Review “Influence of covariance of aerosol and meteorology on co-located precipitating and non-precipitating clouds over INdo-Gangetic Plains” Gulistan et al.

Thank you for your valuable feedback and continued engagement with our manuscript. We appreciate the time and effort you have invested in reviewing our work. We have carefully considered your comments and would like to address your concerns which led to the improvement of the manuscript. Below are the replies to the reviewer's comments, and indications of additions, modifications, or subtractions to the text under discussion. We report the reviewer's comments in italic black, our responses in italic green, and the text added to the manuscript in roman red.

Public justification (visible to the public if the article is accepted and published): *I have read the responses to my review of the article "Influence of covariance of aerosol and meteorology on co-located precipitating and non-precipitating clouds over the Indo-Gangetic Plains". I thank the authors for responding to the various comments, the article is much improved in my opinion.*

- *Thank you for the encouraging remarks and appreciation.*

Nevertheless, some comments have not been properly answered in my opinion and I would like the authors to consider some changes in the article, which I detail below:

1. *Regarding the uncertainties, the authors now refer to the various uncertainties in the article, but there is no quantification of the aforementioned uncertainties, nor of the propagation to the results. I am particularly concerned that the observed differences are within the uncertainty range and therefore not significant. Can the authors quantify the uncertainties in their data set? For example, the authors refer to “influence the findings in the current investigation”, can they quantify this influence?*

Reply: Thank you for your valuable suggestion and concern for the quantification of uncertainties. We comply with the expert’s valuable suggestion. In this regard the two-sample t test is adopted to characterize the probability ‘p’ value of datasets at 95% confidence level for MODIS-derived AOD and cloud parameters. Further, figures 8 and 9 are revised as follows for indication of ‘p’ value in each plot along with the relevant discussion in section 3.4.1 as follows:

The impact of aerosols on CDNC and CER of PCs and NPCs is illustrated as scatter plots in Fig. 8-9. The quantification of the AOD-CER and AOD-CDNC relationships is demonstrated through detailed linear regressed slopes, regression coefficients (R^2) and Pearson's correlation coefficient (R). The color bar represents the variations in LTS. The results show that the two-sample student's t test is carried out to analyze the AOD-CER and AOD-CDNC relationship in view of statistics. The results illustrate that the relationships are statistically significant at 95% ($p < 0.05$) significance level for all study areas.

