Referee #1:

I am satisfied with the authors' response to my comments, except for my intermittency comment. The authors state, "However, when applying this criterion to our large-scale macroscopic computational domain simulations, we encountered specific challenges that affect the effectiveness of f_Q in distinguishing the influence of different boundary layer thicknesses: even when the wind speeds approach the rebound threshold—defined by the cessation of intermittent transport—the fraction of time during which saltation is inactive across the entire large-scale computational domain remains very small." This is, of course, true if the considered domain is too large, like in this case where the authors use the entire simulation domain. However, in Martin & Kok (2018), f_Q refers only to a limited (x,y)-domain (the domain covered by the sensors they used) and all elevations z. So, my comment from my previous review still stands. It cannot be dismissed in such a hand-waving manner. Please, try a bit harder.

Comment from my previous review:

A much better way to define intermittency is through bursts of overall activity, e.g., see Carneiro et al. (2015, doi: 10.1038/srep11109), Martin and Kok (2018, doi: 10.1029/2017JF004416), Comola et al. (2019, doi: 10.1029/2019GL085739). For example, the latter two studies looked at the fraction of time, f_Q, at which aeolian transport is active, defined through a non-zero overall particle count over a period of 2s (approximate particle response time to turbulent wind fluctuations). The authors could adapt a similar measure. If it is defined appropriately, the ratio Q/f_Q between the intermittent transport rate Q and f_Q should behave like a universal function (see Comola et al., Eq. (3)), independent of the boundary layer thickness. In regard to my previous comment, this function could then be extrapolated to zero to obtain the actual rebound threshold.

Authors' response: Thank you for your further valuable comments on our response regarding the definition of intermittency. We fully endorse your view that f_Q represents a more standard and theoretically more rigorous measure of intermittency. Prompted by this, we have carried out a more in-depth quantitative analysis of f_Q under different boundary layer thicknesses, and on that basis we have more clearly articulated why, within the specific context of the present study, retaining α_p as a metric is both necessary and prudent.

(1) Analysis of f_Q in a finite domain

Following your suggestion, we abandoned the use of the entire computational domain and instead defined f_Q over a finite (x, y) domain. Taking the near-threshold wind velocity (θ_* =0.0032) as an example, we selected three different domains, all centered within the computational domain: 0.05 m × 0.05 m, 0.1 m × 0.1 m, and 0.2 m × 0.2 m. In accordance with Martin and Kok (2018) and Comola et al. (2019), f_Q is defined as the fraction of time that saltation is in an "active" state within Δt (2 s), evaluated over the selected finite horizontal domain in all elevations and based on a total time series exceeding 60 s. The results are shown in Fig. R1(a), where it can be seen that for the thin boundary layer (δ =1.0 m), f_Q approaches zero in any of the finite domains, whereas for the thick boundary layers (δ =5.0 m and 10.0 m), f_Q is close to 1 in all finite domains.

This occurs because, under the thin boundary layer, θ_* =0.0032 is close to the rebound threshold, and the transport consists of extremely sparse, localized, and transient spot events that can barely establish sustained activity within any of the monitored finite areas. Under the thick boundary layers, in contrast, the transport takes the form of a domain-wide weak transport state, and therefore appears as sustained activity in all finite domains. In this situation, when comparing different boundary layer thicknesses, f_Q jumps between values of "0" and "1", depriving it of the ability to resolve intermediate states and the continuous variation of spatial structure. As a result, it fails to serve our core research objective, which is to capture the global differences in transport spatial structure induced by boundary layer thickness.

For further substantiation, we present the height-dependent intermittency factor f_{QH} (y) for the boundary layers with δ =5.0 m and 10.0 m in Fig. R1(b). It can be seen that f_{QH} (y) decays exponentially with height, and its magnitude depends strongly on the arbitrarily chosen size of the observation domain — as is to be expected. This is essentially analogous to the issue you pointed out regarding the dependence of α_p on grid size, namely that the results are contingent upon the observation scale.

This runs counter to our original intention of providing a metric that is independent of the observation domain and can capture the most intrinsic spatial heterogeneity of the entire flow field. We therefore conclude that, although f_Q is closer in definition to the intermittency, its discriminatory power in our specific simulations is severely constrained by the stark dichotomy of transport states. In contrast, while α_p does depend numerically on the grid resolution, under a fixed grid resolution its variation with height and boundary layer thickness can effectively characterize the sparseness or denseness of particle distribution and the accompanying differences in spatial structure. This is precisely the key information needed to study the transition from spot-like to stream-like transport near the threshold.

