NUMERICAL SIMULATION OF MESOSCALE CIRCULATIONS IN THE TARIM BASIN ASSOCIATED WITH DUST EVENTS

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ABSTRACT

We investigate the dust dispersion at the Taklimakan Desert in the Tarim Basin, one of the key sources of aeolian dust in East Asia. Dust events in the Taklimakan Desert, including floating dust and blowing dust, have rather long-lasting features, while in the Gobi Desert, dust events occur in phase with the passage of synoptic cyclone. A relationship between the local circulation system and the dust dispersion is focused on. Numerical simulations are conducted for several dust events in spring seasons from 2000 to 2002. The Regional Spectral Model (RSM) of the Japan Meteorological Agency (JMA) is employed (the equivalent horizontal grid size is 20km). To further simulate regional dust transport, the nonhydrostatic model is coupled with RSM and the dust emission model proposed by Shao (2001) and the Lagrangian dispersion model are incorporated. The model reasonably simulates time variations and spatial distributions in the surface wind field. Three characteristic types of mesoscale flow were revealed in the simulation. We can say that the formation of the various types of flow contributes to the relatively persistent dust suspension in the Tarim Basin. The dust dispersion at the Taklimakan Desert is dependent on not only the surface wind intensification, but also the vertical motions arising in or between these circulations. Closer examination shows that the developments of these local circulations are closely related to the large-scale flow field behind the surface low pressure system.

1.INTRODUCTION

Dust storms in East Asia provide a large amount of aeolian mineral dust, which causes 'Kosa' (yellow sand) over the Far Eastern region including Japan. Higher frequencies of Kosa events in Japan from 2000 to 2002 throws a question what affects their activity. Detailed understandings of dust emission and transport processes are required.

We focus on one of the principal source regions of dust emission, the Tarim Basin, which is largely occupied with the Taklimakan Desert. Relationship between the local circulation system and dust emission is investigated. Numerical simulations have been done for several dust events in the spring from 2000 to 2002.

2. CHARACTERISTICS OF DUST EVENT IN THE TARIM BASIN

The 3-hourly present weather (WMO code "ww") data can be extracted from synoptic reports as well as other surface meteorological observational data. Figure 1 shows time sequences of the dust event frequency in the Tarim Basin in April 2002. Dust storms (defined as ww= 9, 30-35, 98 in this study) and blowing dust (ww=7-8) took place several times this month. Floating dust (ww=6) was observed in longer duration at a larger number of stations. A series of floating dust event started with the occurrence of the dust storm. A remarkable feature of dust events in the Tarim Basin is the high frequencies of the long-lasting floating dust [1] In

other source regions in Northeast Asia, areas of dust weather are associated and shifted along with the mid-latitude cyclone [2].

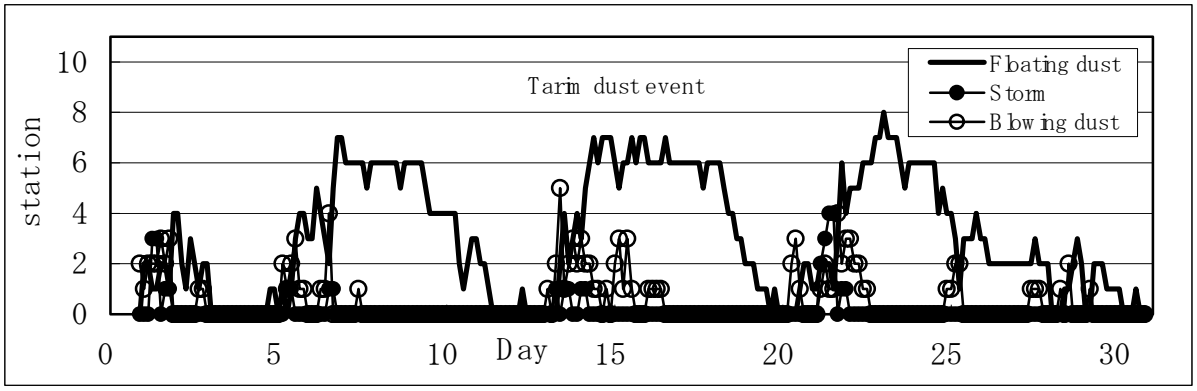

Figure 1. Time series of observed frequencies of dust storms, blowing dust, and floating dust in the Tarim Basin for April 2002. The total number of the reporting stations is 11.

