Towards High-Resolution Urban Weather and Climate Modelling for Singapore: Overview of Effort at CCRS

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uSINGV, urban meteorology, weather and climate modelling, high resolution

Background

- Singapore, a coastal city-state near the equator, has a unique tropical weather and climate.
- Urbanization strongly influences the local weather and climate, making Singapore vulnerable to extreme heat, extreme rainfall, and Urban Heat Island (UHI).
- Understanding the dynamics between urbanization and associated meteorological phenomena is crucial for sustainable planning and policy formulation.

Research gap

- Impacts of urbanization and urban activities on the local weather and climate in Singapore, especially at the high-resolution scale, are not well understood.

Results

- Detailed model evaluation with observation data, Fig. 3.
- 100 m uSINGV can resolve more small-scale features, such as clouds and turbulent structures as illustrated in Fig. 4.
- Applications of uSINGV in extreme hot and rainfall days, as shown in Fig. 5 and 6.

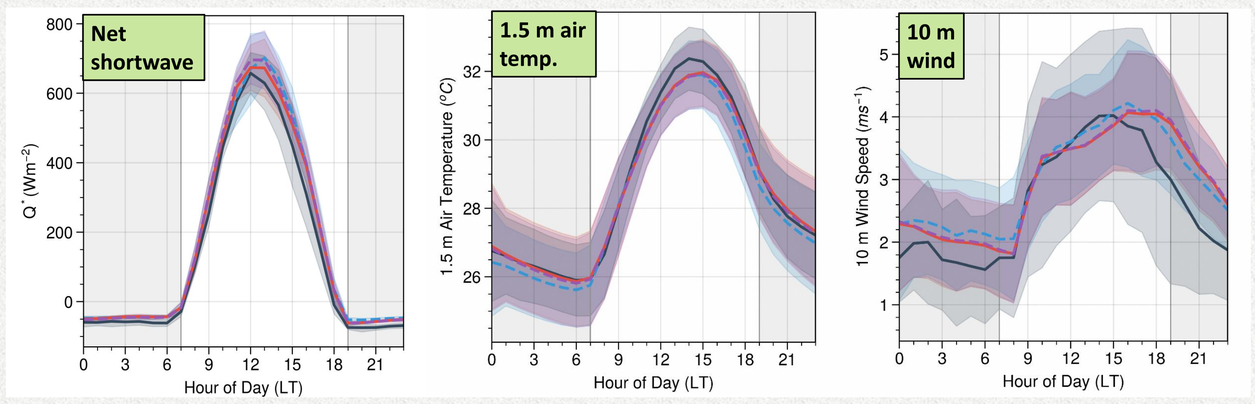

Figure 3. Validation of 100 m uSINGV with observations: net shortwave radiation (left), 1.5 m air temperature (middle), and 10 m wind (right).

