Summary of An Analysis on COVID-19's effect on Air Pollution using Spatial Data along with ground observations

Introduction

Air pollution is a mixture of dangerous elements that come from both natural and man-made sources which includes both indoor and outdoor environment. It changes the natural characteristics of the atmosphere. Household combustion devices, motor vehicles, industrial facilities and forest fires are common sources of air pollution.

According to WHO, Air pollution kills an estimated seven million people worldwide every year. WHO data shows that almost all the global population (99%) breathe air that exceeds WHO guideline limits containing high levels of pollutants, with low- and middle-income countries suffering from the highest exposures.

There are six common air pollutants, also known as criteria air pollutants, that can harm our health and the environment, as specified by the US Environmental Protection Agency (EPA):

1. Sulfur dioxide (SO_2)
2. Nitrogen dioxide (NO_2)
3. Carbon monoxide (CO)
4. Ozone (O_3)
5. Particulate matter (PM)
6. Lead

Objective

To use space-based satellite data combined with ground observations like air pollution, social-economic activity, traffic or transportation, mobility, industrial activity perform exploratory data analysis, find a correlation between changes in ground activities and their impact on the environment. Compare data across different time periods and geographic regions and explore changes in Earth-related attributes (such as land use, land cover, and other characteristics) in response to COVID-19.

Methodology

- Analyses starts from 1st Jan 2019, approximately a year before the onset of COVID-19.
- Area of Interest/Analysis: India
- Nationwide lockdown was imposed on 25th March 2020.
- Unlock was planned in a phased manner:
    - Unlock 1.0 - 1st June 2020 to 30th June 2020
    - Unlock 2.0 - 1st July 2020 to 31st July 2020
    - .
    - .
    - .
    - Unlock 22 - 1st March 2022 to 31st March 2022

Data Used

1. Daily Air Pollution Data – India & USA - Average Air Quality Index data measured by pm2.5
2. Sentinel 2 – NDVI
3. Sentinel 5P – CO, CH4, SO2, O3, HCHO, NO2 and Aerosol AI 354/388mm
4. Landset 8 – Thermal Visualization

Platform Used for Geospatial Analysis

1. Sentinel Hub EO Browser

Air Quality Index

The Air Quality Index (AQI) is a measure of the quality of air in each area. It's a measure of the concentration of pollutants in the air and the value is between 0 and 500. The higher the AQI value, the greater the level of air pollution and the greater the health concern.
Eight pollutants namely particulate matter (PM) 10, PM2. 5, Ozone (O3), Sulphur dioxide (SO2), nitrogen dioxide (NO2), carbon monoxide (CO), lead (Pb) and ammonia (NH3) act as major parameters in deriving the AQI of an area.

AQI	Associated Health Impacts
Good (0–50)	Minimal Impact
Satisfactory (51–100)	May cause minor breathing discomfort to sensitive people.
Moderately polluted (101–200)	May cause breathing discomfort to people with lung disease such as asthma, and discomfort to people with heart disease, children and older adults.
Poor (201–300)	May cause breathing discomfort to people on prolonged exposure, and discomfort to people with heart disease
Very Poor (301–400)	May cause respiratory illness to the people on prolonged exposure. Effect may be more pronounced in people with lung and heart diseases.
Severe (401-500)	May cause respiratory impact even on healthy people, and serious health impacts on people with lung/heart disease. The health impacts may be experienced even during light physical activity.

Satellite Used for collecting Geospatial data

1. Sentinel 5P

   Sentinel-5 Precursor (S-5P) carries only one sensor, called TROPOMI, which is one of the most advanced multispectral imaging spectrometer.

   TROPOMI observes the sunlight that is scattered back to space by the surface of the Earth and by the atmosphere, and it detects the unique fingerprints of gases in different parts of the electromagnetic spectrum.

   It can detect a wide range of pollutants, because it measures in the Ultra Violet, Visible, Near Infrared and Short Wave Infrared parts of the electromagnetic spectrum.

