

ATMOSPHERIC PRESSURE

PRESSURE

- **Pressure** (the symbol: p) is the ratio of force to the area over which that force is distributed.
- In other words, pressure is force per unit area applied in a direction perpendicular to the surface of an object.
- Gauge pressure (also spelled *gage* pressure) is the pressure relative to the local atmospheric or ambient pressure.
- While pressure may be measured in any unit of force divided by any unit of area, the SI unit of pressure (the Newton per square metre) is called the *pascal* (Pa) after the seventeenth-century theologian and scientist Blaise Pascal.
- A pressure of 1 Pa is small; it approximately equals the pressure exerted by a dollar bill resting flat on a table. Science types more often use kilopascals (1 kPa = 1000 Pa).

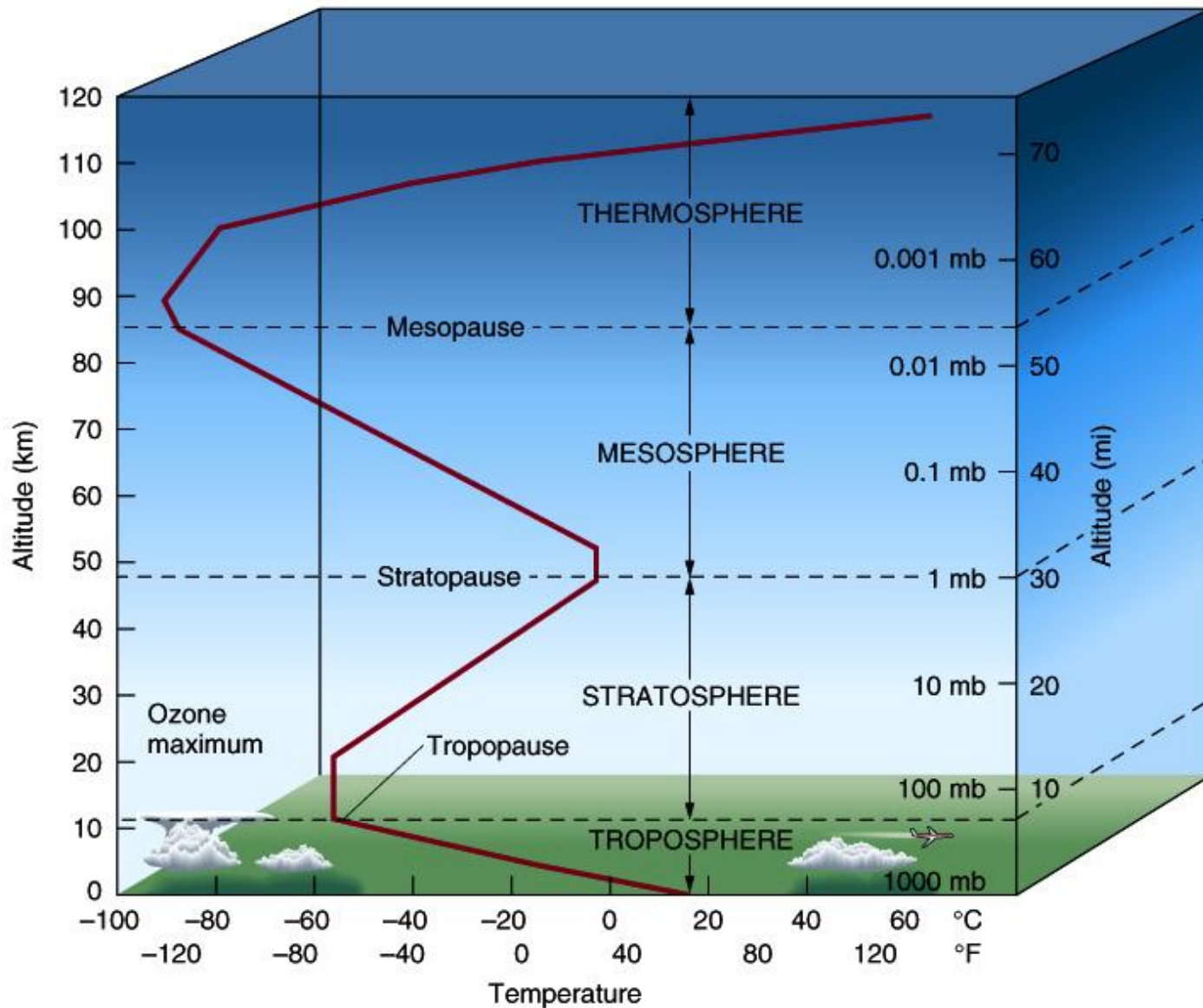
Atmospheric Thickness

- No defined top to the atmosphere
- The atmosphere is very shallow—and is less than 2% of the Earth's thickness



Over 90% of atmosphere in the lowest 16km & is where nearly all weather occurs

Temperature Layers



Pressure Essentials

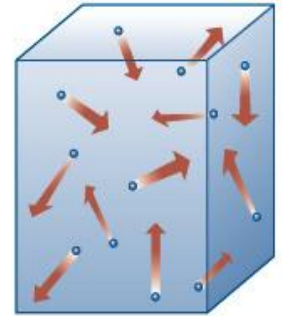
- Pressure – force exerted/unit area (weight above you)
- units - Pascals (Pa) or millibars (mb) (1 mb = 100 Pa)
Average surface pressure over globe: 1013.2 mb.
- Atmosphere is mixture of gases -> partial pressure.
Dalton's Law: sum of partial pressures equals total pressure
- **Pressure gradient (pressure difference between two locations/distance) gives rise to a force (pressure gradient force), which sets the air in motion.**

- Atmospheric pressure is a measure of the force pressing down on the Earth's surface from the overlying air.
- Pressure is often measured in different units including:
 - atmospheres (1 atmosphere is the average atmospheric pressure at sea level),
 - millibars (1 atmosphere = 1013.25 millibars),
 - pounds per square inch or psi (1 atmosphere = 14.7 pounds per square inch),
 - mm or inches of mercury (1 atmosphere = 760 mm or 29.92 inches of mercury)
 - torrs (1 torr = the pressure exerted by 1 cm of mercury).
- Low air density results in rising air and low surface pressure.
- High air density results in descending air and high surface pressure.

