Studies of surface ozone in Indian scenario

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Abstract:

In Indian region, various groups have been actively involving to carrying out long term measurements of surface ozone (O_3) and their observations are quite relevant to estimate the regional air quality. The data from various locations of India has been taken from numerous scientific journals and analyzed diurnal and seasonal variations. The analysis suggests that even rural sites also had significant O_3. This study helps to know the trace gases chemistry at different geometric locations of India and get to know the scientific evidences for distinct variations.

Keywords: surface ozone, oxidation process, monthly and seasonal variation

Introduction:

As a result of substantial urban and industrial development over India, air quality across this region continues to deteriorate. This deterioration is reflected in higher concentrations of ozone (O_3) and its precursors such as sulfur dioxide (SO_2), and particulate matter (PM) with aerodynamic diameters $\leq$10 μm) (PM_{10}). Thus, observation and analysis of the concentrations of these species provides an understanding of the current state of the air in a given area. O_3 and its precursors is an important chemical constituent of the atmosphere and play a vital role in air quality degradation, tropospheric chemistry, and global climate change. O_3 is formed by photochemical reactions among oxides of nitrogen (NOx), carbon monoxide (CO), and volatile organic compounds with solar radiation and has risen substantially in the troposphere.

Results and Discussion:

Surface ozone concentration and its behaviour with aerosols at Mohal, a semi-urban site, in the Kullu valley of the northwestern part of the Indian Himalaya by [1] found that the monthly pattern of O_3 was to increase from January to May and thereafter started decreasing up to July. Maximum diurnal monthly mean concentration of O_3 was 84 ± 23.9 ppbv at 16:00 hrs in May followed by 79 ± 20.6 ppbv at 16:00 hrs in April, and 77 ± 8.3 ppbv at 16:00 hrs in June. Further, the annual average of O_3 on high insolation days was estimated to be 41.7 ± 13.8 ppbv and on low insolation days it was 33.3 ± 9.76 ppbv. The largest ozone build-up was calculated 14.7 ppbv in May followed by 13.3 ppbv in June, however, its lowest value was 1.0 ppbv in July. Variations in surface ozone at Nainital, a high-altitude site in the central Himalayas by [2] found that diurnal variations in ozone do not show the daytime photochemical build-up typical of urban or rural sites. The seasonal variation showed a distinct ozone maximum in late spring with values sometimes exceeding 100 ppbv and a minimum in the summer/monsoon season. Further, background

ozone values are estimated to 30-35 ppbv. Regional pollution was shown to have a maximum contribution (16.5 ppbv) to ozone levels during May-June and was about 7 ppbv on an annual basis, while the contribution of long range transport was greatest during January-March.

Surface ozone observations at a smi-urban site, Pantnagar in the IGP region by [3], revealed that ozone mixing ratios showed a day time photochemical build up with ozone levels sometimes as high as 100 ppbv. Seasonal variation in 24 hrs average ozone showed a distinct spring maximum while daytime (11:30-16:30 hrs) average ozone showed an additional peak during autumn in November. Average ozone levels were highest in May, while these lower in January and August. Although monthly average ozone levels remain below 40 ppbv throughout the year but hourly average ozone levels in excess of 80 ppbv occasionally particularly during spring. Analysis of surface O_3 and its precursor at Dayalbagh, Agra by [4] found that the daytime maxima O_3 is observed around 12:00–14:00 hrs due to in-situ photochemical production. Further, seasonal variations in O_3 concentrations show pronounced maxima in the summer, winter seasons and minima in monsoon, post monsoon seasons.

Measurements of surface O_3 and its precursor gases over Ahmedabad by [5] reported that the day time O_3 production was basically due to the photo-oxidation of its precursor gases. In addition to this, boundary layer processes, surface wind patterns, meteorology also control the diurnal variations of pollutants at this site. Further, they found that seasonal variation of O_3 during 1954-1955 was found maximum in winter-spring and during 1991-1995 in winter-autumn. This difference in seasonal variations indicates that, earlier seasonal variation was dominated by solar radiation, but now it is dominated by pollutants. Trace gases over Indian region was studied by [6] reported that the night time and early morning values were around 42-43 ppbv and a dip around noon hours was found over Mt. Abu. The monthly average values increased in September onwards and highest was found in October.

The role of precursor gases and meteorology on temporal evolution of ozone in northeast India at [7] found that the ozone concentration starts to increase gradually after sunrise attained a peak level at around 15:00 hrs and then decreased from evening till sunrise next day. The highest and lowest monthly maximum concentration of O_3 was observed in March and July respectively. Further, they reported the characteristics of O_3 were similar in all the seasons except in monsoon, when the diurnal was nearly flat. The daytime O_3 concentration was almost comparable in all other seasons except during post-monsoon 2010, when it is lowest. This may be attributed to the prevailing heavy rainfall started in pre-monsoon till post- monsoon in that year. The night time O_3 values gradually decreased from pre-monsoon to its lowest level in winter through monsoon and post-monsoon. Analysis of surface O_3 concentration at a tropical megacity, Delhi by [8] found that the surface O_3 levels in the city are high enough to exceed “Critical Levels” which are considered to be safe for human health, vegetation and forest. The human health threshold was exceeded for up to ~45 days per year. Additionally, they revealed that accumulated exposure over a threshold of 40

ppb of O_3 exceeded significantly during winter and pre-monsoon season in India.

