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ORIGINAL ARTICLE

Synoptical Analysis of Mashhad Air Pollution

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ABSTRACT
In order to analyze synoptically the pollution of Mashhad's air, the data of air pollution gained from the department of environment protection of Razavi Khorasan related to Vahdat station located in the center of Mashhad was used. The pollutants include carbon monoxide , nitrogen dioxide , sulfur dioxide , ozone and particulate matters (PM10) provided and processed on a daily scale for a seven-year statistical period (2005-2011). To study the atmospheric conditions, the data of National Centers for Environmental Prediction (NCEP) / National Centers for Atmospheric Research (NCAR) was used. Atmospheric data includes the sea-level pressure, geo- potential height (levels 500-700-850), vertical velocity and orbital (u) and wind meridian components. The result of this research showed that the heaviest polluted days in Mashhad may be categorized into four main circulation patterns configurations including. In Siberian compositional high pressure-subtropical ridge pattern, the simultaneously extension and prevailing of Siberian high pressure systems (Siberian high) in lower level and subtropical ridge in middle levels of atmosphere cause the increase of air stability and occurrence of heavy polluted days at cold period of the year. In migratory high pressure pattern, passing a wave over the zone causes the settlement of a strong ridge across the Oral Mountains and Caspian Sea resulted in forming an anticyclonic circulation with eastern direction from the Caspian Sea to northern parts of Khorasan in lower levels. Subtropical ridge pattern causes the pollution in Mashhad only in the hot period of the year in contrary to the other patterns and in perpendicular cross-section of atmosphere it displays a very significant and obvious pattern of inversion type resulted from subsidence. A low pressure pattern is identified by a relatively deep syncline (trough) passing from the half north of Iran in middle levels and formation and east displacement toward an anticyclonic circulation center in lower levels of atmosphere.

Keywords*: synoptic analysis, air pollution, Mashhad city*

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INTRODUCTION

Air pollution, as one of the most important factors affecting on urban environment especially in big cities has caused abnormalities, problems and damages for many of the residents in cities. Identifying the relationship between atmospheric conditions and the air quality of the cities makes it possible for the researchers to minimize the side effects of this relationship. With respect to the importance of the factors influencing on the problem of air pollution in Mashhad, this survey studies and synoptically analyzes the air pollution of Mashhad. A great deal of research has been done in Iran and all over the world concerning air pollution, atmospheric patterns and effective patterns on it. For example; Sandro Finardi et al. [1] studied the prevailing conditions on one case of very sever urban air pollution episodes over Po Valley in Italy. The results showed that the advection of hot air over the hot layers and over the cold layers near the earth level causes a stable temperature construct in lower atmosphere. Inversion or vertical profiles of high stable temperature have been seen in zero heights and in 2000m in cases of severs pollutions. Studying the synoptic maps on atmospheric conditions has shown that in all cases high-pressure systems have been prevailed on the earth level. Ccoyllo et al. [2] in an article titled as "meteorological conditions and their impact on pollution concentration in Siapaolo, Brazil" have evaluated the relationship between meteorological systems and pollutants concentration. The results of this survey indicate that high rates of

