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Using LCZ data to run an urban energy balance model

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In recent years a number of models have been developed that describe the urban surface and simulate its climatic effects. Their great advantage is that they can be applied in environments outside the cities in which they have been developed and evaluated. Thus, they may be applied to cities in the economically developing world, which are growing rapidly, and where the results of such models may have greatest impact with respect to informing planning decisions. However, data requirements, particularly for the more complex urban models, represent a major obstacle to their employment. Here, we examine the potential for running the Surface Urban Energy and Water Balance model (SUEWS) using readily obtained data. SUEWS was designed to simulate energy and water balance terms at a neighbourhood scale ($\geqslant$1 km^2) and requires site-specific meteorological data and a detailed description of the surface. Here, its simulations are evaluated by comparison with measurements made over a seven month (approximately 3 seasons) period (April–October) at two flux tower sites (representing urban and suburban landscapes) in Dublin, Ireland. However, the main purpose of this work is to test the performance of the model under 'ideal' and 'imperfect' circumstances in relation to the input data required to run SUEWS. The ideal case uses detailed urban land cover data and meteorological data from the tower sites. The imperfect cases use parameters derived from the Local Climate Zone (LCZ) classification scheme and meteorological data from a standard weather station located beyond the urban area. For the period of record examined, the simulations show good

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agreement with the observations in both ideal and imperfect cases, suggesting that the model can be used with data that is more easily derived. The comparison also shows the importance of including vegetative cover and of the initial moisture state in simulating the urban energy budget.

1. Introduction

Within the next four decades the global population is projected to increase by 2.3 billion, within the same period it is expected that urban areas will gain 2.6 billion (UN, 2012), absorbing projected growth and continuing to draw from existing rural populations. While this trend appears globally, there are regional differences. The urban population in more economically developed regions has already reached 78%, whereas in less developed regions it currently stands at 47%. Taking the projections for Asia and Africa together, their urban population will grow by 2.3 billion by the middle of the century. If these projections are realised, most of the urbanisation in the future will occur in the economically developing world (Satterthwaite, 2007). Responding to this challenge will result in large-scale housing and critical infrastructure projects (e.g. energy and water supply, waste removal facilities and transport) that, once in place, create an urban form that is difficult to change; hence, it is important that urban growth is well managed. At least two responses might be expected: horizontal expansion of the urban area and densification of the existing urban fabric (Moonen et al., 2012). If future urban development is to reduce environmental impacts (e.g. air quality, hydrology and thermal effects) that result from conventional urbanisation some guidance on development pathways is needed (Schwela, 2000; Schuster et al., 2005; Arnfield, 2003; Chen and Ng, 2012). One component of this guidance should be physically-based models that can simulate the effect of alternative urban plans and designs and inform decision-making. However, these models only have value if they have been tested, that is, applied to urban places, evaluated against observations and validated. Unfortunately, there are few examples of the application of urban climate models to these types of problems (Oke, 2006).

Although there are an increasing number of diverse urban climate models available, there is little evidence that they are routinely applied. A significant impediment to their route use includes the paucity of relevant information on: the physical character of cities (that is the buildings, materials, layout, etc.) needed to derive model parameters and; the meteorological data needed to 'force' the models and evaluate their simulations. In fact, the lack of urban specific data has been recently highlighted in the 5th assessment report (AR5) of the Intergovernmental Panel on Climate Change (IPCC, 2014). Specifically AR5 highlights serious data limitations with respect to geophysical, biological and socio-economic data, as well as inadequate knowledge surrounding the vulnerability of the built environment and building materials to climate change. These issues are particularly acute for the rapidly growing cities of the economically developing world, many of which are outside the mid-latitude climates where the models have been developed and may lack the necessary urban and meteorological information required. Recently, a protocol for collecting urban parameters in an efficient and standardised manner has been proposed to address this problem (Ching, 2013; Bechtel et al., 2015).

This paper examines the issue of information quality and its impact on the performance of an urban energy balance model (UEB). The Surface Urban Energy and Water Balance model (SUEWS) is a moderately complex UEB that requires detailed information on the urban landscape and is usually run using on-site meteorological data. We use SUEWS to simulate the energy budget at two Dublin locations for which we have detailed energy flux stations and detailed spatial information (e.g. individual building footprints, heights) on the surrounding urban landscape. This allows us to run the model and evaluate its simulations of turbulent fluxes over a period of time. We then use readily available standard meteorological data and coarse land-cover data and perform the same evaluation. The