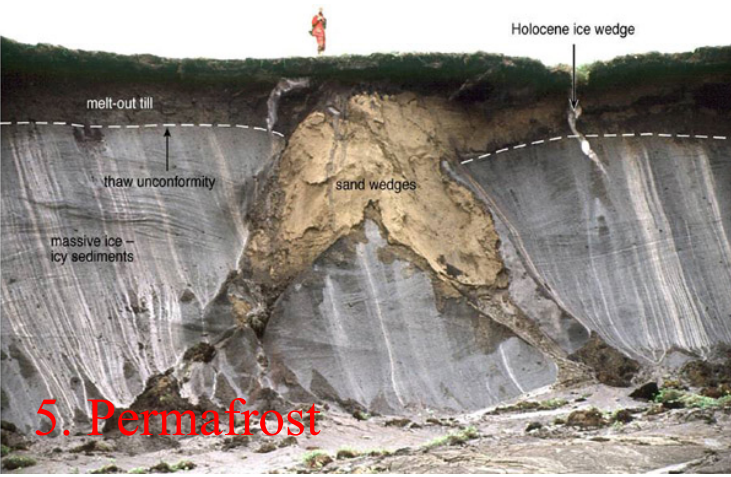
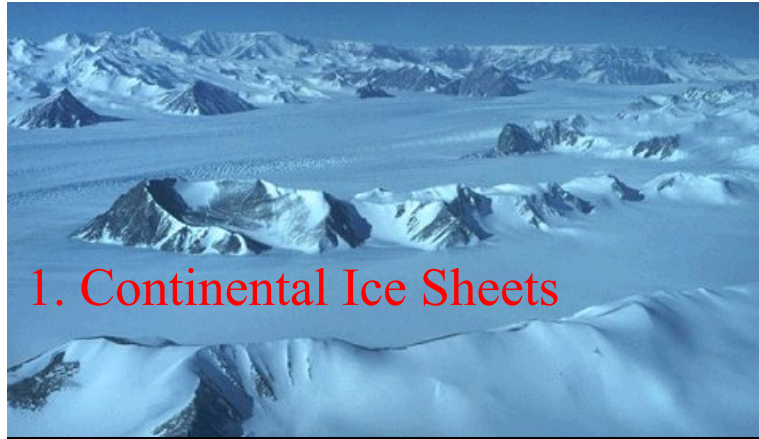
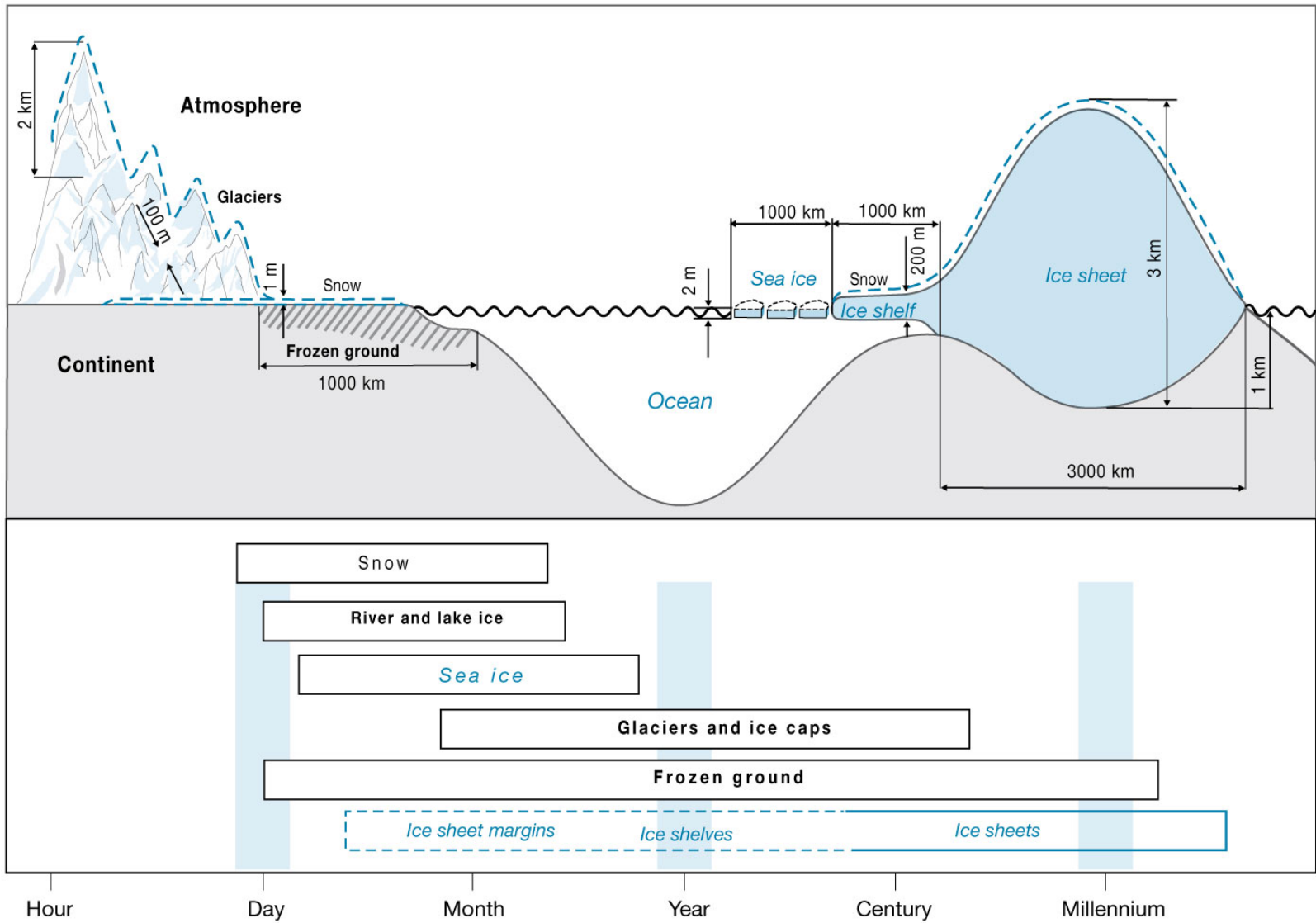


Chapter 6: The Cryosphere



Highest point in Switzerland: Dufourspitze





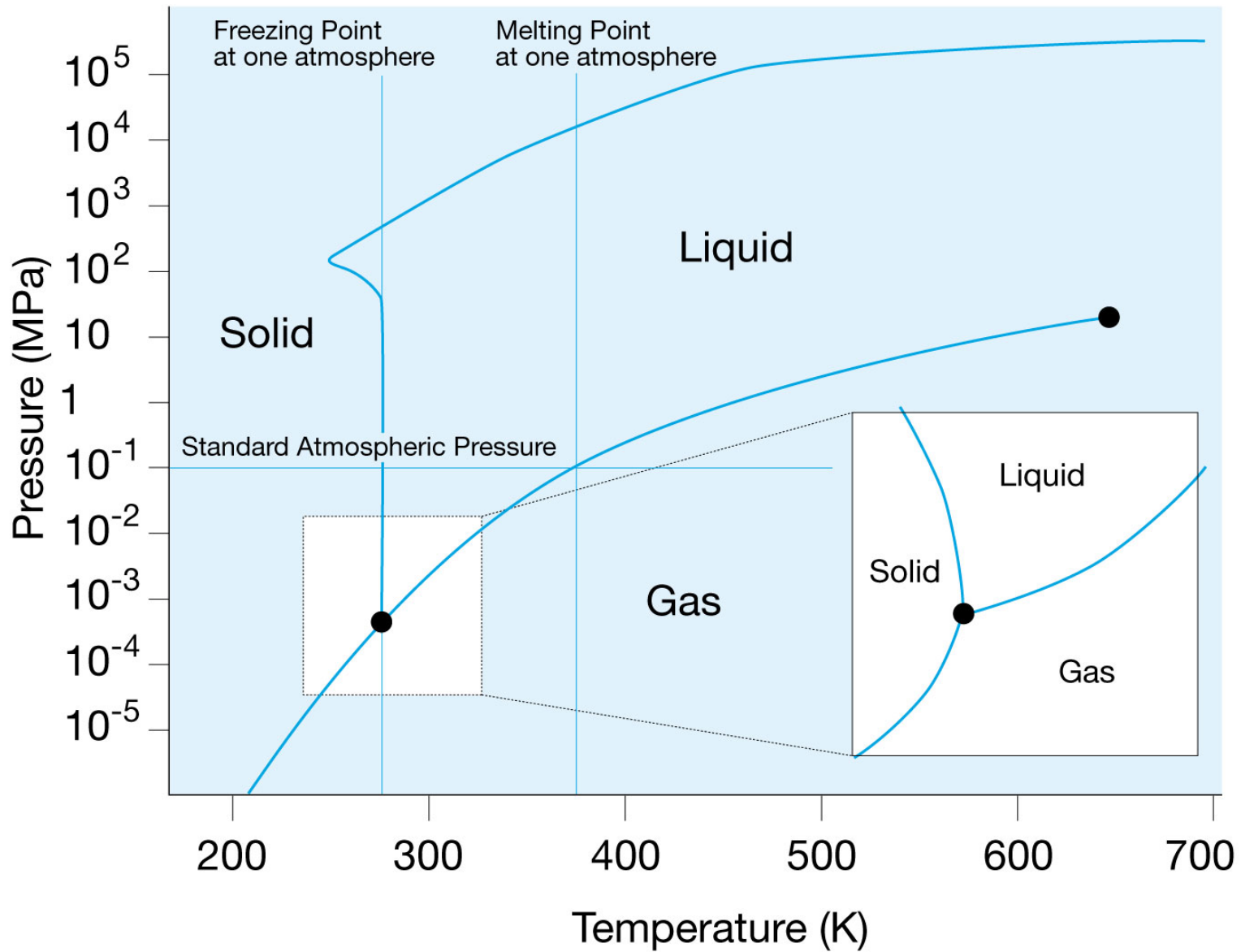
The mountain snowpack in the American West contributes about 75% of the available water. The “slow release” snowpack acts as a kind of reservoir for water. Without snowpack, we would need a lot more dams!

