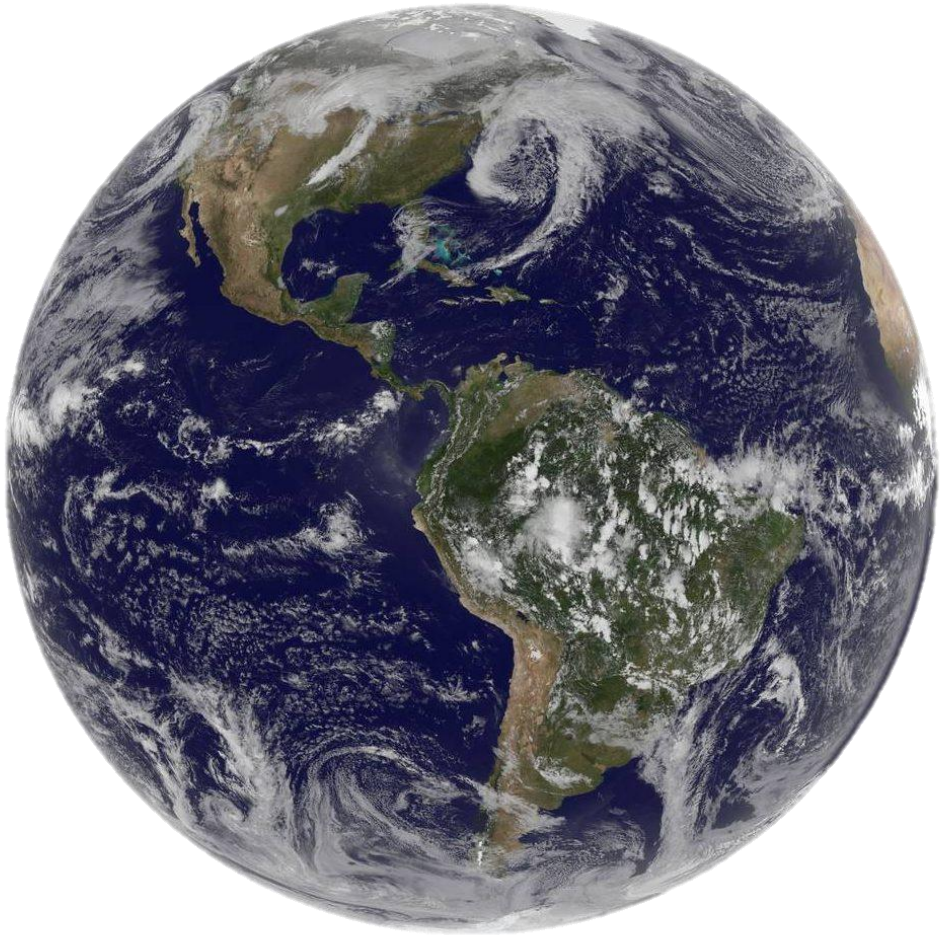
# Hydrogeology
## GLI 101

Lecture 1

# The Blue planet!!



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| Source | Percentage % |
|---|---|
| Oceans | 97.2 |
| Glaciers and Ice caps | 2.14 |
| Groundwater | 0.61 |
| Soil Moisture | 0.005 |
| Fresh water Lakes | 0.009 |
| Saline lakes | 0.008 |
| Rivers | 0.0001 |

Total water on land is only 2.8 %

# Hydrogeology

- The study of water concerned with its occurrence, distribution, movement and chemistry on Earth is called Hydrology.
- The branch of hydrology dealing with the interrelationship between geological materials and processes with water is called hydrogeology.
- Water helps shape the land surface which in turn controls, to a great extent, the creation and distribution of precipitation.
- The movement and chemistry of water is heavily dependent upon geology.

