Climate vs. Weather

- Weather
  The physical condition of the atmosphere (moisture, temperature, pressure, wind)
- Climate
  Long term pattern of the weather in a particular area

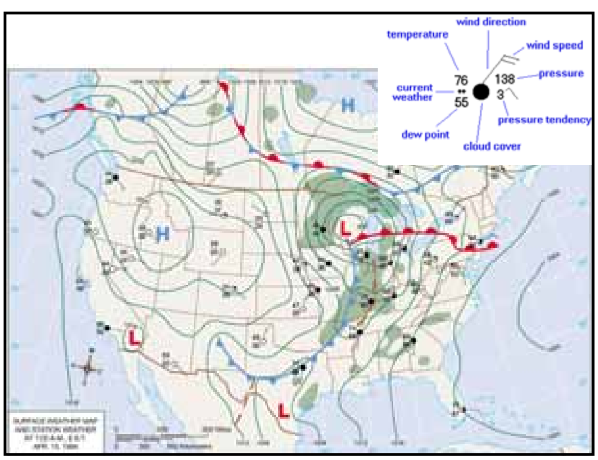
Table 1–1 • Averages of Annual Fatalities and Financial Costs of Weather Events During the 1990s

Event	Annual Mean Number of Fatalities	Annual Mean Loss (adjusted to 1999 dollars)
Floods	98	$5,300,000,000
Hurricanes	21	$5,400,000,000
Winter Storms	57	$329,000,000
Tornadoes	56	$777,000,000
Extreme Heat	282	$85,000,000
Extreme Cold	292	$368,000,000
Lightning	69	$38,000,000
Hail	1	$938,000,000
Total	**876**	**$13,000,000,000**

Source: Data from Pielke and Carbone, Bulletin of American Meteorological Society, March 2002.

Weather Basics

- Temperature
- Pressure
- Wind
- Humidity



Temperature

- Tends to stay the same over large horizontal distances.
- Changes rapidly across “fronts”.
  - Narrow zones that separate relatively warm from colder air.
- Reliable records have been kept for approximately 150 years.
- Good evidence that the average T of the globe has risen due to human influence.

Temperature Versus Heat

- Temperature is a measure of the average kinetic energy of all the atoms in a body.
- Heat is the total kinetic energy of all the atoms in the substance.
- The thermosphere has a very high temperature because each atom is going very fast.
- The thermosphere has a very low heat content because there are very few molecules.
  - Even though they are fast, there are so few that their total energy is low.

Pressure

- Air moves from high pressure to low pressure and creates wind.
- Pressure at the surface depends on the density of the air above and the elevation.
  - Low density air = low pressure at surface
  - High density air = high pressure at surface
  - Higher elevation=less air above=lower pressure
- Lines of equal pressure (at a given elevation) drawn on maps called “isobars”.
- Measured in millibars (mb – U.S.) or kilopascals (kPa – Canada) or inches of mercury (inHg – traditional).

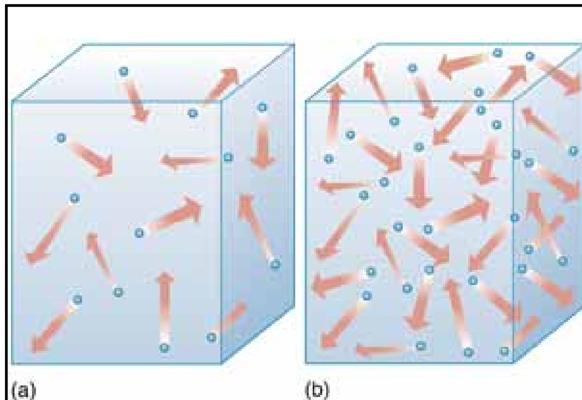
Ideal Gas Law

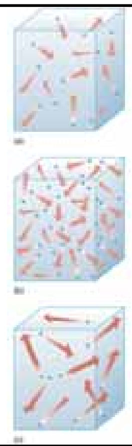
$PV=nRT$ or $P=\rho RT$

- Pressure times Volume equals the number of molecules times the gas constant times Temperature

$$PV \approx T$$

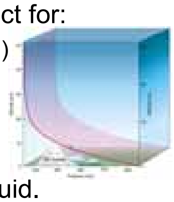
$$P \approx T/V$$





Measuring Pressure

- Use a barometer
- Mercury barometer must correct for:
  - Elevation (corrected to sea level)
  - Temperature (corrected to 0°C)
  - Gravity (set to 45° latitude)
- Report in mb, Pa, or inHg
- Aneroid barometer uses no liquid.
  - Collapsible chamber from which some air has been removed.



