International Journal of Applied Environmental Sciences
ISSN 0973-6077 Volume 17, Number 1 (2022), pp. 29-41

http://www.ripublication.com/ijaes.htm

Tropospheric and Stratospheric Ozone Relationship at Thrissur and Chennai, India and Their Effect on Human Health and Environment

Dipak Kumar Saha

Department of Chemistry, Dinabandhu Mahavidyalaya, Bongaon, (N) 24 PGS- 743235, West Bengal, India,

Abstract

The purpose of the paper is to present the nature of long-term seasonal and yearly variations of tropospheric and stratospheric ozone over Thrissur (10.52^0 N, 76.21^0 E) and Chennai (13^0 N, 80.27^0 E), India. It is concluded that seasonal variations of stratospheric ozone concentration attained relatively higher value in the months from July to September while lower tropospheric ozone concentration at the same time at these stations during the period 1979–2005. Yearly variation for the period of our study shows that increasing trend in tropospheric ozone but decreasing trend in stratospheric ozone. Due to such tropospheric rise and stratospheric decline in ozone there are some harmful effects on human health which are also discussed.

Keywords: Stratospheric ozone, Tropospheric ozone, Ozone concentrations

INTRODUCTION:

Ozone is an important constituent of stratosphere which forms ozone layer in this region, but a little amount of ozone is found in the troposphere. Although tropospheric ozone is less concentrated but it is very much important due to its health hazards of human. Tropospherering ozone is a pollutant. It is a constituent of smog and a powerful oxidizing agent that reacts readily with other chemicals to produce many types of toxic oxides (Wayne, 2000). It is a greenhouse gas also. It absorbs some of the infrared radiation that has radiative forcing of about 25 % of that of CO_2 (Watson et al., 2002 and Eggleston et al., 2006) and initiates the chemical removal of methane and other hydrocarbons from the atmosphere (Inter.gov.Panel on Climate Change., 2007). The upper tropospheric ozone as an important greenhouse molecule which influences global outgoing long wave radiation was observed by Worden et al. (2000).

There are many chemical reactions which produce tropospheric ozone such as combustions to photocopying. A smell of ozone gas is found very often in laser printers, which in high concentrations is toxic (Seinfeld and Pandis, 1998) in nature. When carbon monoxide (CO), nitrogen oxides (NO_x), volatile organic compounds (VOCs) etc react in the atmosphere in presence of sunlight then tropospheric ozone is formed. Some other major anthropogenic sources of these ozone precursors are motor vehicle exhaust, industrial emissions and chemical solvents. These chemicals are mainly originated from urban areas but winds can conduct those hundreds of kilometers. So ozone formation reactions take place in less populated regions also (Seinfeld and Pandis, 1998).

Ozone is declining everywhere by a very little amount which is confirmed by recent ozone assessment study (Bojkov, 1992). The dramatic decrease of ozone concentrations occurs at Antarctica during spring causing an ozone hole (Farman et al., 1985). "Ozone though a minor constituent plays a significant role in the chemical kinetics of the atmosphere. Stratospheric and tropospheric ozone are mutually correlated". Natural, dynamical and chemical theories for intense depletion ozone have been reported by Midya et al. (2011). Ozone was naturally formed from water molecules and stratospheric oxygen before industrialization. They react with each other in presence of solar UV-radiation to produce a broad band of ozone which is commonly known as ozonelayer. A very small fraction of this ozone naturally comes down to the earth's surface that includes very small amount of tropospheric ozone. This tropospheric ozone has been supplemented by ozone which is produced by various human activities during twentieth century. Due to various human processes there are some changes in trace gas emissions that have a significant impact on both the stratosphere and troposphere ozone (Tian et al., 2005). Pollutants from several industries and factories, the exhaust emissions from automobiles, burning vegetation and garbage etc. increases the concentration of carbon and nitrogen containing molecules in the lower atmosphere. When there is an interaction between them in presence of sunlight larger amount of tropospheric ozone is produced. It is reported by National Environmental Satellite, National Climatic Data Center, NOAA Satellite and Information Service, Data and Information Service, U.S. Department of Commerce (NCDC, 2010). The concentration has enhanced approximately 30 % since pre industrial era. The Intergovernmental Panel on Climate Change considered tropospheric ozone as the third most important greenhouse gas after CO_2 and CH_4.

Recently researchers observed stratosphere–troposphere exchange (STE) processes over the tropics which are mostly related to cyclone or land convection (Bellevue et al., 2007 and Das, 2009). Bellevue et al. (2007) found out the rising ozone values close intense to tropical cyclone at Reunion related to the tropical cyclone Marlene. The upper tropospheric ozone enhancement on the outer boundary of Marlene had been explained with a mesoscale model (MESO-NH) that was ready to reproduce a stratospheric potential vorticity (PV) filament into the troposphere, crossing isentropes to the 350 K level. Das (2009) reported that stratospheric intrusion into troposphere during passage of tropical cyclone using mesosphere–stratosphere–troposphere (MST) radar located at Gadanki (13.5°N, 79.2°E).

