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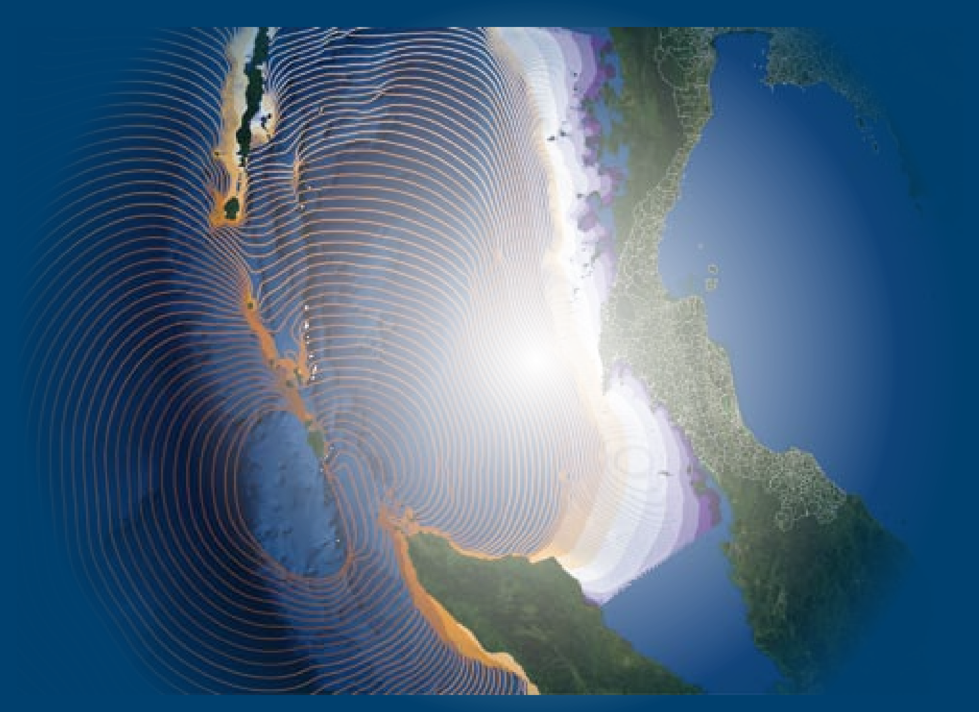
Distant Early Warning System
DEWS

Lessons Learned -
From Concept to Demonstrator



Proceedings of the DEWS-Midterm-Conference 2009

July 7 - 8, 2009
Helmholtz Centre Potsdam
German Research Centre for Geosciences - GFZ,
Potsdam, Germany

SIXTH FRAMEWORK PROGAMME

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Specific Targeted Research Project
Project No: 045453