Unequal pressure

- If two fluids have unequal pressure and there is a pathway between them, the higher pressure fluid will move into the lower pressure fluid to equalize the pressure.
- Wind

Vertical changes in pressure

- Surface pressure vs. Sea level pressure
- Sea level pressure allows us to compare pressure at different locations to determine wind direction.
- At lower elevations we can assume 1mb/10m with change in elevation.
- Becomes unreliable at higher elevations.
  - Becomes less than 1mb/10m due to compressibility of gas.

Horizontal changes in pressure

- Cause of wind.
- Much smaller than vertical changes.
- Over N. America the total pressure difference may be 25mb.
  - A modest hill or tall building would afford the same pressure change.
- To visualize sea level pressure over the surface, isobars are plotted on maps.
  - Isobars = lines of equal pressure.
  - Closer isobars indicate stronger pressure gradient.

Horizontal pressure gradient

- Pressure gradients provide the force to move air and make wind.
- Pressure gradient force (PGF)
  - Larger pressure gradient force=stronger wind.
- Horizontal PGF can be measured at any altitude.
  - Gradients can range from 1mb/6km for very strong hurricanes to 1mb/1000km for stable air masses.
    - Vertical gradient can be 1mb/0.5km

Why isn't the air blowing up?

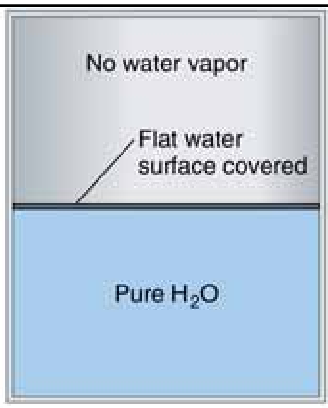
- Hydrostatic equilibrium between vertical PGF and gravity (weight).
- If no other forces in the vertical direction:
  - Gravity > vPGF → air sinks
  - Gravity < vPGF → air rises
  - Gravity = vPGF → no vertical motion

Measuring Wind

- **Wind vane** gives wind direction.
- **Anemometer** gives wind speed.
- **Aerovane** gives wind speed and direction.

Humidity

- Moisture in the air brings precipitation.
- Moisture in the air modifies temperature.
- Moisture carries heat from one location to another.
- Specific Humidity
- Relative Humidity
- Dew Point



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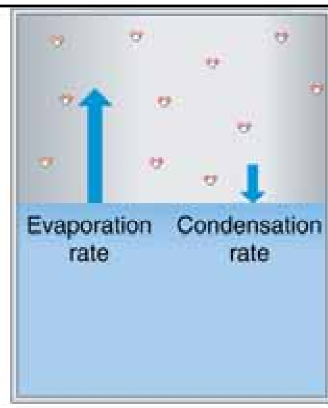

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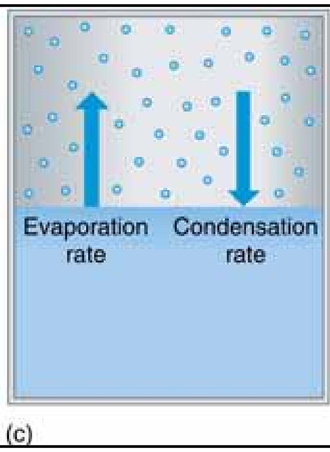
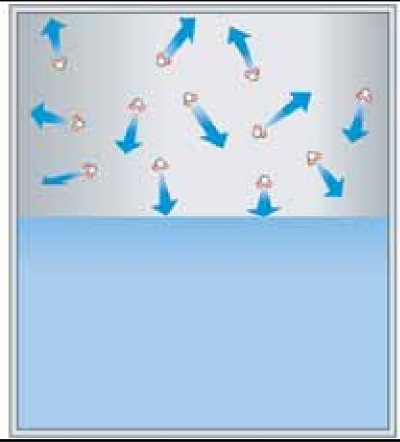




