DESERT

DESERT
Online at http://jdesert.ut.ac.ir

DESERT 17 (2012) 49-55

Study of Dust Storm Synoptical Patterns in Southwest of Iran

E. Fattahi[a*], K. Noohi[a], H. Shiravand[b]

[a] *Faculty member, Atmospheric Science & Meteorological Research Center, Tehran, Iran*
[b] *Lorestan Meteorological Research Center, Khorram Abad, Iran*

Received: 15 November 2009; Received in revised form: 11 March 2010; Accepted: 16 April 2012

Abstract

As widespread deserts is located in west and southwest of Iran plateau, dust storms form due to west and southwest systems over Syria or Iraq as well as Arabian Peninsula. These systems severely affect west and southwest regions. Sometimes the fine dusts transmit to central, north east, and east regions. In this study for investigating dusty synoptical patterns, meteorological data at 5 synoptic stations were studied during recent ten years. Mean daily sea level pressure data were selected from the NCEP reanalysis data encompassing the region from 20°-60°N latitude by 20°-80°E longitude, with a 2.5 spatial resolution and for the 10 year period 1961-2003 in dusty days. Selected territory is located in a geographical situation that covers all the effecting systems on Iran. For classification and delineate synoptical patterns Principal Component Analysis (PCA) and clustering method were used. Results showed that in this region, days with dust have three general circulation patterns. Analyzing these patterns show that there is a trough which restricted to 30-45°E longitude in 850 hPa chart, and at least one relatively strong low pressure over Arabian Peninsula in sea level pressure extending to the west, south west and the study region. This study shows that above aspects are the major specifications of dusty days.

Keywords: Synoptical patterns; Dusty systems; Principal Component Analysis; Iran

1. Introduction

Iran is located in world's arid and semi arid belt and a great part of it is surrounded by desert and arid regions. Dust storm phenomenon in arid and desert regions causes some difficulties. Moisture is one of the most important conditions in rising dust. Abundance of dust particles in atmosphere depends on wind speed, dryness of soil particles, and diameter size of them. Also type and vegetation cover plays an important role in dust storm intensity. In fact rising dust may be a reaction to changing ground vegetation cover. During summer, thermal turbulence is seen over the Arabian Peninsula up to 12000 feet (Marcal, 1980). Wind convergence at central and south east of Iraq, as source areas of dust; cause to lift dust particles into a plume form (kalu, 1979). Dust remains in suspension form in the air as long as the upward vertical component of wind in atmosphere is greater than the minimum force required to hold the particles aloft (Gillette, 1979).

Walter (1991) surveyed dust and sand storm forecasting in Iraq and adjoining countries. He found that there are three main dust storm types: shamal, frontal, and convective. The most common type across the Middle East is shamal. The term “Shamal” means north in Arabic and refers to the prevailing wind direction from which this type of dust storm is produced (Middleton, 1986). Shamal dust storms occur across Iraq, Kuwait, and the Arabian Peninsula. The synoptical feature that creates potential situation for Shamal is a zone of convergence between the subtropical ridge extending into the northern Arabian Peninsula and Iraq from the Mediterranean Sea and the Monsoon Trough across southern Iran and the Southern Arabian Peninsula.

Dayan (1985) studied air flowing patterns in relation to dust storm on the basis of trajectory of dust storm and analyzing of five days back trajectory maps in 850 hpa level in Palestine and

[*] Corresponding author. Tel.: +98 21 44580651,
Fax: +98 2144580651.
E-mail address: ebfat2002@yahoo.com

Lebanon. He also classified the predominant air flow situation in the region. Fang (2002) showed that dust storms occurrences have increasing trend in China during recent years. Gody and Midelton, (2001) identified dust storms and the extent effect of them in north of Africa. Orlovsky (2004) studied dust storms in Turkmenistan from the viewpoint of spatial distribution, frequency, and seasonal variation. He found that the most frequency of storms occurred in spring season and the major origin of these storms is Garaghom desert. Wang (2005) studied the formation of dust storms from synoptical view point and found that development of these storms occur when a system moves to desert regions.

