RESULTS OF THE WMO INTERCOMPARISON OF THERMOMETER SCREENS / SHIELDS AND HYGROMETERS IN HOT DESERT CONDITIONS

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ABSTRACT

The Joint Expert Team on Surface-Based Instrument Intercomparisons and Calibration Methods (ET) and International Organizing Committee on Surface-Based Instrument Intercomparisons (IOC), according to the CIMO Plan of WMO Intercomparisons, started the WMO Intercomparison of thermometer screens and humidity measuring instruments on the 1st of November 2008, for a full year of measurements. The campaign was held at the meteorological station of Ghardaïa, Algeria. A group of 29 screens/shields both artificially-ventilated (7 different models) and naturally-ventilated (11 different models) and 17 humidity sensors (8 different models) were involved in this intercomparison. Most of sensors were installed in pairs.

A summary of the results of the intercomparison is presented. One temperature probe in an Eigenbrodt screen is chosen as the working reference for temperature measurements. The four large Stevenson screens provided very good results. Small passive multi-plate screens exhibited warmer temperatures than the reference, except two that had results close to the reference. Artificially-ventilated screens gave disappointing results. The air temperature calculated from the Thies ultrasonic anemometers was much colder than all other screens.

The MeteoLabor Thygan is the primary reference for relative humidity measurements. One Vaisala HMP45D is an extra working reference. Five models gave very good results over the test period. Two models showed medium results. Only one model demonstrated poor results. No clear influence of the an overestimated temperature on the relative humidity values was detected.

Keywords: temperature, relative humidity, hot desert conditions, WMO Intercomparison

INTRODUCTION

Background

Several intercomparisons of radiation screens/shields with respect to temperature measurements were organized by National Meteorological Services in temperate climatic regions. No such intercomparison was held in arctic or tropical regions. Knowledge of the characteristics of temperature measurements in these regions is particularly important for climatological studies and climate change.

The effect of screen design was in particular evaluated in [1]. Methods for comparing the performance of thermometer shields/screens are defined in an ISO standard [2].

Since the last WMO intercomparison of humidity sensor was held in the period 1985-1989, there was a need to update the knowledge about sensors that are available on the market and are widely used.

Objectives

The main objective of this intercomparison is to test the performance of radiation screens/shields and of humidity sensors especially in high temperatures and low relative humidity conditions.

Further objectives are also to estimate the impact of radiation, wind speed, precipitation on temperature and humidity measurements inside the different screens/shields; to draft recommendations for consideration by CIMO.

METHODS AND PROCEDURES

Site

The intercomparison site adopted was positioned at the meteorological station of Ghardaïa, Algeria (Figure 1). It is a flat, rocky area of 1120 m^2, equipped with 36 small concrete acquisition platforms, separated one from another by 4 meters. The area is situated at more than 30 meters from the meteorological station building.

The intercomparison was held from the 1st of November, 2008 to the 31st of October, 2009.

Over the 12 months period of the intercomparison, more than 500 000 minutes of data are available for the majority of screens and hygrometers, allowing a deep data analysis.

Figure 1. Intercomparison site - Ghardaïa, Algeria

During the intercomparison period, the temperature reached a maximum of 45.1°C on the 16th of August, 2009. Figure 2 and figure 3 show the evolution of the temperature and the relative humidity over the test period.

