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Improvements in the observation of the Canopy Layer Urban Heat Island in Milano

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Urban Canopy Layer (UCL)

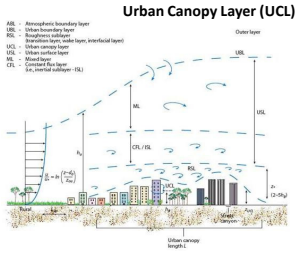


Figure adapted from H.J.S. Fernando, Fluid dynamics of urban atmospheres in complex terrain, Ann. Review of Fluid Mechanics, vol. 42(1) pp. 365-389, 2010

(**ref.**: T.R. Oke, Boundary Layer Climates, Routledge, 1988)

DEFINITIONS

Urban Heat Island (UHI)

- Definition: UCL warmer and deeper than the "normal" BL in the surrounding (rural) area, due to anthropogenic sources in cities.
- UHI Index: $I \equiv \Delta T_{UHI} = T_u - T_r$ where T_u : Urban Temperature (representative value in city) and T_r : Rural Temperature (mean of the surrounding area.
- $I = f(F_z)$, but **f** varies with the definition of T_u **and** T_r and could be anisotropic! (F_z : vertical fluxes)

Different urban temperatures

- **SUHI:** Surface Temperatures (remote sensing: satellites, ...)
- **CUHI:** Canopy Layer Temperatures (in situ by thermometers, ...)
- **BUHI:** Boundary Layer Temperature (in situ by instrumented towers and sounding, or remote sensing by vertical profilers)

NB: not directly comparable! ***Treat separately!***

In this work we deal only with in situ measurements in the Urban Canopy Layer: CUHI

METHODOLOGY

Rural background

- Must be representative of the surrounding undisturbed synoptic situation (Metadata!)
- Anisotropic in general (need considering horizontal gradients!)

➢ Accurate selection of homogenous reference stations

Measure uncertainties (**ref.**: WMO CIMO Guide Nr. 8 – 2008)

- Urban: affected by siting and sensor exposure (U> 1 °C and up to 5 °C)
- Rural: as for synoptic/climatological stations (U> 0.1 °C)

➢ Reduce as possible by calibration, homogeneity, siting and exposure, and filtering local and synptic noise

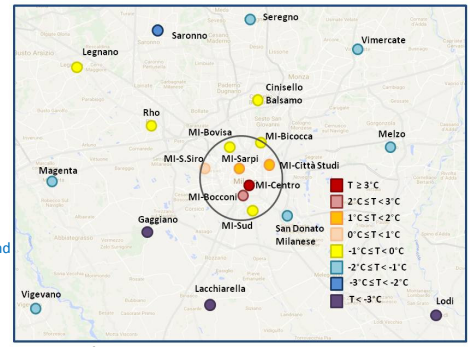
FOMD CN®: a unique example of nationwide homogenous urban meteorological network planned and managed with "metrological" criteria.

OBSERVATIONS

FOMD Urban Climate Network (CN®) in and around Milano

- **20** compact AWS with redundant thermometers on top of buildings (top of UCL) in typical urbanized environment
- Underlying surface Albedo: **≃ 0.2**
- Detailed metadata, especially for siting and exposure (**ref.**: T.R. Oke , Siting and exposure of meteorological instruments at urban sites, in Air Pollution Modelling and its Application XVII (Berlin: Springer) pp 615–32, 2007)
- Homogenous HW/SW end management
- Multi level validation procedures
- Annual calibration/traceability to nat. Standards (**ref.:** S. Curci et al., Automatic weather station traceability: an example of emerging need and calibration procedure, MMC Intern. Conf., Brdo -SLO, 2014)
- Reduced uncertainties for urban measurements (< 1°C) (**ref.**: S. Curci et al., Assessing measurement uncertainty in meteorology in urban environments, IOP Publishing, Meas. Sci. Technol. 28 (2017) 104002 (8pp))

Rural stations: 6, chosen from a careful selection of different providers and well covering the almost flat land around Milano .

