Modeling of Dust Emission in Northwest China

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The arid and semi-arid regions in northwest China are important source areas of dust emission in Asian continent. Vast mineral dust aerosols influence atmospheric radiations through absorption and scattering and through modifying the optical and physical properties of clouds (Shen et al., 2000), and then influence the regional and globe climate. However, very little is known about the dust emission rate in this area during a dusty weather.

A numerical forecast model for sand and dust emissions in northwest China is generated by combining MM5 with the mineral dust emission model developed by Shao (2001). It can be seen from the comparison with observational data that the simulations of friction velocity, vegetation fraction and surface relative humidity from MM5 are basically satisfactory, modeling of surface soil moisture is very difference with observational result, and soil type from MM5 is consistent with the fact only in some regions. Therefore, in this paper the soil type from MM5 is corrected and Gobi surface is added, which is assumed non-erodible; influence of surface soil moisture on wind erosion is replaced by surface relative humidity factor; variations of air density with time and space are considered. From these three corrections, simulated results of distributions of sand and dust emissions by wind erosion in temporal and special vary greatly. The main equations of the model are as:

$$F(d_i,d_s)=c_Y\left[(1-\gamma)+\gamma\frac{p_m(d_i)}{p_f(d_i)}\right]\frac{Qg}{u_*^2 m}(\rho_b\eta_{fi}\Omega+\eta_{ci}m)$$

$$Q(d_s)=\begin{cases}\dfrac{c\rho_a u_*^3}{g}\left[1-\left(\dfrac{u_{*t}}{u_*}\right)^2\right] & u_*>u_{*t}\\ 0 & u_*\le u_{*t}\end{cases}$$

$$Q_c(d_s)=E\cdot Q(d_s)$$

$$(u_{*t})_c=R(\lambda)\sqrt{A_N\left(\sigma_p g d_s+\frac{\varepsilon}{\rho_a d_s}\right)}$$

$$E=\begin{cases}(1-RH/RH_0) & for \quad RH<RH_0\\ 0 & for \quad RH\ge RH_0\end{cases}$$

where F is vertical dust flux, representing dust emission rate, Q is streamwise sand flux, u_* is friction velocity, u_{*t} is threshold friction velocity and ρ_a is air density. H(w) and R(λ) indicate the influence of surface soil water content (w) and roughness element density (λ) on dust emission respectively. RH_0 is threshold relative humidity, and according on the research of Zhang (1984), Wang et al. (2000) took RH_0 as 40%. Other parameters in these equations are introduced in Shao (2001) in detail.

It can be seen from simulated results of intense dust storm process during March 18~22, 2002 (Fig. 1) that sand and dust emissions in modeling area in this process are weak in west area and strong in east area. On the west of 95°E, there are disperse dust emissions only around Taklimakan Desert

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and the vertical dust fluxes are not too large, so this region only is weak dust source area during this dusty weather process, which is consist with concerned observational data. On the south of 40°N and between 90°E～100°E, because the modeled friction velocities often exceed 1.0ms^{-1}, sand and dust emissions are always high and the vertical dust fluxes even exceed 10^{-7}kgm^{-2}s^{-1}, however, the simulated results in this process are almost not consistent with observational results of visibility, so this region is likely a bogus dust source area. On the east of 100°E, dust emission areas in this process are very wide and their intensities are very high, which is consistent with the phenomenon reflected by concerned observational data; at the same time, wind directions in this region are mainly in west or in leaning to west, leading that dusts suspended in air are easily transported eastwardly and arousing far and wide dusty weather, therefore, this region should be main dust source area in this process.

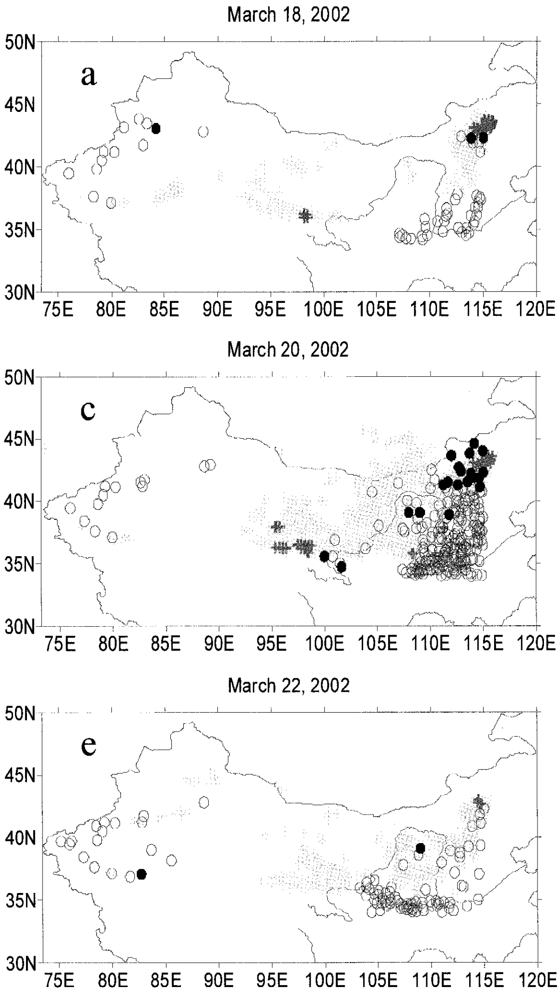

Figure 1 Comparison of simulated vertical dust flux (F) with observed visibility (VV) at every 06 o'clock (UTC) during March 18-22, 2002. '○' denotes VV between 1～10km, '●' denotes VV less than 1km, '+' denotes F between 10^{-7}～10^{-6}kgm^{-2}s^{-1}, and '✚' denotes F more than 10^{-6}kgm^{-2}s^{-1}

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