OUTLINE AND PERFORMANCE OF NEW TSUNAMI FORECAST SERVICE IN THE JAPAN METEOROLOGICAL AGENCY

by

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ABSTRACT

The Japan Meteorological Agency (JMA) started a new tsunami forecast service on 1 April, 1999. In the new service, the JMA issues calculated tsunami heights in a specific number using tsunami numerical simulation. The ratio between calculated tsunami heights and observed ones correlates with a configuration of the coast at an observation point and the source area. With this correlation, we can improve the accuracy of tsunami height forecasts.

KEY WORDS: Tsunami Forecast
Numerical Simulation
Tsunami Height
Accuracy of Forecast

1. INTRODUCTION

Japan is one of the most seismically active areas in the world, and has frequently suffered from the tsunami disasters caused by earthquakes. In order to mitigate the tsunami disasters, the Japan Meteorological Agency (JMA) has issued tsunami forecasts since 1952.

The JMA started a new tsunami forecast service using tsunami numerical simulation on 1 April, 1999. In the new service, estimated tsunami heights are available in a specific number, while only rough scale were available in the previous service. Main features of the new service are following:

- Using numerical simulation,
- Estimated tsunami height being available in a specific number,
- Subdivision of the previous 18 tsunami forecast regions into 66.

This paper is intended to show the outline and the performance of the new tsunami forecast service.

2. OUTLINE OF THE NEW TSUNAMI FORECAST SERVICE

2.1 Application of numerical simulation to tsunami forecast

Over the past few decades a considerable number of studies have been made on the method of tsunami numerical simulation. It has been very difficult, however, to apply it to tsunami forecast, which ought to be issued within a few minutes after the occurrence of an earthquake. The reason is that numerical simulation is very time-consuming. Even if you begin the simulation just after the occurrence of an earthquake, it cannot be completed before tsunami arrival.

The JMA has made it possible to apply tsunami numerical simulation to tsunami forecast by a new scheme (Tatehata, 1998a). Heights and arrival times of tsunamis have already been computed by

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numerical simulation for a large number of earthquakes, of which fault planes with various magnitudes and depths were located as Fig.1, and a database set have been made of the computed results. When a large earthquake occurs, appropriate tsunami heights and tsunami arrival times are searched from the database immediately, and the tsunami forecast is issued.

Just after an earthquake occurs, its hypocenter and magnitude are only information that can be obtained about it. We need, however, a fault plane model of an earthquake for tsunami numerical simulation. Hence, a fault plane is set up from the hypocenter and magnitude of an earthquake using the following assumptions (hereafter, referred to as "Model-V"):

- The length (L), width (W) and slip (D) of a fault model are related to the magnitude (M) of an earthquake as follows.
  $\log L = 0.5M - 1.9$
  $\log W = 0.5M - 2.2$
  $\log D = 0.5M - 3.2$
- The dip (δ) and slip (λ) angles of a fault plane, which are uniform everywhere, are as follows.
  $\delta = 45^\circ$
  $\lambda = 90^\circ$ (reverse fault)
- The strike of a fault is parallel to the trenches (or the coastline).
- A hypocenter is located at the center of a fault plane.

The JMA has done computer simulations for about 100,000 fault plane models set up in the way mentioned above. With a view to obtaining the average tsunami height along a 20 or 30km-long coastline, tsunami heights at the shore were calculated by Green's formula, as shown in Fig.2 (Tatehata, 1998b).

2.2 Forecast of tsunami height

Three types of tsunami bulletins were issued in the previous service (Table 1). As shown in Table 1, "Major Tsunami", for example, one of tsunami forecast bulletins, implied only that the height of tsunami was expected to be more than 3 meters in the worst places and did not show the height quantitatively. Consequently, it was not sufficient information for disaster prevention organizations to decide adequate measures for tsunami disaster mitigation.

The new tsunami forecast service provides the expected tsunami height for each tsunami forecast region in a specific number such as "3m", "4m" or "6m", in addition to the categorized bulletins "Major Tsunami", "Tsunami" or "Tsunami Attention" (Table 2). Using the new forecast, they can decide the detailed countermeasure for tsunami disasters.

2.3 Subdivision of tsunami forecast regions

The JMA had divided the entire Japan coast into 18 tsunami forecast regions, the average length of which was several hundred kilometers (Fig. 3a). Hence, sometimes only part of a tsunami forecast region was struck by tsunami when a tsunami warning was issued for the entire tsunami forecast region. In consequence, disaster prevention organizations often had to take excessive countermeasures.

