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Bioclimatic building design considering urban microclimate

Nicolas Lauzet [1,2]**, Dasaraden Mauree** [3]**, Thibaut Colinart** [2]**, Marjorie Musy** [4]**, Karine Lapray** [1]

[1] TRIBU, Environmental & Sustainable Development consulting agency, 69003 Lyon, France
[2] Univ. Bretagne Sud, UMR CNRS 6027, IRDL, F-56100 Lorient, France
[3] Solar Energy and Building Physics Laboratory, Ecole Polytechnique Fédérale de Lausanne, Lausanne CH-1015, Switzerland
[4] Cerema, Equipe-Projet BPE, F-44000, Nantes, France

Corresponding author: Nicolas Lauzet, lyon@tribu-concevoirdurable.fr

Abstract. The urban context is often simplified or neglected in building energy models (BEM) due to their incapacity to consider accurately all heat fluxes provided from the environment. Simplifying too much the urban context can have consequences on the accuracy of the BEM predictions. Many approaches exist to consider the impact of the urban environment on a building's dynamic behaviour, its heating demand as well as the thermal comfort in summer. Taking into account BEM capabilities and the way consulting agencies work, a method is tested to consider the urban microclimate at the bioclimatic design stage of a building project.

Keywords: Urban Microclimate, Bioclimatic buildings, CitySim, CIM, Building Energy Model

1. Introduction

Global warming, world population growth and migration to cities, are facts that highly impact life in cities. The building sector is one of the key sectors to succeed in this transition. Regulations and labels at national and at local scale urge this transition to a better environmental performance.

As the least impacting energy is the one that has not been consumed, bioclimatic design offers optimized buildings envelopes, designed to take advantage of the site and capture the passive heat gains in winter but protected from them in summer. This approach can be facilitated using Building Energy Simulation (BES).

To carry out these simulations, engineers need to enter both building's data and climatic conditions (temperature, solar radiation, wind, etc.) which are generally from airport weather stations. Recent studies have shown that there are differences between suburban (airport) and urban climate [1]. This leads to the following issue: how to consider urban microclimate in bioclimatic building design?

2. Urban microclimate: measurement observations

Climate and weather are different, climatology is the statistical study of the weather conditions for a time period defined and for a space scale specified. Several climatic scales exist and are impacting with each other. Climate can be studied at macro (or global), meso (or regional), local (or city) and micro (or district) scale. The specific characteristics of urbanized places such as district or city lead to climate modifications known as urban heat island (UHI) [2]. This phenomenon translates in a warmer temperature in cities than in suburban or rural areas. A UHI at microscale was the subject of a case study in Confluence (Lyon, France).

2.1. Study case of Lyon Confluence

The study case selected is an urban zone of 56 hectares (about 800*700m, Figure 2) located in Confluence, second district of Lyon (France). This area is surrounded by two rivers, the Saône at the Ouest side and the Rhône at the Est one. TRIBU agency is involved in the development of the zone since 2003 and so has strong knowledge of the site. In 2013, 2014 and 2015, a UHI study of Confluence has been done and is presented in the following part.

Figure 2. Boundary limits of the Lyon Confluence study case (geoportail.gouv.fr)

Figure 1. Weather stations locations: urban zone [Confluence & ENS], suburban [Bron & ENTPE], (geoportail.gouv.fr)

2.2. Weather stations in Lyon area: urban & suburban measures

We describe here the weather data acquired at different stations in the Lyon agglomeration. First, the TRIBU's study of the UHI in Confluence, compared with Bron (weather station of Météo France, defined as reference) is presented (Figure 1). The second study is a validation of the air temperature measured in Confluence thanks to open access data from two stations nearby: ENS & ENTPE.

2.2.1. Lyon Bron & Lyon Confluence, experimental UHI observations.

TRIBU's measurement of UHI in the Confluence district has been performed over 3 years: in 2013, 2014 and 2015. For this period, the Confluence measured data (urban zone, Greenbee an Azimut Monitoring's multi-sensor measurement station) have been compared to those acquired by Météo France in Bron (suburban zone). Table 1 shows that over the year, in Confluence, the mean air temperature during the night is 1,8°C warmer than in the suburban zone of Bron.

