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Sensitivity of Surface Urban Energy and Water Balance Scheme (SUEWS) to downscaling of reanalysis forcing data

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Often the meteorological forcing data required for urban hydrological models are unavailable at the required temporal resolution or for the desired period. Although reanalysis data can provide this information, the spatial resolution is often coarse relative to cities, so downscaling is required prior to use as realistic forcing. In this study, WATCH WFDEI reanalysis data are used to force the Surface Urban Energy and Water Balance Scheme (SUEWS). From sensitivity tests in two cities, Vancouver and London with different orography, we conclude precipitation is the most important meteorological variable to be properly downscaled to obtain reliable surface hydrology results, with relative humidity being the second most important. Overestimation of precipitation in reanalysis data at the three sites gives 6–21% higher annual modelled evaporation, 26–39% higher runoff at one site and 4% lower value at one site when compared to modelled values using observed forcing data. Application of a bias correction method to the reanalysis precipitation reduces the model bias compared to using observed forcing data, when evaluated using eddy covariance evaporation measurements.

1. Introduction

Modelling urban water balance components, including evaporation and runoff, are crucial to understand, forecast and predict the hydrological cycle (including extreme events) in cities. With current global urban

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growth and development, there is increasing need for fine-scale hydrological information, particularly in areas where few or no routine observations exist, or under future urbanization scenarios.

The high fraction of impervious surfaces in urban areas generally increases surface runoff flow velocities and volumes and decreases infiltration and evaporation, all altering the probability of flooding (e.g. Rodriguez et al., 2003). High volumes of urban runoff impact water quality and hydrological regimes in local streams, inland waters and coastal zones, modifying ecological conditions and increasing the environmental burden (Knight and Cuffney, 2012; Konrad and Booth, 2002; Paul and Meyer, 2001).

Detailed information is needed (e.g. from numerical models and/or from observational campaigns) in different macroclimates and city structures (e.g. city centre and suburban areas) to inform urban development. To undertake fine-scale urban hydrological modelling (Kanamitsu and Kanamaru, 2007; Wood et al., 2004) detailed, location-specific meteorological forcing data are required. High-resolution input data allow rapid changes in hydrological conditions (e.g. after a heavy rain event) to be explored. However direct observations of required variables to force urban climate and hydrological models are rare. Grimmond et al. (2010b) and the 5th assessment report of the Intergovernmental Panel on Climate Change (IPCC, 2014) have highlighted the lack of urban observations and the need to have observations in a greater variety of locations. Due to the complexity and diversity of cities observational studies are typically limited to individual sites in a few cities.

Global reanalysis products can provide the essential variables to enable modelling where and when observations are unavailable (e.g. in data sparse regions of the world where cities are growing rapidly, or for past events before instruments were installed). Reanalysis data can also be used to supplement datasets that are missing required variables, or to provide higher temporal resolution data if only coarse information is available (e.g. daily totals). Reanalysis data are generated by rerunning global meteorological models but with data assimilation of a large amount of observations (e.g. remote sensing and ground based observations). Although there are a number of reanalysis products available (e.g. ERA-Interim (Dee et al., 2011), MERRA (Rienecker et al., 2011), JRA-55 (Kobayashi et al., 2015), NCEP (Kalnay et al., 1996), WFDEI (Weedon et al., 2014)), they are typically spatially coarse (e.g. 0.5°). This means that downscaling is needed prior to use for local-scale urban hydrological modelling (Bastola and Misra, 2014; Fowler et al., 2007; Wilby et al., 2000). For example, large variations in topography can cause the mean grid height of the reanalysis product to be different from the height of the study site (Frei et al., 2003). As the fine-scale distribution of precipitation is highly dependent on orography (e.g. Brunsdon et al., 2001; Oke and Hay, 1994), accounting for it may be crucial for reliable model results (e.g. Bastola and Misra, 2014). Convection-resolving numerical weather prediction allows precipitation distributions to be modelled (Brisson et al., 2016) but requires a large amount of computer resources for climate runs. Although this method has the advantage of not requiring *a priori* observations for application, convection-resolving modelling is an area of active research because of the many challenges with cloud processes relative to the grid size (Holloway et al., 2014).

To reduce the computational needs for applications, bias correction with quantile mapping (BCQM) has been found to be an effective method to correct daily precipitation intensities in climate projections (e.g. Gudmundsson et al., 2012; Räty et al., 2014; Sunyer et al., 2015; Teutschbein and Seibert, 2012). Although this method has the disadvantage of requiring observations to undertake the corrections, it does retain the observed distributions as a constraint. As the temporal resolution of reanalysis products is typically 3 to 6 h, i.e. too coarse for detailed hydrological modelling (Bastola and Misra, 2014), interpolation to finer temporal resolution is needed. To date, reanalysis products have been used rarely in the modelling of urban water and energy exchanges. As the WATCH WFDEI reanalysis data (Weedon et al. 2011, 2014) are specifically derived for hydrological modelling from ERA-Interim, and have been used to model surface energy fluxes in 20 different urban areas (Best and Grimmond, 2016), they are chosen for this study.

There are a large number of urban land surface models (Grimmond et al., 2009) that take a wide variety of approaches to describing urban surface exchange processes (Grimmond et al., 2010a, 2011). Given the importance of vegetation to urban hydrology and turbulent exchange (Best and Grimmond, 2014, 2016) and its significant presence in suburban areas and central business districts it is critical that a scheme can simulate its influence on the surface energy and water balances (Best and Grimmond, 2013, 2014; Grimmond et al., 2011; Loridan and Grimmond, 2012; Nordbo et al., 2015). Where many gardens and parks are present, irrigation can become an important component of the local water balance (Grimmond and Oke, 1986; Mitchell et al., 2001, 2003) thereby also influencing energy exchange.

The urban land surface model used in this study is the Surface Urban Energy and Water Balance Scheme (SUEWS). This local (neighbourhood) scale scheme can simulate both energy and water balance components

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