Characterization of Dust Storm Sources in Western Iran Using a Synthetic Approach

A. Darvishi Boloorani, S.O. Nabavi, R. Azizi, and H.A. Bahrami

Abstract Encountering numerous problems, many areas of the world experience dust storms every year. The west of Iran is considered as an area with numerous dust events because of vast deserts in Syria, Iraq, and the Arabian Peninsula. In recent years, the number of dust storms and the affected areas has remarkably increased. The present study is an attempt to identify west of Iran's dust sources using a synthetic approach including remote sensing technique of dust detection, physical–meteorological model called HYSPLIT, and analysis of the studied area's soil texture, land covering, and wind velocity data. Results show that there are two main dust storm sources affecting western Iran: The first region is the area between the west bank of Euphrates and east bank of Tigris, and the second one is the east and south eastern Arabian Peninsula a region called Rub' Al Khali.

1 Introduction

Concerning the definition of World Meteorological Organization, dust storms are resultant of weather turbulences which introduce a high mass of dust in the atmosphere, and consequently decrease the horizontal visibility to less than 1,000 m (Goudie and Middleton 2006). In a general perspective, primary sources

A.D. Boloorani
Department of Cartography, University of Tehran, Tehran, Iran

S.O. Nabavi (✉)
Department of Physical Geography, University of Tehran, Tehran, Iran
e-mail: s.o.nabavi@gmail.com

R. Azizi
Department of Mathematical Science, Sharif University of Technology, Tehran, Iran

H.A. Bahrami
Department of Soil Science, Tarbiat Modares University, Tehran, Iran

C.G. Helmis and P.T. Nastos (eds.), *Advances in Meteorology, Climatology and Atmospheric Physics*, Springer Atmospheric Sciences,
DOI 10.1007/978-3-642-29172-2_59,

of generating dust storms are located in the world's desert regions in Asia, Middle East, Europe, Latin America, North America, Australia, east and south Africa, and Sahara. Among them, Middle East has various sources of generating dust such as Arabian Peninsula, Syria, Egypt, Iraq and Iran (Shao et al. 2011).

Dramatic increase in occurrence of this phenomenon in the world's various regions, such as Iran, has led to the increasing attention of researchers to do numerous studies from various viewpoints. Li et al. (2010) have analyzed the greatest dust in the east of Australia using both satellite images, MODIS satellite, and Brightness Temperature Differences (BTD); denoting the significant effectiveness of this method in identification of dust masses, recognized how this phenomenon is occurred. Gerivani et al. (2011) characterized the source of dust storms in Iran based on geological maps and information on wind erosion of susceptible lands. Dust storm tracking is also a way of detecting dust sources which is primarily done by implementing remote sensing techniques and satellite imagery in short intervals, but another effective and convenient way to detect dust storm sources is HYSPLIT physical model (Draxler and Hess 1998) being used in areas with no access to satellite images to increase the validity of results acquired from satellite imagery. Kutiel and Furman (2003) have mainly studied temporal–spatial features of dust storms in Middle East. Summer was mentioned to be the time dust storms frequently occurred in Iran, north-east Iraq, Syria, Persian Gulf, south Arabia, Yemen, and Oman. Although each of the aforementioned studies have suggested remarkable results, the fact that dust events result from various factors necessitates adopting synthetic approaches and utilization of different sciences. Using various methods and information sources such as scientific techniques of remote sensing, specific physical model of wind tracking, and also soil texture, land cover and wind velocity data, current research attempts to achieve identification of dust sources in the area west of Iran.

2 Data and Methodology

2.1 Data

To study the effective conditions in which dust storms affect west of Iran, daily visibility data of ten synoptic stations, located in studied area, in the period of 2000–2008 have been used. Daily Visibility data were derived from Iran's Meteorology Organization archived database. The wind data for 1,000 hPa level is taken from National Centers for Environmental Prediction of US (Kalnay et al. 1996). MODIS satellite images are derived from http://rapidfire.sci.gsfc.nasa.gov/realtime website. Data used in HYSPLIT model are accessible at http://ready.arl.noaa.gov/ready2-bin/extract/extracta.pl. Soil texture data of studied area is extracted from the Harmonized World Soil Database (FAO/IIASA/ISRIC/ISSCAS/JRC 2009) and land cover data are accessible at www.esa.int/esaEO/SEM5N3TRJHG_index_0.html.

