Reply to comments of Anonymous Referee #2

General comments:

Comment 1:

Observations show a variety of crystal habits that can contribute to blowing snow, and even dendritic crystals can have various amounts of riming on them. How can this be factored into your model? How may this impact the validation to prior work?

Response: We appreciate the reviewer's comment regarding the variety of crystal habits and their contribution to blowing snow. Different crystal habits can indeed exhibit aerodynamic and sublimation process. However, our study focuses specifically on the fragmentation of snow particles on sublimation, rather than considering all influencing factors on blowing snow. While the diversity of crystal habits is an interesting aspect, our simplified assumptions in our model, which exclude snow growth processes such as riming, are designed to isolate the effects of fragmentation on sublimation. We believe that this approach does not compromise the validity of our main conclusions.

Riming is one of the main growth processes of snow crystal by collecting supercooled cloud droplets. It plays a significant role in the formation of precipitation in cold clouds. It can change crystal habits such as density, shape, size, and deposition velocity. Riming normally occurs in a high-humidity environment, thus is less important in blowing and drifting snow with dry air environment. Blowing and drifting snow primarily involves sublimation, resuspension and fragmentation of snow particles, rather than their growth process.

We have added the above into the Conclusion section in the revised manuscript: "*Crystal habits is another important factor in influencing the sublimation rate of snow particles, such as density, size, and specific surface area. Future numerical simulation should be carried out regarding crystal habits factors.*"

Comment 2:

The validation of the model is limited and not thoroughly explained/discussed. Did you consider comparing your model results to other blowing snow observation studies such as those conducted in Franklin Bay (Gordon et al. 2009) or at Mizuho station, Antarctica (Nishimura and Nemoto 2005)? Think about this from the perspective from an observer… what observations do we need to validate the model? I would elaborate on what your results mean. Figure 5 suggests it is critical that our observations are capable of detecting particles < 100 um in diameter. It's unclear how this relates to height above ground. Overall, the presentation of results is more limited than what it should be.

Response: Thank you for pointing out this point. We have compared our model results to field observation studies of Gordon et al. (2009) and Nishimura and Nemoto (2005), as is shown in Fig 2. Our simulation results are consistent with the field observation results. Particle sizes are smaller at higher altitudes, exhibiting a narrow range of 0-90 μm. In contrast, within the saltation layer (up to 0.1 m in height), particle sizes display a broader distribution, ranging from 50-450 μm.

Furthermore, we have added more descriptions on Fig. 5.

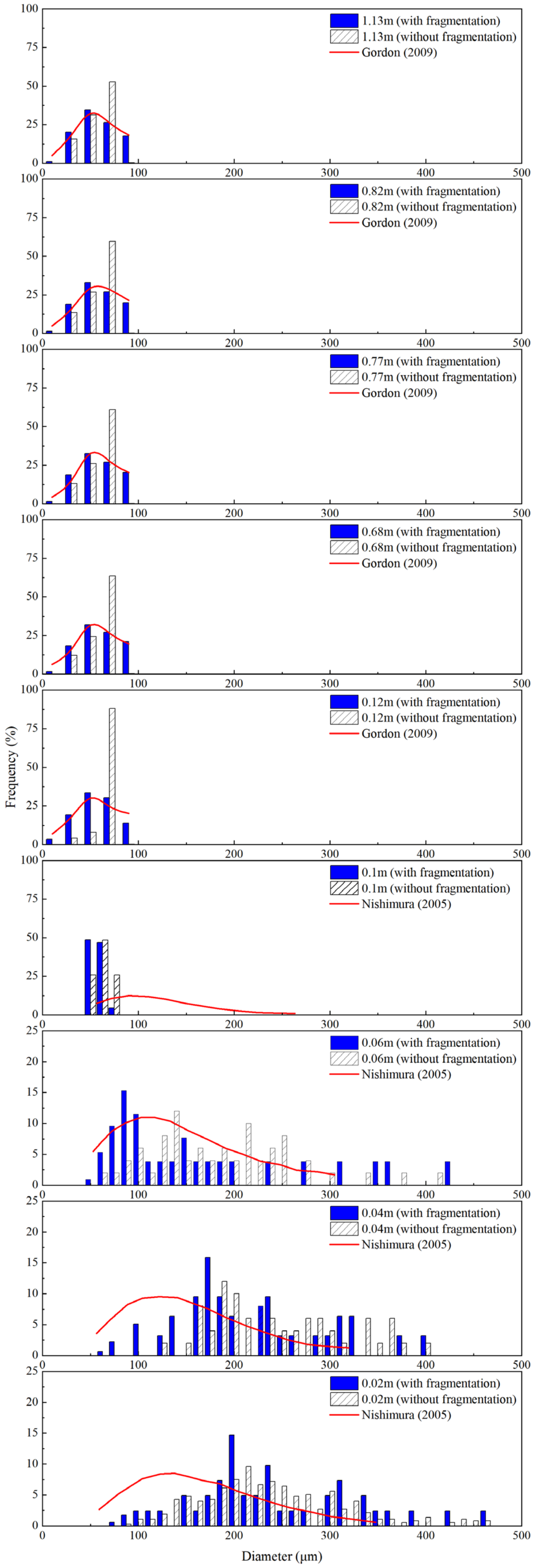

Figure 2. Particle size distribution along the height.

