Convection-Permitting Model Simulation based on Local Climate Zones (LCZs) for winter in Istanbul

Kwok P. Chun[1*], Ping Yu Fan[2], Qing He[3], Omer Yetemen[4], Emir Toker[4], Yasemin Ezber[4] and Omer Lutif Sen[4]

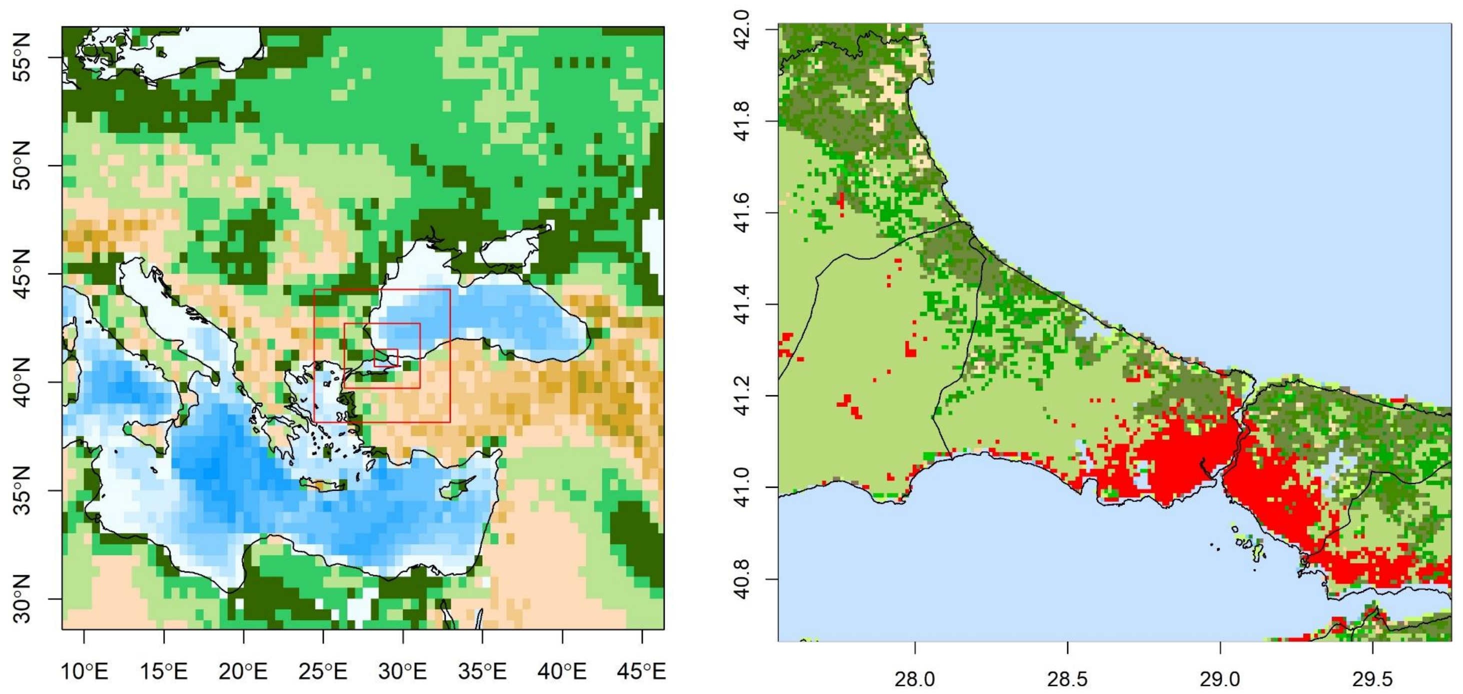
1. Department of Geography and Environmental Management, University of the West of England, 2. Department of Geography, Hong Kong Baptist University, 4. MOE Key Laboratory of Fundamental Physical Quantities Measurement & Hubei Key Laboratory of Gravitation and Quantum Physics, PGMF and School of Physics, Huazhong University of Science and Technology, Wuhan, China, and 4. Eurasia Institute of Earth Sciences, Istanbul Technical University

