ESS 123/223/ BIO 125: Ecophysiology and Land Surface Processes
Problem Set 3
Due Wednesday November 15th, 2017 at the start of class. Please bring a hard copy of your solutions to class. Include a print-out of your code, but don’t include code you were given and didn’t modify.

The objective of this problem set is to work with some data collected at an eddy-covariance (also known as eddy correlation) site in Manaus, Brazil in the Central Amazon.

We will use the meteorological drivers measured at this site to model the energy balance and photosynthesis at the site, using the iterative approach discussed in class. To help you along, we’ve provided you with a set of R scripts that do this main iteration. The main photosynthesis model contained in the doPS files should look familiar to you from problems 4 and 5 on problem set 2 (although these are adapted to work for either C3 or C4 plants, and to account for temperature effects that were not accounted for in problem set 2), and other equations should look familiar from class and earlier problem set questions. The goal of this problem set is not to make you grapple unnecessarily with a long piece of code, but to allow you to learn from it how the coupled systems work.

Aside from the processing code, input drivers are contained in the file “ManausMet.csv.” It contains flux measurements and meteorology collected from a tower extending above the forest. The columns of this file are as follows:

- column 1 is the time given in the format yymmddhh (83090300 = 0hr, 03 Sept 1983. There are 15 days of data with data for each hour. You don't have to concern yourself with this, but if you are interested, R has powerful ways to deal with time data.
- column 2 'iqcaws' is a quality control file. 2 means the met data is OK.
- column 3 ‘swdown’ is shortwave radiation down (W m-2)
- column 4 'rnetm' is net radiation (W m-2) (N.b., this is an observation)
- column 5 'zlwd' is longwave radiation down (W m-2)
- column 6 'em' is the ambient water vapor partial pressure (mbar)
- column 7 'tm' is the air temperature at measurement height above the canopy (˚K)
- column 8 'um' is the wind speed (m s-1)
- column 9 'tprec' is the total precipitation (mm)
- column 10 'iqchyd' is a quality control flag for the flux measurements, 0=complete
- column 11 'mevap' is the measured Latent Heat Flux (W m-2)
- column 12 'msensh' is the measured Sensible Heat Flux (W m-2)
- column 13 'mustar' is the momentum flux (m s-1)

These last three columns (11-13) and column 4 are measurements that are useful for comparing with simulations.

DoFlux.R is the main script – it iteratively solves for the energy budget, photosynthesis and stomatal conductance. Pset3_metloop.R puts the DoFlux code into a loop to iterate through the met dataset. A few things it might be useful to note here:

1) The relationship gb=1.47*(u/d)^{1/2} is used to relate the boundary layer conductance to the wind speed. A value of 10 cm is used as d, the characteristic leaf dimension.
2) There are two other variables in the program that you haven't encountered before; 'rstfac' is a stress parameter. rstfac=1 under unstressed conditions, and 'cif' is the canopy integration factor. This is a function of leaf area index (LAI). We don't know the LAI for this site, so we can treat cif as an adjustable parameter.

The specific objectives of this problem set are as follows. If you are able to produce the deliverables below, you should meet these objectives along the way:

1) to compare your simulations with the sparse observations of sensible and latent heat collected at the site. You should try adjusting the "canopy integration factor" (cif) in the program to see its effect on the fluxes and photosynthesis. This factor works by changing the effective Vmax of Rubisco for the integrated canopy. Note how the biophysics of the canopy changes with the biochemical capacity.

(2) to extend the simulations to calculate the carbon isotope fractionation during CO_2 uptake during the simulations. This may seem daunting at first, but the process has rather simple dependence on parameters you have already calculated in the simulations.

(3) to add code to obtain a flux weighted average of the isotope fractionation (ignoring times when there is net respiration) during the time interval of your simulation. To flux weight a variable like discrimination, you can use the equation:

$$\bar{\delta} = \frac{\sum \delta A_n}{\sum A_n}$$

where A_n is net photosynthesis, d is the value at each time-step, and the $\bar{\delta}$ is the flux-weighted average over the time interval that the sums are collected.

(4) to explore the impact of plant adaptation by using a parameter set for a needle leaf temperate forest (type 4) and C4 (type 6a) in place of the more appropriate broad leaf evergreen (type 1). Also explore the role of humidity by scaling the input value of ambient humidity (ea) to 2/3 and 1/3 of the observed values (em).

Deliverables:

1. A diagram of the program blocks, the iteration loops and how the variables are adjusted in these loops.

Hint: As you try to understand the code structure, it may be helpful to run through and look at how numbers change over different loop evaluations. The R debugger tools may be useful for this. See here: https://support.rstudio.com/hc/en-us/articles/205612627-Debugging-with-RStudio

2. A plot of LE, H, Rn over the first two days
3. A plot of photosynthesis over the first two days
4. Plots contrasting the effects of selecting different vegetation density (cif) and vegetation types on the fluxes. Just pick something that interests you.
5. A table showing the flux-weighted isotope discrimination in the simulations, and how those change in response to changing the ambient humidity.
6. A copy of the code you used to do this.
7. A very brief paragraph stating what you learned from this.