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Environmental characteristics of sandstorm of Minqin Oasis in China for recent 50 years

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Abstract: The purpose of this present study is to investigate the frequency and variation of sandstorm in Minqin Oasis. Using daily observational data of sandstorm and other meteorologic data from 1954 to 2000, we have illuminated the relationship between sandstorm, meteorological parameters and human activities. The results of the analysis show that the highest frequency of sandstorms occurrence and their duration mainly focus on March, April and May, especially in April. Most of sandstorms occur from midday to nightfall, but relative few appear from midnight to forenoon, which apparently correlates to the daily variations of atmospheric thermal stability within atmospheric boundary layer. Monthly mean and annual mean duration of sandstorms coincide well with the frequencies of sandstorm occurrence.

Keywords: Minqin Oasis; sandstorm; environmental characteristics

Introduction

A sandstorm is a kind of severe weather phenomena where strong winds blow a huge amount of sand and dust into the air, reducing the horizontal visibility to less than 1 km (Wang, 2003a). It is not only an important process of accelerating land desertification but also an indicator reflecting the degree of desertification (Wang, 2000). Being an issue concerning human health and eco-environment, it has been studied by many scholars for centuries (Griffin, 2004; Goudie, 2001; Gillies, 1996; Chen, 2003). Atmospheric dispersion of wind-blown dust particles from desert can cause serious air-pollution and environmental problems (Ologunorisa, 2003; Goossens, 2000; Ta, 2003; 2004). Sandstorms have some negative consequences including delays and reduction in pasture for livestock, roads closure, and settlements and villages can become enshroud with sand (Natsagdorj, 2003). China is one of the countries suffered from sandstorm very frequently, especially in northwest regions, which is one part of the central Asia sandstorm area. The desert-distributed regions, accounting for 13% of total China's areas, are major sources of Asian dust (Song, 2004). A good illustration is Hexi corridor, where six severe sandstorms have happened since 1950s (Xia, 1996). In this paper, the environmental characteristics of sandstorm in Minqin Oasis were investigated. Minqin Oasis (102°45′—103°55′E, 38°20′—39°10′N), with an area of 1500 km^2, located at lower reaches of Shiyang River, Gansu Province, Northwest China. It is surrounded by Badai Jaran Desert and Tengger Desert, and about 91% of total area is covered by desert, Gobi, salina and deflation basin. Minqin Oasis has low rainfall with about 115 mm averagely, while average evaporation capacity in many years reach high to 2640 mm. There are more than 30 d with sandstorm in a year and annual wind speed about 2.8 m/s. On average, the strong wind more than 17 m/s exceed 25 d in a year and the prevailing wind direction is NW (Chang, 2002). Due to arid climate and scarce water resources, the ecosystem of Minqin Oasis is very fragile. During the recent 50 years, with the increase of water resources utilization at the upper reaches of Shiyang River, the water discharged into Minqin Oasis gradually decreases. This has brought many negative effects on local environment, including soil salinization, vegetation degeneration and land desertification. Statistics show that there is 6.13×10^4 hm^2 of farmland before 1950s, but in recent years, encroached by wind-blown sand, the deteriorated area of Oasis is more than 480×10^4 hm^2 and the area of farmland reduced to 4×10^4 hm^2. There are about 88×10^4 hm^2 *Elaeagnus angustifolia* and 2.3×10^4 hm^2 *Nitraria sibirica Pall.* and *Tamarix ramosissima* on the withered or dead edge. Especially in 1990s, more than 32×10^4 hm^2 grass land and 3.2×10^4 hm^2 forest land were suffered from land desertification (Wang, 2003b; Ma, 2003a).

The aims of this study were to analysis the temporal characteristic of sandstorm during the past 50 years in Minqin Oasis and to reveal the relationships between sandstorm and meteorological data.

1 Data sources

Meteorologic data, such as air temperature, precipitation, days with sandstorm and strong wind ($\geq$ 17 m/s) used in this paper were sourced from Minqin Meteorological Station (103°05′E, 38°38′N, 1367 m above the sea level), which, as one of basic station, belongs to National Meteorological Bureau. All data cover the period 1954—2000. Collected data of rainfall is based on the single precipitation more than 0.1 mm. In this study a sandstorm is defined as having an instantaneous wind velocity of 17 m/s and a horizontal visibility < 1000 m, and the beginning and ending times of sandstorm is routinely recorded. Data of farmland in this paper are sourced from Statistical Bureau of Minqin County and abandoned land is the difference between the areas of farmland in former year and next year.

