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 **Referee1**' comments, we give a substantial revision of the original manuscript such that a clear description of the research is displayed in the revised version. I hope that our efforts will make our works recognized. The authors also would like to kindly thank the **Referee1** for give us a chance to modify this article. The detailed responses are as follows.

Responses to Comments of Reviewer#1:

Main comments:

The author presents a numerical study of the impact of straw checkerboard barriers (SCB) on the aeolian sand transport. Large eddy simulation are performed in presence of SCB with different laying lengths. Saltation is enhanced through the splash process. The inhibition effects of SCB on the sand transport is investigated. When the layer length increases, the wind speed and the sand transport rate decreases. The study help to understand the impact of SCB and may be useful for antidesertification projects.

This paper bring a few new insights on the effects of SCB. I then recommend to accept this article with major revisions.

The article should be proofread to correct English. Some sentences are not correct. For example in the sentence line 21-23, there is no verb. I do not understand the sentence 95-96.

Basic conventions such as: do not put a title at the end of a page should be respected. A figure legend should be on the same page as the corresponding figure. Put a space between the paragraph number and the title (line 183).

Authors' main Response

Thanks for Referee1's carefully and objectively reviewing of the manuscript, and the comment: '**useful for anti-desertification**', '**a few new insights**', this is a great affirmation to the authors' work. Referee has made a series of instructive suggestions which help us to improve the integrity of the introduction and enhance the readability and the profundity of the paper.

The authors have modified the original manuscript carefully on the grammar and writing style, and we have made many changes in the revised version, such as, we have modified the sentence "Moreover, the longer the laying lengths, the lower the wind speed in the stable stage behind SCBs, and the lower the sand transport rate." as "Moreover, the longer the laying lengths are, the lower the wind speed and the sand transport rate in the stable stage behind SCBs will be.", we have modified the sentence "Moreover, since the actual three-dimensional SCB is simplified into two-dimensional plane with only streamwise direction and vertical direction. And the impact of this simplification is uncertain." as "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.", please see lines 21-22, 94-97, ... for detailed information. English is always a tough challenge for us who are non-native English speakers. We also had the article retouched using some proof-reading services. Perhaps it can improve our writing ability as soon as possible.

We also have revised the manuscript according to the notes "do not put a title at the end of a page should be respected" and "A figure legend should be on the same page as the corresponding figure" mentioned by the reviewer.

Item 1:

Section 2.1:

(1) Line 137: *the force Fi (equation 1) should be detailed. The formula and a reference should be given.*

(2) Line 152: *on the ground, the author say that a rigid condition is used. Is the velocity put to zero or are the ARPS wall function used? How is the SBC taken into account? It is not possible to construct a boundary with sharp angles with the code ARPS.*

(3) Line 156: *the variable D is not defined.*

(4) Line 161: *just give the reference not a figure number of another paper to avoid confusion with the figures of the present paper.*

Authors' Response 1:

Thank you for your suggestion and question.

(1):

The authors have added the detailed description about F_i in the revised manuscript.

$F_i = F_{pi} + F_{di}$ is the main feedback force, including the feedback force provided by sand particles (F_{pi}, as shown in Section 2.2) and the SCBs (F_{di}, as shown in Section 2.5).

In Section 2.2, we introduced the feedback force provided by sand particles:

$$m_p \frac{d^2x}{dt^2} = F_{px} = \frac{C_D \pi D^2 \rho_f}{8}(\tilde{u} - \frac{dx}{dt})^2 + F_{nx} + F_{sx},$$

$$m_p \frac{d^2y}{dt^2} = F_{py} = \frac{C_D \pi D^2 \rho_f}{8}(\tilde{v} - \frac{dy}{dt})^2 + F_{ny} + F_{sy},$$

$$m_p \frac{d^2 z}{dt^2} = F_{pz} = -\frac{\pi g \rho_p D^3}{6} + \frac{C_D \pi D^2 \rho_f}{8} (\tilde{w} - \frac{dz}{dt})^2 + F_{nz} + F_{sz}.$$

In Section 2.5, we introduced the feedback force provided by SCBs:

$$F_{di} = -C_d a |U| u_i.$$

And we have explained "i = 1, 2 and 3 correspond to the streamwise, spanwise and wall-normal directions" in the line 137.