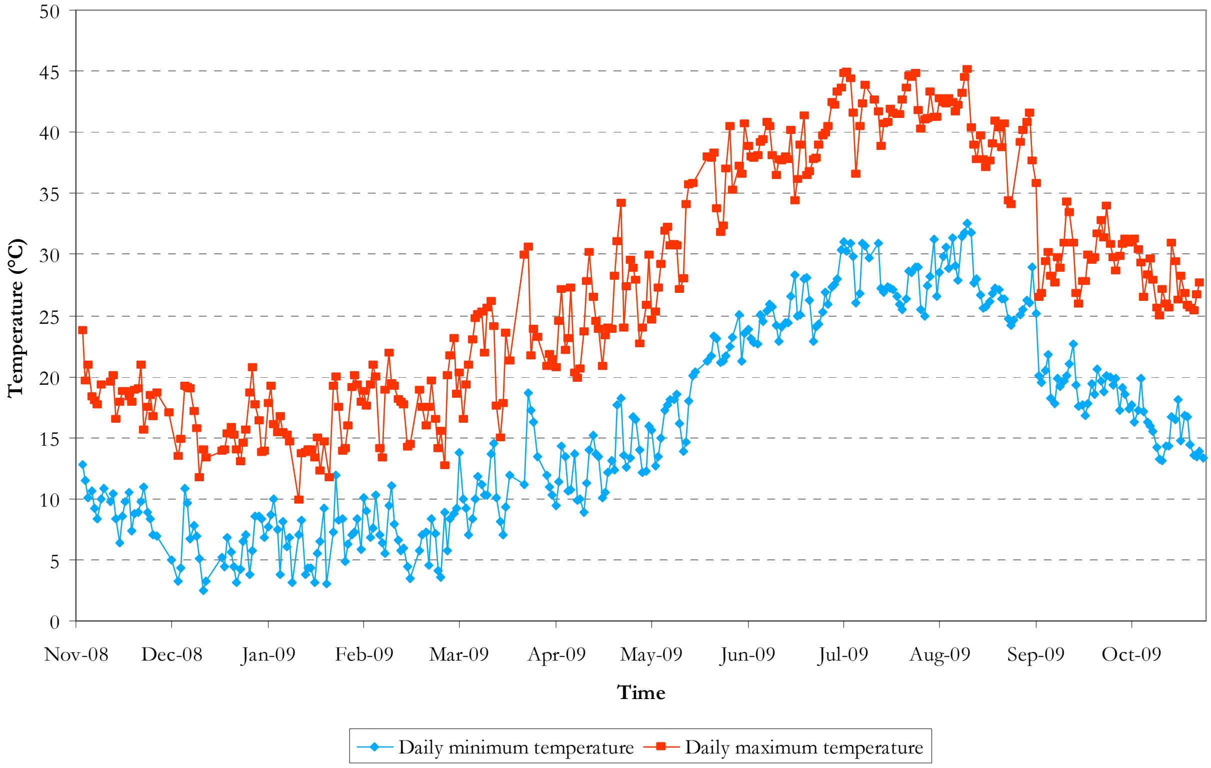

Figure 2. Daily extreme temperatures over the intercomparison period

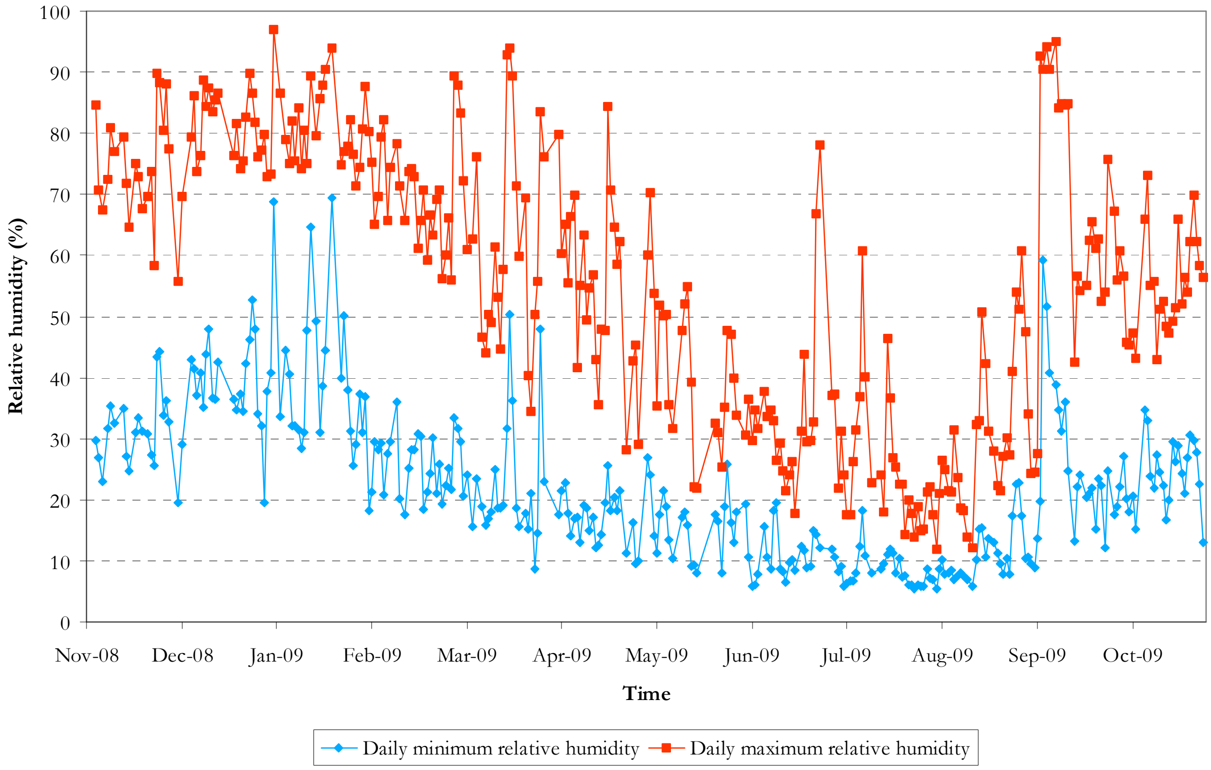

Figure 3. Daily extreme values of relative humidity over the intercomparison period

The distribution of relative humidity measurements over the whole period of the intercomparison is plotted on figure 4.

