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Reply on RC1

Saleem Ali et al.

Author comment on "Temporal and vertical distributions of the occurrence of cirrus clouds over a coastal station in the Indian monsoon region" by Saleem Ali et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2021-798-AC1, 2021

Response to the Reviewer #1

Manuscript Titled "Temporal and vertical distributions of the occurrence of the cirrus clouds over the coastal station in the Indian monsoon region" by Ali et al.,

General Comment

This paper discusses on the vertical distribution of tropical cirrus based on Micro-Pulsed Lidar observations carried out at a tropical station, Kattankulathur (12.82° N, 80.04°E), near Chennai, during 2016, 2017 and 2018. The highlight of the study is on the diurnal variation of the tropical cirrus, which is rarely reported elsewhere. Though the general characteristics of the tropical cirrus over the study/near-by region (e.g., lidar observations from Gadanki) are well known, the study on the diurnal variation of tropical cirrus is being reported for the first time. The authors have showed the diurnal variation of cirrus for different seasons, based on extensive MPL observations carried out in each month during 2016, 2017 and 2018 and delineated the occurrence of single-layer and multi-layer cirrus and their inter-annual variations. The authors also tried to correlate the cirrus occurrence with the convection and tropopause temperature.

Reply: We thank the Reviewer for going through the manuscript and providing positive comments and valuable suggestions to improve it further. We have incorporated all the necessary corrections suggested in the revised manuscript.

Major comments:

- Occurrence of cirrus is frequent in the altitude region 12-16 km. The POC shown in Figure 6 shows cirrus occurrence very close to CPT and even above CPT altitude. During July and August, cirrus (cirrus-top) is observed at CPT and also above the CPT altitude. Mean altitude separation of cirrus-top from CPT altitude also shows significant seasonal variation. Cirrus/ice particles at the vicinity of CPT and above have large implications. The authors may quantify the occurrence of cirrus above CPT (and the altitude separation from CPT-altitude) for different seasons (from hourly/high-resolution data on different days in a month/season) and highlight the implications of cirrus near/above the CPT in the revised version.

Reply Thanks for the Reviewer's suggestion. Cirrus clouds frequently occur

above the CPT during May (~7%), July (~10%), and August (~9%) above the CPT. During the rest of the months, cirrus occurrence above the CPT is less than 2-3%. We have calculated the altitude separation between CPT and cirrus cloud top occurring above the CPT in May, July, and August, which are ~ 0.35±0.22 km, 0.28±0.20 km, 0.43±0.35 km, respectively. The occurrence of the cirrus top above the CPT indicates the transport of the water vapor into the lower stratosphere. Such water vapor transport by means of the formation of the cirrus clouds can radiatively affect the stratospheric chemistry. Our observations indicate that the cirrus top occurring above the CPT varies between ~0.1 km to 0.7 km. It is to be noted that the occurrence of the cirrus top above the CPT is calculated relative to the mean CPT altitude at 5:30 IST and 17:30 IST. However, CPT shows significant diurnal variation with amplitude ranging between 0.2–0.5 km (Mushin et al., 2017).

- Authors can check, if the same cirrus persists more than a day from the consecutive days of MPL observations. Persistence of cirrus for longer time has large implications in the upper troposphere/near tropopause region.

Reply: Thanks for the suggestions. We have checked the occurrence of the cirrus clouds persisting for more than a day. In total 665 days, cirrus clouds were observed during 2016-2018. Out of which, for 93 days (i.e., 14%), cirrus clouds persist more than a dayThe persistence of the cirrus clouds longer than a day frequently occurs during May to August (covering SW monsoon) and during October-November (covering NE monsoon).

- The manuscript requires some more tightening, by editing unnecessary discussion/presentation, removing the repetitions in the text and highlighting the essence of the results. Results should be presented in clear and effective way, without losing the crisp. Figure 8 can be avoided, as the details shown in this figure are already seen in figure 7.