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

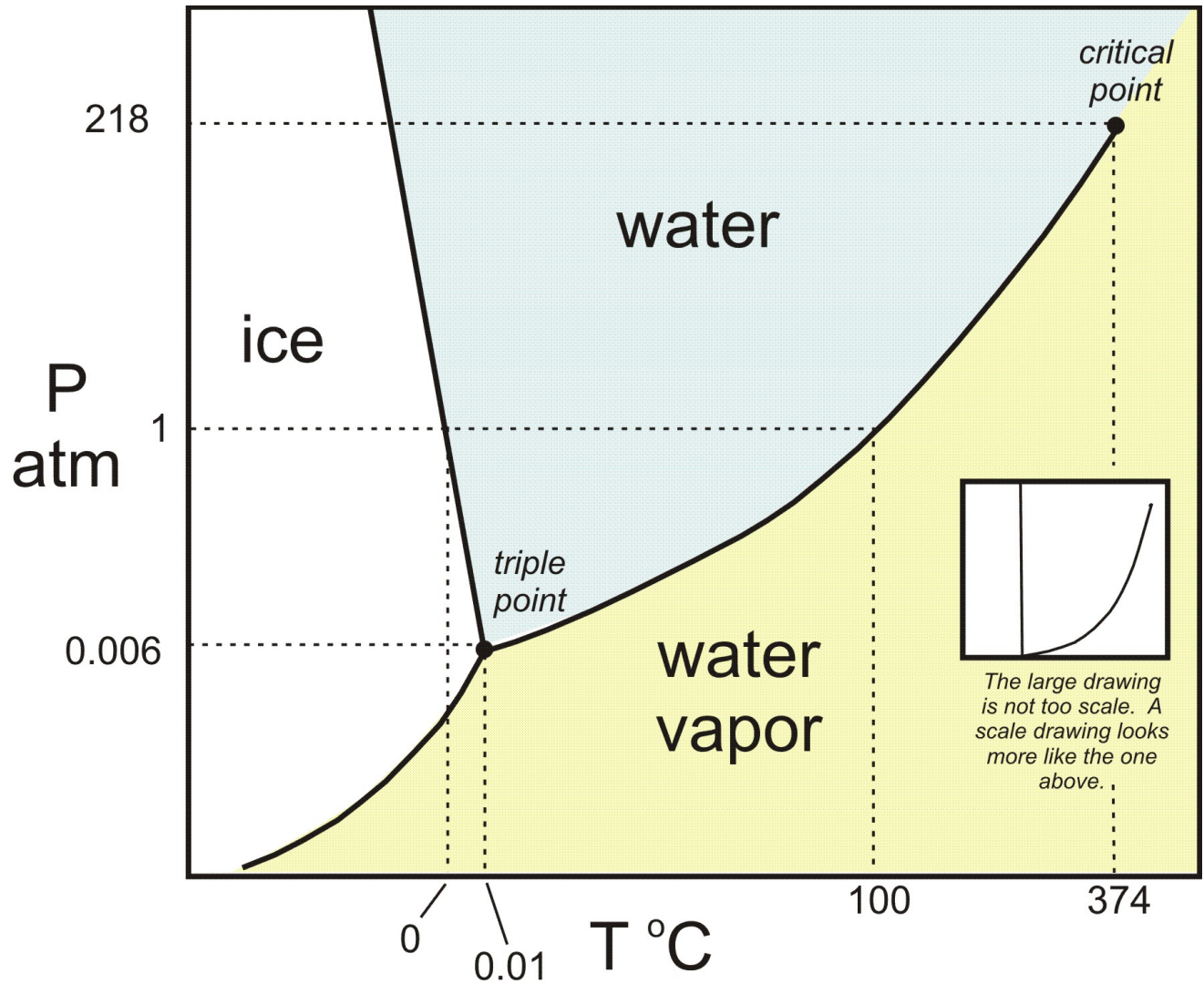
*Northern Hemisphere

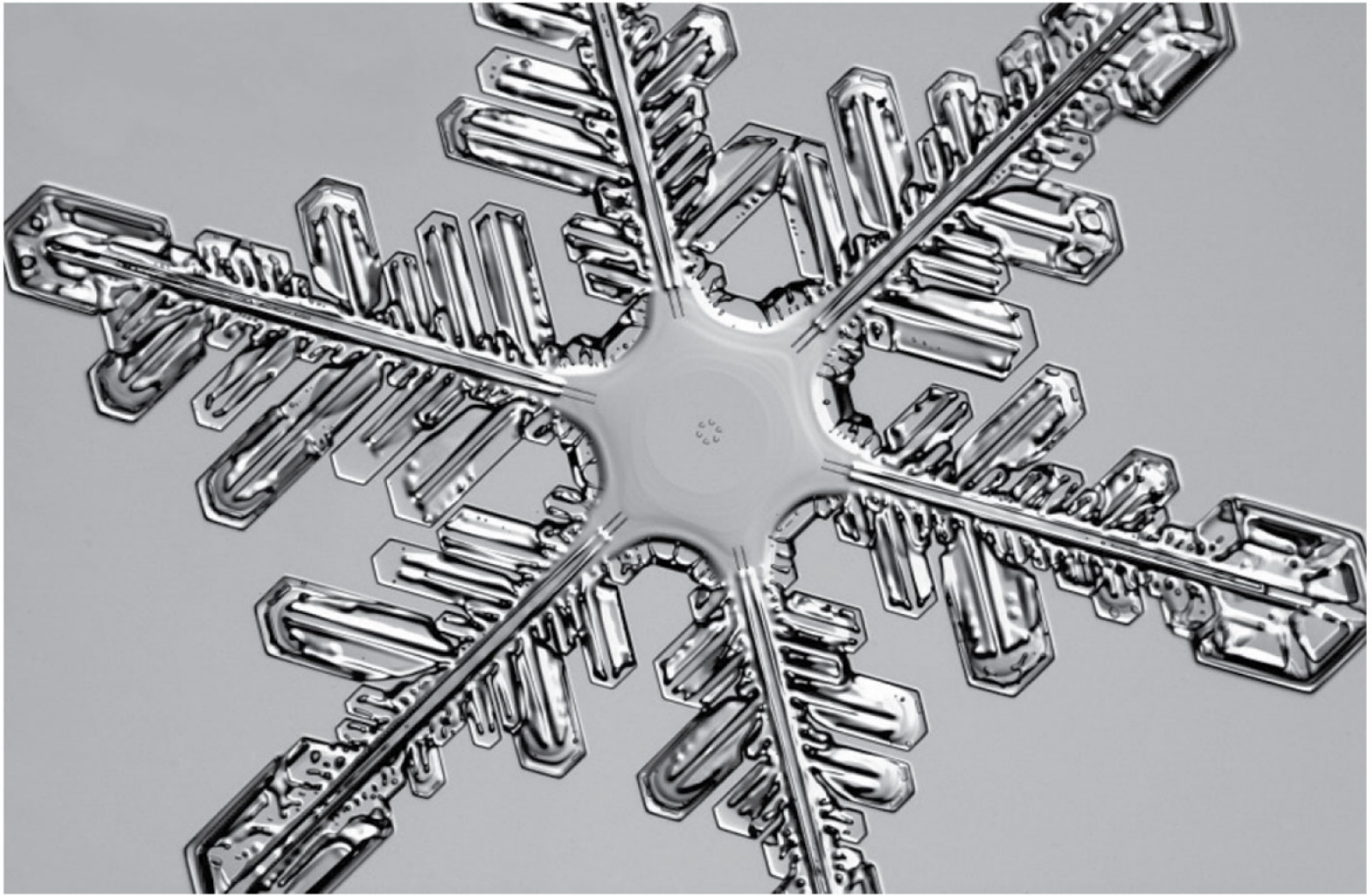
Source: Lemke, P., J. Ren, R. B. Alley, I. Allison, J. Carrasco, G. Flato, Y. Fujii, G. Kaser, P. Mote, R. H. Thomas, and T. Zhang, 2007: “Observations: Changes in Snow, Ice and Frozen Ground.” In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment 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.

