Authors' Responses to the Comments on the Manuscript

"Modeling the Inhibition Effect of Straw Checkerboard Barriers on Wind-blown Sand"

General Response to the Comments and the Suggestions:

According to the suggestion of the **Referee2**' comments, we give a substantial revision of the original manuscript such that a clear description of the research is displayed in the revised version. Many Thanks **Referee2** for reviewing of the manuscript carefully and objectively, and the comment: '**interesting**', '**positive significance**', '**important contribution**', which is a great affirmation to author's work. We have carefully revised the language and format of the manuscript mentioned by **Referee2**, and the detailed response are as follows.

Responses to Comments of Reviewer#2:

General comments:

This is an interesting paper that uses numerical simulation to study the inhibition effect of straw checkboard barriers (SCBs) on wind-blown sand, and also the influence of SCB's laying length was discussed. Based on the simulation results, the wind field, particle concentration and transport rules around the SCBs are revealed and analyzed. These works have positive significance for people to deeply understand the function of SCB and effectively improve its use effect. This article thus has the potential to be an important contribution. However, there are several major issues with the article.

Item 1:

First of all, it is suggested that the language and format of the full text should be carefully examined and revised. There are many obvious grammatical and formatting errors, such as in line 95-96, line 190, 195, 198, 220, 226, line 231-232, line 273, line 314-318…

Authors' Response 1:

Thank Referee for the reminder.

The authors have modified the original manuscript carefully on the grammar and formatting errors, and we have made many changes in the revised version, please see lines 94-97, 137, 191, 196, 199, 221, 227, 232-233, 253, 275-277, 316-320 for detailed information.

For example:

"Moreover, since the three-dimensional SCB is simplified into a two-dimensional plane with only the streamwise direction and vertical direction, the impact of this simplification is uncertain."

"where i = 1, 2 and 3 correspond to the streamwise,"

"where k_n =2×10^6 is the normal stiffness coefficient;"

"where m_i and m_j are the mass of particle i and j,"

"where k_t =2×10^6 is the tangential stiffness coefficient,"

"where n_0=0.4, A=0.68, B=0.39, ζ=5, C=0.92, and D=1.39 (Huang et al., 2017)."

"where v_{ej} is the ejection speed and the overbar represents a mean value"

"Following the idea of Dupont et al. (2013), aerodynamic entrainment is not considered in our model."

"where C_d is the drag coefficient,"

"We first simulate the clean air field flow in the presence of SCBs for 30 seconds to obtain the full development of the flow field. Then, we add sand particles to the flow field to obtain a sand-laden flow."

"This is because the streamwise position of x = 6 m is in the peak region of the "overshoot" phenomenon, while the streamwise positions of x = 1 m and x = 14.5 m are in the rising region and stable region, respectively. Due to the massive accumulation of sand particles near the surface (0-20 mm), the concentrations cannot be easily measured."

We also had the article retouched using some proof-reading services. Perhaps it can improve our writing ability as soon as possible.

Item 2:

Line 161, In Figure 1 we don't see any information about the inlet condition setting.

Authors' Response 2:

Thank Referee for the reminder.

We should not have misled the reviewer by giving a figure number of the reference. The authors have corrected it. Please see lines 160-163 in the revised manuscript.

", the LWS method (Lund et al., 1998) is applied to the inlet condition and the recycling plane at x_{ref}/Lx=12.5% (Inoue and Pullin, 2011). x_{ref} =5 m is the position of the recycling plane, and Lx=40 m is the total length of the flow direction."

Item 3:

Line 254-256, is there any evidence to confirm that SCB can be approximated as vegetation when evaluate rfa in equation 16?

Authors' Response 3:

Thank Referee for the question.

This resistance force equation is widely used to describe the equivalent resistance of vegetation, shub, tree and so on (Wilson, 1988, Li et al., 1990, Green, 1992, Katul et al., 2004, Dupont et al., 2014). In recent years, this formula has also been extended to describe the equivalent resistance of SCBs (Bo et al., 2015).

