



This study employed ERA5-Land reanalysis data to analyse heatwaves, overcoming the scarcity or near absence of publicly accessible and long enough series of daily temperature records.

Heatwaves in Portugal: An Analysis Using ERA5-Land Reanalysis Data (1980-2021)



A local resident uses a garden hose to try to stop a forest fire from reaching houses in the village of Figueiras, outside Leiria, central Portugal, Tuesday, July 12, 2022.

Joao Henriques/AP

Luis Angel Espinosa*

Maria Manuela Portela

Laryssa Moreira Freitas

Salem Gharbia

*The Association of Instituto Superior Técnico for Research and Development (IST-ID), Civil Engineering Research and Innovation for Sustainability (CERIS), Lisbon University (UL), Lisbon, Portugal

luis.espinosa@tecnico.ulisboa.pt

**9º Seminário do Núcleo
Regional do Norte – APRH**

Porto, FEUP, 16 November 2023

IST-ID
Associação do Instituto Superior Técnico
para a Investigação e Desenvolvimento

score

IFT TÉCNICO
LISBOA

CERIS

1. Introduction

Heatwaves, as extreme weather events, exert significant impacts on human health, ecosystems, and infrastructure.

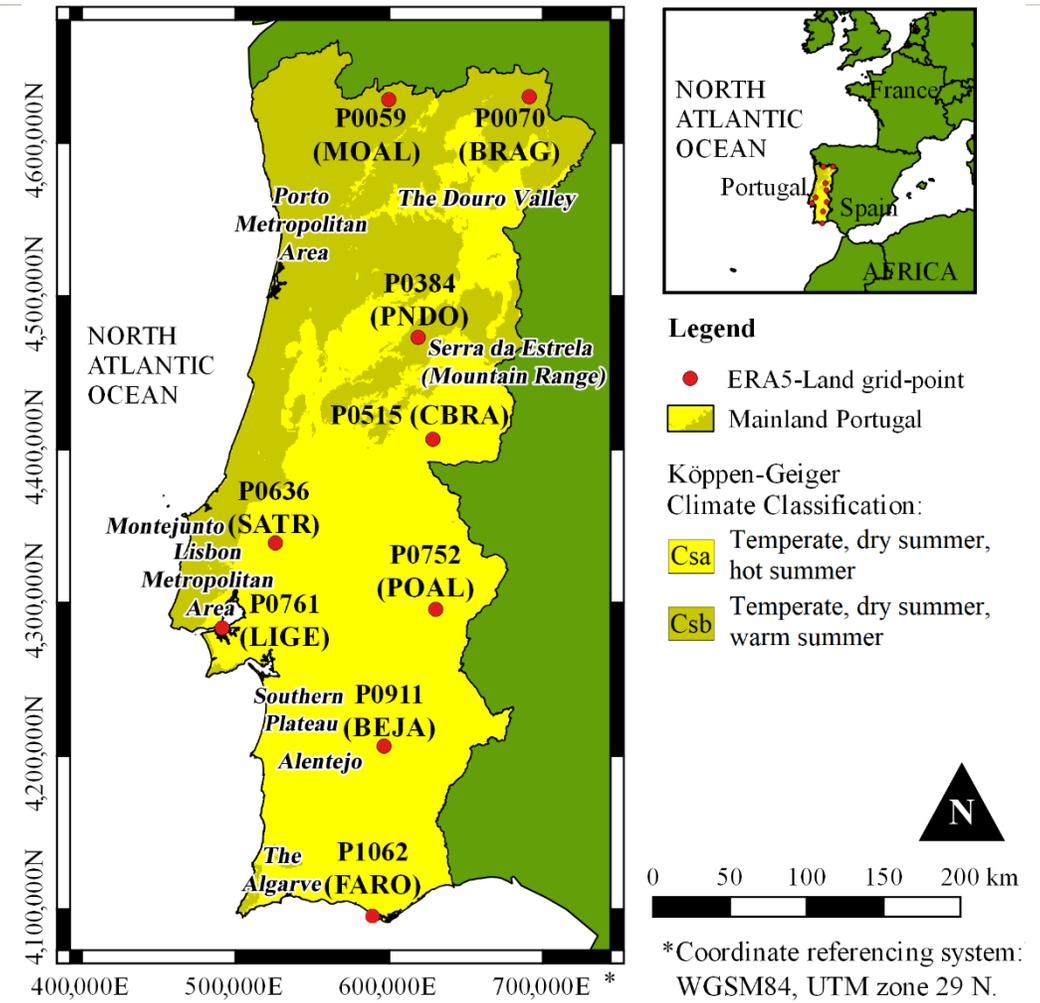
- Heatwaves are extreme weather events with severe impacts on human health, ecosystems, and infrastructure.
- Frequency and severity of heatwaves increasing worldwide due to climate change.
- Portugal has experienced several severe heatwaves in recent years.



