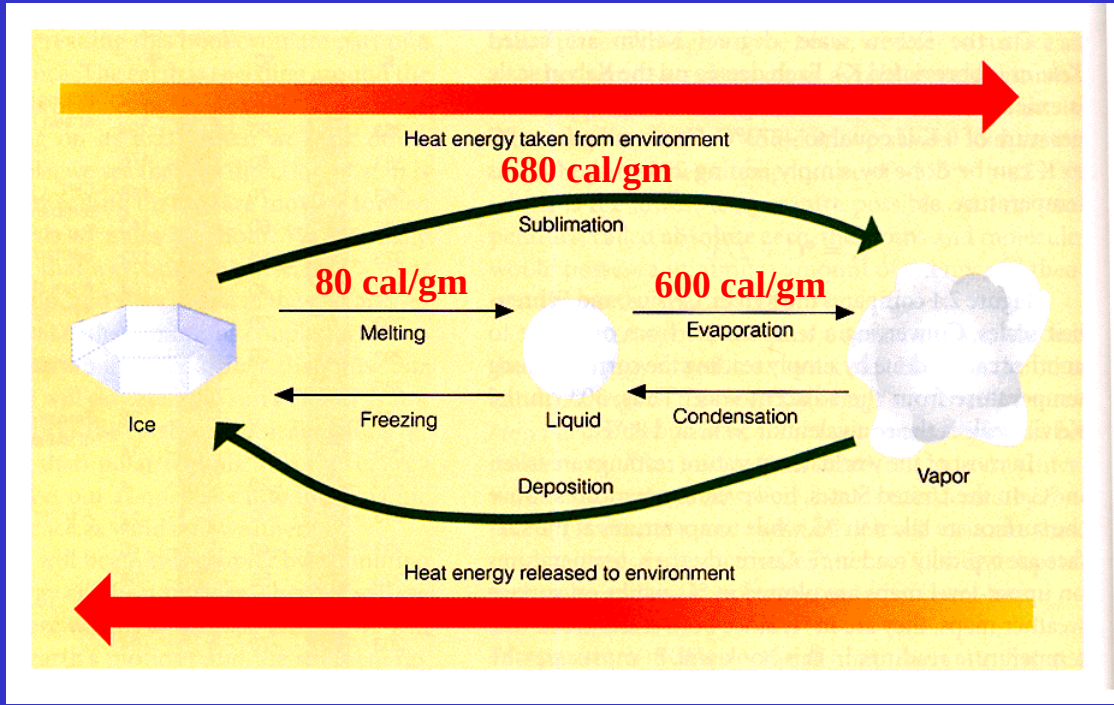
Chapter 5: Atmospheric Moisture

- Water Vapor and Liquid Water
- Indices of Water Vapor Content
- Distribution of Water Vapor
- Measuring Humidity

Introduction

- Over 70% of the planet is covered by water
- Water is unique in that it can simultaneously exist in all three states (solid, liquid, gas) at the same temperature
- Water is able to shift between states very easily
- The hydrologic cycle refers to the regular cycle of water through the earth-atmosphere system
- Liquification of water occurs frequently at normal Earth temperatures
  - Occurs when air is saturated with respect to water vapor
  - The addition of water vapor, or the lowering of temperature, in saturated air will lead to condensation

