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Ground tilt changes in Japan caused by the 2010 Maule, Chile, earthquake tsunami

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The 2010 Maule, Chile, earthquake generated a tsunami in the Pacific Ocean, and the tsunami reached Japan approximately 24 hours after the earthquake. Ground deformations caused by the tsunami loading were observed in a broad area along Pacific Ocean coastline of Japan by high-sensitivity accelerometers (tiltmeters) installed at Hi-net stations operated by National Research Institute for Earth Science and Disaster Prevention [Kimura et al., 2010]. Some previous studies had already reported that ground deformations were observed at a few seismic and/or geodetic stations caused by several massive tsunamis such as the 1960 Chile tsunami [Ozawa, 1961; Tanaka and Tanaka, 1961] and the 2004 Indian Ocean tsunami [Yuan et al., 2005; Nawa et al., 2007]. However, the 2010 Maule earthquake tsunami is the first case where tsunami-loading effects are detected by a high-density wide area observation network such as Hi-net. In this study, using the ground tilt data observed at Hi-net stations in Japan, we investigate characteristics of ground tilt changes due to the tsunami loading and the availability of these data.

We analyzed ground tilt data in a frequency band of 0.1-1.0 mHz observed at ~570 Hi-net stations and obtained the following results. 1) The directions of ground tilt changes are generally perpendicular to the coastline near each station. 2) Maximum amplitudes of ground tilt changes are ~5 x 10^{-2} micro radian at the distances of several hundred meters to the coastline. The amplitudes decay with the distance and reached ~5 x 10^{-3} micro radian at the distance of ~50 km to the coast. 3) The amplitude decay curve against the distance to the coast has a corner. At the distance of one km or smaller, the amplitudes decay very little, and at larger distances, they decrease inversely with the distance. 4) The rate of amplitude decay against the distance depends on the frequency of tilt changes. In the high frequency band, the amplitudes decay more sharply than those in the low frequencies.

We simulated the propagation of the 2010 Maule earthquake tsunami and the ground tilt changes caused by this tsunami loading, and successfully reproduced above characteristics of the ground tilt changes. This indicates that observed tilt changes must be caused by the ocean loading due to the Maule tsunami.

The observed ground tilt changes induced by the tsunami contain information on the tsunami behavior near the coast. For example, the corner in the amplitude decay curve against the distance to the coast strongly depends on the width of the area where large sea-level variations occur near the coast. Therefore, the ground tilt data observed by the inland network will be important to understand the spatiotemporal evolution of tsunami near the coast.