Response to Reviewers (Seismica)

We again thank the reviewer for their critical reading and review of our manuscript. We greatly appreciate the time and effort invested in providing valuable feedback of our study to improve the quality of the manuscript.

We have carefully considered the reviewer's comments and made modifications accordingly to enhance the clarity and impact of our study. Detailed responses to each comment are provided below.

Here, we also offer a summary of response to the concerns raised by the reviewer.

Summary of responses:

1. **Distinction between RSQSim and FakeQuakes catalogs:** We have added a new figure comparing magnitude and location distributions for the two catalogs. The Methods and Discussion sections have been revised to clarify differences in how rupture scenarios are generated by each modeling approach and to correct or highlight relevant details.

2. **GNSS Ground Motion Models (GMMs) and residual analysis:** We have clarified which GMMs were used by revising the methodology and results descriptions. A table with the regression coefficients for the GMMs has been added, and differences between the GMM used for validation and the GMM used in G-FAST are now explicitly described in the Methods section.

3. **GNSS Network and EEW components:** We have updated the New Zealand GNSS network count to explicitly identify the high-rate stations and corrected related text throughout the manuscript. The discussion of EEW components has also been expanded for greater technical accuracy.

Reviewer A:

Using ruptures from earthquake cycle simulators to test geodetic early warning systems performance

(also refer to separate pdf document with comments)

These were addressed in the manuscript or in the responses below (if there were overlaps).

This paper presents a study of the performance of the GFAST algorithm using synthetic displacement data for New Zealand specific earthquakes. These synthetic data are generated for rupture scenario produced using RSQSim an earthquake cycle simulator. The authors compare synthetic peak displacement values from scenarios produced either by the earthquake simulator or by a semi-stochastic rupture with empirically derived PGD. They show the earthquake simulator produces more realistic PGD f (M) therefore more realistic scenario.

This manuscript is very well written and illustrated. Concepts are clearly explained. The topic is important to international earthquake and tsunami hazard communities and timely for NZ as NZ is moving toward operational EW systems.

The methods are mostly thorough (2 earthquake simulator, generating synthetic and empirical GMM models). The generation of synthetic displacements is also very detailed and robust. However more info is required for the scenarios generated using FakeQuake and for the GMM. The authors could have discussed impact of stations going offline during an event but there was a lot already included in the study; this would be a great future addition.

Yes, we focused on the generation and validation of GNSS displacements using RSQSim and testing magnitude estimation with G-FAST. We agree that a valuable next step would be to assess the impact of station dropouts and/or latency.

Main comments

- The title says: **earthquake cycle simulatorS** but only 1 was tested (the other one based on FakeQuake isn't if I understood correctly?).

Yes, the reviewer is exactly right, and we have updated the title to: “Using ruptures from an earthquake cycle simulator to test geodetic early warning system performance”.

- The abstract should include the conclusions on the comparative studies (does RSQSIm produces realistic scenarios? Is it better than stochastic simulator?)

We have modified the abstract in response to the reviewer’s suggestion, clarifying the study findings and explicitly noting the comparison of different methods used, as follows:

Before:

“[…] We analyze synthetic rupture scenarios along the Hikurangi subduction margin generated by the earthquake simulator RSQSim. Synthetic displacement data are simulated at continuous GNSS sites for all rupture scenarios and compared with known Peak Ground Displacement (PGD) scaling relationships. We also compare these results with those from a simpler semi-stochastic kinematic model. Finally, we test G-FAST’s performance using synthetic displacement data, finding that PGD-based estimates accurately capture moment magnitude in 90% of RSQSim scenarios. This framework enhances our ability to characterize large subduction earthquakes in New Zealand, with a focus on the North Island region, using the current GNSS network configuration.”

