DESIGN AND MANAGEMENT OF THE ITALIAN URBAN WEATHER NETWORK BY FONDAZIONE OSSERVATORIO METEOROLOGICO MILANO DUOMO

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FONDAZIONE OMD

How to designed a weather stations network to get high quality measure and comparable data and to contain management costs ?

Generally, the set up of a weather stations network has to meet both technical and operational requirements and it has to take into account the overall cost over time.

It's a tough balance, but it can be achieved with appropriate design choices:

1. **Standardization** of the network, i.e. same station model with equal sensors, data logger, power supply, software and data transmission protocol
2. **Digital sensor** (i.e. digital output) easily removable and replaceable with another maintened and calibrated sensor of the same type
3. **Its own traceability chain**: depending on the number of stations, it may be more convenient to perform the calibration process internally
4. **Traceability of data**: each data record must contain a time stamp, the station code, the sensor serial number, the corrected measurement value, the calibration parameters and possibly the raw measurement value. It must always be possible to rectify data values with new calibration parameters if it is necessary.
5. **Redundancy**. With reference to the most important weather parameter for network purposes, a redundant sensor keeps controlled any drift and malfunctions.

These requirements can be applied also in the case of a small number of stations.

Climate Network®: a new Italian urban network

Climate Network® (CN) is a private professional network of Automatic Weather Stations (AWS) in Italy, currently accounting for almost 50 stations located in the main Italian cities.

The network can be considered the technological evolution of the historical urban climate observatories, whose weather stations had been located on top of buildings, and it contributes to the continuity of urban historical climate series. CN also supports business users, such as energy industries requiring continuous supply of comparable and high quality weather/climate data in main Italian towns to bill energy consumption and evaluate performances of thermal plants and air conditioning systems.

It was planned in 2010 to meet the following requirements:

CN homogeneity:
– same type of weather sensors
– internal calibration laboratory
– same calibration method and standards for all sensors
– same Control and Assurance Quality procedures
– daily data validation by meteorologists

CN target and task:
– continuity with past climate data
– measurement at top Urban Canopy Layer
– measurement of Urban Heat Island
– applied meteorology and climatology (public health, energy, insurance, finance, …)

CN siting criteria:
– urban sites, building roof terrace free of very local effects, fulfilling WMO/TD-No. 1250 2006 requirements *(… but in some cases logistics conditioned !)*

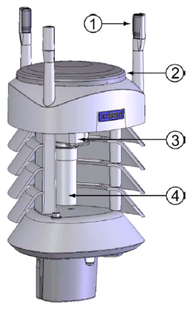
OMD Foundation is a collaborator

METEOMET
Metrology for Meteorology

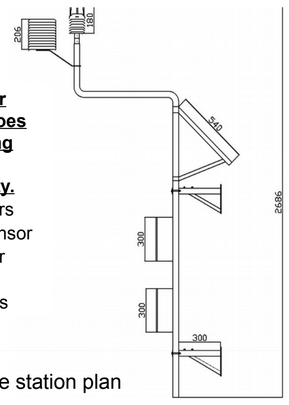
Metrology for pressure, temperature, humidity and airspeed in the atmosphere

Homogeneity by standardization in order to get comparable data

Comparability is the level of confidence we get when different data series are compared. It results, for example, when we compare temperatures in city centers to temperatures in peripheral areas in order to determine the presence of a urban heat island (UHI) effect.
We have to compare data not only referring to different sites or cities but also to different time intervals, for example assessing the evolution of temperatures in decades in climatological studies.
One of the goal of Climate Network is building climatic databases with the highest level of comparability among data. We can obtain this goal, standardizing hardware and software of our stations and using identical and documented criteria in weather station positioning.



