Given the current state of the manuscript, I recommend substantial revisions and resubmission, addressing the following comments to align with the journal's standards for scientific quality, clarity, and rigor.

We thank the reviewer for the recommendation as well as for proving constructive comments and suggestions to improve the manuscript further. We have addressed all your comments and our response is provided below.

Comment: Mention the specific version of the CALIPSO data used in the current study. This is critical for understanding the availability and applicability of the data, especially since CALIPSO data is not available beyond 2020/2023, depending on the version.

Reply: In this study, CALIPSO lidar level 2, 5 km standard aerosol profile product of version 4.51(CAL_LID_L2_05kmAPro-Standard-V4-51) available over the period between June 2006-June 2023. We used dataset between 2015 and 2023 for the present study. This information is provided in the revised manuscript.

Comment: Line 105: It was mentioned that that CALIPSO data was used "during December–March between 2015 and 2024." However, the CALIPSO dataset does not extend beyond 2020/2023 (depending on the version). This needs clarification.

Reply: We thank the reviewer for pointing out this typo, which we have corrected in the revised manuscript. CALIPSO datasets over the period between December and March during 2015-2023 is utilized in this study.

Comment: Line 130 (U, V, and Speed): Mention "Speed," but it is unclear what this refers to in the context of winds (U, V components). Clarify whether this represents the resultant wind speed or another parameter.

Reply: We have clarified it in the revised manuscript as Zonal wind (U), Meridional Wind (V) and resultant wind speed ($\sqrt{U^2 + V^2}$).

Comment: On what basis it is identified that aerosols being transported from the Indo-Gangetic Plain (IGP) to Chennai? Was any pathway analysis (e.g., HYSPLIT trajectories, wind back-trajectory models, etc.) carried out to confirm the transport of aerosols?

Reply: We thank the reviewer for this comment. The main basis for aerosol transport from the Indo-Gangetic Plain to the southern Peninsula is divergence associated with the anticyclonic circulations prevalent during the winter season. It provides a pathway for the transport of pollutants from IGP to the Bay of Bengal (BoB) and further inland over the southern Indian peninsula. We have included detailed back-trajectory analysis now in the revised manuscript. Although the wind system at 850 hPa (as shown in Fig.1c of revised manuscript) provides an

estimate of such transport, we also utilized the HYSPLIT wind back trajectory model to better understand the pathway characteristics. Figure 1 e, f presents the number density of NOAA-HYSPLIT trajectory analysis for the RTE and clear days between surface (50m) and 4 km, illustrating the 5-day backward trajectories from Chennai, computed for every 6-hour interval. It also confirms that pollutants are predominantly transported across the BoB from the northern parts of India during RTE. In addition, there also observed transport from inland areas of the eastern coasts. On the other hand, the transport is predominantly from the nearby oceanic region during the clear days

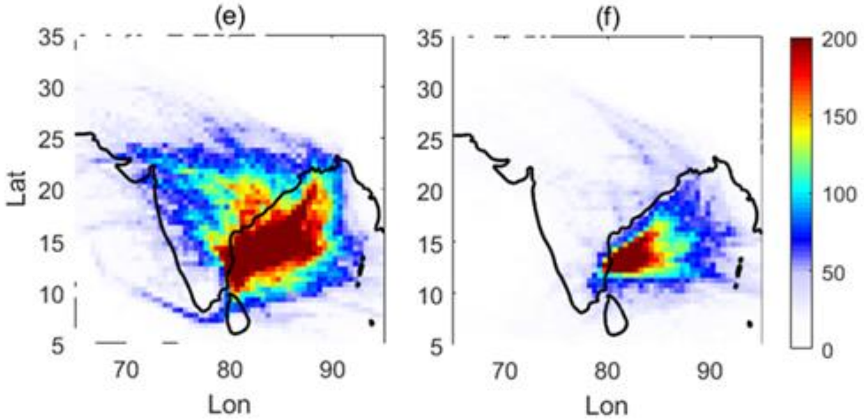

Figure 1. The number density of 5-day backward trajectories initiated from Chennai between surface and 4 km during (e) RTE and (f) Clear days.

Comment: Elaborate more on how clear days and Regional Transport Events (RTE) are categorized, including specific criteria and thresholds.

