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Influence of a reflective glass façade on surrounding microclimate and building cooling load: Case of an office building in Algiers

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Influence of a reflective glass façade on surrounding microclimate and building cooling load: Case of an office building in Algiers

Abstract

The urban landscape of the city of Algiers, Algeria, has seen a spread of reflective glass façades of new and rehabilitated office buildings. This type of glass can create visual glare in outdoor spaces and may lead to indoor thermal discomfort. The objective of this paper is to investigate experimentally and numerically the impact of the reflective glass façade of an existing building on the neighboring microclimate and the building cooling load. The modeling of the microclimate around the case study building is performed with ENVI-met software. The impact of the microclimate is investigated by calculating the cooling load of the case study building with three weather data files. The cooling load is calculated with the building energy simulation software Ecotect for a typical summer day. The weather data files investigated are the experimental data from the reference station of Algiers airport, experimental data measured on the case study building roof, and the data modeled by ENVI-met taking into account the microclimate created by the glazed building. It is found that the air temperature surrounding the building significantly increases due to the multiple reflections of the radiation heat flux, leading to an increase in the cooling demand.

Keywords: reflective glass façade; microclimate; urban heat island; cooling load; building surface temperature

Highlights

- Reflective glazed façades have an important influence on the urban microclimate.
- Reflected sunbeams increase air temperatures.
- Cooling load is strongly impacted by the local solar radiation environment.
- Main reason is the high reflectance of the curtain-wall.

1. Introduction

In Algeria, the building sector is the largest consumer of energy among all economic sectors, accounting for 42% of the total energy. The building energy consumption has increased by over 30% over the last 30 years and this trend will continue through 2030 [1]. Additionally, the lack of land in urban sites has led to a proliferation of tall buildings since the 1990s, and most of them use curtain-wall to enhance their aesthetics. Typically, these glass surfaces are reflective, and incident solar radiation is largely reflected. They reach a reflectance of about 30-90% in order to reduce the cooling load [2], [3]. Yet, the reflected sunbeams not only cast surplus light [4], [5], but also add a supplementary thermal load to the neighboring environment [6].

At building scale, several studies have addressed the effect of the envelope on the energy performance of buildings based on the percentage of glass façade and its thermoradiative properties.

Barbosa and Ip [7] and Pomponi et al. [8] have shown that highly glazed façades, if designed carefully, such as double skin façades, can exhibit significantly better behavior than conventional windows. Indeed, the exterior walls respond dynamically to varying ambient conditions, and can incorporate a range of integrated sun-shading, natural ventilation, and thermal insulation strategies. Yet, if they are poorly designed, they not only increase the building energy consumption, but also affect the occupants' thermal comfort, due to the thermal radiation coming from the hot glazing surfaces. Other authors are interested in the effect of the glass types and their ratios to the wall surface (Window to Wall Ratio, WWR) on the energy performance of indoor spaces. For example, Bouden [9] investigates the impact of glass façades on annual cooling and heating loads in the Mediterranean climatic conditions of Tunisia. His set of cases consist of seven types of glass and five window to wall ratios. He shows that glazed façades, according to their types and orientation, can provide lower annual energy load than the currently used 20%-WWR masonry wall buildings with single glazed window. The optimal results are found for a 90%-WWR, with a curtain wall made of one clear and one reflecting panes. Lartigue et al. [10] provide a methodology for optimizing the envelope of a building with respect to a triple objective of heating load, cooling load and daylight. The optimized variables are the WWR and thirteen window glass types characterized by their visual and thermal characteristics (visual and solar transmittance and *U*-value). This method offers the advantage of quickly and accurately giving the optimal solutions of the problem, providing guidelines for construction decision.

However, these studies do not take into account the effect of buildings on the microclimate, which is a significant factor in the building energy consumption. In fact, Yuan et al. [11] affirm that half of the city's anthropogenic heat results from buildings.

At urban scale, the microclimate is influenced by the heat island phenomenon (Urban Heat Island, UHI), which has a direct impact on the thermal comfort in the building, as well as on the energy demand. If in winter the effect can be positive by reducing heating consumption, in summer air-conditioned buildings increase their energy consumption. Some studies highlight the important impact of the UHI on ambient air temperature differences between urban and rural areas, as well as its implications on the building energy performance [12], [13]. Santamouris et al. [14] use the survey of thirty weather stations of urban climates in Athens, Greece, in order to simulate the heating and cooling loads of a reference building. They note that the impact of high air temperature in the city is extremely important and can double the cooling load peak of the building under consideration. Toparlar et al. [15] compute buildings' cooling demands in three locations, in Antwerp, Belgium: a rural location; an urban location, away from an urban park; and another urban location, close to the same park. They combine two building types and six sets of construction characteristics. They show that buildings with better thermal insulation and lower infiltration rates increase the cooling demand by 48% once moved from the rural location to an urban location. Residential buildings close to the park are found to have on average 13.9% less cooling demand, compared with buildings away from the same park. Bozonnet et al. [16] study by CFD simulations the interaction between urban microclimate and energy demand for air conditioning in a typical case of a street canyon, taking into account anthropogenic dissipation of air conditioners on façades. They show that the computed building energy consumption in summer could be more than 30% higher if calculated with the street canyon air temperature rather than the weather station temperature. Bouyer et al. [17] evaluate the energy demand of one building in a district in Lyon, France, over one week in winter and one week in summer. They study the impact of two types of urban landscape, a full-mineralized one and a vegetated one. They show that the vegetated case leads to 9% reduction in cooling energy demand compared to the mineralized one. Mirzaei et al. [18] study the surrounding radial areas of buildings that impact the indoor temperature to propose a method for forecasting it.

In fact, the material composition of urban surfaces is a crucial parameter in the development of microclimates inside the cities, thereby also affecting energy use in buildings [19]. Built environment modifies solar incidence, while material properties affect the energy balance of surfaces. Several experimental and numerical studies ([20], [21], [22] and [23]) have shown the effectiveness of using reflective materials for roofs and pavements. They dissipate solar radiation and mitigate the effects of the UHI. Yet, when reflective materials are used in façades, multi-reflections of sun's rays with surrounding surfaces create a radiative trapping that increases air temperatures and energy consumption of buildings. Danks et al. [5] have shown that high reflectance of reflective glass raises the surface temperatures of the surrounding spaces (façades, parks, sidewalks and roof tops). Consequently, they propose to limit the reflected irradiance of façades to 1500 W/m².

Lately, in order to reflect the solar radiation beyond the urban canopy, Nagahama et al. [6] developed a façade material that achieves thermal comfort of both indoor and outdoor spaces. To do so, the authors propose a transparent solar control window coating that reflects near-infrared rays to the sky. Its microstructure enables to return infrared rays to the sky. Other researchers such as Rossi et al. [23] and Yuan et al. [24] also show that retro-reflective materials, applied as coatings on urban paving and building envelopes, can effectively mitigate urban heat island.

Yet, to our knowledge, no study has been performed specifically to evaluate the impact of the façades reflectance on both outside and inside building environment. In this article, we are studying experimentally and numerically the microclimate around an existing reflective glass building in Algiers, Algeria, as well as the impact of the microclimate on the building energy cooling load.

