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Atmospheric Chemistry and Physics
Discussions

# *Interactive comment on* "Microphysical Properties of Three Types of Snow Clouds: Implication to Satellite Snowfall Retrievals" *by* Hwayoung Jeoung et al.

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Specific comments:

How generalized are the findings and conclusions? For instance, Kulie (2016) found that shallow snow cloud can be associated with strong convection and heavy snowfall while almost all the shallow (and near-surface) snowfall in this study is less than 0.5 mm/hr (Fig.6). Please add some discussions to answer this question.

We added that following discussions in section 4.2: "Kulie et al. (2016) found that globally shallow snow clouds can be associated with strong convections and heavy



snowfall. The snowfall rates for shallow and near-surface snow clouds observed in this study are mostly lower than 0.5 mm h-1; heavy snowfall is mainly associated with deep snow clouds. One possible explanation of the difference is as follows. The snowfall from shallow and near-surface snow clouds in this study mostly comes from convections associated with cold airmass outbreak from the northwest. Since the observation site is in the mountains in the east coastal region of the Korean Peninsula, substantial portion of the moisture picked up by the cold air from the warm ocean in the Yellow Sea (west of the Korean Peninsula) has been already transformed to snow before reaching the observation site. In addition, the convective clouds and easterly flow can cross the mountains and produce heavy snowfall over the site in the case of strong winds and lower thermal stability. However, these types of events occurred relatively infrequently during the experiment when compared to the other snowfall types. Consequently, the snowfall associated with shallow and near-surface clouds at this site is relatively moderate."

-Line 279: Add a sentence about the common cause of near-surface snowfall. Is it usually convective?

The following sentence is added: "Similar to the case of shallow snow clouds, the near-surface snow clouds also mostly occur after front passing or during northeasterly/easterly flow, and are convective in nature."

-Line 320: What caused melting snow? What's the temperature profile like?

The melting is caused by temperature near 0°C. See the PARSIVEL data below [attached fig.1]. Surface temperature is solid line with axis on the right. We added "with surface air temperature near 0°C" in the sentence.

-Line 321-325: Was riming also occurring during heavy snowfall? LWP was quite high at the time.

The following are MASC pictures measured at 05-06UTC and around 20-21UTC [attached fig.2]. Both are large fluffy flakes, and seemed to show some riming. A phrase "snowflakes observed at surface are large aggregates and show indications of riming occurred" is added.

-Line 356-359 The conclusion might be partially true for reflectivity between 2 and 10 but it's not universal. It looks to me that Fig. 8(b) mainly shows high LWP associated with large surface reflectivity, i.e. heavy snowfall. The text needs to be modified. & Line 359-361: Again, the conclusion is not universal, and the text needs to be modified.

This paragraph is rewritten as follows. "The diagrams for mean and standard deviation of liquid water path shown in Figs.8b and 8c appear to indicate the following. For deep snow clouds (top higher than 4 km) with surface radar reflectivity greater than 6 dBZ, liquid water path has a large mean value but a small standard deviation. On the other hand, shallow snow clouds (top between 1.5 and 4 km) with moderate surface radar reflectivity (0-5 dBZ) have a moderate mean value but a high variability of liquid water path. There is an area with high mean value and high variability of liquid water path located at surface radar reflectivity between -10 and 0 dBZ and cloud top height between 4 and 6 km, possibly corresponding to convective cells in early developing stage. For near-surface and shallow clouds, both the mean value and standard deviation of liquid water path appear to increase as surface radar reflectivity increases."

-Lines 368-370: It's interesting that Fig.9(a) shows a concentration of data with high cloud top heights (>5 km) but GR between 50%-75% rather than close to 100%. Can you add some comments about the phenomena and maybe its cause?

We suspected that this may be caused by clouds with multiple layers or decoupled upper and lower layers. The following sentence is added. "In Fig.9a, there is a concentration of points with high cloud top (>5 km) but glaciation ratio between 50% and 75% rather than 100%. It is likely that the phenomena are caused by clouds that have multiple layers or a cloud layer with dynamically decoupled upper and lower portions"

-Line397-398: There is a shift in this tendency at 4km for deep snowing clouds: fall



velocity becomes slower at 4km. There also seems a shift in the spectral width at this height. Is there an explanation for it? What's the significance of this height?

Interesting observation. In fact, the radar reflectivity CFADs also shows the shift near 4 km – below it, the frequency shows a vertical pattern while above it a left-leaning pattern. This seems to indicate the main precipitation growth occurs above 4 km. It must be related to large-scale updraft, namely, on average, bulk of the updraft occurs above 4 km in these deep clouds. We added a few sentences to describe this phenomenon. "It is also interesting to notice that there seems to be a regime shift for deep snow clouds near 4 km altitude; the frequency patterns appear to be different below and above this level for all the CFADs of radar reflectivity, Doppler velocity and spectrum width. Additionally, the slope of reflectivity suddenly changes around 8 km and the absolute value of Doppler velocity reduced dramatically below 8 km. A similar feature also appeared in the long-term observation with cloud radar (see Figs. 16 and 17 of Ye et al. 2020). The shift of growth regime was appeared at 8 km height (3$\sim$3.5 km above the bright band peak and corresponding to $\sim$ -17 °C). This regime shift induced the updraft (reached 1 m s-1) below this layer. However, Ye et al. (2020) could not explain the linkage between this regime shift and updraft below. While it is beyond the scope of this study, this phenomenon will be an interesting topic for future research on the cloud microphysics in this region."

