Mass Flux in Continental Shallow Cumulus Clouds: Large-eddy Simulation vs Long-term Radar Observation

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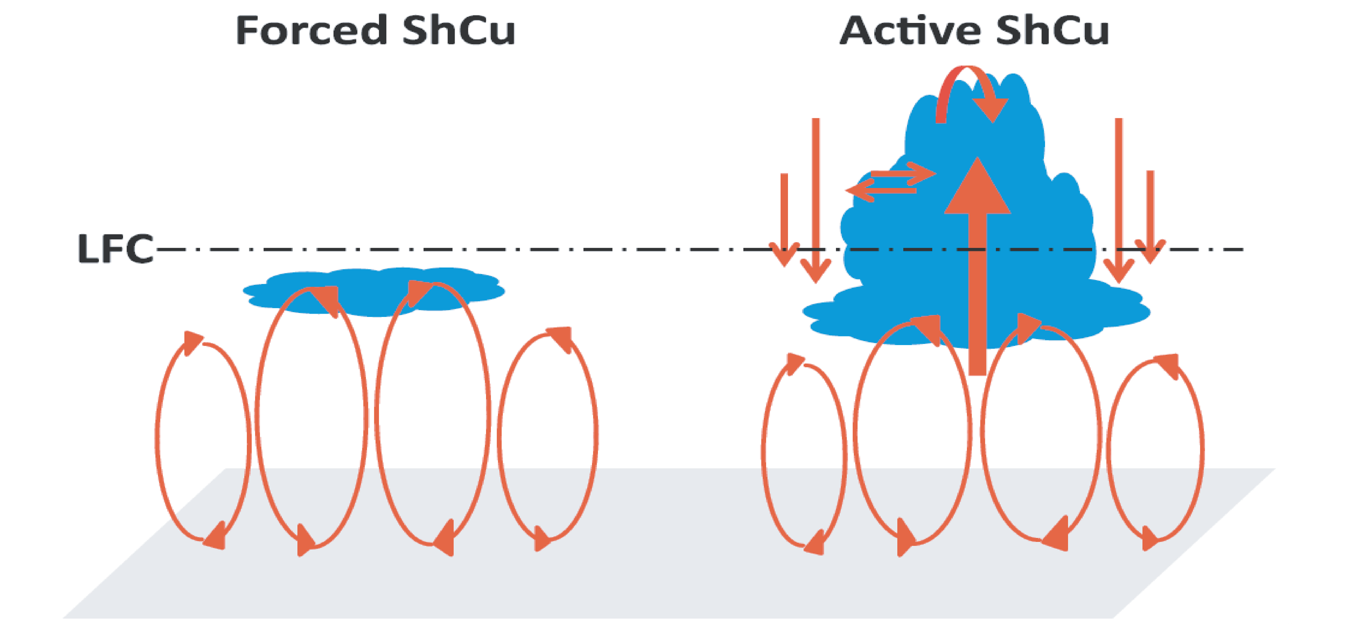
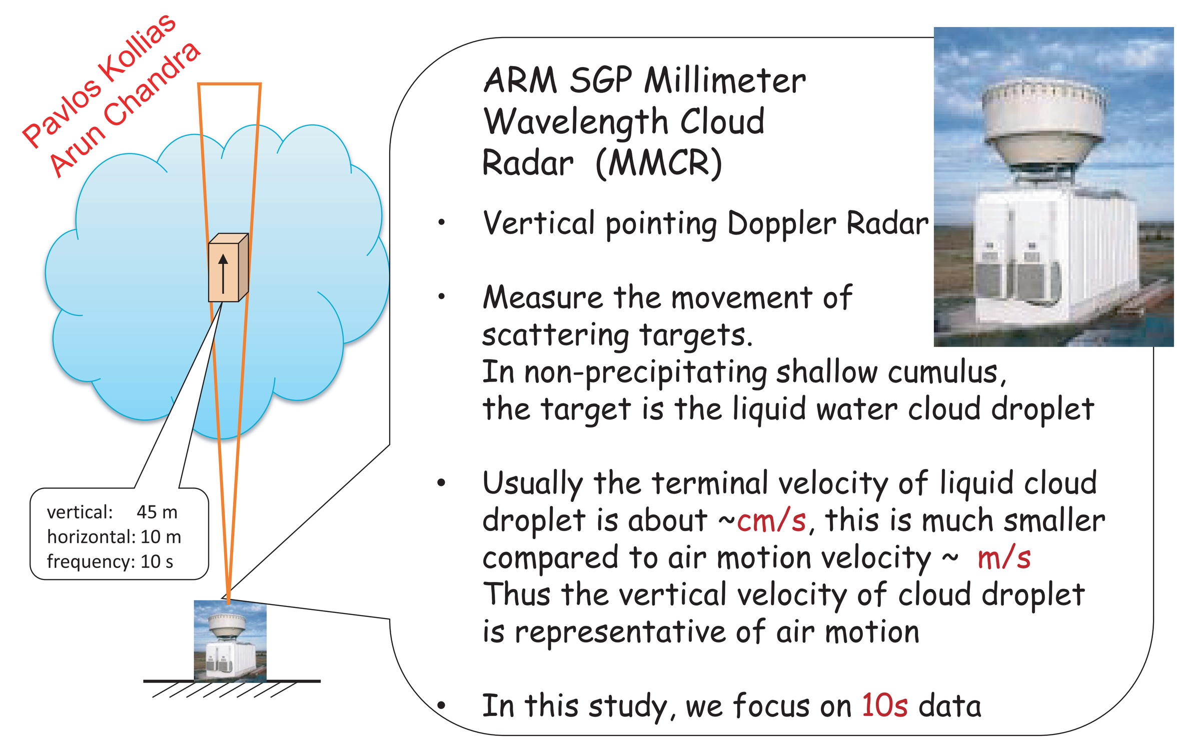
Introduction



