Dear Editor and Referee:

We would like to take this opportunity thank to you for taking time off your busy schedules to review the manuscript.

We have completed the comments of Referee #3. The comments of Referee #3 are based on the online discussion Version (acp-2021-952-manuscript-version3.pdf), rather than the revised Version (acp-2021-952-manuscript-version4.pdf) based on the comments of Referee #1 and Referee #2. The main comments concerned by Referee #3 have been considered in the revised Version (acp-2021-952-manuscript-version4.pdf). Nevertheless, we have reconsidered carefully all the comments raised by Referee #3.

Thank you for your consideration. We look forward to hearing from you.

Sincerely,

Jiyao Xu

Referee #3

General comment:

This paper presents results on GW propagation from the lower to the upper atmosphere during the 2016 typhoon Chaba. The applied methods include 1) reanalysis, 2) airglow emissions from the OH in the mesopause region and from the OI 630 nm emission (emission height ~250 km), and 3) ray tracing calculations of GWs. Due to the coverage of the mainland of China with corresponding instruments, 2D images of gravity wave (GW) signatures in the OH and OI emissions can be linked to GW signatures in the stratosphere as seen in ERA5-reanalysis. The major conclusions from this paper are that GW images in the mesopause region are found to be consistent with stratospheric GWs in reanalysis, and that GW signatures in the thermosphere can be explained by assuming that these waves were generated around or above the mesopause. In this respect, the present paper addresses a current hot topic in the atmospheric dynamics community, namely the mechanism of "multi-step vertical coupling" (Vadas and Becker, 2019), which means that GW effects at higher altitudes are often not directly due to primary GWs generated in the troposphere, but are due to higher-order GWs. The present paper manuscript, however, has a number of significant shortcomings that need to be addressed/solved before this study can be considered for publication in ACP. These shortcomings pertain to 1) the writing (the English and the arrangements of thoughts are often confusing, the citations are incomplete, and the summary section is insufficient), 2) the methods by which the major conclusions are derived, and 3) contradictions of the conclusions to previous studies and even to results within this present paper.

Thank you very much for your good comments concerning our manuscript. Those comments are all valuable and very helpful for revising and improving our paper, as well as the important guiding significance to our researches. We have studied comments carefully and have made corrections which we hope meet with approval.

The detailed point-by-point responses are given below.

Major comments:

#1 The English is often confusing. It is beyond the scope of this review to name all the places in the manuscript to which this comment applies and make suggestions. I strongly recommend that the paper should be carefully iterated by a native English speaker after a substantial revision is completed.

The arrangement of thoughts is sometimes confusing as well. As an example, I would like mention that some introductory sentences (e.g., L171-173, L296-298, L236-238) seem to refer to results and conclusions already made. Then, one or two paragraphs later the reader has to learn that the authors simply anticipated some conclusion or summary statement related to results that had yet to be presented in the respective section.

The writing and the content of the summary section appears to be insufficient.

Response：

Thank you very much for your comments.

According to your review opinions, we have improved the English writing and arrangement of the whole manuscript by the Wiley Editing Services. Also, we give a more sufficient description in the summary part of the manuscript.

The language editing certificate is attached at the end.

#2 A main conclusion of this paper is that the stratospheric GWs shown in Fig. 4c (having a predominant horizontal wavelength of ~156 km) reach the mesopause region prior to the larger-scale GWs seen Fig. 4a (having a predominant horizontal wavelength of ~295 km). This conclusion is not consistent with Figs. 4b, c, which suggest that concentric GWs having larger horizontal scales are seen earlier at higher altitudes. Note that a body of studies by Vadas and colleagues exist about the propagation characteristics of concentric GWs (e.g., Vadas et al. (2012), Yue et al. (2009), Vadas and Azeem (2021)). Some of these studies are even cited in the current manuscript. According to these former studies, the concentric GWs from convective sources that have larger horizontal wavelengths propagate faster to higher altitudes and are less prone to dissipation. The reason is that the GWs from such sources with larger horizontal wavelengths also have larger vertical wavelengths and, therefore, larger vertical group velocities. The conclusion made on page 13 of the paper contradicts these former results (and Figs. 4b, c as well).

Response：

Thank you very much for your comments. I'm very sorry that this issue has not been clearly expressed.
Because the time of reanalysis data of three layers is inconsistent, the reanalysis data of 20 km and 40 km altitude is 23:00 LT, and the reanalysis data of 60 km is 24:00 LT (Please check Figure 4 of the manuscript version you reviewed), so it seems like that the CGW in 60 km layer propagates slowly.
In order to more clearly show the propagation characteristics of gravity waves with different scales at different altitudes， we set the time of the three layer temperature perturbations to 23:00 LT in the revised manuscript.