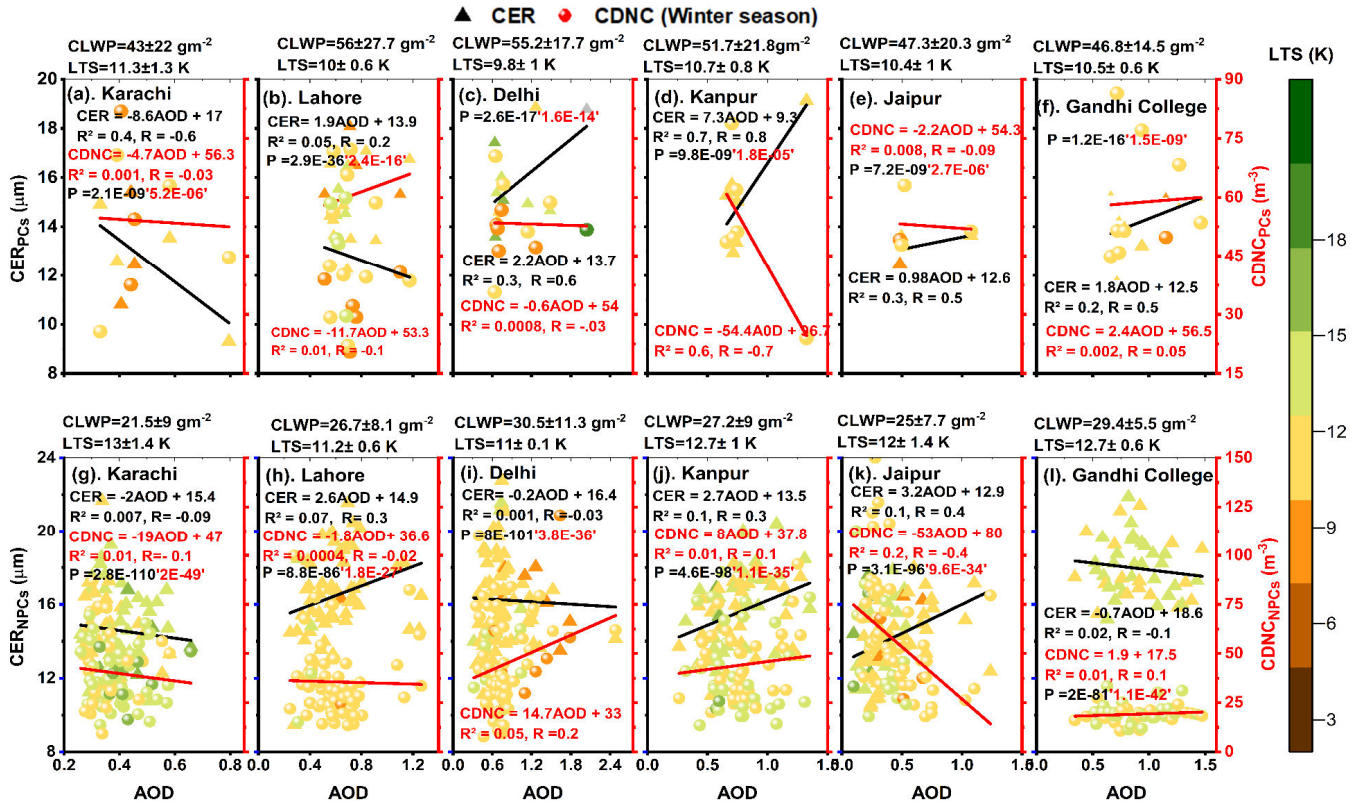

Fig. 8. AOD-CER and AOD-CDNC regression and correlation coefficient considered at 95% significance level for PCs and NPCs over all study areas in winter season.

