100m uSINGV modelling of the Record-Breaking Extreme Heat in Singapore on May 2023

SCIENCE OF CITIES SYMPOSIUM

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High-resolution model, uSINGV, urban climate, extreme heat

BACKGROUND

- Increasing urbanization can significantly alter the land surface-atmosphere heat and water fluxes and the dynamics of atmospheric boundary layer.
- Extreme hot days are among the most significant climatic stressors for public health, economies, energy consumption, and ecosystems.
- A record-breaking extreme hot day in Singapore occurred on 13th May 2023, reaching 37 degrees at Ang Mo Kio.

RESEARCH GAP

- The intricate interactions of nature and urban environments in shaping extreme heat events in Singapore tropical cities is less studied.

AIM

- To better understand the extreme heat event on May 2023 using the CCRS/MSS developed high resolution urban modelling system, 100m uSINGV, with latest updated local datasets and finely tuned model physics.

METHODS

Simulations are conducted on 13th May 2023

- Urban-scale uSINGV with two physics configurations (RA2T and RAL3); three nested domains (D1-1.5km, D2-300m, and D3-100m) are shown in **Fig. 1**.
- Model for Prediction Across Scales (MPAS) developed by NCAR, one domain with 3km resolution shown in **Fig. 2**.
- Observation data from weather stations, radiosonde, and wind profiler are used for model evaluation.
- Location of the stations is shown in **Fig. 3**.

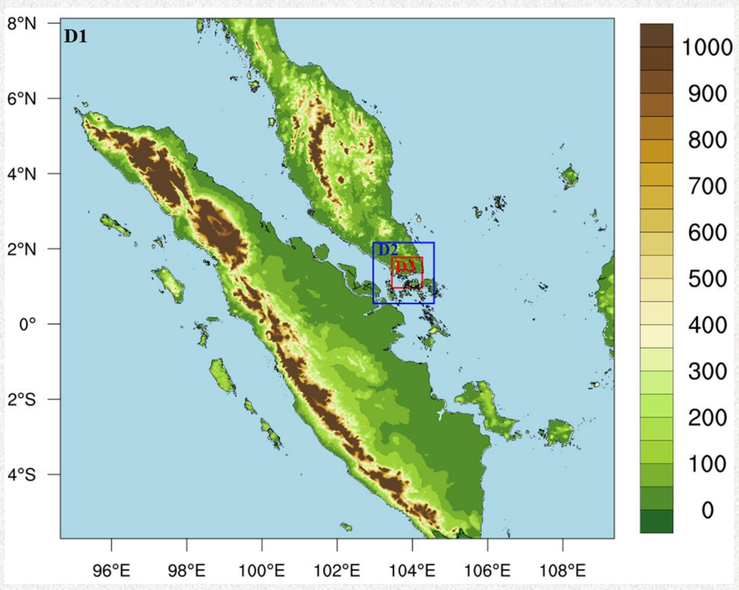

Figure 1. Topography and uSINGV domains

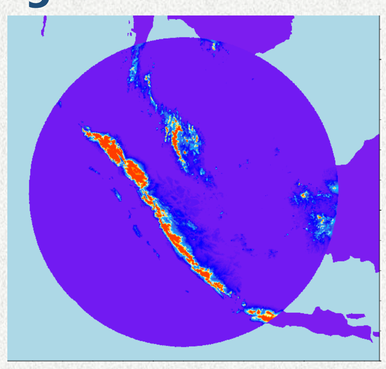

Figure 2. Topography and MPAS domain

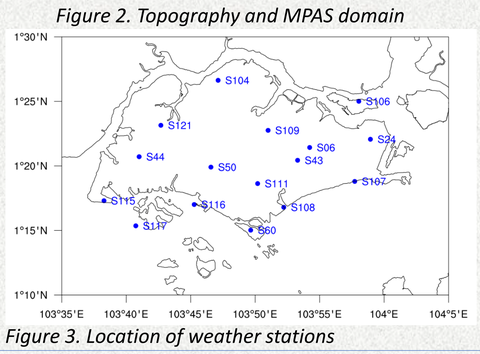

Figure 3. Location of weather stations

FINDINGS

- Near surface temperatures from different models, **Figs. 4, 5, 8;** near surface temperatures from stations, **Fig. 5**.
- Winds from model and stations, **Fig. 6**.
- Land surface temperature from satellite, **Fig. 7**.
- Model data vs radiosonde, **Fig. 9**.
- Compared to 1.5km-resolution SINGV, the 3km-resolution MPAS simulations show lower air temperatures (see Figs 4 and 8), potentially due to differences in, e.g., model physics, land scheme, land-use data, soil-moisture initialization and lack of urban representation in MPAS.

