Introduction

InaTEWS-Monitoring and Warning Service

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GITEWS

InaTEWS-MONITORING and WARNING SERVICE

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Content

Monitoring and Warning Service – the “upstream” process 01

Earthquake monitoring – the first reference for tsunami early warning 05

Ocean Observation – confirmation or cancellation? 07

Global Positioning System (GPS) – has anything moved? 09

Communication System – real time! 10

Simulation system – completes the picture 11

Decision Support System – when quick reaction is required 13

Monitoring and Warning Services – an international affair 15

Monitoring and Warning Service – the "upstream" process

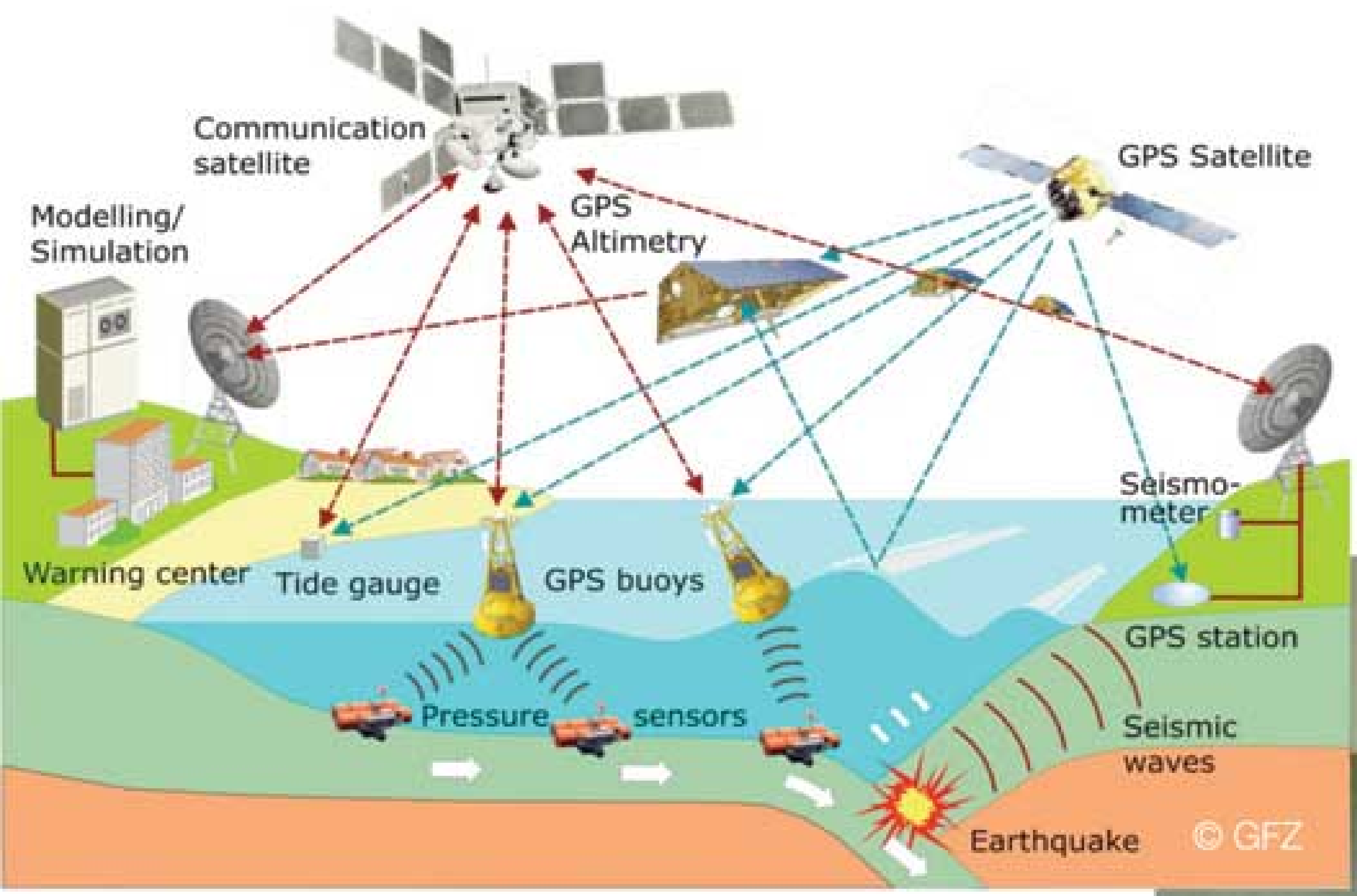
Tsunami early warning requires the continuous monitoring of earthquakes. Once a strong earthquake has been detected by the Indonesian Tsunami Early Warning System (InaTEWS), sea level monitoring and the detection of ground deformation are activated to confirm whether a tsunami had been triggered.

International cooperation and coordination is needed to set up and maintain such an observation network that must cover an ocean wide area.

All data flows "**upstream**" to the **National Tsunami Warning Center** (NTWC), which is a core element of the Early Warning System. The Indonesian NTWC is operated by the National Agency for Meteorology, Climatology and Geophysics (BMKG) in Jakarta. As real time data is required, a network based on satellite communication has been established. In the NTWC all incoming data is analyzed and compared with a tsunami data base to evaluate the tsunami threat and to decide whether to send out a warning message. A Decision Support System (DSS) was developed to assist the staff at the NTWC to evaluate the situation and to take a decision in the shortest time possible.

Once the NTWC at BMKG has decided to issue a tsunami warning, the **downstream** process starts. From the NTWC, information flows "downstream" to Interface Institutions and local Governments, the public media and to the community at risk, where the population, the institutions and the private sector need to convert the warning effectively into action.

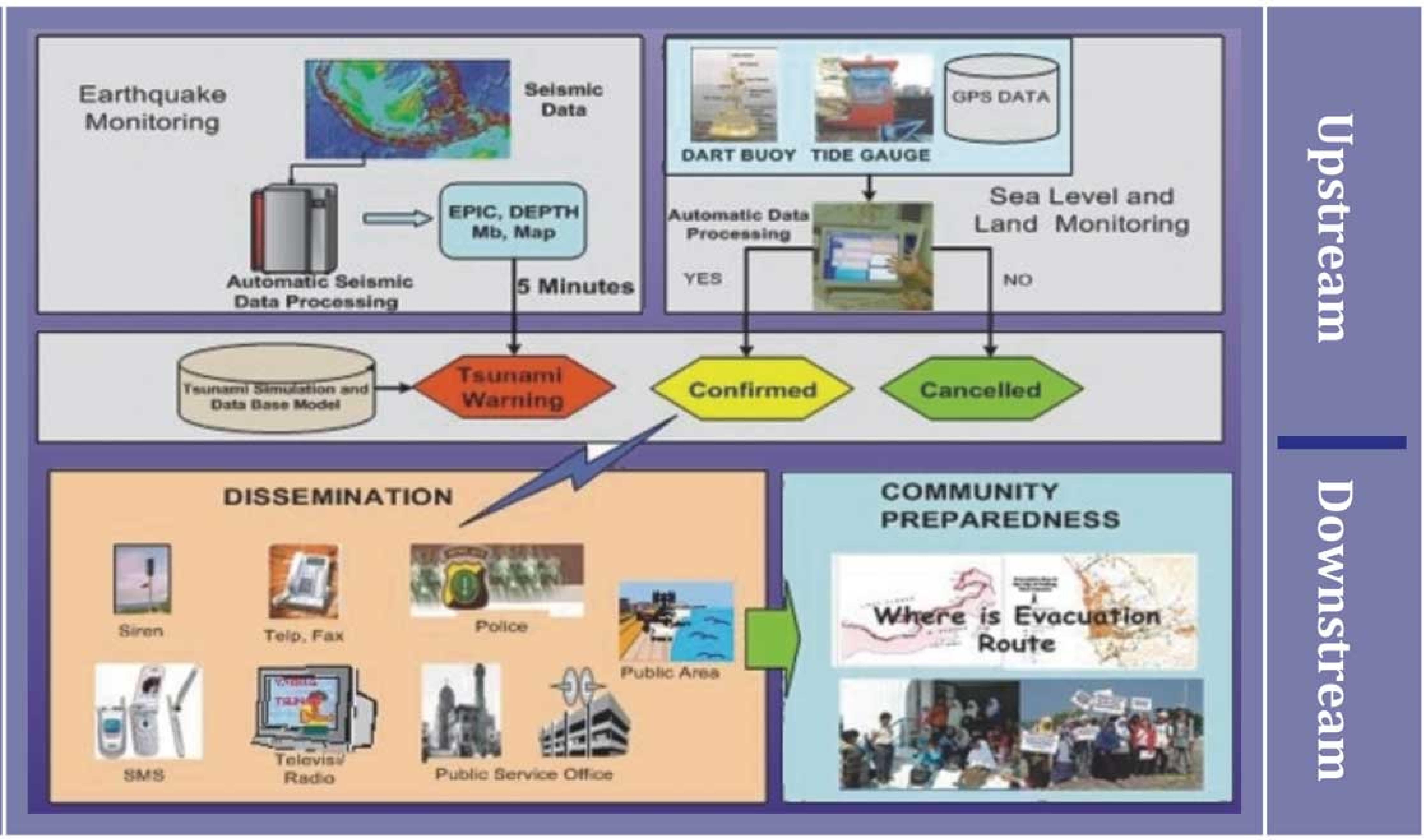
Since 2007 the National Tsunami Warning Center at BMKG in Jakarta is operative and provides tsunami early warnings in case of a tsunami threat. Warnings are sent out within 5 to 7 minutes after a large earthquake occurs.



