RESPONSE

We thank Anonymous Referee #2 for the comments. We will first address the Key comments of the referee, followed by specific comments

RESPONSE TO KEY COMMENTS

18069, L18-9: "Steady-state solutions were obtained for all cases" – is that referring to the current work? And "..code was validated..." is that referring to the Ketzel et al work, or the current study? This is unclear, a little more detail required to establish what the authors have done themselves in terms of validation.

18069, L20: good comparisons of which variables? K-epsilon codes may simulate mean flow fields adequately but can struggle in simulating the turbulence fields accurately, particularly in the vicinity of flow separation points. This is important to establish, to understand whether the tool being used for the study has limitations

18069 L18 should read: "Steady-state solutions were obtained for all cases of this study." We agree that further details of validation should be included. We will include them in the ACP paper (See appendix for details)

18069 L20 should read "good comparisons of horizontal velocity flow field"

We agree with the reviewer regarding the limitations of the k-ε turbulence model used. We have established that in 18082 L3 to L15 when we mentioned that compared with Large Eddy Simulation (LES) results there is an under-prediction of turbulent diffusion/ turbulent mixing by the *k*– ε model. In response to the reviewer's comments, we will expand the discussion regarding the limitations of the model.

18072, L7: is it realistic to use exhaust temperature 10K above background air temperature? If buoyancy effects due to the exhaust are "ignored" as stated earlier, why not set it to the ambient temperature? Otherwise it seems an unrealistically small temperature difference.

The temperature of the exhaust was set to ambient temperature when isothermal cases were assumed (and temperature equation was not solved).

The temperature of the exhaust was set at 10K above background air only when temperature equation was solved (heated wall cases) and buoyancy effects characterised by the Boussinesq approximation.

The exhaust within the computational domain is a distance (approximately 0.5- 1 m) from the exhaust pipe. This study therefore investigates the evolution of the plume within the canyon after the ‘initial dilution and cooling process’. The temperature of the exhaust was taken to be 300K, after the initial cooling process, cooling from an initial temperature estimated to be ~423- ~573 K (Matti Maricq, 2007) within the exhaust pipe. Uhrner, *et al.* (2007) measured and modelled the evolution of the plume during the initial dilution, and found that the temperature cooled to ambient temperatures (~290 K) 1m from the exhaust and temperatures could reach up to 30K above ambient at 0.5m. The assumption of 10K is therefore within the expected range.

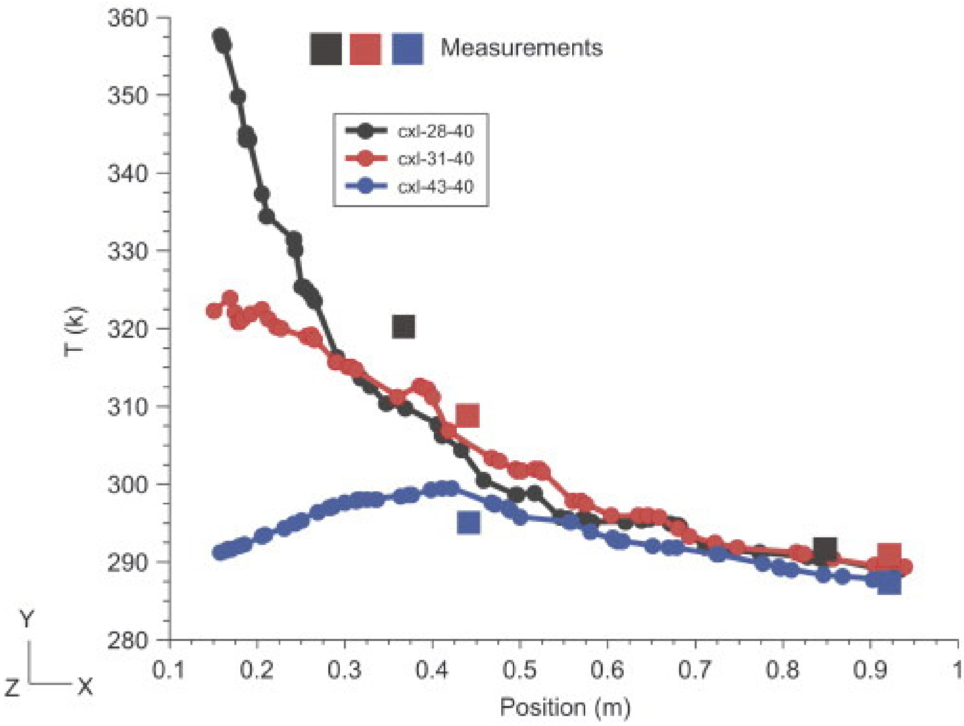


Figure 1: Temperature (K) measured and modelled within the exhaust plume (Urhner *et al.*, 2007)

18075, section 3.2.2: is it possible to compare the aerosol results with Meroney/Pavageau results for tracer gas from a line source? It is not clear whether your aerosol modelling includes deposition, and other inertial effects: comparing with gas concentration distributions is not ideal, but given the lack of data, general windward/ leeward wall concentration profile trends could be compared. This also would help to highlight the differences between particulate and gaseous pollutant behaviour.

Comparison with wind tunnel results of Meroney, et al. (1996) will be included in the ACP paper as suggested.

Inertial effects were not considered as the aerosol particles are within the fine/ ultra-fine modes (< 1 micron) where inertial effects may be ignored. A simplified treatment of deposition was employed through the "zero concentration" wall boundary condition (perfectly absorbing wall) for aerosol particles, (ignoring re-entrainment). It is said to be a "good approximation for commonly encountered aerosols in ambient air" (Gallis *et al.*, 2008), although this simplified estimate may overestimate deposition flux.

18081, L10: the authors report that the heat flux is always negative (meaning downward, into canyon?), and the canyon temperature steadily increases – this seems physically implausible, especially given that the temperature gradient is negative (i.e. street is warmer than air above), so how can there be a counter gradient heat flux for heat but not for aerosols, especially in such a turbulent flow and where both have in-canyon sources? I agree with the authors that there may be overall differences in flux magnitudes due to differences in diffusivity, but differences in sign? Is there a problem in the definition of heat flux? How is the turbulent eddy diffusivity for heat defined? The paper records no details about wall boundary conditions for the heat flux (see e.g. Sini et al 1996). These are important points to cover, otherwise the validity of this section and perhaps the heated wall results, is doubtful.

Both net heat flux and aerosol flux in the vertical direction were evaluated at the roof level (z/H: 1) of the canyon by integration across all points defining the interface between the canyon top and the airflow above. The temperature/ aerosol gradients are negative (due to the skimming flow regime) and updraft takes places at the leeward side whilst it transitions to downdraft at the windward side on the canyon (due to the circulatory vortex flow within the canyon see Figure 2 for variation in vertical advective heat flux along the horizontal axis ar roof level (z/H: 1)). Details of the standard boundary conditions for the heat flux have been included as requested (see paragraphs below).

