Chapter 5 - Atmospheric Moisture

Understanding Weather and Climate
Aguado and Burt

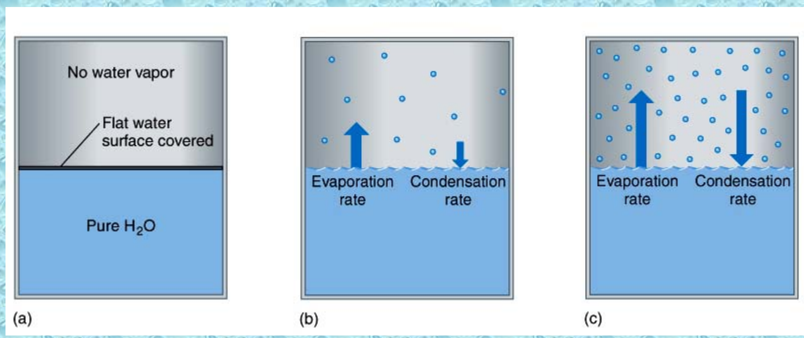
Water

- Water Vapor - water in a gaseous form, not droplets.
- Water can also achieve solid and liquid phases on Earth
  - Temperature and pressure
- Saturation – The maximum amount of water that can exist in the atmosphere as a vapor.

Evaporation and Condensation

- Evaporation – Change in phase from liquid to vapor. The process in which molecules break free of the liquid volume.
- Condensation – Change in phase from vapor to liquid. The process whereby molecules collide with the water surface and bond with adjacent molecules.

Evaporation and Condensation



Sublimation and Deposition

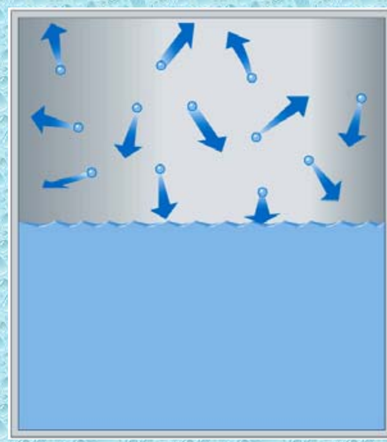
- Sublimation - Change of phase from a solid into a vapor without passing through the liquid phase.
- Deposition – Change of phase from vapor to solid.

Humidity

- Humidity – an expression of the amount of water vapor in the air.
- There are several ways to measure humidity:
  - *Vapor Pressure* *(Pressure)*
  - *Absolute Humidity* *(Density)*
  - *Specific Humidity* *(Mass Ratio)*
  - *Mixing Ratio* *(Mass Ratio)*
  - *Relative Humidity* *(Percentage)*
  - *Dew Point Temperature* *(Temperature)*

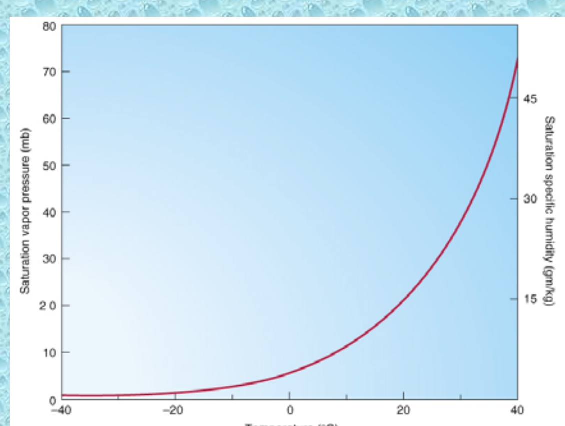
Vapor Pressure

- Vapor Pressure – The part of the total atmospheric pressure due to water vapor.
- Dependencies: Temperature
- Unit: Pascal (Pa), millibar (mb), Kilopascal (kPa)



Saturation Vapor Pressure

- The vapor pressure of the atmosphere when it is saturated.
- Dependencies: Temperature



Absolute Humidity

- Absolute Humidity – The density of water vapor (mass of water vapor in a volume of air).
- Dependencies: Volume of the air
- Not widely used.

