The urban "Climate Network®" *temperature* interpolation at the site of Milano- Brera historical series

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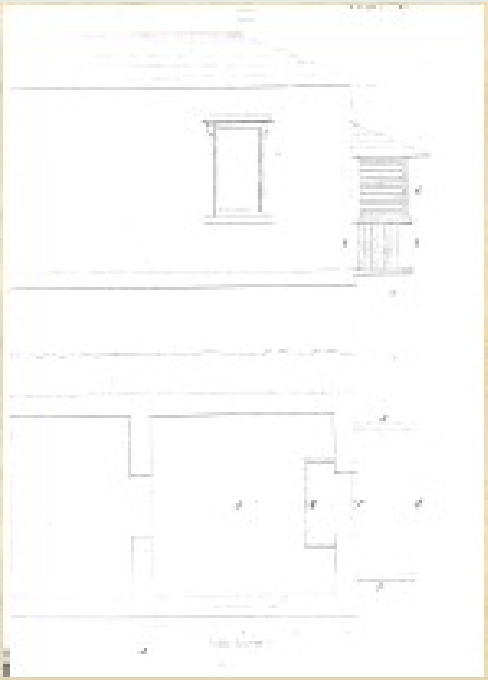
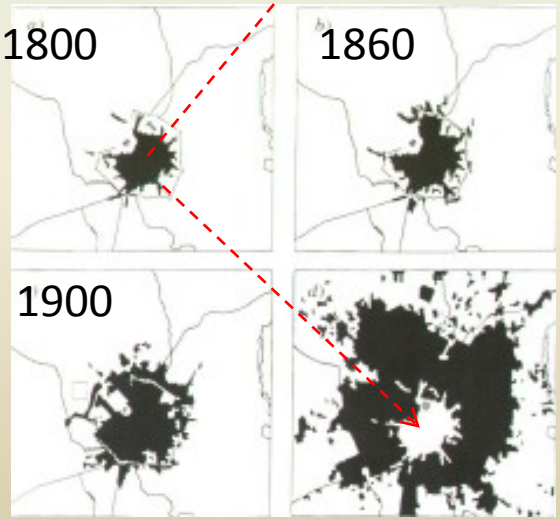
EMS2013-180 (ASI10)

Milano historical series

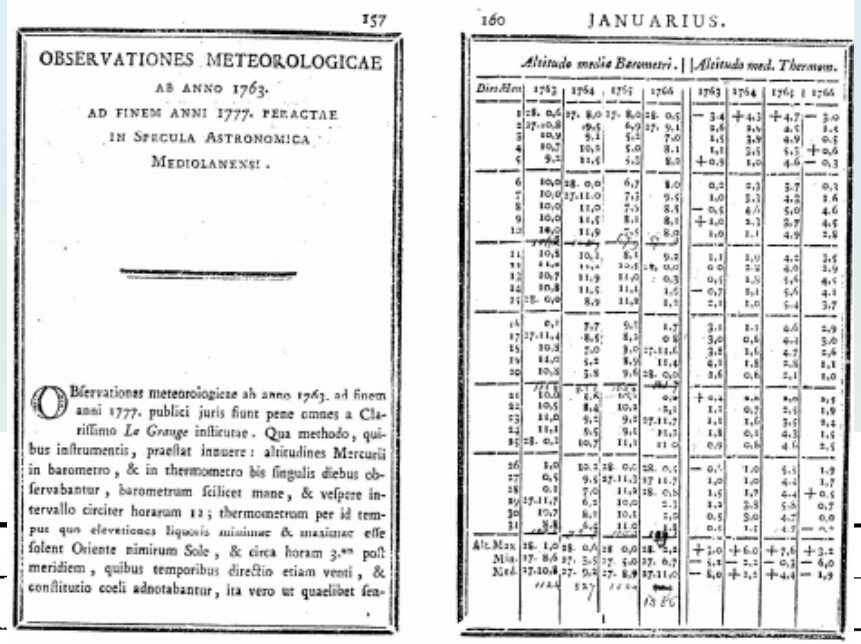
Palazzo Brera in Milano:
meteorological measurements since 1763





Adapted from Maugeri, 2013

Milano temperature historical series



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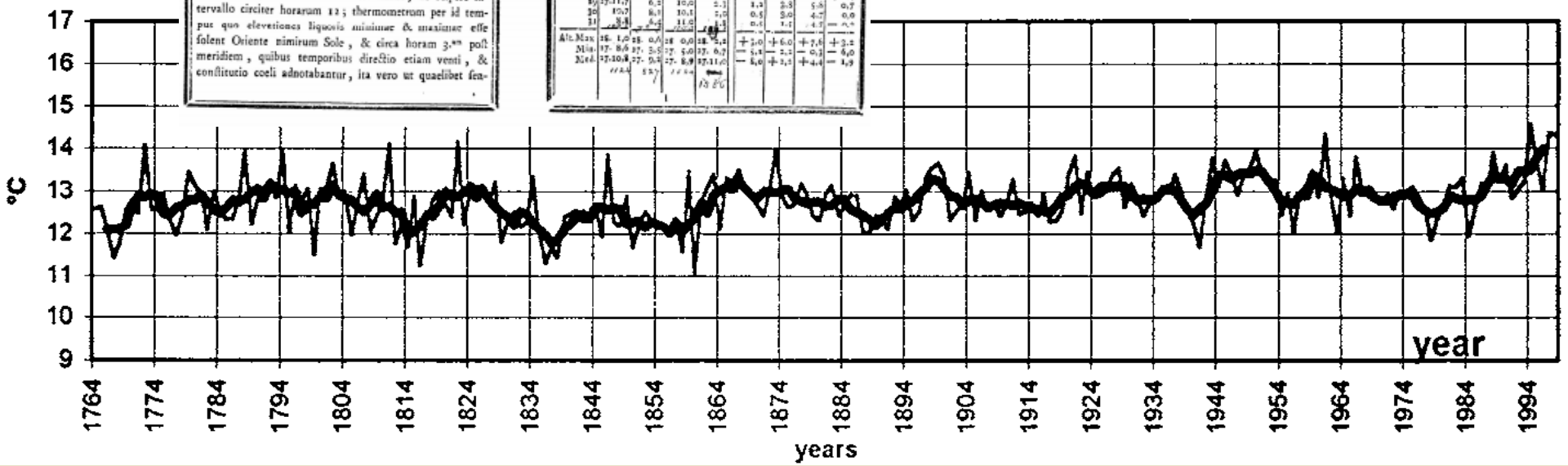
OBSERVATIONES METEOROLOGICAE
AB ANNO 1763.
AD FINEM ANNI 1777. PERACTAE
IN SPECULA ASTRONOMICA
MEDIOLANENSI.

