Climate Change Service

National Collaboration Programme

Studying the evolution of heat waves in Italy over the present century

Giulio Settanta, ISPRA

EWC User Workshop 2026

PROGRAMME OF THE EUROPEAN UNION

Copernicus Europe's eyes on Earth

Climate Change Service climate.copernicus.eu

IMPLEMENTED BY ECMWF

NCP

Italy Project for C3S NCP
C3S2_461-1_IT_ISPRA

ISPRA Istituto Superiore per la Protezione e la Ricerca Ambientale

Sistema Nazionale per la Protezione dell'Ambiente

Aeronautica Militare

ItaliaMeteo

CIMA

ENEA Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile

Consiglio Nazionale delle Ricerche Istituto per la BioEconomia

igg Istituto di Geoscienze e Georisorse

ARPA Valle d'Aosta

ARPA Lombardia Agenzia Regionale per la Protezione dell'Ambiente

Arpa Piemonte Agenzia Regionale per la Protezione Ambientale

ARPAC Campania

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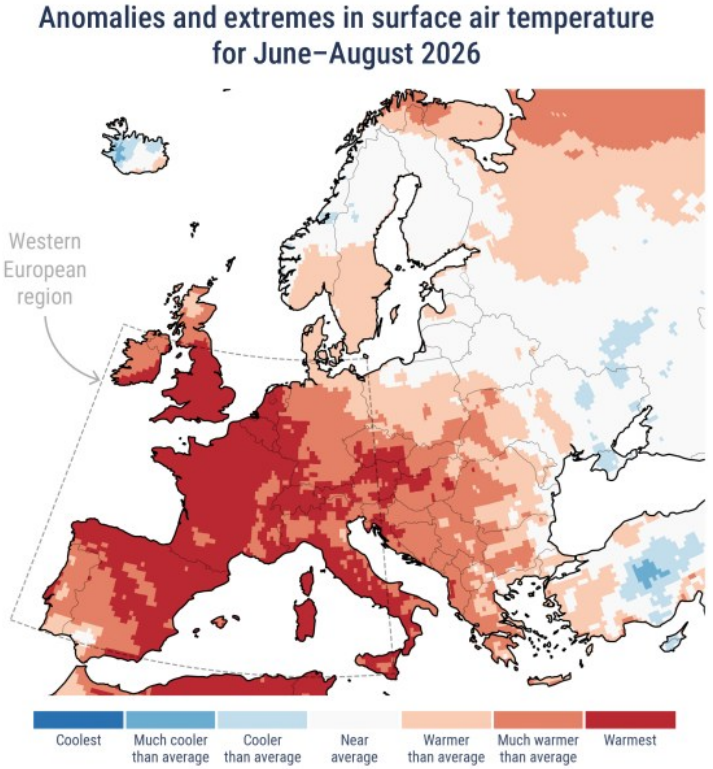
Introduction

- Escalating frequencies and intensities of extreme thermal events have rapidly sharpened the scientific and public focus on the phenomenon of heat waves.
- The hot European summer of 2022 served as a bright indicator of the deep impacts of a warming climate, resulting in a measured heat-related excess mortality burden across the continent.
- 2026 summer recorded a long series of unusual warm days: for western Europe, it's been **the hottest summer ever recorded**.
- Across decades, severe heatwaves went from being occasional events to be now **a major concern for people's health**.
- At present time, it is essential to systematically monitor and model the evolving temporal dynamics, frequency, and severity of extreme heat events.
- In the framework of the **C3S National Collaboration Programme**, the **Italian initiative C3S2_461-1_IT_ISPRA** is ongoing to deliver reliable, country-specific climate and environmental information to guide adaptation strategies, policy formulation, and risk management.



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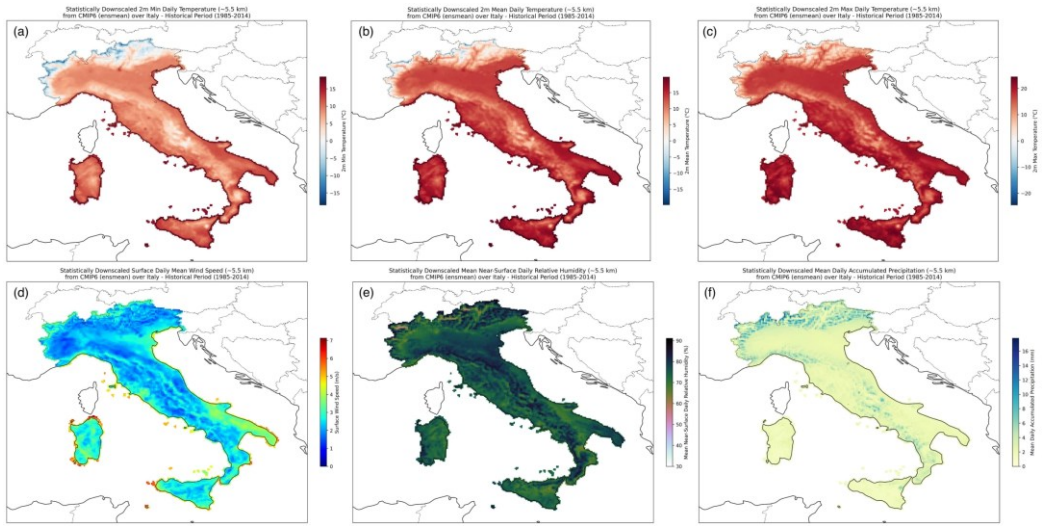
Data layer

- The challenge is to provide a quantitative assessment of heatwaves (HW) evolution over Italy for the present century, by means of several metrics which are widely used within the scientific community.
- Base data layer: the **SD-EQM_GCMS_IT dataset**, developed by CMCC and refined by the ItaliaMeteo Agency as part of the Italian initiative for the C3S NCP
  - statistically downscaled outputs (~5.5 km)
  - from an ensemble of CMIP6 Global Climate Models
  - bias-corrected using the Empirical Quantile Mapping technique
  - The downscaling uses the Copernicus European Regional Reanalysis (CERRA) as reference, ensuring high spatial accuracy
  - Period: 1985 – 2100 (scenarios SSP1-2.6 and SSP3-7.0)
    - Reference: 1985 – 2014
    - Projection: 2015 – 2100
  - datasets are integrated with a high-resolution static orographic layer interpolated using ERA5 orography
  - Variable: daily maximum temperature (T_{MAX})



NCP Copernicus Europe's eyes on Earth European Commission

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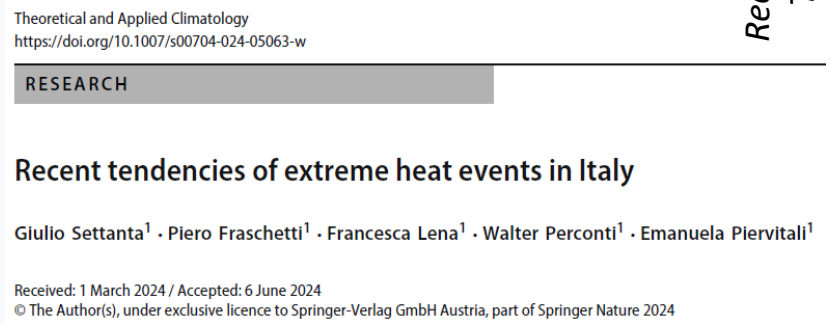
Definitions

- For each year, we consider the extended summer (May – September) only
- Daily temperature above the 90th percentile of the reference distribution, where percentile threshold is calculated for each calendar day using a 15-day running window around it (-7d, +7d)

  → define a **Hot Day (HD)**
- + persistency of at least 3 days

  → define a **Heatwave (HW)**
- We applied such analysis in a work from 2024, using ground stations
  - 1991 – 2020 period
- Next: move from point-like to a spatial analysis


Theoretical and Applied Climatology
https://doi.org/10.1007/s00704-024-05063-w

RESEARCH

Recent tendencies of extreme heat events in Italy

Giulio Settanta[1] · Piero Fraschetti[1] · Francesca Lena[1] · Walter Perconti[1] · Emanuela Piervitali[1]

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Several metrics defined:

*Recommended by the WMO's Expert Team on Sector-Specific Climate Indices **(ET-SCI)***

Heatwave number **HWN** [events]	number of individual heatwaves
Heatwave frequency **HWF** [days]	number of days contributing to heatwaves
Heatwave duration **HWD** [days]	total duration of the longest heatwave
Heatwave magnitude **HWM** [°C]	mean temperature of all heatwaves
Heatwave amplitude **HWA** [°C]	max daily value in the heat wave with the highest HWM
Cumulative heat intensity ΔT_{90P} [°C]	linear sum of °C degrees above 90th percentile

Computing resources

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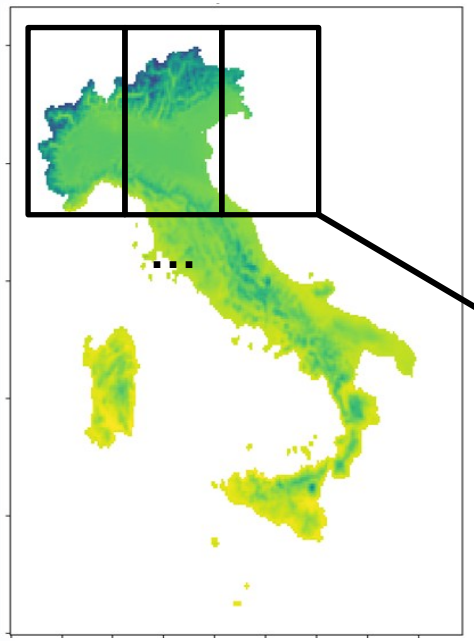
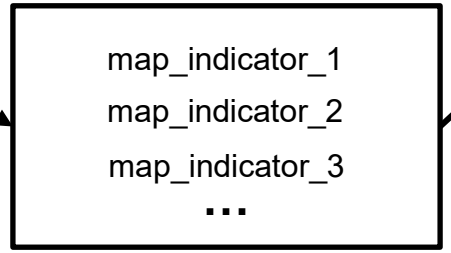
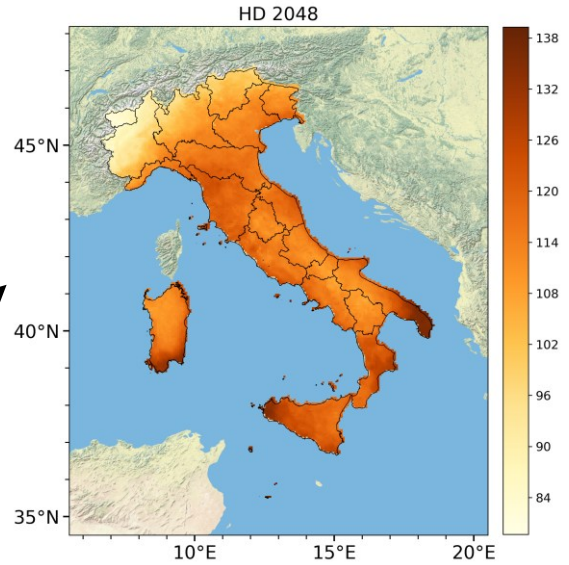
- With respect to the station – based analysis, we have an increase between 1 and 2 orders of magnitude in data volume
  - Local resources would have made the analysis computationally challenging
- In the framework of the Italian initiative for the C3S NCP (as already done in the context of the Italian initiative for the CAMS NCP) adequate resources were granted and allocated on the EWC
  - multiple CPUs, large memory budget
  - tenancy activated at the end of December 2025
- Optimization of the analysis, to fully exploit multiple CPU configuration
  - Each year in chain, to reduce memory use
  - Immediate export on external rasters
  - Initial geographic range divided into subdomains, processed in parallel and eventually re-assembled



