We thanks both Reviewers for the provided comments and suggestions that helped us to improve to manuscript and to clarify some points. In the following, we provide one-to-one answers to the raised questions.

Reviewer 1

Line 29: Please specify what type of non-uniqueness is meant in the spectral decomposition — e.g., trade-offs among source, path, and site terms.

We specified that the trade-offs mentioned at line 29 are those among source, propagation and site terms.

Line 68: The statement about constraining the average site amplification for six selected stations to match Campbell and Boore (2016) is unclear. Could you briefly elaborate on how the site amplification was defined and applied, even if it was discussed in Bindi et al. (2023a)?

We provided additional information about the site amplification constraints applied by Bindi et al (2023s) but, as observed by the Reviewer, details are provided in the previous publications. The reference amplification model used by Bindi et al (2023s) to constrain the average amplification of the six reference stations is shown in Figure 5 (left panel). In this study, as written in the text, we are not following the same procedure but we selected four stations and we directly constrained the site amplification at these stations to the results obtained by Bindi et al (2023a). The locations of the four stations are now shown in Figure 1.

Line 82 (Equation 2): The 2D attenuation modeling framework is also widely used in non-ergodic ground motion modeling. I suggest adding references to:

- Lavrentiadis et al. (2022), Overview and introduction to development of non-ergodic earthquake ground-motion models, Bulletin of Earthquake Engineering.
- Lavrentiadis et al. (2023), A non-ergodic effective amplitude ground-motion model for California, Bulletin of Earthquake Engineering.

We added the reference to the Lavrentiadis's (2023) article where we also cited Grendas et al (2022) and Chen et al (2024), which are the most pertinent references to the applied 2D cell grid approach.

Line 92: Suggest changing "represented" to "approximated," since a straight line is a simplification of the true 3D ray path.

Line 92: The geometry of the ray path is frequency-dependent. A straight-line approximation may be more appropriate when lateral heterogeneity is subtle, particularly at high frequencies. It would be helpful to acknowledge this.

We changed text in "By construction, the 3D ray path from source to station is **simplified** by considering a 2D straight line connecting the epicentre to the receiving stations." because indeed more than approximating the 3D ray path with a straight line (approximation that we agree would depend on frequency and, in general, on the 3D velocity structure and on the length of the traveled path), the cell-grid approach strongly simplify the attenuation term by considering a simple 2D straight line connecting station location with the event epicenter.

Line 108 (Figure 3 right panels): In Figure 3, the HYPO model appears generally lower than the 2D azimuthal curves, especially in the lower right panel (14 Hz).Since the HYPO model is a 1D attenuation model, I would expect it to approximate the average of the 2D analysis. Please clarify why the HYPO curves consistently lie below the 2D results.

