J. Basic. Appl. Sci. Res., 3(5)140-146, 2013
© 2013, TextRoad Publication

ISSN 2090-4304
Journal of Basic and Applied Scientific Research
www.textroad.com

Classification Synoptic Circulation Patterns Impacting on Air Pollution in Tehran

Mohammad Darand[1], Amir Hossein Halabian[2]

[1]Dept. of Climatology, University of Kurdistan, Iran
[2]Dept. of Geography, University of Payam-e Noor, Iran

ABSTRACT

The influence of synoptic-scale circulations on air quality is an area of increasing interest to air quality management. Tehran has long been ranked as one of the world's most polluted cities. In order to determine the impact of atmospheric circulation patterns on the air pollution, the average daily concentration measurement of Pollution Standard Index (PSI) during 2002 to 2007 is used. The results showed five different circulation patterns result in extreme value of pollution in Tehran. Each synoptic pattern dictates a distinctive air mass affecting concentration and subsidence conditions. The highest value of air pollution observed during the extension of the Azores High pressure over Tehran, covered by a strong ridge on the upper level in 850 and 500 hPa and accompanied by a low thermal pressure in the surface over the Pakistan and Iran.
KEYWORDS: Synoptic analysis, Circulation patterns, air pollution, Tehran.

1. INTRODUCTION

Air pollution is a common problem in many places around the world, where widespread industrial and urban development have occurred. The main sources of anthropogenic emission are industrial plants, mobile sources and residential use [1]. The Metropolitan Area of Tehran, 25° 40' N, 51° 25' E in Iran, is the largest industrialized region in Iran with more 12 million inhabitants. As the political and cultural center of Iran, Tehran has long been ranked as one of the world's most polluted cities. Air pollution has become one of the top environmental concerns facing Tehran. Increased air pollutant concentrations in the urban environment do not typically result from sudden increases in emissions, but rather from meteorological conditions that impede dispersion in the atmosphere or result in increased pollutant generation [2]. Synoptic climatological approaches are becoming increasingly popular to evaluate the impact of climate on a wide variety of environmental problems [3]. Methods in synoptic climatology typically employ one of two fundamentally different approaches [4]. The circulation-to-environment approach structures the circulation data, often by classifying or clustering synoptic-scale maps, prior to seeking links with the local-scale environment. Conversely, environment- to-circulation approaches, such as compositing, structure the circulation data based on criteria defined by the environmental variable. Classifications of atmospheric circulation patterns have been applied for a variety of purposes, one of the major applications of circulation classifications being in synoptic climatological analyses. Development of a synoptic climatology is generally defined as a two stage process involving determination of a relatively small set of atmospheric circulation types (often on the basis of synoptic scale weather maps), and secondly, the assessment of weather elements (or environmental variable) in relation to these classes[5]. Implicit in this procedure is the assumption that particular modes of atmospheric circulation produce distinctive environmental conditions at particular locations [6]. Applications of synoptic climatology approach for investigating the impact of Atmospheric circulation patterns on air pollution concentration has been well developed in Turkey [7,8]; Australia [9], United States [10,11,12], Northern China [13],Southern Taiwan[14], Northwest Continental Europe [15], Southern Poland [16], Northeast of Portugal [17], Continental Spain [18], Malaysia [19]. The aim of this study is to associate the synoptic circulation patterns and air pollution in Tehran. In order to determine the impact of circulation patterns on the air pollution, the average daily concentration measurement of Pollution Standard Index (PSI) during 2002 to 2007 is used. In the analysis, we define a high pollutant day to be one in which Pollution Standard Index (PSI) above 100(PSI>100). During the study period 100 days have this circumstance. Then Gridded sea level pressure (SLP), 850 and 500-hPa geopotential height data from the National Centers for Environmental Prediction–National Center for Atmospheric Research (NCEP–NCAR) were used. Data were extracted for a region extending from 0° to 120°E and from 0° to 80° N to best represent synoptic patterns in selected days. In the present study, the Cluster analysis technique by Ward linkage method is applied to the sea level pressure (SLP), 850 and 500-hPa geopotential height data. The geographic location of Tehran on Iran has been shown in Figure 1.