Stratosphere–troposphere exchange has been observed from ozonesonde, aircraft or MST radar in station data for a particular period Over Indian region (Mandal et al., 1998; Gupta et al., 2007; Kumar and Uma, 2009; and Sahu et al., 2009 –17). Mandal et al. (1998) on the basis of analysis of vertical profiles of ozone mixing ratio retrieved from microwave limber sounder aboard earth observing system (EOS) AURA satellite for the period 2005–2009 and tropospheric emission spectrometer aboard (EOS) AURA for the period 2006–2007 showed the evidence of downward propagation of ozone (100–200 ppbv) due to stratospheric intrusion during winter and pre-monsoon season and also reported the regular feature of increasing of ozone in the top troposphere level. The enhancement of ozone mixing ratios in the upper troposphere due to intrusion of stratospheric air on a strong fogy day at Kanpur, India during a land campaign in December 2004 was reported by Gupta et al. (2007). Kumar and Uma (2009) with the help of a high temporal resolution VHF radar experiment determined the time localized inclined echoes in the height region of 12–16 km giving evidence for stratospheric air intervention into the upper troposphere. This observation confirmed by the height-time section of vertical velocity that depicted the intense downdraughts in the height region of inclined radar echoes. The strong seasonal variations in the vertical mixing ratios of both O_3 and H_2O were reported by Sahu et al. (2009). During the period of winter and spring the mixing ratio of ozone below 40 ppbv was observed in the free troposphere. This is because of the long-range transport of ozone and its precursors accompanied by the westerly-north westerly circulation. Due to prevailing summer monsoon circulation over Indian subcontinent the low mixing ratio of ozone (20–30 ppbv) in the lower and middle troposphere happened during the period of July–September. “The upper tropospheric ozone intensification would be the result of convective lifting of surface ozone, in situ generation by anthropogenic NO_x, lightning NO_x and partly by HO_x radicals that originated from stratospheric intrusion and formaldehyde” (Cooper, 2007). Most of the trace gases transmitted from stratosphere spread into surrounding troposphere attribute to horizontal combining during the time of intrusion. Intrusion can come down to the surface in this way. The evidence of downward movement of ozone (100–200 ppb) due to stratospheric intervention during winter and pre-monsoon was shown by Fadnavis et al. (2010). P k Jana et al. (2012) had showed the relation between strasoepheric and tropospheric ozone at Thumba and Bangalore. Due to stratospheric intrusion the seasonal increasing of ozone in the upper troposphere was occurred over Bay of Bengal (Lal et al., 2007). Watanabe et al. (2005) reported a spring ozone maximum and summer ozone minimum in the marine boundary layer over the northern North Pacific Ocean. The effect of stratospheric ozone depletion over tropospheric ozone at Thrissur (10.52^0 N, 76.21^0 E) and Chennai (13^0 N, 80.27^0 E), India has been presented in this paper.

RESULTS AND DISCUSSIONS:

Monthly mean concentration of column ozone is obtained from the Convective Cloud Differential Method (Ziemke et al., 1998). Yearly mean ozone concentration is calculated from its monthly mean values. Mean seasonal variations of stratospheric and tropospheric ozone concentration over Thrissur and Chennai during the period 1979–2005 have been presented in Figure 1. Generally, the concentration of tropospheric ozone is about one-tenth of that of stratospheric ozone. Concentration of Tropospheric ozone has been multiplied by ten in order to show the variation of both the tropospheric and stratospheric ozone in the same figure with the same scale. It is evident from the figures that maximum stratospheric ozone was happened from July to September whereas minimum tropospheric ozone was occured at the same time at the both stations. Isaksen et al. (2005) also reported the reduction ozone at ground level at Mouna Loa (20°N, 156°W).