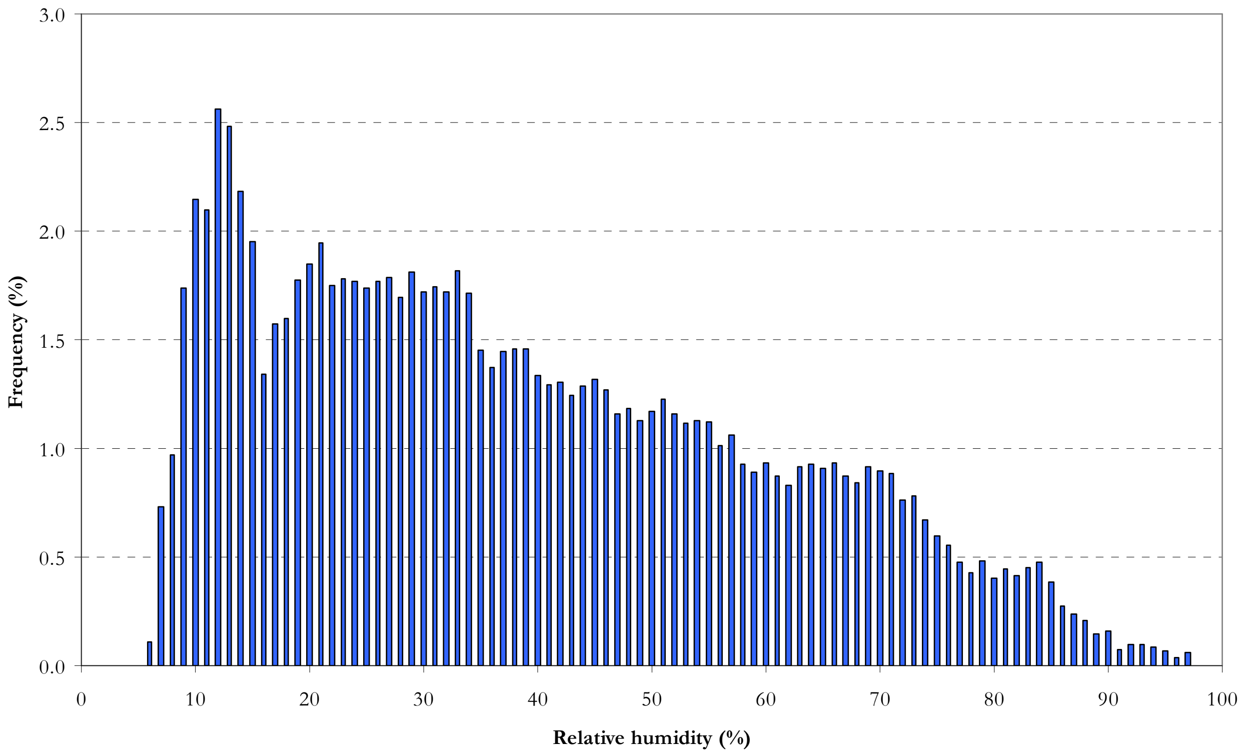

Figure 4. Distribution of relative humidity over the whole period of intercomparison

This intercomparison included many periods with very low values of relative humidity.

Participating instruments

This intercomparison hosted 29 screens/shields both artificially-ventilated (7 different models) and naturally-ventilated (9 different models) and 17 humidity sensors (8 different models). Most of sensors were installed in pairs. Two extra wind sensors from manufacturer Thies (Germany) were also tested, to evaluate ultrasonic temperature measurement [3].

The list of participating screens/shields is available in table 1.

Table 1. List of participating screens/shields

Member country	Manufacturer	Model	Number	Acronym
Algeria	Socrima	Large Stevenson Screen	1	LSOC
Australia	BoM	Small Stevenson screen	1	LBOM
Austria	Lanser		2	LLAN
France	Socrima	BMO1195D	2	SSOC
Germany	Fischer	431411	2	VFIS
Germany	Vaisala	HMT337 & HMT 330 MIK	2	SVAI
Germany	Eigenbrodt	LAM630	2	VEIG
Italy	CAE	TU20AS	2	SCAE
Sudan	Casella	Stevenson Screen	1	LCAS
Switzerland	Meteolabor	Thygan VTP37 Airport Thygan VTP37 Thermohygrometer	1 1	VTHY
Switzerland	Rotronic	AG/RS12T & Hygroclip S3	2	VROT
UK/HMEI	Windspeed	T351-PX-D/3	2	SWIN

Member country	Manufacturer	Model	Number	Acronym
USA	Davis	PN7714	2	SDAV
USA	Davis	07755	2	VDAV
USA/HMEI	Young	41003	2	SYOU
USA/HMEI	Young	43502	2	VYOU

Screens whose acronym starts with “V” letter are artificially-ventilated screens. Screens in “S” are small naturally-ventilated screens. Screens in “L” are large Stevenson screens. All are naturally ventilated except one: LLAN is artificially-ventilated.

Hygrometers involved in the intercomparison are in table 2. All sensors are based on capacitive measurement except the chilled mirror hygrometer Thygan from Meteolabor.

Table 2. List of participating RH sensors

Member country	Manufacturer	Model	Number	Acronym
Australia	Vaisala	HMP45DB	1	LBOM
Germany	Fischer	431411	2	VFIS
Germany	Vaisala	HMT337 & HMT 330 MIK	2	SVAI
Germany	Vaisala	HMP45D	4	UHMP
Germany	Testo	AG/63379742	2	UTES
Italy	CAE	TU20AS	2	SCAE
Switzerland	Meteolabor	Thygan VTP37 Airport Thygan VTP37 Thermohygrometer	1 1	VTHY
Switzerland	Rotronic	AG/RS12T & Hygroclip S3	2	VROT

Calibration of instruments

Prior to the beginning of the field intercomparison almost all temperature and humidity sensors were calibrated at the metrology laboratory of the Regional Instrument Center of Trappes (France).

Météo-France had provided calibrated Pt100 probes that were suitable with most of the selected screens/shields. Screens that do not suited the proposed probe were shipped to Trappes, for calibration of the temperature sensor provided by the manufacturers. This was done in agreement with the manufacturer.

All humidity sensors were also delivered to Trappes for calibration. Due to the delayed start of the intercomparison, a subset of hygrometers was calibrated again in June 2008, on site, with a portable humidity generator and a relative reference hygrometer.

It was planned to re-calibrate the temperature probes and the hygrometers in Trappes, after the end of the intercomparison. But the delays due to custom problems did not allow it before the elaboration of this paper.

Quality assurance

The local staff performed a daily visual check of the correct acquisition of all sensors. Once per month, radiation sensors and solar panels were cleaned. Pictures of the instruments were taken. All information on visual inspection, maintenance and repair were stored in an electronic local logbook.

Météo-France has developed a specific software to process one-minute averages and quality control for all parameters from the raw data. The quality control of data was processed according the specifications of CBS-IOS ET-AWS4 final report [4].

RESULTS – DATA ANALYSIS

Screens

The first step of data analysis was the establishment of a reference. According to standard ISO17714:2007 [2], screens "that are cooler during the day and warmer during the night are likely to be giving measurements that are closest to the truth". The reference screen should ideally have a fast response which is generally the case for artificially ventilated screens.

Therefore, the daily maximum temperatures (Tx) were compared to the median of maximum temperatures for all artificially-ventilated screens (Figure 5).

