# (TOO) HOT OR NOT?

# FIELD EXPERIMENT WITH THE KNMI THERMOMETER SCREEN

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## ABSTRACT

The design and first results of a field experiment are described to assess the overall uncertainty of the air temperature observation in the Dutch surface network. In recent years, increased attention has been paid at KNMI to achieve an integrated approach for the determination of the quality of each measurement chain. For air temperature, it is known that several important error sources exist when operating temperature sensors in the field. These are mainly related to siting and the radiation screen used with the sensor. In order to quantify the screen effects such as the radiation error and wetting effect, a field experiment was prepared and started in the summer of 2013. Prior to the test, a number of laboratory experiments were conducted in order to study the thermal response and flow characteristics of the screen.

The field experiment (ONATIS) is conducted at the test site in De Bilt and will last for at least 1 year to cover all possible meteorological conditions. The main purpose is to investigate the impact of the screen and sensor setup under field conditions and to compare the non-aspirated, naturally ventilated KNMI multi-plate screen with an updated, artificially ventilated screen. The experiment is supported by a variety of ancillary measurements of temperature and other relevant meteorological variables. For example, the screens are monitored continuously by a thermal imaging camera and equipped with a dense network of thermistors to obtain the temperature of the lamellas.

## *1. Introduction*

### 1.1 Backgrounds

Worldwide, many different screen designs exist that can be applied for shielding thermometers used for the measurement of air temperature. The main functions of thermometer screens are to protect the sensor from direct or indirect radiation from the sun during the day and from radiation from the sensor to the sky at night. Furthermore screens are used to protect the sensor from wetting and incidental damage (WMO, 2008). Often, the choice for a certain screen design is tuned to the climatological region of its application or made for historical or practical reasons insufficiently taking into account the impact of the screen on the measurement of air temperature. In the meteorological observation network in the Netherlands, KNMI operates a proprietary design, plastic multi-plate screen without artificial ventilation, since the 1980's.

An exploration into the error budget of operational air temperature measurements was initiated at KNMI some years ago and resulted in very relevant knowledge on the measurement uncertainty under laboratory conditions (Bijma, 2012). This study mainly touched the propagation of errors during calibration, signal conversion and data processing in the operational measurement chain. However, the factors that may affect the air temperature measurement in the field were not studied. From an earlier thermometer screen intercomparison held at KNMI (Brandsma and Van der Meulen, 2008; Van der Meulen and Brandsma, 2008) between 1989 and 1995 in De Bilt, rough estimates could be established for errors in the temperature measurement under various meteorological conditions. For the influence of solar radiation at low wind speeds, the maximum overestimation of air temperature measured in the KNMI screen is estimated at 1.0°C of more, based on 10-minute values. The wet bulb effects caused by fog and precipitation are negligible, but effects of roughly 0.5°C have been found in cases with strong reflection of sunlight above snow cover at the surface. Nevertheless, the duration of the abovementioned effects is generally considered to be of an acceptable level, such that the impact on operations is low. More recently, an intercomparison of temperature screens and humidity measuring instruments was organized under the umbrella of WMO in Ghardaïa, Algeria (WMO, 2011). 18 different types of screens/shields both ventilated (7) and non-ventilated (11) were compared with an aspirated Eigenbrodt screen which was used as working reference. The main objectives of this intercomparison were to gain knowledge on the performance characteristics and operational factors of radiation screens/shields and humidity sensors. However, the focus was mainly on the hot desert conditions valid for Algeria. The KNMI screen was not included in this intercomparison.

As the quality of the air temperature observation is regularly a topic of discussion, a new field trial with the KNMI thermometer screen is currently performed in De Bilt (Proksch, 2013). The main goal is to integrate the results with the findings under laboratory conditions in order to make a quantitative estimate of the uncertainty throughout the entire chain. The new trial should give appropriate answers to the following questions:

- What is the magnitude of the screen effects on the operational air temperature measurements, such as the radiation errors (direct and indirect), insufficient ventilation, screen contamination, wet bulb effects by precipitation, fog, icing and dew deposition, and heat transport from the mast and mounting material?
- What is the frequency of occurrence of abovementioned effects?
- What are the advantages and drawbacks of an aspirated version of the KNMI screen?

### 1.2 Contents of this paper

The design and first results of a field experiment are described to assess the uncertainty of the operational air temperature measurement in the Dutch surface observation network. As the project is underway for just a couple of months, only some preliminary findings can be reported and no final conclusions can be drawn yet. The paper will discuss the laboratory experiments that were conducted prior to the test in Section 2. Section 3 contains the setup and gives an overview of the measurement techniques used in the field trial. In addition, an interesting case from the first months of the field experiment will be presented in Section 4. Finally, the paper is summarized and concluded in Section 5.

## *2. Laboratory experiments*

### 2.1 Setup

Prior to the field test, a number of laboratory experiments has been conducted in order to select appropriate equipment and to gain knowledge on the properties of the different screens involved. Two main questions had to be answered:

- How much air flow is needed to refresh the air inside the KNMI screen in a timely manner?
- How fast does the screen respond to temperature variations of the air?

To characterize the screens under investigation, i.e. the KNMI screen and the Eigenbrodt LAM630 screen, the experiments discussed in Sections 2.2-2.4 were performed. Note that the LAM630 screen is operationally used by DWD and was also used as working reference during the WMO intercomparison in Algeria (WMO, 2011).

### 2.2 Flow experiments

A hot-wire anemometer was used to characterize the flow in and around the two screens. The type of instrument used is a Dantec FlowMaster with a measuring range of 0.005 to 25 m/s and an accuracy of ±0.1 m/s. In total, 120 sample readings were taken at each height, with the anemometer positioned between the lamellas when measuring outside. The summarized results of this experiment conducted on the Eigenbrodt LAM630 screen and the KNMI design screen are depicted in Figure 2.

