Response to the reviewer

Olivier Fontaine

June 2026

1 For author and editor

We sincerely thank the reviewers for their careful reading of the manuscript and supplementary and followed their constructive comments. We are pleased that they found the theoretical framework and its application to be a valuable contribution to the analysis of DAS amplitude sensitivity. In response to the reviewer's suggestions, we have substantially revised the manuscript to improve its clarity, precision, and presentation. We structured our answer using blue text and olive colored text for the modifications in the text. We believe that these revisions have significantly strengthened the manuscript.
Thank you again for your time and energy.

2 First reviewer

This manuscript develops a theoretical framework for understanding the amplitude sensitivity of Distributed Acoustic Sensing (DAS) to seismic wavefields. To achieve this, the authors derive transfer functions for linear fiber segments with arbitrary azimuth and dip, extend the formulation to looped gauge-length geometries as potential polarization filters, and integrate the resulting sensitivity into a ray-theory-based forward model. The framework is applied to a dataset from Brady Hot Springs in Nevada, where the comparison between modeled and measured amplitudes is used to separate fiber-orientation effects from local site amplification. This work is highly valuable and represents an important contribution to future studies using DAS data. Therefore, I recommend reconsideration of the manuscript for publication after the revisions outlined below are made.

2.1 Major comments

[1]:
Figure 1, together with the statement that DAS measures strain rate, is likely to confuse readers and requires revision. The formulation in this manuscript follows the standard seismological convention, in which displacement, velocity, and acceleration are treated as dynamic quantities representing variations relative to a pre-arrival baseline. The displacement vector that serves as the starting point of the Supplementary derivation is written in this framework, which is appropriate. However, the placement of DAS in Figure 1 reflects a conflation of physical measurement principle and output format. What a DAS interrogator physically measures as its primary quantity is the optical phase shift proportional to the relative position change between scatterers separated by the gauge length. This corresponds to the spatial derivative of the dynamic displacement after wave arrival, that is, dynamic strain. A time derivative is not part of the DAS measurement principle itself. In practice,

the output format of DAS interrogators varies by model. The Silixa iDAS used in this study is a typical strain-rate-output instrument, but interrogators that directly output dynamic strain also exist. The current Figure 1, which uniquely associates DAS with the strain-rate position, therefore reflects a classification based on a specific output format rather than on the underlying physical principle. This is also inconsistent with the classification on the seismometer side of the figure (seismometer = velocity, accelerometer = acceleration), which is based on the physical principle of each instrument. To align the logical hierarchy, both DSS and DAS should be classified as instruments that measure dynamic strain, with their differences lying in time resolution, frequency band, and output format. Indeed, this can bring confusion. I have modified the text in a few places to make that difference clearer, making sure to use strain when talking about the quantity recorded and strain rate only for the data. I also updated figure 1

L 40 - 41 : In practice, however, some DAS interrogators, including the one used in this study, output strain rate rather than strain.

Figure 1 legend : Native DAS measurements are proportional to strain through optical phase changes. However, many interrogators, like the Silixa IDAS, output the data in strain rate (DAS*). However, in terms of orientation dependent sensitivity, the data can be expressed in strain or strain rate, the geometrical factor remains the same. Therefore, our study is valid for both strain and strain rate measurement

L 113 - 115 :Hereafter, this angular dependence is referred to as the fiber sensitivity. It plays a key role in the characterization of DAS broadside sensitivity, regardless of whether the DAS response is expressed in terms of strain or strain rate. [2]

L185–186: The linear stacking of 11 channels (1 m spacing, yielding an effective length of 11 m) inherently mixes channels with different orientations near the zigzag vertices. Given that this manuscript focuses on broadside sensitivity, please clarify how this stacking is handled at the bends of the fiber, and whether channels near the vertices are excluded or treated differently.

Indeed, this should have been addressed. This problem was taken care of by applying a smoothing on the model and the data as this mixes the responses of the channels on both sides of the corner.

