REVIEWER 1

This manuscript presents the use of RS sensors for earthquake location. The authors have integrated RS sensors with GeoNet sensors to detect seismic activity in Wellington, New Zealand, and have evaluated the benefits of including RS sensors in the study of seismicity. Their results suggest that the addition of RS sensors significantly improves the precision of earthquake location. The manuscript is commendable, and I have included a few minor comments for consideration in the PDF (attached).

REVIEWER 2

In this study, the authors assess the potential to complement the existing national GeoNet seismic network in New Zealand (which is relatively sparse with an average spacing of 30 km in the North Island) with low-cost Raspberry Shake (RS) seismometers.

The authors focus on 19 earthquakes with magnitudes equal or smaller than 3.5 that occurred between 2020-12-07 and 2022-12-13 as part of a seismic swarm beneath Wainuiomata. (By the way, I am not sure if the term “swarm” is appropriate if the events occur over a 2-year period and spread over a quite large area?) The authors use 20 short-period and broadband GeoNet seismometers and 22 RS geophones to locate the 19 events, to determine focal mechanisms for 7, and a moment tensor solution for the largest event.

The authors point out that the use of (community-hosted) RS Shake seismometers comes with a number of challenges: (1) RS installations are unregulated and are selected at the discretion of the user, (2) RS seismometers have relatively high levels of self-noise due to their internal electronics, (3) RS seismometer positions are obfuscated for up to 1 km to protect user privacy, and (4) RS seismometers are concentrated in the more populated urban areas.

Despite these challenges, the authors show that the location uncertainties for the 19 earthquakes decrease, and the focal mechanism calculations stabilize with the additional use of picks and polarities obtained from the RS seismometers.

The paper is well organized and written, and I believe that only minor revisions are needed to make this paper ready for publication.

My main concern is that the authors focus mainly on event locations. It would be interesting to see if/how the RS seismometers could contribute to the (local) magnitude estimates, bearing in mind that the amplitudes from the low-cost sensors tend to be noisy. The question arises whether RS can also be used to determine magnitude, or whether their application would be limited mainly to location estimates (and in some rare events to focal mechanism or moment tensor solutions)? Do you foresee the integration of RS into automated processing, possibly as part of earthquake early warning?

Finally, in case the authors aren't aware, as far as I know, you can request the exact locations of the Raspberry Shake sensors from the company for your usage if you sign a waiver agreeing not to publish those locations for privacy reasons. So, in principle there is no need to work with the obfuscated locations.

Specific comments

Abstract:

- "…for improving detection…" -> This is not shown in this paper.
- "…effective for both the locating and characterisation of seismic earthquakes..." -> I believe this sentence (as well as the title) is a bit misleading, since this study focuses mainly on event locations rather than on magnitudes.
- It would be important to give the magnitude and distance range for the events studied in this paper.
- Are you using data from the vertical components of the RS seismometers only? If so, this should be mentioned.

Introduction

- **Figures 2, 3:**
    - Axis labels are missing.
    - Consider merging Figures 2 and 3 in a single plot with a) and b).
- **Figure 7**
    - I suspect that more than just the one GeoNet station shown on the map was used to locate the event. In any case, the azimuthal gap is huge and I am surprised that you can determine the hypocenter at all for this (and a few other) event(s) which occurred outside of the seismic network.
- **Figures 7, 8:**
    - The two figures could probably be merged in a single plot with 2 subplots a) and b).

Results

- Do I understand correctly that both P- and S-waves were picked on the vertical component? Does this apply to the RS or also to the GeoNet sensors? I think it should be better emphasized in general which components were used in this study.
- **Figure 5 and text**: Why don't you also show the results for GeoNet stations and RS stations with obfuscated locations? I am in general missing a detailed analysis of the results from the stations with obfuscated locations in the paper. This analysis appears to be limited to the single case study shown in Figure 8?
- It is unclear why the authors do not attempt to determine the magnitudes for the events. If the earthquakes in this study are too small or the data are too noisy, this needs to be explained. Would this possibly work better for larger events?

Discussion

- "… However, through comparing best-fit hypocenters and PDFs of earthquakes located by our combined network with precise station locations and the same earthquakes located with the **obfuscated station** locations available through the Raspberry Shake FDSN, we find that the precision of the station location does not significantly impact the best-fit location nor its uncertainty…" If I understand correctly, there is only a single case study shown in Figure 8 that supports this statement.
- "…though this will be dependent on network geometry and earthquake location errors will be underestimated…" I think this is an extremely important statement that should be highlighted, possibly also in the abstract.

