Referee comment #2

Thank you very much for your careful review, valuable comments, and suggestions for improvement!

Our response is displayed in regular blue font, while the revised text is displayed in italic font and highlighted in the revised draft manuscript.

Major comments

1. The manuscript presents three case studies, but only one of them is thoroughly characterized and utilized. We appreciate that the authors make use of a rich suite of instruments and observational approaches to describe and/or interpret the cases (including radio soundings, total sky images, radar-lidar target classifications, back-trajectories). However, the derivation of wave parameters, which is of particular interest to the community given the general lack of measurements of HFGWs, appears very brief (lines 244-255) and a bit disproportionate compared to the amount of data introduced. The manuscript would greatly benefit from further and more explicit details on how the wave parameters are calculated and on their relative uncertainties, as well as from the derivation of additional wave parameters.

The authors could independently determine the wave characteristics to validate their current estimates by only using radio soundings, following the methodology of Guest et al. (2000). In particular, the vertical profiles of zonal (u) and meridional (v) velocity could be used to make a hodograph, which is expected to reveal an elliptical polarization (at least in the altitude range of most intense wave activity). The aspect ratio of the ellipse should allow the determination of the wave frequency, the direction of its major axis would indicate the orientation of the horizontal wave vector, while the anticyclonic (cyclonic) rotation of the hodograph with altitude would inform on the upward (downward) energy propagation. Finally, the vertical wavelength can be determined by fitting a polynomial to the vertical profiles of u and v with the least-squares method, as outlined in Guest et al. (2000).

Using wind profiles from radiosoundings, the authors could also compute the wave intrinsic frequency and intrinsic phase speed, which account for the Doppler shift induced by the background wind (ruled out as unimportant, hence neglected in the present version of the manuscript, cf. lines 356-357). If radiosoundings were performed regularly throughout the campaign, it would be very interesting to see what Figure 11d looks like when plotting the intrinsic period instead of the ground-relative one, e.g., would the data collapse?

Response: We agree that a more explicit description of the wave parameter derivation is needed. In the revised manuscript, we have clarified the calculation procedures for the wave parameters and added the relevant equations. We have also added a discussion of the uncertainties associated with these derived parameters in Discussion section.

We agree that radiosonde-based hodograph analysis, following the methodology of Guest et al. (2000), is a useful approach for characterizing gravity waves when the wave signal is clearly resolved in the wind profiles. However, we consider that this method is not directly applicable for the present HFGW analysis. The HFGWs identified in this study are dependent on temporal filtering of continuous MWACR Doppler velocity observations. In contrast, radiosonde measurements provide instantaneous vertical profiles and cannot be subjected to the same temporal filtering procedure. Therefore, a radiosonde-based hodograph analysis would likely characterize gravity waves with larger amplitudes and longer periods rather than the high-frequency waves identified from the radar observations. Furthermore, the hodograph method requires a reliable estimation of the wave's elliptical polarization. For high-frequency gravity waves, the polarization can become nearly linear, which may introduce substantial uncertainty into ellipse fitting and the subsequent derivation of wave parameters. Therefore, the Guest et al. (2000) methodology, although valuable, would not provide a reliable independent validation of the HFGW parameters in this case. This limitation has been clarified in the revised manuscript.

The intrinsic frequency and intrinsic phase speed can, in principle, be derived by correcting for the background wind. However, this requires reliable estimates of the horizontal wavenumber and the background wind component along the wave propagation direction. In the present study, the horizontal wavelength is inferred from the gravity wave dispersion relation, while the propagation direction cannot be independently determined from the available single-site observations. Therefore, the intrinsic wave parameters cannot be estimated robustly.

Lines 270-279: *The FFT spectrum, shown in Fig. 6(b), exhibits a well-defined peak, with a dominant period of 10.24 minutes. The corresponding frequency, denoted by* ω*, is defined as* $\omega = \frac{2\pi}{T}$*, where* T *is the wave period. In this case,* $\omega \approx 0.0102\ s^{-1}$*. The observed frequency is marginally smaller than the Brunt-Väisälä frequency,* $N = \sqrt{\frac{g}{\theta}\frac{\partial\theta}{\partial z}} = 0.0144\ s^{-1}$*, which corresponds to a buoyancy oscillation period of 7.28 min. Here,* g *is the gravitational acceleration,* θ *is the potential temperature, and* z *is altitude. The value of* N *is calculated from the radiosonde profile at 5.5 km altitude. These values satisfy the theoretical conditions for HFGWs, where the wave frequency* ω *lies between the inertial frequency* f *and the Brunt-Väisälä frequency* N*, and is close to* N *(*$f < \omega \lesssim N$*). The vertical spacing between successive MWACR reflectivity maxima (or banded structures) observed in the MWACR data suggests a vertical wavelength* λ_z *of approximately 3 km, which implies a horizontal wavelength of* $\lambda_x = \lambda_z\sqrt{\frac{N^2}{\omega^2} - 1} \approx 2.97$ km*. The corresponding vertical and horizontal wavenumbers are* $m = \frac{2\pi}{\lambda_z} = 2.09 \times 10^{-3}\ m^{-1}$ *and* $k = \frac{2\pi}{\lambda_x} = 2.12 \times 10^{-3}\ m^{-1}$*, respectively. The horizontal phase speed of this wave can be estimated to be* $c = \frac{\omega}{k} = 4.83\ m\ s^{-1}$*.*

