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Research Article

A Comparative Study of Atmospheric Black Carbon Aerosols over Thar Desert: Jaisalmer

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Abstract

To investigate the monthly mean variability on average BC mass concentration, the individual day values are grouped into 24-hour periods, sunlight hours, night hours and complete average day-to-day changes in the 24-hour average BC values. Sunlight hours BC values and Night Hours BC level variation along with mean monthly BC aerosols levels for the complete study period from March, 2009 to Feb., 2014. Average monthly BC aerosols magnitudes are illustrated that during entire study period of BC observation, a large day to day BC aerosols variations in their 24 hourly average, Sun light hours along with, night time hours values occur within ranges of 0.12 to 12.16 $\mu\text{g m}^{-3}$, 0.95 to 14.29 $\mu\text{g m}^{-3}$ and 0.12 to 16.87 $\mu\text{g m}^{-3}$, respectively Their annual mean values of above study period as well as Annual BC behaviors clearly reveal peak during December and January (~ 6.5 to $10 \mu\text{g m}^{-3}$), a gradual decline to the annual lowest (~ 0.7 to $1.8 \mu\text{g m}^{-3}$) attained during May through September months (summer and monsoon) with a maximum to minimum monthly BC values ratio of >6 . The overall combined annual long-term means BC level value of five years at Jaisalmer is $2.3 \pm 1.9 \mu\text{g m}^{-3}$ for the whole day mean BC levels.

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1. INTRODUCTION

Atmospheric Black Carbon (BC) aerosols, i.e., the most prominent light-absorbing carbonaceous aerosols, are mostly of an anthropogenic nature, and it is prominent optically available in small amounts to a significant portion of fine-size particulate matter (Cachier, 1988) [11]. It is largely produced as the by-product of incomplete burning processes like fossil fuel burning (for example, exhaust from automobiles, industrial and power plants, emissions from ships and aircraft, etc.) and biomass burning activities (for example, burning of bio-fuels, agricultural waste, forest fires, etc.) (Koelmans *et al.*, 2006) [24]. Although BC shares only a small fraction of the total composite aerosols mass concentration, it shows a large spatial variability mostly associated with varieties of the living patterns, urban and industrial activities (Cachier, 1988; Gelencser, 2004) [11, 20]. BC is a strong optical absorber of solar and outgoing terrestrial useful radiations over a wide wavelength range from near-UV (ultraviolet) to IR (infrared) and is a potential contributor to mainly positive aerosol radiative forcing and thereby warming of the earth atmosphere and cooling of the earth surface (Jacobson, 2001; Babu *et al.*, 2004; Ramanathan and Carmichael, 2008) [23, 7, 38]. In the last few decades researcher estimates by IPCC that the global mean clear sky radiative forcing by BC aerosols is 0.05 and 1.0 Wm^{-2} (IPCC, 2013) [22]. Recent works have also demonstrated the indirect effects of BC aerosols through modification of cloud albedo and lifetime properties in the cloud radiative forcing (Ackerman *et al.*, 2000; Corrigan *et al.*, 2006) [2, 14]. This large atmospheric warming potential of BC has raised several hypotheses and questions recently, such as BC building homes in the upper atmosphere, increasing atmospheric instability and the lifetime of BC (Babu *et al.*, 2011) [8] and lofting to the stratosphere, leading to the slowing down of stratosphere ozone recovery (Satheesh *et al.*, 2013) [43]. Being mostly chemical inert and in the fine size range of aerosol size spectrum, BC aerosols species has relatively longer residence life time in atmosphere from several days to weeks depending on the precipitation conditions etc., (Reddy and Venkataraman, 1999; Babu and Moorthy, 2001, 2002) [40, 3, 4] and hence is amenable for long range and intercontinental transportation of air pollutants outflow as BC aerosols (Babu *et al.*, 2011) [8]. Despite the above, BC responds quickly to emission change by reducing the short term local anthropogenic sources activity period such as in National strike call period (Kompalli *et al.*, 2013) [25] or rapidly remove from the air either by deposition or wash out by precipitation (Bond *et al.*, 2013) [10], therefore, mitigation of BC as anthropogenic aerosols is often projected as a short-term climate forcing agent and ad hoc solution to slow down global warming (Bond *et al.*, 2013) [10].

