Geophysical Research Abstracts
Vol. 15, EGU2013-1643, 2013
EGU General Assembly 2013

A Theory on the Ventilation over Hypothetical Urban Areas

Chun-Ho Liu, Chi-To Ng, and Colman C.C. Wong

The University of Hong Kong, Department of Mechanical Engineering, Hong Kong (liuchunho@graduate.hku.hk, (852) 2858 5415)

Urban roughness is one of the major factors affecting the flows and turbulence structures in the bottom of the atmospheric boundary layer (ABL). Whereas, our understanding of their relation is limited. In this paper, we attempt to examine the interaction among aerodynamic resistance (friction factor f), ventilation (air exchange rate ACH), and pollutant removal (pollutant removal rate PCH). Using the method of characteristic, analytical solution shows that the turbulent ventilation of a hypothetical urban area is directly proportional to the square root of friction factor ($ACH'' \propto f^{1/2}$) regardless of the building geometry. Next, a series of computational fluid dynamics (CFD) sensitivity tests are performed to verify the theory. In addition to the commonly employed rectangular building models, seven types of urban roughness elements, in the form of idealized building models, are tested. As a pilot study, the building models are of the same height so a roof level is easily defined across the entire hypothetical urban areas. Two configurations of passive scalar sources, ground-level-only (vehicular emission) and all-solid-boundary (heat dissipation), are employed to contrast their transport behaviors. To look into the mechanism of ventilation and pollutant removal, the ACH and PCH are partitioned into their respective mean and turbulent components. The CFD results show that both the ventilation and pollutant removal are mainly attributed to their turbulent components (over 60%). Moreover, the ACH'' and $f^{1/2}$ calculation from the CFD results agree very well with the analytical solution (correlation coefficient over 0.9). However, the pollutant and heat exhibit different removal behaviors so simple estimates using friction factor have not yet arrived. Because of the substantial aged air removal by ACH'' and its linear relation with $f^{1/2}$, it is proposed to use friction factor, which can be determined by wind tunnel experiments or mathematical modeling, as a parameterization for the (minimum) ventilation of urban areas. Additional tests for urban roughness elements of other geometries and non-uniform height are currently undertaken.