Review of "Observed large-scale trapping of gravity waves within the free troposphere"

Summary of article and general comment

This manuscript presents a detailed observational investigation of gravity waves in the free troposphere over the tropical Atlantic during the MAESTRO campaign. By combining airborne in situ measurements, lidar and radar observations, radiosoundings, and satellite imagery, the authors characterize a wave packet and investigate the environmental conditions that may support its confinement. The analysis goes beyond identifying wave signatures: it examines their polarization and vertical structure, proposes a cavity model to interpret the different dominant scales in horizontal and vertical velocity, and introduces the Trapping Likelihood Index (TraLI) to explore the broader occurrence of potentially favourable environments.

A particular strength of the manuscript is the depth of the physical analysis and the resourceful use of complementary observations. The authors make a substantial effort to connect the measured signals to dynamical mechanisms, including features that are not immediately explained by a simple travelling-wave interpretation. I particularly appreciate the amount of dynamical information extracted from the available measurements through their combination with linear wave theory and an idealized model. This is a thoughtful and scientifically substantial study, with a valuable observational contribution and an ambitious attempt to connect an individual event to a more general understanding of tropospheric wave trapping.

My main comments concern the physical consistency and scope of several interpretations built on this observational foundation. In particular, the relationship between the cavity eigenfunctions and the observed velocity components, the distinction between propagation reference frames, and the physical meaning of TraLI require clarification. These points affect central conclusions and lead me to recommend major revision. Addressing them would strengthen the connection between the observations, the proposed mechanisms, and the broader diagnostic, while allowing the considerable strengths of the study to emerge more clearly.

Major comments

1 Physical meaning of TraLI

Section 4, lines 412-440; Equations 14-15

Equation 15 requires lower and upper levels with $S_0 < S_c$, does not require an intervening layer with $S_0 > S_c$. A profile below the threshold throughout the column therefore satisfies the criterion, although it contains no propagating cavity at the target wavelength within the adopted approximation. This differs from the waveguide configuration described in Section 3.4.

Could the authors add the intermediate propagation condition, or explicitly describe TraLI as the spatial co-occurrence of two potential evanescent regions? Even with this condition, a candidate waveguide does not establish that trapped modes are excited. Likewise, cloud bands establish wave activity without independently identifying vertical confinement. The statement that high TraLI is sufficient for trapping should therefore be qualified to reflect what the index and observations actually establish.

2 Cavity eigenfunctions and observed polarization

Section 3.5, lines 330-362; Equations 11-13; Figures 6-7

The explanation of the different horizontal- and vertical-velocity peaks is appealing, but appears inconsistent with the stated cavity geometry. Under the symmetric boundary conditions, continuity with the decaying exterior solutions gives

$$\widetilde{w}_n(z) \propto \cos[m_n(z - z_b) - \frac{\psi}{2}], \qquad m_n H = n\pi + \psi.$$

For mode 2, the vertical-velocity antinode and horizontal-velocity node lie at $z_b + H/2 = 6.1$ km for $z_b = 4.5$ km and $H = 3.2$ km. The aircraft flew at approximately 5.8 km. Using the rounded values of N and $\widehat{\omega}$ in Tables 1-2 and $\tilde{u} = (i/k)\,\partial_z \widetilde{w}$ gives $|\tilde{u}_2/\widetilde{w}_2| \simeq 1.9$ there, rather than a horizontal-velocity node.

Could the authors reconcile Figure 7 with these boundary conditions and explain whether the predicted component amplitudes at flight level support the proposed mechanism? Since H was fitted to the spectral peaks, this polarization comparison is particularly useful for establishing what the model explains beyond their positions.

3 Propagation reference frames and source attribution

Section 3.3, lines 245-254; Figure 4c; Table 2; Section 5.1, lines 484-496

The quadrature argument should distinguish intrinsic from ground-relative phase propagation. The linear thermodynamic equation is

$$(\partial_t + \mathbf{U} \cdot \nabla_h)\theta' = -w' \, \partial_z \overline{\theta}.$$

Thus, upward motion determines the temperature tendency following the background flow; it does not alone determine the tendency at a fixed ground location. Table 2 illustrates why this matters: the intrinsic and ground-relative phase speeds along the $125°$ axis are +5.6 and -2.9 $\mathrm{m\,s^{-1}}$. Please make the reference frame of Figure 4c and its fixed-location explanation consistent with these opposite signs.