L 309- 316 : Finally, we consider the response at fiber corners, characterized by multiple orientations within a gauge length whih is expected to increase the angular sensitivity (Kuvshinov, 2016). It should result in positive residuals and larger errors. A more rigorous treatment would require to discretize each channel into multiple subsegments, solving the forward problem for each segment, and averaging the responses to approximate the corner gauge length response. However, such an approach would be computationally expensive. Instead, we applied a smoothing to both the modeled and measured data. This approach mixes the angular sensitivity between the different orientations around the corners, while maintaining a negligible computational cost. As shown in Figure 9, corners do not appear as anomalies.

Regarding Eqs. 8, 9, and 10, I would appreciate some clarification on the dimensions. My understanding is that the integration of strain rate over the loop g would be evaluated as $1/g \oint \dot{\epsilon} ds = 1/(2\pi r) \int \dot{\epsilon} d\theta_{DAS}$. If this is the case, the radius (r) seems to cancel out. However, I noticed an extra $\frac{1}{r}$ term in the denominators of Eqs. 8, 9, and 10. Could the authors please check if there might be a dimensional error here, or clarify if I have missed something in the derivation? Indeed the multiplication by R was missing, the modification has been made in the main text and in the equations in the supplementary materials

L242 - 244 : The loop, of radius R, is made to have a perimeter equal to a gauge length so $g = 2\pi R$. For a vertical loop, we average over all dips by solving $\frac{1}{2\pi R} \oint \dot{\epsilon} R d\theta_{DAS}$ for P, SV and SH waves yielding

L250 : For a horizontal loop we average over all azimuth using $\frac{1}{2\pi R} \oint \dot{\epsilon} R d\varphi_{DAS}$

2.2 Minor comments

L201−202: "presented in figure ??" unresolved figure reference. Please fix.
Fixed
L256: "the equations in table ??" unresolved table reference. Please fix.
Fixed
L267: "Masurement" → "Measurement". Typo.
Fixed

3 Second reviewer

This article provides a way of using ray theoretical methods for assessing DAS amplitude anomalies as well as suggestions for the use of gauge length cable loops to even out angular response.

The approach uses well established expressions expressed in a more general context of arbitrary DAS cable orientation. The generality at times leads to complex expressions that are not easy to comprehend. The notation with subscripts "ray" and "DAS" was presumably chosen for clarity, but leads to unduely long expressions that are actually difficult to read. Subscripts "r" and "D" would simplify and still be intelligible.

The material show signs of having been assembled rather quickly with missing internal cross-referencing and other avoidable errors. There are problems in both the main paper and the Supplementary Materials.

The abstract refers to the various aspects of the paper but does so in an order rather different from the paper itself. It could benefit from reorganisation.
Thank you for pointing it out. I have restructured as follow:
When analyzing signals from Distributed Acoustic Sensing (DAS), the recorded amplitude can be difficult to interpret, as it is influenced by many parameters. To explore the foundations of fiber sensing amplitude transfer functions, we first generalize existing sensitivity expressions to arbitrary fiber orientations. Building from those, we characterize DAS sensitivity at the scale of the full deployment and investigate the influence of a layered medium. Finally, we demonstrate how loop gauge length could suppress shear waves polarized in the plane of the loop. From these transfer functions, we explore the wavefield as seen by DAS through a forward model based on ray theory. This model predicts the distribution of amplitude measurments along the fiber from a point source at low computational cost. Comparing the predicted and observed wavefields provides an estimate of local amplification effects. The proposed framework provides the basis for a wide range of applications, including fiber deployment optimization, synthetic DAS generation, and amplitude-based grid search.

