Study of Total Ozone Column Content and its association with Sunspot Number and Total Rainfall over two close tropical Indian stations during1981

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Abstract : Present paper is based on analysis of the variation of Total Ozone Column content (TOC) with sunspot number and total rainfall during different seasons over the two neighbouring Indian tropical stations (Udaipur and Banswara) for the period 1981. A negative correlation is observed between TOC and sunspot number over both stations during monsoon period and positive correlation is observed during pre monsoon and post monsoon period. It is also observed that amount of TOC start decreasing in monsoon period, became minimum in post monsoon period and maximum in pre monsoon period. The value of TOC for Banswara is found to be lower in comparison to Udaipur during pre and post monsoon season, whereas reverse value is obtain in monsoon period, specially in this year.

***Index Terms* - TOC, Sunspot number, Rainfall.**

I. INTRODUCTION

Ozone is one of the important ingredients of the atmosphere; it plays a vital role in determining the earth's climate. About 90 percent of ozone is present in stratosphere (a region from 16 to 50 km above earth's surface) and form a layer, known as ozone layer and the remaining 10 percent in the troposphere (10 to 16 km above the earth surface). Stratospheric ozone is known as good ozone, because it protects us from harmful ultra violet radiation (UV-B) by absorbing them (Lacis et al., 1990; Forster & Shine, 1997; Dave, 2007). Stratospheric ozone is formed by photolysis of oxygen molecules by ultra violet radiation. UV radiations splits one oxygen molecule into two oxygen atoms, which then combine with another oxygen molecule to produce an ozone molecule (O_3) (Madhu, 2014). Ozone is produced only by UV radiation, but can be destroyed by visible light also. Tropospheric, or ground level ozone is not emitted directly into the air, but is created by chemical reactions between oxides of nitrogen (NOx) and volatile organic compounds (VOC) present in the atmosphere with the sun light. Since ozone is very good oxidizing agent, it reacts with other chemical compounds and produce other harmful toxic oxides and therefore tropospheric (or surface) ozone are sometimes called bad ozone. Surface ozone is harmful to breathe, because it damages living cells and tissues inside the human body, it causes asthma and respiratory problems and increase in surface ozone levels leads to premature death. It is also harmful to vegetation. Tropospheric ozone acts as a green house gas and leads to global warming (Lacis et al., 1990; Forster & Shine, 1997). It is a main component of smog. TOC (Total column ozone) is a total amount of ozone present in vertical column of air above the earth's surface. It is measured in Dobson unit (DU). Amount of ozone in atmosphere also represent in parts per million by volume (ppmv) and parts per billion by volume (ppbv). The term ozone hole is used in region, where the level of stratospheric ozone falls below 200 DU. Ozone loss occurs during every spring season after winters in Antarctica stratosphere and in lesser amount in arctic, where very low air temperature and special meteorological conditions destroy the ozone by ozone depleting chemicals, originated from human activities such as chlorine, bromine, HCL, etc. (Jain et al., 2005). It is very well known fact from earlier studies that the total amount of ozone present in tropics (where it is produced in maximum amount) is very less (about 250 DU), because it is transported to higher latitudes and maximum amount of it is present in polar regions (about 400 DU), because the photochemical losses are minimum there (Lal et al., 2008). Also it is found that amount of ozone is maximum in the spring season after winter of each hemisphere region, because it deposits during winter of each hemisphere, and it starts decreasing in the summer season, there is no much seasonal variation of ozone in tropical region is observed (Kondratyev & Varotsos, 2000; Mohankumar, 2008).

