EGU General Assembly

6052

FONDAZIONE OMD

Photography encouraged

Canopy UHI observations in Milano: methodological aspects and recent climatology.

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Outline

- Urban Heat Island (UHI): Definitions and Problems
- How to measure UHI? A methodology for the Canopy Layer
- Milano Urban Climate Network and extra-urban reference
- Recent Milano Climatology and case studies
- Conclusions

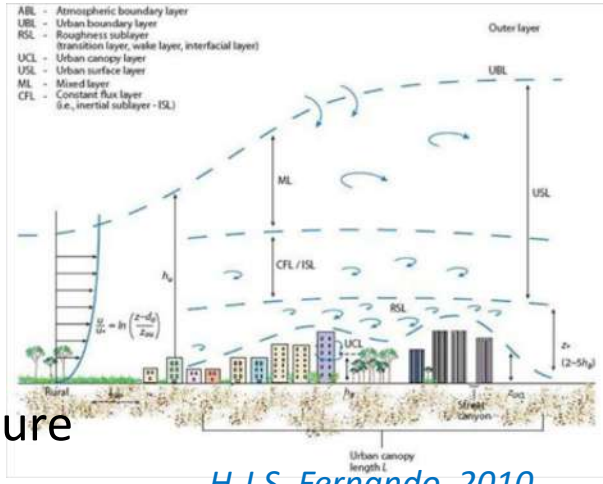
UHI: Definitions

Urban Heat Island Phenomenon:

well known warming of towns relative to the non-urban environment due to:

- Multiple interactions in the complex urban Boundary Layer
- Differences between urban and rural Atmospheric Boundary Layer

- SUHI: surface temperatures
- CUHI: canopy temperatures (top?, bottom?, other?)
- BUHI (?): boundary layer (inertial?, …)…



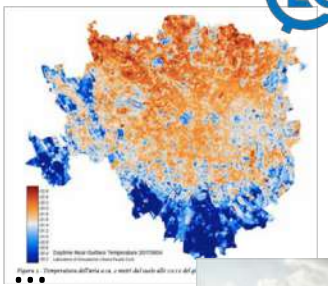
H.J.S. Fernando, 2010

- UHI Intensity: difference “urban“ minus “rural“ temperature

$$I_{UHI} \equiv T_u - T_r$$

- Intensity: max / mean, hourly, daily, seasonal, yearly or climatic

How to measure UHI's?



- Surface UHI: remote sensing observations (from space, etc.)
- Canopy UHI: in situ measurements by fixed stations located at …
  - Street level (2 m? Where? …)
  - Building roofs (h? Roof material? …)
- Boundary UHI: soundings, airplanes, drones, remote sensing, …

UHI magnitude:

- Related to city core…?
- Maximum value…?
- Related to LCZs as in **Stewart** I.D., Oke T. R. and Krayenhoff E. Scott : *Evaluation of the 'local climate zone' scheme using temperature observations and model simulations*, Int. J. Climatol. **34**: 1062–1080 (**2014**)

Critics about methodology:

Stewart I.D.: *A systematic review and scientific critique of methodology in modern urban heat island literature*, Int. J. Climatol. 3**1**: 200–217 (**2011**), DOI: 10.1002/joc.2141

Reference temperatures

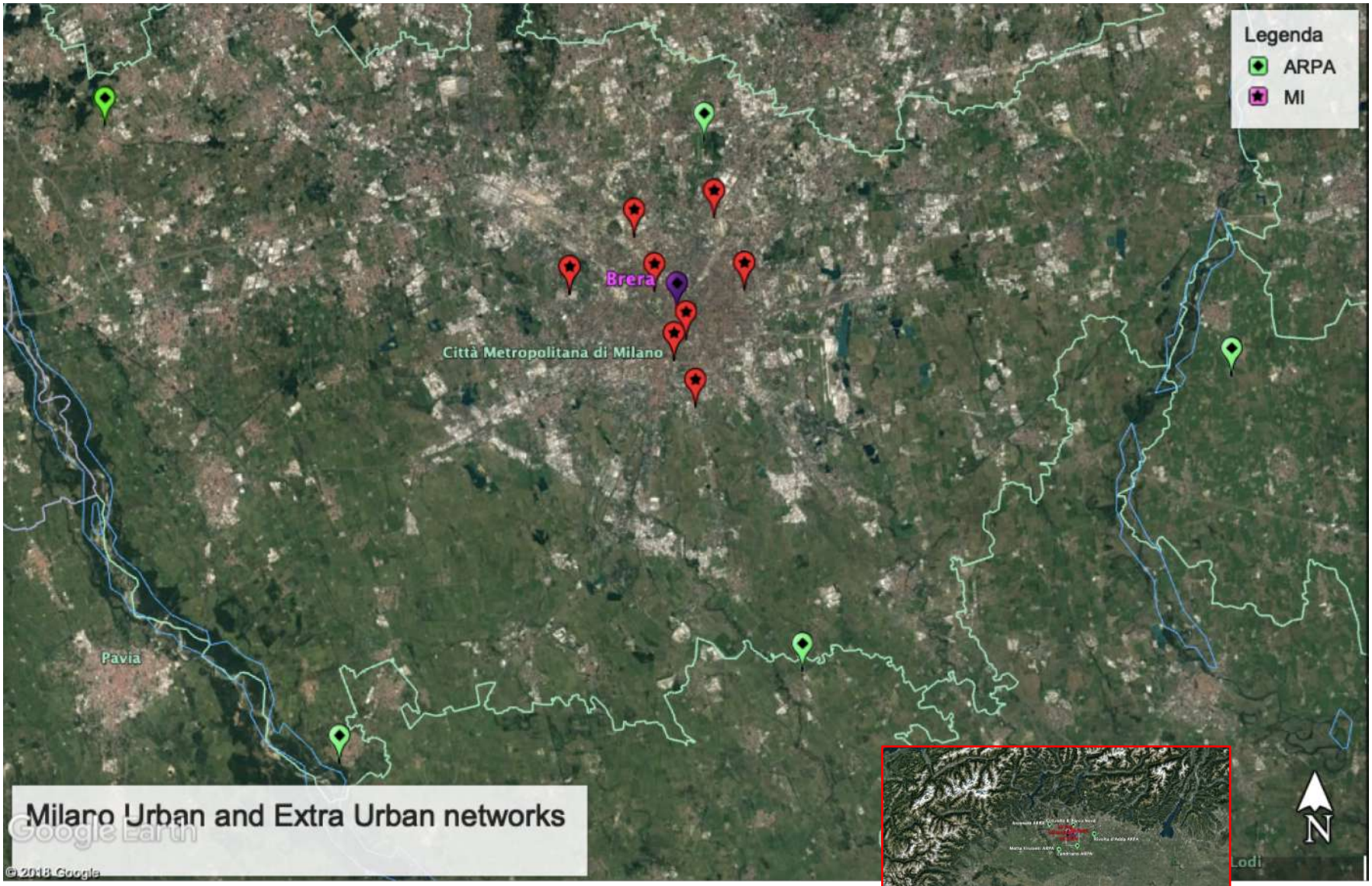
Rural (r, or Extra-Urban EU):

- Must be representative of the local non-urban environment (no urb. influence)
- Synoptic (climatological) stations are "generally" well suited (as above)
- Agrometeorological stations sometime better
- Isotropic distribution all around the town needed to allow for local/regional gradients
- Mean values to reduce uncertainties