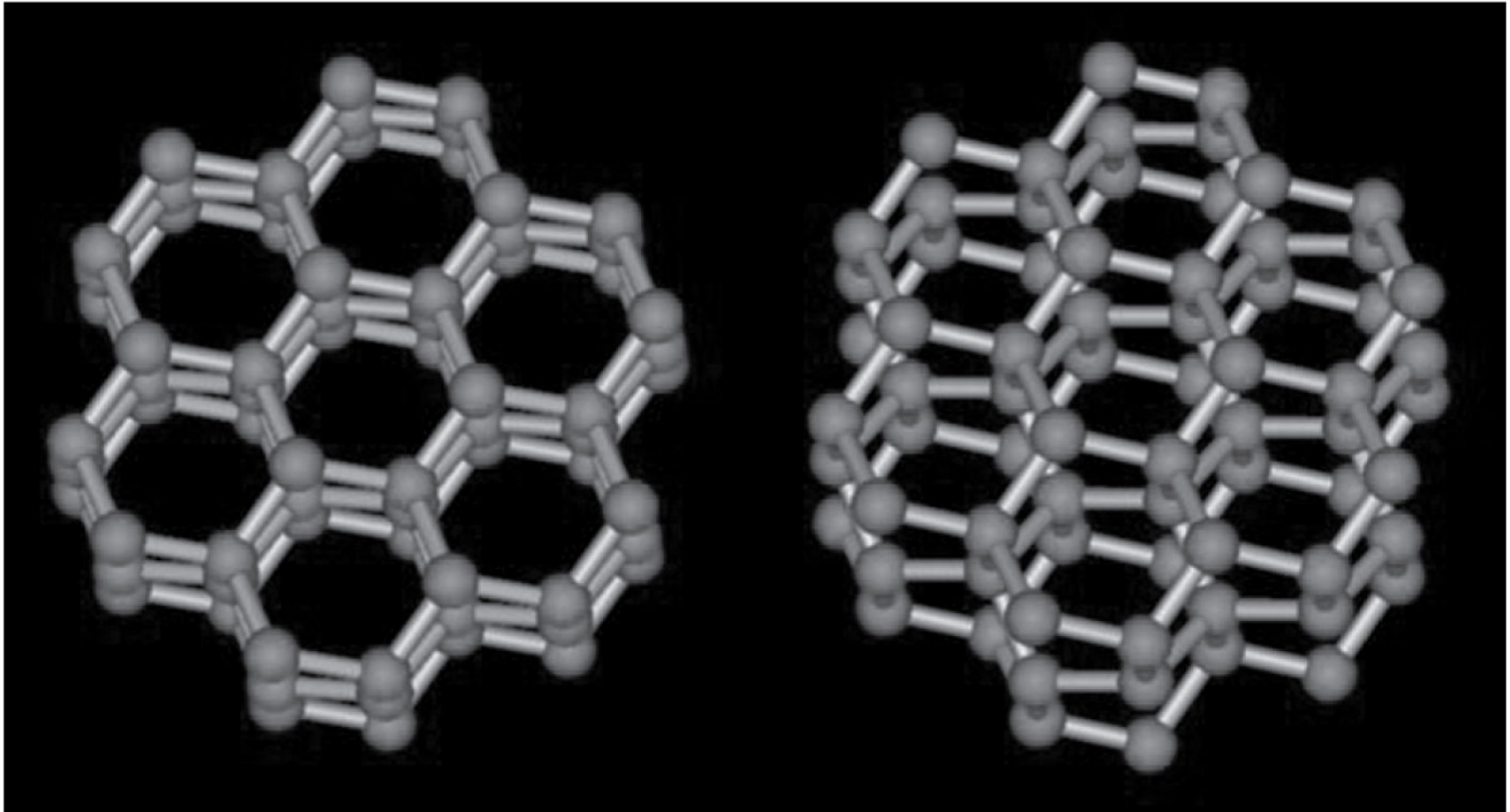


H₂O phase diagram

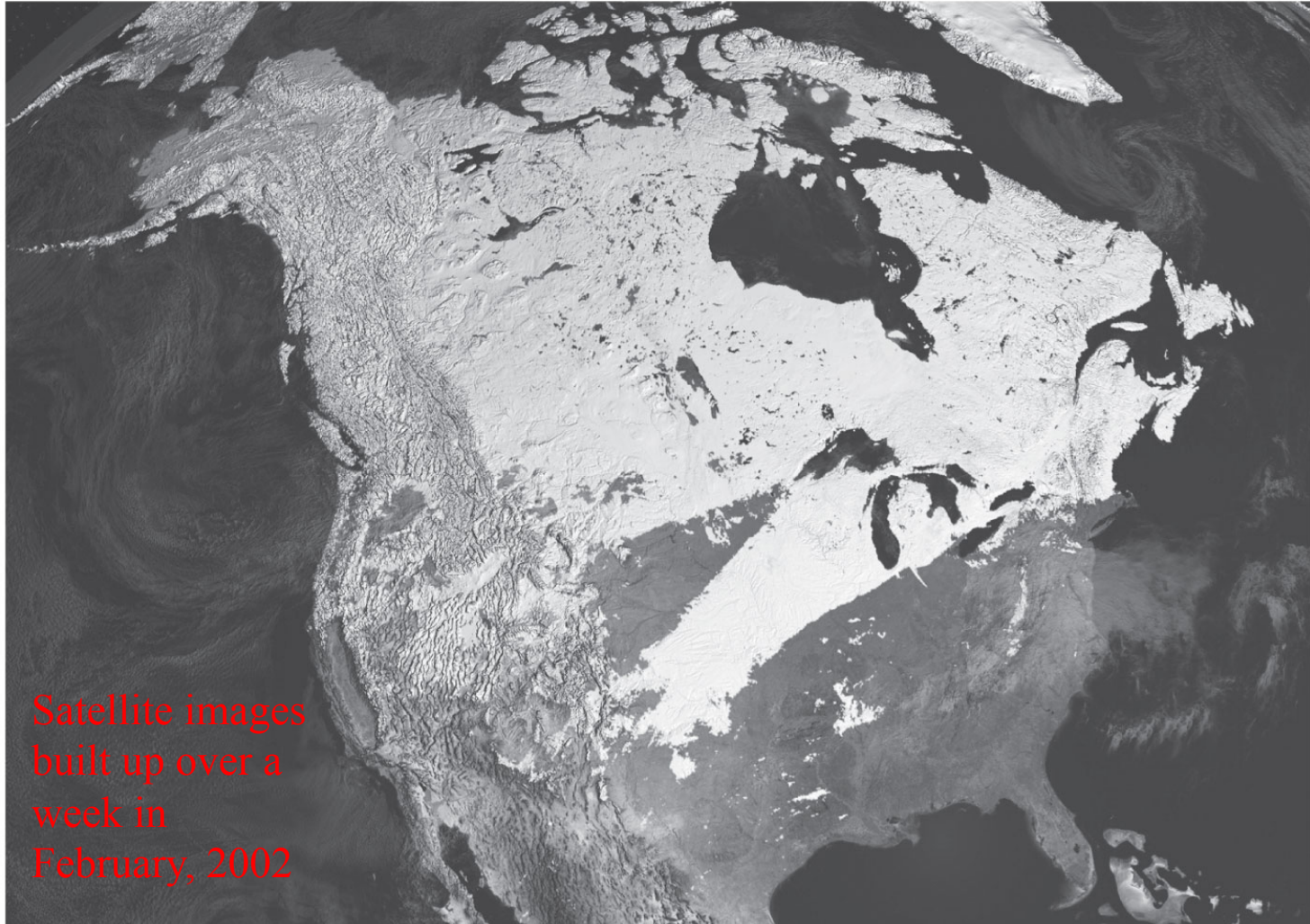
- At 1 atm...
- Triple Point
- Critical Point
- Ice/Water boundary
- Mars?







Builds thermal inertia into the system:



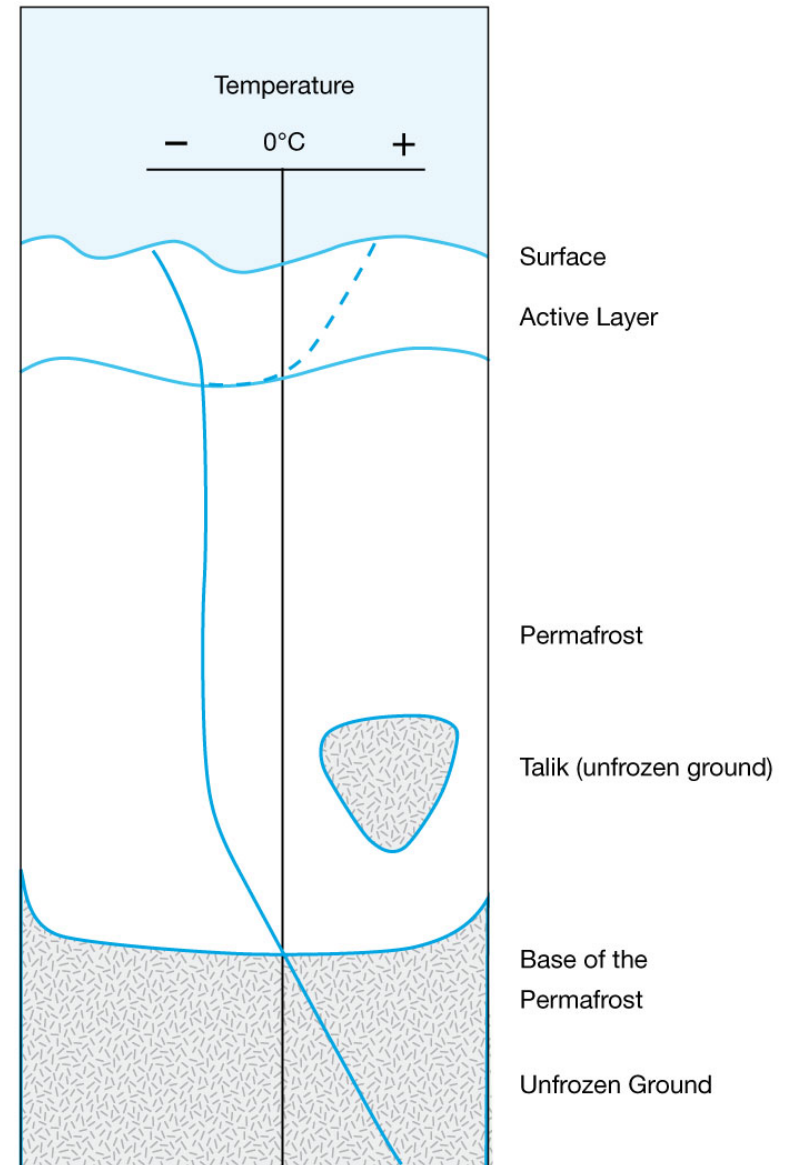
© 2010 Pearson Education, Inc.

