Science of the Total Environment xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Optical and radiative properties of aerosols over Desalpar, a remote site in western India: Source identification, modification processes and aerosol type discrimination

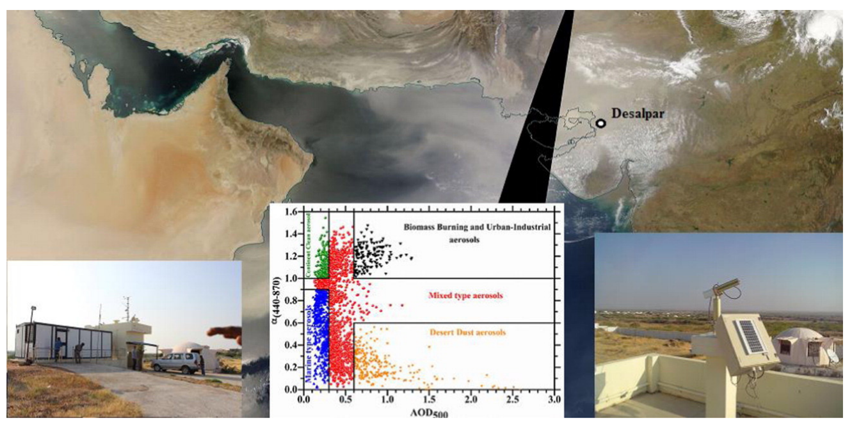
Piyushkumar N. Patel [a], U.C. Dumka [b,*], D.G. Kaskaoutis [c], K.N. Babu [a], Alok K. Mathur [a]

[a] Calibration & Validation Division, Space Applications Centre, ISRO, Ahmedabad 380 015, India.
[b] Aryabhatta Research Institute of Observational Sciences, Nainital 263 001, India
[c] Atmospheric Research Team, Institute for Environmental Research and Sustainable Development, National Observatory of Athens, GR, 11810 Athens, Greece

HIGHLIGHTS

- Aerosol characterization carried out for the first time over Desalpar, a semi-arid site in western India.
- The aerosol optical properties exhibit important seasonality.
- Dominance of mixed-type aerosols with significant contribution of marine-influenced particles.
- Increase in direct radiative forcing and atmospheric heating rate due to dust advection.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 5 August 2016
Received in revised form 1 September 2016
Accepted 4 September 2016
Available online xxxx

Editor: D. Barcelo

Keywords:
Aerosol physical-optical properties
Aerosol types
Radiative forcing
Sector influence
Western India

ABSTRACT

Aerosol optical properties are analyzed for the first time over Desalpar (23.74°N, 70.69°E, 30 m above mean sea level) a remote site in western India during October 2014 to August 2015. Spectral aerosol optical depth (AOD) measurements were performed using the CIMEL CE-318 automatic Sun/sky radiometer. The annual-averaged AOD_{500} and Ångström exponent ($\alpha_{440-870}$) values are found to be 0.43 ± 0.26 and 0.69 ± 0.39, respectively. On the seasonal basis, high AOD_{500} of 0.45 ± 0.30 and 0.61 ± 0.34 along with low $\alpha_{440-870}$ of 0.41 ± 0.27 and 0.41 ± 0.35 during spring (March–May) and summer (June–August), respectively, suggest the dominance of coarse-mode aerosols, while significant contribution from anthropogenic sources is observed in autumn ($AOD_{500} = 0.47 \pm 0.26$, $\alpha_{440-870} = 1.02 \pm 0.27$). The volume size distribution and the spectral single-scattering albedo also confirm the presence of coarse-mode aerosols during March–August. An overall dominance of a mixed type of aerosols (~56%) mostly from October to February is found via the AOD_{500} vs $\alpha_{440-870}$ relationship, while marine aerosols contribute to ~18%. Spectral dependence of α and its second derivative (α′) are also used for studying the aerosol modification processes. The average direct aerosol radiative forcing (DARF) computed via the SBDART model is estimated to range from -27.08 W m^{-2} to -10.74 W m^{-2} at the top of the atmosphere, from -52.21 W m^{-2} to -21.71 W m^{-2} at the surface and from 10.97 W m^{-2} to 26.54 W m^{-2} within