Urban (u):

- Must be representative of the "local" urban environment (LCZ)
- Must be representative of one urban atmospheric layer (S- or C-UHI)
- Station siting and sensor exposure are critical (open sky at building top)
- Environmental characteristics/changes must be fully documented

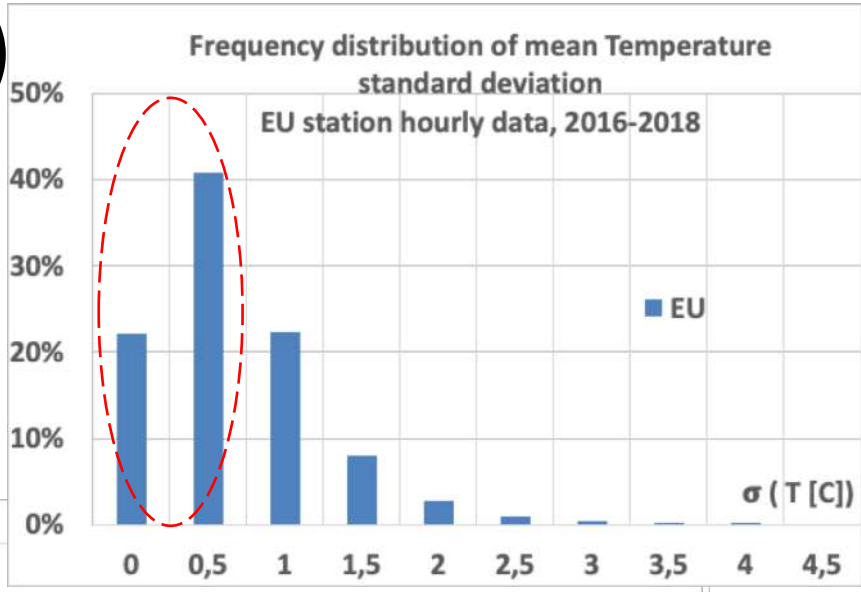
CN + EU stations in and around Milano

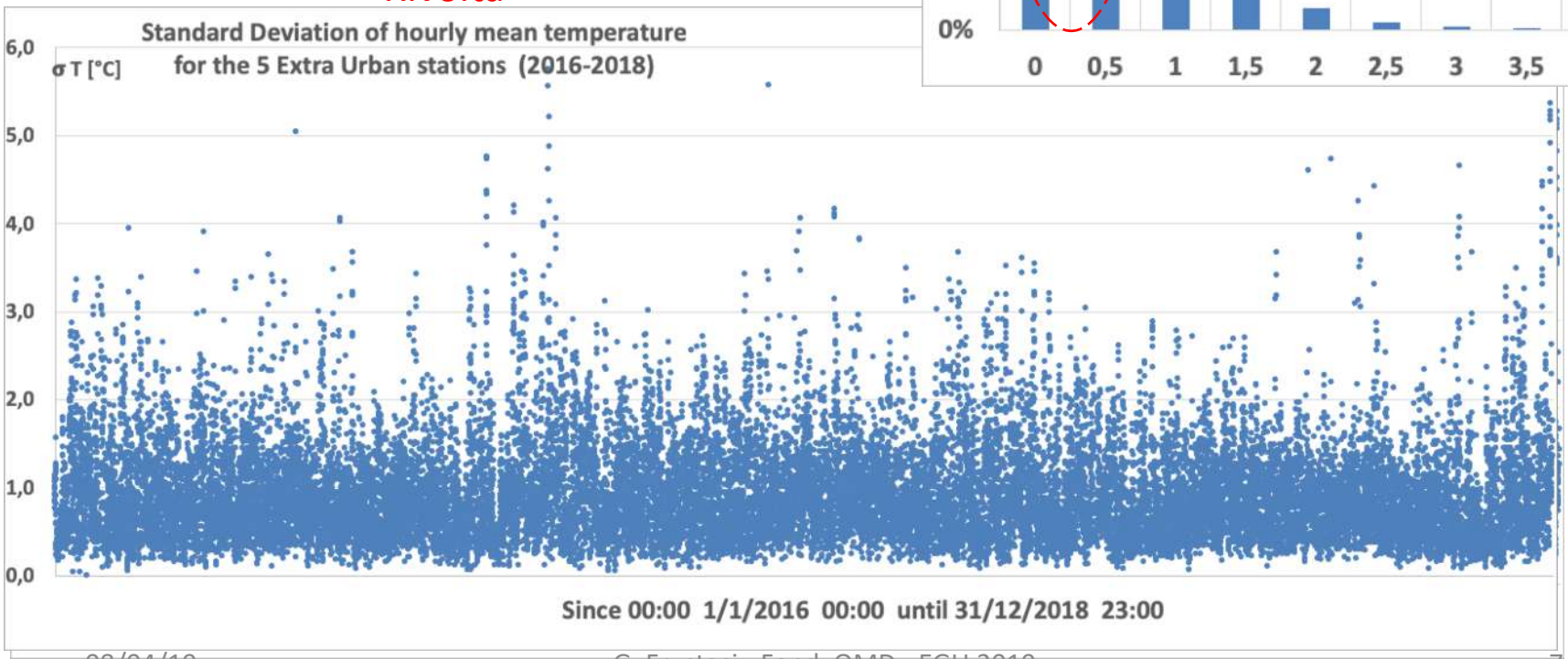


Statistics for EU stations: Mean hourly Temperature (3y: 2016÷18)

ARPA Lombardia: - Arconate

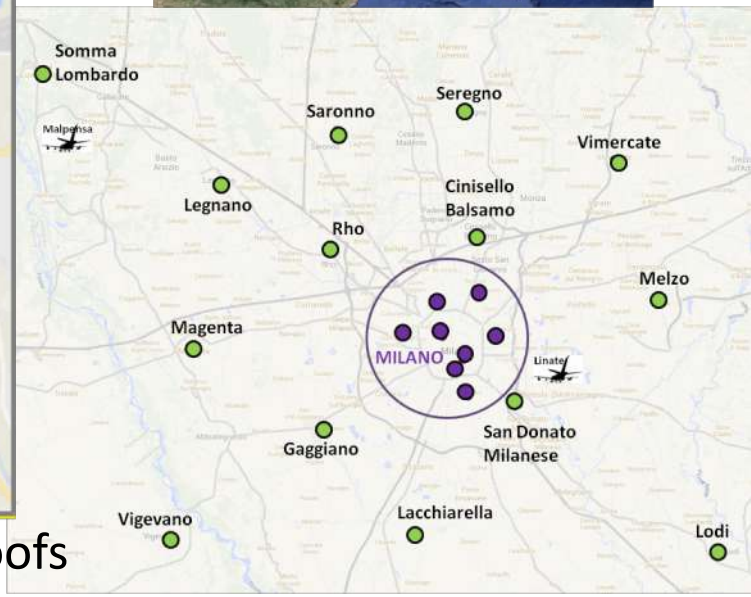
- Landriano
- Motta Visconti
- Cinisello B. Parco Nord
- Rivolta





Milano Urban Climate Network (CN)

Owned and managed by Fondazione
Osservatorio Meteorologico Milano Duomo (OMD)



Milano downtown Network: 8 stations on building roofs

Operational Measurements by Climate Network in Milano 2011-2019

- Network implementation since 2011, ended 2014
- 8 + 12 Automatic Weather Stations (WXT520) in/around Milano
- Siting and exposure at top of Urban Canopy Layer (Oke, IOM Report Nr. 81, 2004)
- Managed with «metrological» criteria as in MeteoMet (Merlone et al., MST, 2017)
- Periodical calibration/maintenance and reference to national standards
- Extended and detailed metadata (Sensor exposure, Albedo, LCZ, etc.)