**Figure 1. Setup of the air flow experiment conducted on the LAM630 screen.**

Note that due to the different geometry the measurement heights are shifted with respect to each other. Therefore the normalized height $z^*$ ($z/H$ where $H$ is the height of the screen) is introduced as z-coordinate. It can be seen that the LAM630 screen, which has a ventilator (capacity: ±450 l/min) built in just below the cover lamella, demonstrates an air flow of a few tenths of m/s at the bottom, increasing to a maximum of around 0.5 m/s at higher levels. It is assumed that the Coanda effect (Albright, 1990) is responsible for the large variation in flow speeds observed in and around the screen. The aspirated KNMI screen is equipped with a ventilator with a capacity of ±600 l/min, sucking out the air via a tube fitted to a hole in the base plate of the screen. At sensor height the flow is roughly 0.25 m/s for the LAM630 screen and 0.50 m/s for the KNMI screen. The large air flow measured at the top of the ventilated KNMI screen, reaching values close to 2.5 m/s, is quite remarkable and cannot be fully explained without further investigation. Note however that for the aspirated KNMI screen the ventilator configuration was not completely similar to the setup used in the field. It is planned to repeat the laboratory experiments after the field test has finished.

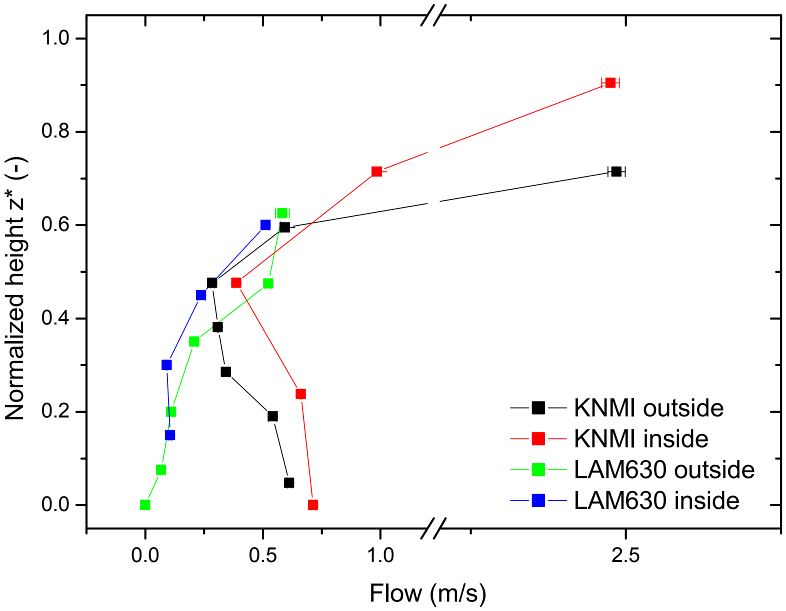

**Figure 2. Flow measured in the KNMI and LAM630 screens with a Dantec hot-wire anemometer as a function of normalized height z* where "0" represents the location of the bottom and "1" the top of the screen.**

## 2.3 Ventilation factor

The ventilation factor of the screen was measured in order to investigate the blocking effect of the lamellas on a certain amount of air flow present outside the screen. This is a relevant piece of information when you want to know how much of the natural ventilation in the form of wind is actually able to refresh the air inside the screen. One screen may be more efficient than another.

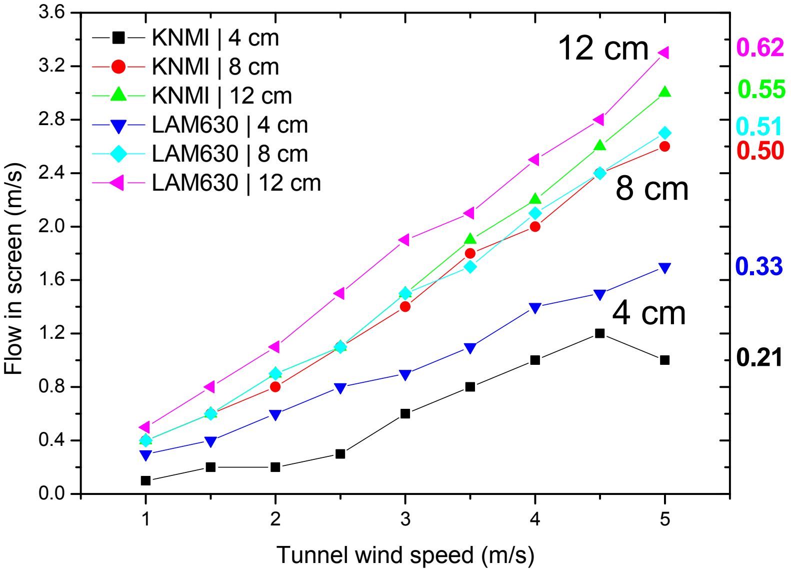

**Figure 3. Flow measured in the centre of the KNMI and LAM630 screens at three different heights, as a function of tunnel wind speed. Note that the ventilation factor is here defined as the percentage of the tunnel speed reaching the centre of the screen. The calculated factors for each position are listed next to the right Y-axis.**

This experiment was performed in the KNMI wind tunnel where the hot-wire anemometer was operated at three different heights (4, 8 and 12 cm) near the centre of each screen. In Figure 3 the results are presented as a function of tunnel speed, which was increased from 1 to 5 m/s in steps of 0.5 m/s. The ventilation factor *a* is derived from the fit $y=ax$ where $y$ is the measured speed inside the screen and $x$ is the tunnel speed. The derived ventilation factor for the KNMI screen amounts to 0.55 (i.e. 55% of the air flow reaches the sensor) at 12 cm where the LAM630 screen has a slightly higher ventilation factor (0.62) at the same measuring height. Lower in the screen the calculated ventilation factors are much lower: 0.21 and 0.33 at 4 cm, and 0.50 and 0.51 at 8 cm, respectively. It is uncertain whether this can completely be ascribed to the screen as it may also be partially explained by the wind tunnel design. The difference in ventilation factor between the KNMI and LAM screen is in good agreement with the expectations based on the design of both screens, where for the LAM screen more attention seems to be paid to proper aerodynamics.

