Response to Reviewer #1

Author reponses are black, bolded, and italicized
Text updated in the paper are green, bolded, and italicized

The topic of relating observed surface snowfall rates to local enhancements in radar reflectivity is relevant, interesting, and well within the scope of ACP. However, in ACP's Aim & Scope it is mentioned that "articles with a local focus must clearly explain how the results extend and compare with current knowledge." It is not clear how the local focus (NE U.S.) could be extended/applied to non-orographic snowfall in other parts of the word, so the paper would benefit from some additional context.

Snow bands have been documented in many regions outside of the US including Europe (Mazon et al. (2015), Norris et al. (2013)), Asia (Fujiyoshi et al. (1998), Murakami (2019), Sato et al. (2022), Zhao et al. (2020)), and the Southern Hemisphere (Comin et al. (2018)). The snowbanding literature from Europe and Japan has primarily focused on lake/sea-effect snow banding (Mazon et al. (2015), Norris et al. (2013), Fujiyoshi et al. (1998), Murakami (2019), Sato et al. (2022)). Snowbanding in the Southern Hemisphere in Chile and Argentina is orographic in nature and is not relevant to this work (Comin et al. (2018)). Winter storms in eastern Asia (China, Russia, Korea) can exhibit banded features, and this work could be extended to these types of storms (Zhao et al. (2020)).

We have added the following to the Introduction (line 50):

"While most of the snow band literature has focused on the northeast US, non-orographic snow bands have been documented in winter storms across the world. Lake/sea-effect snow banding has been investigated in Europe and Japan (Mazon et al., 2015; Norris et al., 2013; Fujiyoshi et al., 1998; Murakami, 2019; Sato et al., 2022). Winter storms in eastern Asia (China, Russia, Korea) also exhibit banded features (Zhao et al., 2020)."

- ***Comin, Alcimoni Nelci, et al. "Impact of different microphysical parameterizations on extreme snowfall events in the Southern Andes." Weather and climate extremes 21 (2018): 65-75.***

- ***Fujiyoshi, Yasushi, Naohiro Yoshimoto, and Takao Takeda. "A dual-Doppler radar study of longitudinal-mode snowbands. Part I: A three-dimensional kinematic structure of meso-γ-scale convective cloud systems within a longitudinal-mode snowband." Monthly weather review 126.1 (1998): 72-91.***
- ***Mazon, Jordi, et al. "Snow bands over the Gulf of Finland in wintertime." Tellus A: Dynamic Meteorology and Oceanography 67.1 (2015): 25102.***
- ***Murakami, Masataka. "Inner structures of snow clouds over the Sea of Japan observed by instrumented aircraft: A review." Journal of the Meteorological Society of Japan. Ser. II 97.1 (2019): 5-38.***
- ***Norris, Jesse, Geraint Vaughan, and David M. Schultz. "Snowbands over the English Channel and Irish Sea during cold‐air outbreaks." Quarterly Journal of the Royal Meteorological Society 139.676 (2013): 1747-1761.***
- ***Sato, Kazutoshi, Takao Kameda, and Tatsuo Shirakawa. "Heavy snowfall at Iwamizawa influenced by the Tsushima warm current." Journal of the Meteorological Society of Japan. Ser. II 100.6 (2022): 873-891.***
- ***Zhao, Yu, et al. "Case study of a heavy snowstorm associated with an extratropical cyclone featuring a back-bent warm front structure." Atmosphere 11.12 (2020): 1272.***

This work presents relatively extensive and comprehensive analyses of snowfall data spanning 11 winter seasons and 264 storms days, leading to some novel findings about the relationship between the spatial distribution of enhanced radar echoes and associated snowfall amounts at the surface. The primary conclusion is that—contrary to more limited case studies focusing on extreme snowfall events in the northeastern U.S.—high rates of snowfall do not necessarily correspond to locally enhanced reflectivity features (i.e., mesoscale snow bands) in a large dataset such as this. In fact, only about one out of every four hourly occurrences have heavy surface snow rates when these enhanced reflectivity features pass over a site. This conclusion is indeed substantial.