(2):

SCBs are not added to ARPS in the form of a boundary. The resistance force source method has been used to equate the effect of SCBs.

In Section 2.5, we introduced this method:

"The SCBs are equivalent to a volume resistance force through the resistance coefficient and leaf area coefficient, that is, the flow in these regions will be subject to additional resistance force, which can be expressed as

$$F_{di} = -C_d a_d |U| u_i,$$

where, C_d is the drag coefficient, a_d is the leaf area coefficient, and U is the inflow wind speed."

As far as the authors know, ARPS does not provide wall functions, nor do we add them here. Large eddy simulation without wall correction is also acceptable, such as our previous work (*Huang, H. J.: Modeling the effect of saltation on surface layer turbulence, Earth Surf. Proc. Land. 45(15), 3943-3954, 2020.*) and other research group works (*Dupont S, Bergametti G, Marticorena B, Simoëns S.: Modeling saltation intermittency. J. Geophys. Res. Atmos. 118(13), 7109-7128, 2013.*).

(3):

Thank you for your reminder.

We have modified the sentence "z_0=D/30 is the aerodynamic surface roughness" as "z_0=d_{mean}/30 is the aerodynamic surface roughness, and d_{mean} is the mean diameter of the sand particles".

(4):

Thank you for your reminder.

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 2:

Section 2.2:

***(1) Line 177:** the particle Reynolds number is defined and do not appear in the equations.*

Authors' Response 2:

$C_D = (0.63 + 4.8 / \mathrm{Re}_p^{0.5})^2$ is the drag coefficient of sand particle, but the display is incomplete in the original manuscript. We have supplemented it. Thank you for your reminder.

Item 3:

Section 2.4:

(1) Line 236: *wind-blwon*

Authors' Response 3:

The author has corrected it.

Item 4:

Section 2.5:

(1) *The figure 1 is not clear. The variables N, SCB side length, SBC side thickness and the laying length of SCB should appear on the figure. The side length is defined as 100x100cm in the text (line 240) and as 100cm in the table.*

Authors' Response 4:

Thank you for your suggestion. We have made the following modifications to Figure 1:

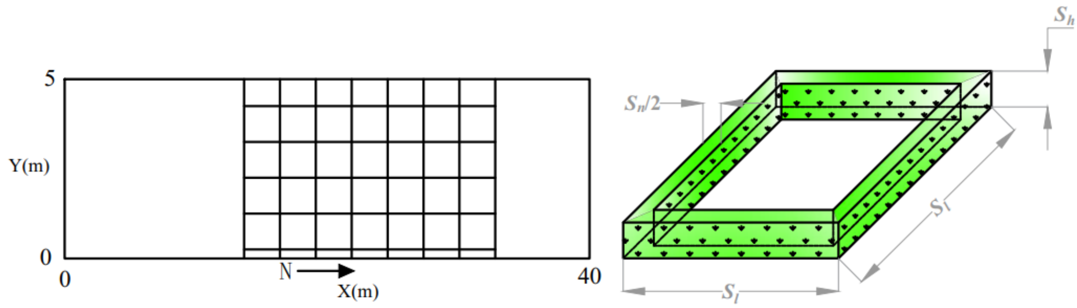


Figure 1. (a) The diagram of the laying SCBs. (b) The diagram of a single SCB.

We also have corrected the definition of SCBs side length. Please see line ?? in the revised manuscript.

", the side length of a single SCB (S_l) is set to 100 cm, and the side thickness of the SCB (S_n) is set to 10 cm."

Item 5:

Section 2.6:

(1) *Figure 2 is not clear. Which quantity is presented? There is no legend. The size of*

the mesh and the checkerboards could be plotted instead.
(2) *The first sentence of the paragraph (line 261-263) does not seem to belong to this section, but to the section 3.*
(3) *The grid step should be added in the Table2.*

Authors' Response 5:

(1):

In Figure 2, we have added a legend and the coordinates in three directions. As the flow velocity at the SCBs position is relatively low, it can also be well distinguished in the figure.