***Corresponding Author:** Mohammad Darand, Dept. of Climatology, University of Kurdistan, Iran

2. RESULT AND DISCUSSION

The cluster analysis using Ward method on the data sea level pressure in selected days showed that five different atmospheric circulation patterns result in extreme value of air pollution in Tehran. High-pressure system is usually considered to be the governing synoptic pattern that leads to air pollution. Seasonal variability is evident in virtually all of circulation patterns. Pattern 2, 4 and 5 dominating in the cooler months while patterns 3 and 1 dominating in the warmer months. According to table 1 patterns 3 with frequency %39 most observed during pollutant days. The pattern 4 has lowest frequency. The most value of air pollution has been observed during occurrence of patterns 3 and 4 respectively. Figure 2.a exhibits the composite map of mean sea level pressure for cluster 1. In this pattern, two high pressure centers observed on the Europe and Siberian that affected on the transport of cold air to Tehran. The Pakistan thermal low pressure tongue governed to Iran and result in transport warm air to the upper level of Tehran. The warm air is located on the high while cold air is located on the surface that can result in occurrence of inversion. In Figure 2.b, well-developed the ridge of the large scale Azores high pressure extend to east and located on the north part of Iran. In the 500 hPa ridge of Azores high pressure is observed. In this situation subsidence occurs on the Tehran. This kinds of pressure pattern is most frequent in the warm season over Asia region. The center of a continental Siberian high pressure system is located over 90°E. The European high pressure because of weakness in sub polar low pressure, displacement to the north. In the 850 hPa level Siberian high pressure tongue observed over Iran and a depth trough formed on the European eastern (Figure 3.b). In upper level (500 hPa), westerly wind ridge presences over north part of Iran (Figure 3.c). This pattern occurs in cold seasons (autumn and winter). The dominant synoptic condition prevailing during the summer over the Iran is influenced by two major systems surrounding the region, resulting in overall monotonic weather conditions. From the east, mid- and south Asia, land warming during the summer leads to the development of the Pakistan Low which extends from the Pakistan towards the north part of Iran. In the upper level in 850 and 500 hPa, westerly to the region, the Azorean high influences the area as part of the subtropics belts of highs. The Azorean high is centralized at the Atlantic Ocean, near the Azorean islands, and dictates subsidence and stability. Figure 4.a depicts the extension of the Azores High over the North Africa and Iran, covered by a strong ridge and accompanied by a low pressure over the Pakistan. This situation mostly occurs in the summer. The interactions between the low pressures centered at the Pakistan to the north part of Iran with Azores high pressure result in inversion occurrence in Tehran. This pattern is the most frequent and the associated concentration of pollution is very high. In summary, the circulation atmospheric pattern in pattern 3 reflect the highest concentrations to be associated with dominant strong ridge on the upper level(850 and 500) and the presence of a thermal low pressure in the surface.