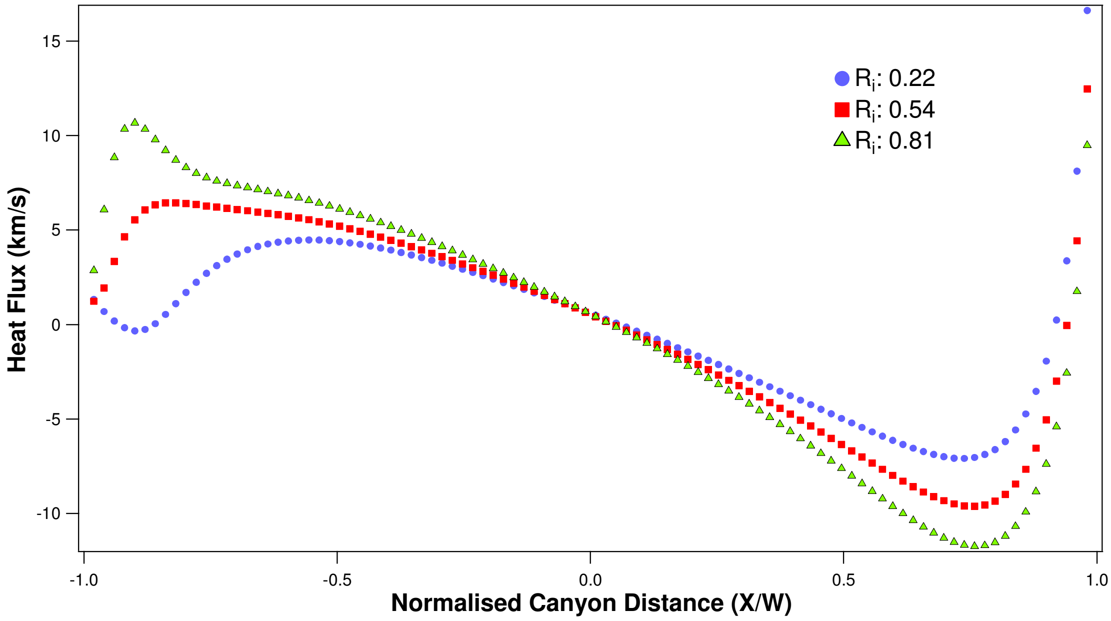


Figure 2: Heat Vertical advective heat flux (km/s) (due to mean flow) along the horizontal axis at roof level across the canyon width

Background

The difference in direction of aerosol flux and heat flux is due to the different process that drives the flux of both properties: turbulence drives aerosol flux and vertical advection drives heat flux (due to a much lower temperature gradient). These findings are a result of the boundary conditions incorporated in the model and the method (1st order eddy viscosity model) used to evaluate turbulent flux. Further work will be needed to further investigate the processes that drive the ventilation of both properties at a range of turbulence levels and boundary conditions. Further background information is included to explain and clarify the finding and to address the comments above:

Boundary conditions

The walls within the computation domain were assumed to be:

- Isothermal (constant temperature)
  - 2 vertical walls and 1 'horizontal wall' (ground) within the street canyon: 300K
  - 2 roofs extending to the inlet and outlet boundary conditions: 290K.
- Fully absorbing walls of aerosol particles
  - Zero concentration of aerosol particles

Other sources:

- Heat: 300 K at the exhaust
- Aerosol Particles: Emission exhaust within the canyon (1×10^{11} p/m^3)

Flux Definition

The net flux F_{Net} for both heat (*temperature: T*) and aerosol particles (C) at the roof level (Z/H=1.0) of the canyon were defined as integrated sum of ***vertical*** turbulent flux $K_\chi \frac{\partial \chi}{\partial z}$ due to turbulence and ***vertical*** advective flux $\overline{\chi}\overline{w}$ due to bulk motion and is mathematically expressed as: $F_{Net} = \int_w \left(-K_\chi \frac{\partial \chi}{\partial z} + \overline{\chi}\overline{w} \right) dx$

Where W is the length of the horizontal extent of the canyon

When heat flux is considered: χ is T and K_T is turbulent eddy diffusivity for heat

When aerosol flux is considered: χ is C and K_C is turbulent eddy diffusivity for particles

(Both K_T and K_C are corrected forms of the momentum eddy viscosity by dividing by Turbulent Prandtl Number (0.9) and Turbulent Schmidt Numbers (1.0) respectively.)

<u>General Observations</u>

For both aerosol particles and heat, the overall effect of

- turbulent flux is positive (out of the canyon, consistent with the negative concentration and temperature gradient at the roof level)

- advective flux is negative (into the canyon) (*except for AR 0.5, isothermal cases*) consistent with the skimming flow regime where the roof-level wind restricts upward movement, playing the role of a lid for the street canyon whilst the vortex is maintained by the momentum transfer from the roof level wind (Baik & Kim,1999).

Explanation for the difference in sign between heat and aerosol flux

For all cases, we observe a net vertical aerosol particle flux out of the canyon due to the dominance of turbulent flux. Turbulent flux of heat is less dominant than convective heat flux. Heat flux is dominated by vertical advective flux. Mathematically, this is due to the smaller vertical gradient of heat compared with aerosol particles. This smaller gradient is 'expected' due to the computational set-up where the range of temperature is 290K- 300K and for aerosol particles (0- $1 \times 10^{11} p/m^3$). This difference in gradient is illustrated in the Figure 3 for temperature and particle concentrations.

Therefore, net heat flux is always negative as heat generated within the canyon is re-circulated into the canyon by the bulk fluid motion. This is observed by the steady-state temperature patterns where entrainment of 290K air from the above canyon air and transfer of heat from the heated walls is re-circulated into the canyon.

The steady state result therefore is the layer above the canopy remaining at approximately 290K and heat is maintained within the canyon. These processes do not lead to a 'steadily increasing temperature' as misinterpreted by the referee (probably due to the lack of clarity of the manuscript for which we apologize) but leads to a steady-state 'canyon temperature distribution pattern' such that temperatures are between that of the above canyon air and the wall temperature (to maintain the temperature gradient.

