Analysis of Aerosols in Indo-GangeticPlain the Week before and After of India's Nationwide Covid-19 Lockdown, 2020

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Abstract:- Aerosols, consisting of liquid and solid particles suspended in the air, have significant implications for public health, agriculture, visibility, and climate. This research focuses on managing surface air quality, particularly in the Indo-Gangetic Plain (IGP), a major aerosols hotspot in India. Aerosol Optical Depth (AOD) and particulate matter (PM2.5) and (PM10) are used as key indicators to assess air quality. The study analyzes aerosol variations before and after the nationwide lockdown imposed in India on March 24, 2020. While the lockdown significantly reduced aerosol levels due to suspended industrial, transportation, and construction activities, it is essential to investigate whether other factors, such as precipitation and fire, also influenced aerosol patterns. Data from four IGP stations, NASA's Aqua and Terra satellites, IMREG, and MODIS, were used for analysis. Results demonstrate a rapid reduction in aerosols after the lockdown, with PM10 experiencing a greater decrease. Spatial analysis indicates that precipitation and fire events contributed to lower AOD values in specific regions.In conclusion, the lockdown considerably improved air quality, but natural factors like precipitation and fires also influenced aerosol levels. Understanding these complexities is vital for formulating effective air quality management strategies.

I. INTRODUCTION

Aerosols generally consist of liquid and solid particles suspended in the air, arising from both natural emissions and anthropogenic activities. Due to the possible effect on public health, agricultural output,aesthetic values and visibility, the management of surface air quality is necessary. When aerosol is inhaled by people, particularly those with asthma or other respiratory illnesses it causes hazourdous effect.(WMO). There are various sources of atmospheric aerosols, such as, pollution from factories, smoke from fires, dust from dust storms, sea salt, and volcanic ash and smog. (Alaa Mhawish et al).

Aerosols effect on the weather and climate is still a point of debate for the meterologist. It can causes cooling or warming the Earth, helping or preventing clouds from forming. (Tomasi et. al.) Aerosol Optical Depth (AOD) and atmospheric particulate matter that has a diameter of fewer than 2.5 micrometers (PM2.5) and PM 10 are two of the best indicator to assess air quality. While AOD shows column integrated value of aerosols from the top of the atmosphere (TOA), then the PM 2.5 and PM 10 shows the ground level mass per unit volume of aerosols which are less than 2.5 μm. (Alaa Mhawish et. Al.) Aerosol Optical Depth (AOD) (or Aerosol Optical Thickness) indicates the level at which particles in the air (aerosols) prevent light from traveling through the atmosphere. Aerosols scatter and absorb incoming sunlight, which reduces visibility (Xiaoli Wei et.al).The Indo-Gangetic Plain (IGP) is one of the few major aerosols hotspot of the world (Vishnu Murari). The region mainly consists of mixed type of aerosols. Soots and finer dust generally prevails over lower plain and coarser material on the upper part. The presence of high aerosols over the IGP, reportedly undergoes long range transport of aerosols from its source to the Indo-Himalayan Range and Bay of Bengal (M. Kumar et. al.)The government of India imposes a nationwide lockdown on the evening of 24th March 2020. The lockdown causes a sudden shutdown of all the economic activities all over India. So that themajor aerosols sources, such as, Industrial, Transportational, and Constructional sectors were forced to stop their work. This sudden shutdown led to the reduction of aersols in the IGP. The overarching question that this article asks is that, whether the Gangetic plain's aerosols' properties has changed only due to the lockdown or any other reasons?More specifically, the article deals with the changing pattern of aerosols and it's major variables in Indo-Gangetic Plain before and after the lockdown .

- *Objective;*

Being one of the major aersols hotspot region of the world,Indo-Gangatic region has high aersol in the atmosphere allover the world. Generally, Industrial and transport sector contribute greatly behind the constant presence of high amount of aerosols in this region. Apart from this, in winter burning of various crop residues causes high aerosols concentration in this region.

This paper will analyze,whether there was any change in the quantity of aerosols in the post lockdown week or not? The study found, yes there was a change. Now the study will examine what was the satialpattern of the change?

The former statement, arises one instant question in our mind. With that question this paper carved to it's next objective. Whether the change was only due to sudden lockdown or there was other implicit reasons behind or not? This paper examine two major parameter that can influence the aerosols in the atmosphere, namely, precipitation and fire. While precipitation helps to reduce the aerosols, then the fire leads to increase the aerosols in the atmosphere.

➢ *So, in a Nutshell, this Paper has Two Fold Objectives-*

- *To understand the spatial changes of aerosols the weeks before and after the lockdown*
- *To identify whether the lockdown changes the changes the aerosols solely, or there was otherinfluences?*

➢ *Datasets:*

Technically the database has been divided into two parts, firstly Station based data and and secondly thesatellite based data. In station based data, mainly the aerosols data (PM 2.5 and PM 10) has been collected in 24 hours interval from CPCB (Central Control Room for Air Quality Management) website.

The data is collected in two part, the week before lockdown and after lockdown (17th March 2020 to 30th March 2020).

Four stations have been chosen from Indo-Gangatic Plain to describe the PM2.5 and PM10 data,namely,

- *Tran Gangetic Stage- Lodhi Road, Delhi, IMD*
- *Upper Gangetic stage- Nehru Nagar, Kanpur, UPPCB*
- *Middle Gangetic Stage- Govt. High School Shikarpur, Patna - BSPCB, and,*
- *Lower Gangetic stage- Ballygunge, Kolkata. WBPCB*

One of the drawback of the datasets is that, PM 10 data is not available for Upper Gangetic stage- Nehru Nagar, Kanpur, UPPCB

The satellite based data is collected from NASA WORLD VIEW. The Worldview tool from NASAprovides full-resolution satellite imagery layers and then download the underlying data. All 3 over layered Satellite imagery used in this article, namely, AOD, Precipitation, and Fire and Teperature anomaly, has been collected from this particular website.