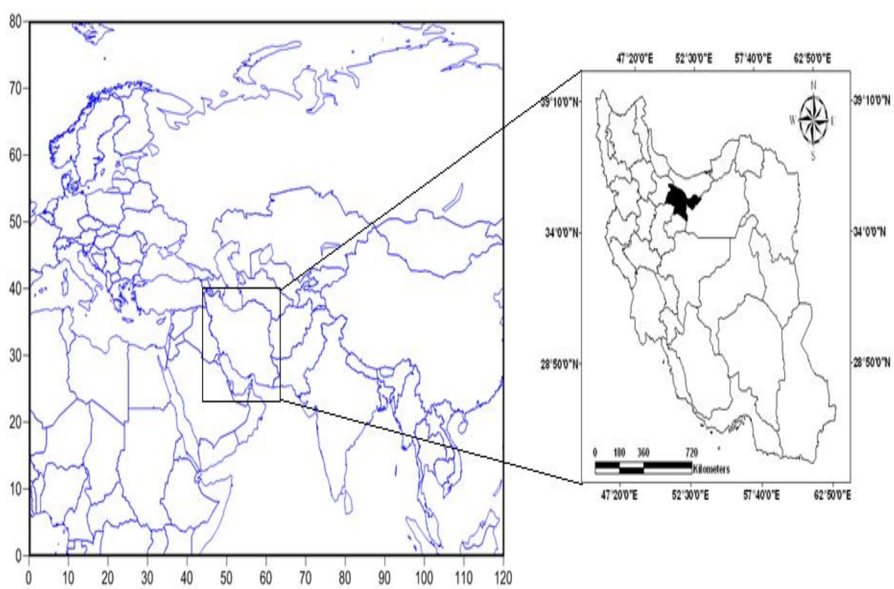


Figure1. The geographic location of Tehran metropolitan in Iran (in black).

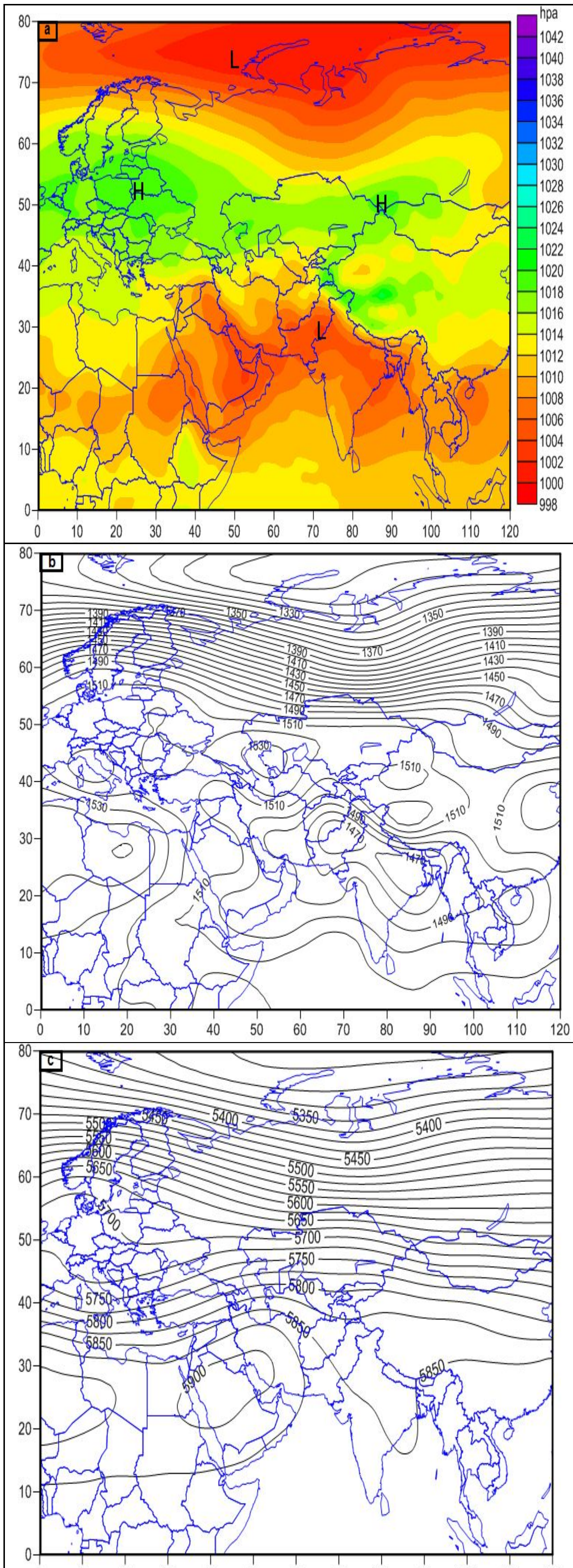


Figure 2.Composite map of sea level pressure in pattern 1 (a), composite map of 850-hPa and 500-hPa level during pattern 1.