## 2.4 Response time

Another relevant property of the temperature measurement setup is the response time of the screen, commonly expressed in the time constant (τ), i.e. the time for which the temperature reaches a value of 1-1/e (63.2%) of its end value when stepwise perturbed to lower or higher temperatures. The response time determines to large extent the effect of the screen material on the measured air temperature inside the screen. An international standard was developed (ISO, 2007) recommending the so-called equidistant method for calculation of the time constant (τ), making use of three temperature records measured at equidistant intervals from each other in time.

**Figure 4. Setup of the KNMI screen in de wind tunnel where the response time was estimated by cooling the screen starting at roughly 45°C.**

Three fast response thermistors were fitted to the 1st, 4th and 7th lamella of the KNMI screen. Next, the screen was heated in the climate chamber to approximately 45°C and transported to the wind tunnel in a styrofoam isolation box to remain at a more or less constant temperature. As the screen was installed within the measurement area of the tunnel, the screen temperature decreased under influence of the ambient temperature (±22°C). For different tunnel speeds, the temperature measured by the thermistors was recorded every 2 seconds. The results are presented in Figure 5, for the situation without ventilation (0 m/s) and for tunnel speeds of 2 and 5 m/s. As expected the cooling is far more rapid when the tunnel speed is increased.

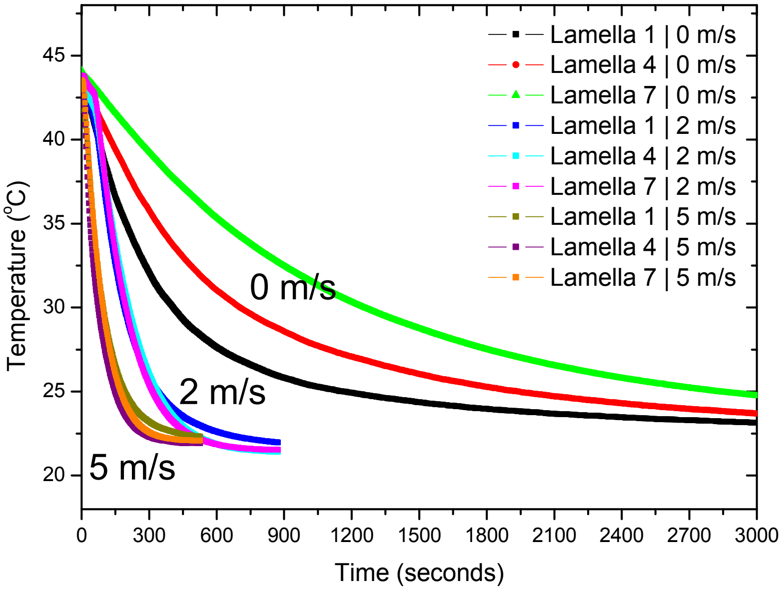

**Figure 5. Temperature measured in the wind tunnel at three different lamellas of the heated KNMI screen for wind speeds of 0, 2 and 5 m/s. Using the equidistant method the response time of the screen (τ) is calculated.**

The time constant of the KNMI screen at a wind speed of 2 m/s is determined at 133-182 s for the three measurement heights considered, i.e. in the order of 2-3 minutes. This is assumed to be the value closest in accordance with the calculation from the ISO standard, which prescribes a ventilation of 1 m/s. For the situation without ventilation, the values for $\tau$ varies between 303 and 1035 s, whereas under strong ventilation (tunnel speed 5 m/s), the response time drastically reduces to values between 68 and 94 s.

## *3. Field test*

### 3.1 Introduction

The test site for the ONATIS field trial (Figure 6) was established close to the KNMI premises in De Bilt, situated in the centre of The Netherlands (N 52.10 E 5.18) in a flat semi-rural area at 2 m above mean sea level. De Bilt has an average annual temperature (1981-2010) of 10.1°C, around 830 mm of precipitation and 1600 hours of sunshine. The average number of days with fog and snowfall is 63 and 25 per year, respectively (see www.klimaatatlas.nl). The site is well maintained and consists of short cut grass cover. From south to north-northeast of the test site some lines of 20-30 m high trees are present that may affect the observed air temperature due to sheltering. However, it is assumed that all temperatures measured at the ONATIS site are affected in a similar way. Note that the operational air temperature for De Bilt (WMO ID 06260) is observed at a less sheltered site located 200 m eastwards.

Beside the air temperature measurements in the non-aspirated and aspirated KNMI screens and the LAM630 screen, a variety of additional instruments is installed at the test site to measure temperature, surface wind, shortwave and longwave radiation, and precipitation detection. The total area has a size of approximately 10x10 m. Moreover, new measurement techniques were deployed in the field setup in order to gain an optimal monitoring system for the thermometer screens under investigation. A thermal infrared camera provides continuous insight in the heat distribution over the screens and its surroundings and a small network of 18 thermistors fitted to the lamellas and the mast report the temperatures measured at different spots directly on and below the screen. The analysis is supported by ancillary measurements from the AWS site close by.