From the perspective of the above, characteristics of BC by direct measurements, especially over the Indian region, have been studied by the Indian Space Research Organisation (ISRO) under its Geo-sphere Biosphere Programme (GBP) research

project with the establishment of a regional network of aerosol observatories.

ARFINET (Babu *et al.*, 2013) [6], covering distinct geographical environments. The long-term BC measurement is being carried out along with other aerosol parameters (Moorthy & Satheesh, 2011) [29]. extensive and long-term regular measurements of BC were also initiated from a western Indian region in March 2009, by establishing an atmospheric aerosols observatory at Jaisalmer (Geo. Lat. 26.95°N, Geo. Long. 70.55°E, ALT. 225m above mean sea level; amsl), a tropical arid and typical rural hot climate site located in the Thar Desert region. This site has been considered primarily the scarcity of such long term data specific to this region as well as its distinct nature of proximity to the tropical Thar desert activity and dust dominated arid environment, which experiences large change in seasonal source regions from where significant surface aerosols of local as well as regional manmade mixed natural mineral dust aerosols contributed activities sources are low vehicular exhaust, biomass burning, high windblown dust, long range transportation of air pollutants from distant desert, human made activities at polluted sources region to experimental site.

The extensive multiyear regular BC aerosols data collected so far throughout the five years, i.e., from March, 2009 to Feb., 2014, have been examined for the first time for the characterisation of various time variability of BC aerosols of different time scales over Jaisalmer.

2. DATA AND METHODOLOGY

The long-term BC measurement is being carried out along with other aerosol parameters (Moorthy & Satheesh, 2011) [29]. And, some of the region-specific features from the southern, central, and eastern parts of India have already been reported by several earlier groups. Under this activity, extensive and long term regular measurements of BC was also initiated from a western Indian region in March, 2009, by establishing atmospheric aerosols observatory at Jaisalmer (Geo. Lat. 26.95°N, Geo. Long. 70.55°E, ALT. 225m above mean sea level; amsl), a tropical arid and typical rural hot climate site located in the Thar Desert region. This site has been considered primarily the scarcity of such long term data specific to this region as well as its distinct nature of proximity to the tropical Thar desert activity and dust dominated arid environment, which experiences large change in seasonal source regions from where significant surface aerosols of local as well as regional manmade mixed natural mineral dust aerosols contributed activities sources are low vehicular exhaust, biomass burning, high windblown dust, long range transportation of air pollutants from distant desert, human made activities at polluted sources region to experimental site.

The extensive multiyear regular BC aerosols data collected so far throughout the five years i.e., from March, 2009 to Feb., 2014 have been examined first time for characterization of various time variability of BC aerosols of different time scales over Jaisalmer and their impact of local, regional and synoptic

meteorological conditions, boundary layer dynamics parameters, wind trajectories on the surface BC aerosols pollution level, over less populated desert influences areas.

3. RESULTS AND DISCUSSIONS

The inspection of individual annual BC values in different periods, a remarkable gradual decreasing trend is large inter-annual variation in BC levels is also clearly visible from their yielded annual mean values of 2.7 ± 2.2 , 2.4 ± 2.1 , 2.2 ± 1.5 , 2.7 ± 1.7 , and $3.1 \pm 1.6 \mu\text{g m}^{-3}$ for the period 2009-10, 2010-11, 2011-12, 2012-13, and 2013-14, respectively. Thus, to compare the present study results with other reported annual BC values over several Indian cities, as well as from this study in the Indian map, as shown in Figure 1.

It is a clear evident from the earlier workers that such typical BC values (2.7 ± 2.2 , 2.4 ± 2.1 , 2.2 ± 1.5 , 2.7 ± 1.7 , and $3.1 \pm 1.6 \mu\text{g m}^{-3}$) are quite lower values then relative to those reported annual BC values from other suburban and semi-urban