Measurements of O_3 at a semi urban site in Pune by [9] observed a peak in amplitude of O_3 during noontime. Further, they found that O_3 was highly influenced by regional/long range transport of pollution in this region. [10] studied the surface O_3 variability at the five different sites of western Maharashtra during 2001 and 2005 and the results revealed that seasonal variation in O_3 showed a pronounced maximum in the summer and winter season in the urban and rural site. Further, they found that local pollutants played a major role in the increasing O_3 concentrations at the urban and rural sites, while regional transport played a role at high altitude mountains site.

Distribution of ozone in the marine boundary layer of Arabian Sea during the premonsoon months, April-May 2006 was investigated by [11], they found that ozone mixing ratio over the Arabian Sea varied in the range 3-22 ppbv with the mean of 13.5 ± 2 ppbv. The ozone mixing ratio remained high near the coast even during night when photochemical production was not possible. They suggested it could be due to the direct intrusion of O_3 rich air over to the marine region, rather than the precursors got advected and subsequently produced O_3 photochemically. The spatially pattern did not showed any evidence of transport from nearby landmass or in situ photochemistry. Further, the ozone mixing ratio showed positive correlation with aerosol mass loading. The role of chloride ion in depleting O_3 was also investigated.

The observational study of surface ozone and its precursors at Kannur by [12] revealed that the diurnal cycle for surface O_3 had a peak in the afternoon and declined during night time. The seasonal variation of ozone was high in winter and low during monsoon seasons. During winter, maximum (44.20 ± 5.7 ppbv) and minimum (4.75 ± 1.75 ppbv) concentrations of O_3 had observed at 15:00 hrs and 07:00 hrs respectively. Temporal variations in surface O_3 at Thumba a tropical coastal site in Trivandrum by [13] reported that distinct diurnal variations. They found that wind pattern from sea breeze to land breeze at Thumba played a crucial role in the production of O_3. During night-time, polluted air from land side moves to the nearby marine region relatively increasing the levels of O_3 and precursor gases. Diurnal and seasonal characteristics of ozone and its precursors were studied by [14] at Ooty, found that the ozone and oxides of nitrogen concentrations were higher during warmer months and prominent seasonal variations were recorded. A seasonal variation in ozone showed a pronounced maximum in summer with values sometimes exceeding 90 ppbv and a minimum in the monsoon and post monsoon season. Further they found the diurnal pattern of ozone did not show any day time build up throughout the study period.

In Andhra Pradesh, only a few groups have been actively involving in the study of surface O_3 using ground based observations to determine the regional air quality. Measurement of surface ozone at Anantapur were studied by [15-17] found that O_3 and its precursors showed distinct diurnal and seasonal variabilities. The measured NO_2/NOx ratio is a convenient variable of the extent and completeness of atmospheric oxidation processes. The seasonal mean NO_2/NOx ratios for monsoon, post monsoon,

winter and summer were about 0.88, 0.91, 0.76 and 0.80 respectively, indicating a higher conversion of NO to NO_2. Surface O_3 and precursor gases measurement at Gadanki by [6] observed a poor correlation between O_3 and NOx which indicates that NOx levels at Gadanki are not controlled by fresh combustion or emissions and could be due to transport from the nearby major cities. The temporal variations of surface ozone were investigated by [6] at Hyderabad. They found that mean ozone concentrations increased from the early hours of the day, then attained a peak value in the late noon and thereafter dropped at night. High O_3 concentrations were observed in March, April, October and December. The increase or decrease in O_3 concentration could be the seasonal variations and related chemical transformations. Seasonal variations clearly showed maximum O_3 in summer which is attributed to regional photochemistry. In monsoon, the peak time O_3 level was observed to be low due to wet surface deposition of air pollutants by monsoonal rains and scarce availability of solar radiation. Further, they observed higher O_3 concentrations on weekends than weekdays and the effect was high during winter and found that local emissions and meteorology played a significant role in diurnal variations of surface O_3.

Conclusions:

The monthly pattern of O_3 was to increase from January to May and thereafter started decreasing up to July at Mohal in Himalaya region. The seasonal variation in Nainital showed a distinct ozone maximum in late spring with values sometimes exceeding 100 ppbv and a minimum in the summer/monsoon season. Average ozone levels were highest in May, while these lower in January and August in Pantnagar in the IGP region. Seasonal variation of O_3 during 1954-1955 was found maximum in winter-spring and during 1991-1995 in winter-autumn in Ahmedabad. Analysis of surface O_3 concentration at a tropical megacity, Delhi showed that the surface O_3 levels in the city are high enough to exceed "Critical Levels". Ozone mixing ratio over the Arabian Sea varied in the range 3-22 ppbv with the mean of 13.5 ± 2 ppbv. The substantial O_3 was observed over rural sites and which is higher than that of urban sites.

