Natural Hazards
and Earth System
Sciences

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Discussions

Interactive comment on "Infrasound array criteria for automatic detection and front velocity estimation of snow avalanches: towards a real-time early-warning system" *by* E. Marchetti et al.

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General comments

The aim of the paper is to present an infrasound avalanche detection system using specific criteria based on the obtained characteristics of infrasound signals of previous avalanches. The area of installation is specific. Data are compared with those obtained with a Doppler radar installed at the same area. The conclusions and results are interesting. In general, the paper is valid, and the subject is suitable for publication in

NHESS. However, major revision is needed. The paper must be reorganised and the aims clarified indicating on the one hand the geographical situation of the set up of the instrumentation, the instrumentation itself and the data processing, and on the other hand the results: Avalanche characteristic inferred and the detection system, and the discussion and conclusions. Moreover, a major revision of the English is necessary. More detailed comments below

Abstract

The authors state that they present a new method. They mention that the method is based on array derived parameters and threshold criteria, considering avalanche as a moving source of infrasound. The authors must emphasize the novelty of their approach in the text. If this is not new, eliminate the word new in the abstract. Instead of dynamic parameters indicate that velocity and back azimuth are derived. The authors have to mention that events additional to those detected by the Doppler radar were obtained from their infrasound array measurements. Since this could be due to the different avalanche characteristics, perhaps a new conclusion could be incorporated. In this case, indicate it in the abstract. Add that the criteria are area depending. Introduction The introduction is correct; however, some changes must be made.

L. 43 The authors mention e.g. the paper of Gubbler and Hiller, (1984) to illustrate detection systems of avalanches. I suggest that the authors should mention the paper Rammer et al. (2007) Cold Reg. Sci. Technol. 50, 35–54. and Vriend, et al. (2013). Geophys. Res. Lett. 40, 727–731. For the purpose of illustration, the radars mentioned in these papers are more appropriate than the FCMW radar mentioned in the paper of Gubbler and Hiller, (1984).

L. 59 The authors mention that the seismic observations provide the exact time of occurrence and that seismic arrays allow us to obtain an accurate location of the avalanche. I would be more prudent and eliminate the words "exact" and "accurate". Seismic observations provide the time of occurrence, but not the exact time of occur-

rence and provide the location, but not accurately (if you use accurate, you must specify the accuracy).The literature leads you to this conclusion.

L. 90 It is necessary to add "Kogelnig et al., (2011)" here. In this paper, a clear power spectrum of avalanche infrasound signal is presented, which will help the reader.

L.92 The authors state that the infrasound generated by the events mentioned have a similar wave form or that they can also be masked by different background noise. Note that the different events can be discriminated owing to the characteristics of their spectrograms. The authors must be more cautious in describing characteristics. Adding some references will help the reader (examples of different infrasound signals are shown e.g. in figs. 13 and 14 in Kogelnig et al, 2011).

L. 93 Specify the results obtained.

L.94 Note that more than one avalanche occurred in the area (eg. in December). An avalanche is a natural process. Although in the literature the area of study is termed Grosstal avalanche (e.g. Kogelnig et al., 2012), I would be more precise and would mention the events as avalanches and the geographic situation of the area by its name (e.g. Grosstal avalanche area, or Grosstal avalanche zone).

L.98 In this sentence, the authors qualify the parameters as kinetic, in other parts of the manuscript they are dynamic. As they are referring to angles and velocities, the term kinematic parameters must be used because no forces are involved.

Section 2

L. 101 It is not clear whether the aim of the authors is to describe one specific avalanche, the avalanches that occurred on the 23 December, or the area where the avalanches occurred, - If the purpose is to describe avalanche data, then indicate observations in the title: Grosstal Avalanche observations - If the purpose is to describe a geographical area, then the title would be The Grosstal Avalanche area.

