Large Eddy Observations and LES of Liquid Stratus over the ACRF

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1 Motivation and objectives

The evolution of low cloud systems is inextricably linked to dynamical processes: heat, moisture, mass, and momentum transports, and of course, entrainment.

Studies employing continuous years of low cloud observations over the southern great plains ARM Climate Research Facility (ACRF) emphasized their climatological, microphysical, and radiative characteristics. The recently enhanced capabilities of the ARM cloud radar suite, specifically, the higher sampling rate of the boundary layer, are ideal for exploring the dynamic aspects of these cloud systems.

These upgraded sensors enable "large eddy observations" (LEOs; Kollias and Albrecht, *JAS* 2000) — the coherent sampling of boundary layer turbulence structures responsible for most of the transport.

Here we present preliminary observational and modeling analyses from a typical springtime postfrontal boundary layer stratocumulus case. Cloud structure and turbulent quantities suggest both similarities and differences relative to marine stratocumulus.

2 Continental postfrontal stratocumulus

- The classical studies of low clouds focused on stratocumulus and trade cumulus in marine environments.
- Midlatitude low clouds are also frequently associated with the passage of synoptic waves.
- Low clouds in the subsidence region behind the cold front bear significant structural resemblance to marine stratocumulus.

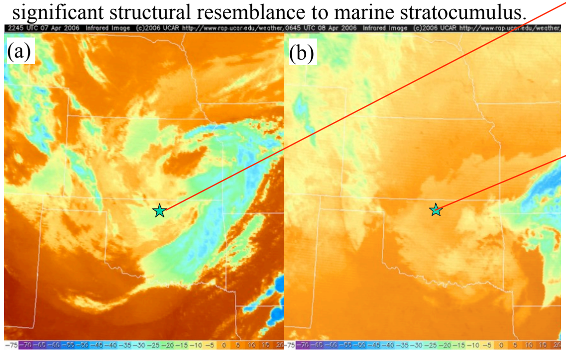

Fig. 1. GOES IR imagery from (a) 2245 UTC 7 April 2006 and (b) 0645 UTC 8 April 2006. Star indicates location of ACRF.

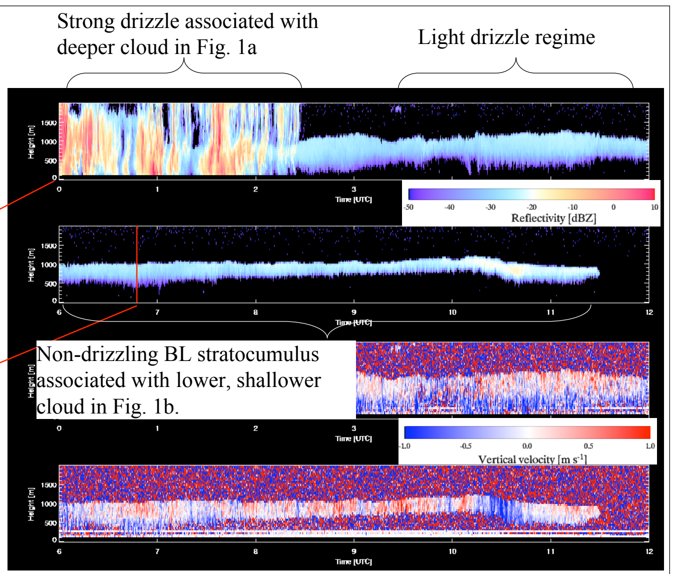

Fig. 2. Reflectivity and Doppler velocity from the W-band ARM Cloud Radar (WACR) from 0000–1200 UTC. Positive velocities are upward. Note that Fig. 1a corresponds to a time 75 min before the earliest radar profile shown here.

3 Large eddy observations

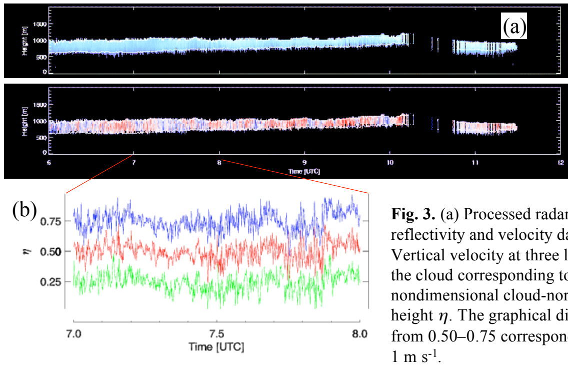

Fig. 3. (a) Processed radar reflectivity and velocity data. (b) Vertical velocity at three levels in the cloud corresponding to nondimensional cloud-normalized height η. The graphical distance from 0.50–0.75 corresponds to 1 m s^{-1}.

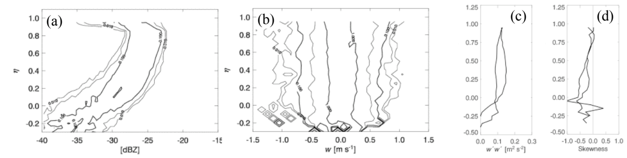

Fig. 4. CFADs of (a) reflectivity and (b) velocity, calculated from 0700–0800 UTC. (c) Mean vertical velocity variance and (d) skewness profiles from 0600–0700 and 0700–0800 UTC.

4 LES

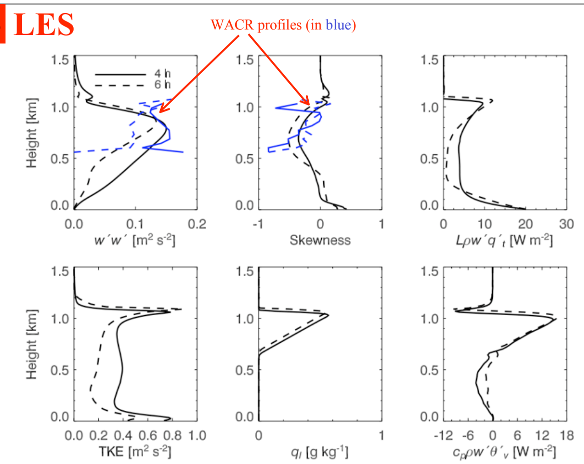

Fig. 5. LES statistics for the nondrizzling SGP stratus case. Variance and skewness statistics calculated from the WACR data are overlaid on the LES profiles.

5 Discussion

- For clouds containing little or no precipitation, boundary layer turbulence structures sampled by the WACR are coherent in both time and in the vertical.
- CFADs indicate a slightly subadiabatic cloud layer and an eddy structure dominated by updrafts and downdrafts of roughly similar properties. The small negative skewness implies that downdrafts were slightly narrower and stronger than updrafts, a characteristic of boundary layer convection driven top-down by cloud top longwave cooling. The overall magnitude of in-cloud turbulence was relatively weak, compared to typical marine cases.
- Levels of in-cloud turbulence and skewness are similar for both LES and LEO.
- LES fluxes indicate signals typical of an entraining stratocumulus layer — negative buoyancy flux at cloud top and near cloud base, both associated with entrainment; moistening and drying of the subcloud and cloud layers, respectively; and a sharp reduction in turbulence below the cloud.
- Relative to marine clouds, which are typically studied in a Lagrangian framework with relatively weak advective forcings, continental clouds associated with synoptic systems require highly constrained estimates of these advective terms. These forcing terms could be obtained from ARM variational analysis or from the proposed ARM LES testbed.

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