pollutants concentration in this zone are affected by subtropical high pressure systems of north Atlas. Yimin Maa'b & T.J Lyonsa [3] studied recirculation of air pollution and the impact of synoptic scale thermal in coastal city of Perth in western Australia. The studies show that in western coast of Australia, synoptic scale influenced by temperature causes reactions increasing the flow of the sea breeze and consequently pollutant substances may penetrate more into the earth. Moussiopoulos et al. [4] in an article titled as "modeling for transboundary estimation of air pollution in southeastern Europe" , after modeling and categorizing atmospheric circulations in 1995 concerning NOx & SO2 displacement in Greece border , identified that the daily calculations of the model have similarities with the total year and this model is a specific applied tool for long-time periods. Chen et al. [5 in an article titled as "the study of relationship between air pollution and short processes of pressure patterns in northern China using API index in 10 towns in the north and pressure [5] patterns during autumn and winter (2002-2006)", through applying statistical methods, found that index increase (API) with high and low pressure of the air, back part of low pressure and its decreasing with rising slopes of the pressure are related to them. Marina Asthitha et al. [6] in an article titled as "air pollution modeling in Mediterranean region" studied the techniques of modeling through emphasizing on predicting the episodes of air pollution using atmospheric dust systems, SKIRONIET, atmospheric modeling system, RAMS and air quality model, CAMX. The results of this survey show that air quality predictions are consistent with the desired observations. Yuvala et al. [7] studied the impact of the pressure reduction on traffic volumes on urban air pollution as well as stable air conditions in east Mediterranean during the winter. The results of this study showed that lowered traffic volume causes lowered rate of NO2, hydrocarbons and particulates. Jacob Baker [8] studied long-range of air transport pathways and pollutant concentration in England and four-day returning paths from January, 1998 to December, 2001 at three heights of boundary layer input. Buchholz et al. [9] in an article titled as "air pollution characteristics and their association with middle atmospheric patterns in northwest Europe" studied the impact of daily air quality index in 15 air quality monitoring stations in Belgium, France, Germany and Luxembourg in comparison with atmosphere middle level pattern during 2001-2007. The results showed that circulation regime has been more effective than anticyclonic and meridian regimes in increasing air quality. John L. Pearce.A et al. [10] in an article titled "investigation of meteorology influence on synoptic scale on air quality using self-organized maps and generalized additive modeling" state that circulation patterns range in synoptic scale in Melborne region in Australia is related to the regional air quality. In Iran, Ansari Moghadam [11] in his thesis studied Tehran's air in relation to the stability and atmosphere temperature inversion and showed that the amounts of three main pollutants including CO, NO2 and SO2 have not been fitted with a suitable statistical distribution and not addressed a specific trend in pollutions distribution. Sedaghat Kerdar [12] in an article titled as "potential capacities of statistical models in long-term air conditions broadcasting" indicates that statistical models are suitable in short-term forecasting of SO2 concentration, controlling the pollutants and analyzing and forecasting time series of urban pollutants. Entezari [13] in his ph.D thesis studied air pollution of Tehran statistically and synoptically. Safavi and Alijani [14] studied geographical factors in polluting Tehran's air and concluded that natural features of Tehran have much effect on air pollution and temperature inversion meaning that the feature of a cold period is occurred as the result of settling the anticyclones of stable urban air. Ezzation [15] in his ph.D thesis titled as "the study of meteorological parameters on air quality index in Isfahan" presented some matters on pollutant sources in Isfahan , the type of used fuels and the rate of pollutants dispersion from these sources and studied the contribution of meteorological parameters in pollutants dispersion. Waseghi et al. [16] in an article titled as "forecasting air pollution of Shiraz city" studied one-year time series of air pollution standard index as daily through the air pollution monitoring station of Shiraz using regression and non-regression methods. Mashhad city is one of the most polluted cities of Iran so that some research has been done so far. For example; Alijani and Najafi Nik [17] studied inversion synoptic patterns in Mashhad using factor analysis and concluded that two types indicating summer pattern, three types a winter pattern and two types autumn pattern and cold season inversions are stronger and more stable and durable. Then, a layer of pollutant substances will remain across the city and are more durable. Fahimi Fard and Afshar [18] studied and measured air pollution of Mashhad. The results of studying air pollutant sources of Mashhad showed that with respect to the direction of prevailing winds, the settlement places of Mashhad and Shariati power stations and brick-making furnaces are inappropriate. In addition, regarding the position of settlement, type of production pollution, type of used fuel and direction of prevailing winds, motor vehicles, automobiles, industries, trains and Sarakhs industries of axis are at the first priorities of air pollution production.

