Investigating links among heatwaves, precipitation, and land use types using the Convection-Permitting Model in the Southwest UK for the 2022 boreal summer EGU23-9500

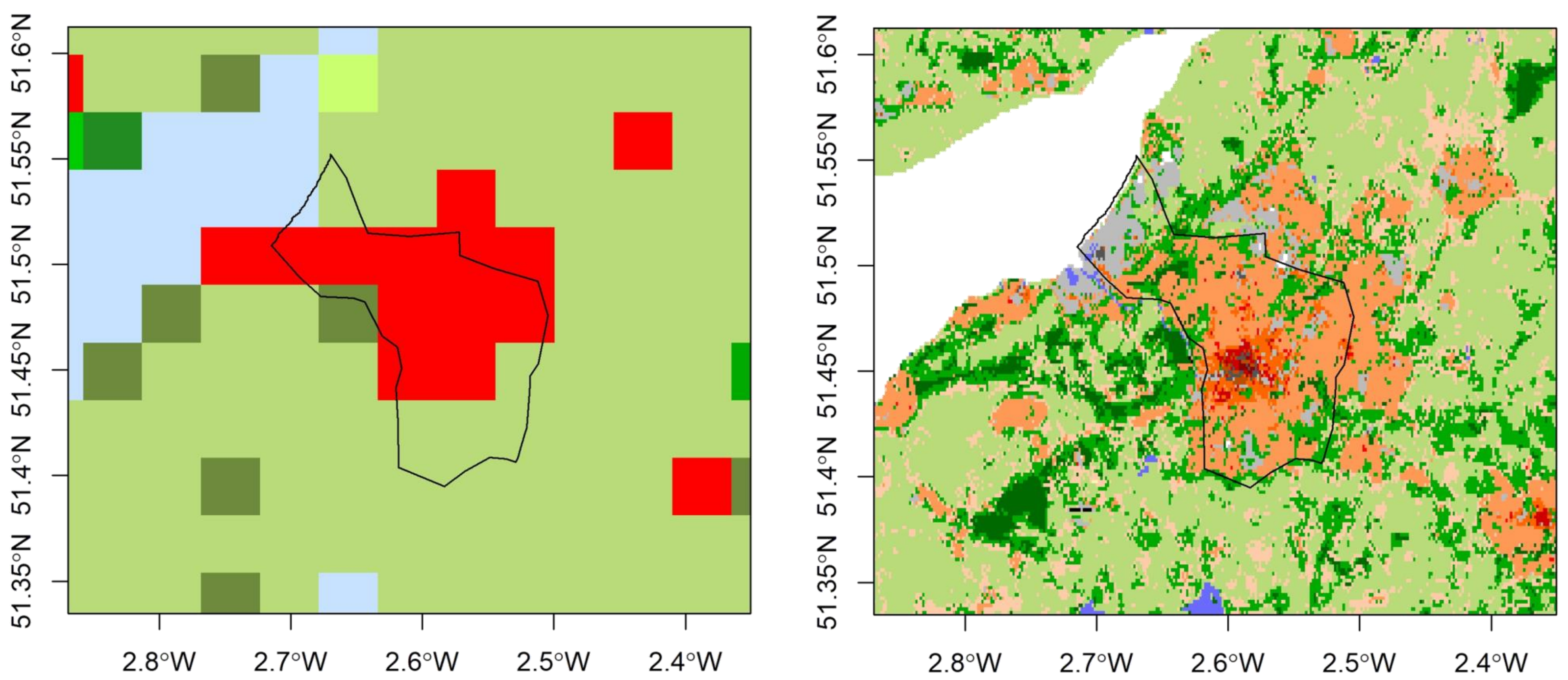
K. P. Chun[1*], Y. Ezber[2], E. Toker[2], M. Reboita[3], R. Rocha[4], B. Risanto[5], O. Yetemen[2], T. Octavianti[1], N. Quinn[1], O. Sens[2], and C. Castro[5]

