German-Indonesian Tsunami Early Warning System

The
German Contribution to the Tsunami Early Warning System for the Indian Ocean

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C O N T E N D S

P R E F A C E

The extreme natural disasters of recent years such as earthquakes, volcanic eruptions, flooding, and last but not least, the tsunami in the Indian Ocean have shown us that modern societies are becoming increasingly vulnerable. Prevention against all types of natural hazards is now more important than ever before. Early warning is therefore a top priority for science and research. It helps us to protect human lives and avoid major damage to the economy and society.

German research institutions have developed within a very short period of time a modern tsunami early warning system which is to be realized within three years. It is based on tried and tested cutting-edge technologies. Less than twelve months after the disaster, it was possible to install the first measuring facilities such as seismometers, tide gauges, GPS buoys and ocean floor equipment for the early warning system in Indonesia. Our good scientific relations with Indonesia are based on many years of trusting cooperation within the framework of the STC Agreement signed in 1979.

Acting quickly after the tsunami disaster in December 2004, Germany was able to assist the people in Indonesia and the Indian Ocean rim countries and provided hope and confidence. German reconstruction activities in the tsunami region are supported with 500 million, of which 45 million are spent on the establishment of a tsunami early warning system.

The international community has commissioned the Intergovernmental Oceanographic Commission of UNESCO to coordinate the establishment of a tsunami early warning system for the entire Indian Ocean. Germany and Indonesia are making substantial contributions to this system, which will also benefit all other countries bordering on the Indian Ocean. The data generated by the German-Indonesian early warning system will be available to all countries, for use in issuing their own national warnings. All countries in the region are therefore invited to contribute to an early warning system covering the entire Indian Ocean.

In the future we will need more advanced early warning systems to warn against other natural hazards and reduce the risk for those affected. The German Government will initiate the necessary steps.

Annette Schavan

Dr. Annette Schavan
Federal Minister of Education and Research

A CLEAR SIGNAL

The Way to a German-Indonesian Tsunami Early Warning System in the Indian Ocean

After the severe earthquake off Sumatra on 26 December 2004, a tsunami hit the coasts around the Indian Ocean. More than 230,000 people lost their lives. Waves, many metres in height, destroyed 600,000 houses, and around 1.8 million people were made homeless.

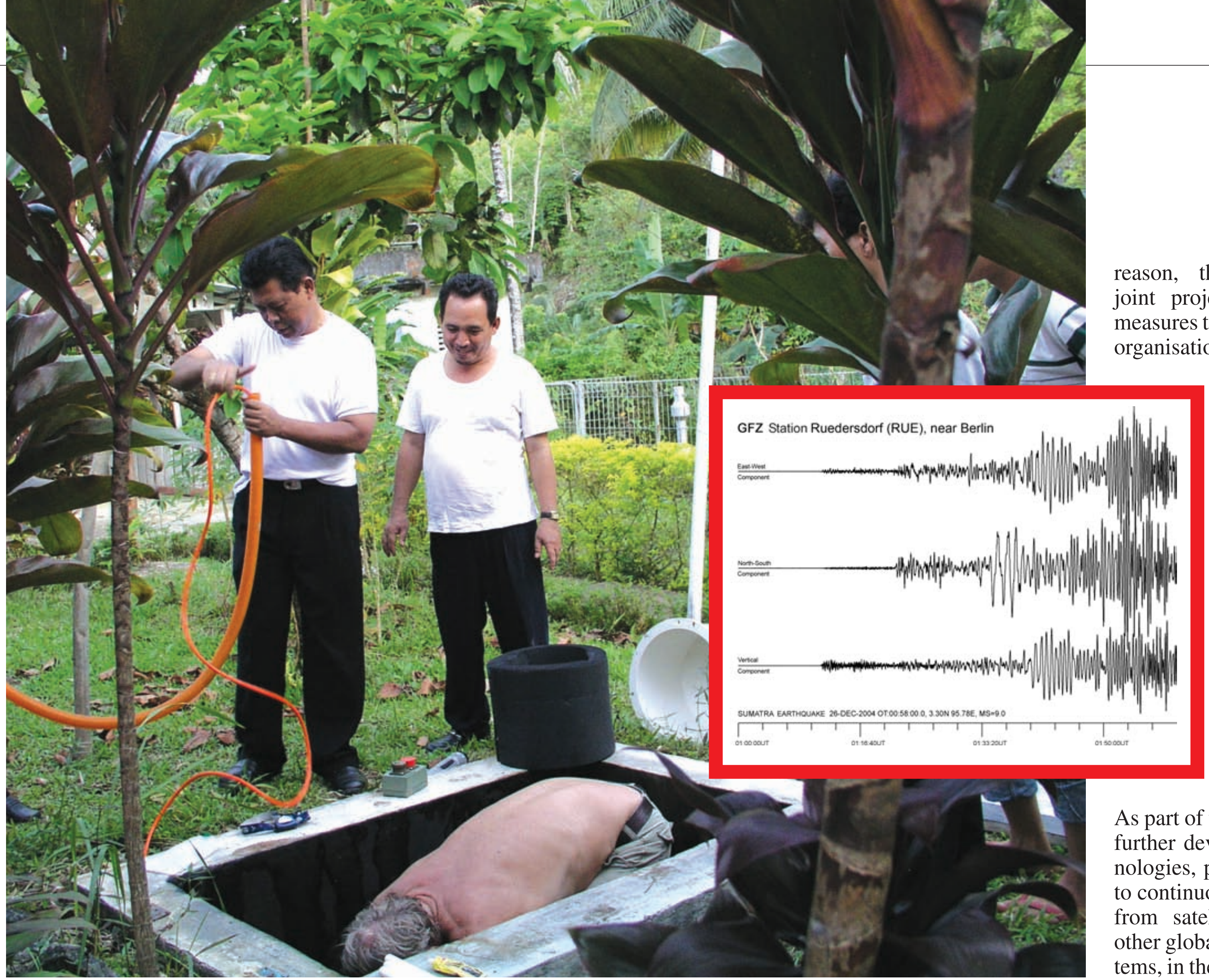
Germany was quick to agree aid for rebuilding in the region. In addition, everything was to be done to ensure that such a disaster does not happen again. A consortium of German research institutes developed a concept for a tsunami early warning system in the Indian Ocean. In a joint declaration of 14 March 2005, Indonesia and Germany agreed to set up such a system to be coordinated by the UNESCO Intergovernmental Oceanographic Commission (IOC).

Most tsunamis are preceded by a clear signal in the form of a major earthquake. Thus the warning system is based on a dense network of seismometers. The instruments are distributed in such a way that in the Sunda Arc, the point of origin for the greatest risk of a tsunami in the Indian Ocean, any earthquake can be recorded within two minutes at a minimum of three instrument locations. The first German measuring stations were installed on land as early as 2005.

Also in 2005, the German research vessel "Sonne" deployed the first oceanographic measuring devices in the Indian Ocean to carry out related tests. Their purpose is to provide early detection of a tsunami. Pressure sensors, anchored on the ocean floor along the Sunda Arc, indicate the passage of a tsunami wave, where it is not just the sea surface that rises and falls, but the entire column of water right down to the seabed. The sensors send their data to buoys on the surface. These buoys also detect current sea levels using a second, independent method - the Global Positioning System (GPS).

The First Steps

...from recording the earthquake of 26 December 2004 with the GEOFON network and building the first seismic station on the island of Nias (June 2005), to handover of the first tsunami buoys to Indonesia in Hamburg in August 2005, and deploying them into the water off the coast of Sumatra in November 2005.



To be able to quickly assess the situation, a national warning centre is being set up in Jakarta. In an emergency, it falls back on the computer simulations that have previously been calculated for conceivable tsunami events. These generate the possible consequences for individual sections of the coastline. The aim is to be able to transmit a warning after around ten minutes via clearly defined communications pathways.

The sensors are to be installed and the data centre ready for operation by the end of 2008. A two-year operating phase with German support is then envisaged. A comprehensive training and in-service training programme for scientists, technicians and managers shall ensure efficient operation, maintenance and ongoing development of the system.

In 2010 the tsunami early warning system will be handed over in its entirety to the Indonesian government. Its purpose is to provide rapid and reliable information to the population at risk. Here the greatest challenges are rapid transmission of a warning in the event of a disaster. For this reason, the German-Indonesian joint project involves extensive measures to help regional and local organisations develop evacuation plans and educate the population about the dangers of tsunamis, as well as escape options.

The tsunami early warning system for the Indian Ocean should be seen as part of a warning system whose purpose is to detect other natural disasters such as earthquakes, volcanic eruptions and storms. The data acquired is to be made available to all littoral states. As part of the project, there will be further development of new technologies, particularly with respect to continuous sea level monitoring from satellites. Interlinked with other global Earth observation systems, in the future they could make an important contribution to warning coastal inhabitants well in advance of disasters, and improving our understanding of the environment in terms of climate change.

WAVE OF TERROR

Sunday 26 December 2004 - Disaster Log

At 01:59 hours CET (07:59 hours local time), 150 kilometres off the island of Sumatra the earth opens up deep underneath the sea. The second largest earthquake ever recorded sends tremors through Indonesia and the coastal region around the Bay of Bengal. It reaches 9.3 on the Richter scale. No less than 10,000 kilometres away in Europe, earth movements of one and a half centimetres are recorded. But it is not the immediate effect of the quake - the destruction of houses and bridges - that turn it into one of the worst natural disasters in the history of mankind, but the tsunami which it triggers. In the hours that follow, waves several metres high crash over the beaches of the Indian Ocean as far as East Africa. They are even recorded in the Atlantic and the Pacific.

02:14 hours: Indonesia is hit the hardest by the tsunami. The breaking waves lay waste to the northern coasts of the island of Sumatra, even tearing down reinforced concrete buildings that meet modern building standards. In Banda Aceh the waves drag 30,000 people to their deaths, and in the outlying district of Meuraxa only 10,000 of its former 40,000 inhabitants survive. According to official estimates, the tsunami claims 170,000 dead in Indonesia alone, and more than 550,000 are rendered homeless.

