# URBAN AREAS FACING EXTREME TEMPERATURES: WHAT ARE THE CNRM-AROME PROJECTIONS?

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## 01 | Motivation

Urban areas are **complex systems** due to their specific characteristics (complex 3-D shape, artificial material properties…). The **dynamical and physical processes** in urban areas compared to that of the surrounding rural areas initiate the well-known **Urban Heat Island** (UHI) phenomenon, especially during night.
The **urban climate** is expected to evolve with climate change, with significant **economic, environmental and human impacts on city and population**. Such studies motivate the use of high-resolution regional climate models with online urban canopy model to explicit coupling the effects and derived impacts.

**Objectives. Evaluate the urban climate evolution with climate change and quantify the impacts of future heatwaves on urban areas and population in French cities by using:**

- **CNRM-AROME**, a Convection-permitting Regional Climate Model (CP-RCM) at 2.5-km of horizontal resolution ;
- **Town Energy Balance** (TEB, Masson, 2000), a dedicated surface model that represent explicitly the urban area

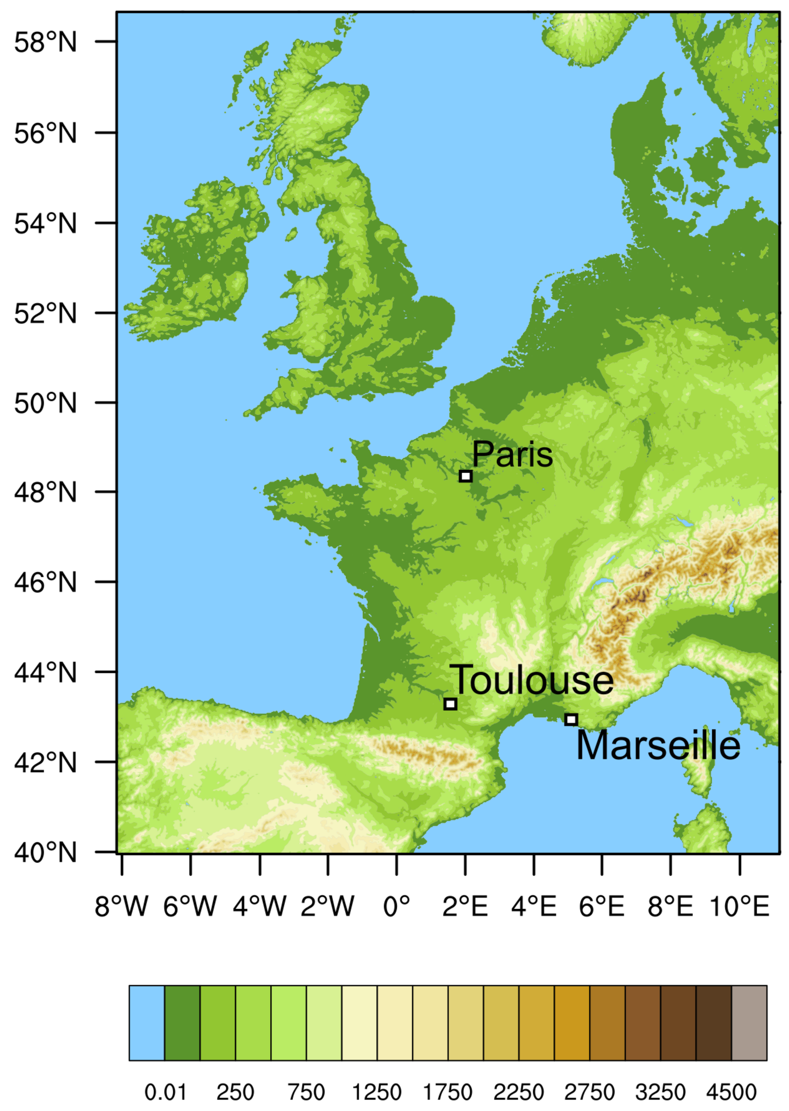


_Fig. 1_: *Topography (in m) on the domain simulation.*

## 02 | Simulations

Climate simulations were performed over the **northwestern Europe** during an **historical** period (1986-2005) and two **future** periods (midterm, 2041-2050 and longterm, 2080-2099) using the **RCP8.5 emission scenario**.

## 03 | Methodology

### Application on Paris, FRANCE

A **geographical region** centred over the city center and covering a square area with sides of 100-km is selected.