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Specific Humidity

- Specific Humidity- The mass of water vapor per unit mass of air.
- Dependencies: Atmospheric pressure
- Units: grams per kilogram (g/kg)
- Widely used

$$q = \frac{m_v}{m} = \frac{m_v}{(m_v + m_d)}$$

 – q=specific humidity, m_v=mass of water vapor, m_d=mass of dry air

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Mixing Ratio

- Mixing Ratio - The mass of water vapor relative to the mass of the other gases.
- Offers same advantages as specific humidity

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

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Relative Humidity

- Relative Humidity – The amount of water vapor in the air relative to the maximum amount possible.
- Dependencies: <u>Temperature</u>
- Unit: percentage (%)
- Widely used, but not necessarily good

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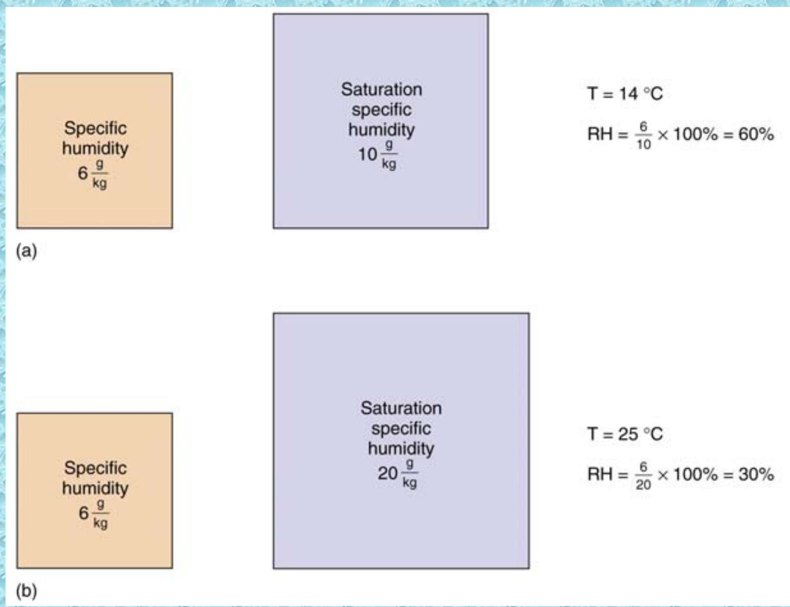
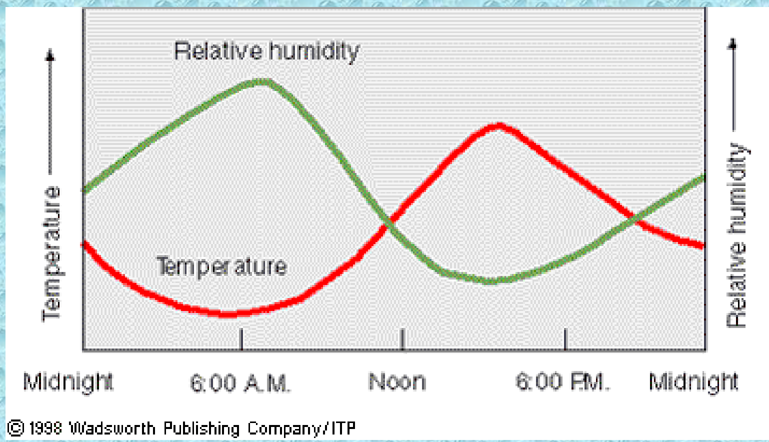
Relative Humidity



