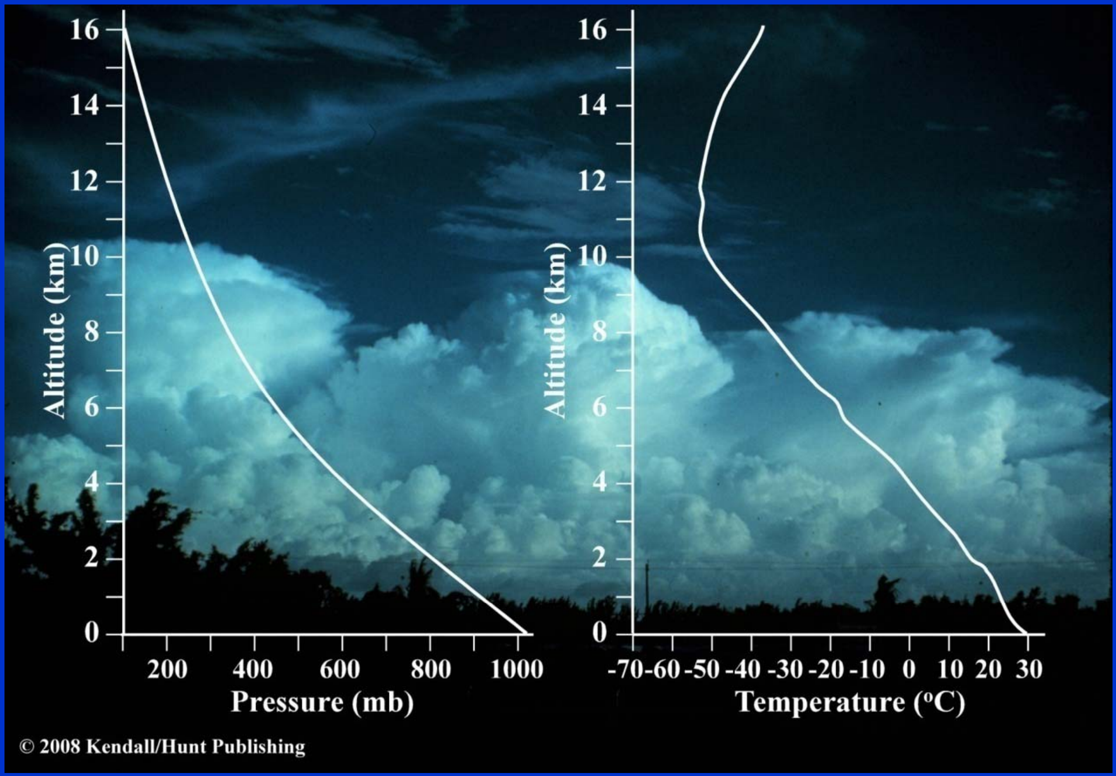
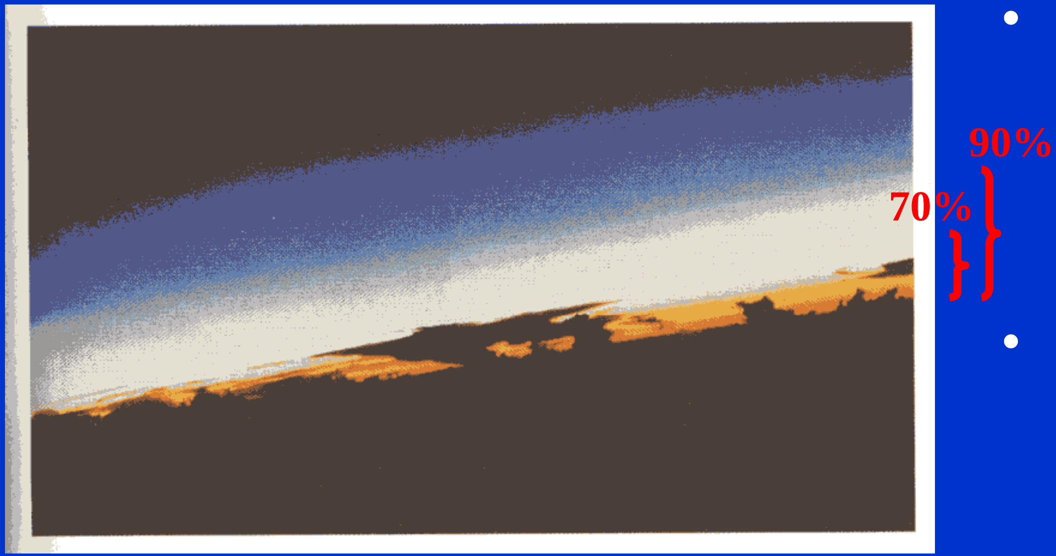
Chapter 1: Properties of Atmosphere



- Temperature
- Pressure
- Wind
- Moisture

Thickness of the Atmosphere

(from *Meteorology Today*)



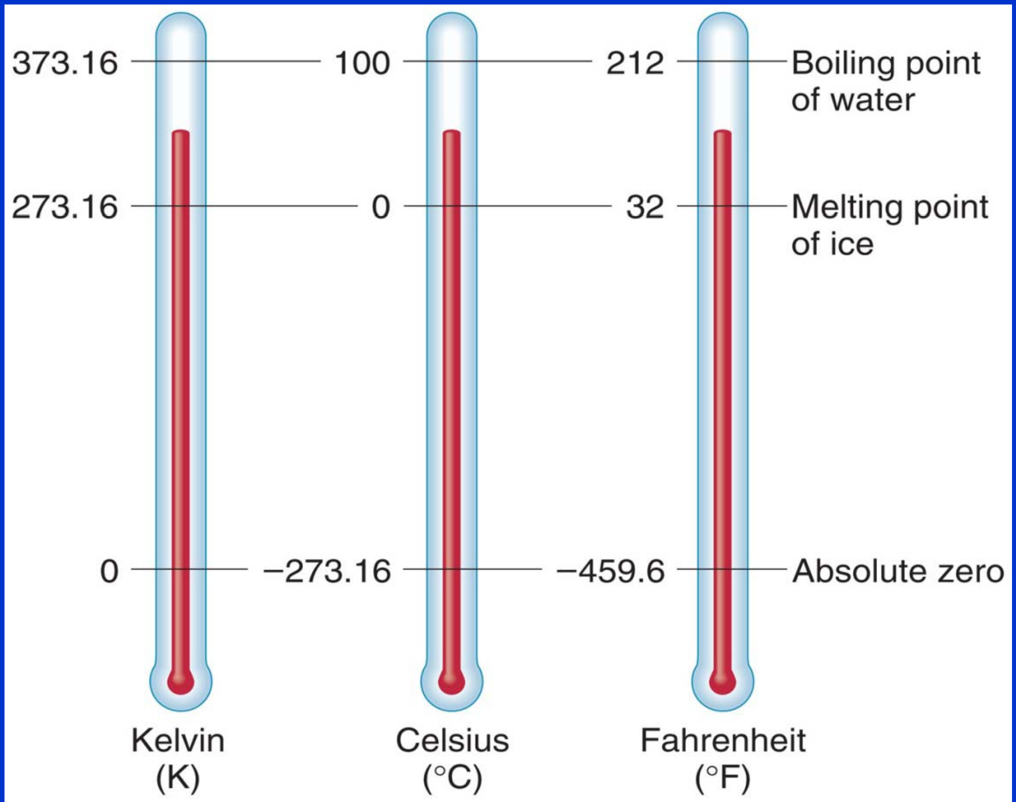
- The thickness of the atmosphere is only about 2% of Earth's thickness (Earth's radius = ~6400km).
- Most of the atmospheric mass is confined in the lowest 100 km above the sea level.

❑ Because of the shallowness of the atmosphere, its motions over large areas are primarily horizontal.

➔Typically, horizontal wind speeds are a thousands time greater than vertical wind speeds.

(But the small vertical displacements of air have an important impact on the state of the atmosphere.)

Units of Air Temperature



- Fahrenheit (ºF)
- Celsius (ºC)

➔ ºC = (ºF-32)/1.8

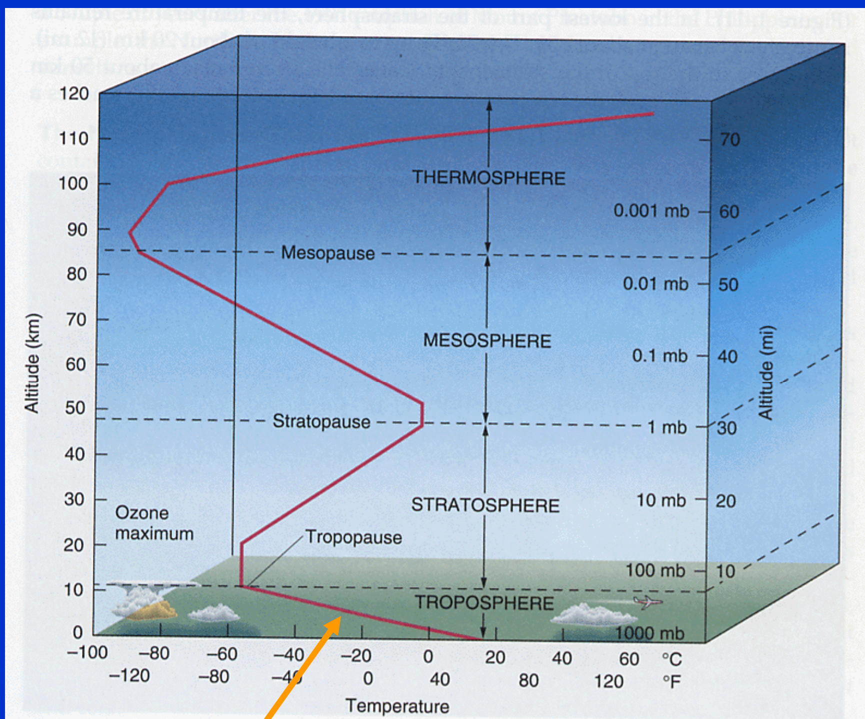
- Kelvin (K): a SI unit

➔ K= ºC+273

1 K = 1 ºC > 1 ºF

Vertical Thermal Structure

Standard Atmosphere



(from *Understanding Weather & Climate*)

lapse rate = 6.5 C/km

Troposphere (“overturning” sphere)

- contains 80% of the mass
- surface heated by solar radiation
- strong vertical motion
- where most weather events occur

Stratosphere (“layer” sphere)

- weak vertical motions
- dominated by radiative processes
- heated by ozone absorption of solar ultraviolet (UV) radiation
- warmest (coldest) temperatures at summer (winter) pole

middle atmosphere

Mesosphere

- heated by solar radiation at the base
- heat dispersed upward by vertical motion

