



DEVELOPMENT AND APPLICATION OF THE WARM SPELL MAGNITUDE INDEX DAILY (WSMID) IN HISTORICAL EUROPEAN HEATWAVES

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Introduction

- Global warming is accelerating, leading to longer, more intense, and more frequent extreme heat events.
- In Europe, the warm season is expanding with record-breaking temperatures now occurring throughout the year.
- Traditional heatwave metrics focus on summer extremes, missing the growing risk of off-season warm spells.
- To address this, we introduce the **Warm Spell** Magnitude Index daily (WSMId):
 - A year-round index that captures the magnitude of prolonged anomalous warmth.
 - Extends the existing **Heat Wave Magnitude Index daily (HWMId)** by Russo et al. (2015).

Methodology

Data Requirements

- \circ Daily maximum temperature at 2 meters (T_{χ}) (station or a grid point).
- A Reference Period of 30 Years (e.g., 1981-2010).

Building the WSMId: Step-by-Step Process

Step 1: Calculation of the 90th Percentile Threshold

By centering every calendar day, with a 31-day window, for every year inside the 30-year reference period, the 90th percentile is calculated. (e.g., day 167 below)



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Step 2: Defining "Warm Spell days"

Warm spell days are considered those for which T_{χ} is larger than the 90th percentile threshold for 3 or more consecutive days.

Step 3: Calculation of the 25th and 75th Temperature Percentiles (T_{30y25p}, T_{30y75p}), using Warm Spell Anomalies

For every warm spell day in the reference period, the anomaly from the 90th percentile is computed. Then, out of these warm spell day anomalies the 25th and 75th percentile are calculated (a_{25p}, a_{75p}) :



Step 4: Calculation of WSMId for Warm Spell Days

Every warm spell day with temperature T_d , goes through the WSMId normalization function:

if $T_d < T_{30y25p}$: if $T_d \ge T_{30\nu 25p}$:

 $M_d(T_d) = 0$ $T_d - T_{30y25p}$ $\Gamma_{30y75p} - T_{30y25p}$

Daily index values of a warm spell event can be summed up resulting in the total warm spell magnitude of that event.









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Results

WSMId vs. HWMId

○ T_{30y25p}, T_{30y75p} overlap during mid summer, yielding the same index values as HWMId for events like the 12-day heatwave in Carcassonne, France in 2003.

Outside summer, HWMId=0, but WSMId capture anomaly magnitude appropriately.





WSMId evidently shows that last decade's warm spells are more frequent and intense, with longer duration.





OptimESM

Optimal high resolution Earth System Models exploring future climate change

This research is supported by the European Union's Horizon Europe research and innovation programme under grant agreement No 101081193.

- Total magnitude of the maximum cumulative WSMId event for all days in the selected periods.
- WSMId captures mega heatwaves like the ones in western Europe (2003) and Russia (2010).

Conclusions

- The Warm Spell Magnitude Index daily (WSMId) provides a seasonally adapted extension of HWMId.
- It enables the **detection and quantification** of **year-round warm spells**, not just summer
 - Performs consistently with HWMId during midsummer, while crucially captures offseason extremes that are increasingly relevant under climate change
- Offers a valuable tool for **climate monitoring**, impact assessment, and adaptation