Weather Trasmitter Vaisala WXT520 does not include moving parts and this increases reliability.
1 = Wind transducers
2 = Precipitation sensor
3 = Pressure sensor
4 = Humidity and temperature sensors



Some Climate Network meteorological stations with their Weather Trasmitter Vaisala WXT520 and the station plan

Planning maintenance and calibration procedures

Any operating WTX520 must be maintened and calibrated once a year: how to do it better ? How to manage 50 stations distributed throughout Italy ?
We have WXT520 spares that allow us to replace up to 5 stations at a time according to a defined rotation scheme. Besides, 5 more WXT520 are always ready to replace malfunctioning ones in the meantime.

Make economies of scale

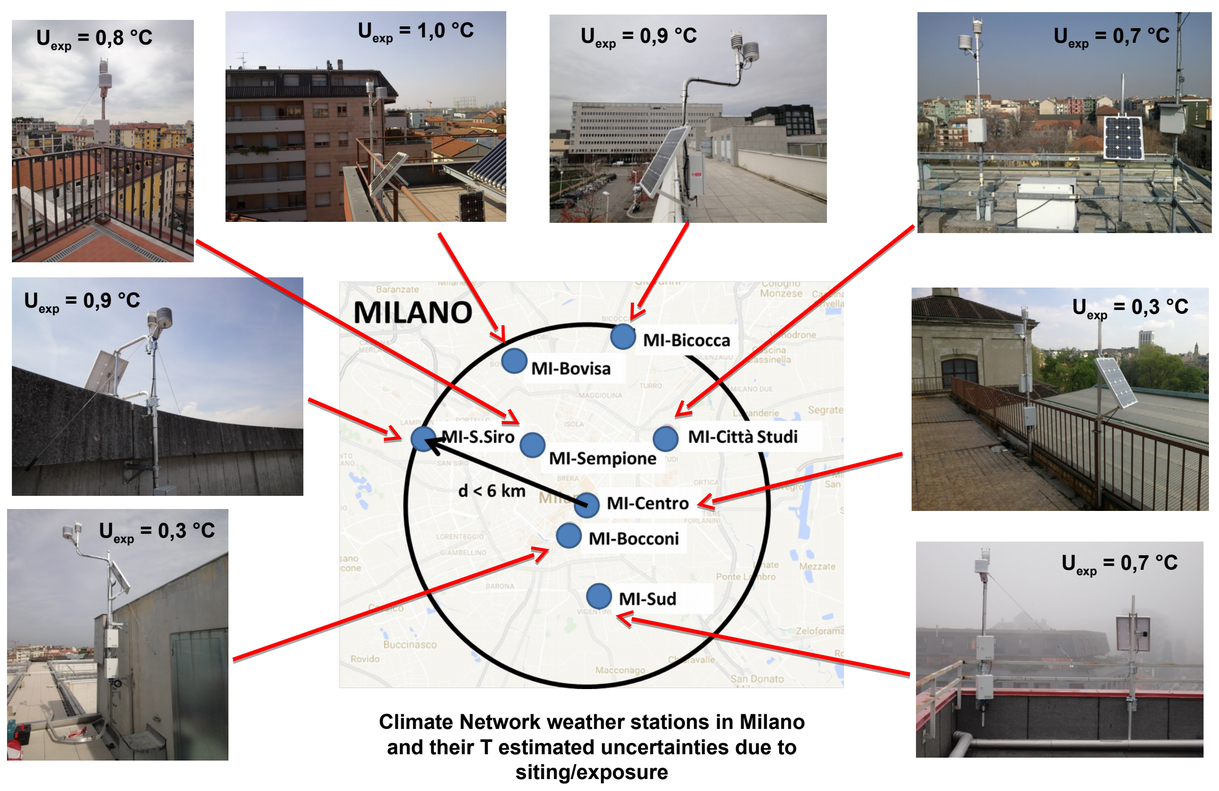
Standardization has another positive effect: maintenance procedures are facilitated because the warehouse spare parts are unique and the individual parts can be exchanged. For example cleaning, such as painting of yellow screens, can be performed in series.

