Wind Erosion Processes during Dust Storm in Dunhuang, China

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Abstract: In order to clarify the process of dust outbreak and the relationship between ground surface condition, such as surface soil water content, temperature, vegetation cover etc, and dust outbreak, two automatic observation stations have settled in Dunhuang, China where is one of the main regions of dust storm occurring and passing. Analysis the obtained data during March 23 to May 18 shows that wind erosion occurs during dust storms occurring or passing in Dunhuang. These dust storms are probably generated by cold frontal systems with dry squall lines. Dust concentration Index in the air (DCI) increases exponentially with wind speed or friction velocity when strong wind blown (wind speed at 10m is over about 6m/s or friction velocity is over about 0.2m/s). Wind erosion processes can be divided into 4 stages as (1) pre-erosion; (2) outbreak; (3) passing and (4) calming down stages.
Keywords: automatic observation station, dust outbreak, dunhuang, wind erosion processes

1 Introduction

Dust generated by wind (aeolian dust) has great impacts on the agriculture and living activities in its original arid and semiarid area. Furthermore, aeolian dust influences directly or indirectly the atmospheric radiation balance and hence global climatic variations as the largest source of aerosols. Aeolian dust emission or wind erosion occurs when strong wind blow on a loosened ground surface where is devoid of vegetation and the soil water content is very limited. When wind erosion occurs, especially when dust storm occurs, dust particles will lift up into the atmosphere and may be transported to very long distance. For example, dust generated in Taklimakan Desert, China can be transported to Japan (usually called as Kosa) and even to the Pacific Ocean and North America (Merrill *et al*., 1989; Zhang, *et al*., 1997). There is a very long history in the research literature of studies of dramatic dust transport and deposition as reviewed by McTainsh (1999) and Shao (2001). Although there has been some works on the dust outbreak and emission (e.g. Gillette, 1977, Garratt, 1984, Gillette *et al*., 1997), there still some unknown features about the relationship between surface conditions and dust outbreak. To clarify the process of dust outbreak and the relationship between ground surface conditions, such as surface vegetation cover, soil water content, temperature, etc, and dust outbreak and to obtain basic data for applying it to dust outbreak model in the course of parameterization and verification, as a part of the Japan-China Cooperation Project on aeolian dust experiment on climate impact (ADEC), continuous field observation of dust concentration and meteorological elements on different surface such as sandy desert and agricultural field are planed. An automatic observation station has settled in March 2001 on a sandy desert in Dunhuang, China. Another automatic observation station has settled on an agricultural field in September 2001. This paper tries to show the wind erosion processes during dust event by using the observed data in the sandy desert station in Dunhuang, China, during March to May 2001.

2 Description of observation

2.1 Observation station and observation system

One automatic station has settled in a flat moveable sandy desert or Gobi with moveable sand area near the Mogao Grottoes 20km apart from Dunhuang Oasis. The ground surface are covered by small stones and sands. The stones have diameters of about 2mm—10mm. There is fine sand under the small stones. The details of the observation stations and observation system has introduced by Du *et al*. (2001, 2002). Campbell Scientific, Inc.'s weather systems are used in our observations. CR10X Measurement and Control Systems are used for all meteorological elements (wind, air temperature, humidity, pressure radiation, soil temperature and water content, heat flux etc.), except visibility. The station in desert is a 10m tower with 4 levels wind and air temperature and humidity observations at 1m, 2m, 4m and 10m and 2 levels (3 levels from September of 2001) of visibility observation.

2.2 Observation method

2.2.1 Sampling

By the CR10X control systems, all the elements (wind, temperature, humidity, radiation and pressure) above the ground is sampled every 10 second. Soil temperature and moisture (TDR) are sampled every 10 minutes. Sampling dada are averaged and recorded for 30 minutes intervals during ordinary observation period and sampling data are recorded during IOP period (Intensive Observation Period). Maximum and minimum of wind and their standard deviation within the recording 30 minutes intervals were also recorded. Fast sampling mode of the visibility sensor was used. In this mode the light beam is transmitted every 6 seconds and average data for 30 minutes was recorded.