The AOD data is primarily based on Modis Aqua and Terra sensors. And the data obtained by merged DTand DB algorithms.

Additionally, fire and thermal anomalies data is is collected Soumi NPP/VIIRS satellite. Precipitation data is collected from IMERG. The IMERG algorithm combines information from the GPM satellite constellation to estimate rainfall and snowfall over the earth surface.

➢ *Study Domain:*

The term IGP actually denotes the combined plains of the Indus and the Ganga river. Entire IGP is subjected to high aerosols load. But due to political constrain, the study only focuses on India. So in thisarticle IGP streached from Punjab plain to to West Bengal Delta. The entire stretch is divided into four parts, a.Trans Gangetic b. Upper Gangetic c. Middle Gangetic and d.lower gangetic. The PM 2.5 and PM10 data collected from each of the four parts of IGP. All four stations are located in the urban sectors where the aerosls are coparatively more than other regions. The stations are-

- *Tran Gangetic Stage- Lodhi Road, Delhi, IMD*
- *Upper Gangetic stage- Nehru Nagar, Kanpur, UPPCB*
- *Middle Gangetic Stage- Govt. High School Shikarpur, Patna - BSPCB, and,*
- *Lower Gangetic stage- Ballygunge, Kolkata. WBPCB*
- *The satellite images covers the whole IGP.*