Concept of InaTEWS

National Tsunami Warning Center
at BMKG Jakarta

Decision Support System

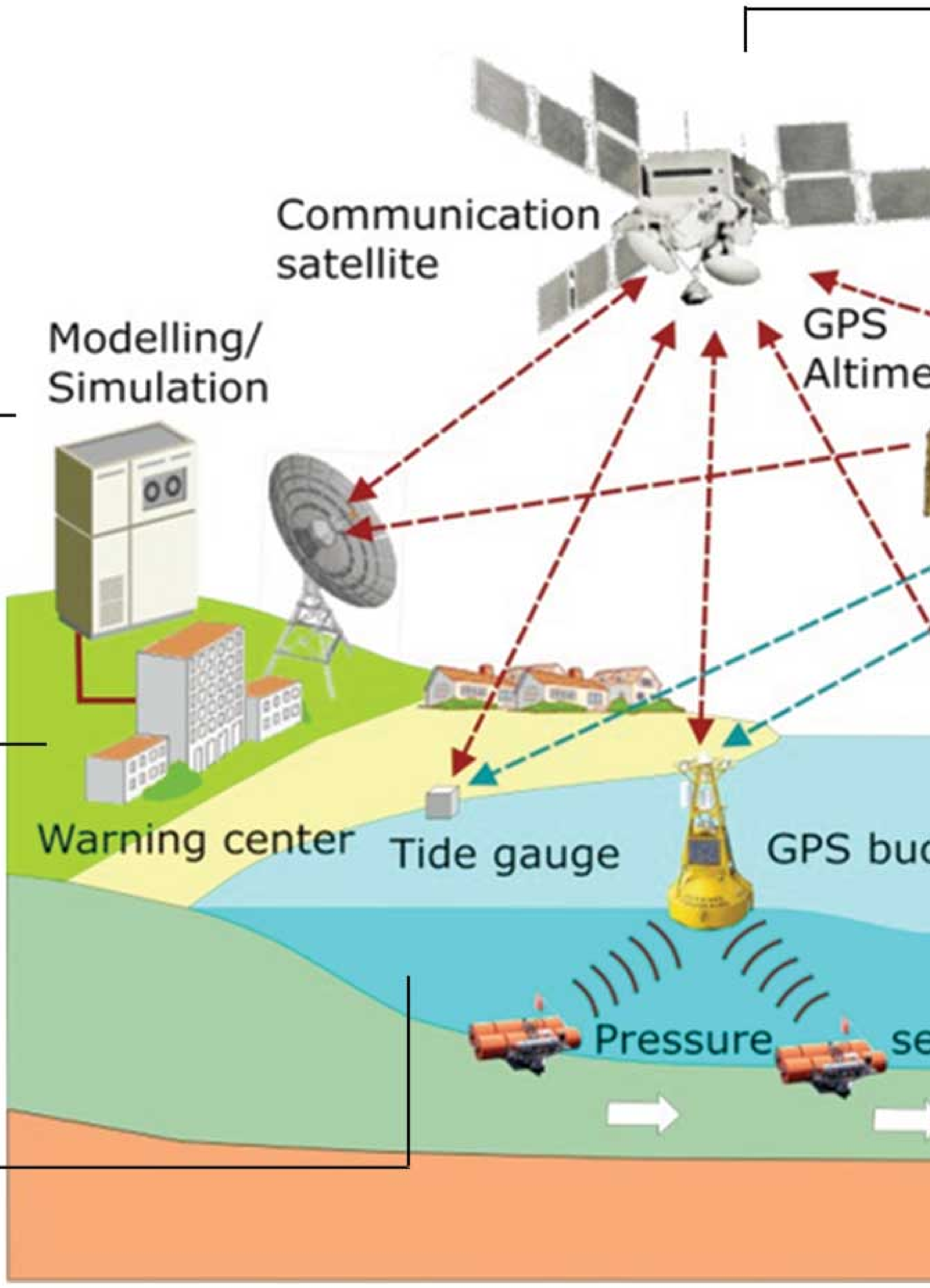


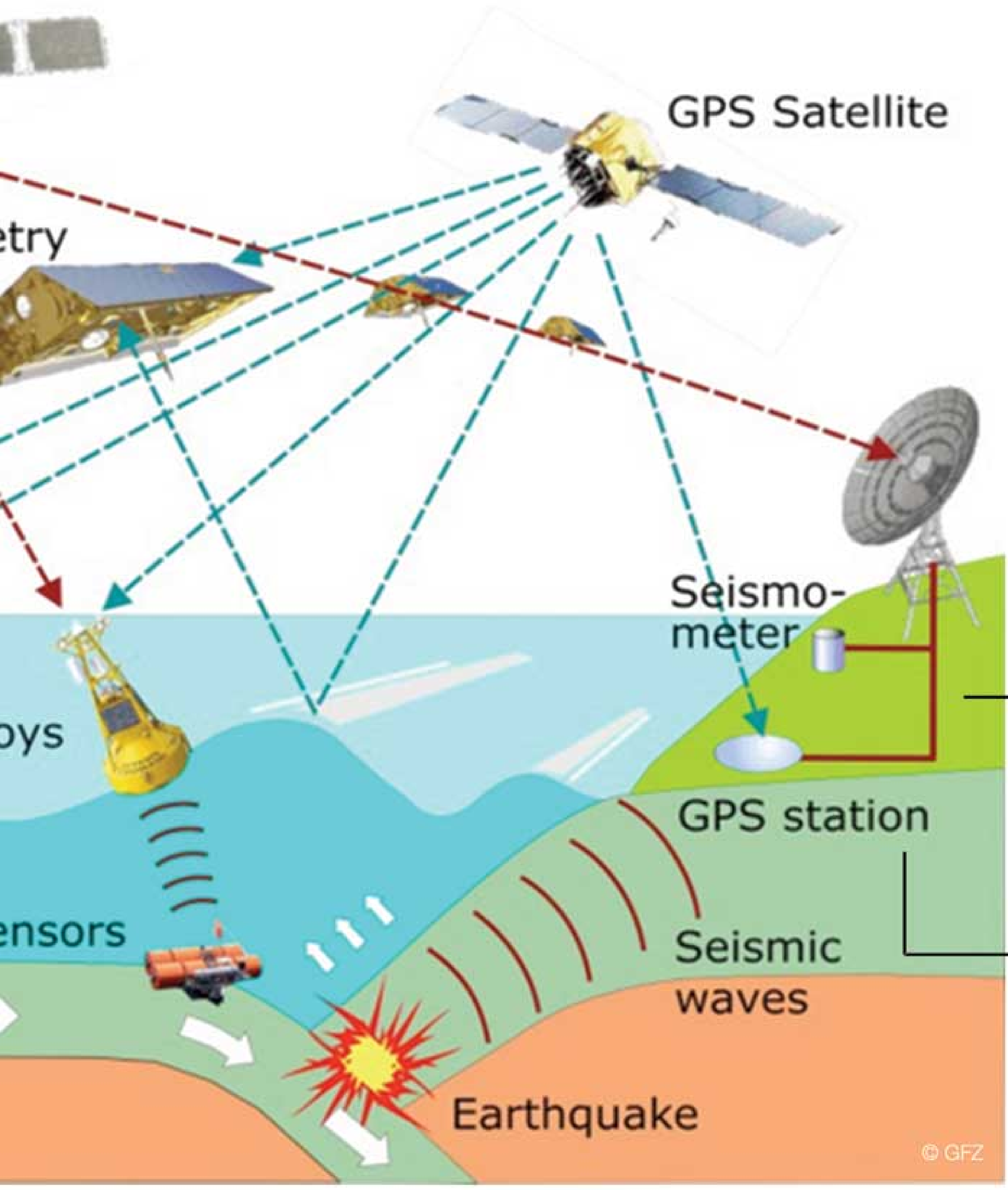
InaTEWS – the "upstream" process

All observed data is compared with pre-calculated scenarios to evaluate which areas will be affected and to what degree.
Page 11