Most dust storm studies in Iran are done in the form of dissertations. Marjany (1993) studied sever winds more than 15 m/s in Khorasan province. He classified the effective factors in occurring dust storms by using of synoptic charts and patterns. Hematy, (1995) surveyed the frequency occurrence of dust storms in central and south west of Iran and found that the main factor in occurring sever storms is the existence of cyclonic systems in central regions of Iraq and north of Saudi Arabia. Dehghanpor (2005) studied dust storms in central and interior regions of Iran from statistical and synoptical view point. He considers the NAO index and polar vortex effects, as synoptical factors, in frequency and time occurrence of dust storms. Hoseinzade, (1997) Studied the frequency of dusty days in the country and showed that occurrence of dusty days is the most in central desert of Iran.

Investigation of literature about the subject shows that the most studies is concentrated on physical specifications, such as effect on air quality, hygienic and medicine effects of dust. Habibinokhandan (1997) studied dust damages on building view and beauty.

Hoseinzadeh (1997) studied the relation between dust and hygienic, respiratory, and optic difficulties in central regions of Iran. Visibility decrease and environmental consequences of this phenomenon in transport is discussed by (Noohi, 1994). Kaviyani (2001) quoted that dust formation in deserts is due to instability. He believes that the air above desert surfaces is very unstable due to convection and has genesis conditions of instability phenomenon like small dust vortex. Engelstadler (2001) emphasizes on the role of dry bed lakes and African great desert as the major producers of dust.

Goudie and Midelton (2001) quoted that African Sahara produce dust more than any other desert in the world. They found that north east of Moritani, west of Malli, and south Algeria are more important. Wang (2005) studied the relation between dust storm formation and synoptic evolution of them at North West of Asia. He found that when a system moves to desert regions, a dust storm develops.

Zolfaghari (2005) analyzed the synoptically dust systems in west of Iran. He showed that the most important source of dust that comes to the west of Iran, are deserts stand in north of Saudi Arabian peninsula and north of African Sahara. He found that when low pressure over Saudi Arabian peninsula is coming toward Iran has the most effect in creating dust in the region.

Qian (2004) concluded that identification of climatologically characteristics of major dust storms are quit representative for all of dust storm events. Qian (2002) studied the variations in dust storms in China during 1948-1999 and their climatic control through statistical correlation analysis.

Most dust storm studies have analyzed the circulation patterns in the lower troposphere and dust initial source and transport. Thus visibility decrease is one of the major specifications of dusty systems. In some regions of Sistan and Balochestan province there are 120 winds blowing days. Alijani (1997) quoted that in this province frequency of dusty days are more than 150 days per year.

In regions at west and south west of the country that stand at the vicinity of major deserts, frequency of dusty days is also important and the average of these days is 15 per year. Studies showed that frequency of dusty days in August are more than other months. Average of dusty days in Khoramabad is reported 14.2 days at (1961-2003) period and frequency occurrence of these days is increasing from March to July. The pollution intensity by rising dust in Khozestan and Lorestan provinces is because of the sand storm occurrence in Iraq and Saudi Arabian countries which make serious difficulties in these provinces. These occurrences are increasing in recent years. For example this phenomenon occurs at 16 April 2009 and lasted to 18 April. Department of environment reported that at 16April 2009 air pollution in Lorestan province was 1.5 times of standard limit and has reached to 7 times in next two days (2009/04/18, IRIB). The main cause of this phenomenon is desiccation of many ponds and existence of deserts in eastern Mediterranean countries, Iraq and Saudi Arabia. Meteorological office of Lorestan province said that the densest of dust were reported in Alashtar and Khoramabad (Sarmayeh Magazine, 18/04/2009). Frequent occurrences of the phenomenon in Lorestan province tend to that the environmental authorities request help from the decision making center.

Geographical and climatological situation of the study region show that precipitation is significant and the vegetation covers is in a suitable condition so the region does not include as a source of rising dust. As a result, the source of dust that observed in the region is from other countries.

Besides, the study area is on the entrance path of low pressures and bringing dust systems to the country. During recent years in west and southwest of the country dust storms has increasing trend and make some difficulties in hygiene, agriculture, and transportation. The object of this research is to analysis synoptical patterns of dust storms in west and southwest regions of the country. First time occurrence of dust storms is classified and then genesis and severity conditions of them were considered from the synoptical view point. Then prediction of time and spatial occurrences of these storms is the major object of this study.

2. Materials and Methods

The violent winds and reduced visibility heavily influence traffic, aviation, construction, and can even cause great loss of human life and property damages.

