CE 361A : Engineering Hydrology

Abstraction from Precipitation

Lecture -9

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?

Abstraction from Precipitation

Interception: The volume of precipitation that is retained by vegetation and subsequently evaporated

- Factors effecting interception
- Measurement of interception
- Estimation of interception
- Importance of interception

How important are interception losses?

Distribution of incident rainfall in different forests during the monsoon season (values were averaged for two years, 1981 and 1982)

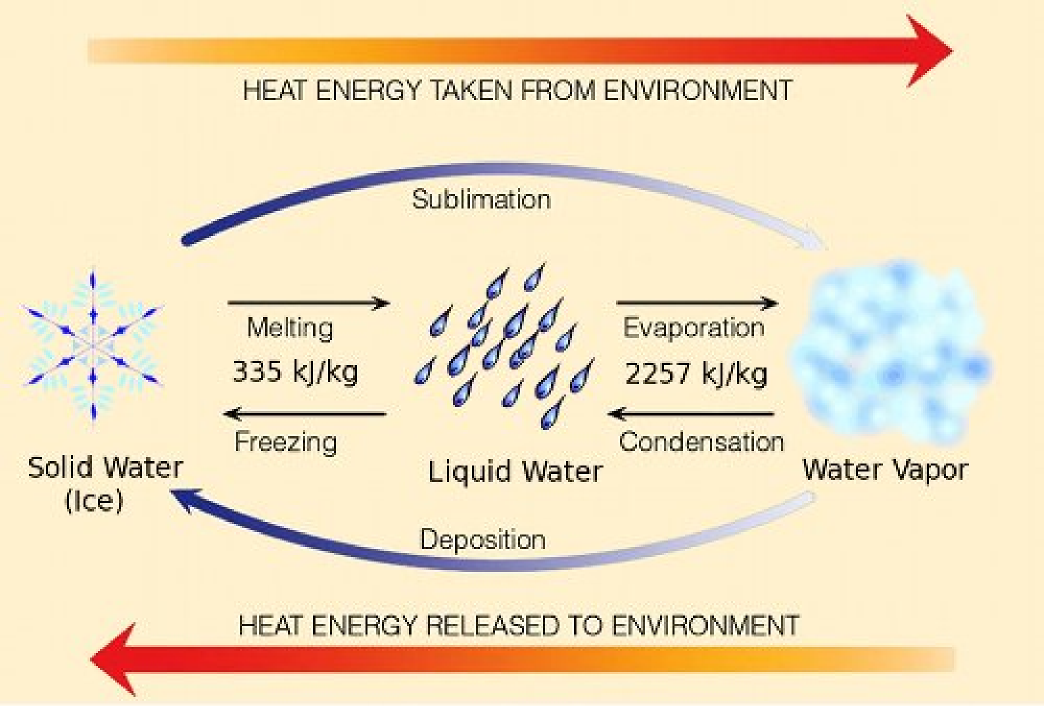
Forest	Gross rainfall (mm)	Stand throughfall (mm)	Stand stemflow (mm)	Stand interception (mm)
Sal forest	1,153	950 (82.4)	10 (0.85)	193 (16.7)
Pine—mixed-broadleaf forest	1,179	1,079 (91.5)	5 (0.42)	95 (8.0)
Pine forest	1,234	922 (74.7)	3 (0.28)	308 (25.0)
Mixed-oak—pine forest	915	758 (82.8)	3 (0.35)	154 (16.8)
Tilonj-dominated mixed-oak forest	1,364	1,155 (84.7)	5 (0.38)	204 (14.9)
Rianj-dominated mixed-oak forest	1,240	1,002 (80.8)	11 (0.89)	227 (18.3)

Values in parentheses are percentages of gross rainfall. Gross rainfall for the monsoon seasons of 1981 and 1982 was measured and reported in Pathak et al. (1984).

Interception process has a very significant impact on ecology, *in situ* water harvesting, and regional water balance. However, not very important for flood studies - Subramanya (2010)