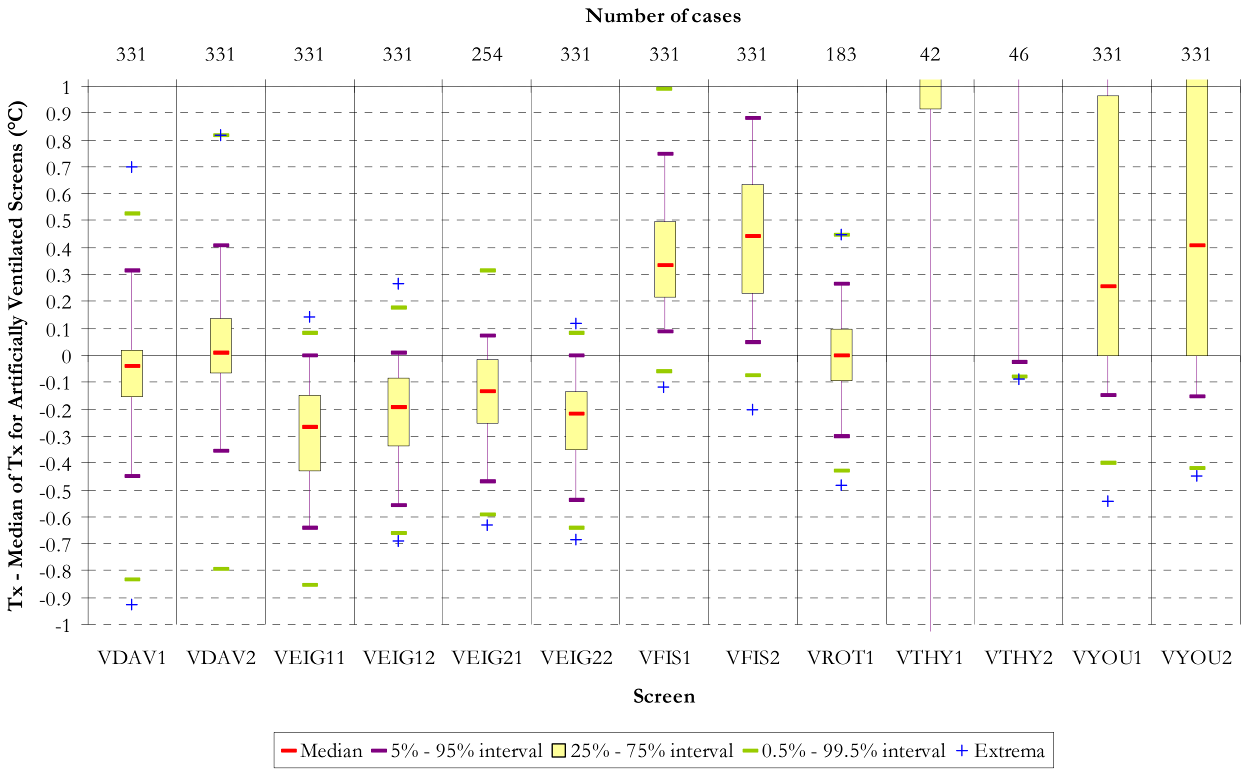

Figure 5. Distribution of the differences of Tx of artificially-ventilated screens

The Eigenbrodt (VEIG) screens were the most legitimate to be chosen as reference. Each VEIG screen had two temperature probes, which offered the option of selecting as the reference either one of these probes or the average of the two probes in the same screen. A further analysis showed no influence of the position of the sun on the measurements.

Therefore the VEIG22 probe is considered as the working reference for temperature measurement.

The distribution of the differences with the reference for all screens is shown on figure 6. This global analysis reveals that SCAE sensors are significantly warmer than the reference. Thies sensors (ATHI) exhibit large differences one from the other. Nearly all small naturally-ventilated screens are warmer than the reference. Among large Stevenson screens, the LBOM reveals a noteworthy cooler behaviour regarding the reference. Artificially-ventilated screens are not significantly colder than the reference.