2. Study area

Mainland Portugal was selected as the study case in this research.

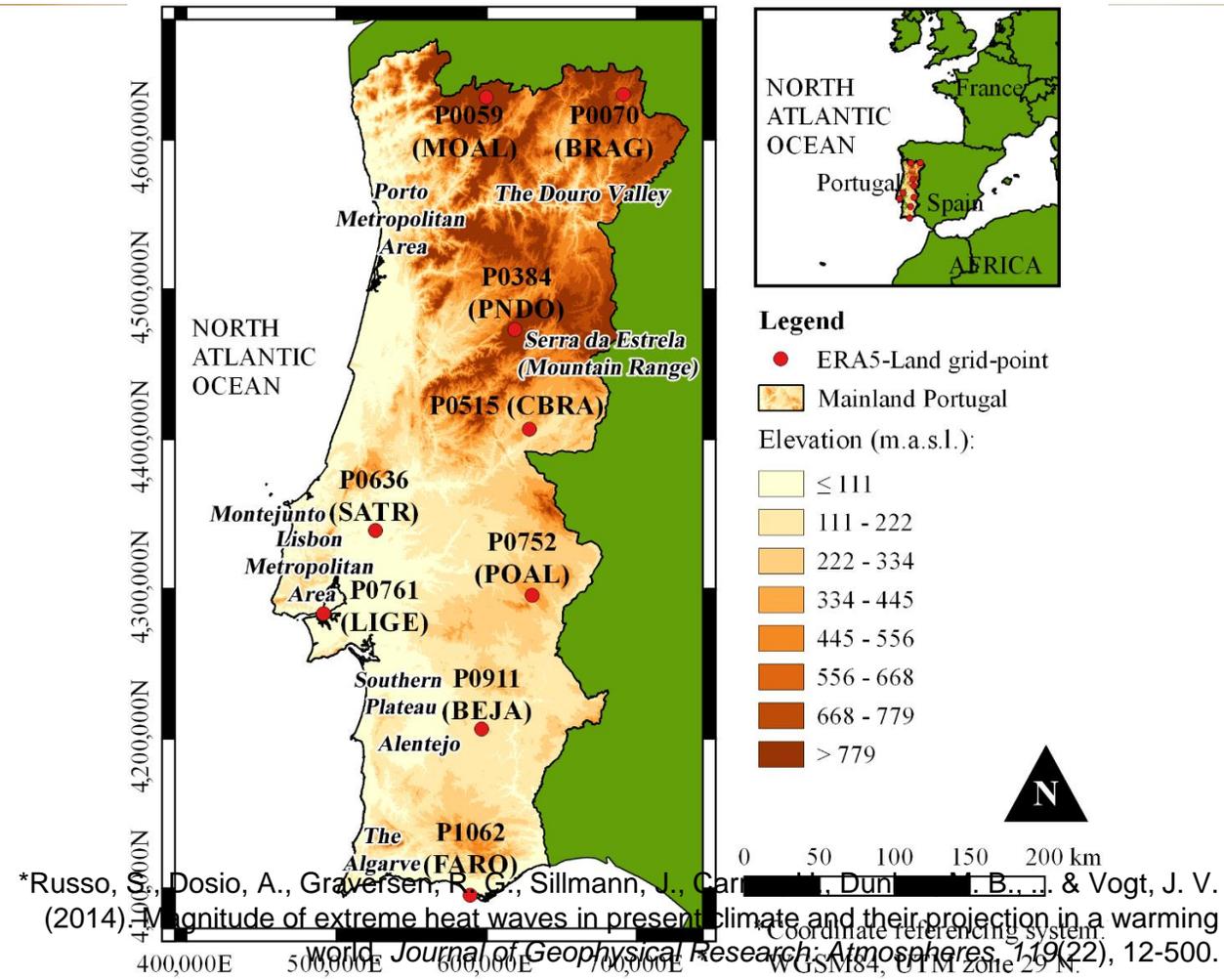
- Mainland Portugal selected as the study case.
- Diverse topography and regional climate variations.
- Northern region with temperate climate, southern region with semi-arid climate.
- Nine representative grid-points from the ERA5-Land dataset were selected.



