AIR POLLUTION MONITORING OVER INDIAN ATMOSPHERE USING SATELLITE INFORMATIONS (A Curtain Raiser)

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ABSTRACT

Advancing technologies has shown that the artificial earth satellites can be used to remotely sense the air pollution in a better way. Air pollutant aerosols and gases can be assessed for their concentrations and dispersed areas (coverage) over the earth surfaces. Other concerns of Satellite application for air pollution includes identification of air sheds, prediction of critical pollution events, and surveillance of non-compliant polluting sources. A satellite can view large areas minutely, depending upon its resolution strength, and can transfer the coded information in image form a predetermined orbital frequency or interval. A satellites needs specific sensing tools to estimate polluting air / gaseous emissions, particulate matters (aerosols) and volatile organic compounds (VOCs). This paper focuses over the present air pollution management practices, and strategies required for the savoir-faire of satellite for the same in India.

KEYWORDS

Remote, Sensor, Satellite, Air Quality, Unmanned Vehicle, Aerosol

1. INTRODUCTION

Among various types of environmental problems air pollution offers least control in its generation, dispersion, impact, purification, management and mitigation. Air pollution poses great long term environmental risk to health. According to the World Health Organisation (WHO) in 2019, 99% of the world's population was living in the places where air pollution levels were not met (WHO, 2022). The combined effects of ambient air pollution and household air pollution are associated with 6.7 million premature deaths annually. Ambient (outdoor) air pollution is estimated to have caused 4.2 million premature deaths worldwide in 2019. Some 89% of those premature deaths occurred in low- and middle-income countries of S-E Asia and Western Pacific Regions (WHO, 2022). The indiscriminate use of fossil fuels, sub optimal fuel utilization processes in machines, absence of energy efficient technologies, higher costs of renewable energy base devices and poor regulatory control are the reasons for the dangerous levels of air pollution. Various abatement and management measures were instigated to control air quality but satisfactory eradication could not be achieved as evident through episodic events across the globe (UNEP, 2018).

Conventionally, air pollution events were reported through perceptions and based on the inferences from ground based air quality monitoring instruments over a limited areal extent. Prevailing meteorological conditions cause the air pollutants to disperse over the large areas and higher altitude in the atmosphere and greatly influences their chemical concentrations thus posing limitations in monitoring and management for an efficient outcome. The gigantic spatial and temporal extents of air pollution, climate change monitoring, and natural disaster requires a stereoscopic measurement devices based on Remote Sensing (RS) monitoring, Big Data analytics and advanced software based processing (Badr, 2021).

With the time many devices are developed to address the issues of air monitoring and other atmospheric measurement however, their operating limitations could not make them generalised. All these atmospheric measurement are now a days being performed using satellite based system in advanced countries and other countries too collaborating with the space monitoring program with their limited resources.

2. AIR QUALITY MANAGEMENT IN INDIA

In India Central Pollution Control Board (CPCB) is main agency responsible for the execution of National Air Quality Monitoring Programme (NAMP) for ambient air quality monitoring in whole country. The objectives of the NAMP are to determine status and trends of ambient air quality; to ascertain that ambient air quality standards should not violate; to Identify Non-attainment Cities; to obtain the necessary knowledge and understanding for developing preventive and corrective measures and to understand the natural cleansing process undergoing in the environment through dilution, dispersion, wind based movement, dry deposition, precipitation and chemical transformation of pollutants generated (Web Resource A, 2023).

Presently, the NAMP network covers 883 (as on 15.09.2022) manual operating stations (7 year 1984) spread over 379 cities/towns in 28 states and 7 Union Territories (UT) of the country (Web Resource B, 2023). The NAMP requires regular monitoring of sulphur dioxide (SO2) and oxides of nitrogen (as NO2) for 24 hours (4-hourly sampling), respirable suspended particulate matter (RSPM / PM10) and fine particulate matter (PM2.5) for 24 hours (8-hourly sampling) with a frequency of twice a week, to have a total of 104 observations in a year at all the locations (Web Resource A, 2023).. The responsible agencies to carry out air monitoring are CPCB, State Pollution Control Boards and National Environmental Engineering Research Institute (NEERI), Nagpur. The monitoring of meteorological parameters such as wind speed and direction, relative humidity (RH) and temperature etc. are also integrated with the monitoring of air quality through Indian Meteorological Department (IMD) observatories (Web Resource A, 2023).

The ground based air pollutant monitoring if done precisely could provide high temporal resolution, but lacks the spatial coverage. Large number of personnel and equipments are involved in the sampling, chemical analyses, data reporting etc. It increases the probability of variation and personnel biases reflecting in the data, hence it is pertinent to mention that these data be treated as indicative rather than absolute (Web Resource A, 2023). With the time this individual, isolated and time consuming system spun underprovided to accomplish increasing air monitoring demands in the country beside rising episodes of poor air quality.

