ENV-410 - Graded assignment: Solution

Instructions

- This assignment counts for 25 % of your final grade
- You can work in groups of up to four people. Only one person per group should submit the assignment on Moodle, but all group members need to be listed on the first page of the document.
- Please submit the solution as one pdf file (i.e. not a zip folder, not a Microsoft Word document) on Moodle. Please do not submit a copy of handwritten notes. The file name should be formatted as follows: *Group_X_ENV410_assignment.pdf (where X = group number)*
- Provide details of your calculations for all answers.
- Respect the lines limit when answering questions. Whatever is well conceived is clearly and succinctly said!
- **Deadline: Monday, 28 November 2024, at 23:59**.

1 Radiation [24 points]

Below you can see sample radiative flux density data for a rural site in in the Indo-Gangetic plain, just south of the Himalayas, over the year 2020:

- Mean incoming shortwave radiation: 175 W/m^2
- Mean reflected shortwave radiation: 52 W/m^2
- Mean incoming longwave radiation: 324 W/m^2
- Mean outgoing longwave radiation: 390 W/m^2

i) What is the net radiation at this site? [1 point]

ii) Calculate the albedo at this rural site. [2 points]

iii) iii) At the end of the rice-growing season in 2020, the crop fields were burned to prepare the fields for the upcoming wheat crop. As the fields were burned, the green rice fields were replaced by dark burned crop residue and ash, decreasing the albedo by 0.05. Calculate the net radiation change due to the darkening of the surface as the fields were burned. [3 points].

iv) Estimate the temperatures at the top of the atmosphere over the Himalayas as well as over the Arctic from Figure 1. At which wavelengths do the spectral radiances of these two regions peak? Provide details of your calculation. [5 points]

v) The Himalayas are well-known for their mountainous terrain. The different atmospheric conditions at high altitudes affect both incoming solar radiation and outgoing terrestrial radiation. Discuss how altitude impacts both short- and long-wave radiation, respectively. [4 points, 10 lines total].

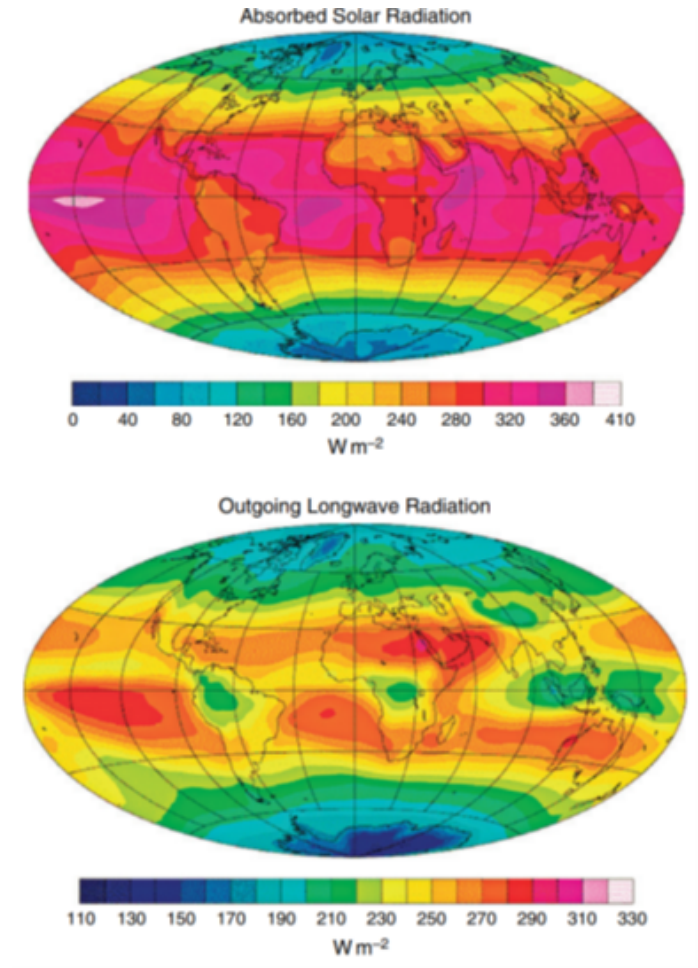

Figure 1: Global distributions of the annual-mean radiation at the top of the atmosphere.

At a different site in Potsdam, Germany, radiation measurements have been taken continuously since 1947 (Wild et al., 2021). Figure 2 shows the observed annual mean surface solar radiation as measured at Potsdam between 1947 and 2017.

