Assignment 1

GEOG 321 — Climatic Environments • Knox • Winter 2026

Radiation and soil thermal regimes

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 British Columbia.

You will be provided with data from a single day (the actual day is selected based on your student number, as shown on the webpage). Data are available for download in various formats:

- **Radiation data:** https://geog321.github.io/assignment1_radiation/
- **Soil data:** https://geog321.github.io/assignment1_soils/

Radiation variables

The radiation files include measurements of:

- Incoming and reflected short-wave radiation ($K_{\downarrow}$, $K_{\uparrow}$)
- Incoming and outgoing long-wave radiation ($L_{\downarrow}$, $L_{\uparrow}$)
- Air temperature (T_a)
- Relative humidity (RH)

All measurements are from the instrument setup on Totem Field at UBC.

Use the Stefan–Boltzmann constant:
$\sigma = 5.67 \times 10^{-8}$ W m^{-2} K^{-4}

Soil variables

The soil dataset includes 15-minute averages of:

- Four soil temperatures (T_1, T_2, T_3, 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

- Sensible heat flux density in the atmosphere (Q_H) measured 2 m above the surface

Soil properties (laboratory analysis)

The soil has been analyzed in the lab and the following values were determined:

- Porosity: $P = 0.57$

- Bulk density of dry soil: $\rho_s = 1.13$ Mg m^{-3}

- Soil organic mass fraction: 3.77% (of total dry soil mass)

Assume these values apply to the entire vertical profile.

Based on the lab analysis, soil heat capacity C is presented in **Table 1 (p. 5)** and will be required for the soils portion of the assignment.

> **Graphing note:** Label all axes and include units. You may not need all variables provided in the data tables.

Submission instructions

Submit **one well-structured report** (PDF or HTML) containing your calculations, figures, and discussion.

Instructions for exporting HTML from RStudio Server and submitting it to myCourses are on the course site under:
R Resources → RStudio Server or Running R on your own computer

Your report must include your name, student number, course, and year.

Due: Monday, February 16, 2026 at **11:59 pm**
Do **not** upload spreadsheets.

Marks are indicated in square brackets. There are **60 marks** total. This assignment is worth **14%** of the final course grade.

Questions

1. **Daily radiation balance [3]**
   Calculate the average net short-wave (K^*), net long-wave (L^*), and net all-wave (Q^*) radiative flux densities in W m^{-2} over the 24-hour cycle.
   Convert these averages to daily energy totals (energy per square metre per day), expressed in MJ m^{-2} day^{-1}. †

2. **Solar declination [3]**
   Calculate solar declination (δ) for your day.

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

4. **Atmospheric transmissivity [5]**
   Estimate the approximate bulk transmissivity of the total atmospheric column (Ψ_a) at noon.
   Comment on the reasons for the magnitude of Ψ_a you obtain.

5. **Surface albedo [5]** †
   Estimate the approximate surface albedo of the grass surface for that day. Justify your calculation.
   Plot your calculated albedo over the course of the day and comment on whether you observe any diurnal variation.

   Note: Values around sunrise and sunset can be numerically unstable and very large. Do not include these extreme values in your analysis. You can better view changes in albedo if you set your y-axis limit to 0–1 (done for you in the sample .Rmd script).

6. **Surface emissivity and temperature [4]**
   Use Topic 7 Slide 5 to estimate the surface emissivity of grass (ε_0).
   Using this value, calculate the true surface temperature (T_0) at noon (treating the surface as a grey body).

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

8. **Radiation time series and interpretation [4]**
   Plot the measured radiative flux densities over the day: $K_\downarrow$, $K_\uparrow$, $L_\downarrow$, $L_\uparrow$, and Q^*.

Based on your graph and your calculations up to this point, infer the likely weather and surface conditions during your day. Is there evidence for clear skies, haze, high clouds, or fog? Support your argument using the measurements.

9. **Soil temperature profile and heat-flux direction [3]** †
   Calculate the daily average soil temperature for each depth (T_1 to T_4).
   Using these, determine the direction of the daily total Q_G in the soil layers from 5–10 cm, 10–20 cm, and 20–50 cm.

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

11. **Thermal conductivity (k) [4]**
   Identify a method to estimate soil thermal conductivity k at noon.
   Is k constant throughout the day? Support your answer by providing a plot of k over the day.

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

13. **Surface soil heat flux correction [5]**
   Q_G is not measured at the surface, but at 7.5 cm depth. Using $\Delta T_1/\Delta t$ as a surrogate for the average warming/cooling rate in the layer from 0 to 7.5 cm, correct the measured soil heat flux and estimate the surface value $Q_{G(0)}$ at 10:00 and at 19:00.

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

Notes on questions marked †

For questions marked †, using a computer and graphing software (e.g., R or Excel) is strongly recommended. See the course webpage for help documents on using R.

If you choose not to use a computer, it is appropriate to use only full-hour values (00:00, 01:00, 02:00, ...) and manually compute results and draw graphs using the reduced dataset of 24 values.

Table 1 — Soil heat capacity

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