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AEROSOL CLOUD INTERACTION OVER DIFFERENT EMISSION REGIONS OF INDIA

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Abstract— **The relationship between aerosol optical depth (AOD) and cloud parameters has been analyzed over different Indian regions recognized as sources regions of different aerosol emissions. Moderate Resolution Imaging Spectroradiometer (MODIS) derived aerosol optical depth (AOD) and Cloud parameters such as cloud optical depth (COD), cloud effective radius (CER), Cloud top pressure (CTP), Cloud top temperature (CTT) from MODIS Terra was used in the study. AOD loading was higher over Northern region as compared with Southern regions of India. Over the other regions regional scale meteorological facts such as regional transport processes and local atmospheric circulation have impact on the trends. This study also examined the temporal changes to understand the relationship between AOD and cloud parameters. From the results, a positive correlation was found between AOD and CF and a negative correlation was found between AOD and CTT, CTP. COD was found increase with increase in AOD in those regions dominated by wet deposition processes of moisture absorbing aerosols. The correlation between AOD and COD was found to be positive except South India (R4). Similarly, the correlation between AOD and CER was also found to be positive except some regions (North- East India (R1), East India (R2)).**

Keywords— **Aerosol, clouds, decadal trend**

I. INTRODUCTION

Aerosol-cloud interaction has been a less understood phenomenon and it alters the earth's radiation budget in a significant scale. Aerosols indirectly influence the climate by acting as cloud condensation nuclei (CCN). Aerosol cloud interaction is quantified as Aerosol indirect effect (AIE), which results in enhancement in cloud albedo and increase in cloud lifetime (Twomey, 1977; Albrecht, 1989). While most of the studies report positive indirect effect (Increase in cloud radius with increase in aerosol), many studies have reported the opposite effect also in different part of the world (eg. Yuan et al. 2008). Aerosol -cloud interaction is reported to influence large scale systems such as monsoons (Panicker et al. 2010; Manoj et al. 2012). The aircraft-based cloud aerosol interaction and precipitation enhancement experiment (CAIPEEX) carried out has provided a deep insight into aerosol- cloud mechanism over Indian region (Kulkarni et al. 2012). Konwar et al. (2012) has shown the depth of aerosol control in warm clouds over Indian region. Harikrishnan et al. (2015) has shown that dust aerosols induce indirect effect on warm cloud over Arabian sea region. Leena et al. (2022) has studied the influence of physio-chemical properties of aerosols on cloud microphysics. Pandithurai et al. (2012) and Anil et al. 2016) has reported that the dispersion effect can significantly offset the indirect effect. Panicker et al. (2016) proposed a method to estimate the forcing arising due to aerosol-cloud interaction over Indian region. The impact of aerosol-cloud interaction on monsoon depression was studied and was found that size of cloud condensation nuclei is instrumental in activation and suppression of rainfall (Raja et al. 2020).

Many studies report the spanning of cloud cover over different Indian regions (eg: Ali et al. 2022). Different studies report the variation of cloud properties in different regions (eg: Bera et al. 2022; Leena et al. 2022). However, Studies on different properties of aerosols and its influence on clouds are sparse over Indian region. In this scenario, the present paper is intended to examine the variation of cloud properties with respect to changes in AOD over six different regions of India, which has been identified as source regions of various aerosol emissions.

II. DATA AND METHOD

To study the trends and correlations, we choose six regions (North-East India, Indo-Gangetic Plain, South India, West India, North-West India, East India) (Habib et al., 2006; Panicker and shaima. 2022) of India dominated by emissions from different sources. North-East India (R1; 24-20 ^{o}N; 88-97 ^{o} E) and East India (R2; 15-21 o N; 81-88 ^{o} E) was dominated by biomass burning, Indo-Gangetic Plain (R3 22-28 ^{o}N; 81-88E), South India (R4; 8-12 ^{o}N; 75-81 ^{o} E), West India (R5; 18-24 ^{o}N; 66-74 ^{o} E) dominated by fossil fuels and North-West India (R6; 24-32 ^{o}N;62-78 ^{o} E) dominated by desert dust

(Panicker et al. 2010). The map of selected locations are available elsewhere (Habib et al., 2006; Panicker and shaima. 2022).

