Dear Editor,

We are very grateful to the referee for his/her appropriate and constructive suggestions and for his/her proposed corrections to improve the paper. We have addressed the issues raised and have modified the paper accordingly. If you and the referee agree on that, we are also ready to submit a revised version of the paper where all these changes have been introduced. We believe that, thanks to these precious inputs, the manuscript has now sensitively improved. Below is a summary of the changes we performed and our responses to the referee's comments and recommendations.

Summary of the changes
(in black is the original comments of the referee and in red our responses)

Responses to referee 1

My recommendation is to accept the manuscript after minor revision.

Specific Comments
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The measurements discussed in this study were collected during the COPS field campaign. This is of course worth mentioning in the text. However, the manuscript deals with hydrometeors observations of a stratus cloud. Therefore, it is misleading to focus the reader on "convective and orographically induced precipitation" in the title and at beginning of the abstract.

We have modified the title and the abstract as proposed by the referee. Specifically, we removed the explicit mention to the COPS field campaign from the title, which now reads: "Lidar and Radar Measurements of the melting layer: observations of dark and bright band phenomena". Reference to COPS has been also removed from the first sentence of the abstract, which now reads: "Multi-wavelength lidar measurements in the melting layer revealing the presence of the dark and bright bands were performed by the University of BASILicata Raman lidar system (*BASIL)*." First mention to COPS in the abstract now appears in the third sentence.

The readability would benefit from separating the description of what was observed and the interpretation of the observations; presently there are several repetitions which is confusing.

We have prepared a revised version of the paper where the observations and their interpretation are clearly separated. Furthermore, the revised version of the paper has been also improved by removing repetitions which generated confusion.

The figures should be more focused. Some figures can be omitted, some should be merged. See below for details.

Figures for the revised version of the paper have been improved following the suggestions and indications provided by the referee. Specifically, some figures have been removed (former figures 8 and 13) and some have been merged (former figures 9 and 11, now figure 8, now including panels (a) and (b)).

I suggest adding a table with instrument acronyms and main characteristics (wavelength, resolution, power, pulse repetition frequency etc.).

As suggested by the referee, in the revised version of the paper we introduced a table (table 1) with the instruments' acronyms (when available) and their main characteristics, namely band, frequency, wavelength, power, pulse repetition frequency, range and time resolution, to be introduced in the revised version of the paper. In the text of section 2 the following sentence has been also inserted to introduce the table: “The main specifications of the lidar and the radars are provided in Table 1.”

Please check the numbering of the figures; the numbers are presently not in order in the text.

The numbering of the figures was carefully checked and any incongruence in the text concerning figure numbering and order has been removed.

Page 30951, line 5: Please write “Simultaneously with the lidar observations, radar measurements were performed from the same site” … or similar.

In the modified version of the paper the sentence has been modified in the way proposed by the referee.

Page 30951, line 5: What do you mean with “among others”? I suggest that you delete references to dates in the abstract which are anyway not discussed in the present manuscript.

As suggested by the referee, we removed from the abstract any reference to dates which are not discussed in the present manuscript.

Page 30952, line 2: Please change to “snowflakes change into raindrops” or similar.

We decided to keep the wording “snowflakes collapse into raindrops” because this is the wording used by Sassen et al. (2005) in their reference paper on this topic. As in the paper by Sassen et al. (2005), here we refer to the structural collapse of melted snowflakes, taking place when water coatings accumulate on the ice crystal branches and inter-branch cavities of the shrinking particles, and the subsequent collapse which happens when the surface tension of the accumulating liquid overwhelms the structural strength of weakened crystal branches. This is now more clearly specified in the text of the paper (see section 1 – Introduction, section 3.1 - Lidar and radar measurements, and section 3.3 - 2DC Probe, rain radar and disdrometer measurements - of the revised version of the paper).

Page 30952, line 5ff: How about other radar bands, especially C and X band?

The radar bright band is visible also in the C and X band. In the modified version of the paper the corresponding sentence has been modified as follows: “While the radar bright band is ubiquitous in the S, L, C and X band (Smith and Illingworth, 1998; Matrosov *et al*., 2005), only intermittent evidence is found in the K and W bands (Sannen *et al*., 2005), because of the dominance in these latter bands of non-Rayleigh scattering effects.” The new references to Smith and Illingworth (1998) and to Matrosov *et al*. (2005) are for the C band and X band radar bright band, respectively.

Page 30952, line 14: Please change to “partly melted” or similar.

In the revised version of the paper the sentence was modified in the way proposed by the referee.

Page 30952, line 20: Please explain what you mean by “reaches its plateau”.

