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Statistical Analysis of Surface Ozone and Black Carbon over Distinct Regions of India

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ABSTRACT

Since India has different climatology, statistical analysis of trace gases over distinct regions is very important to take necessary actions to control the pollutants. A network of stations has been initiated by Indian Space Research Organization in India to retrieve data on atmospheric trace gases. However, only few studies have been done on statistical analysis of trace gases on distinct regions of India. In this paper discussed statistical behavior of surface ozone (O_3) and black carbon (BC) mass concentration in different regions of lndia like rural, semi-urban, urban, and hill stations. The diurnal variation of rate of change of O_3 is used to analyze trace gases chemical environments of various locations. Results showed that surface ozone at Anantapur is similar to Kannur, and lower than that at Dayalbagh, an urban site; Darjeeling and Port Blair, a high altitude and hill site. In India, some locations reported lower surface ozone mixing ratios than Anantapur like Dibrugarh, a semi-urban location; Kullu, Pantnagar, semi-urban; Hyderabad, an urban site; Trivendrum, a coastal site; Chennai, an urban site; and Joharapur, a rural site. High concentrations of black carbon were observed at Kanpur, an urban site (6-20 μg/m^3) followed by Hyderabd, an urban site (1.5-11.2 μg/m^3), and Ahmedabad (0.2-10.2 μg/m^3). Results showed that Mohal-Kullu, and Darjeeling reported high BC compared with other hill stations like Ooty and Nainital, and semi-arid rural stations also reported substantial BC.

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Introduction

Since past decades the emission of trace gases (O_3, NO, NO_2, CO, SO_2, CH_4 and NMHCs etc.) has been increasing in the lower troposphere due to globalization and industrialization. The increase in mixing ratios of these trace gases substantially modulates the Earth's climate because of their competence to modify the radiation and energy balance of the earth-atmosphere-system [1]. Surface ozone is an important constituent of lower atmospheric trace gases in troposphere; they are low in amount but they play a vital role in the greenhouse effect, radiative forcing, and atmospheric chemistry. Surface O_3 is not directly emitted into the air, but is produced by chemical reactions between volatile organic compounds (VOC) and oxides of nitrogen (NOx). The main sources of O_3 precursors are carbon monoxide (CO), methane (CH4), VOCs, etc. are generated from fossil fuel combustion, biomass burning, and other anthropogenic activities. Surface O_3 plays a central role in tropospheric photo-oxidation, thereby regulating their lifetime and directly changes in the photolysis rate constant and indirectly by the NOx and HOx budget. Black carbon (BC) aerosol particles are one of the most variable components of the Earth's atmosphere and directly affect the Earth's radiative balance by scattering and absorbing solar radiation [2]. Also, aerosol particles play an important role in atmospheric chemistry and so affect the concentration of other minor atmospheric constituents like ozone [3]. Black carbon aerosols have the potential to absorb solar radiation at visible and near-infrared wavelengths that might lead to positive and negative radiative forcing [4-5]. High concentrations of O_3 and BC have a negative impact on human health, regional hydrological cycle, and agricultural productivity [6-7].

A network stations has been initiated by Indian Space Research Organization in India to retrieve the data of atmospheric trace gases at various regions in the Indian subcontinent and various groups are being vigorously involved in the long-term measurements of surface O_3 and its precursors [8-10]. The study showed that trace gases follow distinct seasonal and temporal variations and suggested long term measurements are essential to analyze its budget at different regions. In this paper discussed statistical behavior of O_3 and BC mass concentration in different regions of lndia like rural, semi-urban, urban, and hill stations.