MATERIAL AND METHODS

To perform a synoptic analysis of Mashhad air pollution, the data of air pollution was used provided by department of environment of Razavi Khorasan. The data of air pollution was related to Vahdat station located in the center of Mashhad. The pollutants were contained carbon monoxide, nitrogen dioxide , sulfur dioxide , ozone and particulate matters (PM10) provided and processed on daily scale for a 7-year statistical period (2005-2011) (Fig. 2). To study atmosphere conditions, the data of Vational Center Environmental Prediction and National Center Atmospheric Research (NCEP / NCAR) was used. Atmospheric data was involved the sea level pressure, geo-potential height (levels 500, 700 and 850), vertical velocity and orbital (u) and meridian (v) wind components. After collecting the data as daily and hourly regarding the size of statistics and information, the data was organized and transformed to the standardized statistical tables using excel software. After calculating standard index for each year during the year, the days which were index 200 were determined and based on this index, frequency percent was obtained on each year. Then, respecting annual data, the polluted days were calculated for a 7-year period (2005-2011) and finally with respect to the limitation of much polluted days, handy synoptic analysis method was applied to a synoptic analysis.

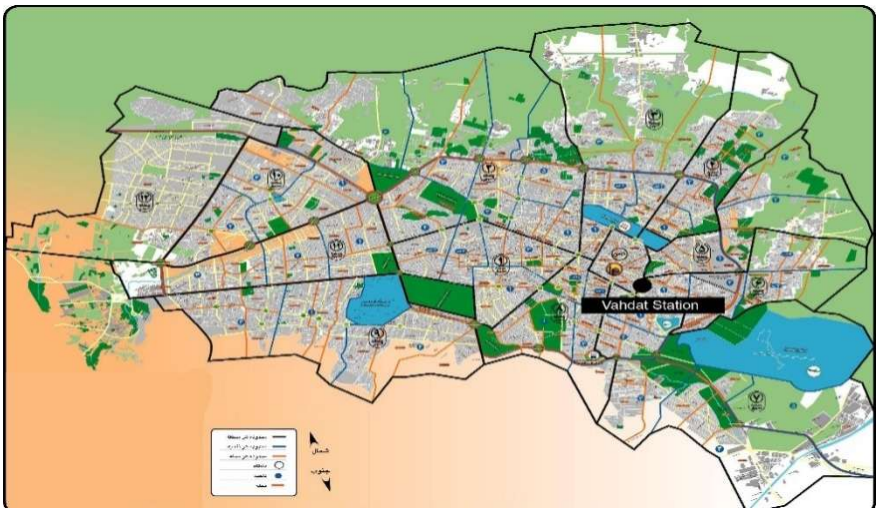

Fig. 2. The position of air pollution monitoring stations across Mashhad city

RESULTS OF DISCUSSION

Regarding the data processing on Mashhad air pollution related to a seven-year statistical period (2005-2011) and considering index 200 ,the most polluted days were obtained (Tab. 1). It is necessary to state that in this survey, synoptic analysis of the days with Ozone amounts was ignored due to the difference in seasonal distribution related to this pollutant. At last, analyzing the polluted days caused that the main circulation patterns on much polluted days in Mashhad to be detected. The main circulation patterns of much polluted days in Mashhad are as the following: Siberian high pressure - subtropical ridge pattern, migratory high pressure, subtropical ridge and extra-tropical low pressure pattern but in this survey, of each pattern one day has been studied as example.

In Siberian high pressure pattern and subtropical ridge, the day 21 November, 2005 has been studied. In this day, a high pressure system has been placed on Turkey with a central pressure of 1010 hpa and proceeded the east across the Caspian Sea. In addition, a secondary system of which has been extended across the Zagros Mountains toward south west of Iran. In this pattern, Mashhad has been under the influence and prevailing of this anticyclone and the settlement of this high pressure system caused the penetration of cold air on Mashhad. Temperature is 4˚c at this day. On the map, a deep descending 500 hpa level has been generated causing the displacement of western flows on the center and north of Khorasan province.

The distance of isohypses curves have been increased that is an indicator of the wave attenuation. The wind speed is 3 knot/s. the map of vertical velocity also indicates the air descending and stability and increased potential of pollution in this day. The pollution concentration is 201.99.

