Int. J. Environ. Res., 9(2):673-682, Spring 2015
ISSN: 1735-6865

Analyzing and Tracing of Dust Hazard in Recent Years in Kermanshah Province

Akbary, M.* and Farahbakhshi, M.

Department of Geographical Science, Kharazmi University, Tehran, Iran

Received 25 July 2014; Revised 7 Nov. 2014; Accepted 13 Nov. 2014

ABSTRACT: Different patterns of pressure systems together with local factors, leads in generation, rising and spread of dust in West of Iran. In this study, to investigate the factors causing the occurrence of dust in Kermanshah province, 132 cases of dust phenomena (code: 06) were selected and analyzed using Kermanshah synoptic station data for the spring and summer seasons in a period of 5 years (2005-2009). The Factor analysis had been implemented and days with higher correlation coefficient extracted, then clustering operation was performed on the data. 4 dust emission patterns were identified and from each pattern, a certain pattern was selected as a representative day. Using GRADS and NCEP data, maps of geopotential heights, wind speed and vorticity advection were produced and analyzed. To identify the source of dust generation, tracing and simulating the path of dust, HYSPLIT model Lagrangian approach of backward trajectory was used. Generally existence of low pressure cells in the central and southern regions of Iran can lead to the convergence and air intake at near ground levels and strong positive vorticity, which result in cyclonic movements in western regions of Iran Including Kermanshah. These results in the transfer of dust from the dry desert areas of Iraq and high speed winds in the lower levels of dust particles in the region has accelerated the transfer rate. Based on the HYSPLIT outputs, major sources of dust generation, were arid zones of Southern Turkey, Iraq deserts, Syria, North East of Saudi Arabia and Kuwait.

Key words: Dust, Kermanshah, HYSPLIT, Tracing, Synoptic

INTRODUCTION

Dust emissions in the atmosphere is considered to be one of the most common hazards of climate and most important environmental problem in arid and semiarid regions of the world, especially the Middle East. This, of course will occur in many parts of the world but statistical reviews showed the frequency of occurrence of this phenomenon in arid and semiarid regions (Alijani, 2002). It should be noted that dust is an important climate component that role in the physical and biochemical interactions of atmosphere, land and water (Shine and Forster, 1999). According to Fung and Tegen (1995), an increase of dust in the atmosphere leads to changing patterns of land use for areas that have been exposed to it.

One of the most important environmental impacts of dust in the atmosphere is its major effect on climate condition and air quality. This phenomenon can affect the temperature, absorption and distribution of solar radiation, changes in shortwave radiation and outgoing long wave radiation from the Earth's surface (Takemi and Seino, 2005). In recent years, much research has been done in relation to areas that have the potential to generate and emit dust and specific regions of the globe, including the Middle East have been identified as the center of the generating and emitting dust . Earth conditions and soil type, vegetation, influence of mountains and surface water with the perspective of containment and anomalous removal of water resource, the construction of dams and river diversion, rainfall decrease and droughts, and even occurrence of wars, especially in recent decades, are including factors that directly affect the generating of dust particles. Every year in Iran, a large part of the country, particularly the western and southwestern parts of the country are affected by dust risk. Based on previous studies, the major source of this phenomenon can be known as the neighboring regions specially the deserts of southern Iraq and Saudi Arabia, and at longer distances Syrian deserts and North Africa. As a UNEP program mentions occurrence of drought in the South West region of Iran and neighboring countries such as Iraq with surface and subsurface moisture loss, vegetation loss and development of the sedimentary area and superfine in these areas,

*Corresponding author E-mail: mehryakbary@khu.ac.ir

considered to be the foremost intensification reasons this phenomenon. In addition, human factors, such as the successive wars in the region and construction of dams on the rivers leading into the basin of Mesopotamia (Iraq) by countries in the region, are among the factors affecting the frequency of dust events in the region. Considering the importance of dust hazard and the problems that arise from its spread in recent years, conducting such research is necessitated. Analysis of Statistical data, identification of sources and routes of entry of dust, in further identification of this phenomenon and However anticipating of this event in local and regional planning can lead to lower costs and create physical and psychological readiness to cope with damaging effects.