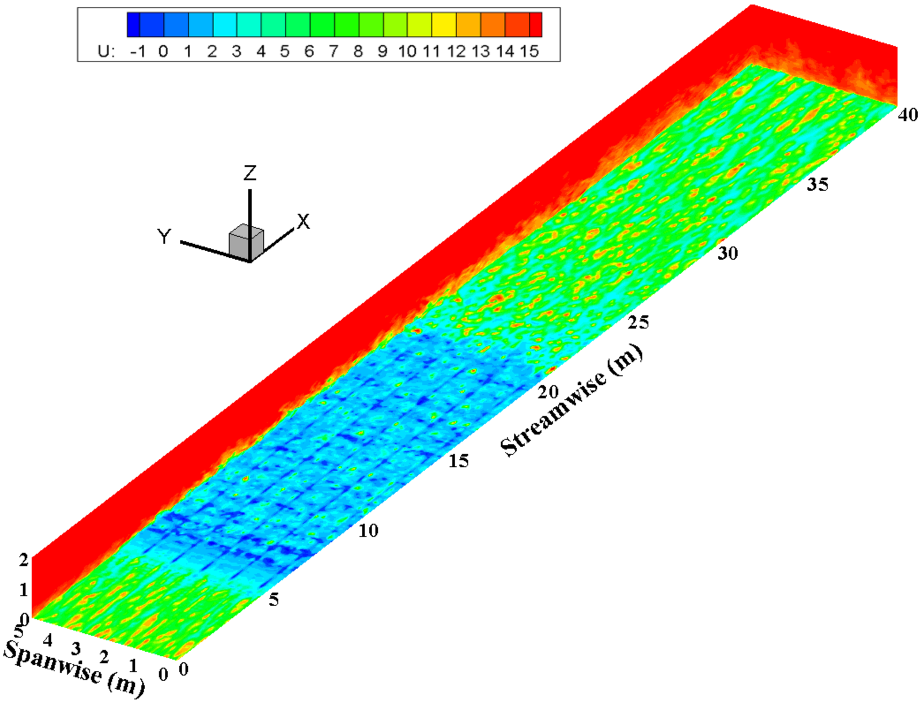


Figure 2. Schematic diagram of three-dimensional wind-blown sand in presence of SCBs.

(2):

"Wind tunnel experiments conducted by Shao and Raupach (1992) indicated that a complete "overshoot" had more than 10 m in streamwise (Huang et al., 2014; Ma and Zheng, 2011)." What we want to express in this sentence is that our flow direction computing domain is long enough.

(3):

In the original manuscript, we mentioned the grid information:
"To capture this structure, the mesh spacing is N_x=0.1 m and N_y=0.05 m in the streamwise and spanwise directions, respectively. In addition, in the near-wall region, logarithmic stretching has been adopted to ensure precision. The mean and minimum mesh spacing in the vertical direction is N_z=0.025 m and N_{zmin}=0.005 m, respectively. Therefore, the grids of the streamwise, spanwise and vertical directions are 400×100×80, respectively.".

Following the suggestion of the reviewer, we have added the grid information in the Table 2.

Table 2 Main Simulation Parameters

Name	Symbol	Value	Unit
streamwise computational domain	Lx	40	m
spanwise computational domain	Ly	5	m
wall-normal computational domain	Lz	2	m
fluid time step	Δt_s	0.0002	s
friction wind speed	u_*	0.3, 0.44, 0.6	m/s
particle time step	Δt_p	0.00005	s
sand density	ρ_a	2650	kg/m^3
air density	ρ_f	1.225	kg/m^3
gravity	g	9.81	m/s^2
streamwise mesh spacing	N_x	0.1	m
spanwise mesh spacing	N_y	0.05	m
wall-normal mean mesh spacing	N_z	0.025	m

Item 6:

Section 3:

(1) *This section should be divided into two subsection: Particle field validation and Velocity field validation.*

(2) *Line 314: the work 'direction' seems not correct. Do you mean the location of the section?*

(3) *Line 317: suppressed the word 'exist'.*

(4) *Line 335: Define H,M,L. Are M and L equal to the grid step? Is H equal to Lz?*

(5) *Why is the friction velocity equal to 0.3 m/s in the figure 4 and to 0.6 m/s in the figure 5?*

(6) *The author could complete the analysis by plotting the recirculation zones that should appear inside the SBS.*

(7) *The mesh is very stretched near the wall with a ratio 5/100 between dz and dx. This may create diffusion problem. The authors should present mean and rms velocity profiles of the boundary layer without the SBS to validate the velocity field.*

Authors' Response 6:

(1), (7):

We fully agree with you. Thank you for your suggestion.