Table. 1. (PSI > 200) in Vahdat station during under study period (2005-2011)

features	PSI	features	row	PSI	Type of pollutant	features	row
227.9	Pm10	19 April, 2008	17	2190.81	Pm10	20 Oct. , 2005	1
203.45	Pm10	11 May , 2008	18	264.9	Pm10	21 Oct. , 2005	2
201.45	Pm10	29 My , 2008	19	204.19	co	17 Nov.2005	3
210	Pm10	14 June , 2008	20	201.99	co	21 Nov. 2005	4
279.15	Pm10	16 Mar. 2009	21	211	Pm10	16 Dec. 2005	5
462.36	Pm10	16 Sep. 2009	22	218.15	Pm10	11 May ,2006	6
248.75	O3	17 Sep. 2009	23	266.9	co	27 July , 2007	7
206.25	O3	21 Sep.2009	24	206.99	Pm10	5 Nov. 2007	8
251.25	O3	22 Nov. 2009	25	365.125	Pm10	13 Nov. 2007	9
223.75	O3	20 Feb. 2010	26	234.62	Pm10	14 Nov.2007	10
212.5	O3	21 Feb. 2010	27	225.28	Pm10	20 Nov. 2007	11
233.75	O3	24 Feb. 2010	28	227.57	Pm10	21 Nov. 2007	12
327.84	Pm10	1 Dec. 2010	29	220.9	Pm10	18 Feb. 2008	13
310.55	Pm10	11 Dec. 2010	30	219.9	Pm10	19 Feb .2008	14
418.69	Pm10	31Dec. 2010	31	216.95	Pm10	4 Mar. 2008	15
231	O3	9 Feb. 2012	32	346	Pm10	15 Mar. 2008	16