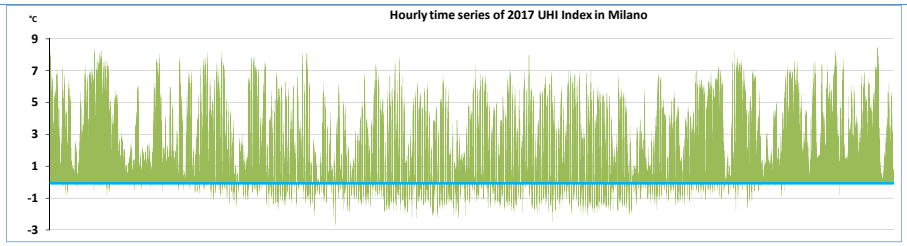


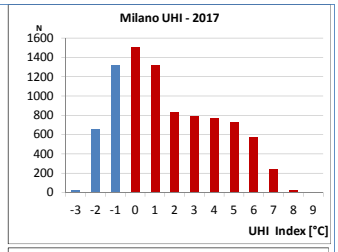
FOMD CN® in the metropolitan area of Milano: UHI temperatures on 1st January 2017 at 5:00 AM

RESULTS

Milano CUHI in 2017

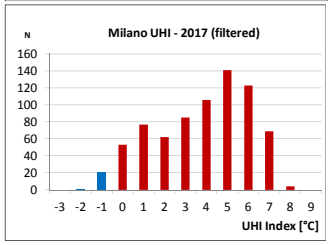
- Index based on a selected **CN®** station inside Milano (Milano Centro) and **6 rural stations of** different providers. (**ref.**: www.arpalombardia.it; www.politicheagricole.it)
- Statistics shows positive and negative UHI Index values: **Mean: +2.17°C; Median: + 1.62°C** Max: +8.52°C; Min: -2.71°C and a bi-modal distribution with evident diurnal and seasonal variability.
- Diurnal trend: the UHI Index is normally positive at night with maxima before sunrise, while negative values are present mainly in the afternoon (see case study below)





The histogram above shows the **frequency distribution** of the UHI Index, with an evident bimodal distribution, due on one side to measurement uncertainties and (meso-)synoptic "noise", and on the other to the UHI effect.

Filtering out as much as possible the (meso-)synoptic meteorological disturbance, selecting weather situations typical for the development of an UHI (weak circulation, no precipitation, clear skies), the **UHI effect frequency distribution** is more evident with a maximum at about **5 °C**, as shown in the histogram below .



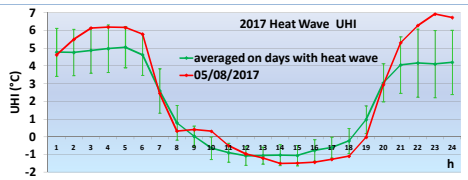
A CASE STUDY

A case study: UHI during 2017 Heat Waves (HW) in Milano

(**ref.**: C. Lavecchia et al., A meteorological monitoring network to investigate climate changes in towns: six Mediterranean Urban case studies, MESAEP 19th Int. Symposium, Rome , 2017)

Heath Wave Day adopted definition: a 2 days long (at least) time period with T_{max} and T_{min} > 95th percentile of 1961- 1990 climatology

- UHI strongly enhanced by HW during the night
- Canopy layer still colder than the surrounding rural environment during day



CONCLUSIONS

- **An operational definition of an UHI Index has been introduced and tested to describe the canopy layer UHI in Milano;**
- **the Milano canopy layer UHI can now be observed and described with unprecedented details by accurate in situ measurements and data selection;**
- **Milano UHI Index reached in 2017 more than 8.5 °C with a maximum frequency (140 hourly mean values) between 5 and 6 °C in case of filtered synoptic disturbance;**
- **UHI negative values are observed mainly in summer during daytime;**
- **Heat Waves strongly enhance the UHI effects, with relevant consequences for energy and health in the urban environment;**

More in general:

- **the different aspects of the complex urban atmosphere must be measured with specifically designed homogeneous networks;**
- **special attention has to be payed to AWS siting and (especially) sensor exposure, both detailed by constantly updated metadata;**
- **strict metrological procedures are mandatory for reliable urban climatological services, but this is affordable only for a network of reasonable dimension;**
- **low cost and dense sensor networks are likely necessary to extensively monitor the different urban environments, but they must be linked to reliable "metrologically" managed reference networks to keep uncertainties to a reasonable level.**

⇒ **FOMD CN® is an affordable attempt to provide an Urban Reference Meteorological Observatory and to provide reliable Urban Climatological Services**