Constructing an empirical envelope function of seismic waveforms for the evaluation of EEW in Japan

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Earthquake early warning (EEW) system analyzes the data from seismic networks and predicts the seismic intensity (SI) at locations where the strong ground motion has not arrived. In Japan, there are two working EEW systems: integrated particle filter (IPF) and propagation of local undamped motion (PLUM). IPF predicts the SI through seismic source inversion, which is different from PLUM that directly predicts the SI by using waveform propagation theory on real-time seismic waveform data. As a result, IPF is generally faster but less accurate than PLUM. Regarding the hazard assessment, Japan Meteorological Agency (JMA) will select the largest SI between the two systems and broadcasts a single warning to the public. Here we propose a new method that can evaluate the performance of the two systems in real-time. The effectiveness of our method will be tested on K-net and KiK-net in Future.

Data and Method

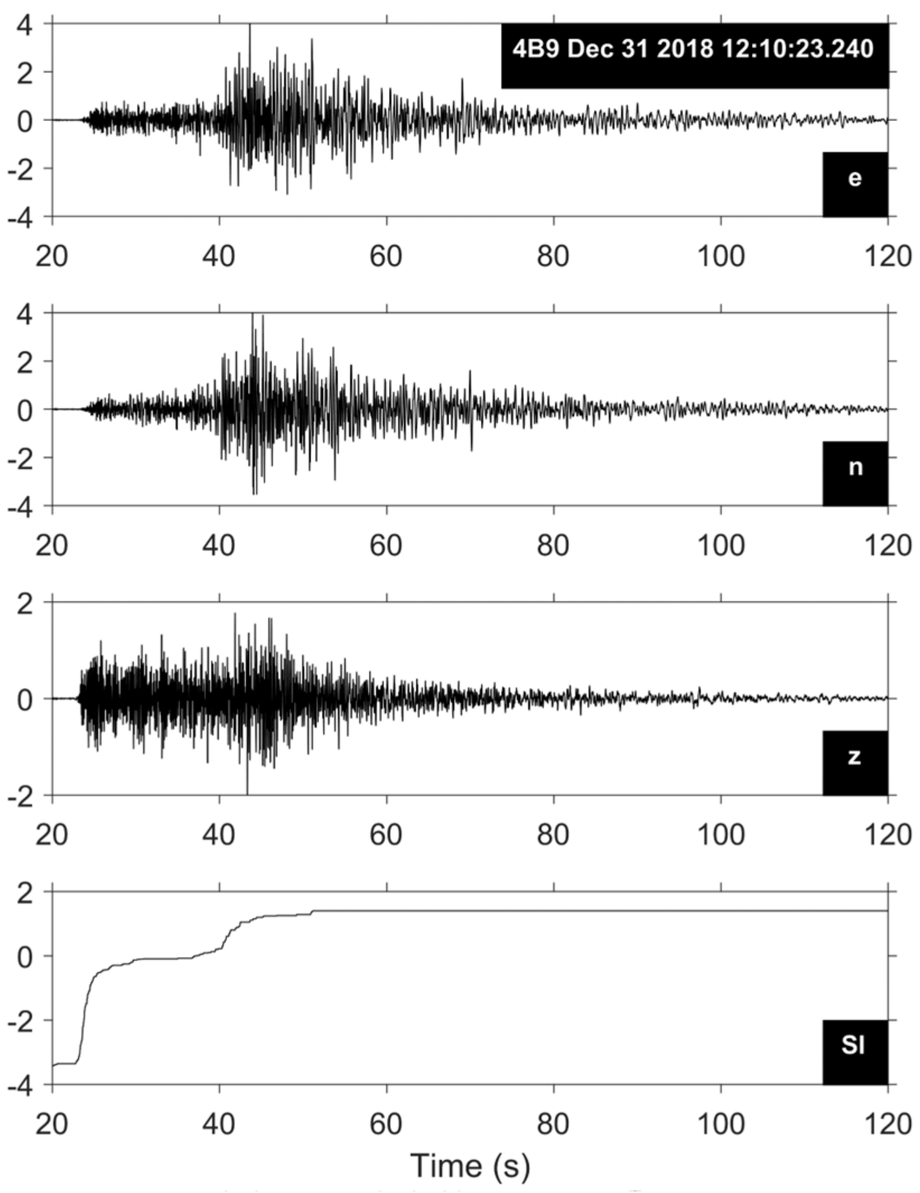

Fig. 1 The waveforms and seismic intensity (SI) of an event on December 31, 2018.

For more than 73,000 waveform recordings from Hi-net, we have manually selected 53,000 good waveform recordings to calculate the seismic intensity (SI) by using the following equation:

$$\mathrm{SI} = 2\log(\sqrt{A_e^2 + A_n^2 + A_z^2}) + 0.94$$

where A_e, A_n and A_e are the amplitude of east, north and vertical components of an event, as shown in Fig. 1.

