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Data Article

Data collected by coupling fix and wearable sensors for addressing urban microclimate variability in an historical Italian city

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A R T I C L E I N F O

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A B S T R A C T

This article presents the data collected through an extensive research work conducted in a historic hilly town in central Italy during the period 2016–2017. Data concern two different datasets: long-term hygrothermal histories collected in two specific positions of the town object of the research, and three environmental transects collected following on foot the same designed path at three different time of the same day, i.e. during a heat wave event in summer. The short-term monitoring campaign is carried out by means of an innovative wearable weather station specifically developed by the authors and settled upon a bike helmet. Data provided within the short-term monitoring campaign are analysed by computing the apparent temperature, a direct indicator of human thermal comfort in the outdoors. All provided environmental data are geo-referenced. These data are used in order to examine the intra-urban microclimate variability. Outcomes from both long- and short-term monitoring campaigns allow to confirm the existing correlation between the urban forms and functionalities and the corresponding local microclimate conditions, also generated by anthropogenic actions. In detail, higher fractions of built surfaces are associated to generally higher temperatures as emerges by comparing the two long-term air temperature data series, i.e. temperature collected at point 1 is higher than

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temperature collated at point 2 for the 75% of the monitored period with an average of +2.8 °C. Furthermore, gathered environmental transects demonstrate the high variability of the main environmental parameters below the Urban Canopy. Diversification of the urban thermal behaviour leads to a computed apparent temperature range in between 33.2 °C and 46.7 °C at 2 p.m. along the monitoring path. Reuse of these data may be helpful for further investigating interesting correlations among urban configuration, anthropogenic actions and microclimate variables affecting outdoor comfort. Additionally, the proposed dataset may be compared to other similar datasets collected in other urban contexts around the world. Finally, it can be compared to other monitoring methodologies such as weather stations and satellite measurements available in the location at the same time.

Specifications Table

Subject	Management, Monitoring, Policy and Law
Specific subject area	Short-term monitoring; environmental transects; urban microclimate investigation; human thermal comfort evaluation; urban heat island
Type of data	Tables and graphs
How data were acquired	Two different datasets are provided: 1. A long-term monitoring of air temperature and relative humidity collected through stand-alone probes (Tinytag TGP-4500) located in two specific areas of the case study town; 2. A short-term, movable transects monitoring conducted on foot by means of a wearable miniaturized weather station specifically developed by the authors and designed in order to be settled upon a common bike helmet
Data format	Raw and analysed
Parameters for data collection	The two hygrothermal probes associated to long-term monitoring are located in the urban outdoors and are carefully shaded from direct solar radiation; the moving monitoring data were collected during a heat wave event in order to analyse the critical condition related to overheating risk for pedestrians
Description of data collection	Provided data were collected by (i) two stand-alone thermo-hygrometers (Tinytag TGP-4500) and (ii) an innovative wearable monitoring system set upon a bike helmet worn by the operator walking along a pre-defined path in the case study town. This portable weather station was directly developed by the authors. The Tinytag TGP-4500 collected air temperature and relative humidity every 10 minutes with an accuracy of ±0.5 °C and ±3.0% respectively. The wearable system collected every 2 seconds and all the technical specification are reported in the data article.
Data source location	Gubbio, Italy 43°21′06.44″N; 12°34′38.16″E
Data accessibility	Repository name: Mendeley Data Pioppi, Benedetta; Pigliautile, Ilaria; Pisello, Anna Laura (2020), “DATA COLLECTED BY COUPLING FIX AND WEARABLE SENSORS FOR ADDRESSING URBAN MICROCLIMATE VARIABILITY IN AN HISTORICAL ITALIAN CITY ”, Mendeley Data, v2, https://doi.org/10.17632/wndf6vdzj2.2
Related research article	Benedetta Pioppi, Ilaria Pigliautile, Cristina Piselli, Anna Laura Pisello, Cultural heritage microclimate change: Human-centric approach to experimentally investigate intra-urban overheating and numerically assess foreseen future scenarios impact, Science of The Total Environment, https://doi.org/10.1016/j.scitotenv.2019.134448.