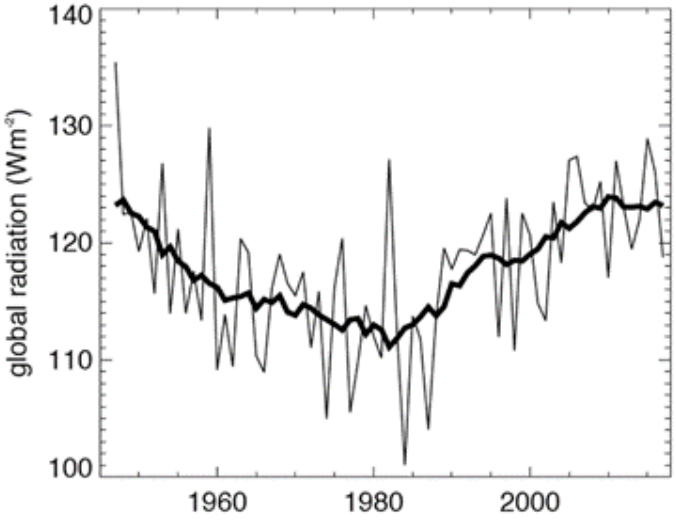

Figure 2: Observed annual mean surface solar radiation as measured at Potsdam between 1947 and 2017 (thin lines) together with a five-year running mean (thick lines).

In order to understand the trend of the global radiation above, we will investigate the atmospheric solar transmission. Below is a table of decadal means of maximum transmission ("clear sky") and mean transmission ("all sky"):

Decade	1947–1956	1957–1966	1967–1976	1977–1986	1987–1996	1997–2006	2007–2016
"clear sky" transmission	0.754	0.732	0.727	0.714	0.732	0.740	0.743
"all sky" transmission	0.415	0.394	0.389	0.382	0.399	0.417	0.42

vi) Plot the time series of decadal means of Maximum Transmission ("Clear Sky") and Mean Transmission ("All Sky") at the Potsdam site. Explain the cause of the difference between the two time series [2 points].

vii) Now, calculate and plot the time series of the annual anomalies of both maximum ("clear-sky") and mean ("all-sky") transmission from their long-term means (hint: average over the 1947–2017 period). What is the cause of the trend observed up to the 1980s? What is the name of the effect by which this trend occurs(is it a direct or indirect interaction with solar radiation?)? [5 points]

viii) Looking back at Figure 1, there is a noticeable shift in the trend since the 1980s in Potsdam, Germany. List two possible measures which could have led to this trend shift. [2 points]

Bibliography:

- Wild, M., Wacker, S., Yang, S., and Sanchez-Lorenzo, A. (2021). Evidence for clear-sky dimming and brightening in central Europe. Geophysical Research Letters, 48(6), e2020GL092216.

2 Greenhouse gases [13 points]

a) The CO_2 levels recorded at Mauna Loa show a distinct seasonal pattern. What natural processes might explain this, and would you expect these seasonal variations to be less noticeable or more noticeable in places with less plant life? (maximum 4 lines) [1 point]

b) The Mauna Loa Observatory has been measuring CO_2 levels since 1958. What human activities have been linked to this increase, and how do these measurements support this connection? (maximum 4 lines) [1 point]

c) CO_2 measurements are often reported in parts per million (ppm), which is a measure of mole fraction, instead of mass concentration (e.g., grams per cubic meter). Explain why mole fraction is the preferred way to report atmospheric CO_2. (max 5 lines) [2 points]

d) For each statement below, indicate whether it is true or false and shortly explain why (max. 1-4 lines per subquestion). [9 points]

   (i) Earth's climate has varied naturally in the past million years, so humans cannot be the cause of climate change. [4 points]

   (ii) How much a greenhouse gas contributes to global warming only depends on how much of it gets emitted into the atmosphere. [3 points]

   (iii) The Montreal protocol, that emerged as a response to stratospheric ozone destruction, prevented a part of climate change by controlling the use of chlorofluorocarbons. [2 points]

3 Urban Heat Island Effect [17 points]

Heat hotspots have become a hot topic for urban centres around the world due to the dangers of heat stress. Heat stress is exacerbated in highly populated, dense areas filled with concrete buildings and lacking in open green spaces and shaded regions. The tight alleyways and high rise buildings found in many modern cities cause a build up of heat that can get trapped within an urban centre leading to what is known as the Urban Heat Island effect.

