Water Balance and Budyko Framework

What is a Watershed

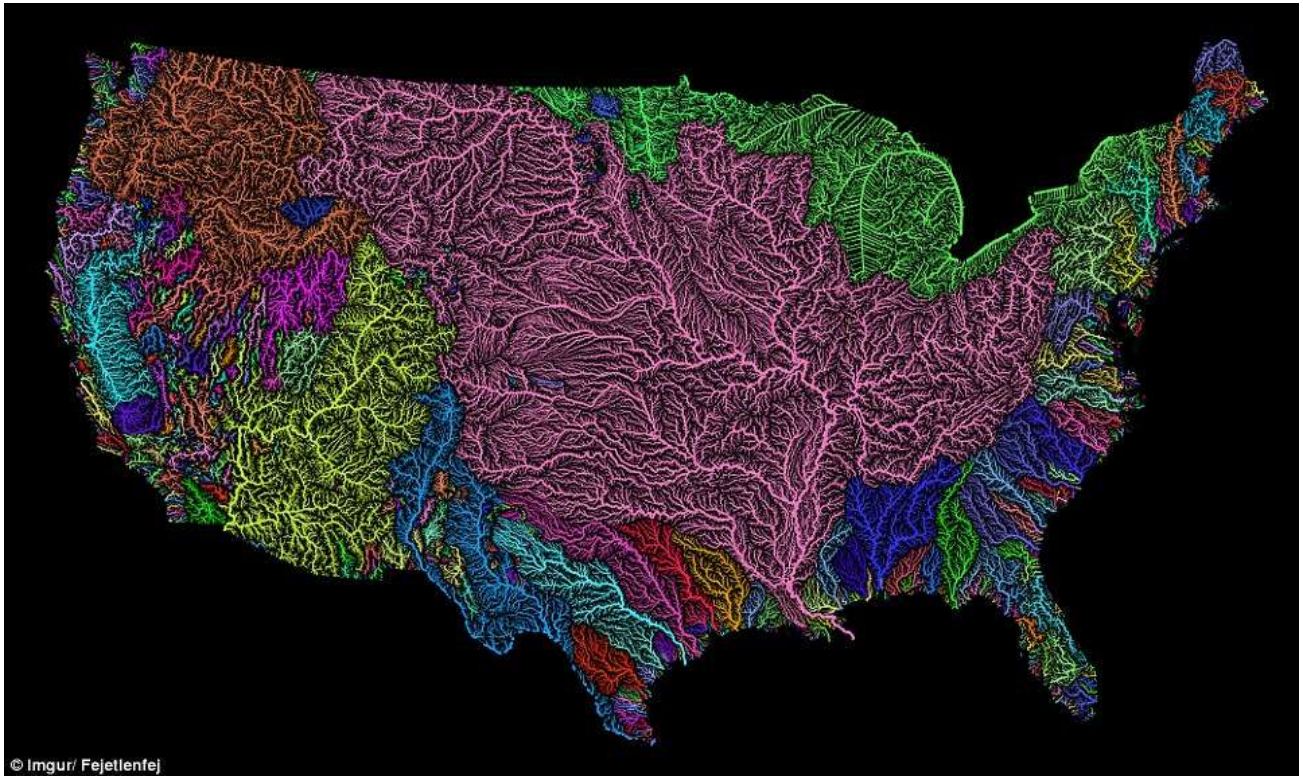
- A land area that channels precipitation to a common outlet such as reservoirs, bays, and the ocean.
- An area of land that drains or "sheds" water into a specific waterbody

- Watersheds are defined based on topography
- Topography is the arrangement of the natural and artificial physical features of an area.

