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Microclimate effect on the indoor thermal comfort in a building

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Abstract : In 2014, 60% of the Moroccan population lives in cities and this proportion is constantly increasing. The high population density and activity results in higher energy use for cooling and heating buildings. Also high urban density and different urban shapes result in different microclimates which are in general hotter in urban areas than sub-urban ones which is known as the urban heat island phenomenon (UHI). Hence, the way cities are planned and built is important for reducing the building energy consumption. Nevertheless, current building energy simulation tools do not take into account the influence of the surrounding urban microclimate on the energy consumption of buildings. Our aim in this paper is to understand the effect of microclimate on thermal comfort by investigating the interactions between the existing climate and the urban form. This study aims to quantify the impact of the microclimate on the indoor temperature based on the wind direction and the aspect ratio of the urban canyon by using ENVI-met V4.1.0 and TRNSys 17.

Key-words : cooling buildings, energy use, urban heat island building energy simulation, microclimate, urban form, urban canyon.

1. Introduction

Building energy consumption represents the largest share of the overall energy bill and could still grow due to the continuing increase of population and the increase of users requirements to maintain their comfort. Globally, more people live in urban areas than in rural areas, with 54% of the world's population residing in urban areas in 2014[1]. Powerful building energy simulation tools (BES) based on the dynamic thermal simulation are used to predict space cooling and heating demands for buildings. They allow simulating, with great precision, the thermal behavior of the buildings and thus to suggest to best solutions and requirements to save energy and be more efficient. Moreover, to assess the energy performance of buildings with the building energy simulation tools, we use the reference weather data or data from the nearest weather station that can be locally very different from real weather data.
However, the building energy performance is not only affected by its construction, but depends primarily on the outside conditions as well as the energy fluxes with the surrounding environmental conditions. Indeed, the climate in large cities, the associated urban densification encourages the development of the urban heat island phenomenon (UHI). The intensity of the heat island is mainly determined by the thermal balance of the urban region and can result in up 10 degrees of temperature difference.

Many works treat UHI effects and identify as responsible for a significant change in the local energy balance resulting in the change of outdoor space in comfortable conditions and the increase in consumption of buildings [2].

Comparisons were made between changes in external air temperature and that of domestic energy consumption and showed that the electrical power of air conditioning increases by nearly 540 MW gap degree of ambient temperature [4].

In addition, mitigation of urban heat islands can potentially reduce energy consumption in national air conditioning by 20% and save more than $ 10B annually and improve the quality of urban air [5].

[Santamouris et al, 2001] showed that the UHI in Athens doubled the air conditioning load and triple the peak electricity demand by reducing 25% of the COP of air conditioning materials [2].

The reduction of the wind speed by the presence of buildings, the aspect ratio of the street canyons, the decrease of the evaporative cooling effect of water surfaces and green areas less present then the storage of solar radiation by the absorbing surface coatings such as asphalt or concrete, anthropogenic flow corresponding to the sum of the heat production of motor vehicles, buildings, industries and urban facilities, contribute significantly to the intensification of the urban heat island [3].

Therefore, the structure of a city, its shape and orientation are decisive factors in relation to its energy consumption. In particular, each climatic region requires a separate form and urban configuration helping to cool or heat the buildings.