Thermosphere

- very little mass

Variations in Tropopause Height

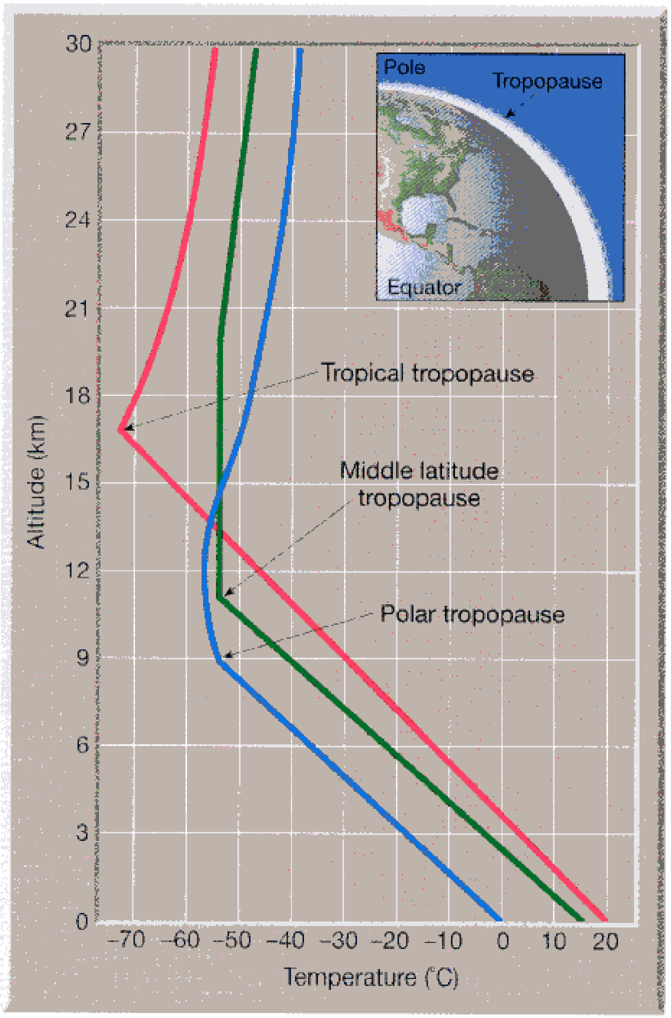
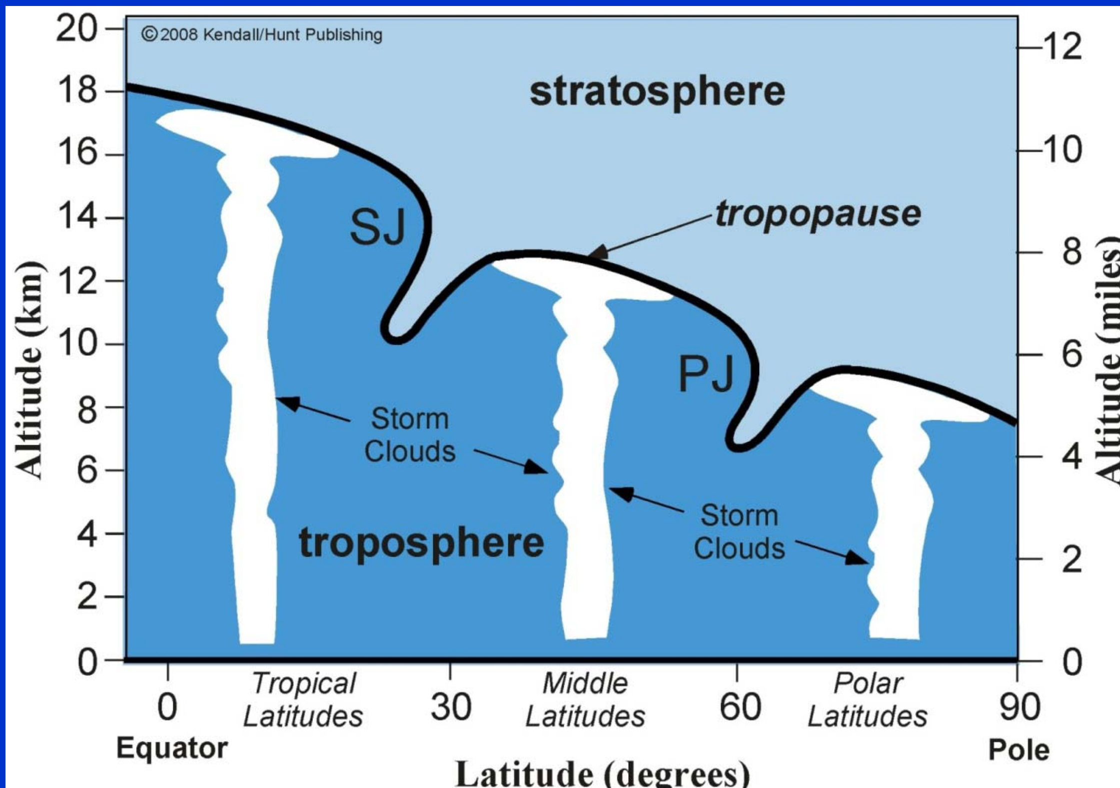
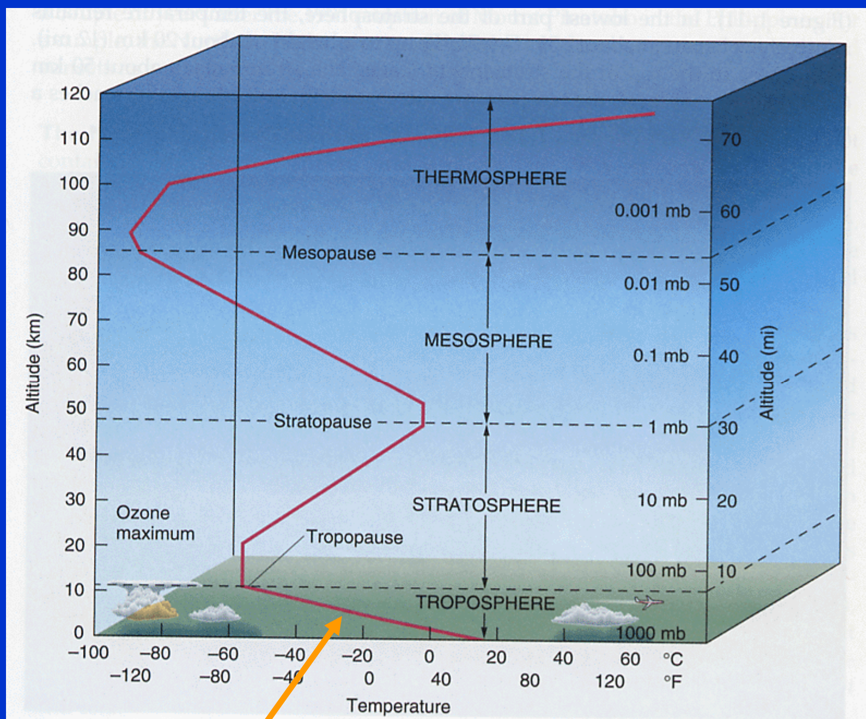


FIGURE 1-23 Differences in the height of the tropopause. The variation in the height of the tropopause, as shown on the small inset diagram, is greatly exaggerated.



Stratosphere

Standard Atmosphere



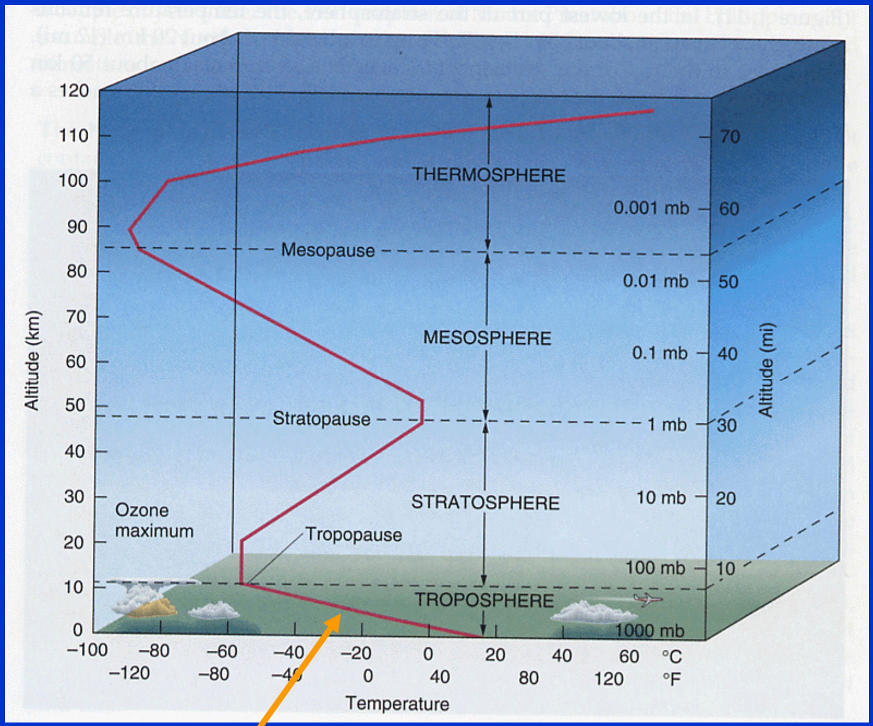
(from *Understanding Weather & Climate*)

lapse rate = 6.5 C/km

- The reasons for the inversion in the stratosphere is due to the ozone absorption of ultraviolet solar energy.
- Although maximum ozone concentration occurs at 25km, the lower air density at 50km allows solar energy to heat up temperature there at a much greater degree.
- Also, much solar energy is absorbed in the upper stratosphere and can not reach the level of ozone maximum.

Mesosphere

Standard Atmosphere



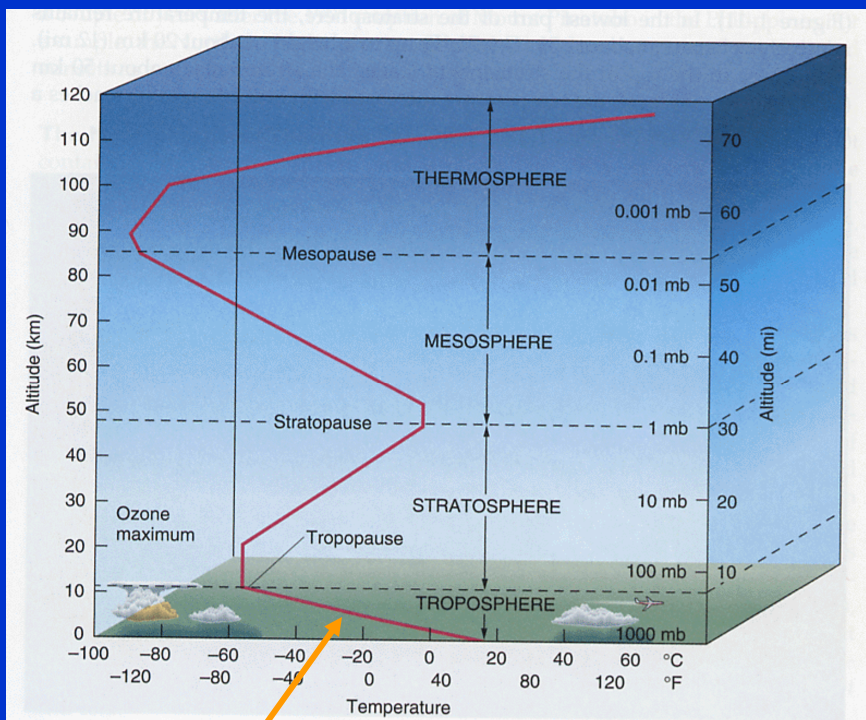
(from *Understanding Weather & Climate*)

lapse rate = 6.5 C/km

- There is little ozone to absorb solar energy in the mesosphere, and therefore, the air temperature in the mesosphere decreases with height.
- Also, air molecules are able to lose more energy than they absorb. This cooling effect is particularly large near the top of the mesosphere.

Thermosphere

Standard Atmosphere



(from *Understanding Weather & Climate*)

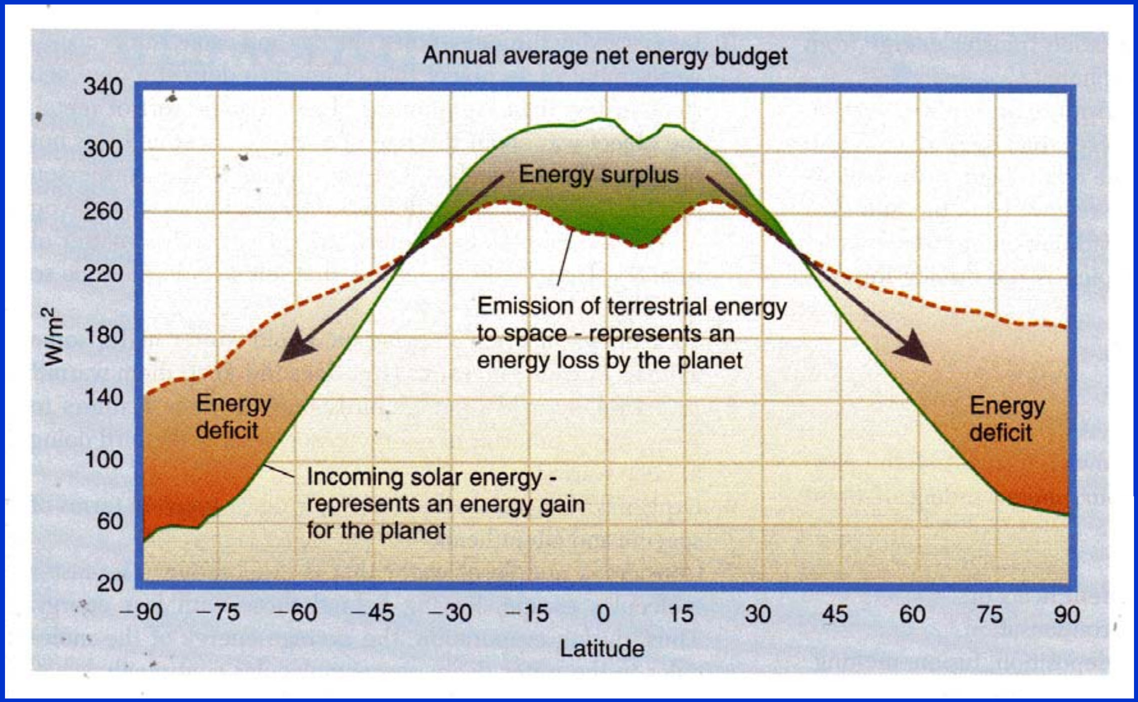
lapse rate = 6.5 C/km

❑ In thermosphere, oxygen molecules absorb solar rays and warms the air.

❑ Because this layer has a low air density, the absorption of small amount of solar energy can cause large temperature increase.

❑ The air temperature in the thermosphere is affected greatly by solar activity.

