Potential civil applications

The Utilization of International Monitoring System Seismic Data by the Northwest Pacific Tsunami Advisory Center

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Japan has a long history of suffering the effects from a number of local tsunamis due to its geographical and geological environment. In order to mitigate tsunami disasters, the Japan Meteorological Agency (JMA) started a national Tsunami Warning Service that covered the whole region of Japan in 1952, expanding on the local tsunami warning service that was already operating in some areas.

The JMA has made continuous and earnest efforts to improve the Tsunami Warning Service since its inception, through the development of seismological observation networks, earthquake analysis systems and data communication systems. One of the epoch-making achievements of the last decade was the JMA's introduction of the world's first tsunami warning service in 1999, which uses a numerical simulation technique. This technique has produced greater accuracy and a quicker issuance of tsunami warnings than the previous empirical method.

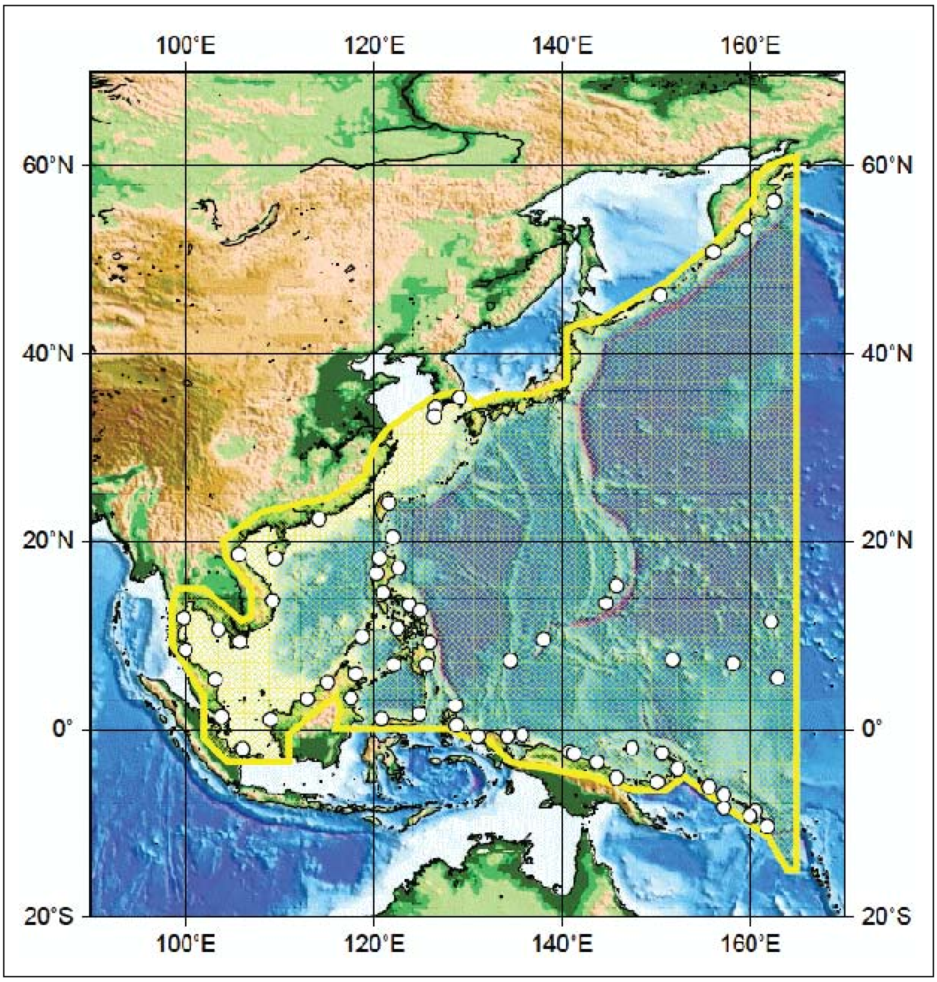

FIG.1 THE GEOGRAPHICAL COVERAGE (SHADED AREA) AND THE FORECAST POINTS (OPEN CIRCLES) OF THE ADVISORY

Massive tsunami highlights importance of international cooperation

During the early developmental stages of the Tsunami Warning Service in Japan, an event occurred that stressed the importance of international cooperation in the area of tsunami mitigation. On 22 May 1960, a magnitude 9.5 earthquake off the coast of Chile generated a massive tsunami that caused serious damage to countries in the Pacific Ocean region. The tsunami killed more than 60 people in Hawaii after travelling halfway across the Pacific and killed over 140 people in Japan after crossing the entire Ocean in less than one day. It was claimed the loss could have been avoided had a proper data and information exchange system for countries in the region been in existence.

This disaster marked a turning point: in 1965 the International Coordination Group for the Tsunami Warning System in the Pacific, now reorganized as the Intergovernmental Coordination Group for the Pacific Tsunami Warning and Mitigation System (ICG/PTWS), was established under the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational Scientific and Cultural Organization (UNESCO). The group's aim is to prevent tsunami disasters through the exchange of seismological and tsunami observation data among the member states.

Establishment of the Northwest Pacific Tsunami Advisory Center

The ICG/PTWS has implemented various activities through the cooperation of its member states, including the ocean-wide tsunami warning provision by the Pacific Tsunami Warning Center based in Hawaii. As a contribution to the

