Dear Editor,

We thank for the careful and detailed review from Reviewer 2. We checked again signal processing concerning about Figure 6 and we confirm that the filtered ground motions are correct as long as we can do now. In the following, we reply to each comment.

Hideo Aochi and Authors.

This study considers the complete chain of events resulting from the rockslide in Karrat Fjord, Greenland. A number of substantial improvements have been made to the original landscape but there are still a number of clarifications that I think are needed before it can be considered for publication. My greatest worries regard the correct interpretation of the seismic data and I think a lot more clarity about how the raw waveforms are processed to arrive at the conclusions reached. I have been unable to match the waveforms displayed in Figure 6. I may have made errors in processing the data but this is all the more reason to show explicitly what has been done, for the sake of reproducibility.

Thank you very much for your scrutinization and a script to analyze the observed waveforms.

The new sentence "The volume was estimated …". I feel this sentence loses a bit of meaning without saying what the estimate and uncertainty are. These numbers are more important than the number of seismic stations involved. Later in the abstract we read about "uncertainties in the landslide volume"- maybe it is easier just to remove the new sentence and be more precise about the measurement and the uncertainties later?

*I see later (e.g. line 193-194) the value 44 * 10^6 m^3 which is qualitatively in-line with other estimates (lines 207-209). What are the error bounds associated with the 44 from thiscalculation?*

In Abstract, we change **"The volume of the landslide was estimated to 44 * 10^6 m^3 from the seismological analysis and empirical relation."** In the main text, we also precise that **"According to Ekstrom and Stark (2013), the empirical relationship has +-50% in estimation variation"**. (Section 3.1).

Can we adjust the terms "sea level change" and "ground deformation"?

"sea-level-change" almost always refers to a slow change in the long-term baseline level, not a wave-associated change in water height. I suggest "A 1m water surface elevation …" – it is semantics but it creates a completely different impression.

We replaced "Sea level change" by **"water surface elevation"**.

Similarly, ground deformation tends to imply a permanent remoulding of the rock which is also not the case here – this is also an elastic response to the forcing. Can we use "ground displacement"? The seismograms eventually return to their normal displacement as a result of the water wave.

Speaking exactly, we compute "displacement field". We replaced "deformation" to **"displacement"**.

(It says still in lines 170-171 "The seismic waves usually propagate at a speed of a few kilometres per second, and the static displacement remains after the passage of the seismic waves" – I really

cannot reproduce this! I have read in a very long segment of data from station DK.NUUG and converted to displacement and I do not see any permanent deformation. Can you please demonstrate – e.g. in the supplement - the code you use to demonstrate a permanent deformation. I may have made a mistake or an assumption here, e.g. in the way I have removed the instrument response, but I cannot find an offset in the data.)

This phrase was aimed for explaining the seismic waves to non-seismologists. The seismologists know that the displacement at far field is zero. Permanent displacement is only observable in the near field of the origin of the seismic wave radiation. In the practical observation, the velocity sensor cannot record the permanent displacement. The instrument response is limited in a band frequency without permanent response (frequency = 0). See also the last comment/response for the response correction.

In the start of the introduction we say "have been melting at unprecedented rates for 4 millennia" – do you mean "melting now at rates that are unprecedented given the estimated melting rates over the last 4 millennia"? As the sentence stands now it sounds that the melt has been going on at this rate for thousands of years …

Thank you for this remark. We modified the phrase. **"As the climate is warming, coastal and marine-terminated glaciers in Greenland are retreating (e.g., Meredith et al., 2019; Constable et al., 2022)."**

Line 66-69: Are we talking about the Greenland seismic network here? Is it actively being used for early warning purposes? If so I think this needs a reference. The use of seismic data for early warning has very special usage in seismological literature and I am not aware of the Greenland network being specially applied for early warning. It is true that the seismic waves travel faster than the tsunami waves but this is of little consequence if there are not systems in place to monitor this in near-real-time.

Here this sentence talked about the general case such as in the Pacific ocean. We modified the expression **" … can be used for the early detection….. if the data are corrected at real time…"**

In the caption to Figure 1, panel b) says > 0.001 Hz but in the caption, it says highpass filtered at 0.0005 Hz. Why is the seismic coda in panel (c) labelled "Initial tsunami"? On what basis are these waves identified as coming from the tsunami rather than seismic coda waves? (I am not saying that it is not the tsunami, and it may be contributing, but to me this looks completely normal for coda from a non-tsunamigenic source. In lines 104-105, it too mentions "smaller amplitude waves related to the beginning of the tsunami" – what is it that makes it clear that this is the source?

Figure 1b had a typo, it was >0.005 Hz. We fixed it.