Reviewer 1 PDF (starts on next page), followed by Response Letter by the Authors

This manuscript presents the use of RS sensors for earthquake location. The authors have integrated RS sensors with GeoNet sensors to detect seismic activity in Wellington, New Zealand, and have evaluated the benefits of including RS sensors in the study of seismicity. Their results suggest that the addition of RS sensors significantly improves the precision of earthquake location. The manuscript is commendable, and I have included a few minor comments for consideration.

Line 44: The frequency range 0.05-30Hz is not correct for all versions of RS, please indicate for which version of RS works on what range of frequency.

Line 48-53:
The RS is designed for both purposes, education and basic research and there are several articles on which RS have been used for education purposes. In addition, recently, there is a paper where earthquake location is done using 'only' RS sensors and compared with the broadband solutions. See here and feel free to add suitable references: https://link.springer.com/article/10.1186/s40623-024-02047-y
https://doi.org/10.3389/feart.2020.00073

Line: 57-59
Please mention what kinds of seismometers have been used for GeoNet and some details of the instrument, such as response frequency range.

Line 62-63:
It needs to be made clear which instruments are used for the RS network. The authors mentioned the network's primary purpose is testing the Earthquake Early Warning system, which means the sensor should be RS4D (3MEMS+1Geophone). The single-component records are used for location purposes?

Figure 1:
Adding seismicity would give more sense for the location of newly installed RS seismometers.

Line 95:
Indicate which bandpass filtering is used.

Figure 2:
This is because of RS sensor has been installed in high-noise areas. I suggest presenting another example where RS is installed in less noisy locations. It is already verified that Rs are capable of locating earthquakes <M1 at > 21km distance if the site is good in terms of noise level. In addition, it is good to present a comparison plot of the Power spectral density (PSD) of the given stations.

Line 111:
Since the authors are picking on the S phase on the vertical component, what is the uncertainty used for P and S arrival picking?

Reviewer 1

Line 44: The frequency range 0.05-30Hz is not correct for all versions of RS, please indicate for which version of RS works on what range of frequency.

We have clarified that this refers to the RS4D sensor

Line 48-53:
The RS is designed for both purposes, education and basic research and there are several articles on which RS have been used for education purposes. In addition, recently, there is a paper where earthquake location is done using 'only' RS sensors and compared with the broadband solutions. See here and feel free to add suitable references: https://link.springer.com/article/10.1186/s40623-024-02047-y https://doi.org/10.3389/feart.2020.00073

Thank you, we have added both these references

Line: 57-59
Please mention what kinds of seismometers have been used for GeoNet and some details of the instrument, such as response frequency range.

We have now added the details of the GeoNet seismometers.

Line 62-63:
It needs to be made clear which instruments are used for the RS network. The authors mentioned the network's primary purpose is testing the Earthquake Early Warning system, which means the sensor should be RS4D (3MEMS+1Geophone). The single-component records are used for location purposes?

We used RS4D sensors and this has now been added to the text

Figure 1: Adding seismicity would give more sense for the location of newly installed RS seismometers.

We have now added seismicity to Figure 1

Line 95:
Indicate which bandpass filtering is used.

The picking was done through an interactive software (snuffler) which allows an adjustable bandpass filtering, hence there was no single filter used

Figure 2:
This is because of RS sensor has been installed in high-noise areas. I suggest presenting another example where RS is installed in less noisy locations. It is already verified that Rs are capable of locating earthquakes <M1 at > 21km distance if the site is good in

terms of noise level. In addition, it is good to present a comparison plot of the Power spectral density (PSD) of the given stations.

This particular RS sensor is in fact in a low-noise area. The sensor is in someone's home, not a vault, and the purpose of our paper is to show that even with these "low effort" deployments the RS sensors can still be used to locate low magnitude earthquakes. We therefore do not think it necessary to present a PSD.

Line 111:
Since the authors are picking on the S phase on the vertical component, what is the uncertainty used for P and S arrival picking?

Pick uncertainties (0.5s for both P and S) have now been added to the text.

