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Original Article

Study on Origin of Dust and its Relationship With Climatic Elements in Ilam Province

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Abstract

Background & Aims: Atmospheric phenomena can directly influence the occurrence of dust events. The western and southwestern parts of Iran are considered dust hotspots. This study aimed to examine and determine the origin of dust particles in Ilam province and its relationship with climatic components in the period 2012-2018.

Materials and Methods: In this descriptive-applied study, satellite images were obtained from the data transmitted from the Landsat TM satellite. In addition, HYSPLIT model was used to search for dust sources at an altitude of 1500 m or less (dust occurrence altitude class). Using SPSS 18 and OriginPro 2018, time series of data and linear regression equations were analyzed to determine the relationship between particulate matter and climate indicators.

Results: The results for the origin of particulate matter in Ilam province indicated that out of a total of 165 daily dust events that occurred in this province from 2012 to 2017, 69 (daily) dust events (42%) originated from Iraq, 36 (22%) from Syria, 29 (17%) from Saudi Arabia, 16 (10%) from the Persian Gulf, and 15 (9%) from Jordan. The results of multiple regression analysis based on the influence coefficient of the absolute value of the standardized coefficients indicated that temperature with an influence coefficient of 0.370 was identified as a significant factor related to the particulate matter. In the correlation analysis, the variables of temperature, humidity, dew point, and cloudiness showed a significant correlation with particulate matter at the level of 0.03.

Conclusion: Considering the relationships between dust phenomena and climatic factors, they can be used to predict dust phenomenon.

Keywords: Particulate matter, Dust, Climate change, Remote sensing technology

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1. Introduction

Dust has been one of the most important natural hazards and forms of pollution in recent years which has been the focus of many scholars in various dimensions [1]. In the field of dust, various studies have been carried out with different approaches. Source identification studies are one of the most important approaches to the environmental management of this phenomenon. Airborne dust events in the western and southwestern regions of Iran have severe adverse health effects, increasing cardiovascular and respiratory diseases and premature death in vulnerable groups [2,3]. Due to its location in the arid and semi-arid regions of the Earth, Iran is frequently exposed to numerous local and synoptic dust systems [4]. Various studies have indicated that atmospheric factors are directly related to dust phenomena. The nature of this relationship varies by region and is based on the climatic factors that influence weather phenomena. One of these phenomena is atmospheric instability. Humidity also has a significant effect on this phenomenon [5]. The advantage of such studies is to increase the ability to predict the occurrence of this phenomenon and the possibility of better management of dust storms.

Dust storms generally contain small soil particles that can be scattered up to several kilometers above the ground [6]. Strong winds and dust carry large amounts of dirt and sand from dry land, suspend it in the air, and darken it. This air, saturated with earthy matter, forms a cloud that covers the sun or makes it looks like a molten and pale pill [7]. Based on the travel path of particulate matter and its landing site, its origin and direction of travel can be determined [8]. Several studies have been conducted on the spatial origin of dust phenomena and their relationship with climatic factors. Darmany et al [9] used the dust particle source identification method based on the physical and chemical properties of the particles. Wang and Draxler [1] used the HYSPLIT model to identify the origin of particulate matter in North China and Mongolia, proposing management solutions to reduce the occurrence of the phenomenon. Rivandi et al [10] in the atmospheric studies of the dust phenomenon with the Lagrangian-Eulerian model of particle diffusion in the

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HYSPLIT model, analyzed the simulation of dust pathways entering Iran from the west and southwest, identifying Iraq and Syria as the major sources of these events (more from 80% of events). Likewise, Bouchlaghem et al [11] used the HYSPLIT model algorithms to determine the path of sand and dust storms in the Tunisian desert. In general, the use of remote sensing data has proven to be very effective in studying the particulate matter pathways and identifying their origins [12].

Various studies have been conducted on the main sources of dust imported into Iran, including the Arabian Peninsula, the Persian Gulf countries, the north of the Jordan Desert, the eastern regions of Syria, and parts of Iraq that move dust and affect Iran as the storm moves towards the east [13,14]. In particular, the west and southwest of Iran, including Ilam, seem to be greatly affected by the dust from the north wind, which is a warm northwest wind, often blowing during the spring and bringing large amounts of dust from Iraq [15]. Recent observations have demonstrated that the occurrence of this phenomenon is increasing in Iran, especially in the western, southwestern, and central parts of the country. Therefore, the dust phenomenon has become an important challenge and concern in the western and southwestern provinces [16]. Iran's geographical situation and longer border (420 km) with Iraq, as one of the main sources of dust in the region, and its proximity to other important dust centers (e.g., Eastern Syria, Saudi Arabia, and Kuwait) have extremely exposed this province to the dust phenomena [17]. By studying the origin of dust events and examining their relationship with climatic factors, it seems possible to estimate and manage this phenomenon as accurately as possible. The existence of a link between climatic indicators and the dust phenomenon has been confirmed in various studies. The current study analyzed the relationship between climatic parameters and dust occurrence and identified the origin of dust events in Ilam during 2011-2016 using HYSPLIT models.

