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Application of air pollution models and remote sensing in Air Quality Management

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ABSTRACT *The problem of air pollution in the atmosphere has attracted a new interest with the recent scientific evidence of the ill-health effects of air pollutants (gaseous and particulate). The monitoring of aerosol concentrations becomes a high environmental priority particularly in urban areas. They have several local and global environmental impacts. At the regional level, they reduces the visibility in the form of haze and to acid deposition, at the global level they play a role in climate change. So it is very important to monitor air quality. It is done with networks of ground monitoring stations and the use of various dispersion models that evaluate emissions and predict changes in air quality at separate points. The increasing availability of earth observing satellite systems and onboard imaging sensors together with advances in digital image processing techniques provide a new avenue to monitor urban air quality at a local and regional scale. Various air pollution dispersion models being used to predict the pollution load of an area for the current period and predict for the future. These models can be use in combination with the satellite models to have a good idea about any area. This chapter highlight the use of various air pollution dispersion models and its combination with satellite helps in determination of air quality of any area particularly remote areas.*

Introduction:
In India, pollution has become a great topic of debate at all levels. Among various types of pollution air pollution is having great concern and it is because of the enhanced anthropogenic activities such as burning of fossil fuels, i.e., natural gas, coal and oil to power, industrial processes and automobiles (motor vehicles), etc. It is one of the most critical environmental problems in developing countries and it is the outcome of economic development, rapid industrialization and the demand for energy. Air quality is important simply because we cannot avoid breathing in the air around us. The average adult breathes in about 20 cubic meters, or 20,000 litres of air a day. The air we breathe is a mixture of gases and small solid and liquid particles. It has been a widely recognised problem and becomes a basic problem in today's world. This emits wide variety of air pollutants, particularly carbon monoxide (CO), oxides of nitrogen (NOx), volatile organic compounds (VOCs), particulate matter (PM) and sulphur dioxide (SO_2) (Ozcan, 2012). The relative abundances of these atmospheric components in particulate matter are temporally and spatially highly variable. Some of them are directly emitted into the atmosphere by both natural and anthropogenic sources (primary particles), while some others are the result of homogeneous or heterogeneous nucleation and condensation of gaseous precursors (secondary particles) (Murillo et al., 2013; Chan and Kwok, 2001; Morawska and Zhang, 2002).

Air pollution management:
Management of air quality is done by selecting strategic locations and monitoring the concentration of pollutants by using ground based instruments on those locations, which are costly and lacking in spatial continuity and these instruments are quite expensive and the coverage is limited by the number of the air pollutant station in each area. So, they cannot provide a good spatial distribution of air pollutant readings over a city/area. In addition, measuring stations may not be readily available in remote areas and developing countries (Gupta et al, 2006). The atmosphere affects satellite images of the Earth's surface in the solar spectrum. So, the signal observe by the satellite sensor was the sum of the effects from the ground and atmosphere. Tropospheric aerosols act to significantly alter the Earth's radiation budget, but quantification of the change in radiation is difficult because atmospheric aerosol distributions vary greatly in type, size, space and time (Penner, et al. 2002).

Remote sensing capabilities are being explored in the area of air pollution monitoring and management. It offers a platform for creating an inventory database and thematic map for air pollution studies. It is used to graphically illustrate the spatial patterns of emissions from different sources and to visualize the impact the congestion of such sources has on the emissions (Andersons et al., 1996). Ahmad et al (2006) used NOAA-14 AVHRR to estimate air quality index (AQI) over Peninsular Malaysia using GIS to interpolate haze conditions from isolines to determine the spatial representation of PM_{10} over the Peninsular.

Use of dispersion modelling in air pollution management:
Air quality dispersion modeling is a computer simulation that offers a solution by being able to estimate the impact of point, line, volume and area sources to surface air quality in the atmosphere from specified emission sources and meteorological scenario, land use, terrain, meteorological data and a measure of the total atmospheric concentration of the metrics in the model domain (Johnson et al., 2010; Dubey et al., 2013 and Mark et al., 2013). It uses meteorological data such as temperature, mixing height, wind direction and wind speed to calculate concentrations. This is used for various gaseous and particulate pollutants in the atmosphere. Like, in coal mining area dispersion of fugitive dust generated by various processes (drilling, blasting, overburden loading and unloading, coal loading and unloading), road transport over unpaved roads and losses from exposed overburden dumps, coal handling plants and exposed pit faces can be done by applying this model (Huertas, 2012). On the basis of temporal and spatial variation of PM it helps in categorization of area into highly, fairly and moderately polluted region. There are various models which are in use like FDM (Fugitive dust model), Industrial Source Complex Short Term Version 3 (ISCST3), American Meteorological Society and U.S. Environmental Protection Agency Regulatory Model (AERMOD) and PAL2 (point, area and lines sources model).

Among all AERMOD is most widely used model. It was developed by the Industrial Sources Complex Short Term Model (ISCST3) by incorporating more complex algorithms and concepts, i.e., planetary boundary layer (PBL) theory and advanced methods for complex terrains. It was introduced by the American Meteorological Society/EPA Regulatory Model Improvement Committee to provide a state–of–the–art dispersion model for routine regulatory applications (EPA, 2004;

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Zou et al., 2009).

AERMOD is a steady–state Gaussian plume dispersion model aimed at short range (<50 km) air pollution dispersion from point, line area and volume sources (Cimorelli et al., 2003; Perry et al., 2005). AERMOD incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts, including treatment of both surface and elevated sources, and both simple and complex terrains (Cohan et al., 2011; Cimorelli et al., 2005). This information would enable the environmental authority to implement new decontaminating measures based on the pollution classification. Also, the results of the study could be used to estimate the contribution of each mine to the pollution in each population center within the mining region, thereby allowing the environmental authority to determine the appropriate contribution of each mining company toward financing decontamination measures.