locations in India, such as at Hissar ($1.5\text{-}7.2 \mu\text{g m}^{-3}$; Ramachandran *et al.*, 2006) [37], at Pune ($4.1 \mu\text{g m}^{-3}$; Safai *et al.*, 2007) [42], Bhubaneswar ($5.2 \mu\text{g m}^{-3}$; Das *et al.*, 2009), Darjeeling ($5.6 \mu\text{g m}^{-3}$; Chatterjee *et al.*, 2010) [12], Kulu ($4.6 \mu\text{g m}^{-3}$; Kuniyal, 2010) [42], Shillong ($5 \mu\text{g m}^{-3}$; Kundu & Borgohain, 2010) [26] and Trivandrum ($5 \mu\text{g m}^{-3}$; Babu & Moorthy, 2002; Abish *et al.*, 2007) [4, 1] despite of their different altitudes and above the mean sea level or even some of urban centers such as at Ahmadabad ($6.2 \mu\text{g m}^{-3}$; Ramachandran & Kedia, 2010) [35], Hyderabad ($5.5 \mu\text{g m}^{-3}$; Dumaka *et al.*, 2010b), while BC over Jaisalmer is also much lower than those reported from urban conglomerations or industrial cities such as Delhi ($16 \mu\text{g m}^{-3}$; Tiwari *et al.*, 2009; Singh *et al.*, 2010) [45, 44], Kanpur ($12.3 \mu\text{g m}^{-3}$; Tripathi *et al.*, 2005b) [47], Mumbai ($12.5 \mu\text{g m}^{-3}$; Venkatraman *et al.*, 2002) [48], Agra ($20.6 \mu\text{g m}^{-3}$; Safai *et al.*, 2007 & 2008) [42, 41], and Dibrugarh ($11 \mu\text{g m}^{-3}$; Pathak *et al.*, 2010) [32].

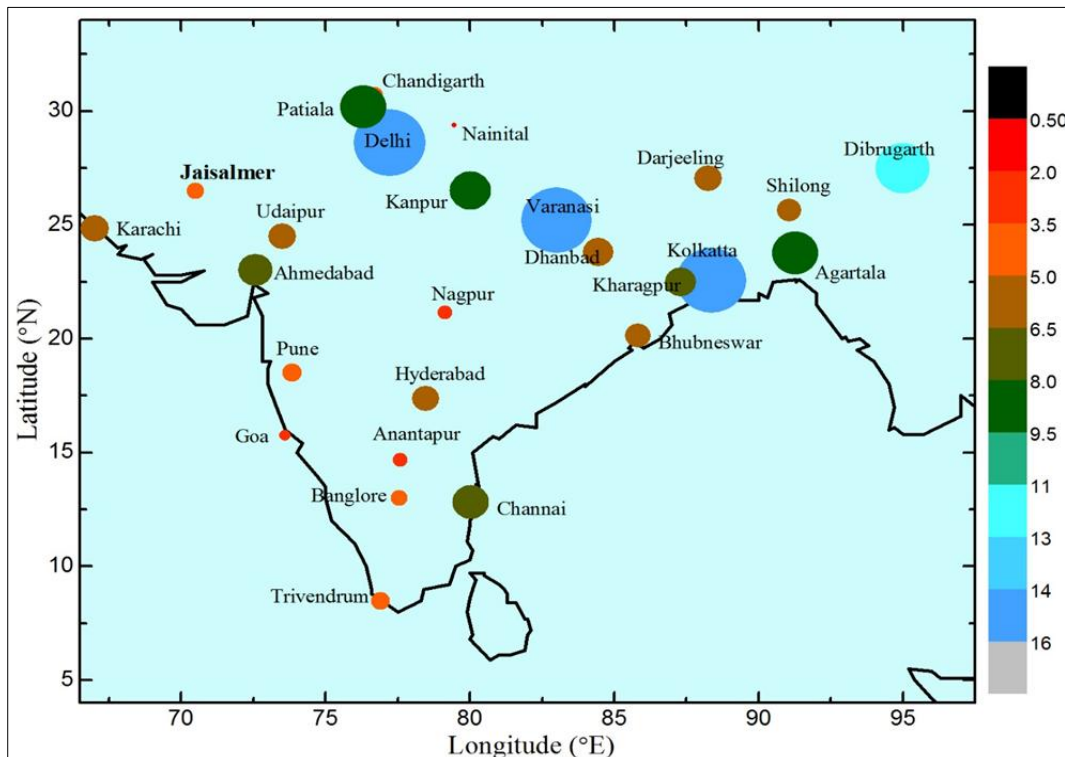


Fig 1: Annual BC Mass concentration ($\mu\text{g m}^{-3}$) over several different Indian Locations, along with observed location Jaisalmer, Colour Bar shows the (also BC magnitude of circle) annual Magnitude of BC Mass concentration of reference locations.

