Dear editor and reviewers,

Please find attached a revised version of our manuscript “Assessing the impact of the Kuroshio Current on vertical cloud structure using CloudSat data (acp-2017-1134)”, which we would like to resubmit for publication as Atmospheric Chemistry and Physics.

Comments of you and reviewers were highly insightful and enabled us to greatly improve the quality of our manuscript. The following pages are our point-by-point responses to each of the comments of the reviewers.

Revisions in the text are shown using yellow highlight for additions. We hope that the revisions in the manuscript and our accompanying responses will be sufficient to make our manuscript suitable for publication in Atmospheric Chemistry and Physics.

We shall look forward to hearing from you at your earliest convenience.

Yours sincerely,

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EC: Editor comment

RC: Referee comment

AC: Author comment

Response to Editor

EC : Thank you for addressing the reviewers comments. I believe you have done so satisfactorily to provide a worthwhile contribution on the effect of the Kuroshio on cloud properties.

One request is that the reviewer request for a comment on the effects of aerosols be ignored and the corresponding text on p. 9 be removed. I do not see an obvious relationship between the path of aerosol pollution and the oceanic current and feel that relating your study to aerosols is out of context.

AC: We removed the corresponding text on p.9.

Response to Referee #1

Major comments:

RC: p2, l1-2: The authors cite two papers by Koike et al. (2012, 2016) that investigate the impact of aerosol on liquid clouds in relation to Kuroshio current. It would be nice to mention this effect and clarify how the present study fits in the context of this previous literature. Could some of the cloud and precipitation changes observed in this manuscript result from fast cloud adjustments to aerosol perturbations induced by the current? I realize that this is not the main topic here, and disentangling aerosol-cloud-meteorology effects is extremely difficult, but this issue could be briefly addressed.

AC: Fast cloud adjustments to aerosol perturbations could be induced by the Kuroshio, and then some of the cloud and precipitation changes occurred. However, it is difficult to investigate the effect of aerosols with CloudSat only. We removed the corresponding text (Koike et al. 2012, 2016). For future work, we will investigate the effect of aerosol using CALIPSO data and climate model outputs.

RC: p3, l17-18: I strongly encourage the authors to expand their analyses to the entire A-Train period (2006-2016). This would greatly improve the statistical significance of the results presented here, and I think could even help the authors to make their conclusions stronger by reducing weather noise. The data is freely available and I do not see any reason to only use 3 years of data. Perhaps because the night-time data is not available later on? Also, have you have merged day and night overpasses in the analyses and, if so, are there any consequences on the results by comparison to using day-only and night-only statistics?

AC: We expanded the target period to 2016. Although we analyzed satellite data separately between day and night, there was no large difference in the results.

RC: p3, l20-23: Using a strict SST threshold is perhaps not the best option to determine the ON and OFF regions. This method implies that transition areas are included and could blur the expected changes in statistics of cloud properties and precipitation between the two regions. Another option could be to select ON and OFF regions based on separate ranges of temperatures, for instance corresponding to the first and last quartiles (or other percentiles, depending on the desired sensibility) of region-mean SSTs. This way, both regimes are better defined and can be distinguished.

AC: We performed reanalysis using different thresholds in May (23.08℃) and June (24.70°C). The thresholds were higher by 1 ℃ than the regional average temperatures in each month. (P3, L24 - P4, L2)

RC: Section 3: As previously mentioned, and in relation to the previous point, the differences between properties observed in ON and OFF regions aren't always obvious. For example, the authors have mixed interpretations of Fig. 2, sometimes stating that no clear differences are observed (e.g. p5 l2-3, l6-7, and I'd agree with that) and later that the Kuroshio impacts heating at high altitude. It is not clear to me from Fig. 2k where this impact is, could you clarify? Also, based on Figure 5 (analyses in section 3.4) I do not see any clear signal of perturbation by the

Kuroshio current, except perhaps in 4e. More statistics (more A-Train data) could help clarify if this is within weather noise or not. In general, all the 3.x subsections appear a bit as lists of figure descriptions without a consistent in-depth analysis, until the very end where interesting arguments based on cloud processes are provided (beginning of p.8). It would be good to improve how each figure and their respective results fit all together, to make the final conclusions more convincing. I had some troubles understanding towards the end how all the presented results connect, maybe an extra section would help.

AC: We added figures of cloud properties and radiation at TOA and surface (Fig. 2, 3) using some satellite data. We could show the characteristics more clearly over the Kuroshio. (P4, L22-P5, L15)

Minor comments:

RC: p2, l.12: This is a detail, but isn't the across-track resolution of 1.4 km? This information, and the following technical details, could go in section 2.

AC: We replaced '1.3 km' to '1.4 km', and this information moved to section 2. (P3, L10)

RC: p4, l.18: Any reason to subset the previous region (yellow box)? Especially that this thick dotted rectangle region only is used in section 3.1.

AC: The yellow box indicated an area with a large difference between east and west region in atmospheric condition on the map.