03:45 hours: The tsunami reaches Sri Lanka. In the east and south of the island the waves destroy 100,000 houses; 35,000 people die, and more than half a million lose their homes and all their worldly possessions. Around the same time, South West Thailand is also inundated, particularly the province of Phang Nga and the tourist regions around Phuket. Among the 8,000 dead and missing are 2,500 foreign nationals from 30 countries.

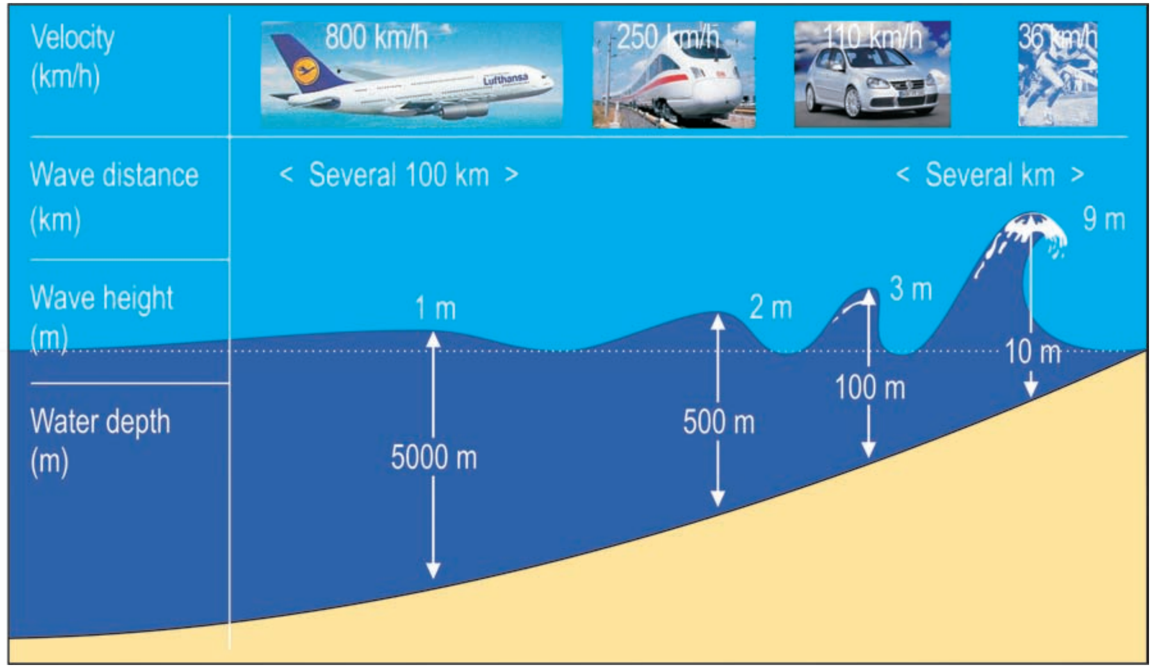
04:45 hours: Although almost three hours have passed since the earthquake, the tsunami also strikes the population of India after previously inundating the Andaman and Nicobar islands. More than 18,000 people drown in the tsunami waves, which rise to heights of up to six metres in the most severely devastated district of Nagapattinam. As a result of the tsunami, more than 600,000 Indians are made homeless.

05:00 hours: The tsunami moves on across the low-lying islands of the Maldives. Two thirds of the economic base of a country living from tourism and fishing is destroyed, and more than 11,000 people become homeless.

Around 09:00 hours: By now the tsunami has also left the Seychelles in its wake and reaches East Africa. Whereas in Kenya most beaches have been able to be evacuated in time, in Somalia around 300 people lose their lives - seven hours after the quake.

The Big Wave in the Harbour

The term "tsunami" (Japanese 津波r harbour wave; from 津 "tsu" - harbour, and 波 "nami" - wave) was coined by Japanese fishermen who would return from a fishing expedition to find their harbours devastated by the sea, even though they had not noticed any unusual wave pass them out at sea. The reason for this is Japan's steep coast, which falls away into deep water. The gigantic waves more or less only start to build up shortly before the shore, and then break over the harbour walls, destroying everything in their path.



THE SUMATRA FAULT ZONE

One of the Earth's Most Turbulent Regions: the Sunda Arc off Indonesia

There can hardly be a region where the forces which shape our planet make themselves felt more greatly than in Indonesia. Two great tectonic plates meet just off Sumatra, and the tensions between them repeatedly result in violent earthquakes. On the fault line between these plates, a volcanic archipelago and an ocean trench have developed.

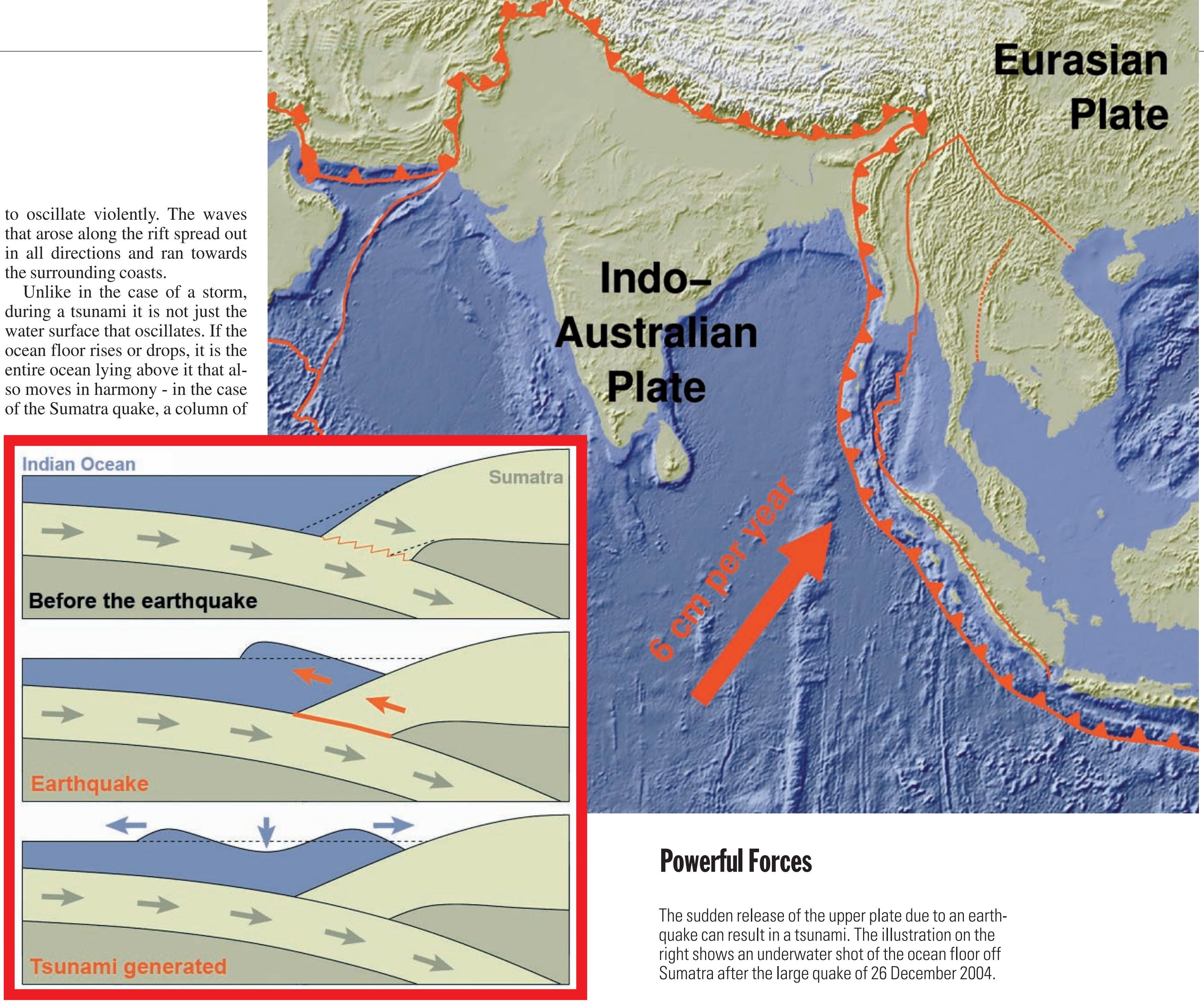
The earth's crust consists of about a dozen such plates. They are in constant motion against each other. The continents are on average 40 kilometres thick, their rocks being over two billion years old. The ocean floor, on the other hand, is at least ten times more recent and considerably thinner. Its rocks are formed at the mid-oceanic ridges and are moved away to the plate edges as if on a great conveyor belt. If an oceanic plate meets a continental plate at its edges, then its relatively heavy rocks are submerged under the latter. They are swallowed up, and their component materials are recycled within the Earth.

In the Sunda trench off Indonesia, the Indian-Australian Plate is moving at a speed of six centimetres a year (hardly faster than it takes for a fingernail to grow), sliding under an appendage of the Eurasian Plate. But this is not happening without resistance. The conveyor belt is shaking. Between the interlinked rocks, stresses develop, and after the passage of many decades these may suddenly be discharged.

On 26 December 2004, the Eurasian Plate suddenly made a quick advance, causing the strongest earthquake ever recorded in this region. In the seabed a crevice yawned open, which within eight minutes, extended for 1,200 kilometres northwards - a fault more or less the same as the distance between Berlin and Rome. Along this fault line the earth's crust was thrown upwards by up to fifteen metres.

The worst consequences were not however produced by the earth tremors themselves, but the tidal waves they triggered - the tsunami. As the quake happened, the ocean floor was lifted in some parts by a few metres, and in others it dropped. This jolting movement made the Indian Ocean start to oscillate violently. The waves that arose along the rift spread out in all directions and ran towards the surrounding coasts.

