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INFLUENCE OF HEATED FACADE AIR ON THE RESULTS OF CLIMATE DATA MEASUREMENT

Peter Kysela*, Radoslav Ponechal, Ján Rybárik

University of Zilina, Faculty of Civil Engineering, Department of Building Engineering and Urban Planning, Univerzitna 8215/1, 010 26 Zilina, Slovakia

* corresponding author: peter.kysela@uniza.sk

Abstract. Measuring climate data is a lengthy and technically challenging task. To record temperature data, small meteorological stations are located on the facade of the Research Centre building. Due to the position of the meteorological stations, which are mounted directly on the facade of the building, the temperature measurement sensor is not only affected by the solar radiation falling on the sensor housing, but also by the solar radiation falling on the facade of the building. The illuminated surface of the facade gradually heats up during the day and warms the air flowing near the facade. The temperature readings during the day may therefore be significantly distorted. To avoid this phenomenon, better-quality radiation shields have been purchased. The new radiation shield is characterized by a design that resembles eddy currents. The relationship between the shape of the outer and inner spiral is optimized, allowing vortices to form even in virtually windless conditions. In this paper, we would like to point out the differences in the measured air temperature data, according to the radiation shield used and the distance of the temperature sensor from the building facade.

Keywords: Climate measurement, facade, radiation shield.

1. Introduction – Measuring climate data

The need for climate data measurement has been increasing in recent years as it is proving to be an integral part of the proper design of the indoor environment of buildings. Simulation programs that are used in building design, either for the correct design of the indoor environment or for energy calculations, work with climate data sets. Climate datasets come in different sizes and details, depending on the intended use and the design of the indoor environment. The most used is the test reference year, which is defined as the year of hourly data of selected meteorological parameters that characterize the long-term climate. Such a dataset is suitable for some simple energy calculations or the assessment of long-term climate change [1]. But for many simulation tasks, more accurate temperature data characterized by smaller time steps or distances between the measurement site and the future building are needed for the proper design of technical equipment and indoor microclimate in buildings [2].

Since November 2016, small meteorological stations have been placed on the facade of the Research Centre building for this purpose, shows in Figure 1. The meteorological stations measure basic climatic parameters such as air temperature and humidity, solar radiation intensity, and wind speed and direction using a powerful anemometer. These are placed on the walls of the building, shows in Figure 2, facing the four cardinal directions at different heights and positions on the facade [3].

Figure 1. View of the west facade of the Research Centre.

Measuring air temperature is a technically challenging task because the measured data can be significantly distorted by various extraneous factors. For representative results, it is also necessary to consider factors that influence the measurement results, such as the influence of solar radiation, shading technology, urban heat islands, or the heating of the ambient air from the building facade.

It is the heating of the ambient air from the facade that has been shown to be a significant factor influencing the temperature data from the small meteorological stations located on the facade of the Research Centre building. The surface heated by solar radiation

Figure 2. Meteo-stations located on the west facade of the Research Centre.

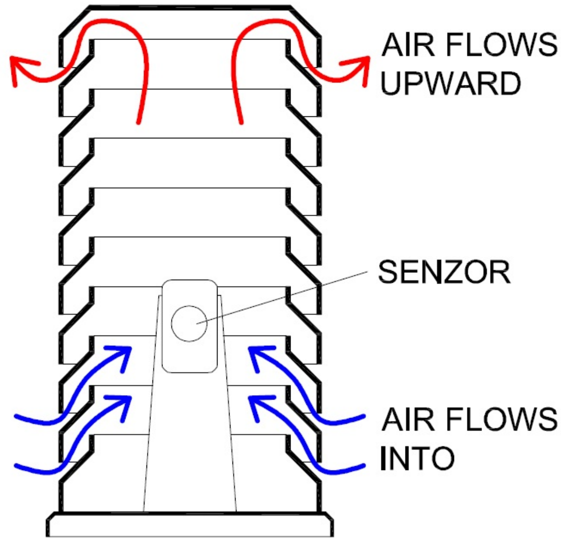

Figure 3. Illustration of airflow in the old shield.

can influence the airflow along the facade of a high-rise building during windless periods. Heated air enters the interior when windows are opened and can cause lower passive cooling efficiency [4]. To refine the measured temperature data, new radiation-resistant shields for the temperature sensors were purchased to make them more resistant to overheating from solar radiation and to overheated air that heats and flows near the building facade. The shields were placed on the facades of the Research Centre building, which are most affected by solar radiation, and at varying distances from the facade surface.