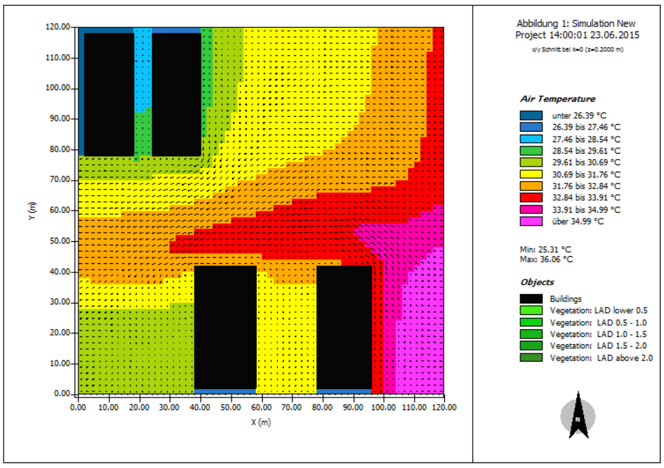


Figure1. Influence of the aspect ratio of the street on the temperature

2. The case study

Fez, with more than one million inhabitants, is the second largest city in Morocco. Fez is situated 33°58'N 04°59'W, at 571 m above sea level in a valley between the Atlas Mountains in the South and the Rif mountains in the North. The climate of Fez is characterised by hot and dry summers and cold winters with rare snow. Seffarine in the Medina is one of the most densely developed areas. Introverted courtyard buildings in two to four stories surround the narrow streets, which cut deep ravines through the city [6].

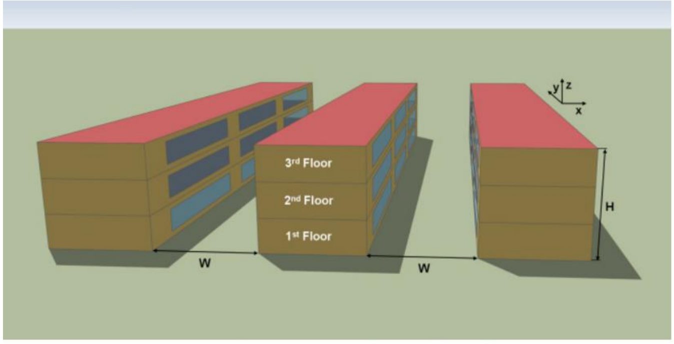
Figure2. Part of the seffarine district

3. Problem

Indeed, urban open spaces in general and the urban street in particular consist on “shared” active facets between the building envelope and the open urban canopy their design affect both outdoor and indoor environments. [7]. Thus, Different urban shapes result in different urban microclimates.
Urban geometry and thermal properties of urban surfaces have been found to be the two main parameters influencing urban climate [8] and [9]. The ratio between the height of buildings (H) and the distance between them (W) influences the amount of both incoming and outgoing radiation and also affects wind speeds.
This study seeks to define relevance of the wind direction parameter in improving the indoor thermal comfort in living areas to be used in guidelines for future housing development in Morocco.

4. Method

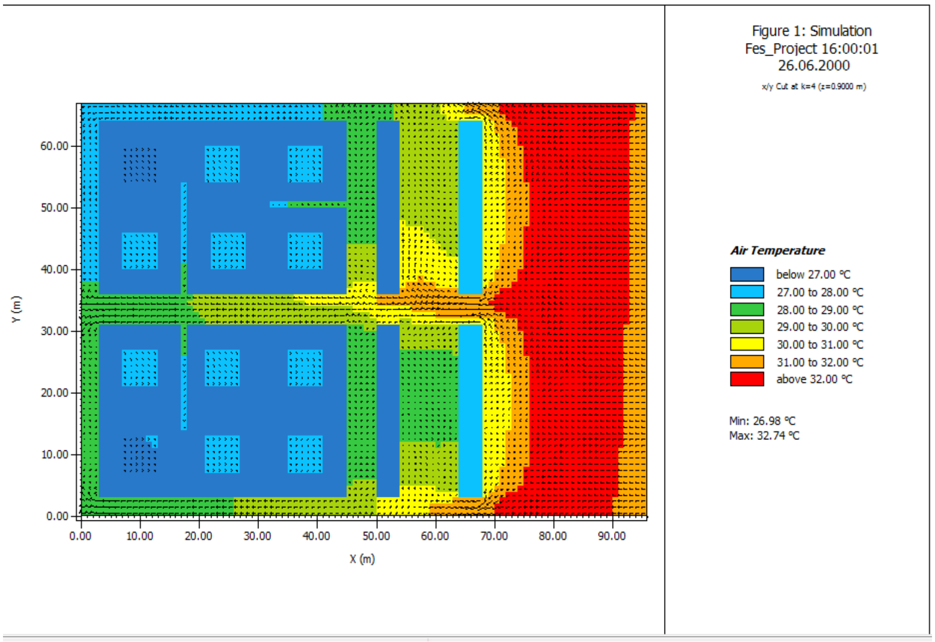
The effect of wind direction on two different types of urban canyons was investigated. The width of the largest one was 8m and 2m for the narrowest one. The directions of the wind taken into account were: 0°, 45°, 90°, 135° and180 °.
As the present study aims to assess the urban microclimate we used the tree-dimensional model ENVI-met numerical simulation. This software is a 3D prognostic microclimate model based on computational fluid dynamics and thermodynamics. The microclimate model designed to simulate the surface-plant-air interactions in urban environment with a typical resolution down to 0.5 m in space and 1- 5 sec in time. Typical areas of application are Architecture, Landscape Architecture, Building Design or Environmental Planning, just to name a few.
The model is capable of simulating: flow around and between buildings, exchange processes of heat and vapor at urban surfaces, turbulence, and exchanges of energy and mass between vegetation and its surroundings. Its input parameters include then weather conditions, initial soil wetness and temperature profiles, structures and physical properties of urban surfaces, and plants and its reliability is certified by different scientific studies. [10-11]
Microclimatic conditions were simulated for selected urban canyons containing main street and local street with different orientations and different height to width (H/W) ratio of the street canyons: 1.6, 3 and 15.



