

Title: Advancement of air temperature metrology capabilities

Abstract

Air temperature measurements serve a myriad of purposes and hold pivotal importance in various fields such as complex industrial applications like energy storage, production, indoor climate control, meteorological observations, climate studies, relative humidity realisation and dimensional and mass metrology. Despite their critical importance, air temperature measurements are presumed to have reached their accuracy limits and there are currently no standardised specifications or guidelines for conducting air temperature measurements consistently. This lack of uniformity results in disparities in calibration capabilities among metrological laboratories. Proposals addressing this SRT should aim to enhance the capabilities and to disseminate the knowledge in the field of air temperature measurements, coupled with a comprehensive evaluation of factors influencing the measured quantity. Proposals should also focus on developing and characterising a climatic sub-chamber system, facilitating the comparison of measurement techniques among laboratories with low uncertainty levels.

Keywords

Air temperature, climatic chamber, contact measurements, environmental measurements

Background to the Metrological Challenges

The comprehension and thorough assessment of measurement uncertainty associated with air temperature measurements represent on-going scientific and technical challenges, sparking research endeavours and discussions within the organisations like EURAMET TC-T, BIPM CCT and WMO. Currently, there are no specifications or guidelines for uniformly conducting air temperature measurements and calibrations using contact temperature sensors. To ensure comparability and accurate calibration of such sensors, a standardised procedure is imperative. Additionally, standardisation in establishing a measurement uncertainty budget is essential to achieve comparability in measurement and calibration results.

The lack of a standardised guide for the calibration of thermometers in air was highlighted at the EURAMET TC-T meeting in 2017, leading to initiatives to promote collaborative research for its development under the EURAMET TC-T WG on guides. In addition, numerous experiments have addressed specific aspects of atmospheric air temperature measurements, including factors like sensor dynamics, site characteristics, radiation, wind, and rain, with projects such as EMRP ENV07 MeteoMet and EMRP ENV58 MeteoMet2 focusing on these aspects. However, challenges persist both in the uncertainty of in situ air temperature measurements and the calibration of thermometers in air, requiring further definition of procedures and guidelines.

Discrepancies in air temperature measurements, primarily caused by radiant errors, are frequently underestimated, even within highly controlled environments with low thermal radiance found in metrological laboratories. These variations are affected by factors such as the radiant environment, air speed, surface emissivity, and the size of the thermometer or object under scrutiny. Surprisingly, even in ideal laboratory settings, these variables can result in thermometers diverging from air temperature by around 0.1 °C, while larger objects may display variances of several tenths of degrees. Despite appearing minor, these disparities carry considerable significance across diverse fields of precision metrology.

At the present the common practice to calibrate air temperature sensor varies in many laboratories. They range from measurements performed in climatic chamber, through measurements of submerged volumes in stirred baths up to measurements in furnaces or baths directly. These methods offer different levels of precision and

temperature ranges with their specific caveats. A common challenge among these methods is the absence of specifications or guidelines for conducting air temperature measurements in a consistent manner. Establishing a standard procedure is crucial to ensure comparability and accuracy in calibrations. This standardisation effort should focus on defining how to conduct interlaboratory comparisons and develop a measuring system tailored for air temperature measurements in climatic chambers. Additionally, it should outline the variables (such as temperature, radiation, humidity, pressure, and wind speed) to be considered to comprehensively determine uncertainty, thus facilitating comparability of measurement results.

Objectives

Proposers should address the objectives stated below, which are based on the PRT submissions. Proposers may identify amendments to the objectives or choose to address a subset of them in order to maximise the overall impact, or address budgetary or scientific / technical constraints, but the reasons for this should be clearly stated in the protocol.

The proposal shall focus on the development of metrology capability in air temperature measurements.

