Taking into account climate change adaptation in urban area through the CFD FLUENT simulation model example: an urban sector of the ORAN agglomeration

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Abstract. Large cities cause microclimatic changes, the largest of which is known as the urban Heat Island Effect .The acceleration of urban development has caused variations in microclimatic conditions. Urban geometry and human activities in the urban environment interact with microclimatic parameters (wind speed and direction, air and surface temperature, solar radiation), also transforming the climate of our cities. It is for us to study the impact of climate change on urban environments and to understand the consequences of geometric and morphological factors on microclimatic conditions at the city scale, using tools called Computational Fluid Dynamics (CFD) model, we will try to show how urban geometry, in all its states interacts with microclimatic parameters (solar radiation, wind flows, air and surface temperature). Applied to the agglomeration of ORAN / ALGERIA on an existing urban sector (district HLM),we will try to show the strong correlation between failures and errors of urban design and the increase and generalization of Heat Island Effect in urban area.

1. Introduction

Actually, the debate on climate change has focused on all its physical aspects [1]. However, the effects of climate are felt by both populations and their living spaces [2].The large agglomerations of today are designated as environments conducive to the development of several microclimatic problems [3]. Urban development, which is accelerating more and more in its last decades under the process of metropolization, leads to the modification of microclimatic conditions [4].Climate change is now an issue and a challenge for climatologists, developers, architects and producers of urban environments that are increasingly adapted to the new climate[5]. We have adopted this topic, which consists in questioning the relationship between the urban form and various climatic parameters of the urban climate. The urban geometry of urban morphology as well as human activities in the urban environment interact with microclimatic parameters (solar radiation, wind flow, air and surface temperature), thus modifying the climate of our cities [6].

2. Methodology

The present research aims to study the relationship between urban morphology and microclimatic elements inscribed in a problem of adaptation of cities to climate change. To do this, we opted for an agglomeration: ORAN/ALGERIA. The observation of the phenomenon will take place on a portion of the urban space of ORAN agglomeration. It is in an existing neighborhood: HLM.

To answer our previously described problematic, we have used the simulation model CFD FLUENT to estimate the influence of certain meteorological elements (wind flow, temperature, and solar radiation) in urban area. CFD (Computational Fluid Dynamics) is a software used to simulate all fluid flows, compressible or incompressible, it is based on the method of finite volumes. CFD FLUENT is composed of three elements: The GAMBIT pre-processor is a 2D / 3D mesh maker that allows us to mesh the geometry domain. It generates msh*files for FLUENT. The FLUENT post processor allows us to solve and simulate fluid mechanics and heat transfer problems using the finite volume method. We have followed in the GAMBIT software the following steps: we have started by defining the geometry of the problem, then we realized the mesh and we checked it, in the end we defined the boundary conditions and definitions of the computational domains .The visualization of the results was realized by the postprocessor "FLUENT". [7]

3. Results

The simulation was carried out using the FLUENT software belonging to the CFD (Computational Fluid Dynamics) group, which is part of the eulerian numerical models [7]. In this section we have tried to show the importance of this tool for numerical modeling, particularly the results obtained in the area of building design and urban planning. Applied to these, the model requires taking into account local climate data.In our case, the basic climatological data are generally measured in the meteorological station of the IHFR stations (Hydrometeorological Training and Research Institute) and ONM (National Office of Meteorology) of ORAN**.**

3.1 Application of FLUENT software to Oran urban space

In this work, using this simulation model, it is for us to try to apply it to on a portion of the existing urban space HLM neighborhood Gambetta that is characterized by high densities and urban spreading to place ORAN among the most important cities in Algeria. It was chosen for its proximity to the IHFR so that the climatological data of the station are the closest to reality.

Figure 1: Satellite photography of the HLM city (Source: Google Earth-2014)

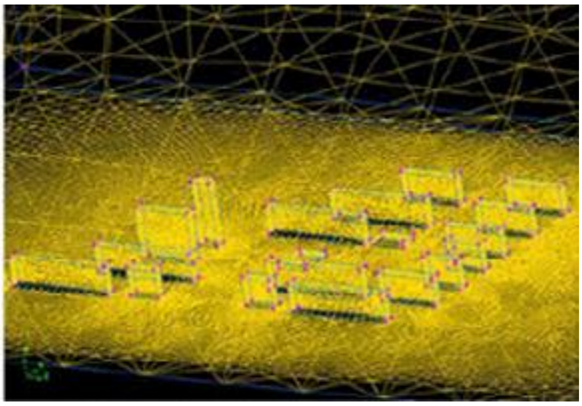

Figure 2: representation of the geometric design by GAMBIT 2.4 of the HLM district (ORAN) in3D