2 Results and discussion

2.1 Temporal characteristics of sandstorm occurrences

Fig. 1 illustrates annual variation characteristics of sandstorm in Minqin Oasis from 1954 to 2000. During this period, the numbers of sandstorm in each year is decreasing in general and this trend is more obvious after 1990s. With the land reclamation increasing, ecological environment in this region became worse gradually. Large area of Gobi,

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which covered with desert vegetation, such as *Nitraria sibirica Pall*., *Haloxylon ammodendron Bunge*, *Elaeagnus angustifolia*, etc., had been reclaimed and planted with seed melon, which is a kind of annual herb. After autumn harvest, formerly-fixed Gobi surface took on an exposed state and suffered from wind erosion easily. It can provide abundant materiel condition for sandstorm occurrence. In addition, ground water had been overexploited severely to meet water demand of a large acreage of land reclamation. Statistics show that there are 1.1×10^4 wells used for extracting groundwater since 1970s, of which 260 wells has the depth about 200—300 m. At present, about 6.0×10^8 m^3 underground water is extracted in one year and 3×10^8 m^3 exceeds their most tolerance(Ma, 2003b). This phenomenon resulted in groundwater level declined rapidly and brought many negative effects on local eco-environment, including soil salinization, vegetation and natural grassland degradation, and land desertification.

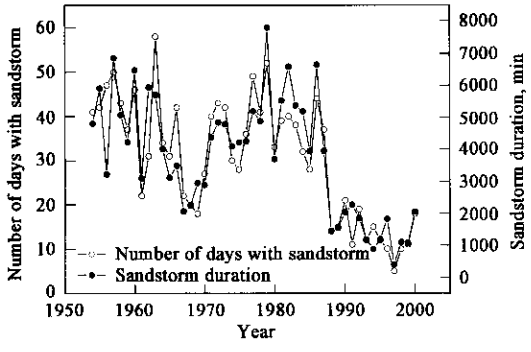

Fig.1 Annual variation of sandstorm occurrence in Minqin Oasis

Fig.2 shows that there is a clear annual variation in sandstorm occurrences in Minqin Oasis. It can be found that sandstorm mainly focus on March, April and May, especially in April. The highest frequency of sandstorm occurs in spring and the lowest frequency occurs in autumn(September). In spring, due to high temperature and little rainfall, surface soils frozen in the previous winter begins to defreeze and makes soil loosen. Therefore, it provides a favorable condition for wind erosion. In addition, in this period cyclonic activity is more intensive under the control of Mongolia high pressure, which provides dynamical foundation for sandstorm occurrence and development. The statistic temporal characteristics of single sandstorm have been listed in Table 1.

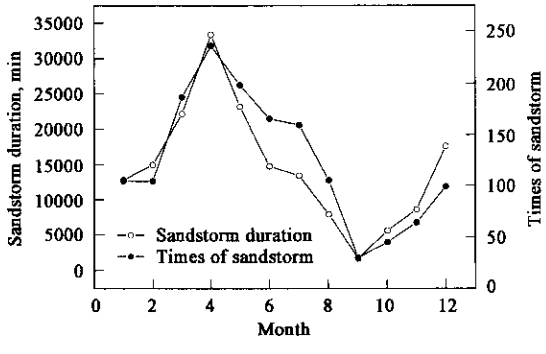

Fig.2 Monthly variation of sandstorm occurrence in Minqin Oasis from 1954 to 2000

In general, the duration of a sandstorm is 1—2 h. Table 1 shows that the number of sandstorm lasted 0—120 min is 917 times, accounted for 63.86 of all statistic sandstorm times from 1954 to 2000. The sandstorm lasted more time (exceed 6 h) is scarce. The number of sandstorm's duration exceeded 10 h is only 11, accounted for 7.6% of total times in this period. Therefore, we can draw a conclusion that the frequency of very strong sandstorm occurrence is not very high. That is to say, sandstorm is a short-lived weather phenomenon caused by instable atmosphere structure in the condition of large-scale climatic background, due to the factor of local topography and special underlying surface.

Table 1 Statistics of sandstorm duration in Minqin Oasis (1954 to 2000)

Duration, min	Times of sandstorm occurrence	Frequency, %
0—120	917	63.86
120—240	305	21.24
240—360	119	8.29
360—480	61	4.25
480—600	23	1.60
≥600	11	0.76
Σ	1436	100

Most of sandstorms occur from midday to nightfall, but relative few from midnight to forenoon (Table 2). This apparently correlates to the daily variations of atmospheric thermal stability of atmospheric boundary layer. During the afternoon, fluctuation of airflow present more severe because of the increase of temperature and atmospheric convection. Under this condition, sand particle's entrainment becomes easier, thus provides stable environmental condition for sandstorm. When cold air passes through this region, convection from high to low altitude enhances and sandstorm more likely to occur (Li, 2002). We calculated the relationship($R = 0.886$) between duration of sandstorm and number of days with sandstorm in a year. On the condition of confidence level $a = 0.01$, we do hypothesis testing with T method and find $T = 12.81 > T_{a/2} = 2.66(n = 60)$. This illustrates that there is a conspicuous relative between the number of sandstorm days and their duration in a year.

