JP1.2 IMPLEMENTATION OF A NEW ROOFTOP RECIRCULATION PARAMETERIZATION INTO THE QUIC FAST RESPONSE URBAN WIND MODEL

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1. INTRODUCTION

Buildings change the local flow characteristics and introduce various complex flow features that have an impact on the transport and dispersion of airborne contaminants. Material released in the vicinity of a building may become entrapped in the various recirculation zones around a building altering the ground-level concentration. The Quick Urban & Industrial Complex (QUIC) dispersion modeling system has been developed to rapidly provide 3D wind and concentration fields around buildings in cities. A new rooftop recirculation parameterization has been implemented into the wind model and in this paper the scheme is evaluated by comparison of model output and experimental measurements of the mean flow above building rooftop. The wind-tunnel experiments included buildings of various width, length and height and an incident wind angle perpendicular to the front face of the building.

2. BACKGROUND

The QUIC dispersion model is comprised of the QUIC-URB wind model, the QUIC-PLUME Lagrangian random-walk model, and the QUIC-GUI graphical user interface. QUIC-URB is a fast running empirical diagnostic wind model used to compute the 3-D wind fields for flow around buildings. It is based on the original idea of Röckle (1990) and the work of Kaplan and Dinar (1996). This approach uses empirical parameterizations to define recirculation regions around and between buildings and mass conservation to generate a mass consistent flow field. In QUIC-URB, an initial wind field is prescribed for the domain based on either a power-law, logarithmic, urban canopy or user-specified profile. For isolated buildings, empirical parameterizations that are a function of the building geometry are applied to the front, rooftop, and cavity recirculation zones and velocity deficit wake zone. The final 3-D velocity field is obtained by forcing this initial velocity field to be mass consistent.

Several of the building recirculation algorithms have been modified in the QUIC-URB model, including the upwind rotor (Bagal et al., 2004). The original model of Röckle did not include a rooftop recirculation zone, a characteristic feature of isolated buildings and buildings taller than the surrounding nearby buildings. Bagal et al. (2004) implemented a rooftop scheme into QUIC-URB, but it has been found to give poor results for tall buildings. In this paper, a new rooftop scheme is proposed and is compared with Bagal's original scheme and with wind-tunnel flow data. The description of the experimental set up and the two rooftop flow parameterizations are presented in the subsequent sections.

3. EXPERIMENTAL DESCRIPTION

The experiments were conducted in the USEPA Meteorological Wind Tunnel, an open return type tunnel that had a test section that was 3.7m wide, 2.1m high and 18.3m long. The wind speed in the wind tunnel could be varied between 0.3-8m/s (Snyder, 1979). The experimental setup consisted of one rectangular block used as a proxy for a building immersed in a simulated atmospheric boundary layer that was approximately 1.8m deep. The boundary layer was initiated with Irwin (1981) system of "spires" and maintained with roughness on the floor downwind. The boundary-layer velocity profile was well characterized by a power-law profile with an exponent of 0.16 and a freestream value of 4 m/s. A log-law profile was found in the surface layer with a friction velocity u* equal to 0.05 m/s and with a roughness length z_0 equal to 1 mm.

For these experiments, velocity measurements were obtained around smooth blocks with different height, width, and length dimensions. The standard reference was a cubical "building" with dimensions of 200mm on each side. The crosswind dimension W of the building was increased to 2, 4 and 10 times that of the cube for the "wide" building experiments. The along-wind dimension L was increased to 2 and 4 times that of the cube for the "long" building experiments. The height H was increased to 2 and 3 times that of the cube for the tall building experiments.

A pulsed-wire anemometer (PWA) was used for measuring the velocity components (one at a time) in the longitudinal and vertical directions. Measurements were obtained along the centerline in the x-z plane. Further details of this experiment can be found in Snyder and Lawson (1994).

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4. ROOFTOP FLOW PARAMETRIZATIONS

To capture the rooftop recirculation region associated with flow separation from the leading edge of an isolated building, Bagal et. al. (2004) developed a scheme for the initial wind field for the case of incident wind within +/-15 degrees of perpendicular to the front face. In this scheme an ellipsoidal recirculation region was implemented above rooftop with length (L_c) and height (H_{cm}) parameters from Wilson (1979):

H_{cm} (Height of vortex) =0.22*R
L_c (Length of vortex) =0.9*R
R (scaling parameter) =0.67*B_s+0.33*B_l
B_s=Smaller of upwind building height or width
B_l=Larger of upwind building height or width,

where H_{cm} is the height of the recirculation cavity. The ellipsoidal region was divided into two regions as shown in Fig. 1. A logarithmic profile was implemented in the total ellipsoidal region and then the logarithmic profile was reversed in Region 1. The rooftop flow field computed by the above scheme, hereafter called the “old” scheme, was in far better agreement with the experimental data as compared to having no rooftop scheme (Bagal et. al., 2004). However, for tall buildings, the scheme broke down and gave unphysical results.

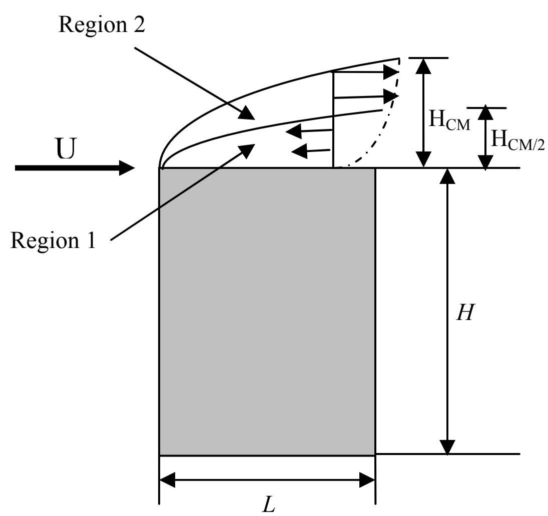

Figure 1: Schematic of the “old” rooftop recirculation initial wind field scheme in the QUIC-URB model. A logarithmic wind profile is implemented in Region 1 in the opposite direction to the prevailing wind, while a positive logarithmic profile is implemented in Region 2 (Bagal et al., 2004).

With the goal of improving the model performance a new scheme was developed for the rooftop initial wind field. This scheme also has an ellipsoidal recirculation region with length and height parameters specified by Wilson (1979). A profile with high velocities near the roof and zero velocity at the top of the recirculation region (inverted wedge shape) is implemented through the whole recirculation region for the initial velocity field as shown in Fig. 2. The initial velocity profile is given by:

$$U(z) = -U_0(z')\left|\frac{(H + H_{CM}) - z}{H_{CM}}\right| \qquad (1)$$

where H is the building height, H_{cm} is the height of the recirculation region, and U_o is the velocity at a height z’ (where, z’=H+H_{cm}-z) above the roof level obtained by an exponential profile having exponent equal to 0.16. This profile was selected in order to create an initial wind field at the leading edge of the building in which the winds were in exact balance, i.e., winds of opposite direction but equal magnitude. After mass conservation, a near-zero value should be obtained at the leading edge grid cell, representative of the flow at the separation point. The zero velocity at H_{cm} in Eq. (1) ensures that the recirculation region smoothly transitions to the ambient flow. After mass conservation is imposed, a rooftop vortex is created. In the following section, both schemes are compared with experimental data.

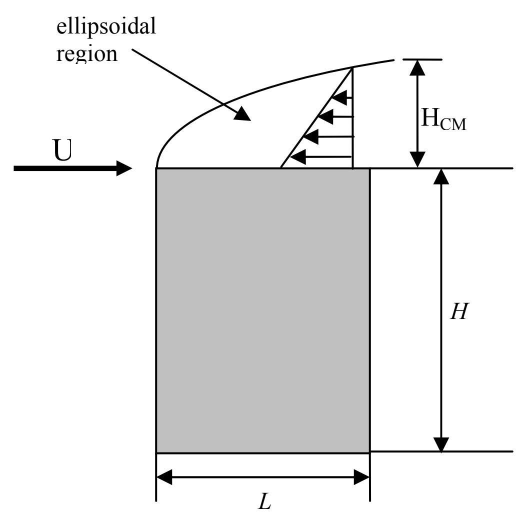

Figure 2: Schematic of the new rooftop recirculation initial wind field scheme in the QUIC-URB model. A linear profile with high velocities near the roof and near zero velocity at the fop of the recirculation region is implemented through the whole recirculation region.

5. MODEL EVALUATION

The wind fields produced by both rooftop schemes are compared to the experimental measurements of flow over buildings of varying width, height and length. The incident wind direction in all the cases was perpendicular to one of the faces of the building. The QUIC-URB inflow velocity profile was specified to be a power law with an exponent of 0.16 to match the experimental conditions. Experimental measurements were made at approximately 300 points in the vertical center plane both upwind and downwind of the buildings for each case (Snyder and Lawson 1994). The model was run at a higher resolution than the available experimental data with a grid cell size of $1/20H_{cube}$. The simulations were performed on a domain of 2400 by 500 by 400 grid cells for the base case. The numbers of grid cells in the lateral direction were increased for wide building cases.

4.1 Cubical building:

Model-computed and experimentally-measured wind fields in the center-plane are compared in Fig. 3 for a cube *(W=H=L)*. The plot shows that the new parameterization reproduces the rooftop recirculation zone fairly well, although the data is sparse within the recirculation region. The mean wind has an upwardly motion as it approaches the cube. The region showing the upwardly motion of the wind is followed by the recirculation zone over the roof top. The streamwise length of this recirculation zone is slightly lesser than the length of the cube. The vector plot further shows that the magnitude of the velocity is high very close to the roof surface; this may not be true in real cases as flow should slow down near a surface.

Profiles of normalized streamwise velocity above roof top obtained through both schemes are compared to the experimental data in Fig. 4. Here for the cubical building case *(W=H=L)* the building center was at x/H=0 and the streamwise extent of the building was form x/H=-0.5 to x/H=0.5. The new scheme has a better match with the experimental data for z/H locations between 1 and 1.2. There is a gradual shift from negative to positive values in streamwise velocity for the new scheme as compared to abrupt shifts predicted by the old scheme for the roof top recirculation region. Both schemes fail to exactly match the experimental data at z/H location equal to 1.2. Further both schemes predict very high values of velocity very close to the roof.

