ROLE OF SMOKE AEROSOLS IN GOVERNING WINTER TIME LOW-LEVEL CLOUD PROPERTIES OVER THE INDIAN REGION

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ABSTRACT

The influence of smoke aerosols on the low-level clouds over the Indian landmass during winter is examined using fifteen years (2005–2019) of long-term multi-satellite and reanalyses observations. Climatologically higher values of aerosol optical depth (AOD) (> 0.6), Angstrom exponent (> 1.5), UV-aerosol index (> 0.7), and black carbon and organic carbon (BC + OC) extinction aerosol optical thickness (EXTAOT) (> 0.18) are observed over the Indo-Gangetic Plain (IGP) compared to the rest of India. It indicates the dominance of carbonaceous aerosols over the IGP region. However, noticeable rise in AOD (~ 60%) and (BC + OC) EXTAOT (20–40%) are found over eastern parts of India, particularly Odisha and Chhattisgarh, and central-south India compared to IGP (< 10% and < 5% respectively) in the recent years. Interestingly, fire activities are also increasing over these areas and it neighborhood. This rise in aerosol loading over eastern and central-south India could be due to long-range transport from the northwestern parts and beyond and local anthropogenic emissions, including biomass burning. Besides, a significant enhancement in cloud fraction (CF) (50–60%) is noticed in and around the regions, where smoke aerosols increased considerably, implying the possible influence of smoke aerosols on the cloud properties. The present study suggests that low-level clouds persisted over most parts of the considered area during wintertime. While CF and cloud effective radius showed a noticeable increase in the polluted condition, cloud optical thickness and liquid cloud water path decreased with increase in aerosol loading. CALIPSO images suggest that a mixture of dust, polluted dust, and polluted continental/smoke aerosols dominated over the inland areas, mostly confined within 2 km altitude over the considered region. However, an elevated layer of absorbing aerosols (smoke and polluted dust) over the low-level cloud supports increased CF through the 'aerosol-cloud-boundary layer' feedback mechanism.

Keywords: Biomass burning, Smoke, Aerosol, Low-level cloud

#Abstract ID:WCP_35

Role of smoke aerosols in governing winter time low-level cloud properties over the Indian region

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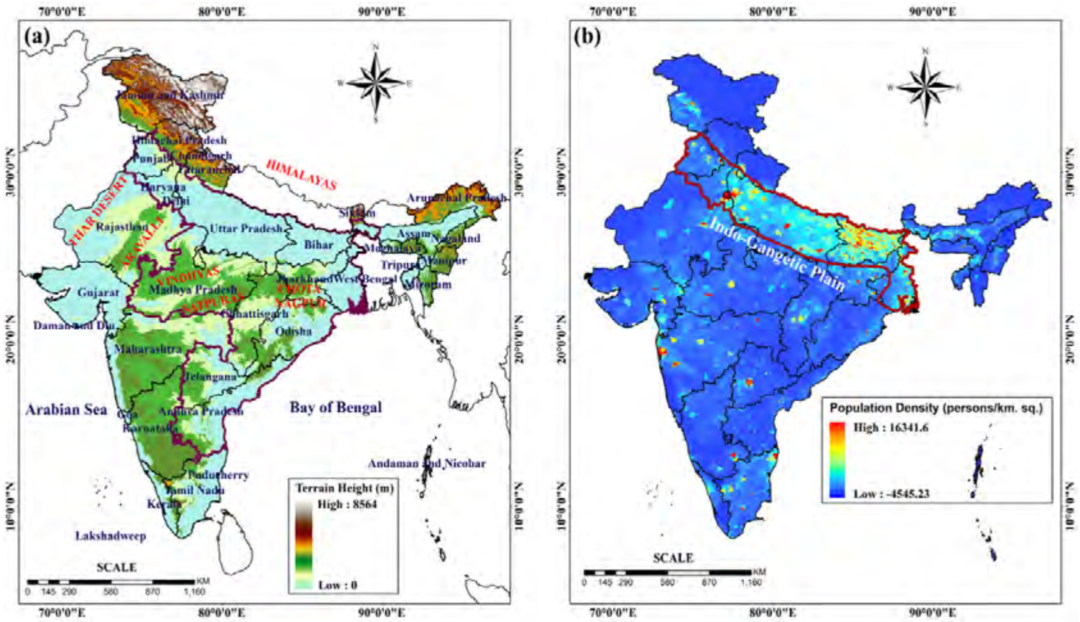