2.2.2 Data analysis

Routine data are recorded as Excel files for 30 minutes intervals and IOP data are recorded for 10 seconds intervals. The Mira Visibility Sensor 3,544 has nominal calibration coefficients, which are the same for all 3,544 sensors. To convert the raw data reading (N) made by the Data logger 3660 to the corresponding engineering units, use the following general formula:

$$Visibility\ (\mathrm{m}) = A + BN + CN^2 + DN^3, \tag{1}$$

where the coefficients $A = -0.5517$, $B = 2.936$, $C = D = 0$.

However, this formula does not fit for dust because the sensor is designed to detect fog and haze. For example, the visual visibility data in the Dunhuang meteorological station recorded at 16:00 on April 28, 2001 was less than 50m, while formula 1 showed a visibility of 600m. Therefore, we assume that visibility is directly proportional to dust concentration. Thus, we define a Dust Concentration Index as

$$DCI = (a - N) / a, \tag{2}$$

where the coefficients a = 1,022, the maximum raw data reading. *DCI* will be between 0 (no heavy dust event) and 1 (the most heavy dust event as visibility = 0). Relationship between *DCI* and dust concentration and between DCI and visibility will be given in our further studies.

3 Resouls

There were 5 big dust events or dust storms were recorded during March 23 to May 18, according to the observation data (*DCI* was over 0.6) and there were about 23 times of dust outbreak (*DCI* changes from 0 to over 0.2 within one hour) were observed. Of the 23 times of dust outbreak or wind erosion event, there are 12 times that *DCI* increased very quickly with wind speed as shown in Figure 1. Figure 2 shows diurnal variations of several elements during a typical case of dust storm on April 28, 2001, including *DCI*, solar radiation, pressure, wind speed and direction, air temperature and humidity. As shown in Fig. 2, air pressure, wind speed and relative humidity were the lowest of the day before the dust storm passing the station on April 28. Cloud appeared (radiation decreased compared with that on April 29)

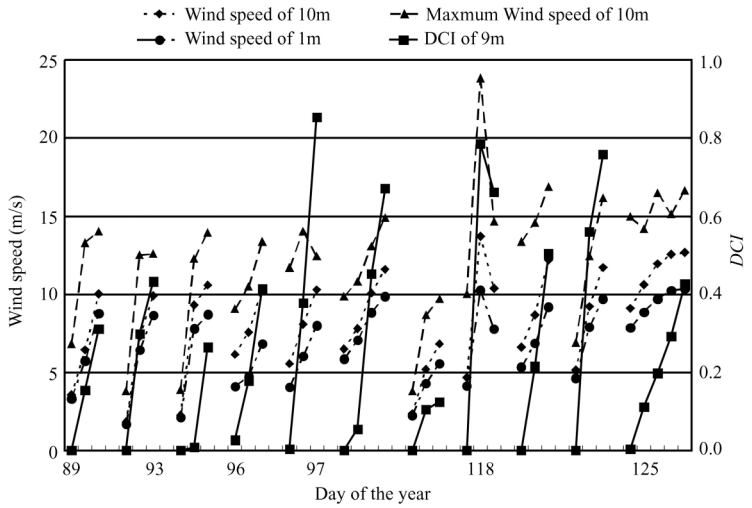

Fig. 1 Relation between the *DCI* and wind speed at 10m, 1m and maximum wind speed at 10m