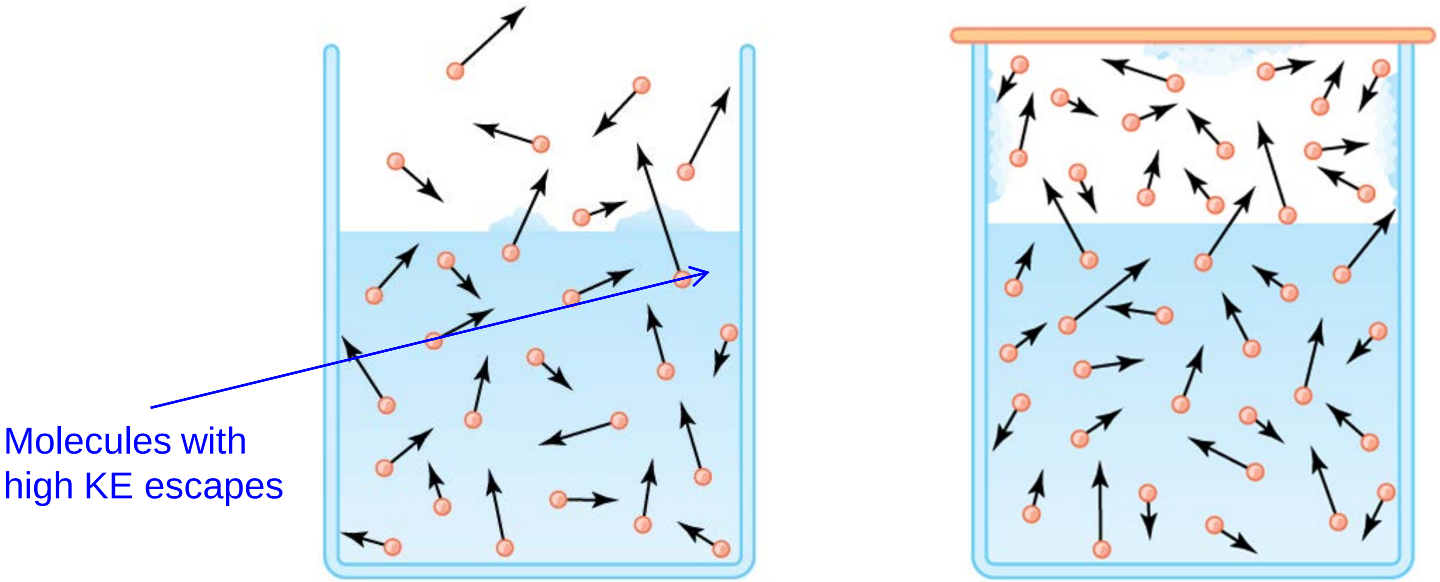
Evaporation

The process by which water is changed from the liquid into the gaseous state through the transfer of heat energy.



Source: http://theresilientearth.com/ by Doug L. Hoffman

Evaporation



Vapor pressure (e_a): The partial pressure of air that is exerted by water vapor

Saturation or equilibrium (e_s or e_w): Condition of the atmosphere when the evaporation rate is equal to the condensation rate. When air is saturated, the amount of water vapor is the maximum that can exist at a particular temperature and pressure

Vapor pressure deficit $VPD = e_s - e_a$

Source: https://www.boundless.com/physics/heat-and-heat-transfer/phase-equilbrium/evaporation/

Clausius-Clapeyron Relation

Relationship between the saturation vapor pressure (e_s)and temperature (T, in K)

$$ln\left(\frac{e_s}{e_{s0}}\right) = \frac{L}{R_v}\left(\frac{1}{T_0} - \frac{1}{T}\right)$$