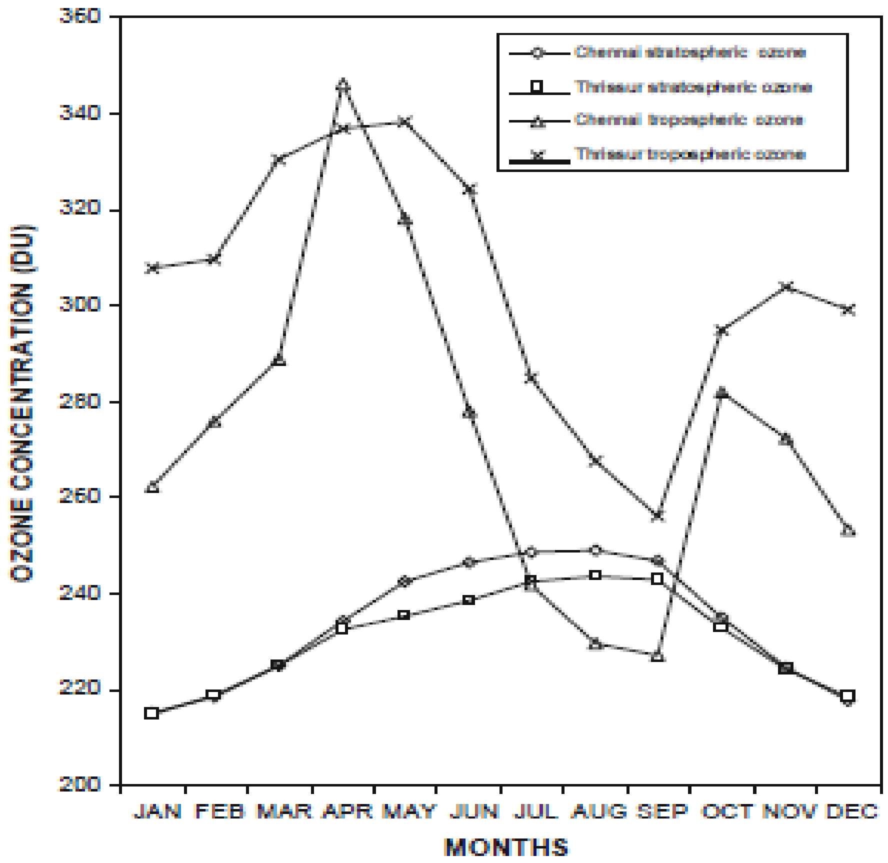

Fig. 1 Seasonal variations of tropospheric and stratospheric ozone concentration in DU at Thrissur and Chennai

Variations of yearly mean values of stratospheric and tro pospheric ozone (10 times) over Thrissur and Chennai from 1979 to 2005 have been represented in Fig. 2. The nature of yearly variations of stratospheric ozone though oscillatory had decreasing trend and that of tropospheric ozone though oscillatory had increasing trend from 1979 to 2005.

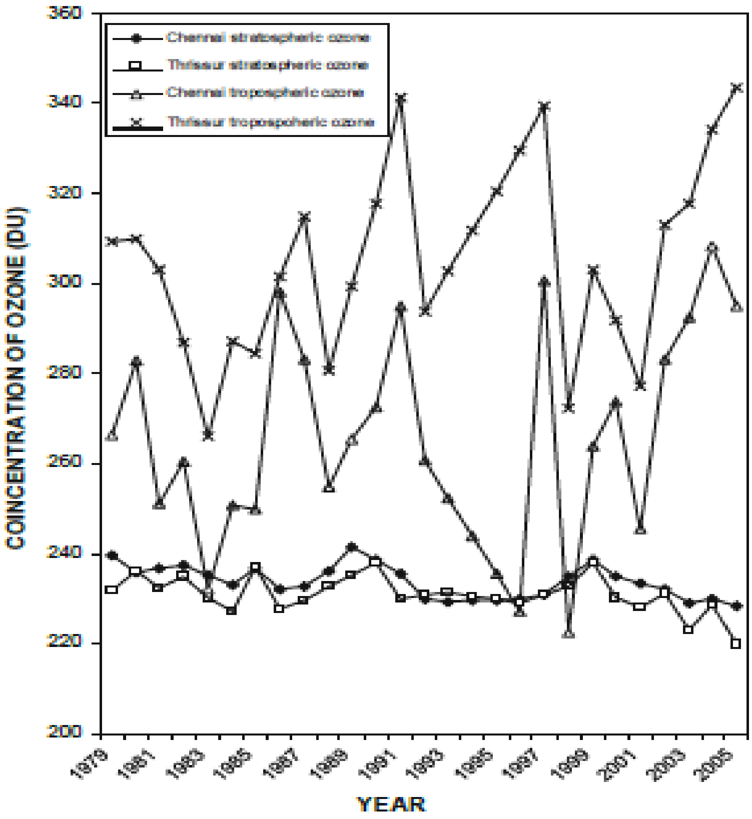

Fig. 2 Yearly variations of tropospheric and stratospheric ozone concentration in DU at Thrissur and Chennai from 1979 to 2005

Figures 3 and 4 indicate the scattered diagram of yearly mean concentration of tropospheric ozone against that of stratospheric ozone at Thrissur and Bangalore, respectively, for the same period. It shows 1.6856 and 0.829 DU decrease in tropospheric ozone/ unit increase in stratospheric ozone, respectively.