3. Materials and methods

Heatwaves in Portugal were analysed using high-resolution daily temperature data (ERA5-Land).

- Analysis based on high-resolution daily temperature data from ERA5-Land from October 1980 to September 2021.
- Validation of ERA5-Land data against IPMA ground-based observations from 1980 to 2018 (39 years).
- Heatwaves identified using the heatwave magnitude index (HWTI), A_d , by Russo *et al.*, 2014*.
- The frequency of heatwaves addressed via a kernel rate estimation technique.



3. Materials and methods

Heatwaves in Portugal were analysed using high-resolution daily temperature data (ERA5-Land).

- Analysis based on high-resolution daily temperature data from ERA5-Land from October 1980 to September 2021.
- Validation of ERA5-Land data against IPMA ground-based observations from 1980 to 2018 (39 years).
- Heatwaves identified using the heatwave magnitude index (HWMI), A_d , by Russo *et al.*, 2014*.
- The frequency of heatwaves addressed via a kernel rate estimation technique.

The HWMI is defined as the maximum magnitude of the heatwaves in a year, where a heatwave is the period ≥ 3 consecutive days with Tmin (or Tmax) above the daily threshold. The threshold is defined as the 90th percentile of daily Tmin (or Tmax), centred on a 31-day window. Hence, for a given day d , the threshold series A_d of the dataset is given by:

$$A_d = \bigcup_{y=1980}^{2021} \bigcup_{i=d-15}^{d+15} T_{y,i},$$

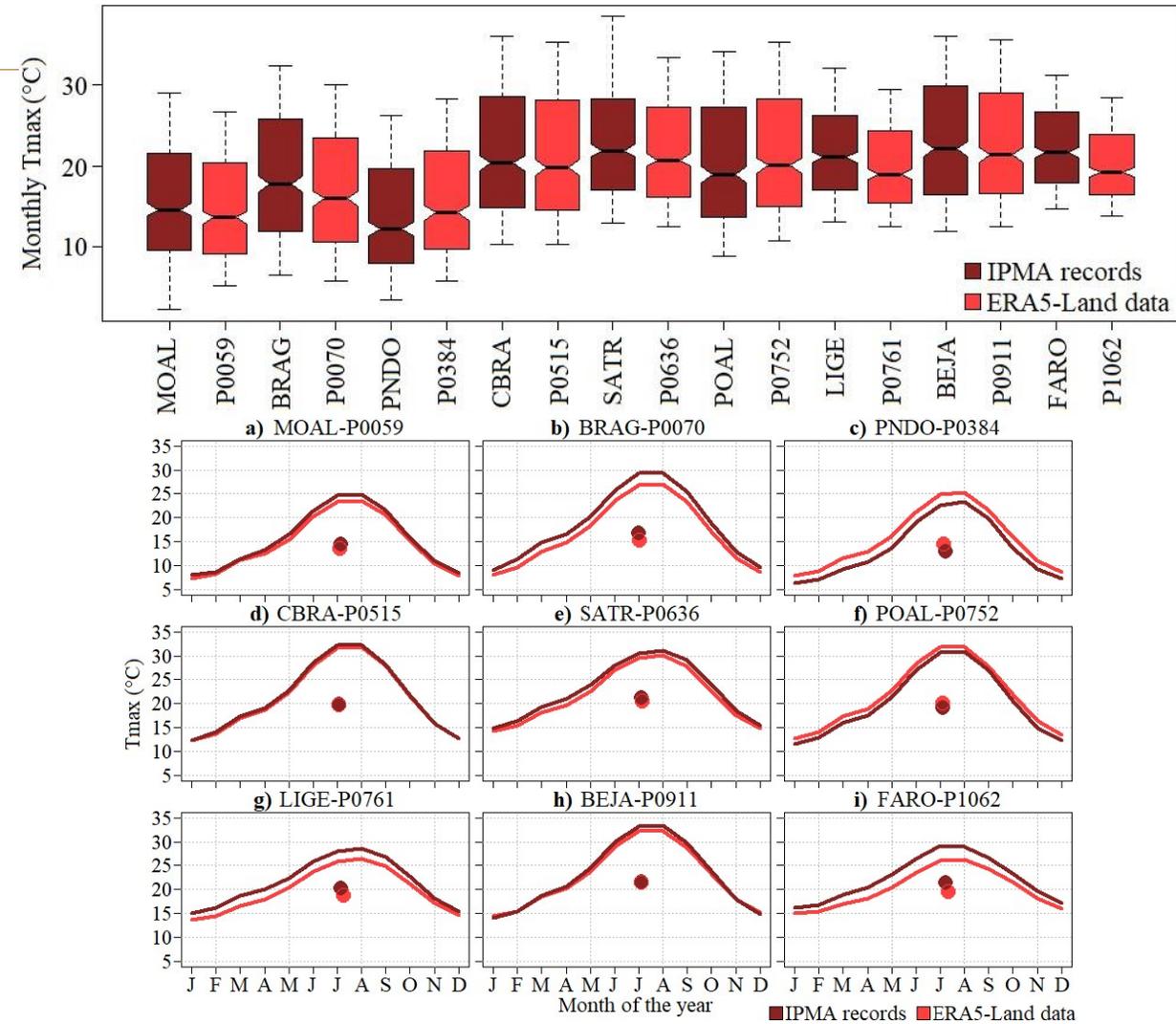
where \bigcup denotes the union of sets and $T_{y,i}$ is daily temperature of the day i in the year y . To obtain A_d , the daily temperature ERA5-Land data in the 15-day period before the 1 October 1980 and after the 30 September 2021 were used.