Value of the Data

- The data are representative of intra-urban microclimate conditions at pedestrian height during a heat wave in a historical hilly town located in central Italy (Cfb climate according to the Koppen and Geiger classification).
- These data can be used to investigate microclimate variation within the city imputable to urban configuration and architectural layout, human activity and anthropogenic actions responsible for local overheating, and to compute direct thermal indexes for human comfort evaluation.
- The gathered data can be integrated with other open data sources, such as satellite images, fixed weather station data, or GIS maps or other visualization techniques, to better define time-space variation of urban climate. Further experiments may be carried out by replicating the methodology in other urban, weather and climate contexts, or also within the same area but with comparing other monitoring technique for a wide validation.
- The data collected have high-space granularity and are human centred, thus allow to deeply analyse the heterogeneity of the urban environment from a realistic citizens' perspective. The proposed technique, indeed, for the first time, is able to deal with pedestrian-only areas such as squares, parks etc.

1. Data description

The provided datasets consist of environmental data collected by means of two distinctive monitoring systems: (i) two fix thermo-hygrometers, and (ii) a miniaturized weather station developed by the authors. The monitoring campaigns are carried out in Gubbio, an historical hilly town in central Italy. According to the Koppen and Geiger classification [1], Gubbio climate is Cfb that stands for temperate climate at middle latitude, with balanced heating and cooling prevalence in winter and summer, respectively, and no dry season. Table 1 shows the main environmental parameters for a typical weather year as generated by the stochastic model used in Meteonorm [2].

The data provided by this article are organized in two supplementary files. The microclimatic variables data are organized in an excel file composed by four datasheets. The datasheets called "Moving_transect*X*" are referred to the three short dynamic monitoring campaigns and each datasheet presents collected raw environmental parameters, i.e. VOC and CO_2 concentration, air temperature, relative humidity, wind direction, wind speed, and global solar radiation, and apparent temperature which is a direct thermal comfort index [3].The collection time-step is 2 seconds and all the environmental parameters are related to GPS coordinates. The datasheet named "Fix-probes" includes the environmental data collected during the long-monitoring session by two thermo-hygrometers installed in different areas of the city. For the system, the collection time-step is 10 minutes.

Table 2 gives an overview of collected variables which are provided by the supplementary file and a further explanation is also given in the pdf file within Mendeley repository (see Table 3).

Table 1
Weather data referred to the case study, i.e. Gubbio (Italy), as given by Meteonorm software.

	Global Horizontal Radiation [kWh/m^2]	Air Temperature [°C]	Dew point temperature [°C]	Wind Speed [m/s]
January	48	4,5	0,2	2,9
February	63	5,3	0,3	2,8
March	102	8,8	2,6	3,1
April	133	12,5	5,8	2,3
May	180	18,3	10,1	2,4
June	190	22,5	12	2,4
July	208	25,1	11,6	2,9
August	176	24,5	12,9	2,5
September	126	18,4	11,6	2,3
October	85	14,6	10,7	2,3
November	52	9,6	6	2,9
December	41	5,5	2,3	2,9
Annual	1401	14,1	7,2	2,6

Table 2
Columns labels of the monitored variables as provided in the supplementary excel file.

Moving_transect spreadsheets Variable	Column label [unit]
Timestamp	DATA [dd/MM/yyyy hh:mm:ss]
Latitude	LAT [° E]
Longitude	LON [° N]
Elevation	ELEVATION [m.a.s.l.]
Volatile organic compounds concentration	VOC [kOhm]
Carbon Dioxide concentration	CO_2 [ppm]
Air Temperature	TA [°C]
Relative Humidity	RH [%]
Atmospheric pressure	Patm [hPa]
Wind Direction[a]	WD [deg]
Wind Speed[a]	WS [m/s]
Solar Radiation	SR [W/m^2]
Apparent Temperature	AT [°C]
Fix-probes spreadsheet Variable	**Column label [unit]**
Timestamp	DATA [dd/MM/yyyy hh:mm]
Air Temperature at location 1[b]	TA1 [°C]
Relative Humidity at location 1[b]	RH1 [%]
Air Temperature at location 2[c]	TA2 [°C]
Relative Humidity at location 2[c]	RH2 [%]

[a] Reported values of wind speed and direction are already corrected with respect to monitoring system speed and direction.
[b] Geographical coordinates: 43°21′11.3″N 12°34′45.6″E.
[c] Geographical coordinates: 43°21′11.3″N, 12°34′56.7″E.