1.1. Study Area

Ilam province, with 19 086 km^2, occupies about 1.4% of the area of Iran. It is located at 45° 24′ to 48°10′ East longitude from the Greenwich meridian and 31° 58′ to 34° 15′ North latitude from the equator in the westernmost point of Iran. The center of Ilam province is located at an altitude of 1427 m above sea level, and to the west, it shares a common border of 420 km with Iraq [18] as shown in Figure 1.

According to the information of the General Environment Department of Ilam, there were 11.4 days of heavy dust (with an average of more than 250 μg/m^3) in Ilam in an 8-year period from 2004 to 2011 (the period prior to this survey) on average. The dustiest days with a frequency of 35% days and the lowest number of dusty days were recorded in 2012 and 2006, respectively. Moreover, the heaviest dust and the maximum concentration of PM_{10} occurred in 2012, reaching 4970 μg/m^3 [19].

2. Materials and Methods

This is a descriptive-applied study aiming to identify the source of dust particles using the HYSPLIT model and also the correlation of dust events with climatic parameters in Ilam province in 2021. The study period was from 2011 to 2016 (early March 2012 to late February 2018). Considering that the data sent by satellite correspond to the months of the Gregorian calendar, the relevant calculations were made based on this calendar. Therefore, the time intervals include 2012-2013, 2013-2014, 2014-2015, 2015-2016, 2016-2017, and 2017-2018. Four sources were used to collect the data. First, the meteorological data include various parameters such as wind speed, relative humidity, dew point, air temperature, and standard pressure. The amount of PM_{10} was collected with three-hour time steps from the Environmental

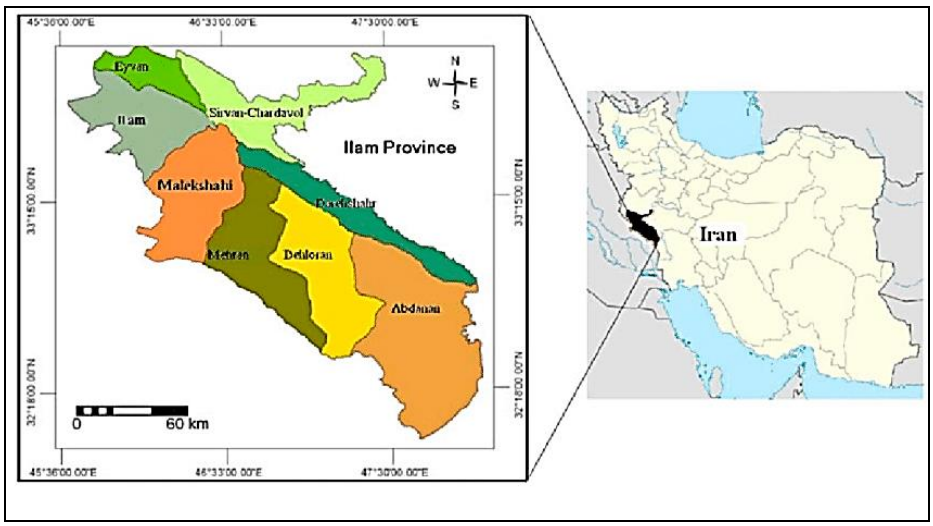

Figure 1. The Geographical location of Ilam province. *Note.* Studied area is marked with a star.

Protection Organization for Ilam province. The satellite images were also prepared by the NOAA specialized site that stores the data sent by the Landsat satellite. Further, the required data were prepared based on the date of dust events (e.g., the time and place of the event) using the HYSPLIT model. The presented times are based on UTC and Gregorian calendar, and the model was implemented at an altitude of 1500 m above the level. The movement path of particulate matter and its origin in dust events were identified using HYSPLIT. The HYSPLIT model is a dual model for calculating the trajectory of dust movement as well as dispersion and simulation of its settling using PUFF and particle approaches [20]. Moreover, data time series and linear regression equations were analyzed using Excel, SPSS 18, and OriginPro 2018 to determine the relationship between particulate matter and climate indicators.

3. Results

Time series of data is required for the analysis and statistical modeling of dust events in this descriptive-applied study. In time series graphs, the general trend of data values in an interval can be seen. According to the variables used in the research, the time series graphs of PM_{10} data, temperature, relative humidity, standard pressure, wind speed, and dew point in the interval from 2012 to 2018 are presented in Figures 2, 3, and 4.

