

Study of Surface Ozone over an American Station for a Period of 3.5 Decade

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Abstract

In this research paper we have evaluated the relation between surface Ozone (O₃), Sun Spot Number (SSN) and Carbon Monoxide (CO) over an American station "Tutuila" for the long period of 35 years (1980-2015). It was analyzed that CO and O₃ show an increasing trend over the maximum months of the year, whereas SSN shows decreasing trend throughout the year. We have concluded that, for O₃ the increasing trend is found to be maximum in the month of December, whereas surprisingly just a month before it i.e., in November, the value was negative. We also analyze here the CO data for the same period. It is observed that the CO increases from January to June. Its increment is found to be minimum in January month and maximum in the month of April. After it, the CO shows the decay trend from July to September, and then again increases from October to December months. NO2 data of 11 years is also studied here and concluded that, the variation observed in March month is very small and is positive. In the same way, a positive trend is observed for NO₂ data in June month, but in rest all the months the value is negative.

Keywords

Surface Ozone, Sunspot Number, Carbon Monoxide, Nitrogen Dioxide

1. Introduction

The Earth's atmosphere is split into 5 layers: troposphere, stratosphere, mesosphere, thermosphere, and exosphere (Perevedentsev et al., 2019). Many of the human activities are badly affecting the atmosphere (Lu et al., 2018), and the stratosphere layer is a matter of great concern which is harmful to human itself (Anwar et al., 2016). It has been observed from past studies that concentrations of ozone in the upper stratosphere have increased in the last 15 years (Rozema et al., 2005). Depletion of the ozone layer by chlorine and bromine species has been a major environmental issue (Sivasakthivel & Reddy, 2011). The ozone layer, which absorbs and scatters the solar UV radiations, lies in this region (Brenna et al., 2019). The ozone layer is a naturally occurring gas in the region of the stratosphere, where ozone particles are accumulated (Wargan, 2018). But the thickness of the ozone layer varies with altitude and seasonal change (Davis et al., 2017). Life is protected from UV rays by the stratospheric ozone layer, which acts as a shield or sunscreen (Park et al., 2020). Surface ozone is a highly efficient greenhouse gas; its global warming potential is about 1200-2000 times that of CO_2 . Ozone is produced in the troposphere by photochemical oxidation of CO (Minschwaner et al., 2010), CH₄, and Non-Methane Volatile Organic Carbons (NMVOCs) in the presence of NO_x (Minschwaner & Manney, 2015). Loss of ozone in troposphere takes place through chemical reactions and dry deposition. As an important greenhouse gas, O₃ is making significant contributions to climate change. The concentration of photochemical oxidants can be decreased by controlling their precursors such as: nitrogen oxides NO_x (NO and NO₂) and Volatile Organic Compounds (VOCs) etc. (Ravishankara et al., 2009). Sunspots are areas that appear dark on the surface of the sun because of some temperature variation (Solanki, 2003). They are electrically charged gases that generate areas of powerful magnetic fields. These are regions of reduced surface temperature caused by concentrations of magnetic flux. Sunspots usually appear in pairs. The amount of solar activities changes with the stages in the solar cycle (Willett, 1962). Observational evidence for a relation between atmospheric total ozone amount and sunspot number (SSN) has been presented and debated for more than two decades (Angell, 1989).

Generally, ozone production depends on several factors such as temperature, solar activity, wind, speed, and direction (Fleming et al., 2020). This work represents the influence of solar activity. However, previous studies have shown that ozone formation totally depends on the activities taking place on sun such as sunspots, solar winds, etc., which can alter the concentration of ozone (Arsenovic et al., 2018). They affect human health and have an impact on climatic change. One of the various problems caused by air pollution in urban areas is photochemical oxidants. The formation of ground-level ozone depends on several factors like, the intensity of solar radiation, the concentrations of NO_x and VOCs, and also on the ratio of NO_x to VOCs (Qin et al., 2004). Variability of ground air temperature, wind speed and direction, relative humidity, and precipitation associated with climate change have the potential to affect the distribution and deposition of O₃. Nitrogenous compounds emitted by humans in a small amount like NO, N₂O and NO₂ are considered to be most responsible for the depletion of the ozone layer (Zoran et al., 2020). Nitrous oxide is also a greenhouse gas, so reducing its emission from man-made sources would be good for both the ozone layer and climate. A study on Arctic and Antarctic ozone depletion has helped us in understanding ozone depletion more clearly (Solomon et al., 2014; Tilmes et al., 2005; Dameris et al., 2021; Bernhard et al., 2020). The main causes of ozone depletion are chlorofluorocarbons (CFCs), HCFCs and halons, apart from it CO and NO_x also affect the stratospheric and tropospheric ozone, so here in the present study our main focus is only on the CO and NO_x. Since the stratospheric ozone is formed by molecular ozone in the presence of solar UV radiation and hence solar activity i.e., the sunspot number, which represents how the sun is active, plays a major role. So, we have discussed the relation between ozone, sunspot number, NO₂ and CO data. This paper explores the interactions between these gases and stratospheric ozone.