# Hydrogeology

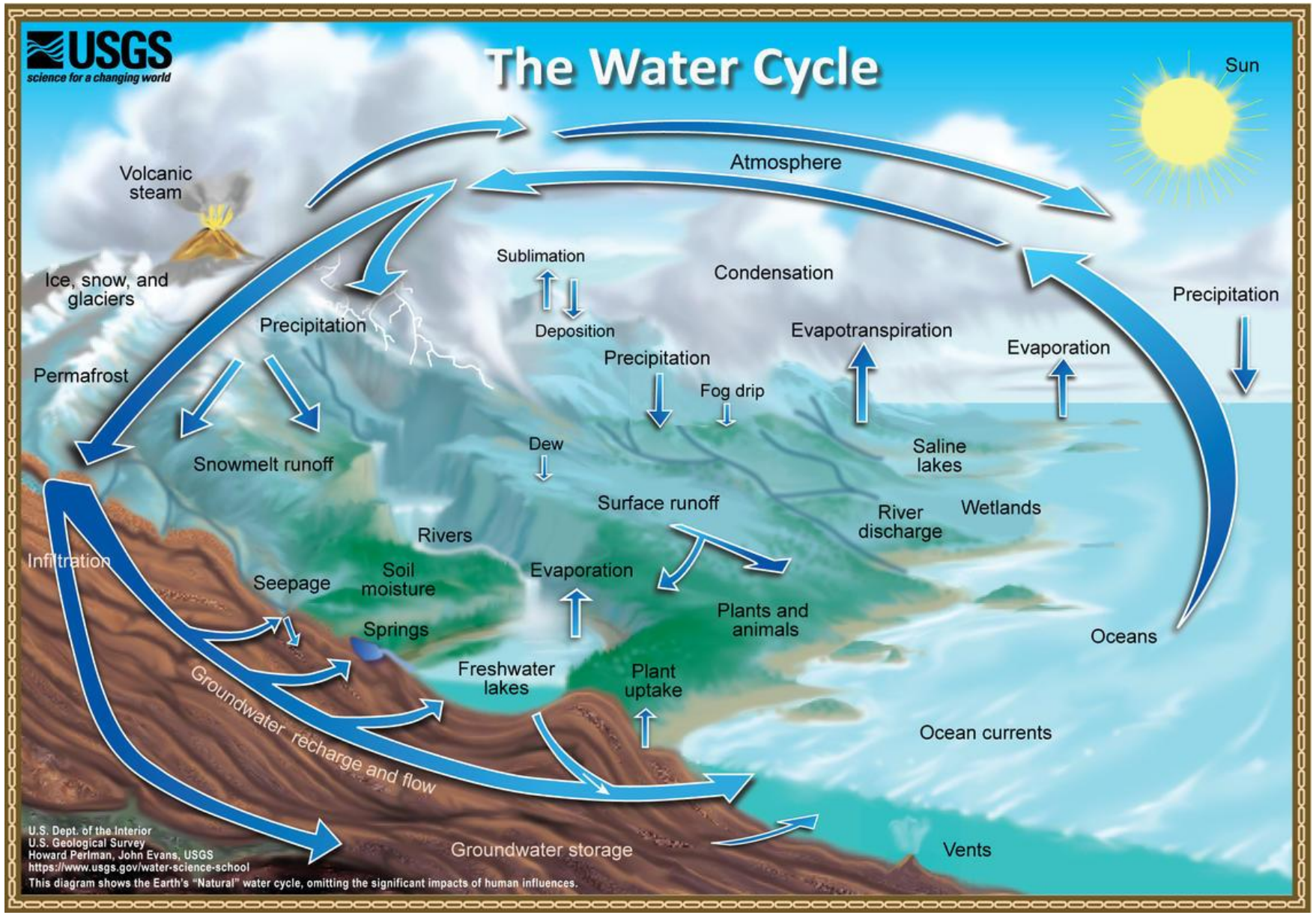
- Occurrence: Physiography and topography of a terrain controls the accumulation of surficial and ground water. Ex- High altitude, desert
- Distribution: presence of mountain ranges and other topographic features control precipitation and its geographical distribution
- Movement: Topographical features are deeply related to water movement, both on land and air. Ex- rivers, monsoon
- Chemistry: Geological make of a region controls the dissolution and precipitation of chemicals to/from water.