Profiles of normalized vertical component of velocity above the building roof top obtained through both schemes are compared to the experimental data in Fig. 5. The new rooftop recirculation scheme better predicts the vertical velocity magnitude at x/H location equal to -0.4. However, both schemes predict higher negative vertical velocity values near the roof level at x/H location equal to 0.4. From the velocity vector plot in Fig. 3 it can be observed that the vertical velocity values are highly exaggerated at the downwind edge of the roof. This behavior can be attributed to high negative values of streamwise velocity set at the rooftop and continuity being enforced.

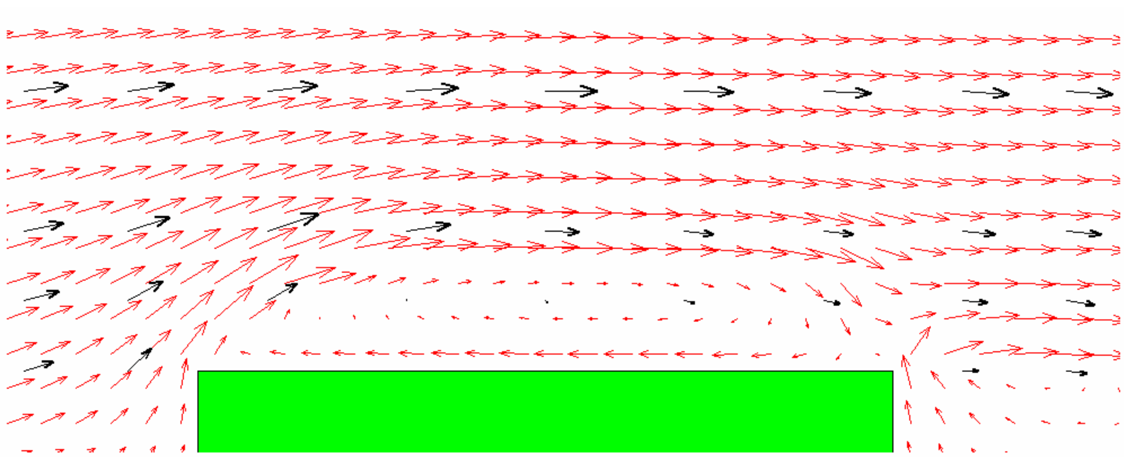

Figure 3: Velocity vector plot with experimental data (→) and model computed with new roof top recirculation scheme (→) for a cubical building (W=H=L) along the center plane for incoming flow perpendicular to the building.

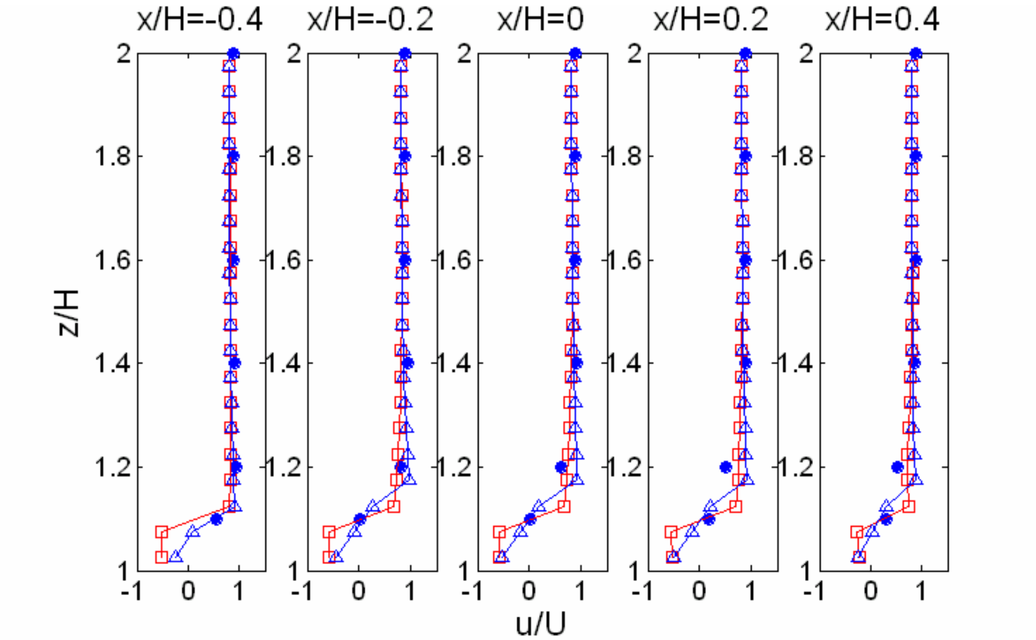

Figure 4: Comparison of normalized streamwise velocity above the rooftop for experimental measurements of Snyder and Lawson (1994) (●), for QUIC-URB with old rooftop recirculation scheme (-□-) and with new rooftop recirculation scheme (-Δ-) for a cube (W=H=L).

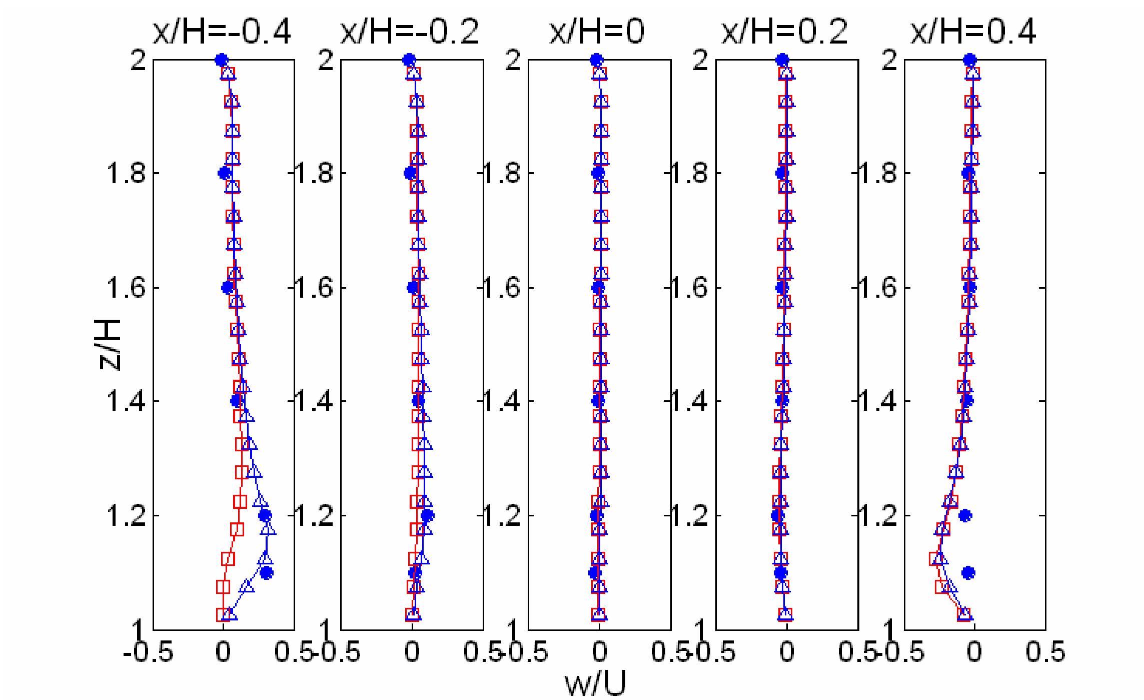

Figure 5: Comparison of normalized vertical component of velocity above the rooftop for experimental measurements of Snyder and Lawson (1994) (●), for QUIC-URB with old rooftop recirculation scheme (-□-) and with new rooftop recirculation scheme (-Δ-) for a cube (W=H=L).

4.2 Wide building (W/H=2, H=L):

Model-computed and experimentally-measured wind fields in the center-plane are compared in Fig. 6 for a wide building *(W/H=2, H=L).* The plot shows that the new parameterization reproduces the rooftop recirculation zone fairly well. The flow separates from the upwind edge and reattaches itself to the roof, as observed for the cubical building case. The length of the recirculation zone does not change much as compared to the base case. However, the vertical velocity values are further exaggerated at the downwind edge of the roof as compared to the cubical building case. The velocity values near the roof surface are high.

Profiles of normalized streamwise velocity above roof top obtained through both schemes are compared to the experimental data in Fig. 7. Here for the wide building *(W/H=2, H=L)* the building center was at x/H=0 and the streamwise extent of the building was form x/H=-0.5 to x/H=0.5. The new scheme has a better match with the experimental data for z/H locations between 1 and 1.2 as compared to the old scheme. There is a gradual shift from negative to positive values in streamwise velocity for the new scheme as compared to abrupt shifts predicted by the old scheme for the roof top recirculation region. Both schemes fail to match the experimental data at z/H location equal to 1.2. Both schemes predict high values of velocity close to the roof. The normalized values of the streamwise velocity as predicted by the old scheme reach unity at z/H location of around 1.1, thus under predicting the height of the recirculation zone as these values reach unity at z/H location of around 1.2. However, the new rooftop recirculation scheme better predicts the height of the rooftop recirculation zone.

Profiles of normalized vertical component of velocity above the building roof top obtained through both schemes are compared to the experimental data in Fig. 8 for this case. The new rooftop recirculation scheme better predicts the vertical velocity magnitude at x/H location equal to -0.4. Both schemes perform equally well at other locations.

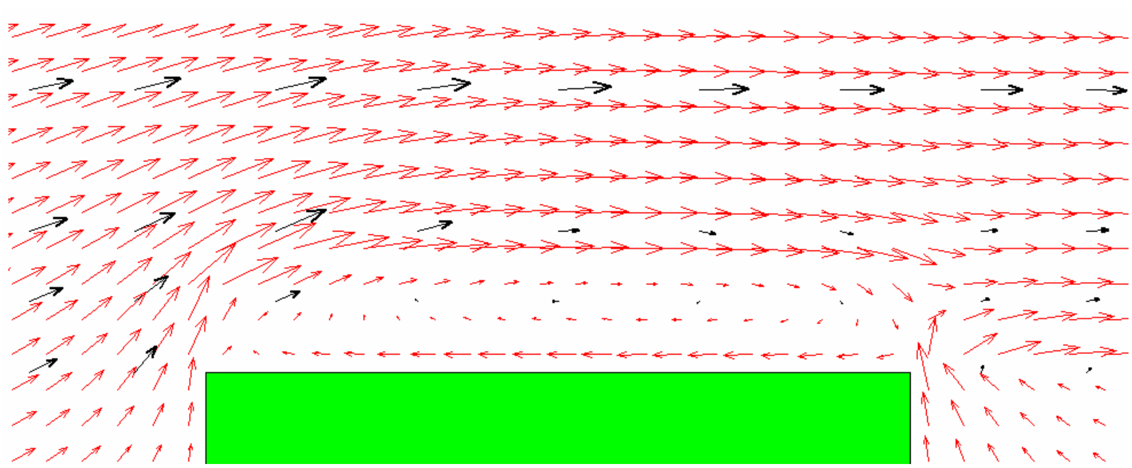

Figure 6: Velocity vector plot with experimental data (→) and model computed with new roof top recirculation scheme (→) for a wide building (W/H=2, H=L) along the center plane for incoming flow perpendicular to the building.