References:

[1] P. Sharma, K. Jagdish Chandra, G. Chand Raj Paul, D. Prasad C. Chetan, "Surface ozone concentration and its behaviour with aerosols in the north western Himalaya, India", "Atmospheric Environment" 71, 44-53, 2013.

[2] Rejesh Kumar, Manish Naja, S. Venkataramani, O. Wild, "Variations in surface ozone at Nainital: A high-altitude site in the central Himalayas", "Journal of Geophysical Research" 115, 2010.

[3] N. Ojha, M. Naja, K.P. Singh, T. Sarangi, R. Kumar, S. Lal, M.G. Lawrnce, T.M. Butler, H.C. Chandola, :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, 2012.

[4] V. Singla, A. Satsangi, T. Pachauri, A. Lakhani, K.M. Kumari, "O_3 formation and destruction at a sub-urban site in North Central region of India" "Atmospheric Research" 101, 373–385, 2011.

[5] S. Lal, M. Naja, B.H. Subbaraya, "Seasonal variations in surface O_3 and its precursors

over an urban site in India", "Atmospheric Environment" 34, 2713-2724, 2000.

[6] S. Lal, "Trace gases over the Indian region", "Indian Journal of Radio & Space Physics" 36, 556-570, 2007.

[7] S.B. Debaje, and A.D. Kakade, "Surface O_3 variability over western Maharashtra, India", "Journal of Hazardous Materials" 161, 686–700, 2009.

[8] D. Ghude, S.L. Jain, B.C. Arya, G. Beig, Y.N. Ahammed, A. Kumar, B. Tyagi, "O_3 in ambient air at a tropical megacity, Delhi: characteristics, trends and cumulative O_3 exposure indices" "Journal of Atmospheric Chemistry", 60, 237–252, 2008.

[9] G. Beig, S. Gunthe, D.B. Jadhav, "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, 2007.

[10] P.K. Bhuyan, B. Chandrakala B. Pathak, K. Gayatry, "The role of precursors gases and meteorology on temporal evolution of O_3 at a tropical location in northeast India" "Environmental Science and Pollution Research", 2014 doi: 10.1007/s11356-014-2587-3.

[11] P.R. Nair, L.M. David, S. Aryasree, K. Susan George, "Distribution of ozone in the marine boundary layer of Arabian Sea prior to monsoon: Prevailing air mass and effect of aerosols", "Atmospheric Environment" 7, 18-28, 2013.

[12] T. Nishanth, K.M. Praseed, M.K. Satheesh Kumar, K.T. Valsaraj, "Observational Study of Surface O_3, NOx, CH_4 and Total NMHCs at Kannur, India" "Aerosol and Air Quality Research" x, 1–15, 2014.

[13] P.R. Nair, D. Chand, S. Lal, K.S. Modh, M. Naja, K. Parameswaran, S. Ravindran, S. Venkataramani, "Temporal variations in surface O_3 at Thumba (8.6^{o}N , 77^{o}E) -a tropical coastal site in India", "Atmospheric Environment" 36, 603–610, 2002.

[14] C. Udayasoorian, R.M. Jayabalakrishana, A.R. Suguna, S. Venkataramani, S. Lal, "Diurnal and seasonal characteristics of ozone and NOx over a high altitude Western Ghats location in Southern India", "Advances in Applied Science Research" 4(5), 309-320, 2007.

[15] R.R. Reddy, K.R. Gopal, L.S.S. Reddy, K. Narasimhulu, K.R. Kumar, Y.N. Ahammed, C.V.K. Reddy, "Measurements of surface O_3 at semi arid site Anantapur (14.62°N, 77.65°E, 331 m asl) in India", "Journal of Atmospheric Chemistry" 59, 47–59, 2008.

[16] B.S.K. Reddy, K.R. Kumar, G. Balakrishnaiah, K.R. Gopal, R.R. Reddy, K. Narasimhulu, Y.N. Ahammed, L.S.S. Reddy, S. Lal, S, "Observational Studies on the variations in surface ozone Concentrations at Anantapur in southern India" "Atmospheric Research" 98, 125-139, 2010.

[17] K. Rama Gopal, A.P. Lingaswamy, S.Md. Arafath, G. Balakrishnaiah, S. Pavan Kumari, K. Uma Devi, N. Siva Kumar Reddy, K. Raja Obul Reddy, R.R. Reddy, S. Lal, "Seasonal heterogeneity in ozone and its precursors (NOx) by in-situn and model observations on semi-arid station in Anantapur (A.P)" "Atmospheric Environment" 84, 294-306, 2013.