With a view to fitting tsunami forecasts to real tsunami phenomena and making names and sections of the forecast regions understood easily by residents, the JMA has subdivided the previous 18 tsunami forecast regions into 66 regions, roughly each prefecture corresponding to one of the regions, in the new tsunami forecast service (Fig 3b). With this subdivision, tsunami forecasts are expected to fit tsunami phenomena much better than the previous forecast.

3. PERFORMANCE OF THE NEW TSUNAMI FORECAST SERVICE

Performance of the new tsunami forecast service was investigated by comparing calculated tsunami heights and observed ones with the following tests.

3.1 Correlation with configurations of coastlines

From the feature of a configuration, the entire Japan coast was divided into six categories, island, cape, rias coast, large bay (over several ten kilometers size), small bay (under several ten kilometers size) and other configuration. On each of the categories, the geometric mean and variance of the ratio between calculated tsunami heights and observed ones are shown in Table 3 using observation data of 27 earthquakes which occurred near Japan Islands from 1896 to 1996. The list of earthquakes used in this test is presented in Appendix 1.

In order to reduce the influence due to the situation that the fault planes used for the calculation of tsunami heights were different from the actual fault planes, reliable fault models estimated from seismic wave data and/or other observed data (hereafter, referred to as "Model-R") were used for tsunami height calculation instead of Model-V in this test.

Table 3 indicates that observed data tends to be higher than calculated ones in "island" area, while smaller in "small bay" area.

3.2 Correlation with earthquake source areas

Using the same earthquakes data as listed in Appendix 1, the geometric mean and variance of the ratio between calculated tsunami heights from Model-R and those from Model-V about earthquakes occurring in each source area are presented in Table 4. Earthquakes in the Nansei-Shoto area or the Japan Sea tend to cause larger tsunamis than those expected from Model-V, while earthquakes in the Pacific except the Nansei-Shoto area tend to cause smaller ones.

3.3 Influences of the relative location of a hypocenter to the earthquake fault and the error of the strike of the fault

Although hypocenters are assumed to be located at the center of the fault planes in Model-V, it is possible for an actual earthquake hypocenter to be located anywhere on the fault plane. If an actual hypocenter is located at the edge of the fault plane, a tsunami height at each observation point differs from a calculated value using Model-V even though the whole tsunami size is the same.

In Model-V, the strike of a fault plane is assumed to be parallel to the trench (or the coastline). As a result, a tsunami height at each observation point differs from a calculated one too, if an actual strike is different from that of Model-V. Figure 4 shows the distribution of the difference between the strike of an actual fault and that of Model-V. Since the differences of 83% earthquakes of all are within 25 degrees, it seems reasonable to suppose the error of the assumed strike to be 25 degrees.

The numerical experiments were done to estimate the influence of these assumptions. The location of a hypocenter was fixed and the relative position of the fault plane was moved as shown in Fig. 5. At the same time, the strike of the fault plane was shifted to –25, 0 and 25 degrees relative to that of Model-V. Tsunami heights at each observation point calculated from these 18 trial fault models were compared to those of Model-V for earthquakes with various locations and magnitudes. Fig. 6 shows the geometric variance of the ratio between tsunami heights of those trial models and those of Model-V versus the epicentral distance to an observation point for each magnitude. The variance is small for an observation point far from an epicenter, while large for a point near to the epicenter and increases with the magnitude. Figure 7 shows, on the other hand, the variance of the ratio between the maximum value of tsunami heights for each trial model and that of Model-V. The variance is approximately constant, 1.2, for all the magnitude.

These results can be explained by the following consideration. At a point far from the epicenter, the variation of the tsunami height between each trial model and Model-V is small, since the effect of the change of the fault plane location is relatively small. It grows relatively larger with an observation point getting near to the epicenter. It also grows larger with the magnitude of an earthquake, because the size of the fault plane grows larger in keeping with the magnitude.

On the other hand, the whole tsunami size of each trial model is nearly as large as that of Model-V. For this reason, the maximum tsunami height of each trial model is not so different from that of Model-V, although a tsunami height at each point is quite different.

4. CONCLUSION

It depends on its accuracy whether the new tsunami forecast service is effective to mitigate tsunami disaster. The accuracy can be improved by correcting the calculated tsunami heights using the result of performance tests mentioned above. We intend to improve the accuracy of the forecast further by investigation of appropriate correction and making the computational method better.

5. References

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