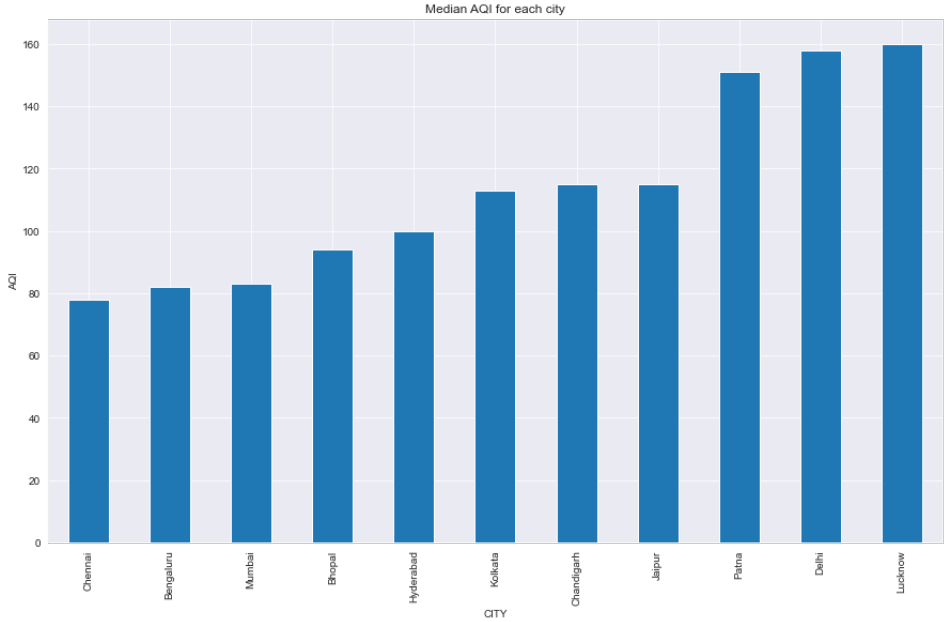
   Following pollutants were used in the study of air quality before and after the lockdown:

   - Nitrogen Dioxide (NO_2)
   - Sulphur Dioxide (SO_2)
   - Carbon Monoxide (CO)
   - Methane (CH_4)
   - Formaldehyde (HCHO)
   - AER AI (Aerosol Index)
2. Combination of Sentinel 2 and Sentinel 1 sensor data was used to study forest fires.
3. Environmental changes due to lockdown was studied with the help of Scene Classification and NDVI using Sentinel 2 data.
4. Landsat 8

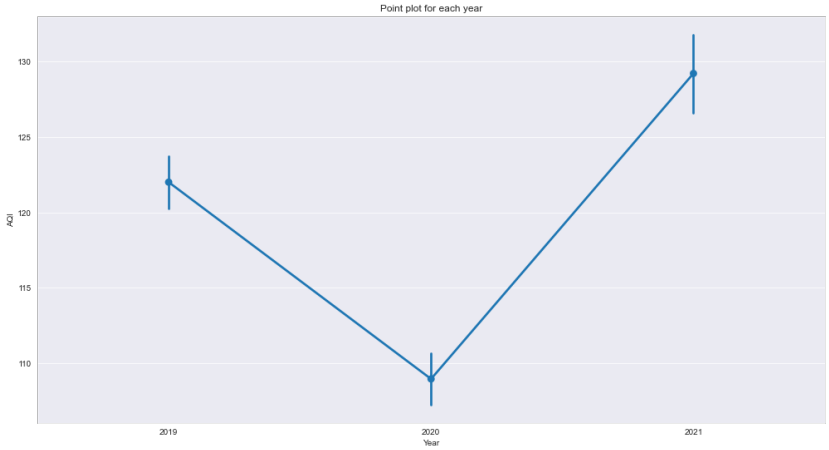
   This thermal visualization is based on band 10 (a band is a region of the electromagnetic spectrum; a satellite sensor can image Earth in different bands). At the central wavelength of 10895 nm it measures in the thermal infrared, or TIR. Instead of measuring the temperature of the air, like weather stations do, band 10 reports on the ground itself, which is often much hotter. Thermal band 10 is useful in providing surface temperatures and is collected with a 100-meter resolution.