Observationes meteorologicae ab anno 1763. ad finem anni 1777. publici juris fiunt pene omnes a Clarissimo *Le Grange* institutae. Qua methodo, quibus instrumentis, praestat innuere: altitudines Mercurii in barometro, & in thermometro bis singulis diebus observabantur, barometrum scilicet mane, & vespere intervallo circiter horarum 12; thermometrum per id tempus quo elevationes liquoris minimae & maximae esse solent Oriente nimirum Sole, & circa horam 3.am post meridiem, quibus temporibus directio etiam venti, & constitutio coeli adnotabantur, ita vero ut quaelibet sen-

160 JANUARIUS.

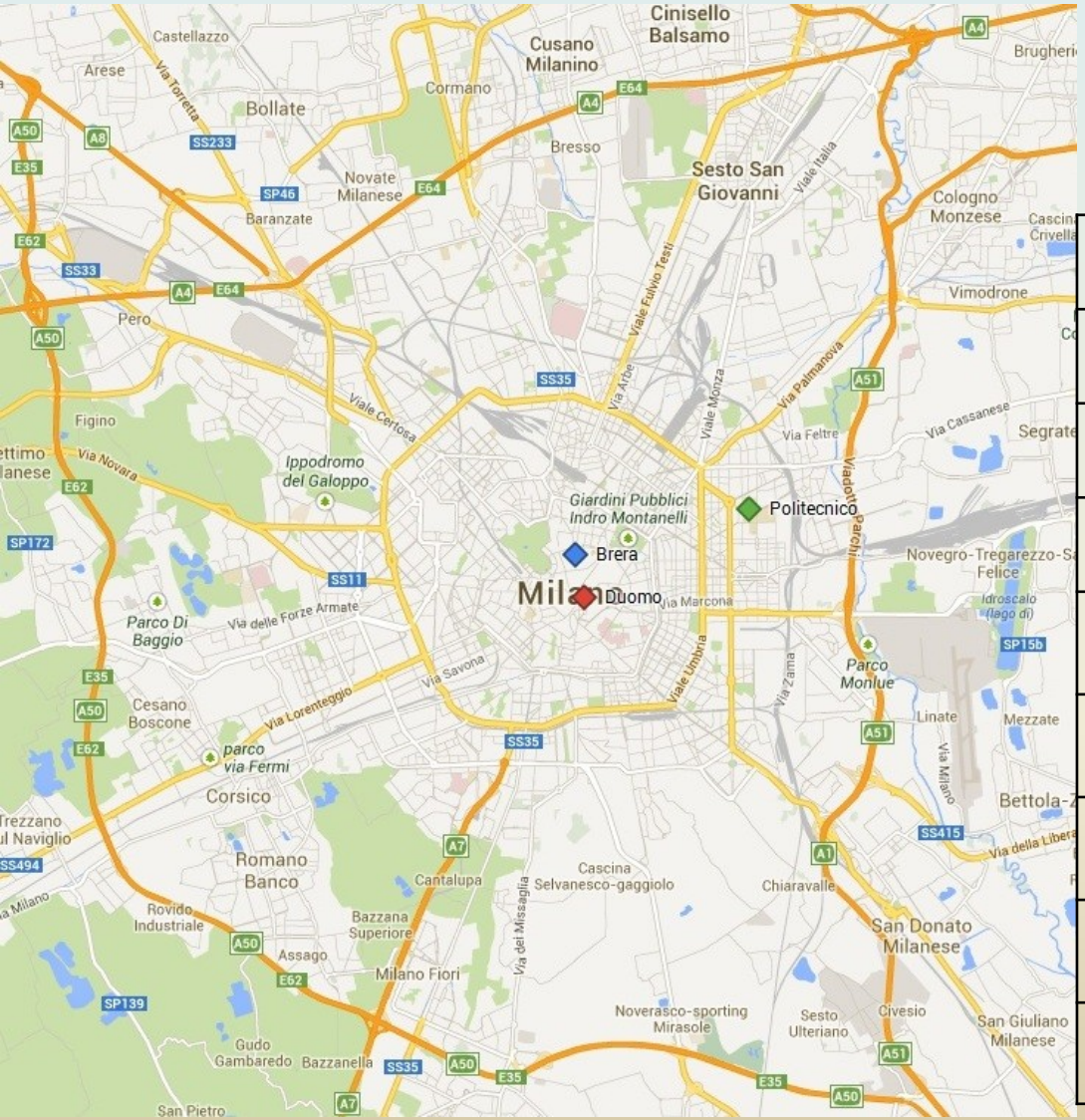
Dies Men	Altitudo media Barometri. 1763	1764	1765	1766	Altitudo med. Thermom. 1763	1764	1765	1766
1	28. 0,6	27. 8,0	27. 8,0	28. 0,5	− 3,4	+ 4,3	+ 4,7	− 3,0
2	27. 0,8	9,5	8,9	27. 9,1	2,6	2,6	4,5	1,5
3	10,9	9,1	9,1	7,0	1,1	3,9	4,9	0,5
4	10,7	10,5	9,0	8,1	1,1	3,5	5,1	+ 0,6
5	9,2	11,5	9,2	8,0	+ 0,5	1,0	4,6	− 0,3
6	10,0	28. 0,0	6,7	8,0	0,2	2,3	3,7	0,1
7	10,0	27. 11,0	7,1	9,5	1,0	3,1	4,2	1,6
8	10,0	11,0	7,9	8,5	− 0,5	4,0	5,0	4,6
9	10,0	11,5	8,1	8,1	+ 1,0	2,3	2,7	4,5
10	10,0	11,9	7,5	8,0	1,0	1,1	4,9	2,8
11	10,5	10,1	8,1	9,2	1,1	1,0	4,2	3,5
12	11,0	11,0	10,5	28. 0,0	0,0	2,2	4,0	2,9
13	10,7	11,9	11,0	0,3	0,1	1,5	1,6	4,1
14	10,8	11,5	11,1	1,5	− 0,7	2,1	5,6	4,1
15	28. 0,0	8,9	11,8	1,1	2,1	1,0	5,4	3,7
16	0,1	7,7	9,1	1,7	3,1	1,1	0,6	2,9
17	27. 11,4	8,5	8,1	0,8	3,0	0,6	0,1	3,0
18	10,3	7,0	8,0	27. 11,6	3,8	1,6	4,7	2,6
19	11,0	5,2	8,6	11,4	4,1	1,8	2,3	1,1
20	10,8	5,8	9,6	28. 0,0	3,6	0,6	2,1	1,0
21	10,3	6,6	10,5	0,4	+ 0,4	0,0	2,0	2,3
22	10,5	8,4	10,9	1,1	1,1	0,7	2,1	1,9
23	11,0	9,7	9,2	27. 11,7	1,6	1,6	3,3	2,4
24	11,1	9,5	9,1	11,2	1,8	0,1	4,1	1,5
25	28. 0,1	10,7	11,1	11,0	0,9	0,6	4,1	2,5
26	1,0	10,1	28. 0,0	28. 0,5	− 0,1	1,0	5,5	1,9
27	0,5	9,5	27. 11,3	27. 11,7	1,0	1,0	4,1	1,7
28	0,1	7,0	11,9	28. 0,0	1,5	1,9	4,4	+ 0,5
29	27. 11,7	6,2	10,0	2,1	1,2	2,5	5,0	0,7
30	10,7	8,1	10,1	2,0	0,5	3,0	4,7	0,0
31	9,8	8,5	11,0	1,8	0,1	1,7	4,7	− 0,1
Alt. Max	28. 1,0	28. 0,0	28 0,0	28. 2,1	+ 3,0	+ 6,0	+ 7,6	+ 3,2
Min	27. 8,6	27. 5,5	27. 5,0	27. 6,7	− 5,1	− 2,2	− 0,1	− 6,0
Med.	27. 10,8	27. 9,6	27. 8,9	27. 11,0	− 1,0	+ 2,1	+ 4,4	− 1,9



