International Journal of Engineering Applied Sciences and Technology, 2024
Vol. 8, Issue 10, ISSN No. 2455-2143, Pages 45-52
Published Online February 2024 in IJEAST (http://www.ijeast.com)

RADIATIVE IMPACTS OF ORGANIC AND ELEMENTAL CARBON AEROSOLS OVER TWO URBAN LOCATIONS IN INDIA.

Aditi Rathod, Abhilash S. Panicker
Indian Institute of Tropical Meteorology,
Pune 411008, India

Gufran Beig
National Institute of Advanced Studies,
Bangalore

Kaushar Ali
Indian Institute of Tropical Meteorology,
Pune 411008, India

Abstract: **This study concentrates on the estimates ofradiative forcing impacted by two important carbonaceous climate forcing aerosols viz. Elemental Carbon (Black Carbon) and Organic Carbon (OC) aerosols over two urban environments in India.The elemental carbon concentrations was up to 11.18 ± 4.4 µg m^{-3} over Hyderabad (HYD) and wasas high as 11.8 ± 3.6 µg m^{-3} over Pune (PUN), whereas the corresponding OC concentrations were much higher in different months (as high as 24.09 ± 6.38 µg m^{-3} over HYD and 29± 9.3 µg m^{-3} over PUN).During monsoon season the OC forcing over HYD was estimated to be -1.35 ± 1 at the surface (SRF) and -0.62 ± 0.48 at the Top of the Atmosphere (TOA); and -0.81 ± 0.5 over PUN. EC forcing during monsoon season was observed to be -14.51 ± 8.12 at SRF and 6.8 ± 3.74 at TOA. As the concentration of EC and OC were high during the Winter period and the corresponding forcing for EC were -26.81 ± 13.74 at SRF and 12.46 ± 6.39 at TOA over HYD and -36.11 ± 15.23 at SRF and 16.68 ± 7.05 at TOA over PUN; OC SRF and TOA over HYD were -2.5 ±1.34 and -1.04 ± 0.55 respectively and SRF of -4.05 ± 1.9 and TOA of -2.03 ± 0.92 was observed over Pune.**

keywords: **Elemental carbon (EC); Organic carbon (OC); Radiative forcing.**

I. INTRODUCTION

Elemental and organic carbon are two most important carbonaceous aerosol species. Although both OC and EC are emitted from the same combustion source they are different in terms of physical and chemical properties [1].OC,is associated with organic compounds, categorized as either primary OC (POC) when directly emitted into the atmosphere or secondary OC (SOC) when formed through the condensation of compounds resulting from atmospheric photochemical reactions involving anthropogenic and biogenic volatile organic precursors. The compositional diversity of SOC includes various different organic compounds, each exhibiting unique atmospheric behaviour[2,3]. OC is a scattering aerosol species and it also acts as a potential cloud condensation nuclei [4–6]OC contains Water Soluble (WSOC) and Water Insoluble (WIOC) components. The WSOC/OC ratios are a unique tracer to understand secondary organic aerosols (SOA) formation mechanism [7–9].Elemental carbon (EC) has absorption characteristics that are similar to those of black carbon (BC)[10]the names are different due to the methodologies used for its extraction. Therefore, the terms EC and BC has been used interchangeably. EC or BC is mainly emitted into the atmosphere by anthropogenic means like automobile exhaust, industries, coal burning, biofuel, agricultural activities[11–14]and naturally by volcanic activities and forest fires [15–17]Black carbon (BC), also known as elemental carbon (EC) or light-absorbing carbon (LAC), plays a significant role among atmospheric aerosols, contributing to positive radiative forcing (warming) at the top of the atmosphere (TOA) and negative radiative forcing (cooling) at the surface level[18]. EC is a mixture of graphite-like particles and is primarily absorbing particulate species in the atmosphere[19]Optical properties of EC in atmosphere gets altered due to atmospheric processes like ageing,coating and mixing[20–22]When BC is coated with non-BC species the surface of BC cores can enhance BC light absorption via the lensing effect [23–26]. Uncoated BC effectively acts as ice nuclei [27] The warming potential of EC can impact the atmospheric circulation pattern and the efficiency of cloud precipitation in the regions of South and Southeast Asia[28–31]. Despite the fact that BC aerosols make up a relatively small portion of atmospheric aerosols in terms of mass and number density, their influence on altering aerosol radiative properties is substantial [32,33]In this study we are estimating radiative forcing caused by OC along with EC over Pune (PUN) and Hyderabad (HYD).

