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Crustal deformation in Hokkaido after the 2003 Tokachi-oki earthquake using GNSS data

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The Tokachi-oki earthquake (M_w = 8.0) occurred on the plate interface along the Kurile trench on 26 September 2003. Large interplate earthquakes like this are generally accompanied by the postseismic deformation. Postseismic deformation of this earthquake is well observed by GNSS. It is proposed that afterslip and viscoelastic relaxation are dominant mechanisms for the postseismic deformation. Afterslip is aseismic slip that occurs in and around the slip area of the mainshock. It lasts for several days to several years. Viscoelastic relaxation is the crustal deformation caused by flow of viscoelastic material due to the change of stress distribution. It lasts for several years to several decades and its effect is more widely distributed than that of afterslip [e.g. Scholz, 2002]. The effect of viscoelastic relaxation should be eliminated from the observed data when we infer the interplate coupling, especially its healing process after the mainshock, so an estimation of that is important. Theoretically, we can use a difference of relaxation times between two mechanisms to eliminate it, but we don't know when it actually starts to play a dominant role in postseismic crustal deformation.

Several previous studies, such as Miyazaki et al. (2003), Ozawa et al. (2004), and Baba et al. (2006) inverted the observed displacement data and inferred the afterslip distribution of this earthquake. Tanaka (2007) showed that the effect of viscoelastic relaxation is detectable in the observed data by a forward calculation. However, all of them use the data observed for only 2 years after the event, so we analyze the crustal deformation data for 7 years after the event observed by GNSS at the GEONET stations and investigate the effect of both afterslip and viscoelastic relaxation. We, here, describe the feature of the observed deformation after the Tokachi-oki earthquake.

Before the calculation of the deformation velocity after the event, we eliminate linear trends and the significant coseismic displacement of 3 earthquakes occurred near Hokkaido on 15 November 2006, 11 September 2008 and 5 June 2009 [Kimura & Miyahara, 2013]. We estimate the velocity by piecewise linear approximation. The horizontal velocity is estimated every year. The vertical velocity is estimated every year for first 3 years after the earthquake and every 2 years for the remaining period.

The observed data in the Tokachi, the Kushiro and the Nemuro regions were affected by double Kushiro-oki earthquakes on 29 November and 6 December 2004 (M = 7.1, 6.9, respectively). The postseismic deformation of these earthquakes lasted for 2 years in the eastern Tokachi, the Kushiro and the Nemuro regions near the hypocenter. In the western Tokachi region, the postseismic deformation lasted for 1 year. From 3 years after the Tokachi-oki earthquake, vertical velocity in the Tokachi and Kushiro regions was larger than that of in the stations near Cape Erimo, so we propose that the effect of viscoelastic relaxation was increasing there relatively and/or afterslip area moved to northeast.

In the Douou region, that is northwestern region of hypocenter, from 4 years after the mainshock, spatial decay of horizontal velocity is notably smaller than that in the northern and northeastern regions.

From examining the data analysis, we concluded that viscoelastic deformation started to play a dominant role in postseismic deformation after 3 years following the mainshock. We assumed a 2-layers structure model consisting of an elastic layer overlying a viscoelastic half-space and estimated the thickness of the first layer and the viscosity of the half-space by grid search. As a preliminary result, we obtained 60 km and 8.0×10^{18} Pa s for the elastic thickness and the half-space viscosity, respectively. The viscoelastic model almost explains the deformation in the northwest and southeast region of Asahikawa.

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Keywords: postseismic crustal deformation, viscoelastic relaxation, 2003 Tokachi-oki earthquake, GNSS