Rotation of all WXT520s in calibration and maintenance

Installing a maintened and calibrated WXT520 — Meanwhile another WXT520 is maintened and calibrated in laboratory — After a year the new calibrated WXT520 substitutes the old one

Siting and representativity – Measurement uncertainty estimation

Urban areas are, from the climatic point of view, a sort of "hot spot" due to the urban heat island (UHI) effect. Thus we need a solid study base to position meteorological stations in cities. Thanks to the large number of CN stations in Milan, we could make a sort of validation of positioning criteria and general approach to the urban climate.
Statistical analysis of temperature differences respect to a suitable urban reference has been performed for a 3 years database, representative of meteorological conditions quite homogeneous in the area of study at synoptic and meso/local scale.
It revealed for some stations a strict dependence on explicitly defined exposure parameters, especially related to distance from underlying vertical walls exposed to solar irradiation and to shadowing.
Moreover, with clearly stated objectives (in our case: measurements at top UCL, homogeneous sensor technical characteristics, well documented technical, siting and exposure metadata and a correct metrological procedure), **the additional uncertainty on long term hourly averages of temperature due to siting/exposure has been estimated at less than 1°C also in the complex urban environments**. This is much less than the estimated 5°C uncertainty indicated by WMO Guide No.8, but significantly larger than the calibration uncertainty of about 0.2 °C.



Climate Network weather stations in Milano and their T estimated uncertainties due to siting/exposure

How to built a traceability chain

Traceability is the property of a measurement result, where the result can be related to a reference through a documented unbroken chain of calibrations each contributing to the measurement uncertainty.

Metrological traceability became a mandatory requirement after the signing of the CIPM-MRA (Mutual Recognition Agreement) by the WMO (World Meteorological Organization): every meteorological measure has to be related to national or international reference standards.

Our traceability chain starts from a Secondary Reference Platinum Resistance Thermometer (Fluke 5616), which has been calibrated together with his multimeter (Fluke Hydra 2620A) at a National Metrological Institute every 5 years. The first line standard and the multimeter are combined in a single equipment: they have been calibrated together in order to maintain a single measurement chain. The second line standards are three Resistance Thermometers (PT100 ohm in Class A according to IEC 751), used as transfer standards.

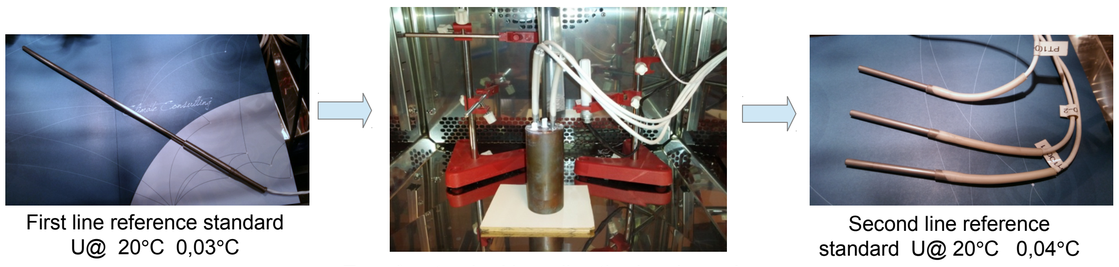
First step - calibration of the reference sample shall be performed at a National Metrological Institute

INRiM ISTITUTO NAZIONALE DI RICERCA METROLOGICA

Univerza v Ljubljani Fakulteta za elektrotehniko

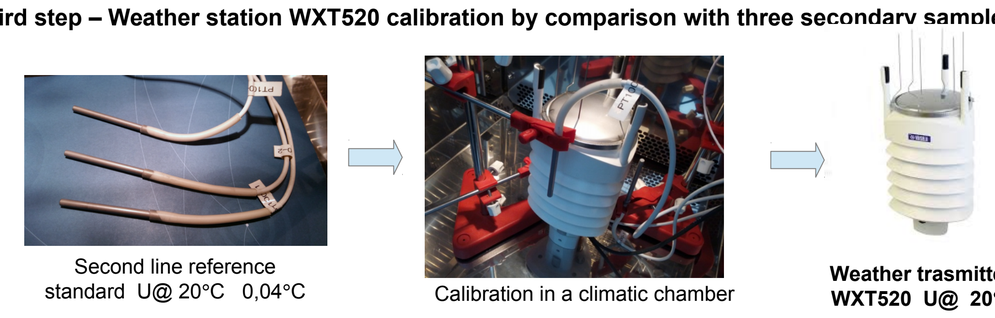
First line reference standard U@ 20°C 0,03°C

