AN EXPLORATORY ANALYSIS OF THE IMPACT OF THE CHANGEOVER TO AUTOMATIC WEATHER STATIONS CONSIDERING THE PRIMARY NATIONAL STANDARDS CALIBRATION PROCEDURES: OBSERVATORI DE L'EBRE CASE STUDY

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INTRODUCTION

Since the second half of the 20th century, a worldwide changeover to Automatic Weather Stations (AWS) has taken place, which has incorporated a bias on climate time series (Holder *et al.* 2006, Milewska *et al.* 2002).

The observing sites where historical temperature observations have been recorded, collected and archived for decades (or more) provide a valuable opportunity to assess the impact of the AWS bias in their combined long-term temperature time-series, especially in those equipped with both old and new instrumentation.

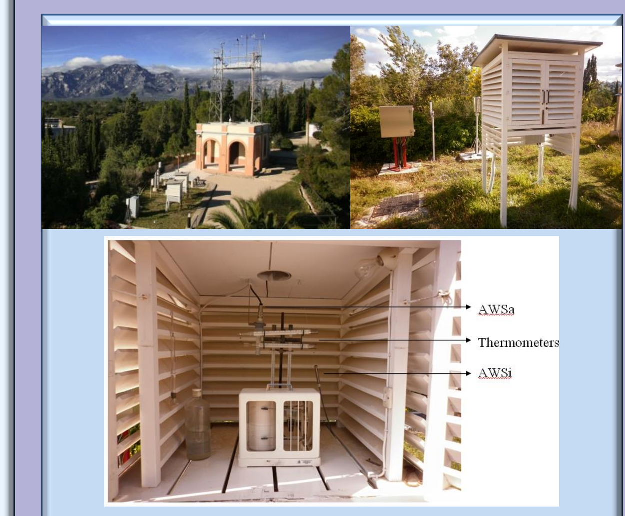

Fig 1. Ebro's observatory's setting

DATA AND METHODS

- The meteorological garden of the Ebro's Observatory (managed by the Aemet) located in Roquetes, Northeast Spain (40º49'14''N - 00º29'29''E, elevation: 50m). The overlap period with Automatic Weather stations uncalibrated (AWSu) and CON (liquid-in-glass thermometers) measurements runs from 01/07/1991 to 15/01/2014. A calibrated automatic sensor was installed on 2013, January the 1st, which is still in operation. To analyse CON, AWSu and Automatic Weather Stations calibrated (AWSc)observations, we have used the 01/06/2013 - 15/01/2014 period. (Fig. 1)
- From the paired time-series, we have extracted maximum (Tx) and minimum (Tn) temperature data at the daily scale and computed the daily maximum and minimum temperature differences ΔTx and ΔTn between the AWSu – CON, AWSc – CON and AWSc – AWSu. Then these difference series are subjected to a quality control.
- The first step is ensuring that the difference series is homogeneous and it only represents the AWS vs CON bias. For the detection of the break points (BP) of the residual differences series it's used and SNHT routine.
- The calibration of the AWSc sensor was carried out by direct comparison with a pattern thermoeter SPRT25 calibrated at the fixed points of ITS-90. The Climatic chamber EDIE-1 was used for the calibration (Bertiglia *et al.* 2015),
- To analyse difference series characteristics, some basics statistics of the daily ΔTx and ΔTn series are computed. These are their means, standard deviation (SD), Root-Mean-Square Error Deviation (RMSD).

RESULTS

- During those 22 years of parallel measurements AWSu – CON we identified 9 different Homogeneous Subperiods (HSP) although three of them (HSP6.1, HSP5.1 and HSP4.1) (fig. 2) are too short and could be possibly caused by improper functioning of the sensors. The other BPs could be partially related to changes in the AWS instrumentation.
- Our approach to characterise size and shape of the AWS bias indicate it is dependent of the different HSP detected, since each HSP shows a different AWS bias magnitude and sign (fig. 3). This makes difficult to establish global characteristics of the AWS bias and preclude the usage of any state-of the-art methods to account for this bias.
- The mean of the ΔTx (ΔTn) series are between 0.31 ºC for HSP2 (0.56 ºC for HSP3) and -1.13 ºC for HSP6 (-0.94 ºC for HSP6) (fig. 3). RMSE estimator for the ΔTx (ΔTn) are between 0.32 ºC for HSP4 (0.22 ºC for also HSP4) and 1.18 ºC for HSP6 (0.96 ºC for also HSP6).