- The **nighttime UHI** is calculated according to: **UHIN = ΔTN =** $T_{Urb} - T_{Rur}$**.**

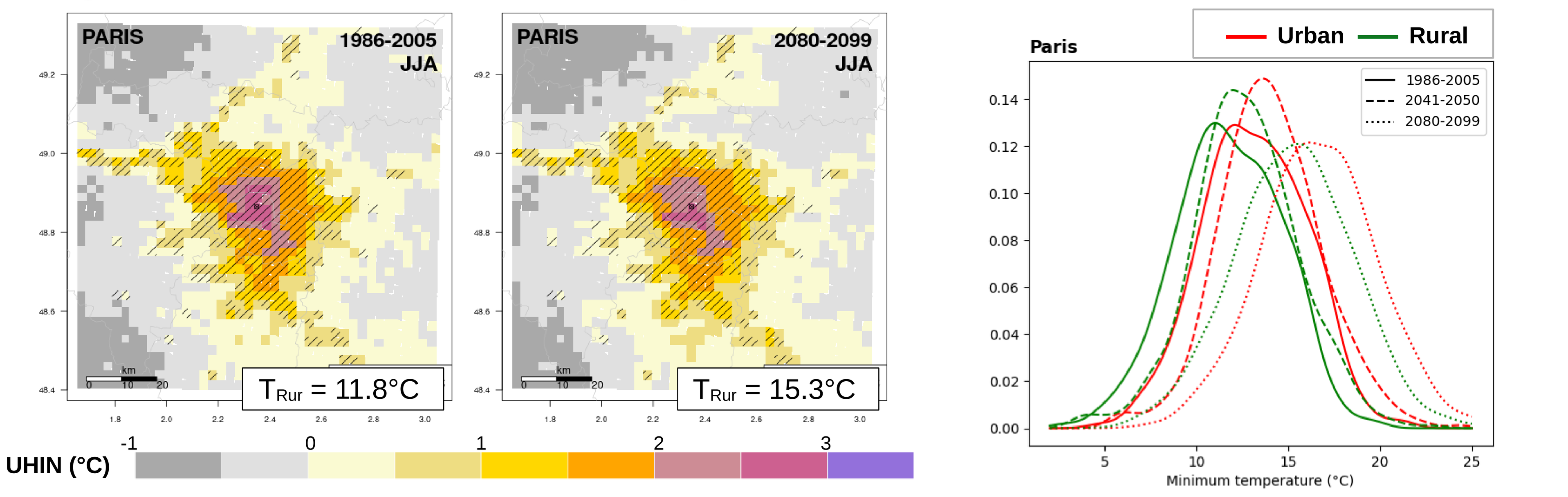


_Fig. 2_: *Left – Simulated nighttime UHI (in °C) in Paris for 1986-2005 (left) and 2080-2099 (right).* $T_{Rur}$ *is defined as the spatial average of the TN time series over the rural grid points, i.e. for which the fraction of natural cover of the cell is greater than 50% according to the ECOCLIMAP database.* $T_{urb}$ *defined the TN time series over the urban grid points. Right – Rural and urban minimum temperatures distributions during the historical, the midterm and the longterm period.*

During the historical period, CNRM-AROME simulates maximum UHINs over Paris urban area varying between **+2 and +2.5°C**. With climate change, the simulated UHIN intensity remains **comparable** to that of the period 1986-2006 even though background temperatures increase by 3.5°C (Fig.1, left). It suggests that the urban effects on average are not enhanced by the regional warming, which is confirmed by the distributions of minimum temperature over rural and urban areas (Fig.1, right).

- Heatwave (HW) detection is performed following the method developed by **Ouzeau et al., (2016)**. It is based on the **99.5 percentile threshold** on **daily mean temperatures** for peak detection and **two additional percentile thresholds** to define adjacent days. Each HW is defined by three indexes: **maximum intensity** (in °C), **duration** (in days) and **severity** (see details in 4 | Results).

