Characterization of outdoor thermo-hygrometric conditions in two Italian cities in recent years

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BACKGROUND and AIM

BACKGROUND

- ✓ Several studies underline that the Mediterranean region is heavily affected by global warming
- ✓ Multiple metrics have been developed to quantitatively describe and compare Heat Waves (HWs), while the monitoring of the outdoor thermal stress conditions is unusual
- ✓ Air temperature is the main driver of the outdoor thermal comfort, nevertheless other biometeorological parameters contribute to the individual thermal sensations
- ✓ Bioclimatic indices such as MOCI (Salata et al., 2016) quantify human thermal sensations including multiple weather variables and personal factors (e.g., age, expectations, adaptation, health condition)

AIM

- ✓ An innovative method for detection and characterization of thermo-hygrometric stress events based on MOCI has been developed by Falasca et al., (2023)
- ✓ The **aim** of this work is the application of this new method to the city of Rome and Milan in order to compare the features of the events in the two cities

METHODOLOGY

The Mediterranean Outdoor Thermal Comfort Index (MOCI)

The Mediterranean Outdoor Thermal Comfort Index (MOCI, Eq. 1) is a thermo-hygrometric comfort index for outdoor environments and allows quantification of the thermal sensations of a Mediterranean normotype (Salata et al., 2016) .

$$MOCI = -4.257 + 0.146 \cdot T_A + 0.325 \cdot I_{CL} + 0.005 \cdot RH + 0.001 \cdot I_S - 0.235 \cdot W_S \quad \text{(Eq. 1)}$$

T_A = air temperature [°C], RH= relative humidity [%], I_S =solar incident irradiance [Wm^{-2}], W_S =wind speed [ms^{-1}], I_{CL} (thermal resistance of the clothing)= $1.608 - 0.038 \cdot T_A$

- ✓ MOCI categories based on an ASHRAE 7-point scale [-3; − 2; − 1; 0; +1; +2; +3]:
  - -0.5 and 0.5 comfort conditions.
  - > 0.5 sensation of increasing heat
  - < -0.5 sensation of increasing cold.

Data collection and processing

- ✓ In this work, MOCI values are computed using hourly values of quantities recorded by the ARPA weather stations of :
  - Juvara station (Milan) of the ARPA Lombardia network
  - Boncompagni station (Rome) of the ARPA Lazio network
- ✓ This analysis is focused on:
  - daytime MOCI (08-22 CET)
  - May-September period
  - years 2015-2023

Indices for the characterization of outdoor thermo-hygrometric stress events

- ✓ In this work, the surveying of outdoor thermo-hygrometric stress events is based on the rearrangement of the Heat Wave definition, as shown below:

Heat Wave ↔ A spell of at least six consecutive days with maximum temperatures exceeding the local 90th percentile of the control period (Fischer and Schar, 2010)

↓

Thermo-hygrometric stress event ↔ A period of at least six consecutive days characterized by maximum daily values of MOCI higher than 0.5

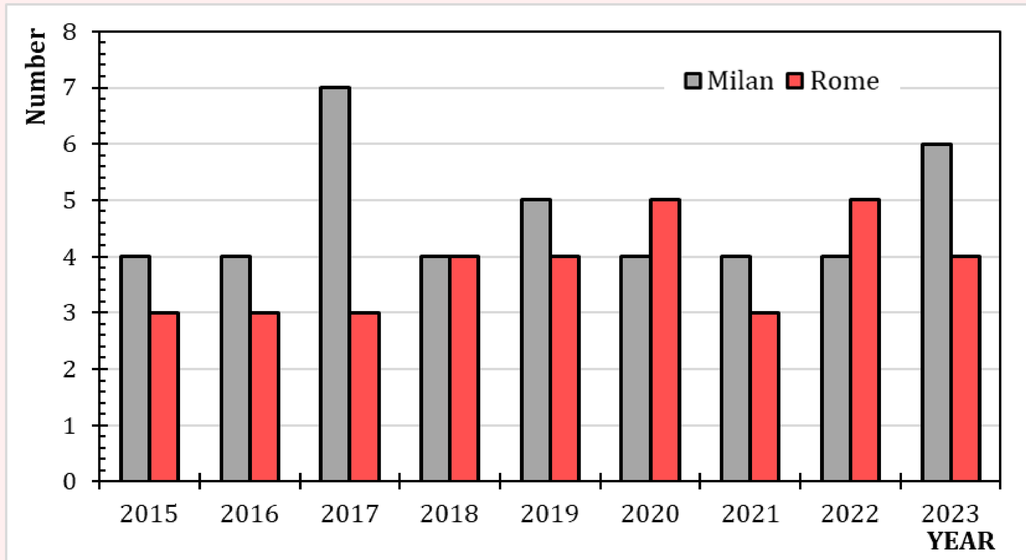
- ✓ Furthermore, indices for identification and characterization of outdoor thermo-hygrometric stress are derived from corresponding quantities conceived for HWs. Such indices are listed in Table I .