Here is the reference:

Bo, T. L., Ma, P., and Zheng, X. J.: Numerical study on the effect of semi-buried straw checkerboard sand barriers belt on the wind speed, Aeolian Res. 16, 101-107, 2015.

Item 4:

How to describe the dynamic behavior after the collision of saltation particles and SCB?

Authors' Response 4:

It a good question. Because of the limitation of the drag force method, the SCBs only affect the velocity of the flow field rather than the real presence. Our model considers more the effect of the flow field on the particles and does not simulate the collision process between the particles and the SCBs.

In the section "Conclusions and outlook" of the original manuscript, the limitations of our model are described:

"Although our model has been able to reveal the inhibition effect of the SCBs on wind-blown sand, there are still some aspects that need improvement, such as aerodynamic entrainment, particle deposition on the SCB, and collision between the sand particles and the SCBs."

Item 5:

Line 264, what is wall-normal direction. There are several walls in the simulation region.

Authors' Response 5:

When defining the flow field, we emphasized that the **z** direction is wall-normal direction. In our model, the inlet, outlet, spanwise boundary and upper boundary are not wall conditions, but only the bottom surface is wall condition. Therefore, wall-normal direction is always used to represent the vertical direction in this paper.

$$\frac{\partial \tilde{u}_i}{\partial t}+\tilde{u}_j\frac{\partial \tilde{u}_i}{\partial x_j}=-\frac{1}{\bar{\rho}_f}\frac{\partial}{\partial x_i}(\tilde{p}-\nu\frac{\partial \bar{\rho}_f\tilde{u}_j}{\partial x_j})-\frac{\partial \tau_{ij}}{\partial x_j}-\delta_{i3}g(\frac{\tilde{\theta}}{\bar{\theta}}-\frac{c_p}{c_v}\frac{\tilde{p}}{\bar{p}})+\frac{F_i}{\bar{\rho}_f},$$

where i = 1, 2 and 3 correspond to the streamwise, spanwise and wall-normal directions (i.e., $x_1=x,\ x_2=y,\ x_3=z,\ u_1=u,\ u_2=v,\ u_3=w$), respectively.

Item 6:

Line 293, what are delta t, H and M in Eq. 17? What is the meaning of 'mass in the range'? Is it similar to concentration? Why dx is divided here? From the physical concept, the scale information in the x direction should not appear here (should be y direction). Anyway, please check and define all the variables involved in the Eq. 17 and give the dimension of q.

Authors' Response 6:

Thank you for your reminder.

The streamwise sand transport rate means the mass of sand particles passing through the plane perpendicular to the flow direction in a unit time and unit length. What we calculate is the sand transport rate in each interval of the flow direction. The unit of q is kg/m/s.

We have modified the Eqs. (17) and (18).

The original:

$$q = \sum_{z=0}^{z=H} \sum_{y=0}^{y=M} m(x) / \Delta x / \Delta t_s .$$

$$C = \sum_{z=0}^{z=H} \sum_{y=0}^{y=M} \sum_{x=0}^{x=L} m(x) / Lx / Ly / Lz .$$

The revised:

$$q(x) = \sum_{z=0}^{z=Lx} \sum_{y=0}^{y=Ly} m(x,y,z) / \Delta x / \Delta t_s .$$

$$C = \sum_{z=0}^{z=Lz} \sum_{y=0}^{y=Ly} \sum_{x=0}^{x=Lx} m(x,y,z) / Lx / Ly / Lz .$$

Item 7:

Line 309, what is the difference between the transport rate density and the transport rate defined in eq. 17?

Authors' Response 7:

Thank you for your question.

The integral of sand transport rate density along the height is the sand transport rate.

$$q(x) = \int_0^{Lz} q(x,z) dz$$

Item 8:

Line 301-350, the author spent a great deal of space to analyze and discuss the structural characteristics of aeolian sand flow without SCBs, but it seems that this is not the focus of this paper. Appropriate reduction is recommended.