In addition to this, I suggest reorganizing this section 2, describing the Grosstal area

with all the instrumentation installed (2.1 and 2.2). I presume that the authors are interested in presenting the large avalanche on 23 December to illustrate the behaviour of the instrumentation or the type of data obtained. In this case, the presentation of the data could be done after introducing the instrumentation. The authors have to indicate the type of avalanches that occurred in the area or the avalanches studied. Even though the interest of the authors is to present their avalanche detection system, it is necessary to include a paragraph indicating the type and size of the avalanches that occurred or that normally occur in the study area. This is an important piece of information to evaluate the detection system. For example, in figure 9 the 3 infrasound signals presented are different in shape, indicating a different type of process. There is no reference to this in all the manuscript.

L. 107 Please, indicate the characteristics of the 23 Dec avalanche.

L. 113 Add "Doppler radar". As different types of radar are used to study snow avalanches today, it is necessary to mention the type of radar in the title of this section.

L. 129 Replace "depends on" by "corresponds to".

L. 130 Note that there is only one event. Perhaps the authors confuse detections with avalanches. In this case, clarify the situation.

L.124 and 132 Add "Doppler".

L.135 In this section, you are describing information on the Grosstal avalanche area. To avoid misunderstanding, omit the word "Isggl" from the title. You can keep it in the text.

L. 143 Add " including the Grosstal avalanche path".

I would include after L.170 the paragraphs from L. 233 to 245. These sentences correspond to data processing. The authors can also include some of the previous comments (L. 224-232) if they wish.

From L. 171 The information of this paragraph does not correspond to data processing. It corresponds to a description of the results. I suggest incorporating this part into Section 3. If the authors need to include the signals in this section, a reorganisation is needed. In L.191 there is also information directly connected to this.

L. 172 Replace "many" by "different" or "various".

L.174 Indicate ° N in all the angles. e.g. 309° N to 330°N.

L. 175 Note that it is " values" not value.

L. 177 ...between..... add "and the array location". L. 178-180 Please, explain the difference between how you obtain 440 m/s and 460 m/s. Are all these values obtained from the array results? Please clarify. L. 183. Is the word "peculiar" the correct word?

Section 3 This section must be rewritten considering the points below.

As mentioned above, dynamic parameters are not inferred, only kinematic ones are. When studying avalanche dynamics (or kinematics) the knowledge of the size and type of the avalanche is necessary. The data presented in the paper show interesting information that the authors do not consider. Phase 2 has a spindle shape that differs from the one of phase 1 (Fig.3). To understand better the information obtained from the infrasound signal, a description of the type of the avalanche is necessary. The three sections (phases) are very different, not only in their back-azimuth and speed but also in their amplitude. I would include all the results devoted to the 23 December avalanche (radar and array infrasound) and would also compare the results in this section.

L. 191 I suggest adding here the whole paragraph beginning in L.171.

L. 193 Add "showing an energetic wave packet". The peak of pressure amplitude is important but so is its length and shape.

L.198 Phase 3 presents apparent values of the sound propagation velocity of 330 m/s. The authors assumed 333 m/s for the sound speed (L.179). They also obtained an

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avalanche front speed of the 330 m/s from the infrasound array. A comment on the resolution of the system and its implications would be interesting.

L. 200 Please, explain the difference in the back azimuths and velocities obtained when considering an extended moving source or a punctual moving source.

L. 202 Please, explain this statement or indicate references to help the reader.

L. 205-207 Please, explain this sentence a little more. First of all, the mentioned paper is devoted to pyroclastic density currents. The similitude between the two types of density currents must be explained or clarified with references. In addition, a shape and azimuth similar to those of phase 2 of avalanche 2012/12/23 (Fig. 3) are also observed in avalanche 2013/03/11 (Fig. 8 c). However, this part is observed before the energetic part. An explanation of this characteristic must be given.

L.207 In addition to mentioning the third phase, the same type of shape 2 (in Fig 3) is also observed in Kogelnig et al, (2011). A detailed explanation of all these observations is necessary. This phase corresponds to the latter part of the infrasound signal for a specific type of avalanche. Other parts of your signals are also similar to signals presented in the mentioned paper (Kogelnig et al., 2011).

