The Dust Storm: Historical evolution of Inner Mongolia and the impacts of the climate change

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Dust storm, a kind of meteorological disasters, occurs in all ages in Inner Mongolia. The central-west area of Inner Mongolia is one of dust storm source area in China. This study includes the historical evolution of dust storm in Inner Mongolia, dust storm influence and its temporal and spatial distribution, the surface ecological environment variations over the main source areas and the impacts of the climate change and human activities on the surface and dust storms.

When dust storm happens, a great deal of surface sand-dust is blown up into high sky by gales, makes the air being dim and the horizontal visibility below 1000m. In recent years, especially in the springs of 2000, 2001 and 2002, dust storm attacked the Northwest of China more frequently than other years of the 1990's. The phenomenon has attracted much attention from many directions.

Inner Mongolia Autonomous Region is located in the north part of China with areas of 1.183 million sq. km in total. The central-west region of I.M. (CW-I.M.), 36-46N, 96-118E, belongs to arid and semiarid areas of Central-East Asia. Less than 300 mm annual precipitation on average and most of them fall in summer-autumn seasons, which accounting for 90.4% of the yearly rainfall [1]. There are 6 deserts or sandy-lands from west to east in CW-I.M, where, less vegetables growing and own abundance sand and dust materials. Therefore, it is one of the main dust storm source regions in China.

Dust storm occurs not only in the modern time, but also in the ancient time. The earliest dust storm was recorded in a book named_Nature History_(in Chinese) written by Zhang Hua during the 16th century BC. He did some descriptions about gusty wind and dust storm phenomenon. According to the result of Huang Zhaohua's statistics from some Chinese historical materials, there were totally 53 records described dust storms from the 3rd to 19th century [2]. Some of them happened in Inner Mongolia (Table 1).

Since there were many ancient wars and other reasons, generally, the descriptions of dust storm in Chinese historical materials are very simple and incomplete. Rarity records describe the situation of dust storm disasters. But in any way, the records still can give us much message about ancient dust storms. On the other hand, people shouldn't deduce a result as dust storm occurred infrequently in ancient time from the historical records. For the ancient, they had no any definition of dust storms, only tremendous and disastrous dust storms could be written into historical books generally. For instance, a record in a book of A.D. 488 described a 6-day dust storm took place in the central areas of I.M. and the north part of Shanxi Province made the sky with dust fog and smothered everywhere, according to the record, it was very difficult for brothering.

Table 1. Ancient dust storms occurred in Inner Mongolia

Time	Region
5th century	Central region of I.M.

9th century	Wushen and Hangjin County of CW-I.M.
13th century	I.M.
14th century	Ih Ju League and Ulanqab League of I.M.
15th century	I.M.
16th century	Ih Ju League of I.M.
17th century	Ih Ju League of I.M.
19th century	Ulanqab League of I.M.

Since 1949, after the establishment of the People's Republic of China, many observatories and meteorological stations have been set up in China. Up to now, it has 2,700 sites for meteorological observation, and 118 of them are situated in I.M. Along with the improvement of instruments and observing conditions, the meteorological records have become more detail and more precise than any other historical times. The dust storms occurred in I.M. in the last four decades (1961-2000) was counted following the Criterion of Sandstorm[3] and the definition of dust storm intensity of I.M.[4]. The dust storm frequencies in tow intensity degrees are listed in Table 2, where strong dust storm means its influence radium is more than 60 km and a very strong dust storm (Black Storm) affects more than 100 km in radium.

Table 2. Dust storm frequency of I.M. in the last 4 decades

Time	Frequency (day)			
	Strong events	%	Very strong events	%
1960's	186	38.7	64	34.2
1970's	154	32.0	73	39.0
1980's	95	19.8	31	16.6
1990's	46	9.5	19	10.2

According to our previous counting, spring (from March to May) is a dust storm frequent happening season in modern time. 4.5 events on average per spring, accounting for 85.4% of the annual frequency. This season is about the same to the ancient dust storm frequent occurrence season.

Figure 1 indicates the distribution of spring dust storm frequency of CW-I.M. It shows that the north part of the west League, Alxa is the most dust storm frequent occurrence areas, which is the first one of sand-dust source region in I.M. Another one is the Hunshdak sand-lands located in southwest region of Xilin Gol League.

Surface sand-dust is the essential material for dust storm formation. Some places in I.M. have become deserts, wield lands or deteriorated grasslands impacted by the climate change and unreasonable human activities synthetically. Dust storm and desertification process interact each other and get into a vicious circle. On the one hand, frequently occurred dust storms speed up the process of desertification. On the other hand, the deteriorated grasslands and deserted surface soil, in turn, provides plentiful sand-dust to dust storms.

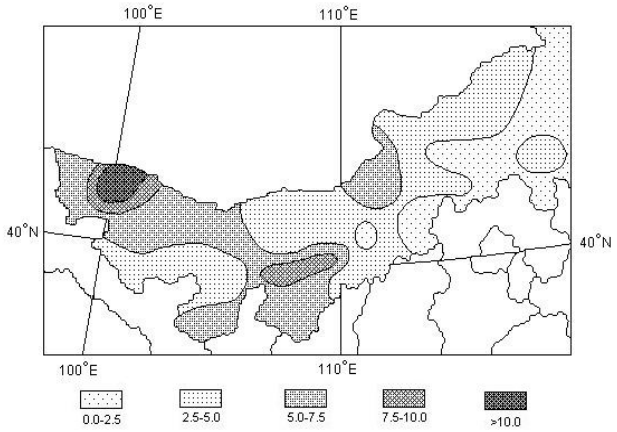

Figure1. Spatial distribution of spring dust storm frequency in CW-I.M. (day)