Table I
Summary of indices for the characterization of outdoor thermo-hygrometric stress

Quantity	Definition for HWs	Definition for outdoor thermo-hygrometric stress events
Event	A spell of at least six consecutive days with maximum temperatures exceeding the local 90th percentile of the control period	A period of at least six consecutive days characterized by maximum daily values of MOCI always above the comfort threshold (i.e., MOCI greater than 0.5)
Frequency	Sum of all HW days	Sum of all MOCI events days
Intensity	Average intensity across all HW days	Average intensity across all MOCI events days
Duration	Duration of the longest event	Duration of the longest event
Cumulative heat and extra-MOCI	Extra heat produced by HWs over a given season computed as the sum of the anomaly between each HW day and the calendar-day 90th percentile across all HW days in that season	Cumulative extra-MOCI for thermo-hygrometric stress events days

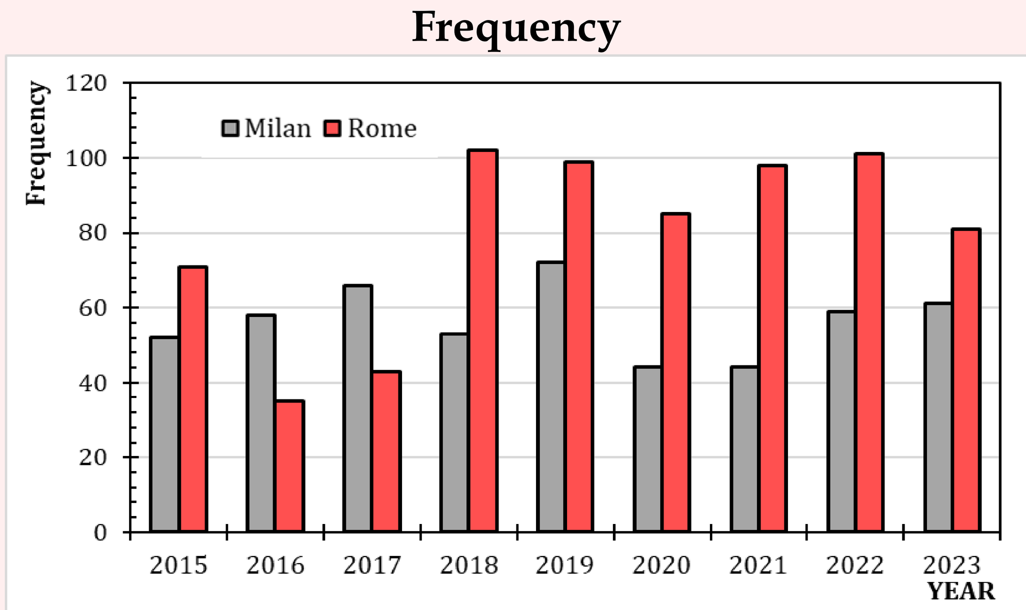
RESULTS

Number



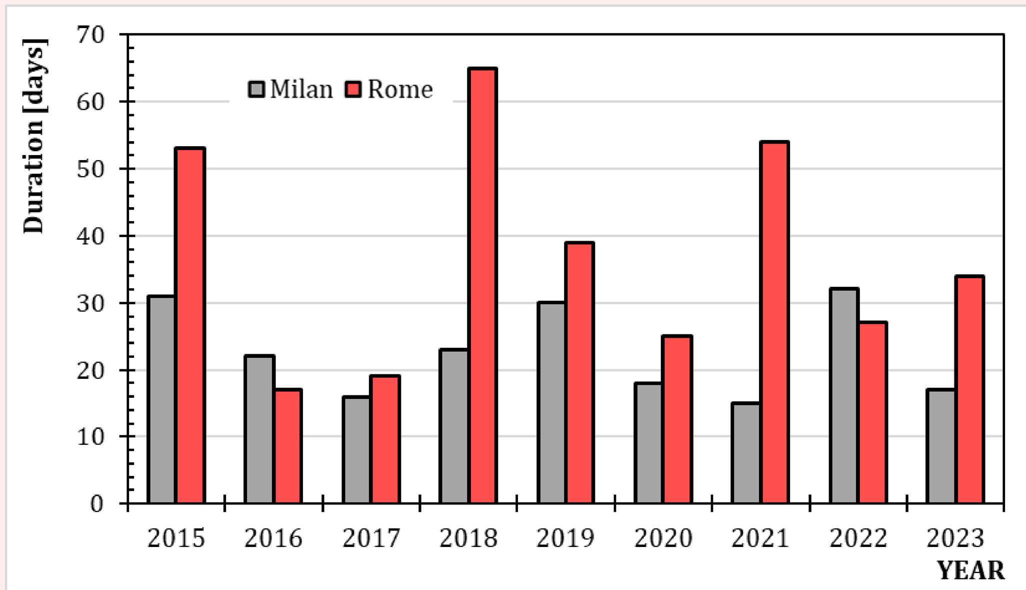
The number of events in Milan is higher than that in Rome in 6 out of the 9 years considered. The exceptions are 2017 and 2022 when 4 and 5 events were recorded in Milan and Rome, respectively. In 2018, 4 events occurred both in Rome and Milan. The highest number of events were recorded in 2017 (7) and 2023 (6 events) in Milan and in 2020 and 2022 in Rome, with 5 events in both years.

Frequency



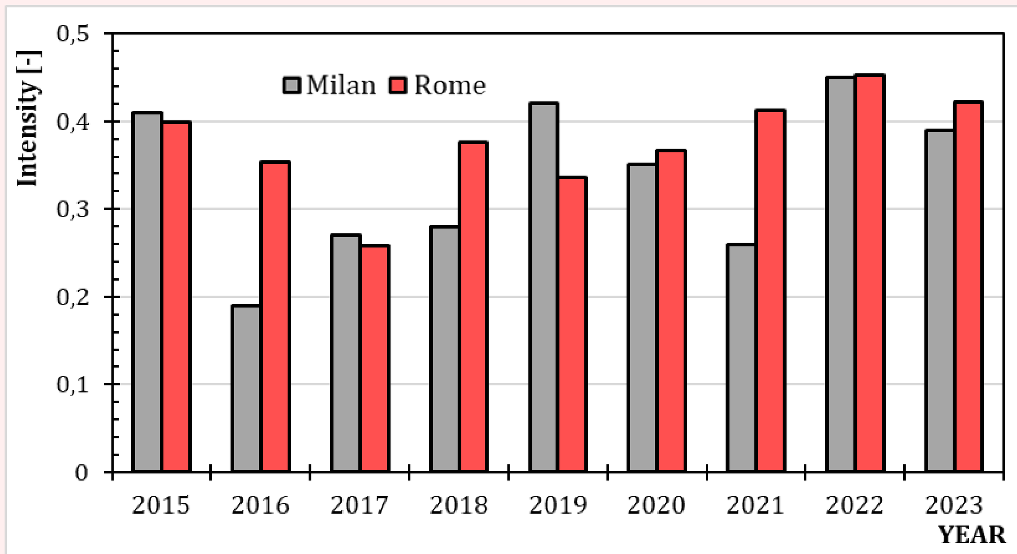
The frequency, i.e., the total sum of days of events during the year, is almost always higher in Rome than in Milan. In Milan, the maximum frequency in the time span considered is 72 days, while in Rome the frequency is always higher than 72 days except for 2016 and 2017, when the amount of missing data in the ARPA dataset is greater (less than 20%). The maximum frequency values in Rome are around 100 days.

