Feasibility Study of an Intercomparison of Thermometers and Radiation Shields.

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Structure of the document:

1. Scope of the project. Defines the needs to be satisfied by the projects and the motivations from which the project is born. Moreover, it defines project products and the functionality of each deliverable.
2. Requirements and Strategy. Defines the characteristics and requirements (technical, functional, quality) of each deliverable. It also defines the approach that will be adopted to develop the project and to satisfy the defined requirements. Also defines processes and quality standards to be adopted during the project
3. Gross estimations. Estimations of times and costs
4. Evaluation. The most important section. The evaluation is the so called Business Case (evaluation of the benefits of the project).
5. References.

1. Scope of the project.

1.1. Introduction:

The demand of information on climate has never been greater that today. Long-term, ***high-quality****, and uninterrupted observations of the atmosphere, land and oceans are vital for all countries, as their economies and societies become increasingly affected by climate variability and change* [1].

A robust climate evolution evaluation and quantification, as well as, solid weather forecasts need to be based on high-quality measurements, reliable analysis and consistent comparability of the measurements performed in different places and at different times. An essential tool for the establishment of compatible data sets across the Earth and over the time is the Intercomparisons of instruments and observing systems. That, due to their importance and relevance, their organization should be performed by international organizations at the highest level, WMO. This fact would allow saving costs and efforts to be done in possible multiple comparisons organized at regional or national level. Besides, these type of international intercomparisons should be carried out by teams with enough expertise and knowledge in the different fields involved in this kind of activities, like climate, instrumentation, meteorology, metrology, observation, onsite measurements and data analysis. The expertise team would plan, coordinate and evaluate the intercomparison results with the appropriate level of confidence and using the suitable procedures to maintain an adequate and uniform level of measurements during the intercomparison.

Air temperature near the Earth's surface is one of the most widely measured environmental variable and their measurements have been performed for more than hundred years. This fact, among

others, makes the air temperature near Earth's surface a dominant benchmark in studying and quantifying the climate change. It is also one of the most important data for daily operational meteorological services

Having in mind the importance of the instrument intercomparisons for ensuring the quality of measurements and observations, and that air temperature, near Earth's surface, is a key parameter in climate, meteorology and in the study of many physical phenomena related with Earth Science, this document proposes the organization of an intercomparison of thermometers and radiation shields.

1.2. Needs and motivations:

Long-term, accurate, unbiased and comparable observations of air temperature are essential to understand the current state of the global integrated Earth system, its history, and its future variability and change. Long-term stability and accuracy are difficult to achieve when thermometers, radiation shields and technologies to measure air temperature change over time. It is essential to know the impact on data when thermometers, systems to measure air temperature or data acquisition transmitters are replaced. This fact, together with the consideration that the climate community requires an uncertainty of surface air temperature within 0.5 K [2], a tool to determine the operational comparability between different systems (thermometer plus radiation shield) is needed. An intercomparison of thermometers should recognize their limits, in terms of measurement uncertainty, due to instrumental, geophysical and sampling issues, in combination with reliable calibrations and thorough studies of the characteristics of the systems used to measure air temperature.

The project, here proposed, addresses two different and linked intercomparisons: intercomparison of thermometers and intercomparison of radiation shields, both of them consistent since a metrological point of view [3] [4] and considering the inputs from the EMRP projects ENV.7 MeteoMet [5] and ENV58. MeteoMet2 [6]:

1.2.1. Intercomparison of thermometers

Different thermometers, based on different physical phenomena, are currently used by National Meteorological and Hydrological Services (NMHS) and by Climate community. Ranging from liquid in glass thermometers to thermometers based on optical properties of the air which temperature is measured. The most common sensors used for meteorological and climate applications are the ones based on the change of the electrical resistance of an element with temperature. But again, this group is composed by a lot of different sensor designs and with a lot of different configurations, being thermistors and platinum resistance thermometers the most important ones. The platinum resistance thermometers (PRT), for meteorological and climate applications, have, as well, different designs that can be classified in two groups. In the first group, the sensing element is a thin platinum wire supported by glass or ceramic material. In the second PRT design, the resistance element is a platinum film deposited on a ceramic substrate [7]. Independently of the design, the platinum resistance thermometers can also be divided by its different resistance value at the triple pint of

water (0.01 ºC), being the most common in meteorology and climate, pt-100, pt-500 and pt-1000. Another aspect to be considered is that the thermometers could stand alone or can be in combination with a humidity sensor in a unique system.

