Atmospheric Humidity Concepts and Definitions
(Subtitle: Ways to Circumvent Steve's Pet Peeves)

Kinetic Theory – all molecules warmer than absolute zero are in constant rapid motion.

Kinetic Definition of Temperature – temperature is the **average speed** of the molecules in a gas. The molecular speed will vary about the average, some molecules being faster, some molecules being slower.

Equipartitioning – each gas gets a share of the any heat (kinetic) energy added to the system. The share each gas gets is not necessarily equal, but proportional to the heat capacity of the gas. In other words some gasses can absorb more heat and they get their share.

Some of the energy added to a molecule becomes **internal energy,** increasing the vibrational and rotational energy levels. This is ignored in simple considerations of Kinetic Theory and is a source of some error.

READ THE NEXT PARAGRAPH CAREFULLY
The atmosphere is **NOT** like a sponge and **air does NOT "hold" water vapor**. Dalton's Law of Partial Pressures says the major gasses are a **MECHANICAL** mixture and the individual gasses are independent, more like a jar of different colored marbles. The gasses of the atmosphere are merely roommates, sharing the same space.

Total atmospheric pressure is the sum of the individual pressures **(PARTIAL PRESSURES)** of all the gasses.

For convenience we divide the air into the **DRY GASSES** (oxygen, nitrogen, argon, carbon dioxide and other trace gasses) and **WATER VAPOR**.

A water molecule evaporates when collisions with neighboring liquid molecules impart enough kinetic energy (i.e. the molecule gains sufficient velocity) to break free of the attractive forces **(i.e. electrostatic forces = hydrogen bonds or alternately the force fields)** of neighboring molecules. AIR molecules can add to remove heat (kinetic energy) but the number density of gas molecules is so small that evaporation is primarily a function of water temperature and collisions between molecules in the liquid, not collisions with molecules above the interface.

A water vapor molecule condenses when collisions with neighboring gaseous molecules slow the vapor molecule enough so that when the vapor molecule gets close to the water surface the attractive forces **(i.e. electrostatic forces or hydrogen bonds)** of the liquid molecules can over come the velocity of the vapor molecule.

Removing energy from a parcel of air removes energy from each gas, but like equipartitioning when adding energy, molecules lose different amounts of energy with each degree of temperature change.

Water is the only atmospheric constituent that exists as a solid, liquid and gas at the same time in conditions found on earth. This is partly due to the bi-polar nature of the water molecule and resulting hydrogen bonds.

Vapor pressure is the partial pressure of water vapor, that is, the portion of total atmospheric pressure contributed by water vapor.

Saturation (ugh!!!) vapor pressure, more accurately known as **equilibrium vapor pressure** is a measure of the amount of water vapor in the air **when all available energy for evaporation has been used.** The **Equilibrium is dynamic,** that is evaporation and condensation are taking place at a break-neck pace but **the amount of condensation equals (thus EQUI-librium) the amount of evaporation.**

NOW……A THOUGHT EXPERIMENT

1. Place dry air (i.e. zero water vapor) over a water surface
2. Let it stand without changing the energy of the system (i.e. add or remove no heat)
3. Evaporation will take place, as soon as evaporation begins so too does condensation
4. The rate of condensation increases as the number of water vapor molecules increases but the rate of evaporation gradually slows. WHY?
5. Because there are **more and more vapor molecules to share the available energy** there will be more and **more slow molecules** therefore **more molecules that can be captured** by the electrostatic forces present at the liquid surface. **The rate of evaporation gradually slows** because the water surface cools as water molecules evaporate. This is simple, evaporating molecules take with them kinetic energy leaving behind less energetic (cooler) molelcules.
6. Eventually the rate of evaporation equals the rate of condensation and at that point the vapor pressure, the partial pressure of water vapor is the **EQUILIBRIUM VAPOR PRESSURE**, a.k.a. to less sophisticated students of the atmosphere as **SATURATION (ugh!!!) VAPOR PRESSURE**. Note both condensation and evaporation still occur.
7. Now add heat and the rate of evaporation increases, followed by the rate of condensation, stop adding heat and a new, higher equilibrium vapor pressure is reached.

Other Measures of Humidity –based on my diatribe above.

Relative Humidity – ask the question **RELATIVE TO WHAT???** Think of relative humidity as indicating the percent of energy available for evaporation that has been used. A RH of 50% means half the available energy has been used, a RH of 93% indicates 93% has been used **a relative humidity of 100% means that ALL the available energy has been used**, but **IT DOES NOT MEAN** that evaporation stops because we know the equilibrium is dynamic. If a molecule evaporates one must condense.

Dew Point Temperature (Frost Point Temperature if below freezing)

Common Definition: the temperature **to which a parcel of air must be cooled** for condensation to begin, or to reach 100% RH, or to reach equilibrium.

Molecular point-of-view: Begin to remove heat from a parcel of air that is not at equilibrium (remember this means evaporation > condensation). All the molecules slow and the rate of condensation increases at the same time the rate of evaporation decreases. Eventually the rates are equal and the RH is 100%. The temperature of the air is the Dew Point Temperature.

Wet Bulb Temperature

Common Definition: the temperature to which a parcel can be cooled by evaporating moisture into it.

Molecular point-of-view: A parcel not at equilibrium supplies energy to a water surface increasing the number of water molelcules ejected by collisions into the air. The air cools, this continues until equilibrium. The temperature of the air is the Wet Bulb Temperature.

Dew Point vs. Wet Bulb

DP is determined by removing energy in any way but evaporation and pressure change. Applications include nocturnal radiational cooling and contact cooling of air. WB is determined by removing energy only by evaporation. Applications include evaporative cooler air conditioning in desert climates and cooling air by evaporating water from water bodies and snow fields.

Rarely do meteorological situations fit into one of the above, example warm air passing over a cool ocean is cooled by contact cooling and by evaporation.

The Other Humidity Temperature

When cooling is by the lifting of air, the temperature at which condensation occurs is the **Adiabatic Condensation Temperature**, it is the temperature at the LCL. This will be familiar soon.