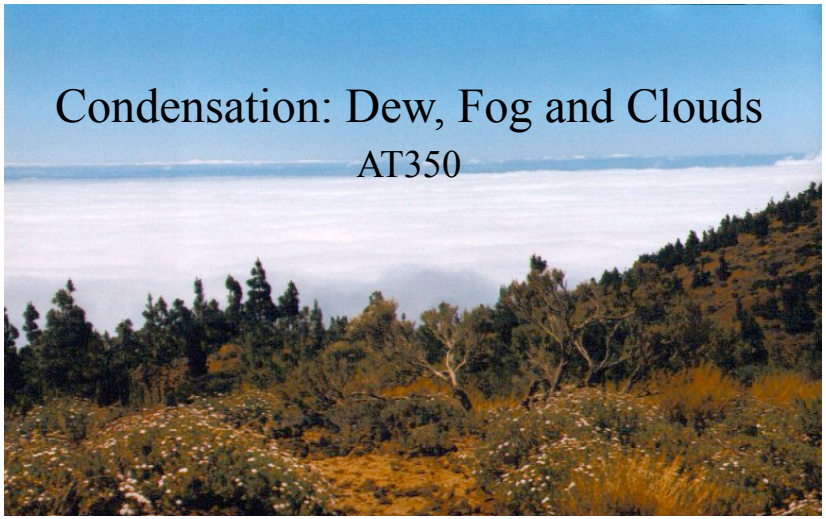
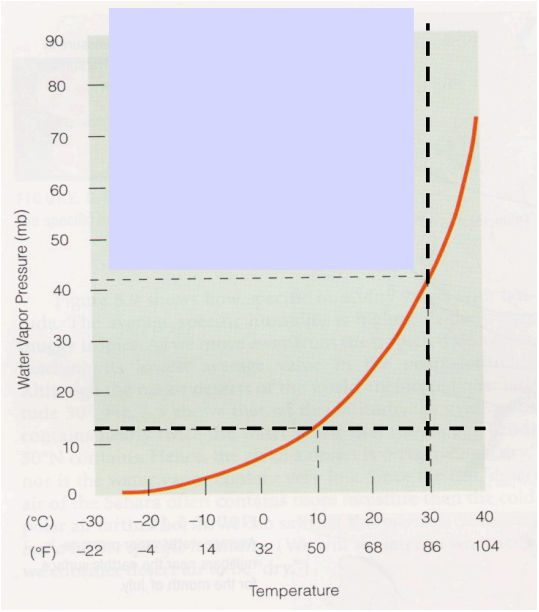
Condensation: Dew, Fog and Clouds

AT350



- T=30 C
- Water vapor pressure=12mb

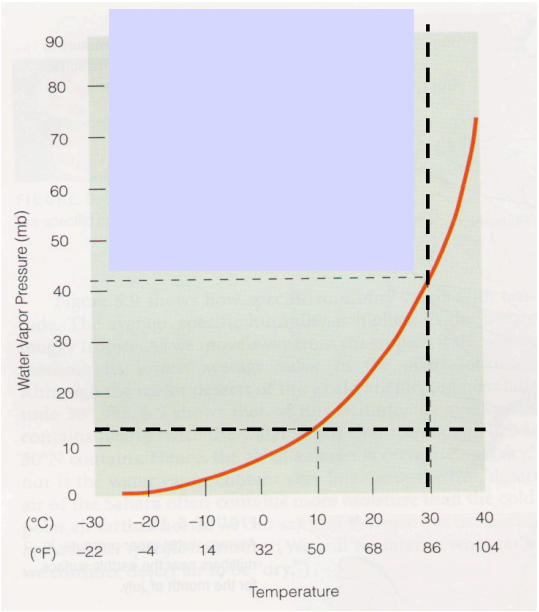
- What is Td?
- What is the sat. water vapor pressure?
- What is the relative humidity?



- T=30 C
- Water vapor pressure=12mb

- What is Td?
- What is the sat. water vapor pressure?
- What is the relative humidity?

