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 2

The authors strongly agree with referee # 2 that the paper does not provide a different interpretation with respect to the one provided by Sassen et al. (2005). On the contrary, the observations illustrated and discussed in the present paper confirm the model interpretation by Sassen et al. (2005), proving additional experimental evidence to that. There was no plan from the authors to disregard, confute or provide a different the interpretation with respect to the one provided by Sassen et al. (2005), which is extremely accurate and appropriate. We are sorry we gave this wrong message in the previous version of the paper. We have rewritten the paper (especially the introduction, the results section, the model section and the interpretation section) with the specific goal to make this message very clear.
It is now clearly and explicitly mentioned several times in the text that we attribute the lidar and radar dark and bright bands to same mechanisms suggested by Sassen et al. (2005) and that we recognize the uniqueness and enormous validity of the physical/conceptual model of the melting layer and EM scattering presented by Sassen et al. (2005).
Measurements and model results reported in Sassen's papers, and his physical/conceptual model interpretation of phenomena taking place in the melting layer, are now explicitly referred to and 42 additional citations to Sassen's papers (Sassen *et al*., 2005; Sassen *et al*., 2003; Sassen and Chen, 1995; Sassen, 1977a; Sassen, 1977b, Sassen, 1975) have been introduced throughout the paper.

This paper summarizes multi-wavelength active remote sensing observations, in-situ measurements and theoretical light-scattering model calculations for the melting layer in precipitating clouds. The transition between melting snowflakes and liquid water droplets has long been studied and conceptualized for the anomalous bright/dark band phenomena observed from radar/lidar datasets.
The authors present a detailed and well-written study of their field observations and modeling calculations. In this review, I'm returning a copy of the paper that includes my comments and some basic technical editing/thoughts. For the most part, the paper is clear, coherent and figures are appropriate for publication.
That said, I must be critical in this review for these primary reasons.
1.) What is the hypothesis of this paper?
2.) How does this paper improve upon the model described by Sassen et al. (2005)?
Because I cannot clearly answer these questions, and I do not believe that the authors make a compelling case that they have them answered either, I cannot recommend this paper for publication in its present form.
With respect to point 1, there is discussion and context of previous dark/bright band observations, thus establishing some relevance for these new observations. However, aside from the description of new/ancillary measurements being available, its not established where/how this paper fits within our existing understanding or where improvements to any physical model of the melting layer are being manifested.

As mentioned above, the measurements and the model results illustrated in the present paper confirm and support the physical model of the melting layer elaborated by Sassen et al. (2005) and are not meant to provide an improvement to this physical model. A different physical interpretation with respect to the one provided by Sassen et al. (2005) is also not needed to give scientific dignity to the paper. Measurements and model results in this paper well fit within the existing understanding of the melting layer processes primarily elaborated by Sassen and his co-workers. This is now clearly specified and stated in the text of the revised version of the paper from the very beginning, where in the abstract the following sentence has been introduced: "Measurements and model results are found to confirm and support the conceptual microphysical/scattering model elaborated by Sassen *et al.* (2005)." The goal of our paper is to provide additional experimental and model evidence of the observed phenomena that confirm the physical model representation of the melting layer conceived and reported by Sassen *et al.* (2005). The text of the paper has been substantially modified to properly highlight this aspect and put in the right light the essential work done by Sassen and his co-authors.

Modeling and in-situ observations aren't described in the introduction, nor how they enhance the motivation.

