# TIMING: Sanriku network for the exchange of tsunami information

**Fumihiko Imamura[1], Shunichi Koshimura[2], Hidenori Iwasa[3], Shuji Imoto[3], Kenichi Sato[4], and Nobuo Shuto[5]**

[1]***Disaster Control Research Center, Tohoku University, Aoba, Sendai, Japan***
[2]***NOAA/Pacific Marine Environmental Laboratory, Seattle, Washington, U.S.A.***
[3]***Weathernews Inc., Mihama-ku, Chiba, Japan***
[4]***Kesennuma City Office, Miyagi, Japan***
[5]***Faculty of Policy Studies, Iwate Prefectural University, Iwate, Japan***

**Abstract.** Tsunami gauges have been widely installed by local autonomies along the Sanriku coast, an area that has been stricken and damaged by tsunamis more frequently than any in the world. Since most of the tsunami gauges are installed at ports and harbors to measure the tsunami height in the shallow sea, there have been difficulties utilizing them for providing evacuation information even if they detect tsunamis. We propose a system to exchange and share information from a number of gauges in real time, and make use of it for warning and prediction. Although the measured data may not be in time for issuing a tsunami warning to a local community operating the gauge itself, its data, if transferred to the other communities in real time, will be useful for warning and evacuation in the nearby communities that may be stricken afterwards. We develop a prototype system, which is called TIMING (Tsunami Integrated Media INformation Guide), to construct a real-time network system for sharing the data measured by tsunami gauges.

## 1. Introduction

In April 1999 the Japan Meteorological Agency started operating a new tsunami warning system to provide quantitative information on tsunami arrival time and its height, dividing the coast of Japan into 66 operational regions. This system is expected to provide the coastal communities with more detailed information for appropriate evacuation (Tatehata, 1998; ITSU, 1999). The system, using a seismograph network composed of 150 highly sensitive sensors, can determine the epicenter and magnitude of an earthquake. Based on this information and a tsunami modeling database obtained prior to the event, they estimate tsunami arrival time and height, retrieving this information from the database in a short time. The quantitative forecast is issued to the communities through Satellite/TV media within 5 to 7 min after the tsunamigenic earthquake. However, questionnaire surveys to residents suggest that problems concerning density of information and accuracy of the forecast still remain, because the information from the present tsunami warning system is limited to provide one issue in each prefecture, i.e.,

[1]Disaster Control Research Center, Graduate School of Engineering, Tohoku University, Aoba 06, Sendai 980-8579, Japan (imamura@tsunami2.civil.tohoku.ac.jp)
[2]Pacific Marine Environmental Laboratory, NOAA, 7600 Sand Point Way NE, Building 3, Seattle, WA 98115-6349, U.S.A. (koshi@pmel.noaa.gov)
[3]Weathernews Inc., D22, 1-3 Nakase, Mihama-ku, Chiba 261-0023, Japan
[4]Kesennuma City Office, 1-1-1, Youkamachi, Kesennuma, Miyagi 988-8501, Japan
[5]Faculty of Policy Studies, Iwate Prefectural University, Iwate 020-0193, Japan (shuto@iwate-pu.ac.jp)

one value of forecast in a coastal area 100 to 200 km wide (Imamura, 1998). The behavior of tsunamis is so complicated that more detailed information is essential for people in the coastal communities. Moreover, the modeling result from the database would fail to estimate tsunami height in the case of tsunami earthquakes and non-seismic tsunamis such as landslides and volcano eruptions, because the simulation in the database does not assume such tsunamis.

Tsunami gauges have been widely installed by local autonomies along the Sanriku coast, an area that has been stricken and damaged by tsunamis more frequently than any in the world. The purpose of the installation is to watch for an abnormal change in sea level when a tsunami warning is issued. Since most tsunami gauges are installed at ports and harbors to measure the tsunami height in the shallow sea, there are difficulties utilizing them for providing evacuation information, even if they detect tsunamis. However, it is possible to solve these problems and improve the accuracy of forecasts, if the measured data by the tsunami gauges can be exchanged among the JMA and local governments. The present study discusses the utilization of tsunami gauges in a broad network to provide more detailed and accurate information on tsunamis.