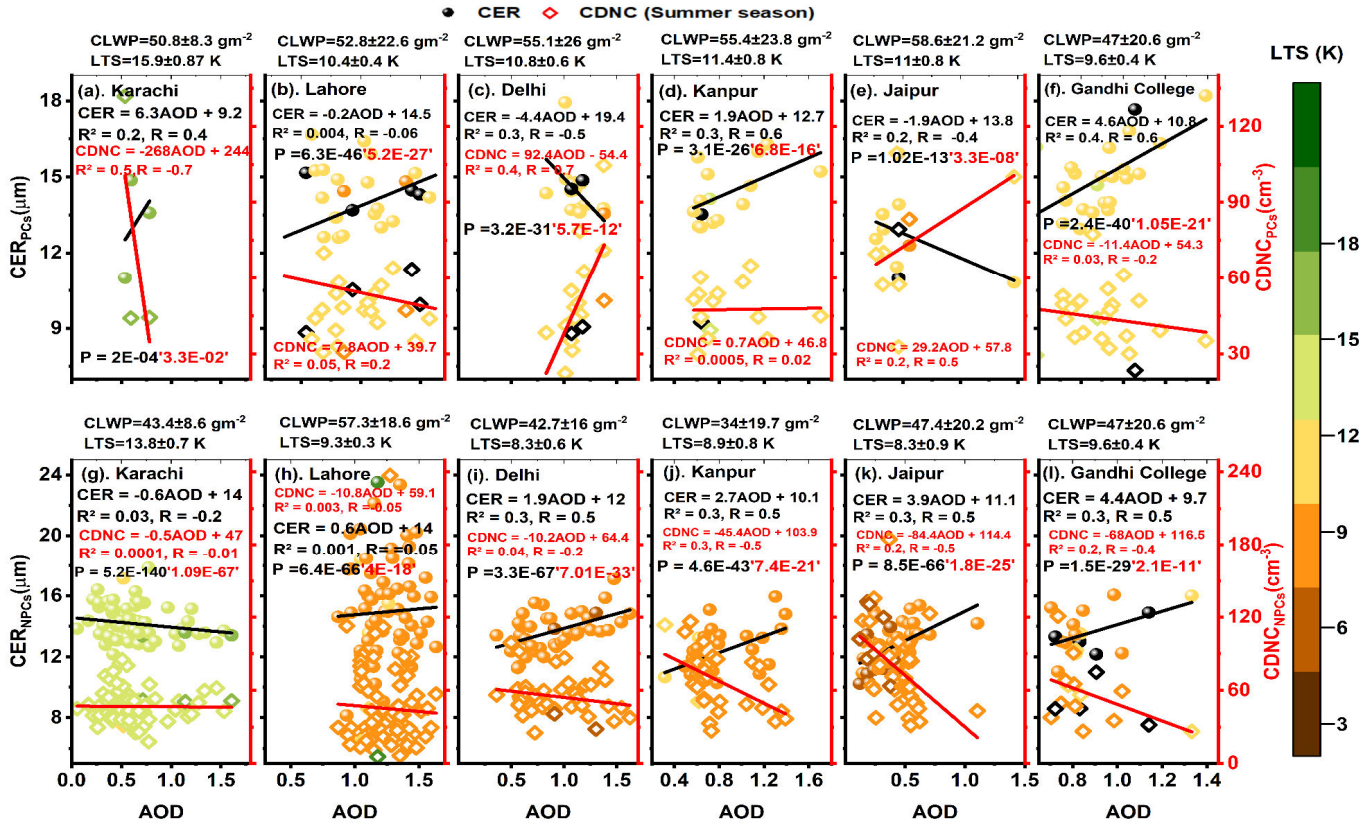

Fig. 9. Same as Fig. 8 but in summer season.

2. The table with the number of data points is useful, but does not appear in the article. The number of data is key to the statistical analysis, so I think the reader should have this information. Also regarding the number of data points, the different regimes are associated with relatively low numbers of data. I would like to let the editor judge this and decide whether there are enough data points to infer statistics (a threshold of 15 is applied but is it enough?). However, I was concerned about using the mean instead of the median, as the mean is affected by potential outliers and can be especially important when there is less than 100 points.

Reply: Thank you for your concern about the significance of our results, as this really led to the improvement of the manuscript. Following is the clarification of your concerns about the data points.

- *The table with the number of data points is inserted in the supplementary material for the readers.*
- *The Student's* t*-test is widely used when the sample size is reasonably small (less than approximately 30) (King & Eckersley, 2019). Therefore, two sample student's t test is adopted to compute the value of 'p' at 95% confidence level. In each case it is found to be $p < 0.05$. In this regard Fig. 8-9 are revised (refer to first comment) for indication of 'p' value.*
- *Median is computed instead of mean. In this regard, table 2 in the main manuscript and table 2s in the supplementary material is revised (refer to the following comments).*

3. The dataset colocates cloud and aerosol information based on daily information and does a temporal interpolation using a "statistical function" to fill in data where there is none (aerosol on cloudy day). Can the authors say what the statistical function is? Is it linear? I would also like to see this information in the paper as it is key if someone wants to reproduce the analysis. Also, is there a threshold for the number of days for which AOD is not retrieved? For example, extreme cases: If there is no aerosol information for 30 days, will the authors still collocate an inferred AOD value to colocate with cloud information?

Reply: We are grateful to reviewer 2 for the careful reading and continued engagement with our manuscript. To accommodate the comment the following text is added in the revised manuscript in the methodology section as follows:

Subsequently, in this analysis, the VLOOKUP function is utilized for linear interpolation/alignment of the data. This function is available as a built-in feature in Microsoft Excel.

- *Further, if there is no aerosol information then an inferred AOD value is not colocated with cloud information.*

4. Response to the "liquid cloud comment". "Low level clouds can refer to mixed phase or ice clouds, for example in the Arctic and Southern Ocean. I would mention in the article that the study is only about Arctic low-level clouds for readers.

Reply: Thank you for your insightful comment. Following is the explanation/clarification regarding concerns of data retrieval for liquid clouds.

