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Black carbon radiative forcing over the Indian Arctic station, Himadri during the Arctic Summer of 2012

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ABSTRACT

The warming of Arctic region has recently gained worldwide attention due to its projected impacts on global climate system. The effect of anthropogenic black carbon (BC) aerosol on snow is of enduring interest due to its role in aerosol radiative forcing and further consequences for Arctic and global climate change. Using an A ethalometer, measurements of BC aerosols were continuously carried out over the Indian Arctic Station, Himadri during the Arctic Summer (23 July to 19 August) of 2012. Monthly mean BC mass concentration during July and August was found to be 0.093 ± 0.046 and 0.069 ± 0.050 μg/m^3, respectively. BC mass concentration showed maximum loading during 0800–1600 LT. Transport from distant sources (as observed from air mass back trajectories) apart from some local anthropogenic activities (emissions from shipping and power plant) could be the possible sources for observed BC concentration at Himadri. Using the OPAC and SBDART models, optical properties and aerosol radiative forcing (ARF) in the spectral range 0.2 to 4 μm for composite aerosol and without-BC aerosol at the top of the atmosphere, surface and atmosphere were computed. The presence of BC resulted in positive radiative forcing in the atmosphere leading to warming effect (+2.1 W/m^2) whereas cooling was observed at the top of the atmosphere (−0.4 W/m^2) and at surface (−2.5 W/m^2). BC formed about 57% of atmospheric ARF.

1. Introduction

The Cryosphere that comprises snow, river and lake ice, sea ice, glaciers, ice shelves and ice sheets, and frozen ground, plays a major role in the Earth's climate system through its impact on the surface energy budget, the water cycle, primary productivity, surface gas exchange and sea level. Annual Arctic sea ice extent decreased over the period 1979–2012 and the rate of this decrease was very likely between 3.5 and 4.1% per decade (IPCC, 2013). Several studies have reported that the Arctic climate is warming rapidly and consequent changes in Arctic and thereby in global climate are projected (Rahn, 1981; Barrie, 1986; Hyvärinen et al., 2011; Rahul et al., 2014). Aerosol sources such as biomass and fossil fuel combustion can produce positive climate forcing in the Arctic because of their effects on snow and ice (Bond et al., 2013).

Being an important component of Arctic haze, the highly absorbing type black carbon (BC) aerosols reduce surface albedo and accelerate snow/ice melting, thereby playing an important role in changes in the Arctic climate (Sand et al., 2013; Flanner, 2013). Shindell and Faluvegi (2009) estimated that decreasing concentrations of sulfate aerosols and increasing concentrations of BC in the Arctic have substantially contributed to rapid Arctic warming during the past three decades (1.1 ± 0.8 °C). A very comprehensive report on BC related climate effects for the Arctic region has been published by Arctic Monitoring Assessment Program (Quinn et al., 2011). It is reported that the BC concentrations at Arctic region decreased from the 1980s to 2000, followed by a slight increase in the past decade (Sharma et al., 2006; Eleftheriadis et al., 2009; Hirdman et al., 2010). Hansen and Nazarenko (2004) have estimated a positive

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hemispheric radiative forcing of + 0.3 Wm^2 due to the decrease in surface albedo that was attributed to the presence of BC in Arctic snow. From the Indian point of view, Arctic climate has a special importance as some studies have showed a tale-connection between Arctic snow and Indian monsoon intensity (Bamzai and Shukla, 1999; Khare, 2008). In the present study, we present the results of BC mass concentration and its role in short wave (SW) radiative forcing over the Indian Arctic Station, Himadri (78.9°N, 11.9°E, 42 m AMSL) during 23 July to 19 August 2012 in the Arctic Summer.

2. Methodology

The observational field campaign for monitoring surface BC mass concentrations was conducted at the Indian Arctic station Himadri (Fig. 1) during July and August 2012, using a seven channel Aethalometer (Magee Sci., Inc., USA, Model AE-42). The flow rate of the sampled air was set at 3 LPM and the time base for observations was set at 5 min interval during the present study. The operating principle of an Aethalometer is the measure of attenuated beam of light transmitted at seven wavelengths viz., 370, 470, 520, 590, 660, 880 and 950 nm through its filter tape, while the filter is continuously collecting aerosol sample. The increase in optical attenuation (ATN) from one period to the next is due to the increment of BC aerosol collected from the air stream during the period; dividing this increment by the volume of air sampled during that time, we calculate the mean BC concentration in the sampled air stream during the period. The BC concentration reported from the Aethalometer is calculated from the rate of change of ATN. It is observed that the BC concentrations obtained using an Aethalometer apparently rise after the filter tape advances and therefore, the relationship between ATN change and BC concentration is not linear (Weingartner et al., 2003; Arnott et al., 2005). Therefore, as the ATN increases, the measured BC concentration becomes underestimated. This Loading Effect should be taken into account when using empirical correction algorithms. In order to account for this effect, we have used the correction algorithm presented by Virkkula et al. (2007). The methodology used for correction of raw BC data is described in Raju et al. (2011) and Safai et al. (2013). Overall uncertainty in the BC measurements by an Aethalometer is reported to be about 10% (Ramachandran and Rajesh, 2007).

Apart from continuous BC measurements, sampling of PM_{10} and $PM_{2.5}$ (particulate matter less than 10 μm and 2.5 μm, respectively) was carried out using a fine dust sampler

Fig. 1. Indian Arctic station, Himadri (Ny-Alesund).