Unlike in the case of a storm, during a tsunami it is not just the water surface that oscillates. If the ocean floor rises or drops, it is the entire ocean lying above it that also moves in harmony - in the case of the Sumatra quake, a column of water around 5,000 metres in height. This is what accounts for the powerful energy in the gigantic waves and which can be carried over many thousands of kilometres to the surrounding coasts.



Powerful Forces

The sudden release of the upper plate due to an earthquake can result in a tsunami. The illustration on the right shows an underwater shot of the ocean floor off Sumatra after the large quake of 26 December 2004.

On the open seas, the waves that formed off the island of Sumatra were initially only 60 centimetres in height, and with a wavelength of around 250 kilometres they were barely detectable by ships' crews. It was only near the coasts that the tsunami showed its true face. In the shallow coastal waters, the ocean floor acted as a brake on the waves, making them tower up and roll on towards the land. In some areas, the tsunami forced the water many kilometres inland. In Banda Aceh, for instance, 500 metres of coast were simply carried off, washed away, whereas later on a large salt lake developed in the hinterland.

A RACE AGAINST TIME

Overview of the Early Warning System

You do not have to wait long for the first warning signal. During an earthquake, the shockwaves radiate out through the subsurface at breakneck speeds, some of them at 30,000 kilometres an hour. This means that in Indonesia, with the help of a dense network of seismometer stations, you can determine within a couple of minutes whether an earthquake has happened along the Sunda Arc.

Such rapid measurements open up the possibility of giving advance warning of what in certain circumstances is the still greater danger - a tsunami. In comparison to seismic waves, the tidal waves triggered by an earthquake are slow. In December 2004, it took up to one and three quarter hours after the quake until the coasts of Sri Lanka and Thailand were inundated; with proper preparations this gives a lot of time in which to alert the population.

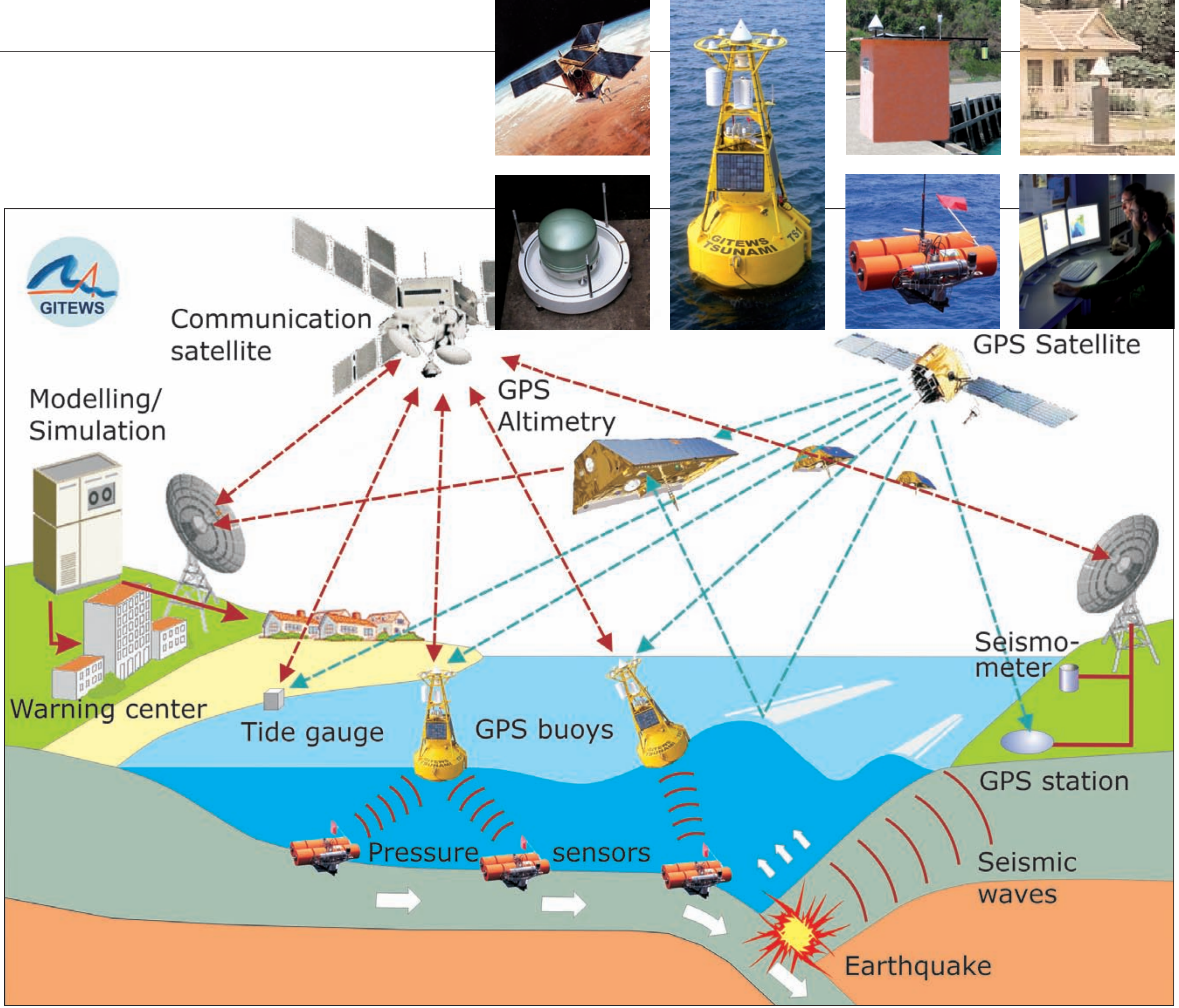
It only took a quarter of an hour, on the other hand, for the tsunami to break over the coast of Sumatra. This is where the great challenge lies when it comes to constructing an early warning system in the Indian Ocean. How to give a reliable tsunami warning within just ten minutes so that it also reaches the inhabitants of the endangered regions of Indonesia in good time?

On the other hand, not every violent earthquake triggers a tsunami. On 28 March 2005, for instance, the ocean floor once again split open off Sumatra during a quake of 8.7. This time a fracture of more than 300 kilometres developed; but contrary to fears, this time it was not followed by the kind of devastating tsunami of three months previously. It would appear that during this earthquake the vertical displacement was only very small.

To be able to alert the population quickly and reliably, the early warning system in the Indian Ocean is therefore based on a combination of several components:

1) The land-supported observation network

Fully automated seismometers monitor the region constantly and are able to detect and locate an earthquake in a very short time, as well as determine its strength. They also trace the faulting process, which may last for minutes. For this, the measuring stations are also equipped with Global Positioning System (GPS) receivers. These give precise determination of the displacement of the Earth's crust (pages 12 and 13).



2) The marine measuring network

Only measurements in the ocean itself can determine whether a tsunami has actually been triggered. This requires a series of buoys along the Sunda Arc. These link up with pressure measuring devices on the ocean floor and also detect the mean sea level via GPS sensors. If waves now run against the coast, their height is once again measured on the offshore islands using tide gauges (pages 14 and 15).

3) Modelling wave propagation

As soon as the measuring instruments have detected a possible tsunami, the next step is to estimate what part of the coast might see the tsunami piling up to a dangerous height and what the estimated time of arrival of the waves might be there. Model calculations of this kind take a lot of time. This is why conceivable scenarios must be generated in advance for the entire region, so that in an emergency the most likely scenario based on the current data is to hand in a very short time (pages 16 and 17).

4) The national warning centre

All the data from the measuring stations converge via satellite on an incident centre in Jakarta. Those responsible at national level analyse the risk and send out a warning if there are signs that a tsunami might follow a large earthquake. This warning is disseminated via predetermined communication channels. It contains details of the likely loss and damage in terms of the population and infrastructure (pages 18 and 19).

5) Alerting the inhabitants, education and organisation

Only well trained staff can use the warning system to its fullest and improve it. The staff can enhance their specialist and organisational skills in training units and workshops, and scientists and PhD students have the opportunity to spend time researching in Germany. As part of this "Capacity Building", the inhabitants are also educated on the dangers of tsunamis and the proper procedures, a process that begins at school and finishes with evacuation exercises (pages 20 and 21).

ALARMING READINGS

The Land-Supported Observation Network

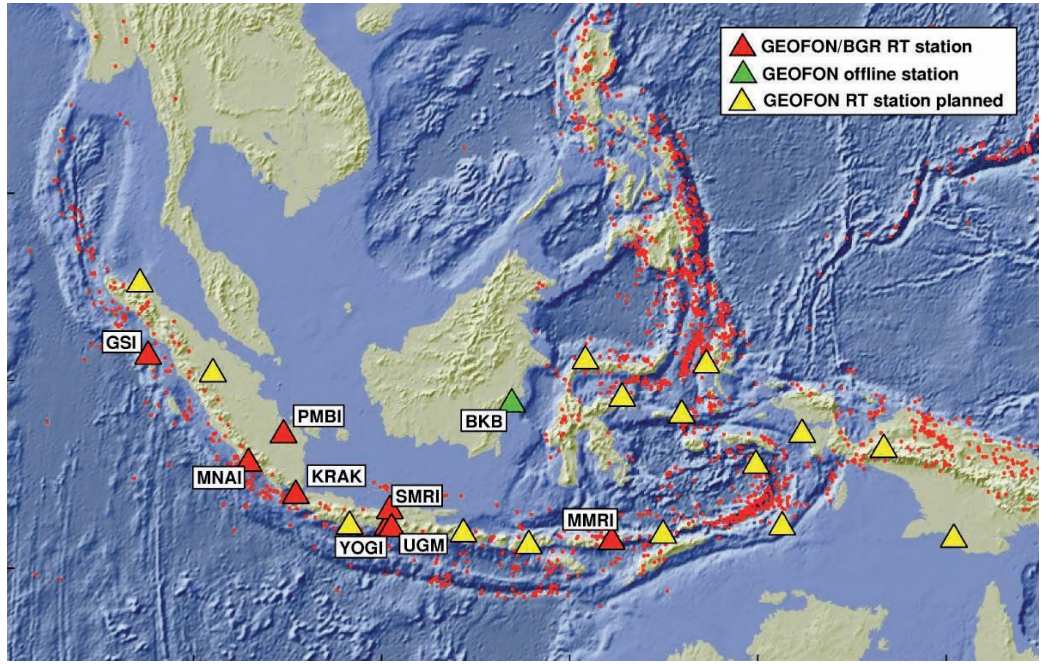
An earthquake is a violent jolt where millions of tons of rock move against each other in a very short time. Part of this energy is distributed into the Earth's centre and in the form of waves across the Earth's surface. These seismic waves may travel around the entire globe a number of times.

