**UK extreme monthly and daily rainfall**

This practical has two steps, a computer based practical lab (A), to be done during the practical and a report (B) to be written afterwards (this is intended to be a short writeup explaining method and results, and putting them in context, which should not take very long). We are looking at monthly precipitation first, recognizing that monthly precipitation extremes have a large role in flooding providing the well saturated grounds on which extreme daily precipitation can lead to flooding. The UK winter climate is strongly influenced by the location of the Atlantic storm tracks, and one way to characterize this is the North Atlantic Oscillation, which quantifies the pressure difference between the Azores and Iceland (as air masses flow along isobars, strong pressure gradients between Iceland and the Azores indicate stronger westerly winds and more transport of air from the Atlantic ocean region over land).

**A) computational work/analysis**

***Winter extremes: Monthly rainfall variability and its drivers***

We start out by considering the background conditions and role in large scale circulation. For this, we focus on monthly precipitation and check out the North Atlantic Oscillation, which is a diagnostic of the prevailing circulation over the North Atlantic region: <https://www.metoffice.gov.uk/weather/learn-about/weather/atmosphere/north-atlantic-oscillation> (and a nice graphic is here, although the page is a bit aged: <https://www.ldeo.columbia.edu/res/pi/NAO/> ) Just check it out and read quickly over it, you can come back to it for writing up and see if you like any of the other pages that are available on it, from NCAR and NOAA in the US, for example. Make sure to take note of the papers and references you find and give credit to sources when writing the report.

The second step is to download a timeseries of the North Atlantic Oscillation (NAO) monthly index. This index is based on the pressure gradient (sea level pressure) of a station in Iceland minus one in the Azores, expressed in standard deviation units and centered on 0 (i.e. 0 is ‘average pressure gradient’, 1 stands for 1 standard deviation stronger than average etc). The NAO expresses if the Icelandic low is deeper than usual, and the Azores high stronger than usual, or if both are weaker than usual (as pressure is the weight of the atmosphere above, and winter circulation is very large scale averaged over a month, this captures pretty well the main variability). You find the timeseries here:

[https://crudata.uea.ac.uk/cru/data/nao](https://crudata.uea.ac.uk/cru/data/nao/nao.dat)

On that site, you can also see references to papers on the NAO, and the format, if you click at nao.dat [https://crudata.uea.ac.uk/cru/data/nao](https://crudata.uea.ac.uk/cru/data/nao/nao.dat)/nao.dat you can download the data at monthly resolution. (also, on the page <https://crudata.uea.ac.uk/cru/data/nao/index.htm> you can learn a bit more about the data, and the link I gave you is for the 2 decimal points NAO data – each row contains year, then monthly values starting from January, then annual).

Now download the timeseries, and save it in a matrix (e.g., year, monthly values, annual value).

*We now construct a timeseries of 191 winters consisting of months relevant for the NAO:* Delete all values prior to December 1830. Delete all months other than December, January, February and March – these remaining months are the months when the NAO has the strongest influence on winter climate (note for enthusiasts: there is such a thing as the summer NAO which has a different pattern). Delete December 2021 (the very last value which will be -99.99 which is a missing value)

Now you have 191 years of NAO data x 4 months. Calculate the mean of all Januaries, Februarys, Marches and Decembers and remove that mean of all from each January, February etc (so that from each January, for example, the average of all Januaries is subtracted etc). Now arrange the values consecutively, so that it is 764 monthly values in order of time, such as J1910, F1910, M1910,D1910, J1911….. You could plot to see the variations in the NAO against time which is a good check (and interesting). Then set a vector of logical values that identifies positive NAO values (ie a 4x191 long logical index).

Now we look at how the rainfall in winter months behaves differently for positive and negative NAO values.

For this, we first download the England/Wales pcp (<https://www.metoffice.gov.uk/hadobs/hadukp/>) monthly values. Go to this website, look at what is available and click download for monthly totals EWP (you could also download another region that you are interested in but then the timeseries get shorter and you would have to cut the NAO to start later, so I don’t recommend it). https://www.metoffice.gov.uk/hadobs/hadukp/data/monthly/HadEWP\_monthly\_qc.txt

*Now identify data for the same winter months you have for the NAO*: Delete 2022 and Dec 2021 and the period prior to 1829, and all values prior to Dec 1830 and again delete all months other than the months December, January, February, March (for example, in a matrix 4x191) in the same sequential order as for the NAO, you may wish to turn them into a 4x191 long vector (but do not remove the means).

A good step to identify if the NAO has an influence on precipitation is to plot on the x axis NAO and on the y axis monthly precipitation as a cloud of points. Is it circular or do you detect a correlation visually? what is the correlation (eg pearson correlation coefficient) between NAO and rainfall? As rainfall is very variable, it will be a cloud of points but are there regions of the diagram that are less occupied by points and some that are more? Save your picture and later add to report.