*Russo, S., Dosio, A., Graversen, R. G., Sillmann, J., Carrao, H., Dunbar, M. B., ... & Vogt, J. V. (2014). Magnitude of extreme heat waves in present climate and their projection in a warming world. *Journal of Geophysical Research: Atmospheres*, 119(22), 12-500.

4. Results

Comparison between ERA5-Land data and Meteorological Stations (IPMA) records from 1980 to 2018.

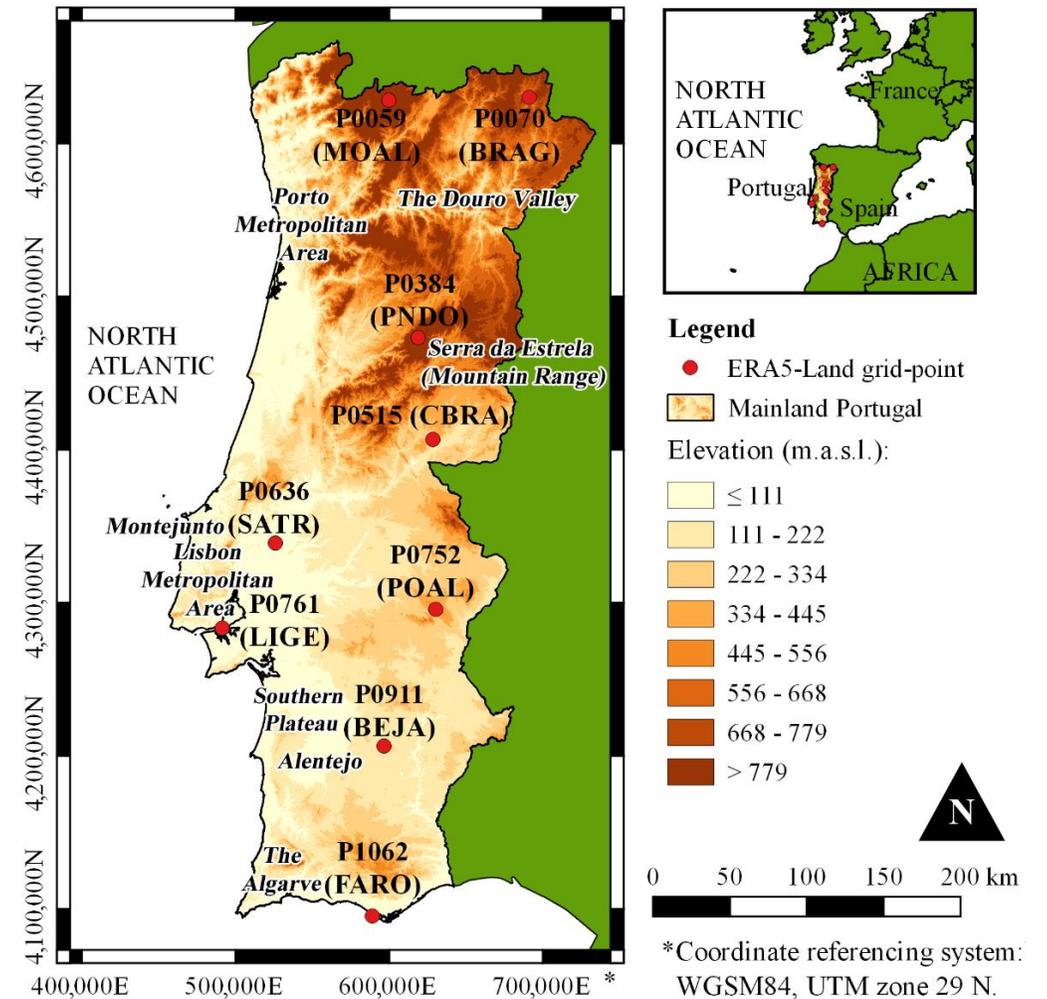
- Strong linear relationship between ERA5-Land and IPMA temperature data.
- Higher maximum temperatures recorded by IPMA. Smoother values for ERA5-Land Tmax due to retrieval method.
- Good agreement for the long-term mean monthly temperature and their centroids for the common 39 years.