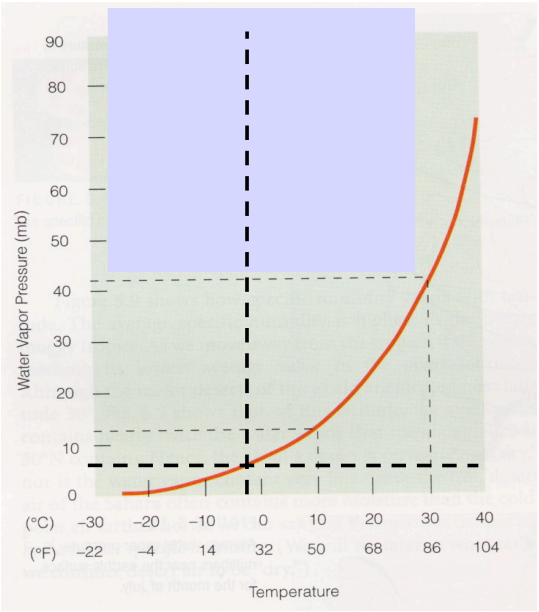
~12/42~29%



POLAR AIR

- T=-2 C
- Td=-2 C

- What is water vapor pressure?
- What is sat. water vapor pressure?
- What is the relative humidity?



DESERT AIR

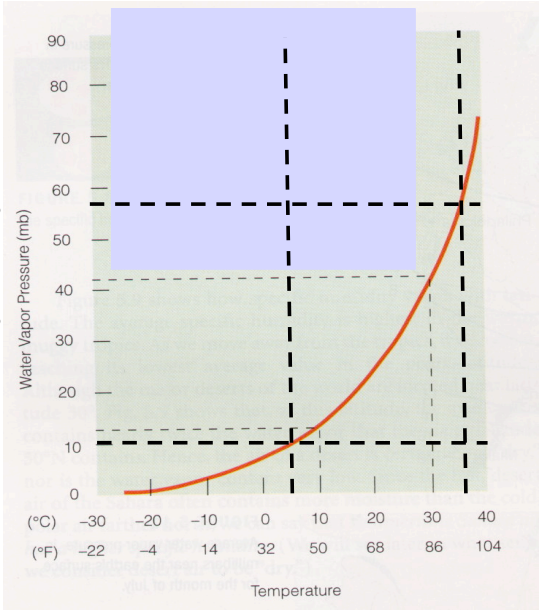
•T=35 C

•Td= 5 C

•What is water vapor pressure?

•What is sat. water vapor pressure?

•What is the relative humidity?



DESERT AIR

•T=35 C

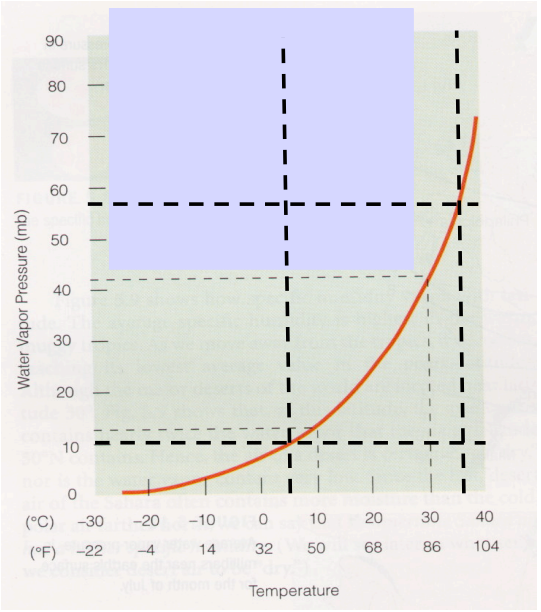
•Td= 5 C

•What is water vapor pressure?

•What is sat. water vapor pressure?

•What is the relative humidity?

