Response to referee #3's interactive comment on the manuscript "Impact of Turbulence on Aeolian Sand and Dust Entrainment: Results from Wind-tunnel Experiment"

This paper uses wind tunnel simulation and modelling to investigate the response of the sediment entrainment rate to large scale, quasi-convective eddies in boundary-layer air flows. This is a very important topic of interest within the aeolian research community, such that this paper is well aligned with current research needs.
With moderate revision, particularly the inclusion of a great deal of missing information, it may be suitable for publication.
Response: *Many thanks for Prof. Cheryl McKenna Neuman for her constructive comments. We will supplement the missing information in the revised version and improve the quality of the manuscript as possible as we can.*

Minor corrections:
Title: Define the term 'dust' in the context of this study. You should be clear that you actually do not measure/profile the aerosol concentration of the airflow in this study, so the title is misleading. Perhaps you should say 'silt' instead or drop it altogether.
Response: *thanks for suggestion. This work does not specifically deal with dust. In fact, we study the entrainment of particles with different sizes. So we prefer to change the title to: "**Impact of Turbulence on Aeolian Particle Entrainment: Results from Wind-tunnel Experiment**".*

Line 20: Circular argument or poor wording, "turbulent flow is also turbulent"
Response: *thanks for pointing it out. We will modify it as "…hence saltation driven by atmospheric boundary-layer (ABL) flows is also turbulent."*

Lines 27-28: Poor wording - "impact" (geophysical process associated with saltation) should be "effect". In addition, "flow is turbulent, and aeolian processes also." Aeolian processes are affected by turbulence but are stochastic.
Response: *agree, "effect" will be better. We will modify it in the revision version.*
The next sentence will be changed to:"In reality, the flow and the flow-driven aeolian processes are both impossible to stabilize. Although people can analyze the relevant average variables, the existence of nonlinear relations (e.g., Eq. 1) makes it difficult to determine the quantitative relations between the average variables."

Line 74: "scan valve" perhaps should read "scanivalve"
Response: *sorry for our mistake. We will revise it as "scanivalve" in the revision.*

Lines 84-84: Define what you mean by 'flutter" versus "flap".
Response: *"flutter" corresponds to the delicate swing due to the soft texture of the cloth, while "flap" relates to quick swing determined by the structure of the cloth.*

Line 80: Define what you mean by "positive skewness" with regard to vertical velocity fluctuation. Does positive refer to eddies bursting up away from the bed (+ve w) and negative to eddies sinking down toward the bed (-ve w)? This section is a bit vague.
Response: *The "positive skewness" here means the horizontal velocity distribution is not symmetrical as the Gaussian distribution, but towards to positive direction (more weight for the part large than mean value), as shown in Fig. 2b. We will add more description on it in the revision.*

Line 89: The fan speed in rpm is meaningless to the reader. Provide free stream velocities for WP instead.
Response: *thanks for the suggestion. We will use the axis wind speed of the incoming flow to replace the fan speed.*

Line 93: Either provide the standard deviations to indicated the sorting for each test sediment or a figure showing the full distribution of particle diameter within each sample. This is important as most test beds will undergo some degree of grain scale armouring when subjected to an air flow and this is likely to be strongly affected by τ'.
Response: *thanks for the suggestion. We will add the full distribution of particle diameter within each sample.*

Figures Much too small and almost impossible to read.
Response: *thanks for the suggestions. All figures will be improved accordingly.*

Symbols:
A number of mathematical symbols appear in the manuscript well before they are defined and sometimes, they are either not defined at all or the symbol has an inconsistent typeface.
Response: *thanks for pointing it out. We will check the text carefully and add the lost definition. If necessary, a list of relevant symbols will be added as an appendix.*

Line 165 Specifically you mean the net mass loss (integrated over time).
Response: *yes it is the net mass loss. We only weighted the tray after a run of experiment with time of* ΔT_i *to determine the loss the mass. The sentence will be modified to make it clear.*

Lines 163 and 170 "Emission rate" interchanged with the "entrainment rate". The former is usually used when talking about dust and the later with the mass transport of sand. This may confuse some readers. Since you are not measuring the dust flux (aerosol concentration) then if might be best to just say "entrainment rate" everywhere.
Response: *agree, we will consistently use "entrainment rate".*

Substantive comments:
Figure 1 and Section 2. This is the weakest section of the paper with a great deal of missing information and weak justification of the experimental design.
Response: *thanks for suggestion, we will improve these parts in revision.*

Flapping cloth:

i) This is not a novel solution for creating turbulence in wind tunnels. Provide one or more references to previous work.

