Response to Anonymous Referee #2

We thank Anonymous Referee #2 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.

This manuscript presents an analysis of aircraft measurements of mesoscale gravity waves associated with topography and the upper tropospheric jet region. Fourier and wavelet spectra are investigated, and wavelet cross-correlations are compared to theoretical values for gravity waves. Overall, the results of these comparisons are mixed: some mesoscale features are consistent with gravity waves, but others show inconsistencies that are attributed to measurement errors and flight track fluctuations.

Overall, this is a well written manuscript and a detailed, careful analysis of the START08 data. There are a few issues that the authors gloss over, which I think could be better explored (see below), but generally I have only suggestions for minor revisions.

1. The discussion of spectral slopes from Fig. 4 is superficial and should be better connected to the literature. Reference curves with slopes of -3 and -5/3 are shown, presumably for comparison with the Nastrom-Gage spectrum. But Nastrom & Gage found spectral slopes of -3 only at scales larger than those considered here! The spectra in Fig. 4 are all inside the -5/3 part of the Nastrom-Gage spectrum, so it is not clear why the -3 reference is included. Overall, the u/v/theta spectra seem to be similar to -5/3 at "larger" scales (256 down to ~16 km), as expected, but are steeper (maybe -3) at smaller scales. It would be interesting to explore the reason for the steepening at small scales. In fact, this small-scale steepening has been noted before (Bacmeister et al., 1996), which should be discussed.

Per this review comment, we will add more discussions of the spectral slopes and make more connections to the literature in the revision. More specifically, there are two main reasons why the -3 power law (red lines in Figure 4 and 5) is included in the current study. First, theoretically speaking, the -3 power law is expected for quasigeostrophic turbulence theory (e.g., Charney, 1971). Second, observationally speaking, the small-scale steepening (slopes of around -3 instead of -5/3) in some cases has been verified in the observational aircraft measurements (e.g., u, v, θ in J1, J2, J3, and M1 as indicated in Figure 4), even though the exact range of the small-scale steepening (slopes of around -3) may be sensitive to the selection of smoothing method or tapering method. It is worth noting that the spectral slope in M2 for u, v, and θ generally follows -5/3 (even at small scales), and that the spectral slope in M1 for u, v, and θ tends to follow -3 at small scales. Even though we are still investigating the physical reason for the above-mentioned slope behavior differences between M1 and M2, one possibility highlighted in the current manuscript is that the differences may be due to the changing background flow (please check the discussion from line 9 in page 4735 to line 2 in 4736).

2. Section 5 compares the cross-correlations with gravity wave theory for a few different cases. Discrepancies are found for some cases, especially at small scales, and this is attributed to measurement error or flight track fluctuations. But there seems to be another possible explanation: maybe these fluctuations are just not gravity waves. Could these fluctuations be due to other phenomena, such as shear instabilities, stratified turbulence, etc? This possibility should at least be discussed, and ruled out if possible, if not explored in detail.

The below sentences will be added around line 4 on page 4746.

"The current study mainly attempts to verify fluctuations with the use of linear theory for monochromatic gravity waves. Therefore, in addition to the measurement error, the possibilities that those fluctuations may be due to other physical phenomena (e.g., nonlinear dynamics, shear instability and/or turbulence) cannot be completely ruled out."

Minor comments:

1. Fig. 2 caption: what is the "mesoscale component" of horizontal divergence? Presumably this is just the filtered divergence (not "component"), but how and over what scales?

As stated in the last sentence of Figure 2 caption, "*A band-pass filter is applied to extract signals with wavelength from 50 to 500km for horizontal divergence.*"

2. Some figures are too small and difficult to read. For example, Fig. 4, has 25 panels! I had to zoom 400% to look at this. I suggest breaking this figure into multiple figures, or being more selective about what to show.

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.

Per reviewer's recommendation, and also per suggestion of another reviewer, we will revise Figure 4 and Figure 5 using Figure R2.01 and Figure R2.02 given in this response below.

3. How are power spectra computed? Are time series windowed (what kind?) or made periodic in some other way?

The power spectra in Figure 4, including their significant tests, are computed with the function provided by the NCAR Command Language (NCL), and the description of the function can be found in the below link.

http://www.ncl.ucar.edu/Document/Functions/Built-in/specx_anal.shtml

First, the series mean and least squares linear trend are removed (i.e., iopt = 1 in the above function). Second, perform the smoothing by averaging 7 periodogram estimates (i.e., jave=7 in the above function). Third, 10% of the series is tapered (i.e., pct=0.10 in the above function).