The previous paragraph shows the very different thermometers that can be used for meteorological and climate applications and although these thermometers have been compared, partially, in laboratories, there is no evidence of an intercomparison of thermometers under real conditions of use [8].

1.2.2. Intercomparison of radiation shields

No standard thermometer radiation shield or screen has been defined yet. Consequently, many different designs of thermometer screens are in use throughout the world, each one, with its own specific features. These different behaviours gave as a result that the differences between the air temperature inside the screens and the real ambient temperature depends on the radiation shield itself. Besides, the behavior of each radiation shield depends on weather conditions, therefore, the Commission for Instruments and Methods of Observation (CIMO) recommended organizing international comparison of thermometers screens in different climatological regions [9] [10]. Following this recommendation, comparisons were already organized in the desert climates [11], but there is still needed an intercomparison of radiation screens in tropical climate and/or in polar or high mountain climate.

On the other side, comparisons of radiation shields were also organized in midlatitudes during the past decades: in Netherlands [12], [13] and [14] and Germany [15], but all of them with their own goals and specific measurement setup. More generic answers on the measurement uncertainty of air temperature that can be used worldwide, require a multisite experiment with a uniform approach.

Independently if the comparison is carried out in a unique place or as a multisite experiment, this project has also the aim to address some issues and suggestions emerged in the Algeria comparison [11]:

-Study of the sonic anemometers as temperature reference systems for screen intercomparisons, since this device is not affected, in principle, by sun radiation. This study would imply a thoughtful analysis of the sonic anemometer behaviour in the laboratory, as well as, in situ conditions. Both studies will allow the understanding their limitations and their main sources of uncertainty when they are used as thermometer.

-In active ventilated radiation shields, the influence of the fan speed on air temperature measurements should be studied.

- Evaluation of the screen effects on the air temperature measurements as a function of (Solar and heat) radiation errors, insufficient ventilation, screen contamination, wet bulb effects by precipitation, fog, icing and dew deposition and heat transport from the surrounding instrument setup.

2. Requirements and Strategy

The project will be divided in four phases.

2.1. Previous Activities [8].

As it is established in the CIMO guide [8], a WMO intercomparison of instruments and methods of observation shall be agreed upon by the WMO constituent body concerned so that it is recognized as a WMO intercomparison. The Executive Council will consider the approval of the intercomparison and its inclusion in the programme and budget of WMO.

Before each intercomparison, the Secretary-General, in cooperation with the president of CIMO and possibly with presidents of other technical commissions or regional associations, or heads of programmes concerned, should make inquiries as to the willingness of one or more Members to act as a host country and as to the interest of Members in participating in the intercomparison. When at least one Member has agreed to act as host country and a reasonable number of Members have expressed their interest in participating, an international organizing committee should be established by the president of CIMO in consultation with the heads of the constituent bodies concerned, if appropriate.

2.2 Preparation of the intercomparison*.*

2.2.1. Selection of the Organizing Committee (M0).

Experts in the different involved fields like climate, data analysis, instrumentation, meteorology, metrology, will composed the Organizing Committee. Before the beginning of the intercomparison , the organizing committee should agree on several factors like, for example, the main objectives, place, date and duration of the intercomparison, conditions for participation, data acquisition, processing and analysis methodology, plans for the publication of results, intercomparison rules, and the responsibilities of the host country (countries)and the participants [8].

2.2.2. Nomination of the project leader and analysis of the comparison location (M1)

Once the host country (or host countries, in case a multisite experiment) is decided, the project leader will be defined and the proposed location will be analysed by the Organizing Committee. (M1)

2.2.3. Literature study (M3)

The Organizing Committee will perform a literature study about what has already been performed regarding air temperature measurements in the climate of the selected place. The Organizing Committee will organize a consultation of potential stakeholders. This will include people already measuring in the climate of the selected place, manufacturers and researchers. The consultation will be focus on the specific needs to be solved by the comparison of temperature screens and sensors and about what they would like such a comparison to reveal..