In the context of climate risk, numerous studies have been performed worldwide and in Iran, which a few examples are mentioned hereunder. Goudie and Middleton (2001) have done an extensive research on cyclical changes in dust phenomena on a global scale using data from synoptic stations and concluded that there is no certain pattern of dust phenomenon cyclical changes. Zhao *et al.*(2006) based on statistical studies found out that the annual average occurrence of dust storms in China during the years 1980 to 1997 declined and then until 2000 followed a rising trend resulting from the relation of the frequency of occurrence of dust storms with an average decrease in rain and relative temperature increase. Jacques *et al.* (2006) examined how to detect and track the dust storms by using satellite imagery bands of MODIS infrared band. Weihong *et al.* (2001) have studied on the phenomenon of dust in Seoul and showed that most dust events have occurred in the spring and April and this phenomenon was more severe. Also found that by creating a strong pressure gradient arid region between China and Mongolia, leading to stronger winds and dust storms in the region has been. Also found that by creating a strong pressure gradient in an arid region between China and Mongolia, it leads to stronger winds and dust storms in the region. Mao *et al.* (2011) had studied synoptic reports of a 40-year period (1960-1999) and concluded that the Mongolian Gobi is considered to be the most important source of dust in East Asia. Other similar studies such as Zhang (2006), Chun *et al.* (2001), Qian *et al.* (2002) Natsagdorj *et al.* (2003) and Shao and Wang. (2003) are performed for East Asian climate and synoptic analyzes of dust storm. . Also Lim and Chun (2006) in a research have analyzed the characteristics of Asian dust in Eastern part in spring during the period 1993-2004, using hourly data and based on two normalized difference vegetation and the dust storm. At the national level, Alijani (2002) beside of studying the causes of dust in Iran has provided the zonation map of the spatial and temporal occurrence of this phenomenon. Zolfaghari and Abedzadeh (2005) examined the synoptic dust emissions systems in West Iran in a five-year period and concluded the troughs and westerly winds migratory cyclones and low-pressure thermal ground, is the effective factor in occurring dust and transferring it to the Western part of Iran. Also Zolfaghari *et al.* (2011*)* studied dust Storms in western regions of Iran from 2005 to 2010 synoptically and investigated the widespread wave of July 2009. Lashkari and Keykhosravi (2008) implemented a statistical - synoptic analysis of dust storms in Khorasan Razavi province and on the basis of their results, most dust storms formed after 12 p.m. and thermodynamic factors are effective in the formation and spread of dust and local factors are effective in intensifying them. Khosravi (2010) by using a model of NAAPS, investigated the vertical distribution of dust in the Sistan province and be based on the results of his research, boundary changes of the vertical distribution of dust, which has a circadian period that the maximum of it is affected by motion of transition during the middle days and the minimum can be seen at night. In another research, Khosravi *et al.* (2010) with identifying the synoptic atmospheric patterns, determined the influencing factors on dust events in the Khuzestan province (from 1996 to 2005) and by dividing synoptic patterns into two categories of cool and warm, concluded that in the cold period, the migrated west winds systems and Polar Front jet stream and in warm period of the year, thermal-low-pressure are the effective factors in producing dust.

In recent studies, the results of Mofidi and Jafari (2011) Studies, which has done with utilizing a HYSPLIT Lagrangian model, show that in general, the main sources of dust for dust storms in the South-West Iran, is the area between the center to north of Iraq, East of Syria to North of Saudi Arabia, in three patterns such as paired summery, paired transitional and western wave trough, dust particles in a layer of low life expectancy and in the lowest layer of the atmosphere is transferred to the region; with this difference that in the two western trough and paired transitional patterns, high pressure share of Saudi Arabia in controlling of entering dust to the South West region of Iran is more that the share of this center in paired summery pattern. In another research Kais and Morwa (2013) using satellite images, aerosols index and synoptic weather maps, analyzed dust storms occurrence in Iraq and the results showed that dust storms form when a low-pressure system forms over Iran which can lead in blowing Shamal winds; which carry cool air from that region toward warmer regions like eastern Syria and Iraq.

Hamidi *et al*. (2012) in an article entitled synoptic analysis of dust storms in the Middle East, using MODIS satellite images and synoptic analysis, confirmed that the Shamal is related to the anticyclones located over northern Africa to Eastern Europe and the monsoon trough over Iraq, southern Iran, Pakistan and the Indian Subcontinent. Azizi *et al.* (2002) in an article entitled tracking dust phenomenon in the western half of Iran by using HYSPLIT model precede to trace the path of dust particles for days after the first entering the area and reached the conclusion that the change in direction of flow in the region causes changes in the transition of dust path to different regions of the western half of Iran and finally by debilitation of the flows and cutting off the sustenance route of entering dust to Iran, this phenomenon can be eliminated.

MATERIALS & METHODS

Kermanshah city is surrounded by some mountains which are from north by Farokhshad Mountain, from northwestern by the Taq-e-Bostan Mountain and from south by the White Mountain. Kermanshah Province is located in the east longitude of 47° 4'E and latitude of 34° 19' N and has 24,500 square kilometers area and a height of 1200 meters above sea level. Land distance of Kermanshah to Baghdad is 390 Km and to Tehran is 590 Km and to Khosravi border (border of Iran and Iraq) is about 200 km and air distance is 413 km to Tehran. According to the conducted researches, the most important factor in air pollution of Kermanshah is dust from the deserts of neighboring countries that causes shutting down of offices, schools and canceled flights due to the extreme decreases in sight ability in some days. The view visibility in some days dropped from 100 to 200 meters and on 5 July 2009, pollution reached to 21 times above pollution limit; that causes dozens of people to be hospitalized due to respiratory and cardiac problems. This phenomenon has also caused severe damage to oak forests, destroying vegetation and drought in region. In this study, a combination of statistical techniques, synoptic and simulation and a model used to examine the phenomenon of dust for a statistical period of 5 years (2005-2009) (Table. 1).

