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Interpretations of water pressure response during the 2011 Tohoku earthquake

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Water pressure change have been recorded during the 2011 Tohoku earthquake (Mw9.0) by two ocean-bottom pressure gauges of the JAMSTEC cabled observatory off Hokkaido, and they have been interpreted in terms of the tsunami numerical simulation. The acquired data have demonstrated that two kinds of water waves involved in the tsunami generation process from the 2011 Tohoku earthquake; that is, one is water waves preceding the tsunami having relatively short period to the tsunami and the other is long period wave well known as tsunami. Their features are summarized in order as,

1. As for the tsunami, it was detected 20 min after the main shock by the water pressure gauges located approximately 400 km north from the earthquake epicenter. The first arrival tsunami had a maximum height of 0.6 m and its period of about 40 min. There is no significant difference except for the arrival time among two ocean-bottom pressure gauges. The tsunami had a gentle rise followed by a solitary wave with a height of about 3 m and duration of about 5min in the other similar ocean-bottom pressure gauges deployed near the tsunami source (e.g., Maeda et al., 2011), whereas such a solitary wave was not recorded by the JAMSTEC ocean-bottom pressure gauges. This feature might be attributed to the tectonic mechanism. Difference of the tsunami features between two observatories are attributed not only to the source distance but also the directivity of the tsunami energy, because the JAMSTEC cabled observatory was located parallel to the seismic fault strike direction.

2. The water waves preceding the tsunami were detected in an early stage of the water pressure change. Comparing water pressure together with the data of the ocean-bottom seismometers nearby, it has been revealed that this is associated with the forced oscillation response of water layer by ground motion acceleration, i.e. hydro-dynamic response. This kind of waves was seemingly attributed to a moderate-to-large ocean-bottom displacement associated with the Rayleigh waves, because of some features similar to the seismic ocean-bottom displacement induced by the Rayleigh waves such as the directivity, an elliptical particle orbit, and a rather long predominant period. In addition, the preceding waves were also observed at several DART buoy stations deployed in the Pacific Ocean. The pressure perturbations lasted much long and had amplitude more than ten times larger than that associated with the tsunami, i.e. hydro-static response.

Although some unsolved problems, e.g., on the continuous perturbations of water pressure or on the discrepancies of the tsunami arrival time still remain, these two kinds of water waves could be reproduced by author's dynamic 3D tsunami numerical simulation based on the seismic faulting process. Thus, the above-mentioned two kinds of water waves must be generated in the 2011 Tohoku earthquake.