Lines 430-442: *For the Mawson case, the estimated wave parameters are subject to uncertainty. The wave period uncertainty arises mainly from the finite frequency resolution of the FFT analysis, corresponding to approximately tens of seconds for a 10-min wave period based on the 3-hour analysis window. The vertical wavelength determination is primarily affected by the identification of reflectivity maxima, particularly when reflectivity structures are weak or maxima are poorly defined. The Brunt–Väisälä frequency derived from radiosonde temperature profiles is sensitive to small-scale fluctuations in the potential temperature gradient; therefore, smoothing is applied to reduce noise-induced variability in the estimated N^2 profile. Radiosonde-based hodograph analysis (Guest et al., 2000) was not applied because radiosonde profiles cannot isolate the high-frequency signals identified from continuous MWACR observations and would more likely characterize larger-scale, longer-period gravity waves. In addition, the near-linear polarization that can occur for HFGWs may introduce substantial uncertainty in hodograph ellipse fitting and the derived wave parameters. Similarly, the intrinsic frequency and intrinsic phase speed cannot be robustly derived because the wave propagation direction cannot be determined from the available single-site observations.*

2. Echoing the first point raised above, the availability of radiosoundings would also allow for a deeper investigation of the large-scale environmental conditions than currently presented. In the conclusions, the authors claim that these HFGWs can persist "for up to 48 hours under favorable conditions" (line 383), but a systematic analysis is missing in this respect. For instance, the presence of wave ducting at least on the day of the Mawson case study should be more rigorously assessed using the Scorer parameter (e.g.,Stephan, 2020), computed directly from radiosoundings. The Scorer parameter quantifies the relative roles of thermal stratification and wind shear in creating wave ducts and would provide a solid physical validation for the wave trapping mechanism, rather than just qualitatively invoking it, as done at lines 357-358 in the present version of the manuscript. It might well be that wind shear plays a role in defining the boundaries of a possible duct, since strongly sheared layers appear to be present at several levels (e.g.,at 1.5 km and 9 km in the first two soundings in Figure 5b,e). The authors need to confirm their argument on the thermal duct (lines 354-355 and 357-358) with a more quantitative approach and, if measurements are available, determine to which extent the environment can generally sustain wave ducting.

Response: We have calculated the Scorer parameter using the radiosonde observations at Mawson and added a quantitative assessment of the contributions from thermal stratification and wind shear. The revised analysis (Fig. 14) shows that the enhancement of the Scorer parameter is mainly associated with the thermal stratification term, while the wind shear contribution is relatively small. This supports our interpretation that the observed wave trapping was primarily related to thermal ducting rather than shear-induced ducting.

We agree that a systematic assessment of waveguide conditions using more radiosonde profiles would contribute to a deeper understanding of the general occurrence of waveguide environments. However, such an analysis is challenging and beyond the scope of the present study because identifying and characterizing high-frequency gravity waves requires simultaneous continuous cloud radar observations, suitable cloud conditions, and coincident radiosonde measurements. In this study, the waveguide mechanism is discussed only as a possible explanation for the prolonged (e.g. 48 h) HFGW activity observed by the cloud radar, rather than as a statistically demonstrated controlling factor. Therefore, we conducted a Scorer parameter analysis for the Mawson case, where the required observations were available, to provide a quantitative assessment of the possible ducting conditions. The corresponding discussion has been added to the revised manuscript.

Lines 403-414: *The Scorer parameter l^2, which characterizes the vertical propagation conditions of gravity waves, can be expressed as: $l^2 = \frac{N^2}{(c-U)^2} + [\frac{1}{c-U}] \times \frac{d^2U}{dz^2}$, where U represents the background horizontal wind component and c is the approximate horizontal phase speed of the gravity wave at Mawson on 8 February 2018 (Stephan, 2020). The two terms represent thermal stratification (T1) and wind shear (T2) contributions, respectively. The Scorer parameter profile in Fig. 14 (a) and (b) shows an enhanced positive l^2 layer bounded by regions with lower (or negative) l^2, indicating a vertically confined propagation channel consistent with gravity wave ducting. There is less sign of ducting in Fig. 14 (c), but no cloud is observed in this period, so we can not identify whether this influences the wave. The enhanced l^2 profiles in Fig. 14 (a) and (b) are primarily associated with the thermal stratification term, while the wind shear term contributes relatively little, suggesting that the ducting structure is mainly controlled by thermal stratification rather than wind shear (Fritts and Alexander, 2003). Given the relatively weak background winds (mean speed < 10 m s^{-1} below 8 km), Doppler shifting is likely negligible, so this ducting environment may have contributed to the persistence of HFGWs below 8 km.*

3. The discussion introduces several interesting directions of research, but still lacks some focus. In our opinion, the discussion around potential gravity wave sources currently feels a bit general and it is difficult to determine which mechanism is most likely responsible for the waves observed in the analyzed case. It would be highly beneficial to link the proposed mechanisms more directly to the specific case study, rather than referring the reader to previous literature, as often done here. The identification of a direction of propagation from the hodograph, as suggested in point 1 above, could help for this purpose.