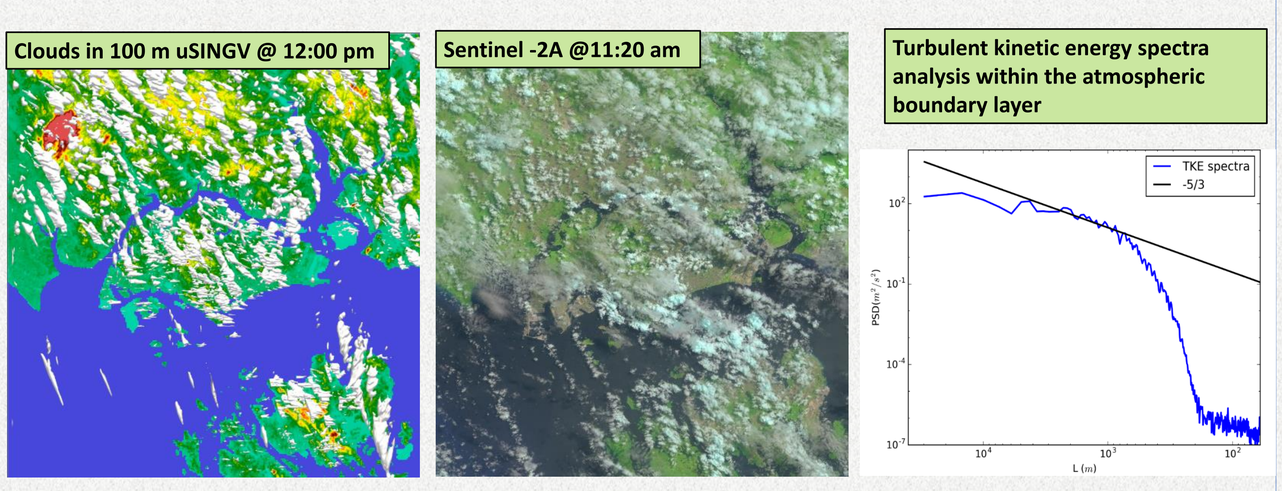

Figure 4. Clouds from 100 m uSINGV (left), clouds from a satellite image (middle), and turbulent kinetic energy spectra within the atmospheric boundary layer (right).

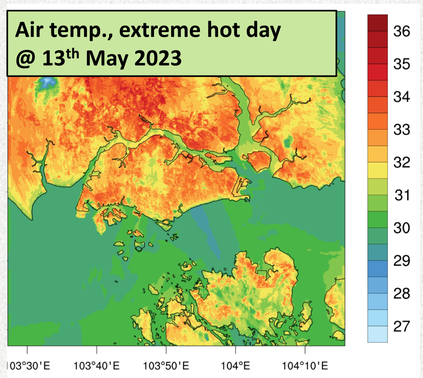

Figure 5. uSINGV simulation for the record-breaking hot day at the 13th May 2023: 1.5 m air temperature at 3:00 pm.

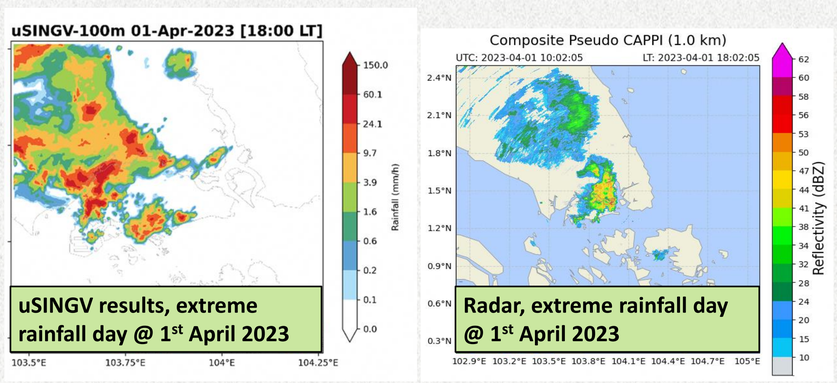

Figure 6. uSINGV simulation for an extreme rainfall day at the 1st April 2023: 100 m uSINGV model results (left) and radar reflectivity observed (right).

Aim

- To develop a high-resolution urban weather/climate modelling system, 100 m uSINGV, for Singapore to better understand the meteorological processes and contribute to city planning and policy making.

Methods

- uSINGV is developed from the 1.5 km resolution operational weather forecast model SINGV at MSS, which was based on Unified Model from the UK Met Office
- uSINGV has a grid length of 100 m and is run in a nested way: 1.5 km → 300 m → 100 m shown in Fig. 1.

