A CASE STUDY: THE DIURNAL VARIATION OF THE DUST LAYER HEIGHT IN THE TAKLIMAKAN DESERT AFTER THE DUST STORMS IN APRIL 2002

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ABSTRACT

The depolarization lidar observation was performed to investigate the vertical distribution of dust particles over the northern part of the Taklimakan Desert in April 2002. Three dust storms were occurred during the observation period and the diurnal variations of the dust layer height (DLH) were observed clearly after the dust storms. The DLH is low and high in the daytime and the nighttime, respectively. The low DLH is influenced by the return flows of the valley winds along the Tienshan Mountains in the daytime because the observation site is located near the Teinshan Mountains. After the dust storms, the low DLH is more lowered and it is considered the influence of synoptic scale flows with local effect, high Tienshan Mountains. In this study, it is analyzed using the data of the lidar observation and the results of the numerical simulation.

1. INTRODUCTION

In the Taklimakan desert, East Asia, dust events are frequently observed in spring season [1] and are occasionally transported to east by westerlies. The dust has influence on human activation related to economics and human health directly by the low visibility and air pollution. It has influence indirectly on climate impact in the global scale by radiative forcing [2].

Then the Aeolian Dust Experiment on Climate Impact (ADEC) project, supported by Japan and China, was initiated to investigate the dust phenomena using GCM scale dust model [3]: how dust is generated and how much dust is transported into the atmospheric boundary layer (ABL) and is deposited at the surface. In this project, several observations were performed to understand the wind erosion process in the source region and to improve the model with respect to dust transport and its deposition to the surface.

In present study, the results of the lidar observation performed in ADEC project is reported to investigate the vertical distribution of dust particles over Aksu in the Taklimakan desert.

2. LIDAR OBSERVATION

2.1 Lidar system

The schematic diagram of the depolarization lidar system is shown in Fig. 1. The specifications of the lidar system used in this study are described briefly as follows [4]:

- The transmitter employs a Nd:YAG laser and operates at a 532nm wavelength, with the pulse energy of 300mJ, and a 10Hz repetition rate.
- The receiver utilizes two telescopes with diameters of 200nm and 350nm to obtain the superior data with the height. The smaller one is set up on the same axle with the transmitting laser light. To receive the backscattering signals above 1km, the larger one is set up parallel to the smaller one at the distance, 60cm.
- Five photomultiplier tubes are used to receive the parallel (P) and perpendicular (S) components of the signal detected from the two telescopes; the two tubes, P_{200} and S_{200}, in the smaller and the three tubes, considering the ratio of the signal strength of the two parallel channels, 9:1, $P_{350\text{-}90}$, $P_{350\text{-}10}$ and S_{350} in the larger.
- The signal from the telescopes is recorded every 5 minutes with a vertical resolution of 7.5m up to 75km.

In this study, the detected signals were treated to compute the valuable indexes in the analysis of aerosol characteristics; the aerosol optical thickness, the backscattering ratio and the depolarization ratio.

2.2 Observation at Aksu

The Taklimakan desert is one of the main source regions in Asian dust events [5] and is located at the Tarim Basin surrounded by the Tienshan Mountains to the north, the Pamir Plateau to the west and the Kunlun Mountains to the south (Fig. 2). These high mountain ranges affect not only the diurnal circulation within ABL but also the process of the dust generation and its concentration in the basin. Dust storms in the basin are occurred by the mesoscale cold wind system induced by a synoptic-scale cold air mass behind a cold front [6]. The intruding paths of cold air mass are altered by the height of the Tienshan Mountain and its strength is influenced by the mountain-valley winds. It is important to understand the role of the Tienshan Mountains in the study of dust events.

Therefore the lidar observation was carried out over Aksu (40.62°N, 80.83°E), satisfying the stated above,

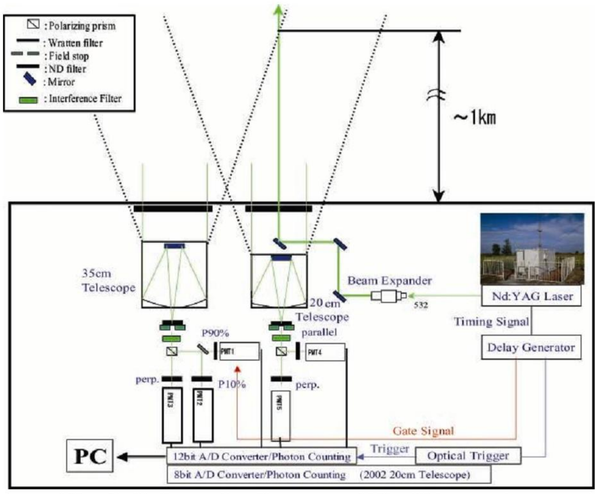


Fig. 1. Schematic diagram of the lidar system.