Response: *We essentially want to produce a flow that leads to a different distribution of surface shear stress. In the experiment, we measured the distribution of surface shear stress and verified the effect of this cloth. We speculated that the effect of cloth is not only to create turbulence, but also to cause a flow effect similar to convection. We didn't focus on the details of flow because they are not the main topic of this article. However, thanks for the reviewer's reminder, we will adjust the expression of this part to make it more appropriate. Previous works of convection simulation (**water tanks**, e.g., Willis and Deardorff, 1974, Yuan et al., 2013; **saline tanks**, e.g., Hibberd and Sawford, 1994; **thermally-stratified wind tunnels**, Hancock and Hayden, 2018) in laboratory will be added as references. In relation to comments iv), it is important to note that for conventional wind-tunnels, to the best of our knowledge, there has been no previous reports of simple ways to generate turbulence similar to convective turbulence which in terms of probability density function has a positive skewness. The positive skewness of convective turbulence plays an important role in aeolian particle entrainment.*

ii) Details of the flapping cloth are missing. What type and weight of fabric? Width is given but more importantly, how long was the sheet? What was the wavelength, amplitude and frequency of its oscillation?

Response: *thanks for suggestion. We will add the details of the cloth, including type, weight and size. Since how the cloth changed the flow was not the focus of this experiment, the wavelength, amplitude, frequency of the oscillation were not investigated and recorded in the experiment. But this is a very interesting topic, we can do some special researches in the future work.*

iii) Rationale is not provided for the placement of the cloth relative to the test surface. Is the elevation scaled with the length of the cloth or distance from the leading edge of the sample tray?

Response: *As mentioned above, the focus of this paper is not to study the effect of cloth on flow. What we're more interested in at that time is whether this cloth in the wind tunnel can provide the conditions that we need for our experiment, i.e. whether it can produce quasi-convective flow and shear with different distributions on the surface. We did a series of tests before the experiment to check the effect of the cloth, and empirically determine the length of the cloth (1.5m), the height of the arrangement (0.7m) and the distance from the leading edge of the sample tray (1.5m). We will add this information in revision.*

Of cause, the rationale for the placement of the cloth relative to the test surface in significant and deserves further study.

iv) Spires are much more commonly used to generate large scale eddies in wind tunnel simulation work and these are typically placed upwind of the roughness element array. There is also a large literature on the effect of spires on turbulent flow and shear. Why did you elect to use a flapping cloth over spires?

Response: *it is indeed that several methods have been proposed to generated turbulence in wind tunnels, including spires, roughness element, grid etc. But all of these methods are for neutral boundary layers, and inefficient for the simulation of large eddies commonly observed in convective ABLs. To generate convective turbulence usually requires the use of additional thermal forcing from the surface (**EnFlo stratified flow wind tunnel**, Hancock et al., 2013; Hancock and Farr, 2014; Hancock and Zhang, 2015; Hancock and Hayden, 2018; **controlling temperature of recirculating air and floor panels,** Inagaki et al., 2012; Zhang et al., 2013; Kanda and Yamao, 2016; **thermally-stratified wind tunnels**, Marucci and Hayden, 2018; Marucci and Carpentieri, 2020). To apply surface heating requires normally a large wind tunnel. In any case, to the best of our knowledge, studying the effect of convective eddies on aeolian processes has never been done in wind-tunnel experiments, mainly because we have so far no adequate means to generate convective turbulence in a wind tunnel for aeolian experiments. ,*

For this work, our hypothesis is that the change of the distribution mode of surface shear caused by large eddies (like convection) may significantly influence aerodynamic entrainment, and this influence could not be determined by the mean surface shear. Therefore, we need to first simulate flow conditions similar to convection to produce distinct distribution of surface shear in wind tunnel, which is the reason for the use of the cloth. Although we have not studied the intrinsic mechanism how cloth induces large eddies, so far, it does not affect our research on the quantitative characterization of aerodynamic entrainment. This study does provide an inexpensive and practical way to generate the quasi-convective eddies without involing surface heating..

More information about the motivation for the using of cloth will be added in the revision.

Pitot tubes:

i) Provide dimensions. Pitot tubes come in a range of sizes, while large tubes places in a fixed vertical array can initiate flow stagnation – bluff body effect.

Response: *thanks for comment. There are two types of pitot tubes used in this work. The outer diameter of the small pitot tubes is 1mm, and inner diameter is 0.5mm. 11 these pitot tubes make up a wind profiler, which could simultaneously measure the wind speed profiles. A bigger one with outer diameter of 5mm and inner diameter of 2mm is used to standardize all the small pitot tubes. We will add them in the revision. We will add the size information of Pitot tubes in the revision.*

ii) What did you sample the pressure difference with? State precision and sampling time.