The Government of India has started the Continuous Ambient Air Quality Monitoring Systems (CAAQMS) in the year 1990 for the constant and perpetual surveillance of air quality and generate instantaneous (real time) data with higher frequency. The CPCB has reported 278 CAAQMS are operating in 147 urban areas of 24 states connected to a web-based system showing Air quality index daily at 4 PM. (Web Resources C, 2023). Further, the Ministry of Environment, Forest and Climate Change (MoEFCC) on 22 November, 2019 has announced initiatives for prevention, control and abatement of air pollution in the country (Web Resource C, 2023). Recently Government of India has launched National Clean Air Program (NCAP) with the target for 20 to 30 % reduction in particulate matter (PM10 and PM2.5) by the year 2024 (base line 2017). Graded Response Action Plan (GRAP) 2017 and Comprehensive Action Plan (CAP) 2018 were notified to combat air pollution of Delhi and NCR. SAMEER app, and National Green Corps (NGC) have launched as part of several steps taken for creating awareness amongst the general population (Web Resource D, 2023).

According to the report by CEEW (2020), even with this proposed increase, the number of monitoring stations would remain inadequate as per the thumb rule proposed by the CPCB that required about 4,000 monitoring stations (2,800 in urban areas and 1,200 in rural areas) to spatially, temporally, and statistically represent the air quality levels for the entire population of India. Brauer et al. (2019), reported the estimated Air Quality Monitoring Network (AQMN) density of India is about ~0.14 monitors / million persons (one monitor for every 6.8 million people), much lower than the AQMN density maintained by some developed but having considerable population densities as shown in Table 1.

Table 1: AQMN Density in some countries

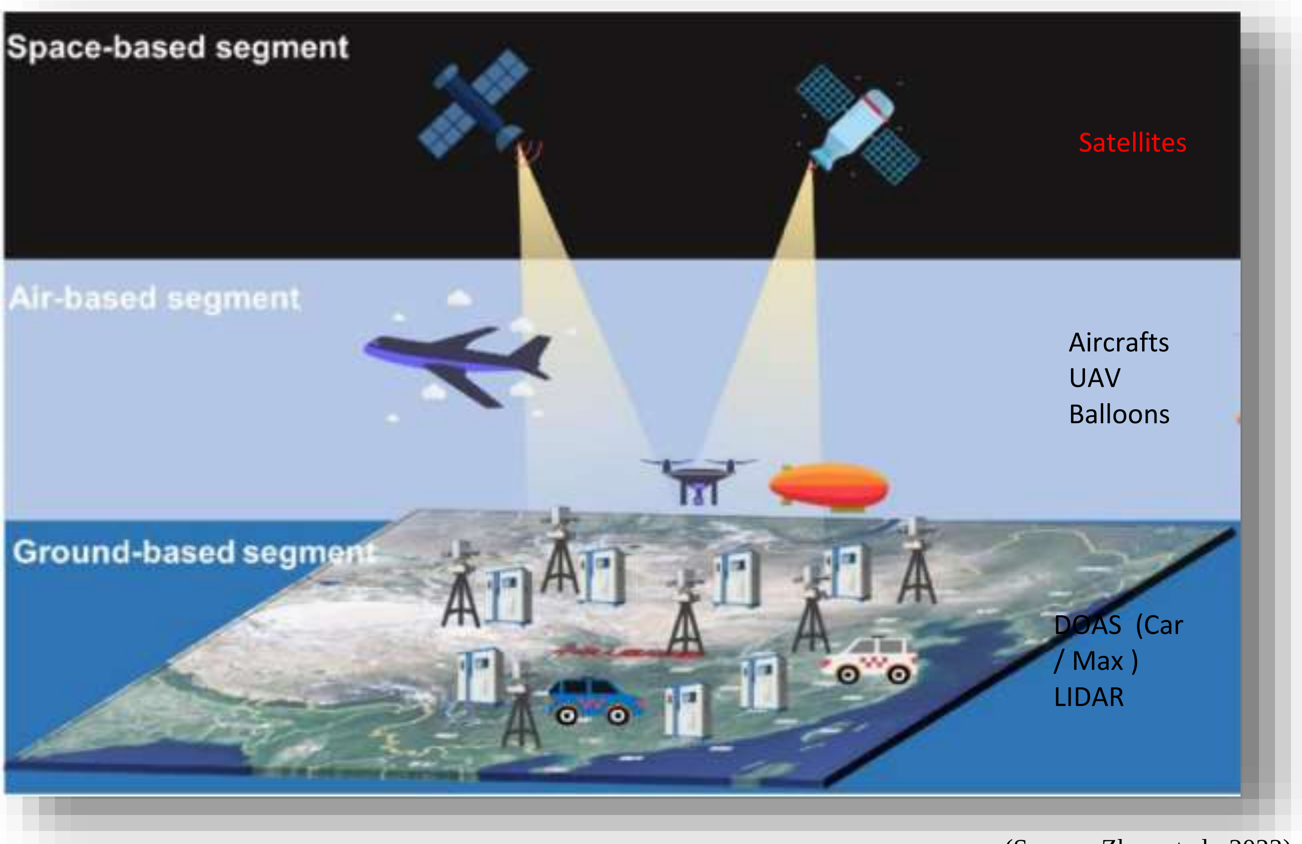
Country	India	China	USA	Japan	EU	Brazil
AQMN density (monitors / million)	0.14	1.2	3.4	0.5	2-3	1.8

Source: Brauer et al. 2019.