The exclusion of convection southeast of the packet also needs reconsideration: a source-to-packet connection concerns ground-relative group propagation, including background advection, rather than intrinsic phase direction alone. An unidentified source additionally leaves its contribution to the observed spectrum unresolved. Environmental filtering remains a plausible influence, but its dominance over the forcing is not established by the absence of source identification.

4 Common frequency and packet identification

Section 3.5, lines 364-370; Supplement, Sections 4.1-4.2.

A shared propagation direction does not establish a common intrinsic frequency or source; even one source can generate a broad frequency spectrum. Section 4.1 of the Supplement also identifies a differently oriented component, particularly for the first mode. Please distinguish the modes attributed to the main packet and present the common frequency as a modelling assumption unless it is independently constrained.

The extension to shear in Supplement Section 4.2 raises a related physical question. For fixed ground-relative frequencies, $\hat{\omega}_j(z) = \omega_j - k_j U(z)$. Modes sharing an intrinsic frequency at one level generally acquire different Doppler shifts elsewhere when their horizontal wavenumbers differ. Could the authors clarify the conditions under which one effective stratification profile can represent all modes? A shared vertical deformation does not follow automatically, even for linear shear.

5 Scope of the conservative criterion

Section 4, lines 385-408; Section 5.2, lines 509-510

The proposed direction favours upper-level evanescence, but this does not generally optimize the complete waveguide: the lower boundary and intervening propagating layer must also be compatible, especially when wind direction changes with height.

Setting $c = 0$ does not provide a universal limit either. For antiparallel U_h and c, retaining c increases $|U_h - c|$ and reduces the first Scorer term, potentially allowing evanescence where the zero-speed approximation does not.

Consequently, failure of the adopted criterion does not generally rule out trapping at another direction or phase speed. Please state the restrictions under which the exclusion in lines 399-400 holds, or describe TraLI as a diagnostic for the chosen wave parameters without this exclusion claim.

Minor comments

1. **Amplitudes at different altitudes.** Lines 217-222 combine lidar displacement below flight level with vertical velocity at flight level through $\tilde{w} = -i\hat{\omega}\tilde{\zeta}$. This relation applies locally. Please explain how the different measurement heights are reconciled with the vertically varying eigenfunctions invoked later (manuscript, p. 10).
2. **Direction of the dominant component.** *Lines 223-243; Supplement Section 4.1.* The hodograph in Figure 4b uses band-pass periods of 20–40 s in the aircraft record, whereas the dominant w′ and θ′ signal has a crossing period of about one minute. Please make the connection between their propagation directions explicit, referring to the mode-specific hodographs in the Supplement where appropriate.
3. **Water vapour observations.** *Section 2.2; lines 129-134 and 432-434.* Please identify the water-vapour channels used to support wave activity in clear sky and describe their effective resolution, vertical sensitivity and relevant processing. A representative image would help clarify how these observations support the inferred regional extent and relate to the proposed waveguide.
4. **Finite barriers.** The leakage estimate in Supplement Section 4.2 uses the neutral-exterior decay scale $1/k_h$. In a general evanescent region, the local decay parameter is $\kappa(z) = \sqrt{k_h^2 - S^2(z)}$. Please distinguish the idealized estimate from a conclusion about leakage through the observed thermal-wind barriers; their geometrical thickness alone does not determine attenuation.

Technical clarifications and corrections

Equations 12-13. Please use a quadrant-aware definition of the reflection phase, for example with atan2. This does not affect the central frequency ratio of the case studied.

Figure 6. Please specify the Fourier normalization and explain the “m” unit on the amplitude axis.

Page 4, line 112. Remove the stray “s” in “Yet, s a more detailed examination…” and change “examination … reveal” to “examination … reveals”.

Page 22, line 469. Replace “key takeouts” with “key findings”.