With regards to cloud-wave interactions, the methodology to obtain cloud geometrical properties appears quite concise (line 322). We are not entirely sure whether the manuscript demonstrates a direct influence of waves on clouds (thereby indicating a causality), as also suggested by the manuscript's title, or just a correlation between wave activity and cloud geometrical properties. How significant is this correlation? Could the authors speculate on the physical processes responsible for the differences in cloud geometrical properties with and without HFGWs? Moreover, a discussion on the limits of the present approach would be useful, e.g., how challenging is it for the Doppler radar to detect thin clouds and the signature of wave activity within them? Finally, the periodic modulation of cloud properties by the waves is a very interesting aspect. The discussion here currently feels somewhat descriptive. Commenting on the physical processes that can contribute to this modulation would definitely add value.

Response: We agree that identifying the dominant gravity wave source is important. However, source attribution is particularly challenging for the present case because the observations were made in the Antarctic coastal region, where multiple gravity wave generation mechanisms may coexist. The discussion in the manuscript is intended to evaluate the plausible source mechanisms in the context of this specific HFGW event, rather than to provide a general overview. Although we cannot definitively identify the wave source, we compared the amplitude of the high-frequency gravity waves (HFGWs) with the ship's latitude (Fig. 10e). The HFGW amplitude shows little variation with latitude, suggesting that katabatic winds, which are primarily confined to the East Antarctic coastal region, are unlikely to be the dominant source. Instead, the observations are more consistent with gravity waves generated by mechanisms with a broader spatial extent, such as frontal systems and jet imbalance. This has been incorporated into the revised manuscript.

The analysis in Figure 11 aims to characterize the cloud-top and cloud-base heights of cloud layers associated with HFGW events, which helps identify the cloud environments where HFGWs occur and provides context for interpreting their propagation conditions and possible waveguiding structures. Evidence of wave–cloud interaction in this study is primarily manifested through the modulation of radar reflectivity associated with HFGWs. We have added a quantitative analysis of the reflectivity occurrence frequency and expanded the discussion of the physical processes that may contribute to the modulation of cloud properties by HFGWs.

Furthermore, the differences in cloud geometrical properties between periods with and without HFGWs may result from a combination of factors, including variations in the background thermodynamic environment, water vapor availability, and cloud formation processes. A detailed investigation of the relative contributions of these factors is beyond the scope of the present study and will be addressed in future research. In addition, we have added a discussion of the limitations of the present approach in the revised manuscript.

Lines 346-350: *Figure 10 (e) displays the latitude of the vessel as a function of time. Comparison of the HFGW amplitudes with the latitude of the vessel shows little sign of a latitudinal variation. This implies that the different sources detailed in Section 4.2 produce gravity waves of comparable magnitudes since the katabatic forcing would only be observed near the East Antarctic coastline. Potentially highlighting that frontal and jet sources dominate.*

Lines 362-377: *To investigate whether HFGWs influence cloud properties, MWACR reflectivity was analysed. As shown in Fig. 12, the MWACR reflectivity exhibits a clear periodic signal in the FFT spectrum, with a dominant period of 10.67 minutes, closely matching the 10.24 minutes period derived from the Doppler velocity using the same analysis window and altitude (Fig. 6). Because reflectivity variability can also arise from cloud inhomogeneity, fall streaks, and virga, a more stringent spectral criterion (peak ratio > 2.0) was adopted for the statistical analysis to isolate robust wave signatures. Periodic reflectivity oscillations were identified for approximately 13,800 min, accounting for 22% of the total time that clouds were observed (Table 1). Among these, HFGW signatures were simultaneously detected in both Doppler velocity and reflectivity for approximately 10,320 min, corresponding to 16% of the total period where clouds were present (Fig. 10(c)). Reflectivity-based HFGW signatures occupied 75% of cloudy days, while coincident detections occurred on 61% of cloudy days. The majority of reflectivity-based HFGW detections coincided with Doppler velocity signatures, whereas only about one-third of the Doppler velocity detections exhibited corresponding periodic reflectivity variations. This suggests that although HFGWs commonly produce coherent vertical velocity oscillations, only a subset generates sufficiently strong changes in cloud microphysical properties to produce detectable reflectivity oscillations. Such reflectivity variations may result from wave-induced vertical motions and associated thermodynamic perturbations. The alternating upward and downward phases of HFGWs potentially modify supersaturation and condensate conditions, influencing hydrometeor properties and consequently radar reflectivity. However, radar reflectivity alone cannot identify the specific microphysical processes responsible for these variations or quantify their magnitude.*