Comparison of temperature data during the hottest days of the year (June, July) showed a significant difference according to the cover used [5]. A less significant difference lies in the distance of the shield from the façade. The use of the new better-quality shields gives more accurate temperature data during the hottest summer days, which will be used for simulation calculations concerning the assessment of overheating of buildings during the summer period. This can be assessed by many indicators where the impact can be demonstrated over a longer time. The assessment would thus be further affected by high temperatures introduced by inaccurate measurements, the influence of heated air from the building facade [6].

2. Methods of measurement – the importance of radiation shields

2.1. Facade Meteorological Station (FMS)

The FMS itself consists of a metal frame that is mounted on the facade under the window and is connected to the power supply by a cable. Sensors measuring temperature, relative humidity, and atmospheric air pressure are mounted on the frame. For measurement used capacitive digital sensor AHT10 for humidity and temperature, accuracy typical ±0.3 K at 5 to 60 °C, operative range −40 to +80 °C. It is protected by a radiation shield, shows in Figure 3. This is followed by a pyrgeometer to measure longwave solar radiation, a pyranometer to measure and monitor global solar radiation, and an ultrasonic anemometer to measure wind speed and direction. The data collection is wireless. Measured data with a one-minute write interval is collected and stored on a remote data storage server located in the building [4, 7, 8].

2.2. Radiation shield

The new radiation shield features a design that is reminiscent of the eddy currents that occur in nature. The unique continuous 27-piece double helix design serves the designed purpose in achieving superior measurement and sensor protection characteristics. Figure 4. shows how air can pass freely through the enclosure wall to the interior of the enclosure, where it is formed into a vortex shape by the spiral shape that flows around the sensor. The hot air flows upwards and exits the enclosure through the top. Figure 5 shows how the vortex from the inner spiral lead's particles heavier than air particles naturally away from the sensor, such as dirt, sand, snow, and water. The relationship between the shape of the outer and inner spiral allows vortices to form even in virtually wind-

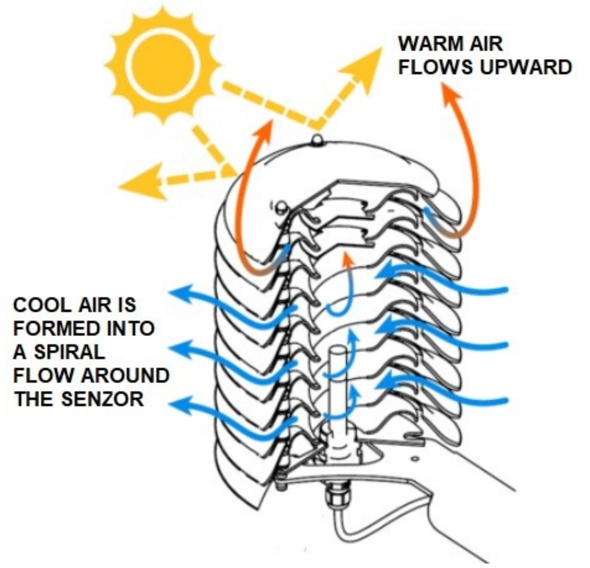

FIGURE 4. Illustration of airflow in the new shield [9].

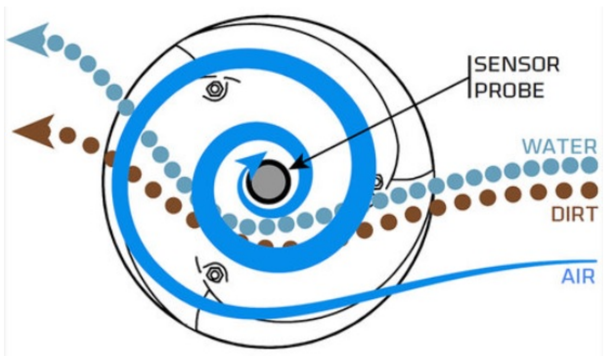

FIGURE 5. Schematic illustration of the eddy flow in the shield [9].

less conditions. This ensures that the air is constantly flowing around the sensor and prevents the stagnant air in the enclosure from overheating [9, 10].