Table 2 Time-interval statistics of sandstorm occurred in Minqin Oasis

Time-interval	Times of sandstorm occurrence	Frequency, %
0:00—3:00	70	4.87
3:00—6:00	55	3.83
6:00—9:00	119	8.29
9:00—12:00	199	13.86
12:00—15:00	264	18.38
15:00—18:00	227	15.81
18:00—21:00	436	30.36
21:00—24:00	66	4.60
Σ	1436	100

2.2 Relationship between sandstorm and other meteorological parameters

Aeolian dust transport involves three stages, i. e. entrainment, dispersion and deposition. There have several influencing factors of sand initiation and sandstorm, including strong wind power, abundant sand-dust materials and instable atmosphere structure (Bagnold, 1941; Logie, 1981; Nicking, 1988). Wind provides a dynamical condition, sand-dust is material foundation and instable atmosphere

structure supplies a good environmental condition for sandstorm occurrence. So it is of importance to study the relationships between sandstorm and other meteorological data.

2.2.1 Strong wind

Researched results indicate that sandstorms occurrence needs strong wind and loose and dry sand-dust materials over ground surface. In other words, wind and sand-dust materials are two major factors of sandstorm occurrence. The area of desertification land in China is rapidly enlarged with a speed of 1560 km^2/a on average from 1950s to 1970s and even reached high to the speed of 2460 km^2/a in 1990s (Dong, 1999). It is implied that the vegetation coverage presented a deteriorate trend in whole and the material source of sandstorm become more enriched. Based on these conditions, the number of sandstorm days will be more frequent. This deduction does not match even contradict with the fact of decreasing trend of sandstorm. This implies that strong wind likely play a dominant role in sandstorms occurrence. Therefore, we analyzed the relationship between numbers of sandstorm days and strong windy days from 1954 to 2000 (Fig.3).

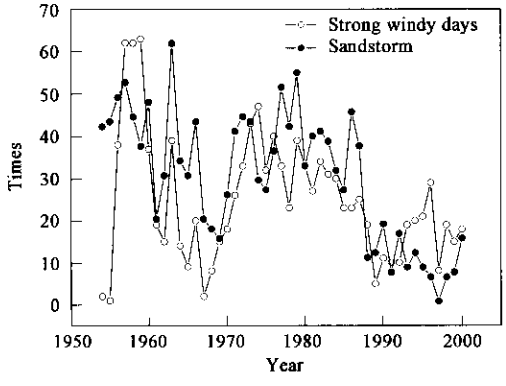

Fig.3 Relationship between sandstorm and strong windy days each year

Fig. 3 indicates that number of days (N_D) with sandstorm coincides well with the strong windy days (N_W), and their relationship can be expressed as: $N_D = 18.45 + 0.49N_W$ ($R = 0.542$, $N = 47$). On the condition of confidence level $a = 0.01$, we do hypothesis testing with T method and obtained the value of $T = 4.32 > T_{a/2} = 2.66$ (degree of freedom $n = 60$). This illustrates that there is a conspicuous correlation between the number of days with sandstorm and strong windy days in a year.

2.2.2 Precipitation

Precipitation affects the humidity of earth surface and material source of sandstorm. If the humidity of soil is high, the cohesive forces and drag velocity of sand particles will be increased and the initial threshold velocity of sand entrainment will be improved. Therefore, the frequency of sandstorm occurrence will be reduced greatly (Fig.4).

Fig.4 indicates the number of days with sandstorm took a decreasing trend in the year with much precipitation. Furthermore, we analyzed the relationship between the days with sandstorm and annual precipitation and found they have a reverse correlation and coincided well negatively. However, we also noticed that the reverse correlation between sandstorm and precipitation is not clear before 1980s. This is maybe

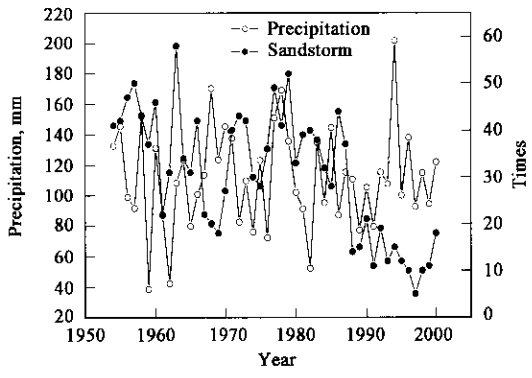

Fig.4 Relationship between sandstorm and precipitation each year

that the main source impacting sandstorm occurrence and development in Minqin Oasis is not in local region but in other places before 1980s. After 1980s, the occurrence of sandstorm is mainly caused by wind erosion in local region because of the variation of agricultural structure. During this period, local peasants reclaimed a lot of virgin land for planting seed-melon and then abandoned them due to little benefit. So, these formerly reclaimed farmlands were in exposed state, easily suffered from wind erosion and supplied many materials for sandstorm occurrence.

