P2.7 A Case Study of 7-9 April 2001 Dust Storm in Northern China

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1. Introduction

Dust storms occurred in Northern China caused tremendous environmental hazards, especially in recent years. This motivated a number of case studies (Wang et al. 1995; Takemi 1997; Tratt et al. 2001), including the case study of the April 2001 dust storm presented in this paper.

2. Episodes of the April 2001 dust storm

On 6 April 2001, a dust storm was initiated in the north of China and south of Mongolia due to high winds and favorable thermodynamic conditions over Gobi Desert – one of the major natural dust sources in East Asia. The storm reached its peak intensity on April 8th, then moved further east and reached the Korean Peninsula on the 10th. During this period, wind–blown and suspending sands affected total 10^7 km^2 areas between 30 and 50°N, 70 and 140°E in China and its neighboring downwind countries. Three areas were worst impacted (Fig. 1). Satellite images showed that the dust plume drafted along with the westerly across the North Pacific Ocean in the subsequent days and reached the North American continent on 15 April. Air samples taken by a NASA plane over Boulder, Colorado revealed a dust plume about 6.4 km thick, stretching from roughly 4,500 to 10,700 m above the Earth's surface. This dust plume arrived over the Atlantic Ocean on 21 April and then traveled nearly a full cycle of the Northern Hemisphere.

3. COAMPS and its aerosol model

The atmospheric component of the Navy's operational Coupled Ocean/Atmospheric Mesoscale Prediction System (COAMPS™) is used to simulate the dust storm with data assimilation cycled every 12 hrs. The Navy's global analyses and forecasts provide the initial fields and lateral boundary conditions (updated every 6 hrs). A mineral dust model, with dust mobilization, transport and microphysics, is embedded in COAMPS that uses exactly the model fields of wind, temperature and precipitation etc. at each time step (Liu and Westphal 2001). The dust source areas are specified based on USGS 1-km land use database. The dust production is proportional to the 4th power of surface friction velocity [Nickling and Gillies 1993].

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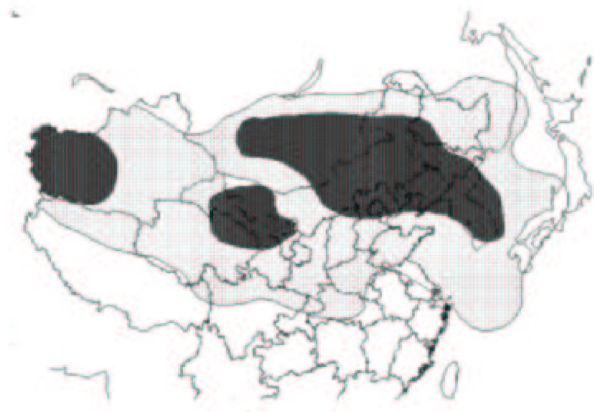

Fig. 1. Dust storm affected areas (shaded) and heavy dust areas (dark shad) during 6-10 April 2001.

4. Numerical simulation and analyses

Both the COAMPS simulation and weather map analyses showed that the high winds and favorable thermodynamic conditions for dust lifting over Gobi Desert (including Hexi Corridor) were produced first by an east-moving Mongolian cyclonic depression and then enhanced by a southeast-moving Siberian cold front. The Mongolia cyclonic depression played an important role in the early stage of the storm. At the beginning of this stage, the large-scale circulation was characterized by a short-wave trough situated at the bottom of the wide trough over Lake Baikal and this trough developed rapidly due to strong thermal advection. Consequently, a cyclonic depression was formed and deepened at the surface level over the Central Mongolia with the surface pressure low reached 992.5 mb at 00UTC on 6 April. As this system moved slowly eastward and reached its maximum intensity with the surface pressure down to 977.5 mb at 18UTC, a huge amount of dust sand was lifted and formed a dust storm swiped most areas over northeast China.

As the Mongolian depression moved to Northeastern China on 8 April (Fig. 2), the Siberian cold front pushed into the upstream area of the dust storm in Northwestern China. High winds associated with this cold front generated strong dust fluxes over Taklamakan Desert in Talimu basin of Xinjiang. This greatly extended the range of the dust storm to the west and upstream side of the storm generated by the Mongolian depression.

