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Earth Surface Dynamics Discussions

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

Anonymous Referee #2

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Overall Comments

The paper reviews the recent achievements in the field of seismology applied to geomorphic processes, and in particular to fluvial processes, debris flows and hill-slope processes such as rock falls and landslides. The authors provide in the introduction a qualitative discussion on the basics of seismic monitoring as well as on the relation between the seismic signal and an excitation applied on the Earth's surface. Then, the authors describe the techniques associated with the detection and processing of seismic signals, as well as detail suited designs of seismic arrays for geomorphologic purposes. Finally, a taste of using the seismic technique for geomorphologic purpose is given at the scale of a catchment in section 6, before perspectives are provided in the outlook section.

In the context of our growing use of seismic approaches to study Earth surface pro-

cesses, I strongly encourage such a review effort. However, I think that the paper here proposed does not fulfill the requirements of a review paper for two main reasons:

-First, the authors aim to provide a review paper on studying a variety of geomorphic processes from the use of seismology. While the review is somewhat complete regarding fluvial seismology and debris flows, I think that it is largely incomplete regarding rock falls and landslides, which are fields where numerous key advances are not mentioned (I think for example about the work of Mangeney, Larose, etc. . .).

-Second, even when considering this paper as being more a review paper on "Seismic monitoring of fluvial and debris flow processes" (which I think would in itself justify a review effort given the growing interest of the scientific community in that topic), I think the authors only partially succeed in providing to both seismologists and geomorphologists a comprehensive view on the main questions that they raise in their introduction, and that a non-specialist would hope to find answers to, which are: (1) how can the seismic signal be exploited in order to extract reliable information on the various geomorphic sources and what does it rely on regarding our knowledge in seismology, i.e. the effect of ground properties, heterogeneities, wave types, etc. . .?; and (2) what type of key physical quantities can be accessed from the seismic signal and could not (or at least less easily) be accessed using other measurement techniques?

For these two main reasons, I do not recommend this paper to be published in the present state unless the authors (1) refocus on the fluvial seismology and debris flow side of the work (which does not mean removing rock falls, landslide and earthquake examples, which are useful for pedagogic comparisons), and (2) provide major changes in the manuscript related to the criticisms listed below, which apply in view of a review paper being more focused on fluvial and debris flow seismology.

Major Comments

While I find that section 1 (introduction) nicely exposes the potential of seismology to study surface processes (and orients the reader to the two main questions listed

above), I am disappointed by the answers provided in the rest of the paper, which almost entirely focuses on the very technical side of the bibliography, while sometimes omitting to underline the physics involved as well as to highlight and replace in a broader context the main scientific achievements acquired in previous studies. More specifically, my main criticisms are threefold:

1-First, very little sense is provided to the reader on the role of seismic wave propagation (and subsequently ground properties) in affecting the seismic signal, and thus in modifying the source characteristics. I think that this point is a crucial point, since it is always the main source of worrying for people who do not know much about seismology, but are interested in the application. How good is our knowledge on ground properties, how well can we account for these effects when aiming to retrieve the source from the seismic signal? Green's function formulations exist in seismology, and I suggest that the authors clearly show these formulations and discuss more specifically the role of the different physical terms and our knowledge of them. In particular, an extensive discussion is provided in section 3.2. on the seismic signature of the various seismic events provided in Figure 5, but little is discussed on the effect of wave propagation. The authors should acknowledge that, while the signature of the source affects the seismic signal, a large part of this seismic signal is also affected by the propagation of surface waves into the ground, and thus by ground properties. As an example, the spectrum associated with rivers (and not necessary entirely bedload as suggested on Figure 5...) is much higher frequency than another river signal reported for example by Burtin et al. (2008), which would look more like the rockslide or car signals also shown on Figure 5. Why is that? Theoretical concepts must be provided to convince the reader that seismology provides solid grounds and methods to quantitatively analyze the signal, which goes beyond being able to qualitatively discuss the apparent relative variations of the signal in space, time and frequency.