Authors' Response 8:

Thank you for your suggestion.

These contents are the verification part of our code, which is very important. In our previous article (*Huang, H. J.: Modeling the effect of saltation on surface layer turbulence, Earth Surf. Proc. Land. 45(15), 3943-3954, 2020.*), we verified the wind speed and speed fluctuations of clean air flow, but did not discuss the structural characteristics of aeolian streamers. In this manuscript, we want to add these contents to the verification part and compare it with the experimental results of Baas and Sherman (2005). The whole content is a good complement to the part of the program verification. We use the simulated aeolian streamers to compare with the existing results, which will help readers to recognize our results more. In addition, the streaks of the clean air flow in presence of SCBs have been shown in the results and discussion section, which can let the readers intuitively feel the difference.

Item 9:

In the part of model validation, the verification of the simulation results of sand flow with SCBs is not sufficient. The qualitative comparison cannot prove that the simulation results of the adopted model are credible in the presence of SCBs. Some quantitative comparisons are necessary. I believe the author should be able to find the observation data of the sand flow in the presence of SCB.

Authors' Response 9:

Thank you for your suggestion.

There are few directly comparable experimental data. We found one experimental work that is close to our SCBs model. According to the suggestion of reviewer, we made a comparison from the following aspects.

In the verification part, we supplement the simulation results of the velocity profile with SCBs and compare them with the experimental results. The experimental data we used are from Tao et al. (2020). Accordingly, we have added Figure 6b to the revised manuscript and illustrated it. Please see lines 390-403 in the revised manuscript.

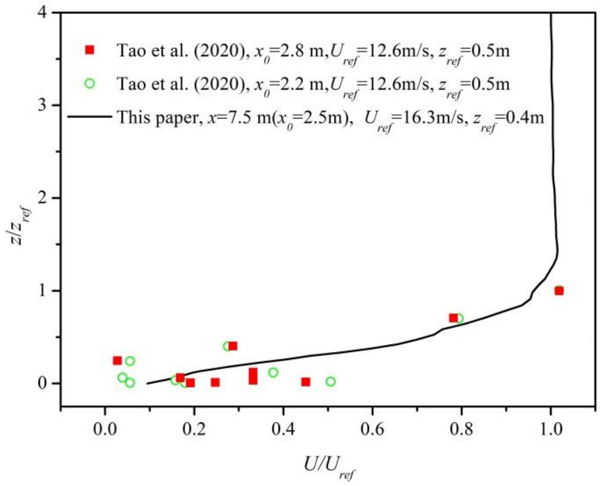


Figure 6. (b) The dimensionless wind speed varying with dimensionless height, comparison between our simulated results and the existing experiment.

"In addition, we compared the wind speed profiles with the experimental results of Tao et al. (2020). In Figure 6b, the streamwise wind speed in the horizontal coordinate is dimensionless with the reference wind speed U_{ref} and the height in the vertical coordinate is dimensionless with the reference height z_{ref}. In the wind tunnel experiment conducted by Tao et al. (2020), the maximum boundary layer thickness is given as 0.5 m, so the reference height is taken as z_{ref}=0.5 m. Then, the wind speed at z=0.5 m is determined as the reference wind speed U_{ref}=12.58 m/s based on their inlet wind profiles. In our simulation case, z_{ref}=0.4 m is the initial inlet boundary layer thickness, and U_{ref}=16.3 m/s is the reference wind speed. We select the experimental results of wind speed profiles at the SCB belt positions x_0=2.2 m and 2.8 m along the flow direction to compare with our numerical results at x_0=2.5 m (streamwise position x=7.5 m). The dimensionless results show that our results are consistent with the experimental results in quantitative and qualitative, which indicates that our model can well reveal the inhibition effect of SCBs on the flow field."

Here are the references:

Wang, T., Qu, J. J., and Niu, Q. H.: Comparative study of the shelter efficacy of straw checkerboard barriers and rocky checkerboard barriers in a wind tunnel, Aeolian Res. 43, 100575, 2020.