3.1 Comments

line 51: The issue here is that the strain field has sensitivity not the fiber!
Indeed this is true. However, I believe this point has been answer here is the current text version:
Furthermore, recent studies suggest that the strain wavefield has a strong response to heterogeneity in the earth's subsurface much smaller than the minimum considered wavelength
line 85: k missing ahead of bracket

Fixed
lines 95-98: The complex subscripts do not aid comprehension. The designators of wave type would probably be better as superscripts
Fixed, Indeed, this allows to highlight the wavetype and make it more visible
lines 101-106: The subscripts get worse! and similar problems occur below (and in the Supplementary)
Fixed
Figure 3: "On the write" should read "On the right".
Fixed
It would be helpful to link the numbered vibroseis sites with the designators used in the text and figures. This is Done in Figure 4, but not in Figure 7.
Fixed
Line 202: "Figure ??"" presumably refers to the panels to the right of figure 3. This should be made explicit.
Fixed
Section 3.1.3 I was surprised in this discussion of looped cables to see no mention of the work on helical cables for improving P wave response as in the work of Kuvshinov (2016) Geophys. Prospect. - the scale may be different but the concept is similar.
Done
Figure 6: Reference is made to equations in table ??, but no equations appear in a table!
This table has been removed as there was to many tables and figures in the paper
Figure 7: "Comparaison" is misspelt in the heading. No indication is given of the location of sweep 5636.
Fixed
Data and Code availability:
The DOI given works but seems excessively complicated.
It is a temporary DOI so modifications to the repository could be Done if something major was spotted in the review process. Once reviews are completed, the link will be frozen and will be more classic
References:
Doi's are missing for several items, and initials appear to have been unnecessarily truncated.
I have checked and couldn't fin any DOI for the following documents:

- Aki, K. and Richards, P. G. Quantitative Seismology. University Science Books, Jan. 2002.
- Han, L., Wong, J., and Bancroft, J. C. Time picking and random noise reduction on microseismic data. CREWES Research Reports, 2009.
- Zeng, X., Thurber, C., Wang, H., Fratta, D., Matzel, E., and PoroTomo Team. High-resolution shallow structure revealed with ambient noise tomography on a dense array. Feb. 2017

I fixed all the initials
Supplementary Material:
Matrix multiplication is indicated by both * and . - should be consistent throughout.
Fixed
Some subscripts are misplaced in the Latex e.g. xx' and zz in equation (1).
Fixed
As noted above simplifying subscripts would improve the readability of the equations.
Done, I also simplified most equations by removing some steps

The use of Brackets around complex expressions needs to be improved *use* [*and*] *etc.* and some terms are broken over two lines in a confusing manner.
Done
It would be helpful if multiplication signs were used wherever expressions extend over multiple lines.
Done
The P wave expression for a horizontal loop needs 'ray" as a subscript.
Done
Similar problems occur in other places and need to carefully checked.
Done
In section 3.2 it would be best to refer to Figure 1 as Figure S1.
Done
The mode values given in the caption to this figure are not consistent with the Figure or the text.
Done

4 Third reviewer

In "Understanding fiber-optic sensitivity to a wavefield: A framework to separate site amplification from orientation effects," Fontaine et al. derive the directional response of DAS based on the combination of a tensor rotation, gauge-length averaging, and ray-theoretical seismic wave polarization. They then apply this model to sources in different locations and fibers in different geometries, and discuss how to separate physical from directional amplitude effects.

The paper is well written, and I find no errors in the analysis. I do believe that some elements could be better described and/or contextualized, and I have an important question about the methodology. It is also possible that parts of the main text and, particularly, the supplement can be shortened. Consequently, I recommend that the manuscript be accepted for publication pending minor revisions.

