Agronomy 406
World Climates

February 13, 2018

Hydrologic cycle.

Team 4 Climate News presentation this Thursday.

Review:

METED module, Understanding the Hydrologic Cycle

Active review session for the midterm

Your team will be given two questions, selected from questions submitted by other teams.

- Each question will be answered by the individuals in two or three teams.
- After answering each question as individuals the team will work together to formulate an answer.

The format will be almost the same as the midterm:

- You will have limited time (about 15 minutes) to answer each question.
- Closed book, no calculators.
- Answers will be graded as an in-class assignment.

Submitting your questions

Each team will submit three potential exam questions using the form linked from the course schedule (due by start of class Thursday). See syllabus and form for details.

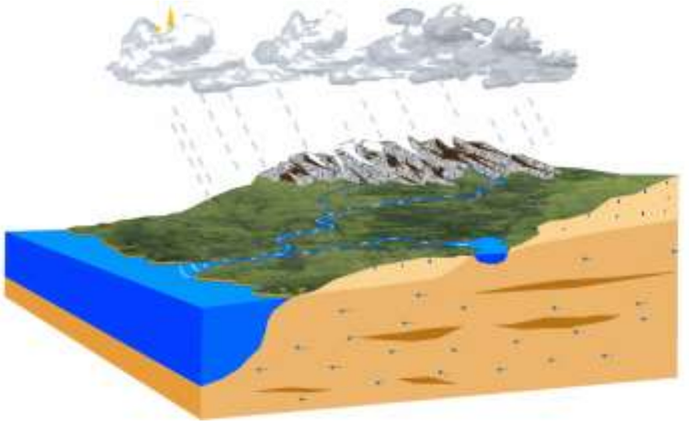
A midterm exam from a previous year is also linked to give you an idea of appropriate questions.

Questions should focus on understanding and not just memorization. Example:

> Instead of "List the places where rainfall increases during an El Niño."
>
> Ask "Why does rainfall increase in some places along the equator and decrease in others during an El Niño?"

It is to your advantage to submit questions that will end up being used on the exam, since you will know the answer!

What is hydrology?



From the module:

Hydrology is the scientific study of the waters of the earth.

Hydrology examines the properties of water as well as its planetary occurrence, distribution, and movement.

U.S. Geological Survey definition is a little more detailed:

Hydrology is the science that encompasses the occurrence, distribution, movement and properties of the waters of the earth and their relationship with the environment within each phase of the hydrologic cycle.

animation from Michigan State University Department of Civil & Environmental Engineering, http://www.egr.msu.edu/hydrology/Home/index.html

Where's the water?

About 97% of the water on Earth is in oceans.

Sea water is not **potable** (suitable for drinking) or usable for agriculture:

- Salt content of sea water is …?
- California standard for drinking water is < 0.1%.
- Salinity > 0.5% can affect sensitive crops (beans, carrots, onions, peppers, lettuce).

Estuaries are places where fresh water (from rivers) mixes with salt water.

- Examples: Chesapeake Bay, Gulf of St. Lawrence, Thames, Rio de la Plata

Where's the fresh water?

Less than 3% of the water on Earth is potable.

About **2%** is in the **cryosphere:** glaciers and polar ice caps (mostly Antarctica).

A little less than **1%** is in **groundwater**, i.e., water stored beneath the surface.

Lakes and rivers hold only about 0.01%.

- **Lake Baikal** is the largest single lake by volume – contains about 1/5 of the world's liquid fresh water.
- All five Great Lakes together contain almost as much water as Lake Baikal.

About **0.001%** is in the **atmosphere.**

Atmospheric moisture: Precipitable water

If all the water vapor in the atmosphere was condensed it would produce about 2.5 cm (1 inch) depth of liquid water when averaged over Earth's surface.

The depth of water that would result if all the vapor in a column of air was condensed to liquid is called **precipitable water.**

