India NO_2 AIR POLLUTION MAP

HIGHLIGHTING INDIA's WORST NO_2 EMISSION HOTSPOTS

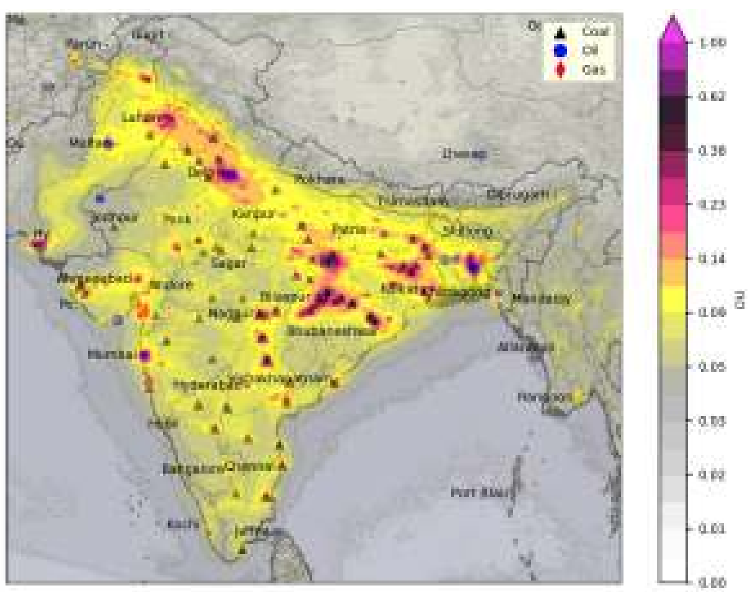
July 2019

Summary

Greenpeace's updated analysis of TROPOMI NO_2 satellite data confirms that the coal-fired power plants and industrial clusters in India are the country's worst NOx hotspots. The data highlights the power plant and industrial clusters eg., Singrauli, Korba, Talcher, Chandrapur, Mundra,, Durgapur as the most polluting regions/hotspots along with cities like Delhi-NCR, Mumbai, Bengaluru, Kolkata, Chennai and Hyderabad etc. This high concentrations occur predominantly near power plants which are fueled by coal, oil and gas and in cities which has high vehicular population . The finding corresponds to earlier studies done by IIT kanpur which highlighted NOx emissions from Coal based power plants as one of the major contributors to air pollution crises over Delhi-NCR.

NOx emissions contribute to three types of toxic air pollution: $PM_{2.5}$, NO_2 and ozone, each of which is responsible for thousands of premature deaths each year in India. It is estimated that air pollution (ambient $PM_{2.5}$ Household and ozone air pollution collectively) caused 3.4 million deaths worldwide in 2017 and over 1.2 in India[1,2]. Out of the total deaths in India ambient particulate matter pollution alone results in 673,129 deaths. Tropospheric ozone (O_3) is a secondary gaseous pollutant produced by photochemical oxidation of volatile organic compounds (VOCs) and carbon monoxide (CO) in the presence of nitrogen oxides (NO_x). Increased anthropogenic emissions of O_3 precursors since the preindustrial have led to large-scale enhancements in O_3 throughout the troposphere. Long-term exposure to ambient O_3 contributes to the risk of premature mortality. The Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) in 2016 attributed 233,638 annual premature mortalities to ambient O_3 exposure globally, with 39% of the disease burden in India.

Given the seriousness of the spread of NOx pollution across the country, It is essential for the country's decision-makers to ensure the power sector complies with the emission standards notified for coal based power plants in December 2015 (7th December 2015) and notify stricter emission standards for other polluting industries and introduce caps on emission loads for transport and other sectors in and around cities and critically polluted areas in order to help the country come out of the air pollution and health crises we face today. While there are some steps like leapfrogging to BS VI will be helpful towards reducing NOx pollution, It's important to ensure that the power and industry sector also adheres to strict NOx standards.



[1] http://ghdx.healthdata.org/gbd-results-tool

2 https://www.icmr.nic.in/sites/default/files/icmr_in_news.pdf

Introduction

It is estimated that air pollution (ambient $PM_{2.5}$ Household and ozone air pollution collectively) caused 3.4 million deaths worldwide in 2017 and over 1.2 in India[3,4]. Out of the total deaths in India ambient particulate matter pollution alone results in 673,129 deaths. NO_x emissions[5] from the burning of coal and oil are the key contributor to the ambient air pollution by formulation of secondary nitrates ($PM_{2.5}$) and Ozone (O_3), two of the most important air-borne pollutants in terms of public health damage across the world[6].NO_x are dangerous air pollutants, causing respiratory symptoms and lung damage on acute exposure, increasing the risk of chronic diseases in long-term exposure[7].

