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Atmospheric Chemistry and Physics Discussions

Interactive comment on "The Climatology of Brewer-Dobson Circulation and the Contribution of Gravity Waves" *by* Kaoru Sato and Soichiro Hirano

Kaoru Sato and Soichiro Hirano

kaoru@eps.s.u-tokyo.ac.jp

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The authors are extremely grateful to the reviewers' valuable and constructive comments on our manuscript. We are very sorry that we were not aware of the important reference, Abalos et al. (2015, hereafter referred to as A2015). Unfortunately, however, our methodology seems to be completely misunderstood by both reviewers (Anonymous referee #1 and Dr. Marta Abalos). We think that it is necessary to carefully revise the methodology part so as not to confuse the readers. However, here we will explain this method in detail as a quick response to comments from the reviewers. The motivation of our research is partly similar to A2015, but the handling of the gravity

wave drag is quite different.

We used the zonal momentum equation in the TEM framework, but we did not use the gravity wave drag calculated from gravity wave parameterizations. This is because we do "not" think that the gravity wave parameterizations accurately represent real gravity waves. In a group work regarding gravity waves published as Geller et al. (J. Climate, 2013), we showed a significant difference between observations and parameterized gravity waves, and concluded that further improvement through constraints by observations would be necessary for the gravity wave parameterizations. Candidates that may cause this significant difference from observations are that horizontal propagation of gravity waves is not included in most parameterizations (e.g., Sato et al., 2009; 2012), that small islands as a source of gravity waves are not included (e.g., Alexander et al., 2009), and that there is a large uncertainty in non-orographic gravity wave sources and distribution. Thus, we examined and adopted an estimation method without using the parameterized gravity wave drag.

A2015 reported that the residual mean flow $\overline{v}^*$ estimated from the zonal momentum equation using $\frac{\partial \overline{u}}{\partial t}$, $\frac{1}{\rho_0}\nabla \cdot F$, and parameterized gravity wave drag did not match what was obtained directly from its definition (Eq. 3 in the present ACPD manuscript). This is possible evidence of deficiency of the gravity wave parameterizations.

In our study, we used the same zonal momentum equation, but not for the purpose of estimating the residual mean flow $\overline{v}^*$, but for the purpose of estimating gravity wave drag in the real atmosphere (not parameterized gravity wave drag). The residual mean flow $\overline{v}^*$ was directly estimated from its definition in our study. We will explain the difference between the A2015's method and our method by using the following simplified zonal momentum equation:

$$\underset{(1)}{\frac{\partial \overline{u}}{\partial t}} \quad \underset{(2)}{-f\overline{v}^*} \quad = \quad \underset{(3)}{\frac{1}{\rho_0}\nabla \cdot F} \quad \underset{(4)}{+GWD} \quad \underset{(5)}{+X}$$

Here, *GWD* [Term (4)] is "not" parameterized gravity wave drag but real gravity wave drag, and Term (5) is a friction and/or viscosity term.

A2015 used directly-calculated Term (1) and Term (3) and the parameterized gravity wave drag as Term (4), ignored Term (5), and estimated Term (2). Thus, difference of the parameterized gravity wave drag from the real gravity wave drag can cause large estimation error in the residual mean flow [i.e., Term (2)]. The difference between the parameterized gravity wave drag and the real gravity wave drag would be expressed as an increment in the assimilation system.

In contrast, we used directly-calculated Term (1), Term (2), and Term (3), ignored Term (5), and estimated Term (4). It is important that we calculated Term (2) by its definition (Eq. 3 in the present ACPD manuscript). As is well known, the residual mean flow $\overline{v}^*$ estimated by its definition is a good approximate of Lagrangian mean flow (Eulerian mean flow + a quadratic term of Stokes drift) and is frequently used to estimate upward mass flux etc. quantitatively.

We showed in Okamoto et al. (2011) that this method is effective to estimate Term (4) [in other words, Term (5) is negligible compared with Term (4)] using data from a chemistry climate model (CCM). Note that gravity waves are parameterized components only in this CCM where no assimilation module is implemented.

We hope that our methodology will be clarified by this explanation.

We will also revise as much as possible following all other comments by the reviewers, if there is opportunity for revision.

References

Alexander, M. J., S. D. Eckermann, D. Broutman, and J. Ma (2009), Momentum flux estimates for South Georgia Island mountain waves in the stratosphere observed

via satellite, Geophys. Res. Lett., 36, L12816, doi: 10.1029/2009GL038587.

Geller, M. A., M. J. Alexander, P. T. Love, J. Bacmeister, M. Ern, A. Hertzog, E. Manzini. P. Preusse, K. Sato, A. A. Scaife and T. Zhou (2013), A Comparison Between Gravity Wave Momentum Fluxes in Observations and Climate Models, J. Climate, 26, 6383-6405, doi:10.1175/JCLI-D-12-00545.1

Okamoto, K., K. Sato, and H. Akiyoshi (2011), A study on the formation and trend of the Brewer-Dobson circulation, J. Geophys. Res., 116, D10117, doi:10.1029/2010JD014953

Sato, K., S. Watanabe, Y. Kawatani, Y. Tomikawa, K. Miyazaki, and M. Takahashi (2009), On the origins of mesospheric gravity waves, Geophys. Res. Lett., 36, L19801, doi:10.1029/2009GL039908.

Sato, K., S. Tateno S. Watanabe, and Y. Kawatani (2012), Gravity wave characteristics in the Southern Hemisphere revealed by a high-resolution middle-atmosphere general circulation model, J. Atmos. Sci., 69, 1378–1396, doi:10.1175/JAS-D-11-0101.1.

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