3.2 The effect of the wind

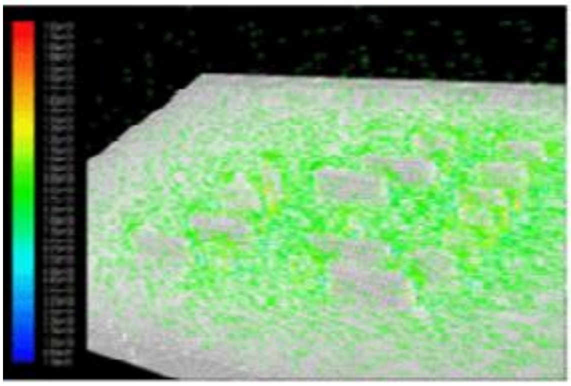

Figure 3: Illustration of the 3D velocity field with their mesh

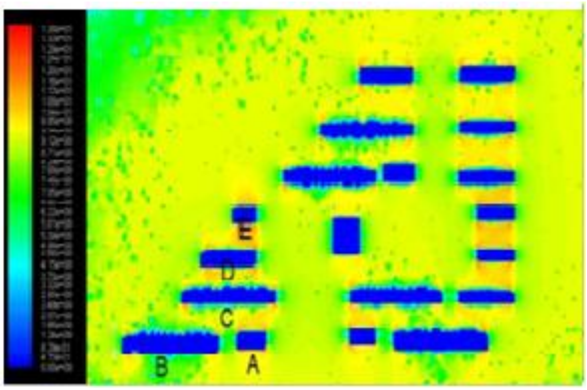

Figure 4: Wind contour ($m.s^{-1}$) at z = 3m

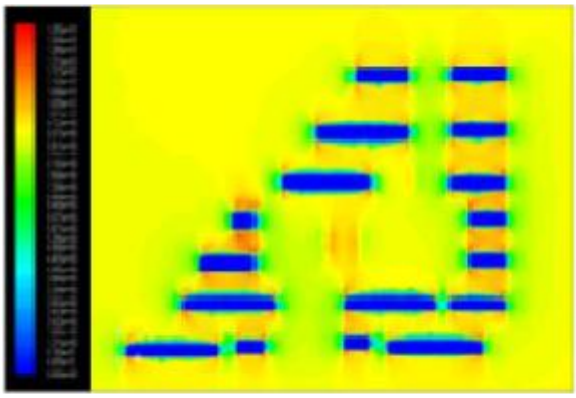

Figure 5: Wind contour ($m.s^{-1}$) at z = 10m

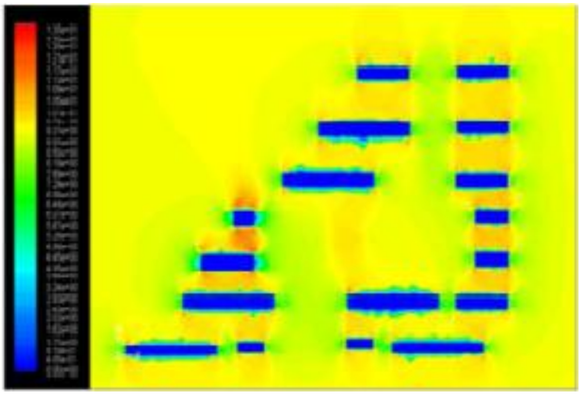

Figure 6: Wind contour ($m .s^{-1}$) at z = 20m

3.3 The effect of temperature

3.3.1. In winter

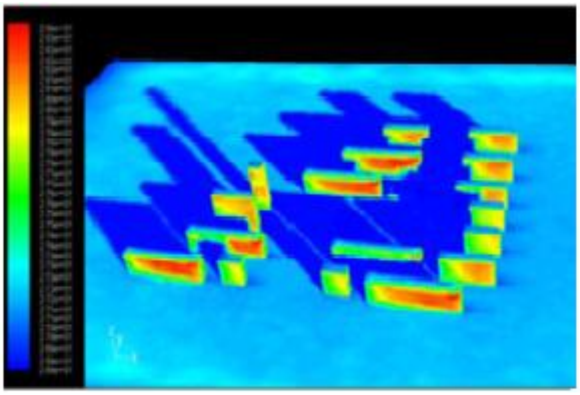

Figure 7: Static temperature contour (° C) for the 21/12/2014 at 09:00

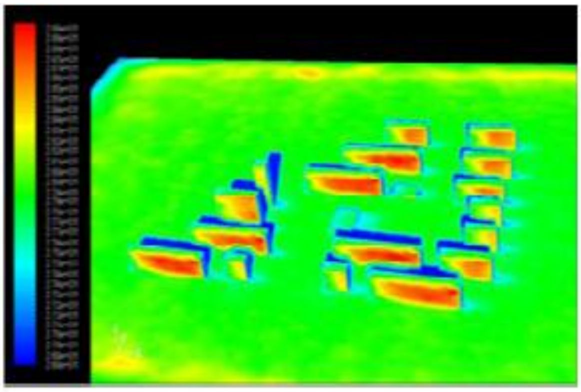

Figure 8: Static temperature contour (° C) for the 21/12/2014 at 12:00