"Tropospheric ozone (O_3) is a secondary gaseous pollutant produced by photochemical oxidation of volatile organic compounds (VOCs) and carbon monoxide (CO) in the presence of nitrogen oxides (NO_x). Increased anthropogenic emissions of O_3 precursors since the preindustrial have led to large-scale enhancements in O_3 throughout the troposphere (Young et al., 2013). Long-term exposure to ambient O_3 contributes to the risk of premature mortality (Atkinson et al., 2016; Jerrett et al., 2009; Turner et al., 2016; U.S. EnvironmentalProtection Agency, 2013; World Health Organization, 2013). The Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) in 2016 attributed 233,638 annual premature mortalities to ambient O_3 exposure globally, with 39% of the disease burden in India (Cohen et al.,2017; GBD 2016 Risk Factors Collaborators, 2017)."[8]

"Population-weighted seasonal ambient O_3 concentrations in India have increased by 27% from 62 parts per billion (ppb) in 1990 to 77 ppb in 2016 (Health Effects Institute, 2018)."

Also, one of the most recent and significant assessments of sources of pollution in Delhi done by IIT, Kanpur in 2015[9] highlights the impact of NOx emission (especially from Power plants) on air quality as:

"Based on the study done by Quazi (2013), it was shown that power plants contribute nearly 80% of sulfates and 50% nitrates to the receptor (Delhi-NCR) concentration." Page xv

"90% reduction in NOx from Power Plants can reduce the nitrates by 45%. This will effectively reduce PM10 and PM2.5 concentration by about 37 µg/m3 and 23 µg/m3 respectively." Page xv

It is evident from the past research that NO_x have huge impact on human health and to control this hazardous pollutant we need to understand and know more about its spread and sources. The information of air quality not being readily available in the public domain in a format easily understandable to the general public and them being relatively unaware of the quality of the air they breathe and health impacts it causes is one of the biggest hindrances in building up of political will to act on big pollution sources. Availability of reliable data in the public domain is the key to cleaner skies but in the absence of such measured data using the proxy becomes the only available alternative to quantify the pollutants and trends over time in such regions. The satellite-based identification of hotspots is a proxy for emissions rather than local ground-level pollutant concentrations.

The satellite-based data doesn't allow the major polluters to hide The data is also useful in showing the urgency of applying stringent regulation for polluting sources. The vast volume of NOx emissions from Delhi NCR, Singrauli, Korba, Talcher, Chandrapur affects health over a large area, including the neighboring cities.

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3 http://ghdx.healthdata.org/gbd-results-tool
4 https://www.icmr.nic.in/sites/default/files/icmr_in_news.pdf
5 NO_x is the general name for all nitrogen oxides, including the two most abundant NO_2 and NO.
6 https://www.who.int/airpollution/ambient/pollutants/en/
7 https://journals.lww.com/epidem/Fulltext/2018/07000/Long_term_Concentrations_of_Nitrogen_Dioxide_and.2.aspx
8 https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1029/2018GH000168
9 http://cerca.iitd.ac.in/files/reports/IITK%20study%202016.pdf

Methodology

The Tropomi sensor on board the Sentinel-5P satellite is operational since February 2018. It monitors the vertically integrated amount (column amount) of several atmospheric trace gases, including NO_2. Performing about 14 polar orbits per day, it visits every point on Earth at least once around 13:30 local solar time.[10, 11] Locations in high latitudes can be visited multiple times per day. Tropomi measurements have a spatial resolution of about 7km.[12]

In this study, we analysed the first sixteen months of Tropomi NO_2 observations from February 2018 through May 2019. Data were accessed from the TEMIS [13]and ESA Copernicus[14] platforms. The data of each orbit was first remapped from the native sensor grid onto a time-constant regular latitude-longitude grid with 0.02°x 0.02° resolution (~2x2km^2), which is finer than the 7-km native satellite grid. Although this does not provide higher effective spatial resolution for instantaneous measurements, it can do so for temporal averages.[15] The value of a cell on the target grid was computed as follows:

- If all of the surrounding 2x2 cells of the satellite grid hold valid values, the target value is the mean of these values, weighted by $1/d^2$, with d being the distance between the satellite cell and the target cell.
- Otherwise, the 4x4 environment is used instead, applying the same weighting while discarding any invalid values.

