

Street Canyon Ventilation using Wind Tunnel and Numerical Modelling

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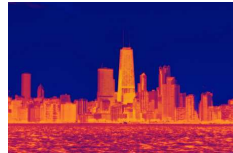
Royal Meteorological Society Student Conference
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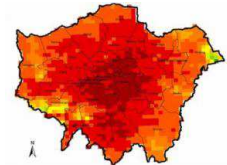
Motivation



Panoram of Sao Paulo



Chicago (sustainablecitiesnet.com)



London UHI (greencarcongress.com)

Motivation - Boundary Layer?

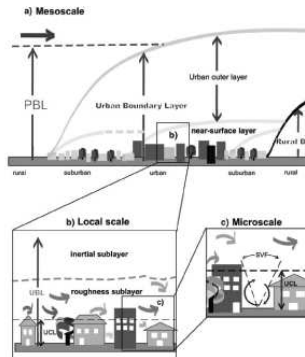
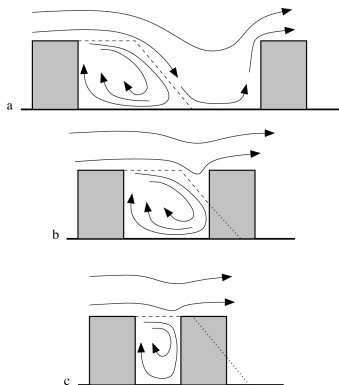


Fig. 1 Sketch of the urban boundary-layer structure indicating the various (sub)layers and their names (from Rotach et al. 2004; modified after Oke 1987)

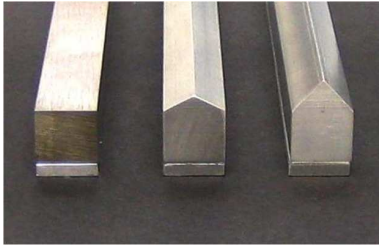
Structure of the Urban Boundary Layer (atmoz.org)

The Street Canyon

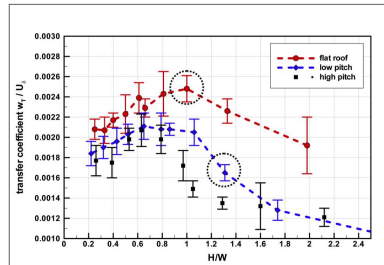


Street Canyon Set-Up (Oke, 1987)

Motivational Results



Roof Shapes

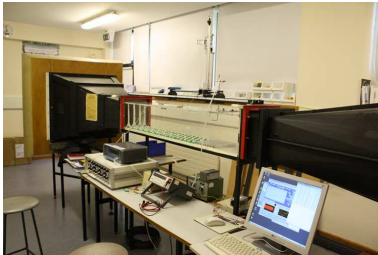


Transfer Coefficient vs Aspect Ratio

From Pascheke, 2005

Wind Tunnel

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



- ▶ For a neutral surface layer

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

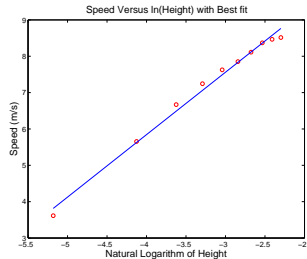
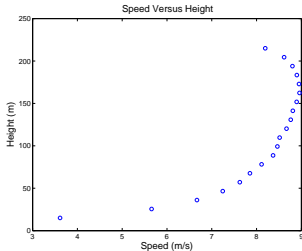
- ▶ Rearranging, gives

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

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

Experimental Boundary Layer

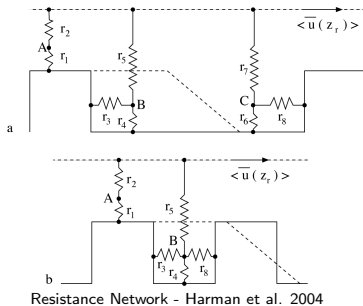
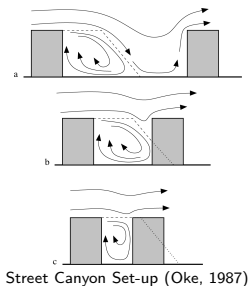
- ▶ Roughness length $\approx 0.16\text{mm}$ (0.32m full scale).



The Resistance Network

Representing fluxes numerically?