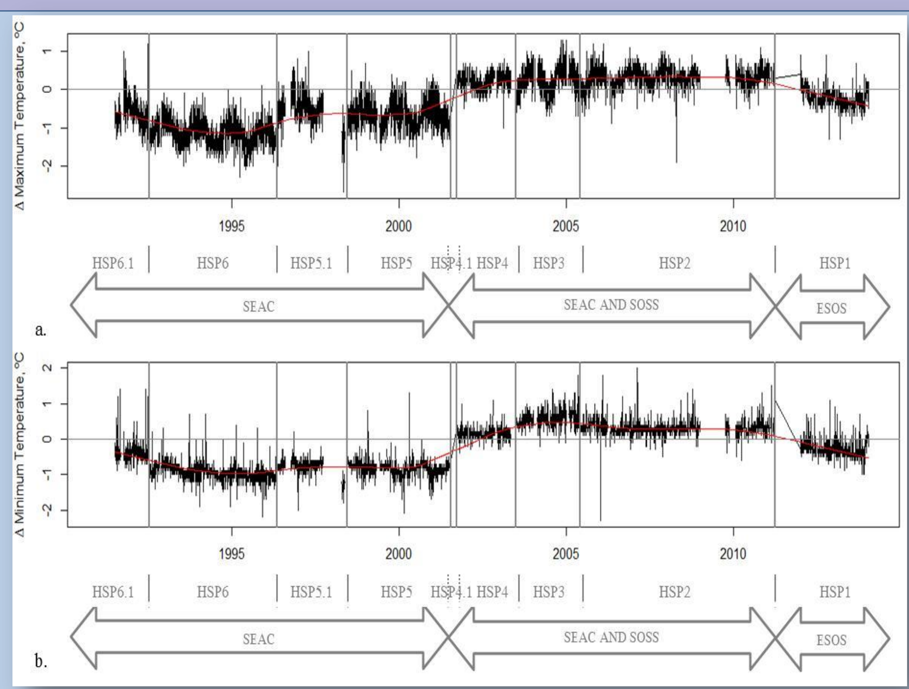

Fig 2. The ΔTx (a) and ΔTn (b) between the AWSu and the CON, horizontal black lines the BPs

		HSP1	HSP2	HSP3	HSP4	HSP5	HSP6
N		537	1578	618	518	1079	1337
Mean	ΔTx	-0.29	0.31	0.28	0.22	-0.66	-1.13
	ΔTn	-0.32	0.31	0.56	0.15	-0.83	-0.94
SD	ΔTx	0.23	0.27	0.35	0.23	0.36	0.34
	ΔTn	0.29	0.21	0.21	0.16	0.20	0.23
RMSD	ΔTx	0.36	0.41	0.45	0.32	0.76	1.18
	ΔTn	0.43	0.37	0.60	0.22	0.85	0.96

