ATOC 1060-002
OUR CHANGING ENVIRONMENT

Class 19 (Chp 6)

Objectives of Today's Class: The Cryosphere

[1] Components, time scales;

[2] Seasonal snow cover, permafrost, river and lake ice, ;

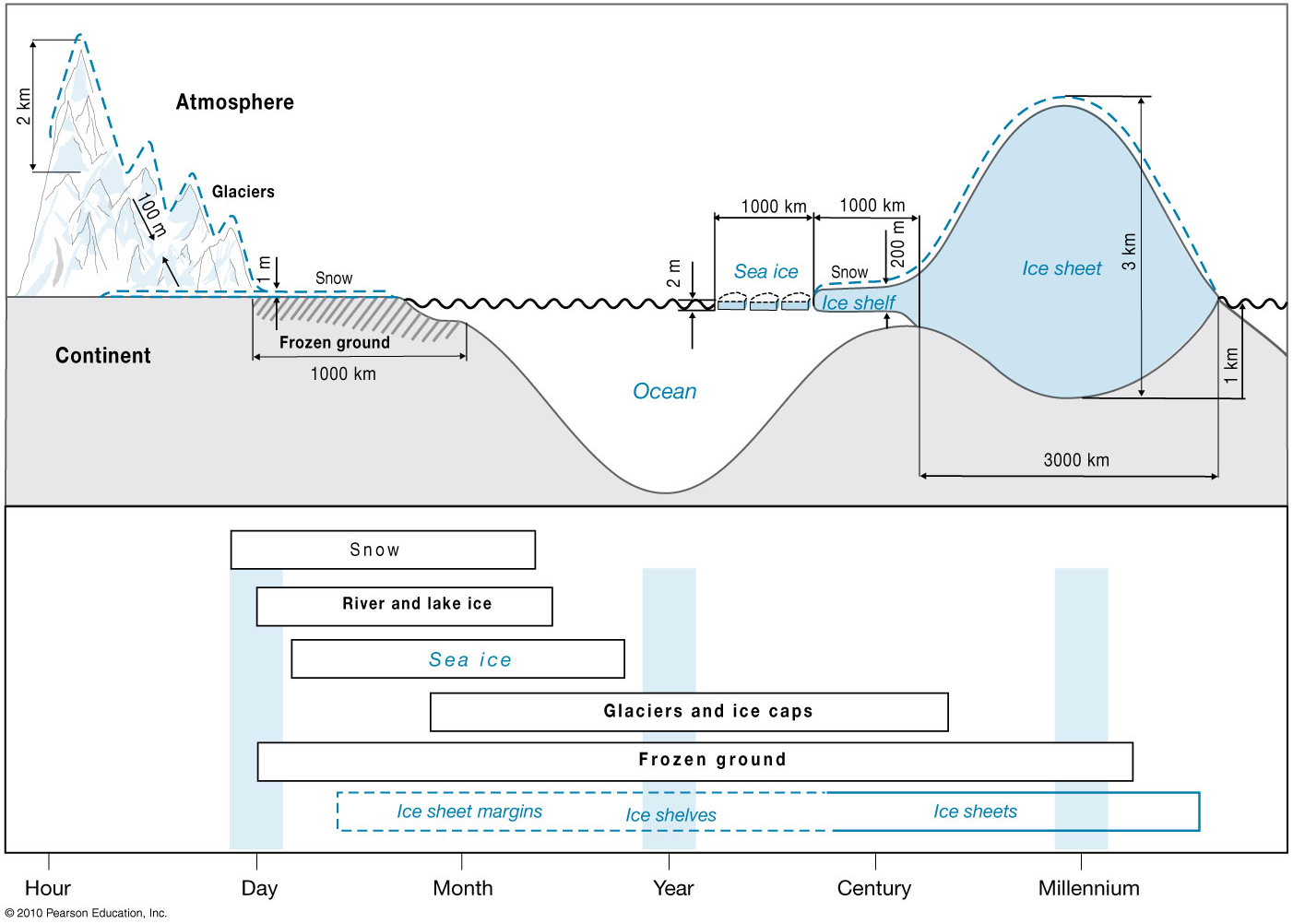
[3]Glaciers and ice sheets;

[4] Sea ice and Climate.

1. Components of the Cryosphere, time scales

Primarily components: (1) Continental ice sheets, ice shelves, mountain glaciers; (2) sea ice, river and lake ice, snow cover;
and (3) permafrost (frozen ground).