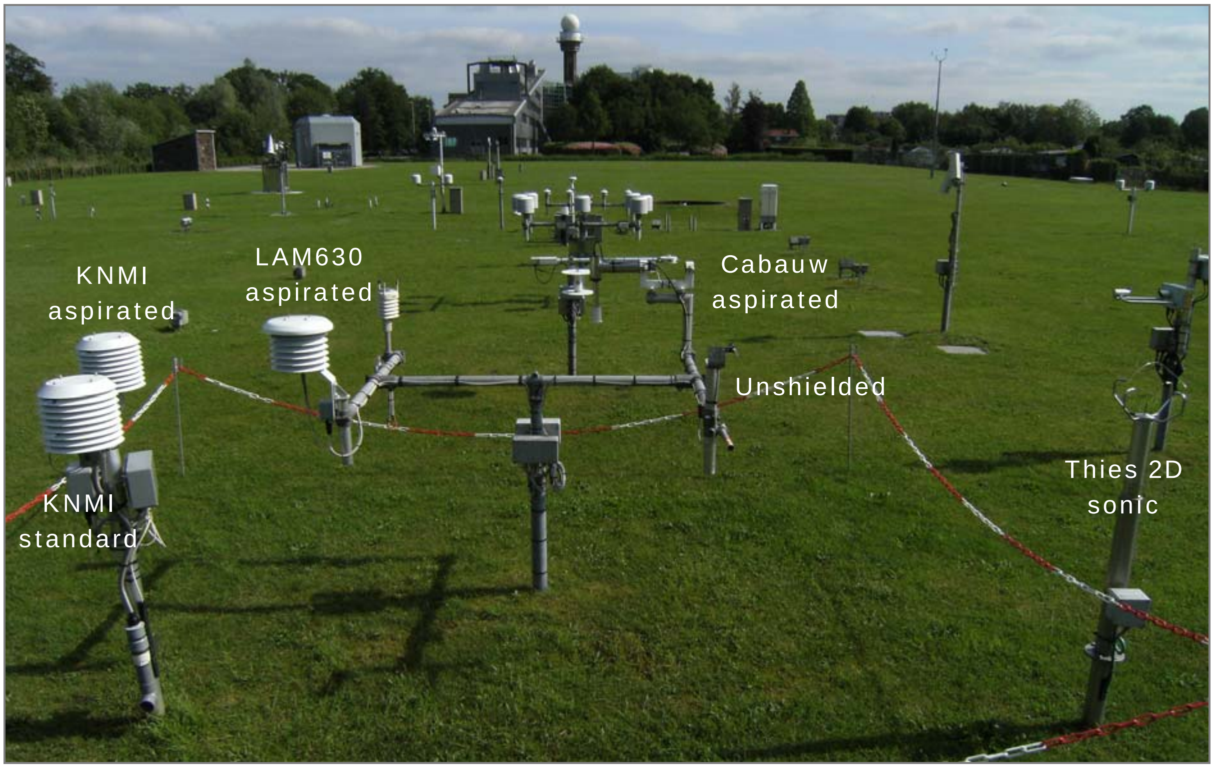

**Figure 6. Overview of the ONATIS field trial setup in De Bilt, with the KNMI office buildings in the background. The photo shows the entire test site and an indication of the location of the different air temperature measurements performed by the Pt500 sensors and the Thies 2D sonic anemometer.**

**Figure 7. Instrumentation used in the field trial. The upper panels present: (left) the KNMI aspirated screen, the LAM630 screen and the KNMI standard screen with clearly visible the thermistors fitted to the lamellas and (right) the instrument setup for total and shortwave upward and downward radiation. The bottom panels show: (left) the camera enclosure with its contents and (right) an example of the FLIR thermal image pointed at the three main screens under study, presenting the minimum and maximum temperatures for selected areas.**

## 3.2 Instruments and equipment used

An overview of the most relevant measurements in the field experiment, a brief description and the variable name used in the figures in Section 4 is given in Table 1.

**Table 1. List with most relevant measurements in the ONATIS field trial conducted in De Bilt in 2013/2014 .**

| **Parameters/ Observation method** | **Description** | **Variable name** |
|---|---|---|
| **Air temperature (Pt500)** | | |
| KNMI screen | Naturally ventilated | TASTD |
| KNMI screen | Aspirated (~600 l/min) | TAVEN |
| Eigenbrodt LAM630 screen | Aspirated (~450 l/min) | TALAM |
| Unshielded | Naturally ventilated | TAUNS |
| Cabauw dry bulb setup | Aspirated (~600 l/min) | TACAB |
| **Air/Lamella temperature (NTC)** | | |
| Fitted to standard KNMI screen | Base plate, lamella 2, 7 NE and SW (in+out), $T_{air}$ at lamella 2 | T1STD-T8STD |
| Fitted to aspirated KNMI screen | Base plate, lamella 2, 7 NE and SW (in+out), $T_{air}$ at lamella 2 | T1VEN-T8VEN |
| Fitted along the mast | Air temperature at 0.30, 0.65 m | T1MAS,T2MAS |
| **Ancillary data** | | |
| Thies 2D sonic anemometer | Wind speed/direction 1.5 m<br>Virtual temperature | WSSON, WRSON<br>TVSON |

| | | |
|---|---|---|
| Kipp CM5 albedometer | Shortwave upward/downward | QSWUP, QSWDN |
| Schulze LXG055 net radiometer | Total upward/downward | QTLUP, QTLDN |
| Ott Parsivel disdrometer | Precipitation detection/intensity | NIPAR |
| Thies LPM disdrometer | Precipitation detection/intensity | NILPM |
| Solar elevation data | Solar elevation/azimuth angle (calculated) | SUNEL, SUNAZ |

### Pt500 Temperature sensors

The air temperature measurements are performed with Pt500 sensors, which are also used operationally in the surface network. This includes the measurements taken in the KNMI standard and aspirated screens, the Eigenbrodt LAM630 screen, an unshielded sensor and the dry bulb setup of the Cabauw psychrometer (see Table 1). The sensors are calibrated before installation in the field and have a measurement uncertainty of 0.1°C under laboratory conditions. The time constant is around 60 seconds starting from 1 m/s wind speed, which is a bit longer than recommended by WMO (2008). It reduces to 30 seconds for higher wind speeds (Bijma, 2012). All Pt500 sensors are installed close to a height of 1.50 m so that differences due to vertical temperature gradients are eliminated as far as possible. The KNMI screens and the LAM630 screen (see Figure 7, upper panel) are installed in a triangle with mutual distances of approximately 90 cm.

