Response to reviewer 1

We thank this reviewer for the detailed and constructive comments, which have significantly improved the presentation of the manuscript. Numerous changes have been made to the figures and throughout the text to address the reviewer's comments, as highlighted in the point-by-point response below.

General comments

We have added a paragraph (see following) to introduce VOCALS-REx at the beginning.

"VOCALS-REx (**V**ariability of the American Monsoons **O**cean-**C**loud-**A**tmosphere-**L**and **S**tudy-**R**egional **Ex**periment) took place off the west coast of Chile/Peru in the Southeast Pacific during October and November 2008. Two primary focuses of the field campaign are: (1) the aerosol-cloud-precipitation interaction in stratocumulus clouds; and (2) the coupled ocean-atmosphere-land system in the Southeast Pacific. Comprehensive measurements were made on many platforms including aircrafts, ships, buoys, and land-based instruments. Wood et al. (2011) gave a comprehensive review regarding the objectives, scope, and specific operations of VOCALS-REx."

A summary of the questions that are addressed in the study are introduced near the end of the introduction.

Specific comments

A few figure labels are too small, for example the labels of Fig 3 should be enlarged.

We have gone through all the figures to make sure the label fonts are large enough.

1. ***Maybe a few words what exactly is meant by "decoupling" would help***

   We have included the following statement to explain "decoupling" at the end of the introduction.

   "For example, one specific issue that has drawn much attention is about decoupling in the cloud-topped MBL, a process that tends to create different turbulent heating/moistening rates between the cloud and subcloud layer, leading to a two-layered structure (e.g., Nicholls et al., 1984)."

2. S. Bott is changed to A. Bott.

3. ***Page 4947, line13ff: You compare the observations in Fig 1 with the LES results***

   q_v and θ are changed to q_t and θ_l . q_v and q_c are explained in the caption of Fig. 1.

4. ***P4948,line 1: the vertical structure of observed w'ˆ2 is hardly to interpret …***

We believe that the *w* variance is very important in terms of both the magnitude and the vertical profile. Even though uncertainty exists regarding its values as for any observationally derived turbulence quantity, the *w* variance minimum just below clouds is physically significant in that a decoupled turbulence structure is clearly indicated. Because there are limited horizontal turbulence legs (5 in-cloud legs) and limited length for a leg (only 10 minutes long) from aircraft measurements, it is difficult to derive error bars for $\overline{w'^2}$ using the measurements. It is, however, noteworthy that the observationally derived $\overline{w'^2}$ is in general consistent with those derived from other twin-otter flights as shown in Zheng et al. (2011) in terms of both magnitudes and vertical structure. This statement is included in the revised manuscript. We have also computed the in-cloud averages of the mean and some turbulence variables from both LES and measurements and listed in Table 2 (see attached table 2) for comparison.

5. P4948; ***Line 5-13. Can you briefly explain the reason of the correlation between W'ˆ2 and***

   It is true that $\overline{w'^2}$ depends on both the buoyant and the shear production of turbulence. Because the shear occurs in the inversion, its effect is more-or-less concentrated within and near the inversion where $\overline{w'^2}$ tends to be increased. Just below the cloud base, there is no turbulence production in terms of both buoyancy (zero from Fig. 3e) and the shear (no shear in the MBL). Therefore, $\overline{w'^2}$ exhibits a minimum there. In the cloud layer, even though positive buoyancy flux is present, its magnitude is reduced in SS because the radiative cooling is reduced due to the decrease in the liquid water and due to more buoyant air entrained in SS. Consequently, the in-cloud $\overline{w'^2}$ value in SS is the minimum among the three cases.

