CEE6400 Physical Hydrology

Midterm Review

Learning Objectives (what you should be able to do)

Hydrologic data, the hydrologic cycle and water balance (HW 1)

- Work with hydrologic data, quantify uncertainty and variability, and apply conservation laws to the solution of hydrologic problems.

The Climate System and Global Hydrology (HW 2)

- Analyze the global energy balance and sensitivity of surface temperature to factors involved, such as albedo and the greenhouse effect.
- To quantify the water balance and its sensitivity to climate for a watershed of interest.

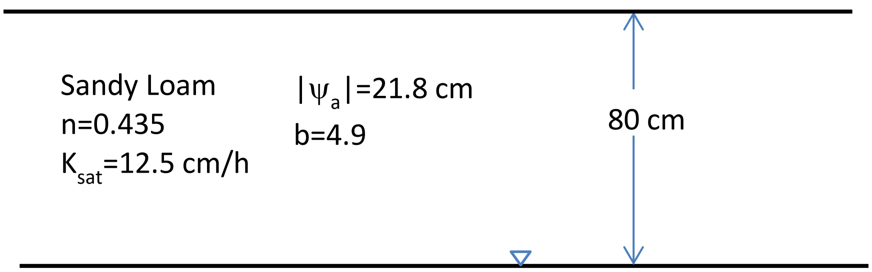
Precipitation (HW 3)

- Estimate area average precipitation from point measurements using a variety of methods
- Quantify the uncertainty in an areal precipitation estimate
- Estimate design rainfall amounts and intensities
- [Use ArcGIS for analysis of hydrologic data]

Runoff generation and water in soil (HW 4)

- Use the terminology used in hydrology and the study of rainfall-runoff processes (Workbook chapter 1).
- Describe the processes involved in runoff generation (Workbook chapter 2)
- Distinguish between infiltration excess, saturation excess and subsurface stormflow runoff generation mechanisms and identify when and where each is more likely to occur (Workbook chapter 2)
- Describe the physical factors resulting in the occurrence of runoff by the different mechanisms (Workbook chapter 3)
- Quantify the properties of water held in and flowing through soil (Workbook chapter 4)

1. **Water in Soil.** Consider a sandy loam soil under hydrostatic conditions with water table located at a depth of 80 cm.



The parameters indicated are Clapp and Hornberger (1978) parameters from Table 1, page 4:18 of the Rainfall Runoff Processes workbook.

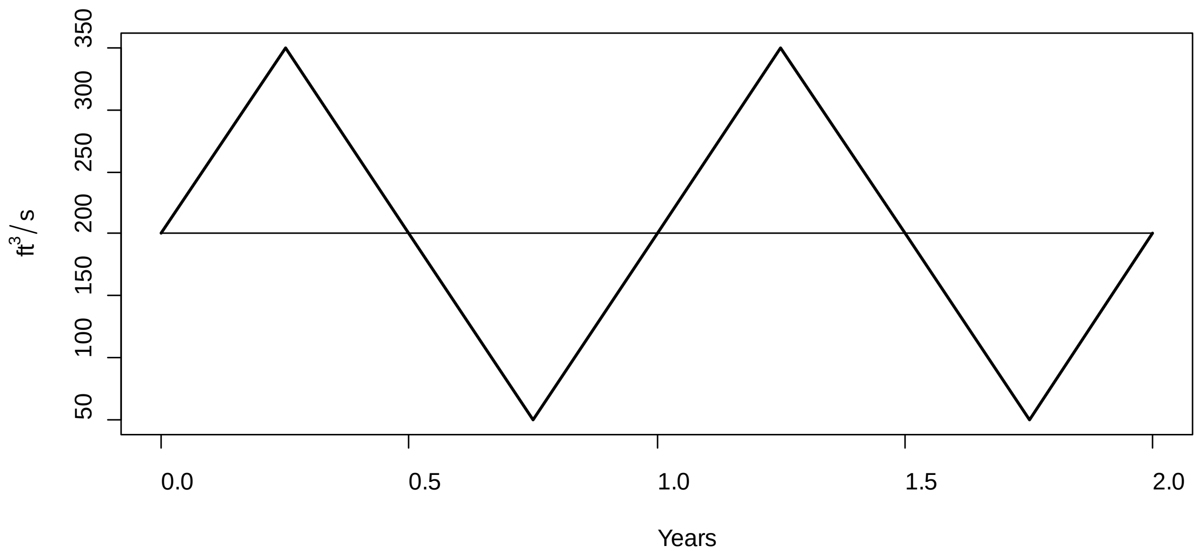
a. Plot the pressure head (matric potential) versus depth through the soil. [5]
b. Indicate the height of the top of the capillary fringe. [5]
c. Plot the water content versus depth through the soil. Indicate numerical values at the water table, top of capillary fringe, depth of 40 cm, and surface. [5]
d. Calculate the soil moisture deficit (cm). [For expediency you may use a reasonable numerical approximation.] [5]

