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Development and evaluation of a comprehensive building energy model in the Town Energy Balance scheme

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Waste heat released by air-conditioning systems is an important factor for analysing and mitigating the increase in air temperature produced by urbanization, a phenomenon known as the Urban Heat Island effect. This phenomenon has also an impact on the energy consumption of buildings to an extent that has not been completely characterized yet. The use of air-conditioning systems is expected to increase in the following years as a consequence of global-scale and urban-scale climate warming. Therefore, urban climate models, such as the Town Energy Balance (TEB) scheme, must be improved to be able to represent future scenarios of urban climate and building energy consumption. This study presents a building energy model that has been developed in TEB (BEM-TEB) to evaluate the reciprocal interactions between buildings and the urban environment. The new BEM-TEB calculates the energy demand of a building applying a heat balance method and differentiating between convective and radiative heat components. Multi-storey buildings are represented by an internal thermal mass. The model accounts for heat gains due to transmitted solar radiation, heat conduction through the enclosure, infiltration, and internal heat gains. As a difference with respect to other building parameterizations used in urban climate models that consider idealized air-conditioning systems, BEM-TEB calculates the energy consumption of an air-conditioning system considering the dependence of the system capacity and efficiency on indoor and outdoor temperatures, as well as on situations of part-load performance. As a result, BEM-TEB is able to approximate the real consumption and waste heat emissions of air-conditioning systems in urban environments. It also solves the psychrometrics transformations of the air passing through the system, which allows the analysis of the latent heat interactions between the indoor and the outdoor environment. BEM-TEM is tested comparing it with an industry-standard building simulation program (EnergyPlus) and is evaluated using energy consumption and urban climate data from experiments in Toulouse. A discussion of applications, limitations, and future developments of the model is presented at the end.