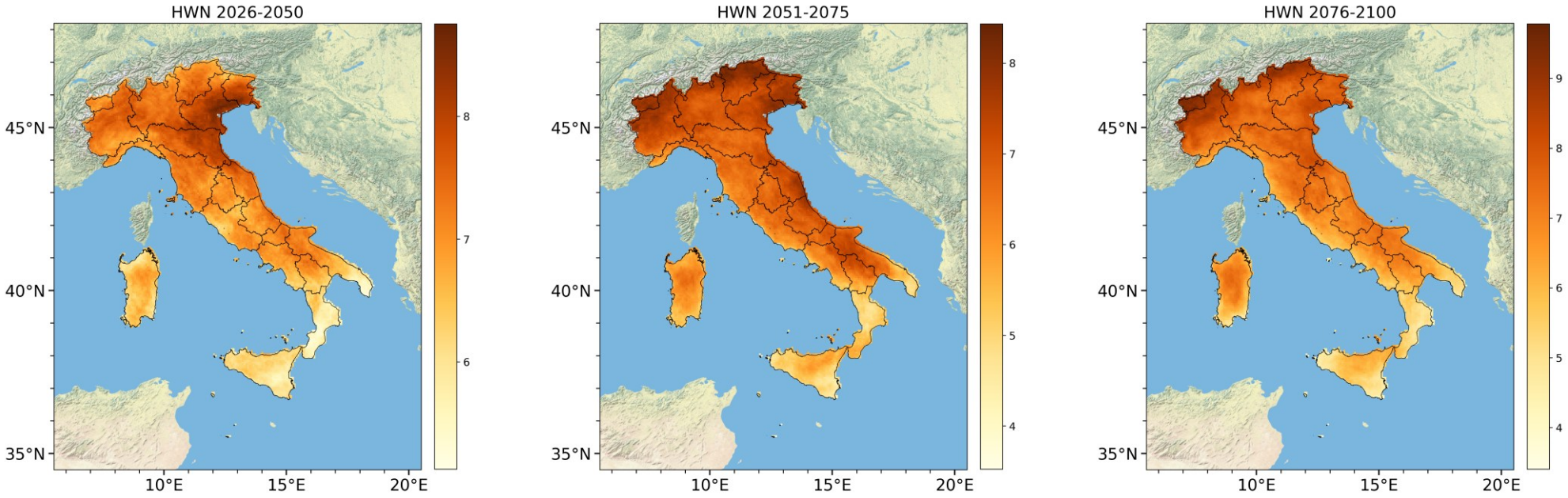




Analysis

- First step: compute the 1985 – 2014 climate normals and reference distributions
- Second step: compute the heatwave indices in terms of absolute values
- Third step: compute the anomalies with respect to the climate normals
- Fourth step: compute 25-years averages, to ensure the statistical robustness of the result:
  - 2026 – 2050, 2051 – 2075, 2076 – 2100

Example: HWN anomaly projections for SSP1-2.6 scenario:



Results – anomalies

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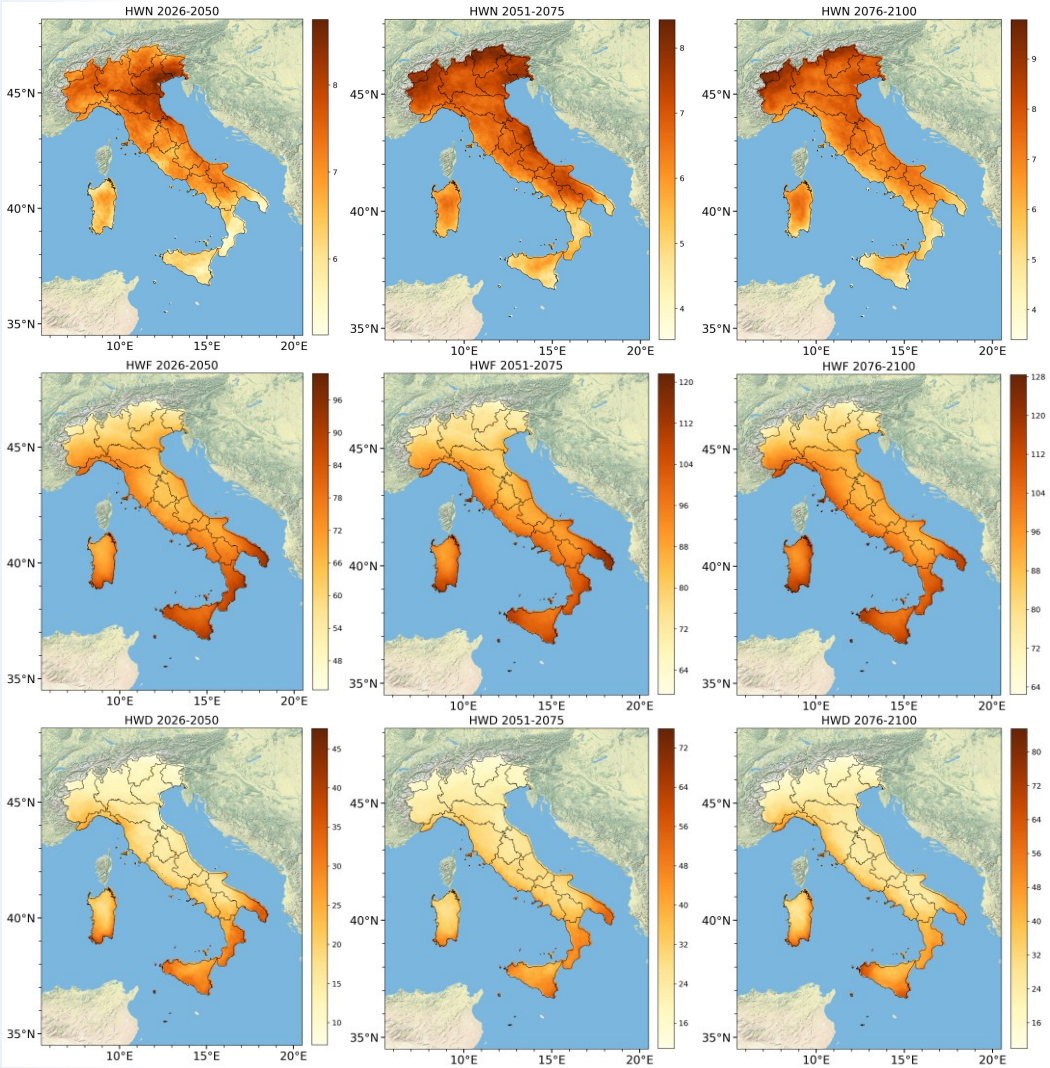
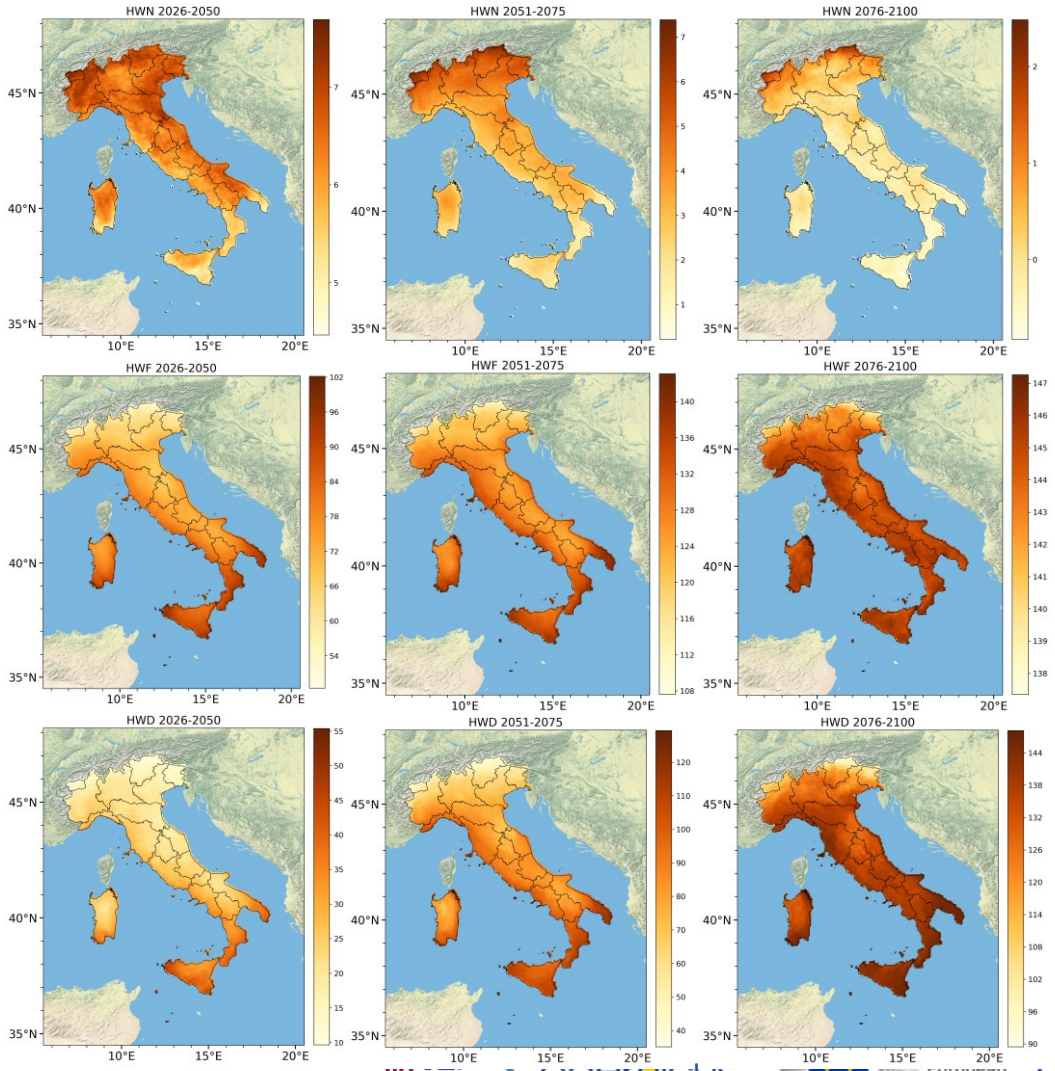
- SSP1 – 2.6: HWN, HWF, HWD



- SSP3 – 7.0: HWN, HWF, HWD



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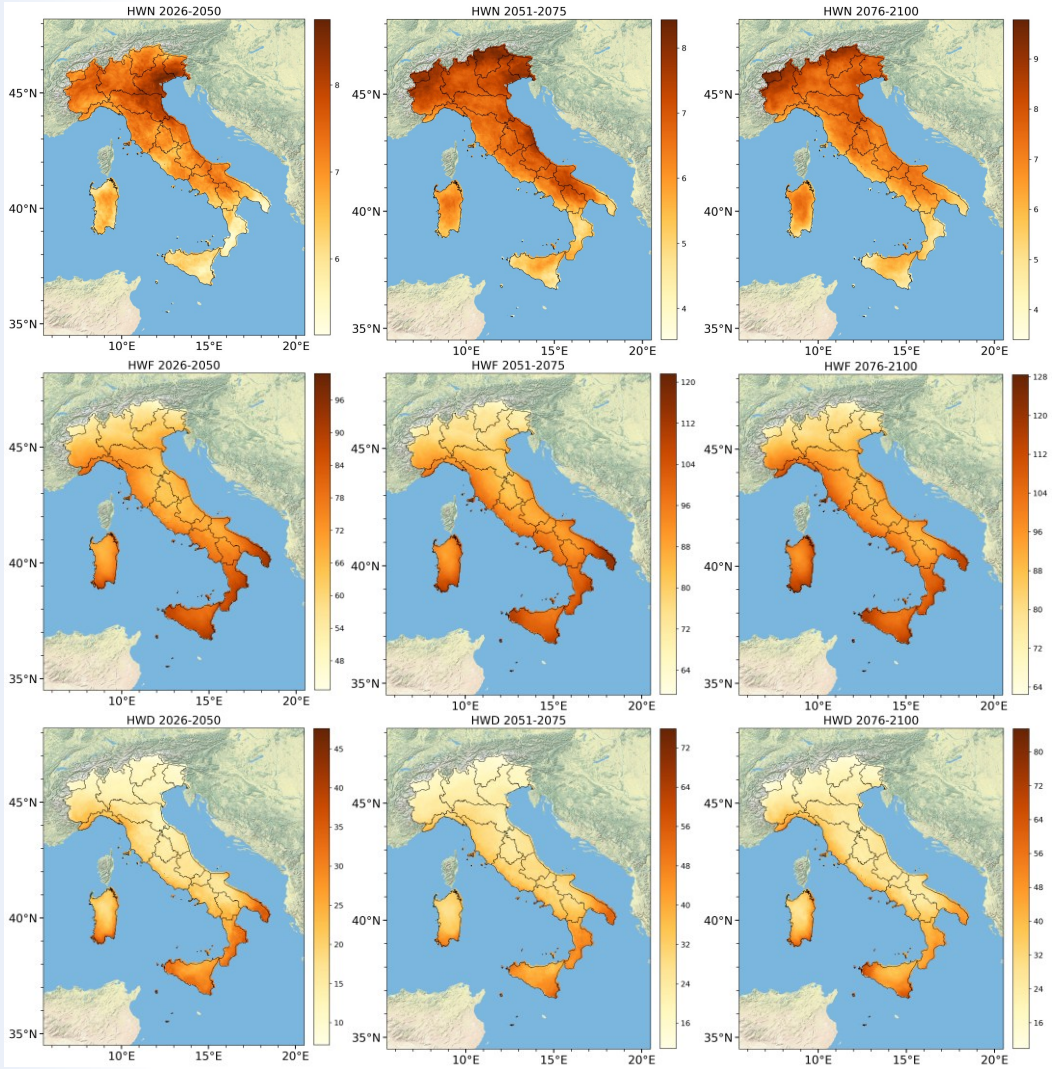

