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)

Infiltration (HW 5)

- Calculate infiltration, infiltration capacity and runoff rates using the methods described in the Rainfall Runoff Processes workbook chapter 5.

Review Questions (from past exams)

1. **Infiltration.** Consider a soil with the following properties

   Porosity n = 0.4

   Saturated hydraulic conductivity, K_{sat} = 1.5 cm/h

   Air entry head $|\psi_a|$ = 29 cm

   Pore size distribution index b = 7

   The water table is 1.2 m below the surface and conditions are hydrostatic.

   a) What is the position of the top of the capillary fringe? [5]
   b) Plot the moisture content versus depth through the soil. Indicate numerical values for the moisture content at the water table, top of capillary fringe, and surface. [7]
   c) Calculate the soil moisture deficit (cm). [8]
   d) Explain the difference between infiltration excess and saturation excess runoff generation and the role played by this soil moisture deficit in these mechanisms. [5]
   e) Suppose that in a different location with the same soil the depth to the water table is 0.25 m. Calculate the soil moisture deficit in this location. [5]

   [30 points]

2. **Infiltration and Runoff Generation.** Consider the following storm

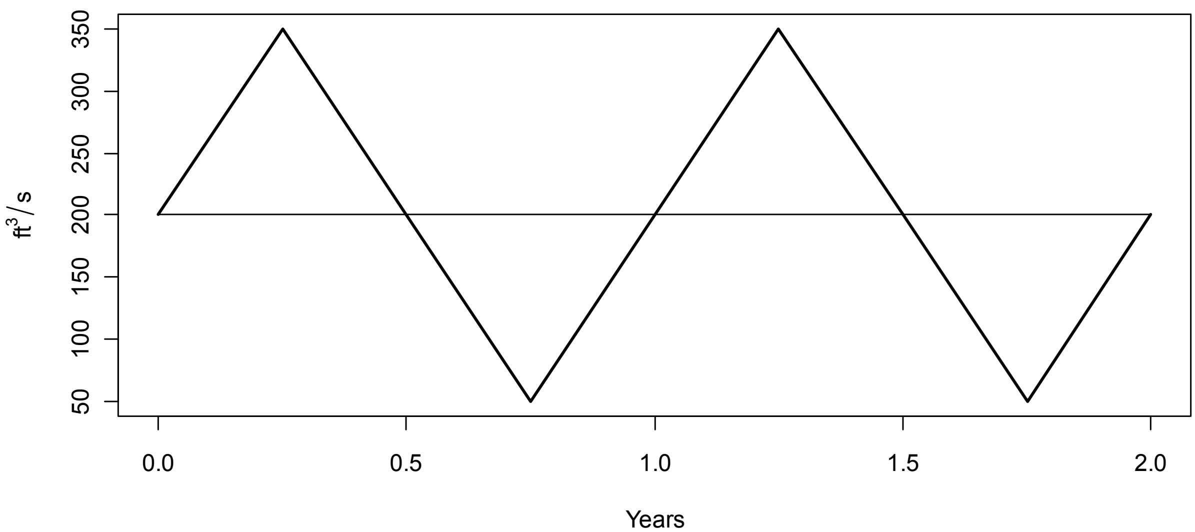
Time (h)	0-1	1-2
Rainfall Intensity (cm/h)	1	3

   Philip's equation is applicable with K_p = 0.3 cm/h and S_p = 3 cm/h$^{0.5}$

   a. Plot a graph of infiltration capacity as a function of infiltrated depth for this soil [8]
   b. What it the time that ponding first occurs in this storm [8]
   c. Determine the infiltration and runoff generated in each hour increment [8]

   [24 points]

