Chapter 5 Condensation

Formation of dew and frost
Condensation nuclei
Haze
Fog: radiation, advection, mixing
Cloud classification & examples of main types
Cloud ceiling
Satellite orbits: geostationary and polar

Condensation nuclei (p. 109)

- Condensation nuclei: tiny particles on which condensation can occur.
- Abundant! (100's to 10,000's in cubic centimeter)
  - **Small:** less than 0.2 micrometers. Most abundant, least effective
  - **Large:** 0.2 to 1 micrometer (wavelength of light)
  - **Giant:** bigger than 1 micrometer. Least abundant, most effective
- All condensation nuclei in the atmosphere are too small to see well even with a microscope, especially small nuclei
- Consist of dust, smoke, salt, products of chemical reactions, etc.

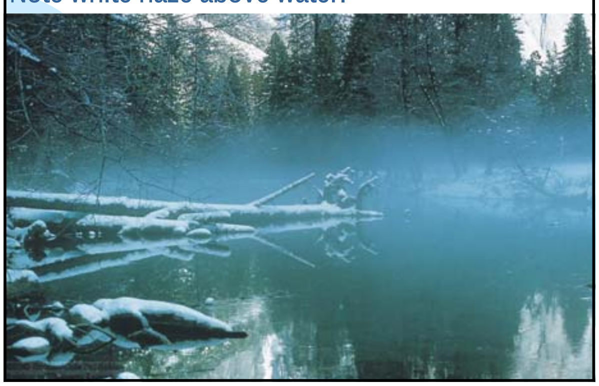
Condensation Nuclei (cont.)

- Some are "wettable": water spreads out on them, as on an unwaxed car
- Some are not wettable ("hydrophobic"): water beads up on them, as on a waxed car
- Some (such as salts) are "hygroscopic": they dissolve and allow condensation at < 100% relative humidity (can be as low as 75% relative humidity, p. 110)
  - Table salt clumps in salt shaker because of this.
  - "Damp Rid" is a kind of salt sold for drying air in closets
- Condensation usually forms in air around 100% relative humidity

Haze (pp. 109-110)

- Dry haze: very small particles. Recall that very small particles scatter more blue light than red light.
  - If dark background, dry haze looks blue. (Light from elsewhere scattered toward you, as blue of sky.)
  - If light background, the light from background travels toward your eyes. As it passes through the dry haze, more blue light is scattered out, so haze looks yellowish, just as the sun does.
- Wet haze: condensation occurred, so particles are larger & scatter all colors. Wet haze looks whitish.
  - Forms at relative humidity as low as 75% if salt is in air, typically from evaporated sea spray.
  - Scatters more light than dry haze

Wet haze example (Fig. 5.4, p. 110 of text)
Note white haze above water.



Fog (pp. 110-116)

- Fog = cloud next to ground
- Fog in city usually thicker than fog over ocean. Cities are polluted and have very many condensation particles. Ocean fog is made of fewer but larger water droplets.
- **Radiation fog** (= ground fog, p. 111): infrared radiation from ground cools air next to it until condensation occurs.
  - The longer the night, the more the cooling, so radiation fog is most common in late fall and winter
  - Light breeze stirs air, bringing more air in contact with cold ground, increasing amount of condensation & fog
  - Strong wind inhibits fog formation by even greater mixing, which brings down drier from above
  - Light winds and clear skies common near center of high pressure, so that is where fog often occurs.
  - Thickest at sunrise after cooling all night. As the sun heats the air, the fog evaporates ("burns off"), starting at thin edge of fog.

Radiation fog (fig. 5.5, p. 111) Drains into in valley. Clear above.

Advection Fog (pp. 112-113)

- Advection fog = warm moist air advects over cold surface
  - Advection means that a wind is required, in contrast to radiation fog.
  - Occurs along Pacific Coast when warm moist air from Pacific blows over cold ocean current next to California coast. Example: Fog by San Francisco's Golden Gate Bridge.
  - Occurs over Grand Banks when wam moist air from Gulf Stream blows over cold water of Labrador Current.
  - In winter, occurs along U.S. Gulf Coast and in England when warm moist air blows onto land cooled by radiation (called advection-radiation fog).

Advection fog (fig. 5.7, p. 113)

Summary of Radiation and Advection Fog

- Both radiation fog and advection fog involve warm moist air over cold surface
  - Cold fog drains into low lying areas
  - In these cases, air is stable (warm air has risen, cold air has sunk) so fog has clearly defined upper surface.
  - Radiation and advection fog occur in stable environments (covered in chapter 6). Are fairly uniform and featureless in appearance.