Fig 3. For each HSP the mean, SD and RMSD for the ΔTx and the ΔTn

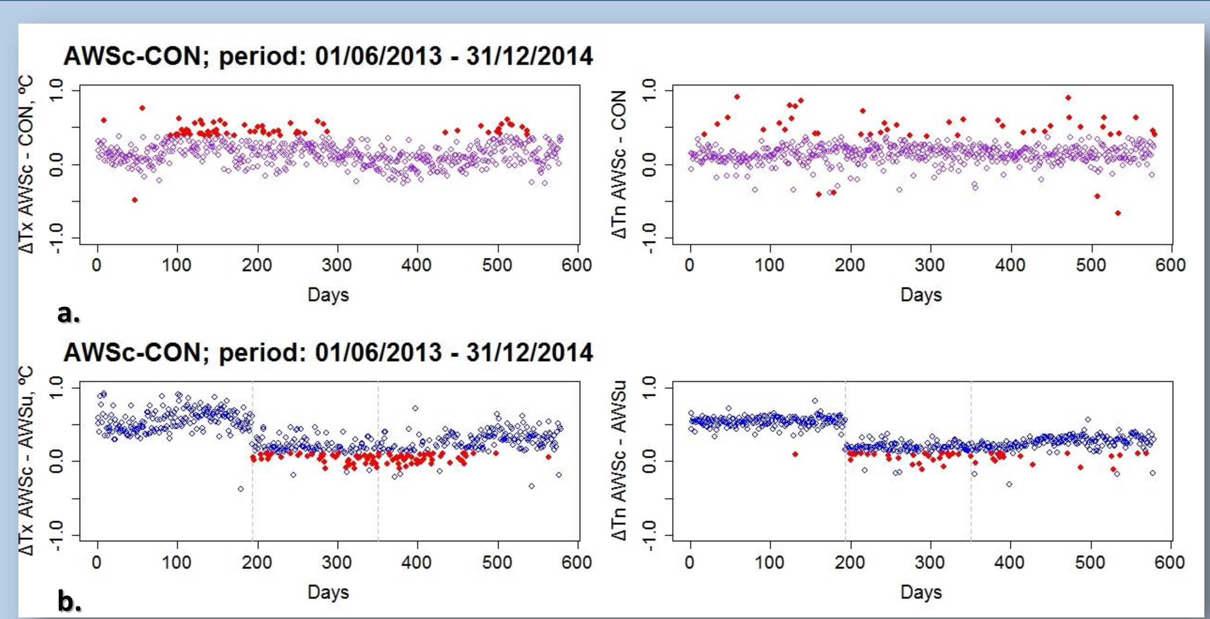

Fig 4. For the Tx and Tn the differences between the AWS calibrated (AWSc) and conventional measurements (CON) (a) and AWS calibrated and uncalibrated (AWSu) (b) at Observatori de l'Ebre. Red points when the differences are without the combined calibration uncertainty

		AWSc - CON	AWSc - AWSu
Mean (ºC)	ΔTx	0.16	0.33
	ΔTn	0.15	0.32
RMSD (ºC)	ΔTx	0.24	0.40
	ΔTn	0.28	0.37
% |U|	ΔTx	88.26	14.85
	ΔTn	90.33	7.77

Fig 5. The mean, RMSD and % of observations within the calibration uncertainty

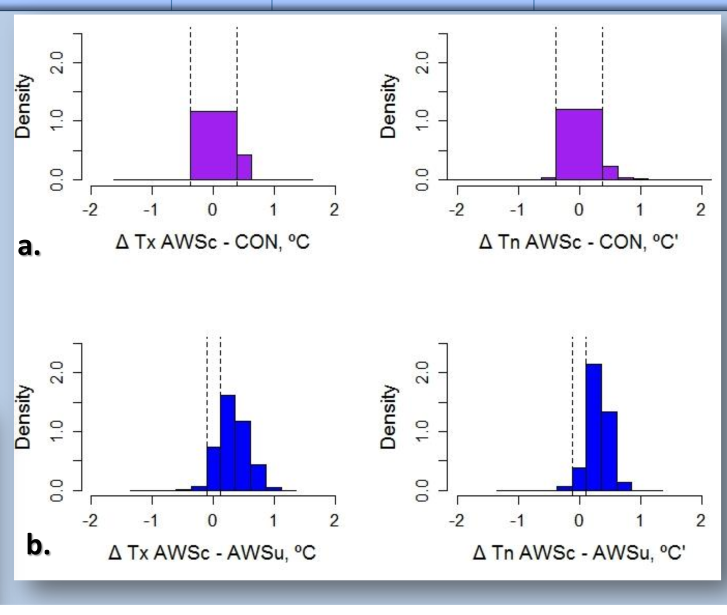

Fig 6. For the AWSc-CON (a) and AWSc-AWSu (b) histogram of the ΔTx (left plots) and ΔTn (right plots)