2-Second, I think that significant theoretical progress realized recently in the field of fluvial seismology are not properly discussed and in an incomplete manner. In par-

ticular, the reader has to wait until the perspective (outlook) section to realize that modelling approaches have been done in the past to translate the seismic signal in terms of a bedload source (see line 5 of page 1248). Does it mean that from these modelling approaches we understand the quantitative relationship between the river spectral features discussed previously on Figure 5 in terms of source properties and their modulation by wave propagation? If yes, it would be worth mentioning earlier. To me, these modelling approaches are essential to identify the sources and have access to the physical properties to which geomorphologists are interested in. For these reasons, they are worthwhile dedicating a section to them, or at list a section that talks about the physics. As an example, the authors mention numerous times throughout the manuscript that larger grains or rocks impacting the ground generate lower frequencies: I think the reader would like to know what is the physical reason for that? The authors do the analogy with earthquakes (i.e. larger earthquakes generate lower frequencies), but the source mechanisms associated with grain impacts and earthquakes are different. Then what is the argument in both cases? Is it a similar argument? All this is not trivial and needs to be addressed. Also, while the authors discuss the possibility of water flow to generate seismic noise, they omit to acknowledge recent theoretical work on that topic (Gimbert et al., 2014), which provides a physically-based work that sometimes supports their statements, and sometimes contradict them. It would be necessary to have a discussion about this, the physics that we understand, and the physics that we do not.

3-Finally, I think that too many technical details are provided on the instrumentation (example: seismometer versus geophone versus velocimeter... not sure there is fundamental differences between those, if yes it is not made clear) as well as on signal processing (Welch's versus other techniques, spectral whitening for cross correlation techniques, etc...). While these details may be helpful for people who start doing seismic monitoring of geomorphic processes, I think that they are rather of "practical" order, but are not necessarily helpful scientifically as compared to providing a more physical sense on seismic wave propagation and source mechanics (cf my previous comments

1 and 2).

Technical Comments

Line 25, p 1219: “fast displacement” : large velocity (or kinetic energy)?

Line 19 to 21, p 1221: “forces . . . determine the frequency content of the seismic signal. . .”: only partly, wave propagation also does. Also, why larger rocks generate lower frequencies? What is the reason for earthquakes? Is it similar?

Line 23 p 1221 to line 4 p 1222: I would show here a generic formulation of the green’s function, and explain the different terms, and what role they play in attenuation, initial amplitude, etc. . .

Line 19 p1222 to l 9 p1223: I find this discussion confusing, and at the end I do not understand the difference between seismometers, velocimeters and geophones.

Line 4-5 p 1225: geophone plate sensors are more maintenance free than seismometers deployed on the ground? I would be surprised by this, since the instrument is basically the same, and one is exposed to floods within the channel (water, strong vibrations, etc. . .) while the other is in a quiet place, often in a hole drilled into the ground (little temperature variation, little exposure to storms, rains, etc. . .).

Line 13-14 p 1225: I don’t think a broader spatial coverage is the only advantage of ambient monitoring. Ambient monitoring allows investigating fluvial mechanics in natural conditions!

Line 16 to 24 of page 1226: some of the statements provided here have then been supported (or contested) by Gimbert et al., 2014. This should be mentioned.

Line 25 p1226 to Line 2 p 1227: Again, why does the signal depend on grain sizes? Do any of these cited studies explain why?

Line 11 p 1227: “To understand what is recorded. . ., a source characterization needs to be performed”: I think that the characterization of seismic signals is a first step to

understand the record, but then conducting source physics is the essential next step, which the authors should talk about.

Line 22 p 1227: The authors could refer here to figure 3a.

Line 14 to 17, p 1229: I don’t see a high frequency signal on the rockslide example. Low frequency?

Line 4 to 6 p 1230: Not clear. Again, a Green’s function expression would simplify the explanations.

Line 24 to 26, p 1230: again, why is coarser bedload causing lower frequencies? If not know, then this should be discussed.

Line 4 to 7, p1231: Missing references and discussion for the flowing water.

Line 20 to 23, p1231: Seismic attenuation also occurs for the other sources, but was not discussed.

Line 20 to end of p 1238: I think here should be acknowledged that this processing type is done in any noise correlation technique analyses.

Page 1248: I think the discussion about modelling approaches should not be made here, but much earlier in the manuscript since these modelling approaches help providing a better understanding to the reader.

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