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Interactive comment on "Dry-Air Entrainment and Advection during Alpine Blowing Snow Events" *by* Nikolas Olson Aksamit and John Pomeroy

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Summary: This paper presents measurements of high frequency atmospheric conditions during five blowing snow events in the fall/winter of 2015/2016 observed at the Fortress Mountain Snow Laboratory (FMSL) in southwestern Alberta, Canada. The dataset includes 3-D air temperature and wind speed fluctuations from two sonic anemometers and meteorological conditions at three proximal automatic weather stations. Blowing snow conditions are stratified into "sweep" or "ejection" events based on the combination of horizontal and vertical wind speed anomalies. The observations reveal periodic incursions of dry air from aloft that sustain or enhance blowing snow sublimation during wind transport events. Sudden increases of up to 1°C in air temperatures from dry/warm air entrainment suggests increased available thermal energy for

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the sublimation process. As such, dry air advection can suppress the thermodynamic feedback associated with blowing snow sublimation.

This is an interesting effort that will be of interest to the readership of The Cryosphere. The paper is very well-written and figures are generally clear and entirely appropriate to illustrate key points. My general and specific/technical comments on the paper are as follows:

General Comments:

1) The abstract lacks key information such as the period of study and the specific study site (Fortress Mountain in southwestern Alberta, Canada).

2) Section 2.1 should provide a short description of the study area and its climate. Provide the coordinates and elevation of the blowing snow study site, some information on the local topography and climate to provide the reader some geographical context.

3) Are ultrasonic humidity measurements also available at the FMSL during this field campaign? If so, it would be quite interesting to see if blowing snow sublimation, and hence humidity, responds to the rapid air temperature and wind speed fluctuations during blowing snow events. In any case, if both ultrasonic air temperature and wind speed data are available during the five blowing snow events, why not plot the corresponding sensible heat fluxes observed along with the meteorological data shown in Figure 2? At the very least, Figure 2 should include the corresponding wind speed data for all three sites.

4) At no point does the text specify whether the relative humidity data recorded at the three other FMSL stations are with respect to water or to ice. Standard meteorological instruments usually provide the former, and so if this is the case, the relative humidity data must be converted to respect to ice to make any claims or conclusions about the absence of saturation during these five blowing snow events. It should also be clear that the Powerline site is sheltered by trees and hence does not likely experi-

ence blowing snow and may not reveal evidence of thermodynamic feedbacks from its sublimation.

5) Table 1 (mis-labelled as Table 2) provides data on Monin-Obhukhov lengths but it is not clear how these are derived. Similarly the definition for turbulence intensity reported in this table is not defined in the text.

6) Blowing snow conditions are stratified into "sweep" events (u' > 0, w' < 0) and "ejection" events (u' < 0, w' > 0); yet there may also be blowing snow conditions when the horizontal and vertical wind speed anomalies are both of the same sign; therefore it is unclear why observations are provided only for the sweep and ejection events.

7) Further to this, is an assumption made that blowing snow particles have no inertia and respond instantaneously to wind speed fluctuations?

Specific Comments:

1) P. 1, line 19: Fix the language in "model modeled described provides".

2) P. 1, line 27: Snow at the surface is often subjected to transport by wind only in relatively open and windy areas; areas such as the boreal forest and taiga are much less prone to wind transport of snow. The statement here should not be so general given blowing snow is not important component of the water budget in all areas experiencing snow.

3) P. 2, lines 48-50: Some prior studies (e.g. Grazioli et al. 2017; Déry and Yau 2001) have explored turbulent mixing and entrainment of dry air into the atmospheric boundary layer with impacts to the blowing snow sublimation and should be cited here.

4) P. 2, line 54: Delete "in order".

5) P. 2, line 59: Insert "air" before "temperature". Are the relative humidity data with respect to water or to ice?

6) P. 3, line 64: Perhaps this subsection could be titled "Field data"?

7) P. 3, line 75: How strong were the winds during the chinook event on January 21, 2016?

8) P. 3, lines 76 and 77: The degree symbol is missing in the air temperature values reported here and elsewhere in the paper.

9) P. 3, line 83: Rather than “protected” use “sheltered”.

10) P. 3, line 84: Replace “include” by “including”.

11) P. 3, lines 87-89: At what temporal scales of the meteorological measurements are these coefficients of determination valid for? What are the associated probability values and sample numbers for each?

12) P. 4, Figure 1 and caption: Should the arrow on the map indicate the “Predominant” wind direction?

13) P. 4, Table 1: Note that this table is reported as “Table 2” but it should instead be “Table 1”. Under “Date”, the years for the events should also be reported. There is disparate information provided for the meteorological data, namely the range for wind speeds and Monin-Obhukov lengths and means for air temperatures. It would be more useful to have mean values and corresponding standard deviations for all events. What do the “lower” and “upper” air temperature measurements mean? At what depth are the snow temperature measurements collected? Why not report one decimal value for the snow temperature measurements in a similar fashion as to the air temperatures? Apart from these meteorological variables, why not report the mean and standard deviation in relative humidity with respect to ice?