Dynamic system: Constant motion, Changing with Time.



Cryosphere: interacts with the climate system

- Melting of continent ice sheets, glaciers affect global sea level;
- Mountain snow cover and glaciers are an important source of freshwater; (~75% of western USA)
- Melting of permafrost releases greenhouse gases, etc;
- Changes in the distribution of sea ice and snow cover change the albedo and feedback to regional and global temperatures;
- Sea-ice formation increases sea surface salinity at high latitudes, affects ocean density, bottom-water formation and thus thermohaline circulation.

Area, volume, and sea level equivalent of the cryosphere

TABLE 6-1 Area, Volume, and Sea Level Equivalent (SLE) of the Cryosphere

Cryosphere Component	Area (10^6 km^2)	Ice Volume (10^6 km^3)	Potential Sea-Level Rise (SLE) (m)
Snow on land (NH*)	1.9–45.2	0.0005–0.005	0.001–0.01
Sea ice	19–27	0.019–0.025	~0
Glaciers and small ice caps			
Smallest estimate	0.51	0.05	0.15
Largest estimate	0.54	0.13	0.37
Ice shelves	1.5	0.7	~0
Ice sheets	14.0	27.6	63.9
Greenland	1.7	2.9	7.3
Antarctica	12.3	24.7	56.6
Seasonally frozen ground (NH)	5.9–48.1	0.006–0.065	~0
Permafrost (NH)	22.8	0.011–0.037	0.03–0.10

*Northern Hemisphere

Source: Lemke, P., J. Ren, R. B. Alley, I. Allison, J. Carrasco, G. Flato, Y. Fujii, G. Kaser, P. Mote, R. H. Thomas, and T. Zhang, 2007: "Observations: Changes in Snow, Ice and Frozen Ground." In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor, and H. L. Miller [eds.]). Cambridge University Press, Cambridge, United Kingdom, and New York, NY, USA.

Clicker's question 1

Choose the most complete statement:

A. Cryosphere includes continental ice sheet, mountain glaciers, sea ice and clouds;

B. Cryosphere includes continental ice sheet, mountain glaciers, sea ice and permafrost;

C. Melting of sea ice will increase sea level by few meters;

D. Melting of Greenland and Atarctica ice sheets will increase sea level by less than 10 meters;

E. Both B and D.

2. Seasonal snow cover, permafrost, river and lake ice

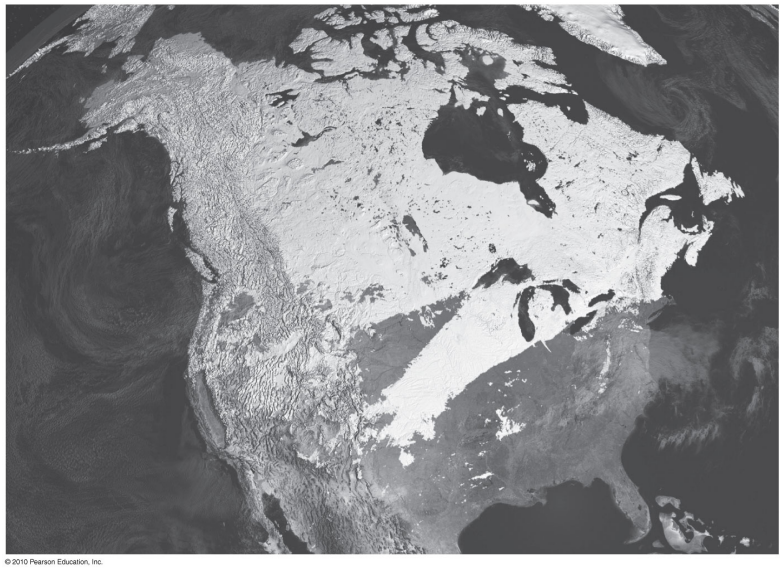
- Snow cover – seasonal variations - possible effects on interannual climate; Seasonal freezing/thawing of lakes, rivers – important local ecosystems and human activities; but not so much on global scales - only brief discussion.

Increased snow cover

– increase albedo (reflectivity)

– cools the earth's surface.

