EGU24-21451, updated on 20 May 2024
https://doi.org/10.5194/egusphere-egu24-21451
EGU General Assembly 2024

On the modification of neighbourhood-scale atmospheric dispersion within urban morphologies by the buoyancy effect - a CFD study

Ka-Ming Wai[1,2] and Chao Yuan[1,2]
[1]Singapore-ETH Centre, Future Resilient Systems, Singapore
[2]Department of Architecture, College of Design and Engineering, National University of Singapore, Singapore

Extreme weather conditions associated with climate change could impact urban living in many ways. These conditions include flooding caused by extreme rainfall events and tidal surges caused by super tropical cyclones. Among these weather extremes, the extreme regional calm wind condition (ERCWC or weak synoptic forcing condition) relevant to air pollution has been less studied. Meanwhile, current urban planning guidelines for air quality consider only prevailing weather conditions without taking extreme weather into account. The current computational fluid dynamics (CFD) study examines urban air pollution dispersion under the influence of urban heat associated with ERCWC. First, our large-eddy simulation (LES) turbulent model results were validated with the results of the ETH Zürich Atmospheric Boundary Layer Water Tunnel experiment. We then examined the simulated airflow patterns and dispersion patterns inside representative urban parametric models. The National Supercomputing Centre Singapore provided all computing resources for our simulations. The adopted parametric models were developed based on urban density analysis to reflect the real urban morphology of Singapore. The models consist of nine building clusters, each containing 24 generic building blocks. The study compared the prevailing wind scenario with calm scenario driven by buoyancy. Inlet boundary conditions for the former and latter scenarios were determined by using the annual-average wind velocity measured at an urban weather station and zero wind velocity, respectively. In the latter scenario, ground and building surfaces were set at 5°C above ambient temperatures, which is within Singapore's measured values. There were a total of four sources of line emission in the computational domain. New insights and implications were found regarding urban air dispersion within the urban canopy layer for the buoyancy-driven scenario (the ERCWC) over the prevailing wind scenario. Wind reversal at certain areas for the buoyancy-driven scenario is an example, which leads to upwind sites to become downwind sites. We recommend upgrading the current guidelines for urban planning to improve urban resilience during extreme weather conditions by implementing mitigation measures, some of which were discussed in this study.