- **Good agreement between the ERA5-Land and IPMA temperature data. Higher Tmax recorded by IPMA, but consistent patterns observed.**

After the validation of the ERA5-Land dataset, the study addressed heatwaves via the heatwave magnitude index (HWMI) applied to the daily temperature dataset at each of the nine grid-point locations.

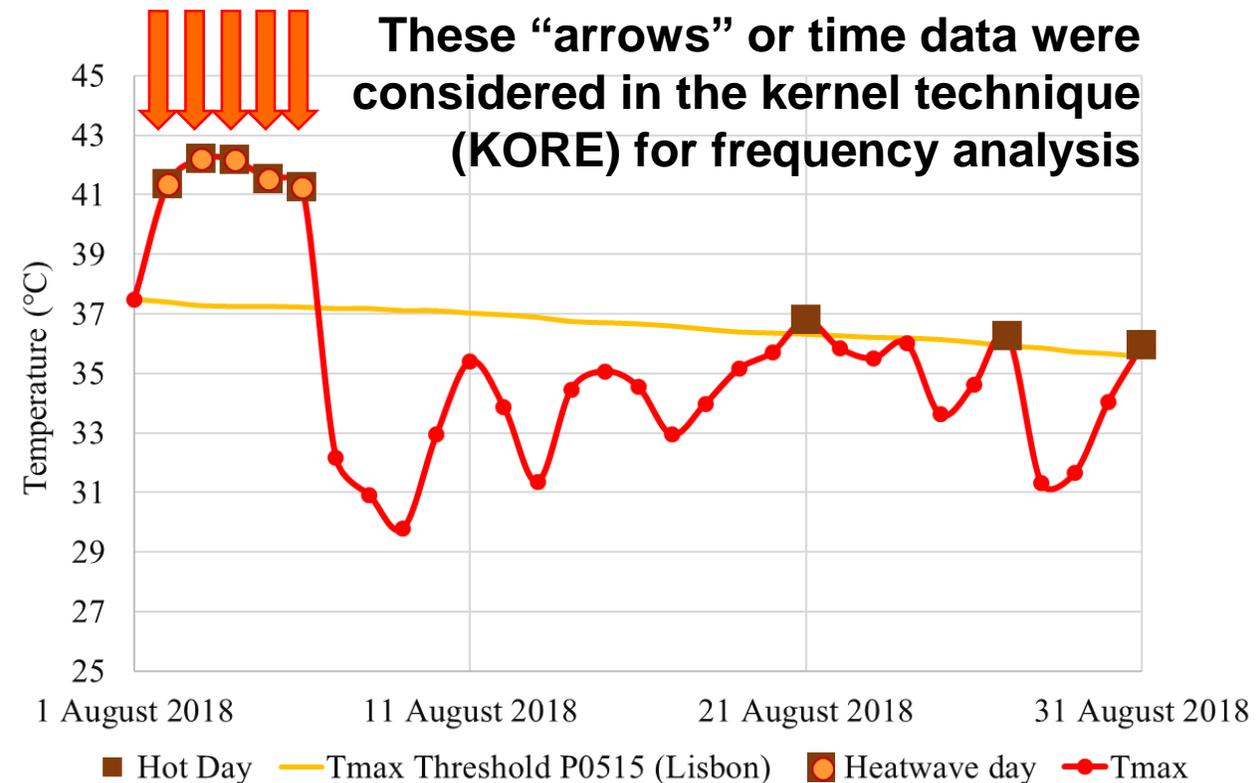
The daily temperature thresholds for the reference period from 1 October 1980 to 30 September 2021 were firstly calculated.



4. Results

A closer look to what a heatwave day is.

