Street Canyon Ventilation using Wind Tunnel and Numerical Modelling

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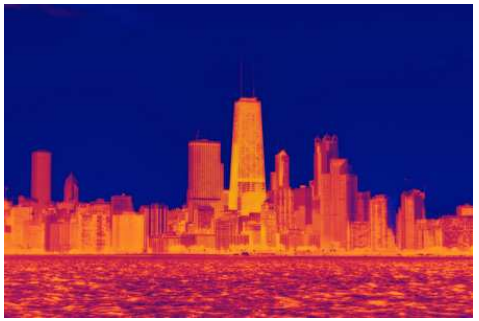
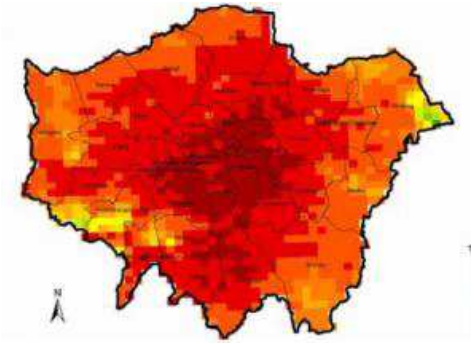
Motivation

Panoram of Sao Paulo



Chicago (sustainablecitiesnet.com)



London UHI (greencarcongress.com)

Motivation - Boundary Layer?

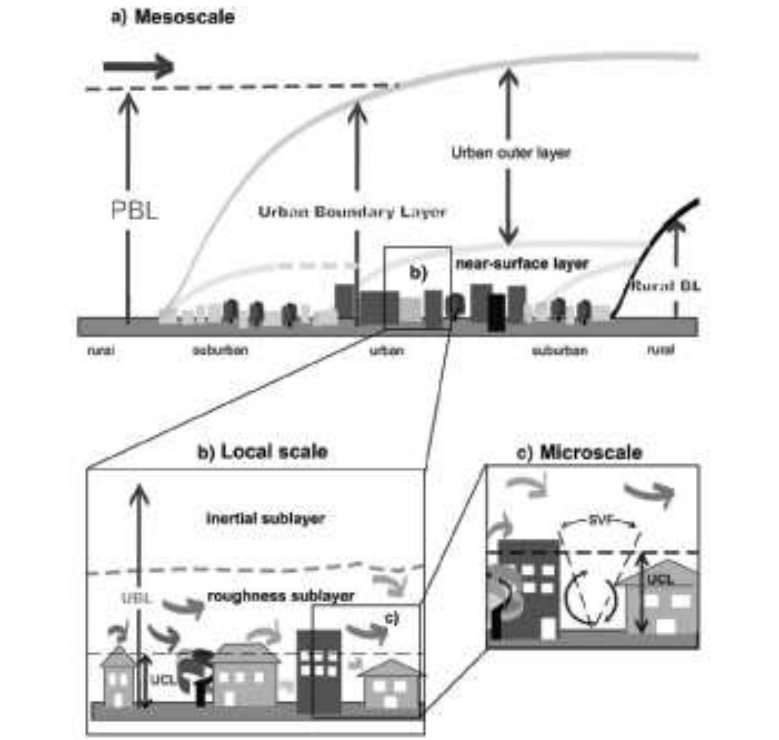
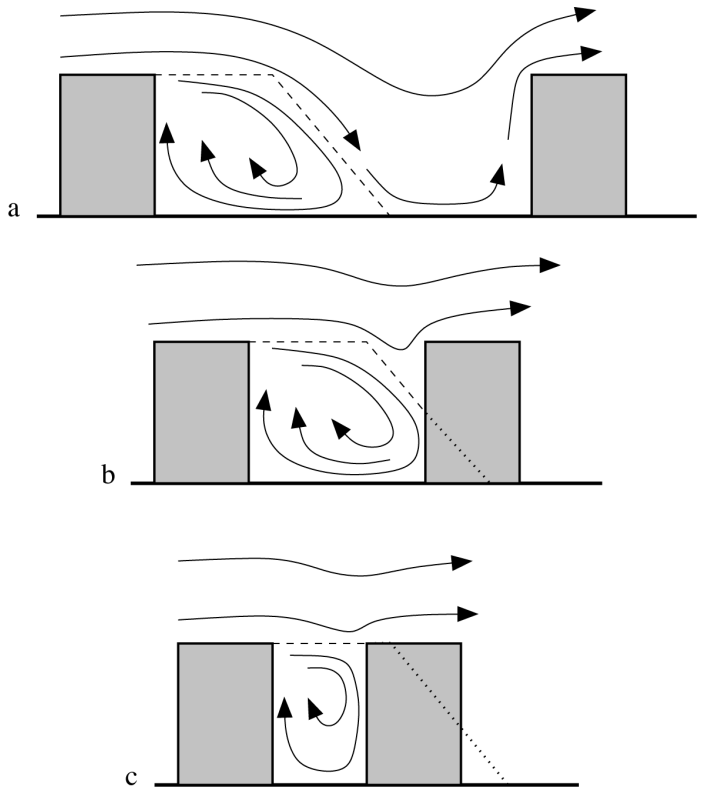