Item 10:

Line 434-443, the sand accumulation pattern in a single SCB should be related to the vortex structure of the local flow. It seems to be too far-fetched to explain it only from the result of time-averaged wind speed.

Authors' Response 10:

Thank you for your question.

Our SCBs model is based on the volume resistance force method, which is different from the SCBs completely equivalent to the solid wall. If the SCB is a solid wall, there will be obvious vortex structure similar to that in the backward-facing step flow, such as Xu et al. (2018, JGR)

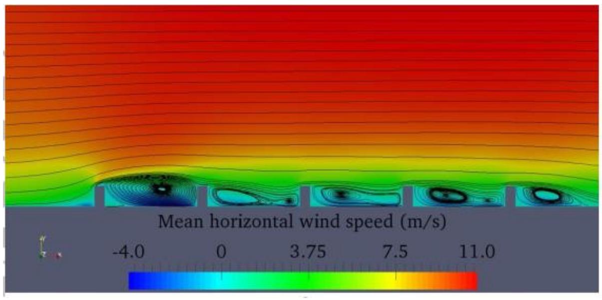


Figure 4. Contour maps of velocity in the center section. (a) Mean horizontal velocity;

However, this backflow vortex phenomenon does not appear in our model, because the wind is able to pass through the SCBs (only weakened, not very strong backflow), which is also closer to reality. In addition, the side length of our SCBs is 1 m, which is twice their side length (0.5m), so this regular backflow vortex phenomenon is not significant in our model.

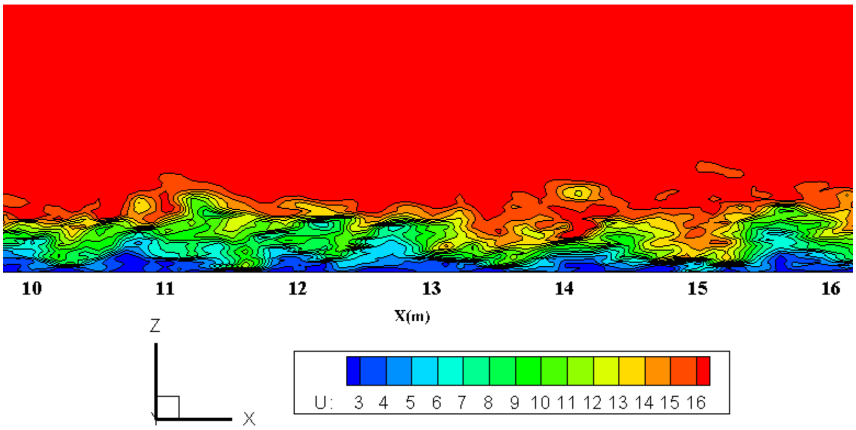
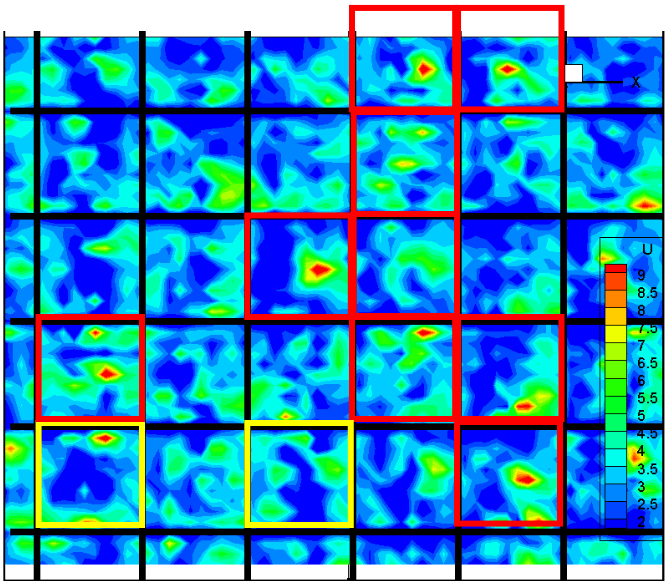


Figure. The side view of X-Z plane streamwise velocity after containing the SCBs (u_τ=0.6 m/s, N=5~20 m, y=0 m).

