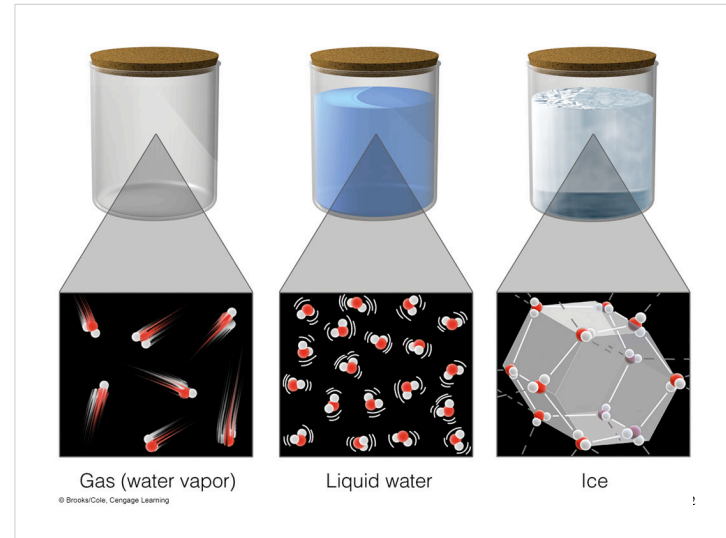


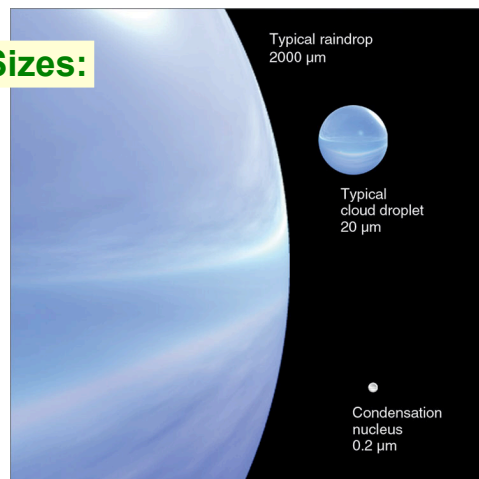
## Water Vapor: Saturation, Relative Humidity

- 'warm air can hold more water' – why?
- What does relative humidity measure?

1



## Typical Sizes:

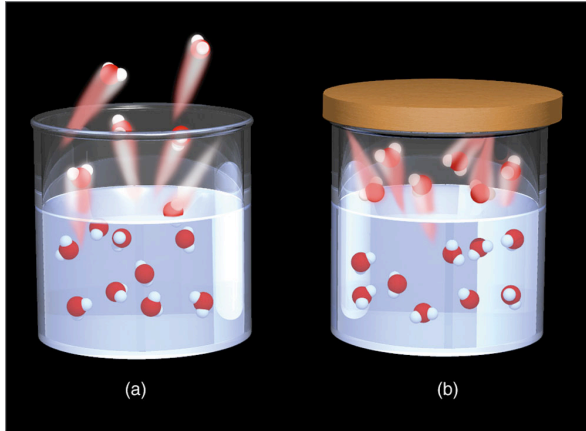


## Water Vapor Pressure

- Molecules in an air parcel all contribute to pressure
- Each subset of molecules (e.g.  $\text{N}_2$ ,  $\text{O}_2$ ,  $\text{H}_2\text{O}$ ) exerts a **partial pressure**
- The **vapor pressure,  $e$** , is the (partial) pressure exerted by water vapor molecules in the air
  - **similar** to atmospheric pressure, but due only to the water vapor molecules
  - often expressed in millibar (mb): 2-30 mb common at the surface (compare to total surface pressure of 1000 mb)

4

## Saturation Vapor Pressure (1)



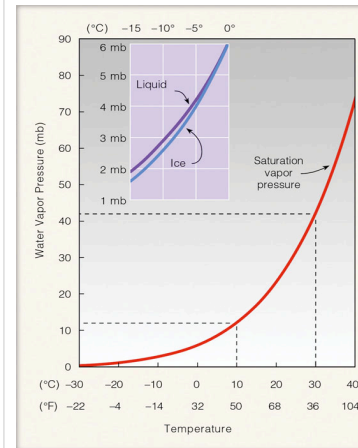
## Saturation Vapor Pressure (2)

- Water molecules over a surface of water will jump back and forth from vapor to liquid form
- If you put a lid on and close the container to the outside air, an equilibrium will eventually be reached where as many molecules evaporate from the liquid than condense on the liquid → **saturation**
- At this equilibrium the water vapor pressure becomes the **saturation vapor pressure**, which gives a measure of the water vapor content of the saturated air

## Saturation Vapor Pressure (3)

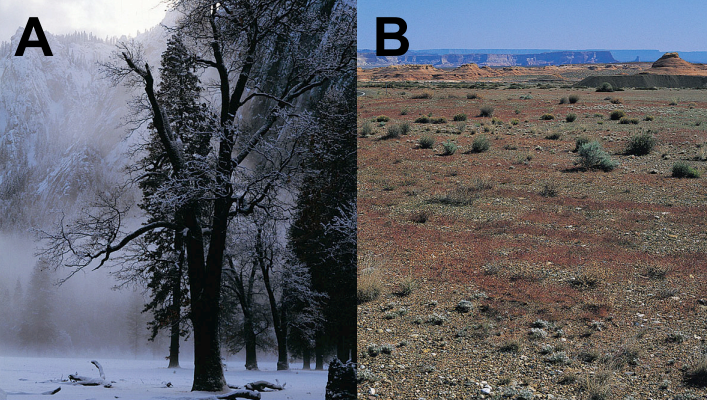
- At higher temperature, molecules are more energetic and more can escape from water to air. The saturation vapor pressure is consequently higher for higher temperatures (hence the expression, sometimes used, “warmer air can hold more water”)
- **The saturation vapor pressure over a surface of water is a strong function of temperature.**
- Saturation vapor pressure varies as a function of solute in the water, including salt: the saturation vapor pressure over the salty ocean is lower than over pure water. This also affects cloud formation.