The below sentences will be added around line 6 on page 4734.

"The calculations of the spectra are performed with the "specx_anal" function in the NCAR Command Language (NCL). Several steps are done before the calculations. Firstly, the series mean and least squares linear trend are removed. Secondly, perform the smoothing by averaging 7 periodogram estimates. Thirdly, 10% of the series are tapered."

4. In the discussion of the spectral slopes: instead of saying things like "consistent with -5/3" etc, why not actually measure and report the slopes with a least squares fit?

We thank the reviewer for the suggestion. However, the current manuscript mainly shows that -5/3 and -3 are the representative spectral slopes to be compared with. Yes, one could estimate the slope with a least-squares fit with a running window (e.g., the examples in Figure R2.03 and Figure R2.04 given in this response below), but the estimation will be quite sensitive to the width of the running window and the rather arbitrarily chosen transition wavelength (not shown). We believe showing the reference slopes of -5/3 and -3 is adequate to justify our statement and will not change the final conclusion in the manuscript. Nevertheless, we revise the phrase to be "grossly *consistent with -5/3" and alike.*

References

Charney, J. G.: Geostrophic turbulence, J. Atmos. Sci., 28, 1087–1095, 1971.

Nastrom, G. D. and Gage, K. S.: A climatology of atmospheric wavenumber spectra of wind and temperature observed by commercial aircraft, J. Atmos. Sci., 42, 950–960, 1985.