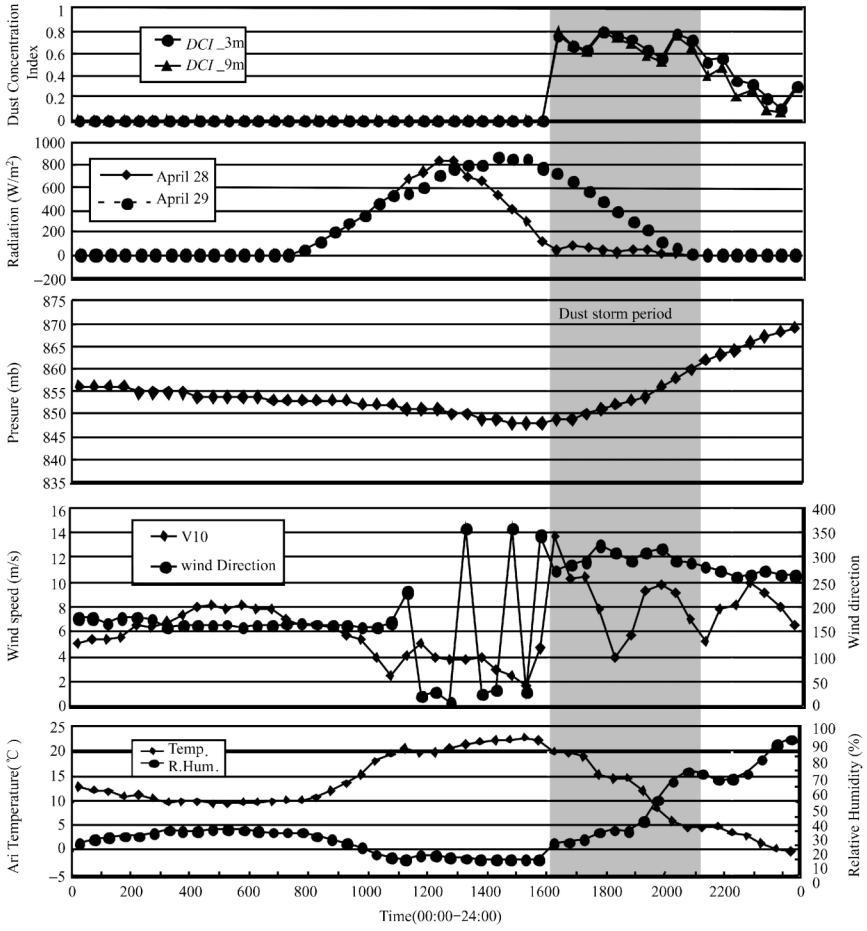

Fig. 2 Diurnal variations of several elements during a typical case of dust storm on April 28, 2001 in Dunhuang China

and wind direction changed several hours before dust storm. When dust storm passing the station, strong wind speed appeared and *DCI* at 9m became bigger than that at 3m. Air Pressure increased and temperature decreased with relative humidity increasing with time after the dust front passing. By

comparing the 5 times of dust storm, we find that most dust storms in spring in Dunhuang are probably generated by cold frontal systems with dry squall lines as proposed by Shao (2000) and Jakel (2001). The process of wind erosion or dust outbreak can be divided into 4 stages in Dunhuang, China as follows.

3.1 Pre- erosion stage

Pre-erosion stage lasts several hours before the dust storm comes. In this stage, wind speed becomes weak and weak. Wind speed is usually lower than 4m/s (sometimes below 1.0m/s) and wind direction changes (usually clockwise). Air pressure decreases to lowest value and there will be some cloud appears indicates that there will be a cold front coming.

3.2 Dust outbreak stage or wind erosion beginning stage

This stage only lasts about one hour occurred when cold front passing. As wind speed suddenly increasing, *DCI* increase very quickly. The most important features of this stage are the variation of roughness length and friction velocity and the dust concentration (*DCI*) at 9m is larger than that at 3m. Fig. 3 shows the relation between the DCI and wind speed at 10m and friction velocity during these 23 dust outbreak times. Dust concentration in the air (*DCI*) increases exponentially with wind speed or friction velocity when strong wind blown (wind speed at 10m is over about 6m/s or friction velocity is over about 0.2m/s). Due to saltation occurs in the sandy desert surface, wind profile and roughness length change with wind speed as shown in Fig. 4 and Fig. 5.

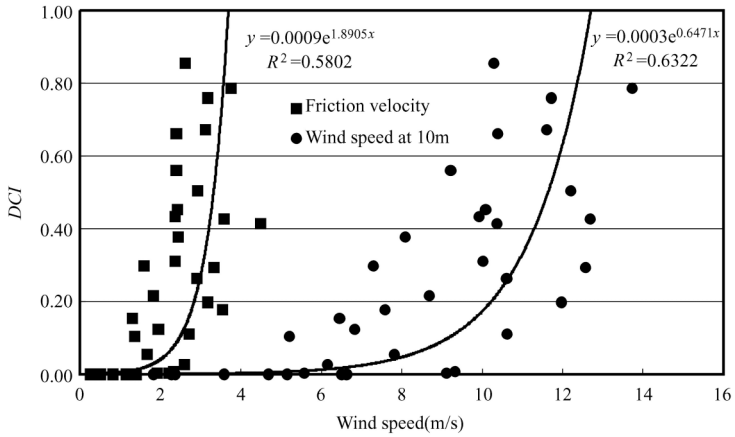

Fig. 3 Relations between *DCI* and wind speed and friction velocity during dust outbreak stage in Dunhuang, China