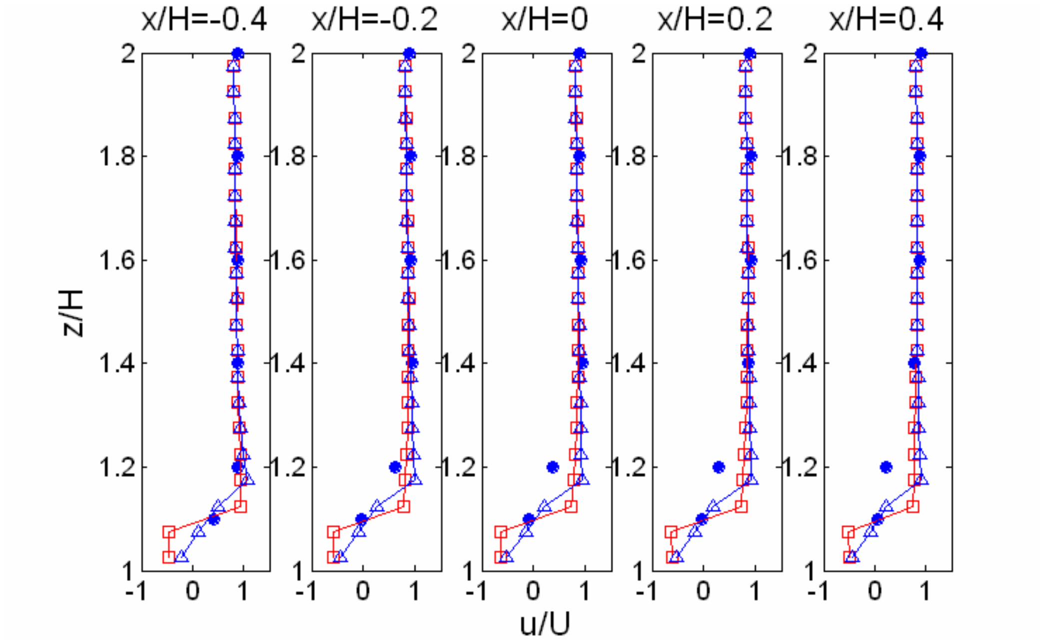

Figure 7: Comparison of normalized streamwise velocity above the rooftop for experimental measurements of Snyder and Lawson (1994) (●), for QUIC-URB with old rooftop recirculation scheme (-□-) and with new rooftop recirculation scheme (-Δ-) for a wide building (W/H=2, H=L).

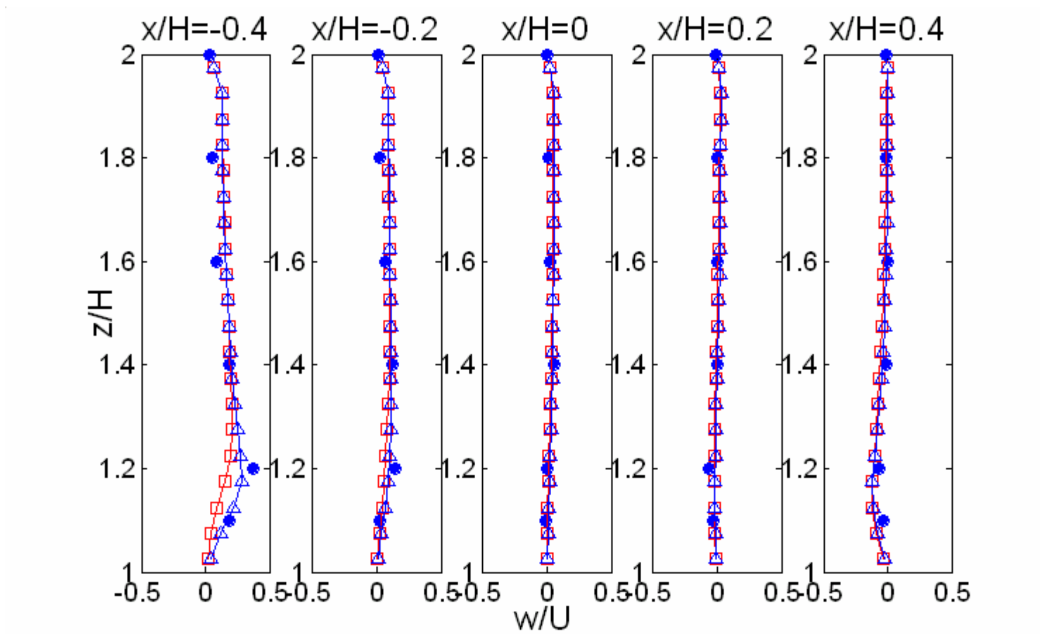

Figure 8: Comparison of normalized vertical component of velocity above the rooftop for experimental measurements of Snyder and Lawson (1994) (●), for QUIC-URB with old rooftop recirculation scheme (-□-) and with new rooftop recirculation scheme (-Δ-) for a wide building (W/H=2, H=L).

4.3 Wide building (W/H=4, H=L):

Model-computed and experimentally-measured wind fields in the center-plane are compared in Fig. 9 for a wide building *(W/H=4, H=L)*. The plot shows that the new parameterization reproduces the rooftop recirculation zone fairly well. The length of the recirculation zone does not change as compared to the base case. However there is increase in the height of the recirculation zone as compared to the previous cases. The vertical velocity values are further exaggerated at the downwind edge of the roof as compared to the cubical building case.

Profiles of normalized streamwise velocity above roof top obtained through both schemes are compared to the experimental data in Fig. 10. Here for the wide building *(W/H=4, H=L)* the building center was at x/H=0 and the streamwise extent of the building was form x/H=-0.5 to x/H=0.5. The new scheme has a better match with the experimental data for z/H locations between 1 and 1.2 as compared to the old scheme. There is a gradual shift from negative to positive values in streamwise velocity for the new scheme as compared to abrupt shifts predicted by the old scheme for the roof top recirculation region. The old recirculation scheme fails to exactly match the experimental data at z/H location equal to 1.2. Both schemes predict very high values of velocity close to the roof. The normalized values of the streamwise velocity as predicted by the old scheme reach unity at z/H location of around 1.1, thus under predicting the height of the recirculation zone as these values reach unity at z/H location of around 1.2. However, the new rooftop recirculation scheme better predicts the height of the rooftop recirculation zone.

Profiles of normalized vertical component of velocity above the building roof top obtained through both schemes are compared to the experimental data in Fig. 11 for this case. The new rooftop recirculation scheme better predicts the vertical velocity magnitude at x/H location equal to -0.4.

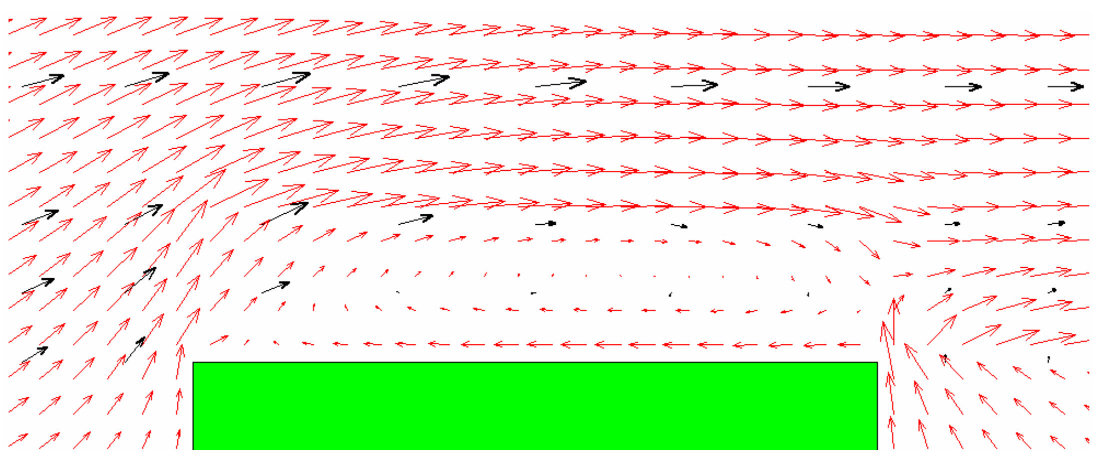

Figure 9: Velocity vector plot with experimental data (→) and model computed with new roof top recirculation scheme (→) for a wide building (W/H=4, H=L) along the center plane for incoming flow perpendicular to the building.

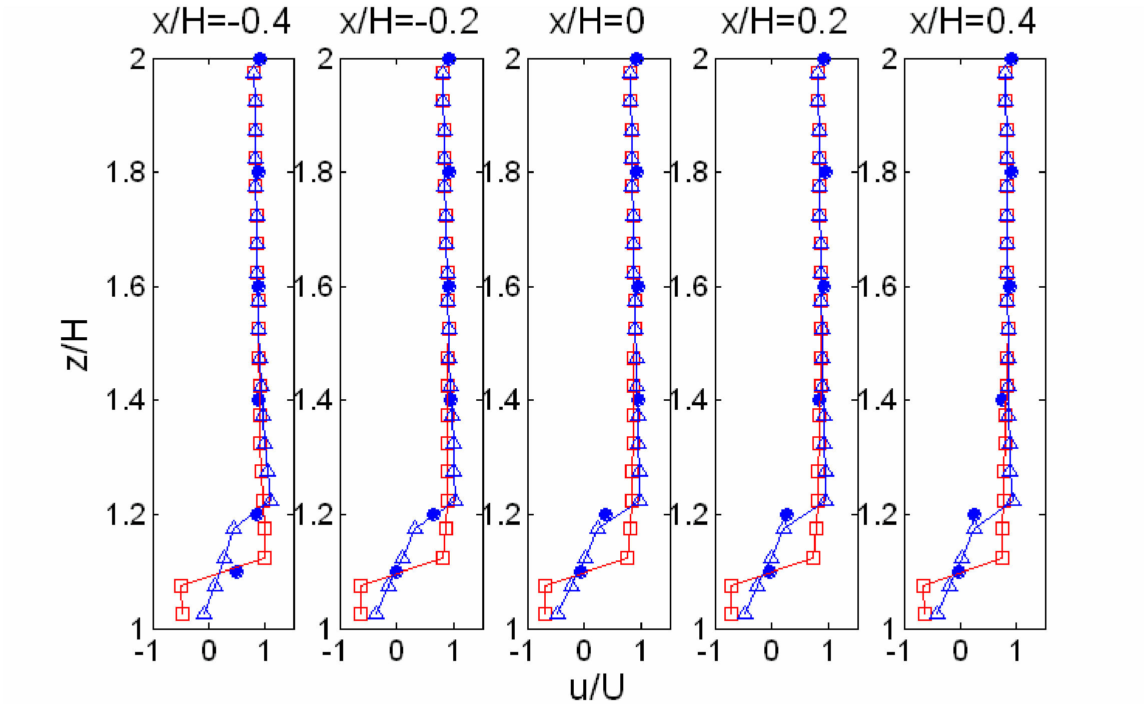

Figure 10: Comparison of normalized streamwise velocity above the rooftop for experimental measurements of Snyder and Lawson (1994) (●), for QUIC-URB with old rooftop recirculation scheme (-□-) and with new rooftop recirculation scheme (-Δ-) for a wide building (W/H=4, H=L).

