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On-site calibration of instruments in the Arctic: assessment of temperature records at Climate Change Tower in Ny-Ålesund, Svalbard

Graziano Coppa[a], **Chiara Musacchio**[a], **Francesca Becherini**[b], **Mauro Mazzola**[c], **Angelo Viola**[d], and **Andrea Merlone**[a]

[a]Istituto Nazionale di Ricerca Metrologica (INRiM), Strada delle Cacce, 91, Torino, Italy; [b]CNR-ISP, Venezia, Italy; [c]CNR-ISP, Bologna, Italy; [d]CNR-ISP, Roma, Italy

Corresponding author: **Graziano Coppa** (email: g.coppa@inrim.it)

Abstract

The Arctic is as a key place to perform environmental measurements given its combination of reduced human activity and increased sensitivity to climate change. The Svalbard archipelago constitutes an invaluable measurement location, due to its ease of access and the presence of the Ny-Ålesund research center. Sensors are usually not designed to sustain prolonged periods of time in demanding environments like the Arctic; therefore, chances of failures, drift, and errors are higher than elsewhere. Maintenance and calibration of these sensors must be rigorous and frequent, to avoid poor-quality data, or even their loss. Within the frame of EURAMET EMRP project “MeteoMet 2”, calibration of the temperature sensors hosted by the Climate Change Tower (CCT), a unique research facility designed to monitor lower-atmosphere profiles of several meteorological quantities, has been performed. The calibration campaign pointed out sensor errors up to 1 °C and corrected the measurements, straightening the skewed temperature profiles. Absolute calibration uncertainties have been evaluated at ~0.2 °C, less than half of those stated by the manufacturer, while an evaluation of relative uncertainties yielded values of just few 0.01 °C. This experience stimulated the creation of an in-situ calibration facility, to the benefit of the whole scientific community based in Ny-Ålesund.

Key words: arctic metrology, atmospheric sensor calibration, Svalbard, air temperature, thermal vertical profile, MeteoMet

1. Introduction

Climate change has come up to four times faster in the Arctic than the rest of the globe since late 1970s (Rantanen et al. 2022). For this reason, accurate monitoring of the Essential Climate Variables (ECVs)—especially the thermodynamical ones—in this sensitive area is of paramount importance to detect faster and with less uncertainty the signal due to the heat increase in the atmosphere and in the oceans (Robinson et al. 2021; Wong 2023; Li et al. 2023*b*).

Climate monitoring in the Arctic dates back to the end of the 19th century (Ekholm 1901) and by the 1930s a relative warming since the beginning of systematic instrumental measurements (~1860) had already been detected, leading to a wider discussion on the physical reasons and on the reliability of these measurements (Wood and Overland 2010). While the anthropogenic global rise in temperatures has been validated beyond any doubt, and its magnitude as well (IPCC 2022), a lot remains to be said about the instrumental uncertainty and its effect on the climate change regression and model confidence bands (Merchant et al. 2017; Madonna et al. 2022). Historical temperature data have often been subject to scrutiny for their accuracy (Menne et al. 2010; Acquaotta and Fratianni 2014), and attempts have been made at the uncertainty evaluation of those old records, in different domains (Thorne et al. 2011; Morice et al. 2012); in this context, Brohan et al. (2006), for instance, made assumptions on the uncertainties of temperature records in the HadCRUT dataset and concluded that in the earlier periods uncertainties are large, but the temperature increase over the twentieth century is still significantly larger than its uncertainty. However, very little information is available for the Arctic measurements in terms of reliability and accuracy (Hari et al. 2017).

Scientific instruments, especially meteorological ones, are often not really suited for continuous use in harsh environments such as the polar regions, and can therefore be particularly subject to malfunctions, drifts, and measurement errors (Summerhayes 2016). Periodic calibration of meteorological sensors in the Arctic is therefore necessary, but the logistics needed to access and work in such an environment are challenging and may require particular care.

It is therefore of great importance that in-situ observations in polar regions are carried out with metrological rigor, to retrieve high-accuracy measurements and capture trends with high reliability and robust comparability, which are the basis of climate change studies (see, in a broader scope not only focused on the Arctic, Merlone et al. 2024*a*). Metrological procedures such as calibration, traceability, and uncertainty evaluation are fundamental for the correct retrieval of atmospheric parameters used in a number of scientific studies, from ABL interactions to the assessment of climate change.

The aim of this paper is to show the importance of these metrological procedures for the reliable operation of weather stations, especially in remote and critical areas such as the Arctic.