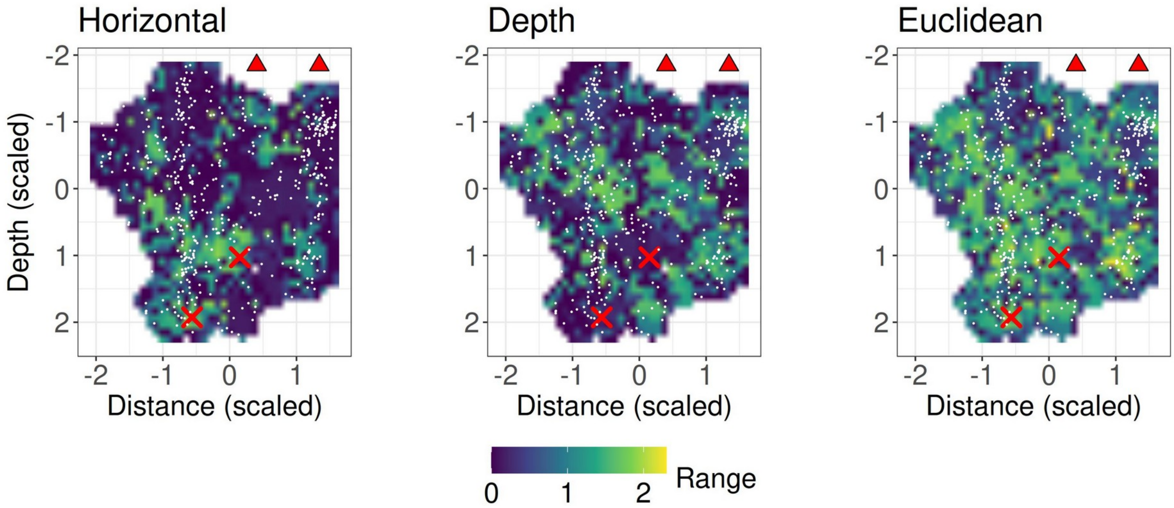
We agree that a direct comparison between the HYPO and 2D attenuation models is not straightforward. As stated in the caption of Figure 3, a comparison in terms of absolute values is not meaningful because the two models adopt different reference distances. To allow for visual comparison, the HYPO model was arbitrarily shifted to match the 2D model at short distances. We acknowledge that the HYPO and 2D models show different attenuation trends, with the HYPO model exhibiting a steeper decay. However, we do not share the expectation that the HYPO curve should lie between the two 2D curves. This expectation would only be justified if the HYPO model represented an azimuthal average of the 2D model, which it does not. The two models are only weakly connected, sharing station and epicenter coordinates, but derived from fundamentally different assumptions. When comparing the HYPO model with the EpiH model, constructed using consistent reference anchoring, the HYPO curve lies within the range of EpiH curves, as shown in Figure 5 of Bindi et al. (2021), supporting the internal consistency of the HYPO model within that framework. The differences observed in attenuation rates between HYPO and 2D in Figure 3 reflect the complexity of projecting a 3D attenuation structure onto a 2D plane. This transformation is not tightly constrained and cannot be expected to preserve averaged attenuation behavior.

Line 150: When applying kriging to the vertical plane, did you observe any depth dependence in the spatial correlation of stress drop? It would be useful to know if the correlation length changes with depth.

We investigated this interesting question by fitting a local Gaussian Process (GP), assuming a Gaussian structure for the covariance of the GP. The fit of the GP is done using the km() function of the DiceKriging library in R. First, we removed from the stress drop the trend with seismic moment Mo through a simple linear regression between logMo and logStressDrop, considering for the analysis the residuals RES=logStressDrop – predicted_value_from_bestfit. Then, we implemented a rolling process to fit locally the GP for each grid point, considering the stress drop residuals. As a result, for each grid point we obtained the range (i.e., the scale length) along the horizontal direction and along the depth, that we plot separately in the figure below (left and middle panels). In the right panel, we plot the square root of the sum of the two ranges squared.

Rather than displaying a single systematic trend with depth, the spatial correlation of residuals reveals multiple localized patterns. For instance, in regions surrounding the mainshocks, the lateral correlation is clearly more pronounced, while correlation along depth appears weak. Conversely, in the high stress drop area located between the two indicated stations, we observe the opposite behavior: lateral correlation is limited, but correlation along depth is strong. Furthermore, as seen in the left panel, lateral correlation tends to be more pronounced at shallower depths, particularly in the portion of the section preceding the two stations. This pattern is less evident in the upper half of the section. Correlation along depth is more scattered and distributed across the section, yet notably reduced in proximity to the mainshock areas. These observations suggest that spatial correlation patterns are influenced by both structural heterogeneity and source complexity, rather than being solely depth-dependent.

This topic is of interest but it deserves a dedicated investigation before drawing final conclusions. We plan to develop in a future study a Bayesian spatial linear model using MCMC (spBayes library in R) to capture the spatial variability of the stress drop residuals. We prefer not to include these preliminary results in the current manuscript.