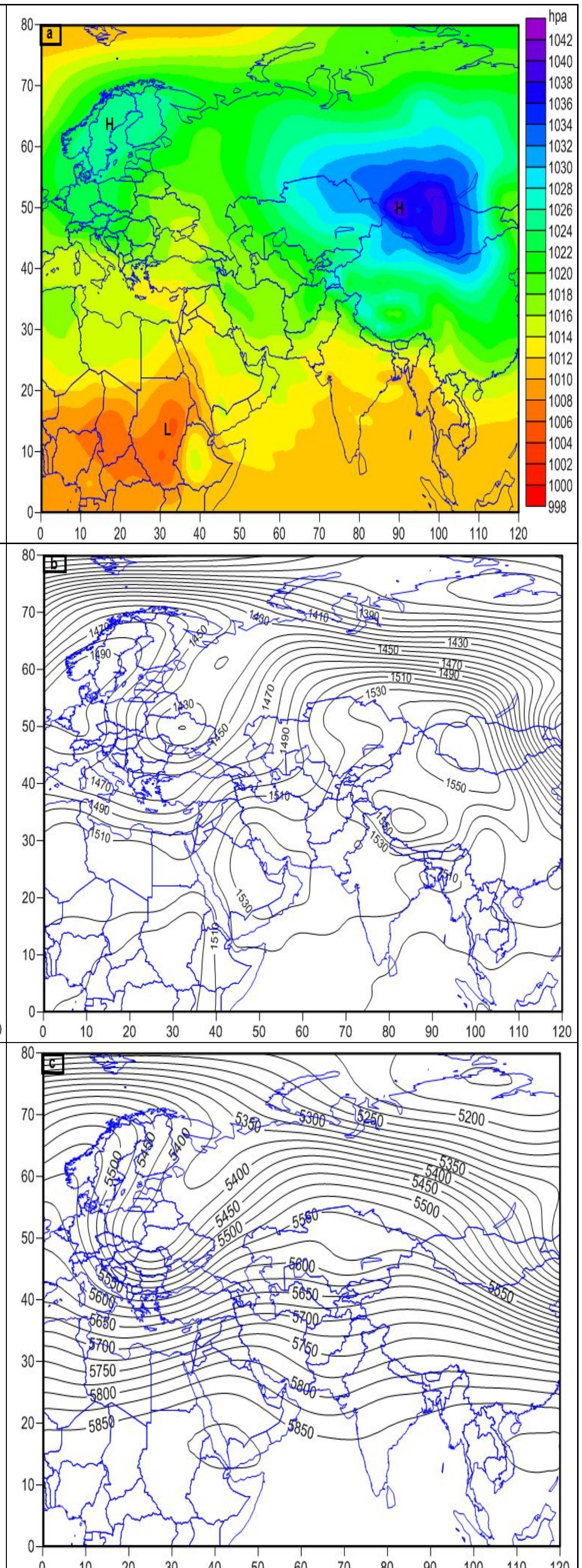
