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Saltation Activity on Non-Dust Days in the Taklimakan Desert, China

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Abstract: Dust aerosols persistently affect nearly all landscapes worldwide, and the saltation activity caused by dusty weather (e.g., dust days) releases considerable amounts of aerosol into the atmosphere. Nevertheless, dust-induced saltation activity may also occur on non-dust days. To date, few studies have investigated the saltation activity characteristics on non-dust days. Moreover, the contribution of non-dust days to the total saltation activity remains ambiguous. This study comprehensively investigates the characteristics of saltation activity on non-dust days. Specifically, we analyze the influence of the saltation activity of non-dust days on dust aerosols by utilizing saltation, atmospheric, soil, dust aerosol (i.e., PM_{10} and aerosol optical depth), and weather record data obtained from the Taklimakan Desert, China, between 2008 and 2010. Our results show that lower temperature, vapor pressure, and soil moisture on non-dust days reduces the saltation threshold velocity (5.9 m/s) more compared to on dust days (6.5 m/s). Furthermore, regarding wind speed, relatively strong monthly saltation activity occurs from March to August, and daily saltation activity occurs from 9:00 to 16:00. Although non-dust days only contribute 18.5% and 7.7% to saltation time and saltation count, respectively, both significantly influence the dust aerosols. Therefore, the effect of saltation activity on non-dust days cannot be undervalued, particularly while performing dust aerosol studies.

Keywords: saltation activity; threshold velocity; dust aerosols; non-dust days; Taklimakan Desert

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1. Introduction

As a common occurrence in arid and semiarid areas globally, wind erosion is a critical component of the surface soil process. During this process, the sand particle size determines the differentiation of sand motion patterns with respect to creep, saltation, and suspension [1]. The saltation activity pattern drives the sand motion, accounting for about 3/4 of all aeolian sand [1–3]. It is the causal factor of soil erosion, desertification, sand burial (e.g., road, village, and cropland), and nutrient loss in soil [4–7]. Above all, saltation activity defines the critical mechanism of dust emissions [3,8–11]. Gillette [8] demonstrates that the dust emission amount is significantly connected to saltation flux. Gillette [9] also indicates that the impact of saltating sand easily disrupts interparticle bonds, and bombardment is the dominant mechanism responsible for eolian dust entrainment. Shao et al. [10] corroborate Gillette's findings [9], utilizing the tunnel experiment and the developed theoretical model of dust emission [3,12]. The three dust-emission mechanisms are aerodynamic lift, saltation bombardment, and disaggregation of soil aggregates—the latter two mechanisms are closely related to saltation, and the dust emission caused by them is two to three times greater than that caused by aerodynamic lift [3]. Recent research indicates that dust aerosols derived from saltation activity account for approximately 75% of the total dust emission flux [13], and the amount negatively correlates with the clay content during saltation [14]. The large volume of dust aerosols induced by dust emission are transported, suspended, or deposited into the atmosphere and can persistently affect several aspects of the global ecosystem, including the global and regional climate, ecological environment, human physical health, industrial production, and agricultural activities [6,15–19]. Therefore, saltation activity is one of the causal factors of global change.

Conventionally, sand samplers are the primary tools employed to measure the saltation activity in fields and wind tunnels, and the saltation flux of one dust storm or a specific period of observation time can be obtained using this equipment [1,20–22]. Nevertheless, the lack of automaticity severely limits their performance, and information on the temporal patterns of saltation activity may not be obtained. In the past few years, saltation sensors, which can be categorized as piezoelectric [23–29], acoustic [30–32], and optical sensors [33–38], have been deployed. The principal strengths and weaknesses among the three classes of saltation sensors have been comprehensively analyzed [38]. Specifically, the piezoelectric saltation sensor has a crystal, when exposed to sand particles; it can convert the impact force to electric pulses and assess particle counts [23,24]. Nevertheless, this sensor is incapable of measuring sand flux and, typically, is insensitive to sand particles less than 50 μm [25,27,29]. An acoustic saltation sensor can convert acoustical pressure to voltage signals, which requires the transport signals to be differentiated from the noise generated by the electronics and wind [30–32]. Laser saltation sensors are generally adopted because of their sensitivity and reasonable cost. However, the sensor lens can be easily contaminated by sand particles during dust storms, which dramatically reduces sensitivity [35,38]. Despite these limitations, they are adequate for the continuous monitoring of saltation activity.

In fieldwork, most saltation activity appears during dust storms [1,8,24,39]. Therefore, most research studies on saltation activity are conducted by observing representative dust storms [1,8,24,33,37,40]. The climatic characteristics of saltation activity were also evaluated based on long-term observations [41–44]. However, research on saltation activity from non-dust days is limited in comparison to dust days due to the limitations of monitoring resources and the shortage of observational dust weather data. Observational studies have shown that saltation activity can also occur on non-dust days due to gusts [43]. The climatic characteristics, contribution, and effect of saltation activity on dust aerosols during non-dust days have not yet been clearly comprehended, limiting our overall understanding of saltation activity.

The Taklimakan Desert is a significant source of blowing dust events (e.g., dust storm and blowing sand) in China, where blowing dust events typically occur more than 40 days per year over the entire desert [45]. This condition is favorable for thoroughly exploring saltation activity. We conducted observational experiments on saltation activity and dust weather in the Taklimakan Desert between March 2008 and February 2010. Based on an observational experiment design, this study aimed to investigate the characteristics of saltation activity, including atmospheric and soil conditions, threshold velocity of saltation activity, saltation time, and saltation count on non-dust days and to achieve an in-depth understanding of saltation activity on non-dust days in contrast to dust days.

2. Materials and Methods

2.1. Experimental Site and Data

The experimental site for this study is Tazhong, located at the core region of the Taklimakan Desert (Figure 1). The climate in this region is arid, with only marginal precipitation, as low as 25.9 mm per year, and a substantially high evaporation rate, exceeding 3600 mm per year. The surface is desertified, covered by drifting sand, mainly classified as fine and very fine sand, with a typical particle size of 147 μm [45]. This location has the ideal conditions for dust weather formation due to the rich sand abundance and arid climate. On average, Tazhong experiences 78.7 d of blowing dust events annually [45].