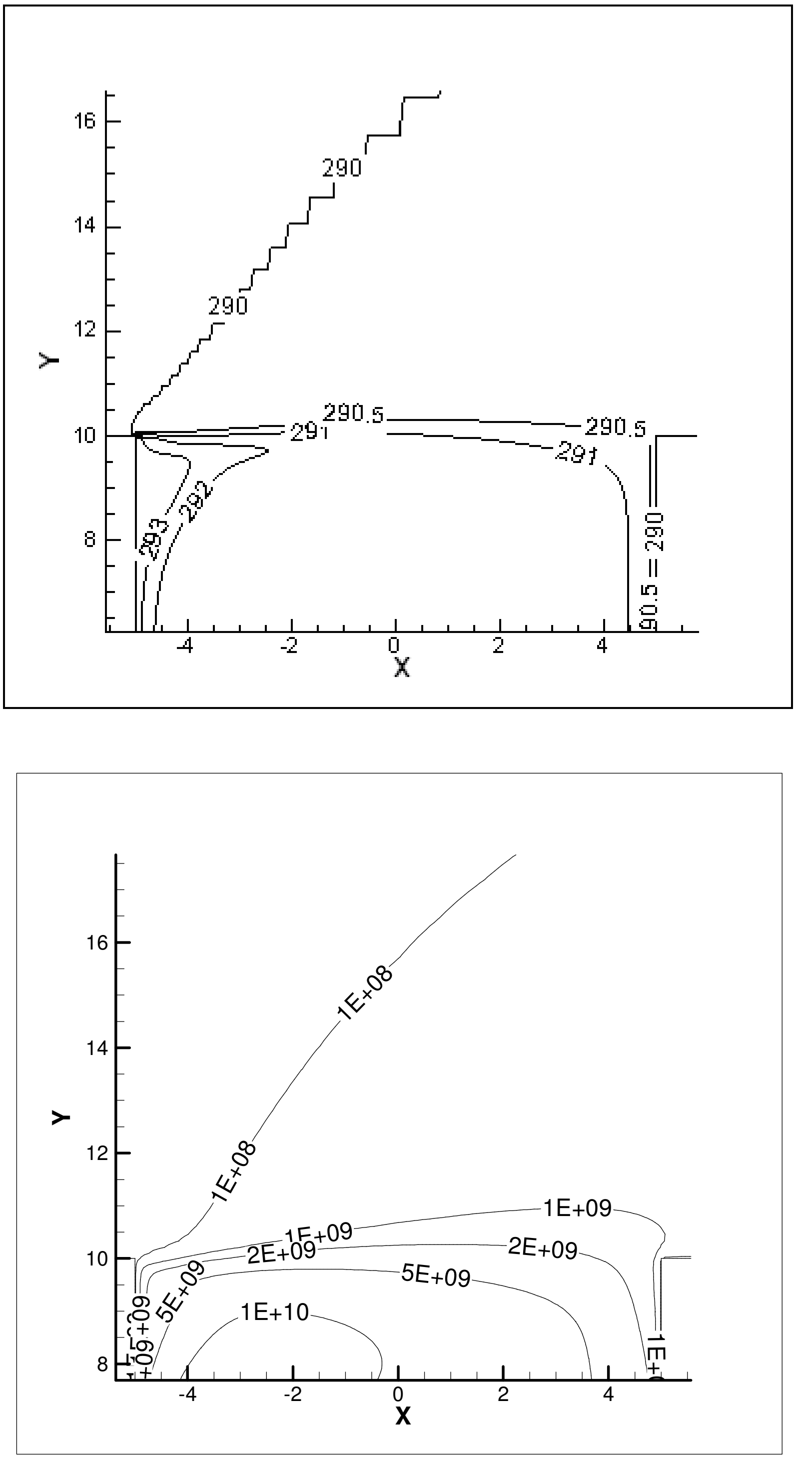


Figure 3: (a) Temperature (K) (*above*) (b) Particle concentration (p/m^3) at the interface of the canyon and the free flow region above the canyon (*X and Y are in m*)

Discussion of Relationship between Heat Flux and Aerosol Flux

For both leeward and windward heated walls, the average turbulent flux of aerosol particles increases with increasing wind speeds and the average magnitudes of advective flux of heat increases with wind speed as advective flux is a product of wind speed and temperature (*Note the progression from circles, squares and triangles in Figures 4 and 5*).

Leeward Discussions

For a given wind speed, as the temperature of the leeward wall is increased, the amount of heat and aerosol particles re-entrained into the canyon decreases *as buoyancy effects at the leeward side of the wall is increased*, leading to enhanced advective heat and aerosol particle flux out of the canyon with increasing temperature. This observation is consistent with the fact that leeward heated walls reinforce the vortex and enhances the updraft of the leeward side. We therefore note the positive trend between the change in heat and aerosol fluxes out of the canyon (Figure 4).

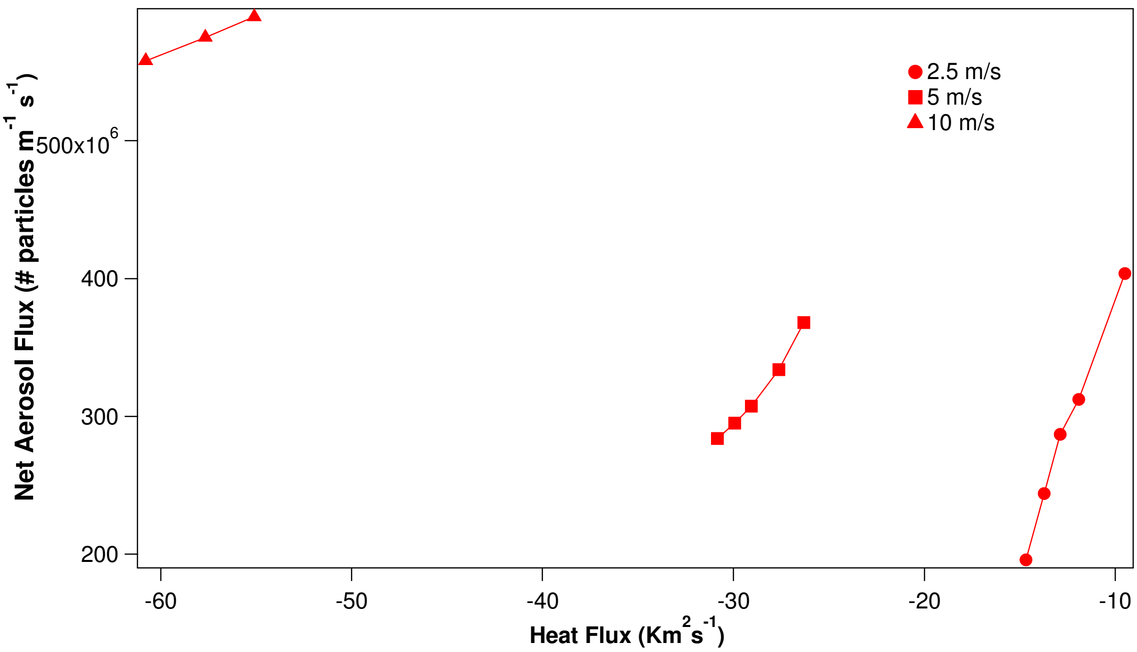


Figure 4*: Net aerosol flux (#/m/s) against Net Heat Flux (Km^2/s) Leeward Heated Walls*

Windward Discussions

For a given wind speed and single-vortex flow regime (5 m/s & 10 m/s), the increase in buoyancy with increasing temperature at the windward side of the wall has minimal impact on the advective flux (unlike the leeward heated case which enhances convective flux). For a given wind speed, the increase in temperature will weaken the vortex. With increasing temperature:

- Turbulent heat flux out of the canyon increases slightly (*due to an increase in the vertical temperature gradient*) resulting in a slight decrease in heat flux into the canyon.
- Turbulent aerosol flux decreases slightly *(due to a slight decrease in the vertical concentration gradient at roof level*) resulting in a slight decrease in aerosol flux.

For the above cases, we therefore note that an increase in net heat flux out of the canyon does not necessarily lead to an enhanced net aerosol particle flux out of the canyon in all cases.

At 2.5 m/s, we observe a change in regime from a single clockwise vortex to a dual vortex (*note the illustration in the figure below*) which is made up of the lower anti-clockwise vortex circulating a region of high aerosol concentration and a weaker upper clockwise vortex of cleaner air. With the change in regime (*and a weakened upper vortex*):

- Advective heat flux into the canyon decreases slightly resulting in a decrease in heat flux into the canyon
- Turbulent aerosol particle flux decreases by an order of magnitude *(due to a reduction in vertical concentration gradient*) resulting in a decrease in aerosol flux.

A further increase in temperature for the double vortex regime leads to a decrease in aerosol and heat flux out of the canyon due to the weakening of the upper clockwise vortex and corresponding enhancement of the lower vortex.

- Advective heat flux into the canyon increases slightly (*due to a weaker horizontal velocity and stronger vertical velocity downwards of the weakened upper vortex*) resulting in a decrease in heat flux out of the canyon
- Turbulent aerosol particle flux decreases *(due to continued reduction in vertical concentration gradient*) resulting in a decrease in net aerosol flux.

