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A sensitivity study relating to local urban climate modelling within the built environment

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Abstract

The rapid increase in urban populations during the last century, together with the threat of climate change has motivated research focusing on the impact of land-use on urban climates. High-resolution neighbourhood-scale modelling tools developed to account for the complex three-dimensional surfaces and volumes within an urban area are able to predict temperature perturbations over an urban domain with reference to varying land-use. However, land-use classes chosen to model the urban landscape often reflect the function, rather than the material, and hence overlook different building materials that compose the built environment.

The purpose of this study is to demonstrate that in order to robustly assess local climate variations, it is important to use representative land-use parameters that account for materials that form the urban landscape, instead of functions. The response of a high-resolution local climate model to an improved parameterization of the built environment is investigated using the local-scale urban climate modelling tool, ADMS-Urban. In this study, a more elaborate set of land-use classes is collated which distinguishes between different building materials that have varying thermal parameters. A novel approach to calculating the thermal admittance is proposed, reflecting different building materials used for the building facades and the roofs.

This study demonstrates that refining model input parameters to correctly represent various construction materials used within the urban tissue, as well as the proposed, advanced method for calculating thermal admittance leads to significant temperature differences compared to when broad assumptions are used, especially under low wind conditions common in equatorial cities.

Validation studies are planned that will demonstrate the accuracy of model predictions in comparison to observed temperature data in order to identify threshold criteria required to produce realistic urban climate predictions.

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Following this example of best practice, the existing modelling tools can reliably be used for the simulation of complex future scenarios and for a robust assessment of the relevant health implications.

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Keywords: land-use, urban heat island, thermal admittance, ADMS-Urban

1. Introduction

Extreme heat events in urban areas can cause serious health problems, even mortality, especially in women (Hajat et al., 2006) above 65 years of age (Huynen et al., 2001), while future projections show that the mortality rate can drastically rise with increasing global temperatures (Hajat et al., 2014). Overheating of cities also increases the anthropogenic forcing to the environment with increasing energy demand for cooling purposes, which further exacerbates the urban heat island due to the additional waste heat output by AC systems (Salamanca et al., 2014). As local urban warming is coupled to greenhouse gas-induced global warming, heat waves and associated problems constitute environmental hazards associated with highly urbanized areas, in particular in arid and semi-arid areas. It is important to evaluate and quantify the vulnerabilities of an urban domain to heat-induced risks in order to: accurately assess the impact of urban planning strategies; gain insight into the future projections for energy demand; and appraise potential health problems. Whilst temperature monitors deployed in locations throughout a city are required for some of these assessments, urban climate models are also necessary, for instance, to assess current and future planning strategies.

Urban climate modelling can be performed at a range of spatial scales. Mesoscale meteorological model such as WRF (Skamarock et al., 2008) and the UK Met Office Unified Model (Bohnenstengel et al. 2011) include modules that account for the build-up of the urban heat islands on the city scale whereas neighborhood-scale models such as ADMS (Virk et al., 2015) are able to resolve local temperature variations at street level that relate to, for instance, the distribution of green space within the urban landscape. In contrast to the mesoscale models, local-scale models are able to perform fast simulations of a series of land-use scenarios; these tools have been widely used in the last decade or so to further understand the temperature perturbations due to land use in urban domains (Hamilton et al., 2014), and hence can be used to identify risk areas and appraise the severity of future problems relating to urbanization and climate change (Virk et al., 2014).

This study considers how refinements to urban climate model inputs alter model predictions, specifically those values that define the capacity of the various materials that form the urban landscape to absorb/reflect, store and reradiate energy. We pose and discuss three questions that relate to how the land use parametrization can be improved. The findings of this work are then discussed within the context of health implications; future work requirements are presented.

Nomenclature

TA_{eff}	effective thermal admittance
A_g	ground area
ΣA_r	total roof area within a grid
ΣA_b	total building façade area within a grid
TA_g	ground thermal admittance
TA_r	roof thermal admittance
TA_b	building thermal admittance
λ_f	frontal density
λ_p	planar density
V_{be}	volume of the building envelope
V_b	volume of the building