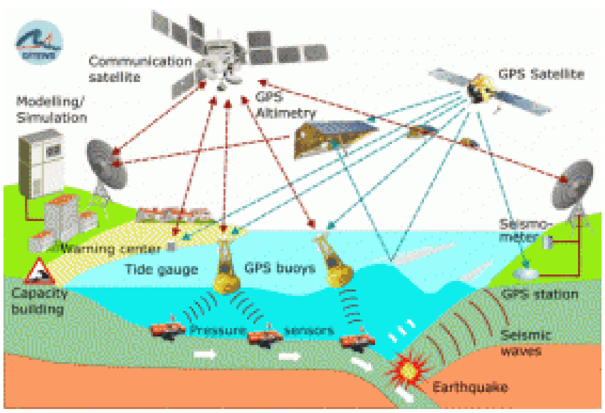
A new approach in tsunami-early warning

November 10 2008



GITEWS components

The newly implemented Tsunami Early Warning System for the Indian Ocean, GITEWS, goes into operation today and with this, the system enters its final phase of optimisation. As foreseen, the system was officially handed over to the BMKG (Meteorological, Climatology and Geophysical Agency of Indonesia) by the President of Indonesia, Susilo Bambang Yudhoyono, in the Indonesian capital Jakarta, slightly less than four years after the catastrophe of 2004.

“We are very pleased to put the Tsunami Early Warning System into operation today, exactly on schedule”, explains Professor Reinhard Huettl, Chair of the Scientific Executive Board of the responsible GFZ - German Research Centre for Geosciences. “All partners have, through enormous effort and dedication, contributed to achieving today’s result. And for this, I would like to sincerely thank all those involved”.

This system differs from previous Tsunami Warning Systems through new scientific procedures and technologies. Due to the unique geological situation in Indonesia it turned out that the systems used up to now, such as the Pacific Tsunami Warning System, for example, are not at all optimal for Indonesia. Earthquakes in the Indian Ocean off the coast of Indonesia occur along a subduction zone, the Sunda Arc, which extends in the form of an arch from the north western corner of Sumatra to Flores in the east of Indonesia. Should a tsunami occur here, the waves, in an extreme case, will reach the coast within 20 minutes, so that only very little time remains to warn the areas at risk. This prevailing situation formed the basis when developing the concept for the entire system.

So new procedures for the fast and reliable determination of strong earthquakes, the modelling of tsunamis and the assessment of the situation have been applied in the Warning System. In particular, the direct incorporation of abroad variety of different sensors for a secure determination of a tsunami is a big challenge.

Progress in the scientific seismology

More than 90% of all tsunamis result from strong earthquakes. The catastrophe of December 2004 was, with a magnitude of 9.3, the second largest earthquake ever registered. One quarter of an hour after the quake, the tsunami reached the province of Banda Aceh and resulted alone here in the death of more than 140,000 people. In total approximately a quarter million people lost their lives.

A fast and accurate determination of the earthquake parameters (location, magnitude, source depth) is, therefore, essential for a fast Tsunami Early Warning System. A compact measuring network shortens, on the one hand, the time for the shock wave to reach the measuring instrument. On the other hand, however, it is extremely difficult to register and to evaluate the signals of strong earthquakes in the near field. New measuring and evaluation procedures were, therefore, developed for GITEWS.

SeisComP3 is the name of the software programme developed by scientists at the GFZ which, within minutes, determines the location and the magnitude of an earthquake. In this way several strong earthquakes and their individual parameters could already be determined within a good two minutes. The entire seismological network in Indonesia currently avails of over 120 stations. This evaluation software sets new standards worldwide. SeisComP3 is also meanwhile used by other neighbouring states of the Indian Ocean, for example in the Indian Early Warning System. And in addition this software is further applied on the Maldives, in Pakistan, in Thailand and in South Africa with other countries ready to follow.