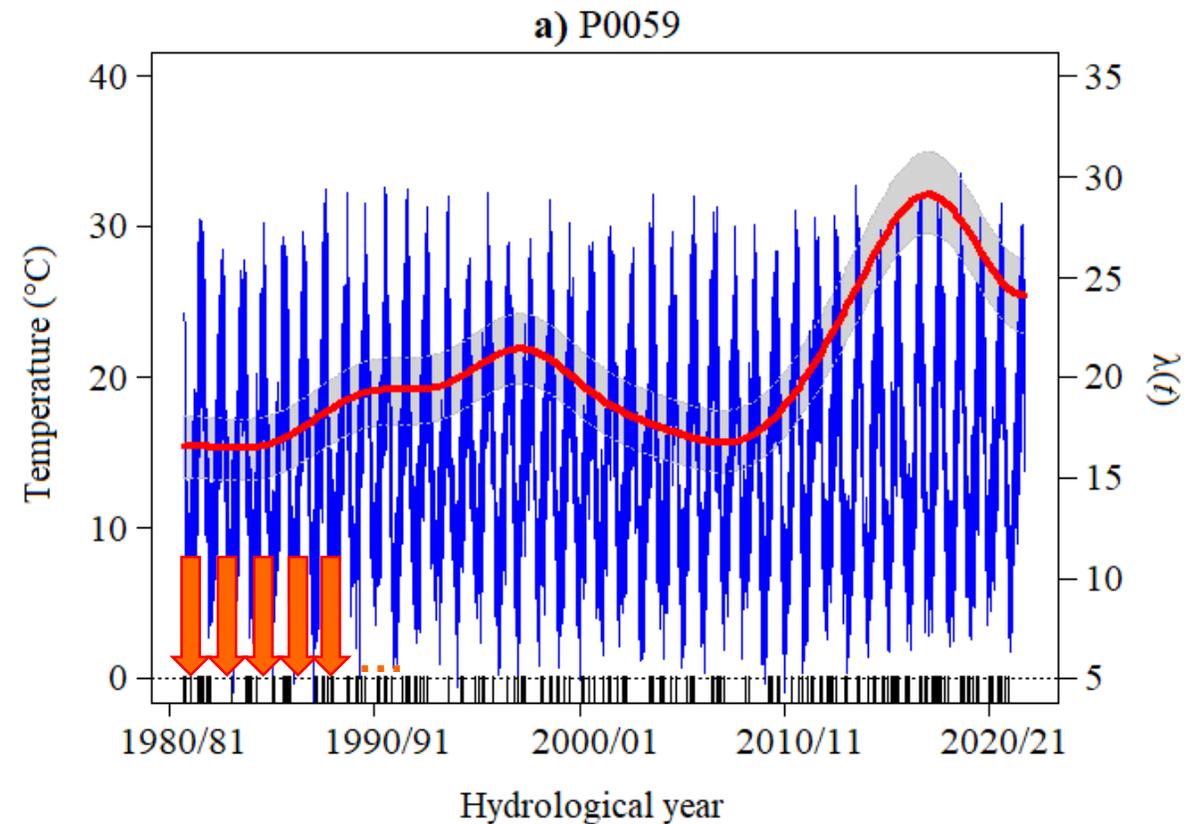
- The HWMI is defined as the maximum magnitude of the heatwaves in a year, where **a heatwave is the period of three or more consecutive days with Tmax above the daily threshold.**



4. Results

Frequency analysis of the Tmax heatwave days.