Modeling and in-situ observations are now described in the introduction. Specifically, in the introduction of the revised version of the paper we are now providing a brief description of both the two-layered hydrometeor representation, of the concentric/eccentric sphere Lorentz-Mie scattering models and of the melting model. In the introduction we are now also describing the in-situ observations provided by the two-dimensional cloud (2 DC) probe onboard the ATR 42 SAFIRE. In the introduction we are now also describing how the illustrated model data and in-situ observations support the motivation of the paper, i.e. how these confirm the physical/conceptual model provided by Sassen et al. (2005) and provide additional experimental/model evidence to it.
More detail on the the two-layered hydrometeor representation, of the concentric/eccentric sphere Lorentz-Mie scattering models and of the melting model are now also provided in section 3.2 (model simulations). Specifically, we have now specified the size distribution type (log-normal) and its parameters (number concentration, mode radius and width) which has been considered for the simulations and the refractive index selections. Concerning the melting model, we are now also specifying what are the assumptions behind it, i.e.: a) melting frozen drops are spherical and evenly covered with melted water, b) precipitation rate is constant and steady at any level, c) lapse rate of temperature is constant (8 ^{0}C km^{-1} resulting from the radiosonde data on the day of the measurements), d) the atmosphere is saturated with water vapour, e) mass is conserved through the melting stages, f) the heat budget equation proposed by Wexler (1955) is considered, and g) that coalescence and breakup are completely ignored.

The objectives of the study are weakly motivated.

We believe that in the revised version of the paper the objectives of the study are now much more clearly specified. The main objective is represented by the provision of measurements (remote sensing and in-situ) and model results that provide additional experimental/model evidence that support the microphysical/scattering model interpretation of the melting layer phenomena conceived and provided by Sassen et al. (2005). Results illustrated and discussed in this paper represent an independent set of measurements, similar to those reported by Sassen et al., 2005, (lidar + three-wavelength radar reflectivity and Doppler velocity), but in some extent complementary (three-wavelength lidar backscatter + lidar and radar depolarization + in-situ measurements), which support and confirm the physical/conceptual model of the melting layer and the interpretation of the scattering phenomena (dark/bright bands) involving melting hydrometeors

conceived by Sassen et al. (2005). Measurements concentrate on a case study characterized by a reduced precipitation intensity, revealing the presence of the full repertoire of the dark/bright band phenomena in lidar (backscatter/depolarization) and radar (reflectivity, Doppler velocity, depolarization) measurements. Lidar measurements highlight the presence of a lidar dark band few hundred meters below the melting level and of two backscatter maxima (lidar bright bands), one more marked located in the proximity of the melting level and one weaker located few hundred meters below the dark band.
In specifying the original new aspects of this paper, we wish to point out that 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, 27 km East of the measurement site, whose measurements have now been introduced in the paper). Such light precipitation conditions certainly represent an interesting case study that integrates the measurement conditions reported by Sassen et al. (2005), who reported measurements in the presence of slightly higher intensity rain showers (0.07-0.09 mm h^{-1}). Additionally, this dataset allows to reveal the presence of the lidar dark and bright bands at different wavelengths and specifically highlights that, in such light precipitation conditions, the strong lidar bright band usually observed in the proximity of the melting level displays a wavelength behaviour with a more marked presence at 532 and 1064 nm than at 355 nm because of the more pronounced attenuation of the laser beam through the snow at the formed wavelengths. Furthermore, the particle backscatter profiles display a very limited wavelength dependence of the dark and weak bright band features, not unexpectedly indicating that the sounded particles are much larger than the sounding wavelength and behave as geometric optics scatters.
Remote sensing measurements are supported by in-situ data from a two-dimensional cloud (2DC) probe hosted on-board the ATR42 SAFIRE, providing two-dimensional images of the melting hydrometeors and measurements of their size distribution, which provide further experimental evidence that support the microphysical/scattering model interpretation of the melting layer phenomena conceived by Sassen et al. (2005).

With respect to point 2, the authors have shown no evidence that disagrees with the conceptual model of the melting layer and EM scattering presented by Sassen et al. (2005) . They do provide new and compelling measurements for lidar/radar depolarization and in-situ profiling of droplet size within the melting layer. However, the former reinforce Ken's model, and the latter are artifacts of precipitation efficiencies that Ken argued in his conclusions would be relative to the inherent dynamics causing precipitation for a given event.