Here we mean that the radar Doppler velocity reaches a maximum - almost constant - value. A more proper wording has been used in this sentence for the revised version of the paper. Now the sentence reads: “The lidar dark-band minimum occurs in the melting region, just below (approx.

100-200 m) the radar bright band peak, close to where radar Doppler velocity reaches maximum values.”.

Page 30953, section 2: I think it would be worth noting that there have been four additional COPS supersites with similar instrumentation.

In the revised version of the paper we have now clearly specified the presence of four additional COPS supersites, with similar instrumentation. Specifically, the following sentence has been introduced: “As part of COPS, a transect of five Supersites, equipped with advanced in-situ and remote sensing instrumentation, was set up from the Vosges Mountains (supersite V) to the lee side of the Black Forest close to Stuttgart (supersite S), crossing the Rhine valley (supersite R), the Hornisgrinde Mountain (supersite H) and the Murg Valley (supersite M).”

Page 30953, line 14: Here references to other publications using BASIL measurements during COPS could be added.

As suggested by the referee, in the revised version of the paper we introduced references to six other publications which are using BASIL measurements during COPS. Specifically, we cited the papers by Behrendt *et al*. (2011), Chaboureau *et al*. (2011), Bennett *et al*. (2011), Corsmeier *et al*. (2011), Kiemle *et al*. (2011 and Di Girolamo *et al.* (2012). Title of these papers are in the reference list below.

Page 30954, line 3: Please write “During COPS, BASIL was collocated with: : :” or similar.

In the revised version of the paper the sentence was modified in the way proposed by the referee.

Page 30955: Why do you focus on the case of 23 July 2007? Are there meteorological reasons? Can you tell whether this case is special or common?

We focused on 23 July 2007 because this is an interesting case study both in terms of the encountered meteorological conditions and in terms of the available instruments. From a meteorological point of view, on this day we have the presence of midlevel stratiform clouds reaching the site and producing stratiform rainfall events at the time of the lidar and radar measurements. These conditions are more favourable for the observation of radar and lidar melting-layer phenomena than those found in the presence of strong thunderstorms, as in fact in this latter case radar and lidar signals may be overwhelmed by the strong hydrometeors echoes. Dark/bright lidar bands are observed in the presence of relatively light precipitation events, as those present in this specific day, where the signal throughout the melting layer is not significantly attenuated by the rain droplets.
In terms of available instruments, on this day the full “ensemble” of ground-based remote sensing and in-situ instruments were operational, as well as it was the ATR42 from Service des Avions Français Instrumentés pout la Recherche en Environnement (SAFIRE), making a dedicated flight with several overpasses on the instrument site. We wish to recall that the SAFIRE-ATR42 was hosting a two-dimensional cloud (2DC) probe capable to provide two-dimensional images of cloud particles and hydrometeors and measurements of their size distributions. These aspects are now more explicitly specified in section 3.1 of the revised version of the paper. Specifically, for what concerns the meteorological conditions, the following sentences have been introduced: “Dark/bright lidar bands are observed in the presence of relatively light precipitation events, as those present in this specific day, where the signal throughout the melting layer is not significantly attenuated by the rain droplets. The present measurements were carried out in very light precipitation conditions (rainfall rate was 0.02-0.05 mm h^{-1} as measured by the disdrometer located in Besenfeld).”

Page 30955, line 14: Please write ": : : from clouds above the lidar and radar site".

In the revised version of the paper the sentence was modified in the way proposed by the referee.

Page 30955, line 22ff: Here a reference to the temperature profile (Fig. 7) should be added. Or you show the temperature profile also together with the time-height plots of the lidar and radar data.

As suggested by the referee, in the revised version of the paper a sentence was introduced here to refer to the temperature profile in Fig. 7. Specifically, the following sentence was introduced: "The temperature profile from this radiosonde is illustrated in figure 7."

Page 30955, line 24: Please quantify "smaller".

As requested by the referee, in the revised version of the paper we have quantified what we mean with the adjective "smaller". In this respect, the following sentence was introduced: "More specifically, values of the particle backscatter ratio at this altitude are ~ 2 times smaller that those found few hundred meters below in the melting layer (weak lidar bright band) and up to a factor of 10 smaller than those found higher up (strong lidar bright band)."

Page 30955, line 26: Please delete "but the lidar dark band presumably continues…" This is pure speculation.

As suggested by the referee, in the revised version of the paper this portion of sentence has been removed.

