Atmospheric Research 120–121 (2013) 343–355

Contents lists available at SciVerse ScienceDirect

Atmospheric Research

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

Retrieval of aerosol optical and physical properties from ground-based measurements for Zanjan, a city in Northwest Iran

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ARTICLE INFO

Article history:
Received 25 March 2012
Received in revised form 24 September 2012
Accepted 24 September 2012

Keywords:
Atmospheric aerosol
Aerosol optical properties
Aerosol physical properties
Dust
Northwest Iran
Tigris–Euphrates basin
Sunphotometer

ABSTRACT

A ground-based sun and sky scanning radiometer, CIMEL CE 318-2 sunphotometer, has been used to study the atmosphere of Zanjan, a city in Northwest Iran (36.70°N, 48.51°E, and 1800 m above the mean sea level) in the periods of October 2006–October 2008, and January–September 2010. Direct sun and solar principal plane sky radiance measurements by the sunphotometer have been used to retrieve the optical and physical properties of atmospheric aerosols, such as aerosol optical depth (AOD), Ångström exponent (α), single scattering albedo (SSA), refractive index, and volume size distributions. About 50 dusty days (daily averaged AOD (870) > 0.35, α < 0.5) have been recorded during the mentioned periods. Considering the different values obtained for SSA, real part of refractive index, and volume size distributions, it has been found that just dust and anthropogenic aerosols are making the atmospheric aerosols in this region. In these recordings it has been observed that AODs (Ångström exponents) were increasing (decreasing) during spring and early summer. This was accompanied by increase of SSA, real part of refractive index, and coarse mode part of volume size distributions of aerosols. This behavior could be due to transport of dust, mostly from Tigris–Euphrates basin or sometimes with lower probability from the region between Caspian and Aral seas and rarely from sources inside the Iran plateau like the Qom dry lake, especially in dry seasons. In this work NCEP/NCAR reanalysis, HYSPLIT model back trajectories, and MODIS Deep Blue AODs have been used to track the air masses and dust plumes during the recorded dust events.

1. Introduction

Aerosol particles affect the radiative forcing of the Earth's climate via direct and indirect mechanisms. They scatter and absorb both solar and thermal radiations and change cloud characteristics in different ways. Therefore optical and physical properties of aerosols are important in the assessment of such effects (IPCC, 2007; Haywood and Boucher, 2000; Lohmann and Feichter, 2005). Distributions of atmospheric aerosols are highly inhomogeneous and variable. Therefore their temporal and spatial evolution should be studied in local and global scales. Ground-based remote sensing together with in situ measurements and satellite observations are complementary tools for the mentioned purpose (Heintzenberg et al., 1997; Kaufman et al., 1997; Dubovik et al., 2002).

Iran as a country in the Middle East is located on the center of the so-called dust belt and surrounded by some powerful dust sources such as Tigris–Euphrates basin in the west, the region between Caspian and Aral seas in the north, and Arabian Peninsula in the south and southwest (Prospero et al., 2002; Abdi et al., 2011). The Tigris–Euphrates basin is a powerful dust source in the Middle East and is active mainly in spring and summer times. The well-known northwesterly Shamal wind, transfers the dust plumes from the Mesopotamian region toward the Iran plateau and the Persian Gulf area (Goudie and Middleton, 2006; Prospero et al., 2002; Abdi et al., 2011). In severe conditions, such dust activities may be intensified by other dust sources like those inside the Arabian Peninsula and

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http://dx.doi.org/10.1016/j.atmosres.2012.09.022

covers a quite wide region even up to the Arabian Sea, Indian Ocean and Indian subcontinent (Badarinath et al., 2010; Badarinath et al., 2011). Dust sources inside the Arabian Peninsula mostly are distributed in the south and east sides of the Peninsula and their maximal annual activities are during April to September (Goudie and Middleton, 2006; Prospero et al., 2002). These sources mostly affect the Arabian Sea and the Indian subcontinent but do not have a considerable impact on the Iran plateau (Goudie and Middleton, 2006; Abdi et al., 2011; Badarinath et al., 2010; Badarinath et al., 2011; Kaskaoutis et al., 2012). Meanwhile the region between Caspian and Aral seas has some minor impact over the observed dust activities in central and northern parts of Iran (Goudie and Middleton, 2006; Prospero et al., 2002; Abdi et al., 2011). There are some dust sources inside the Iran plateau such as Qom dry lake in its central part, that have negligible share on the observed dust events in the region but some sources like Hamoun lake in the Sistan region at the southeast of Iran, may influence southwest Asian region like Southeast Iran and West Pakistan (Abdi et al., 2011; Abdi et al., 2012; Rashki et al., 2012). These sources are mainly located in the vicinity of dry salt lakes, seasonal lakes, and drainage basins in mountainous areas (Prospero et al., 2002; Middleton, 1986).