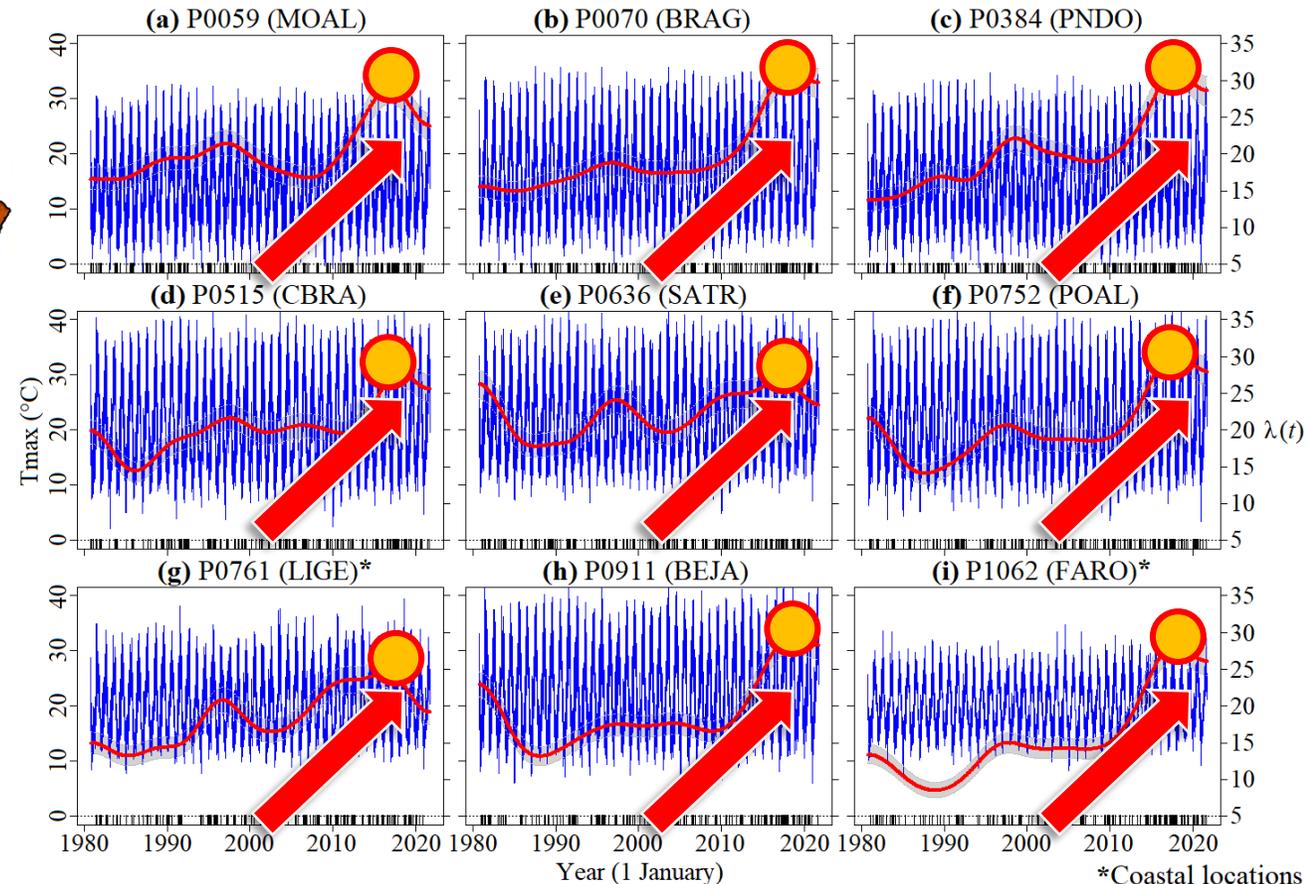
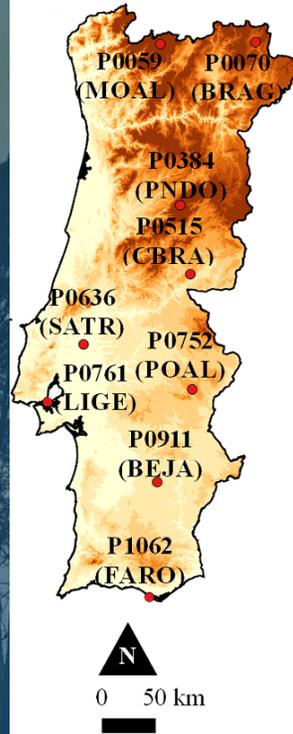
- Heatwaves identified using HMMI based on daily thresholds.
- Kernel rate estimation technique (KORE) used for annual frequency analysis.



4. Results

Frequency analysis of the Tmax heatwave days.

- Heatwaves identified using HWMI based on daily thresholds.
- Kernel rate estimation technique (KORE) used for annual frequency analysis.
- Time-dependent occurrence rates of T_{max} heatwave days from 1 October 1980 to 30 September 2021 at the ERA5-Land grid-points. Left y-axis: ERA5-Land daily T_{max} in blue. Right y-axis: the number of heatwave days per year, $\lambda(t)$, in red (confidence band in grey). Dates of occurrence of heatwave days: vertical ticks.

