Pressure Gradients

GEOG/ENST 2331 – Lecture 7
Ahrens: Chapter 8
Lab 2

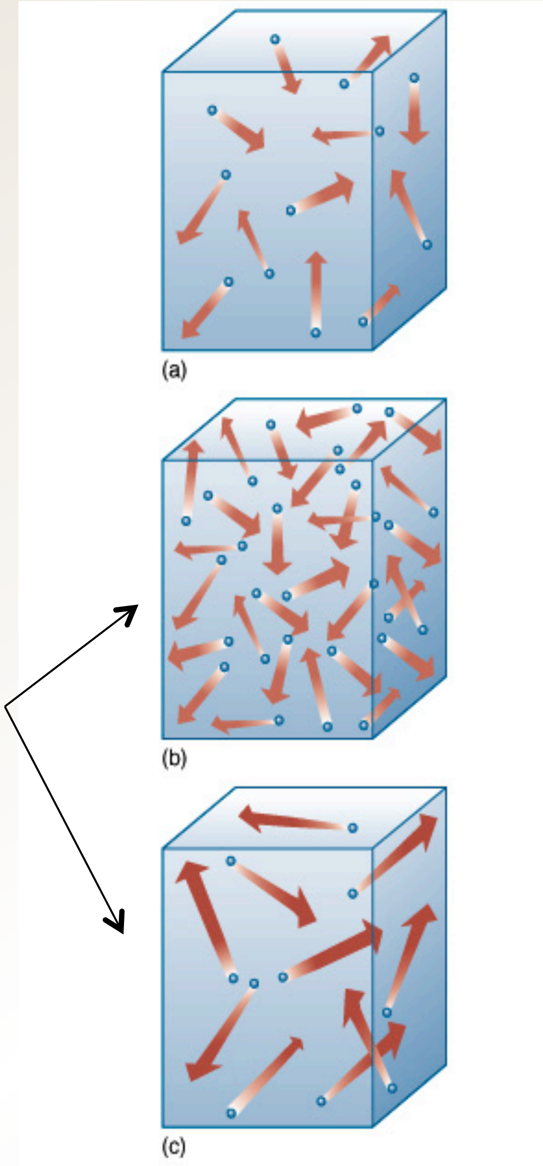
Mechanics: $F = ma$

- What exerts force in the atmosphere?
  - Pressure gradients
  - Gravity
  - Coriolis effect
  - Friction

Review: Pressure

- Atmospheric pressure is force per unit area exerted by atmospheric gases (all directions)
- Commonly expressed in ***millibars*** or ***hectopascals***
  - ***1 hPa = 100 Pa = 1 mb***
- Surface pressure is close to 1000 hPa
  - Varies with time and place

Ideal Gas Law



Higher P

A&B: Figure 4-1

- Pressure, density and temperature of air are related by the Ideal Gas Law:
  - $P = \rho T C$
  - C is the gas constant
  - For air, $C = 287$ [J/kg·K]
- See Ahrens pp. 228-229

Partial Pressures

- In a mixture of gases, each individual gas exerts its own *partial pressure*
  - E.g. pCO_2 or pH_2O

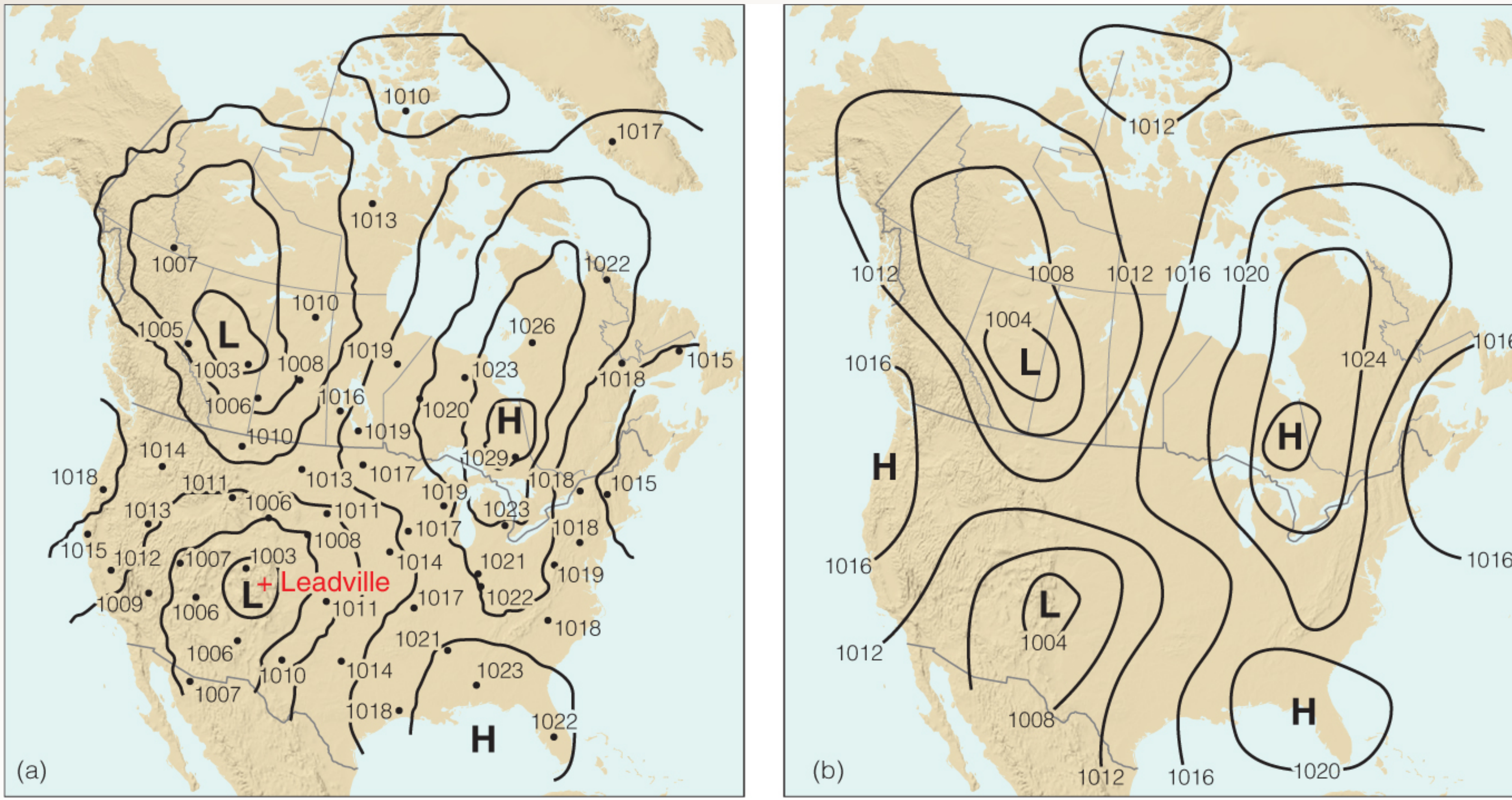
- Dalton's Law: the sum of the partial pressures equals the total pressure