# Types of Ground Water

- Connate Water: Water that has been out of contact with the atmosphere for an appreciable geological period (fossil water)
- Juvenile water: New water of magmatic or cosmic origin that has not been a part of hydrosphere
- Metamorphic water: water that has been associated with rocks during metamorphism
- Hydrogen-3 (tritium) (half life 12.33 years) and Carbon 14 (half life 5730 years) are used to date water
- Tritium is applicable for estimating groundwater residence times of up to 50 years, while carbon-14 spans the age bracket of a several hundred to about 50,000 years.

# Hydrologic Cycle

- Hydrologic cycle is the combination of all possible waterways between the atmosphere, lithosphere, biosphere, and hydrosphere in addition to specific ways within each sphere.
- The water in Earth circulates among these environments from the hydrosphere to the atmosphere and then to the lithosphere due to solar energy.
- Weather and climate are largely controlled by the hydrologic cycle.
- The dynamic processes and interactions form the foundation for hydrologic studies.




14 components of the water cycle:

- Water storage in oceans
- Evaporation
- Sublimation
- Evapotranspiration
- Water in the atmosphere
- Condensation
- Precipitation
- Water storage in ice and snow
- Snowmelt runoff to streams
- Surface runoff
- Streamflow
- Freshwater storage
- Infiltration
- Ground-water storage

Ground-water discharge

# Hydrologic Cycle Characteristics

- A closed system where no water is created or destroyed, and solar radiation acts as the source of energy for driving the water cycle.
- A dynamic and interactive system characterized by water's readily changing states and movement between the atmosphere, ground-water aquifers, and surface water bodies.
- A system in balance except for the generally adverse impacts of anthropogenic activities.
- A system consists of three components, namely- source, sink, and flux
- While the reservoirs of water act as source/sink, the processes contributing to the flow of water are termed as the flux or flow paths.

# Components of hydrologic cycle

**Evaporation:**

- Evaporation is the process by which liquid water is converted into a gaseous state. This process requires large amounts of energy, e.g., $2.4 \times 10^6$ J ($5.7 \times 10^5$ calories) of heat energy is required to convert 1 kilogram of liquid water to the vapor phase.
- The amount of evaporated water varies, being greatest near the equator, where solar radiation is more intense.
- Evaporation of water leads to accumulation of humidity in the airmass.

# Components of hydrologic cycle

- Evaporated water is pure, because when it is carried into the atmosphere the salts of the sea are left behind.
- Evaporation is not restricted to open water bodies, such as the ocean, lakes, streams, and reservoirs. Rain water arrested by leaves and vegetative matter, water detained in land-surface depressions as well as soil moisture from the upper layers can also contribute to evaporation.
- Direct evaporation of ground water can take place when the saturated zone is at or near the land surface.

# Components of hydrologic cycle

**Sublimation:**

- Sublimation is the direct conversion between the solid and the gaseous phases of matter, with no intermediate liquid stage.
- sublimation is most often used to describe the process of snow and ice changing into water vapor in the air without first melting into water.
- Sublimation occurs more readily when certain weather conditions are present, such as low relative humidity, dry winds, and strong sunlight. Sublimation also occurs more at higher altitudes, where the air pressure is less than that of lower altitudes. Ex- Mt. Everest
- Chinook or “snow eater” winds of the western U.S.