Homogenised Milan daily mean temperature series (thin lines) and 5-years moving averages (adapted from Buffoni et al., 2002).

See also: Camuffo, D. and P. Jones, 2002: Improved Understanding of Past Climatic Variability from Early Daily European Instrumental Sources, Kluwer Academic Publishers

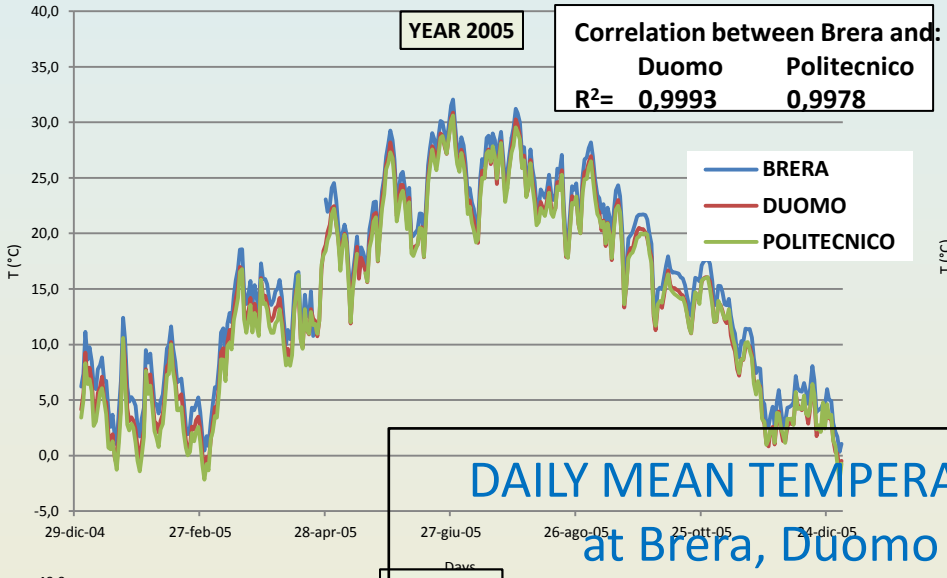
Recent overlap with other stations

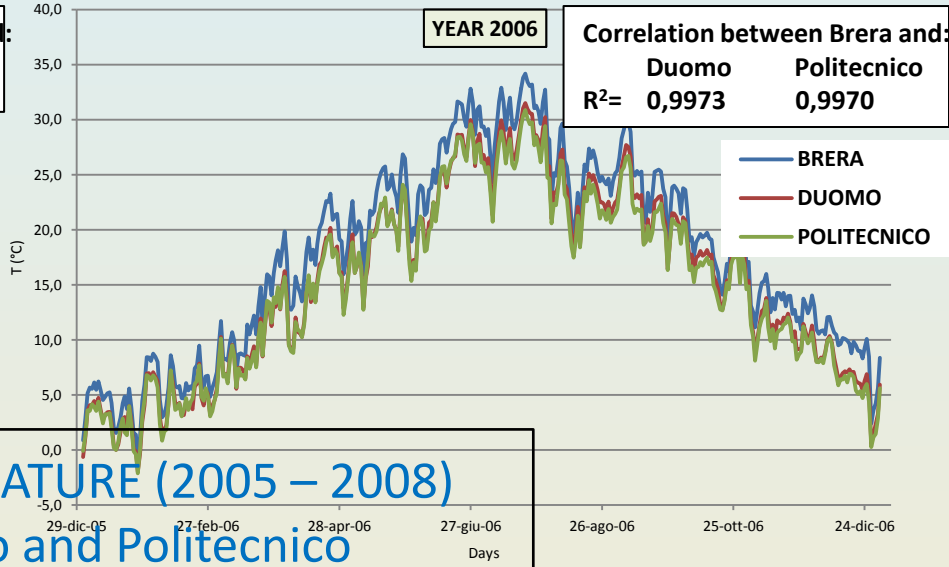


Directly managed by Osservatorio Meteo Duomo (OMD): http://www.meteoduomo.it/

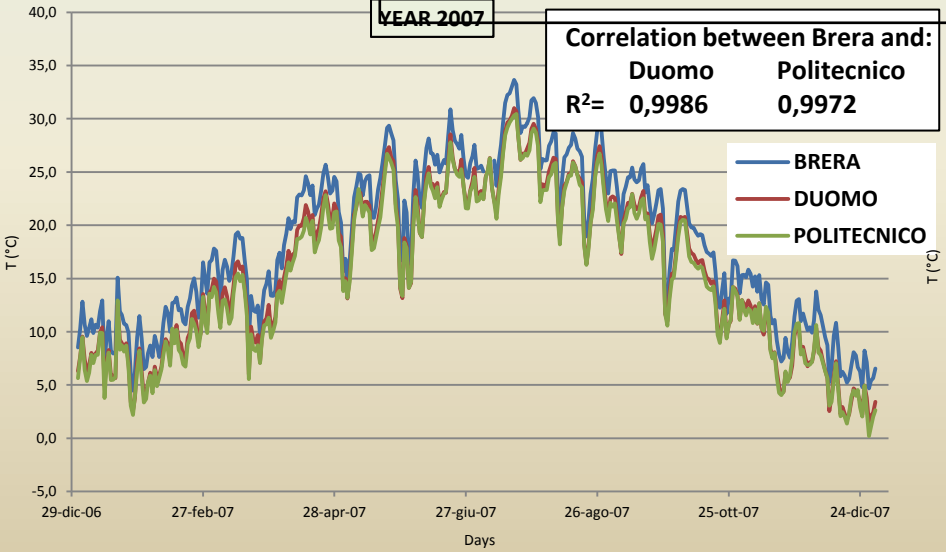
YEARS	BRERA	DUOMO	POLITECNICO
2002	Since 03/06/02		
2003			
2004			Since 24/09/04
2005			
2006		OVERLAP INTERVAL	
2007			
2008			
2009		Until 30/07/09	

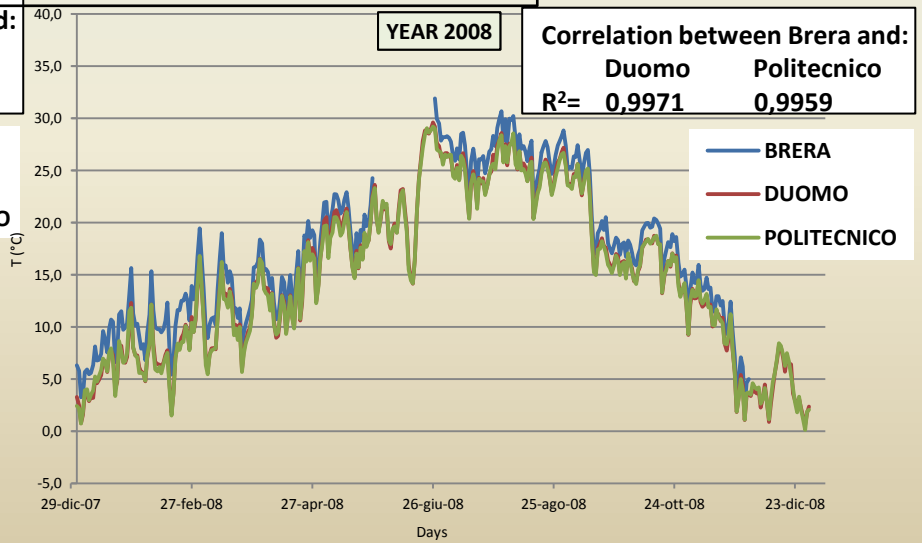
Comparison of TM-series





DAILY MEAN TEMPERATURE (2005 – 2008)