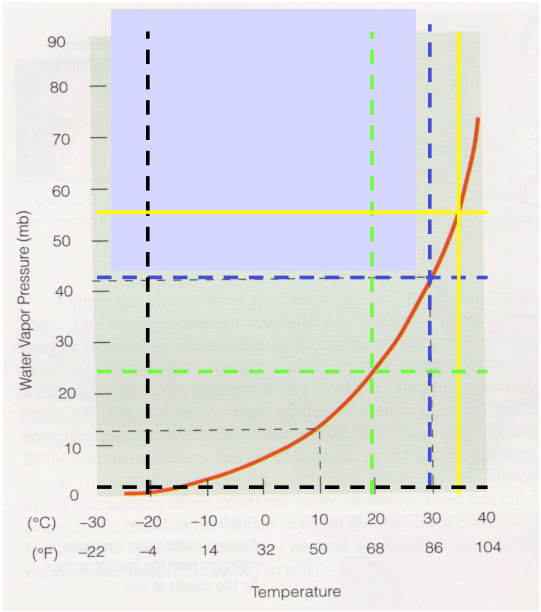
~9/56~16%



•If air is saturated at T=30 C and warms to 35 C, what is the relative humidity?

•If air is saturated at T=20 C and warms to 35 C, what is the relative humidity?

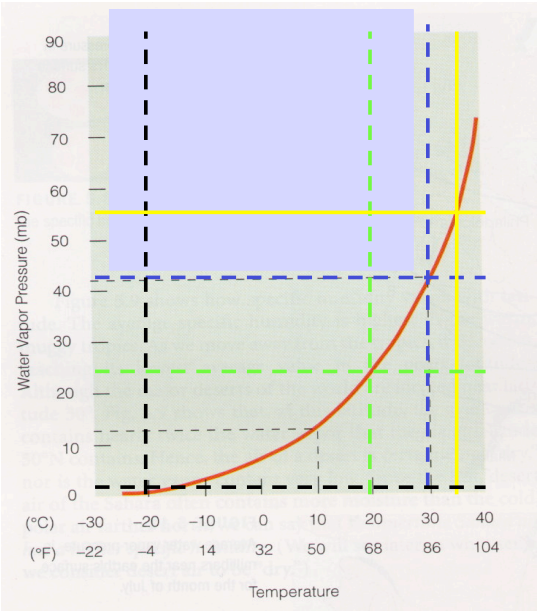
•If air is saturated at T=-20 C and warms to 35 C, what is the relative humidity?



•If air is saturated at T=30 C and warms to 35 C, what is the relative humidity? ~75%

•If air is saturated at T=20 C and warms to 35 C, what is the relative humidity? ~43%

•If air is saturated at T=-20 C and warms to 35 C, what is the relative humidity? ~2%



Condensation

- Condensation is the phase transformation of water vapor to liquid water
- Water does not easily condense without a surface present
  - Vegetation, soil, buildings provide surface for dew and frost formation
  - Particles act as sites for cloud and fog drop formation

Dew

- Surfaces cool strongly at night by radiative cooling
  - Strongest on clear, calm nights
- The *dew point* is the temperature at which the air is saturated with water vapor
- If a surface cools below the dew point, water condenses on the surface and dew drops are formed

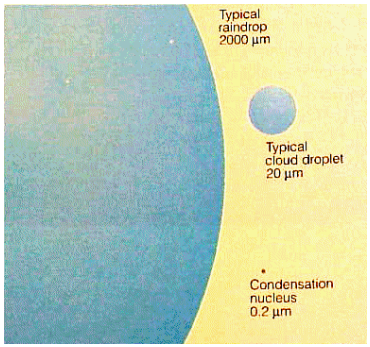
Frost

- If the temperature is below freezing, the dew point is called the frost point
- If the surface temperature falls below the frost point water vapor is deposited directly as ice crystals
  - *deposition*
- The resulting crystals are known as frost, hoarfrost, or white frost

Cloud and fog drop formation

- If the air temperature cools below the dew point (RH > 100%), water vapor will tend to condense and form cloud/fog drops
- Drop formation occurs on particles known as cloud condensation nuclei (CCN)
- The most effective CCN are water soluble.
- Without particles clouds would not form in the atmosphere
  - RH of several hundred percent required for pure water drop formation