The Sunspots are darker regions on the Sun's photosphere as compared to the surrounding areas (Prince et al., 2013). They are colder than their surrounding by few thousand degrees having temperature of about 3700 K as compared to 5700 K of the surrounding photosphere (Chakrabarty & Chakraborty, 2013). This region is colder, because they are formed in regions, where magnetic field is very strong. These strong magnetic field keep some of the heat within the sun from reaching the surface that is inhibits convection motion and hence less energy is carried upward resulting in forming of areas of reduced temperature at sun's photosphere. They may last from few hours to few months. Their number on the surface of the sun varies in a regular pattern according to solar cycle which is approximately of 11.5 year (Prince et al., 2013). Scientists track solar cycles by counting sunspots continuously all across the world and a period of 24 × 7, means each hour of each day. To study about Hα spectral line of hydrogen in the solar atmosphere a Global Oscillation Network Group (GONG) is established, which is a community based program for studying solar internal structure and dynamics using helioseismology. This program is managed by the National Solar Observatory and in this programme six observatories are involved Teide Observatory (Canary Islands), the Learmonth Solar Observatory (Western Australia), the Big Bear Solar Observatory (California), the Mauna Loa Solar Observatory (Hawaii), the Udaipur Solar

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Observatory (India) and the Cerro Tololo Inter-American Observatory (Chile). These observatories took almost unbroken observation of the Sun (https://en.wikipedia.org/wiki/Global_Oscillations_Network_Group). The Wolf number (also known as the International sunspot number, or Zürich number) is a quantity that measures the number of sunspots and groups of sunspots present on the surface of the sun (Liu et al., 2004).They are calculated by the procedure or formula given by Rudolf Wolf in 1848 in Zurich, Switzerland (Tribble, 2003). They appear in pairs of opposite magnetic polarity having very strong magnetic field about thousands of times stronger than the Earth's magnetic field, that is one spot of the pair have positive or north magnetic field, while the other spot have negative or south magnetic field. They have two parts that is the central Umbra, the darkest part having strongest magnetic field, which is normal to the Sun’s surface and the outer lighter part penumbra, where the field is weaker and more inclined (Liu et al., 2004). They do not emit any radiation that reaches the Earth, but sunspots indicates level of activity of the Sun (de Jager, 2005). Thus the knowledge of sunspots is important to understand the space weather and effect of variation in the activity of Sun on the Earth. The effect of sunspots on ozone could be better understood by finding relationship between them. Many researchers evaluated the relationship between the atmospheric ozone and the sunspot numbers. The results were observed different for different time periods. Willet studied the relationship between the total atmospheric ozone and sunspot number for the 27-year period (1933-1959) and he observed a highly significant negative correlation between the relative sunspot number and the worldwide average of total atmospheric ozone (Willet, 1962). Angell and Korshover (1976) predicted from their research that the variation in total ozone is nearly in phase with sunspot numbers. They stated on the basis of collected data from 1960 to 1974 that it must be possible that the main cause of decrease in ozone from 1970 to 1974 is due to decrease in sunspot number following the sunspot maximum in 1969 and not due to anthropogenic effects. Furthermore Angell (1989) also evaluated that the seasonal values of sunspot number and global total ozone are correlated by 0.48 significant at 1% level on basis of data between 1960 and 1987. Rabiu and Omotosho (2003) studied the impact of Solar Activity on TOC Variation four years (1993-1997) in Lagos, Nigeria and found a significant negative correlation between them both at monthly level and annual level and showed that the total column ozone decreases with increasing solar activity. Selvara et al., (2010a) studied the relationship between surface ozone and smoothed sunspot numbers (SSN) on east coast of southeast India and found that there was increase in surface ozone with the increase in sunspot numbers during the months May and October in the time period 1996-2004. Selvara et al., (2010b) also investigated the statistical relationship between surface ozone and solar activity in a tropical rural coastal site, India during the same time period and obtained a strong positive correlation (0.94) between annual sunspot number and ozone content by multiple regression analysis method. They obtained higher positive values of rank correlation coefficients which were 0.76 and 0.62 for the years 2000 and 2002 respectively, indicating the higher impact of solar activity over the surface ozone levels. Isikwe et al., (2010) evaluated the relationship between sunspot number and the stratospheric ozone variation at five different cities in Nigeria during 1998-2005 and obtained by multiple regression analysis method both are positively correlated at 99% level of significance, which indicates that sunspot number directly, influences variation in stratospheric ozone in all the cities. Most of the researchers found that the variation in total ozone is nearly in phase with sunspot numbers, but some researchers found negative correlation between them. Bisht et al., (2014) studied the relationship between SN and TOC along with other things at two hill stations (Nainital and Mussoorie) of Uttarakhand for 28 years from 1986 to 2013 and found a positive correlation between annually averaged TCO and SN for both the stations. The correlation coefficient of TOC with SN at both the stations was 0.51 and 0.45 respectively. The other aim of this paper is to find relation between TOC and rainfall. Midya et al., (2011) investigated the significant relationship between total ozone concentration and rainfall over some important stations of India. They observed from their critical analysis that that low temperature of troposphere, presence of sufficient water vapor, and CCN (Cloud Condensation Nuclei) are not the sufficient conditions of rainfall. They observed that depletion of ozone concentration also effects rainfall, rainfall increases and ozone decreases with the increase of time. Rainfall occurs, only when ozone concentration lies in a certain concentration level. The study of long term changes in TOC was also done by Vyas and Saraswat (2013) over a 25 year period over two neighbouring tropical Asian stations Karachi and Mout Abu and found a strong declining trend in TOC at both sites, with a significance level of over 95% and a higher magnitude of 4 to 10 DU per decade in September to December and a weak statistical significance level of below 85% and a lower magnitude of 2 to 4 DU per decade in pre-monsoon months. During monsoon period a statistically insignificant small declining trend (about 1 DU per decade) was observed. They found that there is a strong relationship between the seasonal dependence of the long-term declining trend of TOC on air temperature at 10 mb or stratospheric cooling, and there is a less significant long-term variation in TOC due to altered solar activity levels. Pandey and Vyas (2004) measured TOC at Udaipur using the Microtop II Sun photometer and compared it with the TOMS data for two months, spaced a year apart. The values obtain by Sun photometer are found to within 10% of the TOMS value.