Considering the heavy infrastructural and instrumental investment and limited spatial coverage of CAAQMS and NCAP, Indian authorities has to plan to couple both these monitoring networks with satellite based observations to acknowledge the country's growing requirements towards air pollution monitoring and management.

3. REMOTE SENSING TOOLS FOR AIR QUALITY MANAGEMENT

Considering the limited applicability the ground based air quality monitoring system, technology is improved as depicted in figure 1 and table 2. In the first stage refracted / reflected electromagnetic radiations from air pollutants were captured through elevated objects and concentration is measured indirectly through spectroscopy based techniques. Here the included mechanisms included are remote sensor based simple and multi axial Differential Optical Absorption Spectroscopy (DOAS and Max DOAS), Fourier Transform Infrared Spectroscopy (FT-IR), light detection and ranging (LiDAR), multi-band photometer and microwave radiometer (Zhou et al., 2023).



(Source: Zhou et al., 2023)

Figure 1: Recent Techniques of Air Pollutant Monitoring and Measurement

In RS monitoring the electromagnetic radiation (EMR) based sensors are used to capture the reflected EMR from the air pollutants spread over the atmosphere to a wider spatial extent. These sensors can work round the clock over a wide temporal range except during extremely adverse weather conditions. Remotely placed air monitoring sensor can give information about the air quality by after analysis of received signals. The ability of RS to provide site specific information is highly dependent upon the resolution capacity of the mechanism used and prevailing atmospheric conditions to pass over the clear wavelength band.

The next stage advances includes balloons, unmanned vehicles, airborne platforms capable to capture vertical variations of dispersed air pollutants. Recent application of satellite images in monitoring air pollution started in the 1970s when Advanced Very High Resolution Radiometer (AVHRR), Landsat, and GOES, the three instruments designed to measure meteorological parameters were used to detect air borne particles and sulphates over the sea and volcanoes respectively (AbdelSattar, 2019). The specific air quality measurements have started since the year 1978 through Nimbus G (7) a meteorological satellite using total ozone mapping spectrometer (TOMS) sensor. Till the time a number of space crafts have been launched with advanced air quality monitoring features as detailed in Table 4 (Yang, 2022)

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Table 2: State-of-the-Art Air Quality Monitoring Approaches

System	Scale (kms)	Monitoring Method	Resolution	Mobility	Cost	Real Time	Accuracy
Official Station	0 -100	2D / Sensor	Low	Static	High	No	Low
Air Cloud	0 - 5	2D / Sensor	Medium	Static	Low	No	Medium
Mosaic	0 - 5	2D / Sensor	Medium	Mobile	Low	No	Medium
Mobile Nodes	0 - 1	2D / Sensor	Medium	Mobile	Medium	Yes	Medium
Balloons	0 - 1	3D / Sensor	High	Mobile	Medium	No	Low
BlueAer	0 - 10	3D / Sensor	Medium	Static + Mobile	High	No	High
ARMS	0 - 100	3D / Sensor	High	Mobile	High	Yes	High

AQNET	0 - 2	3D / Sensor	High	Static + Mobile	Low	Yes	High
Cell Phone	0 - 4	2D / Vision	Low	Mobile	Low	Yes	Medium
IBAQMS	0 - 1	2D / Vision	Low	Static	Medium	No	Medium
ImgSensingNet	0 - 10	3D / Sensor + Vision	High	Static + Mobile	Low	Yes	High

(Source: Yang, 2022)

In air pollution studies satellite based information can be obtained for a vast temporal observations (short term arbitrary pollution data to long term trend in air pollutants) to large scale spatial measurements (at point, line, area and volume source) extending from local to regional to global scale (across national boundaries) (Chowdhury et al., 2019). The satellite measurements could be adjusted for a frequent or instantaneous mode at a particular location. The finer and vast coverage capabilities of satellite sensors can be used to supplement the data gaps that generally exist in ground based air quality monitoring system owed to the geographical inconsistencies many a times.

In the absence of a dedicated indigenous satellite of country and constraints due to restricted availabilities of air pollution monitoring data through foreign satellites use of Unmanned Air Vehicles (UAM) or DRONE is a better option for an object specific atmospheric observations in India. UAV can be used in air pollution risk areas at various heights and horizontal levels to have an idea of real time air pollutants profiles. UAV supports both the sensor and vision based mechanism and can easily enter within high rise infrastructural domains for air quality measurements and surveillances. The limitation of UAV applications in air quality monitoring are detailed in Table 3.