Figure 1. (a) Topography map of the study area (i.e., the Indian region). Shade denotes terrain height (in m). The purple-colored polygon represents the area considered for the statistical analysis of this study. (b) Spatial distribution of population density (persons/km^2) growth from 2010 to 2020 over India. The red polygon represents the Indo-Gangetic Plain (IGP) region, where a distinct increase in population density is observed

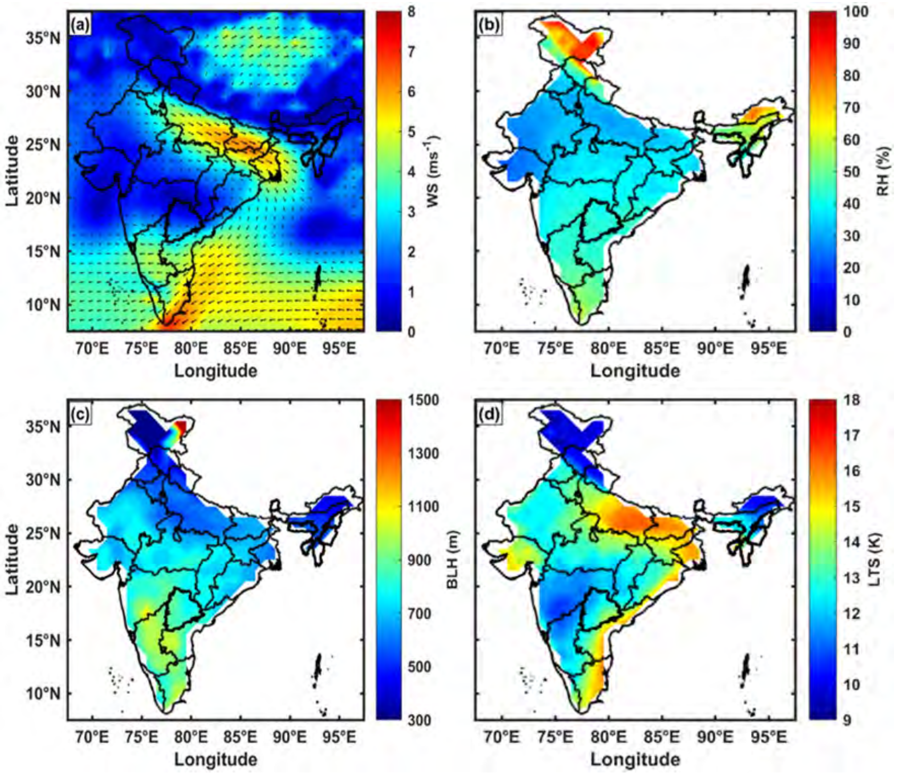

Figure 2. Spatial distribution of the climatological mean of (a) wind pattern at 850 hPa (shaded contour shows mean wind speed (WS) in ms^{-1}), (b) mid-tropospheric (700-900 hPa) relative humidity (RH) (in %), (c) daily maximum boundary layer height (BLH) (in m) and (d) lower tropospheric stability (LTS) (in K) for the period 2005-2019 during winter months (December-February) over the Indian region.