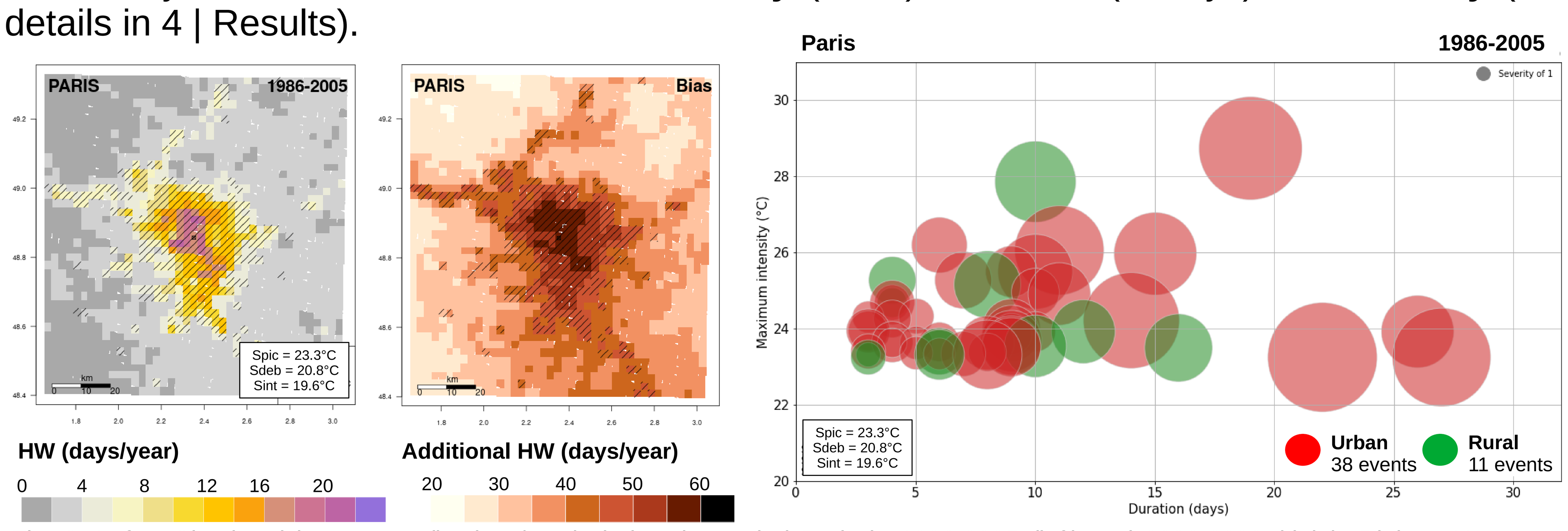


_Fig. 3_: *Left – Simulated heatwaves (in days/year) during the period Paris in 1986-2005 (left) and 2080-2099 (right). Right – Heatwaves detected during 1886-2005 period. Bubble gives the duration (x axis), maximum temperature (y axis) and the severity (bubble size).*

During the historical period, HW are **longer**, more **frequent**, and more **severe** over urban than over rural areas, in agreement with the **UHIN spatial pattern** (Fig.3). Between 2080 and 2099, CNRM-AROME simulates **71 events** characterized by between 36 and 85 HW days/year over **urban** areas versus **67 events** with less than 44 HW days/year over **rural** areas (Fig.3). It suggests that, under climate change, HW are as numerous as during the historical period, but much longer over cities than in rural area, in response to an increase of local temperature.

## 04 | Results

### Multi-city analysis

Analysis of HWs are extended to large and medium-sized French cities with **contrasted climatic and geographical context** (Fig.1, here Paris, Marseille and Toulouse).