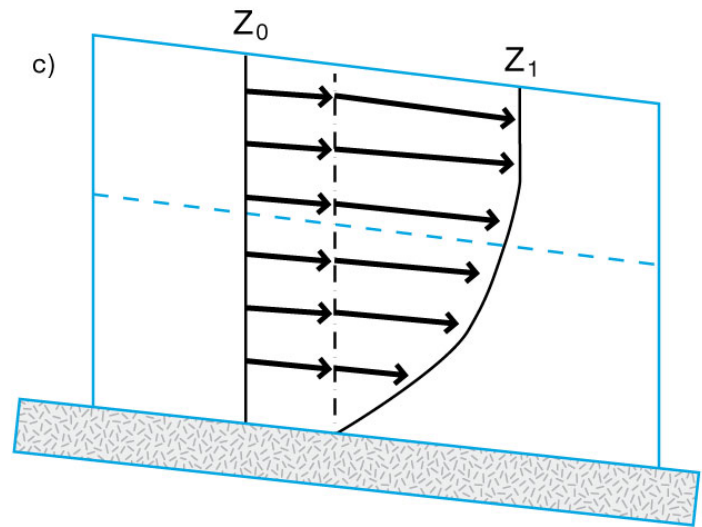
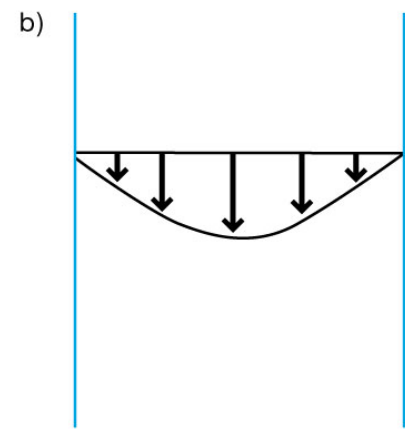
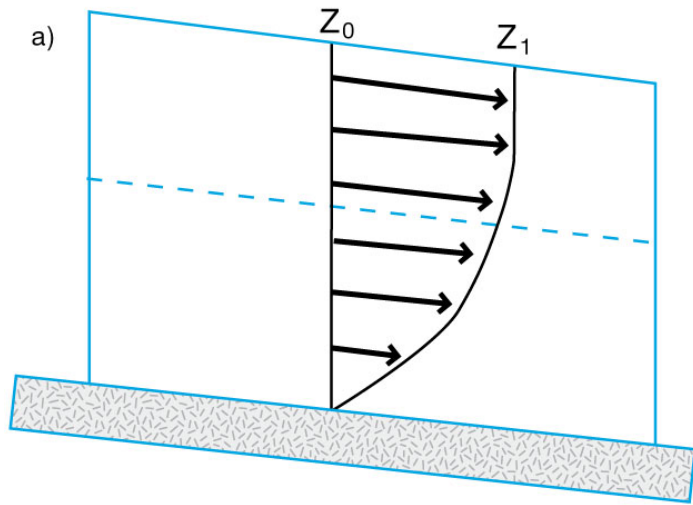
- Albedo; reflected light keeps ground from warming up
- It takes 335,000 J of energy to convert 1 kg ice into water

-Permafrost: By definition, ground temperature is 0°C or less for two years or more (based on temperature – not presence of any particular amount of ice).

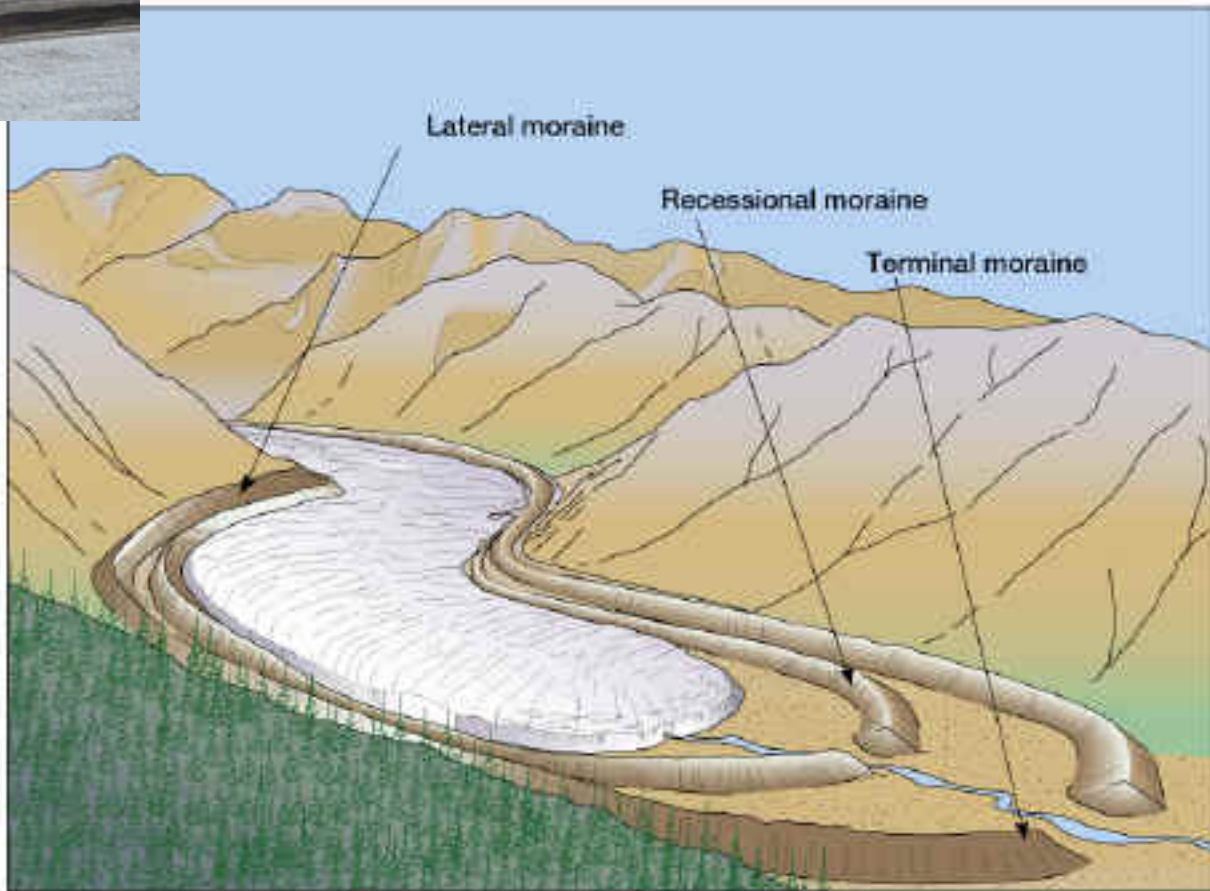
-Heated from below, cooled from surface; base is where these forces balance out to 0°C .

-Arctic areas have already warmed more than the rest of the globe, and methane emissions from permafrost areas could increase substantially.











