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On the Flows over Two-Dimensional Idealized street canyons with Height Variation

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Introduction

- Understanding the relationship between geometry, roughness parameters and pollutant dispersion in urban boundary layer (UBL) could help improving air quality in urban area.
- Previous study (Wong and Liu, 2012) have shows that variables used in pollutant dispersion parameterization as well as air exchange rate (ACH) in urban boundary layer (UBL) over 2D idealized street canyons with uniform building height vary with aerodynamic roughness systematically.

Methodology & Computational Domain

- Large-eddy simulation (LES) in OpenFOAM 1.7.0 (2013) is used.
- One-equation turbulent kinetic energy (TKE) conservation, Smagorinsky subgrid-scale (SGS) model and Eddy-diffusivity for SGS pollutant transport are adopt.
- Idealized 2D street canyons of building-height-to-street-width (aspect) ratio (h/b) = 1, 0.5, 0.25 and 0.125 and building height variability (BHVs) = 0.2, 0.4 and 0.6 were studied.

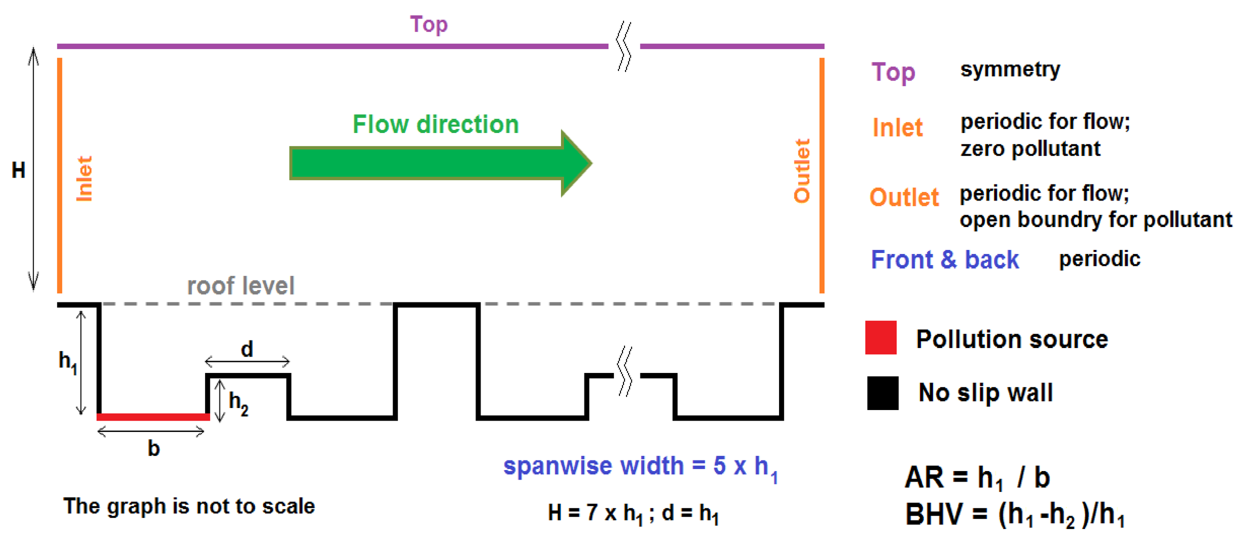
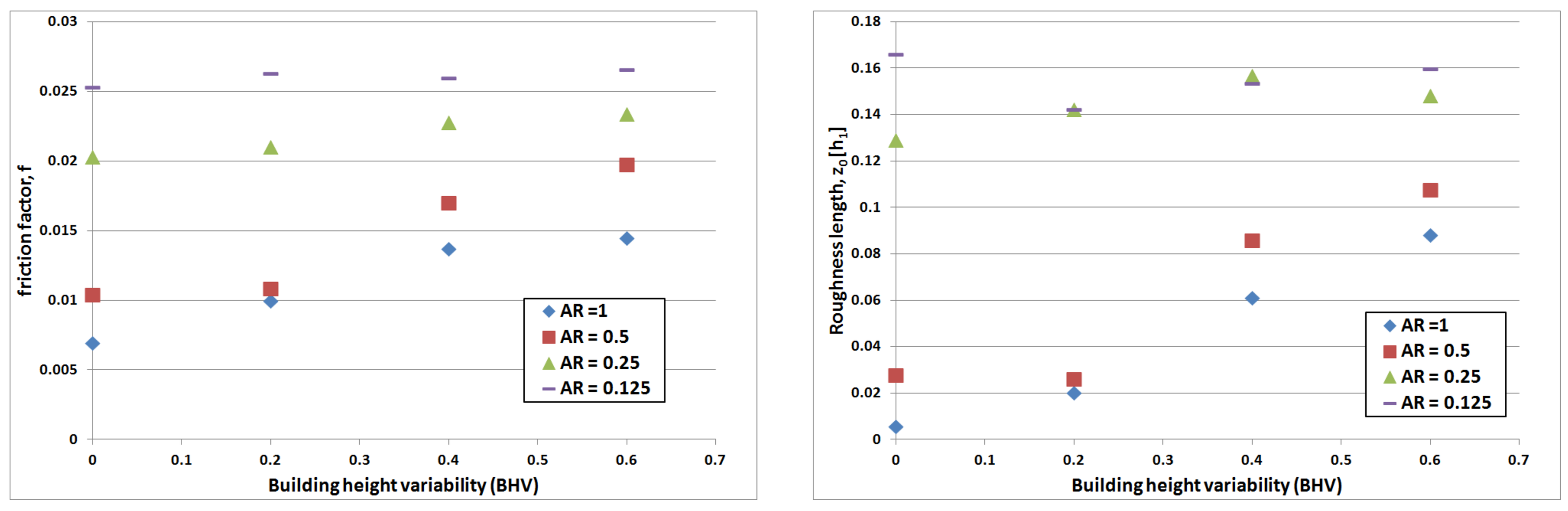


