Geophysical Research Abstracts
Vol. 13, EGU2011-2935, 2011
EGU General Assembly 2011

Flow Pattern and Pollutant Removal Behavior for Idealized 2D Urban Street Canyons in Different Thermal Stratifications using Large-Eddy Simulation

Wai Chi Cheng (2) and Chun-Ho Liu (1)

(1) Department of Mechanical Engineering, the University of Hong Kong, Hong Kong, China (liuchunho@graduate.hku.hk / (852) 2858 5415), (2) Department of Mechanical Engineering, the University of Hong Kong, Hong Kong, China (wccheng2007@yahoo.com.hk)

Air pollution problem in urban areas affects the health of urban inhabitants. Major air pollutants in a city are emitted from vehicles at street level then disperse within the city area. Its dispersion pattern is closely related to the building-and-street configuration of the city. Besides, thermal stratification of the urban boundary layer, which mainly governs the vertical atmospheric flows, has dominant effects on the pollutant dispersion. Most previous studies have focused on different building configurations but have often overlooked the role of thermal stratification. In view of the obvious knowledge gap, the current study attempts to use computational fluid dynamics (CFD) to investigate the contribution of thermal stratification to pollutant dispersion in urban areas.

Large-eddy simulation (LES) is sought to calculate the turbulent flows and pollutant transport within and above an idealized 2D street canyon of unity building-height-to-street-width (aspect) ratio under different thermal stratification. The subgrid-scale (SGS) motions are modeled using the one-equation SGS turbulence model. Hypothetical cases of different atmospheric thermal stratification are set up by applying uniform temperature boundary conditions on the streets. Configurations of a hotter (cooler) ground surface and a cooler (hotter) free-stream prevailing flow represent unstable (stable) stratified urban atmospheric boundary layers. The buoyancy is modeled using the Boussinesq approximation. Five sets of LES, with two in slightly stable, two in slightly unstable and one in neutral stratification, are performed to investigate the turbulence characteristics and pollutant dispersion patterns.

The flow patterns in neutral and unstable stratification are similar to each other. The unstable stratification enhances the mean wind speed and turbulence within the street canyon. In stable stratification, a temperature inversion layer is developed near the ground surface that deeply suppresses the mean wind and turbulence in the street canyons. Differing from the stratified flows over a 3D obstacle array, a mild peak of turbulence intensity is developed at the center of the street canyon that could be explained by the weakened downward turbulence transport from the roof level to the ground-level leeward region of the street canyon. The pollutant concentration distribution in the street canyon is strongly correlated with the thermal stratification. Owing to the enhanced street-level mean wind and turbulence in unstable stratification, the air quality is significantly improved compared with that in neutral stratification. In contrast, under the calm wind and turbulence in stable stratification, the pollutant emitted at ground level is not effectively removed due to the weak recirculating flows and turbulence that eventually leads to locally elevated ground-level pollutant concentrations in a city.