Air pollution and topography in Tehran

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ABSTRACT

Tehran is one of the most polluted cities in the world with 48 days of air pollution exceeding the admissible threshold (AQI > 150) for 3 months of the 15 years studied. This period coincides with the time when Tehran's inversion reaches its maximum stability. The purpose of this study was to determine the height of air pollution in Tehran in the days when pollution exceeds the permissible limit. Continuing to study the pressure and temperature conditions of these days, we then considered the geographical and topographic conditions, and finally identified the best of these cells for potential theoretical air turbulence. The results of this study, based on the Harmonic Analysis method and based on Tehran temperature and pressure data over a 15-year period (2003–2017), show that the highest elevation of Tehran inversion does not exceed 1800 m on polluted days. Only within 6 days of those beyond the admissible threshold, temperature and pressure cells with the highest Newtonian mass are formed. The center of these cells formed with a compressive difference of 32 mg in November, 7 mg in January, 11 mg in December, and temperature difference of 1.1° in November, 4.4° in January, and 1.9° in December. Generally, we considered the formed cells by the temperature and pressure difference and the gradient between them, as well as the difference in height between the cells and their location. This information, combined with the local winds causing the differences in temperature and pressure, allows us to elucidate conditions for creating air turbulence in Tehran and mitigating the amount and degree of air pollution.

KEYWORDS

inversion; air pollution; thermal cells; pressure cells; air quality

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1. Introduction

Air quality significantly impacts human life and the condition of ecosystems, both directly and through processes related to climate change.

Air pollution is associated with respiratory and eye diseases such as asthma, lung cancer and conjunctivitis, especially in the young and elderly (UNEP/WHO 1992; Patel 1994). Lead as a pollutant is particularly serious for children, since relatively low concentrations of lead in the blood may have a damaging and permanent effect on their mental development (Needleman et al. 1991). In the environment, air pollution is a major contributor to effects such as acid rain, which has been responsible for much damage to soil, fish resources and vegetation, often very far away from the source of the pollutant (Shahid and Hussain 2013).

Air pollution is identified by the World Health Organization (WHO) as responsible for several million deaths per year. In most industrialized countries, particulate matter emissions are regulated by severe environmental laws because smog crises can involve large territories and affect their residents. Several studies carried out in the U.S.A. and Europe indicate high risks for lung cancer due to small particulate matter (e.g. Vineis et al. 2006).

Tehran is one of the largest and the most crowded cities that suffer from air pollution. In some days of the year, the amount of contaminating and pollution elements increases so much that breathing is very difficult for inhabitants. Increasing atmospheric pollutants has made Tehran one of the most polluted cities in the world. Air pollution concentrations vary substantially within a year. The AQI varies over the course of a year in Tehran. During autumn and winter, Tehran becomes more polluted. Atmospheric temperature inversion worsens air pollution during that period. Spring and summer are usually less polluted. August, for example, was the cleanest month of the year in 2015. There are occasional dust storms at the end of spring and beginning of summer that increase PM concentrations and result in unhealthy air. The unhealthy days due to dust storms are relatively rare compared to those caused by combustion sources during the cold seasons (Sarraf and Heger 2018). To design an effective approach to air pollution management, it is important to diagnose the problem, determine its sources, and identify affordable and sustainable solutions (Gwilliam et al. 2004).

There are more than 17 million vehicular trips per day in Tehran (Shahbazi et al. 2017), and many of the vehicles have outdated technology. Thus, the air in Tehran is amongst the most polluted in the world. Topography and climate add to the pollution problem. Tehran is at a high altitude and is surrounded by the Alborz Mountain Range, which traps polluted air. Temperature inversion, a phenomenon particularly occurring during the winter months, prevents the pollutants from being diluted. Several recent trends indicate that reducing air pollution will not be straightforward: rapid population growth (partially due to migration from other cities and villages), industrial development, urbanization, and increasing fuel consumption are pressure points for clean air in Tehran.

The two factors of climate and topography are affecting air pollution in Tehran; these are 2 major issues emphasized in this research. In fact, using these factors, we are looking for a way to eliminate or at least decrease the pollution of Tehran's air.

All studies on atmospheric pollution in Tehran have focused on urban management, such as days free from school or work; avoidance of moving polluted cars; relocation of industrial factories, and so on.

This research focuses on vertical and horizontal exchanges via atmospheric mixing, by defining the good conditions for instability during the inversion periods in Tehran. If we have suitable mixing conditions (identified with cells of pressure and/or temperature), we should try to define the best status for instability. We must better know the differences of temperature and pressure that give rise to air turbulence.

2. Background

Related to air pollution many studies have been conducted and some of these have focused on physical factors such as climatology and topography.

Mage et al. (1996) made maps based on information from WHO and UNEP's creation of an air pollution monitoring network as part of the Global Environment Monitoring System. They described an increased population in the next century, mainly in the developing countries with a lack of capital resources for air pollution control, which means that there is a great potential that conditions will worsen in many more cities reaching megacity status[1]. This paper maps the potential for air pollution that cities will experience in the future unless control strategies are developed and implemented during the next several decades.

Thadathil and Gosh (1992) studied surface layer temperature inversion in the Arabian Sea during winter. They found that the inversion in this area is a stable seasonal feature and the occurrence is limited to the coastal regions. Finally, the possible forcing mechanism for such an advection (the causative factor for the inversion is identified to be the winter-time surface-advection of cold less saline Bay of Bengal water over the warm saline Arabian Sea water along the west coast of India) was examined using a

1 According to some recourses megacity is the city with more than 10 million people in habitants.

hydrographic section and wind observations along the west coast of India.

Kejna (2008) described the spatial differentiation of topoclimatic conditions in the vicinity of the Arctowski Station (King George Island, Antarctica). The paper analyzes meteorological elements such as air temperature, air humidity (eight sites) and wind direction and velocity (three sites). Significant topoclimatic diversities resulting from denivelation, exposure, ground properties and local air circulation were recorded in the study area.

Nowadays due to the increasing population, energy consumption, pollution caused by transport systems, and the increasing number of vehicles, industrial, and mining activities, in most big cities the important of environmental issues, has doubled, particularly with air pollution (Sarraf and Heger 2018).

Sánchez-Coyllo et al. (2002) studied the observed behavior of pollution concentrations due to prevailing meteorological conditions for the period from June 13 to September 2, 1994, for the Metropolitan Area of Sao Paulo (MASP). They observed that for both the synoptic conditions, namely the South Atlantic Subtropical High and Polar High, high concentration pollution values prevailed due to weak ventilation, low relative humidity and absence of precipitation.

Buchholz et al. (2010) studied impacts related to daily air quality index (DAQx), calculated for 15 air quality monitoring stations (traffic, background, and industry) in Belgium, France, Germany and Luxembourg, all compared to meso-scale atmospheric patterns between 2001 and 2007. The investigation of weather regimes indicates that zonal and mixed cyclonic circulation regimes are associated with better air quality than meridional and anticyclone weather regimes. In general, weather regimes with high daily precipitation lead to better air quality than dryer air masses because of lower contribution of PM10 to the air quality index.

Bityukova et al. (2013) in a research report in Russia, found that 60 million people live in the cities with high levels of air pollution. Comparative statistical analysis of pollutant emission and emission processes in 1099 cities in the country revealed the role of climate and other environmental factors, including fuel mix, and the impact of agglomeration effecton the distribution of pollutants in the cities' atmosphere.

Bidokhty and Hashem (1998) explained about the atmospheric boundary layer (ABL) and its effect on air pollution. They created a turbulent and integral model for prediction of air pollution in city.