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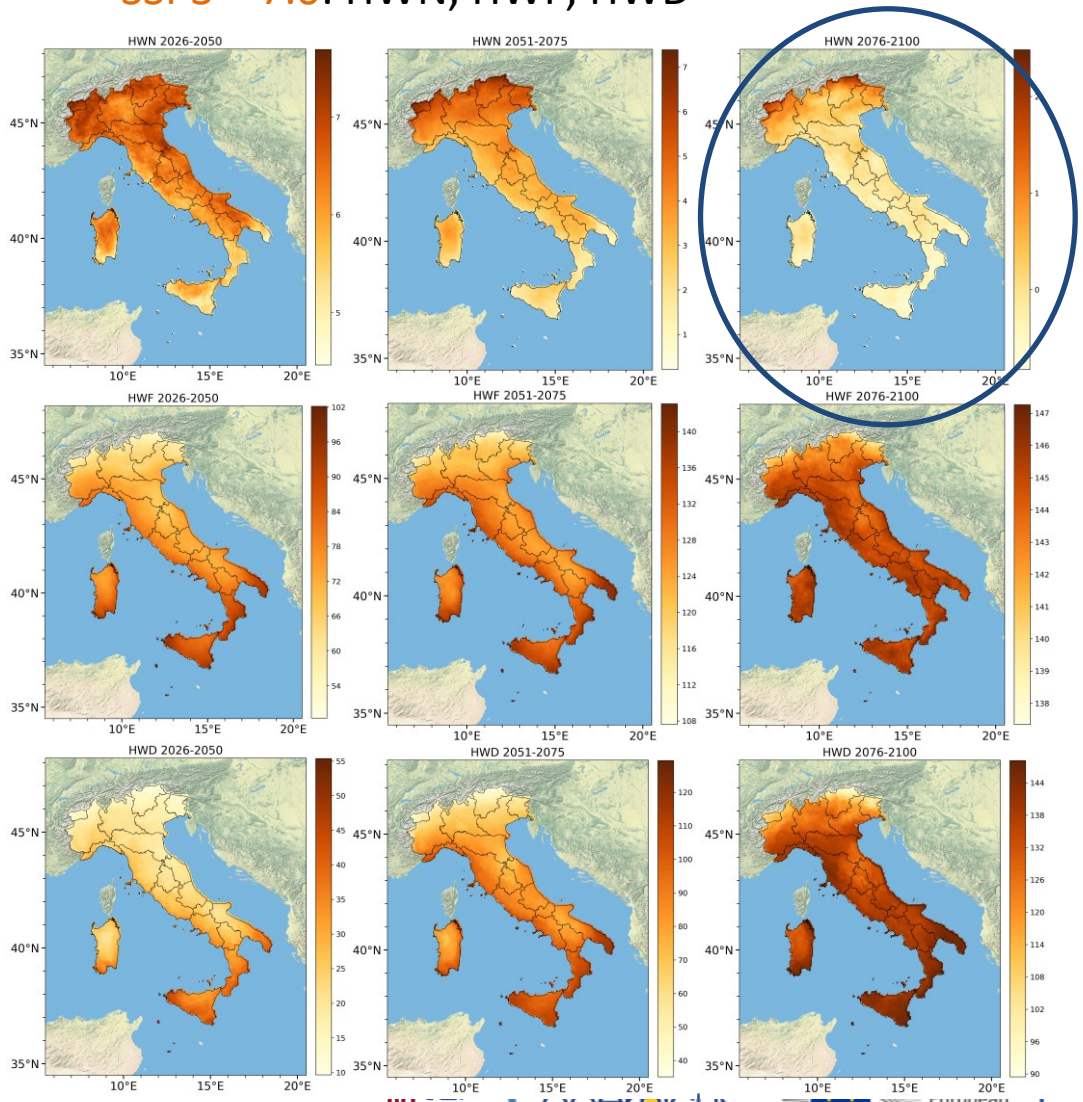

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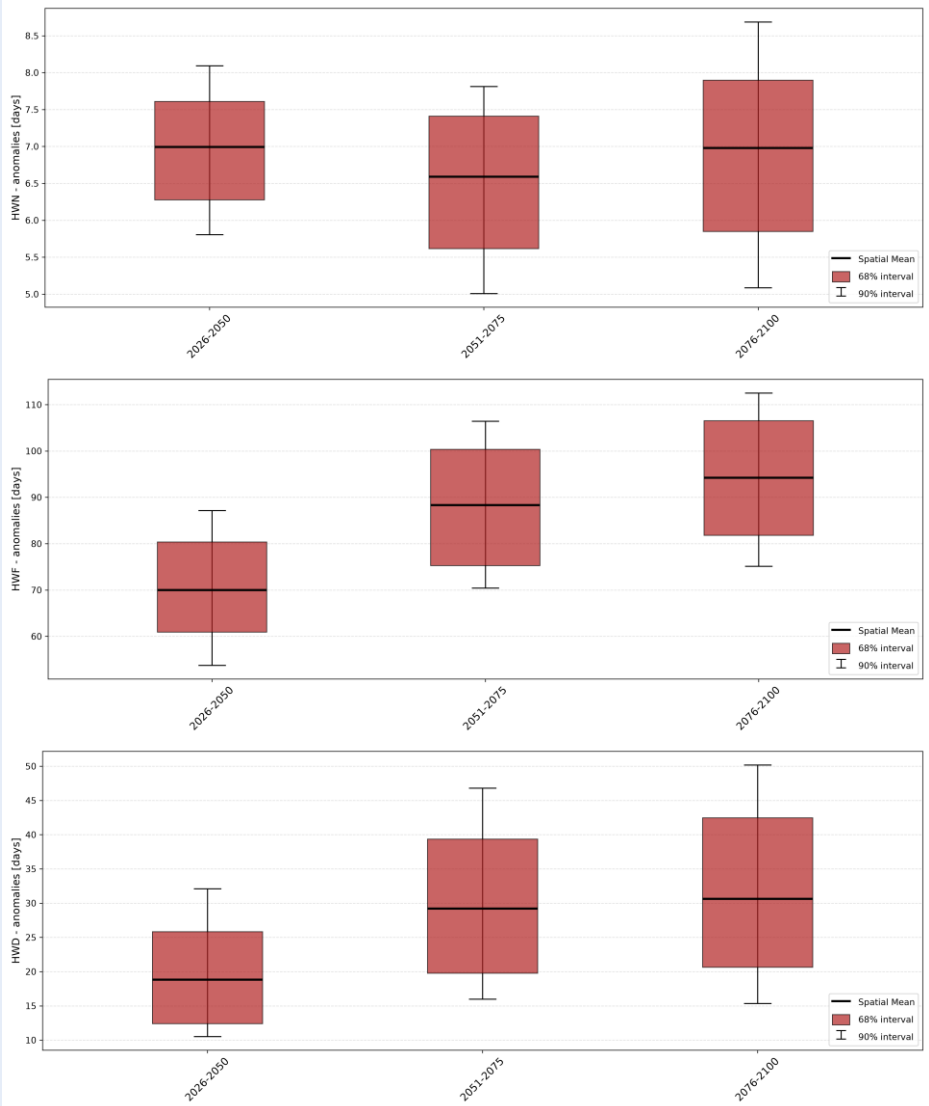

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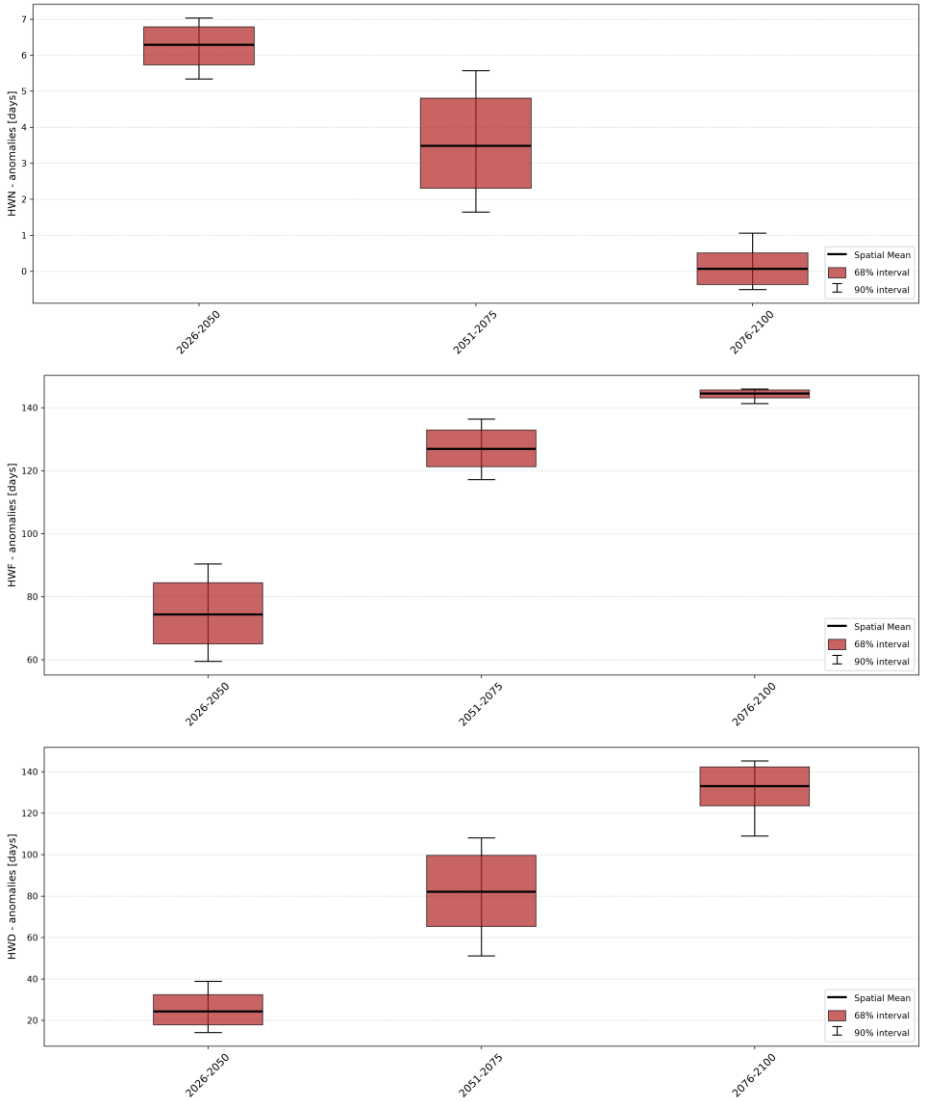