MODIS (Terra) aerosol product Level 3 1˚ monthly 550 nm, area averaged time series aerosol optical depth (AOD) is utilized in the study. Cloud parameters such as Cloud fraction(CF), Cloud optical depth(COD), Cloud effective radius(CER), Cloud top pressure(CTP), and Cloud top temperature(CTT) also from MODIS Terra with spatial resolution of 1˚ used in the study. The linear regression method has been used to calculate the trends in different aerosol optical properties.

III. RESULTS AND DISCUSSIONS

A. Seasonal variation in aerosol optical depth (AOD)–

The large aerosol burden over India are mainly attributed due to: (i) Large source of local dust that tends to be lofted under hot and dry conditions, (ii) Smoke from agricultural burning, (iii) Anthropogenic pollution and (iv) Long range transport from deserts in Asia and Africa..

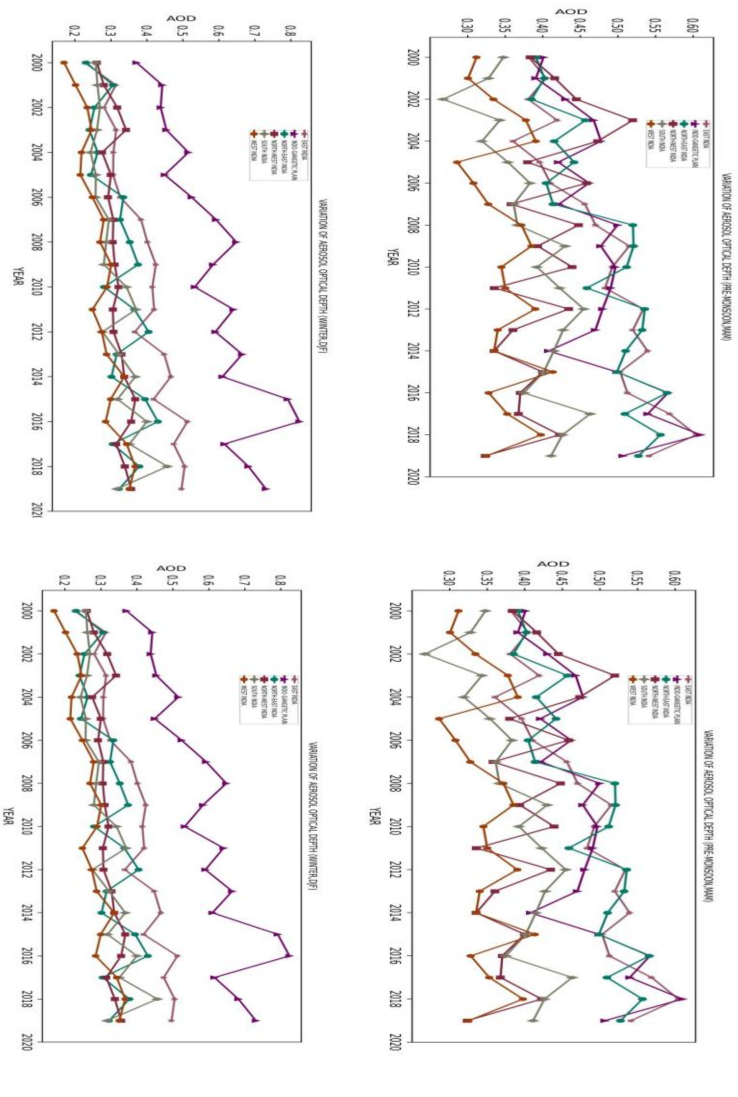

Fig 1. Seasonal variation of AOD over selected study region for the period of 2000-2019.

Major source of fine-mode aerosol is likely to be secondary aerosol formed from emission such as SO_2 with contribution from BC. Fig 1. shows the seasonal mean variation in AOD from 2000 to 2019 over the selected study regions as mentioned in section 2. Using monthly data, seasonal mean for the four seasons ie., Winter (December-January-February (DJF)), Pre-Monsoon (March-April-May (MAM)), Monsoon (June-July-August-September (JJAS)), Post-Monsoon (October-November (ON)) has been obtained. Indo Gangetic Plains (IGP) has a tendency to retain pollution within the region during winter and Monsoon. Marine air masses prevail over much of southern India, surrounded in the east, west, and south by oceans; hence, cleaner air is generally expected over this region compared to others. While Eastern India is likely to be highly influenced by what happens over IGP, Northern India is unlikely to be influenced by the emissions from the rest of India. We see the highest AOD over the IGP, followed by North-West India, East India, West India, North-East India and South India (Fig 1). The AOD loading is higher in northern India compared to the southern region. In summer months (MAM) we can see higher AOD over South India and North-East India suggested that transport of mineral dust from Arabian by westerly winds. In the post-monsoon season, the southwesterly winds weaken and reduce the dust transport to the Indian subcontinent.