(Curci et al., MST, 2017)

Use: urban energy applications

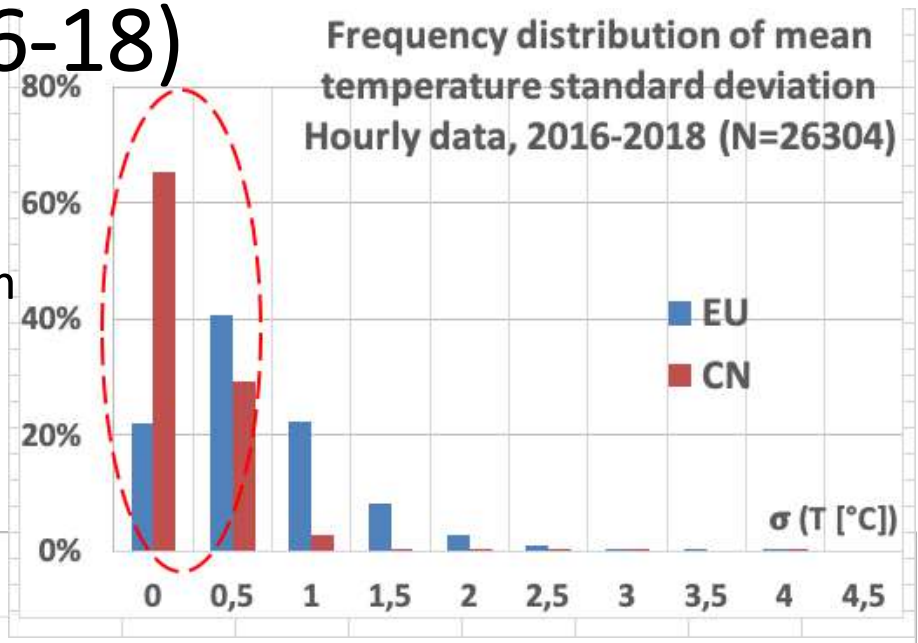
Aim: urban climatological services

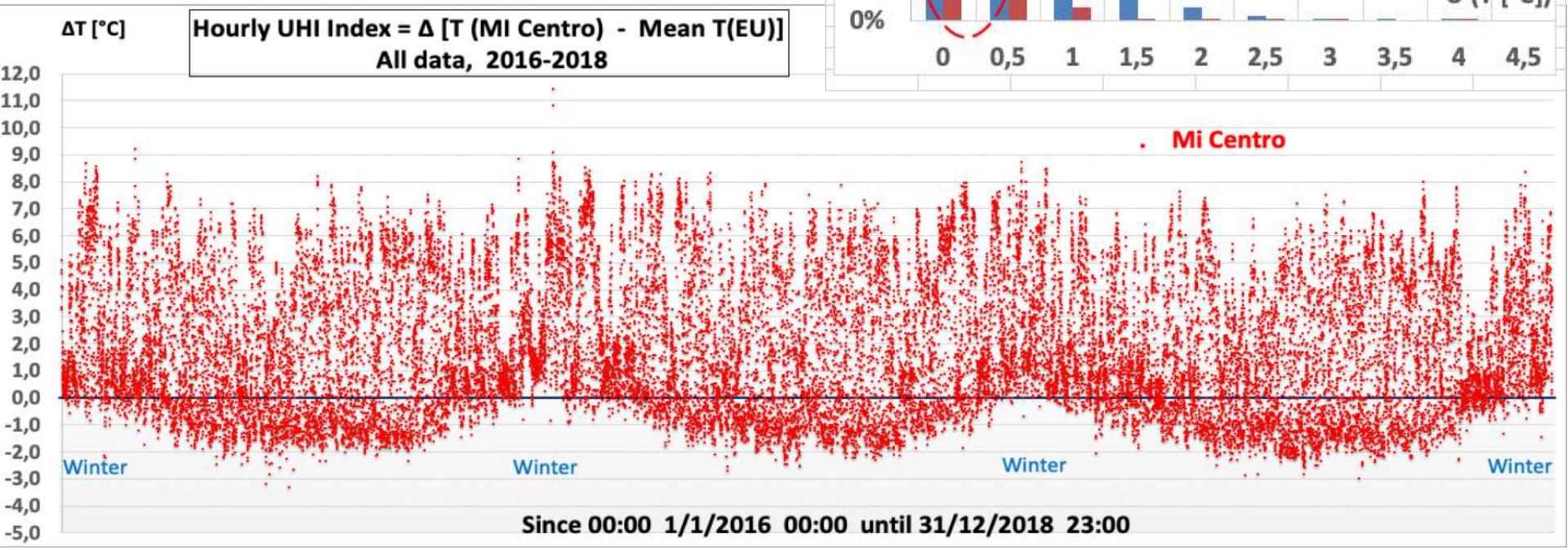
Involved in Projects:

- METEOMET I+II 2013-2019
- CLIMAMI, 2019-2021

Statistics of CN stations: Mean hourly Temperature (3y: 2016-18)

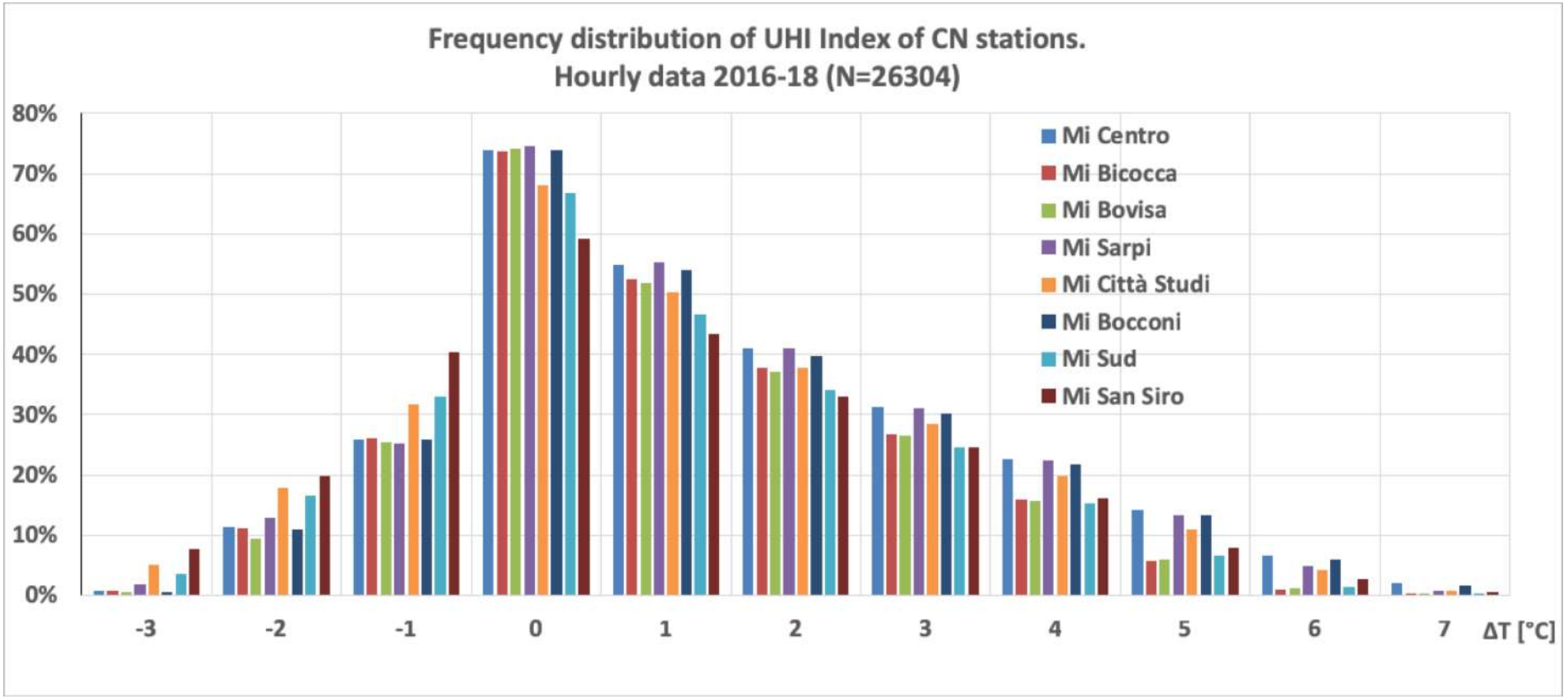
- Mi Centro is most representative for the inner / central part of the city (0,4 km from Duomo).
- It is also only 1,4 km away from Milano Brera (*250 years long historical series*)





