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Development of a GPS buoy system for monitoring tsunami, sea waves, ocean bottom crustal deformation and atmospheric water vapor

Teruyuki Kato (1), Yukihiro Terada (2), Toshihiko Nagai (3), and Shun'ichi Koshimura (4)

(1) The University of Tokyo, Earthquake Research Institute, Tokyo, Japan (teru@eri.u-tokyo.ac.jp), (2) Department of Civil Engineering, Kochi National College of Technology, Kochi, Japan, (3) Port and Airport Research Institute, Kanagawa, Japan, (4) Graduate School of Engineering, Tohoku University, Miyagi, Japan

We have developed a GPS buoy system for monitoring tsunami for over 12 years. The idea was that a buoy equipped with a GPS antenna and placed offshore may be an effective way of monitoring tsunami before its arrival to the coast and to give warning to the coastal residents. The key technology for the system is real-time kinematic (RTK) GPS technology. We have successfully developed the system; we have detected tsunamis of about 10cm in height for three large earthquakes, namely, the 23 June 2001 Peru earthquake (Mw8.4), the 26 September 2003 Tokachi earthquake (Mw8.3) and the 5 September 2004 earthquake (Mw7.4).

The developed GPS buoy system is also capable of monitoring sea waves that are mainly caused by winds. Only the difference between tsunami and sea waves is their frequency range and can be segregated each other by a simple filtering technique. Given the success of GPS buoy experiments, the system has been adopted as a part of the Nationwide Ocean Wave information system for Port and HArborS (NOWPHAS) by the Ministry of Land, Infrastructure, Transport and Tourism of Japan. They have established more than eight GPS buoys along the Japanese coasts and the system has been operated by the Port and Airport Research Institute.

As a future scope, we are now planning to implement some other additional facilities for the GPS buoy system. The first application is a so-called GPS/Acoustic system for monitoring ocean bottom crustal deformation. The system requires acoustic waves to detect ocean bottom reference position, which is the geometrical center of an array of transponders, by measuring distances between a position at the sea surface (vessel) and ocean bottom equipments to return the received sonic wave. The position of the vessel is measured using GPS. The system was first proposed by a research group at the Scripps Institution of Oceanography in early 1980's. The system was extensively developed by Japanese researchers and is now capable of detecting ocean bottom positions with a few centimeters in accuracy. The system is now operational for more than ten sites along the Japanese coasts. Currently, however, the measurements are not continuous but have been done once to several times a year using a boat. If a GPS and acoustic system is placed on a buoy, ocean bottom position could be monitored in near real-time and continuous manner. This will allow us to monitor more detailed and short term crustal deformations at the sea bottom.

Another application plan is for an atmospheric research. Previous researchers have shown that GPS is capable of measuring atmospheric water vapor through estimating tropospheric zenith delay measurements of GPS at the sea surface. Information of water vapor content and its temporal variation over sea surface will much contribute to weather forecast on land which has mostly been conducted only by land observations. Considering that the atmospheric mass moves from west to east in general in and around Japanese islands, information of water vapor together with other atmospheric data from an array of GPS buoy placed in the west of Japanese Islands, will much improve weather forecast. We try to examine if this is also feasible.

As a conclusion of a series of GPS buoy experiments, we could assert that GPS buoy system will be a powerful tool to monitor ocean surface and much contribute to provide safe and secure life of people.