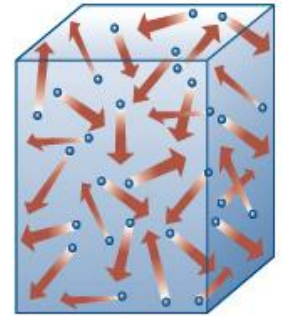
The Equation of State (Ideal Gas Law)

$$\text{Pressure} = \text{density} \times \text{temperature} \times 287 \text{ J kg}^{-1} \text{ K}^{-1}$$
$$[p = \rho TR]$$

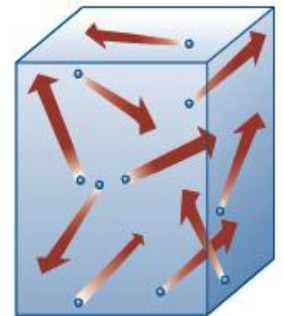
- Describes relationships between pressure, temperature, and density (Start w/ molecular movement in sealed container → Pressure proportional to rate of collisions between molecules and walls).
- At constant temperatures, an increase in air density will cause a pressure increase (Add more molecules → increase density → increase rate of collisions → raise pressure)
- Under constant density, an increase in temperature will lead to an increase in pressure (Raise temperature → increase speed of molecules → increase rate of collisions → raise pressure)



(a)

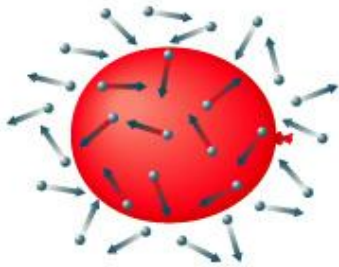


(b)

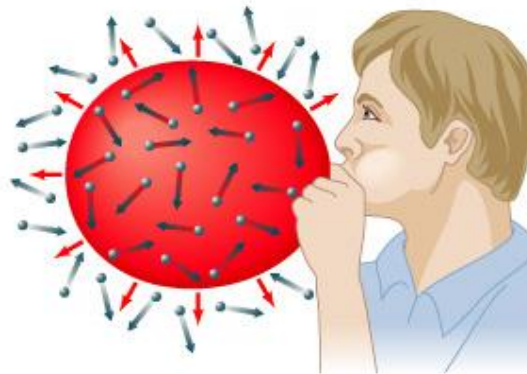


(c)

Atmospheric Pressure



Gas pressure depends on both density and temperature.



Adding air molecules increases the pressure in a balloon.



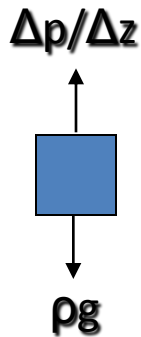
Heating the air also increases the pressure.

Vertical pressure distribution: Hydrostatic equilibrium

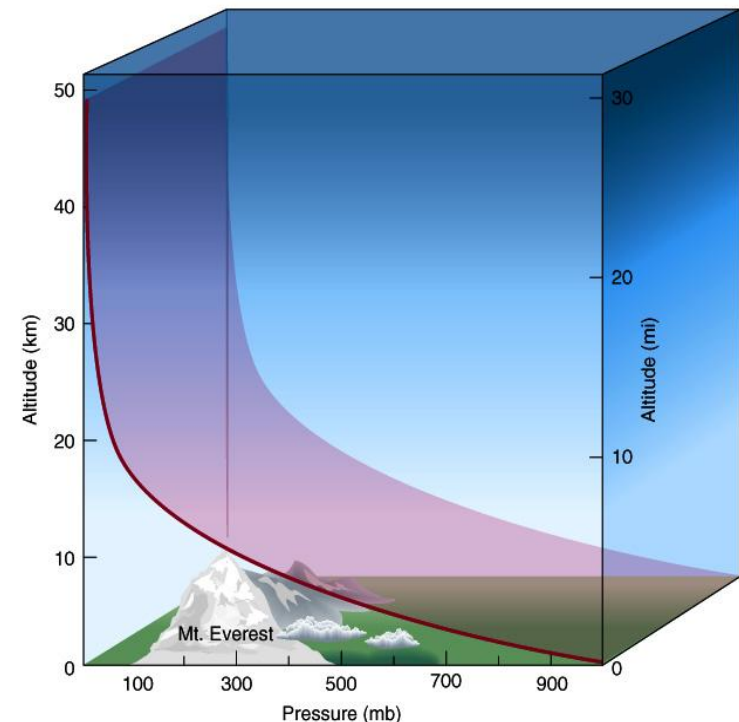
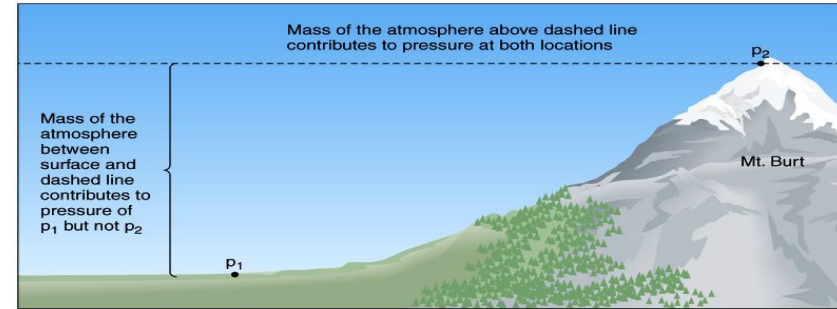
- Pressure decreases with height

Why? Because downward gravity force is balanced by vertical pressure gradient (called *hydrostatic equilibrium*)