2. Case study: a glass office building in Algiers

2.1 Location

The case study is an existing reflective glass office building located in Algiers, the biggest city in Algeria in terms of inhabitants and urbanization growth. It is located on the Mediterranean coastline at 36°.43 northern latitude and 3°.15 longitude. It has a Mediterranean climate where summers are hot and wet, while winters are cold and short, with rains from 400 to 1000 mm per year, and with more than 250 sunny days per year and 16 hours of sunlight per day.

The building is surrounded by a nine-story office building in the North-East, with a white façade; by four villas of two levels each in the South-East; by an apartment building of four levels in the South-West, and another office building of five levels in the North-West. The adjacent horizontal surfaces are asphalt roads. Figure 1 shows the ground plane of the case study building and its surroundings.

Figure 2 shows the evolution of monthly maximal temperatures averaged over 29 years from 1981 to 2010, in Algiers [25]. From the graph, the highest temperature is 31.8°C and it is recorded in August, the hottest month of the year. According to the National Office of Meteorology of Algeria, the rise in temperatures has affected the entire country. Recent heat waves (2012, 2015) overwhelmed the country with temperatures reaching 47°C in the shade and 54°C in the sun. These elevated temperatures increase the peak of the electric demand for air conditioning, which leads to possible decreases in voltage on the electrical networks. This increased our interest in investigating the cooling load of the case study building.

2.2 Building envelope

Inhabited since 1999, the building under consideration is composed of three blocks (9, 10 and 11 floors) and one central courtyard in each block. Its dimensions are 132 m in length, 56 m and 32 m in maximal and minimal widths, and three different heights of 38 m, 35 m and 32 m (Figure 3). The volume to be air-conditioned is 206 720 m^3. The global floor plan of 2 756 m² has a rectangular shape with two kinds of offices: peripheral with view on the exterior, and central with view on the courtyard. The glass used for this building reflects a large part of sunlight. The selective action of the coating used in the reflective layer has the effect of preventing the solar heat from entering the building by reflecting light and infrared radiation (Figure 4, above and below).

Figure 5 shows the optical characteristics of the glass. A significant reflection (20-35%) is observed in the region of the visible light and a low transmission (15-20%) of ultraviolet. The transmission peaks near the orange part of the visible region (the glass appears brown in transmission from the inside) and is blue in reflection because the reflection curve peaks around the blue band of the visible spectrum [2]. The reflective glass has a solar reflectance of around 0.32 for our case of reflective blue glass. The low transmission of the visible radiation (a maximum of about 20%) requires the use of artificial lighting all day and all year long.

3. Methodology

Figure 6 summarizes the methodology of the study. The microclimate around an existing reflective glass building in Algiers has been investigated experimentally and numerically (Figure 6.a). Then, the study of the impact of the microclimate on the cooling energy load of such a glazed building has been conducted (Figure 6.b). To do so, we have computed with the software Ecotect the cooling load of the building using three different weather files: one from the weather station located at the airport far from the building (Case 1), another issued from a micro-station located on the roof of the building (Case 2), and the last one computed with the microclimate ENVI-met software, taking into account the building envelope and its surroundings (Case 3).

3.1 Experimental data

The experiments have been conducted during a typical summer day, on 2nd August 2013. It was a clear and sunny day, with no wind.

3.1.1 Weather data measured by a micro-station on the roof

A Hobo weather micro-station was used to measure the air temperature, the relative humidity and the wind speed. Table 1 describes the characteristics of the sensors. The micro-station was located on the building roof, and the data were recorded during the representative day (2nd August 2013).

3.1.2 Thermograms of the façades

To characterize the microclimate surrounding the glazed building, we have taken thermograms of the four façades using a thermographic camera. The characteristics of the instruments are reported in Table 1. The thermograms have been recorded three times during the day, at 9:00, 12:00 and 15:00, on the four façades.

3.1.3 Weather data measured at 2 m from the ground

The software ENVI-met is able to compute the microclimate around the building, taking into account the effect of the reflective glass of the building façades and the district configuration. To do so, the air temperature, the relative humidity and the air speed have been measured at 2 m from the ground, by a mobile hygro-thermometer, whose characteristics can been found in Table 1. These values are used as input for ENVI-met. The data were recorded once, at 7:00, quite far from the surrounding buildings as recommended by ENVI-met. The position of the measurements is indicated on Figure 7.

3.2 Modeling of the microclimate using ENVI-met

The experimental measures give precious local information on the microclimate surrounding the building. Yet, they are not sufficient to provide an extensive characterization of the close outdoor environment. ENVI-met is able to provide data all around the building, taking into account the reflective envelope and the district configuration.

3.2.1 Description of the software

ENVI-met V4.0 is a 3D prognostic microclimate model based on computational fluid dynamics and thermodynamics. The software simulates airflow around buildings, heat and vapor exchanges, energy and mass exchanges between vegetation and its surroundings [26].

To simulate the microclimate, ENVI-met requires some input parameters such as weather conditions, urban structure and physical properties of the urban surfaces and vegetation. The computed climatic variables include direct/diffuse solar radiation, long wave radiation, and vertical profile of atmospheric parameters (air temperature, air velocity, and air humidity) calculated from 0 to 2500 m above ground.

For the simulation, the three-dimensional building envelope is divided into 3D parallelepipedic grid cells with the dimensions (x), (y) and (z). The horizontal spacing (x) and (y) is constant for all grid cells. In a vertical grid, all grid cells have the same height (z) - except the lowest grid cells that are divided into five sub grid cells so that the vertical height of these grid cells is $0.2(z)$. The vertical higher resolution of the grid cells closer to the ground leads to higher accuracy and has the advantage that the exchange processes between atmosphere and ground, which have a substantial influence on the microclimate at ground level, can be simulated more accurately [27].

ENVI-met has been verified with field experimental data by many researchers. In [28] and [29], Huttner validates the use of ENVI-met by implementing an enhanced module for the calculation of the fluxes of energy and temperature within façades and roofs. He shows the good agreement between the temperatures measured on the roof and the simulated values. Other studies [30], [31], [32] evaluate the impact of the street geometry on the ambient temperatures and on pedestrian comfort levels. They show the good agreement between field measurements and comfort surveys with urban climate simulations using ENVI-met.

3.2.2 Simulation settings

The case study implemented for the present analysis is an office building located in a densely urbanized area in the center of Algiers. The settings of the ENVI-met simulations are presented in Table 2. A study of the grid sensitivity has been implemented. The microclimate along one façade has been computed with a tighter mesh of $dx = dy = dz = 0.5$ m, instead of 2 m. The results of the air temperature profiles for the two meshes, according to the height are given in Table 3. The temperature profiles follow the same tendency, with values slightly higher for the actual mesh. The maximum difference reaches 0.5°C. This gap is in the range of the experimental uncertainty (between 0.2°C and 0.5°C in Table 1). Due to a lower computation time, the mesh of dx = dy = dz = 2 m has been chosen.

In our study, the data measured on site by the hygro-thermometer, at 2 m from the ground, are entered in ENVI-met as input, to simulate the microclimate around the case study building, as explained above in § 3.1.3. The outdoor microclimate parameters are calculated in specific points called receptors. Figure 7 shows the horizontal positions of the 7 receptors that were chosen around the building, 4 (R) at 1 m in front of each façade and 3 (P) inside the atria. Three floors of the building were investigated: ground (H=1.80 m), middle (H=17.00 m) and top floors (H=31.00 m), as seen in Figure 8

3.3 Modeling of the energy load using Ecotect

To show the impact of the microclimate on the indoor thermal environment of the building, we have computed the cooling load according to three weather data files.