(Please check Figure 4 and line 207-231 in the revised manuscript)

In this context the authors may notice that the temperature perturbations shown in Fig. 4 from reanalysis are extremely small compared to other estimates of typical stratospheric GWs. For example, Becker et al. (2022) showed that typical temperature perturbation amplitudes simulated by a high-resolution GCM in the wintertime lower stratosphere are +- 1-2 K, and about +- 5 K in the stratopause region. For a major typhoon we would expect even larger amplitudes. Figure 4, on the other hand, shows GW perturbation amplitudes from reanalysis that are too weak by at least a factor of 100 in the stratopause region! It is well known that reanalyses generally underestimate the stratospheric GWs by a significant amount. Furthermore, a height of 60 km (Fig. 4a) appears to be well within the sponge layer of the reanalysis model (the GWs amplitudes DECREASE with height in Figs. 4a,b,c by a factor of 5 from the lower to the upper stratosphere). The authors did not take into account or discuss these deficiencies. Indeed, the realism of the concentric GW structures shown in Fig. 4 seems very questionable. Hence, the concentric GWs seen in OH airglow (Fig. 5) are likely not the same GWs as those shown in Fig.4.

Response：
Thank you very much for your comments. Yes, you are right. The real temperature disturbances shown in Fig. 4 is wrong.
Because we only want to show the gravity wave more clearly, we ignore the display of the real temperature disturbance. When we remove the background, the sliding window is too small, so the background is not completely removed. We recalculated the temperature disturbance. Temperature perturbations were calculated by subtracting the background with a 7 ×7 grid point running mean at 20 km and 17 ×17 grid point running mean at 40 km and 60 km. We found that the temperature disturbance was about ±1.5－2 K at 20 km and ±3－4K at 40 km. Using the ECMWF reanalysis data, Kim et al.(2009) reported a similar temperature disturbance(±4K) at 40 km altitude. Becker et al. (2022) showed that typical temperature perturbation amplitudes simulated by a High Altitude Mechanistic general Circulation Model were ±1-2K in the wintertime lower stratosphere and ±5 K in the stratopause region. However, the temperature disturbance at 60 km altitude was only ±1.3 K and did not increase with increasing altitude, which may be caused by this altitude being well within the sponge layer of the reanalysis model.

(Please check Figure 4 and line 168-180 in the revised manuscript)

#3 The connection from the upper mesosphere and GWs to the thermosphere is made via backward ray tracing of GWs seen in the OI emissions. Figure 7c indicates the corresponding concentric ring structures in OI. According to the aforementioned studies of concentric GWs, the center of the red rings in Fig. 7c should correspond to the geographical location of the assumed GW source. The authors argue that this source is in the mesopause region where the primary waves from the typhoon presumably dissipate. However, the backward rays (red lines in that Fig. 7c) end very far away from the center of the rings. In other words, the ray tracing result for the assumed GW source and the assumed center of the center of the partial concentric ring GWs in Fig. 7c do not match at all. This mismatch is not even mentioned in the present manuscript.

Response：

I'm very sorry that this issue has not been clearly expressed. The fitting center of the thermospheric CGW (blue arcs) is a blue cross rather than a red dot. The red dot is the fitting center of the CGW (solid circles) in the OH layer. Please See Figure 9 below.

However, the backward tracing terminal positions (red diamonds in Fig. 9) did not coincide with the fitting circle center position (blue cross in Fig. 9). Nevertheless, according to numerical simulation work by Vadas et al. (2009), large winds can shift the apparent center of concentric rings from the location of the convective plume. Indeed, we found strong southward winds from100 km to 140 km (with a peak value of 50 m/s at 150 km altitude) and from 160 km to 220 km (with a peak value of 25 m/s at 175 km altitude) altitudes (right panel of Figure 8a). So the center of the thermospheric CGW can be shifted southward from the location of the thermospheric CGW sources in the mesopause region. For the zonal wind, the westward wind dominated from the upper mesosphere to the thermosphere (left panel of Figure 8a). Similarly, the thermospheric CGW center position shifted westward. Therefore, the assumed center (blue cross) of the partial concentric ring GWs (blue arcs) actually shifted to the southwest from the real source location , which can explain why the ray-tracing result for the assumed GW source did not match the fitting center of the partial concentric ring thermospheric GWs.

The above description is added to the revised manuscript.