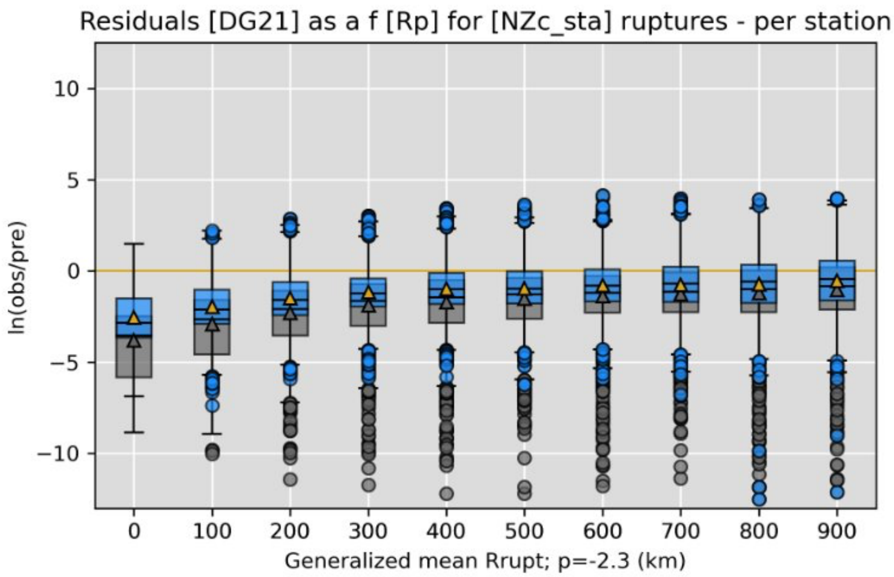
After:

"[…] We analyze synthetic rupture scenarios along the Hikurangi subduction margin generated by the earthquake simulator RSQSim. For each rupture, GNSS displacements are generated at each site and compared with Peak Ground Displacement (PGD) scaling relationships to test whether they replicate real earthquakes. While we also assess PGD values from rupture scenarios produced with simpler semi-stochastic kinematic modeling, those from RSQSim yield ground motions more consistent with expected values. Given these results, synthetic displacement data from RSQSim ruptures were ingested into G-FAST to evaluate performance for rapid earthquake characterization, finding that PGD-based estimates capture moment magnitude in 90% of cases. This framework demonstrates the utility of synthetic catalogs for testing geodetic EEW performance in characterizing large subduction earthquakes in the North Island region and provides a pathway toward tsunami early warning procedures."

- Isn't it obvious/circular that GFAST PGD process will work well with RSQSIM generated data? Indeed, magnitude specific synthetic waveforms are shown to match empirical GMM in the manuscript and GFAST uses the same GMM to derive moment magnitude?

The reviewer raises a valid question, and in fact, this was the starting point of our analysis. As stated in the introduction, we began by evaluating whether RSQSim ruptures realistically represent earthquakes, and we later elaborated on this in the discussion: "Before ingesting simulated GNSS waveforms from these rupture scenarios into G-FAST, we validated the synthetic displacement data against a modified GNSS-based GMM (Crowell et al., 2013; Goldberg et al., 2021) derived from earthquake data. This step ensured that the simulated data produced ground motions comparable to those observed from real earthquakes, as not every rupture result in 30 meters of displacement".

As part of this process, we went through two iterations of RSQSim catalogs for the same region to fine-tune the rupture generation process. The initial simulations consistently underestimated PGD values, as shown in the PGD residuals vs. rupture distance plot below, using stations within 1000 km distance from the hypocenter and ruptures with slip below −33°. In this case, RSQSim-generated ruptures (shown in gray) underperformed (residuals below zero; gold line) relative to those from FakeQuakes (in blue). Interestingly, FakeQuakes performed better despite being a simpler kinematic model, highlighting that RSQSim's physics-based approach does not automatically guarantee better results.