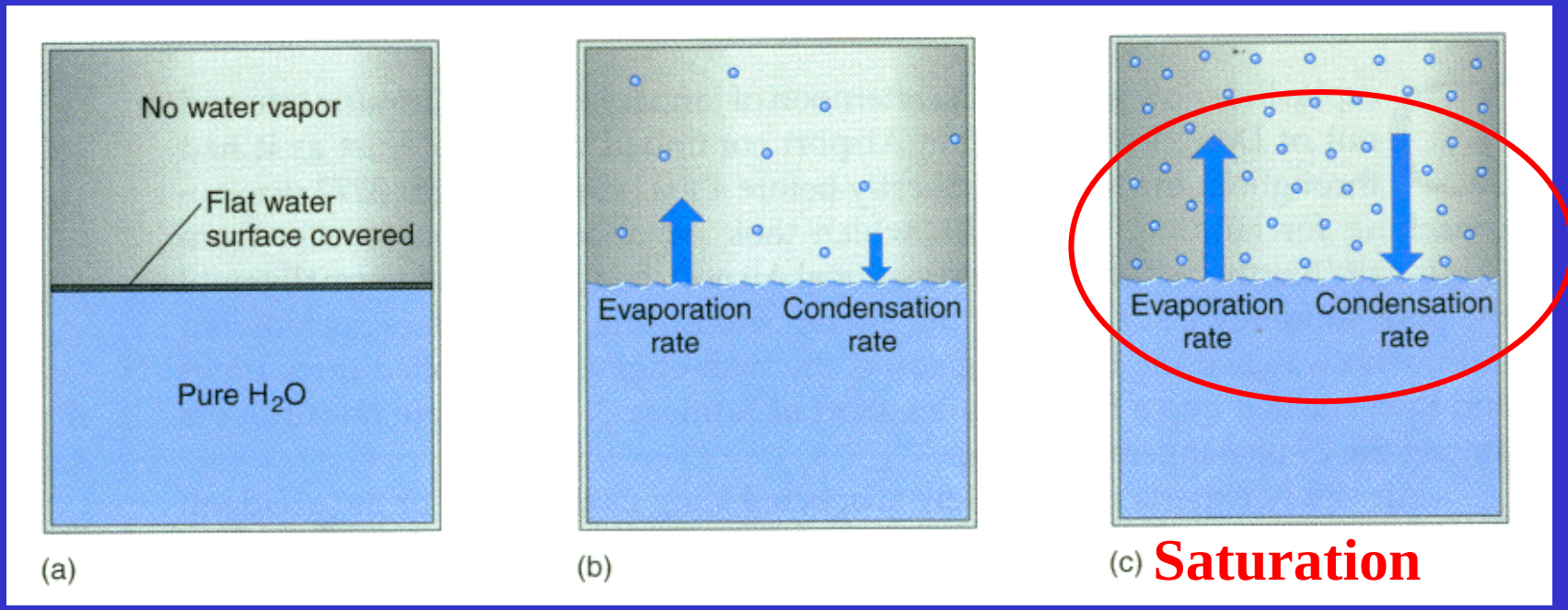
Phase Changes of Water



(from *Meteorology: Understanding the Atmosphere*)

- Latent heat is the heat released or absorbed per unit mass when water changes phase.
- Latent heating is an efficient way of transferring energy globally and is an important energy source for Earth's weather and climate.

Water Vapor In the Air



(from *Understanding Weather & Climate*)

- **Evaporation:** the process whereby molecules break free of the liquid volume.
- **Condensation:** water vapor molecules randomly collide with the water surface and bond with adjacent molecules.

Indices of Water Vapor Content

- by mass

$$\text{Mixing ratio} = \frac{\text{mass of water vapor}}{\text{mass of dry air}}.$$

$$\text{Specific humidity} = \frac{\text{mass of water vapor}}{\text{total mass of air}}$$

in unit of g/kg

$$\text{Absolute humidity} = \frac{\text{mass of water vapor}}{\text{volume of air}}$$

