Atmospheric Physics

Lecture 6

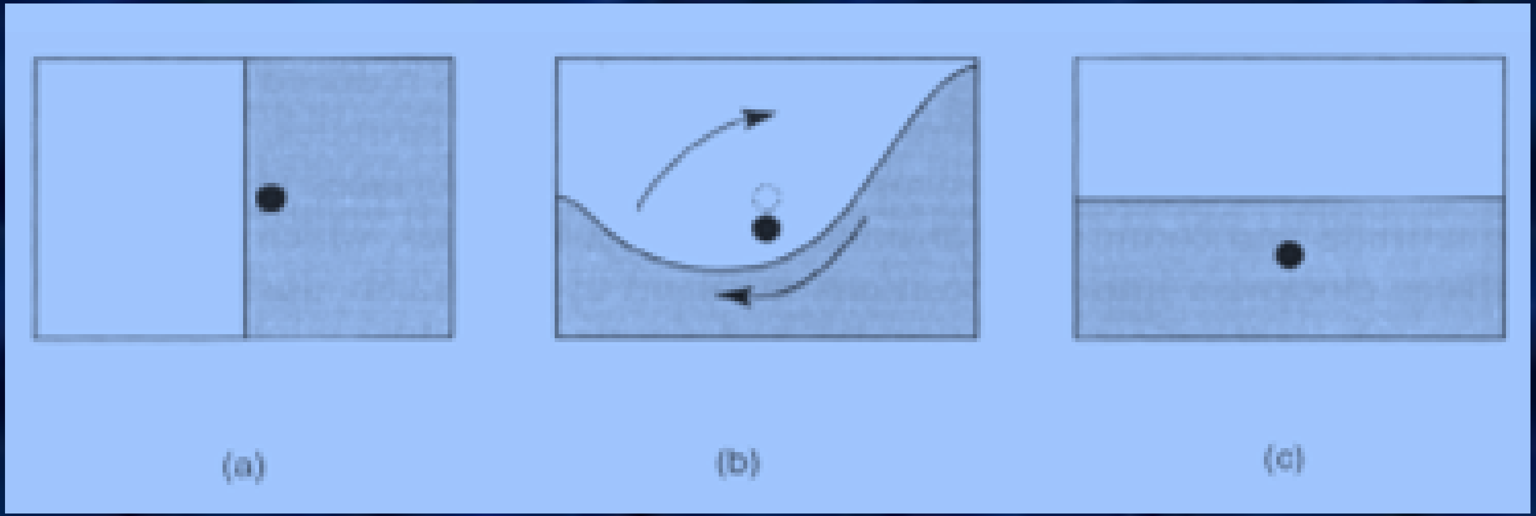
J. Sahraei

Physics Department,

Razi University

https://sci.razi.ac.ir/~sahraei

The available potential energy



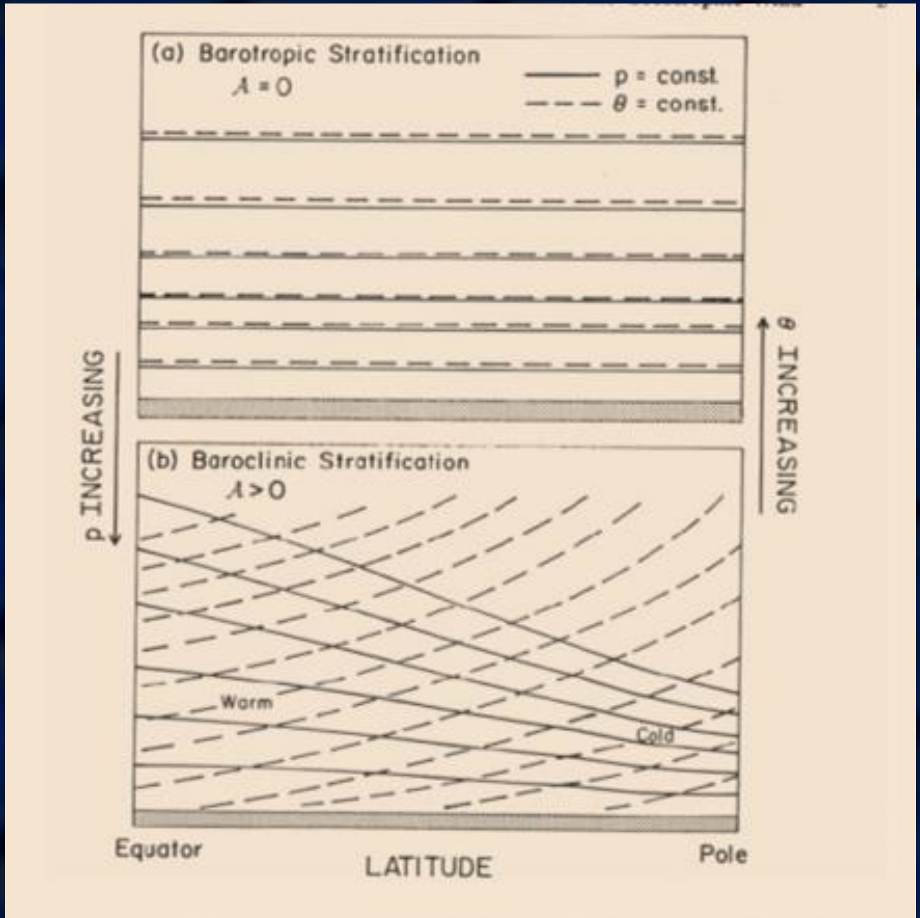


Figure 2: **Barotropic and Baroclinic stratifications.**

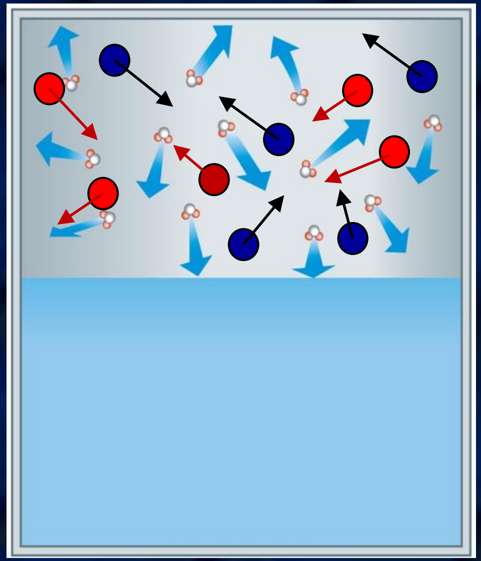
Moisture in the atmosphere

Indices of Water Vapor Content

