Characteristics on Postseismic Deformation following the 2003 Tokachi-oki Earthquake and Estimation of the Viscoelastic Structure in Hokkaido, Northern Japan

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1. Introduction
The 2003 Tokachi-oki earthquake is an interplate earthquake along the Kurile trench and is followed by postseismic deformation. Postseismic deformation is mainly caused by afterslip and viscoelastic relaxation. Previous studies estimated the afterslip in the 1st year but didn't consider viscoelastic relaxation. The viscoelastic structure has never estimated in the region. Estimation of spatiotemporal afterslip distribution is a key to reveal the healing process of the fault strength, however, estimated afterslip can include a systematic error if viscoelastic relaxation is ignored. In this study, we evaluate the both effect in postseismic deformation during the 2nd-7th year and estimate parameters of viscoelastic structure.
2. Data analysis
We use the data observed at 81 stations of the GEONET in Hokkaido and don’t use stations in southwest Hokkaido because the signals of postseismic deformation of the 1993 Hokkaido-Nansei-oki earthquake and volcanic activity of Mt. Usu were observed. First, we eliminate linear component and significant displacement due to several earthquakes, such as the 2004 Kushiro-oki, the 2006 Central Kurile, and the 2007, 2008, 2009 Tokachi-oki earthquakes. We estimate the horizontal and vertical velocity by piecewise linear approximation every year and every 2 years, respectively, with considering annual and semi-annual variations.
3. Modeling and Estimation
Displacement $U(x,t)$ at the station x and the time t due to afterslip is modeled by the following equation (1),
$U(x,t)=Au(x)\ln(1+t/B)$ (1)
where $u(x)$ is the calculated displacement at x from the afterslip model for the first 4 months, which we estimate with the inversion method of Nishimura [2009]. We assume that spatial distribution of afterslip doesn’t change temporally. Because $u(x)$ is calculated from the 4-month model, A and B is constrained by the following equation (2) and B is estimated.
$A\ln(1+1/3B)=1$ (2)
We model viscoelastic relaxation due to the 2003 Tokachi-oki and the 2004 Kushiro-oki earthquakes. We use the Fortran code PSGRN/PSCMP [Wang et al., 2006] to calculate. We use the coseismic model of GSI [2003] and Nishimura [2009], respectively, and assume the 2 layers model, which consists of an elastic layer with thickness H overlying a viscoelastic half-space with viscosity η.
We estimate B, H, $\eta$and translation components of the whole network by grid search.
4. Results and Discussion
The estimated values of B, H and $\eta$are 0.115 year, 50 km and 2.0×10^{19} Pa s, respectively. The estimated viscoelastic structure is consistent with that in the Tohoku region, northern Japan (e.g. Diao et al., 2014).
Our model explains the horizontal velocity roughly but systematic misfits are distributed locally in all the periods, which is due to afterslip of the 2004 Kushiro-oki, the 2008 and 2009 Tokachi-oki earthquakes. Our model explains the uplift in the Pacific coastal region qualitatively but not quantitatively and large systematic misfits are broadly distributed mainly in the Tokachi Plain area. These misfits suggest that the 4-month distribution of afterslip changes and that

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afterslip velocity is faster than that calculated from the logarithmic model in the down-dip side of the coseismic source area.
Our study suggests that afterslip plays the dominant role at most stations in the 2nd year and is still sustained near the coseismic source area in the 7th year, and that viscoelastic relaxation is large enough to be detected in the northern area in the 7th year. Deformation due to viscoelastic relaxation of the 2004 Kushiro-oki earthquakes is much smaller than that of the 2003 Tokachi-oki earthquake.
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Keywords: The 2003 Tokachi-oki earthquake, Viscoelastic relaxation, Afterslip, Postseismic deformation, GNSS

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