UHI Index Statistics (all data)

UHI Index definition: $\Delta T_i = T_i(CN) - \underline{T}(EU)$



Meteorological Filter and UHI event selection

1. UHI selection: UHI Index $\geqslant$ 3°C at MI Centro

   [3 years mean hourly $\Delta T = T_{max} - T_{min}$ at the 8 CN stations: (1,4 ± 0,7)°C]

2. Meteorological filter on hourly data:

   a) No precipitation (RR = 0) at all the 13 stations (CN and EU)

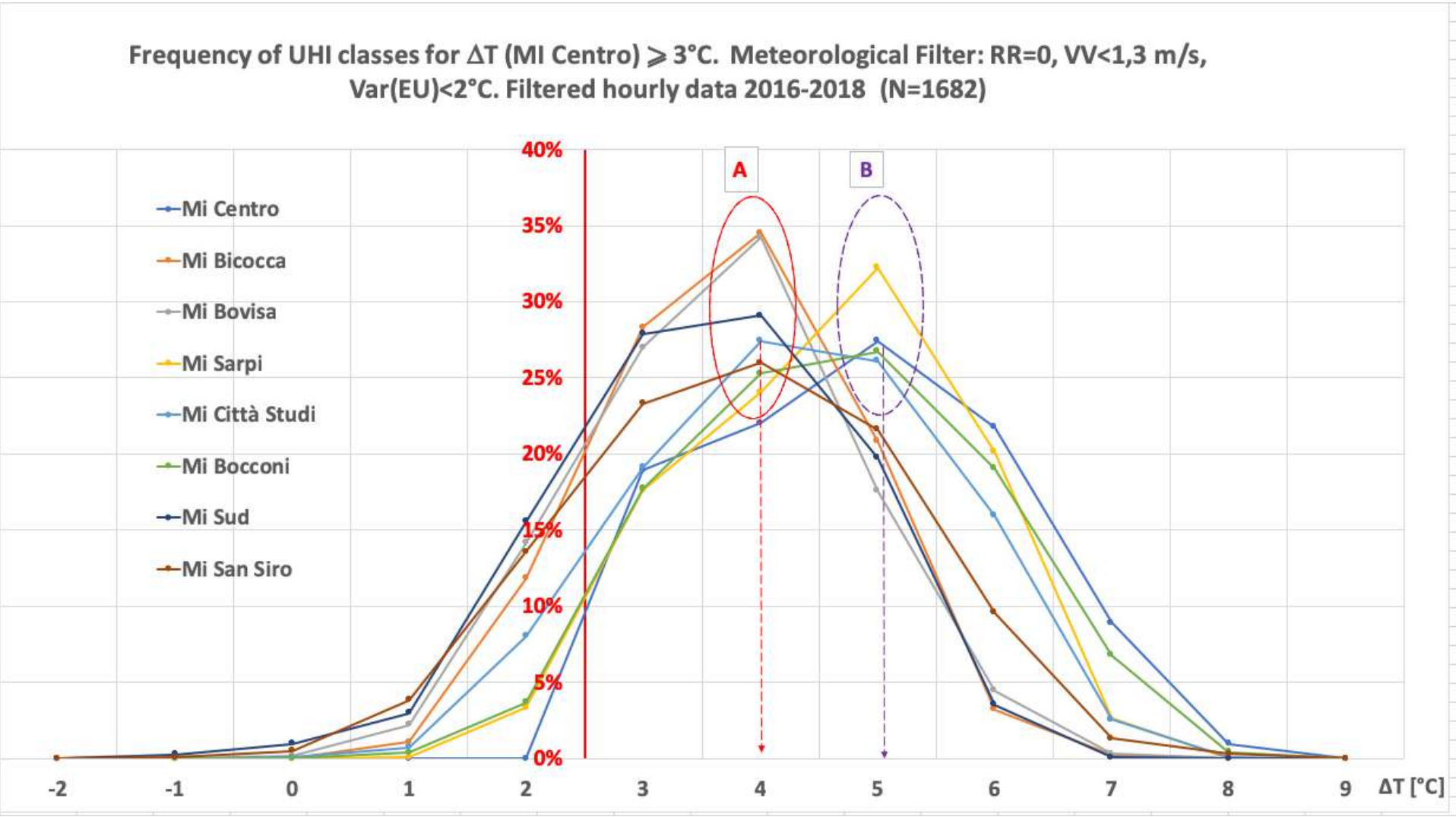
   b) Weak winds (VV < 1,3 m/s, based on local climatology) at all the 13 stations (CN and EU)