Humidity: The amount of water vapor in air

Expressed in many ways:

Vapor pressure: Pressure exerted on the atmosphere by water vapor

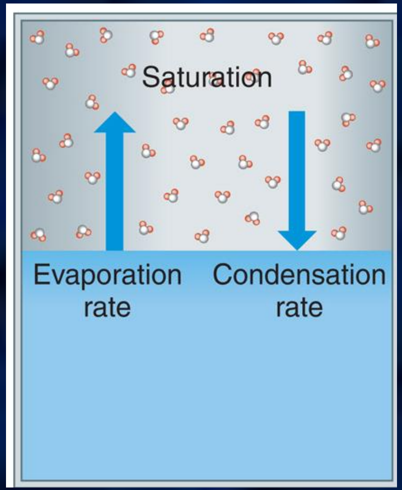


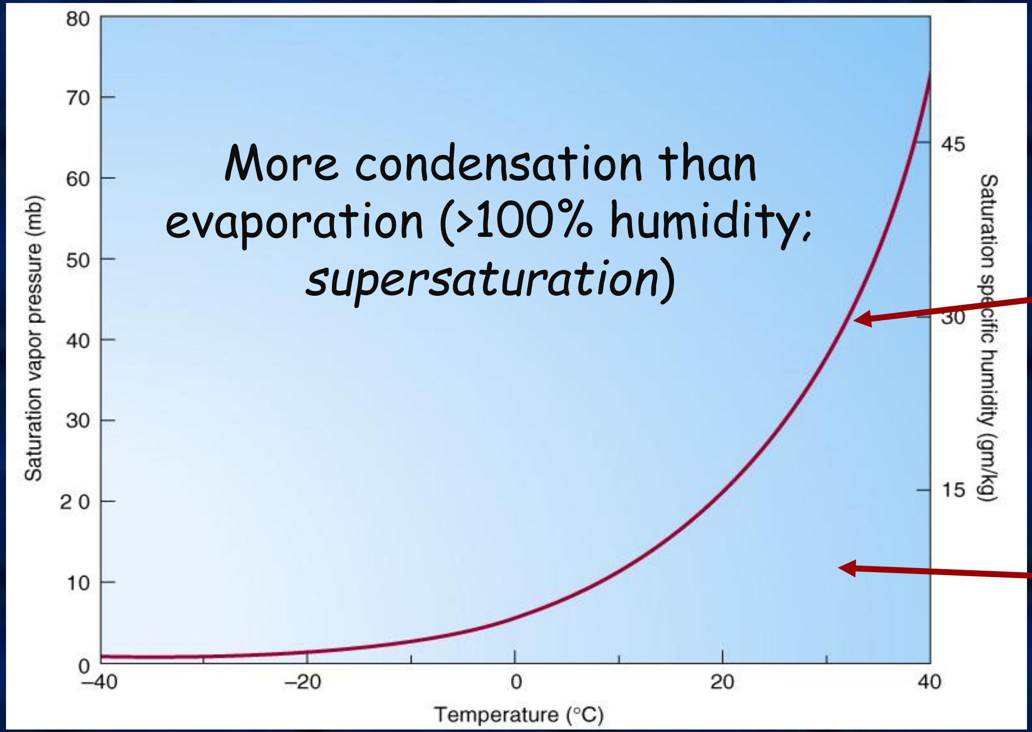
The movement of water vapor molecules exerts vapor pressure

Dependent on temperature and density

Saturation Vapor Pressure = maximum water vapor pressure possible (100% humidity)