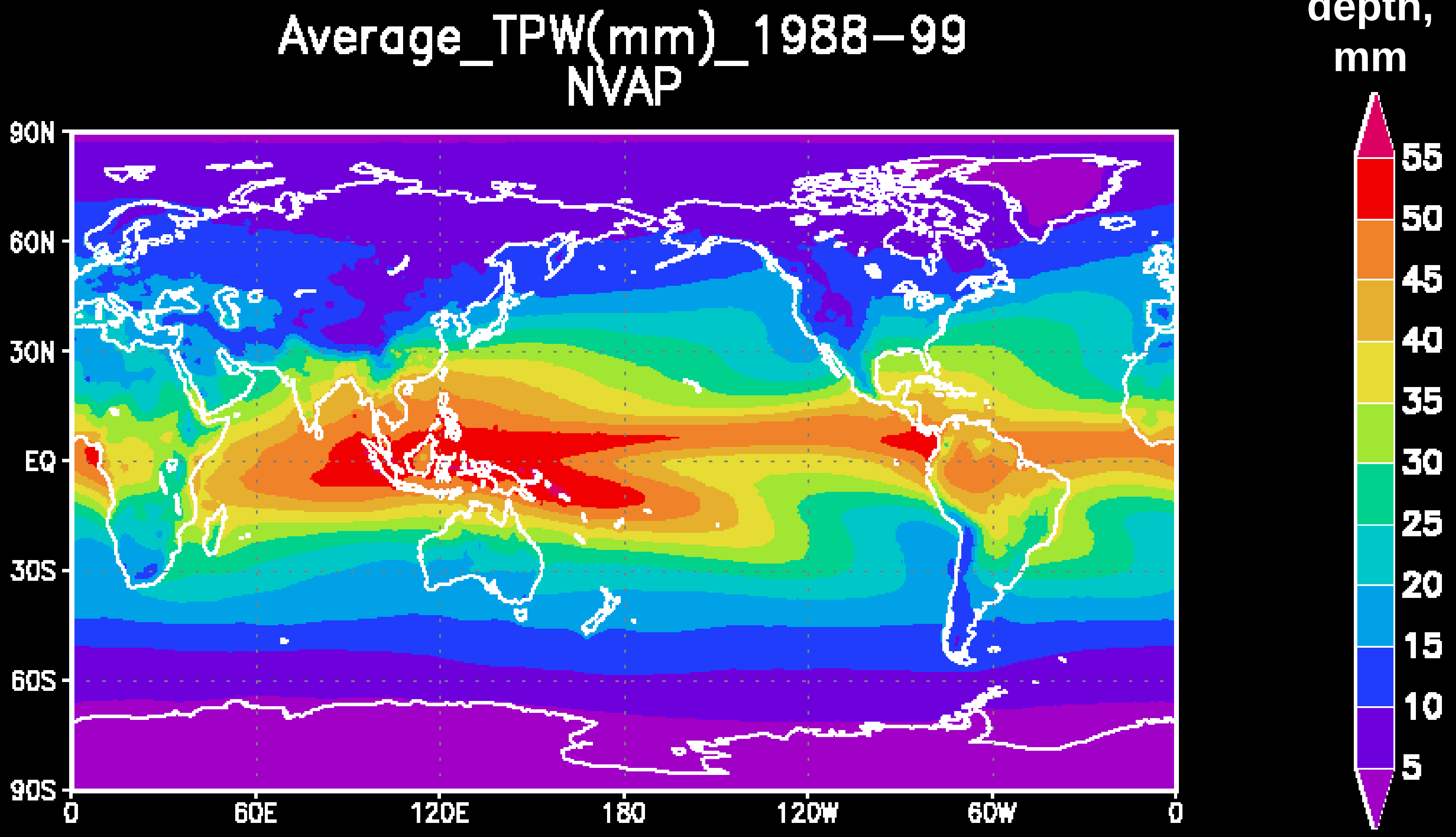
Distribution of atmospheric moisture (precipitable water) is uneven.

In what regions on Earth do you expect precipitable water to be high?

In what regions do you expect precipitable water to be low?

Explain your answers.

Estimate of climatological average precipitable water (combined radiosondes and satellites)



Distribution of atmospheric moisture

Distribution of atmospheric moisture is uneven, **mostly** because of differences in temperature (and thus saturation vapor pressure):

Tropical locations average about 5 cm of precipitable water.

Polar latitudes average about 0.5 cm.

Other influences include terrain height, ocean surface temperature, etc.

Water budgets

The most basic form of the water budget is:

"The difference between inflows and outflows of water leads to an increase or decrease in water storage." (in English)

$I - O = \Delta S$ (as an equation)