3. Installation and positioning on the facade, selection of representative days

3.1. Installation of new radiation shields

Replacement of shields on individual FMS was carried out as part of the meteorological station inspection. For the replacement of the radiation covers, it was necessary to modify not only the fitting of the new shield but also the location of the sensor itself, since the outer diameter of the radiation shield is larger than the original type, shows in Figures 6 and 7. The new position of the sensor is therefore approximately 15 cm further away from the facade of the Research Centre building, shows as Figure 8. The positioning of the new enclosures has therefore also affected the distance of the sensor from the facade of the building. For a relevant assessment of the effectiveness of the new shield compared to the previous shield, the sensors with the previous shield type were placed in the same position on the two FMS as for the new shields. This means that it is possible to compare how not only the type of shield used but also the distance of the sensor from the building facade affects the measurement results.

FIGURE 6. FMS with the previous type of shield on the facade.

FIGURE 7. Installation and replacement of the new type of shield.

Figure 8. FMS with the new type of shield on the facade.

3.2. Location of FMS and used shields

The location of the new shields was chosen so that at least one FMS with a new type of shield was placed on the west, south and east sides of the building. No new shields were placed on the north side of the building as it receives minimal glare in the morning hours. The results shown in the graphs present the temperature data from four FMS with new radiant shields, one on the east and south sides of the building and two on the west side of the building. The FMS with the previous type of shield, placed in the new position, were mounted on the west and south sides of the building. A schematic of the location of each FMS is shown in Figure 9.

The installation of new radiation shields on the FMS took place during the months of March, April during the FMS inspection. For the best assessment of the heated air factor from the building facade, the period when air temperatures reach the highest values is suitable. According to the observed data, it was evident that the new type of shield is significantly more resistant to this factor. Due to the size of the new radiation-resistant shields, the sensors and the shield mounting were more distant from the facade surface. Thus, not only the new type of radiation shield influenced the measured data, but also the displacement of the sensor position further away from the building facade. To evaluate this factor, the sensors with the previous cover were mounted in the same position as the sensors with the new type of cover on two FMS. By comparing the data, it is thus possible to evaluate what effect the position or distance of the sensor from the building facade has.

3.3. Meteorological control station

For evaluating the measured data from the individual FMS on the facade of the Research Centre building, the temperature from the meteorological station located on the roof of the adjacent building is also shown in the graphs. This automatic meteorological station is used for all the experimental research carried out by the department. For all the research tasks carried out, monitoring of climatic parameters with very accurate and high resolution is required [11]. The temperature sensor is placed in an open space, far enough away from the roof surface, thus avoiding heating from the roof surface.

4. Evaluation of measured results

The difference in the resistance of the shields used is especially noticeable on warm sunny days [10]. The graphs present measurements from a series of warm days in early July 2021, namely from 0:00 on 6 July 2021 to 23:59 on 9 July 2021, recorded in minute intervals. The graph in Figure 10 presents the results from the west façade of the building where the two FMS with the new shield (T17-N, T24-N) are located, shown by the solid blue and red lines, for temperature comparison the dashed line shows the temperature data from FMS with the original type of shield (T21, T23, T28), located close to the FMS with the new shield. For reference, the temperature data is shown in red solid bold line with the air temperature from the meteorological station (T M37) located on the roof of the adjacent building, in Figure 10.

