Notes for Lecture 5

Evaporation

Heat is absorbed during evaporation.
The energy absorbed by water molecules during evaporation is used to give them the motion needed to escape the surface of the liquid and become a gas.
This heat is referred to as the Heat of vaporization (2.5x106 J/kg).
It is the higher-temperature (faster-moving) molecules that escape the surface.
As a result the average molecular motion of the remaining water is reduced (evaporation is a cooling process, e.g., water evaporating on your skin)

Condensation

Heat is released during condensation.
The energy released by water molecules during condensation is equivalent to what is absorbed during evaporation and is referred to as the Heat of vaporization (2.5x106 J/kg) (condensation)
When it happens in the atmosphere it results in the formation of fog and clouds.
When water vapor condenses to form clouds it releases energy into the air, warming it and making it more buoyant.
The evaporation of water over tropical oceans and the resulting condensation (precipitation) over higher latitudes results in a significant transfer of energy from equatorial to Polar regions.

Water Vapor is completely invisible at visible wavelength, if you had IR goggles you could see it.

Partial Pressure: DEFINITION: The pressure exerted by some subset of molecules in a gas
Ex: Partial Pressure of N_2 = 78% of 100kPa
P_{N2}= 78kPa
Partial Pressure of O_2 = 21% of 100kPa
P_{O2}= 21kPa
Partial Pressure of Ar = 1% of 100kPa
P_{Ar}= 1 kPa
$P_{tot} = P_{N2} + P_{O2} + P_{Ar}$
P_{H2O} is variable and depends largely on the temperature of the air.

Saturation Vapor Pressure (of Water) (SVP)
Definition: SVP is the partial pressure of water vapor at equilibrium with liquid water at equilibrium or Steady State over a plane surface of water. Evaporation and Condensation happens at the same rate when the system is at Steady State.

There doesn't have to be air, AIR doesn't HOLD anything
- This is all regardless of # N2 or O2
- All you need is H_20_{liq} *and* H_2O_{vap}

Evaporation is caused by collisions in the liquid phase. Increase T = Increase number and intensity of collisions, which leads to increased evaporation.

Condensation caused by gas molecules colliding with the liquid surface. Condensation rate will depend on the concentration of water vapor in the air, which increases as Partial Pressure of water vapor increases.

Partial Pressures (PP) and Saturation Vapor Pressures (SVP) for Water

Saturated air is at equilibrium
So, what is the PP_{H2O} (PP hereafter)?
→ Go to figure 1 at bottom or a table in the text and look it up by temperature!
For 25°C the PP = 2.99 kPa at saturation.

Let's assume the air is not at equilibrium: e.g., PP < 2.99 kPa
Added a little bit of H_2O vapor? What happens to Evaporation?
Evaporation rate is the same because the temp. didn't change.
What happens to condensation? Condensation rate will go up. Condensation depends on collisions of the water vapor with the liquid!

EVAPORATION depends on TEMPERATURE
CONDENSATION depends on COLLISIONS

SVP represents the maximum amount of water vapor that can be present as a gas. If there's more of this gas then (the limit is exceeded) condensation will occur to bring the PP of water vapor to this limit which is equilibrium.

Some Definitions
Mixing ratio – mass of water vapor/mass of dry air (g/kg)
Specific Humidity - is the ratio of the mass of water vapor to the mass of dry air plus water vapor, and is sometimes referred to as humidity ratio.
Dew point temperature – temperature to which an air parcel must be cooled for condensation to take place.
Wet bulb temperature – temperature to which evaporation will cool a wet thermometer.

Relative Humidity
Measures how much water vapor is actually present relative to the 'limit' - the amount of water vapor at saturation for a given temperature.
- How close to the 'limit' we are

Example:
- SVP @ 25°C = 3 kPa
- If an air parcel is @25°C with a PP of 1.5 kPa… What is it's RH?

$$RH = \frac{\text{Partial Pressure of } H_2O \text{ Vapor}}{\text{SVP at the T of the air parcel}} = \frac{1.5 \text{ kPa}}{3 \text{ kPa}} = 0.5 = 50\%$$

If PP = 2.kPa, RH = 2 kPa/3kPa = 0.66666 = 0.67 = 67%

If PP = 4.kPa, RH = 4 kPa/3kPa = 1.3333333 = 1.3 = 130%

Eventually the PP would drop after condensation occurs (Condensation = when a cloud forms) and would ultimately settle at an RH = 100%

Such that: PP = 3kPa, RH = 3kPa /3kPa = 1 = 100%

Let's say PP = 1.5 kPa, T=25°C, RH = 50%
Are we at equilibrium? NO, the RH is 50% so we are not at equilibrium.
What happens if we cool this air parcel? To 20°C?
First, the SVP decreases to SVP @ 20°C = 22.kPa (see graph below).
What happens to the partial pressure?
PP Stays the same, we haven't added or taken away any water molecules.
What is the RH?
RH = 1.5kPa/2.2kPa = 68% by virtue of cooling the air parcel we caused the RH to go up. We did this by decreasing the 'limit'!