The climate change is one major influence factor on surface environment of the dust storm source regions in I.M. Varying of precipitation, rising temperature, increasing of evaporation and the frequently serious drought, all of these impact on the ground. As a result, water source become wither, and desertification areas extend continuously (Table 3). From 1956 to 1969, I.M. had 43,860-million m^3 water source in total. But during the following 20 years (1970-1989), the mean figure declined to 32,520 million m^3 with yearly 11,340 million m^3 in decrease. Moreover, the climate change makes the size of some lakes become small and small, or even dried up in some places. For example, the Juyan Lake in the north part of Alxa League, originally divided into two parts in last several decades called East and West Juyan Lake. It had totally 75 sq. km of water surface in the 1950's with 1,000-million m^3 annual runoff poured into the lakes. But during the 1960's, the runoff of the river yearly decreased 300 million m^3 on average. Furthermore, the river dried up from April to October each year in the next decade. After that, the East Juyan Lake dried out in the 1980's, and the area of the West Juyan Lake became smaller not more than 40 sq. km. Later, in 1993, the West Juyan Lake dried up, too [5]. In addition, the wind erosion is another important factor. So far, it has about 744,000 sq. km soil eroded by wind in I.M., accounting for 64.6% to the total of cultivated area, 20% of the areas is seriously deserted [6].

Table 3. Deserted areas of two dust storm source regions in I.M. (ha)

Region	1960's	1970's	1980's	1990's
Whole region of I.M.			30,433,066	31,352,001
Alxa League	7,597,000	8,456,000		12,887,004
Hunshdak Sand-lands	_	2,658,700	_	3,069,087

Besides nature factors, the impacts of unreasonable human activities should not be neglected. Human behaviors have made the sand-dust source areas expanded seriously. Table 4 lists the variations of grasslands and deteriorated grasslands in the two sand-dust source areas for the last twenty years. It can be learnt from the figures that the area of grasslands has become smaller and the deteriorated areas has expanded.

Dust storm affects on people's life tremendously as it threaten the safety of transportation, pollute the atmosphere, impact agriculture and livestock husbandry, destroy power, irrigation, communication systems and damage buildings. Sometimes, even can kill people or animus.

Table 4. The areas of grasslands and Deteriorated grasslands in the two source regions (ha)

Time	Alxa League		Hunskdak Sand-lands	
	Total area of grasslands	Deteriorated area	Total area of grasslands	Deteriorated area
1980's	17,534,933	1,561,267	2,054,400	971,133

1990's	16,665,133	3,651,933	1,995,400	1,925,133

To confront the serious situation of desertification and frequently occurrence of dust storms, Chinese Government pay much attention to the issue. Huge sum of money has been invited in order to improve the surface environment, control or decrease the speed of desertification process, restore the ecosystem. Also, the Government has taken some sufficient measures and good policies for environmental recovery and protection. Following the nature law to adjust the distribution of water using over the whole region, to return the open up lands for forest and grass, emigration people to some suitable living places from the vulnerable ecological regions. Under the leading of the Chinese Central Government, some plans and policies for ecological system recovery have been taking into actions by Inner Mongolia Local government. There is a hope that the local surface environment might be recovered during the next 10-20 years or even in longer time.

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References

[1] Gao Tao, Su Lijuan, Li Haiying et al. Climate analyses on increasing dust storm frequency in the springs of 2000 and 2001 in Inner Mongolia. *J. International Journal of Climatology*, Vol. 23, Issue 14, pp1743-1755 (2003).

[2] Huang Zhaohua. The wind and sandstorm occurred in Northwest China during the history (in Chinese). In *Sandstorm Study in China*, Fang Zongyi et al (eds). China Meteorological Press, pp31-36, Beijing (1997).

[3] Xu qiyun, Hu jingsong. The analyses on temporal and spatial distribution features of dust storm in Northwest China (in Chinese). In *Sandstorm Study in China*, Fang Zongyi et al (eds). China Meteorological Press, pp11-15, Beijing (1997).

[4] Gao Tao, Yu Xiao and Ma Qingxia et al. Climatology and trends of the temporal and spatial distribution of sandstorms in Inner Mongolia. *J. Water, Air & Soil pollution*: Focus 3(2), pp51-66 (2003).

[5] Xiao Shengchun and Xiao Honglang. Influencing factors of oasis evolution in Heihe River Basin. *J. China Desert Research,* Vol.23, No. 4, pp385-390 (2003).

[6] Bai Meilan, Pei Hao, Shen Jianguo et al. Assessment of climate change impact on desertification (in Chinese). *J. Climatic and Environmental Research*, Vol. 7, No. 4, pp457-464 (2002).

First author's biographical sketch

Gao Tao, female, graduated from Math Dept. of Inner Mongolia University in 1983. Have been working on meteorology and computer applications more than 20 years. Got engineer title in 1991, senior engineer, in 1996, professor title in 2003. More than 40 papers have been published, 3 of them were issued in abroad. Now, being the office chief of Weather and Environmental Research Division of Inner Mongolia Meteorological Institute. Invited as a visiting professor of the State Key Laboratory of Atmospheric Boundary Layer Physics and Atmospheric Chemistry, Institute of Atmospheric Physics, Chinese Academy of Sciences since Jan. 2004. Studied in the Institute of Meteorological and Physics, Agricultural and Science University of Vienna, Austria as a visiting scholar financed by the China Scholarship Council within Oct. 1998-Oct. 1999.