RC: p2, l.12: Analysis of Fig. 2i,j: What are the vertical black bands?

AC: The blacks bands mean missing values.

RC: p2, l.17: net radiative heating here means SW + LW?

AC: Net radiative heating means SW + LW, and We added 'SW + LW' in the figure caption.

RC: p5, l.24: Could you clarify what are "contoured frequencies by altitude diagrams" and their advantage by comparison to the previous PDF?

AC: Contoured Frequency by Altitude Diagrams (CFADs) is defined as the probability distribution of radar reflectivity normalized at each altitude. CFADs can get information on precipitation intensity for each altitude. We added those descriptions in section 3.2. (P6, L22- 24)

RC: p6, l.8: "for higher altitudes": Do you mean above 6 km? The statistical significance doesn't seem high in regions where the difference if positive at higher altitude. It seems more clear from this figure that heavy precipitation below 6km is reduced but there is more drizzle.

AC: 'at high altitudes' mean above 6 km. We remove a text after 'at high altitude ~', and added the text as follows. 'heavy precipitation below 6km is reduced but there is more drizzle over the Kuroshio.' (P7, L7)

RC: p6, l.15: Can you precise how the geometrical thickness is computed? Please keep in mind that CloudSat is sensitive to the surface echo (so the cloud base of low clouds is difficult to get) and not sensitive to thin layers (so could miss cloud-top). I am not sure how this impacts the conclusions made here.

AC: We used CloudSat product only. You are right, we cannot observe thin cloud top and cloud bottom near the ground surface. Even if we use the radar-lidar product, this analysis cannot be performed because data on the radar reflectivity cannot be obtained in the thin clouds and the near the ground surface.

RC: p7, l2-3: "the frequency of occurrence of the precipitating clouds with a geometric thickness of 7 to 10 km significantly increased ON Kuroshio." - True, but does it mean that thick clouds precipitate more or that there are more thick clouds in ON Kuroshio

regions (consequence of stronger updrafts). This is an example where coupled analyses with results from previous figures would be helpful.

AC: It means that there are more thick clouds over the Kuroshio regions. We added a description of 'Geometrically thick clouds occurred more because strong updrafts (Fig 2a) took place over the Kuroshio.' (P8, L4)

RC: Figure 4: How did you bin the geometric thickness? How is the PDF

normalized?

AC: First, we calculated PDFs of geometrical thickness in each 500m for ON and OFF Kuroshio clouds, and then we took the difference of two PDFs, respectively.

Technical corrections:

RC: p2, l.4: "General" instead of "Generation" or "Generation of general"? I assume that the authors refer to the "too bright too few" problem, but the sentence is a bit confusing.

AC: We replaced 'generation' with 'general' and added description of 'so-called 'too few, too bright' problem.' to the end of the sentence. (P2, L3-5)

RC: p2, l.12: "cloud particle size, which ranges from drizzle to precipitation" can be misleading. Replace by "large cloud particles and hydrometeors"?

AC: We replaced 'cloud particle size, which ranges from drizzle to precipitation' with 'large cloud particles and hydrometeors'. (P2, L11-12)

RC: p4, l.10: why "(divergence)"?

AC: we deleted "(divergence)".

RC: p4, l.19: Are the sections not meridional instead of zonal?

AC: We replaced 'zonal' with 'meridional' (P5, L17)

RC: p6, l.4: "for both" instead of "both"?

AC: We added 'for'. (P7, L3)

Response to Referee #2

Specific Comments:

RC: 1. Figure 1: The yellow box, representing the target region, as well as the sub-domain represented by the thick-dashed box, should be shown in each panel of Figure 1, which would aid the reader in orientating the main features more readily from each of the fields displayed. Again, adding considerably more data, and possibly MODIS cloud fraction, would make Fig. 1f much more meaningful than it is now, which stands currently as a fairly chaotic field of cloud fraction due to the noisiness.

AC: We added yellow box and dashed box in each panel of Fig.1. We added MODIS cloud fraction (Fig. 1g), and we show that cloud fraction of CloudSat could have a possibility of underestimation compared to that of MODIS. (P4, L23 -25)

RC: Please also consider an improved color scheme, especially for Fig. 1d, which shows the skin temperature. The gradations are very subtle between about 23◦ - 26◦C, even though this encompasses the critical threshold for defining ON-Kuroshio and OFF-Kuroshio. 2)

AC: We improved color scheme in Fig. 1d.

RC: Figure 2: As stated in the summary and overarching comments at the beginning of this review, many of the CloudSat-derived or retrieved profiles are almost meaningless here, partly because of the sparse and limited sampling (with data striping!), and perhaps in some cases, because of the color schemes chosen. For the SW HR, LW HR, and Net HR plots, while it is possible to distinguish between reds (warming) and blues (cooling), it is very difficult to discern the seemingly more subtle differences across the cross section analyzed. Also, there appears to

be an inconsistency between the manuscript text and the caption in Figure 2 – the latter states the thick dotted box between (25-34N, 126.5-131E), but the figures themselves show longitude values between 120 – 131E, as does the box itself in Fig. 1. Also, the latitude range from Fig. 1 is 28-31.5N, which is also stated in the text body, but this is different from the caption of Fig. 2. Please correct. 3)

AC: We expanded the target period to 2016, and sample size increased. We corrected the region (28–31.5°N, 120–131°E) of the manuscript and the caption in Fig.2.