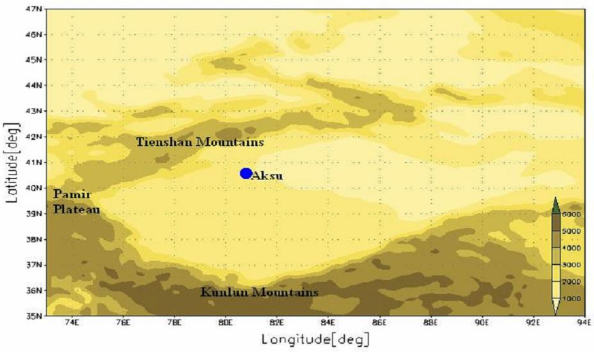


Fig. 2. Topography around the Taklimakan Desert.

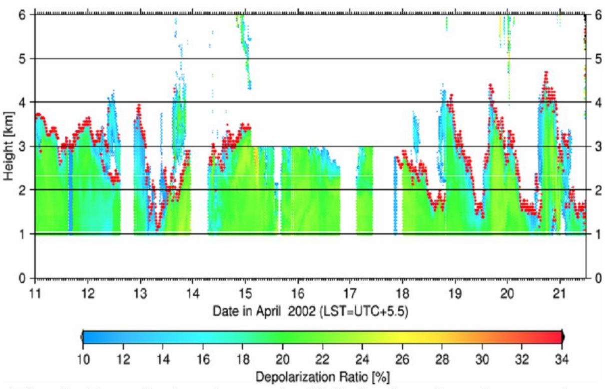


Fig. 3. Depolarization ratio [%] during the observation period in April 2002.

close to the Tienshan Mountains. The observation was performed from 11 to 21 April 2002.

2.3 Observation results

During the observation period, we could observe three dust storms and the vertical variation of the dust layer before and after the dust storms. The severe dust storms occurred in April 13, 15 and 21, 2002.

Fig. 3 shows the total depolarization ratio from 1km to 6km and the red dots indicate the DLHs. The DLHs are defined as the height with the 10% depolarization ratio. In this definition, the percentage was chosen as the value of the reference height where the depolarization ratio is fewer than 10% over Aksu in the troposphere in April 2004. We could not decide the DLH in case of the dense concentration of dust particles like during the dust storms and immediately after.

Before the dust storms (April 11), the DLH varied from 2.6km to 3.7km and the average of the DLHs is 3.5km. The DLH is lowered with the developing mixed layer and then the rebounded DLH after 1100LST remains unchanged till sunset. We can see that the DLH is slightly lower in the daytime than in the nighttime.

After the dust storms (April 18-19), the range of the DLHs (about 2.7km) is wide and the low DLH in the daytime is delayed in comparison with before the dust storms. For April 18, the DLH is lowered with the developing mixed layer from 1100LST. The mixed layer is started to develop from 0900LST with the increasing backscattering ratio at 187m (not shown). The low DLH (about 1.7km) is remained till 1900LST and then the DLH rises rapidly to 4km. For April 19, we can see the similar variation in the previous day. However the low DLH is more lowered and the duration time is shortening in the daytime.

3. THE DUST LYAER HIEGHT AFTER THE DUST STORMS: APRIL 18-19, 2002

In the results of the lidar observation, the diurnal variations of the DLH were shown more clearly after the dust storms than before. In this section, therefore, the numerical simulation and the isobaric weather charts by the NCEP/NCAR reanalysis data are applied to understand the meteorological condition affecting the diurnal variation of the DLH.

3.1 Numerical Simulation

The meteorological model used in this study is MM5, the fifth-generation mesoscale model of nonhydrostatic version 3 (Pennsylvania State University/National Center for Atmospheric Research), defined in the x, y, and σ-coordinate. The physics options of MM5 used in this study include the Grell convective parameterization that contains the parameterized shallow convective effects, an explicit moisture scheme that contains prognostic equations for cloud water and rainwater, the PBL scheme in the Medium-Range Forecast model that consists of an nonlocal K scheme [7] and a multi-layer soil model to predict land surface temperatures by using the surface energy budget equation [8]. National Centers for Environment Prediction/National Center for Atmospheric Research (NCEP/NCAR) 6-hourly reanalysis data are interpolated linearly into the outermost coarse-mesh lateral boundary conditions.