Fig. 1 Sketch of the urban boundary-layer structure indicating the various (sub)layers and their names (from Rotach et al. 2004; modified after Oke 1987)

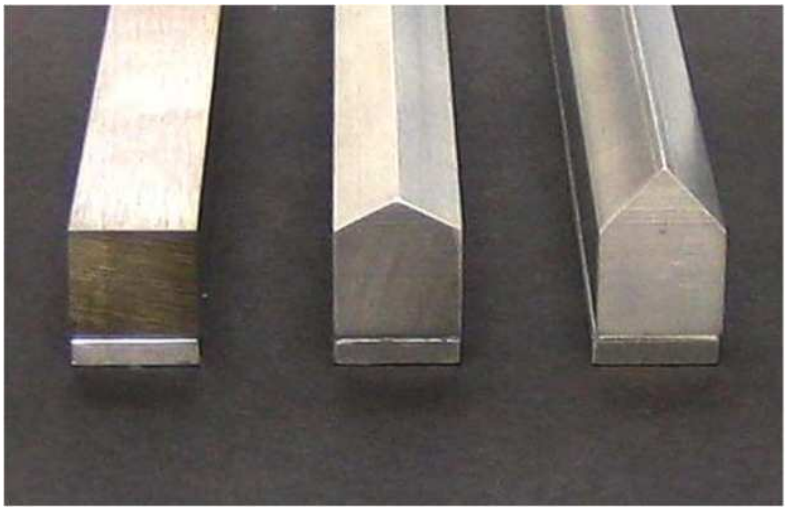
Structure of the Urban Boundary Layer (atmoz.org)

The Street Canyon

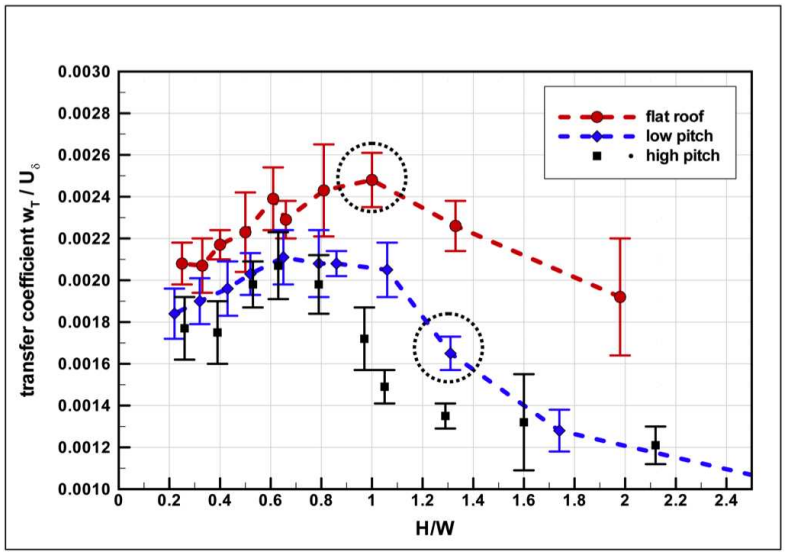


Street Canyon Set-Up (Oke, 1987)

