Changes of Long-wave and Short-wave Radiations at Ground Surface during Dust Storms at Dunhuang, China

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Abstract. Aerosols have a direct radioactive and forcing because they scatter and absorb solar and infrared radiation in the atmosphere. Mineral dust is a major contributor to aerosol loading and optical thickness. The characteristics of short-wave and long-wave radiation variations at ground surfaces during some dust storms were analyzed by intensive observations at two different environments: desert and oasis. When a dust storm occurs, the incoming short-wave radiation decreases and long-wave radiation increases. Increasing in long-wave radiation is greater in oasis than in desert indicating there is a warmer dust layer there.

Keywords: Dunhuang, Dust Storm, Observation, Radiation, Visibility.

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. Aerosols have a direct radioactive and forcing because they scatter and absorb solar and infrared radiation in the atmosphere. Mineral dust is a major contributor to aerosol loading and optical thickness. Aeolian dust emission 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 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. There is a very long history in the research literature of studies of dramatic dust transport and deposition as reviewed by McTainsh [1] and Shao [2]. In order 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 surfaces such as sandy desert and agricultural field were induced [3]. Two automatic observation stations have settled in Dunhuang, China. One of the stations was settled on a Gobi Desert in March 2001 and another has settled on a cropland inside the Dunhuang oasis in September 2001. This paper tries to show the characteristics of short-wave and long-wave radiation variations at the two ground surfaces during dust storms.
2. Study Area and Data

Figure 1 shows the location and topography of the observation sites. Station 1 has settled in a flat moveable sandy desert or Gobi Desert with moveable sand area near the Mogao Grottoes 20km apart from Dunhuang Oasis. Small stones and sands cover the ground surfaces. The stones have diameters of about 2-10mm. There is fine sand under the small stones. Station 2 has settled in an agriculture field in the central part of Dunhuang Oasis. This site is a cotton field during May to November and the other time is bare soil. Both sites located in very flat area as shown in Fig. 2. The flat area has a diameter of over 2km. However, the oasis site is inside of windbreak network. The grid of the network is about 200-500m * 200-500m. The station is settled in the center of a grid about 400m*400m.

![Figure 1. Location and topography of the observation sites.](image1)

![Figure 2. View of the experimental sites.](image2)
CR10X Measurement and Control Systems (Campbell Scientific, Inc.) are used for all meteorological elements (wind, air temperature, humidity, pressure, radiation, soil temperature and water content, heat flux etc.), except visibility. The energy balance between the incoming spectral short-wave and long-wave radiation, from 0.3 to 50 mm, relative to the surface reflected short-wave and outgoing long-wave radiation were measured by The CNR 1 Net Radiometer (Kipp & Zonen INC.). 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. The station in oasis is a 4m tower with 3 levels as shown in Fig. 2.

Dust concentrations were measured using an optical particle counter (OPC) (Yamatronics, Japan) and a visibility sensor, the MIRA Visibility Sensor 3544 (Aanderaa Instruments, Norway), which is designed to fulfill the demand for a small, low power (DC) unit to be operated with Aandera measuring stations. Due to the visibility sensor is designed to detect fog and haze, we define a Dust Concentration Index (DCI) for use it to detect dust as

\[ \text{DCI} = \frac{(a - N)}{a} \]  

Where the coefficients \(a = 1022\), the maximum raw data reading and \(N\) is the raw data reading. DCI will be between 0 (no heavy dust event) and 1 (the heaviest dust event as visibility = 0). Fast sampling mode of the visibility sensor was used. In this mode, the light beam is transmitted every 6 seconds and average data for 10 minutes was recorded.

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. One minutes sampling data are averaged and recorded for 10 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 10 minutes intervals were also recorded. The details of the observation stations and observation system has introduced by Du et al. [4]

3. Results

3.1. Dust Storm Process

Most dust storms in spring in Dunhuang are probably generated by cold frontal systems with dry squall lines. As shown in Fig. 3, air pressure, wind speed and relative humidity were the lowest of the day before the dust storm passing the station on April 28, 2001. Cloud appeared (radiation decreased compared with that on April 29) 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.