After testing different algorithms, this turned out to be the one which yielded the most satisfying results, retaining a very local scope where data is complete while robustly filling gaps by using information of a wider environment where data is missing.

The remapped orbit data were then aggregated into global daily data.[16] In areas with overlapping measurements of consecutive orbits, for each grid cell the observation with the higher quality assurance (qa) value was used. The qa-value is a measure of the data quality which is delivered with the data product. It is based on various factors, such as cloud cover, signal-to-noise ratio, etc.

Averages for months[17] were computed from the daily files by weighting each daily measurement with its qa-value. A monthly qa-value is computed for each grid cell by weighting the daily qa-values by themselves (i. e. applying the same weighting as for the actual measurement).

Annual averages were computed from the monthly averages by weighting them with their above described monthly qa-value. We note that this is slightly imprecise because (Gregorian calendar) months are not of equal length; a flaw that may be subject to future improvements of our processing algorithm.

Hotspots were identified by selecting locations with elevated NO_2 concentrations seen in the satellite data. The average NO_2 levels within r=25km of each satellite grid cell was calculated and local maxima were identified. Hotspots are then defined as a circle with radius r, centered on the cell with the highest NO_2 concentration. The choice of radius was based on observing the size of NO_2 hotspots around isolated sources with no other major emission sources in the area. When there were hotspots less than 4·r (100km) apart, all but the one with the highest NO_2 level was discarded to avoid including multiple locations within one cluster of emissions sources.

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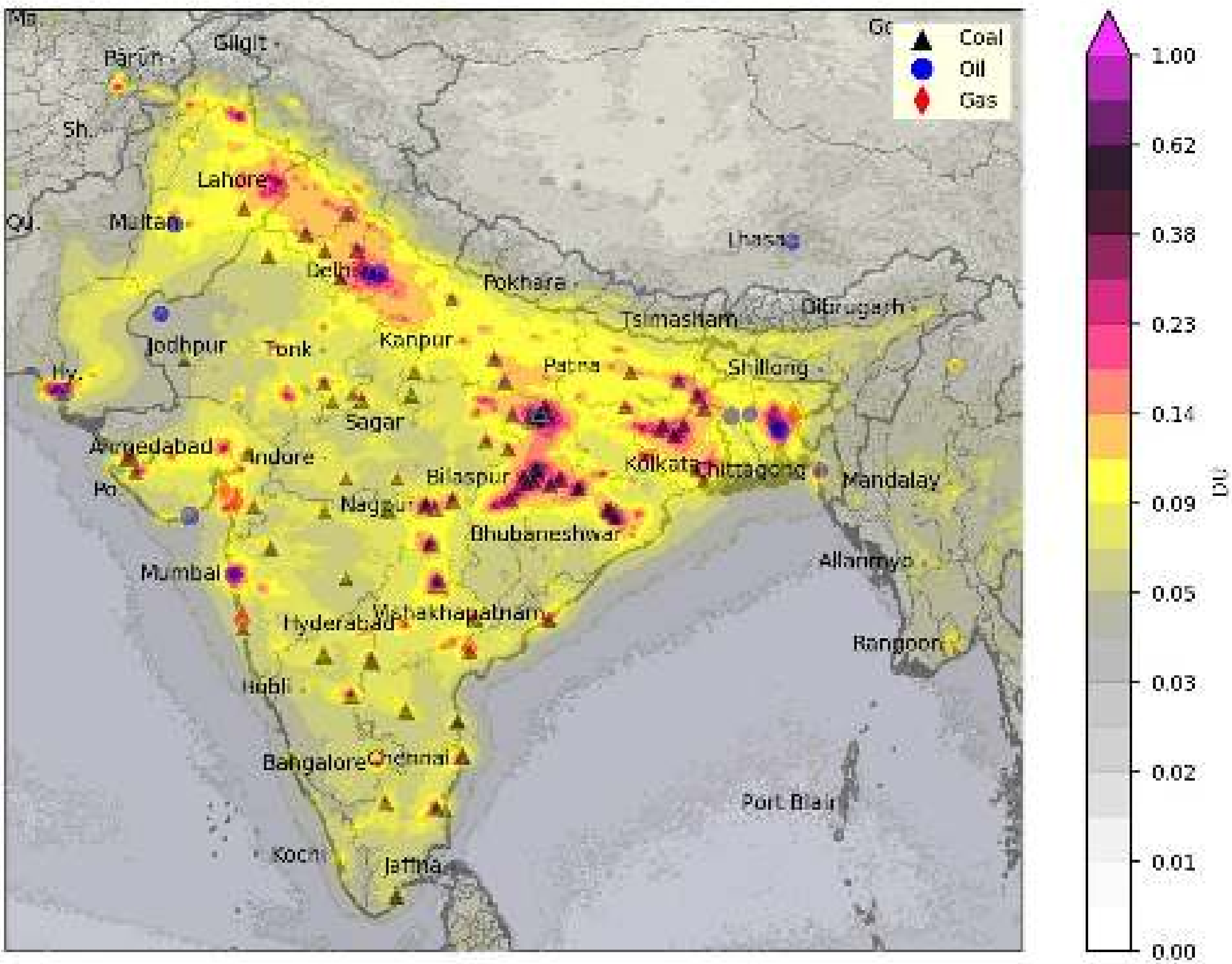
[10] and once more on the night side of the Earth, but Tropomi relies on sunlight to take measurements
[11] https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-5p/orbit (accessed 2019-06-28)
[12] https://earth.esa.int/web/guest/missions/esa-eo-missions/sentinel-5p (accessed 2019-06-28)
[13] http://www.temis.nl/airpollution/no2col/no2regio_tropomi.php
[14] https://s5phub.copernicus.eu/
[15] Chris A. McLinden et al., Space-based detection of missing sulfur dioxide sources of global air pollution, Nature Geoscience **9**, 496–500 (2016), DOI: 10.1038/ngeo2724
[16] a day being defined as starting at 00:00 UTC
[17] of the Gregorian calendar

