CEE6400 Physical Hydrology

Homework 1. Hydrologic data, conservation Laws and Reservoir Yield

Date: 8/26/13
Due: 9/9/13

Objective. The objective of this homework is to gain experience working with hydrologic data, quantifying uncertainty and variability and applying conservation laws to the solution of hydrologic problems.

General guidance. Whenever you hand in a homework which involves program codes and/or spreadsheet work, you need to describe your work briefly using text that explains what you did. For example you might write. The daily flow was downloaded from web site …. Then Excel was used to compute …, using the formula …. The result is …. If you give a computer program it is helpful to include comment statements and descriptive variable names.

1. Dingman 2.1.

2-1 Using Equation (2-16) and assuming no model error, compute (a) the estimated evapotranspiration; and (b) the absolute and relative uncertainties in the estimate for the following situations:

Location	Connecticut River	Yukon River	Euphrates River	Mekong River
Watershed area, A (km^2)	20,370	932,400	261,100	663,000
Precipitation, m_p (mm yr^{-1})	1,100	570	300	1,460
Relative error in P, u_P	0.10	0.20	0.10	0.15
Streamflow, m_Q, (m^3 s^{-1})	386	5,100	911	13,200
Relative error in Q, u_Q	0.05	0.10	0.10	0.05

2. Dingman 3.8. Calculate the residence times for all the global reservoirs in Figure 3-16. [Do not be put off by this being in chapter 3. It does not require concepts from Chapter 3. It uses residence time concepts from chapter 2.]

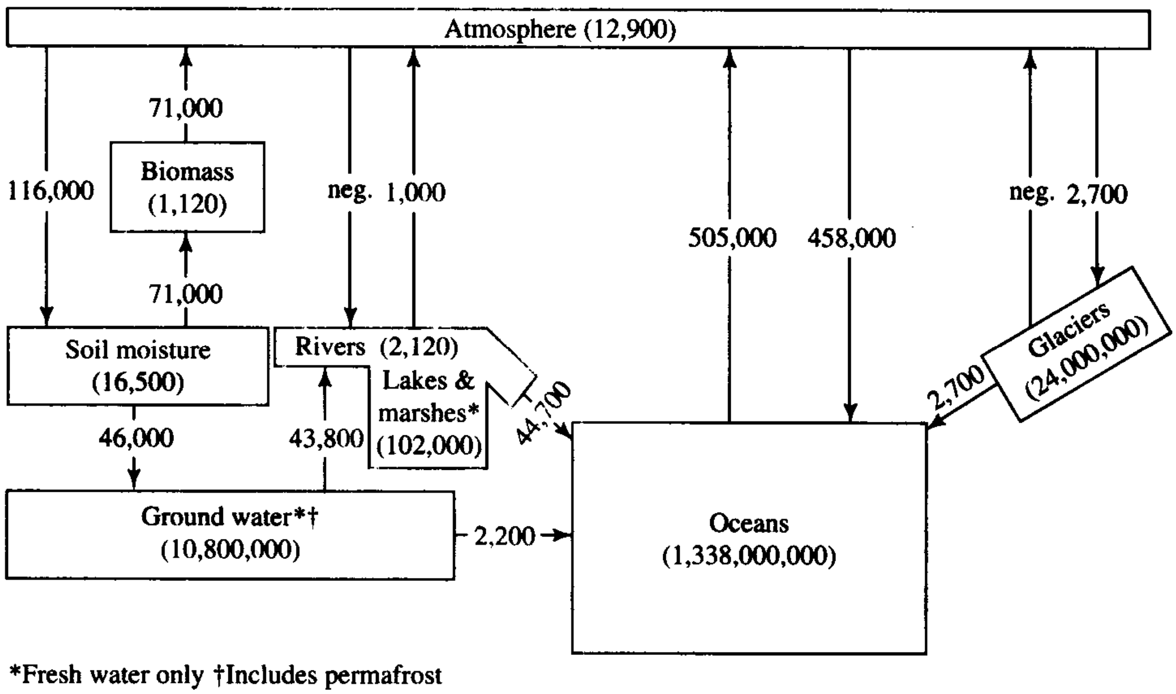

Figure 3-16. Schematic diagram of stocks and annual fluxes in the global hydrologic cycle. Inflows and outflows may not balance for all compartments due to rounding.

