Note on the revised manuscript

We have provided two versions of the revised manuscript for ease of review.
1. The first is a tracked-changes version showing additions/revisions in green and text removed from the original submission in red.
2. The second is the final version.

Similarly, the Supplementary Information document also has two versions for the ease of review.
1. The first is a tracked-changes version showing additions/revisions in green and text removed from the original submission in red.
2. The second is the final version.

All line numbers cited in this response document refer to the final version of the revised manuscript.

Reviewer 1 (John-Morgan Manos)

Major Comments

Reviewer comment:

Uncertainty caused by phase velocity selection: *Figure S2.2 shows the process by which the phase velocity for source localization in a range of frequency bands is chosen. However, some frequency windows show significant variability around the chosen phase velocity (e.g. for the 8-10 Hz band, the Bartlett amplitude is virtually flat above 400 m/s). It is worth discussing the location uncertainty as it relates to the use of the max phase velocity for the MFP analysis. Is it possible that the wave velocity changes significantly, particularly during a flood event, as to impact the estimated location of the source?*

Revisions made in the Main Text, Section 4.1, and Supplementary Information, Text S2

Response:

We thank the reviewer for raising this point. We agree that the phase velocity is less well constrained in some frequency bands, particularly around 8-10 Hz. This frequency range lies close to the transition between the two array-processing regimes used in this study. At lower frequencies, the full-network aperture provides a well-resolved coherent response, whereas with increasing frequency the wavelength becomes progressively small relative to the full-network aperture and the response develops increasing sidelobe ambiguity. Conversely, the subarrays become better suited to source localization above this transition. A similar loss of velocity resolution occurs toward the upper end of the investigated frequency range, around 38-40 Hz, where wavelengths become small relative to the individual subarray dimensions. We now state

more explicitly in Supplementary Information **(Text S2, Lines 40-45)** and in the Main text **(Section 4.1, Lines 282-283)** that phase-velocity estimates near these limits are less well resolved.

Response to the velocity uncertainty: We evaluate whether the uncertainty in inferred seismic wave velocity in the frequency range 8-10 Hz affects the inferred source distribution by repeating the localization procedure given 100 m/s bounds below and above the central value considered initially. We think the choice of 100 m/s bounds is realistic given the added constraints that phase velocity in the 8-10 Hz band must satisfy a relatively good continuity with that in the neighboring frequency bands, which are considerably better constrained. The resulting source-density maps are shown in Figure R1. The absolute density and the detailed distribution vary between the three cases, as expected, but the first-order spatial pattern remains similar: the dominant source region is consistently located within the same central part of the active channel, with broadly comparable spatial extent and clustering. This indicates that, although the precise phase velocity is poorly resolved around the transition frequency, the main spatial interpretation is not strongly dependent on the precise phase velocity selected within this range. We now state this explicitly in both the Supplementary Information **(Text S2, Lines 49--54; Figure S2.3)** and the Main Text **(Section 4.1, Lines 284--285)**

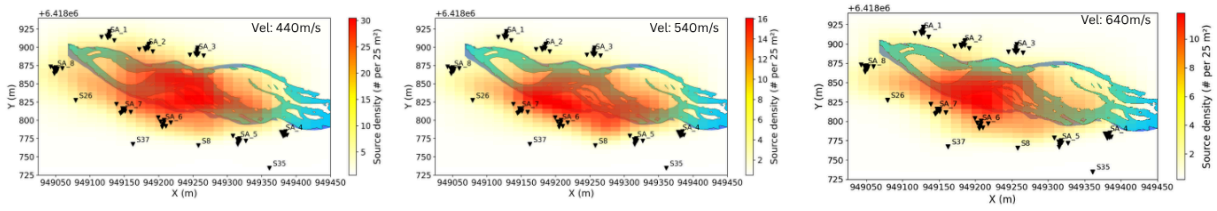


Figure R1: Source-density maps for the 8-10 Hz frequency band obtained using phase velocities of **left)** 440m/s, **centre)** 540 m/s and **right)** 640 m/s

Response to the velocity change: The reviewer also asks whether the propagation velocity itself may vary substantially during the flood. To examine this independently of the MFP velocity-selection procedure, we estimated apparent phase velocity through time from the slowness obtained using conventional plane wave beamforming. Figure R2 shows the resulting apparent velocity at approximately 9 Hz between 2 and 6 July 2019, together with the relative velocity change calculated with respect to the median plane wave beamforming-derived velocity over this interval. The analysis shows clear temporal variability in apparent velocity. Most variations remain within approximately 10% of the reference value, with short excursions approaching approximately ±15%. For comparison, the ±100 m/s sensitivity range applied around the 540 m/s MFP velocity corresponds to approximately ±18.5%. The perturbations used in Figure R1 therefore span a relative range at least as large as the temporal variability observed independently from the plane wave analysis.