Image courtesy: Edwards et. al 2015

No Matter Where You Are, You Are in a Watershed

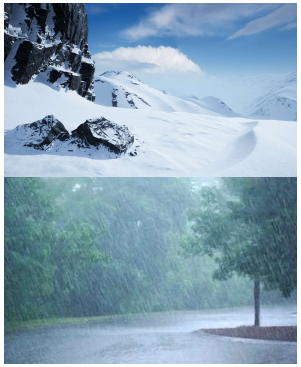
Nature's arteries to transport water, nutrients & sediments

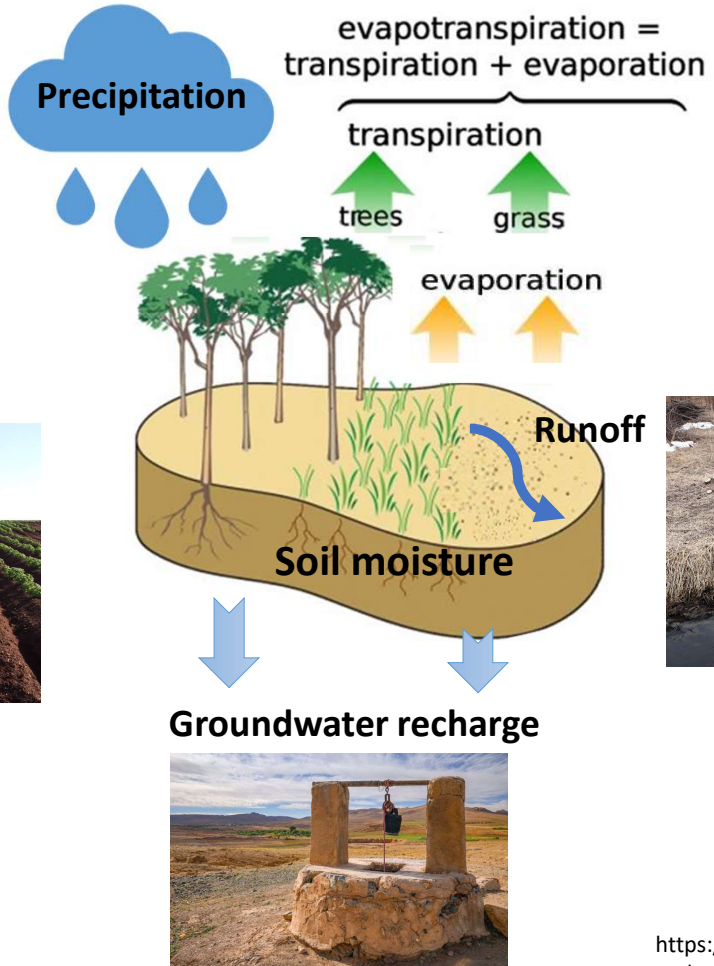


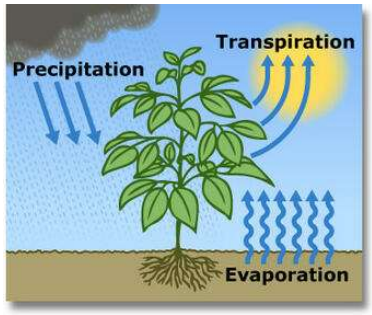
Know your watershed: https://mywaterway.epa.gov/

Image courtesy: https://www.dailymail.co.uk/sciencetech/article-3860062/The-veins-America-Stunning-map-shows-river-basin-US.html

Components of Hydrological Cycle







https://www.usgs.gov/special-topics/water-science-school/science/evapotranspiration-and-water-cycle

Question 1

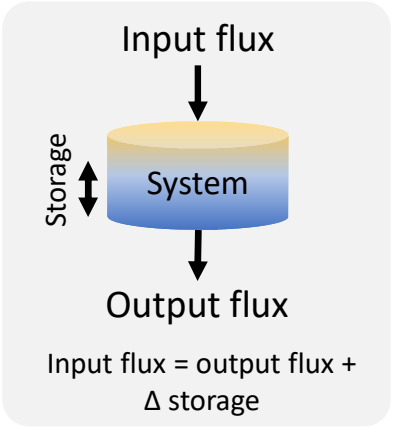
What type of system is Earth's hydrological cycle?

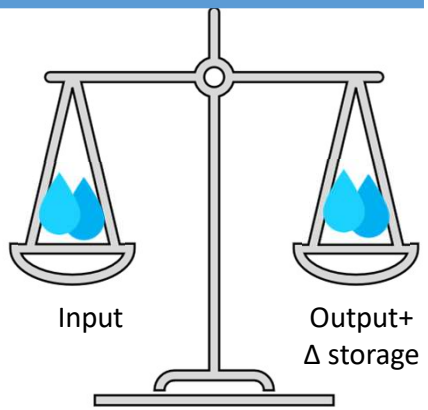
1.A Closed system?