In order to determine dusty days, return books of synoptic stations were studied at the period of 1999-2008 for five synoptic stations including Ahwaz, Abadan, Khoramabad, Ilam, and Kermanshah. Table (1) shows geographical characteristics of the stations. In this study days with wind velocity above 10 m/s and horizontal visibility less than 1000 meter, and dust as a predominant phenomena, were identified as a dusty day. By this definition 191 days with dust storms were identified and listed in the period.
Then date of start, persistency, intensity, and spread of storms were extracted in the study region. To recognize widespread dust storms, visible images of MODIS were used.

Table1. Geographical characteristics of the stations

Number	Station	Longitude (° ')	Latitude (° ')	Elevation (m)
1	Ahwaz	46 26	33 38	22.5
2	Abadan	48 15	30 22	606
3	Khoramabad	48 17	33 26	1147.8
4	Ilam	46 26	33 38	1327
5	Kermanshah	47 09	34 21	1318.6

In this relation a picture of dusty days at 7 and 8 August 2005 is shown in (Figure1). Although reports describe the dust as orange at ground level, but it appears light beige in both of these images. The storm swept southeast through Iraq toward the Persian Gulf with the city of Baghdad in the middle of its path. Some of the dust spilled eastward across the border of Iraq into Iran (NASA).

In order to study and classifying dust storm synoptical patterns, daily data were extracted from National Center of Environmental Prediction (NCEP), in 850 hPa and sea level pressure at 1200 UTC, in days with dust. Then a network consist of 408 point with 2.5 degree resulation which cover a territory by 20 to 60 northern and 20 to 80 eastern degree, were considered for synoptical pattern classification of days with dust storm. Figure 2 shows Geopotential height data at 850 hPa and sea level pressure related to this network are considered as the base of calculations. In order to study variations such as wind component pattern related to dusty days, composite maps for NCEP data were used.

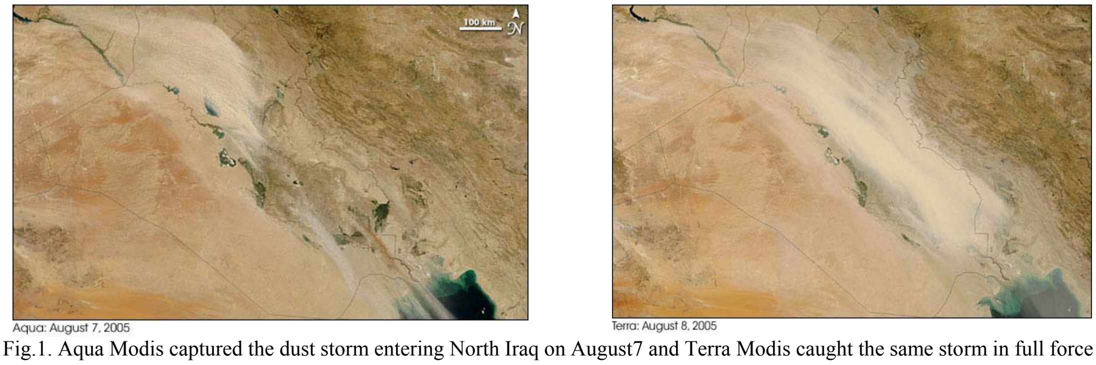

Fig.1. Aqua Modis captured the dust storm entering North Iraq on August7 and Terra Modis caught the same storm in full force on August 8

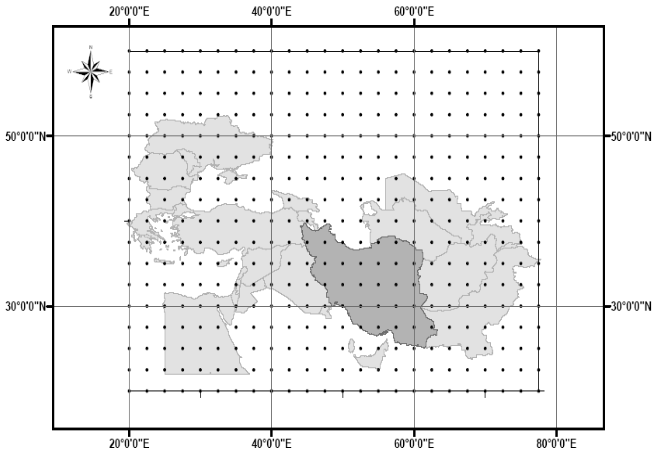

Fig. 2. Network of sea surface and 850 hPa level pressure data with 2.5 x 2.5 resolutions in study region

By performing Principal Component Analysis (PCA) on extracted data from dusty days (191 days), four components obtained which cover 83.2 percent of the variables. Virtually through loading related components and by using of clustering method, days with the most similarity in geopotential height, at 850 hPa and sea level pressure, were identified.

