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Comparison Between Boussinesq Type Dispersion and Numerical Dispersion Models in Far-field Tsunami Calculation

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For calculations of far-field tsunamis, it is necessary to consider dispersibility of the tsunami. We oftern substituded numerical error that occur in differentiating shallow water equations for physical dispersion. However the numerical dispersion method should keep lattice interval to be coarse in order to make the numerical error term equal to the dispersion term. On the other hand, development of large-scale computers became possible to calculate the far-field tsunami directly solving the physical dispersion term in a wide area with fine lattice interval. In this study, we compared the Boussinesq type physical dispersion and the numerical dispersion models for far-field tsunami caused by the 2011 Tohoku, Japan, earthquake. In the calculation of Boussinesq dispersion, we used lattice interval of 30 arc-seconds and time step of 0.5 seconds to suppress the numerical error. In the calculation of numerical dispersion, we used lattice interval of 270 arc-seconds and time step of 1 second to substitute the numerical error for the physial dispersion. The calculation region was set to be the entire Pacific Ocean, and the integration time was 28 hours. We also included effects of elastic deformation of the Earth due to tsunami load and seawater density stratification in the calculation. We compared tsunami waveforms at DART stations.

Calcuated tsunami waveforms of the leading and second waves were almost the same between the Boussinesq type dispersion (upper in Fig.1) and the numerical dispersion (middle in Fig.1) models. However, differences were apprant in later phases especially at the observation points close to the source of the tsunami (see arrows in Fig.1). Because the later phases are relfected waves from the coast lines, lattice spatial resolution of 270 arc-seconds in the numerical dispesion model would be insufficent to simulate the reflection at the coast. Therefore, we applied three layered nested grids to the numerical dispersion model. The lattice interval of the layered nested grids were 270, 90, and 30 arc-seconds (Fig.2). The nested numerical dispersion model successfully simulated the 2011 Tohoku tsunami not only the leading wave but also the later waves (lower in Fig. 1). The calculation time of the Boussinesq type dispersion and the nested numerical dispersion models were about 151 hours and 14 hours, respectively.

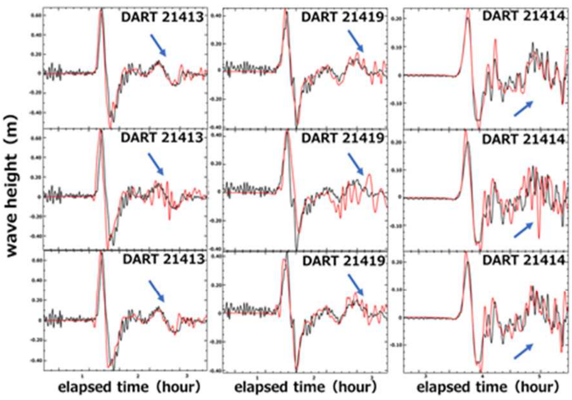

Fig 1. Comparison of tsunami waveforms. Black and red lines show observation and calculation. Upper panels are calculated from the Boussinesq model. Middle panels are from the numerical dispersion model. Lower panels are from the nested numerical dispersion model.

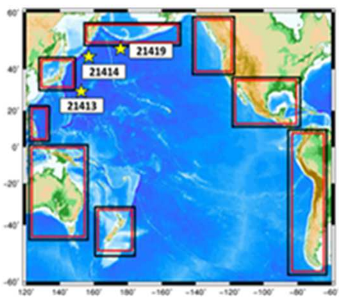

Fig 2. Distribution of the observation points and the nested grids