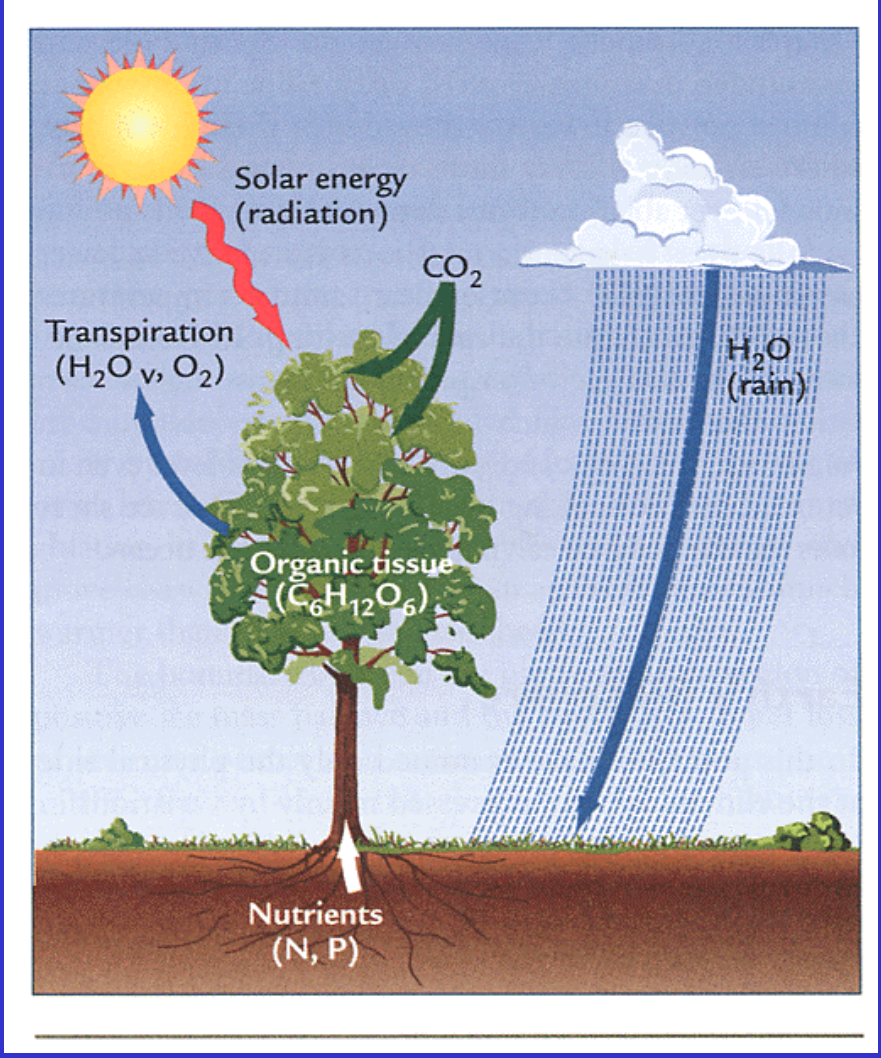
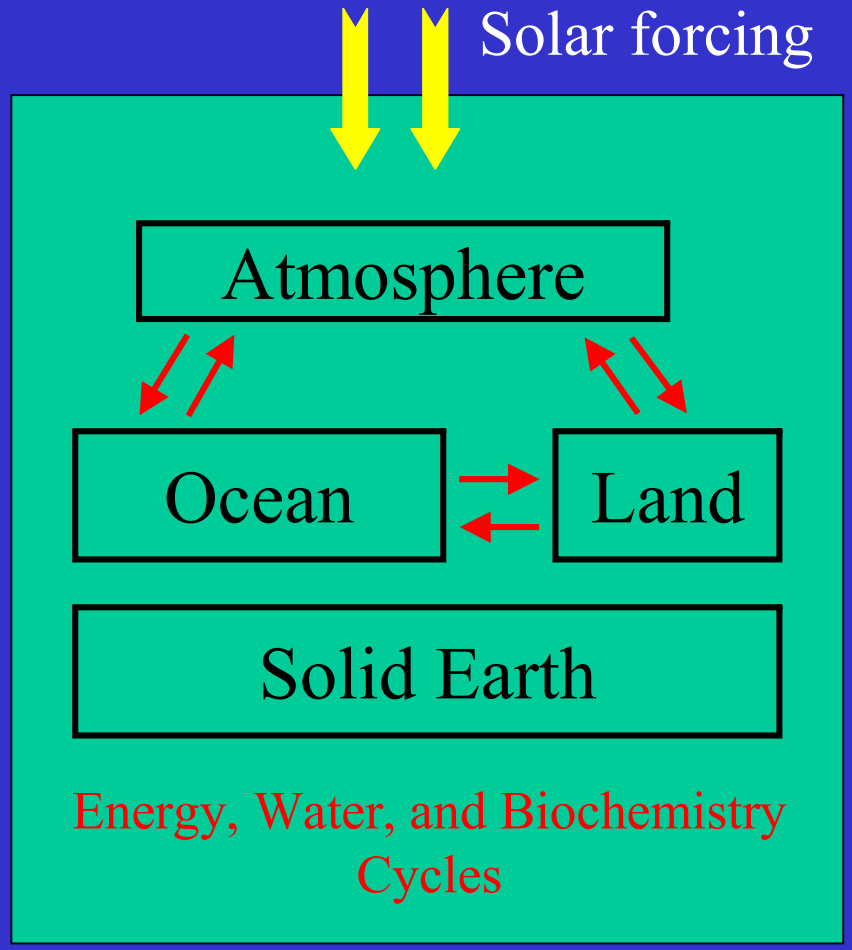
Lecture 5: Land Surface and Cryosphere (Outline)



(from *Our Changing Planet*)

- Land Surface
- Sea Ice
- Land Ice

Earth's Climate System



Climate Roles of Land Surface

- greenhouse gas emissions
  - ➔ affects global energy and biogeochemical cycles
- creation of aerosols
  - ➔ affects global energy and water cycles
- surface reflectivity (albedo)
  - ➔ affects global energy cycle
- impacts on surface hydrology
  - ➔ affect global water cycle