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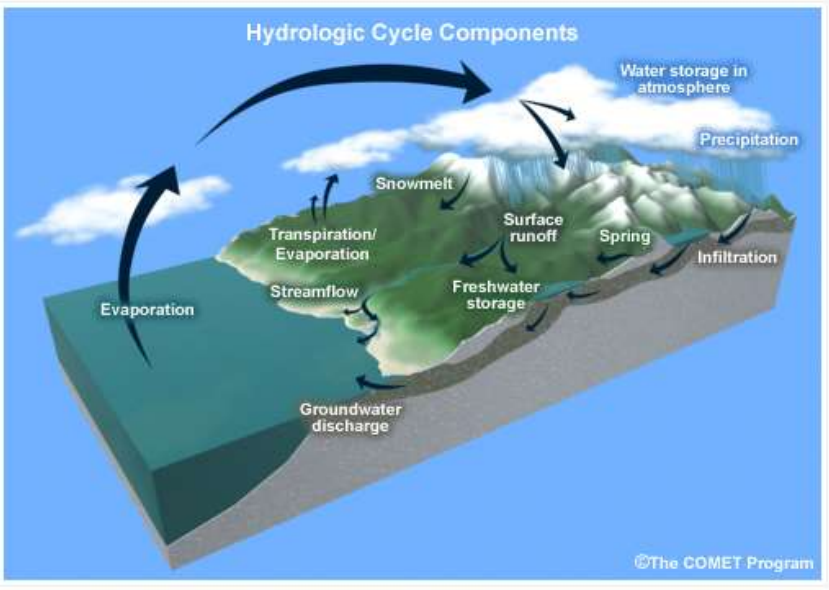
This is a form of **conservation of mass:** mass cannot be created or destroyed (in this case, mass of water).

Difference between inflow and outflow must be taken out of or enter into storage – not magically appear or disappear!

Studying the hydrologic cycle

Since we are studying a **cycle,** we can begin at any point.

We will start at the bottom: **groundwater and soil water.**



Subsurface water

Water beneath Earth's surface exists in two main zones:

A **saturated zone** exists where all or nearly all of the space between solid components is filled with water.

Top of the saturated zone is the **water table.**

Saturated zone may serve as an **aquifer** (implies water can be readily extracted).

In the **unsaturated zone** the spaces between the solid parts are not completely filled with water.

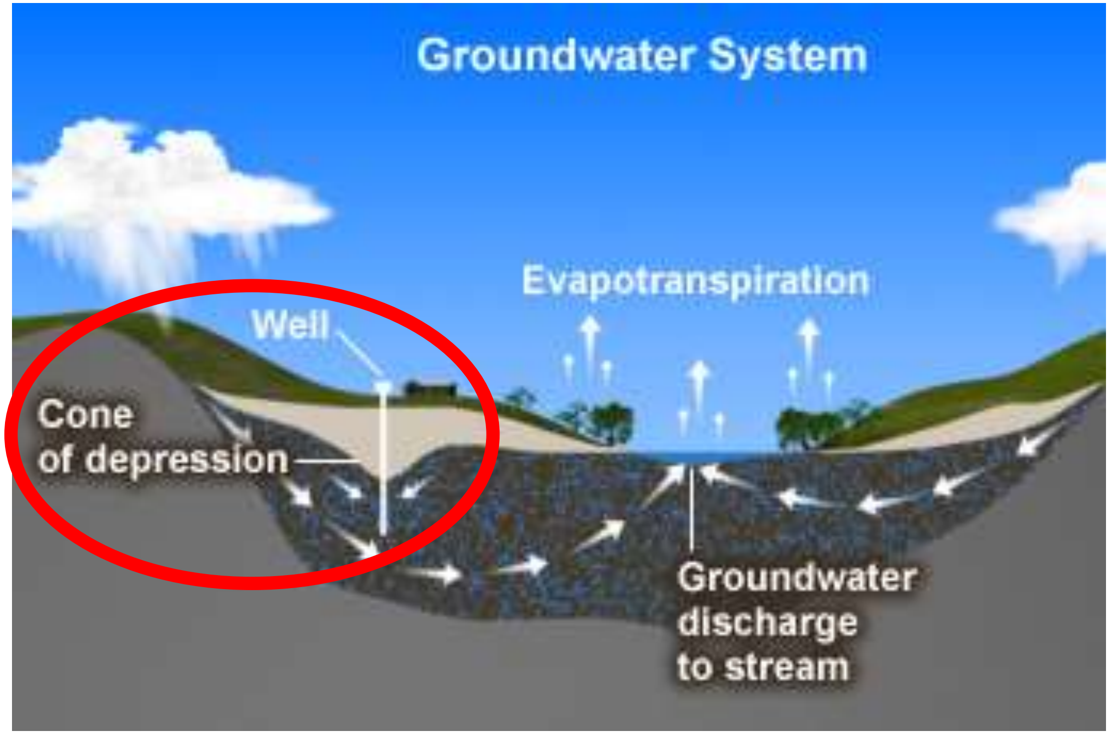
Also called the **zone of aeration** or the **vadose zone.**

Usually "groundwater" refers to water in the saturated zone. Sometimes "groundwater" is used to include all subsurface water (including soil water, ice, etc).

Subsurface water

Effects of groundwater withdrawals

The **water table** is the top of the saturated zone.



Withdrawal of ground water causes a cone or "dimple" in the water table.