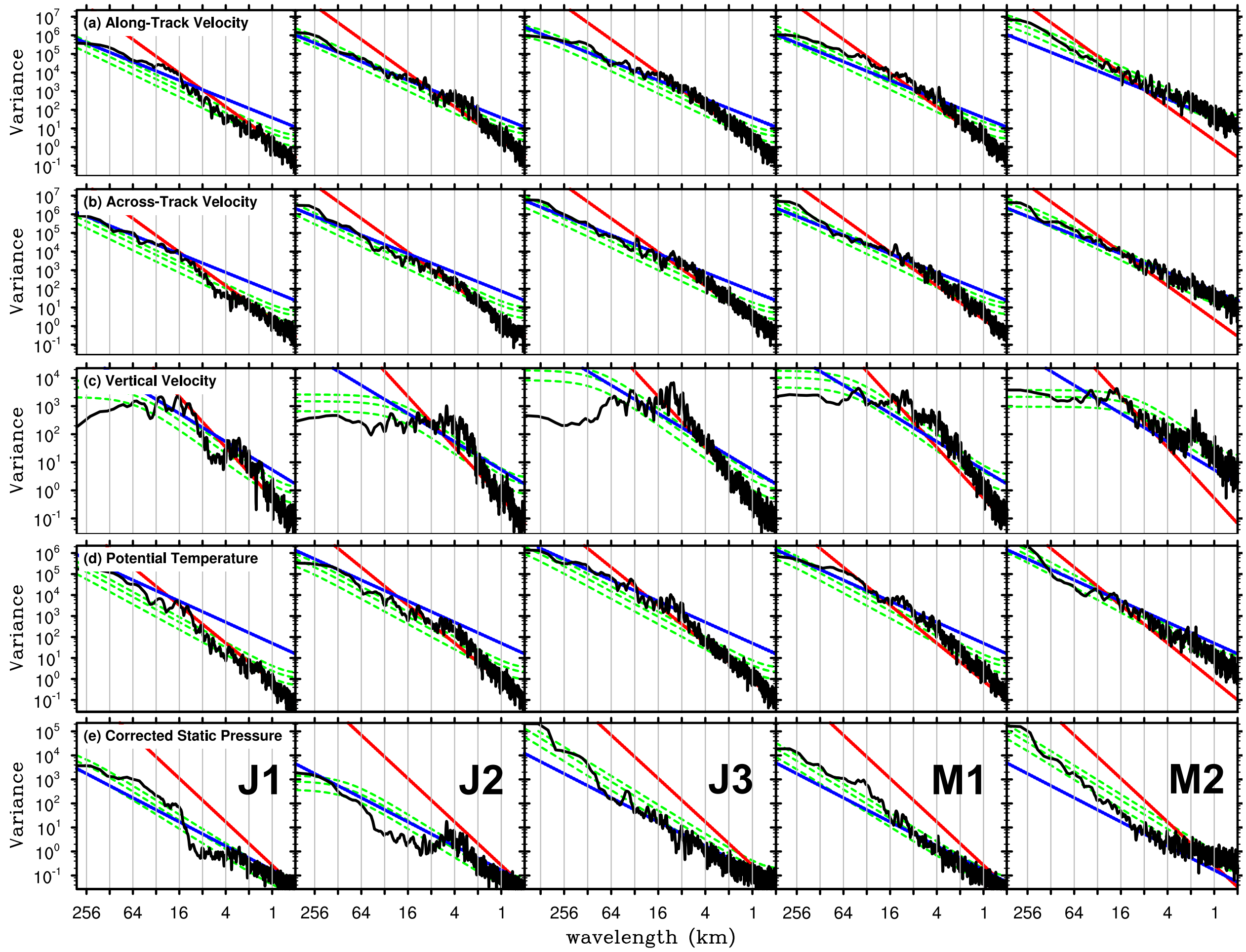

Figure R2.01 The spectrum (black line) of GV flight-level aircraft measurement during 5 selected segments (from left to right: J1, J2, J3, M1 and M2) of RF02 in START08: (a) along-track velocity component (unit: $m^2 s^{-2} \bullet m$), (b) across-track velocity component (unit: $m^2 s^{-2} \bullet m$), (c) vertical velocity component (unit: $m^2 s^{-2} \bullet m$), (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).

