

Interactive comment on “Gravitational separation in the stratosphere – a new indicator of atmospheric circulation” by S. Ishidoya et al.

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This manuscript shows provocative new data, is of excellent quality, and is well written. The potential implications are significant, if gravitational separation can be used as an indicator of the relative strength of molecular diffusion versus eddy diffusion/advection replacement in the stratosphere. The manuscript needs only minor revision and should be published, in my opinion. I have just a few minor comments.

It is puzzling to me, intuitively, that the model predicts divergent behavior of fractionation with age under an enhanced Brewer-Dobson circulation scenario. This may just be a function of my ignorance as I am far out of my area of expertise. But shouldn't the timescale for transient approach toward a steady-state gravitational (dis)equilibrium be set just by the effective vertical eddy diffusivity and the relevant length scale?

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For example, let us assume that the effective vertical eddy diffusivity is about 1000 times larger than the molecular diffusivity. In this case the steady state gravitational profile would be about 1000 times weaker than the stagnant air case (or about 5 per meg per km per mass unit difference). For a 10 km thick layer this would imply a value of delta of -50 per meg at the top of the layer (assuming vertically-constant diffusivities for simplicity).

When unfractionated tropospheric air is injected into the stratosphere, it starts approaching the steady state in a transient fashion. The timescale for this transient approach to the steady state should be set almost entirely by the relevant length scale and the eddy diffusivity. Taking a notional value of 10 km for the former and 1 m²/s for the latter, the notional time scale should be about 10⁸ s or three years.

I don't understand why this time scale would vary under an enhanced Brewer-Dobson circulation, or alternatively, why the eddy diffusivity would decrease under such an enhancement (which would increase the amount of fractionation at steady state, but increase the time required to reach that steady state). It would be helpful if the authors could explain this in a fashion that is intuitively accessible to the reader.

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