3.3.1 Description of the software

The building cooling load is calculated with the software Ecotect. Ecotect is an environmental analysis tool with a wide range of performance analysis functions such as thermal analysis, solar exposure, acoustics, lighting and shading. It gives optimal solutions for the existing construction and proposes modifications to new designs for improved energy performance [33], [34]. Ecotect uses CIBSE Admittance Method (Chartered Institution of Building Services Engineers) to estimate the heating and cooling loads for the thermal zones of a given building.

The Ecotect weather tool provides a psychometric chart to determine the comfort zone of each region, and can provide optimal analysis corresponding to various passive strategies according to local weather characteristics [35]. It can also analyze the solar radiation, and calculate the best orientation for buildings. Many studies use this software to analyze energy loads for different systems such as air conditioning, energy saving especially from solar heat, day-lighting and natural airflow, and for many existing or new buildings [34], [35], [36], [37], and [38].

3.3.2 Simulation settings

One of the objectives of our study is to show the impact of the microclimate on the energy performance of the glazed buildings. We have therefore considered three microclimates, by creating three weather data files with Ecotect.

- **Case 1 – Reference weather station** (referred as Ref-St): this file uses meteorological data measured by the reference station of the city, located at the airport, 25 km from the city center of Algiers. The data of 2nd August 2013 have been used to create the weather file for the simulation.
- **Case 2 – Micro-station on the roof** (referred as Roof): these data capture part of the microclimate as they have been recorded on the roof of the building. Yet, they are very localized and do not capture the temperatures along the façades.
- **Case 3 – Modeling of the microclimate with ENVI-met** (referred as ENVI-met): uses weather data computed by the ENVI-met microclimate software. This modeling is based on experimental mobile measurements as explained above.

The cooling load of the case study building is calculated with the resource consumption function, for one typical summer day. The three microclimates investigated are used as weather files in Ecotect. The building in Ecotect is divided in 7 thermal zones at each level. Figure 9 shows the seven thermal zones chosen for the simulation. Four thermal zones correspond to the four orientations of the building, and the three others correspond to the three atria. In Cases 1 and 3, there is only one weather file for the 7 thermal zones. In Case 3, the cooling load is calculated with the weather file simulated at its closest receptor. The horizontal positions of the 7 receptors are given in Figure 7. The details of the simulation settings are given in Table 4.

4. Results and discussion

4.1 Experimental façades temperatures

To better understand the thermal effects of coated glass curtain walls in an urban context, thermograms have been performed to analyze the wall surface temperatures. Figure 10 shows the surface temperature of the four glazed façades, for three sequences of the representative summer day of 2nd August: 9:00, 12:00 and 15:00. The wall surface temperatures, measured using a thermographic camera, show significant variations between the different façades for the 3 sequences. The marked values on Figure 10 are the temperatures measured in the center of the picture. The surface temperatures depend obviously on the orientation.

- **Building surface temperature vs. time**

The North-East façade shows a maximum surface temperature of 44.4°C in the morning at 9:00. This is due to the incident radiation after sunrise. The surface temperatures decrease and reach 27.7°C at 12:00 and 30.6°C at 15:00 when the sun is far from this façade. That increase at 15:00 can be explained by the reflectance of the façade of the opposite 9-level building (Figure 1). That building has a white façade.

On the South-East façade, the thermogram shows a maximum value of 48.4°C at 12:00 due to the incident radiation. At 9:00, the temperature measured is 34.9°C, due to the sun exposure. At 15:00, the temperature decreases because the façade is hidden from the sun.

For the South-West side, the first heating effects appear at the third sequence of the day with more significant values according to the North-East and South-East façades. Indeed, at 15:00, the maximum surface temperature reaches 55.4°C. Due to the sun exposure, the façades temperatures become very high and cause the atmosphere to warm up. During the morning at 9:00, the South-West façade displays the lowest surface temperature of 18.8°C because it is shaded until 12:00 when it receives solar energy from the Zenith and reaches 28.9°C.

At the first hours of the day, the North-West façade does not receive direct solar radiation at all, so its surface temperatures are 20.7°C at 9:00 and 28.5°C at 12:00. In the afternoon, a temperature of 39.0°C is recorded at 15:00.

As mentioned above, the absorption coefficient of the glass façade is around 40%. This can be seen on Figure 5. This absorption increases significantly the surface temperatures. Then, the envelope emits IR radiation to the inside and outside environments.

- **Building surface temperature vs. height**

Several pictures on Figure 10 show the evolution of the surface temperature with the height. It can be seen that the temperature decreases with height, particularly on the North-East façade all day long, but also on the South-East and South-West façades at 15:00, and at the North-West façade at 12:00. The top of the building is cooler than the lower levels.

This is explained by the dihedral effect. The façades in contact with the horizontal surface (asphalt road) create a dihedral effect [39], which allows heat exchange between the two adjacent surfaces – horizontal and vertical. Therefore, there is an additional heat received by the lower levels of the building, coming from the reflection on the asphalt. These heat exchange effects have a key role in the warming of the air. In our case study, the building is surrounded by asphalt roads (Figure 1).

Priyadarsini et al. [40] and Gros et al. [41] also showed in numerical and experimental studies the decrease of the surface temperature with the height of the building. Both of them explain the higher temperatures at the lower levels by the proximity of the road surface, which increases the air temperature and therefore, the surface temperature of the building by convection heat transfer.

4.2 Computed microclimate around the building

The microclimate around the building is modeled with ENVI-met.

Figure 11 compares air temperatures around the building for the three different levels showed on Figure 8. It is observed that the highest air temperatures occur at the lowest level 1.80 m. Then, the temperature decreases with height, reaching an average of 34°C at H=17 m and 33.3°C at H=31 m.

The lowest levels of the building are impacted by the horizontal surface of the asphalt road. A lot of studies have highlighted the strong influence of asphalt on the heat exchanges [42]. For example, Chatzimitriou and Yannas [43] tested different horizontal materials and showed that, with an albedo of 0.15, the hottest surface's material is asphalt. The multiple reflections between the building's façade and the asphalt lead to an increase of the air temperature at the lower levels, which is relevant with the same tendency recorded by the experimental thermograms on the building surface temperatures.

For the atria, the mean air temperature ranges between 34.0°C for the first level, 33.7°C for the second level, and 33.5°C for the third level. The hottest atrium is the smallest one because of the entrapping of solar radiation. These results show the impact of the reflectance of the building glass façade on the surrounding microclimate due to the multiple reflections between the façades and the ground, with the presence of dihedral effects [39], leading to higher air temperatures.

In order to compare the measured air temperatures with the computed ones, the temperatures calculated by ENVI-met at the outdoor receptors (R) near the 4 façades are studied in detail. The receptors are located at a distance of 1 m from the building façades according to the four orientations (NE, SE, SW and NW) and can be seen on Figure7.