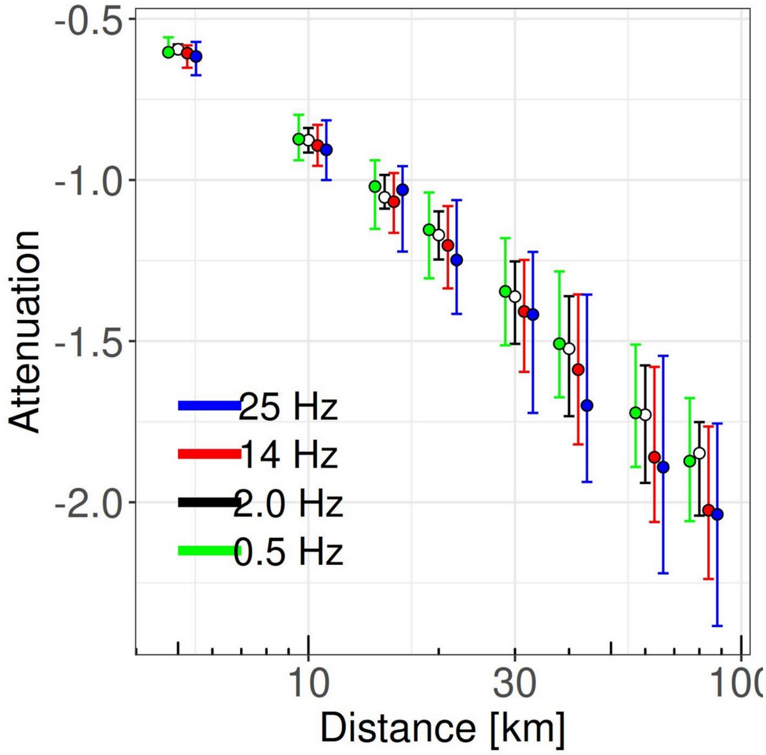


Line 153 and Figure 10a: In Figure 10a, a very high stress drop region appears near 10,000 m along strike and ~11,000 m depth, but individual estimates (Figure 9) do not show particularly high values there. Could this high value result from the kriging interpolation? Please clarify.

We harmonized the limits of the color scale in Figures 9 ans 10 and now the presence of the high stress drop events is clear.

Line 176: Have you analyzed azimuthal variability of attenuation at other frequencies beyond 2 Hz and 14 Hz? If so, it would be helpful to briefly describe the general trend over a broader frequency range.

We added in Figure 4 the results for 0.5 Hz and 25 Hz. Both added frequencies show large azimuthal variability, in particular at 25 Hz.



Line 135 (Equation 4): Please cite Brune (1970) in situ for the 0.37 constant. Additionally, I suggest briefly discussing the uncertainty associated with the choice of source model. Alternative models such as Madariaga (1976), Kaneko and Shearer (2014), and Wang and Day (2017) offer different scaling factors, which could influence the estimated stress drop.

Added

Line 205–206: You state that "the 2D model generally produces higher stress drop amplitudes at depth."Considering the limitations you discussed regarding the 2D ray path approximation, do you believe this trend is physically defendable or possibly an artifact of the modeling approach?

Source parameters and attenuation are strongly interconnected, and we emphasize that attenuation terms and source characteristics must be considered jointly, particularly in applications such as ground-motion simulation. Our results show that the HYPO and 2D attenuation models yield broadly similar trends. In contrast, the EpiH model, which partially accounts for the dependence of attenuation on source depth, produces distinct attenuation behaviors. This divergence suggests that incorporating depth-dependent attenuation, as done in EpiH, may capture features that are not addressed in simpler models. These findings highlight a potential limitation of 2D approach: depth-dependent effects may be mapped into lateral variations, leading to possible misinterpretation of attenuation structure. The different depth trends observed in the EpiH model serve as a cautionary indication that results from HYPO and 2D models should be interpreted with care. Ultimately, we believe that a fully 3D attenuation tomography approach may be the most robust path forward to resolve these complexities and disentangle the depth and lateral components of attenuation.