Reply: Thanking you for your suggestions. We have edited the manuscript carefully wherever required. As suggested, figure 8 is removed from the main manuscript and kept as supplementary Figure S2 in the revised manuscript.

- Authors should carefully modify the text in the manuscript correcting the grammar errors.

Reply: We corrected the grammatical errors with the help of the native English speaker and using Grammarly software.

Specific/Minor comments

Minor comments are commented as notes at the required places of the text in PDF version of the manuscript.

Reply: Responses of the minor comments annotated to the PDF version of the manuscripts are as follows

L131 Delete was

Reply: Deleted

L154 what are those high frequency variations?

Reply: These high-frequency variations are generally known due to short-scale waves such as long-lived gravity waves and turbulence mainly detected using the doppler weather lidar (Liu et al., 2014). Such signals are also present in the MPL, however, not they are not characterized yet and are generally referred to as random variation arising due to background noise. The content is suitably incorporated in the revised manuscript.

L159 Background NRB signal of ambient air? Do you mean background NRB noise?

Please clarify.

Reply: Yes, we mean here the background noise that is the signals from ambient air or cloud-free air.

L182 source of data?

Reply: We have used the same source of the data, i.e., MPL observations during 2016-2018, for the seasonal mean altitude profiles of the extinction coefficients. The details of deriving the extinction coefficients are provided in Ananthavel et al., (2021a); Ananthavel et al., (2021b).

L258 what is threshold value fixed? is this threshold value fixed/same for all the time and/or all the seasons?

Reply: We have already mentioned the threshold criteria used in the manuscript in line numbers 159-160 of the first version of the manuscript. The threshold value is taken as the mean plus two standard deviations of the background NRB signal from ambient air. This threshold value is calculated for each profile, so it is not a fixed value rather a fixed criterion.

L315 Correct this sentence

Reply: The sentence is suitably corrected in the revised manuscript.

L339 This information needs to be included in the figure caption.

Reply: We have included it in the figure caption of Figure 4 of the revised manuscript.

L386 Incomplete sentence. Combine the previous sentence with this sentence.
Above three sentences can be combined

390 Cirrus is closely associated with turbulence. Stro2ng turbulence occurs in afternoon /evening hours. This sentence requires modification.

Reply: Thank you for the nice suggestions. We agree with the Reviewer that the cirrus clouds occurrence is closely associated with the turbulence and it

generally becomes stronger during afternoon and evening hours (Parameswaran et al., 2004; Mushin et al., 2016) consistent with our findings of the higher occurrence of the cirrus clouds during afternoon and evening hours.

407 Rapid fall in cirrus occurrence observed after sun rise and before sun set, in all seasons. Is it due to dominance of noise before sunset and after sunrise, limiting the detection of cirrus signal at higher heights?

Reply: In the first version of the manuscript, we have already mentioned the content related to less occurrence or rapid decrease in the cirrus clouds occurrence after sunrise and before sunset (lines 406-408). It could be due to the limited detection capability of MPL under solar noise. Additionally, dissipation of the subvisible and thin cirrus clouds just after sunrise may cause a rapid decrease in the POC. Thus, lesser POC in the daytime is partly due to the dominance of noise before sunset and after sunrise, limiting the detection of cirrus signals at higher heights.

413 This is a casual sentence... correction required

Reply: This sentence is corrected in the revised manuscript.

415 How do you confirm that cirrus near COT during night hours is due to turbulence. In other time also, turbulence can exist.

Reply: We agree with the Reviewer that turbulence is closely associated with cirrus clouds, and it can occur anytime. However, studies on the turbulence at Gadanki (13.45, 79.2) close to this station over the Indian monsoon region reveal frequent turbulence during the night time than daytime (Mushin et al., 2016). Thus, cirrus clouds occurring during the evening and early night cloud be related to turbulence.

419 is the second peak due to remnants of deep convective outflows?

