CE 361A : Engineering Hydrology

Abstraction from Precipitation

Lecture -10

Water balance

Abstractions = Precipitation - Runoff

Abstractions or losses

1. Interception
2. Evaporation
3. Transpiration
4. Depression storages
5. Infiltration

Objective

- What are these losses?
- What factors effect them?
- How are they measured?
- How are they estimated?

Evaporation

Difference between Vaporization and Evaporation

Vaporization of an element or compound is a phase transition from the liquid phase to vapor. Two types –

1. **Evaporation**: Evaporation is a phase transition from the liquid phase to vapor that occurs at temperatures below the boiling temperature at a given pressure. It is a surface phenomenon.

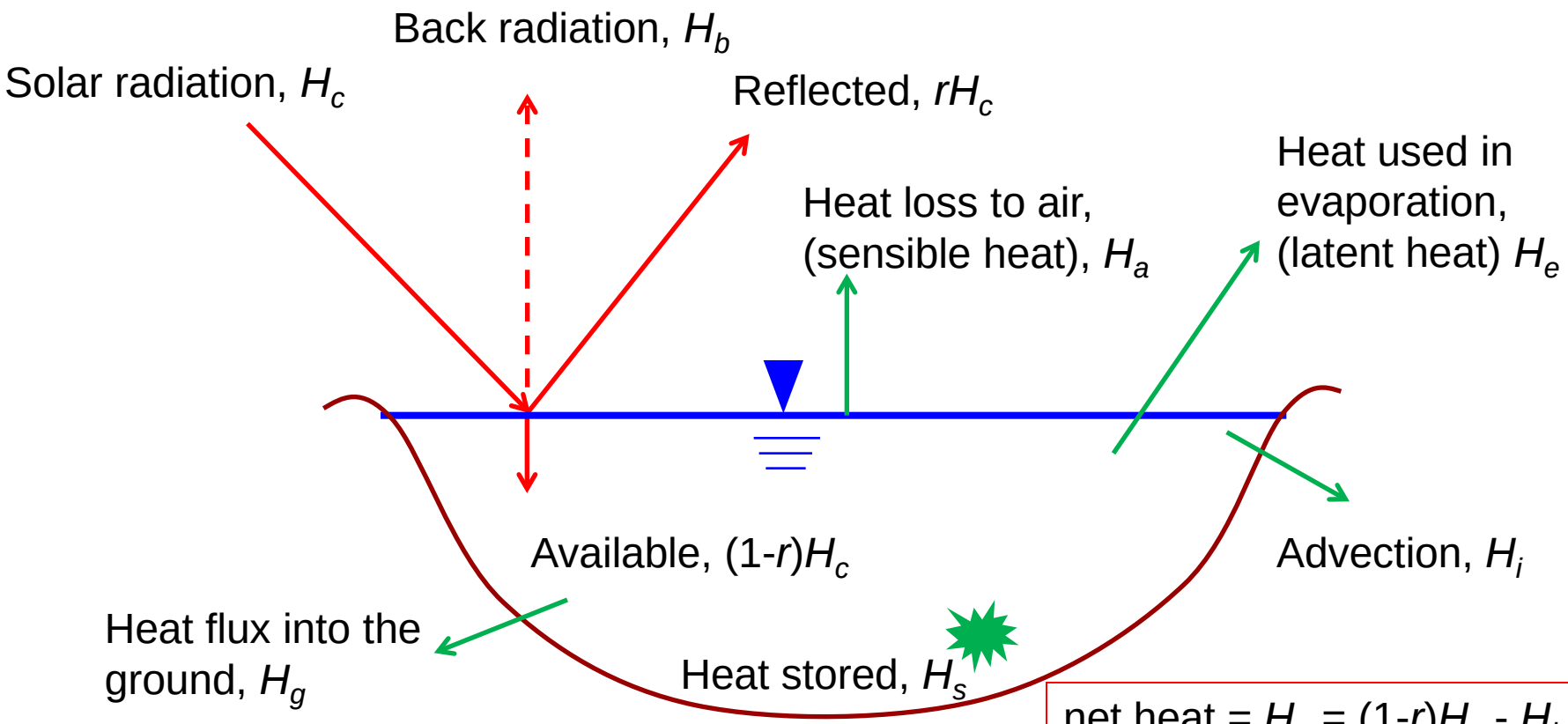
2. **Boiling**: Boiling is also a phase transition from the liquid phase to gas phase, but occurs at boiling temperature or boiling point. It is a bulk phenomenon in that the formation of vapor as bubbles of vapor transpires below the surface of the liquid.