4.1 Major comments

- Is the free-surface effect considered in the calculated response? This would seemingly be very important at oblique incidence due to (1) the rotation in polarization between an upgoing wave and its free-surface reflection, and (2) the coupling of P into S (and vice versa). If not, I think the authors need to state this explicitly quite early on and provide some degree of justification/explanation.
Actually, yes, free-surface is in some way considered in our analysis, but not as an element of the forward model. Boundary conditions can indeed be important and strongly depend on the surface condition which are unknown. Therefore, we recover them as part of our scaling factor. Furthermore, since our source and fiber are both at the surface and nearby, the reflections and conversion of rays grazing the surface are more likely to induce surface waves. However, our ray-based framework does not allow us to quantify the associated energy transfer into these surface waves.Therefore, this effect falls within the correction factor.
L75-L78 : The mismatch between the theoretical and the recorded amplitude distribution provides a lumped estimate of the local DAS response along the fiber, integrating the combined influence of near-surface effects, small-scale heterogeneity, cable coupling, and spatial variations in the elastic properties of the medium itself encompassing free-surface effects.

- Unless I am fundamentally missing something, the extraordinarily detailed expressions for strain in terms of four angles are excessive. Why? First, I believe that these are all redundant with results

published in Martin et al. (2018 - preprint, 2021- book chapter) just with a change of coordinates. Second, could this not just be written as a tensor product in a couple lines? That would make the manuscript much easier to read, even if the authors want to include the complete element-by-element results in the supplement.
I see what you mean, however, I would not agree on this statement for two reasons. First, although the derivation is very close to the one in Martin et al. 2018, we consider a fiber that can dip as well. The result is not the same as applying a rotation (dip) to the final equations in Martin et al. 2018. You could find tricks to rotate a simplified version for instance by using the angle in a 2D plane containing the fiber and ray and using a $sin(2\alpha)$ or a $\cos(\alpha)^2$ but you would have no clue on the relative sensitivity to SV and SH waves, which have to be considered separately. This description in 4 angles allows considering any fiber orientation and allows considering fiber orientation outside of a 2D plane. For instance, if the fiber runs at the surface to then dive in a deviated borehole. Similarly, deriving the expression for vertical loops can only be done if adding the dip to the expression. Overall, these expressions are building blocks to understand fiber angular sensitivity outside of linear horizontal gauge length. Secondly, it might be possible to write the problem using different methods. However, this description is very efficient to visualize the angular sensitivity of the fiber as it forms a term in an equation that can be simply used and understood through its component. For stance the decay in cos() for SH waves for increasing dip is very apparent in the equation and would be less apparent in a tensor product.
- I was perpetually (mildly) confused throughout when the authors were including DAS coupling in the term "site effects" versus talking about physical wave field amplification by shallow low-velocity structure and cable-coupling separately. The two are not separated in the results, given that the ray theory is purely a "geometrical skeleton" – it's "wave flesh" has not been "sewn on," to paraphrase Yuri Kravtsov. I belive this deserves some word-smithing (including in the abstract), since most seismologists (at least in the earthquake/engineering seismology world, perhaps not in the global seismology world) would say a "site effect" is strictly the physical amplification/deamplification by velocity structure, excluding effects of instrumental response and installation. It also deserves some more explicit discussion, being the most obvious shortcoming of the model for the data comparison in Figures 7-9.
I can see how this terminology can create confusion between the different branches of seismology. I suggest local DAS response as an umbrella term that encompasses a large range of potential candidates as specified in the modification bellow. Our method aims at identifying outlying areas not differentiate between them, other methods more in the wave flesh to take your analogy should be used for that.
L75-L78 : The mismatch between the theoretical and the recorded amplitude distribution provides a lumped estimate of the local DAS response along the fiber, integrating the combined influence of near-surface effects, small-scale heterogeneity, cable coupling, and spatial variations in the elastic properties of the medium itself encompassing free-surface effects.
L350 - 352 From the amplitude difference between the forward modeled and the recording, we could separate the fiber orientation and local amplification effects at low computational cost, giving us an array specific amplitude correction factor.
in L286 I have left site effect as this is the word used in Wang et al. (2018)