6. ***P4949, line 8: You mention that for negative w'3 we have "narrow and strong …."***
   The sign of $\overline{w'^3}$ is related to asymmetry of the *w* PDF. It is negative when large positive values of w'^3 are not as frequent as the large negative values. Therefore, *w'* must have large negative values. Furthermore, the net mass flux due to turbulent motion at a level must be zero, thus negative *w'* must have smaller area in order to have a balance between upward mass and downward mass flux for a negative $\overline{w'^3}$. Consequently, turbulence field with a negative $\overline{w'^3}$ must have stronger downdrafts with narrower fractional area. Vice versa for positive $\overline{w'^3}$. The downdraft fraction, up/down-draft velocities are calculated and presented in Fig. 4 in the revised manuscript; they clearly demonstrate this feature.

7. ***General comment to Sec 3: It is not completely clear why you have the three….***

   Why are three simulations performed? Three simulations with different large-scale forcing conditions are performed to understand the impact of wind shear. In the meantime, we would like to use realistic environment conditions such as solar radiation as much as possible for comparison with observations. The large-scale condition in SS matches the reality better than other simulations. It is our expectation that the SS result should compares with observations better than others. It is not a surprise. We revised relevant sentences to improve the clarity.

8. ***Section 4. Inversion Layer: I would suggest including profiles of the mean values***

The variances of temperature and moisture provide overall description of the inversion, as they are not only related to the gradient, but also to the turbulence intensity. The cloud-top heights can be easily identified by the level at which $\overline{q'^2_c}$ diminishes (Fig. 5b). One could argue that the inversion layer thickness may be better defined in terms of the scalar variances. We agree with the reviewer that both the variances and mean temperature/moisture profiles should be presented side by side for comparison. The $\bar{\theta}_l$ profile is shown in Fig. 7b along with cloud fraction (Fig. 7c) in connection with the Richardson number PDF. It would be repetitive to present $\bar{\theta}_l$ profile in both figures. We really have a dilemma here about where the inversion layer profile should be presented. In the final analysis, we still feel it is better to show $\bar{\theta}_l$ profile in Fig. 7b as it is important to illustrate where the levels are within the inversion in the figure. The z_{tiop} and z_{ibase} are also marked in Fig5a for comparison in the revised manuscript.

The cloud fraction is also presented in Fig. 7c for identifying the cloud-free sublayer. In the paper, we present various turbulence statistics and mean profiles to allow readers view the MBL (including inversion) structure from various perspectives. For example, the vertical inversion structure can be viewed in terms of both the mean and the variance profiles. The unit of the q_c variance was indeed wrong; it has been corrected.

9. ***P4950, line 12. Why do you deduce all these statements from variance profiles……***

See response above.

10. ***What exactly do you mean with "inversion structure" on page 4950…..***

"Inversion structure" includes the thickness, turbulence intensity, cloud fraction, and turbulence PDF among other things. Because *Ri* represents the dynamic stability of the inversion layer, it is expected the structure is linked to *Ri*. For example, we are trying to show the relationship between the inversion thickness and Ri (Fig. 5 and 6), and turbulent fluctuations and Ri (Fig. 7 and 8). $\overline{\theta_{vl}}$ is defined immediately after Ri formulation (1). Because $\overline{\theta_{vl}}$ includes water vapor effect, it is more precise than $\bar{\theta}_l$ for Ri.

11. ***The Richardson number should be briefly discussed; what does a Ri > 0.25 means …***

We have added more discussions on *Ri* in a number of places. After the Richardson number is introduced, the following statements are included.

"It is commonly accepted that the critical value of *Ri* is 0.25, below which the flow becomes turbulent, although suggestions in the literature range from 0.2 to 1.0 (Galprin et al., 2007). For the boundary layer flow with *Ri* between 0.25 and 1, intermittency turbulence may dominate at a moderate to low intensity (Sun et al., 2011)."

We have also included the following in the discussion of Fig. 6.

"The phenomenon that an equilibrium bulk Richardson number can be reached with the increasing wind shear have been studied by a number of authors as highlighted in the introduction section. For example, Conzemius and Fedorovich (2006) argue that the equilibrium value of *Ri* (0.25) points to a balance between shear production and buoyancy consumption of TKE for a clear sheared convection regime. In other LES simulations, the Kelvin–Helmholtz instability is developed within the inversion layer with a slightly larger *Ri* value ~ 0.5 (Kim et al., 2003)."