Result and Discussion

Surface ozone concentration

We selected different geographical locations such as urban, semi-urban, rural, semi-arid, and coastal locations for surface ozone analysis in India and results were shown in Table 1. Surface ozone concentration at Anantapur is similar to ozone concentrations in Kannur (50.83 ppbv), Delhi (51.7 ppbv), Udaipur (51.7 ppbv), and Pune (54.6 ppbv). The observed O_3 at Anantapur and Kannur is lower than that measured in other locations like Dayalbagh, an urban site (75 ppbv); Darjeeling (63 ppbv), a high-altitude site; and Port Blair (60 ppbv), a hill area. In India some locations reported lower surface ozone mixing ratios than Anantapur like Dibrugarh (24 ppbv), a semi-urban location; Kullu (40 ppbv), a hill site; Pantnagar (39.3 ppbv), a semi-urban; Hyderabad (43 ppbv), an urban site; Trivendrum (47.5 ppbv), a coastal site; Chennai (41 ppbv), an urban site; and Joharapur (44 ppbv), a rural site. This variation is mainly attributable to local sources, long range transport, and meteorology. Hill areas reported higher ozone mixing ratios like Port Blair (60 ppbv), Ooty (61 ppbv), and Darjeeling (63 ppbv), due to regional transport from urban regions [11]. Study revealed that in India most of the locations (urban, semi-urban, and rural) have surface ozone day time build- up. In contrast, the diurnal pattern of ozone did not show any day time build up in Nainital and Ooty [12-13]. In Thumba, a tropical coastal site, distinct diurnal variations of surface ozone were found, mainly attributed to the wind pattern from sea breeze to land breeze. Polluted air from land is being moved towards marine regions and significantly increasing ozone levels [14].

Table 1: Surface ozone concentration at different locations in India

Location	Site description	O_3 (ppbv)	Reference
Anantapur (14.60 N, 77.60E)	Semi-arid rural	18-55.8	[15]
Delhi (28.70N, 77.20E)	Urban	30-51.7	[16]
Udaipur	Semi-arid Urban	5-53	[17]
Port Blair (11.04 N, 92.45 E)	Hill area	5-60	[18]
Dibrugarh (27.30N, 94.60E)	Semi-urban	8-24	[19]
Kannur (11.90N, 75.40E)	Rural	15.76-50.83	[20]
Mohal-Kullu (31.90N, 77.120E)	High altitude	40	[10]
Ooty (11.20N, 76.430E)	High altitude	17-61	[13]
Pantnagar (29.00N, 79.50E)	Semi-urban	10.8-39.3	[21]
Hyderabad (17.470N, 78.580E)	Urban	20-43	[22]
Dayalbagh (27.10N, 780E)	Urban	10-75	[9]
Trivendrum (8.50N, 770E)	Tropical coastal	15.7-47.5	[23]
Pune (18.540N, 73.810E)	Tropical semi-urban	12.2-54.6	[24]
Darjeeling (27.10N, 88.70E)	High altitude	18-63	[25]
Chennai (13.040N, 80.230E)	Urban	15-41	[26]
Joharapur (19.30N, 75.20E)	Rural	15-44	[11]
Gadanki (13.50N, 79.20E)	Rural	18.1-33.6	[27]

Rate of change of surface ozone

Table 2 shows the average rate of change of ozone during morning and evening hours for different locations in India. The average rate of change of ozone in morning was more (6.08 ppbv h^{-1}) than change in evening (-3.15 ppbv h^{-1}) at Anantapur. Results indicate that the rate of change of ozone is similar in many rural and semi-urban locations in India namely Mohal, Gadanki, Pune, and Kanpur (Table 1). The average rate of increase of ozone over Mohal, Ahmedabad, Pantnagar, and kannur was 7.3, 5.9, 5.6, and 4.9 ppbv h^{-1}, suggesting the fast production of ozone by freshly emitted of its anthropogenic precursors. The average rate of change of O3 in morning and evening hours at Anantapur is higher than in Agra, Gadanki, Pune, Kanpur and Dayalbagh, indicating the more photochemical oxidation and titration process. In contrast, the average rate of increase of ozone during morning hours was less than evening hours on urban location in India like Delhi, Udaipur, Ahmedabad, and Pantnagar, mainly due to the high emissions of NOx and fast titration with ozone during evening.

Table 2: Observed rates of change of ozone at different locations in India

Sites	(08:00-11:00 hrs) ppbv h^{-1}	(17:00-19:00 hrs) ppbv h^{-1}	References
Anantapur	6.0	-3.1	[15]
Delhi	4.7	-5.5	[28]
Udaipur	3.7	-4.5	[17]
Ahmedabad	5.9	-6.4	[27]
Mohal	7.3	-5.9	[10]
Agra	2.5	-2.4	[9]
Kannur	4.9	-6.4	[8]
Gadanki	4.6	-2.6	[27]
Pune	4.8	-2.6	[29]
Panthnagar	5.6	-8.5	[21]
Kanpur	3.3	-2.6	[30]
Dayalbag	2.2	-2.3	[9]