We have divided section 3 into two parts: (3.1) particle field validation and (3.2) velocity field validation.

Section 3.2 is the model verification part of this paper, which should have contained the verification of the clean air flow. However, considering our previous work, we mentioned "The verification of the flow field part of the program is covered in great detail in our previous works (*Huang, H. J.: Modeling the effect of saltation on* *surface layer turbulence, Earth Surf. Proc. Land. 45(15), 3943-3954, 2020*)."

The clean air flow field procedure in this article is based on the code of our previous work, and the meshing and flow field conditions are similar.

You can find the information in our previous work:

Velocity field validation:

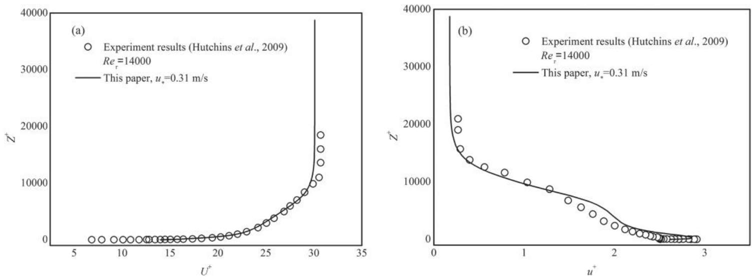


FIGURE 2. The mean velocity profile (a) and the streamwise turbulence intensity profile (b), with comparisons between the simulation results from this article with the experiment results of Hutchins et al. (2009) under the same friction Reynolds number.

Mesh information:

"To capture this structure, the mesh spacing is 0.1m and 0.05m in the streamwise and spanwise directions, respectively. Additionally, in the near-wall region, the logarithmic stretching has been adopted to ensure the precision. The mean and minimum mesh spacings in the vertical directions are 0.025 and 0.005m, respectively."

So we think that this part of the verification of clean air flow field can refer to our previous work, and the focus of section 3.2 is the flow field verification after considering the SCBs.

The mesh information above also answers your concern about the mesh in question 7. In our previous work, the mesh stretching ratio between streamwise and vertical directions was 1:20. And, as you can see from other literature (Dupont et al., 2013), similar mesh stretching ratios for ARPS can be as high as 1:10, so the stretching ratios in this article are acceptable and do not cause divergence problems.

(2):

The authors have modified the sentence "This is because the flow direction of x = 6 m is in the peak region of the "overshoot" phenomenon, while the flow direction of x = 1 m and x = 14.5 m is in the rising region and stable region, respectively." as "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.". Please see lines 316-318 in the revised manuscript.

(3):

We have removed the word "exist".

(4):

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:

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

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

(5):

In this paper, three different friction wind speeds (0.3, 0.44, 0.6 m/s) are set in the simulation cases. We want to show the results of different friction wind speeds as much as possible.

(6):

We are not sure whether you mean the recirculation zones are similar to the results in Xu et al. (2018, JGR), as shown below.

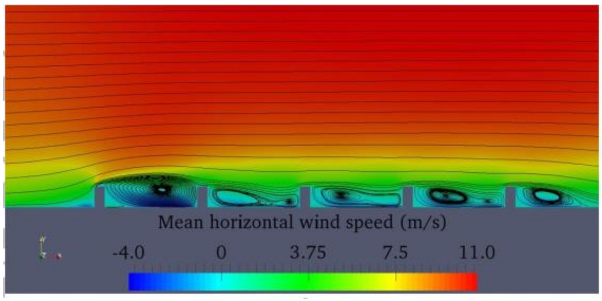


Figure 4. Contour maps of velocity in the center section. (a) Mean horizontal velocity;

If so, I'd like to clarify. The SCBs equivalence method we used is different from the method used in Xu et al. (2018, JGR), which I mentioned in the introduction: "However, the SCBs are completely equivalent to the solid as the bottom boundary condition in their model. As a nonsolid material, SCBs can be penetrated by wind in practice. It only weakens the wind speed and is thus not equivalent to a solid."

The results in Xu et al. (2018, JGR) are similar to the recirculation zones that appear in the backward-facing step flow. In this paper, the SCBs are equivalent to a volume resistance force.

Therefore, 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.