Charting pressure

- *Isobars* – lines of constant pressure

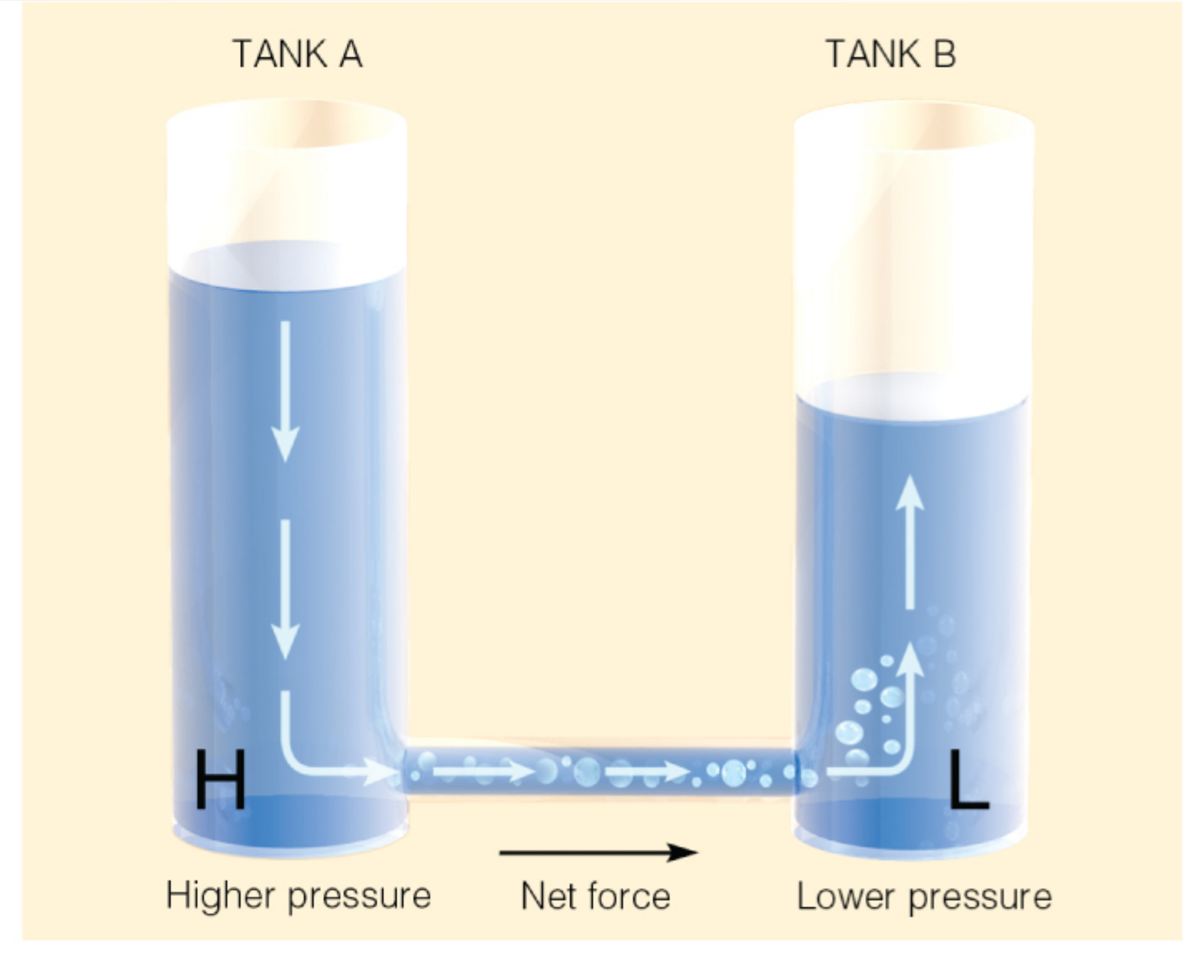
- *Pressure Gradient* – the change in pressure over distance
  - Zonal
  - Meridional
  - or Vertical

  - Blocking situations



Ahrens: Figure 8.10

Pressure gradient force



- Tendency for fluids to flow from high pressure to low pressure

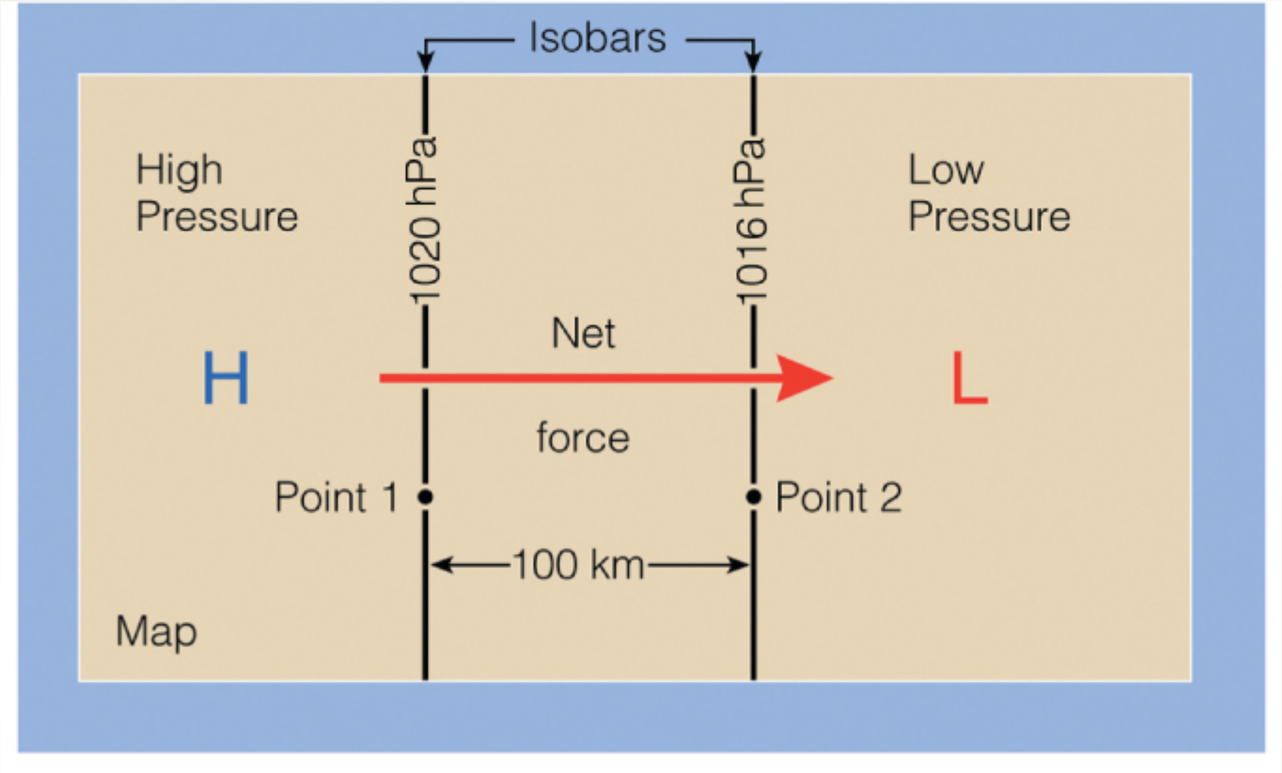
Ahrens: Fig. 8.17

Horizontal pressure gradient force

Horizontal pressure differences are usually slight.

Strong pressure gradients indicate strong winds and storms.

Ahrens: Fig. 8.18



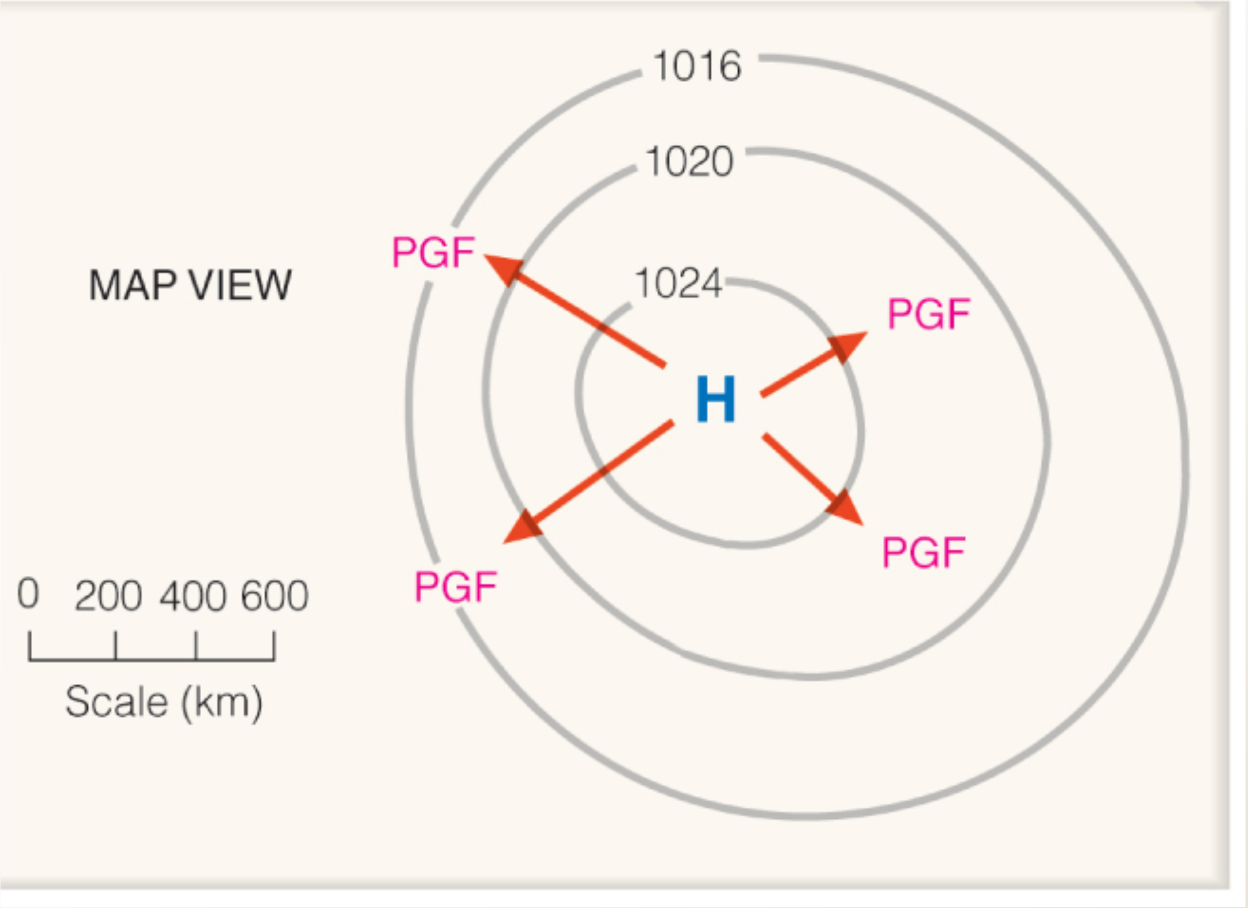
$$\mathrm{PGF} = -\frac{1}{\rho}\frac{\Delta P}{\Delta x}$$