Now form a vector pcp\_pos for the values of precipitation in months where the NAO is positive (you can do this by a command similar to pcp\_pos = pcp(naopos) and pcp\_neg=pcp(naoneg).

Plot histograms of pcp(naopos) and pcp(naoneg) in a way that you can compare them well – what do you observe, are they systematically different? Save the image and describe the differences and similarities for positive and negative NAO in your report.

Look also (and discuss in the report) the difference for extremely wet months. One way to do it is to count how many months exceed a suitable threshold for ‘very wet’ in NAO positive and negative months. What is the ratio for that count for positive vs negative NAO (count\_naopos/count\_naoneg)? Explain and justify your threshold in the writeup choosing between finding quite extreme months and having enough samples for either case.

Monthly extreme precipitation is important because it sets the scene for making daily extremes more damaging when it falls on saturated ground.

**Now we look at extreme daily precipitation.**

Go again to this website and now download DAILY precipitation (rubric daily totals in download data) <https://www.metoffice.gov.uk/hadobs/hadukp/>

You can choose if you want to look at Scotland, England, or northern Ireland.

These are daily data starting from 1931 on a text file.

Read the data month by month and extract the highest value for each month (note that -99.99 is a no-value entry but as we look for the highest you might ignore this if it occurs) and save. Having the monthly maxima will help you later determine when in a year an extreme occurred.

This should give you a timeseries of monthly maximum daily rainfall values for 91 years. Find the maximum of each year, and save in a 91 year vector which we will use to fit a general extreme value distribution: use a suitable software package. Plot the GEV, evaluating fit in a reasonable way (we saw methods how to do this in the course – use one suitable method; and if time is sparse, a simple one is fine) and discuss results in the writeup later. Is the tail shape one you expected and why?

Plot the timeseries of the wettest day in a year and discuss if it shows any evidence of a trend – high latitude rainfall is expected to increase, but also remember that weather variability is high. Identify a few suitable high cases – and identify their year and month– what seasons do they occur in? Is there a high value that occurred in December – March, and what is the NAO value and monthly total rainfall in that month - is it high as well? Between your extreme cases, decide on two cases that you would like to read up on – can you find any reports on the internet if any flooding or reports on heavy rain were reported? If time allows, check their return value (probability of being below it (p(value) using the cumulative distribution fitted, and remember that the return period is 1/(1-p(value)). If you are running out of time, a rough estimate is fine.

**B) Written report**

Your marks will be based on the written report, which will include the results of part A as graphs. Write a report on the topic of the North Atlantic Oscillation influence on UK precipitation, and the return values for heavy rainfall in your regions. This should contain the following sections:

*1. Introduction:* the North Atlantic Oscillation (NAO). In addition to the websites given above, there is a very good Wikipedia entry on it with good graphs, but you should definitely check out some of the publications cited in it. Discuss roughly the mechanism by which the NAO influences UK climate, what it diagnoses in terms of short term weather variability, and how it is measured.

*2.Methods*: explain the methods you used in your analysis, you don’t have to write down the GEV equations but clearly explain what steps you took to fit the distribution and arrive at your figures.

*3. Results section*: show your results in diagrams; label all axises etc and include a discussion of the following

- Does the NAO affect monthly average and extreme (high/low) rainfall and is its influence strong?

- Discuss your cases of extreme daily values and put them in the context of the monthly rainfall value (was it a very wet month so would this be some flood risk?). Were there any impacts reported in the media, e.g. was it in the context of a named storm?

- what does the distribution you fitted to daily data tell you about daily extreme rainfall return values for your chosen region, and the rarity of the extreme daily values you selected? Is the distribution you fitted long-tailed, neutral or shorttailed?

4. Summary   
Summarize your findings critially.

References – all references cited and websites used. Cite papers for the data sources.

**In total about 5, and no more than 10 pages (depends a bit on the size of your figures).**

**Assessment:** Marks are equally attributed to the quality of

1) background section (top marks: evidence of outside reading, eg citing appropriately literature and good context setting)

2) method description (top marks for all methods fully explain and clearly written. You don’t need to copy in equations such as GEV – referring to Coles for that is fine. But do explain your parameters you fitted, and the tools you used. Including clarity on mean removed etc).

3) monthly analysis results: (top marks for nice clear well labelled graphs, with clear brief description and interpretation of results)

4) daily analysis results: (top marks for good graph, good interpretation and evaluation)

5) discussion of results including context of extreme values discussed. Ensure your interpretation is appropriate, so be critical. (top marks for well chosen cases discussed briefly but thoughtfully and critically)

**Handin for assessed workshop report (20% of mark): Thursday week 7, March 10, 12 noon; turnitin.**