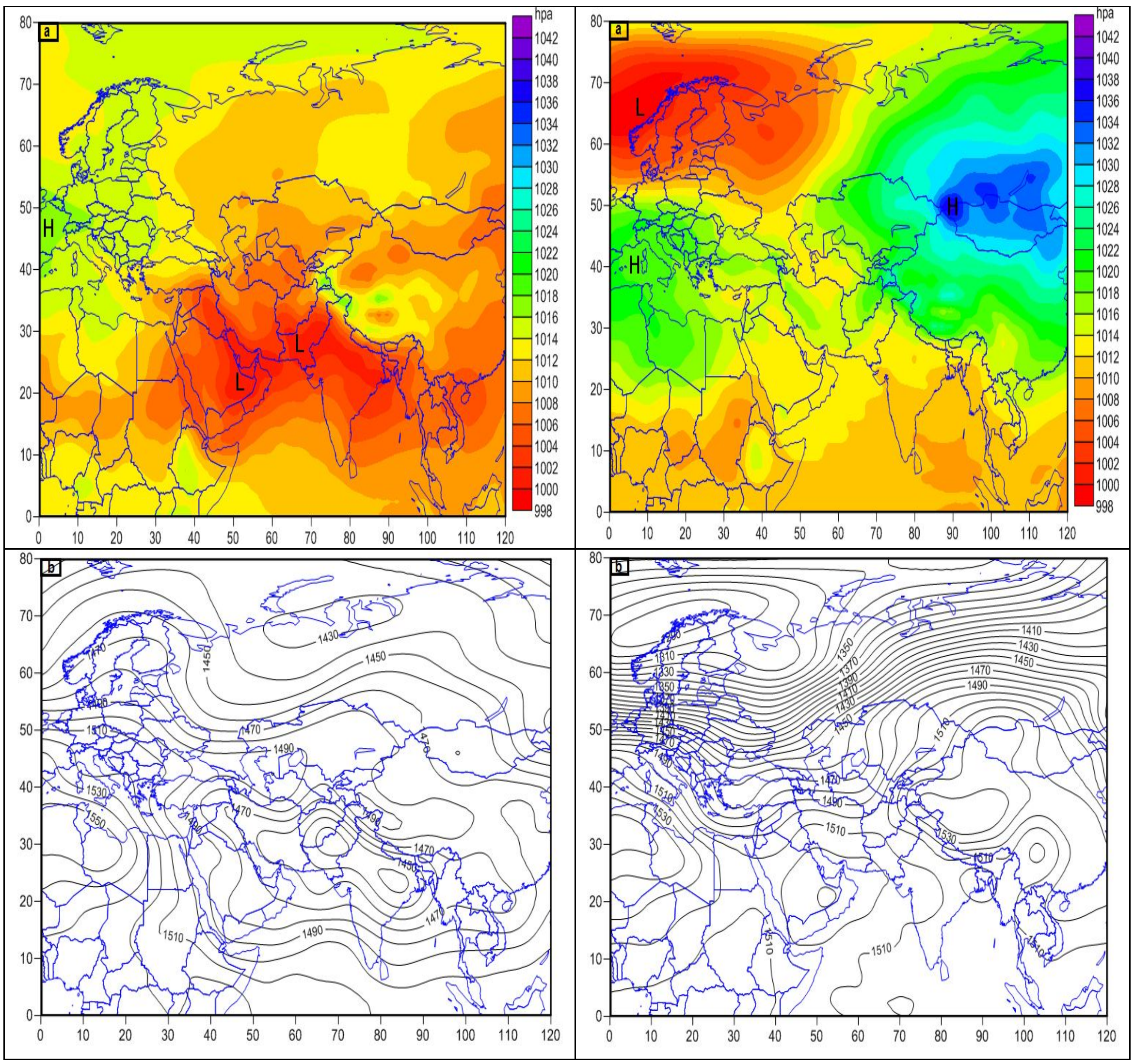