Eleven minutes after the December 2004 earthquake, the shock waves emanating from the Sunda Arc reached Europe. The GEOFON earthquake measuring network, developed in Potsdam, automatically recorded the quake and evaluated the data. Only two minutes later - also without any human intervention - an earthquake message was broadcast on the Internet, and e-mails and SMS texts were sent to linked users.

So far, the stations of this network have mainly been concentrated in Europe and linked with measuring networks of other countries. For tsunami early warning, the GEOFON network is being extended in the region around the Indian Ocean. The first four German stations have already been installed in 2005, with 30 to 40 new stations planned, half of which are to be located in Indonesia. In addition, Indonesia, Japan and China are extending their earthquake monitoring system, and measuring locations already in existence are being updated to include automatic operation and satellite communication. The full monitoring system in the region is to comprise more than 100 stations in total.

At the various locations, seismometers constantly measure earth movements over broad frequency ranges, especially along the Sunda Arc, which extends for more than 5,000 kilometres. Many stations are being built parallel to the cost and on the offshore islands. However to obtain the most accurate picture possible of future quakes, distribution by area is also required. Basically, the nearer the stations are to the epicentre, the quicker they record the quake; but equally the harder it is to filter out the relevant information. At more remote stations, the seismic waves do indeed arrive rather later, but it is only these measurements that enable the location and strength of the tremors to be precisely delimited.

It should not take more than one or two minutes to automatically detect and evaluate an earthquake off Indonesia at three or four locations, given the density of measuring devices envisaged. After another two or three minutes a more accurate estimation of the location of the epicentre and of earthquake magnitude becomes possible. The location and strength of an earthquake provide the first indications to suggest the possible occurrence of a tsunami wave. What is now vital for the model calculations is that additional information be provided as quickly as possible as to the direction the rupture in the Earth's crust takes and how long it is.



Realtime Signals

The earthquake stations set up so far (the illustrations on the left) deliver their data via satellite links more or less in real time to the centre in Jakarta. There the information is collected via a great satellite antenna from the whole of the country. The intention is to provide all measuring locations with realtime communication.

Seismometers distributed across a wide area can follow the faulting process throughout the entire earthquake. A supplementary picture of where the greatest displacements in the Earth's crust have occurred will also result from highly accurate GPS measurements. Today, satellite navigation with the Global Positioning System (GPS) allows very precise location detection of any point on the Earth. This procedure therefore also allows us to determine whether the position of islands and sections of coast in the fault zone has changed significantly. In the case of the December 2004 earthquake, for instance, some of the Andaman and Nicobar islands were moved laterally by up to six metres and lifted by a maximum of two metres, whereas in other places they dropped by up to one metre.

An early warning system needs to be able to acquire a rapid picture of shifts of this kind. And so, in future, GPS will constantly record the movements of the earth in the fault zone. The receivers for the satellite signals are being installed on the offshore islands in the Sunda Arc. This combination of two interlinked GPS stations allows minimisation of any potential errors on position calculation.

Along with the equivalent reference stations on the mainland, they provide detailed information on lateral movements and rates of lift and sinkage.

WATCHER OF THE SEAS

The Marine Monitoring Network

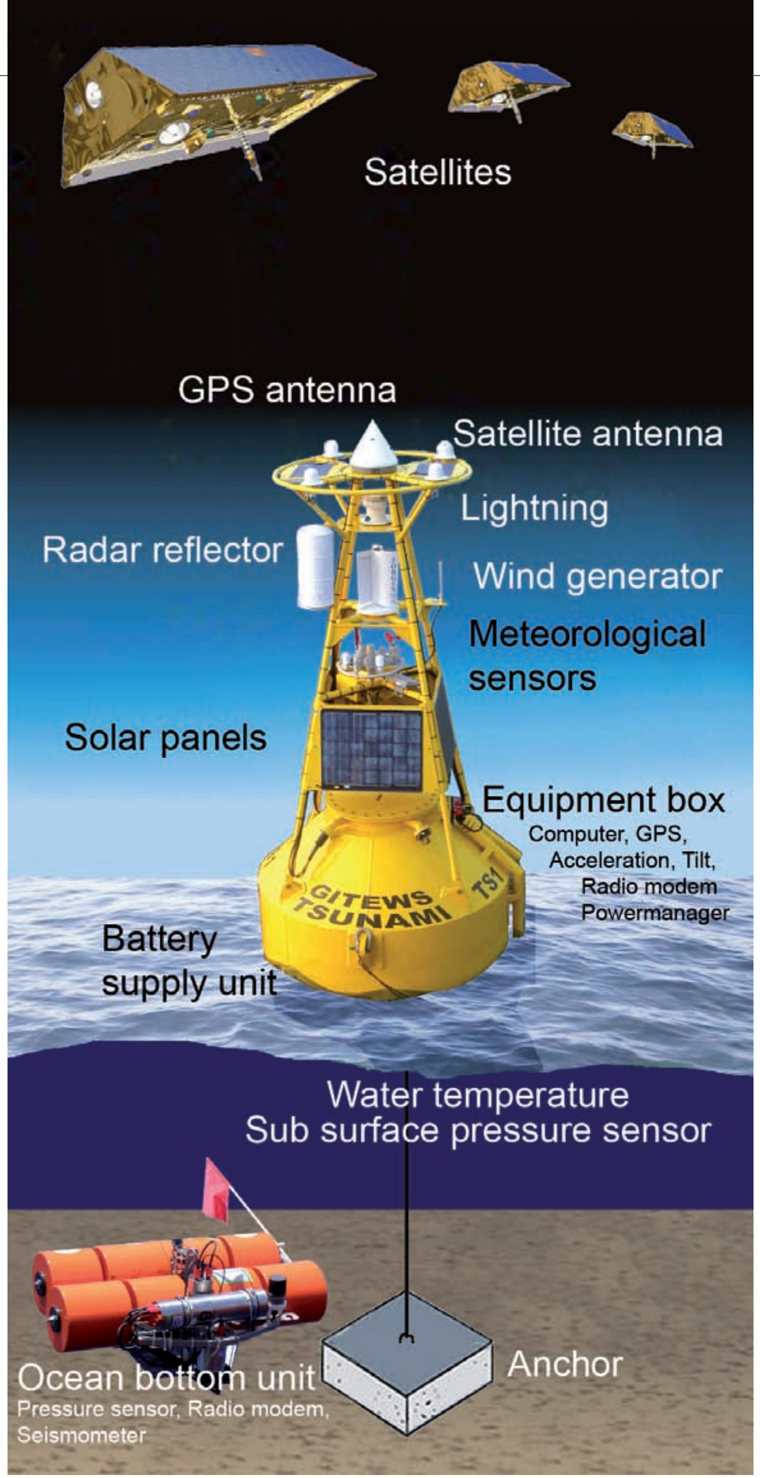
When in November 2005 the German research vessel "Sonne" deployed an almost seven metres long buoy onto the open seas, an important milestone in the construction of the early warning system was achieved. The yellow buoy and its counterpart deep down on the ocean floor are prototypes of the measuring instruments that are to be able to detect a tsunami even when out at sea, i.e. during the formation phase.

The alarm comes from depths of up to 5,000 metres. The underwater unit records the passage of the wave. This is possible because during a tsunami the entire volume of water is set in motion - from the sea surface right down to the ocean floor. Every 15 seconds a sensor on the ocean floor measures the pressure exerted by the column of water above it.

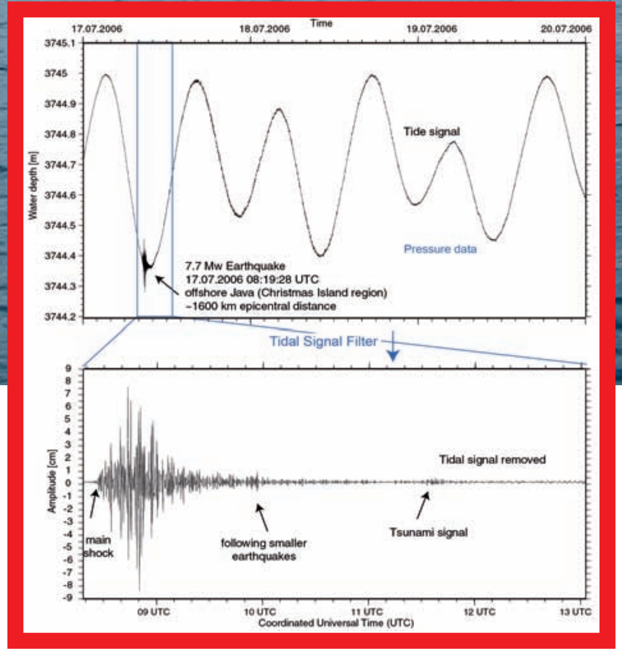
There are good reasons for measuring the tsunami on the ocean floor. A pressure sensor on the seabed can detect sea level fluctuations of a few millimetres. The procedure is elegant because a measuring device at such a depth does not register short-term sea movements. It is blind to small, wind-driven surface waves and only retains the mean water level. The pressure sensor is supplemented by a seismometer, which can immediately detect a quake when it happens.

A number of times each day, the underwater unit transmits the accumulated data to the buoy via an acoustic signal. In an emergency, however, when the water level has exceeded a threshold value, the data is transmitted immediately. The buoy itself is the relay station for data transfer between the measuring device on the ocean floor and a satellite that then relays communication to the warning centre. It also records meteorological factors, and registers for example air pressure and wind speed. Changes in air pressure in particular could simulate a tsunami. This has to be kept in mind when calculating the height of the water, as is also the case with the regular tides.