← Vegetation
Soil Moisture
Snow/Ice Cover

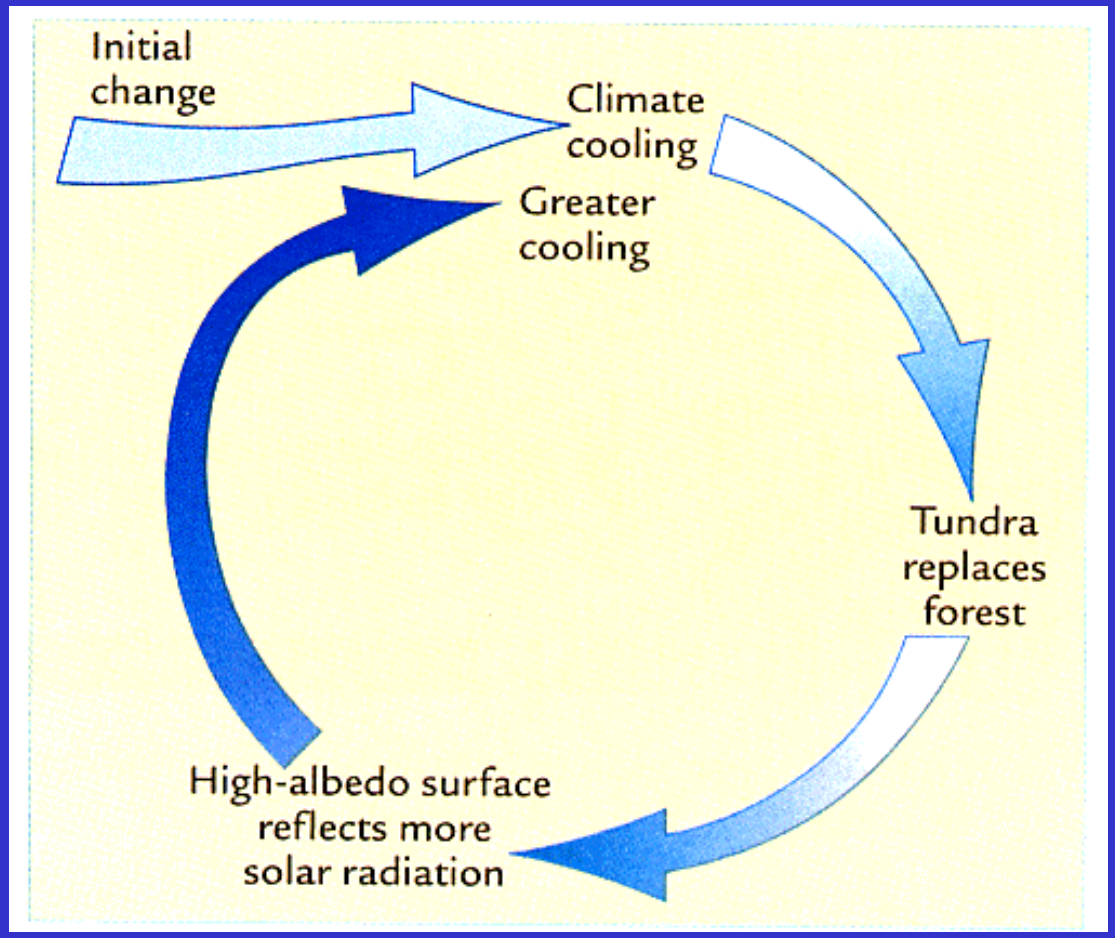
Surface Albedo

TABLE 2-1 Average Albedo Range of Earth's Surfaces

Surface	Albedo range (percent)
Fresh snow or ice	60–90%
Old, melting snow	40–70
Clouds	40–90
Desert sand	30–50
Soil	5–30
Tundra	15–35
Grasslands	18–25
Forest	5–20
Water	5–10

Adapted from W. D. Sellers, Physical Climatology *(Chicago: University of Chicago Press, 1965), and from R. G. Barry and R. J. Chorley,* Atmosphere, Weather, and Climate, *4th ed. (New York: Methuen, 1982).*

Feedback Mechanism: Albedo ➔ Energy Cycle

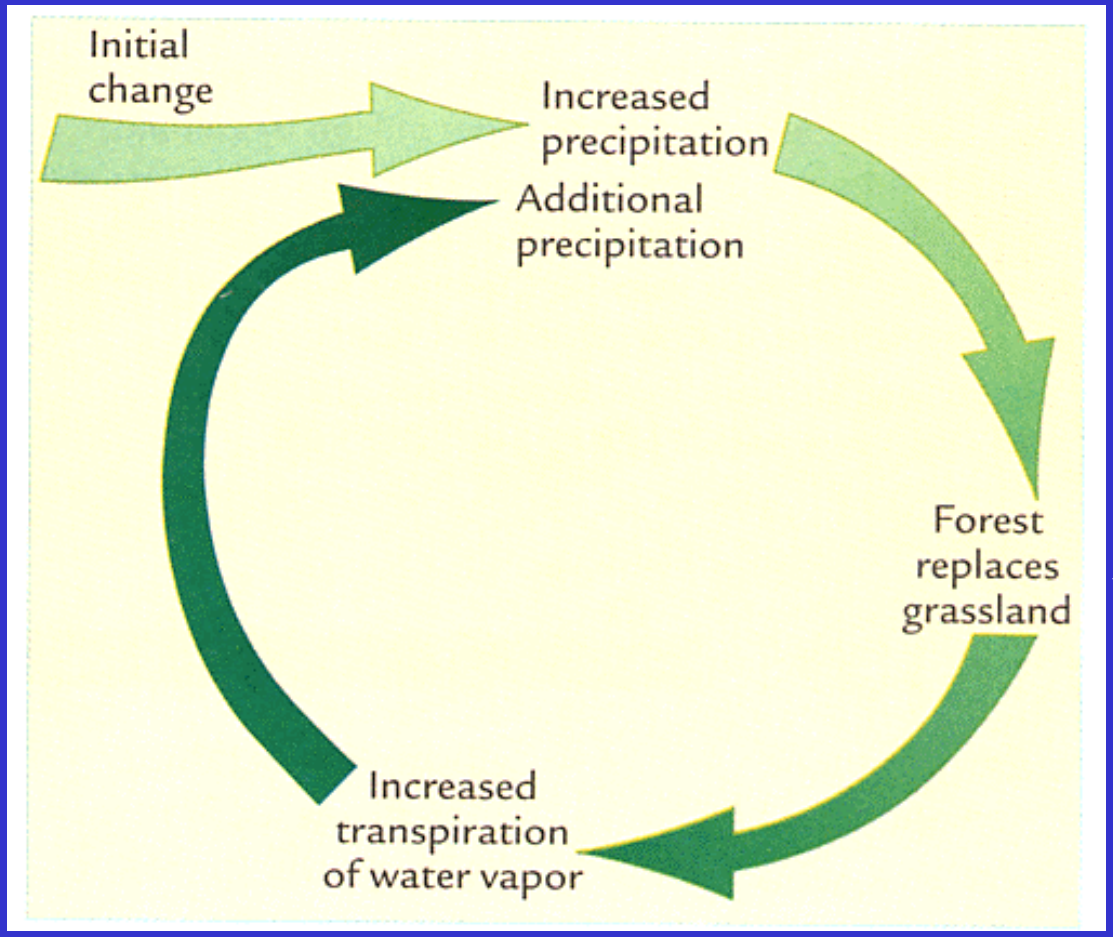


or

Snow cover replaces Vegetation cover

(from *Earth's Climate: Past and Future*)

Feedback Mechanism: Transpiration ➔ Water Cycle



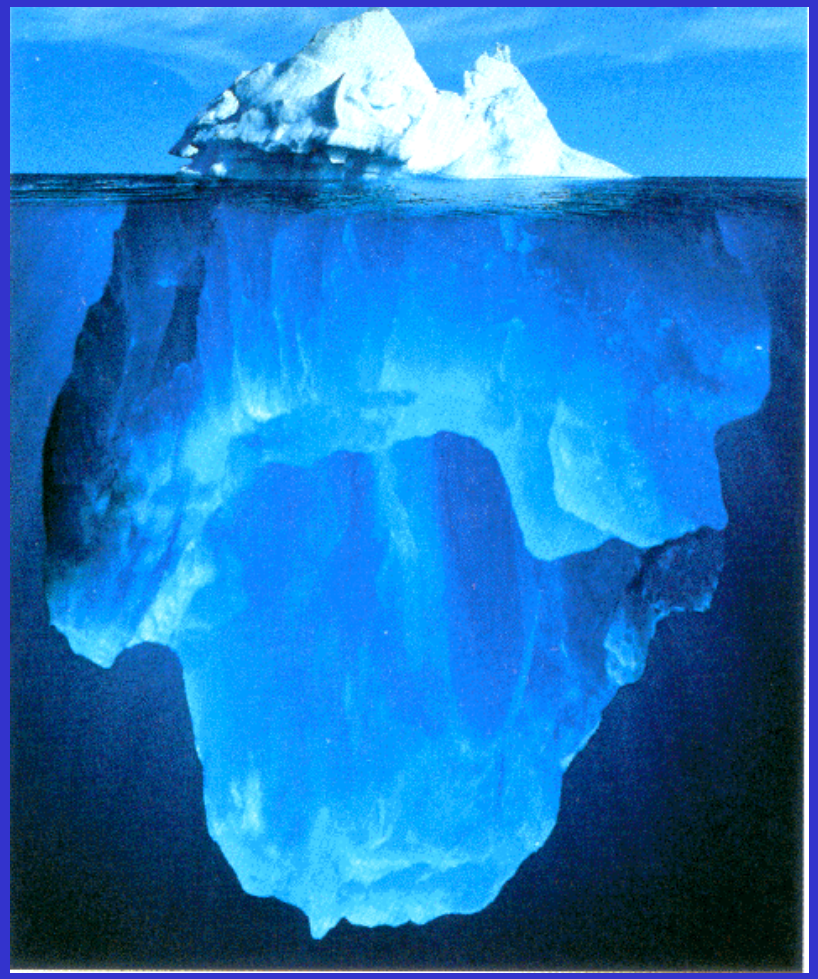
or

Wet soil replaces Dry soil

(from *Earth's Climate: Past and Future*)