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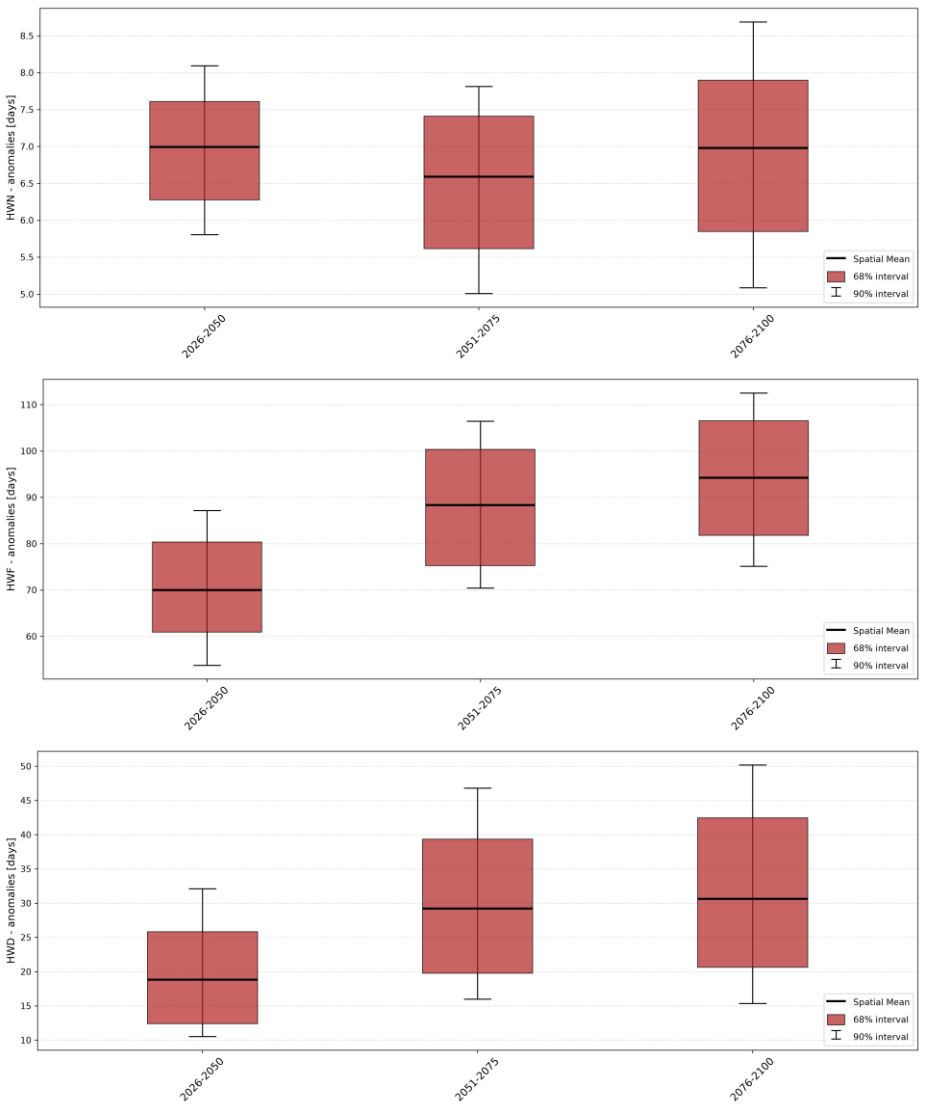

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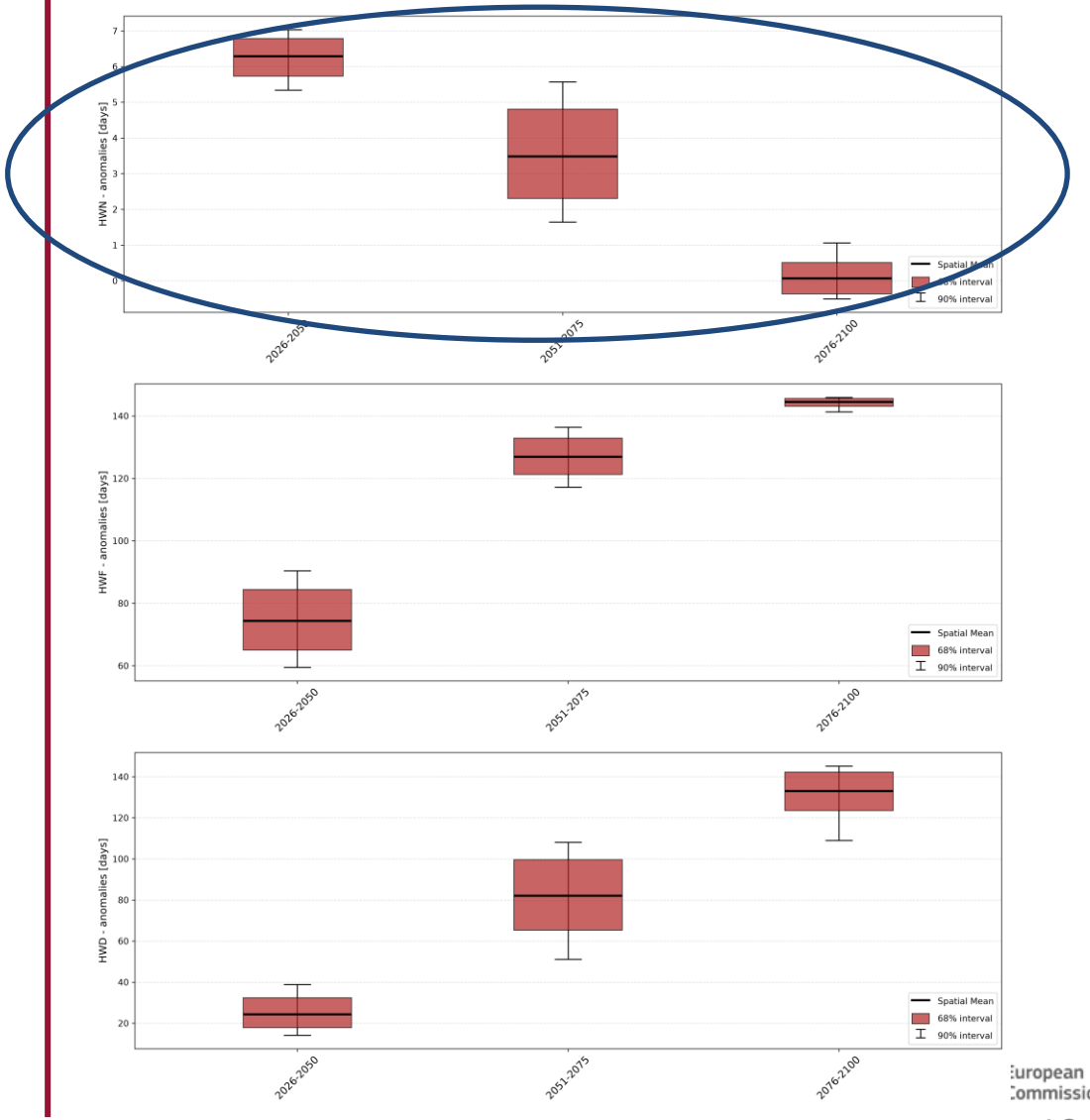
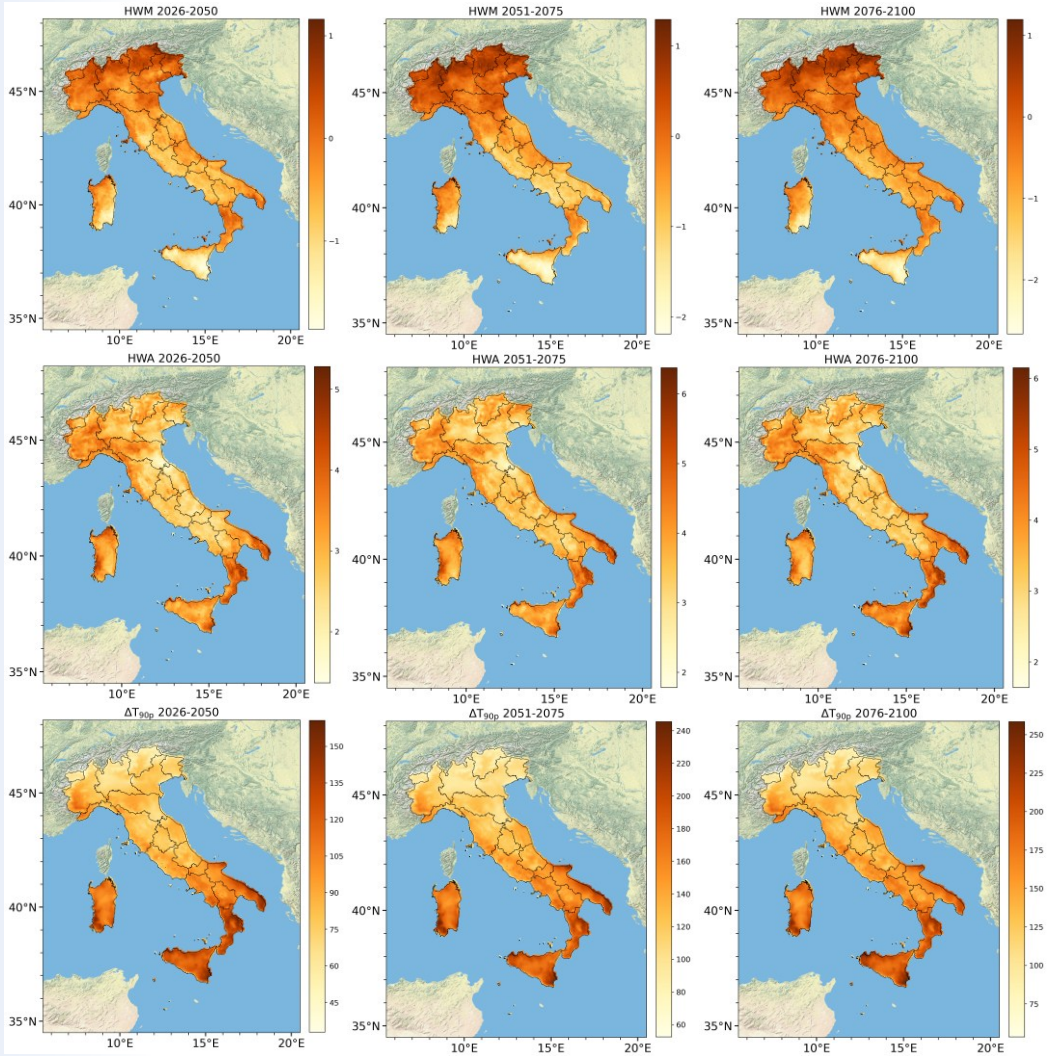


Climate Change

Results – anomalies

- SSP1 – 2.6: HWM, HWA, ΔT_{90P}



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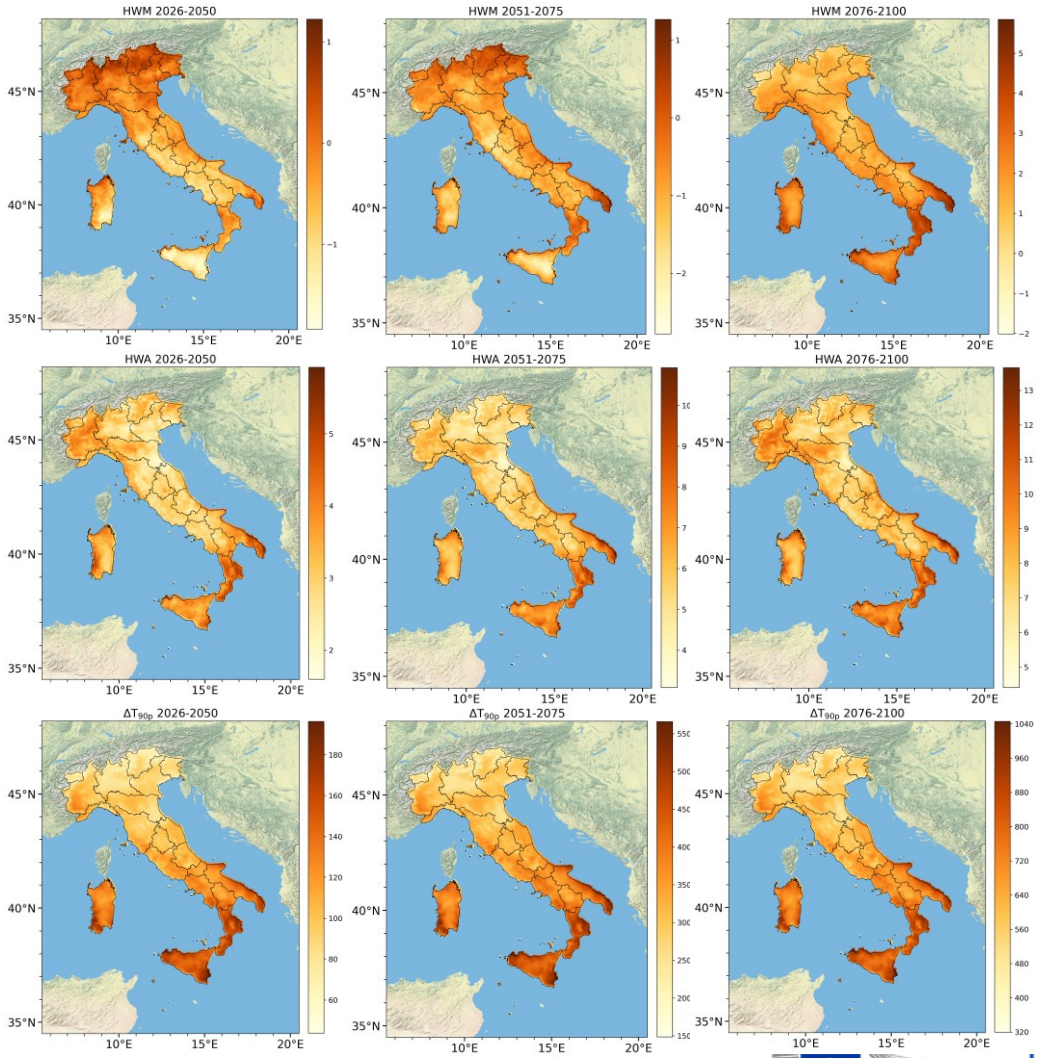