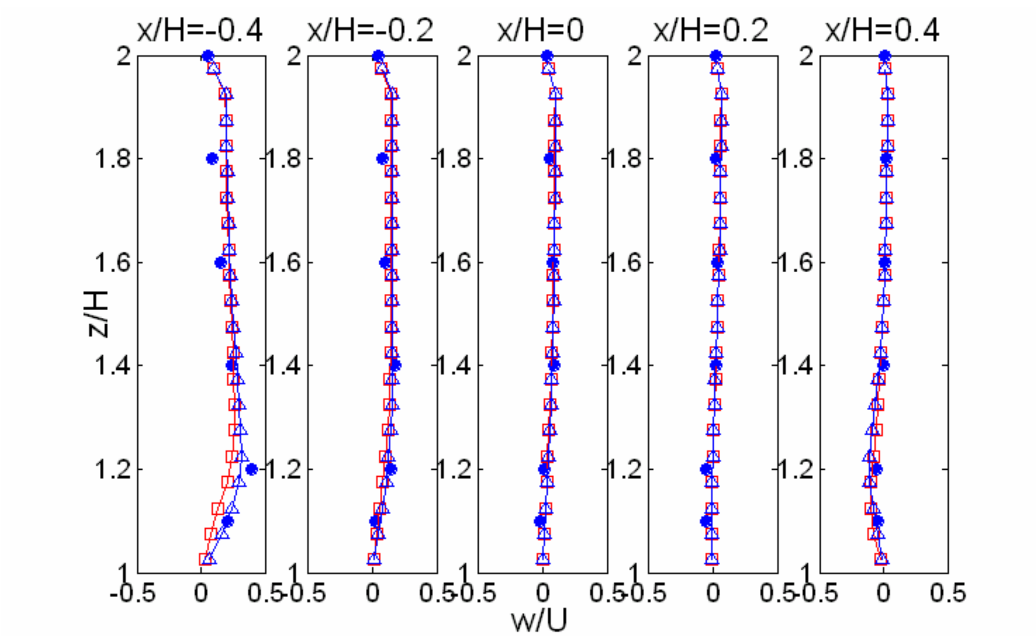

Figure 11: Comparison of normalized vertical component of velocity above the rooftop for experimental measurements of Snyder and Lawson (1994) (●), for QUIC-URB with old rooftop recirculation scheme (-□-) and with new rooftop recirculation scheme (-Δ-) for a wide building (W/H=4, H=L).

4.4 Wide building (W/H=10, H=L):

Model-computed and experimentally-measured wind fields in the center-plane are compared in Fig. 12 for a wide building *(W/H=10, H=L)*. The plot shows that the new parameterization reproduces the rooftop recirculation zone fairly well. The length of the recirculation zone is equal as compared to previous cases. However, the normalized height of the recirculation zone is greater as compared to the cubical building case and as observed by Snyder and Lawson (1994). The vertical velocity values are further exaggerated at the downwind edge of the roof as compared to the cubical building case.

Profiles of normalized streamwise velocity above roof top obtained through both schemes are compared to the experimental data in Fig. 13. Here for the wide building *(W/H=10, H=L)* the building center was at x/H=0 and the streamwise extent of the building was form x/H=-0.5 to x/H=0.5. The new scheme has a better match with the experimental data for z/H locations between 1 and 1.2 as compared to the old scheme. There is a gradual shift from negative to positive values in streamwise velocity for the new scheme as compared to abrupt shifts predicted by the old scheme for the roof top recirculation region. The old recirculation scheme fails to exactly match the experimental data at z/H location equal to 1.2. Both schemes predict high values of velocity close to the roof. The normalized values of the streamwise velocity as predicted by the old scheme reach unity at z/H location just below 1.2, thus under predicting the height of the recirculation zone. These values should reach unity at z/H location of around 1.3. However, the new rooftop recirculation scheme better predicts the height of the rooftop recirculation zone.

Profiles of normalized vertical component of velocity above the building roof top obtained through both schemes are compared to the experimental data in Fig. 14 for this case. The new rooftop recirculation scheme better predicts the vertical velocity magnitude especially at x/H location equal to 0.4.

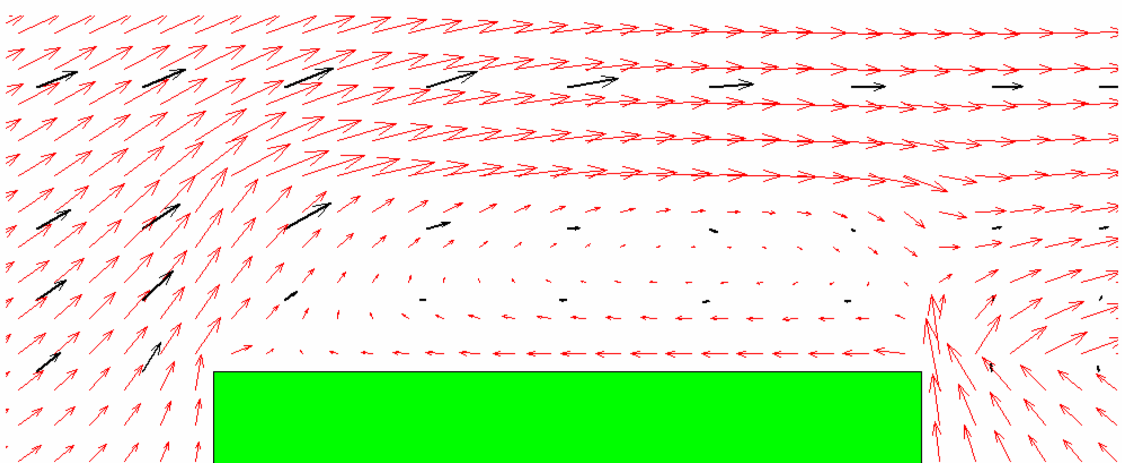

Figure 12: Velocity vector plot with experimental data (→) and model computed with new roof top recirculation scheme (→) for a wide building (W/H=10, H=L) along the center plane for incoming flow perpendicular to the building.

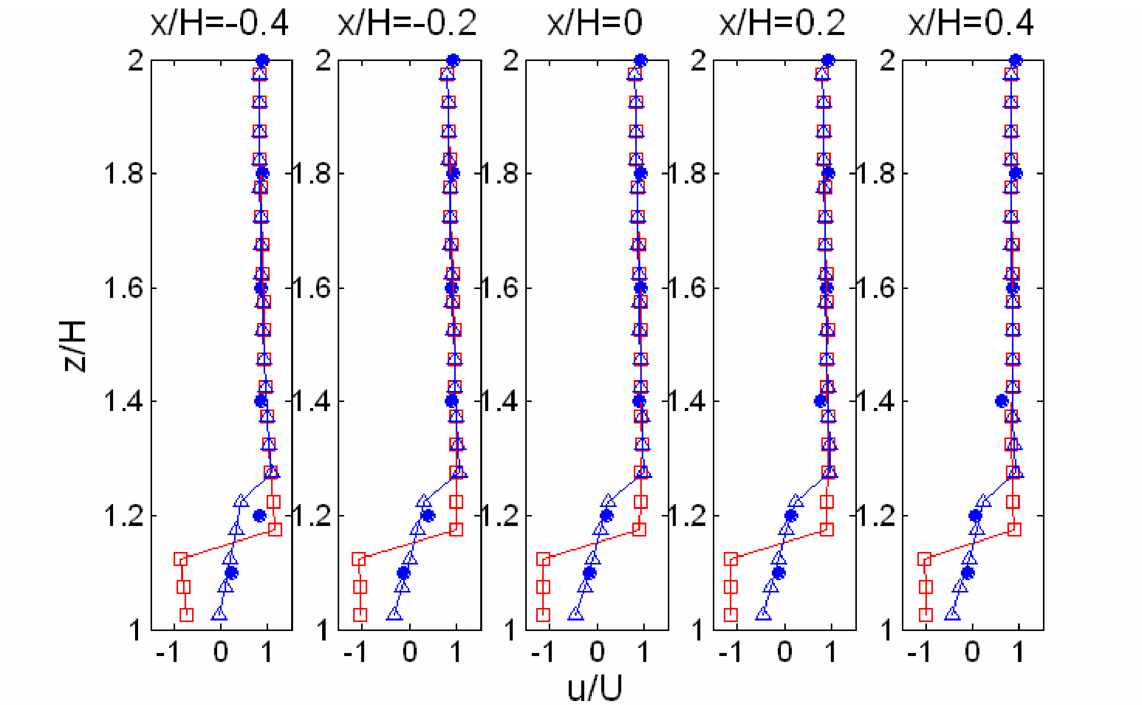

Figure 13: Comparison of normalized streamwise velocity above the rooftop for experimental measurements of Snyder and Lawson (1994) (●), for QUIC-URB with old rooftop recirculation scheme (-□-) and with new rooftop recirculation scheme (-Δ-) for a wide building (W/H=10, H=L).