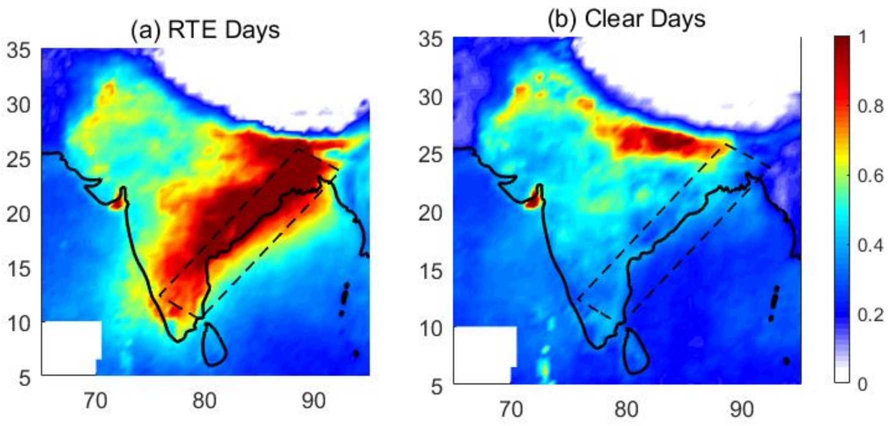

Figure 1.Composites of AOD observations from MODIS are shown separately for (a) RTE and (b) Clear days. The spatial region used to identify the RTE and Clear days are shown as a dotted box, named as eastern coastal box.

Reply: The methods for the categorization of Regional Transport Events (RTE) and clear days are elaborated on in the revised manuscript. The RTE days are characterized by significant aerosol transport from northern India to the peninsular regions, resulting in widespread haziness

across these areas. These aerosol transport events are identified based on the sudden temporal variation of aerosol optical depth (AOD) estimated from MODIS observations. Specifically, "RTE days" are defined as those days when the mean AOD exceeds 0.7 over the southeastern coastal box and adjacent regions, as illustrated in Fig. 1. In contrast, days with significantly reduced values of mean AOD (AOD < 0.3) over the spatial box are classified as "clear days".

Further, we performed back-trajectory analysis for all the identified days as RTE and Clear. The composite analysis provided the confirmatory test that RTE days are the days with visible aerosol transport from the Indo-Gangetic Plain (IGP) towards the southern Indian peninsula, as depicted in Supplementary Figure S1, are included in the analysis. While, the clear days are the days without long-range transport from North-India. The variability in MODIS-observed daily AOD values within the east coast box was analysed and it was found that AOD values equal to 0.7 and 0.3 represent the 70^{th} and 30^{th} percentile values, respectively

Moreover, it is important to note that days affected by cloud cover are excluded (i.e days with mean Cloud Fraction > 0.1) from the segregation process to ensure the reliability of both RTE and clear day classifications.

Comment: The methodology section is weak and lacks details. I recommend to rewrite this section and provide clear and elaborate explanations for all methods, including RTE categorization, endurance estimation, and aerosol transport identification.

Reply: We thank the reviewer for the suggestion to improve the methodology section. We have rewritten the section as suggested to provide detailed explanations of RTE categorization and aerosol transport identification in the revised manuscript. The HYSPLIT trajectory analysis and prevalent wind system shows evident haze transport from the northern parts of the India.

As per reviewer's suggestion, the endurance estimation of RTE events is also elaborated, and provided in detail to the comment followed.

Comment: On what basis is the endurance of RTE days estimated? Specify the data source used to determine the endurance period. What criteria or threshold are used to distinguish clear days from RTE days on a diurnal scale? Are there any previous studies reporting RTE endurance over the Indian domain? Citing prior works could strengthen your findings.

Reply: The endurance of RTE days is estimated based on the prevalence of mean AOD obtained from MODIS observation, exceeding 0.7 over the eastern-coastal box, as shown in Fig.1. Figure 1a shows the composite of the RTE days estimated between 2015 and 2024. The RTE characterization are based on a day, as MODIS AOD products (Terra+ Aqua combined) are available for 1 day period only; hence diurnal variation of such aspects are not attempted using MODIS.

As mentioned in the manuscript, the RTE generally occurs for 1 day to 4-6 days. However, we observed a prolonged RTE event sustained for 12 days during 2022. Supplementary figure Fig.S2a shows the year wise number of observations of RTE episodes during the winter season lapsed for 1 day to 5 days and, for more than 5 days. Our motivation was to highlight the endurance period of the RTE events and hence we weighted the number of observations with the duration day bins (N multiplied by day bins) as shown in Fig.S2b. For instance, the total observation of RTE endurance during 2015 for 1 day to 4 day are equal (Fig.S2a), but Fig.S2b signifies the duration of such episodes by adding weights to the day bins. Figure S2c shows the similar weighted observation as shown in Fig.S2b; however, shown for 1 day, and cumulative weighted observation between 2-4 day and more than 4 days. The discussions are included in the revised manuscript as a supplement.