Figure 12 shows the evolution of the air temperatures vs. time, both for the experimental temperatures and computed ones. The experimental temperatures are the ones measured at the reference station (Ref-St) and the ones measured by the micro-station on the roof (Roof). The computed temperatures are the ones calculated at the four orientations, at the height of H=1.80 m. From 8:00 to 20:00, the experimental temperatures are lower than the computed ones, the lowest being the temperatures measured at the weather station. This is understandable since the weather station is located far from the city center, and therefore does not measure the effect of the urban heat island.

The air temperature measured on the roof is globally higher than the air temperature measured at the reference station, especially starting from noon. The micro-station on the roof actually takes into account the microclimate due to the reflective glass building.

At last, the air temperatures computed by ENVI-met are higher than the measured ones, all along the day. The temperatures calculated on the East façade (NE and SE) are logically the highest in the morning, while the ones calculated on the West (NW and SW) façade are higher in the afternoon. That shows the effect of the microclimate, taken into account in the modeling, due to the reflective glass building.

4.3 Impact of the microclimate on the cooling load of the building

After having shown the impact of the glazed building on its surrounding microclimate, we have conducted a study to quantify the impact of the microclimate on the cooling load. The modeling of the cooling load has been performed with Ecotect. The cooling energy load of the building is calculated for the typical summer day of 2 August, for three microclimates (Cases 1, 2, and 3). The cooling loads are computed in the 7 thermal zones shown in Figure 9, and for 3 levels (Figure 8).

For the three cases, the first step is to create the weather files with Ecotect. According to the cases, they are either measured by the weather station (Case 1), the micro-station on the roof (Case 2), or computed by ENVI-met (Case 3). In this last Case 3, the weather file is created from the climatic data calculated at the 7 receptors (R and P, on Figure 7), and for the 3 heights. A total of 21 weather files have been generated to calculate precisely the cooling load at the 21 thermal zones.

Figure 13 shows the average cooling load during the air-conditioned time period (8:00–20:00), for the three microclimates. As expected, the highest cooling load is obtained in the Case 3, corresponding to the microclimate computed with ENVI-met. This microclimate takes into account the urban heat island due to the reflective glass building, and therefore the air temperature is higher than for the other weather files (Figure 12). The cooling load calculated in Case 2 with the measured weather data on the roof is 8% lower. Indeed, the micro-station measures the urban microclimate, but only on a localized position, on the roof, and cannot precisely take into account the impact on the air temperature of the vertical reflections of the building. At last, the lowest cooling load is calculated in Case 1, with the data measured at the reference station far from the building. The value is 15% lower than Case 3.

The results show the significant impact of the microclimate on the energy demand, which is strongly affected by the amount of solar radiation reaching the building surface. They are in agreement with other studies in the literature, that have shown the impact of the microclimate on the energy demand such as [15], [16] and [17].

5. Conclusion

The impact of a reflective glass building on its outdoor and indoor environment is investigated in the city of Algiers, Algeria. The outdoor environment has been studied experimentally and numerically. A weather micro-station has been installed on the building's roof, and thermograms have been recorded to measure the surface temperature of the building. Some weather data measured by a mobile thermo-hygrometer allow the computing of the microclimate surrounding the building with the software ENVI-met. It is found that the high surface temperatures of the building increase the nearby air temperature. The computed air temperatures around the building are higher than the measures performed on the roof, followed by the ones from the city weather station at the airport. Both the experimental measures (through the thermograms), and the ENVI-met computed microclimate with ENVI-met, show that the air temperature decreases with the building height. This is due to the dihedral effect that occurs on the ground, between the hot asphalt and the low levels of the building.

The cooling load of the building has been calculated with the software Ecotect, with the three weather files. The cooling load calculated with the computed microclimate is 8% higher than the one calculated with the measured data from the roof, and 15% higher than the one calculated with the city weather station. When it is not considered, the urban heat island effect leads to an important underestimation of the cooling demand.

Even if reflective glass façades are conceived to decrease the entering solar radiation, in hot climates such in Algeria, they tend to notably increase the surrounding air temperature. That ultimately increases the building cooling load, in addition to causing outdoor visual glare.

Use of reflective glass with high reflectance is found to have a serious thermal impact by increasing the external air temperature and the energy cooling load. To evaluate this cooling load, calculation of the accurate microclimate around the building seems to be necessary. Future work will conduct a sensitivity analysis to take into account all the impacting parameters such as the thermal and optical properties of the glass, the district configuration and the orientation, on the energy demand of the building.

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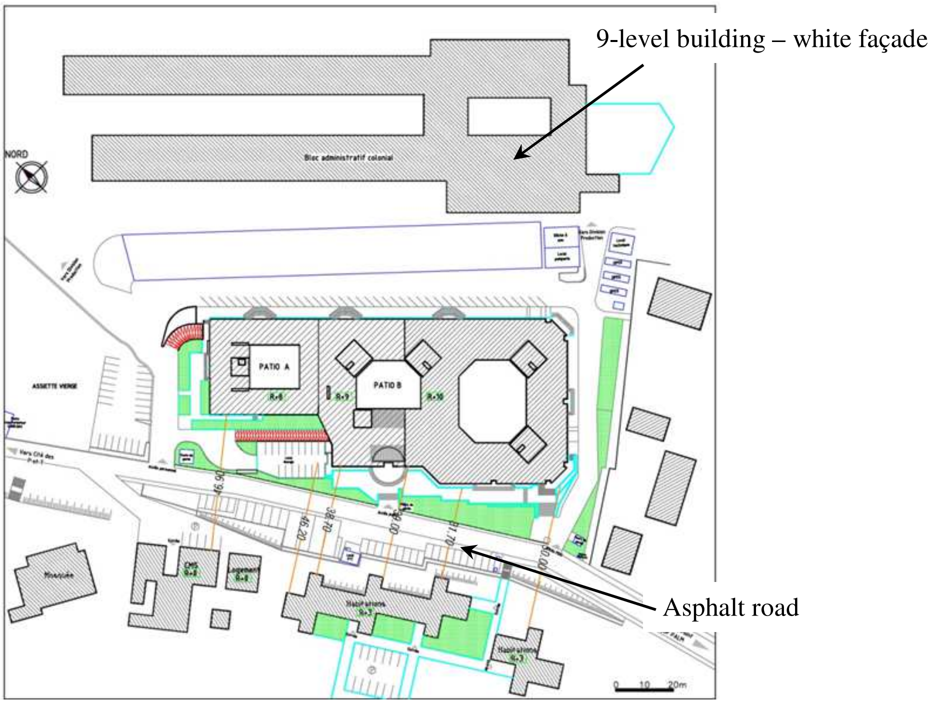