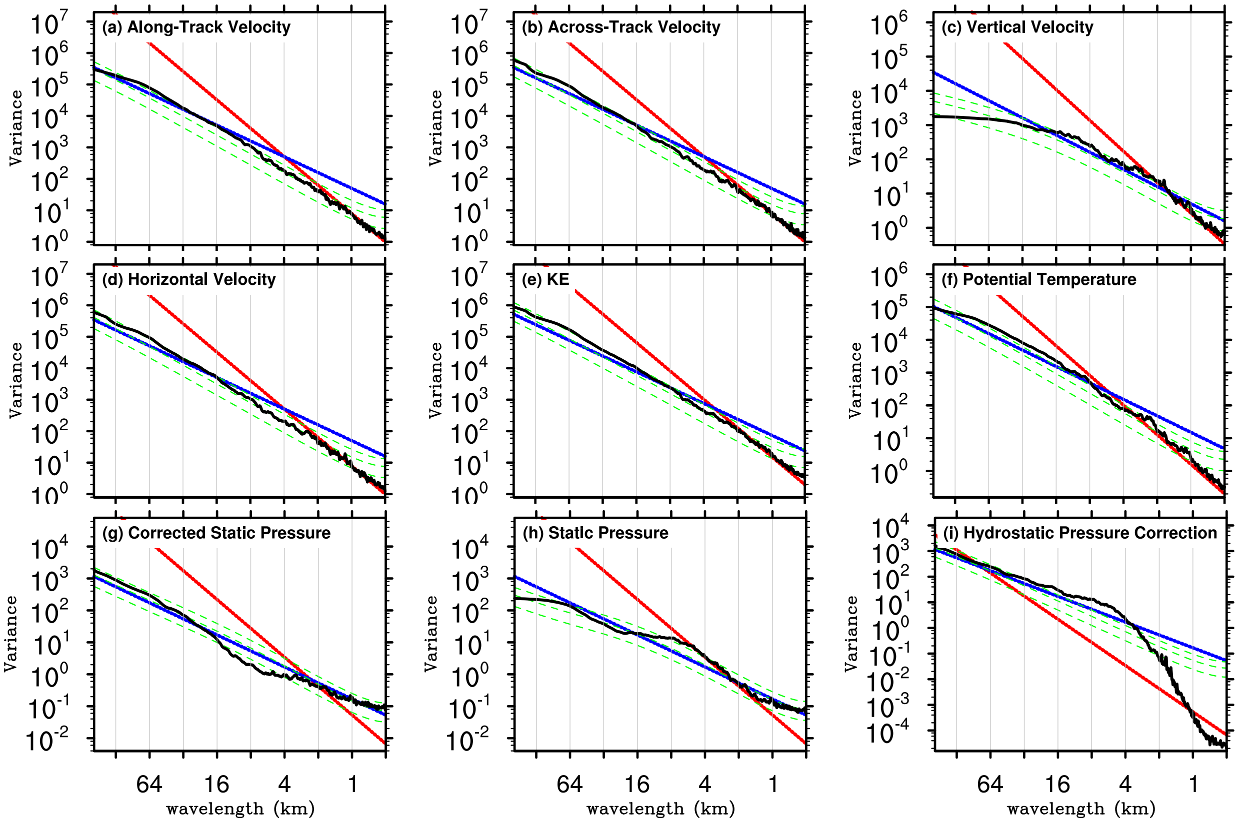

Figure R2.02 Composite spectrum (black line) of GV flight-level aircraft measurement averaging over all 68 segments in START08 (colored lines in Fig. 1): (a) along-track velocity component (unit: $m^2s^{-2} \bullet m$), (b) across-track velocity component (unit: $m^2s^{-2} \bullet m$), (c) vertical velocity 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).

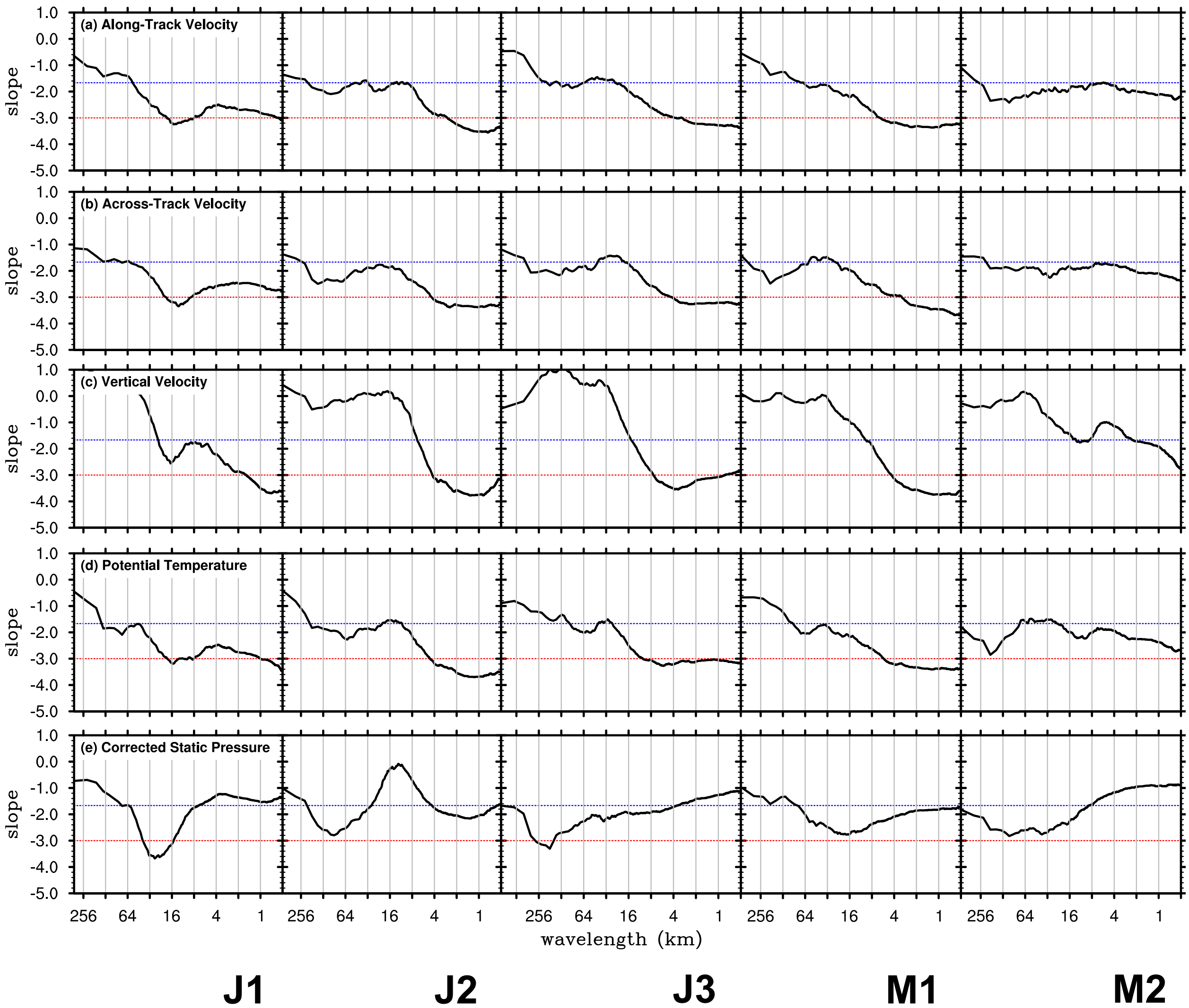

Figure R2.03 An example of the spectral slopes based on the results in Figure R2.01. The slopes are calculated with the linear regression coefficient between the log base 10 of the wavenumber and the log base 10 of the spectral power. A running window is used over the entire spectrum. The left boundary of the window is the maximum between wavenumber 1 and one quarter of the local wavenumber. The right boundary of the window is the minimum between maximum wavenumber (e.g., half of the total grid points) and four times the local wavenumber.

