Response to Referee #1

I'd like to express my gratitude to the reviewer for providing thoughtful and insightful comments on this work, which have led to an improved paper.

Major comments:

1. The following discussion regarding the fixed number concentration has been added to Section 2:
   In this work the cloud droplet number concentration (CDNC) is constant. Observations of the shallow cumulus case described in Section 2.1 show an approximately constant droplet concentration with height (vanZanten et al. 2011). Slawinska et al. (2012) demonstrated the reason behind the observed constant CDNC being due to significant in-cloud activation of cloud condensation nuclei. Using a bin microphysics LES, Wyszogrodzki et al. (2013) showed that while CDNC were constant with height for the majority of occurrences in their simulations, there is variability in the CDNC fields. Therefore, while the use of a constant CDNC is a good assumption, variations in CDNC will likely affect the development of precipitation and this will not be captured in the simulations presented in this work.

2. The discussion on neglecting the effects of turbulence on the collision efficiencies has been expanded to read:
   Limited data are available for the effects of turbulence on collision efficiencies.Currently the DNS data only provide two data points, for dissipation rates of 100 and 400 cm^2s^{-3} (Wang et al. 2008). To include the turbulent collision efficiencies in this work would require them to be extrapolated out to dissipation rates of 1500 cm^2s^{-3}. The collision kernel results show that the effects of turbulence do not scale linearly with dissipation rate and two data points does not provide enough information to represent this process with any certainty for the high dissipation rates. Therefore, the decision was made not to include the turbulent collision efficiencies until more DNS data become available.

3. Wyszogrodzki et al. (2013) speculated that the dynamical enhancement was due to the off-loading of greater rain water contents acting to increase the buoyancy, but they did not analyse the buoyancy fluxes. In this work the buoyancy is examined and shows that in fact the greater rain water does not increase but rather decreases the buoyancy due to the increased water loading. Further analysis has been undertaken that examines the cloud properties in the cloud cores – the cloudy regions that are positively buoyant. The following discussion and figure have been added:
   To further examine the buoyancy characteristics of the clouds and estimate the entrainment rates, the conditional averages of vertical velocity, total and liquid water contents within cloud cores are analysed. Cloud cores are defined as the cloudy regions that have positive buoyancy as compared to the slab average. Figure 6a shows that the simulation with the turbulent microphysics has a larger area of cloud cores throughout the mid and upper cloud levels as compared to the simulation with the non-turbulent microphysics. However, comparing these profiles to Fig. 3e, we see that the turbulent microphysics case has a smaller proportion of positively buoyant cloud regions in the levels above 1300 m. The average vertical velocities in the cloud core are very similar in the simulations with the non-

turbulent and turbulent microphysics schemes, with the turbulent case having slightly weaker updrafts in the upper cloud core levels. This result together with the vertical velocities averaged over all cloudy regions illustrated in Figure 5f, shows that the turbulent microphysics simulation has increased vertical velocities in the cloudy regions that are not positively buoyant. This demonstrates that in this simulation it is not the reduced water loading associated with greater precipitation that acts to increase the buoyancy and hence the vertical velocities. Figure 6c shows that the turbulent microphysics simulation has larger average total water contents in the cloud core upper levels and this applies to the cloud liquid water as well (Fig. 6c). Diagnosing the mass flux and fractional entrainment rates using equations 11 and 16 of Stevens et al. (2001) and the total moisture mixing ratio, shows that the mass flux in the upper levels is larger for the turbulent microphysics simulation (Fig. 6d) and this is due to the greater area of the cloud cores in this case. The turbulent microphysics simulation has a smaller entrainment rate throughout the vertical compared to the simulation with the non-turbulent microphysics parameterisations, in agreement with the larger water contents in the simulation that includes the effects of turbulence on the droplet collision rates. Note that the application of the mass flux approach with a simple entraining plume model breaks down in the inversion at about 2 km (Siebesma et al. 2003) and explains the sharp gradient in Figure 6f.