at Brera, Duomo and Politecnico





Continuing the time series in Brera...?

- The correlation, expressed by is on average (2005 – 2008) :

  R^2 = 0.9981 for Brera–Duomo: close proximity and more similar microclimatic conditions

  R^2 = 0.9970 for Brera–Politecnico
- No definite seasonality.
- Trends Duomo – Politecnico more constant and regular during the year

  - However, much remains to be investigated about continuous or occasional deviations between the different data sets (many factors: microclimate, instrumental, etc.) → **Work in progress!**

- Others Stations (even if less documented)?

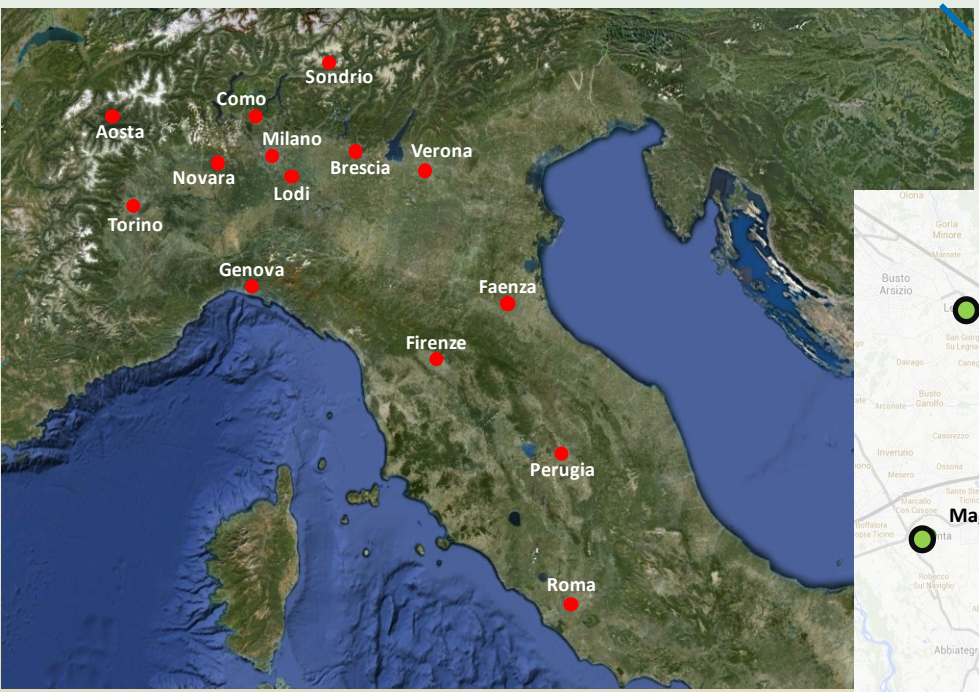
- And after 2008? - **Climate Network®** since 2011 (C01, C02,…)
  - **Politecnico**: continuing as a **CN station** (C06) since 2011