Typical sizes



Fogs

- Fogs are clouds in contact with the ground
- Several types of fogs commonly form
  - Radiation fog
  - Advection fog
  - Upslope fog
  - Evaporation (mixing) fog

Radiation Fog

- Surface radiation and conduction of heat away from the overlying air cool air temperatures near the ground
- A layer of air near the ground becomes saturated and fog forms
- Fog deepens as radiative cooling from the fog top continues overnight
- Solar heating warms the ground and causes the fog to "burn off" from the ground up
- What type of meteorological conditions would favor radiation fog?

Advection Fog

- Warm air moves (is *advected*) over cold surface
- Cold surface cools warm air
- If saturation is reached, fog forms
- Common on west coast of U.S.
  - Warm moist air from Pacific is advected over upwelling cold coastal waters
  - As foggy air moves ashore, solar heating warms the ground and overlying surface
    - Fog evaporates near ground
  - Coastal advection fogs are key moisture sources for California Redwoods

Other Fog Types

- Evaporation (mixing) fog
  - Mixing of warm, moist air with colder air produces saturated air parcel
  - Examples
    - Exhale on a cold day
    - Evaporation of water from relatively warm, wet surface and mixing with colder air above.
    - (Smokestack plume, contrails)
- Upslope fog
  - Moist air flows up along sloped plain, hill or mountain
  - Expansion of rising air causes cooling and RH increases

Clouds

- Clouds result when air becomes saturated away from the ground
- They can
  - be thick or thin, large or small
  - contain water drops and/or ice crystals
  - form high or low in the troposphere
  - even form in the stratosphere (important for the ozone hole!)

- Clouds impact the environment in many ways
  - Radiative balance, water cycle, pollutant processing, earth-atmosphere charge balance, etc….

Cloud classification

- Clouds are categorized by their height, appearance and vertical development
  - High Clouds - generally above 16,000 ft at middle latitudes
    - Main types - **Cirrus, Cirrostratus, Cirrocumulus**
  - Middle Clouds – 7,000-23,000 feet
    - Main types – **Altostratus, Altocumulus**
  - Low Clouds - below 7,000 ft
    - Main types – **Stratus, stratocumulus, nimbostratus**
  - Vertically developed clouds (via convection)
    - Main types – **Cumulus, Cumulonimbus**

High Clouds

- High clouds
  - White in day; red/orange/ yellow at sunrise and sunset
  - Made of ice crystals
  - Cirrus
    - Thin and wispy
    - Move west to east
    - Indicate fair weather
  - Cirrocumulus
    - Less common than cirrus
    - Small, rounded white puffs individually or in long rows (fish scales; mackerel sky)

  - Cirrostratus
    - Thin and sheetlike
    - Sun and moon clearly visible through them
    - Halo common
    - Often precede precipitation