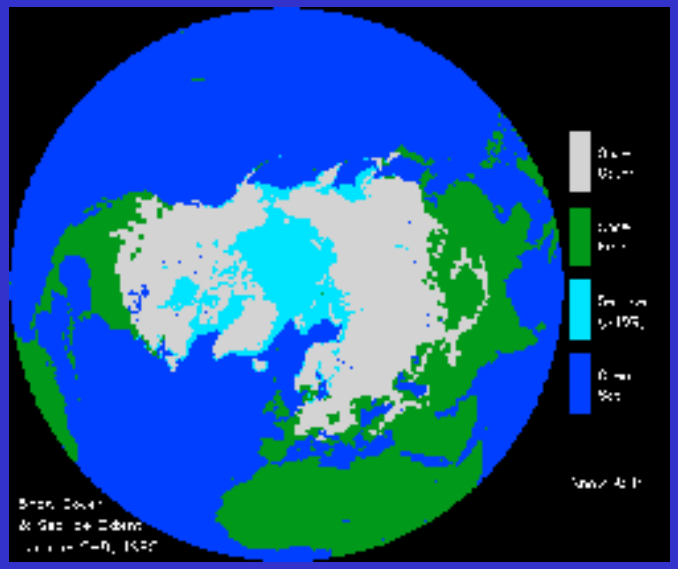
Cryosphere

Sea Ice



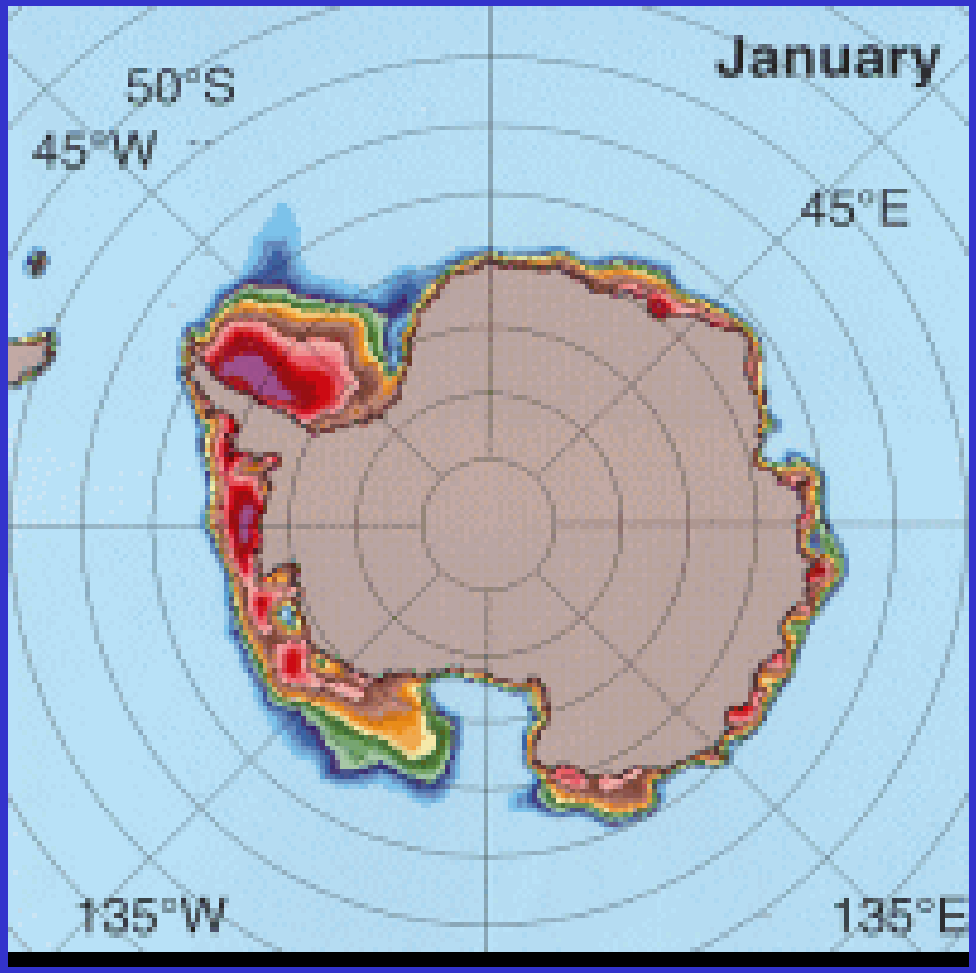
(from *The Blue Planet*)

Land Ice



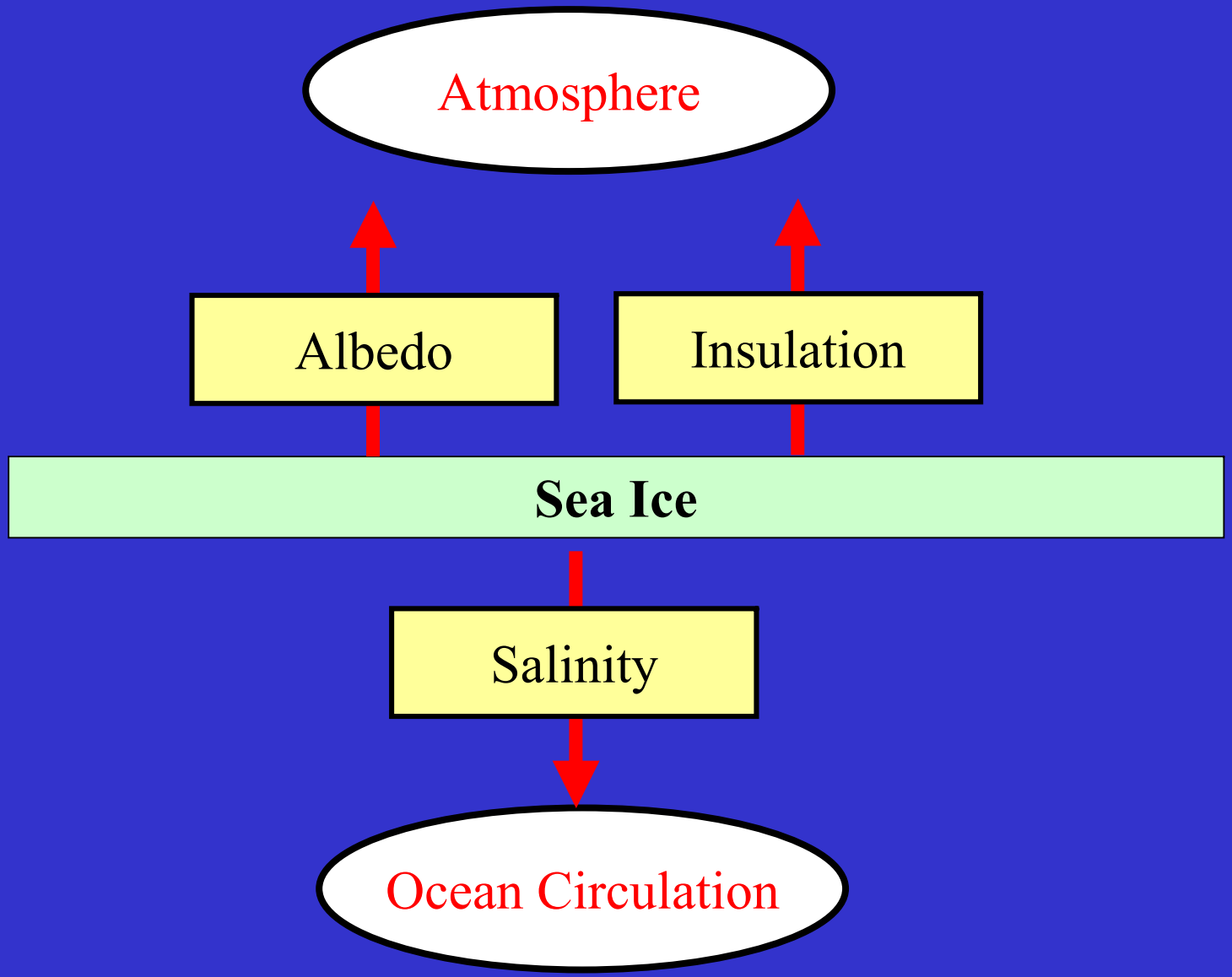
- The cryosphere is referred to all the ice near the surface of Earth: including sea ice and land ice.
- For climate, both the surface and the mass of ice are importance.
- At present, year-round ice covers 11% of the land area and 7% of the world ocean.

