Predicting the Annual Dusty Days in Khorasan Razavi Province Using Spatial-Temporal Analysis

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1. Introduction

One of the most important environmental challenges in recent years in Khorasan Razavi province is the dust storm phenomenon. A survey on the average number of annual dust storm days in the Khorasan Razavi province shows that it has risen from an average of 6 days to 21 days from 1951 to 2016. And since 1993, it has grown strongly, which shows that reviewing and forecasting the coming years is of high importance. For the purpose of the study Gstat, Space time, SP, Raster, Spdep, and R Google Maps packages of R software are used alongside with Kriging method of spatial-temporal changes to investigate the number of annual dusty days and to predict their occurrence in the coming years.

2. Materials and Methods

In this study, the wind speed of 15 meters per second and more and a horizontal view below 1000 meters were considered by the World Meteorological Organization as a dusty day. Then, the SP Data array (Pebesma, 2013) was constructed as a combination of the matrix and vector in STFDF and STF classes (Hengel et al., 2015) according to the following equation:

$$\{z(s_{i,j}); s_{i,j} = (X_{i,} Y_{i,} \ t_{i,}); i = 1,2, \dots, n; j = 1,2, \dots, T\}$$

Where the index i refers to the location number (position of view) and the j index to the time number. After that, the empirical Spatial –Temporal variogram were calculated using the Kriging method (Mohammadzadeh, 2012) and were calculated from the following equation:

$$2\hat{\gamma}(h_s, h_t) = \frac{1}{|N(h_s, h_t)|} \sum_{N(h_s, h_t)} \left(Z(s + r_s, t + r_1) - Z(s, t)\right)^2, h_s \in R^d, h_t \in R^+$$

where in: $N(h_s, h_t)$
Represents the set of all couples of observations whose distance is in the neighborhood of the vector h_s and its time interval near h_t .Then all the separable and non-separable

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models were fitted to experimental data model, where the metric variogram with the least average square error was selected as the best model for predicting the number of dust storm days in the year.

3. Results and Discussion

The output of the model showed that data up to 5 years have a spatial-temporal dependence, and it is possible to estimate the number of dust storm days until 2022. Therefore, the most important spatial points are the annual number of dust storm days from higher values. They include: Northeast, Northwest and South East of Razavi Khorasan province. The predicted values of annual dust storm days in the central areas of Khorasan Razavi province in 2018 and 2019 shows that these areas will have the smallest number of dust storm days, but will gradually face with an increase in the number of dust storm days.

Accordingly, in 2022 most points except the limited points in the east, west and south east will have a significant increase in the number of dust storm days in the central areas. The results show in 2019, Ghochan, Mashhad, Sarakhs, Sabzevar, Khaf, Torbat Jam and Fariman stations, with a maximum reliability of 95%, will have 40.48.41.46,56,47.41,41 dusty days, respectively. The highest number of dust storm days is related to Sabzevar station with 56 days, and after that Sarakhs with 47 days. Spatial-temporal forecasting trend of the number of dusty days in 2022 indicates that Gonabad Station has the best air quality index of 7 days. Furthermore, the maximum probability of occurrence of dusty days in Ghouchan, Mashhad, Sarakhs, Sabzevar, Khaf, Torbat Jam, and Fariman stations reaches up to 51, 46, 49, 61, 51, 44, and 45 days respectively, and will increase from 39 days to 43 days throughout the province in 2022.

4. Conclusion

According to the increasing number of dusty days in Khorasan Razavi province, investigating the prediction models is very important. Spatial-temporal Kriging method can use the intrinsic stability of the data to predict the number of dusty days in three dimensions of x, y, and t. This means that we can predict the number of dusty days in different places and times. Indeed, the intrinsic structure of the data plays a significant role in this regard. If the data algorithm is annual, monthly or daily, the output of the model will be proportional to the algorithm. Annual algorithm was able to deliver acceptable results in this research.

Keywords: Spatial-temporal Variogram, Prediction, Number of Dusty Days, Razavi Khorasan Province, Kriging, Dust and Sand Storm.

