On the Apparent Duration of Low-Frequency Earthquakes

Chao Song¹,¹ and Allan Rubin¹,¹

¹Princeton University

January 20, 2023

Abstract

The broadband stacks (templates) of velocity seismograms of nearly co-located low-frequency earthquakes (LFEs) detected using a 1-8 Hz passband beneath southern Vancouver Island tend to exhibit a simple dipolar shape with a characteristic duration of ˜0.3-0.5 s, which is also found to be nearly independent of the seismic moment. An important question left unanswered is whether the duration is due to the nature of the source, is set by attenuation near the source region, or is just a bias introduced by the narrow passband used to detect LFEs. In tremor catalogs detected using a relatively low-frequency passband, 0.5-1.25 Hz, we have found some tremor windows that contain relatively isolated dipole arrivals similar to LFEs. A few of these have a duration apparently longer than that of the LFE templates. Notably, the same location on the fault also seems capable of generating signals with a shorter duration at other times. Figure 1 shows seismograms, at 3 stations, of one such example in the vicinity of LFE family 001 of Bostock et al. (2012), in which the main arrival has a duration of ˜1 s, whereas another signal 3 s earlier with a duration of only ˜0.4 s comes from roughly the same location (same move-out between the stations). This significant variability in duration at approximately the same location suggests that the long-duration events owe their duration to source processes and not attenuation, provided that attenuation does not vary on extremely short time and space scales during the episodic tremor and slip episode. The relative isolation in time also makes the longer duration less likely to result from the temporal clustering of multiple typical LFEs. We will undertake a more systematic search of our longer- and shorter-period tremor catalogs to assess this possibility. Addressing this question will shed more light on the factors that control the apparent duration of LFEs. Figure 1 The top panel shows the long-duration tremor signal in a relatively lower-frequency band, 0.5-1.25 Hz, whereas the second panel from the top is the same 32-s segment in a higher-frequency band, 1.25-6.5 Hz. The third panel shows the trace in a broader passband, 0.5-6.5 Hz. The bottom panel shows the stacked LFE templates of the same family filtered through 0.5-6.5 Hz.
exp. 1. find long-duration events

fig. 1 two examples of tremor signals that are isolated in time and longer in duration than the LFE templates used to obtain the shear-wave splitting correction and particle motion direction which are then used to process data to imagine the area around the templates better. note that for the example on the right that has a duration of ~1 s, another signal ~3 s earlier coming from roughly the same location only has a duration of ~0.4 s. However, the number of this kind of long-duration signal is small, on the order of ten throughout our catalog.

Fig. 2 (a) Velocity seismograms of the LFE templates for LFE family 002. There seems to be a characteristic duration of ~0.5 s. (b) Spectral density of the main dipole (solid) and noise (dashed) approximated by the same-length segments before and after the dipole. A characteristic corner frequency of ~4 Hz is clear.

Summary

- Any variability in duration of LFE-like signals from the same location may provide insight on whether it is set by the source process or attenuation, but we found very few long-duration LFEs with a high signal-to-noise ratio.
- That the reproducible band-like feature with a non-zero slope is only seen at station SILB, but not at other stations, does not support the hypothesis of a temporal reduction in LFE duration caused by a shear-wave velocity increase in the VL beneath the source.
- That the band-like structure at these stations is seen only when tremor is active around LFE family 002, but not at other times at the same stations (not shown here), suggests that it is not due to near-site effects.
- Unfortunately, the 2 experiments cannot determine what factors control the apparent duration of LFEs, but the model in Fig. 2c is still an appealing explanation for the near-constant duration of LFEs even without a time-dependence.