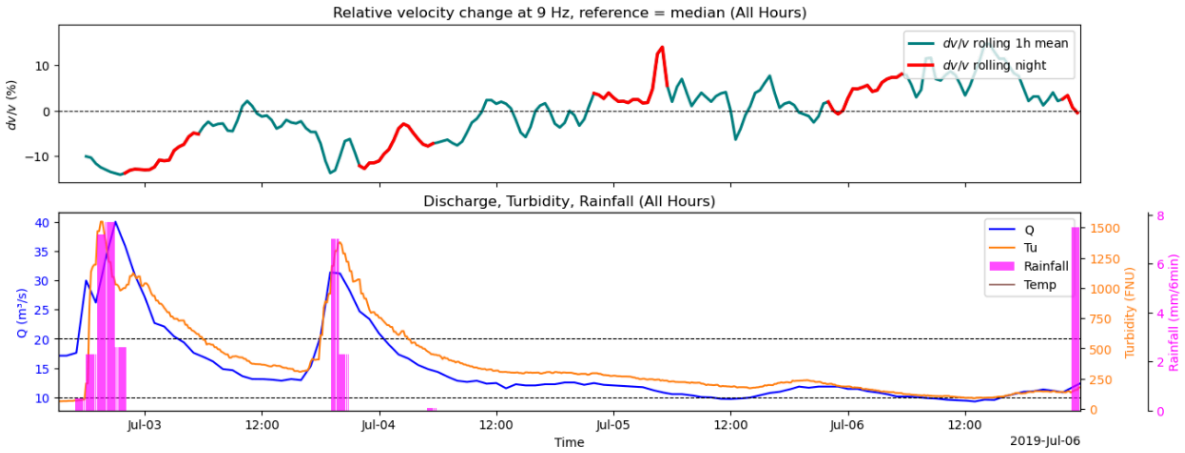


Figure R2: Temporal variability of apparent phase velocity at approximately 9 Hz between 2 and 6 July 2019, estimated from slowness measurements obtained using plane wave beamforming. The upper panel shows the relative velocity change with respect to the median velocity over the analysed interval, and the lower panel provides the corresponding hydrological context.

Minor Comments:

Reviewer comment 1:

1) Calculation of wavelengths of seismic noise of interest. The authors state on Line 142 that the corresponding wavelengths of interest are between 10 m and 300 m yet, when using the suggested values of 200–600 m s^{-1} and 2–40 Hz, the range of corresponding wavelengths should be 5 m to 300 m, should it not?

Revisions made in Main text, Section 2.2

Response:

The reviewer is correct: for phase velocities of 200–600 m s^{-1} and frequencies of 2–40 Hz, the corresponding wavelength range is approximately 5–300 m. We have corrected this value in the revised manuscript **(Line 142)**.

Minor feedback on figure design and captions:

Reviewer comment 1:

Figure 3) The Bartlett amplitude, particularly for the left-hand column panels, is obscured by the

river. I suggest plotting the Bartlett amplitude maps on top of the river geometry and increasing the river transparency to better highlight the spatial pattern of the Bartlett amplitude maps.

Revisions made in Main text, Figure 3

Response:

We have revised Figure 3 so that the Bartlett amplitude maps are more clearly visible relative to the river geometry, and increased the transparency of the river layer. Changed the marker for the estimated event from cyan x to blue circle. This makes the spatial structure of the array response, particularly the sidelobes in the full-network configuration, easier to identify.

Reviewer comment 2:

Figure 5b) Does the change in marker type indicate the change from a full network MFP and a subarray MFP? If so, this should be noted in the caption. Otherwise, the change in marker type should be explained or made to be consistent.

Revisions made in Main text, Figure 5 caption

Response:

Yes, the change in marker type indicates the transition between the two MFP configurations: full-network MFP at low frequencies and subarray-averaged MFP at higher frequencies. We have revised the Figure 5 caption to explicitly define the two marker types.