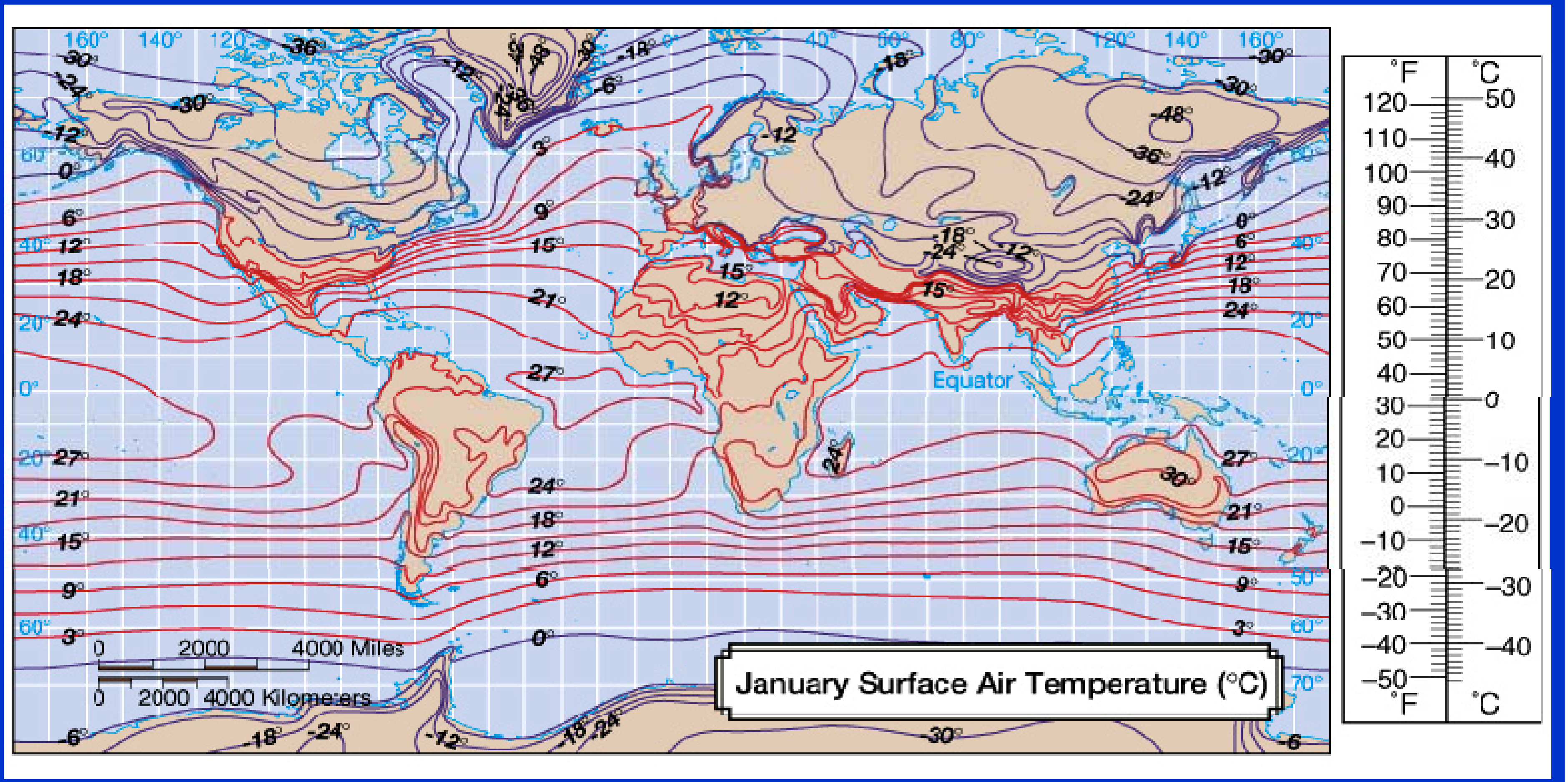
Latitudinal Variations of Net Energy



(from *Meteorology: Understanding the Atmosphere*)

- Polarward heat flux is needed to transport radiation energy from the tropics to higher latitudes.

Isotherm



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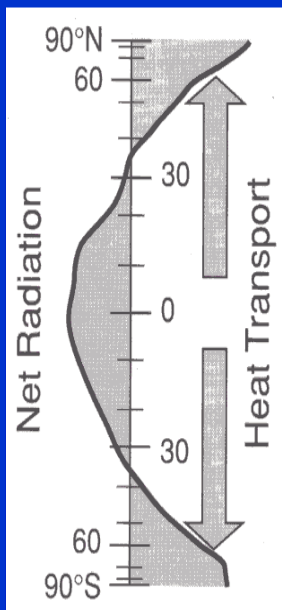
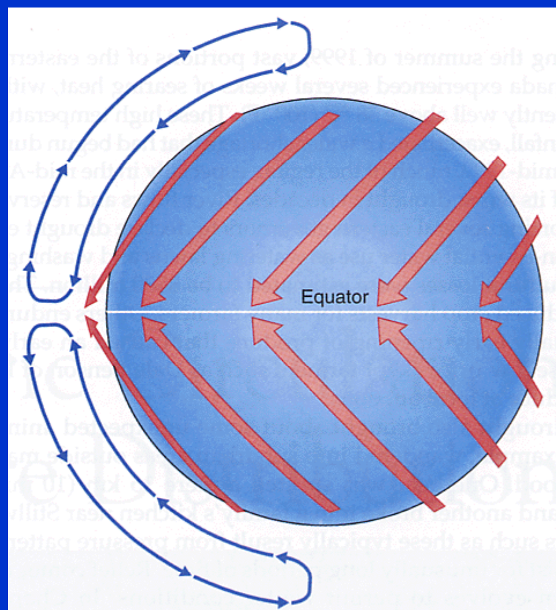
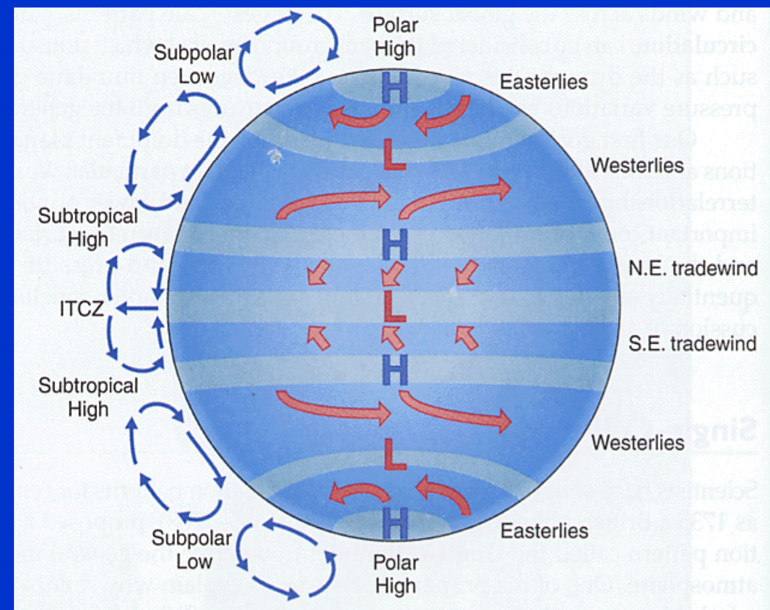
Atmospheric Circulation: Zonal-mean Views

Single-Cell Model | Three-Cell Model

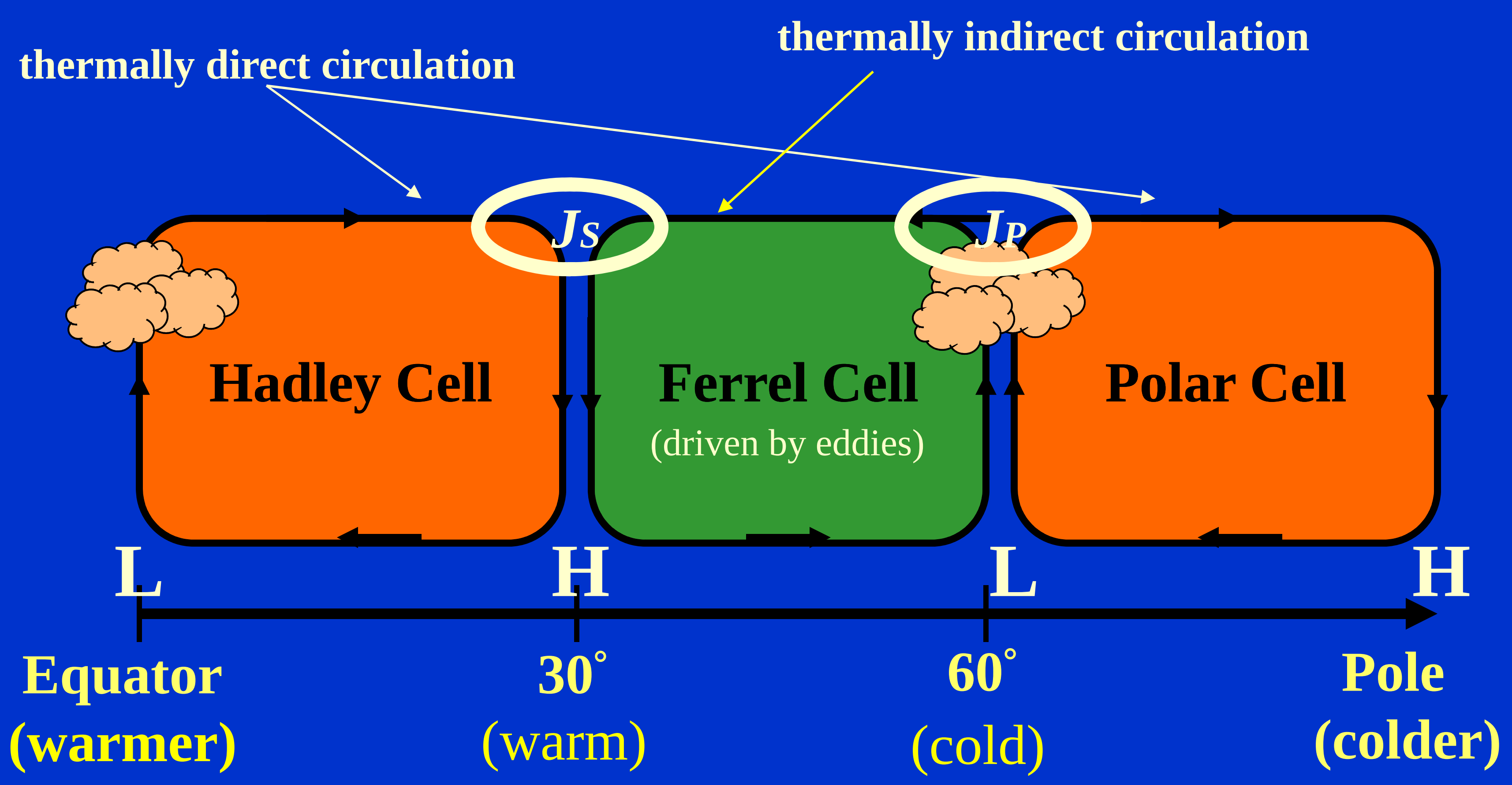






(Figures from *Understanding Weather & Climate* and *The Earth System*)

Properties of the Three Cells



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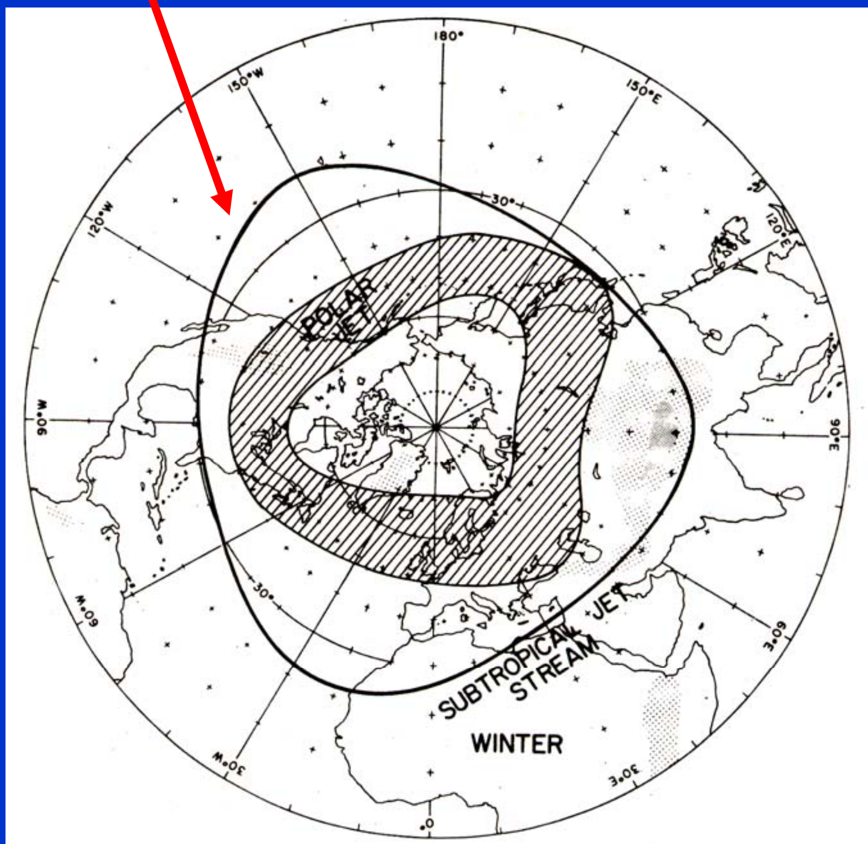
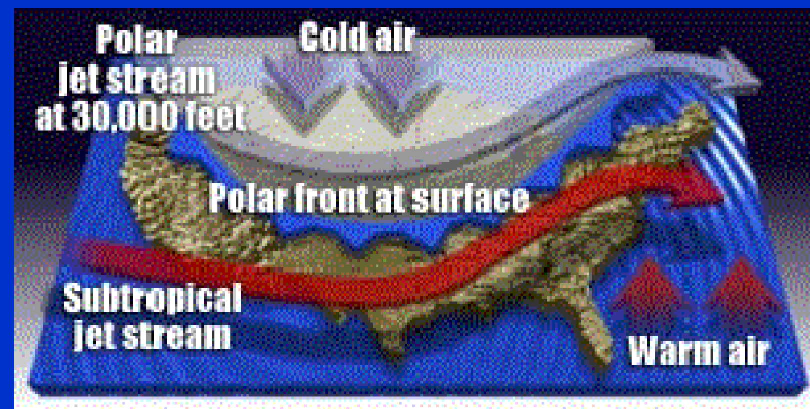
Jet Streams Near the Western US

Pineapple Express



(from *Riehl (1962), Palmen and Newton (1969)*)