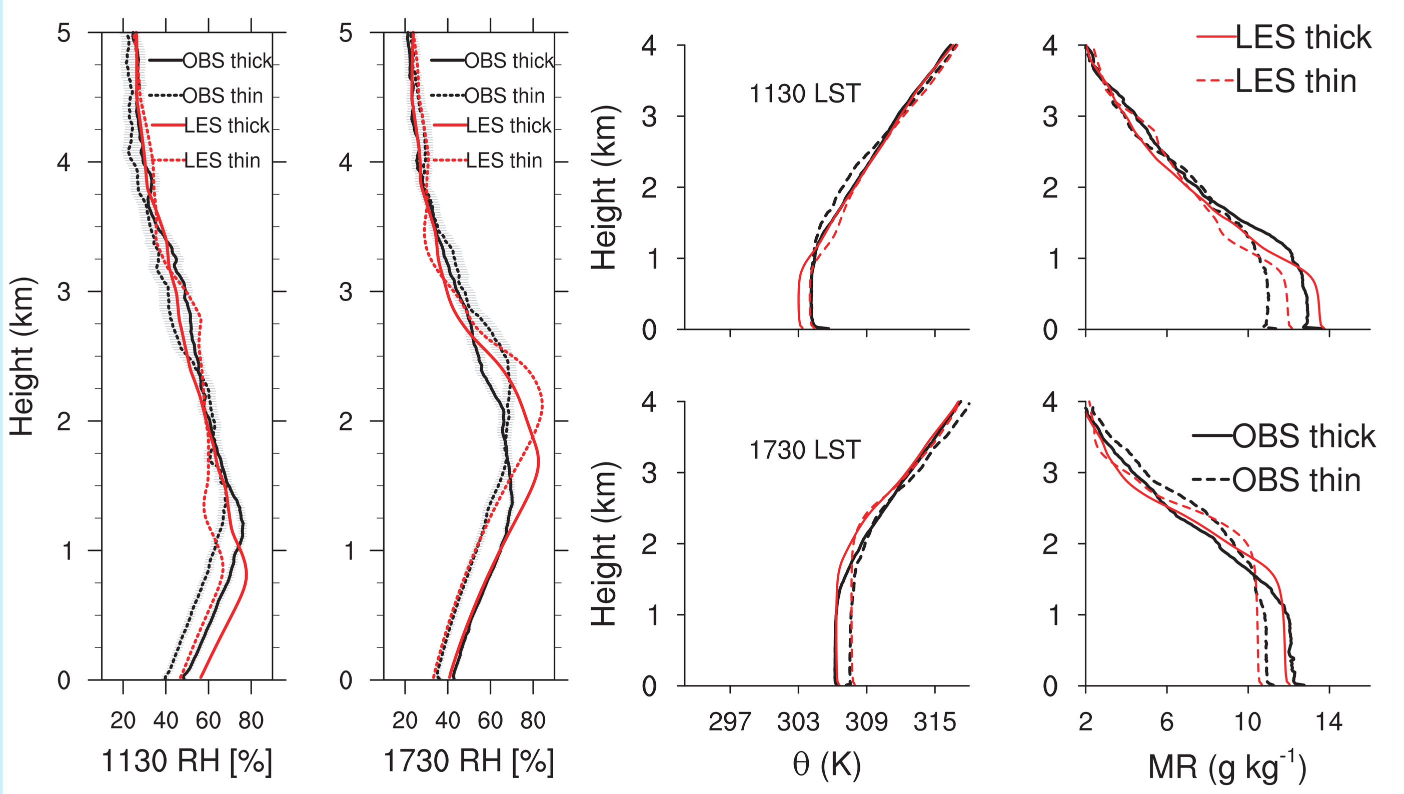
We have developed long-term observational statistics for forced (thin) and active (thick) shallow cumulus using data SGP site and identified that boundary layer humidity and atmospheric stability above cloud top are key factors to affect cloud vertical extent (Zhang and Klein, 2013). In this study,
1. We use long-term ARM MilliMeter Cloud Radar (MMCR) retrievals of vertical velocity to derive mass flux for ShCu day.
2. We perform Large Eddy Simulation (LES) based on the observed composite case (LES CC)
3. and LES for each individual ShCu day in the composite.
By so doing, we make an apple to apple comparison between LES results and Radar Observation, in order to gain more insights of the physical processes of how boundary layer humidity and atmospheric stability affect cloud macrophysics, such as cloud fraction, cloud size and vertical extent and so on.

