A JOINT-METROLOGICAL AND CLIMATOLOGICAL APPROACH TO IMPROVE QUALITY OF CLIMATE TIME-SERIES

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Background

- Under the umbrella of the EU/EMRP-funded project "MeteoMet - Metrology for Meteorology" (www.meteomet.org), leaded by the INRiM (Torino, Italy) and aimed at ensuring the metrological traceability to the International System of Units (SI) in meteorological observations and climate data, the EMRP Research Grant (ENV07/REG5) was funded with the aim of exploring the impact in temperature data series of the changeover to AWS by combining and harmonising metrological and statistical homogenisation approaches.

- Conventional stations have been replaced by automatic weather stations (AWS) since the last third of the 20th century. This changeover has introduced systematic bias in temperature time-series that compromise their homogeneity and, therefore, their confident use in any climatic study.

- In 2006 the World Meteorological Organization (WMO) Commission for Basic Systems (CBS) stated that AWS introduction lead to an improvement in the observations and in the spatial resolution, but it could also bring negative effects such as the introduction of biases in historical series.

- Besides, the meteorological network managers, in the past and nowadays tend to not adopt the metrological procedures and the B-Type uncertainties associated with information on the measurements.

Objectives

- Analyse the impact of the introduction of uncalibrated and calibrated AWSs following metrological standard procedures in temperature series

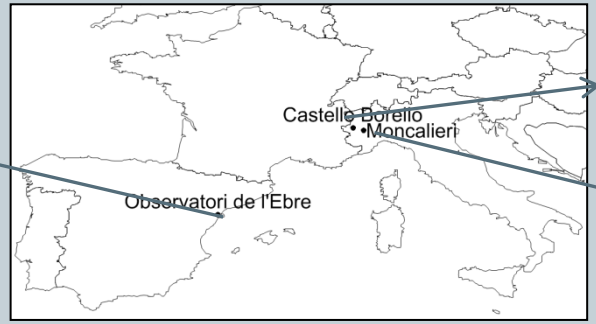
- Determine the impact of the introduction of the metrological standard procedures to ensure traceability to national standard of the recorded observations

Metrological and climatological concepts

- The WMO (1992) meteorological vocabulary defines **air temperature** as “the temperature indicated by a thermometer exposed to the air in a place sheltered from direct solar radiation”.
- In the CIMO Guide, **traceability** is defined as “a property of the result of a measurement or the value of a standard whereby it can be related to stated references, usually national or international standards, thorough an unbroken chain of comparisons all having stated uncertainties”
- **Measurement uncertainty** as a “non-negative parameter characterising the dispersion of the quantity values being attributed to a measurand based on the information used”. The **Type A uncertainty** is estimated by a statistical evaluation, whilst the **Type B** is evaluated based on the “practical” information.

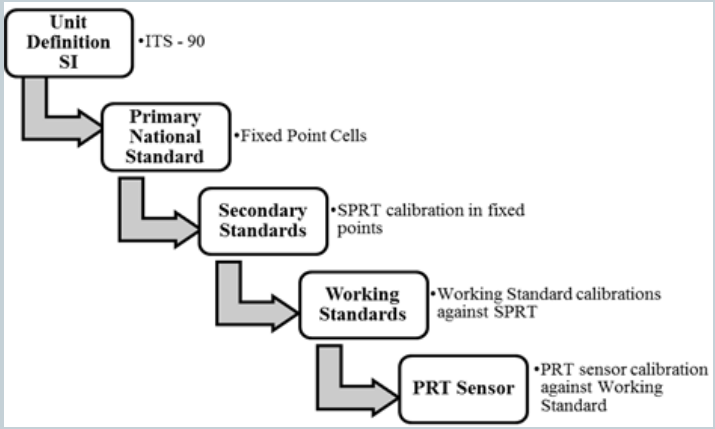
Field trials

- Three experimental sites:
  - Ebro's Observatory (Spain): a long-standing (1905 onwards) meteorological station. 22 years (1991 onwards) of paired temperature observations AWS uncalibrated and CON. From 01/06/2013 onwards also a observations from AWS calibrated at the Istituto Nazionale di Ricerca Metrologica (INRiM)
  - Observatory of the Società Meteorologica Italina in Castello Borello: located in a typical countryside, meteorological observations began in 2005, at 22/04/2013 was installed a new AWS calibrated at the INRiM.
  - Moncalieri's Observatory: temperature measurements began in 1865 and continued up to the present, the current AWS was installed in 2001 and calibrated at the INRiM in June 2012.