Response: *thanks for comment. The sampling frequency is 1 Hz, and the mean horizontal velocity is averaged by 5 minutes. We will add the sampling information of Pitot tubes in the revision.*

Measurement of the mass transport rate:

i) One of the greatest challenges with accuracy in measuring mass in the lab using an electronic balance is drift associated with changing air pressure in the room. So it is possible that any instantaneous fluctuation in F is the a consequence of both the change in mass of particles in the tray and the pressure perturbation in the flow. This would be particularly exacerbated by the presence of large scale eddies. Please explain in detail how you accounted for this in your analysis. Was the total mass loss obtained from measurements in the absence of an airflow or did you average the instantaneous mass transport rate throughout the test?

Response: *sorry for this misunderstanding. In fact, we did not weight the tray instantaneously. The tray is only weighted after a test to calculate the average entrainment rate. We will revise the relevant wording to eliminate misunderstanding.*

The revision will be: "Each tray will be weighted by an electronic balancer with a precision of 0.01 g in the range 5 kg, which measures the total mass loss from the tray after a test."

Hot wire anemometer and Irwin sensors:

ii) Please state in line 70 that the instrument only samples in 1D

Response: *thanks for comment, we will add it in the revision.*

iii) Was the wire ruggedized to withstand particle impact during saltation? If so, how did this affect sensitivity (time constant and precision)?

Response: *the wire anemometer was used only in clean-flow to protect from particle impact.*

iv) Please provide exact dimensions of the Irwin sensor rather than a citation. The height of the central port does vary from study to study and is important to know relative to the roughness of the bed surface. Describe also the roughness of the bed surface upwind of the sample trays. Was it smooth or roughened to give a suitable aerodynamic roughness matched to that of the sand in the tray?

Response: *the diameter of inner port is 1.65mm, and 1.75mm in height; the diameter of the outer port is 2.57mm; the diameter of the sensor is 12.5mm. The bed surface upwind is cover by a sandpaper (40 mesh) as follow picture. We will add them in the revision.*

Section 2.1 Results

Table 1

i) Why so many missing experiments? Indeed, there are so few experiments at the 0.5 X1000 rpm increment that it might be better to exclude these data altogether. Add the freestream velocity values for the NP experiments, as rpm will make little sense to the reader.

Response: *actually, the cases of 0.5 X1000 rpm are supplementary tests. In the case of large surface shear, the erodible surface (S2 and S3) rapidly appeared obvious surface-concave which would affect the test results. So we added several test in low surface shear. We will explain this in revision.*

We will use the axis wind speed of the incoming flow to replace the fan speed.

ii) Describe the bed surface composition for your control runs without a tray/soil.

Response: *sorry for the loss of relevant information, we will add the description of the tunnel floor.*

Figure 3

i) I am not clear on the surface/sediment texture characteristics pertaining to these data. Have the data for all textures been lumped together?

Response: *Figure 3 illustrates the average wind speed profiles over the wind tunnel floor for all of the tested cases. There is only one texture of wind tunnel floor and the tested particles are filled in trays mounted flush to the tunnel floor. The tray is small in area and the surface is smoothed, so we believe that its influence on the wind profile is very limited. We will add descriptions of experimental conditions to make this information clearer.*

ii) The NP vertical profiles of the total velocity look great – a deep well-structured boundary-layer flow following the law of the wall. The WP profiles also look very good, but I think even more might be inferred from them than what is provided. There is indeed a high degree of flow stagnation in the upper part of the profile above 20 cm associated with partitioning of momentum to the flapping cloth turbulent but also turbulent energy dissipation within the wake flow downwind. However, little is said about the proportionate acceleration of the air flow (~0.5 m/s) at all levels below 20 cm in all WP experiments. This is unexpected and could be a wind tunnel artifact associated with a small degree of compression of the flow that was redirected beneath the cloth and between the confining walls.

Response: *Yes, for the cases of NP, the wind profiles are normal. According to the analysis of regression based on the logarithmic law (Eq. 5 with* Ψ_m*=0), we obtained the friction velocity for each case to calibrate the Irwin sensor.*

When we use the same method to analyze the data of WP conditions, there are a great difference between the estimated friction wind speed and ones measured by Irwin probe. However, if we take the effect of ψ_M *into account in the regression equation (i.e., not set to zero), the obtained friction is very close to Irwin's result. Therefore, we speculate that the cloth induce a flow similar to the convection in ABL.*

We noticed an increase in wind speed near the surface, which we think is a result of the presence of the cloth increasing the exchange of horizontal momentum in the vertical direction.