   c) Variance of Temperature: Var (T) < 2°C for EU stations

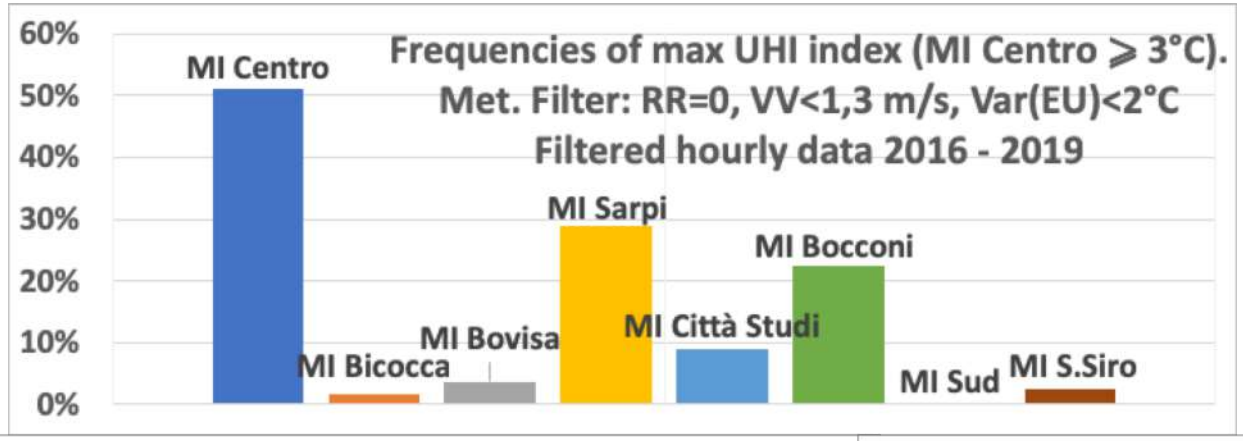
   Var (T) > 1°C for CN stations

Meteorological filtered UHI Index

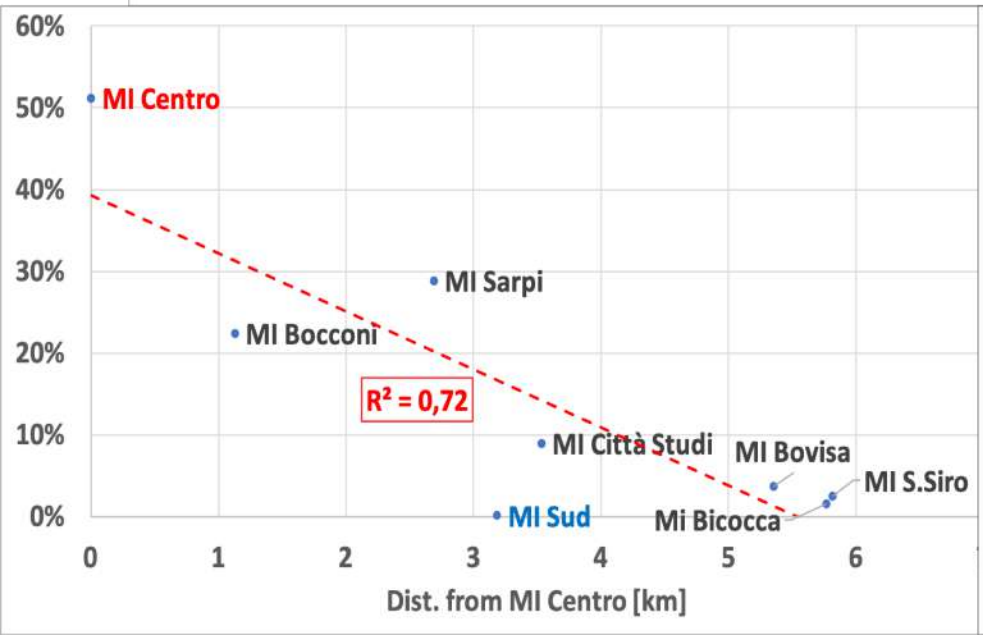
Different behaviour of CN stations

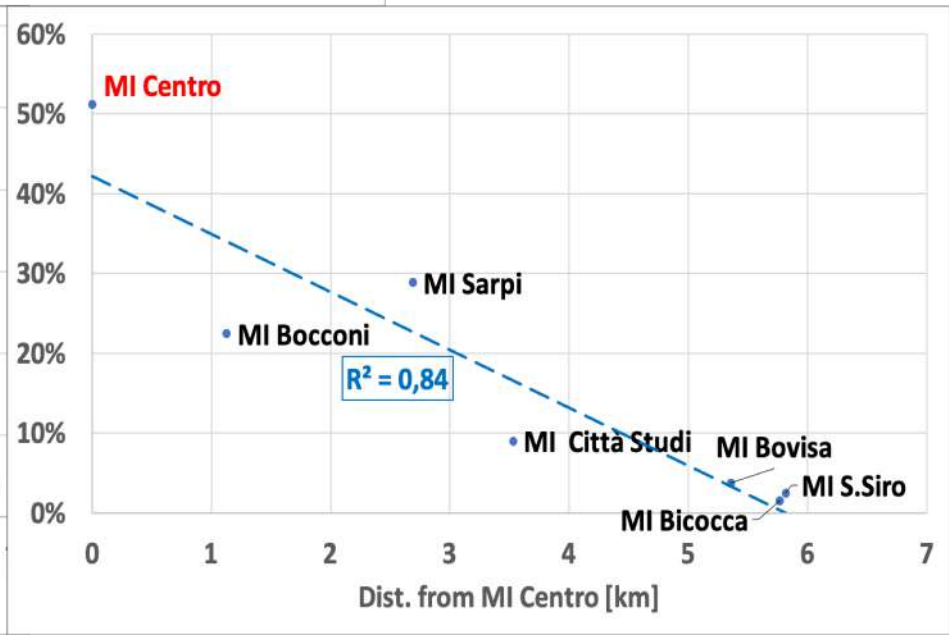


UHI Index and distance from MI Centro

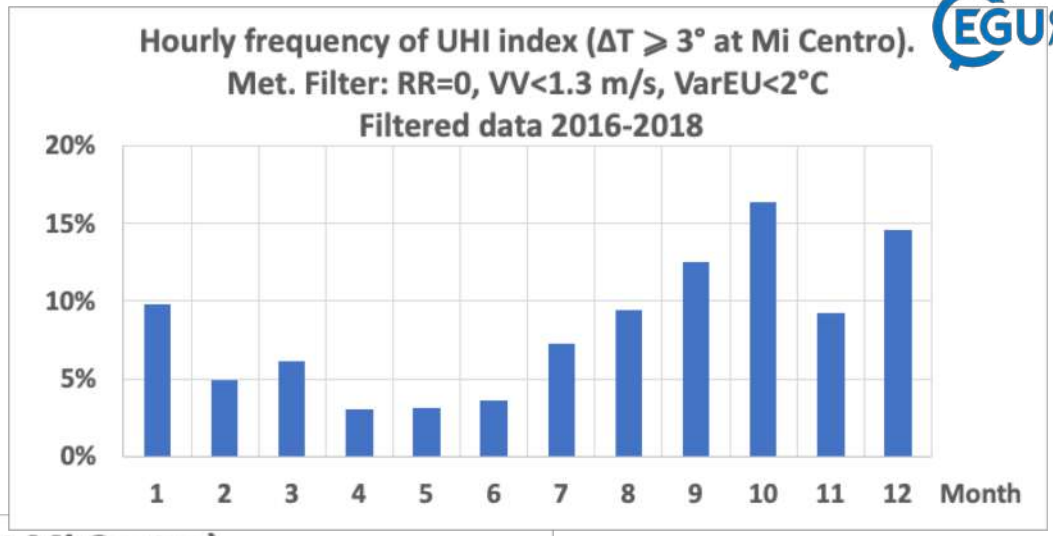


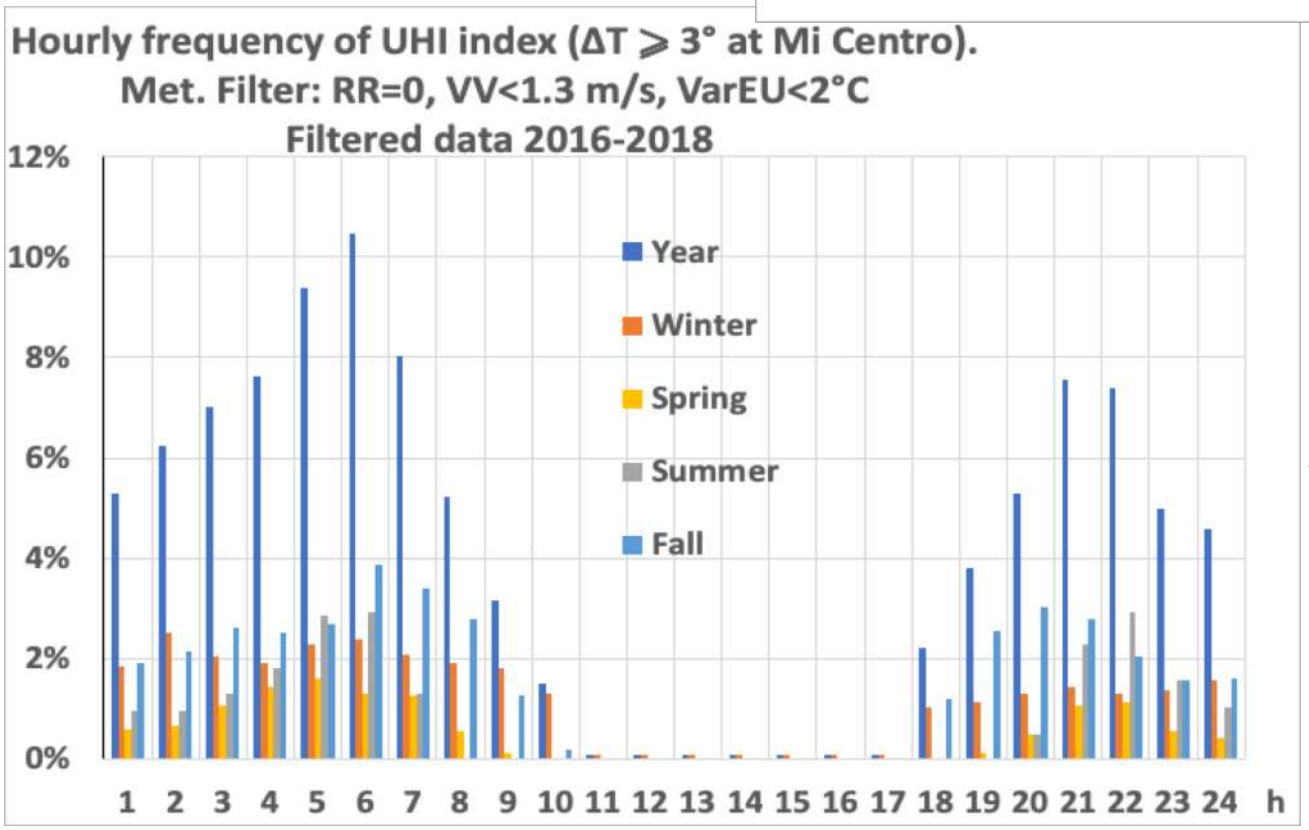
NB: no correlation found with LCZ of the CN stations





Daily and seasonal behaviour





NB: unusual weather conditions during Fall 2017

UHI less frequent in Spring and Summer and in late morning and in the afternoon.

3D Gaussian fitting

Error Listing

Indep. Data 1	Indep. Data 2	Dependent Data	Predicted	Abs Error	Rel Error
4.5540894E+01	8.848024E+00	0.0E+00	-1.0000429858E-01	-1.000043E-01	n/a