in unit of g/m^3

- by vapor pressure

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

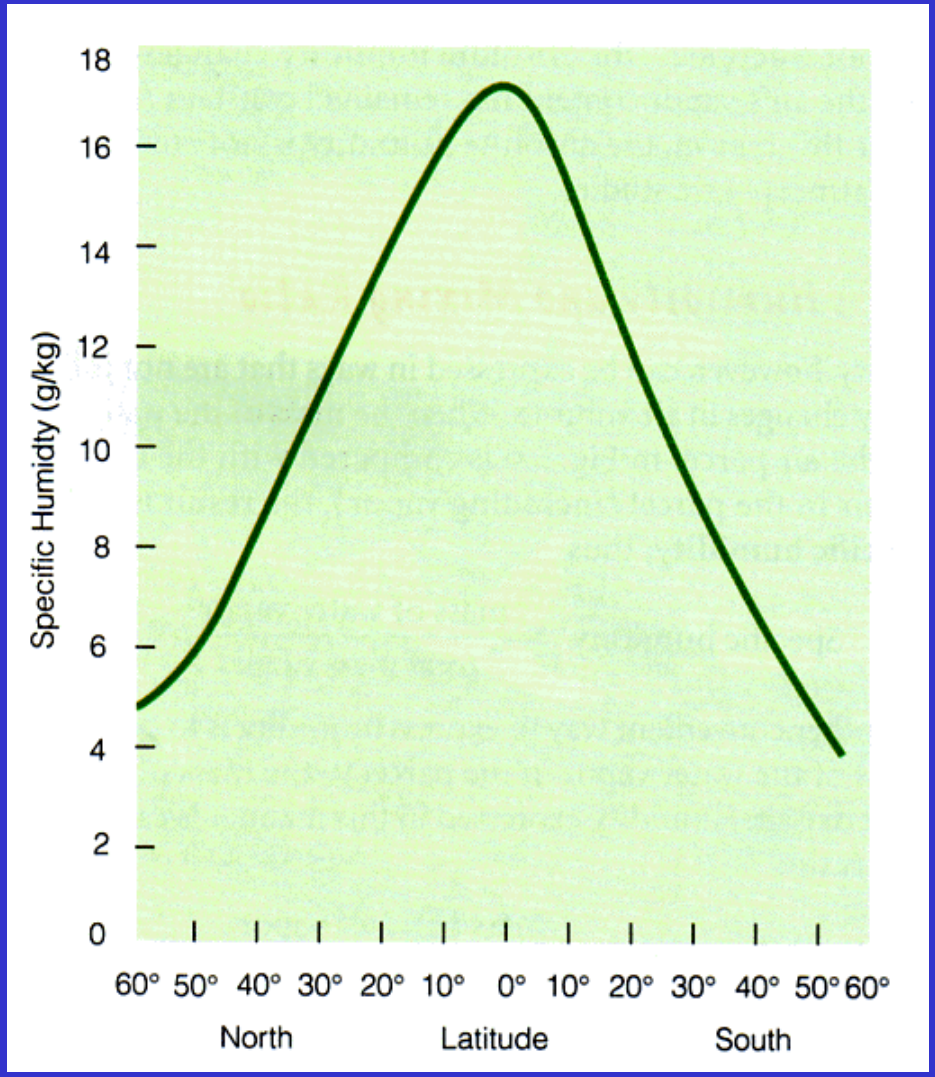
relative humidity

$$RH = \frac{\text{actual mixing ratio}}{\text{saturation mixing ratio}} \times 100 \text{ percent},$$