To compare the effect of the sensor location or distance from the building facade, the solid green line shows the temperature from the FMS with the previous type of shield and the sensor at the same position from the facade as the new shield types. The deviation of the individual sensors from the air temperature sensed by the meteorological station on the adjacent building (M37) can be observed from the temperature course during the daily maximum. In Figure 11, which shows the deviation of the sensors with the new type of shield is about 2 to 3 °C, which represents a measurement error of approximately 5 to 6 % compared to meteorological station M37, during the maximum temperature during the day. The deviation of the sensors with the previous type of shield is significantly higher, by 8 to 10 °C, which represents a measurement error of approximately 26 to 27 % compared to meteorological station M37. The deviation of the sensor with the previous type of shield placed in the same position as the sensors with the new shield (T26-S), i.e., 15 to

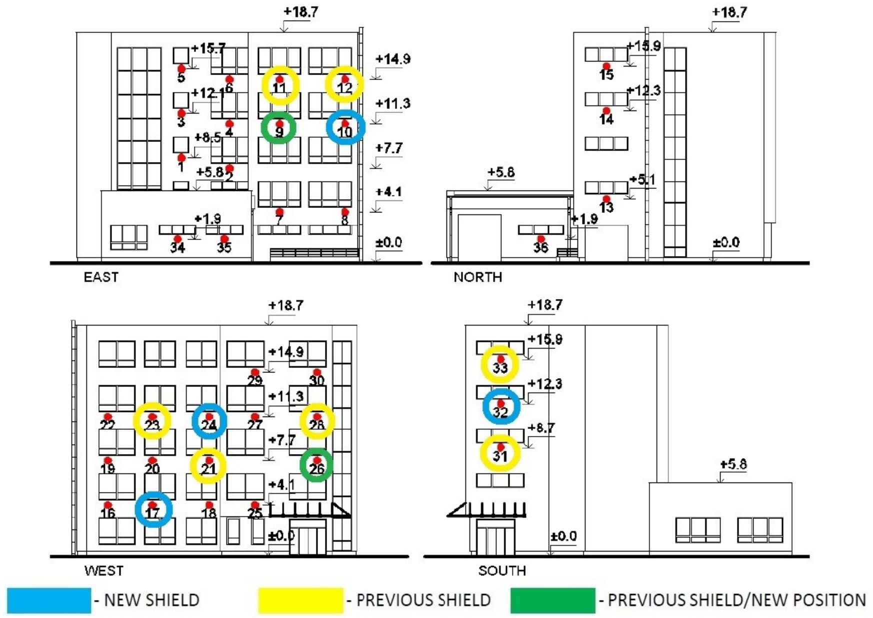

FIGURE 9. Schematic layout of the FMS on the facades of the Research Centre building.

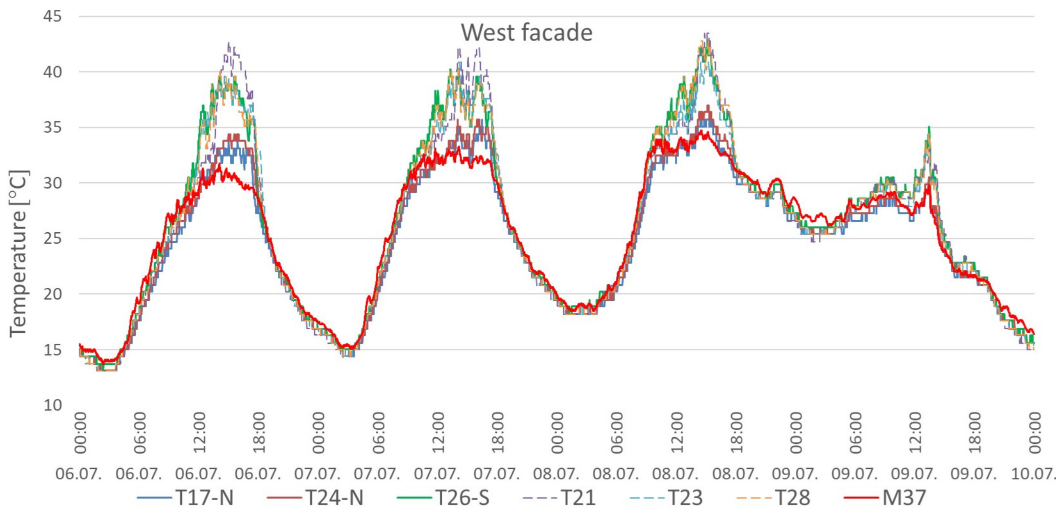

FIGURE 10. Temperature recorded at the FMS sensors on the west facade of the Research Centre building during 6 July 2021 to 9 July 2021.