First, according to the position of Kermanshah synoptic station at the entrance of the dust storms to the country affected by Iraq and Syria, daily data were taken - for Kermanshah synoptic stations with an interval of three hours and processed. After determining the number of days with dust events (Code No. 06) from IRIMO[1] for the first half of year (April and September) occurrence frequency table (Table 1) were prepared. In the next step, 132 dust events recorded at selected stations, using MATLAB software, principal component analysis and extracting days with a correlation coefficient greater than 0.7, the clustering was carried out on the data and each cluster was chosen as representative of each group. Furthermore to identify the source of dust and tracking the path of the dust particles, Lagrangian approach of HYSPLIT Model was used. This model which is one of the distribution and transport of atmospheric pollutants models, has the most frequently usage in large-scale studies and is designed and developed by the National Oceanic and Atmospheric Air Lab of United States. In Lagrangian approach, the particle essentially is considered on the equator and pursued it until its destination and in fact it will illustrate the movement of a particle in a given time period. Actually to reconstruct the path of the dust particles there is two methods, navigation and backward methods and in this study the backward method is used. For represented days in each group, with a correlation coefficient of 0.7, by using this model for tracing the path of the dust particles movement was done and finally, after obtaining the required data with a resolution of 2.5× 2.5° from the NCEP/NCAR, Synoptic maps of the pressure levels of 850, 700 and 500 hPa, vorticity maps, and wind velocity and direction by using of programming in GrADS software were drawn and then analyzed.

Table 1. Frequency of dust storm event in each month

Year	April	May	June	July	August	September
2005	1	*	3	6	4	*
Frequency%	7.1	*	21.4	42.9	28.6	*
2006	*	*	*	*	1	*
Frequency%	*	*	*	*	100	*
2007	3	*	1	7	5	*
Frequency%	18.8	*	6.2	43.8	32.2	*
2008	8	6	9	11	5	8
Frequency%	17	12.8	19.2	23.4	10.6	17
2009	2	8	12	21	7	4
Frequency%	3.7	14.8	22.2	38.8	13	7.5

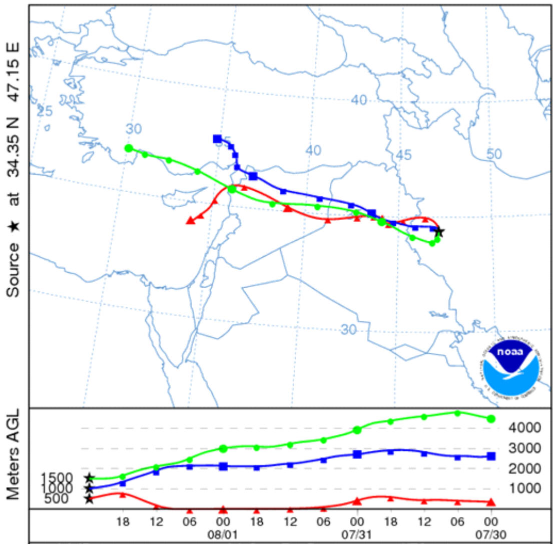

Fig. 1. The Outputs of HYSPIT model and tracing dust storm of 02/08/2009

RESULTS & DISCUSSION

As shown in Table 1, generally, , 132 cases of dust events were occurred at selected station in recent years and the occurrence of dust has increased from 14 cases in 2005 to 47 and 54 cases in 2008 and 2009, respectively. The most frequent seasonal and monthly scale is connected to the summer, especially July. Synoptic maps analysis - showed that the relative humidity of the atmosphere in the region, minimized and evaporation maximized. Excessive dry air with high temperature and creation of high surface pressure above the dry deserts of Iraq and Syria causes the particles to rise and carries them into the other areas. As mentioned earlier, in the analysis of the synoptic station of Kermanshah, the most common occurrence of dust was in 2009 that it can be justified due to the intensification of the storm by Iraqi origin due to the gradual increase in stiffness due to the recent war in this country which consequently led to the intensification of soil erosion and ultimately increase wind erosion in deserts in this region.