(2) Conclusions and revisions

Based on the above quantitative analysis, we have taken the following measures in the revised manuscript to ensure the rigor and clarity of the discussion. First, we have clearly defined α_p as a measure of the “spatial heterogeneity” of particle distribution, rather than intermittency in the conventional sense. Second, we have explicitly emphasized that its intended use is for relative comparison under a fixed resolution. In addition, we have incorporated Fig. R1 and the associated analysis (concerning why f_Q fails to discriminate different boundary layer thicknesses under near-threshold conditions) into the manuscript as supporting discussion to elucidate our rationale for choosing α_p. Finally, we have clearly stated in the manuscript that in this study α_p is adopted to compare the tendency of particle transport toward spatial dispersion or clustering under different boundary layer thicknesses — precisely the kind of global structural information that the spatiotemporal metric f_Q is inherently unable to capture. See lines 398–413.

We sincerely appreciate your rigor; it is precisely this kind of exchange that has prompted us to think through the issues more thoroughly. We are confident that, with the above revisions, the arguments presented in the manuscript will be all the more convincing.

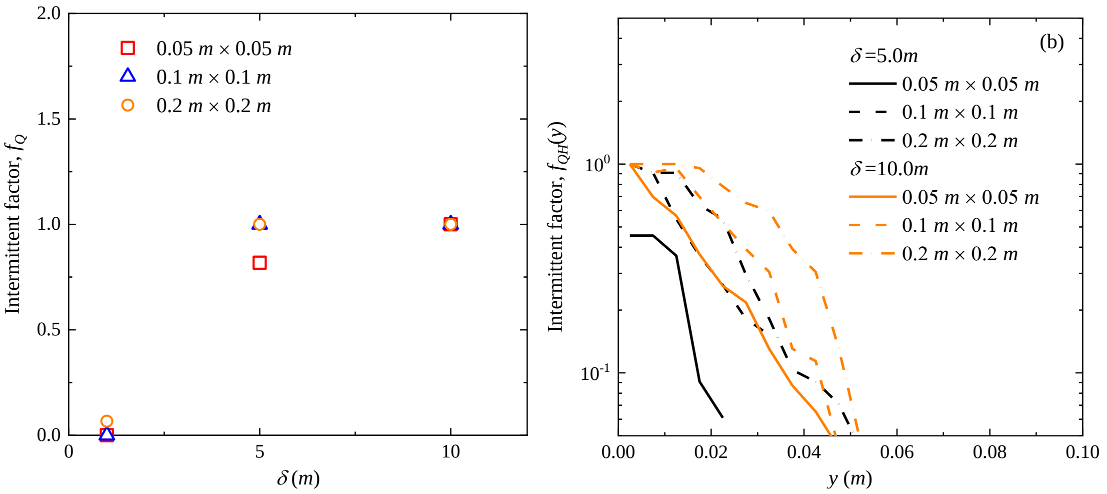

Fig. R1. (a) Fraction of time f_Q for which saltation is in an “active” state, and (b) the height-dependent intermittency factor f_{QH} (y), under different boundary-layer thicknesses.

Referee #2:

The manuscript has been significantly improved following the authors' revisions. It is now much clearer and more complete, and can be considered for publication after addressing a few remaining minor issues:

Lines 175-180: The authors state that the boundary layer thickness δ does not affect turbulence structures independently, but rather acts on the friction Reynolds number Reτ, which appears to be too strong. In wall-bounded turbulence, δ may also influence outer-layer structures and inner–outer interactions beyond its role in determining Reτ, especially in developing or rough-wall boundary layers. The assumption of a constant u_* with changed δ makes the physical model in this study somewhat abstract and difficult to relate directly to real-world cases. Could the authors explain in which situations this process can happen, to give readers a more intuitive understanding?

Authors' response: We sincerely thank the reviewer for this insightful comment. The original statement was indeed overly absolute. We have revised the text accordingly, as shown below (see lines 175–176 in the revised manuscript).

"The boundary layer thickness δ not only affects outer-layer structures and inner–outer interactions, but also acts through the friction Reynolds number $\mathrm{Re}_\tau = u_*\delta/\nu$."

In fact, the approach adopted in this study — fixing the friction velocity u_* while independently varying the boundary layer thickness δ — is precisely designed to isolate the independent effect of δ from the coupling effects, thereby explaining the discrepancies between wind-tunnel and field observations. Convective boundary layers can reach thicknesses of 1-2 *km*, neutral boundary layers are typically on the order of hundreds of meters, and stable boundary layers may contract to tens of meters. The range of thicknesses simulated in this study precisely spans the transitional interval from typical wind tunnel scales (approximately 0.1 *m*) to natural atmospheric scales (>100 *m*). Thus, this configuration has a clear physical basis and provides a crucial mechanistic explanation for the systematic differences in sediment transport thresholds and rates between wind-tunnel and field observations. We have already noted this in the manuscript (see lines 523–524).

Fig.2(a): The probability density distribution of the fluctuating shear stress in Fig. 2(a) appears somewhat unusual. The peaks of all three cases are located near zero; however, the cases with $\delta = 5\ m$ and $10\ m$ exhibit a clear right skewness. This would imply a positive mean of the fluctuations, which is inconsistent with the definition that the mean of the fluctuating component should be zero. The authors are encouraged to re-examine this result.

