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Interactive comment on "Seismic monitoring of geomorphic processes" *by* A. Burtin et al.

Anonymous Referee #3

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General comments:

This manuscript offers a useful overview of a growing field that is much in need of a summary review. It is well written and should be valuable to anyone interested in exploring seismic monitoring approaches, especially of fluvial processes. However, the manuscript falls a little short of its ambitious potential as a truly comprehensive reference on the theory, background, and methods for seismic monitoring of geomorphic processes (as its title and subsection titles seem to promise). The discussion seems too general or qualitative in many places, and often lacks physical explanations or relevant details that could make discussions of fundamental concepts or methods more clear or practically applicable. In other places, discussion is too narrow and only applicable to specific cases, where a more generalized explanation would be more helpful. Where relevant technical details are included, while usually immensely useful and generally well-explained, they are often limited to one or two specific approaches,

sometimes drawn from a single or few example(s) of prior research, and sometimes with no examples cited. The coverage of fluvial processes also heavily overshadows the discussion of other types of geomorphic processes, which are not covered in nearly as much depth or detail.

Overall, I think the manuscript would benefit from the following:

1) Either expand the text significantly in scope (specific suggestions for doing this below), or change the title/subsections and redefine the manuscript's focus to an overview of a few selected studies' approaches to monitoring fluvial processes, perhaps with other processes discussed in brief where appropriate. Personally, I would much prefer the former, as I think such a comprehensive review would be a huge benefit to the community, as well as a landmark citation, but obviously this would require significantly more work.

2) I think more comprehensive citations in almost all sections of the manuscript are necessary, regardless of which approach is taken in (1).

3) As noted in later comments on section 3.2.1, I recommend either the addition of an introductory section briefly but comprehensively discussing the background/prior seismic monitoring work for each geomorphic process. Additionally, as your audience may include seismologists without geomorphic backgrounds, I'd suggest a simple overview of what each process is, its basic mechanics and relative role/importance in shaping landscapes, and the mechanism by which it generates seismic waves and specific distinguishing seismic characteristics (with mechanistic explanations for those characteristics).

4) Provide a thorough background with in-depth physical/mechanistic explanations for basic seismic wave characteristics and how they pertain to geomorphic processes... for example, Green's functions are not mentioned anywhere in the text (probably belongs in the background discussion of seismic wave generation and propagation, and also under methods), which seems like a significant oversight, as signal attenuation

is a significant issue in any geomorphic monitoring study. As mentioned above in (3), physical explanations for the frequency characteristics of different processes should be included. Other specific examples are included in the comments below.

5) In many sections (e.g., methods, detection and location of processes, etc.), the manuscript would benefit from the inclusion of a broader and more thorough range of specific approaches/techniques and examples where they have been used in research.

6) Some reorganization of the entire manuscript might be helpful. More systematic organization of the discussion of each process within each section would make the manuscript more navigable as a reference and might make it more clear to you where more information should be provided on a given process. The overall order of some of the sections is a little confusing as well; for example, array geometry seems like it might go better before detection and location, and might tie in more intuitively following the discussion of wave components excited in section 2.1. It might make sense to order the manuscript in the order a research might need to reference topics, for example: general seismic wave and geomorphic processes background, detailed background in seismic signals of specific geomorphic processes, set up and installation of arrays, seismic data pre-processing and spectral processing methods, event detection methods, event location methods, monitoring catchment dynamics. The authors can decide what makes the most sense, but I personally find the current organization a little unintuitive.

Specific comments:

2. Seismic signals and their monitoring

I think the titles for these sections are a little misleading, as the discussion focuses very heavily on fluvial bedload monitoring, without nearly as much detail on geomorphic processes such as landslides, debris flows, rock falls, etc.

2.1 Signal generation, propagation and recording

It would be helpful to reference the relationship between seismic wavelengths and their minimum scattering length scale for heterogeneities (pg. 1222, lines 13-15). This is especially relevant when considering, for example, the effects of source-receiver distance in fluvial monitoring, since alluvial river beds/banks are often composed of alluvium with characteristic grain sizes, in contrast to the more homogenous substrate of bedrock rivers.

Define “natural frequency” (pg. 1223, line 5).

I think the statement that the seismic signal will be larger on horizontal components since they reflect both Rayleigh and Love waves, while the vertical component only records Rayleigh waves (pg. 1223, lines 12-16) needs a bit more discussion and may not be fully justified… for instance, Tsai et al (2012) assumed Rayleigh waves would be the dominant wave type generated by fluvial bedload sediment impacts, since they assumed roughly vertical impacts, and therefore analyzed only the vertical component of their signal. Roth et al (2014) also observed the largest amplitudes in the vertical component of displacement for bedload sediment transport.

This section would benefit from some concrete examples of geomorphic processes and the types of waves they are expected to excite (with relevant citations). Also, a discussion of instrument distance from the intended source (e.g., river, debris flow channel, etc.) with respect to the resulting near- and far-field effects would be very helpful.

