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Stronger early-spring dust outbreaks across the Northern Hemispheric mid-latitudes in a warmer climate

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This research focuses on changes in early-spring dust emissions from Northern Hemispheric mid-latitudes, in the context of global warming. Our study was motivated by the abnormally early and strong dust storms across East Asia in March 2021 and March 2023. These two recent dust extremes opposed the decadal decline of East Asian dust activities. Past studies have attributed this dustiness decline to expanded vegetation cover and resultant weaker near-surface winds in April and May; while in March, dust source regions in the Northern Hemispheric mid-latitudes have been mainly covered by snow or frozen soil instead of vegetation. Inspired by the abnormally warm and snow-free conditions associated with both the 2021 and 2023 early-spring dust extremes, our study examines an alternative hypothesis on dust regimes over the Northern Hemispheric mid-latitudes: in a warmer climate, earlier snow melt may cause stronger early-spring dust outbreaks. Here, using multiple observational datasets and model simulations, we show a 10-35% increase in March dust emission across the East Asian, Central Asian and North American drylands, from the 1980s towards the end of the 21st century, bringing ~20% extra PM_{10} to Beijing and Denver. This hemispherical enhancement in early-spring dust emission is primarily caused by reduced snow cover in response to warming, and further promoted by dynamical coupling between snow, wind, and soil moisture changes. The increased amount of dust, a light absorbing aerosol, may in turn accelerate larger-scale snow melt when it deposits, thereby triggering positive feedbacks between snow melting, dust emission, and warming. Our findings call for adaptation to the anticipated stronger early-spring dust storms across the North Hemispheric mid-latitudes in the upcoming decades.