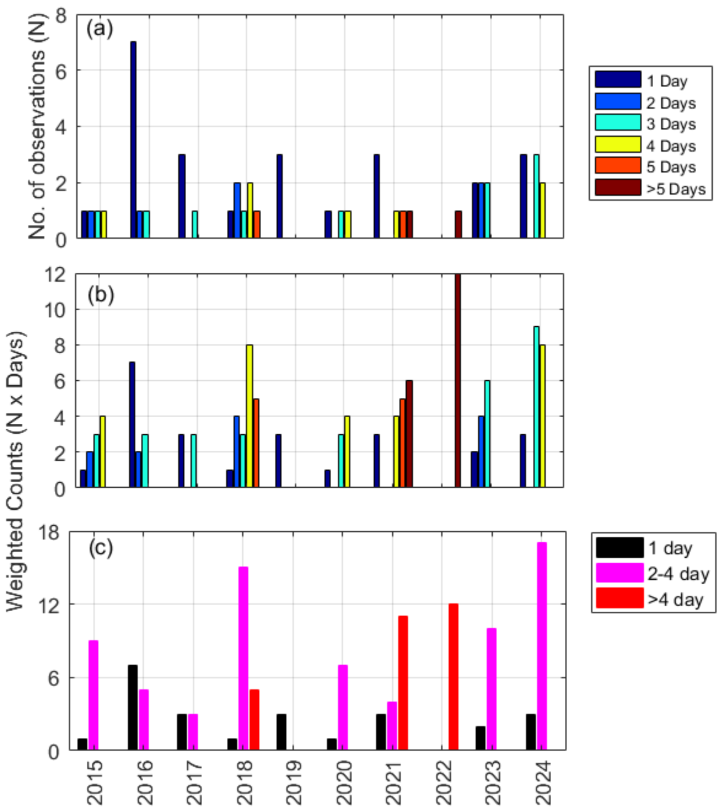

Figure S2. Annual variation of RTE occurrence duration. (a) Total number of observations (N) obtained for 1 day, 2 day, 3 day, 4 day, 5 day and more than 5 day (colour coded separately). (b) The number of observations (N) weighted by the day bins, shown separately for different day bins. (c) Same as (b) but shown the cumulative counts for 1 day (black), 2-4 day (magenta) and more than 4 day (red)

We agree with the Reviewer that, there might be diurnal variation as these RTEs is controlled by the stable boundary layer. However, we also see that the RTE episodes are generally phenomena

spanning from 1 to 5 days, so the endurance is calculated at daily resolution. This study provides a first observational framework for the transported pollutants and its impact on the boundary layer dynamics over Chennai; we have not come across with the similar observational evidence of the transport, as of our knowledge.

Comment: The region referred to as the "south-eastern coast box" is not shown in any figure. Include this region clearly in a figure for better understanding.

Reply: Thanks for the comment. The region is added in the revised manuscript as shown in Figure 1 of the manuscript.

Comment: The RH on clear days is relatively higher than on RTE days. How does hygroscopic growth contribute to the increase in endurance during RTE periods, given these RH differences?

Reply: We thank the reviewer for this thoughtful comment. However, the RH differences during RTE and clear days alone are not sufficient to infer the endurance of the RTE period in regard to the hygroscopic growth of the aerosols. Given the limited samples and instrumentations to address such factors, the statements relating to the hygroscopic growth and influence of RH on the RTE and TAL are removed from the revised manuscript.

Comment: Differences in wind fields between RTE and clear days alone may not be sufficient evidence for aerosol optical depth (AOD) enhancement over the southeastern coast and peninsular region. Provide additional supporting evidence or analysis to strengthen this.

Reply: We agree to the reviewer that the difference in the wind field during the RTE and clear day are not only factors for the AOD enhancement over the eastern coast, rather they also influenced by the aerosol loading over northern India and inland, also its transport towards the southern Indian peninsula. Figure 1e and f depicts the number density of backward trajectories obtained from the HYSPLIT back trajectory model and it shows that the aerosols observed over the southern Indian peninsula are predominantly transported from northern India during the RTE days compared to the clear days; however, it limits to the nearby oceanic region during the clear days.