A case study will be presented, with the effects of in-situ calibration of a series of commonly used atmospheric temperature sensors, installed on a meteorological tower at the Svalbard Islands, on their records.

The paper is organized as follows: in Section 2, the instrumentation and, in particular, the temperature sensors are described; in Section 3, instruments and methods used for the calibration are presented; Section 4 is dedicated to the results of the calibration, which are discussed in the subsequent Section 5; finally, some conclusions are drawn, and further questions are posed in Section 6.

2. Site and measurements

In 2009, the Italian National Research Council's Institute of Atmospheric Sciences and Climate (CNR-ISAC) installed the Amundsen-Nobile Climate Change Tower (CCT) (Mazzola et al. 2016*b*) in the research area of Ny-Ålesund, Svalbard. The tower (Fig. 1) is a 34-m-high truss hosting different meteorological instruments at various heights, and has its main scientific driver in the study of atmospheric boundary layer (ABL) turbulence in an Arctic environment (Tampieri et al. 2016; Mazzola et al. 2016*a*). In high-latitude regions, the ABL is frequently marked by a highly stable vertical stratification and vertical temperature inversions are commonly observed during polar night conditions due to the combination of intense surface radiative cooling and stable stratification (Overland and Guest 1991).

The tower is installed at 50 m a.s.l., at 78°55′N 11°52′E, 2 km NW of the Ny-Ålesund Research Station, to avoid the influence of human activities in town. It features instruments at different heights from the ground to provide a vertical profile of the characteristics of the atmosphere from near surface (2 m) to its full height of 34 m, while reducing disturbance and footprint size (Becherini et al. 2021). Vaisala HMP45AC thermo-hygrometers, encased in their standard, non-ventilated solar screens are installed at 2, 5, 10 and 34 m; other instruments like anemometers, radiometers, snow skin temperature sensors and barometers are installed at different levels of the tower.

According to the climatology acquired so far, sensors at the CCT experience temperatures as low as −30 °C during winter and spring and as high as about 20 °C in summer. Wind speed (1 min averages) can reach values as high as 30 m/s, but gusts values can be frequently much higher. Due to the high latitude of the site, solar radiation does not reach high values as in other places (<1000 W/m^2), but during summer insolation can last for several days continuously. Such meteorological conditions (low temperature, high wind, prolonged solar radiation) could lead to the stiffening of signal and power cables, shields and measuring devices, including datalogger boxes, with possible breaks. During the operation period of the CCT (more than 13 years) ruptures were experienced primarily by the anemometers' moving parts, and by the shields of the thermo-hygrometers, due to hardening caused by temperature and radiation effects.

Fig. 1. The Amundsen-Nobile Climate Change Tower (photo by G. Coppa).

2.1. Temperature sensors

Vaisala humidity and temperature probes HMP45 are well known and widely used in meteorological applications. They consist of a capacitive thin film polymer sensor for relative humidity measurements integrated with a Pt1000 resistive platinum thermometer.

The "accuracy" declared in the operating manual[1] provided by the manufacturer is of 0.2 °C at 20 °C, which degrades linearly to 0.5 °C at −40 °C. It is a common mistake in technical sheets to use the term "accuracy", which is a qualitative-only term (BIPM and Joint Committee For Guides In Metrology 2008) instead of "uncertainty", that indicates a quantitative

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[1] https://www.vaisala.com/sites/default/files/documents/HMP45AD-User-Guide-U274EN.pdf.

parameter. It is therefore assumed that the values reported in the operating manual are referred to an uncertainty, possibly at 95% level of confidence (or $k = 2$).

The producer recommends calibration of these sensors once per year, depending on the conditions of use and desired accuracy. As a matter of fact, they come out with an internal calibration certificate where it is stated that the sensors have been calibrated only at one value of temperature (usually 20 °C or 23 °C).

Although this can be sufficient for some specific applications—even though it is technically incorrect to use the term "calibration"—the meteorological conditions in the Arctic call for a more thorough multi-point calibration and a rigorous evaluation of at least the calibration uncertainty.

For this reason, and given that the sensors were never calibrated after their installation on the CCT in October 2009, a plan for calibrating them regularly has been agreed upon between the Institute of Polar Sciences of the National Research Council of Italy (CNR-ISP), which currently manages the CCT, and the Italian National Institute for the Metrological Research (INRiM), which possesses the knowledge and the equipment for in-situ calibration. This initial plan later evolved into the establishment of a permanent calibration laboratory at Ny-Ålesund, serving the CCT and the whole scientific community at the research facility.