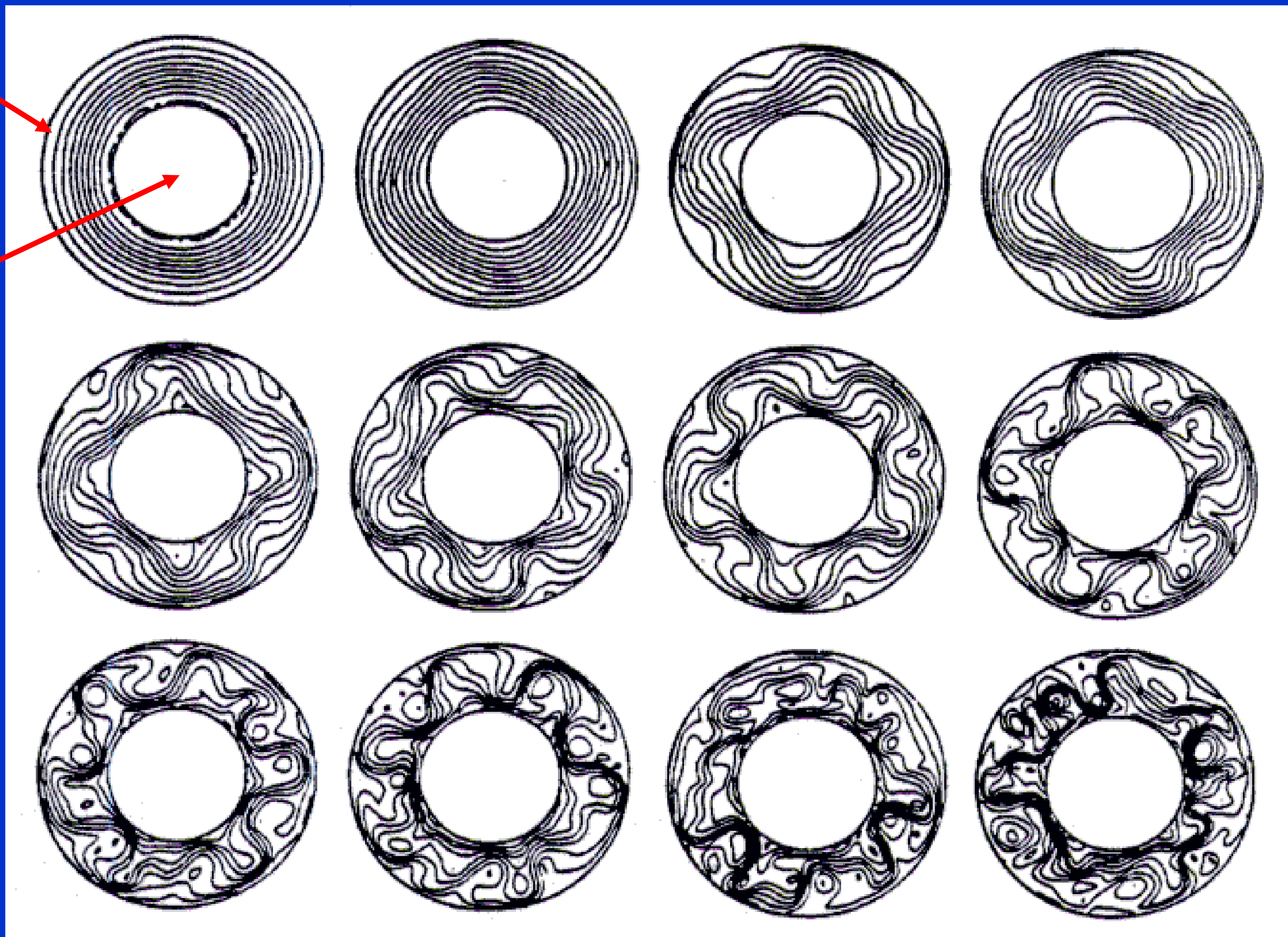


- ❑ Both the polar and subtropical jet streams can affect weather and climate in the western US (such as California).
- ❑ El Nino can affect western US climate by changing the locations and strengths of these two jet streams.

Rotating Annulus Experiment

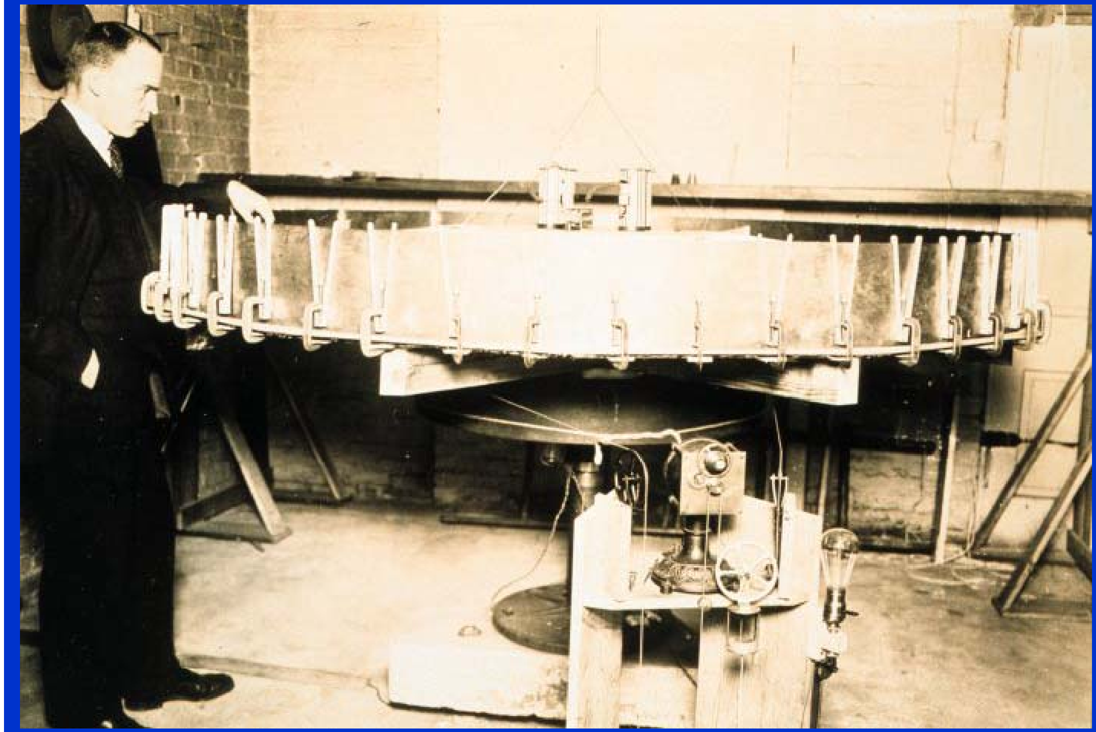
Cooling Outside

Heating Inside



(from *"Is The Temperature Rising?"*)

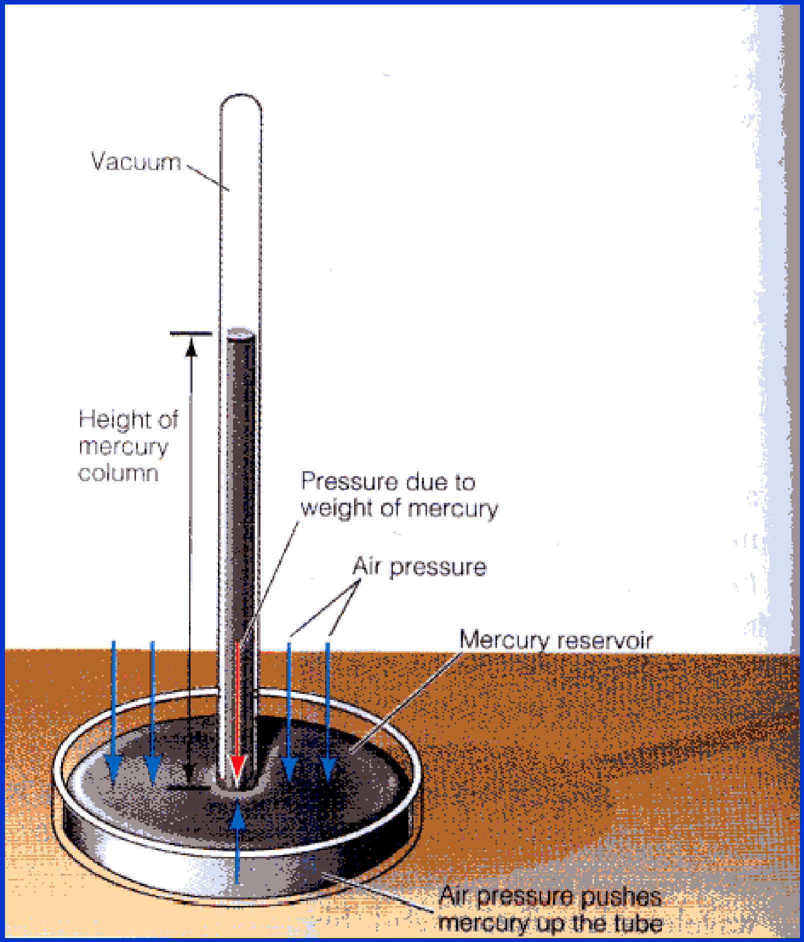
New Understanding of Cyclone after WWII



Carl Gustav Rossby (1898-1957)

- Carl Rossby mathematically expressed relationships between mid-latitude cyclones and the upper air during WWII.
- Mid-latitude cyclones are a large-scale waves (now called Rossby waves) that grow from the "baroclinic" instabiloity associated with the north-south temperature differences in middle latitudes.

One Atmospheric Pressure



(from *The Blue Planet*)

- The average air pressure at sea level is equivalent to the pressure produced by a column of water about 10 meters (or about 76 cm of mercury column).
- This standard atmosphere pressure is often expressed as 1013 mb (millibars), which means a pressure of about 1 kilogram per square centimeter.

Units of Atmospheric Pressure

- **Pascal (Pa):** a SI (Systeme Internationale) unit for air pressure.

  1 Pa = a force of 1 newton acting on a surface of one square meter

  1 hectopascal (hPa) = 1 millibar (mb) [hecto = one hundred =100]

- **Bar:** a more popular unit for air pressure.

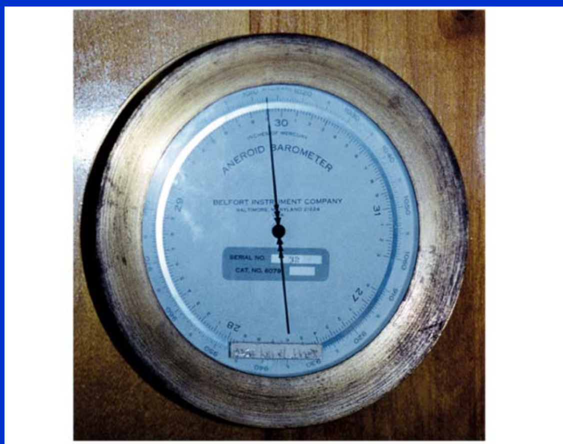
  1 bar = a force of 100,000 newtons acting on a surface of one square meter

  = 100,000 Pa

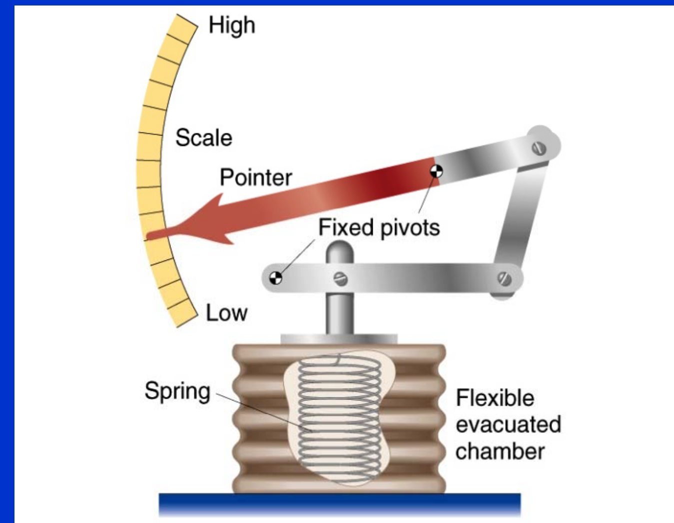
  = 1000 hPa

  = 1000 mb

- **One atmospheric pressure** = standard value of atmospheric pressure at lea level = 1013.25 mb = 1013.25 hPa.