2.An Open System?

- Earth's water/hydrological cycle is a closed system
- No water escapes or enters the system.

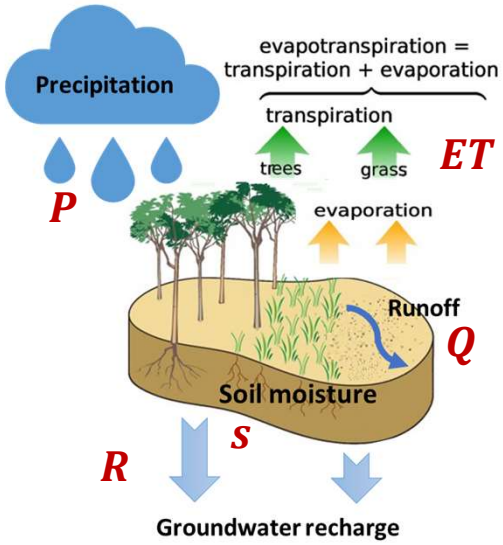
Conservation of Mass & Energy

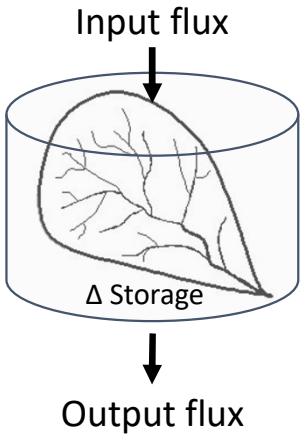


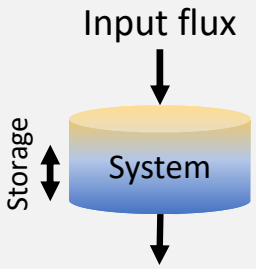


Redistribution matters

Hydrological Water Balance







Input flux = output flux
+ Δ storage

P

Loss+Δs

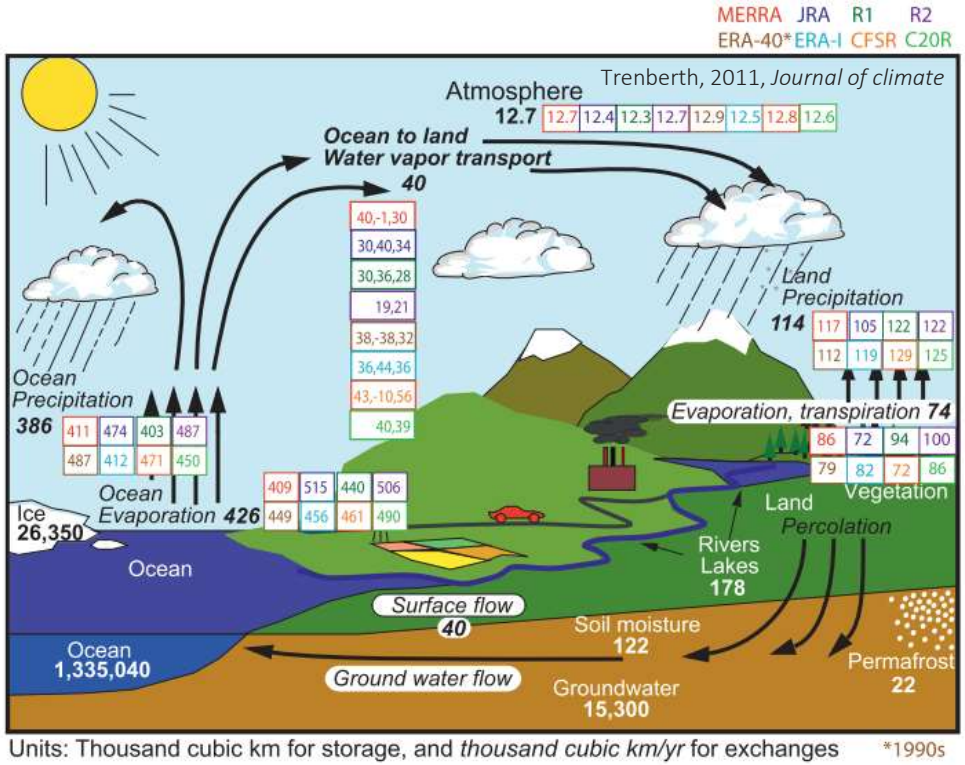
P

$(Q + ET + R)$+ Δs

Static

$$P = Q + ET + R + \Delta s$$

Water Balance



Units: Thousand cubic km for storage, and *thousand cubic km/yr* for exchanges *1990s

$$P = Q + ET + GW + \Delta s$$

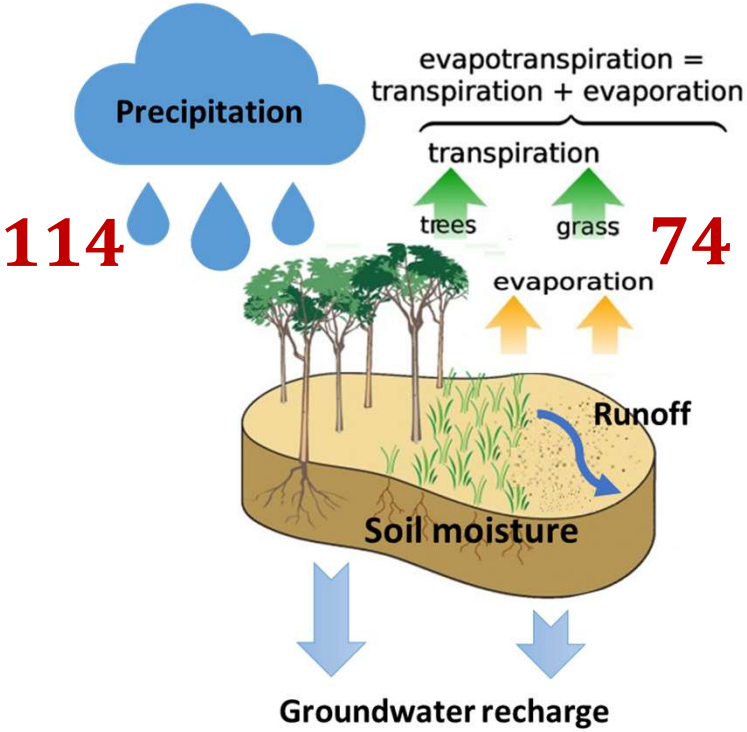