Table 3: Difficulties in Air Quality Monitoring through UAV

Point of Concern	Description
Sensor performance	Satisfactory with low resolution sensors, needs periodic calibration
Localization	Exact 3D positioning of UAV is not obtained using GPS
Coordination	Synchronisation of horizontal and vertical movements is difficult
Site Specifies	Approach to vertical height limits the horizontal coverage
Power consumption	Call for frequent power recharge restricts long time operations
Operational time and cost	Depends upon engine efficiency and power consumption. Static station and experts for UAV operations e.g. air monitoring are expensive
Vibration	UAV vibration disturbs both the air pollutants dispersion and levels.
Communication	Deprived in online data transfer and work with high range tools

4. MECHANISM OF AIR MONITORING THROUGH SATELLITE

Efficacy of air pollutant measurement through satellite remote sensing is highly dependent upon the satellite orbits e.g. polar, low-Earth (less than 2000 kms), geostationary; sensors, and retrieval algorithms. The remote monitoring and measurement of air pollution is done by either through sensors or optical visualisation or combination of both types of tools. Previously, satellite monitoring of air quality was done through the sensor-based methods, which necessitates installation of data transfer devices (phone, car, balloon, mast etc.) inside the sites of concern. Sensor based technology provides large area coverage, precise pollutant informations but temporal and spatial variations of air pollutant dispersion could not be well captured beside higher energy consumptions and cost of operations. Table 1 provides the details of some commonly used air quality monitoring approaches (tools).

With the advances in photogrammetric techniques vision based air quality monitoring tools have been taken place in remote and satellite monitoring too. The photographs taken through high resolution cameras fitted in satellites can be well interpreted to fill the gaps of sensor based monitoring. Now a days all air pollution monitoring satellite are working in coupled mode of sensor and vision based electromagnetic data transfer system.

Innovations of advanced and versatile electronic tools capable of decoding electromagnetic signals reflecting from materials have found several applications in air pollution management through satellite based remote sensing observations. Capturing of such signals through remotely placed satellites is made to have visual evidence of every major environmental occurrence like nuclear leakage, the drought, forest fire, desiccating water resources, canopy of polluting air etc. resulting in pollution episode simultaneously revealing the associated geographical changes in land use, vegetation cover, settlement patterns etc. (Alam et. Al., 2020).

The extent of satellite application in air pollution includes identifying, monitoring, measuring and tracking the air pollutant along with their consistently non-compliant sources. The monitoring products from satellite are further used in analysis and interpretation of observed information (data); forecast modeling (estimate short / long-term concentrations and trends); air shed identification; development of emission inventories; management of possible episodic air pollution incident; air pollution impact / health studies. Several airborne or space-borne instruments are mounted over the satellite to observer the variations in air quality. Sensors are capable of measuring and signifying the harmful pollution level above the standard safe concentration (Web Resource 1).

In US and China scientist have developed an accurate early air quality warning system using satellite measurements that can be used even for forecasting of air pollution hot spots and traffic management. In US the NOAA and EPA are using Aqua and Terra satellites for air quality observation, processed by Moderate Resolution Imaging Spectroradiometers (MODIS) (Poteet 2019). Fioletov et al. (2015) have developed SO_2 emission inventories and estimated long-term emission trends from anthropogenic sources across the globe from the data collected from Ozone Monitoring Instrument (OMI) installed in NASA Aura satellite.

5. ACQUIRING AIR QUALITY INFORMATION FROM SATELLITES

The air pollution measurement in atmosphere is done primarily by detecting parameters like Aerosol Optical Depth (AOD) for particulate matters and Vertical Column Densities (VCD) for gaseous pollutants through EM sensors fitted in Satellite. These perceived EM signals are then decoded (translated) to provide informations about the atmospheric concentrations of particulates and gaseous emissions (CEEW, 2020). The complete process of satellite monitoring is framed in figure 2 ((Badr et al., 2021).