Data and Inference

The data highlights the power plant and industrial clusters eg., Singrauli, Korba, Talcher, Chandrapur, Mundra, Mumbai, Durgapur as the most polluting regions/hotspots along with cities like Delhi-NCR, Bengaluru, Kolkata, Chennai and Hyderabad etc.

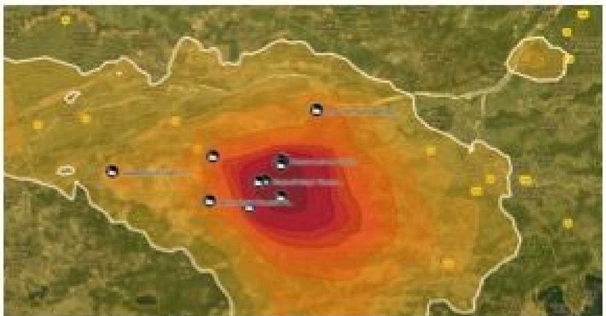


India annual mean NO_2 hotspot (June 2018 through May 2019)

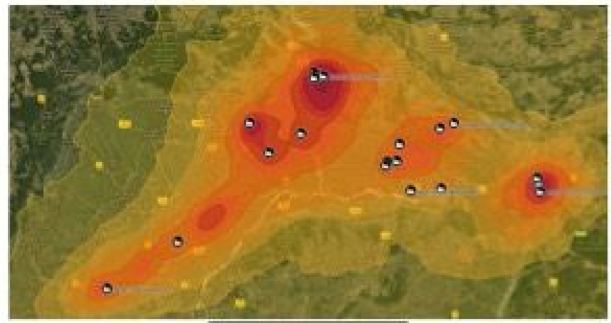
The locations with high intensity of coal burning, petro-refining facilities and cities with high emissions from the transport sector are the worst hotspots. But not only the industrial clusters and mega cities it's also the tier-2 cities and smaller towns where relatively high emission of NO_2 can be detected using the satellite data, so a future pathway which moves us away from this high fossil fuel dependent path to a sustainable development path should urgently be thought about and acted upon. While we can't do away with these detrimental sources of pollution in a day, till the time we phase these out slowly in near future, we need technologies to reduce pollution to be implemented at source which can eliminate the toxic gases and pollutants from the flue gas/tail pipes.