At the same time, the annual mean BC over Jaisalmer reported (Table 1) is a comparatively higher than those reported from other rural, high altitude and less polluted regions, such as, Annantpur ($1.97 \mu\text{g m}^{-3}$; Kumar *et al.*, 2011), Nanital ($1.10 \mu\text{g m}^{-3}$; Dumka, 2010a) [16], Sinhadgad ($1.5 \mu\text{g m}^{-3}$; Raju *et al.*, 2011), Minicoy ($0.4 \mu\text{g m}^{-3}$; Vinoj *et al.*, 2010) and Port Blair ($1.8 \mu\text{g m}^{-3}$; Moorthy & Babu, 2006). Hence, Jaisalmer represents a significant amount of BC absorbing anthropogenic

aerosols, loading characteristics of the atmospheric air pollution level. Thus, marginally higher BC aerosol concentration at the observing location is noticed relative to a similar range of other Indian rural areas, along with a profound interannual BC aerosol variation over the entire observational period. However, anthropogenic BC aerosol levels over highly polluted, heavily populated and industrialised major Indian cities are observed to be higher than their observed annual BC values at Jaisalmer.

Table 1: BC Mass Concentration ($\mu\text{g m}^{-3}$) at Study Location of Thar Desert, i.e. Jaisalmer, other Indian locations, and nearby study locations.

Location	Type	Period	BC Concentration ($\mu\text{g m}^{-3}$)	References
Jaisalmer	Rural	March 2009 to Feb., 2014	2.6±1.9 (0.8, Pre-Monsoon - 8.5, Winter)	Present study
Trivandrum	Urban Coastal	Aug., 2000 to Oct., 2001	0.3-5	Babu <i>et al.</i> (2002) ^[4]
Bangalore	Urban	November 2001	4.2	Babu <i>et al.</i> (2002) ^[4]
Hyderabad	Urban	January to July 2003	0.5-68 (dry), 0.5-45 (wet)	Latha and Badrinath (2003) ^[28]
		(Feb, 2004)	2	Ganguly <i>et al.</i> (2005b) ^[19]
		(Jan, 2006)	21	Beegum <i>et al.</i> (2009) ^[9]
		(Dry, 2003)	0.5-68	Latha and Badarinath (2003) ^[28]
Mumbai	Urban Industrial	(Dry, 1999)	12.4 -5.1	Venkataraman <i>et al.</i> (2002) ^[48]
		(Dry, 2001)	8.2	Chowdhury <i>et al.</i> (2007) ^[13]
Delhi	Urban Industrial	(Annual, 2006-2007)	4-15	Singh <i>et al.</i> (2010) ^[44]
		(Annual, 2007)	14 -12	Tiwari <i>et al.</i> (2009) ^[45]
		(Jan, 2006)	27	Beegum <i>et al.</i> (2009) ^[9]
Agra		(Dec, 2004)	20.6	Safai <i>et al.</i> (2007) ^[42]
Kanpur	Urban	December 2004	6-20	Tripathi <i>et al.</i> (2005a) ^[46]
		(Dry, 2007-2008)	4.9-1.5	Ram <i>et al.</i> (2010) ^[33, 34]
Nainital	Rural (high altitude)	December 2004	1.36	Pant <i>et al.</i> (2006) ^[31]
Pune		(Annual, 2005)	4.1	Safai <i>et al.</i> (2007) ^[42]
		(Annual, 2002)	2.1	Rastogi and Sarin (2009) ^[39]
Ahmadabad		(Dry, 2002-2005)	5.5- 2.8	Ganguly <i>et al.</i> (2006) ^[18]
		(Dry, 2008)	11.6 -2.9	Ramachandran and Kedia, 2010 ^[35]
		(Jan, 2004)	5	Ramachandran and Rajesh (2007) ^[36]
Chandigarh		(Annual, 2001)	3.7	Chowdhury <i>et al.</i> (2007) ^[13]
Karachi		(Annual, 2006-2007)	2-3	Dutkiewicz <i>et al.</i> (2009) ^[17]
Allahabad		(Dec, 2004)	6.2-2.0	Ram and Sarin (2010) ^[33, 34]
Hisar		(Dec, 2004)	1.5-7.2	Ramachandran <i>et al.</i> (2006) ^[37]
Kharaghpur		(Dec, 2004)	8.0-28.0	Nair <i>et al.</i> (2007) ^[30]
		(Jan, 2006)	9.3	Beegum <i>et al.</i> (2009) ^[9]
Kolkata		(Dry, 2001)	26.5	Chowdhury <i>et al.</i> (2007) ^[13]
Lahore		(Dry, 2005-2006)	21.7	Husain <i>et al.</i> (2007) ^[21]