$$\Delta p / \Delta z = \rho g$$



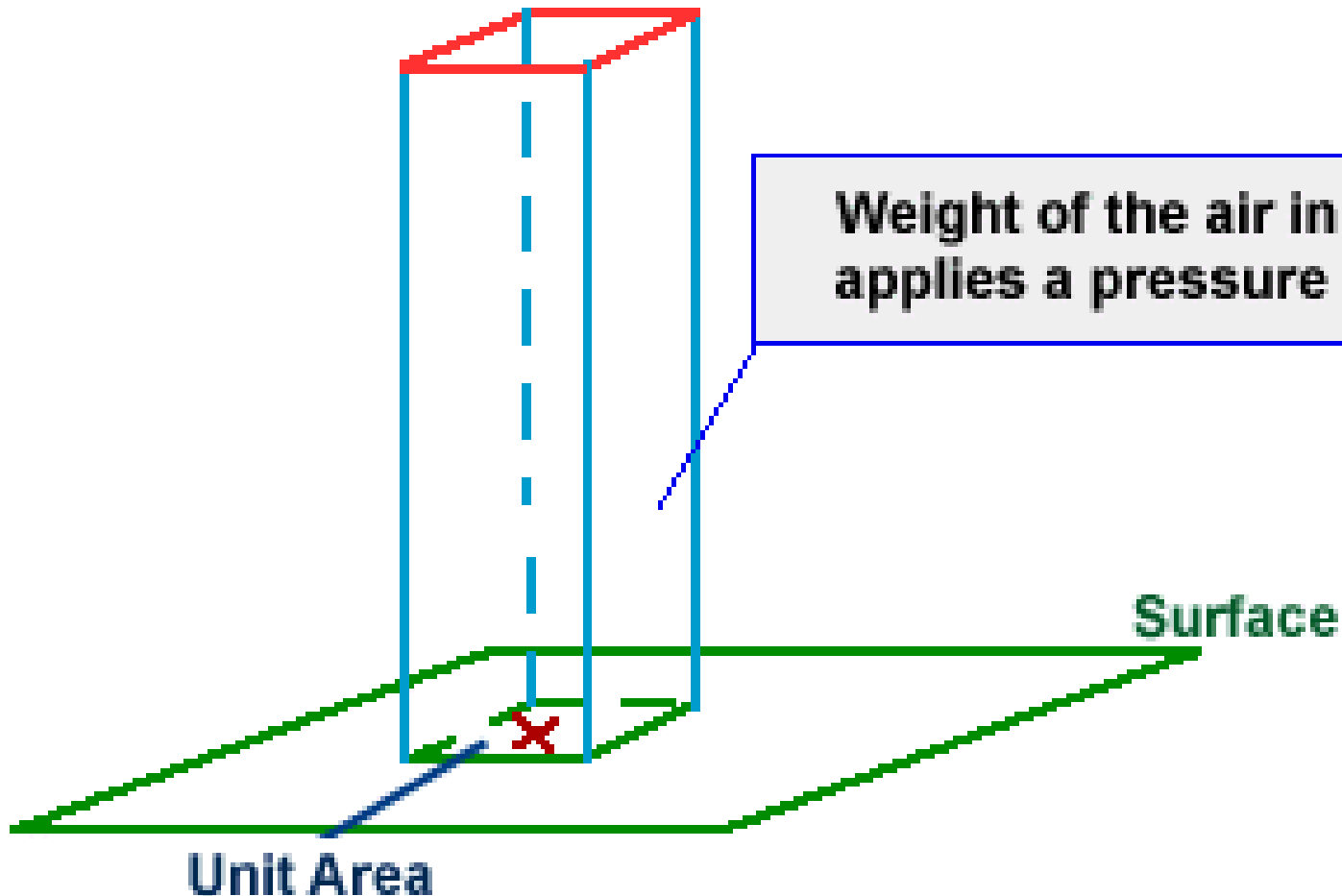
- Pressure decreases non-linearly w/ height (Why? Because air is compressible, so denser near the surface)



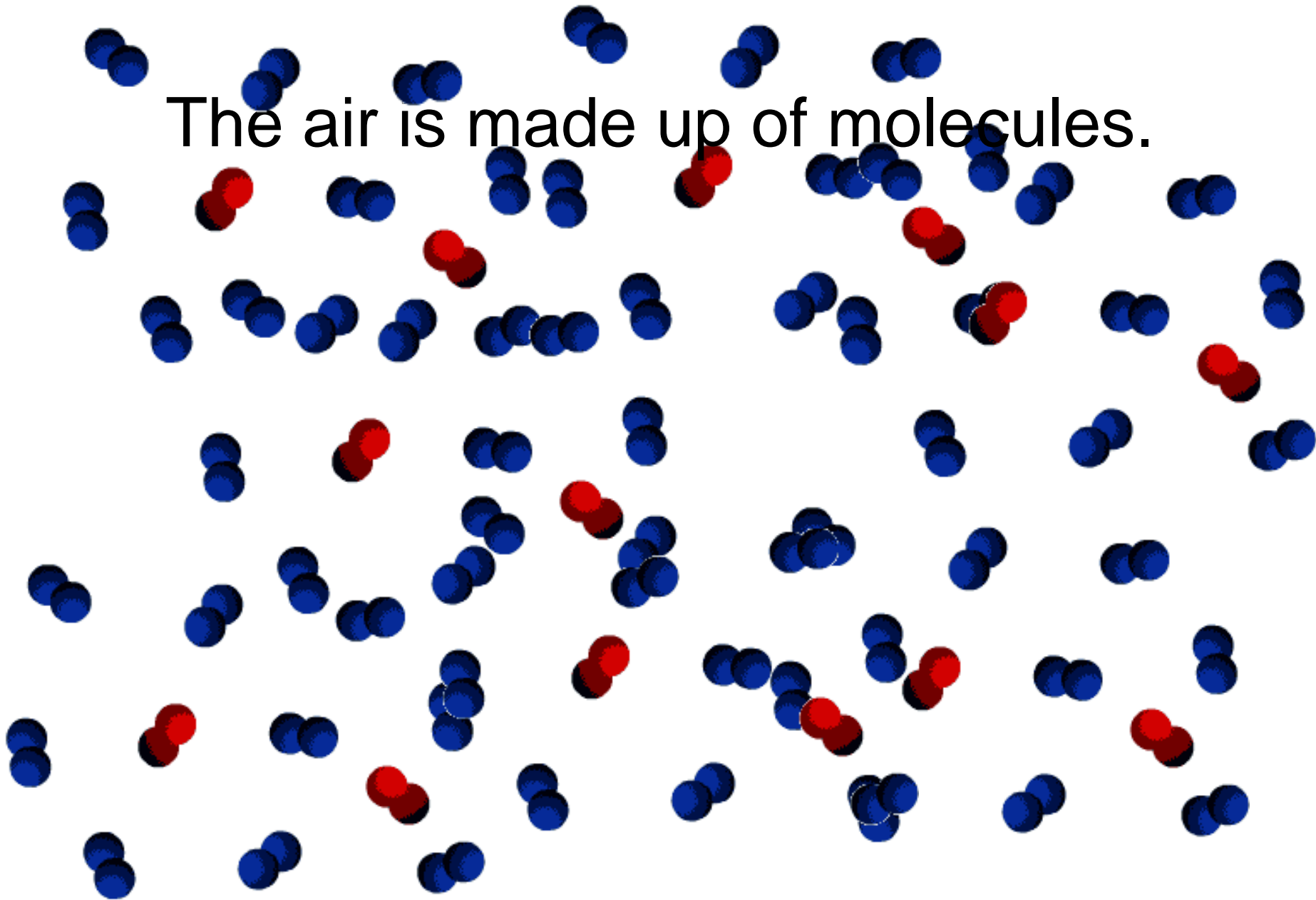
Gravity and Atmospheric Pressure

- The stronger the gravity, the more gas is held by the world and the greater the weight of atm. on a point