3. MODEL

The Regional Spectral Model (RSM) of the Japan Meteorological Agency (JMA) was employed to simulate mesoscale meteorological field. RSM has been used operationally at JMA for numerical weather prediction of East Asian region [3]. The present model domain was more than 4000 km square, covering northwestern China and Tibet plateau. The main purpose of the present simulation, different from the operational forecast, is the examination of mesoscale features. Therefore initial and boundary conditions are taken from Objective Global Analysis (GANAL) data of JMA, which enables the simulation under realistic synoptic conditions. Spectral boundary coupling method developed for regional climate modelling was adopted in the nesting procedure between RSM and GANAL [4]. The present RSM has a horizontal resolution equivalent to a grid interval of 20 km and 36 vertical layers in σ -p hybrid coordinate.

4. RESULTS AND DISCUSSION

72-hr Simulations with RSM were performed for well-defined dust events in April from 2000 to 2002. A dust event in 13-14 April 2002 took place during the Intensive Observation Period of a research program, Aeolian Dust Experiment on Climate impact (ADEC).

As can be seen in the time series at the station Tazhong, located in the middle of the desert area, blowing dust began in phase with the increase in the surface wind speed (Fig. 2). It should be noted that the wind-blown dusts were observed with increasing westerly or northerly wind at the beginning, and later lasted under the wind shift to the easterly. In the simulation starting at 00 UTC 11 April 2002, temporal variations in the surface wind speed and direction agreed well with the observation. Diurnal variations in surface temperature and pressure tendency were rather poorly simulated, although performances were reasonable outside the basin. Improved

land surface scheme should be implemented for better representation in the boundary layer.

The observed and simulated surface wind fields are shown in Fig. 3.

Simulation results demonstrated the characteristic flow in the basin that appeared during the dust event. In early stage of the dust event, relatively weak westerly winds were dominant in the basin. In the next stage at around 06UTC-15UTC 13, intense northerly wind appeared over the Tianshan Mountains and entered downstream the Tarim Basin with an increasing easterly component. In the present case, dust weather was most widely observed in this stage. Thermal deviation associated with the northeasterly wind was not very clear in contrast to that in the following stage. In later stage, easterly winds appearing from the eastern part of the Tarim Basin gradually extend westward into the basin. Cold air outbreak connected with a predominant high pressure occurred along the Hexi corridor in this stage and thus the temperature decreased.

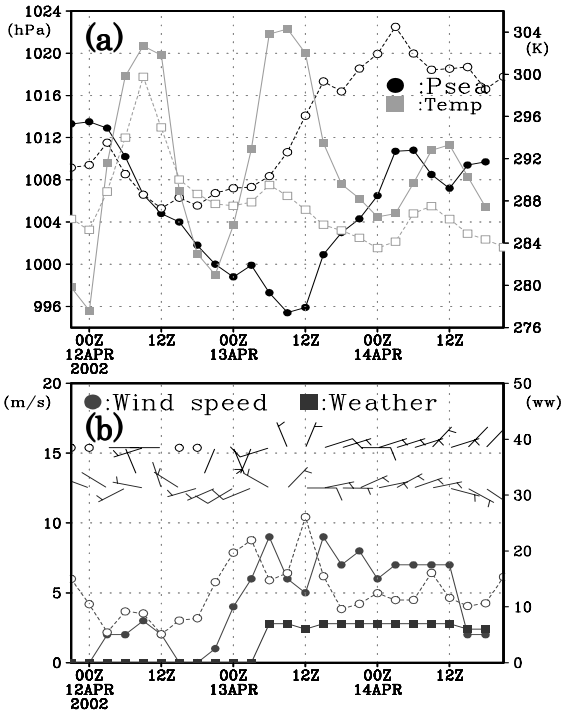

Figure 2. Observed and simulated time sequenses of (a) sea level pressure, surface temperature, and (b) surface wind speed at the station Tazhong. Solid symbols and barbs in the upper line indicate the observation. Open symbols denote simulation results. The full barb denotes 10 m/s.