Seasonal Cycle of Antarctic Ice



(figures from Gloersen, P. et al. 1992; animated by D. B. Reush)

Climate Roles of Sec Ice



Surface Albedo

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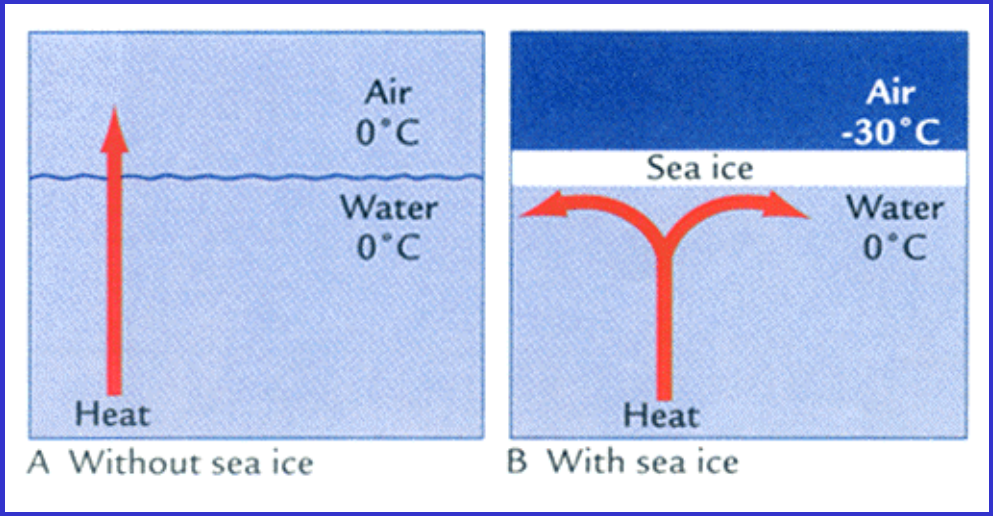
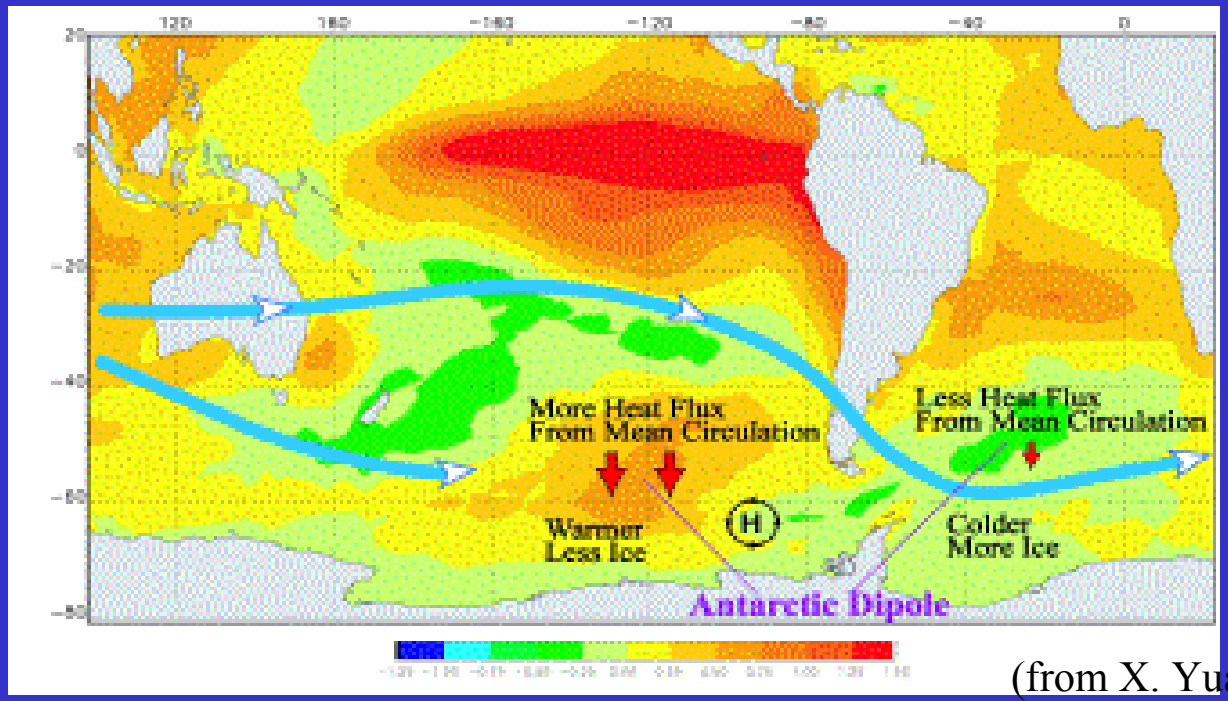
Sea Ice



(from *Earth's Climate: Past and Future*)

- One major climate effect of sea ice is to seal off the underlying ocean from interaction with the atmosphere.
- Without an sea ice cover, high-latitude oceans transfers large amount of heat to the atmosphere, especially in winter.
- With an sea ice cover, the heat flux into the atmosphere is stopped. In addition, the ice surface absorbs little incoming solar radiation. Winter air temperature can cool 30°C or more near a sea-ice cover.

Antarctic Dipole (ADP)



(from X. Yuan, LDEO)

- The "Antarctic Dipole" (ADP) is characterized by an out-of-phase relationship between the ice and temperature anomalies in the central/eastern Pacific and Atlantic sectors of the Antarctic.