RCs: Line 3, page 4: Please consider adding "Frisch et al. 1995" for an additional, more historical citation – e.g. this is an early paper which uses -15 dBZ to discriminate between non-drizzling and drizzling/precipitating clouds. Reference: Frisch, A. S., C. W. Fairall, and J. B. Snider, 1995: Measurement of stratus cloud and drizzle parameters in ASTEX with a Ka-band Dopper radar and a microwave radiometer. J. Atmos. Sci., 52, 2788-2799. 4)

AC: We added 'Frisch et al. 1995' as one of the references. (P4, L8-9)

RC: Line 8, page 5: The sentence: "The total water content (TWC: CWC+PLWC+PIWC) corresponded to LTS, which peaked around 124.5E", is very vague and confusing, and needs to be rewritten. 5)

AC: We added a description of 'LTS peaked around 124.5E°, LTS peaked around 124.5E°, and TWC was the lowest there.' (P6, L6)

RC: Line 18, page 5: The phrase, "As previously described, TWC increased over the Kuroshio" is rather difficult for me to discern from Fig. 2k. Perhaps the black striping and the color scheme make this result a difficult one to view. In another vein, if the authors decide to assess any other A-Train data, examining cloud radiative forcing in a similar way from CERES, including Longwave, Shortwave, and net, might be complementary to Figure 2 and the paper in general. The real question is – do clouds over the Kuroshio have a larger net TOA radiative effect? Profiles of cloud radiative effects can also be assessed from CERES, if there is space to perform this analysis. 6)

AC: We reduced black striping from Fig. 2k, and we added figures of TOA and surface flux (Figure 3 a to f) from CERES products. Those figures showed that the cooling effect worked at the surface over the Kuroshio in the same manner as TOA. (P5, L8-15)

RC: Lines 4-5, page 6: Please consider re-writing the sentence as follows: “These results show that clouds with the highest rainfall intensity measurable by CloudSat at lower altitudes (1-6 km) are common in the target region.” 7)

AC: We rewrote the sentence as follows ‘These results show that clouds with the highest rainfall intensity measurable by CloudSat at lower altitudes (1-6 km) are common in the target region.’ (P7, L2-3)

RC: Lines 4-7, page 7: Why are mid-thickness drizzling clouds more abundant in the OFF-Kuroshio region (Fig. 4b)? Is this because the ascending motion is weaker and more bottom-heavy than over the Kuroshio current, leading to a greater abundance presumably of mid-level clouds? This is also the case for precipitating clouds; mid-thickness clouds are more pervasive in the OFF-Kuroshio regions. Can we say anything about total precipitation from this Figure (or Figure 5)? It would be interesting to know how much the different categories contribute to total precipitation, and this is where an independent, additional sensor which does not attenuate for dBZ>15 dBZ would be helpful, such as AMSR-E. 8)

AC: As you suggested, the updrafts is weaker and more bottom-heavy over the OFF Kuroshio than over the ON Kuroshio. It is the reason to occur mid-thickness clouds over the OFF Kuroshio. We added a figure of mean precipitation rate (Fig. 2a). This figure showed that mean precipitation rate in target period reached 10-12 mm day^{-1} over the Kuroshio, and it was twice as large as that in the surrounding Kuroshio area (5-6 mm day^{-1}). (P5, L3-9)

In this study, we focused on clouds that could be detected with CloudSat satellite. In future work, we will try to different precipitating categories using Ku-band and Ka-band.

RC: Lines 25-26, page 7: “. . .taking 0 and 1 at the cloud top and the cloud base, respectively. . .” There’s no need to repeat this here, as it is already explicitly described at the beginning of that paragraph.

AC: We deleted the text.

RC: Grammatical Suggestions and an Incomplete List of Typos (Please have a professional English editor carefully proof this manuscript) 1) As an illustration of the tense problem reported above, Lines 6-10, page 3 are in past tense, but this is inappropriate as it discusses the organizational structure of the paper – e.g. should instead be: “In section 2, we show the

data . . . In section 3.1, we describe the influence. . .". The authors seesaw between past and present tense, sometimes opening paragraphs in present tense, but then reverting to past tense by mid-paragraph.

AC: We unified the tense in each section.

RC: Please correct this – it happens during so many instances that it's not convenient to enumerate them all here. 2) Line 1, page 5: change "less than" to "west of" 3) Line 4, page 6: add "over" before "both" 4) Line 20, page 8: a period is missing after "ON Kuroshio". 5) Line 21, page 8: change "updraft" to "updrafts"

AC: We rewrote these points.