Understanding the reduction of low clouds in the smoky boundary layer of the remote SE Atlantic using LASIC observations and regional climate modeling

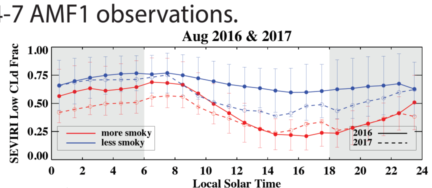
Jianhao Zhang, Paquita Zuidema, U of Miami jzhang@, pzuidema@, miami.edu   Calvin Howes, Pablo Saide UCLA calvinhowes@g.ucla.edu saide@atmos.ucla.edu

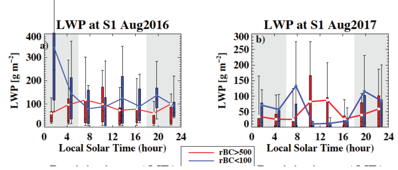
the dominant semi-direct effect in August is from smoke in the boundary layer, not in the free troposphere

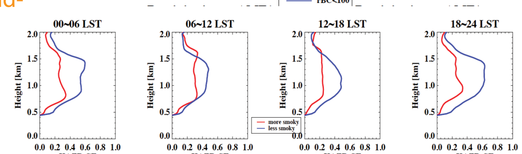
Previous observational studies of the SE Atlantic emphasize increased low cloud cover when shortwave-absorbing aerosols are present in the free-troposphere (e.g. Wilcox, 2010). Recent field measurements at Ascension Island (8S, 14.5W) reveal that smoke is often present in the marine boundary layer, most evident in August when the smoke is highly absorbing of sunlight (Zuidema et al., 2018), the boundary layer is deeper, the cloud-top inversion is weaker, and a climatologically lower cloud fraction eases penetration of the sunlight to the surface, compared to later months (Zhang and Zuidema, 2019). How do the low clouds respond to smokier boundary layers across the diurnal cycle, in a typically warm, moist, deep boundary layer ? Why?

Approach: We composite August 2016 and 2017 time periods by less/more in-situ black carbon mass concentrations (rBC): rBC<100 ng m^{-3} vs. rBC>500 ng m^{-3}. A focus on the diurnal cycle reduces the convolution with meteorology and capitalizes on the 24-7 AMF1 observations.

Cloud cover is most strongly reduced during the afternoon (not new) but cloud liquid water paths reduce more during the night, then surge in the mid-morning , with cloud radar tops indicating mid-morning cloud deepening (new)

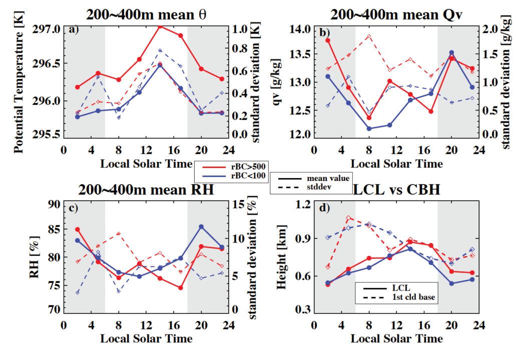






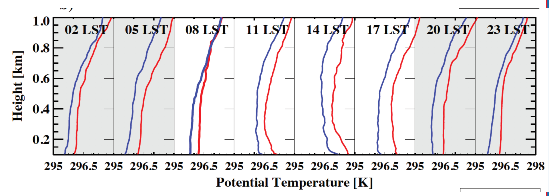
What's going on?

thermodynamic quantities averaged over the sub-cloud layer provide clues: the smokier boundary layer is warmer, by 0.5K, most clearly in the afternoon, when it reduces relative humidity, but persisting through the night. The nighttime smoky sub-cloud layer is more moist (see Qv) but often decoupled from the cloud layer (consistent with lower LWPs). A more decoupled nighttime boundary layer when smoky is consistent w/ less turbulence.

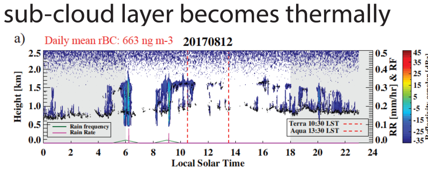


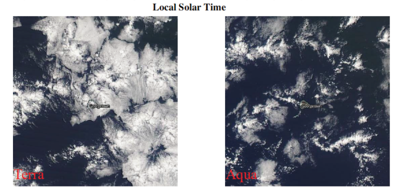
Why the mid-morning cloud deepening?

the smoky night sub-cloud layer cools and becomes well-mixed. We speculate that early-morning radiative warming from sunlight initially drives vertical ascent, before the sub-cloud layer becomes thermally stratified again later in the day.



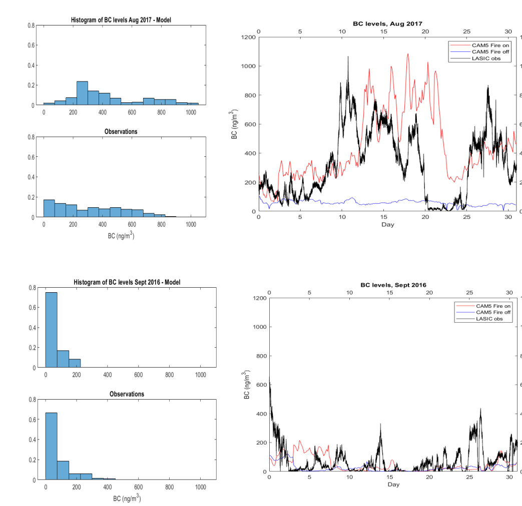
An example helps visualize the statistical composite. Note the rising cloud base during the day, and the mid-morning cloud development. More in Zhang and Zuidema (2019).



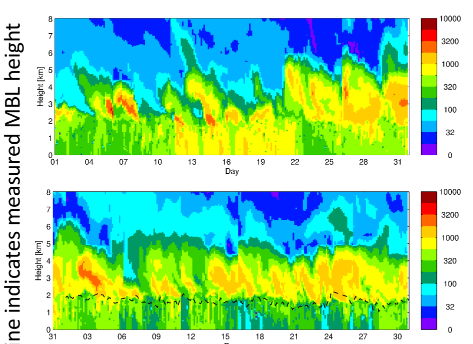


How can the model help?

Similar analysis separating clean and polluted cases can be done for the model (WRF-CAM5). Smoke emissions in the model can be turned on and off to assess if differences are due to smoke-climate interactions or due to the meteorological conditions that bring smoke to Ascension. **BUT**, first we need to analyze if the model is properly representing the observed conditions, something hard to achieve in this region!



Curtain plots of BC [ng/m3] over ascension for August 2017 (top) and September 2016 (bottom). Segmented line indicates measured MBL height



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