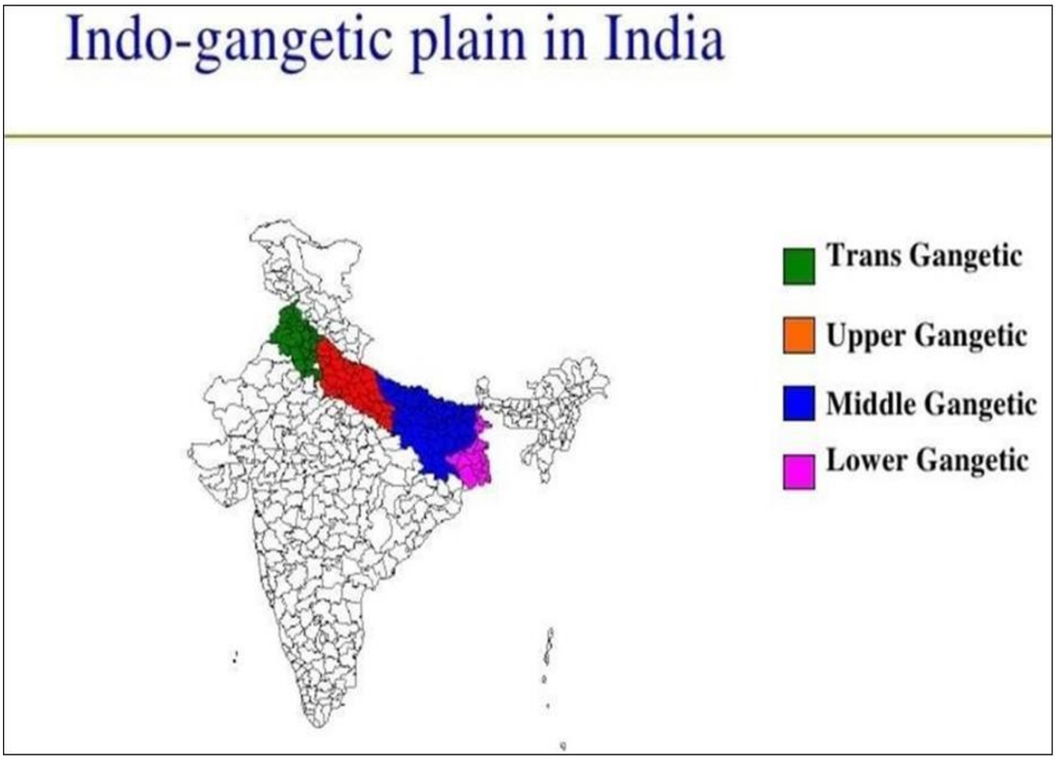


Fig 1 IGP Plains and four major divisions

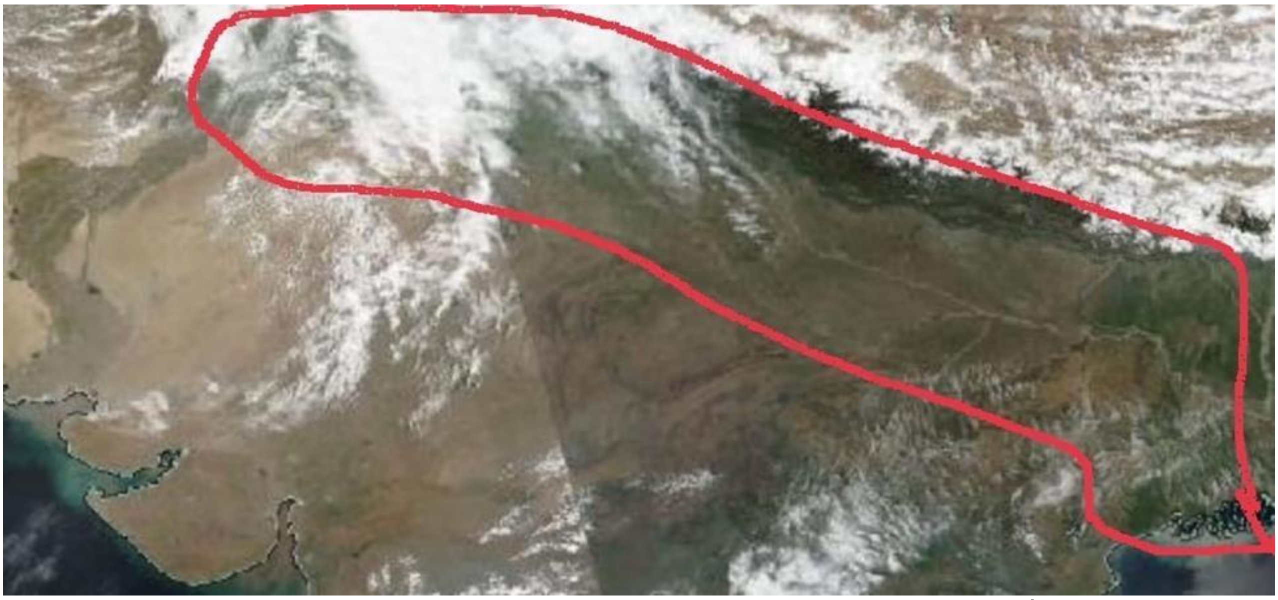


Fig 2 True Colour Composite Image Collected from Soumi NPP/VIIRS collected on 26th March, 2020

II. METHODOLOGY

The mehodology part of this article broadly divided into two parts, firstly the statistical analysis of CPCB pollution data of the 4 stations and secondly analysis of overlayed satellite imagery. In this section IOD, Precipitation and fire and thermal images has been analysed. This article primarily investigates the 4 major CPCB station's datasets which are distributed over the IGP through some statistical analysis. And the paper will try to understand the trend and variability of the dataset. Then the changes of PM2.5 and PM 10 will be compared with AOD values from NASA. And finally, this paper will analyze, whether this change was due to lockdown or other variables like Precipitation and Fires through satellite imagery.

A. PM 2.5 and PM 10 datasets from 4 stations of IGP:

The collected primary data from CPCB has been divided into two parts, from 17th to 23rd March,2020 and from 24th to 30th March 2020. Then the mean has been calculated for PM2.5 and PM10 for both of the time period. And finally, the change has been calculated for each section in percentage.

Table 1 Average PM 2.5 and PM 10

Stations	PM 2.5 (17TH March – 23rd March)	PM 2.5 (24TH March – 30rd March)	Changes in percentage	PM 10 (17TH March – 23rd March)	PM 10 (24TH March – 30rd March)	Changes in percentage
Trans Gangetic Stage- Lodhi Road,Delhi IMD	56.46714286	26.91142857	-52.34%	119.5642857	53.92714286	-121.71%
Upper Gangeticstage- Nehru Nagar, Kanpur,UPPCB	65.74	42.76571	-34.94%	Unavailable	Unavailable	Unavailable
Middle Gangetic Stage- Govt.High School Shikarpur, Patna – BSPCB	151.5114	68.11714	-55.04%	134.2871	54.20857	-147.72%
Lower Gangetic stage- Ballygunge, Kolkata	55.61286	41.13857	-26.02%	100.5814	72.71286	-38.32%

B. Merged DT/DB AOD from Terra and Aqua Modis:

AOD or Aerosol optical depth is the indication for the obstruc tion of solar radiation from space to atmosphere. Aerosols generally scatter and absorb insolation, thus the visibility also reduces. According to meterologist, AOD less than 0.1 is the Most clean atmosphere that one can feel. When the aerosols increases it also decreased the visibility. AOD greater than 3.0 indicates the atmosphere is full of aerosols that the sun is obscured.

The AOD data has been collected from both of MODIS Aqua and Terra satellite. Terra is morning satellite while Aqua is afternoon satellite. MODIS has total 36 spectral bands. MODIS Generally observed the earth surface at 700 km altitude. It has more or less 55° scanning capability, which almost 2330 km. It uses 3 seperate algorithm for determining the aerosols properties, namely, DT or Dark Target over land (dark vegetation, or cropland) or over ocean and DB or Deep Blue algorithm over the land (mainly bright surface such as desert). In the following images both DT DB merged algorithm has been used from both of Aqua and Terra Modis to know the actual situation of aerosols in the atmosphere.