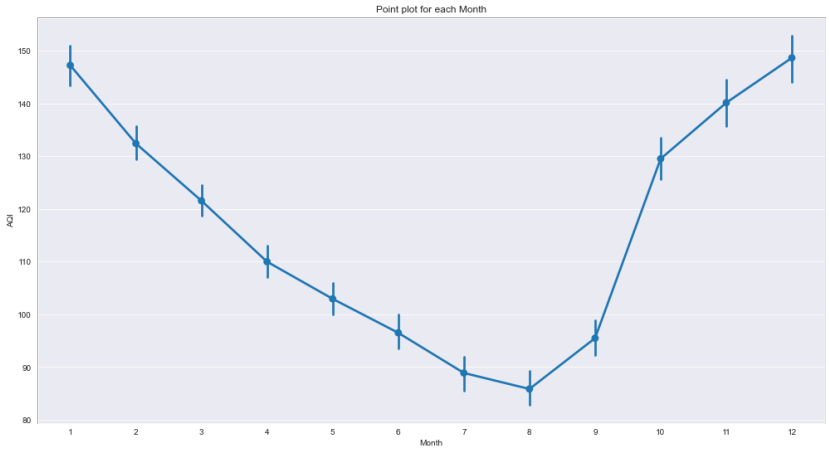
Key Takeaways

1. Chennai has the best average AQI, and Lucknow has the worst from Jan 2019 till March 2021.

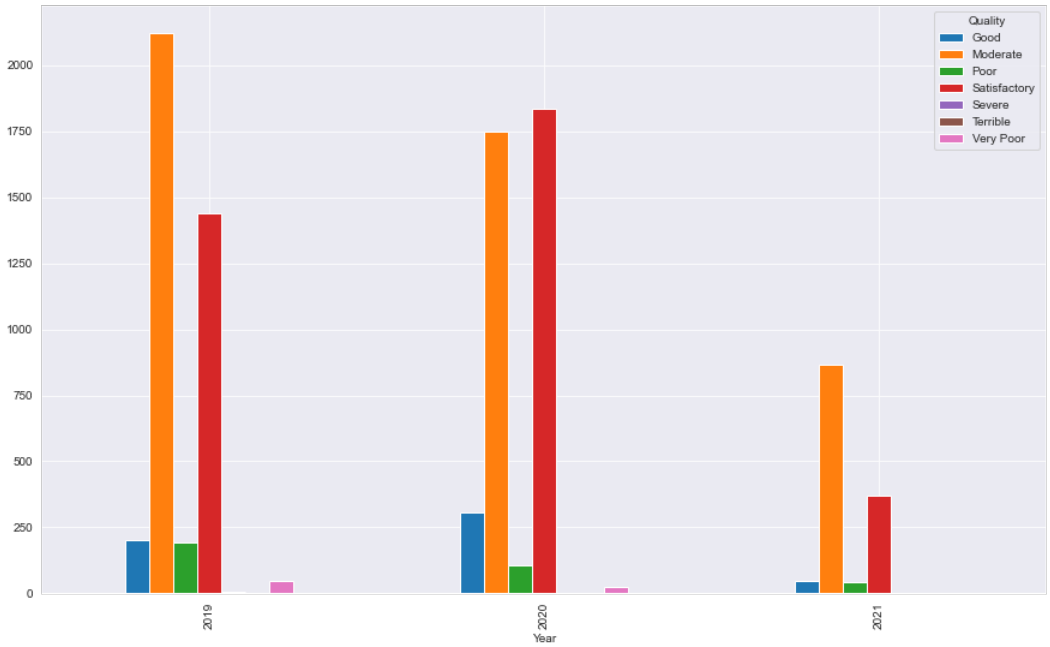


2. The AQI decreased in the year 2020 due to restricted movements amid lockdown. Also, there is a downward trend in AQI from January to August and sudden increase in the month of September and October due to bursting of firecrackers which increases the concentration of dust and pollutants (like oxides of Sulphur and nitrogen) in the air.