A Decision Support System (DSS) in the National Warning Center helps the officers on duty to evaluate the situation and to decide whether a warning has to be sent out.
Page 13

Buoys, ocean bottom units & tide gauges are used to confirm whether a tsunami was generated.
Page 7





Satellite communication is used to transfer all data in real time to the National Warning Center at BMKG.
Page 10

Seismometers provide information about location, magnitude and depth of an earthquake to evaluate whether the earthquake has the potential to trigger a tsunami.
Page 5

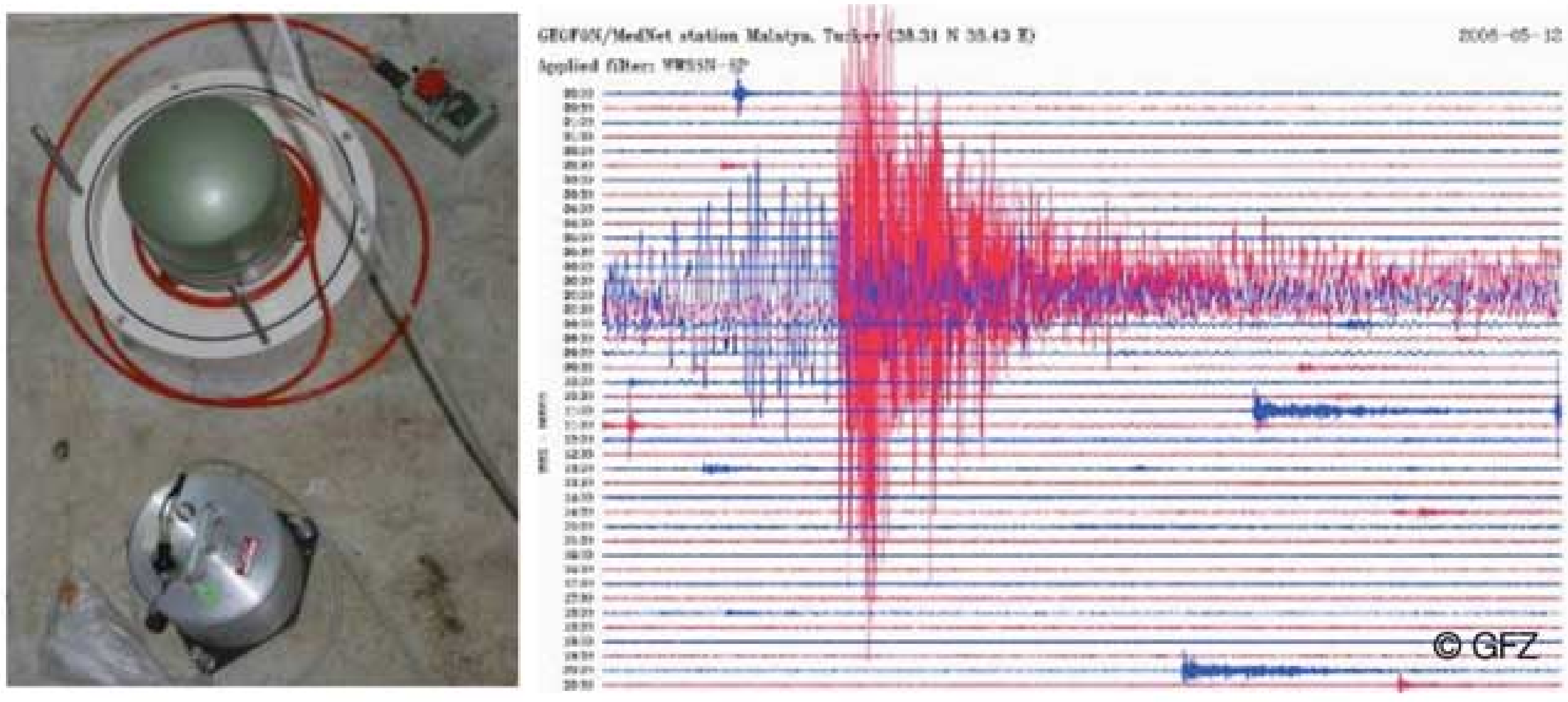
GPS stations provide information whether the earthquake did cause a vertical uplift of the land surface.
Page 9

Earthquake monitoring – the first reference for tsunami early warning

More than 90% of all tsunamis result from strong and shallow earthquakes. For that reason earthquake monitoring plays a central role for tsunami early warning.

But not all earthquakes trigger tsunamis. An earthquake is considered to have a potential for a tsunami if it is located under the sea, with a depth of less than 70-100 km and a magnitude bigger than 7.

That is why a quick and accurate determination of the earthquake parameters (location, magnitude and source depth) is essential. For this purpose seismometers are used. These instruments are able to measure the seismic waves.

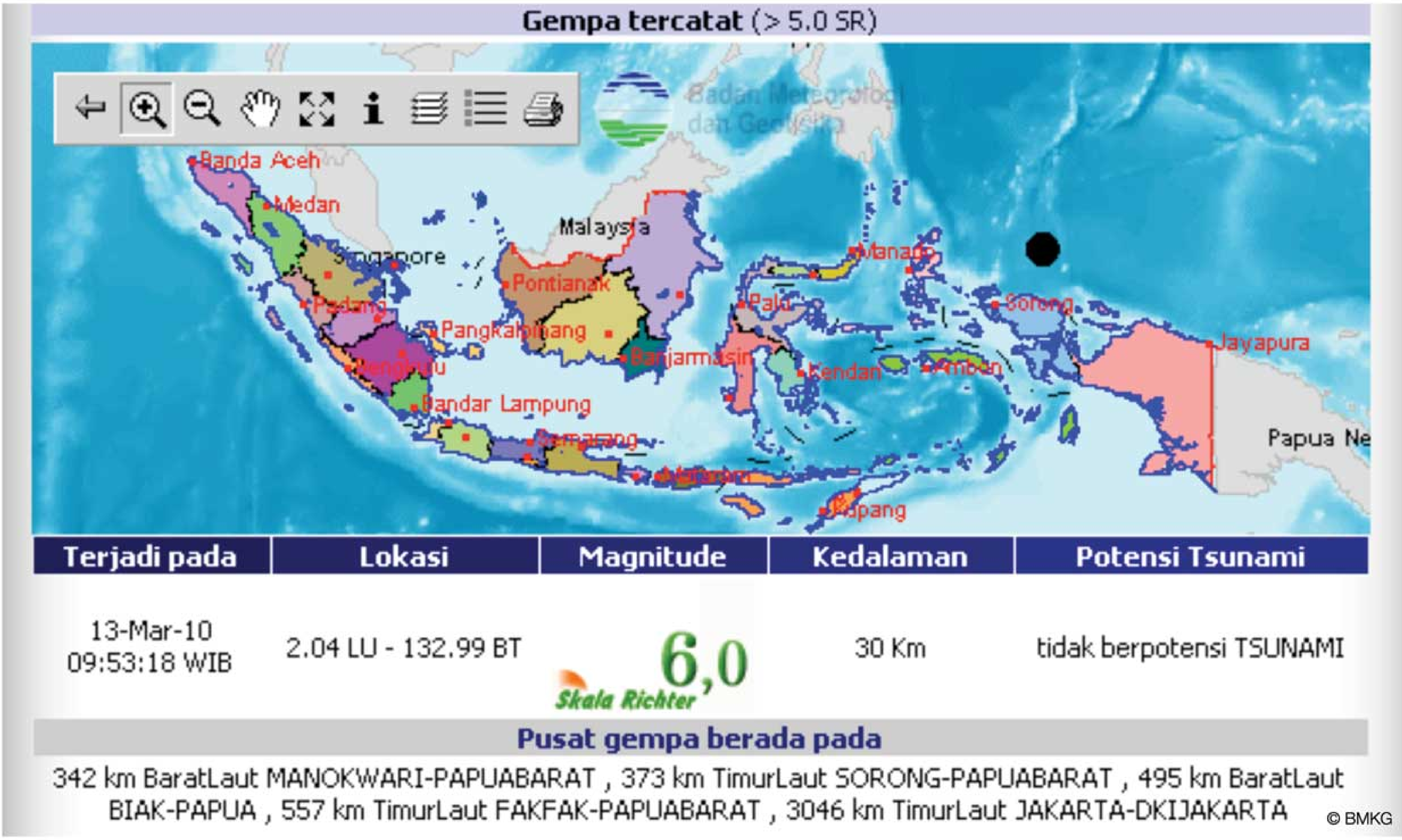


Seismometer & Seismogram

With the data from several seismometers it is possible to determine the exact location, time, depth and magnitude of an earthquake. Therefore, a network of seismometers has been installed in Indonesia and the ASEAN member states that are connected via communication satellite to the National Tsunami Warning Centre at BMKG in Jakarta.

