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High-resolution modelling of urban environment in Singapore using coupled WRF/UCM system

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The urban environment is crucial for urban inhabitants' health and comfort. A high-resolution modelling study of the urban environment in Singapore is carried out utilizing the coupled Weather Research and Forecasting (WRF)/Urban Canopy Model (UCM) system. This project is focused on the interaction between local scale and mesoscale processes. The objectives are to study (1) the effect of urbanization on the local weather; (2) the urban heat island features and possible mitigation strategies; and (3) the local-scale recirculation characteristics (i.e. sea breeze) in Singapore.

The Noah land surface model (LSM) coupled with single-layer urban canopy model (UCM) is utilized to parameterize the effect of urban areas on the overlying atmosphere. Other physics schemes used are RRTM long-wave radiation scheme, Dudhia short-wave radiation scheme, MYJ PBL scheme, WRF single-moment 6-class microphysics scheme and Kain-Fritsch cumulus scheme. Five one-way nested domains are used with resolutions ranging from 24.3 km to 0.3 km. 38 vertical sigma levels are used, with the first 14 levels within PBL to better resolve the boundary layer. High-resolution land use data and topography data at 90 m are used in the innermost domain, which covers the whole Singapore island. The land use of urban areas is further categorized into 3 sub-classes,i.e. high-density residential, low-density residential, and commercial/industrial.

To study the urban environment in chaotic conditions and with the coexistence of many environmental variations, we adopt the ensemble approach. Singapore's local weather is categorized according to (a) wind shear, (b) CAPE (Convective Available Potential Energy), and (c) monsoon season. For some selected categories (e.g., low wind shear, high CAPE and inter-monsoon season), several simulations are carried out and the ensemble mean values are obtained from these simulations.

To evaluate the model's performance in producing key characteristics in the urban area in Singapore, several observational datasets are used to compare with the WRF results in different ways: (1) A systematically statistical comparison of surface temperature with the observational data around the island; and (2) statistical comparison of surface energy balance components with the flux tower measurements at Telok Kurau Lor J. It is demonstrated that the coupled WRF/UCM system can successfully simulate the temperature distribution and surface energy balance characteristics.

After the model evaluation, a thorough investigation of Singapore's local-scale recirculation (i.e. sea breeze) and urban heat island feature is performed. The obtained results are helpful for both theoretical research and urban planning.