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Analysing distribution of SO2 over India using Google Earth Engine

Reedhi Shukla[1], Sampath Kumar[2], Satish Jayanthi[3], Kamini J[4], Sreenivas k[5]
National Remote Sensing Centre, ISRO, India, Hyderabad

Abstract*: According to the report of World Health Organization(WHO) air pollution is a major threat for the human health. According to the report almost 7 million people die every year due to the pollution. While considering the pollution into account there are multiple components like Nitrogen Di Oxide (NO2), Sulphur dioxide (SO2), Carbon monoxide (CO), Carbon dioxide (CO2) etc. which are responsible for the Air quality index of any country. Among the various components mentioned above, sulphur dioxide (SO2) is one of the most gaseous air pollutants which can be emitted by natural and anthropogenic sources and it has an adverse health effects on the human respiratory, cardiovascular and nervous systems and causes Type 2 diabetes and non-accidental deaths [2]. The present study done in this paper will discuss the concentration of SO2 over India and how Covid lockdown has impacted SO2 levels using Sentinel 5P Tropomi data using Google Earth Engine.*

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I. Introduction

Air pollution continues to be a critical global environmental and public health issue, significantly impacting ecosystems, biodiversity, and human health. According to the World Health Organization (WHO), air pollution leads to approximately 7 million premature deaths each year, making it one of the primary risk factors for noncommunicable diseases worldwide (WHO, 2021). These alarming figures have prompted increasing attention toward understanding the various components of air pollution, their sources, and their health implications. Sulfur dioxide (SO_2) is a pollutant that has garnered significant focus due to its widespread presence and harmful impacts.

SO_2 is a colorless gas primarily emitted from anthropogenic sources, such as burning fossil fuels in power plants, industrial facilities, and motor vehicles. It also arises from natural sources like volcanic activity (Kampa & Castanas, 2008). Once released into the atmosphere, SO_2 can lead to the formation of fine particulate matter (PM2.5) and acid rain, both of which contribute to adverse environmental and health outcomes. Exposure to high concentrations of SO_2 is linked to a variety of health problems, particularly respiratory disorders such as asthma, bronchitis, and emphysema, as well as exacerbations of cardiovascular diseases (Pope et al., 2015). Additionally, chronic exposure has been associated with metabolic disorders and increased mortality rates (EPA, 2022).

The global outbreak of the COVID-19 pandemic in 2020 resulted in unprecedented changes in human activity, mainly due to lockdown measures that restricted transportation, industrial operations, and energy consumption. These shifts provided researchers with a unique opportunity to observe how reductions in anthropogenic emissions affect air quality. In this context, the current study aims to investigate the temporal and spatial variations in SO_2 levels in India, one of the world's most populous and polluted countries, during the COVID-19 lockdown. Using data from the Sentinel-5P Tropomi satellite sensor, this research harnesses the capabilities of Google Earth Engine to analyze SO_2 concentrations before, during, and after the lockdown period.

India experienced substantial reductions in air pollutant levels during the initial phases of the lockdown, primarily due to decreased industrial activities and transportation (Mahato et al., 2020). However, the extent to which SO_2 levels were affected and the corresponding implications for public health remain underexplored. By analyzing these data, this study seeks to quantify the changes in SO_2 emissions and evaluate their potential impacts on respiratory, cardiovascular, and metabolic health outcomes. Furthermore, it aims to provide insights into the broader implications of air pollution mitigation strategies, as evidenced by the temporary reductions during the lockdown, and to highlight the importance of sustained policy interventions for long-term air quality improvements.

The results of this research could contribute to the growing body of literature on air pollution control, particularly in the context of developing nations where pollution levels remain critically high. By demonstrating the health benefits of reduced SO_2 emissions, this study underscores the urgency of adopting comprehensive and sustainable air quality management strategies to safeguard public health and mitigate the detrimental effects of pollution.

Data Used: The Copernicus Sentinel-5 Precursor mission is the first Copernicus mission for performing atmospheric measurements with high spatial and temporal resolution .The data can be used for analysing for air quality, ozone & UV radiation and climate monitoring & forecasting. [3].For the study explained in this paper this data is used for studying the SO_2 component in the atmosphere over India using google earth engine. Sentinel 5p data is available from 2018 to till on daily based covering globe. GEE is platform where petabyte of satellite data is stored over cloud and analysis can be done in code editor provided [4]. Sentinel 5p has TROPOMI multispectral sensor records reflectance of wavelengths for measuring atmospheric concentrations of ozone, methane, formaldehyde, aerosol, carbon monoxide, nitrogen oxide, and sulphur dioxide, as well as cloud characteristics with spatial resolution 0.01 arc degrees [5].