The revised Model verification is as follows:

Model verification

To verify the model, we compared simulated particle size distribution, sublimation rate, and mass concentration to observational data. We first compare the particle size distribution at all heights with the field observation data of Gordon (2009) and Nishimura (2005), shown in Fig. 2. The simulated results are consistent in the size distribution range and variation trend, compared to field observation. Overall, the size distribution variation with height deviates more significantly in the near-surface (0.02 m to 0.1 m), compared to that in higher space (0.12 m to 1.13 m). The proportion of smaller-sized particles increases when considering the fragmentation (blue columns in Fig. 2), which is closer to the observation results (white columns in Fig. 2). For particles in height between 0.12 m to 1.13 m, particle size is in a narrow range of 0-90 μm. In contrast, within the saltation layer (up to 0.1 m in height), particle sizes display a broader distribution, ranging from 50-450 μm, and the simulated average particle size decreases with increasing height. However, this trend is not evident in the field, which might be due to the complexities of the field environment compared to ideal simulation, as well as limitations in the accuracy of measurement sensors.

Fig. 3 shows the comparison of the total sublimation rate between the numerical simulation and the field observation data (Schmidt, 1982). Comparing these two curves, we see that the sublimation rate is the same order of magnitude, which shows that the model is suitable for calculating the sublimation rate of blowing snow. The mass concentration from the simulation and field observations for the same friction velocity and temperature is shown in Fig. 4 (measured by Pomeroy and Male (1992) near Saskatoon).

The suspension sublimation rate from this paper and from other sublimation models under the same conditions are compared (Fig. 2). The black line is the sublimation rate of suspension in the case of fragmentation of snow particles, and the other five curves are the simulation results of suspension sublimation of jump without fragmentation of snow particles (Xiao et al., 2000; Huang and Shi, 2017). The results demonstrate that drifting snow sublimation is important, particularly in the near-surface saltation layer. However, most previous models underestimate the sublimation rate near the surface, which significantly impacts the assessment of the drifting snow sublimation. Accounting for fragmentation increases the sublimation rate by approximately 1.3 times, which suggests that it is necessary to conclude snow particle fragmentation in drifting snow and blowing snow models.

Specific comments:

Comment 1:

Line 30: Strike 'the'

Response: Thanks for mentioning it, we have revised this sentence to: "*To date, there is only one model (Comola et al., 2017) considering the fragmentation of snow particles during drifting snow*".

Comment 2:

Line 31-32: Sentence reads weird. Perhaps: This work used a statistical mechanics model to calculate the fragmented number of particles from the perspective of energy and mass balance and simply analyzed the effects of fragmentation on the particle size distribution.

Response: Thanks for your suggestion, we have revised this sentence to: "*That study, using a statistical mechanics model, calculates the fragmented number of particles from the perspective of energy and mass balance and analyzes the effect of fragmentation on the particle size distribution*".

Comment 3:

Line 50: reintroduce

Response: Thanks for your suggestion, we have revised this sentence to: "*Here, we **reintroduce** them briefly*".

Comment 4:

Line 101: Had some trouble understanding this sentence. Is this what you mean?···Equation 10 is used to determine whether it is broken. The number of snow particles N is calculated and λ represents the ratio···

Response: Sorry for the misunderstanding. Yes, it is what we mean. This sentence has been revised to: "*When a snow particle falls back to the ground (initial velocity v_i > 0.5 m/s), Eq. 10 is used to determine whether it breaks and then the number of snow particles N is calculated (Eq. 11. λ is the ratio of particle size before and after fragmentation, again following Comola et al. (2017) (Eq. 12).*"

Comment 5:

Line ~10: crushing = shattering or fragmenting?

Response: Sorry for the misunderstanding, here we want to express fragmenting. This sentence has been revised to: "*The velocity and the direction angle of the newly produced snow particles is kept same as that of the original snow particles.*"

Comment 6:

Figure 3: Move the legend a bit to the right or put a box around it. At first glance the legend symbol for P&M 92 could be interpreted as a data point.

Response: Thank you for mentioning it. We have moved the legend to the left corner to prevent interpreting data points.