B. Trends in Cloud Parameters over the Study Regions–

The trends in aerosol parameters over the selected regions were reported by Panicker and Shaima (2022). It is found that the enhancement in aerosol trend has decreased in the second decade (2010-2019) compared to first decade in (2000-2009) most of the above selected regions. Up on analyzing the trends in cloud properties, Over North-East India(R1), the trend in CF, CER and COD increased from -0.547% to 1.491% , -0.157% to -0.103% and -0.022% to 0.0802% respectively during the above decades and the trend in CTP and CTT decreased from 0.184% to 0.0412% and 0.082% to - 0.0003% respectively (table 1). Similarly in South India (R4) also the trend in CF showed a decrease of -0.0181% during 1st decade and 0.0378% during 2nd decade. Trend analysis of Cloud Fraction (CF) (Table 1) showed an increase of 0.526% during the 1st decade and a decrease of -0.247% during 2nd decade overR2. ie., the trend was about 0.773% lower in the 2nd decade than the 1st decade. Cloud Effective Radius (CER) showed an increase of 0.184% during 1st decade and the value is reduced to -0.169% during 2nd decade (Table 1). The COD trend showed an increase of 0.648% during 1st decade and -0.413% during 2nd decade over R4. CTP showed an increase of 0.382% during 1st decade, while during 2nd decade it was -0.0739% over R4 (Table 2).

Table 1: CF, CER and COD trend from 2000-2009 and 2010-2019 over selected study regions.

Sl. No.	Decadal increase/decrease					
	CF		CER		COD	
	1st decade	2nd decade	1st decade	1st decade	1st decade	2nd decade
R1	-0.547%	1.491%	-0.157%	-0.103%	-0.022%	0.0802%
R2	0.526%	-0.247%	0.184%	-0.169%	0.422%	0.539%
R3	0.550%	0.900%	0.440%	-0.081%	0.183%	0.264%
R4	-0.0181%	0.0378%	0.155%	-0.255%	0.648%	-0.413%
R5	1.455%	0.422%	0.303%	-0.441%	1.708%	-0.191%
R6	2.717%	0.278%	0.315%	-0.589%	1.635%	-0.533%

Over the IGP (R3), trend analysis of Cloud Fraction (CF) (Table 1) showed an increase of 0.550% during the 1st decade and an increase of 0.900% during 2nd decade. ie., the trend was about 0.350% higher in the 2nd decade than 1st decade. Cloud Effective Radius (CER) showed an increase of 0.114% during 1st decade and to be decreased to -0.081% during 2nd decade (Table 1). Similarly, the COD also increased from 0.183% to 0.264% during these decades (Table 2). The other parameters like Cloud Top Temperature (CTT) (Table 2) and Cloud Top Pressure (CTP) (Table 2) showed an increase of 0.074% and 0.107% during 1st decade and 0.512%, and -0.0786% during 2nd decade respectively. Ie., the trend decreased in the 2nd decade than in the 1st decade.

Table 2: CTP and CTT trend from 2000-2009 and 2010- 2019 over the selected study regions

Sl. No.	Decadal increase/decrease			
	CTP		CTT	
	1st decade	2nd decade	1st decade	2nd decade
R1	0.184%	0.0412%	0.0818%	-0.000313%
R2	0171%	0.207%	0.0221%	0.0720%
R3	0.107%	-0.0786%	0.0735%	0.0512%
R4	0.382%	-0.0739%	0.0254%	-0.0173%
R5	-0.281%	-0.252%	-0.0335%	-0.043%
R6	-0.358%	-0.0383%	-0.0074%	0.0579%

