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Bioaerosol and ice-nucleating particle responses to convective storm processes at a semiarid grassland area in Colorado

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Biological aerosol particles influence atmospheric processes, including cloud ice nucleation through action as ice-nucleating particles (INPs). Their abundance is altered by convective storm processes such as precipitation and cold pools. To improve the understanding of bioaerosol characteristics, sources, and variability during convective storms, we conducted two intensive field campaigns in May–June 2022 and 2023 at a semiarid grassland area in Colorado. The two seasons had contrasting environmental conditions, with exceptionally dry conditions in 2022 and unusually wet conditions in 2023. Bioaerosols were characterized using fluorescence and chemical tracers, while INPs were measured in air (before, during, and after rainfall), precipitation water, and terrestrial source samples; these measurements were aligned with disdrometer- and drone-based observations. Peak fluorescent particle concentrations correlated significantly with cold pool strength (r_s=0.81, $p<0.05$, n=12), indicating that cold pools increase local bioaerosol concentration. Near-surface warm-temperature INP concentrations reached very high values during rainfall, with a maximum value across 15 events of 2.4 INP standard L^{-1} active at –10 °C. Much of the observed variability in during-precipitation concentration of INPs active between –8 °C and –25 °C was explained by cumulative rainfall kinetic energy (r_s=0.71-0.91, $p<0.006$, n=14), suggesting that raindrops and hailstone impacts on land surfaces aerosolize bioaerosols and INPs. These rain-induced INPs were associated with particles <10 μm, based on size-segregated samples. Heat-treatment experiments (50 °C and 95 °C) revealed that INP properties in during-precipitation air were more similar to plants than to soil. Overall, the results indicate that rain-induced INPs are most likely dominated by fungi that reside on plant surfaces. Finally, cloud-resolving model simulations further suggest that a small fraction of rain-sourced tracers of bioaerosols reaches the upper levels of the parent storms, where INPs could influence cloud ice fraction and initiate precipitation, contributing to an aerosol-cloud-precipitation feedback.

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