Black carbon concentration

The scientific studies showed that high concentrations of black carbon were observed at Kanpur, an urban site (6-20 µg/m^3), followed by Hyderabd, an urban site (1.5-11.2 µg/m^3), and Ahmedabad (0.2-10.2 µg/m^3). The high hill stations reported very low BC as Ooty (0.6 µg/m^3), Nainital (1.36 µg/m^3), and results showed that Mohal-Kullu (4.6 µg/m^3), and Darjeeling (5.6 µg/m^3) reported high BC compare with other hill stations. The semi-arid rural stations also reported substantial BC as Anantapur (3.03 µg/m^3) and Udaipur (5.6 µg/m^3).

Table 3: Black carbon mass concentration at different regions in India

Station	Site description	Concentration (µg/m^3)	Reference
Anantapur	Semi-arid, rural	3.03	[31]
Udaipur	Semi-arid	5.6	[32]
Pune	Urban	4.1	[33]
Kanpur	urban	6-20	[34]
Hyderabad	urban	1.5-11.2	[35]
Bhubaneswar	Urban	5.2	[36]
Thivandrum	Costal, urban	0.5-8	[37]
Ahmedabad	Urban	0.2-10.2	[38]
Delhi	Urban	3-27	[39]
Ooty	High altitude	0.6	[40]
Kullu	High altitude	4.6	[5]
Darjeeling	High altitude	5.6	[41]
Nainital	High altitude	1.36	[42]

Conclusions

In this paper analyzed statistical behavior of surface ozone (O_3) and black carbon (BC) mass concentration over distinct regions of India. We selected different geographical locations such as urban, semi-urban, rural, semi-arid, and coastal locations for better understanding across India. Results showed that the hill areas reported high ozone mixing ratios like Port Blair (60 ppbv), Ooty (61 ppbv), and Darjeeling (63 ppbv), due to regional transport from urban regions. The observed O_3 at Anantapur and Kannur is lower than that measured in other locations like Dayalbagh, an urban site; Darjeeling, a high-altitude site; and Port Blair, a hill area. Dibrugarh, a semi-urban site, was reported to have less O_3. In India most of the location have surface ozone day time build- up. In contrast, the diurnal pattern of ozone did not show any day time build up in Nainital and Ooty. Results elucidated that the rate of change of ozone is similar in many rural and semi-urban locations in India namely Mohal, Gadanki, Pune, and Kanpur. The average rate of increase of ozone during morning hours was less than evening hours on urban location in India like Delhi, Udaipur, Ahmedabad, and Pantnagar. Studies showed that high concentrations of black carbon were observed at Kanpur, an urban site, followed by Hyderabad, and Ahmedabad. Results showed that Mohal-Kullu, and Darjeeling reported high BC compared with other hill stations like Ooty and Nainital, and semi-arid rural stations also reported substantial BC. The present study revealed that rural and hill sites also reported significant pollutant trace gases budget; hence government has to initiate necessary actions to control pollution besides urban sites.

References

1. K Rama Gopal, SMd Arafath, G Balakrishnaiah, K Raja Obul Reddy, N Siva Kumar Reddy, et al. (2015) Columnar-integrated aerosol optical properties and classification of different aerosol types over the semi-arid region, Anantapur, Andhra Pradesh, Science of the Total Environment, 527: 507-519.
2. P Foster, V Ramaswamy, P Artaxo, T Berntsen, R Betts, et al. (2007) Changes in Atmospheric Constituents and in Radiative Forcing, in: Climate Change, The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
3. SE Schwartz, F Arnold, JP Blanchet, PA Durke, DJ Hofmann, et al. (1995) Group report: connections between aerosol properties and forcing of climate, in: Aerosol of Climate, edited by: J. Heintzenberg, and R.J. Charlson, Wiley, New York 251-280.
4. QP Wang, JP Schwarz, JJ Cao, RS Gao, DW Fahey, et al. (2012) Single particle characterization of black carbon aerosol in the Northeast Tibetan Plateau, China, Atmos- pheric Chemistry Physics Discuss 12:21947-21976.
5. MP Raju, PD Safai, PSP Rao, PCS Devara, KB Budhavant (2011) Seasonal characteristics of black carbon aerosols over a high altitude station in Southwest India, Atmospheric Research 100: 103-110.
6. V Ramanathan, MV Ramana (2003) Atmospheric brown clouds: long-range transport and climate impacts, EM 12: 28-33.
7. RE Kopp, DL Mauzerall (2010) Assessing the climate benefits of black carbon mitigation. P Natl Acad Sci 107: 11703-11708.
8. T Nishanth, KM Praseed, SK Satheesh Kumar, KT Valsaraj (2012) Analysis of Ground Level O3 and NOx measured at Kanuur, India, Journal of Earth Science climate Change 3:1.
9. V Singla, A Satsangi, T Pachauri, A Lakhani, KM Kumari, et al. (2011) O3 formation and destruction at a sub-urban site in North Central region of India, Atmospheric Research 101: 373-385.
10. P Sharma, K Jagdish Chandra, G Raj Paul, P Prasad Dhyani, C Chetan, (2013) Surface ozone concentration and its behaviour with aerosols in the north western Himalaya, India, Atmospheric Environment 71: 44-53.
11. SB Debaje, AD Kakade (2009) Surface O3 variability over western Maharashtra, India, Journal of Hazardous Materials 161: 686-700.