in unit of %

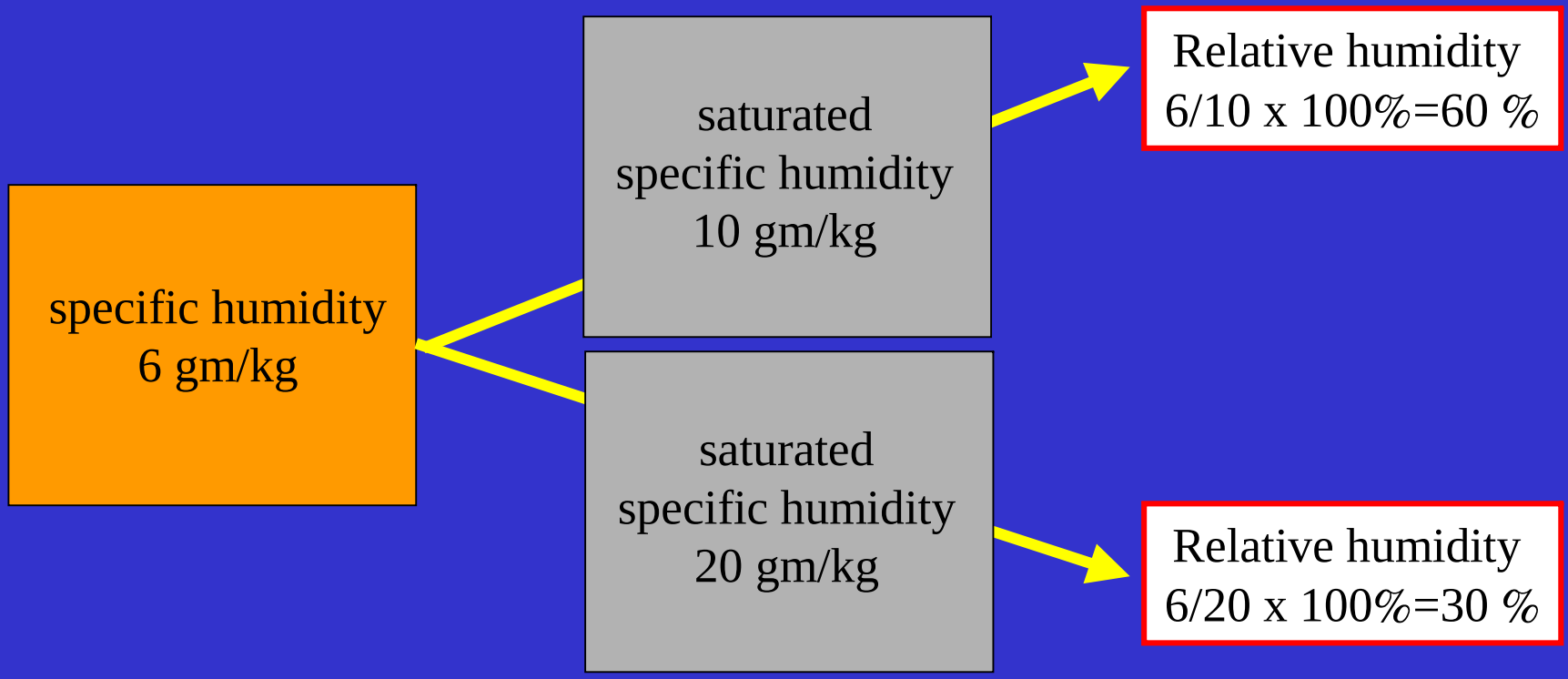
- by temperature ➔ Dew Point Temperature