II. DATA AND METHODOLOGY

2.1. Study Region:

The data used for this work is based on the sampling of $PM_{2.5}$ at the urban location of Hyderabad (17.53°N,78.40°E) and Pune (18.5°N,73.80°E). Over Hyderabad (HYD), the sampling is done at Indian National Centre for Ocean Information Services (INCOIS), this is a semi-urban location surrounded by dense vegetation there is residential complex to its northwest. Traffic sustains to its southwest and southeast. Over Pune (PUN), sampling has been carried out at Indian Institute of Tropical Meteorology (IITM). Sampling location is 3Km away from the urban site and IITM is surrounded by vegetative cover. At all the locations the sample collecting instrument (APM 550 MFC) was placed over the terrace of the Institute building. The location maps of the sampling sites are depicted in Fig 1. $PM_{2.5}$ samples were collected over Hyderabad from December 2010 to July 2011 and Pune between October 2010 to February 2012.

2.2. Data Sampling and Extraction

OC and EC sampling over PUN and HYD was performed using an APM 550 MFC fine-particulate-matter sampler (Envirotech Instrument Pvt. Ltd.) with a flow rate of 16.7 L min^{-1} and quartz filter paper (Palls, 2500 QAO-UP, 47 mm diameter). Palls quartz filter papers was subjected to a 4-hour pre-treatment at 900°C in muffle furnace to eliminate any contamination through human error. Sampling occurred at six-hour intervals. DRI Thermal/Optical Carbon Analyzer (Model 2001, Atmoslytic Inc., USA) was used to analyze filter papers for OC and EC concentrations following the IMPROVE_A protocol. A detailed description of data extraction using a DRI analyzer is available elsewhere [15,34,35].

2.3. Methodology

The aerosol optical model OPAC (Optical Properties of Aerosols and Clouds) [36]along with SBDART (Santa Barbara Discrete ordinate Atmospheric Radiative Transfer) [37]model were used for obtaining the radiative forcing of OC and EC.The Aerosol optical properties of EC (Aerosol Optical Depth (AOD), Single Scattering Albedo (SSA) and Angstrom exponent (ANG) obtained from OPAC model were further used in SBDART to get the EC radiative forcing. OPAC model does not containdefault OC component. Hence to include OC, we divided the OC mass concentration in to water-soluble OC (WSOC) and water-insoluble OC (WIOC) [38]. Further the default refractive index of water-solubleand insoluble components of the OPAC model were replaced with the refractive index of WSOC and WIOC[39] at 450 and 650 nm.Subsequently the AOD,SSA and ANG for OC was obtained and used in SBDART model to obtain the OC forcing at the surface and Top of the Atmosphere (TOA) and hence in the atmosphere. A detailed methodology for extraction of OC and EC forcing is explained elsewhere[15].

III. RESULTS AND DISCUSSIONS :

The monthly variations in EC and OC mass are presented in in Table1. The OC mass varied between 4.8 ± 2.2 to 29 ± 9.3µg/m^{3}over Pune and 5 ± 2.4 to 24 ± 0.97 µg/m^{3}over Hyderabad **.**The EC mass varied between 2±0.7 to 11.8±3.6 over Pune and 3.24±1to 11.18±4.4 over Hyderabad. A detailed discussion of measurement methods, variations and basic characteristics for OC and EC over HYD and PUN is provided in [35]. The variations of OC, EC and their source characteristics over HYD and PUN are discussed elsewhere in [35]

Table 1. Monthly concentration of OC and EC over PUN and HYD [35]

PUNE (PUN)					HYDERABAD (HYD)			
Month	EC	EC_SD	OC	OC_SD	OC	OC_SD	HYD EC	EC_SD
Oct-10	4.8	1.4	19.0	7.0	NA	NA	NA	NA
Nov-10	4.5	1.5	15.9	2.9	NA	NA	NA	NA
Dec-10	10.4	3.4	29.0	9.3	24.1	6.4	11.2	4.4
Jan-11	11.8	3.6	26.4	7.2	19.7	4.1	9.6	4.0
Feb-11	8.9	2.7	21.9	8.3	15.2	4.1	8.9	3.1
Mar-11	8.0	2.3	17.2	4.3	15.2	4.3	7.9	3.3
Apr-11	5.2	1.3	15.4	4.4	16.3	6.0	6.9	2.8
May-11	3.4	1.4	11.0	4.2	14.0	4.9	6.1	2.1
Jun-11	2.2	1.1	7.8	4.2	7.1	2.8	4.1	1.4
Jul-11	2.0	0.7	5.6	3.1	5.1	2.4	3.2	1.0
Aug-11	2.6	0.6	4.8	2.2	NA	NA	NA	NA

Sep-11	3.2	1.4	7.0	3.6	NA	NA	NA	NA
Oct-11	7.0	2.9	9.9	3.7	NA	NA	NA	NA
Nov-11	9.6	3.0	13.9	2.0	NA	NA	NA	NA
Dec-11	NA	NA	NA	NA	NA	NA	NA	NA
Jan-12	10.3	3.8	17.1	7.0	NA	NA	NA	NA
Feb-12	9.1	2.6	15.9	4.2	NA	NA	NA	NA

3.1 Radiative Forcing of EC and OC over HYD:

The Variation of EC and OC forcing is shown in Fig 1 (a and b) respectively.Over HYD the EC forcings were propotionl to EC concentrations. The highest EC forcing at the surface was estimated in the month of December-2010 (-28.58±14.55 W/m^2). The corresponding TOA forcing was +13.02±6.62 W/m^2.As EC concentration were lower in the month of July-11, the EC Forcings was also less(-13.37±7.57 W/m^2 at the surface and6.25 ± 3.5 at TOA) . OC forcing was less as compared to EC forcing. The highest OC forcing was -2.92±1.48 W/m^{2}at the surface and the corresponding TOA was -1.2±0.97 W/m^{2}inDec -2010.The OC forcing varied between -2.92 ± 1.4 to -1.23 ± 0.97over HYD in different monthsFig 1b.