Table 3
Specifics of the miniaturized sensors embedded in the developed wearable system [4].

Monitored parameters	Model of the sensor	Sensor accuracy
Air temperature [°C]	BME 280	±0.5 °C at 25 °C
Relative Humidity [%]	BME 280	±3%
Atmospheric Pressure [hPa]	BME 280	±0.25%
Global Solar Radiation [W/m^2]	SP-215	±5%
Wind speed [m/s]	LCJ-CAPTEURS-CV7-OEM	±0.13 m/s
Wind direction [deg]	LCJ-CAPTEURS CV7-OEM	±1°
CO_2 concentration [ppm]	DYNAMENT MSH-P-CO2/NC	±2% full scale @20 °C/1000 hPa
VOC concentration [kOhm]	FIGARO TGS 8100	Response time (T90): ≤15s
GPS coordinates	NEO-M8	Horizontal spatial accuracy: 2.5 m

2. Experimental design, materials, and methods

This paper provides data from two different monitoring campaigns conducted by means of the two previously mentioned systems. The two monitoring campaigns are intended as complementary in environmental data collection for the investigation of the intra-urban microclimate diversification. The two thermo-hygrometers were used to collect data in two different positions of the case study town throughout almost a year, i.e. long-term monitoring. The two probes provided air temperature and relative humidity fluctuations during different seasons and under different weather boundaries (see Fig. 1). The short-term environmental transects were collected at pedestrian height three times in one single day, during a heat wave event in summer 2017. This was a focus on the further microclimate diversification occurring below the canopy and thus directly affecting pedestrians' perception as reported by the computed apparent temperature.

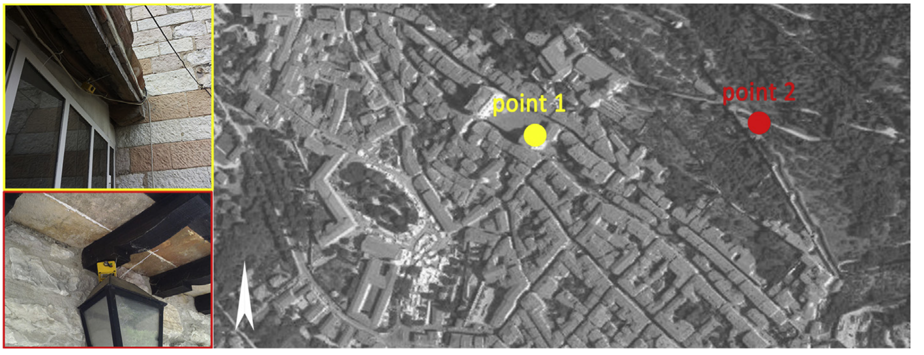

Fig. 1. Stand-alone thermo-hygrometers location within the case study.

The long-term and short term monitoring campaigns are thus specifically described in the following sub-sections.

2.1. Fixed long-term monitoring

Two stand-alone thermo-hygrometer probes were used to gather and datalog air temperature and relative humidity data from November 2016 to October 2017, i.e. one-year long campaign. The two probes were installed in two different areas of the city (Fig. 2): (i) on the terrace of the municipality building facing the main square of the town within the historic city centre (43°21′11.3″N 12°34′45.6″E); (ii) close to the ancient town walls, at the border between the Medieval city and the surrounding woods (43°21′11.3″N, 12°34′56.7″E). The purpose of this positioning was motivated by the necessity to investigate dense urban context compared to the surrounding green belt of the city.