12. J Kumar, M Naja, S Venkataramani, O Wild (2010) Variations in surface ozone at Nainital: A high-altitude site in the central Himalayas, Journal of Geophysical Research 115.
13. C Udayasoorian, RM Jayabalakrishana, AR Suguna, S Venkataramani, S Lal, et al. (2013) Diurnal and seasonal characteristics of ozone and NOx over a high-altitude Western Ghats location in Southern India, Advances in Applied Sciences Research 4: 309-320.
14. PR Nair, D Chand, S Lal, KS Modh, M Naja, et al. (2002) Temporal variations in surface O3 at Thumba (8.6oN, 77oE) -a tropical coastal site in India, Atmospheric Environment 36: 603-610.
15. K Rama Gopal, AP Lingaswamy, SMd Arafath, G Balakrishnaiah, S Pavan Kumari, et al. (2013a) Seasonal heterogeneity in ozone and its precursors (NOx) by in-situ and model observations on semi-arid station in Anantapur (A.P), Atmospheric Environment 84: 294-306.
16. S Tyagi, S Tiwari, A Mishra, K Philip, SD Hopke, et al. (2016) Spatial variability of concentrations of gaseous pollutants across the National Capital Region of Delhi, India, Atmospheric Pollution and Research 7: 808-816.
17. R Yadav, LK Sahu, G Beig, SNA Jaaffrey (2016) Role of long-range transport and local meteorology in seasonal variation of surface ozone and its precursors at an urban site in India, Atmospheric Research, 176: 96-107.
18. TK Mandal, SK Peshin, C Sharma, PK Gupta, R Raj, et al. (2015) Study of surface ozone at Port Blair, India, a remote marine station in the Bay of Bengal, Journal of Atmospheric Solar and Terrestial Physics 129:142-152.
19. PK Bhuyan, B Chandrakala, B Pathak, K Gayatry (2014) The role of precursors gases and meteorology on temporal evolution of O3 at a tropical location in northeast India, Environmental Science and Pollution Research doi: 10.1007/s11356-014-2587-3.
20. T Nishanth, KM Praseed, MK Satheesh Kumar, KT Valsaraj (2014) Observational Study of Surface O3, NOx, CH4 and Total NMHCs at Kannur, India, Aerosol and Air Quality Research 1-15.
21. N Ojha, M Naja, KP Singh, T Sarangi, R Kumar, et al. (2012) Variabilities in ozone at a semi-urban site in the Indo-Gangetic Plain region: Association with the meteorology and regional processes, Journal of Geophysical Research 117.
22. YV Swamy, R Venkanna, GN Nikhil1, DNSK Chitanya, PR Sinha, et al. (2012) Impact of oxides of Nitrogen, Volatile Organic Carbons and Black Carbon emissions on Ozone weekend/weekday variations at a semi- arid urban site in Hyderabad, Aerosol and Air Quality Research doi: 10.4209/aaqr.2012.01.0019.
23. LM David, PR Nair (2011) Diurnal and Seasonal Variability of Surface Ozone and NOx at a Tropical Coastal Site: Association with Mesoscale and Synoptic Meteorological Conditions, Journal of Geophysical Research 116: D10303.
24. G Beig, S Gunthe, DB Jadhav (2007) Simultaneous measurements of ozone and its precursors on a diurnal scale at a semi urban site in India, "Journal of Atmospheric Chemistry 57: 239-253.
25. S Lal (2007) Trace gases over the Indian region. Indian Journal of Radio and Space Physics 36: 556-570.
26. M Pulikesi, P Baskaralingam, VN Rayudu, D Elango, V Ramamurthi, et al. (2006) Surface ozone measurements at urban coastal site Chennai, in India, Journal of Hazardous Materials B137:1554-1559.