Observed Vertical Velocity



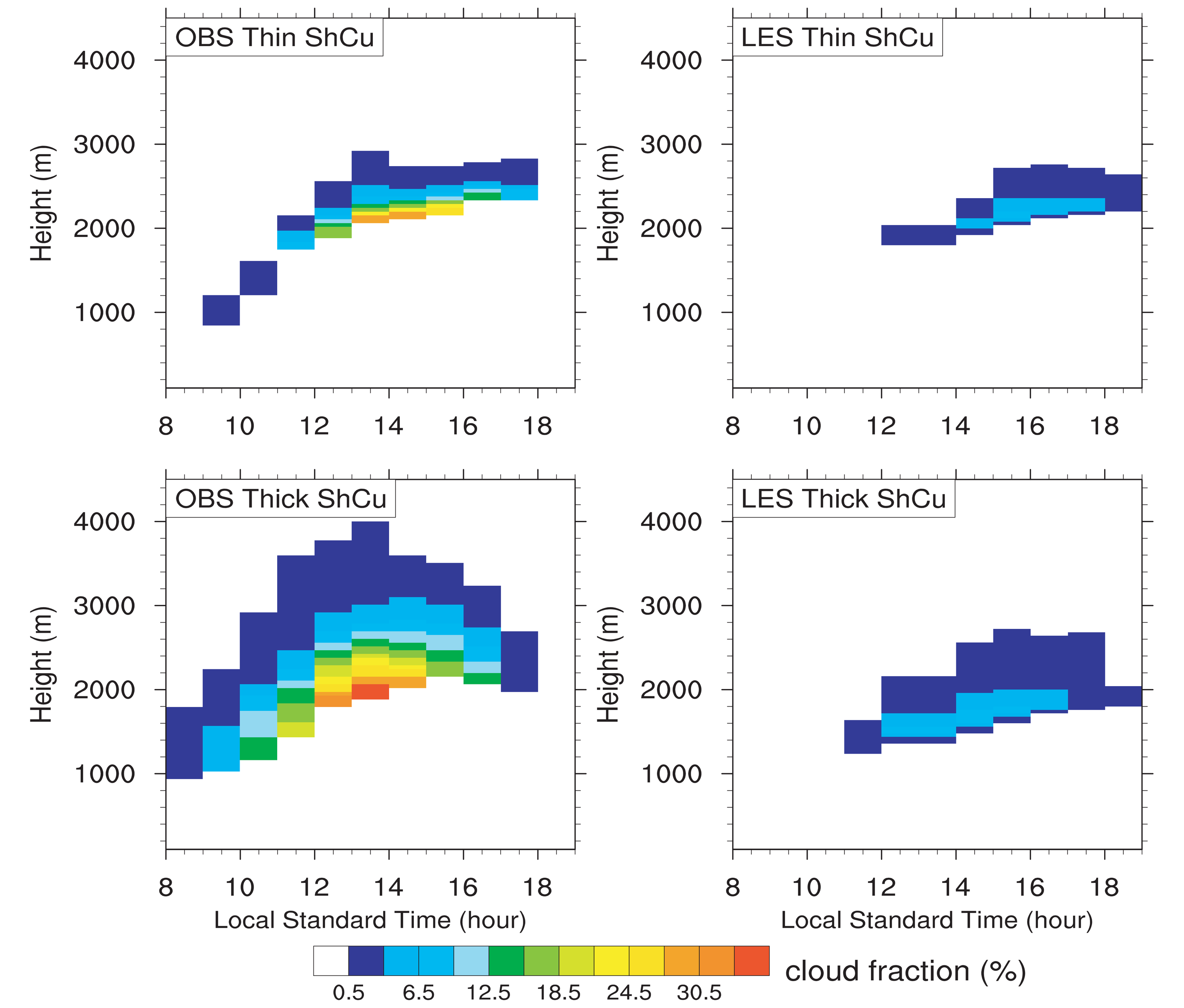
- Vertical pointing Doppler Radar
- Measure the movement of scattering targets. In non-precipitating shallow cumulus, the target is the liquid water cloud droplet
- Usually the terminal velocity of liquid cloud droplet is about ~cm/s, this is much smaller compared to air motion velocity ~ m/s. Thus the vertical velocity of cloud droplet is representative of air motion
- In this study, we focus on 10s data