2. Data Set and Site Description

For the present study, we required sufficient long-term data for a station, so we choose an American station "Tutuila" (Figure 1). A sufficient amount of ozone data for this station is available on https://www.esrl.noaa.gov/ this data were actually collected at ground by earlier researcher and hence the ozone data, which we used here is surface ozone, and now data is worldwide available on net. So here we called it ground based satellite ozone data. It means in our present study



Figure 1. Location map of the Tutuila.

we used surface ozone, which were collected at American station "Tutila" and this data is retrieved from <u>https://www.esrl.noaa.gov/</u>. The ESRL Global Monitoring Division has been measuring surface ozone at several global locations since 1973. Tutuila is the main and the largest island of American Samoa. It is the third-largest island in the Samoan Islands chain of the Central Pacific. It is located roughly 4000 kilometers northeast of Brisbane, Australia, and lies something over 1200 kilometers to the northeast of Fiji. The American Samoa Observatory (SMO) is located in the middle of the South Pacific, about midway between Hawaii and New Zealand and its coordinates are 14.295°S, 170.70°W. The observatory is situated on the northeastern tip of Tutuila Island, American Samoa, at Cape Matatula. The observatory was established in 1974 on a 26.7-acre site.

The CO data for the current study is downloaded from

<u>https://giovanni.gsfc.nasa.gov/</u>. Giovanni is a tool that displays earth science data from NASA satellite directly on the internet. We have selected time series, areaaveraged data of American station Tutuila, the same station for which ozone data was collected. For a comparative study of O_3 , SSN and CO we have downloaded CO surface concentration data for the same period of 35 years from 1980 to 2015. The source used for this data is MERRA-2 model and of spatial resolution 0.5 × 0.625 degree in the unit of ppbv. NO₂ data for the period of 11 years from 2005-2015 is downloaded from the same site and for the same station i.e., Tutuila. The source used for this data is OMI and spatial resolution of 0.25 degree in the unit of 1/cm².

3. Methodology

For analyzing the data, we have selected one American station "Tutuila" and downloaded ozone data of the years 1980 to 2015 from the above-mentioned site. This data includes everyday hourly ground base ozone data. For better comparative study, SSN, CO, and NO_2 data are also downloaded for the same period of the same station from their respective sites.

All the raw data downloaded was in grid form, which we have converted into the appropriate form. Further, we have calculated the monthly mean for every year data and got 12 data values i.e., one for each month. After it, we have plotted the monthly mean values of all the three substituent (O_3 , CO, SSN) against the years, so that the variation in all the three substituent can be easily concluded. The results obtained from each graph i.e., the slope and correlation coefficient for each month are collected and mentioned them in tabulated form. Similar graphs for NO_2 data are also drawn. The result and conclusion obtained based on this study are given in the next section.

4. Result and Discussion

The monthly mean variation in CO, O_3 , SSN with years are shown in **Figure 2**. This variation is for 35 years i.e., from 1980 to 2015.

It is observed from these figures and Table 1 that the value of surface ozone





Figure 2. The variation of CO, O_3 and SSN from year 1980 to 2015 in a specific month.

