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Parameterization of Dust Emission for Convective Atmospheric Conditions

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In this study, we develop a scheme for parameterization of dust emission under convective conditions for use in regional and global dust models. In desert areas, where convective turbulence develops, dust emission could be significant in the absence of strong mean wind. Most existing dust emission schemes only apply to strong wind conditions and neglect the effect of convection. In our study, a scheme is developed to account for the convective dust emission process. For this purpose, the structure of the convective atmospheric boundary layer is analyzed and the relation between turbulent eddies and dust emission is investigated. Parameterizations of particle size distribution, cohesive force, and lifting force are considered. The cohesive forces and the subgrid-scale wind lifting forces are described as probabilistic distributions. Turbulent momentum transfer, which is the main contribution to the lifting force, is estimated using a joint probability density function of horizontal and vertical wind components. Subsequently, dust emission flux is obtained based on the difference between the lifting and cohesive forces. The theory is combined as a parameterization scheme and built into the modeling system WRF/Chem. The model is implemented for the Taklimakan desert in China and the performance of the scheme is tested against lidar measurements and compared to large-eddy simulations. It is found that the new dust emission scheme is able to reproduce the characteristic patterns of the dust-structural development. Limitations, especially in situations when convective turbulence is weak, are observed due to changing emission mechanisms. The parameterization of the probabilistic distribution of momentum transfer is compared to probability density functions derived from resolved wind components in LES and good agreements are observed. In periods of strong convection, the simulated convective emission flux reaches maximum values of 500 $\mu g/(m^2s)$ and can therefore be considered as an important contribution to the global dust cycle. A comparison to the emission scheme of Shao (2004) shows that the newly developed scheme yields a clear improvement for the prediction of dust emission under the condition of prevailing convection, whereas situations with stronger wind shear are better reproduced by the Shao (2004) scheme. This underlines the necessity to develop a unified dust emission scheme, which applies to all atmospheric conditions. This study provides a first step in this direction.