

## ATS 761: Land-Atmosphere Interactions

Assignment #2

Due Thurs Oct 25

1. Suppose you have sampled soil from three sites with the following soil textures:

Site 1: Sand (10%), Clay (60%)

Site 2: Sand (70%), Clay (15%)

Site 3: Sand (40%), Clay (20%)

- a. Use the relationships in Cosby et al (1984, Table 4) to calculate the following parameters:
    - Exponent "b" for Clapp and Hornberger (1978) formulae
    - Saturated hydraulic conductivity ( $k_{sat}$ )
    - Matric potential at saturation ( $\Psi_{sat}$ )
    - Volumetric water content (vwc) at saturation ( $\theta_{sat}$ )
    - Field Capacity (vwc), assuming a matric potential  $\Psi = 1000$  mm
    - Wilting point (vwc) assuming a matric potential  $\Psi = 150,000$  mm
  - b. Use the method of Clapp and Hornberger (1978, equations 1 and 2) to plot the soil matric potential and hydraulic conductivity of each soil for water contents (vwc) from 5% to 100% of saturation.

Basically, I'm asking you to re-create Figs 9.8 and 9.10 in Bonan's textbook. Please use a logarithmic y-axis for each plot, and use different colors or symbols to denote soil from each hypothetical site.

2. Suppose a soil composed of 43% sand, 27% clay, and 30% silt has a volumetric water content (vwc) of 40% at 100 mm below the surface and that vwc = 35% at 300 mm below the surface. Use Darcy's Law to calculate the rate of vertical flow of water through between these two positions in this soil.
3. Download the file '**FCL.monthly.txt**' from the class website. Use the monthly mean temperature data for 2012 and 2013 to estimate potential evapotranspiration (PET) for each month using Thornthwaite's method, which is explained in section 11.4 of Bonan's textbook (equations 11.1 and 11.2). Make a plot of monthly precipitation and monthly PET for Fort Collins in 2012 and 2013.

**HINT:** the length of each day of the year can be obtained for any latitude and season using the hour angle calculation from Homework #1. Find the hour angle at sunrise and sunset from

$$h_0 = \cos^{-1}(-\tan \phi \tan \delta)$$

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where  $\phi$  is latitude and  $\delta$  is declination. The length of the day in angular radians is then  $2 h_0$ , so the length of the day in hours is

$$\frac{24 \text{ hours}}{2\pi} 2h_0 .$$

4. Construct a simple water balance model using your model of PET from problem (3) above. Imagine that the total water stored in the soil can be represented as a simple reservoir or “bucket” with a depth of 150 mm (about six inches).

Assume that the actual evapotranspiration (AET) in a month depends on the amount of water in the soil “bucket” according to

$$AET = \beta PET$$

where

$$\beta = \frac{\text{bucket}(t)}{\text{bucket}_{\max}}$$

is the ratio of the current amount of water in the “bucket” to the maximum amount the bucket can ever hold.

Further, assume that when precipitation falls the fraction  $i$  that infiltrates into the soil bucket is 75% when the bucket is empty, 25% when the bucket is full, and that this fraction scales linearly with  $\beta$  as

$$i = 0.75 - 0.5\beta .$$

For each month, add  $(\text{precipitation} * i) - AET$  to the bucket.

The rest of the precipitation [  $(1-i)* \text{precipitation}$ ] is “infiltration excess” runoff. If the bucket “overflows,” add this “saturation excess” water to the runoff for that month.

Using the monthly temperature and precipitation data from the file ‘**FCL.monthly.txt**’ which you downloaded for problem 3 above with the assumptions outlined here, estimate PET, AET, and runoff over Fort Collins for each month in 2012 and 2013 by updating your bucket model each month. Assume that there is 125 mm of water in your bucket at the beginning of 2012.

Make a plot of precipitation, AET, and runoff for 2012-2013 for Fort Collins, and turn this in along with your program code.