Three level of two-way nested domain is used with grid resolutions of 108km, 36km and 12km. The total of 30 sigma-levels in the vertical direction is used, with the model top at 100hPa. In this study, the meteorological fields are simulated from 1800UTC 16 to 0000UTC 21 April 2002, and the fields of 72 hours from 0000UTC 18 April 2002 are analyzed.

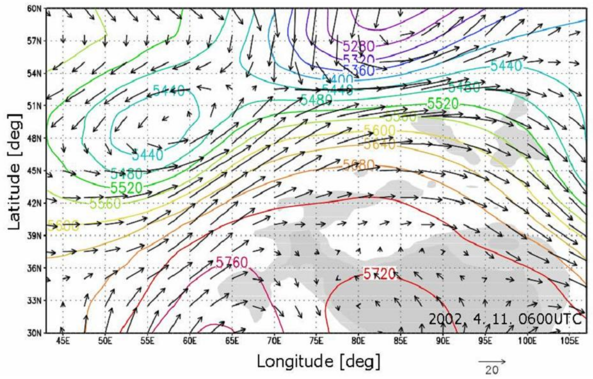
3.2 The diurnal variation of the dust layer height

Fig. 4 shows the 500hPa isobaric weather charts of NCEP/NCAR reanalysis data before and after the dust storms. Before the dust storms, the Tarim Basin undergoes influences of the 500hPa ridge over the Tibet Plateau and the weak westerly wind (Fig. 4(a)). After the dust storms, the 500hPa trough is located in the northwest of the basin and the westerly wind is relatively strong (Fig. 4(b)). These conditions are staying in 2 days after the dust storms and we can see that the synoptic winds have influence on the wide range variation of the DLH.

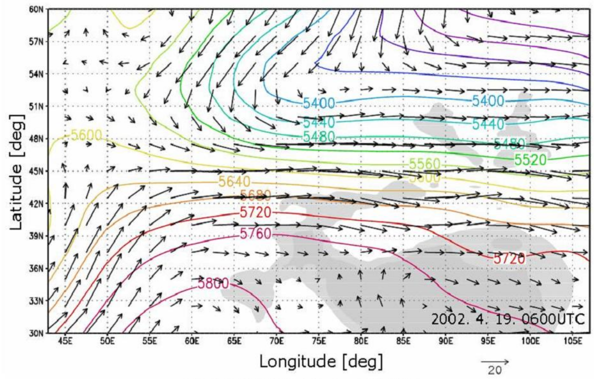
It is considered that the diurnal variation of the DLH is influenced by the mountain-valley winds due to the location of the observation site near the Tienshan Mountains. In case of before the dust storms, the winds over the Tarim Basin are clam generally and the valley winds along the Tienshan Mountains is generated slightly (not shown). However the westerly winds prevail over the basin by the synoptic scale flows and the valley wind blows to the slope after the dust storms. Therefore we can infer from the difference that the return flows are deeper into near surface and are maintained longer after the dust storms than before. It is regarded that the diurnal variation of the DLH is shown clearly after the dust storms. In order to investigate them, the results from the third domain of numerical simulation are used in this section.

Fig. 5(a) shows the valley winds over the northeast of Aksu at 1000LST 18 April 2002. The westerly winds in the west part of the basin get to weak and the wind near Aksu is calm. The valley winds blow to the slope of the Tienshan Mountains and their return flows blow over Aksu (Fig. 6(a)). It makes to hard to develop the mixed layer. The downward winds remain unchanged with the upper wind going across the Tienshan Mountains during the daytime. It corresponds to the DLH continued in the daytime till 1900LST.

Then the valley winds are weak on the slope of the mountains and the cold northerly winds from the Tienshan Mountains into the Tarim Basin from 1430LST. The wind direction from the mountains is changed to northeast by the wind from Kunlun Mountains influenced by the 500hPa ridge over the Tibet Plateau, and the northeasterly winds move to Aksu. The northeasterly winds meet with the westerly winds from the Pamir Plateau (Fig. 5(b)) and it is considered that the convergence leads the dust layer to