Page 30955, last paragraph of section 3.1: I suggest that you delete this paragraph and the related figure 8. The determination of fall velocities from such fall streaks seen in vertical data is prone to errors because of horizontal heterogeneities in the structure of the precipitation. The Doppler radar data provide measurements with much higher accuracy.

As proposed by the referee, in the revised version of the paper this paragraph and the related figure (former figure 8) have been removed.

Page 30955, line 28: Please add brackets around the reference.

Here we believe the referee refers to page 30958, line 28. In the revised version of the paper brackets around the reference were added as proposed by the referee.

Page 30959, line 1: Please rewrite "myriad" and omit "actually".

In the revised version of the paper this sentence was improved in the way suggested by the referee, but also in coherence with the requests from the other referee.

Page 30959, line 5: Is the simulation for a radius of 1.5 mm or independent of the particle radius? Please clarify.

The simulation was performed for a particle radius of 1.5 mm. Namely, we considered a log-normal distribution with parameters taken from Willis [1984, number concentration $N = 10^3$ m^{-3}, mode radius r_s = 1.5 mm, width σ = 1.7]. However, similar results are found also for smaller and larger radii. An extensive study was performed in this direction by Griaznov *et al*. (2004). This aspect is now clearly specified in the revised version of the paper, where the following sentence was introduced: “As mentioned above the present results are for a mode radius of 1.5 mm, but similar results are also found for smaller and larger radii. An extensive study in this direction was performed by Griaznov *et al.* (2004).” Additionally, higher up in the text we introduced information on the considered particle size distribution. The following sentence was introduced: “In the present computations we considered a log-normal distribution with parameters taken from Willis [1984, number concentration N = 10^3 m^{-3}, mode radius r_s = 1.5 mm, width σ = 1.7].”

Page 30959, line 19: Especially the measured profile of the particle backscatter coefficient at 355 nm (green line in the middle panel of Fig. 7) looks not quite similar to Fig. 9 but the particle backscatter coefficient at 1064 nm does. Can you explain this? I strongly recommend that you extend the discussion of the differences seen for the different laser wavelengths. It is a specialty of this study that observations are available at three lidar wavelengths simultaneously (as pointed out correctly, e.g., in the summary).

The particle backscatter maximum which is observed in the middle panel of figure 7, now panel (c), is the lidar bright band phenomenon owing its existence to the increasingly strong snowflake backscattering with height coupled with the overwhelming attenuation rate in the snowfall surrounding the melting level (0^0C); this is the bright band phenomenon described by Sassen et al. (2005). This type of bright band is often present in lidar echoes from the melting layer, but is different from the lower intensity bright band phenomenon, associated with the partial melting of the snowflake, which is modelled in figure 9 and is observed in the particle backscatter coefficient profile measurements lower down in the melting layer. The particle backscatter maximum characterizing the upper bright band phenomenon may appear at different altitudes depending on the wavelength and energy of the laser beam, and consequently its overwhelming attenuation rate in the snowfall. In our case, the maximum in the particle backscatter coefficient at 355 nm (formerly green line in the middle panel of figure 7, now blue line following the comment of the referee for figure 7) appears at a higher altitude than the one observed at 532 and 1064 in this same figure (now green and red line, respectively), and is actually out of scale in this figure. This is now clearly specified in the text and, following the suggestion of the referee to extend the discussion to the differences seen at the different wavelengths, the following sentence has been introduced: “It is to be noticed that this bright band phenomenon may appear at different altitudes depending on the wavelength and energy of the laser beam which gets attenuated by the snow. In the present case, the maximum in the particle backscatter coefficient at 355 nm (blue line in panel (c)) appears at a higher altitude than the one observed at 532 and 1064 (red and green line in panel (c)) and is actually out of scale in this figure.”

Page 30960, section 3.3: This section is quite lengthy and the number of figures not in proportion. Please focus on what is relevant for the interpretation of the bright and dark band phenomena. Please introduce all measurements first (both in-situ and remote sensing data) and discuss the interpretation afterwards.

As requested by the referee, in the revised version of the paper we have shortened this section focusing on those aspects that are more relevant for the interpretation of the melting layer processes and the bright and dark band phenomena, and we have removed one figure (formerly figure 13). Now all measurements are introduced first and the interpretation is discussed afterwards in the text.

Page 30961, line 1: What was the direction between location of the aircraft and remote sensing observations? It is probably important to use information about the orography below the aircraft for the joint interpretation of the data.