In addition to the above synoptic-scale impact of the Siberian cold front, the frontal system also produced a mesoscale low pressure center ahead of the cold front. This mesolow became fully developed on 8 April in the middle and low troposphere (not shown) over the dust source area in the central Hexi Corridor of Gansu. Its associated cyclonic flow produced very strong surface winds (28 m/s) over the dust source area. This maximized surface dust fluxes over the source area and further intensified the dust storm with the visibility reduced dramatically down to 0 m over the mesoscale areas within and immediately downstream of the dust source.

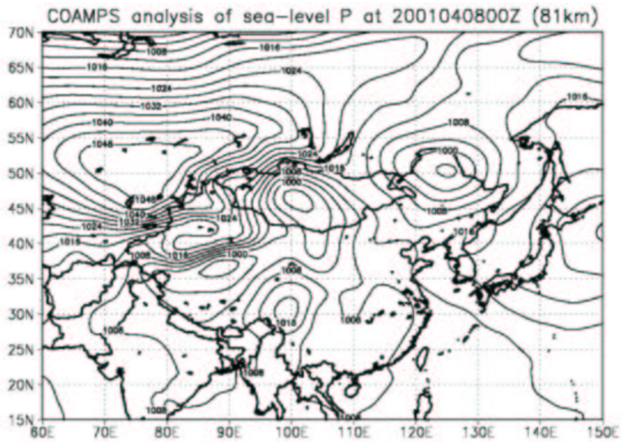

Fig. 2. Model analyses of sea-level pressure at 08:00UTC of April 8 with grid resolution 81km.

5. Dust distribution and air quality

As revealed by the dust model outputs and verified by surface observations, dust mass fluxes were generated mainly in southwestern Mongolia, Northern Xinjiang and the surrounding areas of Talimu basin of Xinjiang in China before April 7th. After the 7th, the range of dust fluxes extended gradually eastward following the east-moving Mongolia depression. At 06UTC the 7th, dust fluxes showed a local maximum around the area between southern Mongolian and northern China. At this time, the Siberian cold front moved into Northern Xinjiang and generated heavy dust over Taklamakan Desert. As the range of dust fluxes in Xinjiang extended following the southeast-moving front, high-flux areas became connected from southeastern Xinjiang to northwestern Qinghai and to western Hexi Corridor of Gansu. From 06 to 09UTC (local afternoon 2-5PM) on 8 April, the surface sensible heat flux reached a peak value (more than 500W/m^2) and the maximum dust flux reached 30mg/m^2 over this area. The dust mass load (vertical integral of concentration) also reached the maximum of 160-180 Kg/m^2 on April 8 (Fig. 3). The strong dust fluxes and heavy dust loads caused heavy air pollution in 20 major cities of Northern China. Among these 20 cities, 6 cities recorded highest air pollution on April 8th, and 5 cities recorded highest air pollution on the 7th and 9th.

6. Conclusions

The results of this study suggest that the succession of the east-moving Mongolian depression and the southeast-moving Siberian cold front played a key role in generating and subsequently intensifying the 7-9 April 2001 dust storm on the synoptic and large scales. The mesolow produced in the central Hexi Corridor during the succession of the above two synoptic systems further intensified the dust storm on the mesoscale. The simulated dust fluxes showed close connections to the wind and thermodynamic conditions over the dust source areas, while the mass load and their spatial distributions showed a strong dependence on the three-dimensional wind field on the synoptic and large scales.

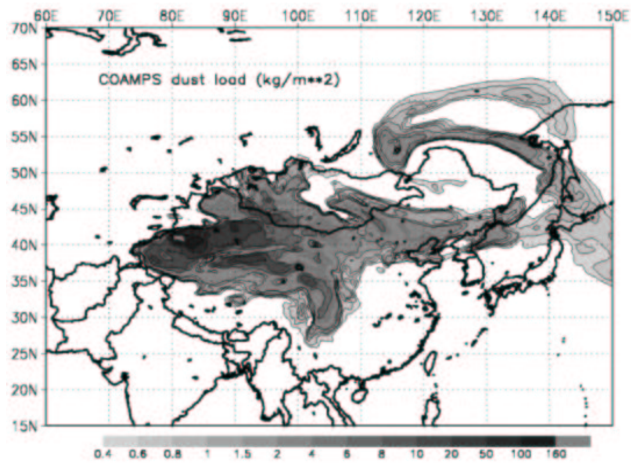

Fig. 3. Dust mass load of model simulation at 08:00UTC of April 8 in grid resolution 27 km.

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