(Warms the underlying surface)



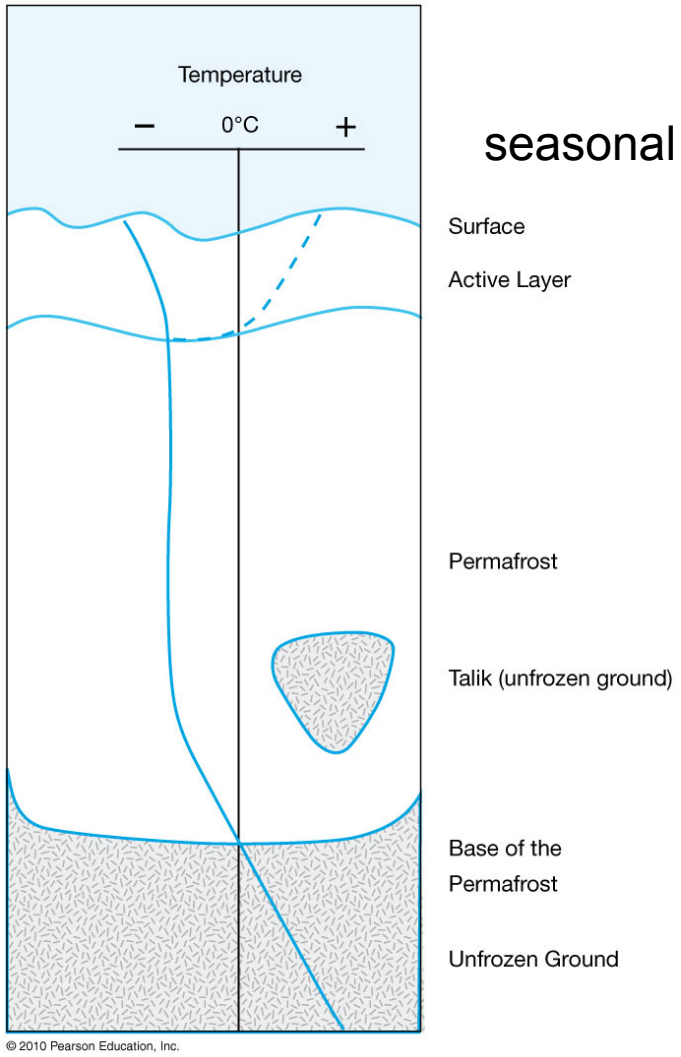
North American snow cover, feb 2-9, 2002.

Permafrost:

- Permafrost is considered to be present if the ground remains at or below 0°C for 2 or more years.

- Warmer air (to a lesser degree, increased snow insolation) decreases permafrost;

IPCC AR4 – indicates some degree of permafrost warming during the 2nd half of the 20th century.

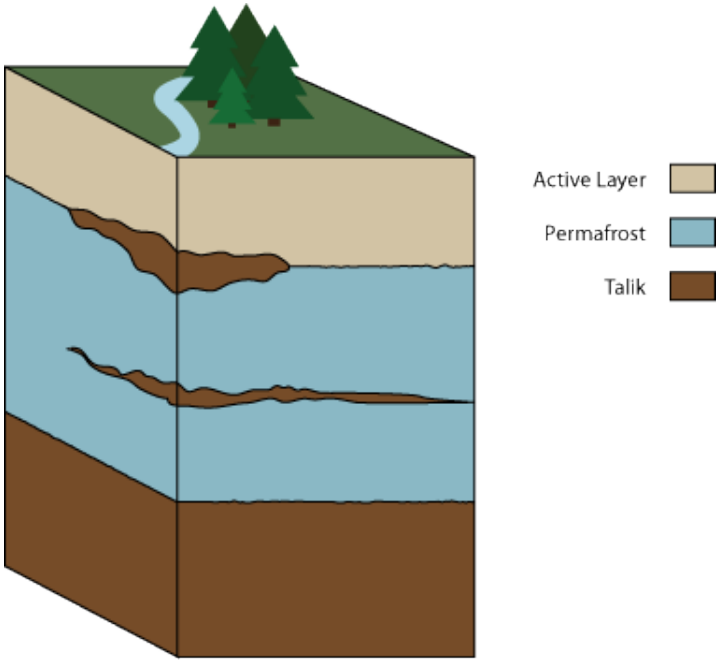


Effects of permafrost melting

a) Potential increase of methane – an important greenhouse gas. Its near-surface Melting – low oxygen in Lakes & water-logged soil – methane

Producing organism can flourish.

b) Affect local ecosystems, construction and infrastructure development




Houses undermined by melting Permafrost

Clicker question 2

Choose the most complete statement.