Temperature and Humidity

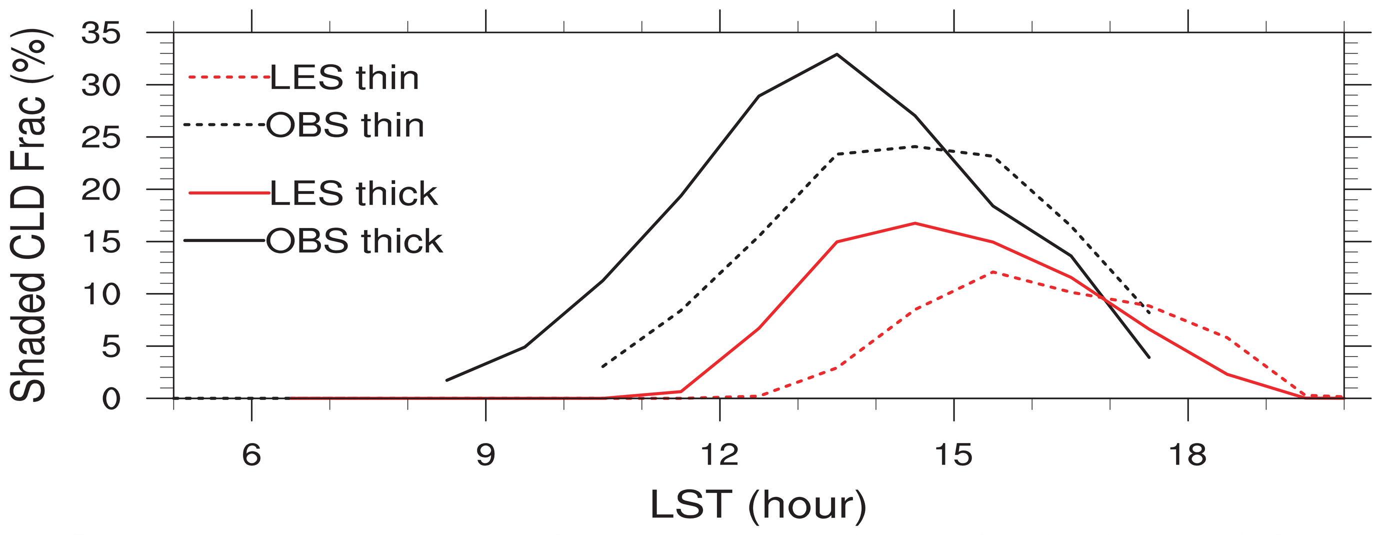


At 1130 LST, on thick cloud days, LES composite case (CC) boundary layer is cooler and moister than OBS, and the mixed layer height is also lower. These suggest no enough turbulence mixing in LES CC at this time. At 1730 LST, LES-CC mixed layer height is higher, boundary layer is slightly drier than OBS.

Cloud Fraction

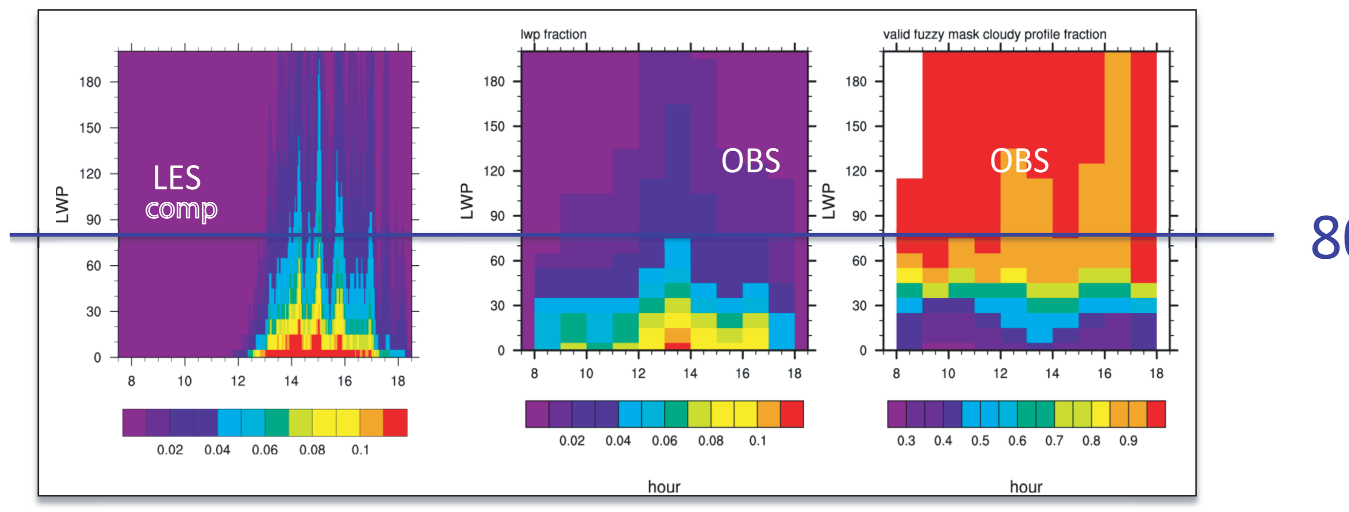


LES composite case shows diurnal evolution of cloud fraction and cloud base gradually increases with time, cloud base difference between thin and thick clouds, and the difference in cloud vertical extent; however, LES composite case has much less cloud fraction and a later onset of clouds than observation.