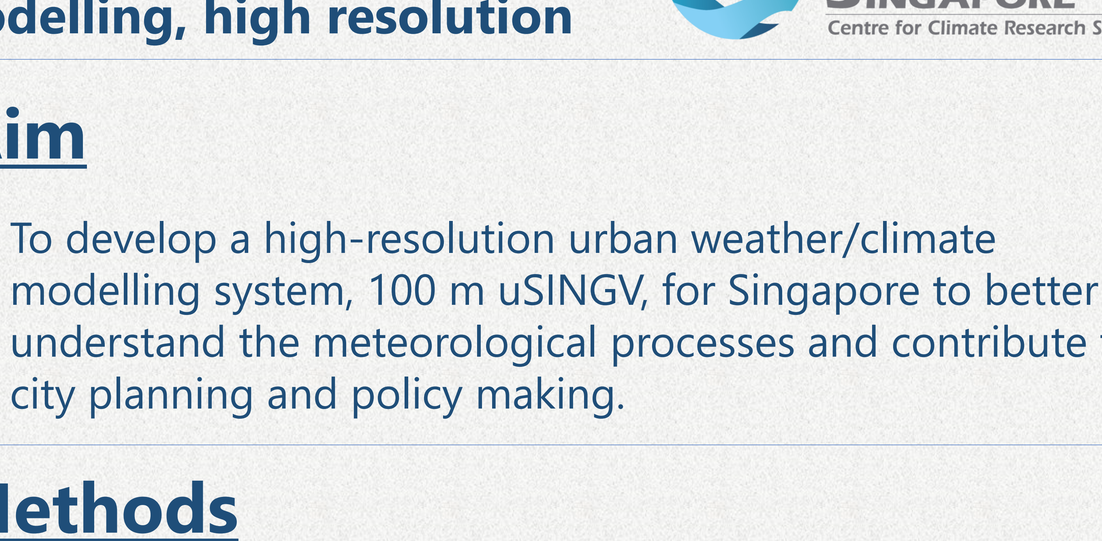

Figure 1. About 100 m uSINGV: nested domain configuration

- An urban canopy model, MORUSES, is implemented to account for the effects from buildings, canyons, and anthropogenic heat (AH) in cities.
- uSINGV takes in the updated local datasets in Singapore and the region for Land Use/Land Cover, urban morphology, and AH, as shown in Fig. 2.
- Tunes model physics (e.g., boundary layer, turbulence, and cloud microphysics) for the deep tropics.

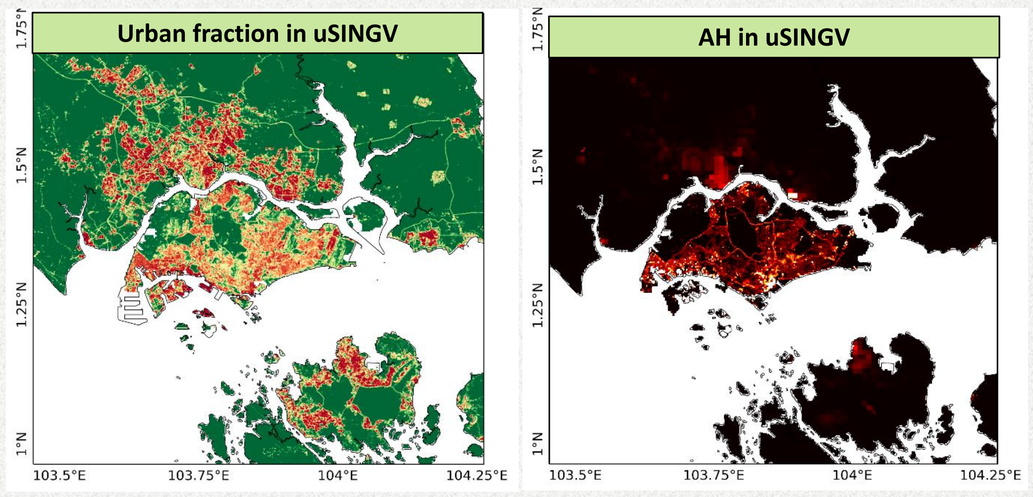

Figure 2. Local datasets used in 100 m uSINGV: urban fraction (left) and anthropogenic heat (right)

Conclusions

- A high-res urban weather and climate modelling system, 100 m uSINGV, is developed at CCRS for Singapore.
- 100 m uSINGV can capture key fluxes that drive the atmospheric physical processes, better represent fine-scale features in cities, and show good agreements with observations on meteorological parameters.
- Applications of 100 m uSINGV on extreme heat and rainfall days (and more cases) are on-going.

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