12. ***P4951, Line 20. I do not understand the reason for the small jumps.***

    We have removed the "small jumps" statement. We instead state, "It is notable that Ri_b of SS decreases, but tends to stay slightly above 0.3 for last 3 hours despite the increase of the overall wind shear $\sqrt{(\Delta\bar{u})^2 + (\Delta\bar{v})^2}$ (Fig. 6d) and Δz_i."

    "These LES results in general agree with the detailed observation analysis by Katzwinkel et al. (2011). Their analysis shows that the inversion layer is turbulent with the gradient *Ri* ranging between 0.2 to 0.7 in the inversion layer and the depth of the cloud-free sublayer between 37m and 85 m." However, their results show that the entrainment rate should decrease with an increase in the depth of the turbulent and cloud-free sublayer. We have not obtained this result. The difference is clearly stated at the end of section 5 in the revised manuscript.

13. ***Please include a reference for your Ri interpretation on p4952, line 17.***

    We have included Moeng et al. (2005) and Galprin et al. (2007) in the manuscript. "turbulence activity" is changed to "turbulence".

14. ***you mention always the "cloud-free sublayer"; there is no figure which really shows that such a layer exists?....***

    In Fig. 5a, we have included z_{itop} and z_{ibase}. The level at which $\overline{q_c'^2}$ vanishes should be the cloud-top. One clearly sees the difference between z_{itop} and z_{ctop}.
    In Fig. 6, time series of z_{itop}, z_{ibase}, and z_{ctop} are plotted for each simulation in previous and current version of the manuscript.

15. ***Fig 8; caption: "For the WS simulation (third column)" should be "for the NS simulation.." Why do you show the third column? …***

    "WS" is changed to "NS". In previous version, only scatter plots were given for NS. In the revised manuscript, the actual PDFs are calculated and presented in the 3rd column in Fig. 8. (see attached figure) The vertical motion is extremely weak ($w < 0.13$ ms^{-1}) for NS, indicating weak or no turbulence at all.

16. ***P4952; line 27: What do you exactly mean with "Large flow variability. . .".…***

We are discussing how the variability of *w'*, θ' and q'_v depends on *Ri*, which is not discussed in previous results. We have added more statements to make this point more clear. These joint PDFs demonstrate that local flow characteristics within the inversion layer are a strong function of the instantaneous local Richardson number.

17. ***P4953, line 22: This sentence makes no real sense to me ….***

    This is a very good point. Even though the solar radiation is present in all the simulations, the impact of the shear on the decoupling may not be readily identified because the total effect of the two processes (solar radiation and shear) is not necessarily an addition of the effect by each isolated individual process. Fig. 3e shows very similar and decoupling-like buoyancy flux from three solar-simulations, promoting us to ask: does shear alone have any impact on the decoupling? Is it possible that the decoupling occurs during nights due to strong shear? We include these statements to clarify our intention.

18. ***P4959, line 6: Isn't the statement "Wind shear always exists. . ." a little bit too general?***
    This is changed to "Wind shear exists most of the time."

19. ***Not sure if a table (Table 1) with one line is really needed.***
    Table 1 is combined with Table 2 now.

Table 2. Comparison between LES and observation results averaged in the cloud layer

Cloud Layer Avg.	$\overline{\theta_l}$ K	$\overline{q_t}$ g kg^{-1}	$\overline{q_c}$ g kg^{-1}	$\bar{u}$ m s^{-1}	$\bar{v}$ m s^{-1}	$\overline{w'^2}$ m^{2}s^{-2}	$\overline{w'\theta_v'}$ W m^{-2}	$\overline{w'^3}$ m^3 s^{-3}	Stress N m^{-2}	$\overline{w'q_t'}$ W m^{-2}
OBS	290.5	7.86	0.09	0.4	-2.0	0.1	3	-0. 017	0.02	8.0
SS	290.2	7.87	0.15	5.1	-0.5	0.09	4.2	-0.005	0.03	21.8
WS	290.0	7.98	0.23	2.5	0.9	0.11	8.8	-0.013	0.015	21.3
NS	289.9	7.98	0.27	0	0.0	0.14	11.2	-0.020	0.004	17.3