### NTC Thermistors

The thermistors used in the experiment are of type TS-NTC-103A manufactured by B+B ThermoTechnik, with a specified resistance of 10,0kΩ ± 0,5% at 25°C. The measuring range of the thermistors is -60 to +150°C. A series of 20 thermistors were calibrated in the KNMI laboratory between -25 and 40°C in steps of 5°C and the individual calibration constants were calculated using the Steinhart-Hart equation. Given the desired measurement uncertainty of maximal 0.1°C, it appeared that the same constants could be used for all thermistors, except for two that failed to meet this criterion. The fixed constants were implemented in the sensor interface for the conversion of the measured resistance to temperature.

The thermistors measuring lamella temperature are fitted to the lamellas of the KNMI standard and aspirated screens following the method schematically presented in Figure 8. To ensure the thermistor is measuring the temperature of the lamella, rather than air temperature, the thermistor (blue) is fixed onto the surface of the lamella (grey) with Locktite Output 315 thermal conductive adhesive compound (red). The thermistor is isolated from the air surrounding the lamella with a thin layer of isolation material (yellow), and covered with metallized reflective tape (light blue) to protect it from direct radiation.

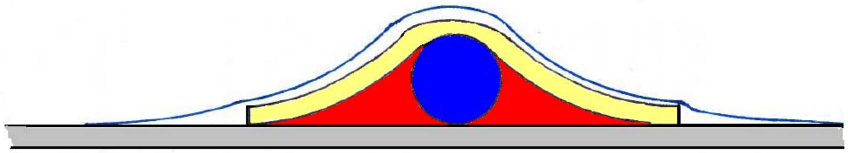

**Figure 8. Schematic drawing of the way the thermistors are fitted to the screen. See text for an explanation of the different parts and colors.**

### Sonic anemometer

A Thies 2D sonic anemometer is installed at a height of 1.5 m to capture the ambient wind at screen height but also to obtain temperature information (i.e. acoustic temperature) using another measurement principle than the contact thermometers described above. Lanzinger and Langmack (2005) showed that it is possible to observe air temperature, after applying appropriate corrections, with a measurement uncertainty <0.1°C for the range -25 to +25°C under zero-wind conditions. For situations with light and moderate wind the uncertainty seems of an acceptable level. Therefore it was considered worthwhile to include the sonic in the field trial mainly for monitoring the relative behavior of air temperature compared to Pt500 and thermistor sensors, for example under extremely cold conditions during winter where sometimes suspicious fluctuations are observed.

### Radiation

Shortwave and longwave albedo is measured close to the test site (see Figure 7, upper panel) by performing upward and downward irradiance measurements. For shortwave radiation, a calibrated Kipp

CM5 albedometer with a spectral range of 0.3 – 2.3µm is used, whereas for the broadband radiation a Schulze LXG055 (spectral range 0.3 to 100µm) net radiometer is installed. These instruments are included in the field trial to support the analysis of the radiation effects affecting the measured air temperature, which can occur either in a direct or in an indirect way, after reflection at the surface.

### Cameras

An enclosure located at approximately 2 m from the main screens under investigation is equipped with two cameras. The enclosure can be seen in the bottom panel of Figure 7. Firstly, a FLIR E40 thermal imager is operated at a recording interval of 1 minute in order to monitor the temperature variations on the screens and their surroundings with a high temporal resolution. The FLIR IR image, taken in the spectrum 7.5-13µm, has a resolution of 160x120 pixels and an absolute temperature accuracy of 2°C. Data is analyzed using the FLIR Research IR software. Secondly, a Canon Powershot camera automatically records images every 10 minutes to obtain information on the actual conditions of the screens (e.g. presence of fog, rime, snow etc.). The orientation of the cameras is such that the entering of direct sunlight in the field of view is avoided.

### Precipitation and AWS data

Two optical disdrometers are located closely to the ONATIS test site and provide information on the precipitation intensity starting at a threshold of approximately 0.005 mm/h, and thus proving very useful for precipitation detection. The disdrometers used are an Ott Parsivel and Thies Laser Precipitation Monitor (LPM). Both are installed at ±1.5 m above the surface. Furthermore, data from the automatic weather station De Bilt Test (06261) provides all standard meteorological parameters for the analysis.