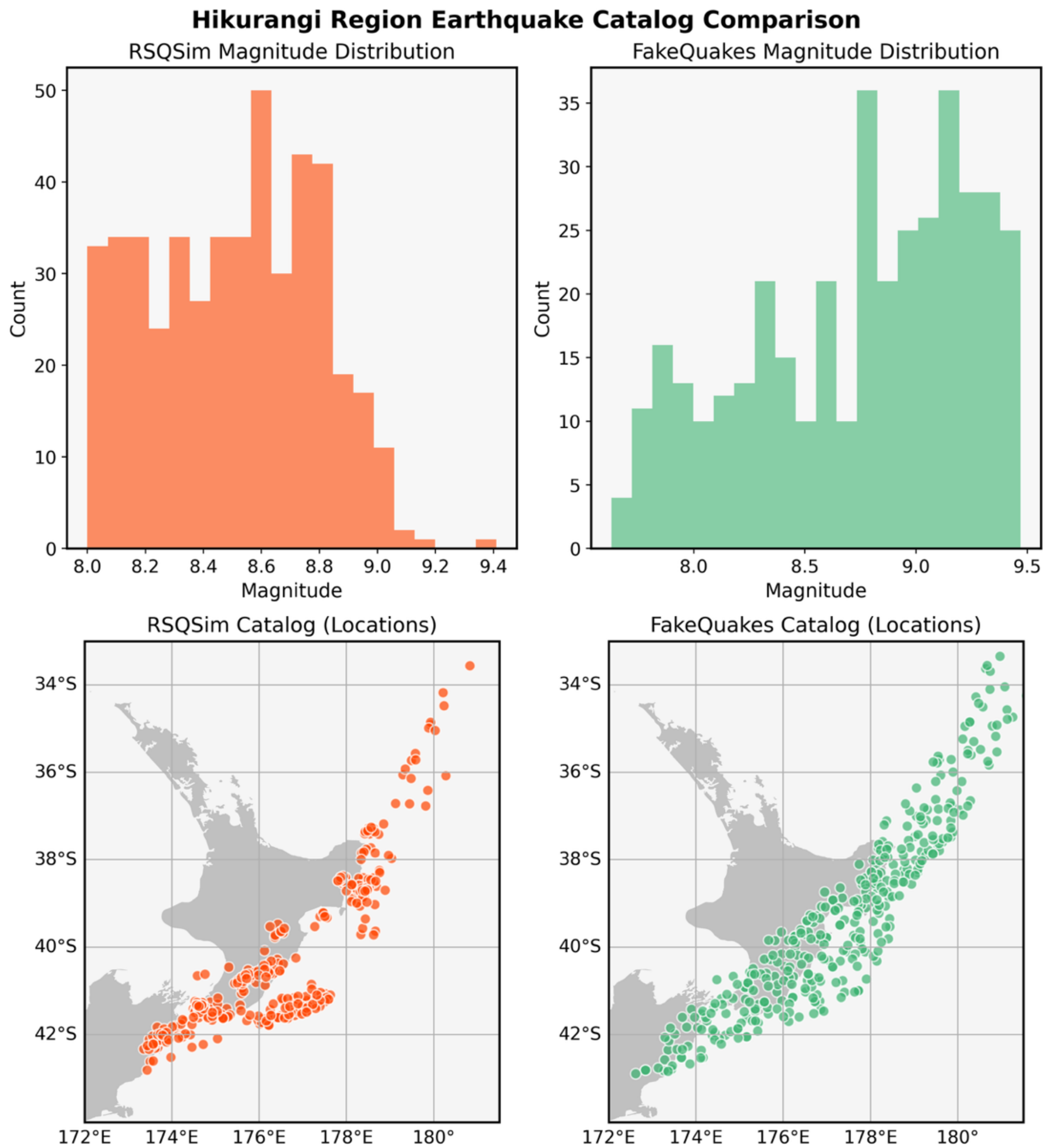


To further investigate this, we tested different station geometries, changed source time function parameters used in computing rise times, and generated an additional set of ruptures using the FakeQuakes module. This allowed us to simulate waveforms and compare PGD predictions across different modeling approaches. Finally, we also introduced noise into the synthetic data to better reflect observational conditions.

- Please include a comparison of the catalogs for RSQSIM and for the stochastic simulator (locations and magnitude, magnitude distribution and (if possible) time period).

Yes, although this was previously inspected, we agree that a plot showing the spatial distribution and magnitude range of events from both catalogs should have been included. In addition, we have added this plot to the supplementary material. Unlike RSQSim, which produces time-dependent synthetic earthquake catalogs spanning 10^5–10^6 years (for this study is a 30,000-year catalog), FakeQuakes does not generate events over a specific time period but instead uses a user-specified origin time.

Figure below shows a comparison of two synthetic earthquake catalogs for New Zealand: RSQSim (in orange) and FakeQuakes (in green). Top panels show the magnitude distribution of earthquakes (histograms) for each catalog, while bottom panels show the spatial distribution of earthquakes (epicenters represented by circles) over the Hikurangi region. Both catalogs exhibit a similar geographic extent but show differences in event density and magnitude distributions that reflect variations in catalog generation methods. RSQSim represents a long-term synthetic seismicity history based on physics-based modeling, whereas FakeQuakes provides a more comprehensive suite of rupture scenarios designed to explore a wide range of magnitudes and locations.



- "ability to estimate the target magnitude within 0.3 units for events" - How is this value defined and what impact does it have on (tsunami) early warning?

This value refers to the expected uncertainty of PGD-based magnitude estimates, defined as ±0.3 magnitude units, following Crowell et al. (2016). We use this threshold as a metric of optimal performance in this study. Achieving magnitude estimates within this range provides reliable preliminary information about the size of an earthquake, which could be critical for downstream modeling (e.g., tsunami forecasting) and for generating timely alerts to emergency management agencies and the public.

We have modified the text in the manuscript to clarify this:

Before:

"Successful performance by G-FAST would yield magnitudes within the uncertainty bounds of ±0.3 magnitude units of the true magnitude (Crowell et al., 2016)."