4. CONCLUSIONS

Based on results obtained from BC data analysis of five years collected in the course of this Paper, the following main salient features of BC were clearly revealed over the typical Indian Thar Desert Station, i.e., Jaisalmer. The present study documents the annual average BC aerosols mass concentration pattern as observed over Jaisalmer during the years from March, 2009 to Feb., 2014

The annual average BC concentrations at Jaisalmer are found to be in the order of $2.3 \pm 1.9 \mu\text{g m}^{-3}$, during March, 2009- Feb., 2014. These BC values are smaller than those earlier reported BC values for other similar Indian semi-urban and urban cities, i.e., Hissar, Pune, Ahmadabad, Hyderabad, Bhubaneswar, Darjeeling, Kulu, Shillong and Trivandrum. Whereas, this typical Jaisalmer BC value is much smaller than those measured in other major industrial and highly polluted areas like Delhi, Kanpur, Mumbai, Agra and Dibrugarh. However, the annual BC magnitude over Jaisalmer is higher than that reported over other semi-rural, high altitude, less polluted coastal and continental regions such as Anantapur, Nainital, Sinhad, Minicoy, Port Blair and Goa.

REFERENCES

1. Abish B, Moorthy KK, Babu SS. Aerosol black carbon over a tropical coastal location: response to mesoscale and synoptic scale processes. *Journal of Marine and Atmospheric Research*. 2007;3(1):118–126.
2. Ackerman AS, Toon OB, Stevens OB, Heymsfield AJ, Ramanathan V, Welton EJ. Reduction of tropical cloudiness by soot. *Science*. 2000;288:1042–1047.
3. Babu SS, Moorthy KK. Anthropogenic impact on aerosol black carbon mass concentration at a tropical coastal station: a case study. *Current Science*. 2001;81(9):1208–1214.
4. Babu SS, Moorthy KK. Aerosol black carbon over a tropical coastal station in India. *Geophysical Research Letters*. 2002;29(23):2098. Available from: <https://doi.org/10.1029/2002GL015662>
5. Babu SS, Chaubey JP, Moorthy KK, Gogoi MM, Kompalli SK, Sreekanth V, *et al.* High altitude measurements of black carbon aerosols over western trans-Himalayas: seasonal heterogeneity and source apportionment. *Journal of Geophysical Research: Atmospheres*. 2011;116:D24201. Available from: <https://doi.org/10.1029/2011JD016722>
6. Babu SS, Manoj MR, Moorthy KK, Gogoi MM, Nair VS, Kompalli SK, *et al.* Trends in aerosol optical depth over the Indian region: potential causes and impact indicators. *Journal of Geophysical Research: Atmospheres*. 2013;118:11794–11806. Available from: <https://doi.org/10.1002/2013JD020507>