The mesoscale circulations simulated over the Tarim Basin seems to be triggered by the passage of the synoptic mid-latitude cyclone. However, these circulations are different from synoptically induced frontal system, which is largely associated with the dust events in other regions in northeast Asia. The relationship between the local circulation, synoptic field, and topographic effect should be further examined.

To resolve finer atmospheric structure, the nonhydrostatic model developed by the Meteorological Research Institute (MRI) and the Numerical Prediction Division of JMA (MRI/NPD-NHM, here referred to as NHM, [5]) was coupled with RSM. NHM has been successfully applied to various mesoscale simulations. A horizontal grid interval of NHM was 10 km in the present study. NHM drives dust emission model and dust transport model [6], [7]. Simulation results of the dust dispersion are shown in Fig. 4. Dust emission in the simulation period was limited to the area in the lee of the Tianshan Mountains, where strong downslope wind occurred. In contrast, dispersed dust spread widely over the Tarim Basin because of the active transport due to the inner circulations mentioned above. Further detailed examination suggests that vertical motions between the mesoscale circulations led to upward dust transport.

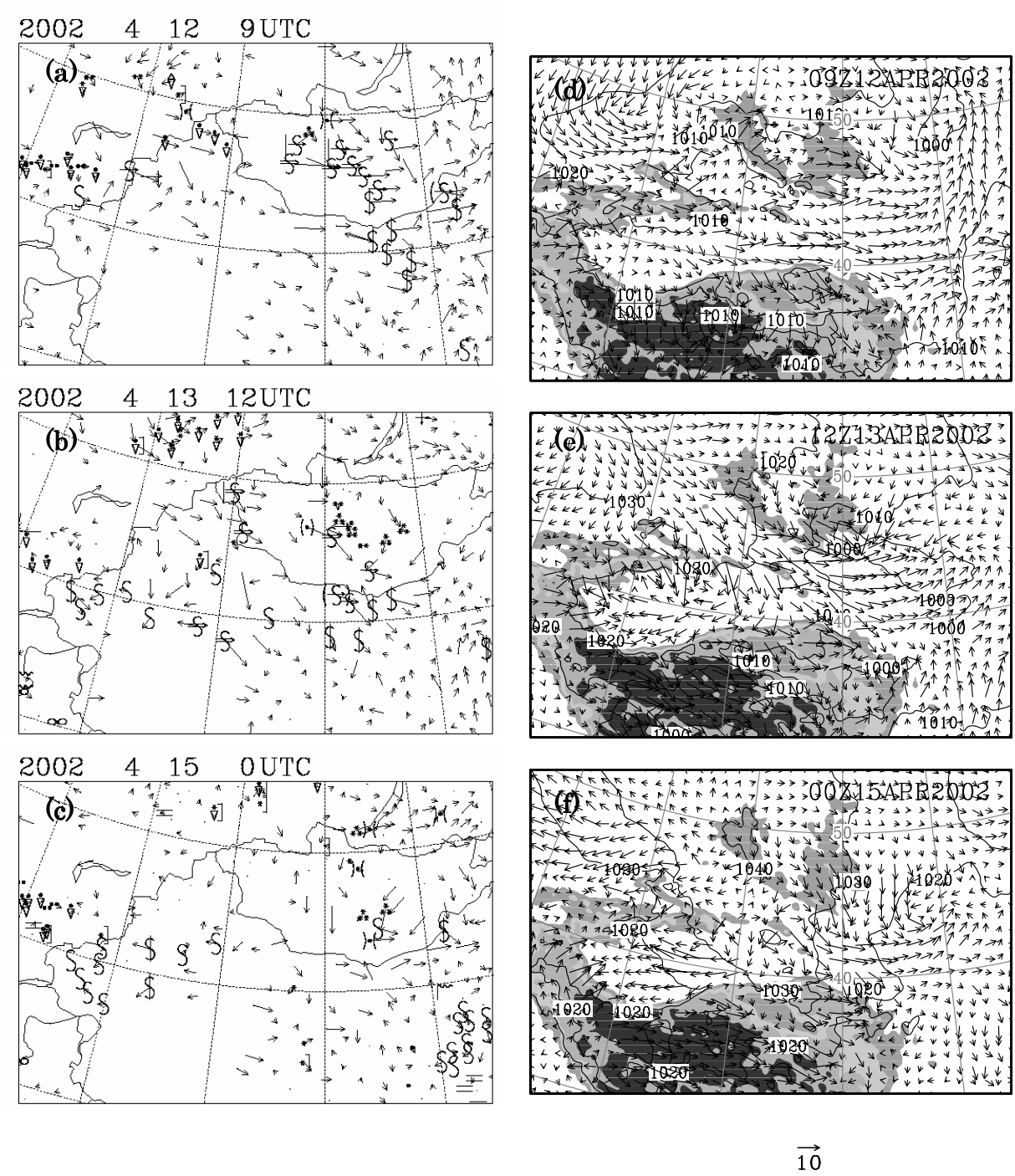

Figure 3. Surface wind field observed (left) and simulated (right) at 0900 UTC 12, 1200 UTC 13, and 0000 UTC 15 April 2002. Significant weather symbols, including dust storm ("S" with a horizontal arrow), blowing dust ($) and floating dust (S) are also drawn.

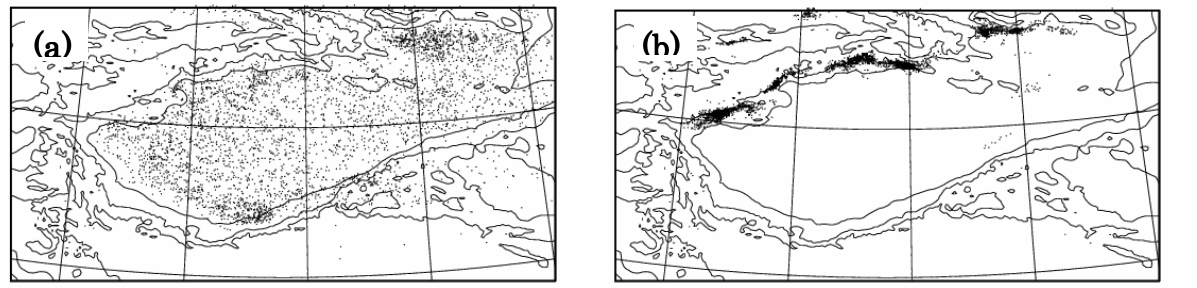

Figure 4. Simulated distribution of (a) the total amount of dust in the atmosphere for 0000 UTC 14 April 2002 after a 30-hour dispersion integration and (b) its source position. Each dot represents $1x10^5$ kg weight of dust.

