Journal of Geographical Sciences 12, 3 (2002) 357-362 ISSN: 1009-637X

Analysis of the severe group dust storms in eastern part of Northwest China

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Abstract: Based on the available original dust storm records from 60 meteorological stations, we discussed the identification standard of severe dust storms at a single station and constructed a quite complete time series of severe group dust storms in the eastern part of Northwest China in 1954-2001. The result shows that there were 99 severe group dust storms in this region in recent 48 years. The spatial distribution indicates that the Alax Plateau, most parts of the Ordos Plateau and most parts of the Hexi Corridor are the main areas influenced by severe group dust storms. In addition, the season and the month with the most frequent severe group dust storms are spring and April, accounting for 78.8% and 41.4% of the total events respectively. During the past 48 years the lowest rate of severe group dust storms occurred in the 1990s. Compared with the other 4 decades, on the average, the duration and the affected area of severe group dust storms are relatively short and small during the 1990s. In 2000 and 2001, there were separately 4 severe group dust storms as the higher value after 1983 in the eastern part of Northwest China.

Key words: eastern part of Northwest China; severe group dust storms; temporal and spatial distribution characteristics
CLC number: P425.55; P445.4

1 Introduction

Regarding the climate characteristics of dust storms in northern China, lots of studies have been conducted by scientists (Littmann, 1991; Wang *et al.*, 1996; Xu *et al.*, 1996; Yang *et al.*, 1998; Zhang *et al.*, 1999; Niu *et al.*, 2000). However, due to the difference of sample cases and data coverage, different studies have achieved various results, especially, with obvious divergence about the inter-annual variability of dust storms in northern China. Recently, by using the long-term data from 681 meteorological stations in China, Zhou (2001) has systemically analyzed the temporal and spatial distributions of the dust storms throughout the country. Because of the more dense observation stations and the longer time of observed data, many conclusions from Zhou (2001) have been acknowledged widely, and embodied in the CAS academician's advisory report (Ye *et al.*, 2001).

In fact, both intensity and damage degree of dust storms are obviously different under different dust storm weather conditions (Joseph *et al.*, 1980; Nickling *et al.*, 1984; Middleton, 1986; Swap R *et al.*, 1996; Sun *et al.*, 2001). The relatively light dust storms have not too much impact on industrial and agricultural production and human activities, but the severe dust storms, especially those with poor horizontal visibility (only 50 m or less), often cause enormous losses to both ecological environment and human society when they occur. The interior characteristics and harmfulness of the dust storms cannot be revealed only by roughly studying the number of days of dust storms occurred annually or monthly. So among all of the research projects, it is the

Received date: 2002-03-10 **Accepted date:** 2002-06-05
Foundation item: The National Key Basic Research Project of China, No. G2000048703; The Knowledge Innovation Project of CAS, No. KZCX2-305; Key Research Project of NSMC, No.NSMC-Y0101
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most important work to understand the entire mechanism, synoptic climate characteristics and predicting methods of dust storms. Xu *et al.* (1979), Yang *et al.* (1991), Liu *et al.* (1996) and Chang *et al.* (1997) have obtained certain information through analyzing and discussing one or two cases of severe dust storms in northern China in the context of synoptic meteorology. However, how many severe dust storms exactly occurred in northern China in the past 5 decades? How did they change from year to year? Up to now, we cannot find the satisfying answers to these hot issues from previous studies. So we planned to use the available original dust storm data from high density observation stations in China in the past 50 years, and construct a quite complete severe dust storm series of the whole country according to the unified standard so as to facilitate future studies on dust storms. However, since the complexity of data, especially lots of wind speed curves from wind-recorders have not been digitized, it is quite difficult to establish a complete severe dust storm time series immediately. A great number of detailed investigations are required to be performed. In this paper, as the first phase of our plan, we concentrated on discussing and summarizing the construction method and temporal and spatial distribution characteristics of the severe group dust storms in the eastern part of Northwest China.

