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Understanding the diurnal cycle characteristics of the smoky boundary layer in the remote SE Atlantic

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Ground-based observational data from Ascension Island in the remote southeast Atlantic during August 2016 and 2017 of the DOE LASIC campaign reveal that smoke within the marine boundary layer (BL) modifies the thermodynamical structure as well as the low-cloud characteristics, through both radiative and microphysical processes. A strength of the data, which include 8x/day radiosondes, is its ability to document the full diurnal cycle, thereby complementing results from day-time-only aircraft campaigns. When smoke is present near the surface, the lowest 500 m of the boundary layer is warmed by 0.5 K, most notably in the mid-to-late afternoon, but persisting through the night. Satellite retrievals and surface-based remote sensing observations indicate a reduction in both day-time and nighttime low-cloud cover and LWP within smokier BLs. Boundary layer decoupling increases when smoke is present. Smokier boundary layers are characterized by the following diurnal cycle: increased warming of the sub-cloud layer reduces its relative humidity, raising the lifting condensation level, and thereby near-surface air must rise to form cloud. This coincides with a diurnal minimum in cloud cover and establishes decoupled conditions that are more clearly evident after sunset. Moisture accumulates within the near-surface layer during the night, increasing moisture stratification. A lack of nighttime recoupling is also evident in lower liquid water paths. A singular feature of smoky BLs is that at sunrise, the boundary layer becomes coupled again, with the BL deepening, cloud top heights rising, and LWPs increasing. Large-eddy-scale simulations are pursued to assess if the simulations can replicate the observations and provide insights into smoke-induced changes in thermodynamics, dynamics, and aerosol-cloud microphysical interactions. The diurnal composite of a smokier BL is illustrated with a case study of a multi-day 2017 mid-August smoke event using both observations and simulations. Associated meteorological conditions indicate that the cloud top inversion strength is reduced when BL biomass burning aerosol is present. This may help support increased entrainment that helps explain the observed persistence of smokier episodes. Although the direct aerosol radiative effect is a cooling, the reduction in cloud fraction from the BL semi-direct effect dominates the overall radiative impact during the month of August.