Further, we also examined the change in the Aerosol Direct Radiative Forcing (ADRF) during the RTE and clear days, where aerosols effectively respond to the radiation, and provided in supplementary figure Fig.S6. Figure S6 shows the ADRF observed during the RTE and clear days, estimated from MERRA2 radiative flux observations at the surface (Thomas et al, 2019;2021). Overall, the ADRF has a net cooling at the surface both during the RTE and clear days. However, RTE episodes triggers to enhance the cooling of the surface to ~-20-40 W/m^2. Such strong cooling is observes to be around the eastern coastal regions where the aerosol transports generally occur. In specific, it reduced to less than -40 W/m^2 over the eastern coastal box where the TAL present.

During clear days (Fig.S6b) the strong cooling is confined over the IGP alone (~-25-30 W/m^2). The difference in the ADRF during the RTE and clear day composite is shown in Fig.S6c, evidencing a cooling of ~-15-20 W/m^2 by the RTE days. It also suggests that aerosol transport from the north India has a profound effect on the radiation and eventually on the ABL development and hence in the PM distributions.

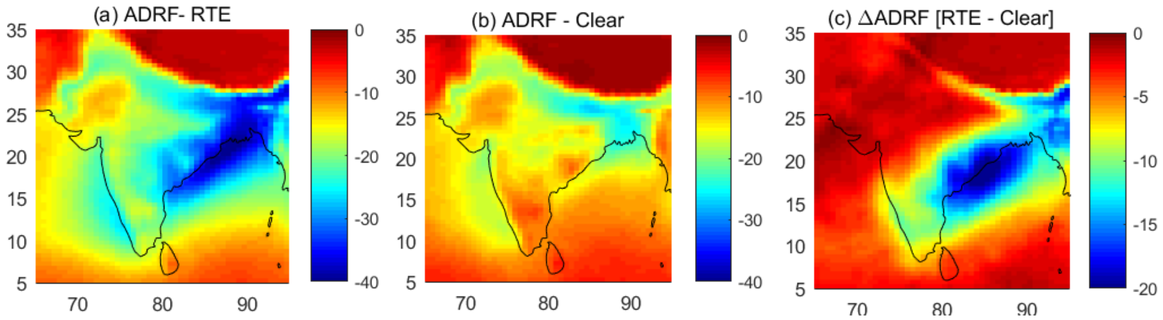

Figure S6. Aerosol Direct Radiative Forcing observed during the(a) RTE and (b) Clear days. (c) Difference between the ADRF of RTE and clear days

Comment: Line 205: Define TAL (Transported Aerosol Layer) when it first appears in the text.

Reply: As suggested, TAL is defined on its first appearance in the revised manuscript

Comment: Lines 241–257 Why were total mean diurnal changes studied instead of individual day differences? Analyzing day-specific differences may offer greater insights into variability.

Reply: We thank the reviewer for insightful suggestion. As suggested, the individual day difference along with the diurnal changes in the year 2018 alone (to avoid the interannual variations) is added in the revised manuscript and shown in Fig. 2d&e respectively.

Figure 2d shows the day averaged profiles of RTE (24,5,26,27 Jan 2018) and clear days (23,28,29, Jan 2018) observed during the typical case from MPL observations, as shown in Fig.2c. Although the extinction values is observed to similar near the surface, it rapidly decreases till ~0.8 km during the RTE days. Further, it maximizes within the altitude range ~1-2.5 km. Overall, the aerosol extinction during the RTE days are observed to be 50-60% higher during the RTE days than clear days, maximising between 1-2.5 km. Such enhancement can be attributed to the presence of TAL. The temporal changes the difference of extinction coefficients between RTE and clear days during the year 2018 is shown in Fig.2e. Similar to the typical events, the extinction coefficient during the RTE days are observed to be more than 0.25 during the forenoon hours near the surface. However, the enhancement observed above the ABL consistently maintains throughout the day.