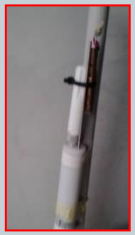


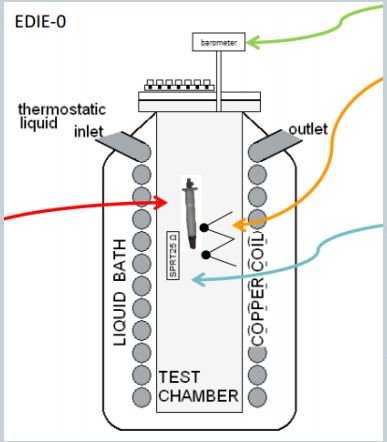
The calibration procedure

Camera climatica trasportabile EDIE – Earth Dynamics Investigation Experiment



Traceability diagram for Platinum Resistance Temperature (PRT) Sensors showing the unbroken chain of comparisons from the Unit Definition of International System of Units (SI), the International Temperature Scale of 1990 (ITS-90) to the calibration of the PRT Sensor.





External barometer DPI740 Druck

Thermopile copper-constantan for the evaluation of temperature gradient

Standard Platinum Resistance Thermometer (SPRT25) calibrated at fixed point of: Triple point H2O - freezing point In Triple point Hg - Triple point H2O- Melting point Ga

Calibration uncertainty

- As we said the Type B uncertainty is evaluated based on the "practical" information. In the case of the calibration uncertainty, there are different factors that contribute to this uncertainty.
- For Moncalieri de calibration uncertainty is 0.34ºC at the confidence level of 95% and the principal contributor was the calibration chamber thermal uniformity.

$$u = \sqrt{(0.029\ °C)^2 + (0.14\ °C)^2 + (0.01\ °C)^2 + (0.09\ °C)^2} = 0.17\ °C$$