The methods are laid out in a way that is mostly clear and easy to follow, although there are a few areas highlighted in my comments below added clarity is needed. All assumptions appear reasonable and results are thoroughly laid out and explained in a good amount of detail, leading to the conclusions in a logical manner. The paper is well-organized and well-written, overall.

Specific comments:

1. Abstract: It would be helpful to include one or two sentences about the purpose of this study. Perhaps something like 'relationship between multi-bands and frontogenesis is not clear' from lines 30-31.

We have added the following text to the abstract (line2):

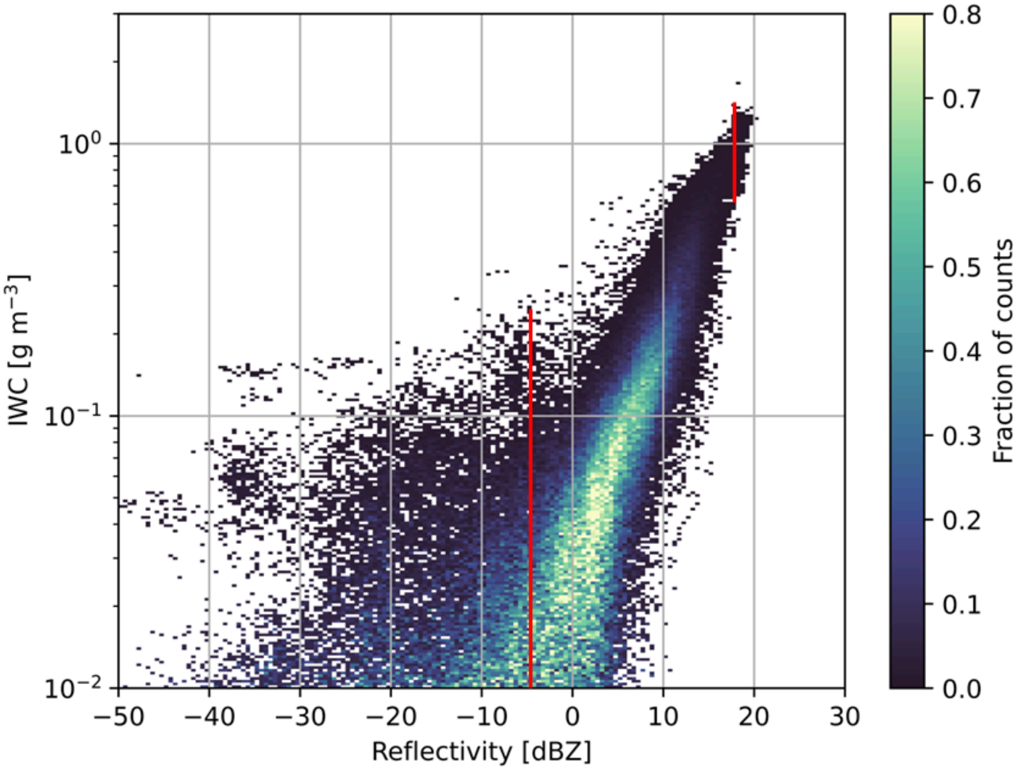
"While primary bands are associated with frontogenesis, multi-bands are found in environments with both frontogenesis and frontolysis."

2. Line 63: I'm not sure what you mean by 'better than a factor of 2'? Is this based on some prior work that you could cite here?

We have rephrased the text and added a reference to the figure as follows (line 76):

"For reflectivities > 0 dBZ, which usually contain some precipitation-size falling ice particles, IWC generally increases as Z increases. But given the spread of the observed values, there is at least a factor of two uncertainty in the volumetric ice mass as a function of radar reflectivity (Fig. 1; Zaremba et al., 2023)."

The figure below shows coincident observations from 1 Hz Nevzorov probe Ice Water Content samples and Wyoming Cloud Radar reflectivities obtained in light snow by the University of Wyoming King Air during the SNOWIE project in the mountains of western Idaho. I annotated some red bars to indicate that for given reflectivity values, the spread of IWC values is such that we cannot quantify the IWC more accurately than within a range that spans a factor of 2.



3. Line 67, 78: Is there no lake-effect snow in upstate New York? Any reason to believe that KALB and KGBM wouldn't be impacted by lake-effect snow (especially KGBM)? What is the reasoning for excluding lake-effect snow and how important is it that the dataset isn't contaminated by these events?

