AGU Advances

Peer Review History of

Rapid Response to the 2019 Ridgecrest Earthquake with Distributed Acoustic Sensing

Zefeng Li, Zhichao Shen, Yan Yang, Ethan Williams, Xin Wang, and Zhongwen Zhan

Seismological Laboratory, Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, California 91125, USA

Files Uploaded Separately

Original Version of Manuscript (2021AV000395)
First Revision of Manuscript [Accepted] (2021AV000395R)
Author Response to Peer Review Comments

Peer Review Comments on 2021AV000395

Reviewer #1

This manuscript describes the data recorded with distributed acoustic sensing (DAS) for the 2019 Ridgecrest aftershock sequence. Using DAS technology to detect earthquakes is an exciting advancement, and it's even more impressive to see the technology deployed rapidly to capture an aftershock sequence. I think this justifies eventual publication in AGU Advances, and the current manuscript and figures are mostly clear. However, in my opinion, the manuscript could be strengthened with modifications to more clearly emphasize the unique strengths of DAS data. For example, the authors could more strongly emphasize the potential benefits of dense spatial sampling. This could be very valuable for structural studies in particular? Other applications?

As a related point, it's worth pointing out that, in the case of Ridgecrest, the event detections achieved here could very likely have been achieved using just the permanent seismic network. Typically, many more new events can be detected than located, so the numbers of events in the Ross et al. (2019) and Shelly (2020) catalog would have been significantly higher for detection only. However, I think the authors could make a very convincing argument that DAS data in some cases could allow a similar catalog to be constructed even in areas lacking the high-quality permanent seismic network that's present around the Ridgecrest sequence.

Furthermore, if DAS is to be used in rapid aftershock monitoring, the processing side needs to be addressed, but I didn't see much discussion of this in the current manuscript. For example, can DAS data be integrated into real-time processing of the Southern California Seismic Network? Or is some other scheme required? Some discussion of this issue seems required, unless the authors wish to de-emphasize "rapid aftershock monitoring" in their manuscript. Of course, the data can still be valuable for studies of earthquake physics even if processing in only applied after some delay.

Minor comments:

Details of the template-matching procedure seem to be missing. For example, how were the waveforms windowed for the templates? How exactly is the SNR criterion for templates applied? How long were these windows? Over what time period was the detection threshold (10 times median absolute deviation above the median noise level) established? Daily? Hourly? Were duplicates removed (i.e. different templates detecting the same event in the data)?

The authors should probably define any acronyms used in the "highlights" bullet points (DAS, SCSN)

What is the reason for bad "channels" in DAS data (i.e. Figure 1c, vertical stripes)?

Units are missing in table S1, for channel spacing (m) and Sampling rate (Hz).

Figure 5: Is "quiescence" supposed to indicate noise level? I have mixed feelings about this figure overall - on the one hand, it's a cool graphical comparison that might be useful to non-specialists. On the other hand, the fact that each "axis" is subjective may limit its utility.

Lines 126-127: For magnitude computation, does this study also use the empirical calibration between amplitude ratio and local magnitude (ML) difference (the factor of 0.831) as Shelly (2020), or does it use something else? If this magnitude approximates ML, it might be helpful to clarify magnitude type on relevant figures.

Lines 146-147: "likely suggesting a higher rate of aftershock production than the average rate along the main fault". Can you make any quantitative comparison to support this? Some measure of seismicity per fault area, perhaps?

David Shelly, USGS

Reviewer #3

Review Zefeng Li et al., 2021

Rapid Response to the 2019 Ridgecrest Earthquake with Distributed Acoustic Sensing

This paper describes the first rapid response to an earthquake using a das array. Overall, the paper is very concise, well written, and reads easily. The paper's content is of interest, although the merit of the method has already been published in Li & Zhan 2018. Indeed, Li & Zhan 2018 showed that template matching with DAS could dramatically increase the number of earthquake detections compared to a traditional seismic network. Therefore, the main novelty of this paper is that Li & Zhan 2018 pipeline is applied to one major California earthquake dataset (Ridgecrest) and those new waveforms "reveal abundant aftershocks on multiple crosscutting faults near the epicenters of the mainshock." I am not a Ridgecrest earthquake specialist, but I think such a finding was highlighted in previous studies, although with a lower density of aftershocks.

The authors claim they "demonstrate the monitoring capability of DAS," but I think this statement, which is repeated several times in the text, is misleading. Since about 2016, many studies have proven das' capability to provide high-fidelity earthquake waveforms but under certain conditions. For example, the coupling of the cable with the ground matters a lot. The angle between the wavefield and the cable matters too, and in fact, it can dramatically deteriorate the response of the DAS array. DAS is generally sensitive to higher frequencies than traditional sensors. Therefore, the distance between the array and the earthquakes is important. I feel the authors had an excellent opportunity to discuss all these points in detail, but unfortunately, they did not. I am not saying that the paper is not of interest but that they did not adequately demonstrate the monitoring capabilities of DAS.

Some ideas that could help to understand the DAS monitoring capabilities better

- Why are the other temporal das arrays not used in this study? What are the TM results for one or two of these other arrays? How do the earthquake detection method capabilities change with respect to the distance of the main chock epicenter? Comparing these array capabilities would highlight a minimum distance required to use DAS for aftershock studies.
- Which section of the cable detected most of the earthquakes? Is it the section closest to the epicenter, in the middle, or is it random? Does it depend on the coupling of the cable with the ground, or is it a function of the distance?
- Why have fewer earthquakes been detected in the northern region of the fault (Fig 3)? Is it because the cable is orthogonal to the earthquake wavefields coming from the north while parallel to earthquakes from the east? This might be a sensitivity issue, and it looks that when the angle between the cable and the

earthquake is >45*, the detection capability of the das sharply drops. Does the Olancha south array show similar findings while being parallel to the earthquake wavefield?

- Kind of unrelated comment: How does your TM work? Do you cross-correlate all the templates with the 1200 channels of the das? If yes, why is it important to consider 1200 channels and not.. 120? the 120 with the highest SNR, for example?

Answering these questions would, of course, require a lot more work. Therefore, I suggest a major review of the paper before it can be re-submitted in Advances.

There are a few minor comments attached in the pdf.

[Please see attachments beginning on the next page for additional comments.]