II. DATA SET AND ANALYSIS

For the present study the daily gridded ozone data are retrieved from Nimbus-7 TOMS (Total Ozone Mapping Spectrometer) from the website http://ozoneaq.gfsc.nasa.gov/data/toms/. Ozone concentration data obtained from TOMS is in the gridded form of resolution 1.25°×1° latitude-longitude data. In the present paper Banswara (23.55°N, 74.45°E) and Udaipur (24.5°N,73.68°E), the two neighbouring tropical stations of India have been taken as our study area, which belong to the southern part of Rajasthan. The rain fall or precipitation data set over study areas is retrieved from the http://www.water.rajasthan.gov.in, and the daily data for Sunspot number is accessed from its related site. The tropic of cancer passes through the Banswara therefore the climate of this region is extremely hot and exhausting as compare to Udaipur during summer. The altitude of Banswara and Udaipur from sea level is 302 metres and 598 metres respectively.

For analyzing the daily gridded ozone data, first the related data is downloaded from its site for each day of year 1981. Since the raw data was in the gridded form and our focus was on two particular stations, so we have extracted the data of the particular coordinates of our selected study regions from this raw data. In this data some data was not related to site, so that data was also eliminated from that. After it we calculate the monthly average value of ozone. To evaluate the seasonal variation of TOC over both the stations during 1981, a graph is plotted between monthly average ozone with pre monsoon (February to May), monsoon (June to September) and post monsoon (October to January) period. We have plotted a graph between monthly ozone values of ozone data with their month for a particular year. In order to establish a relation between TOC and sunspot number, an average value of sunspot number for all the months of the year is calculated from its raw data. And then a curve is plotted between average sunspot number and months on the same graph in which ozone was plotted. Since the monsoon or rainfall in western part of India (study site) mostly comes in months from June to September, so to establish the relation between TOC and total rain fall, we have taken only particular months, which have rainy days. So we have extracted the total rainfall data for these monsoon months of the year 1981 from its downloaded raw data. Similarly the total rainfall is plotted against these months on the same graph in which average ozone was plotted with these months. The results and conclusion obtained on the basis of this study is given in the next section.