Upslope Fog (pp. 112-113)

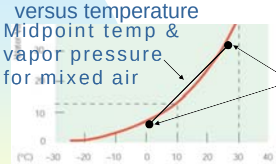
- Fog can form when air cools to saturation as it blows up the side of a mountain. (Recall: Air does work as it expands into lower pressure.)
- Example: Upslope fog on the east side of the Rocky Mountains (fig. 5.9, p. 113)

Steam fog (also called mixing fog, evaporation fog, pp. 113-116)

- Water evaporates from warm surface; warm, moist air rises; mixes with cold air above; air cools to dewpoint
- Air in steam fog not stable near surface (warm air rises), looks wispy with no definite top
- Occurs over:
  - pot of boiling water (hence name "steam fog")
  - outdoor heated pool on cold day
  - hot asphalt after summer rain
  - warm lake in mid-latitudes when cold air in early fall blows in

How steam fog (mixing fog) forms (Special topic, p. 115)

- Imagine two equal-sized blobs of air, both nearly saturated.
- Recall fig. 4.10, p. 91, showing saturation vapor pressure versus temperature



- When the blobs are mixed together, their temperatures and dew points are averaged
- Even if the initial dew points were below saturation, the mixed partial can be above saturation. If so, condensation will result, i.e., mixing fog.

Steam fog (fig. 5.10, p. 116): wispy!

Fog Review & Fog in Florida (pp. 116-117)

- Look at the map on page 116 and explain why coastal California, the Appalachians, New England, and the Gulf Coast are so foggy.
- Fog is a problem on Florida highways. For info on what other states have done to monitor their highways, see http://garnet.acns.fsu.edu/~jelsner/fdot/OtherRWIS.html
- Florida even gets "superfog," which is especially dense fog caused by the abundance of condensation nuclei in forest fire smoke. For more information, do an Internet search on: superfog Florida

Cloud classification (pp. 117-119)

- Classification proposed in 1803 by English scientist Luke Howard
- Uses Latin words to describe cloud appearance
  - Stratus = layer (same root as "stratosphere")
  - Cumulus = heap (root as in "accumulate")
  - Cirrus = lock of hair
  - Nimbus = rain cloud
  - Alto = prefix used to denote middle clouds, just as an alto voice is a middle-pitched voice
- For more info and great pictures, see *The Audubon Society Field Guide to North American Weather* by David Ludlum, c. 1991.

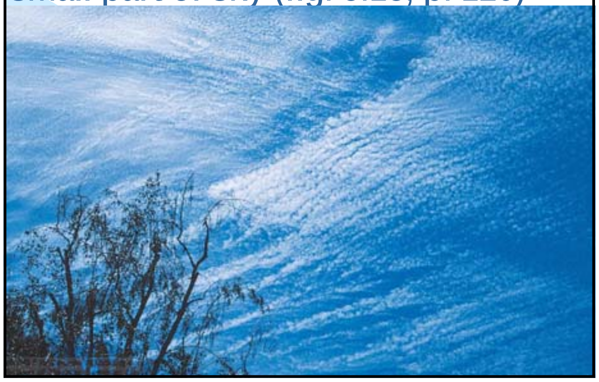
Cloud classification (continued)

- High clouds (ice, halo around sun or moon) (as low as 10-20,000 ft, as high as 26-60,000 ft)
  - cirrus, cirrostratus, cirrocumulus
- Middle clouds (6500 to ~25,000 ft, liquid droplets & sometimes some ice)
  - altostratus, altocumulus
- Low clouds (surface to 6500 ft, liquid water)
  - stratus, stratocumulus, nimbostratus
- Clouds of vertical development
  - cumulus, cumulus congestus, cumulonimbus

Cirrus: ice clouds. Wispy, no sharply defined edges

Fig. 5.12, p. 119

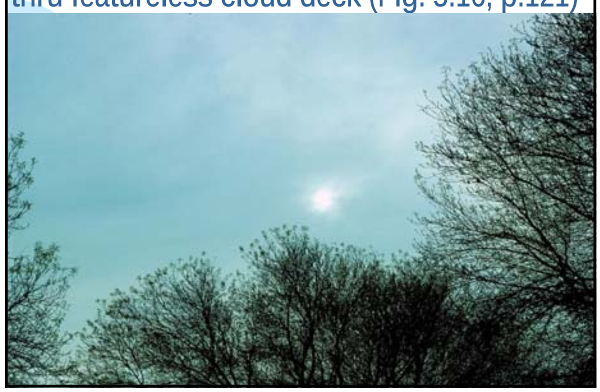
Cirrocumulus: usually cover only small part of sky (fig. 5.13, p. 120)