The aircraft was moving along the Rhine Valley in the SouthEast-NorthWest direction (from NorthWest to SouthEast). Data were collected during the descent phase of the aircraft, just before landing. The landing point (Baden Airport) is located approximately 14 km North of Supersite R, where the lidar and radar systems considered in this paper are located. The direction between location of the aircraft and remote sensing observations is approximately South-North at the landing point, being more SSE-NNW during the landing phase. Additionally, the aircraft - remote sensing site direction was parallel to the mountain ridges of the black forest. Thus, orographic effects on the in-situ aircraft measurements reported in this paper and on the join interpretation of the data should be marginal as both the ground site and aircraft were located over the same flat terrain with same weather situation undergone. This is now clearly specified in the text, where the following sentence was introduced: "The aircraft was moving along the Rhine Valley in the SouthEast-NorthWest direction and the aircraft - remote sensing site direction was parallel to the mountain ridges of the black forest. Orographic effects should therefore be marginal as both the ground site and aircraft were located over the same flat terrain with same weather situation undergone."

Page 30963, first paragraph; Fig. 18: Because the disdrometer data are 2 h after the lidar observations, their discussion should be omitted here. One cannot expect any support in the interpretation of the bright and dark band phenomena.

The referee is indeed right in considering the disdrometer data collected 2 h after the lidar observations of limited support in the interpretation of the bright and dark band phenomena. As an alternative piece of information, we decided to consider the disdrometer data simultaneous to the lidar/radar data from Besenfeld, 27 km East of the lidar/radar site. So former figure 18, now figure 16, is now including the disdrometer data from Besenfeld. In this respect, it is to be pointed out that the space lag between the Supersite R and Besenfeld (27 km) has only minor effects on the comparison between these measurements in case of stratiform precipitation, as in the present case study. This aspect is also clearly specified in the text, where the following sentence is present: "With respect to this aspect, we wish to specify that figures 2 and 3 reveal a very limited variability of the radar reflectivity profiles at 1.29 and 35.5 GHz in the two hour period (14:30-16:30 UTC) following the end of the lidar measurements, indicating a lack of small-scale meteorological variability during this period."

Page 30970, Fig. 1: I suggest that you use gray for marking the lidar dark band because this color is not used for the data. Altitudes above 6000 m or so are not relevant because the lidar beam does not go much beyond the cloud bottom anyway; I suggest that you restrict the plot to this height.

In the revised version of the paper figure 1 was modified in the way suggested by the referee, with the lidar dark band marked in gray and the altitude range restricted to 6000 m.

Page 30970 ff, Fig. 1 to 6: Please use the same height and time scale (not necessarily range) for all these plots so that they are better comparable. I suggest that you join all these data in one figure with different panels.

As suggested by the referee, in the revised version of the paper the same height scale was used for all figures. We have also tried to consider the same time scale for all figures (1 through 6) and merge all of them in a single figure. However, we believe that the final result is not very encouraging. In fact, some instruments (primary the lidar system, but also the cloud radars) did not operate throughout the entire measurement period and the use the same time scale for all figures impose to limit the time scale of all instruments to the time interval of the instrument with the shortest operation duration (1.5 h in the case of the lidar system). Additionally, the use of the same time scale for all figures is difficult to realize because of the very limited overlap between the operation time intervals of the lidar and the cloud radar, which has negative effects on the final layout of the figure. For the above motivations, we are inclined to use the same height scale for all figures, but consider different time scales for them. We believe the referee will understand this motivation. We also believe that the use of the same time scale is a suggestion from the referee side; however, if this is mandatory request we will certainly do it, but we really have the impression that this negatively affects the presentation layout of these figures.

Page 30976, Fig. 7: The text in this figure is difficult to read. It is sufficient to mention date and time in the figure caption, I think. I suggest that you mark bright and dark bands without labels and omit the distances. The colors used for the lidar backscatter coefficients could follow the wavelengths (red for 1064 nm, green for 532 nm, blue for 355 nm).

As requested by the referee, in the revised version of the paper we have modified and improved the layout of figure 7 to make it easier to read. Specifically, information on date and time for each instrument has been moved in the figure caption. Bright and dark bands have been marked omitting the distances. Additionally, the colours used for the lidar backscattering coefficients now follow the wavelengths (red for 1064 nm, green for 532 nm, blue for 355 nm). Finally, all figure panels have now been labelled (a through e).

Page 30978 & 30980, Fig. 7 & 11: These two figures should be merged.

Here we believe that the referee refers to figure 9 and not 7 as in fact page 30078 contains figure 9 and not figure 7. As suggested by the referee, in the revised version of the paper figure 9 and 11 have been merged in a single figure, now figure 8, which includes all model results, with results from the concentric sphere model in the left panel (panel a) and results from the eccentric sphere model in the right panel (panel b).