Lines 415-423: *We note that HFGWs are not expected to occur exclusively under cloudy conditions; however, clouds provide the scattering targets required for MWACR to detect the associated vertical motions. A limitation of this study is that the detectability of HFGW signatures therefore depends on hydrometeor characteristics and cloud radar sensitivity. Thin ice clouds may still allow periodic Doppler velocity oscillations to be observed, whereas very weak echoes can reduce the reliability of velocity retrievals. Conversely, in clouds with strong particle sedimentation or precipitation, the fall velocity of hydrometeors may mask the HFGW-induced vertical motions. Consequently, some HFGW-related cloud responses may not be observable by the cloud radar. Nevertheless, Doppler velocity oscillations remain the primary evidence for HFGWs, while reflectivity variations provide additional information on the associated cloud modulation.*

Specific comments

1. *Title, Abstract* Based on point 3 above, we believe that the expression "influence on cloud properties" in both the title and the abstract (line 3) should be removed or carefully re-evaluated, unless new analysis is provided

to substantiate it.

Response: Following the reviewer's recommendation, we performed a new statistical analysis of HFGW signatures in radar reflectivity throughout the MARCUS campaign. The revised manuscript now includes a new subsection entitled "Influence of HFGWs on Cloud Properties", which quantifies the occurrence of periodic reflectivity oscillations associated with HFGWs. The results show that HFGW signatures identified from reflectivity occurred during approximately 22% of the total cloudy observation period and on 75% of cloudy days with reliable observations. These new analyses provide observational evidence that HFGWs are frequently associated with variations in radar reflectivity, which is consistent with an influence on cloud properties. Accordingly, we retained the corresponding wording in the title and abstract while revising the text to better reflect the observational nature of the evidence.

Lines 362-377: *Same paragraph as above.*

2. *Lines 75, 273* The authors refer to cyclone-generated gravity waves and cite Nolan and Zhang (2017). Since that study focuses on tropical cyclones, the authors need to clarify to what extent their findings are applicable to the extra-tropical cyclones considered here, or alternatively to provide references more directly relevant to the generation of waves by extra-tropical cyclones.

Response: We have added references regarding gravity wave generation mechanisms associated with extratropical cyclones.

Lines 82-87: *Cyclones have previously been identified as sources of HFGWs, for example Nolan and Zhang (2017) showed from satellite imagery that tropical cyclones can efficiently generate short-wavelength HFGWs that radiate outward from the storm center, with tightly wrapped spiral wavefronts shaped by strong shear-induced differential advection and radial wavelengths of approximately 2–10 km. Although the dynamical structures of tropical and extratropical cyclones differ, similar wave-generation mechanisms associated with flow imbalance, frontal dynamics, and strong wind shear have also been reported for extratropical cyclones (Gedzelman and Donn, 1979).*

3. *Lines 149-154* The reliability of the chosen ERA5 variables should be discussed. In particular, the vertical velocity in reanalyzes (presented in Figure 8b) has been questioned a lot, at different scales (Uma et al.,2021).

Response: We have added a sentence about the vertical velocity uncertainty of ERA5 and clarified that it is used only to provide large-scale dynamical background conditions rather than to directly identify or quantify gravity wave vertical motions.

Lines 164-165: *Although uncertainties exist in ERA5 vertical velocity (Uma et al., 2021), it is used here only to characterize the large-scale subsidence near the Antarctic coast.*

4. *Line 182* The authors select the dominant spectral peak within a pre-determined frequency interval and then conclude that the waves satisfy the condition $< N$, with N lying outside (above) the interval (lines 248-251). The condition would be mathematically satisfied by default. Please clarify how this can be considered meaningful.

Response: We have revised the Methodology section to clarify the distinguish between the spectral analysis used for the case studies and that used for the statistical analysis. The pre-determined frequency interval was applied only in the automated identification of HFGWs for the statistical analysis. In contrast, for the case studies, the dominant spectral peak was identified from the full spectrum without imposing any predefined frequency interval. Therefore, the condition $< N$ is an independent physical verification rather than a consequence of the frequency selection. We have revised the Methods section to clarify this distinction.

Lines 202-203: *Note that the predefined frequency interval was used only for the automated identification of HFGWs in the statistical analysis. For the case studies, the dominant spectral peak was identified from the full spectrum.*

5. *Line 208, Figure 4* This figure is hard to interpret in its present version. The cloud stripes are not really visible, so we would not claim they are "evident", as done at line 208. Could you make the figure bigger or increase the contrast? The cardinal direction are not readable. Maybe adding the synoptic scale wind direction at the cloud altitude could be interesting.

