

# A review on the paper "Extreme Concentric Gravity Waves Observed in the Mesosphere and Thermosphere Regions over Southern Brazil Associated with Fast-Moving Severe Thunderstorms"

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## General comments

The paper describes a case study of concentric gravity waves (CGWs) observed with the airglow imager in Brazil on 17-18 September 2023. Also, these CGWs were simultaneously captured by three satellites. Three groups of intense CGWs lasted over 10 hours. The CGWs caused profound airglow emission perturbations exceeding 24%. These CGW events were caused by fast-moving deep convections observed by the GOES-16 satellite. The authors have found that these CGW events represent the most intense vertical transport cases ever recorded, demonstrating remarkable wave coupling between the lower and upper atmosphere.

I have found the paper to be interesting to the atmospheric community. At the same time, I have found a number of issues that should be explained in more detail. That is why I recommend accepting the paper after major revision.

## Specific comments

Line 71: "...dual-layer airglow observations..."

It is not clear what dual-layer the authors talk about? It should be clarified here.

Line 76: "... across these two atmospheric layers was rare."

Across which two layers?

Lines 86-87: "...São Martinho da Serra..."

Please add Brazil here.

Lines 93-95: "The time resolution of the OH airglow image is 112 seconds, while that of the OI 630 nm airglow image is 225 seconds."

Is it the time resolution or exposure time? What is the exposure time?

Line 98: "...the effective observation ranges of OH airglow imager with a 164° field of view"

Before it was said that "fish-eye lens of a 180° field of view"

What is true?

Lines 101-102: "Before effectively extracting the wave parameters, the raw airglow images need to be processed through the following steps:..."

It is not a complete information on the processing of raw images. Among others, the following steps should be described:

How the atmospheric background was subtracted?

How the dark noise of the sensor was subtracted?

How the flat field correction (non-uniformity of the sensor at different wavelengths) was taken into account?

Was the imager absolutely calibrated in a lab?

Does the imager register airglow intensities in relative or absolute units (Rayleigh) ?

At which solar depression angles does the imager operate?

Line 117: “Third, the processed images were projected onto geographic coordinates,...”  
 This information is not enough. It should be described in more detail how the optical model of the imager optical system was determined and calculated?  
 What were the reference points in order to calculate free parameters of the optical model?  
 Stars or lab reference points?  
 What are the errors of projected pixels in the image center and at the edge of FoV ?  
 What is the spatial resolution of the imager in the imager center and at the edge of FoV ?

Lines 122-129.

It should be given a reference on the GOES-16 satellite and addressed visible and infrared parameters.

Lines 139-141: “In this study, the CO<sub>2</sub> radiance emission band with frequencies ranging between 2299.80 cm<sup>-1</sup> and 2422.85 cm<sup>-1</sup> is utilized to measure stratospheric air temperature perturbations.”

It should be given a reference on the Aqua satellite and CO<sub>2</sub> emissions used in this paper.

Lines 143-144: “The Visible Infrared Imaging Radiometer Suite (VIIRS) instrument, onboard the Suomi NPP satellite...”

It should be given a reference on the Suomi NPP satellite.

Lines 166-167: “CGW no. 1 first appeared in the southeast direction of the station.”

Is it in the southeast or in the southwest direction of the station?

Lines 172-175: “...the center moved approximately 436 km westward, with an average speed reaching ~65 km/h. This eastward drift of the wave's center could be indicative of the influence of prevailing wind patterns and the westward movement of the convective system itself.”

I hardly understand was it the eastward or westward drift? Or sometimes westward and sometimes eastward? This should be clarified.

Lines 173-174: “This eastward drift of the wave's center could be indicative of the influence of prevailing wind patterns...”

This is very interesting but it is not entirely clear. At what altitude is the prevailing wind considered ? In the tropopause or in the mesopause?

Lines 176-177: “...are measured to be (30–82)±3 km.”

Having such a large range of wavelengths what is the physical sense of indicating the error of 3 km ? What does this error tell us? Is it the instrumental error or geophysical wave variability or both?

This is again connected to my above-mentioned questions on What are the errors of projected pixels in the image center and at the edge of FoV ?