Assume a rainstorm during which 6 cm falls steadily during 1 day.

e. Calculate the time to ponding. [5]
f. Calculate the depth of runoff generated. [5]

[30 points]

2. **Storage-Yield.** Consider a stream in which the seasonal cycle of monthly streamflow follows a perfect triangular seasonal cycle as illustrated with mean flow of 200 ft^3/s, minimum of 50 ft^3/s and maximum of 350 ft^3/s.



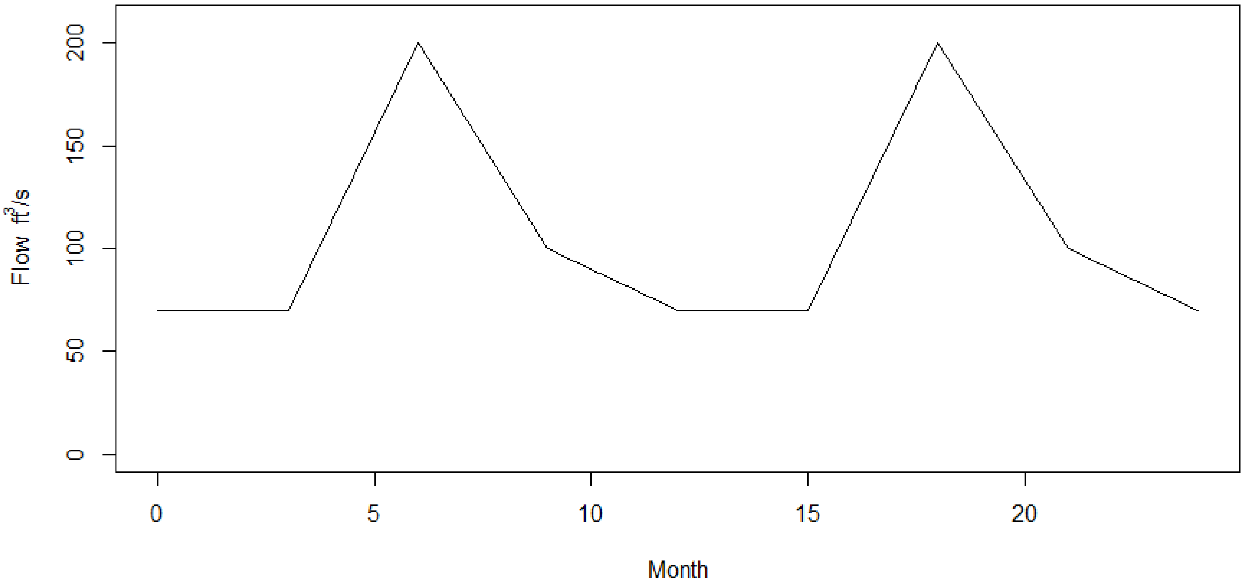
a. Determine the storage (ft^3) required to support a firm yield of 100 ft^3/s [8]

b. Determine the storage (ft^3) required to support a firm yield of 180 ft^3/s [8]

c. Plot a storage-yield diagram for this stream [8]

[24 points]

3. **Watershed Water Balance and Storage-Yield.** Consider a stream in which the seasonal cycle of monthly streamflow is as illustrated



Streamflow values in the graph are

Month	0	3	6	9	12	…
Streamflow	80	80	200	100	80	…

The watershed area is 100 mi^2. Average quarterly precipitation (snow and rain) totals are