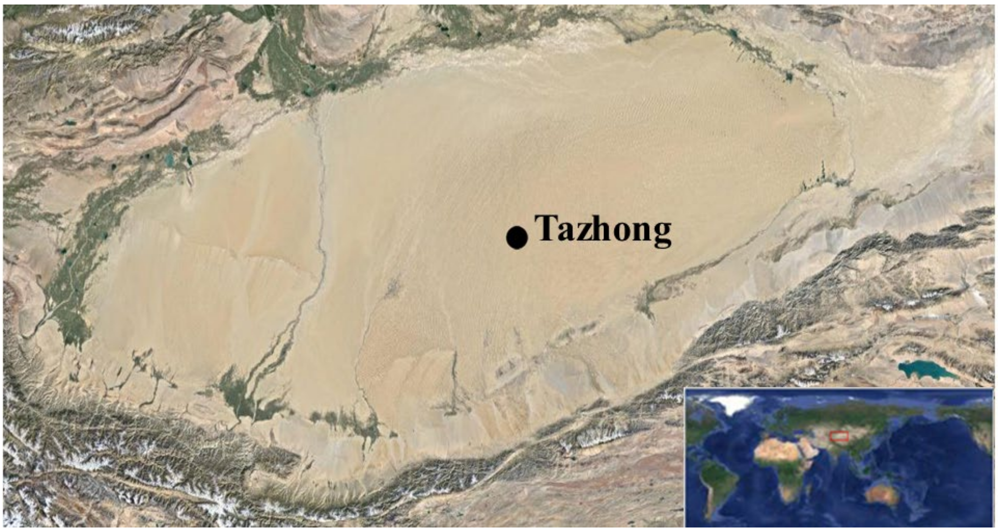

Figure 1. Location of the experimental site in the Taklimakan Desert.

Experiments were conducted over a two-year period on an area with the leveled ground between March 2008 and February 2010. During this experimental period, the wind speed, vapor pressure, air temperature, and soil moisture were collected using the 010C anemometer (Met One, Grants Pass, OR, USA, accuracy: ±1.0%), the HMP45D hygrometer (Vaisala, Vantaa, Finland, accuracy: temperature, ±0.3; relative humidity, ±2.0%), and the CS616 soil moisture gauge (Campbell Scientific, Logan, UT, USA, accuracy: 0.05%), respectively. All statistic variables were collected at the frequency of 1 Hz, and average values were calculated every minute and hour. Among these variables, wind speed, vapor pressure, and air temperature were gathered at a height of 2.0 m, and soil moisture was determined at a depth of 0.01–0.02 m underneath the surface (Figure 2). Saltation activities were measured at 0.05 m height using the H11LIN piezoelectric saltation sensor manufactured by Sensit, Valparaiso, IN, USA (Figure 2), and the sensor can respond to particles with grain sizes larger than 50 μm [46]. Previous research shows that, in over 95.0% of surface soil and aeolian sand samples at the height of 5 cm, the particle sizes were greater than 50 μm at the study site [47]. In addition, the saltation numbers and the quantity of horizontal dust flux collected by Big Spring Number Eight sand sampler per dust storm at 5 cm high had a high level of consistency. This analysis showed that an H11LIN piezoelectric saltation sensor could be deployed to measure the saltation activity at the study site. Saltation activity was measured at a frequency of 1 Hz, and average values were calculated within each minute and hour for consistency. The dust concentration was measured by a Grimm model 1.108 (GRIMM, Ainring, Germany, measurement range: 0.3–20 μm) at a height of 2.0 m and a measuring frequency of 6 s (Figure 2). Aerosol optical depth (AOD) data were obtained from the MODIS Level 2 AOD product at 0.55 μm, and the acquired daily AOD measurements were interpolated onto a rectangular grid with a spatial resolution of $0.1° \times 0.1°$.

According to the meteorological observing criterion from the China Meteorological Administration [48], dust weather can be categorized as floating dust, blowing sand, and dust storm. Floating dust is a weather phenomenon in which fine dust is suspended with lower or calmer wind levels, and horizontal visibility is less than 10,000 m. Blowing sand is a weather phenomenon in which a strong wind carries large amounts of dust and sand, where the horizontal visibility ranges from 1000 to 10,000 m. In contrast, a dust storm is characterized by large amounts of dust and sand being carried by a strong wind, where horizontal visibility is less than 1000 m. In the experimental field, the observation of dust weather was conducted each day by Tazhong Meteorological Station, initiating the recording of these data in 1997. This study adopted dust weather records from the Tazhong Meteorological Station from March 2008 to February 2010 to determine the dust and non-dust days. A day is defined as a dust day when at least one case of dust weather is recorded, regardless of its duration; otherwise, the day is defined as a non-dust day.

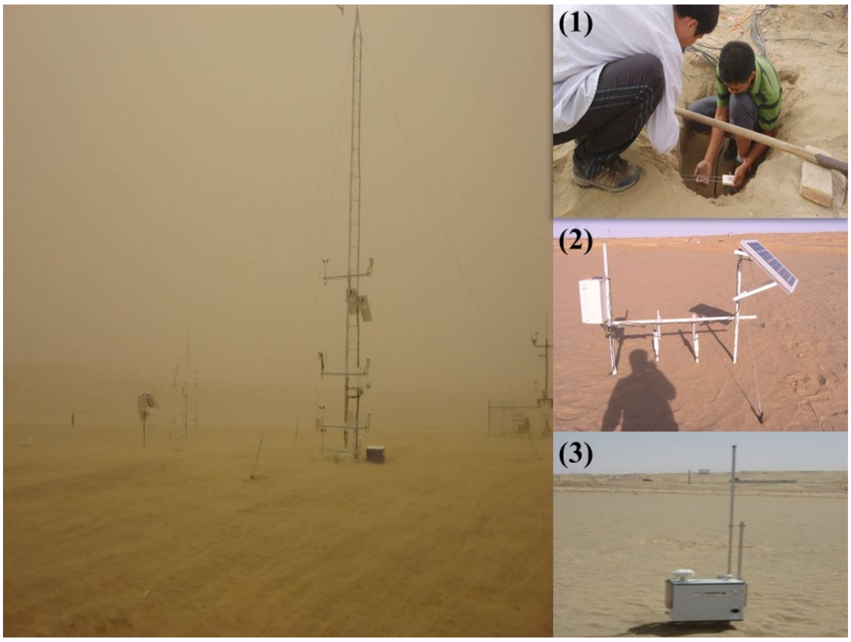

Figure 2. Overview of the entire experimental ground. (**1**) Soil moisture gauge. (**2**) Piezoelectric saltation sensor. (**3**) Grimm model 1.108.

