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POLICY BRIEF

# Red Flags on the Map: A Policy Brief on Exceptional Rainfall and Temperature Events in Portugal

**Luis Angel Espinosa**[1], **and Maria Manuela Portela**[2]

[1] Associação do Instituto Superior Técnico para a Investigação e Desenvolvimento (IST-ID), Civil Engineering Research and Innovation for Sustainability (CERIS); Lisbon, Portugal: **luis.espinosa@tecnico.ulisboa.pt**
[2] Instituto Superior Técnico (IST), CERIS; Portugal: **maria.manuela.portela@tecnico.ulisboa.pt**

**Context and Importance:** Climate change awareness is crucial for understanding the increasing severity of exceptional weather events. Portugal, characterised by diverse topography and climatic variations, has experienced significant shifts in extreme rainfall and temperature patterns over recent decades. These changes pose substantial risks to water resources, infrastructure, agriculture and ecosystem stability. This policy brief summarises key findings from two studies that utilise severity heat maps—as proposed by Espinosa, Portela, and Gharbia [1]—to analyse exceptional rainfall and temperature events in Portugal. The findings highlight the intensification of extreme weather events throughout the past four decades and provide insights into their regional impacts. Furthermore, the brief outlines implications for climate adaptation strategies and policymaking, emphasising the need to strengthen resilience against escalating climate risks.

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## 1 Introduction

Extreme weather events, including exceptional rainfall and maximum temperature (Tmax), have intensified due to climate change, profoundly impacting hydrological forecasting, disaster risk management, and infrastructure planning. Understanding the spatiotemporal distribution of these extremes is critical for developing effective climate adaptation policies. This brief presents insights from two studies using ERA5-Land reanalysis data at 1,012 evenly distributed centroids to map changes in exceptional rainfall and Tmax across Portugal. The studies provide a comparative analysis of these events' evolution over late and recent phases, using severity heat maps to quantify their impacts.

## 2 Findings

**Exceptional Rainfall (1981–2023).** Using the retrieved reanalysis rainfall data, this study identified exceptional rainfall events based on three high quantile thresholds (Q99, Q99.5, Q99.9), revealing:

- A severity heat map (see Figure 1) that classifies regions based on changes in occurrence and cumulative rainfall over threshold from the late and recent phases, highlighting a shift in exceptional rainfall occurrences from the southern to northern regions.
- Increased severity of rainfall events, particularly in urban areas such as Lisbon and Porto, which exhibit higher frequencies of exceptional rainfall events and cumulative rainfall above threshold in the recent phase.

**Exceptional Tmax (1980–2024).** Examining Tmax data over the late and recent phases, the study illustrated shifts in exceptional Tmax events in Portugal (see Figure 2) for the thresholds Q90, Q99, Q99.9:

- Northern and central regions showed the most significant increases in occurrences and temperature excess (More & More, Case 1), while some areas, such as Alentejo, exhibited increased frequency but less temperature excess at higher thresholds (More & Less).
- A few regions, such as Braga and Guarda, showed less occurrences or temperature excess, indicating localised improvements (Cases 3 and 4 for Q99).

## 3 Policy Implications

The findings highlight urgent climate adaptation needs:

- **Improved monitoring systems:** Expanding hydrometeorological networks to enhance early detection and forecasting of extreme events.
- **Resilient Infrastructure and Land-Use Planning:** Develop flood defences, heat-resistant materials, and urban strategies to mitigate extreme weather impacts, integrating shifting climate patterns into development policies.
- **Climate education and awareness:** Strengthening knowledge-sharing initiatives to enhance public and policymaker awareness of climate change risks and adaptation measures.

