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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "Formation time and mean movement velocities of the 7 August Zhouqu debris flows extracted from broadband seismic records" *by* Z. Li et al.

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Firstly, we apologize for the language problems and secondly we are grateful to this comment. With the help of this comment, we realize that this manuscript has lots of problems that make the publication impossible. Still, we want to reply to some of the problems proposed in it.

Reply to problem "1)" in page C384:

About this section, we want to explain three things. The first one is that the seismic signals recorded by seismometers and analyzed in the manuscript are indeed generated

by the debris flow instead of the background noise based on the following reasons. The first reason is that the length of the debris flow channel is about 5 km and the seismic station is only about 150 m away from the exit (figure 1 in the manuscript). In addition, the debris flow destroyed the power system of the seismic station, proving that the debris flow is very close to the seismic station (All of the information above was provided in the manuscript). If this seismic station cannot record the seismic signals generated by the debris flow, nothing can (we forgot to mention in the manuscript that after the debris flow, the earthquake engineers checked the seismometer and found it works well). The second reason is that the figure 2 in the manuscript gives a very long section of background signals. The amplitude distinction can be easily recognized. The second thing we want to explain is that the noise level has been taken into consideration in STA/LTA calculation. The method has been specified in the manuscript, maybe not clearly. "First, the mean absolute values of background signals are calculated for each component. (p 681, line 13)". The third thing we want to explain is that we agree that the calculation of STA/LTA and threshold used in calculation are arbitrary and if some factors change, such as the noise level or the station location, the results could be different. In fact, we realized this problem. This is why we put the description in the manuscript that" It is almost impossible to determine when a debris flow starts developing" and "However, a rough start time can be revealed under a given criterion". We calculated the STA/LTA only want to prove that the N-S component can detect the debris flow earlier than other components, because the debris flow was mainly in the north-south direction.

Reply to problem "2)" in page C384:

We want to explain that "time-by-time normalized spectrogram" was not created by us. It is just the ordinary spectrogram, only normalizing each time component to 0 - 1. We did the normalization because the amplitude of the seismic signals is unbalance, too large in the later and too small in the front. By doing that, we wanted to get the pure energy distribution in the frequency domain. Figure S1 gives the spectrograms of U-D component before and after the normalization. Take two time points as an example. In the ordinary spectrogram, it seems that these two time points have quite different main frequency band, the second one is much wider than the first one. But the fact is that the difference is not that big.

We still say that the frequency content from before and after the start time is distinct. The normalization highlights the frequency content with large amplitude. Before the start time, the amplitude of the low frequent content is larger compared with that of the high frequency content because the seismic signals in that section contain mainly the background signals. After the start time, the amplitude of the high frequency content became larger, which means that a new set of seismic signal with higher frequency content, most probably generated by the debris flow, joined in the signal. And the frequency content indeed changed.

Reply to problem “3)” in page C385:

We first would like to explain how Figure 4 in the manuscript was obtained. Firstly, we applied the Hilbert Transform to the seismic signals to get the envelopes; and subsequently, the envelopes were linearly best-fitted to get their average increasing velocities using a moving time window of 1 minute. Basically, color lines in figure 4 are the mean increasing velocities of the amplitude of the seismic signals. However, as mentioned previously, the amplitude is unbalance over time. To equally show peaks and troughs in the entire time range, the results were multiplied by a scale function that amplify the front part and diminish the later part.

Our explanations in the manuscript based on a simple assumption that the variation patterns of the amplitude of the seismic signals can represent that of the kinematic energy of the debris flow. Kinematic energy of moving materials is determined by two factors, the moving velocity and the mass. The peaks in the figure 4 could correspond to the kinematic energy fast increasing stages of the debris flow that might be result from the increase of the mass or the moving velocity. Then we presented an argument