Table 1. Measurement weather data for 2013, TRIBU's UHI study of Confluence

Study period	Mean temperature [°C]		Mean delta between temperature of Confluence & Bron [°C]		
	Bron	**Confluence**	**Day**	**Night**	**Global**
Annual	12,2	13,2	+0,3	+1,8	+1,1
Winter	3,5	4,8	+0,8	+1,6	+1,2
Summer	21,1	22,1	-0,1	+1,9	+1,1

2.2.2. Validation of the UHI measurement data.

To validate the quality of the UHI measurement in Confluence and confirm the temperature difference observed, the weather data are compared with two open access weather stations: ENTPE (suburban zone similar with Bron) and ENS (urban zone similar with Confluence) (Figure 3).
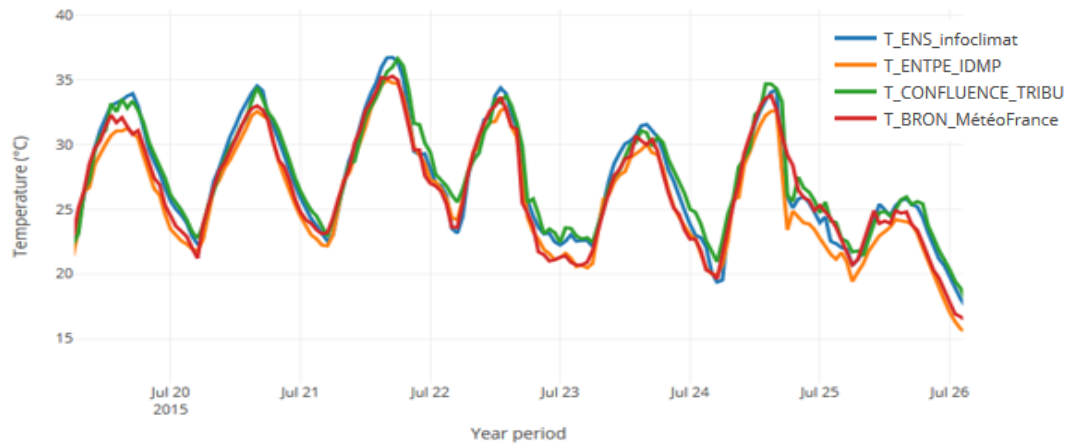

Figure 3. Air temperatures comparison between urban and suburban weather stations

Confluence and ENS weather stations are located very close from each other and the air temperature measurements give similar level of temperature with also a shift of 3 hours at the end of the day when compared to suburban measures, which is due to the inertia of the dense and mineral city center. Now that we consider that we can rely on our data, the second part of this article focuses on the way to consider the urban microclimate for the next building projects within Confluence zone.

3. UCM & BEM links

Building engineering and climatology are two research topics that are interacting. On the one hand, urbanized zones modify directly the climate at the micro scale (district scale) and at the local scale (city scale) [3]. On the other hand, climate and more precisely microclimate conditions impact the hygrothermal behaviour of buildings.

3.1. State of the art

For the study of urban microclimate and of buildings' thermal behaviour, several models have been created in past decades. Nowadays, one of the biggest challenges is to make UCM and BEM communicate. Chaining or coupling these models gives the possibility to link these two scales. A state of the art has been realized on this topic where many examples of UCM and BEM coupled or chained have been studied. From this, the two tools, CitySim and CIM, have been chosen. These models, able to run over a whole year period at hourly timestep are suitable with the climate entry of the BEM. In the next part, a chaining method is proposed starting from these tools.