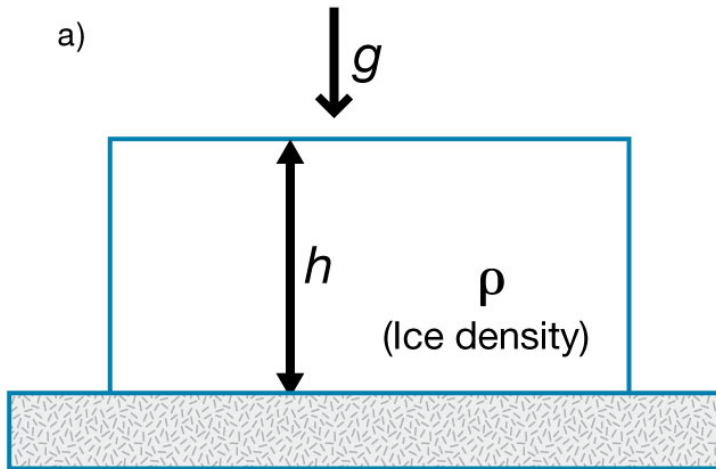
RAO



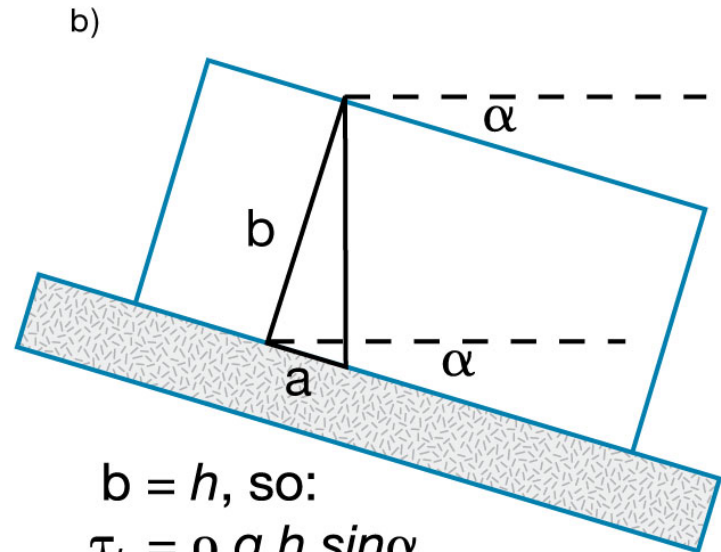
Mer de Glace (Mont Blanc)





