Efficient placement of tsunameters for source characterizations around the Nankai Trough, Japan

*Iyan E. Mulia[1], Aditya Riadi Gusman[1], Kenji Satake[1]

1. Earthquake Research Institute, The University of Tokyo

In response to several unanticipated large tsunami occurrences in the last decades, developments of an effective tsunami observing system have become a major concern among researchers as well as funding agencies. A number of tsunameter networks are currently operating in several major tsunamigenic regions throughout the world. However, details on the selection of locations for effectively placing the tsunameter are limited. Particularly for tsunami observations, the placement is often associated with historical records at the areas of interest supported by expert judgements with various deciding factors, e.g., technical and financial limitations. This study presents a methodological approach to select strategic observation locations for the purpose of tsunami source characterizations, particularly in terms of the fault slip distribution. Though we stressed our design for source characterizations, the accurate source estimate may in turn lead to improved tsunami forecasts.

The use of hypothetical experiments is required in designing future observations. Consequently, we need a wide range of realistic scenarios that can represent the key features of possible future tsunamis in our study area. As a region that had frequently hosted large earthquakes and tsunamis, the Nankai Trough attracted the Japanese authorities to conduct extensive researches in order to mitigate future disasters in the region. Part of the research products advocated by the Central Disaster Management Council (CDMC) of Japan were 11 hypothetical tsunami sources generated by submarine earthquakes with a magnitude of *M*9.1 that can be considered as a reference for the future tsunamis originating from the Nankai subduction zone. Here, we developed a design of a future tsunameter network that is optimal with respect to the CDMC sources. We then run the tsunami simulations emanating from these sources and stored the associated wave fields for the subsequent stages in our study.

Initially, we identified favorable locations and determined the initial number of observations. These locations were selected based on extrema of empirical orthogonal function (EOF) spatial modes derived from wave fields associated with the 11 hypothetical tsunami sources. These extrema provide information concerning the areas where modal activity is at its highest, which correspond to the main energy distribution of the tsunami. Placing the tsunameter at these locations is preferable, if not optimal, to capture the dynamics that largely characterize the source. To further improve the accuracy, we applied an optimization algorithm called a mesh adaptive direct search (MADS) to remove redundant measurement locations from the EOF-generated points. We imposed an optimization setting so that the combinatorial search by the MADS will improve the accuracy and reduce the number of observations simultaneously.

The EOF analysis of the hypothetical tsunamis using first two leading modes with four extrema on each mode resulted in 30 observation points spreading along the trench. This was obtained after replacing some clustered points within the radius of ~30 km with only one representative. Furthermore, the MADS optimization improved the accuracy of the EOF-generated points by approximately 10-20% with fewer observations (23 points). Finally, we compared our result with the existing observation points (68 stations) in the region. The result shows that the optimized design with fewer number of observations can produce better source characterizations with approximately 20-60% improvement of accuracies at all the 11 hypothetical cases. It should be noted, however, that our design is a tsunami-based approach, some of the existing observing systems are equipped with additional devices to measure other parameters of interest, such as seismometer for monitoring seismic activities. Therefore, our design is optimal specifically from the perspective of tsunami observations.

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