Like all major cities, Tehran suffers from air pollution; however here it is particularly intensive. The amount of air pollutants in the warning state[2] has increased considerably. In order to find the solution for decreased air pollution many researchers have addressed the issue from a range of perspectives

2 When the Air Quality Index represents more than 150.

Cheragi (1999) studied air quality in Tehran and Isfahan. He concluded that density of pollutants, in 329 days in Tehran and 34 days in Isfahan exceeded the limit. Shariepour et al. (2006) studied the density of pollution in Tehran. They concluded that Golhak and Tajrish stations are the most polluted stations and that reduced relative humidity was causing increased air pollution during the cold months of the year.

Zahedi et al. (2000) studied about factors that influence at air pollution in Tabriz. They concluded that the most important factor is industries located in the west and south west of this city. Other factors are topography, slope and wind.

Lashkari and Hedayat (2007) studied synoptic patterns of inversions in Tehran and explained four synoptic patterns as causing intense inversions in Tehran. In two of these patterns, creating a ridge in 850 and 700 hectopascals and dynamical stability derived from it, are intense inversion conditions. In another pattern, transfer of cold weather by anticyclonic circulation at ground level creates a trough over Tehran of 850 and 700 hectopascals, thus causing intense inversions.

Esa et al. (2012) studied the air pollution distribution in Tehran. They claimed that concentrations of various air pollutants and inappropriate distribution of resources in the city causes Tehran to have different areas with different situations of air quality, and concluded that the western and southern parts of the city are the most polluted.

Saneie (2016) studied air pollution in Tehran from the perspective of urban planners. He concluded that density of pollution in Tehran follows the topography and that most air pollution is in low areas in Tehran. He considered it impossible to change climate factors that are influencing air pollution. He suggested that a changing pattern of city management and urban planning can better prepare Tehran for changing environmental conditions.

3. Main objective

The main motive of this research is to focus on changing atmospheric patterns for purposes of better management of air pollution risks in the Tehran basin. If this plan (to find a Model for Instability in Thermal and Pressure Cells and thus curtailing air pollution) succeeds, a better understanding of temperature and pressure conditions (quantities from synoptic stations and radiosonde launches, overall gradients both horizontally and vertically, etc.) will be achieved. This new knowledge should better prepare us for preventing air pollution risks in the Tehran region.

The main objective of this research is to find a model for instability in Thermal and Pressure Cells and thus curtailing Tehran air pollution. The more concrete and specific objectives are as follows

– Investigate air conditions in the days when the AQI (Air Quality Index) are greater than 150 in Tehran.

- Determine temperature and pressure cells in different levels of the atmosphere. From this data we can construct maps that most clearly define instability conditions.
- Select a level for which thermal and pressure cells have the most differences, thus defining the most clearly unstable conditions suitable for mixing (and pollution).

4. Research method

To achieve these objectives, different stages will be pursued. Firstly, Tehran's air pollution data was collected from air quality sensors and, according to them, the days when the AQI is greater than 150, have been pre-selected as dangerous days of pollution.

Then, temperature and pressure data were collected for polluted days from synoptic stations and after that, the pressure and temperature maps were drawn at different levels of the atmosphere.

Further, based on these maps, it should be selected the levels that have the most number cells of pressure and temperature with the most gradient.

Then, maps of thermal and pressure cells that have the most differences will be selected for more concrete analysis and consideration.

In the final stage, it will be suggested the amount of differences in temperature and pressure that cells should have to create instability. Upon completion of this, it is anticipated that we will better understand the inversion processes that are major influences on air pollution in Tehran. This will hopefully progress toward knowledge and understanding of how to mitigate air pollution risks.

Tab. 1 Date of dangerous days of pollution.

Year	January	November	December
2017	1, 9		
2016		30	24, 23, 1
2015			30, 29, 14
2014	12		28
2013	8	27, 28	23, 24, 25, 26, 29
2012			2, 3, 4, 5, 20, 31
2011	20		
2010		22, 23, 27, 29	31, 30, 28, 27, 26, 19, 12, 11, 8, 4, 3, 2
2009			
2008			
2007			
2006			
2005	1		6, 7, 4
2004	5		
2003	13		

We have used the synoptic stations and the air pollution testing stations as well as Google earth, Arc GIS, Surfer and Voxler software.

5. Expected analyses

To achieve the research aims, at first, the days when the AQI (Air Quality Index) were greater than 150, during 15 years from 2003 until 2017 (just the three most polluted months of November, December and January) were defined. The reason why we select these 3 months is because they show the most polluted months in all the studied years.

In these days the values of temperature and pressure were defined from the synoptic stations and radiosonde measurements. Levels of inversion height were calculated in these 3 months according to these factors.

In the next step, we draw maps using Surfer software, according to inversion levels, the connections between height and temperature, and height and pressure, in each level.

In the following, from the maps of the above step, some maps will be selected that illustrate the largest gradients among thermal and pressure cells. Now the main aim is to find amounts of temperature and pressure gradients that cells should have between them to create instability.

6. Results and discussion

For the first step we find the days when the AQI (Air Quality Index) were greater than 150 as dangerous days of pollution from 2003 until 2017.

Based on the data in Tab. 1, during the statistical study period, a total of 48 critical days were identified, among which December was the most polluted month of the year with 33 days, followed by January with 8 and November with 7 days.

Temperature and pressure values were then extracted from the synoptic stations of Tehran province for the specified days. Fig. 1 shows the distribution of these stations taking into account their altitude.

According to Fig. 1, the Abali station has the highest altitude with 2462.2 m and the Varamin station has the lowest with 937 m.

Thereafter, upper atmosphere data were extracted for the critical pollution days. The data were collected at Mehrabad Airport, Tehran, and obtained from the University of Wyoming. We then analyzed these data and calculated and determined the ultimate inversion limit for November, December, and January.

In order to calculate the average inversion level using Radio sonde data, temperature and altitude were first evaluated for the critical days. Normally, with increasing altitude, temperature and pressure decrease. However, during inversion, the general

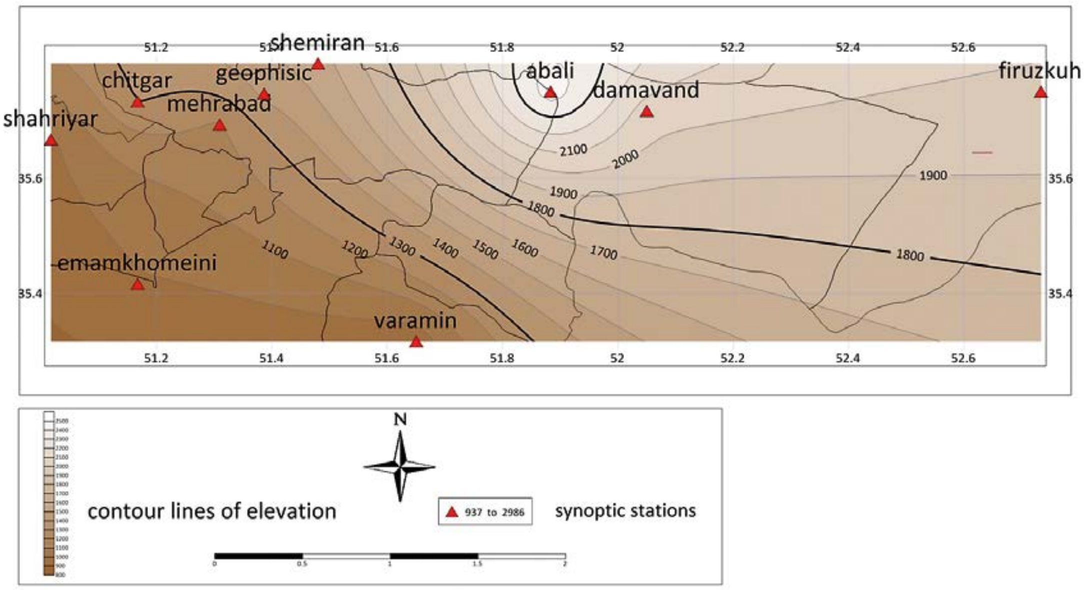

Fig. 1 Map of the synoptic stations in the study area.