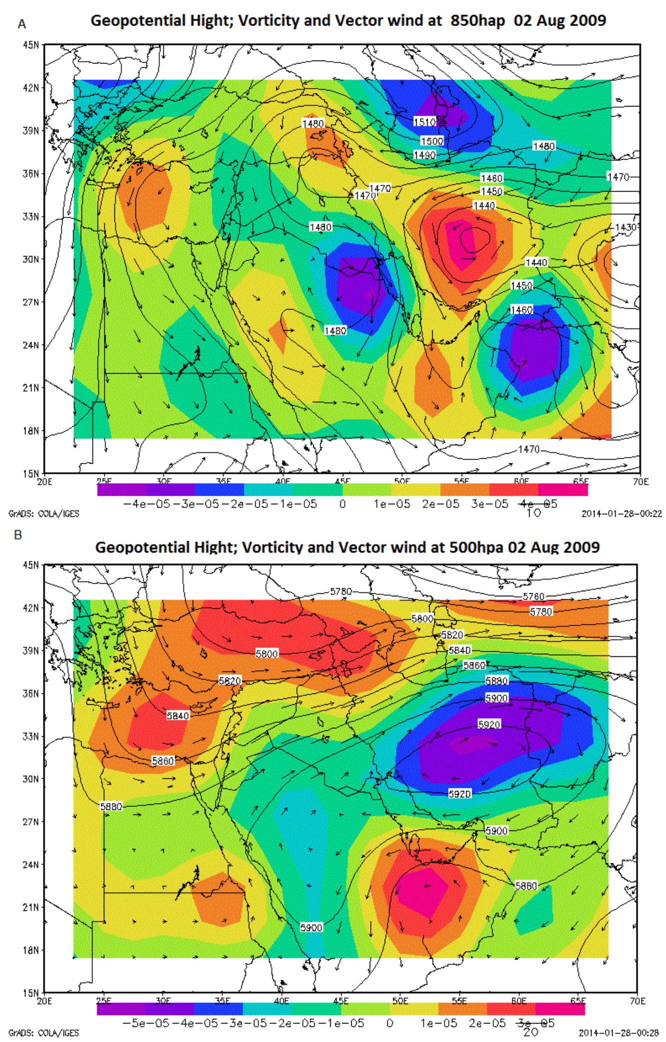

Fig. 2. Geopotential height, vorticity and vector wind maps at 850(A) and 500 hpa (B) in 02/08/2009

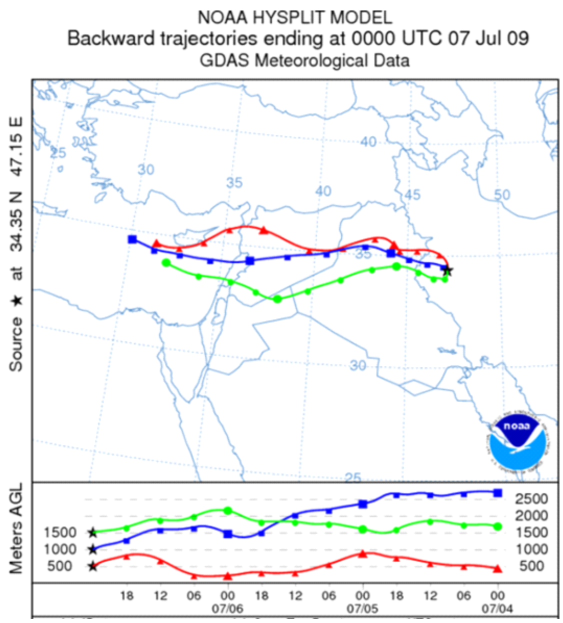

Fig. 3. The Outputs of HYSPIT model and tracing dust storm of 07/07/2009

The output of HYSPLIT model for the first pattern is shown in fig.1 to verify dust particles of storm path on 08.02.2009 as a representative of the first group, for the three altitudes of 500, 1,000 and 1,500 meters. In this model, the origin of the dust in the studying region has been the Dust Belt based on southern Turkey, Syria and Iraq. The air mass located in 500 meter altitude on that day, had been in the elevation of less than 500 meters in the area 48 hours earlier. The air mass entered the province from the North West of the province (Paveh County), while the masses that are located in the vertical distance between 1000 and 1500 m above the ground level, entered from the West part of the province (Qasr-e Shirin and Sarpolzohab); This two masses of the air has slower speed in contrast with the air mass at lower altitudes which entered the province. So the air mass which is located at 1000 meters from station enters the province 12 hours earlier and the air mass at 1,500 meters from the station enters 18 hours earlier while at the lower level of 500 meters, this difference has been only 6 hours. This time delay can be caused by the direction of the masses entered

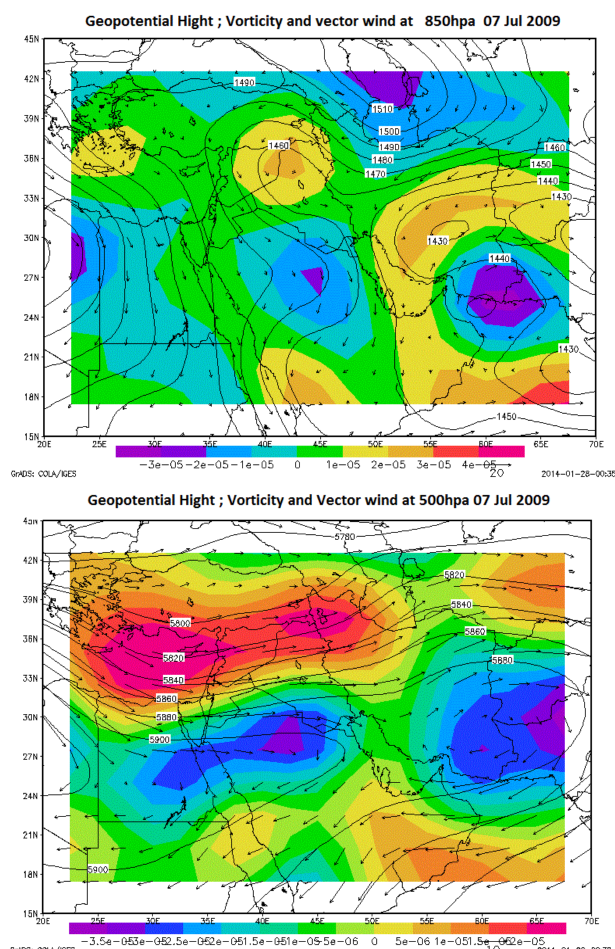

Fig. 4. Geopotential height, vorticity and vector wind maps at 850 (A) and 500 hpa (B) in 07/07/2009