Evaporation equals condensation Saturation vapor pressure

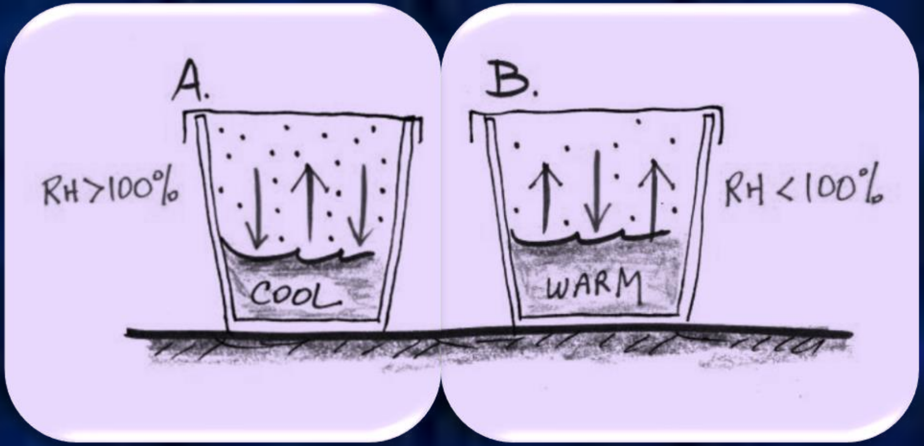




More condensation than evaporation (>100% humidity; *supersaturation*)

Saturation vapor pressure

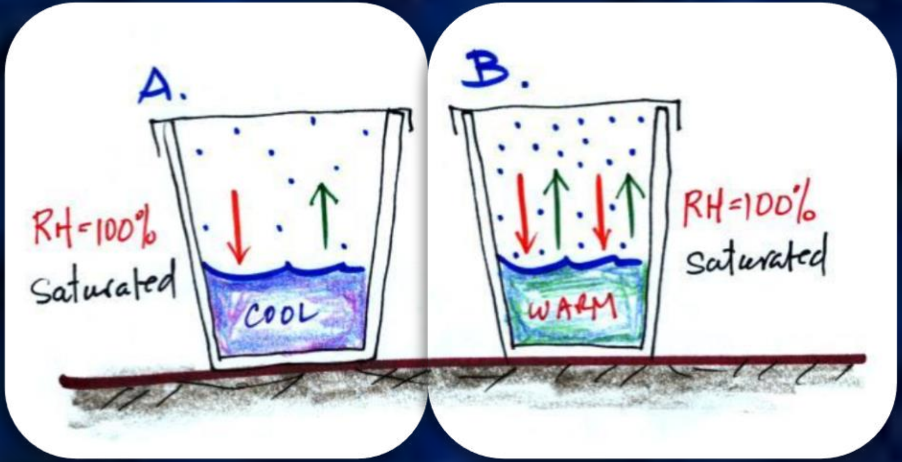
More evaporation than condensation (<100% humidity; *undersaturation*)



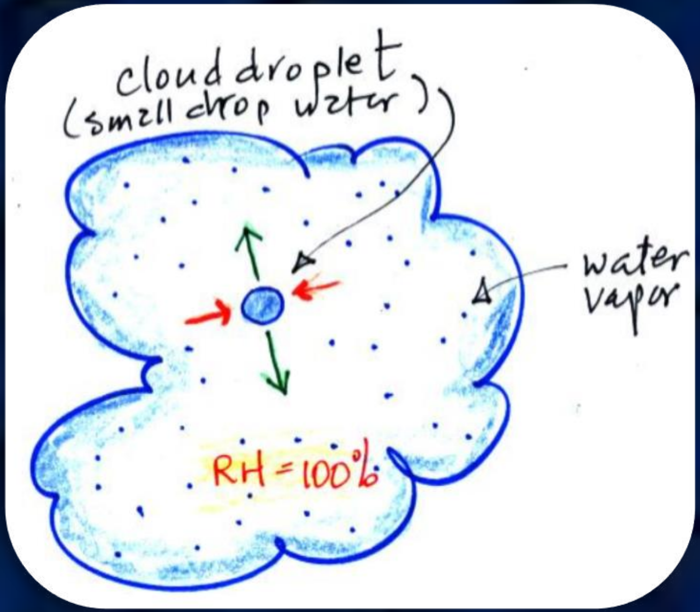
The relative humidity in Glass A is more than 100% (the air is supersaturated).

Because the rate of condensation in Glass A is greater than the rate of evaporation, the rate of condensation in Glass A will decrease.

It will continue to decrease until it is equal to the rate of evaporation.



The air inside the cloud is saturated



The rate of evaporation from the cloud droplet (2 green arrows) is balanced by an equal rate of condensation (2 orange arrows).

