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Development of Small-Scale WRF "Urban" Model for Educational and Research Purposes

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1 Background

Weather Research & Forecasting Model (WRF) is a meso-scale weather model with many potential uses for urban plannings when coupled with urban parameters [2].

Currently, many computational resources are widely available with relatively low price, e.g. mini PC. WRF is also now easily accessible using Linux subsystem on Windows operating system. However, the average size and computational power required for the model limits its use to only inside a large-scale server.

Thus, this research focuses on exploring a WRF model for servers with limited computational power, and potentially apply to new kinds of research and educational context, such as testing various idealized condition, parameters analyses, or hands-on experiment.

2 Methodology

Using Minisforum UM690 with Ubuntu Server 24.04.01 LTS, WRF version 4.6.0 and its pre-processing system are compiled with urban parameters [1] using GCC compiler. A python script is then used for modifying `geo_em.d*`, `met_em.d*`, `wrfbdy_d*`, and `wrfinput_d*` files to create a custom idealized simulation scenario.

An *Urban Grassland* case is used for Anthropogenic Heat Emission (AHE) sensitivity analysis, which is a 200 km×200 km urban grid in the middle of 1 000 km× 1 000 km grassland area. An initial and boundary condition are averaged across each height. A simulation is ran for 2 simulation days with a time step of 30 seconds. `wrf-python` module is then used for visualizing results.

3 Results & Discussion

The current WRF model in this experiment is able to run on a small-scale personal computer, with time spent on each simulation varying from 30 minutes to 2 hours depending on the number of simulation and time step, and approximately 1.5 gigabytes of memory used per simulation.

Two-meter air temperature (`T2`) is analyzed for different heat emission, removing the spin-up time of the first day, which has the following results shown in Figure (1) and (2).

The resulting relation of heat emission and air temperature shows a nonlinear trend, which agrees well with a similar experiment conducted by Wang et. al. [3], which is potentially caused by multiple factors such as heat convection or cloud formation.

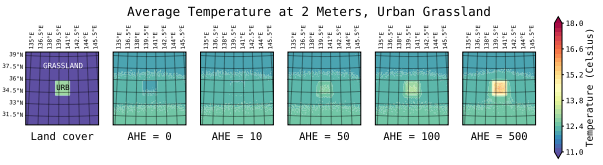

Figure 1: (Left) Land use of Urban Grassland scenario. (Right) Contour plot of average `T2` across March 10-11, 2025 for different AHE values.

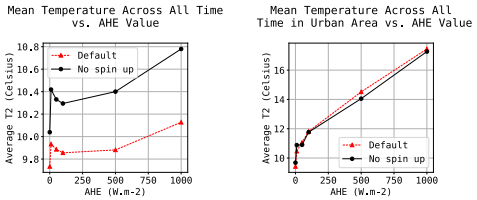

Figure 2: Line plot of average `T2` across all time (red) and with spin-up time removed (black) for different AHE values

4 Conclusion

The model can perform well in an environment with limited resources, and achieve an interpretable results within an hour. It also shows a potential use case for sensitivity analyses in idealized cases as shown in heat emission vs. air temperature analysis of Urban Grassland scenario.

Acknowledgements

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