- *Since NASA Giovanni is a Web-based application and flexible platform developed by the GES DISC that provides a simple and intuitive way for users to visualize, analyze, and access vast amounts of Earth science remote sensing data over time from the website(https://giovanni.gsfc.nasa.gov). From this website, the data of liquid and ice cloud parameters can be retrieved separately. Thus we select variables for liquid clouds only e.g., 'liquid water cloud effective particle radius' CER, 'liquid water cloud optical thickness' COT, 'liquid water cloud water path' CLWP etc.*
- *To further confirm/validate that the retrieved data over IGP are for liquid clouds only, we applied the Integrated Multi-satellite Retrievals (IMERG) for Global Precipitation Measurement (GPM) algorithm and retrieved time average maps of precipitation and its probability of liquid phase as follows:*

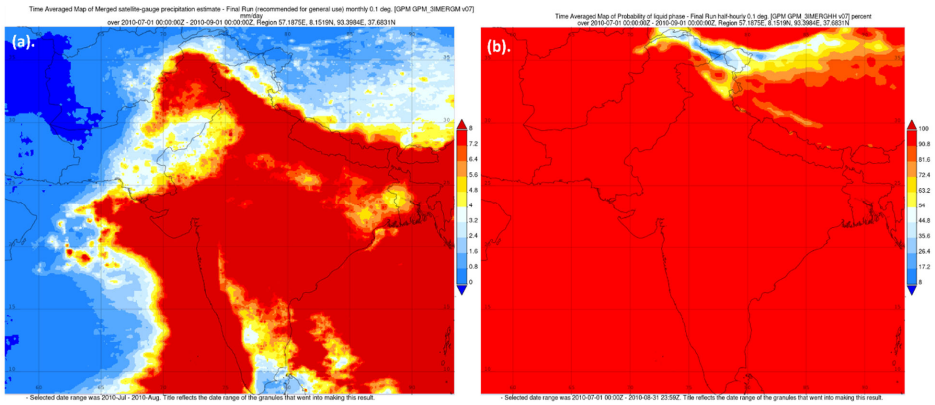

Fig. 1. plot (a) shows the precipitation rate in summer from Junly 1-August 31, 2010 and plot (b) shows probability of liquid phase of precipitation.

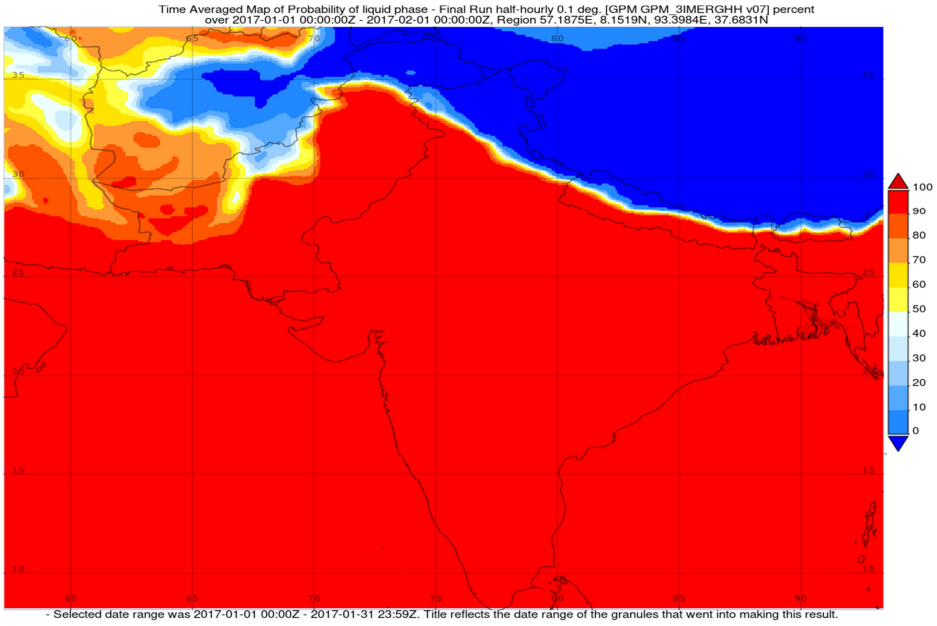

Fig. 2. Probability of liquid phase of precipitation occurred from January 1-31, 2017.

