Response to Anonymous Referee #4

We thank Anonymous Referee #4 for his/her thorough and insightful comments, which are very helpful in our further revision of the manuscript. We have made every effort to address all the concerns raised. Our point-by-point response is given below.

The paper describes aircraft measurements that have been collected in the upper troposphere and lower stratosphere over the continental United States, and analyzes the gravity waves present in these measurements. One research flight of the START08 campaign was dedicated to gravity waves in the Upper Troposphere and Lower Stratosphere. This is, a priori, the first aircraft research flight dedicated to this theme. It is of interest to describe and document it. The paper shows: - that multiple events of gravity waves occured along the flight track, - both orographic and non-orographic waves are captured, - the analysis using wavelets allows to identify wave packets, but there are difficulties; part of the high frequency signal corresponds to measurement noise.

Overall, the paper leaves the impression that the analysis, even with a wealth of highresolution measurements, is difficult. Although much analysis is discussed with care, the paper leaves the reader somewhat unsatisfied. The description of the flights and the results of the spectral analysis of the measurements are valuable and of interest. Perhaps the paper in its present form contains too much information, in particular in the figures, and the reader may have difficulty in clearly singling out essential messages. I recommend publication after some revision to improve the focus of the study.

Major points

1. Many of the figures are difficult to read because they cover too much information. As an example, figure 4 contains 25 panels, each containing 6 curves... This needs to be reduced if information is to be retained from this figure. For instance, is it necessary to distinguish along and across-track spectra? They seem very similar, and unless one fears that the measurements are introducing a bias, I do not see any physical reason not to combine these into a wind speed and plot spectra for the wind speed. Whereas spectra of u_h, w, and potential temperature are common, I do not know of expectations for the spectra of static pressure. I believe one could do without this row of plots. Finally, do all the five legs of the flight really need to be plotted separately, or could some be combined or omitted?

Similarly: - figure 2 could contain less maps (e.g. 1800, 1950, 2210 and 0020UTC) - figure 5 could contain less panels (e.g. c, d, e) - figures 6 and 7 could contain less panels (e.g. horizontal velocity, w, theta for figure 6) - in each of the four figures 8, 9, 10 and 11: several curves are repeated many times, to display phase relationships (e.g. w is plotted 6 times among 9 panels!). This is excessive, there are other ways to present such information (e.g. profiles in a single plot, displaced in the vertical so as not to overlap, and with vertical lines indicating extrema (or zeros) of one reference signal...

The current manuscript attempts to generalize the characteristics and compare the differences among five selected segments in RF02. We believe that it is better to achieve this purpose by presenting an ensemble of results in one plot. In revision for Figure 4, we will try to make the black lines in front of all the other lines in order to make the plots much easier to read.

The updated Figure 4 and Figure 5 are presented as Figure R4.01 and Figure R4.02 in the current document.

In one of the earlier version of the manuscript for Zhang et al. (2015), we have tried to plot all the variables into one plot for Figure 8-10. Even though the results look readable for mesoscale examples, the plots actually look very messy for the short-scale examples. This is one of the reasons why we attempt to verify the phase relationship one by one, and to investigate the propagating characteristics from different aspects in each subplot for Figure 8-10.

2. While the figures provide too much information, it is sometimes difficult to find certain quantitative informations on the gravity waves. For example on p4733, line 27 onward: what are the largest amplitudes mentionned in the text? p4745: line 18: similarly, what are the amplitudes?

The below note will be added around line 28 on page 4733.

"The largest amplitude of w (magnitude of above 2 m/s) is during the middle portion of segment J3 (location 680-780 km) on the lee slopes of the Rocky Mountains (also see the discussion in section 5.2 on Figure 11). "

The below note will be added around line 19 on page 4745.

"…it is found that there are clear signals of significant mesoscale variations with wavelengths ranging from 50 to500 km in almost every segment of the 8 h flight (order ranging from 0.01 m/s to 1.0 m/s in vertical motion), which took place mostly in the lower stratosphere."

3. WRF simulations are used in Figure 2 to exhibit the flow configuration, but the comparison between the simulated GW and the observed ones is hardly discussed.

Figure R4.03 in this document demonstrates the comparison between aircraft measurements and high-resolution WRF simulations. Preliminary analysis shows that WRF successfully captures the variations in wind, potential temperature, and pressure, especially for segment J1, J2, J3, and M1. Probably due to upscale error growth with relatively long-time integration for segment M2, there is indeed a ~150-km distance between the observed V maximum location (at location ~400 km in M2) and the simulated one (at location ~550 km in M2). Also, the observed V maximum is larger than the simulated one (~60 m/s versus ~50 m/s). With that being said, the forecast error is within a reasonable range, and the aircraft did manage to obtain the data within the jet exit region.