The calibration laboratory of Ny-Ålesund would fulfil the need for accurate measurements for the whole scientific community of the settlement, given the difficulty and cost of make instruments travel to the respective National Metrology Institutes or accredited laboratories on the mainland to perform the calibrations, and back.

3. Instruments and methods

In 2014, in the framework of EURAMET EMRP project MeteoMet (Merlone et al. 2015*a*), the first "Arctic Metrology" campaign was carried out, as a cooperation between INRiM, the Alfred Wegener Institut (AWI) of Potsdam and the National Research Council of Italy (CNR) (Musacchio et al. 2015). In that campaign, a calibration of temperature sensors in radiosondes' ground check equipment was performed, utilizing a specially built, portable calibration chamber named EDIE1. Design, construction, characterization and performance of EDIE1 can be found in a dedicated publication (Lopardo et al. 2015).

In the light of such a positive experience, further cooperation was planned and developed within the EURAMET EMRP project MeteoMet 2 (Merlone et al. 2018): in particular, the possibility of creating, installing and managing a permanent metrology laboratory in the Arctic was explored and defined (Musacchio et al. 2016).

In 2017, the first nucleus of the Arctic Metrology Laboratory was installed in Ny-Ålesund. It was equipped with several devices, some of them coming from that first experience in 2014, with some upgrades and additions for a more comprehensive range of possible operations.

Fig. 2. Core calibration equipment installed in 2017 in the calibration laboratory.

The laboratory has been equipped with devices commonly used in calibration labs, as the multimeter SUPER-DAQ (Fluke model 1586A), the thermostatic bath model Polyscience DP07R (using ethyl alcohol as a thermostatic medium) and a set of temperature reference sensors, calibrated regularly at INRiM laboratories and travelling constantly to Ny-Ålesund and vice versa to provide always the best and most up-to-date reference for the local temperature calibrations, and to keep the traceability chain between the sensors and the national and international standard uninterrupted. Other pieces of equipment, on the other hand, are not commercially available, and have been expressly created at INRiM for in-situ calibration of temperature sensors in remote and hard-to-reach locations: the most important of this equipment is the portable climatic chamber EDIE1.

The calibration method is a variation of the method already employed in the past for in-situ thermometer calibration (Bertiglia et al. 2015). The most important improvement of the method is the upgrade of the portable climatic chamber EDIE: while the cited work employed the prototype EDIE0, for this work EDIE1, the same chamber used in the pioneering cooperation with AWI, was used (Fig. 2)—later iteration EDIE2 was sent to permanently equip the metrology laboratory at the CNR Pyramid research centre in the Himalayas (Merlone et al. 2015*b*), while EDIE3 currently resides at INRiM. The differences among these different iterations of EDIE are essentially the size and the materials used. EDIE3 is shorter and wider to accommodate larger instruments and reduce vertical gradients, while EDIE2 is partly made of copper instead of steel, to make it lighter for the transportation to the Everest CNR Pyramid by the local porters. While copper has higher specific weight than steel, much less material has been used, thus resulting in weight reduction.

In May 2017, in conjunction with the creation of the laboratory, the first calibration of the CCT temperature sensors was performed. Sensors, cables and data loggers were dismantled from the CCT and brought to the calibration laboratory, put inside EDIE1 (Fig. 3), connected to the thermostatic bath which drove the temperature stabilization, by means of a fluid (a mixture of 99% and 95% ethylic alcohol) prethermalized inside the bath's reservoir and then sent to the portable

Fig. 3. Details of the inner part of EDIE1 chamber during pre-calibration phase.

chamber EDIE1; running in pipes inside the chamber chassis, the fluid stabilizes the temperature of the inner chamber of EDIE1 and provides a uniform medium in which devices under test (DUTs) and reference thermometers are placed for comparison.

To cover the range of possible atmospheric temperatures, typical of the location, 6 calibration points were set in the chamber: −25 °C, −15 °C, −5 °C, 0 °C, 5 °C and 15 °C, which achieved, at the best stability conditions, the respective chamber temperatures T_c of −25.9 °C, −15.7 °C, −6.6 °C, −1 °C, 4.4 °C and 14.8 °C. Setpoints of the thermostatic bath were set at lower temperatures (respectively −38 °C, −20 °C, −10 °C, −4 °C, 3.5 °C and 13.8 °C) to account for heat dispersion during the process.

The calibration puts therefore in relation the "true" temperature of the chamber T_c, as read by the reference sensors, with the temperature T_R read by each DUT—or better, their difference, by interpolating them with a quadratic equation:

$$T_c - T_r = \Delta T = aT_r^2 + bT_r + c$$

where a, b, and c are the so-called *calibration coefficients* which must be calculated at the interpolation stage.

