Authors' response to Referee 1:
Gabriel Giongo et al.

We thank Reviewer 2 for their comments on our manuscript. We acknowledge the significant concerns raised and have undertaken a comprehensive revision to address these issues. Below, we respond to each of the major comments.
Reviewer comments in black, author's comments in blue.

The paper by Giongo et al. investigates the activity of medium scale gravity waves over the Antarctic Peninsula by developing an algorithm that identifies the waves automatically on the airglow images and estimates their parameters. This automatic process is based on the well known keogram analysis. Although new approaches to improve image analysis are welcome, there are issues that prevent the paper being published in the present form.

Although the paper presents some results on medium-scale gravity waves, its main focus is on the method used to identify the waves and estimate their parameters. However, the description of the method lacks clarity, and the results obtained are not adequately discussed.

Considering the general comments and specific questions from both reviewers, we have written a completely new version of the text, which includes a section dedicated to explaining the main steps of the procedure along with the mathematical and physical concepts underlying the transform and its properties. Additionally, the discussions focus on the new features and advancements of the methodology rather than comparisons with other observation sites. The figures have been updated, and a new title has been suggested.

As the authors propose a new method to analyze images and extract wave parameters, they should be as clear as possible in explaining it. The description of the spectral analysis procedure lacks a clear and logical sequence, making it difficult to follow. While the authors claim the process is fully automatic, it appears to require user intervention at certain stages. To improve clarity, the steps of the analysis should be explicitly defined, distinguishing between automated and manual actions. Ensure that the steps of the analysis are presented in a logical order, from data acquisition to final output. If the process is automatic, specify which steps are handled by the system and which (if any) require user intervention. Additionally, the method should be tested by calculating the wave parameters as in standard keogram analysis, as quoted in the manuscript, and comparing the results with those obtained from their automated method.

In the new version, a subsection was added to organize the ideas behind the analysis and provide an overview of the sequence and physical meaning of the steps. The procedure requires no human intervention, but someone can approve the result after it concludes. A flowchart was included in the text to clarify the logical sequence of the procedure for the reader. Discussions now include comparisons with previous methods and advancements in obtaining phase fitting as a parameter for analysis quality, which was lacking in earlier methods.

Specific questions.
At page 4, lines 101-103, the authors state that "Peaks in the wavelet power spectrum are selected using a peak selection procedure to identify the significant oscillations and their temporal position”. Please describe the details of the procedure.

The procedure has been utilized for over 20 years in numerous publications from our research group, so we did not realize its importance in describing it. However, we agree to include a description of how it works. Details of the procedure are in the text (lines 181-191).

Is the central line of the keograms the horizontal line in Figure 2 that intersects the vertical axis at the zero mark?

Yes, it is also the central pixel of the images over time. The figure was updated to include this information.

In Figure 2, does the vertical axis represent distances from the central point of the image? If so, it should be labeled with appropriate units.

The figure was updated for clarity.

The following sentence needs some clarification.
“The peak identification procedure needs an equally dimensioned array. A linear spline interpolation is performed in the vertical columns of the spectrum to give it the same number of points in the vertical as in the horizontal lines”.
What are vertical and horizontal lines?
I understand that wavelet analysis demands time series equally spaced. The authors inform that they use interpolation. Are the images equally sampled? i.e. is the interval between two images always constant?
What is the source of the difference between the number of vertical and horizontal data points?

The peak finding procedure is applied to the Power Spectrum (Figure 3 of the old version, or Figures 5 and 7 of the new one). The horizontal axis of the power spectrum is time, with the same resolution as the images, and equally sampled. The Vertical axis is period, and it depends on the scale (periods) separation of the Wavelet transform, a log-scale-spaced array. So, the vertical is interpolated to the same number of points and equally spaced as the horizontal (time) axis is. Details of the procedure were included in the text (lines 181-191).

Each data point of the time series is the pixel intensity along the night. What is the source of the unequal time resolution of the zonal and meridional keograms?

There is no unequal time resolution between the zonal and meridional keograms; each column of both is the sample row and column of the same square image.

What the authors mean in the phrase “with temporal variation and combination among them”, in the sentence “Prominent peaks can be seen near 20, 30, 50, 80, and 140 minutes of period, with temporal variation and combination among them”, at page 4, lines 105-106?

The peaks vary in time, which is due to wave interference. The Peak of ~70 min seems to vanish when the 35 and 130 min waves enlarge. For clarity, more discussion on wave interference and analysis reliability was inserted into the text (lines 266-273).

The following sentences are unclear. “The peak identification procedure needs an equally dimensioned array. A linear spline interpolation is performed in the vertical columns of the spectrum to give it the same number of points in the vertical as in the horizontal lines”.

Details on the peak identification procedure and the interpolation applied to the power spectrum were included in the text (lines 181-191).

Do the vertical columns correspond to the meridional keogram and the horizontal ones to the zonal keogram?"

In the keogram figure, both components represent in the vertical axis the slices taken along the image, the difference is that the meridional takes a slice in the vertical of the image, and the zonal takes a slice in the horizontal of the image (but it is arranged in vertical on the keogram figure). The horizontal axis is the time at which the image’s samples were taken.

On page 5, line 112. Does the sentence, “Several lines are selected half period long before and half period long after the peak central position”, mean the authors selected a symmetrical time window centered on the peak position, extending half a period before and half a period after the peak? From which figure are these lines selected?