Estimation of Evaporation

1. Empirical equations
2. Analytical methods
   - Water-budget equation
   - Energy-budget equation
   - Mass transfer method

Estimation of Evaporation

2(b) Energy budget equation



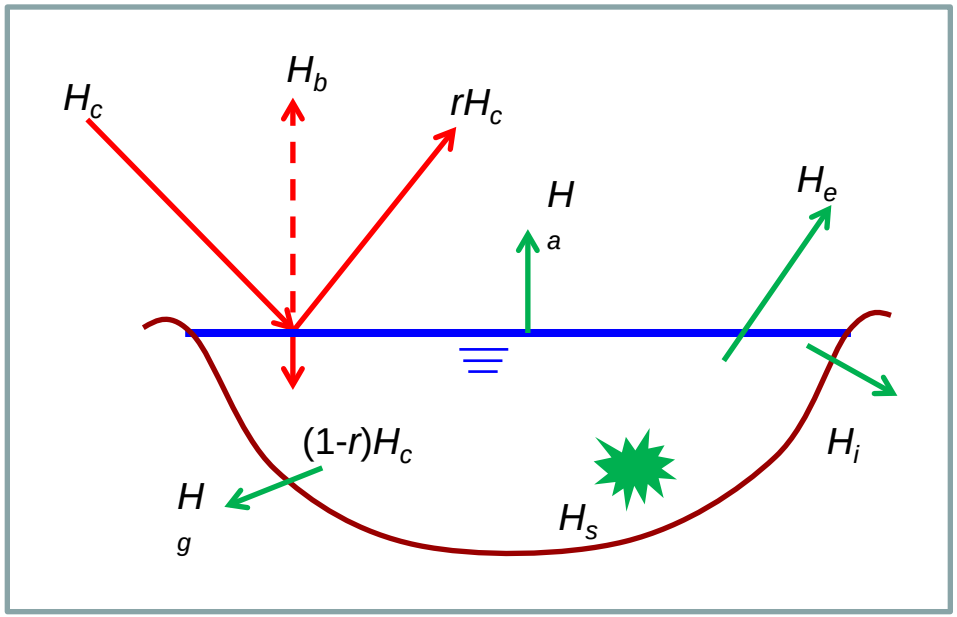
net heat = $H_n = (1-r)H_c - H_b$

r is reflection coefficient (albedo)

$H_n = H_a + H_e + H_g + H_i + H_s$

Estimation of Evaporation

2(b) Energy budget equation



$H_e = \rho L E_L$

ρ – density of water
L – latent heat of vaporization
E_L – evaporation in mm

$$\text{Bowen ratio} = \beta = \frac{H_a}{H_e}$$

Ratio of sensible to latent heat

$$H_n = H_a + H_e + H_g + H_i + H_s$$

$$H_e = H_n - H_a - H_g - H_i - H_s$$

$$E_L = \frac{(H_n - H_g - H_i - H_s)}{\rho L(1+\beta)}$$

Estimation of Evaporation

$$E_L = \frac{(H_n - H_g - H_i - H_s)}{\rho L(1+\beta)}$$

Errors of ~5% for periods less than a week

$H_n = (1\text{-}r)H_c - H_b$

- *H_c can be measured using radiometers ; r – albedo is about 0.08*
- *H_b can be estimated from water temperature (Stefan-Boltzman Law)*