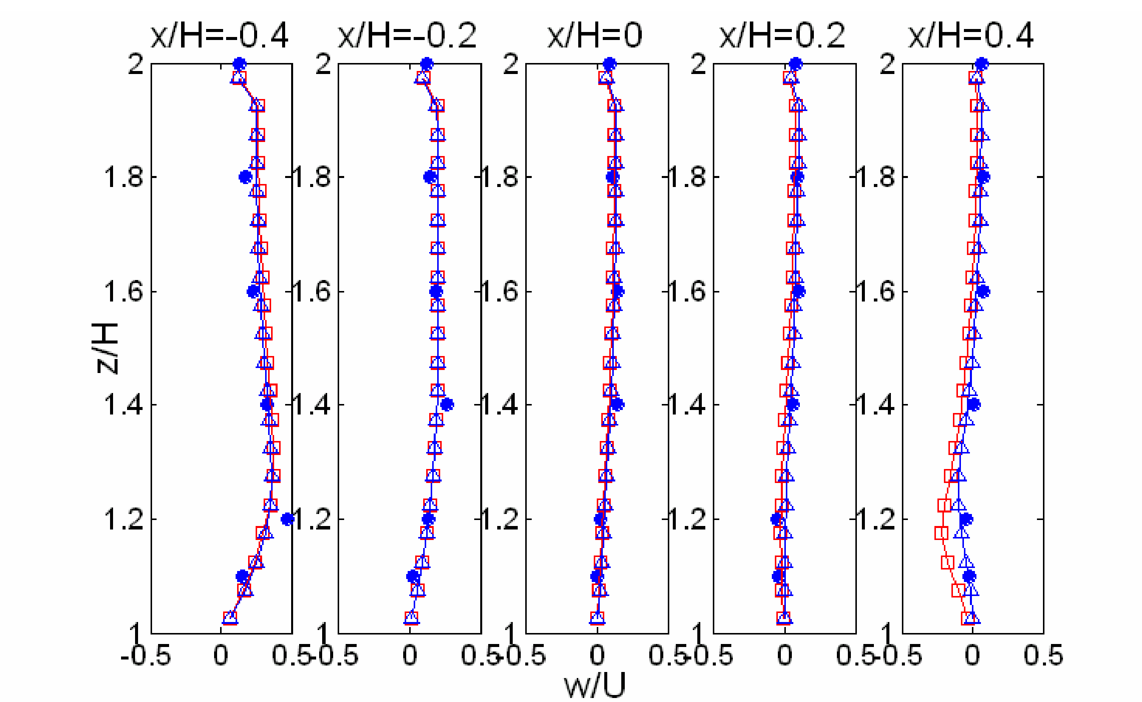

Figure 14: Comparison of normalized vertical component of velocity above the rooftop for experimental measurements of Snyder and Lawson (1994) (●), for QUIC-URB with old rooftop recirculation scheme (-□-) and with new rooftop recirculation scheme (-Δ-) for a wide building (W/H=10, H=L).

4.5 Tall building (H/W=2, L=H):

Model-computed and experimentally-measured wind fields in the center-plane are compared in Fig. 15 for a tall building *(H/W=2, L=H)*. The plot shows that the new parameterization reproduces the rooftop recirculation zone fairly well, although the number of experimental data points has further reduced. Here, the vertical velocity values are not exaggerated at the downwind edge of the roof as predicted in the wide building cases. The normalized height of the recirculation zone is reduced as compared to the experimental observations for a cubical building case. The wind speeds predicted are higher at the roof surfaces for this case.

Profiles of normalized streamwise velocity above roof top obtained through both schemes are compared to the experimental data in Fig. 16. Here for the tall building *(H/W=2, L=H)* the building center was at x/H=0 and the streamwise extent of the building was form x/H=-0.25 to x/H=0.25. The new scheme has a better match with the experimental data at z/H locations below 1.1 as compared to the old scheme. There is a gradual shift from negative to positive values in streamwise velocity for the new scheme as compared to abrupt shifts predicted by the old scheme for the roof top recirculation region. Both schemes predict high values of velocity close to the roof. The normalized values of the streamwise velocity as predicted by the old scheme reach unity at z/H location just below 1.05, thus under predicting the height of the recirculation zone as these values should reach unity at z/H location of around 1.15. The new rooftop recirculation scheme slightly better predicts the height of the rooftop recirculation zone. Both schemes over predict the magnitude of the streamwise velocity near roof level.

Profiles of normalized vertical component of velocity above the building roof top obtained through both schemes are compared to the experimental data in Fig. 17 for this case. The new rooftop recirculation scheme better predicts the vertical velocity magnitude especially at x/H location equal to -0.3, however both schemes over predict the negative vertical velocity magnitudes at x/H location equal to 0.3.

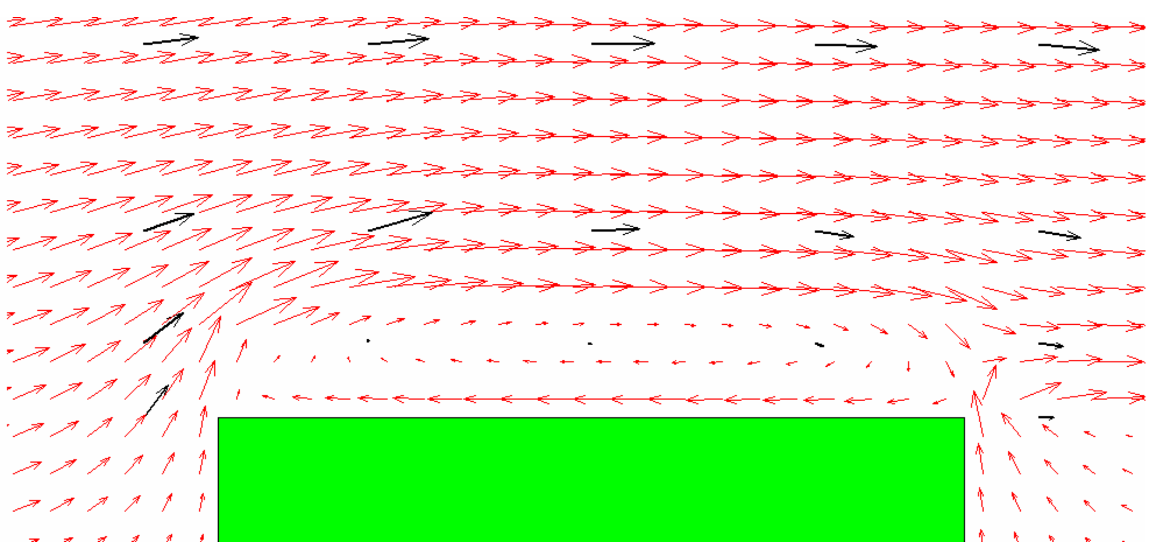

Figure 15: Velocity vector plot with experimental data (→) and model computed with new roof top recirculation scheme (→) for a tall building (H/W=2, L=H) along the center plane for incoming flow perpendicular to the building.

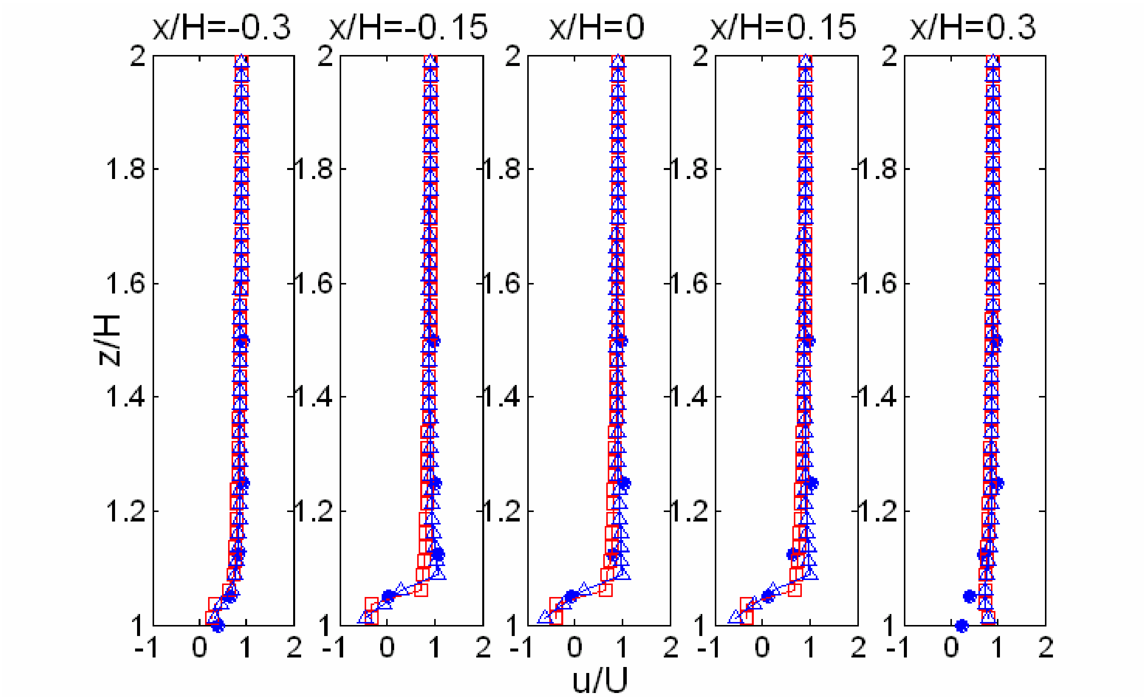

Figure 16: Comparison of normalized streamwise velocity above the rooftop for experimental measurements of Snyder and Lawson (1994) (●), for QUIC-URB with old rooftop recirculation scheme (-□-) and with new rooftop recirculation scheme (-Δ-) for a tall building (H/W=2, L=H).