## Saturation Vapor Pressure (4)



- As temperature goes up, saturation vapor pressure goes up strongly
- Saturation vapor pressure: contribution due to water vapor to total air pressure; gives an indication of the maximum amount of water vapor that can exist in the air at equilibrium
- This curve is the basis for the so-called “water vapor feedback” as is often discussed with global climate change

**Which environment has the higher water vapor content?**



**A** **B**

(a) POLAR AIR: Air temperature  $-2^{\circ}\text{C}$  ( $28^{\circ}\text{F}$ )  
Dew point  $-2^{\circ}\text{C}$  ( $28^{\circ}\text{F}$ )  
Relative humidity 100 percent

(b) DESERT AIR: Air temperature  $35^{\circ}\text{C}$  ( $95^{\circ}\text{F}$ )  
Dew point  $10^{\circ}\text{C}$  ( $50^{\circ}\text{F}$ )  
Relative humidity 21 percent

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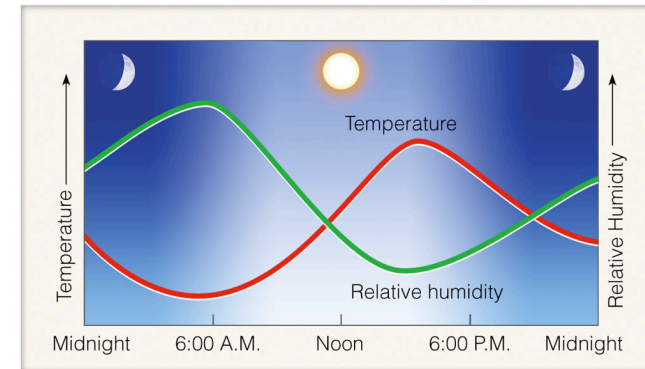
## How do we express the amount of water vapor in an air parcel?

- Absolute humidity
  - mass of water vapor in a given volume of air ( $\text{g}/\text{m}^3$ )
  - *changes when air parcel volume changes*
- Specific humidity (*most widely used in atmospheric science*)
  - mass of water vapor per mass of air ( $\text{g}/\text{kg}$ )
- Mixing ratio
  - mass of water vapor per mass of dry air ( $\text{g}/\text{kg}$ )
- **specific humidity & mixing ratio do not change as long as no phase change takes place, i.e. as long as no water vapor is added/removed to/from the air parcel**
- **Dew point temperature**

## Relative Humidity (RH)

- $\text{RH} = \text{water vapor content} / \text{water vapor capacity}$
- Relative Humidity is the ratio of actual (water) vapor pressure ( $e$ ) to the saturation vapor pressure ( $e_s$ ):
  - (in percent)  $100 * e / e_s$
  - range: 0–100%, but ...  $> 100\%$  does exist
  - air with  $\text{RH} > 100\%$  is said to be **supersaturated**
  - air with  $\text{RH} < 100\%$  is said to be **subsaturated**
- RH can be changed by:
  - changes in water vapor content,  $e$
  - changes in temperature, which alters  $e_s$

## RH might change during the day, even though the actual water vapor content remains the same



- At 6 am, saturation vapor pressure is close to actual water vapor content (vapor pressure).
- At 3 pm, actual water vapor content hasn't changed, but the saturation vapor pressure has risen. Therefore, relative humidity is lower.

## Dewpoint Temperatures

### How to find the dewpoint:

- Decrease air temperature without changing its water vapor content
- When you have lowered the temperature enough to reach saturation, you have reached the dewpoint temperature
- Relative humidity is 100% by definition at the dewpoint
- Dewpoint is a measure of the **water vapor content** of the air
- It is **not a measure of the air's temperature!**

## Dew

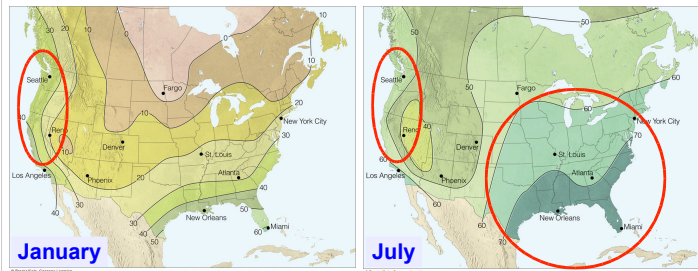
On cloudless, calm nights, temperature of the surface and near surface air can drop to the dewpoint temperature.

This corresponds to  $RH = 100\% \rightarrow$  condensation.

Hence the term **dewpoint**.



## Dewpoint Temperatures



- West coast U.S. has higher water vapor content and dewpoint in summer than in winter, but highest relative humidity in winter when it's "always" raining
- Greatest dewpoints occur in eastern U.S. during summer, sometimes approaching 85 F!

## Frost

On cloudless, calm nights, temperature of the surface and near surface air can drop to the dewpoint temperature.

If this temperature is below freezing, frost forms.

The dewpoint in this case is called "**frostpoint**".