2.2 Methodology

In the present study, the dust storms that had been recorded in at least three synoptic stations were only studied with a non-local origin and leading to horizontal visibility of 1,000 m or less. The occurrence time of dust storms and detection of suspected dust clouds were determined by analysis of satellite images utilizing specific dust detection method (Ackerman 1997; Kaskaoutis et al. 2007). HYSPLIT physical model and its backward method are used to track air masses, as dust transporter, for approval whether the wind is blowing through the dust plumes to our given region. As it was mentioned, wind trajectory method is so helpful for situation lacking in satellite images with short time interval to identify main dust carrying paths and consequently their sources. Tracing the wind starts from stations affected by dust storms simultaneous with the formation of first dust core which terminates at the end of a day before dust occurrence, in altitude of 1,000 m. In fact, tracing the wind leads us to detect approximate dust sources. In the more precise identification phase of dust sources, the Harmonized World Soil Database, surface land cover, and wind velocity data of 1,000 hPa level (lower troposphere) are used in spite of reusing satellite images.

3 Results

Having examined the dust data of the local stations in our study from 2000 to 2008 and analyzed satellite images, and finally, based on the predetermined definition of dust storms, a number of 12 dust storm events have been investigated to identify western Iran's dust storm sources. Dust storm occurrence times and suspected dust clouds were identified by using dust detection method for all 12 dust cases. Generally, all events follow two formation and relocation regimes, from Iraq and Saudi Arabia to the west of Iran, shown for two cases from June 30 to July 3, 2008 and March 1–3, 2007 in Fig. 1.

Wind trajectory maps which are especially used for cases that satellite images are not accessible introduce two paths for carrying dust plumes into the west of Iran. Figure 2 shows two paths for the aforementioned examples determined by wind trajectory model:

1. North-west (west)–South-east (east) trajectory: The formed dust plumes in Iraq and Syria are carried to the west region of Iran by North-Westerly (Westerly) wind. Of 12 dust storms, 10 dust events were carried along this route (Fig. 2a, dust storm of Jun 30, 2008).
2. Southern-northern trajectory: It begins from southern coastline of Persian Gulf and ends at western Iran. Of 12 cases of dust storms, only 2 cases took this path and moved toward the west of Iran (Fig. 2b, dust storm of Mar 1, 2007).

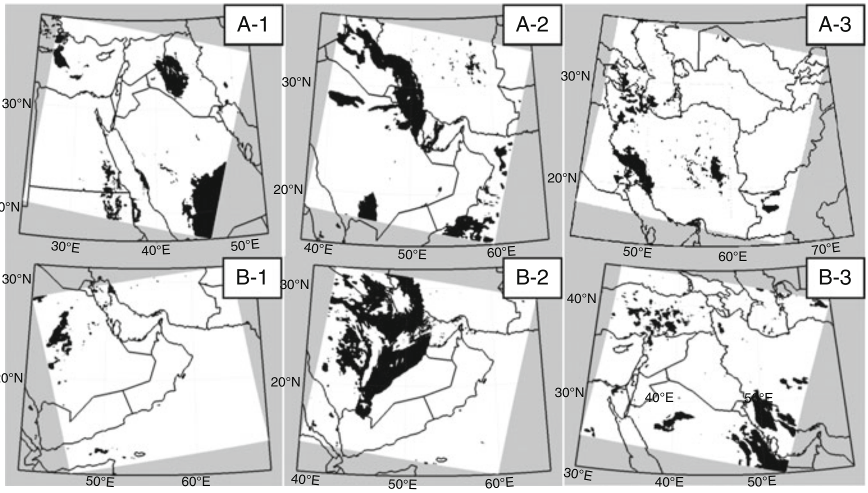

Fig. 1 Formation of dust storm from the area between the eastern bank of Euphrates and the western bank of Tigris on Jun 30, 2008; its expansion on Iran through Jul 2–3, 2008 (**a-1**, **a-2**, **a-3**) and from the eastern and southeastern deserts of Arabia Saudi Arabia on Mar 1, 2007 to Mar 3, 2007 (**b-1**, **b-2**, **b-3**)