The reason why we wrote "initial tsunami" in the panel (c) was that the high-frequency waves are generated by the interaction between the water and landslide mass dropping into the water. We also add that **"The high-frequency waves generated by the interaction between the water and landslide mass dropping into the water is commonly observed in the seismic signal of the landslide (Yamada et al., 2013)."** (As a coda wave generated by the landslide movement, amplitude is too large.)

We agree that "smaller amplitude waves related to the beginning of the tsunami" was a bit confusing. We modified **to "a chain of vibrations of smaller amplitude, which is related to the tsunami propagation"**. This indicates the smaller amplitude after 100s.

Finally, the paragraphs (L.99 – 111) are revisited.

I had a feeling that the numerical resolution of the slide would be about ~10 pixels and this is confirmed here. Is this enough? In line 149-150, it states that the finer resolution would likely not have a great impact on the tsunami simulations – this is correct – a simple "box" shaped source is often used for modelling a landslide's tsunamigenesis. However, is the ~10 pixels enough to model the dynamics of the slide itself? It may be fine, but a word that gives confidence that a model with ~20 pixels or ~200 pixels would give a qualitatively similar result would be appreciated. (This may be completely normal for VolcFlow simulations and it may be well documented that this is sufficient, but it would be nice to say so here for us that are not familiar with VolcFlow.)

Yes, it is enough according to the empirical convention. It is correct that we wrote **"Considering the long-period nature of tsunami waves and the smoothly resampled topography, the inclusion of a finer grid is expected to have a negligible impact on the simulations. "**

In lines 151-155, I understand that at 120 seconds, one model takes over from another. What does the FUNWAVE-TVD code need to initiate the simulation? Is an initial condition that is a direct output from VolcFlow enough?

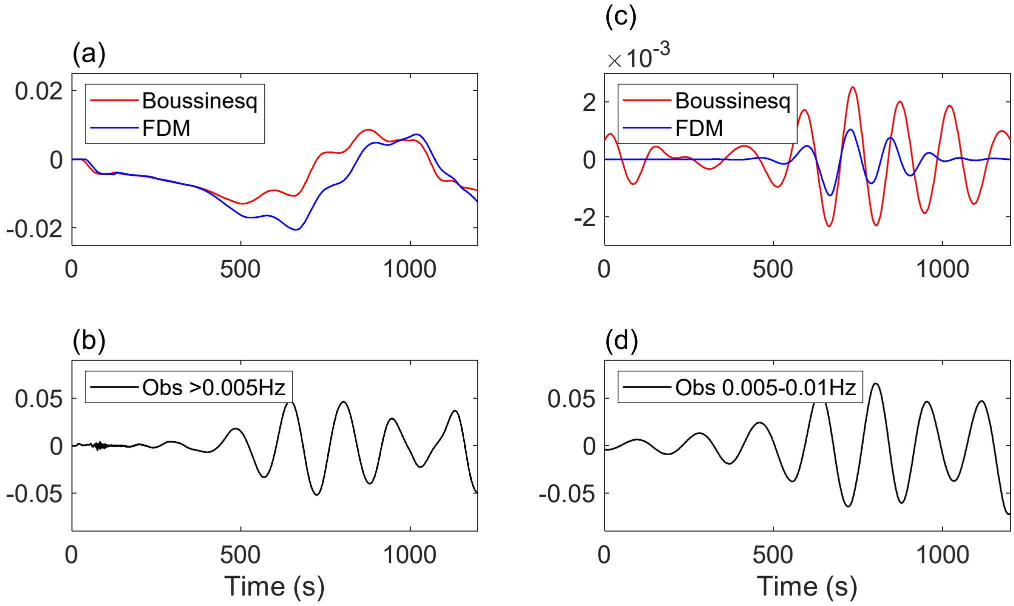
Yes, the condition of direct output from VolcFlow is enough. The governing equations (continuity and momentum equations) require only the input of velocities (u, v) and water elevation (wave height); those are direct output from VolcFlow. These are the standard conditions used to start a simulation. This type of model-coupling is a common method for hydrodynamic simulations when transitioning between dimensions or processes. We added **"The output velocity field and water elevation from VolcFlow are implemented as boundary condition in FUNWAVE-TVD."**

I am happy to see the improvement to Figure 3 resulting from the rotation of the horizontal components of DK.NUUG. Please mention this in the caption (as Paris et al. do) – it helps the literature to serve as a guide to future study.

We added the following sentence in the caption. **"Note that the horizontal components at NUUG station were oriented to 79 and 169 degrees from North, so they were rotated correctly."**

My question about the filtration of the observed data in Figure 6 I think has been misunderstood. Panel (c) says (Obs > 0.001 Hz) which means highpass filter. But it says in the caption lowpass filter. If it is highpass, then please correct the lowpass to highpass. If it is indeed lowpass, then please write (Obs < 0.001 Hz) in the figure. I have tried to reproduce these figures of the observed seismograms and I cannot which is why I would really appreciate the filtering parameters and the exact starting times of the segments shown. (You have the sign the right way around for highpass in Figure 2!)