Special computer software (SeisComp3) was developed to process all incoming data in the shortest time possible. Currently, the NTWC at BMKG is able to provide reliable earthquake information within 5 minutes after the occurrence of an earthquake.

For all earthquakes bigger than magnitude 5 BMKG is sending out EQ-Information via SMS to selected institutions. EQ information can also be obtained from the BMKG website: www.bmkg.go.id



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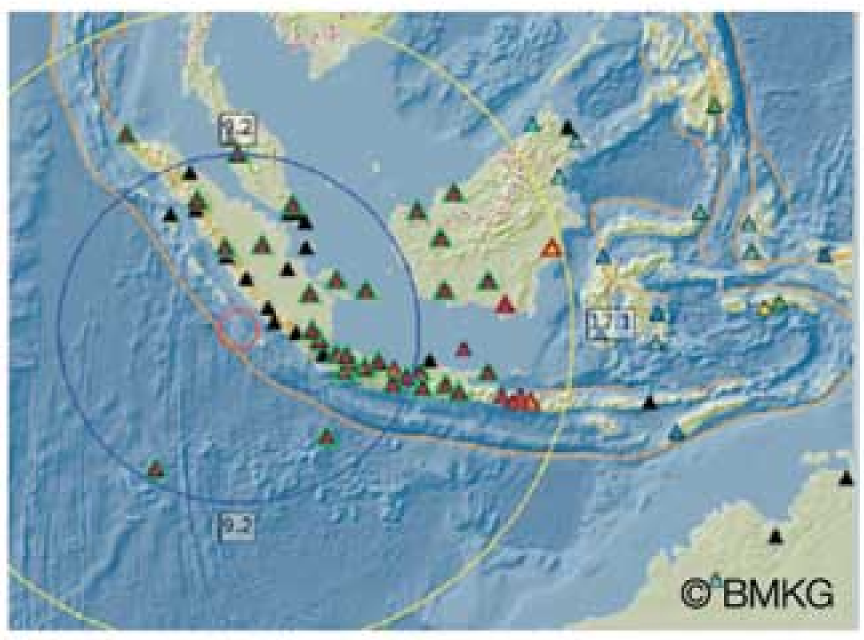
EQ Information on BMKG Website



Network of Seismometer

Results from Earthquake Monitoring

EQ Information Via SMS to Decision Maker

Further information:

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Ocean Observation – confirmation or cancellation?

Even if an earthquake fulfills the parameters (location, depth and magnitude) and has the potential to trigger a tsunami, it does not mean a tsunami was actually generated.

Therefore, a second component of InaTEWS was established to monitor the sea level in the ocean to confirm the generation of a tsunami. Several instruments are used to achieve this goal:

Ocean Bottom Unit / Buoy

Ocean Bottom Units (OBUs) are deployed at the ocean floor. These underwater measuring units are able to detect the change in the water pressure when a tsunami wave is passing by. Once the OBU has detected a tsunami wave, it sends the data to a buoy, which is floating on the ocean surface nearby.

Buoys send the data from the OBUs via satellite communication to the NTWC. Additionally, buoys are equipped with a high precision GPS unit, which measures the sea motion and is able to detect a bypassing tsunami wave.

Tide Gauges are located along the coast and at islands to detect tsunami waves before they reach the mainland. A tide gauge measures changes in the sea water level and can register the receding water minutes before the tsunami waves arrive.

In case no tsunami wave is observed, the warning will be canceled. Tide gauges also play an important role in measuring wave heights during a tsunami.

Tide Gauge

Damaged Buoy

Information Poster on Buoys by BPPT

Tsunami buoys and local fishermen

Buoys have been favored anchoring places for fishing boats. Unfortunately, the instrumentation masts of the buoys - equipped with GPS, meteor sensors and solar panels – have not been able to withstand the mechanical stress from the anchorage and were damaged, resulting in loss of data.

Buoys have now been redesigned and posses a handrail to avoid uncontrolled anchoring. It would be preferable for fishing boats to keep their distance from the buoys and to avoid their nets being entangled in the mooring. BPPT has prepared and distributed a poster to inform local fishermen about the buoys.

Further information:

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Global Positioning System (GPS) – has anything moved?

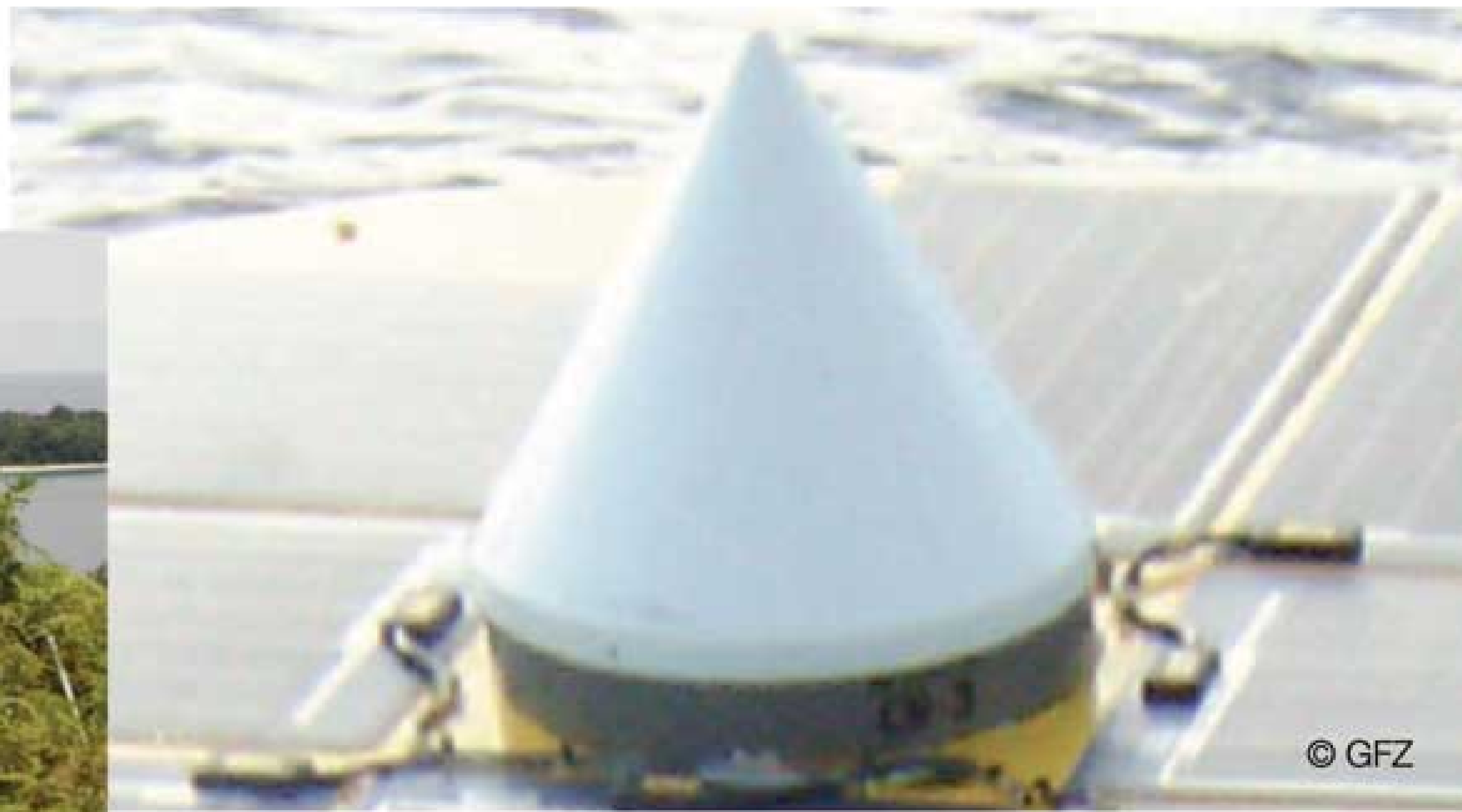
Offshore earthquakes that cause ground deformation on land are particularly dangerous as a vertical movement of the earth surface is often the trigger of a tsunami. The detection of these kinds of movements can provide the NTWC with valuable information to evaluate whether an earthquake is likely to trigger a tsunami or not.