27. M Naja, S Lal (2002) Surface O3 and precursor gases at Gadanki (13.50N, 79.20E), a tropical rural site in India, Journal of Geophysical Research 107.
28. YN Ahammed, RR Reddy, KR Gopal, K Narasimhulu, DB Basha, et al. (2006) Seasonal variation of the surface ozone and its precursor gases during 2001-2003, measured at Anantapur (140 620 N), a semi-arid site in India, Atmospheric Research, 80: 151-64.
29. S Lal, M Naja, BH Subbaraya (2000) Seasonal variations in surface ozone and its precursors over an urban site in India, Atmospheric Environment, 34: 2713-2724.
30. A Gaur, SN Tripathi, VP Kanawade, V Tare, SP Shukla, et al. (2014) Four-year measurements of trace gases (SO2, NOx, CO and O3) at an urban location, Kanpur, in northern India, Journal of Atmospheric Chemistry DOI:10.1007/s10874-014-9295-8.
31. R Suresh Kumar, K Raghavendra Kumar, G Balakrishnaiah, K Rama Gopal, RR Reddy, et al. (2012) Potential Source Regions Contributing to Seasonal Variations of Black Carbon Aerosols over Anantapur in Southeast India, Aerosol and Air Quality Research 12: 344-358.
32. J Srinivasan, S Gadgil (2002) On the Asian brown cloud controversy, Current Science 83:1307-1309.
33. PD Safai, S Kewat, PS Praveen, PSP Rao, GA Momin, et al. (2007) Seasonal Variation of Black Carbon Aerosols over Tropical Urban City of Pune, India, Atmospheric Environment 41: 2699-2709.
34. SN Tripathi, S Dey, V Tare, SK Satheesh (2005) Aerosol Black Carbon Radiative Forcing at an Industrial City in Northern India, Geophysical Research Letters doi:10.1029/2005GL022515.
35. KM Latha, KVS Badarinath, KK Moorthy (2004) Impacts of Diesel Vehicular Emissions on Ambient BC Concentration at an Urban Location in India. Current Science 86: 451-453.
36. N Das, SS Baral, SK Sahoo, RK Mohapatra, TS Ramulu, et al. (2009) Aerosol physical characteristics at Bhubaneswar, East coast of India, Journal of Atmospheric Research 93: 897-901.
37. SS Babu, KK Moorthy (2002) Aerosol Black Carbon over a Tropical Station in India. Geophysical Research Letters doi:10.1029/2002GL015662.
38. S Ramachandran, TA Rajesh (2007) Black Carbon Aerosol Mass Concentration over Ahmedabad, an Urban Location in Western India: Comparison with Urban Sites in Asia, Europe, Canada, and the United States. Journal of Geophysical Research doi:10.1029/2006JD007488.
39. NS Beegum, K Krishnamoorthy, S Suresh Babu, SK Satheesh, V Vinoj, et al. (2009) Spatial distribution of aerosol black carbon over India during premonsoon season. Journal of Atmospheric Environment 43:1071-1078.
40. C Udayasoorian, RM Jayabalakrishnan, AR Suguna, MM Gogoi, S Suresh Babu, et al. (2014) Aerosol black carbon characteristics over a high-altitude Western Ghats location in Southern India, Annales Geophysicae 32:1361-1371.
41. A Chatterjee, A Adak, SK Ghosh, S Raha, AK Singh, et al. (2010) Atmospheric black carbon removal with efficient rainfall scavenging over Darjelling during southwest monsoon, Aerosol and clouds: Climate change prospective, IAST Conference 19: 442-443.
42. P Pant, P Hegde, UC Dumka, R Sagar, SK Satheesh, et al. (2006) Aerosol Characteristics at a High-Altitude Location in Central Himalayas: Optical Properties and Radiative Forcing, Journal of Geophysical Research doi:10.1029/2005JD006768.