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PROCEDURES FOR INTERCOMPARISON OF THERMOMETER SCREENS/SHIELDS, IN CONJUNCTION WITH HUMIDITY MEASUREMENTS, IN VARIOUS CLIMATIC REGIONS

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Summary and purpose of document

The document provides proposals of objectives, place, date, and duration of the intercomparison as well as procedures for combined intercomparison of thermometer screens/shields, in conjunction with humidity measurements, in various climatic regions.

Action proposed

The meeting is invited to consider proposals suggested in the document and agree on procedures of the intercomparison.

1 Background (Introduction)

Commonly used atmospheric humidity sensors require protection from influences of precipitation (rain, snow, icing and others) but also from solar and terrestrial radiation, as the temperature measurements are an inseparable part of the humidity measurements in many cases. Radiation screens and shields protect the thermometers and hygrometers from these influences.

At present, there is neither commonly accepted reference screen design nor generally accepted test methods for determination of the performance characteristics of screens. Several different intercomparisons of radiation screens/shields in conjunction with the temperature measurements were organised by WMO or National Meteorological Services. But this is not the case of humidity measurements. Therefore CIMO, at its last session, considered an organization of the combined intercomparisons of thermometer screens in conjunction with humidity measurements, in various climatic regions.

The first session of the CIMO Management Group (CIMO-MG, 2003) adopted the decision to organise the combined intercomparison of thermometer screens/shields, in conjunction with humidity measurements, in various climatic regions, with the start of the intercomparison in 2004 and publishing the results in 2005.

The numeration of the individual paragraphs is in agreement with the CIMO Guide.

2 Objectives of the intercomparison

The main objectives of the intended intercomparison are as follows:

- To analyse the humidity measurements and compare the performance of the tested radiation screens/shields (especially estimation of the impact of radiation, wind speed, precipitation on humidity measurements);
- To define key performance characteristics and operational factors of radiation screens/shields tested in the intercomparison;
- To analyse performance characteristics (especially reliability, accuracy and long-term stability) of tested humidity sensors;
- To improve the accuracy of the humidity measurements using the tested radiation screens/shields;
- To draft recommendations for consideration by CIMO-IX (to propose the WMO reference radiation screen/shield for humidity measurements);
- To prepare a concise summary report containing the main results for an immediate publication first;
- To publish the final report of the intercomparison within the WMO Instruments and 0bserving Methods Report series (IOM).

3 Place, date, and duration

Considering suitable and appropriate locations for the intercomparison, following should be taken into account:

- A combination of different climate regions with an aspect of temperature and humidity characteristics, i.e. warm/hot humid region, warm/hot dry region, mild humid region, mild dry region, and cold region;

- Existence of Regional Instrument Centres (RICs) in different climate regions with their facilities to assist in the intercomparison and take advantage of them.

It is desirable to start the intercomparison as soon as possible. Taking into account a whole range of work that has to be done in a preparation stage, it is proposed to start the intercomparison during the next summer or autumn season (on the north hemisphere).

Duration of the intercomparison can differs slightly depending on the climate region. In case of a region with no significant annual changes of mean temperature and humidity duration can be shorter but not less than 6 months. Otherwise, duration should be at least 12 months.

4 Participation in the intercomparison

Both naturally and artificially ventilated screens should be considered. In both cases it is proposed:

- To install two identical instruments of each type in order to increase confidence in the data;
- To select the combined temperature/humidity sensors and radiation screens/shields that are in operational use also taking into account new development in the area;
- To select the combined temperature/humidity sensors for humidity measurements with the time constant of about 30 seconds, with the uncertainty of the temperature measurements 0.1 K or less, and with the uncertainty of the humidity measurements 2% or less.
- Taking into account the results of the previous intercomparisons, priority should be given to the screens/shields with the black inside in case of naturally ventilated screens/shields.

For the intercomparison of different naturally ventilated radiation screens/shields with the same type of the temperature/humidity sensor, followed candidates for the intercomparisons are proposed (in the alphabetical order):

The tested screens/shields:

MetSpec Ltd., thermometer screen

Met One Instruments, Inc., Radiation Shield, model 5980;

Meteoservis v.o.s., Radiation Shield, model MetCover3;

Socrima, radiation shield, model BMO 1167A;

Vaisala, Solar Radiation and Precipitation shield, model DTR503A;

Vaisala, Radiation shield, model DTR13;

Vaisala, Radiation shield, model HMP243;

Young, multi-plate radiation shield, model 41003.

The temperature/humidity sensors:

Campbell Scientific Ltd, Temperature and Relative Humidity Probe, model HMP45C;

Delta-T, Relative Humidity & Air Temperature Sensors, types RHT2nl;

Rotronic, Temperature and Relative Humidity Probe, model MP101A;

Vaisala, Temperature and Relative Humidity Probe, model HMP45A/D;

Young, Relative Humidity/Temperature Probe, model 41372.