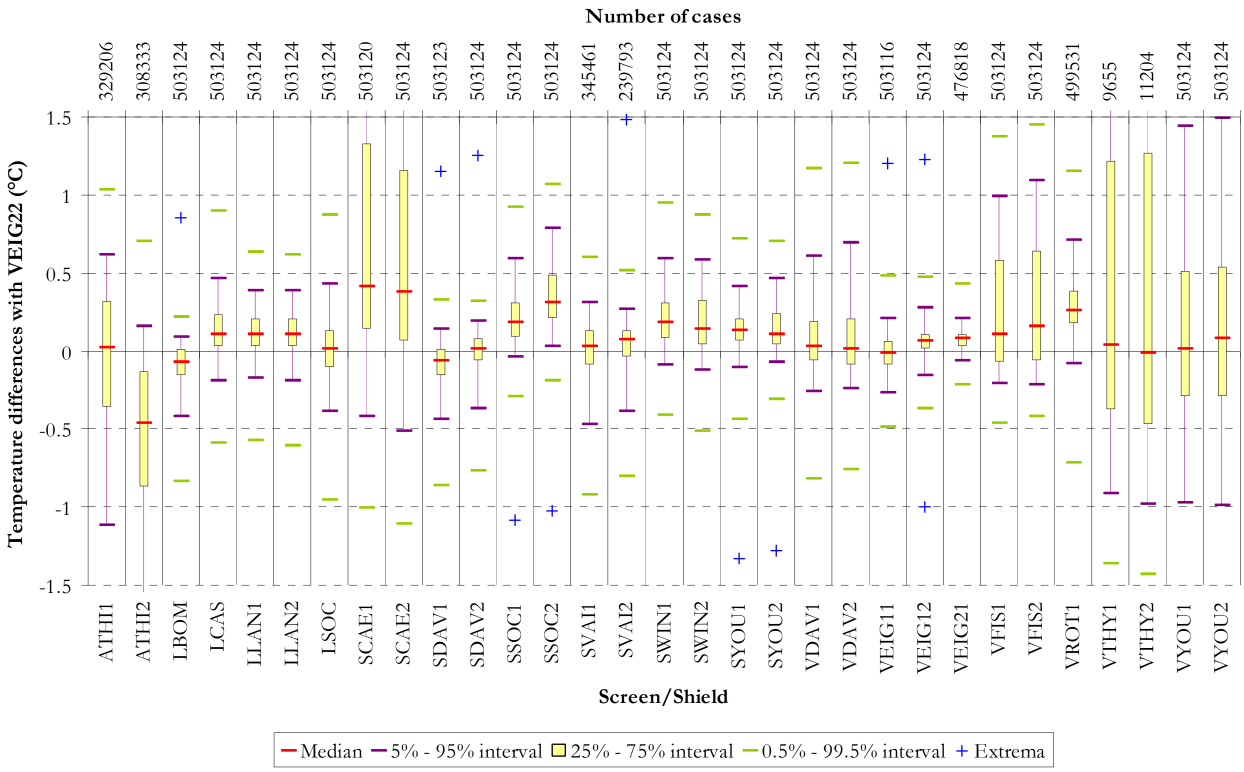

Figure 6. Temperature differences with the reference (1-minute data)

Figure 7 shows the distribution of temperature differences with the reference during clear days and wind speeds at 2-meter height below 2m/s (2-minute average), for the whole period of the intercomparison. Under these conditions the screens are more affected by high solar radiation in combination with low natural ventilation. That may reveal a possible radiation error. Due to ventilation problems, only data in October 2009 are considered for VYOU screens.

The ATHI sensors are significantly colder than the reference by about 1°C. SCAE and VTHY are significantly warmer. Artificially-ventilated screens are not colder, as could be expected in such conditions. On the contrary, some small naturally-ventilated screens are colder than the reference: SDAV, SVAI. Large Stevenson screens are very close to the reference; Only LBOM is slightly colder under these conditions.

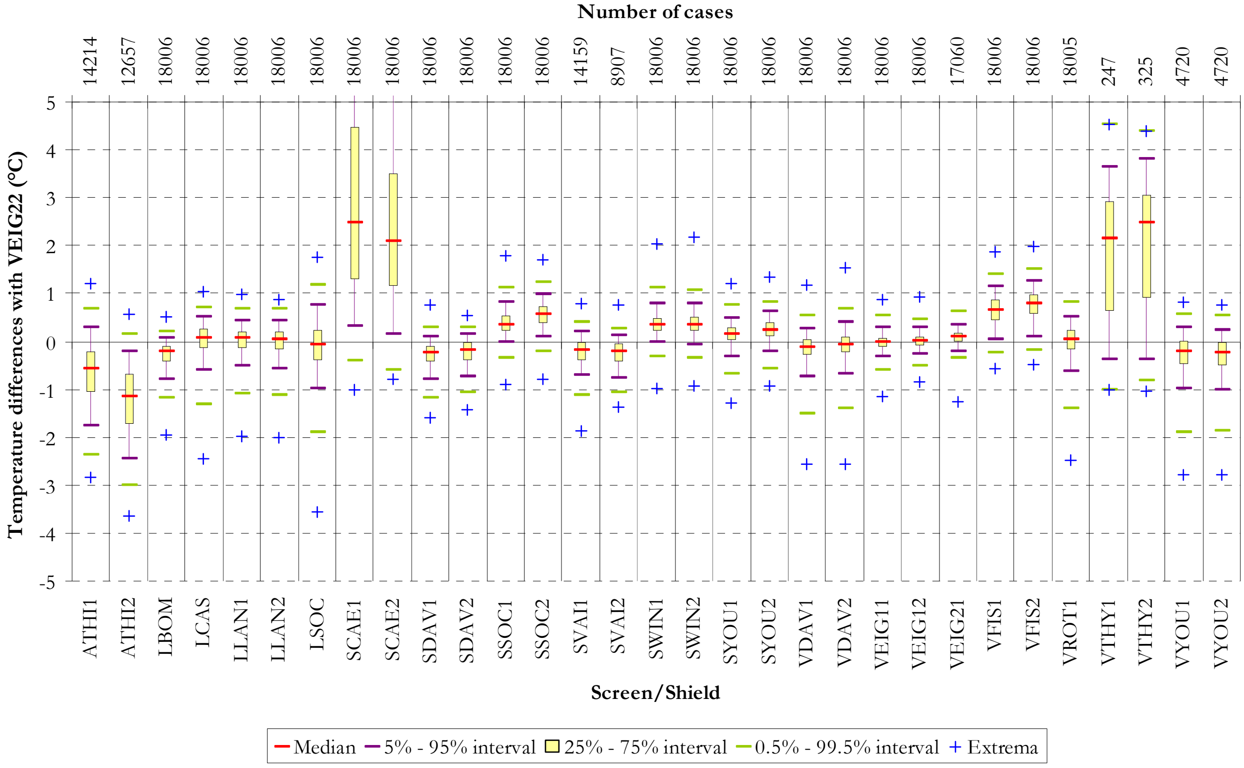

Figure 7. Temperature differences during clear days and wind speeds below 2m/s

To evaluate the time lag of the screens, the distribution of the time differences in minutes when Tx occurred for the reference and for the other screens/shields is plotted on figure 8. A positive difference means that the maximum temperature of the screen under consideration occurs delayed with respect to the reference. Thus a negative difference corresponds to an earlier occurrence of the extreme value.