We strongly agree with the referee that the present measurements are in clear agreement with the conceptual model of the melting layer and EM scattering presented by Sassen et al. (2005). More specifically, we agree with the referee that the new measurements of lidar/radar depolarization within the melting layer presented in this paper reinforce Sassen's model, as in fact low values of lidar depolarization at the heights of the lidar dark and bright bands imply, as conjectured by Sassen *et al*. (2005), that sounded precipitating particles are severely melted snowflakes which have collapsed into mixed phase particles, having a more regular shape, which justifies the small lidar depolarization values. This is now clearly specified in the text of the revised version of the paper, where the sentence has been modified as follows: "The presence of large depolarization values high in the melting layer testifies the predominant presence of irregular shape snowflakes (Sassen, 1975; Sassen, 1977b), while the low values at the heights of the lidar dark band and lower-height bright band confirm the microphysical and scattering conceptual model proposed by Sassen *et al.* (2005), and suggests that sounded precipitating particles are severely melted snowflakes which have collapsed into mixed phase particles, having a more regular shape". We also point out that: "Similar low values (3 %) of lidar depolarization were also reported at the height of the lidar dark band by Sassen and Chen (1995). Additionally, as highlighted by Sassen et al. (2005), we now also clearly

specify in the text that large depolarization values in the microwave domain indicate the presence of wetted snowflakes just before they collapse into raindrops.
With respect to the comment from the referee that in-situ profiling of droplet size : "…are artifacts of precipitation efficiencies that Ken argued in his conclusions would be relative to the inherent dynamics causing precipitation for a given event", we certainly agree that the mechanisms altering precipitation efficiencies may produce artifact in the in-situ droplet size measurements, which can ultimately affect the measurements, as was clearly argued by Sassen in his 2005's paper. Profiles of in-situ droplet size are illustrated here again in support of the physical/conceptual model by Sassen et al. (2005), as in fact the different phases of the melting snowflakes can be inferred from these data, as well as the occurrence of coalescence of rain drops. Concerning this aspect we wish to recall that the occurrence of coalescence was also envisaged by Sassen et al. (2005) to be potentially responsible of noticeable effects on the radar/lidar signals. In this respect, Sassen et al. (2005) properly specify that any radar/lidar bright/dark band theory strongly relying on particle aggregation/coalescence or breakup of snowflakes and raindrops is not likely to be universally successful.

In the introduction, Sassen et al. (2005) is described as a similarly comprehensive field study of dark/bright band phenomenon. However, there is more that goes to this paper, including a conceptual characterization of snowflake/raindrop transition and EM scattering effects at visible and microwave wavelengths. The paper builds off of and is mindful of previous attempts toward developing such a model (Sassen and Chen, 1995; Roy and Bissonnette, 2001; Lhermitte, 2002). The context of the current paper is presently ambivalent to this chronology and model linearge. Reading this paper, you wouldn't know that a model for the melting layer really existed. Most frustrating of all, however, is that the first author himself contributed greatly to this work (Di Girolamo et al., 2003)!

Once again, we recognize the extraordinary merit and validity of the research work carried out by Sassen et al. (2005), and its enormous importance in the definition of a conceptual characterization of snowflake/raindrop transition and of a microphysical/scattering model interpretation of the melting layer phenomena. There was no intention to disregard this work, as well as previous research efforts by Sassen and Chen (1995), Roy and Bissonnette (2001) and Lhermitte (2002), which have put the basis for the comprehensive measurements and model paper by Sassen et al. (2005). We apologise if we gave this ambivalent impression to the reader in the previous version of the paper. We believe that in the revised version of our paper this is no longer true (see more comments on this issue in the next point).

As written, the reader would believe that there was no general agreement within the community on the microphysics of what is occurring in these scenarios. For this reason alone, this paper can not be advocated for publication presently without a contextual rewrite.