A. Reduced snow cover will increase the Earth's surface albedo and thus reduce its temperature;

B. Reduced snow cover will reduce the Earth's surface albedo and thus increase its temperature;

C. Reduction of permafrost can potentially increase methane emission to the atmosphere;

D. Both A and C.

E. Both B and C.

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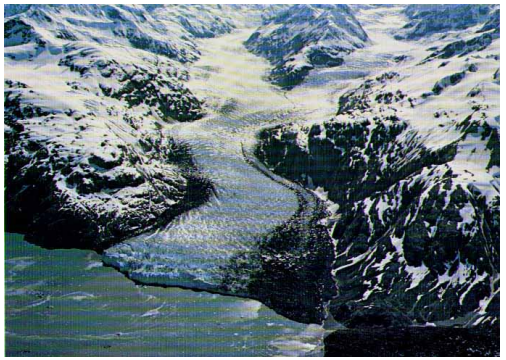
3. Glaciers and ice sheets

- Snow cover persists through the summer, accumulates over time, thickens, compacts and transforms into glacier ice.
- In cold glaciers, T<<0C, takes hundreds to thousands of years to transform (say central Antarctica). The process can be speeded up in regions where surface can melt and refreeze: the melt water can percolate down through the pack and refreeze. – may take a few years…(fresh snow density 50-70 kg/m^3; firn (between snow and glacier ice): 400-800 kg/m^3; glacier ice 850-900kg/m^3)

- Mountain glaciers

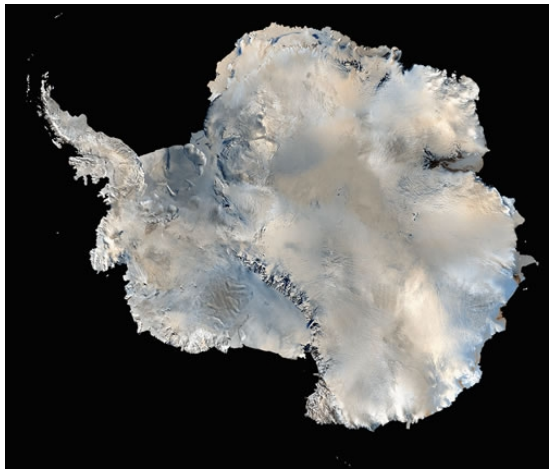
– found in mountainous regions, valleys (European Alps, the Himalaya, and the Andes);



- Continental glaciers: Greenland and Antarctica

– 97% surface land ice area, ~99.6% of the ice volume.