The caption was correct, it was high-pass filtered at 0.001Hz. However, we think it may be too challenging to use 1000s component from the STS-2 sensor. Therefore, we changed the frequency of high-pass filter to 0.005Hz for the panel (b). New Figure 6 is below. The main text corresponding to Figure 6 is rewritten. (The first paragraph in Section 3.3)



I think it would be better to show an extended segment of the filtered seismograms with a "zoom-in window" to the segment shown. In the reply to the reviewers' comments it says "There is an early seismic arrival … which is why the waveform doesn't start at zero." – can you add this to the caption too?

We added it in the caption of the above new Figure 6 as follows. **"Note that the filtered records do not start from zero since we used non-causal Butterworth filter."**

It says in line 233-234 that the observed seismic displacement is much larger: it is over 20 times larger! This is why I am worried that we are looking at something completely unrelated here.

As in the above replies (and also see our last comment below), we checked again the signal processing, and we confirm that the filtered observation is correct. We agree that sensitive the filter process is very sensitive on the waveforms at low frequencies. The difference between the observation and synthetics is discussed in Discussion. We imply several possibilities such as the rigidity of the medium and the mass volume.

Figure 7 is a great improvement! The new colour scale improves our understanding greatly.

Thank you.

I do not understand the time-scale in Figure 8. The label on the x-axis is "Origin Time" – origin time is just a single point, so I presume this should read "Time after Origin Time". I am trying to see the connection between Figure 8 and the numbers in Table 1. The time given in Table 1: "First wave Time" – this is at the source right, not at Nuugaatsiaq (at which place the wave arrives after several hundred seconds. But how is the water reached after ~15 seconds and the wave not generated until ~30 seconds? This is the time of the first negative wave amplitude, meaning the first local minimum. OK, I think I understand – but it says "in the sea area" – so this is not necessarily the same location?

We corrected the horizontal axis as **"Time after origin time".** As observed clearly in time 60 seconds in Figure 4, the first wave of tsunami is positive. So the first wave time (the first negative wave amplitude appearing time) means "water reach time" + "first half-period". It is clarified in the caption of Table 1: **"Note that the Water-Reach Time indicates the time when the landslide mass reached the water and the First-wave time indicates the time of the first negative wave amplitude appearing in the sea area. Since the tsunami wave height is first positive as seen in Figure 4, the First wave time is the sum of the Water**

reach time and half-period of the tsunami.” The timings of the tsunami generation process in Table 1 are in the VolcFlow simulation at the origin of the landslide and tsunami, not correspond to the timing in Nuugaatsiaq.

The numbers in the final two columns of Table 1 are given to cm-precision which is a level of accuracy not warranted by the model. (It was the fact that the number of significant figures given in the second-to-last column are not consistent that drew my attention to the matter!) To me, Table 1 tells us that all the models produce qualitatively similar waves.

The accuracy is only for the purpose of distinguishing the difference among the models, comparing to the different lines in Figure 8.

In line 289 of the Table 1 caption we read “brief estimation” (brief = approximate?)

We changed to “**approximate**”. This is estimated by the empirical law.

The phrasing of 350-351 is a bit strange. (“playing a crucial role in introducing artificial phases”). I think I know what you are saying but …

We changed the expressions. **“It should also be noted that filtering seismic records is sensitive at low frequencies where instrument response is not flat. To our best, the filtered observation shown in Figure 6 seems correctly extracted. Therefore, there remains an important discrepancy, and this is likely because of uncertainties in subsurface rigidity and landslide parameters.”**

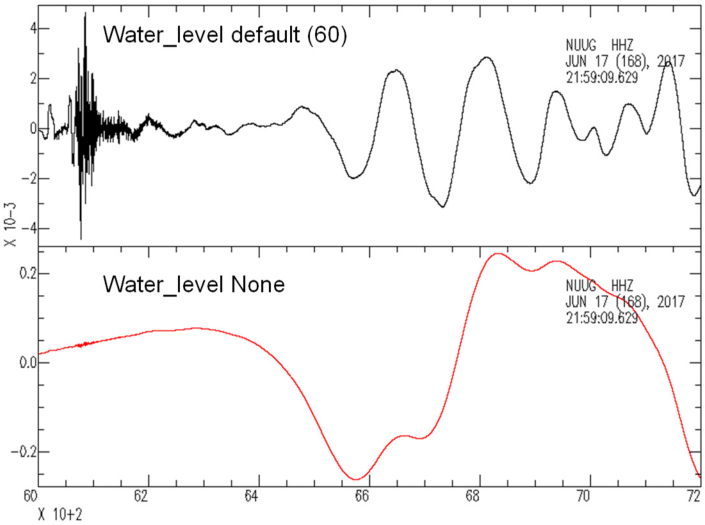
Finally, regarding the motivation of the study, there is much mention of early warning. However, it is not clear how and to what degree this would be implemented in an Urgent Computing mode. Is the entire workflow envisaged in a rapid reaction response? I see that this would be challenging. Or is it just the interpretation of seismic data that would be incorporated into an emergency workflow? How would you distinguish between a tsunamigenic event and a non-tsunamigenic event. It was only the very long period and large amplitude waves at DK.NUUG that alerted the seismological community to the tsunami aspect of this event. But once these are observed and identified, presumably it is too late to use this seismic data for warning purposes – the wave has already washed ashore. I think an Early Warning application is a great goal and a great application, but I do not think it is clearly outlined here how this would work in practice.

