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Assessment of dust activity and dust-plume pathways over Jazmurian Basin, southeast Iran

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ABSTRACT

Jazmurian (or hamun-e Jaz Murian) is a dried lake located in a topographic-low basin in southeast Iran and a major source for high dust emissions under favorable weather conditions. This work examines for the first time the dust activity over the basin by classifying the dust events (DEs, visibility <10 km) and dust-storm events (DSEs, visibility <1 km) based on observations at five local meteorological stations during the period 1990–2013. Analysis of the temporal evolution, seasonality, frequency and persistence (duration) of the DEs and DSEs, along with examination of the backward and forward air-mass trajectories in the Jazmurian Basin are the main objectives of the present study. The DEs exhibit maximum frequency in June–July and lowest in autumn and winter, while the DSEs peak mostly during March–May also presenting large variability between the stations. The frequency of both the DEs and DSEs increases during ~2001–2004 due to a prolonged drought over southeastern Iran, while no significant tendency is found during the period 1990–2013. Further, the DEs and DSEs exhibit a clear diurnal pattern with highest frequency between 15:30 and 18:30 LST due to thermal convection and transported dust plumes. The analysis reveals an average frequency of 12.7 dust-storm days per year, while the DSEs last for 5.1 h, on average, during the dust-storm days. The dust storms originating from Jazmurian affect mostly the northern coast of the Arabian Sea (Makran mountains), the Oman Sea, the southeastern Arabian Peninsula and the western Pakistan, while air masses from the arid/desert areas of central-eastern Iran and Arabia seem to further aggravate the dust-aerosol loading over Jazmurian.

1. Introduction

Dust storms, as recurring phenomena, are considered as natural hazards over the arid and semi-arid areas of the Earth (e.g., Goudie and Middleton, 2001; Yang et al., 2008; Rezazadeh et al., 2013). Dust storms may have both natural and human-induced causes and affect meteorological and climatic conditions from local to global scales (Prospero and Lamb, 2003; Rodriguez et al., 2015; Solmon et al., 2015), radiation and energy budget (Antón et al., 2011; Jish Prakash et al., 2014; Kumar et al., 2015; Valenzuela et al., 2015), ocean bio-geochemistry (Jickells et al., 2005; Jickells and Moore, 2015), ecosystems (Lin, 2002), human health (Pope, 2003; Martiny and Chiapello, 2013; García-Pando et al., 2014) and socio-economic issues (Kurosaki and Mikami, 2003; Sharifikia, 2013). Impaired visibility and high particulate matter (PM) concentrations, as consequences of the dust storms over urban environments, have been linked to traffic accidents and health hazards, i.e., cardiovascular and pulmonary diseases, chronic asthma, eye and nose irritation and breathing impairment (Chang et al., 2006; Holyoak et al., 2011; Sajani et al., 2011; Watanabe et al., 2011; Tam et al., 2012). Analyses based on satellite remote sensing over the globe (Prospero et al., 2002; Washington et al., 2003; Engelstaedter et al., 2006; Baddock et al., 2009; Christopher et al., 2011; Ginoux et al., 2012) highlights the importance of topographic-low basins of internal drainage (e.g. Bodélé depression in Chad, Taoudenni in Mali, Etosha Pan in Namimbia, Great Salt Lake in USA, Eyre in Australia, Tarim in west China, Aral and Balkhash in Kazakhstan, Sistan and Qom in Iran) for large dust emissions with serious impacts in the regional atmospheric environment. Furthermore, these drainage basins are very prone to saline dust storms and entrainment of large concentrations of fine-grain saline and alkaline material into the atmosphere, such as sodium chloride (NaCl), sodium sulfate ($NaSO_4$) and other potentially toxic components (Small et al., 2001; Micklin, 2007; Abuduwaili et al., 2010; Liu et al., 2011; Gholampour et al., 2015).

Numerous studies have examined the dust activity from local to global scales as a function of meteorological conditions, land

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use – land cover changes and topographic characteristics (e.g. Schepanski et al., 2009; Prezerakos et al., 2010; Gkikas et al., 2012; Pey et al., 2013; Bryant, 2013; Guan et al., 2015). In this respect, Wang et al. (2011) examined sand and dust storms over the globe in 2008 and identified four regions i.e., north Africa, Middle East, Mongolia and northwest China with highest frequency. McGowan and Clark (2008) analyzed the pathways of the dust plumes originated from the Australia's arid lake Eyre by means of Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model, finding that the dust plumes may impact the atmospheric composition and air quality thousands of kilometers downwind by transferring significant amounts of dust. Tan et al. (2012) analyzed daily observations at 43 meteorological stations in Inner Mongolia, China from 2000 to 2007 finding that annual and seasonal variations of dust storms are related to local and regional weather conditions, especially wind speed. They also examined the transport routes and altitude layers of the dust storms at two stations with the highest dust-storm frequency and simulated the dust impact on the Yellow river and East China Sea. Ge et al. (2016) assessed the potential dust trajectories in Ebinur lake, a dry region in northwest China, using the HYSPLIT model during the period 1978–2013. The results showed a distinct seasonality in dust activity maximizing in spring and summer. Alam et al. (2011) examined the spatial-temporal variability and the transport routes of dust over selected cities in Pakistan finding that the dusty air masses in winter had a longer pathway than summer; the highest dust concentrations in summer was a result of more frequent and intense dust storms coming mostly from Iranian deserts, southern Afghanistan and eastern Arabian Peninsula.