Observed Specific Humidity



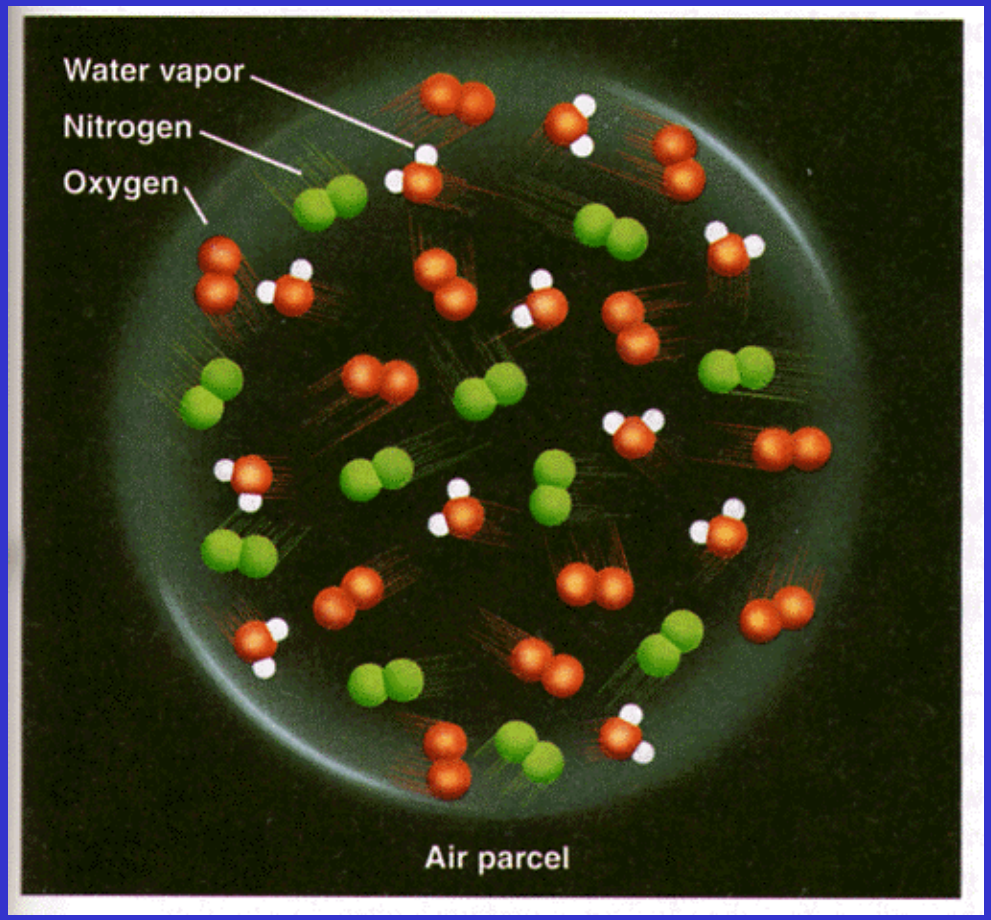
(from *Meteorology Today)*

Specific .vs. Relative Humidity



- Specific Humidity: How many grams of water vapor in one kilogram of air (in unit of gm/kg).
- Relative Humidity: The percentage of current moisture content to the saturated moisture amount (in unit of %).
- Clouds form when the relative humidity reaches 100%.