Consequently three circulation patterns for all dust storms were obtained and named CP1, CP2, and CP3. Average of sea level pressure and 850 hPa were calculated during dusty days at any circulation patterns. Then average charts of any pattern along with low and high pressure centers at sea level pressure and flows at 850 hPa were analyzed.

3. Results and Discussion

Study of selected dust storm samples show that extracted information presents three general synoptical patterns.

Any type pattern was studied at sea level pressure and 850 hPa level as follows:

CP1, sea level pressure:

A low pressure center is closed with 1000 hPa at south eastern of Red Sea. This center extends from south west to the north and north east. Another low pressure trough is seen at the north east of Caspian Sea (Figure 3).

A high pressure center is closed with 1017 hPa at the regions of north east of Europe especially north west of Black Sea. Also a high pressure center is closed with 1025 hPa at north east of Afghanistan or south of Balkhash. By considering this pattern, cold air moves from north to south, between the low pressures located over the north east of Caspian Sea and the high pressure over Eastern Europe. These flows influence north and east areas of Iraq. Also warm air, in front of the cold air, is transferred from southern latitudes to the northern latitudes. This situation cause to increase pressure gradient over south east of Turkey and north of Iraq. Consequently wind blows severely in ground surface and transfer dusts from surface to higher altitudes (Figure 4).

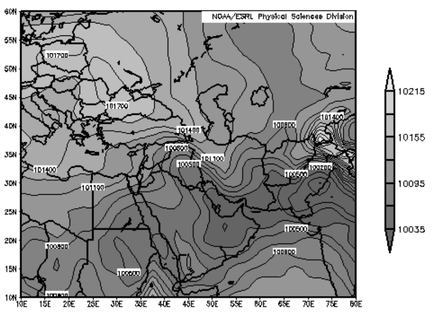

Fig.3. Synoptical pattern governs at sea level pressure in days with dust (first type pattern)

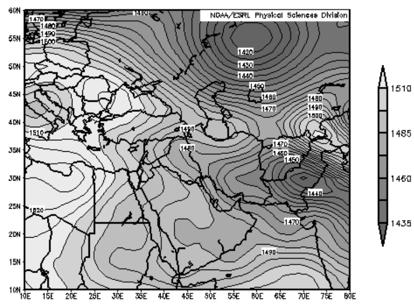

Fig. 4. Synoptical pattern governs at 850 hPa level in days with dust storm (first type pattern)

CP2, sea level pressure:

A low pressure center less than 1000 hPa is closed at the south west regions of Red Sea. Another low pressure center less than 1004 hPa is closed over east of Arabian Peninsula (Figure 5).

Easterly flows are seen at the North side of the low pressure that comes from Oman Sea to the north of Arabian Peninsula, Persian Gulf, and south of Iraq. This situation caused to transfer warm air from south part and also from north east of Arabian Peninsula to north part of Arabian Peninsula and south of Iraq. High pressure more than 1020 hPa is extended over north east of Afghanistan. Southern side of this High pressure transfers the Siberian cold air to the east part of Iran. Then pass the Caspian Sea and by cutting the Alborz Mountain extend to the south of Kerman and back to the west part of Iran and north of Iraq. Thus pressure gradient is increased over ground surface in west parts of Iran especially north of Iraq. In this case pressure gradient is about 10 hPa between north and south of Iraq.

CP2, 850 hPa level:

In this chart a deep trough is seen over the Black Sea which extends to east of Turkey and north of Iraq. This trough is influenced southern regions of Iraq and Arabian Peninsula. Thus west side of the trough transfers the Scandinavian cold air, from more than 55º latitudes, to south part of Iraq and Arabian Peninsula (Figure 6).

What is important here is the west branch of this trough that moves the cold air up to the north of Arabian Peninsula. Also a center of high contour more than 1520 gpm is seen at north east of Afghanistan. This center caused to flows south easterly currents over east, center, and south west of Iran. By considering this situation, currents ahead of the trough are usually south westerly, north easterly, and southern which can transfer warm air from southern latitudes to the northern regions.