2 Study area and data source

In this paper, the eastern part of Northwest China includes Ningxia, western part of Inner Mongolia (to the west of 111°E) and northern parts (to the north of 35°N) of both Gansu and Shaanxi provinces, with a total area of roughly 900,000 km^2 (Figure 1). This area, as a part of the mid-latitude arid and semiarid regions, including the Badain Jaran Desert, the Tengger Desert, the Ulan Buh Desert, the Mu Us Desert, the Hobq Desert and some other sandy lands, is one of the two main dust storm centers in China. Each year there are more than 10 dust storms in most places and over 20 events at some observational stations (Zhou, 2001). At the same time, it is also one of the dominant dust source regions and has major effects on eastern China (Sun *et al.*, 2001; Qiu *et al.*, 2001). So, constructing and discussing the severe dust storm time series of this area is of great significance to the future research into dust storms.

For this investigation, 60 national basic meteorological stations in this area are selected (Figure 1). The daily dust storm records including their life-time, minimum horizontal visibility and wind force of over 60 stations used in this paper are mainly derived from *Surface Meteorological Monthly Bulletin* and the compiled digital products covering the period 1954-2001. All the data have been checked and confirmed record by record, so the data set has high quality and integrity. There are 29 stations that fully cover 48 years, accounting for 48.3% (slightly below national average ratio of 52.1%), 45 stations that cover 45 years, occupying 75%, and 57 stations that cover 40 years, making up 95%. Besides, in order to determine typical severe dust storm cases, some Historical Surface Chart, some wind speed curves from wind-recorder, and some papers on severe dust storm cases (Qian *et al.*, 1997) are consulted and examined as another

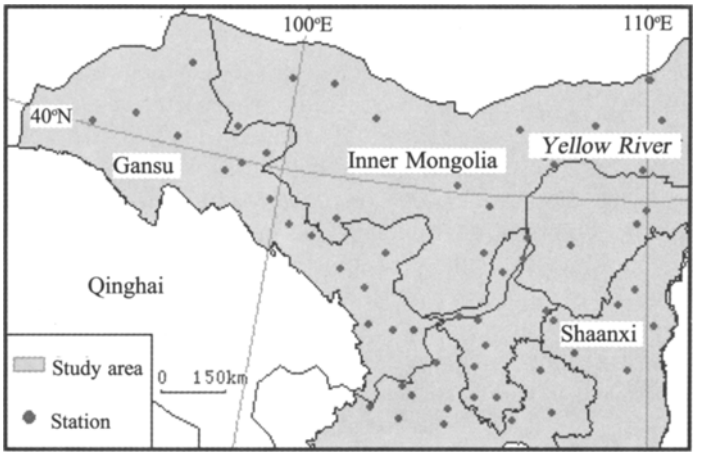

Figure 1 The location of the study area and stations used in this research

data source.

3 Construction of the time series of severe group dust storms

Joseph *et al.* (1980) and Middleton (1986) have classified dust storms in India into three types based on nature of variation of visibility and wind speed, i.e., the standard of light, moderate and severe dust storms. Refer to this criterion, and combined with actual conditions in China, Xu *et al.* (1996) and Qian *et al.* (1997) have brought forward the classification standard of dust storms according to their intensities at the single station in Northwest China (Table 1).

Table 1 Classification standard of dust storms according to intensity

Intensity of dust storm	Instantaneous maximum wind speed [f(m/s)]	Minimum visibility [V(m)]
Severe	≧class 8; or f ≧20	class 1; or V ≦200
Moderate	class 6-8; or f ≧17	class 2; or 200<V≦500
Light	class 4-6; or f ≧10	class 3; or 500<V≦1000

Note: a. The wind force scale is Beaufort scale: 0-12 classes; b. In meteorological observation, visibility unit use meter since 1980, heretofore it was 0-9 classes.

It has already been verified that this classification standard is suitable for the operation of China meteorological departments concerned. So, we adopt it to judge the light, moderate and severe dust storms at single station, and define the severe group dust storms by any one of the following supplementary criteria in our study area:

(a) During the same weather process, there are three or more stations where severe dust storms break out together.

(b) During the same weather process, there are only two stations where severe dust storms break out, but there are three or more stations where moderate dust storms break out, or more than 30% of the total research stations where dust storms break out together.

(c) During the same weather process, there is only one station where severe dust storm breaks out, but there are five or more stations where moderate dust storms break out, or more than 50% of the total research stations where dust storms break out together.

The severe dust storm caused by unsystematic weather process, occurring in one or two individual stations will not be accepted in the severe group dust storm series.

