Assessment of a meteorological mesoscale model’s capability to simulate intra-urban thermal variability in a tropical city

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Large spatial differences in canopy-layer air temperature are found across the city as a consequence of distinct urban morphologies and anthropogenic activities throughout the urban landscape. Model-based studies investigating the spatial and temporal variability of air temperature are commonly employed to assess heat mitigation strategies in cities. It is therefore important that models are capable to accurately predict air temperature variability across the city to account for the local climate context. This study explores the sensitivity of the Weather Research and Forecasting (WRF) model coupled with a multi-layer urban scheme (BEP-BEM) to simulate intra-urban variations of 2-m air temperature during different synoptic conditions in a tropical city, Singapore. An accurate representation of the real heterogeneous urban morphology of Singapore is implemented in the model. Two one-month long simulations are conducted for distinct synoptic weather conditions: (a) a relatively wet period during the SW monsoon and (b) a very dry period during the NE monsoon. The performance of the model is firstly evaluated against micrometeorological data collected by a tall eddy covariance flux tower in a representative low-rise residential neighbourhood. Overall good performance is obtained for wind speed and direction, turbulence parameters and surface energy balance components, in particular during dry conditions. Some difficulties are found in predicting intermittent cloud cover, which results in an overestimation of net radiation increasing model errors during the wetter period. Hence the comparison of 2-m air temperatures against observations results in slightly higher errors during the latter period (RMSE<2.3°C) compared to the dry period (RMSE<1.6°C) using data from nine locations with different urban morphologies. Notable underestimation (overestimation) is obtained for the nighttime temperature at the most densely built-up (rural) area. A significant logarithmic relation between minimum nocturnal temperature and average aspect ratio is nevertheless obtained for both observations and simulations. Further analysis during clear sky conditions in both periods reveals that the spatial distribution of the diurnal temperature range computed at the urban locations varies according to synoptic conditions. The present research demonstrates the capability of the model to predict the intra-urban variability across distinct urban morphologies, however, it fails to accurately capture absolute differences in air temperature.