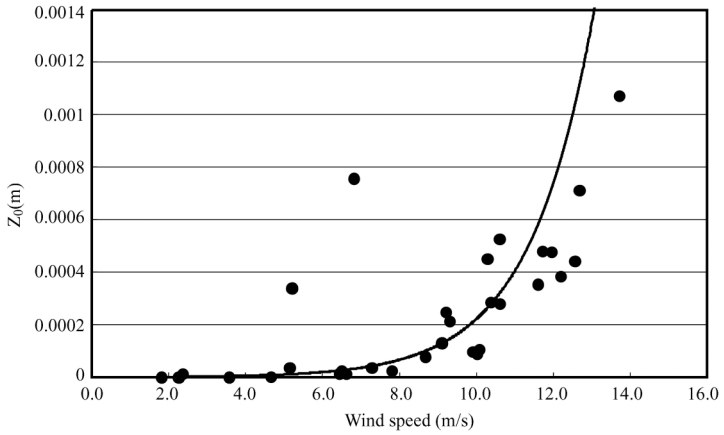

Fig. 4 Relations between wind speed and roughness during dust outbreak stage in Dunhuang, China

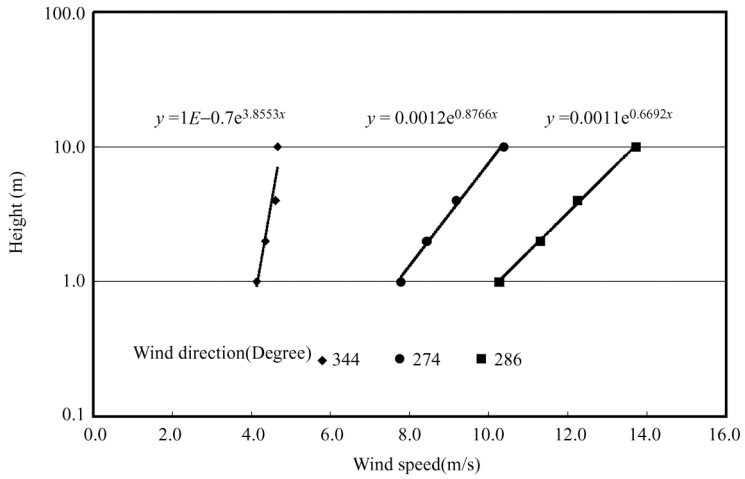

Fig. 5 Wind profile before and after wind erosion and saltation occurs on April 28, 2001 in Dunhuang China

3.3 Dust passing stage

Dust passing stage can last from one hour to over 10 hours. During this stage, air pressure, air temperature and soil temperature decrease and humidity increase with strong wind blows. Sometime wind speed may decrease or increase for several meters as shown in Fig. 2. *DCI* at 9m is lower than that at 3m.

3.4 Calm down stage

This stage lasts several hours too. *DCI* decrease as wind speed decrease. Sometime *DCI* decreased very quickly due to rainfall occurred. Usually air temperature and surface soil temperature will be about several degrees lower that that before the dust event as shown in Fig. 2.

4 Conclusions

(1) Wind erosion is often occurred by strong wind blown in Dunhuang. However, only strong wind could not be treated as a unique index of wind erosion or dust storm occurrence. Most dust storms in spring in Dunhuang are probably generated by cold frontal systems with dry squall lines. Dust outbreak occurred very frequently during March and April than that in May. This is mainly because the soil moisture was lower and ground surface was looser in March and April due to there are some rain in April. Conditions of ground surface (soil moisture, surface hardness) play very important roles on wind erosion or dust outbreak. Also, the distraction of soil under low temperature during winter season might play some roles on the surface conditions and thereafter on the wind erosion or dust outbreak.

(2) Dust emission or wind erosion processes during a dust storm event can be divided into 4 stage: ① pre-erosion stage with very weak wind and decreasing air pressure; ② dust outbreak stage with suddenly strong wind; ③ dust passing stage with strong wind and increasing air pressure and humidity and decreasing in temperature; ④ calming down stages with decreasing wind speed and sometime rainfall.

(3) Further observations and analyzing on dust concentrations and wind characteristics (such as roughness, threshold friction velocity, turbulence) are very important for the understanding of the relationship between ground surface conditions and dust outbreak in Dunhuang, China.

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