Authors' response: After re-examining the data in Fig. 2(a), we find that the fluctuating shear stress at which the probability density function peaks is not strictly zero: for $\delta = 1\ m$, $5\ m$, and $10\ m$ the values are -1.63×10^{-3}, -3.51×10^{-3} and -3.86×10^{-3}, respectively — all very small negative quantities. Because the ordinate is plotted on a logarithmic scale, these tiny offsets are difficult to discern in the figure, making the peaks appear to be located at zero. At the same time, the right-skewness is a feature of the distribution shape and does not alter the mathematical fact that the mean of the fluctuating component is zero (this has been rigorously ensured in the computation). Hence, the results shown in Fig. 2(a) present no contradiction.

Lines 259-260: The measured threshold by Williams et al. (1994) corresponds to the fluid threshold, which decreases with increasing downstream distance in the wind tunnel (effectively equivalent to increasing boundary layer height). This suggests that boundary layer height not only modulates the distribution of surface shear stress but also alters the turbulence structure. In addition, experiments by Li et al. (2020a) and Zhang et al. (2022) indicate that it is not the fluid threshold itself that changes. In principle, this threshold represents the wind strength required for particles to overcome gravity and cohesive forces, and should therefore be a well-defined value. What actually varies is the turbulence structure under different flow conditions, which modifies the instantaneous probability of exceeding the threshold. The authors are encouraged to clarify this point more explicitly.

Authors' response: We fully agree with the reviewer that the fluid threshold physically represents the wind strength required for particles to overcome gravity and cohesive forces. Experimental results reported in the literature (e.g., Li et al., 2020a; Zhang et al., 2022) also show that what actually changes under different flow conditions is the turbulence structure.

In our manuscript (particularly in the discussion at lines 257–259 and Fig. 4), we note that the threshold decreases as the boundary-layer thickness increases. Essentially, this is because a thicker boundary layer enhances turbulent fluctuations. As we have already pointed out at lines 261–263, increasing the boundary-layer thickness significantly alters the turbulence structure (Li et al., 2020a; Zhang et al., 2022), which modifies the instantaneous probability of exceeding the threshold — this is precisely the physical mechanism underlying the threshold reduction. Furthermore, we have explicitly indicated that the threshold measured by Williams et al. (1994) corresponds to the fluid threshold, and its value decreases as turbulence intensifies (effectively equivalent to increasing boundary layer height) (lines 260–261).

Lines 451-457: The comparison between atmospheric stability and boundary layer thickness appears somewhat oversimplified. While stability primarily modifies turbulence production and energy distribution, boundary layer thickness may also influence turbulence structures beyond merely constraining their maximum scale, particularly through outer-layer dynamics and inner–outer interactions. In addition, the statement "by fixing other flow parameters" needs further clarification, as varying δ in practice often involves changes in inflow conditions or flow development, making it difficult to isolate its effect. Finally, the link between larger-scale coherent structures and near-threshold transport intermittency would benefit from a more explicit physical explanation.

Authors' response: We thank the reviewer for the insightful comments. The three issues you raised are very helpful for refining the discussion in our manuscript. We address them point by point below.

(1) Regarding the comparison between atmospheric stability and boundary layer thickness: we agree that the comparison in the original manuscript was indeed overly simplified. Our original intention was primarily to emphasize that boundary layer thickness, as a parameter that limits the largest turbulent scales, differs in its physical mechanism from stability. We acknowledge that boundary layer thickness not only limits the largest turbulent scales but also affects the near-wall turbulence characteristics through the interaction between the inner-outer interactions. We have now explicitly elaborated on this point in the revised manuscript and added supporting references (Guala et al., 2006; Marusic et al., 2010) to underpin this argument. See lines 470–473.

(2) Clarification regarding “fixing other flow parameters”: Since our simulations employ large-eddy simulation with horizontal periodic boundary conditions, there is no issue of natural boundary layer growth due to varying downstream positions as would be the case in a conventional physical wind tunnel. Instead, δ is directly prescribed as an independent input parameter. The “fixing other flow parameters” refer to the kinematic viscosity, the mean wall friction velocity, the boundary conditions, and the manner in which the inflow turbulence is initialized. We have added the above clarification in the revised manuscript. See lines 475–477.

(3) Regarding the link between larger-scale coherent structures and near-threshold transport intermittency: We have supplemented the manuscript with the following specific mechanism. A thicker boundary layer supports large-scale coherent structures, such as low-speed streaks or streamwise vortex pairs. These structures induce high instantaneous shear stresses in the near-wall region. Even when the mean shear stress is low, once this instantaneous stress exceeds the fluid threshold, it can trigger localized burst-like particle motion, thereby dominating the intermittent transport behavior. See lines 478–482.