After:

"Successful performance by G-FAST would yield magnitudes within the uncertainty bounds of ±0.3 magnitude units of the true magnitude. This threshold reflects the expected uncertainty of PGD-based magnitude estimates, as defined by (Crowell et al., (2016). Estimates within this range provide reliable initial earthquake characterization, supporting downstream modeling such as tsunami forecasting (Williamson et al., 2020)."

In the context of tsunamis, rapid source characterization using GNSS data is particularly valuable for identifying large megathrust earthquakes that may generate catastrophic tsunamis, as inertial seismic instruments can suffer from magnitude saturation. GNSS is also critical for detecting tsunami earthquakes, which can produce disproportionately large tsunamis relative to their seismic magnitude due to depleted high-frequency energy. Near-field GNSS data can complement seismic records by capturing low-frequency displacements, helping to correct magnitude underestimation in real time. These capabilities have been demonstrated in studies by Williamson et al. (2020) and Sahakian et al. (2019), which highlight GNSS's role in improving local tsunami warning performance.

- More info is required for the construction of the new GMM model (please provide regression coefficients, uncertainties, a figure etc)

Yes, we have modified the text and added a table in the supplementary material with the regression coefficients for reconstruction of the GMM models. Detail information about the associated uncertainties and figures related to the modified GMM model used for waveform validation can be found in Goldberg et al. (2021). More specifically, Table 4 shows standard deviations for various model iterations and Figure 10 shows PGD vs Generalized mean rupture distance along with the residuals.

Now Table S2 in the Supplementary material

Study	**A**	**B**	**C**
Crowell et al. (2016)*	-6.687	1.500	-0.214
Goldberg et al. (2021)**	-3.841	0.937	-0.127

** Crowell et al. (2016) PGD scaling uses hypocentral distance and applies exponential distance weighting to favor stations closer to the source.*
*** Goldberg et al. (2021) PGD scaling uses generalized mean rupture distance.*

The table above shows GNSS Ground Motion Model coefficients for waveform validation and G-FAST testing. For waveform validation we use Goldberg et al. (2021) using the generalized mean rupture distance, Rp, with a value of – 2.3 for the power of the mean (p). The advantage of using Rp as a distance metric is that it allows for a more realistic treatment of a finite source as opposed to assuming a large rupture is a point source (e.g. as with the hypocenter distance; for more details refer to Goldberg et al., 2021). G-FAST PGD scaling applies exponential weighting as a function of epicentral distance to prioritize stations closer to the source, using a minimum of four stations and a 3 km/s travel-time mask to exclude those that have not yet experienced strong ground shaking, enabling rapid characterization of large events (for more details refer to Crowell et al., 2016).

- Figure 4: Considering the RSQSIM simulations are validated by GMM, how come the residuals between are not nearly zero? Could it be that RSQSIm doesn't do that well at reproducing GMM? It's hard to comment since we don't know how well RSQIM data fitted the GMM.

For context, the residuals shown in Figure 4 are computed as the natural logarithm of the ratio between simulated and expected PGD values, i.e., ln(simulated/expected), where the expected values are based on the GMM. Therefore, a residual of zero will indicate perfect agreement (if the observed and predicted PGD match exactly), while positive or negative values reflect over/under-prediction relative to the empirical model based on observed earthquakes.

The presence of non-zero residuals reflect variability in rupture characteristics, such as source complexity, slip distribution, and rupture directivity, that are not necessarily captured by the GMM. This is particularly true for larger events, where observed data are scarce or unavailable near the source. The GMM relies on a simplified magnitude–distance scaling relationship. The boxplots in Figure 4 are intended to show how these residuals vary as a function of both rupture distance and magnitude with different noise levels to represent real-world conditions, highlighting areas where systematic deviations may occur.

RSQSim ruptures were evaluated for their general consistency with empirical PGD scaling, they were not explicitly calibrated to match the GNSS Ground Motion Model (GMM) on an event-by-event basis.

- Can you please explain how the FakeQuake events are spatially distributed? I see they are constrained by SLAb2 location but what process defines their location on the slab please?

Yes, the fault geometry is constrained by Slab 2.0, but we use the same fault geometry as described for RSQSim in Section 2.1:

"We use synthetic ruptures from one of three synthetic earthquake catalogs generated by Hughes et al. (2025) for the Hikurangi-Kermadec subduction interface. This 30,000-year catalog includes 470 events ranging from M8.0 to M9.4 along the Hikurangi subduction zone (Figure 2). It uses the same subduction interface geometry as the New Zealand National Seismic Hazard Model 2022 Revision (NZSHM22; Gerstenberger et al., 2023), which was created by merging Slab 2.0 (Hayes, 2018) for the Kermadec portion with the Hikurangi interface geometry of Williams et al. (2013)."