Zanjan, a city in Northwest Iran, is located at 36.70°N, 48.51°E, and 1800 m above the mean sea level (AMSL) (Fig. 1). 20-year recordings of synoptic stations of Zanjan meteorological office show that the average of sunny times is more than 7 h per day (Samimi and Anvari, 1997). On the other hand, the Tigris–Euphrates basin in its west side has a considerable impact on the observed dust events and even sometimes, recorded dust activities in this region had been originated from the region between Caspian and Aral seas (Abdi et al., 2011). All of the above mentioned points together with the lack of any AERONET site in a wide area around Zanjan make it a suitable location for aerosol monitoring by ground-based suits. Previously our group used the aerosol optical depth (AOD) measurements by a CIMEL CE 318-2 sunphotometer (SPM), during October 2006 to October 2008 as well as the coefficients of a polynomial fit to *ln* (AOD) variations versus the natural logarithm of the wavelength of the SPM recording channels, to characterize the atmospheric aerosols in this region (Bayat et al., 2011). In this work we are going to characterize other optical and physical properties of the atmospheric aerosols that can be retrieved from the sky mode measurements of the SPM. We have used the direct sun and solar principal plane (SPP) recordings of the SPM during October 2006 to October 2008 and January to September 2010 to retrieve the AOD, Ångström exponent (α), volume size distributions (VSD), single scattering albedo (SSA) and refractive index of the atmospheric aerosols especially during dust events. Looking to the correlations between AOD and α, SSA and AOD, SSA and α as well as SSA and fine mode fraction of AOD, helped us to judge about the type of observed dominant aerosols. To find the most probable resources of different recorded dust events, outputs of NOAA ARL HYbrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) and NCEP/NCAR reanalysis models have been used to track the air parcels and dust plumes during the events. For 655 days of measurement during the mentioned periods, aerosol optical depths have been retrieved from 21,136 direct sun irradiance recordings at four wavelengths, 440, 675, 870, and 1020 nm (Holben et al., 1998; Bodhaine et al., 1999; Toledano et al., 2007). The obtained AODs at three wavelengths, 440, 675, and 870 nm have been used to retrieve Ångström exponent as a qualitative indicator of aerosol size distributions (Toledano et al., 2007; Kaskaoutis et al., 2007; Masoumi et al., 2010). During 147 days of recording periods, 316 SPP sky radiance measurements at 870 nm have been used to retrieve the SSA, volume size distributions, and refractive index of the aerosols (Holben et al., 1998; Vermeulen et al., 2000; Devaux et al., 1998). During the

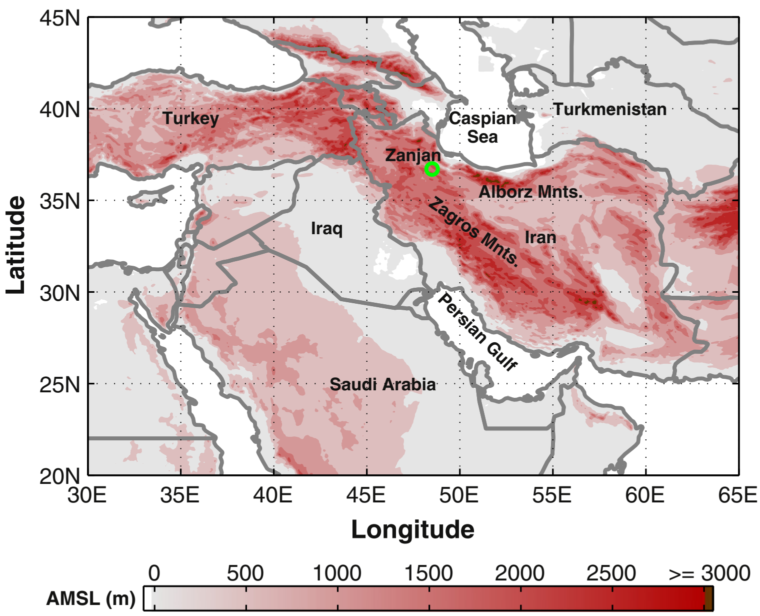

Fig. 1. Orography map of Iran. The location of Zanjan is indicated by a green circle.