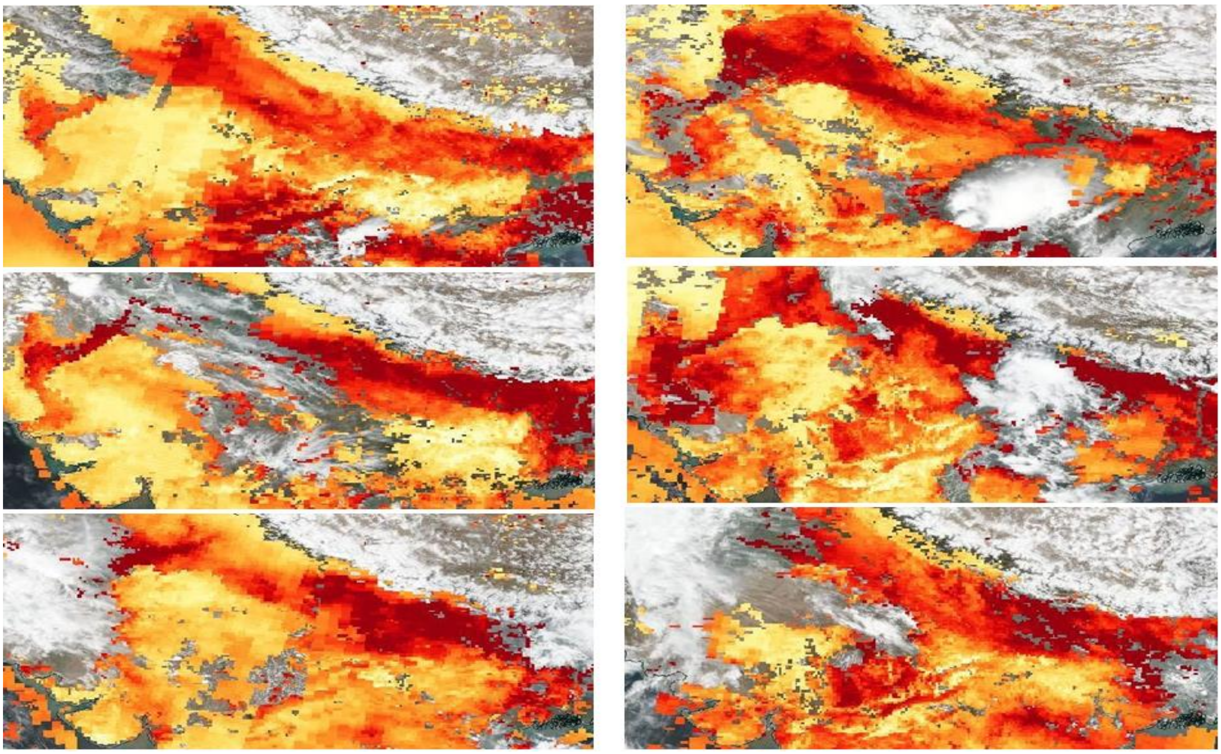


Fig 3 Merged DT/DB AOD from Terra and Aqua Modis from 18th to 23th March, 2020

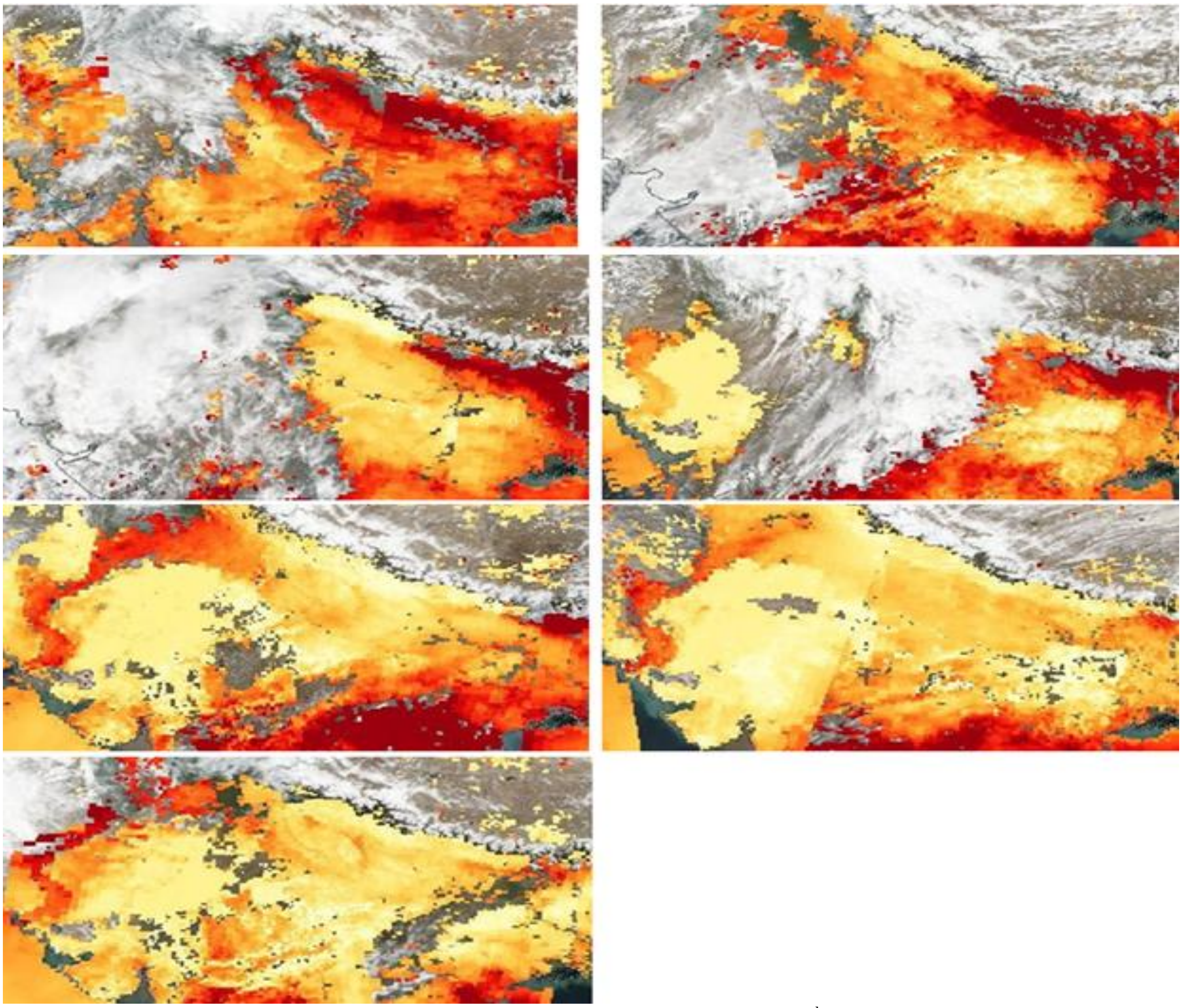
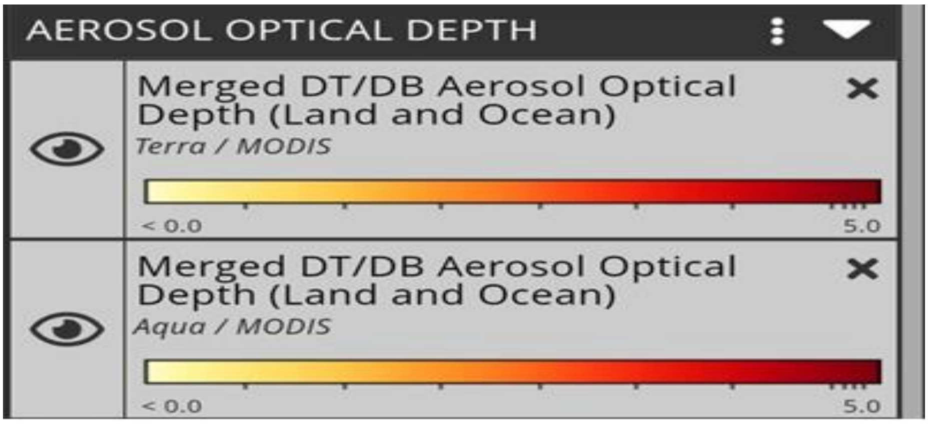