In this study, we utilized data from the Copernicus Sentinel-5 Precursor mission, the first initiative under the Copernicus program specifically designed for atmospheric measurements with high spatial and temporal resolution. The data includes daily observations of various atmospheric components, available from 2018 onwards, providing comprehensive global coverage. The Sentinel-5P mission employs the TROPOMI (Tropospheric Monitoring Instrument) multispectral sensor, which captures reflectance across multiple wavelengths. This capabilities allow for precise measurements of several atmospheric constituents, including ozone, methane, formaldehyde, aerosols, carbon monoxide, nitrogen dioxide, and sulfur dioxide (SO_2). The sensor achieves a spatial resolution of 0.01 arc degrees, enabling detailed analysis. We conducted our analysis using Google Earth Engine (GEE), a cloud-based platform that facilitates the storage and processing of petabytes of satellite data[4] [5]. The GEE environment provides an integrated code editor, allowing for the efficient analysis of the Sentinel-5P data to investigate sulfur dioxide concentrations in the atmosphere over India. The selection of this data is crucial for understanding the trends and impacts of atmospheric sulfur dioxide in the region.

II. Methodology

This study utilized satellite-derived datasets within Google Earth Engine (GEE) to examine the temporal and spatial variations in sulfur dioxide (SO_2) concentrations across India from 2019 to 2023. The methodology encompasses data preparation, retrieval, spatial and temporal filtering, visualization, and trend analysis.

The study area, representing the geographical boundaries of India, was defined using a shapefile created in QGIS. This shapefile was uploaded to GEE's Asset facility, enabling spatially targeted analysis.A shapefile delineating India's boundaries was developed in QGIS to serve as the geographic boundary for the analysis. This shapefile was subsequently uploaded as an asset to GEE for use as a spatial overlay.Within the GEE Code Editor, the uploaded shapefile was converted to an `ee.FeatureCollection`, allowing for the filtering of datasets to focus specifically on India's geographic boundaries.

SO_2 concentration data were obtained from GEE's cloud dataset repository, utilizing measurements from the Ozone Monitoring Instrument (OMI) and/or the Tropospheric Monitoring Instrument (TROPOMI), both of which provide reliable observations of atmospheric pollutants. Monthly averages of SO_2 levels were calculated over the defined study area from January to December for each year from 2019 to 2023. The SO_2 data were accessed from NASA's OMI and TROPOMI datasets within GEE, offering spatially continuous, long-term atmospheric pollution data.For each month during the study period, SO_2 data were averaged to yield monthly mean values. Monthly averaging helps reduce data noise and facilitates meaningful temporal comparisons

SO_2 data were filtered using the India boundary geometry defined within the `ee.FeatureCollection`, ensuring that all observations were restricted to Indian territory,using the `ee.FeatureCollection` geometry, SO_2 data were spatially confined to Indian territory, guaranteeing that all derived statistics and visualizations accurately represented the region.

Color range from 0 to 0.0005 was established to represent typical SO_2 concentration values observed across the study area. A color palette transitioning from black (representing the lowest concentrations) to red (representing the highest) was applied to visually depict concentration gradients, assisting in the identification of pollution hotspots.

To evaluate the impact of the COVID-19 lockdown on SO_2 concentrations, monthly averages from 2020 were compared to baseline values from 2019, particularly during the April to August period when nationwide lockdown restrictions were in effect. SO_2 levels for April through August 2020 were compared to the same months in 2019. Visualization outputs (e.g., Fig. 2 for April 2019 and Fig. 5 for April 2020) provided a direct comparison of SO_2 distribution during these periods. The analysis indicated a significant reduction in SO_2 levels, estimated at 30–40% during the lockdown period, which was attributed to decreased industrial and transportation activities.

The Singareni Collieries Company Limited (SCCL) area, which hosts 48 mines (29 underground and 19 opencast), was identified as a hotspot for in-depth analysis due to its typically high SO_2 emissions associated with mining and related industrial processes. The SCCL region was selected based on its industrial activity level, which significantly contributes to SO_2 emissions. SO_2 concentrations in this region were assessed in May 2020, revealing substantial reductions that coincided with lockdown restrictions limiting mining operations. From September 2020 onward, a gradual increase in SO_2 levels was observed, consistent with the relaxation of lockdown measures and the resumption of industrial activities in India and globally.

This methodology provides a comprehensive framework for analyzing the spatial and temporal dynamics of SO_2 emissions across India using GEE. It captures both the immediate impacts of COVID-19 lockdowns on air quality and sets the stage for future studies on emissions trends and the effects of environmental policy.

