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SATELLITE INVESTIGATION OF DUST IN THE TARIM BASIN

XU XI-HUI

Рассматриваются особенности эволюции облачности, которая отражает формирование, движение и развитие погодных систем. Она может реально характеризоваться космическими снимками разных масштабов. Эти снимки можно использовать для записи и анализа погодных явлений, составления прогнозов, а также для научных исследований.

1. The characteristics of satellite images of the dust devil over the Taklamakan Desert

The normal approach for studying the dust devil over the Taklamakan Desert was based on the limited data from the surface observing stations in the margin area of the Desert because of free meteorological-data area within the Desert. It has caused more difficulties to study the dust devil over the Desert. However, this situation has been changed since first meteorological satellite was launched in 1960. By using the remote-sensing data of meteorological satellites, cloud systems, dust devil, rain trails and snow cover over the Desert can be monitored. Therefore, it is very useful for the study on the desert meteorology, especially dust devil, since the meteorological satellites can provide a plenty of data, i.e., satellite images and digital remote-sensing data over the Desert. The regions of the land surface with water-cover, rain-trails, and forest have the lowest albedo shows dark black on satellite visible images, while the regions with grass, crop and desert show dark gray or gray. The desert with dry climate shows gray or light gray since there is few vegetation. The cloud systems and snow cover of the mountain area have the largest albedo and show gray or white on visible images. The "dust plume", which is formed by fly ash, floating dust, and dust devil, shows gray or white which is similar to that of low-level clouds. Also, on false-color remote-sensing images composted three satellite channels (normally, channels 4, 2, 1), wind-driving dust is shown as light

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blue. But, fly ash, floating dust, and dust devil give distinct colors (i.e., dark or light color) which can be identified by using meteorological data on wind-driving dust observation at the meteorological stations around the desert.

The distinguish between low-level clouds and dust devil is that the former has clear boundary with a typical shape or fluctuating surface which is caused by a disturbance in atmosphere. The fly ash, floating dust, and dust devil show the fuzzy boundary and the homogenous plume which is distributed below the cloud systems so that they can be easily identified on the satellite images. The distribution of the "dust plume" is influenced by topography, and its margin is coincide with the basin border. In addition to the "dust plume", the form of the dust devil over the Taklamakan Desert could be "dust-storm belt" which is caused by the invasion of cold air, and "dust-storm circle" which is produced by a suction tube effect. The thickness, shape, area and movement direction of the dust devil are associated with the background atmospheric circulation, dominant wind, specific topography, and geographic environment. The following will focus on the primary analysis on the severe "dust-storm" weather. The satellite image data, the dust devil and wind data from the meteorological stations around the basin in the period of 1978-1987 were systematically investigated, and the remote-sensing images from the US TIROS-NOAA meteorological satellites in the period of 1991-1995 are monitored and analyzed. We choose 59 cases with significant characteristics of the dust devil in the Desert from the above-mentioned data, and analyze their occurrence time, intensity, weather situation and characteristics on the satellite images. The dominant characteristics of the dust-storms over the Taklamakan Desert is following.

2. The monthly and quarterly distributions of the occurrence frequency of the dust devil

(1) The dust devil weather over the Taklamakan Desert occurs most frequently in April and September which are transitional seasons in the Desert, with 13 and 10 times a year, respectively, which are 20 % and 16,9 % of total annual number.

(2) The occurrence frequency of the dust-devil over the Desert are 52,6 %, 22,1 %, and 22 % in spring (March, April and May), summer (June, July and August) and autumn (September, October and November) compared to the total number over a year, respectively (see Table 1). This indicates that the dust devil occurs in the seasons of the crop growth in the Tarim Basin, especially in spring. Obviously, this situation could cause severe threat to crop growth, exploration and exploitation of patrolmen in the Taklamakan Desert.