3.2. Method proposal: creation of a microclimate file

Our proposal is to rebuild, at the district scale, a meteorological TMY file from data acquired at the nearest weather station (Bron, Météo France, Figure 1). Our case study is the Confluence district (Figure 2), where we have acquired the above-mentioned local climatic data. We start from Lyon Bron airport data, to build local climate files. A chain of two software programs is used (Figure 4) to produce a microclimate file suitable with BEM climatic data needs: CitySim and CIM.
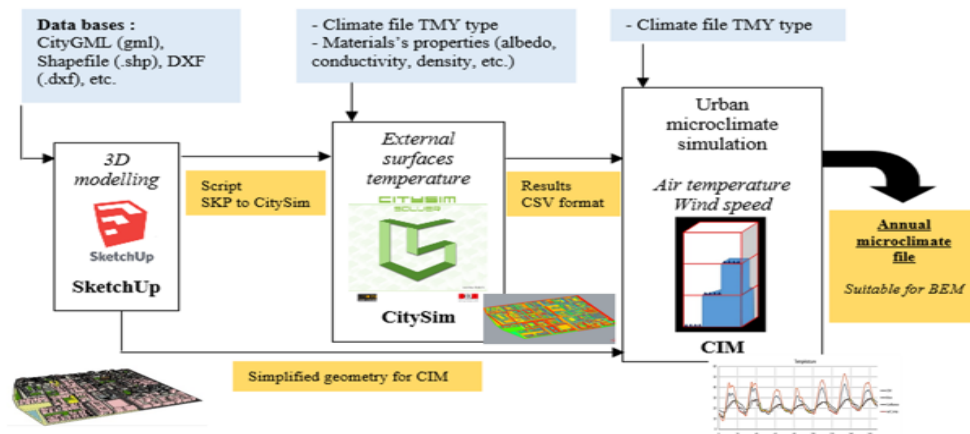
Figure 4. Chaining method for the creation of a microclimate file
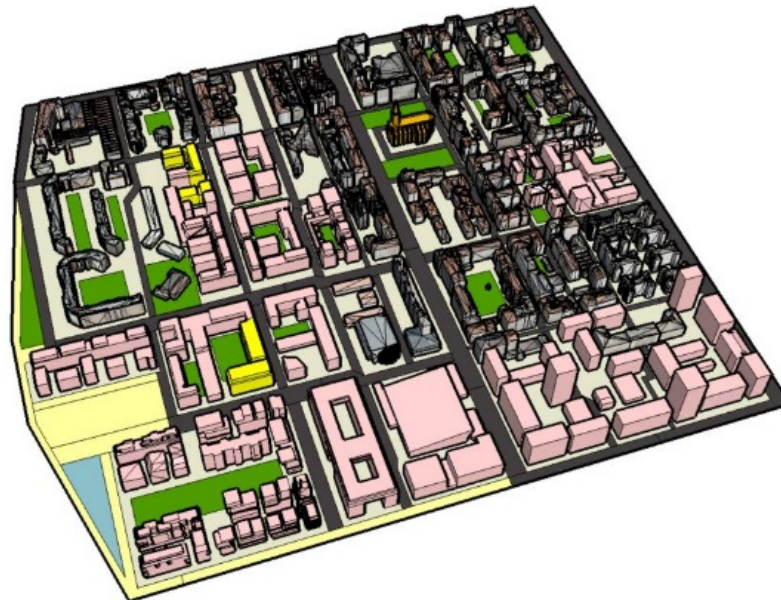

Figure 5. 3D geometry of Confluence, SketchUp

3.2.1. 3D modelling of the study case of Confluence.
To create the 3D geometry of Confluence with SketchUp (Figure 5), 2 open source databases from Grand Lyon have been used: CityGML and Shapefile. CityGML is an international open standardized data model and exchange format to store digital 3D models of cities and landscapes. Shapefile is a database including building footprints with elevation attributes.

3.2.2. CitySim simulation [11].
From the 3D geometry of the district and the types of surface (walls, grounds and roofs), the thermo-radiative tool CitySim calculates the surface temperatures. The latter are then integrated as boundary conditions in CIM model. CitySim considers infrared exchanges, solar inter reflections, and thermal behavior of buildings. Tables 2 & 3 provide the assumptions taken for the simulation.

