Assignment 1

GEOS 300

Term 1 (Autumn 2024)

University of British Columbia

Instructor:

Marysa Laguë, Assistant Professor, Department of Geography

Instructions:

It is strongly recommended that you complete this assignment in Python or R. Templates (this document) are provided for the Python programming language. You may choose to complete this assignment using other software, such as Excel, Sheets, or Numbers.

Please upload your completed assignment as a .pdf file to the course Canvas page as a single, well structured report. Include all figures, tables, graphs, code/calculations, and written answers. We recommend completing the assignment within a Jupyter Notebook document (like this one); you can add "cells" for written answers using the Markdown format for the cell. The completed notebook can then be downloaded as a .pdf file (File -> Save and Export Notebook As -> pdf), which you can upload to canvas.

Upload a *separate file* that includes your code/calculations.

You can choose to instead write your answers in some other document processor (e.g. Word) and paste your figures, code/calculations etc., however, if you choose to do this, please ensure all your code and calculations are legible, and ensure it is clear what language/program was used to perform the calculations. Label the report document with your name, your student number, the course and year. Upload your report to Canvas by the Assignment deadline on the Canvas page. Do not attach a spreadsheet (except as a supplemental code document if you complete the assignment in Sheets/Excel/Numbers etc).

Include **correct units on all plots and all answers**, where applicable. Label all axes with the appropriate variables and units.

Points per question are indicated in square brackets. This assignment is worth 10% of the final course grade.

Getting started: enter your name and student number

In [1]:
```
Student_Name = 'Jeffery Liao'
Student_Number = 42174557
print(f'GEOS 300 Assignment 1 Submission for {Student_Name}: {Student_Number
```

```
GEOS 300 Assignment 1 Submission for Jeffery Liao: 42174557
```

We need to import python "packages" that contain useful functions for the kind of data analysis covered in this assignment.

In [2]:
```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import matplotlib.dates as mdates
```

```
import datetime
from datetime import datetime as dt
import time
```

Question 0:

[1] point

Did you use AI to assist you in completing this assignment? If yes, explain.

No

Question 1:

[6] points

Unit conversions! Note that negative exponents mean that unit is in the denominator, e.g. kg / m^3 is the same as kg m^{-3}. Both formats are commonly used and both are acceptable here.

The energy transfer associated with heat is quantified as heat flux (e.g. "sensible heat flux" and "latent heat flux": the flow of energy per unit time per unit area.

(a) [2] What are the units for energy, and what is this in base SI units? (Report full unit name and SI unit symbol)

(b) [1] What are the units for time? (Report full unit name and SI unit symbol)

(c) [1] What are the units for area? (Report full unit name and SI unit symbol)

(d) [2] Combine the base SI units for energy, time, and area to show that the units of heat flux are W/m^2 (show steps / show your work)

(write your answer here!)

a) Joules, J , base SI units: kg m^2/s^2

b) Seconds, s

c) Square meter, m^2

d) Energy: J
Power = Energy / Time
Heat Flux = Power / Area

Energy: J
Power: W = J / s
Heat Flux = J s^{-1} / m^2

Question 2

[2] The density of water is 1000 kg/m^3. Rainfall rate is often measured as a depth of rain, in mm/s, while evaporation is often measured as the mass of water (kg) that evaporates over 1 square m (m^2) each second (s), i.e. kg/m^2/s. What is the equivalent of 1 mm/s of rain in the units of kg/m^2/s?

Mass = Density * Volume
Density = 1000 kg/m^3

depth of water in meters:
m = kg/m^2/ 1000(kg/m$ ^3$)

depth of water in mm is:
mm = m * 1000 [mm/m]

kg/m^2 = mm only if water density is 1000 kg/m^2

Adding seconds in:
1 mm/s = 1 kg/m^2/s

1 mm/s = 1000 kg/m^3

1 mm/s = 1 mm/2 * 1/1000 m/mm
= 1/1000 m/s * 1000 kg/m^3
= 1 kg/m^2/s
1 mm/s = 1 kg/m^2/s

Question 3

[3] The atmosphere exerts downwards force on Earth's surface. Following Newton's 2nd law of motion, force is equal to mass times acceleration ($F = m a$).

(a) [1] The SI unit for force is a "newton". From Newton's second law, what are the SI base units of force?