Duration



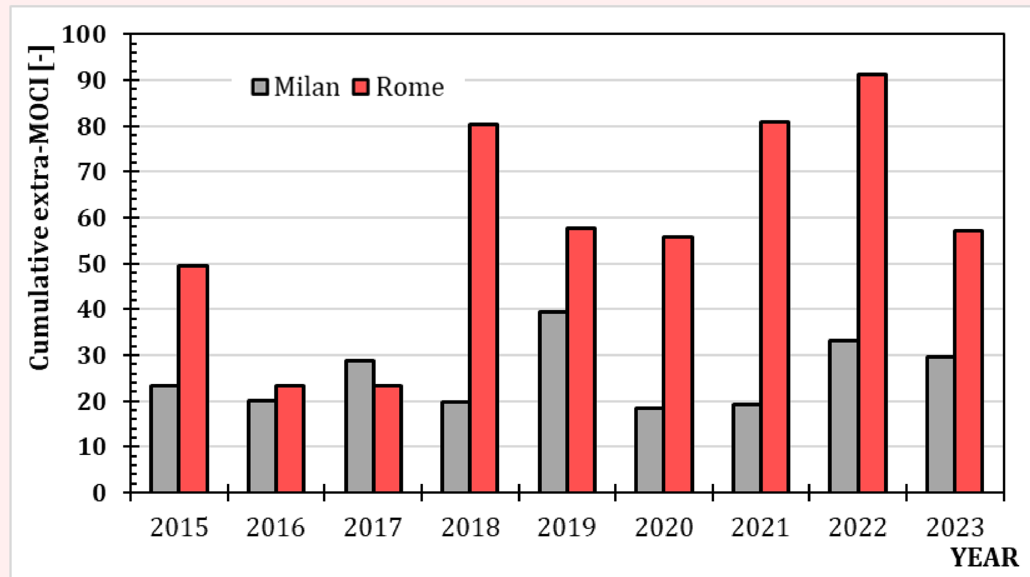
Events in Rome are longer than in Milan in most of the years considered. In some of these years the difference between the duration in the two cities is notable, for example in 2015, 2018, 2021 and 2023. The maximum duration in Rome is 65 days in 2018, followed by 2015 and 2021 with just over 50 days. In Milan, the highest durations are around 30 days and are recorded in 2015, 2019 and 2022.

Intensity



The average value of MOCI across all event days, i.e., the intensity, is rather variable in the period considered, both for Rome and Milan. Apart from a few cases, such as 2016 and 2021, the intensity is very similar in the two cities. In 2022 both Milan and Rome have the highest intensities, equal to 0.45. In Rome, the minimum intensity is 0.26 (in 2017), the only occurrence less than 0.3. In Milan, the minimum intensity value is 0.19 and occurs in 2016.

Cumulative extra-MOCI



Cumulative extra-MOCI values are significantly higher in Rome than in Milan in most of the years considered.
In Rome, the year 2022 has the highest cumulative extra-MOCI (equal to approximately 90), followed by the years 2018 and 2021 (cumulative extra-MOCI equal to about 80).. In Milan, the maximum value of cumulative extra-MOCI is equal to 40 and occurred in 2019.

CONCLUSIONS

➢ Compared to the analogous apparatus for HWs, this method accounts for further parameters in addition to temperature, that is other weather quantities (relative humidity, wind speed and solar radiation) and personal conditions (i.e., the clothing) that significantly affect human thermal sensations.

➢ Thanks to the present application in two Italian cities with different geographical and climatic characteristics, this method has proved to be useful and effective in the characterization of thermo-hygrometric stress events.

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