Measurements of the deformation of the earth's surface are taken by the Global Positioning System (GPS). The GPS technology uses signals from satellites, which are registered by special GPS sensors. The signal from the satellites contains data that allow calculation of the exact position of the sensor.

In the framework of InaTEWS, several **GPS sensor stations on land** have been installed to detect this kind of ground motion due to earthquakes.

GPS sensors at tide gauges -like the sensor stations on land - also register ground motion. Additionally, they help to interpret the sea level data from the respective tide gauge, as it can be determined whether the location of the tide gauge itself was affected by the earthquake.

Movements of the water surface can also be monitored with GPS technology. That is why **GPS sensors** are installed on **buoys**. As a buoy moves with the waves the attached GPS sensor records these movements. Special software is applied to distinguish between normal (tide or wind induced) waves and a tsunami wave.



GPS Sensor on Buoy

GPS Sensor Station on Land

GPS Sensor on Tide Gauge

Further information:

National Coordinating Body for Survey and Mapping (BAKOSURTANAL)
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www.bakosurtanal.go.id

Communication System – real time!

All data required for the assessment of the situation and decision making in the NTWC need to be available "real time".

Therefore, a communication network must be established which will work in a reliable way also during emergency situations.

As public communication facilities are likely to fail in particular during national disasters, a network of satellite links has been set up to provide reliable communication independent from the Internet.


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Satellite Receiver at BMKG

Simulation system – completes the picture

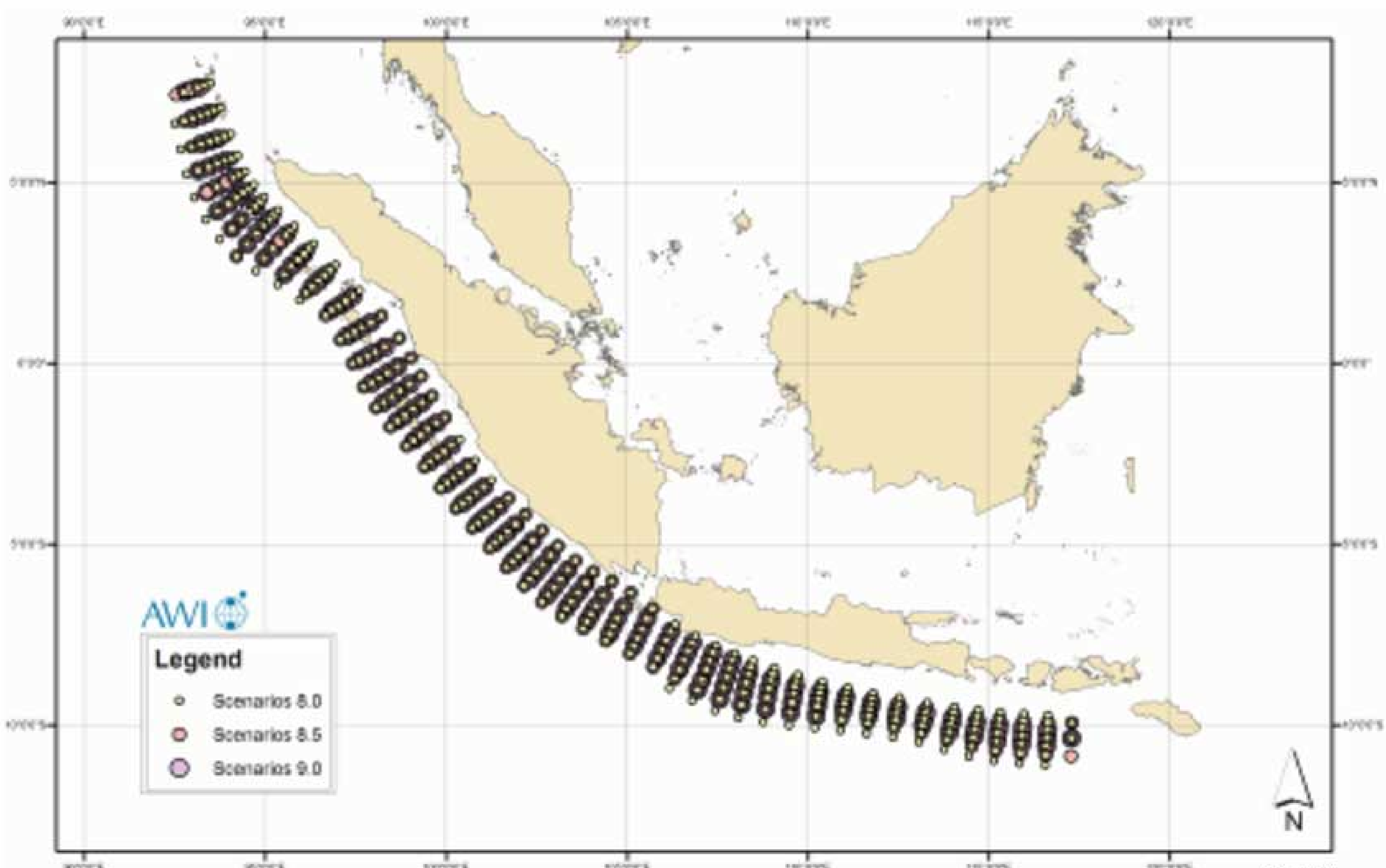
With the data from the earthquake and ocean observation systems, as well as from the GPS, the officers on duty in the NTWC obtain localized information about the earthquake parameters, whether there was vertical movement of the land surface and even possible confirmation that a tsunami wave was generated.

However, they still do not have the full picture. The next questions to answer are: which areas will be affected by the tsunami and what wave height to expect.

Here the simulation system steps in. The simulation system provides the officers on duty with a pre-calculated scenario, which shows how the tsunami waves travel from the earthquake epicenter outwards and which coastal areas may be affected. It provides information on the estimated arrival time of the first wave and what wave heights can be expected.

How does the simulation system work?

The simulation system is basically a collection of pre-calculated scenarios, which represent a large number of possible earthquakes and the tsunamis resulting from them.



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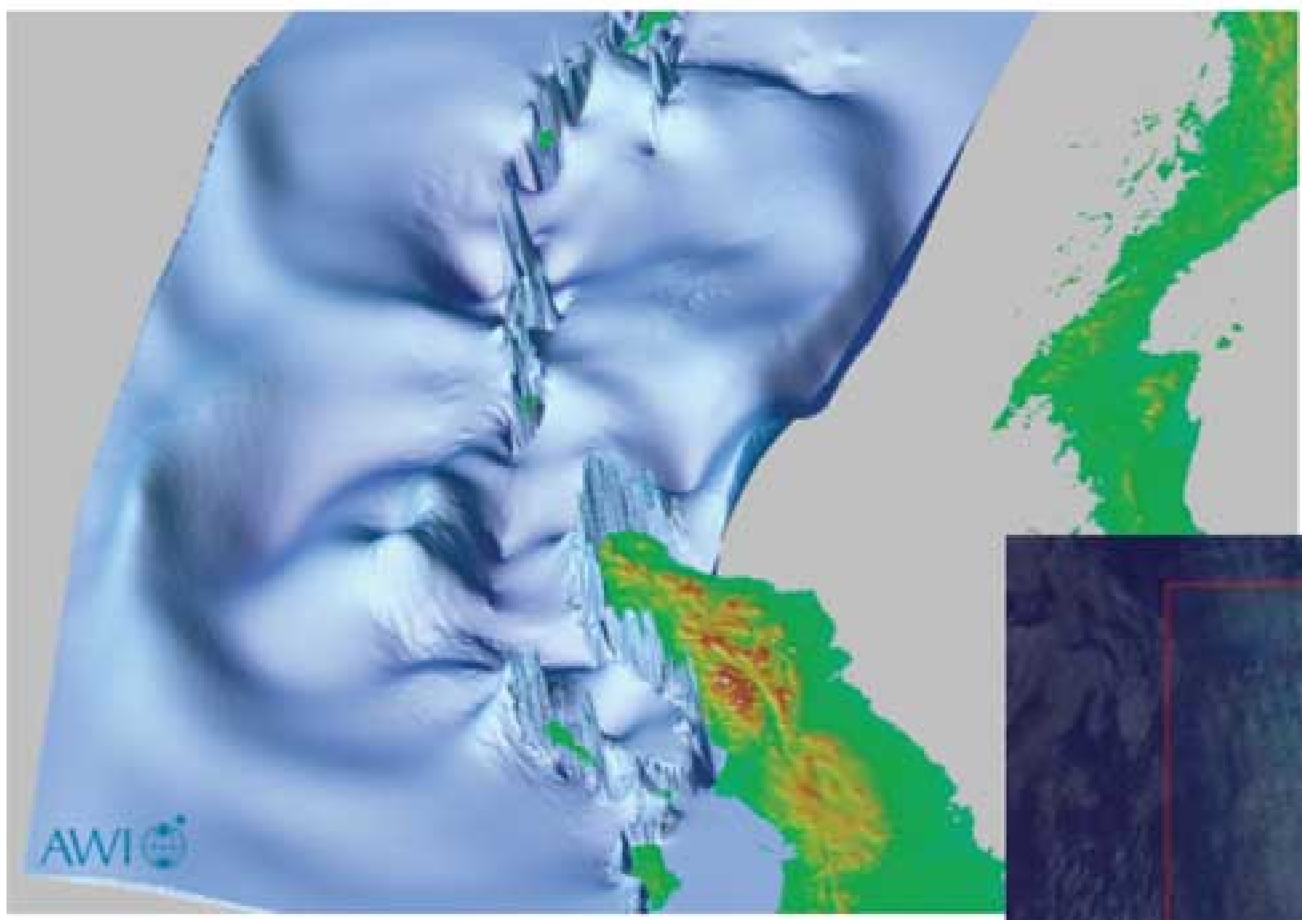
Epicenter Location of Pre-Calculated Scenarios