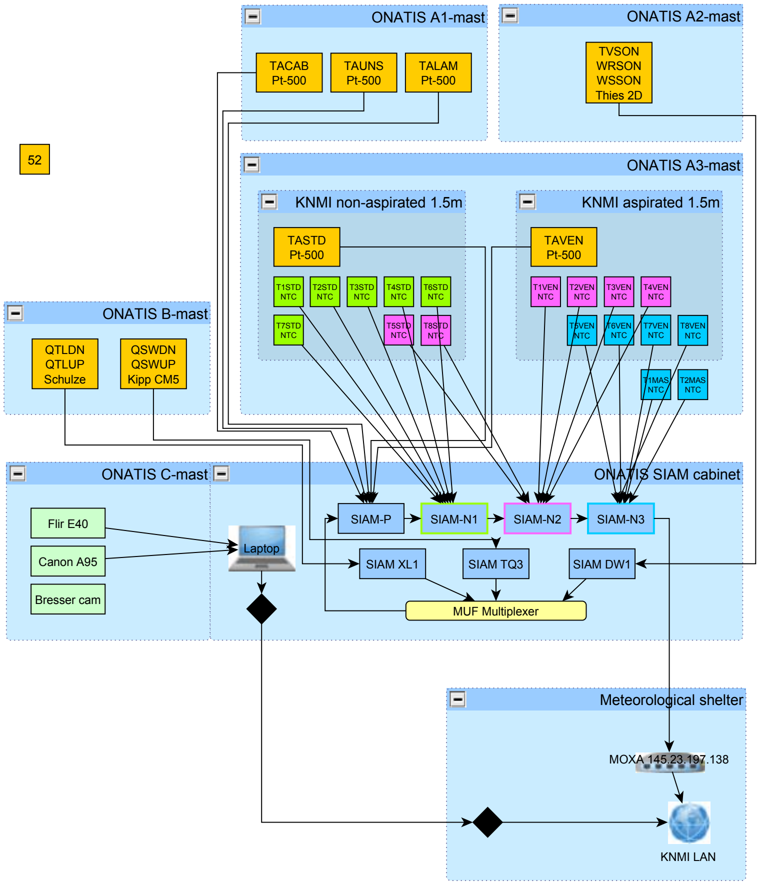

**Figure 9. Data flow diagram for the ONATIS field trial. All measurement data is combined by using standard SIAMs and a multiplexer and made available on the KNMI internal network for visualization and further analysis.**

## 3.3 Data acquisition and processing

KNMI uses the SIAM (Sensor Intelligent Adaptation Module) for operational measurements in the surface observation network. The SIAM concept was also used in the ONATIS field trial. It is an interface between the sensors and the data acquisition systems that was designed by KNMI itself. For each type of sensor there is a unique SIAM. The data sampling interval is 12 seconds by default. The SIAM computes several averages, and it also validates the incoming data.

In total 7 SIAMs were used for the field trial, 3 standard modules and 2 special research versions (SIAM-P and SIAM-N), as indicated in the data flow diagram in Figure 9. The data output of the 3 standard SIAMs is combined using a MUF multiplexer and subsequently forwarded via the SIAM-P and SIAM-N interfaces. The full data stream with all sensor output from the test site is made available on the KNMI network and stored with corresponding time stamp. Given the high number of temperature measurements and other observations that are taken, over 78 million 12-second measurement records will be collected during one year. Note that the data from the cameras (FLIR and Canon) are stored separately after logging on a laptop in the field.

Data reduction is an important point of consideration during the field trial. In order to eliminate small-scale effects and make the data suitable for a statistical analysis, daily and monthly files containing 1-minute and 10-minute averages were generated, requiring at least 75% availability of valid data samples during the corresponding averaging interval.

## 3.4 Quality assurance

Technical status information on the sensors included in the field trial is provided by the SIAM and monitored on a daily basis. Once per week the site is visually inspected to check for irregularities and to verify whether the fans providing ventilation are still functioning properly. Each month an extended inspection round is planned and radiation sensors are cleaned during this round. Furthermore, the alignment and correct functioning of the cameras at the test site is also checked monthly. All information on visual inspection, maintenance and repair are stored in an electronic logbook.

# *4. Results: Case study 18 July 2013*

A good example of the solar radiation effect on the non-aspirated KNMI screen is given in Figure 10 for 18 July 2013. This was a nice summer day with clear sky conditions and temperatures up to 27°C following a well-defined diurnal cycle. The shortwave radiation measured by the CM5 pyranometer reaches values up to 835 W/m² and hardly shows any signs of clouds, given the smooth curve. The temperature differences calculated for the three aspirated screens and the non-aspirated KNMI screen are shown in the second panel. The average and extreme values for each combination, based on 10-minute data, are listed in Table 2. During nighttime, where the solar elevation angle drops has dropped zero, roughly before 04:00 and after 19:30 UTC, the measured air temperatures follow each other closely and the differences are approaching zero on average. During daytime however, as expected, significantly lower temperatures are measured in the aspirated screens, proving that the ventilation refreshes the air in these screens more efficiently than in the non-aspirated KNMI screen. At first glance the behaviour of the aspirated KNMI and the LAM630 screen shows a very similar pattern.

On average the difference during daytime is roughly -0.3°C for the aspirated KNMI and the LAM630 screen. The minimum values are measured between 14 and 15 UTC and is just above -0.6°C for both screens. Although the wind speed at 1.5 m is between 2 and 3 m/s, which is considered to provide a sufficient amount of ventilation, apparently the differences in refreshment of air between non-aspirated and aspirated screens is still large enough to introduce differences of this size. The Cabauw dry bulb setup (TACAB) is even much colder, especially during the first hours after sunrise. This may well be caused by the fact that this aspirated setup is located a little lower than 1.5 m and directly sucks air in from below the temperature sensor. The air at these levels is generally a bit colder during morning conditions. Finally, the unshielded Pt500 sensor (TAUNS) is several degrees warmer than the KNMI standard screen. The difference is on average +2.5°C during daytime, and has a maximum of +4.7°C.