According to synoptic process, all of the 19873 original meteorological records from 60 stations are divided into many groups, and each group are checked and confirmed in accordance with the above criteria. Then the result indicates that there were 99 severe group dust storms, with an average frequency of 2.1 times each year during the period 1954-2001.

4 Spatial and temporal distributions of severe group dust storms

4.1 Spatial distribution

The locations of the above 99 severe group dust storms are depicted in Figure 2. The spatial distribution of severe group dust storms indicates that except for the southern part of Shaanxi province and southwestern part of Gansu province, severe dust storms occur in most areas of the eastern part of Northwest China. The Alax Plateau, most parts of the Ordos Plateau and most parts of the Hexi Corridor are the main areas influenced by severe dust storms, where there are generally more than 10 severe dust storms in most places, and more than 20 events at some stations in recent 48 years. For example, there are 25 events at Minqin, Gansu, 19 at Yanchi, Ningxia, 15 at Bayinmaodao, Inner Mongolia.

The eastern part of Northwest China belongs to mid-latitude arid and semi-arid areas, covered with deserts, sandy lands and dry lands with little vegetation. Numerous case studies have shown that when strong cold and dry air passing over Siberia arrives in Northwest China,

the severe dust storms can be generated easily.

4.2 Seasonal distribution

The monthly distribution of the 99 severe group dust storms in the eastern part of Northwest China (Figure 3) indicates that the severe dust storms occurred mainly in spring (March, April, May), with a total number of 78, occupying 78.8% of the whole year. This is because during spring, the synoptic systems over eastern Asia are highly unstable, temperature is ascending quickly, surface is quite bare, and dust can be entrained to high levels through upward air motion. Furthermore, April is the most favorable month, with 41 severe events and 41.4% of the whole year. The second season of frequent severe dust storms is winter (December, January, February), with 16 severe events and 16.2% of the whole year. On the contrary, there is only one severe group dust storm in autumn in the 48 years.

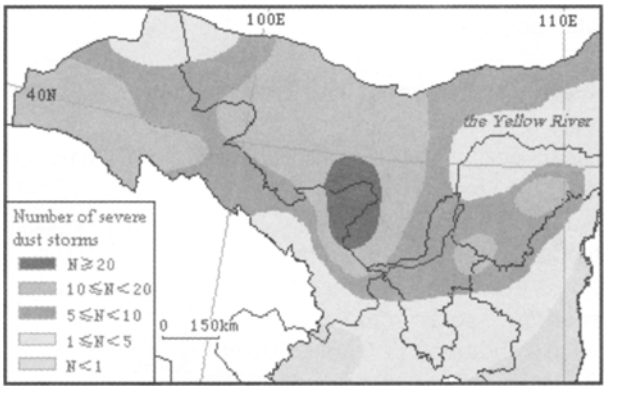

Figure 2 Spatial distribution of severe group dust storms in 1954-2001

4.3 Interannual variability

Annual number of severe group dust storms from 1954 to 2001 in the eastern part of Northwest China is shown in Figure 4. The curve indicates that severe dust storms occurred about 2-5 times annually during the 1950s, 1-3 annually during the 1960s, the 1970s and the early 1980s (except for 1983), below 2 annually in the late 1980s and most years of the 1990s, 4 times in 2000 and 2001 respectively. It is worth mentioning that there were 7 severe group dust storms in 1983, as the maximum value of the 48 years in the study area. Especially on April 27-28, 1983, 14 stations including Tongxin, Yinchuan in Ningxia, Wuwei, Jingtai in Gansu, and Jilantai, Yijinhuoluoqi in Inner Mongolia etc. had severe dust storms, as well as 77.2% of 60 stations in this area witnessed dust storms together. In general, the