Interpolation curve

Reference thermometer calibration

Calibration chamber thermal uniformity

Sensor resolution

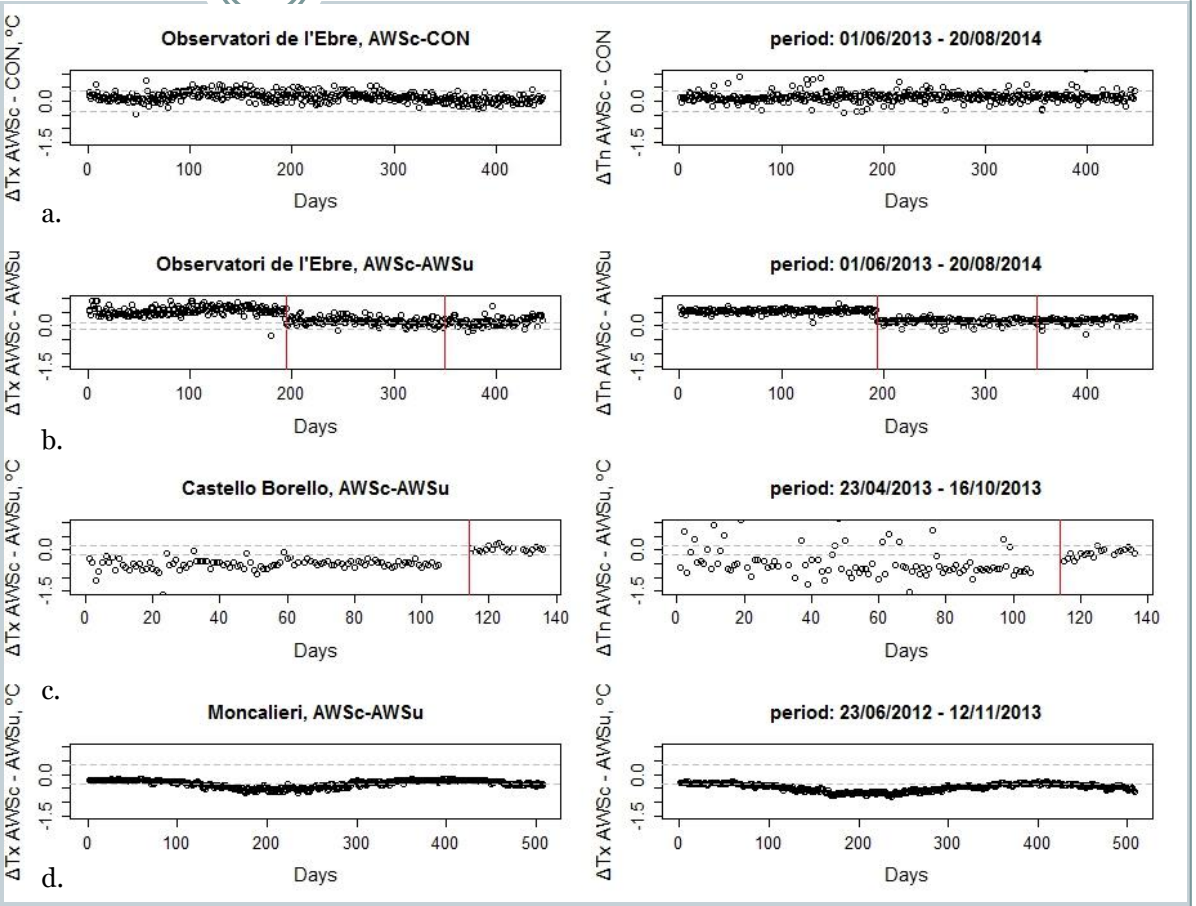
$$U = ku = 2u = 0.34\ °C$$

Confidence level of 95%

EDIE-0

Difference series AWSc – CON and AWSc – AWSu at the three field trials (I)

- From Ebro Observatory field trial, the differences AWSc – CON are smaller than AWSc – AWSu on the same period. In the difference series AWSc – AWSu there are a break for the correction of the AWSu measurements in 11/12/2013.
- At Castello Borello there is another breakpoint on the difference series due to the change of the AWSc
- At Moncalieri the differences are lower than in the other comparison AWSc – AWSu. In this case it's used the same AWS and its compared the measurements taking into account or not the calibration curve



For three different field trials: Observatori de l'Ebre (Spain), Castello Borello (Italy) and Moncalieri (Italy) for the daily maximum and minimum temperature the differences between the AWS calibrated (AWSc) and conventional measurements (CON) and AWS calibrated and uncalibrated (AWSu) at Observatori de l'Ebre, differences between the AWS calibrated and uncalibrated at Castello Borello and differences between adding and not the results of the calibration curve at Moncalieri

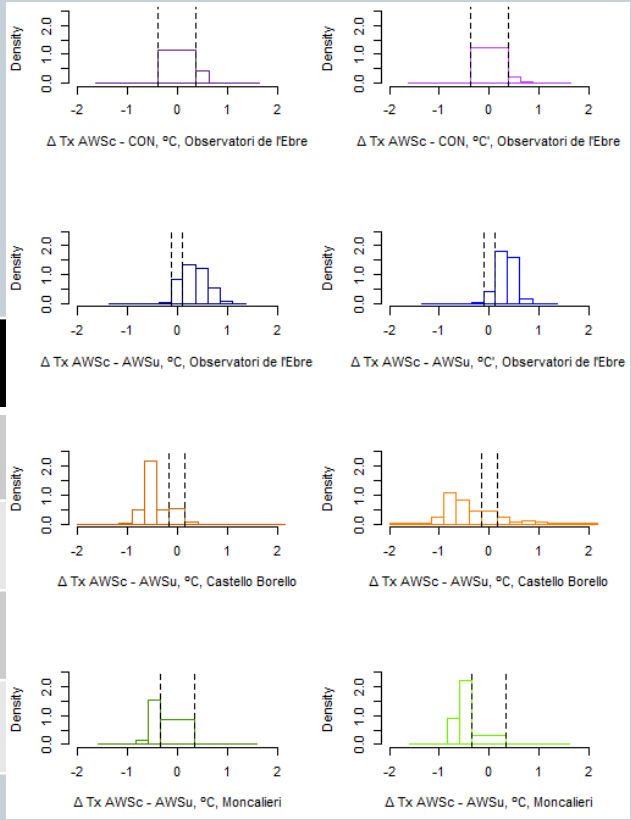
Difference series AWSc – CON and AWSc – AWSu at the three field trials (II)