Why are Green’s functions never mentioned here? This seems highly relevant. I would recommend including an in depth background explanation of attenuation theory, as well as theoretical versus empirical Green’s functions, and challenges such as how the Green’s function is likely to vary in different geomorphic settings, local inhomogeneities, time evolution of substrates in dynamic environments, etc.

2.3 Ambient monitoring

The discussion of hysteresis in seismic signals of bedload sediment transport (page 10) is also supported by Roth et al (2014). It is also worth mentioning that hysteresis in the relationship between bedload sediment transport and water depth or discharge is a well established phenomenon in gravel bedded riversâĂŤthis is perhaps at least as relevant as the suspended sediment hysteresis you already mention. See, for example, Allen (1974), Nanson (1974), Walling (1977), Dunne and Leopold (1978), Ried et al (1985), Dietrich et al (1989), Milhaus and Klingeman (1992), Moog and Whiting (1998), and Humphries et al (2012).

A mechanistic explanation should be provided for the inverse relationship between impactor size and frequency (pg. 1226, lines 25-end). It may be useful to cite Hertzian impulse theory and the relationship between contact time and impactor mass (see, for example, McLaskey and Glaser, 2010).

3.1 Characterization of seismic signals: Methods

Discussion of other methods, or analysis methods once data is in spectral form, would also be helpful. For example, it might be worth mentioning here that several studies (e.g., Hsu et al, 2012; Roth, 2014) have found qualitative results (ie, detecting bedload transport) using only seismic amplitude data (hourly Hilbert envelope within a given bandwidth).

This also seems like an important place to discuss the Green's function, or other approaches to empirically dealing with attenuation. Tsai et al (2012) would be a good reference to cite here. Also, for geomorphologists who may be entirely unfamiliar with the processing of seismic data, things like instrument response removal may be worth a brief mention. The uninformed reader may otherwise get the impression that you can just taper and FFT raw seismic data from a seismometer.

3.2.1 Rockfalls, landslides and river channel processes

Pg. 1230, lines 25-26: Citing Huang et al (2007) here seems a little disingenuous,

as that study specifically referred to the signal generated by debris flows and rocks dropped on dry stream beds (not active fluvial transport of coarse bedload grains). Should cite Gimbert (2014) in the discussion of water signal spectra.

As this is your first detailed discussion of the range of different geomorphic processes that have been seismically monitored, each topic really warrants a much more comprehensive list of citations. I would suggest adding a section (or including in the introduction) with more general comprehensive background and citations for each process mentioned. For example, the following citations might be appropriate to include: debris flows (LaHusen, 2005; Suwa et al, 2003; Arattano, 1999; Marchi et al, 2002); landslides (Sutherland, 2002); bedload transport (Tsai et al, 2012; Gimbert et al, 2014). The bedload transport citations listed here are especially relevant in this section given your discussion of bedload and water frequencies. Only one paper is cited for rock avalanches. Snow avalanches (Vilajosana et al, 2007; Cole et al, 2009) might also be worth mentioning.

3.2.2 Tectonic and meteorological events and anthropogenic acticity

You might also want to mention the signal generated by ocean waves (Adams et al, 2002), which is important in coastal or near-coastal environments.

4.1 Detection

The final discussion of setting STA and LTA for debris flows or floods (pg. 1235, lines 18-22) could be expanded to provide more concrete details for different kinds of geomorphic processes. Also, giving specific numbers as examples (ie, 1-2 minutes for the STA and 30-90 minutes for the LTA) is unhelpful given the large variance possible in real-world floods, which can last from hours to multiple days. Stating example values normalized by or in terms of characteristic flood time scales (e.g., total flood duration or the time between base level excursion and flood peak, etc.) would be more generally useful.

Overall, this section is very helpful, but could use more citations (ie, specific examples of studies that have used this approach), and could be much more expansive in scope. If you're going to call the whole section "Detection and location of geomorphic processes," it would be nice to see a broader collection of detection methods/examples. What about unique frequency signatures? Even the hysteresis in bedload transport studies might be considered a detection method. . .

4.2.1 Discrete geomorphic events

pg. 1237, lines 19-21: Physical explanation for why polarization becomes highly variable for high frequencies.

The last point discussed here (pg. 1237, lines 22-26) on impulsative first arrivals, should be discussed in a little more depth, perhaps through a brief summary of the actual migration technique used in the cited study.

4.2.2 Continuous geomorphic events

pg. 1238, line 13: How do you locate the coherence?

5.3 Array geometry: local to regional 2-D array geometry

pg. 1243, lines 18-22: Shouldn't all of this depend on the frequency you're trying to capture? Giving aperture sizes with respect to the signal you're interested in monitoring, with physical explanations, might be more helpful than absolute values.

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Interactive comment on Earth Surf. Dynam. Discuss., 2, 1217, 2014.