## Feature Summary

### Earthquake information

- Automatic processing of earthquake information (origin time, location, depth, magnitude and MT/CMT solutions)
- Direct connectivity to SeisComP3
- Access to historic events from SeisComP3 database

### Tsunami Simulation

- Support for EasyWave ("on the fly" calculation on CPU/GPU)
- Calculation of sea surface height (SSH), SSHMax, isochrones, arrival times and coastal wave heights
- Automatic and interactive rupture area generation
- Aggregation of scenarios (also from different sources) to determine overall worst case
- Displacement simulation
- Output in Surfer Grid Format (.grd) for further analysis

### Faults

- Configurable fault information
- Definition of fault parameters (dip, slip) for automatic rupture generation
- Linear dip of faults
- Fault editor providing import of ASCII data

### Point of Interest (POI) configuration

- Configuration of different sensor types (tide gage, buoy, etc.)
- Different symbols per POI type

### Bulletins

- Automatic bulletin generation based on pre-configured templates
- ASCII and HTML export

### Sensor data acquisition

- IOC web plug-in (tide gage)
- SeedLink plug-in
- gempa data acquisition server plug-in for real-time and historic tide gage data

## Graphical user interfaces

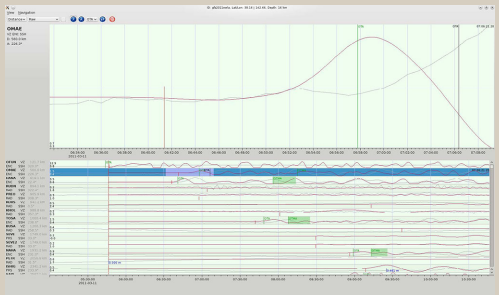


**Figure 5** The manual picker allows to pick observed manual onsets, observed amplitudes and observed periods.

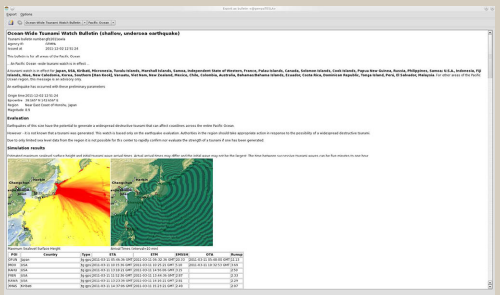
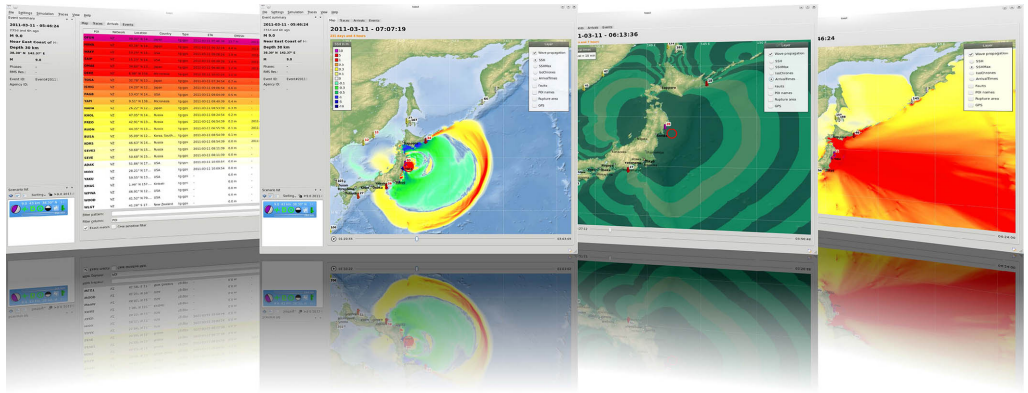


**Figure 6** Bulletin for the Tohuku earthquake and subsequent tsunami

# TOAST

developed by gempa GmbH



## Applications

- Tsunami early warning
- Tsunami simulation
- Oceanographic data visualization
- Interactive tsunami onset, amplitude and period analysis
- Bulletin generation
- Hazard analysis