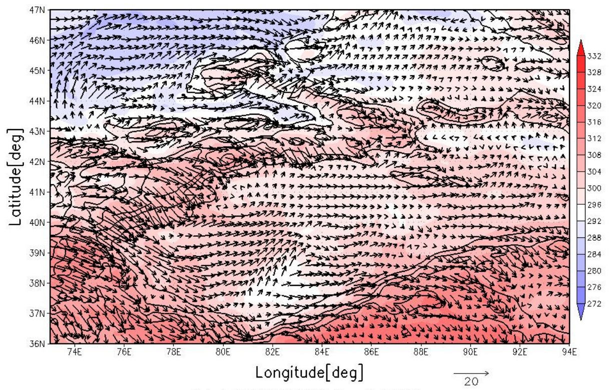


(a) 0600UTC 11 April 2002

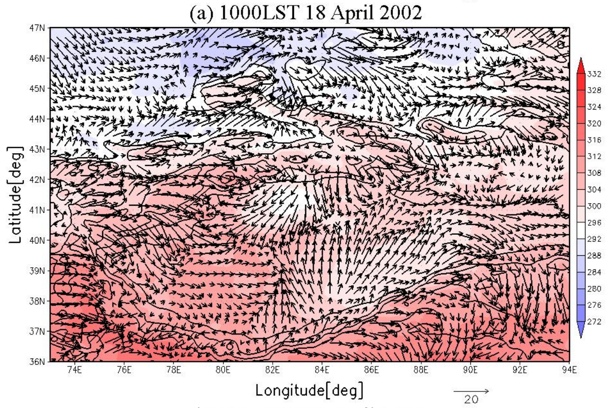


(b) 0600UTC 19 April 2002

Fig. 4. The 500hPa isobar weather charts. The lines indicate the geopotential heights [m].

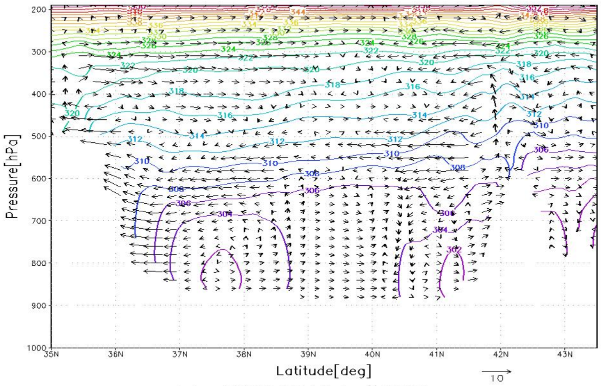


(a) 1000LST 18 April 2002

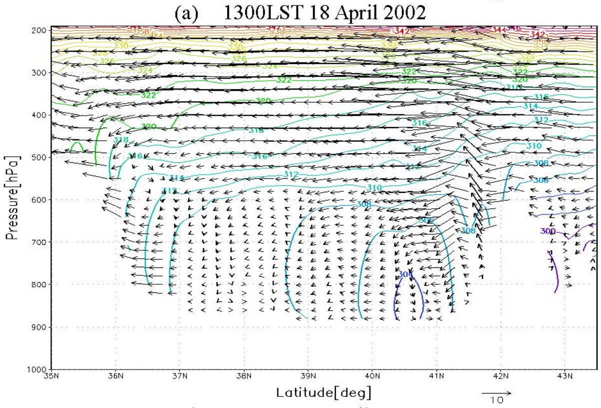


(b) 1900LST 18 April 2002

Fig. 5. Fields of wind and potential temperature at 42m by the numerical simulation.



(a) 1300LST 18 April 2002



(b) 1300LST 19 April 2002

Fig. 6. North-south vertical cross section of wind (v, w*10) and potential temperature on 80.83°E. The Kunlun Mountains and the Tienshan Mountains are located in the west and the east part, respectively.

rise highly at 1900LST.

For April 19, the upper winds going across the Tienshan Mountains grow weaker and the upper weak downward winds are shown over Aksu in the early morning (not shown). The valley winds blow over the north of Aksu and their return flows are generated in the late morning. The downward winds are stronger with the upper wind going across the Tienshan Mountains. The lee waves occur by the strong upper winds and the downward winds grow intense. The low DLH is influenced by not only the return winds of the valley winds but also the lee waves by the Tienshan Mountains. It makes the height is more lowered in comparison with the previous day. The zone of the downdraft moves to the north of Aksu and the DLH rises by the divergence.

After the dust storms, therefore, the DLH over Aksu is lowered by the return flows of the valley winds and the lee waves over the Tienshan Mountains in the daytime. And then the DLH rises with the convergence or divergence of the winds from the Tienshan Mountains.

7. REFERENCES

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