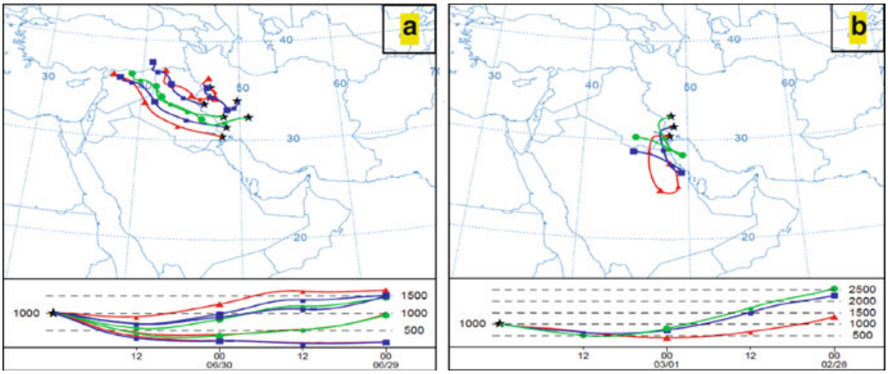

Fig. 2 Two examples of wind trajectory maps on Jun 30, 2008 (**a**) and Mar 1, 2007 (**b**) using HYSPLIT model. The *symbol (*)* shows the locations of synoptic stations affected by dust storm

Having done wind trajectory and known main dust transportation routes, the sources of dust storms are sought based on simultaneous study of Iraq, Syria, and Saudi Arabia's soil texture, land covering and wind velocity data along predetermined paths. In other word, determination of dust sources is due to identifying most influenced regions by wind velocity, with a superfine texture to be blown away by wind and also those without sufficient vegetation and humidity.

According to the Harmonized World Soil Database, along the first path determined by HYSPLIT model, there is an area with gypsum sediments in the northwest

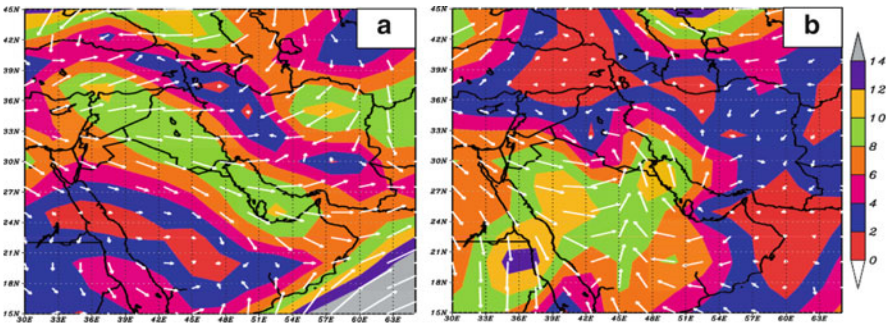

Fig. 3 Two examples of wind velocity maps on Jun 30, 2008 (**a**) and Mar 1, 2007 (**b**). *Vectors* show wind directions and *colored background* represents wind speed (ms^{-1})

of Iraq and the east of Syria called Gypsisols that is mostly developed in arid regions with sporadic vegetation. Presence of having such soil type prepares conditions for wind erosion, whereas southernmost area of the trajectory, i.e. the southeast of Iraq, consists of Solonchaks soil which is also found in arid and semi-arid regions; But one of its significant features is that the water table is high and the soil is moist; A condition that sometimes leads to water stillness on the soil surface Thus, such regions are less liable to develop extensive dust sources. About 20–23% of soil texture in the western bank of Euphrates and the eastern bank of Tigris consists of clay. In addition, the region has got a 50 unit of soil moisture, which is sometimes lowered to 15 units in some areas. These types of soil texture, with low moisture and sporadic vegetation, provide necessary conditions for wind erosion. Although this type of soil texture is also found in the southeast of Iraq (southern area of the trajectory), due to high soil moisture (almost 150 units), grasslands, and brushes, the surface soil is less likely to be removed from this region. The second trajectory includes Persian Gulf and its southern coast. Therefore, the only dust-prone areas along this trajectory are located in its southern parts, i.e. eastern and southeastern areas of Arabia (the desert region of Rub-Al-Khali). This part of Arabia consists of Regosol soil, the most texture of which is composed of gravel and sand coverings. In some parts of this region, more than 30% of soil texture is clay and could be considered as one of the most arid regions (the soil moisture is calculated as negligible, relatively zero) without vegetation (FAO/IIASA/ISRIC/ISSCAS/JRC 2009; IUSS 2007; Global Land Cover 2010). Though, due to coarse soil particles in this region, regional dust occurrence requires winds with higher velocity rather than the northwest of Iraq and the east of Syria ones. This is why we observe winds with velocity of more than 10 and even 12 m/s during dust events originated from the east of Arabia while in most cases in which dust storms originated from the northwest of Iraq and the east of Syria, a velocity of between 8 and 10 m/s is recorded in the region (Fig. 3).