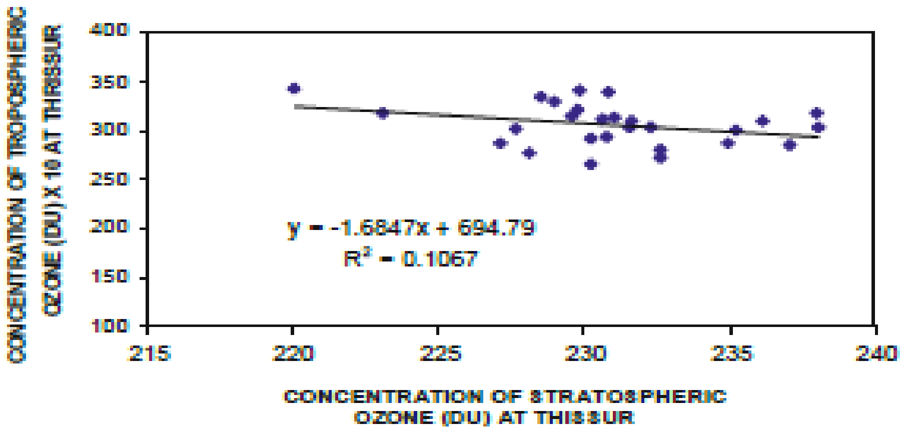

Fig. 3 Scattered *diagram* of tropospheric ozone with stratospheric ozone in DU at Thrissur

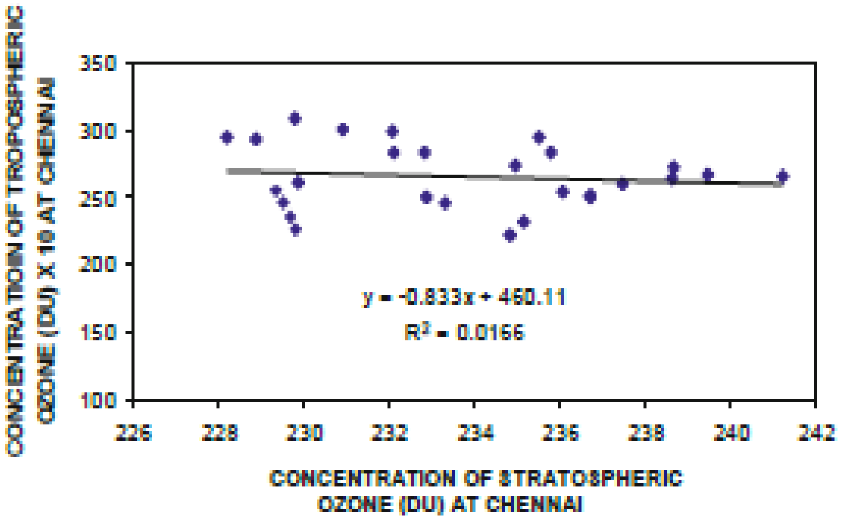

Fig. 4 Scattered diagram of tropospheric ozone with stratospheric ozone in DU at Chennai

The salient features that obtained from the above figures are verified by the coefficient of correlation values. The values of coefficient of correlation between mean seasonal variation of tropospheric and stratospheric ozone is (-0.37) for Thrissur and (-0.20) for Chennai. And the values of coefficient of correlation between mean yearly variation of tropospheric and stratospheric ozone is (-0.31) and (-0.15) for Thrissur and Chennai, respectively. The values are negative and poor. There was an anti-correlation between ground ozone level and total ozone at the Hohenpeissenberg station (48°N, 11°E) was inspected by Isaksen et al. (2005). The effect of equatorial wave, dynamical, chemical and radiative coupling between stratosphere and troposphere may explain this opposite nature of variation in tropospheric and stratospheric ozone. The transportation of trace chemical species, natural and anthropogenic occurs between the stratosphere and the troposphere. Anthropogenic species transportation from the troposphere into the stratosphere has an important and significant role for the depletion of stratospheric ozone chemistry (WMO, 1995). On the contrary, downward transport from stratosphere constitutes the main removal mechanism for many stratospheric species causing ozone depletion. It also contributes a remarkable input of ozone and other chemically reactive species into the tropospheric system. The vertical distribution of air and other chemical species through the depth of the troposphere can occur on time scales as less as few hours via most convection and time scales of days via baroclinic eddy motion. Conversely, vertical transportation through a similar altitude range in stratosphere requires few months, indeed a year or more in the lower stratosphere accompanied by radiative cooling or heating (Holton et al., 1995). A portion of the space time variability of deep tropical cloudiness may be described clearly in terms of equatorially trapped wave modes of shallow water theory (Wheeler et al., 2000). There is a very simple relationship between the organized convection and atmospheric circulation. "The lower frequency equatorial Rossby and Kelvin waves, with periods on the order of a week or more to the upper frequency mixed Rossby-gravity and inertio-gravity (IG) waves, during a period of around a day to a few days". Mixed Rossby-gravity wave propagates to the west with almost a 4–5 day period and modulates off equatorial convection. The Kelvin wave represented eastward moving equatorially centered cloud organization having a longitudinal scale of a few thousand kilometers and a propagation speed of around 10–25 m/s. It is completely different from that of eastward propagating 30-60 days intra seasonal or Madden Julian oscillation which has a lower frequency and speed. Other three coupled equatorial IG waves, eastward IG waves and westward IG can generate a circulation composite of this convectively coupled wave.