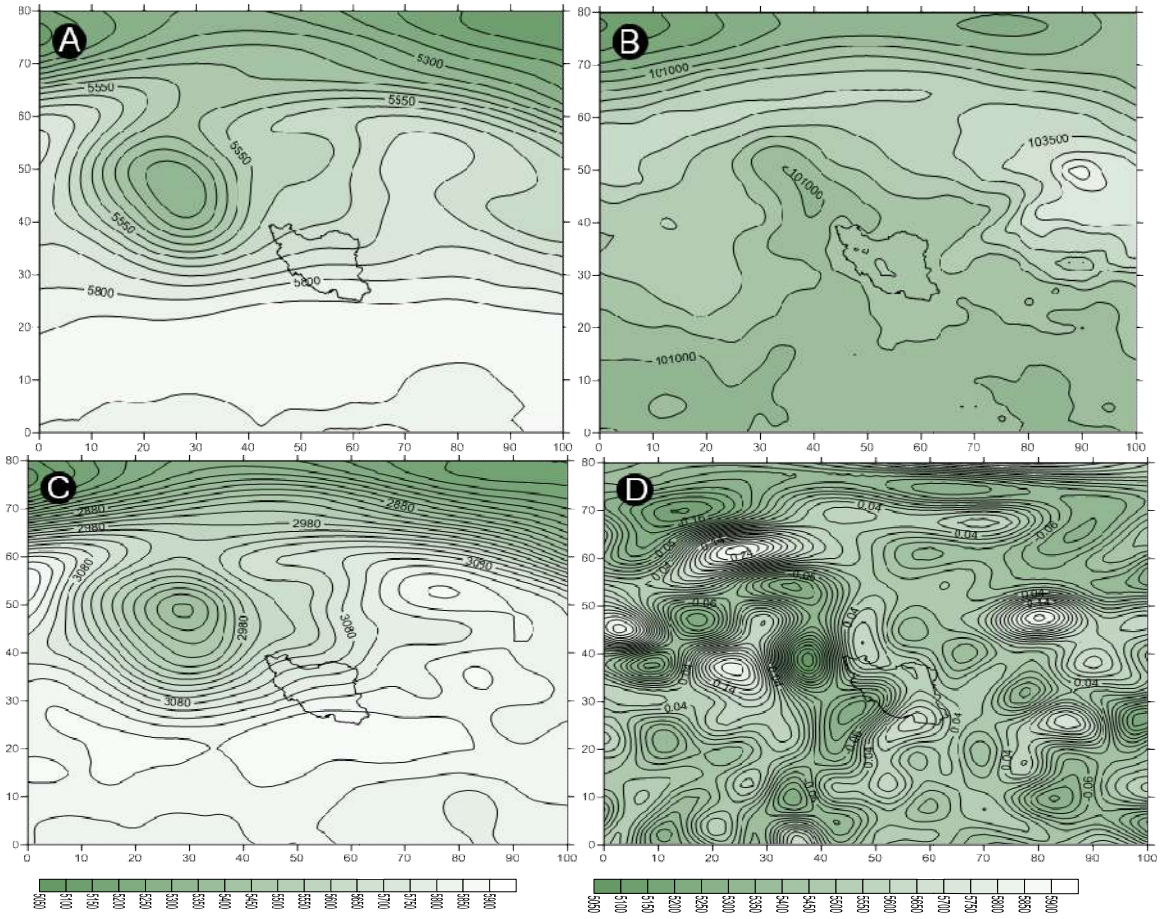

Fig. 3. (a) The map of 500 hectopascals level, (b) the map of the earth level, (c) the map of 700hectopascals level, (d) vertical velocity map in the day of 21 November, 2005.

In migratory high pressure pattern in 13 November, 2007 as shown, the western winds on the level of 500 hectopascals have caused a deep descending on the black Sea and Turkey. On Iran, this descending has an orbital flow. These conditions have caused the penetration of relatively cold air from northern latitude on Mashhad and negative circulation caused the air stability and increased pollution in this day. On the map of the earth level a high pressure core is observable so that its system is moving on Iran from

northwestern. The mean rate of rising and falling the air (omega) shows the formation of two maximum descending zones, one in the west and another in the east of Iran resulted in penetration of cold air and air stability.