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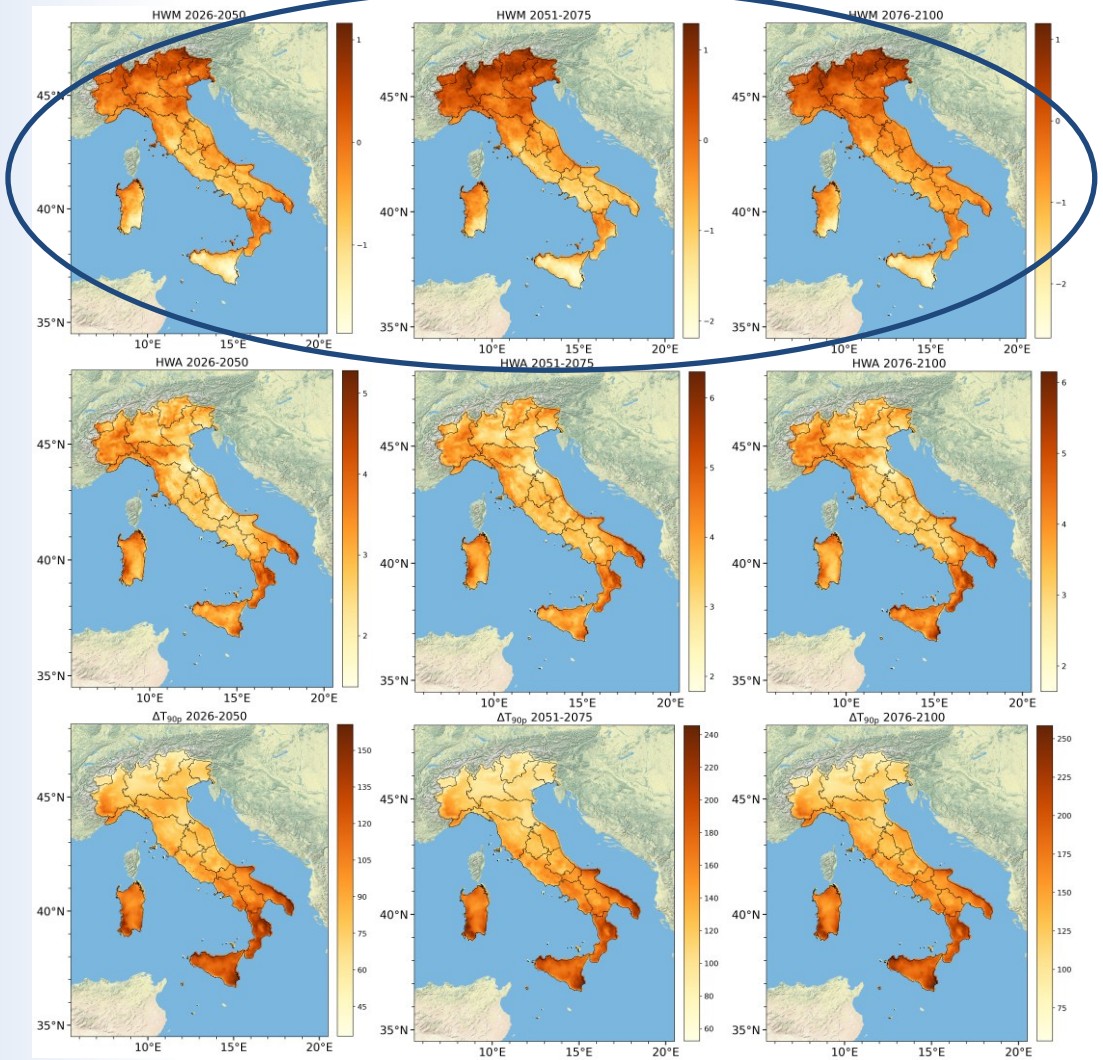

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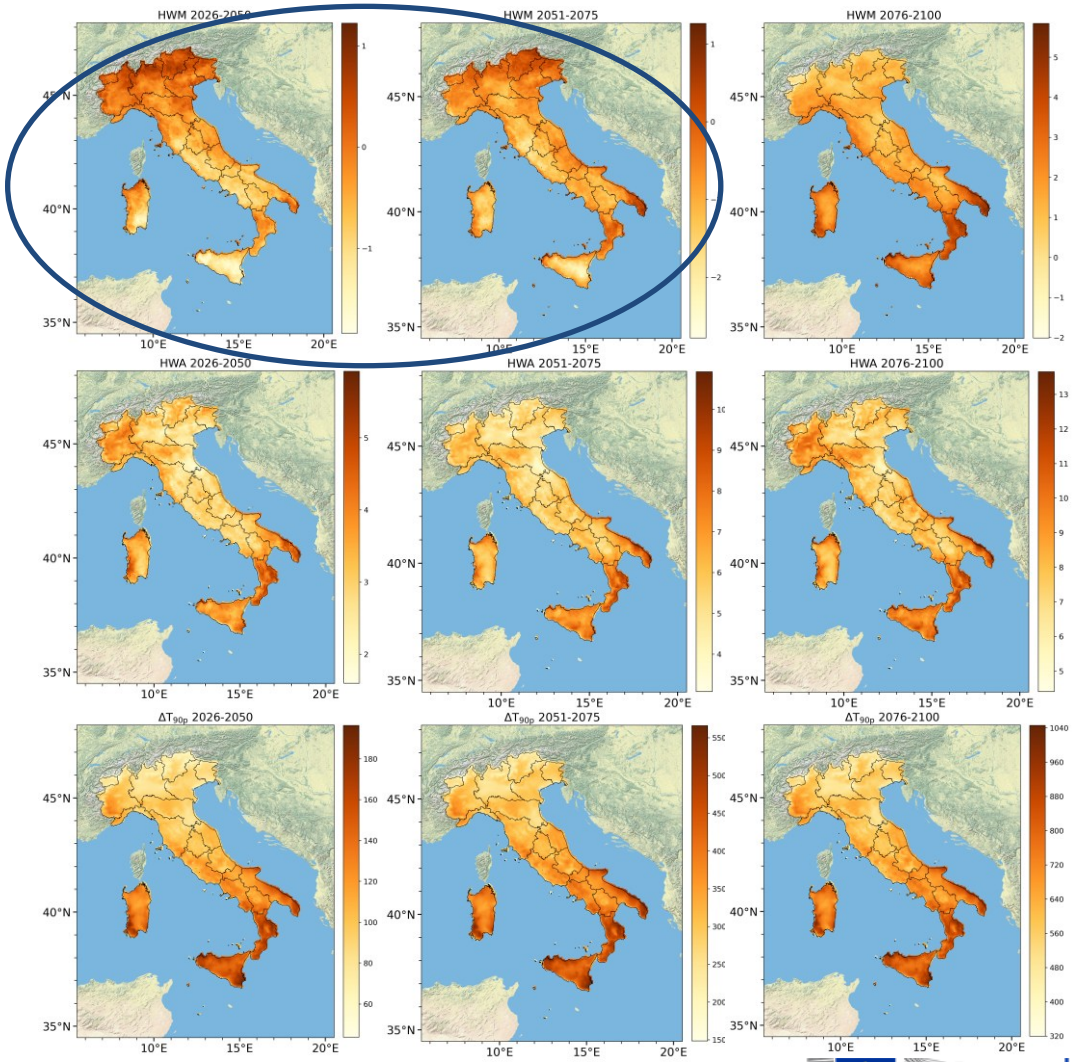

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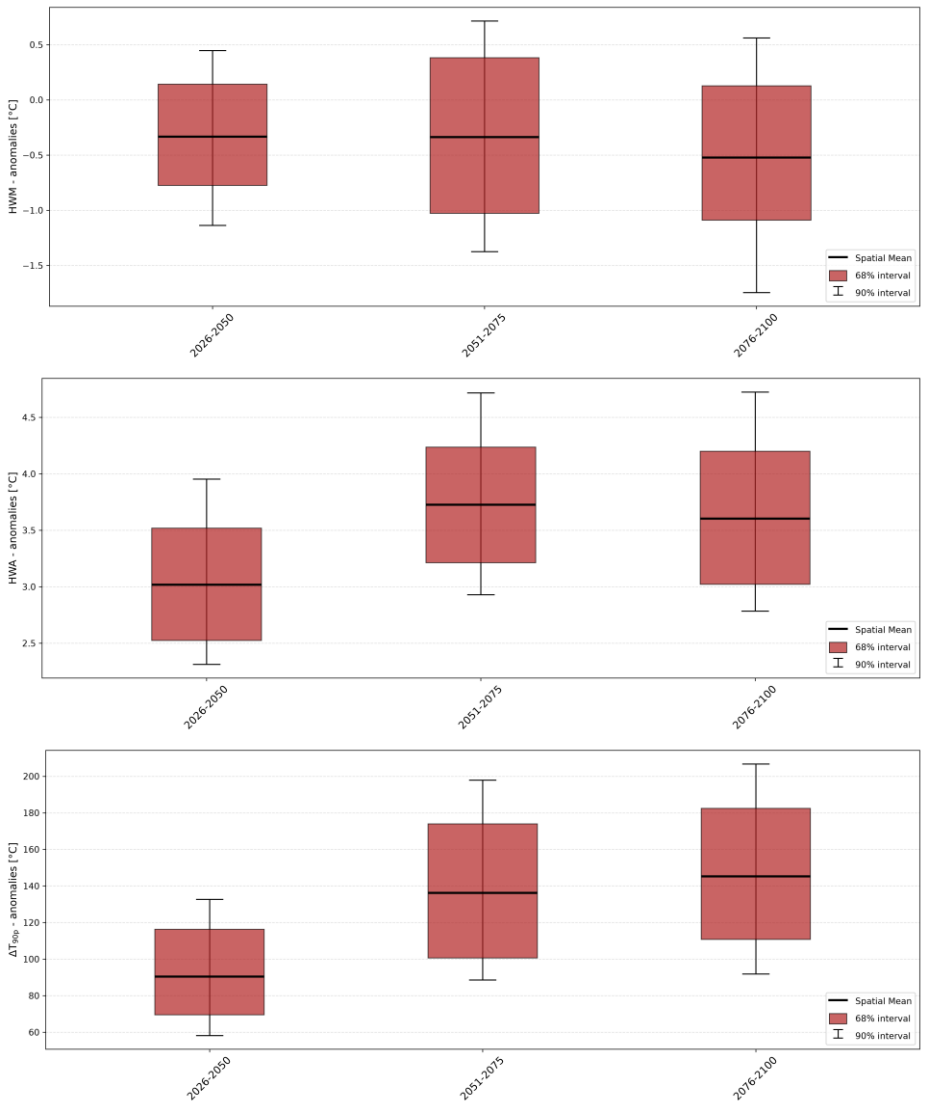