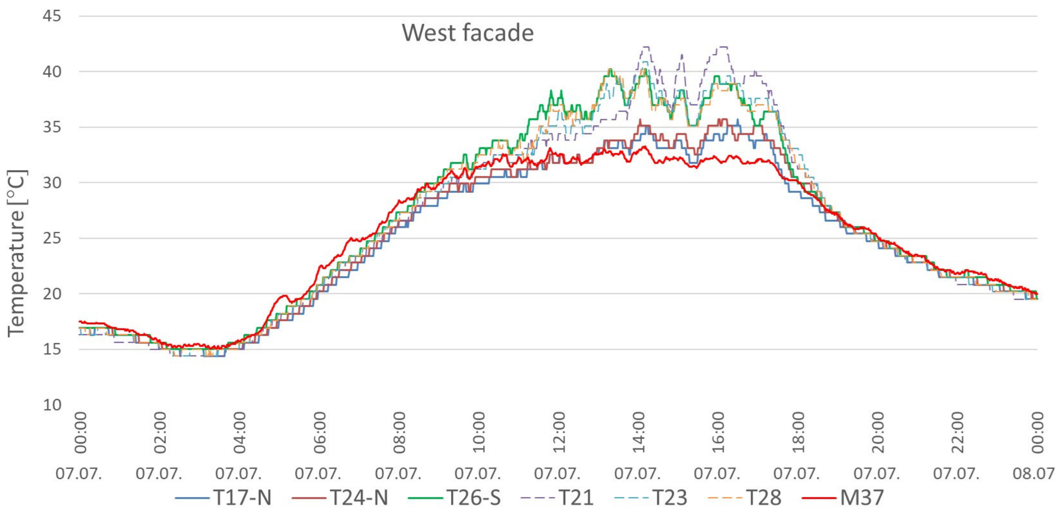

FIGURE 11. Daily temperature course recorded by FMS sensors on the west facade of the Research Centre building during 7 July 2021.

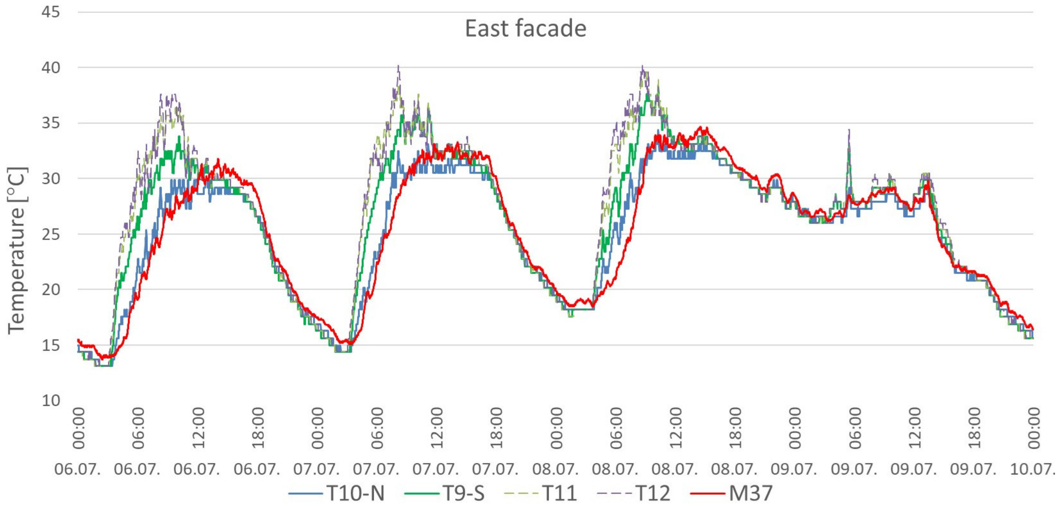

Figure 12. Temperature recorded at the FMS sensors on the east facade of the Research Centre building during 6 July 2021 to 9 July 2021.