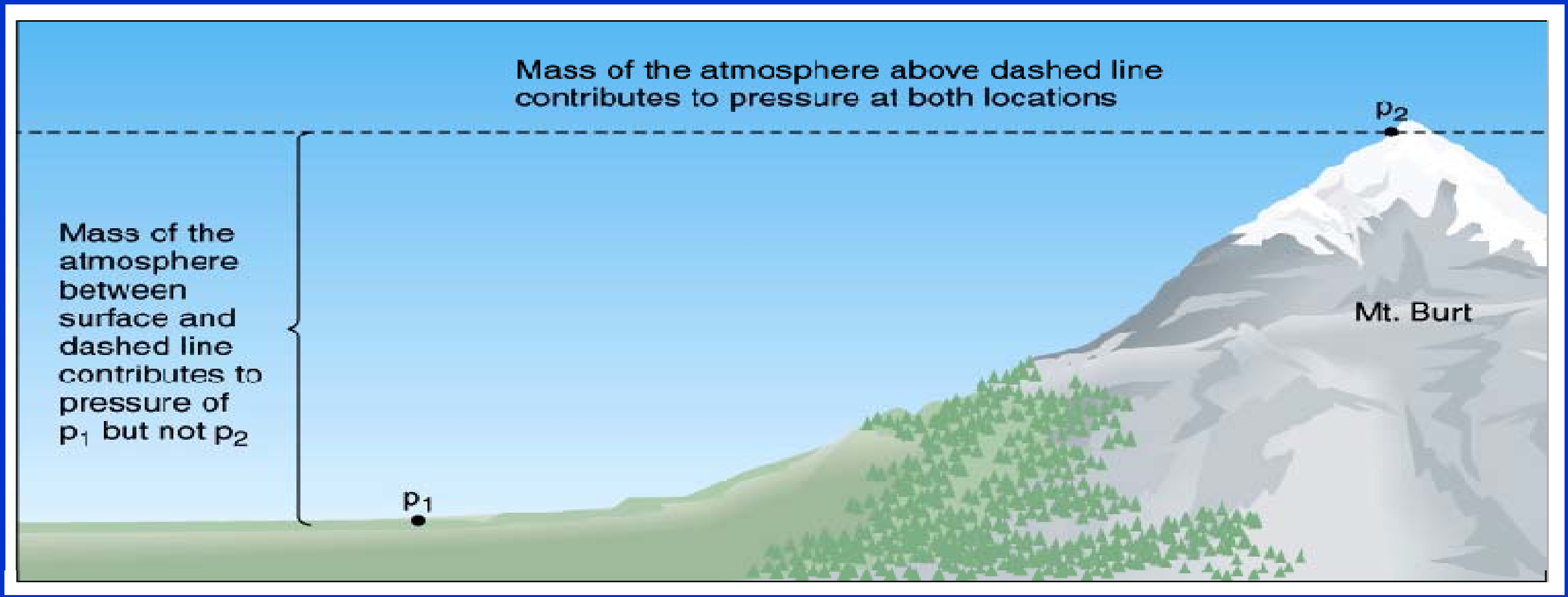


Aneroid barometer (left) and its workings (right)



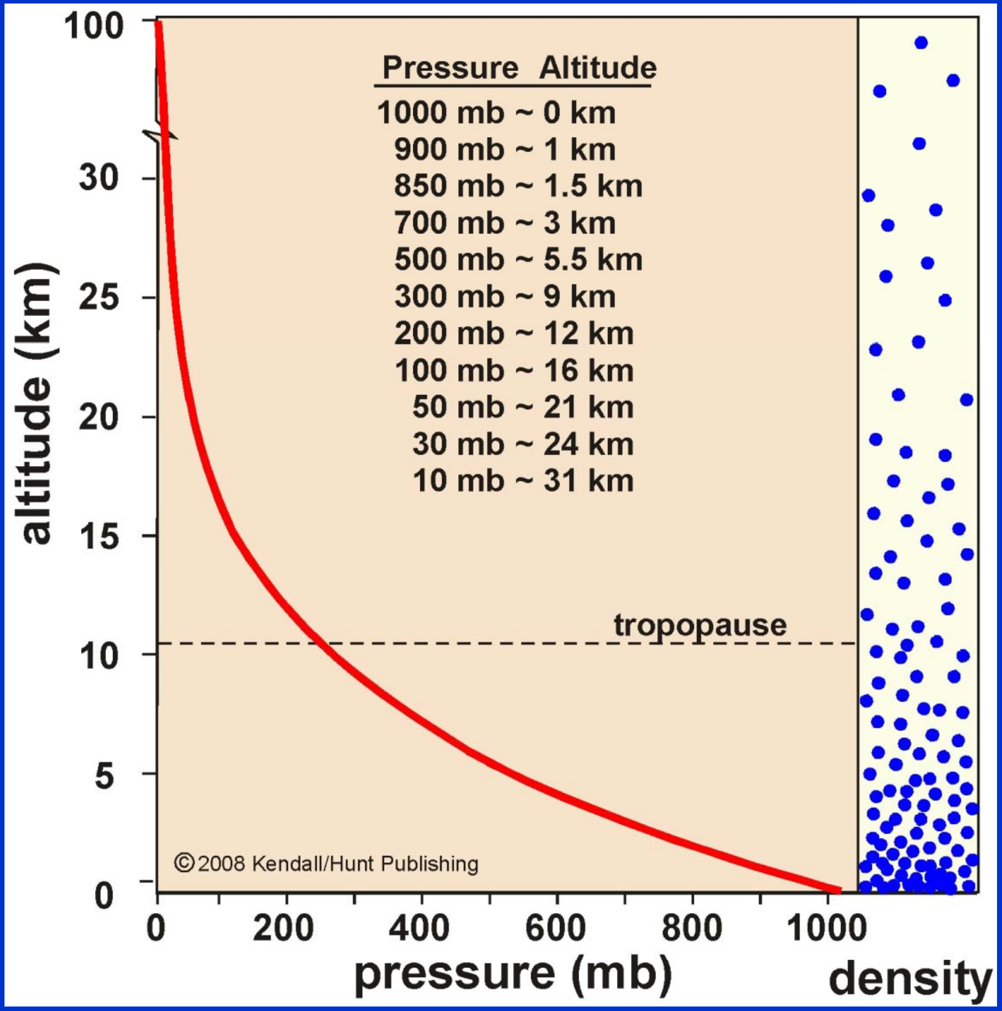
A barograph continually records air pressure through time

Pressure Correction for Elevation

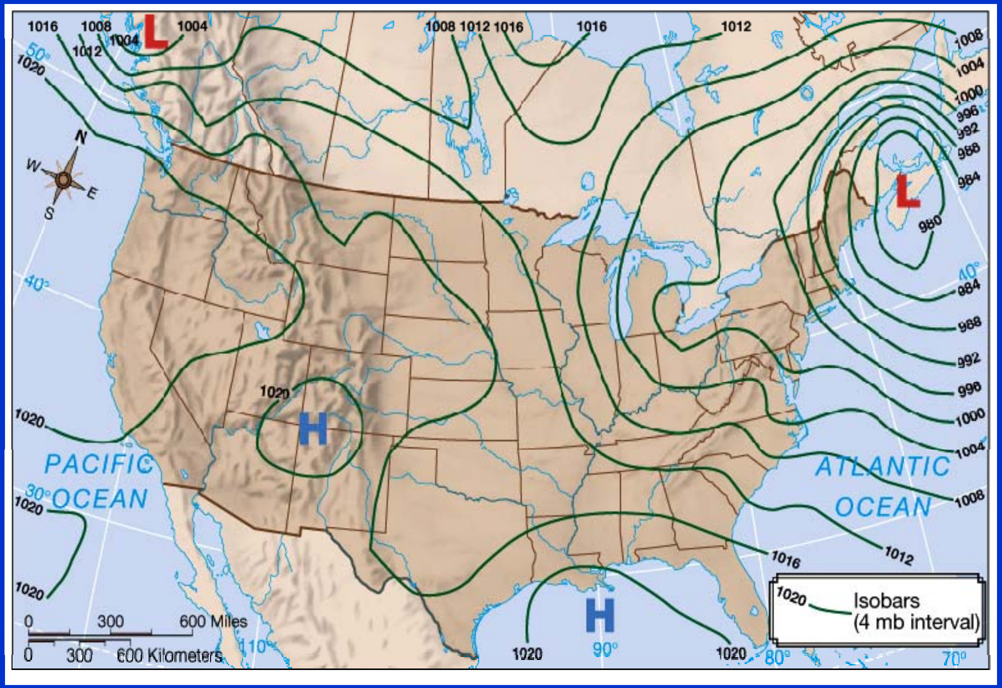


- Pressure decreases with height.
- Recording actual pressures may be misleading as a result.
- All recording stations are reduced to sea level pressure equivalents to facilitate horizontal comparisons.
- Near the surface, the pressure decreases about 100mb by moving 1km higher in elevation.

Pressure and Height

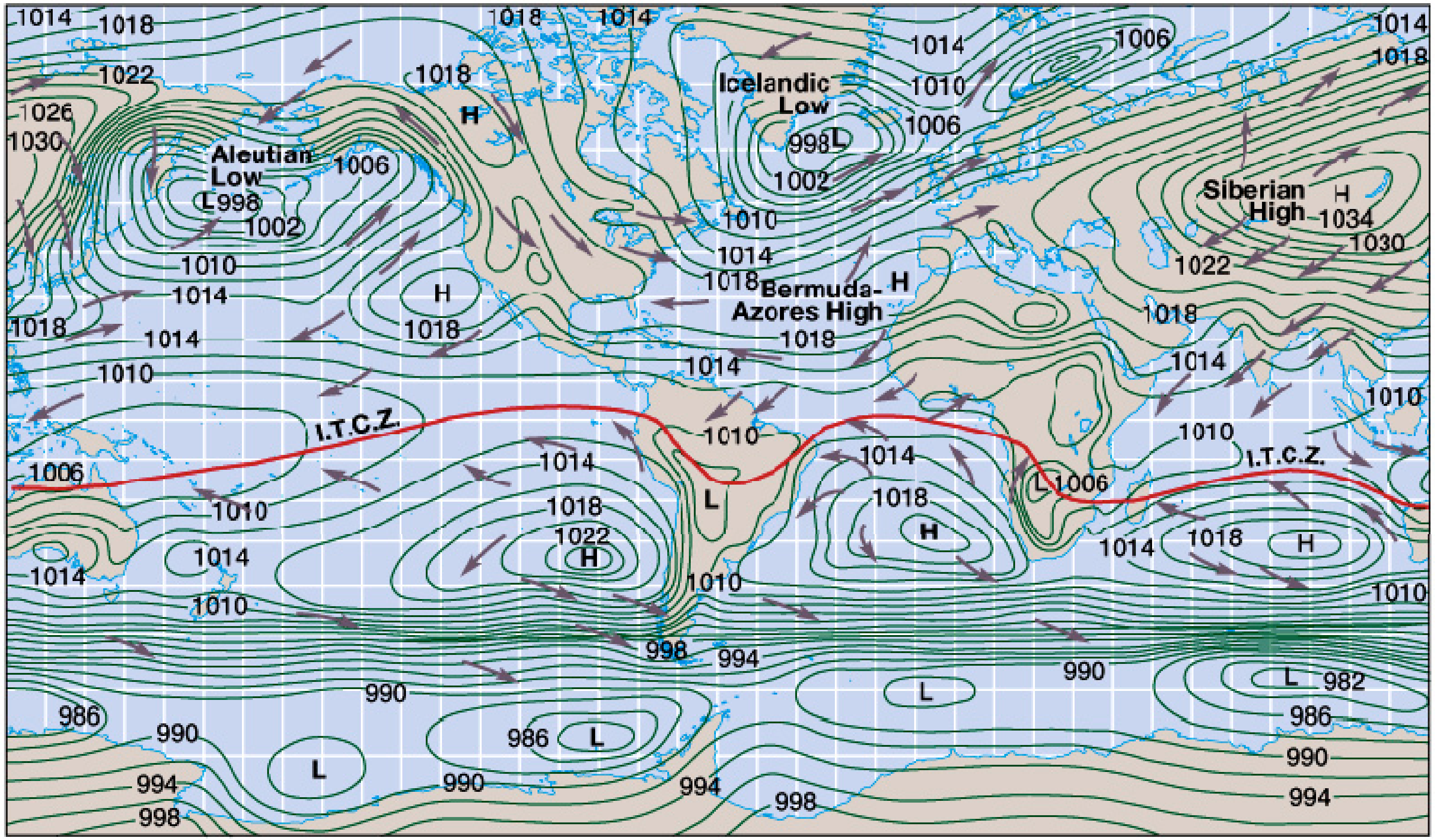


Isobar

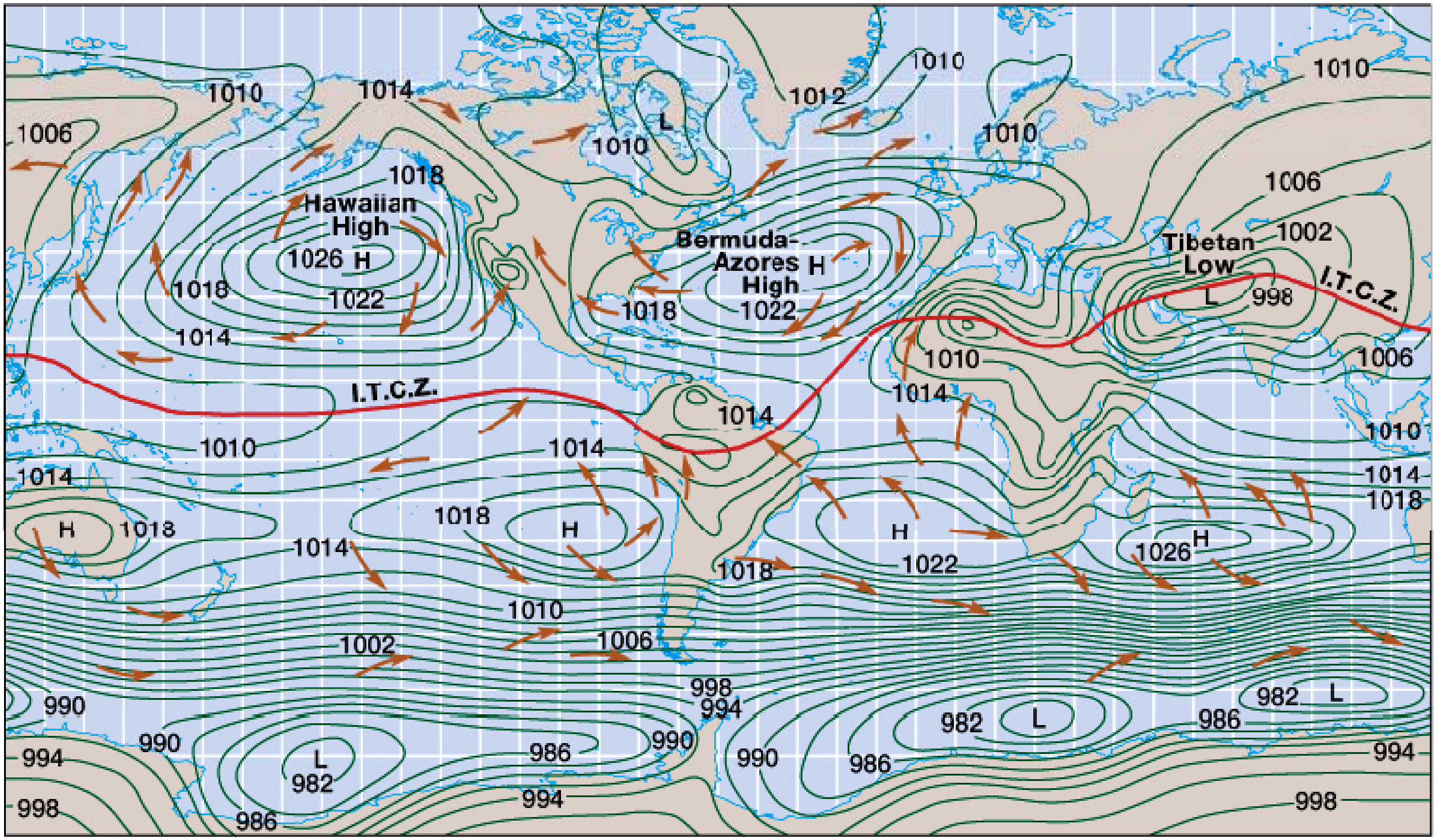


- It is useful to examine horizontal pressure differences across space.
- Pressure maps depict ***isobars***, lines of equal pressure.
- Through analysis of ***isobaric charts***, pressure gradients are apparent.
- Steep (weak) pressure gradients are indicated by closely (widely) spaced isobars.