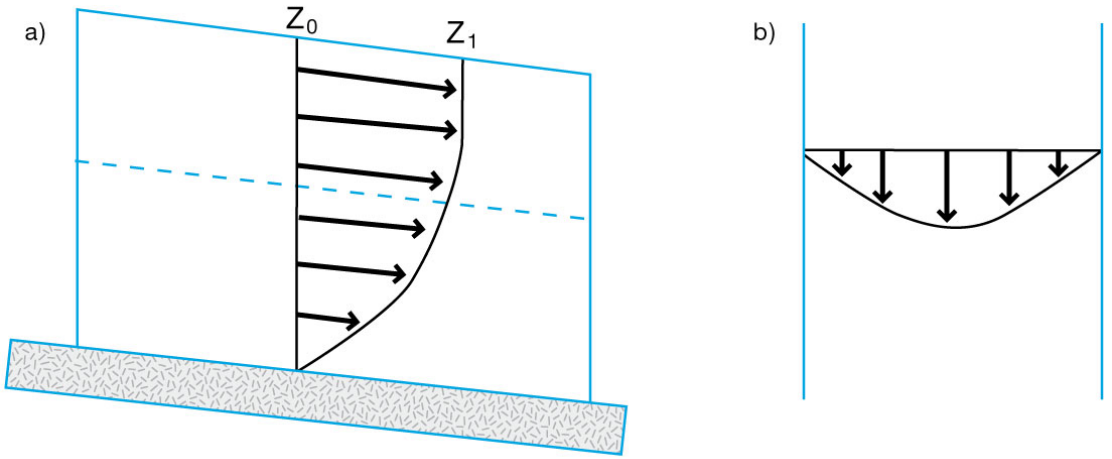
Greenland icesheet



Antarctic icesheet

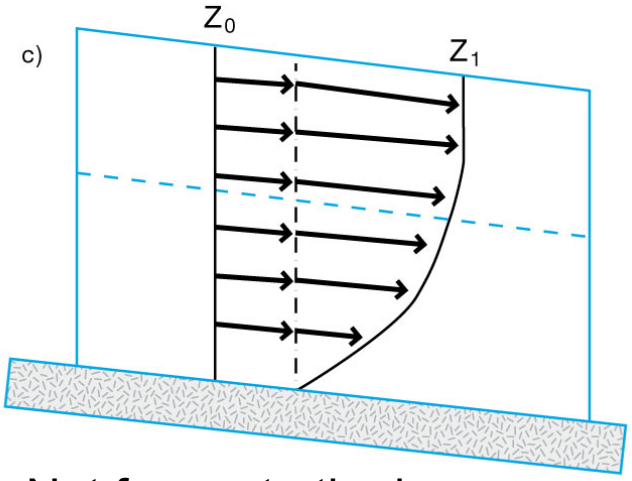
Glacier flow

- Glaciers: are moving.



Deeper – higher stress (due to weight);
Ice frozen to the bed;
Surface (<50m), stress
Small: being carried
by deeper flow;

Bottom, sides – friction
- Slow down.



Not frozen to the beg.

Fig. 6-7.

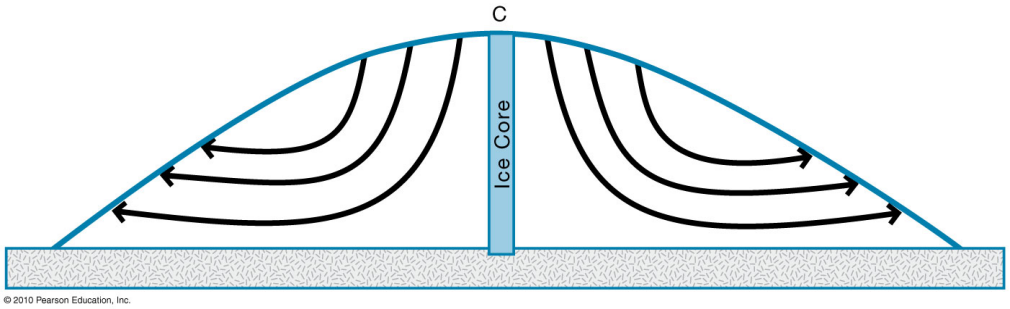
Clicker's question 3

A. The Greenland and Antarctic icesheets together accounts for ~97% surface ice-covered land area, and ~99.7% of the ice volume;
B. Mountain Glaciers move as glacier flows, but continental glaciers (Greenland & Antarctic icesheets) do not move;
C. Glacier flows are fastest at the bottom;
D. All of the above.

- Implications of moving glaciers:

a) ice core data: data back – reconstruct past climate. – should choose a dome region where moving is small or negligible.

(moving affects the "age dating")



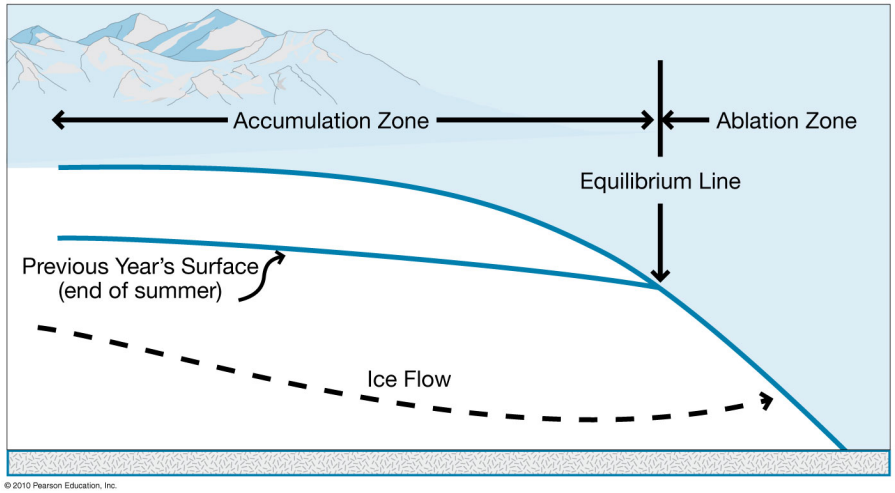
b) Glacier Accumulation and Ablation Zones;

c) Icesheet Dynamics:

unstable, Calving effects

– large uncertainty to sea level change.

