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# Assessment of Future Precipitation Patterns in Greece Using ETCCDI Climate Indices

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## INTRODUCTION & AIM

Anthropogenic climate change is expected to modify precipitation patterns across the globe, with the Mediterranean Basin among the most climate-sensitive regions. Rising temperatures and declining precipitation are projected to intensify droughts and extreme rainfall events, posing serious threats to water resources, biodiversity, productive sectors and human livelihoods [1]. In particular, areas with complex topography, uneven precipitation distribution, and limited adaptive capacity are projected to experience the impacts of climate change to a greater extent.

The present study investigates the spatial and temporal variability of precipitation across Greece for the period 1971–2100. Using regional climate model data under the RCP4.5 and RCP8.5 scenarios, the analysis focuses on trends in extreme precipitation indices to better understand potential hydrological changes. The findings aim to support evidence-based water resource management and regional adaptation planning in response to a progressively drier climate.

The Mann–Kendall test [2,3], a non-parametric statistical method, was used to assess the significance and detect the direction of monotonic trends in the time series of examined precipitation indices. Statistical significance was evaluated at the 95% confidence level ($p < 0.05$).

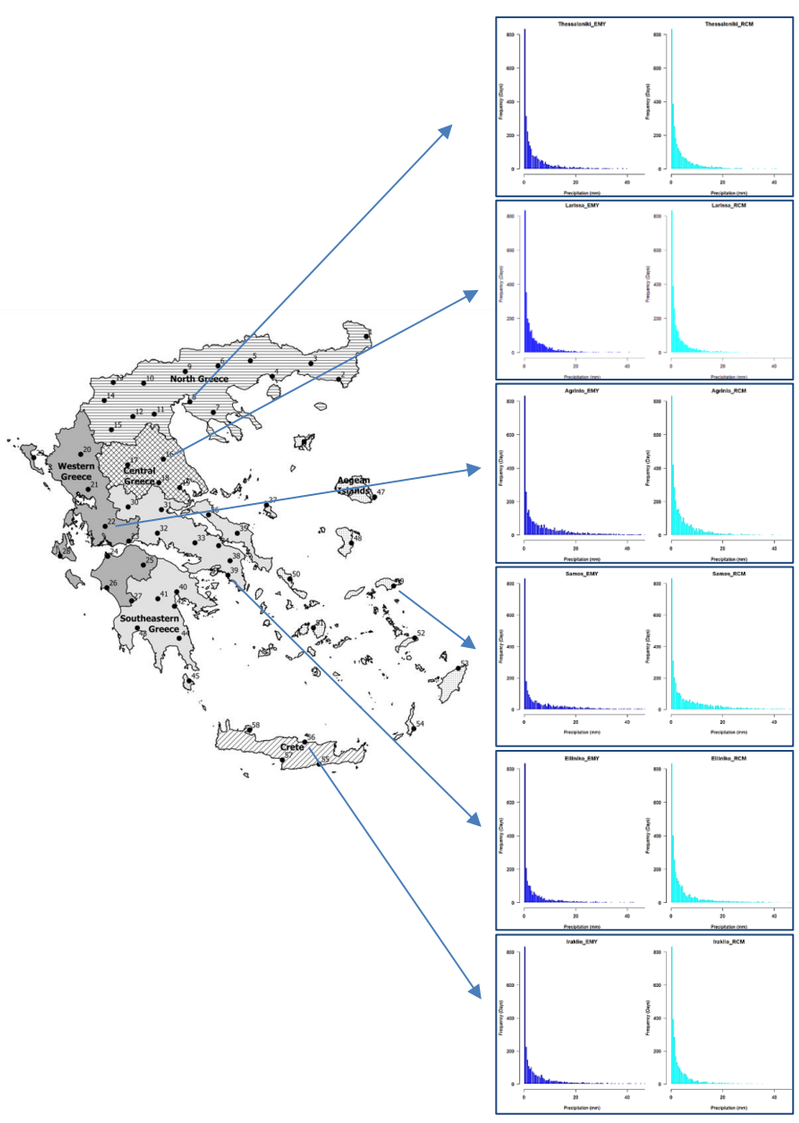
$$S = \sum_{k=1}^{n-1} \sum_{j=i+1}^{n} sgn(x_j - x_k) \qquad Z_S = \begin{cases} \frac{S-1}{\sqrt{Var(S)}}, if\ S > 0 \\ 0 \quad , if\ S = 0 \\ \frac{S+1}{\sqrt{Var(S)}}, if\ S < 0 \end{cases}$$

Sen's Slope estimator [4] was applied to quantify the magnitude of linear trends by calculating the median slope across all data pairs.

$$f(t) = Q_{med} * t + B \qquad Q_i = \frac{x_j - x_k}{j-k}, \ \forall \ j > k$$

## DATA & METHODS

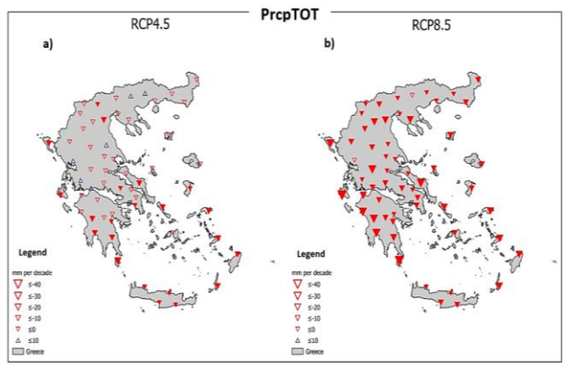
- High-resolution (~12.5 km) projections (RCA4) from the initiative EURO-CORDEX, were utilized to investigate future hydroclimatic conditions in Greece for the period 1971–2100.
- Fifty-eight meteorological stations, uniformly distributed across Greece, were selected for the extraction of our precipitation data, providing sufficient geographic coverage, while the study area was divided into six subregions to enhance the interpretation of the results.
- Simulations were conducted under two Representative Concentration Pathways of the IPCC: a more realistic pathway for greenhouse gas stabilization (RCP4.5), and a pessimistic high-emission scenario without mitigation measures (RCP8.5).
- The model's predictive performance was assessed using statistical metrics and by comparing frequency distributions of the reference period (1971–2000). It reproduces positive skew distributions sufficiently (typical of Mediterranean climates), enabling further analysis, although some biases appear in areas of high spatial variability.