Fig 4 Merged DT/DB AOD from Terra and Aqua Modis from 24th to 30th March, 2020

➢ *INDEX of AOD:*



➢ *Precipitation Data from IMREG*

Precipitation means any forms of water vapour that falls in the earth surface due to gravitational force. Rainfall and snowfall two kinds of precipitation. Generally precipitation reduces the aerosols in the atmosphere and increases the visibility. The full form of IMREG is Integrated Multi-satellitE. It's basicallyconstellation of various satellite datasets. Here rainfalls are shown in millimeters per hours (mm/hr).

The output field has 0.1 x 0.1 degree latitude-longitude resolution (approximately 11 by 11 km at theEquator).

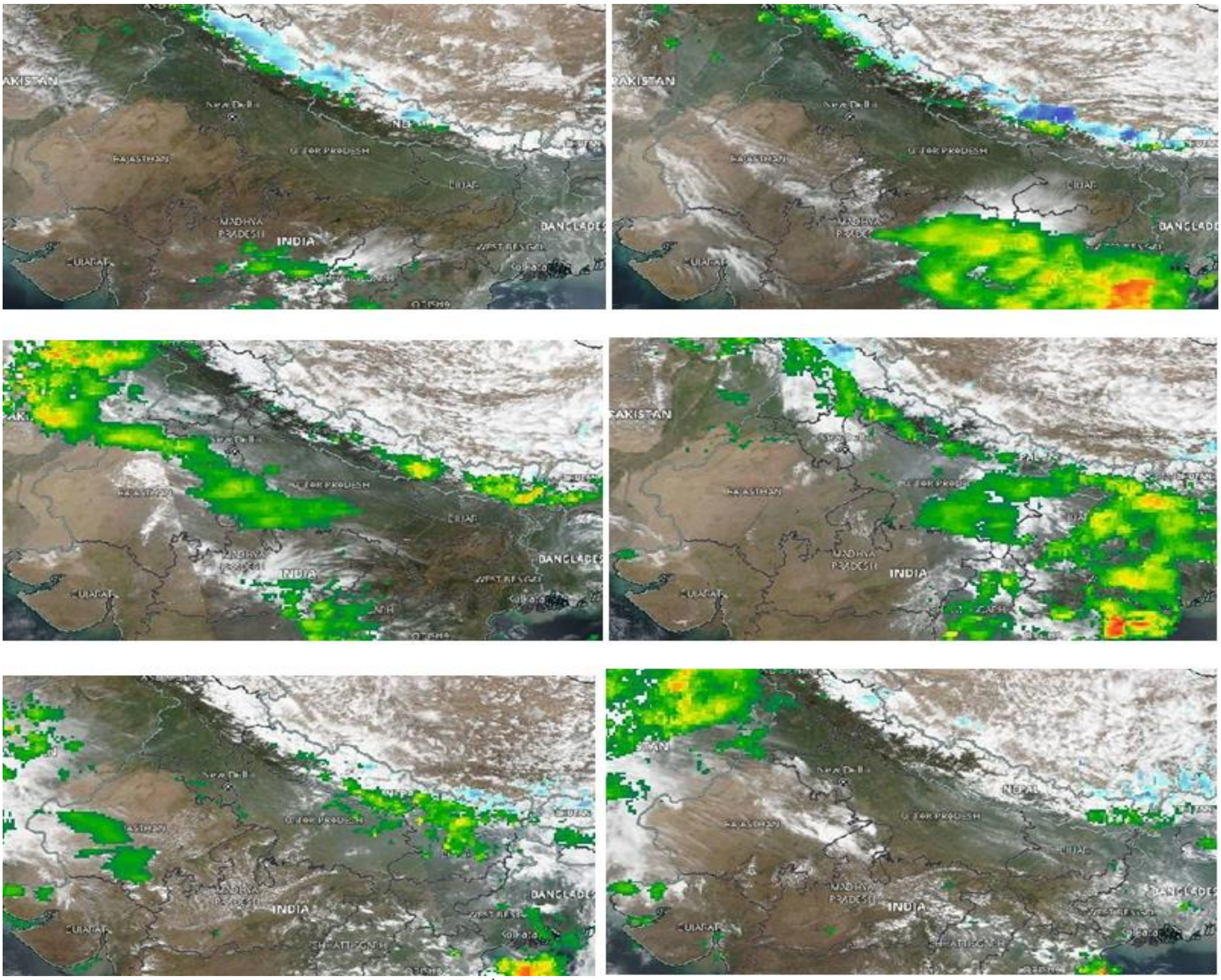


Fig 5 Precipitation Data from 18th March,2020 to 23th March, 2020 Collected from IMREG

