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Interactive comment on "Are Atmospheric Updrafts a Key to Unlocking Climate Forcing and Sensitivity?" *by* L. J. Donner et al.

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Response to Referee #2

We thank the referee for these comments and suggestions.

We have italicized the referee comments and bold-faced material which has been added to the revised manuscript. The revised manuscript is provided as a supplement to this response.

1. The manuscript reads more like a "perspective" than a "review". It seems a bit thin

as a review paper. As a perspective, it could be condensed by consolidating some repetitive texts. Maybe the authors have something in between in mind, based on the sentence "This review presents the perspective that ...." in P2. Guess the decision is between the editor and the authors.

The referee is correct. Our goal is to present a perspective. As such, we do not attempt to present a classical review but to present more selectively key literature and a few original results, intended to stimulate new lines of research going forward. We have also adopted a style more appropriate for a perspective, including emphasizing key points by recapitulating them after they are first explored and then their implications are further developed.

One of us (Bernhard Vogel) contacted editor Ulrich Pöschl regarding the suitability of a perspective for ACP, which does not formally have this category of paper at the present time. We have followed his suggestion in submitting it as a review but with the request that it be viewed as a perspective.

2. It is not clear whether the paper is about deep convection, shallow convection, or convection in general. Please clarify. In fact, the issues in question are very generic.

We do indeed intend that the issues we raise be regarded as generic, applying to vertical velocities on all scales. We have added the following explicit statement in Section 5:

We posit that vertical velocities on all scales (deep and shallow convection, large eddies in stratiform clouds, large-scale ascent) carry important clues to climate forcing and climate sensitivity.

3. The scaling argument in the second paragraph of Section 4 seems incomplete. The resolution dependence derived from the continuity equation should be for vertical velocity difference, not the velocity itself. A relationship between the vertical velocity and its spatial difference seems necessary for the latter?

If the continuity equation is integrated upward from the surface, where (approximately) vertical motion vanishes, the scaling presented here holds. The argument presented is a scaling only. Precisely, as the reviewer suggests, horizontal variations in horizontal velocity are related to vertical differences in vertical velocity. The pressure difference can be considered as part of the proportionality in the velocity scaling on p. 5, l. 18.

4. The discussion on role of vertical velocity in climate sensitivity in Section 3 is not as obvious as one would like. Entrainment and convective mixing are identified; but some link of entrainment and mixing with vertical velocity would help. For example, a recent study by Lu et al (J. Atmos. Sci. 73, 761-773, DOI: 10.1175/JAS-D-15-0050) examined the relationship between vertical velocity and entrainment rate in shallow cu.

We now explicitly note the link between entrainment and vertical velocity at the beginning of Section 3, where studies relating entrainment in climate models to their sensitivities are discussed:

The strongest suggestions of a link emerge from several studies showing that convective entrainment, an important control on vertical velocity, is related to the climate sensitivity in general circulation models...

In Section 4, where the revised manuscript discusses in more detail the modeled and observed convective vertical velocities in Fig. 5, we discuss the possibility that new

formulations for convective entrainment, including Lu et al. (2016), will change distributions of parameterized vertical velocities:

Consistent with radar observations, the modeled median vertical velocities are similar over both time periods analyzed, but the observed strongest 1% of the vertical velocities differ by about a factor of two, while the strongest model velocities change little. Observed convective available potential energy (CAPE) does not differ greatly between the two time periods, consistent with the small changes in median vertical velocities but not the larger changes in the strong tails of the distribution. These early results point to both opportunities and challenges in the development of new parameterization strategies. The excessively strong modeled median vertical velocities suggest examining alternate formulations for entrainment (de Rooy et al., 2013; Zhang et al., 2015; Lu et al., 2016), drawing on recent research in this area. The striking differences in how the median and extreme velocities differ in the two time periods suggest more fundamental changes in the parameterization framework. The parameterization currently forms its plumes in the mean state. The similarity of CAPE during both time periods does not favor large differences in vertical velocities. The explanation could well be sub-grid variability in thermodynamic state, probably related to convective organization and currently not parameterized. Another important factor is a lack of scale awareness in the parameterization, which has been calibrated for scales comparable to those of the GATE campaign. Accounting for sub-grid variability and modeling the transition to explicit representation of these scales as resolution increases are related problems. In this perspective, we do not propose solutions to these issues but emphasize the importance of observation of vertical velocities at convective scales to guide future modeling, explicit and parameterized, of convection in the climate system.

5. Guo et al (Characteristics of vertical velocity in marine stratocumulus: Comparison of LES simulations with observations, Environ. Res. Lett., 3, 0450J. doi:10.1088/1748-9326/3/4/045020) seems a good ref to the discussion in P8, esp. in the context of how well vertical velocity is represented in LES, its PDF, structure function and resolution dependence.

This is an important reference, and we thank the reviewer for reminding us of it. We added the following in Section 4:

Even in large-eddy simulations with resolutions on the order of tens of meters, important details of the distributions of vertical velocities are at variance with observations (Guo et al., 2008).

6. Some subscripts are missing in Fig 1, maybe due to file conversion. Also what do the different colors represent?

The subscripts and a legend box showing the meaning of the colors appear on our PDF versions of the manuscript. Their doing so may depend on how you open the document from http://www.atmos-chem-phys-discuss.net/acp-2016-400/#discussion. If opened embedded inside the Firefox browser, the labels and subscripts are correct. If the very same document is downloaded and opened within Adobe Acrobat Reader DC there are problems of the nature the reviewer describes.

We will work with ACP production staff to resolve any remaining problems with the PDF.