Yes, lake-effect events have banded features and impact this general region but lake-effect snow bands are very different from mesoscale snow bands produced during mid-latitude snow storms which is outside the focus of this study. It is possible that KBGM and KALB would allow for the inclusion of a few lake event storms, however, the majority of our events include a station closer to the coast. If our sample of events included a lot of lake-event cases, it could potentially bias our results in the direction of a strong relationship between banding and surface snowfall since lake-effect snow bands may have a stronger relationship to surface snow rates.

We added the following to the paper (line 92):

"While the majority of the stations we use to define winter storm events are close to the coast, it is possible that by using the Albany, NY and Binghamton, NY stations that some lake-effect events are included in our dataset. Lake-effect snow bands

passing overhead have a documented relationship to heavier snow rates (Kristovich et al., 2017; Kosiba et al., 2019; Mulholland et al., 2017) so their inclusion in the data set could slightly bias the results toward a stronger relationship between snowbands and heavier surface snow than is true for stations further from the Great Lake shores."

4. Line 83: What is difference b/w 29 ASOS stations and 14 stations of GHCNd? Are the 14 GHCNd stations simply for determining dates/times of non-orographic winter storm events? What measurements were included? Just daily snow depth?

The GHCNd database produces daily summaries from some surface stations (some of which are ASOS stations). The daily summaries include snow depth which are used to define our events. We did not use any other information from this dataset. I rephrased the text to clarify (line 89):

"The daily snow depth data at each station was gathered from the Global Historical Climatology Network daily (GHCNd) database (Menne et al., 2012)."

5. Line 91: Do you have a reference for 'do not have a heated rim and thus are subject to capping'? It seems this could be a significant problem that could use more discussion here. For example, are there times that this could be happening and resulting in an underestimation of the snow accumulation? Is it possible that it could happen and report lower-than-actual amounts of snow (rather than no snow at all)?

We included a citation to the Martinaitis text which discusses heated rims in AWPAG sensors. We have rephrased the text to the following (line 112):

"AWPAG sensors do not have a heated rim and thus are subject to capping, although it is difficult to estimate how often this occurs in our dataset (Martinaitis et al., 2015). If capping does occur, no snow would be reported for an hour, resulting in an underestimation of the snow accumulation for that hour. Partial capping can also occur and would result in an underestimation of snow for a period of time followed by an overestimate once the cap releases (Baker Perry, personal communication)."

6. Line 95: Is a collection efficiency of less than one something that you correct/account for? If so, how? If not, why is it not necessary?

Collection efficiency is not something that we can directly consider with this dataset which is why we use the wind speed threshold instead.

7. Line 114: Is the interpolation technique described in detail elsewhere? I see later on that you cite Tomkins et al. (2022) for details. Can you add a few words to describe the technique? Is it linear interpolation? Or is it too lengthy/complicated to mention here?

We are using Cressman weighting in the interpolation. We have included the reference and pointed readers to the Tomkins et al. (2022) citation. Text rephrased as follows (line 137):

"We interpolate the single elevation to yield a 2D grid using Cressman weighting (Cressman, 1959, for full details see Tomkins et al. (2022))."