References (In Persian)

Alijani, B., & Najafi Nik, Z. (2009). بررسی سینوپتیکی اینورژن در مشهد با استفاده از تحلیل عاملی [The Synoptic study of inversion in Mashhad using factor analysis]. *Journal of Geography and Regional Development, 12,* 1-12.

Farajzadeh, A., & Alizadeh, M. (2010). تحلیل زمانی و مکانی طوفان های گرد و غبار در ایران [Temporal and Spatial Analysis of Dust Storms in Iran]. *Space Planning and Planning*, *1*, 65-84.

Ghorbani, M., & Firooz Zare, A. (2010). مقدمه ای بـر ارزش گـذاری محـیط زیسـت. [An introduction to environmental valuation]. Mashhad, Iran: Ferdowsi University Press.

Jahanshiri, M. (2010). بررسی آماری و سینوپتیکی آلودگی هوای مشهد، پایان نامه کارشناسی جغرافیـای طبیعـی اقلـیم شناسـی [Statistical and synoptic study of air pollution in Mashhad], (Unpublished master's thesis) in Natural Geography and Climatology]. Hakim Sabzevari University, Sabzevar, Iran.

Kakhki Mahneh, H. (2013). استفاده از مدل شبکه عصبی مصنوعی در بررسی روابط بـین عناصـر اقلیمـی و نوسـانات آلـودگی هـوا در کلـان شـهر مشـهد [The use of artificial neural network model in the study of the relationship between climatic elements and air pollution fluctuations in the metropolis of Mashhad], (Unpublished master thesis). Kharazmi University, Tehran, Iran.

Lashkari, H., & Kaykhosravi, Gh. (2008). تحلیل آماری سینوپتیکی طوفان های گرد و غبار استان خراسان رضوی در فاصـله ی زمـانی (۲۰۰۵-۱۹۹۳) [Synoptic statistical analysis of dust storms in Khorasan Razavi province in the time interval (1993-2005)]. *Natural Geography Research*, *65*, 17-33.

Mehrshahi, D., & Nekounam, Z. (2009). بررسی آماری پدیده های گرد و غبار و تحلیل الگوی وزش بادهای گرد و غبارزا در شهرسـتان سـبزوار [Statistical study of dust phenomena and analysis of dust wind patterns in Sabzevar city]. *Journal of the Geographical Association of Iran*, *22*, 83-104.

Meteorological Organization of Iran. (2017). آمـار سـرعت بـاد و دیـد افقـی از ۱۹۸۷/۱/۱ لغایـت ۲۰۱۶/۱۲/۳۱ [Statistics of the wind speed and horizontal visibility from 1/1/1987 to 12/31/201] retrieved from https://data.irimo.ir/

Mohammadi Moradian, J., & Hosseinzadeh, S. A. (2015). ، پایش ماهواره ای و تحلیل همدید پدیده گـرد و غبار در کلان شهر مشهد طی دوره آمـاری ۲۰۱۳-۲۰۰۹، [Satellite monitoring and synoptic analysis of dust phenomenon in Mashhad metropolis during the statistical period 2013-2009]. *Geography and Environmental Hazards*, *14*, 35-57.

Mohammadzadeh, M. (2015). *آمـار فضـایی و کاربردهـای آن* [Spatial statistics and its applications]. Tehran, Iran: Tarbiat Modares University Press.

Omidvar, K. Nekounam, Z. (2011). کاربرد گلباد و گل غبار در تحلیل پدیده گـرد و خـاک و تعیـین رژیـم فصـلی بادهای همراه با این پدیده (مطالعـه مـوردی: شـهر سـبزوار) [Application of rose and dust in analyzing dust phenomenon and determining the seasonal regime of winds associated with this phenomenon (Case study: Sabzevar city)]. *Natural Geography Research*, 76, 85-104.

