Spatiotemporal Distribution Characteristics of Sand Transport Potential in the Taklamakan Desert (Postprint)

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Date: 2020-01-06T00:00:00+00:00

Abstract

Using hourly wind records from 22 meteorological stations in the Taklamakan Desert (21 peripheral stations and 1 Tazhong station in the desert hinterland) for the period 2005–2007, we first calculated the sand drift potential (SDP) in 16 directions for each station in 2007 based on the definition of sand drift potential. Second, employing inner product similarity index clustering analysis combined with spatial distribution characteristics, the dynamic aeolian sand environment of the desert was classified into five types: the Korla type (west-southwest type) in the eastern desert, the Xinhe type (southward type) in the northern desert, the Cele type (eastward type) in the western desert, the Minfeng type (east-northeast type) in the southern desert, and a special type. Among these, the Cele type exhibits the largest sand drift potential, whereas the Xinhe type exhibits the smallest; the Minfeng type demonstrates the best directional stability of sand drift potential, while the Korla type demonstrates the worst. Furthermore, regarding seasonal variations in sand drift potential (taking 2007 as an example), the sand drift potential at all stations during spring and summer (March–August) is very strong, accounting for 81.29%–98.79% of the annual average sand drift potential, with May alone contributing 22.7%–56.8% of the annual sand drift potential; in winter (November–February of the following year), sand-raising winds are almost nonexistent. The interannual variation of the resultant sand drift potential in the desert shows: the amplitude of variation in sand drift potential is ±33%, and the amplitude of variation in sand transport direction is ±9.6°, with the Alar station exhibiting the largest amplitude of variation in sand drift potential value (±80%), and the Kuqa station exhibiting the largest directional amplitude (±24.4°).

Full Text

Preamble

DOI: 10.12118/j.issn.1000-6060.2020.01.05
Journal: Arid Land Geography

Abstract

The Taklimakan Desert is the largest sand desert in China, located in the Tarim Basin of Xinjiang. The rate of sand transport by wind plays the most important role in its aeolian surface processes. The "Fryberger Method" provides a useful and accessible way of evaluating the relative rates of sand transport (drift potential, DP) from measurements of wind data. With this method, a number of different estimations of DP about the Taklimakan Desert have been proposed for the past decades. In this paper, we recalculated the DP using the definition equation in which the arguments are the every-measurement of wind velocity rather than the calculation model in which the arguments replaced by the midpoint of each velocity category, in order to clarify the cognition of the wind-energy environments in the sand sea.

The calculations in the paper show that the DP values of 22 meteorological stations ranged from 0.7 VU to 33.4 VU in 2007, thus the wind regimes should be classified into the Low-energy wind environments by using of the "Fryberger classification" . Based on the analysis of resultant drift potential (RDP), involving the RDP similarity (Cluster Analysis of Inner Product Similarity) and the region adjacency of a RDP type, the RDPs have been classified into five types, namely, Korla type in eastern Taklimakan with the RDPs showing W-S directions (abbr. W-S Type), Xinhe type in the northern region as S Type, Cele type in the western region as E Type, Minfeng type in the southern region as E-NE Type, and Special type with the RDPs at three stations being obviously different from their adjacent regions.

The maximum average DP was caused by the NW wind regime, which happened in Cele type, and the lowest ratio of the directional variability of the winds (RDP/DP) was induced by the NE wind regime, which happened in Korla type. As a contrast, in the convergence zone between the NW and the NE wind regimes, the DP was relative lower (Xinhe type with the minimum of DP), and the ratio of RDP/DP was higher (Minfeng type with the multi-direction effective winds) than the above two types.

The cumulative DP from spring to summer in 2007 had reached to 81.29%-98.79% of the annual DP, only in May it accounted for 22.7% to 56.8% of the annual DP; whereas in winter except for February, almost no effective sand-driving winds had occurred over Taklimakan. In the southeast edge of the desert, under the normal weather condition, the north-west wind system moved eastwards between Qiemo and Ruoqiang County in May; however it retreated back to the west of Tazhong region and between Minfeng and Qiemo in February.

This indicated that the positions of the wind convergence zone under the strong wind weather were shifted eastwards.

During the period from 2005 to 2007, the inter-annual variation of RDP showed a ±33% in magnitude and ±9.6° in direction as a whole; but some specific stations displayed larger variations of the RDPs, such as a variation of ±80% in magnitude at Aral station and a variation of ±24.4° in direction at Kuqa station.

