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Timeliness of earthquake magnitude estimation from the prompt elasto-gravity signal using Deep Learning

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Mass redistribution during large earthquakes produces a prompt elasto-gravity signal (PEGS) that travels at the speed of light and can be observed on seismograms before the arrival of P-waves. PEGS carries information about earthquake magnitude and the temporal evolution of seismic moment, therefore it could be used to both improve the accuracy of current early source estimation systems and speed-up early warning. However, PEGS has been detected for only a handful of very large earthquakes so far, and its potential use for operational early warning remains to be established. In this work, we study the timeliness of magnitude estimation for subduction earthquakes in Japan using PEGS waveforms by means of Deep Learning and Bayesian uncertainty analysis. Given the paucity of PEGS observations, we train the model on a database of synthetic seismograms augmented with empirical noise in order to simulate more realistic waveforms. We use about 80 stations from the Japanese F-Net network and from networks with data available through IRIS.

Under this experimental setup, we find that our model is able to track the moment release for earthquakes with a final Mw above 8.0, with a system latency that depends on the signal-to-noise ratio of PEGS. The application of our model to the Mw=9.1 Tohoku-Oki earthquake shows a latency of about 50 s after which the model is able to track well the evolving Mw of the earthquake. After about 2 minutes from the earthquake origin time, a reliable estimate of its final Mw is obtained. Similar performances in terms of timeliness of final Mw estimation are observed for the relatively smaller Hokkaido earthquake (Mw=8.1) although with higher uncertainty.

Our results highlight the potential of PEGS to enhance the performance of existing tsunami early warning systems where estimating the magnitude of very large earthquakes within few minutes is vital.