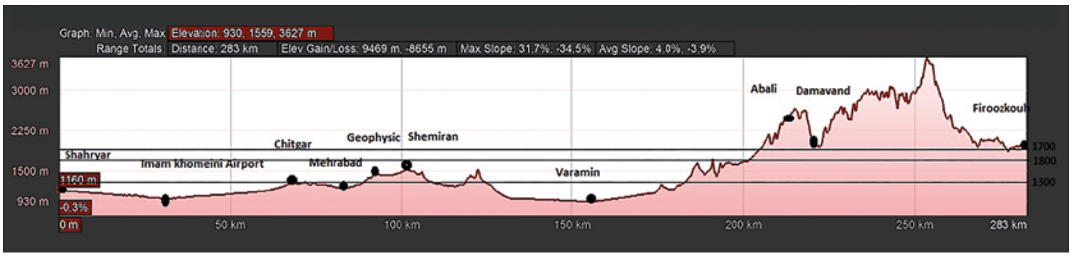

Fig. 2 Inversion height diagram for 3 months in the study area.

process changes and with increasing altitude, temperature also increases. This trend was studied on all critical days of air pollution in the three months in question. In this way, the trend of temperature changes was studied with increasing altitude, and the inversion limit was determined for each station up to the height at which temperature still increased. Accordingly, the inversion level was determined on the critical days for each month and then their averages were calculated for the desired month. The average inversion levels calculated for the three months in question are shown in Fig. 2.

In this diagram (Fig. 2), the position of each station relative to the average final height of inversion is shown for the three months on critical days. Accordingly, the inversion height for critical days is 1300 m and includes Varamin, Mehrabad, Chitgar, Imam Khomeini and Shahriar stations. Other stations fall outside the range of inversion (Damavand, Firouzkouh, Abali, Shemiran, Geophysics).

In December, the average final height of inversion is 1700 m. Therefore, only the Firoozkooh, Damavand, and Abali stations are outside of inversion. And in January, the average final height of inversion rises slightly to 1800 m, so, again, all lower-altitude stations fall into the inversion zone except for Firoozkooh, Damavand, and Abali stations. In fact, the two stations of Damavand and Abali, with the altitude of above 2000 m, will never experience inversion and air pollution because this phenomenon occurs at a maximum height of 2000 m.

The results of this part of study can be summarized as follows.

- The height of inversion phenomenon in Tehran is not the same in the target months (January, November, December).
- The highest inversion height in the target months is 1800 m and the lowest is 1300 m.
- The highest inversion is related to January (1800 m) and the lowest is related to November (1300 m).
- Exceedance of the AQI index or the pollution crisis threshold does not cover all areas of Tehran in the target months, that is, while some districts of Tehran experience higher pollutions than the thresholds, others do not.
- During December, the expanse of pollution in Tehran is wider than other target months.

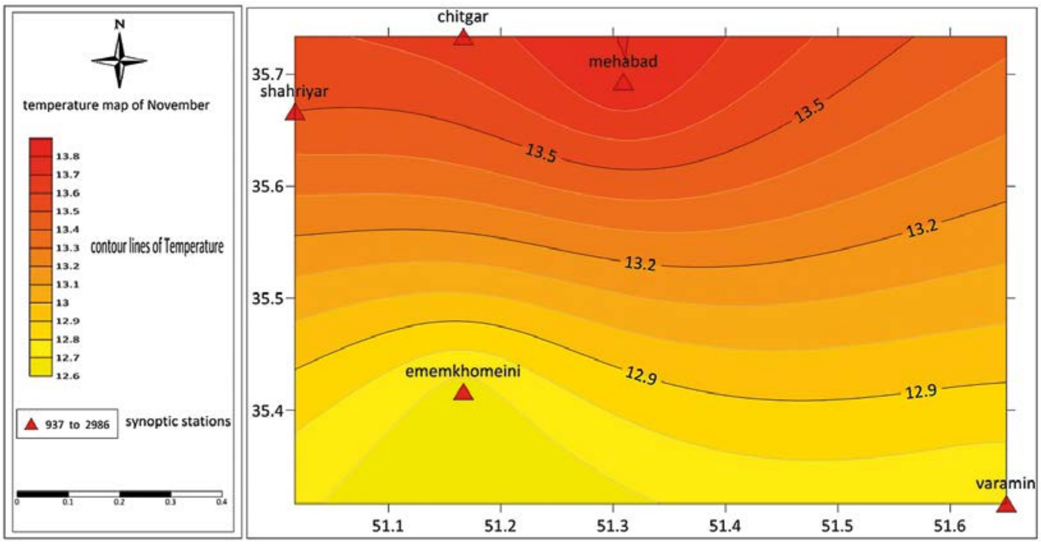

Fig. 3 Map of two temperature cells with the highest Newtonian mass in 28/11/2013 in November.

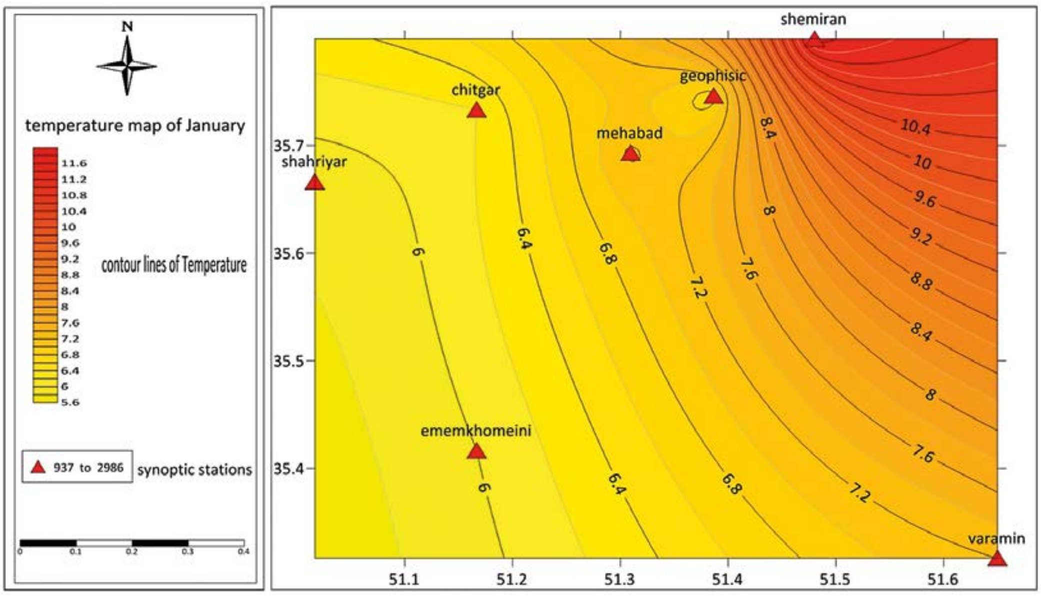

Fig. 4 Map of two temperature cells with the highest Newtonian mass in 8/1/2013 in January.

6.1 Determination of the conditions and location of temperature and pressure cells in critical days of pollution

In this study, after analyzing temperature and pressure data in critical days of pollution during the 15-year statistical period, the inversion was analyzed at different temperature and pressure levels and the mean inversion level was calculated for November, December and January.

Next, based on the determined inversion levels, zoning maps of pressure and temperature on critical days of pollution were drawn in the target months. In this regard, 48 maps of pressure cells and 48 maps of temperature cells were drawn for the critical days of pollution.

From among them, maps containing temperature and pressure cells were selected, and then a matrix was prepared for all cells in the selected maps and their Newtonian mass was calculated.

This matrix represents the cells that have the gradient, because the two factors of cell difference and distances play a major role in their triggering. In order to select the most favorable case from the obtained

Tab. 2 November temperatures Cells Matrix.