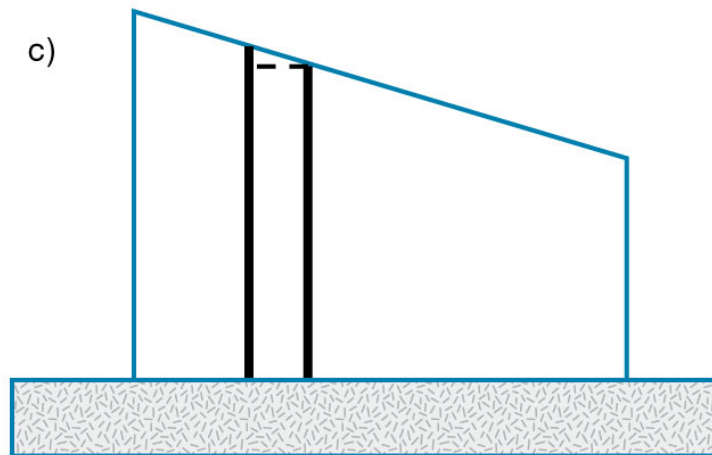


$$\tau = \rho \cdot g \cdot h$$

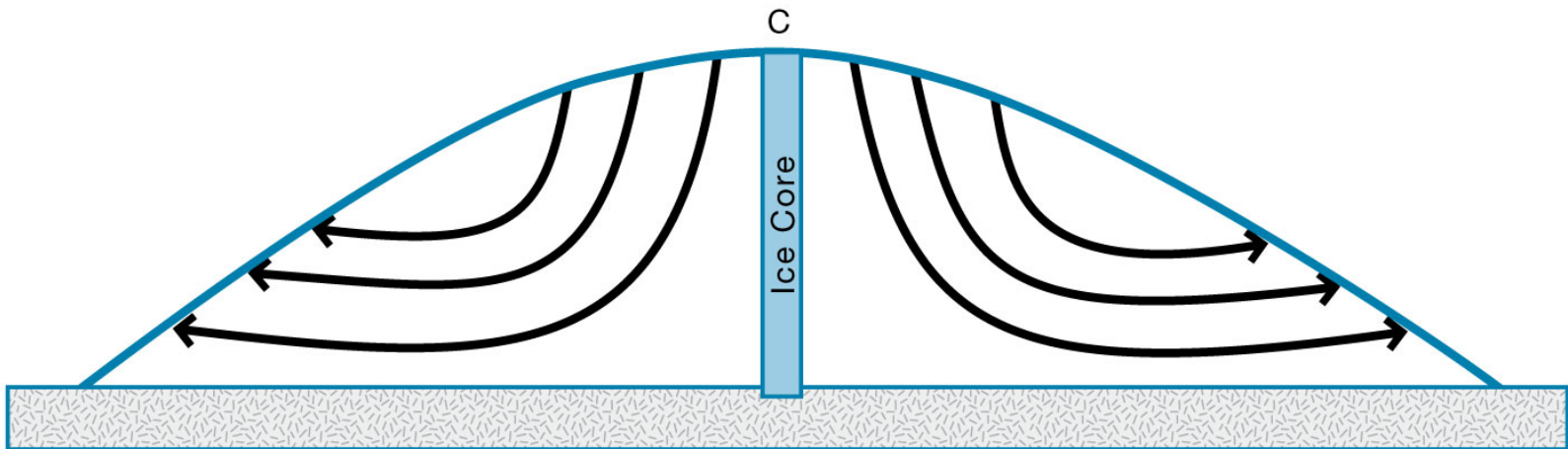


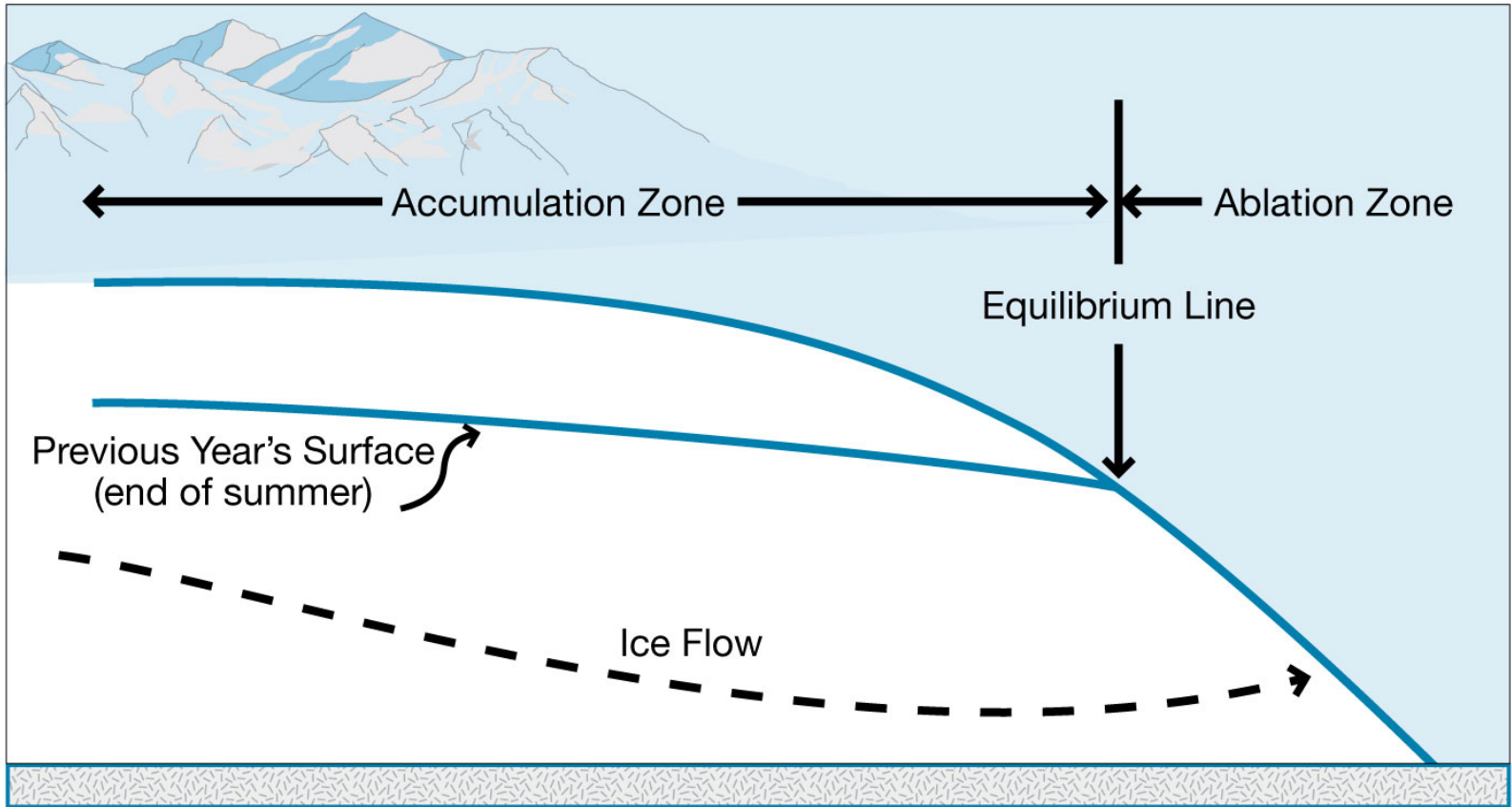
$$b = h, \text{ so:}$$

$$\tau_b = \rho \cdot g \cdot h \cdot \sin \alpha$$

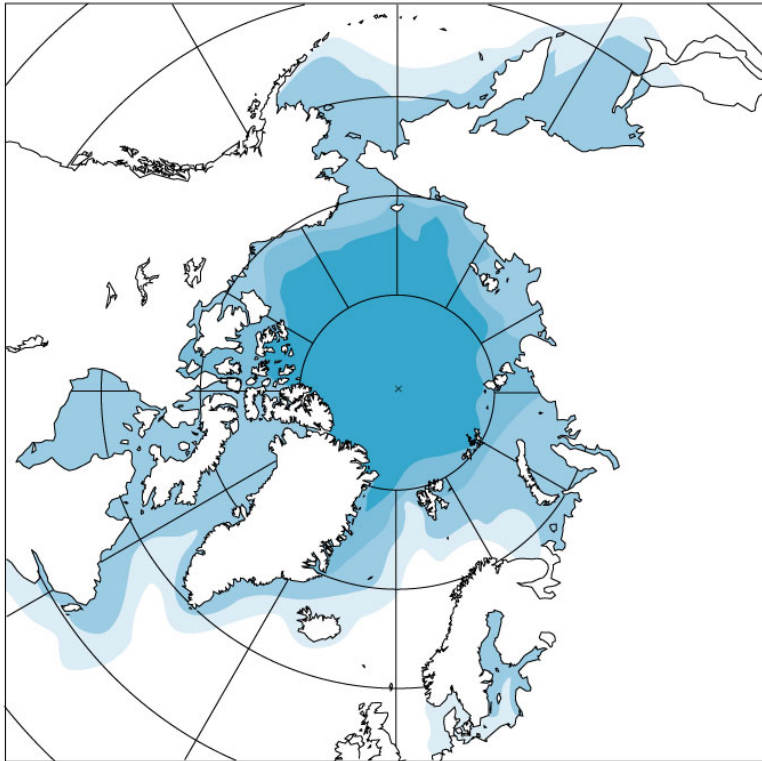


Greenland ice flow: Why you drill in the middle when you want a coherent record of the past

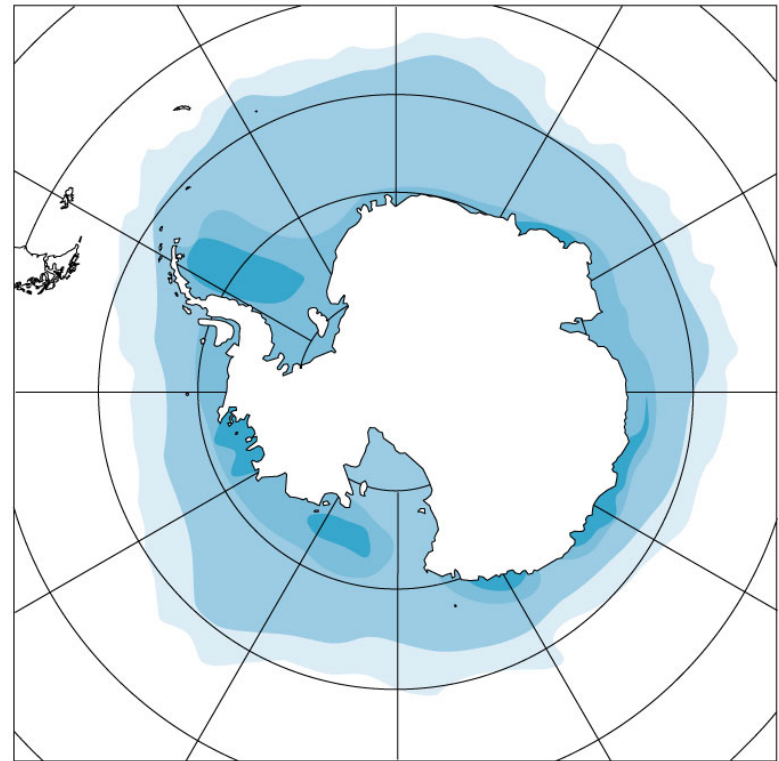




Northern hemisphere sea ice



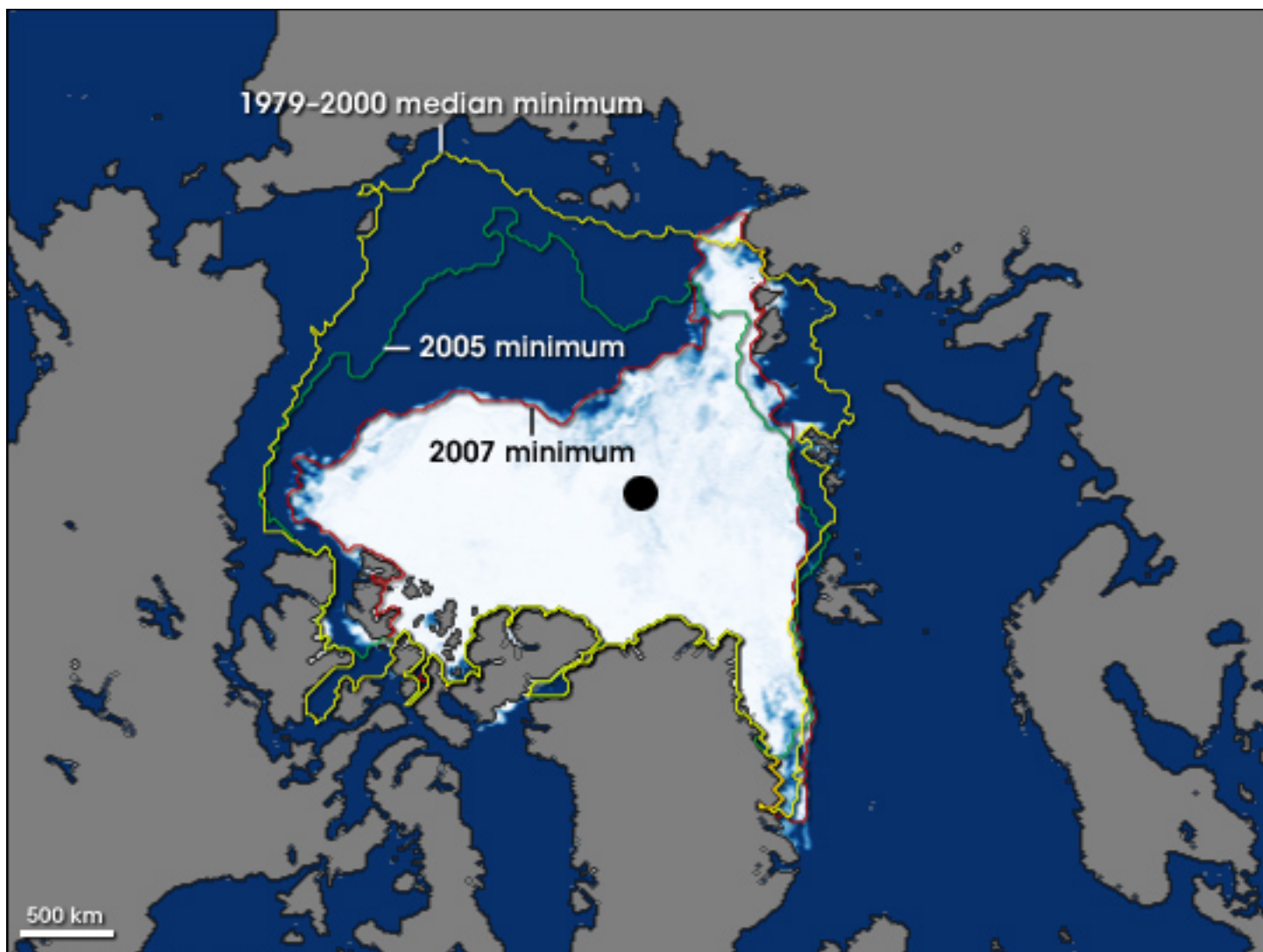
Southern hemisphere sea ice



Legend for sea ice distribution:

Lightest Blue	Absolute	Light Blue	Average	Medium Blue	Average	Darkest Blue	Absolute
Maximum				Minimum			