This is a large uncertain part in IPCC AR4 when estimating the continental Ice melting effects on sea level change.



Clicker's question 4

- There won't be ablation zone if the glaciers are not moving;
- When obtaining ice core data, we should choose the region where glacier flow is small or negligible;
- Unstable motion, or calving effects of glaciers cause large uncertainties in estimating sea level change due to continental ice melting;
- All of the above.

[4] Sea ice and climate

Seasonal distribution of Sea ice:

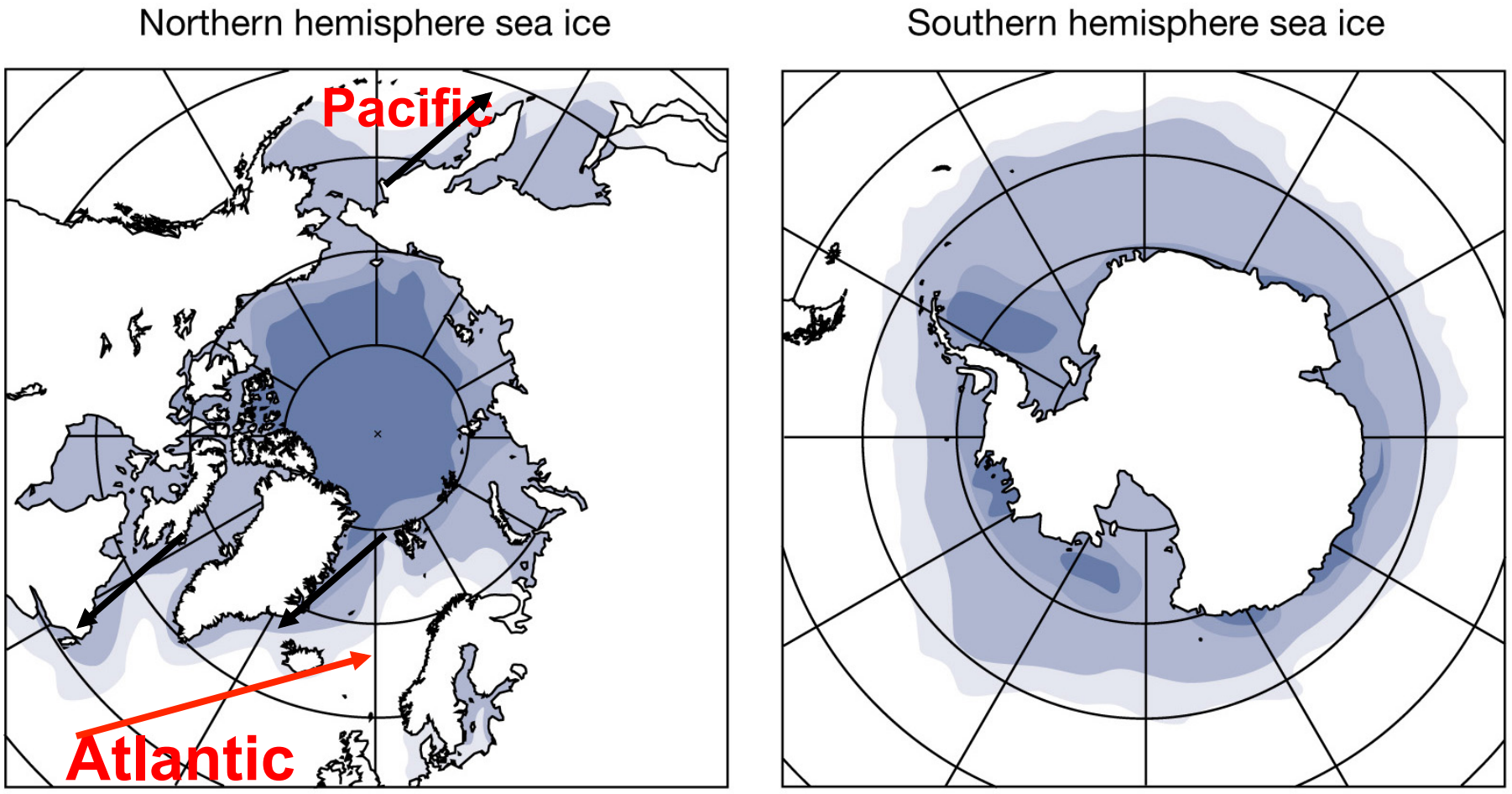
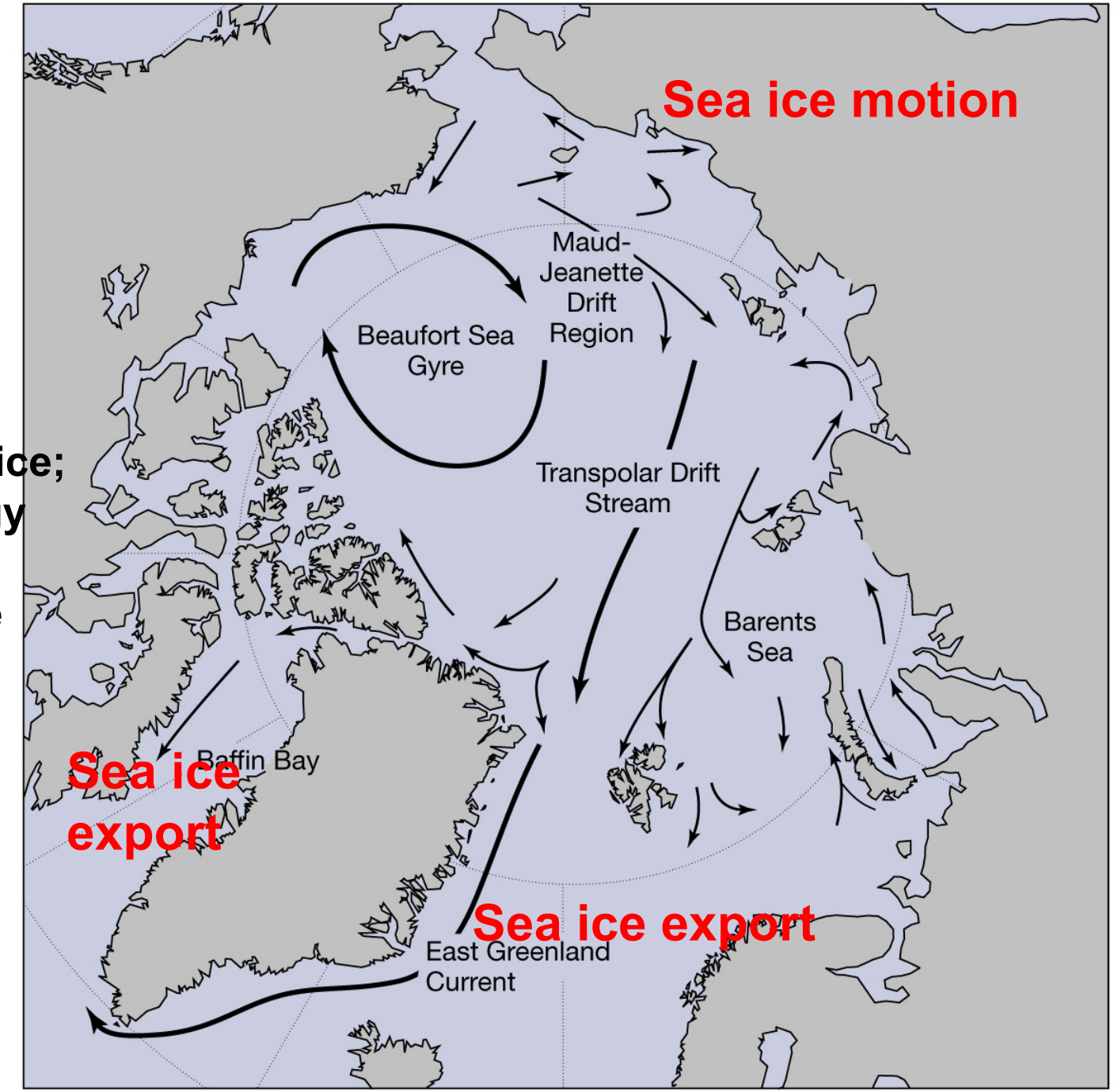


Fig. 15-19

Winds&currents:
Ice floes

Collide;
Break: leads or Polynyii;

=>important:
Open water, new ice;
Open water,energy transfer with atmosphere more efficient than ice.



