Chapter 4 Atmospheric Moisture

- Phase changes of water
- Hydrologic cycle
- Evaporation and saturation
- Vapor pressure & saturation vapor pressure
- Boiling
- Relative humidity & dew point temperature
- Why is Florida more humid than California?
- Humidity and human comfort
- Measuring humidity
- Humidity and musical instruments

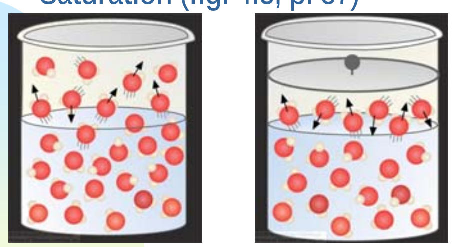
Phase Changes (pp. 86-88)

- Evaporation: liquid to vapor
- Condensation: vapor to liquid
- Sublimation: ice to vapor without liquid
  - Example: freeze drying
- Deposition: vapor to ice without liquid
  - Example: Frost forming on ground and windshields
- Transpiration: plants give up water as vapor to atmosphere through small openings on the underside of leaves

Circulation of Water in Atmosphere: Hydrologic Cycle (p. 88)

- In the Earth's hydrologic cycle, water exists in all 3 phases, solid, liquid, and gas (phase).
- 85% of evaporation occurs over oceans
- If all vapor in atmosphere were to condense and fall out, there would be 1 inch (2.5 cm) of rain or the equivalent in snow (about 10") over the whole Earth.
- Why is it impossible for all the vapor to condense out of the atmosphere?
- Given the 1 inch of rain statement above, how is it possible to have several inches of rain in a day?

Evaporation, Condensation, and Saturation (fig. 4.3, p. 87)



Evaporation: More liquid becomes vapor than vapor becomes liquid. Condensation: opposite is true.

Saturation (or equilibrium): Balance between rates of evaporation & condensation

Expressing amount of vapor in atmosphere (pp. 89-90)

- I will not ask you about absolute humidity, specific humidity, and mixing ratio defined on p. 89.
- If you want to be a meteorology major, learn specific humidity and mixing ratio. Absolute humidity is just water vapor density.

Vapor pressure (pp. 90-91)

- Vapor pressure = that part of air pressure which is due to water vapor.
- Vapor pressure is < 4% of total pressure, and that is found only in the most extremely humid tropical air.
- Saturation vapor pressure = vapor pressure that would exist at equilibrium with flat surface of water. Depends on temperature only. Saturation vapor pressure is normally greater than or equal to vapor pressure.
- You can forget about the rest of the air when talking about water vapor. Air does not "hold" water vapor.

Saturation vapor pressure (pp. 90-91)

- Triple point (temperature and pressure at which all three phases of water coexist at equilibrium): 0°C, 6 mb
- Table of saturation vapor pressure vs temperature For details, see p. fig. 4.10, p. 91

T (°C)	-10	0	10	20	30
Saturation vapor pressure (mb)	3	6	12	23	42

- For each 10°C (roughly 20°F) increase, saturation vapor pressure roughly doubles
- To do all sorts of weather calculations, see: http://www.srh.noaa.gov/elp/wxcalc/wxcalc.shtml

Vapor Pressure and Boiling (p. 92)

- Water boils when it is so hot that the saturation vapor pressure = pressure in the hot water = air pressure + small extra pressure due to weight of liquid water
- Bubbles in boiling water are 100% water vapor. Water is evaporating INSIDE the liquid.
- Higher elevations have lower pressures, so water boils at a lower temperature the higher you go.
- Example: At Denver, the "mile-high city," the surface pressure is about 850 mb instead of the sea level average of 1013 mb. At Denver, water boils at 95°C (203°F) instead of 100°C (212°F) at sea level.
- Because of this lower boiling temperature, boiled or steamed foods take longer to cook at high altitudes.

Relative Humidity (pp. 91-93)

- Relative Humidity = vapor pressure / saturation vapor pressure
- Examples:
  - If actual vapor pressure and saturation vapor pressure are both 12 mb, relative humidity = 12 / 12 = 100%
  - At sunrise, relative humidity is often 100%, so dew.
  - If actual vapor pressure is 12 mb and saturation vapor pressure is 24 mb, relative humidity = 12 / 24 = 50%
  - Relative humidity is often 50% in afternoon at hottest time of day.

Relative Humidity (cont.)