## Features

- Direct connectivity to SeisComP3
- Automatic reception of earthquake information
- simulation "on the fly" with optional GPU calculation
- Calculation of SSH, SSHMax, isochrones, arrival times, coastal wave heights
- Automatic and interactive generation of rupture area
- Aggregation of scenarios to determine overall worst case
- Configuration of POIs with different types of sensors (tide gage, buoy, etc)
- Generation of bulletins based on predefined templates
- Video output of simulation
- Integration of oceanographic sensor data
- Automatic tsunami onset detection

## Introduction

TOAST (Tsunami Observation And Simulation Terminal) is commercial software for tsunami simulation and verification giving a quick hazard assessment. The results can be verified by oceanographic sensors such as tide gages or buoys. TOAST is developed by gempa GmbH, a spin-off from GFZ Potsdam (developer of the real-time earthquake processing and analysis system SeisComP3 ). gempa is part of the SeisComP3 development group and is working within the German Indonesian Tsunami Early Warning System (GITEWS) project. During the development of the GITEWS software used by BMKG in Jakarta it soon became apparent that the system was complex and specialized to an extent which made it hard to offer to other institutes. Therefore gempa started the development of TOAST, a very flexible tsunami early warning software with high scalability. TOAST is the perfect complement to SeisComP3 for the implementation of a fully functional tsunami warning system.
TOAST is optimized for its application *Tsunami Early Warning*. While conventional tsunami early warning systems are based on huge databases of pre-calculated scenarios. By default TOAST uses an "on the fly" simulation approach. Because of this approach TOAST can react on any atypical events, for example earthquakes in unconsidered areas or earthquakes with untypical rupture mechanisms. Additional to this "on the fly" simulation simulation TOASTs flexible simulation interface also allows integration of existing pre-calculated scenario databases.

## Features

TOAST connects to a SeisComP3 system and listens to the incoming earthquake parameters. In case a hypocenter and magnitude arrives, TOAST uses a Wells & Coppersmith (1984) formula to generate the rupture size based on magnitude. By default the rupture area is centered around the epicenter, and the strike and dip information is derived from pre-configured fault information. Once the rupture area is generated the simulation plug-ins are triggered. By default EasyWave, an "on the fly" simulation, is used. But plug-ins for different simulation algorithm also exist including plug-ins for precalculated tsunami databases.

The rupture area can be placed at several pre-configured positions relative to the hypocenter and simulations for several positions can be calculated "on the fly" in parallel. As the earthquake information is changing over time, with each relevant update new simulations are triggered automatically. But also rupture areas can be generated manually and simulations using these can be started.
TOAST provides different perspectives showing the results of the simulation. They show the following features:

- Time dependent simulated Sea Surface Height (Figure 1)
- Simulated maximum Sea Surface Height (Figure 2)
- Simulated Isochrones
- Simulated tsunami travel times (Figure 3)
- Estimated tsunami arrivals
- Estimated tsunami coastal wave height (Figure 4)
- Observed tsunami arrivals through manual onset picking (Figure 5)
- Observed tsunami Wave Heights and Periods through manual picking
- Points of interest and oceanographic sensors
- Fault information
- Rupture area
- Earthquake parameters
- Simulation progress
- Simulation quality
- Bulletin (Figure 6)

To verify the simulation results, TOAST provides a manual tsunami onset picker, which allows to pick onsets, amplitudes and periods based on real-time tide gage observations. The observerd information is then used to calculate a scenario quality which represents how well the simulated and observed values match. For example the quality of the oceanographic sensors is indicated by the color of the tide gage symbol in the simulation widget (upper right corner in figures 1-5). The simulation widget shows these quality parameter not only for the tide gage data, but also for epicenter location, depth, magnitude, comparision with pre-configured rupture mechanisms and existing moment tensors. The quality information can change with time as it compares the simulation information with the actual earthquake information.

## Graphical User Interfaces

**Figure 1** Sea surface height (SSH) and tide gage stations with wave height and arrival times.

**Figure 2** Maximum sea surface height (SSH-max)

**Figure 3** The alternating colors are showing the arrival times. Every change in color represents 10 minutes

**Figure 4** Tsunami arrival table, the tsunami wave height is indicated by colors from dark purple, red, orange, yellow