Pourhashemi, S., Boroughni, M., Zanganeh, M. A., & Amir Ahmadi, A. (2016). تحلیل ارتباط پوشش گیاهی و وقوع تعداد روزهای گرد و غبار استان خراسان رضوی با استفاده از سیستم اطلاعات جغرافیایی و سنجش از دور. [Analysis of the relationship between vegetation and the occurrence of the number of dust days in Khorasan Razavi province using GIS and remote sensing]. *Remote Sensing and Geographic Information System in Natural Resources*, *4*(6), 33-4.

Ziaei Golriz, Z., Sadeghi, H., Motamedi, M., & Jaleh Rajabi, M. (2011). پـیش بینـی ارزش گـذاری و ترسیم نقشه آلـودگی هـوای شـهر مشـهد، مطالعـه مـوردی گـاز مونوکسـید کـربن [Predicting the evaluation and

drawing of air pollution map of Mashhad, Case study of carbon monoxide]. Paper presented at the *1st Conference on Urban Economics in Iran*. Mashhad, Iran.

References (In English)

Bivand, R., Altman, M., & Anselin, L. (2017). Spatial dependence weighting schemes statistics and model. Retrieved from http://github.com/r-spatial/spdep/

Caeiro, F., & Mateus, A. (2015). Testing Randomness in R. Package 'rand tests'. R Development Core Team Version 1.0.

Cressie, N. (1993). *Statistics for spatial data*. New York, NY: John Wily.

De Cesare, L., Myers, D., & Posab, D. (2001). Estimating and modelling spacetime correlation structures. *Statistics & Probability Letters*, *51*(1), 9-14.

Gaetan, C., & Guyon, X. (2010). *Spatial statistics and modeling*. New York, NY: Springer.

Gräler, B., & Pebesma, E. (2016). Spatio-temporal geostatistics using gstat. *Institute for Geoinformatics, University of Münster Rep*, 1-16.

Gräler, B., Pebesma, E., & Heuvelink, G. (2016). Spatio-Temporal Interpolation using gstat. *The R Journal*, *8*(1), 2073-4859.

Hengel, T., Roudier, P., Beaudette, D., & Pebesma, E. (2015). Plot KML: Scientific visualization of spatio-temporal data. *Journal of Statistical Software, 63*(5). Retrieved from http://www.jstatsoft.org/

Hijmans, R. J. (2017). Geographic Data Analysis and Modeling.'Raster'Package.R Core Development Team. Version 2.5-8. Retrieved from http://cran.r-project.org/package=raster

Kilibarda, M. (2013). A Plot Google Maps Tutorial. Serbia: The University of Belgrade.

Loecher, M. (2016). Overlays on Static Maps. Package 'R Google Maps'. R Core Development Team. Version 1.0.4.1.

Mateus, A., & Caeiro, F. (2014). An R implementation of several randomness test. Paper presented at *the International Conference of Computational Methods in Science An Engineering* (*ICCMSE*). Athens, Greek.

Pebesma, E. (2012). Spacetime: Spatio-temporal data in R. *Journal of Statistical Software*, *51*(7), 1-30.

Pebesma, E. (2017). Spatial and Spatio-Temporal Geostatistical Modelling, Prediction and Simulation. 'gstat'Package. R Development Core Team. Version 1.1-5. Retrieved from https://github.com/edzer/gstat/

Pebesma, E. (2020). Spatio-temporal overlay and aggregation. *Ifgi. Institute for Geoinformatics University of Münste, 10*(4), 1-12.

Pebesma, E., & Bivand, R. (2017). Classes and Methods for Spatial Data. Version 1.2-5. Package 'sp'. Retrieved from https://github.com/edzer/sp/

Pebesma, E., Gräler, B., Gottfried, T., & Hijmans, R. (2017). Classes and Methods for Spatio-Temporal Data. Spacetime' Package. R Development Core Team. Version 1.2-1. Retrieved from http://github.com/edzer/spacetime

R Development Core Team. (2011). R: A language and environment for statistical computing.

United Nations. (2005). Environment Programmed, Environmental News Emergencies, Retrieved from http:// www.UNEP.org/ dept/ programmes/emergencies/html