$$e_s = c_1 \exp\left(\frac{c_2 T}{c_3 + T}\right)$$

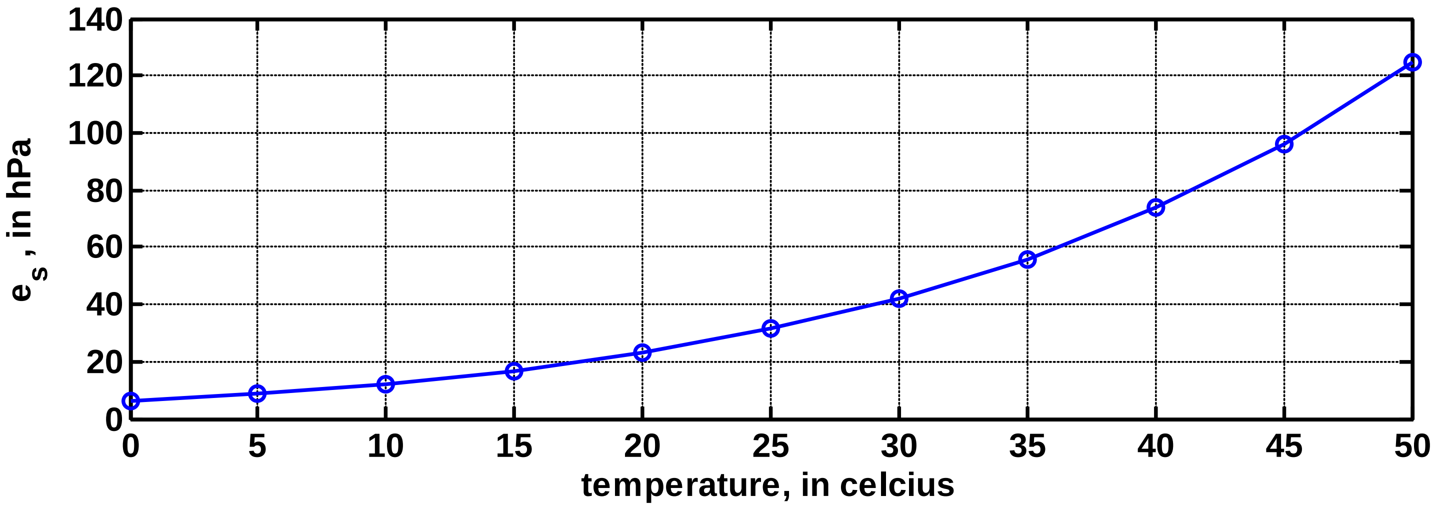
T_o is 273K

e_s is the saturation water vapor pressure in hPa

e_{so} is the saturation water vapor pressure at temperature T_o (6.11 hPa)

L is the latent heat of vaporization (2.453×10^6 J kg^{-1}), and

R_v is the water vapor gas constant (461 J kg^{-1} K^{-1}).



Factors effecting evaporation

1. Vapor pressure deficit

Rate of evaporation is directly proportional to vapor pressure deficit

$$E_L \propto (e_s - e_a)$$

Dalton's law

2. Temperature

- Increase in *water temperature* increases evaporation because it increases KE of the water
- Air temperature do not have high correlation with evaporation

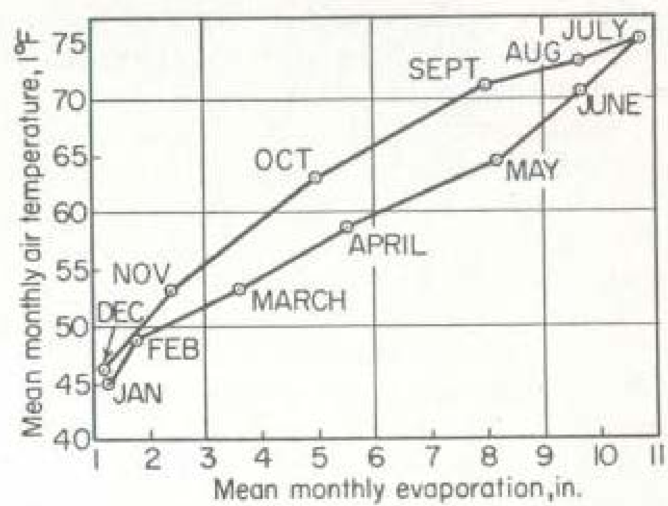


FIG. 11-1. Evaporation from U.S. Weather Bureau Class A pan at Davis, Calif., averaged for 1926 to 1959.

Source: V. T. Chow, Handbook of Applied Hydrology

Factors effecting evaporation

3. Wind

- Wind is effective in removing water molecules in the air and bringing in air that is capable of holding more water thus aiding in evaporation
- Wind velocity above a threshold, where in the velocity is high enough to remove evaporated water, will not influence evaporation
- The threshold will depend on the size of water body –
  - larger the waterbody greater will be the threshold.

Factors effecting evaporation

4. Atmospheric pressure

- Decrease in atmospheric pressure with increased altitude should increase the evaporation rate as there are fewer molecules above the evaporating surface

5. Soluble salts

- Soluble salts reduce the vapor pressure in comparison to pure water thus causing reduction in evaporation rate
- Evaporation from sea-water is 2-3% less than fresh water

6. Heat storage

- Deeper water bodies can store more energy than shallower water bodies
- It effects the lag in evaporation but not total annual evaporation

Measurement of evaporation

Evaporation pan / Evaporimeter

- 1210 mm diameter and 255 mm depth
- Water level maintained at 180-200 mm and measured using stilling well
- Placed on a wooden platform 150 mm above the ground. Why?

US Class A evaporation pan

Can we estimate lake evaporation from pan evaporation data?