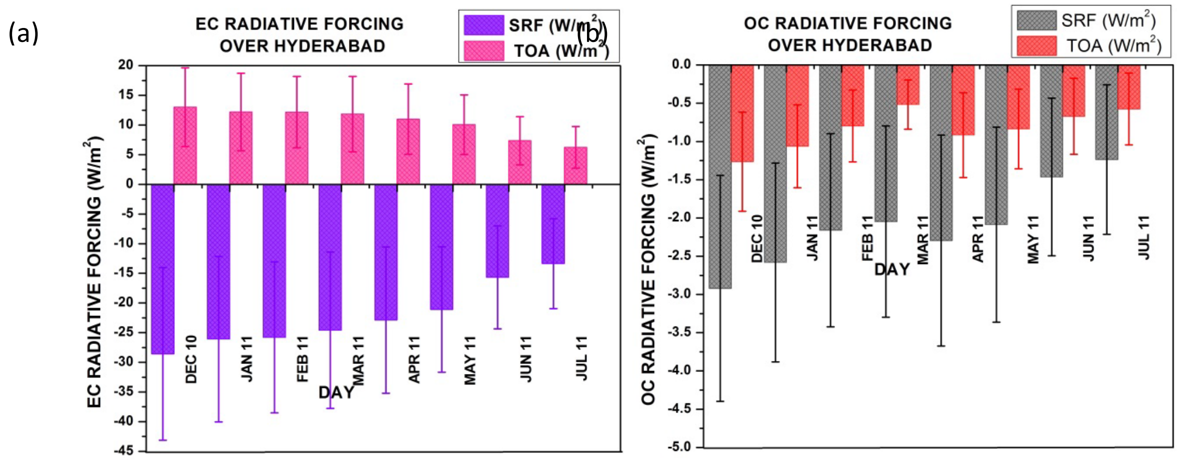

Fig 1 : Radiative Forcing due to EC and OC over HYD

Seasonal variation of radiative forcing due to EC and OC is shown in Fig 2 (a and b) respectively. EC and OC forcings were high in the winter months. The EC forcing in winter season was -26.82±13.74 W/m^2, and corresponding season OC forcing was -2.5±1.34 W/m^{2}at the surface. The TOA was 12.5±6.4 W/m^{2}and -1.04±0.55W/m^2 for EC and OC respectively during the season.

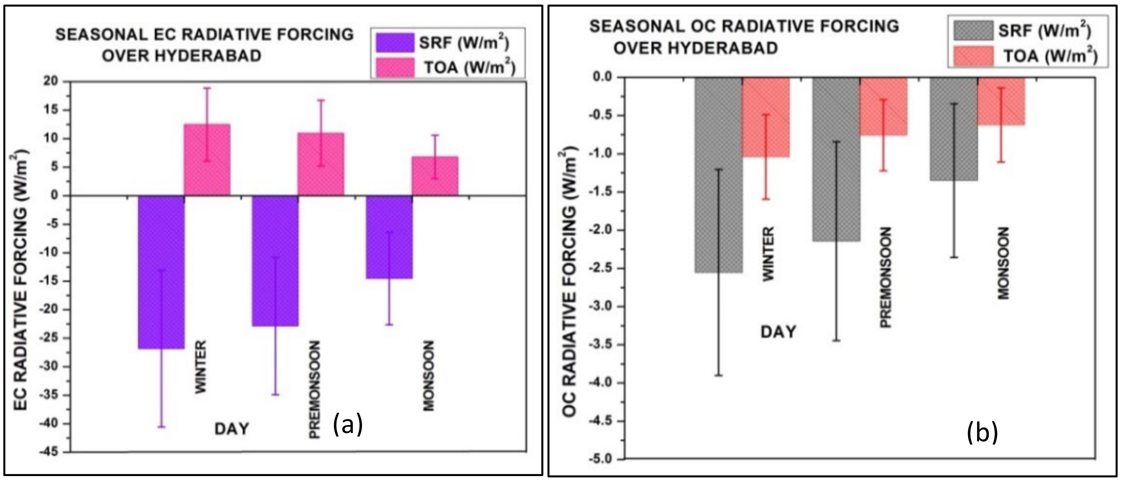

Fig 2 : Seasonal variation of Radiative Forcing due to EC and OC over HYD.