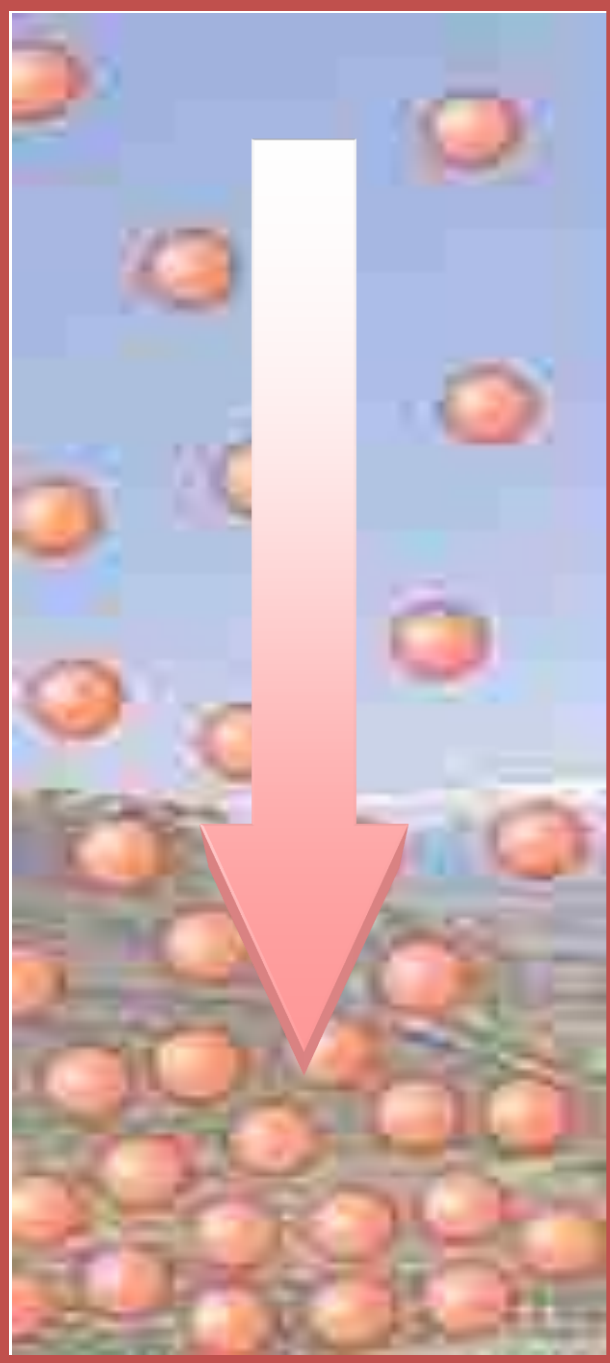
Top of the Atmosphere



The air is made up of molecules.



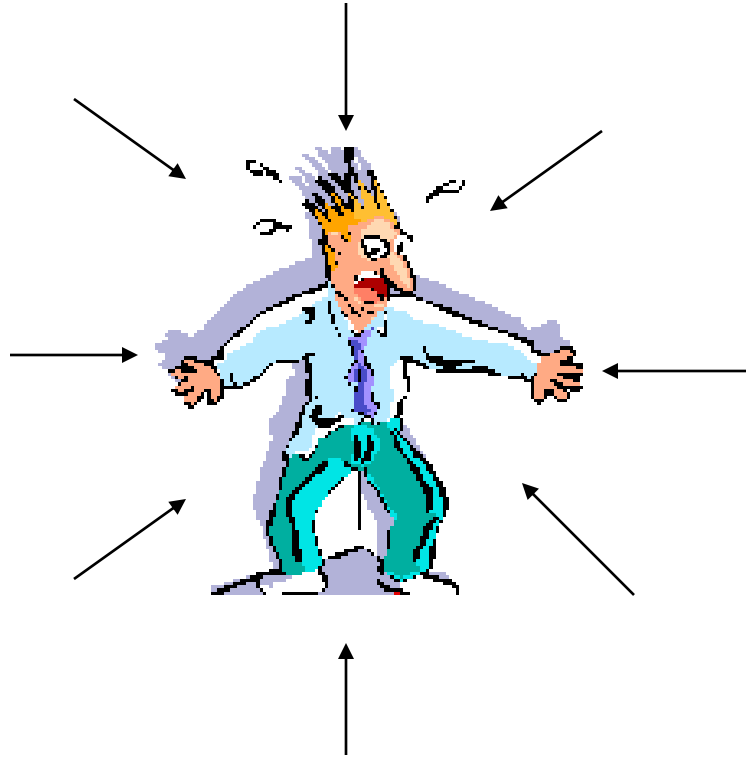
Gravity pulls the air molecules toward the earth, giving them weight. The weight of the air molecules all around us is called the air pressure.



High altitudes = lower pressure

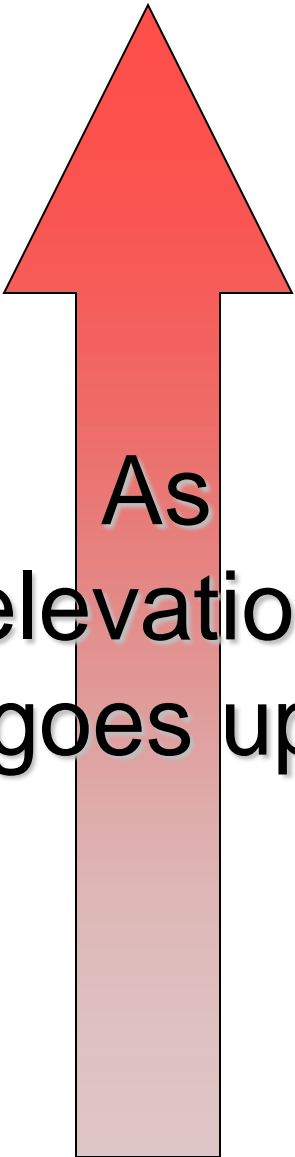


Low altitudes = higher pressure

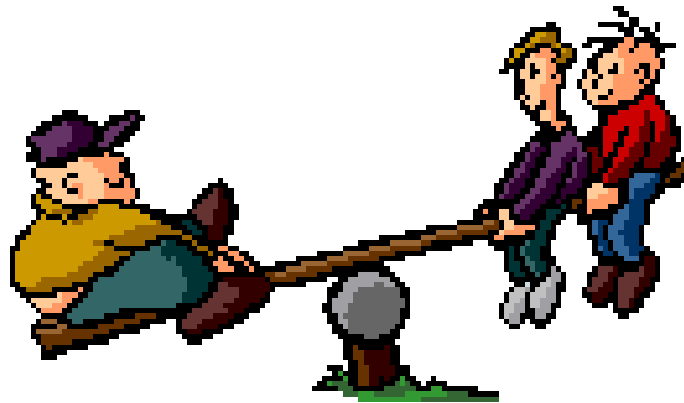


Air pressure is
equal in all
directions.

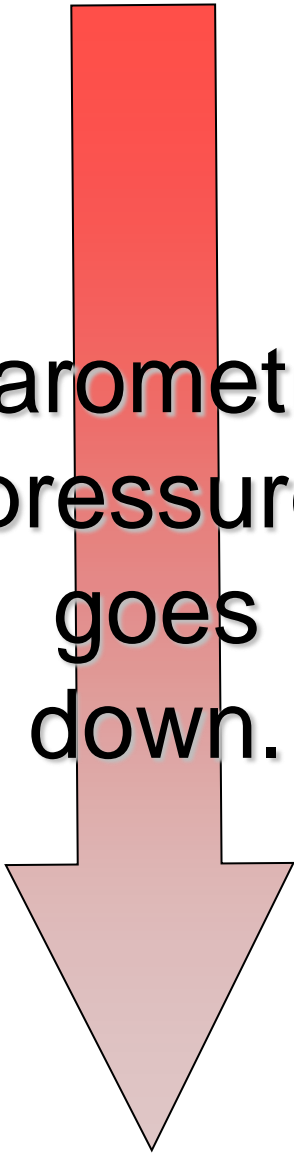
Pressure = force per unit area



As
elevation
goes up



This is an inverse relationship.