2.2. Threshold Velocity for Saltation Activity

Established on the saltation data gauge, employing a piezoelectric saltation sensor (Sensit), Stout [49] presents the following formula to calculate the threshold velocity for saltation activity:

$$u_t = \overline{u} - \sigma \cdot \Phi^{-1}(\gamma) \tag{1}$$

where u_t, $\overline{u}$, σ, γ, and $\Phi^{-1}(\gamma)$ represent the threshold velocity, averaged wind speed within one minute, the standard deviation of wind speed per minute, the proportion of occurrence on saltation activity per minute, and the normal distribution inversion function as γ, respectively. This score has been successfully applied and verified by Tan et al. [39], Deoro and Buschiazzo [41], Barchyn and Hugenholtz [42], and Yang et al. [50] in independent field experiments.

3. Results

3.1. Daily Examples

This study established two daily serials, as experiment and control groups, with different weather on 4 August 2008, as non-dust day, and 5 August 2008, as dust day. Figure 3 shows temperature, vapor pressure, wind speeds, soil moisture, and saltation trends minutely on 4 and 5 August 2008. On 4 August 2008, saltation activity occurred for 302 s, with 10,803 counts, and the maximum minute saltation time and count were 54 s and 5235 counts, corresponding to temperature, vapor pressure, wind speeds, and soil moisture, ranging from 22.8 to 41.0 °C, 4.9 to 6.0 kPa, 0.9 to 6.5 m/s, and 0.019 to 0.021 m^3/m^3, respectively. On 5 August 2008, saltation activity occurred for 34,644 s, with 8,416,533 counts, and the maximum minute saltation time and count were 60 s and 25,837 counts, respectively, corresponding to temperature, vapor pressure, wind speeds, and soil moisture of 21.9 to 34.7 °C, 4.8 to 11.8 kPa, 1.0 to 13.8 m/s, and 0.020 to 0.023 m^3/m^3. In contrast with non-dust days, dust days had a lower temperature and higher vapor pressure, wind speed, and soil moisture at approximately the same time. The saltation intensity on non-dust was much lower than on dust days induced by different atmospheric and soil conditions [40–42,51,52]. The significant differences in saltation activities and atmospheric and soil conditions between dust and non-dust days indicate the importance of understanding saltation activity patterns on non-dust days.

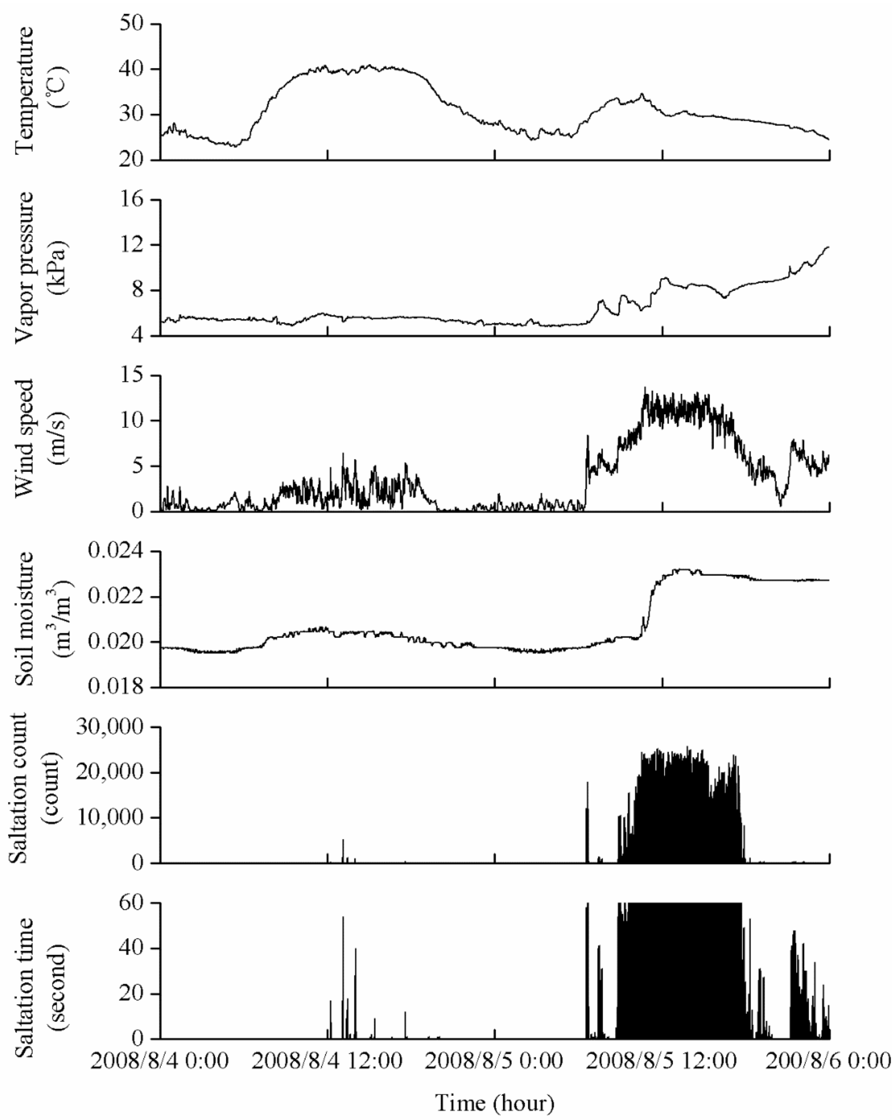

Figure 3. Saltation activities and atmospheric and soil conditions on dust (5 August 2008) and non-dust (4 August 2008) days.