Page 30982 to 30985, Fig. 13 to 16: Please focus on what is relevant for the topic (see above). Please add in the caption that these are aircraft in-situ data.

As requested by the referee, in the attempt to better focus on what is more relevant for the topic (2DC probe measurements of the two-dimensional images of the melting hydrometeors and their size distribution), in the revised version of the paper we removed figure 13 and we provided a briefer and more compelling description of the measurements and their microphysical implications. We also specified in the captions of the figures (former figures 14, 15 and 16, now figures 10, 11 and 12) that these include aircraft in-situ data.

References

Behrendt, A., S. Pal, F. Aoshima, M. Bender, A. Blyth, U. Corsmeier, J. Cuesta, G. Dick, M. Dorninger, C. Flamant, P. Di Girolamo, T. Gorgas, Y. Huang, N. Kalthoff, S. Khodayar, H. Mannstein, V. Wulfmeyer Observation of Convection Initiation Processes with a Suite of State-of-the-Art Research Instruments during COPS IOP8b, *Quarterly Journal of the Royal Meteorological Society*, 137: 81–100. doi: 10.1002/qj.758, 2011.

Bennett, L. J., A. M. Blyth, R. R. Burton, A. Gadian, T. M. Weckwerth, A. Behrendt, P. Di Girolamo, M. Dorninger, S.-J. Lock, V. H. Smith and S. D. Mobbs, Initiation of convection over the Black Forest mountains during COPS IOP15a, *Quarterly Journal of the Royal Meteorological Society*, 137: 176–189. doi: 10.1002/qj.760, 2011.

Chaboureau, J-P., E. Richard, J-P. Pinty, C. Flamant, P. Di Girolamo, and C. Kiemle, A. Behrendt, H. Chepfer, M. Chiriaco, and V. Wulfmeyer, Long-range transport of Saharan dust and its impact on precipitation forecast over western Europe, *Quarterly Journal of the Royal Meteorological Society*, 137: 236–251. doi: 10.1002/qj.719, 2011.

Corsmeier, U., Kalthoff N., Barthlott C., Behrendt A., Di Girolamo P., Dorninger M., Handwerker J., Kottmeier C., Mahlke H., Mobbs S., Smith V., Vaughan G., Wickert J., Wulfmeyer V., Driving processes for deep convection over complex terrain: A multi-scale analysis of observations from COPS-IOP9c, *Quarterly Journal of the Royal Meteorological Society*, 137: 137–155. doi: 10.1002/qj.754, 2011.

Di Girolamo, P., D. Summa, R. Bhawar, T. Di Iorio, M. Cacciani, I. Veselovskii, O. Dubovik, and A. Kolgotin, Raman lidar observations of a Saharan dust outbreak event: characterization of the dust optical properties and determination of particle size and microphysical parameters, *Atmospheric Environment*, Vol. 50, 66-78, 2012, 10.1016/j.atmosenv.2011.12.061.

Griaznov, V, I. Veselovskii, P. Di Girolamo, B. Demoz, D. N. Whiteman, Numerical Simulation of Light Backscattering by Spheres With Off-Center Inclusion. Application to the Lidar Case, Applied Optics, Vol. 43, Issue 29, 5512-5522, Ed: *Optical Society of America*, 10 October 2004, Washington (USA), doi: 10.1364/AO.43.005512.

Kiemle, C., M. Wirth, A. Fix, S. Rahm, U. Corsmeier and P. Di Girolamo, Latent Heat Fluxes over Complex Terrain from Airborne Water Vapour and Wind Lidars, *Quarterly Journal of the Royal Meteorological Society*, 137: 204–223. doi: 10.1002/qj.785, 2011.

Matrosov, S. Y., D. E. Kingsmill, B. E. Martner, F. M. Ralph, The Utility of X-Band Polarimetric Radar for Quantitative Estimates of Rainfall Parameters. *J. Hydrometeor*, **6**, 248–262, 2005.

Sassen, K., J. R. Campbell, J. Zhu, P. Kollias, M. Shupe, C. Williams, Lidar and triple-wavelength Doppler radar measurements of the melting layer: A revised model for dark and bright band phenomena, *J. Appl. Met.*, 44, 301–312, 2005.

Smith, T. J. , and A. J. Illingworth, Radar estimates **of** rainfall rates at the ground in bright band and non-bright band events, Q. J. R. Meteorol. Soc., 124, 2417-2434, 1998.

Willis, P. T., Functional fits of observed drop size distributions and parameterization of rain, J. Atmos. Sci., 41, 1648– 1661, 1984.