Figure 1. Ground plane of the building and its surroundings

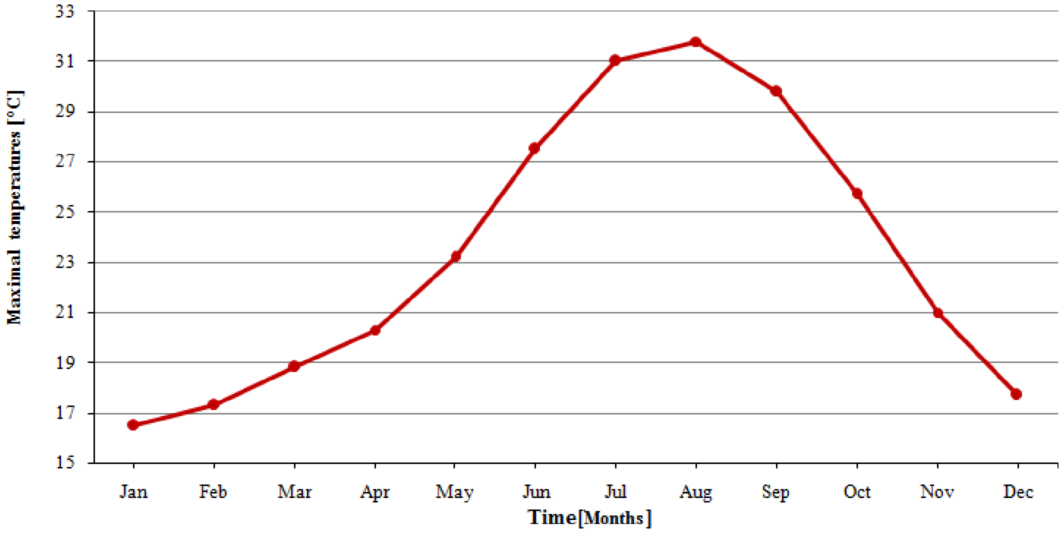

Figure 2. Monthly maximal temperatures averaged over 29 years from 1981 to 2010 (from [25])

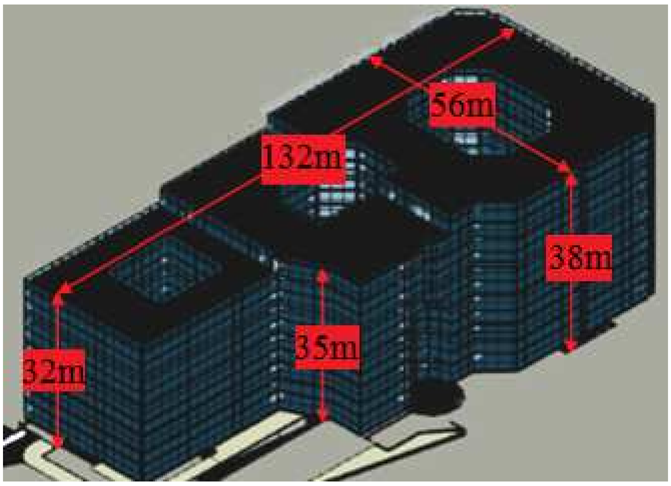

Figure 3. Representation and dimensions of the case study building

Figure 4. The case study building from the outside (above) and the inside (below)

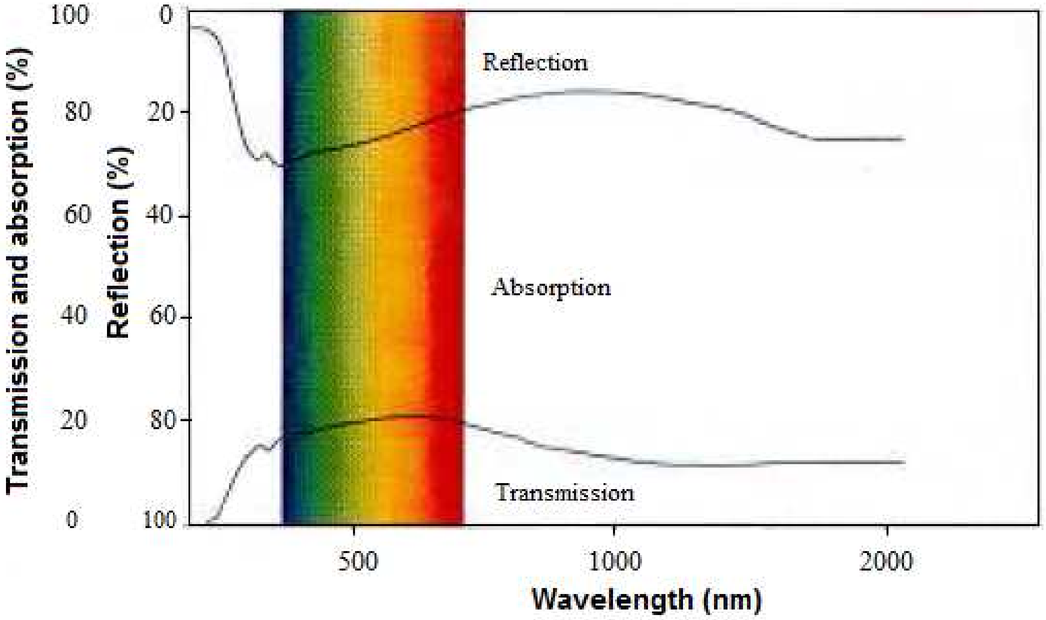

Figure 5. Properties of the reflective blue glass (from [2])

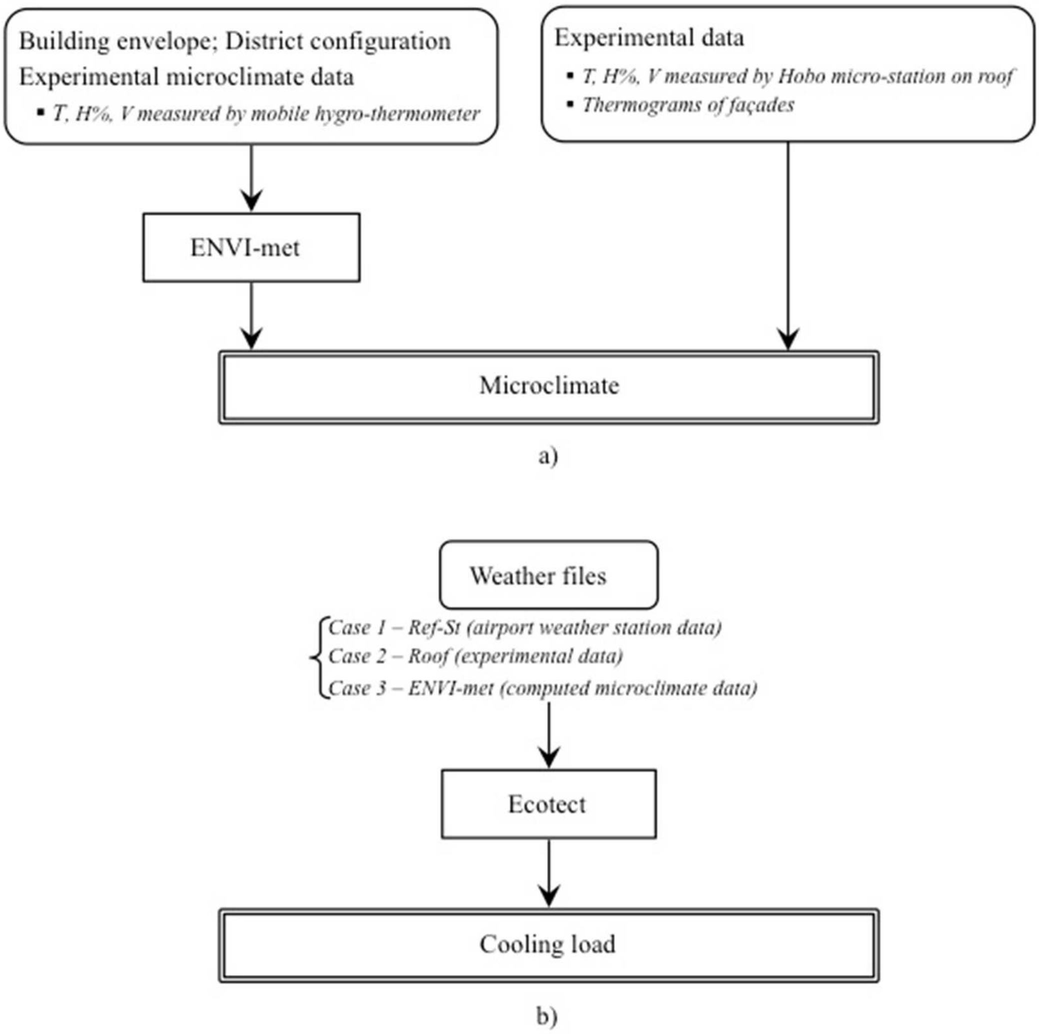

Figure 6. Methodology for the study of a) the microclimate and b) the cooling load