The chemical reactions which are responsible in the stratospheric and tropospheric ozone formation follow a series of complex cycles. Molecular oxygen (O_2), water vapour (H_2O), oxides of nitrogen (NO_x), carbon monoxide (CO) and VOCs play the significant and major role in these cycles. The ozone was produced by photo dissociation of water vapour as follows:

$$H_2O + h\nu \rightarrow OH + H$$

$$OH + h\nu \rightarrow O + H$$

$$O + O + M \rightarrow O_2 + M$$

$$O_2 + O + M \rightarrow O_3 + M$$

Sydney Chapman (1930) proposed ozone formation reaction in the following way.

$$O_2 + UV \rightarrow O + O$$

$$O + O_2 + M \rightarrow O_3 + M$$

$$O_3^* + O \rightarrow O_2 + O + O$$

$$O + O_2 + M \rightarrow O_3 + M$$

M is the third body that conserves energy and momentum. Pitts and Pitts (1997) postulated that the production of atmospheric ozone takes place by the photolysis of NO_2 through following processes.

$$NO_2 + h\nu \rightarrow NO \rightarrow O\ (3p)$$

$$O\ (3p) + O_2 + M \rightarrow O_3$$

If oxides of nitrogen are present in sufficient amounts, peroxy (RO_2) radicals, R = H or CH_3 will react with NO leading to O_3 production as follows (Kley et al., 1996; Chameides et al., 1973 and Crutzen, 1973).

$$RO2 + NO \rightarrow OH + NO_2\ (R = H)$$

$$NO_2 + h\nu \rightarrow NO + O$$

$$O + O_2 + M \rightarrow O_3 + M$$

Crutzen (1973) reported that HO_2 is formed by the following reaction :

$$CO + OH \rightarrow H + CO_2$$

$$H + O_2 + M \rightarrow HO_2 + M$$

Both HO_2 and peroxy radicals CH_3O_2 are formed during the oxidation of methane.

Stratospheric ozone layer absorbs harmful UV- radiation and protects us from its severe harmful effects. Among all the three types of UV- radiation UV-C (wave length 100–280 nm) is completely absorbed by the ozone layer. UV-B (wave length 280-315 nm) are partially absorbed whereas UV-A (315-400 nm) feebly absorbed by the ozone layer and transmitted to the surface of the earth very easily.

Stratospheric ozone occurred over Thrissur and Chennai, India in the month of July to September relatively higher amount. As a result, smaller amount of solar radiation transmitted into the troposphere from stratosphere. It produced lesser amount of tropospheric ozone because of the hindering of the mentioned photodissociation reactions. So low concentration of tropospheric ozone had been found over Thrissur and Chennai which is represented in Fig. 1. Kalita et al. (2010) analyzed the ozone data over Dibrugarh (27.3°N, 94.6°E), India during the period September, 2007 to February, 2009 and also found lower TCO in September-December and higher TCO in April-June. Due to gradual increasing of solar radiation a very little amount of the yearly mean stratospheric ozone concentration gradually decreased. This enhanced the rates of photodissociation reactions for the formation of tropospheric ozone. As a result tropospheric ozone concentrations showed gradual increasing trends from 1979 to 2005 as shown in Fig. 2. There is an anti but poor correlation between the mean seasonal variation of tropospheric and stratospheric ozone as well as the yearly mean variation of tropospheric and stratospheric ozone as represented in the scattered diagrams. The narrow coefficient of correlation value reveals that not only solar radiation but also ozone precursors like CO, VOCs, water vapour, NOx etc. act as a significant role inthe destruction and formation of tropospheric ozone.

Gradual increase in tropospheric ozone and UV-B fluxes are enhanced by slow and gradual decrease in stratospheric ozone. Various pollutants like NOx, SO_2, CH_4, CFCs, tropospheric ozone etc are produced both by naturally and anthropogenically from1979 to 2005, play an important role in global warming. Incomplete combustion of carbon based fuels generated carbon monoxide and CO_2 is produced by the complete combustion of carbon based fuels in homes, factories and automobiles. It is also released by the organisms during respiration. Methane gas is produced by the various human activities over the last fifty years. It is also produced from the natural and anthropogenic sources. Various industrial activities and burning of coal produced oxides of sulphur. NOx are added into the atmosphere by burning of coal and petrol and also by the thermal decomposition of many nitrate salts. Refrigerators and air conditioners released CFCs into the environment. Cement plants, power plants, steel plants and different factories genereted suspended particulate matters to air. The increased UV-B fluxes has increased the tropospheric concentrations of HO_x radicals and H_2O_2 which cause atmospheric pollution (Sigg, and Neftel,1991; Anklin and Bales, 1997 and Neftel, 1995). Mechanical properties of synthetic and naturally occurring polymers are also affected by UV-B sunlight (Andrady et al., 1998). UV-B rays are responsible for sunburn, skin pigmentation consisting immediate pigment darkening, neomelanogenesis and many fatal skin cancers (Slaper et al., 1996 and Holman et al.,1984). UV-B actinic fluxes affect the lens, cornea, vitreous humor and the retina of eye. As a result, many diseases of eye like cataract, photokeratitis, photophobia and twitching etc may occur (McCarty and Taylor, 1996).