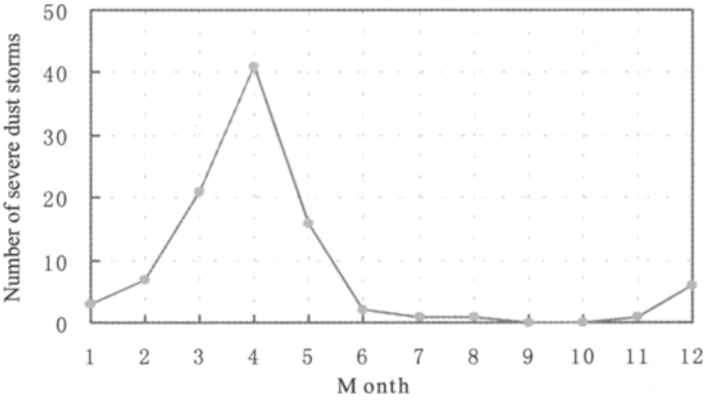

Figure 3 Monthly number of severe group dust storms in 1954-2001

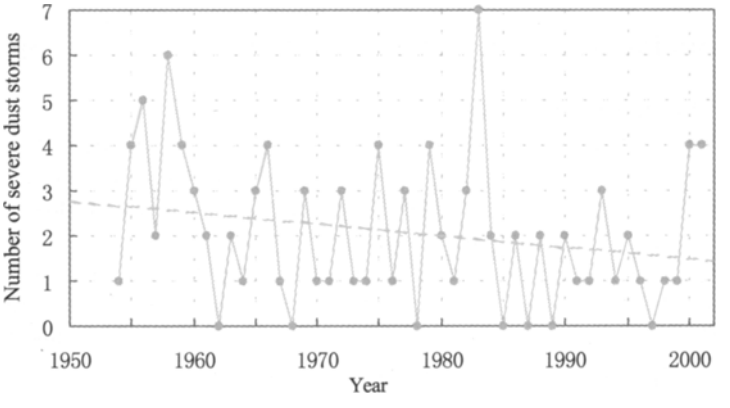

Figure 4 Annual number of severe group dust storms in 1954-2001

Table 2 Decadal variation of severe group dust storms in 1954-2001

	1954-1960	1961-1970	1971-1980	1981-1990	1991-2000	2001
Severe dust storms number	25.00	17.00	20.00	19.00	15.00	4.00
Mean duration (hours)	8.59	9.65	8.60	8.88	7.21	7.48
Mean $N_{duststorm}/N_{total}$ (%)	51.88	45.41	43.07	44.23	30.83	53.83

tendency of severe group dust storms in the eastern part of Northwest China is descending in the past 48 years, but increasing again after 1997. There were 4 severe group dust storms respectively in 2000 and 2001, which are the maximum occurrence of dust storms after 1983.

To provide more detailed information, Table 2 gives the number, the mean duration and the mean affected area (expressed roughly by percentage of stations with dust storms to the total research stations) of severe group dust storms during different periods of the 48 years in the eastern part of Northwest China. The data indicate that there were 25 severe group dust storms during the last 7 years of the 1950s, with an average of 3.6 times annually, which is relatively high frequency. The change from the 1970s to the 1980s is not distinct, with an average of 1.9-2.0 times annually. The average numbers were respectively 1.7 and 1.5 in the 1960s and the 1990s, which was less than half of the 1950s. Compared by the mean duration, it was 7.2 hours during the 1990s, and about 1-2 hours shorter than in the other decades. In addition, the mean affected area of dust storm in the 1990s were about 10-20% smaller than in the other decades too.

The reason why fewer severe dust storms with shorter duration and smaller affected area occurred in the 1990s should be further studied. It may be associated with climate background, or some human biologic measures (such as afforestation), or some engineering measures (such as irrigation by pumping in Ningxia). These artificial measures have improved the surface vegetation. Additionally, the windbreak forest can effectively weaken the wind speed, and restrain the occurrence, development and duration of dust storms.

5 Conclusions

There were 99 severe group dust storms in the eastern part of Northwest China in recent 48 years. The Alax Plateau, most parts of the Ordos Plateau and most parts of the Hexi Corridor are the main areas influenced by severe dust storms, where there are generally more than 10 severe dust storms in most places, and more than 20 events at some stations such as Minqin, Gansu.

The season and the month with the most frequent severe group dust storms are spring and April, respectively accounting for 78.8% and 41.4% of the whole year.

During the past 48 years the lowest occurrence of severe group dust storms was in the 1990s. Compared with the other 4 decades, on the average, the duration and affected area of severe group dust storms were relatively short and small during the 1990s. In 2000 and 2001, there were 4 severe group dust storms, a relatively high occurrence after 1983 in the eastern part of Northwest China.

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