Figure3. Same as Figure 2 but for pattern 2.

In the pattern 4, sub polar low pressure displacement to the south on the Europe. In result, the European high pressure moves toward European southern part. As has been shown in Figure 5.a, the Siberian high pressure is presence and affected east and southern part of country. The European cold tongue with northwest to southeast direction affected north part of Iran. In this situation, the air temperature decreased and results in air stability and air pollution concentrations over Tehran. Pattern 4b shows the displacement of the Azores High southward and sub-polar low pressure. At 850 and 500 hPa, the location and presence of an upper level ridge appears to be an important factor contributing to high level pollution concentrations (Figure 5.b and Figure 5.c). In this situation, upper level north-westerly flow is responsible for the advection of cold air toward Tehran region. This kinds of pressure pattern is most frequent in the cold season of year. In the pattern 5, the sub polar low pressure expands and moves southward. This expansion of the sub polar low pressure results in a southward displacement of the Siberian high pressure. The high pressure observed on the north of Caspian Sea in the north of Iran and result in insulation of cold air to the Tehran (Figure 6.a). The 850 hPa map is characterized by a ridge on the Iran that expands toward the east from the Atlantic Ocean area. Such a synoptic pattern makes the stability in atmosphere and high value concentration of pollution (Figure 6.b). In the 500 hPa map, a broad ridge cell situated over the Arabian Saudi that its axis crosses in north part of Iran (Figure 6.c). Circulation patterns that exhibited situations with a high pressure in the surface on the north part of Iran and ridge in upper level resulted in the largest increases air pollution. This pattern just occurs in autumn season (Table 1).



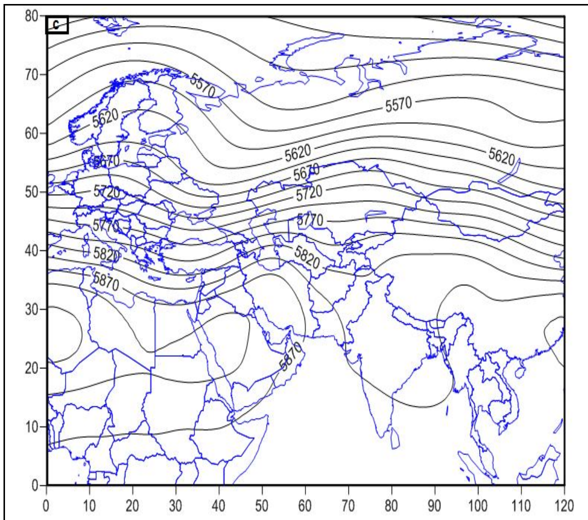


Figure4. Same as Figure 2 but for pattern 3.

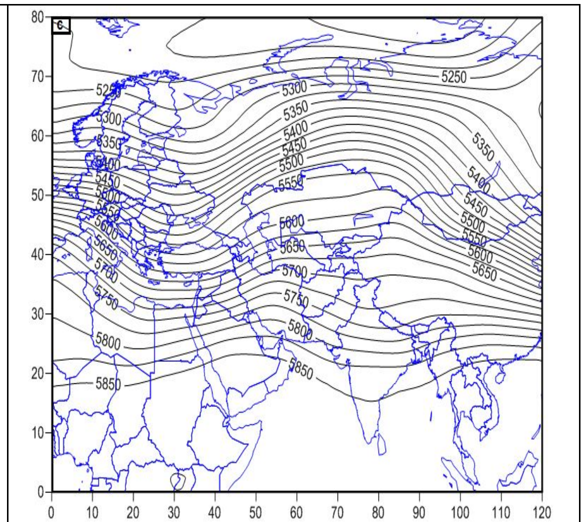


Figure5. Same as Figure 2 but for pattern 4.

Table1. Seasonal differences of circulation patterns

Total	pattern5	pattern4	pattern3	Pattern2	Pattern1	
3		1		2		January
1		1				February
1				1		March
4			1	3		April
2			2			May
2			2			June
8			7		1	July
24			18		6	August
27			7		20	September
17	8	4	2	2	1	October
9	5	2		1	1	November
2		1		1		December
0.100	0.13	0.09	0.39	0.12	0.29	Total frequency (%)
	112	125.5	126.5	122.2	121.7	Mean PSI

4. Conclusions

The relationship between the synoptic atmospheric circulation patterns and air pollution in northern Tehran investigated through classification of days with extreme value of air pollution. The air qualities in the study were represented using Pollution Standard Index (PSI). Applying Cluster Analysis by Ward linkage method on the mean daily sea level pressure shows that five synoptic atmospheric circulation pattern affecting the concentration air pollution in Tehran. It was found that the Atmospheric pollution processes are closely related to synoptic pressure patterns. Overall, the effect of synoptic-scale circulations on pollutant concentrations in Tehran can be summarized that high ridge of Azores high pressure in the upper level result in increased concentration high value of pollution when they are expand to the east and located over north part of Iran. It blocked the convection of surface air, reducing vertical mixing, and thereby increasing air pollutant concentrations near the ground. A subsidence is usually formed under the high-pressure systems. The Azores high pressure is more frequent pattern in the 850 and 500 hPa level. The highest values of PSI, exceeding 126, observed for pattern 3 in warm season.