4. Results

Figure 4 shows the calibration results of the four sensors, in terms of ΔT against T_R. The temperature sensors are named Ti, where i indicates the sequential number of the sensor from top to bottom of the CCT. As it can be seen, all the four sensors show rather large deviations between the calibration values and the original internal calibration, in two cases of the order of 1 °C through the whole temperature range.

For each calibration point and for each sensor, uncertainties shown in the plot have been calculated by taking into account various contributions due to the sensors under test themselves, the reference sensors to which they are compared, and the experimental apparatus employed for the calibration. An example of calibration uncertainty budget is presented in Table 1.

The process of applying calibration to sensors, in general, and more specifically to meteorological thermometers, introduces simultaneously both a correction for the values given by the sensors, and an uncertainty—a degree of confidence in the goodness of the measurement, which characterizes the range of values within which the true value of a measurand lies (BIPM and Joint Committee For Guides In Metrology 2008).

While calibration is an essential part of the deployment and fruition of any measurement system, it is particularly interesting to apply these calibrations, with their unusually large deviations from the raw measurements indicated by the CCT sensors, to actual measurements taken by the sensors on the tower around the period of the calibration.

Figure 5 shows the results of the application of calibration curves to the measurements taken at the CCT during a random day, close to the calibration period. Panel A shows the original measurements taken by the four sensors without any elaboration. The most striking feature of the plot is the difference between the measurements of T3 and the other three sensors. Such constantly lower temperatures measured at 10 m with respect to those at higher (34 m) and lower levels (2 and 5 m) are not explainable physically and therefore are an indication of a problem with the instrument.

Panel B shows the same measurements after the application of the calibration curves calculated during the calibration campaign described in Section 3. Besides the general "cooling" of the measurement results, given by the fact that for all calibration points and for all sensors, $\Delta T < 0$ (Fig. 4) (which means that $T_c < T_R$ so the corrected temperatures are always lower than the ones read by the CCT sensors), a rearrangement of the temperature profile is evident. After calibration, more physically-sound stratification appears, with T1 recording the coldest temperatures and T4 the warmest, with T2 and T3 somewhat in between. During the chosen night, what could have been taken for an almost complete temperature inversion (for example, at around 1:00 AM), gets dramatically overturned by the application of calibration curves, with a more regular and normal vertical thermal gradient. A clearer, zoomed-in version of the comparison between profiles before and after the correction—without the confidence bands to improve readability—is shown in Fig. 6.

Fig. 4. Calibration curves of the four Climate Change Tower temperature sensors. The error bars mark the uncertainties on the measurements of ΔT, while the confidence bands show the $k = 2$ uncertainty of the fit, weighted by the uncertainties.

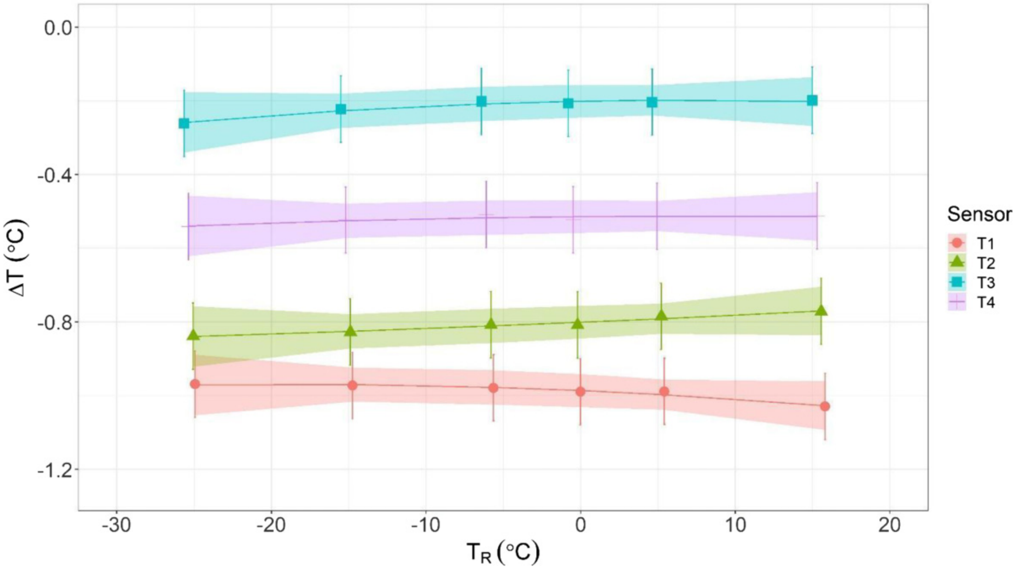


Table 1. Example of uncertainty budget for one sensor (T1) at one temperature calibration point (-25 °C).

