COMPUTER METHODS AND MODELING IN GEOLOGY
LAKE LEVEL CHANGES IN THE ARID WEST

Closed-basin lakes in the western United States have been termed “nature’s rain gauges” because they respond to changes in precipitation by changing their levels. Many basins in the arid West today contain small lakes, but also contain shoreline deposits that indicate these lakes were once much larger. Basin center deposits combined with shoreline materials indicate that lakes oscillated in size during the late Pleistocene. The causes of these oscillations are not yet entirely understood, though many believe that lakes expanded because the jet stream was forced southward by the large Laurentide ice sheet. The jet stream (today found at the latitude of Washington and Oregon) is the locus of storm activity, and computer models of late Pleistocene climate suggest that it split around the ice sheet, with its southern track ending up in Nevada and eastern California.

In today’s lab we’ll explore the impact of changes in climate on the level of lakes in the Owens River system. These lakes, which were separated by bedrock sills and which were fed by runoff from the eastern flank of the Sierra Nevada mountains in California, were headed by Owens Lake. When Owens Lake filled to its maximum level, it overflowed into the China Lake Basin, which in turn overflowed into Searles Lake. During particularly wet periods in the geologic past Searles overflowed into Panamint Lake, which ultimately overflowed into Manly Lake in Death Valley. In our modeling effort today we’ll see what combinations of runoff and evaporation might have led to Pleistocene lake level oscillations.

Readings

Menking, K.M., and Anderson, R.S., unpublished, A Model of Runoff, Evaporation, and Overspill in the Owens River System of Lakes, Eastern California.

Exercises

1) Create a model of the entire chain of lakes. Note that the evaporative outflow from each lake depends on the surface area of the lake. This requires that we incorporate into our model a relationship between lake volume and area for each lake in the chain.

In the Classes>Geo365 folder on your computer you’ll find a file called “hypsometry_data.txt” that contains area/volume/depth relationships for each lake in the chain. Create a scatter graph of area as a function of volume for Owens Lake and then apply a curve fit to this graph to determine the function that relates these two variables. Use this relationship in your model. Note that your relationship will not be linear, but instead a polynomial or power of some sort. Try to get the best possible curve fit between the two variables.

2) Repeat step 1 for the other 5 lakes in the chain.

3) Next, what do you need to do to allow the lakes to overflow when they fill up with water? Write the equation for overflow that you're using for Owens Lake and apply the same logic to the other lakes in the chain.

4) Use the data in the "hypsometry" kaleidagraph file to determine the relationship between depth and volume for each lake.

5) Fill in your remaining initial conditions – initial lake volumes = 0, and evaporation and runoff rates as specified in your reading for the modern climate.

6) Run your model for about 200 years and **describe and explain** the resulting behavior of the lake level curves (depth). What size lakes do you get? Why does the depth of Owens Lake eventually reach steady state?

7) How long does it take for Owens Lake to reach 95% of its steady state depth? Note: I'm asking for 95% of steady state because the lake approaches steady state asymptotically, so it is difficult to determine when it has reached complete steady state. For all future questions regarding time required to reach steady state you may also look at the 95% value.

8) Experiment with changing the amount of runoff into the lake. Double, triple, and halve the runoff. What impact does runoff amount have on the time required for Owens lake to reach steady state?

9) Change your runoff back to the modern value and then experiment with changing evaporation rates. What impact does evaporation rate have on the time required to reach steady state?

10) Change your evaporation rate back to the modern value. Let's mess around with changing the area/volume relationship for Owens Lake to see what

impact lake hypsometry (basin shape) has on the response time for the lake (response time = time required to reach steady state).

Change your exponent in the area/volume equation to values higher and lower than the value you got for Owens Lake. What happens to the response time as you change the exponent? Why?

11) Set your exponent back to its original value. Now determine how much you need to increase runoff by in order to get water to flow all the way to Lake Manly given modern evaporation rates.

12) We know that glacial period evaporation rates were significantly depressed relative to modern because of the colder average surface temperature of Earth. Incorporate a 30% reduction in evaporation rate to all of the lakes and again determine how much water is required to get water to spill into Lake Manly.

13) How long does it take the lake chain to reach a steady state under this glacial scenario?

14) Given the response times you have determined in 12 and 13, comment on the ability of the lake chain to record climatic changes (such as long droughts or exceptionally wet periods) that occur on the timescale of decades.

15) Would the lakes be able to record climatic changes that occur on the timescale of thousands of years?

16) Using your modern evaporation rates, let's put your answers to 14 and 15 to the test. Create an equation that will allow the runoff to vary between modern and 10x modern values with a period of 100 years. What is your equation?

17) Run the model for several hundred years and show the behavior of the lakes. Is the chain in steady state? How do you know?

18) Now change the period to 1000 years and run the model for a few thousand years. Is the chain in steady state now?