One of the goals of the current study was to analyze the origin of dust events in Ilam province. HYSPLIT data were used for this purpose. These data were related to the altitude level below 1500 m. In the first step, the dust events of Ilam province from March 1, 2012 to February 30, 2018 were determined based on the days when the average amount of PM_{10} was more than 154 μg/m^3 in each

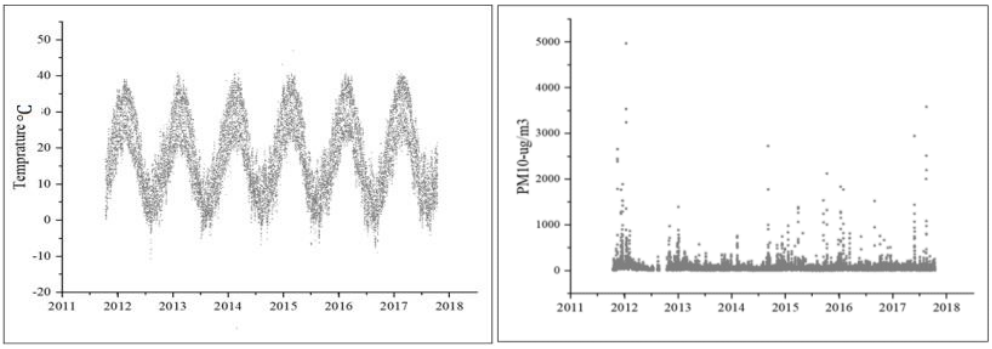

Figure 2. Comparison of time series data from 2012 to 2018: particulate matter (left) and temperature (right).

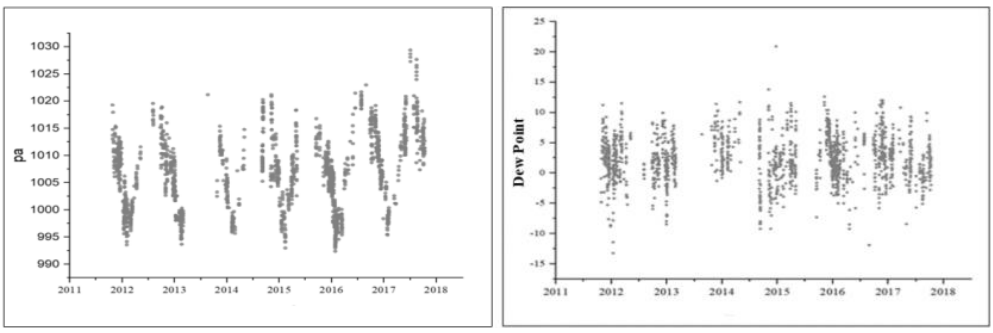

Figure 3. Comparison of time series data from 2012 to 2018: dew point (left) and standard pressure (right).

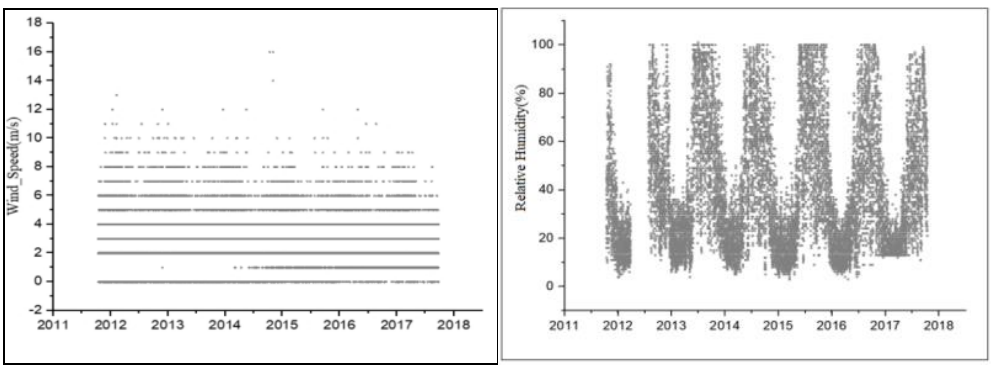

Figure 4. Comparison of time series data from 2012 to 2018: wind speed (left) and relative humidity (right).

day (The basis of dust events is based on the standard of the Environmental Protection Organization of Iran). Other climatic factors and horizontal visibility were also determined in the investigated times. Considering the number of dust events in the research period, one event (June 16, 2016), is analyzed, and an example of the output of HYSPLIT for the origin of dust events in Ilam province is presented in Figure 5. A total of 165 HYSPLIT outputs were drawn and analyzed to investigate dust events in Ilam province from March 2012 to February 2018.