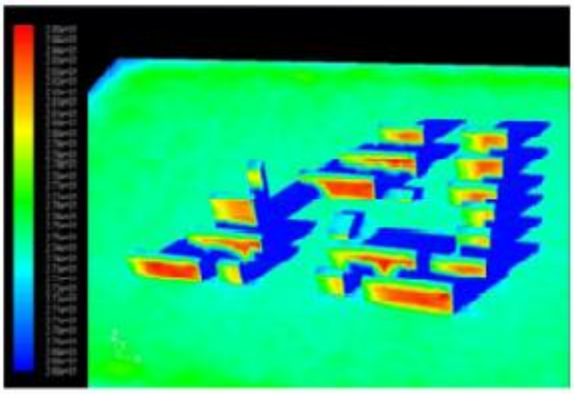

Figure 9: Static temperature contour (°C) for the 21/12/2014 at 16:00

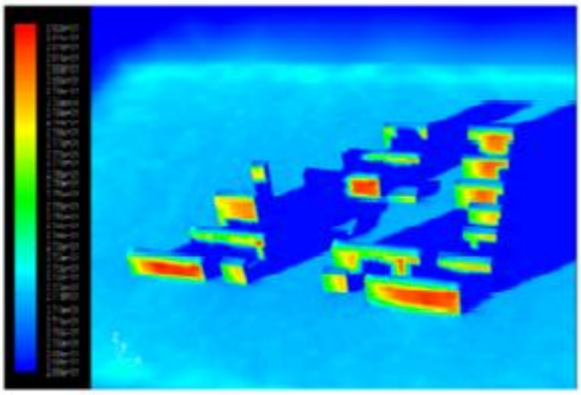

Figure 10: Static temperature contour for the 21/12/2014 à17:00

3.3.2. In summer

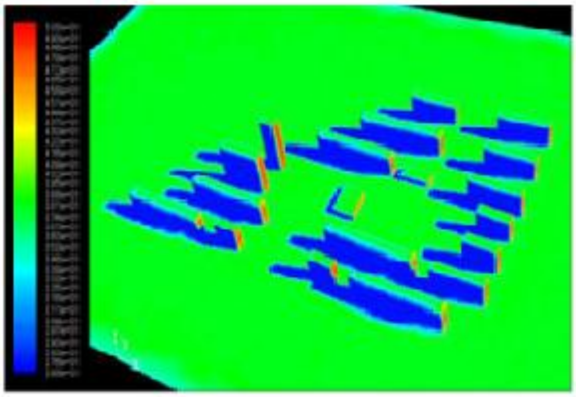

Figure 11: Static temperature contour (°C) for the 06/21/2014 at 08:00

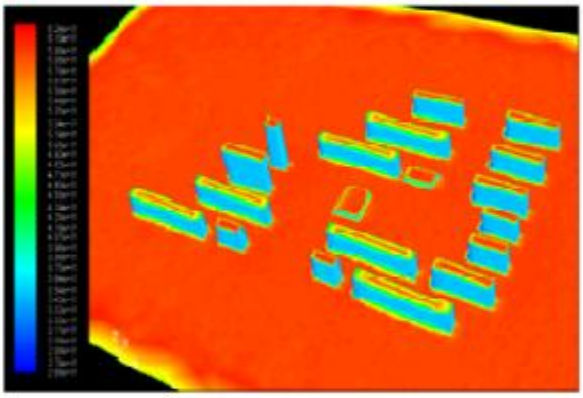

Figure 12: Static temperature contour (°C) for the 06/21/2014 at12:00

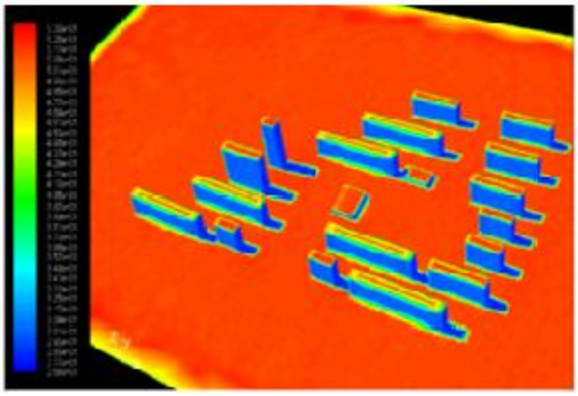

Figure 13: Static temperature contour (°C) for the 06/21/2014 at 16:00

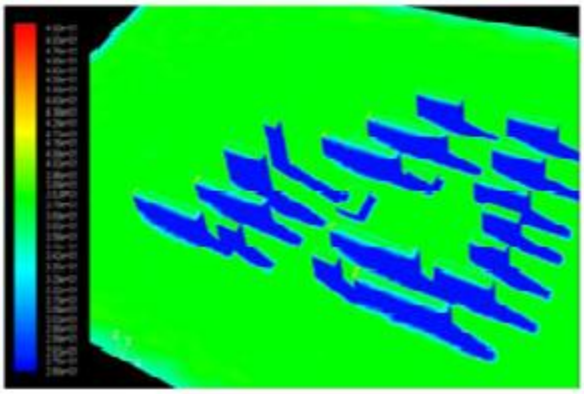

Figure 14: Static temperature contour (°C) for the 06/21/2014 at 18:00