Source: http://en.wikipedia.org

Measurement of evaporation

- Pan has a different heat storing capacity
- Heat transfer from side and bottom
  - 3m dia pan has 20% more evaporation than 1m dia pan
- Rim of the pan effects the action of wind
- The heat transfer characteristic of pan is different from the lake

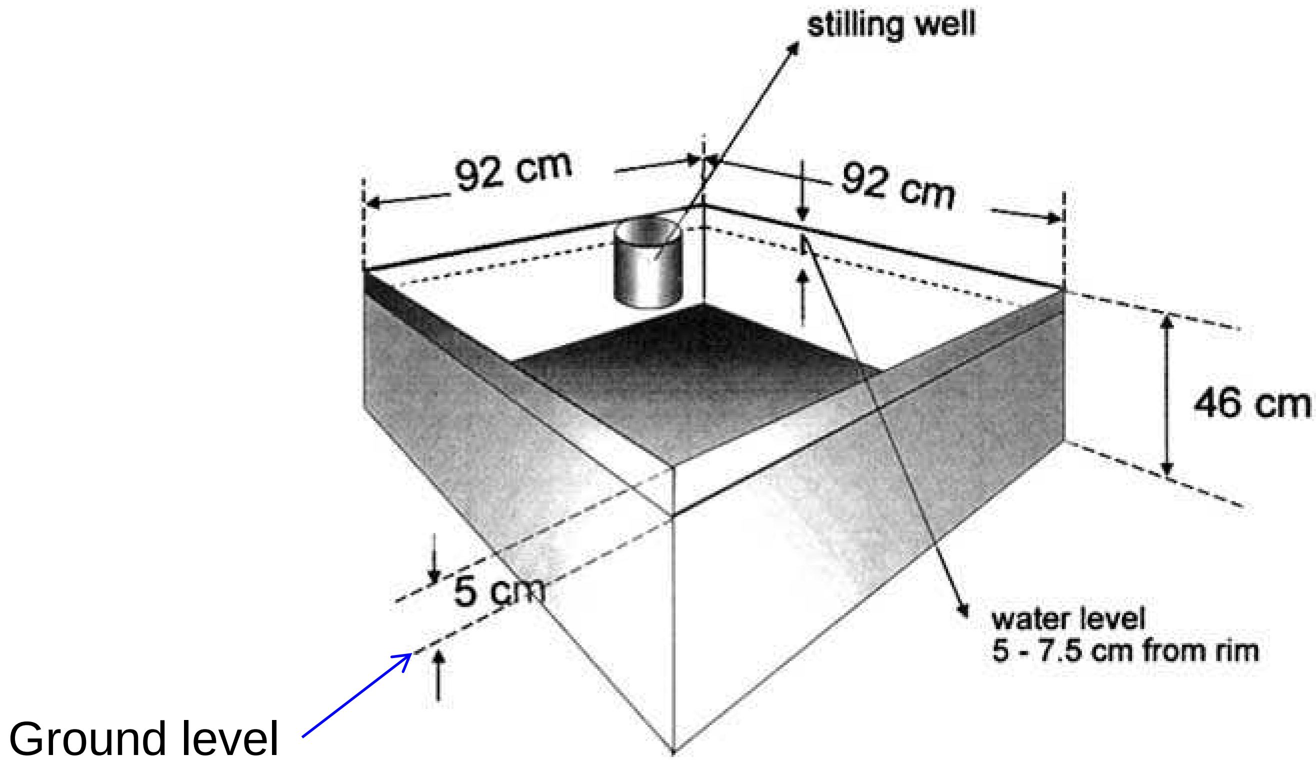
$$\text{Lake evaporation} = C_p \times \text{pan evaporation}$$

- Pan coefficient (C_p) typically ranges from 0.6 to 0.8
- Is C_p always less than 1?

Measurement of evaporation

IS evaporation pan

Measurement of evaporation



Colorado Sunken Pan

Source: http://www.fao.org

Measurement of evaporation

Floating Pan

http://perrylakes.info/overview/chapter-5-water-balance-components

Estimation of Evaporation

1. Empirical equations

2. Analytical methods

   - Water-budget equation

   - Energy-budget equation

   - Mass transfer method

Estimation of Evaporation

1. Empirical equations

Many equations are available that are expressed using the general form

$$E_L = Kf(u)(e_s - e_a)$$

K is a constant and $f(u)$ is a wind correction function

Meyer's formula (1915)

$$E_L = K_M\left(1 + \frac{u_9}{16}\right)(e_s - e_a)$$

K_M is 0.36 for deep water bodies and 0.5 for small shallow water bodies

u_9 is monthly mean wind velocity at 9m above the ground in km/h

E_L in mm/day, and e_s and e_a are in mm of mercury column

Estimation of Evaporation

2(a) Water budget equation

- Simplest but least reliable
- Water budget for a lake at daily time-step

$$P + V_{is} + V_{ig} = V_{os} + V_{og} + E_L + T + \Delta S$$

P is precipitation

V_{is} and V_{os} are inflow and outflow from the lake

V_{ig} and V_{og} are groundwater inflow and seepage losses

E_L is evaporation losses

T is transpiration losses

ΔS is change in lake storage