These probes are small size data-logger (Tinytag TGP-4500) able to collect air temperature values from −25 °C to 85 °C and relative humidity values from 0 to 100%. The time-recording step is set to 10 minutes.

Fig. 2 presents air temperature-time trends collected during the monitoring campaigns. In particular, graph of Fig. 2a shows collected profiles for both the fix probes during the whole monitored year and monthly values associated to the Typical Weather Year (data reported in Table 1). The heatwave event which started on August 2nd is highlighted in the same graph. Fig. 2b presents a specific focus on August 2nd, 2017, when also the three short-term monitoring sessions were carried out. Outcomes of the moving transects are summarized by means of box plots representing statistical distribution of air temperature during the short-term monitoring sessions specifically described in the following section.

2.2. Dynamic microclimate short term monitoring session

An innovative wearable monitoring system is used to monitor the urban microclimatic conditions in Gubbio during a heat wave event. The monitoring system is a miniaturized weather station developed by the authors for the first time, by combining a series of miniaturized sensors whose specifics are given in Table 1. The monitored environmental parameters, listed in Table 1, are always associated to specific GPS coordinates, i.e. latitude, longitude, and elevation, and a timestamp so these can be positioned in space and time. The collection time-rate of the system is 2 seconds.

All the sensors are embedded in a specifically developed support designed in order to be easily worn over a helmet or on a backpack (Fig. 3). This innovative wearable system is developed by the

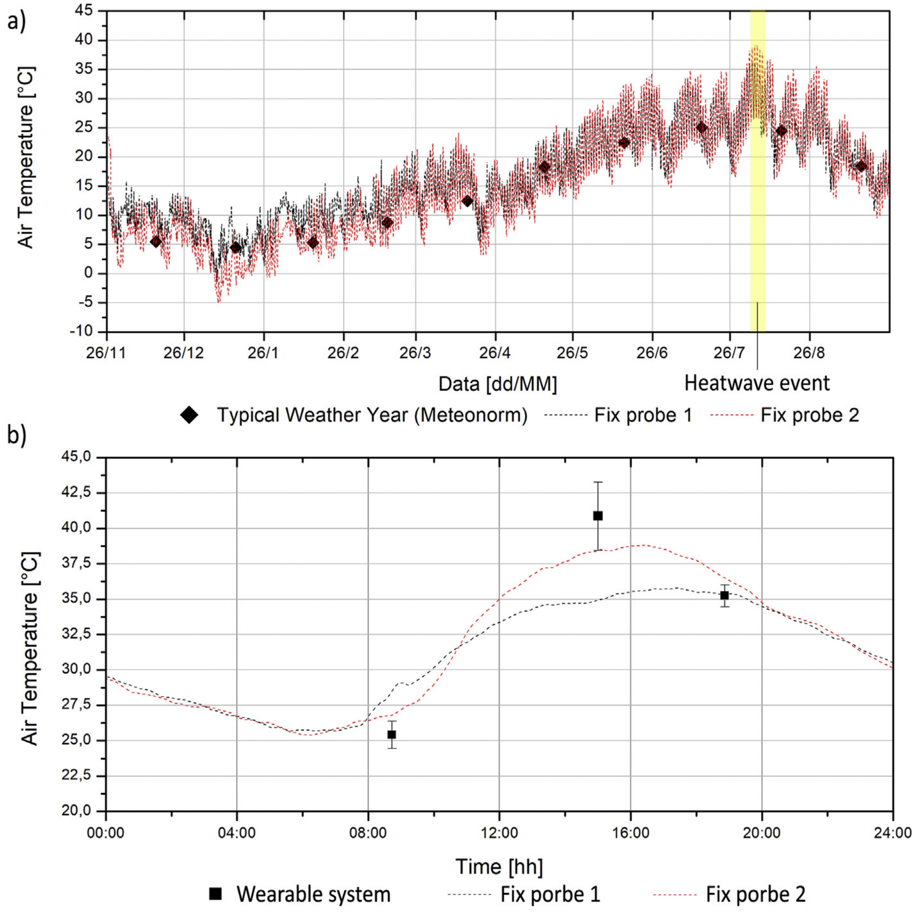

Fig. 2. (a) Air temperature time-trends gathered from the two fix probes in long-term monitoring; (b) air temperature trends on August 2nd collected by fix-probes in long term monitoring and box plots of the three short term monitoring sessions.

authors and is currently under patent pending. The reliability of the system has already been tested as reported in Refs. [4–6]. During the specific monitoring campaign, the system was set upon a bike helmet, i.e. at about 1.70 m height from the ground, worn by an operator walking around the town (Fig. 3b).