Evaporation, Condensation, and Saturation

- When evaporation and condensation are equal, the water vapor in the air is at saturation.
- evaporation > condensation
  - Below saturation
  - Water droplets decrease in size.
- condensation > evaporation
  - Above saturation
  - Water droplets increase in size.

Solid-Vapor H_2O equilibrium

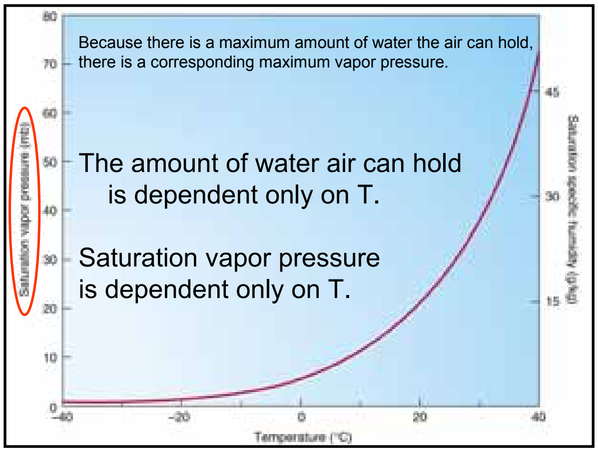
- Ice to vapor called sublimation
- Vapor to ice called deposition (can also be called sublimation).
- Deposition in the atmosphere is in some cases more important than condensation for cloud formation.

Sensible and latent heat

- If you take a block of ice at -40 °C and begin to add heat energy, the ice will increase its temperature until it reaches 0 °C.
  - Sensible heat (20cal/g)
- Additional added heat energy will not increase the temperature of the ice, but will melt it to a liquid.
  - Latent heat (80cal/g)

Indicies of water vapor content

- Partial pressure of water vapor called **vapor pressure.**
- Dependent on temperature and density of water vapor molecules.
  - Higher T = faster molecules that exert a greater pressure.
  - Higher ρ = greater mass to exert pressure.
- Density is much more important influence on vapor pressure than temperature!



Indices – Absolute Humidity

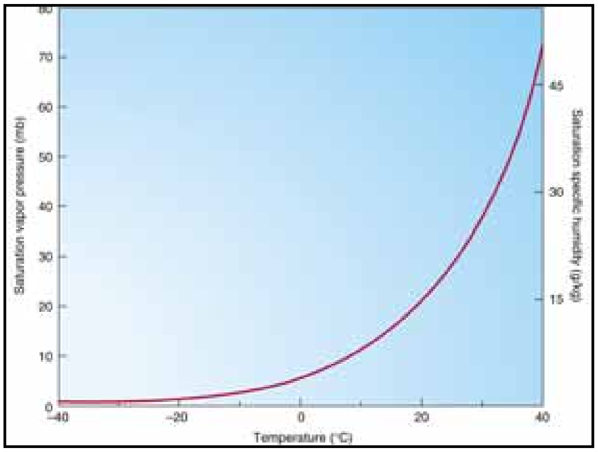
- Density of water vapor (g/m^3).
- Changes when density of air changes.
- Density changes with changes in T or P.
- Makes this a measure that is hard to compare between locations (horizontally and vertically).

Indices – Specific Humidity

- Mass of water in a given mass of air.