Motivational Results



Roof Shapes

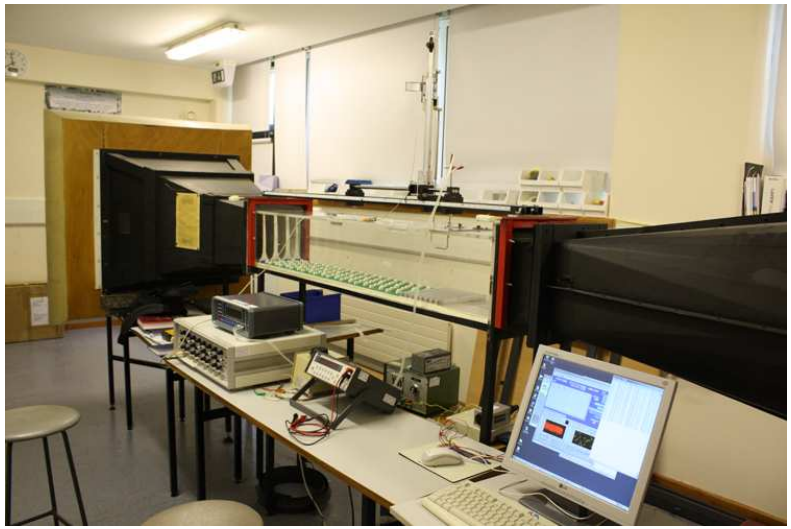


Transfer Coefficient vs Aspect Ratio

From Pascheke, 2005

Wind Tunnel

- Small Wind Tunnel;
- Dimensions 234 x 234 x 1500mm.



- For a neutral surface layer

$$U(z) = \frac{u_*}{\kappa} ln\left(\frac{z - d_0}{z_0}\right) \tag{1}$$

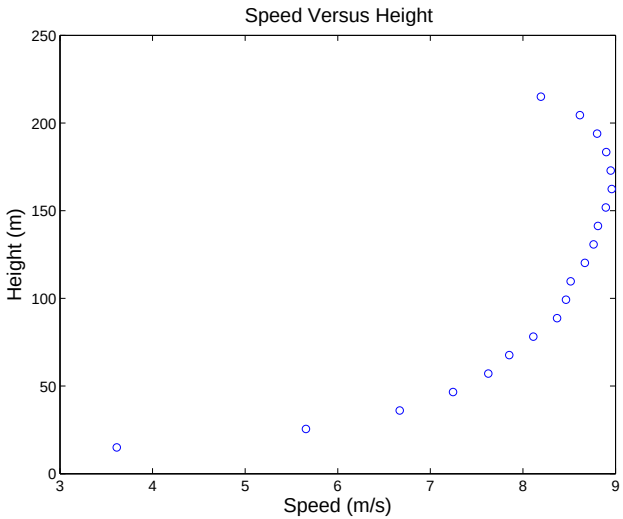
- Rearranging, gives

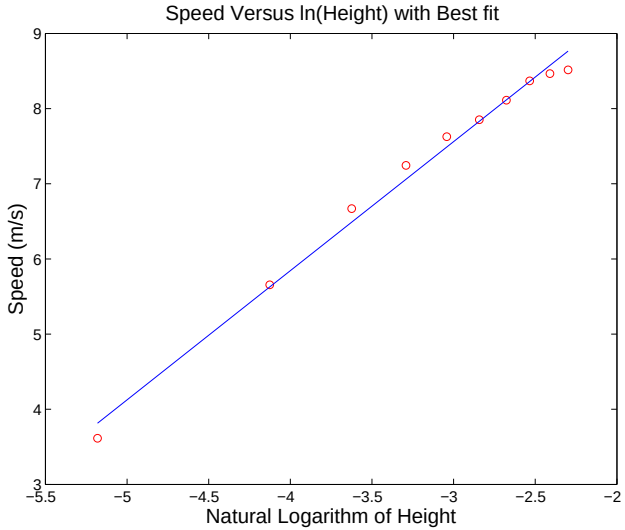
$$U(z) = \frac{u_*}{\kappa} ln(z - d_0) - \frac{u_*}{\kappa} ln(z_0) \tag{2}$$

