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Discussions

Interactive comment on "Rapid Detection and Location of Debris Flow Initiation at Illgraben, Switzerland" *by* Fabian Walter et al.

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Reviewer: 1) reframing "in context of other studies that have used similar techniques and with a more modest/realistic approach to how these methods could be used in warning systems"

Authors: Admittedly, we were unaware of these previous studies. Discussing them will naturally lead to a more modest/realistic presentation of our work as an implementation of an existing technique and an exploratory exercise of its suitability for early warning purposes.

R: 2) include more analysis to convince the reader of some of their claims and to illustrate limitations, which I detail below and in the specific comments

A: We will describe and carry out additional analysis steps. The referee emphasized the need for investigating site effects. Initially we had refrained from this step, because we were looking for a workflow, which is straightforward to apply and highly portable to other debris flow catchments. However, with the hope to improve our location quality, we will investigate coda amplification factors of regional and local earthquakes. For this task we have identified about three local and regional earthquakes, which show good signal-to-noise-ratios on a nearby permanent station of the Swiss Seismological Service.

R: 3) include more specifics about the choices they made, why, and how those choices affect the results

A: This information will be provided.

Specific Comments

R: P1-L18-19: It's not clear to me that the author's alternative solves this challenge. The seismometers still have to be installed in steep terrain and still have to be telemetered.

A: We will explain more clearly how seismometers provide flexibility for installations.

R: P1-L21-23: This implies that geophones aren't seismometers. What is different about the author's method is the algorithm, namely that it doesn't depend on the vibrations detected right next to the channel. This should be clarified.

A: We will adapt this explanation and discuss geophone installations in and near torrent channels in more detail.

R: P1-L24-27: Acoustic flow monitor-type detection systems also use time-averaged ground vibration amplitudes, just the ones right next to the channel, and do not rely on single station detections. The authors should clarify what is actually different about their method.

A: This will be discussed in detail using the references, which this referee provided.

R: P1-L29: This implies that they applied this algorithm in real time, but from what I gather, they did this analysis long after the event occurred and was already characterized. For example, it is stated later on that the data was not even telemetered. Would the outcome have been so good in real time without prior knowledge of the existence of the event and with all the delays and complications of telemetry that the existing system already has to deal with?

A: We will make it clearer that we did our analysis offline in retrospect and discuss challenges for implementation in real time.

R: P2-L22-23: The number quoted for maximum ground velocity surely isn't the highest of any debris flow ever, I would change this sentence to "ground motions of up to 2e-3 m/s have been observed: : :" Also, observable frequencies near the channel are often much higher than 100 Hz, acoustic flow monitoring systems often look at bands of several hundred Hz. For example, see Marcial et al. 1999.

A: These suggestions will be followed.

R: P2-L29: I don't know if I agree that no reliable implementation for debris flows has been found. The authors describe one in the next few pages, and acoustic flow monitoring setups have been pretty reliable at volcanoes, though they certainly could be improved. The method proposed also requires site-specific parameter tuning (seismic velocity structure, station amplification factors etc.), so that's still a factor. Also, the use of the term "single station detections" is misleading. To my knowledge, none of the existing methods are single station systems. They depend on time-delayed detections on multiple stations along the channel, including the method currently in place at Illgraben.

A: As stated above, we will change the scope of our paper and revise/extend our description of existing early warning systems.

R: P3-L4-5: The phrasing of this sentence implies that moving the instruments away

from the torrent decreases the influence of site effects on ground motion, I don't see why this would necessarily change anything regarding site effects, the new site will also have site effects. Increasing the distance also adds another challenge, path effects through an unknown subsurface structure.

A: This part will be rephrased and likely change after our site effect analysis.

R: P5-L29: If the stations had sample rates of 125 to 200 Hz, as stated above, you would only be able to see up to the nyquist frequencies of 63 or 100 Hz, respectively: : :the spectrogram shown in Fig 4 is from a station that Table 1 says was sampled only at 125 Hz, so we should only be able to see up to 63 Hz yet the spectrogram goes up to 100 Hz. This is not informative about the upper limit of the frequencies observed; there could be and probably are higher frequencies present.