This reduces the level of the water table, so that water has to be pumped higher. The water table may become so deep that the aquifer is depleted or pumping becomes uneconomical.

image from the COMET program

Effects of groundwater withdrawals

Replenishment of ground water is called **recharge.**

In many locations ground water is being withdrawn faster than it is recharged.

Since water takes up space below ground, this can cause **subsidence** (sinking) of the local terrain.

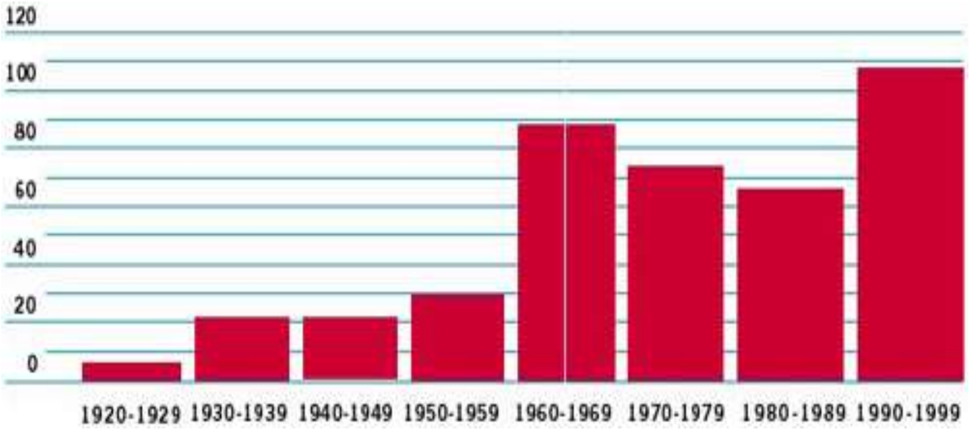
In coastal areas, subsidence can cause relative sea level rise.

Land subsidence: Venice, Italy

Withdrawal of water from aquifers under the city has caused land subsidence.

Since Venice already is at sea level, this has led to flooding events called *acqua alta* ("high water").

Change in annual frequency of *acqua alta* events > 1 meter, 1920-1999



http://www.fodors.com/news/venices-acqua-alta-6194.html
http://people.umass.edu/latour/Italy/venice_water/

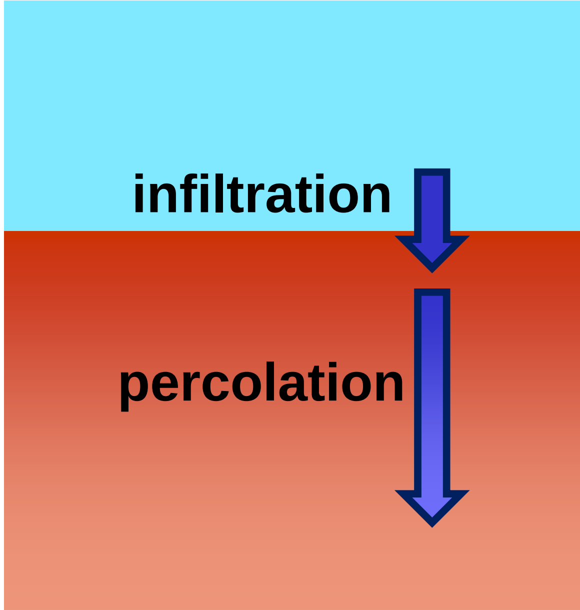
Movement of soil moisture in the unsaturated zone

Two processes:

Infiltration is entry of liquid water **into** the soil.

Percolation is movement of liquid water **within** the soil.

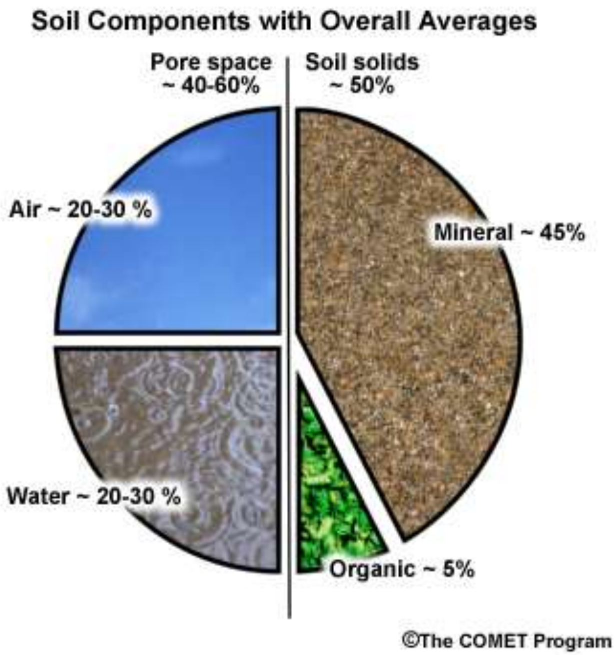
Both infiltration and percolation are strongly affected by soil properties.