The RH = 100%

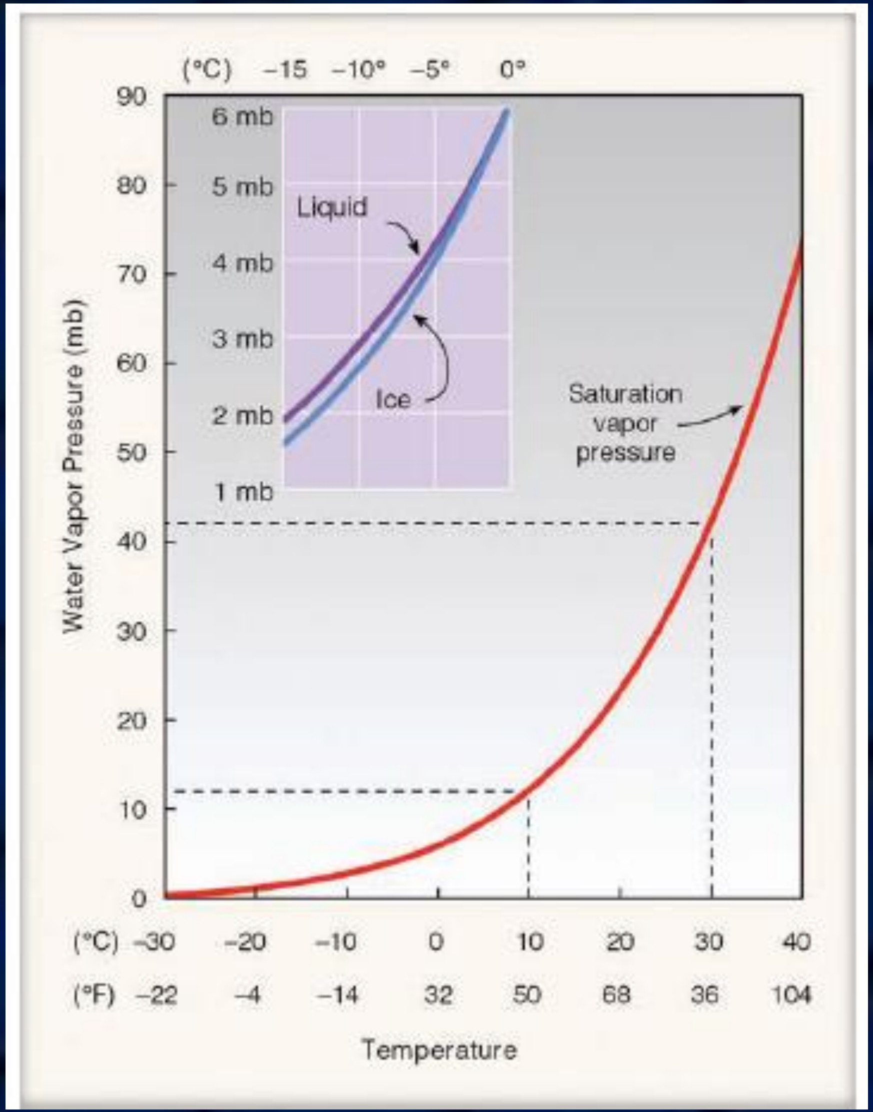
The cloud droplet won't grow any bigger or get any smaller

SATURATION VAPOUR PRESSURE

Saturation vapor pressure depends primarily on the air temperature.

Exponential relationship

When water and ice both exist below freezing at the same temperature, the saturation vapor pressure just above water is greater than the saturation vapor pressure over ice.



Mixing Ratio

Mixing ratio (r) – The ratio of the mass of water vapor to the mass of dry air in a sample.

$$r = \frac{m_v}{m_d}$$

Usually expressed in g/kg, but most correct when unitless (i.e.kg/kg). Typical range = 0-25 g/kg.

$$r = \frac{m_v / v}{m_d / v} = \frac{\rho_v}{\rho_d} \qquad e = \rho_v R_v T \qquad P - e = \rho_d R_d T \qquad r = \frac{\frac{e}{R_v T}}{\frac{P-e}{R_d T}} = \frac{R_d}{R_v}\frac{e}{P-e}$$

$$\frac{R_d}{R_v} = \frac{R^* / M_d}{R^* / M_v} = \frac{M_v}{M_d} = \varepsilon \cong 0.622 \qquad r = \varepsilon \frac{e}{p-e} \approx \varepsilon \frac{e}{p}$$

Saturation Mixing Ratio

$$r_s = \varepsilon \frac{e_s}{p - e_s}$$

Measures of Water Vapor Content in the Air

Absolute Humidity

mass of water vapor/volume of air

gr/m^3

Relative Humidity

Relative Humidity (RH) -Ratio of mixing ratio to its saturation value

Expressed in percent

$$RH = \frac{Actual \quad Amount}{Amount \quad if \quad Saturated} \times 100\ \%$$

$$Amount \quad if \quad Saturated = Max.\ Capacity$$

$$RH = \frac{r}{r_s} \times 100\% \approx \frac{e}{e_s} \times 100\%$$

RH = 100% means air is saturated

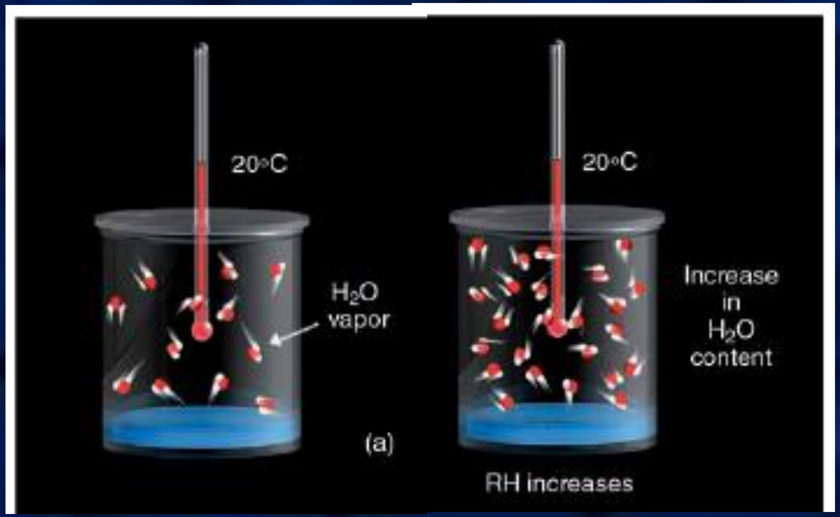
RH > 100% is supersaturated air

Changing Relative Humidity

How do we alter a location's relative humidity?