However, to run FakeQuakes, we implemented a coarser grid with lower spatial resolution (i.e., fewer subfaults). To clarify this matter, we have updated the text in the manuscript, as follows:

"To generate these rupture scenarios, we first defined <u>the fault geometry as before, but with a coarser spatial resolution, and</u> used the same 1-D velocity model from LITHO1.0, with a maximum depth of 25 km and a maximum slip of 50 m."

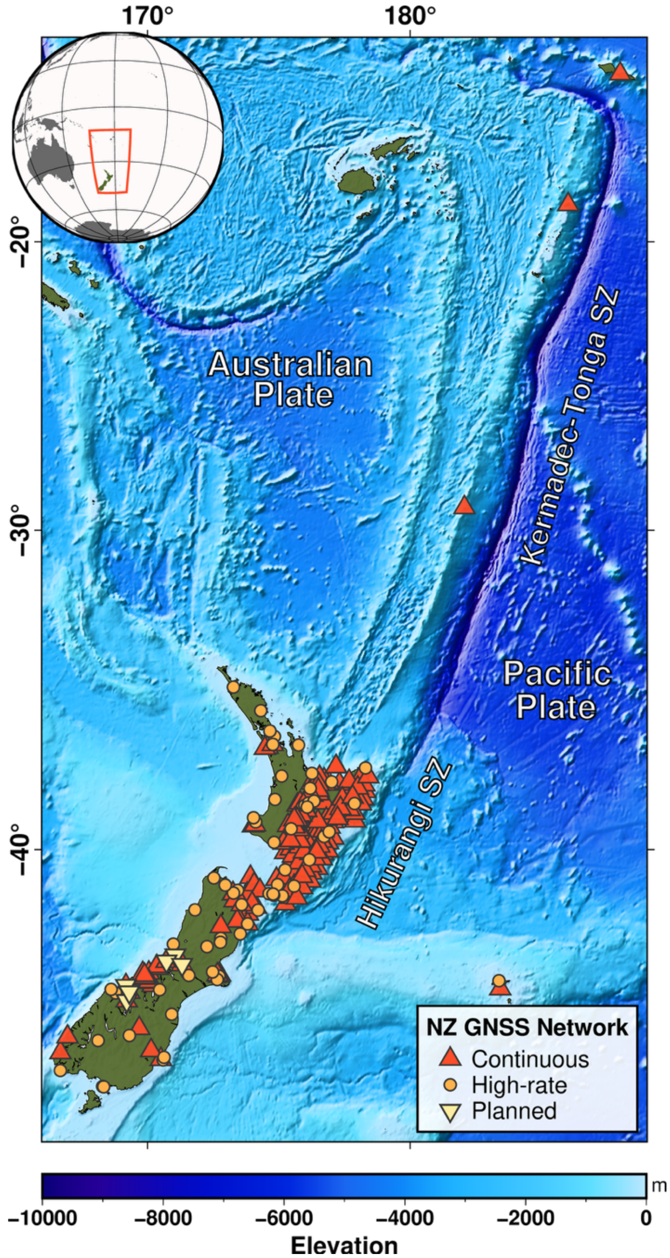
Regarding the locations of these simulations, the hypocenters are not explicitly enforced but are randomly assigned to a subfault within the modeled region, allowing variability in rupture initiation across the domain constrained by the scaling laws as described following previous modified sentence in the manuscript:

*"The fault plane was discretized into a 3D mesh of subfaults, each assigned a displacement (slip vector) along the strike and dip directions. Stochastic rupture dimensions (length and width) were determined using the probabilistic scaling laws of Blaser et al. (2010), **with a randomly selected subfault as the hypocenter.** Slip was distributed across the subfaults using a von Kármán correlation function, following the approach of Mai and Beroza (2002). This ensures consistency with the fault dimensions prescribed by the scaling laws to match the target magnitude. A Karhunen-Loève expansion (LeVeque et al., 2016) approach was then applied to model the spatial pattern of slip vectors, as it more accurately captures the complexity of observed earthquake slip distributions."*

Minor comments

- NZ geodetic network is not real-time yet
- Figure1: needs a better layout (perhaps a close-up of the NZ GNSS network – current layout makes it hard to see the stations)

In response to the reviewer's final two comments regarding the New Zealand geodetic network, we have updated the map in Figure 1 to highlight the high-rate stations currently processing in real time, which represent approximately 25% of the network. The main purpose of the figure is to show the overall density and geographic extent of the continuous GNSS network in New Zealand. In subsequent figures, stations are plotted consistently for reference.