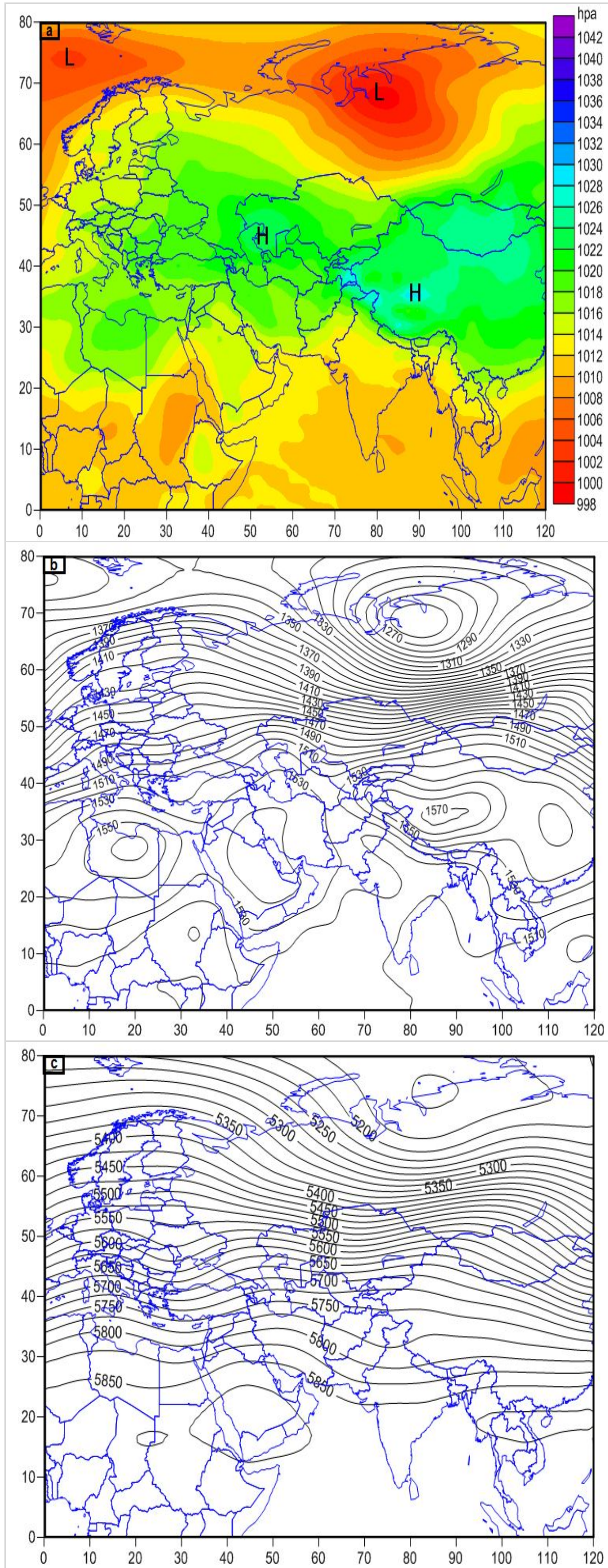


Figure6. Same as Figure 2 but for pattern 5.

