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Application of the Generalized Pareto Principle to Model Maximum Temperatures

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ABSTRACT

According to the Global Environmental Conference 2021, the phenomenon of global warming is expected to result in severe climatic occurrences, impacting an ever-growing population with increasing vulnerability. This phenomenon is not attributable to climate change per se but rather to the potential for an exacerbation of its magnitude. The purpose of this article is to identify the highest temperatures in northeastern Algeria. We utilized the Generalized Pareto Distribution (GPD) to analyze the data obtained from the selected weather station, with the aim of comprehending the characteristics of the maximum values. The findings indicate that, regardless of the duration between occurrences, the monthly mean temperature consistently hovers around 31°C.

Keywords: Pareto General Distribution, temperature, global warming, modeling

1 Introduction

Algeria is a highly impacted area by climate change, experiencing a more rapid increase in temperatures compared to the global average and a growing unpredictability in rainfall patterns. These modifications will exert a substantial influence not solely on the ecosystems of the region but also on agriculture and human health. Climate projections suggest that the average temperatures in the region will increase by 1.5 to 2.5°C by the end of the century (GEC 2021), leading to more frequent and intense occurrences of extreme weather events such as droughts, heat waves, floods, and storms. These changes have resulted in substantial consequences, such as restricted water availability in numerous regions. Extended periods of drought can have significant impacts on agriculture, the availability of drinking water, and the production of energy.

2 Methodology

The initial focus of research in Algeria on the topic of climate, disasters, and risks revolved around the examination of water-related phenomena, specifically the patterns of rainfall and their spatial and temporal changes (Medjerab 1984; Habibi 2013). Researchers have given less focus to other types of climatic hazards, such as those associated with temperature and storm phenomena. Studies on these perils are relatively recent, and their prevalence remains limited. It is observed that the existing studies are frequently restricted to examining only one type of danger, and few studies have tackled this issue comprehensively. In order to achieve this objective, we analyze the highest temperatures recorded on a monthly basis using the Generalized Pareto Distribution (GPD) (Cheratia 2021) with data obtained from the Patna region. The temperature data utilized in this article depict the mean monthly temperatures documented over a substantial number of years (1988 to 2015) at the Batna weather station situated in northern Algeria. The objective is to comprehend variations in peak temperatures and construct appropriate prognostic models that can assist meteorologists and authorities in comprehending these particular occurrences and consequently mitigating climate hazards. Thezyp, evd, extRemes, and R packages were utilized to analyze the data (Bronaugh and al 2013; Stephenson 2014; R Core Team 2015). Consequently, a forecast was made for the next century.

3 Modeling

We selected the Generalized Pareto Distribution (GPD) as our choice for modeling. Additionally, we identified an optimal threshold for this distribution based on the work of Resnick (1987). The return rates calculated using the Maximum Likelihood (ML) method for various monthly maximum temperature return periods, along with 95% confidence intervals (CI) based on profile probability. The return level corresponds

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to the highest quantile of the distribution. These values represent the expected occurrences that are likely to surpass a certain threshold on average every "n" years. The value of "n" is the reciprocal of the probability of surpassing the threshold. For instance, a yield level of 100 years indicates that, on average, you can anticipate surpassing this value once every 100 years. This will aid in evaluating and controlling the hazards linked to increasing temperatures. Anticipate temperatures surpassing 30.96°C every 2 years, 31.03°C every 20 years, 31.045°C every 50 years, and 31.049°C every 100 years.

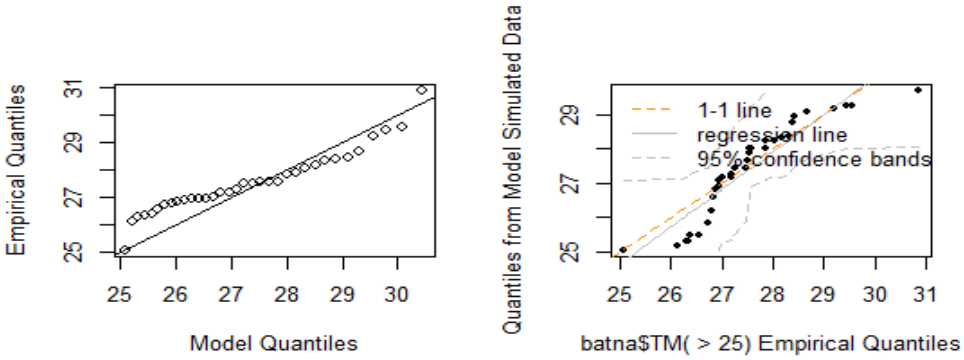

Figure 1: QQ plot for Batna station

4 Conclusion

This study used the Generalized Pareto Distribution (GPD) to model the monthly maximum temperatures recorded at the Batna weather station between 1981 and 2021. The aim was to analyze and forecast the patterns of maximum temperature variations. By employing the maximum likelihood (ML) method to estimate the parameters, it is determined that the Pareto II type (with a confined tail) is better suited for the Batna weather station, with a threshold of 25°C. The estimated return rates are calculated for multiple return periods, and the temperatures stabilize at approximately 31°C within two years. For instance, the model indicates that it will require approximately 100 years for average monthly temperatures to reach a state of stability. The temperature reaches 31.049 °C. This finding suggests that regardless of the time of return, the average monthly temperature is expected to surpass 31°C, thus confirming the arid and enduring drought conditions in the Batna region.

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