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Interactive comment on "Small-scale gravity waves in ER-2 MMS/MTP wind and temperature measurements during CRYSTAL-FACE" *by* L. Wang et al.

L. Wang et al.

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Final response to reviewer #1's comments on "Small-scale gravity waves in ER-2 MMS/MTP wind and temperature measurements during CRYSTAL-FACE" by L. Wang et al.

Attached are itemized replies to the reviewer #1's comments. They are organized as follows: each original comment is shown first (due to the length limitation of ACPD, the original comments are not shown in full) , which is then followed by our response. The regular font is generally used for the original reviewer comments, whereas the **bold**

font is generally used in our response. The *italic* font is also used in the response to quote the relevant texts used in the revised paper.

Reply to Anonymous Referee # 1

Major Comments

1. Much of the analysis is centered around identifying statistics for λ_h', ...

   We agree that λ_h is more physically meaningful than λ_h'. Nevertheless, λ_h' is an important intermediate quantity in dealing with the aircraft data for the following two reasons. Firstly, λ_h' can be directly estimated from the MMS data (by using the S-transform or other wavelet analysis). λ_h, on the other hand, cannot be estimated directly. It has to be derived either from λ_h' and the angle between the GW horizontal propagation direction and the flight direction, or from vertical fluxes of zonal and meridional momentums. Secondly, the existence of a GW event is detected by examining whether coherent wave perturbations show up in both temperature and at least one component of horizontal winds at the same flight distance and at the same λ_h'. Thus, it is worth of showing the statistics of λ_h' in the paper (left panel of Fig. 4 in the revised paper).

   The statistics of λ_h is actually implied in Fig. 10 (of Fig. 9 in the revised paper). *As expected, λ_h is shorter than λ_h', and most of the events have λ_h between 5 and 15 km (in comparison, λ_h' is mostly 10-20 km)*. To address the reviewer's concern on the lack of description of λ_h, we add the above text in italic in the revised paper (L. 219-221).

   In addition, in the revised paper, we define the apparent horizontal wavelength λ_h' when it first appears in the revised paper (L. 124-127) instead of

ACPD
5, S5365–S5370, 2005

deferring it to P. 11384, L. 4-7 in the original manuscript.

2. While the S-transform is obviously ...

   The co-existence of longer and shorter horizontal wavelength waves can be seen more clearly from the 1-D data (in particular in MMS u, MMS & MTP T in Fig. 2). It is evident that the shorter scale signal is embedded in the longer signal for both u and T, and this is consistent with what is revealed from the S-transform analysis (Fig. 4 of the revised paper). It is harder to see the shorter horizontal wavelength signal in the MTP temperature contour plot (Fig. 3, P. 11403 of the original paper) partly because that its amplitude was smaller than that of the longer wave so that it is overshadowed in the contour plot. We remove Fig. 3 in the revised paper, as it contains little information relevant to what are actually done in this study. We use only the MTP temperatures and temperature gradients at the flight level to estimate GW vertical wavelengths in this analysis.

   We neglected to mention in the paper that we actually performed statistical testing on the S-transform analysis. Specifically, for all the wave events we identified, we required that the amplitudes of T and at least one wind component be above the 95% confidence level (in addition to the other requirements stated in the paper). The statistical testing is based on Stockwell, 1999: S-transform analysis of gravity wave activity from a small scale network of airglow imagers, Ph.D. thesis, The University of Western Ontario, 1999. We add this and the reference in the revised paper (L. 143-145). We thank the reviewer for calling this to our attention.

3. A related issue is the possible presence of ...

   We share the concern of the reviewer regarding the possible presence of a sampling bias in the aircraft data. We add the following note on such a bias in the revised paper.

ACPD

5, S5365–S5370, 2005

Interactive Comment

"Also, note that the ER-2 aircraft flight paths were chosen to avoid areas directly above deep rain events where the most vigorous GW motions might be present. Such a sampling bias in the aircraft data likely causes an underestimation of the actual GW amplitudes in the region." **(L. 159-162)**

Minor Comments

1. p. 11383: The physical meaning ...

   In the original draft, the definition of λ'_z was provided on P. 11384, L. 4-7. We move the definition to where we first mention the "apparent horizontal wavelength" in the revised paper (L. 124-127).

2. p. 11383, l. 18. Why is the lower cutoff ...

   The reason why we chose λ'_h being no shorter than 5 km is because that very short GWs are more severely affected by processes such as dissipation, reflection, etc., than longer GWs (e.g., Marks and Eckermann, 1995), so they are more difficult to ray-trace.

3. p. 13385 Because it is rather central to the analysis, ...

   θ is the angle between the flight direction and the GW horizontal direction ϕ (L. 126-127), i.e., $\theta \equiv \phi - \gamma$ where γ is the flight direction (measured contour-clockwise from the East). Since $\cos\theta$ can be either positive or negative depending on which quadrant θ is located in and λ_h is always positive by definition, we replace "$\lambda_h = \lambda'_h \cos\theta$" (P. 11384, L. 5 in the original paper) with "$\lambda_h = \lambda'_h |\cos\theta|$" in the revised paper (L. 125).

4. p. 11386, l. 12 These results could be of rather general interest ...

ACPD

5, S5365–S5370, 2005

We add the following GW dispersion relation on L. 223, as suggested by the reviewer.

$$\frac{1}{{\lambda_z}^2} = \frac{1}{{\lambda_h}^2}\frac{\left(N^2 - \hat{\omega}^2\right)}{\left(\hat{\omega}^2 - f^2\right)} - \frac{1}{4{H_\rho}^2} \quad (1)$$

5. p. 11388, l 16 Perhaps a better word ...

   We change the relevant sentence (P. 11388, L. 14-16 in the original paper) as follows: *"We compared the propagation directions derived using the flux method with those from the Stokes parameter method, and found that they were similar for most events."* (L. 274-276).

6. Fig. 8 seems to have three solid ...

   Fig. 8 (or Fig. 7 in the revised paper) is modified to make the lines more distinct from each other. The July 7 flight segment was chosen in the paper because it had two distinctive GW events in it. The south Florida and Caribbean region is typically rife with convective activities during that period of year. It is hard to find a case for which a GW could be traced to an isolated convective source and at the same time there were multiple GW events in the selected flight segment.

7. p. 11390, l 25 and ...

   Yes, *"vertical flux of horizontal momentum"* is implied here. We use these words in the revised paper to avoid any confusion (L. 340-341).

8. p. 11392, l. 18. Where the ER-2 was sampling ...

   In general, the waves we observe were above levels where ice clouds would form, but they came from below and must have passed through that region. Thus, the statistics on the waves should be relevant to ice cloud modelers who need statistical information about wave properties.

ACPD

5, S5365–S5370, 2005

Interactive comment on Atmos. Chem. Phys. Discuss., 5, 11377, 2005.