# Components of hydrologic cycle

**Transpiration:**

- Plants pump water from the ground to the atmosphere through a process called transpiration.
- Amount of transpiration depends on the size and density of vegetation, but is also controlled by sunlight (transpiration is only important during the growing season).
- The driving force behind transpiration is the **osmotic pressure** created by the plant roots.
- There is a constant tug-of-war between osmotic pressure and water-soil surface tension. Transpiration occurs as long as the osmotic pressure is higher than the surface tension. When the surface tension is higher, no more transpiration occurs and the plant wilts. It is called the **wilting point**.

# Components of hydrologic cycle

- Transpiration alone is difficult to be measured. Thus, evaporation and transpiration are combined together to represent the combined water loss to the atmosphere, called **evapotranspiration**.

*From U. S. Forest Service*

GAGING THE THIRST OF THE AIR

The observer is measuring the depth of water in the evaporation pan with a graduated glass tube (burette)

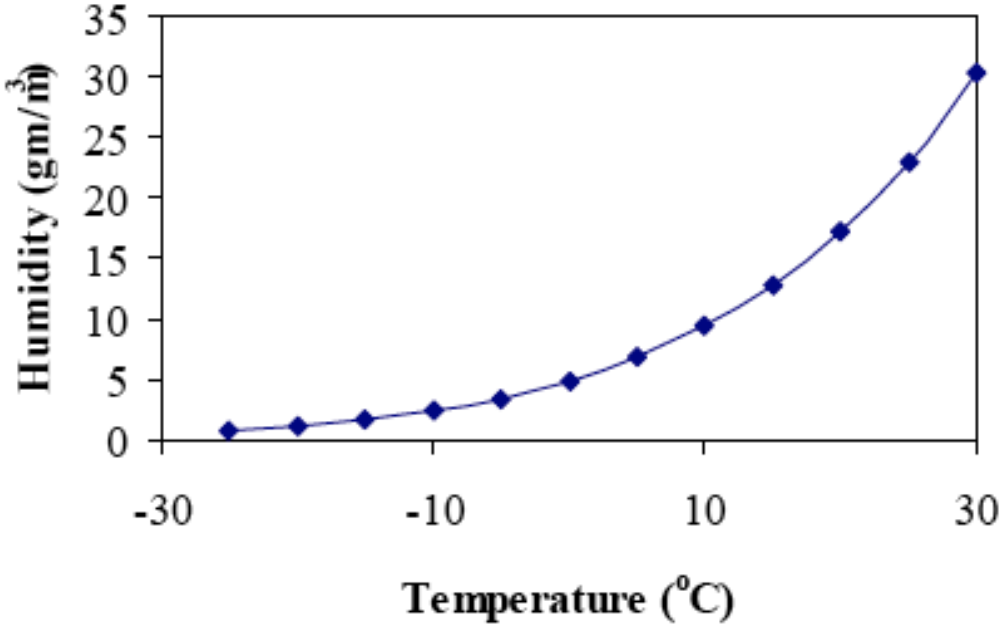
Pan Evaporation

Lysimeter

# Components of hydrologic cycle

**Humidity and Condensation:**

- Vapor pressure of a liquid is directly proportional to the temperature.
- At any given temperature, the air can hold only a given amount of moisture, which is referred to as the **saturation humidity**. Evaporation continues until the saturation humidity is reached.
- The saturation humidity increases with the temperature of the air.



# Components of hydrologic cycle

**Humidity and Condensation:**

- The **absolute humidity** of a given air mass is the number of grams of water per cubic meter of air ($g_{water}/m^3$ air).