The results of the dust event analysis on this date showed that the horizontal visibility was below 500 m, and the highest PM_{10} concentration was 1700 μg/m^3. The maximum concentration of Pm_{10} did not occur concurrently with the maximum decrease in horizontal visibility. In this event, the pressure trough of the Persian Gulf spread to the northwest of Iraq. The summer pattern was dominant, and a high-pressure atmosphere was observed in the middle level (Figure 5A). The surface wind speed field of 850 hPa exhibited a maximum speed of 8 m/s, which is much lower than that of the previous cases. The wind direction is northwest and west (Figure 5B). The wind rose indicated the direction of the prevailing wind in the southwest with a speed of 6 m/s (Figure 5C). Further, a 10-meter wind direction difference and a level of 850 hPa occurred due to the low-pressure summer shallow structure. It seems that the mountainous structure of the region played an effective role in changing the direction of the wind. The satellite image showed the emission of dust in northwest Iraq. Nevertheless, dust mass can also be seen in the northwest regions (Figure 5D).

Figure 6 illustrates the summary of the results of the dust events' origin analysis in Ilam province in the period between 2012-2018. These results indicated that out of 165 analyzed HYSPLIT outputs, a total of 69 dust events (42%) originate from Iraq, 36 (22%) from Syria, 29 (17%) from Saudi Arabia, 16 (10%) from the Persian Gulf, and 15 (9%) from Jordan.

Figure 6 presents the results of the analysis of dust events in Ilam province during 2012-2018 based on the number of dust events by time periods. A total of 666 dust events (3 hours) were reported, and the highest number of dust events was 163 in 2012. In addition, the lowest number of dust events was 31 during 2014-2015. It should be noted that the total number of daily dust events in this period was 165. The results of dust event analysis in the period from 2012 to 2018 revealed that the highest amount of dust events in Ilam was during June (145 events) and May (134 events), while the least dust event was reported in December (6 events). Multiple regression equations and Pearson's correlation coefficient were used to investigate the relationship between the variables of particulate matter and other climatic components (temperature, humidity, standard pressure, dew point, wind speed, and cloudiness). Figure 7 depicts the output of multiple linear regression between climatic variables, horizontal visibility, and particulate matter.

Table 1 presents the summary of the results of the

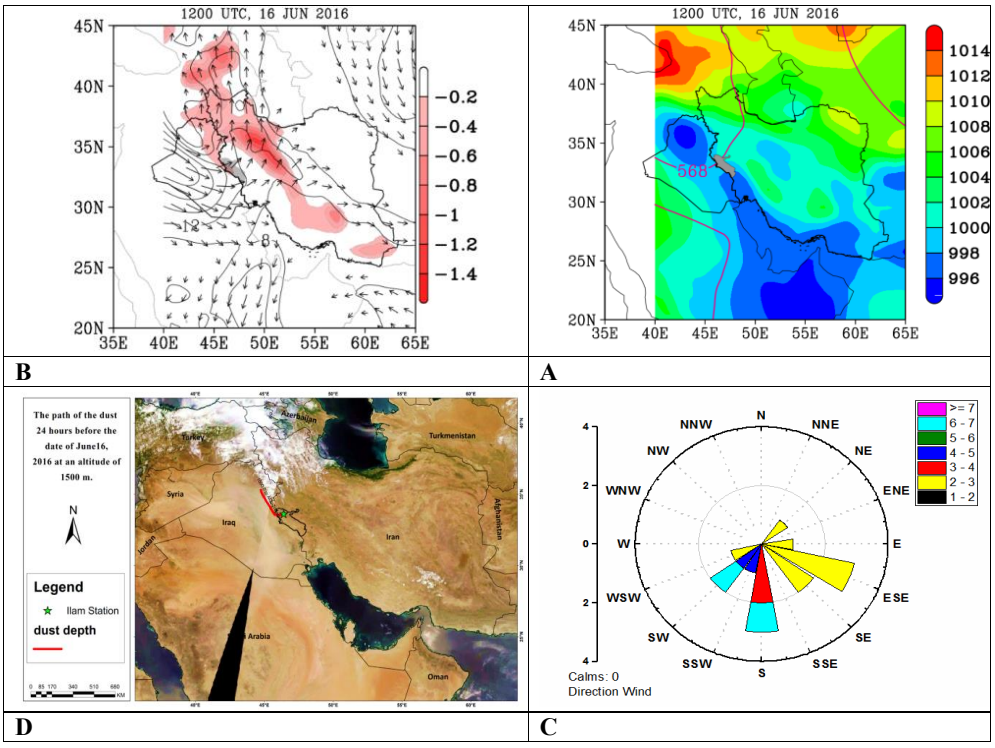

Figure 5. (A) Open sea surface pressure (crosshatch) in hPa and Geopotential Height of 500 hPa (red line) in decameters, (B) Horizontal wind speed (black line) in m/s, horizontal wind direction (arrow) vertical speed (red crosshatch) in hPa/s at 12 UTC, (C) Wind rose on june 16, 2016, and (D) Visible image of MODIS Aqua sensor satellite, output of HYSPLIT model on June 16, 2016

Table 1. Summary of the results of multiple linear regression model between particulate matter and climate variables

Model	R	R-square	Adjusted R-square	Standard error of estimate
1	0.589[a]	0.347	0.337	467.48618

a. Variables: Wind speed, standard pressure, relative humidity, dew point, cloudiness, and temperature.
b. Dependent variable: PM_{10}.

multiple linear regression model between particulate matter and climate indicators. These results showed that, based on the multiple linear regression model, the relationship between climate components and particulate matter is estimated at a medium level (R = 0.589).