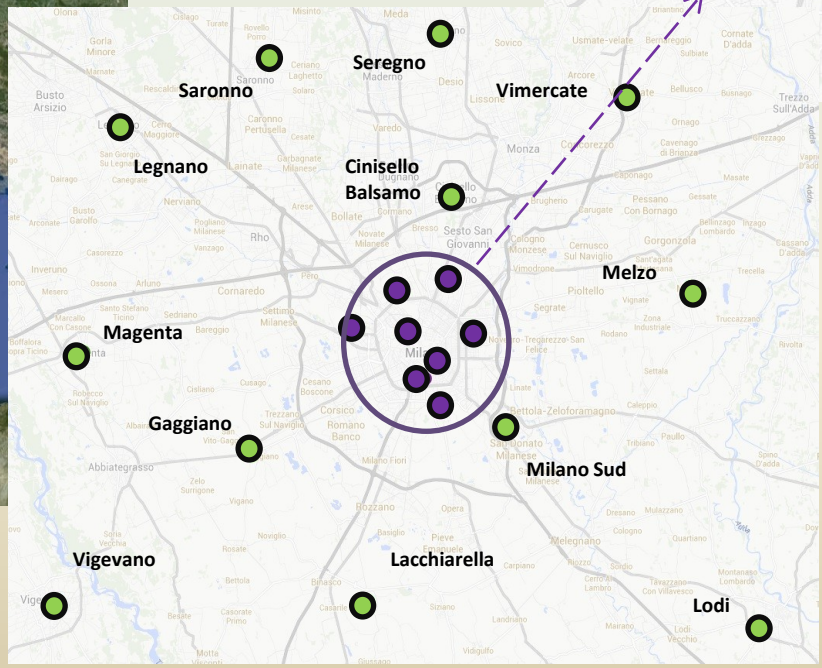
The Climate Network® (CN)

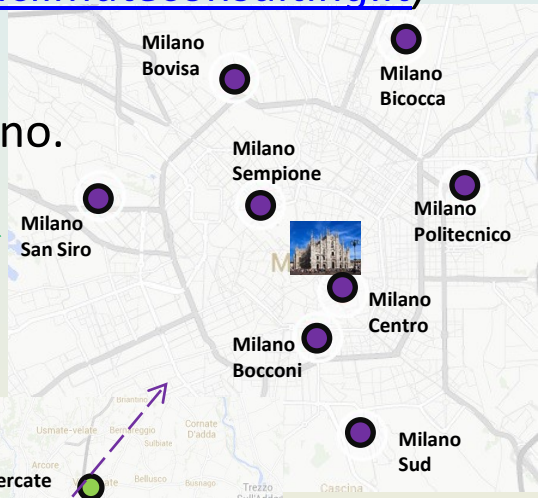
Set up and managed by **Climate Consulting srl**, Milano (*www.climateconsulting.it*)

Network implementation until now (summer 2013):

nationwide and .... around and downtown Milano.







CN tasks and siting criteria

- Task: measures of **Urban canopy layer** (UCL) for (urban) energy applications, more exactly the urban roughness sublayer (building top height)
- Sites: – urban sites, building roofs, free of very local effects
  – fulfilling **WMO/TD-No. 1250 2006** requirements
  – only in few cases logistics conditioned!
- Traceability: – related to a reference through a documented and unbroken chain of calibrations (T, RH)
  – developed in the framework of and with reference to **EURAMET/METEOMET Project**

More details in talk EMS2013-189 (ASI6)

and in Poster EMS2013-296-GF61 (ASI6)

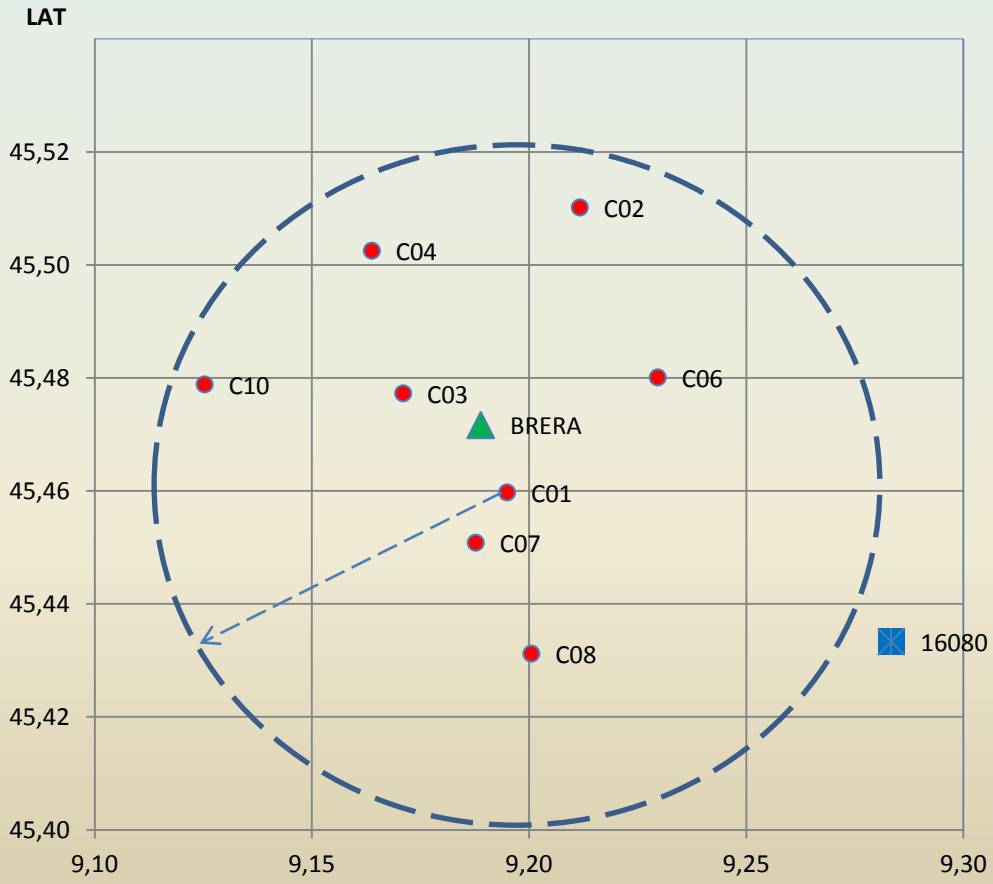
The Climate Network® downtown Milano since 2011