Months	1-3	4-6	7-9	10-12
Precipitation (in)	20	15	5	10

a. Determine the mean annual flow in ft^3/s. [6]

b. Determine the storage (ft^3) required to support a firm yield of 100 ft^3/s. [8]

c. Estimate the mean annual evapotranspiration (in inches). [8]

d. Determine the runoff ratio for this watershed. [8]

[30 points]

4. **Climate and Global Hydrology**. This question refers to the global hydrologic cycle water and energy balance as depicted in Dingman Fig 3-16 (p54) and Dingman Fig 3-2 (p38). These figures are reproduced below for convenience.

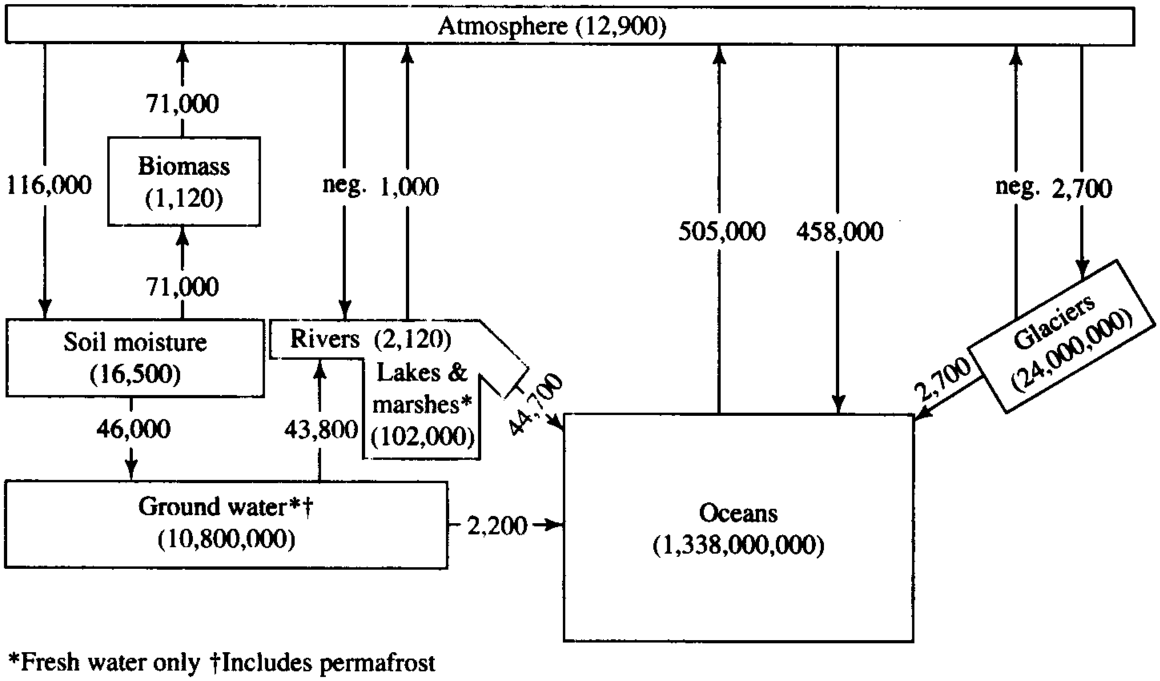


Figure 3-16. In this figure storage units are km^3 and flux units are km^3/yr.