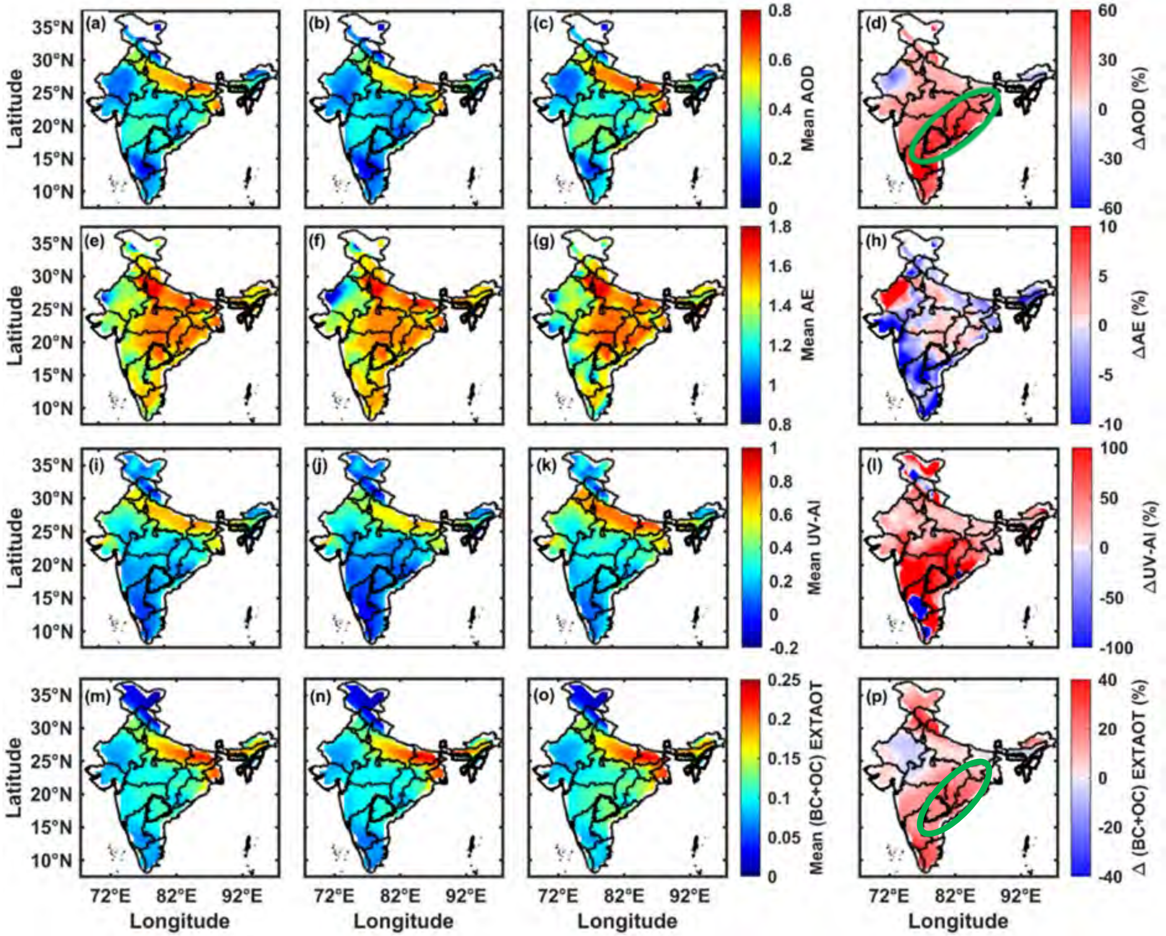

Figure 3. Spatial distribution of aerosol parameters during winter months (December-February) for the total climatological period 2005-2019 (first column), past years 2005-2009 (second column), recent years 2015-2019 (third column), and the percentage difference between recent and past years (fourth column) respectively. The first (a-d), second (e-h), third (i-l), and fourth (m-p) rows respectively represent the spatial distribution of MODIS/Aqua derived Aerosol Optical Depth (AOD), Angstrom Exponent (AE), OMI/AURA derived UV-Aerosol Index (UV-AI), and MERRA-2 derived Black Carbon (BC) and Organic Carbon (OC) Extinction Aerosol Optical Thickness (AOT) or (BC+OC) EXTAOT.

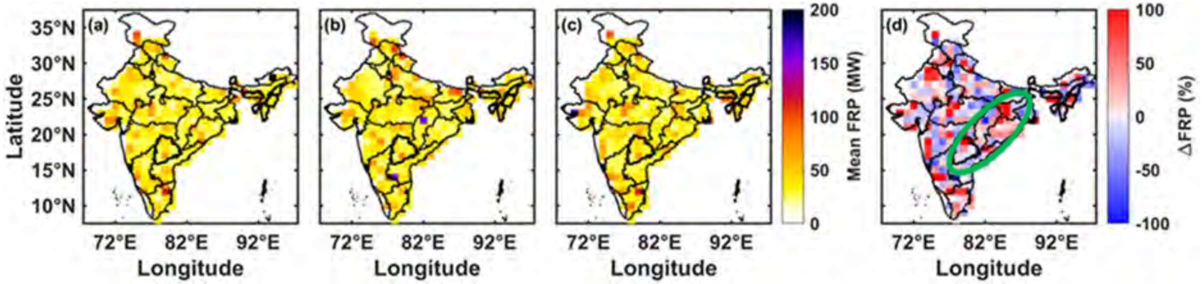

Figure 4. Spatial distribution of Fire Radiative Power (FRP) in MW during winter months (December-February) for (a) the total climatological period (2005-2019), (b) past years (2005-2009), (c) recent years (2015-2019), and (d) the percentage difference between recent and past years respectively.