28/11/2013		
Temperature cell	Temperature	Newtonian's Mass
Mehrabad	13.75	0.1536
Imam Khomeini	12.65	

Tab. 3 January temperatures Cells Matrix.

8/1/2013			
Temperature cell	Temperature	Newtonian's Mass	
Geophysics	7.2	Shemiran-Geophysics	0.8011
Shemiran	11.6	Geophysics-Mehrabad	0.6124
Mehrabad	7.2	Mehrabad-Shemiran	0.2237

Tab. 4 December temperatures Cells Matrix.

12/12/2010			
Temperature cell	Temperature	Newtonian's Mass	
Varamin	8.8	Shemiran-Geophysics	0.7597
Imam Khomeini	8.3	Shemiran-Cheitger	0.0965
Chitgar	9.8	Shemiran-Imam Khomeini	0.0255
Geophysics	9.9	Shemiran-Varamin	0.0256
Shemiran	8.0	Geophysics-Chittger	0.2548
		Geophysics-Imam Khomeini	0.0472
		Geophysics-Varamin	0.0349
		Chitgar-Imam Khomeini	0.0598
		Chitgar-Varamin	0.0228
		Imam Khomeini-Varamin	0.0382

numbers, the Newtonian mass of the cells was calculated f = (Mi × Mj)/D2 ×1000.

Finally, for each month, two temperature and pressure cells with the highest Newtonian mass were selected. Following the temperature and pressure cells with the highest Newtonian mass in all three months, their matrix is provided.

Shown in Fig. 3 is the temperature map of November in extreme inversion up to the height of 1300 m, which indicates two cells at Imam Khomeini Airport Station and Mehrabad Station. These two cells have the highest Newtonian mass than other temperature cells in the other polluted days. The distance between the two existing cells is approximately 33.65 km. Imam Khomeini station is 990.2 m high and Mehrabad station is 1190.2 m high. The temperatures of cell centers are 13.75 °C for Mehrabad and 12.65 °C for Imam Khomeini Airport. Tab. 2 shows the matrix of the cells of the selected map (Fig. 3) and the Newtonian mass of its cells.

Shown in Fig. 4 is the temperature map of January in extreme inversion up to 1800 m. This map shows three temperature cells, with the largest Newtonian mass being related to Geophysics and Shemiran cells. The two cells are approximately 10.21 km apart. Shemiran station is at an altitude of 1548.2 m and Geophysics station at an altitude of 1423.8 m. Meanwhile, the temperature of cell centers is 7.2 ° for Geophysics station and 11.6 ° for Shemiran station.

Tab. 3 calculates the temperature of each cell, as well as the matrix between the cells and their Newtonian mass.

In Fig. 5, the temperature map of December is shown in the inversion up to 1700 m. This map shows the existence of 10 temperature cells, among which, Geophysics and Shemiran have the highest Newtonian mass. The two cells, with the altitude of about 1423.8 and 1548.2 m, respectively, are located at an approximate distance of 10.21 km from each other. Also the temperatures of their centers are 9.9 °C for Geophysics and 8 °C for Shemiran.

In Tab. 4 the Newtonian mass matrix of all temperature cells formed on 8/12/2010 is calculated.

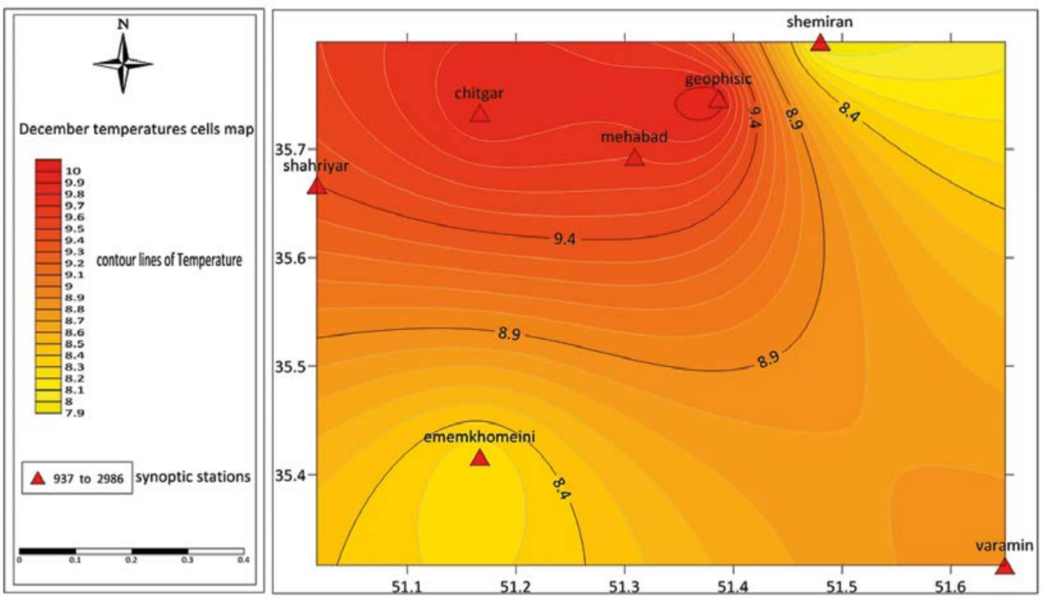

Fig. 5 Map of two temperature cells with the highest Newtonian mass in 12/12/2010 in December.

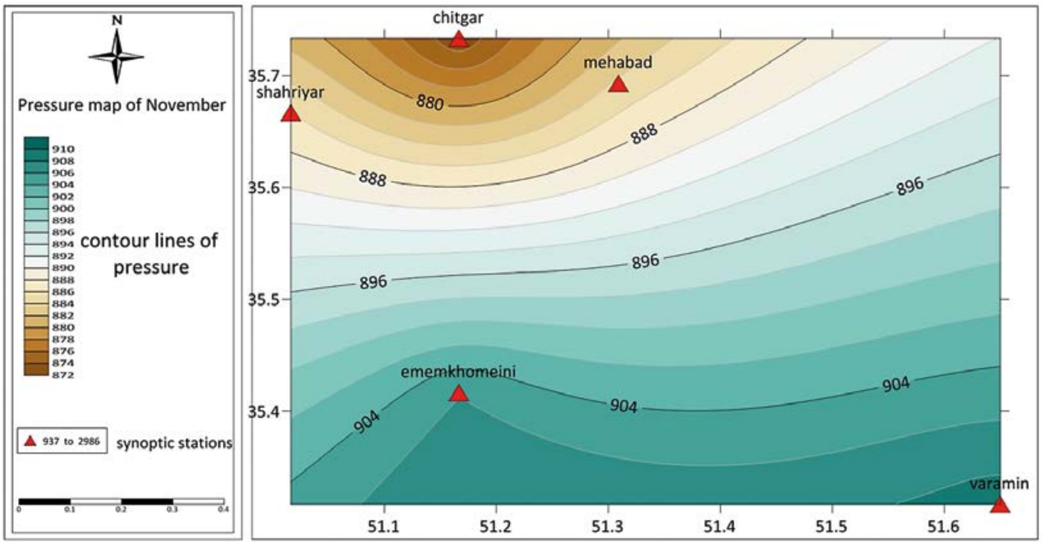

Fig. 6 Map of two Pressure cells with the highest Newtonian mass in 27/11/2013 in November.