Reviewer 2:

Figure 3, how is the slope in the right panel obtained? It is only briefly explained in line 108, (i.e., geometrical spreading and absorption along the path). Also, to be consistent with equation 2, please clarif that the colorbar in left panel is (absorption along the path, or alpha). And in the caption, it refers to "geometrical spreading coefficient n from equation 1", but equation 1 has no "n" parameter.

The attenuation for the different azimuths shown in Figure 3 are obtained directly from Equation (2) applied to the 8 red lines shown in the left panels. We corrected the name of the colorbar. The geometrical spreading coefficient n is in equation 2 not 1. Thanks for spotting the mistakes.

Figure 5, I am confused with the shape of the spectra. If they are displacement spectra, they should be flat at low frequency, and fall off at high frequency, which is not the one observed here.

They are source acceleration spectra. Equation (3) has been updated for consistency.

Relating to the previous question, please clarify what type of FAS is calculated: acceleration, velocity or displacement?

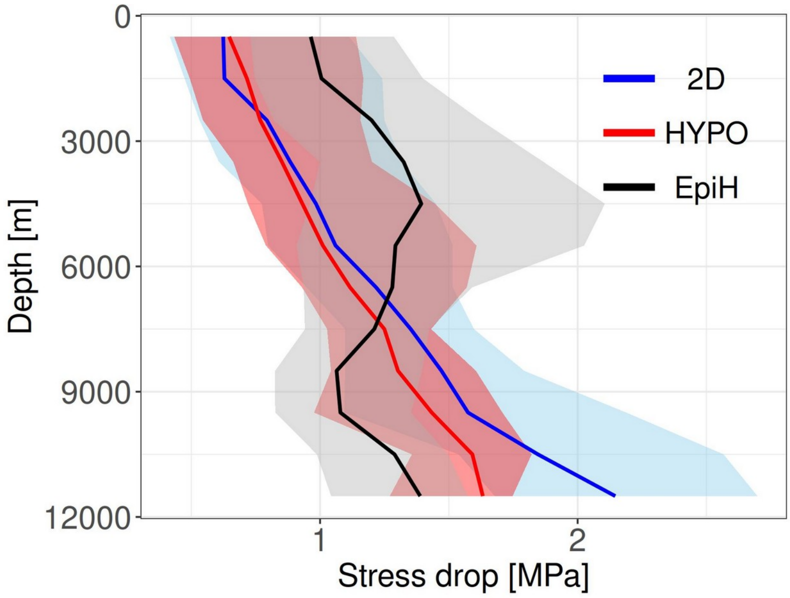
Acceleration spectra.

The depth dependence has been extensively discussed in Abercrombie etl al., 2021. Zhang et al., (2022) examined the gridding approach in both lateral and depth, and found depth being the dominate factor than lateral attenuation correction, which is relavant to the study here. Using the Ridgecrest dataset, Chen et al., (2025) (doi:*10.1785/0120240150*) also analyzed the effect of depth-attenuation in stress drop estimations. The reduced standard deviation with depth dependence is consistent with the values in line 186-187. This can be used to further support the observation of the stronger depth dependence attenuation here.

