

Fig 11. Mean velocity of A-A

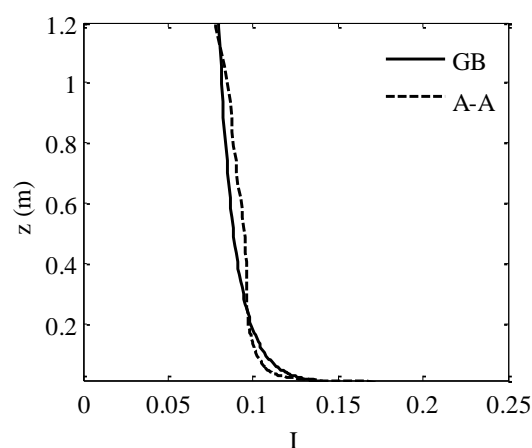


Fig 12. Turbulence intensity of A-A

In order to verify the spectral characteristics of the simulated wind, Fig 13 gives the time history of velocity at four different heights and Fig 14 gives the corresponding wind spectrum. The four heights are nondimensionalized by the boundary layer thickness, i.e.  $\eta = z/1.2 = 0.2, 0.3, 0.5$  and  $0.7$ . By comparing the wind spectrum with Von-Karman spectrum, we can see that the FFT results of velocities fit well to the targets at frequencies less than 10, but the turbulence energy attenuated rapidly at high frequency. The main reason is that in turbulent ABLs, the turbulence energy of high frequency is provided by small-scale vortices and the low frequency's turbulence energy is generated by large-scale vortices. When large eddy simulating the turbulent ABLs, the mesh size and computational time step will determine the filtering size for vortices and the calculation will filter the small-size vortices, which finally results in the attenuation of the high frequency's turbulence energy. So the attenuation of the spectrum has no relationship with the new recycling-rescaling method.

Table 4 lists the integral length scales calculated by wind velocity time history at four heights. The code values are evaluated according to scale ratio  $s=1.2/300=0.04$ . As can be seen from the data, the simulation results increases with the heights increased, which is consistent with the theory and experience.

Table 4 Integral length scale of A-A

Height ( $z/z_g$ )	Integral length scale		
	New Recycling-rescaling method	China Loading Code	Japanese Code
0.2	1.5530	4.8	0.1242
0.3	1.5885	4.8	0.6965
0.5	1.6474	4.8	0.8846
0.7	1.8890	4.8	1.0554

