Spatial-Temporal Analysis of Dust Storm Occurrence in West of IRAN

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Introduction: Earth has ever been exposed to environmental hazards. The hazards are continually occurring in the world in the recent years. Among them, atmospheric elements have created many human and financial losses in different regions.
One of the hazards is dust events and in its severe case is dust storm. It happens more frequently in arid and semiarid regions in deserts and their surrounding areas. Dust events is a natural phenomenon occurring in regions that have large parts of arid and desert regions, devoid of vegetation cover and other surface coatings areas. Lengthy periods of drought and principle of non-interference in nature may be the cause of this phenomenon. In addition to reducing the horizontal sight and ist effects, e.g., traffic issues, it has also many environmental impacts especially on human health. Dust storms can cause transport accidents. Perhaps more importantly, dust emissions from dried lake basins introduce fine particles, salts, and chemicals into the atmosphere, with a suite of health impacts, including not only respiratory complaints, but also other serious illnesses. They can also lead to particulate levels that exceed internationally recommended levels and transport allergens including bacteria and fungi.
In the recent years, dust storms in western part of Iran have caused various problems for people. The main objectives of this study are to monitor and assess the spatial and temporal distribution of the storms over the western of Iran during the last two decades.
Data and case study area: The data for the analysis are including statistical data of dust (taken from Meteorological Organization) in daily basis during the 8-hour observation in period of twenty years (1989-2008). Up to 26 stations in the western portion of Iran with appropriate distribution have been selected (Arak, Ardebil, Oroomieh, Western Islamabad, Omidiyeh, Ahvaz, Ilam, Abadan, ParsAbad, Tabriz, KhorramAbad, Khorramdareh, Khoy, Dezful, Dehloran, Zanjan, Saghez, Sanandaj, Shahrekord, Qazvin, Kermanshah, Makoo, Mianeh, Hamadan, Hamadan Nozheh, Yasooj).
Materials and methods: Reviewing the existence trend in the data has been studied in two forms of spatial and temporal. To investigate the spatial trend in data Trend Analysis in ArcMap10 application has been used. To achieve this, annual and monthly frequency and dust mean in all studied stations have been examined in relation to latitude and longitude.
Several methods have been proposed for the study of time trend in the panel data. It can be classified into parametric (t, trend analysis) and nonparametric (Mann-Kendall, Kendall's Tau Spearman coefficient and Sen's trend Tests) methods. Accordingly, the first step to choose an appropriate parametric and nonparametric method is awareness of the normal distribution of data. In this regard, the normality of the data is investigated based on Kolmogorov - Smirnov test (K-S test).
Kendall's Tau correlation coefficients for all pairs, i=1,2,...n,(xi,yi), can be calculated using the following algorithm. In comparison pairs (xi, yi) with (xi,yi) hold for every i and j, if xi> xj and yi> yj. So, yi<xj,="" are="" called="" isotones="" pairs,="" otherwise="" no="" isotones.="" then,="" the="" number="" of="" pairs="" (ndis)="" (ncon)="" counted="" for="" all="" paired="" comparisons="" kendall's="" tau="" correlation="" coefficient="" is="" calculated="" from="" following="" equation:=""
Mann Kendall theoretical basis according to the logic of Kendall's tau was recommended for reviewing the existence of the linear and nonlinear trends in the most technical reports. For this test, the comparison is limited to the desired time series. The first step is a ranking of the time series. It is assumed yt are values of the time series rank. In the first step, regarding to the first observation, it is compared with xtt= 2,3, ..., n sequence comparison. In other words, comparison is done n-1 times that it can be displayed with n_1. In the next step, y2 is compared with all xt, t=3,4,...,n sequences . In other words, it is compared, n-2 times, showing this time with n2, that continue one times to comparison of yn-1 to yn. In comparison for each i<j, then="" yi="">yj, is added one unit to ni.
Then, Kendall statistic is calculated from the following equation:
For n larger than 40, the central limit theorem can be used. Expected value and variance Tmk are calculated using the following equations:
Where the n, is the group number which have the same rank and is the same level of data in each group.

