Reviewer comments on 'Influence of low-level blocking and turbulence on the microphysics of a mixed-phase cloud in an inner-Alpine valley' by Fabiola Ramelli et al.

Second Response to Reviewer #2

We would like to thank the anonymous referee for his/her constructive and helpful feedback and suggestions on the manuscript. We incorporated the suggestions within the revised manuscript, which significantly improved the quality of the manuscript. In the following, we will address the reviewer's comments and present our responses and changes in the revised manuscript. Reviewer comments are reproduced in blue and the author responses are in black. All line numbers in the author's response refer to the revised manuscript.

General comments

1) *The authors have responded to all review comments satisfactorily. The only issue noted is the wording with respect to the description of what physical process is responsible for the shear layer, and what physical processes the shear layer is responsible for. There are also have some minor comments (mostly technical) which should also be possible to resolve rapidly without need for a further review.*

   Thank you for your helpful comments. Following your suggestions, we changed the description of the physical processes related to the shear layer (see responses to specific comments).

Specific (mostly technical) comments

2) *Line 17: Suggest you rephrase this to '.. in this particular case (since the majority of the precipitation evaporated when falling through the subsaturated layer above), ..'*
   Thank you for this comment. This was changed in the revised manuscript (page 1, line 18).

3) *Line 47: Suggest you rephrase this to 'In this study ..'*
   Thank you for this comment. This was changed in the revised manuscript (page 2, line 49).

4) *Line 63: Suggest you rephrase this to 'This work ..'*
   Thank you for this comment. This was changed in the revised manuscript (page 3, line 65).

5) *Line 96: Suggest you rephrase this to 'During the case study presented here, the large-scale flow was from the south-western direction..'*
   Thank you for this comment. This was changed in the revised manuscript (page 4, line 98-99).

6) *Line 121: The radar wind profiler also uses DBS to obtain the horizontal wind so is not vertically-pointing only. Typical operation may be 3-5 beams, and the elevation angle is usually between 66 and 76 degrees from horizontal.*
   Line 124: DBS is short for Doppler Beam Swinging.
   Line 125: I assume 'an elevation angle of 75 degrees from horizontal'?
   Thank you for pointing this out. Indeed, the wind profiler also operated in DBS mode. We added the following sentence, changed the definition of DBS and specified the elevation angle in the revised manuscript (page 5, line 127-128): *"Both wind profiler and wind lidar operated in Doppler Beam*

Swinging (DBS) mode with one vertical and four oblique beams at an elevation angle of 75° from horizontal."

7) *Line 138: Suggest you rephrase this to 'The observations presented in this case study were measured in a ..'.*
Thank you for this comment. This was changed in the revised manuscript (page 7, line 142).

8) *Line 166: You state the dielectric factor here |K|^2, which is 0.93 for liquid water drops at 0 C at X-band. However, it is not quite constant with radar frequency (0.934 at S-band, 0.881 at Ka-band, and 0.686 at W-band).*
Thank you for pointing this out. We specified the dielectric factor in the Ka-band radar frequency band in the revised manuscript (page 7, line 171-172): *"Liquid water has a higher refractive index (0.88 for Ka-band) than ice (0.197) (Houze Jr, 2014)."*

9) *Line 176: There is unlikely to be any liquid water droplets below the top liquid layer during the period when the low-level cloud was not present (17:45-18:40 UTC) as this would be visible in the lidar backscatter and depolarization fields during this time period. It is likely that there is a liquid layer at the top of the mid-level cloud throughout the time period but this is difficult to state definitively. There may be liquid water present within (rather than only at the top of) the mid-level cloud at other periods but there is no evidence for this. The LWP measurement values cannot easily be used to diagnose whether there are multiple layers either. I suggest removing the sentences starting on line 176.*
Thank you for this comment. Following your suggestion, we remove the sentence regarding the presence of liquid water below 3500 m. Furthermore, we rephrased the sentence about the LWP measured by the microwave radiometer (page 9, line 181-182): *"Indeed, the LWP measured by the microwave radiometer ranged between 20 g m^{-2} and 100 g m^{-2} during the measurement period (Fig. 4c), suggesting the presence of liquid water in some regions (likely at the top) of the mid-level cloud."*

10) *Figures 5 and 7. Suggest stating '.. horizontal wind speed and ..'*
Thank you for this comment. This was changed in the revised manuscript.

11) *Line 228: Suggest 'The observations presented here ..'*
Thank you for this comment. This was changed in the revised manuscript (page 14, line 233).