The early warning system includes ten such buoys and ocean floor units. By the end of 2008 they will form a chain along the Sunda Arc keeping track on the water level around the clock. In addition to the pressure sensors on the seabed a second independent procedure is employed so as to ensure greater reliability of the system - namely GPS devices fitted to the buoys. These communicate with navigation satellites of which there are now many in orbit around the Earth. The distance to the satellite can be calculated from the required runtime of the GPS signals from the satellite to the buoy, and, if the satellite path is known, the mean sea level can also be calculated. The aim is to analyse the data immediately on location at the buoy. In the first phase, however, the desired accuracy of measurement is to be achieved by the buoy interacting with a land-based reference station.



On the open sea a tsunami is only a few decimetres high, whereas on the coast waves several metres high can build up. Here gauge stations are to supply reliable data on the current water level at the time. In the event of a disaster this is an important requirement for targeting rescue measures and giving adequate advance warning to more remote areas. On the seaward side of the islands off the coast of Sumatra, and along the Indonesian coast, the gauge network is being modernised and extended accordingly. In addition, stations with two pressure gauges and a radar gauge are planned, and they will transmit the water level every 15 seconds to the warning centre, as required.



Alarm from the Depths

In 2005 two buoys and pressure sensors were deployed into the water from the research vessel "Sonne". The sensors record signals on the seabed that are sent in the event of an alarm via the buoys to the warning centre.

A COMPLEX BASIN

Modelling Wave Propagation

It was no single impact that set the Indian Ocean in motion on 26 December 2004. The tsunami wave emanated from a 1,200-kilometer long fault. Along this fracture, the waves piled up to form a wide wall of water that ran towards the surrounding coasts and inundated beaches, towns and villages. In certain places the waves were reflected, or else they passed around islands. After the devastating floods, the Indian Ocean carried on reverberating for a whole day.

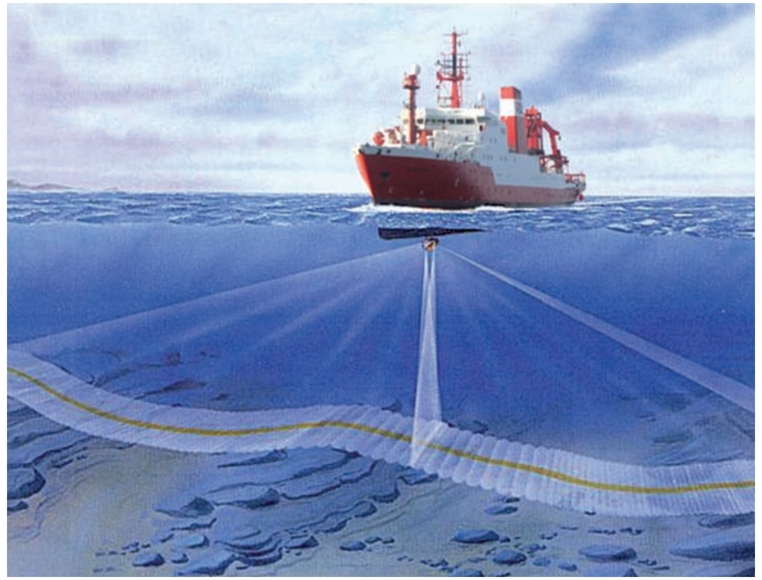
To be able to predict tsunamis, you first need information on the quake. The sea level rises or falls depending on the extent to which the ocean floor rises or drops during the earthquake. The way in which the wave that develops then spreads out and where it finally hits land depend however on the relief of the seabed and its transition to the coast.

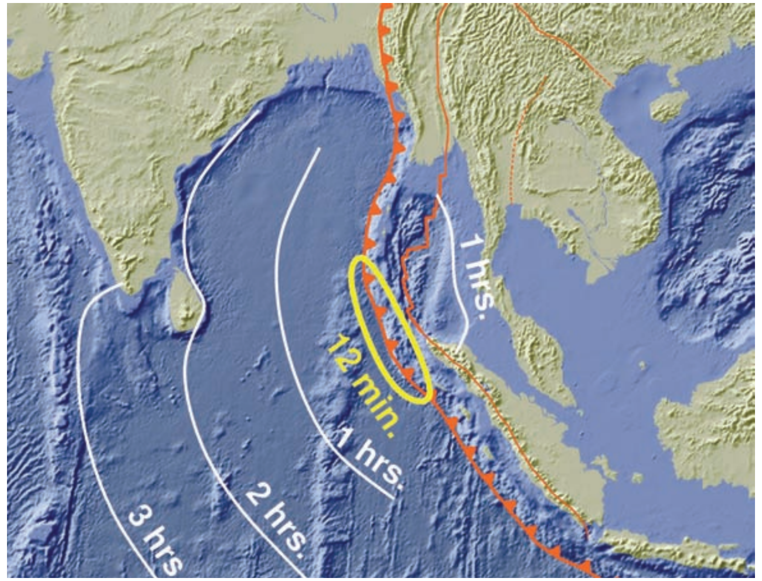
The Indian Ocean is contained in a narrow belt of shallow water - the shelf. Just off this shelf zone, the seabed falls away sharply; up to 4,000 or 6,500 metres deep, depending on the region. The Sunda trench is even deeper in parts. Archipelagos, underwater mountain ranges and ridges divide the ocean into several basins.

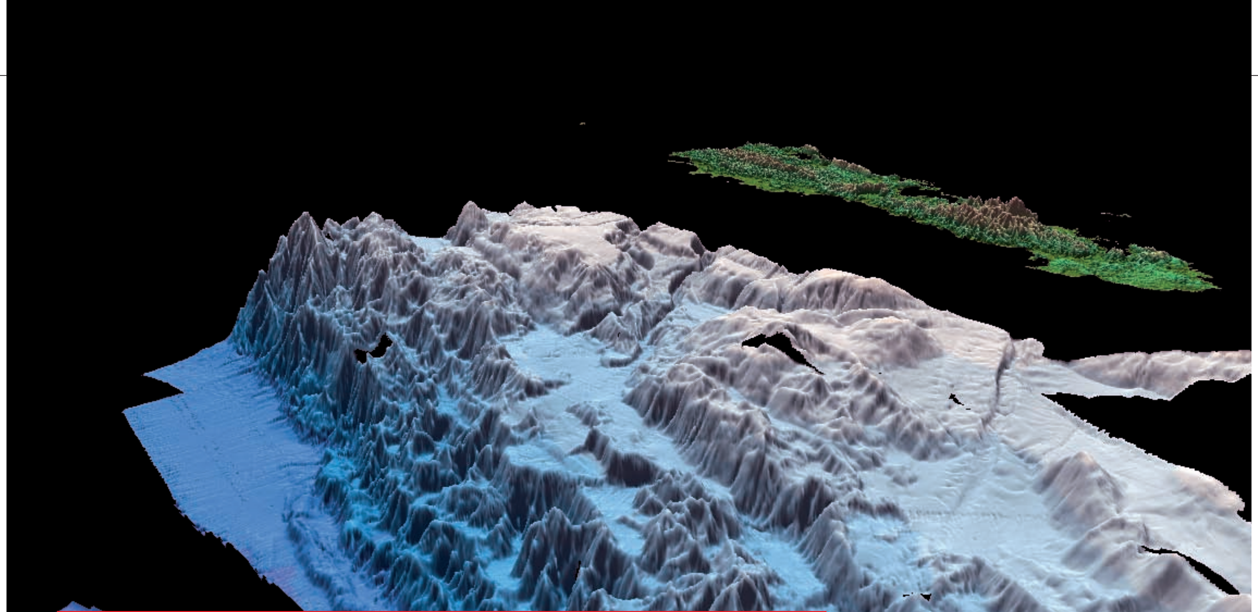
The craggy mountain landscape on the ocean bed is being surveyed, among other features, by the German research vessel "Sonne", to obtain reliable information on water depths. This is because the speed of a tsunami depends exclusively on the depth of water: the deeper the water the faster the wave.

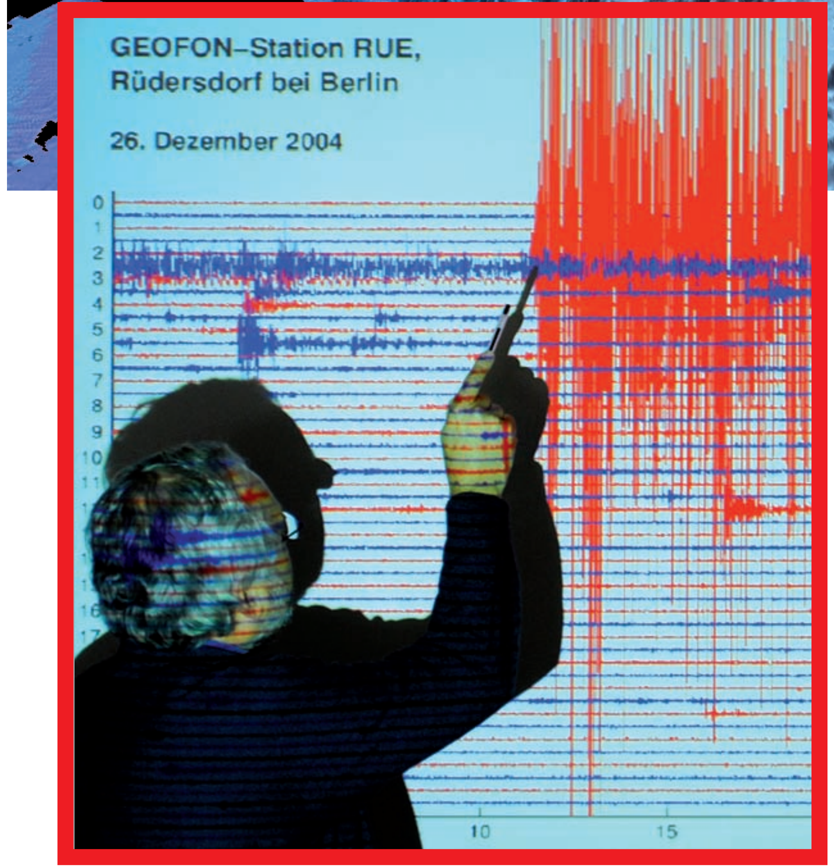
In an ocean of 7,000 metres in depth, the waves spreads out at a speed of 950 kilometres per hour - the speed of a jumbo jet. On the open seas the tsunami wave extends over hundreds of kilometres. However, it only attains the rather unassuming height of a few decimetres. But as it approaches the coast, the speed drops rapidly, already amounting to less than 40 kilometres per hour in shallow water of 10 metres deep. The wave height, on the other hand, rises to several dozen metres. Off Thailand the shallow water zone extends out a long way. This is why in December 2004 the tsunami needed a very long time to reach the coast of Thailand - just as long as the much more remote coasts in East India and Sri Lanka.

