Atmospheric Moisture

Water vapor constitutes only a small fraction of the atmosphere, 0-4 % by volume, but is the single most important gas when it come to understanding atmospheric processes.

The Hydrologic Cycle

A continuous exchange of water among the oceans, the atmosphere, and the continents.

It also represents what is termed the ***water balance*** - a quantitative view of the cycling of water within the earth / atmosphere system.

The vast bulk of water is stored in the global oceans - 97% with less than 1000th of a percent tied up in our atmosphere.

But if the total amount of water in the atmosphere were to condense all at once it would cover the Earth to a depth of one inch.

The hydrologic cycle can be given by:

$$\mathbf{P = R_s + R_g + S + E + T}$$

but over long periods (year or more)

$$\mathbf{P = R_s + E + T}$$

or $\mathbf{P = R_s + ET}$ **(**ET=evapotranspiration)

ET measures the combined amount of evaporation from free water surfaces, soil, etc. and the transpiration from plants and animals.

But ET is hard to measure so we tend to estimate it as:

$$\mathbf{ET = P - R_s}$$

The rate of **ET** is controlled by four factors:

1. Energy availability
2. The humidity gradient from the surface
3. The wind speed immediately above the surface
4. Moisture availability

Other concepts related to **ET**:

Potential evapotranspiration (PET) – the amount of ET that will occur from a actively growing, short green crop that is well watered. Represents the maximum possible ET in the prevailing meteorological conditions. A relative measure of potential agricultural productivity.

Actual evapotranspiration (AET) – the quantity of water actually evaporated from the surface given the prevailing conditions. A measure used for determining soil moisture conditions and a the local water balance.

ET variables are measured from ***evaporation pans*** and ***lysimeters.***

Land ET ≈ 15% of the total; Ocean ET ≈ 85% of the total.

Residence Time: The time for one molecule of water vapor to cycle in and out of the atmosphere - 6-8 days - very efficient cycle!

Atmospheric Moisture

Water is the only substance at earthly temperatures that can exist in three states - a gas, a liquid, and a solid. Water is transferred between these three states by:

- Evaporation - a cooling process
- Condensation - a warming process
- Sublimation - a cooling process
- Deposition - a warming process

(relative to the surface from where the process is happening)

Evaporation is a function of wind and temperature:

Wind E Wind E
T E T E

(energy helps the molecules break the surface tension)

Also: in any parcel of air, they are numerous microscopic particles - dust, smoke, salt, etc. (CN) - and warm air molecules bounce off of CN more readily, cool air molecules are slower and have a better chance of adhering to the CN.

∴ **Condensation is more likely to occur as the air cools and molecular speed decreases.**

∴ **Warm air holds more water vapor molecules before becoming saturated than cool air!**

Moisture variables:

Dalton's law of partial pressures:

$$\sum P_T = P_{N_2} + P_{O_2} + P_{AR} + \ldots + P_{CO_2} + P_{H_2O}$$

where P_{H2O} = vapor pressure = e

e = the pressure exerted by the water molecules per volume of air.

Higher T **P_{h2o} ⇑** **Lower T** **P_{h2o} ⇓**

At dynamic equilibrium, condensation = evaporation and you have saturated air.

Saturation Vapor Pressure = e_s or the maximum amount of water vapor necessary to keep moist air in equilibrium with a surface of pure water or ice.

Also: the maximum amount of water vapor that air can hold at a given Temperature and Pressure.

Parcel Theory - way in which we can examine how various atmospheric processes occur. Usually given as one unit volume of air.

Humidity is a way of specifying the amount of water vapor in the air.

Absolute Humidity: is the mass of water vapor in a given volume of air.

But as air moves, changes in temperature and pressure cause changes in the volume of the air - therefore, this measure is not conservative and not widely used in meteorology. Most of the time you hear about the:

Mixing Ratio: the mass of water vapor in a unit mass of dry air.

Not affected by changes in temperature and pressure!

Relative Humidity: is the ratio of the air's actual water vapor content compared with the amount of water vapor required for saturation to occur at that temperature.

* most misunderstood humidity measure * It simply measures how near the air is to saturation!

$$RH = \frac{w}{w_s} x\ 100 = \frac{\mathrm{e}}{\mathrm{e_s}} x\ 100$$

How relative humidity changes:

Adding or subtracting moisture -

@ constant Temperature add water vapor and RH $\Uparrow$
@ constant Temperature remove water vapor and RH $\Downarrow$

Example: hot shower, in nature this is evaporation from the oceans.

Changing Temperature - since $\mathbf{e}_s$ is a function of Temperature

@ constant **e** increase the T ⇑ and RH ⇓
@ constant **e** decrease the T ⇓ and RH ⇑

Natural Changes in Relative Humidity:

In nature a change in relative humidity is caused by temperature variations occurring in three main ways:

- RH changes as daily temperatures change.
- RH changes as air moves from one location to another.
- RH changes as air moves vertically in the atmosphere.

Relative Humidity and Human Discomfort:

<u>Its not the heat, its the humidity!</u>

True: when T ⇑ and RH ⇓ evaporation from perspiration cools us down.
But: as T ⇑ and RH ⇑ body moisture does not readily evaporate - we feel hotter!

Relative Humidity and Dew Point:

Dew Point Temperature (T_d)- is the temperature to which a parcel of air would need to be cooled to reach saturation. Any further cooling below this point causes condensation to occur - dew, fog, clouds.

High T_d - high water vapor content
Low T_d - low water vapor content

Used to predict formation of dew, frost, fog, and minimum temperatures.

Time	Dew Point T	Temperature	RH
3pm	50°F	60°F	80%
7pm	50°F	55°F	90%
11pm	50°F	50°F	100%
3am	50°F	49°F	100%

Saturation

* Contrary to popular belief, white frost is not frozen dew. Rather, white frost (hoar frost) forms on occasions when the dew point of the air is 0°C or below. Thus, frost forms when the water vapor changes directly from a gas into a solid, without entering the liquid state - this process is called **deposition**.

Other Measurements:

Wet-bulb Temperature (T_w) = is a good measure of how cool the skin can become. It is the lowest temperature that can be obtained by evaporating moisture into the air. Measured by a **psychrometer** (sling).

The wet-bulb depression (**$T - T_w$**) is often used:

Large **$T - T_w$**	Dry air (deserts)
Small **$T - T_w$**	Moist air (tropics)

A comparison of measures:

$$T_d \leq T_w \leq T_a$$

The equality of the three measures on exists when the air is saturated.

Density of Dry -vs- Moist Air:

Dry air is mostly N_2 and O_2

Moist air contains N_2 , O_2 , Ar, + ... + H_2O

If we examine the weight of a mixture with the number of molecules the same:

∴ **The weight of dry air > moist air**

∴ **Hot, humid air is less dense or lighter and has great consequence in cloud formation and precipitation as light air rises. Also in sports - all else being equal, balls travel further and bikers ride faster on hot, humid days - air is light!**

Global Variations in Moisture:

Poles have low dew points and low temperatures but the air is closer to saturation ∴ **high RH.**

Latitudinal Variations - caused by the movement of air masses and their relative position to water bodies. Also major geographical features.

Atmospheric Water Content:

Precipitable Water Vapor (PVW) expresses the amount of water vapor that is available to fall as precipitation and, in a cloud-free atmosphere, the amount that interacts with both short and long wave radiation.