H_g is *measured using flux plates*

H_i and H_s *can be safely neglected if time periods are short*

$$\beta = 6.1 \times 10^{-4} \times P_a \times \frac{(T_w - Ta)}{(e_s - e_a)};$$

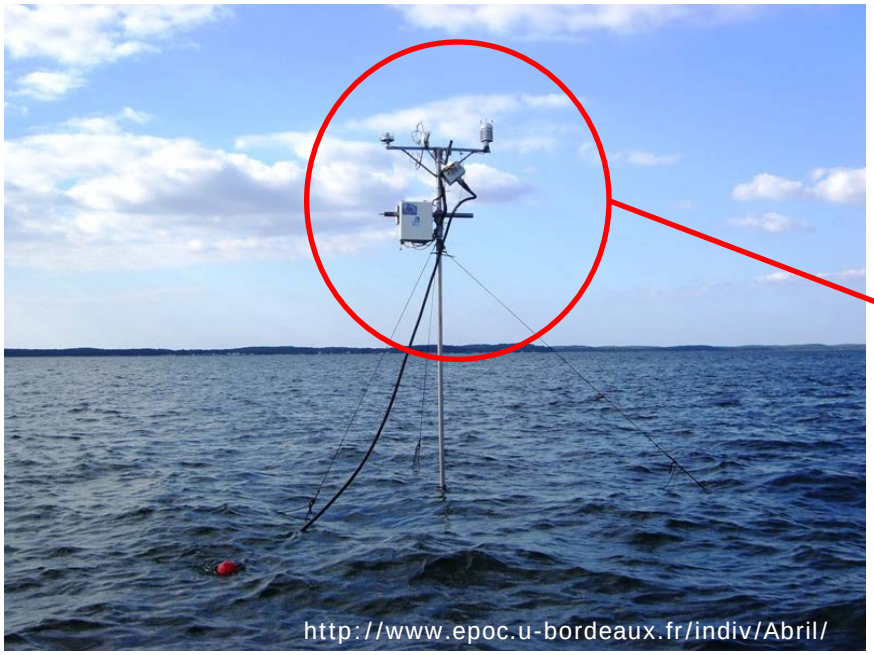
P_a is atmospheric pressure, T_w and T_a are water & air temperature (°C), respectively

Psychrometric constant $\gamma = 6.1 \times 10\text{-}4 \times P_a$

Estimation of Evaporation

2(c) Mass transfer methods

- Based on theories of turbulent mass transfer in atmospheric boundary layer
- Provides evaporation over a large area
- Requires expensive instrumentation
- Example: Eddy covariance method



Methods to reduce evaporation

Average evaporation loss from a water body in Indian condition is about 160 cm in a year

- Reduction of surface area
- Mechanical covers
- Chemical films - cetyl alcohol (hexadecanol)

How large are the reservoirs?