- So, for a given d_0, z_0 can be found.

Experimental Boundary Layer

- Roughness length $\approx 0.16mm$ (0.32m full scale).

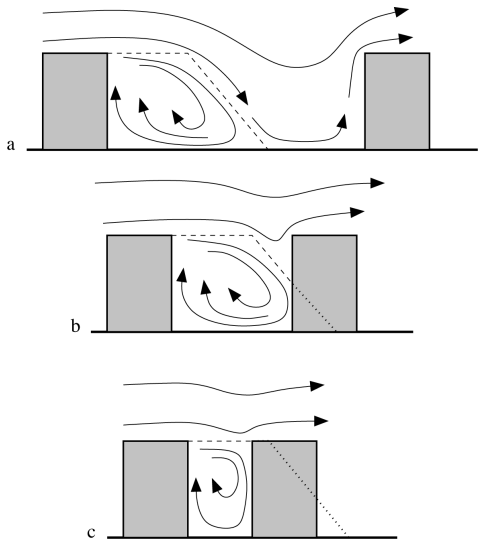




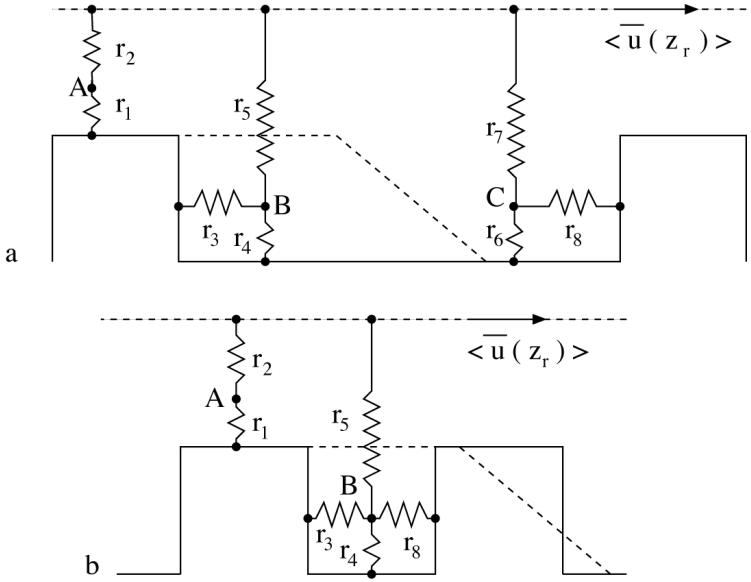
The Resistance Network

Representing fluxes numerically?

- Developed by Ian Harman (2004)
- Representation of scalar fluxes by a system of resistors



Street Canyon Set-up (Oke, 1987)



Resistance Network - Harman et al. 2004

The Path of Scalar Out of the Canyon

- Scalar "breaking free from the surface" and out of the canyon to the air aloft.
- Bulk Aerodynamic Formulation for Fluxes