PGF

PGF is always perpendicular to isobars

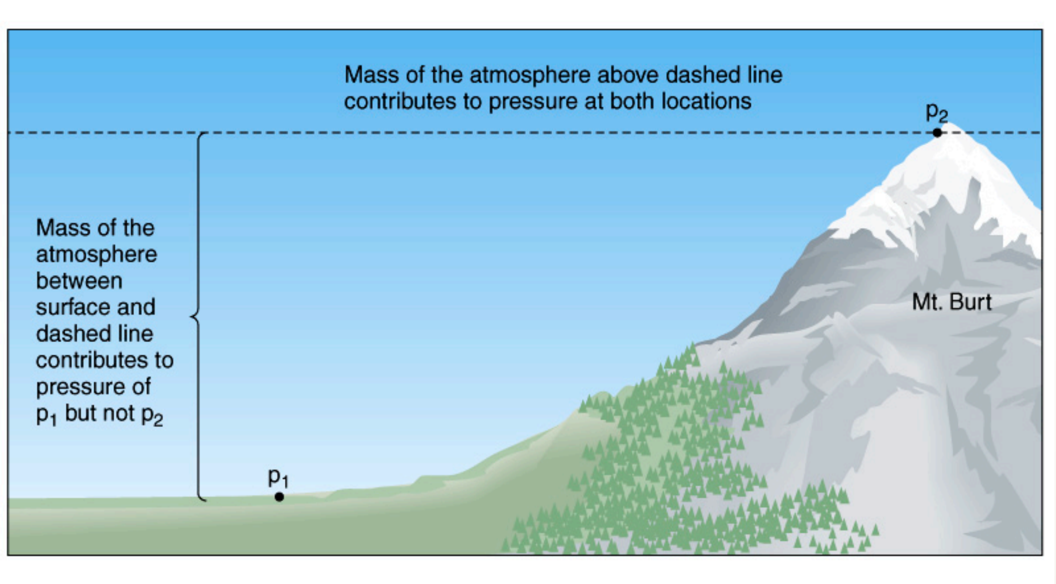
Closely spaced isobars indicate stronger PGF

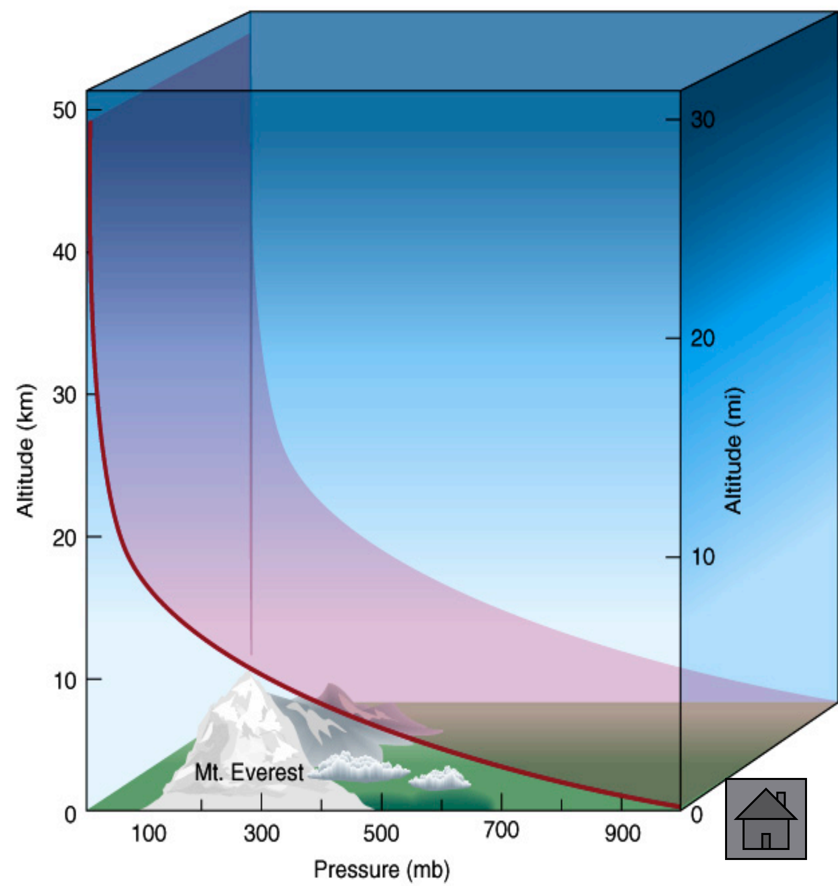
Ahrens: Fig. 8.19



Vertical Changes in Pressure

- Pressure decreases with height
- Exponential: roughly 50% every 5.5 km





A&B: Figures 4-2 and 4-3

Coordinate system

Cartesian system (x,y)

x – zonal (East/West) direction – East is positive

y – meridional (North/South) direction – North is positive

z – vertical – up is positive

u – velocity in the x direction

v – velocity in the y direction

Gravitational force

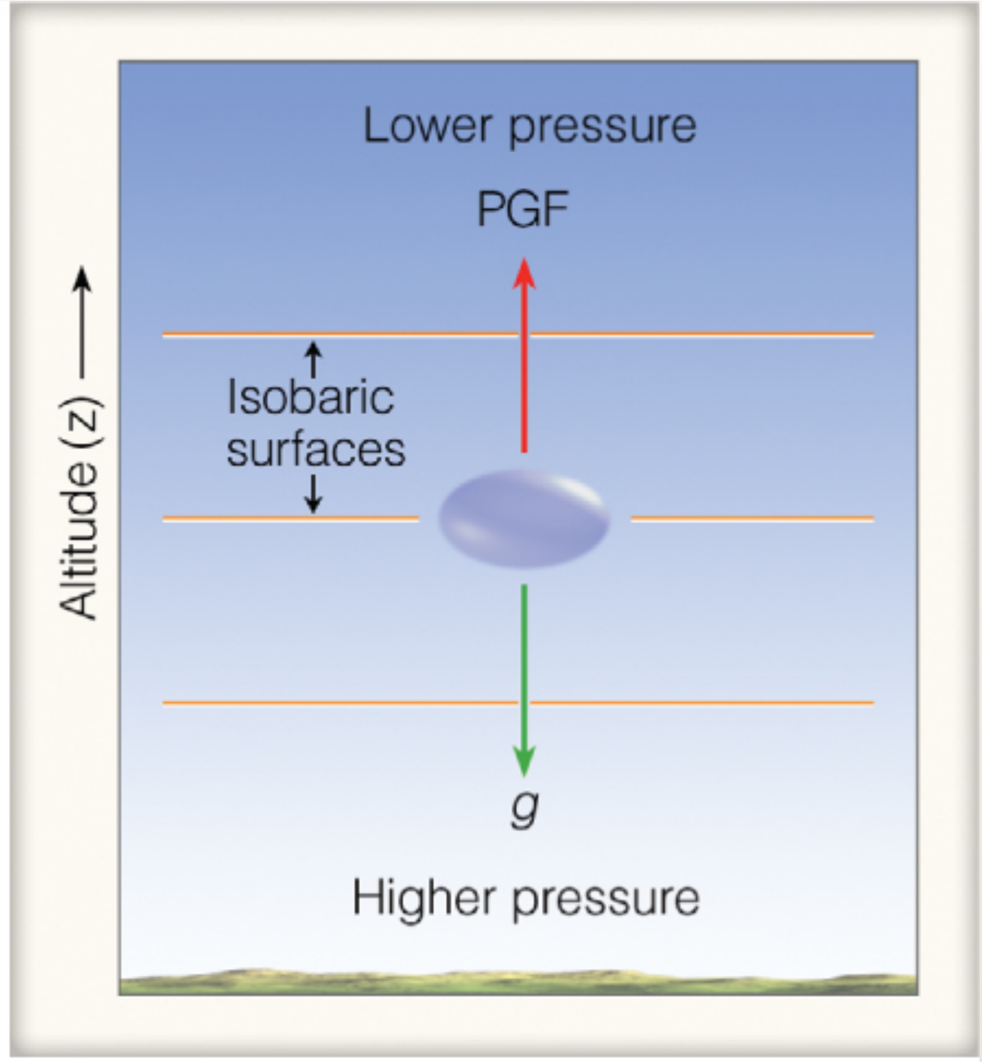
- Force of attraction between two masses
- Earth approximation:
  - GF = mg, g = 9.8 N/kg
- Vertical force (always pulls ‘down’)