The specific objectives are

1. To design and build a mobile sub-chamber system which can be used with typical climatic chambers and laboratory setups. It should enable the control of all the important influential factors (temperature distribution, radiation, humidity, pressure and wind speed) and work in the range of -40 °C to 80 °C with a target reference uncertainty of 15 mK.
2. To develop a measurement and calibration procedure which enables characterisation of the devices under test (DUTs) and reflects the metrological performance of the developed mobile sub-chamber system for the measurement of air temperature primarily by contact thermometry. This procedure should include uncertainty evaluation, determination of key influential factors (temperature distribution, radiation, humidity, pressure and wind speed), dynamic behaviour of sensors, uncertainty and their correlations, and a methodology to perform interlaboratory comparison.
3. To carry out an interlaboratory comparison making use of the developed procedure together with the mobile sub-chamber system which will create a basis for future comparisons in terms of hardware and procedures that will improve the currently used approaches.
4. To transfer knowledge in the field of air temperature measurements and calibration within the consortium to create a common base for further development in research capabilities as well as measurement and calibration techniques of atmospheric air temperature.
5. To facilitate the take up and long-term operation of the capabilities, technology and measurement infrastructure for air temperature measurements developed in the project, by the measurement supply chain (NMIs/DIs, calibration and testing laboratories), and end users (e.g. industry, instrument manufacturers, regulators). The approach should be discussed within the consortium and with other EURAMET NMIs/DIs, e.g. via EURAMET TC-Thermometry (T) and EMN for Climate and Ocean Observation, to ensure that a coordinated and optimised approach to the development of traceability in this field is developed for Europe as a whole.

Joint Research Proposals submitted against this SRT should identify

- the particular metrology needs of stakeholders in the region,
- the research capabilities that should be developed (as clear technical objectives),
- the area for which the capabilities will be built (Green Deal, Digital Transformation, Health, Integrated European Metrology, Industry, Normative or Fundamental Metrology) and in which future main call the developed research capabilities are planned to be employed,
- the impact the developed research capabilities will have on the industrial competitiveness and societal needs of the region,
- how the research capability will be sustained and further developed after the project ends.

Proposers should establish the current state of the art and explain how their proposed research goes beyond this. In particular, proposers should outline the achievements of the EMRP projects ENV07 MeteoMet and ENV58 MeteoMet2 and how their proposal will build on those.

The development of the research potential should be to a level that would enable participation in other TPs.

Proposers should note that the programme funds the activity of researchers to develop the capability, not the required infrastructure and capital equipment, which must be provided from other sources.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 0.7 M€ and has defined an upper limit of 0.9 M€ for this proposal.

EURAMET also expects the EU Contribution to the external funded beneficiaries to not exceed 20 % of the total EU Contribution across all selected projects in this TP.

Any industrial beneficiaries that will receive significant benefit from the results of the proposed project are expected to be beneficiaries without receiving funding or associated partners.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the 'end user' community, describing how the project partners will engage with relevant communities during the project to facilitate knowledge transfer and accelerate the uptake of project outputs. Evidence of support from the "end user" community (e.g. letters of support) is also encouraged.

You should detail how your proposal's results are going to:

- Address the SRT objectives and deliver solutions to the documented needs,
- Provide a lasting improvement in the European metrological capability and infrastructure beyond the lifetime of the project,
- Facilitate improved industrial capability or improved quality of life for European citizens in terms of personal health, protection of the environment and the climate, or energy security,
- Transfer knowledge to industries utilising air temperature measurements including the meteorology sector and the metrology community.

You should detail other impacts of your proposed JRP as specified in the document "Guide 4: Writing Joint Research Projects (JRPs)"

You should also detail how your approach to realising the objectives will further the aim of the Metrology Partnership to develop a coherent approach at the European level in the field of metrology and include the best available contributions from across the metrology community. Specifically, the opportunities for:

- improvement of the efficiency of use of available resources to better meet metrological needs and to assure the traceability of national standards
- the metrology capacity of EURAMET Member States whose metrology programmes are at an early stage of development to be increased
- organisations other than NMIs and DIs to be involved in the work.

Timescale

The project should be of up to 3 years duration.