Operations since:

C01 (Mi Centro): 21/07/2011
C02 (Mi Bicocca): 30/11/2012
C03 (Mi Sempione): 01/07/2011
C04 (Mi Bovisa): 16/09/2011
C06 (Mi Politecnico): 10/03/2011
C07 (Mi Bocconi): 25/06/2012
C08 (Mi Sud): 15/12/2011
C10 (Mi San Siro): 07/10/2011

Old Politecnico: → C06!

Climate Network® in Milano in a radius of about 7 km centered on C01 (Mi Centro)



Network check by interpolation and comparison with measurements

- Overall check of the network capabilities
- Using only 2012-'13 **daily data by CN**
- Variables: Tn, TM, Tx, RH, R, W
- Interpolation: **at each CN site**, excluding that station
- Method: weighted mean with weights as **squared distance** up to a maximum radius of 30 km *and with a minimum (3) and maximum (7) of interpolating stations by recursive range increments of 3 km each*

$$\widehat{X_n} = \sum_{1}^{N-1} W_i \cdot X_i$$

$$W_i = \frac{(R - d_i)^2}{\sum_1^{N-1}(R - d_i)^2} \qquad d_i < R$$

$$W_i = 0 \qquad d_i \geq R$$

where: $n \neq i$ (exclusion of the station to be interpolated)
and N the total number of stations available

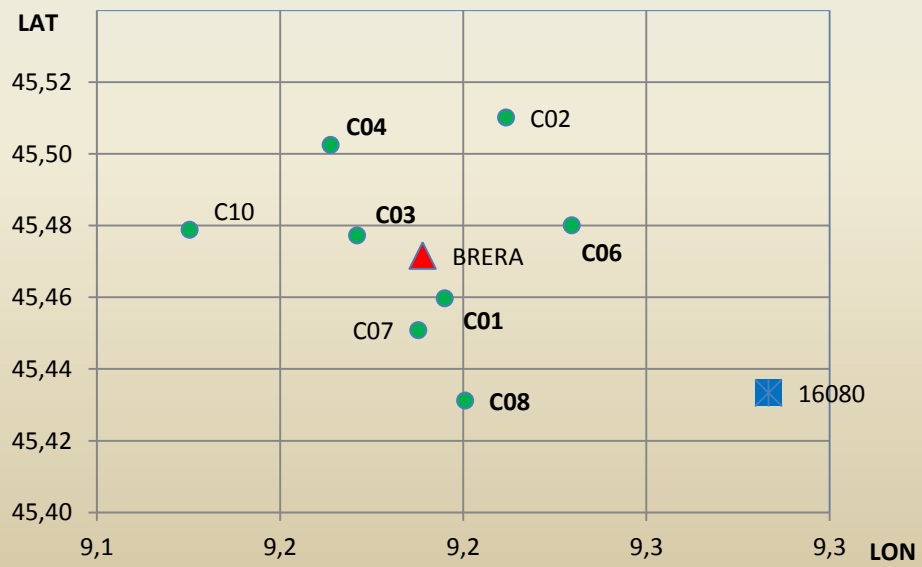
General results for daily mean temperature (TM)

Month	*Jun '12*	*Jul '12*	*Aug '12*	*Sep '12*	*Oct '12*	*Nov '12*	*Dec '12*	*Jan '13*	*Feb '13*	*Mar '13*	*Apr '13*	*May '13*
I-M (metrop. Milano)	**0,11**	**0,15**	**0,16**	**0,15**	**0,18**	**0,13**	**0,20**	**0,18**	**0,20**	**0,16**	**0,12**	**0,06**
Nr. of interpolating Stations	18	19	19	19	20	20	20	20	20	20	20	20
I-M (Milano downtown)	**0,04**	**0,09**	**0,08**	**0,06**	**0,06**	**0,08**	**0,12**	**0,12**	**0,09**	**0,08**	**0,06**	**0,07**
Nr. of interpolating Stations	8	8	8	8	8	8	8	8	8	8	8	8

The 8 stations in the more homogeneous Downtown Milano area (in **green** in the above table and in the map).