Tide gauge measurements and deformation

In deep water a tsunami spreads at the speed of jet aircraft. The tsunami first slows down in shallow water and, in coastal areas, can swell to waves of up to 30 metres high. It is, therefore, extremely important to detect a tsunami in advance, for example at an offshore island, before the wave reaches the mainland. Through the GITEWS-Project, within the framework of UNESCO's Intergovernmental Oceanographic Commission (IOC) a total of 9 measuring stations have been erected in the Indian Ocean. Thus, not only reliable sea level data are available for the coast of Indonesia, but also for the neighbouring states of the Indian Ocean. The data are freely accessible in data bases.

During the catastrophic earthquake of 2004 a horizontal and vertical displacement of several decimetres to meters was evident even at a distance of some hundred kilometres from the quake. The direction of this resulting shift gives reference to the mechanism of the earthquake break and thus to the possible tsunami potential and the expected hazard.

In order to determine the vertical and horizontal displacement immediately, all tide gauges within GITEWS have been additionally equipped with GPS receivers - this too is a completely new component of a Tsunami Early Warning System.

GPS Buoys: A new measuring instrument for Tsunamis

Not every earthquake generates a tsunami. For this reason it must be determined at sea whether or not an earthquake has actually triggered the deadly wave. For this purpose underwater measuring units are usually used where a pressure gauge is employed to record a tsunami. If a tsunami passes the pressure gauge the data are sent to buoys at the surface and passed on from there to a the central warning centre.

If the ocean bottom units lie too closely to quake source, the instruments cannot differentiate between an earth quake and a tsunami wave and could possibly release a false alarm. Consequently, the buoys do not only function as a relay station but also as an independent measuring instruments for tsunami detection. GFZ scientists already used GPS-antenna on buoys to determine sea motion and sea levels. In the GITEWS this new development is also used to detect tsunami waves which with speeds of up to 800 km/h and wavelengths of 200 kilometres in the open sea, are still relatively low. Innovative measuring and filter procedures allow the normal sea motion data to be suppressed. A centimetre-exact determination of the rise in the sea level remains and herewith also the early detection of a tsunami wave.

Currently 2 of the planned 10 buoy-systems are installed and a further 4 buoys are waiting in the port of Jakarta for installation.

Simulations

As the sensor network supplies data at some few points only, simulations are needed, in order to synthesize an overall picture of the situation. In this way, with the help of computer model for the ascertainment of arrival times and wave heights as well as information on the inhabitants and infrastructure, fast risk estimations can be reached which in turn support the decision to issue a warning.

On the basis of the extremely short advance warning time the computer simulations are pre-calculated with the help of the new software TsunAWI which is based on unstructured triangle lattices. This modelling system developed at the Alfred-Wegener Institute for Polar and Marine Research depicts the wave propagation and flooding in a, to date, unique way. A multitude of scenarios covers the possible tsunami events, so that in the case of an emergency a pre-computed scenario serves to help depict the actual real situation.

The data base, which evaluates the different measuring data with mathematical methods putting this, in turn, in relation to possible scenarios (so-called matching), represents a world-wide innovation. Since data from the different measuring systems complement each other, a precise matching can be made within seconds, and an exact description of the position can be given. The ever improving data availability during a tsunami event continuously stabilizes and completes the picture of actual prevailing condition.

Warning Centre and Decision-making Support

All available data, information and modelling flow finally together into a Decision Support System (DSS). The German Aerospace Center, DLR, has developed this system, which is used in reaching a decision on whether a tsunami warning is to be disseminated or not.

All sensor data are gathered within the DSS, all instruments are controlled and steered from here and it is also here that the synthesis of all data follow with the pre-computed simulations as well as the creation of the warning. The responsible person on-duty can on the basis of the available information, very quickly get an overview of the situation and generate suggestions on how to reach a decision. The depiction of the situation together with the recommendations for action is shown on several monitors.

DSS is geared to application in a crisis situation and is arranged in such a way that, also, under high time pressure and stress, fast and reliably decisions can be made. Extensive data bases hold, in addition to general geo-data, advanced processed risk information and hazard maps. This system developed here, is unique in its conception and complexity and is not comparable with any other system world-wide.

GITEWS has, from the beginning on, been developed as an integrating system, incorporating not only the data of the German sensor systems, but also sensor data from Indonesia and the other donor countries. Therefore, all interfaces to the sensor- and dissemination system are based on international standards, in order to guarantee for an interlaced and at the same time open system.

