Assignment 1
GEOG 321 - Climatic Environments / Knox
2025 Winter

Radiation and soil thermal regimes

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Preamble: In this assignment you will use radiation data collected on the University of British Columbia campus, located in Vancouver, BC (49.2°N, 123.2°W) and soil measurements from a climate station in BC.

Using the link below you will be provided with data from a single day (the actual day is selected based on your student number, as shown on the web-page). Data are available for download in various formats:

Radiation data
Soil data

In the radiation files you will find measurements of the following variables: incoming and reflected short-wave radiation ($K_{\downarrow}$, $K_{\uparrow}$), incoming and outgoing long-wave radiation ($L_{\downarrow}$, $L_{\uparrow}$), air temperature (T_a) and relative humidity (RH). All measurements are from the set-up on Totem Field on the UBC campus. Note that for the Stefan–Boltzmann constant (σ) you should use $5.67 \times 10^{-8}\,\mathrm{W\,m^{-2}\,K^{-4}}$.

The soil data-set includes 15-min averages of the following variables: four soil temperatures (T_1, T_2, T_3, and T_4) measured at depths of 5 cm, 10 cm, 20 cm and 50 cm, respectively, soil heat flux density Q_G from a soil heat flux plate installed at a depth of 7.5 cm, soil volumetric water content θ_w measured using TDR at -7.5 cm, net all-wave radiation Q^* measured 2 m above the surface, and sensible heat flux density in the atmosphere Q_H measured 2m above the surface.

The soil at the climate station has been analyzed in the lab and the following values were determined: porosity is $P = 0.57$, bulk density of the dry soil is $\rho_s = 1.13$ Mg m^{-3}. The soil organic mass fraction was determined 3.77 % (of total dry soil mass). Assume that those values apply to the entire vertical profile.

Based on the lab analysis, heat capacity C of the soil is presented in Table 1 below (p. 5). You will need this data for the soils portion of the assignment. Note: When asked to make graphs, make sure to label your y and x axes and include units. Also, you may not need all the variables provided to you in the data tables

Instructions: Please upload your answers including calculations, discussions and graphs in a single, well-structured report (either Word, PDF or HTML file). Instructions on how to download an html and submit it to myCourses can be found on the course website under the section 'R Resources' - 'RStudio Server' - 'Downloading the output to upload your file to myCourses'. Label the report document with your name, your student number, the course and year. Upload your answers to myCourses by Monday, Feb 17, 2025, 11:59 pm. Do not attach a spreadsheet.
Marks are indicated in square brackets. In total, there are 60 marks. This assignment is worth 14% of the final course grade.

1. Calculate the average net short-wave K^*, net long-wave L^*, and net all-wave Q^* radiative flux densities in $\mathrm{W\,m^{-2}}$ over the 24 hour cycle. Then determine the daily energy gain (+) or loss (-) by converting the average $\mathrm{W\,m^{-2}}$ into daily totals (energy per square metre and day, expressed in $\mathrm{MJ\,day^{-1}\,m^{-2}}$) †. [3]

2. Calculate solar declination δ for your day [3].

3. Calculate the incoming solar irradiance at the top of the atmosphere ('extraterrestrial irradiance' K_{Ex}) above the site, for the given day at noon. Note, time in your data (and here) is given in Pacific Standard Time (PST, i.e. no daylight saving offset). Note that PST is UTC-8. [7]

4. What is the approximate bulk transmissivity (Ψ_a) of the total atmospheric column at this time? Comment upon the reasons for the magnitude of Ψ_a you find. [5]

5. Estimate the approximate surface albedo of the grass surface for that day. Justify your calculation of the albedo. Plot your calculated albedo over the course of the day. Do you observe any diurnal variation of the albedo? † [5]
NOTE: values around sunrise and sunset can be numerically unstable

and very large, so do not consider those extreme values in your answer. You can better view the change in albedo over the day if you set your y-axis limit to range between 0 and 1 (this is done for you in the sample .Rmd script).