Change the water vapor content

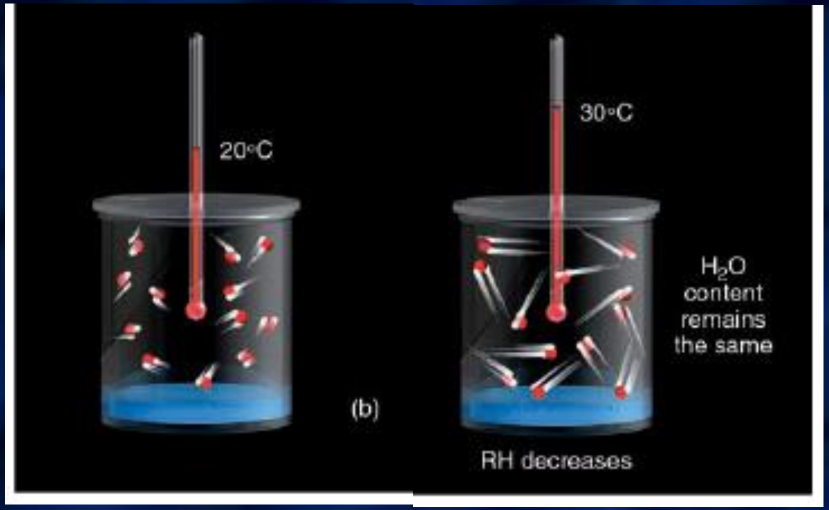
Increase w.v. content ⇒ raise actual vapor pressure ⇒ relative humidity increases

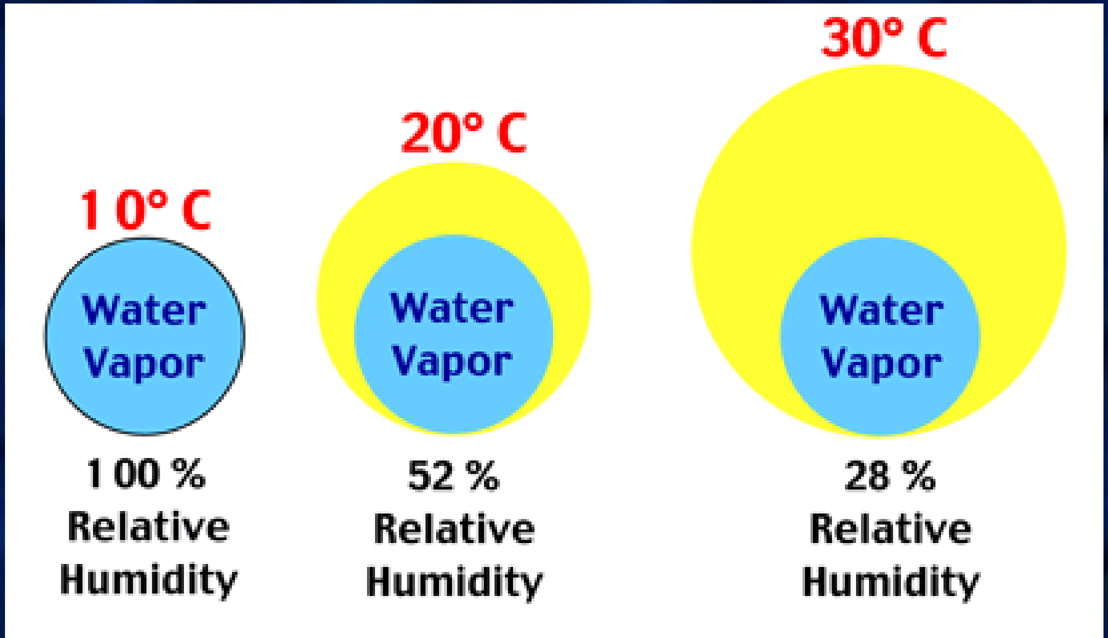


Change the air temperature

Increase temperature ⇒ increase saturation vapor pressure
⇒ relative humidity decreases

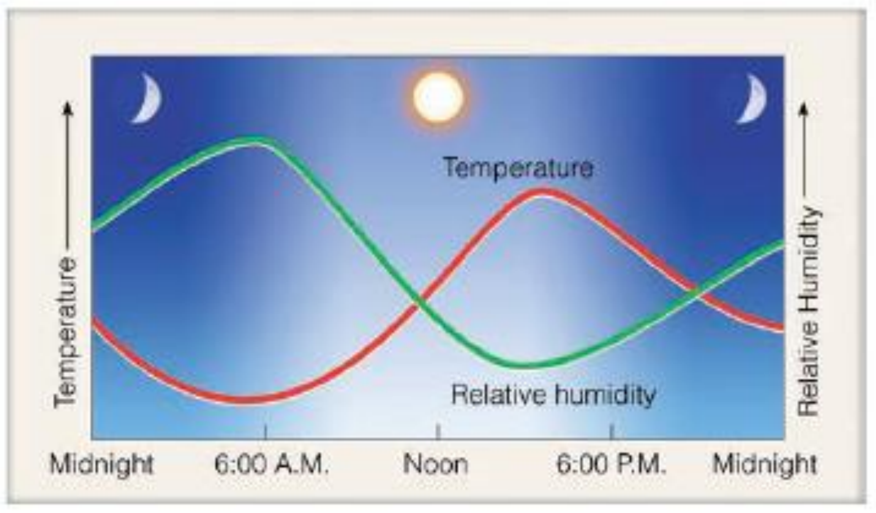
Warm = faster molecules = less likely to condense = lower RH