Surface area of Narmada Sagar at maximum reservoir level is 914 km^2

Mumbai, the largest metropolitan city in India, has as area of 603 km^2

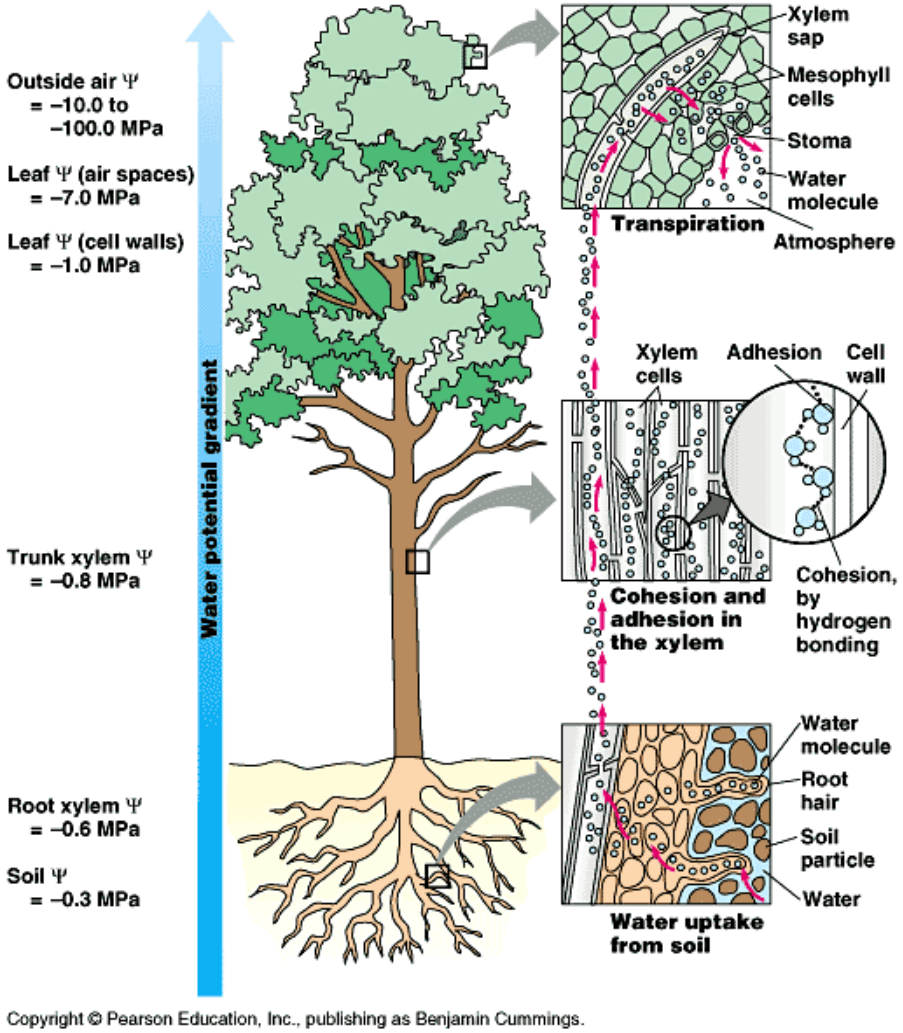
Pan evaporation paradox

- Global warming is suppose to increase the evaporation rate

- But evaporation rates recorded from metal pans at weather stations around the world is decreasing. Why?

Transpiration

- Transpiration is the process by which plants take water from the soil and transfer it to atmosphere as water vapor
- One of the most inefficient system
  - about 90 to 95% of the water that plant absorbs is transpired to atmosphere, the rest is used for building plant tissues
  - Analogy – lamp wick



Source: http://www.uic.edu/uic/academics/

Factors effecting transpiration

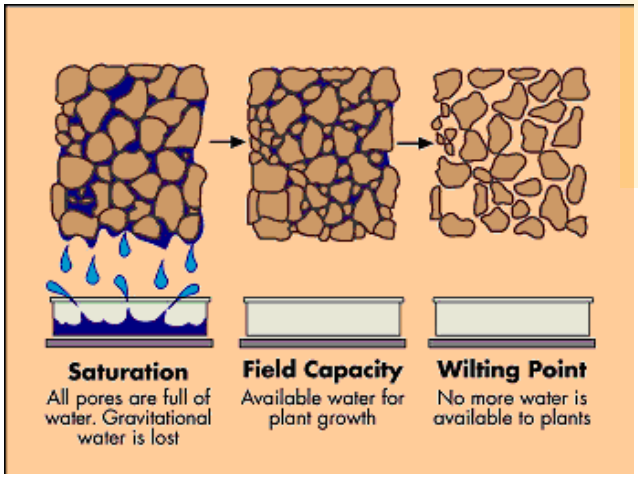
Factors that affect evaporation also affects transpiration

1. Physiological factors (characteristics of plant)
   - density and behavior of stomata
   - leaf structure
   - plant growth period, disease …
2. Environmental factors
   - Vapor pressure
   - Temperature
   - Solar radiation (night vs day)
   - Wind
   - Carbon dioxide (CO_2)
   - Soil moisture

Factors effecting transpiration

Soil moisture (Θ): Amount of moisture present in the soil

- Saturation: All pores in soil are full with water
- Field capacity (FC): Maximum moisture that soil can retain against the force of gravity. Any higher amount will simply drain away
- Permanent wilting point (PWP): Moisture content below which plants cannot take water from soil
- Maximum Available water: Moisture available for plant growth, FC - PWP



- FC and PWP depends upon the soil characteristics.
- How is transpiration related to available water?