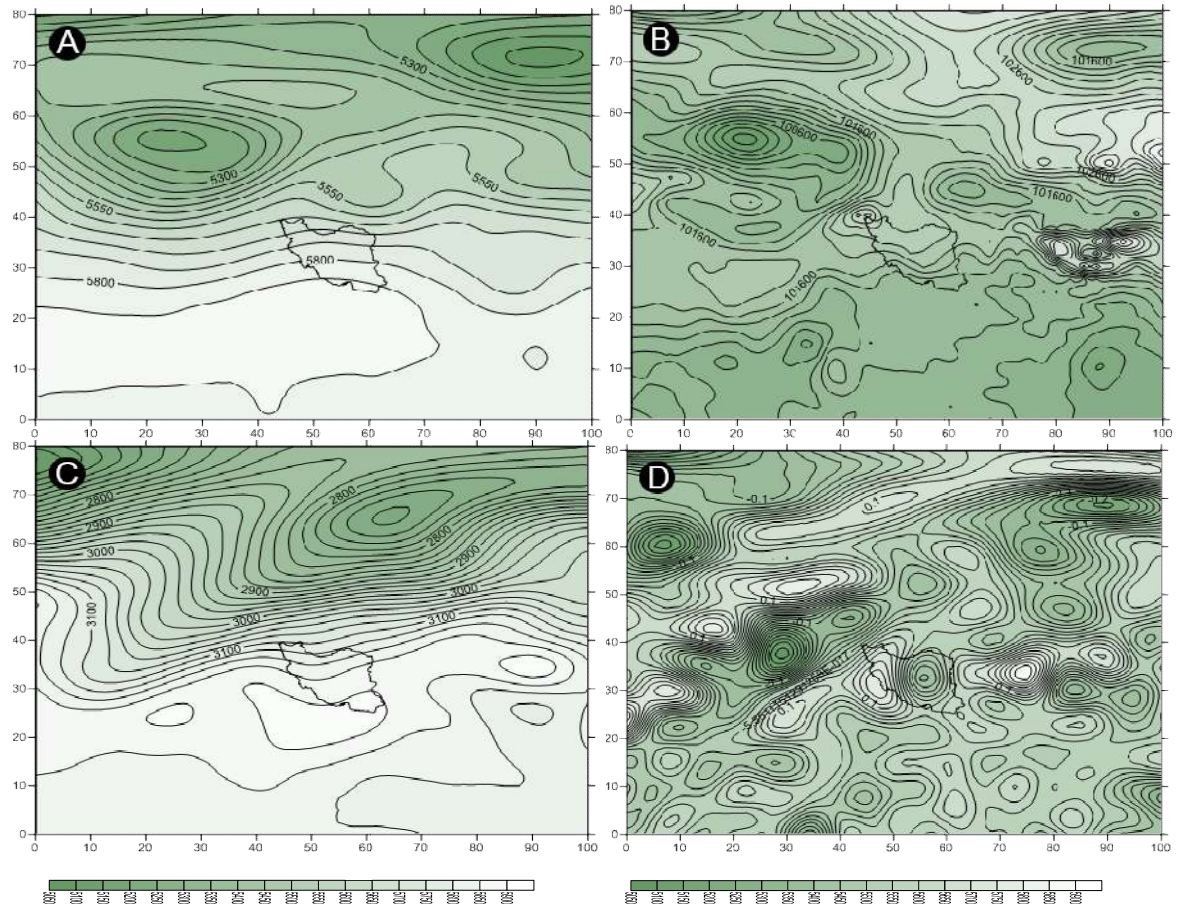

Fig. 4. (a) The map of 500 hectopascals level, (b) the map of earth level, (c) the map of 700 hectopascals level, (d) the vertical velocity map on 13 November, 2007.

Subtropical ridge pattern was studied on 11 May, 2006. In this day, a short and deep wave has been formed on Europe and its axis located on the Black Sea and Iran located in front of this wave. Considering the placement of this pattern at the hot period of year, the trough of western wave penetrates the eastern side of Mediterranean frequently in an extension toward the south and in addition to reinforcement of subtropical high pressure ridge on Middle East, it has caused the extension of the north and east of the ridge on the eastern half of the Middle East. Anticyclonic circulation in lower levels in north east of Iran has extended high pressure systems on the east of Caspian Sea and also provided the necessary stability for occuring a polluted day in Mashhad. In addition, regarding the map of the air vertical velocity in this day and its positive values due to high surface heating in this time of the year, the rate of the air descending is very small.

