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Study of Oxides and aerosols in connection with COVID 19 lockdown scenario over a Metropolitan City, Kolkata

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Abstract

In this paper, the variation of oxides, aerosols and atmospheric parameters have been investigated before, during and after the lockdown period due to COVID 19 over Kolkata, a populated metropolitan city. Major reductions have been observed for CO, SO_2 and AOD especially at the beginning month of the lockdown period. The lower value of SO_2 are reflected in the minima of AOD which further result in a marked reduction in the atmospheric instability. In addition, the temperature profiles depict atmospheric cooling at 700 hPa due to lockdown which is also believed to have some additional contribution on the observed CAPE reduction.

1 Introduction

Corona virus (COVID 19) has impact not only on the health problem, but also on the environment. On March 25, 2020 a nationwide lockdown had been announced by the Government of India. Kolkata is a highly polluted and populated mega city located in the eastern part of India. The air quality of Kolkata is a major concern since long time before the pre-covid scenario. It has been evident that due to COVID 19, the air pollution has been reduced significantly in various parts of the globe due to governmental restrictions on the movement of vehicles, people and industrial activities [1]. The pollution levels, mainly greenhouse gases (Methane, Carbon Monooxide), nitrogen dioxide, ozone, aerosol have also decreased drastically [1]. The toxic gas CO is a major pollutant in urban areas. It has the oxidative capacity of the atmosphere [2]. Next, CH_4 is one of the most important greenhouse gases responsible for global warming [3]. Ground based O_3 is a key parameter to control the chemical composition of the troposphere.

On the other hand, sulphur dioxide emitted from fossil fuels or industry act as a major source of sulphate which is further responsible for cooling the atmosphere by catalyzing the nucleation of cloud particles. Aerosol optical depth (AOD) is a parameter to measure the effect of aerosol in atmosphere. NO2 plays significant role in the formation of tropospheric ozone. The above oxides and pollutants have direct impact on the weather parameters namely, convective available potential energy (CAPE), convective inhibition (CIN), boundary layer (700 hPa) temperature and wind speed etc. Hence, it is necessary to observe the effects of the above oxides and pollutants in the context of Covid 19 lockdown. In this paper we mainly focus on the above pollutant constituents for the years 2016-2020 for January to August covering the Covid 19 lock down period. The variation of 5 days average of the above parameters from mid of January to August have been observed. Main signature has been observed for CO, SO_2 and AOD, temperature at 700 hPa and CAPE.

2 Data & Methodology

To monitor the above-mentioned oxides and atmospheric pollutants, insitu measurements are preferred. However, due to the unavailability of ground-based measurements, satellite observations have to be used. In this purpose, NASA Giovanni data have been used (https://giovanni.gsfc.nasa.gov/giovanni/). The Moderate Resolution Imaging Spectroradiometer (MODIS), is one of the key instruments for NASA's Earth Observing System (EOS). This instrument measures reflectance of the entire Earth every 1-2 days, acquiring data in 36 spectral MODIS bands from 0.4 µm to 14.4 µm with varying spatial resolutions (2 bands at 250 m, 5 bands at 500m, and 29 bands at km). The MODIS Satellite data has a wide range for the study of the land, ocean and atmosphere. Aqua is originally known as EOS PM-1 satellite and launched on May 4, 2002.

The atmospheric infrared sounder (AIRS) was launched on the NASA AQUA satellite on May 4, 2002. AIRS is a high spectral resolution infrared sounder and will greatly improve the accuracy of temperature and moisture soundings. The AIRS instrument suite consists of the hyperspectral AIRS instrument with 2378 infrared channels and 4 visible/near-infrared channels and 15 microwave channels. AIRS has a spectral coverage of 3.7 to 15 micron in 17 arrays with 2378 spectral bands (3.7-4.61 µm, 6.2-8.22 µm, and 8.8-15.4 µm) and hence is capable of creating the three-dimensional maps of surface and air temperature, and cloud properties. AIRS can also measure trace greenhouse gases such as ozone (O_3), carbon monoxide (CO), methane (CH_4) etc.