If a sample watershed receives **500 mm** of precipitation per year, what would be the estimated amount of annual evapotranspiration and runoff for that watershed?

Evapotranspiration (ET) = ???

Runoff (Q) =???

Water Balance

$$P = Q + ET + GW + \Delta s$$



If a sample watershed receives **500 mm** of precipitation per year, what would be the estimated amount of annual evapotranspiration and runoff for that watershed?

$$\text{Evapotranspiration (ET)} = 500 * \frac{ET_{Global}}{P_{Global}} = 500 * \frac{74}{114} = \sim \mathbf{324\ mm}$$

$$\frac{ET}{P} = \frac{74}{114} = \text{evaporative index (EI)}$$

Question 2

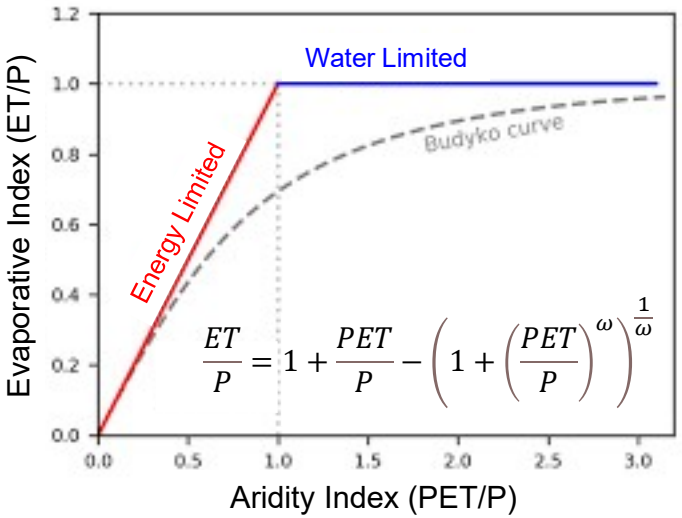
Will water balance estimates change, based on the location of watershed?