Since 2018, the Geographical Institute of the University of Bern has been constantly monitoring urban heat islands with temperature sensors at stations across the city of Bern which take a reading every 10 minutes. There are 76 main measuring stations spread across Bern, some of which are indicated in the map below:

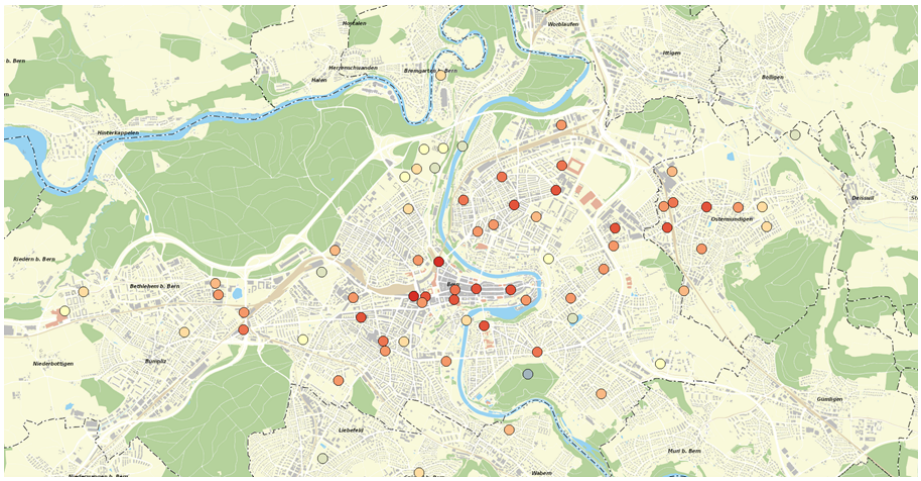

Figure 3: Meteorological Stations across Bern used by the Geographical Institute of the University of Bern

1. Why does heat that builds up within a city not escape effectively to the atmosphere thereby leading to Urban Heat Island (UHI) effect? Give 2 reasons. [2 points]
2. Imagine you are setting up measurement stations across the city of Bern to monitor the increase in temperature due to UHI effect. Name two important considerations you would take into account regarding the locations of the sensors. [1 point]
3. As part of the climate analysis project, the University of Bern designed the *Bernometer* app. Download this app and have fun exploring it. During the day look at the

heatmap under the "Aktuell" tab in the app and with the help of the information from Stadt Bern website regarding infrastructure (https://map.bern.ch/stadtplan/?grundplan=Stadtplan_farbig_Geoportal|Stadtplan_farbig_Extern_Region&koor=2600673,1199976&zoom=1&hl=0&layer=Klimamessdaten)
answer the following:

i) Give an overall description of the temperature variation across Bern with respect to areas of higher or lower temperature. What area of Bern exhibits the highest urban heat island effect and suggest why this may be the case. (*please use a maximum of 5 lines*)[2 points]

ii) Using your understanding of the heatmap, would you say that existing greenspaces are effective in mitigating the urban heat island effect, both in the immediate vicinity of the spaces and throughout Bern as a whole, and why? (*please use a maximum of 5 lines*) [2 points]

iii) The Aktuell tab in Bernometer app is a really good resource for current or near-current temperature data within the city of Bern. Suggest, however, a limitation of using only current temperature data to study UHI effect. What additional data or tools could you use to conduct more comprehensive analysis, give two examples? (*please use a maximum of 6 lines*) [2 points]

The project Urban Heatmap Bern provides access to historical temperature and relative humidity measurements at over 100 stations across the region of Bern.
The data can be found here : https://smart-urban-heat-map.ch/.

4. Download the data for 2023 and 2024 for the stations : Gurten Kulm, Ostermundigen Bäretower and Zollikofen.

   i) Plot a time series of temperature from Gurten Kulm and Ostermundigen Bäretower for the one year time period of 2023-06-01 to 2024-06-30. [1 point]

   ii) Temporal averaging can be useful to reduce the noise and variation in data and give a better idea of trends. For the same time period as above, plot a time series of Gurten Kulm and Ostermundigen Bäretower using daily averaged data [2 points]. (As the raw data is given at a time resolution of 10 minutes, you will have to calculate this average). Comment on the differences between the two stations with respect to each other in the time period plotted. Provide at least two aspects. (*please use a maximum of 6 lines*) [2 points]

   iii) Zollikofen station is used as a reference station by Meteoswiss to calculate UHI effect. Using the data from the 3 stations, at a daily time resolution, calculate the UHI effect for Gurten Kulm and Ostermundigen Bäretower and plot this as a

time series. Compare the two stations, providing 4 points of comparison. Make sure to show your calculation (*please use a maximum of 6 lines*)[3 points]

iv) For the period of 1 July to 31 August, Meteoswiss reported the UHI effect for Ostermundigen Bäretower to be 0.86 °C higher at night compared to during the day. Give 2 suggestions of why this could be the case. [2 point]