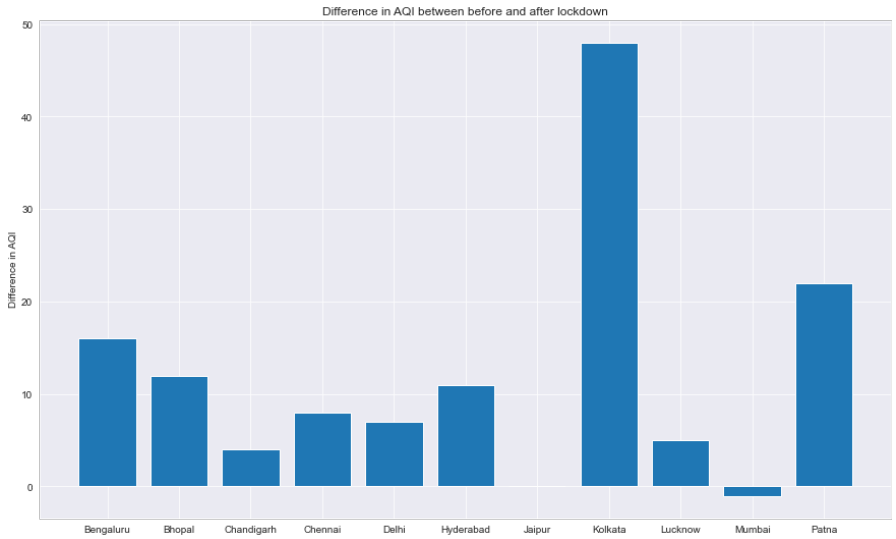




3. The only city showing Terrible AQI (>500) is Delhi.
4. Considering only 2019 and 2020 (since the data for 2021 is up to May):
    a. The Count of moderate, poor, very poor, and severe air quality has decreased from the year 2019 to 2020.
    b. The count of good and satisfactory air quality has increased from the year 2019 to 2020.
    c. The count of terrible air quality has remained the same for the year 2019 and 2020.



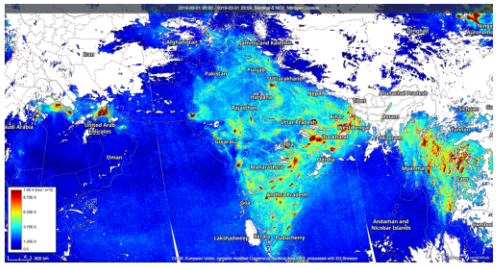
5. Statistics show that the air quality is improving in the year 2020 as the standard deviation is less for Good and Satisfactory air quality whereas for Moderate, Poor, and Severe air quality, the standard deviation is high. This implies there is less variation in the air quality for Good and Satisfactory category but more variation for Moderate, Poor, and Severe air quality.
6. The difference in the AQI before and after lockdown shows that the air-quality is improving in the year 2020 for almost all the cities except for Jaipur (no change) and Mumbai (median AQI increase by one that is the air-quality degraded slightly). Also, it is worth noting that air quality improved the most for Kolkata.



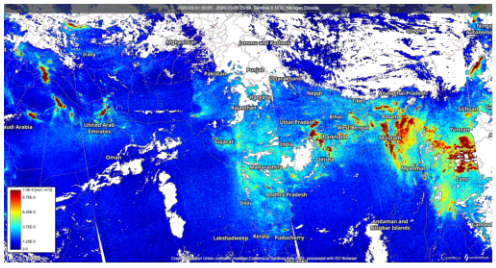
7. Statistically verified:
    a. AQI in India is different for all cities.
    b. AQI is different for each year.
    c. AQI is affected during the Diwali season.
8. NO2 hotspots are mostly located in the central parts of India where major sources of NO2 are located (coal-based power plants).
   During March, NO2 levels are found to be higher in eastern India, where forest fires produce tropospheric NO2. The lockdown impacted mining activities, resulting in a decrease in NO2 concentrations in Jharkhand and Odisha.

NO2 for March 2019, 2020, and 2021

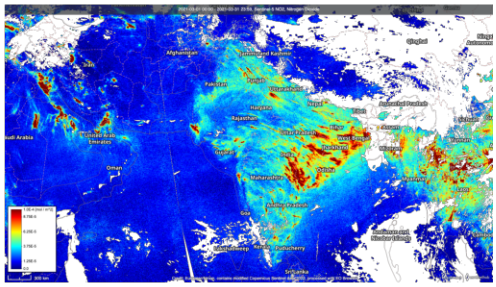
2019



2020



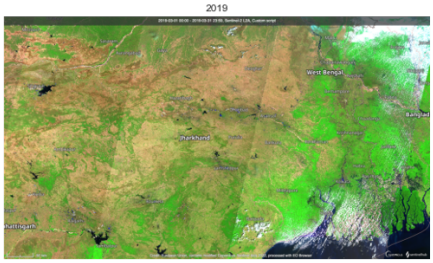
2021



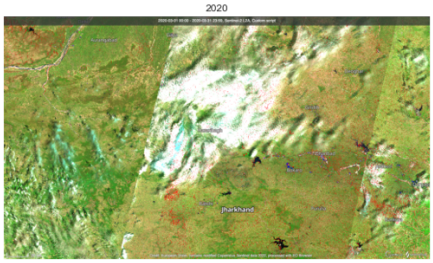
9. In 2020, the forest fire has progressed to the extent of Jharkhand, Odisha and Manipur that contributes towards the increase of NO2 concentration in the atmosphere.