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



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

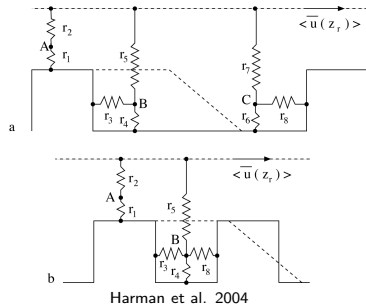
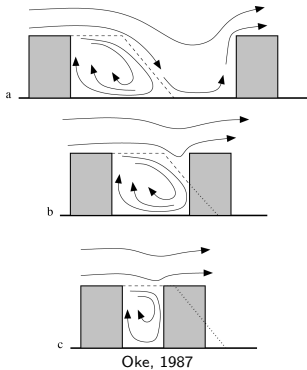
$$F_X = \langle \overline{w'X'} \rangle = w_X \Delta \bar{X} = \frac{\Delta \bar{X}}{r_X} \quad (3)$$

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

- ▶ Balance between advection and turbulent drag,

$$u \frac{\partial u}{\partial x} \sim -C_D u^2 \quad (4)$$

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



- ▶ Resistance at the internal boundary layer:

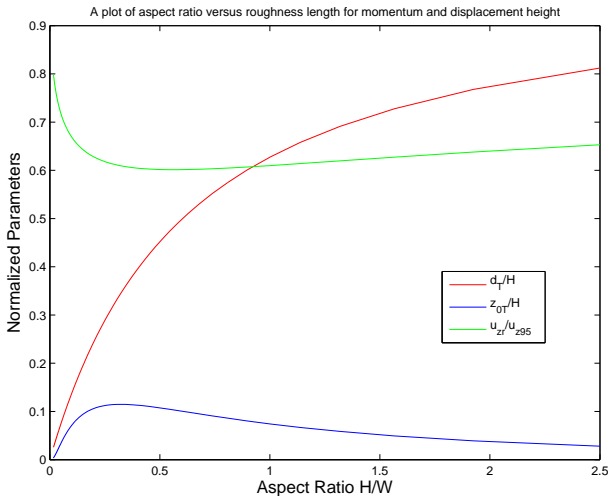
$$r_X(z) = \ln\left(\frac{z}{z_{0m}}\right) \ln\left(\frac{z}{z_{0X}}\right) / \kappa^2 \langle \bar{u}(z) \rangle \quad (5)$$

- ▶ Resistance across a shear layer:

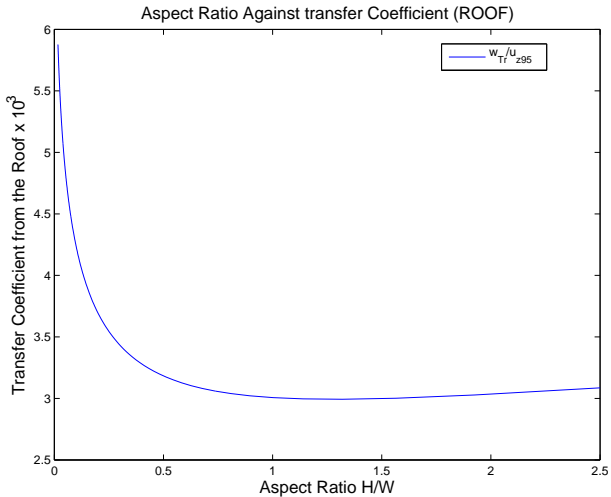
$$r_X(\Delta z) = \frac{\Delta \bar{u}}{u_*^2} \quad (6)$$

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

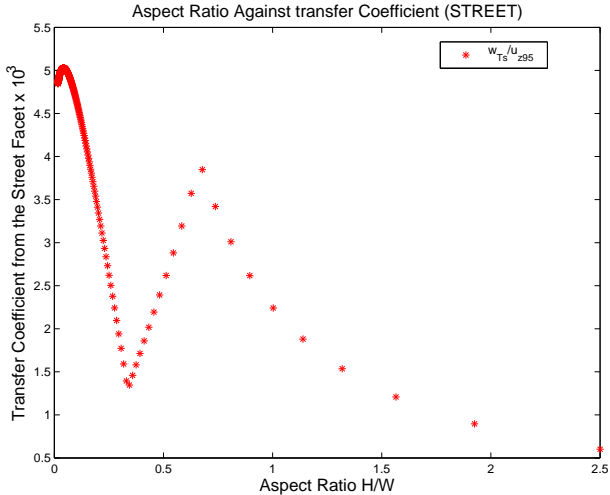
Some Results??



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