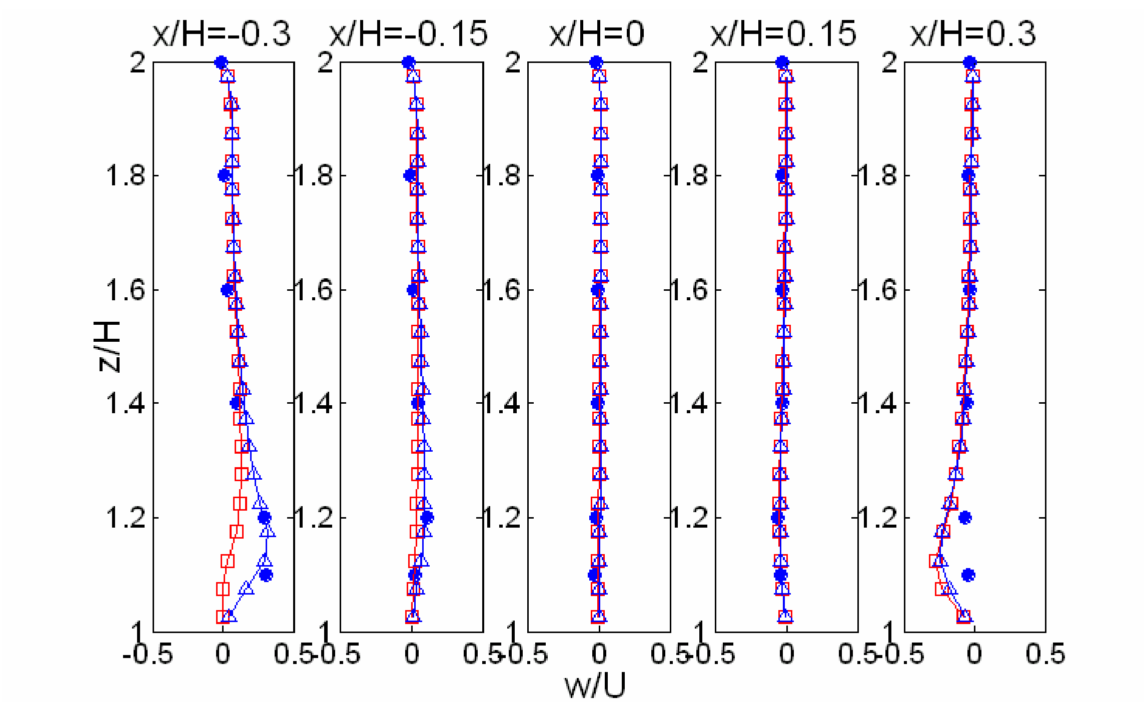

Figure 17: Comparison of normalized vertical component of velocity above the rooftop for experimental measurements of Snyder and Lawson (1994) (●), for QUIC-URB with old rooftop recirculation scheme (-□-) and with new rooftop recirculation scheme (-Δ-) for a tall building (H/W=2, L=H).

4.6 Tall building (H/W=3, L=H):

Model-computed and experimentally-measured wind fields in the center-plane are compared in Fig. 18 for a tall building *(H/W=3, L=H)*. The plot shows that the new parameterization reproduces the rooftop recirculation zone. Since the number of experimental data points has further reduced, it is difficult to conclude from this plot if the recirculation zone is reproduced correctly. Here, the vertical velocity values are not exaggerated at the downwind edge of the roof as predicted in the wide building cases. The normalized height of the recirculation zone is further reduced as compared to the experimental observations for cubical building and the previous case for a tall building.

Profiles of normalized streamwise velocity above roof top obtained through both schemes are compared to the experimental data in Fig. 19. Here for the tall building *(H/W=3, L=H)* the building center was at x/H=0 and the streamwise extent of the building was form x/H=-0.167 to x/H=0.167. The new scheme has a better match with the experimental data at z/H locations below 1.1 as compared to the old scheme. There is a gradual shift from negative to positive values in streamwise velocity for the new scheme as compared to abrupt shifts predicted by the old scheme for the roof top recirculation region. Both schemes predict very high values of velocity very close to the roof. The normalized values of the streamwise velocity as predicted by the old scheme reach close to unity at z/H location just below 1.05, thus under predicting the height of the recirculation zone as these values should reach unity at z/H location of around 1.15. The new rooftop recirculation scheme better predicts the normalized height of the rooftop recirculation zone. Both schemes over predict the magnitude of the streamwise velocity near roof level.

Profiles of normalized vertical component of velocity above the building roof top obtained through both schemes are compared to the experimental data in Fig. 20 for this case. The new rooftop recirculation scheme better predicts the vertical velocity magnitude except at x/H location equal to 0.2.

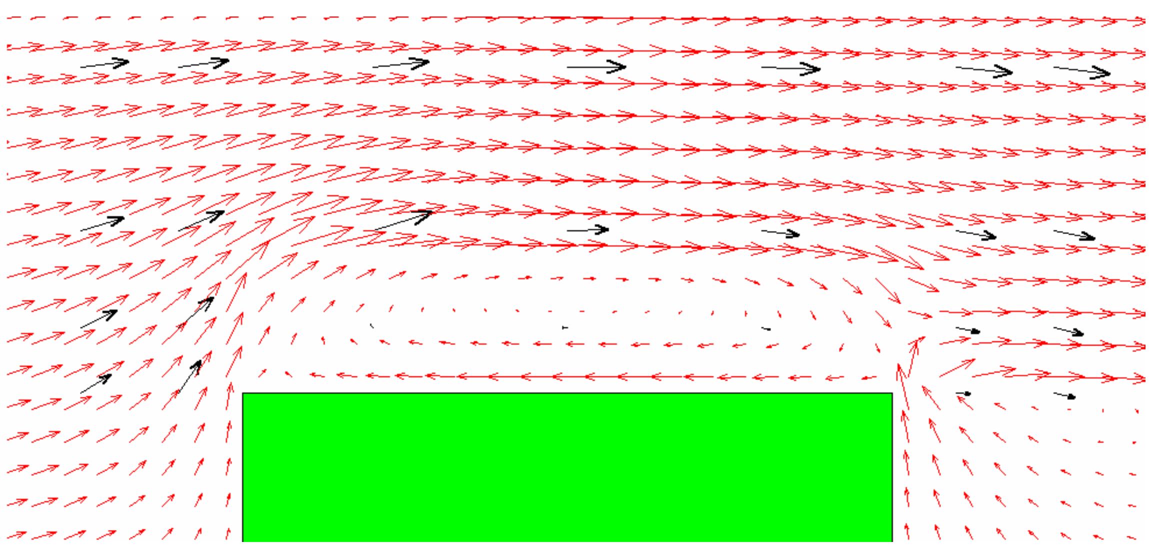

Figure 18: Velocity vector plot with experimental data (→) and model computed with new roof top recirculation scheme (→) for a tall building (H/W=3, L=H) along the center plane for incoming flow perpendicular to the building.

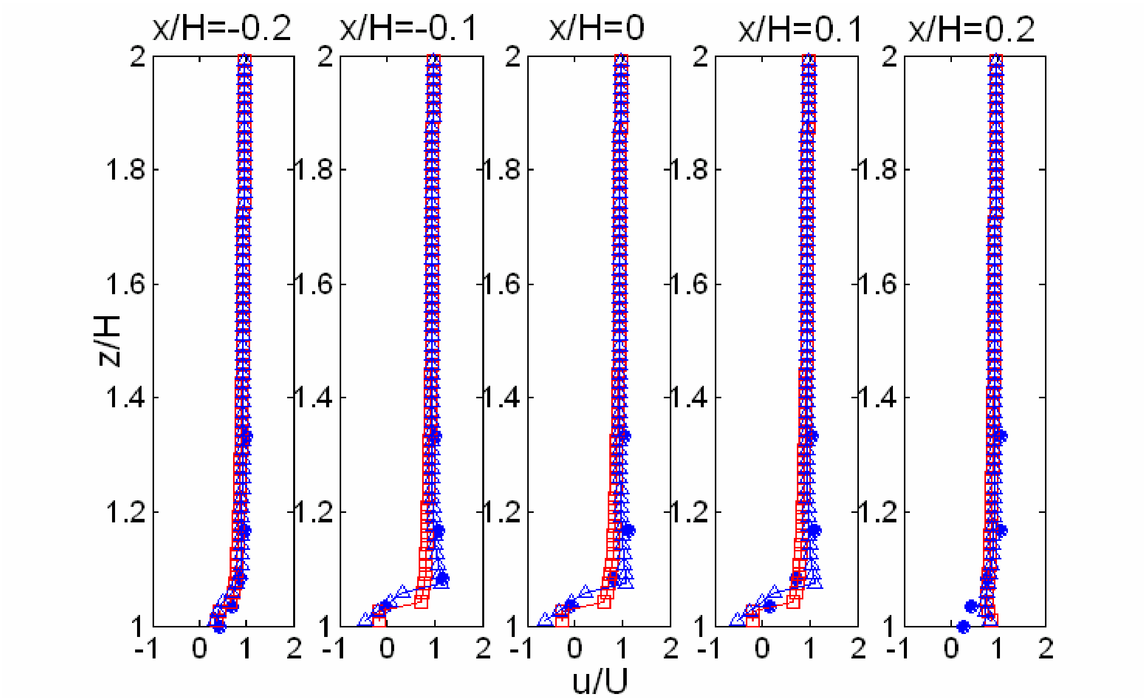

Figure 19: Comparison of normalized streamwise velocity above the rooftop for experimental measurements of Snyder and Lawson (1994) (●), for QUIC-URB with old rooftop recirculation scheme (-□-) and with new rooftop recirculation scheme (-Δ-) for a tall building (H/W=3, L=H).

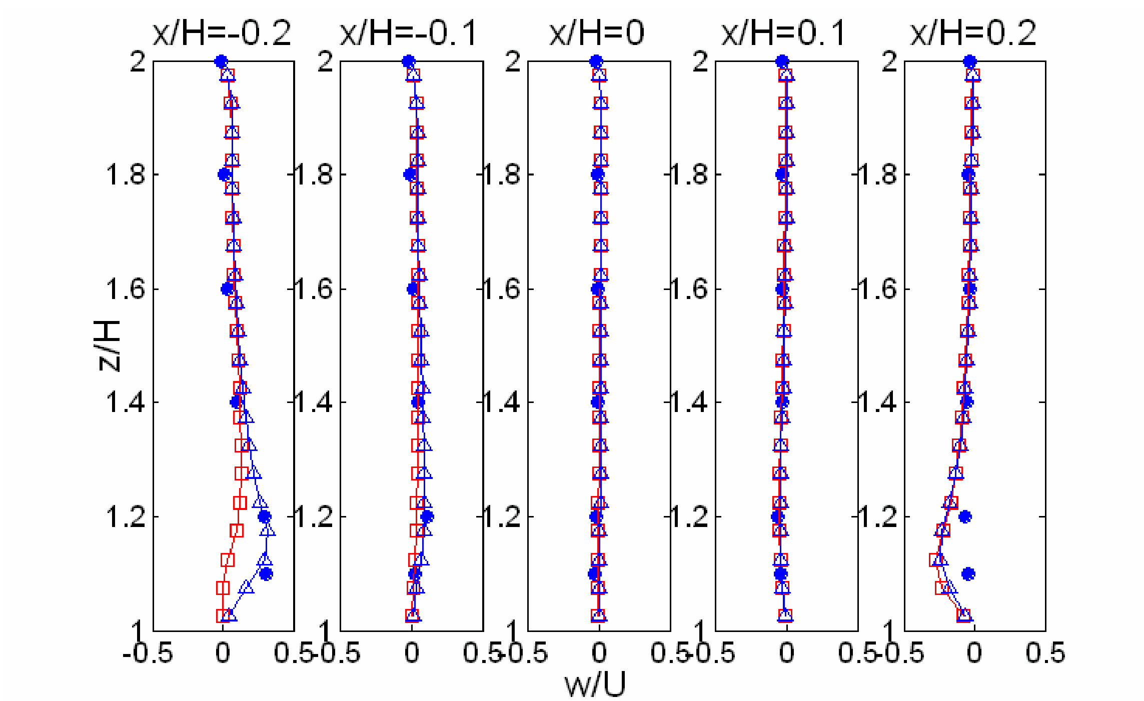

Figure 20: Comparison of normalized vertical component of velocity above the rooftop for experimental measurements of Snyder and Lawson (1994) (●), for QUIC-URB with old rooftop recirculation scheme (-□-) and with new rooftop recirculation scheme (-Δ-) for a tall building (H/W=3, L=H).

