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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Age and gravitational separation of the stratospheric air over Indonesia" *by* Satoshi Sugawara et al.

Anonymous Referee #2

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This paper extends the investigation in earlier papers, by several of the same authors, of the gravitational separation of various species in the stratosphere, and its possible implications for atmospheric transport. What is novel, and welcome, about this paper is its focus on tropical data. In principle, the paper appears to be worthy of publication, subject to attention to a few issues, outlined in what follows.

Gravitational separation does indeed, as the authors claim, provide a new perspective on stratospheric transport, but it is not made very clear just what that perspective is. Some "ad hoc" experiments are illustrated in the 2D model, in which transport parameters are changed, but things would be made much more clear if there were a theoretical exposition of the problem. For example, one could use simplified models to show how separation would manifest itself in the presence of upwelling alone, or verti-

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cal eddy diffusion alone. These would not reproduce the real world, but would provide some theoretical baseline to strengthen understanding of what a more complete model shows. One further shortcoming of the model perturbation experiments discussed in section 3.4 is that the tropics are considered in isolation from the rest of the globe. The authors may get better fits with the tropical data by changing parameters (upwelling, mixing) but that could be at the expense of agreement in the extratropics.

The relationship with the vast literature on stratospheric transport could be better illustrated by citing some of this literature more extensively than has been done. Some suggestions are outlined in the following.

Other issues, as they arise in the text (page, line):

(1,32): Determination of the BD circulation from age observations has been explicitly discussed in a recent paper by Linz et al. (Nature Geosci., 2017).

(2,10): The separate effects of circulation and mixing on age distributions are discussed in Garny et al. (J. Geophys. Res., 2014) and Linz et al. (J. Atmos.Sci., 2016). The strength of the circulation determines the horizontal gradient of age, rather than age itself; both mixing and circulation determine the vertical structure.

(5,31): Is it obvious that gravitational separation depends on mass number difference, rather than, say, mass ratio? If this is a theoretical prediction, please describe it.

(6,3): The claim that Figure 3 suggests a linear relationship seems a little exaggerated. There are basically only two points (to be sure, there are 3, but two of them are very close together). Empirically, one could fit any number of curves to the data shown. If there is an a priori expectation of a straight line (from theory, or from more extensive observations) then you should say so. Further, the line does not appear to pass through the origin, which surely it should?

(8, 25) and elsewhere: Nowhere is it acknowledged that the authors are trying to draw conclusions from data that are highly localized in time, and whose representativeness

is therefore open to question. So, e,g., the differences with the Brazil data may due to temporal, rather than spatial, variations. In general, the limitations of the temporal sampling should be prominently acknowledged.

(9,18): The differences between CO2- and SF6-based age calculations are also discussed in, e.g., Hall and Waugh (J. Geophys. Res., 1998), Ray et al. (J. Geophys. Res., 2017), Linz et al. (Nature Geosci., 2017).

(10,1): Since the CO2 seasonal cycle, like the water vapor "tape recorder" signal, propagates into the tropical lower stratosphere as a decaying sinusoid in the vertical, I do not understand why "the age difference should be larger in the lower stratosphere . . .". It depends on time of year of the data being compared.

(11,15): If it is the mass dependence of Dmi that matters most, could you show us what that dependence is?

(11,25): Given the relatively small variation of T in the stratosphere, does this term matter much in practice?

Figure 7: Why are the altitude scales different on the two frames? And can you comment on the negative ages in the northern lower stratosphere?

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