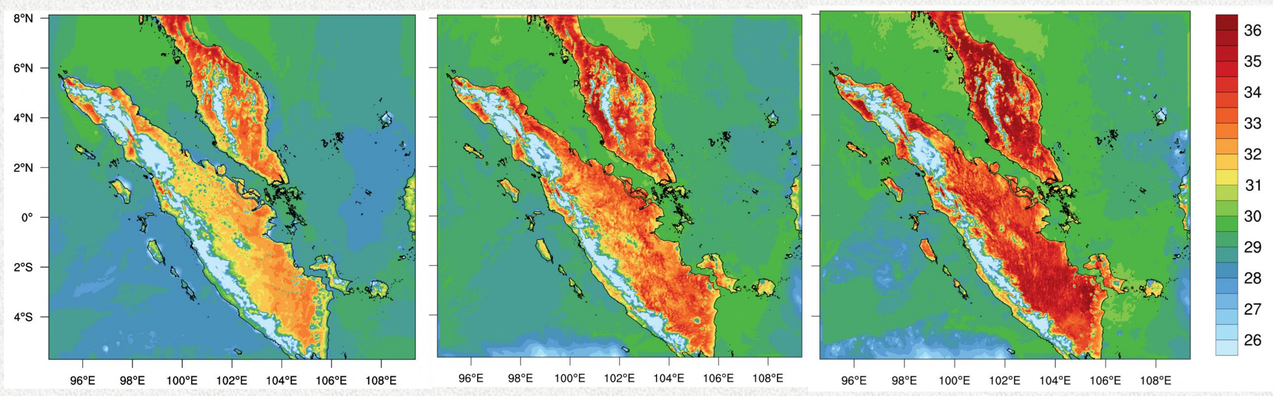

Figure 4: *2m air temperature (°C) for 3km MPAS model (left), 1.5m air temperature (°C) for 1.5km SINGV_RA2T model (middle), 1.5m air temperature (°C) for 1.5km SINGV_RAL3 model (right) at 3:00pm (local time), and land surface temperature from MODIS at 1:30pm (local time) on May 13th, 2023.*

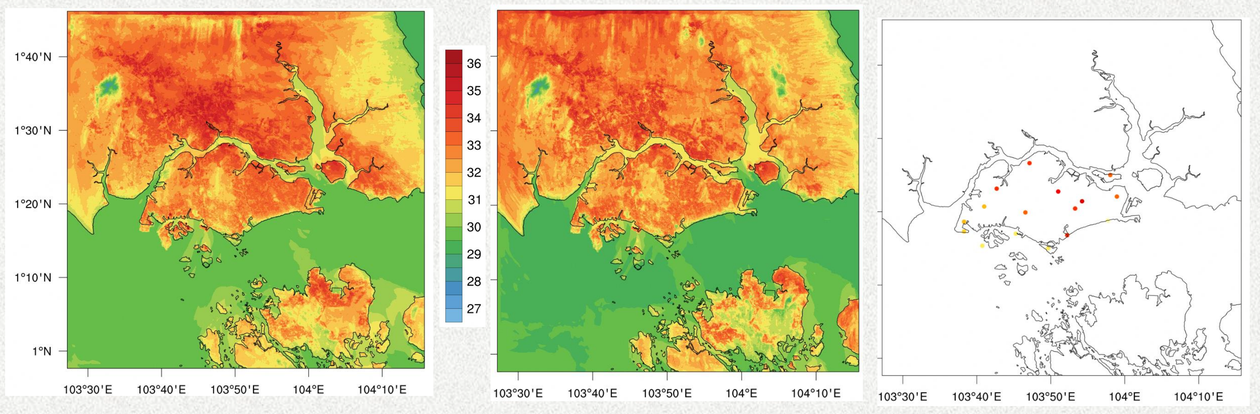

Figure 5: *1.5m air temperature (°C) for 100m uSINGV_RA2T model (left), 100m uSINGV_RAL3 model (middle) and observed data at 3:00pm (local time) on May 13th, 2023.*

