Multi-scale Urban System Modeling for Sustainable Planning and Design

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Abstract

The urban heat island (UHI) phenomenon has become a concern in many major cities worldwide, as high summer temperatures and poor wind flow in high density built-up areas can have negative impacts on thermal comfort and health of residents by trapping air pollution, and increasing energy demand for artificial cooling. As a high-density city in the tropics, Singapore is similarly susceptible to high temperatures and the related negative impacts. With a rapid pace of development in the coming years to meet population and economic needs, it is essential that the microclimatic impacts of these upcoming developments, as well as the long-term effects of climate change, are assessed early during the planning process, and for the appropriate design and mitigation measures to be incorporated upfront in the plans.

Using Mesoscale Spectral Model (MSM) downscaling reanalysis and forecast data, this study seeks to develop a multi-scale coupled natural-human urban system modelling for urban planners, architects, businesses and other stakeholders and decision-makers to refine land use and development plans for maintaining good thermal comfort in both the immediate and longer term future using multiple indicators, including environmental and human response indicators.

The modelling for thermal comfort liveability planning and design is based on a multi-scale coupled environmental urban models using global to very high resolution (sub 1km) mesoscale atmospheric which is integrated with a multi-dimensional statistical model for wind, temperature and humidity ranging from global scales to urban street-level scales in the human residential environment near ground surface, and human comfort. This modelling methodology includes calibration of the environmental conditions using local-scale observations from ground sensors to compute the physiological metrics to measure human comfort (questionnaires) which includes human activity, as a function of individual differences such as ageing, recognising the different physiological responses and needs, and as well as the psychological aspects of human comfort such as the influence of colours, materials, texture and lighting in the design on the perception of heat.

This study addresses in particular the necessity to link different temporal and spatial scales, multi-disciplinary approaches to achieve improved integration of different types of measures and tools to enhance and deepen the understanding of urban ecosystems for the assessment of thermal comfort to support urban design and redevelopment in Singapore.