The results of the multiple linear regression model and the beta coefficient between the particulate matter and climate components are presented separately in Table 2. These results showed that the temperature has a significant relationship with the concentration of particulate matter ($P < 0.05$). According to the results of the study, most dust events occurred from May to August (67% of all dust events), so the existence of such a relationship is statistically justified.

Based on the results presented in Table 2, which is the output of multiple linear regression calculations in SPSS, the linear regression equation is presented as follows:

$$Y(PM_{10}) = 0.370X_1(\text{temperature}) + 0.08X_2(\text{standard pressure}) + 0.169X_3(\text{relative humidity}) + 0.006X_5\ (\text{wind speed}) + 0.22X_6(\text{dew point}) + 0.023X_7(\text{cloudiness})$$

In this equation, the values of PM_{10} (independent variable-Y) are a function of climatic components (standard pressure, wind speed, temperature, relative humidity, dew point, and cloudiness) and horizontal visibility. The effect coefficient of the absolute value of the standardized coefficients is the beta coefficient. Based on this, horizontal visibility with an effect factor

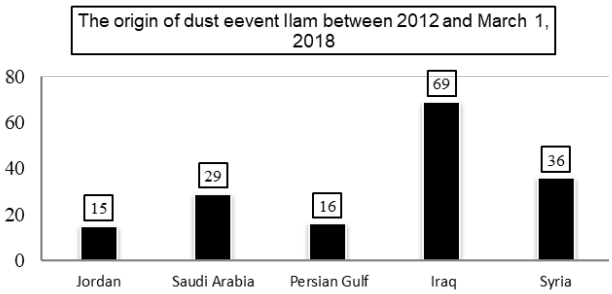

Figure 6. Frequency distribution of dust event origin in Ilam province between 2012 and 2018.