$z_g$  is the gradient heights, i.e. boundary layer thickness 1.2m

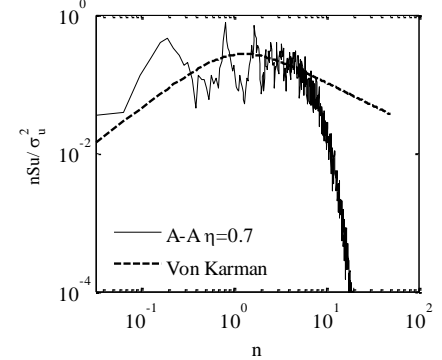
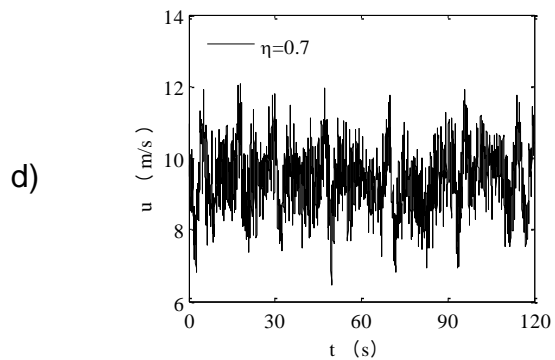
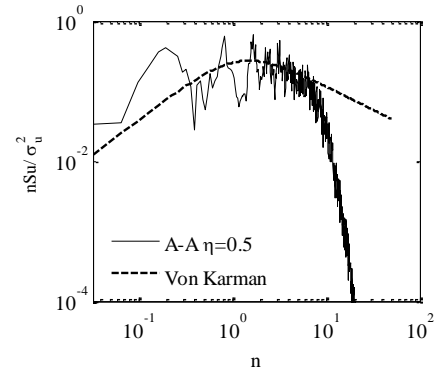
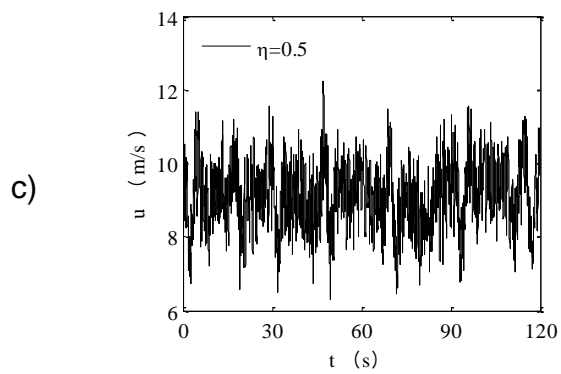
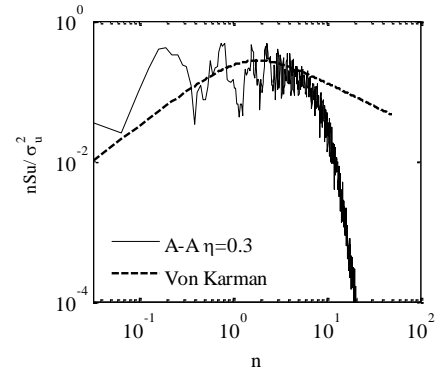
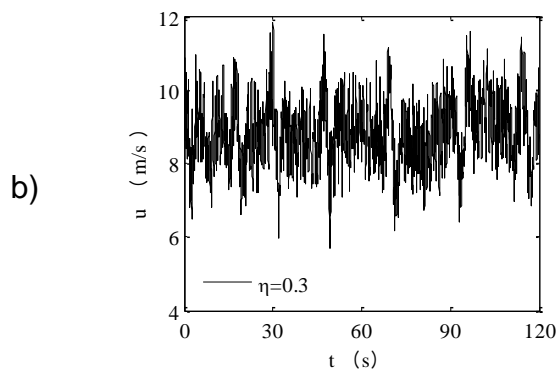
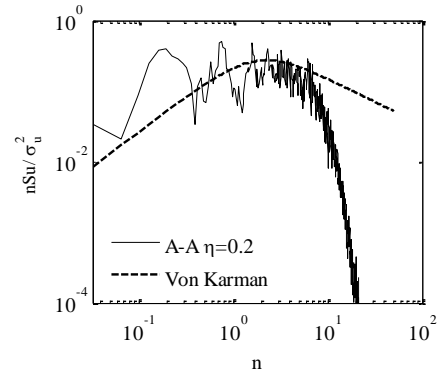
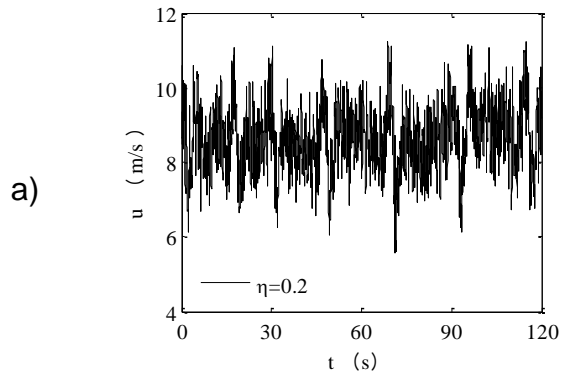


Fig 13. Velocity time history

Fig 14. Wind spectrum

#### 4.2.2 B-type terrain

The simulation results of case B-A are showed in Fig 15~Fig 19.

Fig 15 shows the developing trends of fluctuation coefficient  $\lambda(z,t)$  over time. It clearly that the change of  $\lambda(z,t)$  for case B-A is the same with case A-A. This indicates that the new recycling-rescaling method is also applicable for adjusting the turbulent ABL over B-type terrain which has certain roughness surface condition.