4.5312004E+01	9.261269E+00	0.0E+00	-9.9482922262E-02	-9.948292E-02	n/a
4.5287416E+01	8.993169E+00	0.0E+00	-1.0053370797E-01	-1.005337E-01	n/a
4.5527102E+01	9.195255E+00	0.0E+00	1.8226280840E+00	1.822628E+00	n/a
4.5459211E+01	9.520852E+00	0.0E+00	-9.1984201373E-02	-9.198420E-02	n/a
4.5502578E+01	9.163837E+00	4.3E+00	4.0994147257E+00	-2.005853E-01	n/a
4.5431289E+01	9.200497E+00	4.6E+00	4.3828319180E+00	-2.171681E-01	n/a
4.5478543E+01	9.125393E+00	4.9E+00	4.8649266157E+00	-3.507338E-02	n/a
4.5510154E+01	9.211565E+00	5.1E+00	3.4289844157E+00	-1.671016E+00	n/a
4.5479995E+01	9.229652E+00	5.6E+00	6.0068623770E+00	4.068624E-01	n/a
4.5479822E+01	9.175951E+00	6.2E+00	6.3762967194E+00	1.762967E-01	n/a
4.5450826E+01	9.187711E+00	6.3E+00	6.3056391783E+00	5.639178E-03	n/a
4.5459641E+01	9.194909E+00	6.7E+00	6.8044211456E+00	1.044211E-01	n/a

