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Geog595 Ecological Modeling
Spring 2007
Due: 5pm Feb 7, 2007

Lab 4 Calculating Incoming Solar Radiation with C

1. **Objectives**
   (1) Learning programming in ecological modeling in C.
   (2) Development a module that calculates solar radiation arriving at the Earth surface at any place any day and any time.
2. **Theory**

Solar radiation is the ultimate source of energy that drives all ecosystem process. It is essential to modelers to know how much solar radiation arriving at the Earth surface in order to model other ecological processes. At the very top of the atmosphere, the solar radiation flux density can be considered a constant, Solar Constant (S_0=1367.0 W/m^2). The amount of solar radiation arriving at the Earth surface changes because of the change in atmospheric conditions and position of the Sun in the sky. The atmospheric condition is usually characterized by a parameter called atmospheric transmittance. The direct solar radiation arriving at the horizontal surface on the ground is

$$S_b = S_0 \tau^m \cos(\theta),$$

where S_b is the direct solar radiation, , and θ is the solar zenith angle, θ=90-h, where h is the solar elevation angle. τ is the atmospheric transmittance, and m is the atmospheric optical number The atmospheric optical number quantifies the amount of atmosphere that the sunbeam passing through the atmosphere, i.e.

$$m = \frac{P_a}{101.3\cos(\theta)} = \frac{P_a}{101.3\sin(h)},$$

where P_a is air pressure (kpa) and

$$\sin(h) = \sin(\varphi)\sin(\delta) + \cos(\varphi)\cos(\delta)\cos(\varpi),$$

where φ is latitude, δ is sun declination angle, ω is hour angle. The sun declination angle can be estimated as

$$\delta = 23.45\sin\left(\frac{2\pi(\mathrm{J}+284}{365}\right),$$

where J is Julian date, or the day of the year. The hour angle is calculated as ω=15×(t-12) degrees, where t is the solar hour.

The diffuse radiation arriving at the horizontal surface is

$S_d = 0.3(1-\tau^m)S_0 \cos(\theta)$

3. Programming Experiments

We have a program written in C called radiation.c. The program calculates the direct and diffuse solar radiation arriving at a horizontal surface on the ground anywhere anytime in the Eastern Time zone of the United States given the atmospheric transmittance. The program takes the inputs from command line. Study the program and make sure you understand what each line of the program is doing.

(1) Run the program to figure out the direct and diffuse solar radiation at noon time for winter solstice, spring equinox, and summer solstice at Chapel Hill given the atmospheric transmittance being 0.75, 0.6 and 0.4. Explain: (a) how the two components of solar radiation change with the date at a given atmospheric transmittance, and why; (b) how the two components of solar radiation change with decreasing atmospheric transmittance, and why.

Example code: radiation –m 12 –d 21 –h 12 –i 0 t -0.75	transmittance	Direct radiation (W/m2)	Diffuse radiation (W/m2)
winter solstice: Dec 21	0.75	337.388246	87.753153
	0.6	207.881960	126.605038
	0.4	86.231374	163.100214
spring equinox: March 21	0.75	725.471835	98.463546
	0.6	543.117790	153.169759
	0.4	320.953005	219.819195
summer solstice: June 21	0.75	974.697134	101.967267
	0.6	772.851264	162.521028
	0.4	506.972020	242.284801

a) As the date progresses from winter to summer, both the direct and diffuse radiation increase to a maximum in the summer, for any of the transmittances. This happens because the sun is at a more direct angle with the earth during the summer, which is why summer is warmer than winter.
b) As the transmittance decreases, the amount of direct radiation decreases, but the amount of diffuse radiation increases. This is because lower transmittances are caused by lots of particles in the atmosphere that scatter light, thus creating more diffuse radiation.

(2) Run the program for any of the above date, but pretend you enter a time that is too early or too late (e.g. 21:00), see what you get from the program. Explain why you get what you get.

For an hour of 21:00: radiation –m 12 –d 21 –h 19 –i 0 -t 0.75.
This gives direct solar radiation = -1112.160311 W/m^2, and diffuse solar radiation = 175.154975 W/m^2. The direct radiation is negative because the sun is below the horizon, giving a negative value for the sine of the solar hour.

(3) Modify the program so that it will tell you it's before sunrise or after sunset if you enter such a time to the program, and not printing any wrong values on the screen. Compile the program and make sure it works. Save your new program as radiation_v2.c.

I noticed that it is before sunrise or after sunset if sinh < 0, so I entered this into the program as an if/else statement. If this condition is met, it will output that the sun is below the horizon. If it is not met, then it will output the direct and diffuse solar radiation.

(4) Modify the program still so that the program will work anywhere anytime in the world. Compile the program, and run it to make sure it works. Save your new program as radiation_v3.c.

This requires the GMT hour and minute to be inputted instead of the local hour and minute, and also 2 additional parameters: latitude (l) and longitude (g). An example of running the program for our local area would be as follows:

radiation_v3 –m 12 –d 21 –h 19 –i 0 -t 0.75 –l 39.0 –g -79.0.