street canyons with aspect ratios of (H/W)

Results

In the contrary,during the afternoon the air temperatures measured in the Seffarine varied greatly between different types of streets and different aspect ratio. Ta (Air temperature) decreases moderately with the increase of the aspect ratio H/W showing a peak difference of 5°C between the canyons.



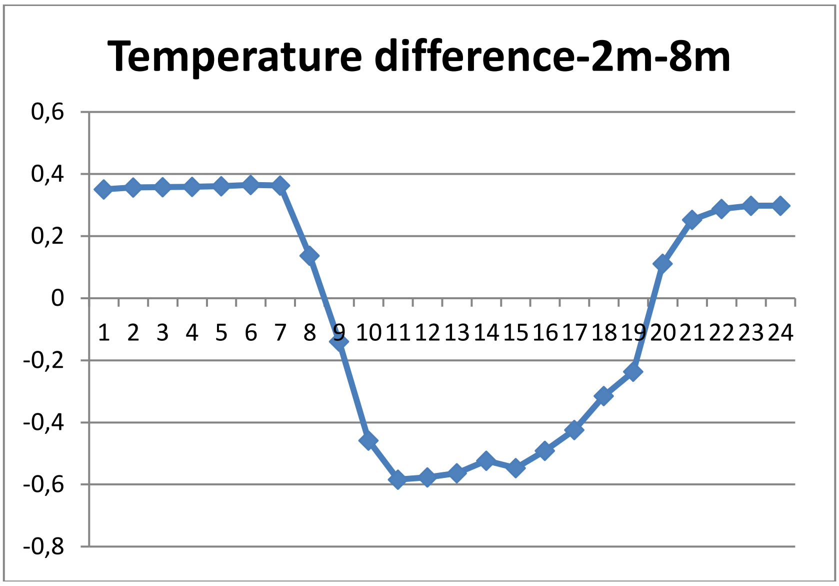


Figure 4: The temperature difference for the Northeast orientation 45° between the two canyons