- The **relative humidity** (expressed as %) for an air mass is the percent ratio of the absolute humidity to the saturation humidity for the temperature of the air mass. As the relative humidity approaches 100%, evaporation ceases.

$$Rh = \frac{Absolute\ humidity}{Saturation\ Humidity}, \%$$

# Components of hydrologic cycle

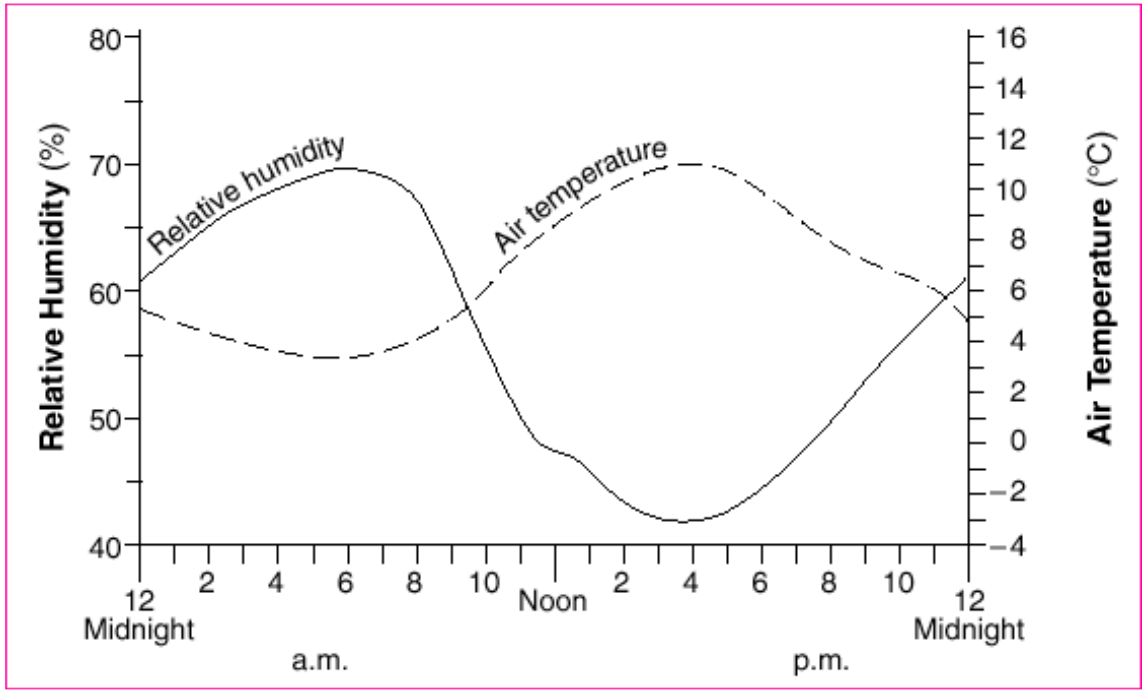
**Humidity and Condensation:**

- Condensation occurs when the vapor phase changes to liquid phase.
- Water condensation releases 590 cal heat to the surrounding per gram of water (**latent heat of condensation**).
- The temperature at which condensation of an air mass occurs is called the **dew point**.
- Condensation might start upon complete saturation of the air mass, i.e- RH ≈ 100%
- Two situations when RH can approach 100%
    1. By increasing the absolute humidity without changing the temperature
    2. By keeping the absolute humidity constant while lowering the temperature

# Components of hydrologic cycle

**Precipitation:**

- When air mass with RH less than 100% starts to cool without loosing moisture, the RH increases to 100% and air mass becomes saturated- condensation occurs.
- Condensation requires a nuclei to form on. e.g- dust, aerosols, etc.
- Why heavy Rainfall mostly occurs at night??



# Components of hydrologic cycle

**Precipitation:**

- Conditions for precipitation
  1. Humid air must be cooled to the dew-point temperature
  2. Presence of condensation nuclei (dust, aerosols)
  3. Coalescence of droplets to form raindrops
  4. Raindrops must be of sufficient size in order to not evaporate before reaching ground