In Figs. 2 and 3, what physical quantity can we see on these images? Is it some raw OH emission intensity? Or is it a corrected emission intensity? Or is it OH emission intensity in absolute values? It should be clarified in the figure captions.

In Fig. 3, it is difficult to see the green and light blue dots and arrows for color-blind readers. I recommend changing the green dots to, for example, green triangles.

Caption to Fig.6, please indicate the approximate altitude at which this temperature map is observed.

Line 267: "...horizontal wavelengths are primarily distributed within the range 267 of  $(38-52) \pm 3$  km"

Having such a large range of wavelengths what is the physical sense of indicating the error of 3 km ?

Lines 301-307. The sentence is repeated twice, please remove the repeated part.

Lines 306-307: "... when their phase velocities fall within the prohibited range."  
What is the prohibited range? How much is it?

Lines 322-327: "We also conducted a statistical analysis of CGWs observed by a meridional airglow observation network across mainland China from September 2023 to August 2024, with data from selected stations including Daicai (25.34°N, 110.34°E), Wendeng (37.18°N, 121.79°E), Mohe (53.48°N, 122.34°E), and Naqu (31.73°N, 92.47°E). The results indicate that the average CGW amplitudes ranged between 1.7% and 2.6%."

It seems to me that this is a completely different study, with completely different regions than the area of Brazil under discussion. A reference to this study is needed here. Otherwise it should be removed.

Lines 332-334: "During the generation and propagation of CGWs, two saber orbits passed over the station and happened to be within the field of view of the airglow imager, as shown in Fig. 11."

How is the field of view of TIMED/SABER oriented in Fig.11 ? Please add this information.

Lines 341-342: "In addition to this, we also observed a double-peaked structure in the airglow emission layer."

Which airglow SABER profiles do demonstrate a double-peaked structure? This should be paid attention to.

Lines 342-346: "From the temperature profiles (Fig. 12b and d), we have detected a rich spectrum of vertically propagating waves with vertical wavelengths between 5 km and 20 km, which consists with concurrent airglow and satellite observations of upward-propagating CGWs."

This sentence sounds very strange to me due to the following reasons:

1. There is no information at all about vertical spectrums of gravity waves derived from airglow and satellite observations. All presented data were about horizontal gravity wave patterns. Of course, using the dispersion relation for gravity waves one can derive a vertical wavelength from a horizontal wavelength, but it was not done in the manuscript so far.
2. Each presented temperature profile shows significant vertical variations, i.e., inside the FoV of the imager and outside it, far away from the imager. How can we be 100% sure that these temperature variations are due to CGWs and not other gravity waves?

This sentence should be redeveloped or removed from the manuscript.

Equation 4. What is  $\omega$  here and how was it calculated? What is  $g$  here?

Lines 365-366: "...u is the wind speed in the wave direction derived from meteor radar,..."  
 I could not find any information on a meteor radar used in this study. This information should be provided. Is a meteor radar located in the proximity to the imager? What is the accuracy of estimation of the horizontal wind speed from meteor radar data in the wave direction discussed here?

Equation 6. Where is  $\alpha$  in this equation?

The authors do not provide information on how they estimated k, m, N parameters in relation to the vertical direction. I assume these parameters were calculated as mean values over the height range from the tropopause to the mesopause. But m and N may significantly vary with altitude, resulting in variations in the GW vertical group velocity (see for example, Fig. 4 in Dalin et al., 2016). This may provide significant deviation of the estimated propagation times. The author should provide a comment on Equation 6.

Lines 388-390: "The vertical group velocities of CGW no. 1, CGW no. 2, and CGW no. 3 are estimated to be 31–37 ms<sup>-1</sup>, 24–30 ms<sup>-1</sup>, and 26–29 ms<sup>-1</sup>, respectively."

What is the source of these estimated ranges of the vertical group velocities? The uncertainty of which parameters affects the uncertainty in the estimation of the group velocities to a greater extent ?

Figure 14. What are the red dashed lines in Fig.14 a and b ? And I assume that the red triangle marks the location of the SMS station. Right?

Lines 463-464: "...demonstrating their substantial impact on atmospheric dynamics and space weather."

Please provide more information on how these waves substantially impact on space weather.