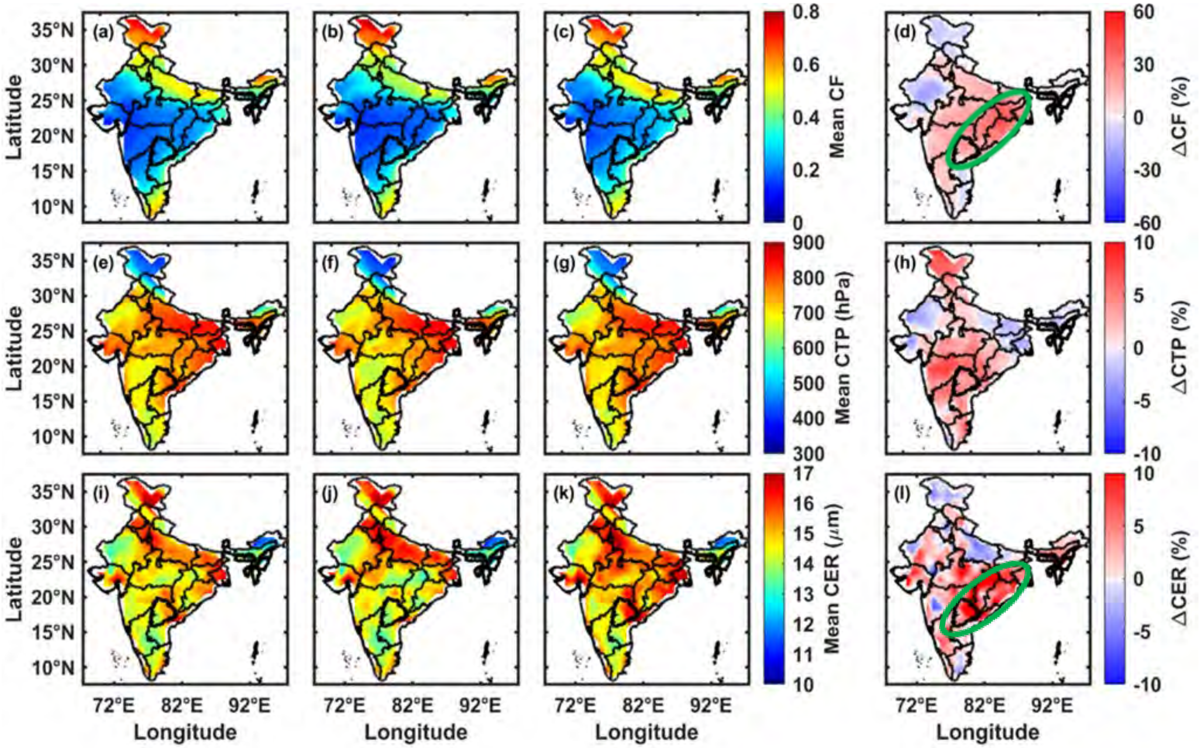

Figure 5. Same as figure 3 but for cloud properties. First (a-d), second (e-h), and third (i-l) rows respectively represent the spatial distribution of MODIS/Aqua derived Cloud Fraction (CF), Cloud Top Pressure (CTP) in hPa and Liquid Cloud Effective Radius (CER) in μm.