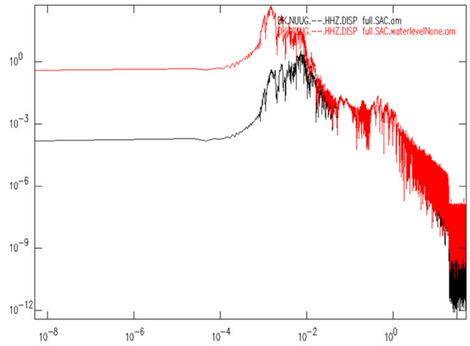
Seismic wave analysis to obtain the source parameters is a classical and solid way. We agree that there remain problems in timing and uncertainty. Besides, a complimentary possibility is to use the ground displacement along the coastline to monitor directly the tsunami waves. We added **“The dominant period between 100 and 200 seconds are similarly found both in the observation and simulation. The direct observation implies propagating tsunami without inverting any source parameters, so that the target-oriented placement of the captor reliable to this period is expected.”**

This is the code I use for converting the seismic data to displacement and then performing a bandpass filtrationh.

Thank you very much for providing the python code. We double check our code (we used SAC), and found the remove_response in obspy applied water-level clipping (default value is 60 dB). If we use water_level=None, the waveform is very similar to us. The following plots are waveforms and spectra computed by obspy (and plotted by SAC).

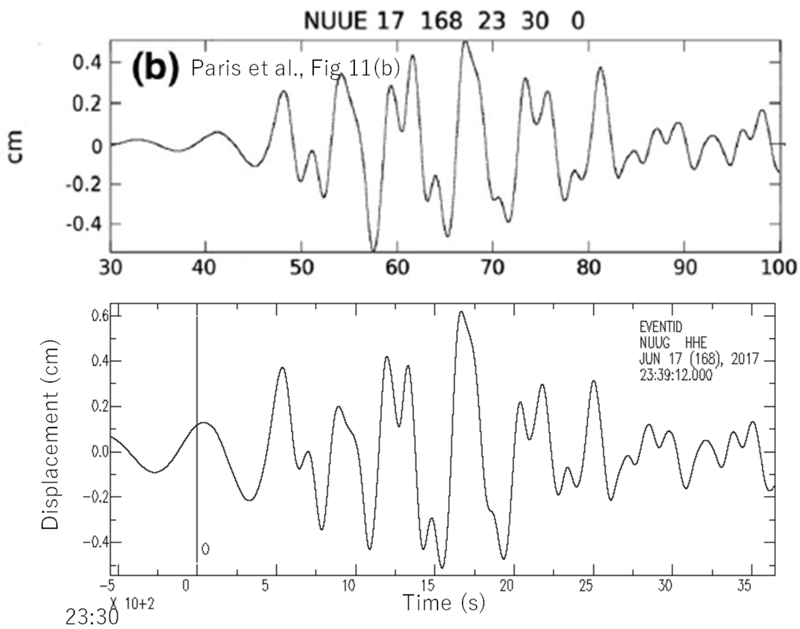
References:
https://docs.obspy.org/packages/autogen/obspy.core.trace.Trace.remove_response.html#obspy.core.trace.Trace.remove_response





```
pre_filt = (0.0008, 0.001, 18.0, 20.0)
st.remove_response(inventory=inv, output="DISP",
     pre_filt=pre_filt,
     water_level=None)
```

We also compared the EW components shown in Paris et al., 2019. Figure 11(b) in the paper shows the result of deconvolving the instrument response in the frequency band 1.7–17 mHz (i.e., 0.0017-0.017Hz). Therefore, we used SAC deconvolution with the frequency remits of 0.0015, 0.0017, 0.017, 0.02 Hz so that the frequency band 1.7–17 mHz has a flat response. The bottom figure shows the comparison. Waveforms are very similar, which suggests the SAC deconvolution is reasonable.



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