Abstract

This report comprehensively describes the characteristics of decay processes of far-field tsunamis observed along the Pacific coast of Japan and proposes an empirical method for forecasting them.

In Chapter 1, the decay processes of 21 far-field tsunamis as well as that of the 2011 Tohoku tsunami are described by using tsunami data observed at 33 tide gauge stations on the Pacific coast of Japan. By converting temporal changes of tsunami amplitudes into moving root mean square (MRMS) amplitudes, the decay process is revealed to consist of an early part, in which the amplitude first increases and then rapidly diminishes, and a later part, during which the amplitude shows slow exponential decay. The exponential decay time evaluated by analyzing all tsunami events together is 50 hours, consistent with past study results. The transition from the early to the later part of the decay process occurs at about 15 hours after the tsunami arrival time, based on when differences are no longer evident among groups of events in the decay pattern of the early part of the decay process, or at about 18 hours, based on when deviation from the exponential decay pattern of the later part is observed. Tsunami events are classified into five groups by their behavior during the early part. Tsunami amplitude during the later part of the decay process quantitatively correlates with seismic magnitude.

In Chapter 2, it is examined whether the dependence of the decay time on the tsunami wave period, which has been pointed out by past studies, influences the present analysis of the decay process. For three tsunami events with different seismic magnitude, 2009 Samoa (M_W 8.1), 2010 Chile (M_W 8.8), and 2011 Tohoku (M_W 9.1), the decay process in different period bands is investigated by using coastal tide gauge data from Japan as well as offshore tsunami observation data from stations in the northwest Pacific. Tsunamis caused by larger earthquakes contain longer period components than ones caused by smaller earthquakes, and even in the coastal tide data from Japan, the shorter period component of tsunamis decay faster. These finding are similar to those obtained by Rabinovich *et al*. (2013) for offshore data. However, the tsunami amplification factors of coastal observations relative to offshore observations are 2–3 times higher in the 6–60 minute period bands than in longer (60–180 minutes) or shorter (2–6 minutes) period bands. Therefore, unlike in offshore observations, in coastal observations the decay process in intermediate period bands tends to be the predominant decay process in the entire period band; as a result, the dependence of the decay time on seismic magnitude is considered to be weaker in coastal observations than in offshore observations. For most tsunami events, the decay time of the early part is shorter than that of the later part, and the period dependence of the decay time is considered to be absorbed into the transition from the early to the later part of decay process, thereby becoming inconspicuous.

In Chapter 3, a method for forecasting the tsunami decay process is proposed based on the decay process characteristics described in Chapter 1. The increase and relatively rapid decay during the early part of the process and the exponential decay during the later part is expressed by the equation (3.1), which includes three exponential functions. Parameters of the three exponential functions are estimated by the

least squares method for each of the five groups classified by the behavior during the early part. Because the groups are related to the sea region where the tsunami source is located, equation (3.1) can be used to forecast the temporal change of the basic MRMS amplitude as soon as the hypocenter of the relevant earthquake is known. Various factors modify the basic MRMS amplitude. The seismic magnitude and the travel time contribute to the amplification and reduction, respectively, of the tsunami amplitude. The site factor is the ratio of the MRMS amplitude at an observation site to the average MRMS amplitude. Site factors can be divided into two groups depending on the tsunami source location: one for sources off the west coast of South America and the other for sources in the North and southwest Pacific. The crest factor is the ratio of tsunami height to MRMS amplitude, and its statistical characteristics are generally similar among major past tsunami events. Thus, to forecast a tsunami envelope curve for each observation site, the basic MRMS amplitude is multiplied by travel time, magnitude, site, and crest factors. If a large value is used for the crest factor, the observed tsunami height is unlikely to exceed its forecasted height, but the time at which the tsunami is forecasted to fall below the specified criterion height may be overestimated. To improve the accuracy of this forecasted time, the crest factor should be set to a smaller value. If the crest factor is set to 2.6, the probability that the observed tsunami height exceeds the forecasted height is less than 1% and forecasted time errors are within ±12 hours.