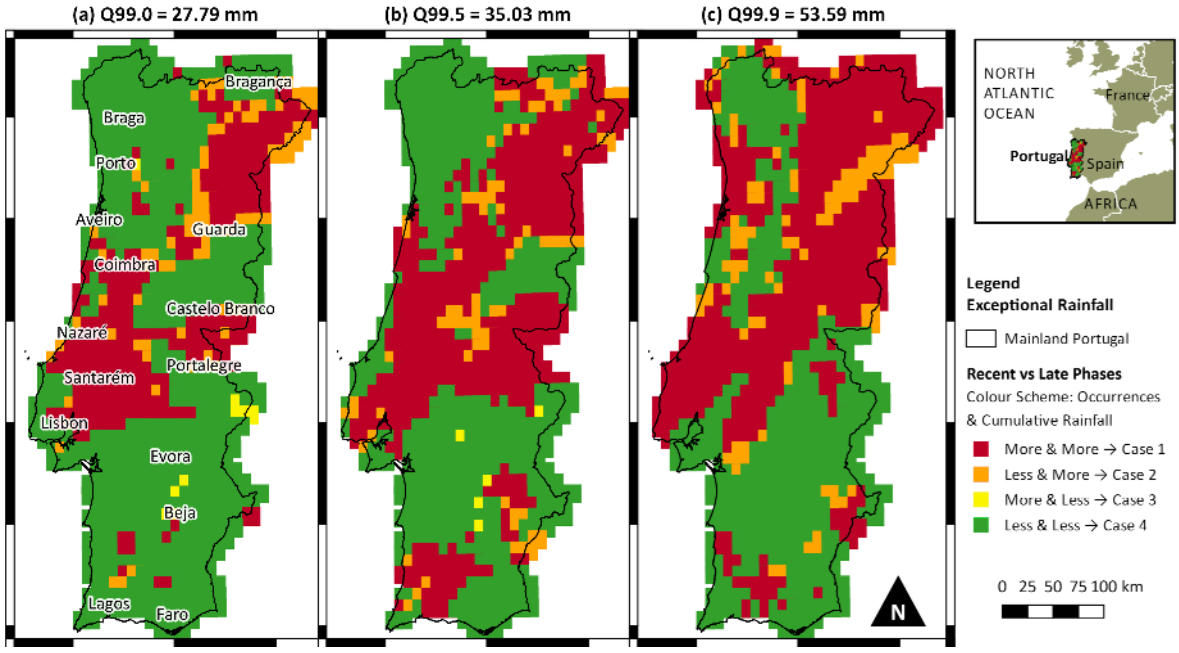


**Fig. 1** Severity heat map of exceptional rainfall events—rainfall above Q—for the late (1981–2002) and recent (2002–2023) phases.

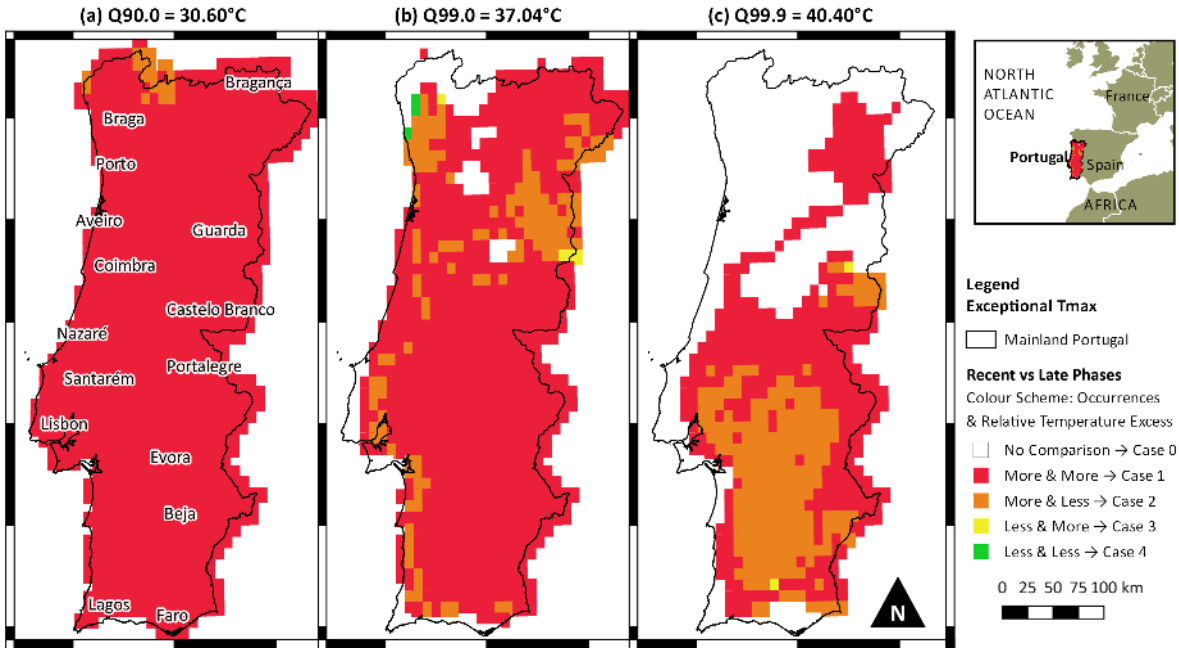


**Fig. 2** Severity heat map of exceptional Tmax events—Tmax above Q—for the late (1980–2002) and recent (2002–2024) phases.

## 4 Conclusions

Climate change is altering Portugal's hydrological and temperature regimes, increasing the severity of exceptional rainfall and Tmax events, as highlighted by severity heat maps that provide essential insights for understanding and mitigating extreme weather risks. Policymakers, engineers, and scientists must collaborate to strengthen resilience and ensure sustainable water and climate governance.

## References

[1] L. A. Espinosa, M. M. Portela, and S. Gharbia, "Assessing Changes in Exceptional Rainfall in Portugal Using ERA5-Land Reanalysis Data (1981/1982–2022/2023)," *Water*, vol. 16, no. 5, p. 628, 2024.