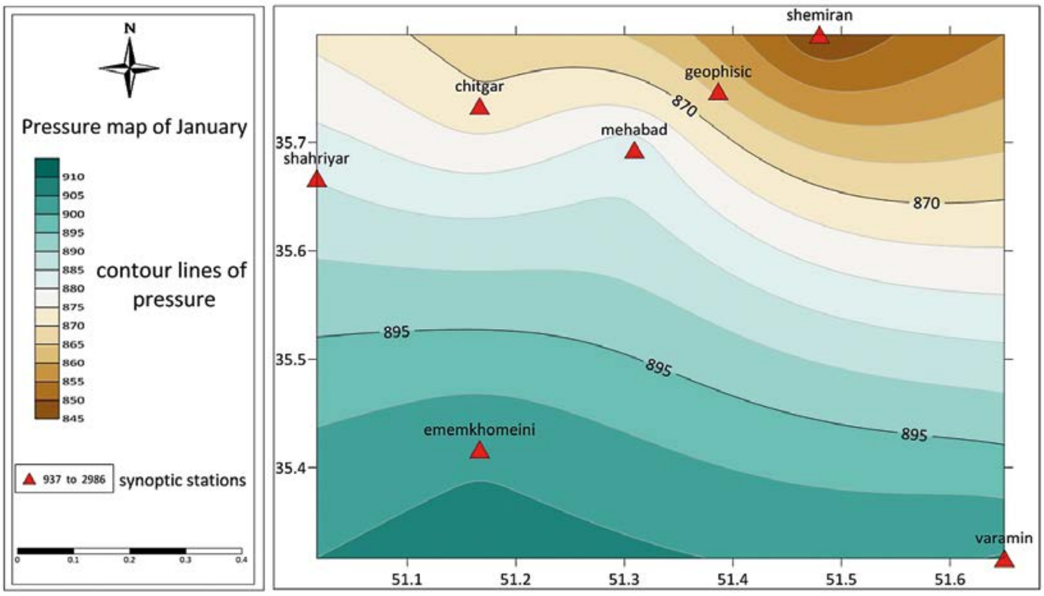

Fig. 7 Map of two Pressure cells with the highest Newtonian mass in 1/1/2017 in January.

Accordingly, the highest Newtonian masses are related to the Geophysics and Shemiran cells. In addition, the temperature values of each cell can also be seen in the table.

Fig. 6 shows a map of the pressure difference in the inversion at an altitude 1300 m in November. This map indicates the existence of two pressure cells, which have the highest Newtonian mass compared to other pressure cells on other polluted days. The two cells are approximately 36.88 km apart. Chitgar station is at the altitude of 1305.2 m and Imam Khomeini Airport station at 990.2 m. Pressure at the centers of Chitgar and Imam Khomeini cells is 874 and 906 hPa, respectively. Tab. 5 shows the temperature of the two cells of Chitgar and Imam Khomeini Airport, as well as their calculated Newtonian mass. Tab. 5 shows the temperature of the two cells of Chitgar and Imam Khomeini Airport, as well as their calculated Newtonian mass.

Fig. 7 shows a map of the pressure difference in the inversion at an altitude of 1800 in January. This map indicates four pressure cells, with Mehrabad and

Tab. 5 November pressure Cells Matrix.

27/11/2013		
Pressure cell	**Pressure**	**Newtonian's Mass**
Chitgar	874	616.8802
Imam Khomeini	906	

Tab. 6 January pressure Cells Matrix.

1/1/2017			
Pressure cell	Pressure	Newtonian's Mass	
Shemiran	850	Shemiran-Mehrabad	200.9521
Mehrabad	880	Shemiran-Imam Khomein	295.2137
Imam Khomein	903	Mehrabad-Imam Khomeini	701.7788
Cheitgar	873	Mehrabad-Cheitgar	3919.5918
		Shemiran-Cheitger	914.2148
		Imam Khomeini-Cheitger	579.5890

Tab. 7 December pressure Cells Matrix.

12/25/2013			
Pressure cell	Temperature	Newtonian's Mass	
Shemiran	895	Shemiran-Geophysics	6915.4999
Geophysics	904	Shemiran-Mehrabad	952.9616
Mehrabad	915	Geophysics-Mehrabad	8708.6483

Chittgar cells having the highest Newtonian mass. The two cells are about 14 km apart. Chitgar cell is at the altitude of 1305.2 m and Mehrabad cell at 1190.2 m. Pressure at the centers of Chitgar and Mehrabad cells was 873 and 880 hPa, respectively. In Tab. 6 the pressure of each cell and the Newtonian mass matrix of all cells are calculated.

In Fig. 8, three pressure cells formed in December can be seen at an altitude of 1700 m. According to calculations, the highest Newtonian masses belong to Geophysics and Mehrabad cells. The two cells, with the altitude of about 1423.8 and 1190.2 m, respectively, are located at an approximate distance of 9.2 km from each other. The pressure at the centers of the geophysical and Mehrabad cells is 904 and 915 hPa, respectively. In Table 7 the pressure of each cell and the Newtonian mass matrix of all cells are calculated.

6.2 Identification of general conditions of the study area on critical days of pollution during 15 years

In order to better analyze the conditions of the critical days of pollution, we calculated the mean of temperature, pressure and wind speed and then maps of these factors were plotted. The matrix of cells formed in each of these maps was then calculated to allow the comparison of the general conditions of the days of contamination with those of the cells with the highest Newtonian mass and temperature.

In the zoning map of the average temperature of the polluted days (Fig. 9), we observe the formation of four temperature cells, among which the Shemiran and Mehrabad cells have the highest Newtonian mass. The distance between the two cells is approximately 19.32 km. The central temperature of Shemiran cell is 16.05 °C and the central point temperature of Mehrabad cell is 18.4 °C. Tab. 8 shows the temperature of the cells in the map as well as their Newtonian mass values.

The following results are obtained by examining the maps of the average temperature of the critical days of pollution over 15 years, as well as a selection of daily temperature cell maps for the three target months.

a. The map of means shows the formation of four temperature cells including Shemiran, Mehrabad, Varamin and Imam Khomeini cells, with the largest Newtonian mass belonging to Shemiran and Mehrabad station.
b. We obtained these results from the daily temperature cell maps for the three months of November, January, and December.

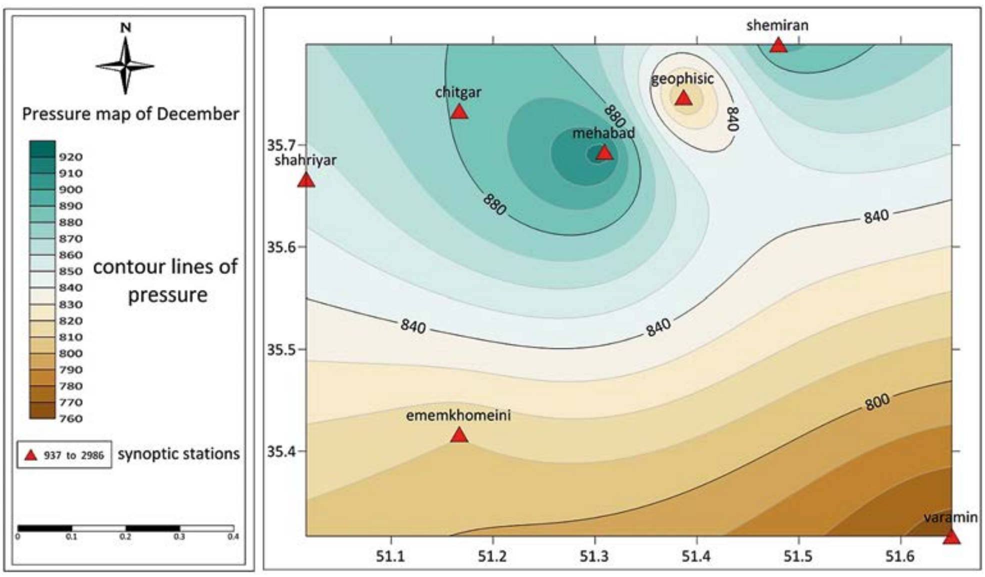

Fig. 8 Map of two Pressure cells with the highest Newtonian mass in 12/25/2013 in December.