We have now gone through a contextual rewrite of the paper in order to properly emphasize that, as a result of the microphysical/scattering model of the melting layer conceived and reported by Sassen et al. (2005), **there is a consolidated general agreement within the scientific community on the microphysics of what is occurring in the melting layer during the snowflake-to-raindrop transition process based on the microphysical/scattering model interpretation provided by Sassen et al. (2005)**. This is now clearly specified several times in the revised version of the paper (in the Abstract, in the Introduction, in the lidar and radar measurements section, in the model simulations section, in the in-situ data section and in the Summary). Specifically, in the Introduction we introduced the following sentence: "There is a consolidated general agreement within the scientific community on the microphysics of what is occurring in the melting layer

during the snowflake-to-raindrop transition process based on the microphysical/scattering model interpretation provided by Sassen et al. (2005)."
As already mentioned above, in order to recognize the proper credit to the compelling and essential research on this topic by Sassen and his co-authors, his papers (Sassen et al., 2005; Sassen *et al.*, 2003; Sassen and Chen, 1995; Sassen, 1977a; Sassen, 1977b, Sassen, 1975) have been explicitly cited and referred to at least 42 additional times in the revised version of the paper.

Doppler velocities relative to measured particle sizes and the effects of depolarization thus relating asphericity to both the dark/bright band phenomena represent important measurements that merit publication and further these previous efforts. I encourage the authors to reconsider the context of this discussion to present their findings in a more consistent manner, and within the framework of our present understanding of light-scattering phenomena within the melting layer that they themselves have greatly contributed.

As proposed by the referee we reconsidered the context of this discussion and we formulated a revised version of the paper which, after a deep contextual rewrite, presents our findings in a more consistent manner within the framework of the microphysical and scattering models conceived by Sassen et al. (2005), as well as in the light of previous studies from Sassen (1977a), Sassen (1977b), Sassen and Chen (1995), Roy and Bissonnette (2001) and Lhermitte (2002).

At that stage, I would gladly endorse this paper for publication. For now, I advise the editor that this manuscript requires a rewrite for consistency, relevance and merit.

The paper went through a substantial rewrite for consistency, relevance and merit. We believe that the present version of the paper has been sensitively improved, now providing the deserved proper credits to previous papers and research efforts on this topic. We hope that the referee and the Editor, based on the anticipated changes, will accept to consider the revised version of the paper for publication in ACP. So, if the referee and the Editor agree on that, we are ready to submit a revised version of the paper where all the above mentioned changes have been introduced.

Please also note the supplement to this comment: http://www.atmos-chem-phys-discuss.net/11/C14207/2012/acpd-11-C14207-2012-supplement.pdf

In the revised version of the paper that we have prepared we also addressed all points and comments and introduced all changes annotated by hand by the referee in the supplement note to his/her comment. In this respect we need to specify that we did our best to interpret the hand writing of the referee, and we believe we were successful in all cases. However, we apologize if we may have miss interpreted any of these hand writings.
A detail list of these additional changes follows below (please note that all wording changes indicated in the supplement note have been performed and are not indicated in the list below, so below we indicate all other more substantial changes in the text).

In page 30952, lines 8-9, with respect to the sentence: "Unlike the radar bright band, the lidar dark band has been poorly investigated and, to date, no systematic and coordinated observations are available.", the referee highlights that "poorly" is an unusually strong word and suggest removing the sentence.

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

In page 30952, lines 13-18, with respect to the sentence: "The lidar dark band is believed to be the result of two conflicting microphysical processes: a) the structural collapse of partly melted snowflakes, leading to a decrease of lidar backscattering due to the reduced particles size and b) the completion of the melting process, leading to an increase of lidar backscattering associated with spherical particle backscattering mechanisms coming into prominence (Sassen and Chen, 1995)", the referee specifies that "a) is incomplete. Suppression of backscatter off of rear face of droplet surrounding collapsed snowflake occurs. See Fig. 5 Sassen et al. 2005."