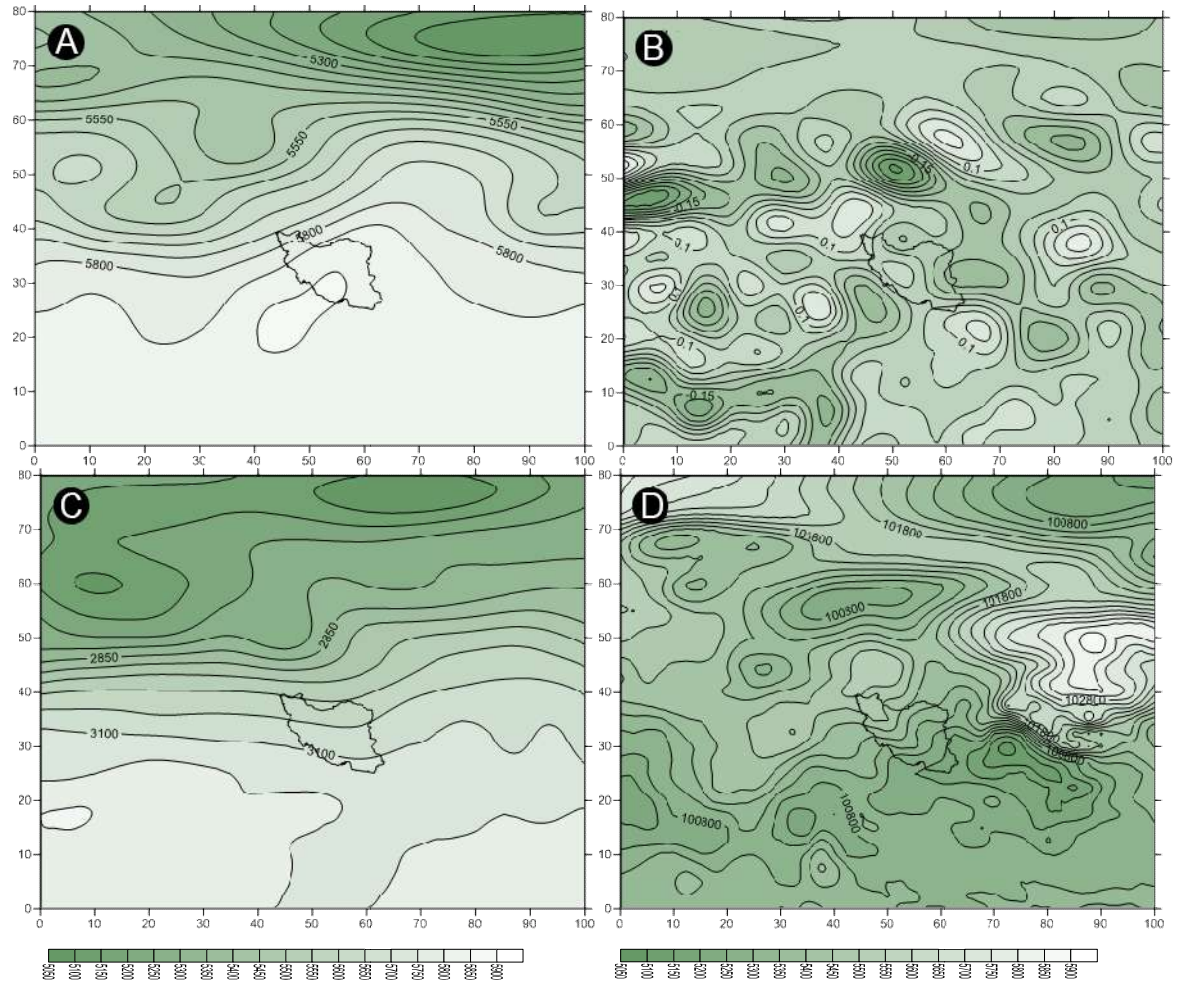

Fig. 5. (a) The map of 500 hectopascals level, (b) the map of the earth level, (c) the map of 700 hectopascal level, (d) the map of vertical velocity on 11 May, 2006.

Finally, in low pressure pattern of 15 March, 2008 due to crossing a subtropical deep unstable atmosphere, the north east of Iran involves a low pressure and unstable atmosphere. In this pattern, relatively deep trough crossing the northern half of the country over middle levels has been coincided with formation and east displacement of a cyclonic circulation center over lower levels of the atmosphere. The mentioned trough has been formed due to penetration a short wave and its getting deep across the Caspian zone and controlled at its settlement time simultaneously by a relatively strong ridge in east, a ridge in west and subtropical ridge in south. The mentioned synoptic conditions have constrained the movement of this trough toward the south. Studying the rising and falling conditions of the air across the Middle East indicates that in this pattern all of the zones located on eastern side of eastern longitude 55˚ and northern side of northern latitude 27˚ experience an extended rising. However, for getting limited of the south extension of trough side in north east zone of the country, the rate of air rising across Mashhad city is not significant at the lowest level of atmosphere.