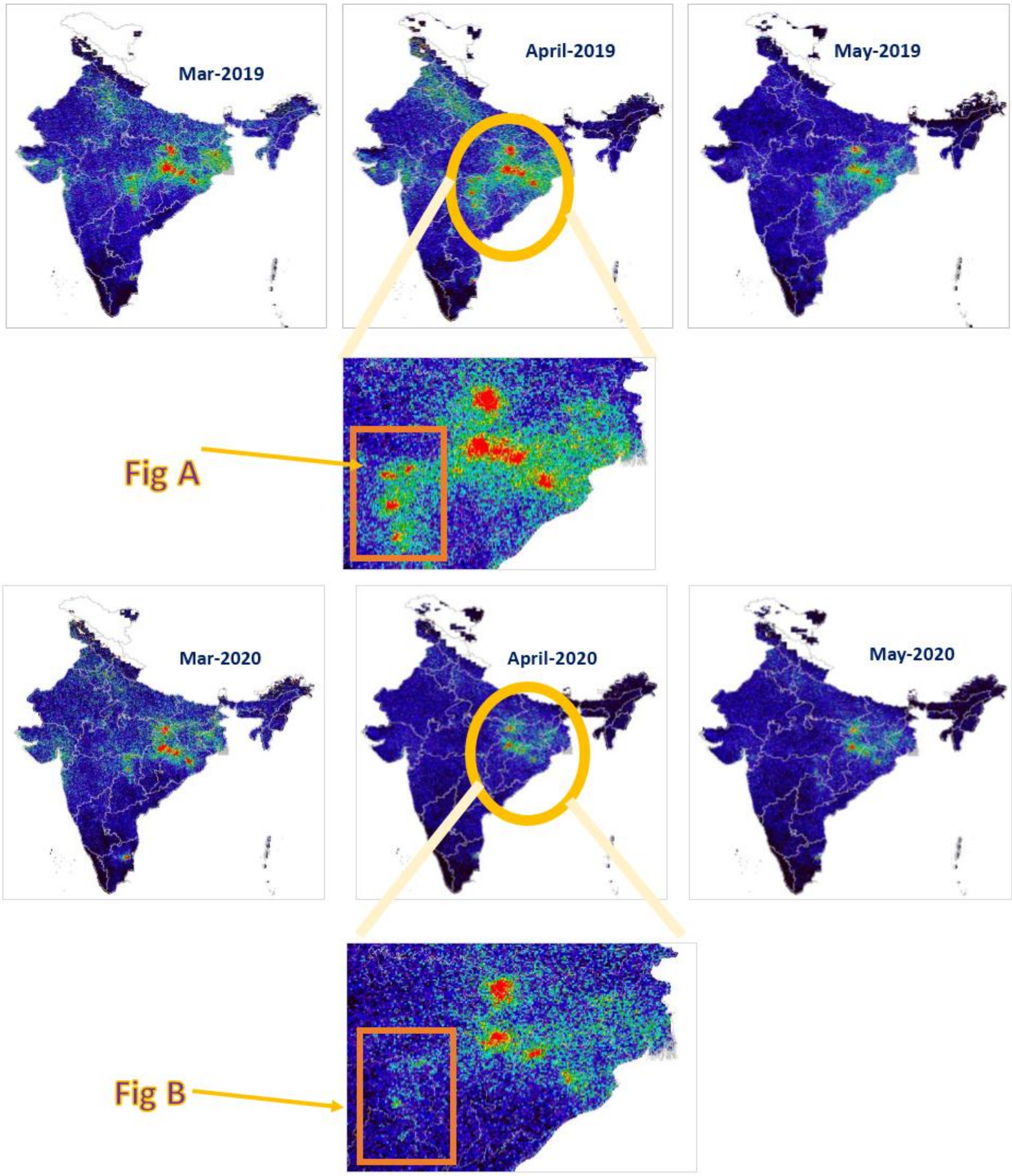
III. Conclusion:

This study comprehensively analyzes sulfur dioxide (SO_2) concentrations across India from 2019 to 2023, utilizing monthly datasets from the Sentinel-5P satellite. By analyzing multi-year satellite data, this research provides valuable insights into the spatial and temporal variations in SO_2 levels, shedding light on the significant role of anthropogenic activities in air pollution dynamics. The findings underscore the impact of SO_2 on air quality and public health, marking a critical step in understanding how such pollutants influence environmental and health outcomes in India.

The COVID-19 lockdown period offered an unprecedented opportunity to examine how large-scale reductions in human and industrial activities could impact pollutant levels. Our analysis, in alignment with multiple studies, reveals that the lockdowns led to a notable reduction in pollution levels in India and globally. Expressly, SO_2 levels declined substantially during periods of restricted human movement and reduced industrial operations [8]. This observed reduction in SO_2 is consistent with declines in other pollutants, including nitrogen dioxide (NO_2) [7, 8], particulate matter (PM_{10}) [9], carbon monoxide (CO) [7, 8], and carbon dioxide (CO_2). Such synchronous reductions emphasize the profound role that anthropogenic sources, particularly industrial emissions and vehicular exhaust, play in driving urban air pollution.