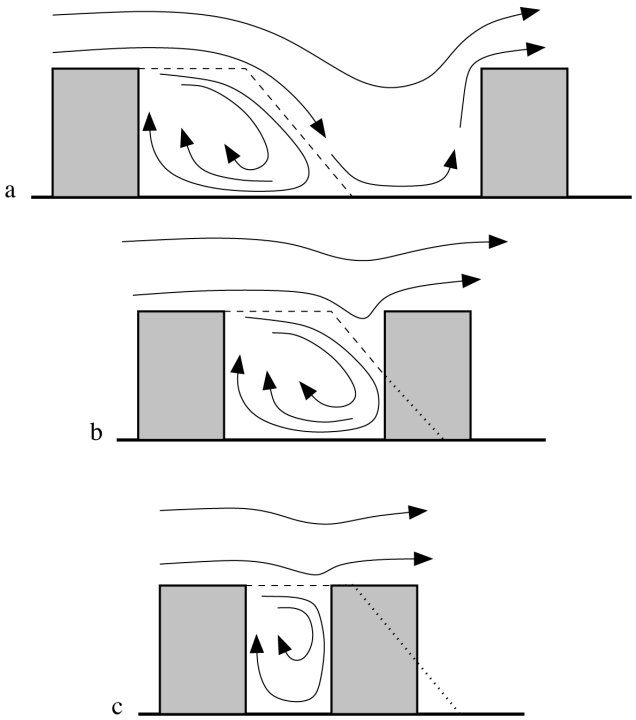
$$F_X = \langle \overline{w'X'} \rangle = w_X \Delta \overline{X} = \frac{\Delta \overline{X}}{r_X} \tag{3}$$

- The parameters u_{zr}, z_0 and d_0 in (1) are determined for each aspect ratio.

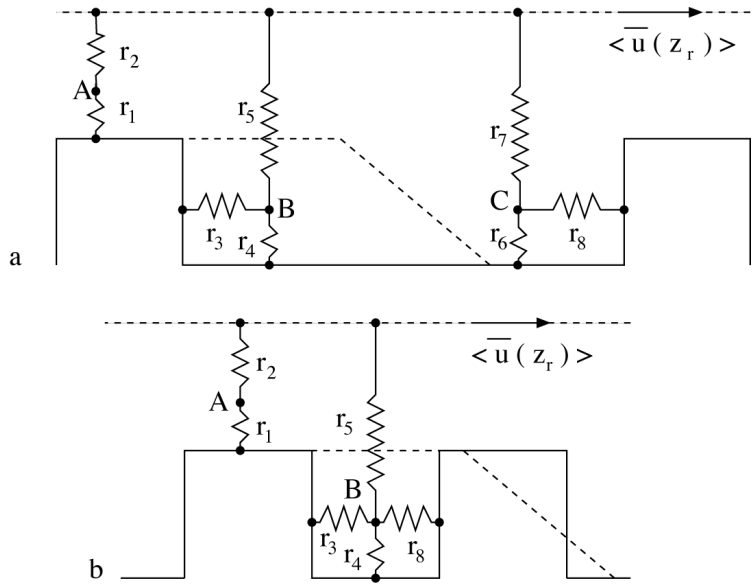
- Balance between advection and turbulent drag,

$$u\frac{\partial u}{\partial x} \sim -C_D u^2 \tag{4}$$

- $\Rightarrow$ Wind decelerated exponentially as it moves around the canyon
- Average wind speeds can be found



Oke, 1987



Harman et al. 2004

- Resistance at the internal boundary layer:

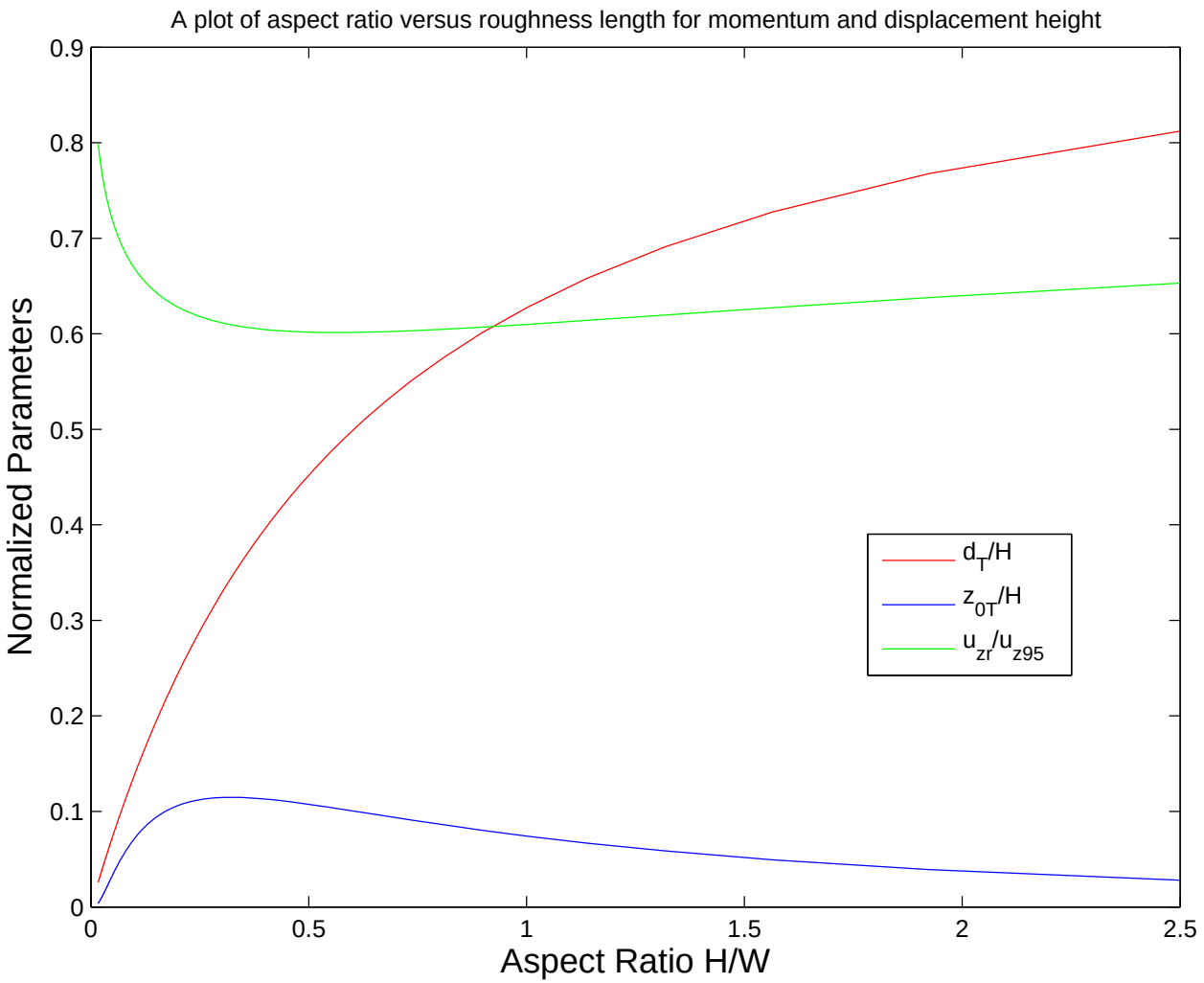
$$r_X(z) = ln\left(\frac{z}{z_{0m}}\right) ln\left(\frac{z}{z_{0X}}\right) / \kappa^2 \langle \overline{u}(z) \rangle \tag{5}$$

- Resistance across a shear layer:

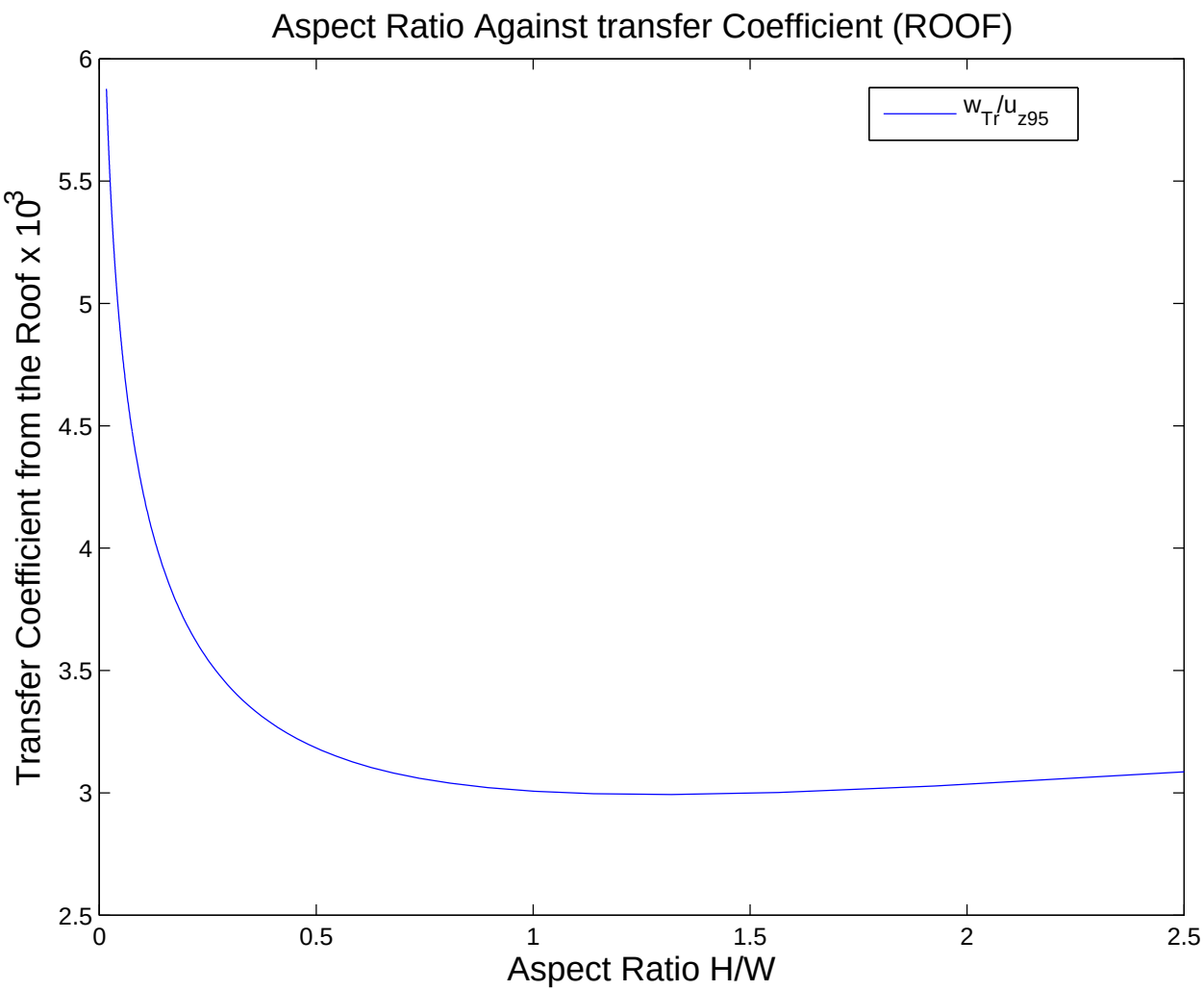
$$r_X(\Delta z) = \frac{\Delta \overline{u}}{u_*^2} \tag{6}$$