- A total of 12 extreme precipitation indices (ETCCDI) were calculated to evaluate long-term changes in the frequency, duration, and intensity of hydrological events for the period 1971–2100.
- ETCCDI indices were selected due to their flexibility in ensuring comparability across different regions, providing a common conceptual framework to interpret extreme hydro-climatic events, and offering a standardized approach for data analysis.

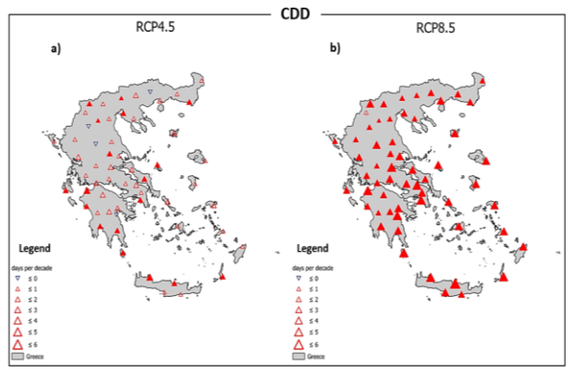
| Index | Definition | Units |
|---|---|---|
| PrcpTOT | Sum of daily PR ≥ 1.0 mm (from wet days) | mm |
| SDII | Annual total PR (PR ≥ 1.0 mm) divided by the number of wet days | mm/day |
| CWD | Maximum annual number of consecutive wet days (PR ≥ 1.0 mm) | days |
| CDD | Maximum number of consecutive dry days (PR < 1.0 mm) | days |
| R10mm | Annual number of days when PR ≥10 mm | days |
| R20mm | Annual number of days when PR≥ 20 mm | days |
| Rx1day | Maximum 1-day PR total | mm |
| Rx5day | Maximum 5-day PR total | mm |
| R95p | Annual total precipitation from days with PR > 95th percentile | mm |
| R99p | Annual total precipitation from days with PR > 99th percentile | mm |
| R95pTOT | Fraction of total wet-day rainfall from very wet days (100*r95p/PrcpTOT) | % |
| R99pTOT | Fraction of total wet-day rainfall from extremely wet days (100*r99p/PrcpTOT) | % |

## RESULTS & DISCUSSION



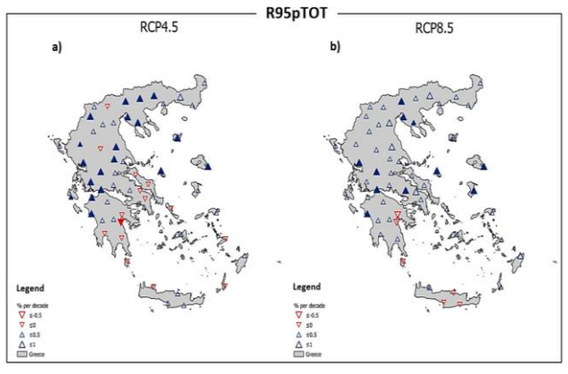

**PrcpTOT – Annual Total Precipitation**

- ↓ 12% (RCP4.5) — ↓ 29% (RCP8.5) by 2100.
- RCP4.5: Statistically significant decreases at 38% of stations (–4.7 to –25.1 mm per decade), mainly in western and southern Greece.
- RCP8.5: Significant declines at 97% of stations (–4.8 to –45.8 mm per decade), indicating a substantial shift toward drier conditions.




**CDD – Consecutive Dry Days**

- ↑12% (RCP4.5) — ↑40% (RCP8.5) by 2100.
- RCP4.5: Significant increases at 31% of stations (+0.7 to +2.6 days per decade), with the strongest signals in Crete and the Peloponnese.
- RCP8.5: Significant increases at 98% of stations (+1.0 to +5.7 days per decade); over 50% exceed +3 days per decade, especially in Attica, Central Greece, Peloponnese and in island regions such as Crete, Karpathos and Kythira.




**R95pTOT – Proportion of annual precipitation when daily precipitation exceeds the 95th percentile.**

- Projected slight increase (≤1%) in most regions under both scenarios.
- Statistically significant trends at 34% (RCP4.5) and 19% (RCP8.5) of stations.
- Most trends are positive, primarily in western and northern Greece and the northern Aegean islands.

## CONCLUSION

The study indicates that Greece's hydrological regime is projected to become drier by the end of the 21st century, with reductions in annual precipitation and longer dry spells, especially under the high-emission scenario RCP8.5. However, extreme rainfall events are projected to intensify, as indicated by rising R95pTOT and R99pTOT indices. These changes will affect water availability, agriculture, tourism, energy demand, and public health, while increasing the risk of desertification and wildfires. Despite uncertainties in climate projections, the results confirm a general trend toward a hotter, drier future, emphasizing the need for sustainable water management and adaptation strategies to mitigate the impacts of climate change.

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