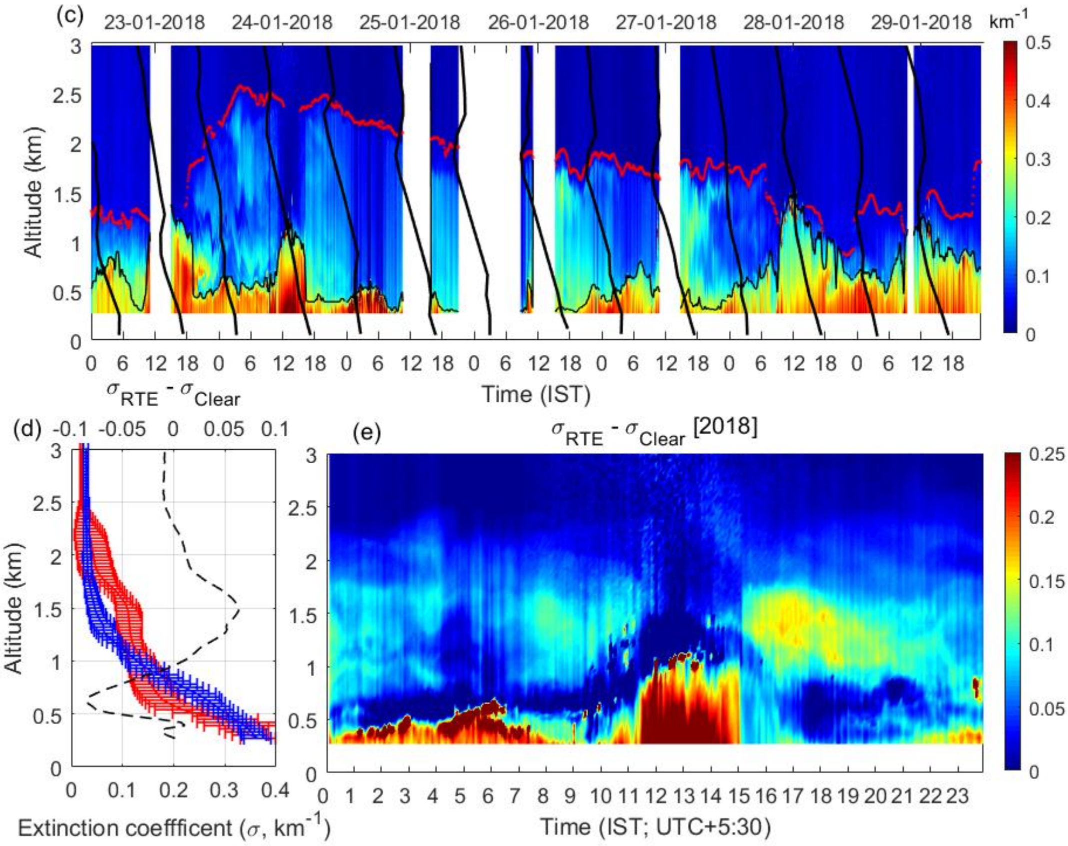

Figure 2(c) Time-Altitude cross-section of the total attenuated extinction coefficient obtained from Micro Pulse Lidar (MPL) observation over Chennai (SRM IST) between 23 and 29 January 2018. The black line corresponds to the temperature profiles from radiosonde over IMD, Chennai. The black dotted line corresponds to the derived ABL-H, and the red dotted lines are the top of the TAL. (d) Mean extinction coefficient observed during a typical RTE (24,25,26,27 Jan 2018) and clear day (23,28,29 Jan 2018) estimated from MPL observation. The difference between the extinction coefficient observed during RTE and clear day is shown as a dotted line (axis on the top). (e) Temporal changes in the difference between the extinction coefficients during the RTE and clear day composite in 2018.

Comment: Care should be taken to reduce the several typo errors in the manuscript.

Reply: The revised manuscript is thoroughly checked for any typos and corrected wherever it is.

Comment: Figure 1**:** Panels (a, b): Why is there a data gap in the bottom-left corner (65°E–70°E and 5°N–10°N)? Panels (c, d): At what altitude are the wind vectors shown? Why are wind vectors missing over the Tibetan Plateau during RTE days, while they are visible on clear days? Panel (e): The description is unclear. How are the weighted counts estimated? Are they based on monthly data or for the entire study period? Panel (f): Why are wind speed differences over high-altitude regions masked?

Justify this masking and its impact on interpretation. Suggest adding Chennai and Karaikal locations on Figure 1 for geographic reference.

Reply: We checked it thoroughly and corrected them in the revised manuscript. The pointwise responses are provided as follows:

Panels (a, b): Why is there a data gap in the bottom-left corner (65°E–70°E and 5°N–10°N)?

This data gap in the spatial distribution of MODIS AOD product is due to the unavailability of datasets in the provided grid box. This region is primarily ignored because it does not come in our area of interest. The number of datasets available in the 0.5-degree grid box (lon x lat) for both the RTE and clear days are provided in Fig R1. We also would like to mention that this area is not masked intentionally.