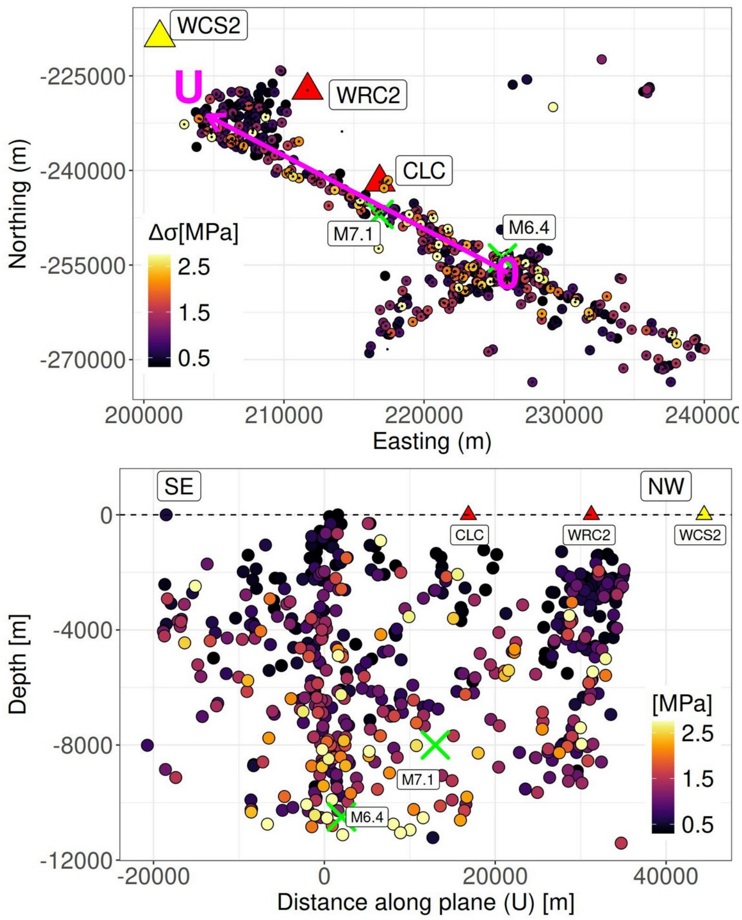
We added the references to Abercrombie et al. (2021) (Introduction), Zhang et al (2022) (Discussions) and Chen et al. (2025) (Discussions). We thank the reviewer for the suggestions.

Figure 10 - to further illustrate the depth variations of stress drop, I wonder if the authors can plot a "median stress drop" versus "depth" for the three cases?

The newly prepared figure (added to the manuscript as Figure 11) confirms that the HYPO and 2D models yield comparable average trends in stress drop as a function of depth. However, accounting for depth-dependent attenuation introduces substantial changes, underscoring its strong influence on the inferred depth dependence of stress drop, as discussed in the text.



The abstract mentioned the low stress drop at shallow depth towards the Coso region and left-lateral fault junction - It would be good to mark this in Figure 1, Figure 9 and Figure 10. Readers unfamiliar with southern California will not know where Coso is, and it is unclear where the junction of M6.4 event is. Also, please label which one is M6.4 and which one is M7.1 for figure 9 and 10.



In Figure 9, we have added the location of station CI.WCS2, installed in Coso Hot Springs, and included labels for the M6.4 and M7.1 events. We also adjusted the color scale limits to match those used in Figure 10 for consistency. The junction with the left-lateral fault is indicated by both the origin of the U coordinates and the location of the M6.4 event. We believe it is not necessary to repeat these labels in Figure 10.

The abstract also mentioned that high stress drop near M6.4 and M7.1, however, based on Figure 10, with the EpiH model, the stress drop constrast near the two larger events is not clear. Maybe the high-stress drop is due to along-depth attenuation correction? To supprt this argument, maybe plot histogram for stress drops near the two larger events and compare with the overall stress drop distribution in Figure 7?

In the abstract, the reference to high stress drop values near the M6.4 and M7.1 events, particularly in the region between their hypocenters, refers specifically to the results from the 2D approach presented in this study. We have clarified this point in the revised version.

Relating to those spation patterns in these previous comments, in the discussion section between lines 200-209, please refer to specific subfigures in Figure 10 and associated models, as the depth pattern in 10a, 10b, and 10c are somewhat different. The "high-stress drop" between station CLC and WRC2 seems to be robustly identified in all three models, which is interesting. It might help to draw a few polygons to highlight those specific areas in the discussion section.

We specified the sub-figure numbers when referring to Figure 10. In Figure 10a, we also added few labels to indicate areas discussed in the text.