Second step – standard transfer to three secondary samples by comparison with the primary sample



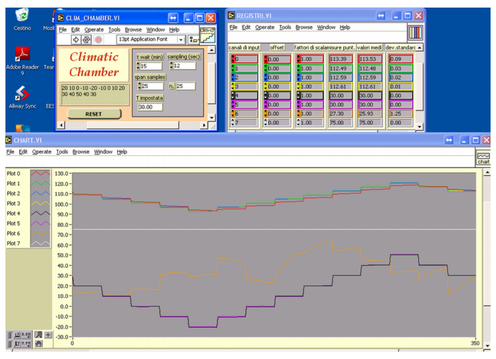
First line reference standard U@ 20°C 0,03°C — Transfer standard in a climatic chamber using a copper block comparator — Second line reference standard U@ 20°C 0,04°C

Third step – Weather station WXT520 calibration by comparison with three secondary sample

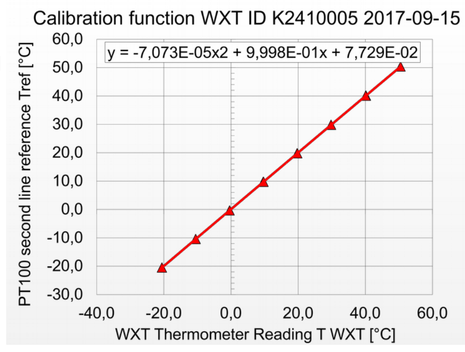


Second line reference standard U@ 20°C 0,04°C — Calibration in a climatic chamber — **Weather trasmitter Vaisala WXT520 U@ 20°C 0,2°C**

Standardization !!! Automated calibration process and standard calibration data format



The entire calibration cycle is handled by computers using a virtual tool, made with Labview®. Sampled data is downloaded to a standard format in an Excel® formatting module that provides data and provides correction parameters and calibration uncertainty.



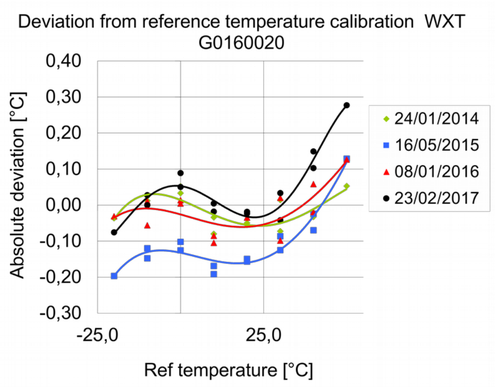
Calibration database in numbers

64 VAISALA WXT520, **50** OPERATING STATIONS, **274** WXTs CALIBRATIONS SINCE 2013, **3** TEMPERATURE FIRST LINE STANDARD CALIBRATIONS AT NATIONAL METROLOGICAL INSTITUTE, **7** INTERNAL TRANSFER STANDARD CALIBRATION FOR TEMPERATURE SECOND LINE STANDARD, **1** HIGROMETER AND **1** BAROMETER FIRST LINE STANDARD CALIBRATION AT SLOVENIAN METROLOGICAL INSTITUTE.

How to control such a large numbers of calibrations ?

WXT calibrations

Absolute measurement differences from reference temperature in calibration could be represent a sort of "fingerprint" of every WXT520. We expect it doesn't change but any significant variations should be investigated.



Second line reference calibrations

The regression function is a third degree polynomial. It is used to describe the calibration curve of the second line standard and to compared it to the first one.
We can check calibrations with a control chart for each parameters of the polynomial equation, using statistical method to detect any outlier.