Burned Area Visualization (Forest Fire) over March 2019, 2020 and 2021

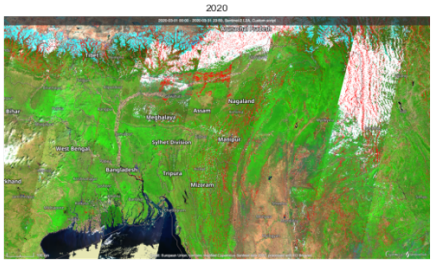
2019



2020



2020



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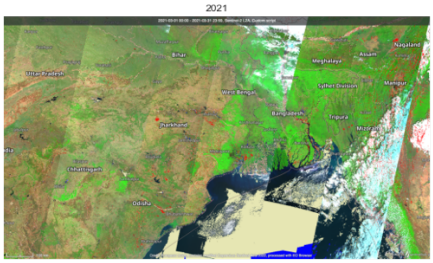
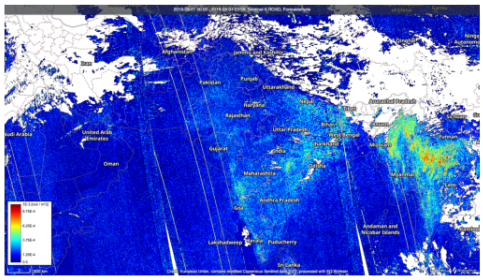


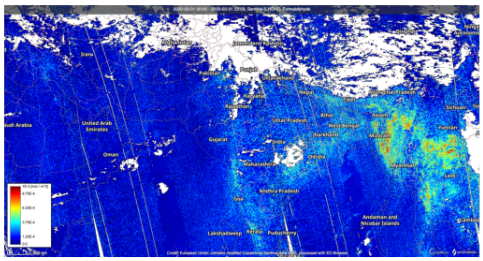
10. HCHO concentrations fell in the northern, western, and north-western portions of the country during March 2020, despite a rise in temperature, due to lockdown, absence, or lower density of road traffic, industrial emissions, and crop burning operations. In comparison to 2019, the average concentration in the central, southern, and south-central areas of India is smaller.

HCHO for March 2019, 2020 and 2021

2019



2020



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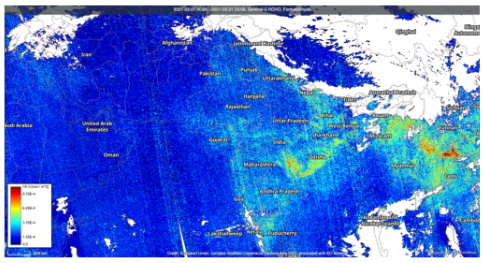
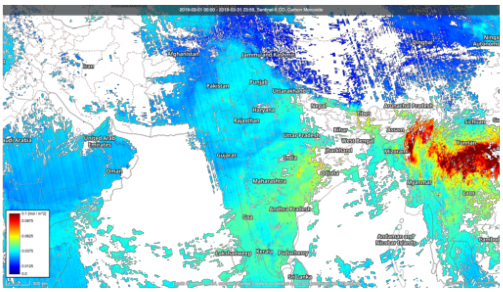


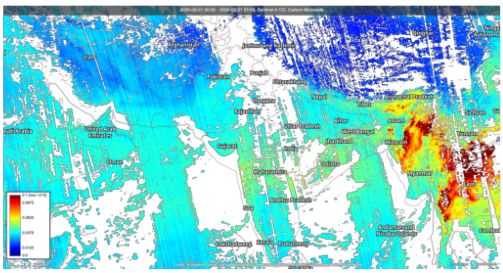
11. Cars, trucks, and other fossil-fuel-burning vehicles and machinery are the most significant emitters of CO in the outdoor air. As a result of the lockdown, automotive traffic was greatly constrained, resulting in a fall in CO concentrations in 2020.