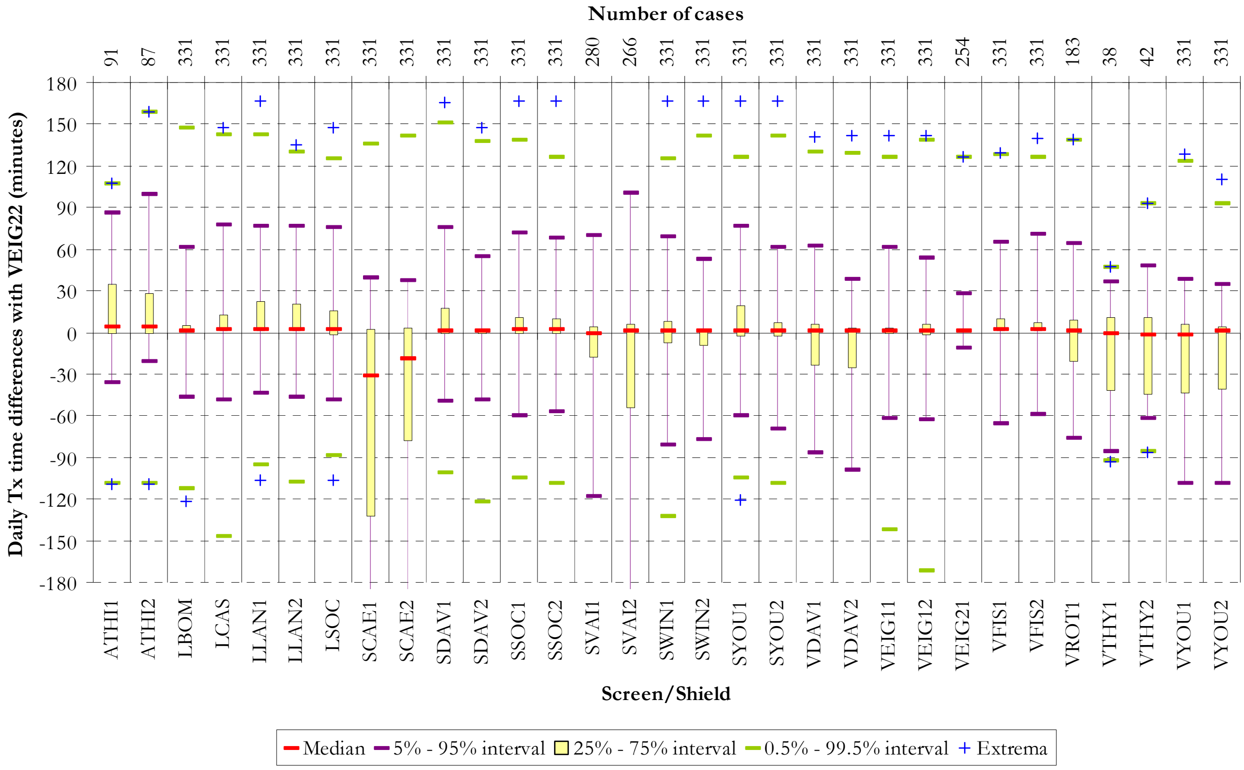

Figure 8. Distribution of the differences in the time of occurrence of daily maximum temperatures

Many screens/shields have medians around 0, i.e. most screens report Tx at the same time as the reference. On the other hand some extreme differences occurred with more than 180 minutes corresponding to days where the screens have recorded their Tx at completely different times compared to the reference. The yellow boxes (intervals with 50% of values) may be more representative of a screen's temporal behaviour than the median values. All large screens show a delay with their yellow boxes shifted to positive values. Some ventilated screens show an advance. SCAE screens are really different from all other screens, being in ahead most of the time.

A similar chart for daily minimum temperatures Tn was processed. Yellow boxes were very small: the majority of Tn occurred at the same time. This is due to the fact that the majority of Tn appears at the end of the night, with a slow decrease of temperature.

Humidity sensors

Problems were encountered for the acquisition of VROT2 and UTES1 sensors so they are not available for data analysis.

Initially, the reference of humidity measurement was designated to be the Thygan from MeteoLabor. During the intercomparison, it turned out that both Thygan sensors sent no measurement from May 2009 to the end of the measurement period. Therefore only five months of reference data were available for analysis. Consequently, Thygan sensors were considered as a primary reference to choose another sensor as a working reference. It should be as close as possible of Thygan.

VTHY2 is selected as the primary reference since it gave a larger number of data. For each valid measure, the distribution of the differences with VTHY2 (quality checked 1-minute values) are computed (Figure 9).