- The differences are different on size and shape depend on the AWS analysed, as in the comparison AWSc-AWSu of the other field trials

- For the AWSc-CON the most proportion of cases within the calibration uncertainty are in ΔTn, for the AWSc-AWSu the most proportion of cases within the calibration uncertainty are in ΔTx. In general the proportion of cases ±1 ºC is negligible.

	Mean ΔTx (ºC)	Mean ΔTn (ºC)	RMSE ΔTx (ºC)	RMSE ΔTn (ºC)	%|U| ΔTx	% |U| ΔTn
Ebro Obs. AWSc-CON	0.16	0.16	0.24	0.23	87.67	90.81
Ebro Obs. AWSc-AWSu	0.34	0.34	0.42	0.39	17.04	8.52
Castello Borello AWSc-AWSu	-0.43	-0.23	0.51	0.90	27.90	19.85
Moncalieri AWSc-AWSu	-0.33	-0.47	0.35	0.48	57.28	19.29

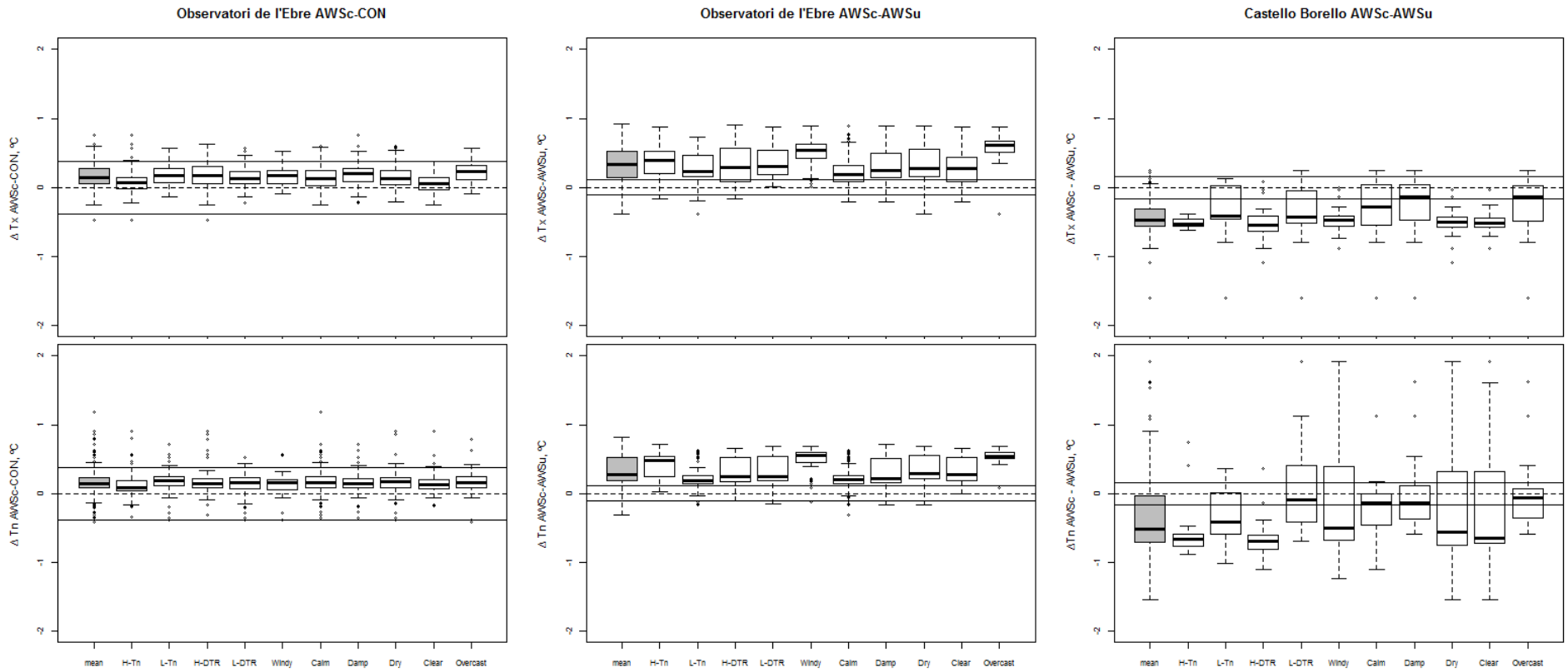
The mean, RMSE and % of observations within the calibration uncertainty