Hydrostatic Balance

A vertical balance of forces

- Pressure gradient force and gravity are equal
- No net vertical acceleration

$$\Delta P = -\rho g \Delta z$$



Ahrens: Fig. 7, p. 250

Vertical pressure gradients

Pressure always decreases with height

Vertical pressure gradients are balanced by gravity

$$P = \rho C T$$

$$\Delta P = -\rho g \Delta z$$

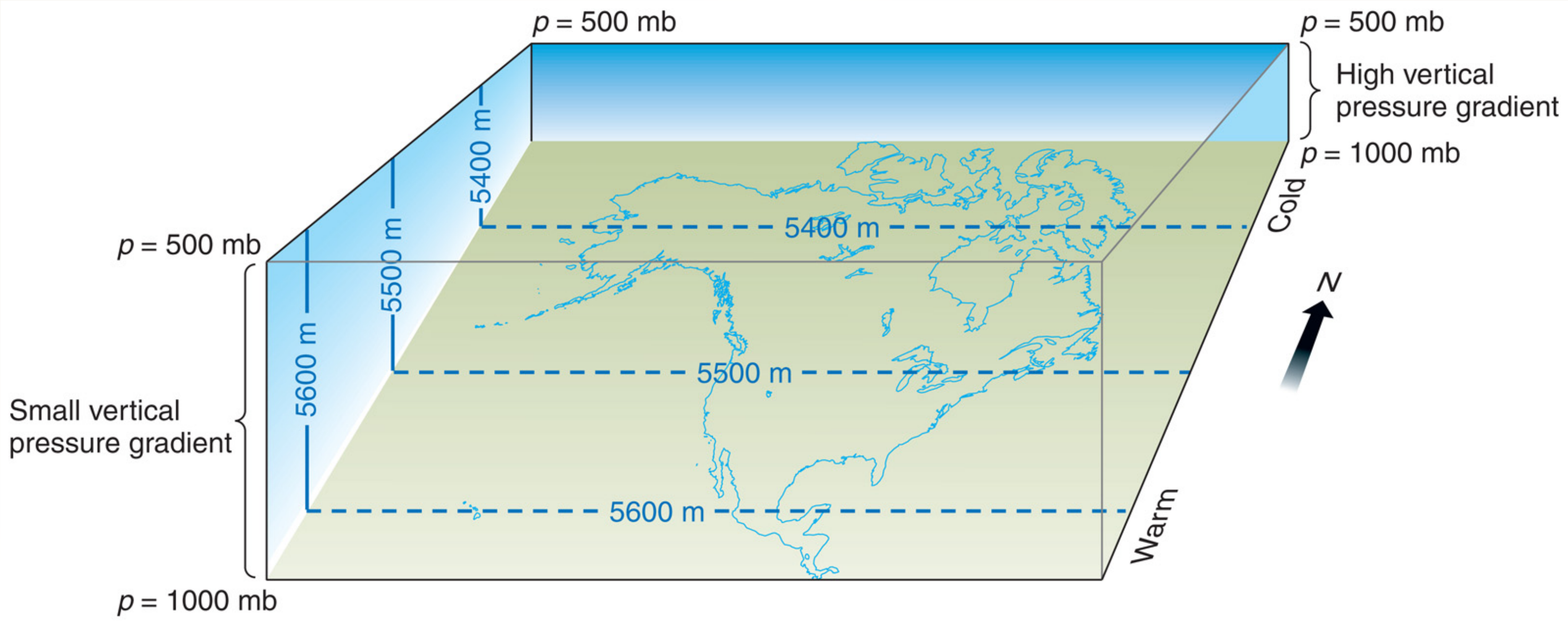
Scale height, *H*, is a vertical distance over which the pressure drops by a constant factor

$$H = \frac{CT}{g}$$

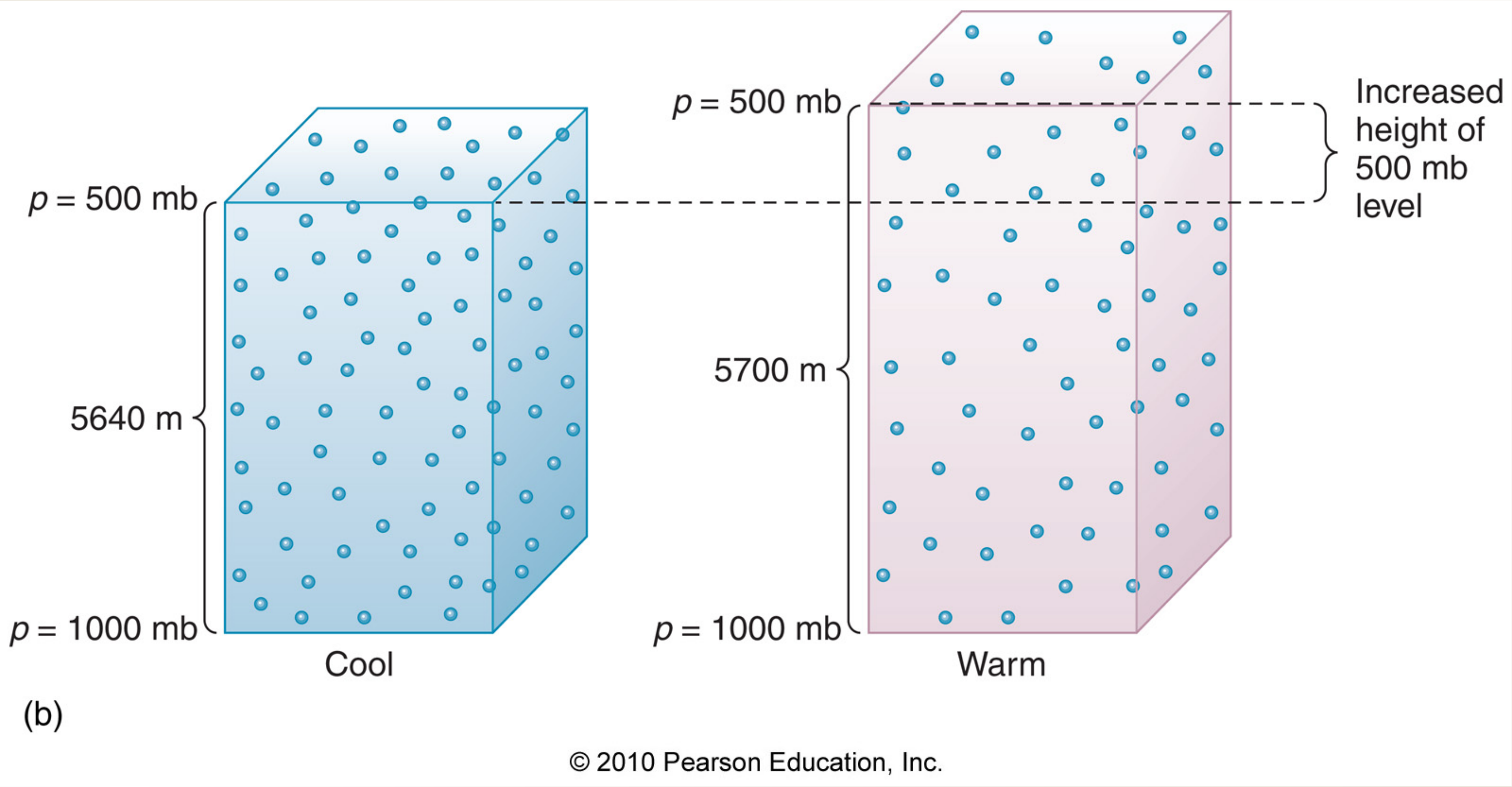
T is the average temperature in the column of height *H*