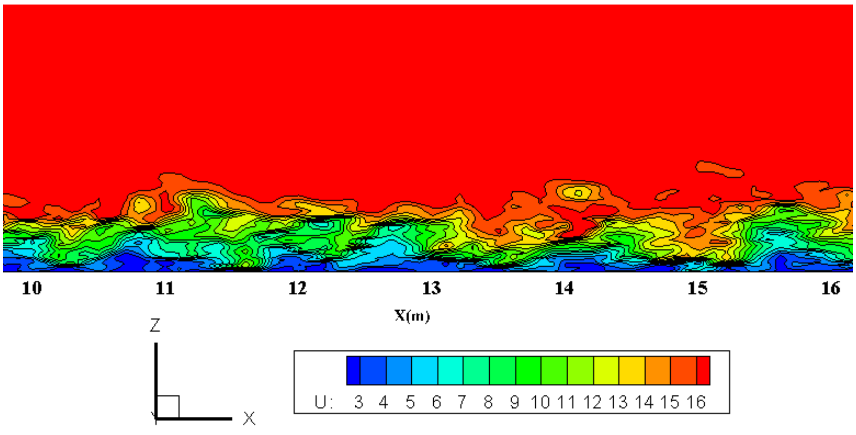


Figure. The side view of X-Z plane streamwise velocity after containing the SCBs (u_τ=0.6 m/s, N=5~20 m, y=0 m).

Item 7:

Section 4.1:

(1) *Section 4.1 discuss of the SBSs influence on the flow. It was already the subject of the precedent paragraph and of the figures 5 and 6. These results should be put into the same paragraph.*

(2) *Line 395: the velocity seems to be smaller and not higher.*

Authors' Response 7:

(1):

Figures 5-7 all show the effect of the SCBs on the clean air flow field. Figures 5-6 focus on the increase of boundary layer thickness. Similar conclusions can be compared, so we put this part into the model validation section. The focus of Figure 7 is that the SCBs destroy the near surface turbulent structure, which is a new result and has not been revealed in the existing literature. So we put this part into the results and discussion section. I hope our explanations will satisfy you.

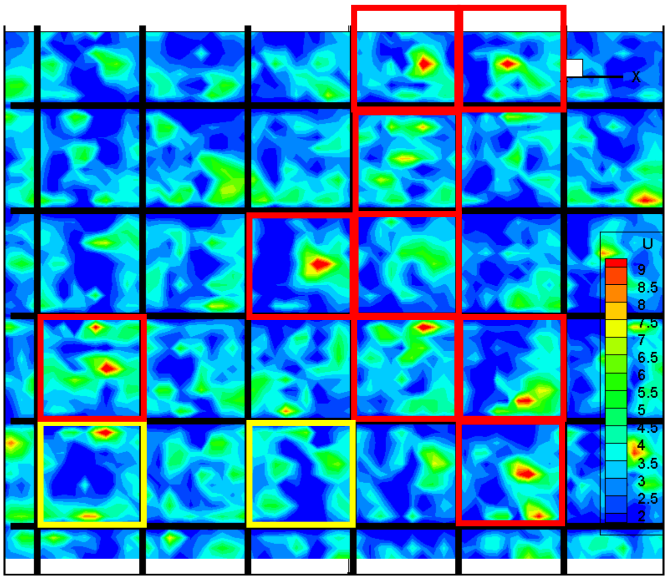
(2):

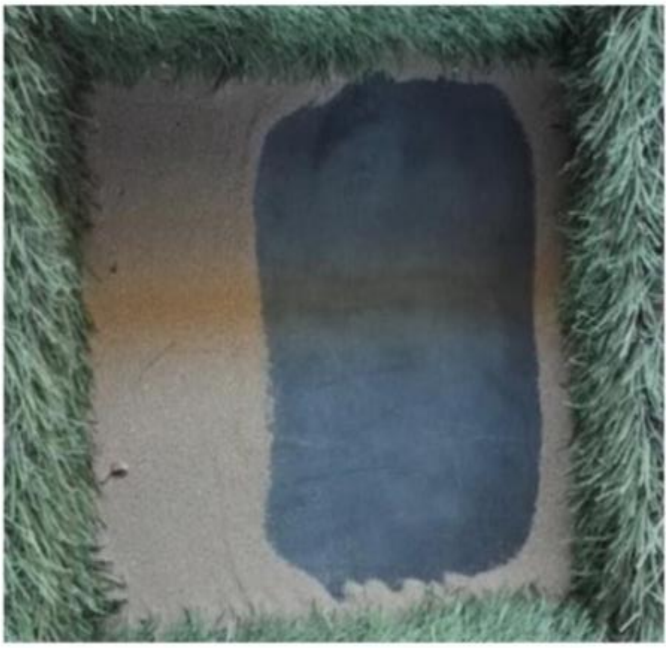
I apologize for the lack of clarity in this part of the presentation. According to the comments of the reviewer, we have zoomed in on the speed diagram inside the SCBs, and you can see:

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).

We have modified the sentence "The wind speed in the central area of a single SCB is significantly higher than that in the surrounding area, showing a block of velocity distribution characteristics." as "In most cases, the wind speed in the central area of a single SCB is significantly higher than that in the surrounding area, showing a block of velocity distribution characteristics."

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.





Item 8:

Section 4.2:

(1) *I don't understand what is presented on the figure 9. The author speaks about 'particle position' but I don't see any particles.*

(2) *Figure 10: Is the concentration obtained at a given height or is it the total concentration at all the height of the SBS?*

Authors' Response 8:

Thank for your question.

(1):

In Figure 9, these colored dots represent the sand particles. Due to the huge number of particles, it is not very clear when shown in the figure. In combination with the reviewer's question, we have selected a small part of the area for zooming, that is, the area corresponding to the red box in Figure 9. You can see the position of each particle in this area after zooming. The color of the particles in the figure represents the streamwise speed of the particles.

We updated the Figure 9 in the revised manuscript, and please see line 440 for detailed information.

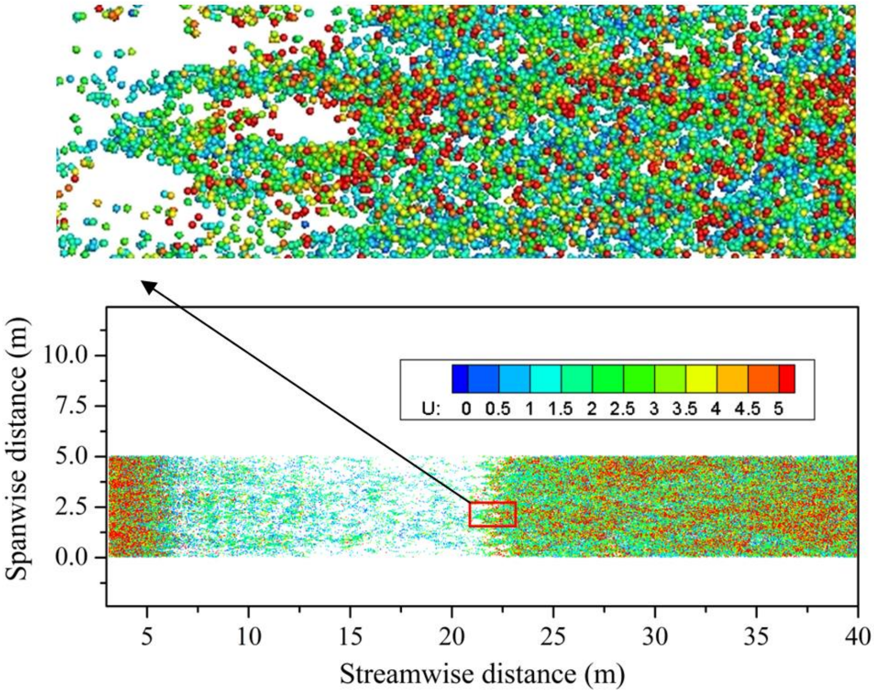


Figure 9. The top view of the particle positions of the wind-blown sand in presence of SCBs, where U represents the speed of the particles (u_τ=0.6 m/s, N=5~20 m).

(2):

According to the concentration formula, the concentration here is for all heights and does not refer specifically to a certain height.