There are particularly abrupt changes in the behaviour of a tsunami at the edge of the shelf. The wave is suddenly subjected to a braking effect and more and more water piles up from behind. The tsunami can even split into two or three waves. On the increasingly shallow shelf, the wave builds up to ever increasing heights, until it becomes unstable and breaks. Finally the water runs onto the beach in the form of a wall several metres high.









Mountain Ranges on the Ocean Floor

Knowledge of the structure of the ocean floor plays a major role in simulating the wave runtimes and heights

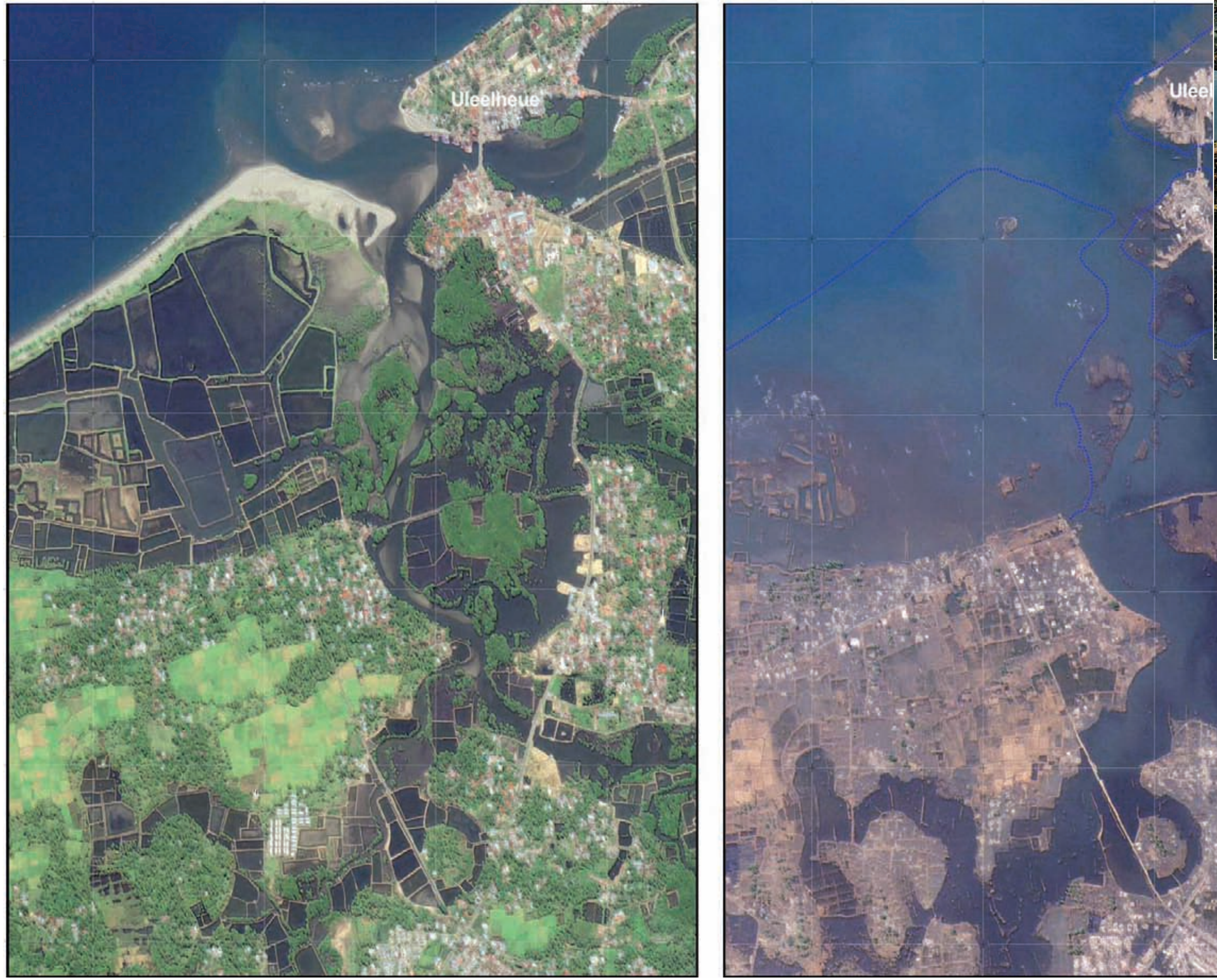
The extent to which the individual sections of coast are at risk can only be predicted if local circumstances are taken into account. Where large islands off the coast form chains as they do off Sumatra, some areas are in the islands' shadow. Elsewhere, on the other hand, there are funnel shaped bays or river estuaries that the water mass runs into, increasing in speed and height. It is a similar story in the hinterland. Here, for instance, there are drains in wide urban streets where there are concrete buildings, and the water mass flows through, whereas dense mangrove forests can slow and stop the floodwater.

Because of the complex topography of the seabed and the coast, determining wave propagation and risk potential with computer simulations is very time-consuming. The relevant calculations approximating to reality must already have been made before any potential disaster. And they must cover hundreds of potential earthquake foci along the Sunda Arc as well as a variety of earthquake intensities. In the event of an earthquake, the simulation model that best matches the current data can then be used.

IN CONSTANT READINESS

The National Warning Centre in Jakarta

The decisive interface of the tsunami early warning system is the national warning centre, which is manned around the clock. This is where all the data arrives from earthquake and GPS measurements, as well as water level heights from ocean buoys and coast gauges. They have to be available to the staff on duty as quickly as possible. On the basis of this information, the assessment is made whether, where and in what strength a tsunami might occur.
In an emergency, the distributing centre extracts the prepared catastrophe scenarios from a database. These contain estimates on the runtime of the wave and the expected wave height, as well as data on the risk areas. This information is sent with a warning to the government, the provinces at risk, local authorities, aid organisations and the general public, to deploy rapid evacuation measures and set humanitarian aid in motion.
Indispensable preconditions for rapid warning are an adequate communications network, and clear communication and command structures. The seismic data is recorded around the clock. On each earthquake recorded, the strength and position of its focus can first be roughly estimated. If it turns out that this is an earthquake that might trigger a tsunami, the entire early warning centre is placed in an increased state of readiness.
In the warning centre the situation is constantly assessed using the current measurement results, with various databases being accessed in the search for a rapid decision. Here the model calculations are also stored. By the time the system is commissioned, as many conceivable scenarios for tsunami events in the Indian Ocean as possible should have been enacted for the entire region. This is how the warning centre will quickly have the best matching scenario available for the constant incoming stream of measuring parameters. From all of this it can be deduced when and at what height the waves will arrive and on what sections of the coast.
In particular, for decision makers it is important to be able to form an overview as quickly as possible of the extent of a possible disaster. For them it is important to know which area and which parts of a town are hit, how many people live there, whether transport routes such as bridges are at risk, and what industries are based in the region. The warning centre also has topographical maps and current data sets on settlement structures, density of population, demographic developments, transport networks, infrastructure and industry. All the relevant information is input into preassembled documents and forwarded to the relevant offices.
In the event of a disaster the warning centre obtains more detailed information on the current situation. In particular, this includes data from Earth observation satellites. This can help to assess the damage caused and coordinate aid. It can also help in quicker exchange of information with neighbouring countries. The national incident centre in Jakarta is integrated in an international network of warning centres in the Indian Ocean, whose construction is being coordinated by UNESCO.



A Picture of Desolation

The satellite pictures show a part of the north western coast of Banda Aceh (Indonesia) before and after the devastating tsunami hit many littoral states of the Indian Ocean on Boxing Day 2004.
The tidal wave swept away almost all of the densely populated spit and many parts of the fields used for aquaculture. Banda Aceh was one of the most severely damaged towns.

THE LAST MILE

Alerting the Inhabitants, Education and Organisation

After the first tsunami wave washed over Banda Aceh on 26 December 2004, taking everything in its wake, many survivors returned to the beaches to look for their missing family members or friends. They were not aware that, with the delay typical for long tsunami waves, a second and third wave were still to come so they ran to their deaths.

Tsunamis are rare occurrences. The disaster in Indonesia has made it clear in many respects how important it is to make the population permanently aware of the dangers of such tsunamis. The people in the areas at risk were not informed of the significance of the sea suddenly receding after an earthquake, or when a first tsunami wave has already devastated the coast.

The most important and most difficult stage of a tsunami early warning system is warning those living in the coastal regions - the last mile. Life-saving measures will only work if the warning reaches the inhabitants quickly and in a comprehensible form, and if as many as possible are already aware of the potential danger.

Even a strong earthquake should result in increased alertness on the part of the population. To achieve this, awareness of the interconnections between earthquakes and tsunamis must be brought into the school curriculum and adult education. The alarm itself can be broadcast on radio and television; typically sirens and loudspeaker systems are used. Since there is no electricity in some rural areas of Indonesia, mosques and other institutions can also be involved and equipped with loudspeakers.

People in the regions at risk must also know where they should escape to in the event of a disaster. Suitable safety zones should be displayed based on risk maps and escape plans; and evacuation-training exercises help to acquaint individuals with disaster protection measures.

