論文の内容の要旨

論文題目：Seismo-geodesy to infer the physical process of the 2011 Tohoku earthquake

(地震測地学から見る 2011 年東北地方太平洋沖地震の物理過程)

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This thesis revealed the physical processes of sequential seismic phenomena, which are the preceding slip deficit and slow slip event, coseismic slip, and following afterslip of the 2011 M_w 9.0 Tohoku earthquake, inferred by the analyses mainly using continuous Global Positioning System (GPS) data. Our analyses showed various features of these seismic phenomena and their relationships. We also constructed a physical model based on the relationships and scales of these phenomena. Our approach presents a new seismo-geodetical comprehension of the 2011 Tohoku earthquake.

The 2011 Tohoku earthquake occurred at 14:46 on 11 March, 2011 (JST = UT + 9 hours) in one of the most active subduction zones in the world, the Japan Trench subduction zone. This disastrous earthquake generated the great tsunami that attacked the Pacific coast of east Japan and caused about twenty thousand of fatalities and missing people. Previously, the possibility of a disastrous *M*9 earthquake in this subduction zone had not been considered. However, prior to this earthquake, the accumulated slip deficit (drag of the overriding plate due to interplate coupling) had been observed. Meanwhile, following this earthquake, the large afterslip has been occurring. These slip deficit and afterslip phenomena provide clues to understanding the condition of the plate boundary where the 2011 Tohoku earthquake occurred. Therefore, we inferred all the pre-, co-, and post-seismic

processes by means of source inversions mainly using the GPS data.

We first inferred the coseismic source process of the 2011 Tohoku earthquake using not only the geodetic but also seismic wave and tsunami datasets. We also assessed the resolving power of each dataset and confirmed the influences of various inversion parameters. Additionally, the influence from the 3-D complicated velocity structure was demonstrated. We then carried out a joint inversion to construct the unified source model that was the most suitable for explaining all of these geophysical datasets. The seismic moment of the obtained model was calculated to be 4.2×10^{22} Nm, which yielded $M_w = 9.0$. This unified source model revealed not only the main rupture around the hypocenter but also a distinct extension of the shallow slip to the Japan Trench, which provided a cause of the disastrous tsunami.

Secondly, we inferred a temporal and spatial evolution of afterslip following the 2011 Tohoku earthquake using the GPS data. Our analyses indicated that the early afterslip was observed after 14:54 on 11 March (JST) and initiated in the western deep area of the hypocenter. This afterslip area extended simultaneously with the occurrence of aftershocks. The seismic moment of the afterslip during eight months was calculated to be 7.3×10^{21} Nm, which yielded $M_w = 8.5$.

Thirdly, preceding slip deficit rate distributions in this subduction zone was obtained by means of source inversion of the GPS data, from which the coseismic and postseismic signals of minor earthquakes were already removed, during the entire period from 1996 to 2010. The obtained distributions show the weakening and migration of slip deficit rates in late 2002. This weakening and migration could have been caused by a very-long-term SSE lasting eight and a half years after 2003, whose seismic moment was calculated to be 2.8×10^{20} Nm, which yielded $M_w = 7.6$. This very-long-term SSE had different features than past SSEs. The slip deficit rate distributions after the weakening and migration coincided with the coseismic slip distribution. This coincidence demonstrated that the very-long-term SSE could have triggered the 2011 Tohoku earthquake and this earthquake might have been able to be foreseen with respect to its location and extent.

By comparing these inversion results, we found the positional relationships of the seismic phenomena. We then constructed a possible physical model based on these relationships using a rate- and state-dependent friction law. The constructed model explained the depths and scales of the seismic phenomena including the preceding very-long-term SSE. In this physical model, when a large slip deficit accumulates sufficiently in the Japan Trench subduction zone, a very-long-term SSE triggers a megathrust earthquake.