**kwok.chun@uwe.ac.uk*

Introduction

Convection-permitting models (CPMs) with high resolution simulations at kilometre scales open new avenues for investigating the dynamics of urban regions related to intensification of thermal conditions and extreme rainfall that do not rely on deep convection parameterisation schemes. As a pilot study, a sensitive study of Weather Research and Forecasting (WRF) models was conducted in Istanbul during a winter week to investigate the relationships between thermal conditions and urban surface representation based on 11 types of Local Climate Zones (LCZs). Three considered surface schemes were the single-layer Urban Canopy Model (UCM), the Building Environment Parameterization (BEP), and the Building Energy Model (BEM).

Figure 1: Simulation domains indicating urban areas

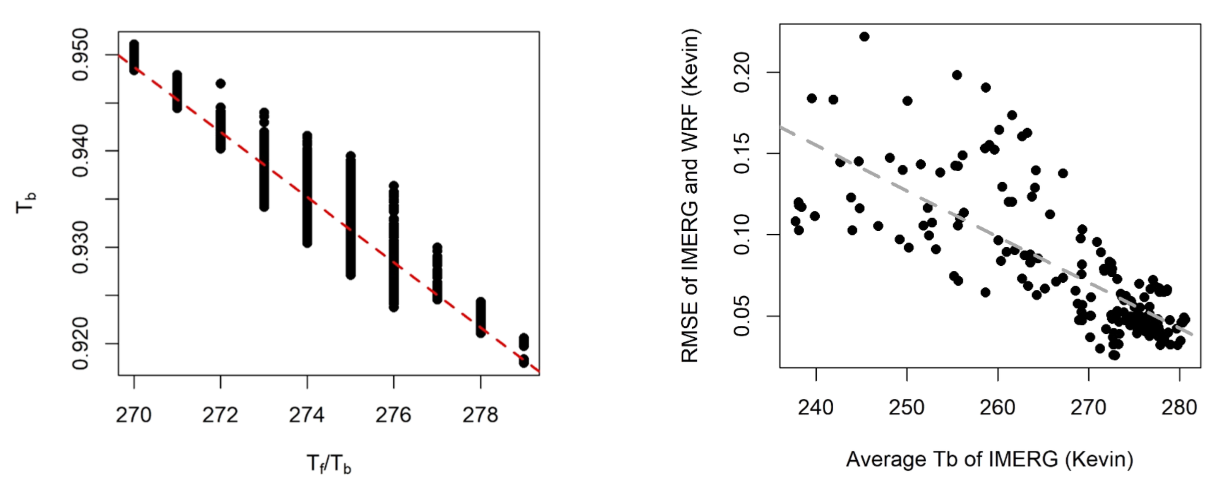


The brightness temperature (T_b) of Integrated Multi-Satellite Retrievals for GPM (IMERG) was used to evaluate the WRF simulation performance. In Yang and Slingo (2001), the brightness temperature T_b of the observed window is related to the flux equivalent brightness temperature T_f.