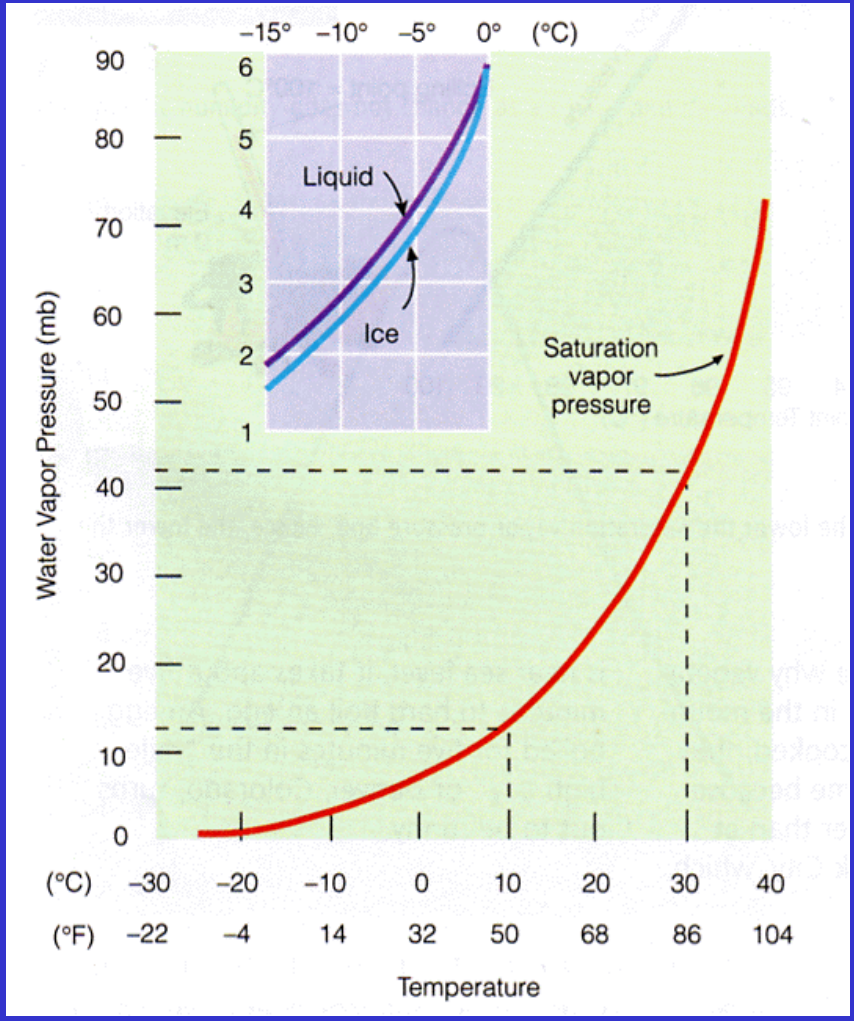
Vapor Pressure



(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.

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:

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

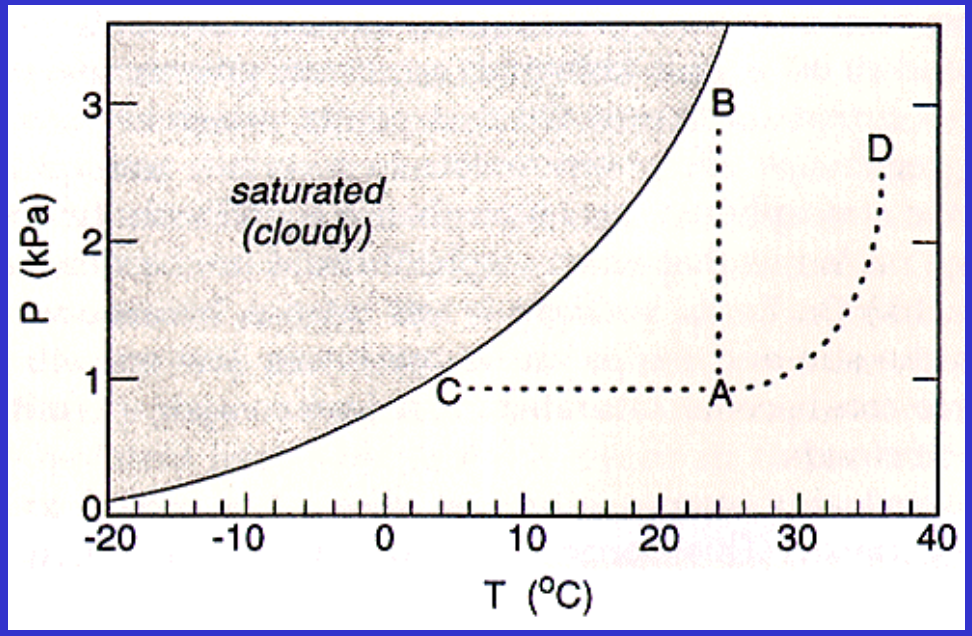
The Clausius-Clapeyron Equation

➔ $$e_s \equiv 6.11 \bullet \exp\left\{\frac{L}{R_v}\left(\frac{1}{273} - \frac{1}{T}\right)\right\}$$

- Saturation pressure increases exponentially with air temperature.

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

How to Saturate the Air?



(from "*IS The Temperature Rising*")

- Three ways:

(1) Increase (inject more) water vapor to the air (A→ B).

(2) Reduce the temperature of the air (A → C).

(3) Mix cold air with warm, moist air.

"Runway" Greenhouse Effect

- If a planet has a very high temperature that the air can never reach a saturation point

➔ Water vapor can be added into the atmosphere.

➔ More water vapor traps more heat (a greenhouse effect)