Over the North-West (R6) and West Indian (R5) region the trend in all cloud parameters shows a decreasing trend during these decades except CER in both regions and CTT over R6. CTT over R6 showed an increase of 0.0653% from 1st decade to the 2nd decade. Over R6, trend analysis of Cloud Fraction (CF) (Table 1) showed an increase of 2.717% during the 1st decade and a decrease of 0.278% during 2nd decade. ie., the trend was about 2.439% lower in the 2nd decade than 1st decade. Over R5 the trend decreased from 1.455% to 0.422% during these decades. Cloud Effective Radius (CER) showed increasing trend of 0.315% during 1st decade and the value is reduced to -0.589% during 2nd decade and CER was 0.303% during 1st and -0.441% during 2nd decades.(Table 1). Over R5, the other parameters like COD, CTT and CTP showed an increase of 1.708%, -0.0335% and -0.252% during 1st decade and decreased to -0.191%, 0.252% and 0.043% during 2nd decade respectively. Ie., the trend decreased in the 2nd decade than in the 1st decade, while over R6 COD decreased from 1.635% to -0.533% and CTP decreased from -0.358% to -0.383% during these decades (Table 2).

C. Relationship between AOD and cloud parameters– Relationship between AOD and CF,CER and COD

Cloud fraction (CF) showed a strong correlation with AOD (Table 3). CF found to increase with AOD in all the regions. During first decade (2000-2009), the observed correlation coefficients were 0.247, 0.546, 0.419, 0.393, 0.825, and 0.234 in the 1st decade and during second decade the coefficients decreased in all regions, except region R5 and R6 (0.0732, 0.234, 0.186, 0.0346, 0.835 and 0.338 in R1, R2, R3, R4, R5 and R6 respectively). The positive correlation is mainly due to the dust and burning particle injected in to the atmosphere due to urban, industrial, anthropogenic activities with the influence of meteorological conditions (Kumar. 2013). R5 is the home of very large industries, which includes foundries, chemical factories, textile plants as well as coal-fired thermal power plants and also emission from vehicles. Next to R5 the highest correlation was observed over R2 followed by R3, R4, R1 where biomass burning particles and fossil fuel burning particles are dominant and the lowest Correlation observed over R6 where desert dusts were dominant. Due to such increase in aerosol concentration, the cloud cover and CF increases and therefore, aerosol concentration changes the cloud properties (Wright et al., 2010).

During the first decade for the five regions out of six regions in India showed a positive correlation (R1, 0.389;R2, 0.338;R3,0.095; R5, 0.694; R6, 0.159) between AOD and COD. R4 region showed a negative correlation (r =-0.099) (Table 3). During second decade four regions out of six regions showed positive correlation (R1, 0.524; R2, 0.072;R5, 0.691; R6, 0.166;) other 2 regions showed less significant correlation (R4, -0.006; R3, -0.008). The reason for the positive correlation could mainly be due to the wet deposition processes of moisture-absorbing aerosols over the region. The negative correlation between AOD and COD could be influenced hydrophobic absorbing aerosols from biomass burning over R4. On the other hand, the dark aerosol in and above the cloud may also decrease the cloud reflectance observed by the satellite, which the satellite retrieval interprets as a decrease in COD (Nyasulu.et.al, 2020).

In the first decade, the three regions out of six regions in India a positive correlation (R3,0.205; R4,0.300; R5, 0.125) has been found between AOD and CER. For R1 and R2 and R6 a negative correlation (r = -0.013, -0.046, -0.204) was noticed (Table 3). During the second decade also the trend remained the same and a negative correlation was observed in the same regions (R1, -0.190; R2, -0.280; R6, -0.150). High positive correlation between AOD and CER over R4 could be due to the presence of organic soluble particle from biomass burning and giant CCN. The positive correlation may also be due to hygroscopic aerosols, which are favorable for cloud formation, contributed by sea salts and also due to coarse mode aerosol resulting from transport of dust particle over R3 and R4. Also aerosol dominated by fine particle with sufficient amount of water vapor that would increase the chance of particle hitting and blending, leading to positive correlation (Huang et al., 2020). However, the negative correlation is leading to typical aerosol indirect effect events leading due to more absorbing aerosols the regions (Panicker et al. 2010).

Table 3: Correlation between AOD and CF, CER and COD over selected study regions in India during 2000-2009 and 2010-2019.

