Near–LES Modeling of Eastern Pacific Stratocumulus Drizzle and Cloud Variability in VOCALS

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1. Introduction and motivation

The VOCALS Regional Experiment (VOCALS–Rex) took place from 6 October to 2 December 2008. As part of the field campaign, the NOAA R/V Ronald H. Brown (RHB) fielded a suite of remote sensing and in-situ instruments that sampled properties of aerosol, cloud, and precipitation in marine stratocumulus.

The shipboard C-band radar captured a wide variety of cloud and precipitation structures, including transitions from open to closed cellular regions and back. In addition to nondrizzling and moderately drizzling cases similar to those observed in previous field campaigns (e.g., DYCOMS-II, EPIC 2001 Sc), the radar sampled frequent incidences of unusually strong convection, with radar reflectivity values as high as 42 dBZ. The snake-like convective feature in Fig. 1 occurring at a transition between broken and unbroken regimes represents one such case of strong, long-lasting convection. The pictured cell is nearly 2 km deep and is associated with an organized inflow/outflow couplet.

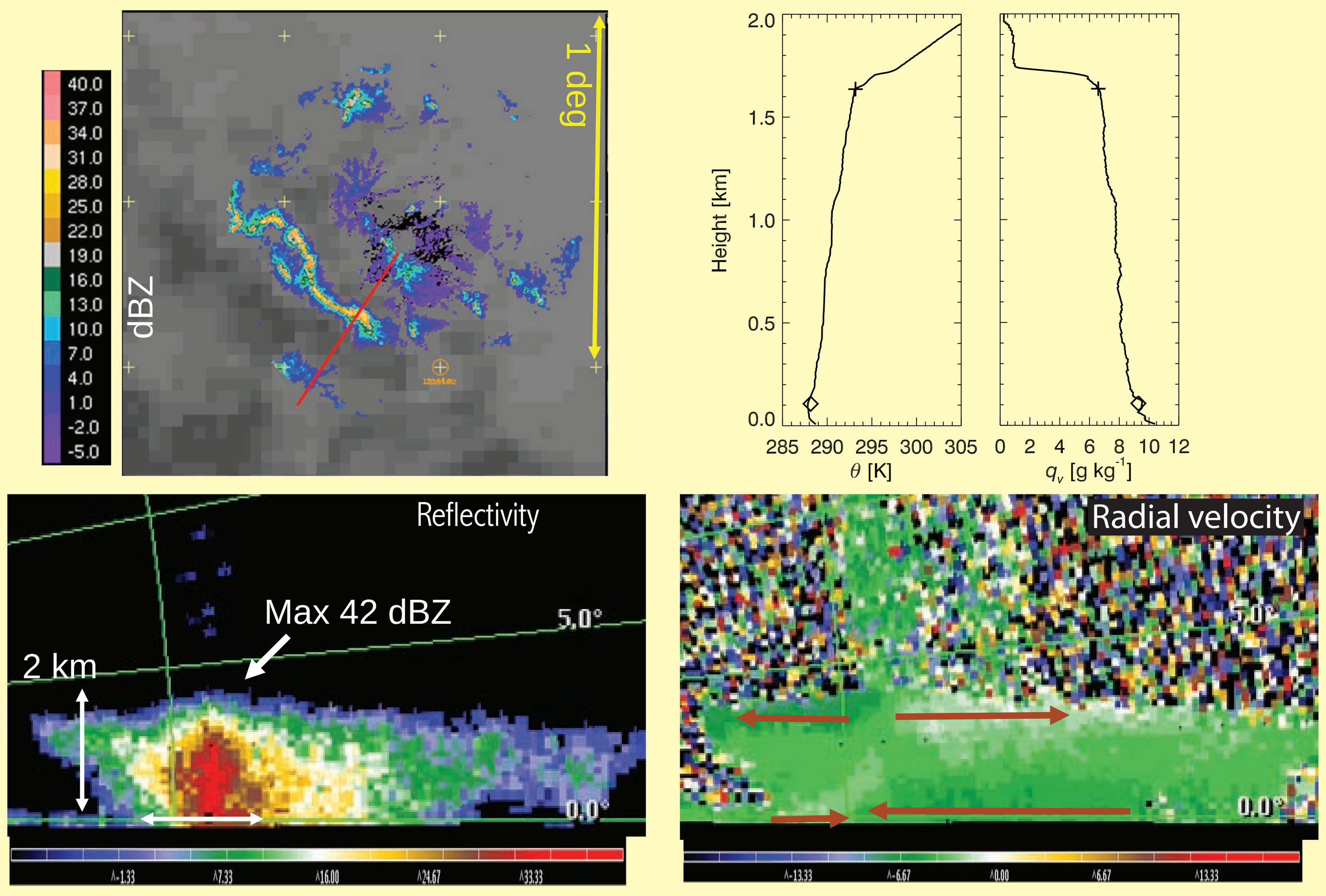


Fig. 1. C-band Radar observations for a case of unusually strong convection occurring on 26 Oct 2008. Profiles of potential temperature and mixing ratio were obtained from the 1100 UTC sounding launched from the RHB. The bottom two panels represent vertical cross sections of reflectivity and radial velocity.

Our work is motivated by two overarching questions:

- What is the explanation for these large reflectivities and drizzle rates?
- What are the leading factors in establishing the behavior of drizzle and mesoscale cloud variability?

2. Environmental conditions

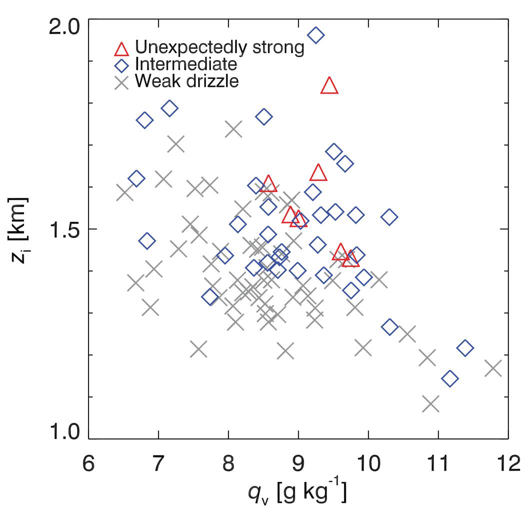


Fig. 2. Mean moisture over the 10–200 m layer (q_v) versus the inversion height (z_i), stratified by different drizzle conditions.

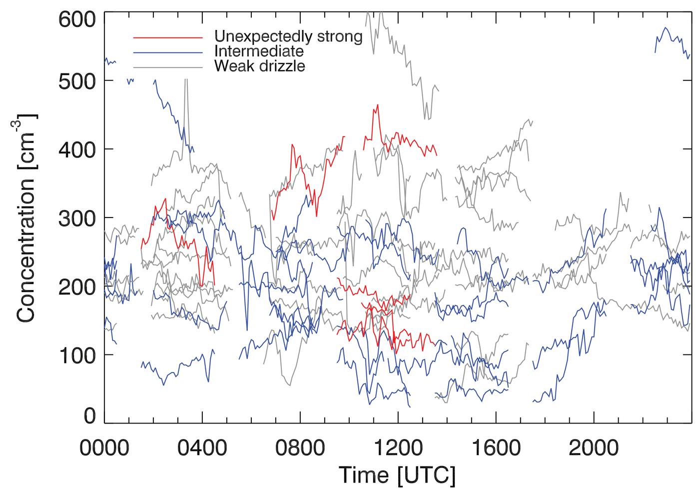


Fig. 3. RHB observations of CCN concentration at 0.6% supersaturation, identified according to drizzle regime. Each CCN trace is ±1.5 h from a sounding time. CCN data courtesy of Dave Covert.