Cirrostratus: thin sheet, often over whole sky. Halo around sun or moon. (Fig. 5.14, p. 120)

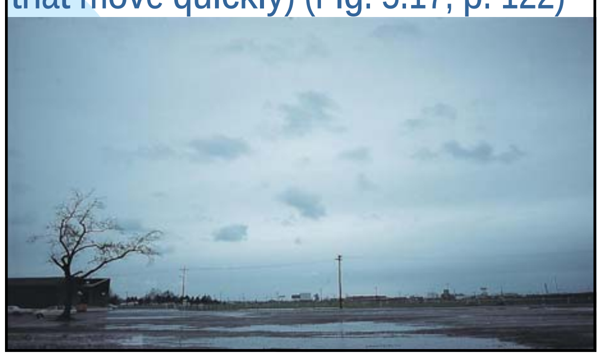
Altocumulus: individual clouds about size of your thumbnail when your arm is extended (Fig. 5.15, p. 121)

Altostratus: glow of sun (not halo) visible thru featureless cloud deck (Fig. 5.16, p.121)



Stratus: featureless cloud blanket. Sun not visible. (Fig. 5.19, p. 123)

Nimbostratus: See wet ground & scud (small, low, torn-looking clouds that move quickly) (Fig. 5.17, p. 122)

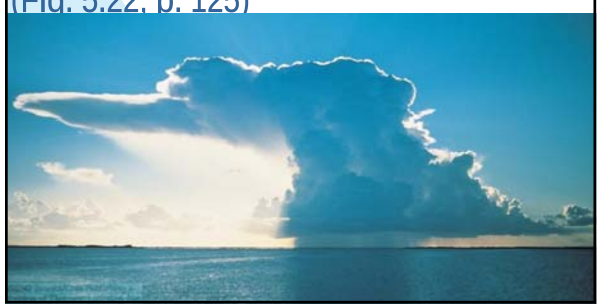


Stratocumulus: individual clouds about size of fist at arm's length (Fig. 5.18, p. 122)

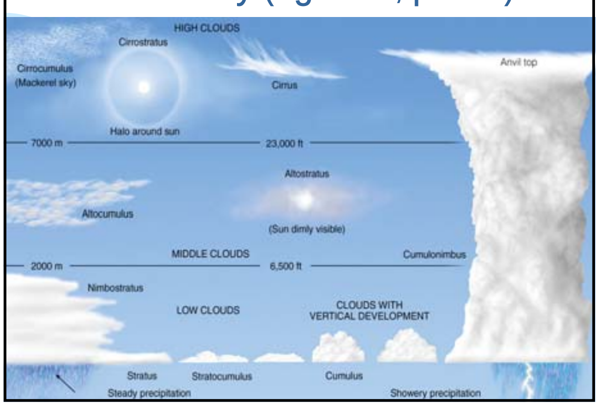
Cumulus humilis ("humility," so low cumulus): Fair weather cumulus (Fig. 5.20, p. 124)

Cumulus congestus: growing cumulus, like cauliflower, sky congested (Fig. 5.21, p. 125)

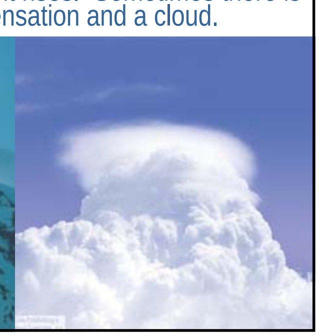
Cumulonimbus: Thunderstorm cloud, flat top. "Anvil" caused by upper level winds. Sharply defined base & sides (liquid water droplets), fuzzy top (ice). (Fig. 5.22, p. 125)



Cloud summary (fig. 5.23, p. 127)



Banner cloud above mtn (Fig. 5.25, p. 127)
Pileus (cap) cloud (Fig. 5.26, p. 128)
Air flows over barrier (mountain or cloud), cooling by doing expansion work as it rises. Sometimes there is enough cooling for condensation and a cloud.



