Towards a fine-scale urban climate simulation of Hong Kong using MesoNH-TEB with a detailed urban land cover description

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Photography encouraged

1. Introduction and Objectives

- Cities face a multitude of **urban climate issues** which pose threats to the health and well-being of urban dwellers.
- **Numerical models** can simulate the altered surface energy balance due to buildings, impervious surfaces, and human activities. They help us better **understand the physical processes of urban climate** and **evaluate the potential impacts of climate change on cities**.
- **Hong Kong** is an ideal study location because
  - a detailed urban database is available;
  - the weather station network is well-established;
  - it is challenging and interesting to model (Figure 1).

Here, we present the **model set-up** and **input parameters** for describing urban land cover and building characteristics in preparation for the **fine-scale simulation** of the thermal microclimate conditions in **downtown Hong Kong (D4)** during a week-long hot spell in September 2009.

Figure 1: Modelling challenges presented by Hong Kong's natural and urban landscapes
(photo source: curiouscatontherun.wordpress.com)

2. Model Configuration and Domains

- The non-hydrostatic mesoscale atmospheric model **Meso-NH**, coupled with the single-layer urban canopy parametrisation **Town Energy Balance** (TEB) to solve the urban surface energy balance, will be employed for the urban climate simulation (Figure 2).
- TEB allows one to provide a detailed description of the street canyon geometry, urban vegetation, building construction materials, and human behaviour related to building energy consumption.
- ECMWF analysis data will be downscaled via **4 nested models** to a **spatial resolution of 250 m** for downtown Hong Kong (Figure 3).

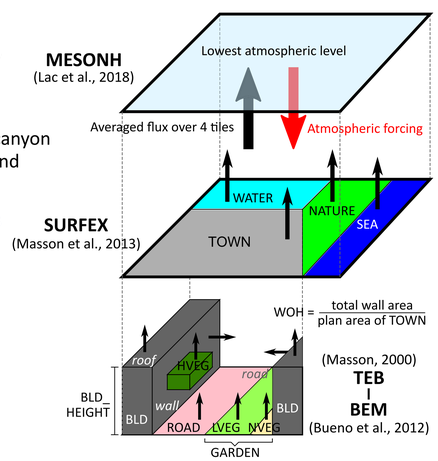

Figure 2: Schematic representation of the MesoNH-SURFEX-TEB coupling and TEB input parameters.

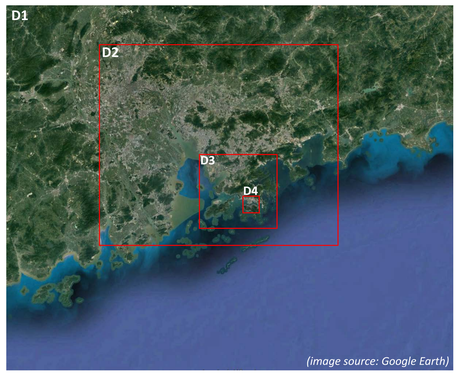

Figure 3: The model domains and their spatial resolutions.
D1 – The Pearl River Delta (PRD) region (8 km)
D2 – Major metropolitan areas in PRD (2 km)
D3 – Hong Kong and southern Shenzhen (1 km)
D4 – Kowloon Peninsula and northern Hong Kong Island i.e. downtown Hong Kong (250 m)

3. Urban Surfaces and Building Geometry

- **Precise data** on **land cover** and **urban morphology** can significantly improve the performance of high-resolution model simulations (Salamanca et al., 2011).
- TEB input parameters for D4 are derived at 100 m resolution by aggregating **administrative data** on building footprint, road networks, and land utilisation, complemented by a **digital elevation model** and vegetation cover retrieved from treated **satellite images**.

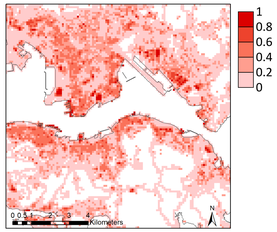

Figure 4: Building surface fraction in D4.

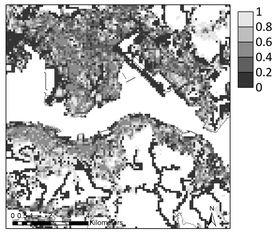

Figure 5: Impervious surface fraction in D4.

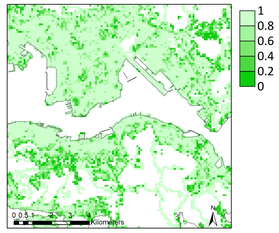

Figure 6: Urban vegetation cover in D4.