5. The authors added 3 stations in the eastern part of the region. But they did not respond to my comments as to why they focused on ground-based stations if they did not use measurements from the ground-based instruments. I would have

expected some comparisons with the ground-based instruments, but this is not shown, so I do not understand why they only used satellite information on single pixels. Their number of data points could be greatly improved by using extended regions. I also wonder why the authors did not include information from the southern part? Finally, the 3 stations added in the analysis (on the eastern part) do not appear in the final manuscript (but only in the supporting information), I recommend to include the additional stations on the plots in the main article and maybe moving other stations in the supporting information if the graph is too busy.

Reply: Thank you for your valuable feedback and precious time. Following is the clarification for this comment.

- *The present study is not focused on ground-based stations, however, due to the lack of in-situ measuring facilities, and as a result utilization of remote-sensing datasets similar to previous studies (Amin et al., 2009; Nirala et al., 2002), the present study is only satellite-based analysis focused to capture localized variations.*
- *The location of Gandhi College (25.87ºN, 84.13ºE) can be inferred as the southern part of IGP. Further, Delhi is located on the northern edge of IGP extended to the south.*
- *In response to your previous detailed and valuable feedback, we have already tried to include our expanded analysis on the eastern part in the main manuscript. However, it was making the main text too busy. For this reason, it is documented as supplementary material instead.*

6. I thank the authors for responding to my comment about the dependence of the dataset. However, I am not convinced by the answer. My point is that the authors use parameters that are directly derived from the satellite retrievals. Therefore, the dependence between the parameters and the retrievals is subject to the equation and hypothesis that links the parameters on the first basis and not solely from the analysis of the dataset.

Reply: We are thankful to the reviewer for the comments and suggestions. Per kind suggestions of the reviewer the statistical significance of relationship/dependence between different parameters

from different datasets/retrievals is checked through t test at 95% confidence interval (Please refer to comment 1).

7. I agree that MOD06 only refers to TERRA measurements, but I recommend to make it explicit in the text for the reader who is not familiar with the NASA nomenclature.

Reply: Thanks, and we revised the sentence in the 'Methodology' section as follows.

This study uses the daily mean of combined dark target and deep blue AOD at 0.55 µm, cloud top pressure (CTP), cloud top temperature (CTT), CF, CER, and COT for liquid clouds from level 3 aerosol-cloud data product MOD08-TERRA.

8. From my comment on Table 2, I do not understand why the authors use the mean instead of the median (as I said in a previous comment, the mean is affected by potential outliers, which can have a significant impact with ~70 data points).

Reply: Thank you for correction. The median values of the respective meteorological parameters are computed. The table 2 and 2S along with relevant discussion are revised as follows:

The median values computed for the remaining meteorological parameters considered in this study are listed in Table 2. The high values in each case are indicated in bold and low values are italicized. The results show that in winter season the temperature at 850 hPa (T_{850}) is relatively high for NPCs ranging from 281 K to 285.6 K. The increase in RH% for PCs during winter ranged from (59.5)% to (71.5)%. Also, the $\Omega > 0$ for NPCs and < 0 for PCs in winter season.

In summer season, it is observed that T_{850} is comparatively higher than that for the winter clouds and ranged from 298.3 to 300.2 K and 296.5 to 298.3 K for NPCs and PCs respectively. The high values of T_{850} are due to intense solar fluxes in summer season that keep the temperature of the earth's surface and adjacent atmospheric layer higher. Also, the increase in RH% during summer ranged between 33.5-51.7 % for NPCs. The reason for the high values of wv and RH% is mainly the suitable thermodynamical conditions such as evaporation and convection due to the high temperature of earth surface and air (Sherwood, Roca, Weckwerth, & Andronova, 2010). The results show high values of RH% 70.1% (85%) in winter (summer) season for PCs over Gandhi College. Conversely, notable fluctuations in RH% are observed over the coastal city, Karachi, with values

of 71.5% (65.9%) in winter (summer). Similarly, Fig. 2S and Table 2S show the LTS conditions for PCs and NPCs. The high LTS values indicate more stable condition over Dhaka. Similarly, Table 2S shows the seasonal average values for other meteorological parameters. The results indicate high values of T_{850}, RH% and Ω 295.5 (297.5) K, 88.8 (83.5)% and -0.19 (-0.17) m/s respectively for PCs (NPCs) for over Patna in summer.