$$\frac{T_f}{T_b} = a + bT_b$$

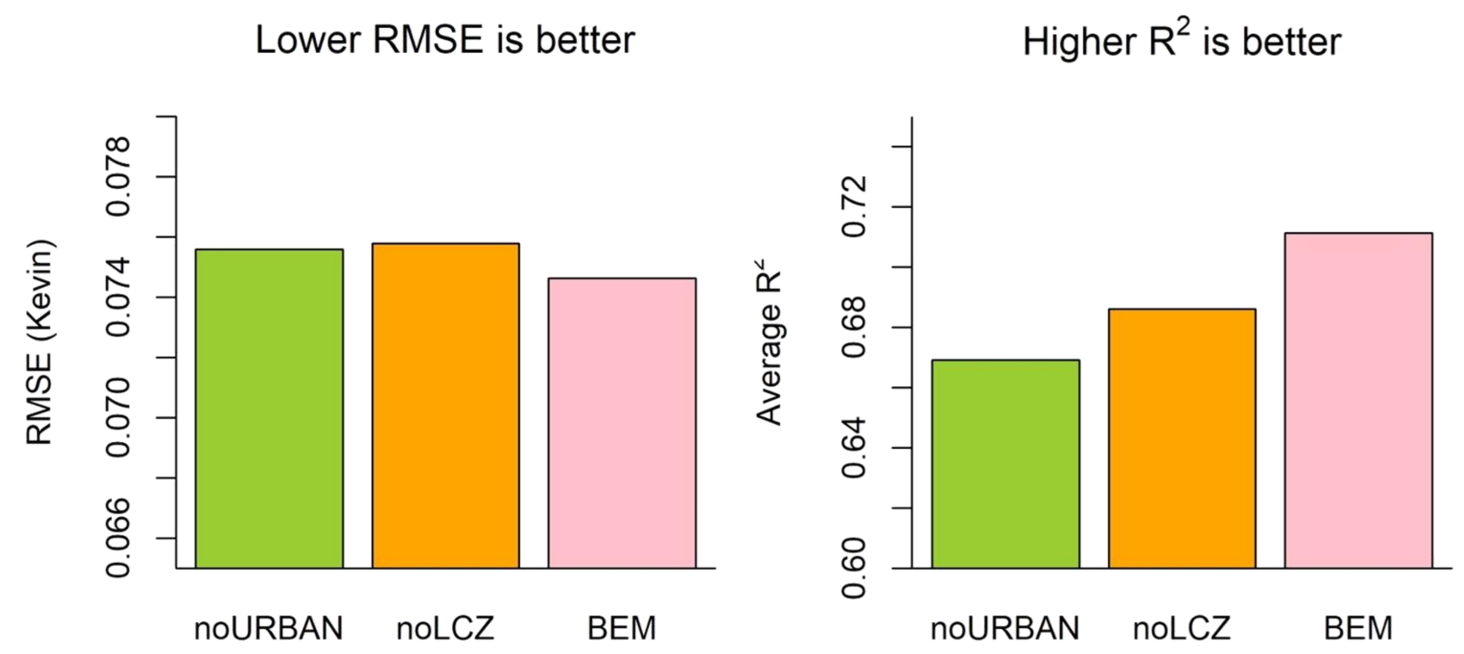
where a and b are regression constants. The computed WRF T_b match the IMERG T_b well.