Unfortunately, we have not measured more wind field information besides the wind speed profile (Pitot tube) and the time series of the wind speed at a certain height (1-dimensional hot wire), so there is impossible to do a deeper analysis of the turbulence structure induced by the cloth.

iii) It is really unfortunate in this study that the vertical component of the total wind speed was not isolated and sampled, as required for analysis of the eddy structure. As first identified by Thom (1975) for truly unstable conditions with convection, mechanical effects (roughness) dominate the near surface flow, but in moving away from the surface the eddies are stretched vertically and the momentum flux is enhanced. Since the vertical velocity is generally one to two orders of magnitude smaller than the horizontal component, the total wind speed as sampled in this study cannot be particularly sensitive to the eddy perturbation that was intentionally created.

Response: *thanks for comment. The simulation and analysis of convective flow in wind tunnel is indeed an interesting and challenging topic. We will continue to focus on this in the future.*

Table 2

i) Again, I am not clear on whether the data have been averaged across all sediment textures or this is just one example for a specific texture.

Response: *as we responded above, there is only a smoothed and mounted sediment surface with a small area employed to test. The wind field is mainly affected by the wind tunnel floor which is unchanged during the experiment.*

ii) Why is the threshold friction velocity also not reported here?

Response: *Table 2 only provides the parameters of wind filed. The threshold friction velocity is a property parameter of the grain surface, which is provided in Table 3.*

iii) Over what elevations were the wind speed data used to calculate u*? If the boundary layer depth is taken to be 20 cm for the WP experiments and the inner constant stress region 15-20% of that, then your calculation might only be based on 4 data points. That is, the shear stress values for the WP experiments would carry greater error than those for the NP experiments. How does this uncertainty compare with the roughly 7% increase in u* associated with introduction of the flapping cloth?

Response: *thanks for comment. There is indeed uncertainty in estimating friction velocity from wind profile. In fact, the shear stresses or friction velocities in the Figs. 4-7 are provided by Irwin probe data.*

iv) Under what conditions were the Irwin sensors calibrated – NP or WP? This has a large bearing on an explanation for why the Irwin sensor u* values sit slightly higher than for the WP data.

Response: *the Irwin sensor is calibrated under NP condition which has been validated for well estimating the friction velocity from wind profile.*

Section 2.1.3

Line 171

"Convective turbulence is much more efficient in lifting particles into the air". Caution should be exercised in making such a broad statement. This may well be true for very light particles (aerosols) entering suspension, given a settling velocity that is lower than the vertical velocity at which eddies burst away from the bed surface, but not so for very large sand particles. Once again, it is unfortunate that you can only infer such effects because you don't have the vertical component measurements.

Response: *thanks for comment. Our results on four tested surfaces with different average particle sizes show that convection facilitates particle entrainment. We prove that this is not only caused by the increase of mean surface shear stress, but also by the change of the distribution surface shear stress.*

Anyway, we're going to use more rigorous language in revision.

Figures 4 and 5

There is no question that positive skewness in the instantaneous bed shear stress should increase the particle entrainment rate at low values near threshold, but the fact that the near surface flow is accelerated (especially at lower elevations) by insertion of the flapping cloth is likely to be equally if not more important in this particular study.

Response: *thanks for comment. We believe that the increase of wind speed in the near-surface region is reflected in the increase of surface average shear stress. But the increase of average shear cannot completely correspond to the increase of particle entrainment (Fig. 4). Only by taking the influence of the change of shear stress distribution into account, the measured results of entrainment are well explained.*

Conclusions

Logic dictates and your study shows that intermittent generation of large shear stresses on the bed surface enhances the entrainment of sand and silt sized particles. This should be qualified by some form of statement to indicate that this effect is greatest at low wind speeds around threshold and when transport is intermittent. In really strong winds mechanical or impact entrainment dominates, while the particle borne stress largely determines the transport under saturated conditions.

Response: *thanks for comment. According to Fig 7, it obviously shows that the effect of the distribution of surface shear is greatest at low wind speeds around threshold and when transport is intermittent. We will modify relevant conclusion according to the suggestion of reviewer.*

"we showed that wind-tunnel turbulence lacks energy containing eddies even compared with ABL flows in neutral conditions, highlighting the deficiency of traditional wind-tunnel experiments on aeolian studies". Again, this is a bit of an overstatement. Most traditional wind tunnel studies have modelled saturated flows (see above) where the particle cloud itself is so dense that it alters the turbulence structure. Since the development of fast response pressure transmitters, cross-wire probes, and laser Doppler anemometers more than 2 decades ago, aeolian researchers working in wind tunnels have indeed provided detailed measurements of the turbulence structure and intensity associated with sediment entrainment and transport while also investigating the effects of wind gusting (e.g. Li and McKenna Neuman 2012, 2014 etc). Similarly, there are many means by which we can and do generate large scale eddies in wind tunnel simulation and these are widely practiced in engineering applications, particularly in investigations of wind loading on urban structures.

Response: *thanks a lot for the comment and providing information. We will modify relevant part to make it more rigorous.*