4 Conclusions

Using the data from synoptic stations in the region, satellite images, and also tracking wind flows during dust events in the western stations in Iran, two main trajectories of dust transfer were recognized: The northwest-southeast trajectory which starts from the northwest of Iraq and the east of Syria, ends in the west of Iran, and the south–north trajectory that starts from the southern banks of Persian Gulf leads to the west of Iran through a south–north path. Utilizing the results of previous section, the simultaneous study of soil maps, land cover, and wind velocity along determined paths, led us to identify two main sources of dust storms in the west of Iran: The area between the eastern bank of Euphrates and the western bank of Tigris as the main dust sources; out of 12 dust storms, 10 cases were formed in this region and the eastern and southeastern deserts of Arabia. Considering more coarse soil texture of the eastern and southeastern deserts of Arabia rather than the first source, higher-velocity winds are required to form dust in this region.

References

Ackerman SA (1997) Remote sensing aerosols using satellite infrared observation. J Geophys Res 102:17069–17079. doi:10.1029/96JD03066

Draxler RR, Hess GD (1998) An overview of the HYSPLIT_4 modeling system for trajectories, dispersion, and deposition. Aust Meteorol Mag 47:295–308

FAO/IIASA/ISRIC/ISSCAS/JRC (2009) Harmonized World Soil Database (version 1.1). FAO, Rome, Italy and IIASA, Laxenburg, Austria

Gerivani H, Lashkaripour GR, Ghafoor IM, Jalili N (2011) The source of dust storm in Iran: a case study based on geological information and rainfall data. Carpathian J Earth Environ Sci 6(1):297–308

Global Land Cover (2010) Accessible at www.esa.int/esaEO/SEM5N3TRJHG_index_0.html

Goudie AS, Middleton NJ (2006) Desert dust in the global system. Springer, Berlin

IUSS Working Group WRB (2007) World reference base for soil resources 2006, first update 2007. World soil resources reports no. 103. FAO, Rome

Kalnay E, Kanamitsu M, Kistler R, Collins W, Deaven D, Gandin L, Iredell M, Saha S, White G, Woollen J, Zhu Y, Leetmaa A, Reynolds B, Chelliah M, Ebisuzaki W, Higgins W, Janowiak J, Mo KC, Ropelewski C, Wang J, Jenne R, Joseph D (1996) TheNCEP/NCAR 40-year reanalysis project. Bull Am Meteorol Soc 77:437–472

Kaskaoutis DG, Kosmopoulos P, Kambezidis HD, Nastos P (2007) Aerosol climatology and discrimination of different types over Athens, Greece based on MODIS data. Atmos Environ 41(34):7315–7329. doi:10.1016/j.atmosenv.2007.05.017

Kutiel H, Furman H (2003) Dust storms in the middle East: sources of origin and their temporal characteristics. Indoor Built Environ 12:419–426. doi:10.1177/1420326X03037110

Li X, Ge L, Dong Y, Chang HC (2010) Estimating the greatest dust storm in eastern Australia with MODIS satellite images. In: Proceedings of IEEE international geoscience and remote sensing symposium (IGARSS), Honolulu, HI, 25–30 July, pp 1039–1042

Shao Y, Wyrwoll K-H, Chappell A, Huang J, Lin Z, McTainsh GH, Mikami M, Tanaka TY, Wang X, Yoon S (2011) Dust cycle: an emerging core theme in Earth system science. Aeolian Res 2:181–204. doi:10.1016/j.aeolia.2011.02.001