Sl.no.	Correlation Coefficient (R)					
	CF		CER		COD	
	1st Decade	2nd Decade	1st Decade	2nd Decade	1st Decade	2nd Decade
R1	0.247	0.0732	-0.013	-0.190	0.389	0.524
R2	0.546	0.234	-0.046	-0.280	0.338	0.072
R3	0.419	0.186	0.205	0.005	0.095	-0.008
R4	0.393	0.0346	0.300	0.011	-0.099	-0.006
R5	0.825	0.835	0.125	0.054	0.694	0.691
R6	0.234	0.338	0.204	-0.150	0.159	0.166

Relationship between AOD and Cloud Top Pressure and Temperature

A negative correlation was found between AOD and CTP in both decades over 5 regions (R1,-0.303; R2,-0.527; R3,-0.428;R4,-0.343; R5,-0.764) except R6 (R6, 0.531) in 1st decade and a decreased negative correlation in the second decade (R1,-0.168; R2,-0.181; R3,-0.110; R4,-0.045;R5,-0.786; R6,-0.656) except over R5 (Table 4). The correlation between CTP and AOD also found to decrease during the 2nd decade. The correlation was higher over R5 in both decades and was lower over R1 during 1st decade and over R4 in 2nd decade. This negative correlation in CTP w.r.to increase in aerosol may be due to the increasing cloud life time as a result of suppression of precipitation which further leads to the change in cloud albedo and cloud top pressure (Balakrishnaiah et al.,2012).

Table 4: Correlation between AOD and CTT and CTP over selected study regions in India during 2000-2009 and 2010-2019

Sl.no.	Correlation Coefficient (R)			
	CTT		CTP	
	1st Decade	2nd Decade	1st Decade	2nd
R1	-0.291	-0.146	-0.303	-0.168
R2	-0.474	-0.106	-0.527	-0.181
R3	-0.410	-0.114	-0.428	-0.110
R4	-0.305	-0.004	-0.343	-0.045
R5	-0.640	-0.706	-0.764	-0.786
R6	-0.053	-0.080	0.531	-0.656

Cloud top temperature (CTT) is the temperature at the cloud top level and plays an important role in the net earth's radiation budget. CTT also followed the same trend as of CTP with a negative correlation wr.to AOD in both the decades in all the regions (Table 4). (R1,-0.291; R2,-0.474; R3,-0.410; R4,-0.305; R5,-0.640; R6,-0.053 in 1st decade R1,-0.146; R2,-0.106; R3,-0.114;R4,-0.004; R5,-0.706; R6,-0.080 in 2nd decade) Enhancement in aerosols (anthropogenic aerosol) changes the cloud top temperature and humidity profile and there by changes the cloud top temperature (Sekiguchi et al., 2003). The results of AOD vs CTT and CTP are in general showing -ve relation illustrates an increase in aerosols are not bringing out high clouds over the regions.

IV. CONCLUSION

- Over North-East India(R1), the trend in CF, CER and COD increased from -0.547% to 1.491% , -0.157% to -0.103% and -0.022% to 0.0802% respectively during the above decades and the trend in CTP and CTT decreased from 0.184% to 0.0412% and 0.082% to - 0.0003% respectively.
- Cloud fraction (CF) showed a strong correlation with AOD. CF increases with AOD in all the regions. The positive correlation is mainly due to the dust and burning particle injected in to the atmosphere due to urban, industrial, anthropogenic activities etc. R5 is the home of very large industries and very high correlation observed. Next to R5 the highest correlation observed over R2 followed by R3, R4, R1 where biomass burning particles and fossil fuel burning particles are dominant and the lowest Correlation observed over R6 where desert dusts were dominant.
- The correlation between CER and AOD found to be positive in general over all regions (except R1 and R2 and R6 in second decade). The positive correlation may also be due to hygroscopic aerosols, which are favorable for cloud formation, contributed by sea salts and also due to coarse mode aerosol resulting from transport of dust particle.
- COD was found to increase with increase in AOD in those regions dominated by wet deposition processes of moisture absorbing aerosol particularly, from biomass burning. Also absorbing aerosols, which don't grow with moisture lead to an increase in COD. The less correlation between AOD and COD could be influenced by reduced anthropogenic activities, change in seasonal circulations and other meteorological factors.
- CTP was observed to be increased with decrease in AOD. ie., CTP decreased in most of the regions as AOD increased (Except R6 in 1st decade). The correlation was higher over R5 and lower over R1 during 1st decade and during 2nd decade correlation was highest over R5 and least over R1 because the emissions were higher over R5 and lower over R1 during these decades. Over R4 very less negative correlation observed. This negative correlation may be due to the increasing cloud lifetime. Also the cloud top pressure decreases there too with AOD, because the cloud effective radius increases with a decreasing cloud top pressure.
- The correlation between AOD and CTT was observed to be negative as CTT increased with decrease in AOD. Here