4.7 Long building (L/H=2, W=H):

Model-computed and experimentally-measured wind fields in the center-plane are compared in Fig. 21 for a tall building *(L/H=2, W=H)*. The plot shows that the new parameterization reproduces the rooftop recirculation zone. Due to lack of experimental data points it is difficult to determine if the recirculation zone is reproduced correctly. The length of the recirculation zone is equal the building height (or 1/4 times building length, similar to previous cases. Here, the vertical velocity values are not exaggerated at the downwind edge of the roof as predicted in the wide building cases.

Profiles of normalized streamwise velocity above roof top obtained through both schemes are compared to the experimental data in Fig. 22. Here for the long building *(L/H=2, W=H)* the building center was at x/H=0 and the streamwise extent of the building was form x/H=-1.0 to x/H=1.0. The new scheme has a better match with the experimental data at z/H locations below 1.3 as compared to the old scheme. There is a gradual shift from negative to positive values in streamwise velocity for the new scheme as compared to abrupt shifts predicted by the old scheme for the roof top recirculation region. Both schemes predict high values of velocity close to the roof. The reattachment point for the recirculation zone as predicted by the new scheme is almost equal to the dimension equal to building height from the upstream edge of the building as observed by Snyder and Lawson (1994).

Profiles of normalized vertical component of velocity above the building roof top obtained through both schemes are compared to the experimental data in Fig. 23 for this case. The new rooftop recirculation scheme better predicts the vertical velocity magnitude except at x/H location equal to 0.

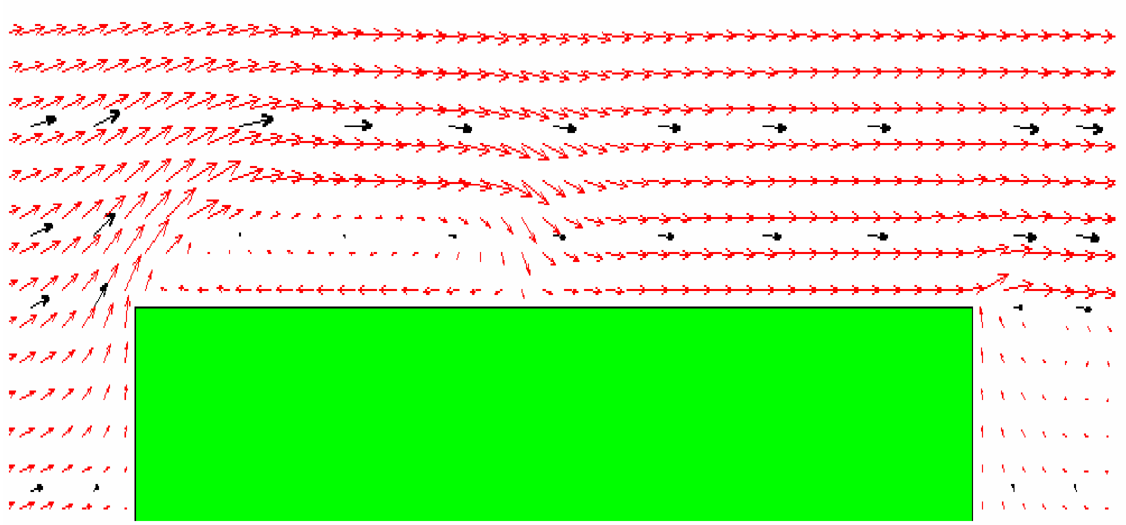

Figure 21: Velocity vector plot with experimental data (→) and model computed with new roof top recirculation scheme (→) for a long building (L/H=2, W=H) along the center plane for incoming flow perpendicular to the building.

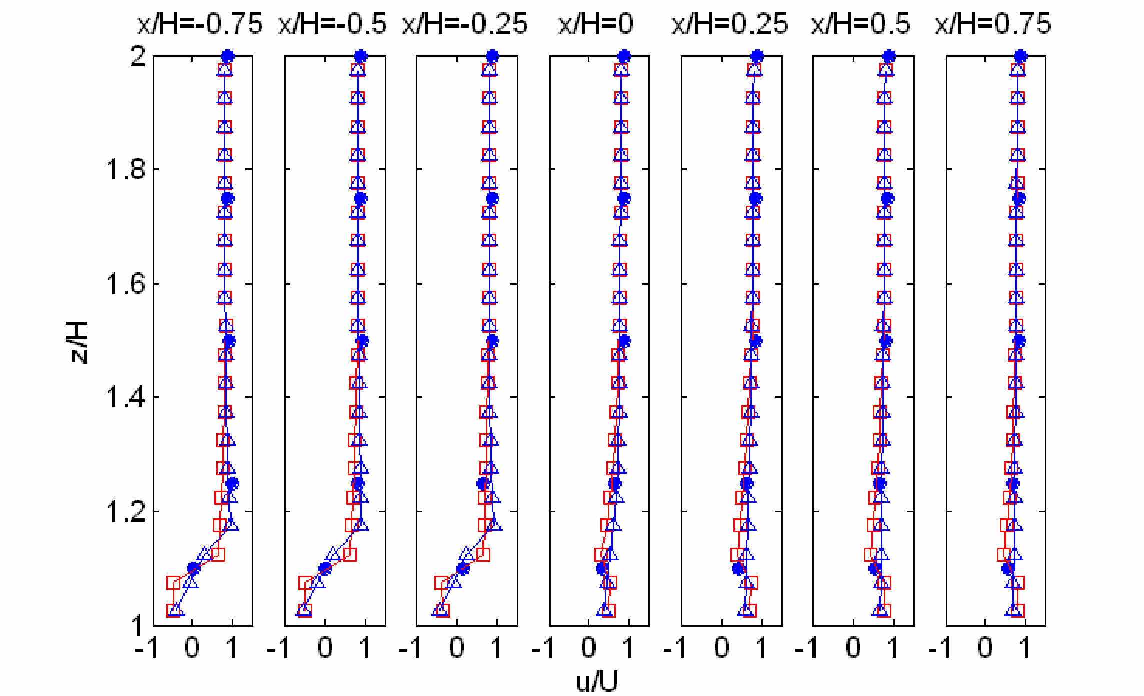

Figure 22: Comparison of normalized streamwise velocity above the rooftop for experimental measurements of Snyder and Lawson (1994) (●), for QUIC-URB with old rooftop recirculation scheme (-□-) and with new rooftop recirculation scheme (-Δ-) for a long building (L/H=2, W=H).

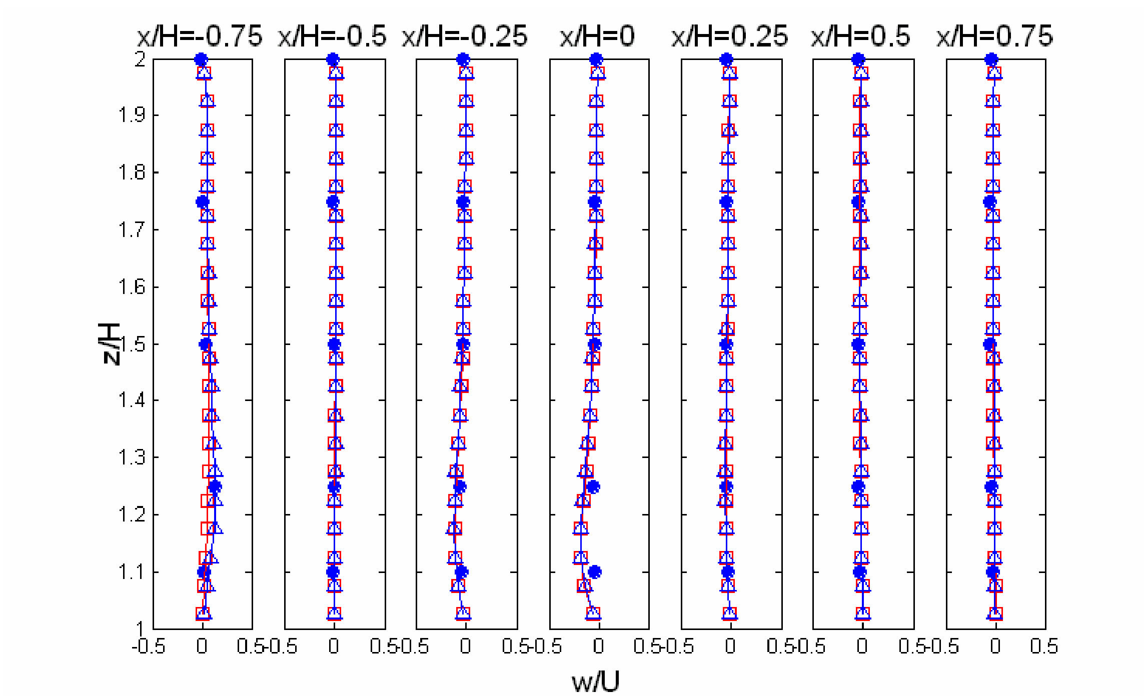

Figure 23: Comparison of normalized vertical component of velocity above the rooftop for experimental measurements of Snyder and Lawson (1994) (●), for QUIC-URB with old rooftop recirculation scheme (-□-) and with new rooftop recirculation scheme (-Δ-) for a tall building (H/W=3, L=H).