	Value (°C)	Divisor	Distribution	Contribution to uncertainty (°C)
Reference sensor	0.007	1	Normal	0.007
Chamber uniformity	0.300	$\sqrt{12}$	Rectangular	0.087
DUT stability	0.007	1	Normal	0.007
Calibration curve	0.006	1	Normal	0.006
Readout resolution	0.001	$\sqrt{12}$	Rectangular	3E-4
Chamber stability	0.001	1	Normal	0.001
Standard unc. ($k = 1$)				**0.088**
Expanded unc. ($k = 2$)				**0.176**

While the uncertainties in the calibration values shown in Fig. 4—due, as it will be discussed in Section 5, to the inhomogeneities in the calibration chamber—are quite large, a different approach can be implemented to reduce the uncertainties in the *relative* calibrations. Not unlike what was done by Merlone et al. (2019), calibrations can be referred to one of the DUTs, instead of the reference sensors: in this manner, the sensors are not calibrated in an absolute but in a relative way, thus cancelling some of the uncertainty contributions that are the same for all the DUTs. This exercise correctly retrieves the mutual differences between each of the sensors in the profile, reduces the relative uncertainties, but as a downside, it cannot retrieve nor correct the absolute temperatures recorded by the sensors.

Figure 7 shows the results of the relative calibration, referred to T1. Obviously, the calibration of T1 referred to itself yields a flat calibration curve with no corrections and no uncertainty; the curves of the other sensors indicate how much they must be corrected with respect to T1 according to the calibration. The application of relative calibrations to the temperature profiles is shown in panel C of Fig. 5. While the absolute values shown in the ordinate axis are uncalibrated (in an absolute way), the relative differences between the sensors are accurate and yield very small uncertainty bands.

5. Discussion

The largest contributor to the overall calibration uncertainty, as apparent from Table 1, is the chamber uniformity. It is one order of magnitude larger than the other contributions and represents almost 95% of the total uncertainty budget. For this reason, the goal of reducing overall uncertainty on in-air calibration of temperature sensors must pass through improvements in the chamber uniformity.

The largest issue that affected the uncertainty regarding the uniformity of the chamber is the fact that EDIE1 was designed to work completely sealed. As apparent in Fig. 3, EDIE1 is made up of an inner chamber, separated from the outer chamber by an empty space; when both EDIE1 chambers are closed by their lids, a vacuum pump (visible in Fig. 2) can be connected to the system and air can be extracted from the gap. In this way, the inner chamber is completely isolated from the outside environment and its influence on the measurement chamber is minimal.

Fig. 5. Plots of temperatures from Climate Change Tower sensors, on a random day close to the calibration date (13 July 2017). Shown in panel A, original raw data from the sensors, with uncertainties bands as stated by manufacturer; in panel B, data after application of calibration curves described in this work, with uncertainties calculated from the calibration; in panel C, data after relative calibration referred to T1, with reduced uncertainties.