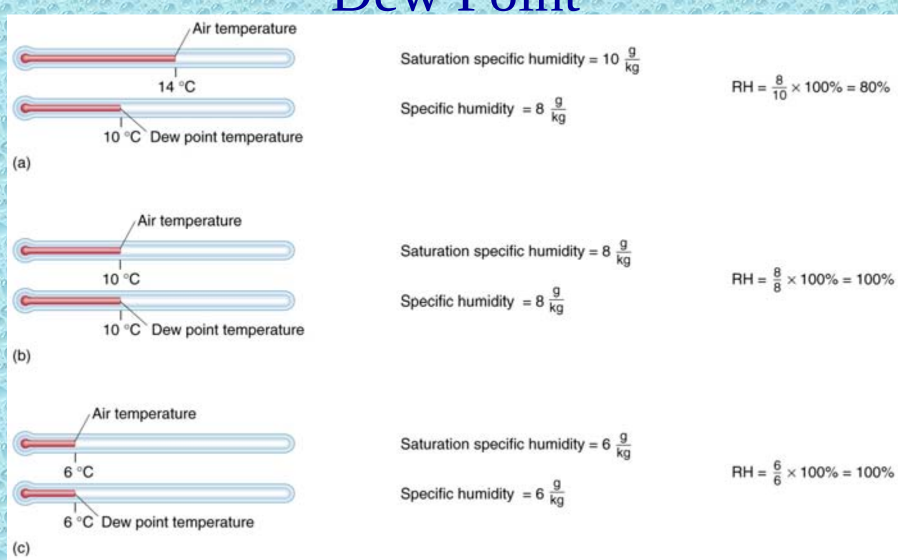
Relative Humidity



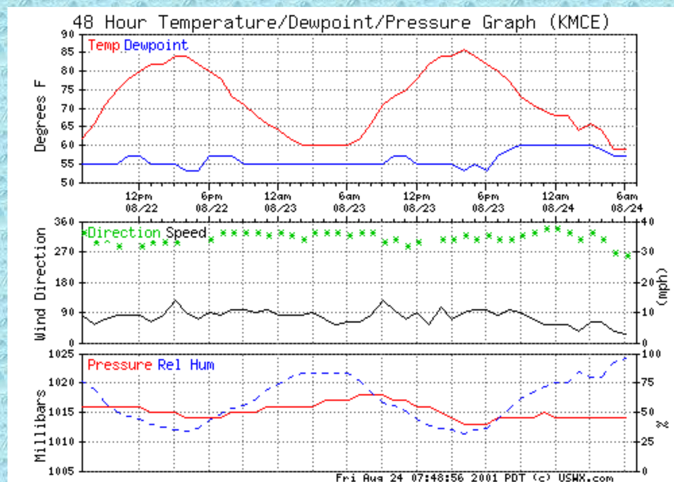
Dew Point

- Dew Point – The temperature at which saturation would occur.
- Unit: °F, °C, K
- Widely used

Dew Point



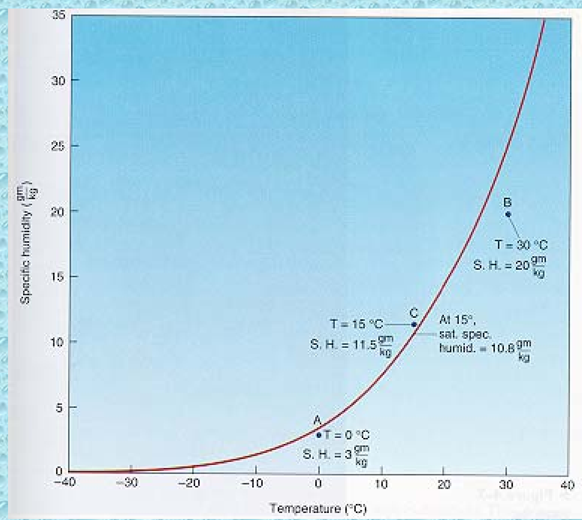
Dew Point Vs. Relative Humidity



Three Ways to Achieve Saturation

- Adding water vapor to the air
- Lowering the temperature to the dew point
- Mixing cold air with warm, moist air.

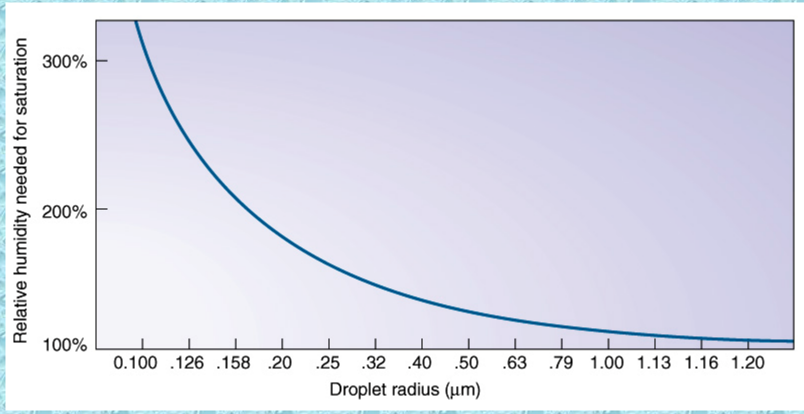
Mixing of Air Parcels



Effects of Curvature

- Smaller drops have more curvature.
- The evaporation rate from curved surfaces is higher relative to those which are flat.
- Curved water droplets have a higher saturation vapor pressure.
- Supersaturation (relative humidity greater than 100%) is necessary to maintain highly curved droplets.