4.2 Minor comment

Abstract, L17: "loop plain" → "loop plane". Typo.
Fixed

- Distributed Acoustic Sensing -¿ distributed acoustic sensing. The name of a technology is not a proper noun.
Fixed
I kept the first one in the abstract with capital to introduce the acronym and the first appearance in the introduction is lower case.
- At line 42, the "e.g." should be in the parentheses and the references need to be ordered either alphabetically or chronologically (and similarly throughout the manuscript).
I have rearranged the references throughout the paper. For the e.g., I have modified the sentence to:
L30 ..., pushing the frontiers in Earth sciences, including monitoring of volcanic and glacial processes ... - At line 51, "the fiber has a strong response...": it is the wave field, not the fiber itself, that responds to heterogeneity.
Fixed
L 52 : Furthermore, recent studies suggest that the strain wave field has a strong response to heterogeneity ...
- At line 60, "Array Derived" should be hyphenated.
Fixed
- Also at line 60, I think that "finite-difference" is too simple a description of the studies grouped in this category. Muir and Zhan (2022) estimate the wave field by compressive sensing and then evaluate the gradients of the reconstructed wave field, not by differencing point measurements (if I remember, I did not re-read it).
Indeed, Muir and Zhan (2022) use a different technique, I rephrased and remove that statement.
L 63 : The first method ADDS, reconstructs the strain rate wave field using a co-located seismometer array
- The details in the paragraph around line 142 could mostly be moved to the supplement to improve the readability of the paper. The parameters in the ray computation and the method for calculating its uncertainty are not essential.
Indeed that section was heavy. However, as I use these uncertainties to weight the linear regression, I believe I must at least touch a word on them. Here is the modified section about them.
L 148 - 151 : Based on the synthetic tests presented in the supplementary materials, we estimated uncertainties of 0.59° at the source and 3.30° at the receiver for the ray parameters. These values were incorporated into a Monte Carlo error-propagation scheme, resulting in an average forward-model amplitude uncertainty of 17.9%.
- At line 157 - please indicate the specific equation(s) in Aki and Richards (2002) that this citation refers to.
fixed
L153 : Finally, to describe the source, we used the direction- and polarization-dependent radiation amplitudes of a single force given by equation (4.23) of Aki and Richards (2002).
- "figure" should probably be "Figure" throughout.
fixed, I also made sure to use Table, Figure, Section but equation with lower case
- Given that the dataset is described in many other papers, the presentation in section 2.3 could be shortened.
I have shortened that section drastically
To validate the amplitude model developed in this study, we use data from the Poroelastic Tomography experiment (PoroTomo) (Feigl, 2019). This open dataset includes a DAS fiber deployed in 2016 at the Brady Hot Springs geothermal field (Nevada, USA). The fiber (DASH) was installed in a zigzagging trench at 1 m depth, visible on Figure 3, providing a wide range of orientation suitable for testing angular sensitivity. The site consists of a Mesozoic crystalline basement (1400