The Increased tropospheric ozone gases intensify global warming directly. As a green house molecule it can absorb infrared radiation (Ramanathan, 1985). Changes in upper tropospheric ozone have a huge impact on the surface temperature is observed by Fadnavis et al. (2010). The increase in tropospheric ozone has produced a global average radiative forcing of $0.35Wm^{-2}$. It also causes lower stratospheric cooling by radiating heat to space which affects the formation of polar stratospheric clouds (PSC). It causes the stratospheric ozone depletion (Kerr, 1998). Fiore et al. (2002) also reported that enhanced upper tropospheric ozone can influence on air quality if it is transmitted to the boundary layer. Throat irritation, coughing, irritation of the respiratory system, uneasy feeling in the chest, persistent decrease in lung function etc. occur due to intense exposure to tropospheric ozone (Berry et al., 1991). It is also noticed that it enhances pneumonia, influenza (Ozkaynak et al., 1990) and asthma (Cody et al., 1992). People having asthma are affected much when concentrations of ozone becomes very high. This happens because ozone makes people more sensitive to allergens which intensify asthma attacks (2002). In addition many health hazards of human are found (Lucas et al., 2019). Symptoms of ozone injury are found many plants such as milkweed, white ash, white pine and black berry etc. (Manning et al., 1991). According to Environmental Protection Agency (EPA) of United States eight-hour average ozone concentrations of 85–104 ppbv are described as ‘‘Unhealthy for Sensitive Groups’’, 105–124 ppbv as ‘‘unhealthy’’ and 125–404 ppbv as ‘‘very unhealthy’’ (Bell et al., 2004).

CONCLUSIONS:

Mean seasonal variations of stratospheric ozone at Thrissur and Chennai show that the concentration of ozone increased gradually from the month of January, reached maximum in July-September and then it slowly decreased during the period 1979–2005 whereas, for the tropospheric ozone, the concentration of ozone shows increasing trends from January and attained maximum in April and May at the above stations. Thereafter it decreases sharply and attained the minimum value in September and then shows increasing trends during 1979–2005. It is observed that the slow decreasing trends of yearly mean stratospheric ozone but sharp decreasing trends from 1979 to 2005 at both the stations. There is an anti but poor correlation is observed between mean seasonal variation of tropospheric and stratospheric ozone trends. Anti but poor correlation is also found between the yearly mean variation of tropospheric and stratospheric ozone trends. This gives us an idea that not only amount of ozone precursors but also some other factors like equatorial wave, influence photochemical activity, chemical, dynamical, and radiative coupling between the stratosphere and the troposphere act as an important role in the tropospheric and the stratospheric ozone budget. Several health issues like asthma, coughing, throat irritation, uncomfortable sensation in the chest, persistent decrease in lung function and irritation of the respiratory system etc. of human are caused by the tropospheric ozone rise and the stratospheric ozone reduction. It also enhanced environment pollution and global warming of the universe.

ACKNOWLEDGEMENT:

The author is highly thankful to Prof. S.K. Midya, Department of Atmospheric Science, University of Calcutta and Dr. P.K. Jana, Institute of Education (P.G) for women, Chandernagar, Hoogly for critical and valuable discussions.

REFERENCES:

[1] Wayne, R. P. (2000). Chemistry of atmosphere. Oxford: Oxford University press. 126-134.

[2] Watson, R. T., Albritton, D. L., Barkar, T., Bashmakov, I. A., Canziani, O., Christ, R. (2001). Radiative Forcing of Climate Change, Working Group I: The Scientific Basis IPCC Third Assessment Report-Climate Change. Cambridge: Cambridge University Press. 248-263.

[3] Eggleston, S. (2006). IPCC Guidelines for National Greenhouse Gas Inventories, IPCC National Greenhouse Gas Inventory Programme. Hayama, Japan. 387-393.

[4] Intergovernmental Panel on Climate Change. (2007). Climate Change 2007—The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. UK: Cambridge University Press. 112-123.

[5] Worden, H. M., Bowman, K. W., Worden, J. R., Eldering, A. and Beer, R. (2008). Retrievals of tropospheric ozone profiles from the synergism of AIRS and OMI: Methodology and validation. Nat. Geosci., 1, 305-312.

