Response to Anonymous Referee #1

We thank reviewer #1 for the constructive criticism, which should lead to a number of improvements in the presentation of our material. Below are point-by-point responses, with the reviewer comments in normal font and our responses in italic font.

Major Comments

1. Ozone mixing ratio height

I think care should be exercised when using this diagnostic during seasons when rainfall is low. During dry seasons, the seasonally averaged ozone mixing ratio at the LNB will be larger. For an individual ozone profile, in which the ozone mixing ratio height is defined as the highest altitude at which ozone is lower than the seasonal ozone mixing ratio at the LNB, one would therefore place the ozone mixing ratio height at a higher altitude. The ozone mixing ratio height will therefore start to lose meaning when the upper tropospheric ozone mixing ratios become decoupled from boundary layer mixing ratios, due to an absence of convection. I would have been more comfortable with an ozone mixing ratio that was related to the seasonal mean value of ozone in the boundary layer, and would recommend sensitivity studies using this alternate definition. I suspect you would get a stronger seasonal variation in the blue curves of Figure 9.

We agree in general that ozone at the LNB may not be the 'best' threshold to be used for the ozone mixing height (note the meaning of 'mixing' is different here from that in 'mixing ratio'). We actually had considered using boundary layer ozone as a reference, however ozone does not typically fall below it's boundary layer values anywhere in the profile. The only way to remedy this issue would be to introduce a 'dilution' factor or offset which would introduce another degree of freedom. We instead opted for the more practical LNB related threshold. Related comments have been added to the text.

Please note that tropospheric ozone is strongly influenced by convection, i.e. it will show elevated values throughout the entire tropospheric profile during dry seasons (see Fig. 9, bottom). At Samoa tropospheric ozone during the dry season is also enhanced due to biomass fire sources. A higher ozone @ LNB value during dry seasons will therefore _*not*_ *generally result in higher but often in lower ozone mixing heights.*

2. Absence of Lower Tropospheric and Surface Cooling from Deep Convection.

It is well established from observations and CRM's that deep convection is associated with cooling in the lower troposphere and boundary layer, especially in the near field (Mitovski, J Clim 23, July 1, 2010; Mapes J Clim 22, Jan 15 2009; Mapes and Houze, JAS, May 15 1995; Mapes, Dyn Atmos Oceans 42, 2006; Benedict and Randall, JAS 66 Nov 2009; Mitovski JGR 117, 2012). Although the focus of this paper is on the upper troposphere, Figure 7 shows only a tiny hint of a cooling near the surface. This inconsistency with previous analyses should be discussed. I suspect the main reason for the difference is that GPS COSMIC temperature is not good enough below 5 km to show the lower tropospheric and boundary layer cooling. But there may be methodological differences also (e.g. using clouds rather than rainfall as a proxy for convection).

This needs indeed to be discussed in the paper, we thank both reviewers for pointing this out. The COSMIC product we used should look like ECMWF analyses in the lower troposphere and it's possible that the lower tropospheric signal is absent because of biases in these analyses. On the other hand, Mitovski et al. 2010 show this cold anomaly exists in ERA-40 and ERA-interim when using rainfall as proxy for deep convection. The more likely explanation for the missing lower tropospheric cold signal here therefore comes from not using rainfall as descriptor of deep convection.

Surface cold-pooling is directly related to rainfall and the more mature stage of deep convection. During the onset of deep convection the lower troposphere is expected to be anomalously warm to support strong convective plumes. Our temperature signal likely includes a broad spectrum of the deep convective life cycle stages resulting in a near cancellation of warm and cold near surface anomalies. Similarly, our lower tropospheric temperature signal will represent (organized) convection on a range of scales: only at small scales does a cold lower tropospheric anomaly show up (e.g. Folkins et al. 2008), at either very large spatial scales or long time scales a vertically coherent tropospheric warm anomaly extending throughout the tropospheric column has been found (e.g. Kiladis et al. 2001, QJRMS, in the case of the MJO and ENSO). Please note that our results are consistent with previous studies looking at temperature correlations / regressions (e.g. Holloway & Neelin 2007).

3. “Convective Influence"

The paper sometimes uses the term “convective influence", as in, "the conventional LNB appears to effectively define the maximum vertical extent of convective influence." (page 19634). However, there are many ways to define convective influence. In the case of chemical tracers, one mainly cares about the convective detrainment profile. In the case of clouds, one mainly cares about the highest altitudes to which clouds can rise, and the locations in which the temperature perturbations associated with convection can give rise to supersaturation (often disconnected from the mass outflow itself). A well known problem here is that cloud top height is often very different whether one is using a thermal or visible signal, so there is an intrinsic ambiguity in its definition. In the case of temperature perturbations, one cares about the locations to which convectively generated waves can propagate, and also the radiative decay timescale (since the height variation of this timescale has such a strong influence on the amplitude and persistence of the temperature perturbations.) In the case of of lower stratospheric ascent forced by dissipating Rossby waves, one could say convective influence extends well into the stratosphere. There is no single way to define a specific highest height of convective influence, and I think it is confusing to the field to think that there is a unique definition. In the case referred to here, it seems as if the author is implicitly defining convective influence as the maximum height to which convective clouds extend. In this case, it is much better to simply be specific about the particular physical process you are referring to, and avoid the term “convective influence” as overly vague.

Agreed – thank you for pointing out this imprecise wording. We have modified the text accordingly in places where ambiguities exist.

4. Larger distance of temperature anomalies during DJF

This comment refers to Figures 7 and 8. From what I understand, these figures only use the latitude range where the sun is directly overhead, so (20S - Eq) for DJF and (Eq - 20 N) for JJA. The fraction of convection over land in the NH during JJA is likely significantly higher than in the SH during DJF. So one possibility is that the differences are due to land/ocean differences rather than intrinsic. For example, if convection over land more easily reaches 17 km for a given rain rate (this seems plausible), then the differences in the temperature anomaly patterns could arise from differences in the rain rates, i.e. the JJA temperature anomalies are weaker because the rain rates corresponding to clouds above 17 km are on average weaker. One could therefore repeat the analysis using a TRMM rainfall threshold rather than a cloud occurrence above 17 km threshold.

Repeating our analysis with TRMM is beyond the scope of the present paper but would be valuable in a future study. CloudSat does not completely truthfully represent the asymmetry between ocean and land in terms of deep convective cloud top heights, i.e. most of the highest clouds are found over the west pacific. This may be due to CloudSat sampling which only overpasses a given point at 1:30 am and pm local time, so likely misses the strongest convection over land. The main difference in cloud tops > 17 km between DJF and JJA appears to be the shift in longitudinal region over which these occur. Understanding the different response between DJF and JJA is something that should be followed up in future work. We have added a panel to Fig. 2 showing JJA statistics and relevant discussion to the text.

Minor Comment:
line 15, page 19633: "In contrast, the LRM and ozone minimum height do not appear to represent deep convective cloud tops well." Yes this would be expected, since the ozone minimum feature is caused by a maximum in convective detrainment, which is several km below cloud top.

Agreed. Text modified.