(Please check Figure 8a and 9 and line 278-305 in the revised manuscript)

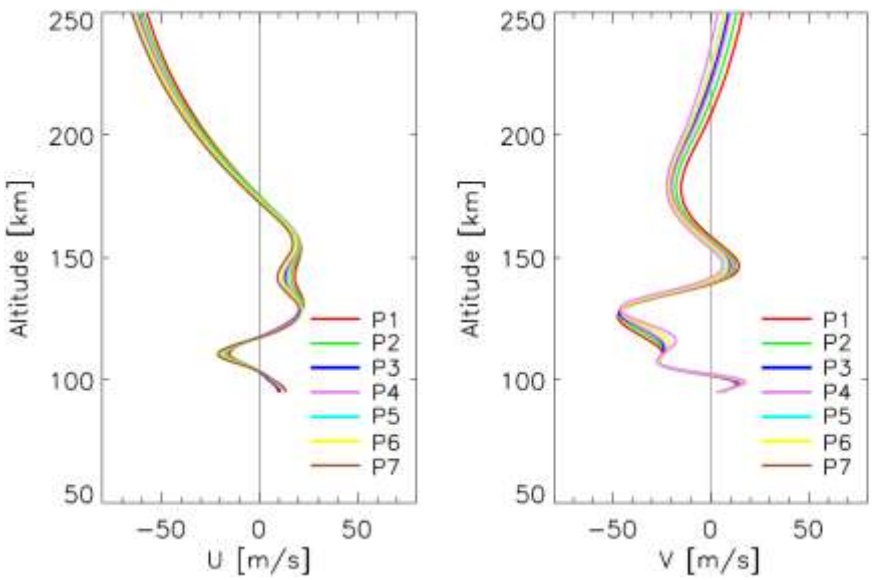

Figure 8. (a) The wind profiles along the seven ray-tracing paths.

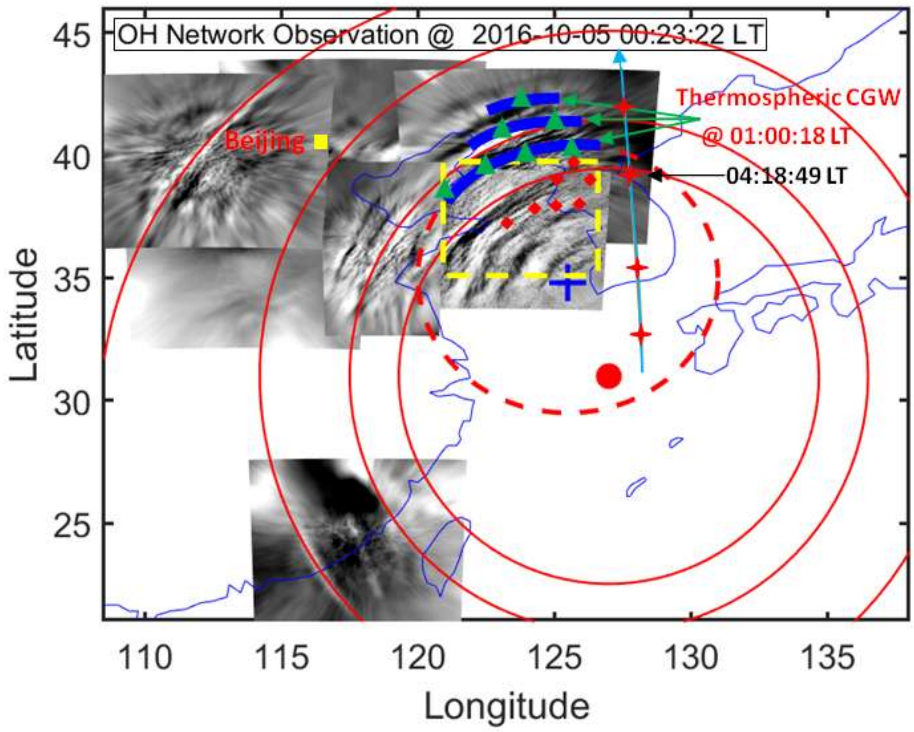

Figure 9. Double layer CGW superimposed graph: The blue arcs represent the thermospheric CGW observed at 01:00:18 LT. The dotted circle represents the approximate fitting blue arcs. The blue cross marks the center of the circle. The solid circles represent the approximate fitting CGWs observed by the OH airglow network. The red dot marks the center of the circles. The green triangles and red diamonds represent the trace start and termination points , respectively. The red crosses represent the sounding footprints of the TIMED/SABER measurements. The yellow box marks the location of the meteor radar station.

Other comments:

The citation is not sufficient regarding the original papers of higher-order GW generation and their effects in the thermosphere/ionosphere. Indeed, the mathematical theory for higher-order GWs was derived in Vadas et al (2003), and a summary of that theory and its implications was given in Vadas et al. (2018). Furthermore, global simulations of concentric higher-order GWs in the thermosphere were first discussed in Vadas and Becker (2019).

