Zoe Maisel
BEE 6740: Week 7 Assignment
Model Calibration
3/16/18

Purpose:
Hydrologic analyses that use multiple models with different assumptions must be carefully understood to ensure that all inputs and assumptions are appropriate for the specific modeling question. Within this complex modeling space, the model may have varying ranges of sensitivity for each parameter. Peak annual streamflow was modeled using Monte Carlo simulations for initial abstraction, forest cover, storage, percent impervious, and wind speed. The Nash Sutcliffe Model Efficiency was calculated to compare USGS observed streamflow data and modeled flow.

Methods:
Using the "EcoHydRology" package and "SnowMelt" function in R, PET data for Ithaca, NY were calculated. The function "SnowMelt" calculated snowmelt in millimeters using inputs of date, precipitation (mm), maximum temperature (Celsius), minimum temperature (Celsius), and latitude. Meteorological data was obtained from NOAA "Global Summary of the Year."

The "Lumped_VSA_Model" calculates the streamflow and saturated area percentage for variable source areas using a lumped model of the watershed. The Thornthwaite-Mather water budget and SCS Curve Number for overland runoff are used in the model. A major assumption of the Thornthwaite-Mather model is that there is a linear relationship between available soil water and evapotranspiration. Additionally, the model does not include a feedback between soil water and plant growth. Plant conditions during the year are not considered as they are in calculations of PET for specific crops.

$$R = \frac{(P - I_a)^2}{(P + S_{max} - I_a])},\ P > I_a$$

$$I_a = 0.2\, S_{max}$$

$$S_{max} = \frac{1000}{CN} - 10$$

where R is runoff, P is daily precipitation, S_{max} is maximum soil-moisture holding capacity, I_a is initial abstraction and the amount of precipitation that must fall before any runoff is generated, and CN is curve number.

The “SnowMelt” and “Lumped_VSA_Model” was run and five years of precipitation, SWE, soil moisture, groundwater storage, and streamflow were plotted and are shown in Figure 1. Function inputs used are shown in Table 2. Daily date series, precipitation (rain and snowmelt), maximum temperature and minimum temperature were obtained from hydrological data and the “SnowMelt” model. The latitude used for Ithaca was 42.44 degrees.

Function Argument	**Definition**	**Value**
Tp (hours)	Time to peak of hydrograph	5
Depth (mm)	Average watershed soil depth	2010
SATper (volumetric fraction 0-1)	Porosity of soil	0.27
AWCper	Available water capacity	0.13
StartCond	Watershed conditions before the first day of runs	wet

Table 2: Function arguments and values for “Lumped_VSA_Model”

A sensitivity analysis was conducted on five parameters within the parameter space defined in Table 1. A Monte Carlo simulation analysis was done to determine peak annual streamflow sensitivity to the different parameters. It was hypothesized that flooding would be sensitive to initial abstraction, forest cover, storage, and percent impervious.

Table 1: Parameter range for Monte Carlo simulations

	Minimum	Maximum
Initial Abstraction, Ia	0.05	0.2
Forest Cover, fc (%)	0	100
Storage, Se	50	150
Percent Impervious, PI (%)	0	50
Wind Speed, u (m/s)	0	5

The Nash Sutcliffe Model Efficiency (NSE) was calculated using

$$NSE = 1 - \frac{\Sigma[(observed - simulated)^2]}{\Sigma[(observed - \overline{observed})^2]}$$

at a daily timestep. The observed data was obtained using the “get_usgs_gage” function for Fall Creek and the simulated data was obtained from the “Lumped_VSA_model.”

Conclusion:

The “Lumped_VSA_model” predicts streamflows that line up with precipitation and snowmelt data, as shown in Figure 1. Snow water equivalent (SWE) increases in winter months and then melts, leading to increased streamflows.

Sensitivity analyses shown in Figure 2 suggest that the runoff model is most sensitive to percent impervious. This positive trend aligns with the equation given for runoff in the Thornthwaite-Mather equation. Physically, it makes sense that runoff increases with percent impervious cover because less water is able to infiltrate the ground as available water content or groundwater recharge.

The NSE found for the model was 0.523. This value can be understood to mean that the model follows observed data to a limited degree, but because the NSE was greater than 0.5, which is an accepted cut-off point, it has some use. Additional parameter and assumption modification could increase the NSE to be closer to 1, which would make it a better model. It is important to note that while there were errors in the model, the physical hydrologic processes are rate-limiting at extremes which means that water balance errors are unlikely to grow without bounds. For example, as precipitation decreases, there is less available water content in the soil so there is higher matric potential and lower evapotranspiration; the soil will not continue to dry at the same rate in wet and dry conditions. The energy balance approach helps keep models within reasonable and desired ranges.

