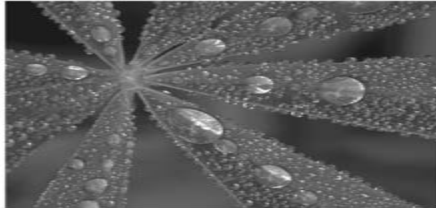


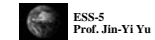
## Chapter 5: Atmospheric Moisture



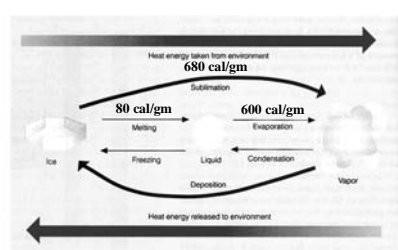
- ❑ Water Vapor and Liquid Water
- ❑ Indices of Water Vapor Content
- ❑ Distribution of Water Vapor
- ❑ Measuring Humidity

## 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

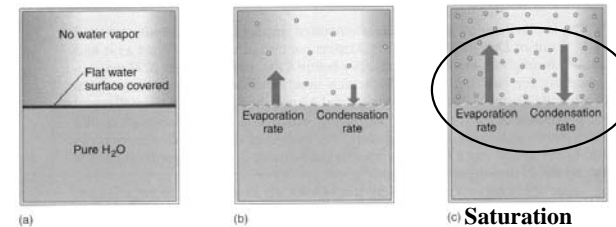


(from *Meteorology: Understanding the Atmosphere*)

- ❑ 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.

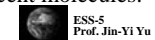


## Water Vapor In the Air



(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

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

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

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

} in unit of g/kg

} in unit of g/m<sup>3</sup>

- by vapor pressure

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

relative humidity

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

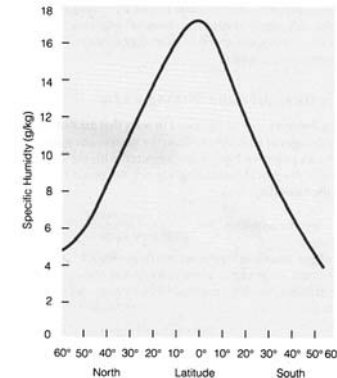
} in unit of %

- by temperature → Dew Point Temperature



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## Observed Specific Humidity

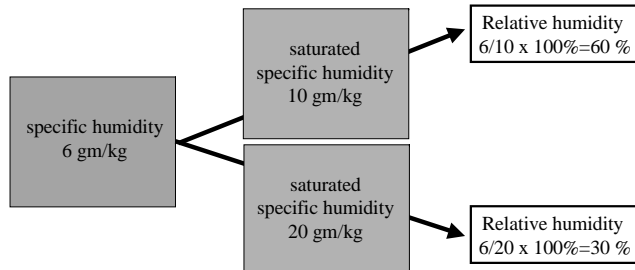


(from *Meteorology Today*)



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## Specific .vs. Relative Humidity

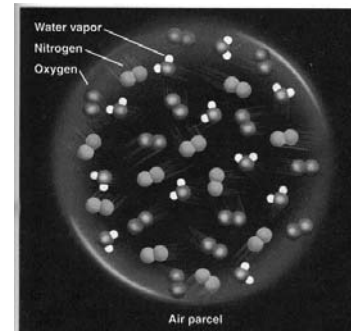


- Specific Humidity: How many grams of water vapor in one kilogram of air (in unit of gm/kg).
- Relative Humidity: The percentage of current moisture content to the saturated moisture amount (in unit of %).
- Clouds form when the relative humidity reaches 100%.



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## Vapor Pressure



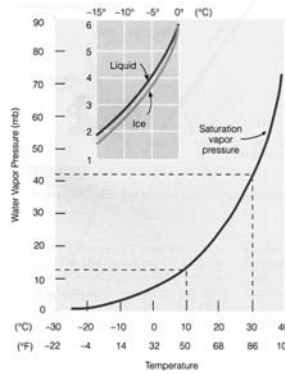
(from *Meteorology Today*)

- 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.



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## Saturation Vapor Pressure



□ Saturation vapor pressure describes how much water vapor is needed to make the air saturated at any given temperature.

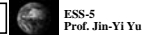
□ Saturation vapor pressure depends primarily on the air temperature in the following way:

$$\frac{de_s}{dT} = \frac{L}{T(\alpha_v - \alpha_l)} \quad \text{The Clausius-Clapeyron Equation}$$

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

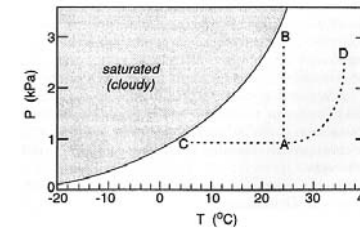
□ Saturation pressure increases exponentially with air temperature.

L: latent heat of evaporation;  $\alpha$ : specific volume of vapor and liquid



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## 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.



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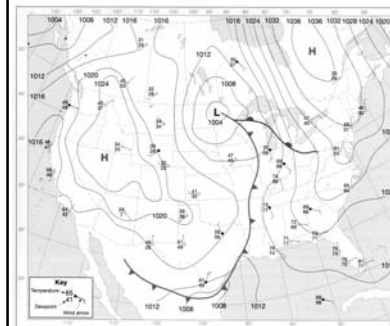
## “Runway” Greenhouse Effect

- 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
- .....



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## 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 cooled to become saturated without changing the pressure.
- The closer 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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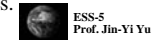
## Frost Point Temperature

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

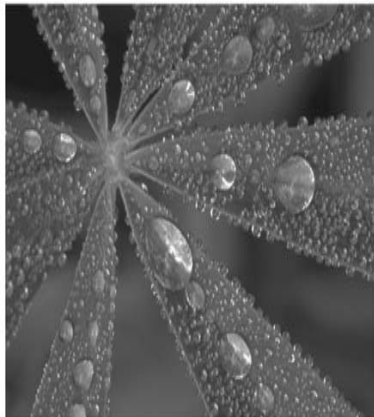


## Measuring Humidity

- ❑ 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

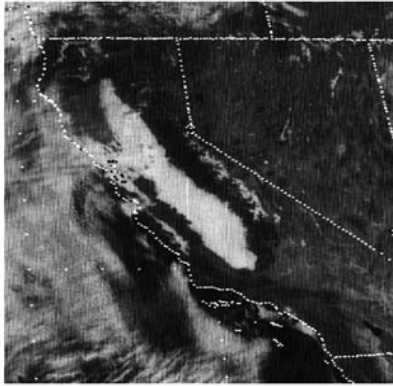


(b)

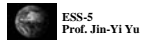
- ❑ Similar to dew except that it forms when surface temperatures are below freezing.
- ❑ Deposition occurs instead of condensation.



# 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.