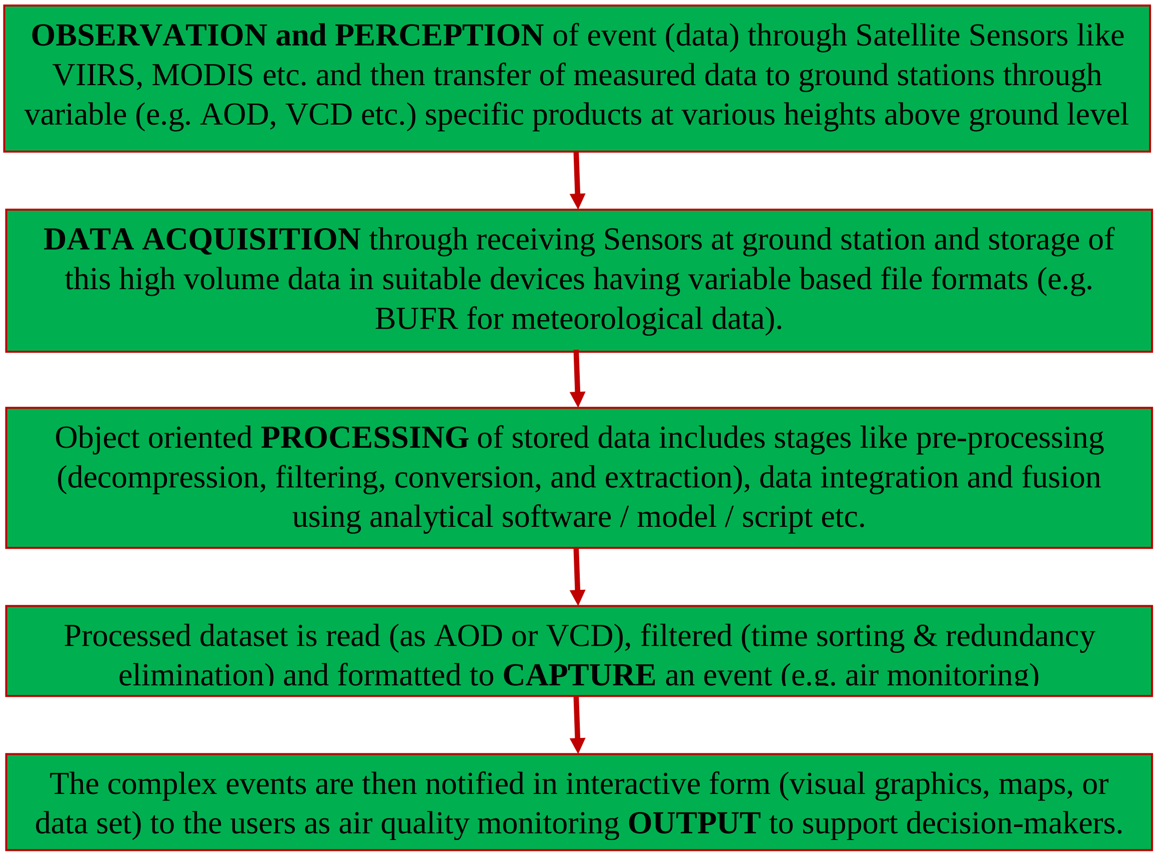

Figure 2: Framework of Satellite based Monitoring Process

Forecasting of air quality is greatly influence many other atmospheric and geographical that too are well addressed through the satellite based measurements and could be synchronised with air monitoring observations. Satellites are well used in continuous observation of weather patterns and monitoring of meteorological parameters (e.g. temperature, relative humidity, wind speed, height of the planetary boundary layer etc.). Satellite imageries are the best tool to capture surficial features of any specified area (city) in earth. High resolution sensors / cameras mounted on satellites are also serving well in identifying dust storms, nuclear leakages, forest and crop fires, and polluted landfills.

The Satellite observations often needs some suitable mathematical models to make remotely sensed EM data useable. A suitable air quality forecasting model incorporates air pollutants concentration data, observations of meteorological parameters responsible for pollutant dispersion and geographical parameters as an input. The inherent mathematical formulations of the model then processes these inputs and simulates closer to the assimilated physical and chemical process (i.e. atmospheric transformations process) as occurring in nature, and then generates an estimates of air pollutant concentrations. The forecasting models can work with both the historical or real time satellite data. The higher resolution capacities of satellite sensors and vast and vivid spatial coverage capacities of satellite cameras are desirable to obtain nearly exact information about the prevalent air quality.

Table 4: List of Air Pollutant Data Available Through the Satellites

Data Field	Time period	Satellite	Agencies	Data source
Domain: Air Quality				
Aerosol optical depth	2014–present	INSAT 3D	ISRO	(Mishra et al. 2014)
	2002–present	MODIS Aqua	NASA	(Giovanni, 2023)
	2000–present	MODIS Terra		
UV aerosol optical depth	2004–present	Aura OMI		
UV aerosol index	2004–present	Aura OMI		
	2018–present	Sentinel 5P	ESA	(ESA Sentinel, 2023)
Aerosol layer height	2006–present	Many	NASA	(NASA 2023)
	2019–present	Sentinel 5P	ESA	(ESA Sentinel, 2023)
Aerosol profile	2006–present	Many	NASA	(NASA 2023)
Carbon monoxide total column (vertical profile)	2019–present	Sentinel 5P	ESA	(ESA Sentinel, 2023)
	2000–present	MOPITT	NASA	(Giovanni 2023)
Nitrogen dioxide and Sulphur dioxide total column	2018–present	Sentinel 5P	ESA	(ESA Sentinel, 2023)
	2006–present	Aura OMI	NASA	(Giovanni 2023)
Formaldehyde total column	2007–present			
Formaldehyde total and Ozone tropospheric column	2018 and 2019 –present	Sentinel 5P	ESA	(ESA Sentinel, 2023)
Domain: Open Fires (forest & biomass burning)				
Thermal anomalies and fire	2002–present	MODIS	NASA	(Earth Data 2023)
	2012–present	SNPP-VIIRS		