What is soil?

Soil contains solids and pore space.

- Solids include **minerals** and **organic matter.**
- Pore space is filled with **water, air,** or a fraction of each.
- Soil water often is expressed as **volumetric moisture:** fraction of **total** soil volume that is made up of water. (**Remember** this definition...)



Percentages of each component vary greatly.

- Large variations can exist over small distances.

Soil composition and texture

Porosity is the fraction of pore space in a sample of a given soil. (**Remember** this definition...)

Porosity varies in a complex way depending on soil **texture:** fraction of particles of different sizes, i.e., sand, silt, or clay.

Porosity varies between about 40-50% depending on soil type.

Texture	**Porosity**
Sand	0.437
Loamy Sand	0.437
Sandy Loam	0.453
Loam	0.463
Silt Loam	0.501
Sandy Clay Loam	0.398
Clay Loam	0.464
Silty Clay Loam	0.471
Sandy Clay	0.430
Silty Clay	0.470
Clay	0.475

from Chow et al., *Applied Hydrology*

Soil texture affects water movement: Gravity and capillary forces

Two main forces affect water movement within the soil:

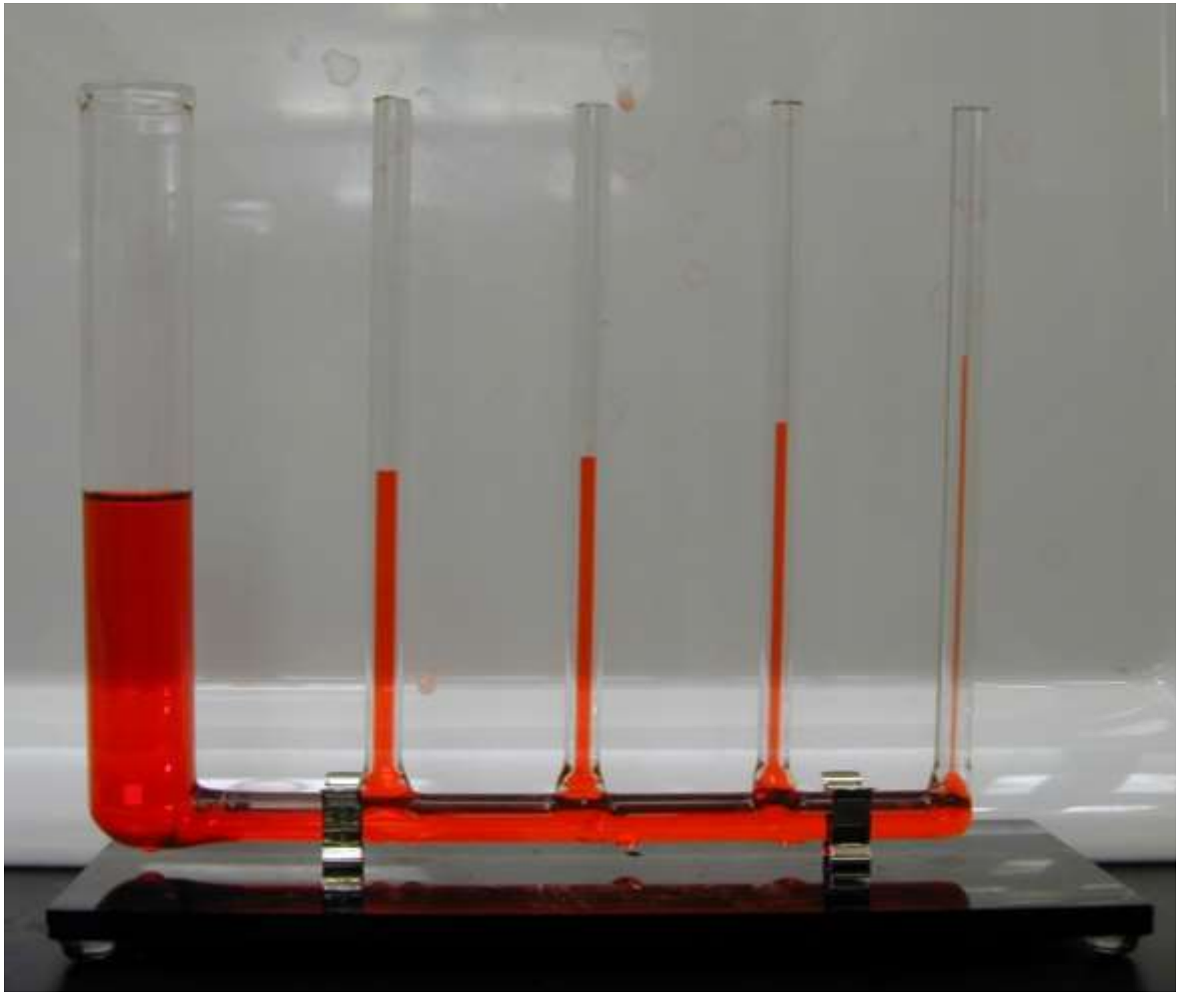
Gravity makes water drain downward.