3.2. Atmospheric and Soil Conditions on Non-Dust Days

The atmospheric and soil conditions were evidently different for the two weather conditions (Table 1 and Figure 4). On dust and non-dust days, the hourly temperature changed between −13.9 and 42.0 °C, −21.5 and 42.3 °C, with average values of 21.3 and 9.9 °C, respectively. As the temperature was lower than approximately 12.0 °C and higher than 40.0 °C, the relative frequency was higher on the non-dust day. In contrast, when the temperature was between 12.0 and 40.0 °C, the trend was reversed. There were 456 non-dust days in our experimental period. The proportions in the seasons were consistent with the pattern of winter (31.5%) > autumn (30.6%) > spring (19.2%) > summer (18.7%), respectively. Dust days were more prominent in spring and summer because of the atmospheric circulation and wind speed conditions [45,53]. Therefore, the greater number of non-dust days observed in colder seasons is consistent with the typically lower temperature of non-dust days. The hourly vapor pressure changed between 0.4 and 19.4 kPa and 0.3 and 18.2 kPa, with average values of 5.7 and 3.2 kPa, respectively, on dust and non-dust days. When the vapor pressure was lower than about 4.8 kPa, the relative frequency was higher on non-dust days than on dust days; when the vapor pressure was higher than about 4.8 kPa, this result was reversed. Dust weather in the study area primarily occurred in spring and summer, the seasons where most of the regional precipitation occurred; these seasons contributed 90.0% of the total rainfall, with vapor pressure increasing during this time [45,54]. In addition, as the weather system responsible for dust weather entered the desert, water vapor was carried with it, increasing air humidity [54], as corroborated by the results in Figure 3. Moreover, the hourly wind speeds changed between 0.0 and 12.8 m/s 0.0 and 10.0 m/s, with average 3.5 and 1.5 m/s values on dust and non-dust days, respectively. When the wind speed was lower than 2.2 m/s, the relative frequency was higher on the non-dust days than on dust days; when the wind speed was higher than about 2.2 m/s, the result was reversed. Hourly soil moisture changed between 0.002 and 0.218 m^3/m^3, and 0.002 and 0.197 m^3/m^3, with average values of 0.021 and 0.019 m^3/m^3 on dust and non-dust days, respectively. Due to the arid climate of the Taklimakan Desert, the ranges and average values of soil moisture on dust and non-dust days were comparable and at a lower level.

Table 1. Total saltation activity and atmospheric and soil conditions on dust and non-dust days from March 2008 to February 2010.

	Weather	Temperature (°C)	Vapor Pressure (kPa)	Wind Speed (m/s)	Soil Moisture (m^3/m^3)	Saltation Time (h)	Saltation Count (10^4)
08–09	Dust days	23.2	6.7	3.9	0.021	311.63	10,539.5
	Non-dust days	10.3	3.3	1.4	0.019	79.88	858.3
09–10	Dust days	19.4	4.7	3.1	0.020	270.61	6821.5
	Non-dust days	9.4	3.1	1.5	0.018	53.68	574.8

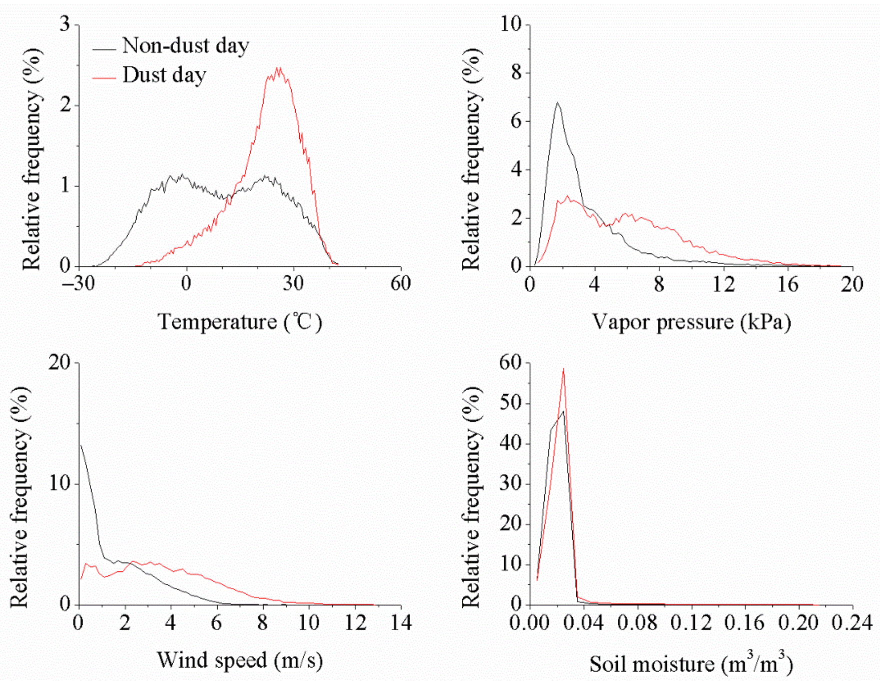

Figure 4. Relative distributions of temperature, wind speed, vapor pressure, and soil moisture on dust and non-dust days.

3.3. Threshold Velocity for Saltation Activity on Non-Dust Days

The threshold velocity is a determining parameter for saltation activity occurrence and reflects the atmospheric and soil conditions [1,3]. Figure 5 shows the frequency distributions of the threshold velocity on both dust and non-dust days. Within the entire study period, the threshold velocity for non-dust days varied between 4.1 and 10.5 m/s, with an average value of 5.9 m/s. Among all observations, approximately 30.0%, 60.0%, and 90.0% had values less than 5.4, 5.9, and 6.8 m/s, respectively. Moreover, approximately 95.0% of the values range from 4.8 to 7.3 m/s. In contrast, the dust days exhibited higher threshold velocities, with values varying from 4.1 to 12.2 m/s, averaging 6.5 m/s. On non-dust days, the threshold velocity exhibited significant monthly variations, varying from 5.3 to 6.4 m/s. The maximum and minimum were recorded in July and November, respectively. Gathering short-term observations at the northern margin of the Taklimakan Desert, Chen et al. [55] determined that the threshold velocity at a height of 2 m was 5.2 m/s lower than the average values for both the dust and non-dust days recorded in our study. This difference may be due to distinct methods for determining the threshold velocity and different observational periods.