**Table 2. Overview of differences observed on 18 July 2013 between the standard, non-aspirated KNMI screen (KNMI std) and three other screens included in the ONATIS field trial. Note that daytime is here defined as that period where the solar elevation angle is positive.**

| **Difference** | | **Average (Daytime)** | **Minimum** | **Maximum** |
|---|---|---|---|---|
| **KNMI asp-KNMI std** | TAVEN-TASTD | -0.18 (-0.28) | -0.57 | +0.14 |
| **LAM630 asp-KNMI std** | TALAM-TASTD | -0.18 (-0.27) | -0.56 | +0.12 |
| **Cabauw asp-KNMI std** | TACAB-TASTD | -0.34 (-0.51) | -1.00 | +0.26 |
| **Unshielded-KNMI std** | TAUNS-TASTD | +1.58 (+2.51) | -0.54 | +4.66 |

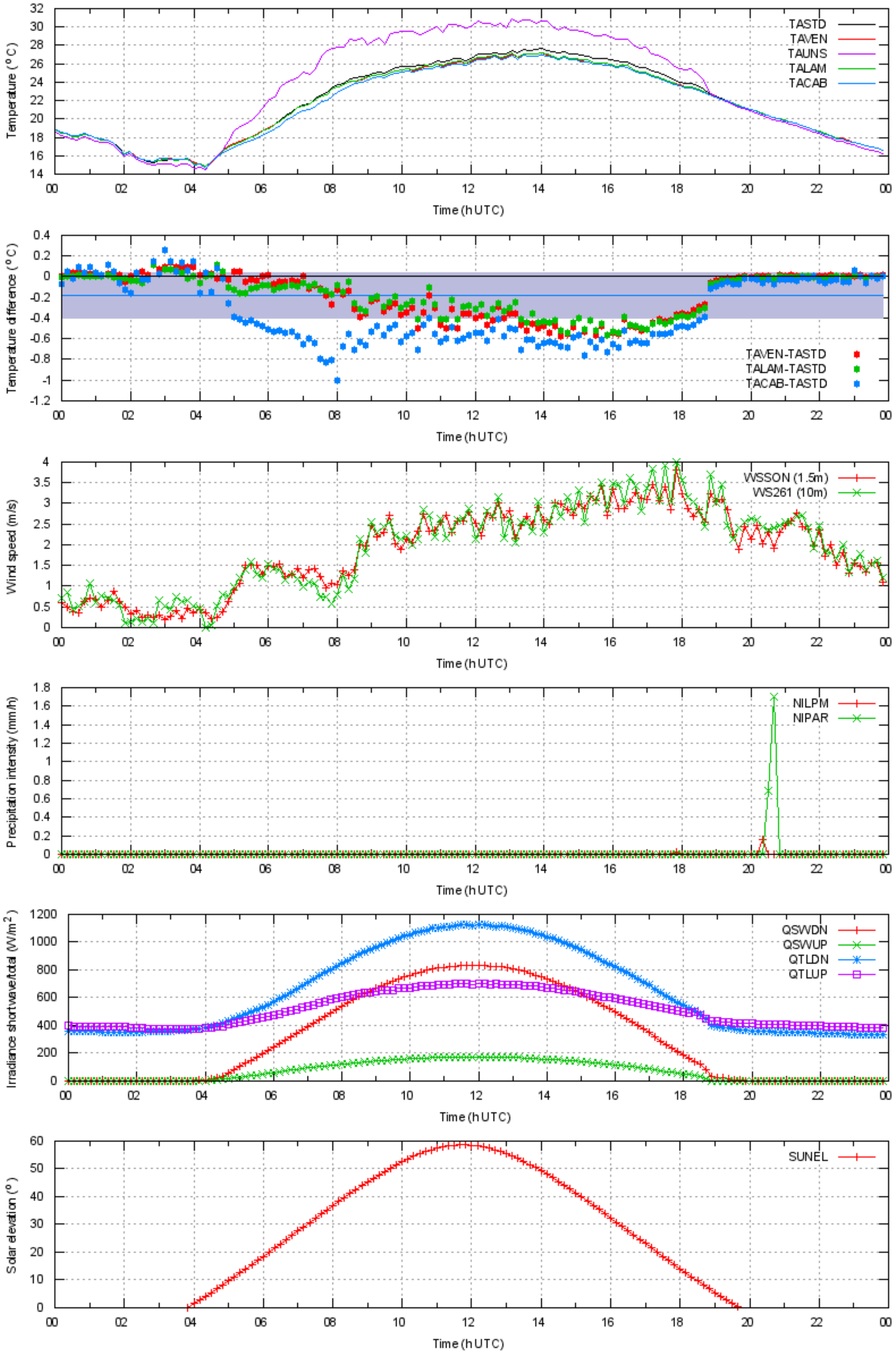

**Figure 10. Overview of derived 10-minute observations for a clear and sunny day in De Bilt on 18 July 2013. The variables used are explained in Table 1. The second panel shows the air temperature differences calculated for all aspirated screens (TAVEN, TALAM and TACAB) compared to the KNMI non-aspirated screen (TASTD).**

Figure 11 shows more temperature differences for the same day, but now including the thermistor temperatures. It becomes clear from the upper two panels of this figure that shortly after sunrise the thermistors fitted to the lamellas in northeast direction (Lamel 2 NE and Lamel 7 NE) are heated by direct solar radiation causing this side of the screen to be heated up to 2°C with respect to the air temperature measured inside the screen. As the day proceeds, this difference decreases, and the southwest thermistors (indicated by 'SW') are getting warmer and warmer towards the end of the day. Another remarkable observation is the obvious heating of the base plate, located at the bottom of the screen. Starting from 08 UTC, the plate gradually becomes 1-2°C warmer than the air temperature measured by the Pt500 inside the screen. Very likely the base plate is heated indirectly by the surface or directly by upwelling hot air or conduction from the mounting plate. The value found is not exceptional for this type of clear and warm summer days.