Satellite observations could be used to supplement the missing or outlier data that exist either of uneven spatial distribution (as in CAAQMS) over the geographical area or measurement errors. The satellite can track and independently collect the pollution data from the sources covered under CAAQMS and other on-ground sources difficult to access through other monitoring devices. An earliest focus towards the air sheds which covers the various types of polluting sources is feasible through the satellite eye. In order to understand the possible long-range transport pattern (or the vertical silhouette) of air pollutant the satellite observations can be collected at various altitude. Thus, satellite based air quality monitoring data could be a prime source for strategic planning towards the control and management of likely air pollution events and episodes. In India remotely monitored air quality information is attained through the observation made available from any of the active satellites of overseas agencies listed in Table 4.

6. SATELLITE APPLICATIONS OVER INDIAN ATMOSPHERE

Air pollution dispersion follows no boundaries as it is governed by existing meteorological conditions mostly horizontal shearing winds and vertical profile of solar insolation. Emissions of any agricultural or forest fire, accidental release from industry, dust storms etc.; during exceptional events can cross regional or national boundaries through long-range transport mechanisms and / or the continental air circulation patterns.

Satellite observations can best demonstrate such adverse circumstances for allocating accountabilities and attainments of air quality episodes that are otherwise difficult to capture through the ground monitoring systems (Sarkar et al., 2018). In such episodic cases, satellite signals helps to adopt safeguard measures at an earlier possible time as during October 2017 in Delhi (India) a long range episodic dust storm emanated from Gulf countries was investigated by satellite data (Beig et al. 2019). In India scientist have limited opportunities to deal with the air pollution related activities because of dependency over the foreign satellite data providers. Some specific uses of satellite towards air pollution management over Indian terrain are enumerated below:

A. Air Pollution Monitoring and Measurement: Satellite sensors (cameras, transducers etc.) can efficiently collet EM radiation from the atmosphere and after adequate processing they provide useful information about the types of air pollutants present in the air at specified height and their concentration levels (numerical values). A well distributed network of satellite observation collects information about the pattern, range, columnar profile, hot spots etc. associated with polluted air, even over the inaccessible places (Web Resource F, 2022).

B. Forest Fire Alerts System: In Indian episodes of forest fire are common especially during the summer days. The Forest department has started use of advanced techniques and available satellite data to analyse the cases of forest fires in terms of intensity, extent and damages.

A real time Fire Alerts System (FAST) 3, has been developed to track the forest fire episodes through satellite (MODIS and SNPP–VIIRS) inputs (FSI, 2019). Improved version of FAST has objective to identify, track and disseminate alerts about large fire events across the country. FAST is also designed to provide feedback system to assess the causes, pattern, intensity and temporal / spatial extent of forest fire. A major fire incident of Uttarakhand in 2016, which affected the air quality of Delhi ominously has been identified through MODIS satellite data (Singh 2016).

C. Monitoring Agricultural Fires: Fire episode in agricultural farm may be natural or intentionally (e.g. paddy burning). A timely satellite information about agricultural fire field (location and periodicity) is of much help for farmer as well as regulatory agencies to save the crop and atmosphere from air pollutants. MODIS and VIIRS satellites observations over Indo Gangatic Plain of India are providing useful information since 2015 (Web Resource G, 2019).

D Impact on Health Due to Air Pollution: A continuously elevated concentration of criteria air pollutants results in adverse impact on properties and health of living being exposed to it. Human health is impacted in terms of increased number of discomfort, occupational diseases, respiratory disease, increased mortality rate and lower life expectancy. Health impact due to air pollution can be studied by estimating the concentration of air pollutant, exposed population, associated diseases and reactive environmental conditions. Air quality data from satellite informations are qualitatively better than ground based monitoring system in determining exposure estimated due to finer spatial resolution.

Lancet (2019), reported that chemical transport model is used to compute $PM_{2.5}$ concentration from satellite based aerosol optical depth (AOD) data to study district level air quality and the it is found that annual population-weighted mean exposure to ambient $PM_{2.5}$ is 89.9 $\mu g/m^3$ and 76.8 % of the population is exposed to $PM_{2.5}$ levels greater than the NAAQS of 40 $\mu g/m^3$.

E. Satellite Based Inspection / Trigger Mechanism: In India where Continuous emission monitoring data from industries are mostly tempered; tracking satellite observations will be useful for authorities to keep record of exceedance of air pollutant levels beyond CPCB standards, source apportioning and non-compliance (Web Resource F, 2022).

F. Identification of emission hotspots

Regular temporal observations of air quality from a tracking satellite over potential polluting areas helps in identifying hotspot's range, responsible pollutant and their strength that in turn could be benefit authorities to strategically accomplish the area and pollutant specific interventions (Web Resource F, 2022).