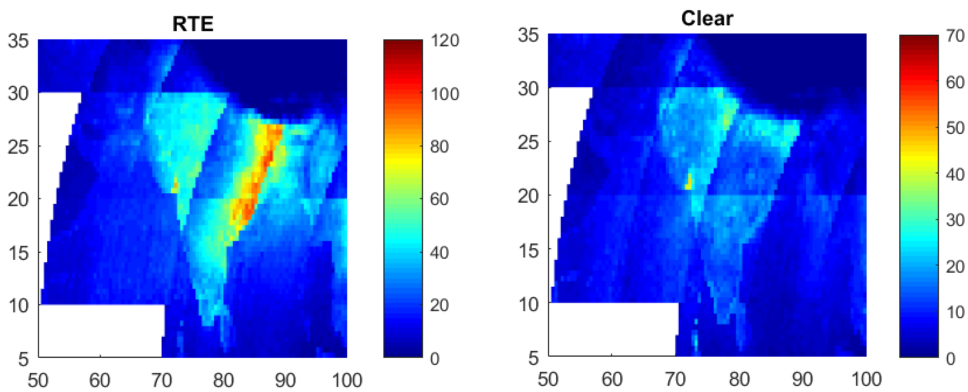

Figure R1. Availability of data samples of MODIS AOD product in a 0.5-degree grid box during both RTE and clear days between 2015 and 2024.

Panels (c, d): At what altitude are the wind vectors shown? Why are wind vectors missing over the Tibetan Plateau during RTE days, while they are visible on clear days?

The wind vectors are shown at 850 hPa, as mentioned in the figure description. The mean wind vectors of available RTE and clear days are shown in panels c and d respectively. The wind vectors across the Tibetan Plateau (TP) are available only for 4 days, hence it is eventually averaged while generating the figures. We revised the figure Fig.1b and c by removing such days since the TP does not have data for at least 70% of the observation times

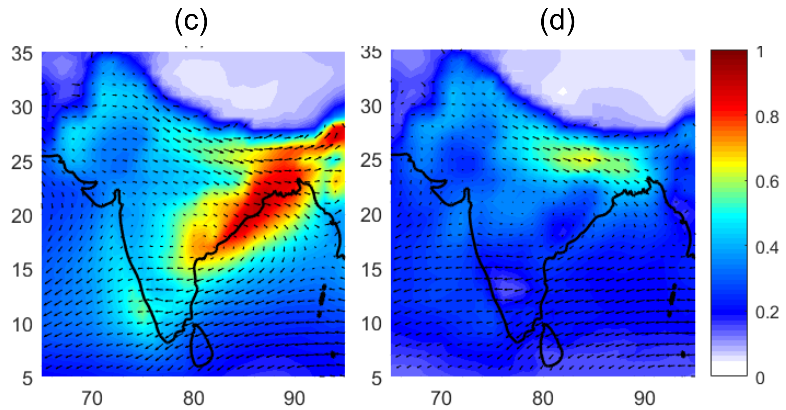

Figure 1. The total aerosol extinction (TAE) from MERRA2 reanalysis dataset observed for the composite of (b) RTE and (c) clear days superimposed with the wind vectors during the respective events

Panel (e): The description is unclear. How are the weighted counts estimated? Are they based on monthly data or for the entire study period?

The RTE episodes are categorized based on the exceedance of mean AOD within the eastern coastal box and it may last for a day to more than 12 days between December to March. Here we attempted to capture the endurance of such events based on the MODIS observations, irrespective of the months. Some events may start to be observed end of a month and last till the first week of the preceding month. Hence, the classification of the endurance of such events is per year.

We tracked the endurance of RTE events, taking the initial occurrence as day 1, till the eastern coastal box became clear day. There are multiple times an RTE occurs in an year, and their duration can be for 1 day up to 12 days. These multiple occurrences are termed as counts (N). The weighted counts are estimated by multiplying the N by the respective days. For instance, the total observation of RTE endurance during 2015 for 1 day to 4 day are equal (Fig.S2a), but Fig.S2b signifies the duration of such episodes by adding weights to the day bins. Figure S2c shows the similar weighted observation as shown in Fig.S2b; however, shown for 1 day, and cumulative weighted observation between 2-4 day and more than 4 days. The following discussions are added in the revised manuscript as a supplement.

Figure 2: Is it possible to highlight the region of interest on the map where the CALIPSO profiles are considered? This would improve clarity. Were there any close overpasses of CALIPSO to the MPL station? If yes, how consistent are the CALIPSO profiles when compared to the MPL observations? Clarify how the Atmospheric Boundary Layer Height (ABL-H) and Transported Aerosol Layer (TAL) are identified from MPL profiles.