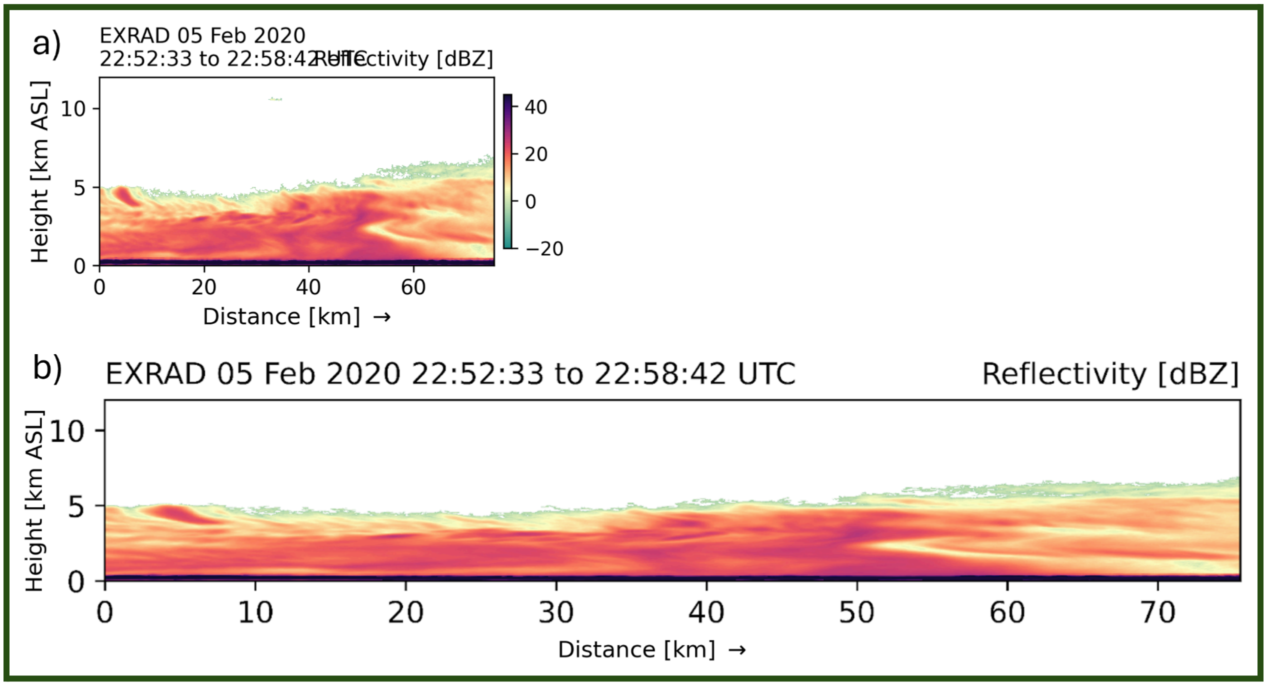
8. Lines 321-322, 325, 327: It has been a little while since I've looked at a VAD wind profile. When you say 'lots of wind shear illustrated by the wind barbs'—please describe what the direction is showing (e.g., any vertical component or horizontal only?). Are there higher wind speeds in the CFAD in 13e that aren't seen in 13a? I think a little bit more description of what we are looking at for wind direction would help here.

The VADs show a distance-height profile of horizontal winds only, no vertical component. The data used to create the CFADs in Fig. 13 e,f are the same as what is plotted in Fig. 13a. We have added the following text to clarify (line 368):

"The wind barbs in the VAD profiles indicate the direction and speed that the wind is coming from and correspond well to the patterns in the reflectivity field. The CFADs summarize the distributions with height of direction and speed of the winds in the VAD profiles along the flight leg."

9. Line 324: For the triangle icons it would be helpful to see a version of one of these images with a 1:1 aspect ratio—perhaps rotated to fit and place in the supplemental? Or just a subset perhaps. This would be nice to reference and easier to see how this would change streamer angles as you describe.

We have added the following image to the supplemental material to illustrate the difference between using a 3:1 (top) and 1:1 (bottom) aspect ratio and how the 3:1 aspect ratio distorts some of the features:



10. Line 336: There is no aircraft vector in 15a like there is in 13a & 14a.

We have updated the figures. Thank you for noticing this.

11. Line 338: Can you comment on features/scales resolved by some of these radars & not by others of note here, and how you would or would not expect that to influence the interpretation?

We have added the following text (line 237):

"EXRAD and HIWRAP are precipitation radars while the CRS is a cloud radar. The cloud radar is more sensitive to smaller ice particles than the precipitation radars and has a smaller radar resolution volume size which is capable of observing finer-scale features (see Table 2 for details including the resolution of each radar at 10 km distance)"

12. Line 342: It didn't become obvious to me until this line that the 3:1 aspect ratio is not image aspect ratio but distance aspect ratio (I think because I am used to seeing

aspect ratio used with respect to image dimensions rather than physical dimensions). Perhaps it is not just me and this could be made clear the first time it is mentioned.