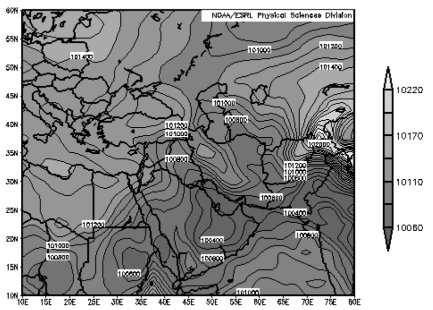

Fig.5. Synoptical pattern governs at sea level pressure in days with dust (second type pattern)

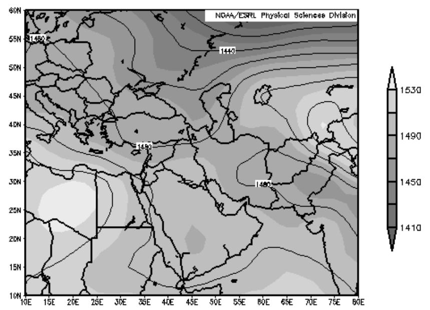

Fig.6. synoptical pattern governs at 850 hPa level in days with dust storm (second type pattern)

CP3, sea level pressure:

A low pressure center with less than 1004 hPa is seen at north east part of Arabian Peninsula. Another low pressure center is located at south west regions of Red Sea which extends to the north east (Figure 7).

A high pressure is seen over the north of Eastern Europe which is extended up to northern regions of Turkey. Also a high pressure center is closed over the north east of Afghanistan with 1024 hPa. This high pressure is merged to the high pressure located over Europe and creates an axe from east to west. South side of this high pressure is extended diagonally from east part of Golestan province to Semnan, Tehran, and then Azarbaijan provinces with approximately east west flows. Thus there is a cold air current over this isoline. By moving to lower latitudes, cold air downfall decreases. But east west flows continue to southern part of Iran, Iraq, and Syria. Also in this pattern, like two others, relatively maximum pressure gradient is seen at northern regions of Iraq and south of Turkey. Downfall of cold air occur from Anatoly mountain slopes to north of Iraq. Relatively violent pressure gradient in this region cause to blows sever winds and consequently cause to create sand storms.

CP3, 850 hPa level:

A high contour with more than 1540 gpm is closed over north Europe which after crossing black sea and center of Turkey is extended to east of Mediterranean Sea and continue up to center of Jordan. Another high contour with more than 1540 gpm is closed over south of Mediterranean Sea. These two high contour centers are extended around fifteen degree east longitude. A high contour with more than 1540 gpm is closed over north east of Afghanistan. South side of this high contour after passing from center of Afghanistan is extended to Khorasan province and then to south east of Caspian Sea and Azarbaijan republic (Figure 8).

The high contour over north east of Afghanistan and high contour over north Europe caused to create a flow in the form of a narrow trough over west part on Iran, center of Iraq, and south of Turkey. This trough is clear better at 700 hPa level. Thus cold air at behind of this trough and relatively warm air transfer at in front the trough caused to increase pressure gradient at ground surface over north part of Iraq, west Iran, and south Turkey. Consequently blowing of sever winds can transfer fine dust to the upper layers. Also in this case, cold air especially at mid troposphere and relatively warm air at lower layers caused to increase lapse rate of temperature and tend to local instability.

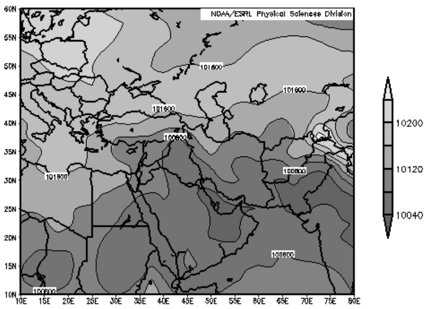

Fig.7. Synoptical pattern governs at sea level pressure in days with dust (third type pattern)

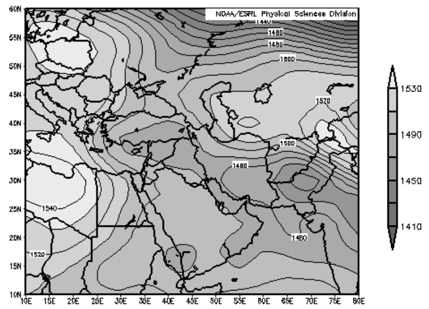

Fig.8. Synoptical pattern governs at 850 hPa level in days with dust storm (third type pattern)

4. Conclusion

Results of the synoptical pattern investigations in dusty days at study region are as follows:

- One of the conditions in forming dusty days is existence of a trough in 850 hPa charts, between 30 to 45° E longitudes that extends at least to 25°N latitude and lower. Because of cold advection in behind of the trough from mid latitudes to the south, and warm advection in ahead of it from south latitudes to the north, increasing of pressure gradient and wind velocity at ground surface is observed. In this case dust particles depending on their size, arise to the air. Since air motion is not horizontal and moves on the isentropic surface, thus dust particles shift gently from low altitudes to high elevations, from north of Arabian Peninsula to the south, south west, and central part of Iran or from north of Iraq and Syria to the west, north west, and central part of Iran. Because of above mentioned, dust thickness increase from south to north as can reach to 10000 feet in the study area. This transformation depends on the wind speed, wind direction, size of particles and lack of rainfall at least 15 days before reaching the trough.
- Existing at least one relatively strong low pressure on the north of Saudi Arabian Peninsula at sea surface charts, associated with a trough over red sea or west of Arabian Peninsula at 850 hPa level, and extending to the west, south west and the region under study in Iran. This situation is one of the most important specifications of dusty days. This low pressure cause to increasing pressure gradient on the north of Saudi Arabian Peninsula and south west of Iran.
- Position of troughs at 850 hPa level are in a form that they can lead and send the air masses from deserts in north of Saudi Arabian Peninsula, Iraq, Syria and Jordan to Iran. Because these areas are at the front of the trough which is very unstable.

References

Alijani, B., Synoptical climatology, University of Payame Noor press, Tehran, in persian.

Dayan, U., 1986. Climatology of back trajectories from Israel based on synoptic analysis. J. Climate App. Meteor., 25:591-595.

Engelstadler, S., 2001. Dust storm frequencies and their relationships to land surface conditions. Freidrich-Schiller University press, Jena, Germany.

Fany, Z. Y., F. K. Zhou, J. X. Jiany and Z. A. Qian, 1997. China dust storm research, China Meteor. Press, Beijing, China, 158pp.

Gillette, D. A. 1979. Environmental factors affecting dust emission by wind erosion in Saharan dust, Ed. Morales, C., John Wiley and Sons, New York, 71-94.

Goudie, A., Midelton N. J., 2001. Saharan and dust storms, nature and consequences, Earth Science Review, 56: 179-204.
Habibinokhandan, M., 1997. Climate and architecture with especial reference to Middle East architecture, Geographical Research Journal
Hematy, N., 1995. Study of dust storm frequency occurrence in central and south west regions of Iran, M.S. thesis, Geophysics Institute, University of Tehran, in Persian.
HoseinZadeh, S. R., 1997. 120 days wind in Sistan, Geographical Research Journal No. 46, in persian.
IRIB, 2009/04/18. Code: 440470
Kalu, A. E., 1979. The African dust plume: Its characteristics and propagation across West Africa in winter, Saharan Dust, obilization, Transport, Deposition, SCOPE
Kaviani, M. R., 2001. “Microclimatology”, SAMT press, Tehran, in Persian.
Marcal, G., 1980. Meteorology of the Persian Gulf and of several airports on the Arabian Coast, FTD-ID
(RS)T-01 13-85, Foreign Technology Division.
Marjany, S., 1993. Synoptical study of severe winds more than 15 m/s in Khorasan, in Persian.
Middleton, N. J., 1986. Dust storms in the Middle East, Journal of No. 46, in Persian.
Noohi, A., 1994. “General eteorology”, Iranian Meteorological Organization, in Persian.
Orlovsky, L., M. Dourikov, and A. Babaev, 2004. Temporal dynamics and productivity of biogenic soil crusts in the Central Karakum Desert, Turkmenistan. Journal of Arid Environments. 56 (4): 579-601
Qian, W., L. Quan, 2002. Variation of the dust storm in China and its climatic control, Journal of Climate, 15, 1216-1229.
Qian, Z. A., Y. Cai, C. M. Liu, J. T. Lin, D. L. Li, and M. H. Sony, 2004. Some advances in the dust storm research in North China, Journal Desert Research 22, 106-111.
Sarmaye magazine, 2009/04/18. No.988
Walter, S., Burgmann, 1991. Dust and sand forecasting in Iraq and adjoining countries, National Technical Information Service.
Wang, W., 2005. Synoptic model on East Asian dust emission and transport. Atmospheric science and air quality conference , Beijing.China.
Zolfaghari, H., and H., abedzadeh, 2005. Synoptical analysis of dust systems in west regions of Iran, J. Geography and Development, 6:173-188, in Persian.