Fig. 1. Computational domain and boundary conditions

Major Findings – aerodynamic roughness

- The aerodynamic roughness, in term of friction factor (f) or roughness length (z_0), for surfaces with BHV increases with increasing street width when AR > 1/8.
- The aerodynamic roughness increase dramatically with BHV over narrow street canyon (AR > 1/4).
- The effect of BHV on roughness is less in wider street canyon (AR = 1/4) and no significant effect on aerodynamic roughness for wider canyon (AR ≥ 1/8).



(a) (b)

Fig. 2. (a) Friction factor f and (b) roughness length z_0 plotted against building height variability (BHV) for street canyons of different aspect ratio AR.

Major Findings – dispersion coefficient

- The variables (A and n) used in parameterize of vertical pollutant dispersion coefficient, $\sigma_z = A(x\text{-}x_0)^n$, over 2D street canyon with BHV vary as the same way as over 2D street canyon of uniform height that the value of A (and n) is monotonically increasing (decreasing) when the surface is smooth until the friction factor reaches a certain value (~0.15) and A and n reach a relatively constant state

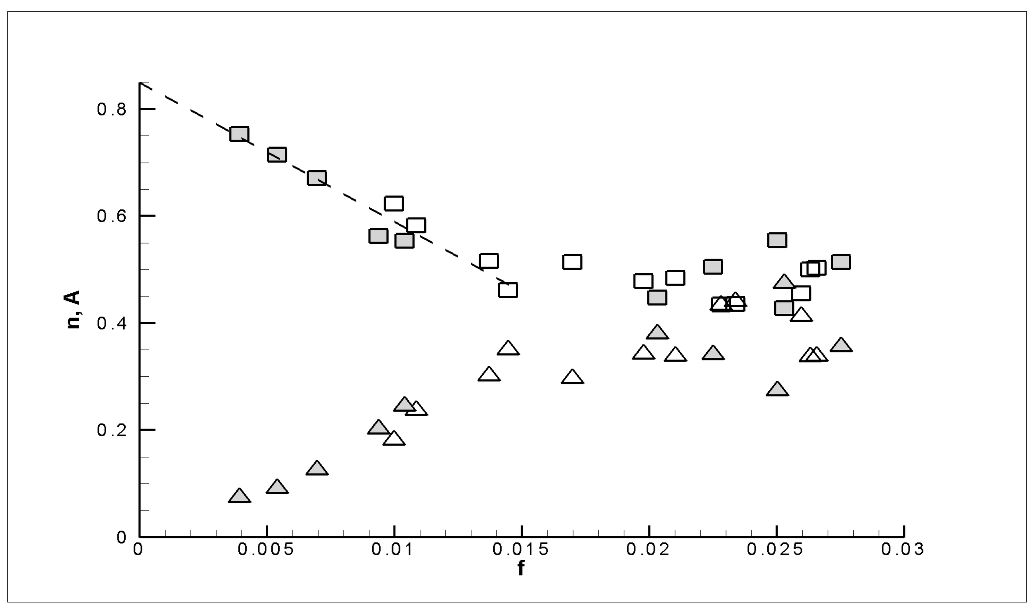