- Recalling that $w_T = 1/r_X$, the transfer velocity can be found

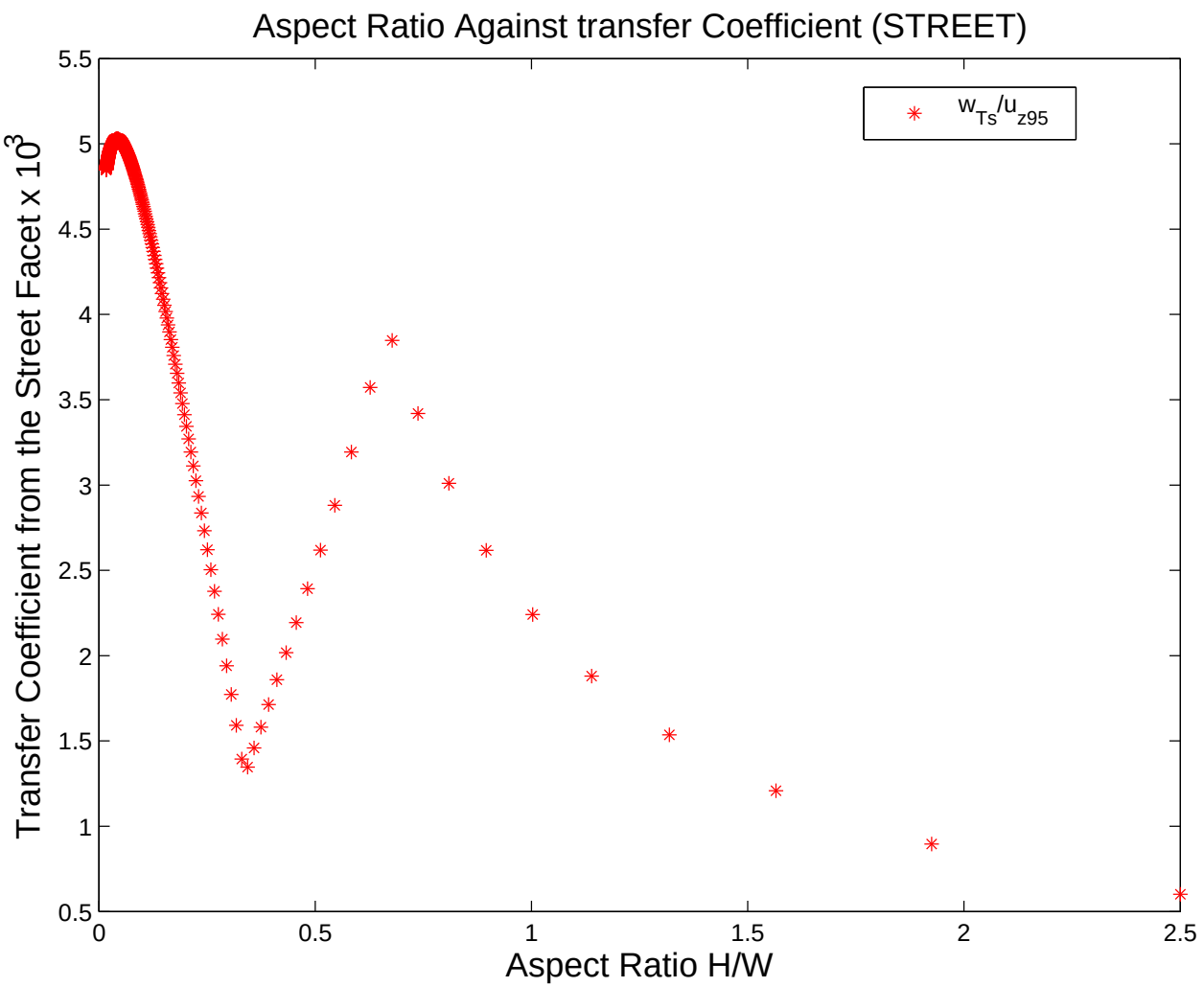
Some Results??



Some Results??



Some Results??



Next Step?

- Conclude work on Harman's Model
- Parametrize different roofs
- Experimentally estimate the influence of wind direction on turbulent exchange and explore this for different known building morphologies, such as courtyard like morphology.

Conclusion

- Early experiments show that scalar fluxes have high sensitivity to building geometry;
- For larger aspect ratios, roof shape can decrease street level fluxes of up to 40%
- Effect of wind direction on scalar turbulent transport still largely unknown.

- Visit us at the http://www.actual.ac.uk - Actual Project Website