m depth) overlain by Miocene to Pleistocene sedimentary and volcanic deposits, including a 50 m sedimentary cover identified from velocity contrasts iler and Pepin, 2021; Zeng et al., 2017). The area is crosscut by SSW–NNE-trending normal faults, which have been shown to significantly affect DAS strain amplitudes.
- Line 202 has a "??" unrecognized reference
Fixed
- While I understand the authors' choice to use a cubic volume for the plots in the context of imaging earthquake sources and their relationship to fiber geometry in Cartesian space, I do think that this obscures the visual interpretation of the plots in Figure 5 because different points have different path length and angle due to compounding effects from the cubic geometry and refraction. The authors might consider a lower-hemispheric distribution of sources instead.
Indeed, a polar projection is a better way to visualize the full angular sensitivity. However, the volumetric view is good to visualize the conflation between the medium effect on the ray path and the fiber sensitivity. I have changed the figure to have the sensitivity kernel and the angular sensitivity in a polar projection to illustrate our results.
- From 217-231, the sensitivity to the upper and lower layers could be discussed more clearly. In particular, the intuition I have for the result is that the shallow low-velocity layer focuses the rays from deep sources towards a narrow range of angles, distorting the mapping between DAS angular sensitivity and source backazimuth/elevation angle. Stepping through such a description by first describing the ray effects and then describing the relationship to DAS response would probably be more intuitive to readers than simply stating the result, e.g. "if horizontal, the sensitivity is predominately within the upper layer."
I agree with you, I rewrote that whole section and that focusing more on the concept than the simple observation. I also liked your sentence describing your intuition, so I integrated it as an introduction to the results.
- At line 232, I don't understand what "better in-line with the Cartesian system" means.
I removed this sentence as this draws attention to detail to apply in the methodology and not so much to the big picture of the paper.
- At line 237, I don't understand what "the polarity inversion for shear waves" refers to.
I changed it by polarity reversal as noted later
- Around the same line, I personally prefer academic writing to avoid a first-person past-tense narrative account of the study process, e.g. "we wondered whether, we explored".
I modified that section as follow:
L252 - 254: Since DAS transfer function can induce creates polarity reversal and a gauge length averages the wave field over a segment of fiber, we could turn this uniqueness in an analog polarity filter. This is done by looping the gauge length.
- At line 260, I am again confused by "the average with the polarity inversion."
We mean averaging over the polarity reversal, so we can cancel the wave field.
- At lines 269 and 275, "log-log" and "log10-log10" should be made stylistically consistent. Also, "a log residual of 1 in log10-log10 space" is redundant.
fixed
- I think the same paragraph could be simplified and clarified by removing the high-school-level explanation of logarithms, which I think the readers of Seismica can live without. Additionally, the description of the many ways errors and residuals are calculated is, at the moment, quite hard to follow.
I have rewritten that section to make it more readable.
To characterize the local DAS response, we compare the amplitudes predicted by our forward model for a given source with the amplitudes recorded along the DAS array. The ratio between the two

provide a proxy for local amplitude anomalies.
An example of the recorded wavefield, the corresponding forward-model prediction, and their divergence is shown in Figure 7, both smoothed using the values of 3 consecutive channels. To quantify the scaling relationship between modeled and recorded amplitudes, we perform a weighted linear regression in $log - log$ space (Figure 8, where the weights are defined by the uncertainties estimated from the forward model. Prior to the regression, the measurements and their errors are median-binned along the measured-amplitude axis to homogenize the distribution of observations. The residuals are then interpreted as amplitude scaling factors, equal to the residual raised to the power of the logarithm base. To reduce uncertainty in the amplitude scaling factors, we retain the 68 out of 81 sweeps with $R^2 > 0.4$ and compute their median. The associated uncertainty is estimated using a bootstrap approach, in which random noise consistent with the standard deviation of the regression residuals is added to each realization.
- Unrecognized table reference in the caption to Figure 6.
fixed

- Figure 9: amplitudes and amplification factors for what phase?
For the P wave, I have added an element in the text and in the legend.
Figure: Comparison between the estimated site amplification factors and the measured P-wave amplitudes for the M 4.3 earthquake.
When compared to the response of the P arrival of the M 4.3 earthquake, similar regions are illuminated by anomalously high response.
- It is only when I got to line 331 that I understood "polarity inversion" meant what I would call "polarity reversal".
Indeed polarity reversal sounds better, I have modified throughout the text.
- Perhaps I am not imaginative enough, but it is not clear how "these looped gauge length could build a bridge between rotational seismology and DAS". (Also "length" -¿ "lengths")
I have added a section at the end of the looped gauge length chapter to make that element clearer:
The lack of sensitivity of the fiber loop to shear waves polarized in its plane is a direct consequence of the divergence-free nature of the shear-wave displacement field. For a linear fiber segment, this manifests as a polarity reversal for different arrival angles. Hence, a loop averaging these different orientations would cancel the wave. An equivalent interpretation can be given in terms of rotational motion. Shear wave induces a rigid-body rotation of the loop without changing its perimeter. Since DAS measures changes in fiber length rather than rigid rotations, this component of the wave field produces no strain in the fiber.
- At line 341, "compared to previous studies, we derived" is a bit strong given how closely the math resembles Martin et al. (2018/2021).
I modified it to:
Building on previous studies, we formulate a single expression for the transfer function of a linear gauge length with arbitrary dip and azimuth.
- In the caption to Figure 2, this figure does not only show "broadside" sensitivity.
Indeed, I have changed it throughout the text by angular response
- There are a lot of typos in the supplement. For example, the title of section 1.1 needs to be capitalized, $M.e.M^T$ should have $\cdot$ instead of ".", equation 1 has exx and ezz instead of e_{xx} and e_{zz}, ... Please proofread more carefully.
Indeed, there were quite a few typos, I have corrected them through the supplementary - Including so many algebra steps in equation 2 of the supplements and others that follow is unnecessary.
I have reduced the algebra steps, keeping enough so if someone wanted to re-derive them, they would at least have 1 or 2 intermediary step.