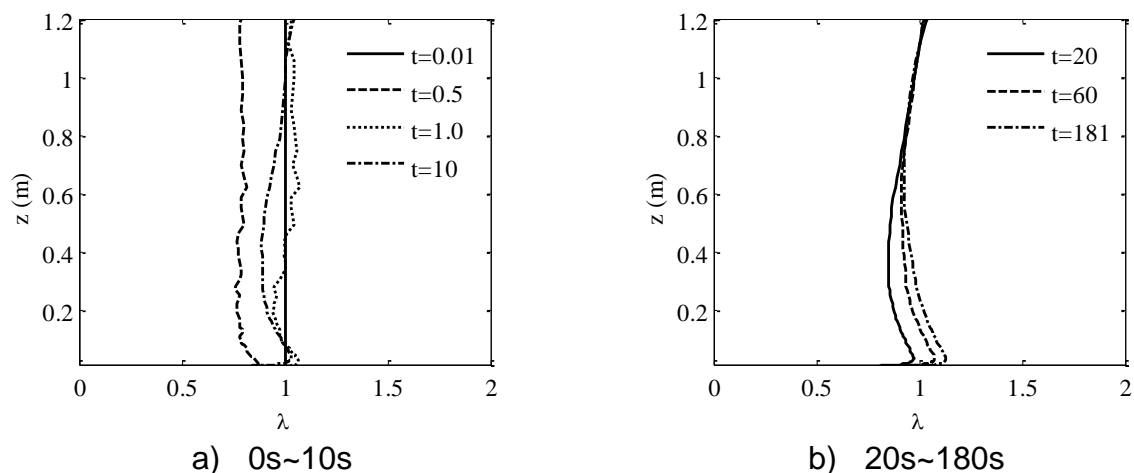


Fig 15. Fluctuating coefficient  $\lambda(z,t)$  for B-A

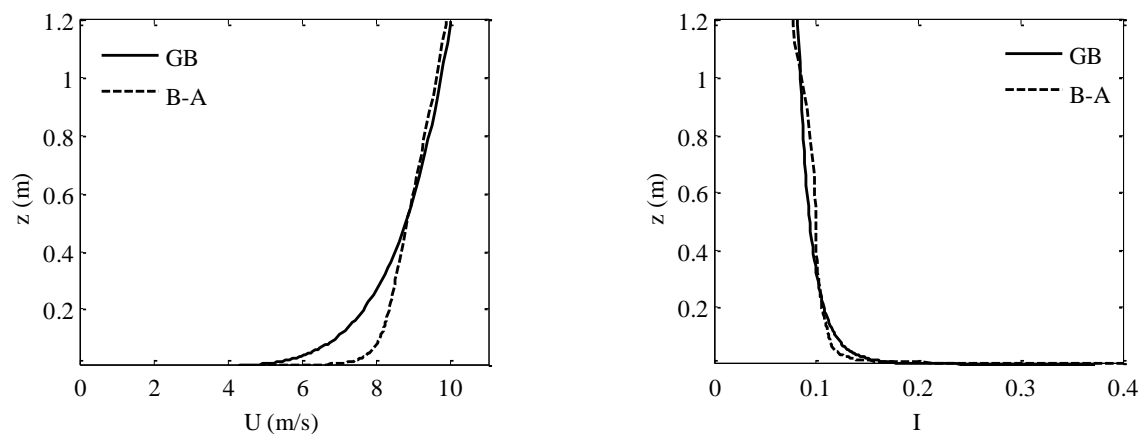


Fig 16. Mean velocity of B-A

Fig 17. Turbulent intensity of B-A

Fig 16 gives the mean velocity profile at recycle plane. The evaluation of this quantity is same with case A-A. GB refers to the target profile of B-type terrain in Table 3. It has the similar distribution with case A-A which means the methodology has no effects on mean flow characteristics.