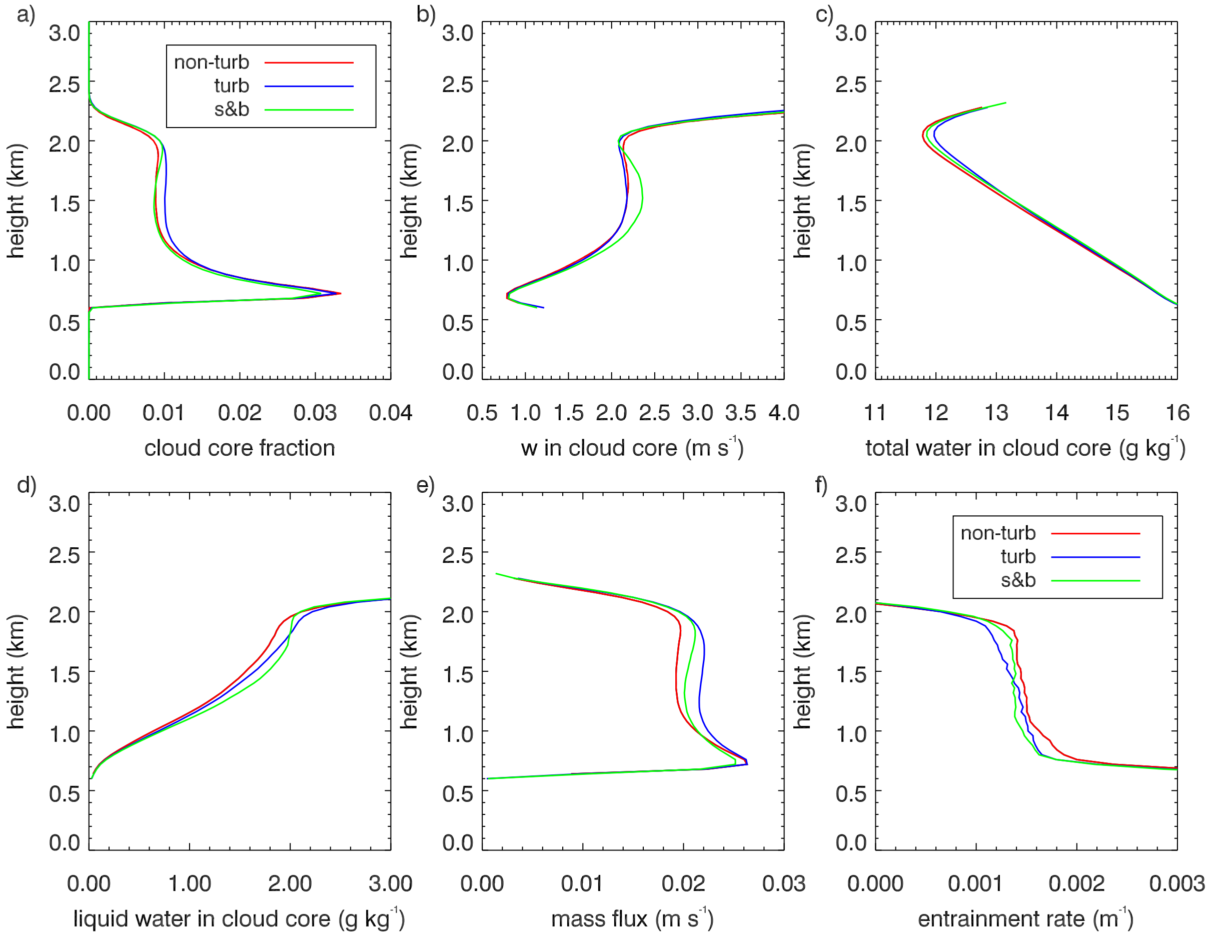

Figure 6. As in Fig. 3 except for, a) cloud core fraction, b) conditional average of vertical velocity inside cloud cores (m s^{-1}), c) conditional average of total water inside cloud cores (g

kg^{-1}), d) conditional average of cloud liquid water in cloud cores (g kg^{-1}), e) mass flux (m s^{-1}), and f) entrainment rate (m^{-1}).

Further to this, an additional comment is made in the summary section regarding the effects of refined resolution on entrainment. Matheou et al. (2011) found that the negative buoyancy surfaces that occur at the cloud-environment interface are unresolved for typical LES resolutions and discussed the impact that this may have on modelling the entrainment process.

4. Comparing the non-turbulent and turbulent microphysics results from both case studies shows that the rain water differences are statistically significant for the RICO case, with the mean rain water paths more than 1 standard deviation apart. For the DYCOMS II case it is the different CDNC that produce statistically significant differences in rainfall, not the inclusion of the turbulence effects. Therefore, for these two cases we find that turbulence has a larger effect than cloud droplet number concentrations on shallow cumuli, however, it is the opposite for the stratocumulus with CDNC having the largest control on the rain water. These statements been added to the abstract, results and summary sections.

   While the RICO case is non-stationary, the thermodynamic profiles between the simulations are very similar. If rather than calculating the rain water path statistics over the last 4 hours (mean and standard deviation of the rain water path over the last 4 hours for the turbulent and non-turbulent microphysics simulations are 7.9 ± 3.3 and 1.9 ± 0.9) and instead different time periods are used that correspond to the same inversion heights (a slightly shorter time period for the turbulent microphysics simulation), the results hardly change with the turbulent rain water path average equal to 7.8 ± 3.4. This is to be expected as the averaging period of 4 hours was chosen to be much longer than the time periods of the precipitating clouds or cloud clusters that give rise to the large variability, which is on the order of tens of minutes to an hour (vanZanten et al. 2011).

   The revised figures (10 and 11) have the standard deviations plotted on the figures. The other figures only include the standard deviation if the results are statistically significant and the means lay outside of the ± 1 standard deviation (rain water and rain water evaporation for the shallow cumuli case). Throughout the paper the results are discussed in terms of the variability and statistical significance, or lack thereof, and we note that the large variability is in agreement with other studies that have investigated the effects of aerosol concentrations on cloud properties (e.g. Xue and Feingold 2006).

Specific comments:

1. This has been corrected to read liquid water potential temperature. The approach used in the UCLA-LES is consistent with the approximation of most LES models that are used to study both precipitating and non-precipitating clouds. Stevens et al. (2005) describe that all of the 10 LES models participating in that particular intercomparison study use liquid water potential temperature as a prognostic variable.

2. The two panels in each of Figures 1 and 2 have been replotted to be larger in size and run vertically in the revised version. The labels on all of the figures have been increased in size for readability.

3. This has been rewritten to read 6.6 km square.

4. The comparison with the other microphysics schemes is now addressed for each of the case studies, as well as in the summary section. It is well established that different microphysics schemes produce distinctly different cloud properties so the fact that we see this result is not surprising. This is why the focus in this present work is on the comparison between the two Franklin (2008) schemes that are derived in the same manner except for one including the effects of turbulence on droplet collisions, and the other not including these effects.

5. The figures referred to (10 and 11 in the revised paper) have been replotted so that the larger symbol refers to the lowest cloud droplet number simulation and the +/- standard deviation has been included for each point. The liquid water in these figures is both cloud and rain.