Response: We have improved the contrast of the figure and added the cardinal directions (north, south, east, and west) to facilitate interpretation. The wind direction at the cloud altitude was not available for this case; instead, we have added an arrow indicating the observed cloud movement direction.

6. *Lines 211* The ubiquitous nature of HFGWs cannot be stated from three snapshots. We suggest leaving "ubiquitous" for later when the statistical analysis is presented.

Response: The sentence "highlighting the ubiquitous nature of HFGWs" has been removed and is now discussed only in the context of the statistical analysis.

7. *Lines 212-213* Could you please rephrase? Assuming that the favorable conditions refer to the presence of clouds, you could write something like "the persistence of clouds allowed a continuous 48-hour monitoring of gravity waves...".

Response: The sentence has been rephrased.

Lines 223-224: *the persistence of the cloud layers allowed continuous monitoring of gravity waves over a 48-hour period (Fig. B1), suggesting sustained HFGW activity over an unusually long duration.*

8. *Figures 2a,c,e and A1* In addition to the gravity wave signal, marked vertical gradients in Z and w are apparent. Are these due to ice accretion

processes? Could you briefly comment on them (even in the appendix if you prefer)? It might not be obvious to the reader.

Response: We have added a brief explanation in the manuscript regarding the causes of the vertical gradients in reflectivity and Doppler velocity.

Lines 233-235: *The pronounced vertical gradients in reflectivity and Doppler velocity mainly reflect the background evolution of ice-cloud microphysical properties (e.g., ice particle growth and sedimentation), with gravity-wave-induced oscillations superimposed on these gradients.*

9. *Lines 221-234* The structure of this paragraph should be made clearer and more precise. At lines 222-223, the authors state that "the radiosondes launched at 05:30 UTC and 11:30 UTC passed through or close to cloud layers", based on the fact that "the dew-point temperature is close to the dry-bulb temperature" (lines 226-227). Radiosoundings indeed measure thermodynamic state variables and in these cases they identify near-saturated conditions. The authors should therefore consider removing the claim of "evidence of clouds" at line 228. They could then discuss the vertical stability structure, and we would recommend replacing the expression "step-like temperature variations" (line 224) with "regions of enhanced stability" (or similar) here and wherever applicable throughout the manuscript.

Response: The wording has been revised accordingly. We have also replaced "step-like temperature variations" with "regions of enhanced stability" throughout the manuscript.

Line 244-245: *Figures 4(a) and (d) show regions of enhanced stability (temperature variations of approximately 0.3–0.7 °C) within the altitude range of the cloud layer.*

Lines 399-400: *The radiosonde temperature profiles in Figs. 4(a), (d), and (g) reveal tropospheric temperature inversions.*

Lines 465-467: *A detailed case study at Mawson on 8 February 2018 reveals regions of enhanced stability within the cloud layer, accompanied by pronounced fluctuations in radiosonde ascent rates.*

10. *Line 235* Could the authors clarify what is meant exactly by "convective generating cells" here?

Response: The term "convective generating cells" has been clarified.

Lines 254-255: *Fluctuations in the radiosonde ascent rate can arise from several processes, including convective generating cells (localized convective cell structures), turbulence, and gravity waves.*

11. *Lines 235-239* Is this statement based on the target classification mask? Could you verify the presence or absence of liquid water with MPL backscatter or depolarization or is the lidar signal fully attenuated?

Response: Based on the target classification, no liquid water was identified in this case. Therefore, this interpretation is limited to the present ice-cloud case and does not exclude the possibility that gravity waves may also influence clouds containing supercooled liquid water, such as virga cases, which will be investigated in future work. To further support our interpretation, we have also added an analysis of the radiosonde balloon trajectory.

Lines 255-261: *The formation of classical generating cells generally requires the presence of a liquid water layer, or at least substantial amounts of liquid water near the cloud top, to enable ice formation through ice-nucleation processes (Alexander et al., 2021). These conditions are unlikely to occur in thin ice clouds in this case, as shown in the classification results in Fig. A1. Given that the horizontal scale of generating cells is typically only a few kilometres (0.6–3.6 km; Alexander et al. (2021)), and that the horizontal drift of the radiosonde within the cloud layer is very limited, it is unlikely that the radiosonde directly sampled the core of an individual generating cell. Therefore, the cloud-top cellular features observed after 12:00 UTC in Fig. 2(f) are not considered to represent generating-cell structures.*

12. *Line 250* Here, what is the hypothesis you make to analyze your snapshots? Do you consider the observation as stationary with respect to the ground? with respect to the instrument? Does it remain valid when looking at the moving ship (avg. 10 km is of the same order of magnitude as the phase speed)? Could be partially solved through major point 1.

Response: Based on the ship navigation data, the vessel remained stationary at a fixed location near the Antarctic coast during the analysis period (05:00–13:00 UTC), with no measurable horizontal displacement. Therefore, the observations can be regarded as fixed-point measurements, and no correction for platform motion is required. The temporal variability discussed in the manuscript thus reflects atmospheric variability at a quasi-fixed location.

