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A Numerical Investigation of the Potential Effects of Aerosol-Induced Warming Aloft and Updraft Width and Slope on Updraft Intensity in Deep Convective Clouds

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The effects of aerosol perturbations on the characteristics of deep convective clouds (updraft strength, precipitation intensity and distribution, anvil properties, etc.) have received considerable attention in the recent literature, especially from a modeling perspective. The invigoration hypothesis states that increased aerosol loading initially suppresses warm rain formation, increasing the liquid condensate aloft, which ultimately freezes and acts to warm the convective region and driving stronger convection. The published responses in precipitation amount and updraft strength vary in both sign and magnitude and may be the result of different models and parameterizations. While modeling studies generally indicate relatively small changes in updraft strength and precipitation, some observational studies have suggested that large effects are possible. Here, we employ a simple numerical framework to determine and constrain the potential effects of added heating due to increased aerosol loading. We also examine the role of updraft width and slope in the same framework, highlighting the relative importance of each factor on the resulting updraft strength. The numerical solutions indicate a relatively small response in updraft velocity for even large amounts of warming and suggest that observations of the aerosol effect will be largely muddled by the natural variability of convective updraft width and slope (which are related to environmental wind shear).