The heating rate was upto 1.32±0.7 K/day due to EC and was 0.055± 0.027 K/day due to OC over HYD as shown in Fig 3 (a and b).The net atmospheric forcing was up to 41.6±21.2 W/m^2 and 1.66±0.61 W/m^2 due to EC and OC respectively as depicted in Fig 4 (a and b).

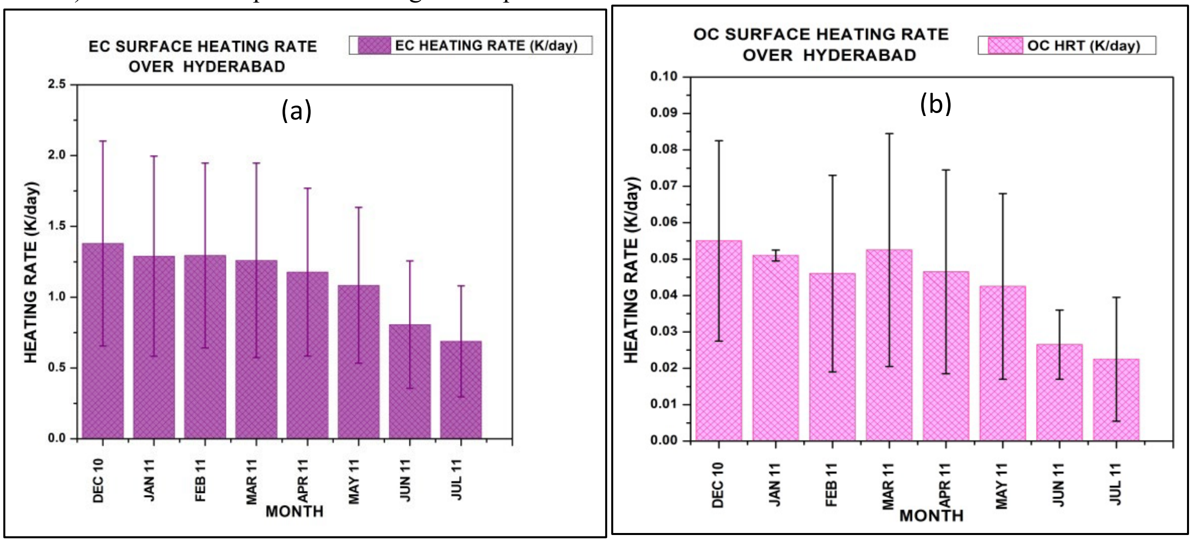

Fig 3 : Monthly variation of Heating rate due to EC and OC over HYD

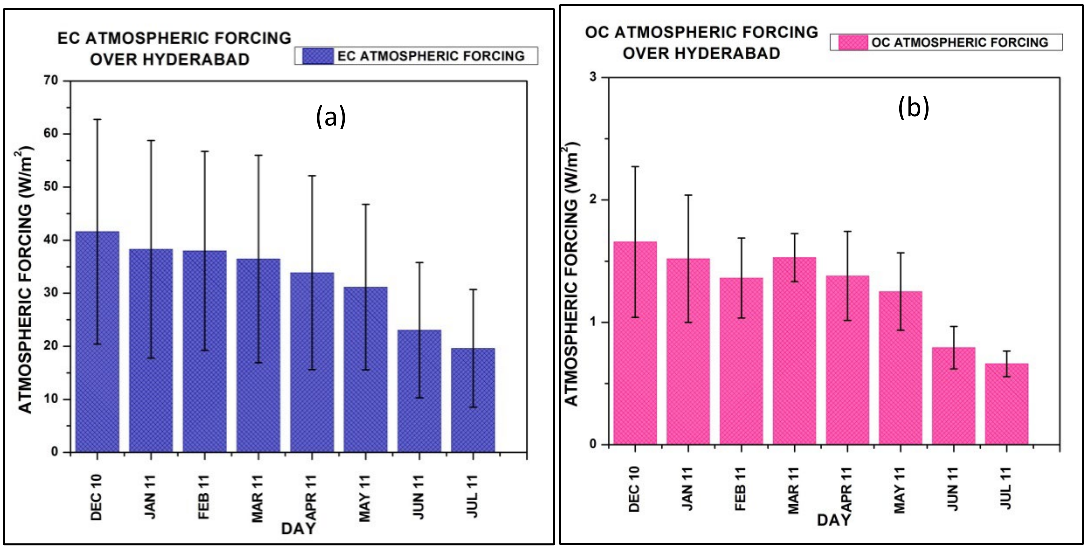

Fig 4 : Atmospheric forcing due to EC and OC over HYD

3.2 Radiative Forcing of EC and OC over PUN:

Variation of EC and OC forcing over PUN is shown in Fig 5 (a and b) respectively.Over PUN the EC forcings were high in the months where the EC concentrations were high. The highest EC forcing was estimated in the month of Jan-11 and was -39.84±13.33 W/m^{2}at the surface. The corresponding TOA was 18.54±7.63 W/m2.As the EC concentrations were lower in the month of May-11 the corresponding EC Forcings was also less i.e. -6.08±3.46 W/m^2.The highest OC forcing was in the same month which was -4.4±2.1 W/m^2 at the surfaceand -2.24 ±0.98 W/m^{2}in TOA.