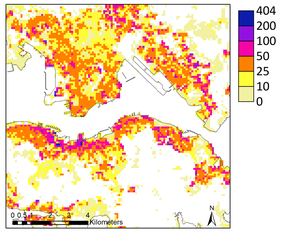

Figure 7: Average building height (m) in D4.

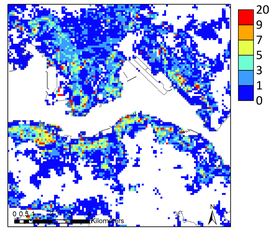

Figure 8: Street canyon aspect ratio in D4.

4. Building Archetypes

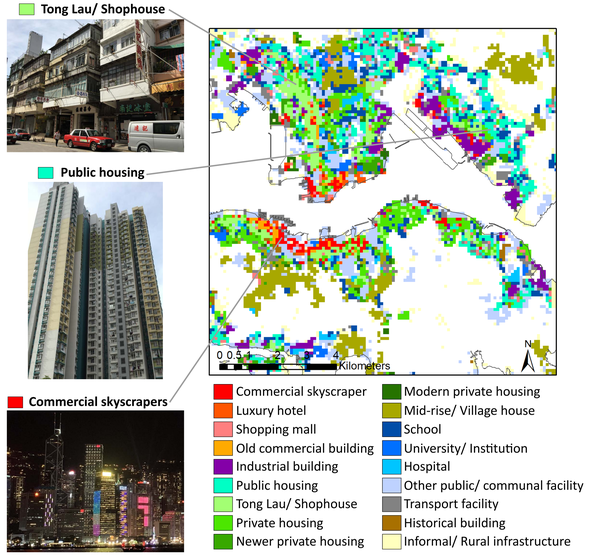

Figure 9: Spatial distribution of the dominant building archetype for each urban grid point in D4 and example photos of selected building archetypes.

- **Building characteristics** (e.g. roof albedo, wall thermal conductivity, window-to-wall ratio) and **occupant behaviours** (e.g. occupancy, cooling schedule and setpoint temperature) influence the urban radiative transfer, storage and anthropogenic heat fluxes, and are therefore of high relevance to city-atmosphere interactions.
- Using an "architect's expertise" approach, 18 building archetypes are defined for Hong Kong as combinations of different **building typology**, **building use**, and **building age** (Kwok et al., 2018; Figure 9).
- Each building archetype is described in TEB with a set of parameters related to building architecture and human behaviour.

5. Extending Data Coverage with LCZs

- The WUDAPT initiative aims to provide a worldwide coherent description of the form and function of urban areas (Ching et al., 2018). Urban morphology is therein described through the **local climate zone (LCZ)** scheme (Stewart and Oke, 2012).
- The LCZ map of Hong Kong derived by Wang et al. (2018) is used to extrapolate the urban data coverage for D3 by means of a geospatial analysis of the TEB input parameters in D4.
- Compared to the 'standard' ranges of surface cover properties for each LCZ, the urban areas in Hong Kong generally have **higher impervious surface fractions** and **lower pervious surface fractions**, particularly for open settings (Figure 10).

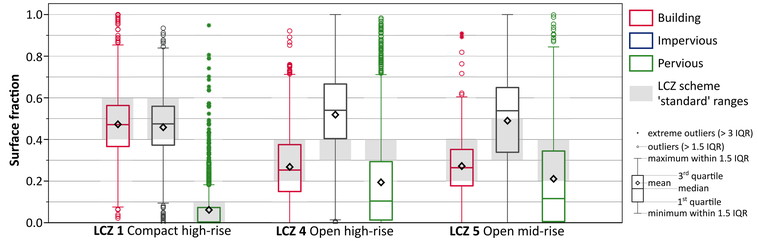

Figure 10: Statistical distributions of building, impervious, and pervious surface fractions for the three most common LCZs in downtown Hong Kong compared to the 'standard' ranges given by Stewart and Oke (2012).

6. Conclusion and Further Work

The novelty of this study lies in the remarkably detailed description of the **urban surface cover** and **morphology**, as well as **building architecture** and **human behaviour**, employed for the initialisation of MesoNH-TEB.

- The urban data reflect the **high building and road density**, **heterogeneous building height**, and **complex mix of building archetypes** in downtown Hong Kong.
- The comparison of detailed input parameters to 'standard' ranges for each **LCZ** demonstrates the importance of **locally adapting** relevant parameters for model application.
- In the next steps, the model configuration will be **optimised** and model results will be **evaluated** against station observations. Ultimately, the study aims to aid **urban planning** by simulating the spatial and temporal variations of the city's urban climate under different development and mitigation scenarios.

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