Table 1

Statistics of monthly and quarterly occurrence of dust devil over the Tarim Basin (1978-1987)

month\term	2	3	4	5	6	7	8	9	10	11	12	Total
occurrence time	1	9	13	9	6	4	3	10	2	1	1	59
monthly percentage	1,7	15,3	22	15,3	10,2	6,8	5,1	16,9	3,4	1,7	1,7	100

quarterly percentage (%)	Spring 52,6	Summer 22,1	Autumn 22,0	Total 96,7

3. Types, occurrence times and evolution characteristics of the dust devil

The types of the weather which causes the dust devil in the Tarim Basin can be summarized as follows:

(1) Type I: cold air sinking after crossing over the mountain;
(2) Type II: cold air pouring back from east;
(3) Type III: cold air invading from west;
(4) Type IV: combination of (1) and (2);
(5) Type V: suction tube effect.

The statistics of the examined 59 cases (see Table 2) indicate that there are 27 dust devils with cold air sinking after crossing over the mountain, which is 45,8 % in the total number.

Table 2

Statistics of occurrence frequency of various type dust devil over the Taklamakan Desert

term Dust devil type	wind direction	occurrence time	percentage (%)
sinking	northwest	8	13,6
east pouring back	northaest and east	27	45,8
west invading	west and southwest	11	18,6
sinking and pouring	northwest and around east	11	18,6
suction tube effect	northwest, southeast, and southwest in upper air	2	3,4
Total		59	100

It indicates that the dust devil was caused by cold air from west invading northern Xinjiang and then pouring back from east. The Tarim Basin is geographically surrounded by mountains, but is opened at the east side. The underlying surface of the Basin is primarily consisted of the Taklamakan Desert without vegetation and with high temperature and drought. In this case, the wind of 4-5 grade in the Beaufort wind scale can blow sand and dust in the Desert up into air. If this blowing spreads widely, a dust devil is produced. It should be noted that the dust devil with a suction tube effect is of the most severe damage although its occurrence frequency is the lowest (3,4 % in the total number).

(1) **Type** I: Cold air sinking after crossing over the mountain.

This type of dust devil is mainly produced by cold air from northwest near the Lake Brackish or by cold air sinking at the hill of the Tianshan Mountain after crossing over the mountain. The cold air makes a strong northwest wind which causes more strong sand-dust-blowing weather in the northwest and western parts of the Tarim Basin. The weather is often accompanied by a dust devil as a form of "dust-storm belt", affecting the whole Basin from north to south.

(2) **Type** II: cold air pouring back from east.

The weather conditions for producing dust devil Type II can be described by the following: the upper-air trough at 500 hPa, which may affect northern Xinjiang, moves east or southeast. It displays a vortex cold-front cloud system on satellite images. This system is developing as it moves east. After the end of the cloud system reaches the east part of the Basin, the cold air from north is poured into the Basin alone the east part. The east gale produces a dust devil weather affecting mainly the southern part of the Basin, from Ruqiang to Minfeng. When the cold air arrives at Hetian, the intensity of the east gale is declined, which is also accompanied by the dust devil weakening into the floating for a few days.

As shown in Table 3, a typical example of this type of dust devil occurred on May 1-2, 1981 is given. At 20:00 of May 1, a severe dust devil occurred and recorded at Quemu, Arnar Keping, and Bachu, accompanying by east gale with 4-5 grade in the Beaufort wind scale. The cold air pouring into the Basin from east was very strong, which caused a severe dust devil in the northern Basin. However, there was a floating dust weather in the southern and middle parts of the Basin because the influence of the cold air was a little weak in the remaining parts of the Basin. After the weather system was passing over the Basin, the area of about 34 km^2 in the Basin was filled with floating dust for six days.

(3) **Type** III: cold air invading from west.

This type of dust devil is produced by a short-wave trough cloud system in a shield form moving from west to east and passing over the Basin. The cloud system is normally the southern branch of the upper-air fronntal zone in spring. It can be observed from the satellite remote-sensing images that most parts of the Desert is covered by the homogenous blue color representing sand-dust plume.

Table 3

Sand-driving records at the meteorological stations at the border of the Tarim basin on May 1-2, 1981

time	Station name and weather phenomena			
	Quemo	Keping	Bachu	Arnar
20:00, 01/05	↑ (S→)	↑ S→	↑ S→	↑ S→
11:00, 02/05		↑ S→		

(4) **Type IV**: combination of cold air sinking after crossing over the mountain with pouring back from east.

This type of dust devil is more severe, and may cause more damage.

(i) Cold air pouring from east after crossing over the mountain.