Northern Winter (January)



Northern Summer (July)

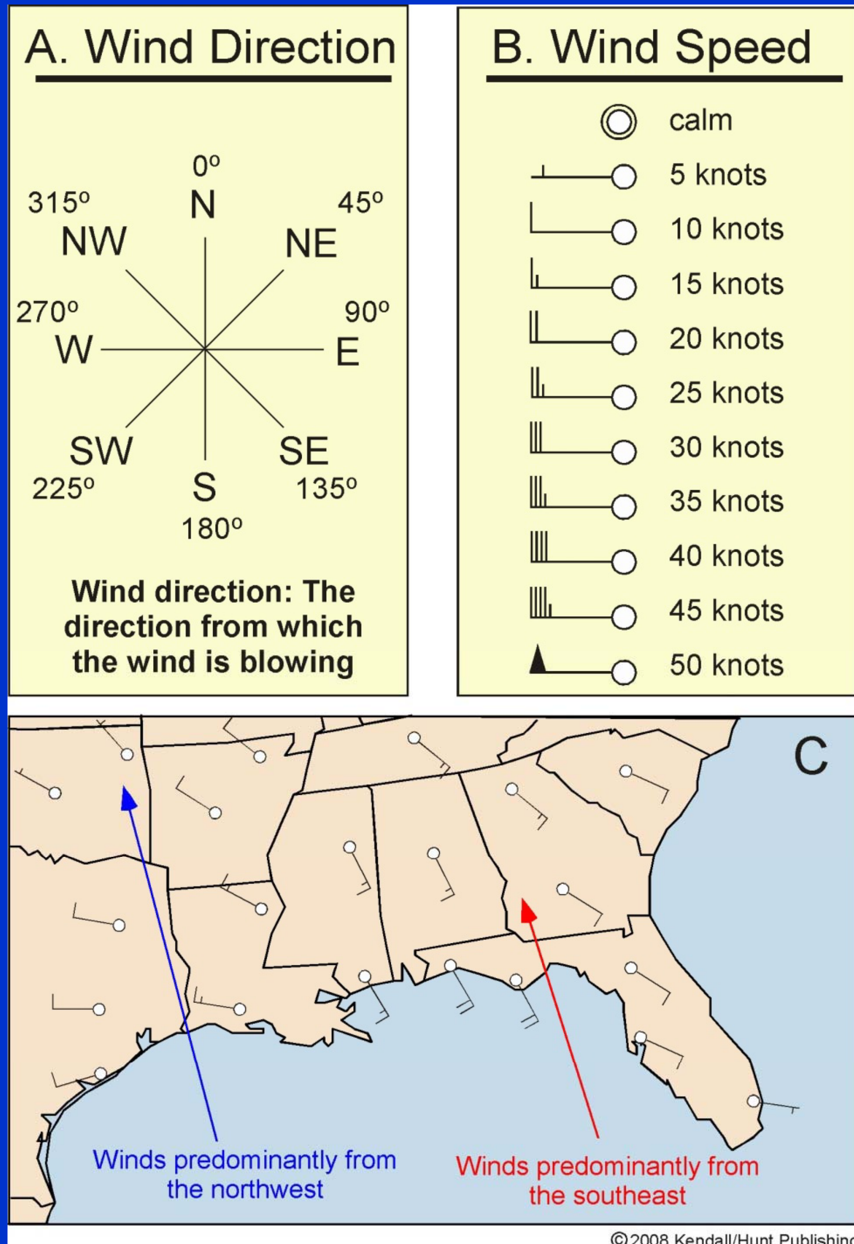


Measuring Winds

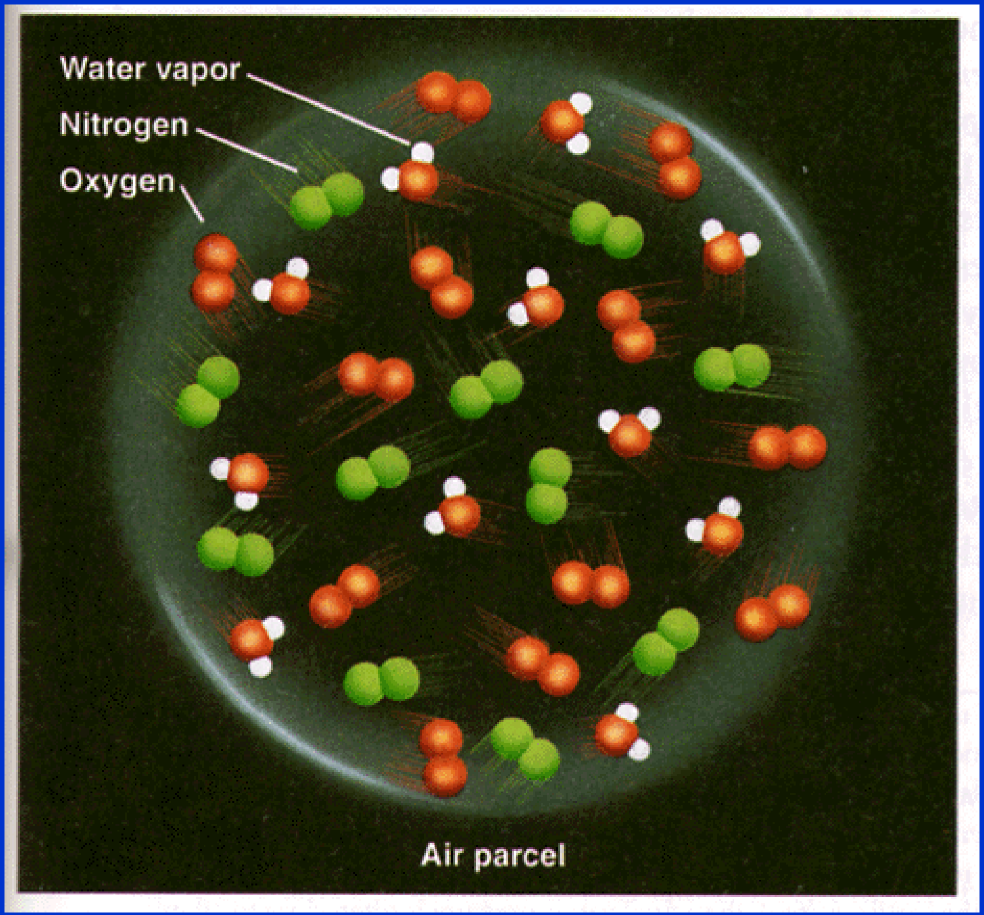
- Wind direction always indicates the direction from which wind blows.
- An ***anemometer*** indicates both wind speed and direction.
- Official measurements of wind at surface are made at an elevation of 10 meters, which is referred to as the ***anemometer height***.
- Meteorologists typically measure wind speed in knots.

➔ 1 knot = 1.15mph =0.51 m/sec

Wind Direction and Speed



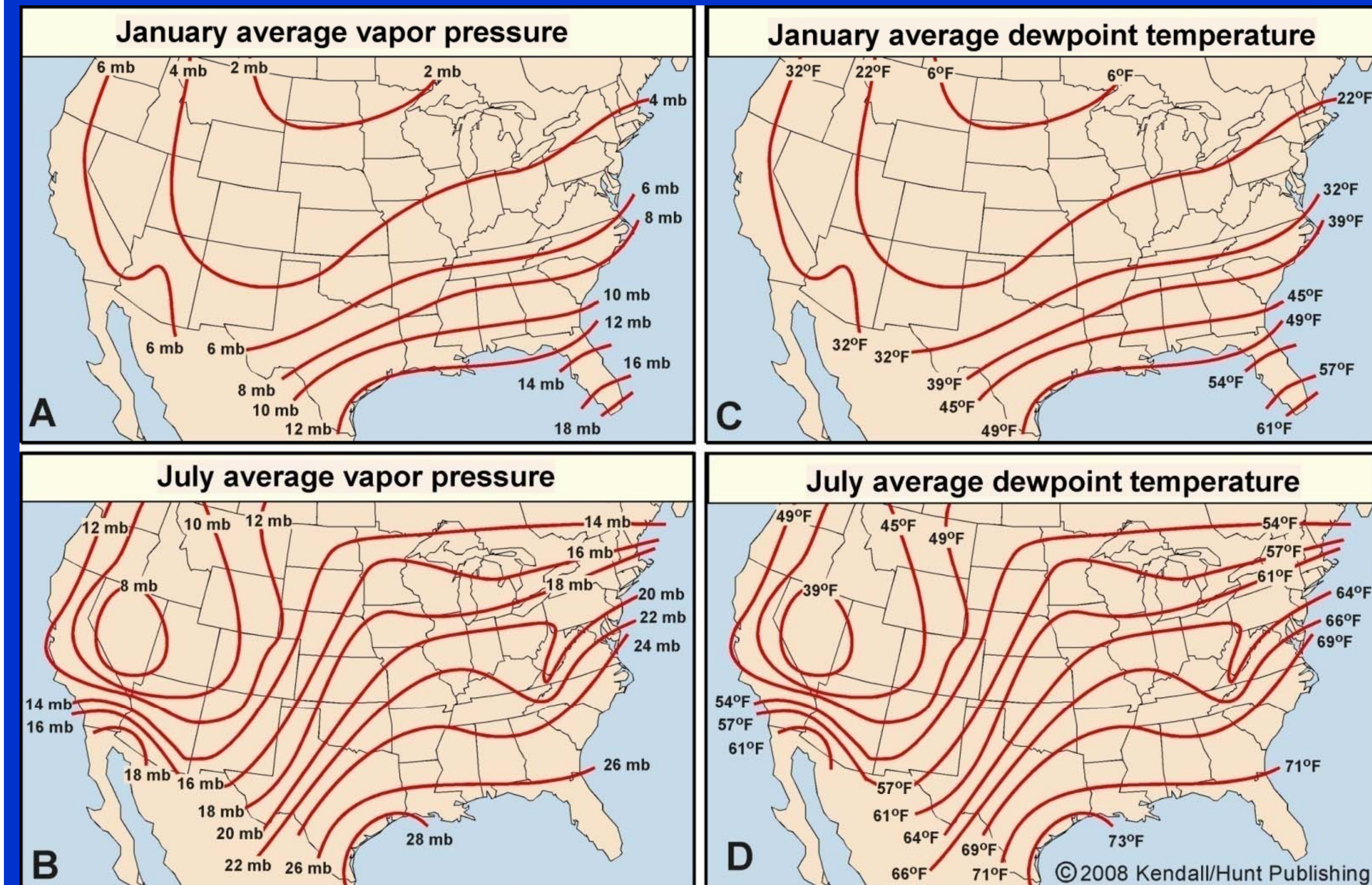
Vapor Pressure



(from *Meteorology Today*)

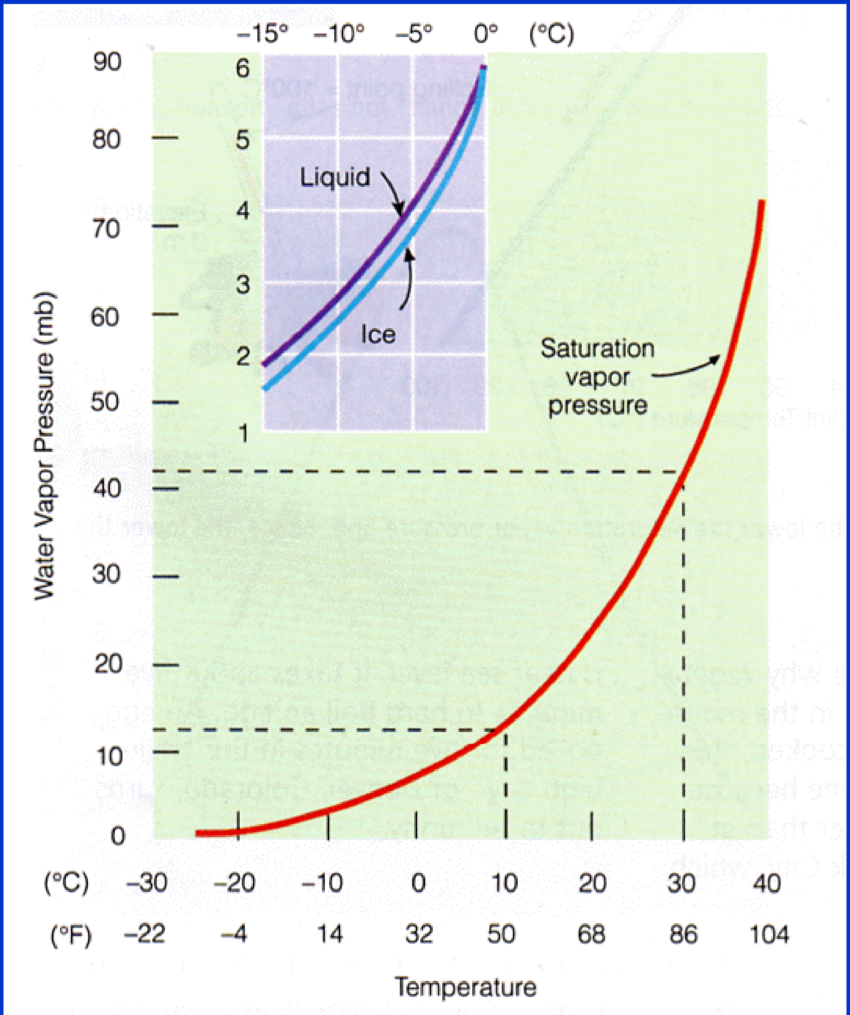
- The air's content of moisture can be measured by the pressure exerted by the water vapor in the air.
- The total pressure inside an air parcel is equal to the sum of pressures of the individual gases.
- In the left figure, the total pressure of the air parcel is equal to sum of vapor pressure plus the pressures exerted by Nitrogen and Oxygen.
- High vapor pressure indicates large numbers of water vapor molecules.
- Unit of vapor pressure is usually in mb.