The study has been done using 5 years data from AIRS, MODIS satellite and including the before and after

COVID lockdown time. The OMI SO2 product (OMSO2_CPR_V003) provides OMI data, produced from global mode UV measurements that are within +/-100 km across the CloudSat track for the A-Train mission. This parameter describes the original OMI SO_2 product (OMSO2) produced from the global mode of the Ozone Monitoring Instrument (OMI). OMI was launched on July 15, 2004 on the EOS Aura satellite and started data collection on August 17, 2004 (orbit 482). The product file, called a data granule, covers the sunlit portion of the orbit with an approximately 2600 km wide swath containing 60 pixels per viewing line. For each OMI pixel 4 different estimates of the column density of SO2 in Dobson Units (1DU=2.69x10^16 molecules/cm2) are obtained by making different assumptions about the vertical distribution of the SO_2. Aerosol Total Optical Thickness is available through Giovanni at 550 nm from MODIS observations.

Radiosonde observations are made twice a day, at around 00 and 12 GMT (1830 and 0630 IST). The data of temperature, pressure and dew point temperature have been measured at different heights. The height resolutions are varying from a few tens of meters to a few hundreds of meters up to a height of 15 km. The type of radiosonde used over Kolkata region in this study is IMD - MK IV [4-5] which has been employed to obtain the daily atmospheric temperature profiles. On the other hand, CAPE and CINE reflects the total amount of positive and negative buoyancy necessary for cumulus development and they are calculated on the basis of temperature and humidity profiles in the atmosphere[6-9].

3 Results and Discussion

We mainly analyzed the data of oxides, AOD and the atmospheric instability parameters before, during and after the lockdown period of 2020 and compared it with previous 4 years data. However, some of the oxides did not reflect very small changes during the lockdown period with respect to other years. So, further analysis has been done in those cases. In this study, the data of CO, SO_2, AOD (deep blue land only at 550 nm) from the NASA GIOVANNI have been analyzed. Apart from that, temperature, CAPE and CIN data have also been investigated to understand the variation of these meteorological parameters for the above said period.

Fixed point 5-day averages of all the above-mentioned parameters have been calculated for the period 20 January to 20 August during 2016-2020. A total of 42 5 days average data have been considered and then have been accordingly plotted in Figure 1. The box plot variation of CO and SO_2 have been shown in Figure 1a and 1b respectively for the period 20 January to 20 August for all the years of 2016-2020. In the x axis, 12 indicates the first five days average value at the start of the lockdown and 1 indicates the first pentad of the study period (Jan 20).

Overall, the value of CO shows decreases in 2020 with prominent reduction in the pentads 11 to 28. SO2 is an important oxide, which responsible for the formation of cloud, and has connection to convection, rain and thunderstorm. SO_2 shows lower value in 2020 compared to the previous years (2016-2019). However, interestingly this reduction in SO_2 is more prominent at the beginning of the lockdown for the first one and half months (pentad number 13-18). On the other hand, the difference between 2020 and the other years is much lower for the later part of the lockdown period (after 15 April). Now this partial restoration effect can be mainly due to transport of aerosol from sea, or biomass burning etc. Dust and SO_2 are the main source of aerosol. However, in this study only the variation of SO_2 before, during and after lockdown have been investigated.

Figure 2a compares the variation of AOD for the 42 pentads of the year 2020 with respect to the average value of AOD during 2016-2019. The pentad variations depict a similar dip in AOD as in case of SO_2 with the dip being mostly evident for the first 1 month of the lockdown period. However, AOD values do not indicate lower values during the latter half of the lockdown. There may be two reasons behind these phenomena. Firstly, the general public may not have obeyed the rule of lockdown properly which has also been evidenced from the news. However, the second reason is that aerosols are not the sole component of the anthropogenic emissions, but the transport of natural aerosol from the adjacent seas and desert regions can also be a major source of aerosol.

However, irrespective of other factors, SO_2 aerosols are believed to be the most efficient aerosol contributor for initiating cloud formations as they act as excellent cloud condensation particles. In addition, cloud formations in the atmosphere also lead to latent heat release which further increases the buoyancy and hence the vertical instability of the atmosphere. Hence a reduction in SO_2 towards the beginning of the lockdown period is expected to experience far lesser cloud growth and instability formation as also evidenced from low CAPE values there.

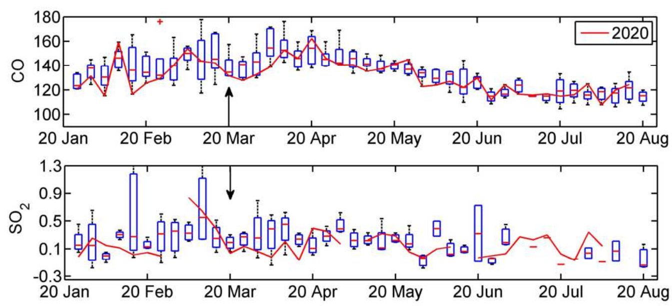

Figure 1. Box plot of (a) CO and (b) SO_2 for the years 2016 to 2020 for 42 pentads from 20 January to 20 August. Arrow indicates the starting of lockdown pentad.