The region of interest of CALIPSO passes are highlighted in Figure 1 in the revised manuscript, as the eastern coastal box. The vertical distribution of aerosols obtained from MPL and CALIPSO

are validated using the profiles having closest proximity to the MPL and presented in our earlier publications (Ananthavel et al., 2021a, 2021b).

The diurnal variability of ABL-H is estimated using the Wavelet Covariance Transformation (WCT) method (Reddy et al., 2021; Davis et al., 2000; Pal et al., 2010; Baars et al., 2008), which estimates the ABL-H from lidar profiles by step changes in signals using Haar function. The TAL is identified using the differential zero crossing method (Mehta et al., 2023; Ali et al., 2022), similar to the methodology followed by Mehta et al., 2023 to identify the elevated aerosol layer. In general, the extinction coefficient gradually decrease above the ABL. However, presence of TAL can increase the extinction values similar to as observed within the ABL. The differential zero crossing method identifies the top of the TAL using the gradient of extinction coefficient profiles. Note that, this method of TAL detection is used only when a valid ABL is identified.

Figure 4: Panel (a): Is this plot representative of Chennai or Karaikal? Provide clarification. Panel (c): Is the exponential fit used in the figure the most appropriate fit for the data? If possible, justify the choice of the exponential model or test alternative fits for robustness. Provide clarity regarding climatology values of ABL-H and PM2.5. Specify the data sources for these values. Indicate which data points in the figure correspond to RTE and clear days to improve interpretability.

The plot is representative of Chennai alone. The analysis is not extended over Karaikal due to the non-availability of datasets such as surface weather observations, PM and MPL.

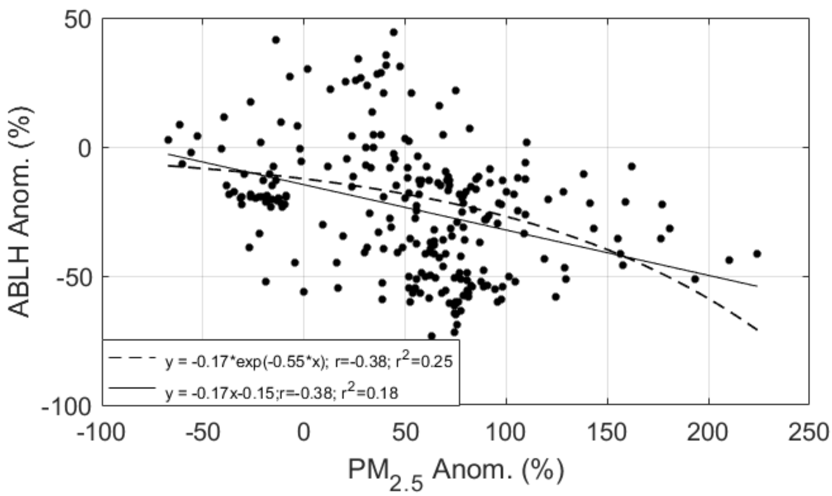

Figure R2. Scatter of PM 2.5 anomaly (%) and ABL-H anomaly over Chennai with the linear and exponential fits.

Figure R2 shows the scatter and both the linear and exponential fit of the relation between PM2.5 and ABLH anomaly. Since the r-squared value of the exponential model fit is 0.25 compared to the linear fit (0.18), the exponential fit is used to infer the relation between PM 2.5 and ABL-H anomaly over Chennai. Such approaches are followed by previous researchers for similar dust transport events in China (Su et al., 2020).

The ABL-H as shown in the panel b is derived from radiosonde thermodynamic profiles (Mehta et al., 2017), whereas panel c is solely derived from MPL observations over SRM IST (Reddy et al., 2021). PM 2.5 is obtained from US Consulate, Chennai through the AirNow data archive. Please note that the presented relation between PM2.5 and ABLH in panel c is shown only for the cases of RTE (N=255).

As discussed earlier, the term climatological values of ABL-H and PM 2.5 are inappropriate to use and hence it is changed as "mean ABL-H between 2016 and 2019" for the ABL-H, and "mean PM 2.5 between 2015 and 2024" for the PM 2.5. While mean ABL-H is estimated from MPL observations, PM 2.5 is over US Consulate, Chennai through AirNow data archive. The following discussions are added in the revised manuscript with additional information from the various radiosonde observations across the eastern coast.