Observed Vapor Pressure



- In winter, the atmosphere in north-central areas of the United States contains only about a quarter of moisture that the deserts do in summer.
- How can this be?

Saturation Vapor Pressure



- Saturation vapor pressure describes how much water vapor is needed to make the air saturated at any given temperature.
- Saturation vapor pressure depends primarily on the air temperature in the following way:

$$\boxed{\frac{de_s}{dT} = \frac{L}{T(\alpha_v - \alpha_l)}}$$

The Clausius-Clapeyron Equation

➔ $$\boxed{e_s \cong 6.11 \cdot \exp\left\{\frac{L}{R_v}\left(\frac{1}{273} - \frac{1}{T}\right)\right\}}$$

- Saturation pressure increases exponentially with air temperature.

L: latent heat of evaporation; α: specific volume of vapor and liquid

Relative Humidity

$$RH = \frac{\text{actual vapor pressure}}{\text{saturation vapor pressure}} \times 100 \text{ percent.}$$

• Humans are sensitive to how close air is to saturation, the quantity "***Relative Humidity***" was invent to describe this atmospheric property.

specific humidity
6 gm/kg

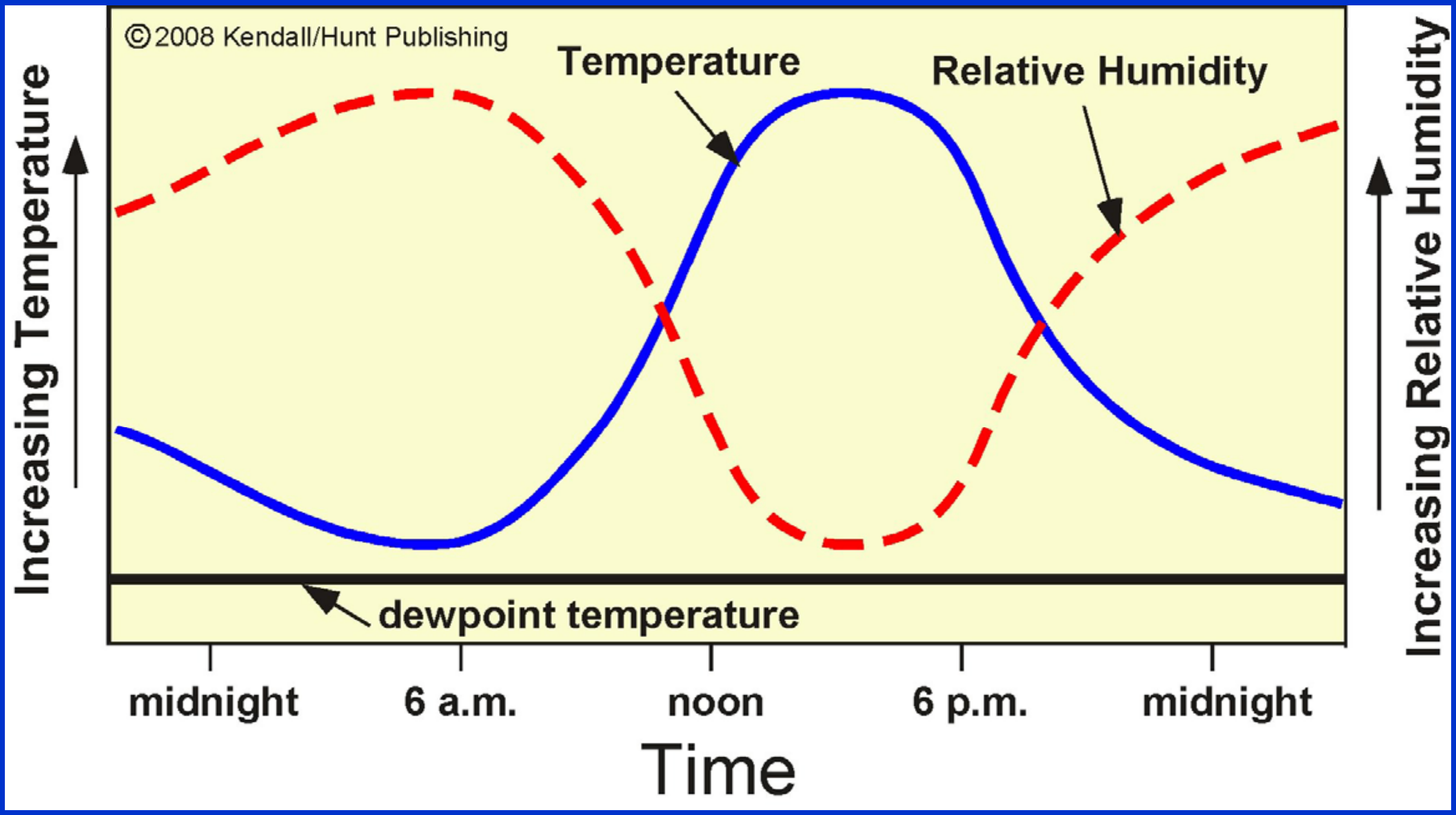
saturated
specific humidity
10 gm/kg

Relative humidity
6/10 x 100%=60 %

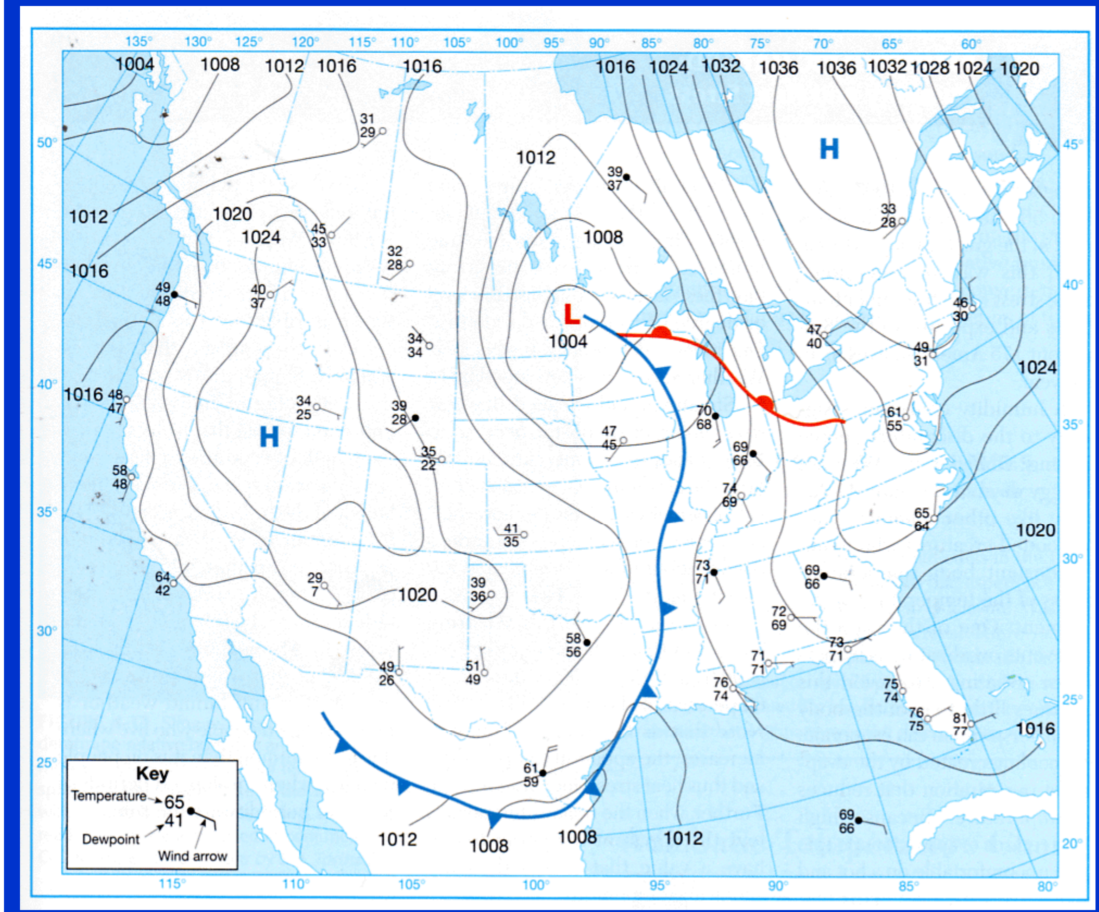
saturated
specific humidity
20 gm/kg

Relative humidity
6/20 x 100%=30 %

Daily Variations of Temperature, Relative Humidity, and Dewpoint Temp.



Dew Point Temperature



(from *The Atmosphere*)

- Dew point temperature is another measurement of air moisture.
- Dew point temperature is defined as the temperature to which moist air must be cool to become saturated without changing the pressure.
- The close the dew point temperature is to the air temperature, the closer the air is to saturation.
- Dew points can be only equal or less than air temperatures.

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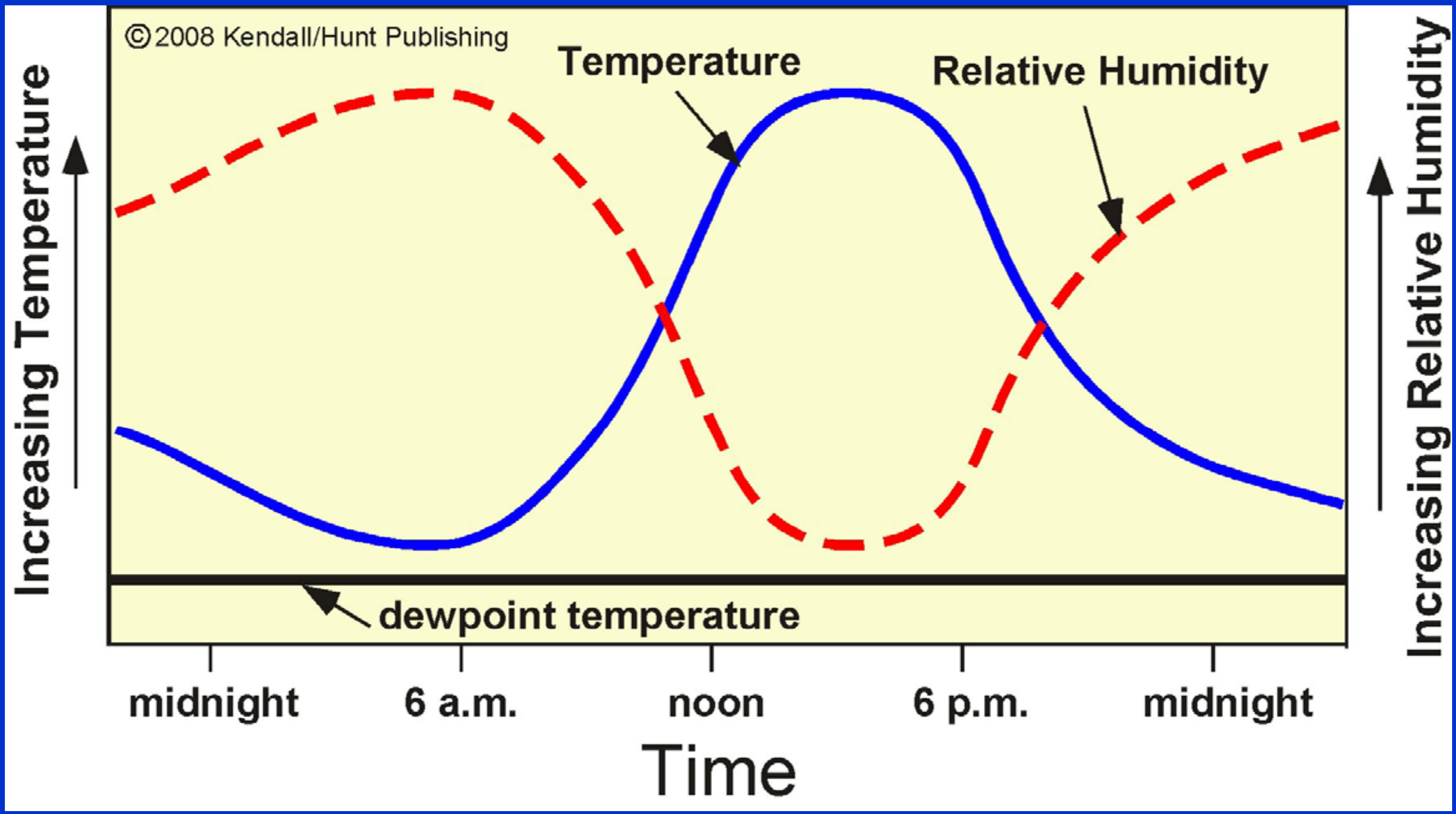
Daily Variations of Temperature, Relative Humidity, and Dewpoint Temp.