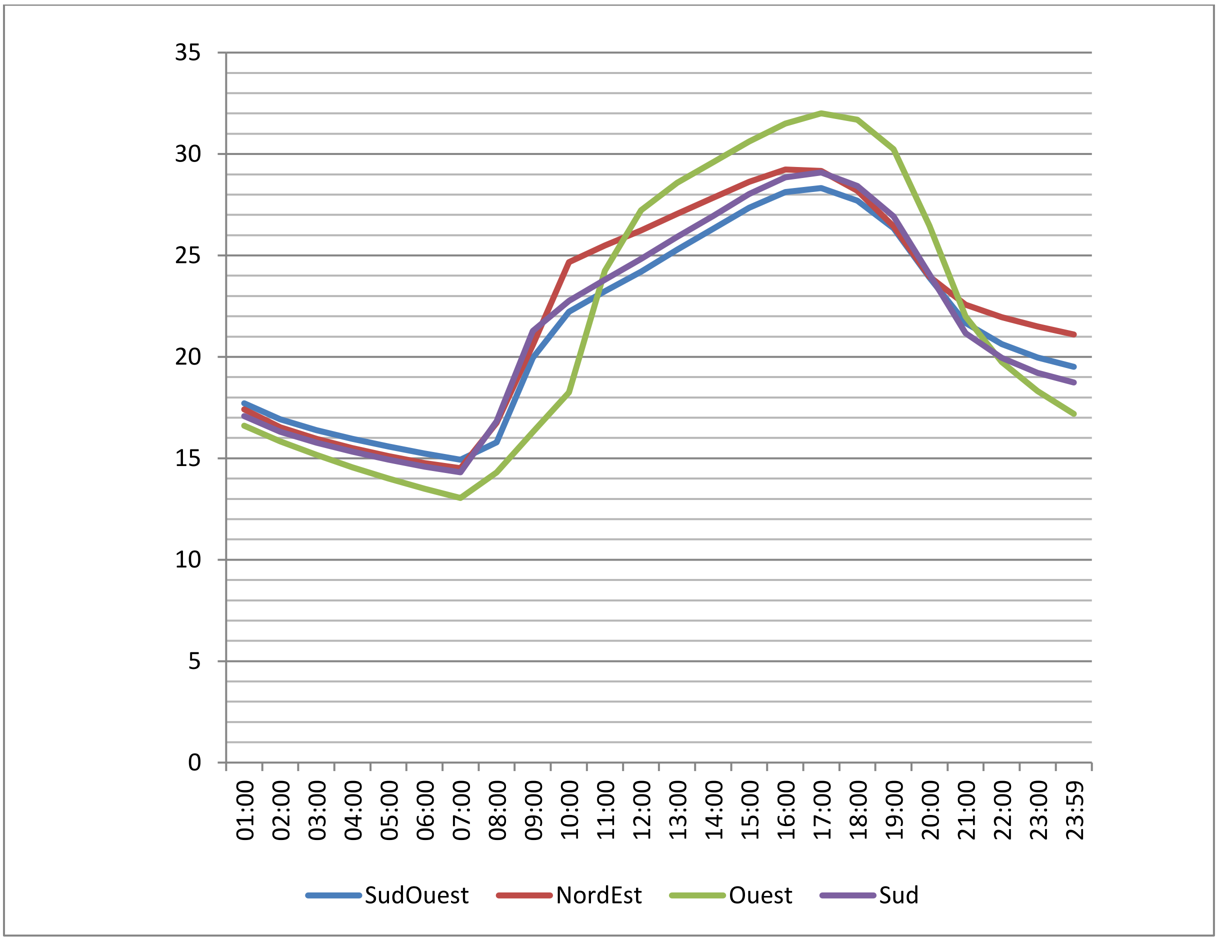


Figure 5: The temperature difference for the different orientations for the largest canyon

5. Conclusion

This study shows that a compact urban form with deep street canyons gives a cooler microclimate during hot summer. A dispersed urban form, on the contrary, created an uncomfortable environment in the summer.

Possible negative effects due to less solar exposure in winter may occur and can make the microclimate cooler. Further investigations are needed in order to promote urban planning and design in hot dry climates that takes microclimate into consideration without creating serious side effects with a compromise between the the summer and the winter.

As urban geometry strongly influences the microclimate in a hot dry climate, therefore, a microclimate created by thoughtful arrangements can be beneficial both for comfort and reduce energy consumption of buildings.

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