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Winter seasons assessment of atmospheric aerosol over Coalfield region of India using geoinformatics

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ABSTRACT

Aerosol optical thickness (AOT), temperature and precipitable water vapour (PWV) were measured using MICROTOPS II Sunphotometer during the month of January 2011 and January 2014 for their analysis in the winter season over South Karanpura Coalfield region, Jharkhand, India. Patterns of AOT concentration (at five different wavelengths 340, 500, 870, 936 and 1020 nm) were measured along with water vapour and temperature, which were then spatially analyzed with reference to land use/land cover (LU/LC) of the region. Spatial distribution of AOT indicated higher concentration over industrial area (1.923–3.333 at 340 nm) and construction sites (>2.955 at 340 nm) and lower concentrations (<0.511 at 340 nm) over planned residential areas. To determine the aerosol size distribution, Ångström parameters (α, β) were calculated at wavelengths 340–870 nm (2011 and 2014) which ranged between 0.422 and 1.286 and 0.472 to 2.593 in January 2011 and 2014 respectively for 'α', whereas 'β' value lies between 0.127 and 1.379 in January 2011 and 0.031 to 1.923 in January 2014. The study indicates the presence of different particle sizes of aerosol associated with industries and coal mining activities which contribute significantly to increased aerosol concentration in the study area.

1. Introduction

Atmospheric aerosol or particulate matter (PM) is an important air pollutant that associated with adverse human health effects, visibility deterioration and uncertain impact on climate change (Pope, 2000; Cheung et al., 2005; IPCC, 2007; Sacks et al., 2011). Aerosols are tiny particles found in either solid or liquid state of

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matter, suspended in the air (excluding cloud particles) with an extensive combination of sizes, ranging from 10^{-2} µm to 10^2 µm (Ranjan et al., 2007; Kumar et al., 2016). These particles have negligible terminal fall speed and are injected into the atmosphere through natural sources originating from volcanoes, dust storms, forests, grasslands, fires, vegetation, or through anthropogenic sources such as burning of fossil fuels and the alteration of surface covers (Kaskaoutis et al., 2007). Aerosols significantly affect the Earth's atmosphere by either scattering or absorbing the incoming solar radiation while it indirectly affects the cloud formation and its optical properties by acting as cloud condensation nuclei (Ranjan et al., 2007; Pawar et al., 2012; Wang et al., 2015).

The study on aerosol concentration has received prominent attention in global science community in the past several years. It study employs long-term systematic measurement of aerosol properties which can quantify their impact on Earth's radiative balance, the region's climate, air quality and human health (IPCC, 2007; Srivastava et al., 2012; Wang et al., 2015). Air pollution leads to early fetal loss, premature delivery and lower birth weight. When fine and ultra-fine materials get inhaled by people, they get carried by the cells of the lungs and penetrate into the circulatory system where it lodges permanently in organs such as heart and liver. Air pollution further affects the functioning of the lung and increased the fatality of the patients with pre-existing heart and lung diseases (Penttinen et al., 2001; Heinrich, 2003; Ibald-Mulli et al., 2004). Children are most vulnerable due to their developing organ systems. Temporary changes in air pollution are associated with short-term changes in the pulmonary health of asthmatic children and also leading causes of inducing asthma in children (Kinney and Lippmann, 2000; Venn et al., 2001). Due to the adverse impact of air pollution on climate, human health and environment, it becomes essential to understand the characteristic of atmospheric aerosol in regional and global scale (Tiwari and Singh, 2013).

Aerosol optical depth (AOD) also called aerosol optical thickness (AOT), and precipitable water vapour (PWV) are two very imperative physical parameters for studying the characteristic of atmospheric aerosol that is related to direct solar radiation by scattering the absorption process (Ranjan et al., 2007). Water vapour is the most abundant greenhouse gas that plays a substantial role in many atmospheric processes, such as radiative cooling, latent heat and convective activity (Zveryaev and Allan, 2005). This makes it imperative to understand the vertical and horizontal distribution of water vapour in analyzing the variance of hydrological cycle, forecasting of climate change and global warming studies (Bernstein et al., 2007).

The Ångström wavelength exponent (α) and Ångström turbidity (β) formula (Ångström, 1964) are the most commonly used parameters to illustrate the wavelength dependence and effects of scattering and absorption of atmospheric aerosol. The Ångström exponent is calculated using the spectral variation of AOT, which has been employed by various researchers as a tool for estimating the particle size distribution and for extrapolating AOT throughout the broad spectral region as well as to distinguish the different aerosol types (Schuster et al., 2006; Kalapureddy and Devara, 2008; Kedia and Ramachandran, 2009). The relationship between the wavelength (α) and turbidity (β) follows a power law called Ångström power law which is a good representation of aerosol that has a wide variety of origin and composition (McCartney, 1976).

Monitoring and evaluating land use/land cover (LU/LC) change in coal mining area has become an important priority for scientists, land managers, and policy makers as LULC changes are typically associated with mining (Prakash and Gupta, 1998). Vast forested areas are cleared due to mining of minerals and fossil fuels (Sarma, 2005). The flora, fauna, hydrology, and soil biology are permanently altered due to the surface or opencast coal mining, which are also responsible for massive overburden dumps (Tiwary and Dhar, 1994). The South Karanpura Coalfield region undertakes both surface and underground mining. Surface coal mining creates extensive environmental pollution and air quality deterioration through the dust and harmful gaseous pollutants not only within the mining premises but also in its adjoining localities (Armstrong et al., 1980). In India, the production of coal demands an increase in the rate by 20–25 Mt/year to meet the energy demand for the next 20–25 years (Ghose and Majee, 2007). The opencast mining technique is an efficient way to increase coal production and maintain the energy demand. In the year 1995–96, the total coal production in the country was 274 Mt which was 68% of the total production through opencast mining. It further increased to 70% during the year 2000 (Kumar, 1995).

There are several sources of aerosol concentration in this study area that can be distinguished according to their different particle sizes. Coarse aerosol particles are emitted by coal mining, transportation activities, pulverization, dumping of overburden and fly ash whereas, fine particulate matter are produced through combustion processes such as coal power stations, iron works, local heating and transportation (Munroe et al., 2008). During biomass combustion, different kind of particles are released such as black carbon, organic