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STREET CANYON VENTILATION AND POLLUTION DISPERSION MODELLING

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Introduction

- Urbanization modifies land surfaces that weakens the street-level ventilation & pollutant removal.
- Parameterization for ventilation & pollutant removal is thus necessary to improve air quality in urban areas.
- Whereas, density, geometry & orientation, etc. of buildings are complicated. Their effects on ventilation & pollutant removal cannot be easily parameterized in terms of urban morphology or atmospheric conditions.

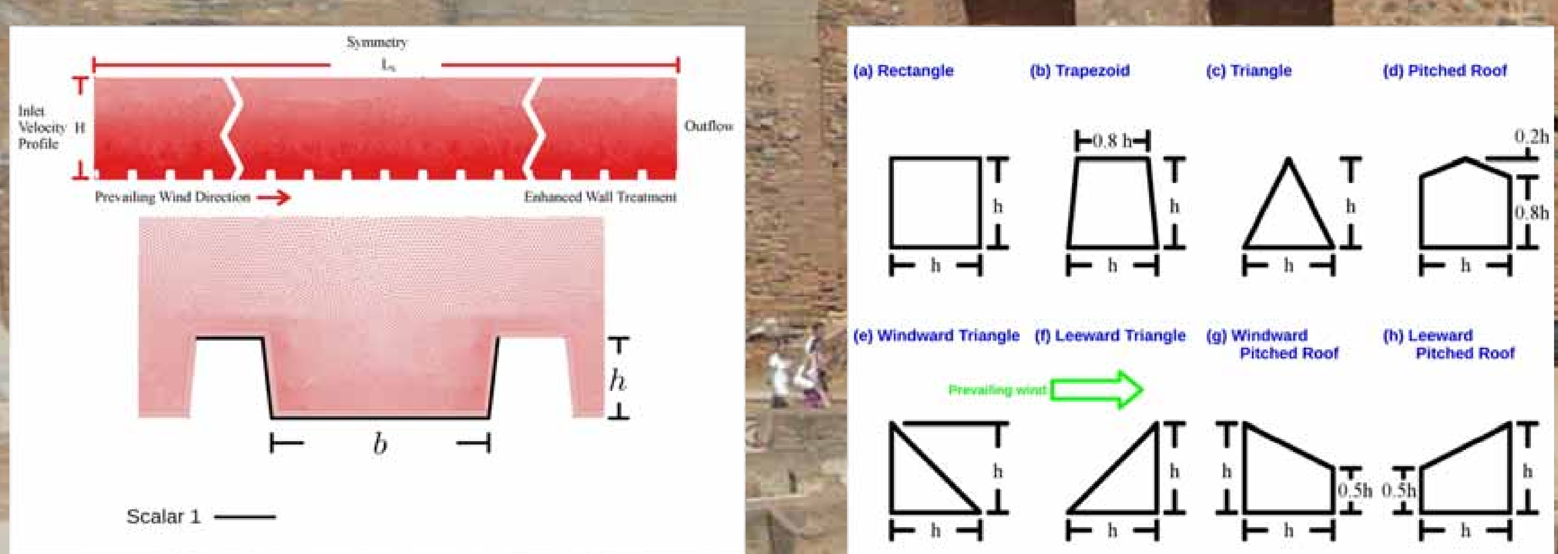

Fig. 1. Computational domain and street canyons geometries

Theory & Indicators

- Flow resistance is measured by the friction factor $f = \tau_w / (1/2\ \rho\ U^2)$ where τ_w is the wall shear stress, ρ is the fluid density & U is the prevailing mean wind speed over a rough surface.
- Ventilation performance is measured by the air exchange rate (ACH) that is equivalent to the characteristic vertical velocity scale $\widehat{w}$ along the roof level of the roughness elements.
- Pollutant removal performance is measured by the pollutant exchange rate (PCH) that is equivalent to the characteristic upward pollutant flux scale $\widehat{w\phi}$ along the roof level of the roughness elements.
- ACH & PCH are partitioned into their mean ($\overline{\blacksquare}$) & turbulent ($\blacksquare''$) components to look into the mechanism of ventilation & pollutant removal (Liu et al. 2013).

Major Findings – Ventilation (Fig. 2)

- Street-level ventilation is dominated by atmospheric turbulence
  - ACH'' is at least 60% of the total ACH & is almost 100% for $f^{1/2} < 0.13$.
  - It exhibits a linear relation with the square root of friction factor (ACH'' $\propto f^{1/2}$) that is represented by the (empirical) linear regression

$$\text{ACH}'' / U / l = 0.4167 f^{1/2} - 0.0106 \qquad (1)$$

  with a fitness coefficient $R^2 = 0.9369$.