REFERENCES

1. Pedrero, P., Carmen, T. & Enrique, L. 2009. Descriptive mathematical techniques to study historical data: An application to sulfur dioxide pollution in the city of Talcahuano – Chile. Atmospheric Environment., 43:6279–6286.
2. Chen, D.S., Cheng S.Y., Liu, L., Chen,T & Guo, X.R. 2007. An integrated MM5-CMAQ modeling approach for assessing trans-boundary PM10 contribution to the host city of 2008 Olympic summer games e Beijing, China. Atmospheric Environment., 41:1237-1250.
3. Kalkstein, L.S., Tan, G & Skindlov, J.A. 1987. An evaluation of three clustering procedure for use in synoptic climatology classification. Journal of climate and applied meteorology., 26: 717-730.
4. Yarnal, B. 1993. Synoptic Climatology in Environmental Analysis. Bellhaven Press, 195 pp.
5. Barry, R.G. & Perry, A.H. 1973. Synoptic Climatology: Methods and Applications. Methuen, 555 pp.
6. McKendry, I.G. 1994. Synoptic circulation and summertime ground level ozone concentrations in Vancouver, British Columbia. Journal of Applied Meteorology., 33: 627–641.
7. Demirci, E. & Cuhadaroglu, B. 2000. Statistical analysis of wind circulation and air pollution in urban Trabzon. Energy and Buildings., 31: 49–53.
8. Triantafyllou, A.G. 2001. PM10 pollution episodes as a function of synoptic climatology in a mountainous industrial area. Environmental Pollution., 112: 491–500.
9. Hart, M., De Dear, R., Hyde, R., 2006. A synoptic climatology of tropospheric ozone episodes in Sydney, Australia. International Journal of Climatology., 26 (12): 1635-1649.
10. Kalkstein, L.S. & Corrigan, P. 1986. A synoptic climatological approach for geographical analysis: assessment of sulfur dioxide concentrations. Annals of the Association of American Geographers., 76(3): 381–395.
11. Davis, R.E. & Gay, D.A. 1993. An assessment of air quality variations in the south– western USA using an upper air synoptic climatology. International Journal of Climatology., 13(7): 755–781.
12. Comrie, A.C. 1996. An all-season synoptic climatology of air pollution in the US– Mexico border region. The Professional Geographer., 48 (3): 237–251.
13. Chen, Z.H., Cheng, S.Y, Li, J.B., Guo, X.R., Wang H.Y. & Chen, D.S. 2008. Relationship Between atmospheric pollution processes and synoptic pressure patterns in northern China. Atmospheric Environment., 42: 6078-6087.
14. Wang, W.C., Chen, K.S., Wang, S.K., Lee, H.C. & Tsai, M.Y. 2009. Modeling atmospheric PM10 concentrations during severe pollution events in southern Taiwan. Atmospheric Research., 92:159–171.
15. Buchholz, S., Junk, J., Krein, A., Heinemann, G. & Hoffmann, L. 2011. Air pollution characteristics associated with mesoscale atmospheric patterns in northwest continental Europe. Atmospheric Environment., 44:5183-5190.
16. Lesniok, M., Malarzewski, L. & Niedzwiedz, T. 2010. Classification of circulation types for Southern Poland with an application to air pollution concentration in Upper Silesia. Physics and Chemistry of the Earth., 35: 516–522.
17. Carvalho, A., Monterio, A., Ribeiro, I., Tchepel, O., Miranda, A.I., Borrego, C., Saavedra, S., Souto, J.A. & Casares, J.J. 2010. High ozone levels in the northeast of Portugal: Analysis and characterization. Atmospheric Environment., 44:1020-1031.
18. Rasilla, D., Garcia-Codron, J.J., Carracedo, V. & Diego, C. 2010. Circulation patterns, wildfire risk and wildfire occurrence at continental Spain. Physics and Chemistry of the Earth., 35: 553–560.
19. Juneng, L., Talib Latif, M. & Tangang, F. 2011. Factors influencing the variations of PM10 aerosol dust in Klang Valley, Malaysia during the summer. Atmospheric Environment. 45: 4370-4378.