4.8 Long building (L/H=4, W=H):

Model-computed and experimentally-measured wind fields in the center-plane are compared in Fig. 24 for a tall building (L/H=4, W=H). The plot shows that the new parameterization reproduces the rooftop recirculation zone. Due to lack of experimental data points it is difficult to determine if the recirculation zone is reproduced correctly. The length of the recirculation zone is equal the building height (or 1/4 times building length), similar to previous cases. Here, the vertical velocity values are not exaggerated at the downwind edge of the roof as predicted in the wide building cases.

Profiles of normalized streamwise velocity above roof top obtained through both schemes are compared to the experimental data in Fig. 25. Here for the long building (L/H=4, W=H) the building center was at x/H=0 and the streamwise extent of the building was form x/H=-2.0 to x/H=2.0. The new scheme has a better match with the experimental data at z/H locations below 1.3 as compared to the old scheme. There is a gradual shift from negative to positive values in streamwise velocity for the new scheme as compared to slightly abrupt shifts predicted by the old scheme for the roof top recirculation region. Both schemes predict very high values of velocity very close to the roof. The reattachment point for the recirculation zone as predicted by the new scheme is almost equal to the dimension equal to building height from the upstream edge of the building as observed by Snyder and Lawson (1994).

Profiles of normalized vertical component of velocity above the building roof top obtained through both schemes are compared to the experimental data in Fig. 26 for this case. Both schemes perform equally well in predicting the vertical component of velocity.

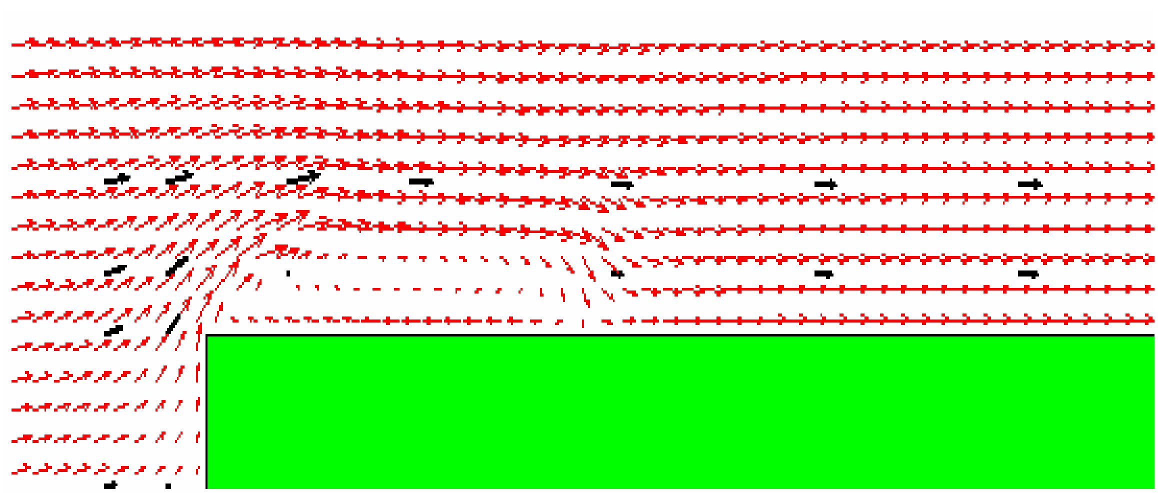

Figure 24: Velocity vector plot with experimental data (→) and model computed with new roof top recirculation scheme (→) for a tall building (L/H=4, W=H) along the center plane for incoming flow perpendicular to the building.

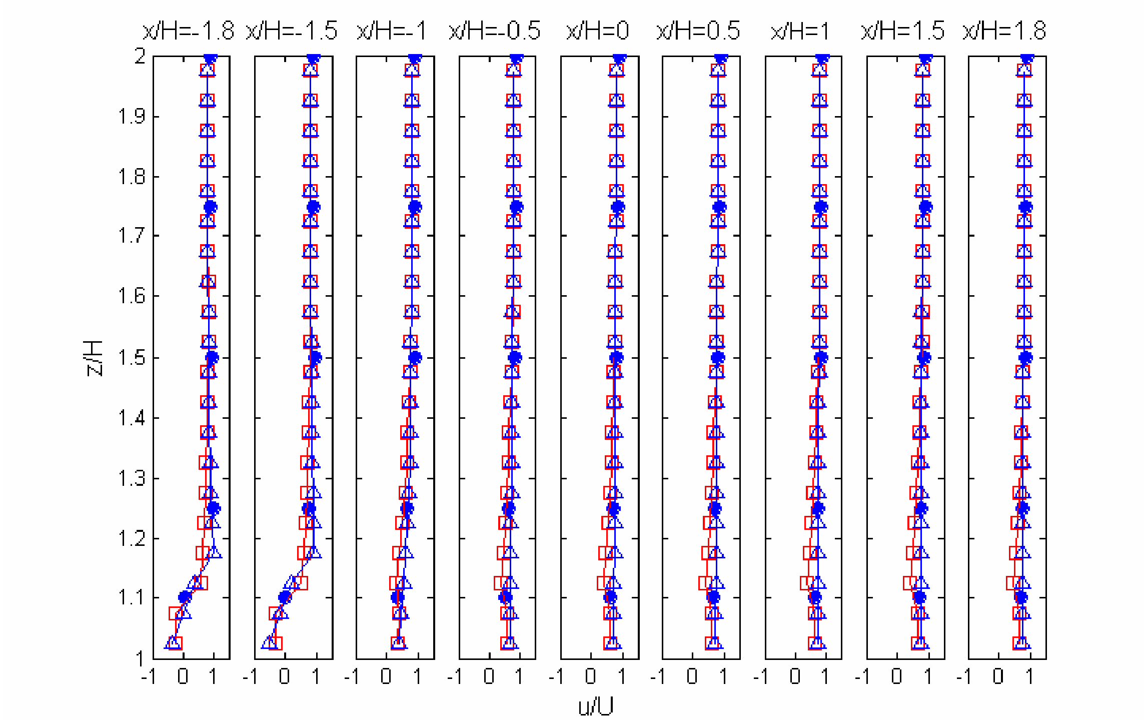

Figure 25: Comparison of normalized streamwise velocity above the rooftop for experimental measurements of Snyder and Lawson (1994) (●), for QUIC-URB with old rooftop recirculation scheme (-□-) and with new rooftop recirculation scheme (-Δ-) for a long building (L/H=4, W=H).

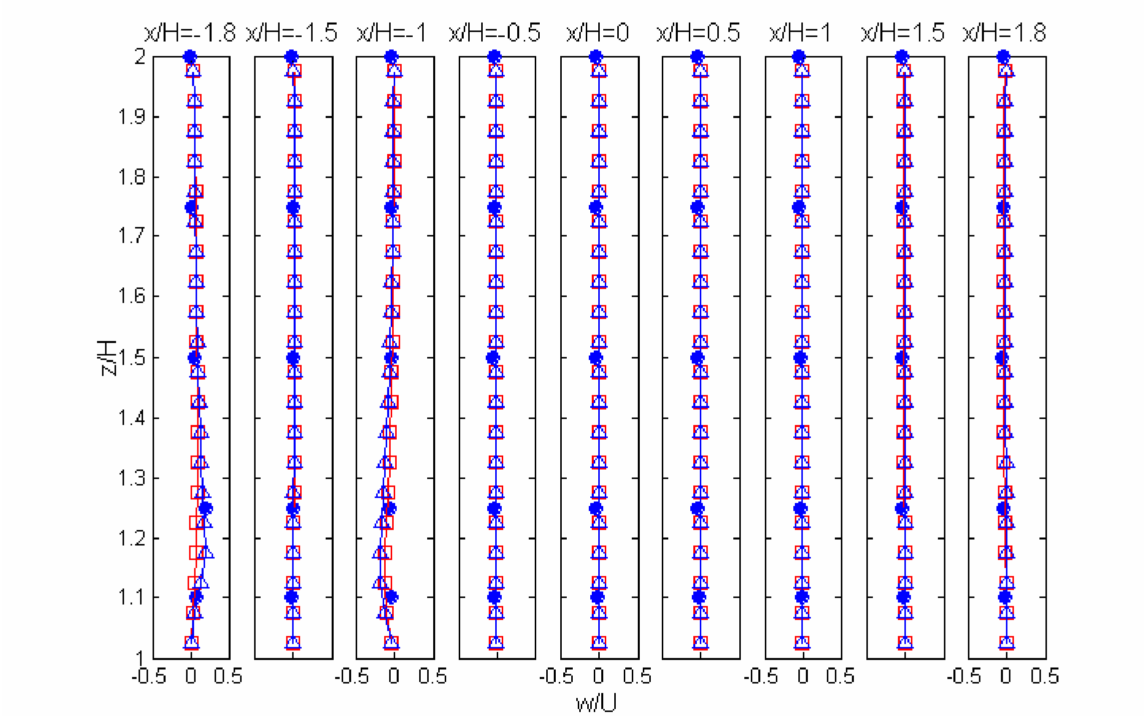

Figure 26: Comparison of normalized vertical component of velocity above the rooftop for experimental measurements of Snyder and Lawson (1994) (●), for QUIC-URB with old rooftop recirculation scheme (-□-) and with new rooftop recirculation scheme (-Δ-) for a long building (L/H=4, W=H).

5. CONCLUSIONS

For this paper the modeled data obtained through two different roof top algorithms and experimental data for building roof top were compared for varying building width, length and heights for an incident wind angle perpendicular to the face of the building. It was found that the new scheme worked better for varying building dimensions especially for the wide building cases. Henceforth, it is more practical to use the new scheme for predicting the rooftop recirculation flow features as it is more flexible to different building dimensions. The new scheme also predicts more gradual change in the streamwise velocity magnitude as compared to abrupt changes in streamwise velocity with height as predicted by the old scheme. The new scheme therefore also predicts the height of the rooftop recirculation region more accurately.

Both schemes predict high values of velocity near the roof. This is certainly occurring due to the nature of the initial wind field schemes that force high values of velocity near roof top surfaces in opposite direction of the incident flow. Such an initial wind field assists in reproducing a vortex like flow on the building roof top upon applying of the mass consistency algorithm. However, forcing higher values near roof surfaces in the initial wind field may lead to higher values of vertical velocity on the down wind face after applying of mass consistency.

Further this model should be evaluated in comparison to data obtained from full-scale measurements in addition to various wind tunnel studies, having higher resolution of measurements. In addition grid resolution studies can be performed to test the sensitivity of the model.

6. REFERENCES

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