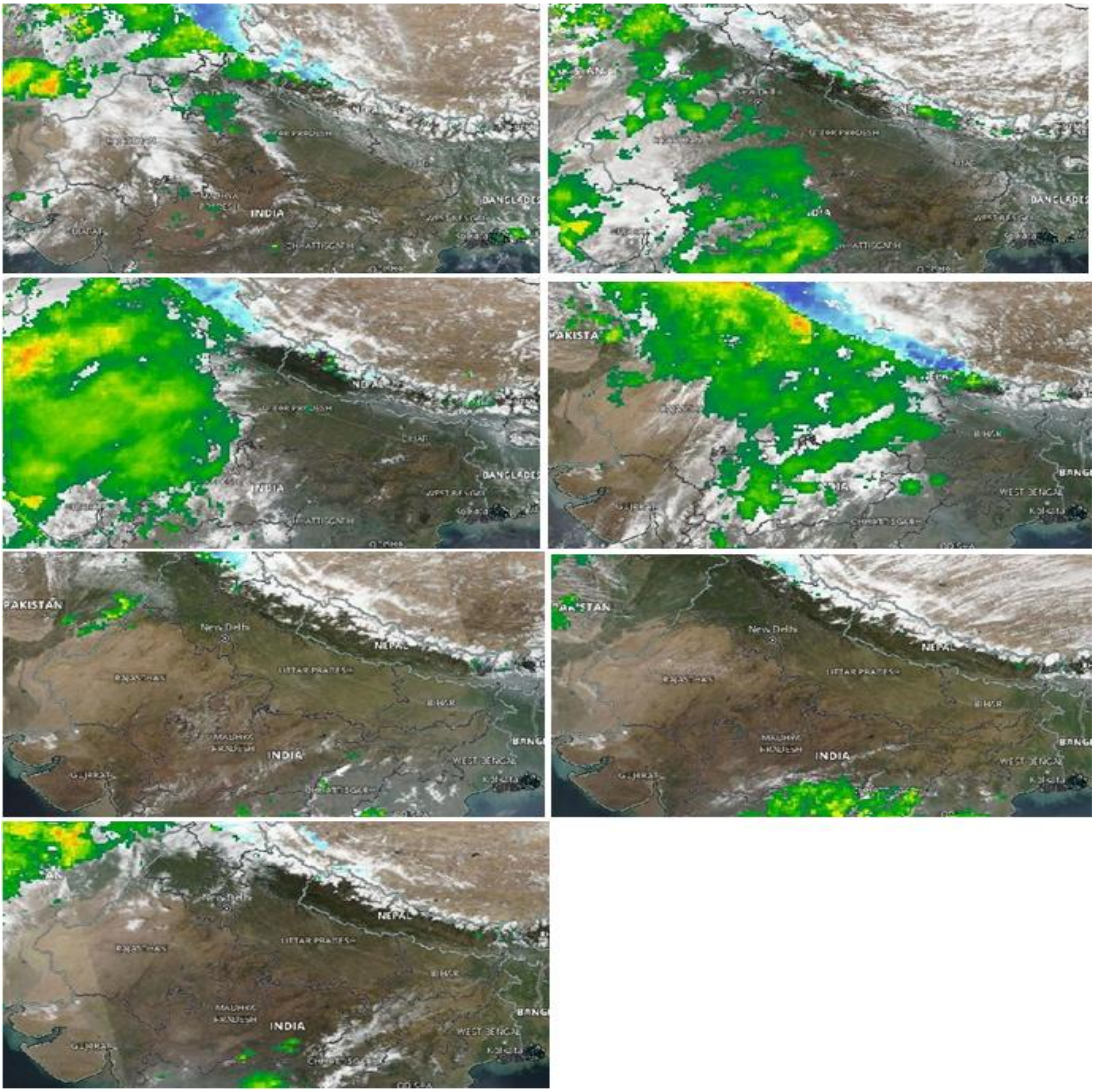
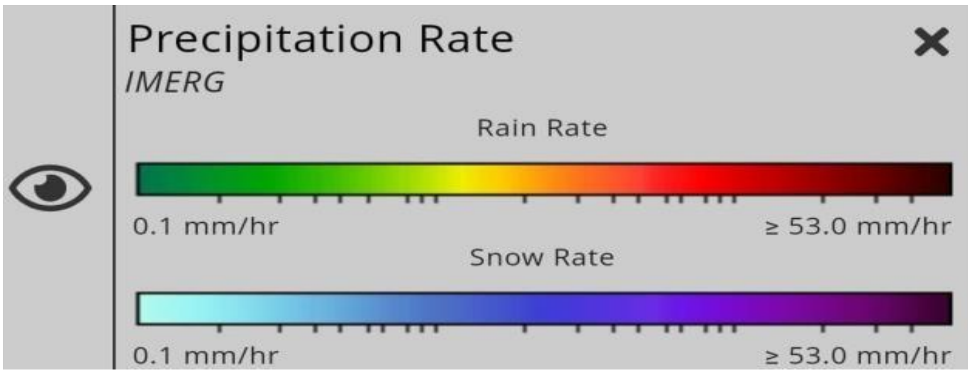


Fig 6 Precipitation Data from 24th March,2020 to 30th March, 2020 Collected from IMREG

- *Index of Precipitation:*



ISSN No:-2456-2165

- *MODIS Fire And Thermal Anomalies Data (Both In Terra MODIS, Day And Night)*

MODIS is capable to identify the fire and thermal anomalies over the earth. Generally, fire and thermal anomalies, whether from natural sources or artifical sources increases AOD. In the following images the data has been collected from Terra and Aqua Satellite product. The sensor resolution is 1 km, and the temporal resolution is daily. The thermal anomalies are represented as points (approximate center of a 1 km pixel) in the Global Imagery Browse Services (GIBS)/Worldview.