that if the kinematic energy increase was caused by the mass increase, the amplitude increase patterns of three components should be similar; otherwise, the amplitude of seismic signals recorded in the debris flow moving direction increases much faster than other directions (suppose a debris flow accelerates in N-S direction, the amplitude of N-S component signals increases faster than other components). Based on the assumptions above, the 3rd stage was recognized using the variation patterns of the horizontal components. In the first part of the 3rd stage (KT2-KT3), the amplitude of the N-S component increases much faster than that of the E-W component, implying that the debris flow accelerated in the N-S direction; in the second part of the 3rd stage (KT3-KT4), the amplitude of the E-W component increased fast, implying that the debris flow accelerated in the E-W direction. This variation pattern consist with the shape of the valley section depicted using an orange line in figure 5. This could be evidence. Besides, according to the previous work (Tang et al., 2011), lots of loose materials was entrained by the debris flow when it went through the colluvial deposit area (see figure 5 in the manuscript), and the kinematic energy of the debris flow significantly increased. There must be some representations on the amplitude of the seismic signals. Combined with that the amplitude increase patterns of three components between KT1 and KT2 are similar and the previous explanation that seismic signals between KT2 and KT3 are mostly likely generated when the debris flow went through the valley section depicted using the orange line in figure 5, we concluded that the seismic signals between KT1 and KT2 were generated when the debris flow went through the colluvial deposit area, depicted using a yellow line in figure 5. Of course there could be other explanations, but we didn’t find enough evidences. We think our explanations are the most rational. And subsequently, we estimated the mean movement velocities when the debris flow went through these two valley sections.

Reply to problem “4)” in page C385:

The main frequency band of the seismic signals has two kinds of variation characteristics with time. The first one is purely moving to the high frequency direction and the second one is widening while moving. The main frequency band widened 0, 22.64 and 61.22% for U-D, E-W and N-S components respectively. We agree that the purely moving is because the debris flow material is getting closer to the seismic stations, and we claim that the main frequency band widening is because of the Doppler Effect.

Doppler Effect is probably detectable by the seismic signals. It is true that the seismic wave speed is much higher than the movement velocity, but not that high. According to the result of an artificial experiment, the seismic wave speed in the earth surface covered by loose deposit materials is approximately between 100 and 350 m/s (Arattano, 1999). The movement velocity of the debris flow is approximately 10 m/s (Tang et al., 2011), about 3 – 10 % of the seismic wave speed. Under Doppler Effect, the relationship between the apparent frequency and the actual frequency is f_app = f_real (v_seis + v_move) / v_seis, where f_app is the apparent frequency recorded by the seismometers, f_real is the actual frequency of the seismic signal, v_seis is the seismic wave speed, and v_move is the movement velocity of the debris flow. The f_app / f_real should be approximately 1.03 – 1.1 in this case. If there were no purely upward moving, this result could be similar to the widening rate. However, the purely upward moving makes the results more complicated.

References

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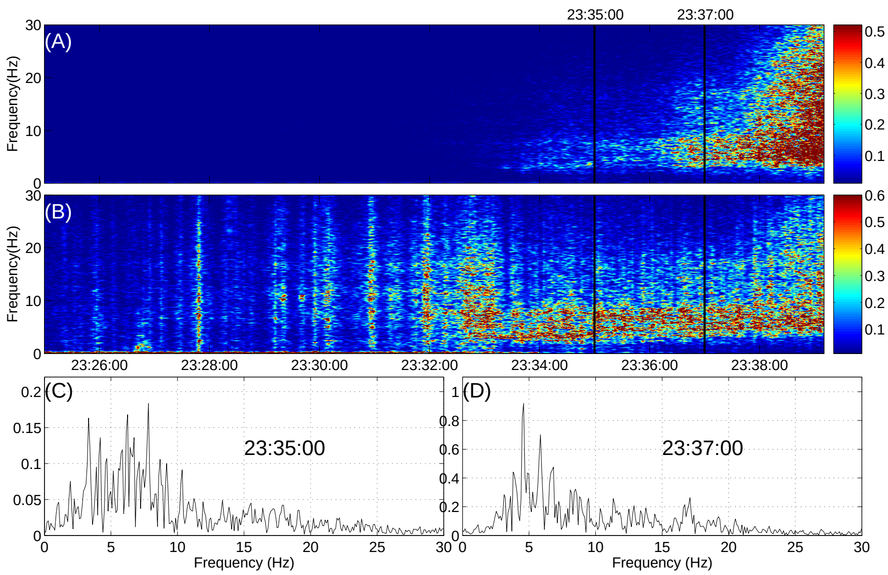

Fig. 1. Figure S1. (A) The ordinary spectrogram; (B) the time-by-time normalized spectrogram; (C) the amplitude spectrum in the time of 23:35:00; (D) the amplitude spectrum in the time of 23:37:00.