➔ The planet's temperature increases furthermore

➔ Ever more water evaporated into the atmosphere

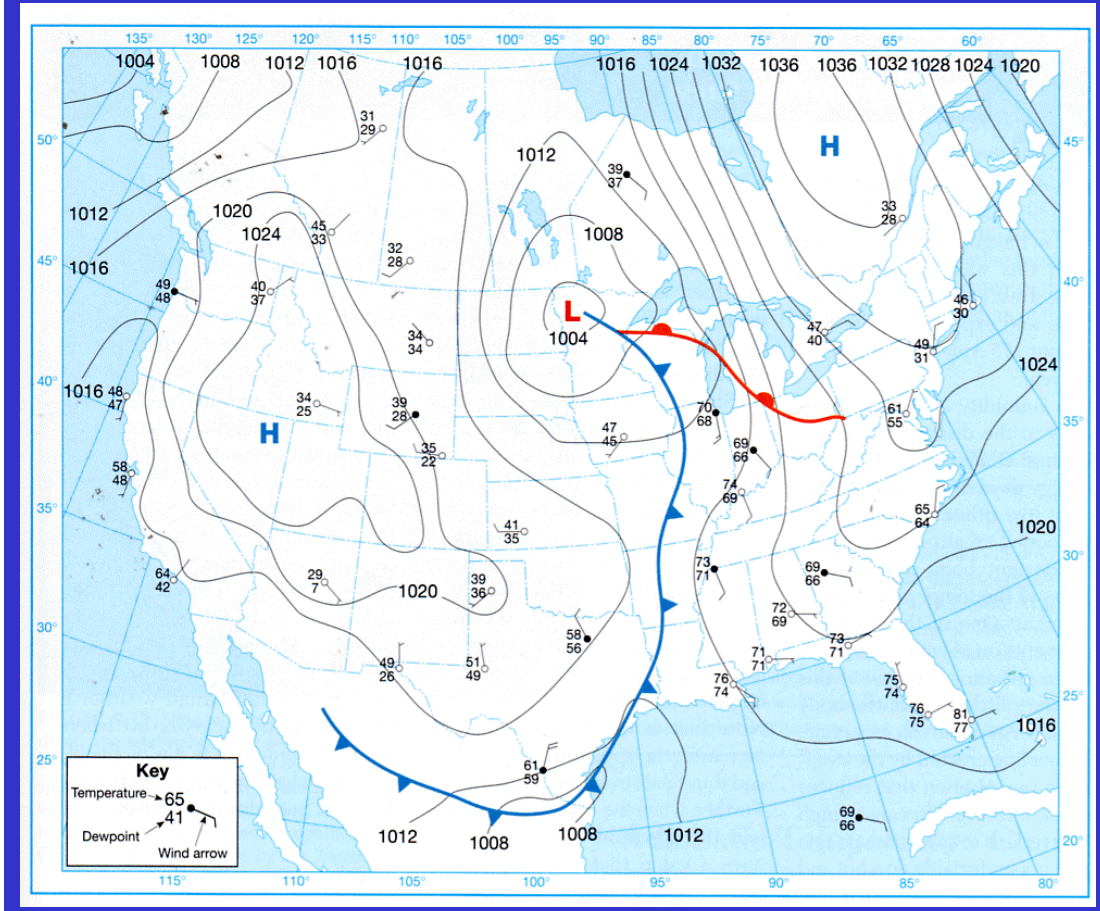
➔ More greenhouse effect

➔ More warming

➔ More water vapor

➔ .....

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.

Frost Point Temperature

- When air reaches saturation at temperatures below freezing the term ***frost point*** is used.

Measuring Humidity

- The easiest way to measure humidity is through use of a ***sling psychrometer*** **-** A pair of thermometers one of which has a wetted cotton wick attached to the bulb.
- The two thermometers measure the wet and dry bulb temperature.
- Swinging the psychrometer causes air to circulate about the bulbs.
- When air is unsaturated, evaporation occurs from the wet bulb which cools the bulb.
- Once evaporation occurs, the wet bulb temperature stabilizes allowing for comparison with the dry bulb temperature.
- The wet bulb depression is found with a greater depression indicative of a dry atmosphere.
- Charts gauge the amount of atmospheric humidity.
- ***Aspirated*** and ***hair hygrometers*** are alternatives.

Dew

(a)

- Liquid condensation on surface objects.