- Affected by size of pore spaces: tight spaces obstruct drainage.
- Gravity force increases as soil becomes **wetter**.

Capillary forces are due to adhesive forces and surface tension of water between soil particles.

- Tend to be larger for **tight pore spaces.**
- Capillary forces increase as the soil becomes **drier**.

Capillary forces



Capillary forces draw water farther into the narrower tubes, just as they act more strongly on water in tight pore spaces.

Soil moisture values

There are three values that you often will see when discussing soil water.

Saturation

Field capacity

Wilting point

What do these mean? How do they relate to something we can understand?

Important soil moisture values

Saturation: All of the pore spaces are filled with water.

At saturation, what is the relation between volumetric moisture and porosity? (**Remember** their definitions?)

Field capacity: Water content where gravity and capillary forces roughly balance, so drainage is small.

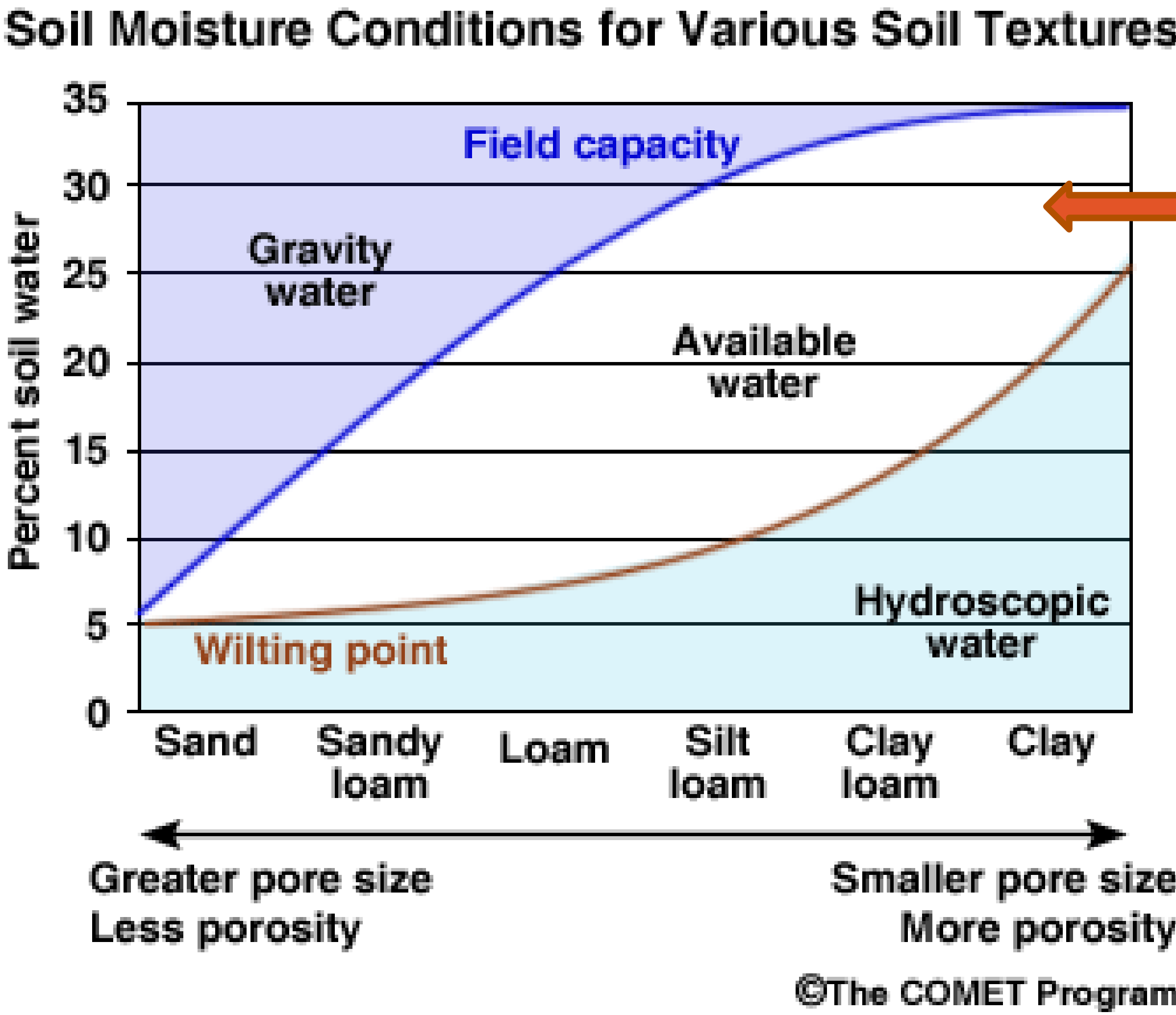
This is **not** saturation.