For the institutions involved it is important to operate the early warning system efficiently and improve it step by step. Above all, communication between the national and regional institutions, as well as the local decision makers should be smooth and problem-free. For this, clearly agreed responsibilities are needed, with local issues being involved at an early stage in the early warning concept.

"Capacity Building" covers a broad programme of training and in service training. Training units are envisaged giving the staff the opportunity to extend their individual and organisational skills. The individual workshops deal with the communications infrastructure, management duties, and the specialist and technical aspects of early warning. Scientists, engineers and technicians from the littoral states are therefore inducted on site in the functioning of the system, its maintenance and further development.

Established researchers can acquire further qualifications as part of an academic educational and training programme. The possibility of engaging in joint research work with German institutions is made available to them. During a four year period, six scientists will be invited to spend one or two months in Germany.

In addition, eight doctoral students from Indonesia and the adjoining countries are on three-year courses in Germany. During this time they are involved in the construction of the system and are continually in contact with the institutions of their home country. Part of the plan is that they will return each year for six to eight weeks. The entire programme of training and in-service training is agreed in close cooperation with UNESCO.

PANDUAN PENDIDIKAN PASCA BENCANA
BAGI ANAK-ANAK PESISIR

LEMBAGA ILMU PENGETAHUAN INDONESIA
BAGIAN PENDIDIKAN KELAUTAN COREMAP
2005

Serial Pembelajaran Anak "Pesisir dan Laut Kita"

TSUNAMI

M. Fikri Afistianto dan M. Farel Adirianto

津波

Lembaga Ilmu Pengetahuan Indonesia
Bidang Pendidikan Kelautan
COREMAP
2005

Information and Training

... play a major role in educating the decision makers.
The evacuation of the inhabitants must be tested ready for the real thing. With illustrative training materials in the language of the country and regular alarm exercises, an awareness of the dangers can be developed early on right now.

THE EYE IN THE SKY

Continuous Tsunami Monitoring with Satellites

Thanks to new technologies, in ten or twenty years a tsunami early warning system could differ significantly from today. Instead of measuring wave movements with buoys and tide gauges at certain points, it would be cleverer to monitor the ocean from space and thus to obtain an overall picture of the tsunami as it develops and spreads.

Satellite observations of 26 December 2004 provide some indication that this should be possible. In the hours after the earthquake, the Franco-American satellite Jason 1, the European satellite Envisat, and the American satellite Geosat all passed over the Indian Ocean and recorded the heights of the waves in succession. Based on this data, scientists later reconstructed the path that the tsunami had taken. They also found that the tsunami waves on the open sea were no more than 60 centimetres high.

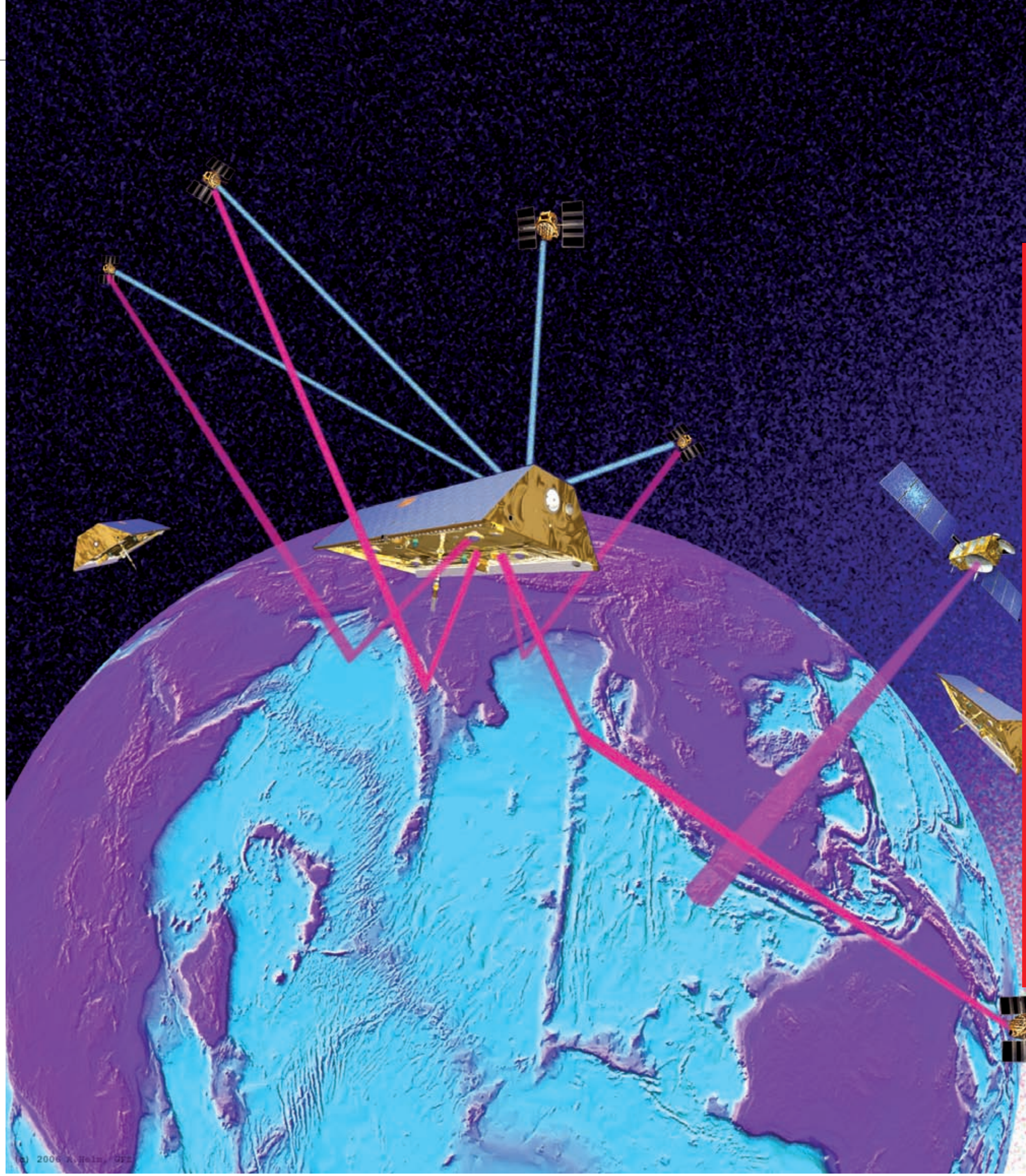
These satellites work with an active radar system. Their antenna transmits radar waves in the form of short, consecutive signals. These waves are propagated at the speed of light and reflect if they strike the surface of the sea. The satellite antenna records the reflected signal. The distance covered can be determined from the runtime, and as a result the distance of the satellite from the sea surface.

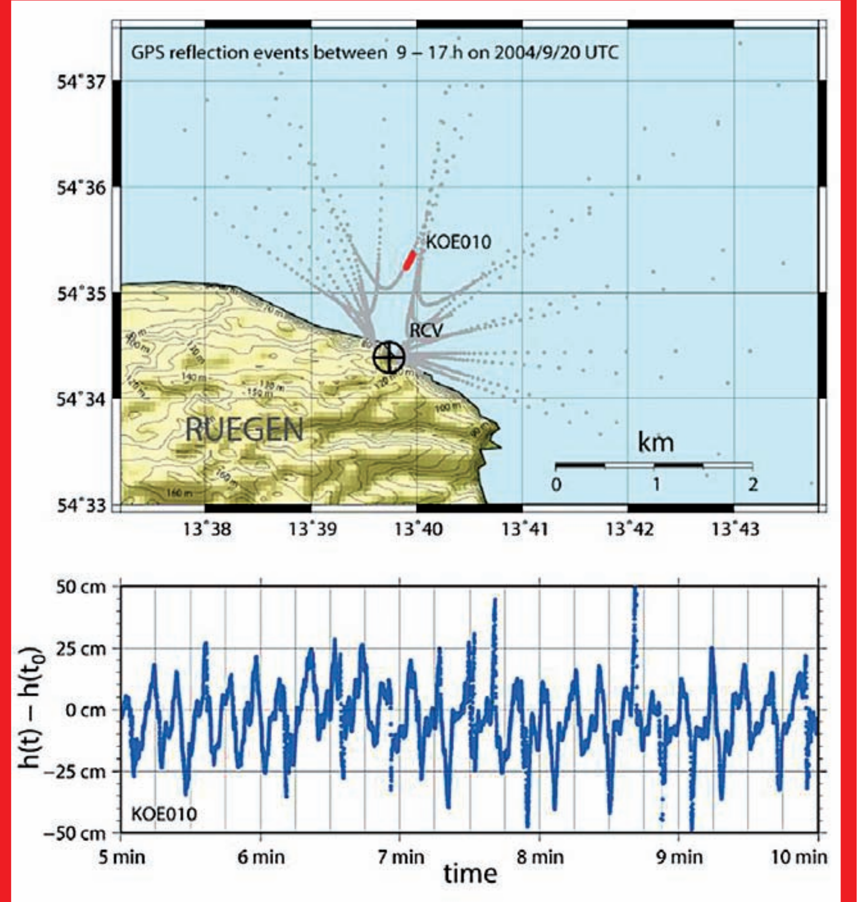
There are already a few satellites that measure mean sea level in this way. However, such satellites are relatively large and expensive. An alternative is to link tsunami observation from space with satellite systems already in existence or currently under construction, such as the Global Positioning System (GPS).

There are currently 24 American GPS satellites orbiting the Earth. With the European Galileo system, this figure will more than double by 2010. Even today, at any point on the Earth's surface, the signals from at least four such satellites can be received. In satellite navigation the runtimes of these various signals are used to determine one's location. They also allow measurement of mean sea level.

It is true that the GPS satellite signals are not as strong as those of the Earth monitoring satellites designed for measuring heights. However, they are distributed over the sea surface in the same way. Additional small satellites can receive these reflected GPS signals in a low orbit and simultaneously measure the distance to the GPS satellite. The combination of this data then gives the mean sea level calculation (see chart).