Next NO_2 shows much lesser values before and during the lockdown period compared to the previous years which again may be due to stringent policy making decisions taken by the Government regarding the vehicular emissions. Next, coming to O_3, no prominent variations were observed as columnar ozone in atmosphere changes very slowly over long-time scales (weeks to months).

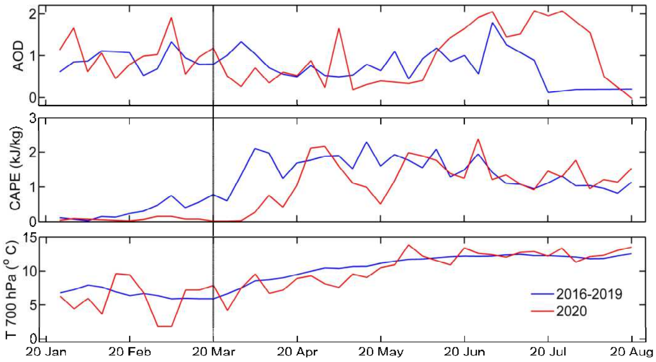

Figure 2. Comparison of (a) AOD, (b) CAPE and (c) temperature of 2020 with respect to the average values for the years 2016 to 2019 for 42 pentads. The position of lockdown has been indicated by the black continuous line

Next, an attempt has been taken to investigate the meteorological impacts of the reduction in the pollutant oxides as depicted from the previous sections of this study. The average pentad-wise variations of CAPE and temperature at 700 hPa are depicted in Figure 2 in a similar manner as shown in the previous figure. It can be seen that in the 1st month of lockdown, CAPE shows much lower values. However, in the later part of lockdown, values of CAPE, AOD and SO_2 started to restore to its climatic average values similar to the variations in CO and SO_2 as shown in the previous sections. Next the implications are observed on the temperature values particularly at 1000 and 700 hPa

Table I Percentage deviation of the pollutants and various atmospheric parameters for the year 2020 with respect to the average of previous 4 years

Lockdown status	CO	SO2	AOD	CAPE	Temperature (700 hPa)
Before	-5.1	-23.69	6.54	-10.77	-4.69
1st month	-6.43	-65.25	-11.53	-35.41	-12.11
Total	-3.53	-38.41	-9.22	-21.54	-8.71
After	-0.65	-5.11	3.22	7.02	2.27
Total	-3.20	-26.11	2.24	-10.36	-3.14

Next, a quantitative assessment of the reduction of all these parameters are depicted in Table 1 by showing the percentage deviation of CO, SO_2, AOD, CAPE and temperature for before, during and after the lockdown period of 2020 with respect to the previous four year average. It has been evident from the table 1, that percentage decrease is more during the first month of lockdown for all the parameters. SO_2 and CAPE shows the highest deviation during the 1st month of lockdown. Also, considering the total lockdown period, the variation show much lower values from the second month of lockdown period.

4 Conclusions

In this paper, the variation of oxides, aerosols and atmospheric parameters have been investigated before, during and after the lockdown due to COVID 19 over a highly polluted and densely populated metropolitan city like Kolkata. Five days average of the above parameters have been calculated for the period 20 January to 20 August for the years 2016 to 2020. Major changes have been observed for CO, SO_2 and AOD. SO_2 shows lower value in 2020 compared to the previous years 2016-2019. The effect is more prominent at the beginning of the lockdown for the first one and half months. The lower value of SO_2 are reflected in the minima of AOD at the start of lockdown period which either arise from public disobedience or from transport of these species from other locations. Now sulphate aerosols act as excellent cloud nuclei; hence lower value of SO_2 and AOD also lead to a marked reduction in the atmospheric instability during the lockdown period as also supported by much lower values of CAPE. In addition, the temperature profiles depict atmospheric cooling at 700 hPa due to lockdown which is also believed to have some additional contribution on the observed CAPE reduction. Finally, no clear signatures are observed in NO_2, CH_4 and O_3 and the probable reasons for it will be addressed in future research attempts.

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