The statistic obtain statistic as the following equation, with a normal distribution.
If the relation| is satisfied, ascending and descending trend is rejected at the significant level α, in which Significant level. Also if0 or 0, the trend is ascending or descending, respectively.
Results: The spatial trend in data analysis was examined using the frequency and mean of dust in all examined stations annually and monthly because of the similarity of graphs. Fixing the spatial trend in the data (annual, seasonal and monthly) can indicate that the sources of dust which enter to west part of the country are constant. Dust events have increasing trend from north to south and from West to East, increases primarily and then decreases again.
Normality of data was evaluated based on Kolmogorov - Smirnov test (KS test). Because the significant rate in the raw data is less than 005/0, so we can assume H0 (the data have normal distribution) with the maximum reliability 995/0 is rejected versus H1 (data have no normal distribution).
This can be concluded that there is not available sufficient evidence to accept the normality of the data and it can be accepted that the data were not normally distributed. The trends of significance in dust data were investigated by Mann Kendall test for existing stations in annual, seasonal, and monthly periods and determined that some of the stations have descending trend and others ascending.
Comparison of the P-Value obtained from the tests with a critical level of 05/0 and 01/0 revealed significant at a confidence level of 95% and 99%.
In this study, time displacements of the dust events in the studied stations were to be analyzed. To achieve this goal, for each station dust events were gathered monthly and then the month with the most occurrence of the events was determined for every year. For example, the Arak station, illustrated the most dust occurrence in 1989 in the fifth and seventh months (May-July) or the most incidence has been recorded in sixth month (June) in 2008 for Yasouj station. For revealing the months with the peak occurrence of dust in each station, time series for each station were created during the period 1989 to 2008. Plotting the corresponding number for each month against the time of occurrence for each station created scatter plot. In this plot, line fitting with equation of the first degree revealed how is the change trend of dust occurrence. Significant results of this research, for determining the temporal changes for each station showed thatthe month with the maximum dust occurrence has been shifted towards warm or cold months over time. The review divided the studied stations into three groups. The first group indicates the maximum displacement of maximum dust to the warm months,The second group represents the displacement less than a month for the maximum dust.Finally, the third group represents displacement to the colder months.
Conclusion: Analyzing the spatial data trend indicates that the dust data in the studied stations have a north - south trend with linear increase while along the west to east it follows second degree polynomial function (curve with an arc). This indicates that frequency of dust is increasing from west to east and then it has been observedto reduce in the east of the region. It seems that the altitude exposure along the north to south particularly, Zagros Mountains on the path of dust progress has been caused this situation. Constant behavior of the spatial trend for dust frequency in monthly, seasonal and annual scales indicate no change in the dust source entry to the studied region. In other words, the origin and time arrival of dust to studied region have particular order.
Time trend of the dust frequency was reviewed in three monthly, quarterly, and annual scales. Significant ascending trend (with 95% confidence level) were observed at Arak, Oroomieh, Western Islamabad, Omidiyeh, Tabriz, Khorramabad, and Sanandaj stations in both monthly and seasonal time scales. However, only two stations (Arak and Khorramabad) have significant ascending trend in an annual scale. In the two stations, Khorramdareh and Qazvinwere also observed in descending trend in dust occurrence frequency with a confidence level of 95% in all time scales.
It was found that the maximum frequency of dust occurrence in some stations (Yasooj, Qazvin, Sanandaj, Khorram Abad and Arak) have been shifted to the warm months and in others (Ardebil, Oroomieh, Abadan, Ahvaz, ParsAbad, Tabriz, Khorramdareh, Khoy, Dezful, Dehloran, Zanjan, Saghez, Shahrekord, Kermanshah, and Hamadan) to cold months. In some stations (Ilam, Omidiyeh, Makoo, Western Islamabad, and Mianeh) there was no significant movement.

Keywords: dust storm, Mann, Kendall, spatial analysis, trend analysis, west of Iran </j,>