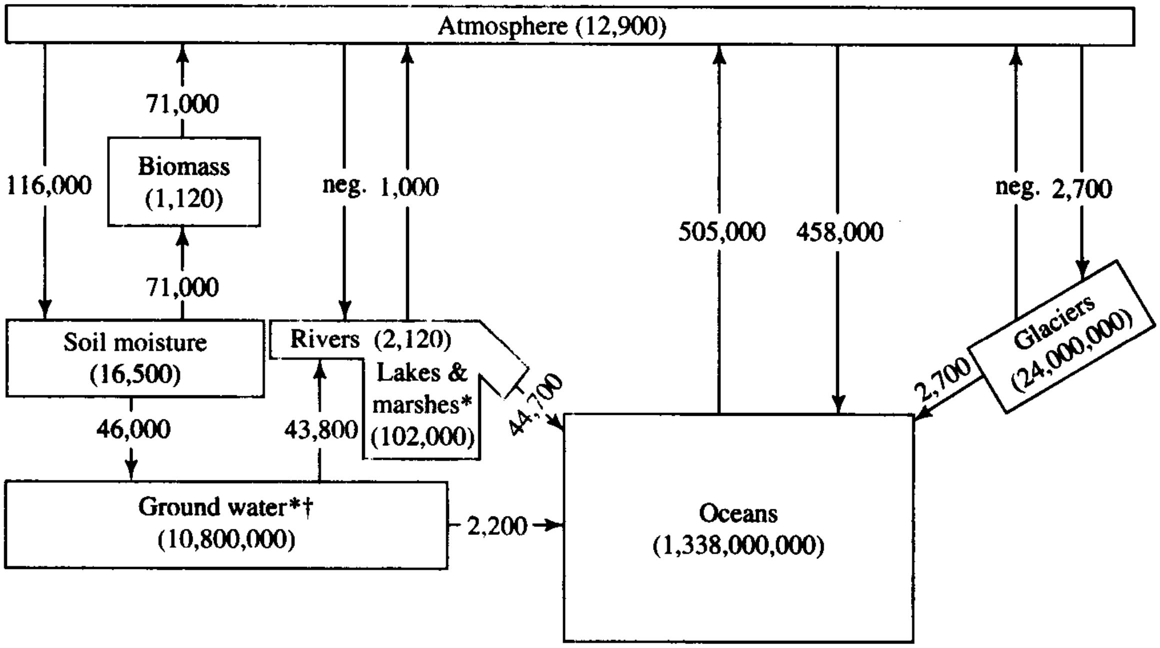
3. **Storage-Yield.** Consider a stream in which the seasonal cycle of monthly streamflow follows a perfect triangular seasonal cycle as illustrated with mean flow of 200 ft^3/s, minimum of 50 ft^3/s and maximum of 350 ft^3/s.



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]

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.



*Fresh water only †Includes permafrost

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

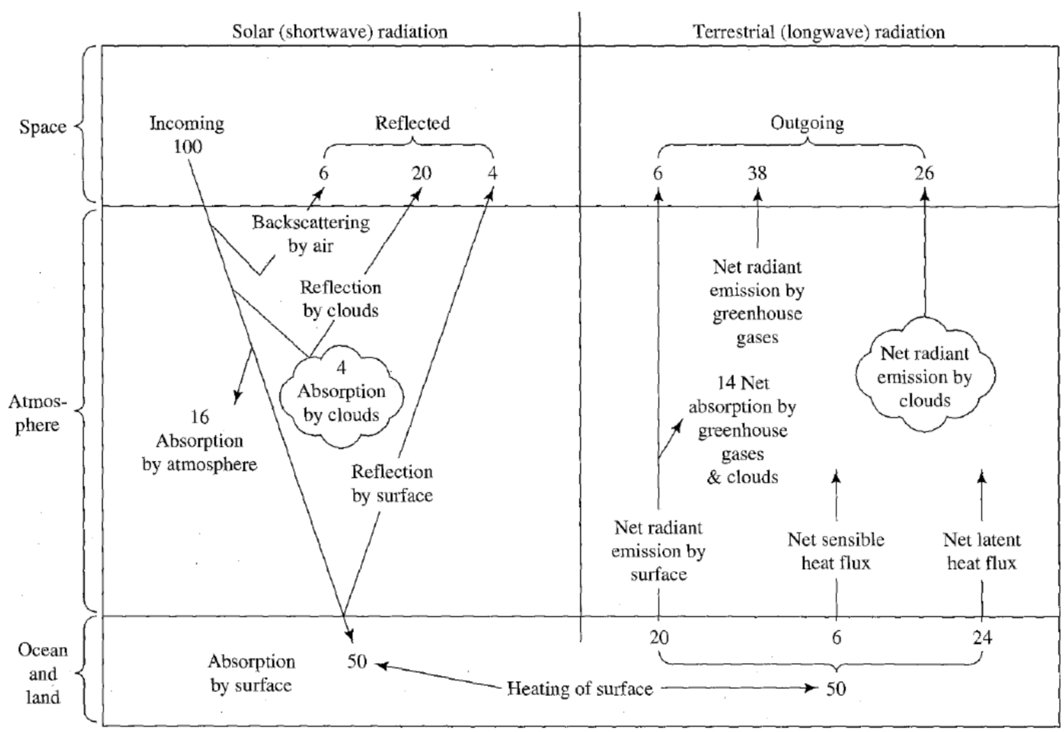


FIGURE 3-2
Average global energy balance of the earth–atmosphere system. Numbers indicate relative energy fluxes; 100 units equals the solar constant, 1367 W m^{-2}. Modified from Shuttleworth (1991); data from Peixoto and Oort (1992).