Pacific South America (PSA) Pattern

PSA

PNA

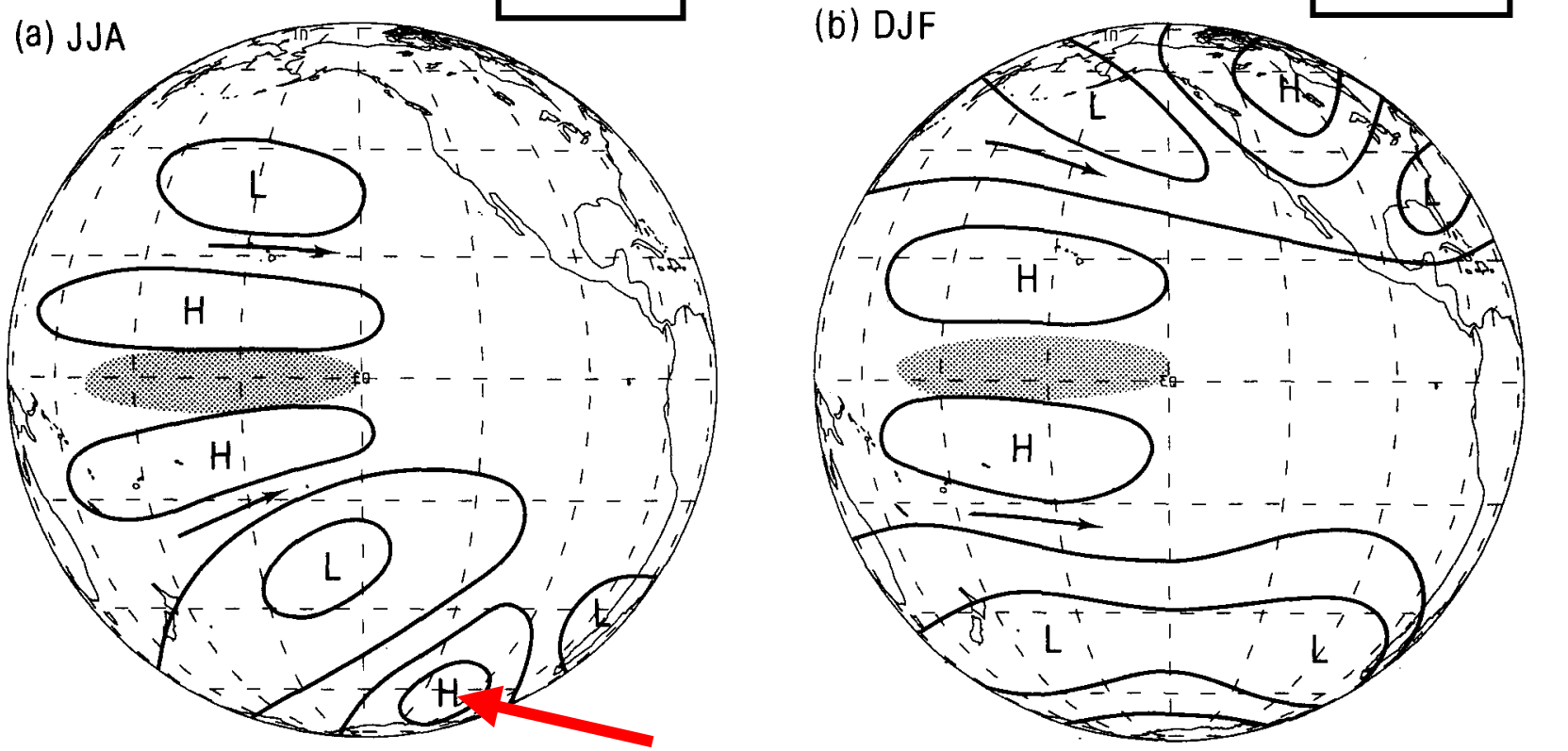


FIG. 11. Schematic illustration of the pattern of upper tropospheric height anomalies over the Pacific Ocean during (a) the early stage of an ENSO event in the SH winter (JJA) and (b) the mature stage of an ENSO event in the SH summer (DJF). The stippling shows the region of enhanced convection over the central equatorial Pacific and the arrows indicate the westerly wind anomalies in the jet streams.

(from Karoly 1989)

What Happened to H_2O?

Table 1.2

An inventory of the hydrosphere[a,b]

Component	Percentage of mass of hydrosphere
Oceans	97.
Ice	2.4
Fresh water (underground)	0.6
Fresh water in lakes, rivers, etc.	0.02
Atmosphere	0.001

[a] Total mass = 1.36×10^{21} kg = 2.66×10^{6} kg m^{-2} over surface of earth.

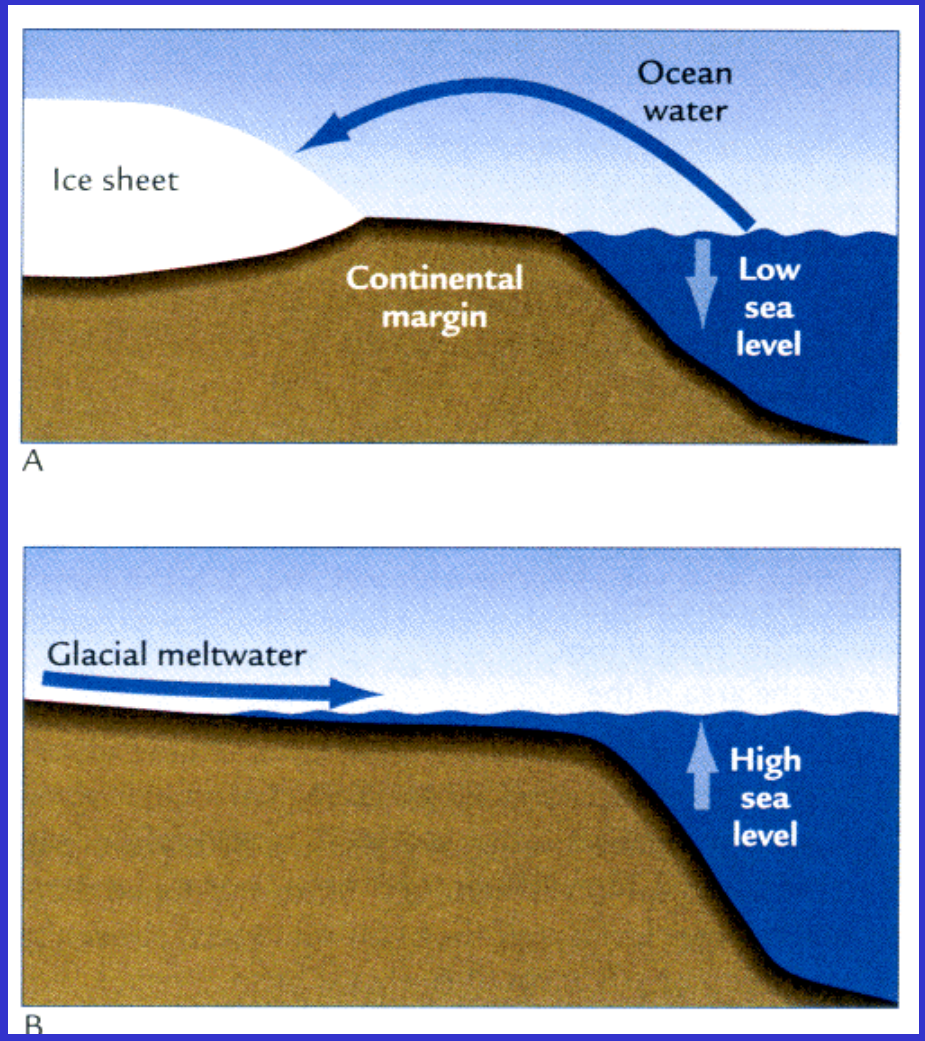
[b] Based on data given in H. H. Lamb, "Climate: Present, Past and Future," Methuen Co. Ltd., London, 1972, p. 482.

(from *Atmospheric Sciences: An Introductory Survey*)

- The atmosphere can only hold small fraction of the mass of water vapor that has been injected into it during volcanic eruption, most of the water vapor was condensed into clouds and rains and gave rise to rivers, lakes, and oceans.

➔ The concentration of water vapor in the atmosphere was substantially reduced.