12) *Lines 266-267 and 384: The shear is very unlikely to be responsible for creating an ice supersaturated environment. The difference in relative humidity is likely to be due to there being two atmospheric layers with different air motion and the shear results from the difference in the wind speeds for these two atmospheric layers.*
Thank you for this comment. We agree that the difference in wind speed between the blocked layer and the cross-barrier flow aloft is responsible for the strong vertical wind shear. Enhanced turbulence within this region of strong vertical wind shear can lead to additional updrafts that help producing supersaturation and enhancing hydrometeor growth (e.g., through riming, aggregation). We changed the sentence in Lines 266-267 in the revised manuscript (page 16, line 270-273): *"The spatial coincidence between maximum radar reflectivity, shear layer and increase in LDR was also observed for other fallstreaks (Fig. 3d), suggesting that the enhanced turbulence at the interface between the*

blocked layer in the valley and the upper cross-barrier flow led to additional updrafts that helped produce supersaturation and enhance hydrometeor growth (e.g., through riming, aggregation).”
The sentence in line 384 now reads as follows (page 23, line 382-387): “*The interface between the blocked layer in the valley and the stronger cross-barrier flow aloft was characterized by a region of enhanced turbulence and vertical wind shear. We found that the region of strong vertical wind shear, the extent of the subsaturated layer within the blocked layer in the valley and as a consequence the amount of precipitation reaching the valley were determined by the strength of the downward propagating cross-barrier flow on the upstream mountain barrier B1 and the strength of the low-level blocking on the windward slope of the downstream mountain barrier B2 (Sect. 4.2).”*

13) *Line 327: The seeder-feeder mechanism was not seen to operate here at all, because there was so little precipitation falling through from above.*
Thank you for this comment. We removed this sentence.

14) *Line 328: Suggest 'We assume that in the case study presented here ..'*
Thank you for this comment. This was changed in the revised manuscript (page 20, line 332).

15) *Line 388: Suggest 'The observations presented here were obtained within a region ..'*
Thank you for this comment. This was changed in the revised manuscript (page 23, line 304).

16) *Line 397: The shear layer is not really a 'separate' layer, it describes the boundary between the in-valley blocked flow and the stronger cross-barrier flow aloft. I.e. enhanced turbulence is present due to there being a strong gradient (shear) in the vertical profile of the horizontal wind. Suggest '.. and the presence of enhanced turbulence in the region of strong vertical wind shear in the boundary between the blocked layer in the valley and the stronger cross-barrier flow aloft.*
Thank you for this comment. Following your suggestion, we rephrased the sentence as follows (page 24, line 403-405): *“The wind observations indicated the transition from a blocked to an unblocked low-level flow during the observational period and the presence of enhanced turbulence in the region of strong vertical wind shear in the boundary between the blocked layer in the valley and the stronger cross-barrier flow aloft.”*
In addition, we also changed the sentence in the abstract accordingly (page 1, line 7-8): “*During this event, the boundary layer was characterized by a blocked low-level flow and enhanced turbulence in the region of strong vertical wind shear at the boundary between the blocked layer in the valley and the stronger cross-barrier flow aloft”.*

17) *Line 411: This statement is the wrong way round. The sublimation layer arises because the upper cross-barrier flow and lower in-valley flow have different humidities, together with the presence of shear because the horizontal winds also differ.*
Line 412: As in the statement above, precipitation reaches the surface when the subsaturated layer is shallower, not because the shear layer extends to lower altitudes.
Thank you for these comments. We agree that the subsaturated layer is associated with the different humidities of the blocked layer and the upper cross-barrier flow and that the amount of precipitation in the valley was determined by the vertical extent of the subsaturated layer. We changed the paragraph as follows (page 24, line 416-422): *“The region of enhanced turbulence at the boundary between the blocked layer in the valley and the cross-barrier flow aloft was determined by a complex*

interplay of upstream and downstream effects. More specifically, the region of strong vertical wind shear was observed to lower as stronger cross-barrier flow propagated downward and the low-level blocking weakened on the windward slope of the downstream mountain barrier. Due to the lower humidity of the blocked layer in the valley, the majority of the hydrometeors that formed in the mid-level cloud sublimated when falling through the subsaturated layer. Accordingly, precipitation was only observed in the valley when the subsaturated layer was shallowest."

18) *Line 416: It is unlikely that it is the altitude of the shear layer that is the major physical reason responsible, rather it is the altitude at which the subsaturated layer begins. The correlation you suggest arises because the altitude of the shear layer corresponds to the altitude of the top of the subsaturated layer.*

Thank you for this comment. Following your suggestion, we changed the sentence in the revised manuscript (page 24, line 422-424): *"Thus, we propose that the amount of precipitation observed in a mountain valley is influenced by several factors such as (1) the strength of the cross-barrier flow and low-level blocking, (2) the vertical extent of the subsaturated layer and (3) the thermodynamic state of the boundary layer."*

19) *Line 424: Do you mean a 'dry layer aloft' here? It's unlikely to be a 'boundary layer aloft'.*

Thank you for this comment. We changed it to 'due to the subsaturated layer aloft' in the revised manuscript (page 24, line 431).