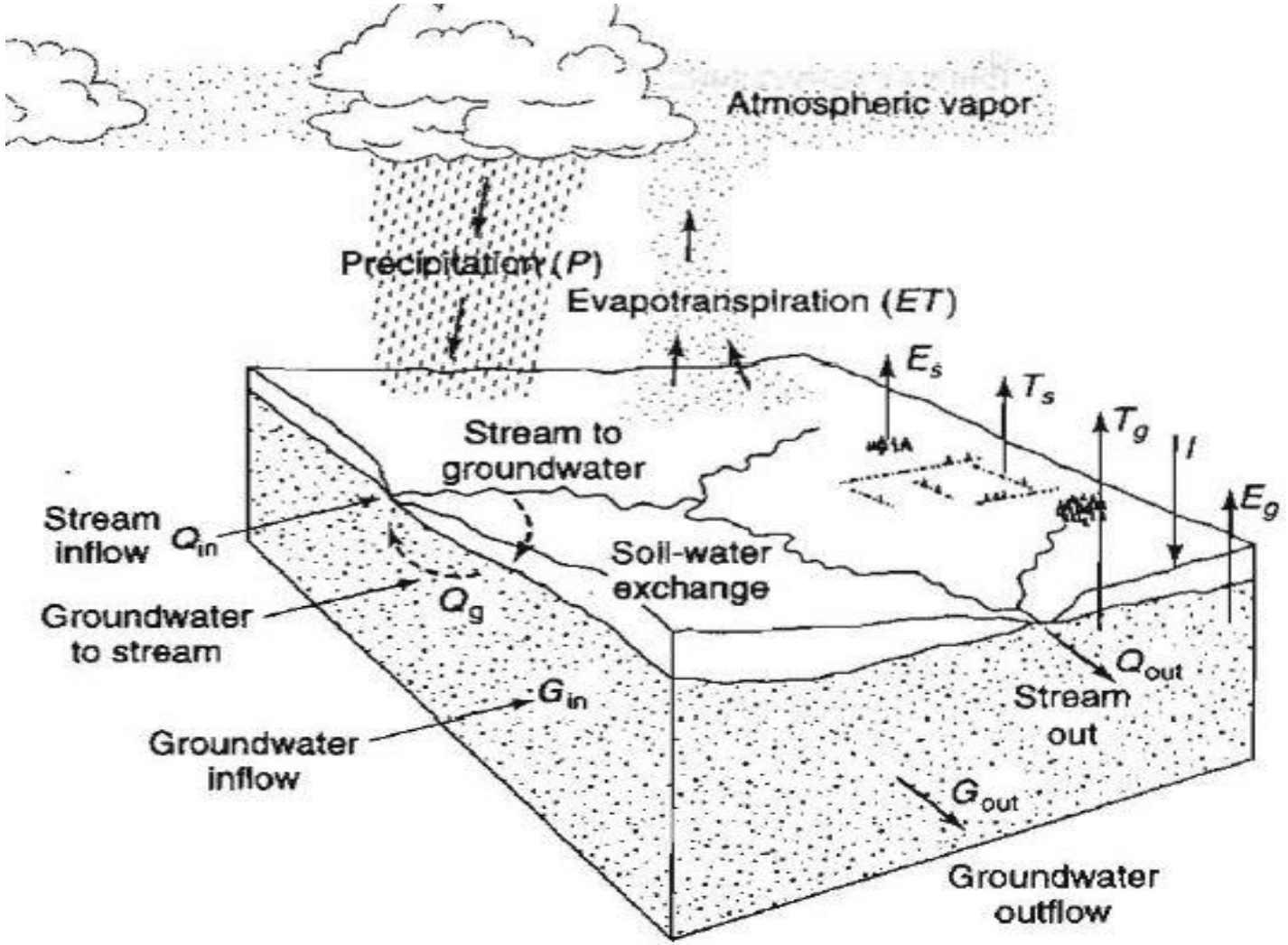
# Hydrologic Budget

- Also called as continuity equation, mass balance or mass conservation principle.
- It is a measurement of continuity of flow of water which holds true for any temporal and spatial interval
  - Conservation of water mass in the hydrologic system is expressed as

**Change in storage (w.r.t time) = Inflow – Outflow**

- The boundary of the drainage basin is determined by the **drainage divide** (the topographic divide between adjacent drainage basins).
- The hydrologic budget is the summation of surface water system and ground water system, both expressed in the units of volume per unit time.