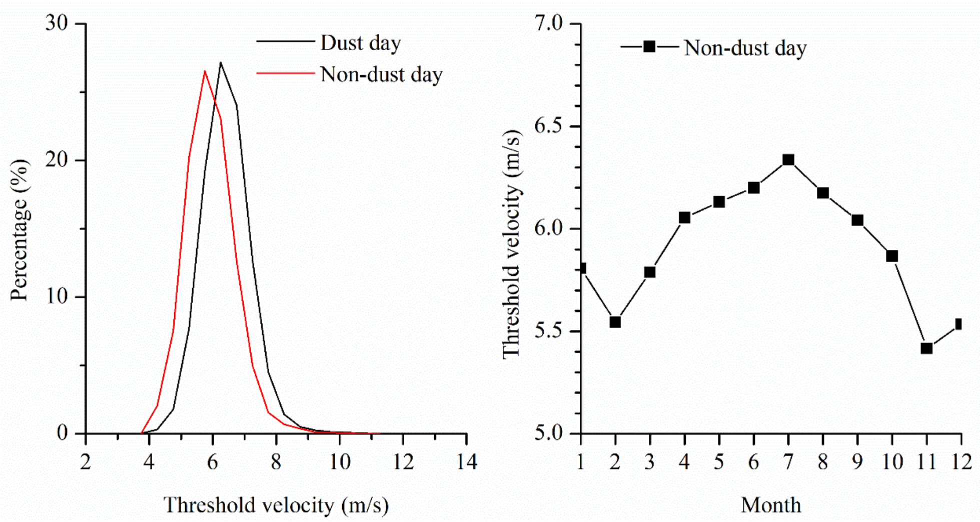

Figure 5. Frequency distributions of the threshold velocity on both dust and non-dust days (**left**) and monthly variations in the threshold velocity on non-dust days (**right**).

3.4. Saltation Time during Non-Dust Days

Considerable saltation differences were observed during the study period. From 2008 to 2009 and from 2009 to 2010, the saltation times were 79.88 and 53.68 h, respectively, accounting for 20.4% and 16.6% of the total annual saltation time, respectively (Table 1). Despite the fact that lower threshold velocities provided favorable conditions for saltation activity during non-dust days, low wind speeds inhibited the occurrence of saltation activity. On non-dust days, only 0.9% of all observed wind speeds were higher than the average threshold velocity (5.9 m/s), whereas on dust days, 8.1% of observed wind speeds were higher than the average threshold velocity (6.5 m/s).

Saltation times also revealed monthly and daily variations on non-dust days (Figure 6). Within the experiment, most saltation activities occurred from March to June and in August, accounting for 73.2% of the total saltation time, whereas saltation activity occurred less frequently in July and from September to February, accounting for only 26.8% of the total saltation time. The maximum and minimum saltation times occurred in August (19.2%) and January (0.4%). In terms of daily variation, saltation times longer than the average value mainly occurred from 9:00 to 16:00, accounting for 68.1% of the total saltation time. In contrast, saltation occurring from 17:00 to 8:00 accounted for only 32.9% of the total saltation time. The maximum and minimum saltation times occurred at 14:00 and 2:00, accounting for 10.8% and 0.1% of the total saltation time. Additionally, monthly and daily variations were observed between the dust and non-dust days. Monthly variations in the saltation time between March and August accounted for a higher proportion of dust days (91.8%), with the maximum and minimum saltation times occurring in July and November. Regarding the daily variations, intense saltation activity occurred over more prolonged periods on the dust days, occurring from 8:00 to 19:00, with the maximum and minimum values occurring at 13:00 and 23:00, respectively.

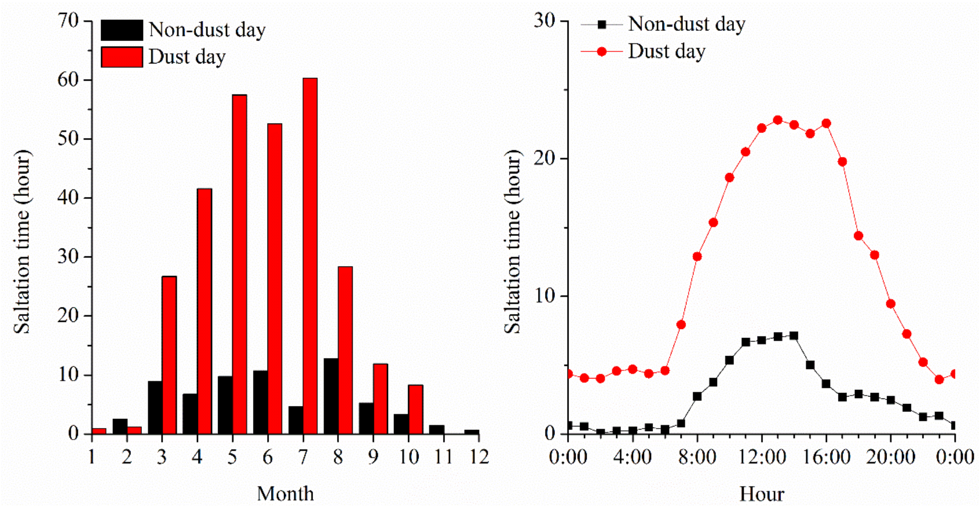

Figure 6. Monthly and diurnal variations in the saltation time on dust and non-dust days.

Figure 7 shows the relative distributions of hourly saltation time on dust and non-dust days. As demonstrated, values were significantly higher on non-dust days than dust days when the hourly saltation time was lower than 0.15 h. The result was reversed when the hourly saltation time was higher than 0.15 h. In the interval of 1.0 h, only 52.7% of saltation events lasted for less than 0.1 h on dust days, whereas the corresponding value for non-dust days was 81.3%. Furthermore, only 63.2% of the saltation events endured for less than 0.2 h on dust days, whereas for non-dust days, the proportion is as high as 92.4%. Only 2.4% of the saltation events lasted a sufficient amount of time—0.9 to 1.0 h on dust days—whereas for non-dust days, only 0.1% stayed for the sufficient period—0.9 to 1.0 h. These results suggest that most saltation events on non-dust days were intermittent and lasted less than 0.2 h.

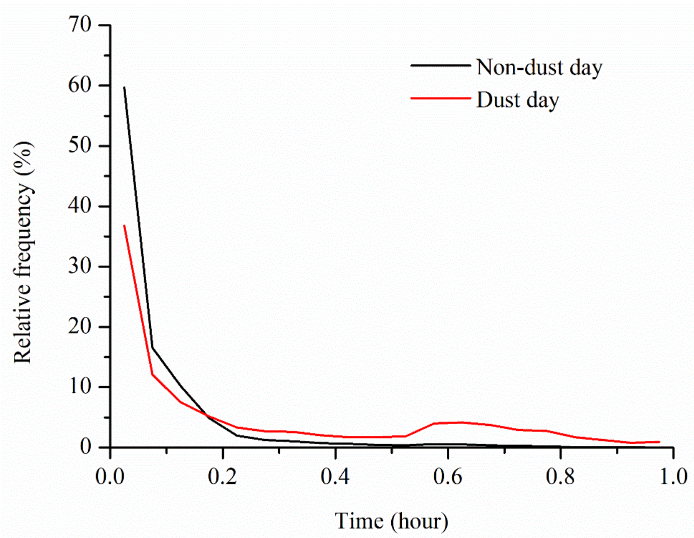

Figure 7. Relative distributions of hourly saltation time on dust and non-dust days.