Scale Height

- If T is large, then H is large and the pressure reduces more slowly with height.
  - If T is small the opposite is true.
- For example, the tropopause occurs at 250 hPa. The height of the tropopause is 8 km at the poles and 13 km at the equator.
  - This is consistent with the scale height analysis $$H = \frac{CT}{g}$$



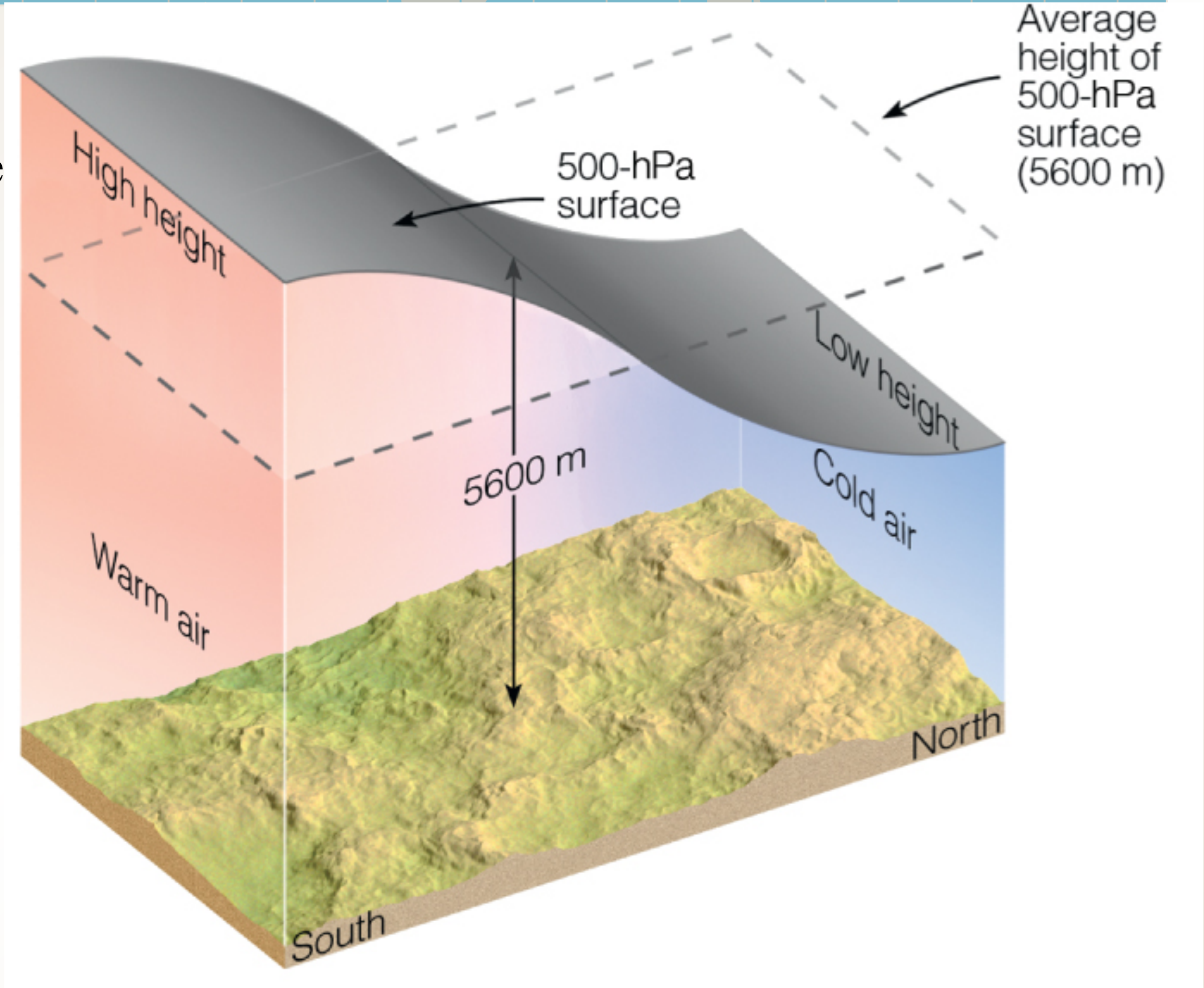
Temperature and scale height



A&B: Figure 4-7