The process of a dust storm can be divided into 4 stages in Dunhuang, China as follows.

1) Pre-emit stage: Pre-emission stage lasts several hours before the dust storm comes. In this stage, wind speed becomes weak and weak (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.

2) Dust outbreak 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. 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.

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. 3. DCI at 9m is lower than that at 3m.
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. 3.

![Figure 3](image-url)

**Figure 3.** Diurnal variations of several elements during a typical case of dust storm on April 28, 2001 in Dunhuang China, including DCI, solar radiation, pressure, wind speed and direction, air temperature and humidity.

3.2. Variation of Radiation during Dust Storms

Figure 4 shows the diurnal variation of air temperature, DCI, short-wave radiation, albedo, long-wave radiation and net radiation at desert station for two cases of dust storm, May 5th and June 18th, 2002. Data of Pre-dust storm day and post-dust storm day were compared in the figure. Dust storm on May 5th, 2002 was very strong but lasted only about 20 (in oasis) to 40 minutes (in desert), while that occurred on June 18th, 2002 was a little bit weaker but lasted about several hours.

1) Short wave radiation:

Solar radiation decreased before dust storm comes as show in Fig. 3 and Fig.4 due to some clouds occur. When dust outbreak begins, solar radiation decreases greatly and even no solar radiation just like at night due to the dust layer cut off the sun shine (be scattered and absorbed). “You cannot find the person in front of you”, “you cannot see your own hands”, local people said for the dust storm in May 5th, 2002. Albedo increased about 0.02 which maybe the effect of scattering of direct solar radiation. When the dust storm calm down, short wave radiation will be recovered.

2) Long wave radiation:
Long wave radiation from the atmosphere (LWRA) increases slightly before dust storm comes as shown in Fig. 4. When dust layer comes, it increases more clearly. This maybe the dust layer has a higher temperature. Due to the decreasing in surface temperature after dust storm occurs, the long wave net radiation increases greatly. When dust storm calm down, LWRA is lower than that before dust storm due to decreasing in air temperature and this lower LWRA could last for several days.

3) Net radiation:
Variation of net radiation during a dust storm shows the same characteristics as short-wave radiation during day time and same characteristics as long wave radiation during night time, that is decrease during day time and increase during night time.

**Figure 4.** Diurnal variation of air temperature, DCI, short-wave radiation, albedo, long-wave radiation and net radiation for three cases of dust storm, May 5th (May 4-6, left) and June 18th (June 17-19, right), 2002.
3.3. Comparison of Radiation between Desert and Oasis

Figure 5 shows the comparison of diurnal variation of sort wave solar radiation, long wave radiation from the atmosphere and net long wave radiation between desert and oasis on June 18, 2002 in Dunhuang, China. Changing patterns of sort wave solar radiation and long wave radiation of both sites are almost the same. Although the DCI in oasis is lower in summer (in spring it is inversed), increasing in LWRA is greater in oasis than in desert indicating a warmer dust layer there.

![Graph showing comparison of radiation changes between desert and oasis during the dust storm on June 18th, 2002.](image)

Figure 5. Comparison of radiation changes between desert and oasis during the dust storm on June 18th, 2002.

4. Conclusions

It is observed that when a dust storm occurs the incoming short-wave radiation decreases and long-wave radiation increases. The incoming spectral short-wave radiation would even completely shutout when a very strong dust storm occurs. Dust emission processes by a dust storm can be divided into 4 stages as 1) pre-emission; 2) outbreak; 3) passing and 4) calming down stages. Sort wave radiation changes before dust storm comes and decreases greatly during the outbreak stage and passing stage. Long wave radiation increases before and during the dust storm. Long wave radiation from the atmosphere will be lower after dust storm calms down due to decreasing temperature. Increasing in long wave radiation is greater in oasis than in desert indicating there is a warmer dust layer there.

Future studies should contribute a further understanding of the role of dust emission in the relationship between dust concentration and radiation change and in the dust transportation process.

5. References

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