2.2.4. Survey study (M3)

The Organizing Committee will perform a survey about the most common thermometers and radiation shields used by the NMHS. Researchers and manufacturers would be included in the survey to collect information about their newest designs. The survey would also request volunteers

to lend instrumentation (3 instruments per model) and to perform the initial and final installation of the corresponding instrumentation in the location of the intercomparison. The number and model of thermometers and radiation shields to be compared would be decided after this survey. Among the others, the Stevenson screen will be included in the intercomparison due to its historical use and due to the general use along the World. Besides this fact, if the comparison includes liquid in glass thermometers, it would give very valuable information to climatologist, but it would imply a more expensive comparison and a harder analysis of the comparison data [15].

2.2.5. Preparation of the intercomparison location (M8)

The host country will prepare the intercomparison location with the inputs from activities 2.2.2. 2.2.3. and 2.2.4.

2.2.6. Intercomparison protocol preparation (M8).

The protocol of the intercomparison will consider the points of this feasibility study, the rules established by WMO [8] and the inputs of the activities 2.2.2. 2.2.3. and 2.2.4 . The protocol will include the description of the involved instrumentation and it will include some of the radiation shields that already took part in the comparison in Algeria [11]. The protocol also will dealt about the rules of the intercomparison, intercomparison methods, establishment of the air temperature reference value, processing and data analysis methodology. It will also include the setting of observations on which the comparison will be focused, e.g. those in use for synoptic or climatological purposes like samples, 1-minute or 10-minute averages,, daily averages, or value/time of day for *T*min and *T*max

The ancillary measurements would be also included in the protocol. They could be:

-Humidity measurements. Hygrometers
-Wind speed and direction at the thermometers height (2 m) and at 10 m. Anemometers
-Direct and indirect sun radiation. Pyranometer
-Earth radiation: Albedometer & Pyrgeometer
-Precipitation. Solid and liquid precipitation
-Soil temperature. Soil thermometers
-Soil moisture measurements
-Fog and visibility.
-Snow level measurements

2.2.7. Analysis of the protocol by experts (M10)

The Organizing Committee will decide a group of Experts, who will analyse the protocol. Besides, the protocol will be circulated among the BIPM-CCT-WG_Env.

2.2.8. Calibration and laboratory characterization of the instrumentation (M3-M10)

Calibration and laboratory characterization of the thermometers [16], [17] radiation shields [18] and the ancillary instrumentation involved in the intercomparison.

2.2.9. Installation of the instrumentation in the place of the intercomparison (M10-M12).

2.3 Intercomparison.

2.3.1. Intercomparison of thermometers in situ. (M12-M24)

A unique model of radiation shield will be selected and each model of thermometer would be inserted in this radiation shield. The model of radiation shield would be selected considering the inputs of 2.2.3.

2.3.2. Intercomparison of radiation shields in situ.(M12-M24)

Platinum resistance thermometers of 100 Ω, Pt-100s, will be inserted in each radiation shield. All the thermometers, Pt-100, will be of the same model. If it is possible and in order to be sure about the quality of the measurements, to have redundant data and not dependence of the possible drift or failure of one of the pt-100, three pt-100 will be inserted in each radiation shield. If the radiation shield does not allow the holding of three Pt-100, other actions will be considered to keep the quality, redundancy and reliability of the measurements. For instance, three radiation shields of the same model with one thermometer in each of them.

2.3.3. Set of thermometers and radiation shields. (M12-M24)

Thermometers designed for a specific radiation shield (decided by the manufacturer) would be included in the intercomparison, following the specifications of the manufacturer..

2.3.4. Removal of the instrumentation (M25)

Removal of the thermometers, radiation shields and ancillary instrumentation.

2.3.5. Final calibration of the instrumentation (M25-M28).

Calibration of the thermometers and the ancillary instrumentation after the onsite measurements.

2.4 Analysis of the measurements

2.4.1. Analysis the data of the intercomparison of thermometers (M24-M34)

Analysis the data of the comparison of thermometers with the establishment of the air temperature reference data and the deviation of the each thermometer readings regarding this reference value. The dependence of these differences with the different weather conditions will be analysed.

