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Fractional velocity changes in Japan Islands related to the 2011 Tohoku-Oki Earthquake

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Using the Passive Image Interferometry (PII) method we investigated the temporal changes of the fractional velocity, dv/v, before and after the 2011 M9.0 Tohoku-Oki earthquake. Recently an increasing number of studies have documented abrupt dv/v changes after large earthquakes, swarms, and volcanic activities. We therefore considered that a huge earthquake, like the 2011 Tohoku event, could produce temporal changes of dv/v that can be found all over Japan. Our purpose is detecting the dv/v temporal change during the earthquake and investigating the relationship between such changes and other geophysical observations, in order to clarify the underlying physical mechanisms.

We applied the PII method to vertical-component continuous waveforms recorded during 2010 and 2011 by the Hi-net system (100 Hz sampling, with a natural frequency of 1 Hz). We divided the continuous record into segments of one hour length, removed the mean and trend and applied 1-3 Hz band-pass filtering and one-bit normalization. Auto-Correlation Functions (ACFs) were calculated for the one-hour segments and stacked for time intervals of one week to obtain good stability. We employed the mean ACFs in 2010 as a reference ACF to calculate phase shifts for daily ACFs. Since the fractional velocity, dv/v, can be estimated by using the phase shift between the reference ACF and the daily ACFs, we could monitor the dv/v before and after the 2011 Tohoku earthquake. We quantified the temporal changes of dv/v by calculating the difference between the mean dv/v for the month before and the one after the Tohoku earthquake, using a bootstrap resampling method. To investigate the cause of the temporal changes, we compare them with the volumetric strain, calculated using source models of the huge earthquake, or Peak Ground Acceleration (PGA), recorded by KiK-net, whose seismometer is installed at the same borehole of Hi-net.

From the comparison of the time periods before and after the Tohoku earthquake, we have obtained a velocity decrease in the Tohoku, Kanto and eastern Chubu regions, as well as in the western part of the Hokkaido district. In contrast, a velocity increase was obtained in eastern Hokkaido, western Chubu, Kinki and Chugoku district, although it was slightly weak. Comparing these dv/v changes with the volumetric strain, calculated using source models of the large earthquake, we have found that the dv/v clearly decreases more than 10-6 in strain. The dv/v also changes in the area where moderate and large PGAs (more than 10 gal) were observed.

Our results suggest that the strain changes in the crust, caused by the huge earthquake, correlate with the dv/v temporal variations. Especially the relationship between the dv/v decrease and the positive volumetric strain appears to be clear. This result was also obtained during the eastern Izu Peninsula swarms. For the area of the dv/v increase, the volumetric strain was less than 10-7 and shows an unstable pattern of compression/extension: compression in the eastern Hokkaido and extension in the west of Chubu district. Furthermore, it is complicated to infer the dv/v increase from PGA data of large earthquakes.

Keywords: seismic interferometry, The 2011 Tohoku-Oki Earthquake, temporal changes