Comment: Provide additional figures and clarifications, such as: Highlighting CALIPSO regions of interest in Figure 2. Marking the south-eastern coast box explicitly. Comparing CALIPSO overpasses to MPL observations.

The manuscript is thoroughly checked and revised as per the constructive comments provided by the reviewer. A comparison between the CALIPSO and MPL during an RTE day is provided in Figure R3.

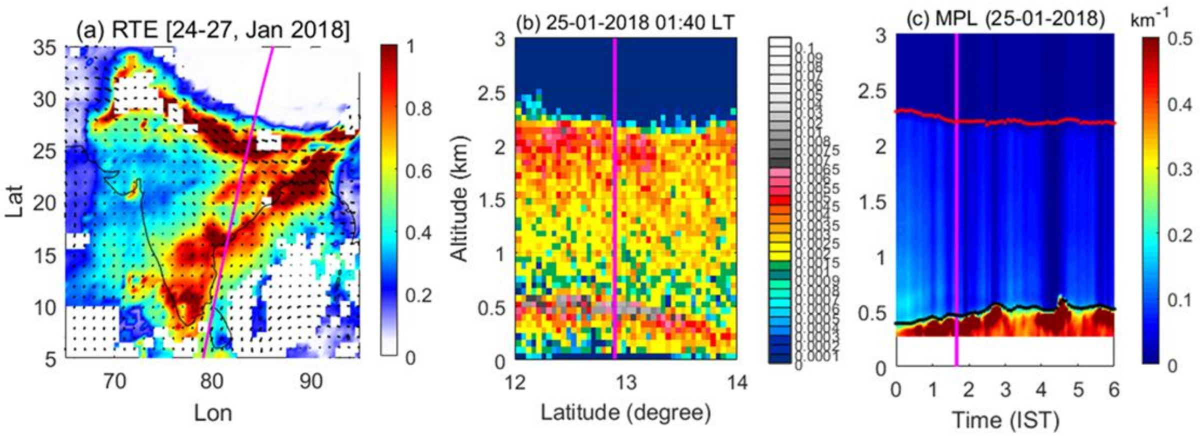

Figure R3. (a) Mean AOD obtained from MODIS between 24-27 January 2018 - typical RTE days. Wind vectors are superimposed over the figure and the magenta line corresponds to the CALIPSO overpass observed on 25-01-2018 (b) Latitude- altitude cross-section of the total attenuated backscatter obtained from CALIPSO on 25-01-2018 (nighttime). The vertical magenta corresponds to the location of SRM IST, where MPL is installed. (c) Vertical variation of aerosol extinction coefficient obtained from MPL on 25-01-2018 between 0-6 IST. The vertical magenta line corresponds to the time of pass of CALIPSO near the station.

Figure R3a shows the spatial distribution of MODIS-AOD during RTE days – 24-27 January 2018, showing a substantial increase in the AOD over the eastern coast, attributed to the aerosol transport from northern India towards the inland regions of the southern Indian

peninsula. The magenta line corresponds to the CALIPSO overpass observed on 25-01-2018 during its descending mode (nighttime). Fig.R3b shows the latitude-altitude cross-section of the total attenuated backscatter between 12-14 degree latitude band- nearest proximity of SRM IST (at ~01:40 IST) where the MPL is situated. It can be directly observed an accumulation of aerosols within 0.5 km, attributed to confinement of the aerosol within the boundary layer. The aerosol observed till ~2.3 km, attributed to the presence of TAL. Fig.R3c shows the aerosol extinction coefficient observed over Chennai (SRM IST). Similar to the CALPSO attenuated backscatter observation, MPL also shows the maximum confinement of aerosol within ~0.5 km as the ABL (shown as the black dotted line) observes at the altitude. The observed TAL, as a layer hangs above the ABL till ~2.3 km, is also observes similar to the CALIPSO detected TAL.

References:

Thomas, A., Sarangi, C., & Kanawade, V. P. (2019). Recent Increase in Winter Hazy Days over Central India and the Arabian Sea. *Scientific Reports*, *9*(1), 1-10. https://doi.org/10.1038/s41598-019-53630-3

Thomas, A., Kanawade, V. P., Sarangi, C., & Srivastava, A. K. (2021). Effect of COVID-19 shutdown on aerosol direct radiative forcing over the Indo-Gangetic Plain outflow region of the Bay of Bengal. *Science of The Total Environment*, *782*, 146918. https://doi.org/10.1016/j.scitotenv.2021.146918