2.4.2. Analysis of the data of the intercomparison of radiation shields (M24-M34)

Analysis of the data of the comparison of radiation shields with the establishment of the air temperature reference data and the deviation of the each system (thermometer+radiation shield) readings regarding this reference value. The dependence of these differences with the different weather conditions will be analysed.

2.4.3. Establishment of the Intercomparisons conclusions (M34-M35)

Establishment of the Intercomparisons conclusions and their comparison with the conclusions of the intercomparison of radiation shields performed in Algeria [11] and in midlatitudes [12], [13], [14] and [15]

2.4.4. Final report of the intercomparison (M36).

3. Gross estimations. Estimations of times and costs

Time: 36 Month: 1 year of preparation, 1 year of measurements and 1 year for analysis and publications

Costs:

- Personnel:
  -Project leader: (12 Man/Month, MM)

  -Comparison team members: Support the project leader, organizing the comparison, preparation of the protocol, control of the running of the intercomparison, discussion and approve the results of the data analysis: 5 people (30MM).

  -Host staff: Preparation of the site for the intercomparison, maintenance of all the instrumentation involved in the comparison and visual checking of the instrumentation and data (8MM per selected place)

  -Initial and final calibration of all the thermometers and ancillary instrumentation: (6MM).

  -Analysis of the measurements: (9MM))

- Location: It is recommended locations where the National Meteorological and Hydrological Services have meteorological station or in a research area. Rental costs could be necessary and budget for the site preparation would be needed too.

- Instrumentation. It is desirable to use instrumentation lent by NMHS or manufacturers. But, there is a high probability that ancillary instrumentation needs to be bought.

4. Evaluation of the benefits of the intercomparison

Intercomparison of instruments allows to check the validity of the measurements performed by each of the involved instruments and to compare the relevance of each instruments regarding the others. This makes the intercomparison of instruments a vital activity for CIMO. The intercomparisons here proposed include a combination of calibration, laboratory testing and onsite functional testing.

The benefits of these intercomparisons are:

- Agreed reference procedures for the intercomparison of thermometers and radiation shields will be established. These procedures in combination with the previous comparison protocols have the aim to establish best practices guides for future intercomparisons, allowing the organization of homogeneous intercomparisons of thermometers and radiation shields at national, regional and global level.

- Conclusions on the improvement of the systems thermometer plus radiation shield will be drawn, allowing manufactures to improve their designs, being less sensitive to sun radiation, with faster response time and with optimal internal ventilation avoiding the development of microclimates within the screen.

- Establishment of a hierarchy of the most common used thermometers and radiation shields as a function of their limits, behaviour and measurement uncertainties. These hierarchies will be valuable information for NMHS and Climate community for the selection of the appropriate air temperature stations as a function of the desired uncertainty.

- In case a multisite experiment is decided, this project will establish a homogenous way to evaluate the most appropriate radiation shield for different climates. If the comparison is carried out in extreme climate like tropical, polar or high mountain climate, this project will emerge the most suitable radiation shield for the selected extreme climate, providing important information to the scientific community working in such environments. Special important are the polar areas where climate variability has bigger impact. Performing reliable air temperature measurements with low uncertainty in polar environments will allow detecting climate trend in less time and, for hence, taking the appropriate decisions for the adaptation to such climate variability in advance.

- The inclusion, in this intercomparison, of radiations shields that already took part in the intercomparison carried out in the desert of Algeria, will allow studying the behaviour of some of the radiation shields at extreme environments. As a result, it will be possible to meet the challenge of the establishment of a maximum correction factor for the air temperature measurements as a function of weather conditions. This factor is also a source of uncertainty and it should be included in the uncertainty budget of the air temperature measurements performed by the same system but in different climates.

  -The transference function between the different systems, thermometers and radiation shield, will be obtained. This is of particular importance for the Stevenson screens to other multiplate screens and for the change of liquid in glass thermometers to other thermometers. It will solve an important source of inhomogeneities in the temperature time series due to the change of the thermometer and/or the change of the design of radiation shield during the time series. The value of this possible inhomogeneity seriously restrict the usefulness of the data since it is a source of uncertainty in air temperature trends. . A multisite experiment would allow the analysis of the dependence of these transference functions with the weather conditions.

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