Figure 2: Brightness temperature (T_b) comparison



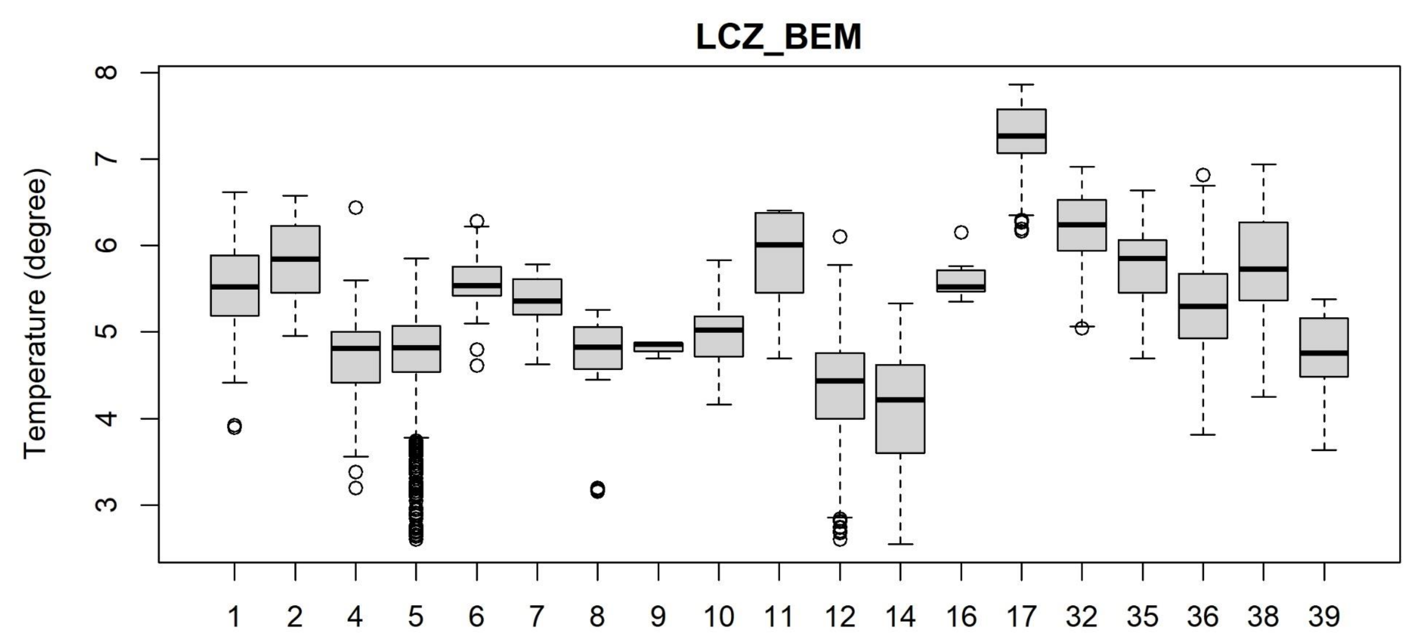
Results

Figure 3: Comparison of experimental schemes



The BEP scheme, as opposed to the single-layer UCM scheme, had a more realistic multi-layer representation that includes a roughness sublayer in addition to the single urban canopy layer. The BEM scheme was an extension of the BEP scheme that included additional heating/AC effects to provide more realistic thermal effects from buildings. Furthermore, the differences between the three schemes and the default urban run (noLCZ UCM) were used to investigate specific LCZ effects. Based on the IMERG data, the performance of the three surface schemes was comparable, despite the fact that the overall BEM model performed slightly better than the other two schemes in terms of correlations and root mean square errors.

