A Method of Real-Time Tsunami Detection

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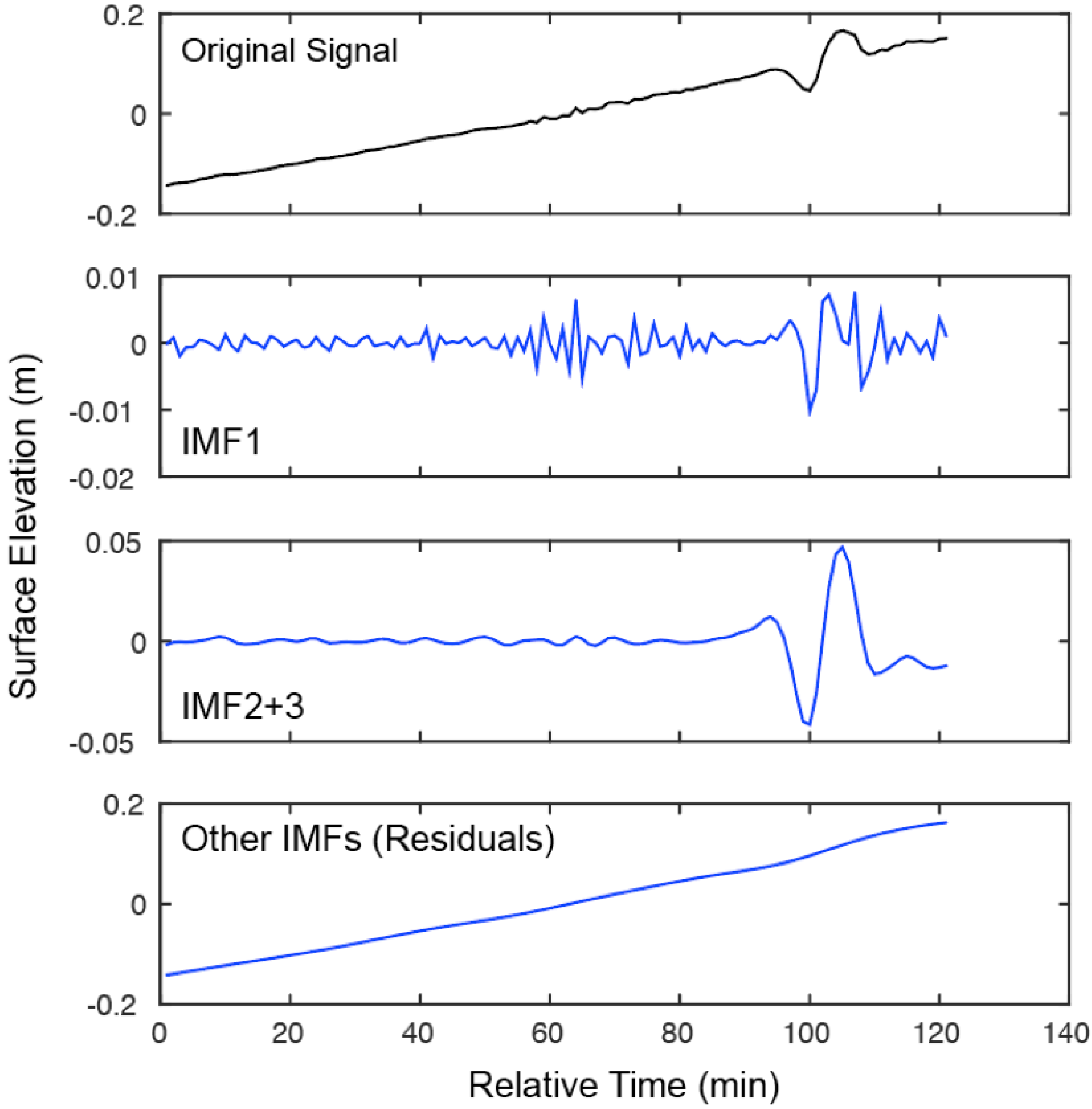
Real-time tsunami detection plays a key role in tsunami early warning system. The best way to confirm the tsunami arrival is to use the ocean bottom pressure gauges (OBPGs) (Sanderson, 2008). A reliable tsunami detection algorithm for OBPGs should be able to identify the tsunami signals and characterize the tsunami amplitude accurately, at a small computational cost. Traditional methods, like the DART algorithm adopted by the National Oceanic and Atmospheric Administration (NOAA), or the Algorithm based on artificial neural network (Beltrami, 2008), have to rely on the prediction of the tides and other lower frequency signals. These algorithms can detect a tsunami by subtracting predicted pressures from the observation, but they cannot properly identify its waveform. And they are unable to capture the feature of the background sea noise.

In our research, we propose a method of real-time tsunami detection based on Ensemble Empirical Mode Decomposition (EEMD). EEMD decomposes the time series into a set of intrinsic mode functions (IMFs) (Huang et al., 1998; Wu, 2005). Unlike Fast Fourier Transform or wavelet analysis, it does not need a priori basis. Instead, it adaptively determines the natural oscillatory modes embedded in the original signal. Therefore, it is applicable to nonlinear, non-stationary data like tsunami signals. In our practice, we use the series of the OBPG record of the past three hours, and then we conduct EEMD and obtain the IMFs. The tsunami signals can be separated from the tide signals, seismic signals, as well as background noise. By comparing the value with the threshold, we could decide whether the tsunami has arrived or not.

We apply our method to the tsunami record of OBPGs of the 2016 Fukushima earthquake (M7.4; Gusman et al., 2017). Five OBPGs owned and operated by the Earthquake Research Institute recorded the tsunami generated by the earthquake. We retroactively conduct EEMD to the data. Our method separates the high-frequency components and extracts tsunami signals automatically, without the need of predicting the tides. The tsunami arrival is easily determined by comparing with a threshold. In addition, the tsunami waveforms are also characterized in the IMFs, without the need of filtering. Because our method uses an ensemble with the help of white noise, it becomes robust to background noise.


Original Signal
IMF1
IMF2+3
Other IMFs (Residuals)
Surface Elevation (m)
Relative Time (min)
0.2
0
-0.2
0.01
-0.01
-0.02
0.05
-0.05
0 20 40 60 80 100 120 140