A: We will change the axis limits of this figure.

R: P6-L8: The two papers referenced are about bedload in river flow, NOT debris flows, though the processes described may be similar between them seismically. Regardless, this should be made clear in the text to justify.

A: Will be changed accordingly.

R: P6-L20-21: I'm not sure panel a is actually showing relative amplitudes as the text implies. I think it may be scaled to the maxes. The relative amplitudes don't look the same in panel b as where the red line is in panel a. For example, IGB09 looks lower in amplitude at the red line than IGB07 in panel a, but the opposite in panel b. Also, the Rhone Valley stations mentioned in the text don't have the highest amplitudes in panel a, other stations look just as high.

A: The referee is right: Panel A shows normalized amplitudes. We will make this clear in the caption.

R: P7-L12: Signal coherence depends on how close the stations are to each other and the frequencies of interest, if the stations were actually in an array configuration designed for the frequencies of interest here, the signals very well could have been coherent.

A: This statement was not intended to be general but was made considering the network configuration of our study. We will clarify this.

R: P7-L18: Kumagai et al. 2009 should be referenced here. They used similar methods for essentially the exact same purpose you did, just on a much larger scale. Others have used these methods for debris flows and other surface flows, see Walsh et al. 2016 and references within.

A: We will include these references.

R: P8-L10-11: Station corrections should not be neglected in my opinion, see main comments.

A: This will be analyzed with earthquake data (see above).

R: P8-L13-L25: Many critical details are missing here regarding why the authors made the choices they did, what those choices were (actual values), and how varying those choices affects the solution (see main comment above). More specifically, why did they decide to assume body waves? Body waves are not going to follow straight line paths, surface waves would (approximately). Some people argue that the strongest waves from surface flows are surface waves. Do the authors have evidence one way or the other here? Could using surface waves produce a similar result? Third, are they assuming P or S waves? Why? What velocity are they using? Why? Why did they choose 100 sec windows for amplitude average? What are the values of alpha and Q that they use that are “within the range expected for body waves near the surface of the earth”?

A: We had outsourced most of these descriptions to Burtin et al. (2013), but we can certainly include them here.

R: P9-L14-15: Since source strength is their best way to distinguish between noise and

debris flow signals, a time series of source strength solutions should be shown on the movie and fig 6 and 7 in a similar way to how the seismic data is shown so we know how to interpret the solution at each point in time.

A: Rather than producing a single parameter, such as source strength, to identify debris flow signals, our approach yields a set of discriminators: source strength, location and fit quality. We will make this clearer and also include a time series of source strength in the movie and figures as requested.

R: P9-L24-26: This statement lacks evidence. It could just as easily be because they aren’t correcting your station amplitudes and that may inflict more of a bias on locations further downstream than upstream. Either show evidence for the statement here or show that the amplitude corrections really don’t make a difference.

A: We expect the site effect analysis to clarify this point.

R: P10-L16: How do the authors exclude these stations to avoid affecting the decay fit?

A: The point of the noise analysis was in fact to show that station exclusion is not necessary. We will state this specifically.

R: P11-L16: It would be more convincing if the authors tried adding white noise comparable to what is sometimes seen, for example, during a storm, to the signals during the debris flow to see how it actually affects the decay fit scheme.

A: Our probability-based noise analysis was meant to show that noise events with PSD comparable to our debris flow event occur rarely or never. We are unaware of the fact that storms map into white noise on a seismic recording, but we will investigate white noise effects with numerical tests.

R: Figure 3: The geophone data looks processed in some way, are these envelopes of the amplitude data? Time averaged absolute values of amplitude? Why is the geophone signal flat before the arrival of the debris flow, is the instrument turned on by some sort of trigger? The label “geophone impulses” is vague in meaning. Please clarify these things either in the text (page 5) or in the caption, or both.

A: Will be clarified.

R: Fig 6 and 7: A0 for the fit at the initiation is lower than A0 for the noise window – this is confusing because the text implies that the A0 value was the main way they were able to differentiate between signal and noise (e.g., Fig 8)

A: We will clarify that A0 by itself is not robust for this very reason. As shown in Figure 8, location has to be taken into account, as well.

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