These findings have significant policy implications. The observed data can guide policymakers in understanding the relative contributions of different pollution sources, particularly during periods of increased or decreased human activity. Policymakers can leverage this information to formulate targeted strategies for air quality management, such as emissions control policies and sustainable urban planning. Furthermore, this study highlights the need for continuous satellite-based monitoring, which provides real-time and geographically extensive data essential for tracking and mitigating pollution levels over time.

Future research should further investigate the mechanisms by which different sectors contribute to SO_2 emissions and evaluate the long-term health and environmental impacts of fluctuating SO_2 levels. This study's results are a foundational reference, providing a dataset and methodological framework for future research into atmospheric pollutants and their relationship with public health, economic activity, and policy interventions. By focusing on SO_2 as a case study, this research contributes to the broader discourse on developing a pollution-free economy, emphasizing the need for collaborative action between government entities, industry stakeholders, and scientific communities to achieve sustainable reductions in air pollution.



References

[1]. Accessed on [04-ept-2023] from url https://thewire.in/environment/india-had-eight-worst-air-pollution-in-2022-report

[2]. Khalaf EM, Mohammadi MJ, Sulistiyani S, Ramírez-Coronel AA, Kiani F, Jalil AT, Almulla AF, Asban P, Farhadi M, Derikondi M. Effects of sulfur dioxide inhalation on human health: a review. Rev Environ Health. 2022 Dec 22. doi: 10.1515/reveh-2022-0237. Epub ahead of print. PMID: 36635910.

[3]. Accessed on [04-ept-2023] from url https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-5p

[4]. Accessed on [04-ept-2023] https://earthengine.google.com/

[5]. Accessed on [04-ept-2023] https://developers.google.com/earth-engine/datasets/catalog/sentinel-5p

[6]. Filonchyk, M., Hurynovich, V., Yan, H., Gusev, A. and Shpilevskaya, N. (2020). Impact Assessment of COVID-19 on Variations of SO2, NO2, CO and AOD over East China. Aerosol Air Qual. Res. 20: 1530–1540. https://doi.org/10.4209/aaqr.2020.05.0226

[7]. https://www.esa.int/Applications/Observing_the_Earth/Copernicus/Sentinel-5P/Sulphur_dioxide_concentrations_drop_over_India_during_COVID-19

[8]. Otmani A, Benchrif A, Tahri M, Bounakhla M, Chakir EM, El Bouch M, Krombi M. Impact of Covid-19 lockdown on PM_{10}, SO2 and NO2 concentrations in Salé City (Morocco). Sci Total Environ. 2020 Sep 15;735:139541. doi: 10.1016/j.scitotenv.2020.139541. Epub 2020 May 19. PMID: 32445829; PMCID: PMC7235599.

[9]. Orak NH, Ozdemir O. The impacts of COVID-19 lockdown on PM_{10} and SO2 concentrations and association with human mobility across Turkey. Environ Res. 2021 Jun;197:111018. doi: 10.1016/j.envres.2021.111018. Epub 2021 Mar 19. PMID: 33745929; PMCID: PMC8542992.
[10]. Nur H. Orak, Ozancan Ozdemir,The impacts of COVID-19 lockdown on PM10 and SO2 concentrations and association with human mobility across Turkey,Environmental Research,Volume 197,2021,111018,ISSN 0013-9351,https://doi.org/10.1016/j.envres.2021.111018.(https://www.sciencedirect.com/science/article/pii/S0013935121003121)
[11]. World Health Organization (WHO). (2021). Air Pollution. Retrieved from https://www.who.int/health-topics/air-pollution
[12]. Kampa, M., & Castanas, E. (2008). Human health effects of air pollution. Environmental Pollution, 151(2), 362-367.
[13]. Pope, C. A., Dockery, D. W., & Turner, M. C. (2015). Exposure to fine particulate air pollution and primary and secondary cardiovascular events. Journal of the American Medical Association, 320(23), 2446-2456.
[14]. U.S. Environmental Protection Agency (EPA). (2022). Sulfur Dioxide (SO_2) Pollution. Retrieved from https://www.epa.gov/so2-pollution
[15]. Mahato, S., Pal, S., & Ghosh, K. G. (2020). Effect of lockdown amid COVID-19 pandemic on air quality in the megacity Delhi, India. Science of The Total Environment, 730, 139086.

Abbreviation

- Gee: Google Earth Engine
- NO2: Nitrogen Di Oxide
- SO2: Sulphur Di Oxide
- CO: Carbon Monoxide
- CO2: Carbon di oxide