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What is the required level of details to represent the impact of the built environment on energy demand?

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Abstract

A full coupling between a CFD code, a thermo-radiative model and a building energy simulation model enables Solene-microclimat software to calculate both building thermal behavior and urban microclimate with the retroaction of buildings on microclimate. However, this full coupling is time consuming and it is legitimate to wonder if it is always necessary to perform such detailed simulations. In the framework of the MERUBBI project, simulations were carried out to answer this question. A set of simulations was designed to explore different kinds of configurations: three cities in France (Nantes, Paris and Strasbourg), three levels of density (from an isolated building to an implementation in the dense city center) and three kinds of buildings (an individual house in Paris, a residential building in Nantes and an office building in Strasbourg). To study the sensitivity of energy demand to the coupling detail, for each thermal flux at the external surfaces of the building, several levels of details were taken into account. For the impact of wind on convection, three modalities were considered: a constant convective heat transfer coefficient, calculated from the wind velocity at 10m; a convective heat transfer coefficient calculated from a vertical wind profile; a convective heat transfer coefficient calculated from the local wind velocity simulated with a CFD code. For the impact of air temperature on convection, two modalities are considered the use of the temperature measured at the nearest meteorological station; a local temperature calculated with the CFD simulation. For the impact of long-wave radiative exchanges, three modalities: the building exchanges with the sky without taking into account the masks of the environment and the long-wave radiative exchanges with the other surfaces; the building exchanges with the sky, taking into account the mask effects but not the exchanges with the surrounding surfaces; long-wave exchanges are taken into account with all kinds of surfaces in function of view factors. For the impact of short-wave radiations, two modalities: only direct and diffuse solar fluxes are taken into account; inter-reflections are considered. The results indicate that if the calculation of air temperature and convective heat transfer coefficient have few impacts in all the cases, the way of calculating long-wave and short wave radioactive fluxes has to be carefully considered, in winter as in summer. More detailed recommendations are given according to the density of the site in which the building will be implemented.

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1. Introduction

As Building Energy Simulation (BES) models have been improved, taking into account local climatic conditions and mask effects is becoming essential to conduct a proper assessment of building energy consumption in urban contexts. Indeed, many studies show that the urban microclimate has a significant impact on the energy consumption of buildings[1-5]. Representing interactions between physical phenomena at various urban scales becomes an important step, and it is necessary to assess the relative impact of the environment on fluxes interacting at the building-environment interface.

Heat exchange by convection depends on both the near-wall air velocity and local variations in outside temperature[6]. Solar net irradiation depends on the masks, the albedo of the surfaces under study and the surrounding surfaces[7]. Long-wave radiation exchanges with the sky and surrounding surfaces depend on form factors, temperatures and emissivities of the considered surfaces ant the surrounding ones[8]. Heat fluxes due to ventilation and infiltration depend on the pressure exerted on the building envelop[9] and local variations in outside temperature.

Only a few physical models address both buildings and their urban environment. An approximate approach consists in evaluating the direct impacts of the environment (masks) on buildings, as the procedure implemented in *SUNtool* and *CitySim*[10-11], which takes into account the luminous and solar masking effects of the urban environment while calculating the energy consumption of buildings. In a more complete way, Yang *et al*. use the hourly 3D distributions of the microclimate (air temperature, air humidity, wind field and ambient surface temperature) extracted from ENVI-met simulation results as outside boundary conditions for the EnergyPlus model without retroaction of building on local climate[5].

A more sophisticated approach entails evaluating the two-way interactions between buildings and their environment; this set-up requires to resolve scale compatibility issues, given the difficulty of accurately representing the urban environment as well as buildings and their uses. Two solutions call for reducing the studied urban land area (e.g., by focusing on a building in a canyon street[3,12]) or simplifying the building thermal model[13]. This full coupling of buildings and the environment is very beneficial in that it allows for 1) the evaluation of both the impact of environment on the thermal behavior of buildings and buildings' impacts on the urban microclimate[2,13-15] , 2) obtaining the direct and indirect impacts of the selected adaptation techniques[16,17]; and 3) deriving a better estimate of charges associated with the human control of indoor spaces based on microclimate models[3]. It has been shown that the coupling of CFD and radiative models improves urban microclimate simulations because it enables a better assessment of external surface temperatures[18]. However, this full coupling is time consuming and it is legitimate to wonder if it is always necessary to perform such detailed simulations. To determine whether this level of detail is necessary for building energy simulation, several coupling techniques have been compared with different representations of airflow, outdoor air temperature distributions and radiative models. We carried out sensitivity analyses using the coupled simulation tool *SOLENE-microclimat*[2,19,20]. The tool features Code_Saturne[†], a computational fluid dynamics (CFD) software program, and *SOLENE*, a thermo-radiative simulation software program dedicated to the urban environment[21].

In the framework of the MERUBBI project, a set of simulations was designed to explore different kinds of configurations: three cities in France (Nantes, Paris and Strasbourg), three levels of density (from an isolated building to an implementation in the dense city center) and three kinds of buildings (an individual house in Paris, a residential building in Nantes and an office building in Strasbourg). These buildings were designed by students in architecture with the aim of optimizing the benefice of natural resources in the different contexts, all sharing the same program and construction technics. They are new buildings and thus well insulated.

[†] http://researchers.edf.com/software/code-saturne/introduction-code-saturne-80058.html Consulted on 2014 Sept. 4th