4 Extreme value analysis [13 points]

The MeteoSuisse Zollikofen station in Bern provides a long time series of temperature data (already starting in 1864). We use the annual maxima of the 5-day rolling average of daily maximum temperature (Tx5d) as a measure for heat extremes.

We will provide the data (1864_2023_Bern_daily_max_temp.csv) and a python jupyter notebook (ENV410_EVA_temp.ipynb) with a step by step guide on moodle but you are free to use the coding language of your choice.

a) In which year did the strongest heatwave occur? What was the maximum temperature? [1 point]

b) What is the empirical return period of the 2023 heatwave? [1 point]

c) What are the return values of the 10, 50, and 100 year return periods? Provide the values based on a GEV fit to the data and create a Gumbel diagram (return periods vs return values). [3 points]

d) What could be a problem in estimating the return periods in that way? *Hint: Have a look at the time series.* [1 point]

e) Plot the histograms and GEV probability density function of the total time period, the first 30, and the last 30 years. What is the exceedance probability (based on the GEV fit) of the 2023 heatwave in the early and late period?[3 points]

f) One method of extreme event attribution compares the probability of an event occurring with climate change (p1, the factual) versus the event occurring without climate change (p0, the counterfactual), and estimates the fraction of attributable risk $FAR = \frac{p1-p0}{p1}$ or the probability ratio $P = \frac{p1}{p0}$.

   (i) Estimate the FAR and P based on your results in e). What statement can you make about the 2023 heatwave? [2 points]

   (ii) What could be problematic about the event attribution estimate from i)? [2 points]

5 Climate denial article [25 points]

Your long-time friends who spent a year traveling in Australia has shared with you the fascination they developed for corals and particularly the Great Barrier Reef. They recently came across articles dismissing the threat that climate change is posing for the corals. Puzzled, they forwarded you the articles asking for your opinion.

a) What are the hints that make you identify the article as a climate change denial text? Give at least 3 hints. [3 points]

b) You check the figures and the sources, and start to doubt your initial opinion. What elements make the figures and sources scientifically legit? Give at least 2 elements. [2 points]

c) Using publications cited in this article and complementary references, explain why coral cover is not enough to describe the health of a coral reef, and how arguments in this article are misinterpreted. Cite an important metric to estimate bleaching exposure, which is ignored in Chris Morrison's articles Peter Ridd's report. Don't forget to build your response as you would do for a scientific and peer-reviewed article with citations. [6 points]

d) List a minimum of 5 typical arguments that are used in this climate denial article to build a case against the threat of climate change [5 points]

e) Peter Ridd is a scientist heavily cited in this article. Searching about him, find at least 2 facts that would make his opinion trustworthy. On the other hand, he is a controversial figure, find at least 2 evidences that show his results might not be reliable anymore. [3 points]

f) There is nothing new in the methodology used in this article to dismiss scientific climate research. In question d, you have established the list of the "tools" used by climate deniers to perpetuate their message. This Australian case study is actually copied from other climate polarized research studies. To go further, read about the "denial machine" (Lubicz-Zaorski et al., 2024; Oreskes and Conway, 2011; Dunlap and McCright, 2011; etc.). Describe the 5 cogs in place to fuel this machine and bias the public opinion. [6 points]

Bibliography:

- Dunlap, R. E., and McCright, A. M. (2011). Organized climate change denial. The Oxford handbook of climate change and society, 1, 144-160.
- Lubicz-Zaorski, C., Newlands, M., and Petray, T. (2024). Fuelling the climate and science 'denial machine'on social media: A case study of the Great Barrier Reef's

2021 ‘in danger’recommendation on Twitter, YouTube and Facebook. Public Understanding of Science, 33(3), 270-289.

- Oreskes, N., and Conway, E. M. (2011). Merchants of doubt: How a handful of scientists obscured the truth on issues from tobacco smoke to global warming. Bloomsbury Publishing USA.