We agree with the referee that this additional aspect, as properly pointed out by Sassen et al. (2005), has also to be accounted for and mentioned at this stage. In the revised version of the paper the corresponding sentence has been now modified as follows: "The lidar dark band is believed to be the result of three conflicting microphysical processes: a) the structural collapse of partly melted snowflakes, leading to a decrease of lidar backscattering due to the reduced particles size, b) the progressive removal from the drops center of the embedded ice mass, due to its final melting, determining an increase of lidar backscatter associated with the paraxial reflection off the rear face of the droplets, and c) the completion of the melting process, leading to an increase of lidar backscattering associated with spherical particle backscattering mechanisms coming into prominence (Sassen and Chen, 1995; Sassen et al., 2005).

In page 30952, line 15, the referee writes: "How does concentration change? "

In the revised version of the paper we have removed any reference to particle concentration or density here, which was misleading.

In page 30952, line 26, the referee requests to introduce the reference by Sassen et al. (2003).

In the revised version of the paper this reference was introduced.

In page 30954, lines 9 and 12, the referee requests to introduce references for the two described phenomena.

In the revised version of the paper, concerning the statement that "atmospheric probing at the shortest wavelengths (0.83 and 1.24 cm) is sensitive to cloud droplets and ice crystals", we introduced references to Sassen *et al*. (2005) and Lhermitte (1988), while concerning the statement that "the UHF radar observes the larger precipitation particles, whose return radar signals can be treated relatively simply with Rayleigh scattering theory", we introduced a reference to Kiran Kumar *et al*. (2006).

In page 30954, lines 12-15, with respect to the sentence: "It should be pointed out that none of the previously reported measurements of the lidar and radar dark/bright bands could rely on multi-wavelength lidar backscatter, extinction and depolarization data, as well as on multi-wavelength radar reflectivity, depolarization and Doppler velocity data.", the referee writes: "why should be pointed out".

In the revised version of the paper this sentence was removed.

In page 30954, lines 12-15, with respect to the sentence: "This large "ensemble" of instruments makes the collected dataset unique for the purpose of studying precipitating hydrometeors in the melting layer.", the referee writes: "you guys keep saying this ?? Said it on previous page too. The Sassen et al. study in 2005 had many of these data streams, as part of NASA CRYSTAL FACE. He just didn't make use of them because they didn't fit what he wanted accomplished in that paper."

We agree with the referee that this data set is certainly not "unique" as in fact in the previous study by Sassen et al. (2005) many of these data streams were available as part of NASA CRYSTAL FACE experiment. Following the suggestion of the referee, the corresponding sentence has been modified and now reads: "This large "ensemble" of instruments makes the collected dataset very useful for the purpose of studying precipitating hydrometeors in the melting layer."

In page 30955, line 10, the referee requires to define the particle backscatter ratio.

In the revised version of the paper the definition of the particle backscatter ratio is provided. Specifically, the following sentence has been introduced: "The particle backscatter ratio, defined as the ratio of the particle backscattering coefficient over the molecular backscattering coefficient, is a parameters which quantifies the cloud/hydrometeor loading and depends on both their size and density."

In page 30955, lines 18-21, the referee comments that: "There is some context lacking here. Dark/bright lidar bands correspond with relatively light precipitation events where the signal is not sufficiently attenuated by the rain droplets. This should be emphasized here."

We completely agree with the referee. In this respect, the following sentences have been introduced in this paragraph in the revised version of the paper: "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)."

In page 30955, line 22, the referee specifies that: "no !! this is the melting level. 0^0 C does not signify a freezing level. You do mean 0^0 C right ? It should probably be explicitly said"

We apologise for the wrong wording here. In the revised version of the paper the corresponding sentence was changes as follows: "The melting level, that is the 0^0 C isotherm level, identified through the radiosonde launched at 14:06 UTC, is located at 3.35 km a.g.l. (black arrow in figure 1)." Additionally, the term "freezing level" was changed into "melting level" throughout the paper.

In page 30955, lines 26-28, concerning the portion of sentence: "… but this lidar dark band presumably continued for approx. 2 hours, as testified by the presence of a bright band in the co-located radar measurements (figures 2, 3 and 4)", the referee comments that: "of course it did as long as it was raining.