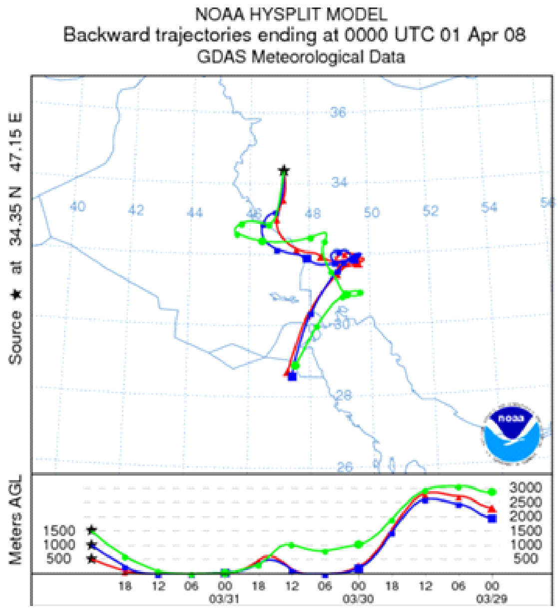

Fig. 5. The Outputs of HYSPIT model and tracing dust storm of 01/04/2008

the province. First air mass (the lowest level) oriented from the North West to South east that according to the orientation of the mountain ranges in North West of the Province, this mass has higher speed due to the passing through the mountains but the other two masses were perpendicular to the Zagros highlands and friction caused by mountainous obstacles has led to a decrease in their speed. Permanence of air mass in the region will cause air resistance, and also subsiding of heavy dust particles.

Synoptic maps of 02.08.2009 as the first group were Analyzed and according to 850 hPa level map (Fig. 2-A), there are low-pressure cells in the center of Iran, south of Pakistan and over Saudi Arabia in this day, that covered the southern half of the country and parts of Iraq. This led to the convergence and air intake at ground surface and divergence in higher levels. Existence of negative vorticity in southern Iraq and relatively strong positive vorticity in the inner regions of Iran caused the cyclonic movements which are resulting wind with orientation of northwest in western ar-

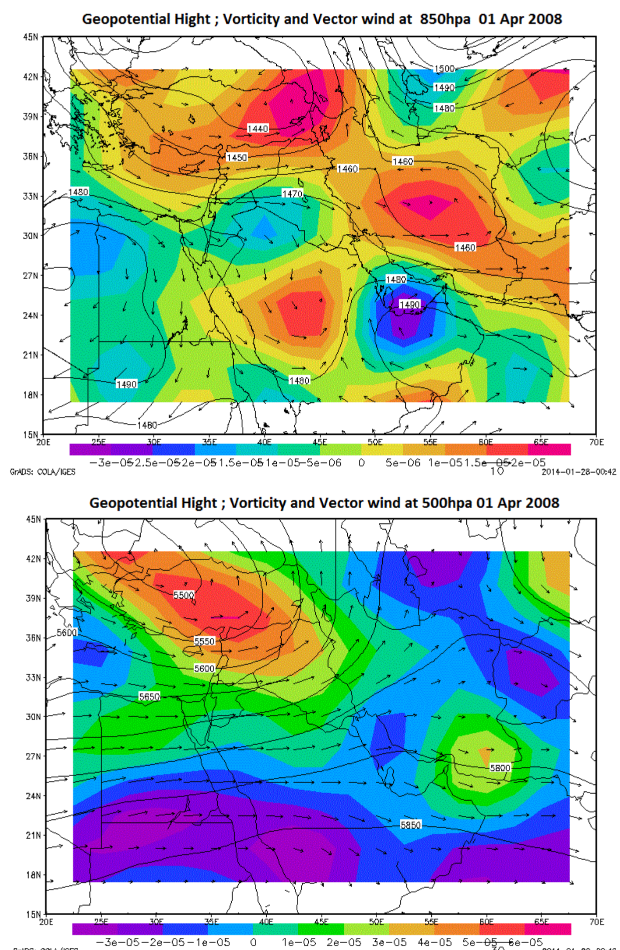

Fig. 6. Geopotential hight, vorticity and vector wind maps at 850 hpa (A) and 500 hpa (B) 04/01/2008