the correlation was higher over R5 due to high fossil fuel emissions and lower over R1 and a very less correlation observed over R6 during 1st decade. Similarly during 2nd decade also the highest correlation was observed over R5 and the least was observed over R2. Also, a very less correlation was found in R4 and R6. AOD vs CTT and CTP are in general showing negative relation means, increase in aerosols are not bringing out high clouds.

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DECLARATIONS
Conflict of Interest Not applicable to the best of our knowledge.

VI. REFERENCE

[1] Alam, K., Khan, R., Blaschke, T., Mukhtiar, A. (2014). Variability of aerosol optical depth and their impact on cloud properties in Pakistan. Journal of Atmospheric and Solar-Terrestrial Physics, 10.1016/j.jastp.2013.11.012, vol.107, (pg.104–112).

[2] ALBRECHT, B. A. (1989). Aerosols, Cloud Microphysics, and Fractional Cloudiness. Science, 245(4923),10.1126/science.245.4923.1227.(pg.1227–1230).

[3] Ali, S., Sanjay Kumar Mehta, Aravindhavel Ananthavel, Ramesh, V. (2022). Temporal and vertical distributions of the occurrence of cirrus clouds over a coastal station in the Indian monsoon region. Atmospheric Chemistry and Physics,10.5194/acp-22-8321-2022,vol.22(12), (pg.8321–8342).

[4] Vasudevan Anil Kumar, Govindan Pandithurai, Parakkatt Parambil Leena , Kundan K. Dani , Palani Murugavel , Sunil M. Sonbawne , Rohit D. Patil , Rajamma Sukumaran Maheskumar (2016). Investigation of aerosol indirect effects on monsoon clouds using ground-based measurements over a high-altitude site in Western Ghats. Atmospheric Chemistry and Physics, 10.5194/acp-16-8423-2016. Vol, 16(13), (pg.8423–8430).

[5] Balakrishnaiah, G., Raghavendra kumar, K., Suresh Kumar Reddy, B., Rama Gopal, K., Reddy, R. R., Reddy, L.S.S.,Suresh Babu, S. (2012). Spatio-temporal variations in aerosol optical and cloud parameters over Southern India retrieved from MODIS satellite data. Atmospheric Environment,. 10.1016/j.atmosenv.2011.10.032, vol.47, (pg.435–445).

[6] Bera, S., Subharthi Chowdhuri, Prabha, T. V. (2022). A new methodology for the statistical descriptions of Particle-by-Particle measurements of liquid droplets in cumulus clouds. Quarterly Journal of the Royal Meteorological Society,. 10.1002/qj.4234. vol.148(743), (pg. 842–859).

[7] Gopal, K. R., Obul Reddy, K. R., Balakrishnaiah, G., Arafath, S. MD., Kumar Reddy, N. S., Rao, T. C., … Reddy, R. R. (2016). Regional trends of aerosol optical depth and their impact on cloud properties over Southern India using MODIS data. Journal of Atmospheric and Solar-Terrestrial Physics,. 10.1016/j.jastp.2016.05.005. vol.146, (pg. 38–48).

[8] Habib, G., Venkataraman, C., Chiapello, I., Ramachandran, S., Boucher, O., Shekar Reddy, M. (2006). Seasonal and interannual variability in absorbing aerosols over India derived from TOMS: Relationship to regional meteorology and emissions. Atmospheric Environment, 10.1016/j.atmosenv.2005.07.077 , vol. 40(11), (pg.1909–1921).

[9] Harikishan, G., Padmakumari, B., Maheskumar, R. S., Kulkarni, J. R. (2015). Radiative effect of dust aerosols on cloud microphysics and meso-scale dynamics during monsoon breaks over Arabian sea. Atmospheric Environment, 10.1016/j.atmosenv.2015.01.037. vol.105, (pg 22–31).