Lines 266-267: *Navigation position data indicate that between 05:00 and 13:00 UTC on 8 February 2018, the vessel remained stationary at Mawson, with no horizontal displacement.*

13. *Line 253* In Figure 2f, the slope of the iso-phase (iso-reflectivity) lines is of about 4 km h−1, which gives a vertical wavelength of 0.5 km for the given period of 7.28 min.

Response: The reviewer appears to combine the apparent phase speed inferred from iso-phase slopes with the Brunt–Väisälä period. However, this combination is not physically consistent in the present analysis. The value of 7.28 min corresponds to the Brunt–Väisälä frequency derived from radiosonde profiles, rather than the observed wave period. Even if the observed wave period (10.24 min) is used, the approach based on multiplying the apparent phase speed derived from iso-phase slopes by a temporal period is not physically consistent for deriving the vertical wavelength in gravity-wave theory. In this study, the vertical wavelength is independently obtained from the dispersion relation using the spectral peak frequency and radiosonde-derived stability (N), rather than from the iso-phase slope.

14. *Lines 292, 321* Given that HFGWs can propagate over long horizontal distances from their source under favorable conditions (e.g, ducting), topographic forcing cannot entirely be ruled out. Maybe it would be better to replace "cannot" with "might not"?

Response: We have revised the statement as suggested. In addition, we would like to clarify that our interpretation is based on the relatively limited phase speed (4.83 m s^{-1}) of the observed HFGW, which constrains their horizontal propagation distance over the analysis period. Given the distance between the Southern Ocean and major orographic features, direct Antarctic topographic forcing is therefore unlikely to be the dominant source, although remote or indirect orographic influences cannot be entirely excluded.

Lines 318-319: *These HFGWs are also observed at numerous locations over the Southern Ocean, far from the coast, during MARCUS (Fig. 1). In these regions, topographic forcing might not be the primary driver.*

15. *Lines 296-302* The expression "could no longer" suggests a permanent malfunctioning after 2 December 2017. Could you please clarify this aspect or provide a clear timeline of the data interval used? Furthermore, it is claimed that Figure 2 demonstrates that the measurements during stationary periods are reliable. Why is this plot a demonstration that the data are reliable?

Response: The phrase "could no longer" was intended to indicate the period from December 2, 2017, to the end of the MARCUS observation period. We have revised the wording to clarify this point. Figure 10(e) has also showed a clear timeline of the data coverage and observation periods.

Regarding the reliability of the measurements shown in Fig. 2, we clarify that the analysis during the stationary periods is considered reliable because the vessel was moored at a fixed location near the coast during these intervals.

Lines 323-324: *The ship's stabilized platform malfunctioned on 2 December 2017, preventing it from providing a stable mounting for the MWACR during the remainder of the MARCUS campaign.*

Lines 327-328: *These include periods when the vessel was stationary near the coastline, as well as the initial phase of stabilized platform operation.*

16. *Line 364, Figure 15* A dominant periodic signal can be seen, but more at periods close to 30 minutes. How does the FFT of reflectivity depend on time bounds? Maybe a third panel could show again for comparison the FFT of Doppler for the same time bounds?

Response: The dominant signal near 30 min is present in the original reflectivity time series. However, the objective of this analysis is to identify high-frequency gravity waves. Therefore, a high-pass filter was applied prior to the FFT analysis to remove lower-frequency variability, including the 30 min component. We have clarified this point in the Methodology section.

During prolonged periods of persistent gravity-wave activity, as illustrated in Fig. B1, the spectral characteristics remain stable across different analysis windows. This indicates that the periodicity identified by FFT is robust and not an artifact of the specific time boundaries chosen. The manuscript has been revised accordingly.

Figure 6 shows the FFT of Doppler velocity for the same time bounds.

Lines 183-185: *Fast Fourier Transform (FFT) spectral analysis was applied to high-pass-filtered MWACR Doppler velocity data. The high-pass filter removed low-frequency variability (periods longer than 30 min), including linear trends, allowing the FFT to focus on oscillations related to gravity-wave frequencies.*

Lines 384-385: *During prolonged periods of continuous gravity-wave activity, as illustrated in Fig. B1, the main spectral peaks remain stable, indicating that the periodicity identified by FFT is robust and not sensitive to the exact choice of time window.*

17. *Discussion* The very weak amplitudes of the observed waves is a finding that could be of interest. Could the authors elaborate a bit more on this, maybe comparing these amplitudes with those found by some previous studies?

Response: We have added a paragraph to the Discussion section to discuss the possible reasons for the weak amplitudes.