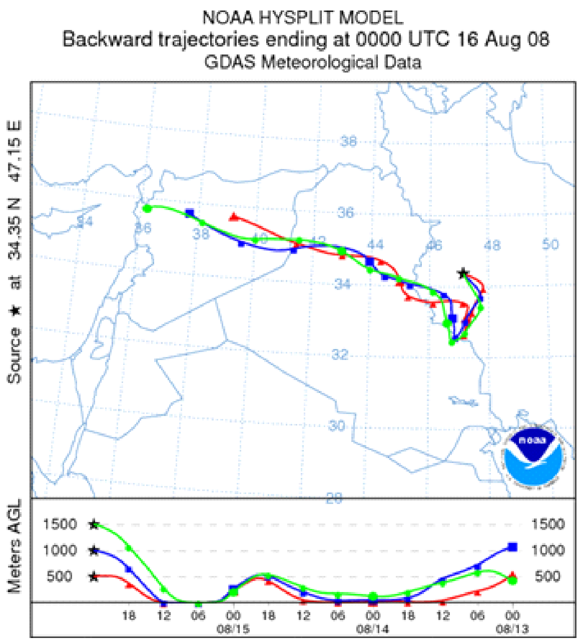

Fig. 7. Dust storm outputs of HYSPIT backing ward model in 08/16/2008

eas of Iran including Kermanshah that result in the transfer of dust from the dry desert areas of west of Iraq to the western areas of Iran. There are also arrows on the map which confirmed the high wind speeds at this level that were effective in faster transferring of the dust particles to the Kermanshah station. As can be seen in fig.2-B, a relatively deep trough is located on the West and North West of Iraq that its eastern extent has been drawn up to the North West of Iran. In the eastern part of the trough that the air movements is along with convergence and positive vorticity advection, is leading to a sharp rise of the dust particles and northwest winds orientation in Iraq regions and northwestern Iran is causing transferring of the dust particles by Western masses into the studying area. The existence of a strong negative vorticity in the East of Iran is leading to the creation of anticyclone weather movement in these areas that is causing major effects on navigating and strengthening winds in this level.

Fig. (3) is the output of HYSPLIT model for evaluating the track of storm's dust particles on 07/07/2009 as a representative of the second pattern.

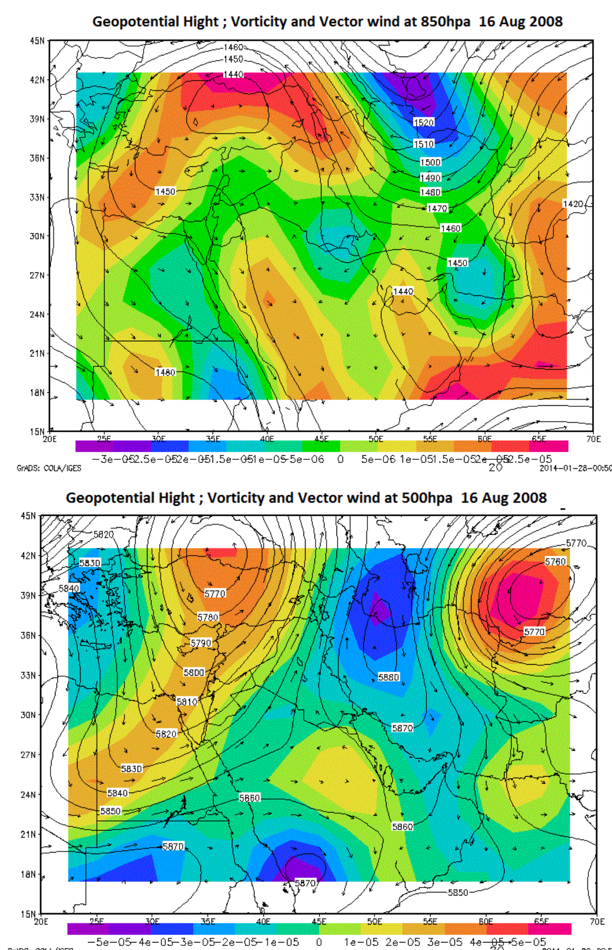

Fig. 8. Geopotential height, vorticity, vector wind maps at 850 hpa (A) and 500 hpa(B) 16/08/2008

The figure suggests that the origin of dust in this pattern is the Dust Belt which is the deserts of Syria and Iraq. In this image, particles have entered the province with a height of 500 m (red lines) from the north and northwest. The height of these particles in the 48 hours prior to the stormy day was less than 500 meters and about this time by crossing the Iraqi hot and dry West desert was denser and horizontal view visibility in this day (7 July) markedly reduced compared to previous days. Particles of this height at the reaching time to the Kermanshah station have been at an altitude much higher than the previous day (more than 500 meters from ground level). Regarding the track of the particles at height of 1000 meters (The blue color) it can be seen that these particles in the 72 hours earlier were located at 2500 height and by arriving to the day of crisis, the height of it reduced eventually. Meanwhile, the particle at arrival in Iran and Kermanshah station has Western orientation than the particles at height of 500 meters. Particles at height of 1,500 meters in the last 48 hours have passed through the center area of Iraq, but it has not much height changes than the day before and after and entered the southwest side of the city of Kermanshah. In this model, the particle at higher height moved faster than those at lower height and entered Kermanshah province earlier.