III. RESULT AND CONCLUSION

A bar graph plotted between average values of Ozone (DU) over the both stations and months during the year 1981 is shown in Fig. 1. It is observed that the value of TOC for Banswara is found to be lower in comparison to Udaipur during pre and post monsoon season, whereas reverse value is obtained in monsoon period specially in this year. The amount of TOC is observed more over Udaipur in comparison to Banswara for maximum time period may be due to the altitude of Udaipur from sea level is more than Banswara, because amount of ozone increases with altitude. The TOC over both sites start declining in monsoon period and further continuously declining in post monsoon period , afterwards it start increasing in pre monsoon period. Hence the rate of change in TOC shows different seasonal dependence. The seasonal variation in values of TOC and sunspot number over Banswara and Udaipur during monsoon period is significantly negatively correlated by 0.71 and 0.98 respectively and positively correlated during pre monsoon and post monsoon period are shown in the Fig. 2 and 3 respectively. The black and red line of the curve in these figures indicates average monthly values of ozone and sunspot number respectively. A very poor positive correlation is found between average TOC values and sunspot number over Banswara and its value is 0.06. A very weak anti-correlation is found between TOC values and sunspot number over Udaipur and its value observed is 0.03. The relationship between average TOC and total rainfall over Banswara and Udaipur are shown in the Fig. 4 and 5. The black and red line of the curve in these figures indicates average monthly values of ozone and total rainfall respectively. Average TOC and total rainfall over Banswara is positively correlated by 0.42, but observed negative correlation over Udaipur and its value is found to be 0.398.