The detailed interactive map for NOx hotspot can be found on the following link: https://bit.ly/2JodHWq

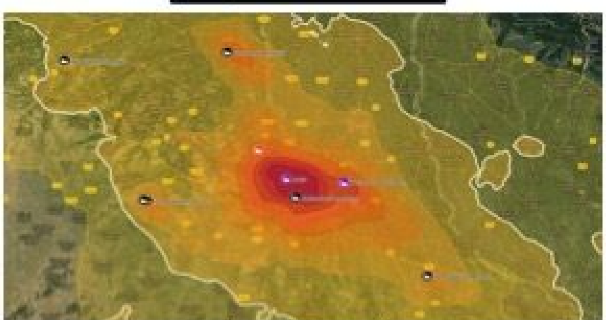
In a recent response to the question asked in Lok Sabha the Environment Minister Mr. Prakash Javadekar[18] mentioned that, “India is leapfrogging from BS-IV to BS-VI fuel standards since 1st April, 2018 in NCT of Delhi and from 1st April, 2020 in the rest of the country which will reduce NO_x emissions of heavy duty diesel vehicles by 88.5% in comparison to BS-IV vehicles.” This statement comes in the wake of hazardous air pollution levels across the country and NO_x contributing to significant share of the pollution. Although this is a very significant step in the process towards reducing NO_x emissions from the transport sector but the satellite data depicted in figure 1 and figure 2 clearly points out toward similar or even bigger emissions hotspots in geographies where the main pollution source is not transport sector but it is coal burning for utility scale power plants or captive power plants and other industrial process, although transport still contributes to overall emissions in these locations as well.



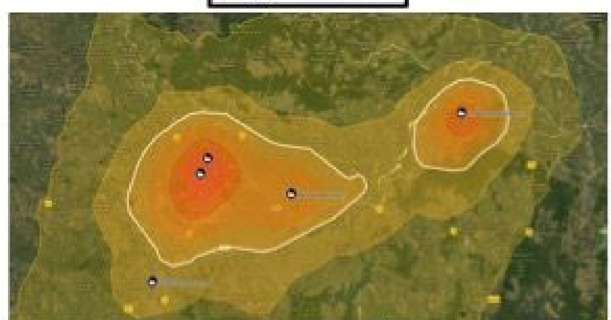
Singrauli-Sonbhadra



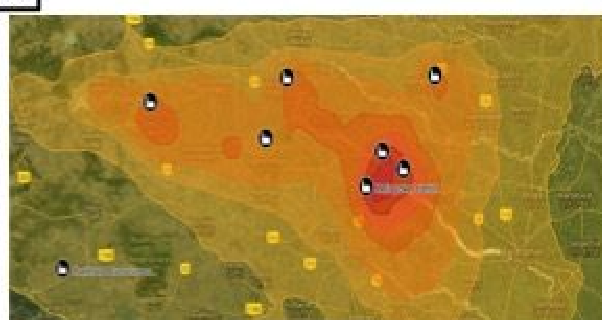
Angul-Talcher



Delhi-NCR



Nagpur



Durgapur

Report done by IIT Kanpur on Delhi’s air pollution mentioned that, “90% reduction in NO_x from power plants can reduce the nitrates by 45%. This will effectively reduce PM_{10} and $PM_{2.5}$ concentration by about 37 $\mu g/m^3$ and 23 $\mu g/m^3$ respectively.” This contribution from the power plants and industries can be even more in geographies like, Singrauli, Korba, Talcher, Chandrapur where the capacity of coal based power plants is much more higher than Delhi-NCR. The figure 1 & 2 clearly depicts the higher intensity and spread of the NO_2 emissions near such locations where coal based power plants have been established in the country.

[18] http://164.100.24.220/loksabhaquestions/annex/171/AS114.pdf

Recognizing the significant contribution of coal based thermal power plants to the air pollution and NO_x/SO_2 emissions, Ministry of Environment, Forest and Climate Change (MoEF&CC) for the first time came-up with NO_x and SO_2 emission limits based on the age of the power plants through gazette notification dated 7th December 2015[19]. The emission limits for NO_x are divided into three categories as follows:

S. No.	Timeline	Standard (mg/Nm^3)
	PPs (units) installed before 31st December 2003	00
	PPs (Units) installed after 1st January 2003, up to 31st December 2016	00
	PPs (units) to be installed from 1st January 2017	00

