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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Contribution of horizontal and vertical advection to the formation of small-scale vertical structures of ozone in the lower and middle stratosphere at Fairbanks, Alaska" *by* Miho Yamamori et al.

Anonymous Referee #3

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Summary:

This manuscript discusses the contribution of horizontal and vertical transport processes induced by gravity waves to the formation of laminated structures identified in the lower and middle stratosphere from vertical profiles of ozone mixing ratio measured by ozonesondes over Fairbanks, Alaska. The authors estimate the ozone fluctuation caused by vertical advection from the vertical gradients present in the background profiles of potential temperature and ozone and the fluctuation of potential tempera-

ture. The difference between the observed and the estimated fluctuations of ozone is attributed to the horizontal advection. Based on the values of the variance and covariance between the estimated and the residual fluctuations of ozone, the author conclude that these fluctuations are dependent on each other and that the horizontal advection generating the residual fluctuation is dominant and is also caused by gravity waves.

General comments:

The topic addressed is relevant to the readers of Atmospheric Chemistry and Physics. There is a need for studies based on observations in order to advance our understanding of the dynamical processes regulating the distribution of ozone in the stratosphere. However, this manuscript suffers from several deficiencies. The authors have not made it clear what is original about the results presented. The relationships between the background gradients and the fluctuations of ozone and potential temperature induced by gravity waves have been documented for decades in several publications including some of the references cited in this manuscript. The authors argue that they quantified the contribution of vertical and horizontal advection to the vertical structure observed in the ozone profile. They claim that the horizontal advection is produced by gravity waves. However, the method and the analysis used the reach these conclusions are questionable as I describe in my main comments listed below. Given the substantial amount of work required to bring this manuscript up to an acceptable new piece of research, rejection is recommended.

Specific comments:

1. The ozone fluctuation due to the vertical advection is estimated from relation (4). This relation is very sensitive to the definition of the fluctuation of potential

temperature and the characterization of the background fields of ozone and potential temperature. The calculation of these important fields is not clear from the manuscript. In addition, the estimation of the contribution of the vertical advection to ozone in relation (4) uses the total fluctuation of potential temperature. Thus, it is implied that the temperature fluctuation is entirely due to the vertical motion. This assumption would be correct if the horizontal gradient of potential temperature on top of which gravity waves evolve is equal to zero. There is no argument in the manuscript supporting this assumption.

2. The authors argue that “The fact that the covariance of χ'_v and χ'_h is not zero implies that the two terms are not independent” (Line 126). They used this fact to rule out “the formation mechanism related to large-scale flow” (Line 170) and to conclude that the “non-zero covariance is possible because a parcel oscillates along a slantwise surface” (Line 171) in the presence of an inertia-gravity wave. Based on the method used to separate the horizontal and the vertical contributions, the dependence between χ'_v and χ'_h is not surprising. In fact, the authors impose relation (1) in deriving the contribution of the horizontal advection to ozone. However, this dependency does not necessary imply that χ'_v and χ'_h are physically dependent on each other through dynamics induced by gravity waves. The relative variance caused by the horizontal contribution alone seems to explain more than the total variance existing in the ozone profile! (22-25km and around 32km in Fig 3). I suggest that the authors analyze the vertical structure of the ozone profile using potential temperature as a vertical coordinate. Since ozone and potential temperature are both conserved under the influence of gravity waves, the wave-induced fluctuation in ozone should largely be removed in this coordinate. The remaining ozone fluctuations would indicate the contribution of transport induced by the large-scale flow along the main isentropes, with no perturbation in the potential temperature field.

3. The manuscript attributes at length the fluctuations of ozone and potential temperature to (inertia) gravity waves. However, little information is given on these waves. What are the vertical and horizontal wavelengths of these waves? What are their frequencies and how do they compare to the Coriolis parameter? What is the generation mechanism of these waves? How do you know that the fluctuations underlying the ozone fluctuations are indeed caused by gravity waves?

4. The spectra of ozone and temperature shown in Fig. 2 do not indicate common distinct peaks as would have been expected in the presence of gravity waves. The cross-sections presented in Fig. 4 indicate that the wave phases in the filtered ozone and the wind fields do not have the same tilts in most of the vertical range of the observations. Given that the group velocity of the waves propagates upward as implied by the downward phase propagation claimed above 30 km, why the ozone phases below 30 km do not show any sign of wave propagation? The authors claim that the two tilted lines in ozone “are almost in phase with the zonal wind component” (Line 136). This claim does not support the presence of gravity waves, as these waves would produce ozone fluctuations that are in quadrature of phase with respect to the wind field according to the linear theory of gravity waves. Also, the phase lines found in the filtered ozone above 30 km are questionable given that they are located near the upper bound of the data samples where the artifacts caused by the end effects of the filtering process are severe.

5. The authors state in Section 3.4 that “the amplitudes and phases of vertical and meridional displacements are determined by utilizing dispersion and polarization relations of inertia gravity waves” (Line 147). These relations are not explicitly given. More importantly, the wavelengths, the frequency and the background flow required for the dispersion relation are not clear. I understand that the authors derive the vertical wavelength from the observed vertical profiles. This wavelength, however, is not necessary the actual vertical wavelength of the waves. The balloon flies through the wave field during its ascent for more than 1.5 hours

(estimated from the values provided in lines 78-79). The wind field causes horizontal drifts of the balloon during its ascent. Given that the wave phases are generally tilted in space, the vertical wavelength apparent to the balloon is expected to be different from the actual vertical wavelength that would have been measured above a fixed location in the horizontal. Correction to the apparent vertical wavelength is not taken into account in the dispersion relation and the analysis presented in Section 3.4. This makes the conclusions drawn in this section incomplete and questionable.

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