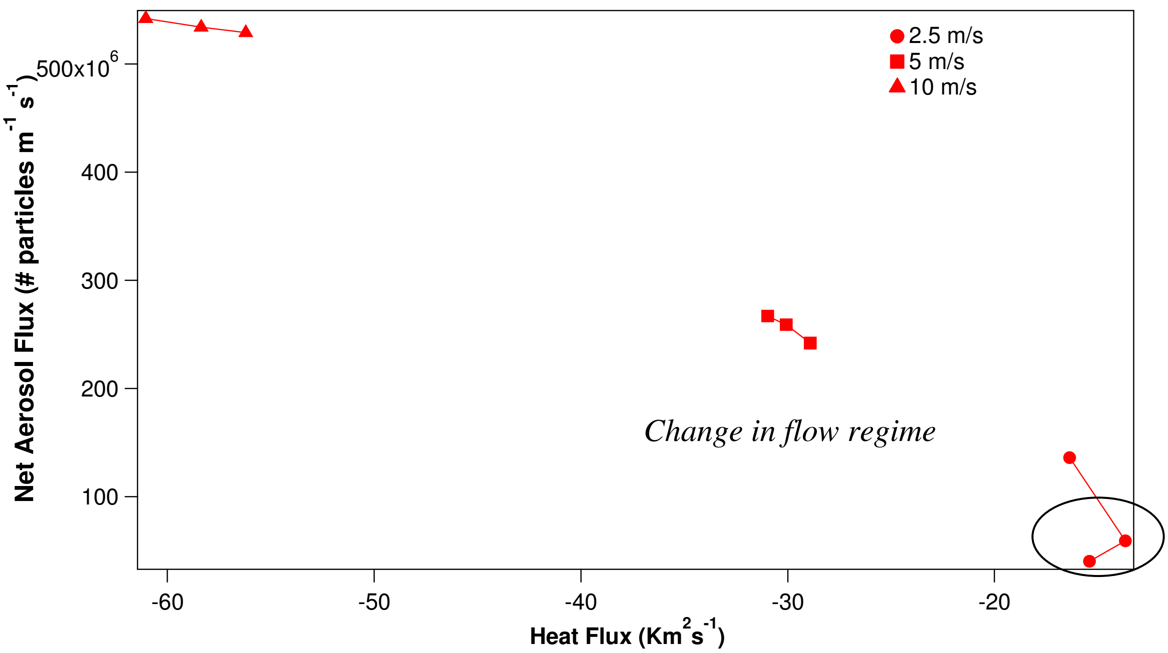


Figure 5*: Net aerosol flux (#/m/s) against Net Heat Flux (Km^2/s) Windward Heated Wall*

Conclusion

This exercise demonstrates that the relationship between net heat flux and net aerosol particle flux from the canyon is not necessarily straightforward and generally ‘tenuous’ (except for the leeward heated case) due to different processes (turbulent or advection) which drive the net flux at different flow conditions.

The authors are therefore of the opinion that when evaluated at the roof level, it is plausible that the fluxes of both heat and aerosol can occur in different directions in some cases due to the different processes that dominate.

We hope that the above description has clarified doubts and lend confidence to the validity of the findings of this study.

18091, Table 2: the values of TI are pretty low for an urban roughness sublayer, where TI can reach 1 near buildings. Please justify why this range of values was chosen and why it should span the typical range of scenarios. The use of a uniform height windspeed profile at the inlet should also be carefully justified, given that in reality there is approximately logarithmic increase with height, as this affects shear in the region of cavity top and crucially affects your results.

The inlet turbulent kinetic energy profile was defined as: $k = 1.5 \times TI^2 \times U_{IN}^2 = \beta U_{IN}^2$ where *TI* is the turbulence intensity, defined as the as the *ratio of the root-mean-square of the velocity fluctuations to the mean velocity flow* and β is an alternative means of representing the level of turbulence intensity.

The choice of *TI* used for this study is within the range of what has been used previously by similar CFD modelling studies: Kim & Baik (2003) studied sensitivities of flow patterns to turbulence level within a 2D street canyon model (H/W=1) by allowing turbulence intensity (β) to vary within the range of 10^{-3}-10^{-1}. Murena et al. (2009) classified inflow turbulence energy as relatively weak for β up to 4.5×10^{-2} (*TI*: 0.17) and relatively strong when β > 4.5×10^{-2}.

To the knowledge of the authors, the highest value of β used by similar modelling studies is 0.1 (TI: 0.26) (Solazzo & Britter 2007; Kumar, et al. 2009; Kim & Baik, 2003). This level of turbulence intensity was observed above the canyon (up to twice its height), during wind tunnel studies conducted by Kaster Klein & Plate (1999) (Jeong & Andrews 2002). Kato, et al. (1992), measuring *TI* at heights of 31 m, 56m and 86 m found *TI* to approach 0.33, 0.28 and 0.23 respectively at high wind speeds, although *TI* values were close to 1 at low wind speeds. Kato, et al. (1992) integrated results of previous full-scale studies and found that beyond a certain height in the atmosphere (> 30m), an inverse relation exists between vertical height and turbulence intensity, consistent with standards proposed by the Architectural Institute of Japan (AIJ). Eliasson, et al. (2006) through long term, full scale measurements exploring wind fields within an urban canyon in Sweden, found that β above the canyon height (up to 2 times the canyon height) ranged between ~0.1 to ~0.2.

However, Jeong and Andrews (2002) argued that 0.1 is not realistic as he could not replicate flow features obtained by field experiments (Rotach, 1995) at this level of turbulence. It is recognized that this level of turbulence (TI: 0.1) is high (Jeong & Andrew, 2002; Solazzo & Britter, 2007; Baik & Kim, 2003; Sini, et al. 1996) and at this level of turbulence, mechanical turbulence originating from the inflow wind conditions will be more dominant than locally generated turbulence due to traffic or geometrical features within the canyon. Therefore, this choice of turbulence intensity may conceal the effects of locally derived turbulence arising due to shear forces within the canyon and at roof level (Sini, et al. 1996).

Lower levels of turbulence intensities were considered: β: 0.03 (*TI* of ~0.1) was chosen by other modelling studies (Jeong &Andrew, 2002 and Murena et al., 2009). It was found that this level of turbulence intensity would yield a greater similarity in flow patterns to field studies conducted by Rotach (1995) (Jeong & Andrews 2002).

An even lower level of β: 3 $\times 10^{-3}$ (*TI* of ~0.05) was chosen for modelling studies (Sini, et al, 1996; Baik & Kim 1999) such that turbulence dispersion characteristics due to geometrical influences may be better studied.

Based on this review a range of values of *TI* chosen were selected; 0.26, 0.1 and 0.05 being used Thus, the range of turbulence intensity (β) chosen 0.1, 0.015 and 0.00375 represents 3 orders of magnitude of turbulence intensities, well within the range of *TI* commonly used and reported for modeling studies and the values chosen reasonably reflect the extent of *TI* expected. Whilst it is acknowledged (as the reviewer has mentioned) that within the urban roughness sublayer, the turbulence intensity (*TI*) may reach up to 1; the authors are of the opinion that this will be more relevant for lower wind speeds (< 2.5 m/s) which are not considered in the study as it was observed that turbulent intensities will increase at lower wind speeds, stabilizing to a lower level at high wind speeds (see e.g. Kato et al, 1992). In addition, as one of the objectives of the study is to study the effects of H/W on ventilation characteristics, this level of turbulence intensity will conceal geometrical influences and thus hinder our investigation. Nonetheless, further investigation into higher levels of *TI*s will complement this work and assess the applicability of the proposed parameterisation beyond the existing range as we suggested.