However, it is beyond to the scope of the current study to investigate the consistencies and differences between aircraft measurements and WRF. WRF simulations and dynamics of the gravity waves will be examined in a separate study. In particular, based on the high-resolution simulations, we will investigate the sensitivity of wave response to the mean flow speed, wind direction, wind shear, and altitude, as suggested in the above comments.

References

Zhang, F., J. Wei, M. Zhang, K.B. Bowman, L.L. Pan, E. Atlas, and S.C. Wofsy, 2015: Aircraft measurements of gravity waves in the upper troposphere and lower stratosphere during the START08 Field Experiment, Atmos. Chem. Phys. Discuss., 15, 4725-4766, doi:10.5194/acpd-15-4725-2015.

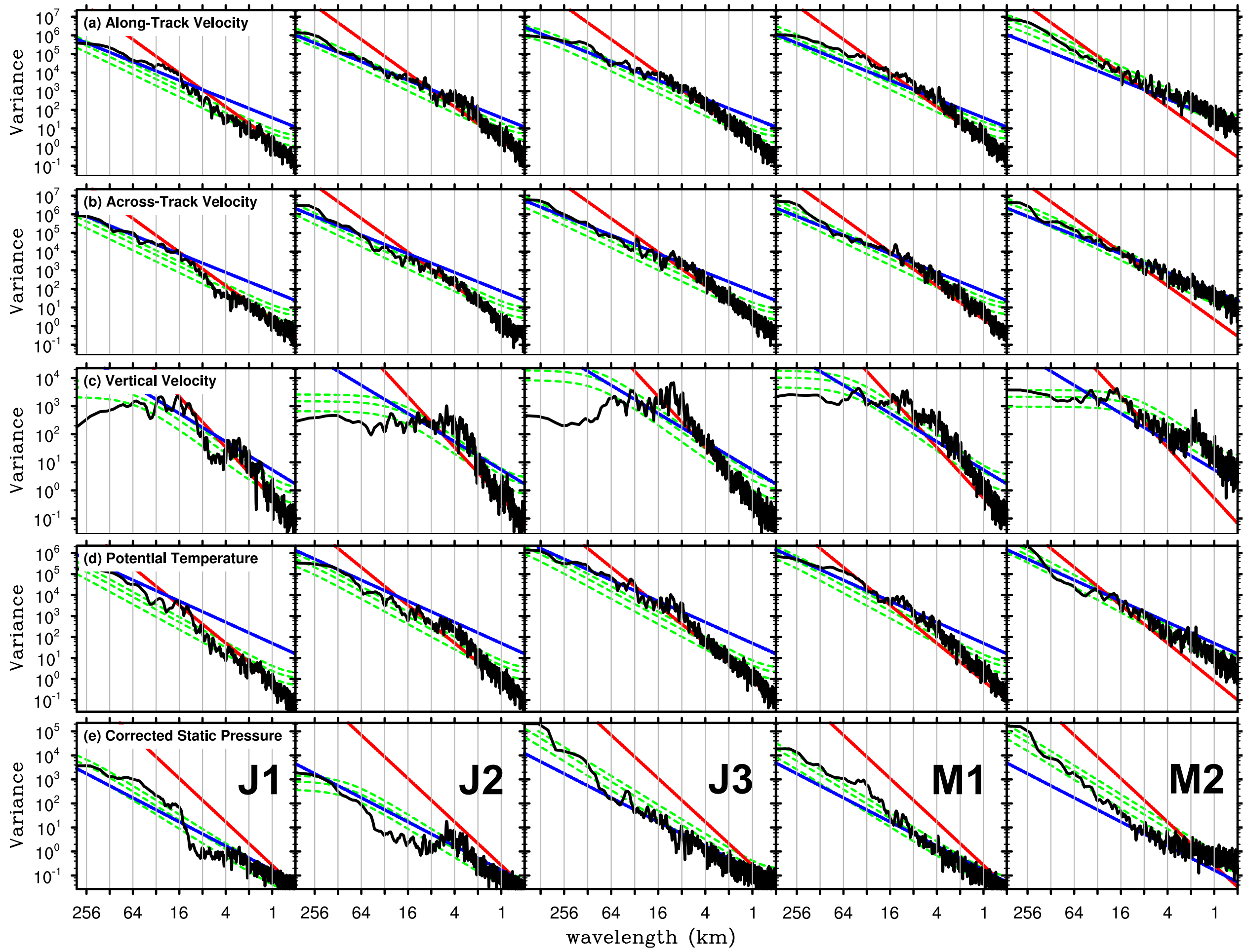

Figure R4.01 The spectrum (black line) of GV flight-level aircraft measurement during 5 selected segments (from left to right: J1, J2, J3, M1 and M2) of RF02 in START08: (a) along-track velocity component (unit: $m^2s^{-2} \bullet m$), (b) across-track velocity component (unit: $m^2s^{-2} \bullet m$), (c) vertical velocity component (unit: $m^2s^{-2} \bullet m$), (d) potential temperature (unit: $K^2 \bullet m$), and (e) corrected static pressure (unit: $hPa^2 \bullet m$). Green lines show the theoretical Markov spectrum and the 5% and 95% confidence curves using the lag 1 autocorrelation. The blue (red) reference lines have slopes of -5/3 (-3).