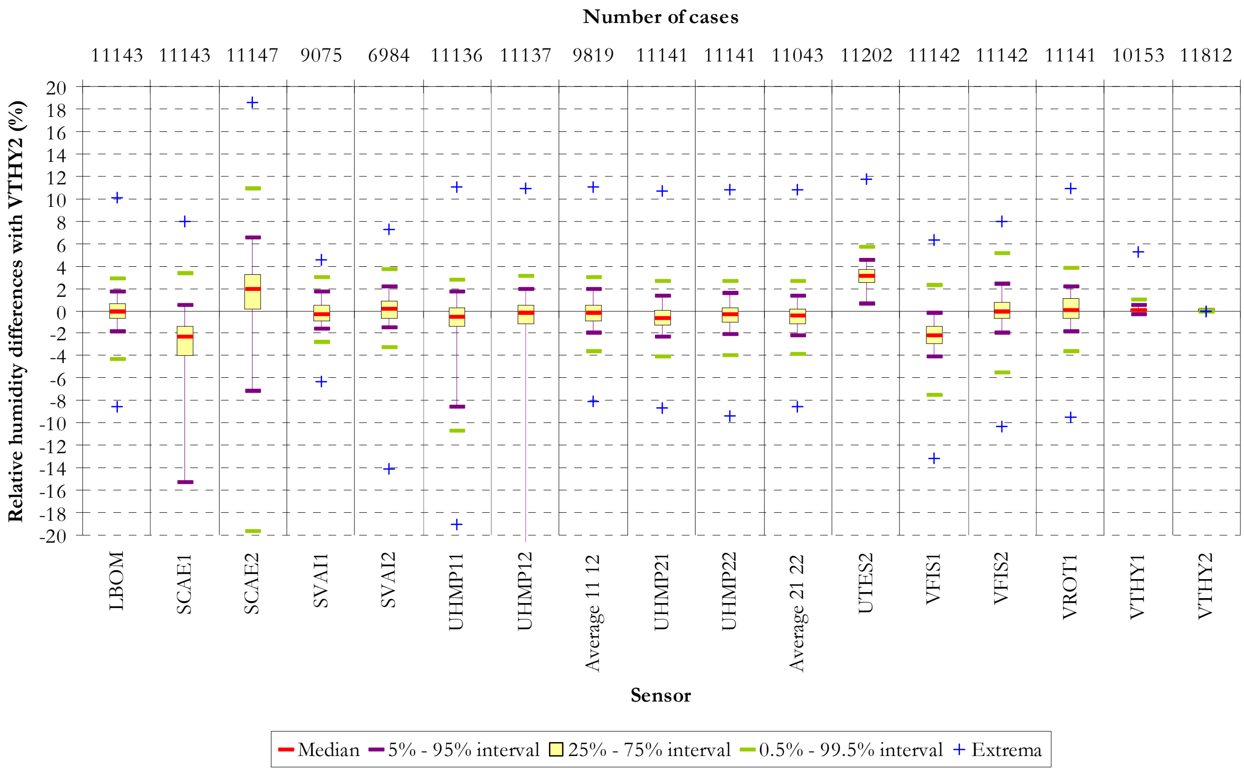

Figure 9. Distribution of differences with VTHY2 for all relative humidity sensors

The second working reference was rather chosen among the UHMP sensors (Vaisala HMP45D probes), since two of them are installed in each of the Eigenbrodt screens. Under the condition that the difference between both probes in the same screen is less than 1%, their average may be considered as a safe value. Probes in screen VEIG2 gave more data than those in screen VEIG1. Moreover, they are in the same screen as the reference temperature probe.

Therefore, the second working reference for humidity measurements, after VTHY2, is processed by averaging UHMP21 and UHMP22, when their absolute difference is less than 1%.

For each valid measure, the distribution of the differences with UHMP2 (quality checked 1-minute values) are computed (figure 10).

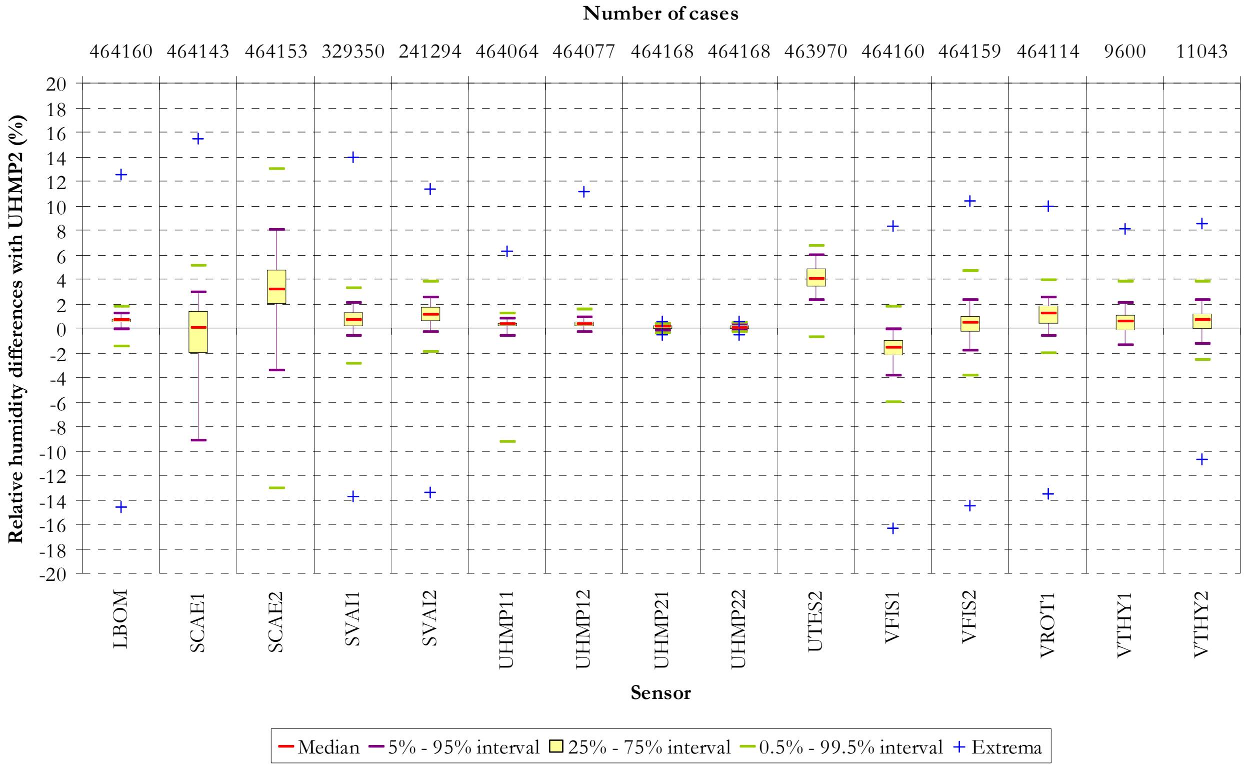

Figure 10. Distribution of differences with UHMP2 reference

Five models gave results closed to the UHMP2 reference (LBOM, SVAI, UHMP, VTHY, VROT): 98% of their measurements are within ± 3% of the reference. VFIS and UTES models stayed within 4% of the reference. SCAE sensors showed large deviations.