The advantage of this method is that the receiving satellites do not need an active radar system, but only an active GPS and communication system. Tsunami observation from space can make do to a large extent with specialised small satellites involving low-level orbits around the Earth. Over time, all the oceans could thus be monitored with just a few cost-effective satellites. These small satellites could also carry out other types of work, such as tasks related to climate modelling. Initial tests for such a system are already being carried out by the German georesearch satellite CHAMP, among others.





New Technologies

First attempts at observing the sea level by satellite have given promising results. It is conceivable that in the future this technology could also be used for early warning.

A VIEW OF THE ENTIRE EARTH

The Tsunami Early Warning System as Part of a Global Earth Observation Network

The tsunami disaster of December 2004 has renewed the discussion as to how people on oceanic coasts can in future be warned of such dangers. The UNESCO Intergovernmental Oceanographic Commission (IOC) is pursuing the aim of setting up a worldwide tsunami early warning system. As early as 1960 the IOC was coordinating a regional warning system in the Pacific. For decades it remained the only one of its kind, although there was repeated insistence on the importance of installing similar systems in other regions.

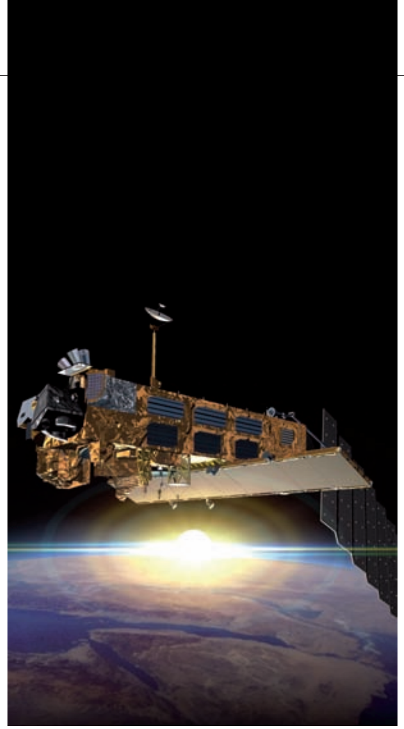
In January 2005 the IOC was commissioned by the United Nations to coordinate the measures of the littoral states in the construction of a tsunami early warning system in the Indian Ocean. The main aim of the German-Indonesian initiative is to create reliable structures, which are usable over the long term, for such a warning system in the region most at risk from earthquakes, the Sunda Arc. The German and Indonesian research ministries signed a cooperation agreement relating to this on 14 March 2005.

All activities within the German-Indonesian project for setting up an early warning system for the Indian Ocean have been agreed with the IOC. The data for rapid warning of the population is to be made available to all the littoral states of the Indian Ocean. The system is of such flexible design that integration of the seismic or oceanographic measuring networks of other countries in the region has proved to be possible.

Over the long term, this kind of system can be transposed to other regions of the Earth. In view of the risk of earthquakes in the Caribbean or Mediterranean, the IOC is considering setting up a tsunami early warning system in these areas as well. Due to the short distances and short advanced warning times, these areas represent similar challenges in terms of technology and management to those in the Indian Ocean.

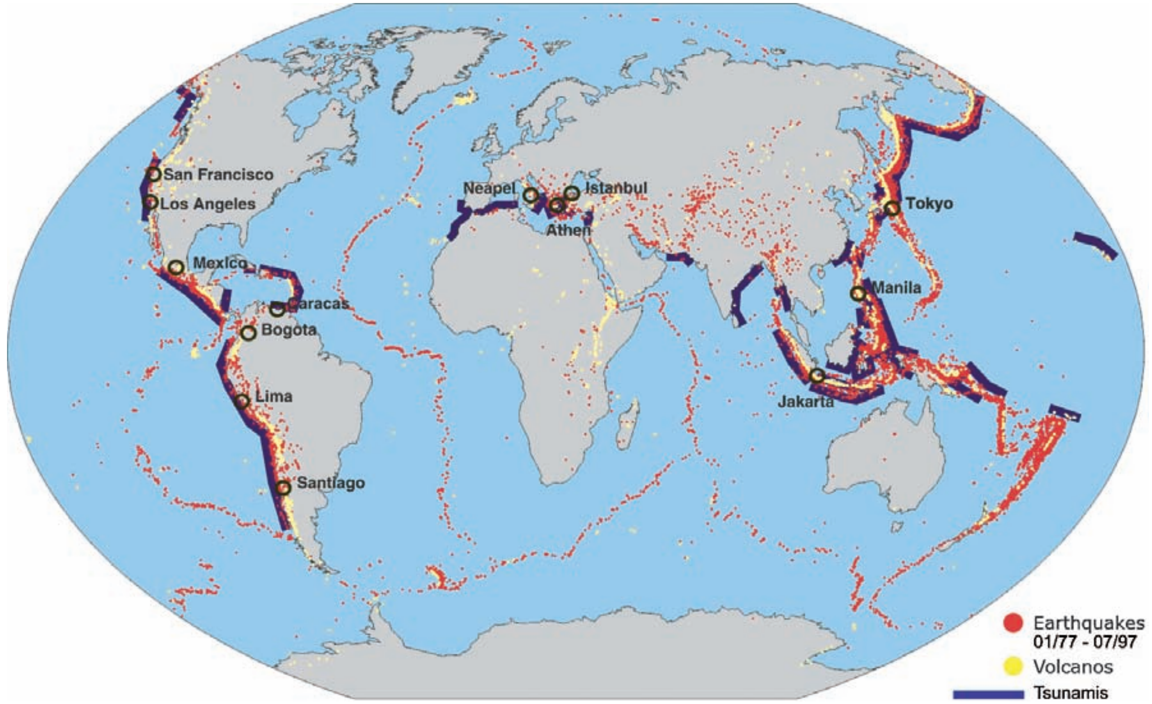
The concept for the German-Indonesian early warning system also envisages later interlinkage with another global monitoring system. The aim of international efforts is to build up a global geophysical observation network (GEOSS or Global Earth Observation System of Systems) over the coming years. The coordination committee between the participating states is based in Geneva, and Europe is making an important contribution in terms of the creation of a set of earth observation systems (GMES or Global Monitoring for Environment and Security).

Nowadays navigation satellites are seen as the lodestars for transport by road, air and sea. Earth observation satellites could become the new lodestars for disaster prevention. They deliver more than just impressive pictures. For years they have been playing an ever increasing role in warning of extreme world events and in diagnosing natural disasters such as storms, tidal waves, or forest blazes, as well as the resulting damage. Advancing desertification and the retreat of glaciers due to climate change are also covered by the Earth observation satellites. It will only be internationally linked, ongoing data acquisition on our environment that will allow us to see how the natural equilibrium formed over millennia is being changed by human activities.



Many Different Dangers

Natural dangers such as earthquakes, tsunamis or volcanic eruptions are distributed more or less throughout the world. Some regions of the Earth, such as Indonesia, however, are especially at risk. To the right of the picture Jakarta is highlighted; the volcanic craters on the island of Java can easily be made out.



WE HAVE BEEN WARNED

Increasing International Cooperation in Disaster Prevention

Earthquakes occur at points where rigid blocks of the Earth's crust strike against each other. If the tensions between such plates suddenly discharge, and one of them suddenly moves forward, it can lift up the entire ocean above it and trigger a powerful tsunami wave. We may assume that in future Indonesia, given its immediacy to the seismically active Sunda Arc, will again be the country to be hit most strongly and most frequently by such tsunami events in the Indian Ocean.

The tsunami of December 2004 devastated beaches and villages, swallowing up houses and vehicles. There was no reliable data on the strong earthquake and no possibility of warning people of the impending disaster. The waves alone, which reached Thailand and Sri Lanka after one and a half hours' delay, and then India still later, took tens of thousands to their deaths because information was not passed on, and because there were no evacuation plans for such a disaster scenario.

The tsunami early warning system that is now being developed under the auspices of German-Indonesian cooperation can make a vital contribution to the region being better equipped in future to predict the waves. It does this through specially developed technology, reliable information and rapid communication. It forms a part of the Intergovernmental Oceanographic Commission (IOC) of the UNESCO coordinated warning system, and as such represents a milestone of international cooperation in disaster prevention.

To a greater degree than ever before, the extent of the tsunami disaster in the Indian Ocean has opened the eyes of the world to the future importance of developing early warning systems and Earth observation. They can do humanity an invaluable service in limiting the effects of natural disasters such as earthquakes and tsunamis, volcanic eruptions and storms, and in extending our knowledge of global and regional changes to the environment.

MASTHEAD

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GITEWS - Consortium

GeoForschungsZentrum Potsdam (GFZ), Potsdam (Consortium Leader)

Alfred Wegener Institute for Polar and Marine Research (AWI), Bremerhaven

Federal Institute for Geosciences and Natural Resources (BGR), Hannover

German Aerospace Centre (DLR), Oberpfaffenhofen

Deutsche Gesellschaft fuer Technische Zusammenarbeit (GTZ) GmbH, Eschborn

GKSS Research Centre, Geesthacht

German Marine Research Consortium (KDM), Berlin

Leibniz Institute of Marine Sciences (IFM-GEOMAR), Kiel

United Nations University, Institute for Environment and Human Security (UNU-EHS), Bonn

Indonesian Partners

- State Ministry of Research and Technology (RISTEK), Jakarta
- Meteorological and Geophysical Agency of Indonesia (BMG), Jakarta
- National Coordinating Agency for Survey and Mapping (BAKOSURTANAL), Cibinong
- Agency for the Assessment and Application of Technology (BPPT)
- National Institute for Aeronautics and Space (LAPAN)
- Indonesian Institute of Sciences (LIPI), Bandung
- Ministry of Communication and Information Technology (DEPKOMINFO), Jakarta
- Secretariat of National Coordinating Board for Disaster Management and IDPs (BAKORNAS PBP), Jakarta

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