Lenticular clouds: Lens-shaped clouds downwind of mountains. Sometimes confused with flying saucers (Fig. 5.24, p. 127)

Mammatus (same root as "mammal") resemble cow's udders. Often seen on underside of cumulonimbus anvil (Fig. 5.27, p. 128)

Measuring Cloud Ceilings (p. 131)

- Cloud ceiling = Height of lowest cloud base above ground.
- Determined by various methods
  - Timing how long it takes a small balloon to rise from ground and disappear into clouds. (Balloon rises at constant rate, so time x rising rate = cloud ceiling.)
  - Rotating-beam ceilometer, which reflects a light beam at an angle off the cloud base and uses trigonometry
  - Timing how long it takes a pulse of laser light to travel up to cloud base and reflect back to detector on Earth's surface (cloud ceiling = 0.5(time/c), where c = speed of light)

Geostationary Satellite Orbit (p. 129)

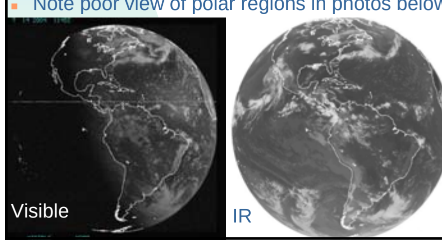
- A satellite 22,300 miles above the Earth's surface will take one day to circle the Earth, so a satellite at this distance above the equator rotates at the same rate as the Earth (360° per day) and appears to remain stationary above the Earth. Orbit is called "geostationary" or "geosynchronous" (synchronized with Earth).
- Satellites in this orbit can take pictures of the same area 24 hrs/day.
- Receiving antennas on Earth ("dishes") don't have to track.

Geostationary Satellite Orbit (cont.)

- Because satellite is 22,300 miles above equator and Earth has 8000 mile diameter, satellite has fairly good view of almost half of Earth.
- US has 2 geostationary weather satellites, 1 over Atlantic and 1 over Pacific. Europe, Russia, India, and Japan each have one geostationary weather satellite. These provide overlapping views east-west.
- Geostationary satellite does not see high latitudes well
- Science fiction author Arthur Clarke published idea for this orbit in 1945. Great for weather & communications satellites. See http://www.lsi.usp.br/~rbianchi/clarke/ACC.ETRelays.html

US Geostationary Satellites: GOES

- GOES: Geostationary Operational Environmental Satellite
- Recent pictures from US GOES satellites are at http://www.goes.noaa.gov, including
  - Views from over Atlantic (GOES East) & Pacific (GOES West)
  - Visible and infrared ("IR"), full disk and US sector
- Note poor view of polar regions in photos below.



GOES East visible (left) and IR (right) from 1145UTC (7:45 am EDT) 14 July 2004. Note day-night line in "visible" photo, not in IR.

Polar orbit (pp. 130-131)

- Polar-orbiting satellite nearly goes over poles, about 500 miles above Earth's surface. Much closer than geostationary.
- As satellite travels in north-south path, Earth spins eastward, so longitude of satellite drifts westward relative to Earth
- Typically sees each point on Earth twice a day, once during day and once during night. Sees poles on every pass.
- For information on US weather satellite program, see: http://noaasis.noaa.gov/NOAASIS/ml/genlsatl.html

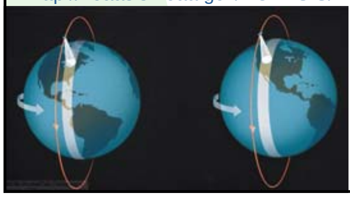


Fig. 5.32, p. 130: On one orbit, a satellite may see the east coast. By the next orbit, the satellite may see the west coast because the Earth has rotated.

Equipment on weather satellites (pp. 131-134)

- Satellite sensors are radiometers, i.e., devices that measure radiation (visible light, infrared, and/or microwave).
- Visible light pictures: higher resolution than infrared, but can only be taken during daytime
- Infrared pictures: lower resolution but day and night, because Earth & clouds emit infrared day & night. Hot things are bright in infrared, but negative of infrared image is shown so that picture resembles standard "visible" satellite picture of Earth: Cold clouds look white, warm Earth looks dark.
- Visible and infrared pictures are actually black & white but are often color-enhanced to bring out details

Sounders (p. 131)

- "Sounders" are radiometers that measure infrared radiation at various wavelengths, from which vertical profiles of temperature and humidity in various layers of the atmosphere can be computed.
- Disadvantage compared to weather balloon: Vertical resolution of satellite sounder is not as good as a weather balloon (radiosonde)
- Advantage compared to weather balloon: One satellite can "sound" many, many places; while a radiosonde only sounds one column.