5 additional elements

- From discussions on the preprint, I noticed that the polar coordinate system I used was confusing some as it is not the direction they expect. Therefore I added an illustration showing the azimuth and dip angle in the supplementary materials to illustrate.

- Following a discussion with Éléonore Stutzmann, I clarified the work frame of the equations as it seemed unclear to her the way it was explained in the text.
  L82 - 84 : To formulate our expression, we consider a plane waves propagating in direction $\vec{K}$ as described in equation 1, with φ_{ray} and θ_{ray} the azimuth and the dip of the ray, both defined to progress in trigonometric direction.

$$\vec{K} = [k_x, k_y, k_z] = k[\cos(\varphi_{ray})\cos(\theta_{ray}), \sin(\varphi_{ray})\cos(\theta_{ray}), \sin(\theta_{ray})] \tag{1}$$

  ...
  L95 - 97 : With the wave displacement amplitude A, the oscillatory term $\psi(x, y, z, t)$, as defined in equation 2 the phase velocity c and wavenumber k.

$$\psi(x, y, z, t) = e^{ik(ct - x\cos(\varphi_{ray})\cos(\theta_{ray}) - y\sin(\varphi_{ray})\cos(\theta_{ray}) - z\sin(\theta_{ray}))} \tag{2}$$

- Additionally I have corrected a few typos and tweaked some connectors to enhance the readability of the text.

- Finally, I added an introduction to results to order all the elements and give a through line.
  From the equations of axial strain-rate sensing, we will look at DAS angular sensitivity from two complementary perspectives. First, we consider the problem from the fiber's point of view across three spatial scales. At the array scale, we assess the directional sensitivity of the entire fiber. We then focus on the channel scale, where we investigate the response of an individual DAS channel embedded in a more complex medium. Finally, at the gauge-length scale, we demonstrate how strain polarity reversal can be used to produce a polarity-filtering effect. Second, we adopt the perspective of a seismic source illuminating the fiber array. This approach provides insight into how a simplified wave field would be recorded along the fiber and allows us to identify and quantify local amplification effects.

Response to the reviewers

Olivier Fontaine

September 2026

1 Response to reveiwers

1.1 Review 1

Dear authors and editor, Thank you for taking the effort to revise the manuscript. I believe it considerably improved in many places in terms of readability, clarity of the mathematical expressions and computational methodology, and description of the results. I am not fully convinced by the authors' assertion that these results can't be obtained by a change of coordinates from the results of Martin et al. (2021), but this is not particularly important, as the manuscript adequately cites this earlier paper and includes many other original analyses. I have not proofread the math again in detail, but all of my comments and requests for clarification were adequately addressed. I therefore recommend that the manuscript be published in its present form. Sincerely,

Thank you very much, Ethan, for your careful and in depth review and constructive feedback. We are pleased that the revisions have improved the readability and clarity of the manuscript and adequately addressing your concerns on the previous version and that the manuscript is now suitable for publication.