What's more, we have zoomed in on the speed diagram inside the SCBs, and you can see:

The streamwise speed in most SCBs is higher in the central area than in the surrounding area (red box), and the streamwise speed in a few SCBs is higher in the surrounding area than in the central area (yellow box).



This conclusion is also quite consistent with the actual situation. The wind speed in the center of a single SCB is high, and then the sand particles are deposited less; the wind speed around the surrounding area is small and the sand particles are deposited more. Such accumulation phenomenon is also consistent with the experimental results (as shown in the figure above). Therefore, we believe that the corresponding deposition pattern can be explained by the time-averaged wind speed. I hope that it will be approved by the reviewer.

Item 11:

Line 466, why does the laying length of SCBs affect the sand transport rate in the upwind area (x<5m)?

Authors' Response 11:

Thank you for your question.

The exit and entrance boundaries of the particles motion are set as periodic boundaries. Our initial particles are randomly distributed, and no more particles will be added later. Therefore, the particle information at the entrance of the whole wind-blown sand flow depends on the particle information at the exit, which can ensure that there are particles at the entrance of the whole wind-blown sand flow all the time. It does not affect the steady-state results because the sand transport rate in the wind-sand flow before the SCBs entrance has decreased to a consistent level.

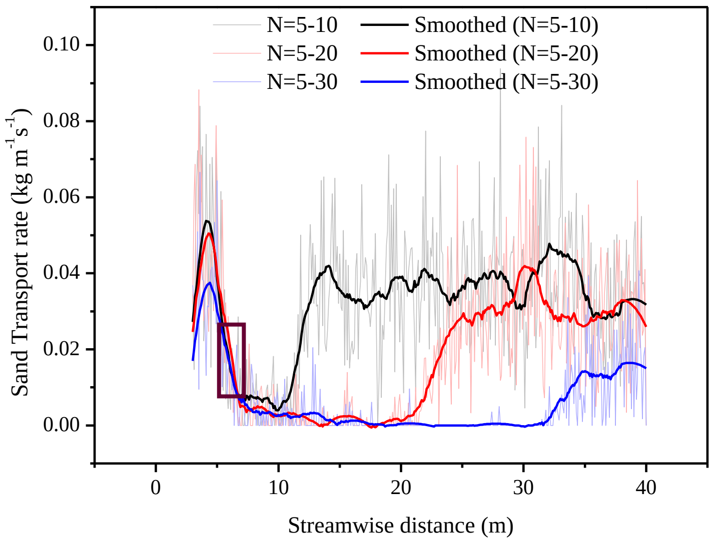


Figure 12. The streamwise sand transport rate in the different laying length cases (u_τ=0.6 m/s, N=5~10 m, 5~20 m, 5~30 m). Dark lines are the result of smoothing.

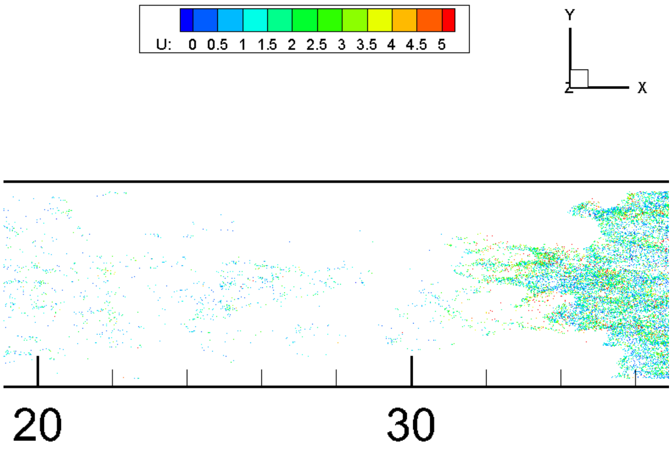
Item 12:

Line 474, 478-479, it is a little strange here that the author did not consider the fluid entrainment. How does the wind-blown sand flow recover in the downwind area of the SCBs where the sand transport rate has reduced to zero?