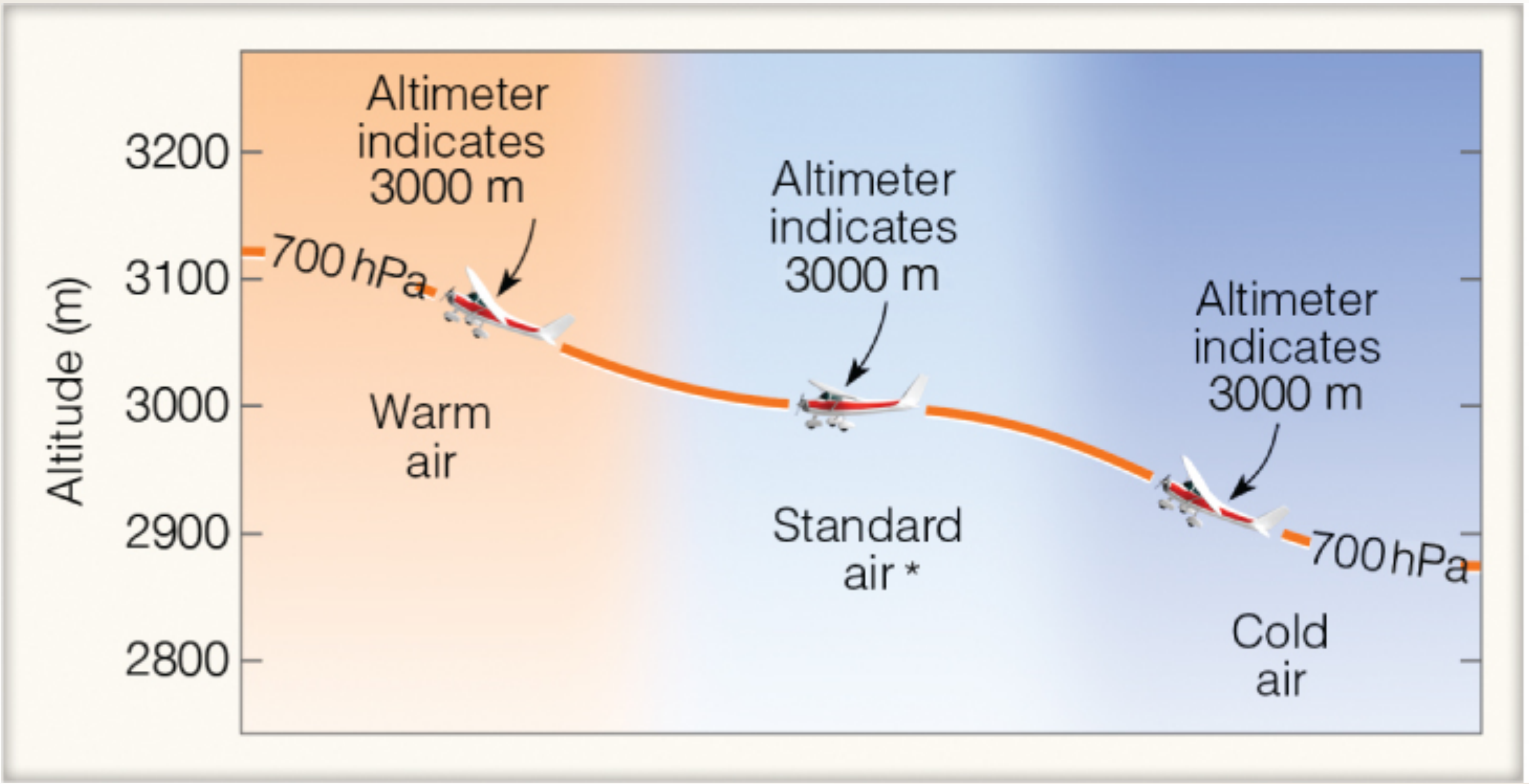
Upper air

Height of constant pressure decreases with temperature

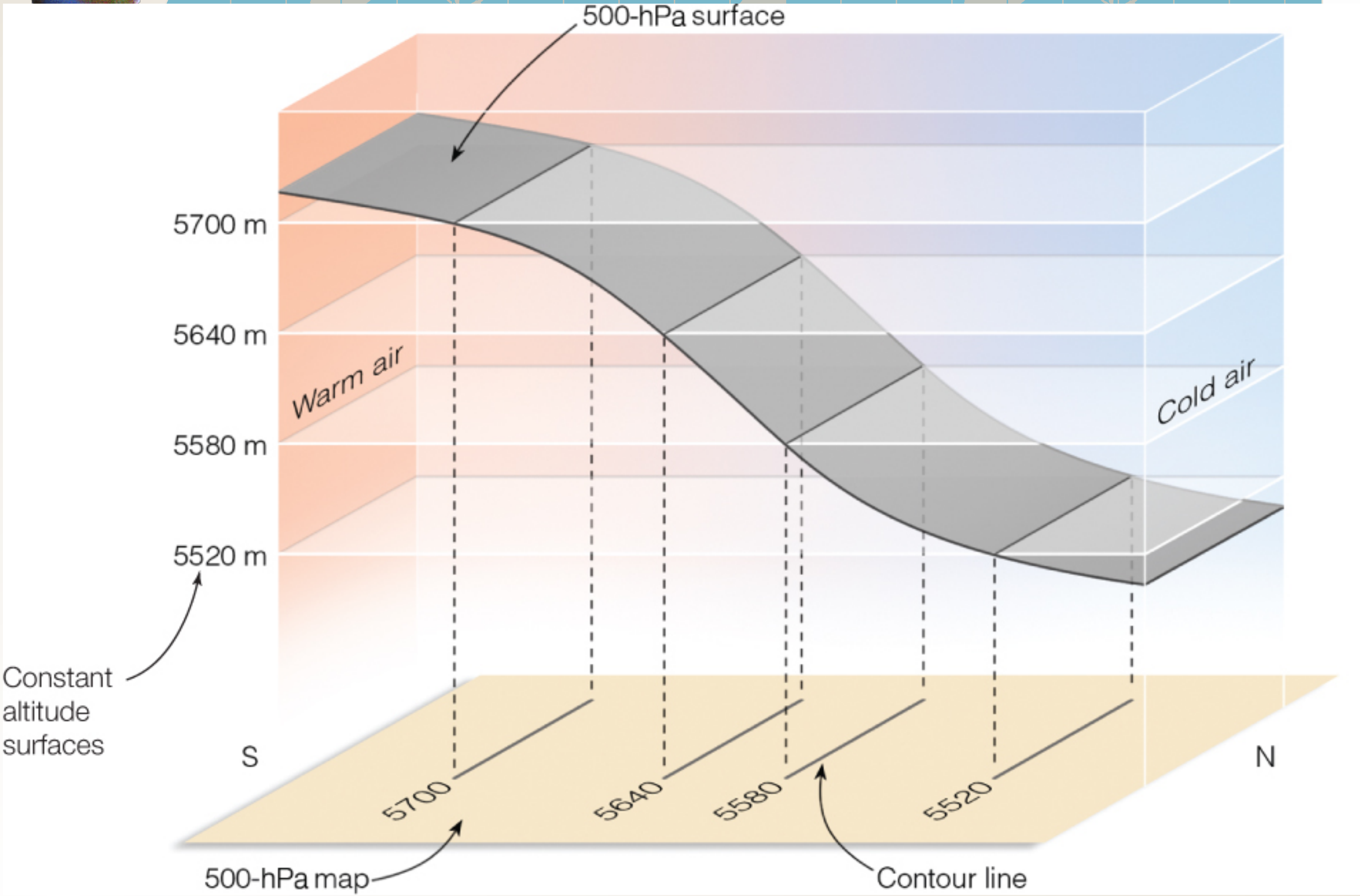


Ahrens: Figure 8.13

Altimeters

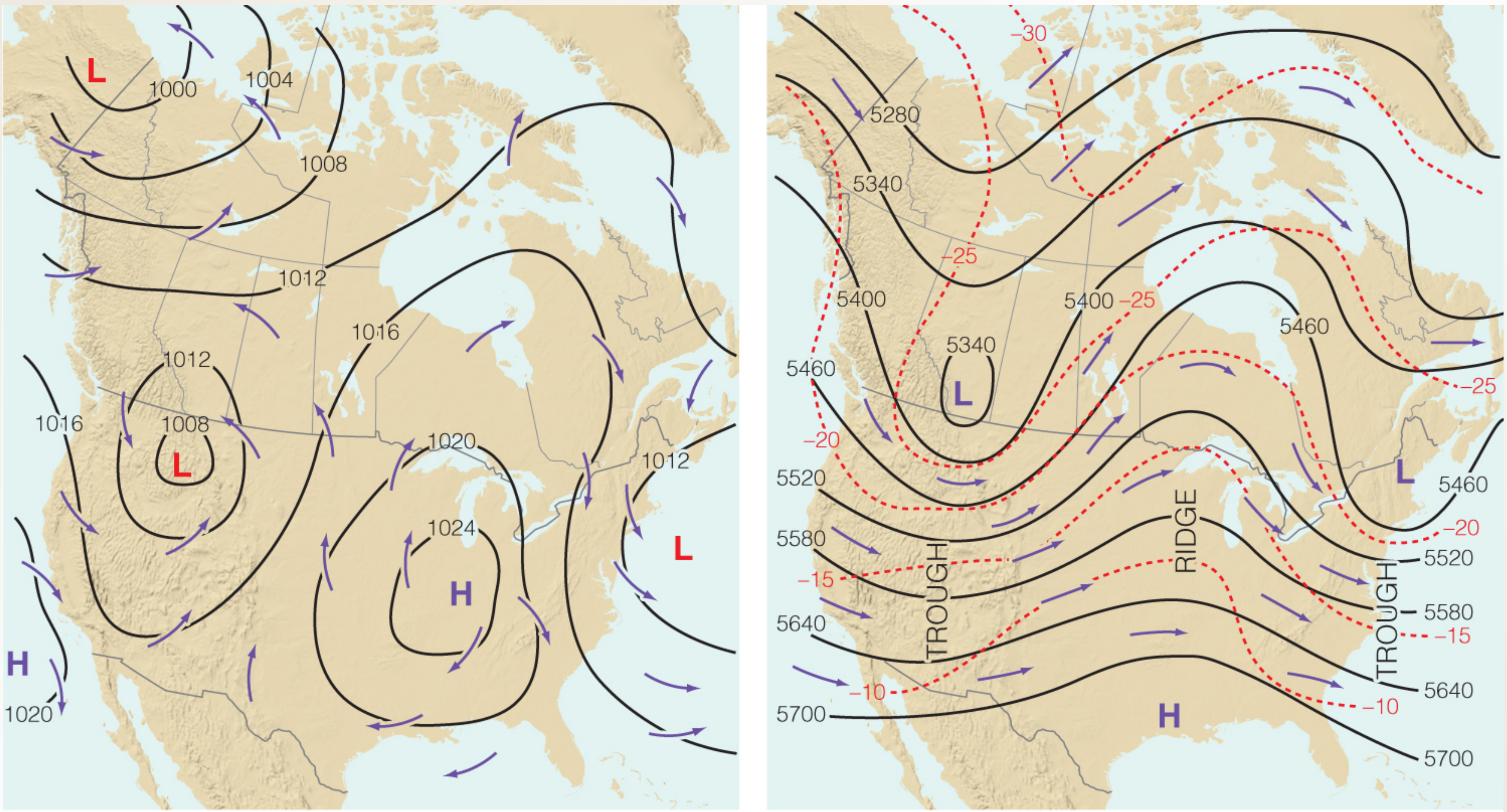


Ahrens: Fig. 2, p. 237



Ahrens: Figure 8.14

Isobaric charts



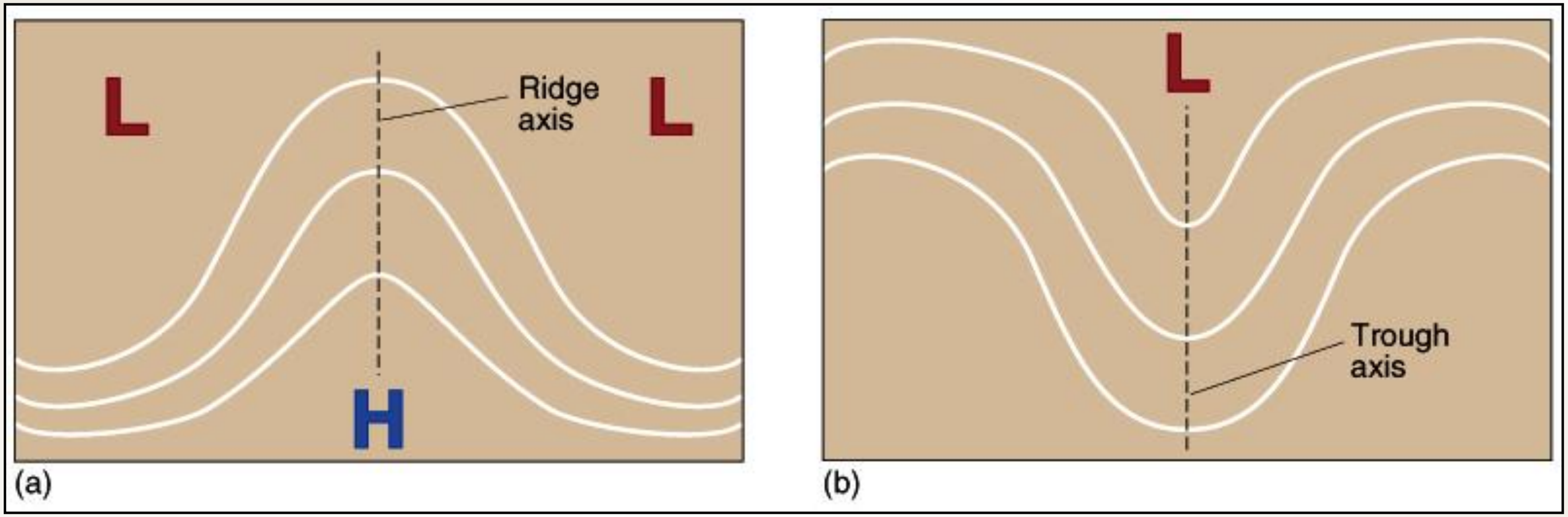
(a) Surface map

(b) Upper-air map (500 hPa)

Pressure (in hPa)

500 hPa height contours (in m).