## 2. Tsunami Gauges Along the Sanriku Coast

We carried out a questionnaire survey to local government employees who are in charge of disaster management, such as employees of fire and police departments. The purpose of the survey was to understand the present situation of tsunami countermeasures and operations for issuing an advisory or warning. The result indicates that they need more detailed information on tsunami arrival time and sea level change at their operational areas. Further, they need such information in real time after tsunamigenic earthquakes. Otherwise there may be delays in issuing an advisory or warning for appropriate evacuation. The tsunami warning system of the Japan Meteorological Agency has been improved, but not enough for the purpose mentioned above. Installation of a tsunami gauge at each local autonomy, which aims to observe local tsunami behavior accurately, was the consequence. So far, 58% of 24 cities, towns, and villages in the Sanriku region have established tsunami gauges in their operational regions. Figure 1 is an example of a tsunami gauge (Sato *et al.*, 1992).

Tsunami observation systems were originally established at a number of coastal areas for the purpose of watching for an abnormal sea level change by fire department employees and police officers. Recently, they have discussed the possibility of operating its system directly for warning or guidance to the communities. There are two possible plans to be considered. The first is to exchange and share the data from all the tsunami gauges via a broad network. We assume that some areas can obtain the data, if the real-time data exchange works, prior to the attack of tsunamis from the gauges that are close to the tsunami source region. The second is to estimate the tsunami amplification factor based on the observations at the offshore tsunami

**Figure 1**: An example of a tsunami gauge established in the Sanriku region (Sato *et al.*, 1992.

gauges or the gauges placed in the bay mouth. For example, Sato *et al.* (1992) studied the tsunami amplification factor in Kesennuma Bay of the Sanriku region, using the observed tsunami data at the head and mouth of the bay. They found that it takes 10 to 15 min for tsunamis to propagate from the mouth of Kesennuma Bay into the head of the bay, which is densely populated. Also, Ishida *et al.* (1998) estimated the tsunami amplification factor in the head of the bay as the function of tsunami wave period observed at the mouth.

## 3. Proposal of Tsunami Integrated Media Information Guide (TIMING) System

We focus on the tsunami gauges in Kesennuma Bay and propose the first-phase prototype of the TIMING (Tsunami Integrated Media INformation Guide) system under the background described in the previous sections. The system has the following properties as its functions: (1) development of a real-time tsunami reporting system, (2) advancement of tsunami informa-