In the synoptic map of 850 hPa level of 7th of July 2009 as a representative of second group (Fig. 4-A) as representative of the second group, isobar lines, show the existence of an extensive low pressure system in southern Iran and Iraq that its center is located on the central region of Iran. This low pressure with positive vorticity of northern Iraq has caused rising air and the impact on winds direction, so that the main direction of the winds was on the western part of the studying area and like the first pattern, causes transfer of dust particles to the North West and the West part of Iran. The map of 500 hPa level (Fig. 5-B), isoheights are more orderly than the previous model.

Over the Mediterranean Sea and west of Iraq, there is a not very deep trough that with strong positive vorticity in the northern Mediterranean, Iran and Iraq causes the Eastern Winds orientation as parallel lines with the isobar lines. The high speed of winds in this level and direction of their move were effective on the dust systems transmission toward Iran.

According to Fig. 5 related to the third pattern of HYSPLIT model's output, the origin of the dust in this model is the North East of the Arabian Peninsula and Kuwait. On this date (April) first spring dust has been reported in Kermanshah. The main route of entry of dust systems is at southern altitudes. Dust particles at an altitude of 500 meters over the past 72 hours, after crossing over Kuwait, entered Iran borders and in the last 48 hours have made turbulence over South West of Iran, especially in Khuzestan Province. At the same time (the last 48 hours) height of particles considerably reduced, the height of the particles was less than 500 meters from the last 48 hours to the day of the incident. Particles at altitudes of 1,000 and 1,500 meters also have a similar pattern. This means that the height of the particles reduced considerably in the past 72 hours, where as the difference of the velocity of the particles decreased by increase of the altitude, which seems to be caused by the friction of the Zagros Mountains on these systems.

According to the synoptic map of 850 hPa level in first of April 2008 as a representative of third group (Fig. 6–A) there are two low-pressure cells on the Black Sea and Mediterranean Sea, which also have affected the northern part of Iraq, and Iran. In addition, in this level, maximum positive vorticity has been observed in central part of Iran and the winds direction also shows the cyclonic circulation. These conditions caused the air to rise and based on the season of study and due to the lack of moisture, generated instability has led to the rise and distribution of dust particles in the atmosphere. The wind direction at this level is from the west of studied area (from Iraq). In the map of 500 hPa (Fig. 6–B), a low pressure center (trough) can be seen along the Mediterranean Sea that extends to the north of Iraq and North West of Iran. The existence of a low pressure at the surface of earth and a trough at upper level has led to creation of a thermal-low-pressure system in large parts of the region. Basically, movements of these thermal-low-pressure systems at the surface of the earth were very fast and occasionally cause shallow jet streams. In the fourth pattern, dust particles entered with south and southeast orientations to Kermanshah province. Path and height of the particles in this pattern are very close together. So, the particles at an altitude of 500 meters in their last 72 and 48 hours have a very low height and were close to the earth's surface and considerably reduced the horizontal view visibility. This is also true about 1000 and 1500 meters. The particle route (blue and green) during the last 72 to 48 hours were at height of 500 m near the Earth's surface that is due to the big and relatively heavy dust particles and low wind power for carrying these particles. As can be seen in Fig. 7, at all levels of 500, 1,000 and 1,500 meters at 6 a.m. of 16 August till 12 p.m., there is a severe height reduction (In these hours the dust system has not entered Kermanshah province yet) but hours after noon, Particle height has increased due to the topography in south of the city and the position of its roughness (White Mountain Heights) that have been effective in the navigating the path of the flow. The movement speed of particles at low altitude (500 m) was much higher than at high altitudes.

As can be seen on 850-hPa level map of 16 August 2008 as a representative of the fourth group (Fig. 8-A), a strong low pressure center formed over Pakistan and surrounded all the southern part of Iran and also Iraq and Syria on 16 August 2008. according to this map, the center of high pressure cell with relatively strong negative vorticity is located on the North East of the Caspian Sea and made the direction of winds to the anticyclonic movement so all the winds in the eastern region at this level have the northeast orientation and vice versa cyclonic movement and the positive vorticity on the Mediterranean Sea causes shifting of winds orientation over the Iraq in the way of west – east. In the map of 500 hPa level (Fig. 8-B) two deep troughs is visible which axis of one is located over the western parts of Iraq and Syria and created positive vorticity and the other is a trough which its axis is located over Iran and has created a strong negative vorticity. These two low height centers with their inverse verticities toward each other, causes an intense air intake and the presence of a ridge over the East and center of Iraq that made the winds direction in a southern direction. Wind direction in west of Iran is similar to Iraq. Necessary Thermodynamic conditions have led to air convergence and therefore transferring of dust particles to the higher levels and carrying them to farther area from their origin.

CONCLUSIONS

From the Synoptic view, in all four identified synoptic patterns in this study, centralization of the low pressure cells over the central and southern parts of the country led to the convergence and air intake over the surface of earth and divergence of air at higher levels; and the negative vorticity in the southern Iraq and relatively strong positive vorticity in inner regions of Iran caused cyclonic movements and airflow with western orientation in western region of Iran including Kermanshah, and this causes the dust transfer from the dry desert of adjacent areas in west of Iran and higher speed of wind at lower levels facilitates the transferring of dust particles to the region. In general, we can consider the reason of prevalence of the cyclones and troughs that causes dust pollution in the studied region to be the weakening of the governing high pressures dynamic over the region in hot season. The dominance of thermal-low-pressure systems in the vicinity of the surface particularly in the South West of Iran is another main factor of the occurrence of dust (the fourth pattern in this study) in the area.