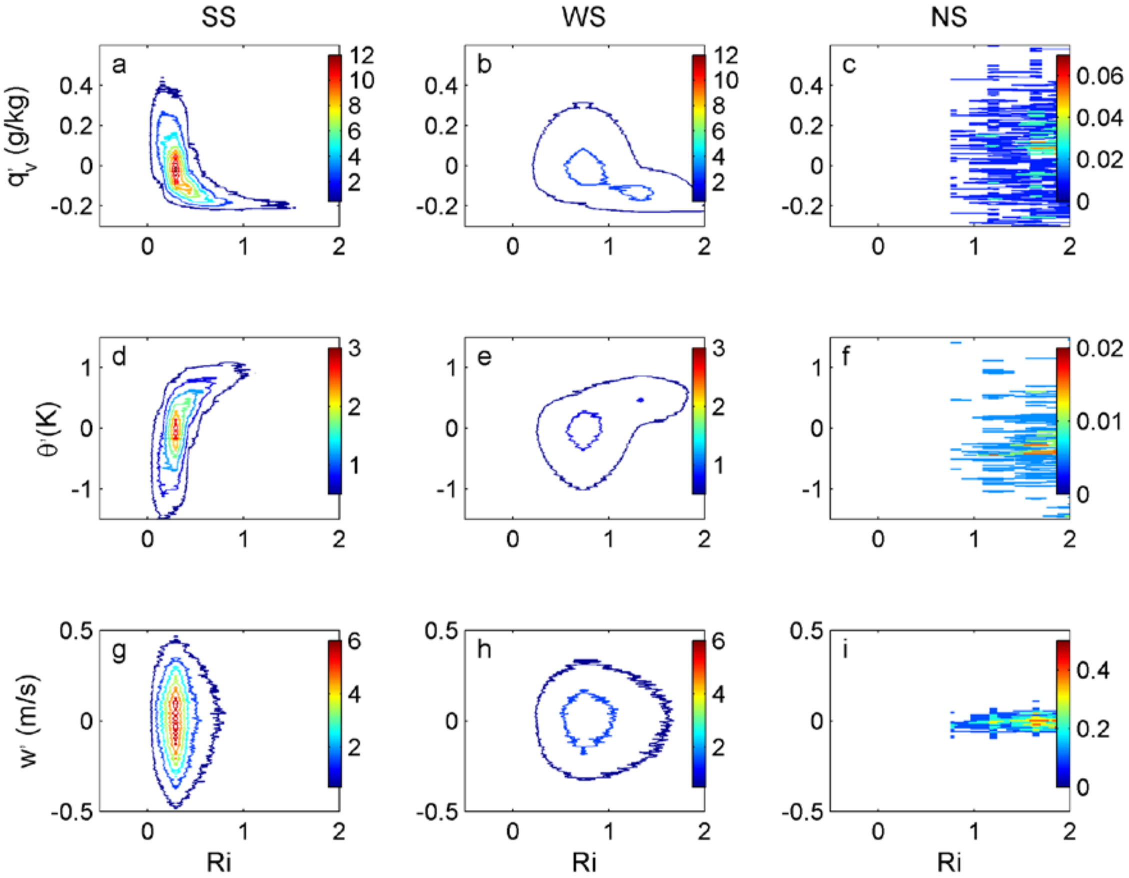

Fig. 8: Joint PDF of R_{il} with other variables (q_v, θ and w) in the cloud-free sublayer. The first column is for SS; the second WS; and the third NS. The first row presents $\boldsymbol{R_{il}-q'_v}$ joint PDF; the second $R_{il} - \theta'$; and the third $R_{il} - w'$.