Relation of decay time constants between postseismic deformation and aftershocks of the 2011 Tohoku-Oki earthquake

*Mikio Tobita[1]

1.Geospatial Information Authority of Japan

Since the 2011 off the Pacific coast of Tohoku Earthquake (Tohoku-Oki earthquake), crustal deformation and aftershocks have continued to occur in eastern Japan. This paper discusses the comparison of their relaxation time constants.

1. Introduction

Tobita(2014, 2015, 2016) proposed combined logarithmic (log) and exponential (exp) function model for fitting postseismic GNSS time series after 2011 Tohoku-Oki earthquake. They are log+exp (Model-1), log+log+exp (Model-2) and log+exp+exp (Model-3). The Model-2 has the best performance for the short-term prediction of the evolution of postseismic deformation. The equation that represents the Model-2 is

$D(t) = a\ln(1+t/b) + c + d\ln(1+t/e) - f\exp(-t/g) + Vt$,

where $D(t)$ denotes a displacement component (east, north, or up), t is the time in days relative to the occurrence of the main shock (11 March 2011), b, e and g denote the timescale parameters of the logarithmic or exponential decays (relaxation times), and V is the steady velocity.

We believe that comparison of relaxation time parameters between cumulative number of aftershocks and the postseismic deformation may contribute to discriminate the subsurface postseismic deformation mechanisms.

As the first step, we began to study function fitting of aftershocks by Omori's formula, Modified Omori's formula and ETAS model, then attempt to adopt single exp and single log functions.

2. Methods and Results

The bold curve in Fig. 1 represents the cumulative number of aftershocks larger than M5 in the rectangle shown in the map in Fig. 1.

(1) A single exponential function cannot fit the curve at all.

(2) Fitting performance by a single logarithmic function is not satisfactory.

(3) We found that a logarithmic function with background seismicity fits the cumulative aftershocks curve very well.

(4) The first log term in the equation with relaxation time constants b=0.03 days (preliminary estimate) with the background seismicity (μ in Fig. 1) was fitted to the curve of the cumulative number of aftershocks.

(5) The second log term in the equation with relaxation time constants e=49.6 days (preliminary estimate) with the background seismicity was fitted to the curve.

(6) The third exp term in the equation with relaxation time constants g=4610 days (preliminary estimate) with the background seismicity was fitted to the curve.

The results of the three fittings (4)-(6) are shown in Fig. 1. While, the second term (log) with mid-term relaxation time (5) and the third term (exp) with long-term relaxation time (6) do not fit the curve at all, the first term (log) with short-term relaxation time (4) fit the curve quite well.

3. Discussion

We found that the relaxation time constants of the cumulative number of aftershocks are very similar to that of the first term (log) with short-term relaxation time of postseismic deformation time-series. Tobita (2016) suggests that the short-term log function may represent postseismic displacements due to mainly the afterslip, while the mid-tem log and long-term exp functions may represent postseismic displacements due to mainly the viscoelastic relaxation. Our finding is consistent with the suggestion.

Good fits of the cumulative aftershocks curve by a single log function (with background seismicity) means validity of the Omori’s law in the Tohoku-Oki earthquake, because the time integral of the Omori’s formula is a logarithmic function.

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