7. INDIAN PROSPECTS FOR MONITORING THROUGH SATELLITE

At present Indian researchers are extracting air quality information from various satellites as listed in Table 3, however, informations available through MODIS, SNPP, INSAT and SENTINEL satellites are widely used for the purposes. Details about the pros and cons of MODIS and SNPP–VIIRS could be read at technical report of FAST 3.0 (FSI, 2019).

Satellite MODIS (Terra and Aqua), INSAT 3D are providing Aerosol Optical Depth (AOD) observations to derive $PM_{2.5}$ and PM_{10} concentrations. AOD at 550 nm and 412 nm band are provided by MODIS and INSAT satellites respectively. The available AOD retrieval algorithm works over wavelength of 650 nm, with an uncertainty of ±30–45 per cent (Mishra 2018). Therefore, even with best transformation abilities the quantification of $PM_{2.5}$ and PM_{10} from AOD could only partially captured. Indigenous Imager satellite INSAT 3D/3DR are also supportive to NCAP in providing meteorological data, weather and disaster warnings.

In the year 2017, the European Space Agency (ESA) has launched the Copernicus Sentinel-5 satellite having fitted with necessary scientific tools the "TROPOspheric Monitoring Instrument (TROPOMI)", for the monitoring and measurements of the atmospheric events and attributes (e.g. meteorological parameters, air pollutants, ozone, UV radiation, weather patterns etc.) respectively with high spatio-temporal resolutions (Web Resource E, 2023). The high speed data transfer capability of Sentinel-5 is providing better details of gaseous pollutants through patented software and Google earth search engine (CEEW, 2020). Sentinel 5P has also helped in identifying many SOx and NOx emission hotspots over the mega Indian cities and industrial clusters through Google Earth Engine processed vertical column density (VCD) data.

Indian Government has launched National Clean Air Program to strengthen the capabilities to derive air quality information from indigenous satellite-based products and techniques to derive air quality information (CEEW, 2020).

The National Clean Air Program (NCAP) has been launched by Indian Government with the aim to develop resources to monitor and forecast air quality using informations from the outsourced or free available satellite data, as listed in Table 4. Accordingly NCAP attempts to grow national capabilities to collect the remotely sensed information related to air quality monitoring, meteorological and geographical observations and made them accessible to the scientific communities for necessary researches and innovations. Further, the NCAP has plans to make available the air quality related informations to the public through online platforms (user interface).

Table 4: NCAP Plan for Air Quality Management using Satellite Outputs

Domain	Action point	Agency	Timeline
Monitoring of agricultural fires	Coordination with ISRO for remote sensing monitoring data for crop residue burning	MoEFCC CPCB SPCBs, ISRO IITM	2019
Air quality monitoring network	Develop indigenous satellite-based system & products for estimating particulate & gaseous pollutant		2024
Air quality forecasting system	Satellite data made available by the ISRO collaborating agencies needs to be integrated for monitoring and forecasting		2022

(Source: CEEW, 2020).

8. INDIA's REQUISITES TO UTILISE AIR MONITORING SATELLITE

At present India is being provided limited atmospheric and air quality informations by the earth (polar) orbiting satellites of NASA and ESA for the places and time intervals covered under their designed path and duration respectively in the sky over the country. This limits accuracy in representative inferences and extent of application since representative interpretations with lesser uncertainties needs more frequent and consistent informations. The challenge in scaling up the satellite data commence with the inadequate infrastructure to store and process big data. Scarcer technical competencies and resources to accurately interpret satellite observations further abates accessibility to succinct outcome. Indian authorities also lacks precise products to decode gaseous pollutants SO_2 and NO_2 (CEEW, 2020).

The limitations in available satellite products and translation facilities many a time misleads our air quality inferences from AOD or VCD data. An absence of efficient software and processing skills in Chennai and Delhi the satellite (NASA Aura) information wrongly apportioned hotspot for the SO_2 emissions (Dahiya et al., 2020) which could otherwise be better explained through an intuitive judgement of interpreter using ground monitoring data and simulation modeling (Brauer et al. 2019).

State of the art for the air quality associated problems in demand that India must have its own high resolution geostationary satellites designed to measure mesoscale atmospheric properties (of particulates, pollutant gases, dust transport etc.) at real time or short temporal (15–30 minutes) and finer spatial variations (less than 10 m). The satellite must be coupled with the advanced facilities to identify, map, observer and measure the air quality attributes and associated atmospheric parameters.

With the launces of satellites coupled with sensors for capturing atmospheric and air quality related activities pertinent data storage, processing and computational capacities will also increase. For an efficient use of satellite data technologically competent manpower (like modeller, interpreter, coding expert, air quality and meteorology scientist etc.); advanced computational facilities (e.g. computer with high speed, and large storage capacity, compatible precise software and model, scanning and interpreting tools etc.) and specifically designed infrastructure at suitable place where satellite observations can smoothly and efficiently be received, transferred and utilized needs to be arranged.

