Geosci. Model Dev. Discuss., 8, C2365–C2368, 2015
www.geosci-model-dev-discuss.net/8/C2365/2015/

Geoscientific Model Development Discussions
Open Access

Interactive comment on "A unified parameterization of clouds and turbulence using CLUBB and subcolumns in the Community Atmosphere Model" *by* K. Thayer-Calder et al.

K. Thayer-Calder et al.

katec@ucar.edu

Received and published: 2 October 2015

The authors wish to begin by thanking the anonymous reviewer for volunteering their time to write this review.

This is an important paper on an essential topic in climate modeling. Developing and implementing more unified parameterizations of clouds, convection and boundary layer mixing is absolutely fundamental for future progress in climate prediction. The method developed and implemented by the authors is indeed a promising one. The paper, however, should not be published before some major revisions are performed that can significantly improve the paper in a fairly easy manner.

1) The paper fails in framing their work in the context of previous research from a variety of perspectives. The main problem is that from reading this paper, the reader is left with the impression that this is basically the first time that pdf cloud parameterizations are used and implemented in atmospheric and climate models. However, cloud parameterizations based on pdf ideas have been proposed in the 1970s and there is a large body of literature over the years discussing pdf cloud parameterizations in atmospheric models: the authors should correct this serious oversight.

The new manuscript writes: "Assumed PDF parameterizations have a long history in atmospheric science (e.g., Manton and Cotton, 1977; Sommeria and Deardorff, 1977; Mellor, 1977; Bougeault, 1981a, b; Lewellen and Yoh, 1993). For several decades, PDF parameterizations have been implemented in regional or global models (e.g., Smith, 1990; Tompkins, 2002; Nakanishi and Niino, 2004)."

2) In addition, the authors fail to discuss in any detail some other topics/developments: How does their work relate to the more traditional developments of cloud microphysics implementation in climate models (and the coupling of microphysics with the other parameterizations)?

The original manuscript stated that "assumptions about subgrid variability, such as those regarding vertical overlap of condensate and vapor, are removed from the microphysics scheme and instead embedded in SILHS (Larson and Schanen, 2013; Storer et al., 2015). This facilitates the implementation of subgrid assumptions that are more general."

However, perhaps the biggest change is that with SILHS, separate microphysics schemes are no longer required in the stratiform and cumulus clouds. To emphasize this, we have added a new paragraph: "Finally, we note that CAM-CLUBB-SILHS deviates from common practice in microphysical parameterization. Namely, climate models typically use separate microphysics schemes for separate cloud types, such as stratiform and cumulus clouds. For instance, a relatively sophisticated microphysics scheme might be used in stratiform cloud, and a simpler microphysics scheme might be used in a mass-flux parameterization (e.g., Donner et al., 2011; Neale et al., 2012). In contrast, CAM-CLUBB-SILHS uses a single microphysics scheme, MG1, in all cloud types. Although we have previously mentioned some advantages of using a single, unified parameterization for clouds and turbulence, there are also advantages to using a single, unified scheme for microphysics. For in- stance, use of a single microphysics scheme avoids complexity and allows aerosol effects on clouds to be parameterized in all cloud types."

How does their work relate to the development and implementation of other methods to unify the parameterizations of convection and boundary layer such as the recent ED-MF parameterization?

As per the reviewer request, we have included a new subsection that highlights some salient differences between CLUBB and EDMF:

"First, we compare and contrast CLUBB-SILHS with the eddy-diffusivity mass-flux (EDMF) approach (e.g., Soares et al., 2004; Siebesma et al., 2007; Neggers et al., 2009; Neggers, 2009; Sušelj et al., 2012, 2013, 2014). Broadly speaking, two types of grid-box averaging ought to be performed, explicitly or implicitly, in large-scale models: 1) grid averaging of subgrid turbulent fluxes, and 2) grid averaging of source terms, such as microphysical tendencies. Whereas CLUBB prognoses the turbulent fluxes of moisture and heat content based on the parameterization of each individual term in the flux budget, EDMF diagnoses those turbulent fluxes based on physical considerations. Whereas CLUBB-SILHS averages microphysical tendencies by Monte Carlo integration, EDMF per se delegates the averaging of those tendencies to other parameterizations. CLUBB-SILHS is more expensive than EDMF, but CLUBB-SILHS' foundation in PDFs facilitates the consistent calculation of, e.g., cloud fraction and virtual potential temperature, and allows the global use of a single microphysics scheme for all clouds."

How essential is the turbulence closure part of CLUBB in the context of their particular

investigation?

The manuscript now includes the sentence: "The inclusion of w allows the buoyancy flux, $\overline{w'\theta_v'}$, to be computed consistently with cloud fraction and cloud water."

3) This paper would improve significantly if the authors would include a couple of schematics illustrating how the pdf concept is coupled to the cloud microphysics. This is the key advancement of this work, and it deserves to be communicated better to the readers.

A schematic (Fig. 1) has been added to the manuscript.

In addition, a 4-step enumerated list of steps in the coupling is contained in Section 2 of Larson and Schanen (2013). The new manuscript now points to this paper more clearly: "SILHS' methodology is described in Larson et al. (2005) and Larson and Schanen (2013)."

4) In the validation part it would be important if the authors would refer to the uncertainties inherent to each of the observational datasets that they are using. All observations have associated errors and the authors should provide a measure of the accuracy for each of the observations used.

Every observational dataset does include uncertainty, and this uncertainty varies not only per set but also per field. NCAR has excellent discussions of the derivation methods, uncertainties, and comparisons of all of the observational data used in our study online on the NCAR Climate Data website. Our revised manuscript now includes a direct reference to the guide, in the added sentence: "More information on each observational field, including specific references and discussion of observational uncertainties, can be found online with the National Center for Atmospheric Research (NCAR) Climate Data Guide at https://climatedataguide.ucar.edu/." We also added specific uncertainty values from Stephens et al. (2012) for the observations listed in Table 4.

Interactive comment on Geosci. Model Dev. Discuss., 8, 5041, 2015.