activities of the group, Japan established the Northwest Pacific Tsunami Advisory Center (NWPTAC) within the JMA. The NWPTAC started its service in March 2005 by providing countries in the region with detailed forecast information about tsunamis generated in the Northwest Pacific using the same numerical simulation technology as the domestic system described earlier.

The NWPTAC monitors and analyses seismic data on a 24/7 basis from the domestic observation network in Japan, the United States Geological Survey Live Internet Seismic Server (LISS), and the Incorporated Research Institutions of Seismology (IRIS). It then issues a Northwest Pacific Tsunami Advisory (NWPTA) when a large earthquake occurs in the region. A NWPTA, hereafter referred to as an Advisory, is provided via the Global Telecommunication System of the World Meteorological Organization, e-mail, and facsimile when the NWPTAC detects a big earthquake of magnitude 6.5 or greater in its coverage (Fig.1). After issuing an Advisory, the NWPTAC monitors sea level data from the global network of tide gauges, and subsequently issues further Advisories, including the tsunami observation data, when it actually detects a tsunami wave.

An Advisory contains the following information:

1) Earthquake parameters;

2) Tsunamigenic potential;

3) Estimated tsunami amplitude and arrival time at coastal points; and

4) Tsunami observational data.

The outline of the system is as follows:

The first step in building the system involves setting a number of possible earthquake fault models and calculating the propagation of the tsunami generated by each fault model. Then the results of the tsunami's arrival time and maximum amplitude at certain places for each case are stored onto the tsunami forecast database. Those processes are conducted and completed in advance. When an actual earthquake occurs, the tsunami's arrival time and amplitude at principal coastal locations (Fig.1) are retrieved from the database according to the determined hypocenter and magnitude, and an Advisory including the above-mentioned information is issued.

Using high-quality seismic data for accurate forecasts

Though the numerical simulation technique has enabled a prediction with a high spatial and amplitude resolution, eventual forecast accuracy greatly depends on hypocenter and magnitude determination accuracy. That means that the acquisition of stable high-quality seismic data is a prerequisite for ensuring high forecast accuracy. While the JMA was able to use such high-quality seismic data from its domestic network along with those of LISS and IRIS, it also recognized the importance of obtaining additional high-quality data to complement those data for overseas locations.

The Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) is tasked to set up the International Monitoring System (IMS), which is a network comprised of 321 stations to monitor the globe for any sign of a nuclear explosion. Included in this network are 170 seismic stations (50 primary stations and 120 auxiliary stations). Prior to 2004, there had been discussions about making use of the IMS seismic data for other purposes than the original aim of detecting nuclear explosions; the potential civil and scientific applications of the data generated even greater interest after the Indian Ocean tsunami disaster in December 2004. JMA therefore decided to conduct research on the effectiveness and

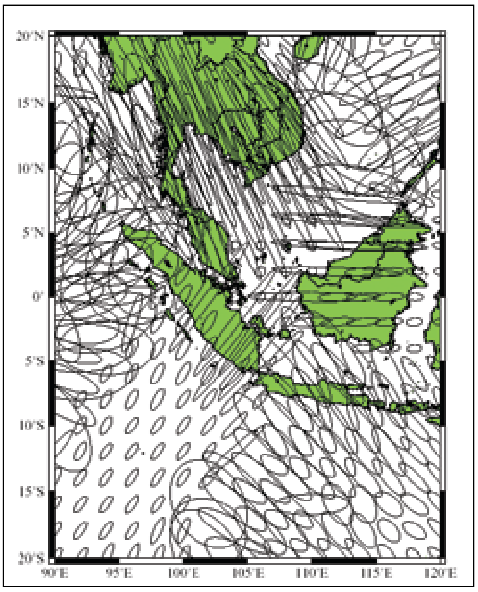

FIG.2 HORIZONTAL ERRORS OF ESTIMATING EARTHQUAKE LOCATION USING ONLY LISS AND IRIS DATA.

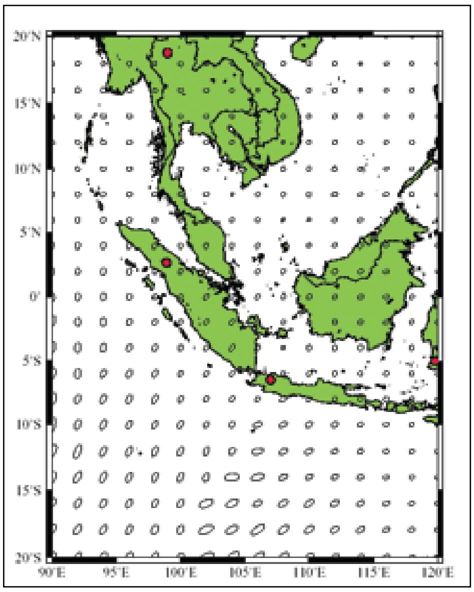

FIG.3 HORIZONTAL ERRORS OF ESTIMATING EARTHQUAKE LOCATION USING IMS DATA (RED CIRCLES) IN ADDITION TO LISS AND IRIS DATA.