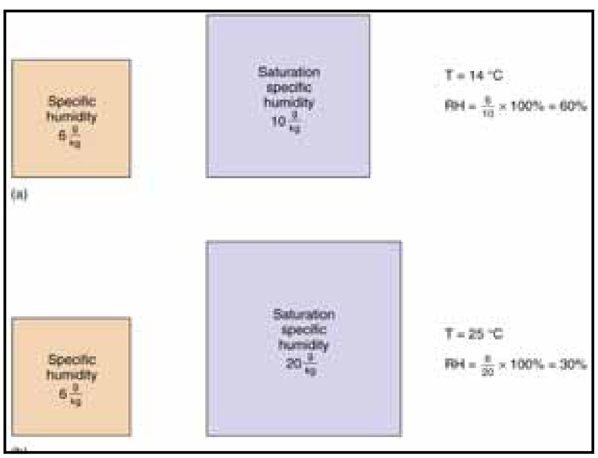
$$q = m_v/m = m_v/(m_v+m_d)$$

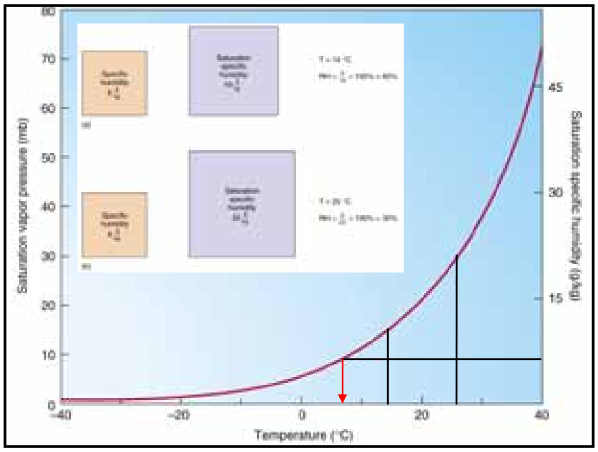
- Not influenced by changes in P or T.
- Water makes up 0.25% of the atmosphere is an example of this measure.
- Very useful, but not often used.
- Has a specific value at saturation.

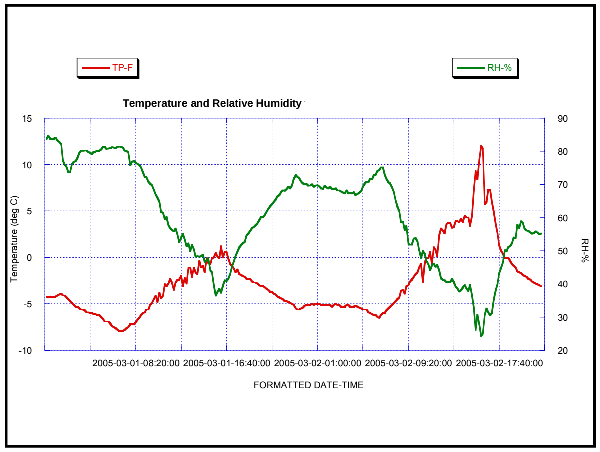


Indices – Relative Humidity

- Percent ratio of the specific humidity to the saturation specific humidity.
- Dependent and inversely proportional to temperature.
- At RH = 100%, condensation/deposition = evaporation/sublimation and water will begin to come out of vapor state.
- Precipitation tends to occur with RH slightly over 100%.