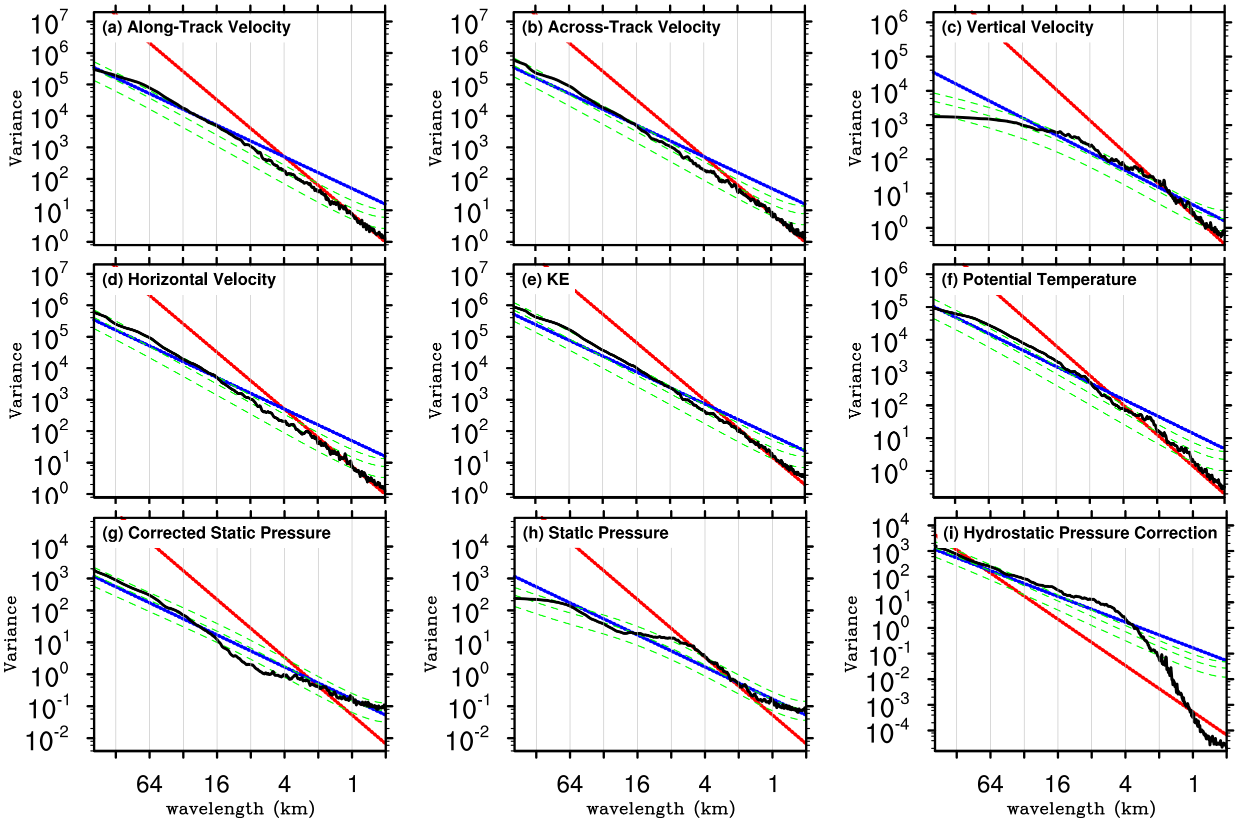

Figure R4.02 Composite spectrum (black line) of GV flight-level aircraft measurement averaging over all 68 segments in START08 (colored lines in Fig. 1): (a) along-track velocity component (unit: $m^2s^{-2} \bullet m$), (b) across-track velocity component (unit: $m^2s^{-2} \bullet m$), (c) vertical velocity component (unit: $m^2s^{-2} \bullet m$), (d) horizontal velocity component (unit: $m^2s^{-2} \bullet m$), (e) KE, (f) potential temperature (unit: $K^2 \bullet m$), (g) corrected static pressure (unit: $hPa^2 \bullet m$), (h) static pressure (unit: $hPa^2 \bullet m$), and (i) hydrostatic pressure correction (unit: $hPa^2 \bullet m$). Green lines show the composite curves of the theoretical Markov spectrum and the 5% and 95% confidence curves using the lag 1 autocorrelation. The blue (red) reference lines have slopes of -5/3 (-3). The subplot (e) KE is the sum of (a)-(c).