(b) [2] A "pascal [Pa]" is the SI unit for pressure, which is has units of force acting per unit area. Write an expression for pascals using newtons, and a separate expression for pascals using only SI base units.

a) F = ma
F = kg * m/s^2
Force SI unit is newton, base units is kg * m/s^2

b) Pa = N/m^2

N = kg m s^{-2}
Pa = kg m s^{-2} / m^2
Pa = kg m^{-1} s^{-2}

Data Analysis Section

For the rest of the questions, we will be analysing radiation data measured on the UBC Vancovuer campus at Totem Field. This data can be found in the file data20100710_py.csv on the Canvas webpage for this assignment. The .csv file contains the following variables: incoming and reflected short-wave radiation (K↓, K↑), incoming and outgoing longwave radiation (L↓, L↑), air temperature (Ta) and relative humidity (RH). Use this dataset to answer the remaining questions. Place the .csv file in the same folder as this .ipynb folder in your JupyterOpen file system.

To help you get started, we have provided a chunk of code below that loads and plots the data. We *strongly encourage* you to step through each line of the code and make sure you understand what is happening (tip: leaving comments in your code is very helpful both for whoever is grading your assignment, but also to remind yourself what you are doing at each step).

First, we need to load the data:

In [3]:
```
# Import the data  - upload this file from Canvas and put it in the same fol
# data_file = 'GEOS300/Fall2024/Assignment1/FromSara/data/data20100710.csv'
data_file = 'data20100710_py.csv'

dateparse = lambda x: dt.strptime(x, '%Y-%m-%d %H:%M')

# Pandas (pd here) allows us to set a timestamp as an index which lets us ea
# It opens the csv file into a data format called a "data frame", so we're g
df = pd.read_csv(data_file,parse_dates=['Date'],date_format='%Y-%m-%d %H:%M'

# df contains all the variables that were column headers of the .csv file.
# the "Date" dimension is the "index" dimension for the dataframe. The dates
# lots of useful things about time, like how to interpret minutes and hours,

# We can get a extra variables (DOY & HOUR) that will be helpful later
df['HOUR'] = df.index.hour
df['DOY'] = df.index.dayofyear
```

```
df['TIME'] = df.index.time

# Take a quick look at the first few entries - the pandas "head()" command p
df.head()

# "NaN" stands for "not a number", and is used in datasets to show where the
```

Out[3]:

	K_in	K_out	L_in	L_out	AirT	RH	HOUR	DOY	TIME
Date									
2010-07-10 00:10:00	0.0	0.0	383.0	403.2	NaN	NaN	0	191	00:10:00
2010-07-10 00:20:00	0.0	0.0	370.9	400.8	NaN	NaN	0	191	00:20:00
2010-07-10 00:30:00	0.0	0.0	363.1	399.1	19.3	70.2	0	191	00:30:00
2010-07-10 00:40:00	0.0	0.0	355.6	397.5	NaN	NaN	0	191	00:40:00
2010-07-10 00:50:00	0.0	0.0	357.3	397.4	NaN	NaN	0	191	00:50:00