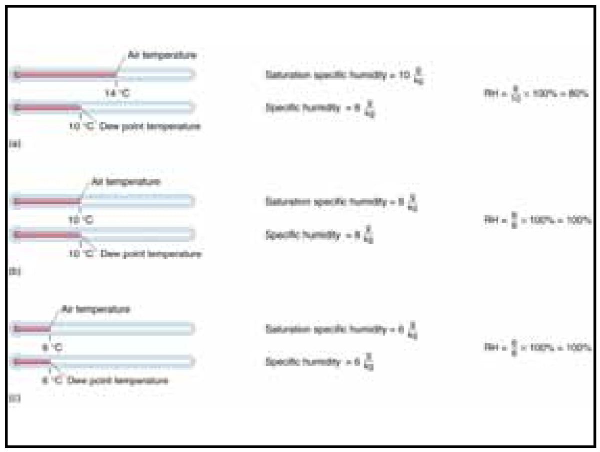


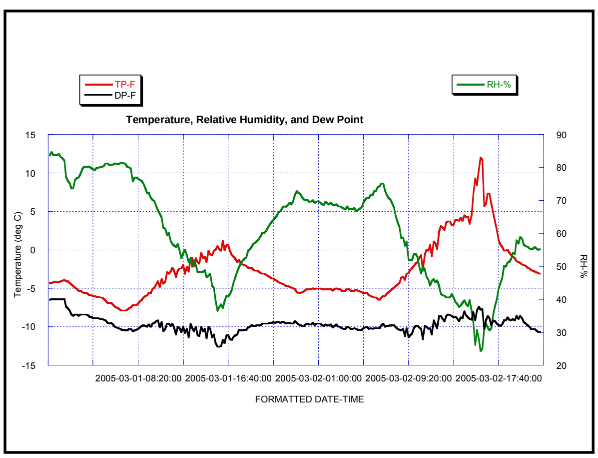


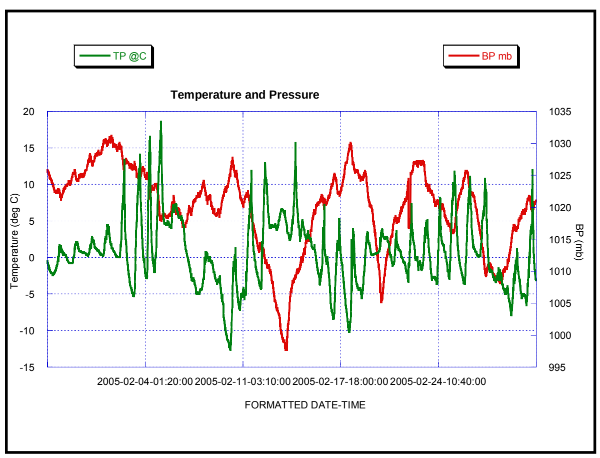


Indices – Dew Point

- Temperature of the air when saturated.
  - Always equal to or less than the air temperature
- Dependent almost exclusively on the amount of water vapor present.
- When combined with actual temperature it gives a measure of RH.