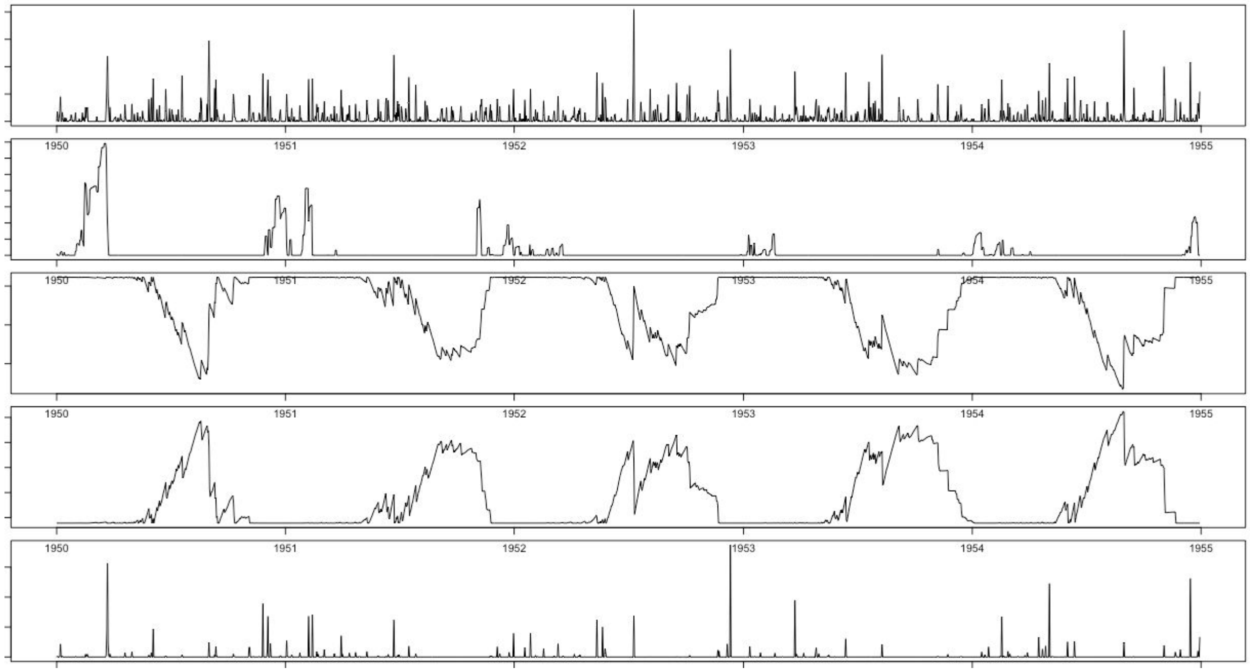

Figure 1: Five years of precipitation, SWE, soil moisture, groundwater storage, and streamflow for Ithaca, NY (mm). Precipitation is shown in the top plot and streamflow is shown in the last.

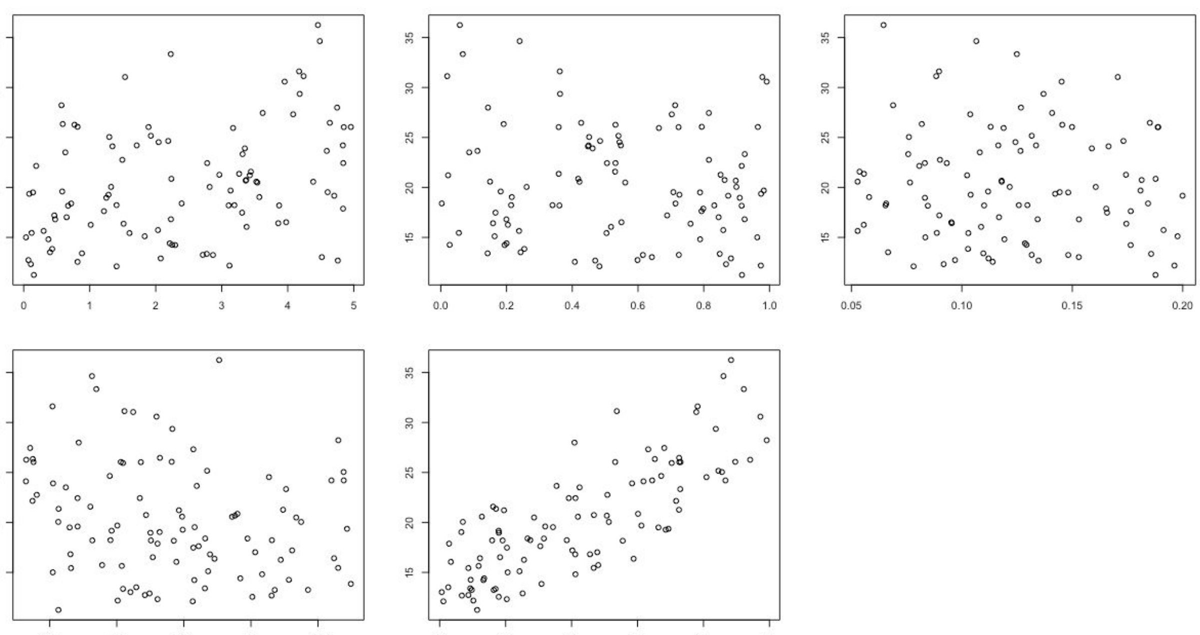

Figure 1: Sensitivity analysis for Monte Carlo simulation parameters by runoff. From top left to bottom right, the parameters plotted were runoff vs. wind speed (m/s), forest cover, initial abstraction, storage, and percent impervious.