Lines 422-429: *The observed amplitudes of the high-frequency gravity waves in this study (0.02 s^{-1}) are smaller than those reported in previous studies (0.2 s^{-1}) (Jia et al., 2019; Banakh and Smalikho, 2016). This discrepancy may be attributed to several factors. First, previous studies investigated different gravity-wave frequency ranges, propagation environments, and background atmospheric conditions, which would contribute to the differences in observed wave amplitudes. Second, HFGWs may experience dissipation during propagation, reducing their amplitudes before reaching the Antarctic coastal region. Finally, the amplitude in this study is calculated by averaging within a finite time window, which is many times the derived periods, unless the wave lasts that long this will introduce a smoothing effect and further reduce the estimated gravity-wave amplitude.*

Technical corrections

1. *Line 1* Wouldn't it be more precise to say that the Southern ocean contains sources?

Response: We have revised the sentence to clarify that the Southern Ocean region contains sources of gravity waves.

Lines 1-2: *The Southern Ocean near the East Antarctic coast contains numerous sources of gravity waves, yet long-lived high-frequency gravity waves (HFGWs) remain poorly documented.*

2. *Line 24* Could the authors further elaborate on the" favourable propagation conditions"?

Response: We have clarified that the "favourable propagation conditions" refer to atmospheric conditions that enable gravity wave propagation, including wave ducting and trapping associated with static stability.

Lines 25-27: *With abundant GW sources and favourable propagation conditions, including wave ducting and trapping associated with suitable static stability and background wind structures, the Southern Ocean, particularly near the Antarctic coastline, is recognized as one of the most active regions for global GW activity.*

3. *Lines 24-25* "the conditions over the Southern Ocean [...] are considered one of the most active regions for GWs globally". Could you please rephrase this sentence, which seems grammatically inconsistent?

Response: The sentence has been rephrased to improve clarity and grammatical consistency.

Lines 25-27: Same sentences as above.

4. *Line 34* Would it be possible to add further references regarding the detection and characteristics of HFGWs?

Response: Additional references regarding the detection and characteristics of high-frequency gravity waves have been added.

Lines 33-38: *High-frequency gravity waves (HFGWs) have small spatial and temporal scales, with typical periods ranging from several to tens of minutes and horizontal wavelengths of a few to several tens of kilometres (Alexander et al., 1995; Fritts and Alexander, 2003). Such waves have been observed using a variety of instruments, including Doppler lidars (Jia et al., 2019; Banakh and Smalikho, 2016), VHF radars (Alexander and Murphy, 2015), airglow imagers (Cao and Liu, 2022), and aircraft observations (Chouza et al., 2016). These studies have shown that HFGWs commonly exhibit periods of 5–30 min and can persist for many wave cycles under favorable atmospheric conditions.*

5. *Line 37* A strong dependence on→ are associated with?

Response: The wording has been revised accordingly.

Lines 41-42: *Dynamically, HFGWs are characterized by frequencies approaching the Brunt–Väisälä frequency (buoyancy frequency) and <u>are associated with</u> stable stratification.*

6. *Line 38* Could you provide a definition of waveguide or a reference? It might not be obvious to the reader.

Response: We have added relevant references.

Line 43: *When trapped within a waveguide (Nappo, 2013; Lindzen and Tung, 1976),*

7. *Line 39* Jia et al. (2019) do not analyze wave-cloud interactions, so we think the reference should be moved to the end of the previous sentence (i.e., after "predominantly transport energy horizontally").

Response: The citation has been moved to the end of the previous sentence as recommended.

Line 43-44: *HFGWs can experience suppressed vertical propagation and predominantly transport energy horizontally (Jia et al., 2019),*

8. *Line 48* Could you expand a bit on which type(s) of satellite products you are referring to?

Response: The satellite products used in this study have now been specified, including VIIRS and NOAA AVHRR.

Lines 53-56: *Among these, satellite products, particularly infrared radiometers such as the Visible Infrared Imaging Radiometer Suite (VIIRS) and the NOAA Advanced Very High Resolution Radiometer (AVHRR), have been particularly valuable for capturing the large-scale spatial distribution of atmospheric GWs.*

9. *Lines 90* jumps→ jump.

Response: Corrected as suggested.

10. *Figure 1* Would it be possible to add to the caption or the colorbar the starting day of the campaign for reference?

Response: The campaign starting date has been added to the Figure 1 caption.

Figure 1: *The campaign started on 29 October 2017, which is defined as Day 0.*

11. *Line 153* Please put citation in brackets.

Response: Corrected as suggested.

Line 162-164: *The data have a horizontal resolution of 0.25° × 0.25° and a temporal resolution of 1 hour (Hersbach et al., 2020) and numerous studies have shown their veracity in this region (McErlich et al., 2023).*

12. *Lines 165-169* Could the authors add a reference for the critical value of the gradient Richardson number?

Response: A reference for the critical Richardson number value has been added.

Lines 178-180: *The gradient Richardson number (Ri), derived from radiosonde temperature, pressure, and horizontal wind profiles, is used to assess the potential for turbulence (Brutsaert, 1972).*

13. *Lines 171* "original irregularly sampled measurements": is there a contradiction with the statement at line 125("measurements acquired every 5 s")?