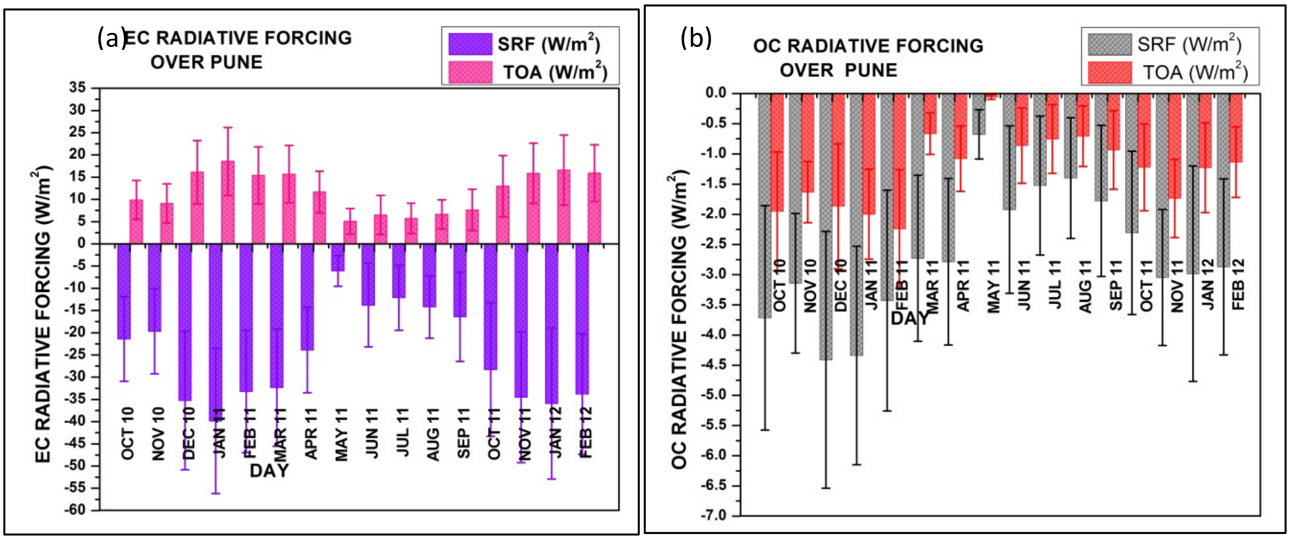

Fig 5 : Radiative Forcing due to EC and OC over PUN

Seasonal variation of radiative forcing due to EC and OC is shown in Fig 6 (a and b) respectively. EC and OC forcings were high in the winter months of 2011 corresponding to the high concentration of EC and OC.The EC forcing in winter-11 season was -36.11±15.23 W/m^2, and OC forcing was -4.06±1.52 W/m^{2}at he surface. TOA was 16.69±7.06 W/m2 and -2.03±0.92 W/m^2 for EC and OC respectively during the season Fig 6 (a and b).