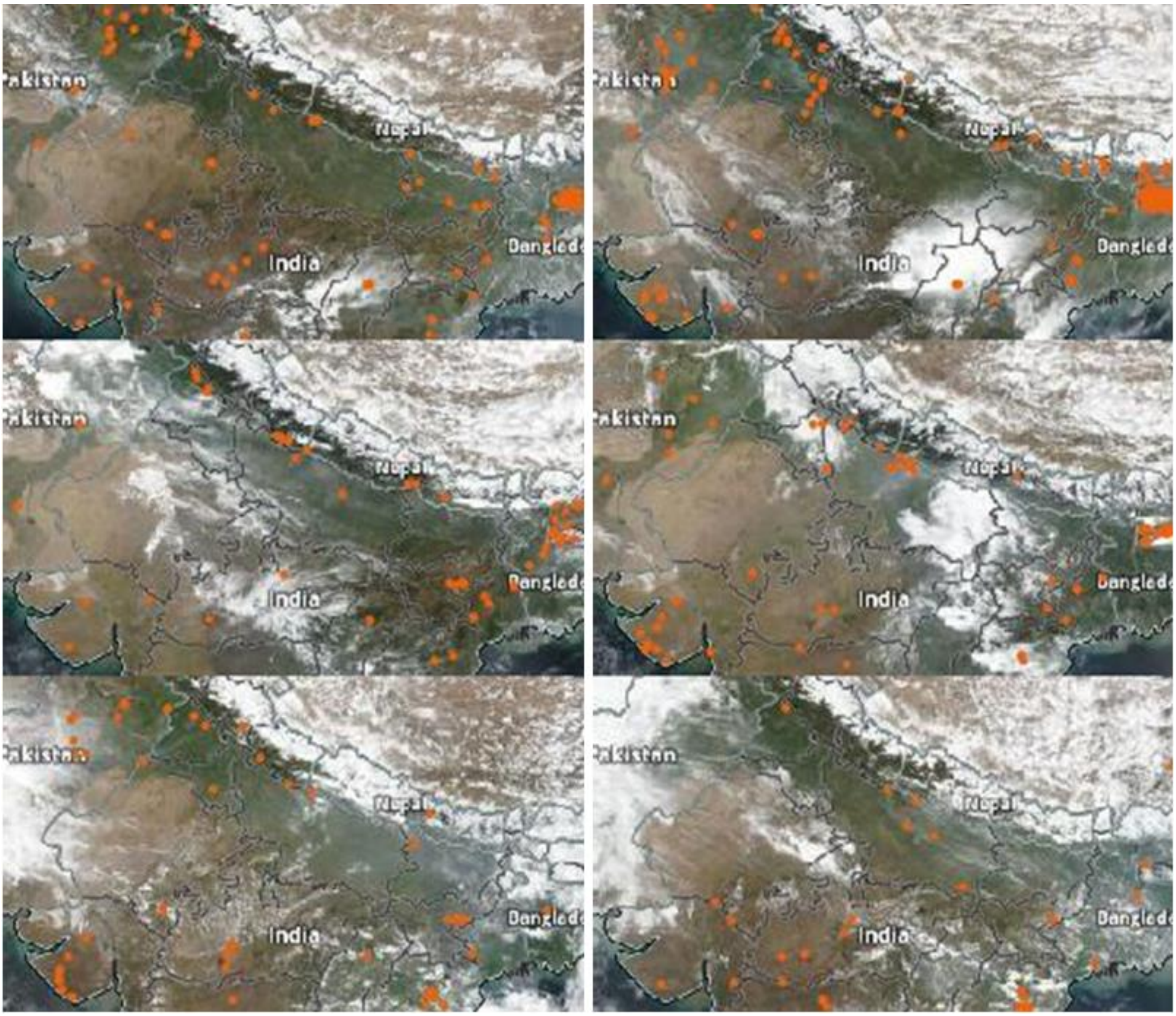


Fig 7 Fires and Thermal Anomalies (Night and Day Collected from MODIS) From 18th March to 23rd March