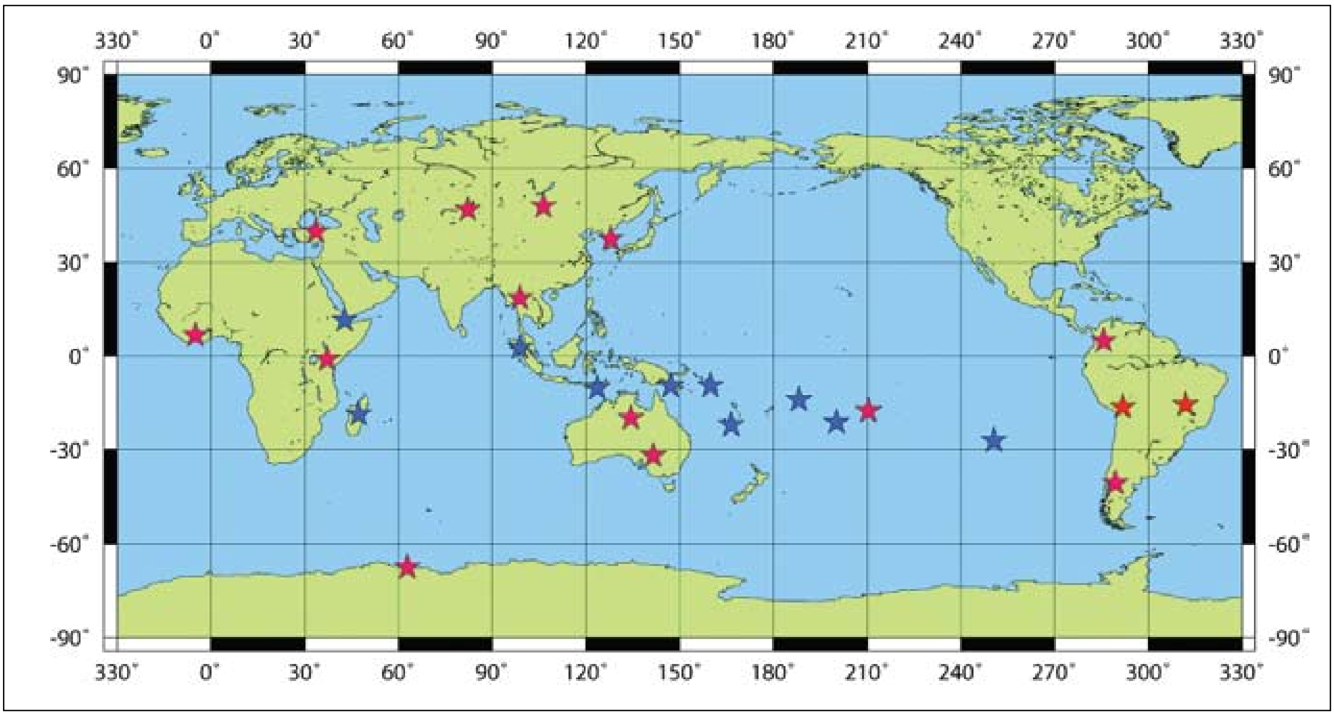

FIG.4 CTBT/IMS SEISMIC OBSERVATION STATIONS USED BY JMA : RED STARS: PRIMARY SEISMIC STATION (15 STATIONS)
BLUE STARS: AUXILIARY SEISMIC STATION (10 STATIONS)

transmission reliability of IMS seismic data for tsunami warning services.

Figures 2 and 3 show horizontal error ellipses for earthquake locations around Sumatra, Indonesia. Fig2 shows the situation when only using LISS and IRIS data, while Fig.3 shows the case when using IMS data in addition to LISS and IRIS data. Error ellipses in Fig.2 are quite large and some of them extend to both land areas and the ocean. In this case we cannot even distinguish between an inland earthquake and one that occurred in an ocean region, which is inappropriate for the purpose of issuing of tsunami warnings. On the other hand, error ellipses in Fig.3 are considerably smaller, so that we can acquire a precise earthquake location. In regard to data latency and transmission reliability, research by the JMA indicated that IMS seismic data have advantages over data sources currently available through the Internet.

Tsunami warning arrangement signed with the CTBTO

After IMS seismic data availability had been verified by the research mentioned above and through subsequent meetings between the CTBTO and UNESCO/IOC, an agreement was reached whereby the CTBTO would provide its seismic data for tsunami warning centres with the formal approval of UNESCO/IOC. In August 2008, the signing of the Tsunami Warning Arrangement took place in Vienna between Ambassador Yukiya Amano, the Permanent Representative of Japan to the International Organizations in Vienna, and Ambassador Tibor Tóth, Executive Secretary of the CTBTO. This arrangement was the first of its kind and of great significance, allowing Japan to receive data from the CTBTO for its Tsunami Warning Service. At present, JMA receives data from the observation stations shown in Fig.4.

As mentioned above, IMS seismic data have great potential to contribute to the Tsunami Warning Service. The JMA highly appreciates the fact that the CTBTO, together with its Member States, decided to provide its seismic data to mitigate the loss of life caused by tsunami disasters in the world, and we would like to express our sincere gratitude to them. The JMA hopes that further cooperation and coordination be enhanced between CTBTO, UNESCO/IOC and relevant tsunami warning organizations of any region and country in the world to save lives from future tsunami disasters. ■

Biographical note

Yohei Hasegawa has been the Senior Coordinator for International Earthquake and Tsunami Information of the Earthquake and Tsunami Observation Division, Seismological and Volcanological Department of the Japan Meteorological Agency (JMA) since 2007. He has also served as a Vice-Chair of the Intergovernmental Coordination Group for the Pacific Tsunami Warning and Mitigation System (ICG/PTWS) since 2007. ■