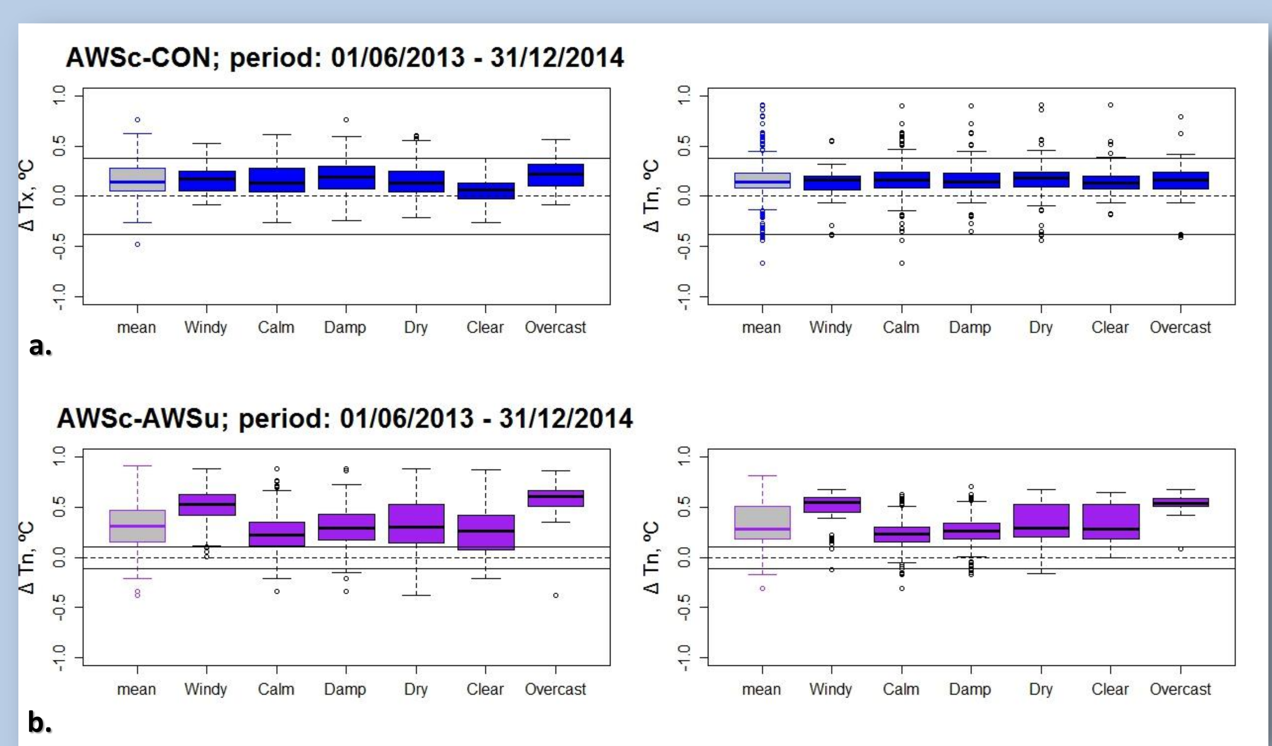

Fig 7. For the AWSc-CON (a) and AWSc-AWSu (b) the boxplot of ΔTx (left plots) and ΔTn (right plots) according windy (48Km/h) or calm (31Km/h) days, clear (2537.5KJ/m2) or overcast (805KJ/m2) days and damp (56.7%) or dry (75.7%) days.