3. Obtain a series of streamflow data for a river of interest from the USGS (e.g. http://water.usgs.gov/, follow the link to surface water) that is current until at least the end of the 2012 water year (Sept 2012). Daily data for 20 years or more is ideal. Prepare a time series plot of the data you downloaded. The USGS has developed a tool dataRetrieval for retrieval of data directly into R that simplifies data retrieval and analysis (if you know R). I encourage you to learn R and to experiment with this tool. See
   - R bare essentials http://www.neng.usu.edu/cee/faculty/dtarb/cee6400/RBareEssentials.html
   - dataRetrieval https://github.com/USGS-R/dataRetrieval/

4. For the series plotted in the question above compute the average annual flow, peak flow and annual seven day minimum flow. Plot your results similar to figure 2.6.

5. Dingman 2.2 for the streamflow data you obtained in problem 3.

   2-2 **Using the methods in Box C-1, compute the sample median and 0.25- and 0.75-quantile values of the three time series in Table 2-2. The data for this table are in file TABLE2-2.XLS on the disk accompanying this text.**

6. Dingman 2.3 for the streamflow data from problem 3.

   2-3 Using the methods in Box C-2, compute the mean, standard deviation, coefficient of variation, and skewness of the three time series in Table 2-2. The data for this table are in file TABLE2-2.XLS on the disk accompanying this text. Which time series is the most variable, relatively speaking? Which is the most asymmetric?

7. Use the procedure in box C-1 (Dingman p556) to compute the exceedence probability associated with each daily flow value for the data from problem 3. Plot these in the form of a flow duration curve (like figure 2-7) where the X axis is the exceedence probability (1-q from box C-1 if ranking from smallest to largest was used) and the Y axis is the daily streamflow. Report the daily flow that has a 90% probability of being exceeded.

8. Monthly mean streamflow is defined as the average of streamflow within each specific month (e.g. average of daily flows in August 2012). The mean of monthly streamflows is defined as the average of monthly mean streamflow across all years for a particular month. For the data obtained in problem 3, compute the monthly mean streamflow and then the mean of monthly streamflows. Plot a graph of the mean of monthly streamflows. This provides an indication of the seasonality associated with the hydrologic cycle.

9. Consider the sizing of a storage reservoir for water supply purposes. Refer to Loucks et al., (2005), chapter 11, pages 343-347 (http://hdl.handle.net/1813/2804) for additional discussion and perspective on this approach. Streamflow into the reservoir is variable. A reservoir stores water when the flows are high and releases flows larger than the inflow to meet the needs of downstream users during times of low flow. The extra release is taken from storage. Given a time series of reservoir inflows a computation based on mass balance may be used to determine the reservoir storage required to meet a certain specified yield or demand. This is called the "sequent peak" procedure. Let R_t denote the release volume at each time step t, and Q_t denote the inflow volume at each time step t. Assume a reservoir starts full, with storage depletion $K_t = 0$. Then the depletion of storage at each time step is:

   $$K_t = K_{t-1} + R_t - Q_t \qquad (1)$$

   If K_t from this equation is negative it means inflow was larger than release plus available unfilled storage capacity so the reservoir fills up in that time step and the excess water is released as spill, and K_t reset to 0 (a reservoir with negative depletion is impossible). It is common to specify release R_t as a constant fraction of mean inflow, $\overline{Q}$,

   $$R_t = y\,\overline{Q}$$

   where y is a fraction between 0 and 1. For a given series of inflows the maximum of all K_t is the storage, S, required to sustain the specified releases or yield fraction. A storage-yield curve is constructed by calculating S for a series of yield fractions, e.g. y = 0.1, 0.2, ... 0.9, 0.95 and plotting $y\,\overline{Q}$ versus S.

   Use monthly time steps with average monthly flow data to compute and plot a storage-yield curve for the river you studied in problem 3. Note that equation (1) assumes that quantities

R, Q and K are in consistent and summable units. This is strictly only the case for volumes (e.g. ft^3) but not for flow rates (e.g. ft^3/s) because the number of days (and hence a different number of seconds) in each month varies. To be precise you should convert the average monthly flow data to monthly flow volumes for this calculation.

The procedure used here was based on past flows. Suppose a reservoir size was determined reading off the storage-yield graph you provided, constructed now and use for water supply purposes. Discuss as many deficiencies and limitations in this procedure for determining reservoir size as you can think of. Comment on how you might address these deficiencies.

Reference:

Loucks, D. P., E. van Beek, J. R. Stedinger, J. P. M. Dijkman and M. T. Villars, (2005), Water Resources Systems Planning and Management: An Introduction to Methods, Models and Applications, UNESCO, Paris, 676 p, http://hdl.handle.net/1813/2804