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Evidence for Convective Invigoration from A-Train Observations

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The ‘convective invigoration’ hypothesis posits that aerosol affects precipitating clouds by delaying the onset of precipitation until the cloud has grown above the freezing level, making more efficient ice-phase precipitation processes available and leading to more intense precipitation than would have been produced by the same cloud in a less polluted atmosphere. In the IPCC AR5, evidence for a systematic aerosol effect on precipitation intensity (i.e., not limited to individual storms) is described as ‘limited and ambiguous’.

We use a combined dataset of spaceborne radar (CloudSat) and lidar (CALIPSO) retrievals of precipitation and cloud thermodynamic phase to derive a climatology of rain occurrence from liquid-phase cloud (‘warm rain’) and ice-phase cloud (‘cold rain’). The cloud-top phase of precipitating cloud serves as a proxy for rain intensity, with warm clouds preferentially producing drizzle and cold clouds preferentially producing more intense rain. This proxy is useful over land, where CloudSat does not retrieve precipitation intensity. In conjunction with aerosol data, the cloud-top phase can be used to test convective invigoration; according to the hypothesis, increasing aerosols should lead to an increase in the cold-rain fraction.

We find that warm rain is extremely rare over the extratropical continents (1.5% of rain occurrences). Warm rain is rarer in the most polluted tercile of observations (measured by reanalysis dry AOD) over wide areas of land and ocean outside the tropics, consistent with expectations under the convective invigoration hypothesis. (In the tropics, the effect is reversed, presumably due to wet scavenging.) Extrapolating the observed relationship between warm-rain fraction and reanalysis dry AOD to preindustrial conditions shows a large anthropogenic aerosol influence on precipitation over the extratropical continents. We propose this as evidence supporting the convective invigoration hypothesis.