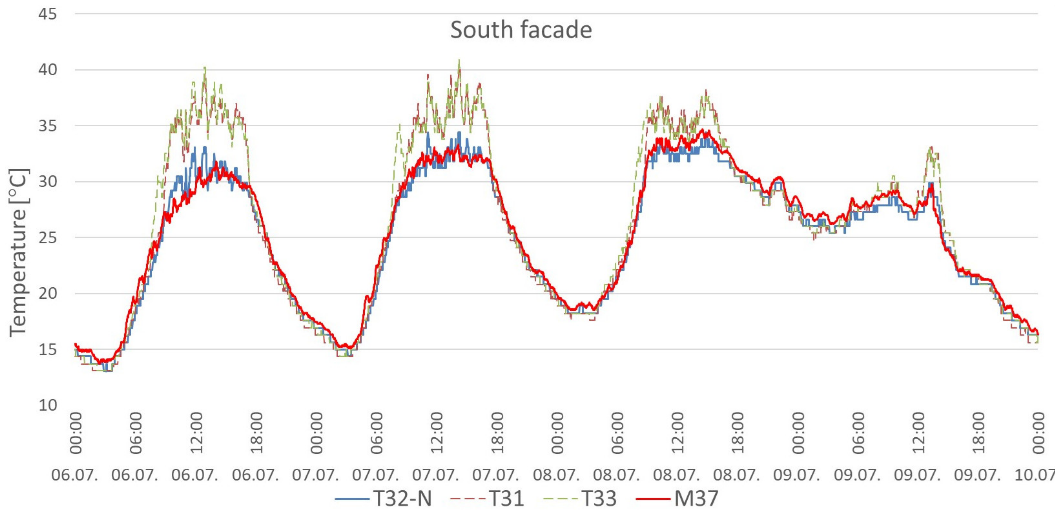

Figure 13. Temperature recorded at the FMS sensors on the south facade of the Research Centre building during 6 July 2021 to 9 July 2021.

20 cm further away from the building facade, is only about 1 to 2 °C lower than for the sensors with the previous type of shield in the previous position (T21, T23, T28), which represents a measurement error of approximately 20 to 21 % compared to meteorological station M37. It is therefore reasonable to assume that the distance of the sensor from the building facade has only a small influence on the resulting sensed temperature. Conversely, the type of radiation shield used has a major influence on the measurement result and hence on the resulting temperature data.

The temperature course from the east and south facade, shows in Figures 12 and 13, showed similar results to the previous west facade. The differences between the sensor temperature with the new type of shield and the air temperature measured by the station on the roof of the adjacent building is up to 1 °C, which is an even smaller difference compared to the west facade. However, on the eastern facade a more significant difference is visible between the sensors with the previous type of shield in the previous (T11, T12) and in the new position (T9-S), i.e., at a greater distance from the facade. This may be due to the gradual heating of the sensor inside the shield during the day, as it is just the eastern facade. It is therefore noticeable how the deviation increases during the day and approaches the values of the sensors with the previous type of shield in the previous position (T11, T12).

The temperature course on the east and south facades (Figures 14 and 15) are used to show the temperature evolution during the day in more detail. In Figure 14, which shows the daily temperature course on the eastern facade, an increasing difference between the temperature on the sensors with the previous type of shield and on the sensor with the previous type of shield but in a more distant position is visible. Insufficient airflow in the previous shield type is heating the air inside the shield from the hot air flowing close to the facade. Moving the sensor shield away reduces