CO for March 2019, 2020 and 2021

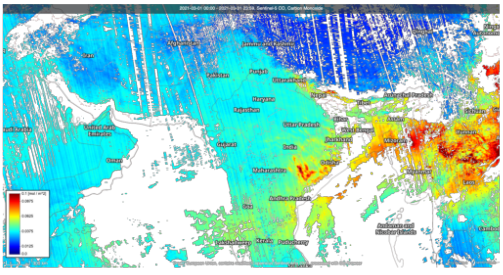
2019



2020



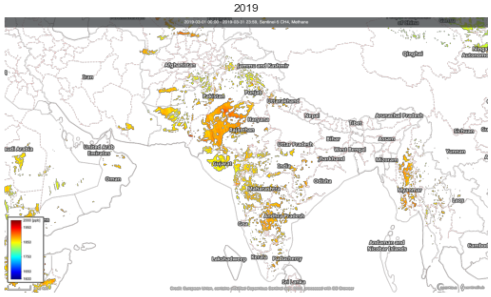
2021



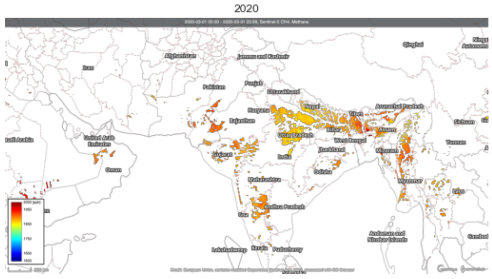
12. Methane, along with CO2, is one of the most significant greenhouse gases in the atmosphere. In Delhi and Kolkata, as well as the Indo-Gangetic plains, methane concentrations increased, however during the 2020 lockdown period, methane concentrations decreased over Hyderabad, Chennai, and Mumbai.
    However, in the year 2021, the CH4 concentration shot up.

CH4 for March 2019, 2020 and 2021

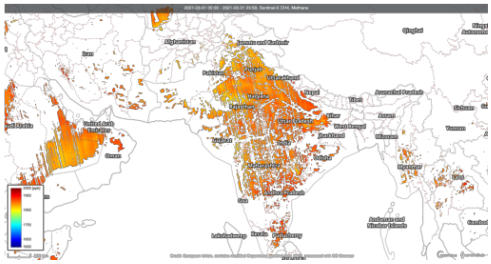
2019



2020



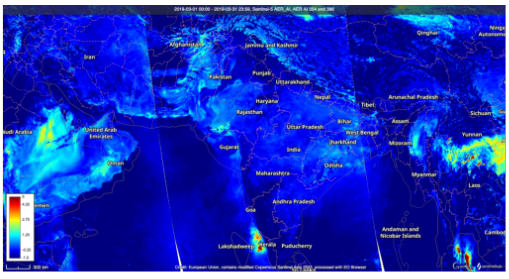
2021



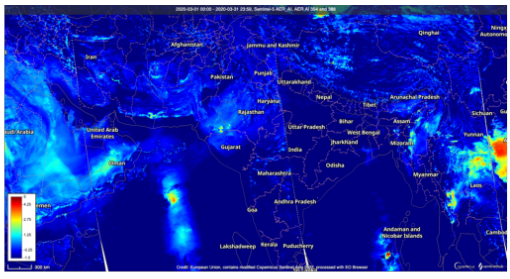
13. Except in the northern and western regions of India, where AI reduced less than in the eastern and southern sections of India during the lockdown, there is a considerable fall in aerosol concentration. After the lockdown, the aerosol concentration in the eastern regions of India increased, but the concentration in the northern and western regions of India decreased or remained similar.

AER Aerosol Index (AI) for March 2019, 2020 and 2021

2019



2020



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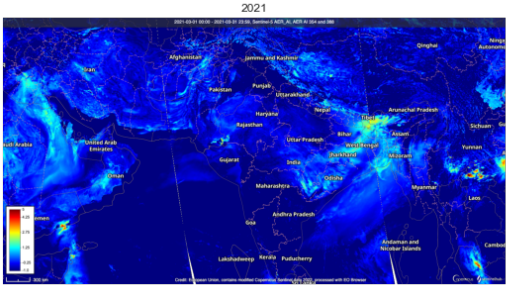
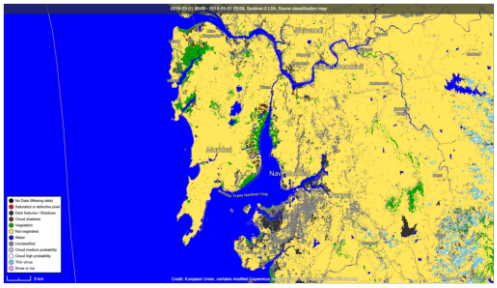