Ice-Climate interactions

Cold temperature => Sea ice; move with winds & currents;
Sea ice: [1] formation => increase salinity,density => deep water formation => global thermohaline circulation;

Summer: **[2]ice => increase albedo => increase reflection=> decrease solar radiation absorption.**

Winter: No solar Radiation In arctic

[3] Both winter & summer

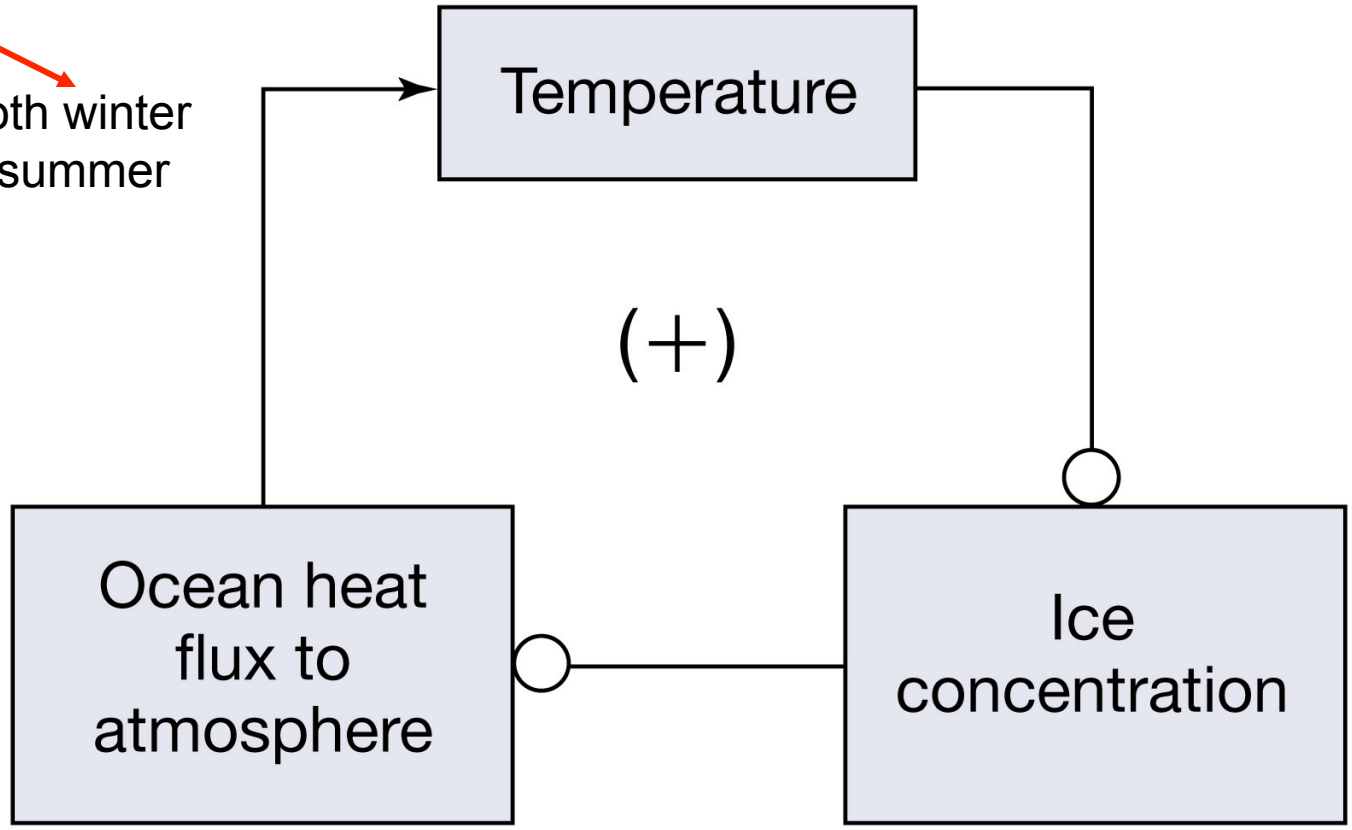


Fig. 15-21

Clicker question 5

Increased sea ice formation in North Atlantic region

[a] decreases sea surface salinity and thus weakens global thermohaline circulation;
[b] increases sea surface salinity and thus enhances global thermohaline circulation;
[c] increases albedo and reduces ocean to atmosphere heat flux, therefore cools the earth and its atmosphere;
[d] does not affect salinity and thus does not change thermohaline circulation;
[e] both [b] and [c].