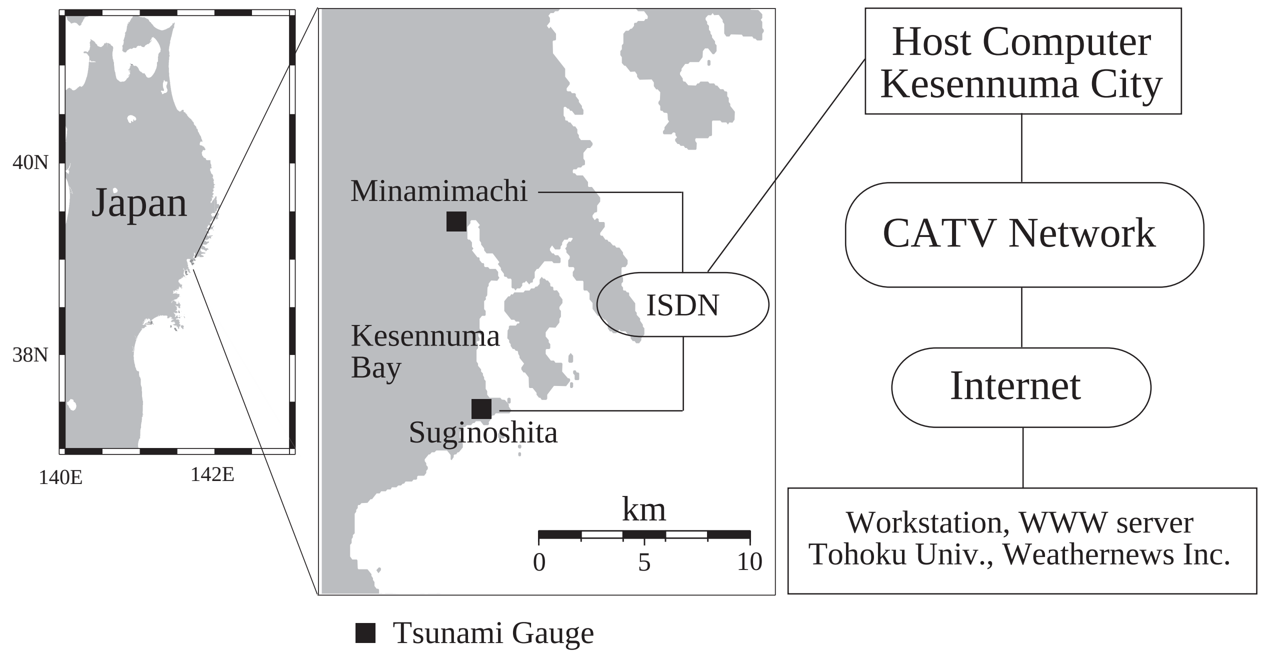


**Figure 2**: Overview of the TIMING system.

tion in terms of immediate notice, and (3) education to the residents about tsunami disaster mitigation. In this paper, we describe the development of a real-time tsunami reporting system to share and integrate the information from the tsunami gauges. The system consists of the following four processes to observe, transfer, and analyze the data and display the information on the World Wide Web.

Kesennuma Bay is located at the Pacific coast of the northern part of Japan (see Fig. 2). Sato *et al.* (1992) developed the tsunami gauges both at the mouth of Kesennuma Bay and the head of the bay (see Fig. 1). One is established at Suginoshita, the mouth of the bay, another is at Minamimachi, the head of the bay. The gauge transmitted the supersonic wave down to the surface of the bay water and measured the height of the water surface with a sampling time of 0.3 s. This system has succeeded in observing the 1994 Shikotan tsunami that occurred off the coast of Shikotan Island.

The sea level data obtained at tsunami gauges is transferred to the host computer of Kesennuma City via an Integrated Services Digital Network (ISDN). ISDN is a method establishing a digital connection between two points in the telephone company's (Nippon Telegraph and Telephone Corporation) switched network. From the host computer of Kesennuma City, we use the CATV network to transfer the data to the work station of Tohoku University and the mirrored server of Weathernews Inc. via internet.

To remove the tide and wind wave components, and to detect tsunamis, we predict the astronomical tide considering eight tidal constituents and deduct from the moving-averaged raw data with an appropriate time-domain window. When the tsunami warning or watch is issued by JMA, the analyzed data is automatically transferred to the WWW server to display the time history of sea level change in real time with a refresh rate of 1 min. Figure 2 summarizes the process described above.

We have not yet succeeded in displaying the real-time observation data, because the studied area has not experienced any tsunamis since the system was deployed. It will be displayed at http://www.timing.civil.tohoku.ac.jp. This system makes it possible not only to view the sea level change in the issued area in real time but to provide the data to develop the tsunami inversion technique (Satake, 1989) for the next generation tsunami warning system. To achieve it, we suggest that all the tsunami gauges in the Sanriku region be linked and aggregated as the general information hub for tsunami disaster mitigation.

## 4. Future of the TIMING system

Not only exchanging the sea level data obtained from the tsunami gauges, but linking the tsunami hazard maps and live-camera image from ports and harbors should be added to the system for advisories and information of appropriate evacuation routes and tsunami-free areas. Also, we will have the TIMING system provide any information that indicates the possible occurrence of earthquakes or tsunamis. For example, unusually large catches of fish, which usually live in the deep sea, are reported at the local harbors. This is caused by unusual currents and turbid seawater, and is believed to be a precursory phenomena prior to the occurrence of earthquakes. There were a number of reports on this phenomena in Japan prior to the 1896 Meiji Sanriku and the 1933 Showa Sanriku earthquakes and tsunamis. When fisheries or coastal residents notice such abnormal phenomena, the TIMING system will exchange the information on the web, which aims to call attention to the coastal communities. The information will be updated on the web, carefully judging its quality and credibility.

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