- It is thus proposed to model the geometrical effects on the flows by friction factor & parameterize ACH'' to estimate the minimum ventilation performance of hypothetical urban areas.

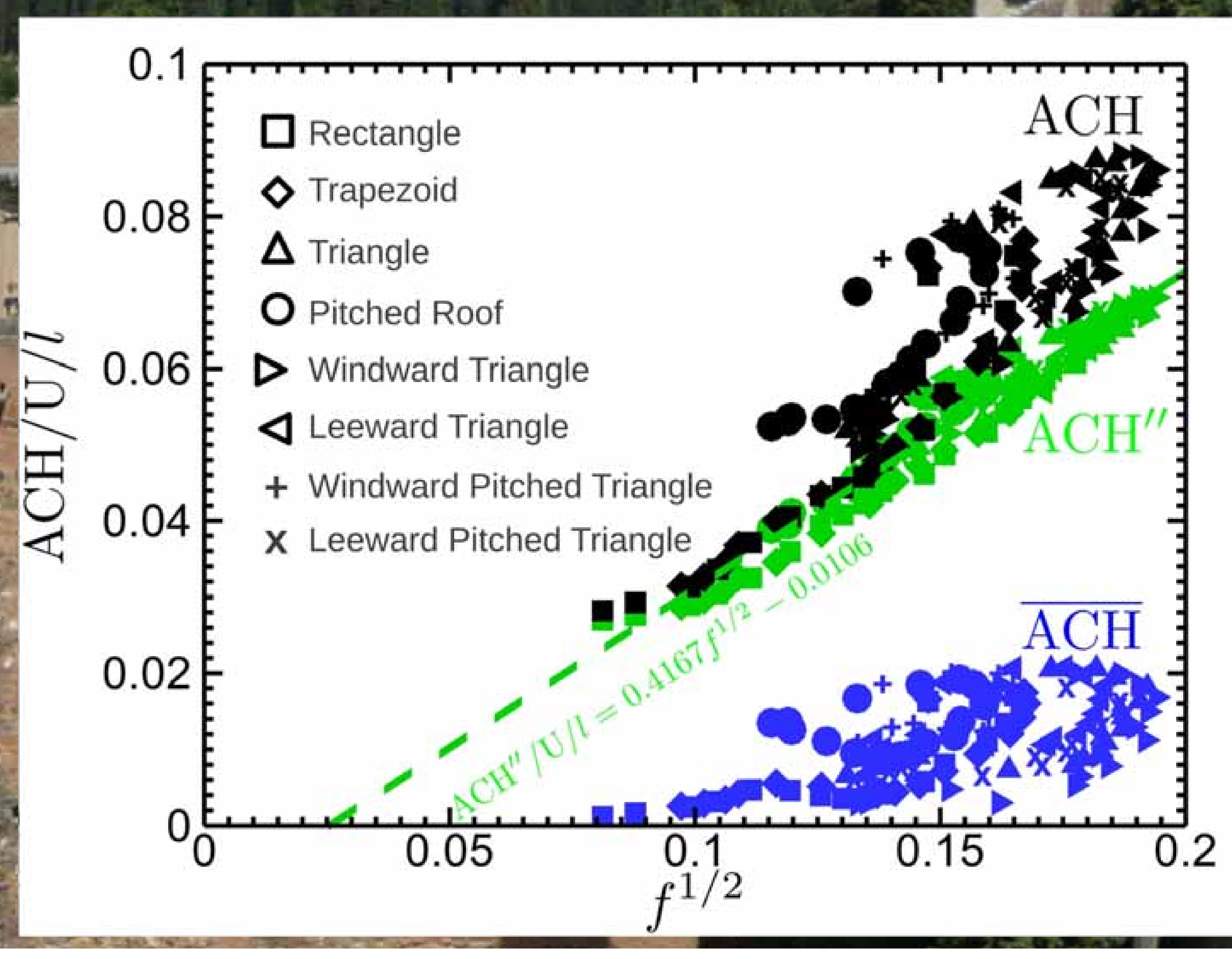

Fig. 2. Dimensionless ACH against square root of friction factor f

Major Findings – Pollutant Removal (Fig. 3)

- PCH shows a different behavior that decreases with increasing friction factor.
- However, it cannot be easily parameterized because there is a sharp drop in PCH at small friction factor.
- Additional effort is necessary to look into the pollutant removal mechanism in details.