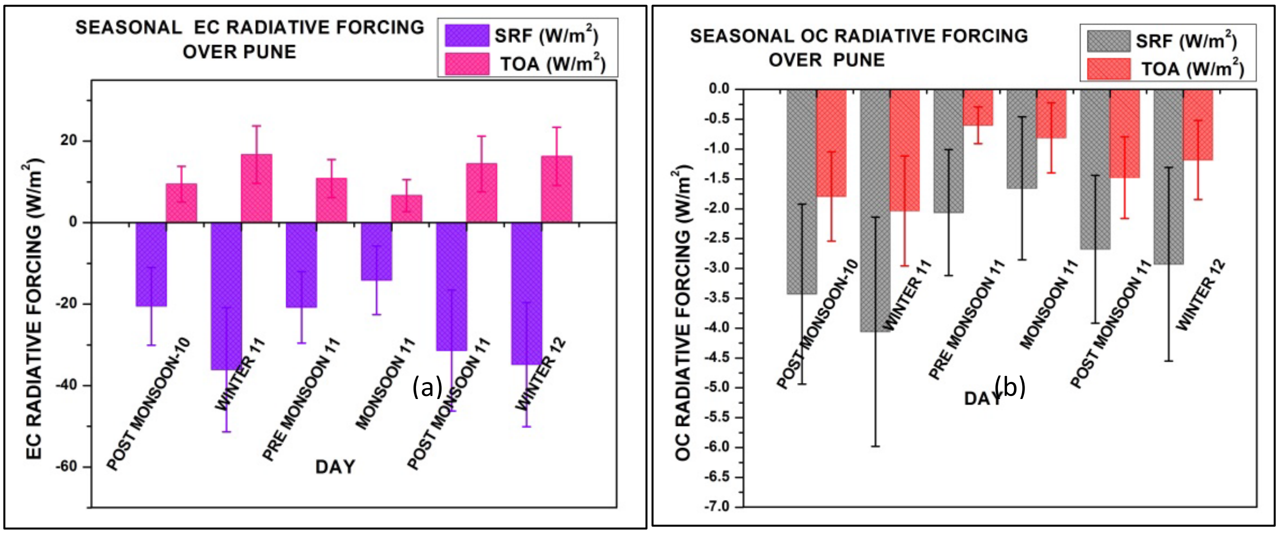

Fig 6 : Seasonal variation of Radiative Forcing due to EC and OC over PUN

The heating rate was upto 1.91 ± 0.83 K/day due to EC and 0.084 ± 0.018 K/day due to OC over PUN as shown in Fig 7 (a and b). The net atmospheric forcing was 52.52 ± 24.87 W/m^2 due to EC and 2.54 ± 1.091 W/m^{2}due to OC as depicted in Fig 8 (a and b).

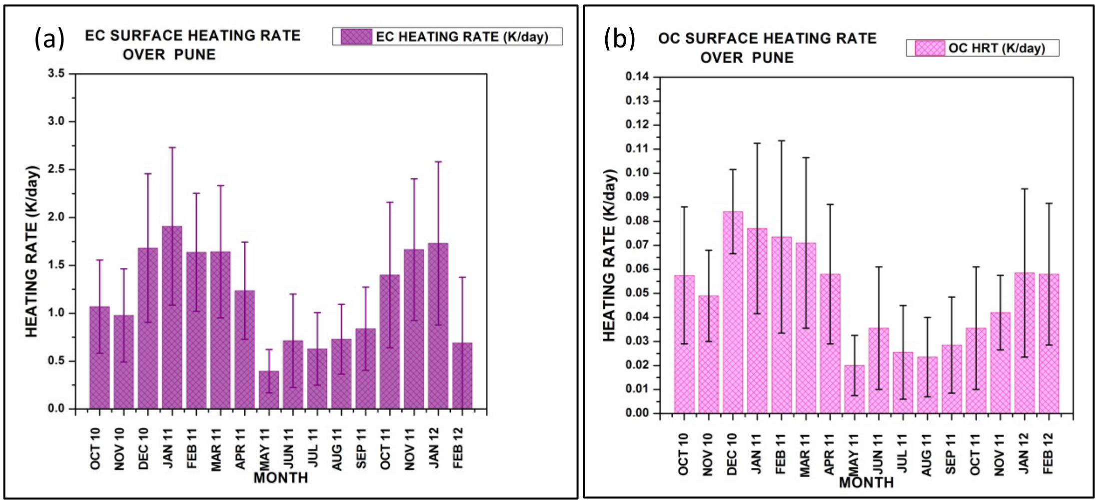

Fig 7 : Monthly variation of heating rate due to EC and OC over PUN

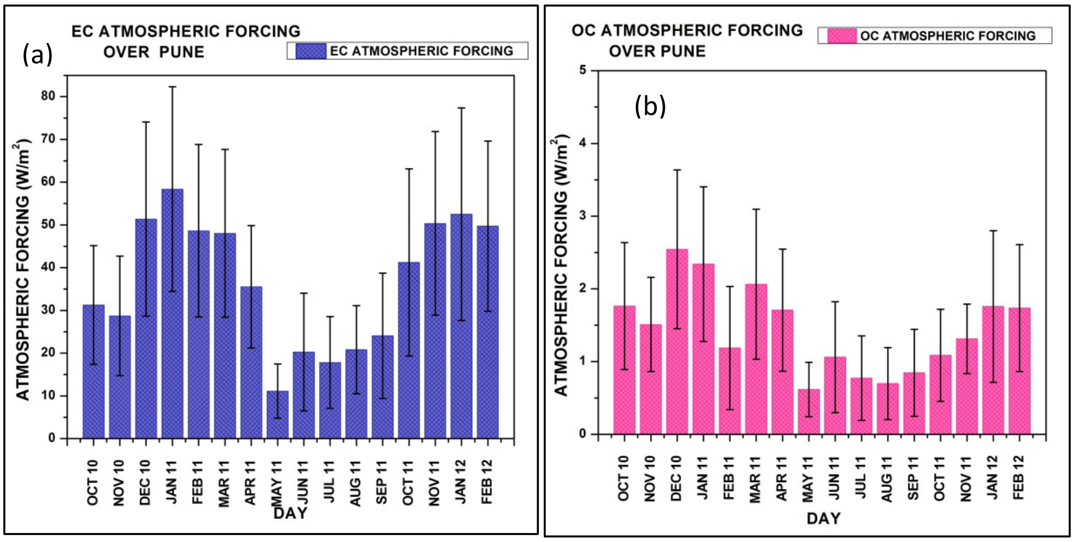

Fig 8 : Atmospheric forcing due to EC and OC over PUN

The study suggests that inspite of high concentration of OC, in the atmosphere, EC exerts high radiative foring due to its strong absorptive nature[15].