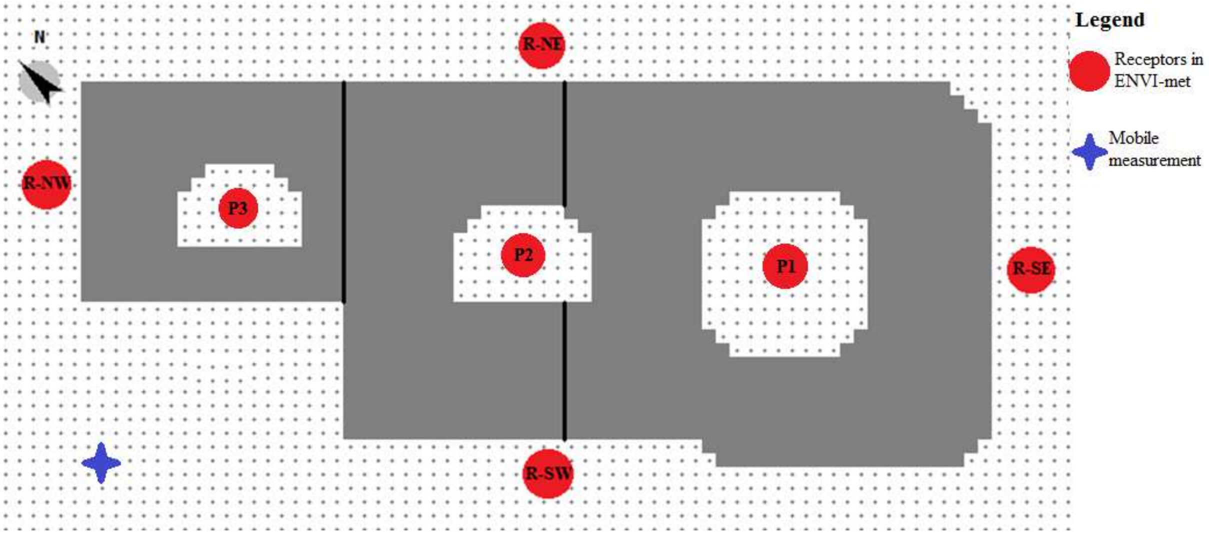

Figure 7. Horizontal positions of the 7 receptors in ENVI-met simulations and the mobile measurement

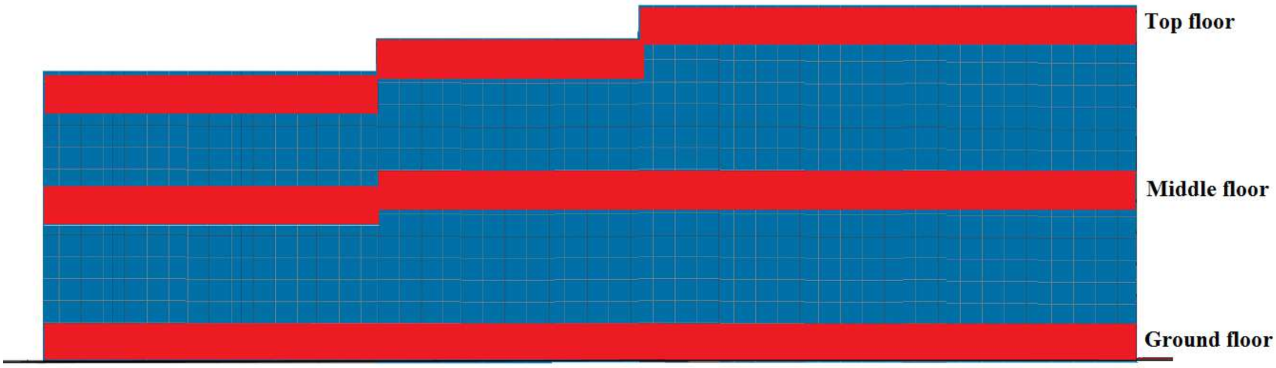

Figure 8. Vertical section showing the three levels considered for the cooling load calculation

Figure 9. Thermal zones under consideration for the calculation of the cooling load