L. 213. The most probable situation is that the array detects all the energy of the existing sources, but the low energy would be masked by the high energy. As a result, the detections would correspond to the most energetic sources. Please, clarify both the sentence and the paragraph.

L. 216 Please, indicate that this sentence is an explanation of the gap between the end of phase 2 and the beginning of phase 3 in Fig. 3. In addition, note that different amplitudes are observed. This perhaps is not an important point in your detection system. In such a case, if your system is independent of the type and size of the avalanches, this independence could also be a merit of your detection system: independent of the type and size of the avalanches and could also form part of the conclusions.

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L.222 Add "front".

L. 231 Explain more this sentence a little to highlight your contribution by comparing it to the usual method of detection (presented in the previous chapter).

L. 238-239 The subindex "a4" is not necessary. Change the name for the sake of simplicity.

L. 246-252 Replace "mutual" by "relative". Rewrite the entire paragraph. What does non-hogeneous azimuthal resolution of the path mean? Try to write short sentences.

L. 261 velocity peaks? Do you mean velocity increases?

L. 263 In Fig. 5 a gap in the velocity (1:20) is observed but not in the angle. An explanation of this is necessary. Please, indicate the units of time in the figures.

L. 268 Indicate units of distance.

L. 272-277 Please, specify the good match to which you are referring. Why do you mention these papers in this context? More detailed explanation concerning this conclusion is needed.

Section 4 L.281-282 This sentence is not necessary. It does not correspond to this section.

L. 286 Add "2013". Here the information on the filtering characteristics is not necessary. In any case, include it in the section of data processing.

L. 289 Replace "recorded for" by "associated with" .

L. 289 Which is the relation between the back-azimuth and the propagation velocity to include a "while" in the sentence? Divide this into two sentences.

L.293 Is there no contradiction between this information and that of L.90? Please, clarify.

L.306 Compare the number of detections indicated here and that of L.323 and L.286.

L.317 An explanation is needed concerning the different shapes of the avalanches, especially that of the avalanche on 2012/12/10 and the others. An explanation is also needed for the differences in the amplitude of the infrasound signals of the 2012/12/23 avalanche and that of the avalanche on 2013/03/11. In theory the 3 avalanches descended down the same couloir.

L.319. Since the only difference of the threshold criteria in this case is that the range of the back-azimuth 310°N -320°N is not considered, highlight this and eliminate the other criteria.

L. 328 Replace "which is in agreement" by "which corresponds to".

L. 330- 332 Rewrite the paragraph with short sentences.

L.336 and 337 Indicate area, zone, path. . .. These are not events, you are referring to areas.

Section 5. Discussion and conclusions.

Some changes are necessary.

L. 346 add references and specify the type of radars.

L.348 Replace "mutual" by "relative".

The authors in this section must mention the different benefits or differences from the array measurements of infrasound and seismic signals. They mention seismic signals in the introduction. It is clear that there is no way of comparing these data in the Grosstal area but a comment on this is opportune. You also have to mention the contribution of Thüring et al., (2015) on infrasound detection.

L. 355-371 Indicate here or in previous sections the difference in the back azimuths and velocities obtained when considering an extended moving source or a punctual moving source. Please, mention that you are determining only the front velocity. Moreover, draw some conclusions in relation to the type of avalanches that the instruments used

can detect. This enhances the value of the infrasound use.

L.371-381. I would include this in the abstract.

In addition, add in this section some comments on the criteria mentioned in the title.

Comments on figures and figure captions.

L.493. Eliminate "in background" put "The profile is represented by the black dashed line".

L.494. "No data" is not equivalent of "decay of velocity". Rephrase.

Figure 3. Indicate the units of time. (s?)

L. 499 Is there one avalanche or more than one?

Figure 5 Indicate the units of time. (s?)

Figure 6 Indicate the source of the data from the radar.

Figure 8 Indicate the units of time. (s?)

Is this the infrasonic signature of the array or is this an infrasound time series of one sensor?