Wilting point: Water content where plants no longer can extract moisture against capillary forces.

This is **not** the point at which soil is totally dry.

You can use a sponge to get an idea of what these mean.

Soil texture has a big effect on soil water movement and availability



Available water (the white area) is the water between field capacity and wilting point.

Soil water budget

$$\Delta S = (P + I) - (E + R + D + \Delta T)$$

As before: The difference between **inflows** and **outflows** leads to a change in **storage.**

Inflows:

P = precipitation

I = irrigation

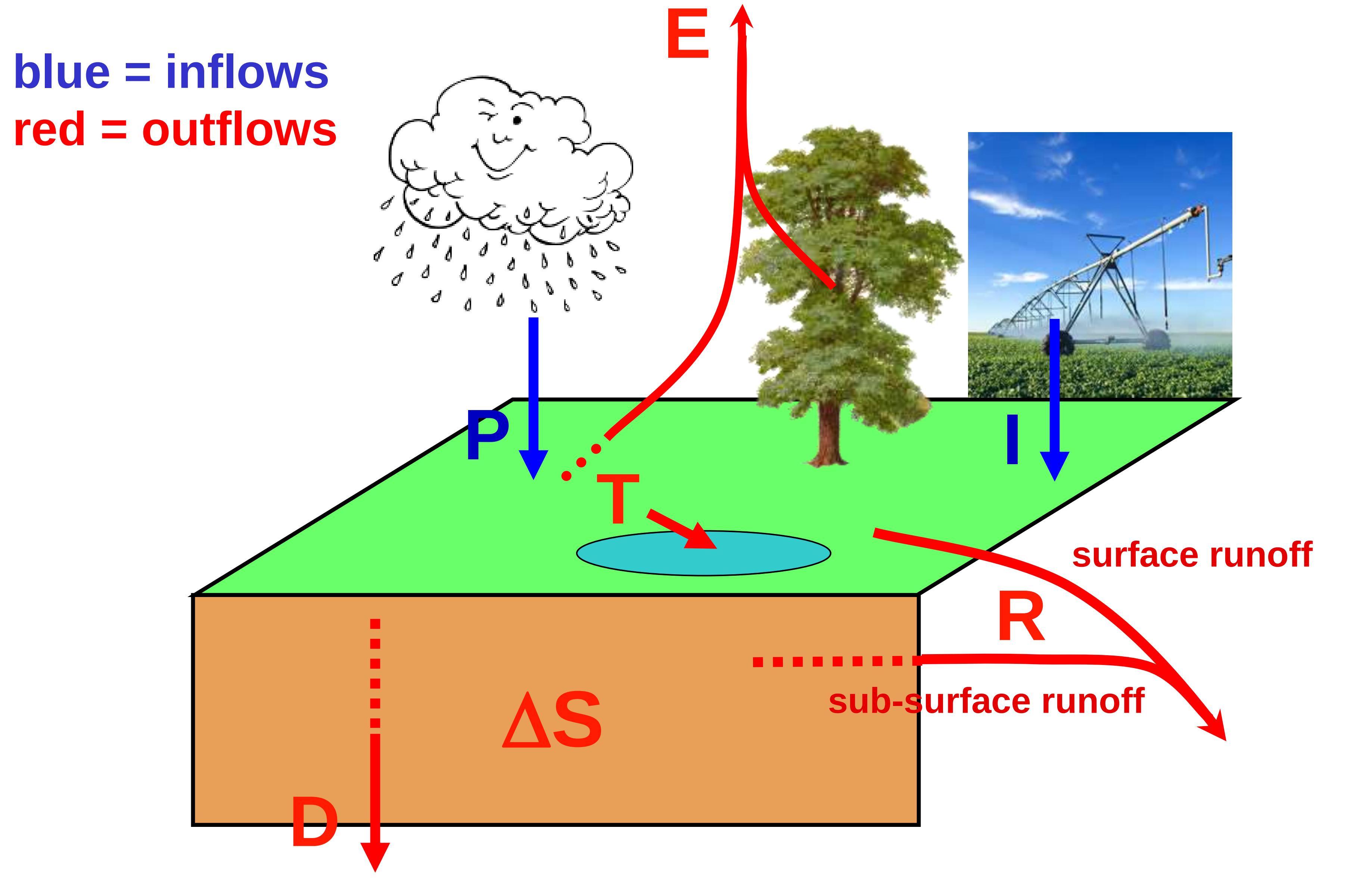
Outflows:

E = evapotranspiration

R = runoff

D = drainage (e.g., to the saturated zone)

ΔT = change in storage in surface water (ponding, etc.)


blue = inflows
red = outflows
E
P
T
I
surface runoff
R
sub-surface runoff
ΔS
D

Applications

In your teams, discuss a **practical application** where it would be useful to understand the **soil water budget** and the **reasons why it varies.**

Moving water from the ground to the atmosphere: Evapotranspiration

What is it?

evaporation (from soil or water)

+ transpiration (by plants)

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evapotranspiration

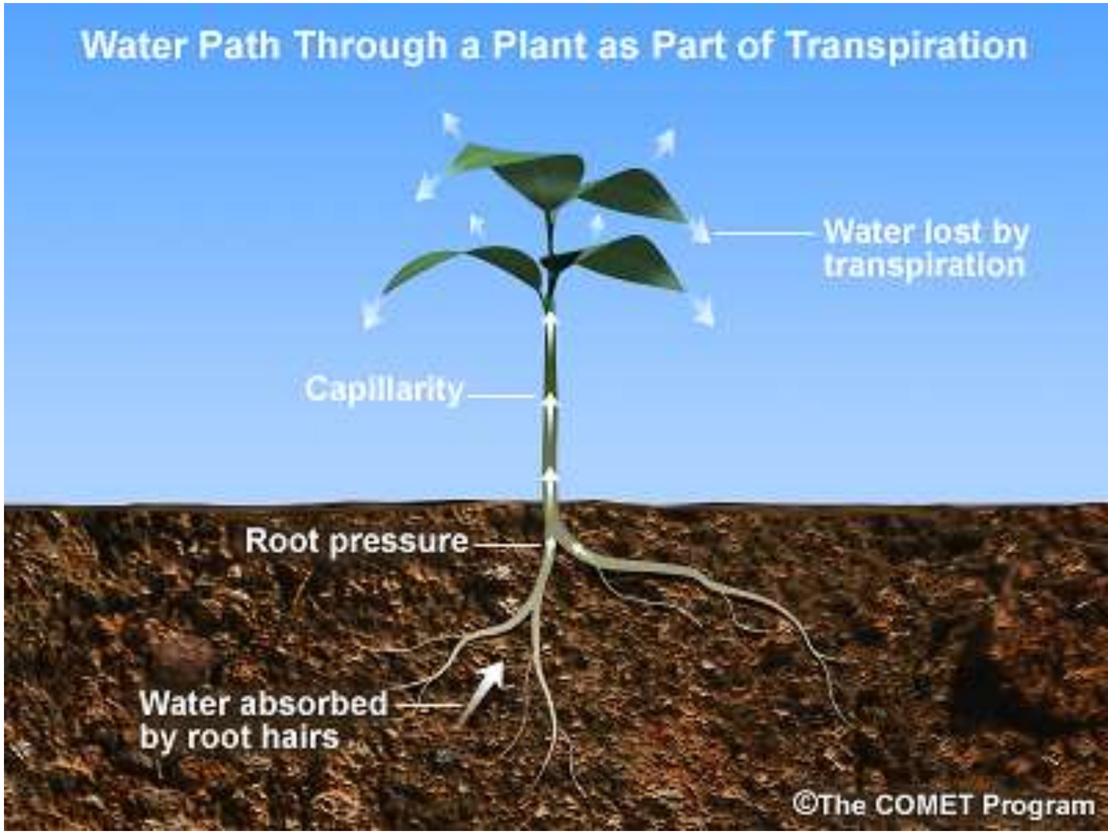
Evapotranspiration is a loss (outflow) from the soil but a gain (inflow) to the atmosphere.

Transpiration

Plant takes up water through fine hairs on their roots.

Water is drawn upward through the plant xylem by capillary action, evaporates in cavities within leaves, and is released through small openings called stomata.

In vegetated areas more water usually is lost by transpiration than by direct evaporation from soil.



Potential and actual evapotranspiration

Potential evapotranspiration (PET or PE):

- PET is a reference maximum rate.
- PET is the evapotranspiration that would be observed from **a freely-watered, vigorously growing short crop** under present atmospheric conditions.
- **Important!** Since PET **assumes** a moist, vegetated surface exists, the actual surface and its properties are ignored. PET is affected **only** by the environment (mainly winds, temperature, sunlight).