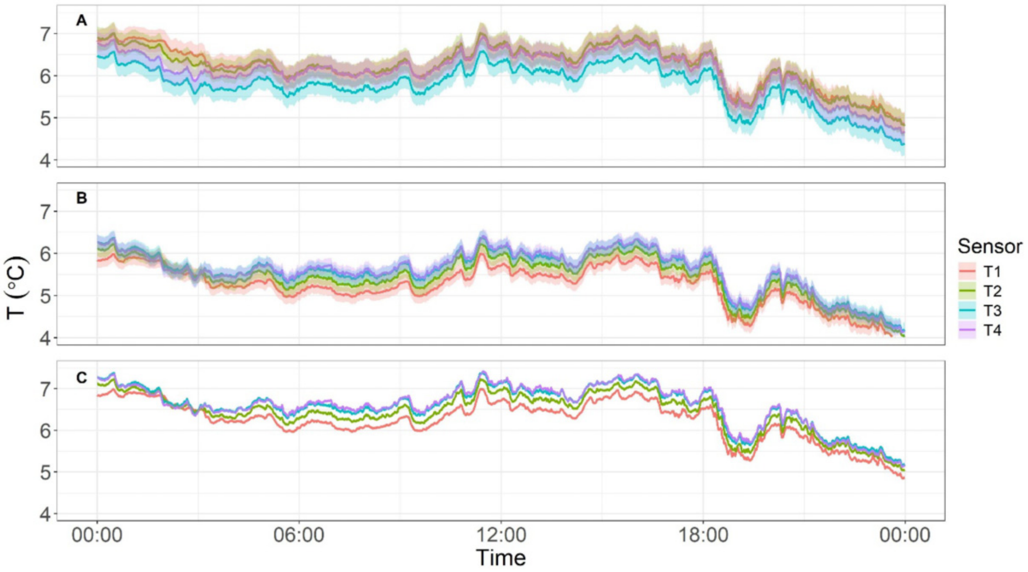
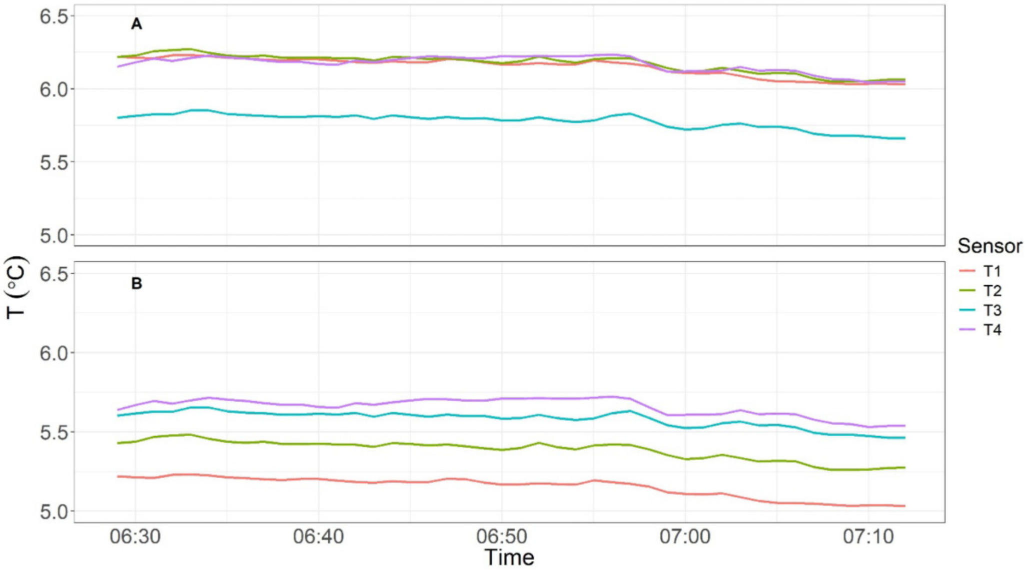


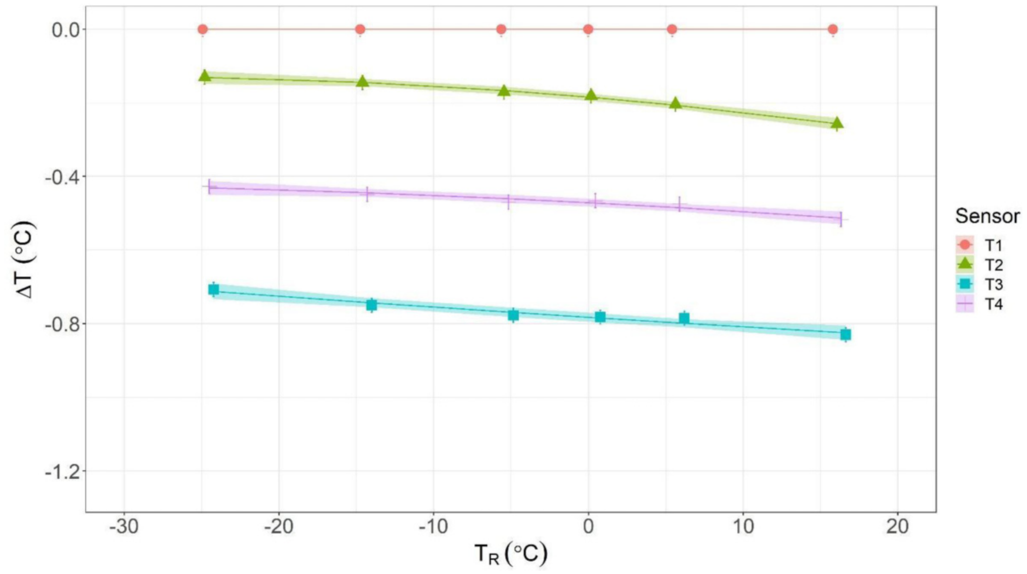
Fig. 6. An example of zoomed-in raw data (panel a) and calibrated data (panel b) profiles extracted from Fig. 5. Uncertainty bands have been removed to better point out the rectification of the profiles after sensors' calibration.