- Please explain your choice of magnitude range wrt tsunamigenic sources (You haven't explained what minimum magnitude required and how this drives your choice of magnitude range. Also how suitable is a target error of 0.3 magnitude unit in this optic? Please detail.

The choice of minimum magnitude threshold is determined by the geodetic data resolution as described in the manuscript:

"Here, we specifically want to assess the performance of the Geodetic First Approximation of Size and Timing (G-FAST; Crowell et al., 2016, Crowell et al., 2018), for rapid source characterization of moderate-to-large earthquakes using synthetic ruptures and geodetic data. Geodetic algorithms are desirable because traditional approaches that rely on inertial instruments, such as

seismometers and accelerometers, can be biased by magnitude saturation and baseline offsets, respectively (refer to review by Allen & Melgar, 2019). During an earthquake response, these factors could result in an inaccurate estimation of earthquake magnitude and an underestimation of seismic risks associated with the event. GNSS observations can address these issues but depend on the time required for slip to accumulate and for the signal to exceed the GNSS noise floor to detect an earthquake. For these reasons, we focus on evaluating large earthquakes (M ≥ 7) with geodetic data."

In this study, we focus on large megathrust earthquakes (Mw >= 8) along the Hikurangi subduction zone, as these are potential tsunami sources. While we did not perform tsunami modeling or forecasting, this would be a valuable next step to more confidently assess tsunami potential across the full magnitude range as in Williamson et al. (2020).

Please refer to the previous response about the uncertainty threshold of 0.3 magnitude and tsunami context.

Recommendation: Revisions Required

Reviewer B:

Review of

Using ruptures from earthquake cycle simulators to test geodetic early warning systems performance

Solares-Colón et al.

The study evaluates the performance of the G-FAST algorithm for sets of synthetic events rupturing offshore of New Zealand. Two sets of synthetic events are used, one model uses RSQSim, the other uses FakeQuakes. The authors set out to answer three questions:

1. Are the RSQSim generated ruptures realistic enough for EEW
2. How do the ruptures from this simulator compare to ones generated by stochastic kinematic modeling
3. How well does GFAST perform in estimating the moment magnitude of these synthetic scenarios.

I enjoyed reading this manuscript and believe this is a very interesting study. I think that the figures are overall clear and easy to read and that the topic is important and would be of interest to the readers of *Seismica*. However, prior to publication, a few parts of the main text need additional clarification/justifications and are listed below as major concerns. A few very minor comments follow.

The authors do a good job at explaining the differences between FakeQuakes and RSQSim, where the latter produces a catalog via modeling long term seismic cycles. In contrast, FakeQuakes produces individual events and is heavily reliant on user described parameters. However I think the authors need to further clarify the differences between the RSQSim catalog and FakeQuake catalog as used in this study. Ultimately, ruptures from both sets of catalogs are treated as "known" events, GNSS waveforms are generated using a prescribed velocity model, and then these waveforms and any added noise are used as an input to GFAST. Do these two catalogs have similar distributions of peak slip, rupture length/width, rupture velocity as a function of magnitude? Are both catalogs generally covering the same spatial extents along the fault? How similar are the slip patterns between the two models and are they using the same or similar fault plane geometries? There is likely an expectation that different catalogs will produce events with different characteristics, but as a reader, knowing these characteristic differences will be helpful when looking at the GFAST results later in the manuscript.

We appreciate the reviewer's thoughtful observations regarding the differences between the RSQSim and FakeQuakes catalogs. While our study focuses primarily on testing G-FAST performance using synthetic GNSS data from two different modeling approaches, we agree that understanding how rupture characteristics vary across catalogs can provide useful context.

As noted, both catalogs are treated as sources of "known" events for GNSS waveform generation. However, a comprehensive comparison of rupture characteristics such as peak slip, rupture dimensions, rupture velocity, or event-by-event slip patterns is beyond the scope of this paper. These parameters can vary widely and are inherently non-unique, especially in a synthetic framework where multiple rupture scenarios may explain the same surface displacements. As in real-world applications, the goal is not to model the exact rupture but to test system response to a range of plausible events.

To better visualize the differences between the catalogs, we have added a new figure comparing their spatial and magnitude distributions to the supplementary material (Figure S1). Please refer to our previous response to Reviewer A for additional details.