5. CONCLUSIONS

Numerical simulations have been done for dust events in the Tarim Basin and the mesoscale atmospheric features were examined. A remarkable feature of dust events in the Tarim Basin is the high frequencies of the floating dust.

The onset of a dust event was in phase with the increase in the surface wind speed. The model reasonably simulated time variations and spatial distributions in the wind field. Dust events in the basin, in contrast to the events in other regions in northeast Asia, were not clearly corresponding to the synoptically induced strong wind. We can see that the surface wind intensification in the Tarim Basin was associated with the development of mesoscale circulations. Three characteristic types of flow in the basin are,

・Westerly flow prevailing in the Tarim Basin in early stage, and later, persisting in southwestern part.

・North-easterly flow appearing over the Tianshan Mountains and gradually spreading downstream into the basin, and

・Easterly flow extending from eastern edge of the basin in the later stage.

Simulation results demonstrated that surface wind field varies remarkably in a period of dust event. Each type of the flow can cause local intensification of the wind sufficient for the dust emission. This explains the relatively long-lasting dust events in the Tarim Basin. Coupling RSM to a nonhydrostatic model with finer resolution and incorporating dust emission and transport schemes, dust dispersion simulation in the Tarim Basin has been also conducted. Vertical motion induced in or between the mesoscale circulations play an important role for the dust transport. Formation processes of these mesoscale circulations and the relationship between the synoptic cyclone are to be further investigated.

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