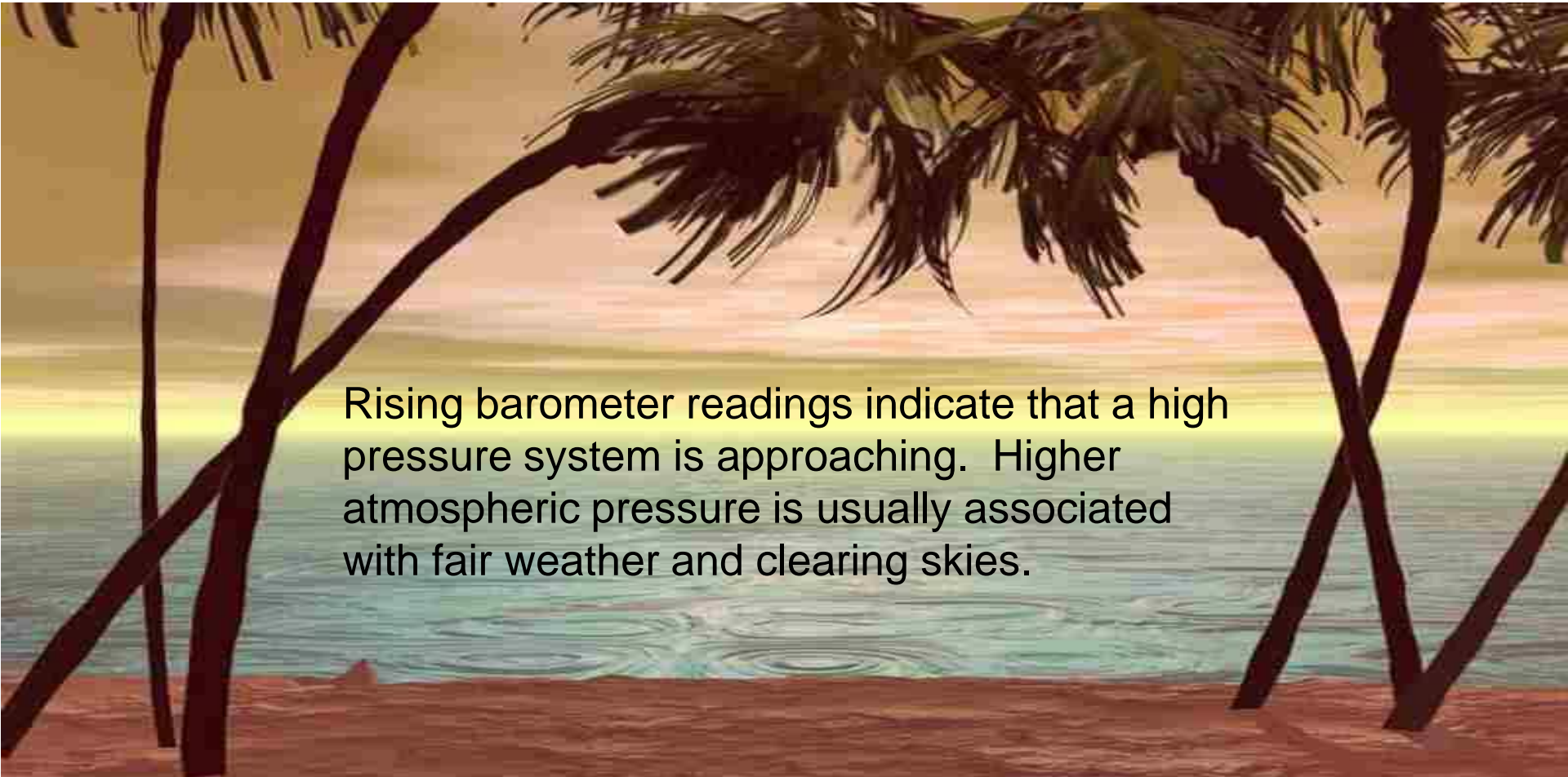


Barometric
pressure
goes
down.

Changing Pressure

A rising barometer = increasing air pressure.

This usually means:

A tropical beach scene with palm trees and a sunset over the ocean. The sky is a mix of orange, yellow, and pink, and the water is a calm, light blue. The palm trees are dark silhouettes against the bright sky.

Rising barometer readings indicate that a high pressure system is approaching. Higher atmospheric pressure is usually associated with fair weather and clearing skies.

Changing Pressure

A falling barometer = decreasing air pressure.

This usually means:

Falling barometer readings usually indicate the approach of an area of low pressure. Low pressure readings are usually associated with storm systems. Tornadoes and hurricanes can produce very low barometric readings.



Things that effect Air Pressure

*Altitude (Elevation)

*Temperature

*Humidity (moisture in the air)

Altitude

- *The higher the altitude, the lower the air pressure.
- *The lower the altitude, the higher the air pressure.

Temperature

- *As the temperature goes up, the air pressure goes down. (hot molecules are further apart- less pressure).
- *As the temperature goes down, the air pressure goes up. (cold air is more dense than warm air).

Humidity

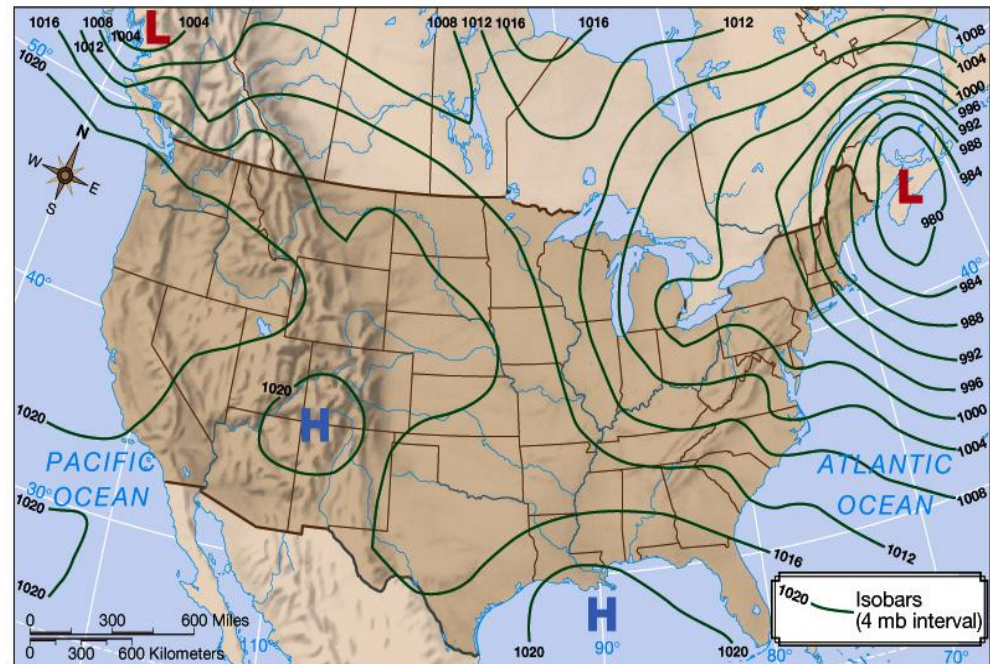
- * Humidity is the amount of moisture in the air.
- * Water vapor weighs less than air molecules.
- * As the air becomes more humid, the air pressure goes down (moist air weighs less than dry air).
- * Drier air has higher pressure because dry air weighs more than moist air, therefore it has greater pressure.