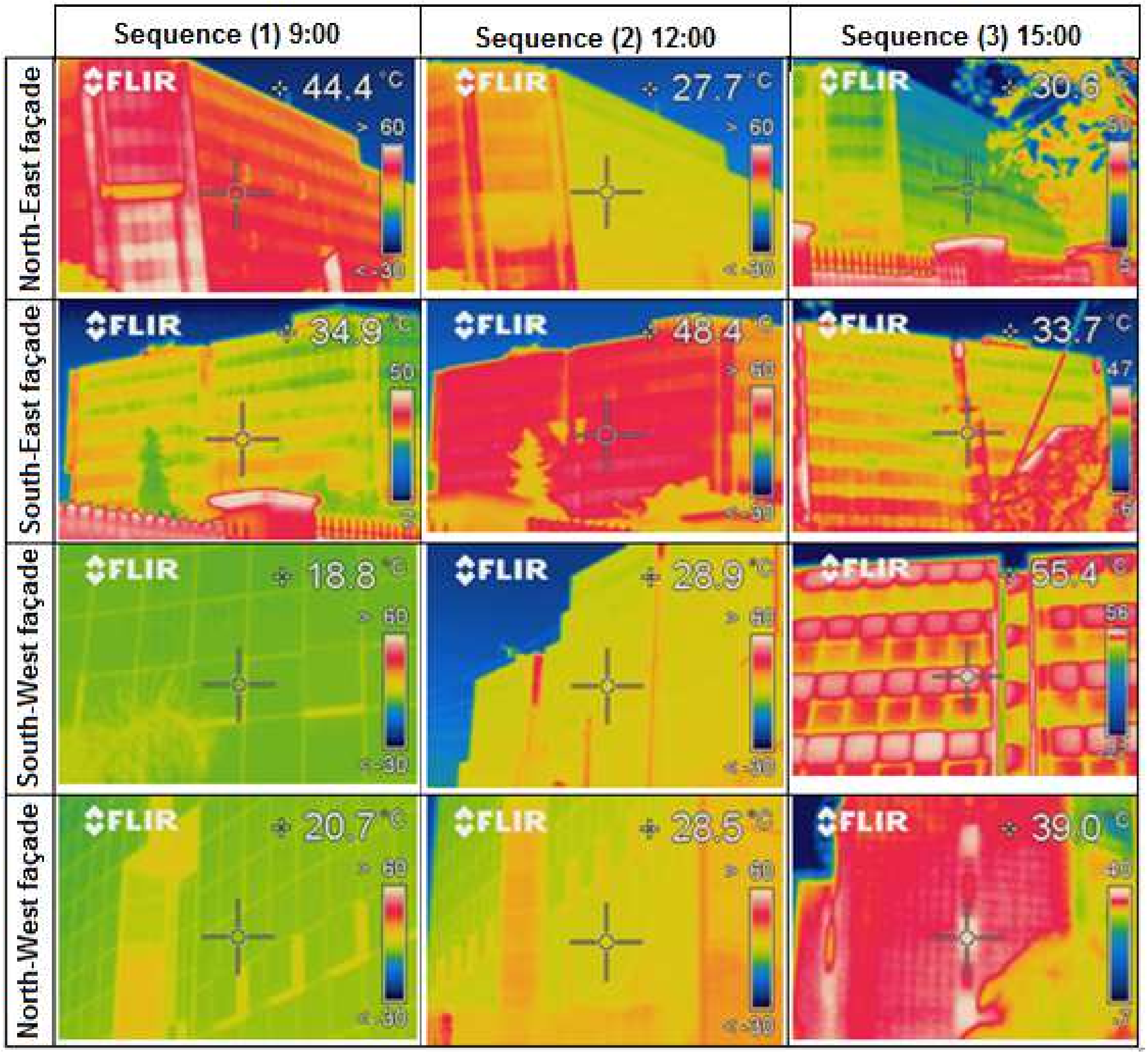

Figure 10. Experimental façades temperatures

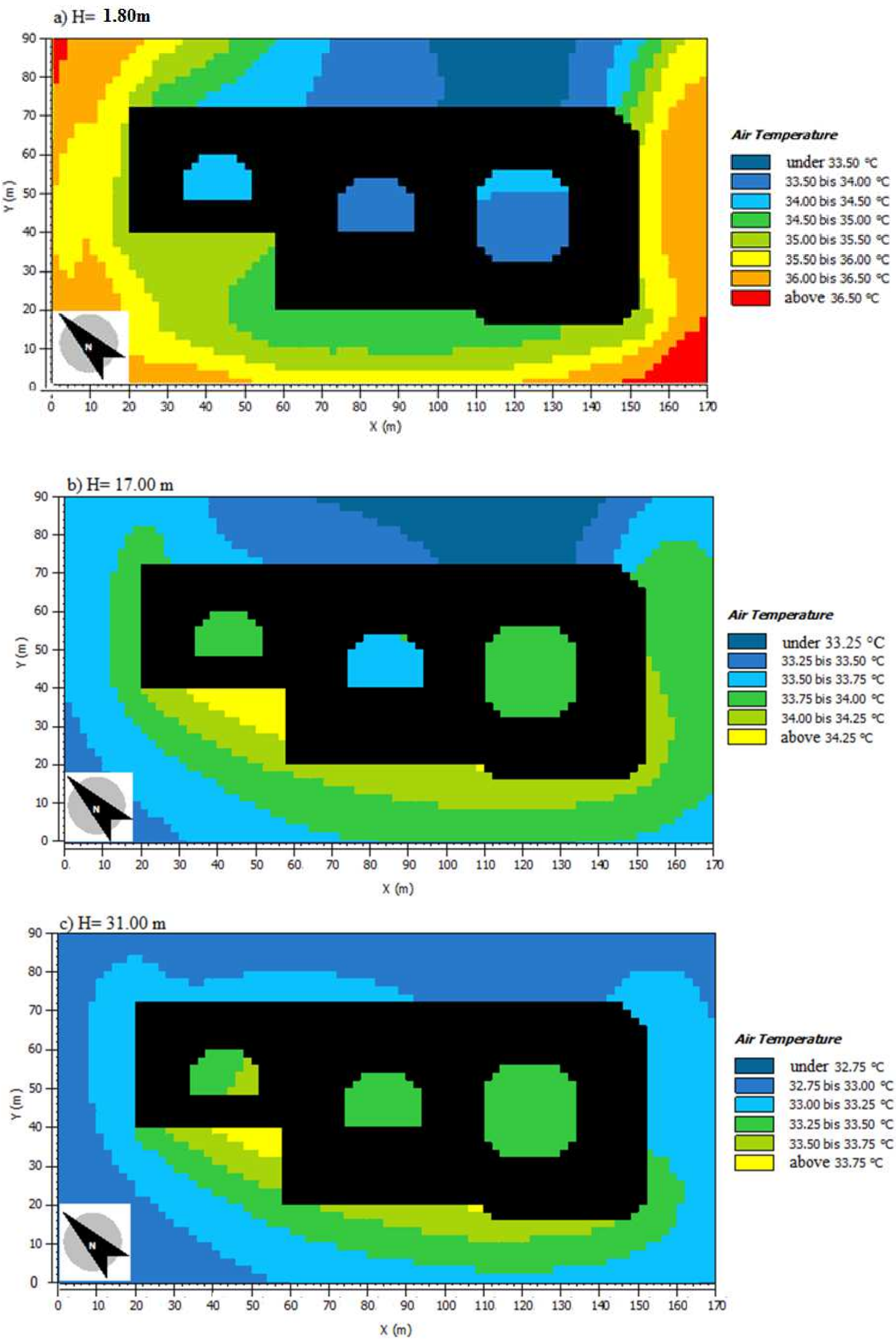

Figure 11. Air temperatures around the building for the three levels at 15:00

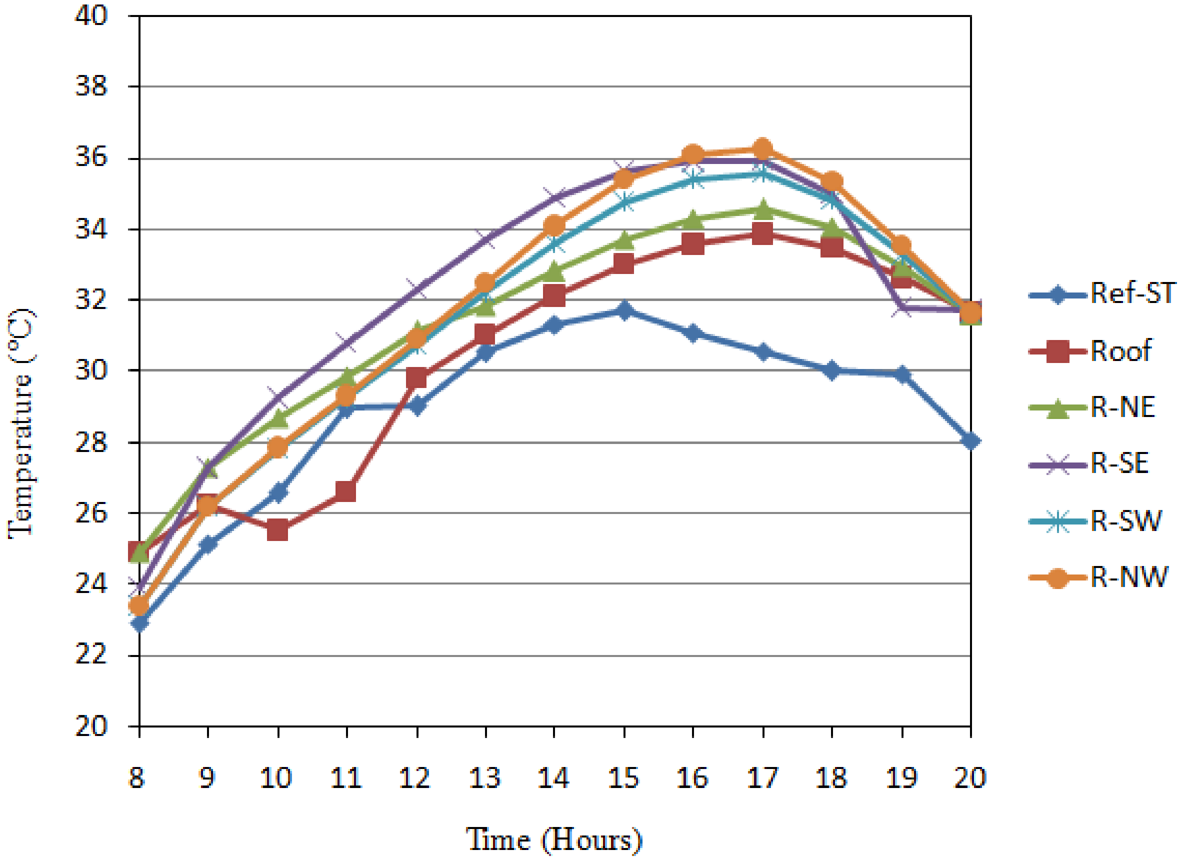

Figure 12. Measured air temperatures at Roof and Ref-St and computed ones at H=1.80 m

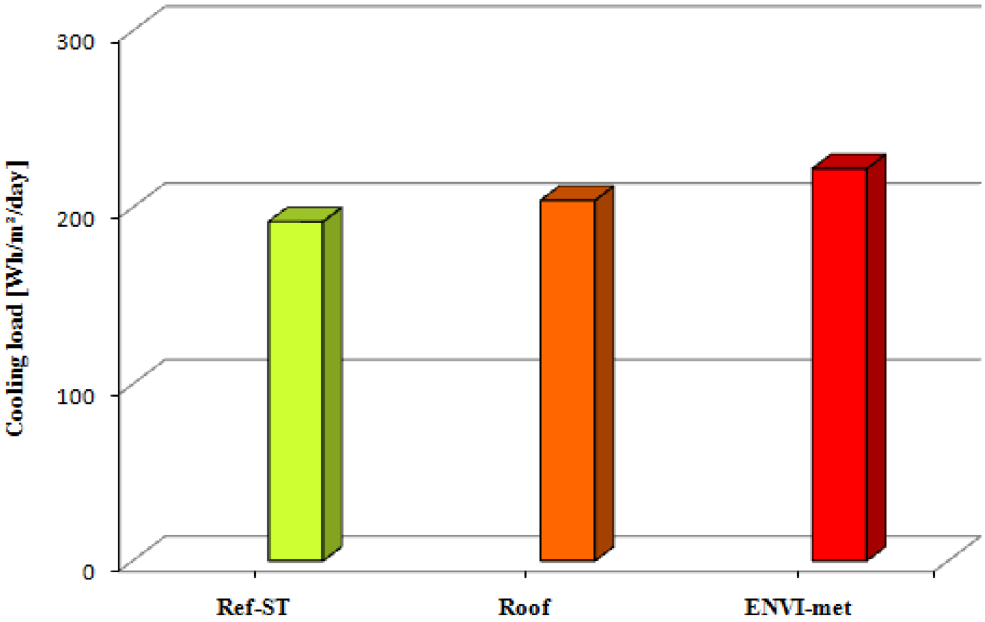

Figure 13. Cooling load for Case 1, Case 2, and Case 3 during the observed summer day

Table 1. Characteristics of the sensors used during the measurement campaign

Instruments	Type of measures and uncertainties	Illustrations
HOBO micro-station	▪ Temperature, relative humidity and air velocity on the roof ▪ Temperature uncertainty ±0.2ºC, relative humidity uncertainty ±3%, air velocity uncertainty ±3%	
Hygro-thermometer Testo 635	▪ Temperature, relative humidity and air velocity at 2 m from the ground ▪ Temperature uncertainty ±0.5ºC, relative humidity uncertainty ±3%, air velocity uncertainty is ±5%	
Thermograph ThermaCAM® B2	▪ Thermograms of the façades ▪ Measurement uncertainty ±0.5ºC	

Table 2. Settings of ENVI-met simulations

Domain	120 m x 170 m x 60 m
Meshes and size	60 x 85 x 30 ($dx = dy = dz = 2$ m)
Day of the study	2 August
Start time	7:00
Weather data input	Actual measurements on site (cf. Figure 7)
Initial variables	Specific humidity 5.40 g water/ kg air at 2500 m Air temperature 28°C Relative humidity 47 % at 2 m Wind direction NE Wind speed 1 m/s