1. Estimates may NOT change significantly
2. Estimates will change

Hint: Think in terms of the governing driver of the water cycle on Earth.

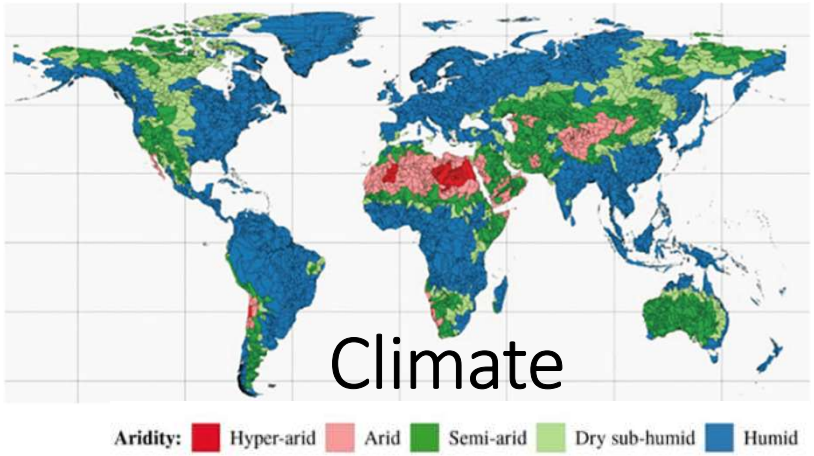
Budyko Curve

$\frac{ET}{P} = \frac{PET}{P}, \frac{PET}{P} < 1$ $\quad \frac{ET}{P} = 1, \frac{PET}{P} > 1$



ω = fitting parameter linked to watershed characteristics such as topography, soil, vegetation, and geographic location of watersheds

ET/P ratio depends on aridity (climate) and watershed characteristics, ω



- **Aridity Index:** Indicator of climate (arid, humid, etc.).

$$\text{Aridity Index} = \frac{\text{Potential Evapotranspiration}}{\text{Precipitation}}$$

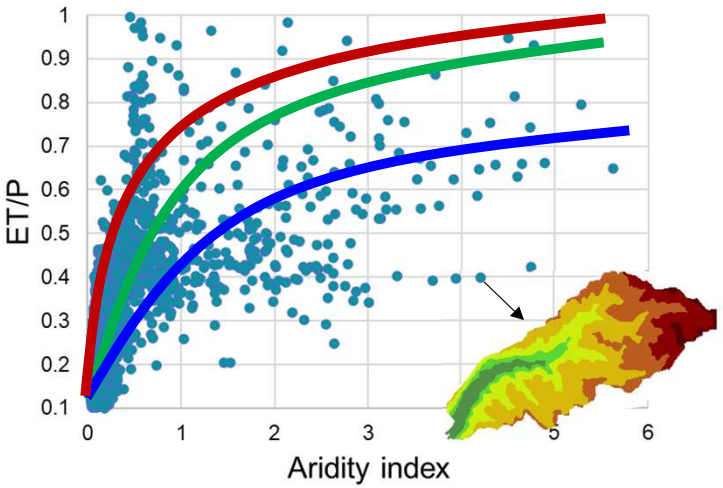
- **Potential Evapotranspiration (PET):** Maximum amount of water that can be removed from land assuming abundant moisture supply.

- PET depends on availability of solar radiation and weather conditions (relative humidity, temperature, wind speed etc).