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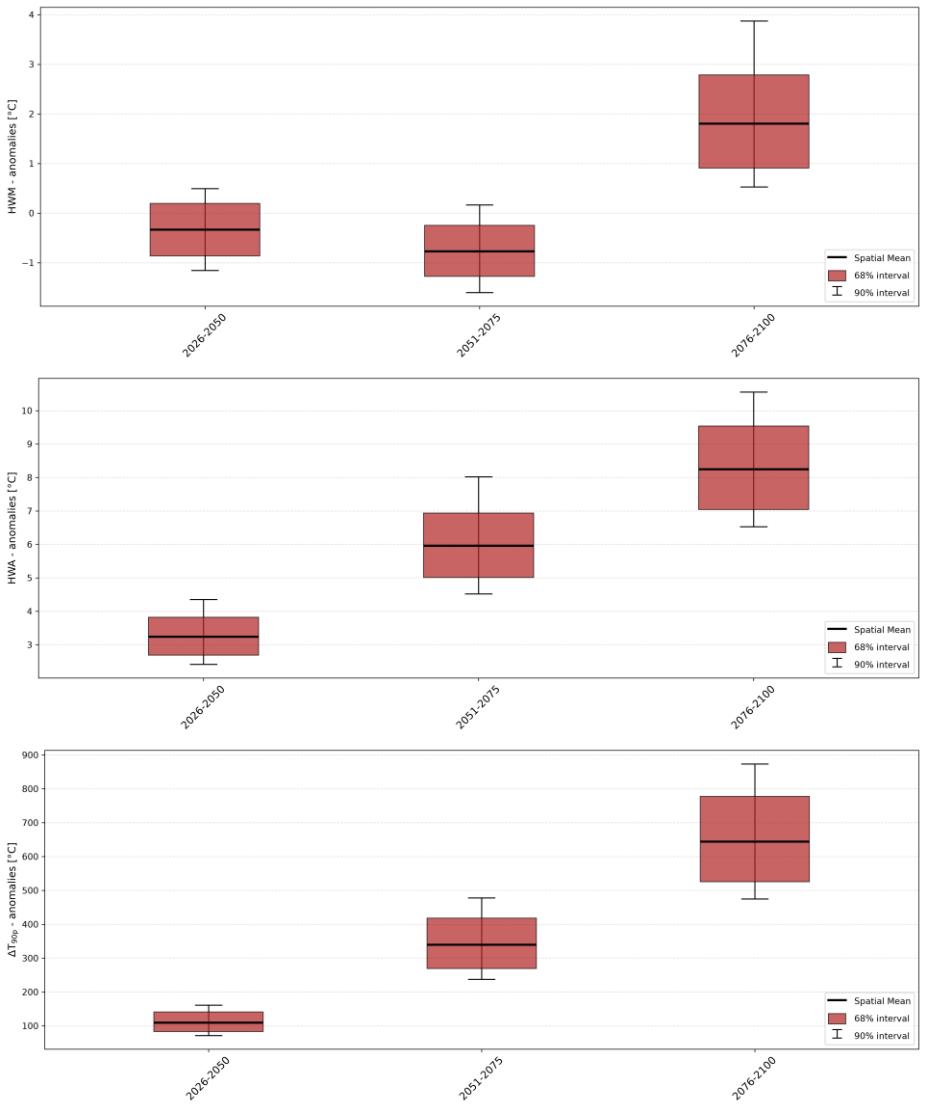

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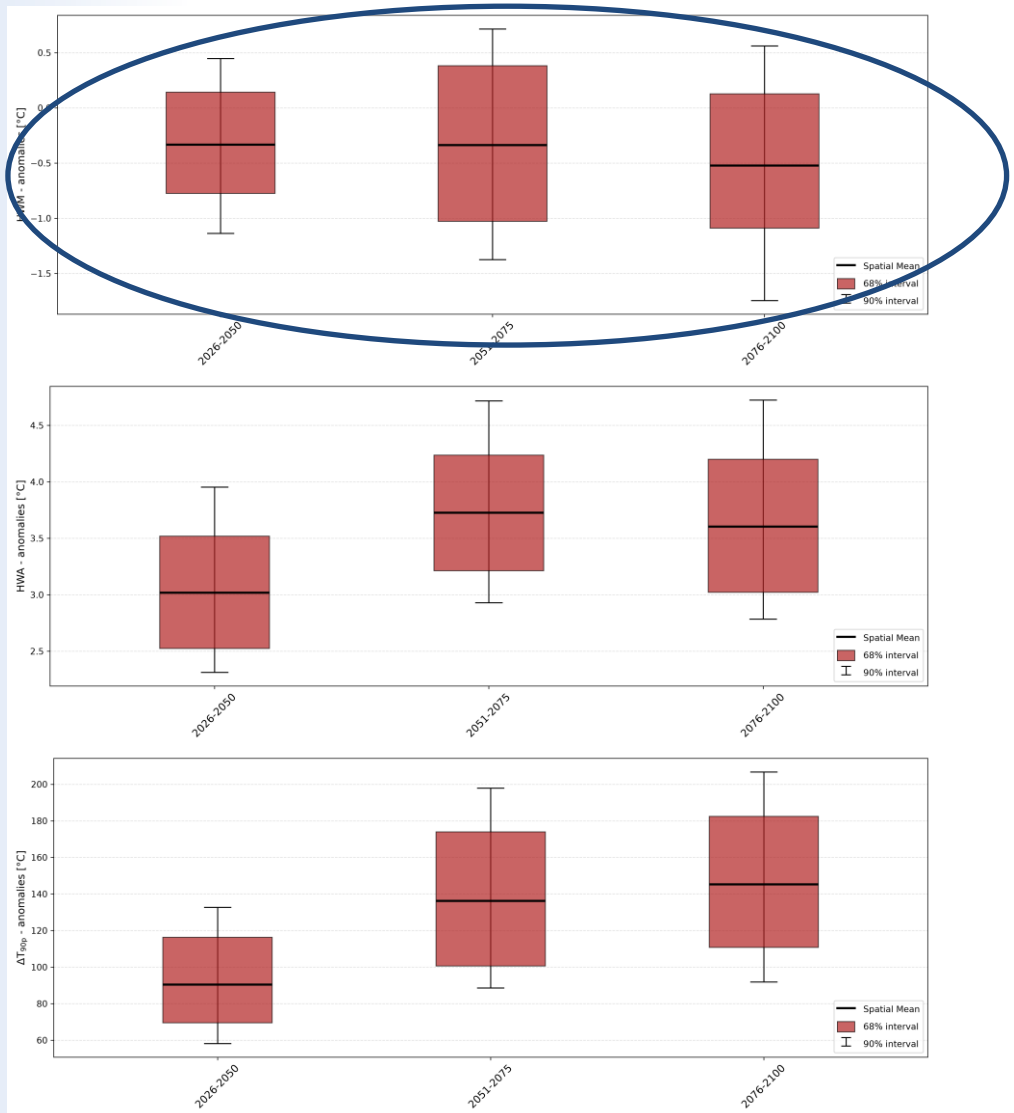
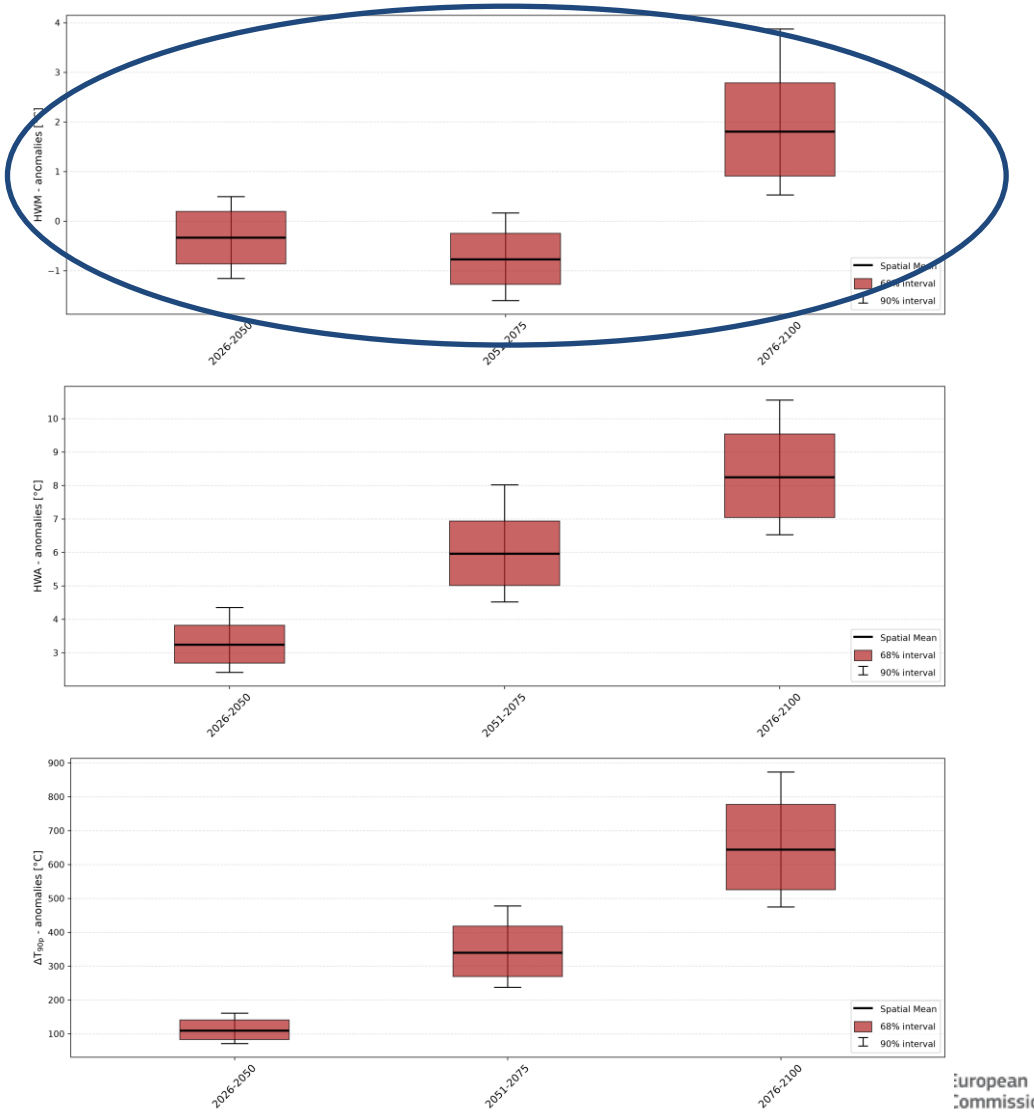


- SSP3 – 7.0: HWM, HWA, ΔT_{90P}



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Results

- Anomalies for HWN and HWM tend to be negative in the SSP3-7.0 case
- Possible interpretation: with respect to the 1985 – 2014 climatology, the SSP3-7.0 scenario will make **the entire summer just one long heatwave**
- Results for HWD and HWF seem to point to the same direction: they almost hit the maximum value of 150 days, which is the total summer length.
- HWM results are less obvious, but can be explained considering that running an average from May to September possibly decreases the overall value.
  - checked by considering only the July month as summer
- All these indices may not be an adequate metric to evaluate the heatwaves evolution throughout this century
- **HWA and ΔT_{90P}**, on the other hand, return a good estimate of how the intensity of the heatwave events will intensify in the future