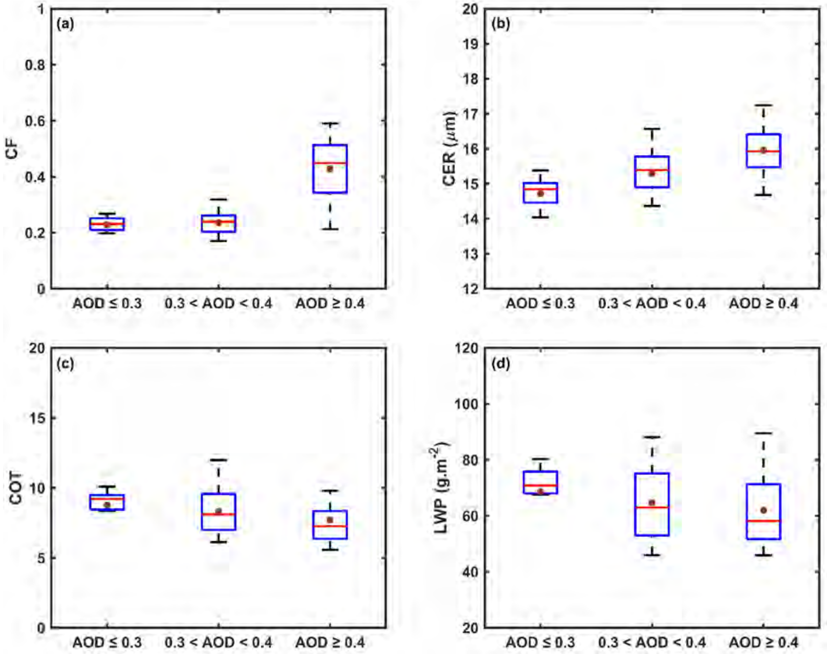

Figure 6. Variation of (a) CF, (b) CER, (c) Cloud Optical Thickness (COT) and (d) Liquid Cloud Water Path (LWP) with three different bins of AOD (AOD ≤ 0.3, 0.3 < AOD < 0.4 and AOD ≥ 0.4) for low clouds during the winter months over the study region. Box plots are produced for 5th -95th percentile ranges.

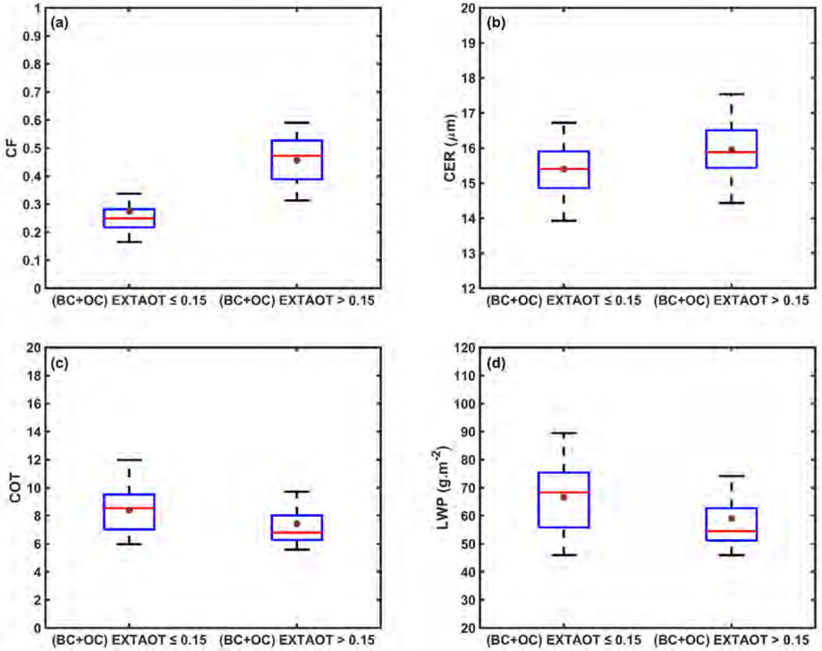

Figure 7. Variation of (a) CF, (b) CER, (c) COT and (d) LWP with two different bins of (BC+OC) EXT AOT (i.e., for ≤ 0.15, and > 0.15) for low clouds during the winter months over the study region. Box plots are produced for 5th -95th percentile ranges.