Koppa, A., et. al 2021. Budyko-Based Long-Term Water and Energy Balance Closure in Global Watersheds From Earth Observations. *Water resources research*

Summary

Static $P = Q + ET + R + \Delta s$



1. Global hydrological cycle is a closed system. Redistribution matters!

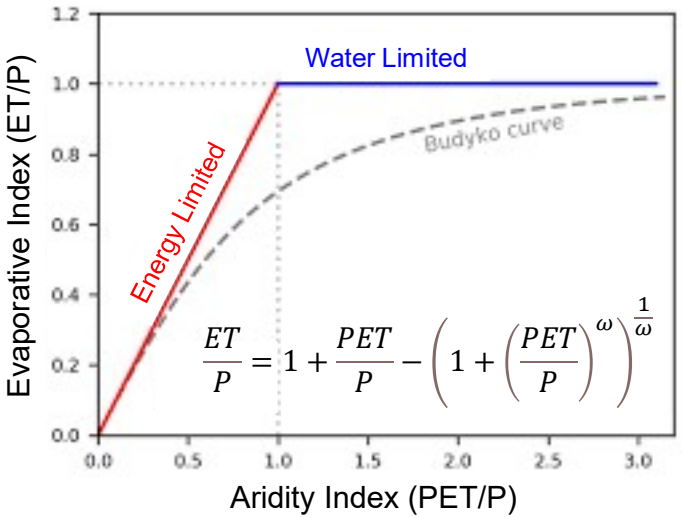
1. Budyko Curve gives relationship between aridity and evaporative index of a watershed.

2. Climate and watershed characteristics govern the evaporative index of watersheds.

Thank you!

Assignment Exercise

$\frac{ET}{P} = \frac{PET}{P}, \frac{PET}{P} < 1$ $\quad \frac{ET}{P} = 1, \frac{PET}{P} > 1$



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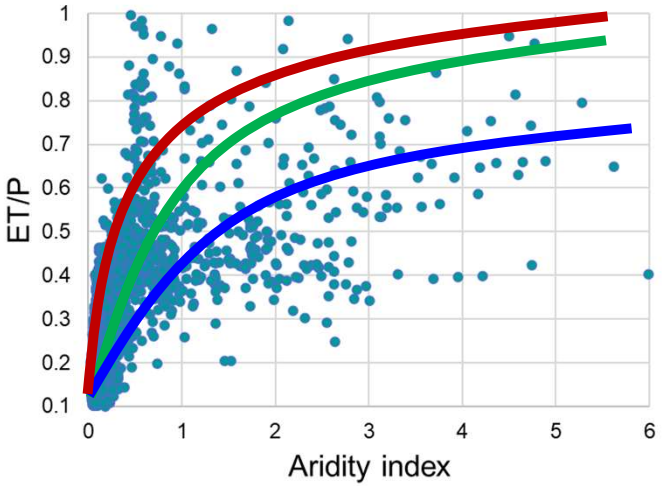
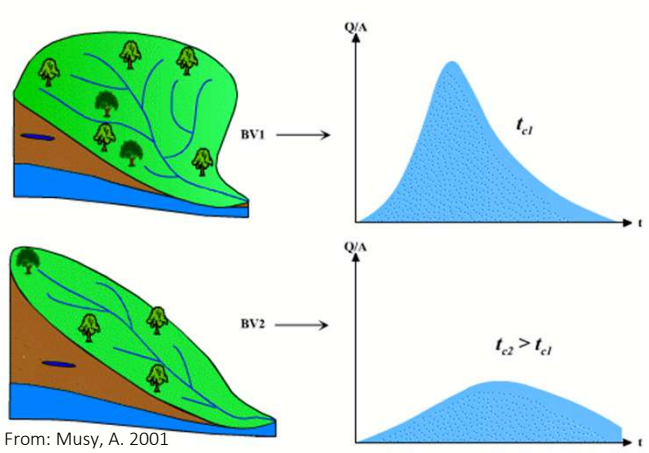


1. Size
2. Slope
3. Shape
4. Drainage density
5. Land use/land cover
6. Geology and soils
7. Vegetation

Open class GIT repository:
https://github.com/Vinit-Sehgal/hydrology

Useful terms and resources:

Watershed slope reflects rate of change of elevation w.r.t distance along principal flow path.



From: Musy, A. 2001

NDVI (Normalized Difference Vegetation Index) is an index that detects and quantifies live green vegetation using multi-spectral remote sensing.

For more details: https://gisgeography.com/ndvi-normalized-difference-vegetation-index/