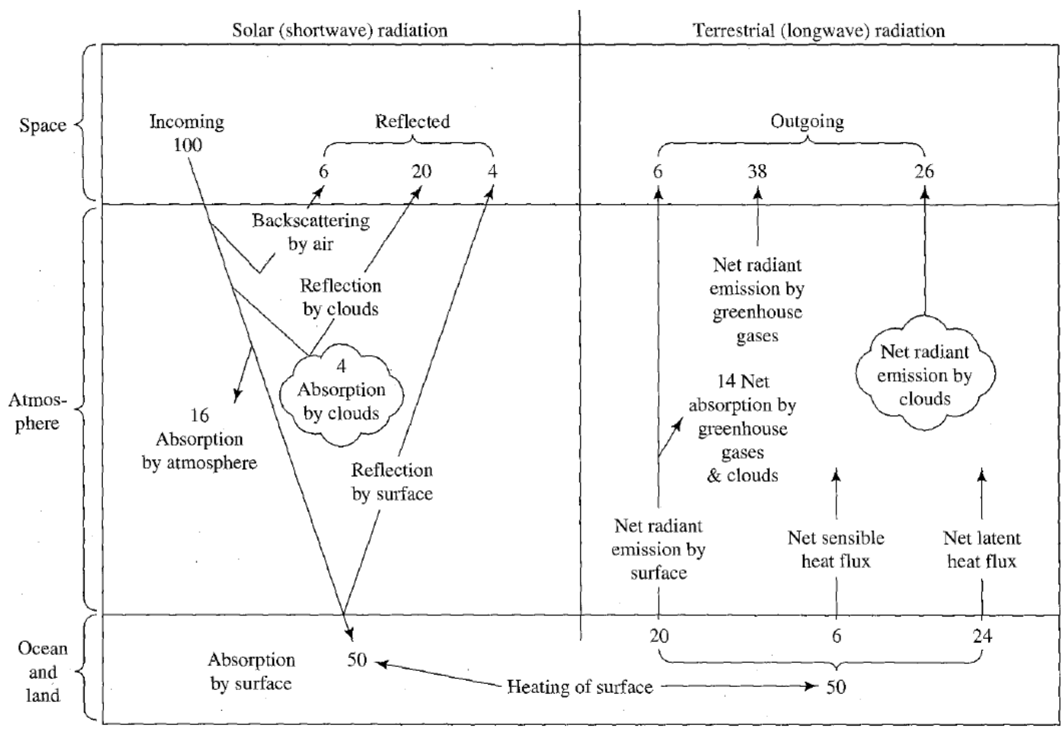


FIGURE 3-2
Average global energy balance of the earth–atmosphere system. Numbers indicate relative energy fluxes; 100 units equals the solar constant, 1367 W m^{-2}. Modified from Shuttleworth (1991); data from Peixoto and Oort (1992).

Reference quantities
Earth Land surface area = 149 x 10^6 km^2
Earth Ocean surface area = 361 x 10^6 km^2
Water latent heat of vaporization = 2.45 x 10^6 J kg^{-1}
Water density = 1000 kg m^{-3}

a) Calculate from Figure 3-16 the average annual evaporation from land surface area expressed in m/yr [4]
b) Calculate the land area latent heat flux in W/m^2 equivalent to your result from (a) [4]
c) Calculate from Figure 3-16 the average annual evaporation from ocean surface area expressed in m/yr [4]
d) Calculate the ocean area latent heat flux in W/m^2 equivalent to your result from (c) [4]
e) Express the net latent heat flux depicted in Figure 3-2 in terms of W/m^2 and reconcile your result with your answers in (b) and (d), commenting on any differences. [4]

[20 points]

5. **Climate.** Consider the earth's radiation balance as depicted in the figure below