7. Babu SS, Moorthy KK, Satheesh SK. Aerosol black carbon over the Arabian Sea during the inter-monsoon and summer monsoon seasons. *Geophysical Research Letters*. 2004;31:L06104. Available from: <https://doi.org/10.1029/2003GL018716>
8. Babu SS, Moorthy KK, Manchanda RK, Sinha PR, Satheesh SK, Vajja DP, *et al.* Free tropospheric black carbon aerosol measurements using a high-altitude balloon. *Geophysical Research Letters*. 2011;38:L08803. Available from: <https://doi.org/10.1029/2011GL046654>
9. Beegum SN, Moorthy KK, Babu SS, Satheesh SK, Vinoy V, Badarinath KVS, *et al.* Spatial distribution of aerosol black carbon over India during the pre-monsoon season. *Atmospheric Environment*. 2009;43:1071–1078.
10. Bond TC, Doherty SJ, Fahey DW, Forster PM, Berntsen T, DeAngelo BJ, *et al.* Bounding the role of black carbon in the climate system: a scientific assessment. *Journal of Geophysical Research: Atmospheres*. 2013. Available from: <https://doi.org/10.1002/jgrd.50171>
11. Cachier H. Carbonaceous combustion particles. In: Harrison M, Van Grieken RE, editors. *Atmospheric Particles*. New York: John Wiley; 1988. p.295–349.
12. Chatterjee A, Adak A, Ghosh SK, Raha S, Singh AK, Yadav Y. Atmospheric black carbon removal with efficient rainfall scavenging over Darjeeling during SW monsoon. *IASTA Bulletin*. 2010;19(1–2):442–443.
13. Chowdhury Z, Zheng M, Schauer JJ, Sheesley RJ, Salmon LG, Cass GR, *et al.* Speciation of ambient fine organic carbon particles and source apportionment of PM_{2.5} in Indian cities. *Journal of Geophysical Research*. 2007;112:D15303. Available from: <https://doi.org/10.1029/2007JD008386>
14. Corrigan CE, Ramanathan V, Schauer JJ. Impact of monsoon transitions on the physical and optical properties of aerosols. *Journal of Geophysical Research*. 2006;111:D18208. Available from: <https://doi.org/10.1029/2005JD006370>
15. Das N, Baral SS, Sahoo SK, Mohapatra RK, Ramulu TS, Das SN, *et al.* Aerosol physical characteristics at Bhubaneswar, the east coast of India. *Atmospheric Research*. 2009;93:897–901.
16. Dumka UC, Sinha PR, Manchanda RK, Sreenivasan S. Seasonal and diurnal variation of black carbon aerosols over Hyderabad, India. *IASTA Bulletin*. 2010;19(1–2):440–441.
17. Dutkiewicz VA, Alvi S, Ghauri BM, Choudhary MI, Husain L. Black carbon aerosols in urban air in South Asia. *Atmospheric Environment*. 2009;43:1737–1744.
18. Ganguly D, Jayaraman A, Gadhavi H. Physical and optical properties of aerosols over an urban location in western India: seasonal variabilities. *Journal of Geophysical Research*. 2006;111:D24206. Available from: <https://doi.org/10.1029/2006JD007392>
19. Ganguly D, Jayaraman A, Gadhavi H, Rajesh TA. Features in the wavelength dependence of aerosol absorption over central India. *Geophysical Research Letters*. 2005b;32:L13821. Available from: <https://doi.org/10.1029/2005GL023023>
20. Gelencser A. *Carbonaceous aerosol*. Dordrecht: Springer; 2004.
21. Husain L, Dutkiewicz VA, Khan AJ, Ghauri BM. Characterisation of carbonaceous aerosols in urban air. *Atmospheric Environment*. 2007;41:6872–6883.
22. Intergovernmental Panel on Climate Change. *Climate change 2013: the physical science basis*. 2013. Available from: <http://www.climatechange2013.org>
23. Jacobson MZ. Strong radiative heating due to the mixing state of black carbon. *Nature*. 2001;409:695–697.
24. Koelmans AA, Jonker MT, Cornelissen G, Bucheli TD, Van Noort PC, Gustafsson O. Black carbon: the reverse of its dark side. *Chemosphere*. 2006;63:365–377.
25. Kompalli SK, Moorthy KK, Babu SS. Rapid response of atmospheric black carbon to anthropogenic sources. *Atmospheric Science Letters*. 2013. Available from: <https://doi.org/10.1002/asl2.483>
26. Kundu SS, Borgohain A. BC mass concentration and AOD characteristics over Meghalaya. ISRO-GBP Report; 2010. p.81–83.
27. Kuniyal JC. Aerosols climatology over the north-western Indian Himalayan region. ISRO-GBP Report; 2010. p.93–99.
28. Latha MK, Badarinath KVS. Black carbon aerosols over a tropical urban environment: a case study. *Atmospheric Research*. 2003;69:125–133.
29. Moorthy KK, Satheesh SK. Black carbon aerosols over India. *Black Carbon Bulletin*. 2011;3(2):1–3.
30. Nair VS, Moorthy KK, Alappattu DP, Kunhikrishnan PK, George S, Nair PR, *et al.* Wintertime aerosol characteristics over the Indo-Gangetic Plain. *Journal of Geophysical Research*. 2007;112:D13205. Available from: <https://doi.org/10.1029/2006JD008099>
31. Pant P, Hedge P, Dumka UC, Sagar R, Satheesh SK, Moorthy KK, *et al.* Aerosol characteristics at a high-altitude location in the central Himalayas: optical properties and radiative forcing. *Journal of Geophysical Research*. 2006;111:D17206. Available from: <https://doi.org/10.1029/2005JD006768>
32. Pathak B, Kalita G, Bhuyan K, Bhuyan PK, Moorthy KK. Aerosols temporal characteristics and their impact on shortwave radiative forcing at a location in the northeast of India. *Journal of Geophysical Research*. 2010;115:D19204. Available from: <https://doi.org/10.1029/2009JD013462>
33. Ram K, Sarin MM. One-year record of carbonaceous aerosols from urban sites in the Indo-Gangetic Plain: characterisation, sources, and temporal variability. *Journal of Geophysical Research*. 2010;115:D24313. Available from: <https://doi.org/10.1029/2010JD014188>
34. Ram K, Sarin MM, Hegde P. Long-term record of aerosol optical properties and chemical compositions from a high-altitude site in the central Himalaya. *Atmospheric*