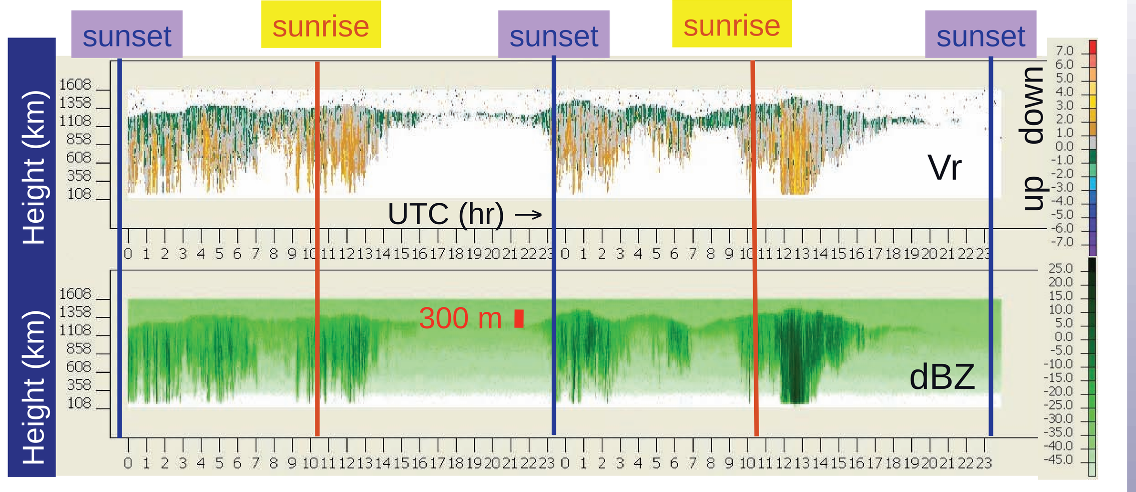


Fig. 4. RHB profiling cloud radar observations for 13-14 Nov 2008.

Analysis of the upper air soundings launched from the RHB reveals that the strongly drizzling cases were generally associated with boundary layers that were both moist and deep, >1.4 km in depth.

Typical, weaker drizzle events tended to be associated with dryer and/or shallower boundary layers.

Cloud radar data from the RHB also suggest that the strongest precipitation is correlated with deep boundary layers.

CCN measurements indicate that the unusually strong cases are not necessarily associated with low CCN concentrations.

3. "Near–LES" approach

System for Atmospheric Modeling–Explicit Microphysics (SAMEX); Khairoutdinov and Randall (2003); Microphysics based on Kogan (1991)

- LW radiation; surface fluxes
- Size-resolved microphysics (34 droplet bins; 19 CCN bins)
- Horizontally homogeneous initial conditions based on 1100 UTC 26 Oct 2008 RHB sounding
- Initial CCN ~104 cm^{-3} (baseline distribution from RICO)
- $dx = dy = 150$ m; 57.6×57.6 km^2
- dz stretched: 25 m at $z = 0$ and 1800 m; 40 m at $z = 800$ m
- 384×384×96; 12 h simulation
- Reflectivity is calculated directly from the DSD

4. Near–LES results

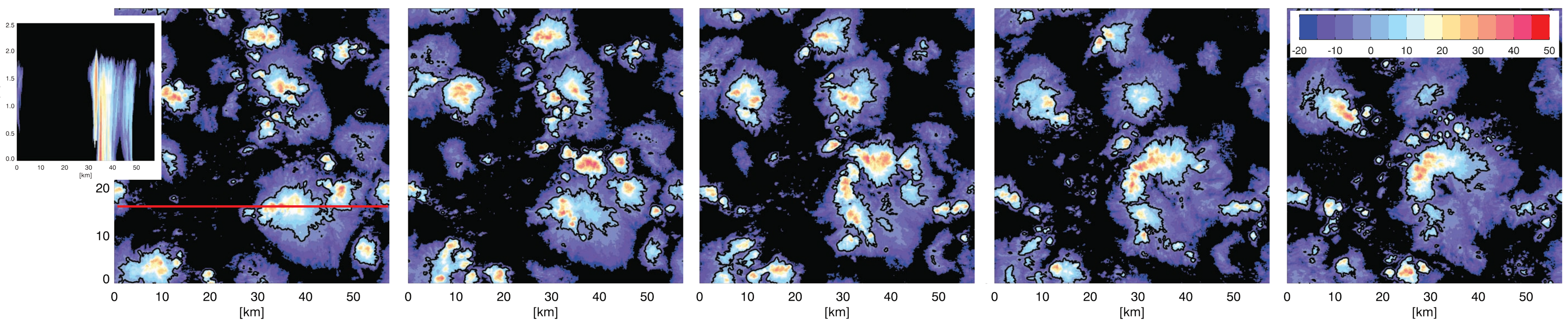


Fig. 5 (top). Evolution of composite reflectivity, taken every 15 minutes, over the last simulation hour. Black contours correspond to 0 dBZ.

