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Interactive comment on "Airborne observation of mixing across the entrainment zone during PARADE 2011" *by* F. Berkes et al.

Anonymous Referee #2

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"Airborne observation of mixing across the entrainment zone during PARADE 2011" by Berkes et al. presents a detailed meteorological analysis of a tropospheric mixing event and shows the dynamical processes that affect the distributions of O3 and CO2. New insights into mixing are presented in a manuscript that is concise and clear. The unique examination of the consequences of cloud structure upon mixing and the use of CO2 as a tracer for mixing make this manuscript a valuable addition to the literature.

The impact of the paper could be enhanced by drawing more connections with current research. The introduction is excellent and thoroughly describes many of the foundations for this work. But it isn't completely clear to me how this research that carefully examines a single event can be used for future studies. Will it be necessary to have the complete suite of measurements and analyses presented here to interrogate mixing?

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Do clouds regularly drive this sort of mixing, and can these results be expected for other locations? Is CO2 a reliable tracer for mixing between the free troposphere and PBL? Can anything be said more generally about when and where this sort of mixing can be expected?

If it is possible to make more general statements about the case study presented here, then the results may be especially helpful for understanding ozone entrainment and mixing in the US. In the western US, vertical transport is particularly important for understanding compliance with air quality regulations, since ozone standards are tightening and some regions are strongly influenced by downward ozone transport from the FT. Referencing a few of the recent papers that discuss baseline ozone in the US and the contribution from downward mixing (e.g. Jaffe, ES&T, 2011; Cooper et al., Science, 2015; Lin et al., JGR, 2012) will help connect this work to a large and active research area.

Many papers use CO rather than CO2 as a tracer for tropospheric air. Why is this the first use of CO2 and O3 to examine mixing (pg 29175, line 6), as both molecules are regularly measured? Justifying the use of CO2, which can be influenced by the biosphere as well as anthropogenic emissions, would be helpful. CO2 has been used as a tracer for pollution in winter, but in summer CO2's utility as a tracer is diminished because uptake and respiration introduces considerable variability. Noting the limitations for using CO2 to diagnose mixing would be helpful. CO2 variability is used here as an indicator of mixing. Quantifying this variability will help to connect these results with other studies. The mixing lines are a consequence of CO2 and O3 differences between the free troposphere and PBL, and comparing the variability to this difference may also provide a metric that could be used to quantify mixing.

The figures are clear, but some of the legends are confusing. The text describing figures 6 and 7 mentions panels a) and b), but those labels don't appear on the figures, or appear with the date so as to be confusing. For figures 6-8, the confusing date/time label should be removed, and the date should be mentioned in the caption (the time

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already is). The label in figure 8 that lists the time contradicts the caption. The legend for figure 5 should change "PBLH/RLH" to "aerosol layer height". I don't understand the CO_2 scale at the top of figure 5. If the times are given in local solar time, then the "morning/noon/afternoon" labels could be removed to declutter the figure.

Smaller comments: 1) Verb tense switches inconsistently between past and present, which leads to some confusion. I recommend that all descriptions of the field measurements from 2011 be written in the past tense and all descriptions of the current analysis be written in the present tense. For example, section 2.2.2 "The pressure was obtained...". Section 3.2 "PBLH decreased..." and "air mass composition was probed..." Section 3.3 "residual layer was..." and "CO_2 was again well mixed...". Section 4.2 "PBLH grew to ..." Section 5 "PBL was convectively driven during that day..."

2) Some of the terminology is unclear. The stable layer is mentioned in the 2nd sentence, but never again in the text, yet it shows up on the figures. The text should discuss more clearly when the term PBL is used, and when SL/RL are used. I don't understand the sentence pg 29174, line 17 that mentions the inversion layer. Which layer is this? And how does the barrier exhibit gradients?

3) Please note time response for all the measurements 2.2.1, which will be important if variability is quantified.

4) pg 29184, line 9: replace "not directly related to clouds" with a sentence that states the measurements were not obtained in clouds. Later, the importance of clouds was noted, and that the measurements are related to clouds.

5) Why do the O_3, CO_2 and water mixing ratios change with altitude in the PBL, as shown in Fig 7? Is the potential temperature constant? Is the PBL well-mixed when there is a strong vertical gradient in mixing ratios?

Pg 29174, line 29: replace aloft with above

Pg 29175, line 21-23: remove sentence, as the air mass influences are described

better in the next paragraph

Pg 29177, line 5: use m asl instead of km to be consistent with the rest of the paper

Pg 29177, line 3: describe the profiles more specifically: spirals, and give the radius of the spirals.

Pg 29178, line 24: replace an with a

Pg 29179, line 3: replace "in 10 min average" with "as 10 min averages"

Pg 29181, line 11: replace "High CO2 values" with "CO2"

Pg 29184, line 13-14: Remove "after discussing" and replace "we use these information" with "are used"

Pg 29185, line 5: replace sentence beginning with "In this altitude…." With "The EZ was sampled at this location and time".

Pg 29187, line 3: replace "has grown" with "grew".

Pg 29190, line 1: difference rather than differences

Pg 29192, line 4: "…lead to variability that can be characterized by mixing lines"

Fig 1 – include Mt Kleiner Feldberg on map

Fig 5 caption: replace rain bow with Rainbow

Fig 7 caption: replace "related due to the mixed air masses.." with "influenced by mixing air masses from the PBL…"

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