1. Department of Geography and Environmental Management, University of the West of England, 2. Eurasia Institute of Earth Sciences, Istanbul Technical University
*3. Federal University of Itajubá, 4. University of Sao Paulo, 5. Department of Hydrology and Atmospheric Sciences, University of Arizona *kwok.chun@uwe.ac.uk*

Introduction

In the summer of 2022, a heatwave and severe drought caused new concern over water security in Europe. Global initiatives have produced convection-permitting model (CPM) outputs with a resolution of less than 10 kilometres for multiple decades to enhance sub-seasonal forecasts. However, these simulations are based solely on a single urban type. Local Climate Zones (LCZs) provide more detailed information on the density and height of the urban canopy. Using LCZ information at a kilometre scale to drive CPMs opens up new possibilities to investigate the dynamics among temperatures, precipitation, and land use types during the 2022 hydroclimate extreme events in the Southwest UK.

Figure 1: Land use maps indicating urban areas

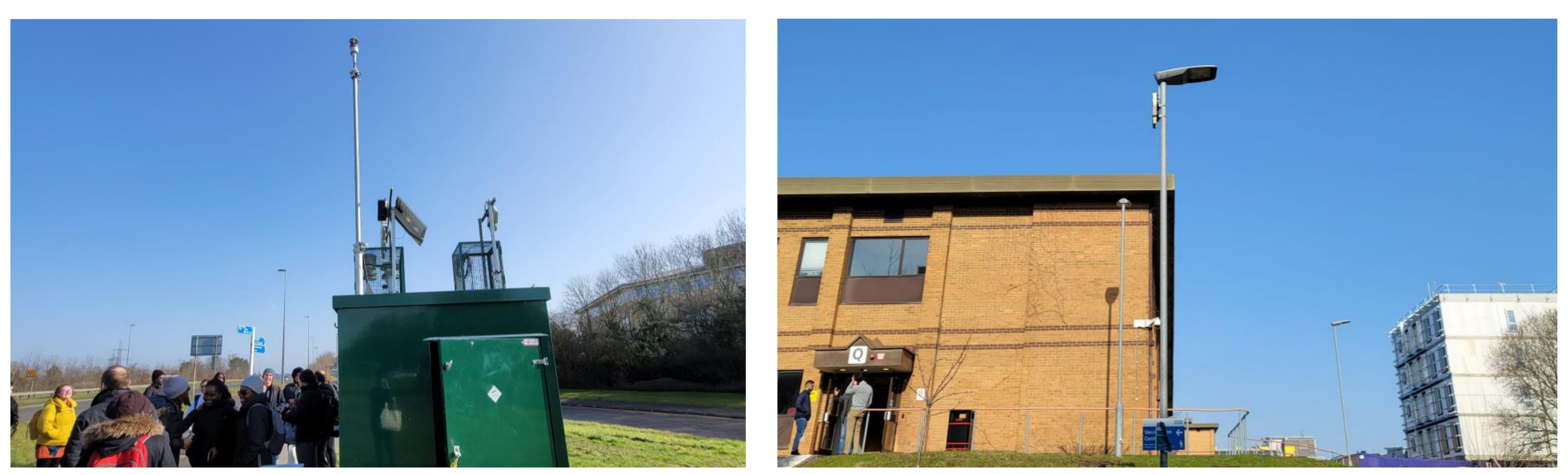


The Quasi-Geostrophic (QG) Omega Equation based on the vorticity and thermal advections

$$\left(\nabla^2+\frac{f_0^2}{\sigma}\frac{\partial^2}{\partial p^2}\right)\omega=\frac{f_0}{\sigma}\frac{\partial}{\partial p}\left[\vec{V_g}\cdot\nabla\left(\frac{1}{f_0}\nabla^2\phi+f\right)\right]+\frac{1}{\sigma}\nabla^2\left[\vec{V_g}\cdot\nabla\left(-\frac{\partial\phi}{\partial P}\right)\right]$$