3.4 The solar radiation effect

3.4.1. In winter

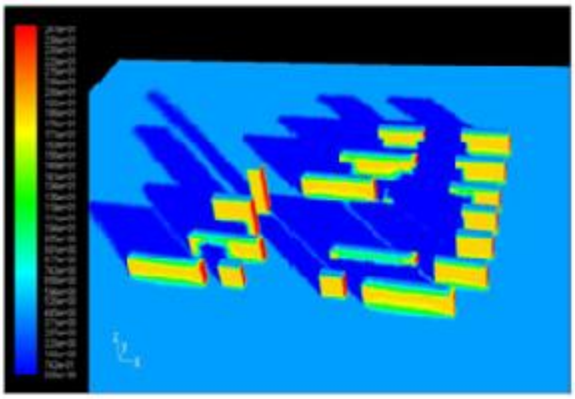

Figure 15: Solar Flux Contour (w.m^{-2}) for the 12/21/2014 at 09:00

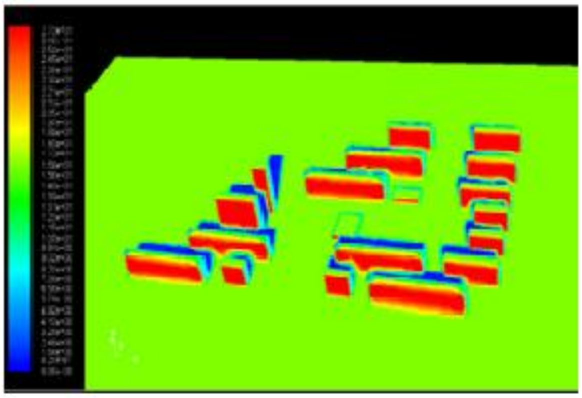

Figure 16: Solar Flux Contour (w.m^{-2}) for the 12/21/2014 at 12:00

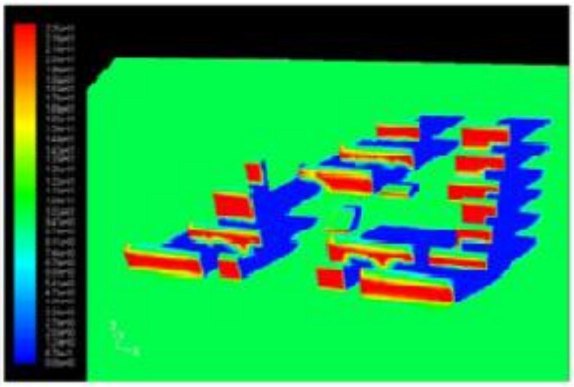

Figure 17: Solar Flux Contour (w.m^{-2}) for the 12/21/2014 at 16:00

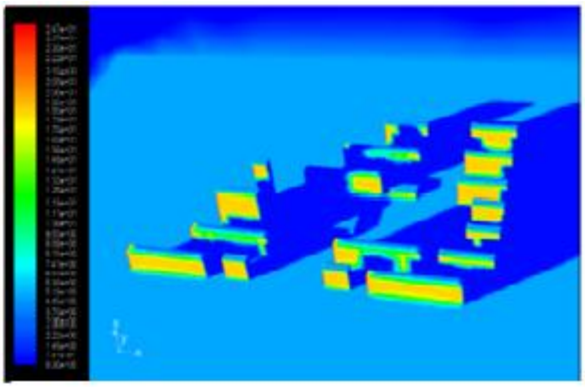

Figure 18: Solar Flux Contour (W.m^{-2}) for the 21/12/2014 at 17:00

3.4.2. In summer

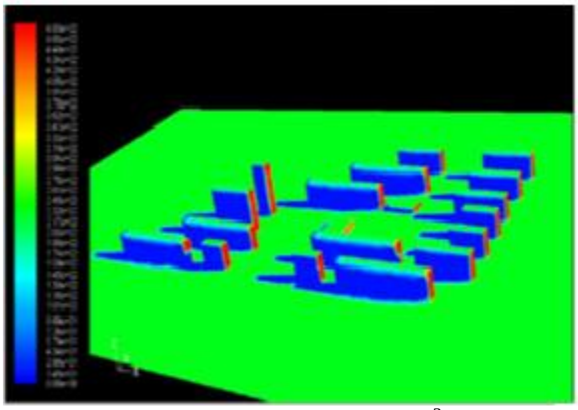

Figure 19: Solar Flux Contour (w.m^{-2}) for the 06/21/2014 at 08:00

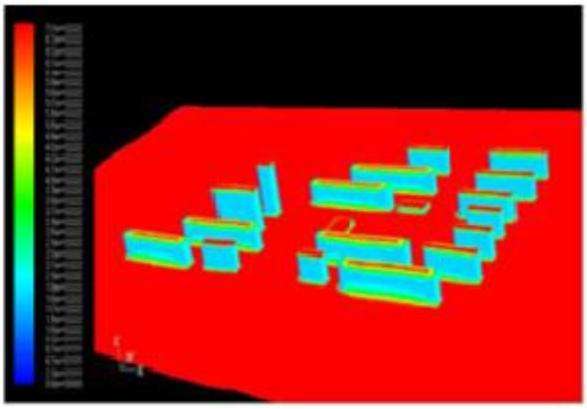