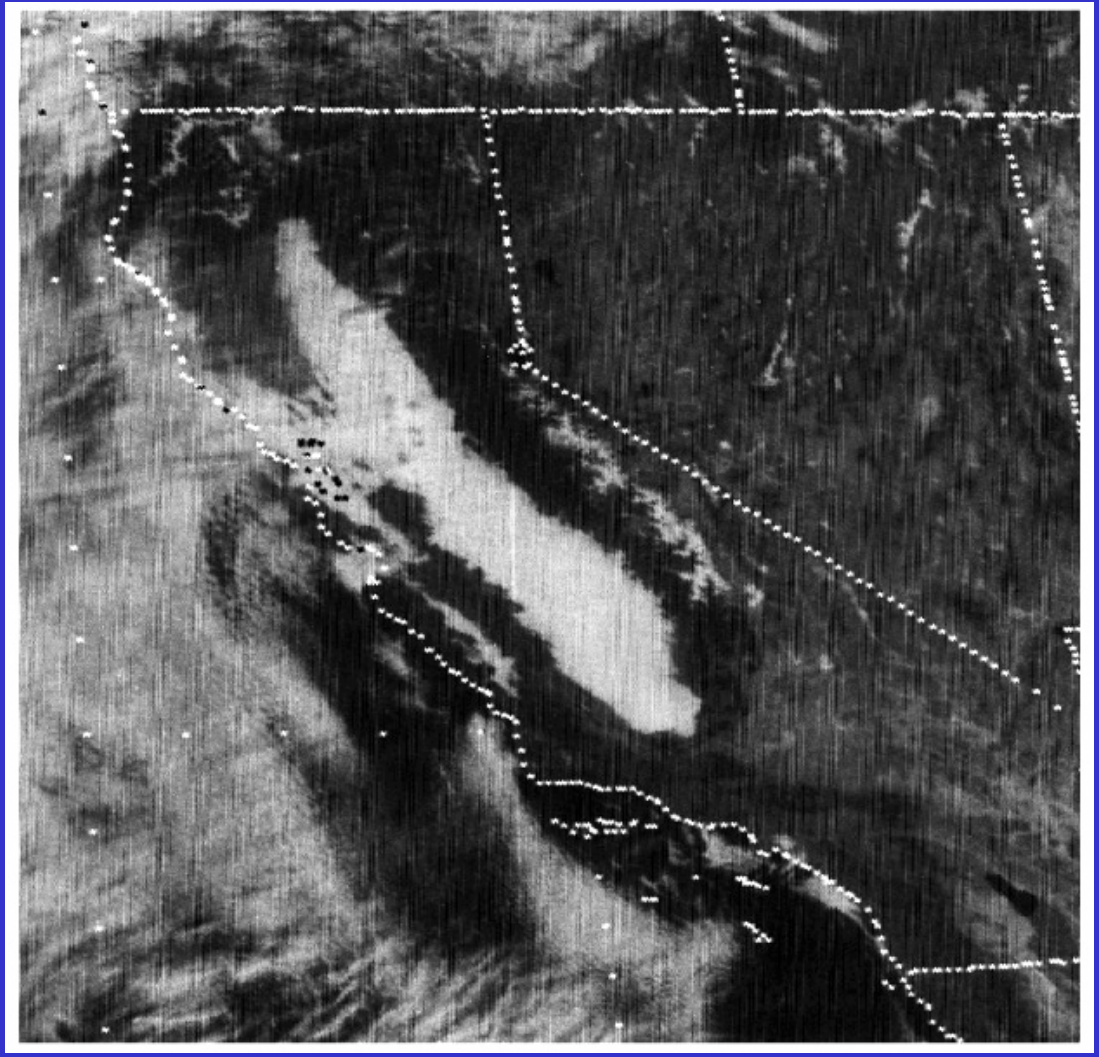
- Diabatic cooling of surface air typically takes place through terrestrial radiation loss on calm, cool, clear nights.

Frost

(b)

- Similar to dew except that it forms when surface temperatures are below freezing.
- Deposition occurs instead of condensation.

Fog



Simply a surface cloud when air either cools to the dew point, has moisture added, or when cooler air is mixed with warmer moister air.

Different types of fog found throughout the U.S.

ESS-5
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