Although a uniform wind speed was incorporated at the inlet boundary condition, the location of the inlet boundary condition 2 H from the canyon, allows the formation a logarithmic wind profile to develop due to velocity shear at the roof, the profile at the inlet boundary does not show this subsequent logarithmic profile but rather the model initialization conditions. It is acknowledged that this method of characterisation is idealised and only for the purposes of sensitivity studies. Future work on more realistic characteristics of atmospheric boundary layer and rough surfaces will be a natural extension of this work.

<u>RESPONSE TO SPECIFIC COMMENTS</u>

18067, L6: I think "urban roughness sublayer" is meant here?
Yes

18067, L9: street canyon, not canyon at least at first time of mention
OK

18068, L1: aspect ratio H/W is probably sufficient – suggest removing AR throughout and replacing with H/W
OK. AR removed as suggested and replaced with H/W.

18068, L5: Baik and Kim do not deal with aerosols, they use a passive tracer.
Yes, noted. Amended in ACP paper.

18068, L17: the reference is Barlow and Belcher (2002), not Barlow (2002)
OK

18068, L27: "surface fluxes" not "surfaces fluxes"
OK

18069, L7: is the CFD code commercially available or was it written in-house? Please state its source, and provide reference for the "standard turbulence model equations"

It is a written in-house code. Reference has been included for the standard turbulence model.

18069, L20: remove "Trapos network" from the brackets
OK

18069, L22, L25: is "vertical cavity dimension" identical to "height of the canyon"? please use consistent words, and better still the symbol H. The geometry of the "inlet scales" and outlet horizontal scales are not clear – are these the dimensions of the computational domain? "outlet horizontal scale was 10x the cavity dimension" is particularly unclear. Consider adding a diagram.

We apologize for the lack of clarity; we have redrafted the domain description for the ACP paper and have included it in the response (in italics) for your information.

The computational domain comprised symmetry, inlet and outlet boundary conditions with a cavity below representing the idealized street canyon (Figure 6). The height of the canyon (H) was chosen to be 10 m, a typical length scale expected in urban environments. Smooth wall boundary conditions were used. The inlet and outlet boundary conditions were 2H and 10H away from the canyon. The symmetry boundary condition was 5H above the canyon.

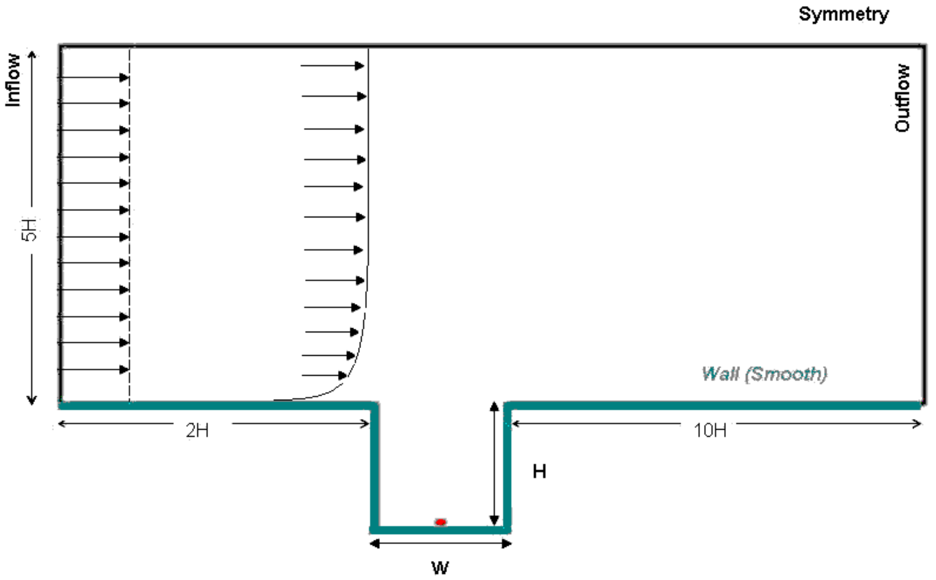


Figure 6: Computational Domain

18070, L1: what does this mean? "domain had a total of e.g. 70, 500 grid cells"

"domain had a total of 70, 500 grid cells when H/W is 1"

18070, L4: please state the range of windspeeds. Is this relevant if you are not simu-lating vehicular turbulence?

The range of wind speeds considered (2.5 m/s, 5 m/s and 10 m/s) was stated and is consistent with this assumption that vehicular turbulence may be ignored as will be discussed and justified further:

At low wind conditions, the added turbulence due to vehicular movement will enhance mixing at street level where emissions take place. The dispersive velocity of a pollutant within the street canyon is defined as (Berkowicz, 2000): $u_s \approx \sqrt{(aU_r)^2 + b\sigma_{TPT}^2}$ where U_r is the rooftop wind speed, σ_{TPT} is the traffic produced turbulence, *a* is empirically set to 0.1 and *b* is a function of traffic density. The dispersive velocity describes the turbulent exchange between the street canyon and rooftop winds. This function illustrates the relative contribution of traffic induced turbulence and roof level wind flow to the dilution of pollutants. This implies that for a given traffic density, beyond a critical level of rooftop wind speed, wind-derived turbulence is more important than the traffic-derived one. It was suggested that the effect of traffic-produced turbulence may be neglected when Ur>1.2 m/s (Solazzo et al., 2007). This is also supported by field measurements conducted within an asymmetrical canyon 22–28 m on one side and 10–18 m on the other. Turbulence intensity was measured at 2 m height at various points within the canyon. Based on these measurements conducted with a mean rooftop wind speed of 2.5 m/s (40^{o} to the canyon axis), it was found that the traffic influence on the turbulent intensity was limited (Longley, 2004). Therefore, the range of wind speed considered is consistent with our assumption.

18096, Fig1: why do the streamlines appear paired in 1a) and more evenly (distributed according to the wind field) in 1b – is this actually what the flow does? Also, please state what "medium level turbulence" means? Does it assume a certain value of TI in equation 1?

The streamlines are the product of typical flow visualization tools to illustrate qualitatively the general flow patterns.

The streamlines show the flow patterns due to the wind field. Figure 1a (ACPD paper) shows the flow-field for the case H/W= 1 where interaction between canyon and above canyon flow is more pronounced that that for the case H/W=2, where weaker interaction shows that the vertical convection is weaker at the leeward side.

Medium level turbulence means TI= 0.1 (please refer to Table 2 of ACPD paper for definitions of High, Medium and Low Turbulence). Admittedly, such descriptions could be confusing and we will enhance the clarity of description in the final ACP paper.

18097, Fig2: in caption, it states "s=2.5 m/s", is this correct or should it be U?
Yes, U. Corrected in ACP paper.

18071, L6: "Reynolds stresses of aerosol concentration" doesn't make sense: the stresses refer to momentum exchange, not a scalar concentration. Please modify sentence.
OK, modified sentence to turbulent flux of aerosols as requested

18071, L11: this I think should be F_t, not F_a
Yes. Corrected in ACP paper.

18071, equation 3: why is the turbulent flux expressed using the 1D K form, rather than the covariance stated above? Is this how it was determined, by calculating Kx and the gradient in aerosol concentration at rooftop?