IV. SUMMARY

The SRF for EC over HYD ranged from -13.36±7.57 to -28.57±14.56 W/m^{2}and TOA ranged from 6.25 ± 3.5 to 13.02 ± 6.62.The SRF for EC over PUN ranged from –6.08 ± 3.4 to -39.84 ± 16.33 W/m^2 TOA ranged from 5.06 ± 2.87 to 18.54 ± 7.63 The SRF for OC over HYD ranged from -5.07 ± 2.4 to -24.09 ± 6.38 W/m^2 and TOA ranged from -0.575 ± 0.47 to -1.26 ± 0.64. The SRF for OC over PUN ranged from –-0.676 ± 0.41 to -4.41 ± 2.12 W/m^{2}TOA ranged from -0.059 ± 0.036 to -2.24 ± 0.98. The heating rate over HYD due to EC was estimated to range from 0.39 ± 0.23 to 1.91±0.82and over PUN due to EC was estimated to range from 0.68 ± 0.39 to 1.38±0.72. The heating rate over HYD due to OC was estimated to range from 0.023 ± 0.017 to 0.055±0.0275 and over PUN due to OC was estimated to range from 0.02 ± 0.013 to 0.084±0.017.

V. REFERENCES:

[1] Lan ZJ, Huang XF, Yu KY, Sun T Le, Zeng LW, et al. .(2013). Light absorption of black carbon aerosol and its enhancement by mixing state in an urban atmosphere in South China. Atmos Environ (pp 118-123).

[2] Choi JK, Heo JB, Ban SJ, Yi SM, Zoh KD .(2012).

Chemical characteristics of PM2.5 aerosol in Incheon, Korea. Atmos Environ (pp 583-592).

[3] Liu D, Li J, Cheng Z, Zhong G, Zhu S, et al. .(2017). Sources of non-fossil-fuel emissions in carbonaceous aerosols during early winter in Chinese cities. Atmos Chem Phys 18 (pp 11491-11502).

[4] Saxena P, Hildemann LM, McMurry PH, Seinfeld JH .(1995). Organics alter hygroscopic behavior of atmospheric particles. J Geophys Res D9 (pp 755-770).

[5] Sahu LK, Kondo Y, Miyazaki Y, Pongkiatkul P, Kim Oanh NT .(2011). Seasonal and diurnal variations of black carbon and organic carbon aerosols in Bangkok. J Geophys Res Atmos 15 (pp 1-14).

[6] Novakov T, Penner JE .(1993). Large contribution of organic aerosols to cloud-condensation-nuclei concentrations. Nature 6449 (pp 823-826).

[7] Miyazaki Y, Aggarwal SG, Singh K, Gupta PK, Kawamura K .(2009). Dicarboxylic acids and water-soluble organic carbon in aerosols in New Delhi, India, in winter: Characteristics and formation processes. J Geophys Res Atmos 19 (pp 1-12).

[8] Miyazaki Y, Kondo Y, Han S, Koike M, Kodama D, et al. .(2007). Chemical characteristics of water-soluble organic carbon in the Asian outflow. J Geophys Res Atmos 22 (pp 1-18).

[9] Ram K, Sarin MM .(2011). Day-night variability of EC, OC, WSOC and inorganic ions in urban environment of Indo-Gangetic Plain: Implications to secondary aerosol formation. Atmos Environ 2 (pp 460-468).

[10] Chung SH, Seinfeld JH .(2002). Global distribution and climate forcing of carbonaceous aerosols. J Geophys Res Atmos 19 (pp AAC 14-1-AAC 14-33).

[11] Cherian R, Venkataraman C, Ramachandran S .(2009). Temporal variability in emission category influence on organic matter aerosols in the Indian region. Geophys Res Lett 6 (pp 1-5).

[12] Kumar KR, Narasimhulu K, Balakrishnaiah G, Reddy BSK, Gopal KR, et al. .(2011). Characterization of aerosol black carbon over a tropical semi-arid region of Anantapur, India. Atmos Res 1 (pp 12-27).

[13] Sahu SK, Beig G, Sharma C .(2008). Decadal growth of black carbon emissions in India. Geophys Res Lett 2 (pp 1-5).

[14] Tiwari S, Dumka UC, Kaskaoutis DG, Ram K, Panicker AS, et al. .(2016). Aerosol chemical characterization and role of carbonaceous aerosol on radiative effect over Varanasi in central Indo-Gangetic Plain. Atmos Environ (pp 437-449).

[15] Panicker AS, Aditi R, Beig G, Ali K, Solmon F .(2018). Radiative Forcing of Carbonaceous Aerosols over Two Urban Environments in Northern India. Aerosol Air Qual Res 4 (pp 884-894).