We have rephrased the text to clarify (line 370):

"It is important to note that the cross sections are plotted in a 3:1 aspect ratio (3 units in vertical to 1 unit in horizontal distance) so features that are tilted appear to be more vertical in the plots (see triangle icons next to Fig. 13c for visualization). An example transect showing a comparison between a 1:1 aspect ratio and a 3:1 aspect ratio is available in the Supplementary Material."

13. Line 344: The streamers appear to be streaming in direction opposite that of wind flow (i.e., the same direction that the aircraft is heading in). Or perhaps I am misunderstanding the wind flow direction or the orientation of the streamers?

In this case the wind barbs indicate the direction that the wind is coming from (opposite to the direction the aircraft is heading). We have rephrased the text to the following (line 368):

"The wind barbs in the VAD profiles indicate the direction and speed that the wind is coming from and correspond well to the patterns in the reflectivity field. The CFADs summarize the distributions with height of direction and speed of the winds in the VAD profiles along the flight leg. It is important to note that the cross sections are plotted in a 3:1 aspect ratio (3 units in vertical to 1 unit in horizontal distance) so features that are tilted appear to be more vertical in the plots (see triangle icons next to Fig. 13c for visualization)."

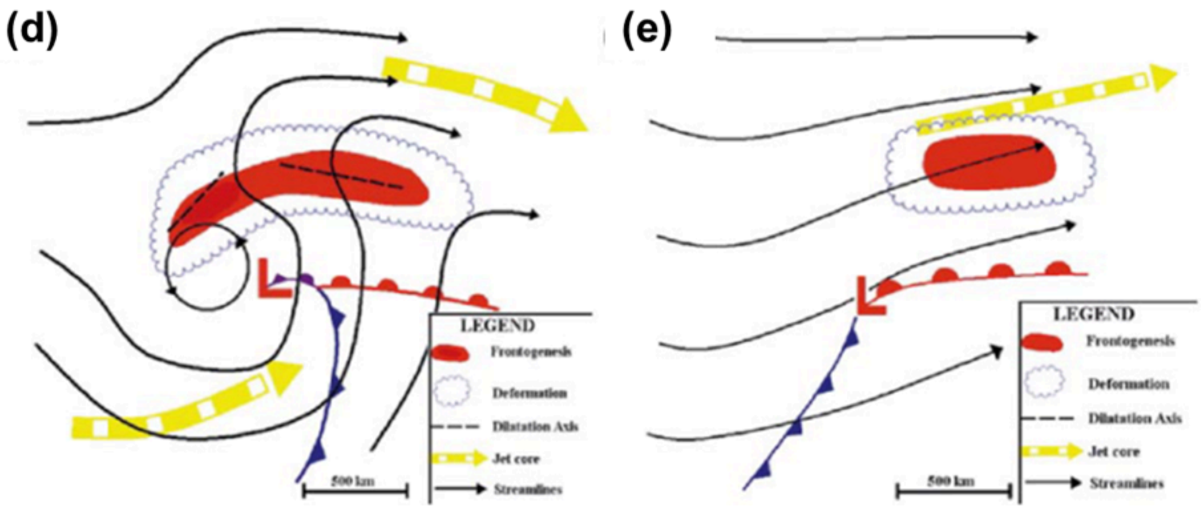
14. Line 429: Is there any physical/dynamical reasoning to support the observation that the highest snow rates tend to be in the northwest and northeast quadrants?

We have added the following paragraph (line 224):

"The northwest quadrant typically contains the occluded front and northeast quadrant typically contains the upward sloping frontal boundary ahead of the warm front. Frontogenesis is typically present in both the NE and NW quadrants (Novak et al., 2004). Additionally, for northeast US winter storms the near surface air in these

quadrants is more often cold enough to support snow as compared to the southwest quadrant cold frontal region that drapes further south and often yields rain."

Relevant figure from Novak et al. (2004):



15. Figure 5: I think it is worth it to explicitly mention here that blue horizontal lines correspond to left-hand side (or coloring the left-hand vertical axis blue?)