The figure 11 shows the distribution of differences with UHMP2 when the reference relative humidity is below 20% and the temperature is above 30℃. No value was available for Thygan sensors. Under these specific conditions, the medians of differences are close to 0 for UHMP and VFIS2 sensors. They are around +1% for LBOM, SVAI and VROT sensors. They are larger in absolute values for SCAE, UTES and VFIS1 sensors.

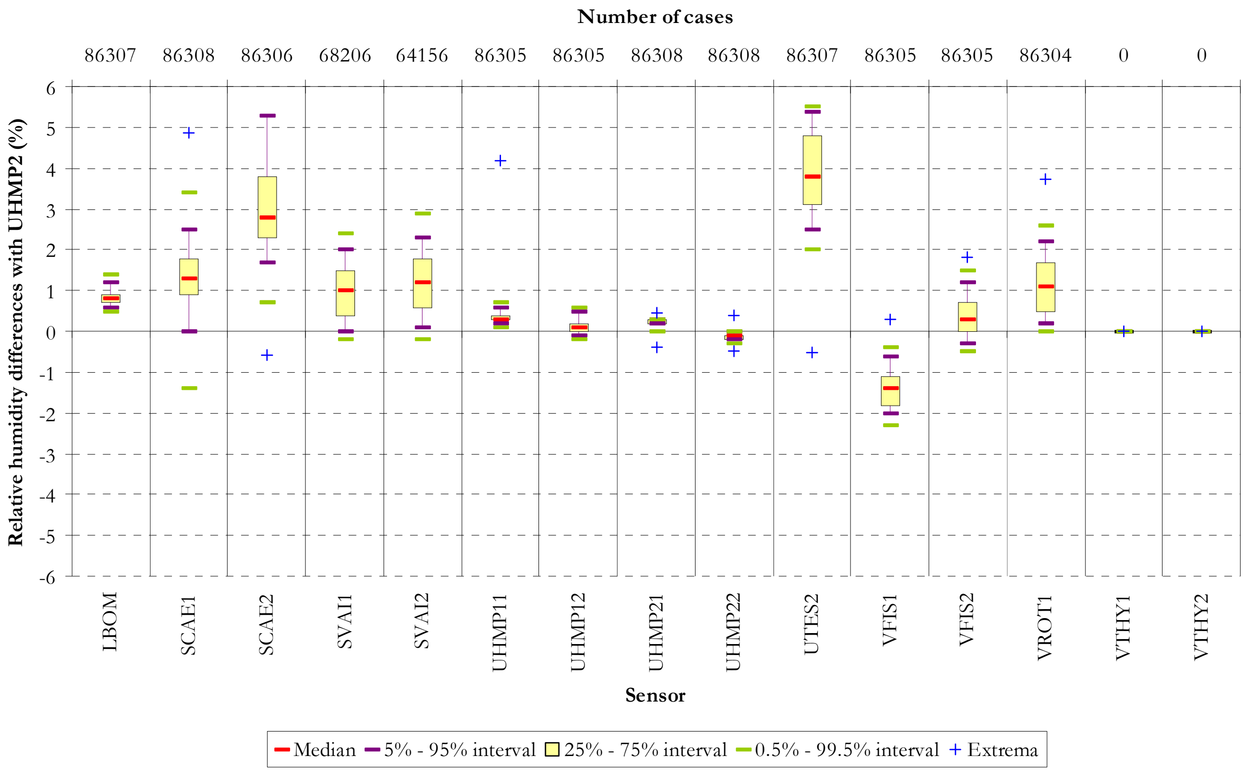

Figure 11. Distribution of differences for relative humidity below 20%

Most sensors showed a drift lower than 0.5% during the intercomparison period. It was not possible to evaluate the drift for Thygan sensors. Only UTES and SCAE sensors showed a drift greater than 1.5%.

CONCLUSIONS

This intercomparison is the first one for screens and hygrometers in hot desert conditions. Even if some uncertainties exist concerning some of the artificial ventilations that might not have worked properly, it is a success: a large data set was available for analysis.

The Eigenbrodt LAM630, a multi-plate screen with artificial ventilation, was selected as the working reference for screens. The four large Stevenson screens provided very good results. They react slower than the working reference, though the LBOM design exhibits a surprisingly fast response (in comparison to its size). Some small passive multi-plate screens exhibited warmer temperatures than the reference (~0.5℃). Two had results close to the reference. The SDAV model gave surprisingly good results, with colder measurements than the reference in case of high solar radiation. Artificially-ventilated screens gave disappointing results: this may be due to their design and/or some faults in the ventilation during the test. The air temperature calculated from the Thies ultrasonic anemometers was much colder than all other screens: this instrument is maybe less influenced by radiation than classical screens.

The Meteolabor Thygan chilled mirror hygrometer was the primary reference for relative humidity measurements. But after an electric overload, no data were available after May 2009. Therefore a second working reference was defined as the average value of two HMP45D hygrometers installed inside the Eigenbrodt screen. This working reference was available during the whole period.

Five models gave very good results over the test period, with no drift (< 0.5%) and more than 98% of values within ± 3% of the reference. These results are much better than what could be expected from the current knowledge about the state of the art. The dry conditions mainly experienced during the intercomparison may be an explanation, in addition to the "quality" of the sensors. Only few events of high RH close to saturation were encountered. Two models showed medium results with deviations up to 4%. One model demonstrated poor results with deviations up to 12%.

In principle, if the temperature inside the screen with an installed hygrometer is different from the temperature of the screen of the reference, an influence of several percentages (up to 6% close to saturation) should occur on the relative humidity measurement. Though significant differences of temperature were seen between screens (e.g; inside the Thygan and the Eigenbrodt), no clear influence on the relative humidity values was detected.

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