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Examination on Numerical Simulation of Tsunami-Induced Extremely Low Frequency Sound Waves with Geospatial Information

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Air pressure changes associated with earthquakes and/or tsunami have been investigated previously. As for air pressure changes associated with tsunami, some observation results have been reported (T. Mikumo (1964), T. Mikumo, et al. (2008) and William L. Donn and Eric S. Posmentier (1964), Y. Tamura (2011), N. Arai, et al. (2011)).

We have measured the air pressure in the terrestrial atmosphere with other meteorological parameters (temperature, humidity, etc.) continuously at Hosokura outdoor observation station (HSK) in Miyagi Prefecture, Japan. The extremely low frequency sound waves (so-called micro barometric waves) are also detected as large changes of air pressure in the 2011 off the Pacific coast of Tohoku Earthquake (M 9.0, origin time;14:46.18JST) (K. Okubo, et al. (2011)).

Although the power failure was caused by the earthquake occurrence, our observation system had been maintained by the UPS system and the private power generation. Therefore, in this earthquake, our observation system successfully observed extremely low frequency sound waves induced by tsunami. The waves were detectable at the observation point on the ground surface sufficiently early before the arrival of tsunami waves at coastal areas, because sound waves propagate faster than ocean waves (tsunami).

These results can encourage early tsunami detection (S. Iwasaki (1992), T. Izumiya (1994)) using multi-site observation and arrival time difference method. That is, detection of tsunamis might be possible by monitoring extremely low frequency sound waves at ground surface observation sites and/or sea-level observation at relatively low cost. It is important to obtain information of tsunami as soon as possible; arrival time, area and scale.

In this study we present a fundamental examination on analysis and visualization of extremely low frequency sound waves caused by tsunami using numeral approach. We employ the numerical simulation using the Finite-Difference method in Time-Domain (FDTD method) (Yee, 1966) with geospatial information for the large-scale sound wave propagation. As an elementary study, it is applied to the estimation of extremely low frequency sound waves' propagation and time-series analysis of sound pressure.

Through our study, we show the numerical results of sound pressure distribution and estimate the propagation phenomena of sound waves, compared with the observed data at HSK. This examination may help the development of the design of early tsunami detection system. In the future, further efforts can suggest new systems for early warning of destructive tsunami using a combination of other measurements.