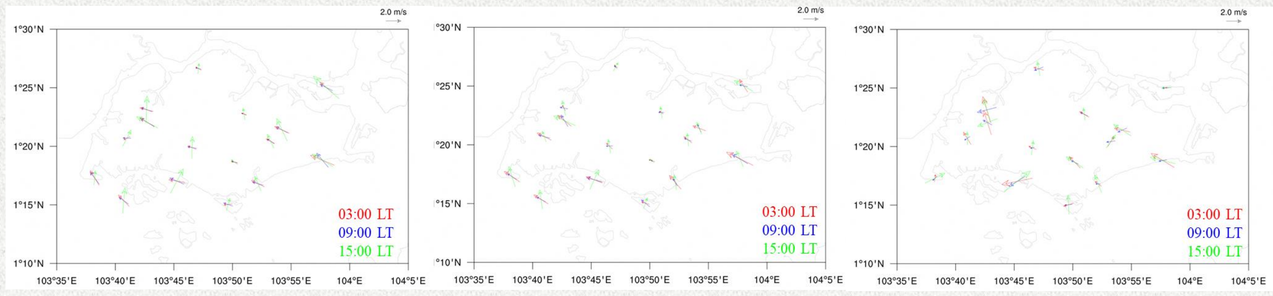

Figure 6: *10m wind speed and direction for 100m uSINGV_RA2T model (left), 100m uSINGV_RAL3 model (middle) and observed data at 3:00am, 9:00am and 3:00pm (local time) on May 13th, 2023.*

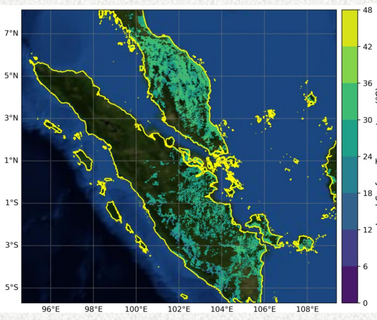

Figure 7: *land surface temperaturer from Modis at 1:30pm on May 13th 2023*

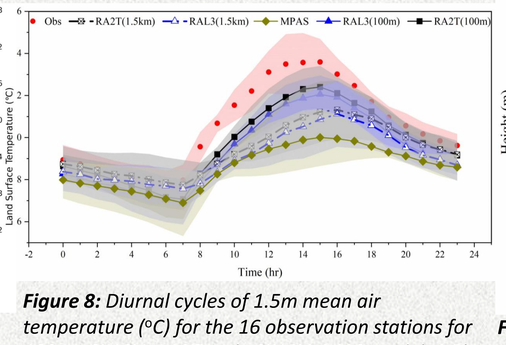

Figure 8: *Diurnal cycles of 1.5m mean air temperature (°C) for the 16 observation stations for 100m uSINGV_RA2T and uSINGV_RAL3 model, 1.5km SINGV_RA2T and SINGV_RAL3 and 2m air temperature (°C) for MPAS model.*

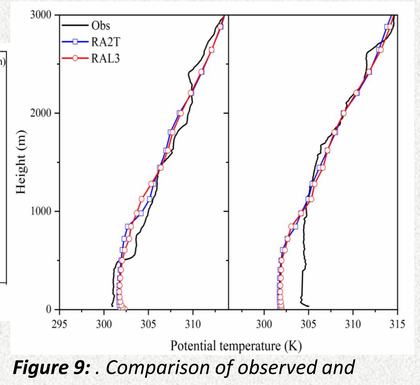

Figure 9: *. Comparison of observed and simulated vertical profiles of potential temperature (K) at 8:00am (left) and 8:00pm (right) (local time) on May 13th 2023.*

CONCLUSIONS

- MPAS shows substantial differences from SINGV models, further investigation of the causes of these differences is needed for future study.
- Overall, 100m uSINGV is able to produce reliable simulations.
- These studies are part of our pathway to the SINGV_NG development, informing us research priorities and can provide guidelines for climate resilience strategies in other tropical urban environments.

Future applications

- Understand the drivers of the differences between the models for the heatwave simulations by comparing uSINGV with different physics (RAL2, RAL3) and MPAS.
- Use the models to explore the domain dynamics driving the extreme heat events in Singapore.
- The results and findings from this study can provide guidelines for climate resilience strategies in tropical environments.

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