When EDIE1 is in operation completely closed, the DUTs should reside inside the inner chamber and no cables are allowed out, in order not to disrupt the vacuum in the gap. This is not a problem with self-contained and self-powered small sensors, with embedded dataloggers (for instance, those described by (Viani et al. 2020; Nigrelli et al. 2022). However, DUTs are usually externally powered and rely on cables to deliver their measurements to an external, often bulky, datalogger that processes and stores the information. For this reason, EDIE1 is equipped with an array of cables and a connector strip, that pass through the body of the chamber and deliver the cables to another external connector strip: in this way, EDIE1 can be closed and the DUTs can still receive power from the outside and deliver measurements to the datalogger.

This operation needs the disassembling of the DUTs connectors or a cut on the cables, to connect both ends to the connector strips inside and outside EDIE1. In this case, it was decided not to proceed in this way, because potential breaks or failures in cables and connectors are much more difficult to repair in a remote location such as Ny-Ålesund. For this reason, instead of the EDIE1 regular steel lids, a spe-

Fig. 7. Relative calibration curves of the four sensors, referred to T1.



cial ArmaFlex® lid with a hole on top was prepared: the hole let the cables come outside of the measurement chamber while the ArmaFlex® cover provided insulation and protection from the outside environment (Fig. 3, bottom picture).

While, in principle, the isolation from the outside should benefit more the stability of the chamber than its inner homogeneity, the fact that the inner chamber of EDIE1 was not closed with its steel lids let air at a different temperature inside the chamber, causing vertical and, to a lesser extent, horizontal inhomogeneity to arise.

Lastly, to speed up operation and minimize the downtime of the sensors, it was decided to perform the calibration of all of them at once. The available space inside the calibration chamber of EDIE1 is not large (inner diameter 22 cm, total volume 15 l) therefore the four sensors had to be put in close contact with one another. This is not the ideal configuration for a calibration because of the self-heating of the sensors: resistance thermometers are crossed by a current for their operation, which heats up the sensitive element and everything in contact with it, such as other sensors and the air itself. While the self-heating itself was not evaluated due to the little time available and the complexity of such a measurement (de Podesta et al. 2018; Pavlasek et al. 2020), it is likely that at least a part of this warming gets transferred to the air inside the calibration chamber, causing inhomogeneity and starting convective phenomena that increase uncertainty.

This last issue can be fixed only by calibrating fewer sensors each time: the downside of having a longer period between calibrations of the same sensor will be more than compensated by a reduced uncertainty for each calibration.

It should be noted that the EDIE system is a work-in-progress, as there is no general metrological consensus on the best procedure to calibrate temperature sensors in air. This is much of an open hot topic in environmental metrology (Merlone et al. 2024*b*), so it would not be correct to present EDIE as a general solution for the particular problem.

The large errors of the measurements performed by the DUT in this work raise a question about the influence of similar errors in weather stations on local climate change evaluation. It should be noted that, if such an evaluation is performed using temperature anomalies based on readings by the same sensor, an absolute error poses no problems and introduces no biases: as a matter of fact, an uncalibrated sensor is still able to correctly retrieve the temperature differences between any of its own measurements (not considering possible drifts of the sensor during time, and neglecting the nonlinearity of their response).

When, on the other hand, temperature anomalies are based on readings on different sensors in space (different AWSs) or time (sensor replaced by others), the errors due to sensors being not calibrated are likely to be a factor. It is difficult to evaluate their impact because it depends on how analyses are made, with how many sensors and for how much time.

The need for standardized procedures for the calibration of thermometers in air is well expressed by both the BIPM and the WMO. Specifically, dedicated calibration procedures for Arctic stations have been presented and discussed at the several Arctic Metrology Workshops and some of the NySMAC meetings. To follow climate trends, anomalies are a valuable starting point, but to compare trends from different stations or to understand atmospheric physics and for measuring gradients in space, accurate measurements are required. These can be achieved only establishing common traceability, through calibrations (Lopardo et al. 2012; Zeng et al. 2019).

Usually, climate change analyses are made considering temperature measurements as values without any uncertainty. Within this scenario, uncertainties in the evaluation of the climate change signal are due to the statistical tool employed only, e.g., confidence bands from a simple linear regression. However, when uncertainties in the data are considered, they are added to those due to the model and contribute to the overall uncertainty of the climate change signal. This leads to the apparent paradox that a metrological approach on such measurements generates *worse* results, because final uncertainties are larger. As a matter of fact, the metrological approach ensures that the final results are more robust, and that they include the "real" value with the correct level of confidence.