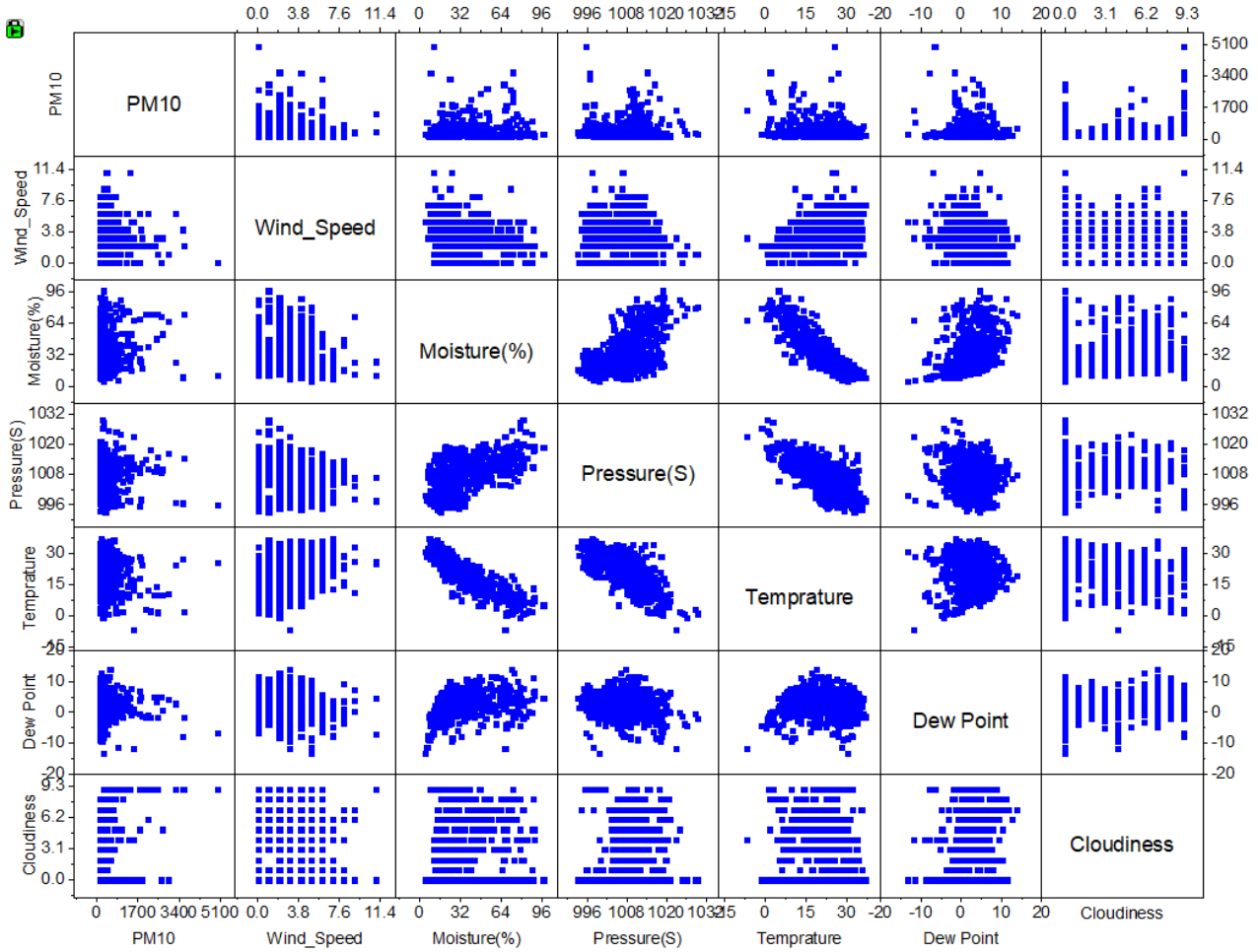

Figure 7. Output from multiple linear regression between climatic variables, horizon, and particulate matter.

of 0.534 and temperature with an effect factor of 0.370 have been identified as related and influencing factors on particulate matter ($P \leq 0.05$). Other variables did not show a significant effect on particulate matter ($P \geq 0.05$). Pearson's correlation coefficients were also used to estimate the relationship between the variables of particulate matter and climatic components, the results of which are presented in Table 3. In the correlation analysis, in addition to the variables of horizontal visibility and temperature, humidity also showed a significant correlation with the particulate matter at the level of 0.03 ($P \leq 0.05$).

4. Discussion

Dust is one of the most important hazardous atmospheric phenomena for various fields of application [21]. Today, the adverse effects of this phenomenon are being clearly observed in agriculture, public health and safety, transportation (air and ground), and the like [22]. Therefore, monitoring and investigating dust occurrence is one of the most useful indicators for decision-makers. This phenomenon has become a natural process and problem that can be seen throughout the globe [23]. Ilam province is one of the semi-arid regions in western Iran, which has recently faced a significant increase in dust events. In several studies such as Ansari and Jamshidi [24] and Su et al [25], the results of the HYSPLIT model for the origin of the dust phenomenon have been found very favorable. In a study conducted on the origin of particulate matter, the results showed that the external origins of the dust events in Ilam province were areas in Iraq, Syria, Saudi Arabia, the coast of the Persian Gulf, and Jordan. Analyzing the origin of dust events in southwestern Iran, Najafi et al [26] and Javadian et al [27] declared Iraq and Syria as the main source of most dust events in these areas, which is consistent with the current study. In the 20-year statistical pattern of dust events in Ilam province, Pilevaran et al [28] announced that, from June to July, the dust occurs in western Iran due to the location of the low-pressure core over the Mediterranean Sea and its landfall over the deserts of Iraq, Syria, and Saudi Arabia. This can justify the reason for the dust's numerous occurrences in these months in the current study. The results of the current research also confirmed the existence of a significant relationship between horizontal visibility and climatic components.

In the correlation analysis, the variables of temperature, humidity, dew point, and cloudiness showed a significant correlation with the particulate matter at the level of 0.03. Similarly, Zolfaghari et al [29] confirmed the existence of a relationship between low-pressure systems and dust events in southwestern Iran, which is consistent with the results of this study. Jorba et al [30] also obtained similar results regarding the effect of the high-pressure flow pattern over Barcelona, Spain. In general, conducting such studies can play a vital role in finding solutions for dust management by obtaining information about the origin and causes of this phenomenon as well as the factors affecting it.

4.1. Limitations

The defect in the climatic data of the synoptic station of Ilam is a limitation of the present research.