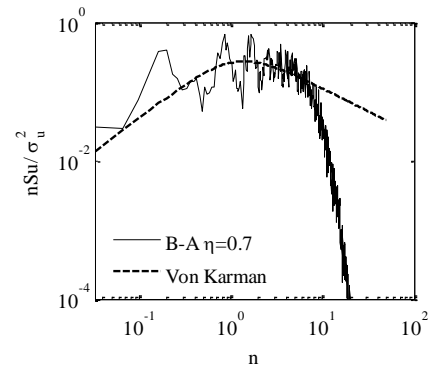
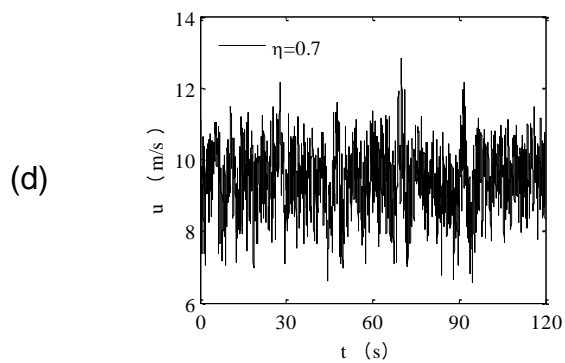
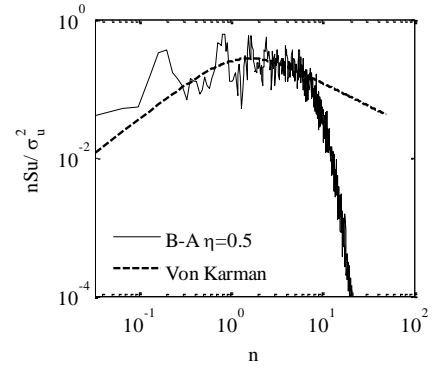
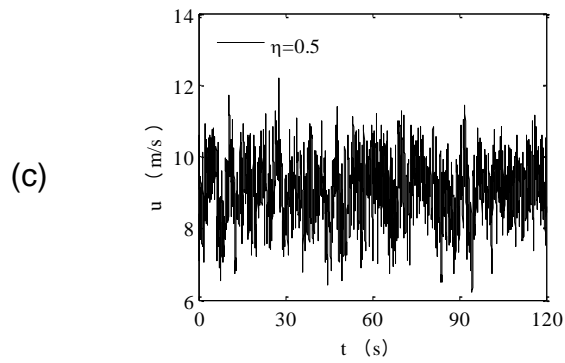
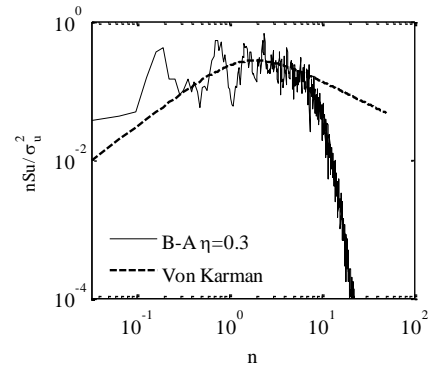
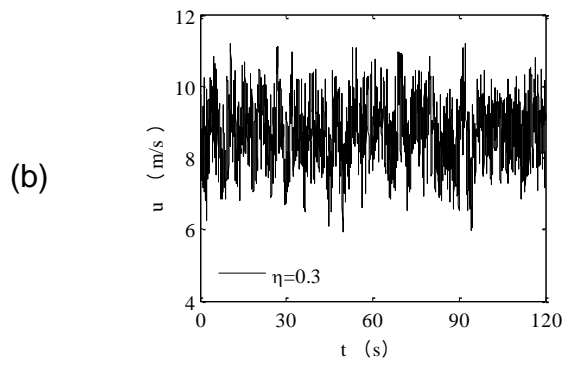
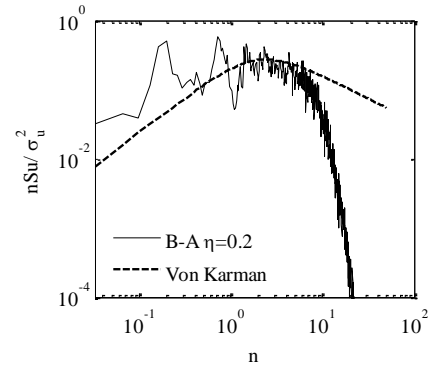
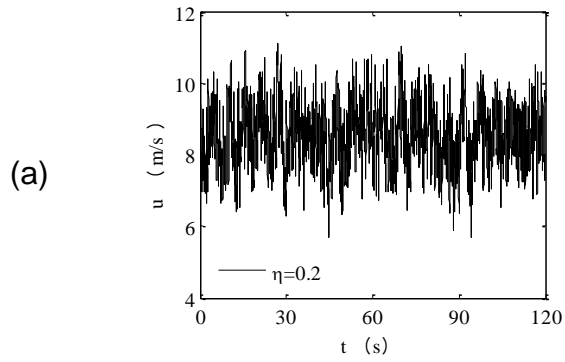