Errors and uncertainties of the sensors in this work can be compared, as an example, to the local temperature increase, variously evaluated, e.g., by Maturilli et al. (2019) as 0.16 ± 0.07 °C/yr and by Ding et al. (2018) as 0.076 ± 0.029 °C/yr, without accounting for the uncertainties in temperature measurements. Even taking into account that these values and uncertainties are calculated in different ways, they are much smaller than the values given in the present work for the single measurement (and uncertainty). Even though these values are not directly comparable, and the effect of errors and uncertainties of sensors on trends should not be overestimated (Bromwich et al. 2013), it appears likely that accurate calibration and uncertainty evaluations would be able to affect and refine these values to a great extent.

One source of uncertainty in temperature measurements, particularly important for air especially in the context of climate change, is the contribution of drift. To evaluate it, two or more calibrations are needed to compute their differences and evaluate the change in electrical resistance of the sensor, at a fixed temperature, with time. The evaluation of drift can be used, with a bit of attention, to extrapolate the results of this first calibration toward the past and apply the results to all the time series since the installation of the sensors in 2009. This procedure is obviously tricky, for many reasons: first, while thermistors in laboratory conditions are known to show linear drifts with time (Kulkarni et al. 2015; Li et al. 2023*a*), environmental sensors are subject to much more strain and stress, and therefore their drifts can vary in ways which are difficult to predict; second, even in presence of a linear drift (or a polynomial one, provided a sufficient number of calibrations are performed), an extrapolation to the past would necessarily carry very large uncertainties, to the point that it could be useless for practical reasons.

While this work only reports one calibration, others have followed. This will be the basis for the evaluation of drift, not only for the backward application of calibration, but more importantly to compare its value to the climate change signal, which may be the basis for a forthcoming paper.

6. Conclusions

In the context of global warming, accurate temperature measurements are required to supply modelers and climate scientists with the best data possible to forecast climate trends and provide policymakers with the most accurate scenarios upon which to base their decisions. This is even more important in the Arctic, given that it is a hotspot for the climate change signal and the relatively short time series available can still be the basis for accurate predictions.

This work describes the establishment of a calibration laboratory in Ny-Ålesund, Svalbard, under the joint effort of INRiM and CNR, and the results of the calibration of the four meteorological temperature sensors installed at different heights by the Amundsen-Nobile CCT, managed by ISP-CNR.

The *absolute* calibration, performed in the laboratory with the help of the portable chamber EDIE1 developed by INRiM, detected very large errors (up to 1 °C) by the sensors which scrambled the temperature profiles of the CCT; after calibration, the profiles were re-aligned and an uncertainty budget was drafted, an improvement over the factory uncertainty evaluation of almost a factor 2.

The *relative* calibration, where reference sensors were replaced by one of the DUTs, was able to reduce even further the uncertainties (which are down to few hundredths of a degree Celsius), at the cost of retrieving only the differences between the indications of the sensors and not the absolute temperatures.

This exercise shows that the calibration of meteorological sensors can be decisive in terms of retrieving the correct measurement of the sensors, which are particularly important even when their differences are calculated to study the atmospheric vertical profile. In addition, the measurements of calibrated sensors can be compared with measurements of sensors—calibrated as well—in other sites.

The calibration facility can play a key role for the creation of a harmonized and comprehensive database of all the temperature measurements in the area—be they atmospheric, ground, or marine. In addition, it raises consciousness of the importance of the traceability chain and of the comparability among temperature measurement series in different fields, to converge toward a more coherent and reliable evaluation of the climate change signal.

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Data availability

Calibration data are available without restrictions at Zenodo platform (Coppa et al. 2024).

Author information

Author ORCIDs

Graziano Coppa https://orcid.org/0000-0002-2847-3286
Chiara Musacchio https://orcid.org/0000-0001-7473-3678
Francesca Becherini https://orcid.org/0000-0002-8408-0102
Mauro Mazzola https://orcid.org/0000-0002-8394-2292
Angelo Viola https://orcid.org/0000-0002-6545-7496
Andrea Merlone https://orcid.org/0000-0002-3651-4586

Author notes

Angelo Viola is deceased.

Author contributions

Conceptualization: AV, AM
Data curation: GC, MM
Formal analysis: GC, CM
Funding acquisition: AM
Investigation: GC, CM, FB, MM, AV
Methodology: GC, FB, MM
Resources: AM
Supervision: AV, AM
Writing – original draft: GC

Competing interests

The authors have no conflicts of interest to disclose.

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