[16] Reddy MS, Venkataraman C .(1999). Direct radiative forcing from anthropogenic carbonaceous aerosols over India. Curr Sci 7 (pp 1005-1011).

[17] Martinsson BG, Brenninkmeijer CAM, Cam SA, Hermann M, Heue KP, et al. .(2009). Influence of the 2008 Kasatochi volcanic eruption on sulfurous and carbonaceous aerosol constituents in the lower stratosphere. Geophys Res Lett 12 (pp 1-5).

[18] Ramanathan V, Crutzen PJ, Kiehl JT, Rosenfeld D .(2001). Aerosols, Climate, and the Hydrological Cycle. Science (80-) December (pp 2119-2125).

[19] Cao JJ, Wu F, Chow JC, Lee SC, Li Y, et al. .(2005). Characterization and source apportionment of atmospheric organic and elemental carbon during fall and winter of 2003 in Xi'an, China. Atmos Chem Phys 11 (pp 3127-3137).

[20] Kuwata M, Kondo Y, Takegawa N .(2009). Critical condensed mass for activation of black carbon as cloud condensation nuclei in Tokyo. J Geophys Res (pp 20202-).

[21] Jacobson Z .(2000). Implications for global direct forcing of aerosols Well-mixed. October 2 (pp 217-220).

[22] Panicker AS, Pandithurai G, Safai PD, Prabha T V. .(2016). Indirect forcing of black carbon on clouds over northeast India. Q J R Meteorol Soc 701 (pp 2968-2973).

[23] Fuller K, Malm W, Kreidenweis S .(1999). Effects of mixing on extinction by carbonaceous particles. J Geophys Res (pp 15941–15954).

[24] Mark Z. Jacobson .(2001). Strong radiative heating due to the mixing state of black carbon in atmospheric aerosols. Nature February (pp 695-697).

[25] Bond TC, Bergstrom RW .(2006). Light absorption by carbonaceous particles: An investigative review. Aerosol Sci Technol 1 (pp 27-67).

[26] Lack DA, Cappa CD .(2010). Impact of brown and clear carbon on light absorption enhancement, single scatter albedo and absorption wavelength dependence of black carbon. Atmos Chem Phys 9 (pp 4207-4220).

[27] Gorbunov B, Baklanov A, Kakutkina N, Windsor HL, Toumi R .(2001). Ice nucleation on soot particles. J Aerosol Sci 2 (pp 199-215).

[28] Bollasina MA, Ming Y, Ramaswamy V .(2011). Anthropogenic aerosols and the weakening of the south asian summer monsoon. Science (80-) 6055 (pp 502-505).

[29] Menon S, Hansen J, Nazarenko L, Luo Y .(2002). Climate effects of black carbon aerosols in China and India. Science 5590 (pp 2250-2253).

[30] Padma Kumari B, Goswami BN .(2010). Seminal role of clouds on solar dimming over the Indian monsoon region. Geophys Res Lett 6 (pp 1-5).

[31] Wang C, Kim D, Ekman AML, Barth MC, Rasch PJ

.(2009). Impact of anthropogenic aerosols on Indian summer monsoon. Geophys Res Lett 21 (pp 1-6).

[32] Ramanthan, V and Carmicheal G .(2008). Climate change due to BC. Nat Geosci (pp 221-227).

[33] Panicker AS, Pandithurai G, Safai PD, Dipu S, Lee DI .(2010). On the contribution of black carbon to the composite aerosol radiative forcing over an urban environment. Atmos Environ 25 (pp 3066-3070).

[34] Panicker AS, Ali K, Beig G, Yadav S .(2015). Characterization of particulate matter and carbonaceous aerosol over two urban environments in Northern India. Aerosol Air Qual Res 7 (pp 2584-2595).

[35] Ali K, Panicker AS, Beig G, Srinivas R, Acharja P .(2015). Carbonaceous aerosols over pune and hyderabad (India) and influence of meteorological factors. J Atmos Chem 1 (pp 1-27).

[36] Hess M, Koepke P, Schult I .(1998). Optical Properties of Aerosols and Clouds: The Software Package OPAC. Bull Am Meteorol Soc 5 (pp 831-844).

[37] Ricchiazzi P, Yang S, Gautier C, Sowle D .(1998). SBDART: A Research and Teaching Software Tool for Plane-Parallel Radiative Transfer in the Earth's Atmosphere. Bull Am Meteorol Soc 10 (pp 2101-2114).

[38] Ram K, Sarin MM, Tripathi SN .(2010). A 1 year record of carbonaceous aerosols from an urban site in the Indo-Gangetic Plain: Characterization, sources, and temporal variability. J Geophys Res Atmos 24.

[39] Arola A, Schuster G, Myhre G, Kazadzis S, Dey S, et al. .(2011). Inferring absorbing organic carbon content from AERONET data. Atmos Chem Phys 1 (pp 215-225).