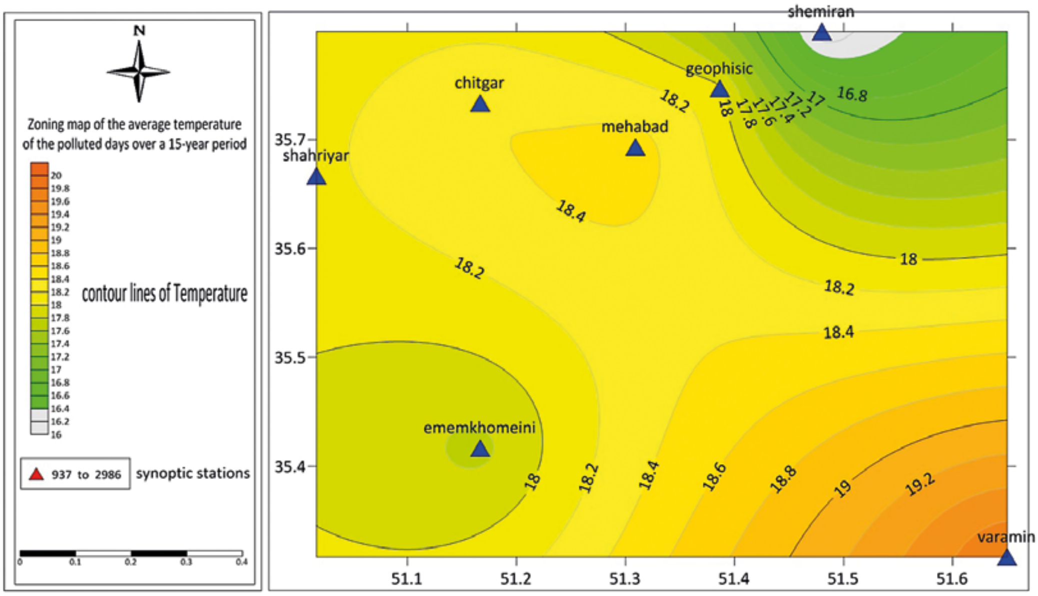

Fig. 9 Zoning map of the average temperature of the polluted days over a 15-year period.

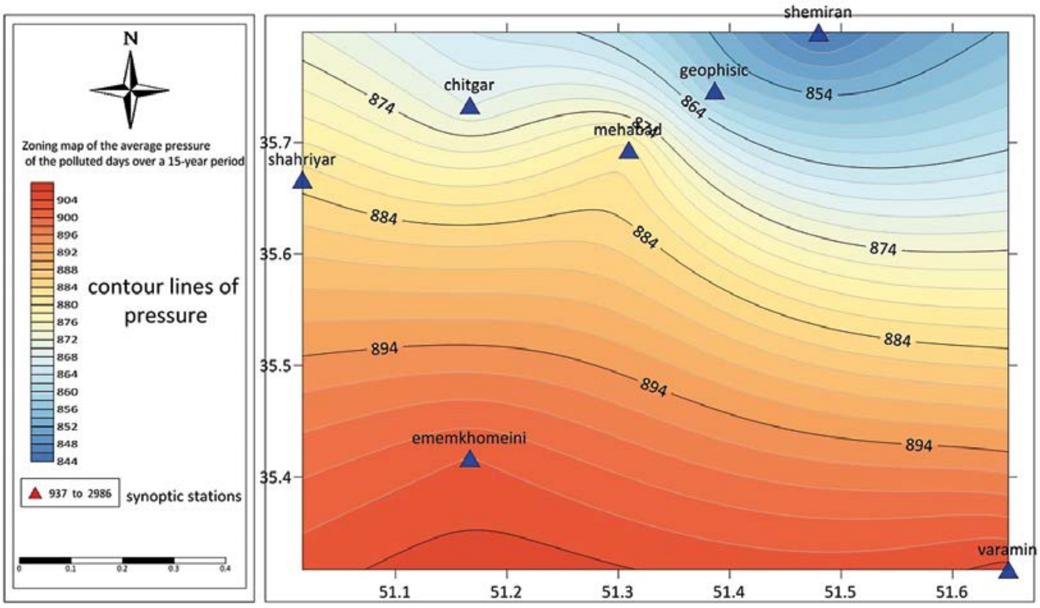

Fig. 10 Zoning map of the average pressure of the polluted days over a 15-year period.

Tab. 8 The average temperature Cells Matrix of the polluted days.

The average temperature over a 15-year period			
Temperature cell	Temperature	Newtonian's Mass	
Shemiran	16.05	Shemiran-Varamin	0.00500
Varamin	19.8	Shemiran-Imam Khomeini	0.00060
Imam Khomeini	17.7	Shemiran-Mehrabad	0.00620
Mehrabad	18.4	Varamin-Imam Khomeini	0.00109
		Varamin-Mehrabad	0.00590
		Imam Khomeini-Mehrabad	0.00061

Tab. 9 The average pressure Cells Matrix of the polluted days.

The average pressure over a 15-year period			
Pressure cell	Temperature	Newtonian's Mass	
Shemiran	845.16	Shemiran-Cheitger	0.030
Chitger	869.84	Shemiran-Imam Khomeini	0.021
Imam Khomeini	902.09	Shemiran-Mehrabad	0.096
Mehrabad	881.10	Chitgar-Imam Khomeini	0.023
		Chitgar-Mehrabad	0.057
		Imam Khomeini-Mehrabad	0.018

Mehrabad and Imam Khomeini cells have the highest Newtonian mass in November. In January, there are the Geophysics, Shemiran and Mehrabad temperature cells, among which, Geophysics and Shemiran have the highest Newtonian mass. December has five temperature cells, including Varamin, Imam Khomeini, Chitgar, Geophysics and Shemiran, among which, Geophysics and Shemiran have the highest Newtonian mass.

Accordingly, it can be concluded that in both types of maps (mean and daily), the location of the temperature cells is almost identical. Mehrabad, Shemiran and Imam Khomeini stations had the highest number of temperature cells in both types of maps.

There are four pressure cells in the mean pressure map of the 15-year period (Fig. 10). Shemiran and Mehrabad cells have the highest Newtonian mass, the values of which are shown in Table 9. The distance between the two cells is 19.32 km. The pressure at the centers of Shemiran and Mehrabad cells is 845.16 and 881.10 hPa.

The following results are obtained by examining the map of the mean pressure of the critical days of pollution over 15 years, and also investigation of the selected daily pressure cell maps for the three target months.

a. The map of means shows the formation of four pressure cells including Shemiran, Mehrabad, Chitgar and Imam Khomeini cells, with the largest Newtonian mass belonging to Shemiran and Mehrabad station.
b. We obtained these results from the daily temperature cell maps for the three months of November, January, and December.

November has Chitgar and Imam Khomeini cells with the highest Newtonian mass, January has four cells of Imam Khomeini, Shemiran, Chitgar and Mehrabad, among which, Chitgar and Mehrabad cells have the highest Newtonian mass, and December has three pressure cells including Mehrabad, Geophysics and Shemiran, with the highest Newtonian mass in Geophysics and Mehrabad cells.

Accordingly, it can be concluded that in both types of maps (mean and daily) the location of the pressure cells is almost identical. Mehrabad, Chitgar and Imam Khomeini stations had the highest number of pressure cells in both types of maps.

The results of comparing the two maps:

The location of the temperature cells is the same in both types of maps (the mean temperature maps of the polluted days in the 15-year period and the maps of heat cells of the polluted days in the three months in question), however, there is no such similarity between the maps in terms of the location of cells with the highest Newtonian mass.

This is also true for pressure cells (similarity of the location of cells and non-similarity of the location of cells with the highest Newtonian mass).