[10] Huang, J., Bu, L., K. Raghavendra Kumar, Khan, R., N.S.M.P. Latha Devi. (2020). Investigating the relationship between aerosol and cloud optical properties inferred from the MODIS sensor in recent decades over East China. Atmospheric Environment,. 10.1016/j.atmosenv.2020.117812.vol,239,(pg.117812–117812).

[11] Jethva, H., Satheesh, S. K., Srinivasan, J. (2005). Seasonal variability of aerosols over the Indo-Gangetic basin. Journal of Geophysical Research, 10.1029/2005jd005938. Vol. 110(D21).

[12] Kang, N., Kumar, K. R., Yin, Y., Diao, Y., Yu, X. (2015). Correlation Analysis between AOD and Cloud Parameters to Study Their Relationship over China Using MODIS Data (2003–2013): Impact on Cloud Formation and Climate Change. Aerosol and Air Quality Research, 10.4209/aaqr.2014.08.0168. vol. 15(3), (pg. 958–973).

[13] Kaufman,Y.J.(2006).Smoke and Pollution Aerosol Effect on Cloud Cover. Science,. 10.1126/science.1126232. 313, (pg.655–658).

[14] Konwar, M., Maheskumar, R. S., Kulkarni, J. R., Freud, E., Goswami, B. N., Rosenfeld, D. (2012). Aerosol control on depth of warm rain in convective clouds. Journal of Geophysical Research: Atmospheres, vol. 117(D13), 10.1029/2012jd017585

[15] Kulkarni, J. R., Maheskumar, R. S., Morwal, S. B., Kumari, B. P., Konwar, M., Deshpande, C. G.,

Vijayakumar, R. (2012). The Cloud Aerosol Interaction and Precipitation Enhancement Experiment (CAIPEEX): overview and preliminary results. Current Science, vol. 102(3), (pg. 413–425).

[16] Kumar, A. (2013). Variability of aerosol optical depth and cloud parameters over North Eastern regions of India retrieved from MODIS satellite data. Journal of Atmospheric and Solar-Terrestrial Physics, 10.1016/j.jastp.2013.03.025. vol. 100-101, (pg.34–49).

[17] Kumar, A. (2014). Long term (2003–2012) spatio-temporal MODIS (Terra/Aqua level 3) derived climatic variations of aerosol optical depth and cloud properties over a semi arid urban tropical region of Northern India. AtmosphericEnvironment,.10.1016/j.atmosenv.2013.10.030. vol. 83, (pg.291–300).

[18] Leena, P. P., Kumar, V. A., Mukherjee, S., Patil, R. D., Sonbawne, S. M., Pandithurai, G. (2022). Influence of aerosol physico-chemical properties on cloud microphysical parameters perceived using in-situ high altitude observations. Atmospheric Research ,vol.271, 10.1016/j.atmosres.2022.106111.

[19] M.G. Manoj, P.C.S. Devara, Joseph, S., Sahai, A. K. (2012). Aerosol indirect effect during the aberrant Indian Summer Monsoon breaks of 2009. Atmospheric Environment,. 10.1016/j.atmosenv.2012.06.007. vol. 60, (pg.153–163).

[20] Myhre, G., Frode Stordal, Johnsrud, M., Kaufman, Y., Rosenfeld, D., Trude Storelvmo, … Isaksen, I. S. A. (2007). Aerosol-cloud interaction inferred from MODIS satellite data and global aerosol models. Atmospheric Chemistry and Physics,. 10.5194/acp-7-3081-2007. Vol.7(12), (pg.3081–3101).

[21] Nyasulu, M., Haque, M. M., Boiyo, R., Kumar, K. R., Zhang, Y.-L.(2020).Seasonal climatology and relationship between AOD and cloud properties inferred from the MODIS over Malawi, Southeast Africa. Atmospheric Pollution Research,.10.1016/j.apr.2020.07.023. vol. 11(11),(pg. 1933–1952).

[22] Pandithurai, G., Sudhakar Dipu, Prabha, T. V., Maheskumar, R. S., Kulkarni, J. R., Goswami, B. N. (2012). Aerosol effect on droplet spectral dispersion in warm continental cumuli. Journal of Geophysical Research ,.10.1029/2011jd016532. Vol.117(D16)

[23] Panicker, A. S., N. Shaima. (2022). Climatology and Trends in Aerosol Optical Properties over Different Emission Regions in India. Pure and Applied Geophysics,. 10.1007/s00024-022-03032-w. vol.179(6-7), (pg.2523–2535).