Figure 20: Solar Flux Contour (w.m^{-2}) for the 06/21/2014 at 12:00

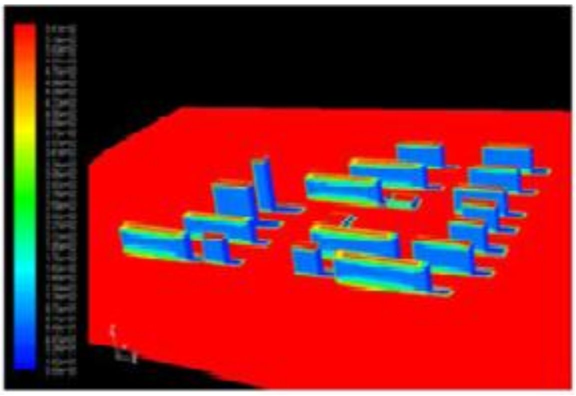

Figure 21: Solar Flux Contour (w.m^{-2}) for the 06/21/2014 at 16:00

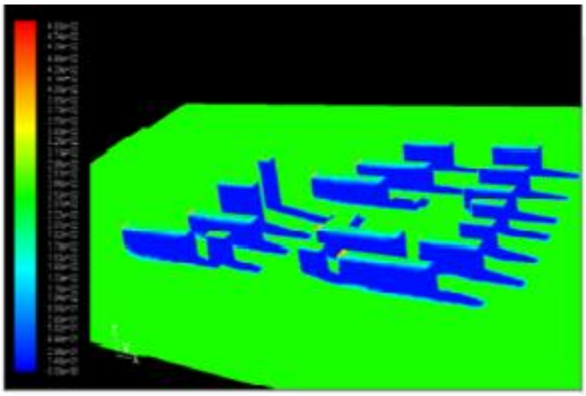

Figure 22: Solar Flux Contour (w.m^{-2}) for the 21/06/2014 at 18:00

4. Discussion

In our work we have chosen to use CFD simulation model for the parametric study of air movements around buildings. The Figure 1 represents the location of the neighborhood studied HLM ORAN, obtained by Google Earth, in Figure 2, we represent the 3 D geometry of the HLM city by Gambit 2.4.The figure 3 illustrates the speed field and their mesh in 3 D.