Capacity Building

For the technical operation, maintenance of the instruments and the advancement of the system, scientists and technical personnel need to be further educated. This has already been done parallel to the construction of the system through training of Indonesian scientists and engineers in Germany, as well as through various training programs on the part-components of the Early Warning System in Indonesia.

GITEWS cooperates closely with the authorities responsible for early warning, in order to convert the warnings into a clear decision-making basis, decision-making aids and instructions to handle and to pass these onto the population as quick as possible (warning and reaction chain). This interface is crucial for an Early Warning System and represents an enormous challenge in particular for the local governments at the district level, in whose hands the responsibility lies. Within the framework of the national responsibility in the case of natural catastrophe Indonesia has begun to create a suitable legal framework.

The introduction of a Tsunami Early Warning System at the local level requires the development of preparation plans. Their development, in particular for urban centres such as in Padang or in South Bali must be based on scientifically founded risk analyses, but also on political decision processes. Activities of the disaster prevention and preventive measures such as building standards or the creation of area utilisation plans are included here.

The probably most important aspect of early warning is the actual target group for the early warning, i.e. the population in the endangered regions. In order to allow effective measures to be taken at all with extremely short early warning times, the consciousness of the people with respect to the latent endangerment and possible preventive measures must be awakened and strengthened (Awareness), and it must be assured for that in the case of emergency the population reacts correctly (Preparedness). This is achieved by regular evacuation exercises and information sessions as well as by the constant teaching of facts in schools.

International consortium

For the construction of the Early Warning System in Indonesia different cooperations with donor countries such as Japan, China, France and the USA were incorporated so as to not only integrate the data of the German and Indonesian components, but to avail of all available sensors. The German activities essentially concentrated on Indonesia, but also in neighbouring states such as Sri Lanka, the Maldives, Yemen, Iran, Kenya, Tanzania and South Africa components and sensor technology as well as software have already been installed.

The integration of the German-Indonesian contribution and the contributions of further neighbouring states into an overall system for the Indian Ocean takes place under the coordination of the Intergovernmental Oceanographic Commission (IOC) of the UNESCO.

Additionally there are efforts to form a Global Early Warning System in which not only working groups from the Indian ocean participate, but also from the Northeast-Atlantic, the Mediterranean Sea, the Caribbean and the Pacific Ocean. Tasks in the coming two-year optimisation phase

The construction and employment of the complex GITEWS in a tectonically complicated area was and is scientifically, technically and organizationally an enormous challenge. In the now to follow two-year phase of the project the most important steps of the system optimisation will take place. “All components are assembled, even if the sensor network still has to be further consolidated”, says Reinhard Huettl, “and only in the daily operation with the interplay of the different components will it become clear where and how individual elements need to be adjusted.”

As with the launching of a newly constructed ship, now the interaction of the component parts need to be optimised, the personnel needs to be trained and eventual problems in the daily operation need to be dealt with. To date individual components (for example the earthquake module) in the provisional Warning Centre of the BMG in Jakarta have been used. With the completion of a new building, the subsequent installation of the necessary communication and computing hardware, and the implementation of the software components during the past weeks, the system is now available, for the first time, in its designed form.

Directly after the catastrophe of 26. December 2004, the German Federal Government commissioned the Helmholtz-Association, represented by the Helmholtz-Centre Potsdam - GFZ German Research Centre for Geosciences, with the development and implementation of an Early Warning System for Tsunamis in the Indian Ocean. Funds amounting to a total of 45 Million Euro represent the contribution of the Federal Government within the framework of the Tsunami Victim Aid.

Even with a perfectly working warning system a natural occurrence such as the tsunami of 2004 cannot be prevent and such catastrophes will continue to cause victims. However, with an Early Warning System the impact of such a natural catastrophe can certainly be minimised. And that is the goal of GITEWS.

Source: Helmholtz Association of German Research Centres

Citation: A new approach in tsunami-early warning (2008, November 10) retrieved 26 April 2024 from https://phys.org/news/2008-11-approach-tsunami-early.html

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