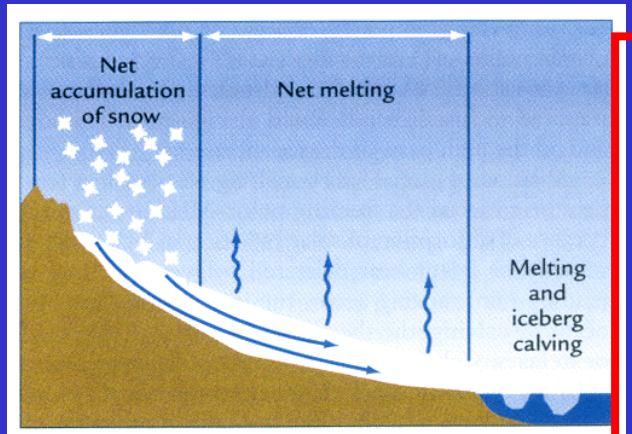
Ice and Sea Level

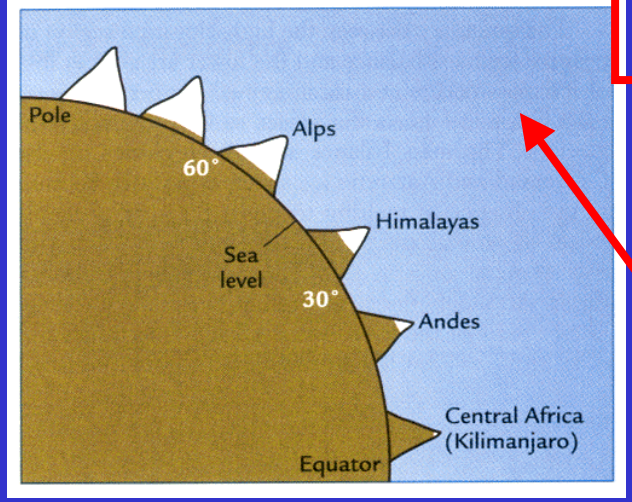


- The Antarctic Ice Sheet holds the equivalent in seawater of 66 meters of global sea level.
- The Greenland Ice Sheet holds the equivalent of 6 meters of global seawater.

(from *Earth's Climate: Past and Future*)

Land Ice





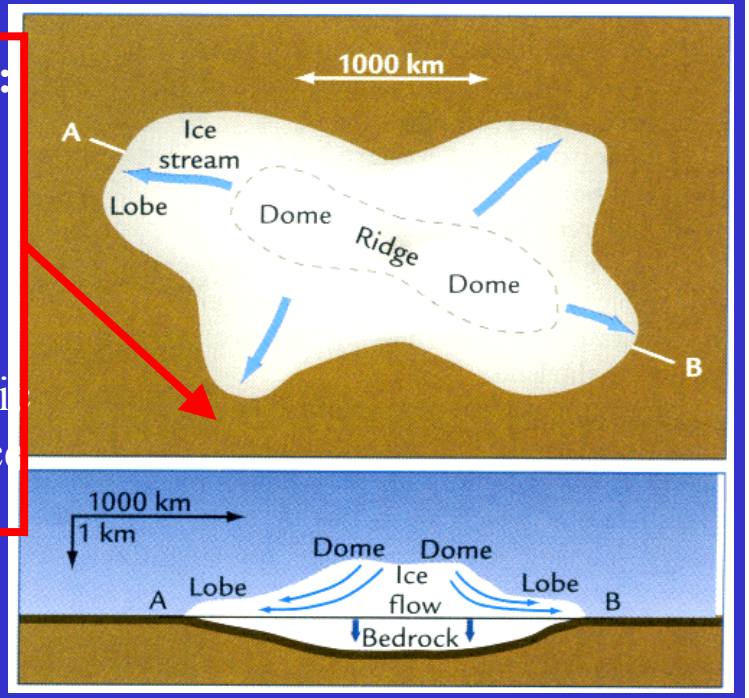
(from *Earth's Climate: Past and Future*)

❑ **Continental Ice Sheets:**

100-1000 km in horizontal extend.

1-4 km in thickness.

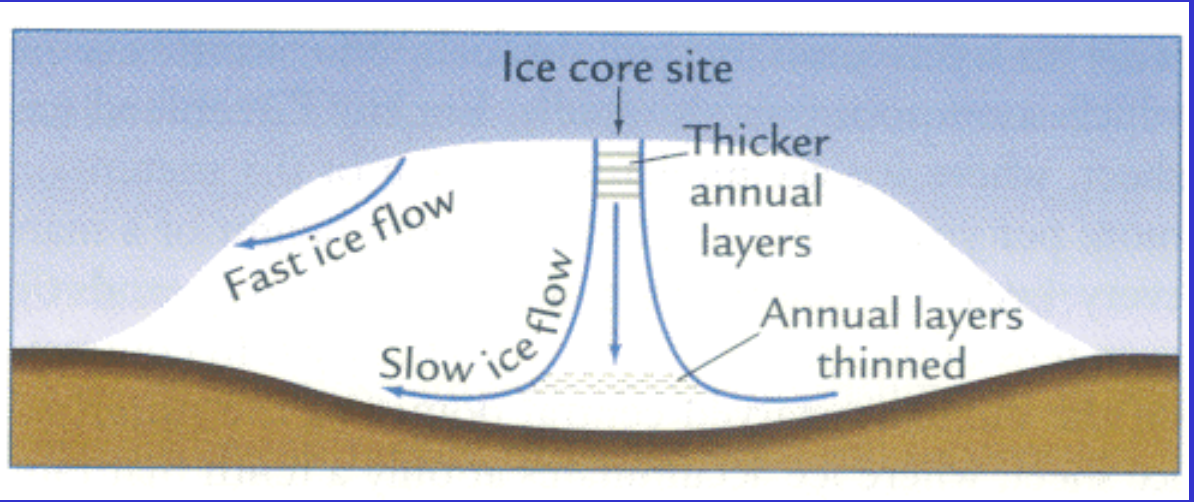
Two larges sheets: Antarcti Ice Sheet and Greenland Ic Sheet.



❑ **Mountain Glaciers:** a few kilometers in length and 10-100 meters in width and thickness.