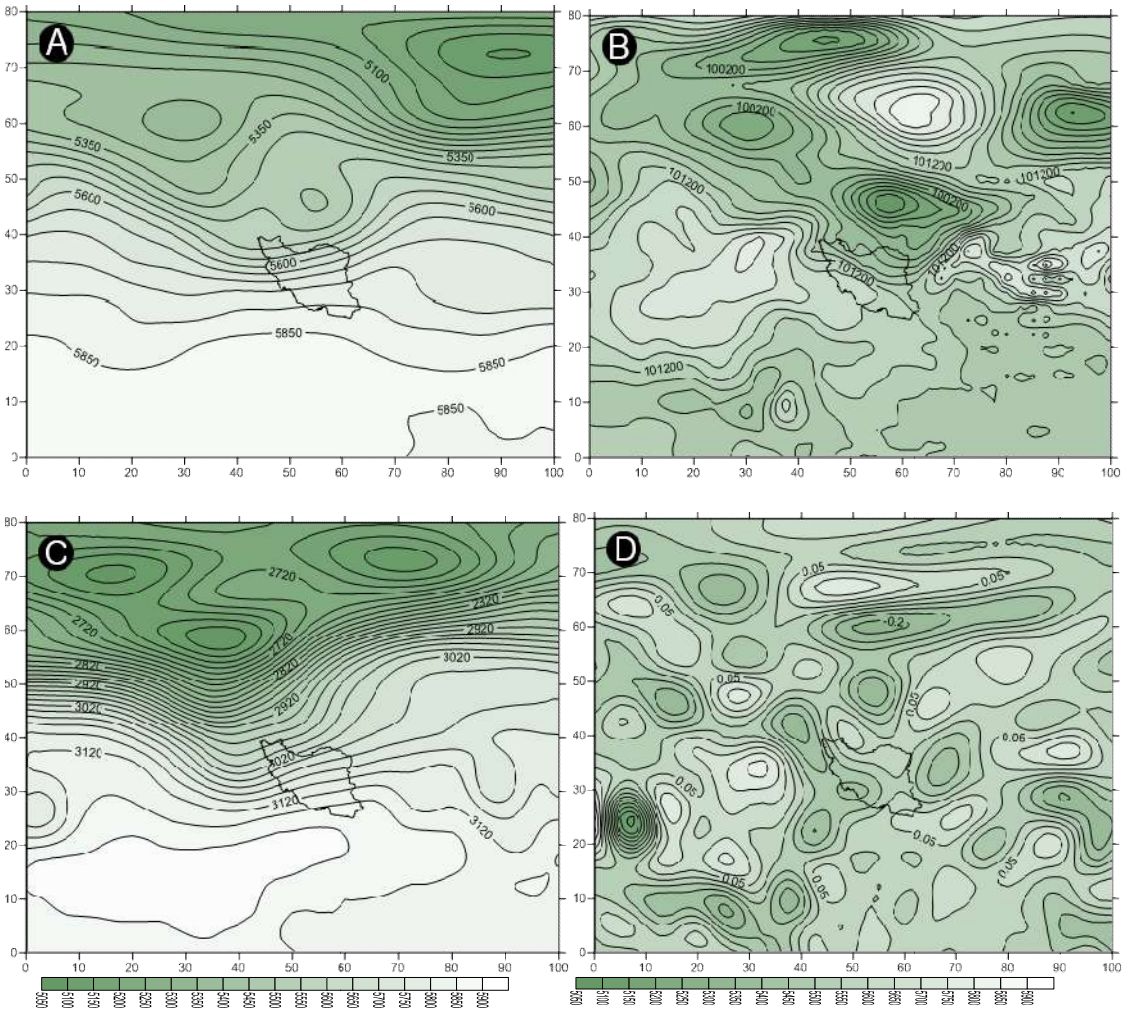

Fig. 6. (a) Map of 500 hectopascals level, (b) map of the earth level, (c) map of 700 hectopascal levels, (d) map of vertical velocity on 15 March, 2008

CONCLUSION

The findings showed that the total days having extreme pollution in Mashhad may be clarified through four synoptic patterns. Accordingly, it may be concluded that the occurrence of extreme pollution in Mashhad is as the result of local conditions interaction with atmosphere circulation on zonal scale than having an origin into local factors. In other words, Mashhad will experience much polluted days only when the atmospheric zonal circulation has provided suitable conditions for increasing the pollutants concentration. In spite that Siberian high has had a role in occurring extreme pollutions in some of the days under study, in general, the main factor of occurring much polluted days in Mashhad includes synoptic patterns and the construction of atmosphere circulation in middle levels (circulation in a free atmosphere). The findings indicate that subtropical ridge has a significant role in occurring extreme pollutions in Mashhad. The mentioned circulation system causes the occurrence of high pollution concentration in Mashhad totally in more than half of the studied days. The results of the present survey showed that formation of unstable conditions due to cyclones crossing may increase the pollutants concentration in Mashhad beyond the emergence range. In other words, in Mashhad the existence of a stable atmosphere and prevailing the phenomenon of temperature inversion may not be adapted as a pre-condition. The rate of contribution and role of four extracted synoptic patterns in this research area function of the year time and season. Moreover, at the peak cold period, the resulted extreme pollutions in Mashhad are mainly resulted from prevailing extratropical systems (migratory anticyclnes and cyclones). In contrary, occurrence of very polluted days in transition seasons (at the beginning of autumn and end of spring) at the hot period of the year is mainly resulted from reinforcement and extension of the north due to subtropical systems (subtropical ridge).

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