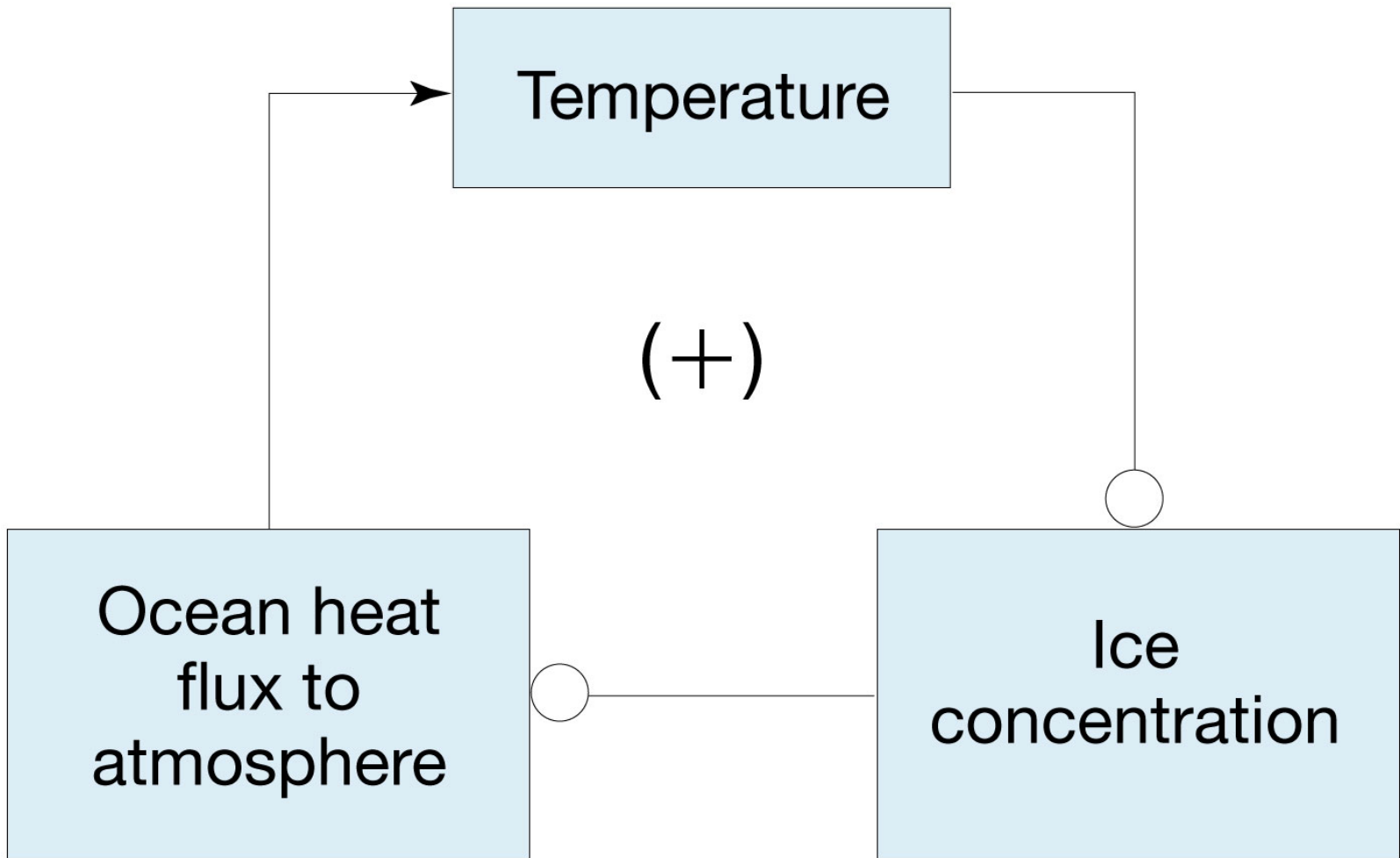




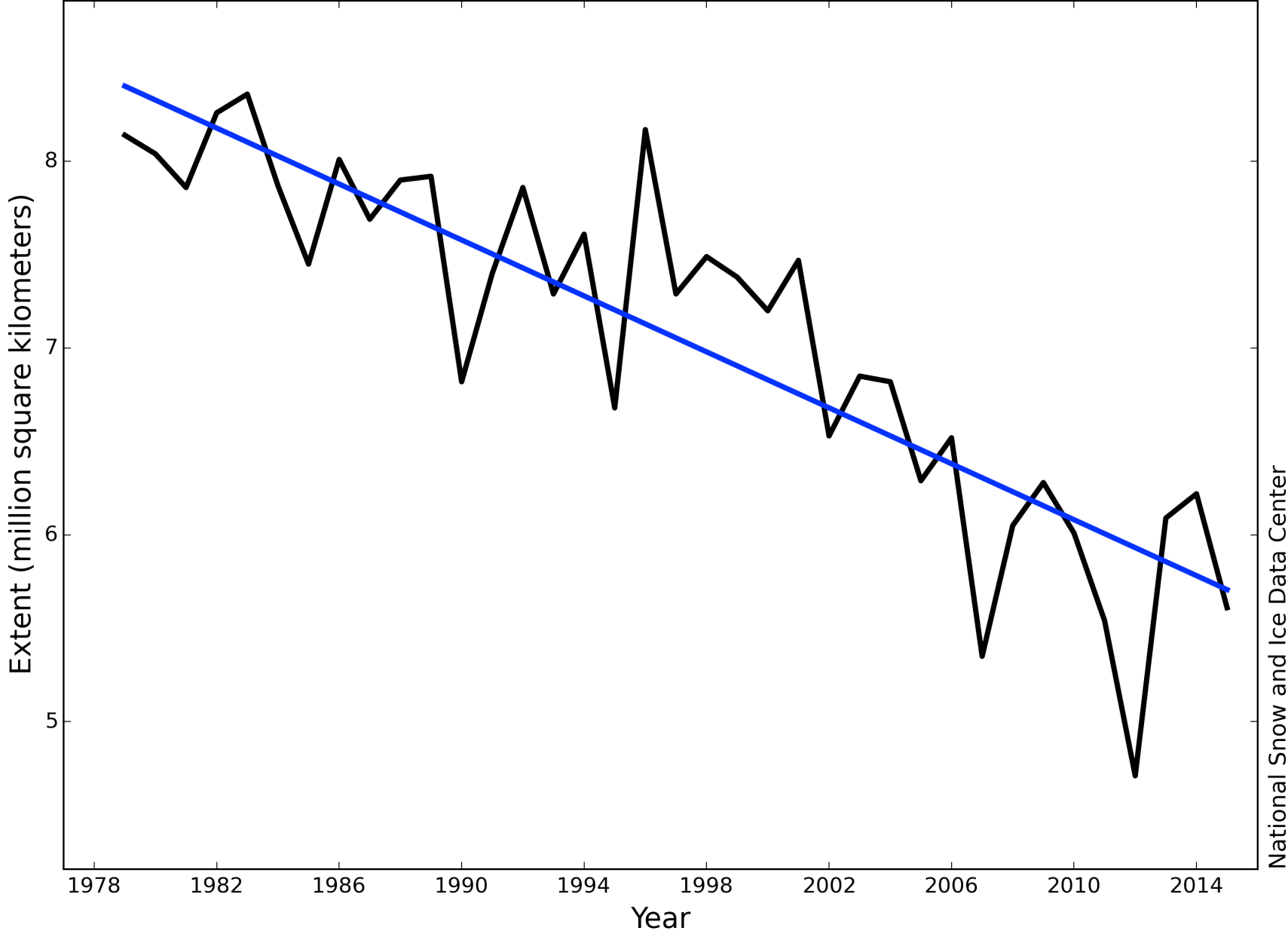
September 16, 2007

Sea Ice Concentration (percent)





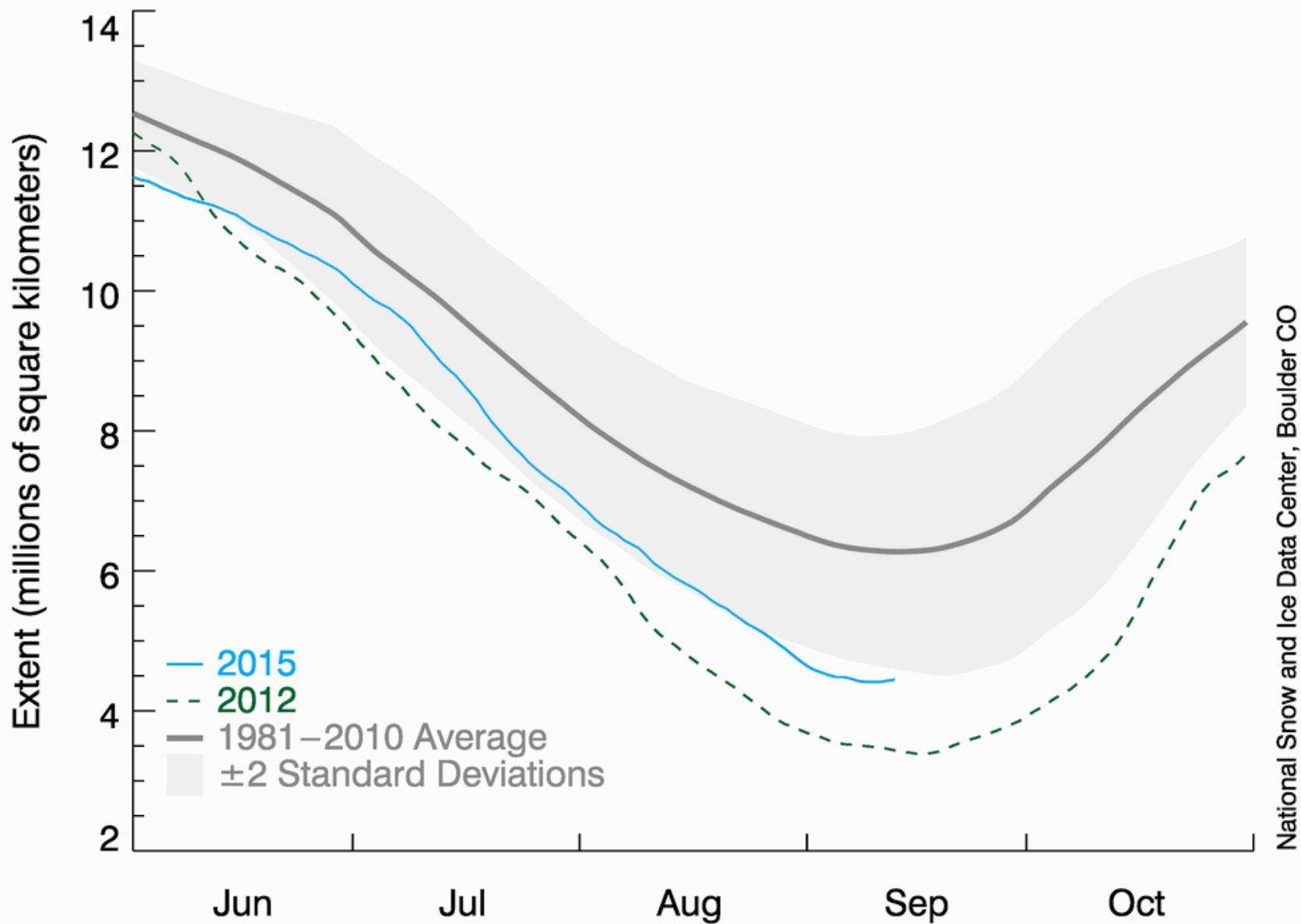
Average Monthly Arctic Sea Ice Extent August 1979 - 2015