The Figures 4, 5, 6 show the results of our simulation carried out using the FLUENT software of the wind flow around buildings raised to different levels (Z = 3m, Z = 10m, Z = 20m) in the middle of the district HLM.The series of air speeds are presented in blue (very low speeds) and in red (very high speeds).

It can be concluded that in Figures 4, 5, 6 : between buildings D and E (these two buildings are on the left in the figures), we notice relatively high wind speeds, there is a circulation of air in this area which implies the presence of the canyon effect [8] , in our example (the height of buildings D = 45m, E = 36m, the width of the street = 18m, the ratio H / W = 2.5),it has a positive effect in the summer and it can refresh the street.

The Figures 7, 8, 9, 10 show the results of simulation for the winter season for the day of December 21st, 2014, expressing the static temperature contour on the HLM district at 9h, 12h, 16h and 17h.

The x-axis; represents the direction East. The y-axis; shows the direction North .The highest values are in red, the lowest values in blue.

At 9h, the temperature of East walls being high, at 12h, the South walls of the buildings are warmer because the position of the sun is in front of these walls, at 16h and17h, we notice the increase of the shade of the buildings because of the decrease of the solar height which has repercussions on the decrease of the temperature of the district.

In conclusion: the orientation of the buildings shows that, in winter, the South and West facing walls remain warmer than those oriented towards the North.

The Figures 11,12,13,14 show the results of our simulation for the summer season for the day of June 21st ,2014 ,expressing the static temperature contour (° C) on the district HLM at 8h, 12h,16h and 18h.we find that: at 8h, the temperature of the East walls is higher than the West due to the sun. From 12h to 16h, the temperature of the walls, terraces and the surface of the soil are very high in this period because the duration of sunshine is long and the height of the sun is maximum. At 18h, it is the West walls that are warm.

The Figures 15,16,17,18 represent the results of our simulation for the winter season for the day of December 21st, 2014 expressing the variation of solar radiation on the HLM district at 9h, 12h, 16h, and 17h. We note that: at 9h the facades exposed to the East receive more solar energy. At 12h, the facades exposed to the South are those that capture the most solar energy, at 16h and 17h, the West facing façades receive the maximum of solar energy. The buildings A, B form a solar mask for buildings C and D they prevent solar radiation from reaching other surfaces, so it is difficult to capture solar radiation in these spaces because of shading created by buildings who are neighbors.

The Figures 19,20,21,22 show the results of our simulation for the summer season for the day of June 21st,2014 explaining the evolution of solar radiation on the district HLM at 8h, 12h, 16h and 18 h According to the results, we find that: The simulations carried out at 8h show that the facades exposed to the East receive a large amount of solar energy, at 12h and 16h the terrace of the buildings are the areas where the energy collected is very high, at 18h the facades exposed to the West receive more energy.

In conclusion; the buildings that mask the sun are generally considered unpleasant because they bring a little shading in summer but become a real obstacles to sunshine in winter. So during the winter season the most favorable direction in the morning is the **South** because it allows to take advantage of solar energy and at night it is the **West** direction that it also allows to take advantage of solar energy and therefore reducing the use of heaters with low temperatures. In summer, the West direction allows to take advantage of the natural ventilation (West wind) during the day where (the temperatures are high) and subsequently the reduction of use of air conditioners. Given these elements, it appears that the **South-West** direction would have better suited to the city of HLM instead of the **North-South** direction that was favored during the design of the city.

5. Conclusion

The results we present, from the CFD FLUENT simulation model make it possible to provide elements of response to architects and urban planners in the design phase of an urban project. FLUENT presented itself as a simplified general code, essential for intensive use in urban design.

This code is part of the movement of works executed in thermal building. In this study, we wanted to illustrate the thermal behaviour of an urban space in the face of radiative and dynamic demands. We have highlighted the creation of a microclimate specific to the urban system, the surface temperature field being a function of the characteristics of the outside climate, but also of the configuration of the studied system.

The simulation relating to the air temperature made it possible to illustrate the phenomenon of Heat Island generated by a set of buildings. We have highlighted significant temperature differences between the system and the external environment. The FLUENT software allows by its modular and multi-model composition, the progression of the mathematical models proposed. However, additional research is needed to experimentally validate this calculation code.

6. References

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