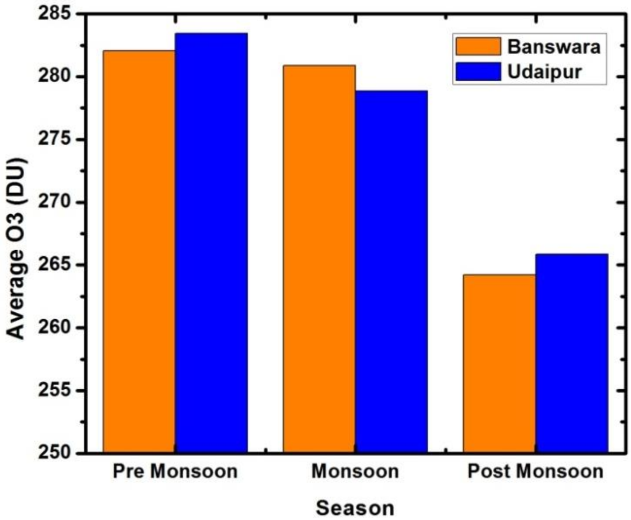

Fig. 1 Seasonal variation of average O3 (DU) during 1981

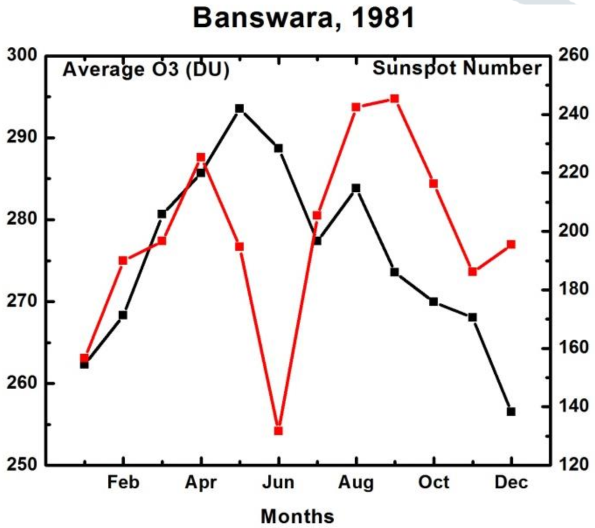

Fig. 2

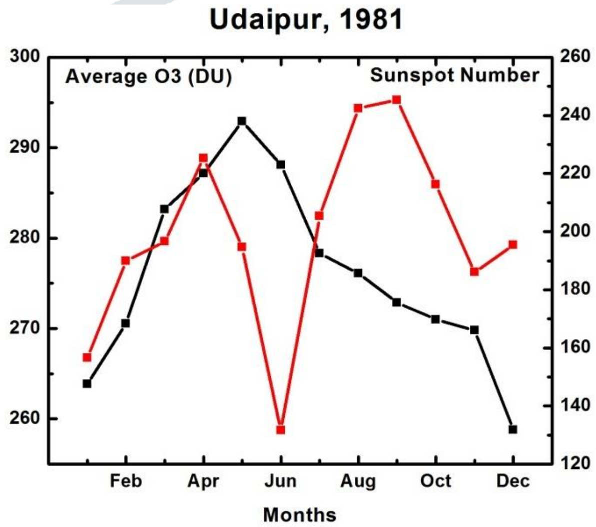

Fig. 3

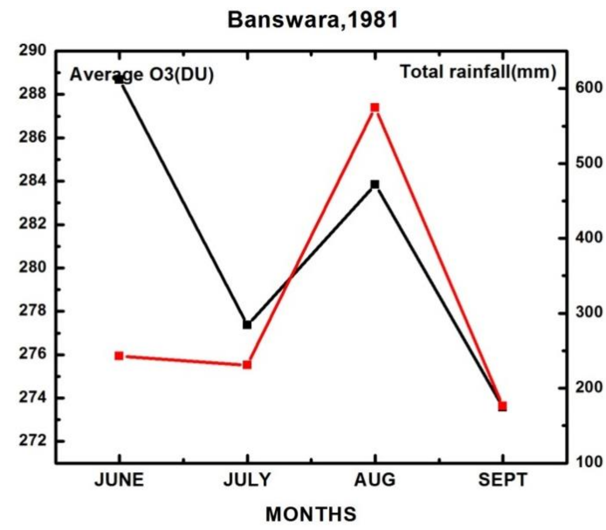

Fig. 4

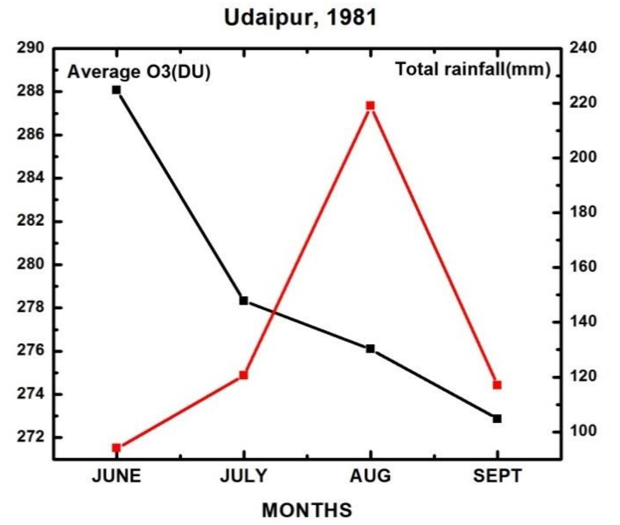

Fig. 5

REFERENCES

[1] Angell J. K. 1989. On the relation between atmospheric ozone and sunspot number. Journal of Climate, 2 (11): 1404–1416.
[2] Angell J. K., and Korshover J. 1976. Global analysis of recent total ozone fluctuations. Monthly Weather Review, 104: 63–75.
[3] Bisht H., Pande B., Chandra R., and Pande S. 2014. Statistical study of different solar activity features with total column ozone at two hill stations of Uttarakhand. Indian journal of Radio & Space Physics, 43 (4-5): 251.
[4] Chakrabarty H., and Chakraborty A. 2013. Sunspot number and severe thunderstorms of Kolkata, India. International Journal of Scientific & Engineering Research, 4 (9).
[5] Dave R. 2007. Study of total column ozone, aerosol optical depth and precipitable water content at Udaipur. Ph.D. thesis, Mohan Lal Sukhadia University, Udaipur, India.
[6] de Jager C. 2005. Solar forcing of climate 1: Solar variability. Space Science Reviews, 120 (3-4): 197–241.
[7] Forster P., and Shine K. 1997. Radiative forcing and temperature trends from stratospheric ozone changes. Journal of Geophysical Research, 102: 10841–10855. DOI: 10.1029/96JD03510.
[8] Isikwue B. C., Agada P. O., and Okeke F. 2010. The contributions of the solar activity indices on the stratospheric ozone variations in Nigeria. Journal of Emerging Trends in Engineering and Applied Sciences, 1 (2): 133–139.
[9] Jain S. L., Arya B. C., Kumar A., Ghude S. D., and Kulkarni P. S. 2005. Observational study of surface ozone at New Delhi, India. International Journal of Remote Sensing, 26 (16): 3515–3524.
[10] Kondratyev Ya. K., and Varotsos C. 2000. Atmospheric Ozone Variability: Springer–Praxis Book.
[11] Lacis A. A., Wuebbles D. J., and Logan J. A. 1990. Radiative forcing of climate by changes in the vertical distribution of ozone. Journal of Geophysical Research, 95: 9971–9981. DOI: 10.1029/JD095iD07p09971.
[12] Lal S., Sahu L. K., Gupta S., Srivastava S., Modh K. S., Venkataramani S., and Rajesh T. A. 2008. Emission characteristic of ozone related trace gases at a semi-urban site in the Indo-Gangetic plain using inter-correlations. J. Atmos. Chem., 60: 189–204. DOI: 10.1007/s10874-008-9115-0.