We have rephrased part of the Fig. 5 caption as follows:

"(c) The corresponding time series of ASOS hourly precipitation rate (left axis) valid from 7 February 2021 06 UTC to 08 February 2021 01 UTC and echo areas (right axis) calculated within 25 km of Boston, MA ASOS station (KBOS: red dot in (a) and purple dot in (b)). "

16. Figure 6: I'm not sure if a) is adding much value. Is it more useful to show the intensity of the low centers than the tracks? Perhaps color-code beginning to end of tracks rather than pressure. Should we be seeing any kind of pattern in the intensity of these low centers? If not then consider omitting or coloring based on beginning to end (e.g., lighter at beginning to dark at end of path).

Yes, we understand that this plot is not the easiest to see but we wanted to include it to provide context for the density plot in (b). We are not expecting the reader to interpret any patterns in the pressure values for this plot.

17. Figure 9 (and possibly others): You don't mention what the gray colors are here. These are where you removed melting/mixed pixels?

We have added the following to the caption of Figs. 9-12:

"In (a), gray colors indicate regions of partially-melted or mixed precipitation."

18. Figure 13: CFADs of (e) wind speed and (f) wind direction; this wind direction in (f) is the direction *from* which the wind is blowing, correct?

We rephrased part of the caption of Figs. 13-15 to read:

"Wind direction CFAD indicates the direction the wind is coming from and is plotted in polar coordinates where the angle represents the direction and each radius represents the altitude (0 km at the center)."

19. Figure 14: Perhaps just say "Same as Figure 13 except for..."

We intentionally repeat the captions for each figure to avoid confusion for the reader.

20. Table 1: How is change to mass per unit volume (IWC/LWC) determined? Is this IWC/LWC a ratio or are you indicating an increase to one or the other or both?

We are listing the change to mass per unit volume as either IWC in the case of frozen precipitation and LWC in the case of liquid precipitation. We have clarified the Table 1 caption as follows to be more clear about this:

"Table of microphysical processes and their associated change to mass per unit volume (IWC and LWC), and radar reflectivity. Radar reflectivity is a function of diameter and dielectric constant.The dielectric constant is larger for liquid water than for ice particles. "

We have also included an expanded version of the table here with 2 extra columns, change to particle diameter and change to dielectric constant to provide more context for the change to mass per unit volume. In the paper, we have included the "Change to particle diameter" column.

Process	Change to mass per unit	Change to radar	Change to particle	Change to dielectric

	volume (IWC and LWC)	reflectivity	diameter	constant
Riming	Increase	Can increase [1,3]	Can increase [1,3]	Slight increase[2]
Vapor Deposition	Increase	Usually increase[1]	Increase	Slight change[2]
Collision-Coalescence	Increase	Increase	Increase	*No change*
Condensation	Increase	Increase	Increase	*No change*
Aggregation	*No change*	Increase	Increase	Slight decrease[2]
Melting	*No change*	Increase	Usually decrease[1]	Increase
Evaporation	Decrease	Decrease	Decrease	*No change*
Sublimation	Decrease	Usually decrease[1]	Decrease	Slight change[2]
Freezing	*No change*	Decrease	Usually increase[1]	Decrease
Ice Fragmentation	*No change*	Decrease	Decrease	Slight increase[2]
Raindrop breakup	*No change*	Decrease	Decrease	*No change*

[1] Depends on ice crystal habit or habits of preexisting precipitation particle

[2] Changes in dielectric constant related to changes ice density are much smaller than those associated with change of phase

[3] Depends on degree of riming. For example, light riming will not change reflectivity or diameter much if at all.

Technical/typing corrections:

21. Abstract (line 7): ‘echo’ should be plural ‘echoes’

Done.

22. Line 60: I believe it should be hyphenated ‘surface-snow-producing’

Done.

23. Line 110: NWS acronym should be defined upon first use in Line 43

Done.

24. Line 199: ‘in terms joint’ should be ‘in terms of joint’?

Done.

25. Line 299: ground-based-scanning-radar-observed (I think would be the proper hyphenation here)

Done.

26. Line 306: snow form should be ‘snow to form’?

Done.

27. Line 337: I think this is supposed to ‘Fig. 15’ not ‘Fig. 15e’

Done.

28. Line 379: ‘is’ should be ‘are’

Done.

29. Line 380: ‘how a individual features’ should be ‘how a storm’s individual features’?

Done.