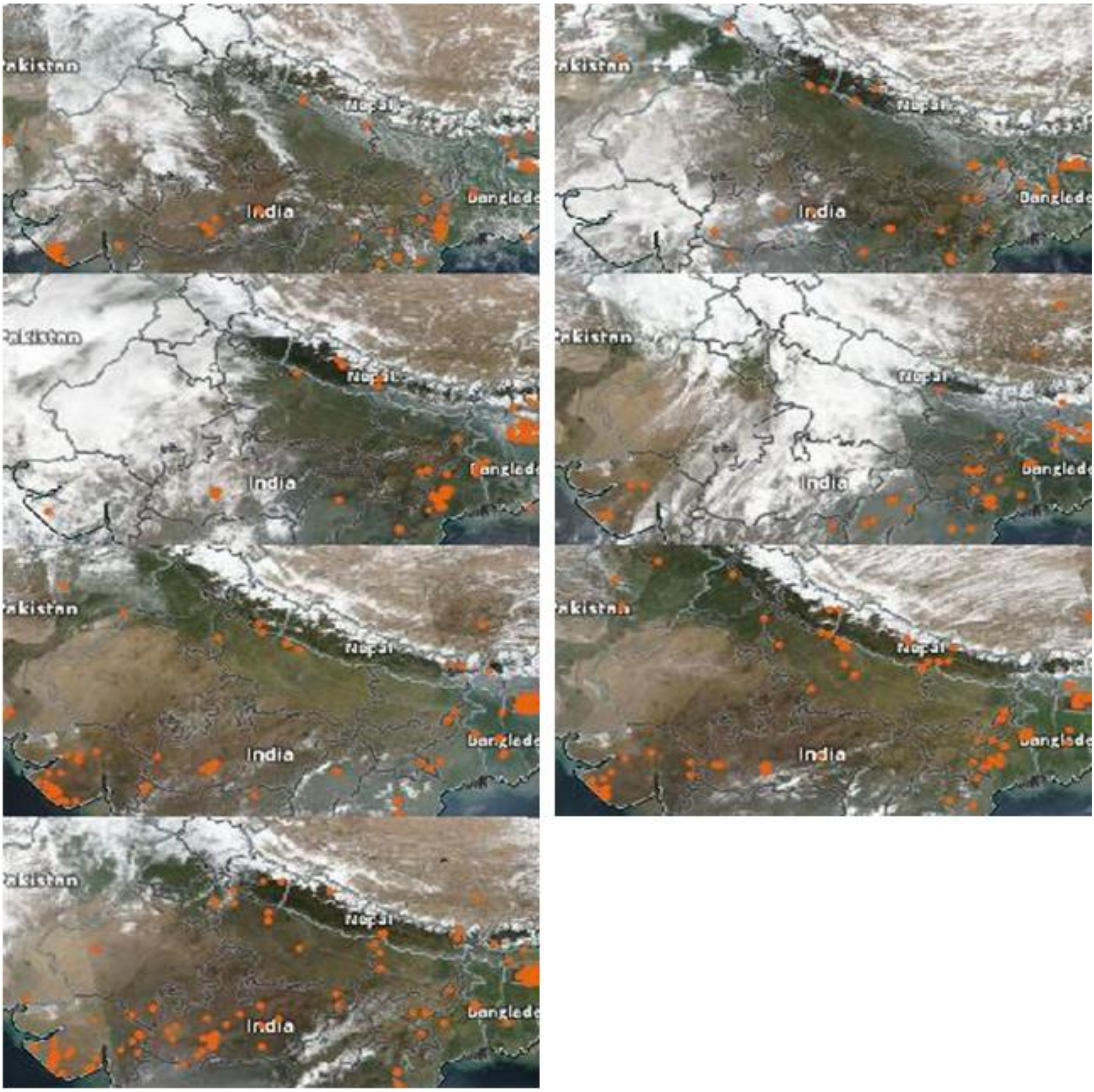


Fig 8 Fires and Thermal Anomalies (Night and Day Collected from MODIS) From 24th March to 30rd March

III. RESULTS AND DISCUSSION (MAJOR FINDING)

The weekly average data of PM2.5 and PM10 clearly indicates a rapid reduction in aerosol quantity at all four stations after the implementation of the lockdown. The reduction in PM10 aerosols was more rapid than PM2.5 due to PM10's higher weight, causing it to settle faster than suspended PM2.5 particles. Station data confirms that Upper and Middle IGP have the highest levels of fine particulate matter, which aligns with the AOD data from MODIS showing the highest AOD values in the upper and middle regions of IGP.

The merged DT/DB AOD data from Terra and Aqua Modis for March 18th to 23rd, 2020, reveals consistently high AOD values throughout the IGP. On March 19th, 20th, and 21st, the AOD values exceeded 1.0 in most urban centers. The slight decrease in AOD on March 22nd and 23rd can be attributed to the implementation of the 14-hour long 'Janata Curfew' by the Prime Minister of India. Additionally, the fire and thermal anomaly data show a decrease in fire incidents during this period. Notably, on March 19th, the Lower IGP experienced relatively lower AOD values due to the 'Kalboishakhi' rainfall in West Bengal.

Following the nationwide lockdown on the evening of March 24th, 2020, aerosol levels reduced rapidly. Station data indicates a significant reduction in both PM10 and PM2.5 across all parts of the IGP during this time, with PM10 showing a remarkable decline of up to 147.72% in the Middle IGP. Consequently, visibility and air quality improved in all areas. However, this improvement did not occur overnight; it gradually happened over a 7-day time period. Moreover, the AOD data illustrates spatial variations in the reduction of AOD. For instance, after March 26th and 27th, the AOD values reduced rapidly in the trans and upper IGP regions due to rainfall. On March 29th and 30th, while the overall IGP experienced the lowest AOD values, the lower portion of the IGP exhibited higher AOD values, possibly due to fire and thermal anomalies. Finally, we need to acknowledge the impact of low wild fire incidence after the lockdown in IGP, due to which the aerosol reduced even further.

From a layman's perspective, it may seem that the reduction in aerosols and pollution was solely due to the shutdown of industries and transport during the lockdown. However, this research reveals that the lockdown was not the sole factor contributing to the reduction in aerosols; precipitation and fire incidence also played crucial roles. Despite this, the lockdown significantly improved air quality over time, resulting in reduced health-related risks for the population.

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