Fig 18. Velocity time history

Fig 19. Wind spectrum

Fig 17 shows the turbulence intensity distribution along with the y-axis central line of recycle plane. The well fitness of the profile indicates that the new recycling-rescaling method is also applicable for turbulent ABL over certain roughness terrain.

Fig 18 gives the velocity time histories at four different heights and Fig 19 gives the corresponding wind spectrum. The attenuation of the high frequency turbulence energy has the same reason with case A-A and the wind spectrum is consistent well with the Von-Karman spectrum at frequency less than 10.

Table 5 lists the integral length scales calculated by velocity time history at the four heights. The codes are evaluated according to the scale ration  $s=1.2/350=0.034$ . Also, it can be seen from the data that integral length scales increase as the heights increases, which is consistent with the theory and experience.

Table 5 Integral length scale of B-A

Height ( $z/z_g$ )	Integral length scale		
	New Recycling-rescaling method	China Loading Code	Japanese Code
0.2	0.7018	4.1143	0.1150
0.3	0.7740	4.1143	0.6448
0.5	0.7978	4.1143	0.8190
0.7	1.0257	4.1143	0.9771

## 5 CONCLUSIONS

In this paper, a modification to Lund's original recycling-rescaling method is proposed, in which a fluctuation coefficient is introduced to the rescaling procedure to account for the roughness effects of ground. Based on large eddy simulation, three key parameters of recycling-rescaling based method are investigated for accuracy and efficiency purposes. For the application of our method in CWE, turbulent ABLs over A-type and B-type terrains of wind-tunnel scale are simulated.

First of all, from the aspects of high efficiency and accuracy, the optimal configurations of key parameters, i.e. three-direction initial condition, mirror manner of velocity re-introducing and the  $0.8 L_x$  from inlet to recycle station are given. Besides, from the finer-grid simulation results of turbulent FPBL over smooth plate we can see that the fluctuation characteristics have a higher requirement on grid resolution, while the mean flow characteristics are more relevant to the exit and top boundary conditions.

The fluctuation coefficient  $\lambda(z,t)$  changes from rapid to moderate guarantee the stabilization of the simulation and the quick adjustment implies the high efficiency of our new recycling-rescaling method for controlling the simulated turbulent ABL wind. Furthermore, the turbulence intensity of simulation shows good consistence with the targets and the wind spectrum coincide with von Karman spectrum in the range of frequency of engineering structures, also the integral length shows reasonable trends with experience, all of these results can prove the feasibility and accuracy of the new method.



Obviously, it cannot be denied that our new recycling-rescaling method has potential to be improved. Firstly, it is the mismatch of rough wall condition with the target ABL terrain that leads to the remarkable mismatch of mean velocity profile. In the present study, only the fluctuation velocity is rescaled to achieve the prescribed turbulence intensity, thus it is feasible to rescale the mean velocity to fit the targets as well. However, the fundamental approach to resolve this problem is to find an explicit relationship between the numerical rough wall condition and real rough terrain. Furthermore, the performance of our new method in simulating turbulent ABL over rougher terrain, such as D-type in the urban center, also need to be evaluated.

## **ACKNOWLEDGEMENTS**

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