Reference quantities
Earth Land surface area = 149×10^6 km^2
Earth Ocean surface area = 361×10^6 km^2
Water latent heat of vaporization = 2.45×10^6 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

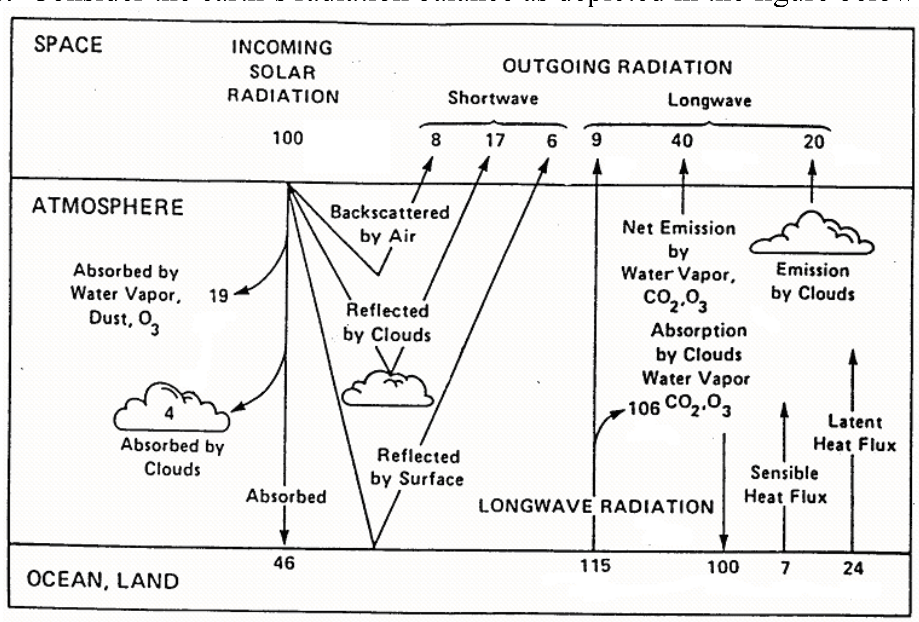


FIG. 6. Schematic representation of the atmospheric heat balance. The units are percent of incoming solar radiation. The solar fluxes shown on the left-hand side, and the longwave (thermal IR) fluxes are on the right-hand side (from MacCracken and Luther 1985).

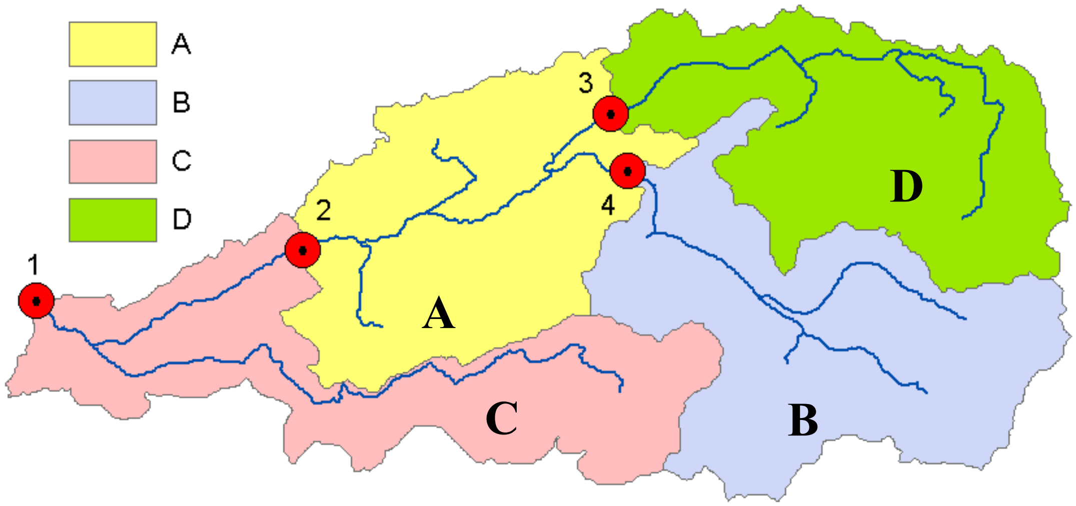
In this figure 100 units of incoming solar radiation may be equated with the planetary average solar radiation forcing of 342 W/m^2.

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]