Months	O ₃	SSN	СО
January	0.00484	-1.95396	0.11313
February	0.03412	-1.73911	0.14663
March	0.07799	-1.81283	0.11735
April	0.02079	-1.73051	0.20437
May	0.01248	-2.26584	0.11514
June	0.03106	-1.92658	0.1385
July	0.03965	-1.82296	-0.01759
August	0.03981	-1.94987	-0.04938
September	0.06877	-1.61318	-0.08106
October	0.05886	-1.8381	0.01371
November	-0.003	-1.42378	0.00678
December	0.09357	-1.84634	0.0429

Table 1. Slope of O₃, SSN and CO over different months.

increases and shows a linear increment. The maximum growth in ozone value is observed in December, and it is found to be 0.09357 and the minimum growth is observed in January, which is 0.00484. The decaying trend i.e., the negative trend is shown by ozone in November which is -0.003. Similarly, from graphs, we conclude that CO value shows a decreasing trend in the monsoon period of July, August, and September, whereas for the rest of the year its value shows an increasing trend with maximum growth in April with a value 0.20437 and minimum growth in the month of November with value 0.00678. We also observe that SSN value shows decreasing trends throughout the whole year with a max-

imum value of -1.42378 in the month of November and a minimum value of -2.26584 in May. Hence, we conclude that Ozone and CO show an increasing trend, while SSN shows a decreasing trend over 12 months.

From Table 2, we observe that the correlation between O_3 and SSN is found to be positive in January, February, April, May, September, October, and November with the highest positive value of 0.2725 in month of November and the lowest positive value of 0.0267 in May. We also observe a negative correlation between O_3 and SSN in the rest of the five months i.e., March, June, July, August, and December with a highest negative correlation of -0.04275 in March and the lowest negative correlation of 0.2912 in June. Hence observing this trend, we conclude that for maximum months the correlation between O_3 and SSN is highly positive. Now studying about the correlation between O_3 and CO, from Table 2 we observe that maximum months through the whole year shows a negative correlation. It is found to be negative in January, February, March, April, May, September, October, and November months with the highest negative correlation of -0.0634 in February and lowest negative correlation of -0.26511 in January, whereas in rest of the months it shows positive correlation.

The monthly mean variation for NO₂ is shown in **Figure 3**. This variation is for 11 years i.e., from the year 2005 to 2015. It is observed from the figure that the value of NO₂ shows different trends every month. Maximum months show the decaying trend, the highest decay is observed in November and the lowest decay is observed in August and their values are -8.2087E12 and -1.0442E12respectively. The variation observed in March is very small and it is found to be positive i.e., 1.4481E12. In the same way, a positive trend is also observed in NO₂ data in June month and its growth rate is 3.4360E12. On the basis of correlation between O₃ and NO₂ it is found that there is not a particular relation between

Months	Correlation between O_3 and SSN	Correlation between O ₃ and CO
January	0.080472	-0.26511
February	0.235077	-0.06346
March	-0.04275	-0.119
April	0.036025	-0.24857
May	0.026713	-0.16902
June	-0.2912	0.026791
July	-0.1316	0.13152
August	-0.17093	0.100537
September	0.193345	-0.12676
October	0.035231	-0.22733
November	0.272573	-0.12313
December	-0.1415	0.118135

Table 2. Correlation of O_3 with SSN and CO over different months.



Figure 3. The variation of NO_2 from year 2005 to 2015 in a specific month in terms of per cm².

these two gases. In some months we got a positive correlation and in other months we got a negative correlation. In February and July months we got physically accepted negative correlation, which are about -0.66 and -0.43 respectively, and in August month a positive correlation of about 0.41, whereas in rest of the months the value of Pearson correlation coefficient is found to be very less, which is not physically accepted.

5. Conclusion

On the basis of present study, in which we analyzed a data of about 35 years raging from 1980 to 2015 of Tutuila (American station) we can conclude that CO and O_3 show an increasing trend over the maximum months of the year, whereas SSN shows decreasing trend throughout the year.

Ozone shows the maximum increasing trend in December month, whereas in the previous month of it i.e., in November month it shows a negative trend.

If we see the CO data for the same period then it is observed that the value of it increases from January to June and its value is found to be minimum in January month and maximum in the April. The decaying trend of CO is observed from July to September, and after it i.e., from October to December months it again increases, but its growth rate is very small.

The analyzed 11 years data of NO_2 concluded that, the variation observed in March month is very small and is positive. In the same way, a positive trend is observed for NO_2 data in June month, but in rest all the months the value is negative. The correlation between O_3 and NO_2 shows that both are negatively correlated in some months and positively correlated in some other months. The negative correlation value between these two gases is found to be physically accepted only in the month of February and July, and positively physically accepted value in the month of August only.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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