3.5. Saltation Count on Non-Dust Days

The saltation count also depicted considerable annual variations on non-dust days. From 2008 to 2009 and from 2009 to 2010, the saltation counts were 858.3 $\times$ 10^4 and 574.8 $\times$ 10^4, respectively, accounting for 7.5% and 7.8% of the total annual saltation count, respectively (Table 1). Corresponding to the saltation time, the contribution of non-dust days to the saltation count was significantly lower. Previous research concluded that the amount of saltation is dominated by the wind speed and is proportional to the quadratic or cubic power of the wind speed [1,20,21].

Figure 8 shows the monthly and daily variations in the saltation counts on non-dust days from 2008 to 2010. Comparable to the saltation time, higher saltation counts occurred between March and August, whereas lower values were recorded between September and February. These two periods contribute 85.3% and 14.7% of the total saltation counts. The maximum and minimum saltation counts occurred in August (141.6 $\times$ 10^4) and January (0.37 $\times$ 10^4), corresponding to 19.8% and 0.05% of the total saltation counts, respectively. Concerning daily variations, high saltation counts (more extensive than the average value) mainly occurred from 10:00 to 16:00 and 19:00 to 21:00, accounting for 73.8% of the total counts. In contrast, low saltation counts occurred from 22:00 to 9:00 and 17:00 to 18:00, accounting for only 26.2%. Compared with the saltation time, high saltation counts frequently occurred and ceased later in the day, showing that the variations in the saltation time and counts were asynchronous. The maximum and minimum values of the saltation counts occurred at 14:00 and 2:00, accounting for 10.9% and 0.01% of the total saltation counts, respectively. Moreover, differences in terms of monthly and daily variations were observed between dust and non-dust days. For monthly variations, the maximum and minimum saltation counts on the dust days occurred in July and November, respectively. Conversely, concerning daily variations, intense saltation activity occurred over more extended periods on dust days between 10:00 and 20:00, with the maximum and minimum values occurring at 16:00 and 6:00.

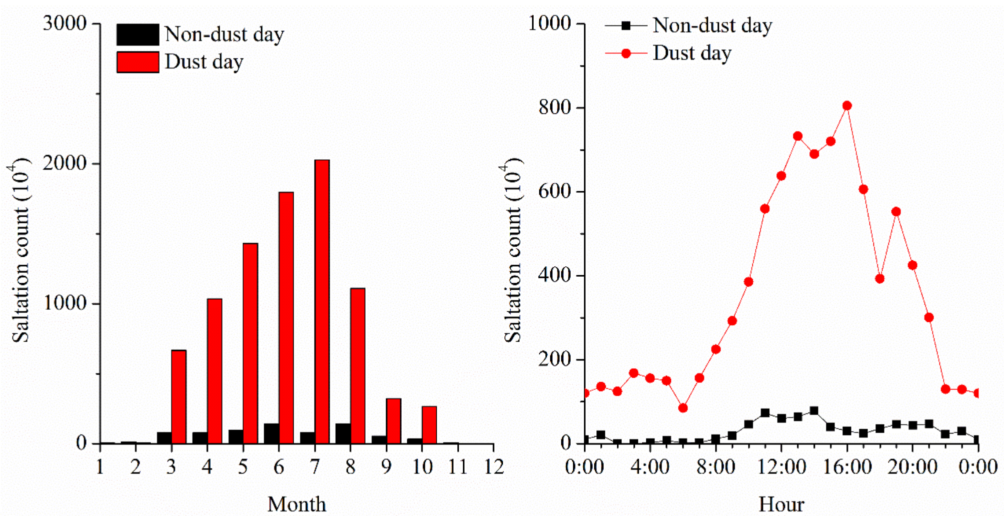

Figure 8. Monthly and diurnal variations in the saltation counts on dust and non-dust days.

Figure 9 illustrates the relative distributions of the hourly saltation counts for both dust and non-dust days. Comparable to saltation time, the values were significantly higher on non-dust days than on dust days when the hourly saltation count was lower than 1.5 $\times$ 10^4. The results reversed when the hourly saltation count was higher than 1.5 $\times$ 10^4. The maximum hourly saltation count for dust and non-dust days was 232.4 $\times$ 10^4 and 55.5 $\times$ 10^4, respectively, which is a 4.1-times difference. About 80.0% of the hourly saltation counts were lower than 0.39 $\times$ 10^4, and 90.0% were lower than 1.0 $\times$ 10^4 on non-dust days. The corresponding values for dust days were only 47.7% and 56.4%, respectively.

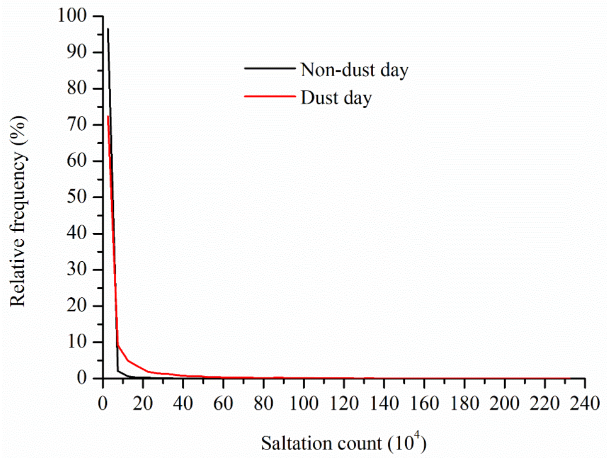

Figure 9. Relative distributions of hourly saltation count on both dust and non-dust days.