- In northern winters, the relative humidity indoors is LOW.
- Example:
  - Suppose outdoor temperature is 30° F and air is saturated
  - Suppose this air comes inside without changing the amount of moisture
  - When air reaches 50° F, amount of moisture hasn't changed but capacity has doubled, so RH = 50%
  - When air reaches 70° F, capacity has doubled again, so RH = 25%
- People use humidifiers to avoid dry skin and wood cracking (furniture & musical instruments)

Dew Point Temperature (pp. 93-96)

- Dew point (temperature) = temperature at which dew forms
- If amount of moisture stays constant during day, dew point is constant.
- You can measure dew point by measuring the temperature of the outside of a cold glass when condensation first begins.
- When air is cooled to the dew point, vapor pressure = saturation vapor pressure so relative humidity = 100%

Dew point & Relative Humidity

- Relative humidity can be 100% in the morning and 50% in the middle of the day with no change in amount of moisture in air.
- Example: Tallahassee during summer
  - Morning temperature: low 70's. Dew point: low 70's, so dew will form. 100% relative humidity.
  - Afternoon high: low 90's. Dew point: low 70's.
  - Recall that saturation vapor pressure doubles with a roughly 10° C (20° F) increase in temperature. This is roughly the change in temperature between morning and afternoon. If dew point does not change but air temperature increases by 10° C, then relative humidity = 50%

Average Dew Point in January (p. 94)

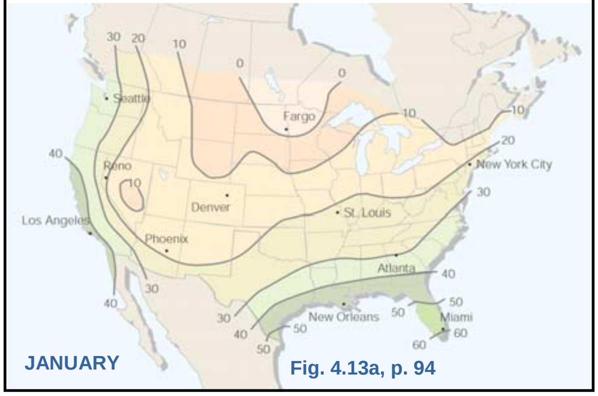


Fig. 4.13a, p. 94

Average Dew Point in July (p. 94)

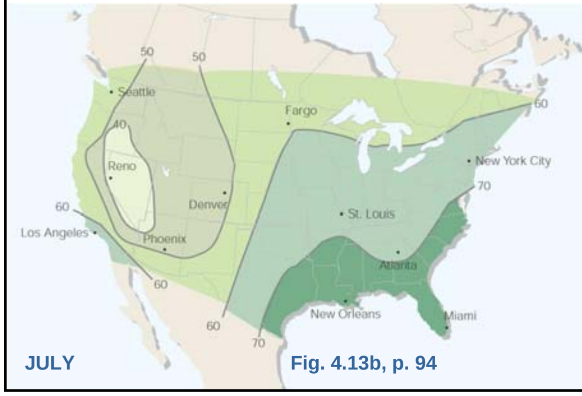


Fig. 4.13b, p. 94

Dew point vs relative humidity (pp. 93-96)

- "Dew point is a good indicator of the air's actual water vapor content. High dew points indicate high water vapor content; low dew points, low water vapor content." (quote, p. 94)
- Relative humidity indicates how close to saturation the air is.
- The air can have:
  - High relative humidity but low water vapor content.
  - Low relative humidity but at least moderate water vapor content.
- Give examples for these cases. Hint: Recall that saturation vapor pressure increases rapidly with increasing temperature.

Fig. 4.14, p.95: Dew point vs rel humidity

T=28°F, Dew point = 28°F, Relative humidity = 100%

T=95°F, Dew point = 50°F, Relative humidity = 21%

Cold example has higher relative humidity (because T=dew point) but less water vapor than hot desert (because of low dew point).

Judging relative humidity and vapor content

- High relative humidity → temperature (T) and dew point (T_d) are close
- Large amount of water vapor → high dew point (T_d)
- Example: Consider these 4 air samples.
  A: T=25°F, Td=20°F, B: T=45°F, Td=43°F,
  C: T=80°F, Td=75°F, D: T=110°F, Td=70°F
- Which sample has the highest relative humidity?
- Which has the lowest relative humidity?
- Which has the highest water vapor content?
- Which has the lowest water vapor content?