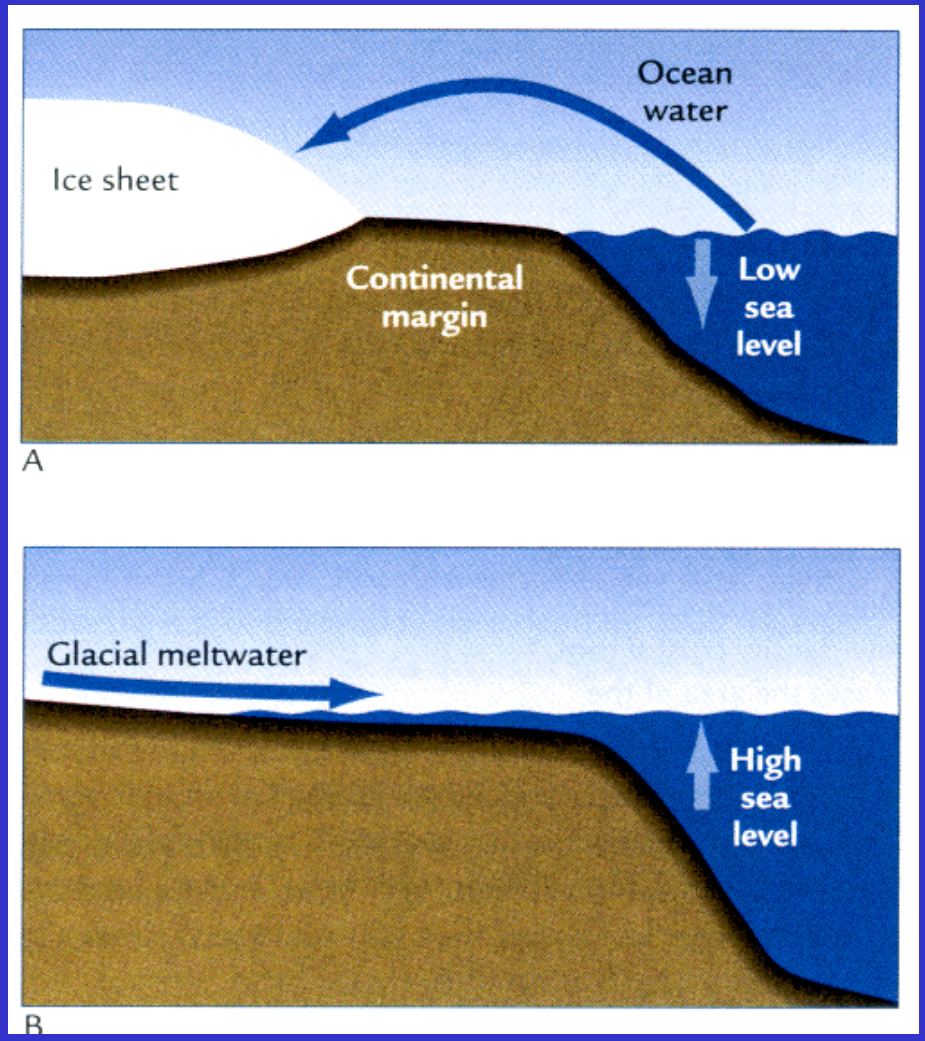
Glacial Ice

(from *Earth's Climate: Past and Future*)



- Ice cores retrieve climate records extending back thousands of years in small mountain glaciers to as much as hundreds of thousands of years in continental sized ice sheets.
- The antarctic ice sheet has layers that extend back over 400,000 years.
- The Greenland ice sheet has layers that extended back 100,000 years.

Ice and Sea Level



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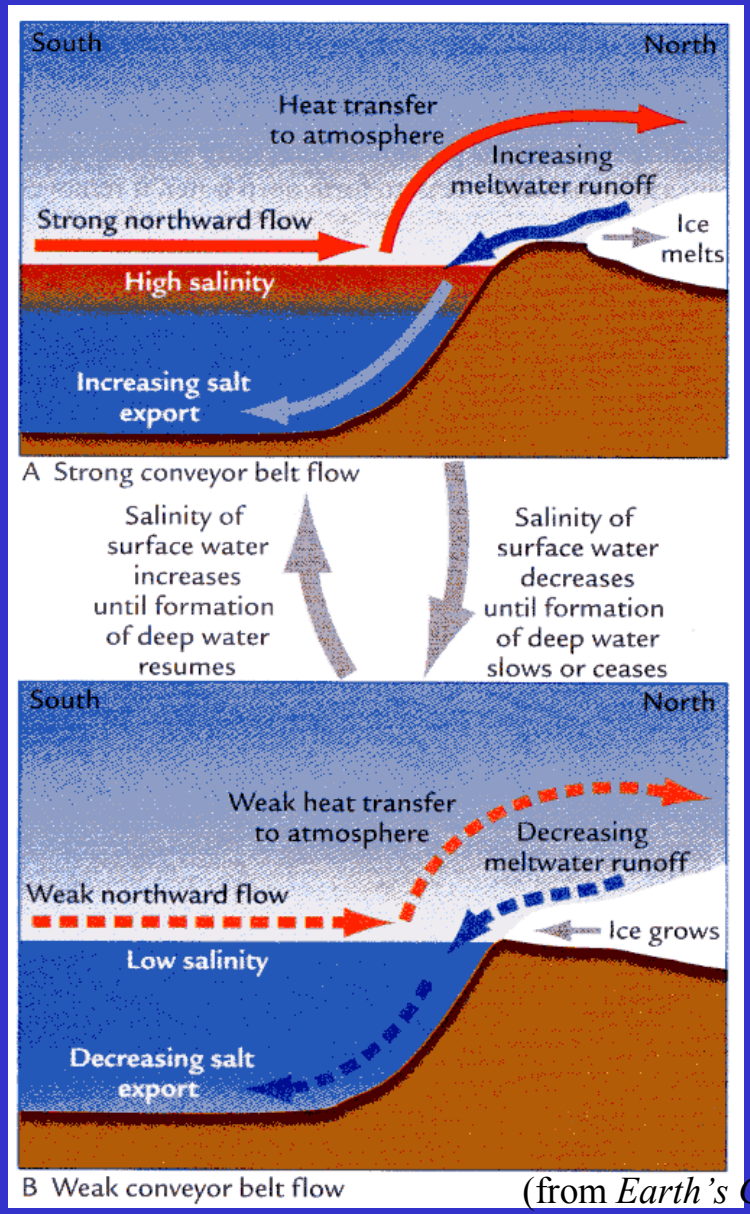
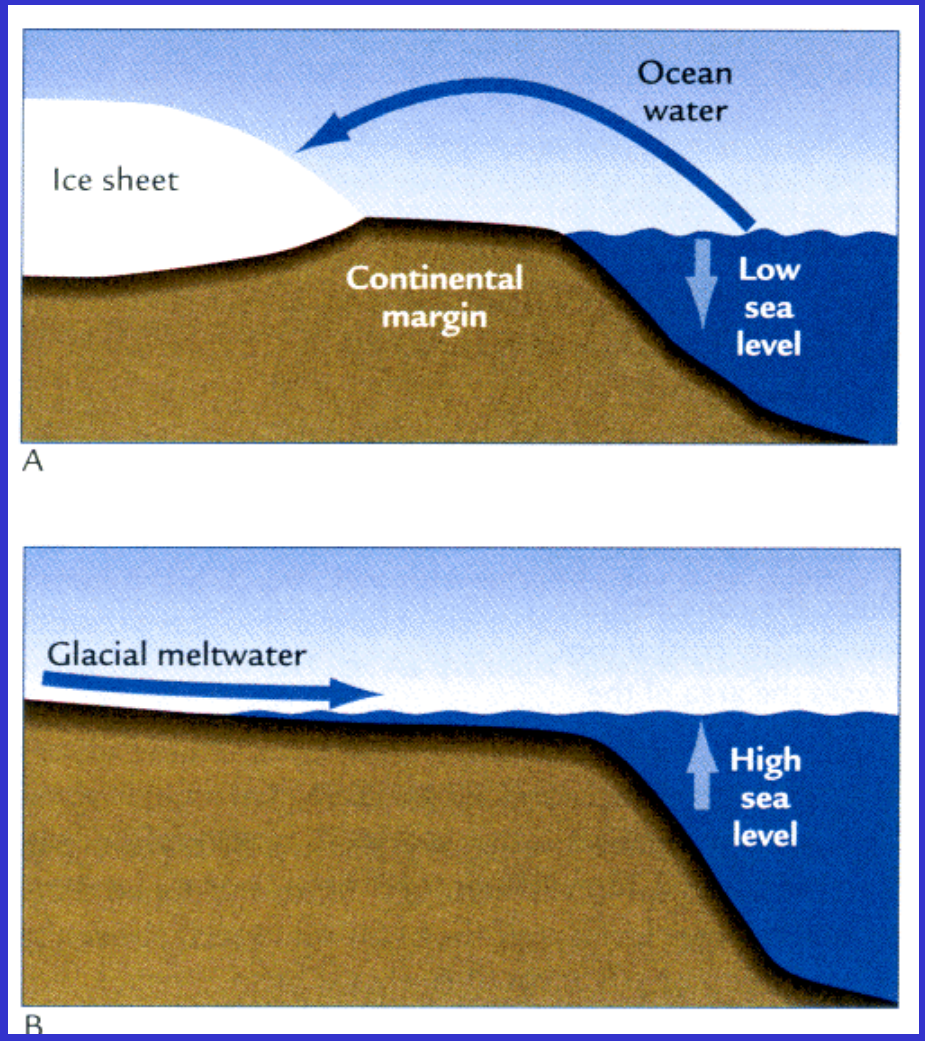
Interactions between Ice and Ocean



- This hypothesis argues that millennial oscillations were produced by the internal interactions among various components of the climate system.
- One most likely internal interaction is the one associated with the deep-water formation in the North Atlantic.
- Millennial oscillations can be produced from changes in northward flow of warm, salty surface water along the conveyor belt.
- Stronger conveyor flow releases heat that melts ice and lowers the salinity of the North Atlantic, eventually slowing or stopping the formation of deep water.
- Weaker flow then causes salinity to rise, completing the cycle.

