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?

**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**

- $T=35 \, ^\circ C$
- $T_d=5 \, ^\circ C$

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

If air is saturated at $T=30 \, ^\circ C$ and warms to 35 $^\circ C$, what is the relative humidity?

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

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

~9/56~16%

~75%

~43%

~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 vapor is deposited directly as ice crystals
  - *deposition*
- The resulting crystals are known as frost, hoarfrost, or white frost

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

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

Fogs
- Fogs are clouds in contact with the ground
- Several types of fogs commonly form
  - Radiation fog
  - Advection fog
  - Upslope fog
  - Evaporation (mixing) fog
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
  – Cirrostratus
    • Less common than cirrus
    • Small, rounded white puffs individually or in long rows (fish scales; mackerel sky)
Cirrus

Cirrus Display at Dawn

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

Altocumulus

Altostratus Castellanus
Altocumulus

Alto Cumulus Radiatus

Alto Cumulus

Altocumulus

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
Looking down on an eastern Atlantic stratus deck

Stratiform cloud layers

Stratus fractus
Stratocumulus cloud streets

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

Stratus

A Layer of Stratocumulus Cloud viewed from above

Cumulonimbus with Pileus caps
Cumulonimbus Clouds Spawn Tornadoes

Mammatus
PSC Cloud Photo
Courtesy of Mark J. Gibbas

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