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Testing impacts of aeolian dust during glacial cycles with an Earth system model of intermediate complexity

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Here we discuss potential effects of aeolian dust using the CLIMBER-2 model, an Earth system model of intermediate complexity. Quaternary evidence of dust deposits show dust variations over orders of magnitude on orbital time scales in northern, tropical and southern latitudes. The amount of dust deposition is largest close to arid and semi-arid areas suggesting that these areas represent the dust source regions. The dust deposition distant from these potential dust source regions changes rapidly between low values in interglacial periods and high values in glacial periods suggesting rapid variations in the source strength and/or in the atmospheric transport efficiency. Aeolian dust is known to impact the balance of the shortwave radiative fluxes through changes of the ice albedo when dust is deposited on ice and snow surfaces, and through changes in scattering and absorption of the atmospheric radiation. Previous simulations showed that dust deposition on ice sheets can be a controlling factor for the spatial extent of ice sheets during the glacial periods in Asia and for glacial termination in northern America. The backscattering of insolation by dust aerosols can produce in certain conditions an extra surface cooling effect during glacial periods. Dust particles can influence the vertical stability of the atmosphere and they can interact with cloud droplets, and both mechanisms can affect the hydrological cycle. Further dust aerosols carry different constituents and the iron constituent could act as a biogeochemical fertilizer of the marine biota whereby dust can interact with the carbon cycle.

So far only crude estimates exist on dust impacts because our understanding of mechanisms is still limited and uncertainties in the parameterization are large. As a step toward getting climate-consistent estimates, an aeolian dust model was developed which calculates the global dust cycle internally coupled with the Earth system model CLIMBER-2. The dust model can simulate dust deposition fluxes during glacial-interglacial climate cycles which agree reasonably with observed dust series from different sites. Simulated space-time distributions of dust will be shown and the uncertainties of the dust radiative forcing in dependence of the dust distribution, the optical properties of dust aerosols and the environmental conditions such as surface albedo and cloudiness will be discussed. The testing of the potential effects of aeolian dust helps to learn more about dust mechanisms and the feedback effects between the dust cycle and the climate system during climate state shifts. This work contributes to test Milankovitch's theory through transient simulations of glacial cycles with an Earth system model.