Fig. 3. Empirical coefficients in Equation 2 expressed as functions of friction factor f. A: square; n: triangle; LES over uniform street canyon: filled symbols; LES over 2D street canyon with BHV: empty symbols; The linear regression n = -26.1f +0.85 with R2 = 0.936 for f < 0:015: dashed line.

Major Findings – air exchange rate

- The normalized ACH with introduction BHV is in line with previous finding that increasing with faction factor.

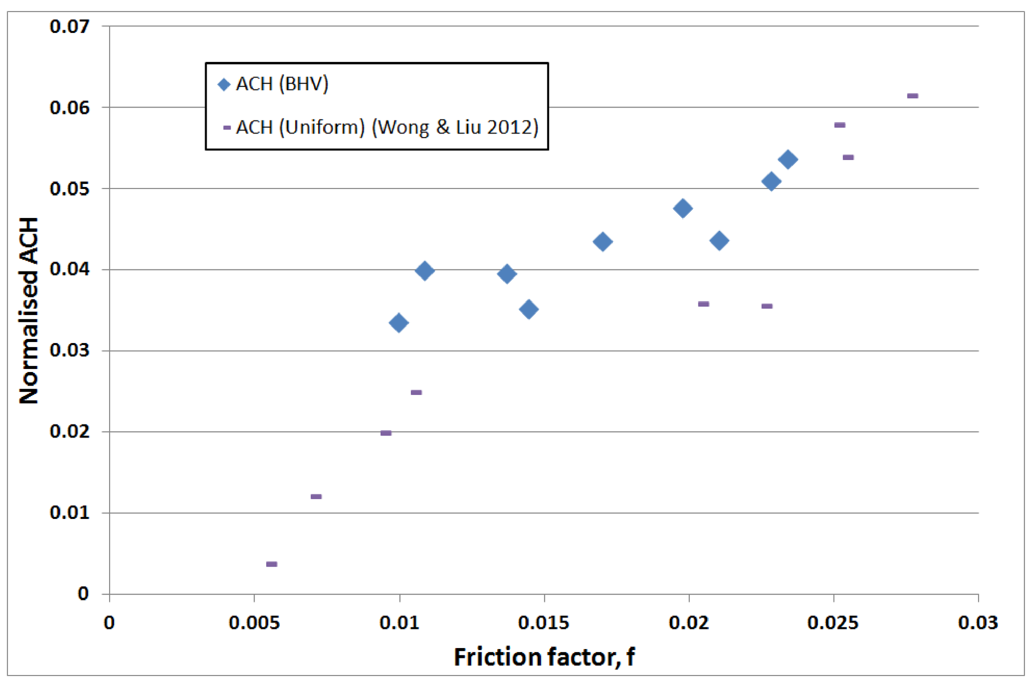


Fig. 4. Normalized air exchange rate ACH plotted against friction factor f.

Conclusion

- The introduction of BHV change the roughness of the urban surface and substantially affect the ACH and pollutant dispersion aloft.
- However, the change in geometry does not seem to have impact on the relationship between f, ACH, and σ_z, f is therefore a single parameter that controlling the other flow properties thus f is good variable for parameterize the flow in UBL.

References

Wong, C.C.C. and C.-H. Liu, 2012: Pollutant Plume Dispersion in the Atmospheric Boundary Layer over Idealized Urban Roughness: *Boundary-Layer Meteorol.*, DOI 10.1007/s10546-012-9785-7.

OpenFOAM (2011), *OpenFOAM: The open source CFD toolbox*. http://www.openfoam.com/.

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