For comparison, **Brera** site and the synoptic station **16080** (at Linate Airport)

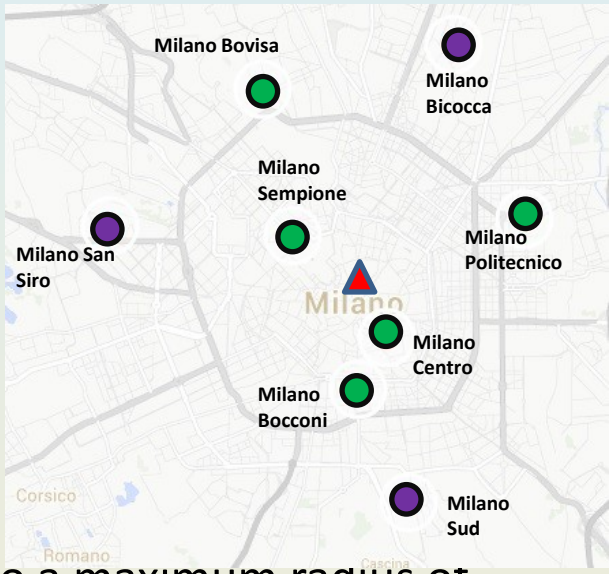
Climate Network® in Milano



Results for Temperatures

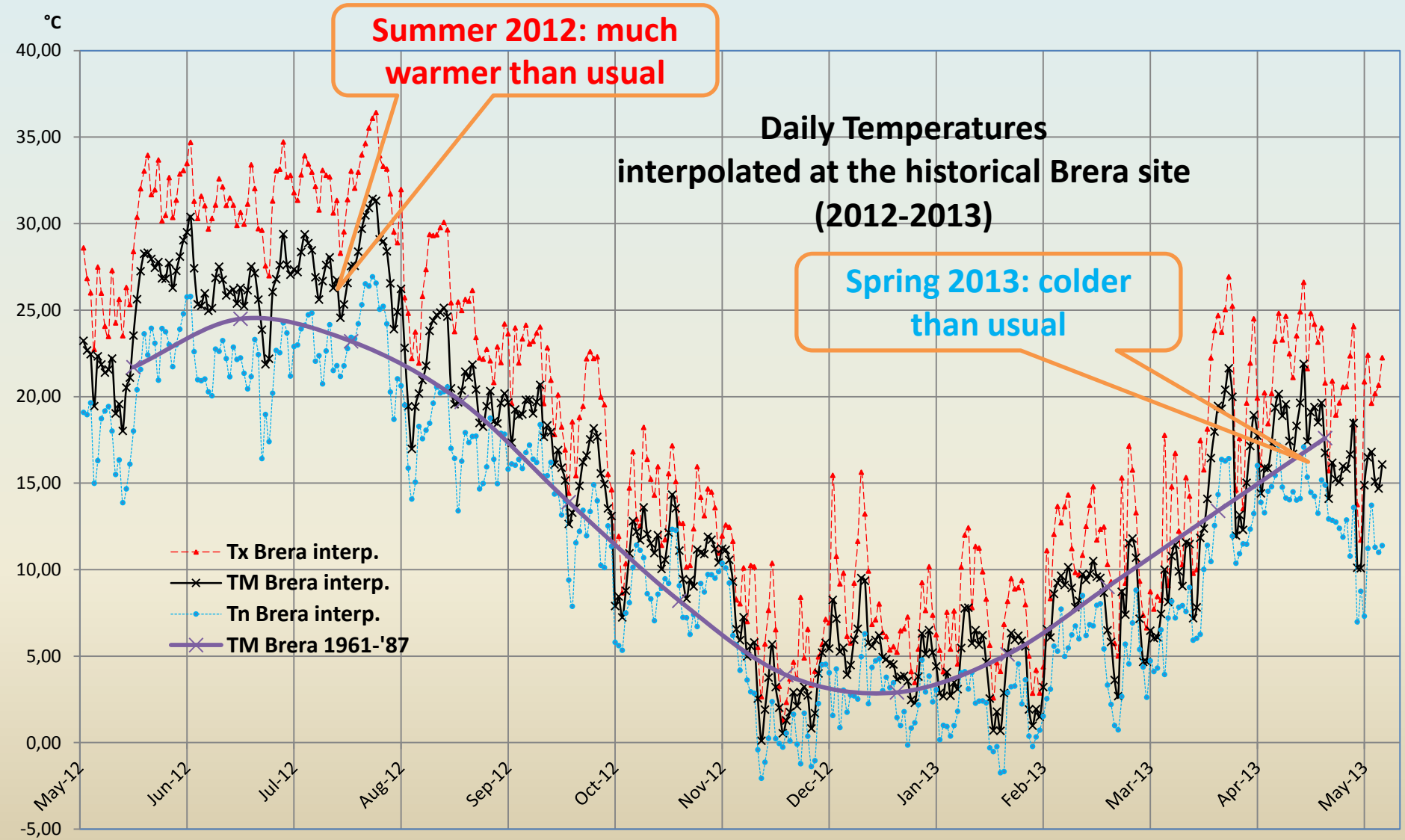
[°C]				Mean Temperature		Min. Temperature		Max. Temperature	
Climate Network® Code	Name	Interp. Radius R [km]	Nr. of interpol. Stations	Yearly mean diff. (I-M)	σ	Yearly mean diff. (I-M)	σ	Yearly mean diff. (I-M)	σ
C06	**MI-Politecnico**	5	5	0,14	0,23	0,04	0,40	0,28	0,43
C04	**MI-Bovisa**	6	7	0,01	0,21	0,27	0,48	-0,35	0,35
C03	**MI-C.so Sempione**	5	5	-0,16	0,19	-0,32	0,34	0,19	0,51
C01	**MI-Centro**	6	7	-0,24	0,24	-0,30	0,35	-0,21	0,37
C10	**MI-San Siro**	7	7	**0,61**	0,30	**0,64**	0,41	0,35	0,73
C08	**MI-Sud**	6	5	0,42	0,31	**0,57**	0,58	0,17	0,48
C07	**MI-Bocconi**	6	5	-0,20	0,18	-0,23	0,33	-0,15	0,36
C02	**Milano Bicocca**	6	6	0,05	0,15	0,14	0,32	-0,14	0,38
C15	Gaggiano	14	6	0,41	0,61	**0,81**	0,94	0,04	0,88
C16	Magenta	23	7	0,03	0,31	0,17	0,49	-0,16	0,58
C11	Cinisello	10	5	0,20	0,20	0,35	0,41	0,01	0,41
C19	Seregno	17	5	0,03	0,30	0,10	0,39	-0,13	0,57
C20	Vimercate	18	5	0,50	0,33	**0,82**	0,58	0,00	0,61
C22	Lodi	28	6	0,32	0,48	**0,57**	0,75	-0,15	0,90
C12	Melzo	17	5	0,02	0,33	-0,02	0,50	0,23	0,72
C14	Lacchiarella	17	5	**0,54**	0,46	**0,70**	0,74	0,19	0,79
C26	Saronno	19	5	**1,03**	0,43	**1,68**	0,87	0,17	0,53
C17	Legnano	23	5	**-0,55**	0,53	**-1,08**	0,81	0,21	0,80
C23	Vigevano	30	6	-0,23	0,30	-0,27	0,48	-0,48	0,78
C13	S. Donato M.	7	5	**0,66**	0,58	**1,08**	0,90	0,17	0,80