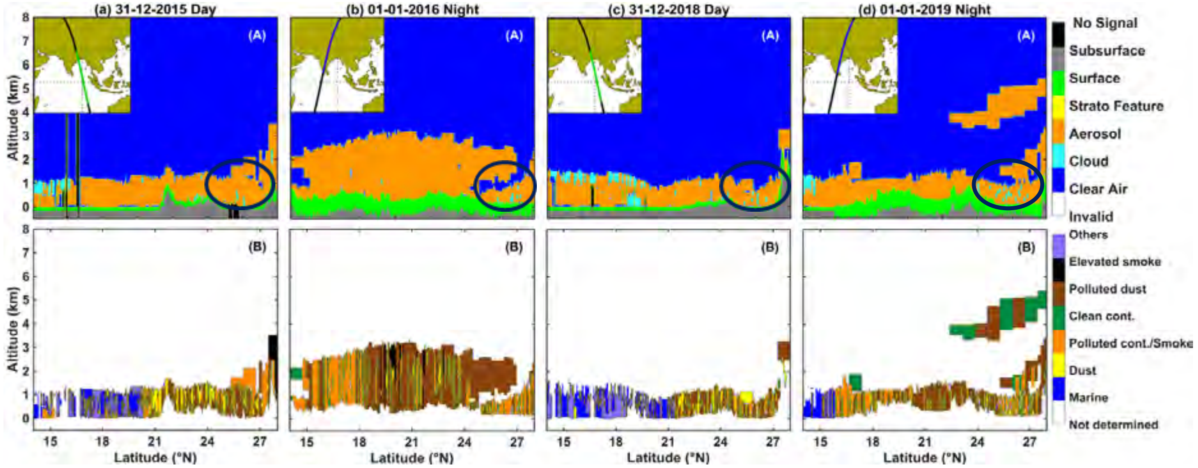

Figure 8. CALIPSO satellite observations: (A) Vertical Feature Mask and (B) Aerosol Subtypes overpass near the study region on (a) 31 December 2015 day time, (b) 1 January 2016 night time, (c) 31 December 2018 day time, and (d) 1 January 2019 night time respectively.

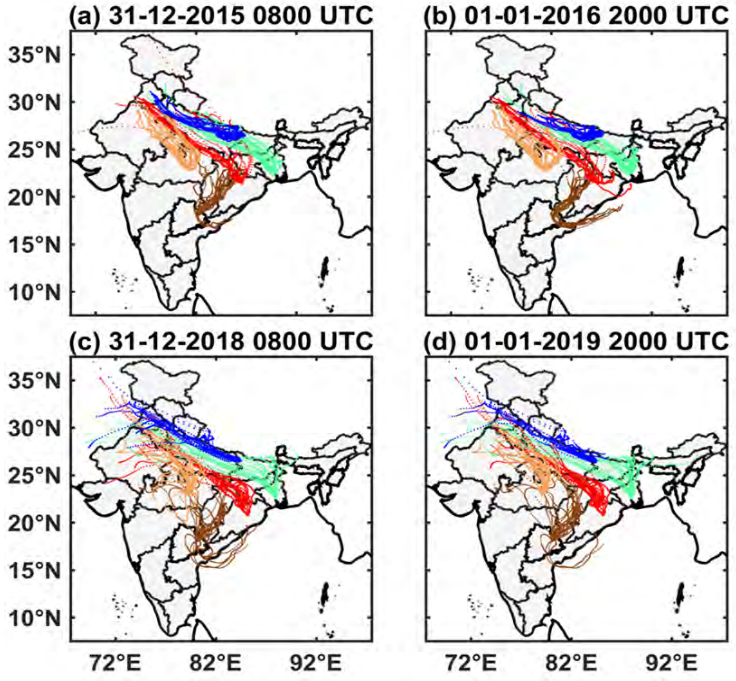

Figure 9. Seven days HYSPLIT backward trajectories ending over the selected places (Blue: latitude-26.5 °N, and longitude-84.5 °E; Green: latitude-22.5 °N, and longitude-88 °E; Red: latitude-21.5 °N, and longitude-84.5 °E; Brown: latitude-18 °N, and longitude-80 °E) in the study region at three different altitudes 500 m, 1500 m, and 3000 m on (a) 31 December 2015 0800 UTC, (b) 1 January 2016 2000 UTC, (c) 31 December 2018 0800 UTC, and (d) 1 January 2000 UTC respectively.

Summary

- The dominance of smoke aerosols is prevalent over the IGP region during winter.
- Increase in smoke aerosols and biomass burning observed over eastern and central-south India in recent years.
- CF and CER showed a considerable increase in polluted conditions.
- A mixture of dust, polluted dust, and polluted continental/smoke aerosols dominated over the inland areas, mostly confined within 2 km altitude over the considered region.
- Absorbing aerosols above the low-level cloud decks increased CF over the central IGP.

Sarkar, A., Panda, J., Kant, S., & Mukherjee, A. (2022). Influence of smoke aerosols on low-level clouds over the Indian region during winter. Atmospheric Research, 278, 106358.

Thank you