* Corresponding author at: ARIES, Manora Peak, Nainital 263 001, Uttarakhand, India.
E-mail addresses: dumka@aries.res.in, ucdumka@gmail.com (U.C. Dumka).

http://dx.doi.org/10.1016/j.scitotenv.2016.09.023

the atmosphere. This atmospheric forcing translates into heating rates of 0.31–0.75 K day^{-1}. The aerosol properties and DARF are also examined for different trajectory clusters in order to identify the sources and to assess the influence of long-range transported aerosols over Desalpar.

1. Introduction

Atmospheric aerosols (natural and anthropogenic) are one of the most important constituents in the Earth-atmosphere system (IPCC, 2013). Aerosols play a crucial role in influencing the Earth radiation budget and local/regional climate specifically in south Asia by interacting with incoming solar and outgoing terrestrial radiation and clouds through the direct and indirect effects. They also affect the monsoon circulation, hydrological cycle and melting of the Himalayan glaciers and snow packs (Hansen et al., 2000; Ramanathan et al., 2001; Bollasina et al., 2008; Gautam et al., 2010; Bond et al., 2013). On the other hand, aerosols constitute one of the largest sources of uncertainty in the estimation of present climate forcing due to their large spatial-temporal heterogeneity and short residence time in the atmosphere (Satheesh and Moorthy, 2005; Lawrence and Lelieveld, 2010; and references therein). The rapid economic development and increasing energy demands have been drastically increasing the aerosol emissions and loading over Asia, especially in India and China (e.g. Lu et al., 2010; Lawrence, 2011; Yoon et al., 2011, 2012, 2014; Saikawa et al., 2011; Babu et al., 2013; Moorthy et al., 2013; Cui et al., 2015; Wang et al., 2016). More specifically, Chin et al. (2003) found that intensive forest and agricultural fires and desertification over specific regions in East Asia contribute around 25%–33% to the global emissions of different aerosol types (e.g. SO_2, organic matter, black carbon and dust).

Aerosol studies over the Indian sub-continent have been mostly focusing on examining the aerosol loading, properties, types, source regions and climate implications over the densely populated and severe-polluted Indo-Gangetic Plains (IGP) (e.g., Singh et al., 2004; Ram et al., 2010; Kaskaoutis et al., 2013, 2014; Srivastava and Ramachandran, 2013; Dumka et al., 2014; Kedia et al., 2014; Das et al., 2015; and references therein). Several studies over sites in the IGP examined the influence of dust plumes originating mostly from the Thar Desert and southwest Asia on aerosol characteristics and radiative forcing (Dey et al., 2004; Prasad and Singh, 2007; Prasad et al., 2007; Sharma et al., 2012; Srivastava et al., 2014a; Alam et al., 2014; Kumar et al., 2015a; and references therein), but few studies refer to sites close or within the Thar Desert (Moorthy et al., 2007). Especially over the western part of India bordering Pakistan, to which the current location (i.e. Desalpar) belongs (see Fig. 1), the aerosol studies were mostly carried out over the urban/industrial area of Ahmedabad (Ganguly and Jayaraman, 2006; Ganguly et al., 2006a; Raman and Ramachandran, 2010; Ramachandran and Kedia, 2010). Furthermore, aerosol properties have been examined over an urban semi-arid site (Udaipur) and a hill-top station representing background conditions (Mt. Abu) located north of Desalpar (Das and Jayaraman, 2011). The megacity Karachi is located about 400 km west from Desalpar, where important studies on aerosol properties have been performed (Alam et al., 2011, 2012).