Cirrus

Cirrus

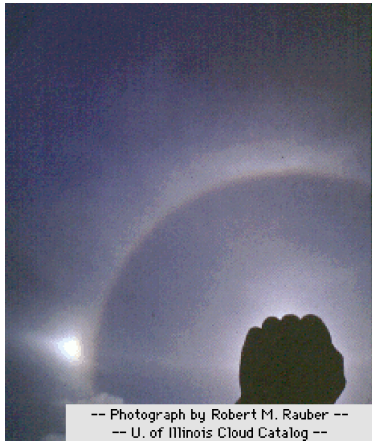
Cirrus Display at Dawn

Cirrocumulus

Cirrocumulus

Cirrocumulus at Sunset

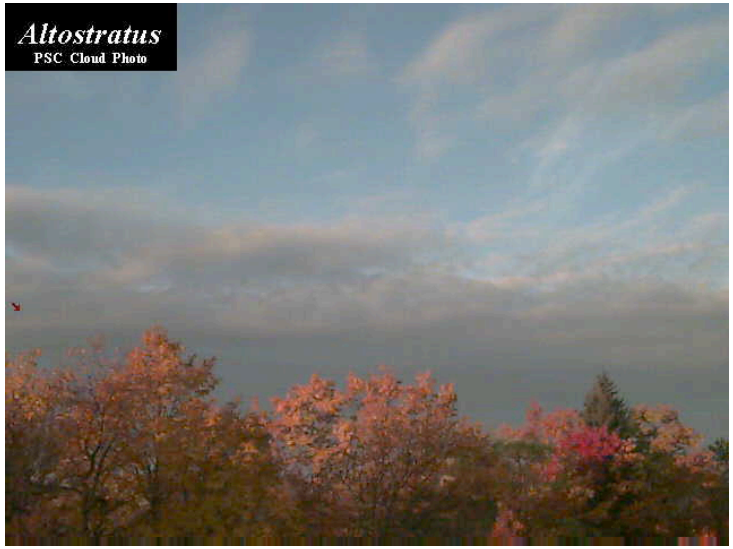
Cirrostratus



Cirrostratus with Halo

Middle Clouds

- Altocumulus
  - <1 km thick
  - mostly water drops
  - Gray, puffy
  - Differences from cirrocumulus
    - Larger puffs
    - More dark/light contrast
- Altostratus
  - Gray, blue-gray
  - Often covers entire sky
  - Sun or moon may show through dimly
    - Usually no shadows



Altostratus

Alto Stratus Castellanus

Altocumulus

Altocumulus

Alto Cumulus Radiatus

Alto Cumulus

Alto Cumulus Undulatus

Low Clouds

- Stratus
  - Uniform, gray
  - Resembles fog that does not reach the ground
  - Usually no precipitation, but light mist/drizzle possible
- Stratocumulus
  - Low lumpy clouds
  - Breaks (usually) between cloud elements
  - Lower base and larger elements than altostratus
- Nimbostratus
  - Dark gray
  - Continuous light to moderate rain or snow
  - Evaporating rain below can form *stratus fractus*

