Operational use of tsunami source inversion in near-field tsunami warning by JMA

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In Japan, Japan Meteorological Agency (JMA) has responsibility for operational tsunami forecast and warning. When a tsunamigenic earthquake occurs around Japan, JMA issues tsunami warning within three min after the earthquake using seismic-wave data, and then the warning is often updated based on tsunami measurements. For the rapid and reliable update, offshore tsunami data take an important role, because tsunamis can be detected at offshore stations earlier than at coastal sites, and the data provide direct information about the impending tsunamis. After the 2011 off the Pacific coast of Tohoku Earthquake (Mw 9.0) (hereafter, 2011 Tohoku earthquake), dense seafloor observation network were deployed by NIED (S-net system) and JAMSTEC (DONET system). These systems equips ocean-bottom pressure gauge (OBPG) that enable us to greatly enhance our ability of real-time tsunami monitoring. Actually, these data are already used in JMA's tsunami-warning operation since 2016. On 26 March, 2019, JMA started operation of a new tsunami-forecasting method in which offshore tsunami data are used more effectively, in order to realize more reliable update of near-field tsunami warnings. In this paper, we present the tsunami forecasting method and its forecasting performance.

In our tsunami-forecasting method (tFISH: Tsushima et al., 2009, JGR), offshore tsunami-waveform data are used to estimate spatial distribution of initial sea-surface displacement in tsunami source area. Then linear combination of the estimated source and the precomputed tsunami-waveforms from sea-surface elements (i.e. Green's functions) are calculated to forecast tsunami waveforms at coastal sites of interest. Actual OBPG data contain pressure variations not only due to tsunami, but also due to other natural phenomena such as permanent seafloor deformation (coseismic offset) and seismic waves (short-period pressure fluctuation). To reduce effect of these non-tsunami components we applied revision of tsunami Green's functions (Tsushima et al., 2012, JGR) and real-time noise reduction such as recursive digital filter (Saito 1978). The retrospective application to the 2003 Tokachi-oki earthquake (Mw 8.3) and the 2011 Tohoku earthquake (Mw 9.0) (e.g. Tsushima et al., 2011, EPS) showed its good tsunami-forecasting ability.

The forecasting accuracy by tFISH depends on station coverage (Tsushima et al., 2009, JGR). Since the present offshore tsunami network, especially S-net, is distributed widely, densely and homogeneously, tFISH expected works well. In the actual pressure records, however, coseismic offset and long-wave-period variations that cannot be interpreted as seafloor deformations and tsunamis are sometimes measured (Wallace et al., 2016, JGR; Kubota et al. 2020, GRL). For example, when the 2016 off Fukushima earthquake (Mw 6.9) occurred, coseismic step appeared in the records of the OBPGs around source area, but the step amount is too large to be explained as coseismic seafloor deformation (Kubota et al., 2020, this meeting). The application of tFISH to these data showed significant tsunami-source artifact, resulting in degrading accuracy of tsunami forecast (overestimation of coastal tsunami height). The source artifact can be decreased substantially by applying the revised tFISH inversion that is proposed by Tsushima and Yamamoto (2017, SSJ Meeting). In the observation equation of the revised inversion, we put assumption that observed waveform at OBPGs can be represented by not only tsunami and seafloor deformation, but also coseismic step function and liner trend function. The reason why we chose these functions is that actual waveforms of non-tsunami signal resembles these

functions: i.e. we do not have physical image. We applied the revised method to the S-net OBPG data of the 2016 Fukushima earthquake and succeeded in improving source model and coastal tsunami forecasts.

Keywords: Tsunami, Real-time forecast, Tsunami warning