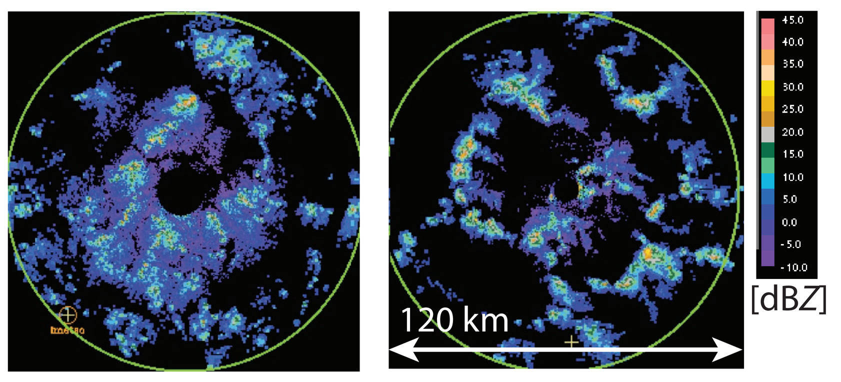


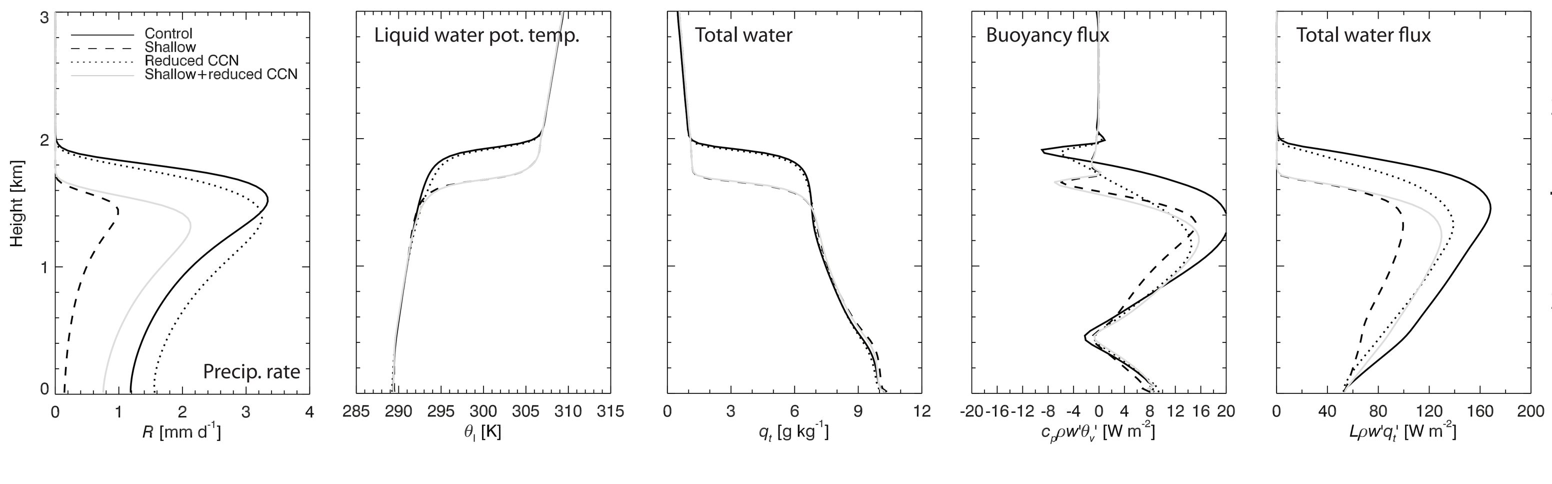
Fig. 6 (right). Variability of mesoscale organization in C-band radar reflectivity.

Simulations contain cell structures qualitatively similar to those observed by C-band radar. Work is underway to compare the simulations statistically (see CFADs [Contoured Frequency by Altitude Diagram] below) with the radar data.

Precipitation rate (left-most profiles) is more sensitive to boundary layer thermodynamics (depth) than CCN concentration .