However, discussions within Ministry of Power (MoP), Central Electricity Authority (CEA) and MoEF&CC (Accessed through RTI) suggests that the power industry is advocating to dilute the stricter emissions standards for NOx to 450mg/m3 from the current value of 100 - 300mg/m3 sighting non availability of technology. So far, Honorable Supreme Court intervention have made sure that the limits are not diluted but it has given order directing NTPC to conduct pilot test for SCR/SNCR technology which should be implemented to reduce NOx emissions from polluting power plants to meet the newer limits of 300 and 100 mg/Nm3. The timeline to submit the result of such tests was December 2018 but the information on the same is still not available in the public domain. However almost all most of the new EIA reports submitted for Environmental Clearance (EC) processes[20,21,22] are making making submissions that they will comply with the new emission standards by installing SCR/SNCR contradicting the claim of lack of availability of appropriate technology. BHEL in a pilot run on SCR also noted that

"SCR can be installed in India with high ash coal and observed that increase in vanadium continent in SCR catalyst leads to increase in De-NOx efficiency at different temperatures. BHEL experiment also found that, No plugging of fly ash particles in catalyst cells was found, during testing "[23].

It has been very well established that NO_x acts as a precursor to both secondary Particulate ($PM_{2.5}$) & Ozone (O_3) and has a huge impact on public health[24,25]. Ozone levels are increasing in part of the country[26] and can be directly attributed to high emissions of NO_x which act as a precursor to the harmful pollutant, So it becomes even critical to control NOx emission due to their significant contribution to $PM_{2.5}$ and O_3 pollution and associated health impacts.

[19] http://moef.gov.in/wp-content/uploads/2017/08/Thermal_plant_gazette_scan.pdf
[20] http://environmentclearance.nic.in/writereaddata/EIA/11062019OGCB0QWIEIAReport.pdf
[21] http://environmentclearance.nic.in/writereaddata/EIA/04042018AFU49XZ4Annexure-documentofEIAreport.pdf
[22] http://environmentclearance.nic.in/writereaddata/EIA/071220166HP7XLOZKhurjaSTPPEIAReport.pdf
[23] http://www.cea.nic.in/reports/others/planning/rd/allpapers.pdf
[24] https://nepis.epa.gov/Exe/ZyPDF.cgi/2000DM8Q.PDF?Dockey=2000DM8Q.PDF
[25] https://www3.epa.gov/ttncatc1/dir1/fnoxdoc.pdf
[26] http://164.100.24.220/loksabhaquestions/annex/171/AS114.pdf

Conclusion

Over the past few years we have identified $PM_{2.5}$, NO_x and O_3 are pollutants which have significant impact on human health. We are also leapfrogging from Bharat IV standards to Bharat VI for vehicles/transport sector for the very same reason,to tackle the NO_x sources in cities and might result in a decrease in its emission from diesel/oil burning in combustion engines. But on the other hand, the other significant and equally or even more important source for NO_x emissions such as coal power plants and industries, are being allowed to miss deadlines and continue to pollute without any stricter measures being taken. The government themselves have been arguing for the industries for relaxing of emissions standards or delaying the implementation which raises questions on the intent of the government in reducing pollution and protecting public health. Power utilities and the Government needs to take public health more seriously and do away with attitude of delaying actions to reduce emissions from power sector and industry, they need to have political will to act and it should come now. The technology has been working across the world and indian tests and experiments have proven that multiple times over the past years.

Government should ensure that all the emission sources/sectors of Nox, i.e., transport, industries and power generation are be tackled keeping in view the health emergency India faces today. We can not afford further delay because every day delay in our action is playing with the health of upcoming generations and leading to huge health damages in the form of economy and number of deaths to the current generation.

Glossary

DU	**Dobson unit.** A unit of measurement for the amount of a trace gas (such as NO_2) over the whole vertical extent of the atmosphere. More precisely, it measures the number of molecules of that gas per surface area in a vertical column integrated over the height of the atmosphere. 1 DU = $2.687\times10^{20}/m^2$ (at this value, an ideal gas would form a 10µm thick layer under standard pressure and temperature).
NO	**Nitrogen monoxide.** A trace gas that is produced in all combustion processes and a precursor to the harmful NO_2.
NO_2	**Nitrogen dioxide.** A harmful trace gas that is produced in all combustion processes. It converts from and to NO.
NO_x	**Mono-nitrogen oxides.** A generic term for NO and NO_2.
SO_2	**Sulfur dioxide.** A trace gas that is produced in all combustion processes with fuel having Sulfur content
Tropomi	A spectrometer instrument on board Tropomi measuring amounts of different trace gases in the Earth's atmosphere, including NO_2.
Sentinel-5P	The satellite that carries Tropomi.
µg	**Microgram.** A millionth of a gram (about the mass an ant's antennae).
µm	**Micrometer.** A thousandth of a millimeter.