This study uses an offline Python version of GFAST. It uses the hypocenter and magnitude from the RSQSim rupture as the initial solution derived from the seismic data. I think it would be fruitful for the authors to include a discussion of how using a perfect/zero error initial location affects the GFAST results. In the ShakeAlert system, GFAST uses an initial location estimate from the other two seismic based location algorithms, EPIC and FinDER. These two codes can sometimes provide poor initial location estimates. EPIC has at times produced estimated locations > 100 km further offshore than the true location. FinDER sometimes does the opposite, and for offshore events, pulls the initial location landward. Would an initial location that is offset 10, 50, 100 km from the true location greatly affect the early magnitude estimates?

How is depth being incorporated into the GFAST solution and is it requiring an accurate depth estimate from the seismic-based cue?

In response to the reviewer's previous two comments/questions regarding how changes in initial location and depth affect G-FAST magnitudes estimates are great observations. Yes, we use the true hypocenter (including depth) and magnitude from RSQSim to initialize the offline G-FAST runs. We acknowledge that this represents a limitation, as real-time systems like ShakeAlert rely on initial locations from seismic-based algorithms such as EPIC and FinDER, which can have substantial location errors. These errors can impact PGD-based magnitude estimation, as they directly affect the computed hypocentral distances to GNSS stations. Although we do not explicitly explore sensitivity to initial location or depth errors in this study, we agree that this is an important consideration for real-time implementation. A more detailed investigation of how depth and location errors affect G-FAST performance is currently underway as part of a separate manuscript in preparation, targeted for submission in September 2025.

We have expanded the discussion section to address this point, adding the following text:

"State-of-the-art tools using seismic data can provide accurate and timely information about large earthquake magnitude and can encompass limitations of GNSS-HR techniques such as the ones presented in this paper. But GNSS-HR is still an invaluable and unique tool to rapidly assess the slip distributions of large events. This is provided by G-FAST and should be examined more closely to validate slip in relation to the gCMT module and slip inversion. Accurately determining magnitude is important but so is generating reliable slip models to gain deeper insight into rupture processes and better inform tsunami warnings. Improving slip models would enhance our ability to interpret rupture processes in real-time applications and better approximate ground motions and tsunami hazards, which depend on the concentration of slip and the earthquake source. However, both magnitude and slip estimates are sensitive to the initial earthquake location, which remains fixed in this study but can introduce errors in real-time applications where depth is uncertain. Building on this work, a forthcoming study (Caballero et al., in preparation) evaluates the impact of depth uncertainty and grid search on the stability and accuracy of G-FAST solutions. The framework presented here could also be extended to adapt the tsunami early warning approach used in Williamson et al. (2020) to the Hikurangi subduction zone."

Am I reading it correctly that Equation 2, a modification of the Crowell (2013) PGD scaling relation, is used to generate the "observed" or expected PGD at each station. However, the "predicted" PGD at each station is calculated using Equation 1, which is what is currently set in GFAST. Or do I have this backwards and the Crowell (2013) relation is used with the synthetic ruptures to create the observation dataset, and the Equation 2 version is used to create the predicted values, presumably also using the GFAST finite fault output to get to the generalized mean rupture distance

Rp. Reading through this section a few times, I cannot quite confirm which way this analysis is being set up.

Yes, we have used a modified version of the GNSS GMM form (Equation 1) from Crowell et al. (2013). This form is applied both for waveform validation, as implemented by Goldberg et al. (2021), and within the G-FAST module, as described by Crowell et al. (2016, 2018). We have also included the regression coefficients used to construct these GNSS GMMs in the supplementary material (refer to our previous response to Reviewer A).

To clarify the GMMs used in this study, we have revised the Data Validation section (to introduce the GNSS GMM formulation and the modified version from Goldberg et al., 2021) and the Testing EEW and Rapid Earthquake Characterization section (to describe the G-FAST implementation using the GMM from Crowell et al., 2016 and 2018).

L303 "*To account for limitations in GMSSs as we move away from the source, we filtered out PGD values for stations located less than 1000 km from the rupture.*" Is this a typo? As written, I would interpret this to mean that only stations > 1000 km are being used. Discarding any nearfield stations would seem counter to the EEW system element.

Thank you for catching this, it was a typo, and we have corrected the sentence to state that we filtered out PGD values of stations located *more* than 1000 km from the rupture.