[6] Seinfeld, H. J. and Pandis, N. S. (1998). Atmospheric Chemistry and Physics—from Air Pollution to Climate Change (New York: Wiley). 277.

[7] Bojkov, R. D. (1992). Changes in Polar zone. WMO Bull. 41,171-185.

[8] Farman, J. C. Gardiner, B. G. and Shanklin, J. D. (1985). The discovery of Antarctic ozone hole. Nature. 315, 207-210.

[9] Midya, S. K., Ghosh, D., Ganda, S. C. and Sarkar, H. (2011). Seasonal variation of daily total column ozone (TCO) and role of its depletion and formation rate on surface temperature over Dumdum at Kolkata, India. Indian

J. Phys. 85(8), 1247-1260.

[10] Tian, W., Chipperfield, M. P., Stevenson, D. S., Damoah, R., Dhomse, S., Dudhia, A., Pumphrey, H. and Bemath, P. (2005). J. Geophys. Res. 115, 11.

[11] NCDC: Greenhouse Gasses, www.ncdc.noaa.gov>NESDIS>NCDC (2010).

[12] Bellevue, J. L. D., Barray, J. L., Baldy, S., Ancellet, G., Diab, R. and Ravetta, F. (2007). Simulations of stratospheric to tropospheric transport during the tropical cyclone Marlene event. Atmos. Environ., 41(31), 6510-6519.

[13] Das, S. S. (2009). A new perspective on MST radar observation of stratospheric intrusions into troposphere associated with tropical cyclone. Geophys. Res. Lett., 36, L15821.

[14] Mandal,T. K., Cho, J. Y. N., Rao, P. B., Jain, A. R., Peshin,S. K., Srivastava, S. K., Bhora A. K., and Mitra, A. P. (1998). Stratosphere-troposphere ozone exchange observed with the Indian MST radar and a simultaneous balloon-borne ozonesonde. Radiat. Sci., 33, 861-870.

[15] Gupta, S., Lal, S., Venkataramani, S., Rajesh, T. A. and Acharya,Y. B.(2007). Variability in the vertical distribution of ozone over a subtropical site in India during a winter month. J. Atmos. Sol. Terr. Phys., 69, 1502-1510.

[16] Kumar, K. K. and Uma, K. N. (2009). Interactive comment on high temporal resolution VHF radar observations of stratospheric air intrusions in to the upper troposphere during the passage of a mesoscale convective system over Gadanki. Atmos. Chem. Phys. Discuss, 9, 13843-13854.

[17] Sahu, L. K. Lal, S., Thouret, V. and Smit, H. G. J. (2009). Seasonality of tropospheric ozone and water vapour over Delhi, India: a study on Mozaic measurement data. J. Atmos. Chem., 62, 151-174.

[18] Cooper, O. R. (2007). Evidence for a recurring eastern North America upper tropospheric ozone maximum during summer. J. Geophys. Res., 112, 12-21.

[19] Fadnavis, S., Chakraborty, T. and Beig, G. (2010). Seasonal stratospheric intrusion of ozone in the upper troposphere over India. Ann. Geophys. 28, 2149-2162.

[20] Jana, P. K. Goswami, S., Midya, S. K. (2012). Relation between tropospheric and stratospheric ozone at Thumba and Bangalore, India and its effect on environment. Indian J.

[21] Lal, S., Sahu, L. K. and Venkataramani, S. (2007). Impact of transport from the surrounding continental regions on the distributions of ozone and related trace gases over the Bay of Bengal. J. Geophys. Res., 112, D14302.

[22] Watanabe, K., Nojiri, Y. and Kariya, S. (2005). Measurements of ozone concentrations on a commercial vessel in the marine boundary layer over the northern North Pacific Ocean. J.Geophys. Res., 110, D11310,

[23] Ziemke, J. R., Chandra, S. and Bharatia, P. K. (1998). Two new methods for

deriving tropospheric column ozone from TOMS measurements: The assimilated UARS MLS/HALOE and convective-cloud differential techniques. J. Geophys. Res., 103, 22115-22127.

[24] Isaksen, I. S. A., Zerefos, C., Kourtidis, K., Meleti, C., Dalsoren, S. B., Sundet,J. K., Grini,A., Zanis, P. and Balis, D. (2005). Tropospheric ozone changes at unpolluted and semipolluted regions by stratospheric ozone changes. J. Geophys. Res., 110, D02302.

[25] World Meteorological Organization. (1995). Scientific Assessment of Ozone Depletion.

[26] Holton, J. R., Haynes, P. H., Molntyre, M. E., Douglass, A. R., Rood, R. B. and Pfister, L. (1995).Stratosphere-troposphere exchange. Rev. Geophys., 33, 403-411.

[27] Wheeler, M., Kiladis, G. N. and Webster, P. J. (2000). Large-Scale Dynamical Fields Associated with Convectively Coupled Equatorial Waves. J. Atmos. Sci., 57, 613-619.