The monitoring campaign consists of three recording sessions carried out during the same day, i.e. August 2, 2017, at different time, i.e. 8 a.m., 2 p.m., 6 p.m. and following the same pre-defined monitoring path.

Collected air temperature, wind speed and relative humidity data are used to calculate the apparent temperature -a heat index based on a mathematical model given by Robert G. Steadman that account for these parameter on the human heat balance-by the formula given below [7]:

$$AT = TA + 0.33\left[\frac{RH}{100}6.105exp\left(17.27\frac{TA}{237.7+TA}\right)\right] - 0.7WS - 4.0 \qquad (1)$$

where, AT is the Apparent Temperature [°C], TA is the dry bulb temperature [°C], RH is the relative humidity [%], and WS is the wind speed [m/s].

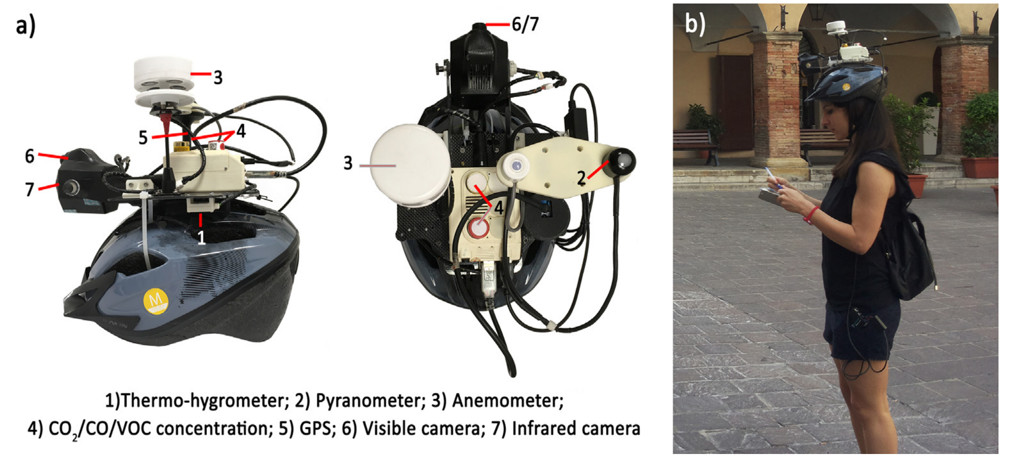

Fig. 3. (a) Developed monitoring system set upon a common bike helmet as it was used during (b) the monitoring campaign whose data are here presented.