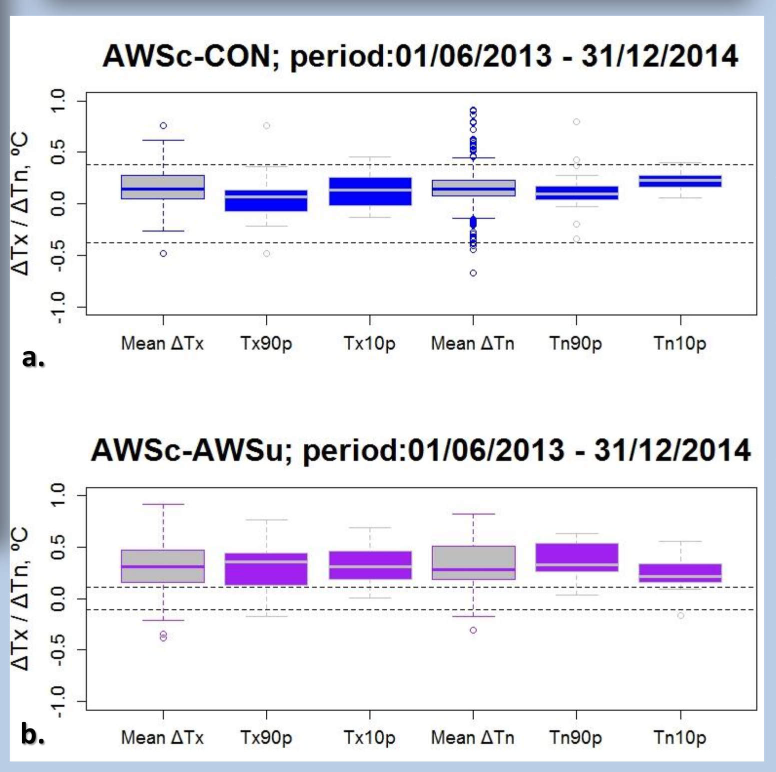

Fig 8. For the AWSc-CON (a) and AWSc-AWSu (b) the boxplot for maximum (ΔTx) and minimum (ΔTn) temperature differences for those days in which daily maximum temperatures (Tx) are higher and lower than the 90th and 10th percentiles and minimum and days in which daily minimum temperatures (Tn) exceed the 90th and 10th percentiles (Tn90p and Tn10p, respectively

- From Ebro Observatory field trial, the differences AWSc – CON are smaller than AWSc – AWSu on the same period (fig. 4). In the difference series AWSc-AWSu there are a break for the correction of the AWSu sensor in 11/12/2013
- Since for Tx AWSc-CON differences, the 88.26% of the observations are within the combined calibration uncertainty (0.38 ºC), while for the ΔTn paired observations the 90.33% of them are within, meanwhile for Tx AWSc-AWSu differences only the 14.85% of the observations are within the combined calibration uncertainty (0.11 ºC) and the 7.77% for ΔTn (fig. 5).
- In the case of the AWSc-AWSu in which the most part of the differences are without the combined calibration uncertainty, also for the ΔTx and ΔTn the gratest part of the differences are positive and less than 1ºC (fig. 6).
- In the case of the extreme temperatures, for the AWSc-CON in general in the hottest extremes the differences are lower, close to 0ºC and for the differences on the Tn10p are also within the combined calibration uncertainty but the mean of this are the largest. For the AWSc-AWSu the minimum differences are for the coldest extremes (Tn10p), for these extreme the mean of the differences are also without the combined calibration uncertainty but it's the lowest mean.
- We also have explored the relationship of the ΔTx and ΔTn in both cases and found that for the AWSc-CON the influence on the differences are less than for the AWSc-AWSu. In this case, also for the ΔTx and ΔTn the differences are influenced especially by the wind and the cloud cover. The windy days and the overcast days increase the differences between the AWSc and AWSu measurements (fig. 7).

CONCLUSIONS

- The introduction of AWS induce a bias in temperature series to being combined measurements from different observing systems
- This bias depend on the AWS used and can be larger than the climate signal, which requires adjustments to avoid cold/warm biases in the affected series. Need to account for this instrumental bias
- Use of calibrated thermometric sensors following a metrological procedure is advisable to improve temperature data quality at the daily scale
- In addition, this approach will also reduce adjustments magnitude related also to frequent changes (replacements) of uncalibrated AWS
- Combining metrological and statistical (homogenisation) approaches to ensure long-term climate series quality should be envisaged, since it can pave the way to better estimate uncertainties related to both measurements and homogenisation adjustments. At the same time it will increase traceability of time-series to include an uncertainty budget for each observation

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