The simulation system compares the incoming measurements from the earthquake and ocean observation systems with the scenario data stored in a database. The system selects the scenario with the best match and provides the officers on duty with a probable picture of the situation.

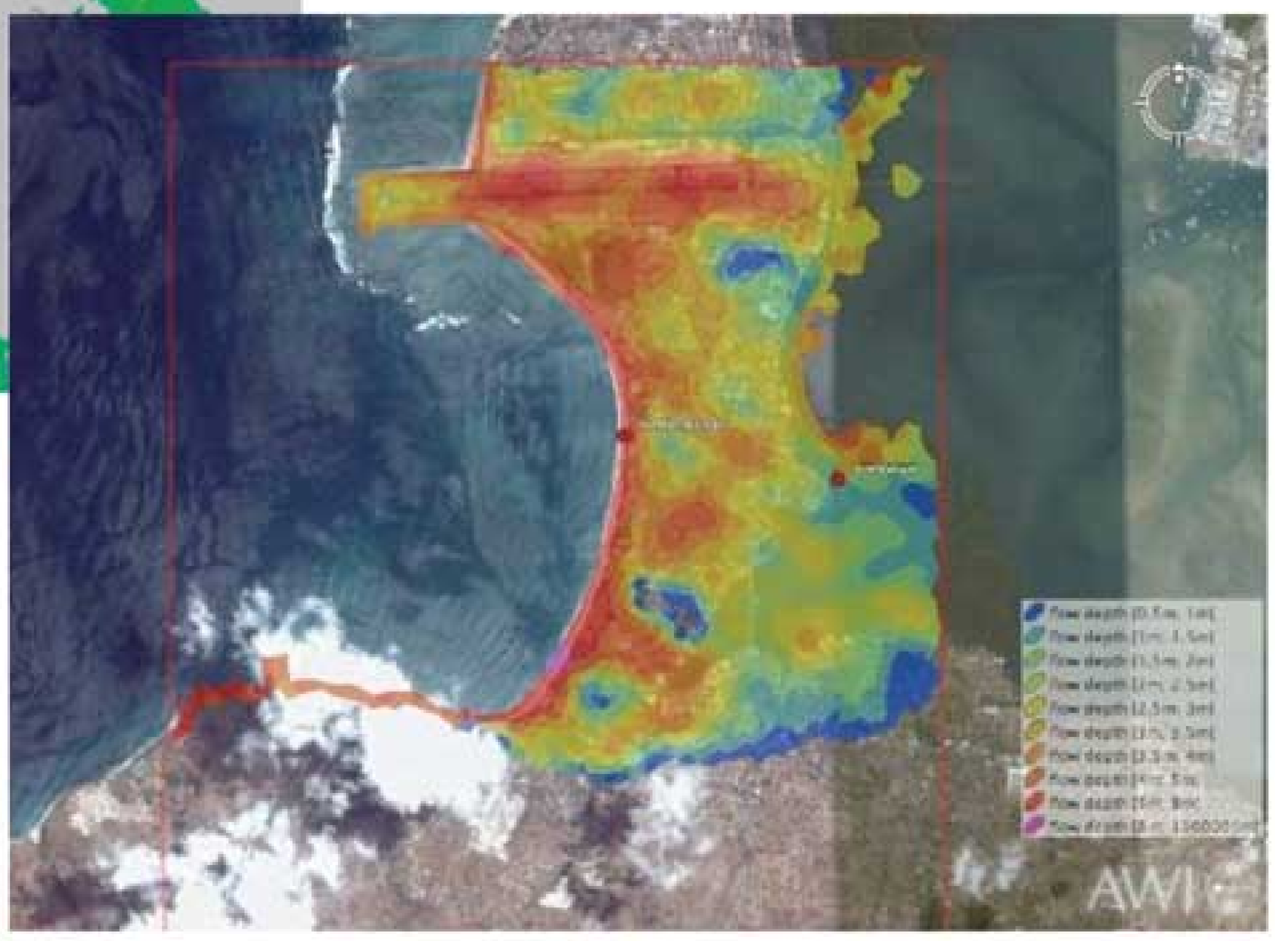
The system uses pre-calculated scenarios since time is too short to start a scenario calculation once incoming data from the observation systems is available. The calculation of a scenario takes several hours, whereas the warning time is usually between 20-35 minutes.

Besides the importance of the tsunami simulation system for the warning process, simulation results are used as key inputs to develop tsunami hazard and inundation maps. These kinds of maps are the basis for local preparedness and mitigation planning and used in particular for tsunami evacuation plans.

Always keep in mind that simulations are only an approximation to the real world. They do not show reality.