Figs. 5a,b,c, 6, 7c, 8: The figure captions do not mention the physical quantities that are shown. Also the color bars with corresponding units are missing.

Response：

The references below are added to the list of references of the revised manuscript and discussed appropriately.

The physical quantities are all shown in the figure caption descriptions. The color bars with corresponding units are all added.

References:

Vadas et al (2003): Mechanisms for the generation of secondary waves in wave breaking regions, J. Atmos. Sci., 60, 194-214.

Vadas, S. L., Yue, J., She, C. Y., Stamus, P., and Liu, A. Z.: A model study of the effects of winds on concentric rings of gravity waves from a convective plume near Fort Collins on 11 May 2004, J. Geophys. Res., 114, 2009.

Vadas et al (2012): Mesospheric concentric gravity waves generated by multiple convective storms over the North American Great Plain. JGR, 117, doi:10.1029/2011JD017025.

Vadas et al. (2018): The excitation of secondary gravity waves from local body forces: Theory and observation, J. Geophys. Res. Atmos., doi:10.1029/2017JD027970.

Vadas and Becker (2019): Numerical modeling of the generation of tertiary gravity waves in the mesosphere and thermosphere during strong mountain wave events over the Southern Andes, J. Geophys. Res. Space Phys., doi:10.1029/2019JA026694.

Becker et al. (2022): A high-resolution whole-atmosphere model with resolved gravity waves and specified large-scale dynamics in the troposphere and stratosphere, J. Geophys. Res. Atmos., doi:10.1029/2021JD035018.

Message from your editor, Will

Dear Author,

It was a pleasure working on your document. Do go through my changes and comments in the edited file.Please send me your feedback or any questions through your account (cn.wileyeditingservices.com).

Editor's report

I have provided feedback on your manuscript through specific comments along with ratings for relevant sections. The key below the table explains my ratings. I hope you find my feedback useful.

Section	Rating
Title	★★
Abstract	★★
Introduction	★★★
Data and methods	★★★
Results and discussion	★★
Summary	★★

★★★ This section required only a few revisions.
★★ Most parts of this section required revision.
★ The entire section required significant revision. Please go through my comments/changes carefully.

Comments

NOVELTY OF THE STUDY

The novelty could be more explicitly stated. E.g., This was the first study to… or This study for the first time…

RELEVANCE AND CONTRIBUTION OF THE STUDY

More discussion on the relevance and contribution of the study could be given in this paper. For example, the discussion should discuss the wider implications of these results, how they can be used. Discuss the potential shortcomings and limitations of the interpretations, their integration into the current understanding of CGWs and how this advances the current views.

SUBMISSION READINESS

No target journal was provided, therefore I edited the language and grammar and edited for general academic tone and writing conventions. Overall, the language was good but there are some areas that required heavier edits. Please see my comments for some specific areas that require your attention.

Abstract

The abstract should generally end with a line or two discussing the wider implications of the paper. What do these findings tell us? How can they be used?

Introduction

Provides a good level of background information and explicitly states the objectives.

Data and Methods

This section was well written and described the methods in sufficient detail. However, there were some methods discussed in the discussion section that were not first described here. For example, TIMED/SABER is not explained here but is discussed later on. This is not clear as the reader doesn't know what TIMED/SABER is.

Results

This was a detailed results section that made good use of figures. Please see my comments for some specific areas that require your attention.

Discussion

This is a good discussion of the data and brings in literature. However, in some areas it feels more like a results section in that data are being listed. More discussion could be given here. This section should discuss the wider implications of these results, how they can be used. Discuss the potential shortcomings and limitations of the interpretations, their integration into the current understanding of CGWs and how this advances the current views.

Summary

A good final summary section.

Quick tip

Guideline

Wordiness (the use of many words to convey an idea) should be avoided in academic writing.

Explanation

The use of too many words to convey one idea can muddle the message and divert the reader's attention. Therefore, in writing, especially academic writing, ideas need to be conveyed as concisely as possible. One way of doing this is to use concise alternatives to phrases. For example, the phrase "all over the world" can be replaced with the word "globally" or "worldwide."

Concise alternatives can also lend a more formal tone to the sentence. For example, "gradually" is considered a more formal alternative to "little by little" and is preferred in academic writing.

Finally, where possible, a direct verb (action) should be used instead of using a noun and verb.

For example, “segmentation of images was done” can be replaced with “images were segmented,” which is clearer and preferred in academic writing.

Example

Before: We found that strong CGWs with clear signs of dissipation and/or nonlinearity were observed by the OH airglow network

After: The OH airglow network observed strong CGWs with clear signs of dissipation and/or nonlinearity