5. Conclusion

Ilam is one of the semi-arid regions in western Iran, which has recently faced a significant increase in dust phenomenon. The results showed that the source of dust can be identified by examining various components, including atmospheric pressure, horizontal and vertical wind, synoptic analysis, and wind rose. In the analysis of four dust events in Ilam province during 2012-2018, the exact origin of each event was determined using the HYSPLIT model. The results also confirmed the existence

Table 2. The results of multiple linear regression model and beta coefficient between particulate matter and climate components

Model		Non-standard coefficients		Standard coefficients	t-statistics	*P* value
		B	Standard error	Beta coefficient		
1	(Constant)	8496.899	5957.004	-	1.426	0.155
	Temperature	-25.659	7.948	-0.370	-3.229	0.001
	Standard pressure	-6.539	5.831	-0.080	-1.121	0.263
	Relative humidity	-4.909	2.725	-0.169	-1.802	0.072
	Wind speed	-1.813	13.108	-0.006	-.138	0.890
	Dew point	-12.529	6.671	-0.220	-1.878	0.061
	Cloudiness	-7.850	7.515	-0.023	-3.706	0.134

Table 3. Results of Pearson correlation test between particulate matter and climatic components

		PM_{10}	Temperature	Pressure	Humidity	Wind speed	Dew point	Cloudiness
PM10	Pearson's correlation	1	-0.702**	0.056	0.636*	-0.395	-0.891*	0.810**
	Significance level		0.000	0.300	0 .012	0 .080	0.019	0.000

of a significant relationship between climatic components and particulate matter. Considering that the results determined the external origin of the dust phenomenon in Ilam province, it is suggested to use these results in formulating plans to deal with haze.

Acknowledgment

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Conflict of Interests

The authors declare that there is no conflict of interests.

Ethical Considerations

This paper is extracted from the doctoral dissertation by Mozhgan Alainejad, a Ph. D student in the field of Environmental Sciences, Islamic Azad University, Ahvaz branch, with the ethics code 10648239100643813971831 96.