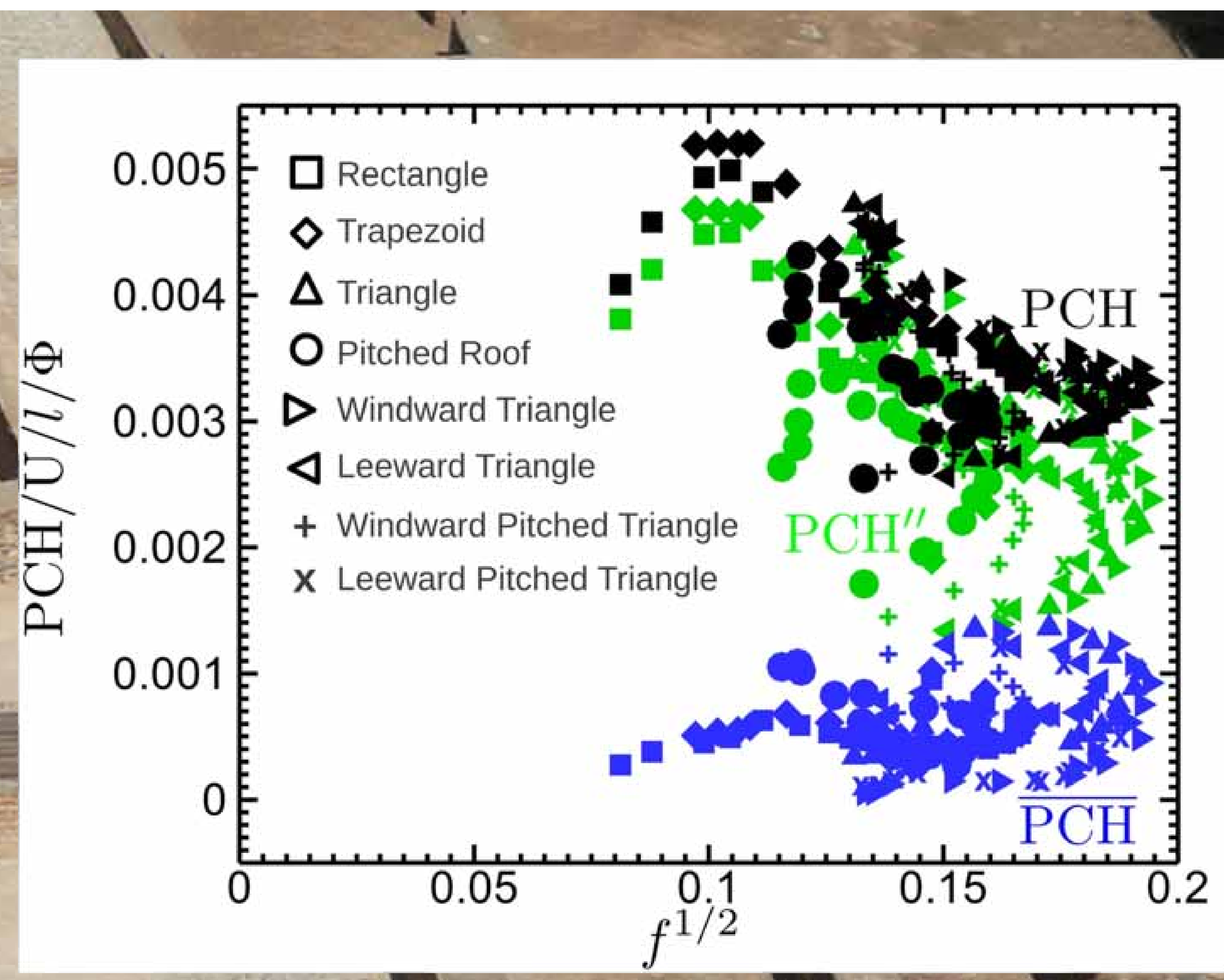

Fig. 3. Dimensionless PCH against square root of friction factor f

Conclusions

- Ventilation & pollutant removal are dominated by atmospheric turbulence (over 60% of the total).
- The newly proposed parameterization for ventilation estimate is applicable to all the idealized roughness elements tested (8 different types with a fitness coefficient over 0.93).
- The newly proposed parameterization Eqn (1) can serve as the estimate of the minimum (guaranteed) ventilation performance of urban areas where consist of various building density/geometry/orientation.

Reference

Liu, C.-H., Ng, C.-T. & Wong, C.C.C. (2013), "A theory of ventilation estimate over hypothetical urban areas", manuscript submitted to *J. Hazard. Mater*.

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