National Snow and Ice Data Center

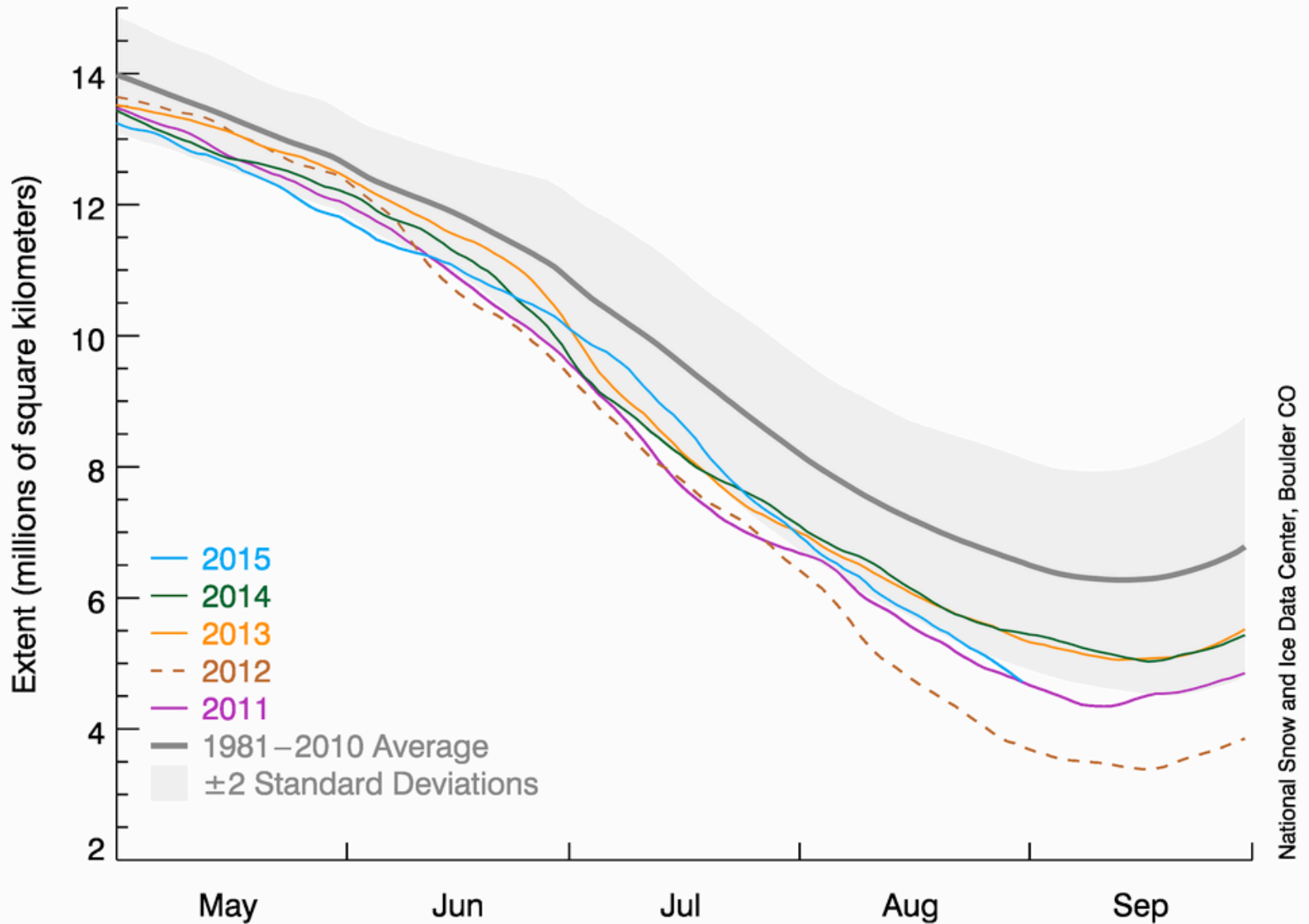
Arctic Sea Ice Extent

(Area of ocean with at least 15% sea ice)



National Snow and Ice Data Center, Boulder CO

Arctic Sea Ice Extent (Area of ocean with at least 15% sea ice)

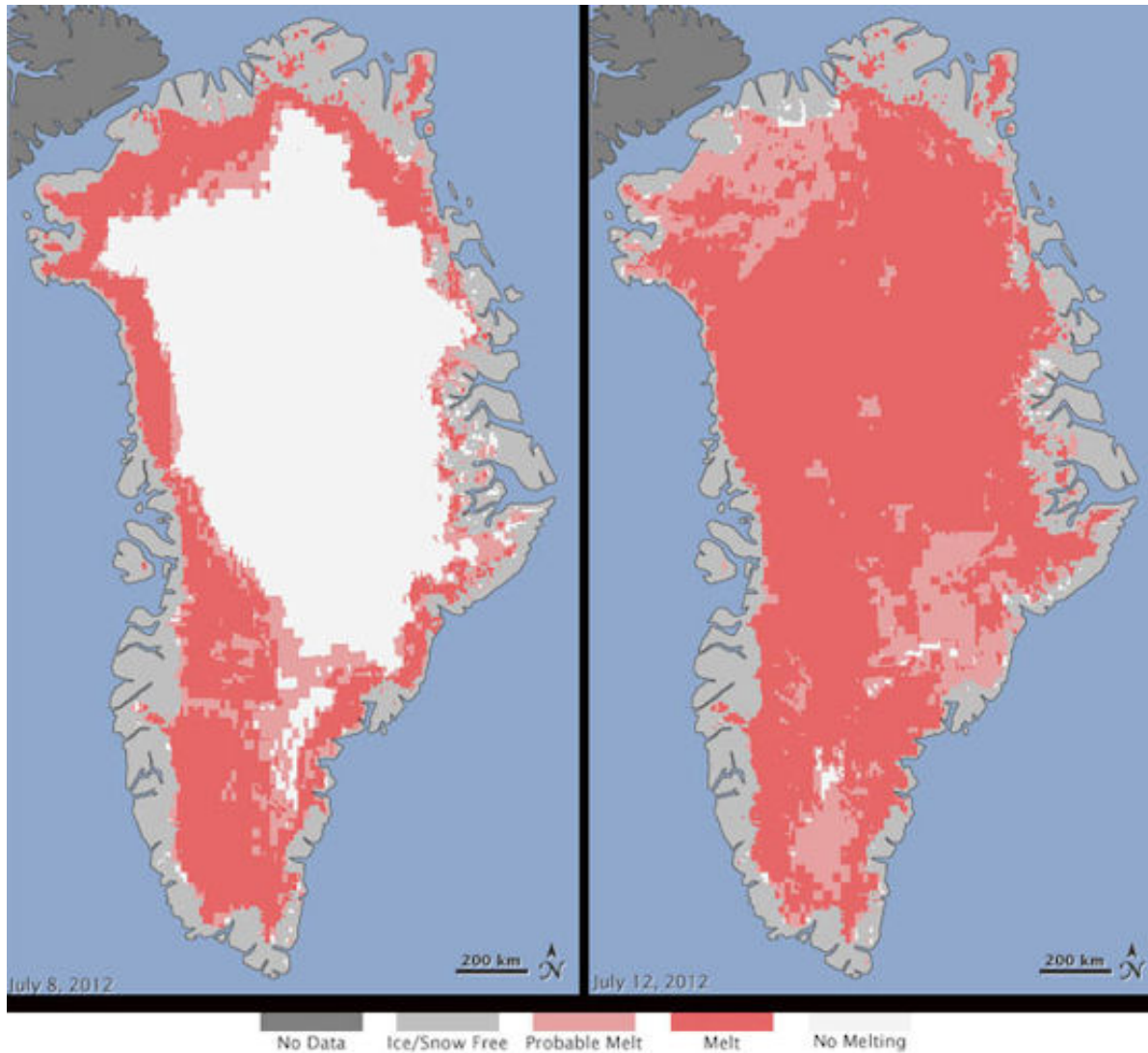


National Snow and Ice Data Center, Boulder CO

GREENLAND ICE SHEET MELT EXTENT



BBC 25 July 2012, "Satellites reveal sudden Greenland ice melt"



July 8, 2012

July 12, 2012

Hard to keep up...