Air Movement and Flow

- Fluids (air and water) flow from areas of high pressure to areas of low pressure.
- Change in pressure across a horizontal distance is a pressure gradient.
 - Greater the difference in pressure and the shorter the distance between them, the steeper the pressure gradient and the stronger the wind.
- Movement of air across a pressure gradient parallel to Earth's surface is called a wind and winds are named for the direction from which they come.

Horizontal pressure distribution and horizontal pressure gradient

- Pressure maps depict isobars, lines of equal pressure
- Through analysis of isobaric charts, pressure gradients are apparent
 - Steep pressure gradients are indicated by **closely spaced isobars**
 - Typically only **small gradients exist across large spatial scales** (4% variation at continental scale), smaller than vertical gradients



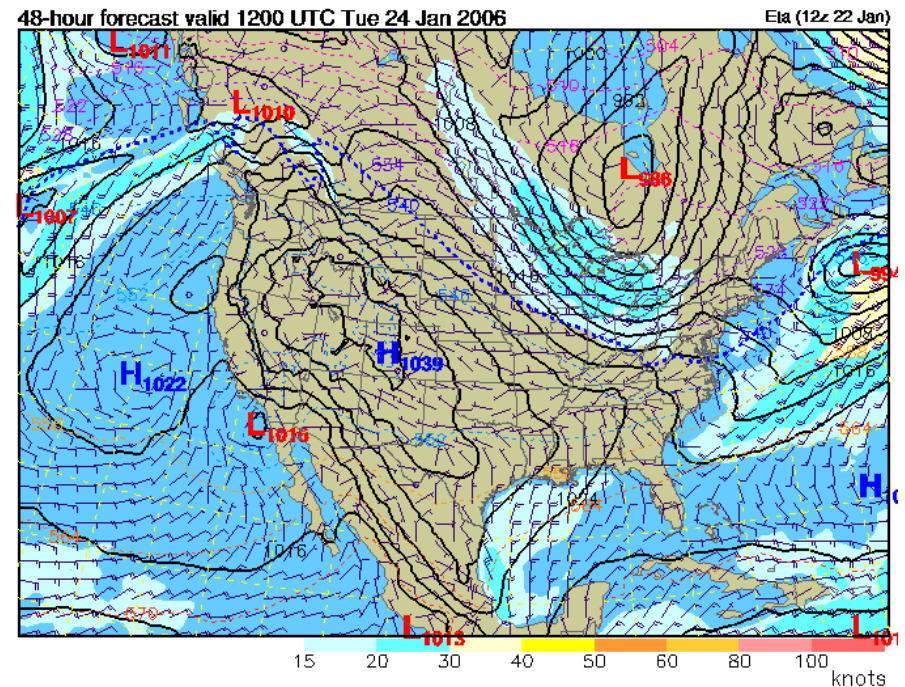
Horizontal Pressure Gradients and wind

- The pressure gradient force initiates movement of atmospheric mass, wind, from areas of higher to areas of lower pressure
- **Horizontal wind speeds** are a function of the **strength of the pressure gradient**

SLP and winds plotted on same chart →

Notice the strong winds in Ohio – due to tight pressure gradient

Surface (10m) Wind Speed (knots) / MSLP (mb)

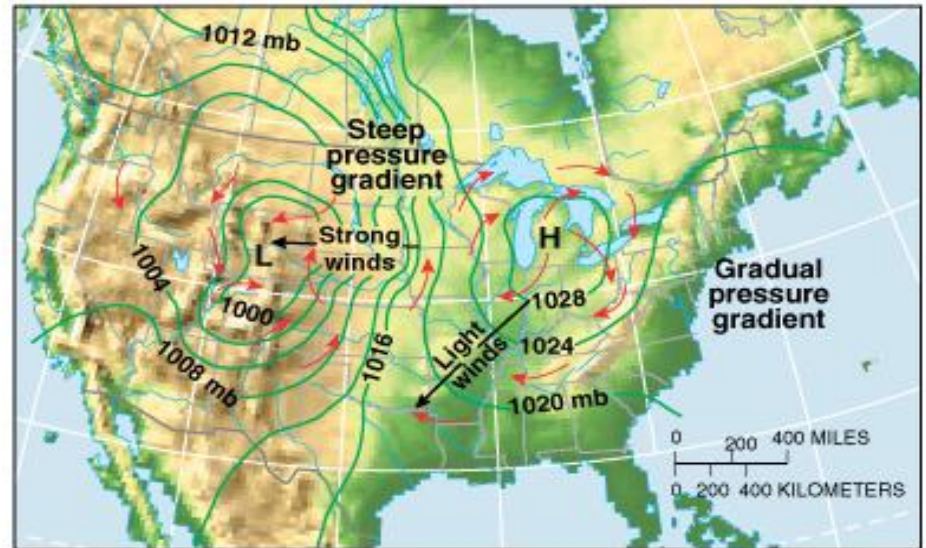


Forces Affecting the Speed and Direction of the Wind

- Horizontal pressure gradients responsible for wind generation
- Three factors affect wind speed and/or direction (*velocity*):
 1. Pressure Gradient Force (PGF)
 2. Coriolis Effect (CE)
 3. Friction Force (FF)