Minor text edits

Reviewer comment 1: *Line 90: "locations(Chmiel", "locations (Chmiel"*

Response: Corrected as suggested. **(Main text, Line 88)**

Reviewer comment 2: *Line 210-211: "entire 600 meters aperture", but on Line 146 it states "aperture, Anet, spans approximately 500 m..." Which one is it?*

Response: This is indeed an inconsistency. The full-network aperture is approximately 500 m. We have corrected the value in Section 3.2.1 to make it consistent with Section 2.2. **(Main text, Line 206)**

Reviewer comment 3: Line 211: *"where equation (7) is satisfied." I believe you mean to refer to equation (1).*

Response: Correct. This was an incorrect equation reference and has been changed from Equation (7) to Equation (1). **(Main text, Line 207)**

Reviewer comment 4: *Line 327, "frequencies(5 - 10 Hz, panel a) ,..."*

Response: Corrected for spacing and punctuation. **(Main text, Line 321)**

Reviewer comment 5: *Line 463: “provide”, “provides”*

Response: Corrected as suggested. **(Main text, Line 418)**

Reviewer 2 (Anonymous reviewer)

Reviewer comment 1:
“ground-based instrumentation” - in-channel might be better?

Revisions made in Main text, Section 1

Response:
Changed to “in-channel instrumentation” as suggested. **(Main text, Line 59)**

Reviewer comment 2:
Are these sensors buried to a few centimetres? I'm curious about their response to rainfall if they are truly deployed at the surface.

Revisions made in Main text, Section 2.2

Response:
We thank the reviewer for raising this point. The wording in the original manuscript was imprecise. The ZLand nodes were not left exposed directly at the ground surface, but were buried entirely with a few centimeters of ground on. We have clarified this in the revised description of the deployment **(Lines 129-130)**. We have additionally made changes to the flow of text in the paragraph **(Lines 128 to 133)**.

Rainfall can indeed generate measurable seismic noise through raindrop impacts on the ground. Bakker et al. (2022) demonstrated relationships between rainfall properties and seismic power, while Rindraharisaona et al. (2022) showed experimentally that the seismic response to rainfall decreases with sensor burial depth. Both studies found that rainfall-induced seismic energy was most prominent at frequencies above approximately 60 Hz. Our MFP analysis is restricted to 2-40 Hz, and the sensors were additionally shallowly buried, which should reduce their sensitivity to rainfall. We therefore do not expect direct rainfall excitation of the sensors to dominate the signals localised in the frequency range considered here.

Reviewer comment 3:
Figure 3: This is a great plot. One note: It is very difficult to distinguish between the true event and estimated event due to the colours used and the fact that they nearly entirely overlap in every panel. Play around with different markers. Maybe an open circle for the estimated event.

Revisions made in Main text, Figure 3 and Figure 3 Caption

Response:

We thank the reviewer for this suggestion. We revised Figure 3 to improve the distinction between the true and estimated source locations. The estimated source is now shown with an open blue circle, instead of the previous cyan cross, while the true source remains indicated by a star. This makes the two locations easier to distinguish even where they nearly overlap.

Reviewer comment 4:

Timelapse or time-lapse should be consistent

Response:

This is indeed an inconsistency. We have now consistently maintained “timelapse” throughout the text

Reviewer comment 5:

One thing that needs to be addressed in more detail -- authors show a difference in how dispersed detections are based on the frequency, but they also use a different threshold for detection at 5 - 10 Hz than at higher frequencies. How do I know that the dispersed nature of the detections at low frequencies isn't related to the threshold that was used?

Furthermore, I think there needs to be explanation as to why "detections" are necessary. Why can't you just show how the Bartlett amplitudes vary across the channel at different times?

Revisions made in Main text, section 4.2

Response:

Response to the threshold question: We thank the reviewer for raising this point. The absolute Bartlett-amplitude distributions differ between the two processing approaches used in this study **(Lines 297-298)**. Below 10 Hz, full-network MFP requires phase consistency across the entire array aperture and generally produces lower maximum Bartlett amplitudes. Above 10 Hz, the analysis is based on spatially averaged subarray responses, for which coherence is preserved over the smaller subarray apertures and the resulting Bartlett values are systematically higher. We therefore define the retention threshold separately for the two frequency ranges rather than applying a single absolute Bartlett value across all frequencies. For full-network MFP below 10 Hz, we retain windows with maximum Bartlett amplitudes above the mean of the corresponding frequency-band distribution, whereas for subarray-averaged MFP above 10 Hz we use the more conservative mean+1std criterion. We acknowledge that the threshold choice can influence the number and detailed density of retained source locations. We therefore do not interpret differences in the absolute number of retained locations quantitatively across frequency bands. Instead, our interpretation focuses on the first-order spatial organisation of the retained source locations **(Lines 304-307)**.