Response: Although the measurements were acquired every 5 s, the original sampling intervals were not perfectly uniform due to occasional missing observations and quality-control procedures. Therefore, the term "original irregularly sampled measurements" refers to the data after quality control before interpolation. To avoid ambiguity, this is expressed as "the sampled measurements".

Line 185: *The sampled measurements are interpolated to uniform 60-s intervals*

14. *Line 200* Strong vertical coherence is not always clearly visible from Figure 2.

Response: We have revised the wording and indicated that strong coherence is identified mainly during the most pronounced periods of the event.

Lines 215-216: *During several periods, the oscillations exhibit strong vertical coherence, with minimal phase variation over the observed height range, indicating vertical wavelengths of several kilometres or longer.*

15. *Line 208* On 03:18→ at? Could you also specify that the image corresponds to the case study of Figure 2a,b?

Response: Corrected as suggested. We have also clarified that the image corresponds to the case study shown in Figs. 2(a) and (b).

Lines 224-226: *Figure 3 shows the cloud cover observed in a TSI image across the entire sky when the ship was near Davis station at 03:18 UTC on 17 November 2017. The image was acquired during the GW event shown in Figs. 2(a) and (b).*

16. *Line 214* Can we confidently say it is only one event?

Response: The 48-hour case described here indeed corresponds to a single event; however, its position within the original paragraph may have suggested otherwise. We have therefore reorganized the relevant paragraphs to improve the logical flow and make this point clearer.

Lines 222-226: *From 08:00 UTC on 16 November to 08:00 UTC on 18 November 2017, the persistence of the cloud layers allowed continuous monitoring of gravity waves over a 48-hour period (Fig. B1), suggesting sustained HFGW activity over an unusually long duration. Figure 3 shows the cloud cover observed in a TSI image across the entire sky when the ship was near Davis station at 03:18 UTC on 17 November 2017. The image was acquired during the GW event shown in Figs. 2(a) and (b).*

17. *Line 219* Why cannot we identify a vertical wavelength for Casey?

Response: The vertical wavelength could not be reliably determined for the Casey case because the observed wave structures were not sufficiently coherent over the available vertical range.

Lines 236-237: *In the Casey case (29–30 December 2017), the vertical wavelength cannot be clearly determined from reflectivity, as the cloud field is highly fragmented and does not exhibit a continuous phase structure with height.*

18. *Figure 3* This figure is not used much except for stating that the clouds are almost entirely composed of ice. Can it be moved to an appendix? Figure *4* 2027→ 2017?

Response: As suggested, we have moved this figure to the Appendix, where it is now presented as Figure A1. We corrected the year in Figure 3 as suggested.

19. *Figure 6* You could consider adding this figure as a panel to Figure 5, perhaps also for the other soundings? Maybe you could also perform some vertical smoothing of the vertical profiles of temperature and horizontal wind, which would make the message more evident.

Response: Figure 5 is intended to provide a separate analysis of the possible gravity wave source mechanism and is therefore presented independently from Figure 4, which characterizes the background atmospheric structure derived from the radiosonde observations. In addition, vertical smoothing was not applied because the small-scale structures in the temperature and potential temperature profiles may represent variations in static stability that are relevant to wave ducting, while the oscillations in the horizontal wind profile may contain gravity wave signatures. Applying smoothing could therefore remove physically meaningful features associated with wave propagation.

20. *Line 282* Does Grazioli et al. (2017) talk about gravity waves?

Response: The reference has been removed because Grazioli et al. (2017) does not specifically discuss gravity waves.

21. *Figure 11* Would it be possible to show the dates of the three case studies as vertical bars in panels a,d,e? Would it be possible to also add a panel on the right of panel d with the KDE of gravity wave periods for Davis, Casey and Mawson?

Response: The dates of the three case studies have been indicated by vertical bars in Figure 10. In addition, the periods for Davis, Casey and Mawson are discretely distributed without a meaningful continuous density variation. Therefore, the KDE results do not provide additional information for comparison and were not included.

22. *Line 341* On which day?

Response: The corresponding date has been added.

23. *Line 352* Could you add the corresponding period?

Response: The corresponding period has been added.

24. *Line 356* Where is the local buoyancy period calculated?

Response: The local buoyancy period is not essential for the present discussion, which focuses on the thermal ducting mechanism based on the vertical structure of the Brunt–Väisälä frequency (N^2). Therefore, this statement has been removed to avoid unnecessary discussion.

25. *Figure 14* Maybe some vertical smoothing could make the stratification profile clearer?

Response: The profile has already been vertically smoothed. Further smoothing could weaken or remove physically meaningful small-scale stable layer structures, which may affect the identification of thermal structures associated with waveguide formation.

26. *Line 393* MAwson→ Mawson

Response: Corrected as suggested.