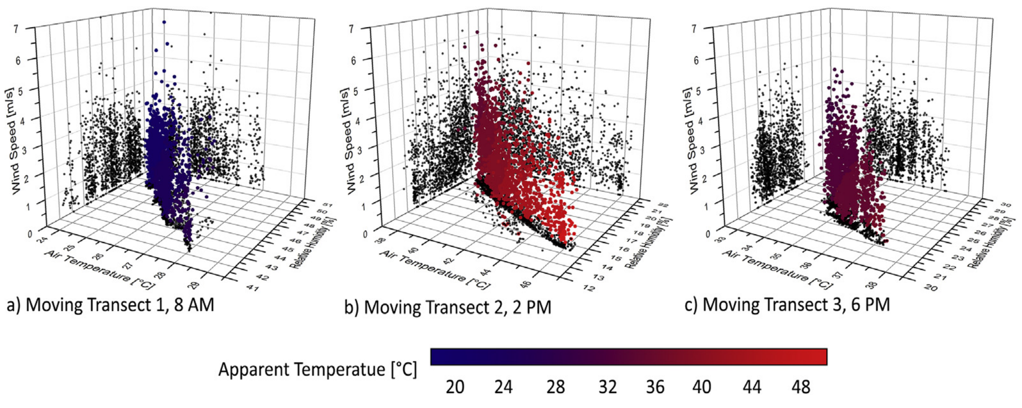

Fig. 4. 3D scatter plots of collected air temperature, relative humidity, and wind speed at (a) 8 a.m., (b) 2 p.m., and (c) 6 p.m.; plots colors give back computed apparent temperature which directly depends on the three monitored environmental data.

Fig. 4 gives an overview of computed apparent temperature variation with respect to the three monitored environmental data included in formula (1), i.e. air temperature, relative humidity and wind speed.

The intra-urban environmental parameters variability can be easily visualized by plotting collected data in space, according to associated GPS coordinates. For example, Fig. 5 shows different CO2 concentration levels as monitored along the designed transect for the three performed sessions. Presented maps are obtained via GPS Visualizer, an online open source tool (http://www.gpsvisualizer.com).

Geo-referenced environmental data as the ones provided in this work allow to deepen the existing correlations between urban forms and functions, and urban microclimate variables directly affecting outdoor comfort. The complex interaction among urban structures and environmental variables needs to be analysed through different data sources, possibly combining fix-long-term data collection, to dynamic environmental transects and, when available, satellite measurements. The presented datasets may help in addressing a comprehensive understanding of the intra-urban microclimate variability and thus defining, in a second step, tailored strategies for enhancing citizens' life quality.

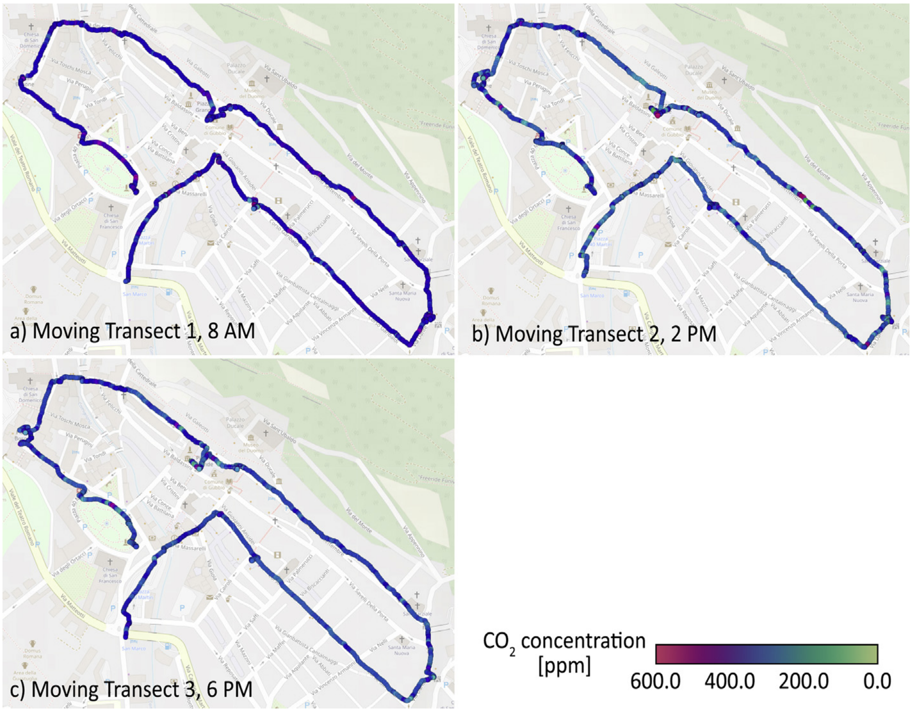

Fig. 5. Spatial distribution of collected CO_2 concentration data at (a) 8 a.m., (b) 2 p.m., (c) 6 p.m.

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Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.dib.2020.105322.

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