- Chemistry and Physics. 2010;10(23):11791–11803. Available from: <https://doi.org/10.5194/acp-10-11791-2010>
35. Ramachandran S, Kedia S. Black carbon aerosols over an urban region: radiative forcing and climate impact. *Journal of Geophysical Research*. 2010;115. Available from: <https://doi.org/10.1029/2009JD013560>
36. Ramachandran S, Rajesh TA. Black carbon aerosol mass concentrations over Ahmadabad: comparison with urban sites in Asia, Europe, Canada, and the United States. *Journal of Geophysical Research*. 2007;112:D06211. Available from: <https://doi.org/10.1029/2006JD007488>
37. Ramachandran S, Rengarajan R, Jayaraman A, Sarin MM, Das SK. Aerosol radiative forcing during clear, hazy and foggy conditions over a continental polluted location in north India. *Journal of Geophysical Research*. 2006;111. Available from: <https://doi.org/10.1029/2006JD007142>
38. Ramanathan V, Carmichael G. Global and regional climate changes due to black carbon. *Nature Geoscience*. 2008;1:221–227.
39. Rastogi N, Sarin MM. Quantitative chemical composition and characteristics of aerosols over western India: one-year record of temporal variability. *Atmospheric Environment*. 2009;43:3481–3488.
40. Reddy MS, Venkataraman C. Direct radiative forcing from anthropogenic carbonaceous aerosols over India. *Current Science*. 1999;76:1005–1011.
41. Safai PD, Kewat S, Pandithurai G, Ali K, Tiwari S, Rao PSP, *et al.* Aerosol characteristics during winter fog at Agra, North India. *Journal of Atmospheric Chemistry*. 2008;61:101–118.
42. Safai PD, Kewat S, Praveen PS, Rao PSP, Momin GA, Ali K, *et al.* Seasonal variation of black carbon aerosols over a tropical urban city of Pune, India. *Atmospheric Environment*. 2007;41:2699–2709.
43. Satheesh SK, Moorthy KK, Srinivasan J. Elevated layers of anthropogenic aerosols aggravate stratospheric ozone loss. *Atmospheric Environment*. 2013;79:879–882. Available from: <https://doi.org/10.1016/atmosenv.2013.07.052>
44. Singh S, Soni K, Bano T, Tanwar RS, Nath S, Arya BC. Clear-sky direct aerosol radiative forcing variations over mega-city Delhi. *Annales Geophysicae*. 2010;28:1157–1166.
45. Tiwari S, Srivastava AK, Bisht DS, Bano T, Singh S, Behura S, *et al.* Black carbon and chemical characteristics of PM10 and PM2.5 at an urban site of North India. *Journal of Atmospheric Chemistry*. 2009;62:193–209.
46. Tripathi SN, Dey S, Tare V, Satheesh SK. Aerosol black carbon radiative forcing at an industrial city in northern India. *Geophysical Research Letters*. 2005a;32:L08802. Available from: <https://doi.org/10.1029/2005GL022515>
47. Tripathi SN, Dey S, Tare V, Satheesh SK, Lal S, Venkataramani S. Enhanced layer of black carbon in a north Indian industrial city. *Geophysical Research Letters*. 2005b;32:L12802. Available from: <https://doi.org/10.1029/2005GL022564>
48. Venkataraman C, Reddy CK, Josson S, Reddy MS. Aerosol size and chemical characteristics at Mumbai, India during INDOEX-IFP (1999). *Atmospheric Environment*. 2002;36:1979–1991.

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