[24] Panicker, A. S.,Pandithurai,G.,Dipu, S.(2010).Aerosol indirect effect during successive contrasting monsoon seasons over Indian subcontinent using MODIS data. Atmospheric Environment.10.1016/j.atmosenv.2010.02. 015. vol. 44(15), (pg.1937–1943).

[25] Panicker, A. S., Pandithurai, G., Safai, P. D., Prabha, T. V. (2016). Indirect forcing of black carbon on clouds over northeast India. Quarterly Journal of the Royal Meteorological Society, vol. 142(701),(pg. 2968–2973). 10.1002/qj.2878.

[26] Porch,W.,Chylek, P., Dubey, M., Massie, S.(2007). Trends in aerosol optical depth for cities in India. Atmospheric Environment,10.1016/j.atmosenv.2007.05. 055. vol. 41(35),(pg. 7524–7532).

[27] Raja, B., Maheskumar, R. S., Padmakumari, B. (2020). System driven changes in aerosol-cloud interactions and its impact on the life-cycle of a monsoon depression. Atmospheric Research, 10.1016/j.atmosres.2019.104765. vol. 235.

[28] Ramachandran,S.,Kedia,S.,Srivastava, R.(2012). Aerosol optical depth trends over different regions of India .Atmospheric Environment,.10.1016/j.atmosenv.2011.11. 017. vol. 49, (pg. 338–347).

[29] S, Twomey. (1977). The Influence of Pollution on the Shortwave Albedo of Clouds. Journal of the Atmospheric Sciences,.10. vol. 34(7),(pg. 1149–1152).

[30] S. Suresh Babu, Manoj, M. R., K. Krishna Moorthy, Gogoi, M. M., Nair, V. S., Sobhan Kumar Kompalli, … Singh, D. (2013). Trends in aerosol optical depth over Indian region: Potential causes and impact indicators, , 10.1002/2013jd020507. vol. 118(20).

[31] Sarkar, S., Chokngamwong, R., Cervone, G., Singh, R. P., Kafatos, M. (2006). Variability of aerosol optical depth and aerosol forcing over India. Advances in Space Research, 10.1016/j.asr.2005.09.043. vol. 37(12), (pg. 2153–2159).

[32] Sekiguchi, M., Nakajima, T., Suzuki, K., Kawamoto, K., Higurashi, A., Rosenfeld, D., Mukai, S. (2003). A study of the direct and indirect effects of aerosols using global satellite data sets of aerosol and cloud parameters. Journal of Geophysical Research: Atmospheres,10.1029/2002j d003359. Vol. 108(D22).

[33] Tang, J., Wang, P., Mickley, L. J., Xia, X., Liao, H., Yue, X., Xia, J. (2014). Positive relationship between liquid cloud droplet effective radius and aerosol optical depth over Eastern China from satellite data. Atmospheric Environment,. 10.1016/j.atmosenv.2013.08.024. vol.84, (pg.244–253).

[34] Tomasi, C., Lupi, A. (2016). Primary and Secondary Sources of Atmospheric Aerosol. Atmospheric Aerosols, 10.1002/9783527336449.ch1. (pg.1–86).

[35] V. Sreekanth. (2016). Discussion on linear long-term trends in aerosol and cloud properties over India and its surrounding waters. Advances in Space Research, 10.1016/j.asr.2016.02.015. vol. 57(10),(pg. 2104–2114).

[36] Wright, M. E., Atkinson, D. B., Ziemba, L., Griffin, R., Hiranuma, N., Brooks, S., Kelley, P. (2010). Extensive aerosol optical properties and aerosol mass related measurements during TRAMP/TexAQS 2006 – Implications for PM compliance and planning. Atmospheric Environment,.10.1016/j.atmosenv.2008.12. 055. vol. 44(33), (pg. 4035–4044).

[37] Yuan, T., Li, Z., Zhang, R., Fan, J. (2008). Increase of cloud droplet size with aerosol optical depth: An observation and modeling study. Journal of Geophysical Research, 10.1029/2007jd008632 . Vol. 113(D4).

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