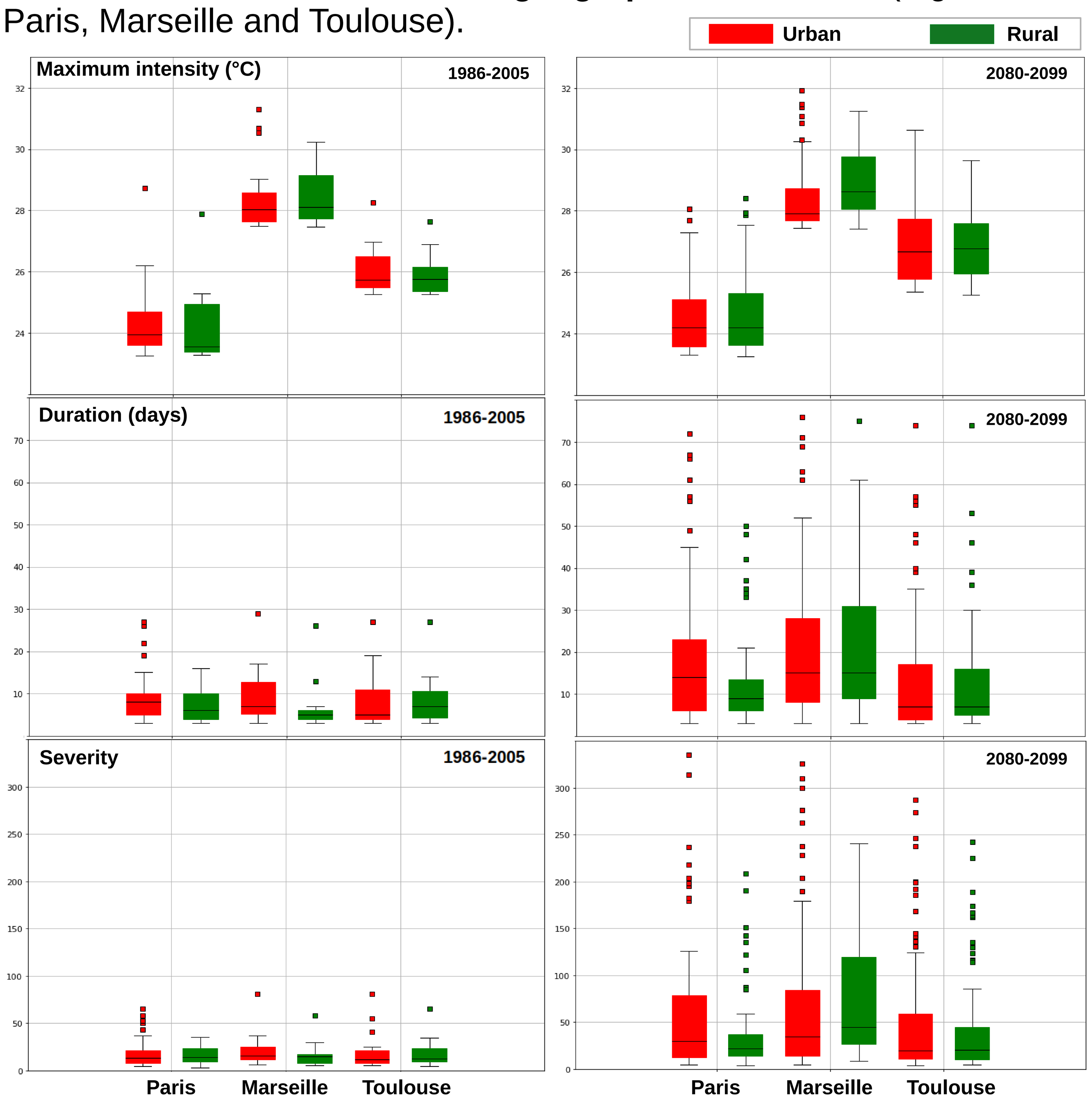


_Fig. 4_: *From the top to the bottom – Simulated maximum intensity (in °C), duration (days) and severity of heatwaves in 1986-2005 (left) and 2080-2099 (right) periods for the city of Paris, Marseille and Toulouse, located in FRANCE. Results for rural areas are in green while those for urban areas are in red.*

The maximum intensity, duration and severity are shown in Fig.4. The severity is calculated according to:

$$\frac{\sum_{i=1}^{n}(T_i - Sdeb)}{(Spic - Sdeb)}$$

With: **Sdeb,** the beginning and the end of HW (percentile 97.5)
**Spic,** the threshold beyond which an event is detected (percentile 99.5)
**T,** the mean temperature series of length **n**

HW indexes **increase** on average, and with greater **dispersion** between historical and future periods. For Paris and Toulouse (both semi-oceanic climate), and to a lesser extent for Marseille (Mediterranean climate), HW indexes are larger over urban than over rural environments for the historical period, suggesting the **impact of the UHI** on urban HW. For the future period, similar findings are noted for Paris and Toulouse, while HW indexes are slightly larger over rural than over urban areas for Marseille. These results can probably be explained by the **specific context** of coastal Mediterranean cities subject to increased heating and drying (Michau et al., 2022).

## 05 | Conclusion

The findings show a significant increase of the **number of heat waves days**, as well as **intensity**, **duration** and **severity** of HW in the future climate, but with a **climatic and geographical variability**. Work is underway to analyze a **set of European cities** in climate change context, in terms of extreme temperatures and precipitation.

**References**

Michau Y, Lemonsu A, Lucas-Picher P and Caillaud C (2022). Evaluation of the Urban Heat Island of 12 cities of France in a high-resolution Regional Climate Model simulation. Submitted to Urban Climate

Ouzeau G, Soubeyroux JM, Schneider M, Vautard R and Planton S (2016). Heat waves analysis over France in present and future climate: Application of a new method on the EURO-CORDEX ensemble. Climate Services, Elsevier BV, 4, 1-12

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