Winter 2024
PPHA 39930
Instructor: Amir Jina
Individual assignment 1
Due: Tuesday 16th January, 2024 (at midnight)

Directions: Please submit a PDF write-up with your answers to questions and any required figures. For data analysis, also submit the file containing your analysis. For example, submit the code / output of your coding language of choice (e.g., a Stata "log file", or R-script, or Excel sheet). This problem set looks longer than it is!

Greenhouse effect with a transparent atmosphere

1. In class, we derived the Earth's surface temperature using a simple energy balance model with a one-layer atmosphere. Now, you'll derive the energy balance with a partly transparent atmosphere.

(a) Draw a diagram like the one on slide 36/120 in "Climate change crash course" lecture slides, but this time *include a term and arrows for a partially transparent atmosphere*

(b) Write out the energy balance equations for an atmosphere with an emissivity[1], ϵ.

(c) Solve the equations for T_S, the temperature of the Earth's surface

(d) Assume the following values and calculate T_S: S = 1370 Wm^{-2}; $\epsilon = 0.78$; A = 0.3

(e) One of our neighbours, Mars, has an average solar constant of $\text{S}_M = 589$ Wm^{-2}, an albedo of A_M 0.24, and a surface temperature of -46°C. What would its atmospheric emissivity, ϵ_M, need to be to achieve that surface temperature?

Australian climate data analysis

2. In late 2019 and early 2020, Australia witnessed some of the worst bushfires in history. There has been concern that precipitation has been gradually decreasing in many parts of Australia over the last 60 or so years. Not all such beliefs are necessarily supported by actual data.

One of the most useful historical climate datasets is the Global Historical Climate Network dataset. Go to NOAA Climate Data Online and you can find daily, monthly, or annual summaries of reporting weather stations from all over the world. For this assignment, I've prepared a dataset for you. Download the file `perth_airport.csv` from Canvas. This is the monthly total precipitation (in mm) and temperature (in °C) records at Perth Airport (station ID: IWMO 94610), in southwestern Australia. You are going to explore some trends. The data are available from 1944 to 2019. Such a long station history makes possible a wealth of statistical experiments. Perth is known to have a "Mediterranean climate" - most of its precipitation is in the winter, very little is during summer.

(a) Plot a figure of the monthly climatology of precipitation. That is, the average for each month of the year taken across the years 1981-2010. What is the rainiest month?

(b) Plot the July rainfall for each year (since 1944) in the dataset and fit a linear trend line. Interpret the trend. Perform a statistical test that the later period (1981-2010) is statistically different than the earlier period (1951-1980). What is the result?

(c) Rainfall may occur over all winter months. Take the average across May-August and plot the trend in average winter rainfall (since 1944). Interpret the trend. Run your test again. What is the result?

[1] Th emissivity is defined as the ratio of the energy emitted by a body to the energy emitted by a "blackbody" at the same temperature. Essentially, it tells you how close to being a perfect emitter you are.

Climate change and inequality

3. Now we are going to begin examining the intersection of climate and inequality. Download the datasets `hw1_us_counties_incomes.csv` and `hw1_us_counties_temperature.csv` from Canvas.

These datasets contain information on annual average temperatures for every county in the United States, starting with the average from the end of the last century. Then there are averages over 20 year periods, projected using RCP 8.5 emissions, up to the end of this century, using all models in the CMIP5 (IPCC) set of climate models. In addition to that, there is data on incomes per capita in 2018 taken from the Bureau of Economic Analysis Regional Economic Accounts data[2].

(a) Plot a histogram of county temperatures for 1981-2010. On the same figure plot a histogram of county temperatures under RCP8.5 emissions from 2080-2099. The answer may be obvious, but describe the plot.

(b) Calculate the income deciles for the counties. Calculate the average temperatures for each time period for these income deciles.

(c) Plot these average temperatures against the income decile group for 1981-2010 and for 2080-2099.

(d) Interpret the plots. What does this imply about who will feel the impacts of climate change?

(e) Now create a variable that is the change in county temperature between the 1981-2010 period and the 2080-2099 period. Which income decile will experience the most change? Look at latitudes. What is the spatial pattern of those changes?

(f) If you were a policy-maker and saw all of these patterns, what would your main considerations be for making an equitable climate adaptation policy in the US? Be brief ($\sim$ 2-3 sentences).

(g) Bonus credit: download and merge in your favourite county-level social indicator that captures something about unequal distributions of wealth, power, and access in the US. The merge doesn't need to be perfect (BEA aggregates some small counties, so quite a few will not merge with the dataset). Explore the relationship between temperature projections and this indicator.

Climate change communication

4. Climate change has been subjected to a vast amount of scientific, political, media, and popular skepticism over the past few decades. Out of this, climate change communication has become a field of study in its own right. There are now many resources and practical guides that aim to help communication across different stakeholder groups. Take a look at the six principles of climate communication in the IPCC's Climate Outreach Handbook[3] and keep them in your mind for the quarter.

One of the most powerful images that has communicated climate change is the global temperature time series that we looked at in class. And yet, it is often considered to be quite dry and uninspiring. In this question, I want you to think about ways that this important dataset has and could be used to communicate the scale of the climate changes we have seen in the past 100 years.

(a) Plot the simple time series plot like the one shown in slide 16/120 in the "Climate Change Crash Course" slides.

[2] CAINC1, available here

[3] Available here: Principles for effective communication and public engagement on climate change: A handbook for IPCC authors

(b) Comment on **at least three** notable aspects of this plot. For example, describe what trends in warming stand out to you.

(c) This image, while powerful, often fails to capture the imagination. Some climate change communicators have used it in a more compelling way. Look at the following two images created by Ed Hawkins:

- The Climate Spiral (available here)
- The Climate Stripes (available here)

Comment on **at least two ways** that each of them act to more effectively communicate the changes over the last 150 years on our planet. You can mention anything, from the use of colour, to the shape of the plots, to the labeling or animation, or anything else that strikes you.

(d) (This answer will get full points regardless of what you say!) I don't expect you to come up with a world-changing and persuasive visualization that changes how urgent the population of the world thinks climate change is, but...

Think deeply about a few ways that you might use this dataset to create a compelling, world-changing visualization. What might you attempt to plot? Plot the figure if you can. In your answer, which should be just a few sentences, think about the answers from parts (a)-(c): what stood out to you in the time series plot? What about the Spiral and Stripes made you respond logically or emotionally in a way you wouldn't have to the simple time series? How would you highlight the aspects that really are striking about the dataset? As I said, any answer at all is fine.