

ESE 148c  
Spring 2008  
Problem Set 2 - due Friday 18 April

Construct a water-balance model for a lake in Bakersfield, California. The lake is a rectangular prism with time-varying level and isotopic ( $\delta D$  and  $\delta^{18}O$ ) compositions. Because we are assuming the lake has vertical size, we only need to balance the level of the lake, relative to the inputs/outputs from precipitation, evaporation, and stream inflow. The lake is fed by a small stream from the Sierras, with a constant discharge equivalent to 4.5 inches per month for the whole lake. The isotopic composition of Sierra precipitation, and hence the stream, is  $\delta D = -85$  permil and  $\delta^{18}O$  of -14 permil.

Climatological values for precipitation, temperature, and humidity are found at:  
<http://www.wrcc.dri.edu/cgi-bin/clilcd.pl?ca23155>

In your model, use the data from the webpage as the monthly precipitation input to the lake. Assume that the lake receives precipitation equal to the monthly mean precipitation times a catchment area ten times that of the lake's own surface area, with a runoff rate of 15%. The isotopic composition of the cloud moisture is  $\delta D = -150$  permil and  $\delta^{18}O = -25$  permil. Use these isotopic values to compute the composition of the precipitation into the lake as a function of temperature, assuming that cloud temperature is 20 K less than the surface temperature. You may also assume that you can ignore the effect of reevaporation of precipitation as it falls, and that the amount of condensation forming over the lake is small enough that it has no significant impact on the cloud vapor isotopic composition.

Water evaporates from the lake at a rate that is 0.7 times the measured pan evaporation rate. Measured pan evaporation rates for Bakersfield are reported at:  
<http://www.sjd.water.ca.gov/landwateruse/evaporation/>

The lake has a constant outlet that keeps the maximum level fixed at 150 inches. If the inputs exceed evaporation, the excess water flows downstream with an isotopic composition equal to that of the lake. If evaporation exceeds precipitation and stream inflow, the lake level can drop.

- (1) Calculate the water balance and lake level over several seasonal cycles. Initialize the lake level at 125 inches. Make a plot of the lake level with time.
- (2) Calculate  $\delta D$  and  $\delta^{18}O$  of evaporation a function of time, using the monthly-mean humidity values, assuming lake values are constant. Initialize the isotopic composition of the lake to  $\delta D = -10$  permil and  $\delta^{18}O = -2$  permil. Plot  $\delta D$  and  $\delta^{18}O$  of the evaporative flux as a function of time. Why do the plots look like they do? Can you generate a local meteoric water line by plotting one against the other? Why or why not?
- (3) Allow the lake isotopic composition to change, using isotopic mass balance at each

time step. Assume that the lake is well-mixed on monthly timescales. Add in precipitation, and plot the isotopic composition of the lake as a function of time. Plot  $\delta D$  vs  $\delta^{18}O$  and calculate the slope. Why is this the slope? If you measured the  $\delta D$  and  $\delta^{18}O$  at any time, could you estimate the relative amounts of precipitation versus streamflow?

(4) Take the model as in part 3, and try to predict what might happen under various climate change scenarios. What happens if evaporation increases by 20% at constant temperature? What happens if temperature increases by 2K at constant evaporation? What if both change? Plot the lake level and isotopic composition for each scenario.

A partially written script `lakemodel.m` is available on the webpage. I've defined the constant values in the simulation and initialized the variables for problem 1. I have also made vectors for `pan`, `Ctemp`, `Chum`, and `Cprecip`. These are 1x12 vectors, with one value for each month taken from the webpages listed above. To run the model, I would suggest making one time step each month, and running the model for a couple seasonal cycles. In the script, I run the model for 10 years. I use the matlab function `'mod'` to compute the month index (1=January, 2=February, etc). As an example, I have defined humidity `'hum'` inside the main loop – you will need to do something similar for temperature, precipitation, and evaporation. For this problem set, you'll need to do more scripting than for problem set 1. Use examples from `daisyworld.m` to flesh out the script in `lakemodel.m`. Feel free to seek help from me or your classmates, but keep in mind that your finished script must be your own work. We would like you to turn in a copy of your script with your problem set.