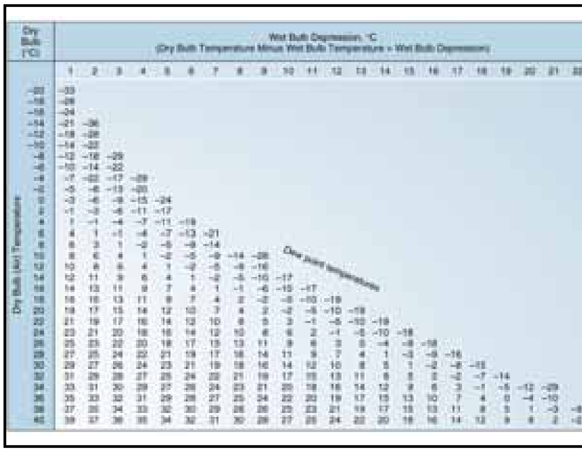


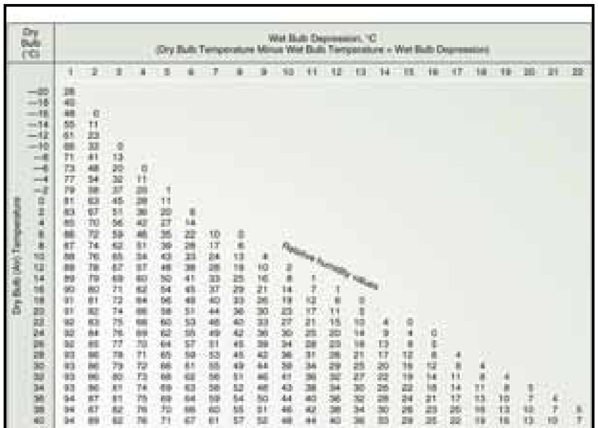


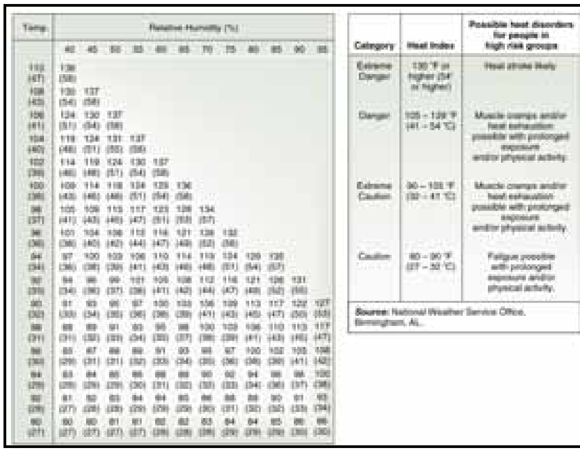


Measuring Humidity

- Sling psychrometer uses two thermometers.
  - Wet bulb and dry bulb.
  - Cooling of wet bulb is a function of the humidity.
    - Higher humidity results in lower wet bulb depression.
    - Use look-up tables to calculate any measure of humidity desired.
- Hair hygrometer uses human hair which expands and contracts with humidity changes.





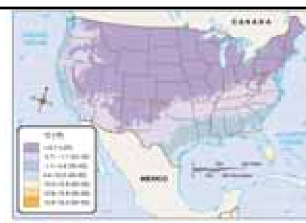


Distribution of Water Vapor

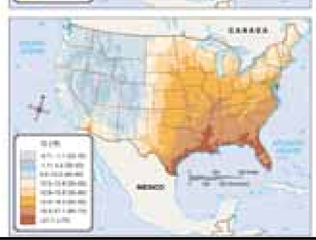
1. Local evaporation
2. Advection from other locations

- Most evaporation occurs over the ocean or large lakes.
- More evaporation near the equator.
- Farther the distance from evaporation source, the lower the water in the air.

Dew Points in January



Dew Points in July



Condensation and evaporation on water droplets in the atmosphere

- Dependent on more than mere temperature.

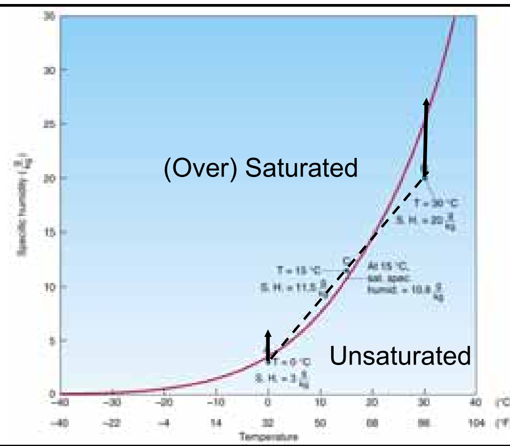
1. Curvature
2. Solution
3. Nuclei

How to reach Saturation

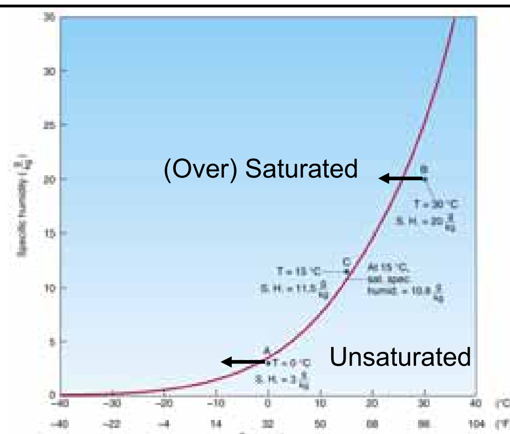
1. Add water
2. Mix cold air with warm moist air
3. Lower T to dew point

Add water

- Ex. Hot shower adds water to bathroom atmosphere leads to condensation on colder surfaces, then a fog forms.
- Precipitation falling through unsaturated air can evaporate and saturate the air.
  - Precipitation fog.



Early morning lake fog



Lowering T to dew point or frost point

- Air temperature changes occur in two general ways:
  1. Diabatic Processes
     - Involves the removal or input of heat.
     - Heat added by conduction from the ground or lost when passing over a cold surface.
     - Common in forming fog.
  2. Adiabatic Processes
     - No heat exchange.
     - Tends to result from expansion or contraction.
     - More important in the formation of higher clouds.