Yes, the flux was calculated by the 1D integration of the product of the eddy viscosity and vertical aerosol concentration gradient along the horizontal axis of the canyon top.

18091, Table 2 and 18076 L23: you define turbulence intensity as the RMS of fluctuations divided by mean wind, why are units squared here?
Units removed.

18073, L18: which "CFD experiments" – do you mean yours? Please clarify or include References
We mean CFD experiments from Kumar, et al. (2009). We have redrafted this portion for clarity.

18098, Fig 3: figure legends, labels too small
OK, enlarged as suggested.

18102 Fig 7: this has confusing labels: the caption says it is net flux, the small axes labels on both sides say advective flux (which is what it is...?). It might be clearer to include all aspect ratio results on the same axis, to better highlight the change in sign: it would also more clearly show the lack of sensitivity to TI of some runs. Some appropriate colour/markers would help an already busy plot. BUT: some very interesting results here!

We apologize for the confusion: it is advective flux. Thank you for the compliments. We have incorporated appropriate colours and markers as suggested, but the authors are of the opinion that it is clearer to have separate Y axes for different H/W, but of the same scale (to illustrate relative sensitivity).

18074, L5-15: please refer to figures where the data is represented so that the reader can verify your statements, even though the figures are discussed in more detail later on.
Ok, done for the ACP paper.

18074, L20 : viscosity – mu seems to be molecular viscosity on 18071, here it is turbulent viscosity, K? Please use consistent notation
Yes, ok noted. We will be using consistent notation for all variables (including what you have mentioned) for the ACP paper.

18074, L21: "concentration shear" is confusing – shear relates to a force/stress – do you mean concentration gradient? Please be clear in following discussion to use shear in relation to wind magnitude/direction gradients.
Yes, vertical concentration gradient.

18074, L25: at what height is the vertical concentration height defined? Roof level?
Yes

18079, L7: "The implications....would need further investigation" – this could be better phrased, as the next two sections seem to report on the "further investigation"?
OK, rephrased for the ACP paper.

18084, L19:"...fit the CFD results to the numerical model (Eq 2.0)". This is not clear –equation 2 is the inlet turbulent dissipation profile. Should it be equation 4, ie the proposed parameterisation?
Yes

This whole section is not clearly written – have you applied the simple parameterisation from CFD results to the observations of Martin? What is "averaged diurnal observation of emission fluxes", compared to the label on fig 17 "averaged diurnal aerosol flux range" – I think it means you have taken the average flux across a diurnal cycle from Martin's observations to compare with parameterization prediction? Figure 17 shows a very good agreement, considering the difference in scales!

Yes, we have applied the parameterization to the diurnal averaged data from Martin's measurement and found a fair correlation. We apologize for the inconsistency in the manuscript used to describe Fig. 17 (in the ACPD paper) and the labeling of Figure 17 (in the ACPD paper). We will align the more general micrometeorological terminology for clarity. Figure 17 (in the ACPD paper) shows the comparison between Martin's "diurnal averaged measurement data" with the prediction results from the parameterization. The whole section will be rewritten for clarity in the ACP paper.

18100, Figure 5: Please label using consistent labels, i.e. aspect ratio values same as other plots. Maybe also avoid shallow, symmetrical/square, deep labels as these are subjective. The vertical axis seems to be mis-labelled – turbulent fluxes are always positive? Should be concentration gradient.
OK. Yes, Mislabeling. Subjective descriptions have been removed and replaced with H/W values to differentiate the different geometries.

18103, Fig 8: the label says 2 m/s, the caption says 2.5?
Yes, apologies for the mislabeling.

CONCLUDING REMARKS

Once again, we thank the referee for taking time to carefully review the paper and for the constructive comments given to enhance the quality of the ACP paper. Undoubtedly, more work is needed to enhance the model set-up and further investigation is required, which will be pursued as future work and a subject of subsequent publications.

References

Berkowicz, R., Operational street pollution model-a parameterized street pollution model. Environmental Monitoring and Assessment 65, 323-331, 2000.

Baik, J.J. and Kim , J.J. A numerical study of flow and pollutant dispersion characteristics in urban street canyons. Journal of Applied Meteorology 38: 1576-1589, 1999

Baik, J.J. and Kim, J.J. On the escape of pollutants from urban street canyons. Atmospheric Environment 36: 527-536, 2002

Baik, J.J. and Kim, J.J. Effects of inflow turbulence intensity on flow and pollutant dispersion in an urban street canyon. Journal of Wind Engineering and Industrial Aerodynamics 91: 309-329, 2003

Dixon, N.S. and Tomlin A.S., Evaluation of a lagrangian model for predicting concentration fluctuations in urban areas. Proceedings 11th International

Conference on Harmonization within Atmospheric Dispersion Modelling for Regulatory Purposes, 2007

Eliasson, I., Offerle, B., Grimmond, C.S.B., Lindquist, S., Wind fields and turbulence statistics in an urban street canyon, Atmospheric Environment, Volume 40(1): 1-16, 2006

Gallis, M. A., Torczynski, J. R. and Rader, D.J., Nonzero-concentration boundary condition for advection-diffusion aerosol-transport modeling. Aerosol Science and Technology 42(10): 829 – 831, 2008

Jeong, S. J. and Andrew M.J. Application of the k-epsilon turbulence model to high reynolds number skimming flow field of an urban street canyon. Atmospheric Environment 36: 1137-1145, 2002

Kastner-Klein, P. and E. J. Plate. "Wind-tunnel study of concentration fields in street canyons." Atmospheric Environment **33**(24-25): 3973-3979, 1999

Kato, N., Ohkuma, T. , Kim, J.R. , Marukawa, H. and Niihori, Y., Full scale Measurements of wind velocity in two urban areas using an ultrasonic anemometer. J. Wind Eng. Ind. Aerodyn. **41–44**:67–78, 1992

Kumar, P., Garmory, A., Ketzel, M., Berkowicz, R. and Britter, R. Comparative study of measured and modelled number concentrations of nanoparticles in an urban street canyon. Atmospheric Environment 43, 949–958, 2009

Longley, I.D. Corrections to a description of turbulence in a trafficked street canyon in Manchester. Atmospheric Environment 38: 4589-4592, 2004

Matti Maricq, M., Chemical characterization of particulate emissions from Diesel engines: A review. Journal of Aerosol Science **38**(11): 1079-1118, 2007

Meroney, R.N., Pavageau, M., Rafailidis, S., Schatzmann, M., 1996. Study of line source characteristics for 2-D physical modelling of pollutant dispersion in street canyons. Journal of Wind Engineering and Industrial Aerodynamics 62, 37–56.

Murena, F., Favale, G., Vardoulakis, S. and Solazzo, E. Modelling dispersion of traffic pollution in a deep street canyon: Application of CFD and operational models, Atmospheric Environment, 43(14): 2303-2311, 2009

Murakami, S., Current Status and future trends in computational wind engineering. Journal of Wind Engineering and Industrial Aerodynamics 67&68:3-34, 1997

Rotach M.W., Profiles of turbulences statistical in and above an urban street canyon. Atmospheric Environment **29** (13):1473–1486, 1995

Sini, J.-F., Anquetin, S., and Mestayer, P.G. Pollutant dispersion and thermal effects in urban street canyon. Atmospheric Environment 30(15): 2659-2677, 1996.

Solazzo, E. Vardoulajis, S., Cai, X. , "Evaluation of Traffic Producing Turbulence Schemes within Operational Pollution Models using Roadside Measurements " Atmospheric Environment 41: 5357-5370, 2007.