(from *Earth's Climate: Past and Future*)

Ice and Sea Level



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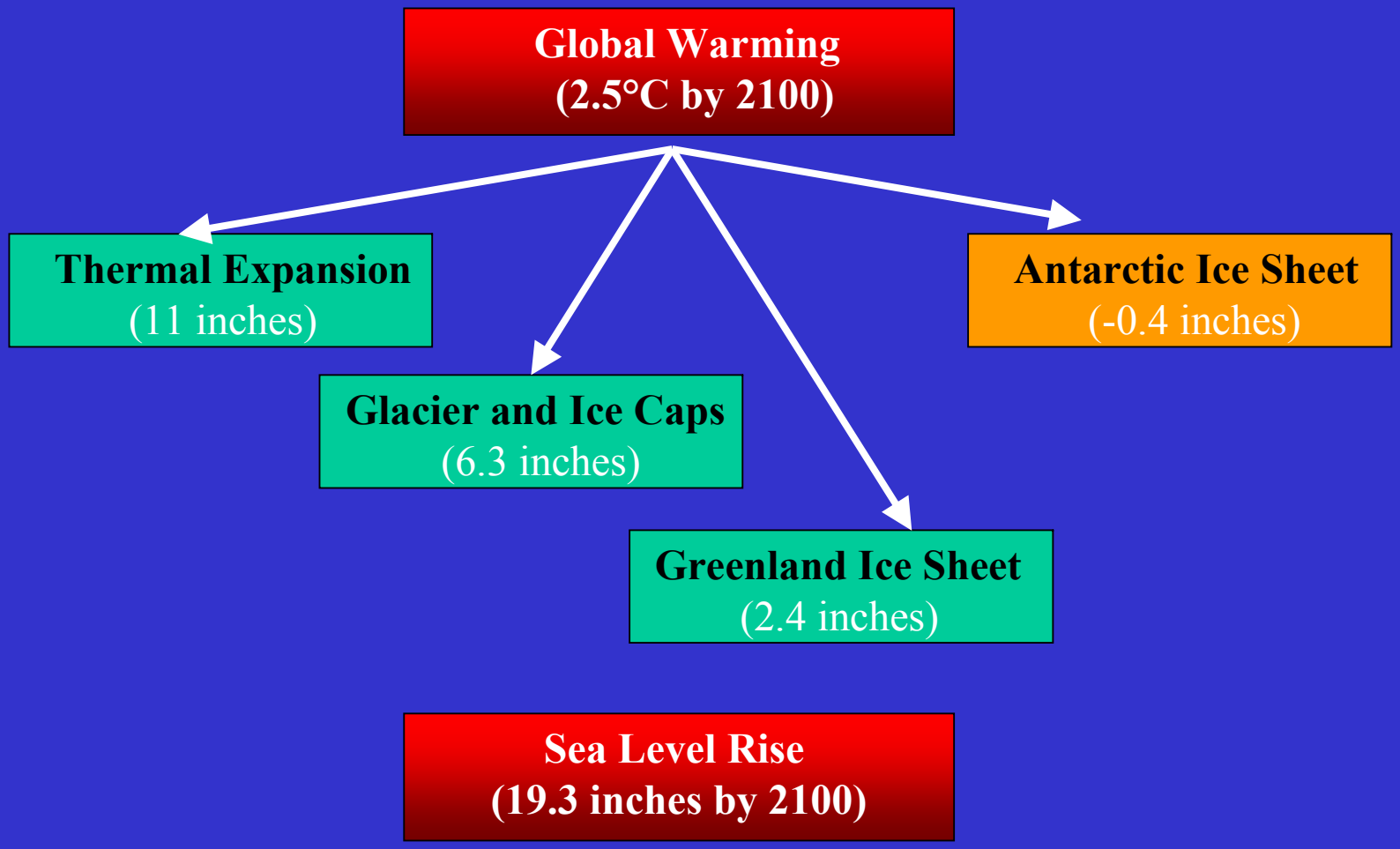
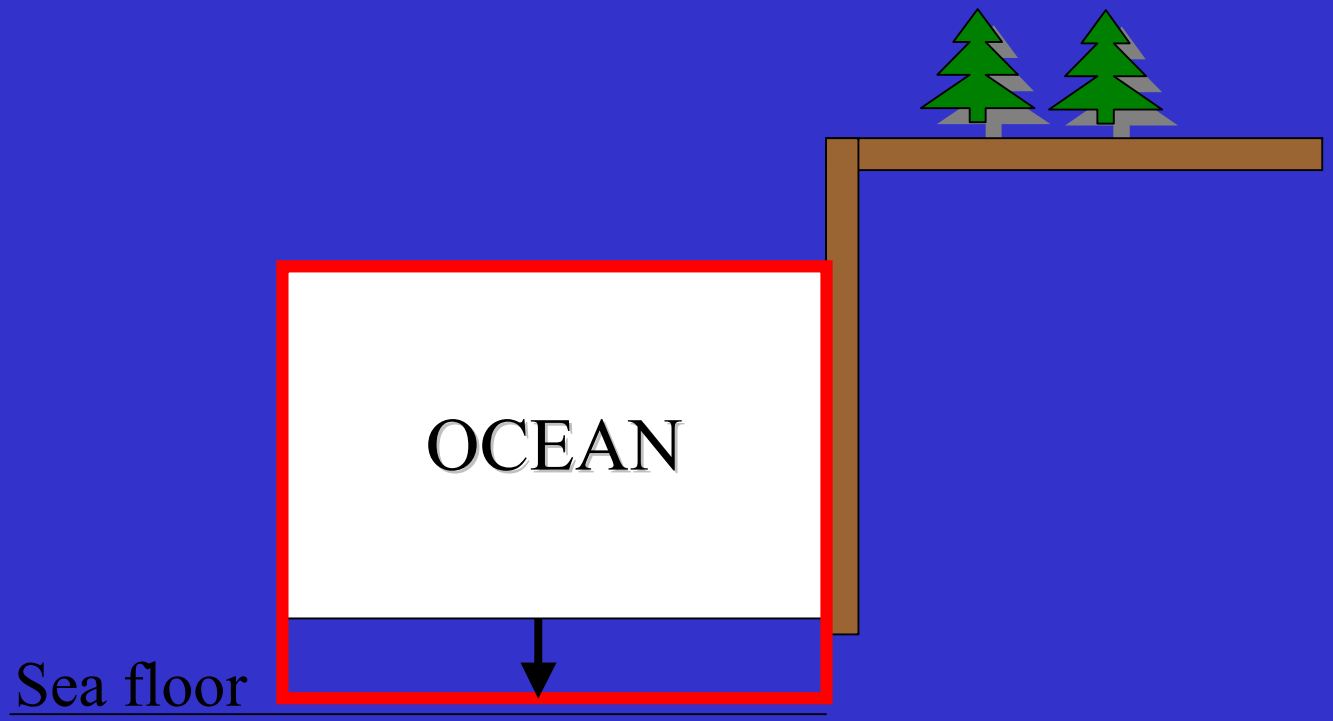
(from *Earth's Climate: Past and Future*)

Global Warming and Sea-Level Change



Sea Level Rise .vs. Sea Floor Sink



After a certain amount of land-supported ice melts, in stead of saying the sea level will rise “so much”, we should say the oceans will get “so much” deeper. -- (Kivioja 2003; *EOS*)