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地震検知の不完全性を考慮に入れた統計モデルの推定
Estimating statistical models of seismicity under incomplete detection of earthquakes

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After a large earthquake, a vast number of aftershocks follow. The clustering property of earthquakes is commonly modeled by the Omori-Utsu formula of aftershock decay or Epidemic type aftershock sequence (ETAS) model. Usually, these statistical models have been directly fitted to the observed data above cut-off magnitudes enduring complete detection. On the other hand, it is well known that early aftershocks are substantially missed from seismic records because of overlaps of seismic waves caused by the main shock and congested aftershocks. In other words, earthquakes catalogues are highly incomplete during the early stages immediately after large earthquakes. Previous studies have applied the models to the datasets either avoiding the early part of the observed period of aftershock activity or taking a higher cut-off magnitude throughout whole period, so that such incompleteness of the data can be mitigated by an adjusted c-value of the Omori-Utsu formula or the ETAS. Nevertheless, such direct analysis of the catalogues may still produce some biased estimate. Also, we need to apply the ETAS model for a long period where the detection rates of earthquakes vary in time due to the development or reduction of seismic networks in and near focal seismogenic region.

Here we present a method for fitting the statistical models by considering the incompleteness of the catalogues. To do this, we developed a method to estimate non-stationary detection rate, based on the state-space model. This model can capture even irregular oscillation of the time-variation of the detection rate (Fig. 1). Then this model is combined with the Omori-Utsu formula of aftershock decay or the ETAS model.

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Figure 1:Time-dependence of the magnitude of 50% detection rate (red line) for the observed afterhocks (closed circle) by PDE/NEIC, which occurred within one day from the 2011 Tohoku-Oki earthquake of M9.0 The estimate shows oscillating behaviour. The steep rise is accompanied with large aftershocks.