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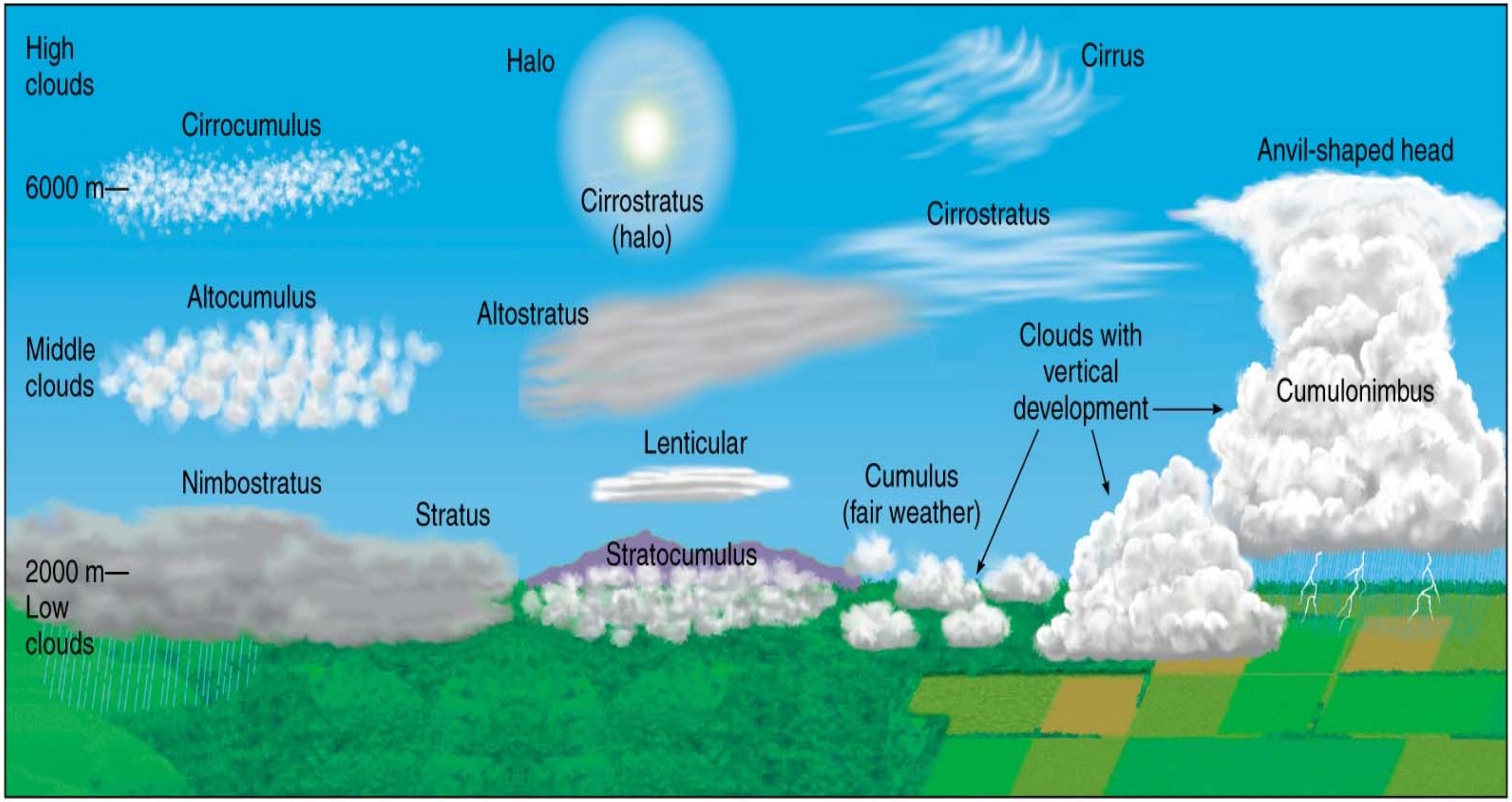
Cloud Type Based On Properties

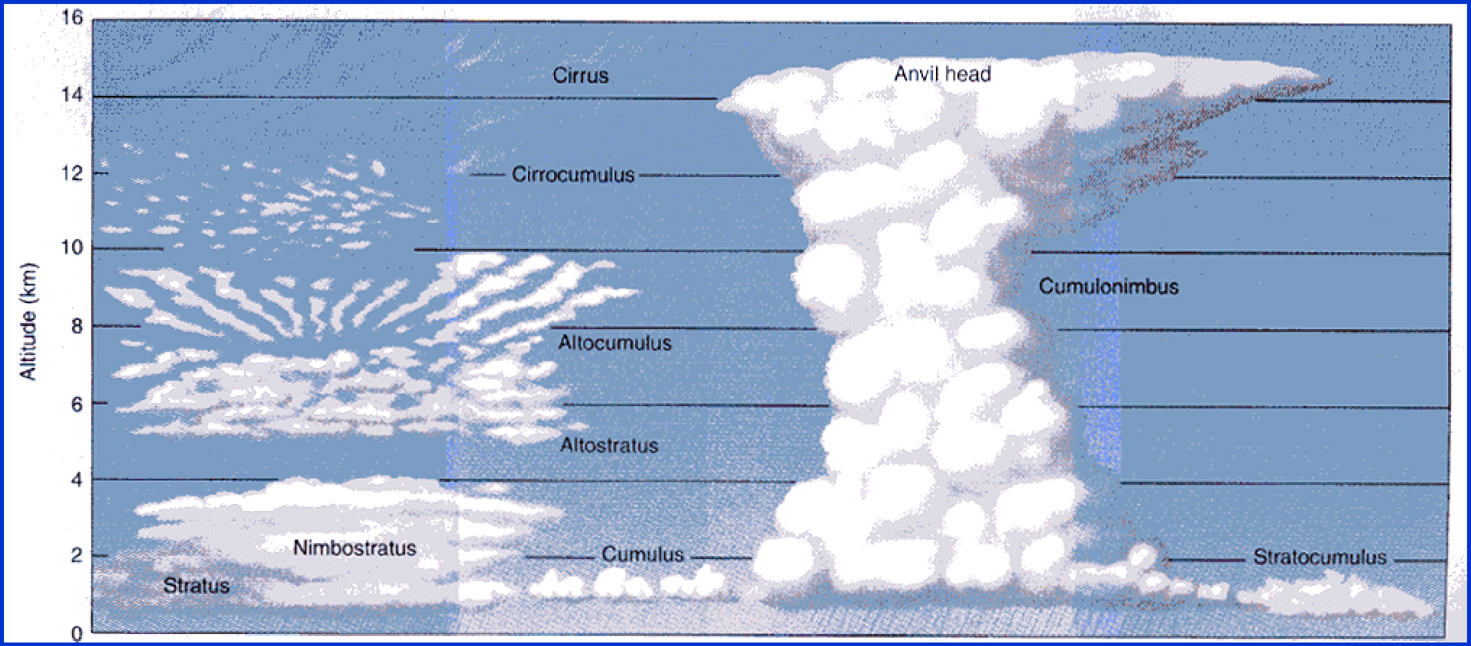
- Four basic cloud categories:
  - ✓ Cirrus --- thin, wispy cloud of ice.
  - ✓ Stratus --- layered cloud
  - ✓ Cumulus --- clouds having vertical development.
  - ✓ Nimbus --- rain-producing cloud

- These basic cloud types can be combined to generate ***ten different cloud types***, such as cirrostratus clouds that have the characteristics of cirrus clouds and stratus clouds.

Cloud Types


High
clouds
Halo
Cirrus
Cirrocumulus
6000 m—
Cirrostratus
(halo)
Cirrostratus
Anvil-shaped head
Altocumulus
Altostratus
Middle
clouds
Clouds with
vertical
development
Cumulonimbus
Lenticular
Nimbostratus
Cumulus
(fair weather)
Stratus
Stratocumulus
2000 m—
Low
clouds

Cloud Types Based On Height



If based on cloud base height, the ten principal cloud types can then grouped into four cloud types:

- ✓ High clouds -- cirrus, cirrostratus, cirroscumulus.
- ✓ Middle clouds – altostratus and altocumulus
- ✓ Low clouds – stratus, stratocumulus, and nimbostratus
- ✓ Clouds with extensive vertical development – cumulus and cumulonimbus.

(from "*The Blue Planet*")

Cloud Classifications

Table 12.1 Classification of Clouds in the Troposphere by Altitude

Height	Name	Shape and Appearance
High-level clouds		
Cloud base 6 to 15 km above sea level	Cirrus	Feathery streaks
	Cirrocumulus	Small ripples and delicate puffs
	Cirrostratus	Translucent to transparent sheet, like a veil across the sky
Middle-level clouds		
Cloud base 2 to 6 km above sea level	Altocumulus	White to dark gray puffs and elongate ripples
	Altostratus	Uniform white to gray sheet covering the sky
Low-level clouds		
Cloud base below 2 km above sea level	Stratus	Uniform dull gray cover over the sky
	Nimbostratus	Uniform gray cover, rain generally falling
	Stratocumulus	Patches of soft gray; in places patches coalescing to a layer
Clouds with great vertical development		
Cloud base below 3 km above sea level	Cumulus	Puffy cauliflower shape with flat base
	Cumulonimbus	Large, puffy; white, gray and black; great vertical extent, often with anvil-shaped head

(from "*The Blue Planet*")

High Clouds

1. Cirrus Clouds

3. Cirrocumulus Clouds

(from Australian Weather Service)

2. Cirrostratus Clouds

- High clouds have low cloud temperature and low water content and consist most of ice crystal.

Middle Clouds

4. Altostratus Clouds

5. Altocumulus Clouds

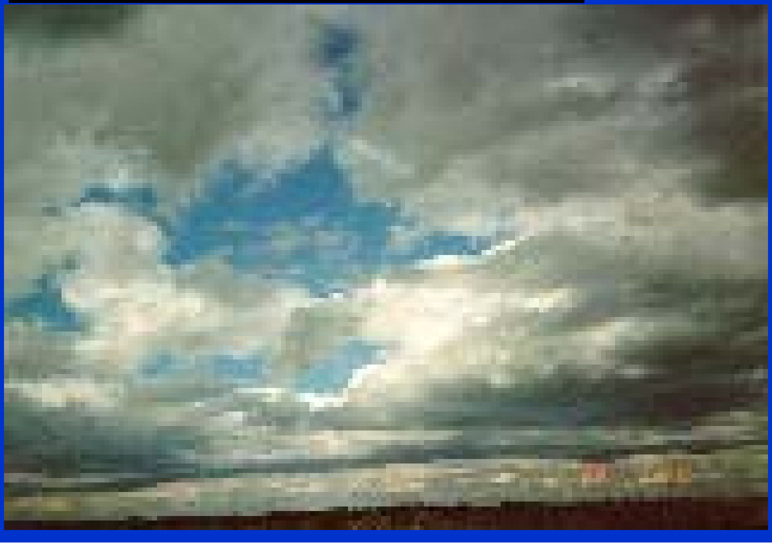
(from Australian Weather Service)

- Middle clouds are usually composite of liquid droplets.
- They block more sunlight to the surface than the high clouds.

Low Clouds

6. Stratus Clouds

7. Stratocumulus Clouds



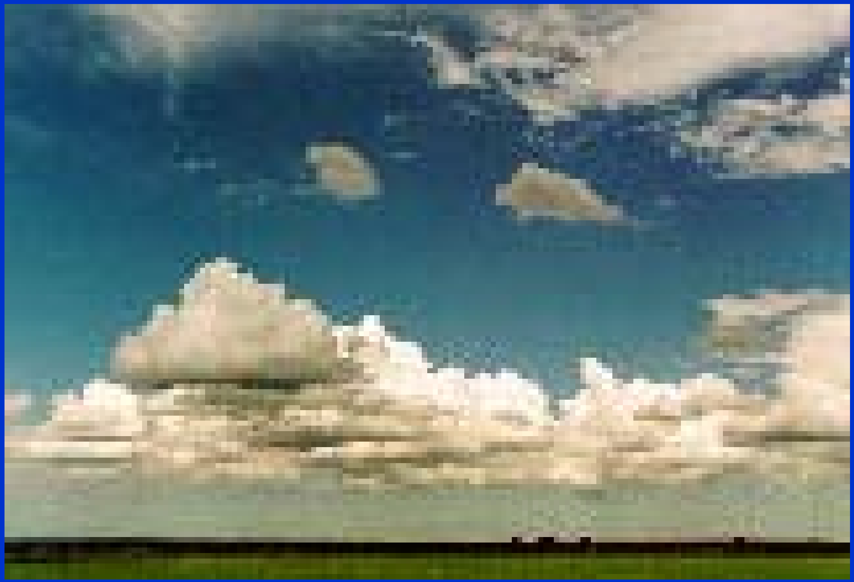
8. Nimbostratus Clouds

(from Australian Weather Service)

- Low, thick, layered clouds with large horizontal extends, which can exceed that of several states.

Clouds With Vertical Development

9. Cumulus Clouds



10. Cumulonimbus Clouds

(from Australian Weather Service)

- They are clouds with substantial vertical development and occur when the air is absolute or conditionally unstable.