CN interpolation at Brera site



- Method: using only a selected subset of CN 2012-'13 data, stations **C01, C03, C04, C06, C07** (the nearest and/or best performing ones)
- Measures: mean daily values
- Interpolation: as before, **squared distance method** up to a maximum radius of 30 km *and with a minimum (3) and maximum (7) of interpolating stations by recursive range increments of 3 km each*
- Variables: **Mean, minimum and maximum Temperature, Mean Relative Humidity, total Precipitation, mean Wind intensity**
- Results: **2012-'13 time series** of all the variables interpolated at Brera

Brera 2012-’13 Daily Temperatures



CN measuring uncertainty

Three different contributions (T):

- **Calibration uncertainty** – defined by the traceability chain using the air in a climatic chamber as transfer standard medium:

$$\sigma_c \approx \mathbf{0{,}18}\ °C \text{ for Temperature,}$$

- **Measurement uncertainty** – also effect of ventilated or not ventilated screens, screen ageing, minimum variability among identical thermometers, etc.:

$$\sigma_m = [(\sigma_c)^2 + (\mathbf{0{,}18}°C)^2]^{1/2} \approx \mathbf{0{,}25°C} \text{ for Temperature}$$

Above results from: G. Lopardo, F. Bertiglia, S. Curci, G. Roggero, A. Merlone "***Comparative analysis of the influence of solar radiation screen ageing on temperature measurements by means of weather Stations***", International Journal of Climatology, 2013, DOI: 10.1002/joc.3765

- **Measurand definition uncertainty** – site effects of meteorological stations in urban environment (Urban Canopy Layer):

?

  - Estimate by indirect methods: **interpolation by nearby stations**

Interpolation uncertainty

For the daily mean temperature:

- with the relative **large number** of measuring stations (up to 20)
- in the **small area** of Milano (R= 30km, or 7 km downtown)
- using the weighted mean interpolation
- in the 1-y time interval June 2012 – May 2013

➢ the standard deviation obtained is:

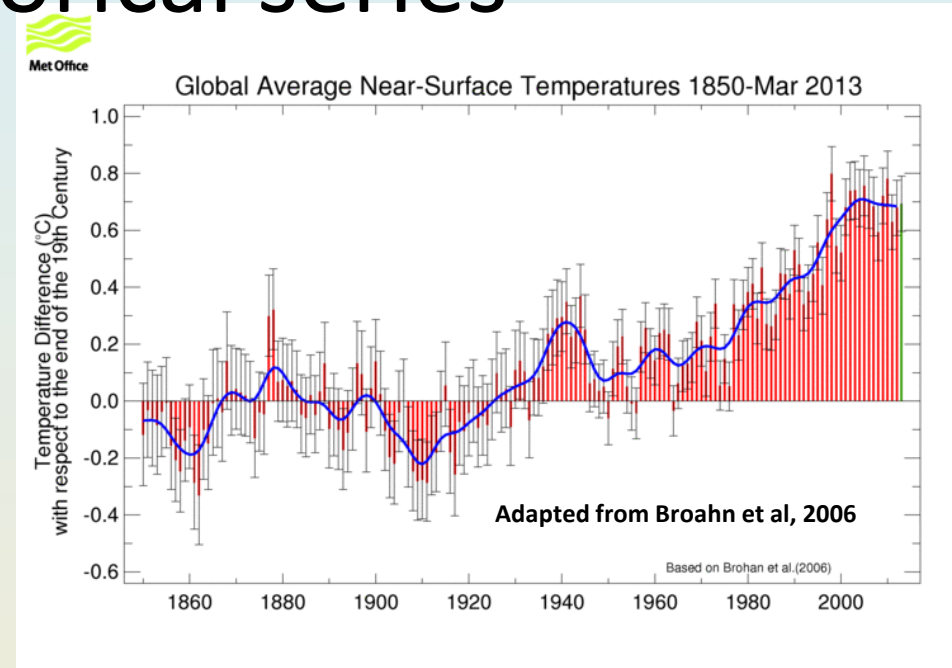
a) for **all stations** (**metrop. area**)

$\sigma_I \approx$ **0,95 °C**

b) for the **5 downtown selected stations (Brera)**

$\sigma_I \approx$ **0,24 °C**

Uncertainty in historical series



- Metadata uncertainties
- Homogenization procedures
- Urbanization effects
- Climate Change

Some concern only in recent years:

- Peter W. **Thorne** et al., A quantification of uncertainties in historical tropical tropospheric temperature trends from radiosondes, JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 116, 2011
- P. **Brohan** et al., Uncertainty estimates in regional and global observed temperature changes: a new dataset from 1850, J. Geophys. Res., 111, 2006

→ Estimates **comparable** or even larger than

Climate Network® uncertainties for **Brera**

Conclusions

- **Climate Network®** has proven to measure **correctly and efficiently** the Milano UCL
- **Uncertainties** are **generally small** due to an accurate calibration chain and a homogeneous siting
- Mean **uncertainties in interpolated data** are also **generally small** over Milano, **compatible** to the measure uncertainties and **comparable** to uncertainties of homogenized time series
  - ***Therefore, interpolating at Brera using Climate Network® data seems a viable way to continue with sufficient accuracy the Milano historical series.***

- **Further work**: - complete reconstruction of data and metadata since 2008 (stop at Brera) and 2011 (start of Climate Network®)
  - statistical tests of historical and interpolated time series to better assess the quality of the interpolated ones
  - examine behaviour of other variables also at a shorter resolution (CN 10 min data)

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Thank you!

www.climateconsulting.it