Simulation suite

- Control experiment
- "Shallow" — boundary layer depth reduced by 200 m
- "Reduced CCN" — CCN concentration reduced to 60% of control value
- "Shallow+Reduced" — Reduced boundary layer depth and CCN concentration



The modal value of reflectivity is largely similar among all four simulations. The simulations differ in the breadth of the mode and the tail of the distribution at higher reflectivity values corresponding to drizzle.

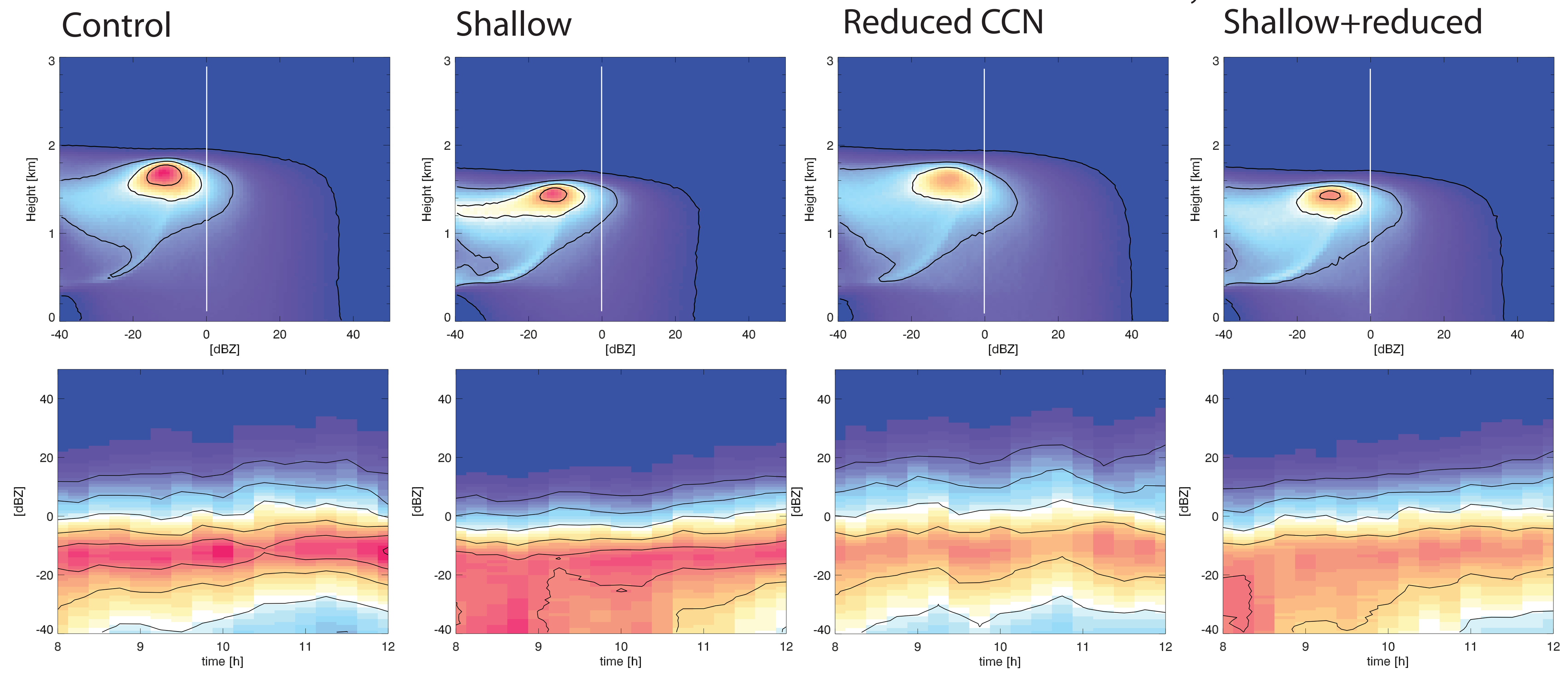


Fig. 7. (top row) Mean CFADs of reflectivity taken over the last four simulation hours; (bottom row) Temporal evolution of the reflectivity distribution.

5. Summary

- Larger drizzle rates are generally associated with deep, moist boundary layers but not necessarily with low CCN concentrations.
- Precipitation is very sensitive to small changes in boundary layer depth (decrease of ~200 m), which swamp the signal of variations in CCN (40% decrease from 105 to 63 cm^{-3}).