Keywords: Taklimakan Desert; spatial distribution characteristics of sand drift potential; seasonal change; inter-annual variation

2.1.2 Data and Methods

The analysis utilized wind data from 22 meteorological stations across the Taklimakan Desert during 2005-2007. The Fryberger method was applied to calculate drift potential (DP) and resultant drift potential (RDP) values. The DP values ranged from 0.8 to 34.6 VU, with RDP ranging from 0.7 to 33.4 VU. The RDP/DP ratio, indicating wind direction variability, varied between 0.36 and 0.98 across stations.

Five distinct types of wind regimes were identified through cluster analysis: (1) W-S type in the eastern region (Korla area), (2) S type in the northern region (Xinhe area), (3) E type in the western region (Cele area), (4) E-NE type in the southern region (Minfeng area), and (5) Special type at three stations with unique characteristics.

The Cele type exhibited the highest DP values (driven by NW winds), while the Korla type showed the lowest directional variability. The Xinhe type represented the convergence zone with relatively low DP, and the Minfeng type displayed multi-directional wind effects with higher RDP/DP ratios.

3 Results

3.1 Spatial Distribution

The spatial analysis revealed significant regional differences in sand drift potential across the Taklimakan Desert. The western region under NW wind influence showed the highest DP values, while the eastern region experienced more consistent wind directions (lower RDP/DP ratios). The convergence zone between NW and NE wind systems exhibited intermediate characteristics.

3.2 Temporal Characteristics

Seasonal Variation: The spring-summer period (March-August) contributed 81.29%-98.79% of the annual DP, with May alone accounting for 22.7%-56.8%. Winter months showed minimal sand-driving activity, except for February which occasionally recorded effective winds.

Inter-annual Variation: From 2005 to 2007, RDP magnitude varied by ±33% and direction by ±9.6° overall. However, individual stations showed greater variability: Aral station exhibited ±80% magnitude variation, while Kuqa station showed ±24.4° directional variation.

4 Discussion and Conclusions

The study demonstrates that the Taklimakan Desert exhibits low-energy wind environments overall, with significant spatial heterogeneity in wind regimes. The NW wind system dominates the western region, while the NE system influences the east. The convergence zone between these systems shows complex, multi-directional wind patterns.

Seasonally, the desert experiences concentrated aeolian activity during spring and summer, particularly in May. The inter-annual stability of wind patterns varies regionally, with some locations showing high sensitivity to climatic fluctuations.

The refined calculation method using actual wind velocity measurements rather than category midpoints provides more accurate DP estimations, enhancing our understanding of aeolian processes in this hyper-arid environment.

References

[1] Li Jiangfeng. Weather and climate in the Taklimakan Desert and surrounding mountains [M]. Beijing: Science Press, 2003: 1-43.

[2] Zhu Zhenda. Aeolian geomorphology study in Taklimakan Desert [M]. Beijing: Science Press, 1981: 1-26.

[3] Zhu Zhenda. Desert, desertization, desertification in China with the solution [M]. Beijing: China Environmental Press, 1999: 33-47.

[4] Fryberger SG, Dean G. Dune forms and wind regime [M]. Washington: United States Government Printing Office, 1979.

[5] Fryberger SG, Al-Saria M, Clisham TTJ, et al. Wind sedimentation in the Jafurah sand sea, Saudi Arabia [J]. Sedimentology, 1984, 31(3): 413-431.

[6] Kalma JD, Speight JG, Wasson RJ. Potential wind erosion [J]. Journal of Water and Soil, 2011, 25(1): 11-18.

[7] Hereher ME. Sand movement patterns in the Western Desert of Egypt: An environmental concern [J]. Environmental Earth Sciences, 2010, 59(5): 1119-1127.

[8] Hereher ME. Sand movement patterns in the Western Desert of Egypt: An environmental concern [J]. Environmental Earth Sciences, 2010, 59(5): 1119-1127.

[9] Jewell PW, Nicoll K. Wind regimes and aeolian transport in the Great Basin, U.S.A [J]. Geomorphology, 2011, 129(1): 1-16.

[10] Mesbahzadeh T, Ahmadi H. Investigation of sand drift potential (case study: Yazd-Ardakan Plain) [J]. Journal of Agricultural Science & Technology, 2012, 14(4): 919-928.

[11] Mesbahzadeh AT, Ahmadi BH. Sand movement patterns in southern Iran [J]. Desert, 2014, 19(1): 11-15.

[12] Zhang Zhengsi, Dong Zhibao, Zhao Aiguo, et al. Characteristics of blown sand activity in the Kumtagh Desert [J]. Arid Land Geography, 2010, 33(6): 939-946.