References

1. Wang Y, Stein AF, Draxler RR, de la Rosa JD, Zhang X. Global sand and dust storms in 2008: observation and HYSPLIT model verification. Atmos Environ. 2011;45(35):6368-81. doi: 10.1016/j.atmosenv.2011.08.035.
2. Rashki A, Middleton NJ, Goudie AS. Dust storms in Iran–Distribution, causes, frequencies and impacts. Aeolian Res. 2021;48:100655. doi: 10.1016/j.aeolia.2020.100655.
3. Naimabadi A, Ghadiri A, Idani E, Babaei AA, Alavi N, Shirmardi M, et al. Chemical composition of PM10 and its in vitro toxicological impacts on lung cells during the Middle Eastern Dust (MED) storms in Ahvaz, Iran. Environ Pollut. 2016;211:316-24. doi: 10.1016/j.envpol.2016.01.006.
4. Maleki H, Sorooshian A, Goudarzi G, Nikfal A, Baneshi MM. Temporal profile of PM10 and associated health effects in one of the most polluted cities of the world (Ahvaz, Iran) between 2009 and 2014. Aeolian Res. 2016;22:135-40. doi: 10.1016/j.aeolia.2016.08.006.
5. Cao H, Liu J, Wang G, Yang G, Luo L. Identification of sand and dust storm source areas in Iran. J Arid Land. 2015;7(5):567-78. doi: 10.1007/s40333-015-0127-8.
6. Goudie AS. Dust storms: recent developments. J Environ Manage. 2009;90(1):89-94. doi: 10.1016/j.jenvman.2008.07.007.
7. Baddock MC, Bullard JE, Bryant RG. Dust source identification using MODIS: a comparison of techniques applied to the Lake Eyre Basin, Australia. Remote Sens Environ. 2009;113(7):1511-28. doi: 10.1016/j.rse.2009.03.002.
8. Rostami D, Hosseini SA. Analysis and tracking dust phenomenon in south and southeast of Iran by using HYSPLIT model and the principles of remote sensing. Journal of Spatial Analysis Environmental Hazards. 2018;5(3):103-19. doi: 10.29252/jsaeh.5.3.103. [Persian].
9. Darmany M, Ara H, Rashki A, Mafi A. Source identifying and characterizing physical and chemical fine dust in Sarakhs city. Journal of Geography and Environmental Hazards. 2020;9(3):21-37. doi: 10.22067/geo.v9i3.87970. [Persian].
10. Rivandi A, Mirrokni M, Mohammadiha A. Investigation of formation and propagation of dust storms entering to the west and southwest of Iran using Lagrangian particle diffusion model, HYSPLIT. J Clim Res. 2013;4(13-14):1-16. [Persian].
11. Bouchlaghem K, Chtioui H, Gazzah MH. Analyzing the impact of Saharan sand and dust storms based on HYSPLIT algorithm in Tunisian regions. Arab J Geosci. 2021;14(10):834. doi: 10.1007/s12517-021-07174-4.
12. Sun K, Su Q, Ming Y. Dust storm remote sensing monitoring supported by MODIS land surface reflectance database. Remote Sens (Basel). 2019;11(15):1772. doi: 10.3390/rs11151772.
13. Broomandi P, Dabir B, Bonakdarpour B, Rashidi Y. Identification of dust storm origin in South-West of Iran. Environ Health Sci Eng. 2017;15(1):16. doi: 10.1186/s40201-017-0280-4.
14. Jafari M, Mesbahzadeh T, Masoudi R, Zehtabian G, Amouei Torkmahalleh M. Dust storm surveying and detection using remote sensing data, wind tracing, and atmospheric thermodynamic conditions (case study: Isfahan province, Iran). Air Qual Atmos Health. 2021;14(9):1301-11. doi: 10.1007/s11869-021-01021-x.
15. Namdari S, Karimi N, Mohammadi G. Pattern analysis of dust storms in the west and southwest provinces of Iran and its relation to the Middle East dust storms. J Clim Res. 2017;8(31-32):103-22. [Persian].
16. Heidari Farsani M, Shirmardi M, Alavi N, Maleki H, Sorooshian A, Babaei A, et al. Evaluation of the relationship between PM10 concentrations and heavy metals during normal and dusty days in Ahvaz, Iran. Aeolian Res. 2018;33:12-22. doi: 10.1016/j.aeolia.2018.04.001.
17. Nikfal A, Ranjbar Saadatabadi A, Rahnama M, Tajbakhsh S, Moradi M. Evaluation of the WRF/Chem aerosol models-a dust episode case study. Iran J Geophys. 2021;14(4):1-18. doi: 10.30499/ijg.2020.104569.
18. Alaghehbandan R, Lari AR, Joghataei MT, Islami A, Motavalian A. A prospective population-based study of suicidal behavior by burns in the province of Ilam, Iran. Burns. 2011;37(1):164-9. doi: 10.1016/j.burns.2010.04.010.
19. Amarloei A, Fazlzadeh M, Jonidi Jafari A, Zarei A, Mazloomi S. Particulate matters and bioaerosols during Middle East dust storms events in Ilam, Iran. Microchem J. 2020;152:104280. doi: 10.1016/j.microc.2019.104280.
20. Draxler RR. HYSPLIT4 User's Guide. Silver Spring, MD: National Oceanic and Atmospheric Administration; 1999.
21. Vandaele AC, Korablev O, Daerden F, Aoki S, Thomas IR, Altieri F, et al. Martian dust storm impact on atmospheric H2O and D/H observed by ExoMars Trace Gas Orbiter. Nature. 2019;568(7753):521-5. doi: 10.1038/s41586-019-1097-3.
22. Viúdez-Moreiras D, Newman CE, Forget F, Lemmon M, Banfield D, Spiga A, et al. Effects of a large dust storm in the near-surface atmosphere as measured by InSight in Elysium Planitia, Mars. Comparison with contemporaneous measurements by Mars Science Laboratory. J Geophys Res Planets. 2020;125(9):e2020JE006493. doi: 10.1029/2020je006493.
23. Elsheikh EAA, Islam MR, Habaebi MH, Ismail AF, Zyoud A. Dust storm attenuation modeling based on measurements in Sudan. IEEE Trans Antennas Propag. 2017;65(8):4200-8. doi: 10.1109/tap.2017.2715369.
24. Ansari A, Jamshidi R. Identification of sources and tracking dust storm routes entering from domestic sources to Arak metropolitan using HYSPLIT model. Environ Sci. 2018;16(1):101-10. [Persian].
25. Su L, Yuan Z, Fung JCH, Lau AKH. A comparison of HYSPLIT backward trajectories generated from two GDAS datasets. Sci Total Environ. 2015;506-507:527-37. doi: 10.1016/j.scitotenv.2014.11.072.
26. Najafi MS, Khoshakhllagh F, Zamanzadeh SM, Shirazi MH, Samadi M, Hajikhani S. Characteristics of TSP loads during the Middle East Springtime Dust Storm (MESDS) in Western Iran. Arab J Geosci. 2014;7(12):5367-81. doi: 10.1007/s12517-013-1086-z.
27. Javadian M, Behrangi A, Sorooshian A. Impact of drought on dust storms: case study over Southwest Iran. Environ Res Lett.

2019;14(12):124029. doi: 10.1088/1748-9326/ab574e.
28. Pilevaran R, Rastgoo Z, Nikfal A, Moradpour B. Combining remote sensing and numerical methods in the study of dust storms, J Environ Sci. 2021;19(2). doi: 10.52547/envs.34186. [Persian].
29. Zolfaghari H, Masoumpour Samakosh J, Shaygan Mehr S, Ahmdi M. 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. 2011;22(3):17-34. [Persian].
30. Jorba O, Pérez C, Rocadenbosch F, Baldasano J. Cluster analysis of 4-day back trajectories arriving in the Barcelona area, Spain, from 1997 to 2002. J Appl Meteorol. 2004;43(6):887-901. doi: 10.1175/1520-0450(2004)043<0887:caodbt>2.0.co;2.