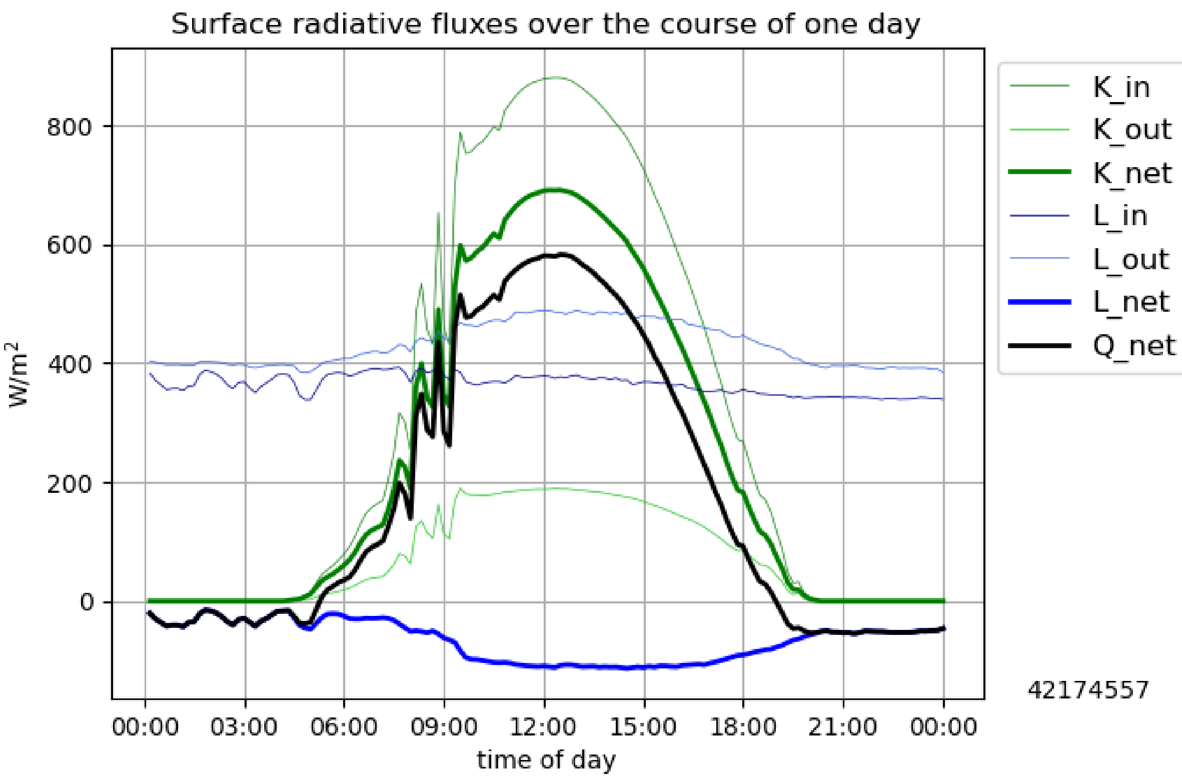
In [4]:

```
# Now calculate the net SW absorbed at the surface, the net LW at the surfac
df['K_net'] = df['K_in'] - df['K_out']
df['L_net'] = df['L_in'] - df['L_out']

df['Q_net'] = df['K_net'] + df['L_net']
```

In [5]:

```
# Now we'll plot the data to help us answer the question:

plt.plot(df.index,df['K_in'],label='K_in',color='forestgreen',linewidth=0.5)
plt.plot(df.index,df['K_out'],label='K_out',color='limegreen',linewidth=0.5)
plt.plot(df.index,df['K_net'],label='K_net',color='green',linewidth=2)

plt.plot(df.index,df['L_in'],label='L_in',color='darkblue',linewidth=0.5)
plt.plot(df.index,df['L_out'],label='L_out',color='royalblue',linewidth=0.5)
plt.plot(df.index,df['L_net'],label='L_net',color='blue',linewidth=2)

plt.plot(df.index,df['Q_net'],label='Q_net',color='black',linewidth=2)


# make the plot prettier:
plt.grid()
plt.legend(fontsize=12,loc='upper left', bbox_to_anchor=(1., 1.))
plt.ylabel('W/m$^2$')
plt.xlabel('time of day')
plt.gca().xaxis.set_major_formatter(mdates.DateFormatter('%H:%M'))

plt.title('Surface radiative fluxes over the course of one day')

# add your student number
plt.text(1.05,0.0,'%1.0f'%42174557,
         fontsize=10,transform=plt.gca().transAxes)
```

```
plt.show()
plt.close()
```



Try tweaking the above code to change the colours of the lines.

You could look at this plot and try to find when R$_{net}$ reached a maximum, and what its value at that time was - but with a bit of code we can find the exact values, as follows:

In [6]:
```
# Using your dataset we'll find the index for the time of the day when we ob
ind_max= df['Q_net'].idxmax()
max_val = df['Q_net'][ind_max]
max_time = df['TIME'][ind_max]

# Using this index, find the time when R_net is maximum  and display output
print("The time of the day we observe the maximum of Q_net is "+ max_time.st
# Now lets print the maximum value using a different way of stuffing a numbe
print("The value of Q_net at this time is %1.1f W/m2"%max_val)
```

```
The time of the day we observe the maximum of Q_net is 12:30.
The value of Q_net at this time is 582.6 W/m2
```

Now its your turn:

Question 4:

[4]

Calculate:

(a) the minimum of Q_net [1]

(b) the maximum of K_net [1]

(c) the maximum of L_net [1]

(d) the minimum of L_net [1]

Include units in answers.