-Line 445-446: Liquid water also has an impact on deep snowing clouds (Fig. 11 c and f) so underestimation is likely for this type of snowfall. Depending on the algorithm, overestimation is also possible for clouds with low LWP. This can be seen in Fig. 12(c) where S is overestimated below 0.2 mm/hr for low LWP. Suggest modifying this sentence accordingly.

You are right. This sentence is modified as "Even for deep snowing clouds, cloud liquid water will impact snowfall retrieval with a result of an overestimation for low and an underestimation for high values of liquid water path."

-Figures 12 and 13: S is mostly underestimated if measured S is greater than about 0.7 mm/hr in deep snowing clouds. Please add some discussions about it.

A paragraph is added to discuss this problem. "In Figs. 12 and 13, it is also noted that an underestimation occurs when snowfall rate is greater than 0.7 mm h-1 for deep snowing clouds regardless over land or ocean. This underestimation may be due to the deficiency of the Bayesian scheme, in which the retrieval is a weighted average of snowfall rates of datum points in the a priori database that are radiometrically consistent with observations. When an observation is close to the upper boundary (i.e., high snowfall rates) in the database, the averaging takes more number of datum points with snowfall rates lower than the actual value than those with higher snowfall rates (no more datum points beyond upper boundary), thus resulting in an underestimation."

-Figures 12 and 13: Besides R2, also calculate bias and RMS for the evaluation of retrievals.

Bias and rms are calculated and the values are added in the figures and text.

-Line 492-496: I can't fully agree with the statements here. First, low LWP (<50) snowfall is underestimated for near-surface snowing clouds but overestimated at the low end for deep snowing clouds so the magnitude of LWP does make a difference. Secondly, this study has shown that the type of snowfall (defined by cloud depth) instead of snowfall rate that has a significant impact on the retrieval skills.

You are right. This statement is not supported by the results. Because this is not a major point we want to make, we decide to delete this sentence.

Technical corrections: - Lines 381-382: There are no (a), (b), and (c) in Fig. 10. Needs to be consistent with the figure caption. / (a,b,c → top, middle, bottom) - Line 471: Change 'merely sensible' to 'not sensitive'. - Figure 12: Make (a) and (b) larger even if the axis ranges will be different from (c). Same with Fig. 13.

All are corrected as suggested. Figs.12 and 13 are replotted. Thank you.



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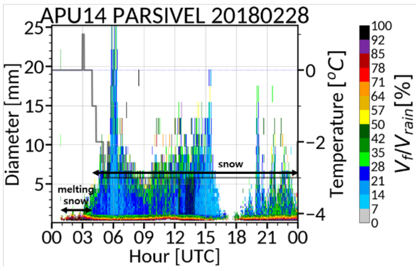
APU14 PARSIVEL 20180228
Diameter [mm]
Temperature [°C]
$V_f/V_{rain}$[%]
Hour [UTC]
melting snow
snow

**Fig. 1.**



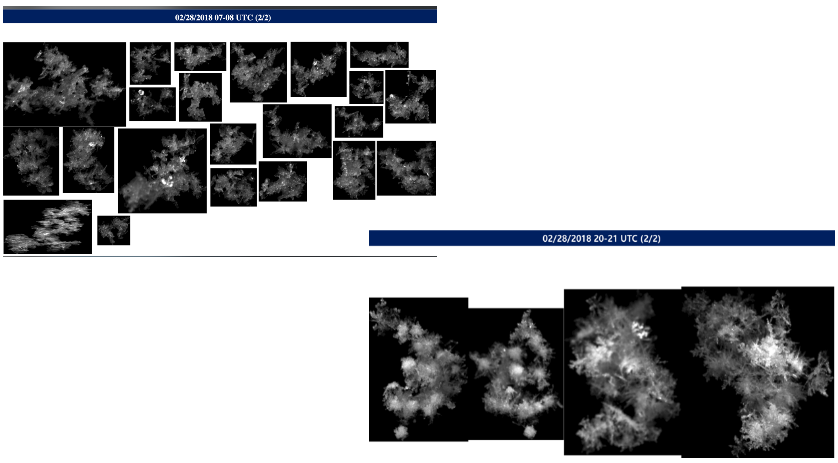
02/28/2018 07-08 UTC (2/2)
02/28/2018 20-21 UTC (2/2)

**Fig. 2.**