The cold-frontal cloud system or the shield-form cloud system, locating normally on the south of the Basin, moves into the Basin after crossing over northern Tianshan Mountain. The accompanied northwest gale caused a dust devil weather in the western and northern parts of the Basin. When the cloud system moves southeast, it makes more cold air from north pouring into the Basin. Meanwhile, the northeast wind in the eastern Basin enters into the Basin, causing the dust-flowing weather in the northern Basin (see Table 4). The strong wind, floating sand, and dust devil phenomena occurred at the meteorological stations around the Basin: Shache → Pishan → Yutian → Minfeng → Tieganlike, and caused a severe damage.

Table 4

Sand-driving records at the meteorological stations at the border of the Tarim basin on May 10-13, 1981

date/time station	May 10 02:00	May 10 05:00	May 11 02:00	May 12 14:00	May 13 02:00	May13 11:00
Shache	↑ S→	↑ S→		＄	↑ S→	
Pishan	＄	S→				
Yutian			S→			
Minfeng			↑ S→			
Tieganlike						↑ ＄

(ii) Cold air in southwest weather system invading after crossing over the mountain and pouring back from east.

The north branch of the cold-frontal cloud system just moves out Xinjiang, the end of the cold-front causes the cold air to pour back from east into the Basin and produce sand-dust plume. At the same time, a belt of jet cloud system moves from southwest into the Basin, and brings west gale to produce a dust devil weather over the western part of the Desert. Also, the east-west wind shear makes more severe dust devil in Quemo and Ruqiang.

(iii) combined influence of the south and north weather systems.

The combination of the south and north weather systems makes more complicated wind direction, more intensified wind, and more severe dust devil over the Taklamakan Desert (see Table 5).

Table 5

Sand-driving records at the meteorological stations at the border of the Tarim basin on April 18-19, 1985

time	Ruqiang	Tiegalike	Keping	Kashi	Bachu	Shaze	Pishan	Hetian	Yutian	Minfeng
17:00, 18/4								S	S	S
20:00, 18/4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	S
02:00, 19/4										[illegible]

(5) **Type V**: suction tube effect.

This type of dust devil occurred twice in the Taklamakan Desert during 1978-1987, accounting for only 3,4 % in the total number of the dust devil. However, they were the most severe and made the most damage to industry, agriculture and human life as they passed over. They are called as "black wind".

For example, a very strong dust devil ("black wind") occurred in the Tarim Basin and the eastern Xinjiang from the late afternoon of May 18 to the early morning of May 20, 1986. The mean wind intensity over the whole Basin was 8-9 grade in the Beaufort wind scale, with the instantaneous wind speed 25 m/s. The visibility in the counties of Hetian, Moyu, and Luopu was close zero, and lasted 42 hours. The "black wind" caused a huge loss: 10 people and 4128 livestock died, 9 people lost, and the Lanzhou-Xinjiang rail seriously damaged.

The occurrence of the "black wind" was closely associated with the thermal low system which was developed over the Tarim Basin from the Wular low trough moving southeast. There was a strong wind shear over the

Basin, which produced a strong convergence in the low-level and a strong divergence in the upper-level. Adding the specific topography of the Tarim Basin, the weather system made very strong "suction tube effect" to produce the most severe dust devil. The suction tube effect was displayed as a "dust-storm circle" on the satellite images. The "dust-storm circle" was connected with the front of the jet cloud system, which was clearly seen on the satellite images.

The application of meteorological satellite remote-sensing data has provided a very useful tool to analyze dust devil over the desert. It is of significant for the present work to serve exploration and exploitation of patrolmen, agriculture development, and ecological environment protection in the Tarim Basin.

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Xinjiang Meteorological Bureau, Urumqi, 830002, China

ТАРИМА АЛҚАБЫНДАҒЫ ШАҢДЫ ДАУЫЛДЫ КОСМОС АРҚЫЛЫ ЗЕРТТЕУ

XU XI XUI

Ауа-райы жүйелерінің өркендеуі мен қозғалысын, қалыптасуын қамтып көрсеттетін бұлттың даму ерекшелігі арқылы қарастырылады. Ол әртүрлі масштабтағы космос суреттері арқылы анық байқалады. Ол суреттерді ауа-райын жазу және талдауда, және ғылыми зерттеулерде қолдануға болады.