Figure 4: Temperature differences among LCZs

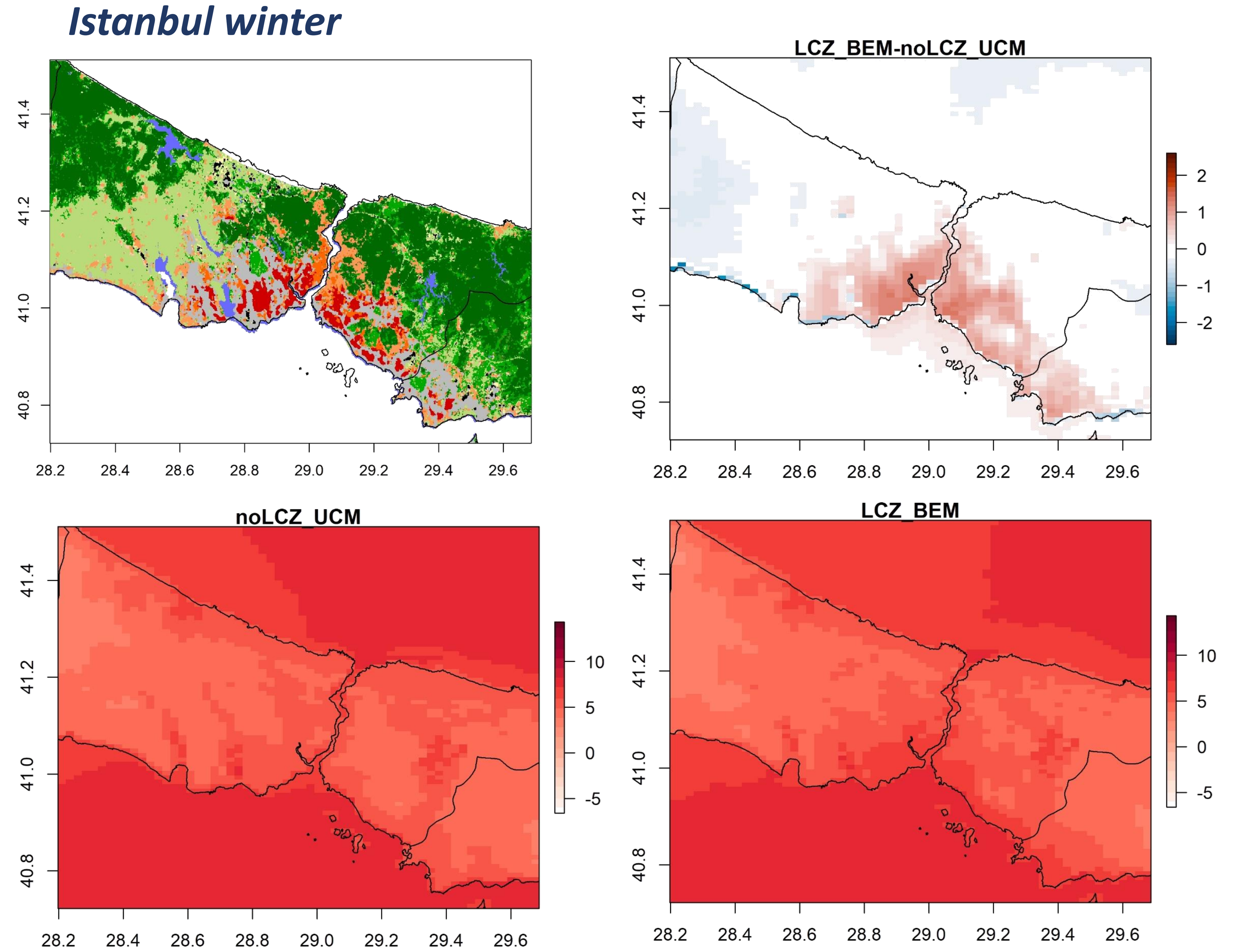


1	M01	Evergreen Needleleaf Forests	10	M10	Grasslands	31	LCZ 1	Compact Highrise
2	M02	Evergreen Broadleaf Forests	11	M11	Permanent Wetlands	32	LCZ 2	Compact Midrise
3	M03	Deciduous Needleleaf Forests	12	M12	Croplands	33	LCZ 3	Compact Lowrise
4	M04	Deciduous Broadleaf Forests	13	M13	Urban and Built-up Lands	34	LCZ 4	Open Highrise
5	M05	Mixed Forests	14	M14	Cropland/Natural Vegetation Mosaics	35	LCZ 5	Open Midrise
6	M06	Closed Shrublands	15	M15	Permanent Snow and Ice	36	LCZ 6	Open Lowrise
7	M07	Open Shrublands	16	M16	Barren	37	LCZ 7	Lightweight lowrise
8	M08	Woody Savannas	17	M17	Water bodies	38	LCZ 8	Large lowrise
9	M09	Savannas				39	LCZ 9	Sparsely built
						40	LCZ10	Heavy industry
						41	LCZ E	Bare rock or paved

Our findings show that evergreen regions are warmer than deciduous regions, and bodies of water and permanent wetlands serve as winter heat reserves. As a result, the area with more "active" vegetation or water is warmer. When the LCZ classes are used in simulations, the relative positions of urban and non-urban classes do not differ from the default MODIS urban class. As a result, additional LCZ-based land use definitions only provide refined spatial details in the default MODIS urban classes by redistributing energy within the area.

Discussion & Conclusions

Figure 5: Temperature simulation and difference fields for the Istanbul winter



Based on the relative locations between LCZ types, compact midrise zones (LCZ 2) have a higher temperature than open midrise zones (LCZ 5). The coldest urban zones are those with few buildings (LCZ 9), whereas the warmest locations are large lowrise zones (LCZ 8). Using the pilot results, a full set of experiments for different seasons is planned to investigate how regional thermal comfort resilience will be promoted for specific LCZ configurations in Istanbul for the emerging challenge of climate change.

Reference: Yang, G.Y. and Slingo, J., 2001. The diurnal cycle in the tropics. Monthly Weather Review, 129(4), pp.784-801.

Acknowledgement: The corresponding author is the awardee of the Accelerator Programme (AP) 2022–24 in the University of the West of England (UWE), Bristol.