6.3 Winds of Tehran

The direction of winds in Tehran province is closely related to the geographical location and its terrains. General air currents in the province are subject to western winds. The general direction of these currents is almost parallel to the Alborz Range, and therefore the impact of these mountains appears as the lower average wind speed in the Southern valleys and foothills. The advance of the southern slopes of the eastern Karaj Heights diverts the surface winds to some parts of the southern plains, such as Shahriar, causing a relative increase in wind speed in these areas. Also, part of the southern slopes of Alborz Range in the north of Tehran has projections.

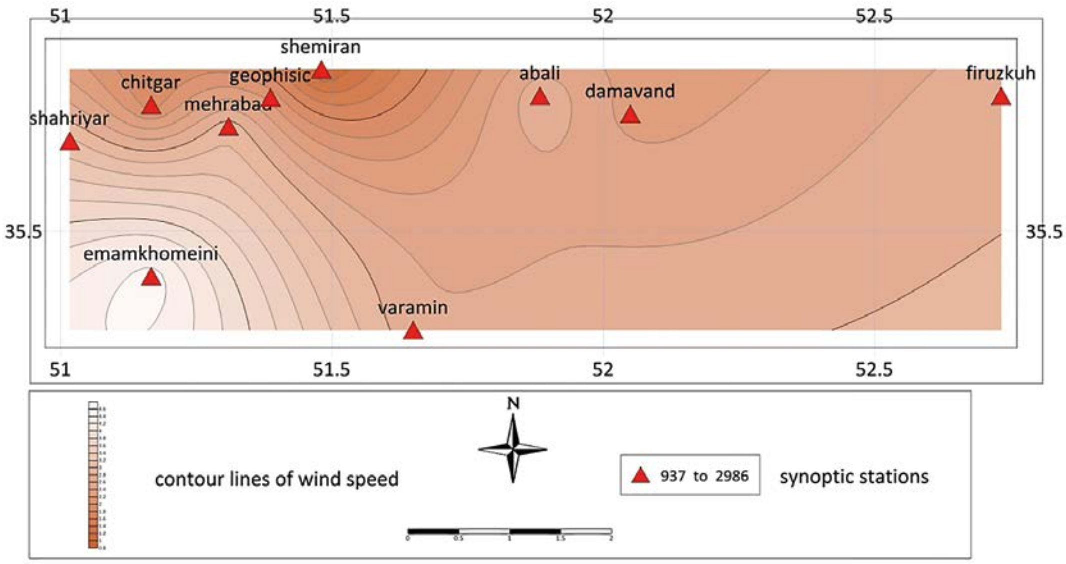

Fig. 11 Zoning map of the average wind speed of the polluted days over a 15-year period.

6.4 Wind direction

It can be said that 70% of Tehran's winds are weak (between 1 and 6 knots) and have no clear direction. Winds in Tehran are mainly from the west. As most of the winds in Tehran are weak , they do not have much effect on reducing air pollution.

In most months of the year, the wind direction is from west, with only two months from the southeast and two months from the north. Thus, for most months the western winds are highly volatile. The general direction of these currents is almost parallel to the Alborz Range; so, the effect of these mountains is mostly the reduction of the average wind speed in the Southern foothills valleys. Overall, Tehran's air is more stable than the surrounding areas and has little wind.

In the following, the zoning map of the average wind speed of the polluted days over the 15-year period is drawn to compare the wind speed at the stations in the study area.

In Fig. 11, the map of the average wind speed on polluted days during the 15-year period, we observe six wind cells that we can call wind holes.

Imam Khomeini cell has the highest average wind speed, followed by Abali, Mehrabad, Chitgar, Damavand and Shamiran stations, with the latter having the lowest average wind speed.

6.5 Topography

With an area of 800 km^2, the city of Tehran is located on the southern slope of Alborz Range. The altitude of the city reaches 1200 m in the south at Mehrabad airport and 2000 m in the north. Although the general slope of the city is southward, there are also lots of terrains. Alborz Range limits the city on the north and BibiShahrbanoo Mountains on the east. But the south and west areas are not so high.

The arrangement of the mountain dams has also led to local winds in Tehran. At night, for example, the mountain breeze brings pollutants downtown and raises the intensity of pollution. During the day, the breeze of the plains and the southern winds carry the pollutants northward and the northern areas become polluted.

6.6 Effect of topographic terrain features on temperature and pressure cells

In order to investigate the effect of topographic terrains on temperature and pressure cells, and to further understand the location of these cells, the temperature and pressure cells were overlain on the topography of the area.

For this purpose, a 3D map of the area's heights was plotted, and the synoptic stations and pressure and temperature cells overlapped for analysis and investigation.

Based on the three-dimensional map, in Fig. 12 two temperature cells of Mehrabad and Imam Khomeini can be observed. Mehrabad Airport cell is located in the projected area of southern Alborz Mountains and the Imam Khomeini Airport cell is located near the low heights of southern Shahriar.

Mehr Abad cell with a height of 1190.2 m and pressure 884.1375 and Imam Khomeini airport cell with a height of 990.2 m and a pressure of 905.5875 have a height difference of 200 m and a pressure difference of 21.45 hPa. These two temperature cells with the highest Newtonian mass have been identified in critical days of contamination for 15 years.

In Fig. 13 the overlapping the temperature cells of January with the topography of the study area, there can be seen three cells of Shemiran, Geophysics and Mehrabad. The two formed cells are located in the recesses of the southern slope of the Alborz Range, and it may be noted that the confinement of cell

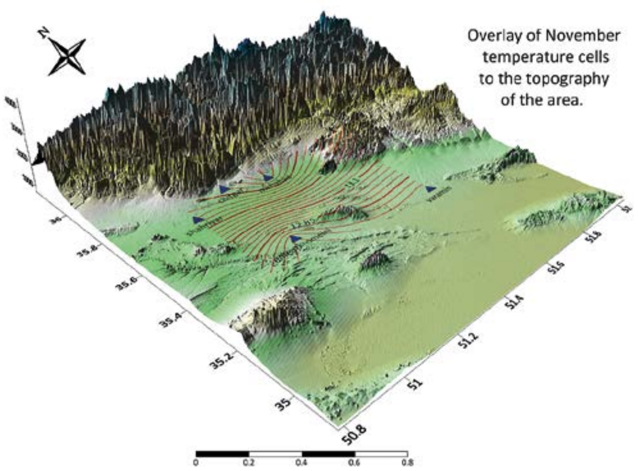

Fig. 12 Overlay of November temperature cells to the topography.

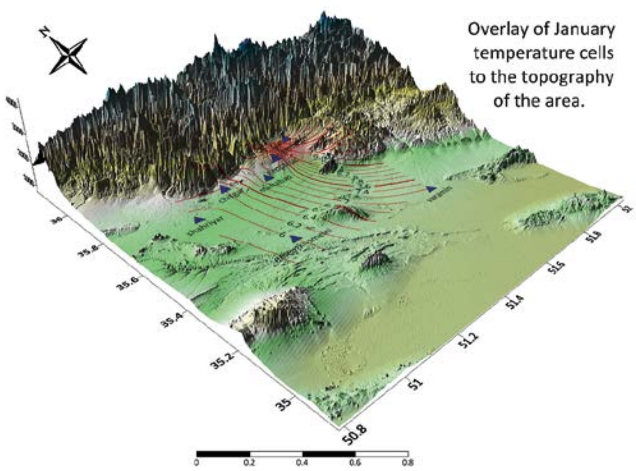

Fig. 13 Overlay of January temperature cells to the topography.

formation zones may influence the formation of these temperature cells.

Meanwhile, Geophysics and Shemiran cells have a higher Newtonian temperature than other cells. Geophysics cell has an altitude of 1423.8 m and a pressure of 854.1. The two cells, with a height difference of 124.4 m and a pressure difference of 9.8, are located on a sloping terrain at the lower end of the Alborz Range.

Based on Fig. 14, five temperature cells of Varamin, Imam Khomeini, Chitgar, Geophysics and Shemiran, are located on Tehran topography. Among these cells, Geophysics and Shemiran cells have the highest Newtonian mass.