Reply: Yes, the second peak in the occurrence of the cirrus clouds could be remnants of the cumulonimbus outflow anvils. We have carefully checked the LDR value to ascertain the cirrus clouds in the cases of cumulonimbus clouds present at a higher altitude.

423 Is it the limitation of MPL in detecting cirrus at higher heights due to solar noise?

Reply: it can be noticed that the daytime cirrus clouds at higher altitudes are significantly less when compared to night-time. At higher altitudes, cirrus clouds are generally thin or subvisible that may remain undetected by the MPL due to high solar noise.

429 If cumulonimbus exits, the lidar signal will not penetrate beyond a certain height above the cloud base.

Reply: We agree with the Reviewer that the MPL signal will not penetrate cumulonimbus clouds. In our study, we checked the LDR value for each profile to ascertain the cirrus clouds.

431 It will be interesting to quantify the amount cirrus (in %) crossing above CPT and the altitude extend up to which it can occur above CPT. This can be examined for all

seasons. The contour figure shows the frequency of cirrus above CPT is observed from May-Sep, with maxim during July and August. Another interesting feature is the occurrence of cirrus top aligning with the CPT, particularly during Aug. and Sep. Hence, it will good to discuss the separation of cirrus top/altitude with the CPT altitude, for deference seasona

Reply: Thank you for your valuable suggestions. Please see the response to your major comments 1.

432 Cirrus layer close to CPT could be in situ generated due to cold temperatures and abundance of moisture transported from deep convection.

Cirrus close to COT could be due to remnants of clouds from deep convective outflows

Reply: We agree with the Reviewer and added the information in the revised manuscript.

436 cannot confirm. It could also be due to the limitation of cirrus detection by MPL.

Reply: We have modified the sentence in the revised manuscript.

477 Does Double peak/multilayer cirrus have any association with generation mechanism of cirrus.

Reply: Yes, peak occurrence of the upper layer cirrus clouds close to CPT could be in-situ generated due to cold temperatures and the abundance of moisture transported from deep convection. At the same time, peak occurrence of the lower layer cirrus clouds close to COT could be due to remnants of clouds from deep convective outflows.

483 this figure can be avoided, as that information are seen in figure 7.

addition information is the interannual variations, which can be discussed in text

Reply: This figure is removed from the main article and kept as a supplementary figure.

502 need to correct the sentence

Reply: The sentence is corrected in the revised manuscript.

522 this is not correct

Reply: The sentence is corrected in the revised manuscript.

564 how it is connected to cirrus occurrence/formation?

Reply: The ENSO and QBO are the well-known interannual components that affect the TTL temperatures. Thus, in the presence of the warm temperature anomalies, cirrus clouds may dissipate, while cirrus clouds may be in-situ generated in the presence of the cold anomalies. It is also known that ENSO significantly affects the tropical convective and Indian monsoon systems. During the warm (El Nino) and cold (La Nina) phases, the Indian monsoon become weak (receives rainfall lesser than the normal) and strong (receives rainfall greater than the normal). Thus, during strong monsoon conditions, more cloudiness and abundance of moisture can result in the more frequent occurrence of the cirrus

clouds than the weak monsoon conditions.

pp 25 Are these profiles smoothed one?

Reply: The NRB gradient and potential temperature gradient profiles are smoothed by 10 points running mean filter. Other profiles are not smoothed.

References:

Ananthavel, A., Mehta, S. K., Ali, S., Reddy, T. R., Annamalai, V., & Rao, D. N. (2021a). Micro Pulse Lidar measurements in coincidence with CALIPSO overpasses: Comparison of tropospheric aerosols over Kattankulathur (12.82 oN, 80.04 oE). Atmospheric Pollution Research, 12(6), 101082.

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Please also note the supplement to this comment:
https://acp.copernicus.org/preprints/acp-2021-798/acp-2021-798-AC1-supplement.pdf