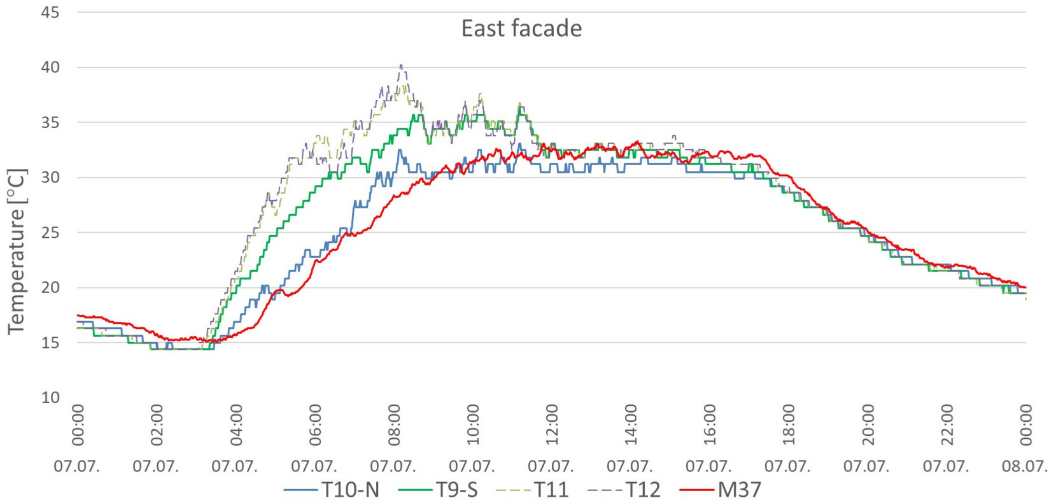

Figure 14. Daily temperature waveform recorded by FMS sensors on the east facade of the Research Centre building during 7 July 2021.

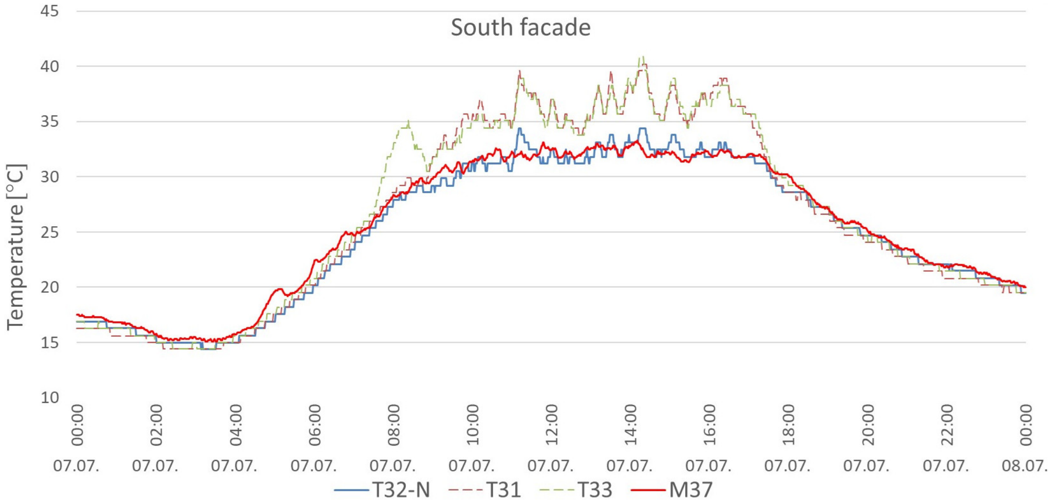

Figure 15. Daily temperature waveform recorded by FMS sensors on the south facade of the Research Centre building during 7 July 2021.

the effect of the hot air, but not nearly enough to achieve similar results as with the new shield type. Then, as the sunlight passes onto the south facade, the temperature on the sensors will gradually converge to a roughly similar position. The slight variations between FMSs with the same type of shield are due to the specific location within the facade.

5. Discussion – suitability of the use of shields in the future and recommendations

As it has been shown, the relevance of measured meteorological data is influenced by several factors, which have varying degrees of influence on the accuracy of the measured data. In this paper, we found that the position of the sensor is less important than the quality of the sensor radiation shield for the influence of heated air from the facade. The proper shape of the shield allows constant airflow inside the shield and prevents the sensor from overheating, and thus the relevance of the data is achieved [12]. It is therefore necessary, when designing the location of the sensors, to evaluate what factors may affect the measured data and accordingly select a suitable type of shield that is resistant to the factors that occur at a given location of the measuring equipment.

Measurements with the new shield and at a greater distance from the building facade fundamentally changed the measured results of heated air from the facade. It can no longer be so strongly argued that the air near the facade prevents passive cooling. Especially on the south side, the air temperature measured by the sensor with the new shield was no different from that on the roof of the adjacent building. It is only different in the morning on the east side. In the future, it would be advisable to produce a smaller shield of similar construction that could be placed closer to the facade. It would also be adequate to investigate the behavior of the shield under artificial weather conditions in climate chambers.

Acknowledgements

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