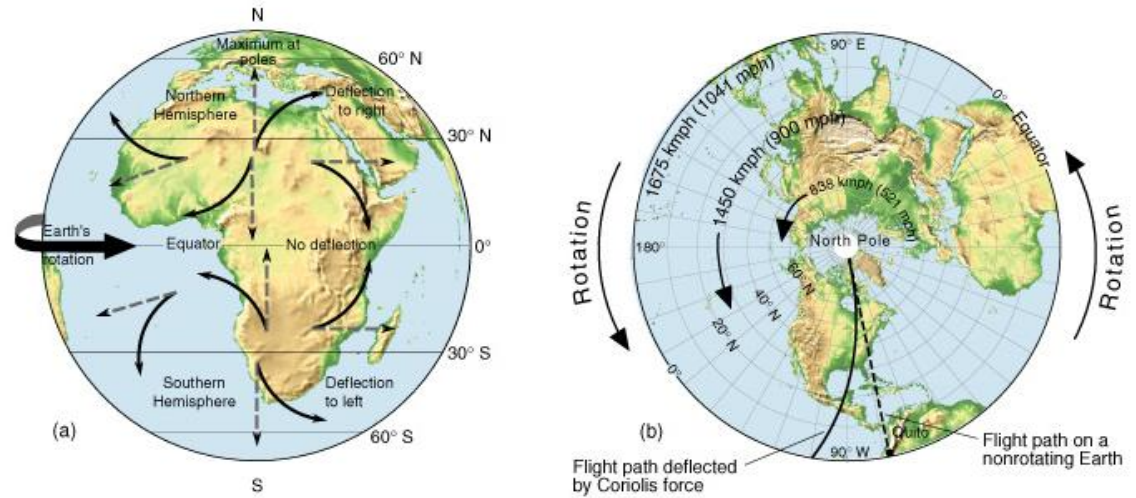
$$\frac{\Delta \bar{V}}{\Delta t} = PGF + CE + FF$$

1. Pressure Gradient Force (PGF)



- pressure gradient: high pressure → low pressure
- pressure differences exist due to unequal heating of Earth's surface
- spacing between isobars indicates intensity of gradient
- flow is perpendicular to isobars

2. The Coriolis Effect



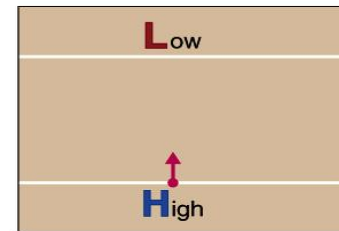
- objects in the atmosphere are influenced by the Earth's rotation
 - Rotation of Earth **is counter-clockwise** looking down from N. Pole.
- Results in an **'apparent'** deflection (relative to surface)
- Deflection to the right in Northern Hemisphere (left in S. Hemisphere)
- Greatest at the poles, 0 at the equator
- Increases with speed of moving object and distance
- **CE changes direction not speed**

Winds in the upper air: Geostrophic Balance

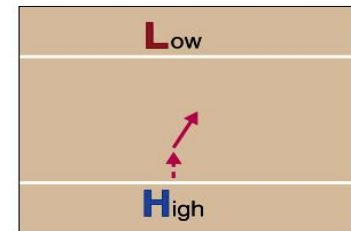
Friction is very small in the upper air:

$$\frac{\Delta \bar{V}}{\Delta t} = PGF + CE + \cancel{FF}$$

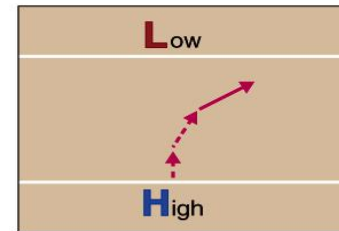
- Now the wind speed/direction is simply a balance between the PGF and CE. This is called ***GEOSTROPHIC BALANCE***.
- Upper air moving from areas of higher to areas of lower pressure undergo Coriolis deflection
- Air will eventually flow parallel to height contours as the pressure gradient force balances with the Coriolis force



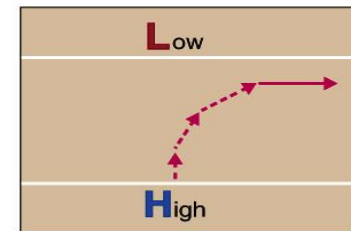
(a)



(b)



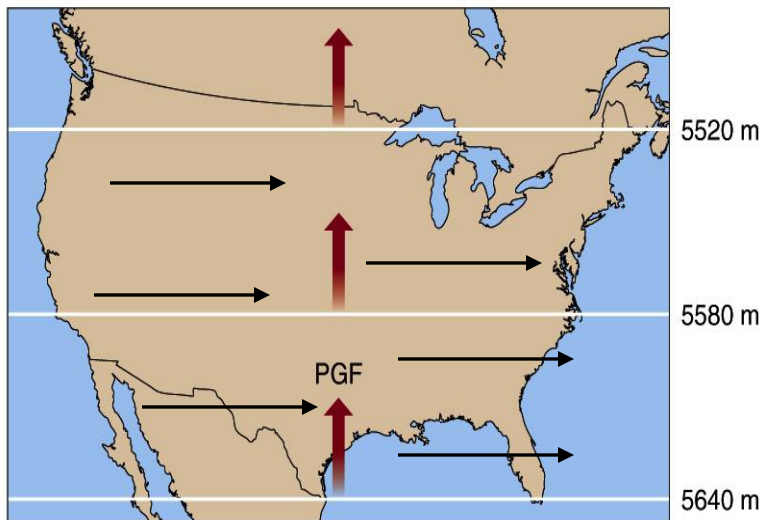
(c)



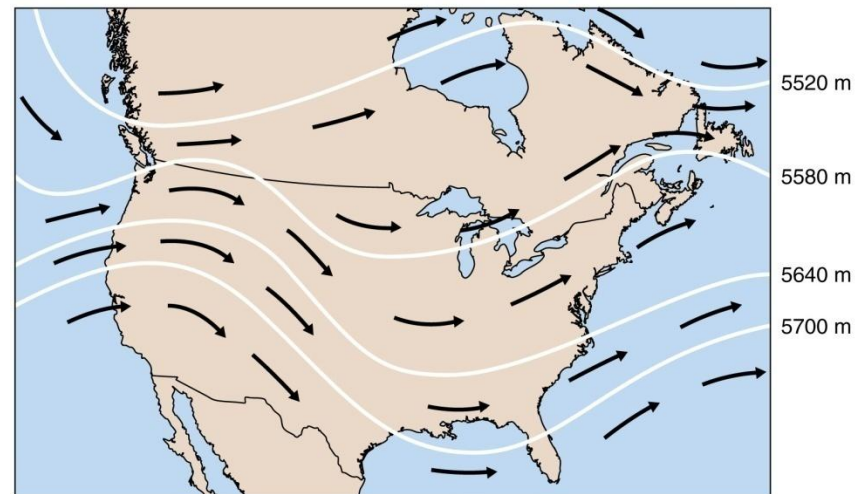
(d)

Geostrophic Versus Gradient Winds

- In reality, PGF is rarely uniform since height contours curve and vary in distance → Geostrophic flow assumption is too simplistic
- wind still flows parallel to contours → **HOWEVER** it is continuously changing direction (and thus experiencing acceleration)
- for isobar-parallel flow to occur an imbalance must exist between PGF and CE → **Gradient Flow**