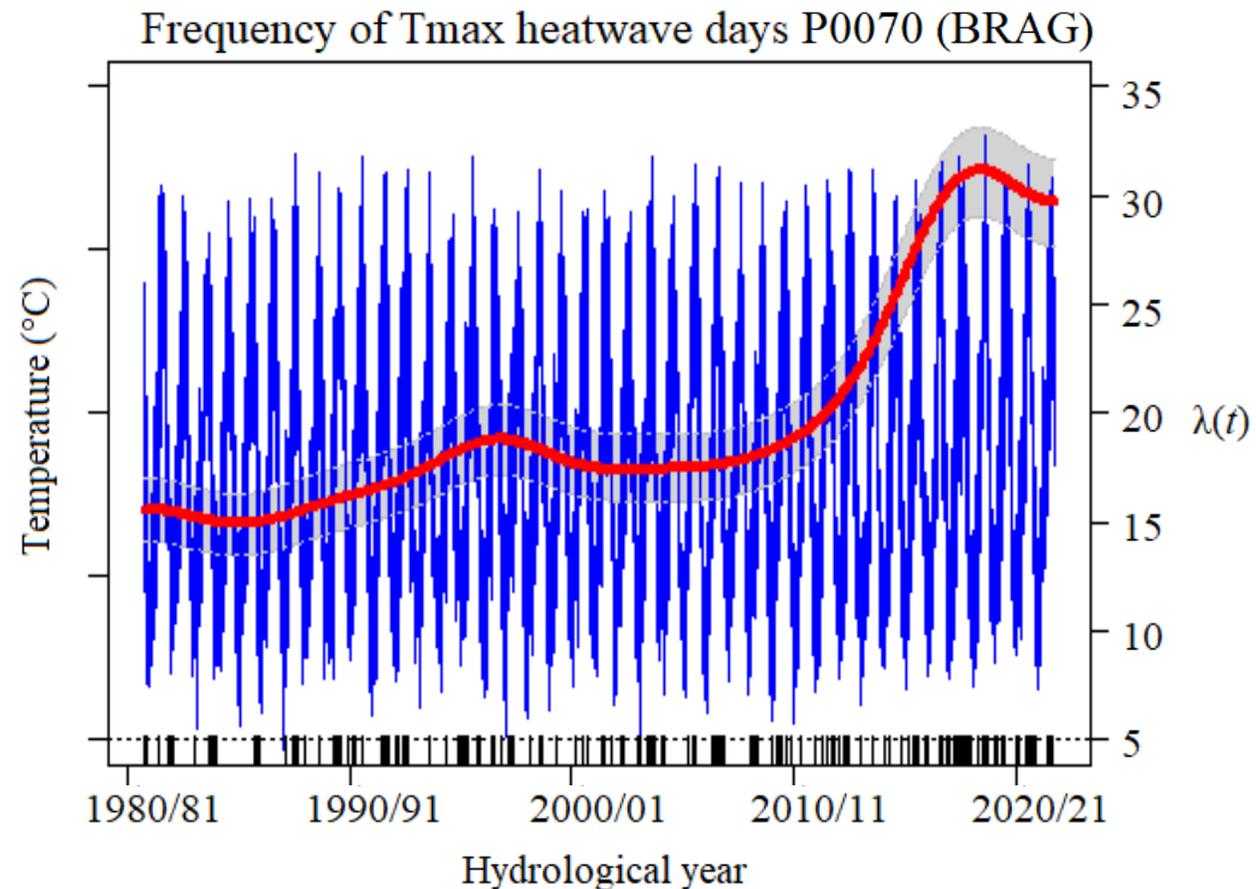


The peak of $\lambda(t)$ occurred between 2017/18 and 2018/19, matching with the historic heatwave that hit Portugal in August 2018.

5. Concluding remarks

Significant increase in Tmax heatwave days in the last two decades.

- Clear increase in frequency of heatwave days in frequency and severity.
- Heatwaves pose health risks and impact ecosystems and infrastructure.
- Increased risk of heat exhaustion, dehydration, and respiratory issues.
- ERA5-Land data provides valuable insights for heatwave analysis.
- Urgent need for further research and adaptation measures.



Heatwaves in Portugal: An Analysis Using ERA5-Land Reanalysis Data (1980-2021)



Luis Angel Espinosa*

Maria Manuela Portela

Laryssa Moreira Freitas

Salem Gharbia

*The Association of Instituto Superior Técnico for Research and Development (IST-ID), Civil Engineering Research and Innovation for Sustainability (CERIS), Lisbon University (UL), Lisbon, Portugal

luis.espinosa@tecnico.ulisboa.pt

**9º Seminário do Núcleo
Regional do Norte – APRH**

Porto, FEUP, 16 November 2023

IST-ID
Associação do Instituto Superior Técnico
para a Investigação e Desenvolvimento



CERIS :

This research was supported by the Foundation for Science and Technology (FCT) through funding UIDB/04625/2020 from the research unit CERIS and by the European Union's Horizon 2020 research and innovation programme SCORE under grant agreement No 101003534.