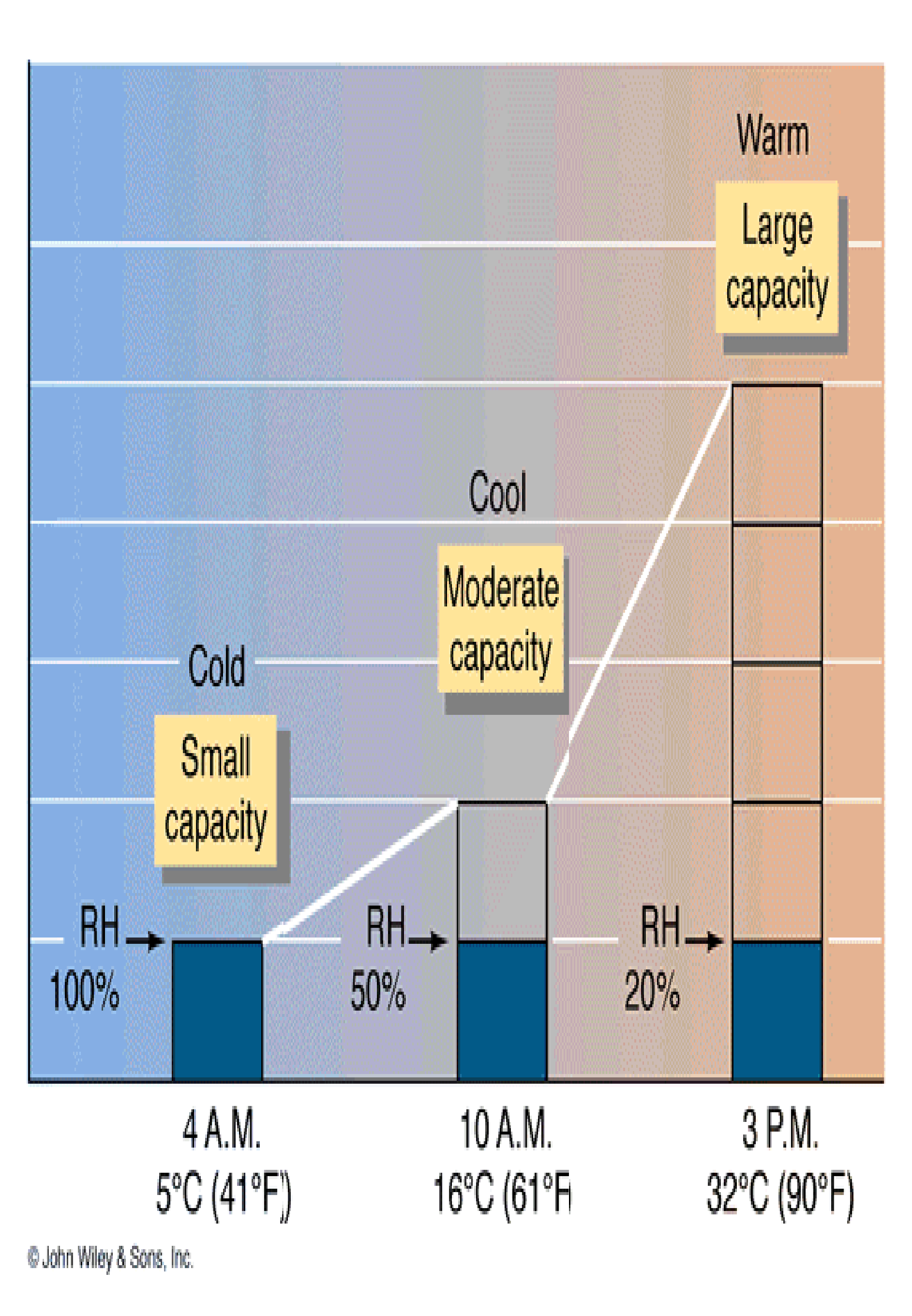


1 0° C
Water
Vapor
1 00 %
Relative
Humidity
20° C
Water
Vapor
52 %
Relative
Humidity
30° C
Water
Vapor
28 %
Relative
Humidity

Since water vapor content generally does not vary much during an entire day, changing air temperature primarily regulates the daily variation in relative humidity



During day, relative humidity and temp. have inverse relationship



4 am :

T = 5°C

actual = 7g/kg

capacity = 7 g/kg

RH = 7 / 7 x 100 = 100%

10 am :

T = 16°C

actual= 7 g/kg

capacity = 14 g/kg

7 / 14 x 100 = 50%

3 pm :