# Hydrologic Budget



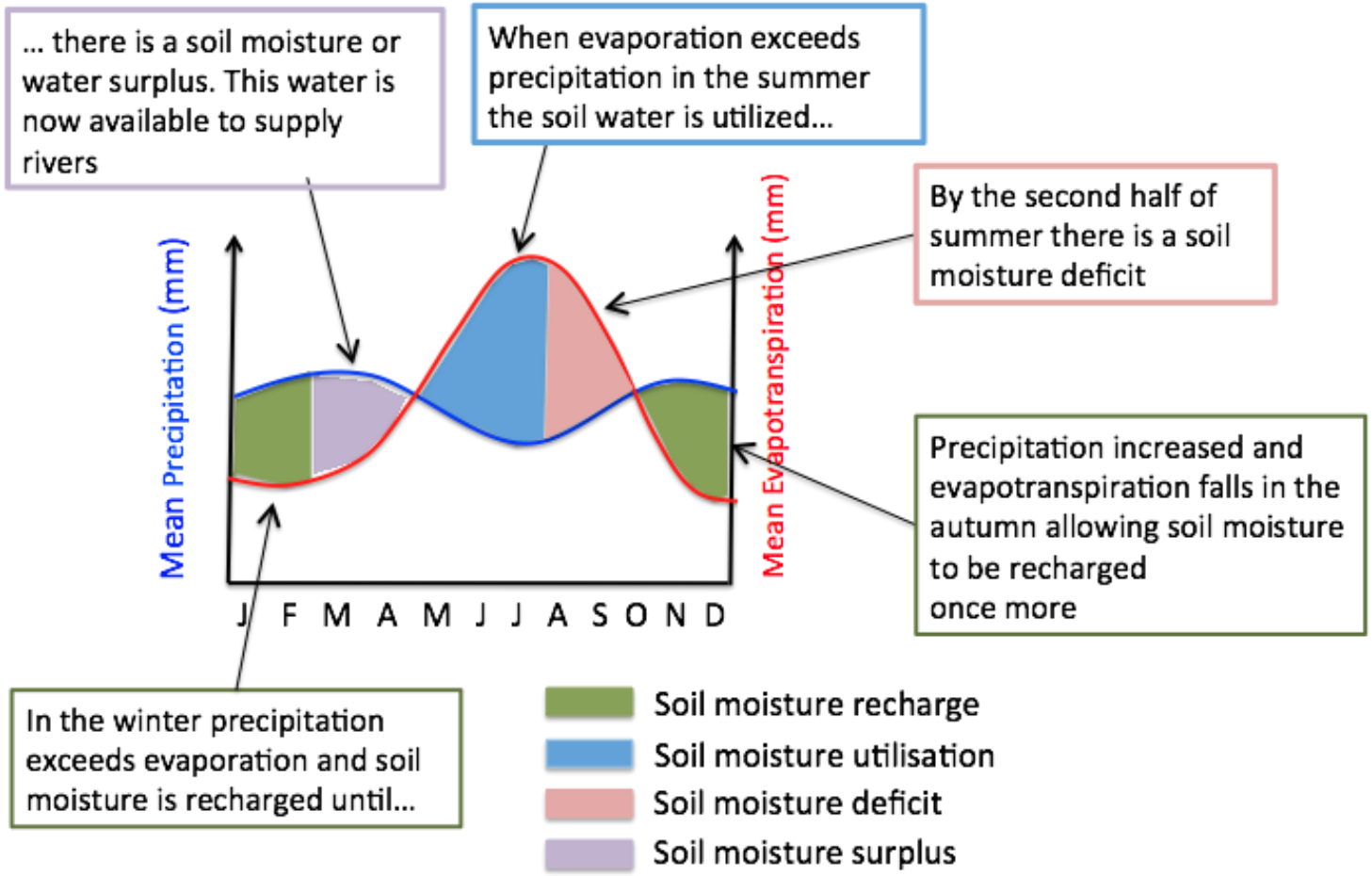
# Hydrologic Budget

- Hence, on a basin-wide scale one might want to determine recharge to the groundwater that occurs from infiltration due to precipitation.
- If all the groundwater inflows, outflows, and storage processes are understood, then one could balance all these known properties to back out the amount of recharge.

- Application of hydrologic budgets
  - Estimating groundwater exchange with lakes