L414: "*[the better fit of the RSQSim ruptures than the FQ ruptures] This indicates that the RSQSim rupture scenarios more accurately represent real earthquakes*." I think this argument needs to be justified a little more. Ultimately, what is being tested are two sets of synthetic catalogs, which always will rely on user defined parameters- even if RSQSim may require less direct parameterization than FakeQuakes. Here, it appears that the argument made is that because one of the two catalogs performs better, it therefore will represent real earthquakes. But performance appears to be based on fit to the same synthetic, not real, events.

We have revised the manuscript to more clearly describe and contextualize the findings, as follows:

"In addition to generating synthetic waveforms, the FakeQuakes module can also generate ruptures scenarios using a kinematic modeling approach, which is not necessarily physics-informed but is more computationally efficient compared to an earthquake simulator. Although FakeQuakes can produce a catalog with as many events as the user specifies, RSQSim generates an earthquake cycle that is arguably more representative of the long-term seismic behavior and fault interactions in a region. Therefore, we expect that ruptures from RSQSim will perform better than those from FakeQuakes. We created a second synthetic catalog using FakeQuakes, with events in the M7.8 to M9.4 range targeted at the Hikurangi region, and generated synthetic waveforms to obtain PGD values. We then compared PGD residuals between RSQSim and FakeQuakes ruptures scenarios as shown in Figure 6. RSQSim ruptures (boxplots with solid fill

color in Figure 6) generally yield residuals closer to zero than FakeQuakes ruptures (boxplots with solid fill and hatch in Figure 6), indicating better agreement with the expected PGD values from the modified GNSS GMM based on observed earthquakes. While both approaches rely on user-defined parameters, these results indicate that the RSQSim rupture scenarios more closely represent real earthquake behavior, as supported by their consistency with expected ground motions."

As a follow-up to the previous comment, L 496 does bring up that the GMM is based on earthquake data, but does not provide enough detail. I think this should be explained further as it may resolve some of the earlier confusion.

Please refer to response in previous comments.

L317 "*G-FAST consists of two main modules*" ... but then the authors proceed to discuss three modules. Please consider rewording.

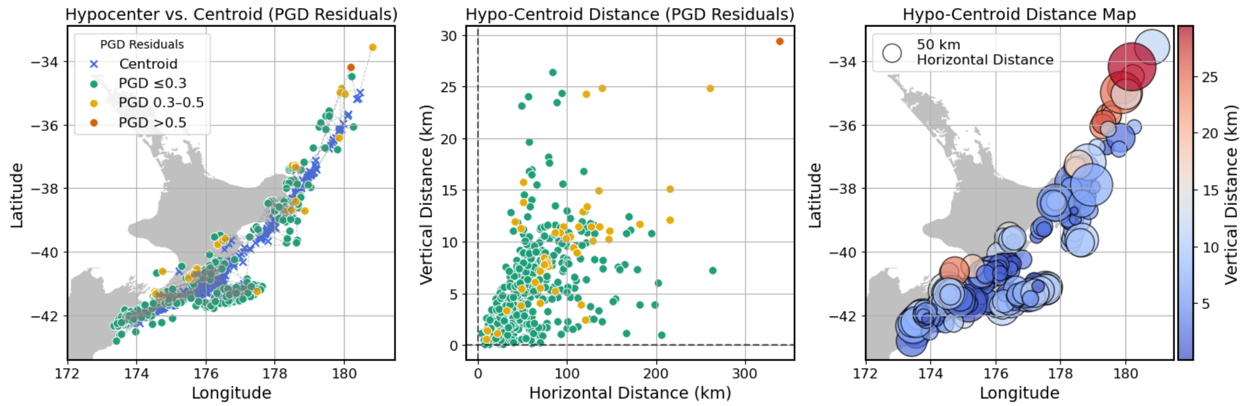
As suggested by the reviewer, we have updated the manuscript to refer to the "*G-FAST consist of three main modules ...*" for clarity.

Unless I missed it, I think the authors should note why there is a small time delay between the first Mw PGD and Mw CMT solutions, as shown in Figure 7 c,d,e.

A few factors contribute to the apparent time delay between the initial Mw(PGD) and Mw(CMT) solutions shown in Figure 7c–e. First, a minimum of four stations is required to compute a solution. Depending on the size and location of the event, it may take several seconds to over a minute for enough stations to register the earthquake signal. Second, the G-FAST modules activate sequentially. The PGD module is triggered first and is less computationally intensive than the gCMT module, which takes longer to initialize and complete.

Figure 9: including the coastline on the far left and right panels would help with reader interpretation.

We have modified Figure 9 in the manuscript and Figure S2 in the supplementary material to include NZ polygon for reference.



Recommendation: Revisions Required