[13] Liu J. Y., Lin C. H., Tsai H. F., and Liou Y. A. 2004. Ionospheric solar flare effects monitored by the ground-based GPS receivers: Theory and observation. Journal of Geophysical Research, 109: A01307. DOI: 10.1029/2003JA009931.
[14] Madhu V. 2014. Spatial and temporal variability of total column ozone over the Indian subcontinent: A study based on Nimbus-7 TOMS satellite. Atmospheric and Climate Sciences, 4 (5): 884–898.
[15] Midya S. K., Saha U., Panda P., Kundu A., Chaudhuri A., and Sarkar H. 2011. Variation of total ozone concentration and rainfall over different stations of India. Pacific Journal of Science and Technology, 12 (1): 580–590.
[16] Mohankumar K. 2008. Stratosphere Troposphere Interactions: An Introduction. Springer, Cochin, India. ISBN: 9781402082160.
[17] Pandey R., and Vyas B. M. 2004. Study of total column ozone, precipitable water content and aerosol optical depth at Udaipur, a tropical station. Current Science, 86 (2): 305–309.
[18] Prince A. M., Thomas S., Jon R., and Jayapandian D. P. 2013. A study on midrange periodicity of sunspot number during solar cycles 21, 22, 23 & 24. International Journal of Scientific and Research Publications, 3 (2): 1-5.
[19] Rabiu A. B., and Omotosho T. V. 2003. Solar activity and total column ozone variation in Lagos, Nigeria. Nigeria Journal of Pure and Applied Physics, 2 (1): 17-20.
[20] Selvaraj R. S., Gopinath T., and Jayalakshmi K. 2010b. Statistical relationship between surface ozone and solar activity in a tropical rural coastal site, India. Indian Journal of Science and Technology, 3 (7): 792–794.
[21] Selvaraj R. S., Selvi S. T., and Priya S. P. V. 2010a. Association between surface ozone and solar activity. Indian Journal of Science and Technology, 3 (3): 332–366.
[22] Tribble A. 2003. The space environment, implications for spacecraft design. Princeton University Press: 15–18.
[23] Vyas B. M., and Saraswat V. 2013. Study Long-term changes in total ozone column content and its association with stratospheric temperature over two neighbouring tropical Asian stations. International Journal of Remote Sensing, 34 (19): 6496–6506.

[24] Wikipedia, the free encyclopedia (2018) [Online]. Available: https://en.wikipedia.org/wiki/Global_Oscillations_Network_Group.
[25] Willet H. C. 1962. The relationship of total atmospheric ozone and sunspot cycle. J. Geophys. Res (USA), 67: 661–670. DOI: 10.1029/JZ067i002p00661.