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High resolution thermo-radiative modeling of an urban fragment in Marseilles city center during the UBL-ESCOMPTE campaign

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ABSTRACT

The thermodynamic exchanges of the old city center of Marseilles during a summer period are analyzed with the SOLENE thermo-radiative model, using measurements of the UBL-ESCOMPTE experimental campaign in June–July 2001. The selected scene is an actual fragment of the urban canopy composed of 4 streets at right angles, with various 19th century houses and yards. The SOLENE software's ability to simulate the heat and radiation exchanges of this urban district with the atmosphere is first evaluated by comparing simulation outputs with surface temperatures of individual roof and façade elements measured by infrared radiation thermometers and with integrated fluxes measured on top of a neighboring meteorological mast. This model assessment is reinforced by a sensitivity study to the interior building temperature, a variable of possible influence which is usually not measured in studies at the scale of an urban fragment or district. The flux sensor position influence on the comparison is also studied by introducing a virtual sensor in the simulated scene. The software is further used to analyze the behavior of individual surface elements of the scene with various orientations during a typical summer diurnal cycle. The contributions of the different surface classes (roofs, façades, streets, yards) to the upward radiation and heat fluxes to the atmosphere are then detailed for several canopy morphologies (H/W).

1. Introduction

Urban climatology and meteorology studies are important for answering such problems as pollutants dispersion, thermal losses from buildings, human activity and urban fabric morphology contributions to urban atmosphere heating, and inhabitant's comfort in the interior as well as in the open air. The answers to these important questions all depend on a good assessment of the various contributions to the energy balance.

The assessment of the surface energy fluxes forms the basis of climatological and meteorological predictions, especially that of the sensible heat flux between the solid surfaces and the atmosphere. Other fluxes intervene in the surface energy budget with non-linear interactions: the absorbed solar flux, the emitted and absorbed infrared fluxes, the heat flux by conduction into the solid, and in the presence of vegetation the latent heat flux due to evapotranspiration. In the case of the urban canopy, these fluxes are difficult to evaluate because of (i) the highly variable anthropogenic contributions, (ii) the strong heterogeneity of the urban fabric materials, and (iii) the complex 3D geometry of this rough surface, actually a folded surface.

Some numerical models have been used for computing the energy exchanges between the cities and the atmosphere; they are of three types: (1) integrated energy budget of one street-canyon or of a multiple street-canyon district, following Refs. [30,32] and often developed as a surface flux preprocessor for mesoscale models such as TEB [26], LUMPS [13], MOSES [5] or SM2U [9]; (2) radiation transfer models, applied to urban fragments with idealized or realistic 3D geometries, without heat transfers, such as DART [11] or TITAN [10]; (3) thermo-radiative models computing radiation budgets, and sometimes energy budgets, at the elementary (façade or facet) scale, including the multiple reflections within the canopy 3D geometries, such as Aida's model [1,2], SM/HM [21,22], TUF-3D [23]. These last models may be applied both to the calculation of the energy balance of an urban fragment and to the analysis of thermal infrared remote sensing data, but unfortunately

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