Reviewer 2

It would be interesting to see if/how the RS seismometers could contribute to the (local) magnitude estimates, bearing in mind that the amplitudes from the low-cost sensors tend to be noisy. The question arises whether RS can also be used to determine magnitude, or whether their application would be limited mainly to location estimates (and in some rare events to focal mechanism or moment tensor solutions)?

We now show in Figure 9 that the amplitudes measured at the RaspberryShake sensors are comparable to those measured at GeoNet sensors, and so it is feasible to incorporate RaspberryShakes into magnitude estimations.

Do you foresee the integration of RS into automated processing, possibly as part of earthquake early warning?

Yes, the integration of RS sensors into earthquake early warning is actually the initial purpose of this RS network in Wellington (see lines 66–68).

in case the authors aren't aware, as far as I know, you can request the exact locations of the Raspberry Shake sensors from the company for your usage if you sign a waiver agreeing not to publish those locations for privacy reasons. So, in principle there is no need to work with the obfuscated locations.

We cannot find this information anywhere and as far as we know this is not publicly described anywhere.

Abstract:

- "...for improving detection..." -> This is not shown in this paper.
  We have edited this
- "...effective for both the locating and characterisation of seismic earthquakes..." -> I believe this sentence (as well as the title) is a bit misleading, since this study focuses mainly on event locations rather than on magnitudes.

We disagree as a significant part of the paper focuses on the calculation of focal mechanisms

- It would be important to give the magnitude and distance range for the events studied in this paper.
  We use a dataset of 19 earthquakes between magnitudes 1.1 and 3.5 and between hypocentral distances of 22 km and 102 km. This has now been added to the abstract.

- Are you using data from the vertical components of the RS seismometers only? If so, this should be mentioned.
  We don't feel that this information is necessary for the abstract, we have detailed this in the main text.

Introduction

- **Figures 2, 3:**
  - Axis labels are missing
  - Consider merging Figures 2 and 3 in a single plot with a) and b)
    We have merged these two figures and added axis labels
- **Figure 7**
  - I suspect that more than just the one GeoNet station shown on the map was used to locate the event. In any case, the azimuthal gap is huge and I am surprised that you can determine the hypocenter at all for this (and a few other) event(s) which occurred outside of the seismic network.
    Yes we also used three GeoNet short period stations on the south island (see Figure 1). This means the azimuthal gap is not that large (142°)
- **Figures 7, 8:**
  - The two figures could probably be merged in a single plot with 2 subplots a) and b).
    We prefer to keep separate to avoid possible confusion

Results

- Do I understand correctly that both P- and S-waves were picked on the vertical component? Does this apply to the RS or also to the GeoNet sensors? I think it should be better emphasized in general which components were used in this study.
  Correct, this is now emphasised in text

- **Figure 5 and text**: Why don't you also show the results for GeoNet stations and RS stations with obfuscated locations? I am in general missing a detailed analysis of the results from the stations with obfuscated locations in the paper. This analysis appears to be limited to the single case study shown in Figure 8?
  The results of using the obfuscated station locations were the same across all of these earthquakes, so for simplicity we use a single case study to illustrate this but describe this result in lines 220–224.
- It is unclear why the authors do not attempt to determine the magnitudes for the events. If the earthquakes in this study are too small or the data are too noisy, this needs to be explained. Would this possibly work better for larger events?

We now show how amplitudes compares for the RaspberryShake sensors, emphasising (lines 190–193) that they are compatible with GeoNet sensors and hence could be used for magnitude estimation.

Discussion

- "... However, through comparing best-fit hypocenters and PDFs of earthquakes located by our combined network with precise station locations and the same earthquakes located with the **obfuscated station** locations available through the Raspberry Shake FDSN, we find that the precision of the station location does not significantly impact the best-fit location nor its uncertainty..." If I understand correctly, there is only a single case study shown in Figure 8 that supports this statement.
  No, we illustrate this result with a single case study (Figure 8), but we performed this analysis for all the earthquakes shown in Figure 5. We have altered the text to clarify this.
- "...though this will be dependent on network geometry and earthquake location errors will be underestimated..." I think this is an extremely important statement that should be highlighted, possibly also in the abstract.
  We have added this detail into the abstract.

A second round of minor review comments (mainly punctuation and clarity) have been provided by the Handling Editor and appropriately accounted for by the Authors.