We agree that this is obvious statement. Thus, in the revised version of the paper this portion of sentence has been removed.

In page 30956, lines 20-23, concerning the sentence: "Although we show the position of the freezing level based on the radio sounding in all figures, it is to be noticed that precipitation processes can significantly alter the local atmospheric structure, with the temperature gradient in the melting layer varying as a result of evaporative cooling and vertical motion (Stewart *et al*., 1984).", the referee suggests to move this sentence at the end of a previous paragraph dedicated to the description of the temperature profile and melting level.

As suggested by the referee, in the revised version of the paper this sentence was moved at the end of the paragraph dedicated to the description of the temperature profile and melting level. This allows to discuss the description of the atmospheric thermal structure at an earlier stage, which makes the comprehension of the melting layer phenomena clearer and the paper easier to read.

In page 30956, line 28, the referee requests to introduce a reference concerning the increased radar depolarization values at the height of the radar bright band.

In the revised version of the paper the reference to the paper by Sassen and Chen. (1995) was introduced in this sentence.

In page 30957, lines 6-29, the referee suggests the different panels of figure 7 to be labelled (a) through (e) in order to avoid confusion.

As suggested by the referee, in the revised version of the paper the different panels of figure 7 have been labelled (a) through (e) in order to avoid confusion.

In page 30957, lines 6-29, concerning the sentence: "These low values of lidar depolarization may imply that precipitating particles are almost spherical or have a more regular shape.", the referee writes: "No. See discussion on line".

As suggested by the referee, in the revised version of the paper we now refer to the comments provided in the online referee comment. Specifically, the paragraph has been changed as follows: "The presence of large depolarization values high in the melting layer testifies the predominant presence of irregular shape snowflakes (Sassen, 1975; Sassen, 1977b), while the low values at the heights of the lidar dark band and lower-height bright band confirm the microphysical and scattering conceptual model proposed by Sassen *et al.* (2005), and suggests that sounded precipitating particles are severely melted snowflakes which have collapsed into mixed phase particles, having a more regular shape. Similar low values (3 %) of lidar depolarization were also reported at the height of the lidar dark band by Sassen and Chen (1995)."

In page 30961, line 1, concerning the sentence: "We need to point out that the aircraft measurements were carried out approximately half an hour after the lidar measurements shown in figure 7 (no lidar measurements were possible after 14:35 UTC because of rain reaching the telescope) and that the footprint of the aircraft is located at a distance of approximately 10-15 km from the lidar station.", the referee writes: "Again, if it's precipitation this shouldn't matter, which your data agree with.

We agree with the referee. In the revised version of the paper the corresponding sentences have been modified as follows: "We need to point out that the aircraft measurements were carried out approximately half an hour after the lidar measurements shown in figure 7 (no lidar measurements were possible after 14:35 UTC because of rain reaching the telescope) and that the footprint of the aircraft is located at a distance of approximately 10-15 km from the lidar station. However this time and space lag between the aircraft and the lidar measurements have only minor effects on the comparison between these measurements in case of stratiform precipitation. With respect to this, we wish to specify that figures 2 and 3 reveal a very limited variability of the radar reflectivity profiles at 1.29 and 36 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." We also added that: "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."

In page 30961, lines 24-27, concerning the sentence: "These results are compatible with the model representation we have considered to simulate the scattering properties of the melting hydrometeors and with the lidar depolarization measurements illustrated in the previous sections (characterized by low values in the melting region), the referee writes: "How is your model any different than Sassen's ?"

We agree with the referee that the conceptual model considered here is the same proposed by Sassen et al. (2005). In the revised version of the paper this sentence was modified as follows: "These results confirm the microphysical model of the melting hydrometers proposed by Sassen *et al*. (2005) and are also compatible with the lidar depolarization measurements illustrated in the previous sections (characterized by low values in the melting region)."

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