Exactly. These lines represent phase lines in space over a specific time period. Since the phase spectrum of the wavelet is a function of the same variables as the power spectrum, the phase lines align temporally with the peak (and half period…) and correspond to the vertical lines of the keogram. In other words, a phase spectrum can be associated with each time and space position of the keogram for a given period. The new version of the text describes how the phase spectrum is calculated and how the phase lines are determined and used for the estimation of gravity wave parameters (Section 2.2.1).

It is not clear how the keogram in figure 4 is reconstructed. The wavelet analysis takes into account only the central line (which is the same for zonal and meridional directions) of the keogram. How are the keograms off the central line reconstructed?

They are reconstructed by applying a wavelet transform to them and an inverse wavelet transform only to the selected period set as non-zero, similar to how the zenith is reconstructed. For the period identified in the zenith wavelet, all the lines will be “enforcedly” reconstructed to that period. This will be used to check for wave presence off-zenith and test its validity by the phase tilt’s linearity. The new version of the text brings this description to section 2.2.1.

In Figure 4, there are vertical red lines indicating the selected lines. Are these lines inserted manually? Those lines are placed at distinct spots in the zonal and meridional keograms. How is their placement?

They are automatically selected in the time domain, half a period before and after the central observation time. In the vertical (spatial domain), they were selected based on the quality of the linear fitting; or in other words, the flattest region.

In Figure 5, what is the meaning of the red phase lines? The figure legend does not inform it. Additionally, the vertical axis lacks units, which I suppose should be kilometers.

The units are degrees. The red part of the phase lines is the sector used for the coeficient estimations, selected automatically by the program based on the quality of the fitting. The figure and legend have been updated to make it clear.

Regarding the two synthetic waves used to test the method. Do they have the same amplitude? The wavelet spectrum in Figure 7 shows distinct power for the waves.

They have the same amplitude, and so does the noise. The difference in the power spectrum is due to the wavelet properties that scatter the power density. This is corrected by the amplitude correction indicated in section 2.3.

Figure 8, what are the units of the vertical axis?

The unit is degree. Figure was updated to make it clear.

Authors state that they used “more than 800 keograms to run the tests of method”. How were those keograms generated? Do the synthetic waves have the same properties (e.g. wavelengths, periods, amplitudes)? Explain the distribution of the wave parameters.

The new version of the text (lines 258-265) details the set of simulations.

At page 11, lines 191-196, the authors state some issues related to the amplitude of the synthetic waves retrieved through their method. The main reason is the superposition of the waves. In the atmosphere, waves do coexist, making this an issue that is difficult to avoid.

The authors agree with this. The new text version discusses this point more in the errors section. We also expect our manuscript to provide more insights on how to lessen this issue, as the method to validate the phase lines indicated an important feature of the wave superposition. Refer to lines 266-273 of Section 4.

On page 12, lines 215-218, the authors suggest that the direction of propagation is isotropic, but say that the waves propagate preferentially eastward. It seems contradictory. Additionally, state that there is no filtering pattern. I infer they are referring to filtering by background wind. It is important to make this clear. Moreover, explain why such filtering is not observed for these waves.

In our research field, we typically seek anisotropies associated with background wind filtering patterns (see, e.g., Giongo et al., 2020), and that is what we meant there and with the presented figure. In addition to MSGW's present anisotropy, where most of the waves propagate eastward, we could not determine whether the eastward propagating waves are the faster ones, which indicates wind filtering anisotropy. No wind filtering is detected because the waves are much faster than the wind, allowing them to propagate from the ground without being absorbed by the background.

On page 14, line 240-244. The expression “Above the equatorial region” is used a couple of times referring to observations at Cariri (7.4º S). This phrasing sounds unusual.

The paragraph was modified to make the text more clear.

On page 15, lines 250-255. Amplitudes of gravity waves inferred from airglow are rare because the all-sky imagers must be calibrated to measure absolute intensity.

That is indeed a current problem. The imagers have not been calibrated to show the airglow brightness in an appropriate unit. Therefore, we must explore the wave amplitudes in terms of relative brightness and somehow convert this to temperature (a procedure being explored in the next paper composing the first author's thesis)

The authors analyzed gravity waves observed in the Antarctic Peninsula and compared them with waves observed in the equatorial region. For the purpose of the paper, which I assume is to validate their methodology, this comparison may not be ideal.

The comparison aimed to discuss the results with other observation sites, a common practice in our research field. The discussions were revised in the current version.

The keogram technique is widely used to investigate medium-scale gravity waves in airglow images. Since the authors are proposing an automatic algorithm, they should validate their results against the standard keogram analysis by manually analyzing the wave parameters.

The authors included in the discussion section a comparison with the older methodology along with the key advancements achieved through the newly developed methodology. Unfortunately, standard analysis methods are not recognized in the literature. The authors are pleased to demonstrate that their method can serve as a reference by showing the error estimation in relation to the phase fitting quality. This new discussion can be found in lines 331-351.

Minor
page 3, line 63
63ºC degree -> 63ºC
page 3, line 79
Fig 1a -> Figure 1a
page 3, line 87
disposing of them -> disposing them
Maybe the word “disposing” is not the best choice to describe the situation. It could be “arranging
them”, “stacking them”.
page 3, lines 87-88
shorter periods representing high-frequency waves easily analyzed by other methods -> shorter
periods representing high-frequency waves can be easily analyzed by other methods

page 4, lines 105-106
Prominent peaks can be seen near 20, 30, 50, 80, and 140 minutes of period ->Prominent peaks can be seen at periods near 20, 30, 50, 80, and 140 minutes

page, 5, line 118 average around ->averaged around

page 12, line 212, 20 min was the lesser value ->20 min was the lowest value

The authors thank the Referee for the minor suggestions.