z = a * exp(-0.5 * (((x-b)/c)2 + ((y-d)/f)2)) + Offset

Fitting target of lowest sum of squared absolute error = 6.4489117202058033E+00

a = 7.0303958075493629E+00

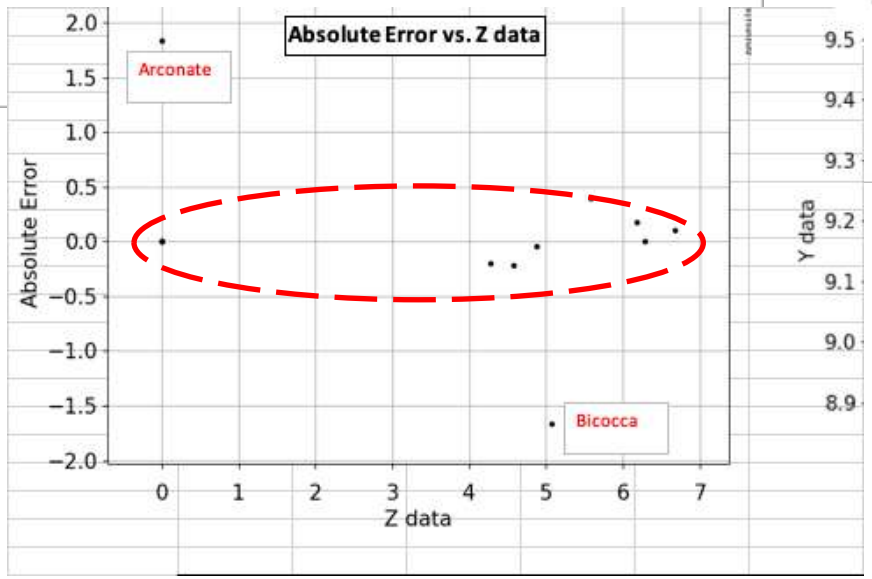
b = 4.5466749424558373E+01

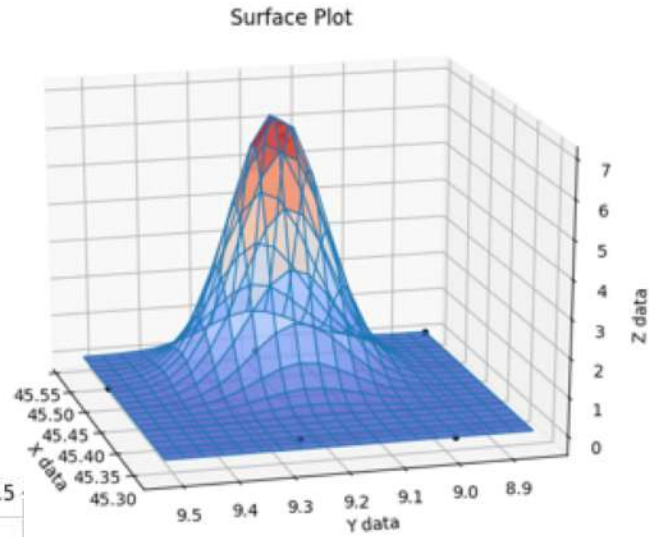
c = 3.7483678933970380E-02

d = 9.1943287013008721E+00

f = 8.9257955285921481E-02

Offset = -1.0053964613523328E-01





07/12/16 00:00 LT

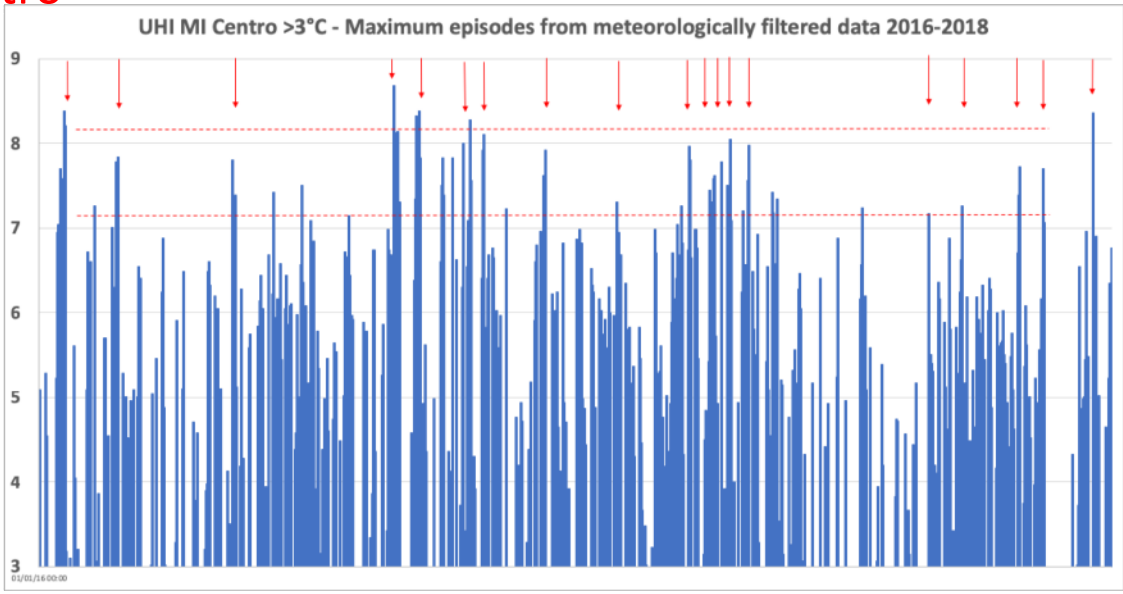
Selection of intense UHI episodes

Episodi	Inizio	Fine	Durata [d]	24-Ora inizio	Ora fine	Durata [h]	Nr. Dati orari con MI Centro >3°C	Val. Max [°C]
1	22/01/2016 03:00:00	23/01/2016 21:00:00	1	21	21	42	15	7,70
a	26/01/16 00:00							
b	20/03/16 00:00							
c	20/07/16 00:00							
2	08/09/2016 02:00:00	09/09/2016 20:00:00	1	22	20	42	16	6,44
3	15/11/2016 18:00:00	16/11/2016 23:00:00	1	6	23	29	21	5,96
4	07/12/2016 00:00:00	09/12/2016 02:00:00	2	00	02	50	26	6,74
d	28/12/16 00:00							
5	30/12/2016 06:00:00	02/01/2017 02:00:00	3	00	02	74	30	8,14
e	21/01/17 00:00							
6	14/02/2017 23:00:00	16/02/2017 06:00:00	2	1	06	31	18	7,82
7	16/03/2017 02:00:00	17/03/2017 07:00:00	1	22	07	29	15	8,28
8	28/03/2017 19:00:00	30/03/2017 07:00:00	2	5	07	36	15	8,10
9	25/08/2017 03:00:00	26/08/2017 22:00:00	1	21	22	43	12	6,12
10	02/10/2017 15:00:00	05/10/2017 06:00:00	3	5	06	59	34	5,02
11	12/10/2017 02:00:00	19/10/2017 03:00:00	7	22	03	169	72	7,98
f	12/10/17 00:00							
12	24/10/2017 17:00:00	27/10/2017 06:00:00	3	7	06	61	25	8,16
13	31/10/2017 05:00:00	03/11/2017 15:00:00	3	19	19	86	31	7,06
14	16/11/2017 17:00:00	21/11/2017 21:00:00	5	7	21	124	43	7,62
g	06/12/17 00:00							
15	03/12/2017 00:00:00	04/12/2017 08:00:00	1	00	08	32	16	8,68
16	18/12/2017 08:00:00	25/12/2017 08:00:00	7	16	08	168	53	7,98
17	29/07/2018 22:00:00	31/07/2018 22:00:00	2	2	22	48	17	7,52
18	12/08/2018 21:00:00	14/08/2018 05:00:00	2	3	05	32	13	4,64
h	25/12/17 00:00							
19	27/08/2018 20:00:00	30/08/2018 05:00:00	3	4	05	57	19	6,40
20	09/09/2018 19:00:00	12/09/2018 07:00:00	3	5	07	60	26	6,28
21	17/09/2018 05:00:00	19/09/2018 21:00:00	2	19	21	64	15	8,68
22	26/09/2018 20:00:00	28/09/2018 20:00:00	2	4	20	48	26	8,32
23	16/10/2018 23:00:00	21/10/2018 08:00:00	5	1	08	105	44	6,50
24	29/11/2018 18:00:00	01/12/2018 20:00:00	2	6	20	50	24	5,16
i	12/12/18 00:00							

- Intensity:

  Maximum intensity above 8°C

⇒ choise: $\Delta T_{max} > 7 \div 8$°C at MI Centro



- Time span:

  Mostly during evening/night

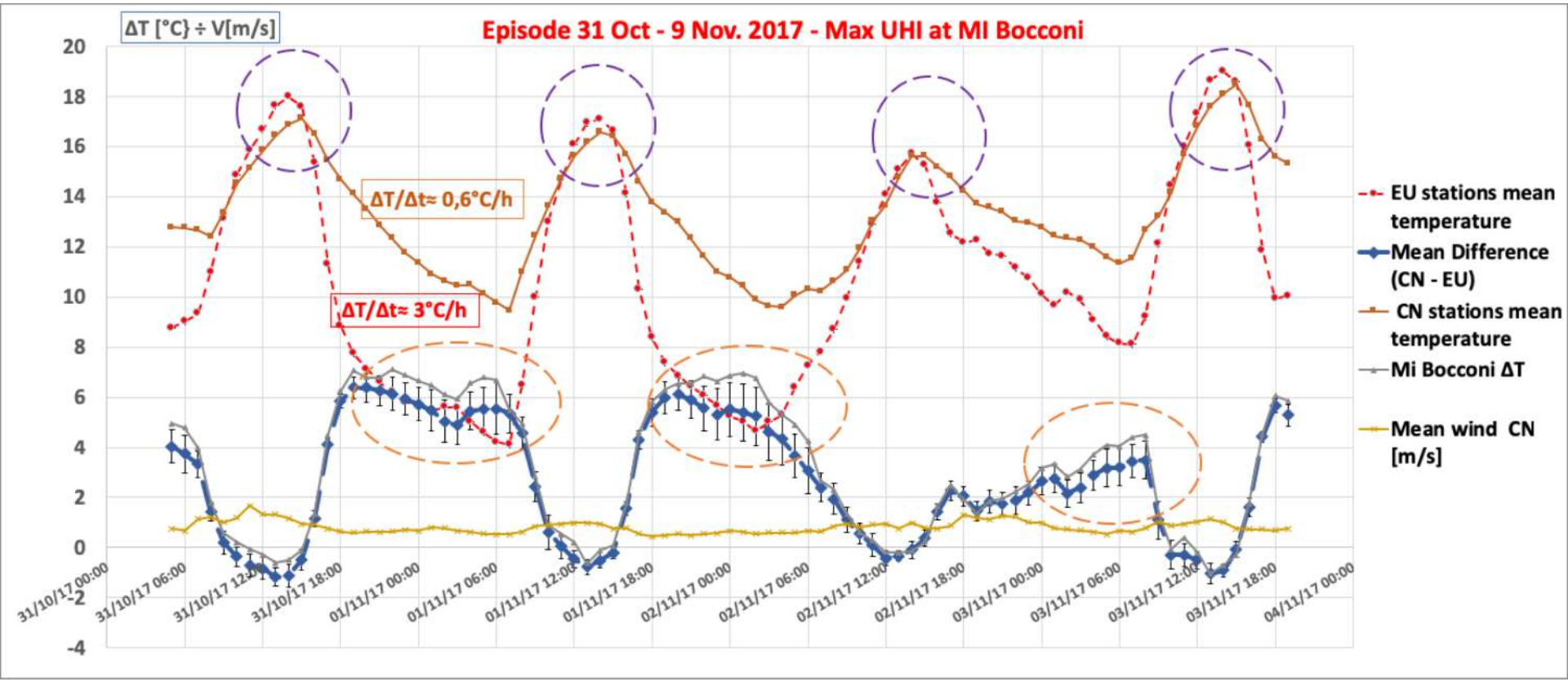
  At least a few consecutive hours

  Persistence for several days

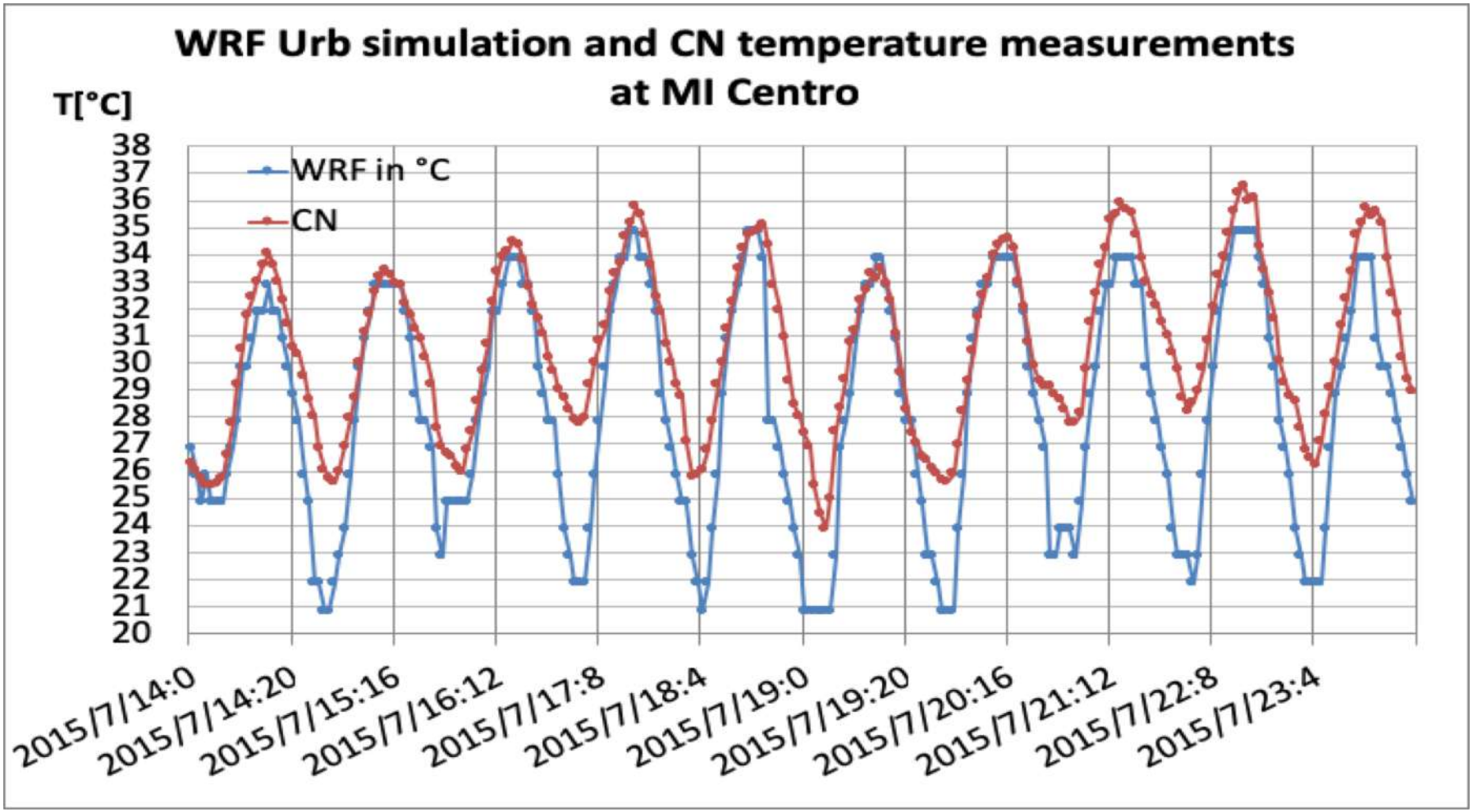
⇒ choise: $\Delta t \geqslant 6$ hours in at least 2 consecutive days

Fall Event with max UHI at MI Bocconi

Very different cooling rate in the evening between city and rural environment



Numerical modelling



S. Falasca and G. Curci, *Urban Sci.:*Impact of Highly Reflective Materials on Meteorology, PM10 and Ozone in Urban Areas: A Modeling Study with WRF-CHIMERE at High Resolution over Milan (Italy) 2018, *2*, 18; doi:10.3390/urbansci2010018

Conclusions

- UHI Methodology developed …
- …. and tested by a dedicated urban network (CN)
- Updated Milano Canopy UHI climatology obtained by "in situ" measurements
- Milano UHI found to be dependent on distance from city centre, not by LCZ

Next (in the framework of CLIMAMI Project): https://www.progettoclimami.it/

- *Detailed comparison with Sat. observations and Numerical Model outputs*
- *Integration of crowdsource/low cost sensor measurements*


Tahk you