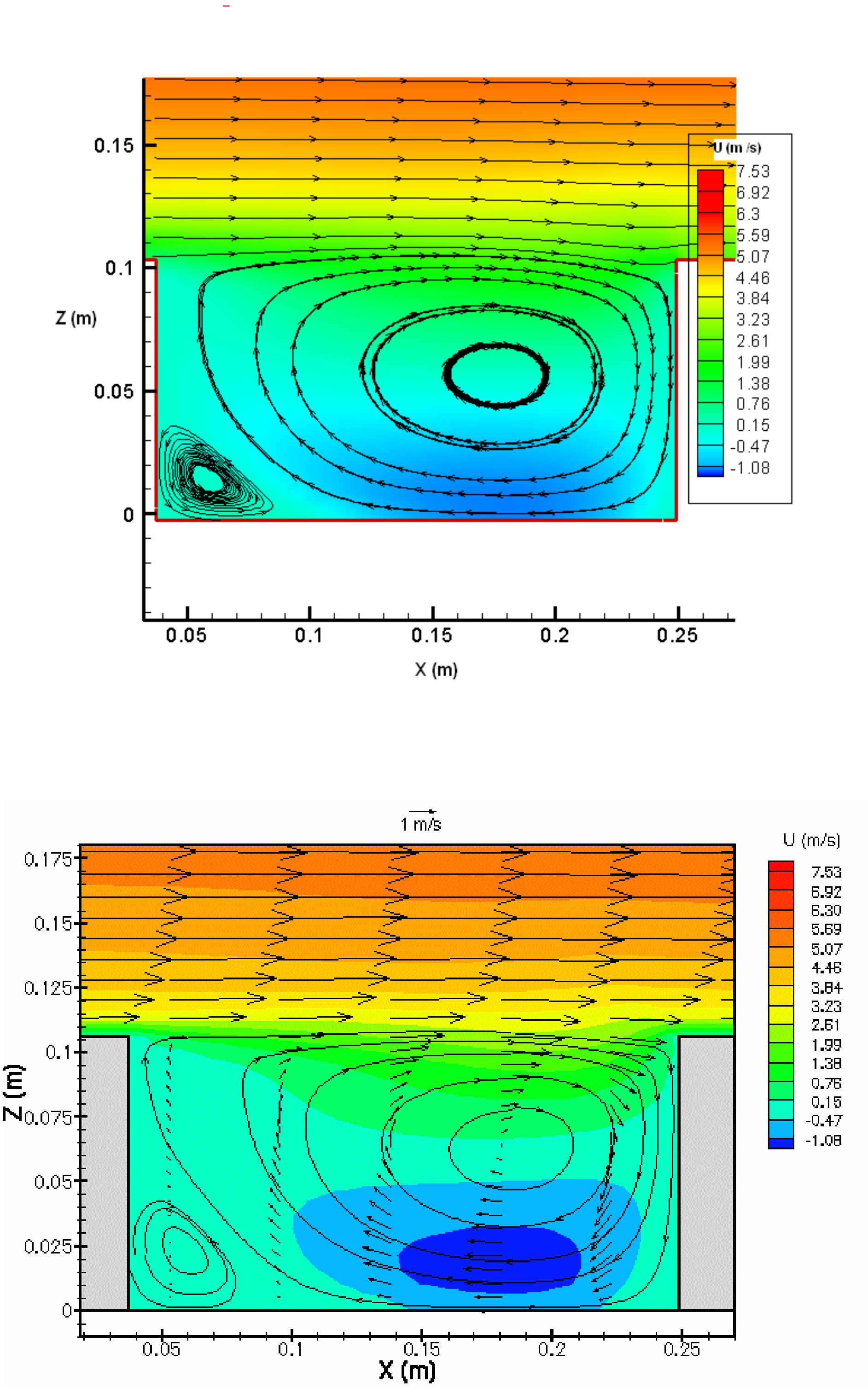
Solazzo, E. and Britter, R.E. Transfer processes in a simulated urban street canyon. Boundary-Layer Meteorology 124: 43-60, 2007.

Uhrner, U., von Lowis, S. , Vehkamaki, H., Wehner, B., Brasel, S., Hermann, M. Stratmann, F., Kulmala, M., Wiedensohler, A. Dilution and aerosol dynamics within a diesel car exhaust plume--CFD simulations of on-road measurement conditions, Atmospheric Environment 41(35):7440-7461, 2007

Appendix

The code was validated against a benchmark 2D cavity test case (Ketzel *et al.*, 2004). The solution of the code was compared with wind tunnel databases to assess the model skill in solving the mass, momentum, turbulence (standard k-ε turbulence model) equations. The flow obtained within the cavity by the model is characterised by a main re-circulation vortex and a secondary vortex at the leeward side of the cavity close to the ground (Fig. Ia). This result is quantitatively consistent with both wind tunnel databases (Fig. II) (Ketzel *et al.*, 2004) and previous numerical simulation (Fig. Ib) (Savory *et al.*, 2004) of the same case. The horizontal velocity profiles obtained using the model of this study along 3 axes within the cavity compares well with wind tunnel database (Fig. IIa, Fig. IIb & Fig. IIc).

(a)



(b)

Figure I:(a) Numerical results **(b)** Previously published model results of the same case of horizontal wind velocity (U) (Savory, *et al.* , 2004)

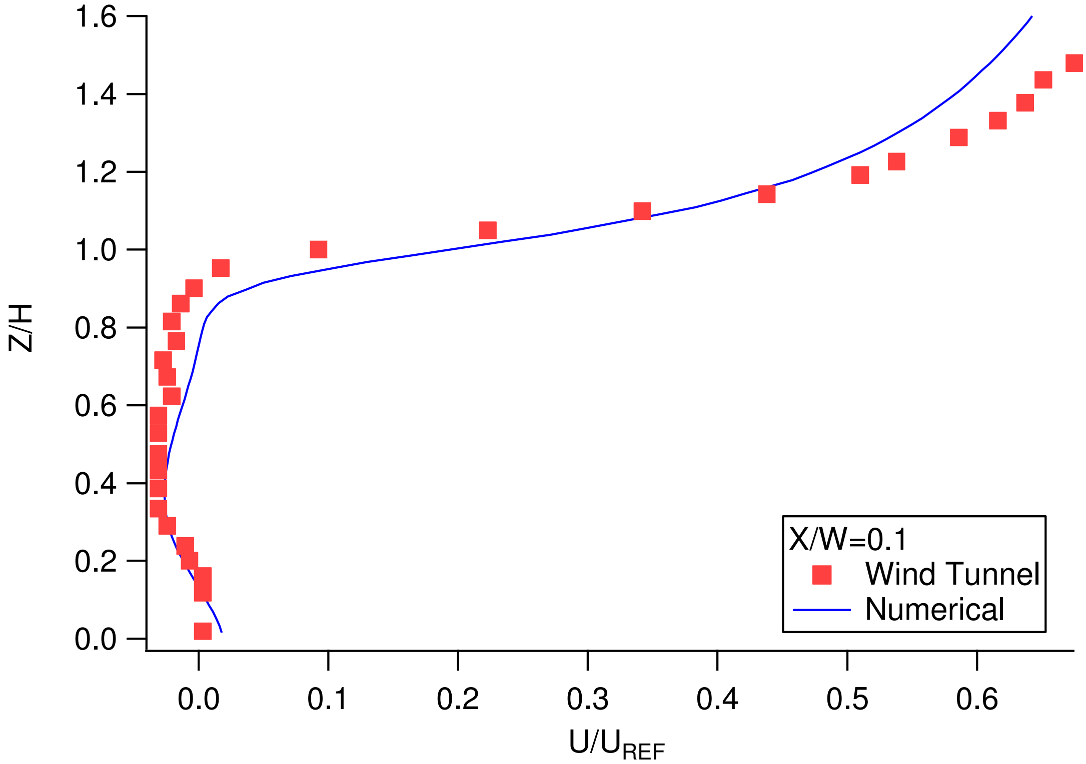


Figure II(a)