Use of remote sensing in air quality monitoring and pollution management:
Classically, monitoring of air pollution and its quality been done using ground based instrumentation, which has predominantly restricted the area of land that can be monitored. The ground based instruments are designed to monitor specific pollutants and many of these instruments cannot provide an accurate description of the total concentration of all pollutants at a citywide level. In connection with this it is very important to use remote sensing satellites to assist the monitoring of air quality of the desired area. Remote sensing is the acquisition of information about an object without being in physical contact with it (Elachi, 1987; Skidmore, 2002). It is an invaluable tool for data acquisition for integration into a Geographic Information System (GIS). Geographic Information Systems (GIS) have been identified as important tools for integrating and analyzing spatial information from different disciplines and sources (Maruo et al, 2002). It is an integrated system which comprises hardware, software and data for capturing, managing, analysing and displaying all form of geographically referenced information. It is a computer-based tool for mapping and analysing things that exist and events that happen on Earth. Sources of data for GIS are maps, tables, satellite remote sensing and Global Positioning Satellite (GPS) system. GIS integrates common database operations such as query and statistical analysis with the unique visualizations and the geographic analysis benefits offered by maps. A GIS is a tool that offers decision-making and problem solving aids to decision-makers by providing alternative solutions to human, environment, planning and general earth-related problems. Various atmospheric studies like, particulate matter and various gaseous pollutant concentration its measurement and assessment of air quality its dispersion, have been widely carried out using on site measurements and by using various mathematical models.

The use of remote sensing arises in those areas where the basic infrastructures are not found and they are remotely located. According to United Nations the remote sensing is defined as the sensing of the Earth's surface from space by making use of the properties of the electromagnetic waves emitted, reflected or diffracted by sensed objects, for the purpose of improving natural resource management, land use and the protection of the environment (UN, 1986).

Integration of air quality models in remote sensing:
The basic stage is to use the standalone software application for simulating the air quality models which is accompanied by inputs and outputs of database. All data can be used independently by other software systems (GIS, RDBMS, Surfer, WWW-presentations). There are four major satellite remote sensing techniques is used to determine air quality in urban areas. The first and most prominent method is measuring the aerosol thickness in the atmosphere, second is black particle measurement, third is a visual inspection of satellite imagery and the fourth is land-use/land-cover change analysis (Tulloch and Li, 2004). One of the most important decisions in determining what pollution monitoring system to implement is the choice of the satellites that will perform the monitoring. Suppose if one has to monitor black particle in aerosol, the best satellite would be one with a good spatial resolution. In this regard the below mentioned table 1.0 is depicting a comparison of some of the more popular satellites and their specifications.

Table 1.0: Specifications of Popular Remote Sensing Satellites for Air Quality Monitoring

Satellite	Altitude	Coverage Cycle	Spatial resolution	Bands
Landsat-7 Multispectral	705 Km	16 Days	30 m	0.45-0.52μm Blue 0.52-0.60 μm Green 0.63-0.58 μm Red 0.76-0.90 μm Near Infrared 1.55-1.75 μm Mid-Infrared
			60m	10.4-12.5Thermal Infrared
			30m	2.08-2.35 μm Mid-Infrared
SPOT-5 Multispectral	822Km	26 Days	10m	0.50-0.59 μm Green 0.61-0.68 μm Red 0.79-0.89 μm Near Infrared
			20m	1.58-1.75 μm Mid-Infrared
IRS1 C/1D Multispectral		24 Days	23m	0.52-0.59 Green 0.62-0.68 Red 0.77-0.86 Near Infrared
			70m	1.55-1.70 SW Infrared
IKONOS Multispectral	681Km	2.9Days	4m	0.45-0.52μm Blue 0.52-0.60 μm Green 0.63-0.69 μm Red 0.76-0.90 μm Near Infrared
Quick Bird Multispectral	450Km	6 Days	825m	0.45-0.52μm Blue 0.52-0.60 μm Green 0.63-0.69 μm Red 0.76-0.90 μm Near Infrared
GOES-8 and -10	35,790Km	Geostationary	1Km	0.55-0.75 μm Visible
			4Km	3.80-4.00 μm Thermal Infrared
			8 Km	6.50-7.00 μm Thermal Infrared
			4 Km	10.2-11.2 μm Thermal Infrared
			4 Km	11.5-12.5 μm Thermal Infrared

(Courtesy: Tulloch and Li, 2004)

Limitations of remote sensing:
Apart from several advantages there are few disadvantages are associated with satellite remote sensing technology (Szczurek et al., 1998).

· One of the major limitations is spectral interference caused by other atmospheric inhabitances (are not pollution).

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- Pollutant with a low concentration will not be detected.
- Satellite observations are restricted to wavelength ranges of atmospheric windows; the results of the observations are subject to the atmospheric conditions.
- A highly qualified staff will be required for this technology and the process is very expensive

Conclusion:
So it can concluded that it will be more profitable when the in-situ air pollution data studies integrate with remote sensing data. Satellite imagery, provide large spatial coverage, reliable and repeated measurements, which would be helpful to monitor aerosols and their transport patterns and air quality on a locale scale. Which ultimately helpful for decision makers to have a complete review of the place, major sources of pollution and its distribution pattern which determine the specified area needed effort to decrease the pollution level and the effect on environment and on human health.

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