<u>RH can change due to:</u>
Change in the amount of water vapor (PP)
Change in the limit of water vapor (SVP depends only on T)

<u>Dew point Temperature</u>
The temperature at which an air parcel would be saturated (RH = 100%)
Another measure of humidity

Example: T=25°C. PP is 1.5kPa, dew point temperature is 14 °C (refer to graph in Figure 1 below).
When SVP = 1.5kPa then the RH would be 100%
If T→30°C RH would decrease.
If T→15°C RH would increase

ALL you need to get the Dew Point Temperature is PP!

<u>Example:</u> T = 20°C, PP = 1kPa

a) RH = ? RH = 1kPa/ 2.2kPa = 45%, Dew Point = 8°C

b) Add 0.5kPa of PP (PP 1.5kPa) → 1kPa/2.2kPa = 68% Dew Point = 14°C

c) T warms to 30°C what is RH? Dew Point?
SVP = 4, 1kPa/4kPa = 25% Dew Point = 8°C

Homework Question
The room you are in has air that has some humidity. Find the RH, PP and Dew Point Temperature for the air in this room.

To find the answers, put a thermometer in an soda/beer can that contains room-temperature water (let the water sit overnight). Add some ice and note the temperature of the water when condensation first forms on the side of the cup. This is the dew point. Use Figure 1 to determine and the RH and PP in the air.

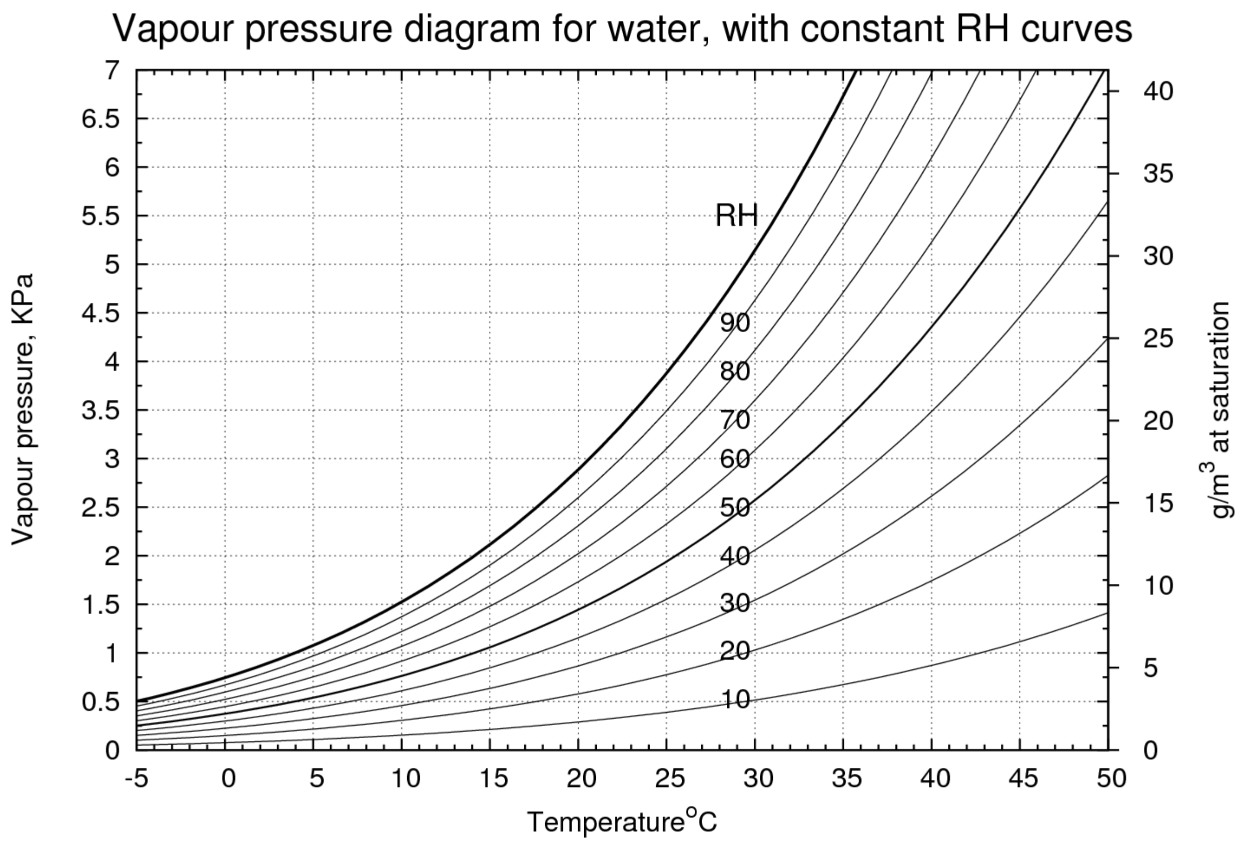

Figure 1 Saturation vapor pressure (KPa) & mixing ratio(g/m^3) vs temperature ˚C valid at sea level.