Building envelope	Double glazing panel: Thickness 6+12+6 mm, albedo 0.32 Roof: Thickness 25 cm, albedo 0.15

Table 3. Difference in air temperature profiles according to the two tested meshes

Hour	Height (m)	Air temperatures (°C)		ΔT
		Actual mesh	Tight mesh	
08:00	1.4	23.4	23.0	0.4
	17	24.1	23.7	0.4
	31	24.5	24.1	0.4
09:00	1.4	26.2	25.8	0.4
	17	26.2	25.8	0.4
	31	26.1	25.7	0.4
10:00	1.4	27.8	27.4	0.4
	17	27.7	27.3	0.4
	31	27.5	27.1	0.4
11:00	1.4	29.2	28.8	0.4
	17	28.9	28.5	0.4
	31	28.6	28.2	0.4
12:00	1.4	30.7	30.3	0.5
	17	30.3	29.8	0.5
	31	30.0	29.5	0.4
13:00	1.4	32.2	31.7	0.5
	17	31.7	31.2	0.5
	31	31.3	30.8	0.5
14:00	1.4	33.6	33.1	0.5
	17	33.0	32.5	0.5
	31	32.6	32.1	0.5
15:00	1.4	34.7	34.2	0.5
	17	34.2	33.6	0.5
	31	33.6	33.1	0.5
16:00	1.4	35.4	34.9	0.5
	17	34.8	34.3	0.5
	31	34.3	33.7	0.5

Table 4. Settings of Ecotect simulations

Building description	Office building with seven thermal zones for each of the three levels
Glass characteristics	Visual transmittance = 0.211 Solar transmittance = 0.391 Solar reflectivity = 0.320 Absorption = 0.380 *U*-value = 2.49 $W.m^2.K^{-1}$ Thickness = 6+12+6 mm
Day of the study	2 August
Occupation period	08:00-20:00
Cooling	Set ON if operative temperature $T_{op} \geq 26$°C during occupation period
Ventilation rates	Air speed not noticeable 0.1 m/s Infiltration rate: 0.1 vol/hr Air change rate: 10 vol/hr
Internal gains	Latent gains: 4 Persons/zone and 90 W/Person Sensible gains: 240 W
Lighting level	Office desk 400 lux
Clothing	Light business suit 1 clo