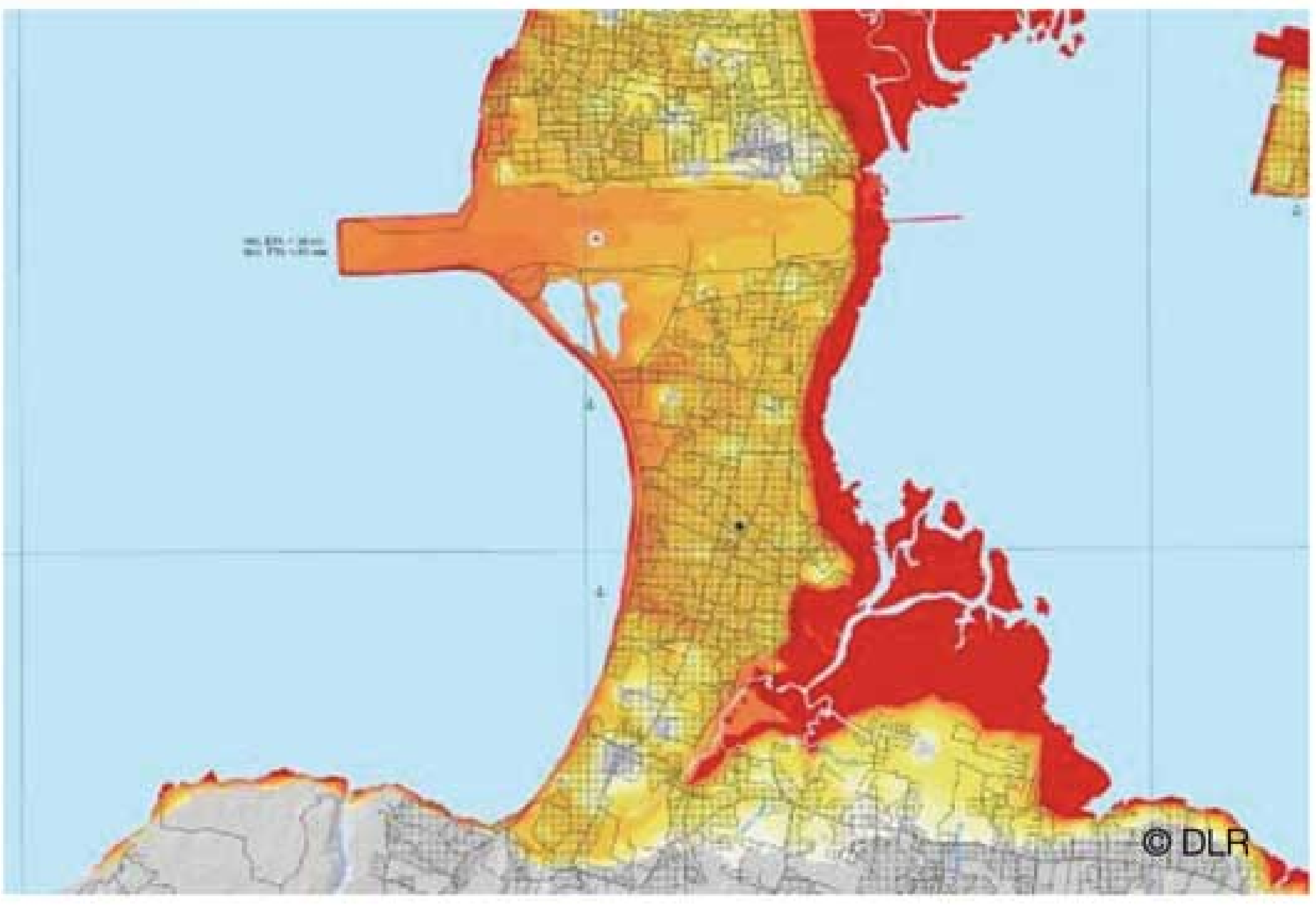


Simulated Wave Profile of Aceh Tsunami 2004



Inundation in Southern Bali for a Simulated Tsunami Scenario

Travel Times of Tsunami Wave



Tsunami Hazard Map Derived from a Number of Tsunami Scenarios

Decision Support System – when quick reaction is required

The source regions for large undersea earthquakes that have the potential to generate tsunamis are related to the subduction zone of the Indo-Australian Plate beneath the Eurasian Plate. This zone is extending from North Sumatra to the Banda Arch in the East of the Indonesian archipelago. As coastlines are at close distance to this 'belt of earthquake activity' the travel time of near-field tsunamis ranges between 20 to 40 minutes. Therefore, warning time to alert people living along the coast is extremely short.

This is a big challenge for the officers in the NTWC as they must assess the situation in the shortest time possible and then have to decide whether to send out a tsunami warning.

To assist them to master this difficult task a Decision Support System (DSS) was developed. The DSS is a computerized tool which provides the staff at the NTWC with all relevant information to assess the situation and assist them during the decision making process. The DSS displays information on four different screens.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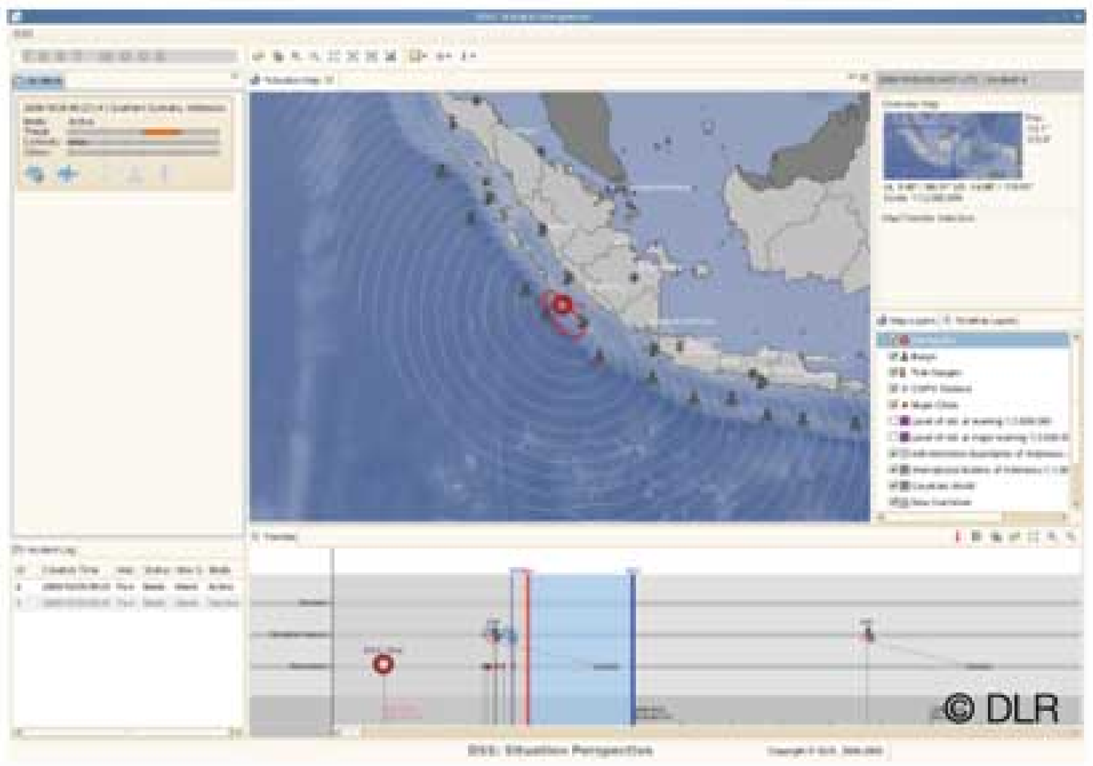
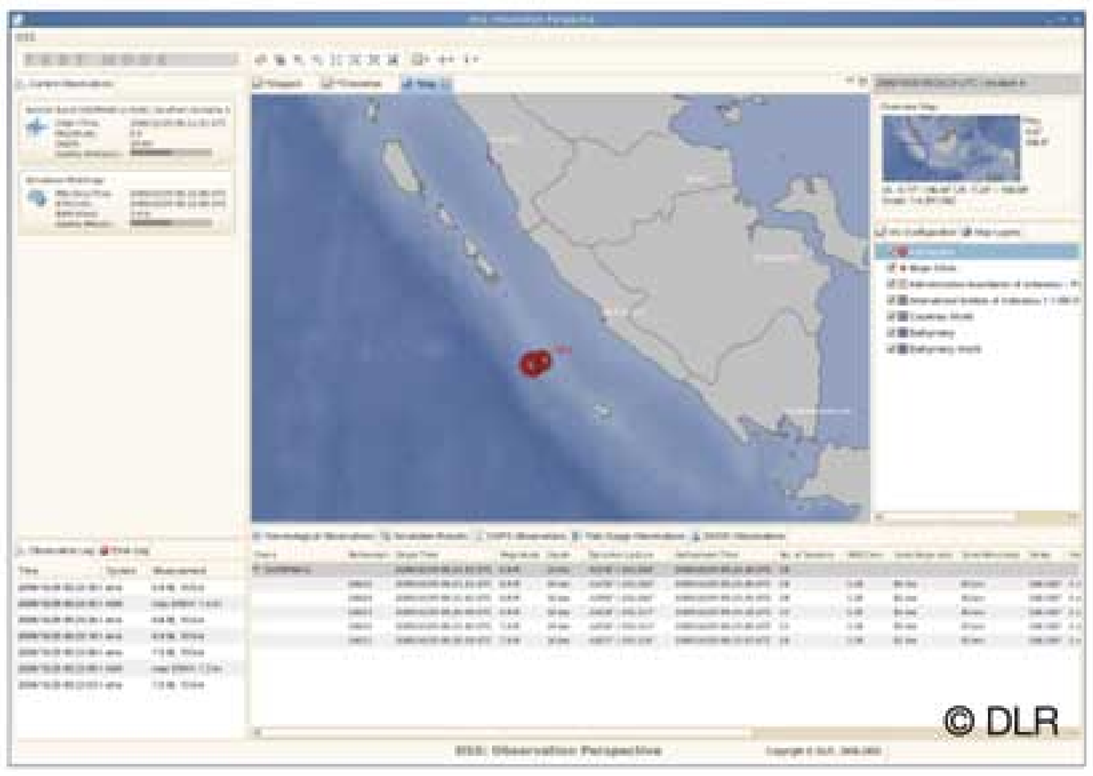


1. Situation overview

The DSS provides an overview of the geographical situation and the time line. A map shows the expected propagation of the tsunami wave according to a pre-calculated scenario and also indicates the position of buoys and tide gauges, which are in the range of the tsunami waves.