  - Estimating surface water and groundwater interaction
  - Computing recharge from a well-hydrograph data

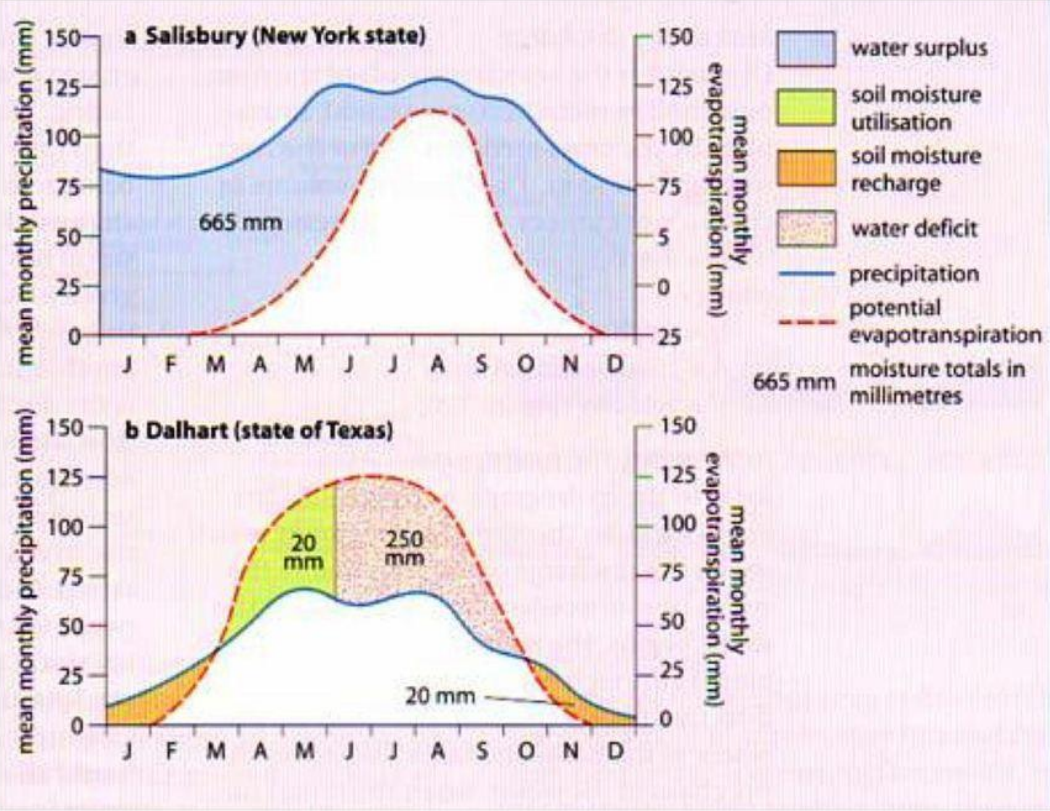
# Hydrologic Budget

## Control of weather over Hydrologic budget



# Hydrologic Budget

## Hydrologic budget and climatic regions




When total precipitation (P) is higher than total potential evapotranspiration ($P_E$) , the climate is **humid**

When total precipitation (P) is lower than total potential evapotranspiration ($P_E$) , the climate is **Arid**