Based on the outputs of HYSPLIT model, dust generating sources that enters the studying area includes arid regions of southern Turkey, the deserts of Iraq, Syria, North East of Saudi Arabia and Kuwait and identified routes for entering the dust were categorized as four models discussed in this paper which include the route to the west and northwest from southern Turkey, Syria and northern Iraq; Northwest route from the deserts of Syria and Iraq, the southern route from the North East of the Arabian Peninsula and Kuwait and the last route is the south and southeast route from the deserts of Syria.

It is noticeable that in northwest route (second model in this study) horizontal view visibility has reduced more sensibly than other routes.

REFERENCES

Alijani, B. (2002), Climatology of Iran, 1st Edition, Payam e Noor Publication, Tehran.

Azizi, GH, Miri, M, and Nabavi, O, (2002), Tracking dust phenomenon in the western half of Iran, Journal of Arid regions Geographics Studies, **2(7),** 63-81.

Fung, I. and Tegen, I., (1995). Contribution to the Atmospheric Mineral Aerosol Load from Land Surface Modification, Journal of Geophysical Research, **100(9),** 18707-18726.

Goudie. A.S. and Middleton, N.J. (2001), Saharan dust storms: nature and consequences, Earth-Science Review, **56,** 179-204.

Hamidi, M., Kavianpour, M.R. and Yaping, Sh. (2013), Synoptic Analysis of Dust Storms in the Middle East, Asia-Pacific J. Atmos. Sci., **49(3),** 279-286.

Kais J.A. and Morwa K.I. (2013), Analysis of synoptic situation for dust storms in Iraq, Journal of Energy and Environment, **4(5),** 851-858.

Khosravi, M. (2010), A Survey on the Vertical Distribution of Dust and in Middle East using NAAPS Model (Case Study: Sistan, Iran), the Forth International Congress of the Islamic World Geographers, **2010,** Zahedan, Iran.

Khosravi, M., Tavoosi, T., and Raeespur, K. (2010), Synoptic Analysis of Dust Systems in Khozestan province, Geography and Development Journal, **20,** 97-118.

Lashkari, H. and Keykhosravi, G., (2008), Synoptic and Statistical Analysis Dust Storm in Khorasan Province, Physical Geography Research Quarterly, **65,** 17-33.

Lim, J. and Chun, Y. (2006), The characteristics of Asian dust events in Northeast Asia during the spring time from 1993 to 2004, Global and Planetary Change **52,** 231-247.

Mao, R., Ho, CH. H., Shao, Y., Gong, D. Y. and Kim, J. (2011), Influence of Arctic Oscillation on Dust Activity over Northeast Asia, Atmospheric Environment, **45,** 326-337.

Mofidi, A. and Jaafary, S. (2011), The role of regional atmospheric circulation over the middle east on the occurrence of summer Dust storm in southwest Iran, Journal of Arid regions Geographic's Studies, **5,** 17-45

Natsagdorj, L., Jugder, D. and Chung, Y.S, (2003), Analysis of Dust Storms Observed in Mongolia during 1937-1999, Atmos. Environ, **37,** 1401-1411.

Qian, W., Quan, L.and Shi, S. (2002), Variations of the Dust Storm in China and its Climatic Control, Journal of Climate, **15,** 1216-1229

Shao, Y. and Wang, J.J., (2003), A Climatology of Northeast Asian Dust Events, Meteorologische Zeitschrift, **12,** 175-183.

Shine, K.P. and Forster, P.M.D. (1999), The Effect of Human Activity on Radiative Forcing of Climate Change: A Review of Recent Developments, Global and Planetary Change, **20,** 205-225.

Takemi, T. and Seino, N. (2005), Dust storms and cyclone tracks over the arid regions in East Asia in spring, Journal of geophysical research **110,** D18S11.

Weihong, Q., Lingshen, Q. and Shaoyin, S. (2001). Variations of the Dust Storm in China and its Climatic Control, Journal of Climate, **15,** 1216-1229.

Zhang, P., Lu, N.M., Hu, X.Q. and Dong, C.H., (2006), Identification and Physical Retrieval of Dust Storm Using Three MODIS Thermal IR Channels, Global and Planetary Change, **52,** 197-206.

Zhao, L. and Zhao, S., (2006), Diagnosis and Simulation of a Rapidly Developing Cyclone, Global and Planetary Change, Volume 52, **1(4),** 105–120.

Zolfaghari, H. and Abedzadeh, H. (2005), Synoptic Analysis of Dust Storm in West of Iran, Geography and Development, **6(3),** 173-187

Zolfaghari, H., Masoumpour Samakosh, J., Shaygan Mehr, SH.and Ahmdi, M., (2011), A Synoptic Investigation of Dust Storms in Western Regions of Iran During 2005-2010 (A Case Study of Widespread Wave in July 2009), Geography and Environmental Planning Journal, **43(3),** 17-34.