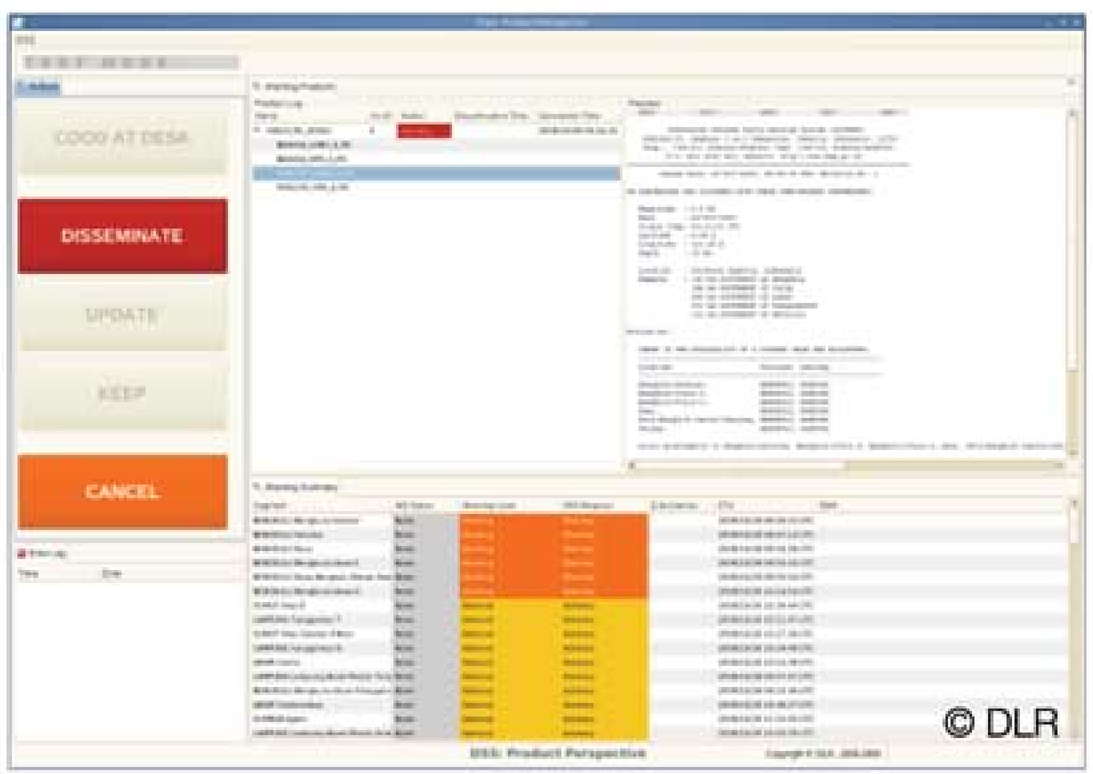


2. Sensor information

On a second screen a more detailed view of the incoming measurements from the different sensors (seismometer, GPS, OBU, buoys and tide gauges) and simulation data is provided.

3. Decision making

An evaluation of the situation is displayed on the third screen. DSS assigns a warning level for each of the affected districts and proposes options for decision making.



4. Warning dissemination

Besides a button to trigger or cancel the warning, the fourth screen provides a summary of the warning and a preview of the warning messages. Once the warning is triggered by the officer on duty, the DSS transmits the messages to the BMKG dissemination system.

08. Monitoring and Warning Services – an international affair

Monitoring and warning services for tsunami early warning requires international cooperation and coordination of various groups of individuals and institutions on the international, national and local level.

End to End System

International coordination

The Intergovernmental Oceanographic Commission (IOC), established in 1960, is the commission for ocean sciences and ocean services and facilitates the international cooperation. IOC is coordinated by UNESCO and cooperating with the World Meteorological Organization (WMO), UN-ISDR and other key partners contributing expertise and exchange of data and knowledge between individual countries and regions. The International Coordination Group (ICG) as a subsidiary body of UNESCO-IOC promotes, organizes and coordinates regional tsunami mitigation services, including issuances of warnings.

International cooperation

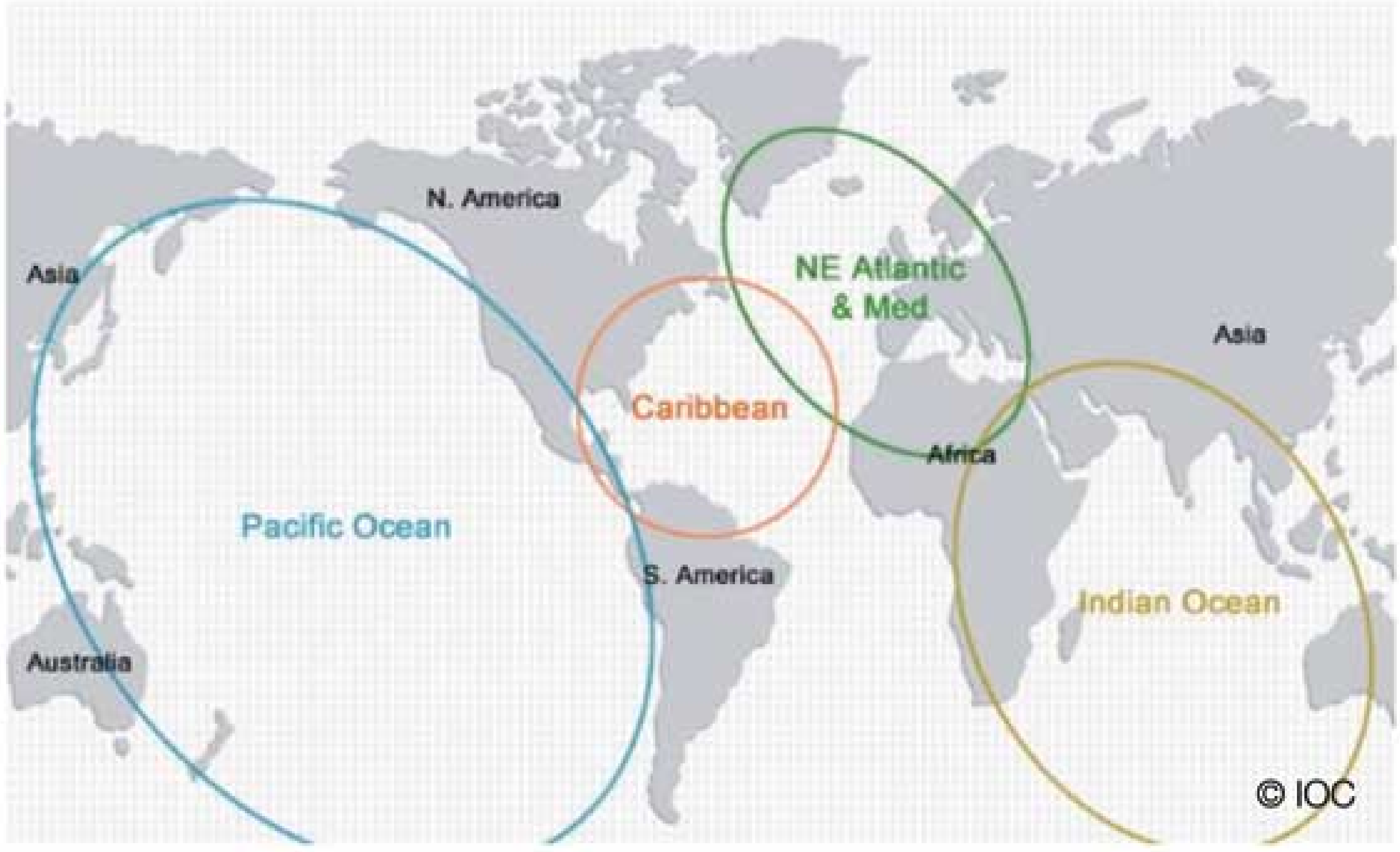
International cooperation supports Indonesia with advisory information, technical assistance, and policy and organizational support to develop InaTEWS and strengthening capacities of the involved institutions to operate the system.

Observation Networks

Earthquake and ocean monitoring requires international networks and cooperation. Several countries and international institutions, such as the United States Geological Survey (USGS), Japan Meteorological Agency (JMA) and the German Geoscience Research Centre Potsdam (GFZ), are involved.

National and Regional Watch Provider

BMKG is the National Tsunami Watch Provider (NTWP) for Indonesia. Additionally, Regional Tsunami Watch Providers (RTWP) have been established to provide ocean wide tsunami early warning services. The Japan Meteorological Agency (JMA) and the Pacific Tsunami Warning Center (PTWC) are providing warning services for the Pacific Ocean and on a temporary basis also for the Indian Ocean Area. Currently Indonesia, India and Australia are preparing to take over this task for the Indian Ocean Area.



International Coordination

Regional Seismographic Network for the Indian Ocean

BMKG - National Tsunami Watch Provider for Indonesia

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