[13] Zhang Kecun, Ao Yinghuan, Qu Jianjun, et al. Dynamic environments of wind-blown sand near lakes surrounded by sand-mountains in the Badain Jaran Desert [J]. Arid Land Geography, 2013, 36(5): 790-794.

[14] Yang X, Scuderi L, Liu T, et al. Formation of the highest sand dunes on Earth [J]. Geomorphology, 2011, 135(1): 108-116.

[15] Zhang Kecun, Qu Jianjun, Yao Zhengyi, et al. Sand damage and its control along the Golha Section of the Qinghai-Tibet Railway [J]. Arid Land Geography, 2014, 37(1): 74-80.

[16] Li Jiangfeng. Weather and climate in the Taklimakan Desert and surrounding mountains [M]. Beijing: Science Press, 2003: 1-43.

[17] Li Hongjun, He Qing, Yang Qing. Analysis of drift potential in Xinjiang in recent 40 years [J]. Journal of Desert Research, 2004, 24(6): 46-50.

[18] Zhou Chenglong, Yang Xinghua, Liu Houyong, et al. Wind power environment of Tazhong area in hinterland of Taklimakan Desert [J]. Bulletin of Soil and Water Conservation, 2014, 34(3): 218-222.

[19] Zu Ruiping, Zhang Kecun, Qu Jianjun. Study on wind regime characteristics in the Taklimakan Desert [J]. Arid Land Geography, 2005, 28(2): 167-170.

[20] Zu Ruiping, Zhang Kecun, Qu Jianjun. The intensity of sand-drift activities in Taklimakan Desert [J]. Geographical Research, 2005, 24(5): 699-707.

[21] Xing Wenjuan, Lei Jiaqiang, Wang Haifeng, et al. Analysis on wind regime and wind-borne sand potential in a desert-oasis ecotone: A case study in Qira County, Xinjiang [J]. Arid Zone Research, 2008, 25(6): 894-898.

[22] Li Zhenshan, Chen Guangting. Effective wind regime in the Taklimakan Desert [J]. Journal of Desert Research, 1999, 19(1): 44-46.

[23] Bullard, Joanna E. A note on the use of the Fryberger method for evaluating potential sand transport by wind [J]. Journal of Sedimentary Research, 1997, 67(3): 499-501.

[24] Lettau K, Lettau HH. Experimental and micro-meteorological field studies of dune migration, exploring the world' s driest climate [C]// Lettau K, Lettau H. Exploring the world' s driest climate. University of Wisconsin-Madison, IES Report 101, 1977: 110-147.

[25] Fang Yanjie, Zhao Jingfeng, Guo Yongping, et al. Magnitude deviations of sand drift potential calculation in the 'FRYBERGER' model: A case of the Taklimakan Desert [J]. Arid Land Geography, 2015, 38(1): 95-102.

[26] Pearce KI, Walker IJ. Frequency and magnitude biases in the Fryberger model, with implications for characterizing geomorphically effective winds [J]. Geomorphology, 2005, 68(1): 39-55.

[27] Zhang Zhengsi, Dong Zhibao, Zhao Aiguo. Effect of different time intervals in assessing sand drift potential [J]. Arid Land Geography, 2010, 36(2): 177-182.

[28] Chen Weinan, Dong Zhibao, Yang Zuotao, et al. Threshold velocities of sand-driving wind in the Taklimakan Desert [J]. Acta Geographica Sinica, 1995, 50(4): 360-367.

[29] Wang Xueqin, Hu Yongfeng, Yang Dongliang, et al. Effect of Alhagi sparsifolia community on wind block and drift sand control in the oasis-desert ecotone [J]. Arid Land Geography, 2011, 34(6): 919-925.

[30] Mao Donglei, Cai Fuyan, Lei Jiaqiang, et al. The characteristics of aeolian activity on sand blown frontier in lower reaches of Cele River, Xinjiang [J]. Journal of Arid Land Resources and Environment, 2016, 30(7): 169-174.

[31] Li Hengpeng, Chen Guangting. Retrograde evolution of barchan on interdune corridor of complex ridges in central Taklimakan Desert [J]. Journal of Desert Research, 1999, 19(2): 39-43.

[32] Zhang Jiawu, Chen Guangting, Chen Fahu, et al. Dynamic processes of linear dunes in central Taklimakan Desert [J]. Journal of Desert Research, 1999, 19(2): 33-38.

Note: Figure translations are in progress. See original paper for figures.