2.3 Relationship between sandstorm and changing of farmland

Excessive reclamation is the main reason for causing land desertification and more frequency of sandstorm (Qu, 2002). Therefore, we analyzed the change of farmland in Minqin Oasis since 1954 (Table 3).

Table 3 Changes of farmland area from 1954 to 2000 in Minqin Oasis ($\times 10^4$ hm^2)

Year	Farmland	Abandoned farmland	Year	Farmland	Abandoned farmland
1954	6.677	-0.083	1977	6.060	-0.029
1955	6.477	0.200	1978	6.103	-0.043
1956	6.885	-0.409	1979	6.154	-0.051
1957	6.853	0.067	1980	6.135	0.019
1958	6.659	0.194	1981	6.114	0.019
1959	6.584	0.075	1982	6.092	0.022
1960	6.359	0.225	1983	6.124	-0.032
1961	6.171	0.188	1984	6.070	0.054
1962	6.117	0.053	1985	6.158	-0.088
1963	6.131	-0.013	1986	6.161	-0.003
1964	6.117	0.014	1987	6.216	-0.055
1965	6.099	0.018	1988	6.227	-0.011
1966	6.135	-0.036	1989	6.236	-0.009
1967	6.112	0.023	1990	6.227	0.009
1968	6.021	0.090	1991	6.093	0.134
1969	6.033	-0.012	1992	6.098	-0.005
1970	5.971	0.063	1993	6.105	-0.007
1971	5.981	-0.011	1994	6.113	-0.008
1972	5.999	-0.018	1995	6.109	0.003
1973	5.998	0.001	1997	6.111	-0.002
1974	6.002	-0.004	1998	6.207	-0.096
1975	6.009	-0.007	1999	6.207	0.000
1976	6.031	-0.022	2000	6.187	0.021

Note: Data sourced from Statistical Bureau of Minqin County

From Table 3, we can clearly find that because many farmlands were abandoned, the cultivated land in Minqin Oasis was taken on a dynamic decreasing trend from 1950s to

1970s. Especially in 1959, 1960 and 1961, the area of abandoned farmland reached to 0.08×10^4, 0.23×10^4 and 0.19×10^4 hm^2, respectively, this coincides well with the more number of days with sandstorm in these years. After 1975, the farmland area was relatively stable and the dominant trend is reclamation. Although there was a great change in 1991 (abandoned area of 0.13×10^4 hm^2), which is closely related to the slump of seed-melon price. Accordingly, the number of days with sandstorm began to rapidly increase after 1991. The number of days with sandstorm in 1991, 1992 and 1993 is 11, 19 and 12, respectively. Thus it can be draw a conclusion that farmland abandonment is a main reason of sandstorm occurrence. How to regulate the structure of land use in Minqin Oasis is an urgent task for improving eco-environment. If we do not deal with this problem properly, Minqin Oasis will be a big source to accelerate sandstorm development and affect ecological environment in North region, even whole China.

Finally, we statistic the number of days with sandstorm and their duration, strong windy days, number of days with precipitation more than 0.1 mm in a year. A regress equation of sandstorm duration could be obtained ($R^2 = 0.761$):

$$T = 751 + 110N_D + 9.8N_W - 6.0N_P - 3.56P.$$

Where, T is the sandstorm duration in a year (min); N_D is the number of days with sandstorm in a year; N_W is strong windy days in a year; N_P is the days with precipitation more than 0.1 mm; P is the precipitation in a year (mm).

3 Conclusions

In this study, we carried out a detailed analysis on the characteristics of sandstorms in Minqin Oasis and obtained the following conclusions. (1) The highest frequency of sandstorm and its duration occurs from March to May, especially in April. (2) Most of sandstorms occur from midday to nightfall, but relative few from midnight to forenoon, which apparently correlates to the daily variations of atmospheric thermal stability within atmospheric boundary layer. (3) Annual amount of precipitation and days with sandstorm have a reverse correlation and they coincided well negatively, while the duration of sandstorm coincided well with strong windy days. (4) Farmland abandonment is a main factor resulted in higher frequency of sandstorm in Minqin Oasis. So, only through adjusting land use structure properly and rationally, the occasion of sandstorm occurrence can be inhibited effectively in Minqin Oasis.

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