For the intercomparison of different artificially ventilated radiation screens/shields using the temperature/humidity sensor predefined by the corresponding producer, followed candidates for the intercomparisons are proposed:

The tested shields:

Climatronics Corporation, Motor Aspirated Shield, model TS-10;

Met One Instruments, Inc., Fan Aspirated Radiation Shield, model 076B;

Yankee Environmental Systems, Inc., Precision meteorological thermo-hygrometer Model MET-2010;

Young, aspirated radiation shield, model 43408.

6 Data processing and analysis

6.1 Database and data availability

The database of one-minute data of all measured parameters is the basic presumption of later statistical analysis and processing of the weather conditions during the intercomparison period. For the purposes of detailed analysis of the special situations, the database of all temperature/humidity samples (signal measurement data) would be useful. Suitable database of all manually observed parameters and results (notes) of the shield checks should be considered, too.

All sensors used in the intercomparison should be calibrated at least at the beginning and at the end of the intercomparison period. The data should be stored without correction. All corrections should be applied later during data processing and analysis. The corrections will be obtained by linear regression from the calibration data taking into account all calibrations made during the intercomparison.

BUFR should serve as the common data format for data transmission as well as for data archiving.

Near-real-time monitoring and data quality control shall be implemented and can consist of several procedures, e.g.:

- Missing data analysis;
- Time-series plots of all measured parameters on a daily (24-hour) basis;
- Statistical analysis of means (10-minute, 1-hour, 24-hour);
- Detection of potential anomalies (extreme values of differences);
- Error data analysis.

During long-term continuous logging of data there are always some values that are not representative and have to be rejected. In case of double installation of the same type of screens there is a possibility to reject any measurements in which the corresponding values in a pair of screens of the same type differed more than 0.5 ºC (in case of temperature) or more than 5 % (in case of relative humidity).

As global radiation can vary rapidly, the radiation data should be smoothed with a low pass exponential filter with a time constant of 20 minutes in order to reduce random errors.

6.2 Data analysis

It is proposed to use the following statistical procedures:

a) Analysis of mean values of humidity measurements

- Analysis of the daily profiles of the temperature and humidity;

- Analysis of the differences of one-minute values of the measured humidity parameter (tested screen – reference screen). A histogram of these differences should be drawn for the whole period to give a first indication of the observed humidity differences. The differences should be further analysed.

- Analysis of one-minute data provides the information on the effect of solar radiation and wind speed respectively on the humidity parameter measured in each screen: means and standard deviations of differences in humidity in various screens for different classes of global radiation (with a span of 100Wm^{-2}) and wind speed (with a span of 1ms^{-1}) respectively should be analysed.

b) Analysis of mean values of differences of humidity measurements (reference screen – tested screen)

- Micrometeorological and short-term effects should be considered first, before any statistical analysis of the mutual differences of the humidity measurements, averaged over a specified time period (e.g. an hour, a day).

- Analysis of mean diurnal/monthly differences of humidity measurements: Analysis of deviation for the tested screen/shield as the function of the reference humidity measurements. The mean difference between the reference humidity measurement and each of the tested screens/shields. The mean differences will be computed for humidity intervals of 5 % and for different temperature classes (with a span of 5 ºC).

Systematic differences of humidity measurements (reference screen – tested screen) have to be presented as a function of relative humidity, and should also be considered as a function of temperature, wind speed and radiation respectively.

c) Analysis of extreme differences of humidity measurements (reference screen – tested screen)

The conditions leading to extreme measurement errors of humidity measurements are not readily apparent. This can be overcome by identifying extreme differences between the reference screen and the tested screen and then investigating the current meteorological conditions during these differences. If the screens have different time constants and relative humidity variation with time is high, this may be the cause of such differences. Therefore, such comparison should be conducted on daily extreme values, to be more representative.

Daily extreme values (minimum and maximum) with time of occurrence should be computed for each screen from the one-minute database. The histograms of the differences of corresponding daily extreme values (reference screen – tested screen) for the whole period should be drawn and the differences should be further analysed.

d) Analysis of humidity measurements for typical conditions experienced during the intercomparison period

A statistical analysis of humidity differences (reference screen – tested screen) for different classes of meteorological conditions should be done with the goal to analyse the effects of the individual meteorological variables and their combinations. Below listed effects should be analysed using the whole database and specific filters on the influence parameters and appropriate combinations of them:

- Direct solar radiation to be consider with the categories:
  - radiation ≤ 1000 Wm^{-2}
  - radiation > 1000 Wm^{-2}
- Wind speed to be consider with the categories:
  - wind speed ≤ 1.0 $m.s^{-1}$
  - 1.0 $m.s^{-1}$ < wind speed ≤ 4.0 $m.s^{-1}$
  - wind speed > 4.0 $m.s^{-1}$.
- Day/night (radiation effect);
- Night time: clear sky/overcast (radiation effect);
- Hygrometeors occurrence, especially precipitation, fog (dry/wet conditions);

A graphical description of weather experienced during the intercomparison should be drawn, with temporal curves of temperature, global radiation, wind speed and significant precipitation occurrence. From this description periods with typical conditions for the whole intercomparison period should be identified. Humidity differences (reference screen – tested screen) should be displayed for these typical conditions. These curves should help to explain the screen performance and to understand the origin of the differences. Differences plotted against time quickly show the changes with respect to changes in the weather conditions.

Another solution is to define typical meteorological conditions and then analyse the performance of the tested screens during periods with these conditions to get a detailed knowledge of the screen performance in known conditions. This may allow an extrapolation of the screen performance in climatic regions other than the test site.

Typical meteorological conditions could be periods of at least 6 (or 4) hours with:

- Direct solar radiation > 1000 Wm^{-2} and wind speed ≤ 1.0 $m.s^{-1}$;
- Direct solar radiation > 1000 Wm^{-2} and 1.0 $m.s^{-1}$ < wind speed ≤ 4.0 $m.s^{-1}$;
- Direct solar radiation > 1000 Wm^{-2} and wind speed > 4.0 $m.s^{-1}$;
- Direct solar radiation < 1000 Wm^{-2} and wind speed ≤ 1.0 $m.s^{-1}$;
- Direct solar radiation < 1000 Wm^{-2} and 1.0 $m.s^{-1}$ < wind speed ≤ 4.0 $m.s^{-1}$;
- Direct solar radiation < 1000 Wm^{-2} and wind speed > 4.0 $m.s^{-1}$;
- Humidity variation > 50 % and wind speed ≤ 1.0 $m.s^{-1}$;
- Humidity variation > 50 % and wind speed > 4.0 $m.s^{-1}$.

e) Analysis of special situations (selected periods containing events of particular significance)

Statistics calculated from a large number of observations can show small differences between screens and hide differences that occur in only a few, rather rare, circumstances. A combination of the daily profiles of those differences with temperature/humidity profiles can reveal these situations. Examples of those could be:

- a day with fog and rapid change of relative humidity;
- a day with precipitation occurrence and rapid change of relative humidity;
- sunrises and sunsets in case of clear sky, etc.

7 Final Report of the intercomparison

Final Report of the intercomparison shall be published in the WMO Instruments and Observing Methods Report series either in hard copy or electronically (CD-ROM). Final Report of the intercomparison should also be made accessible through WMO IMOP/CIMO home page.

It will be highly beneficial to prepare a concise Summary Report containing the most important comparison results first (no later than 6 months after finalizing the intercomparison). The comprehensive Final Report should be published no later than 18 months after the intercomparison.

8 Responsibilities

8.1 Responsibilities of participants

Participants shall be fully responsible for the transportation of all submitted equipment, all import and export arrangements, and any costs arising from these. Correct import/export procedures shall be followed to ensure that no delays are attributable to this process.

Participants shall generally install and remove any equipment under the supervision of the PL, unless the host country has agreed to do this.

Each participant shall provide all necessary accessories, mounting hardware, signal and power cables and connectors (compatible with the standards of the host country), spare parts, and consumables for its equipment. A participant requiring a special or non-standard power supply shall provide his own converter or adapter. Participants shall provide all detailed instructions and manuals needed for installation, operation, calibration, and routine maintenance.

8.2 Responsibilities of a host country

- To provide a description of the proposed intercomparison site and facilities (location, environmental and climatological conditions, major topographic features, etc.).
- To provide the necessary data acquisition system capable of recording the required analogue, pulse and digital (serial and parallel) signals from all participating instruments.
- To provide a description and a block diagram of the full measuring chain.
- To examine and verify the data acquisition system hardware and software before the intercomparison and take measures to prevent gaps in the data record during the intercomparison period.
- To provide, if asked, necessary information to participating Members on temporary and permanent (in the case of consumables) import and export procedures.
- To assist with the unpacking and installation of the participants' equipment and provide rooms or cabinets to house equipment that requires protection from the weather and for storage of spare parts, manuals, consumables, etc.
- To provide necessary electrical power for all instruments. The participants should be informed of the network voltage and frequency and their stability. The connection of instruments to the data acquisition system and the power supply will be done in collaboration with the participants. The PL should agree with each participant on the provision, by the participant or the host country, of power and signal cables of adequate length (and with appropriate connectors).
- To designate a site manager for its country.

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