4. Discussions

4.1. Atmospheric/Soil Conditions and Threshold Velocities on Non-Dust Days

Correlations between the monthly threshold velocity and temperature, vapor pressure, and soil moisture are illustrated in Figure 10. When the temperature was above 0 °C, the temperature had a strong positive correlation with the threshold velocity (r = 0.93, $p < 0.05$). In contrast, when the temperature was lower than 0 °C, a negative correlation (r = 0.79, $p < 0.05$) was observed. Moreover, vapor pressure and threshold velocity positively correlated (r = 0.80, $p < 0.05$). However, soil moisture and threshold velocity only showed a marginal correlation (r = 0.16, $p > 0.05$), indicating that soil moisture is not a causal factor of the threshold velocity. Meanwhile, the threshold velocity is primarily determined by atmospheric and soil conditions [41,42,56–58]. A previous study showed that lower temperatures correspond to weaker cohesion between sand particles and a lower threshold velocity [56]; however, soil erodibility declines due to freezing when the temperature is below 0 °C, thus increasing the threshold velocity [42]. In addition, high air humidity and soil moisture can increase inter-particle cohesion, thus increasing the threshold velocity [41,42,56–58]. Li et al. [40] and Yang et al. [59] reveal that the effect of soil moisture on the threshold was substantial for a single dust storm and was otherwise marginal for the season or year in the Horqin Sandy Land and Taklimakan Desert due to the general shortage of soil moisture. Together, this explains the weak correlation between soil moisture and threshold velocity.

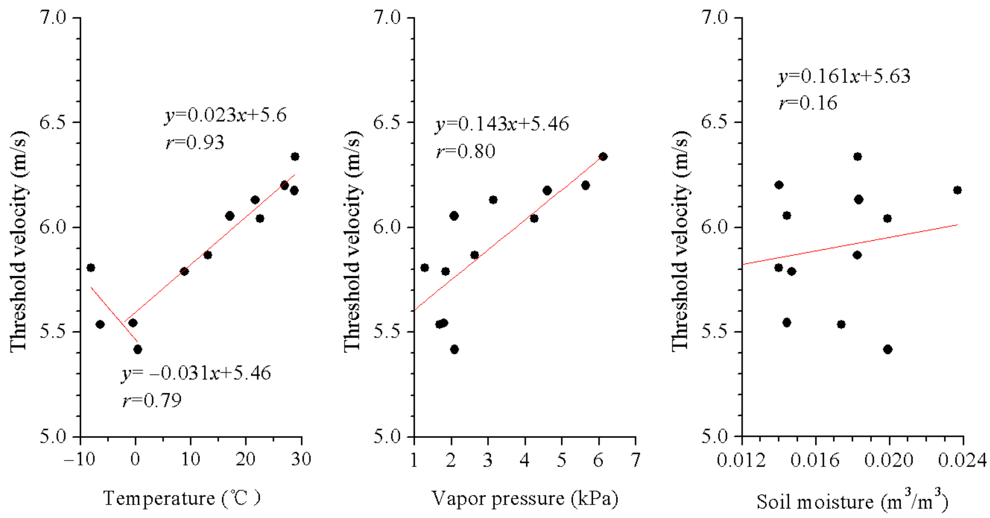

Figure 10. Correlations between monthly threshold velocity and temperature, vapor pressure, and soil moisture.

4.2. Wind Speed Conditions and Saltation Activity on Non-Dust Days

Although the non-dust days were primarily distributed in winter and autumn, and a higher threshold velocity was spread throughout spring and summer, relatively intense saltation activity was still present in spring and summer (Figures 6 and 8). Given the significance of wind speed on saltation activity [1,3,39,51,52], correlations between wind speeds (monthly and diurnal) and saltation activity (saltation time and count) were analyzed (Table 2). A strong linear correlation between them was determined, and the correlation coefficient between monthly wind speeds, saltation time, and saltation count were 0.81 and 0.91 at the 99% significance level; the correlation coefficients between diurnal wind speeds, saltation time, and saltation count were 0.94 and 0.74 at the 99% and 95% significance levels. This was the principal reason for the seasonal and diurnal distributions of saltation intensity on non-dust days.

Table 2. Correlation coefficients between wind speeds and saltation activity.

	Saltation Time (h)	**Saltation Count (10^4)**
Monthly wind speed (m/s)	0.81	0.91
Diurnal wind speed (m/s)	0.94	0.74

4.3. Saltation Activity and Dust Aerosols on Non-Dust Days

Previous studies have shown that saltation activity on dust days significantly influenced the amount of dust aerosol emitted [3,8–14]. The relations between saltation activity on non-dust days and dust aerosols were ambiguous; therefore, another the study is necessary. As dust aerosols originated from saltation, activity on dust days can float in the atmosphere for several days [3,60]. To rule out the influence of dust days which slow down dust aerosols, non-dust days were designated in November 2009 for this study. Synchronous daily saltation activity, PM_{10}, and AOD data from November 2009 were selected, and only the AOD for the rectangular grid in the study area was evaluated (Figure 11). During November, there were 16 d which had saltation activity, and the total saltation time and count were 0.6 h and 1.36×10^4, respectively. The daily PM_{10} and AOD changed from 30.9 to 1301.9 $\mu g/m^3$ and from 0.04 to 0.58, with average values of 160.4 $\mu g/m^3$ and 0.09. The maximum daily saltation count and time emerged on November 15; corresponding PM_{10} and AOD were also at the maximum. Daily saltation activity was associated with dust aerosols, with higher dust aerosol volumes accompanying saltation activities. The daily saltation count and saltation time positively correlated with PM_{10} and AOD, and the coefficients were 0.96, 0.91, 0.92, and 0.87, respectively, with 99% significance tests. Moreover, the correlation between saltation counts and dust aerosols was more substantial than that between saltation time and dust aerosols, suggesting that the amount of saltation significantly influenced dust aerosols.

The spatial distribution of average AOD between March 2008 and February 2010 on non-dust days over the Taklimakan Desert is shown in Figure 12. Relatively high levels of AOD enveloped the entire desert, and AOD values were more extensive than 0.2. Across the entire desert, relatively high values of AOD were distributed in the northwest and northeast regions instead of the central region, implying that there was more vigorous saltation activity on non-dust days. Although the Taklimakan Desert was surrounded by many dust sources (Figure 12), the transportation of dust aerosol was always blocked by the Tianshan Mountain, Pamirs, and Plateau, and only limited dust aerosols could be transported to the Taklimakan Desert from its north, west, and south edges [61]. This indicated that the dust aerosols floating above the Taklimakan Desert were mainly from the local region. Combined with the results shown in Figure 11, the additional results confirm the effects of saltation activities on dust aerosols on non-dust days. Thus, despite the saltation activity on non-dust days being weaker than that on dust days, its contribution to dust aerosols should not be overlooked.