The present work focuses on examining the column-integrated aerosol optical, physical and radiative properties for the first time at Desalpar, located between the southern tips of the Thar Desert and Indus river delta, close to the north-easternmost edge of the Arabian Sea (see Fig. 1). The analysis utilizes eleven months (October 2014 to August 2015) of high-quality level 2 data of aerosol optical and physical properties derived from Sun-photometer (CIMEL CE-318). The main objectives of the current work are to study (i) the temporal (diurnal, daily, seasonal) variability of the aerosol properties, (ii) the dominant aerosol types based on correlations between aerosol optical depth (AOD) and Ångström exponent (α), (iii) the aerosol modification processes in the

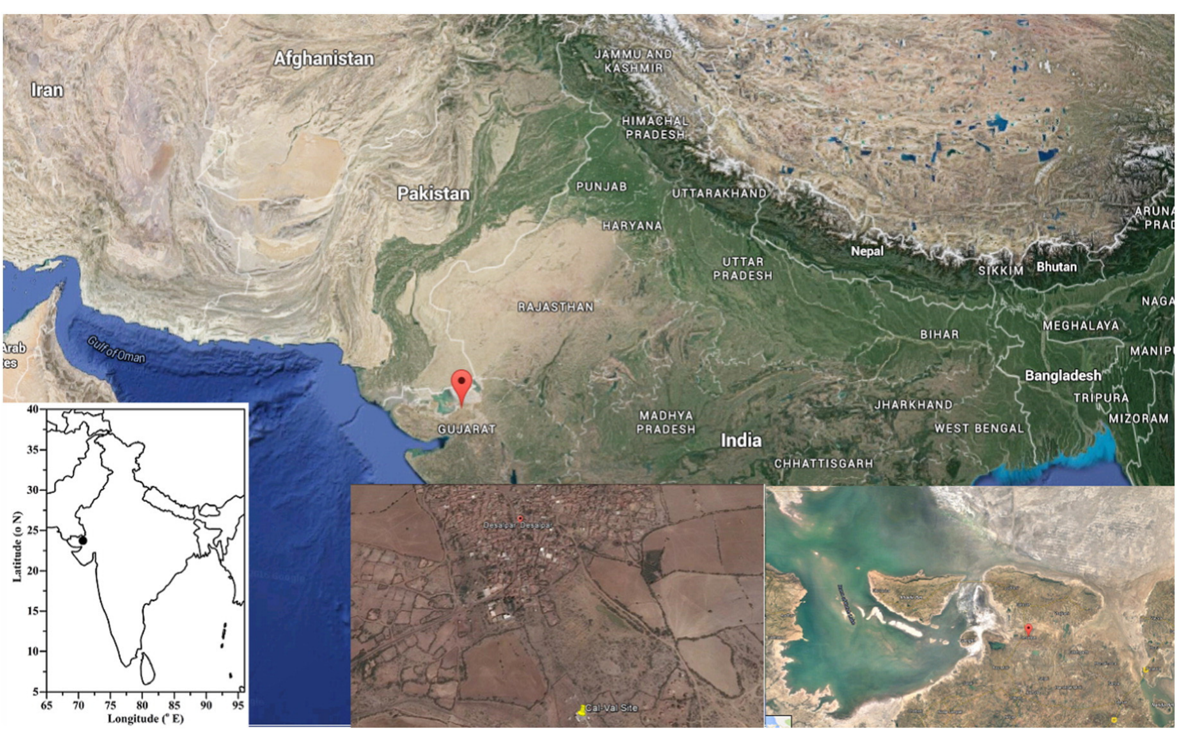


Fig. 1. Geographical location of Desalpar (DES) over Indian subcontinent.

Please cite this article as: Patel, P.N., et al., Optical and radiative properties of aerosols over Desalpar, a remote site in western India: Source identification, modification pr..., Sci Total Environ (2016), http://dx.doi.org/10.1016/j.scitotenv.2016.09.023