1.2 Review 2

This manuscript develops a theoretical framework for understanding the amplitude sensitivity of Distributed Acoustic Sensing (DAS) to seismic wavefields. To achieve this, the authors derive transfer functions for linear fiber segments with arbitrary azimuth and dip, extend the formulation to looped gauge-length geometries as potential polarization filters, and integrate the resulting sensitivity into a ray-theory-based forward model. The framework is applied to a dataset from Brady Hot Springs in Nevada, where the comparison between modeled and measured amplitudes is used to separate fiber-orientation effects from local site amplification. This work is highly valuable and represents an important contribution to future studies using DAS data. I am also satisfied with the authors' responses to my previous comments. All of the points I raised have been addressed appropriately, and I have no further comments. I recommend that the manuscript be accepted in its present form.

Thank you very much for your careful review. We are pleased that you consider the manuscript to be a valuable contribution and that our revisions have adequately addressed your comments. We greatly appreciate your positive assessment and your recommendation for publication.

1.3 Review 3

The authors have responded well to the range of issues in the reviews and the paper is improved. The simplification of notation improves readability of the equations, but their specific form still renders them clumsy. The early expressions are in terms of plane waves but these are then used with rays. I think there needs to be a clear discussion of when the ray approximation is suitable. It should work for a simple linear configuration, but will deviate form the plane wave response when there is change of direction or coupling over a gauge length, where terms dependent on velocity as well as acceleration emerge (see, e.g., Kennett & Saygin, 2025, The Seismic Record).

Thank you very much for this feedback. We are please that our correction could solve some of your concerns on the manuscript. To answer your new comment we changed a part of the discussion starting from the plane wave assumption using the results from Zhang and Schmitt (2026), then talking about the corner response and how our processing has diminished their importance (in blue bellow).

L 328-345: Finally, assumptions in both our model and the criteria used to select the measured amplitudes may introduce biases in the scaling factor. On the modeling side, our angular sensitivity equations describe a plane wave measured by a linear gauge length, which we approximate as a point sensor. This approximation relies on two main assumptions. First, the plane-wave assumption implies that both the wave vector, $\vec{K}$, and the wave amplitude remain constant over the gauge length. In our study, the typical wavelength is approximately 120 m, which, following Zhang and Schmitt (2026), is sufficiently large relative to our 10 m gauge length to approximate the DAS channel as a point sensor. In addition, the sources are distributed across the study area, so that most measurements are obtained from relatively distant sources. Second, we assume that the gauge length is linear. This assumption breaks down at corners, where a single gauge length can encompass multiple orientations and therefore exhibit a different transfer function (Kennett and Saygin, 2025). To account for those, we smooth both the modeled and measured amplitudes. In our model, this mixes the angular sensitivity between the different fiber orientations, consistent with Kennett and Saygin (2025). On the other hand, stacking the channels and the smoothing the measured amplitude reduces the importance of the corner effects. The absence of distinct anomalies at fiber corners in Figure 9 suggests that this approach is sufficient for the present analysis.

On the measurement side, we restrict the analysis to channels with an SNR greater than 2. This selection ensures that the retained amplitudes contain a measurable wavefield signal. However, it also implies that channels experiencing strong sensitivity losses, such as loops in visit chambers, are excluded from the

analysis. Consequently, our analysis is efficient to quantify sensitivity gain, but not losses.

Also, the coupling contribution in the velocity dependent term implies that the scaling factors will change depending on the frequency. Hence we added the 'at a given frequency' in:

L 325-327 : Also, when a correction factor is produced, we note that the residuals are tied to the average sensitivity of the array at a given frequency. This makes them unsuitable for inter-array comparisons or as an absolute amplitude correction factor.

Further more, going back in Muir and Zhan (2022), our residual (scaling factors) are consistent with their papers hence, we added

L 302-303: The residuals, on the other hand, show clear anomalous regions, reaching values from 0.5 up to 0.88 in similar regions and magnitude as in Muir and Zhan (2022).