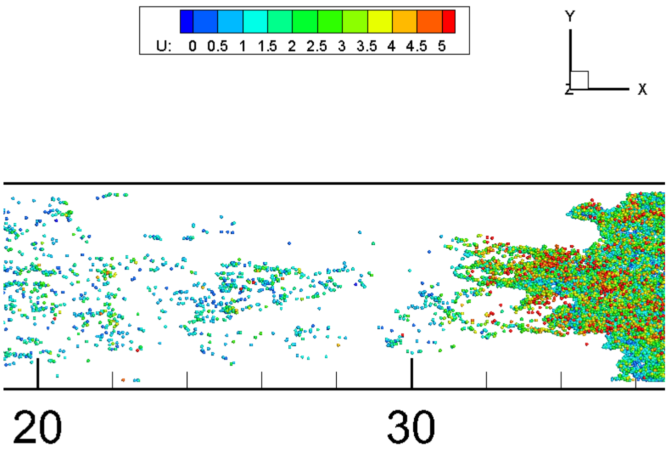
Authors' Response 12:

Thank you for your question.

The sand transport rate you mentioned is close to 0 in some areas, but not exactly equal to 0. For example, in the laying length of N=5-30 m case, we draw the sketch map of the transient particle position inside the SCBs in the following figure. You can clearly see that the number of particles in the 20-30 m flow direction area is very sparse, but it has not completely disappeared. In order to show clearly, we have enlarged the particle size, but the actual particle size is very small. That is to say, as long as a few particles can pass through the SCBs area (in the statistical results, the sand transport rate of this part is infinitely close to 0), and then a stable wind-blown sand flow will soon develop after that.



(Original, N=5-30 m)



(Enlarged, N=5-30 m)

Here we want to explain to the reviewer that although fluid entrainment is very important, the existing literature showed that the minimum friction wind speed to maintain the wind-blown sand flow is the impact threshold rather than the fluid threshold. In other words, as long as there exists particle impact and the wind speed is above the impact threshold, the wind-blown sand flow can be continued. I hope our explanations can answer the doubts of reviewer.

Item 13:

Line 481-482, is it possible that the length of the computation domain is not enough?

Authors' Response 13:

Thank you for your question.

We think the computation domain is sufficient. From our wind field results, the mean wind speed tends to be stable, and the mean wind speed after adding the particles is also stable. The reason why the sand transport rate decreases is that the longer the SCBs are, the greater the fluid consumption is. Even if the wind speed behind the SCBs can recover, it is impossible to recover to the level of the inlet wind speed, so the sand transport rate will decrease.

Item 14:

The results in Figure 14 and Figure 12 do not seem to agree. Fig. 12 shows that there is almost no sand flow in the area of SCB, but Fig. 14 shows a different result.

Authors' Response 14:

Thank you for your question.

This issue is consistent with **Item12**. The sand transport rate is statistically very low at N=5-20 m laying length case, but as long as some particles can pass through the SCBs, then under the condition that the wind speed behind the SCBs recovers to a certain level (larger than impact threshold), this part of particles can rapidly develop into wind-blown sand flow.