These two cells are located in the recesses of the southern slope of the Alborz Range, and the confinement of areas where the cells are located may influence the formation of these temperature cells.

The Geophysics cell with a height of 1423.8 m and pressure of 862.9 and Shemiran cell with a height of 1548.2 m and pressure of 850.2 have a height difference of 124.4 m and a pressure difference of 12.7 hPa.

The Fig. 15 shows two pressure cells at Chitgar and Imam Khomeini Airport Stations. The Chitgar cell lies on the southern slope of the Alborz Range, where the mountain have eaves Imam Khomeini Airport cell is located near the low heights of southern Shahriar. The formation of these pressure cells at the above-mentioned areas may be affected by the air currents of the area. Due to the, eaves of the southern slopes of the eastern mountain these currents divert the surface winds to the southern plains and increase the relative wind speed at these points.

Chitgar station with a height of 1305.2 meters and temperature of 11.55 °C and Imam Khomeini Airport station with a height of 990.2 meters and a temperature of 12.15 °C have a height difference of 315 m and a temperature difference of 0.6 °C.

In Fig. 16, the map of overlapping of pressure cells of January on the heights of the study area, we observe

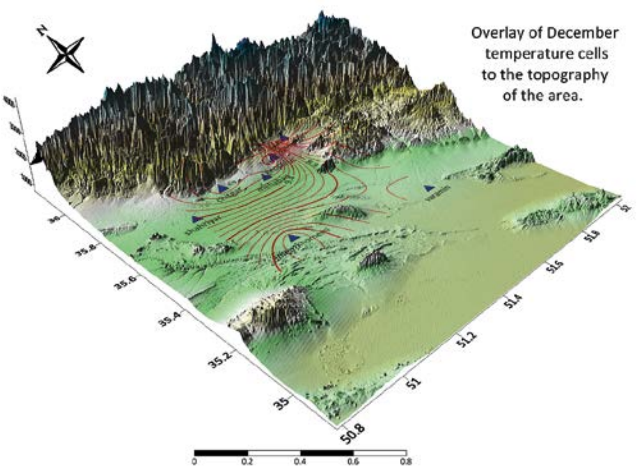

Fig. 14 Overlay of December temperature cells to the topography.

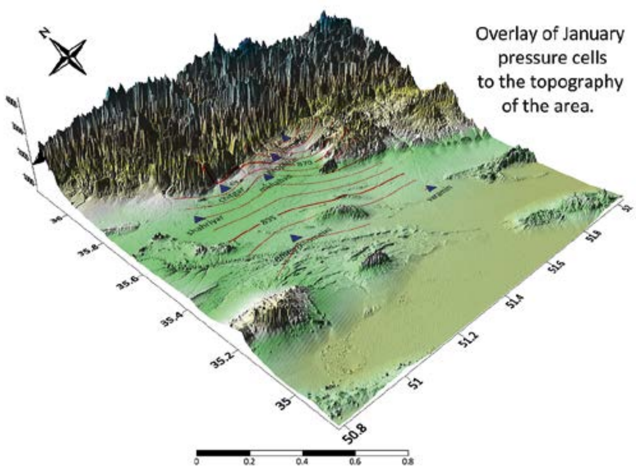

Fig. 16 Overlay of January pressure cells to the topography.

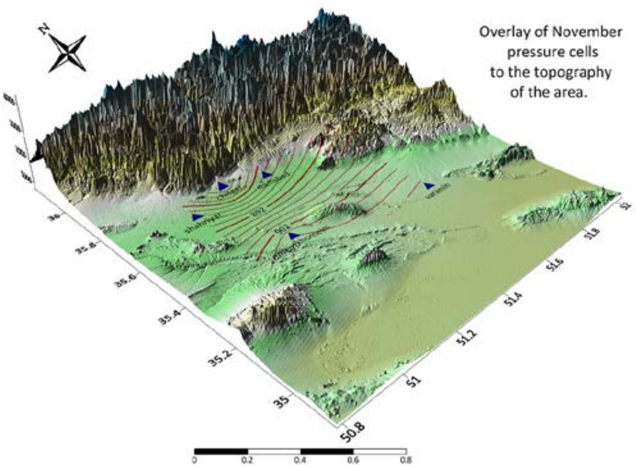

Fig. 15 Overlay of November pressure cells to the topography

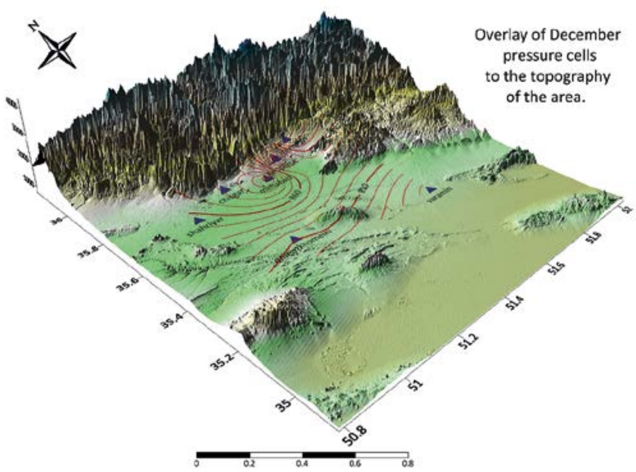

Fig. 17 Overlay of December pressure cells to the topography.

four cells of Shemiran, Mehrabad, Imam Khomeini and Chitgar, which are located at the desired altitudes.

In terms of pressure, the two cells of Mehrabad and Chitgar have the highest Newtonian mass. The two cells are located in the projections of the southern Alborz Range. Chitgar cell with height of 1305.2 m and temperature of 11.05 °C have a height difference of 115 m and a temperature difference of 0.05 °C.

Based on Fig. 17, the three pressure cells of Mehrabad, Geophysics and Shemiran are located on Tehran terrain, among which Mehrabad and Geophysics have the highest Newtonian mass in terms of pressure.

These two cells are located on the northern heights of Tehran. In fact, this part of the southern slope of Alborz Range has a recession that can affect the wind directions and also the formed cells. The Geophysics cell with a height of 1423.8 m and temperature of 3.8 °C and Mehrabad cell with a height of 11190.2 m and a temperature of 3.7 °C have a height difference of 233.6 m and a temperature difference of 0.1 °C.

7. Conclusions

Tehran's air pollution is considered as one of most important environmental problems and so far numerous studies have been done to mitigate this problem. Among the factors that cause air pollution are human factors as well as geographical ones and conditions such as Tehran's topography and the occurrence of inversions, especially during the cold months of the year.

In this study, with emphasis on Tehran geographical factors, we attempted to determine the critical days of air pollution using the data of air pollution measuring stations and synoptic stations in Tehran province from 2003 to 2017. Then after investigating and determining the level of inversion, we studied probability of the existence of closed temperature and pressure cells in these days. Then, by calculating and measuring the cellular properties as well as the existing conditions, the theoretical possibility of their turbulence was studied in order to cause turbulence in Tehran air to reduce air pollution. The results of the determination of the level of inversion showed that AQI > 150 in the target months did not cover all areas of Tehran. This means that while some areas of Tehran are more polluted than others, exceptions to this rule are excluded.

Generally considering the formed cells by the temperature and pressure difference and the gradient between them as well as the difference in height between the cells and their location and pointing out that the local winds cause the difference of temperature and pressure, it is more possible to elucidate conditions for creating air turbulence in Tehran within the study area to control the contamination amount. Results of this study provide new knowledge of the natural conditions in the study area, and there is no uniform pattern for all areas in the subject area. Since this study was conducted only for a limited period of 15 years (from 2003 to 2017) in Tehran province, and also all analyses were performed on the basis of statistics measured in synoptic stations in this area, the results should be interpreted with caution. However, it can be emphasized that all reviews and results are based on this range and data and cannot be over-generalized.

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