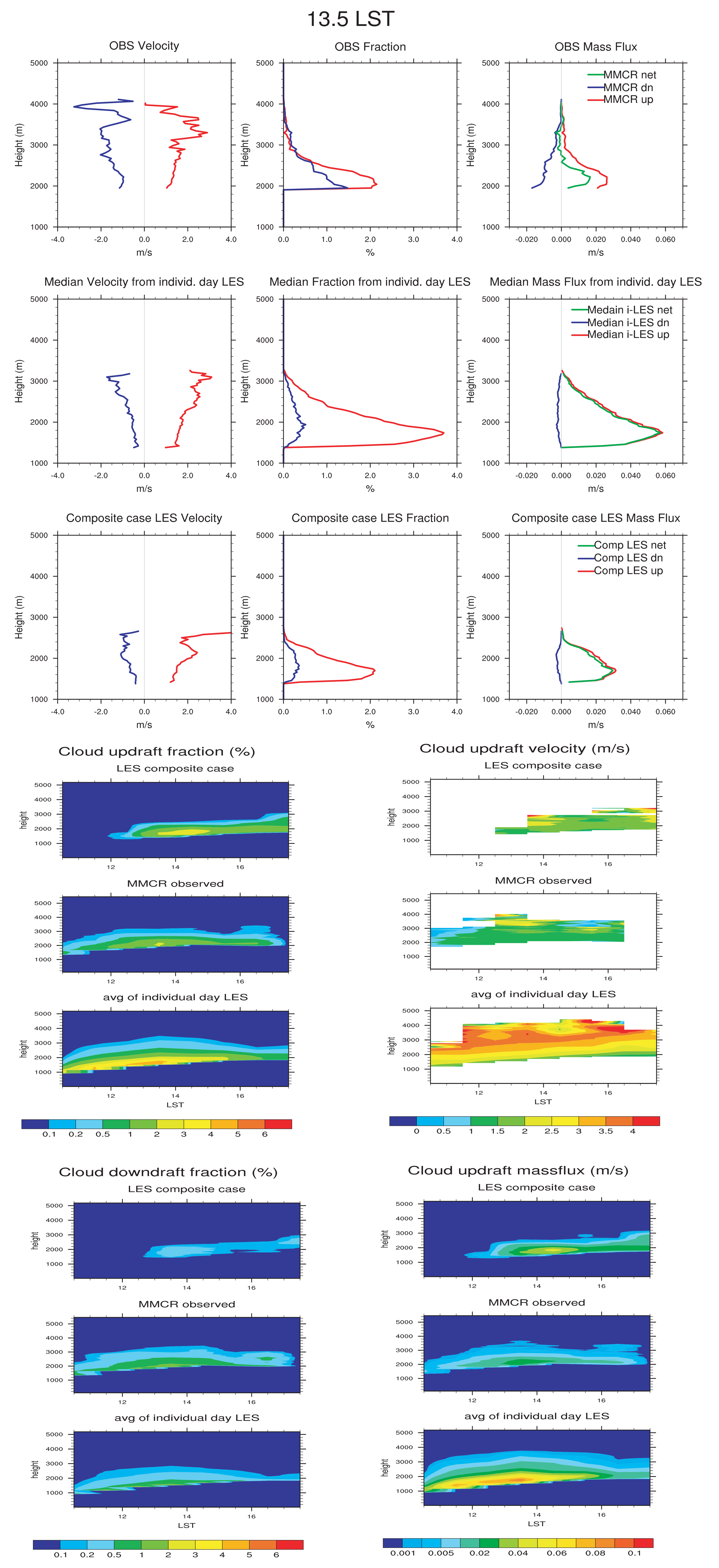
LES composite case surface projected (or shaded) cloud fraction is almost half of the observation and LES composite case clouds start later and cloud fraction diurnal maximum shows

LWP and Comparison Criterion



Left two: contour shows at each hour, the possibility to observe a LWP > certain values. Right: contour shows that at each hour, when lwp > certain value, the possibility that this profile can pass through fuzzy logic algorithm and give valid vertical velocity retrieval. e.g. at 14 LST, both LES compostie case and OBS shows that there is 6% possibility to find a cloudy profile with LWP > 80 g/m^2; at 14 LST, when LWP > 80 g/m^2, the OBS shows that 90% profiles with 80 g/m^2 or more will give valid retrievals. Thus if we use LWP > 80 as a single criterion, we are making a rather fair comparison between LES and observation.

Vertical Velocity and Mass Flux



All the comparisons above are for LWP > 80 data points.

Future Work

1. Sensitivity tests of LES to forcing and initial conditions for both composite case and individual day cases.
2. Extend vertical velocity analysis to include sub-cloud layer statistics (MMCR and recent Lidar data)

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