Atmospheric Chemistry and Physics - Manuscript ACP-2025-4517: “Snow microphysical processes in orographic turbulence revealed by cloud radar and in situ snowfall camera observations” by A. Kötsche , M. Maahn, V. Ettrichrätz and H. Kalesse-Los

1 Summary

This manuscript investigates the influence of a turbulent layer in the wake of the Gothic Mountain (in the Rockies) on the microphysical properties of ice crystals and snowflakes, by means of a vertically pointing K-band radar and a W-band profiler shooting at 40° elevation (in the direction of the K-band system). In addition, a high-resolution spectral lidar, a wind profiler and radiosoundings provide complementary meteorological variables.

Depending on the wind direction, the Gothic Mountain is generating a turbulent layer in its wake, and the present study analyzes its the influence on the microphysical properties of the cloud and precipitation particles, by contrasting the radar variables above and below the turbulent layer. It is concluded that (i) the turbulent layer promote aggregation (associated with strong increase in Z) and secondary ice production (SIP) via ice-ice collision (associated with decrease in the mean Doppler velocity), (ii) riming is frequent (related to the formation of supercooled liquid water droplets via turbulence), and (iii) a dry layer is frequent below the turbulent layer, sublimating the hydrometeors produced in the turbulent layer.

2 Recommendation

The authors take advantage of the nice instrumental set-up during the SAIL campaign, and propose an innovative approach to investigate and quantify the influence of turbulence on the properties of ice hydrometeors. They combine and cross-correlate the various data (radar moments, radar spectral variables, wind profiles from the wind profiler, liquid layer altitude from the lidar...) to pinpoint the dominant microphysical processes in this turbulent layer: aggregation, SIP and riming (not all together at the same time). The proposed approach and the obtained results are sound (although some aspects remain rather speculative), and they are relevant for the ACP readership. I do not have major concerns per se, but some suggestions of modifications or complements to improve the readability of the paper that may take some time to implement. I hence recommend to send the manuscript back to the authors for major revisions. A list of comments and questions is provided below.

3 General comments

1. A map showing the local topography is missing. The text refers several times (ex: p.10, l.212-213 ; p.13, l.261) to the shape of the Gothic Mountain, but the reader does not have

access to this information.

2. Section 3.3 is important but very dense and not easy to follow. I suggest to add a schematics of the main processes and radar variables in each quadrant, to help the reader understand the various configurations and signatures involved in this interpretation.

3. there are various thresholds or interpretation that appear somehow arbitrary. They should be better explained and justified. See specific comments below for more details.

4 Specific comments

1. P.1, l.23-24: wind shear can be in speed, in direction or both, but not only in both (as suggested by "and " between "speed" and "direction".

2. P.5, l.110: what method is used to estimate K_{dp} from Φ_{dp} and what is the final resolution of K_{dp}?

3. P.5, l.127: something is wrong or a definition is missing with "level2match"...

4. P.5, section 2.1.2: there is no mention of possible attenuation effects at W-band (due to atmospheric gases, liquid water and even ice particles). This should be (briefly) discussed as it may influence some of the interpretations.

5. P.6, Fig.2: the height above ground at which the beams of KZAR and LIMRAD94 cross should be indicated (as it is constant, right?).

6. P.7. l.150: the LIMRAD94 sampling volume is distant of 580 m of the KAZR sampling volume used to estimate the EDR, away from the mountain (i.e. downstream from KAZR)? Could this imply that the EDR may be lower at LIMRAD gate?

7. P.7, Eq.2: why using a weighted mean to estimate TLH?

8. P.7, l.156: Define AGL here as it is the first mention (it is done later). And mention the altitude of the top of Gothic Mountain.

9. P.8, l.174: how is this threshold value obtained? Please justify.

10. P.8, l.195: this sentence is a bit confusing: you explain in details in the introduction how turbulence can affect the ice crystals, and here state that the main changes are expected below this turbulent layer. Please elaborate.

11. P.9, l.211: please elaborate on how the shower can influence the wind profile.

12. P.10. l.217-218: "favorable for depositional growth": moisture/saturation is also a key variable for deposition...

13. P.120, l.219: are size and complexity enough to identify graupel?

14. P.10, l.221 + Fig.4: are all the measured particles displayed? There seems to be a limited number of particles for such long periods (1h)... If not, how were those shown selected?

15. P.10, l.226: any comments about the temperature inversion at the height of Gothic Mountain top (and associated drying)?

16. P.10, l.228: how do you diagnose the occurrence of a MPC?

17. P.11, Fig.5: the green solid line figures the dewpoint temperature, not the relative humidity. And what do the green dashed lines figure (the saturation mixing ratio)?
18. P.11, l.238: “mostly”: you have the distribution, you could be more quantitative (ex: x% of the values are below 1000m).
19. P.12, Fig.6: you should provide the number of data points behind the curves displayed in Fig.6. Or at least mention how many “events” occurred in the considered time period.
20. P.12, l.242.243: this “enhanced moisture convergence” is important but remains speculative. Any ways to strengthen this statement (high resolution NWP model runs for instance)?
21. P.12, l.246-247: you could compare the turbulent layer top to see if does match with LLB... Focusing on the regions of sharp negative EDR gradient above the TLH, for instance.
22. P.12, l.251: using the same threshold in occurrence as for the lower limit at 800m (around 0.4-0.5), you end up with an upper limit around 1800-2000 m...
23. P.17, l.298: particles produced by SIP would also be small with lower fall velocities. To be checked?
24. P.18, l.302: why no signal in Kdp? Small non-spherical ice splinters should increase Kdp, no?
25. P.18, l.307 + Fig.11: VISSS does not see well small particles (mentioned resolution about 60 microns), could this introduce biases?
26. P.18, l.319-320: “...be found in PSDs containing..”: I do not understand this sentence. How do you access the PSD?
27. P.18, l.217, 218: a decrease, not an decrease.
28. P.18, l.220-224: why would the MDV decrease for such aggregates (“An increase in Ze in combination with an decrease of MDV”).
29. P.18. l.327: visible
30. P.19, l.346-347: but an increased kinetic energy at the impact (so higher velocity) produces more splinters, no?
31. P.19, l.352: you need supersaturation with respect to liquid water for dendritic growth. Do the radiosounding indicate such supersaturation at those times/heights?
32. P.19, l.367-368: where is it explained how to use the complexity to identify ice crystal habits?
33. P.22, item 3: could the analysis of sZe strengthen the interpretation? To see if the increase in Ze is due to large (relatively) fast falling particles (i.e. the aggregates) or to many smaller ones...