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

Item 9:

Section 4.4:

(1) *The authors presents instationary results and provide no comments about the time evolution.*

(2) *The initial state is not a realistic. Particles are not induced by the incipient motion but randomly dispatched in the field. The time evolution is then not really meaningful and so the author should only present stationary results.*

Authors' Response 9:

(1), (2):

I agree with you. The difference between the random initial distribution and the initial distribution based on aerodynamic entrainment is that the lift-off particles starting at different locations. This will indeed affect the initial stage of the development of wind-blown sand. When the sand flux reaches saturation, this effect is very limited. We know that the main factor that can maintain the wind-blown sand is impact entrainment rather than fluid entrainment.

The existing results showed that the saturation time of wind-blown sand is about 2 seconds. Therefore, we did not provide any discussions about the time evolution. We also did not analyze the results of 0.5 seconds, but focused on the effect of SCBs on the wind-blown sand within 2 to 5 seconds after the wind-blown sand is saturated. Thank you for the reminder, and we have removed the result of 0.5 seconds in the revised manuscript.

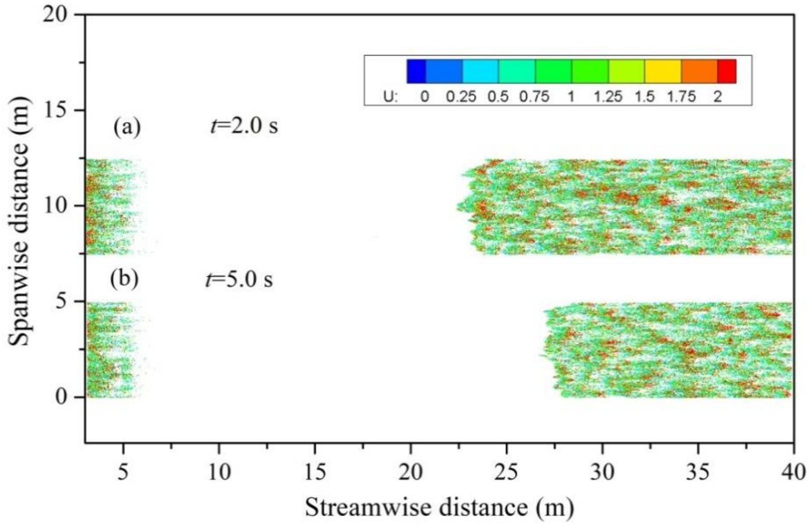


Figure 13. The top view of the particle positions of the wind-blown sand in presence of SCBs at the time t=2.0 s (a) and t=5.0 s (b), where U represents the speed of the particles (u_τ=0.3 m/s, N=5~20 m). The y coordinates are correspondingly shifted up by 7.5 per case.

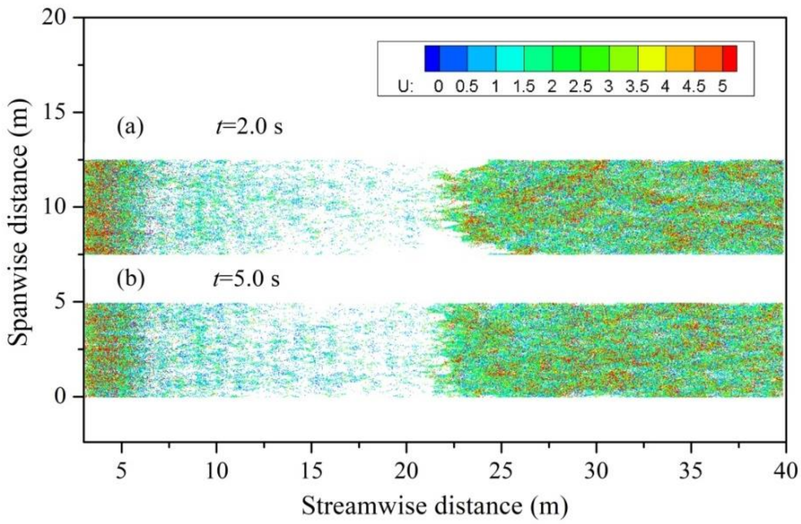


Figure 14. The top view of the particle positions of the wind-blown sand in presence of SCBs at the time *t*=2.0 s (a) and *t*=5.0 s (b), where U represents the speed of the particles (u_τ=0.6 m/s, N=5~20 m). The y coordinates are correspondingly shifted up by 7.5 per case.

Finally, thank you for your help. The authors have accepted Referee2's advice, and modified the paper carefully in the revised version. We hope our efforts can make a little progress in this paper.