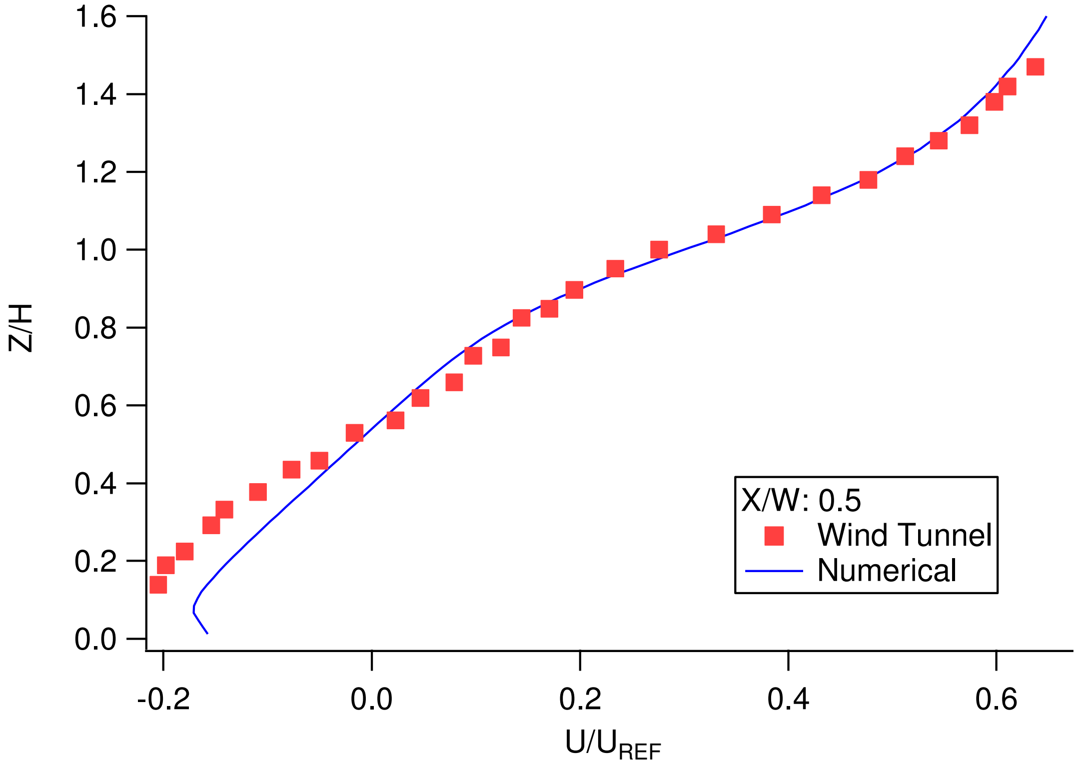


Figure II (b)

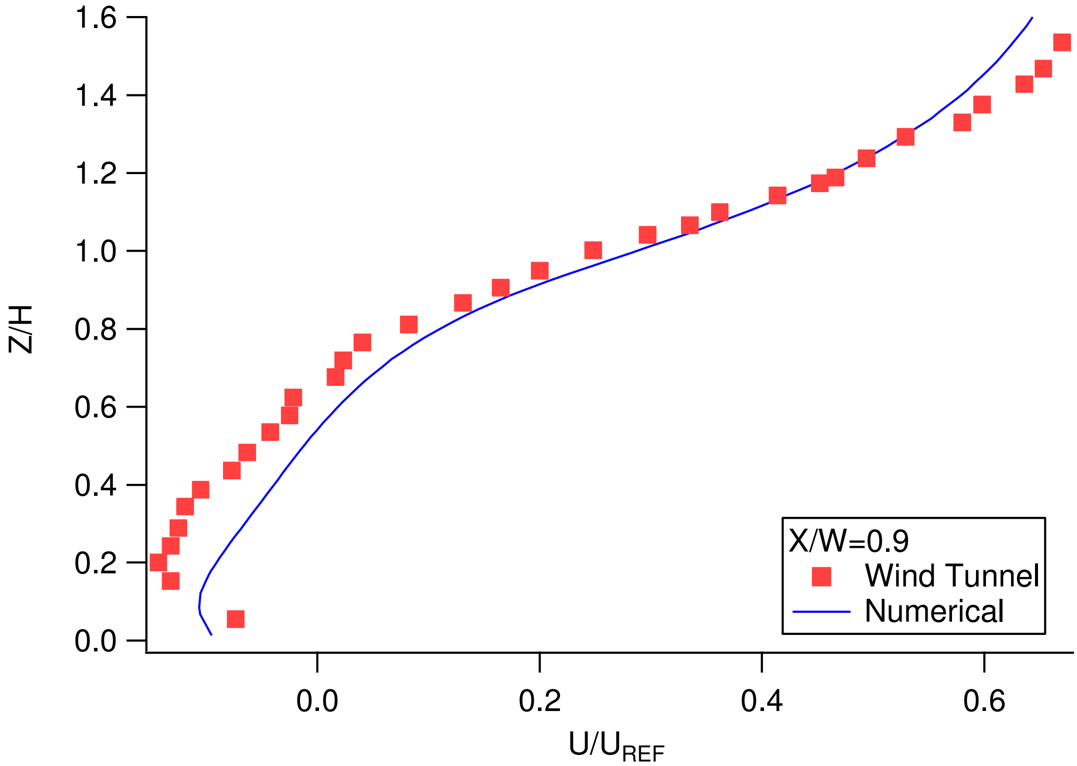


Figure II (c)

Figure II: Comparison of numerically computated wind profile using the model of this study with wind tunnel databases (Ketzel, *et al.* , 2004) at **(a)** X/W= 0.1; **(b)** 0.5 & **(c)** 0.9

Ketzel, K., Louka, P., Sahm, P., Guilloteau, E. & Sini, J.-F. *The use of computational fluid dynamics in modelling air quality in street canyons* in *Optimisation of Modelling Methods for Traffic Pollution in Street,* Final Report for EU Trapos Project, Chapter 2.2: pages 86-93, Editors Berkowicz, R., Britter, R. & Sabatino S.D., published online at http://www2.dmu.dk/AtmosphericEnvironment/trapos/TheBook/TRAPOS_Book.pdf , 2004

Savory, E., Rotach, M.W., Chauver, C., Guilloteau, E., Kaster-Klein, P., Kovar-Panskus, A., Louka, P., Sahm P. & Castelli, S.T., *Street architecture and air quality* in *Optimisation of Modelling Methods for Traffic Pollution in Street,* Final Report for EU Trapos Project, Chapter 1.1: pages 8-24, Editors Berkowicz, R., Britter, R. & Sabatino S.D., published online at http://www2.dmu.dk/AtmosphericEnvironment/trapos/TheBook/TRAPOS_Book.pdf , 2004