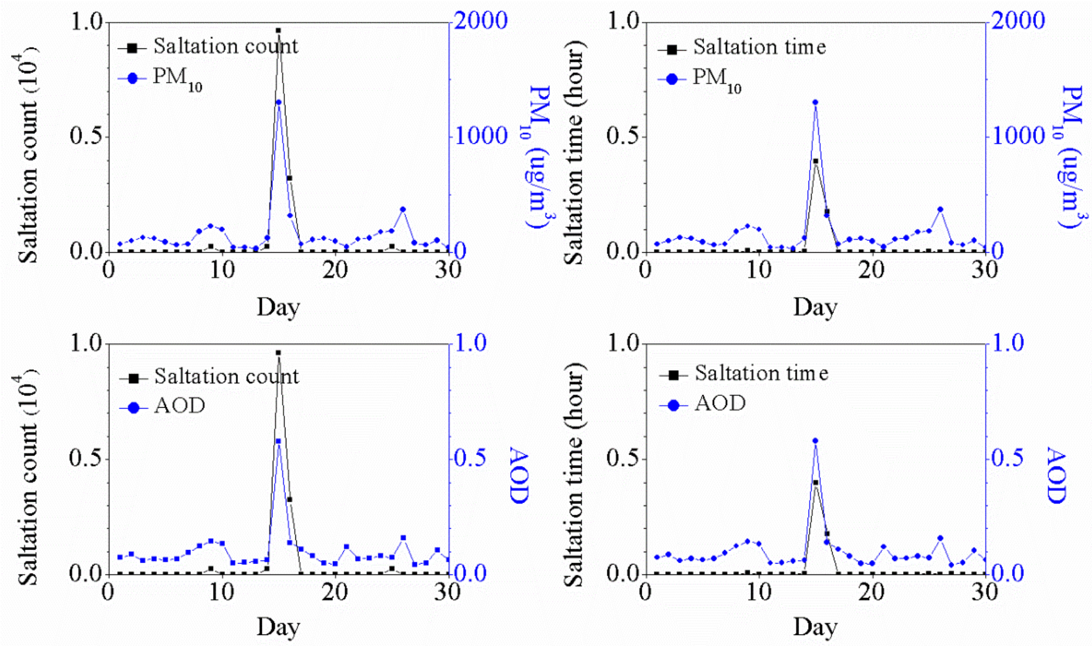

Figure 11. Daily saltation time, saltation count, PM_{10}, and AOD observations during November 2009.

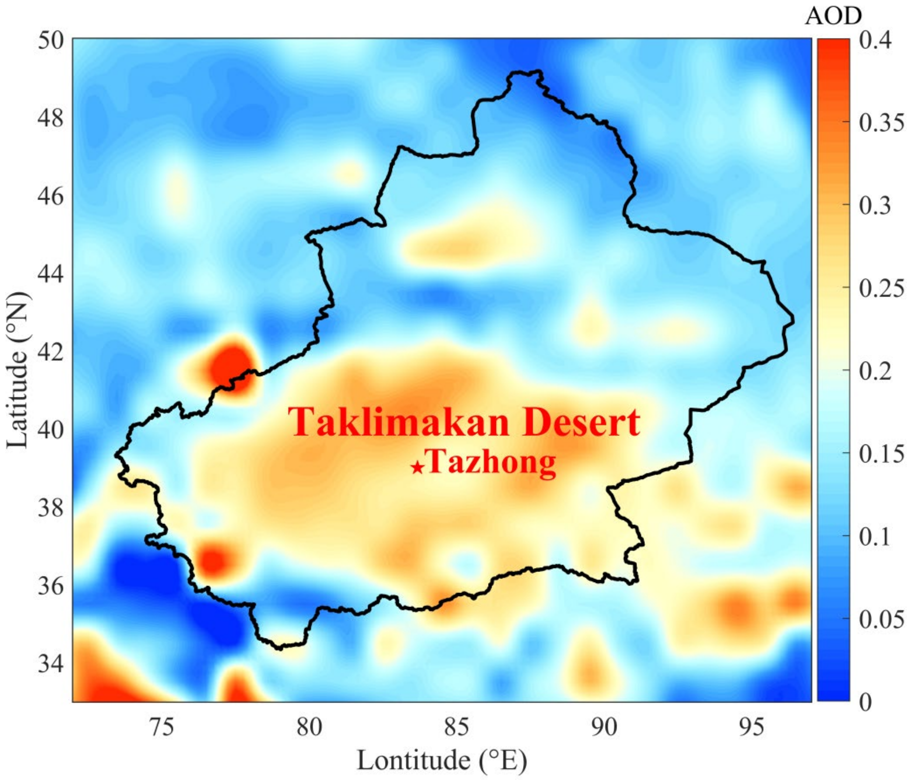

Figure 12. Spatial distribution of average AOD values between March 2008 and February 2010 on non-dust days over the Taklimakan Desert.

5. Conclusions

The saltation activity on non-dust days in the center of the Taklimakan Desert was comprehensively investigated utilizing long-term observation data of the saltation time and counts, atmospheric and soil conditions, dust aerosols, and dust weather from March 2008 to February 2010. Our study derives exciting results: compared with dust days, the characteristics of saltation activity on non-dust days had significant differences. For example, non-dust days had relatively lower temperature, vapor pressure, wind speeds, and soil moisture than dust days due to the differences in seasonal distribution and atmospheric circulation conditions. The favorable atmospheric and soil conditions on non-dust days reduced the saltation threshold velocity (5.9 m/s) more than on dust days (6.5 m/s). Nevertheless, the constraint of wind speed inhibited the saltation activity, the saltation density of non-dust days was remarkably lower than dust days, and the contributions of non-dust days to saltation time and saltation counts were 18.5% and 7.7%, respectively. Dominated by wind speed, relatively intense monthly saltation activity occurred from March to August, and daily saltation activity occurred from 9:00 to 16:00. Although the contribution of non-dust days to saltation time and saltation count was relatively lower than dust days, they had a remarkable influence on dust aerosols. Thus, we emphasize that non-dust day saltation effects on dust aerosols are significant and have been overlooked in previous research.

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