Results

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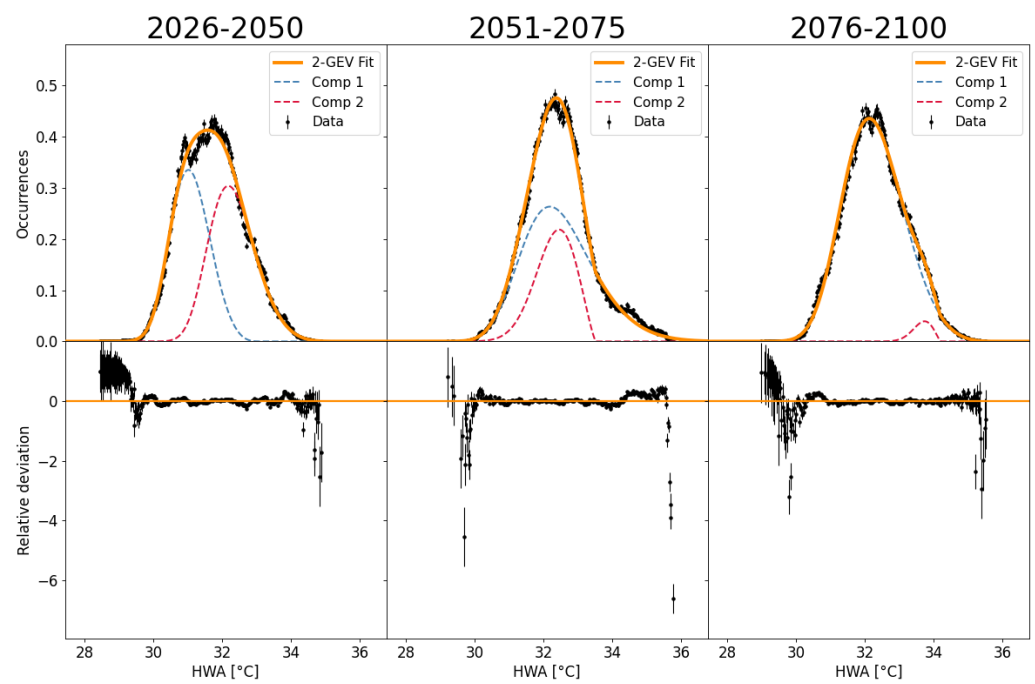
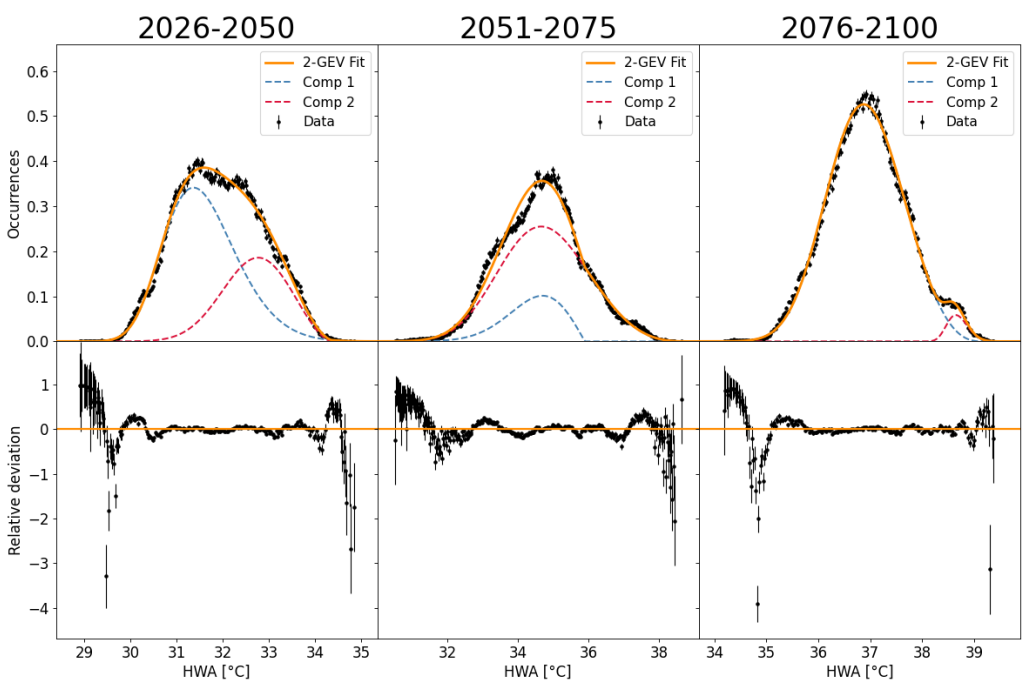
- More in detail: for HWA a preliminary analysis on the distribution shape has been performed
  - more than 1 component seem to be preferred, but more studies are needed
  - the multi-component hypothesis might be linked to a modification in the circulation pattern
  - Fits are still not performing well

SSP1 – 2.6



SSP3 – 7.0



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Conclusions

- The C3S NCP initiative for Italy represents a highly productive framework for collaboration among various groups, in addition to enabling the **use and testing of resources made available by the EWC**
- The present analysis is intended to give a quantitative assessment to the effects of climate change on Italy
- Several metrics have been used, some of which appear to be more representative than others
- Potential users:
  - Policy and decision-makers, competent authorities and institutions in charge of climate adaptation measures
  - Climate science community and climate experts. Local meteorological/environmental agencies. Climate data providers
  - Society and citizens
- The fine spatial resolution of heatwave metrics allows to zoom onto specific areas
  - Areas of interest for the analysis include Italian regions and major cities
- All results will be released on scia.isprambiente.it

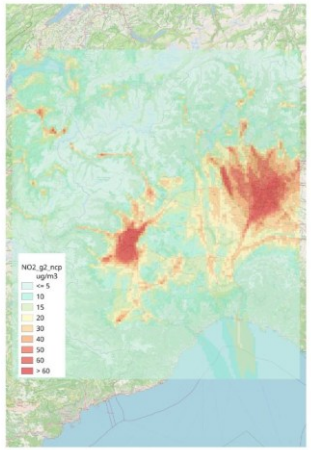
Climate Change

Italian CAMS NCP update

EWC Support to CAMS2_72IT_bis_ISPRA

Objectives

- **Virtual Machine** and **S3-type data storage** to exploit CAMS products for reliable, high-resolution air quality information
- **Daily upload** of model outputs and automated workflow to enhance Italy's national air quality product portfolio, for national and local users



Current state

- Providing high-resolution national model forecasts to regional agencies
- Promoting Quality Assurance concepts and CAMS modelling outputs through LinkedIn

Consolidated Activities

- Hackathon - Second ed. in Bologna (May 2026): multidisciplinary and multinational teams developed innovative solutions addressing challenges in Cultural Heritage, Health, Air Quality and Climate Change

Current activities

- Targeted training with local authorities (with WP7)
- Automated data flows for dissemination
- Use cases

Next steps

- Compare models and ensemble against dust concentration measurements
- Produce national/local downscaled fields using statistical methods

Thank you for your attention!

giulio.settanta@isprambiente.it

Extra material

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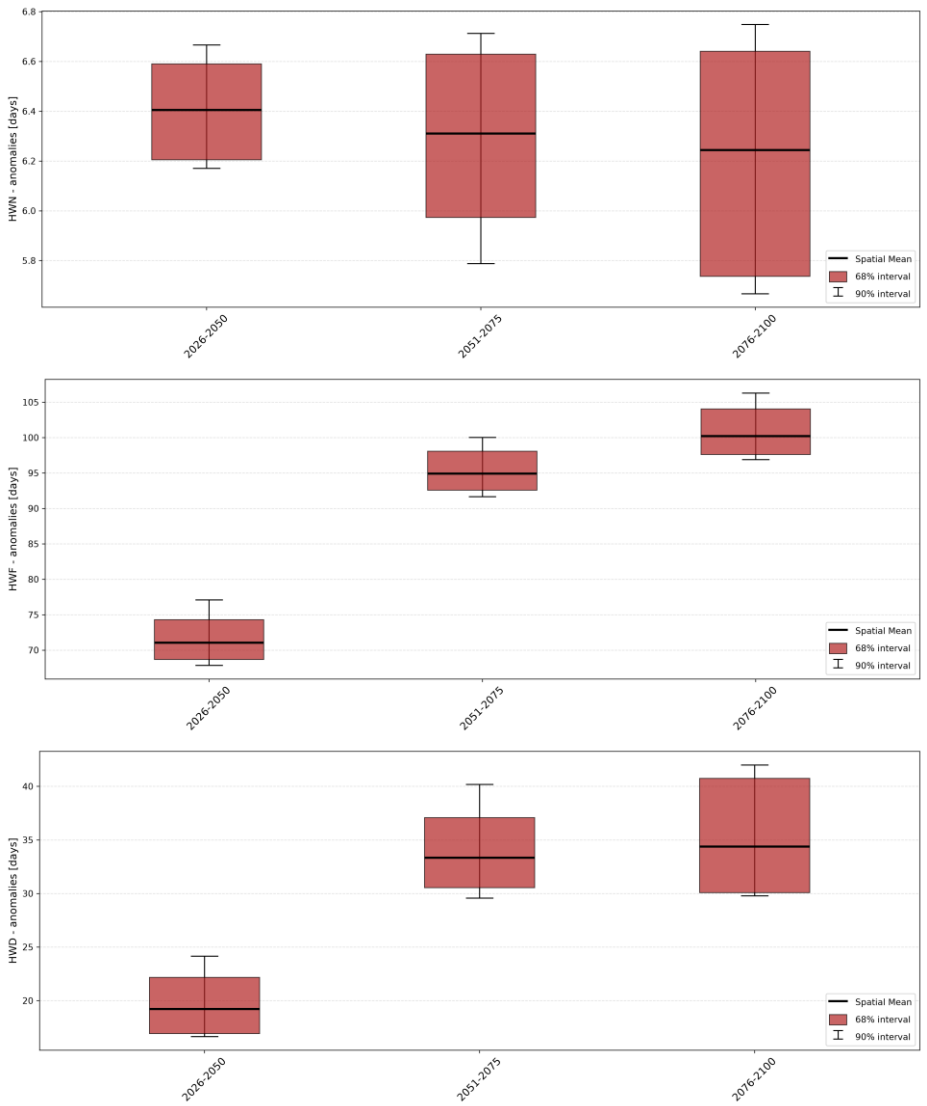
Anomalies for the municipality of Rome

- SSP1 – 2.6: HWN, HWF, HWD



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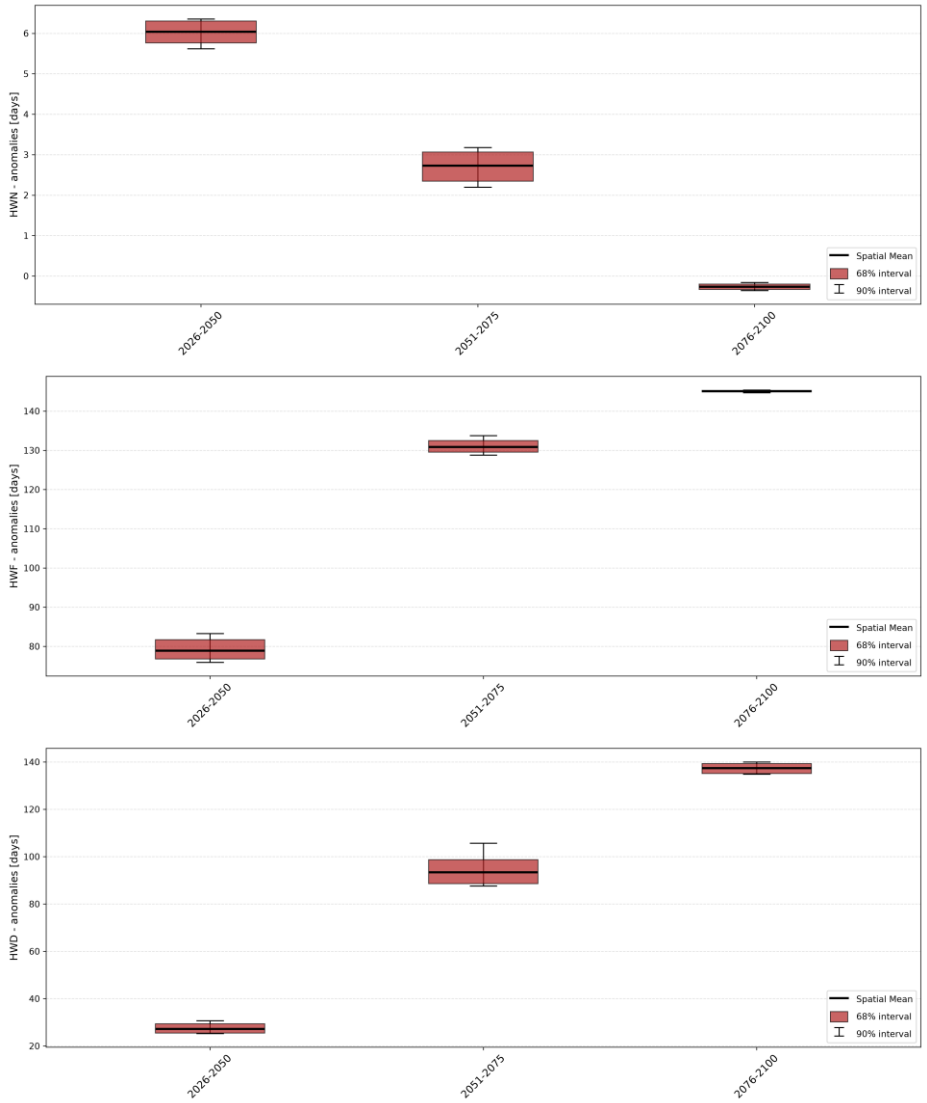