Table 2. Surface albedos

Asphalt	0,1
Clear concrete pavement	0,25
Grass	0,3
Sandy soil	0,5
Building envelope	0,2

Table 3. Building performance assumptions

	Insulation	**U_wall**	**U_roof**	**U_floor**	**Uw**	**g**
	-		W/(m².K)			-
Buildings before 2012 (Grey ones on the Figure 5)	Internal	0,4	0,30	0,70	2,0	0,8
Buildings after 2012 (Pink ones on the Figure 5)	External	0,17	0,10	0,20	1,4	0,6

3.2.3. CIM results
From the boundary conditions calculated with CitySim (surface temperatures), the district morphology and the weather files at Lyon Bron station, CIM [12] rebuilds a local weather file representing the climate of Confluence and keeping the same format than a TMY (Meteonorm) file. CIM is a 1D (vertical) model where air temperature, wind speed and direction are calculated every 3 meters high and are considered homogenous in each mesh element. Finally, the obtained microclimatic file is suitable for BEM with weather data every hour for all the yearlong. Figure 6 gives the first results of this chaining.
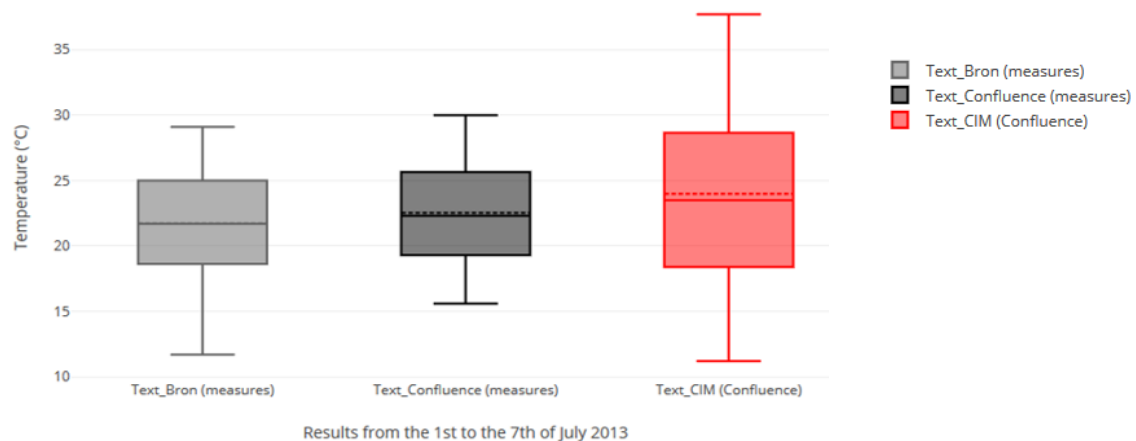
Figure 6. Boxplot, temperatures measured in Bron & Confluence and simulated in Confluence T_CIM

Compared with measurement data at Confluence (Text_Confluence), the simulated data (Text_CIM) overestimates the UHI effect. So far, these results indicate that the current coupling over Lyon, overestimates the air temperature by about 1.5°C and has a much higher spread, especially for the maximum temperature.

4. Discussions
A UHI has been observed in the urban zone of Confluence by a TRIBU study over 2013, 2014 & 2015 and has been validated with data from open access weather stations: ENS & ENTPE. To consider urban microclimate, a chaining method of the CitySim & CIM tools has been tested with so far, results that are not reliable enough to be used as weather data in BEM. CIM seems to be too much impacted by the boundary conditions calculated in CitySim. In CitySim, the inertial effect is not well translated by the 2RC conduction model of the ground or building elements. So, this leads to surface temperatures that are too low at night and too high at daytime with the solar radiation. An R2C model, as used in SOLENE-Microclimat [13], could allow a better representation of this inertial phenomenon for the surface temperature calculations.

6. Abbreviations

BEM: Building Energy Model
BES: Building Energy Simulation
TMY: Typical Meteorological Year
UCM: Urban Climate Model
UHI: Urban Heat Island

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