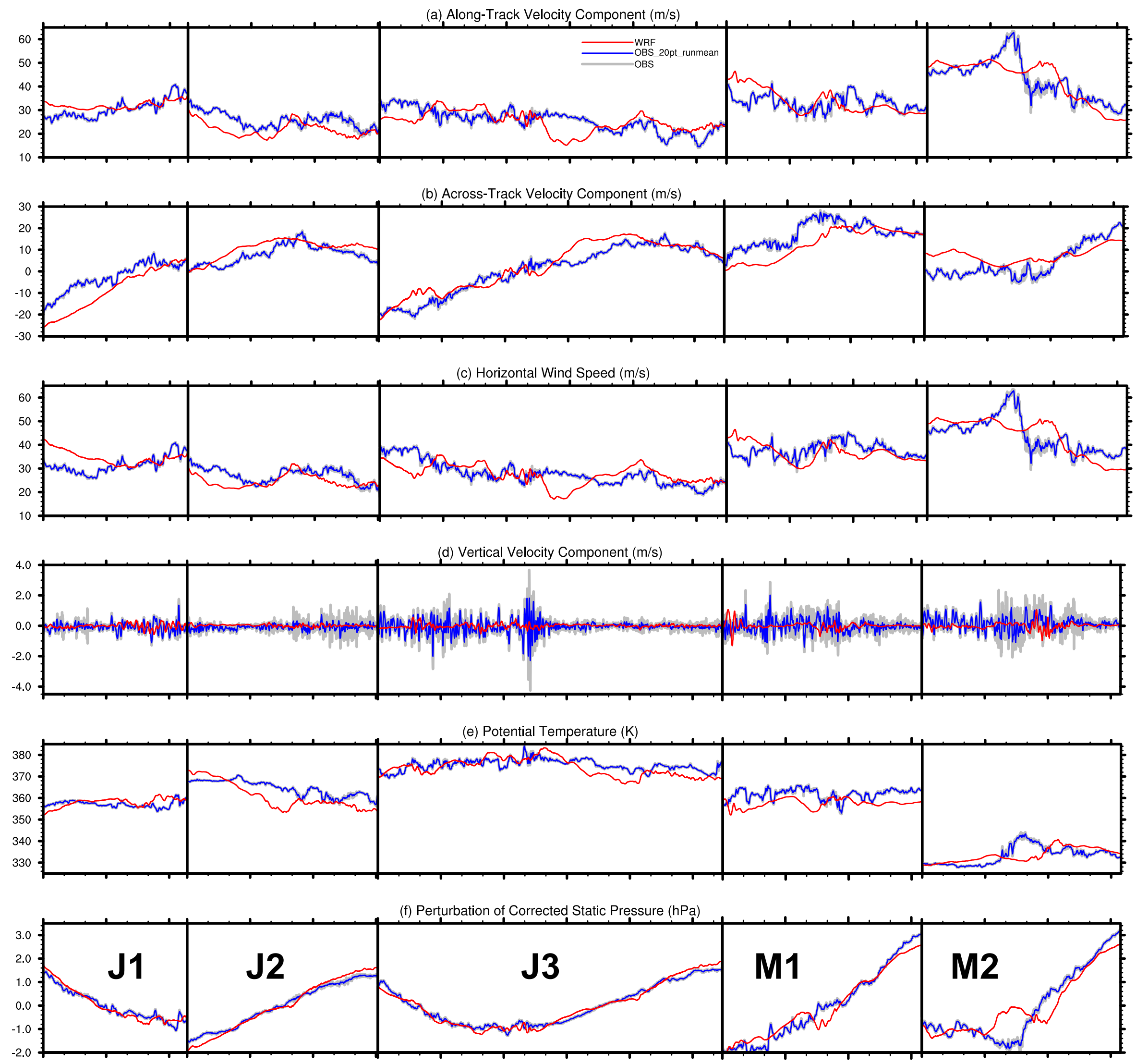

Figure R4.03 Comparision between GV flight-level aircraft measurements and WRF simulations during 5 selected segments (from left to right: J1, J2, J3, M1 and M2) of RF02 in START08: (a) along-track velcotiy component (m/s), (b) across-track velocity component (m/s), (c) horizontal wind speed (m/s), (d) vertical velocity component (m/s), (e) potential temperature (K), and perturbation of corrected static pressure (hPa). The grey lines represent the flight measurements with 250-m resolution, the blue lines represents 20-point running mean of the grey lines, and red lines represents the WRF simulations derived from D4 (1.67-km horizontal resolution) with 10-minute time interval. The series in segment J3 and M2 are reversed to facilitate the comparison with J1+J2 and M1, respectively. The distance between minor tick marks in x axis is 100 km. The perturbations in (f) are defined as the differences between the original data and their mean from their corresponding segments.