Table 12. Meteorological parameters for PCs(NPCs) in summer and winter seasons. Maximum values are for both types of clouds shown in bold and minimum values are indicated as italic.

	Winter Season			Summer Season		
	T_{850} (K)	**RH%**	**Ω (m/s)**	**T_{850} (K)**	**RH%**	**Ω (m/s)**
Karachi	**284.6 (285.8)**	**71.5** (38)	-0.038 *(0.030)*	*295.9* (298.8)	65.9 (45.9)	*0.005* (-0.003*)*
Lahore	*280.5 (281.2)*	*59.5* (35.5)	*-0.02* **(0.065)**	**298.3 (300.2)**	65 *(33.5)*	-0.028 (0.025)
Delhi	284.2 (283.1)	60.2 *(33.8)*	**-0.1** (0.04)	296.5 (299.4)	64.2 (42)	-0.05 *(-0.001)*
Kanpur	283.8 (284.1)	65.7 (36)	**-0.1** (0.048)	296.5 (298.4)	73.7 (43.6)	-0.13 (-0.08)
Jaipur	283.9 (284.1)	66 (40.5)	-0.065 (0.049)	296.8 (298.7)	*64* **(51.7)**	-0.04 (-0.029)
Gandhi College	283.2 (284.1)	70.1 **(45.7)**	**-0.1** (0.05)	296.9 *(298.3)*	**85** (42.5)	**-0.16 (-0.11)**

Table 2S. Meteorological parameters for PCs(NPCs) in summer and winter seasons. Maximum values are for both types of clouds shown in bold and minimum values are indicated as italic.

	Winter Season			Summer Season		
	T_{850} (K)	**RH%**	**Ω (m/s)**	**T_{850} (K)**	**RH%**	**Ω (m/s)**
Kolkata	***286.7*** **(*286*)**	47.4 (39.9)	-0.002 (**0.08**)	***295.5*** (295)	74.8 (72.8)	-0.15 (-0.14)
Dhaka	285.8 (285.3)	*48.5* (*49.2*)	*0.04* (**0.08**)	294.5 (294.4)	76.5 (74.6)	-0.13 (-0.10)
Patna	284.7 (284.3)	***64.6*** **(*55.8*)**	**-0.06** (0.05)	295.3 (**297.3**)	**88.8** **(83.5)**	***-0.19*** **(*-0.17*)**

9. The authors refer to the "quantification of PDF", what does this mean? Distributions do not tell you whether data sets are similar or not as it depends on the number of data considered, I think only a statistical test can answer that (Student's t-test, Kolmogorov-Smirnov test...).

Reply: Thank you for the valuable comment and suggestion. Following is the clarification for this comment.

- *Probability distribution function (PDF) is a normal or Gaussian distribution. It is a type of continuous distribution. Here, the quantification of PDF means to specify the probability of random variable within a particular range of values.*
- *In the current study the PDF is not computed to check the similarity of datasets, but to help visualize the dispersion of a parameter.*
- *Two-sample student's t test is alraedy computed in response to one of your suggestions/comment No.1.*

Commented [LY1]: I do not follow this sentence but it seems unnecessary to address the comment and can be deleted. For example,

Commented [NG2R1]: This is in response to the question asked in the first sentence of the comment.

Commented [LY3]: Better state which suggestion

Commented [NG4R3]: I mentioned the suggestion/comment number.

10. l. 282 in the main article with highlighted changes should have units

Reply: Thank you for the correction. The line 282 is revised as follows.

The results indicate high values of T_{850}, RH% and Ω are 295.5 (297.5) K, 88.8 (83.5)% and -0.19 (-0.17) m/s, respectively for PCs (NPCs) for over Patna in summer.

References

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- Nirala, M. L., & Cracknell, A. P. (2002). The determination of the three-dimensional distribution of rain from the Tropical Rainfall Measuring Mission (TRMM) Precipitation Radar. *International Journal of Remote Sensing*, *23*(20), 4263-4304.