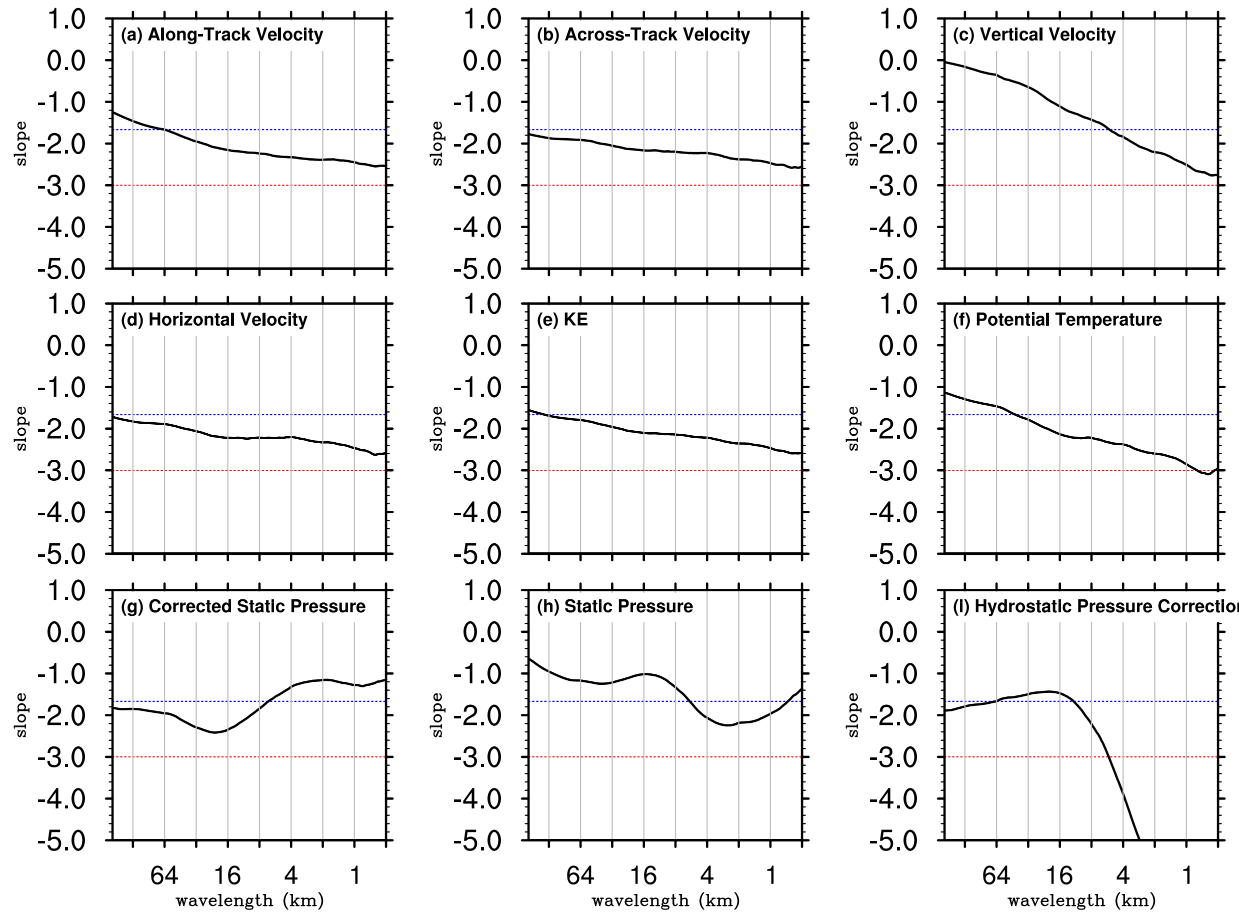

Figure R2.04 Same as Figure R2.03, but the calculations are based on the results in Figure R2.02.