In [7]:
```
# Using your dataset we'll find the index for the time of the day when we ob
ind_min= df['Q_net'].idxmin()
min_val = df['Q_net'][ind_min]
min_time = df['TIME'][ind_min]

# Max k_net

k_net = df['K_net'].idxmax()
maxk_net = df['K_net'][k_net]
maxk_nettime = df['TIME'][k_net]

# max l_net

l_netmax = df['L_net'].idxmax()
maxL_net = df['L_net'][l_netmax]
maxL_nettime = df['TIME'][l_netmax]

# min l_net

l_netmin= df['L_net'].idxmin()
minl_net = df['L_net'][l_netmin]
minl_nettime = df['TIME'][l_netmin]

# Using this index, find the time when R_net is maximum  and display output
print("The time of the day we observe the minimum of Q_net is "+ min_time.st
# Now lets print the maximum value using a different way of stuffing a numbe
print("The value of Q_net at this time is %1.1f W/m2"%min_val+'.')

print("The time of the day we observe the maximum of K_net is "+ maxk_nettim
print ("The value of K_net at this time is %1.1f W/m2"%maxk_net +'.')

print("The time of the day we observe the maximum of L_net is "+ maxL_nettim
print ("The value of L_net at this time is %1.1f W/m2"%maxL_net +'.')

print("The time of the day we observe the minimum of L_net is "+ minl_nettim
print ("The value of L_net at this time is %1.1f W/m2"%minl_net +'.')
```

```
The time of the day we observe the minimum of Q_net is 21:20.
The value of Q_net at this time is -54.5 W/m2.
The time of the day we observe the maximum of K_net is 12:30.
The value of K_net at this time is 690.9 W/m2.
The time of the day we observe the maximum of L_net is 01:50.
The value of L_net at this time is -14.8 W/m2.
The time of the day we observe the minimum of L_net is 14:30.
The value of L_net at this time is -112.9 W/m2.
```

Question 5:

[4]

(a) What is the average value of Q_net over the course of the day? [1]

(b) What surface fluxes balance Q_net at any given point on the land surface? [3]

In [11]:
```
avg = round( df['Q_net'].mean(),2)

print ("a) The average value of Q_net over the course of day is " + str(avg)
```

```
a) The average value of Q_net over the course of day is 171.52 W/m2.
```

The surface fluxes that balance Q_net is Sensible Heat flux, Latent heat flux, and storage flux in soil.

Question 6:

[8]

(a) [4] Calculate the average net short-wave K∗, net long-wave L∗, and net all-wave Q∗ radiative flux densities in W/m2 over the 24 hour cycle.

(b) [4] Then determine the daily energy gain (+) or loss (-) for each flux in (a) by converting the average W/m2 into daily totals (energy per square metre and day, expressed in MJ / day / m2).

Include units in all answers.

In [9]:
```
avg1 = round(df['K_net'].mean(),2)
avg2 = round(df['L_net'].mean(),2)
avg3 = round(df['Q_net'].mean(),2)

print ("a) The average value of K_net over the course of day is " + str(avg1
print ("a) The average value of L_net over the course of day is " + str(avg2
print ("a) The average value of Q_net over the course of day is " + str(avg3
```

```
a) The average value of K_net over the course of day is 237.87 W/m2.
a) The average value of L_net over the course of day is -66.35 W/m2.
a) The average value of Q_net over the course of day is 171.52 W/m2.
```

1 W/m2 = 1 J/m2 s

1 day = 60s * 60min *24h = 86400s

For K_net flux:

237.87 W/m2 = 237.87 J/m2 s

237.87 J/m2 s x 86400 s/1day = 20551968 J/m2 day

20551968 J/m2 day x 1MJ/1000000J = 20.55 MJ/day/m2

For L_net:

-66.35 W/m2 = -66.35 J/m2 s

-66.35 J/m2 s x 86400 s/1day = -5732640 J/m2 day

-5732640 J/m2 day x 1MJ/1000000J = -5.73 MJ/day/m2

For Q_net:

171.52 W/m2 = 171.52 J/m2 s

171.52 J/m2 s x 86400 s/1day = 14819328 J/m2 day

14819328 J/m2 day x 1MJ/1000000J = 14.82 MJ/day/m2

Question 7:

[2]

Why do you think the diel cycle (the day-night cycle) of L_in smaller than the diel cycle of L_out?