Then we use the double sigmoid function (envelope function) to fit the SI curves, with a format:

$$f(x) = \frac{a_1}{1+e^{-\frac{x-b_1}{c_1}}} + \frac{a_2}{1+e^{-\frac{x-b_2}{c_2}}} + d$$

where a_1, b_1, c_1, a_2, b_2, c_2, and d are parameters.

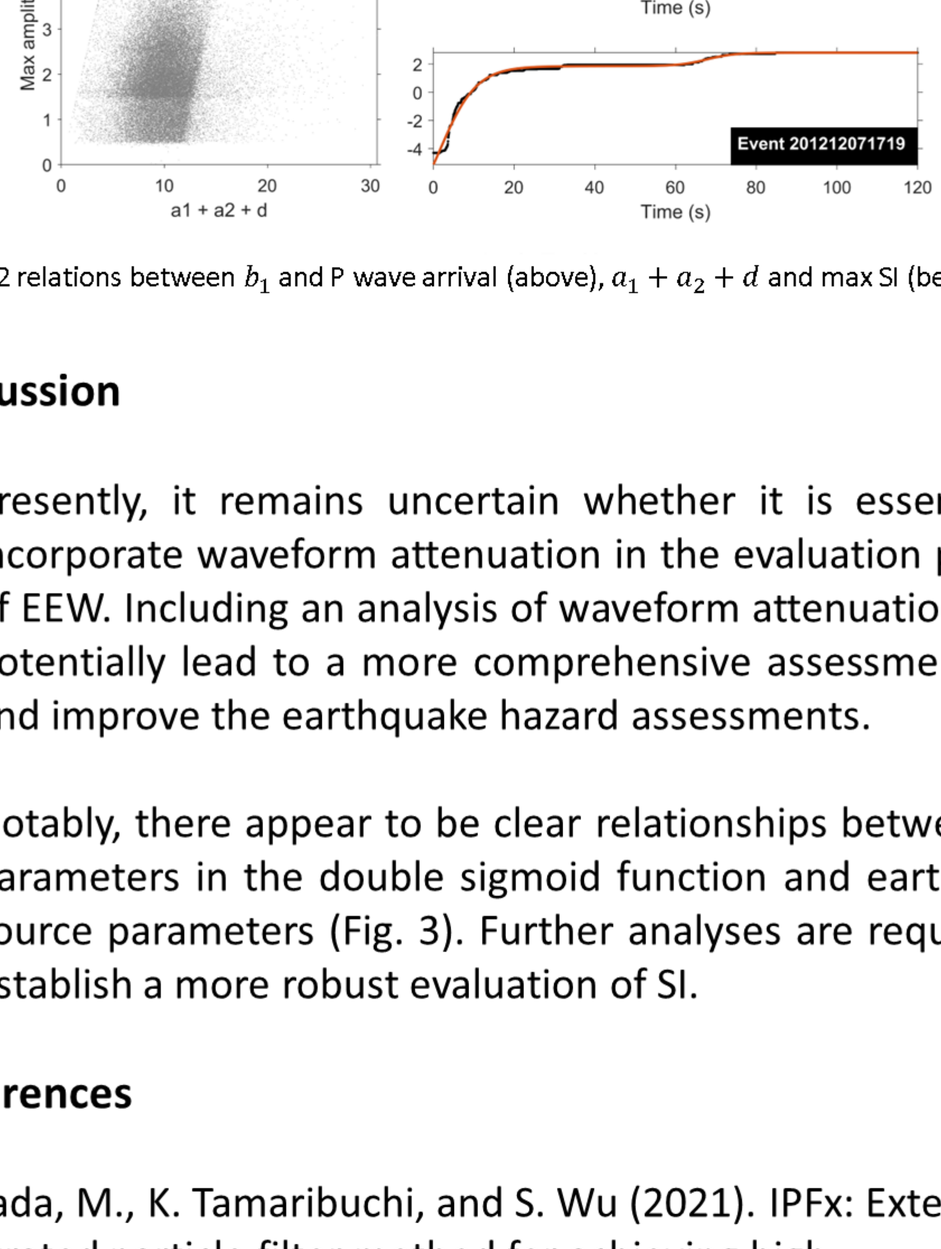

Fig. 2 relations between b_1 and P wave arrival (above), $a_1 + a_2 + d$ and max SI (below).

Discussion

1. Presently, it remains uncertain whether it is essential to incorporate waveform attenuation in the evaluation process of EEW. Including an analysis of waveform attenuation could potentially lead to a more comprehensive assessment of SI and improve the earthquake hazard assessments.

2. Notably, there appear to be clear relationships between the parameters in the double sigmoid function and earthquake source parameters (Fig. 3). Further analyses are required to establish a more robust evaluation of SI.

References

Yamada, M., K. Tamaribuchi, and S. Wu (2021). IPFx: Extended integrated particle filter method for achieving high-performance earthquake early warning system. Bulletin of the Seismological Society of America, 111(3), pp.1263-1272, https://doi.org/10.1785/0120210008