T = 32°C

actual = 7 g/kg

capacity = 35 g/kg

7 / 35 x 100 = 20%

Specific Humidity

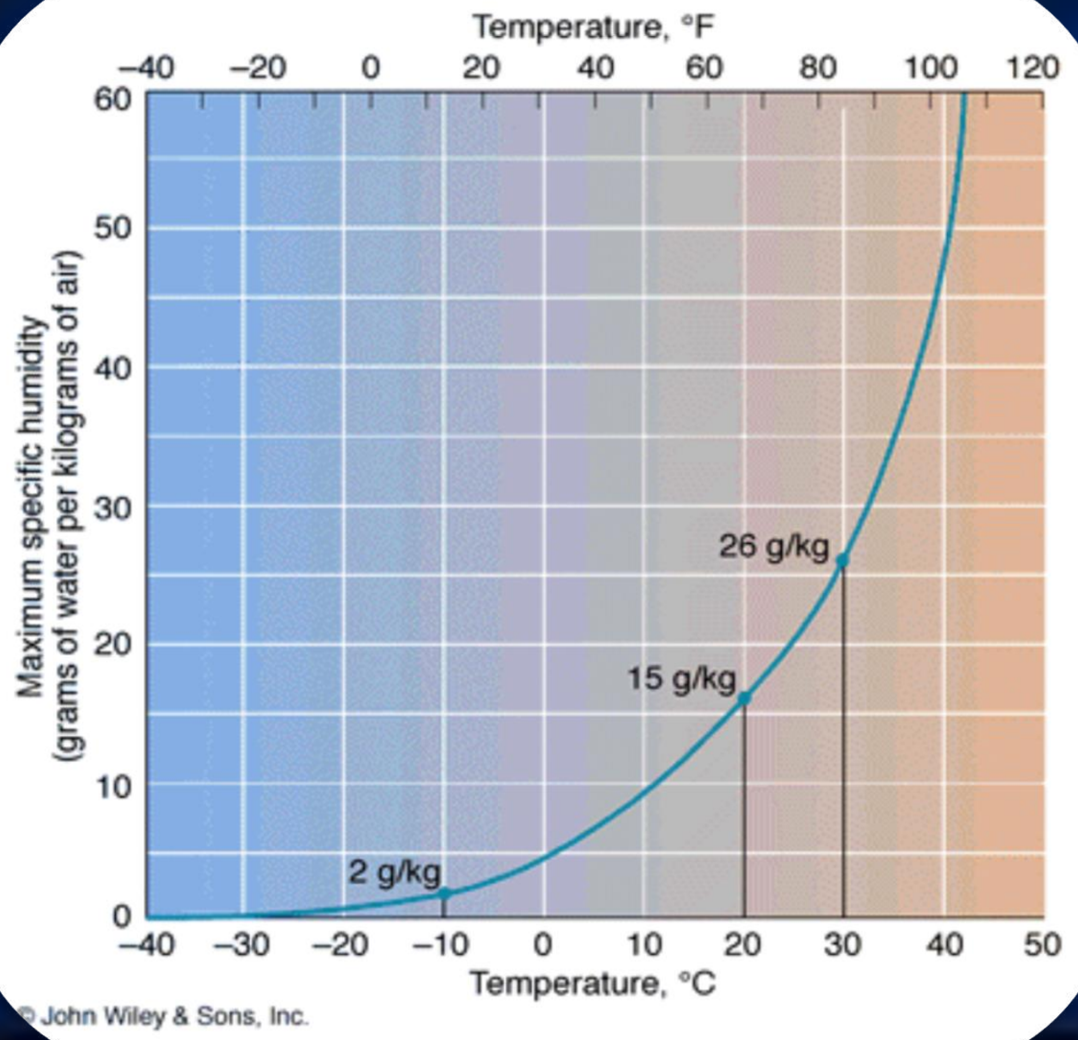
Specific humidity (q) – mass of water vapor per unit mass of moist air. similar to r, but slightly smaller values. (g/kg)

$$q = \frac{m_v}{m_v + m_d}$$

$$q = \frac{\rho_v}{\rho_v + \rho_d} = \varepsilon \frac{e}{p - (1-\varepsilon)e} \approx \varepsilon \frac{e}{p}$$

Warm air can "hold more water" than cold air

Line is maximum (capacity) specific humidity



Calculating RH from specific humidity:

If temperature = 25 °C and actual sp. hum. is 5 g/kg, what is RH?

Solution:

1. Use graph to find capacity amount.

2. RH = (5/20) x 100 = 25%

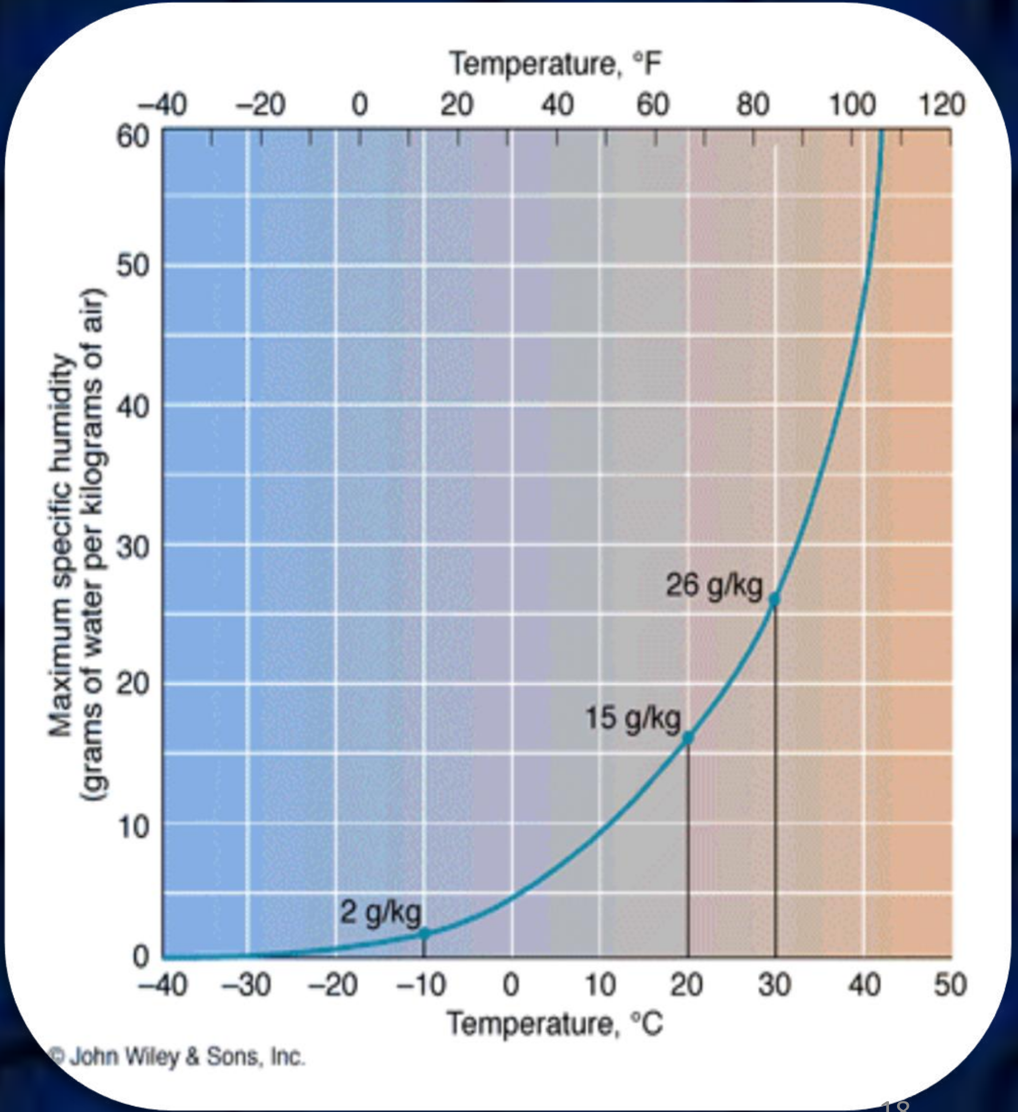
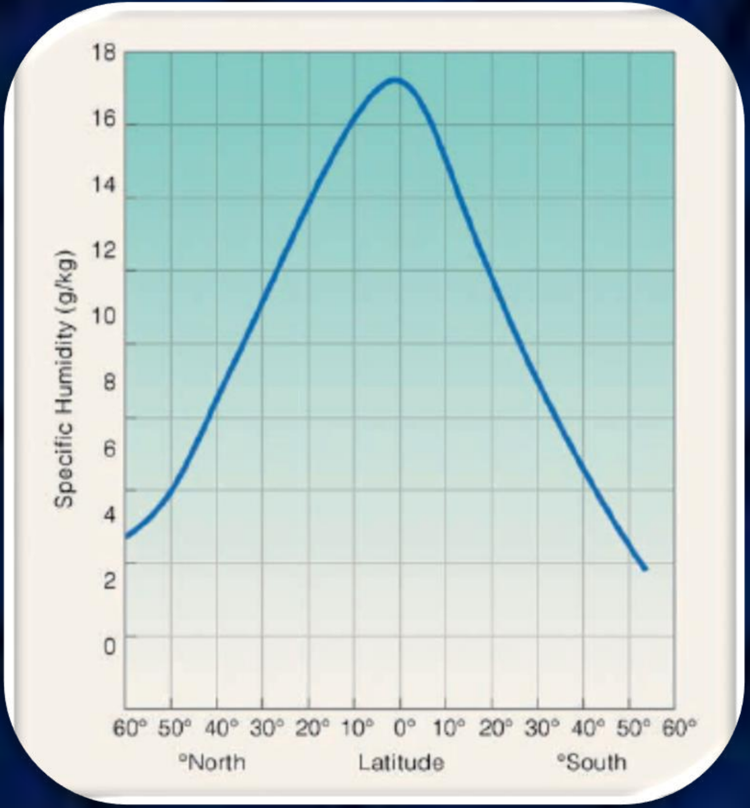


Figure shows how specific humidity varies with latitude

The average specific humidity is highest in the warm, muggy tropics.

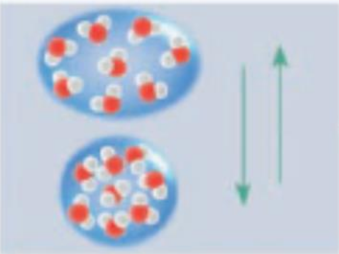
As we move away from the tropics, it decreases, reaching its lowest average value in the polar latitudes.



The specific humidity and mixing ratio of an air parcel remain constant as long as water vapor is not added to or removed from the parcel.

This happens because the total number of molecules (and, hence, the mass of the parcel) remains constant, even as the parcel expands or contracts.

Since changes in parcel size do not affect specific humidity and mixing ratio, these two concepts are used extensively in the study of the atmosphere.



	Mass of Parcel	Mass of H_2O Vapor	Specific Humidity
	1 kg	1 g	1 g/kg
	1 kg	1 g	1 g/kg

● FIGURE 4.8 The specific humidity does not change as air rises and descends.

Dew Point = Temperature above freezing at which saturation occurs (i.e., dew forms)

Frost Point = Temperature where saturation occurs below the freezing point (i.e., frost forms)

deposition

condensation

When the air temperature drops to the dewpoint, the relative humidity is 100%