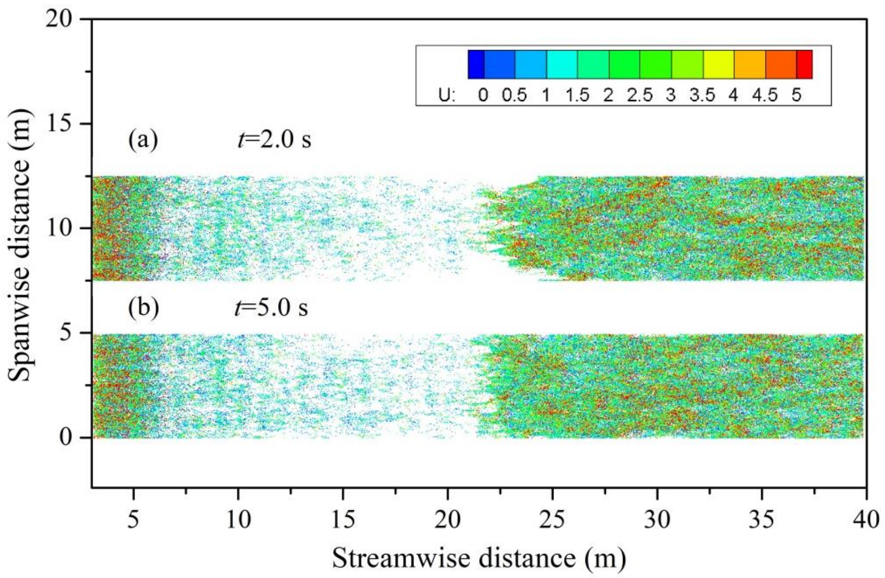
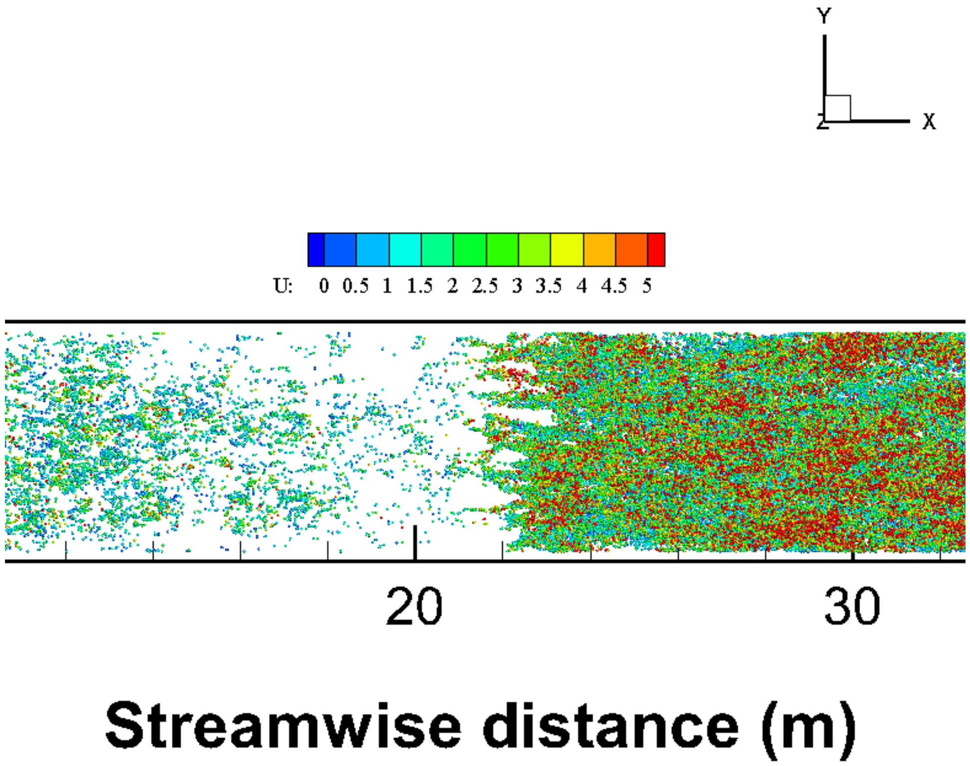


Figure 14. The top view of the particle positions of the wind-blown sand in presence of SCBs at the time t=2.0 s (a) and t=5.0 s (b), where U represents the speed of the particles (u_τ=0.6 m/s, N=5~20 m). The y coordinates are correspondingly shifted up by 7.5 per case.



(Enlarged, N=5-20 m)

Finally, we want to say that we attach great importance to the Referee's comments, and take it seriously. Although there are still some aspects that need improvement, we are really making our contributions to the prevention of desertification.

Once again, we thank the Referee's help.