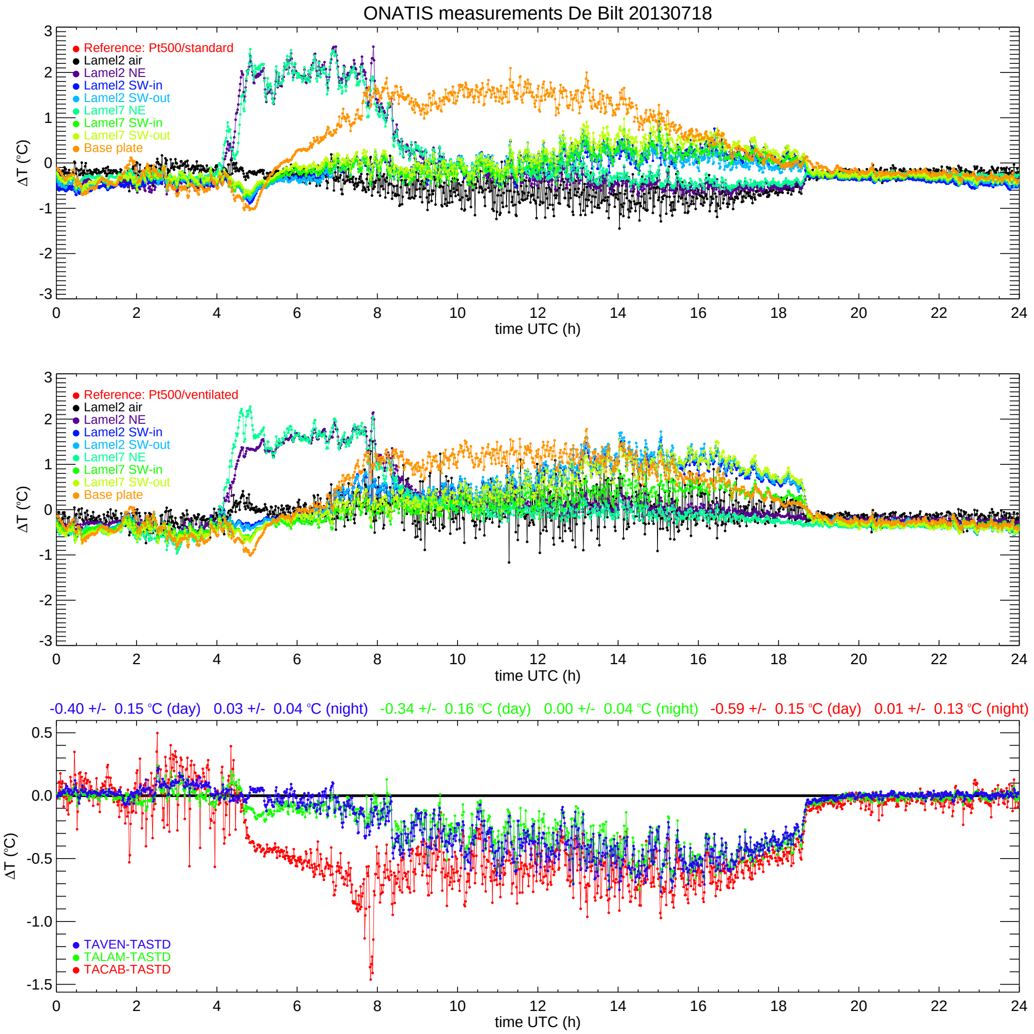

**Figure 11. Data from the ONATIS test site on 18 July 2013, showing: (upper) differences between the thermistor temperatures and Pt500 air temperature for the non-aspirated KNMI screen/TASTD, (middle) same as the upper panel, but for the aspirated KNMI screen/TAVEN, (bottom) temperature differences observed between the KNMI aspirated screen (blue), LAM630 aspirated screen used by DWD (green) and Cabauw aspirated setup (red) and the non-aspirated KNMI standard. Time resolution used in these graphs is 1 minute.**

## *5. Conclusions and Outlook*

The design and characteristics of a field trial (ONATIS) to assess the impact of the KNMI thermometer screen on the operational air temperature measurement is described and discussed. This non-aspirated screen is used since the 1980's for temperature observations in the Dutch surface observing network. The need for a field trial was recognized after a first study on the measurement uncertainty under laboratory conditions, reported in Bijma (2012), was concluded. In order to find the right measuring setup for the field trial several laboratory experiments were conducted, following the guidelines provided by ISO 17714 (2007) as far as possible. First, the ventilation factor of the KNMI and Eigenbrodt LAM630 screens was determined in the wind tunnel. Values between 20-30% for the bottom and 50-60% at the height of the top lamella were found for both screens, with the LAM630 screen showing slightly higher ventilation factors for the whole vertical profile. Furthermore, the response time of the KNMI screen was calculated in order to understand possible differences found in the field during variations in the air temperature. The time constant for the KNMI screen at a tunnel speed of 2 m/s was estimated at 133-182 seconds, or 2-3 minutes.

The ONATIS field trial started in July 2013 and already lead to some interesting cases during summer showing a clear radiation effect on the air temperature measured in the standard KNMI screen. Although very calm conditions (wind speed <1 m/s) did not occur during clear and sunny days, the average daytime difference between the non-aspirated and aspirated screens at the test site reached values up to -0.3°C, with minimum values down to -0.8°C on 10-minute basis. The temperatures measured by the (well-isolated) thermistors fitted to the lamellas of the screens demonstrate a clear diurnal cycle. During the periods around sunrise/sunset the northeast/southwest sides of the screens becomes several degrees warmer than the air temperature inside the screen. The maximum values experienced during the first year are roughly 5-6°C. Furthermore, it was found that the base plate of the screen is significantly heated due to reflection or upwelling hot air or conduction from the mounting plate. Both effects have a possible impact on the measured air temperature in the screen and are subject to further investigation when more data will become available.

Several technical problems have been encountered during the first months and the winter season did not provide any cases particularly of interest for analysis of wintry conditions with solid precipitation, rime and/or icing. The field trial in De Bilt will therefore be extended with one year until the summer of 2015. Note that beside the magnitude of the abovementioned effects also their frequency of occurrence will be investigated as it has a direct relation with their impact on operations for weather and climate.

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