[28] Chapman, S. (1930). A theory of upper atmospheric ozone. Mem. R. Soc., 3, 103-112.

[29] Pitts, B. J. F. and Pitts Jr, J. N. (1997). Tropospheric Air Pollution: Ozone, Airborne Toxics, Polycyclic Aromatic Hydrocarbons, and Particles. Science, 276, 1045-1048.

[30] Kley, D., Crutzen, P. J., Smit, H. G. J., Vomel, H., Oltmans, S. J., Grassi, H. and Ramanatha, V. (1996). Observations of near zero ozone concentrations over the convective pacific: effects on air chemistry. Science, 274, 230-232.

[31] Chameides, W. L. and Walker, J. C. G. (1973). A photochemical theory of tropospheric ozone. J. Geophys. Res., 78, 8751-8759.

[32] Crutzen, P. J. (1973). A discussion of the chemistry of some minor constituents in the stratosphere and troposphere. Pure Appl. Geophys., 1385, 106-114.

[33] Kalita, G., Bhuyan,P. K. and Bhuyan, K. (2010). Variation of Total Columnar Ozone Characteristics over Dibrugarh. Indian J. Phys., 84, 635-648.

[34] Sigg, A. and Neftel, A. (1991). Evidence for a 50% increase in H_2O_2 over the past 200 years from a Greenland ice core. Nature, 351, 557-559.

[35] Anklin, A. and Bales,R. C. (1997). Recent increase in H_20_2 concentration at Summit, Greenland. J. Geophys. Res., 102, 19099-19112.

[36] Neftel, A., Bales,R. C. and Jacob,D. J. 1995. H_2O_2 and HCHO in polar snow and their relation to atmospheric chemistry. NATO ASI Ser., I30, 249.

[37] Andrady, A. L., Hamid,S. H., Hu, X. and Torikai, A. (1998). Effects of increased solar UV radiation on materials. J. Photochem. Photobiol., B 46, 96-107.

[38] . Slaper, H., Velders,G. J. M., Daniel, J. S., de Gruijl,F. R. and Vanderleun,J. C. (1996). Estimates of ozone depletion and skin cancer incidence to examine the Vienna Convention achievements. Nature, 384, 256.

[39] Holman, C. D. J. and Armstrong, B. K. J. (1984). Cutaneous malignant melanoma and indicators of total accumulated exposure to the sun: an analysis separating histologic type. J. Natl. Cancer Inst., 73, 75-87.

[40] McCarty, C. A. and Taylor, H. R. (1996). Recent developments in vision research: light damage in cataract. Investig. Ophthalmol. Vis. Sci., 37, 1720-1729.

[41] Ramanathan, V., Cicerone,R. S., Sing,H. B. and Kiehl,J. T. (1985). Trace gas trends and their potential role in climate change. J. Geophys. Res., 90, 9547-9556.

[42] Kerr, R. A. **(**1998). Deep Chill Triggers Record Ozone Hole. Science, 282, 391-393.

[43] Fiore, A. M., Jacob,D. J., Bay,I., Yantosce,R. M., Field,B. D., Fusco,A. C. and Wilkinson, J. G. (2002). Background ozone over the United States in summer: Origin, trend, and contribution to pollution episodes. J. Geophys. Res., 107, 42775-42783.

[44] Berry, M., Lioy, P. J., Gelperin, K., Buekler, G. and Kholtz, J. (1991). Accumulated exposure to ozone and measurement of health effects in children and counselors at two summer camps. Environ. Res., 54(2), 135-144.

[45] Ozkaynak, H., Kinney, P. L. and Burbank, B. (1990). Recent epidemiological finding on morbidity and mortality effects of ozone. Proc. Annu. Meet—Air Waste Manage. Assoc., June 24-29.

[46] Cody, R. P., Weisel, C. P., Birnbaum, G. and Lioy, P. S. (1992). Relationship between Summertime Ambient Ozone Levels and Emergency Department Visits for Asthma in Central New Jersey. Environ. Res., 58, 184-195.

[47] Lucas, R.M., Yazar,S., Neale, R.E. (2019). Human health in relation to extra exposure to solar UV-radiation under changing stratospheric ozone and climate. Photochem.Photobiol. Sci. 18(3), 641-680.

[48] Manning, W. J., Bergman, J. R. and O'Brien, J. T. (1991). Ozone injury on native vegetation in Class I wilderness areas in New Hampshire and Vermont. Proc. Annu. Meet— Air Waste Manage. Assoc., paper 91-144.5.

[49] Bell, M. L., McDermott, A., Zeger, S. L., Samet, J. M. and Dominici, F. **(**2004). Ozone and Short-term Mortality in 95 US Urban Communities. J. Am. Med. Assoc., 292, 2372-2384.