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Cloud droplet variability in the summertime in the southeast United States: day vs. night

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During the 2013 Southeast Nexus (SENEX) campaign, in-situ observational data were collected on board the NOAA WP-3D aircraft to study the aerosol-cloud droplet link and examine the sensitivity of the cloud droplet number to aerosol physicochemical parameters. In order to do so, observed aerosol number size distributions, chemical composition and vertical-velocity distributions were introduced into a state-of-the-art cloud droplet parameterization from which cloud droplet number and cloud maximum supersaturations were derived. We find that the standard deviation of the vertical velocity (σ_w) exhibits significant diurnal variability ranging from 0.16 m s^{-1} during nighttime to over 1.2 m s^{-1} during day. Total aerosol number (N_a) covaries with σ_w , with lower values observed during nighttime. The covariance between σ_w and N_a enhances the apparent response of N_d to changes in N_a levels by a factor of 5. For the same "cleaner" environments where N_a values are limited and not impacted by local sources, the relative response of N_d to σ_w is almost twice as great during night, compared to the day (24% during day vs. 42% during night). On the other hand, in environment with enhanced concentrations, especially of accumulation-mode particles, the majority of droplet number variability is attributed to changes in total aerosol number rather than changes in σ_w. Chemical composition is found to on-average have a limited effect on N_d variability (4%). Finally, we identify an upper limit to the number of droplets that can form in clouds which depends only on σ_w independently from total aerosol number. Doubling σ_w from 0.2 to 0.3 m s^{-1}increases this limiting droplet number by 52%.When N_d values approach this upper limit the observed droplet variability is driven by σ_w and, subsequently, by vertical-velocity changes only. Therefore only by using this -σ_w relationship in regions where velocity-limited conditions are expected, σ_w can be estimated from retrievals of droplet number and vice versa.