Stratus fractus

Looking down on an eastern Atlantic stratus deck

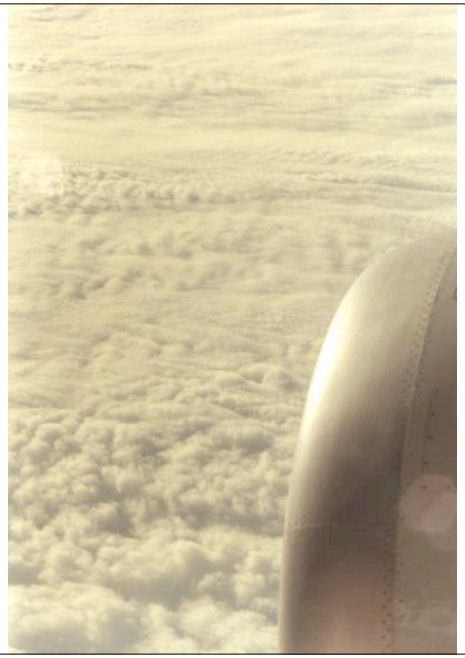
Stratiform cloud layers

Stratocumulus cloud streets

Stratus undulatus

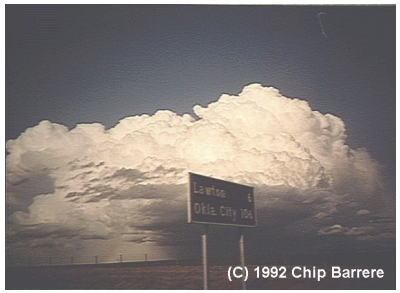
Stratus

A Layer of Stratocumulus Cloud viewed from above



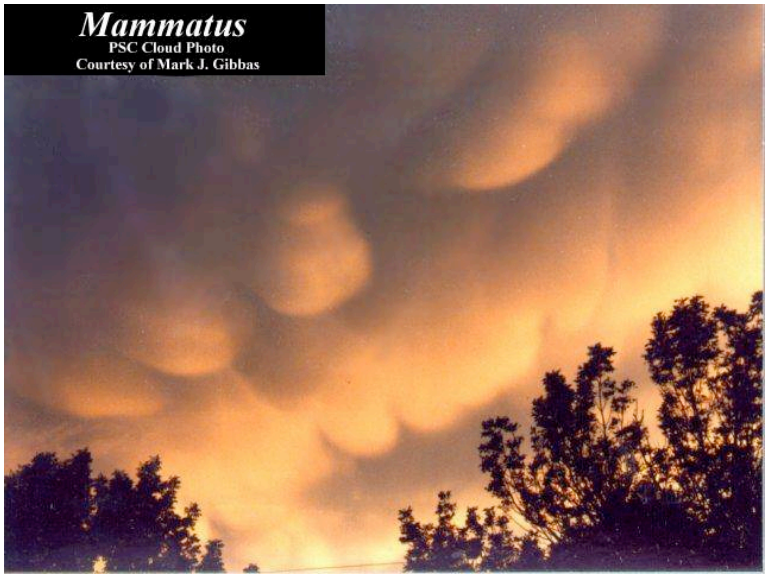
Vertically developed clouds

- Cumulus
  - Puffy “cotton”
  - Flat base, rounded top
  - More space between cloud elements than stratocumulus
- Cumulonimbus
  - Thunderstorm cloud
  - Very tall, often reaching tropopause
  - Individual or grouped
  - Large energy release from water vapor condensation

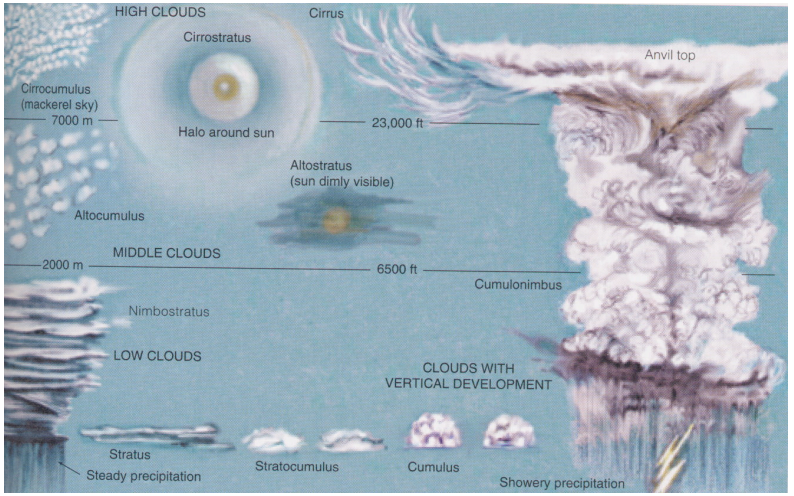


Cumulonimbus with Pileaus caps

Cumulonimbus Clouds Spawn Tornadoes

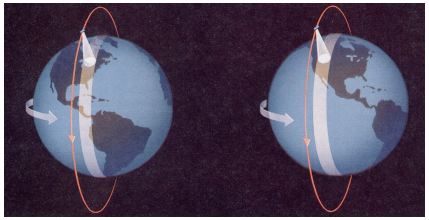


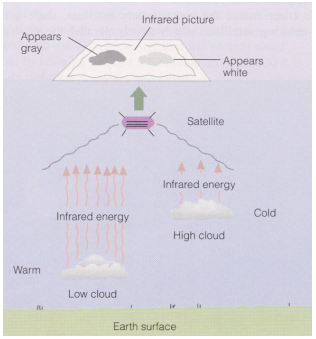
Cloud type summary



Satellite observations

- Satellites can be
  - Geostationary
    - Monitors fixed spot on Earth's surface
  - Polar orbiting
    - Orbit poles with Earth revolving below
- Satellites observe
  - Clouds
  - Water vapor
  - Precipitation
  - Surface properties (temperature, snow cover, vegetation, etc…)





Visible and Infrared Satellite Photos