Part 1: Venice

The vulnerability of the city of Venice and its lagoonal ecosystem to sea level changes is significant. Many scientists attribute the increase in global sea levels, which has led to more frequent and higher occurrences of acqua alta (high water) in Venice, to global warming caused by the combustion of fossil fuels. To safeguard Venice, Italy, and the Venetian Lagoon from flooding, a project called MOSE (Modulo Sperimentale Elettromeccanico or Experimental Electromechanical Module) was initiated. The primary objective of MOSE is to shield the lagoon, its towns, villages, and inhabitants, as well as its renowned historical, artistic, and environmental heritage, from floods, including extreme events. According to MOSE, water levels reaching or exceeding 140 cm are considered extreme high waters.

Figure 1: Venice. Source: `https://thetravelexpert.ie`

Use the dataset of sea levels at Venice called `venice90` available in `R`. It is a subset of a dataset consisting of hourly sea levels from 1940 to 2009. Values greater than 90 cm were extracted, and then declustered (each cluster provides no more than one value, and each value is at least 24 hours apart).

(a) Read in the data. Extract and represent the yearly max values from 1940 to 2009. What do you observe ? should we check if the data is stationary?

(b) We are end of 2009 and would like to predict the yearly maximum values over the next 13 years (from 2010 to 2022). A naive approach consists of fitting a linear model on the observed yearly maxima and predict their values for 2010–2022. Proceed to this prediction and provide confidence intervals.

(c) Represent in the same graph the predicted yearly max values for the period 2010–2022, their pointwise confidence bounds and the observed values greater than 140 cm from the table below.

Now we perform a risk analysis and because we are interested in the period 2010–2022, we want to calculate the 13-years return level., for each year.

(d) Fit a GEV a with constant parameters to the historical yearly max values. Fit a GEV with time varying location parameter. Compare the two embedded models using likelihood ratio test (LRT). Show diagnostic plots. what diagnostic plots, models or LRT? how can we interpret mu0, mu1 and mu2

(e) Add if necessary a time varying scale and or shape GEV parameter. Select the best model according to LRT.

(f) Predict the 13-years return level, each year from 2010 to 2022.

We can't use the extRemes package to calculate the return level on non-stationary GEV models. Works with stationary but doesn't work with NON-STATIONARY

(g) Calculate confidence bands for these predictions.

(h) Represent in the same graph your predictions of the 13-years return levels, their pointwise confidence intervals, the predicted yearly max values from the linear model and the observed values greater than 140 cm from the table below.

(i) Broadly speaking, each year, there is a chance of 1/13 that the observed value is above the 13-years return level. Comment the results for both the linear model prediction and GEV approach. Note that 12 of the 20 events occurred in the 21st century.

Date	Height
22 November 2022	2.04 metres (6 ft 8 in)[12]
4 November 1966	1.94 metres (6 ft 4 in)
12 November 2019	1.87 metres (6 ft 2 in)[13]
22 December 1979	1.66 metres (5 ft 5 in)
1 February 1986	1.59 metres (5 ft 3 in)
29 October 2018	1.56 metres (5 ft 1 in)
1 December 2008	1.56 metres (5 ft 1 in)
15 November 2019	1.54 metres (5 ft 1 in)
15 November 1951	1.51 metres (4 ft 11 in)
11 November 2012	1.49 metres (4 ft 11 in)
16 April 1936	1.47 metres (4 ft 10 in)
16 November 2002	1.47 metres (4 ft 10 in)
25 December 2009	1.45 metres (4 ft 9 in)
15 October 1960	1.45 metres (4 ft 9 in)
13 November 2019	1.44 metres (4 ft 9 in)
23 December 2009	1.44 metres (4 ft 9 in)
6 November 2000	1.44 metres (4 ft 9 in)
12 February 2013	1.43 metres (4 ft 8 in)
1 November 2012	1.43 metres (4 ft 8 in)
8 December 1992	1.42 metres (4 ft 8 in)
17 February 1979	1.40 metres (4 ft 7 in)

Figure 2: Sea levels of 140 cm or greater : https://en.wikipedia.org/wiki/MOSE

Part 2:
Nuclear reactors

In this practical, you will analyse water levels of the Aare at a measuring station in Untersiggenthal, next to the Paul Scherrer Institute. The location is sensitive as it contains several experimental nuclear reactors, and a flood event could cause severe damage.

Figure 3: The Paul Scherrer Institute on the Aare, 2016. Source: `psi.ch/en/about`

The dataset provided by the Swiss Federal Office for the Environment (FOEN) includes daily maximum water levels (above sea level) as measured by the station (which is located at 325m above sea level). The range of the data is approximately 20 years (2000-2021). Your goal is to model the high water levels of the river at this point.

(a) Read in the data. Display a time series plot of the water level across the data range and try to identify times of highest levels.

(b) Now display a histogram of the water levels. What do you observe about the distribution?

The FOEN plans for several degrees of risk. In this assignment, we focus on two risk levels: 50-year events and 100-year events.

(c) Explain how you would model the high water levels using a peaks-over-threshold approach.

(d) Comment on the aspect of clustering of extremes. How do you propose to measure and deal with clustering of the daily water levels?

(e) Perform the analysis you suggest in c) and d) and compute the 50- and 100-year return levels. Explain your choice of threshold and provide an estimate of uncertainty for the return levels. *Note: take care to compute the return level in **yearly** terms.*

(f) Explain the drawbacks and advantages of using a block maxima method instead of the one used in c)-e).

Part 3:
Night temperatures in Lausanne

Usually, temperatures tend to be quite persistent in time and sudden large changes, in temperate climate such as Switzerland, are rare.

Figure 4: Lausanne by night, from LFM (`https://www.lfm.ch/actualite/suisse/romandie/vaud/lausanne-va-eteindre-durant-une-nuit-sept-batiments-emblematiques/`)

In this exercise, we would like to assess whether extremes of temperatures series tend to occur in cluster or not. To do so, we use daily night minima and maxima in Lausanne, in the 2000-2022 period. (`nightmin.csv` for daily night minimum temperatures and `nightmax.csv` for daily night maximum temperatures).

(a) Read in the data for the daily night maximum temperatures in Lausanne. Subset the summer months (June to September).

(b) Assess whether extremes of the subsetted series in (a) occur in cluster.

(c) Decluster the data from (a) using a suitable threshold. Plot the resulting declustered data. (Hint: you may want to use the `extRemes` package.)

(d) Fit a GPD to the data, both raw and declustered. Assess the quality of the fit.

(e) Repeat the above analysis for the negatives of the daily nightly minimum temperatures for the winter months (November-February).