Abstract of Doctoral Dissertation

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Title of Doctoral Dissertation

Development of Early Warning System for Volcanic Sector Collapse Tsunamis
（火山性山体崩壊による津波に対する即時警報システムの開発）

Present tsunami warning systems have been specialized for earthquake-generated tsunamis, but rapidly evaluating the tsunamis caused by volcanic eruptions and/or volcanic sector collapses remains a challenge. Various models are available to simulate landslides and tsunami generation from volcanic sector collapse. However, implementing such models for real-time forecasting is still challenging due to diverse and complex mechanisms in the tsunami generation that make it difficult to immediately estimate the source model for the real-time forecasting simulation. The occurrence of volcanic sector collapse tsunami is less-frequent than that of earthquake-generated tsunamis, but potential catastrophe from volcanic tsunamis including sector collapse cannot be underestimated and should be considered as important tsunami source in terms of hazards and disaster strategies. Present topic study consists of two main parts which discuss about the development of early warning system for tsunamis accompanied by sector collapse of Anak Krakatau volcano in Indonesia and study on the tsunami generation characteristic from the sector collapse of Komagatake volcano, Japan, for tsunami early warning purposes.

A study focuses on the development of early warning system targeting the sector collapse case of Anak Krakatau volcano in Indonesia was presented in first section. The development of real-time forecasting was conducted under several procedures. This study applied a numerical model to the 2018 Sunda Strait tsunami event, which was generated by the sector collapse of Anak Krakatau, investigated a tsunami prediction skill by the model, and developed a real-time forecasting method based on a pre-computed database for future tsunamis accompanied by such eruption of Anak Krakatau. The database stores spatiotemporal changes in water surface level and flux, which are simulated under various collapse scenarios, for confined areas in the vicinity of potential source. The areas also cover the locations of six observation stations that are virtually placed on uninhabited island surrounding the source area. During an actual volcanic tsunami event, a tsunami is expected to be observed at the observation stations. For real-time tsunami forecasting, the most suitable scenarios to reproduce the observed waveforms are searched quickly in the database through waveform fitting procedure at observation stations. The pre-computed water surface level and flux distribution under the identified scenarios are further provided as input for rapid tsunami propagation simulation. Therefore, an effective real-time forecasting can be conducted to densely populated coastal areas located at a considerable distance from the source, such as the coasts of Java and Sumatra. The forecasting performance was examined by applying the method for three hypothetical collapse scenarios assuming different volumes and sliding directions. The numerical experiments using hypothetical collapse scenarios in this study indicated that the tsunamis along the coast of Java and Sumatra were successfully forecasted by applying our forecasting method. This study shows that the combination of a pre-computed database and the utilization of observation stations near the source area was able to produce appropriate tsunami forecasting for the coastal area of Java and Sumatra even in a volcanic tsunami event. Moreover, implementing our method allows us to estimate real-time tsunamis generated by volcanic activity of Anak Krakatau without considering the complex source mechanism.

Further study towards the development of tsunami warning system was conducted by simulating the sector collapse cases of Komagatake volcano located in Hokkaido, Japan. This study aims to

identify the characteristics of tsunami resulting from the sector collapse of Komagatake and its impact on the nearby coastal area for tsunami warning purposes. Preliminary modeling of landslides and tsunamis from the 1640 Komagatake tsunami were first conducted using the similar manner with the 2018 Sunda Strait event. The 1640 Komagatake tsunami was generated by the mass failure of Komagatake volcano that partly collapsed to the eastward from the summit, entered the open ocean, and caused a large tsunami along the coast of Hokkaido. A total volume of 1.2 km^3 was employed to the model as initial collapse volume for simulation of the 1640 Komagatake tsunami. The simulated tsunami was compared with the available tsunami measurement data including tsunami deposit data. Based on the inundation simulation, the distribution of tsunami deposit of the 1640 Komagatake tsunami along the Hokkaido coast were well-explained by our simulation. Furthermore, two hypothetical scenarios were created assuming the future sector collapse of Komagatake to identify the characteristic of tsunami generated by the collapse sector of Komagatake and assess the tsunami impact to the coastal area. In addition, three virtual observation stations were purposely placed in the vicinity of volcano to assess the characteristics of tsunami generated by those hypothetical collapse scenarios. Based on the simulation using two hypothetical scenarios, the sector collapse of Komagatake is characterized by multiple landslide directions resulting in relatively wide coverage of landslide. Tsunami hazard assessment indicates that both collapse scenarios with different volume and collapse plane are similarly resulted in significant tsunami heights along the coast of Muroran and Date which located across the volcano. Further investigation was conducted by analyzing the observed waveforms at three virtual observation stations. The findings in this study show that essential information related to the tsunami generation from the sector collapse can be identified from observed waveforms at virtual observation stations. Moreover, rapid detection of tsunamis at the observation stations allows us to have warning time targeted the coastal area of Hokkaido.

The topic in this study mainly covers a study related to the development of tsunami warning system associated with volcanic sector collapse. The real-time tsunami forecasting method based on the pre-computed database was proposed for volcanic sector collapse case of Anak Krakatau. Furthermore, the study on the sector collapse of Komagatake highlighted the importance and advantage of observation stations for tsunami early warning. Both study on the volcanic sector collapse of Anak Krakatau and Komagatake volcano shows that the existence of observation station in the vicinity of volcano can provide essential information for tsunami warning purposes. A well-constructed tsunami forecasting method based on the utilization of observation should be feasible for future tsunami warning systems even for volcanic tsunami cases.

Keywords: *Sector collapse, Tsunami, Anak Krakatau, Komagatake volcano, Tsunami Warning System*