Effects of Curvature



Effects of Solution

- Fewer water molecules existing at the surface which yield a lower evaporation rate.
- A solution requires less water vapor above the surface to stay in equilibrium.
- Offset the curvature effect allowing for droplets to form with relative humidities near 100%.

Ice Nuclei

- Saturation occurring from 0 to –4°C forms only supercooled water droplets.
- From –10 to –40° C ice or supercooled water droplets can form.
- Below –40°C saturation leads to only the formation of ice crystals.
- Ice nuclei – Particles onto which ice crystals can form when the air becomes saturated.

Cooling Air to the Dew Point

- Heating/cooling can occur in two ways.
  - Diabatic processes – Energy is removed or added.
  - Adiabatic processes – Energy is **not** added or removed (energy remains constant).

Diabatic Processes

- Involves the transfer of energy from higher to lower temperatures.
- Second Law of Thermodynamics – Energy moves from regions of higher to lower temperatures.
- Frequently responsible for fog formation

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Adiabatic Processes

- Energy remains constant *(no heat transfer)*.
- First Law of Thermodynamics – if heat is added there will be some combination of temperature increase and expansion.

$$\Delta H = p \cdot \Delta\alpha + c_v \cdot \Delta T$$

- For an adiabatic process:

$$0 = p \cdot \Delta\alpha + c_v \cdot \Delta T \qquad -p \cdot \Delta\alpha = c_v \cdot \Delta T$$

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Lapse Rates

- Dry adiabatic lapse rate (DALR) –Rate at which rising parcel of unsaturated air cools. (1.0°C/100 m)
- Saturated adiabatic lapse rate (SALR) - Rate at which rising parcel of saturated air cools. (0.5°C/100 m)
- Dew point lapse rate – Rate at which dew point decreases with height. (0.2°C/100 m)
- Environmental lapse rate (ELR) – Vertical change in temperature profile through still air.

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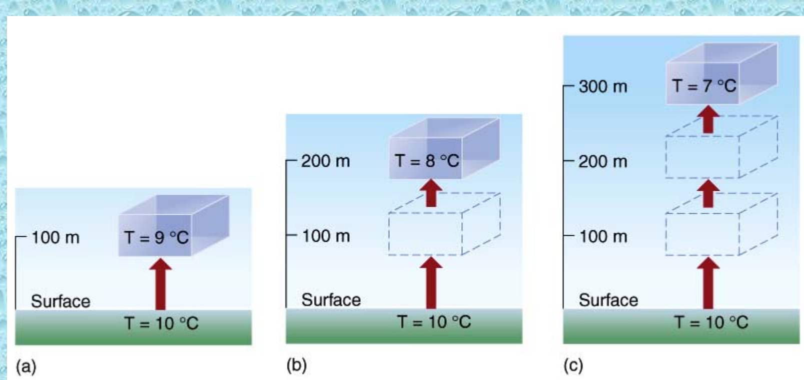
Lapse Rates



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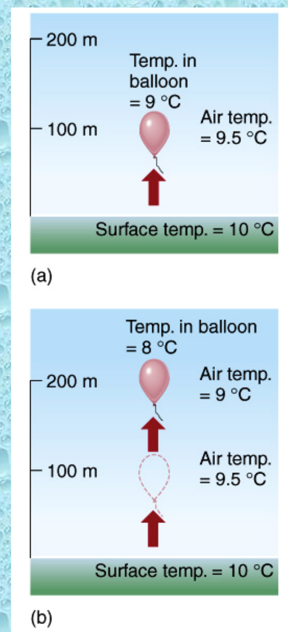
Lapse Rates

- Difference between ELR and DALR/SALR



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Lifting Condensation Level

- LCL: Lifting Condensation Level - level at which saturation is achieved

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Forms of Condensation

- Dew
- Frost
- Frozen Dew
- Fog
  - Radiation
  - Advection
  - Upslope

Fogs