Advanced storage devices; computing method and representative models are needed for the fast transferring, processing and interpretation of huge data sets obtained from satellite observations. Google Earth Engine (GEE), Sentinel Hub, Open data cube, SEPAL (System for Earth Observation, Processing and Analysis for Land Monitoring) etc. are among some cloud-based geospatial analysis platform that enables users to visualize and analyse satellite images for air monitoring using either of remote servers or through Internet connection. Using suitable VCD processing models with satellite observation the apportioning of dominant and unimportant air polluting unit could be marked well (CEEW, 2020).

In order to ascertain that all insights drawn from satellite observations are accurate and suitable for the purpose they must to be compared after suitable evaluation and adequate validation with air quality monitoring data generated through ground based measurements. Therefore, the satellite must be capable to synergies the existing ground based monitoring network of the country. Addition of supplementary products (software, model, skilled manpower etc. for required computations, scaling, need based analysis, applications etc.) also desirable in the planed framework of proposed satellite to take care of NCAP requirements.

9. APPLICABILITY OF SATELLITE BASED AIR QUALITY MANAGEMENT PROGRAM FOR INDIAN COMMUNITY

Air quality of some mega Indian cities are regularly featuring in the World's worst air quality map. Satellite Observations have shown that there are plenty of small cities and towns fronting continuous or periodic worse air quality episodes. Many Indian cities and rural areas have experienced poor air quality episodes in past two decades especially in winter seasons. Effective control and mitigation of such repetitive air pollution events requires regular monitoring of air quality at regular short term frequency. Also, the monitored air quality data must be accurate and precious enough to infer real or representative understandings after adequate scientific analysis to encourage the regulatory agencies and policymakers to have prompt and informed responses. An air quality monitoring system aligned to Sentinel 5 TROPOMI is the need of the hour for the country.

In India academic researchers are using various remotely sensed air monitoring data and observations of atmospheric attributes from foreign satellites without adequate authorisation and hence having very limited access to acumens on India's air pollution crisis.

In future if Indian scientific community need to solely rely on external data sources they must come across some policy agreements to get real and authentic data without any temporal and spatial limitation across the countries' geographical terrain subjected to respective international treaties. However, having countries own satellite committed towards upcoming monitoring needs of atmospheric and environmental attributes over the Indian sub continental area is the proviso of time. There is an early need to launch an indigenous satellites dedicated to monitoring country's air quality with high swathe over and across the territory. A qualitatively synchronised system need to develop to integrate remotely sensed air quality observations with the ground monitoring network so as to produce comprehensive data.

The data base of satellite captured information (except related to national sanctuary) should be made available and accessible (1) to academics and research communities to promote innovations; (2) to the authorities and policymakers for eradication and management of air pollution events; (3) to the policy makers and regulators for framing strategic plans, campaigns, training modules, regulations, etc.; and (4) to the public for health related awareness. Normal real time and time averaged pollution information should be displayed on public platform to support awareness to reduce pollutant loads.

The technological advances for air pollution management using satellite must be ultimately aimed to develop tools, devices, computing systems etc. to enable one having concerns and general technical competencies to have an easy access to the satellite data and its applicable results for an environmentally skilled life. Meanwhile Indian Government could explore the avenue of Drone and other aircraft technologies loaded with air pollution specific sensors and cameras to cover a region of interest. This could serve as the precursor to the much more ambitious satellite network framework. Application of drones for regular air monitoring could help to create a city specific systematic framework for air quality.

Satellite observations should not be limit to supplement the air quality monitoring network and forecasting usage. The satellite based technologies must be directed towards measuring spontaneous air pollution levels, episodic air pollution, air pollution releases from area and point sources, and the peripheral levels of polluting gases. In India attempts are being made to collaborate the potential of air quality monitoring network with satellite monitoring data and augment its policy towards the capacity building for the satellite based air quality monitoring system under National clean air program.

10. CONCLUSION

In most of the developed countries the environmental monitoring especially air quality monitoring is made through remote sensing based satellite applications. However in India the path is still difficult since, a proper robust infrastructure for satellite monitoring is still a long shot. The severity of air pollution and its related ill effects makes it inevitable for India to develop its own robust air quality monitoring system. Seeing the various limitations and inhibitions pertaining to its vast areal extent and economic capabilities, it is the need of hours that the authorities in Indian Government must think of launching country's own satellite or hire the same to meet up long term air monitoring needs of the country.

In order to meet the demands of researchers, administrative agencies and regulatory authorities the Indian Government must collect every possible information about the air monitoring across the country. The vast air quality data set from earthen, areal and space monitoring sources should be made available to the users from a national server / platform. The inferences drawn from the scientific analysis of such qualified data could better deliver towards an useful air pollution management strategy and comply mitigation measures. This could serve the need for the hour in severely hit regions or identifying hidden regions with severe air quality issues across the country until some proper scientific set-ups and infrastructures could be established.

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