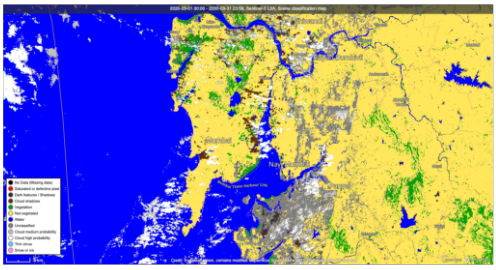
14. The concentration of NO2 during 2020 is much lower than the concentration during 2019 due to the lockdown for the industrial area like Ambattur Industrial Estate, Chennai and Neyveli an industrial town in Cuddalore district of Tamil Nadu.
    Therefore, it can be inferred that the industrial pollution is the major cause of air pollution in India (Here Chennai and Tamil Nadu are two examples taken).
15. For the Mumbai region, it is observed that vegetation started increasing during the lockdown, due to less air pollutants.
    Similarly, for the Delhi region, vegetation started increasing during the lockdown (2020) but decreased after the lockdown (2021).

Scene classification map over March 2019, 2020 and 2021 for Mumbai region

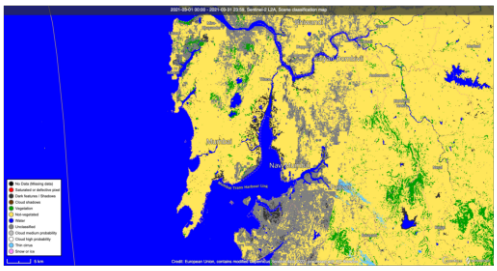
2019



2020

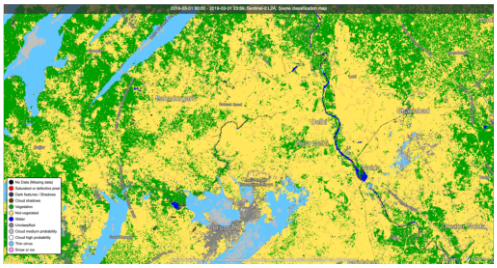


2021

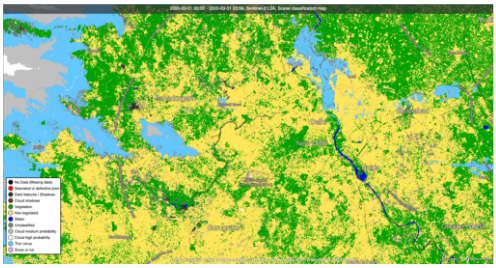


Scene classification map over March 2019, 2020 and 2021 for Delhi region

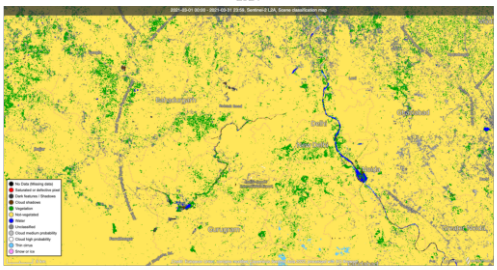
2019



2020



2021



16. Above observation was again verified using the NDVI which is a dimensionless index that describes the difference between visible and near-infrared reflectance of vegetation cover and can be used to estimate the density of green on an area of land. Hence, for the Mumbai region, it is observed that vegetation cover started increasing during the lockdown.
    For Delhi region, the NDVI increased during lockdown but decreased after the lockdown.