Anomalies for the municipality of Rome

Climate Change

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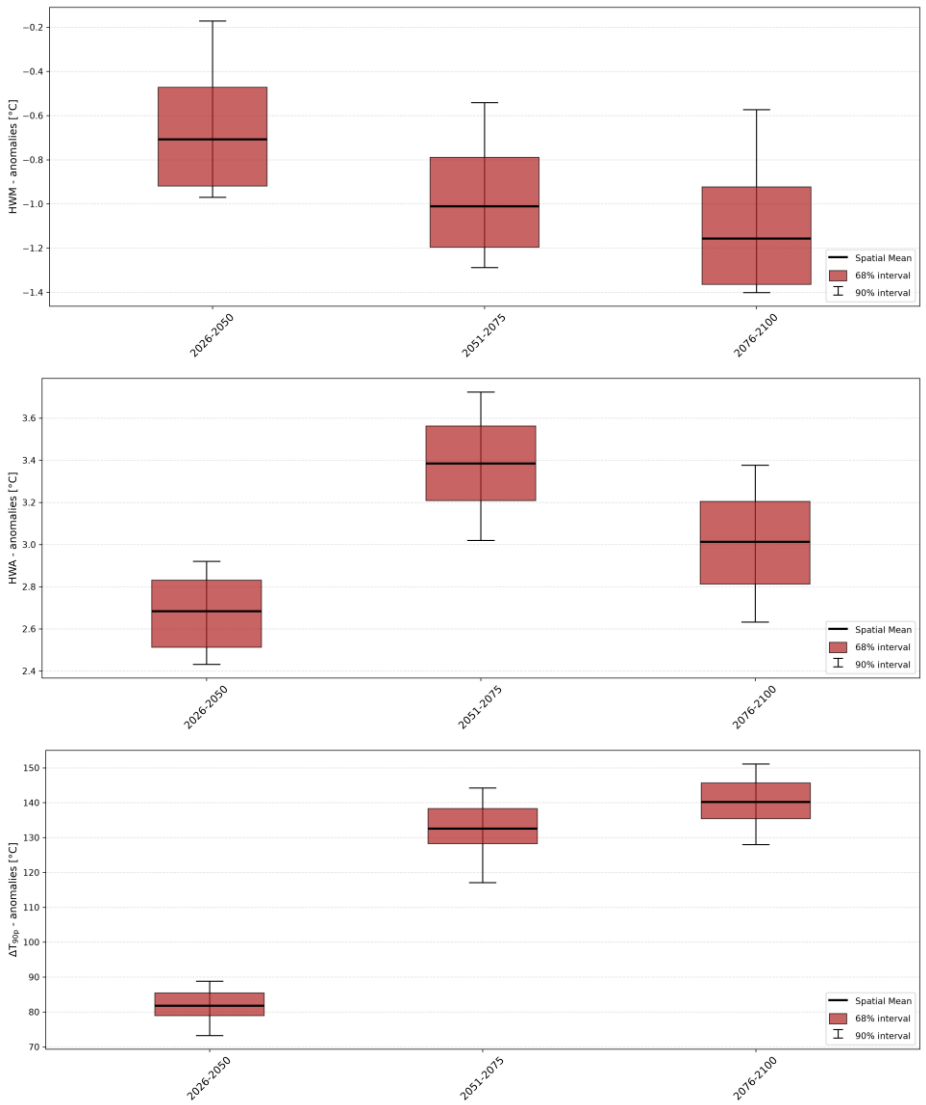

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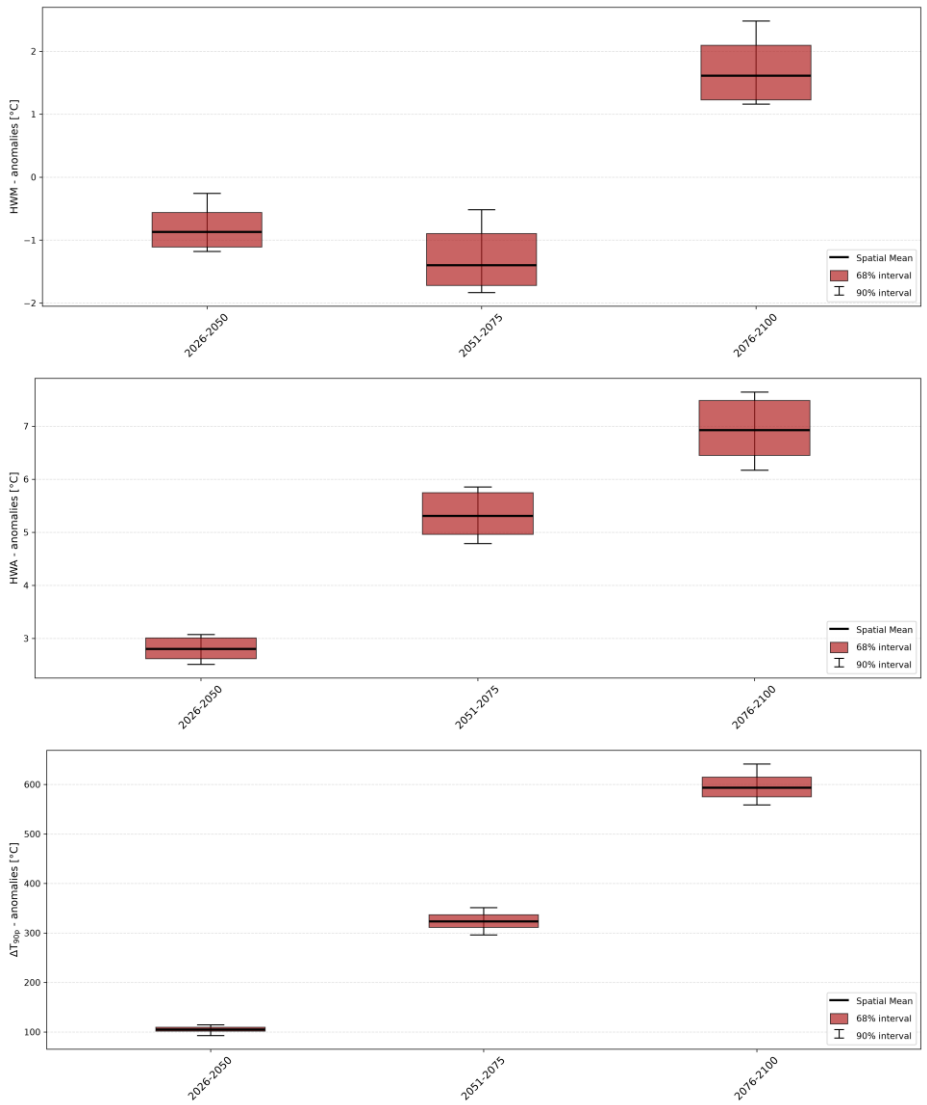
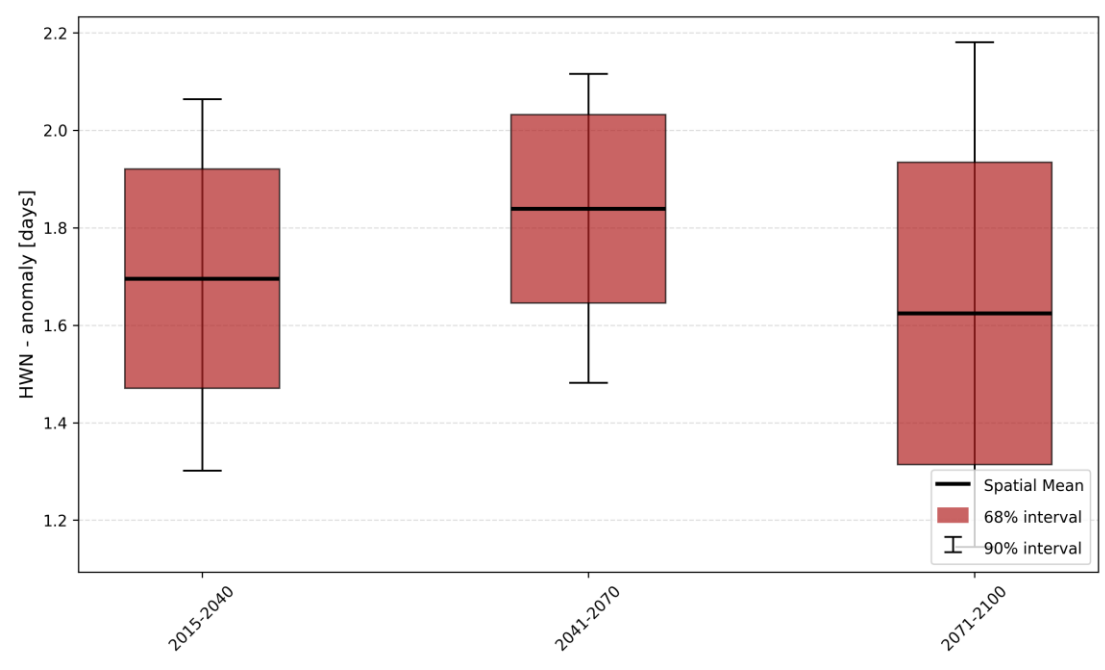
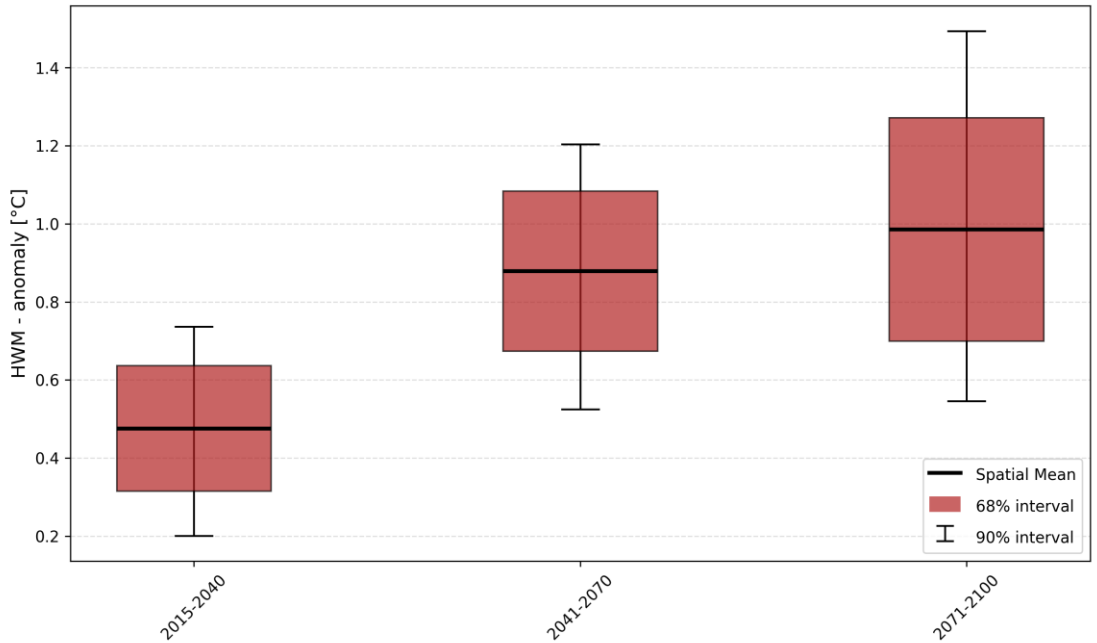


Anomalies for July

Climate Change

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