Focusing on Iran, Cao et al. (2015) identified the main dust sources and areas prone to desertification based on satellite remote sensing, while Rezazadeh et al. (2013) examined the most dust-affected areas over the Middle East and Iran based on visibility data from meteorological stations. Both studies revealed that the most dust-affected areas are the Khuzestan Province in southwest Iran and the Sistan Basin in southeast Iran that borders Afghanistan. These regions have also attracted the highest scientific interest in terms of meteorological regimes controlling dust storms, Total Suspended Particulate (TSP) and PM concentrations, dust mineralogy, health impacts and socio-economic effects (e.g. Miri et al., 2007; Zarasvandi, 2009; Najafi et al., 2014; Rashki et al., 2012, 2013a,b; Sharifikia, 2013; Kaskaoutis et al., 2015a, 2016). Some studies have been also performed over Iran examining the transport routes of the dust storms occurring across the country. In this respect, Vishkaee et al. (2011, 2012) showed that the dust storms affecting the northwest part of Iran were mostly originated from western directions i.e., the Iraqi plains and Syrian desert, with lower contributions from central Asia (Aral Basin and Karakum desert) and internal sources in Iran, i.e., dried salt lakes around Qom and Dasht-e-Kavir. These findings have been verified by Masoumi et al. (2013), who quantified the contribution of each sector on dust frequency and optical properties. Similarly, the severe dusty conditions over Khuzestan are attributed to dust transported from the Iraqi plains and Fertile Crescent (Najafi et al., 2014; Notaro et al., 2015), while the Sistan Basin is considered as the most active and intense dust-source region in southwest Asia (Middleton, 1986; Kaskaoutis et al., 2015a). Furthermore, Baaqhideh and Ahmadi (2013) studied the dust evolution over west and southwest Iran via statistical analysis in 11 synoptic stations finding that the highest frequency of dust storms is in July and August. Another interesting area for examining dust emissions, concentrations, mineralogy and chemical composition is the Urmia lake in northwest Iran due to significant land use – land cover changes as a result of lake desiccation and desertification (Gholampour et al., 2015, 2016).

Except for the Sistan Basin, the eastern part of Iran has remained nearly unexplored with respect to dust-storm evolution, despite the existence of an hyper-arid topographic-low basin the Dasht-e-Lut, which is one of the major desert areas in Iran and southwest Asia (Goudie and Middleton, 2006; Ginoux et al., 2012). The southern edge of the Dasht-e-Lut forms a closed drainage basin consisting of the Jazmurian ephemeral lake, which has been totally dry during the last ~15 years. The alluvial silt and saline material that has been left in the dried lake beds after desiccation is the source area for frequent and intense dust storms that strongly impact the neighboring towns and villages. The present study is the first that identifies the dust events (DEs; visibility <10 km), dust-storm events (DSEs; visibility <1 km) and examines their frequency, seasonality, duration and temporal evolution during the period 1990–2013 based on meteorological observations and visibility records at five stations located around the Jazmurian Basin. Furthermore, the areas that are mostly impacted by the dust storms originating from the Jazmurian Basin are identified via trajectory analysis. The results have significant importance for the atmospheric dust science over the southwest Asia and for aerosol studies over the northern Arabian Sea, Oman and United Arab Emirates that are mostly affected by the Jazmurian dust storms.

2. Study area

Jazmurian is a low depression (topographic-low basin) in southeast Iran straddling the provinces of Kerman and Sistan – Baluchistan (see Fig. 1). It covers an area of ~69,600 km^2, with ~300 km length and maximum width of ~140 km lying at a mean elevation of ~360 m. The Jazmurian Basin is surrounded by high rocky and arid mountainous ranges in excess of 2000–2500 m and is covered by a seasonal lake (hamun-e Jaz Murian), which may remain almost totally dry in years with very low precipitation. In contrast, during wetter years it can hold water during winter and spring, but shrinks in summer. Two rivers flow into the Jazmurian Basin i.e., the Bampur River from the east and the Halil Rud River from the west. However, these small rivers are not capable to bring much water to the central parts of the basin in order to feed the lake since their waters are largely or even totally removed for agricultural irrigation. In some years, during the spring season when the rivers overflow, the central basin is flooded and a very shallow (20–30 cm) slightly saline lake forms; this lake has changeable contours and dimensions with reed growth along the shore. Jazmurian lake has been covered mostly by silty-clay sediments and due to the lack of infiltration some parts of the marshy land become a seasonal lake in certain periods. The annual precipitation in the western part of the basin is about 200 mm, while other parts are very dry with average annual precipitation of less than 100 mm. In contrast, evaporation is very high and reaches to 2500 mm per year due to very hot climate (Gandomkar, 2009). An extensive drought in the beginning of 2000s has resulted in the complete drying of the lake, which has been transformed to a desert area. West and northwest winds seem to have a great impact in creating sand dunes that are mostly barchans, in the south and southeast parts of the basin. West, east and south margins of Jazmurian are considered as the most prone dust-emission regions, while the northwest-to-southeast orientation of the basin (see Fig. 1) plays an important role for the channelization of the wind, dust emissions and transport.

3. Dataset and methodology

3.1. Meteorological parameters and dust classification

In order to assess the long-term dust characteristics, meteorological data from five stations located in the Jazmurian Basin (i.e., Bam, Jiroft, Kahnuj, Khash and Iranshahr) and belonging to the Iran