Why is the Southeast US more humid than California? (pp. 96-97)

- Air blowing from ocean is nearly saturated in both cases
- Summer water temp along California is about 55° F versus 80° F for Gulf coast, so Gulf Coast has 20° higher dew point

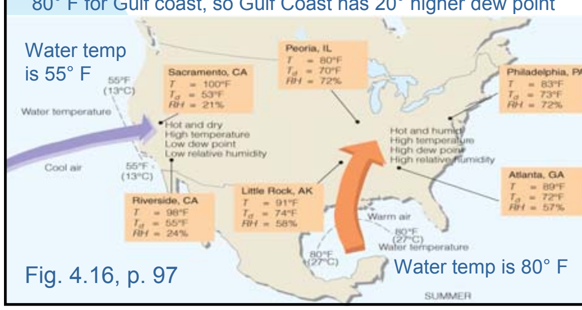


Fig. 4.16, p. 97

Relative humidity and human discomfort (p. 99)

- Text mentions increased number of deaths in hot conditions, such as in Chicago in 1995.
- In summer 2003, Europe suffered catastrophic heat wave. About 15,000 people died from heat in France in August 2003. Temperatures were as high as 40°C = 104°F. For more details, search Internet for: France "heat wave" death toll.
- Any hot day of any year, people working outside & athletes are at risk, as are children & pets in cars.
- Heat index: apparent temperature that "feels like" the measured temperature and humidity. See fig. 4.18 on page 100.

Measuring Humidity (pp. 99, 100, 102)

- Dew-point hygrometer: cool something until dew forms; measure its temperature = dew point temp
- Hair or gut hygrometer: measure length of stretched hair (horse or human) or sheep gut. Hair is about 2.5% longer at 100% rel humidity than at 0% rel hum. Days with high relative humidity are "bad hair days."
- Electrical resistance hygrometer: measure electrical resistance of layer of carbon on a microscope slide. Resistance decreases with increase in relative humidity. Traditional sensor for weather balloon.
- Humicap: humidity affects electrical capacitance of special capacitors. Measure their capacitance and convert to relative humidity. Newer sensor for weather balloons.

Measuring humidity: Psychrometer (pp. 99-100)

- Psychrometer: Two identical thermometers, one plain and one whose bulb is covered by a wet cotton "sock"
- Air blown past thermometers by fan or by swirling.
- Wet thermometer cooled by evaporation. Its temperature stabilizes after a minute or so as evaporative cooling is balanced by warming by surrounding air.
- Use tables in Appendix D (pp. A-8 to A-11) of textbook or see http://www.srh.noaa.gov/elp/wxcalc/wxcalc.shtml to get dew point & relative humidity from dry & wet bulb temps
- Fairly accurate method used for decades

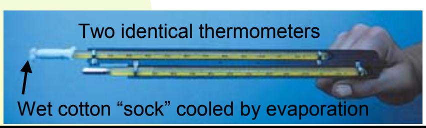


Fig. 4.19 p. 100

Measuring "weather" inside the home

The most common indoor weather station has 3 instruments, thermometer, barometer, and hygrometer, described below.

- Thermometer: bimetallic strip bent into a coil. One end of the coil is attached to the thermometer case. The other end is attached to the pointer in front of the temperature scale. The coil winds slightly tighter or looser depending on the temperature.
- Barometer: Discussed in chapter 8. If you can't wait, see "aneroid barometer" on pp. 195-196.
- Hygrometer: Relative humidity measurement based on length of a hank of hair or strand of gut inside the hygrometer.

Humidity and musical instruments

- Strings for guitars, harps, violins, etc. used to be made of gut.
- Gut is one of the most common humidity sensors, though, so the pitch of gut strings fluctuates noticeably from day to day, requiring retuning.
- Modern strings are typically nylon, which is insensitive to humidity, so they hold their pitch much better. Also, nylon is tougher than gut.
- Instruments made from wood (string instruments, clarinets, piano sound boards, acoustic guitars, etc.) can crack if they get too dry, so humidity monitoring & control is important for them.
- Many modern violin cases have built-in hygrometers
- Some violin cases made of Styrofoam: lightweight, insulating (air trapped in Styrofoam bubbles), protects from impact (just as bicycle helmets often made of Styrofoam).

The seasons and music

- Composers Franz Josef Haydn (Austrian) and Alexander Glazunov (Russian) have written pieces titled "The Seasons."
- Best known, though, is Antonio Vivaldi's "The Four Seasons." He wrote 4 sonnets about the seasons and set them to music as 4 violin concertos. For more about Vivaldi's "Four Seasons," see: http://www.bbc.co.uk/dna/h2g2/alabaster/A423154 http://www.baroquecds.com/vivaldiseasons.html