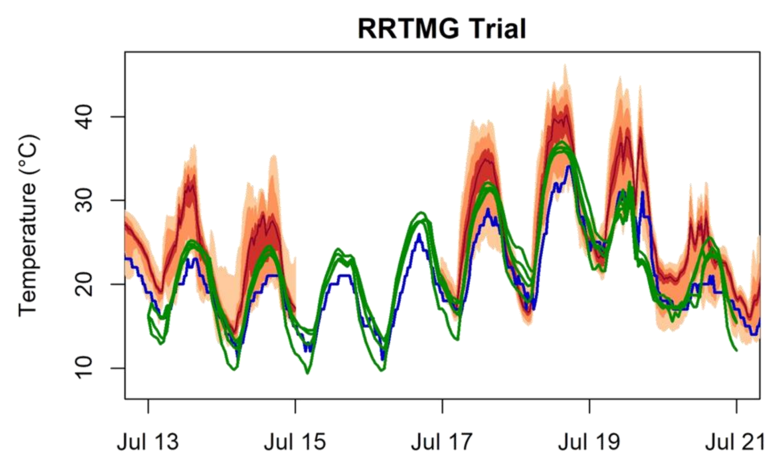
where $\frac{f_0}{\sigma}\frac{\partial}{\partial p}\left[\vec{V_g}\cdot\nabla(\frac{1}{f_0}\nabla^2\phi+f)\right]$ is the differential vorticity advection term and $\frac{1}{\sigma}\nabla^2\left[\vec{V_g}\cdot\nabla(-\frac{\partial\phi}{\partial P})\right]$ is the thermal advection term

Figure 2: Sensor networks on campus and South Gloucestershire



Results

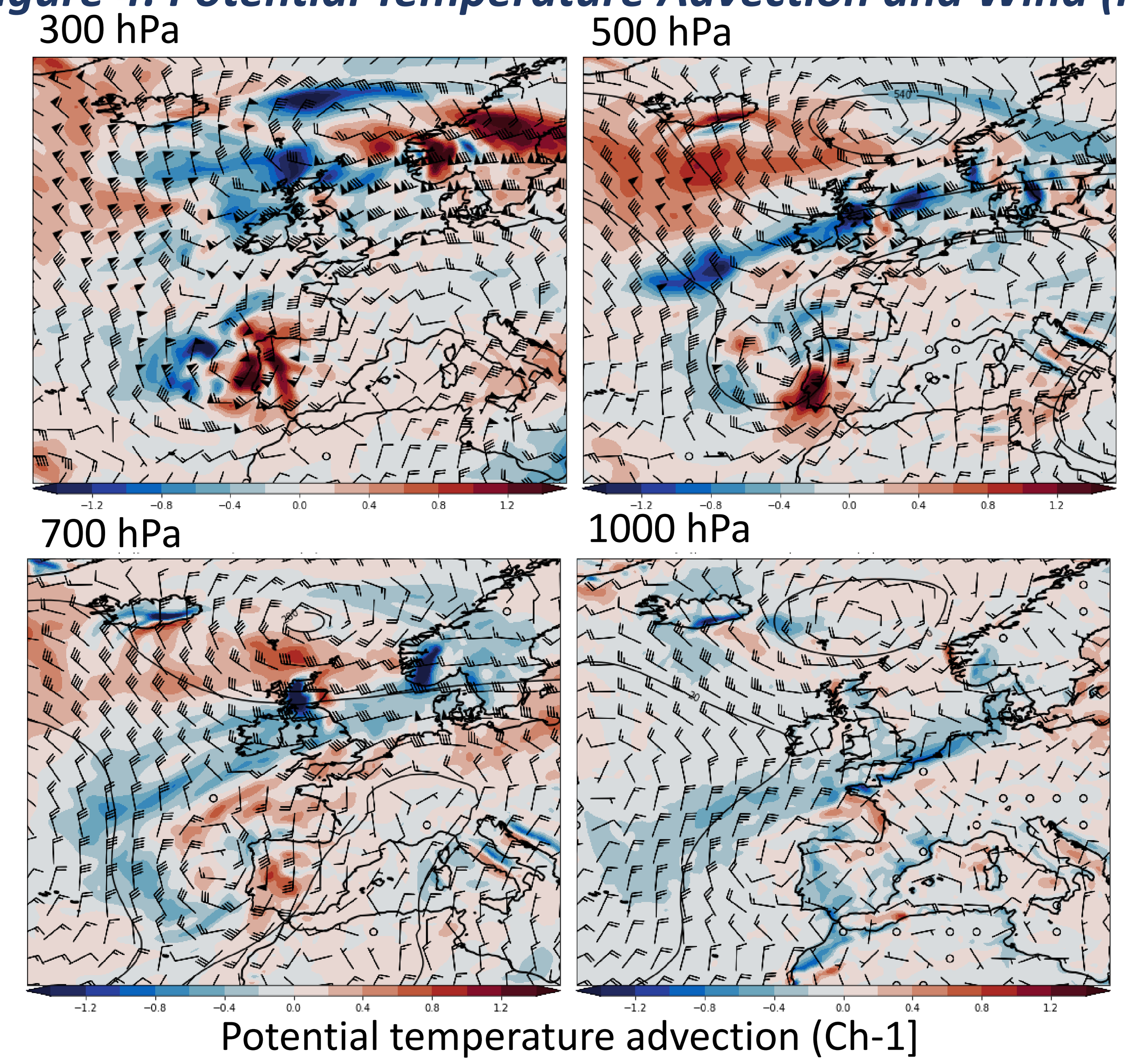
Figure 3: Comparison of observations and simulations