Histogram of the ΔTx and ΔTn for the 3 field trials

Difference series AWSc – CON and AWSc – AWSu at the three field trials (III)

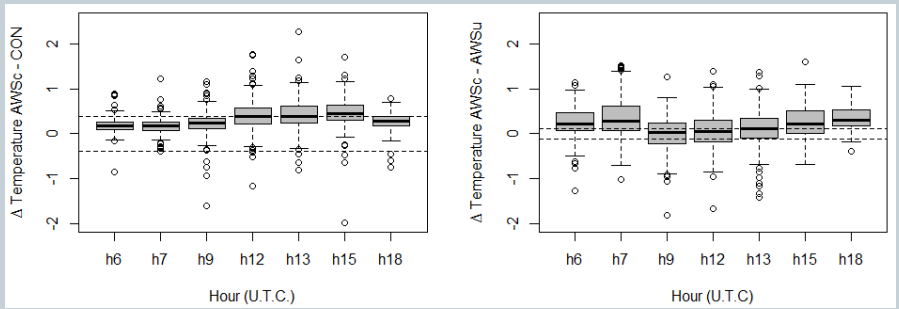
- Relationships of the AWS bias with the other climate variables are lower between the AWSc and CON observations than with the AWSu, especially in Castello Borello.



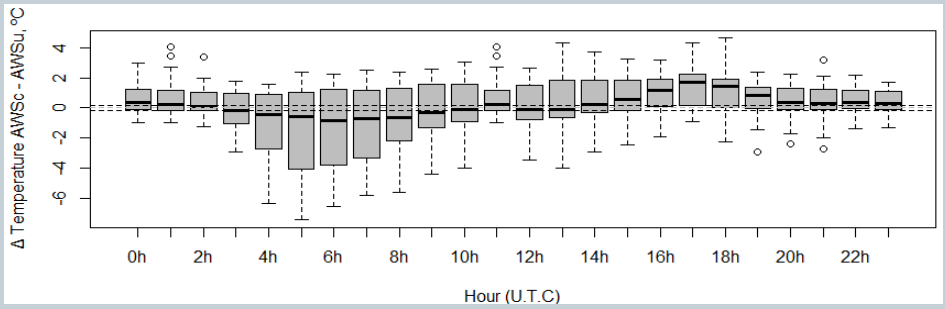
For the AWSc – CON (upper plots) and AWSc-AWSu (lower plots) in Observatori de l'Ebre the ΔTx (left plots) and the ΔTn (right plots) according the stratification of the days depending on the temperature, DTR, wind speed, radiation and humidity

Hourly difference series AWSc – CON and AWSc – AWSu

- In the case of the differences AWSc – CON at the hourly scale are also lower than in the case AWSc – AWSu
- AWSc – CON hourly differences increase at midday and early afternoon. For the AWSc – AWSu, the differences increase at dawn and dusk.
- In the case of Observatori de l'Ebre in both cases the differences are positive but in the case of Castello Borello at dawn most of the differences are negative and at dusk positive



Boxplot of the hourly differences between the AWSc-CON and AWSc-AWSu at Observatori de l'Ebre



Boxplot of the hourly differences between the AWSc and AWSu at Castello Borello

Conclusions

- The introduction of AWS system has introduced a bias on temperature series, which is larger when the data series are measured with uncalibrated sensors
- The bias depend on the AWS used and can be larger than the climate signal
- The calibration or not of the sensor used to record observations is important for generating climate data of high standards and quality and to reduce the breaks on the climate series
- The homogenisation of climate series is also important to generate high quality and longer time-series but it's also important the quantification of the total homogenisation uncertainty (A-Type plus B-Type)

THANKS FOR YOUR ATTENTION