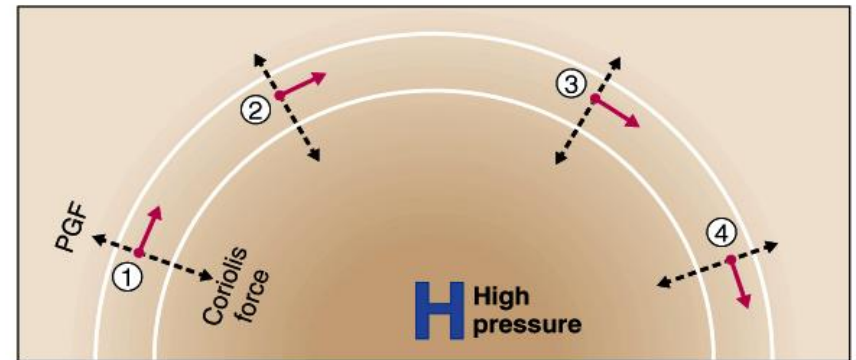
Ideal



Reality

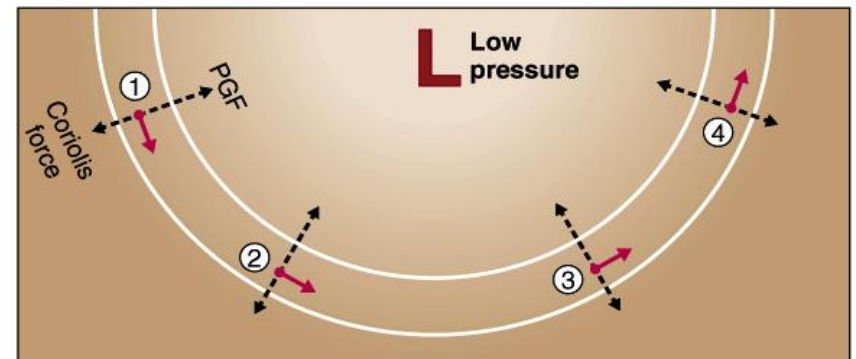
- Two specific types of gradient flow:
 - Supergeostrophic: High pressure systems, $CE > PGF$ (to enable wind to turn), air accelerates
 - Subgeostrophic: Low pressure systems, $PGF > CE$, air decelerates
- supergeostrophic and subgeostrophic conditions lead to airflow parallel to curved height contours

Supergeostrophic flow



(a)

Subgeostrophic flow



(b)

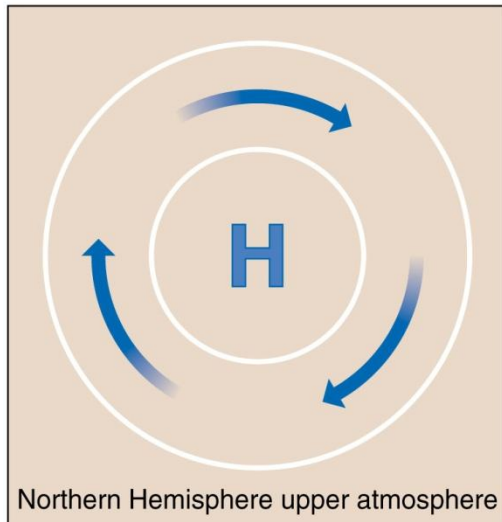
Winds near the surface

The third term (friction) must be considered:

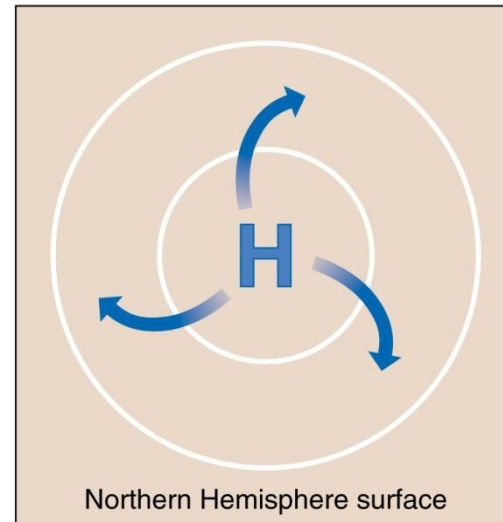
$$\frac{\Delta \bar{V}}{\Delta t} = PGF + CE + FF$$

- Friction slows down wind speed and reduces Coriolis deflection
- Friction is important for air within **~1.5 km** of the surface (the so-called planetary boundary layer).
- It varies with surface texture, wind speed, time of day/year and atmospheric conditions.
- Friction above 1.5 km is often small (often called the free atmosphere), except over regions with storms and gravity waves.

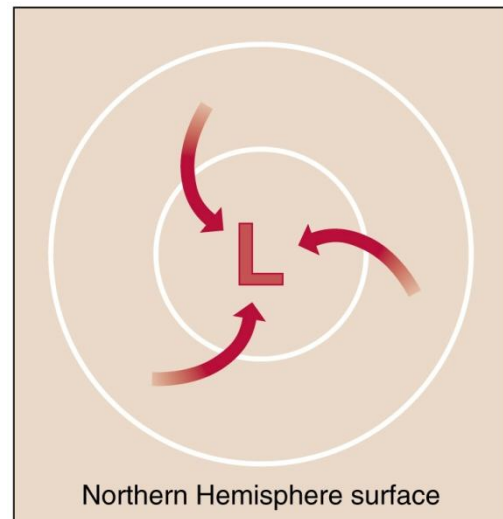
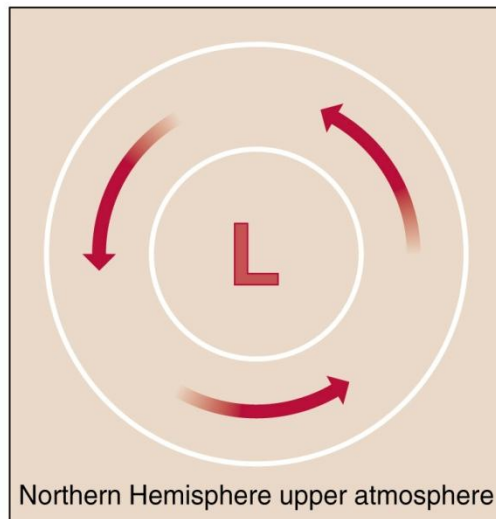
Pressure Gradient + Coriolis + Friction Forces



**w/out Friction
(gradient wind)**



w/ Friction



Cyclones, Anticyclones, Troughs and Ridges

- High pressure areas (**anticyclones**) → clockwise airflow in the Northern Hemisphere (opposite flow direction in S. Hemisphere)
 - Characterized by **descending air** which warms creating clear skies
- Low pressure areas (**cyclones**) → counterclockwise airflow in N. Hemisphere (opposite flow in S. Hemisphere)
 - Air converges toward low pressure centers, cyclones are characterized by **ascending air** which cools to form clouds and possibly precipitation