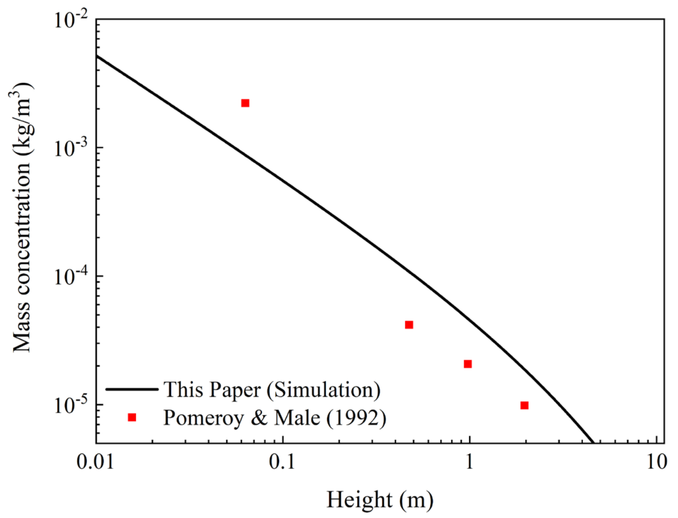

Figure 3. Comparison of mass concentration for this paper and field observations (Pomeroy and Male, 1992) ($u_* = 0.31$ m/s, $T = 265$ K)

Comment 7:

Figure 4: In legend, should read 'snowstorm' Caption: 'Comparison of suspension sublimation rates with other blowing snow models. I think it would be better to put height on the y-axis. I would also go to a higher height. Practically, we are only going to have observations at heights z > 0.1m.

Response: Thanks for your suggestions. We have switched the x-axis and y-axis and revised the caption to: "*Comparison of suspension sublimation rates with other blowing snow models. (u_* = 0.87 m/s, z_0=0.001 m, T = 265 K)*".

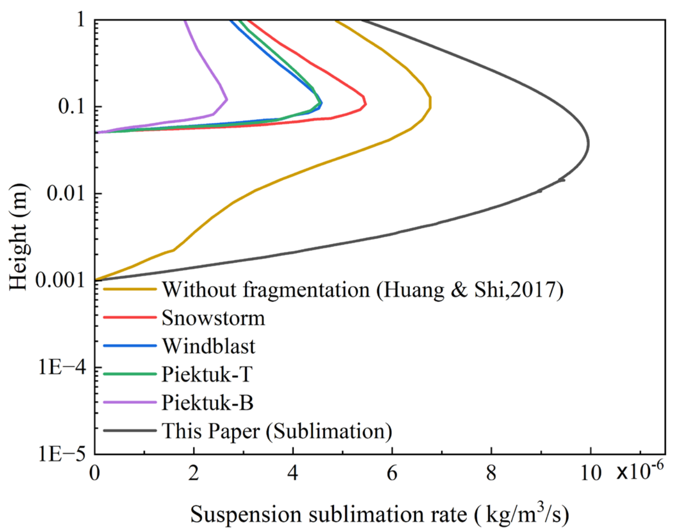

Figure 4. Comparison of suspension sublimation rates with other blowing snow models. (u_* = 0.87 m/s, z_0=0.001 m, T = 265 K)

Comment 8:

Figure 6: How do the PSDs change with height? Once again, I'm thinking about this with my observer hat on.

Response: Thanks for pointing it out. Fig. R1 shows the PSDs at different heights. The particle size becomes more concentrated at higher height levels. Particle size decreases on average with the increasing height. When considering fragmentation, the PSD switched left on the x-axis, which means a lower value on average.

Comment 9:

Line 161: Not a complete sentence. How do results change by mean particle size which will vary depending on location and environmental conditions?

Response: Thank you for pointing it out. This sentence has been revised to: "*Simulations are conducted with a friction velocity u_* = 0.45 m/s, and an initial mean particle size $\bar{d}$ = 200 μm.*" The effects of the mean particle size on simulation results are discussed in Section 3.5. In Section 3.5, we investigated the effects of the average particle diameter and the size proportion on the number of fragmented particle numbers. We found that the larger the average particle diameter of the granular system, the greater the extent of particle fragmentation. For granular systems with the same average particle diameter, a higher proportion of larger particles leads to a greater extent of particle fragmentation. A greater extent of particle fragmentation, in turn, results in a higher sublimation rate of snow particles.

Comment 10:

Line 212: strike the 2nd 'the'

Response: Thanks for mentioning it, we have revised this sentence to: "*In these three cases, the proportion of the particles larger than the threshold diameter is 73% (blue), 85% (green), and 96% (purple).*"

Comment 11:

Friction velocity: there are various comments that discuss how properties change with wind speed although results are for friction velocity. While friction velocity is directly related to wind speed, you also have roughness length and stability considerations to think about so, I'd be careful with how section 3.4 is worded.

Response: Thanks for pointing it out. In this work, we consider neutral boundary layer conditions for drifting and blowing snow mainly happen in near surface area. The roughness length is kept as constant ($z_0 = 3\times10^{-5}$ m). We have changed all the "wind speed" to "friction velocity" in section 3.4.