Measurement Experiment	RMSE	Correlation
Sensor	4.91	0.90
Default	2.81	0.93
BEP	2.46	0.93
BEM	2.68	0.93
NoUrban	2.96	0.89

This study conducted four numerical experiments using Weather Research and Forecasting (WRF) models with a 3 km grid resolution under the following scenarios: (i) no urban, (ii) default MODIS land use, (iii) building environment parameterization (BEP), and (iv) building energy model (BEM). In all experiments, the deep-convection parameterization was turned off to assess the convection effect on precipitation and temperature more realistically. The results were validated using the UMBRELLA sensor network measurements between the University of the West of England and Bath Science Park in collaboration with the South Gloucestershire Council and data from a weather station in Bristol. The numerical simulations of temperature fields agree with the data obtained from the weather station. Moreover, the simulated CPM time series fall within the bounds of the measurement distribution from 123 sensors.

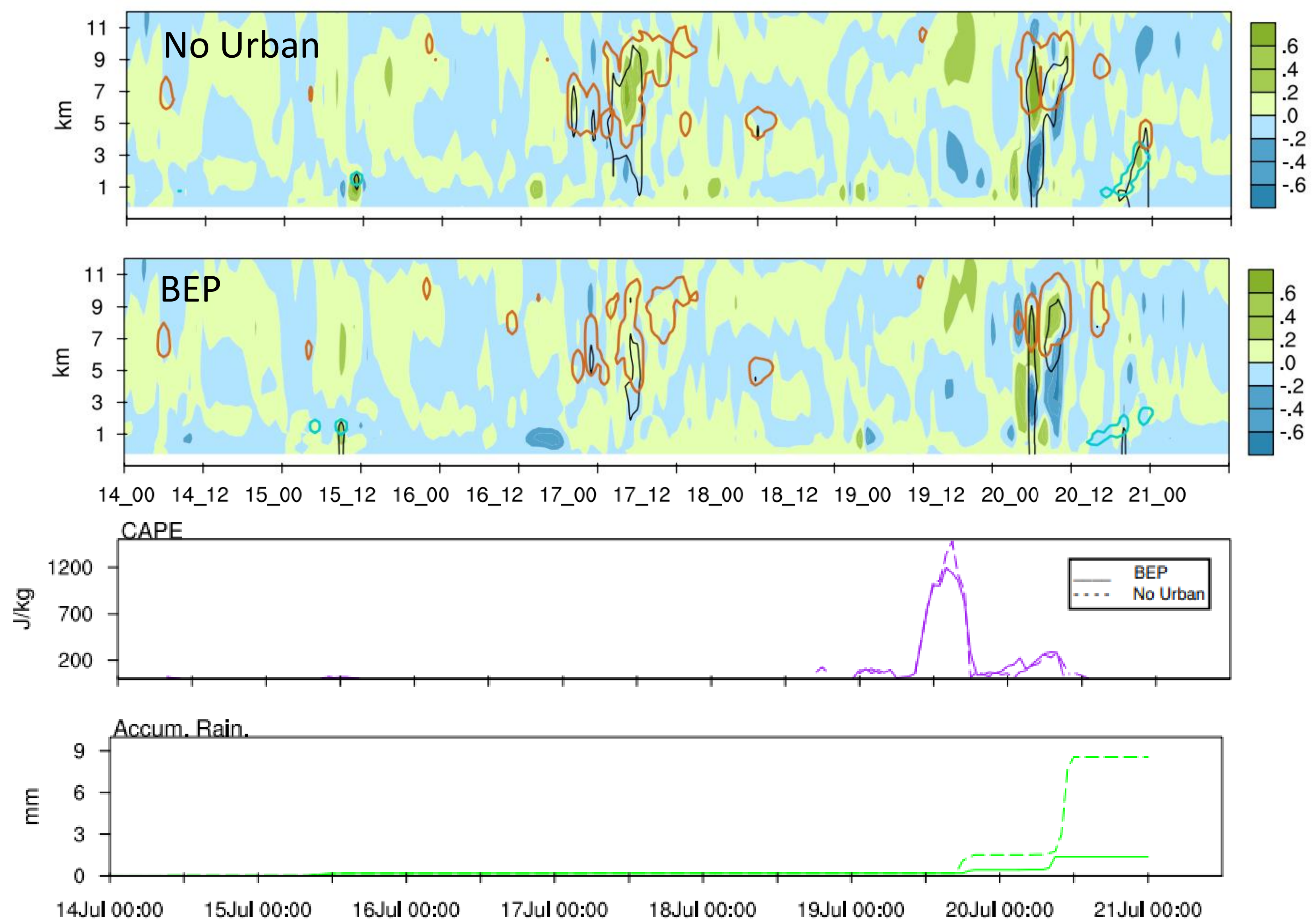
Figure 4: Potential Temperature Advection and Wind (kt)



A Q-vector analysis suggests that the cold advection over the UK caused downward motion, leading to the formation of a heat dome during the 2022 summer heatwave. This is contrary to the hypothesis that the heatwave was due to the hot circulation from Spain and equatorial Africa. Four experiments were conducted to study the impact of land use on water recycling during the dissipating stage of the heatwave. Results show that land use types have varying effects on local convection, which affects water recycling. Investigating land use types is shown to be crucial in hydroclimatic modelling for predicting the 2022 heatwave dissipation and associated precipitation patterns.

Discussion & Conclusions

Figure 5: Cloud ice mixing ratio (0.2 g/kg intervals), CAPE (J/kg) and Accumulated rain (mm)



The findings of this study indicate that urban areas experienced more prolonged heatwaves and weaker rainstorms, as local water recycling was affected. By considering the impact of land use types on water recycling, more effective strategies to mitigate the impact of heatwaves can be formulated by using sensor networks with local communities to reduce the climate risk in urban areas for Sustainable Develop Goal 13.

Acknowledgement: The corresponding author is the awardee of the Accelerator Programme (AP) 2022–24 in the University of the West of England (UWE), Bristol. This study is also supported by his starter programme. The analysis method is developed from the Royal Scoeity International Exchanges 2022 scheme (IEC\NSFC\223132). The UMBRELLA team of South Gloucestershire council provides the sensor network data.