Referee Report

Title: Manuscript: egusphere-2025-2671-manuscript-version2.pdf
Topic: Wave-induced turbulence, non-breaking wave dissipation, and breaking-wave attenuation.

1. Summary

This manuscript presents a theoretical and semi-empirical framework for quantifying turbulent energy dissipation generated by both non-breaking and breaking surface waves. Starting from a unit-volume energy balance, the authors apply a mixing-coefficient turbulence closure in conjunction with linear wave kinematics to derive expressions for wave-generated dissipation in spectral space. The framework is further simplified for deep-water conditions, yielding practical parameterizations (Eqs. 12 to 15) that are suitable for implementation in spectral wave models.

A compact monochromatic formula (Eq. 19) is derived and validated against laboratory measurements, demonstrating that the proposed dissipation model accurately captures the observed dependence on wave amplitude and wavenumber. The framework is further extended to address wave breaking by constructing a statistical post-breaking spectrum and deriving an attenuation coefficient (α_b) based on probabilistic considerations (Eq. 27). Overall, the authors seek to offer a more physically grounded description of both non-breaking and breaking wave dissipation compared to existing empirical formulations.

2. General Assessment

The manuscript addresses a significant problem: the role of wave-induced turbulence in ocean mixing and in shaping the dissipation source terms used in spectral wave models. Both need more exploration. The attempt to unify non-breaking turbulent dissipation with breaking-wave attenuation within a single theoretical framework is ambitious and scientifically valuable.

The work is conceptually strong, and the physical motivation is clear. However, significant revisions are needed to improve the manuscript's structure, primarily in terms of transparency of derivation, justification of parameters, and clarity of exposition. Some modeling steps are only briefly explained, and several constants appear without sufficient context. Furthermore, the organization occasionally obscures the main logic. The manuscript would benefit from editing by a native English speaker, as several sentences are unclear in their current form.

Overall, the manuscript contains potentially impactful contributions to the modeling community, but requires major revision to achieve the clarity and rigor expected for publication.

3. Major Comments

1. Need for clearer derivation structure

Several derivations jump directly from general expressions to reduced forms without showing intermediate steps. This makes it difficult for readers to follow the mathematical logic or reproduce the results. This includes: The reduction steps leading to Eq. 15, which is central to practical modeling; the derivation of the monochromatic dissipation relation (Eq. 19); and the construction of the post-breaking spectrum and attenuation coefficient (Eqs. 24–27). Maybe this could be added in the appendix.

I believe a more explicit presentation of intermediate steps, or a detailed supplementary derivation, would significantly strengthen the work.

2. Clarification of numerical constants and closure assumptions

The manuscript introduces specific numerical coefficients (e.g. 7, 7/8, and others) that originate from minimization principles or closure assumptions. Their physical or mathematical origin should be documented more clearly. For example, it would help to explain more about the constant 7 appearing in the mixing-length formulation, including a brief explanation of the assumptions and limitations. Same with the 7/8 coefficient. Sensitivity to these constants should be briefly discussed.

3. Physical assumptions should be more explicitly addressed

The work is strong but theory relies heavily on assumptions that must be articulated and justified. Including the Quasi-equilibrium between production and dissipation in wave-generated turbulence; Applicability of linear wave theory to turbulence generation; the scaling assumptions connecting orbital velocity gradients to turbulent production; and Statistical assumptions underlying the breaking-wave attenuation model. The work would benefit from a short section discussing the validity and limitations of these assumptions.

4. Notation consistency and clarity

The work relies heavily on mathematical expressions. Nevertheless, the notation usage is occasionally inconsistent or overly dense. For example: The distinction between k and K for wavenumber components vs. magnitude should be standardized. There are inconsistencies with vertical coordinate definitions that vary between sections. It would be beneficial to define every variable used and keep them consistent. Also, the use of overbars, hats, and primes for averaged quantities should be clearly defined and applied uniformly. Maybe a notation table could improve readability.

5. Validation of the model

While the comparison with laboratory data is promising, it is currently limited in scope. To strengthen the validation. A short description of the experimental datasets used could help, and a discussion of the uncertainty in both measurements and model predictions. A comparison with existing dissipation parameterizations could also strengthen the work (e.g. WAM/WW3 whitecapping formulas) and the sensitivity to model parameters such as α_{wt}. Including a short description of the model employed would further aid reader understanding.

5. Recommendation

Major Revision

The manuscript offers significant contributions to the understanding of wave-generated turbulence and dissipation. Nevertheless, clearer derivations, more thorough explanations of constants and assumptions, stronger comparisons with observational data, and a more coherent structure are necessary before the manuscript can be recommended for publication.