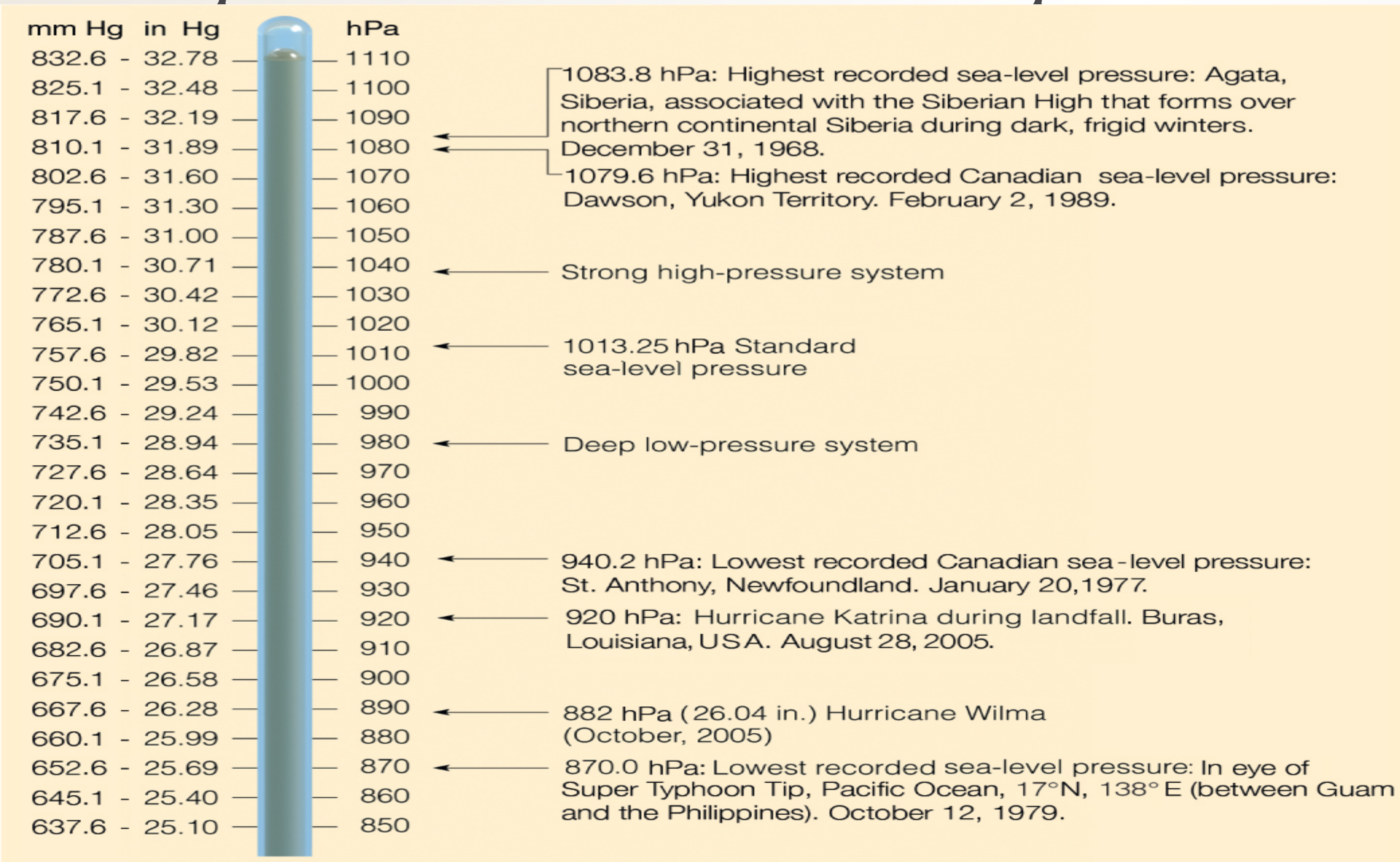
Ahrens: Figure 8.16b

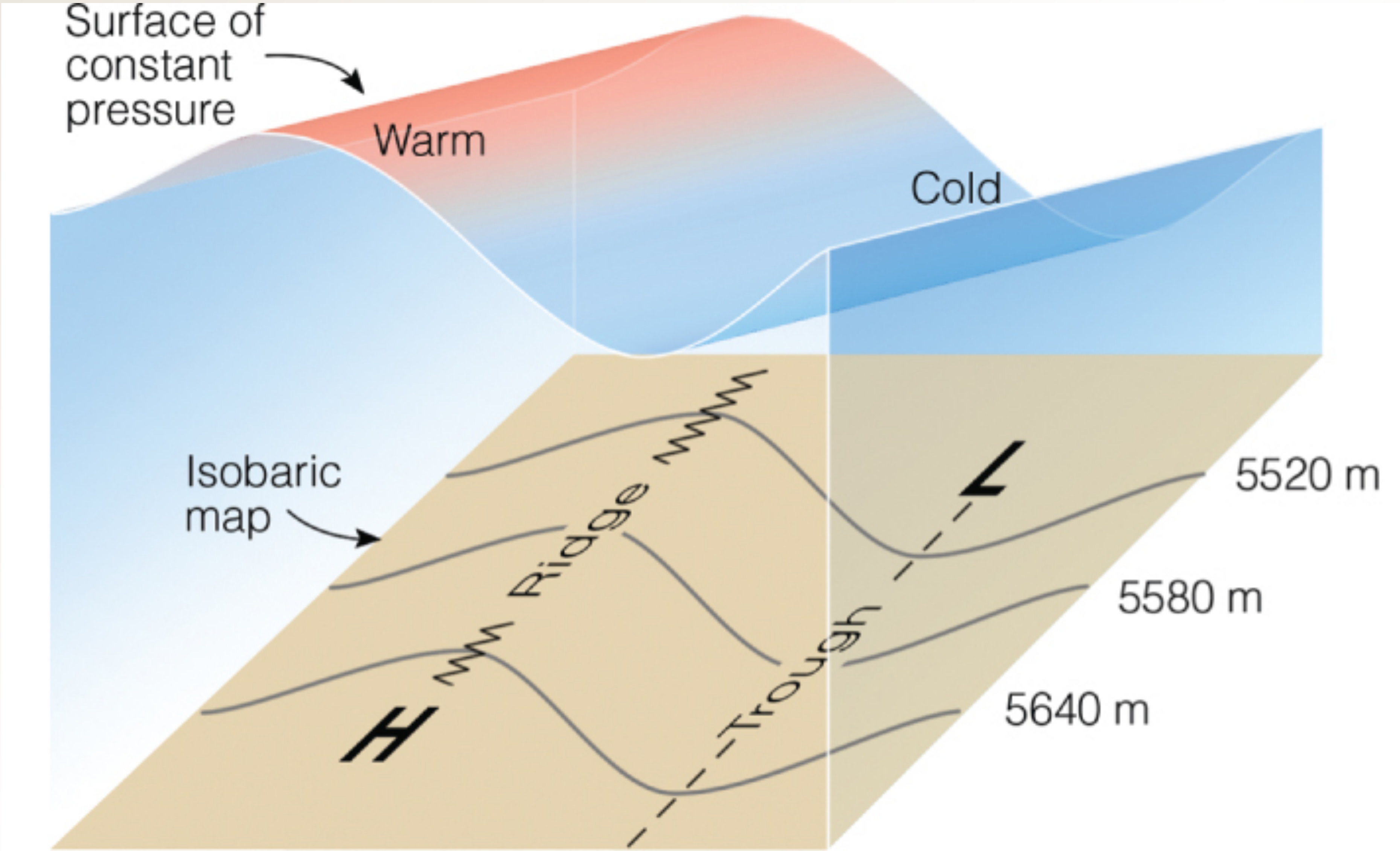


Elongated zones of high and low pressure are called ridges (a) and troughs (b), respectively.

A&B: Figure 4-20

Atmospheric Pressure Examples

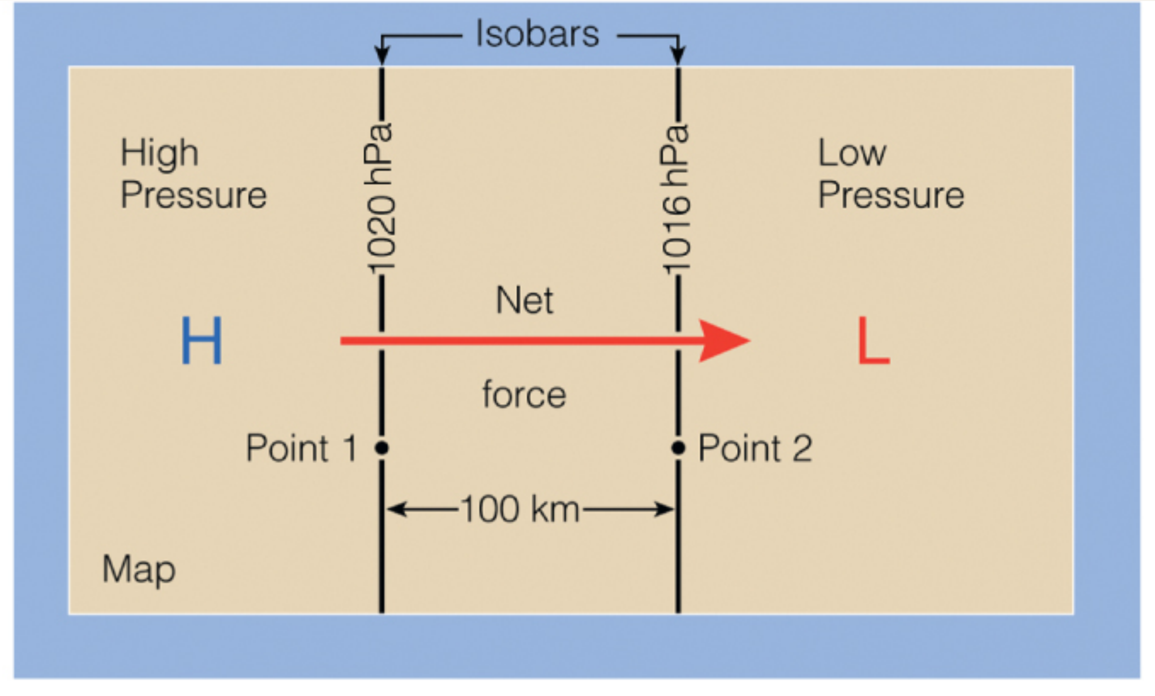




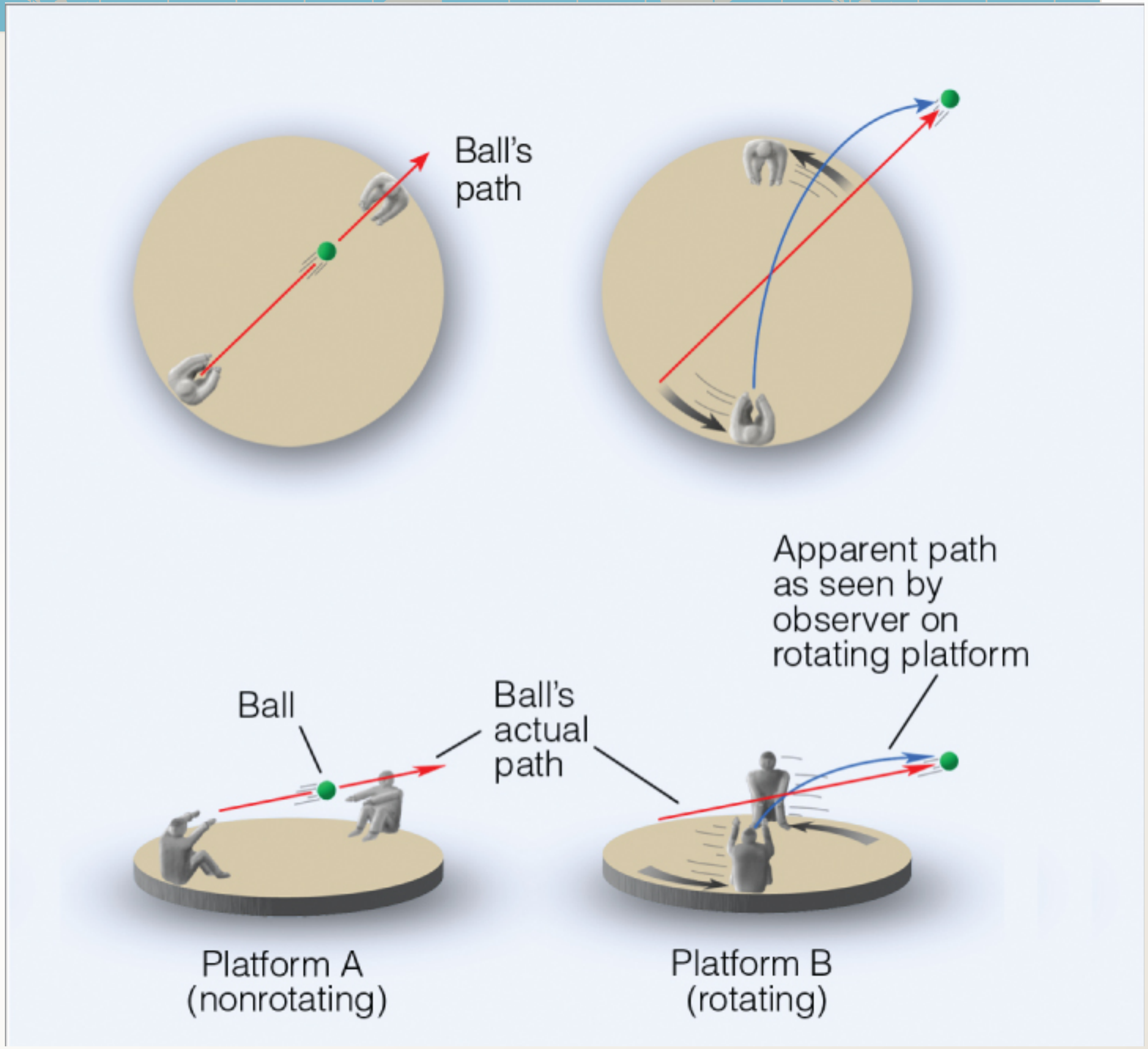
Ahrens: Figure 8.15

Put the air in motion

- Horizontal pressure gradients cause the air to move
- The Earth's surface is a spinning frame of reference
- Push an object within that reference and it will not appear to travel in a straight line



The Coriolis Effect



Ahrens: Fig. 8.21

Next lecture

- Coriolis “force”
- Geostrophic winds
- Cyclones and anticyclones
- More of Ahrens et al., Chapter 8