6. Use the values presented in Topic 7 Slide 5 to get an estimate of the surface emissivity ε_0 of a grass surface. Using this values, calculate the true surface temperature T_0 (i.e. considering that the surface is a grey body and reflects) at noon for the given day. [4]

7. Using measured $L_\downarrow$ and measured air temperature T_a, calculate the actual bulk emissivity of the atmosphere ε_a at noon? [4]

8. Plot the traces of measured radiative flux densities over the course ($K_\downarrow$, $K_\uparrow$, $L_\downarrow$, $L_\uparrow$, and Q*) of the day. Based on your graph and your calculations up to this point, speculate on the weather and surface conditions during your particular day. Is there any evidence for clear skies, haze, high clouds or fog? Support your argumentation using your measurements. [4]

9. Calculate the daily average soil temperature for each of the four depths where temperatures are provided (T_1 to T_4). Using those, determine the direction of the daily total Q_G in the soil layers from 5 - 10 cm, 10 - 20 cm and 20 - 50 cm ? † [3]

10. Calculate the daily total of Q_G at 7.5 cm depth in $\mathrm{MJ\,m^{-2}\,day^{-1}}$ using the measured values from the soil heat flux plate. Compare the direction of Q_G to the direction of the heat flux obtained for the 5 -10 cm layer in question 9. † [4]

11. Find a method to estimate the thermal conductivity of the soil k at noon that day. Is k constant throughout the day? Support your answer by providing a graph of how k varies throughout the day. [4]

12. Using C from Table 1 (p. 5) and k calculated at noon, calculate the depths where you expect the amplitude of the diurnal and yearly waves to drop below 5% of the amplitude of the sinusoidal surface temperature wave. [5]

13. The soil heat flux density Q_G is not measured at the surface, but rather at 7.5 cm depth. Using $\Delta T_1/\Delta t$ as a surrogate for the average warming / cooling rates in the whole layer from 0 to 7.5 cm, correct

the soil heat flux density and find the value at the surface $Q_{G(0)}$ at 10:00 and at 19:00. [5]

14. Predict the time of the maximum temperature at 20 and 50 cm based on the timing of the maximum at 5 cm. Do the times predicted agree with the observed maxima? What could explain any differences? [4]

† To answer questions marked by a † it is highly recommended to use a computer / graph software or R (or other programming language). See the course web-page for help documents on how to use the most common graph software or R. However, if you decide to not use a computer, it is appropriate to consider only the values at each full hour (i.e. 00:00, 01:00, 02:00 etc.) and manually calculate results / draw the graphs using this reduced data-set of 24 values.

Table 1: Values for soil heat capacity C calculated from lab analysis

Student ID	Date	C (MJ m^-3 K^-1)
00/25/50/75	data20090324.xls	2.45
01/26/51/76	data20090329.xls	2.35
02/27/52/77	data20090331.xls	2.39
03/28/53/78	data20090427.xls	2.13
04/29/54/79	data20090501.xls	2.01
05/30/55/80	data20090509.xls	2.08
06/31/56/81	data20090515.xls	2.12
07/32/57/82	data20090528.xls	1.91
08/33/58/83	data20090530.xls	1.84
09/34/59/84	data20090531.xls	1.82
10/35/60/85	data20090603.xls	1.76
11/36/61/86	data20090605.xls	1.73
12/37/62/87	data20090608.xls	1.71
13/38/63/88	data20090613.xls	1.69
14/39/64/89	data20090614.xls	1.69
15/40/65/90	data20090630.xls	1.73
16/41/66/91	data20090701.xls	1.73
17/42/67/92	data20090702.xls	1.73
18/43/68/93	data20090711.xls	1.84
19/44/69/94	data20090716.xls	1.83
20/45/70/95	data20090721.xls	1.84
21/46/71/96	data20090729.xls	1.91
22/47/72/97	data20090730.xls	1.91
23/48/73/98	data20090802.xls	1.93
24/49/74/99	data20090911.xls	2.52