Response to the use of “detections”: We have also clarified our use of the term “detection”. MFP does not inherently produce a binary detection. For each 3~s window, it produces a continuous spatial Bartlett field, B(x). We use “detection” only as shorthand for an accepted

localization window: when the maximum Bartlett amplitude exceeds the adopted retention criterion, which is criterion used to define a source, the position of that maximum is retained as the dominant coherent source location for that window. Thresholding is therefore not required to compute the Bartlett field itself. Its purpose is to exclude weakly coherent windows before summarizing many thousands of consecutive Bartlett fields as source-density maps. Displaying the full Bartlett field for every 3~s window would preserve more information, but would make the spatial evolution over hour-long intervals and across several frequency bands difficult to visualize and compare. We have revised the manuscript to make this distinction explicit and now refer more consistently to “accepted source locations” **(Lines 304, 308 and Caption figure 6)**, rather than implying that MFP itself performs a binary detection.

Reviewer comment 6:

One thing I am still unsure about is why bedload necessarily has to be localized? Could bedload not also be broadly located? You might be able to comment on this by speaking more about the hydrologic context -- maybe bedload fluxes are known to be so low here that particles must be moving in localized pulses? I'm assuming bedload transport in this river is supply limited rather than transport limited. Does this justify the claim?

Revisions made in Main text, section 5.2

Response:

We thank the reviewer for raising this point. We agree that bedload transport does not necessarily have to be spatially localized and may extend over a broad portion of the active channel, particularly under conditions of widespread sediment mobility. We have therefore revised the manuscript to avoid using spatial localization itself as a criterion for identifying bedload-generated seismic sources **(Lines 367–381).**

Our interpretation of the higher-frequency source regions as being sediment-related is based primarily on their frequency content, together with previous observational and theoretical studies showing an increasing contribution of bedload-generated seismic energy at higher frequencies **(Lines 375–381)**. The spatial concentration and heterogeneity of these sources are therefore treated only as supporting characteristics, rather than as evidence for bedload transport by themselves. We have also clarified that spatial heterogeneity in bedload does not require the reach to be supply limited. Instead, the revised Discussion emphasizes that sediment mobility can vary spatially because of local differences in hydraulic forcing, bed structure, grain size, channel geometry, and sediment availability. This point is reflected **(Lines 377–381).**

We further note that bedload transport is intrinsically intermittent at the grain and patch scales. This is now expressed in **Section 5.2, Lines 377–381**. We agree, however, that bedload does not necessarily have to occur in localized patches, so this sentence has been softened to emphasize spatially variable sediment mobility rather than implying localization as a necessary property of bedload transport.

Finally, we revised the interpretation of the timelapse imagery accordingly. Rather than treating the correspondence between compact source regions and specific channel features as proof of bedload activity, we now state that “the higher-frequency source regions are compatible with a stronger contribution from spatially heterogeneous sediment-transport processes within the active channel.” **(Lines 396–398).**

Reviewer comment 7:
Maybe include a parenthetical with the distance uncertainty like you did above.

Revisions made in Main text, Section 5.3.1
Response:
We have added the corresponding dimensional uncertainty for consistency. At λ ≈ 64 m, 0.2λ corresponds to approximately 13 m **(Line 410).**

Reviewer comment 8:
References: Some of these entries have DOIs while others don't. Standardize.

Response:
We have standardised the reference list by adding DOIs to all references for which a DOI could be identified. A few references do not appear to have an assigned DOI, for example, the chapter by Ferguson and Ashworth (1992) in Dynamics of Gravel-Bed Rivers and the book Quantitative Seismology by Aki and Richards (2002). These references have therefore been retained without DOI information.

Additional revisions identified during resubmission - Main text

Revised Conclusions section: (Line 448-583)
While preparing the revised manuscript, we noticed that the Conclusion section had been inadvertently omitted from the original submitted version. We apologise for this oversight. We have now restored the intended Conclusion section in the revised manuscript. It summarises the main findings on frequency-resolved source localization, localization uncertainty and array geometry, discusses the broader implications of the method for monitoring fluvial processes, and provides a concluding perspective on the applicability of the proposed framework. The Conclusion does not introduce new analyses or results, but provides a synthesis of results already presented and discussed elsewhere in the manuscript.

Additional revisions identified during resubmission - Supplementary Information

Revised Supplementary Information summary: (Line 2-6)
We revised the summary at the beginning of the Supplementary Information to more clearly describe its contents. The revised text now explicitly identifies the three main supplementary sections: (Text S1) the matched field processing workflow, (Text S2) the procedure used to estimate frequency-dependent phase velocities from selected coherent flood events, and (Text S3) the synthetic framework used to quantify localisation uncertainty as a function of frequency, signal-to-noise ratio, and array geometry.

Expanded Text S1: (Line 9-15)
We expanded Text S1 to provide a concise description of the complete MFP workflow shown in Figure S1. The added paragraph explains the two main stages of the analysis: first, estimation of frequency-dependent phase velocities from selected coherent seismic events, and second, application of these velocities to the continuous dataset for source localisation. It briefly describes the steps followed in MFP for source localisation.