14) P. 5, line 108: What does the subscript “v” denote in “kv”?

15) P. 5, line 110: Move “criterion” to just after “analysis”. Insert a comma after “1989]”.

16) P. 5, line 113: In Equation (2), is a negative sign needed before “air” given the absolute value of this quantity is taken?

17) P. 5, lines 113 and 114: Equation (2) has a term v' but the next line refers to w'. What does the subscript "Q" refer to in "kQ"?

18) P. 6, line 128: Are the relative humidity data discussed here with respect to water or to ice? Standard meteorological instruments provide the former and so should be converted to respect an ice surface to establish whether saturation is indeed achieved, or not, during blowing snow events in subfreezing conditions.

19) P. 6, Figure 2: The color legend on the bottom right of the plot shows the air temperature in blue and the relative humidity in red; yet the tick labels on the y-axes show air temperature in red and the relative humidity in blue. As such it is not possible to interpret this plot. It would also be useful for interpretation of the meteorological time series to know when blowing snow was occurring during the 5 events shown here, perhaps as grey shading on the plots.

20) P. 6, line 135: Again, specify if the relative humidity measurements are with respect to water or ice. At what temporal frequency are these data presented and at what measurement height? Why not add the corresponding wind speed data here? In the caption, change the text to "Flagged data have" and perhaps add a note that the y-axis scales vary between panels. The caption also states that there is limited correlation between sites for both variables yet on p. 3, line 88 it was reported there was high coefficients of determination for air temperature with lesser values for relative humidity.

21) P. 7, Figure 3: On the y-axis labels, spell out "Temperature".

22) P. 9, line 158: Add the corresponding years for the events.

23) P. 9, Figure 4: On the y-axis label, spell out "Temperature".

24) P. 10, Figure 5: A color legend is missing from this plot and so the results cannot be interpreted.

25) P. 11, lines 190-191: Delete "It is interesting to note that" and start the sentence with "The probability".

26) P. 11, lines 201 and 203: Equation (3) includes a "KV" term but on line 203 the text refers to "KQ". Note also the text includes both upper case and lower case letters for these subscripts.

27) P. 12, lines 211-212: What do all the subscripts used here mean?

28) P. 12, lines 212-213: Fix the language in "common characteristic topographically induced flow."

29) 12, lines 228-229: It should be clear that these statements apply to the study site only and cannot necessarily be generalized.

30) P. 12, line 231: Replace the semi-colon by a comma after "[1993]".

31) P. 12, line 234: Again, it might be useful to refer to prior studies such as Déry and Yau (2001) and Grazioli et al. (2017) that have considered turbulent mixing and dry/warm air entrainment effects on blowing snow sublimation.

32) P. 12, line 235: Did all of these studies report humidity values with respect to ice saturation or with respect to water?

33) P. 13, line 240: It is unclear what the statement "and thermodynamic feedback may require unphysical saturation bounds to be enforced" means. The Déry and Yau (1999) study imposed air at saturation with respect to ice at a lower boundary condition (at the surface) in their numerical model, a valid assumption over a snowpack. Please clarify this statement and how it relates to the present results.

34) P. 13, line 250: Write as "1 s".

35) P. 14, lines 270-272: Again, it is unclear if this statement is accurate given it is not known if the reported relative humidities are with respect to water or to ice. In any case, it is quite possible that the Fortress Mountain Snow Laboratory site is prone to downsloping winds aligned with the valley setting, thus leading to adiabatic warming and dry air intrusions near the surface. This may not be representative of other sites,

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however, that experience blowing snow and so the results must be interpreted with caution as they may not be generalizable to other sites.

36) P. 15, line 300: This should read “Canada Foundation”.

37) P. 15, line 311: Note the extra spaces in “effect”.

38) P. 16, line 320: Insert the article # 4679 here.

39) P. 16, line 340: Add the volume and page numbers for this reference.

40) P. 17, line 352: Is the number in parentheses “(12)” the volume number? If so, then remove the parentheses.

References:

Déry, S. J. and Yau, M. K.: Simulation of an Arctic ground blizzard using a coupled blowing snow-atmosphere model, Journal of Hydrometeorology, 2, 579-598, 2001.

Grazioli, J., Madeleine, J.-B., Gallée, H., Forbes, R. M., Genthon, C., Krinner, G., and Berne, A.: Katabatic winds diminish precipitation contribution to the Antarctic ice mass balance, Proceedings on the National Academy of Sciences, 114(41), 10858-10863, 2017.

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