NDVI over March 2019, 2020 and 2021 for Mumbai region

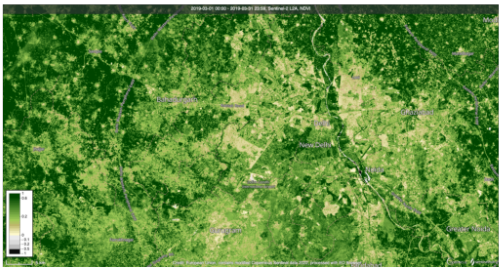
2019

2020

2021

NDVI over March 2019, 2020 and 2021 for Delhi region

2019



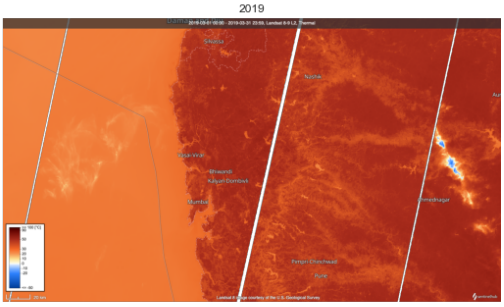
2020

2021

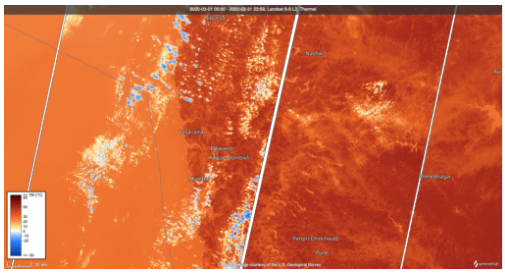
17. The ground thermal temperature over the month of March for Mumbai region shows that during the lockdown, the temperature of the ground was reduced. This is directly linked to the reduction in the concentration of CO_2 in the atmosphere which is a major contributor to the anthropogenic greenhouse effect.
    In Delhi region, there is a drastic variation in the temperature of the ground during lockdown, instead of decreasing, the temperature of the ground increased. And in the following year it is observed that the temperature of the ground decreased again.

Thermal temperature over March 2019, 2020 and 2021 for Mumbai region

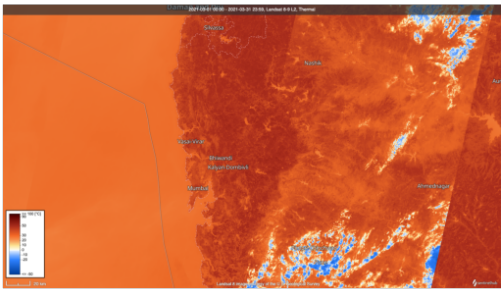
2019



2020

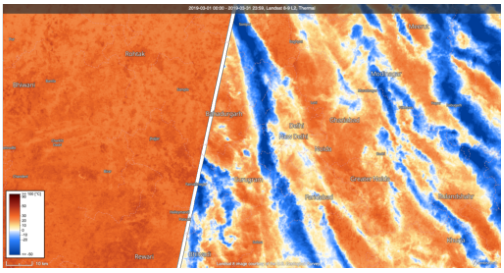


2021

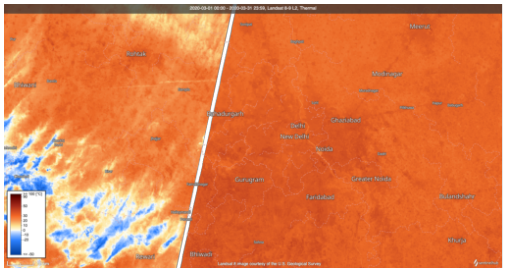


Thermal temperature over March 2019, 2020 and 2021 for Delhi region

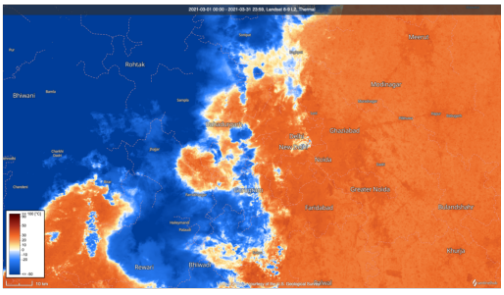
2019



2020



2021



Scope of improvement

- During the feature engineering step, records of AQI of many cities were deleted from the csv file as they were inconsistent when compared to other cities. Hence a more concrete data could be used for analysis.
- The data from other air pollutants like SO2, NO2, etc. could be combined.
- Object detection algorithm could be used to count the number of vehicles on road before and during the lockdown which would further help in verifying the contribution of hydrocarbon burning towards air pollution.
- For deep analysis, several other datasets can be used. For example, Impact of lockdown on women and children like domestic violence or consumption of electronic media, employment rate, impact on real estate, automobiles, e-commerce dependence, etc.

Conclusion

- Due to nation-wide lockdown, several variations were observed in the atmospheric gases and the environmental conditions.
- The tropospheric NO2 levels were found to be lower during the lockdown period i.e., 2020 in northern, western, and south-eastern regions of India.
- In 2020, forest fires in the eastern part of India contributed to the increase in the concentration of NO2.
- The concentration of HCHO was reduced in most parts of India.
- The changes in the concentration of CH4 is less significant due to its longer residence period and secondary pollutants and due to lower anthropogenic emissions during lockdown.
- The less anthropogenic activity led to the increase in the vegetation cover during the lockdown.
- Anthropogenic activity also influences CO levels, which decreases throughout the lockdown period.