Since the sun is warming the planet and the planet is absorbing all of the shortwaves, there is excess heat when night comes. Therefore, the planet emits the L_out in larger amounts that L_in. Also, during the day, there is a lot of shortwave coming in so L_out has to be higher with higher temperature than L_in to keep balance.

Question 8:

[4]

Calculate solar declination δ for the day of the observations.

δ = -23.4˚ cos(2π ((DOY+10)/365))

07/10 is the 191st day of the year.

δ = -23.4˚ cos(2π ((191+10)/365))
δ = -23.4˚ cos(2π (201/365))
δ = -23.4˚ cos(2π (0.55))
δ = -23.4˚ cos(3.46)
δ = -23.4˚ -0.95
δ = 22.22˚

Use equation for gamma for more accurate result

γ = (2π/365)(DOY-1)
γ = (2π/365)(191-1)
γ = (2π/365)(190)
γ = 3.27

$$\begin{aligned} \delta \approx \;& 0.006918 - 0.399912\cos\gamma + 0.070257\sin\gamma \\ & -0.006758\cos(2\gamma) + 0.000907\sin(2\gamma) \\ & -0.002697\cos(3\gamma) + 0.00148\sin(3\gamma) \end{aligned}$$

δ = 0.3902 ??

Question 9:

Calculate the local apparent time (LAT) for sunrise and sunset.

Hint: Set solar altitude to β = 0∘ (for sunrise and sunset) and solve for the hour angle h when $\beta = 0$. Then convert h to an actual time. Note that LAT always ensures solar noon is at 12:00. You will need to use the declination from Q6.

This radiation data was collected on the University of British Columbia campus, located in Vancouver, BC (49.2∘N, 123.2∘ W).

Write the equation you use to calculate LAT for sunrise and sunset using declination, solar altitude, and location [4], then calculate LAT using the site data [4].

[8]

δ = 22.22˚
$\beta = 0$
ϕ = 49.2
Z = 90 - β
Z = 90

cosZ = sinϕ sinδ + cosϕ cosβ cos h
cos90 = sin 49.2 sin 22.22 + cos 49.2 cos 0 cos h
h = 64.02

h = 15˚(12-t)
64.02 = 15˚(12-t)
t = 7.73

Question 10:

[2] Vancouver is located in the Pacific Time Zone (UTC -8), which is centered on the 120 W meridian. Using the equations from lecture, calculate the local meant solar time (LMST) and local apparent time (LAT).

LMST = LST + 4 mins * (LL-LSTM)
LST = 12pm
LL = 123.1207° W
LSTM = 120˚ W

LMST = 12:00 + 4 * (123.12-120)
LMST = 12:00 + 4 * 3.12
LMST = 12:00 + 12.48
LMST = 12:12:29

LAT = LMST – ΔTLAT

γ = (2π/365)(DOY-1)
γ = (2π/365)(191-1)
γ = (2π/365)(190)
γ = 3.27

$$\begin{aligned}\Delta T_{\mathrm{LAT}} &= 229.18\,[0.000075 + 0.001868\cos\gamma - 0.032077\sin\gamma - \\ &\quad 0.014615\cos(2\gamma) - 0.040849(\sin 2\gamma)]\end{aligned}$$

ΔTLAT = -5.08

LAT = 12:12:29 + 5.08 in hours

LAT = 17:17:17

Question 11:

[4]

Assume the incoming solar irradiance at the top of the atmopshere ("extraterrestrial erradiance" KEx) above the site at noon on the day of observations is 1178 W/m2 (recall: irradiance from the sun at the solar equator is 1366.5 W/m2, but irradiance at the top of the atmosphere above any given latitude-longitude point on Earth varies with day of the year, latitude, and longitude).

Assume β = 63.1 ° (the angle between the surface and the incident sun beam).

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

KEx = 1178 W/m^2

β = 90°- Z
63.1 = 90˚ - Z
Z = 26.9˚

K↓ = 877.7 W/m^2

m = 1/cos 26.9
m = 1.12

K↓ = KEx Ψa^m

877.7 = 1178 * Ψa^1.12

0.75 = Ψa^1.12

0.75 ^ 1/1.12 = Ψa

Ψa = 0.77