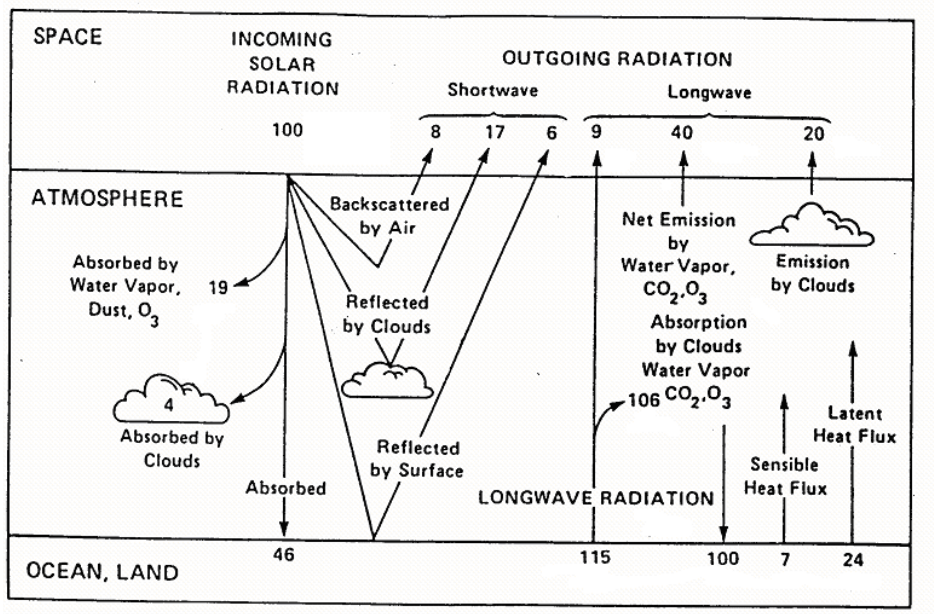


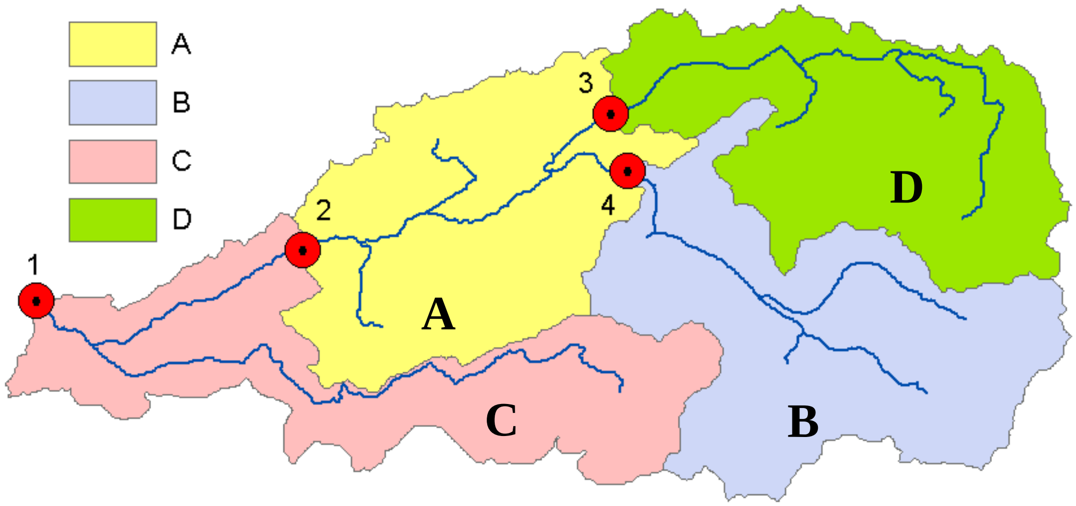
FIG. 6. Schematic representation of the atmospheric heat balance. The units are percent of incoming solar radiation. The solar fluxes shown on the left-hand side, and the longwave (thermal IR) fluxes are on the right-hand side (from MacCracken and Luther 1985).

In this figure 100 units of incoming solar radiation may be equated with the planetary average solar radiation forcing of 342 W/m^2.

Estimate based on values from this figure
a) The planetary albedo [5]
b) The surface albedo [5]
c) The surface radiative temperature (a planetary average) [5]
d) The planet average precipitation [5]

[20 points]

6. **Water Balance.** Consider the following watershed with four stream gages and subwatersheds draining directly to each gage as indicated.



The mean annual streamflow at each gage is

Gage #	m^3/s
1	7.7
2	6.4
3	2.4
4	2.3

This mean annual streamflow includes baseflow.

Subwatershed area and mean annual precipitation for each subwatershed is

Region	Area (km^2)	Precip (mm)
A	62	1400
B	75	1600
C	50	1300
D	58	1900

a) Estimate the mean annual evapotranspiration and runoff ratio for each subwatershed, assuming that deep infiltration losses to groundwater are negligible. [10]

b) Consider a land use change in watershed A that converts 20% of the area from natural vegetation to urban. Indicate the stream gauges where you expect the mean annual streamflow to change and whether it is likely to increase or decrease. Explain why? Estimate upper and lower limits to these changes and explain the basis for your estimates. [10]

[20 points]