Content

Programme DEWS Midterm Conference 2009

Time	Session / Presentation	Speaker	Chair
	Tuesday, 7th July 2009		
9:30	**Registration**		
10:00	Welcome Speech	Dr. Joachim Wächter Head of Data and Computing Centre GFZ, Germany.	
10:20	Conference Opening Session - Welcome to DEWS	José Esteban Lauzan Atos Origin, Spain.	
10:45	Greeting address Republic of Indonesia	HE Ambassador S..Eddy Pratomo	
10:55	Greeting address Kingdom of Thailand	HE Ambassador Sorayouth Prompoj	
11:05	Greeting address Democratic-Socialist Republic of Sri Lanka	HE Ambassador Tikiri Bandara Maduwegedera	
11:15	Coffee break		
11:30	Introduction to DEWS	Joachim Wächter GFZ, Germany	José Esteban Lauzan (Atos)
12:00	**Live Presentation of the DEWS *National Demonstrator* and Discussion**	Edward Mutafungwa TKK, Finland & Training course participants from Indonesia, Thailand, Sri Lanka; Martin Hammitzsch & Matthias Lendholt GFZ, Germany	" "
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14:00	Project presentation **GITEWS** - German Indonesian Tsunami Early Warning System	Jörn Lauterjung GFZ, Germany	Andreas N. Küppers (GFZ)
14:30	Development of InaTEWS toward Regional Tsunami Watch Provider	Prih Harjadi BMKG, Indonesia	" "
14:50	Interoprability and Dissemination system of InaTEWS	Fauzi BMKG, Indonesia	" "
15:10	The Tsunami Early Warning System in the Euro-Mediterranean Region	Stefano Tinti Univ. Bologna, Italy	" "
15:30	Atlantic and Mediterranean France tsunami warning system	Francois Schindelé CEA/DG, France	" "
15:50	Coffee break		
16:05	Tsunami Early Warning - overview an experiences	Costas Synolakis	Stefano Tinti (UNIBO)
16:25	Constitutional, legal and ethical issues	Dieter C. Umbach Univ. of Potsdam, Germany	" "
16:45	DEWS The Training and Education Strategy	Andreas N. Küppers GFZ, Germany	" "
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Time	Session / Presentation	Speaker	Chair
	Wednesday, 8th July 2009		
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9:20	From ORCHESTRA to SANY - An Open Sensor Service Architecture for Early Warning Systems	Desiree Hilbring Fraunhofer, Germany	" "
9:40	Tsunami hazard studies in South East Asia	Finn Løvholt Norwegian Geotechnical Institute	" "
10:00	High-rate GPS data analysis during the Bengkulu (South Sumatra) earthquake and tsunami 2007	Irwan Meilano ITB, Indonesia	" "
10:20	Coffee break		
10:40	Early Warning Experiences in Padang, Sumatra: The Bengkulu earthquake of 12 September 2007	Horst Letz BMKG, Indonesia	Burin Wechbunthung (TMD)
11:00	Tsunami Modeling Achievements at Alfred-Wegener-Institut	Claudia Wekerle AWI, Germany	" "
11:20	National Earthquake Monitoring for Tsunami Early Warning	Sumalee Prachuab & Burin Wechbunthung TMD, Thailand	" "
11:40	The Uniqueness of Adjacent Beaches for Tsunami Mitigation Efforts - A Case Study from Phuket, Thailand	Richard Zobel PSU, Thailand	" "
12:00	The Chorist Warning System (CHOR-WARN) - Communication to Citizen, in case of an emergency	Wim van Setten SPMM, Netherlands	José Esteban Lauzan (Atos)
12:20	Professional Mobile Radio: Providing a Dependable Message Delivery Infrastructure for Early Warning Systems	Edward Mutafungwa TKK, Finland	" "
12:40	Early Warning Systems as Critical Information Infrastructure: Analysis of Potential Threats and Related Concepts	Edward Mutafungwa TKK, Finland	" "
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14:20	Geolgical Records of Tsunami in the Southern Coast of Sri Lanka	Nalin Ratnayake Moratuwa Univ., Sri Lanka	" "
14:40	Standardized Messages from GITEWS DSS - how they are useful for national and international warning dissemination	Tilmann Steinmetz DLR, Germany	" "
15:00	Tsunami Warning and Rescue Services- an overview	Peter Månsson MSB, Sweden	" "

15:20	Coffee break		
15:35	***OPEN LECTURE*** Rescue work and coordination with the national authorities in Thailand	Göran Schnell Swedish Fire Protection Association	Peter Månsson (MSB)
17:00	Conference closing	José Esteban Lauzan ATOS, Spain Joachim Wächter, GFZ, Germany	

DEWS Midterm Conference 2009
Full Papers & Posters

Setup and Architecture of the DEWS Demonstrator
Work Package 1, 2, 3

Implementation, Transfer and Outreach
Work Package 4, 5, 6

Introduction to the Distant Early Warning System (DEWS)

Joachim Wächter, Matthias Lendholt, Martin Hammitzsch

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1 Introduction to DEWS

One of the great scientific, technical and social challenges resulting from the Indian Ocean Tsunami event of 2004 is the development of a cross border regional tsunami warning system in order to enable the nations around the Indian Ocean to improve the disaster resilience of their societies.

The DEWS project, partly funded under the 6th Framework Program of the European Union, has the objective to create a new generation of interoperable tsunami early warning systems based on an open sensor platform. This platform integrates sensor systems for the rapid detection of earthquakes, for the monitoring of sea level, ocean floor events, and ground displacements. Presently seismic networks, tide gauges, buoys, and GPS land stations are available.

In the DEWS project a well balanced consortium of public and private organisations from several EU member states as well as partners from Indonesia, Thailand, and Sri Lanka are working closely together in order to design and implement an open, standard based early warning system (Fig. 1).

The sensor integration platform of DEWS is based on the results of the German Indonesian Tsunami Early Warning System GITEWS.

2 Objectives

The DEWS project is dedicated to the design and implementation of a new generation of open standard based early warning systems realizing both reliable hazard detection and effective warning dissemination. The project follows a multi-hazard approach, so that the application can be used for other types of hazards in different geographic areas.

The DEWS project focuses on the efficient and effective dissemination of warning messages for both national and international/regional warning centres. Key challenge is the aggregation and tailoring of appropriate information for selected people and/or organisations. Information logistics play an important role for the design and optimisation of these information flows.

On a technical level the time interval between an initial strong earthquake and the detection of the tsu-nami has to be drastically reduced. Warning messages should be generated more rapidly and should only be disseminated to responsible authorities and people at risk. Initial warnings should be followed by timely and in-depth information that is understandable and reliable for people.

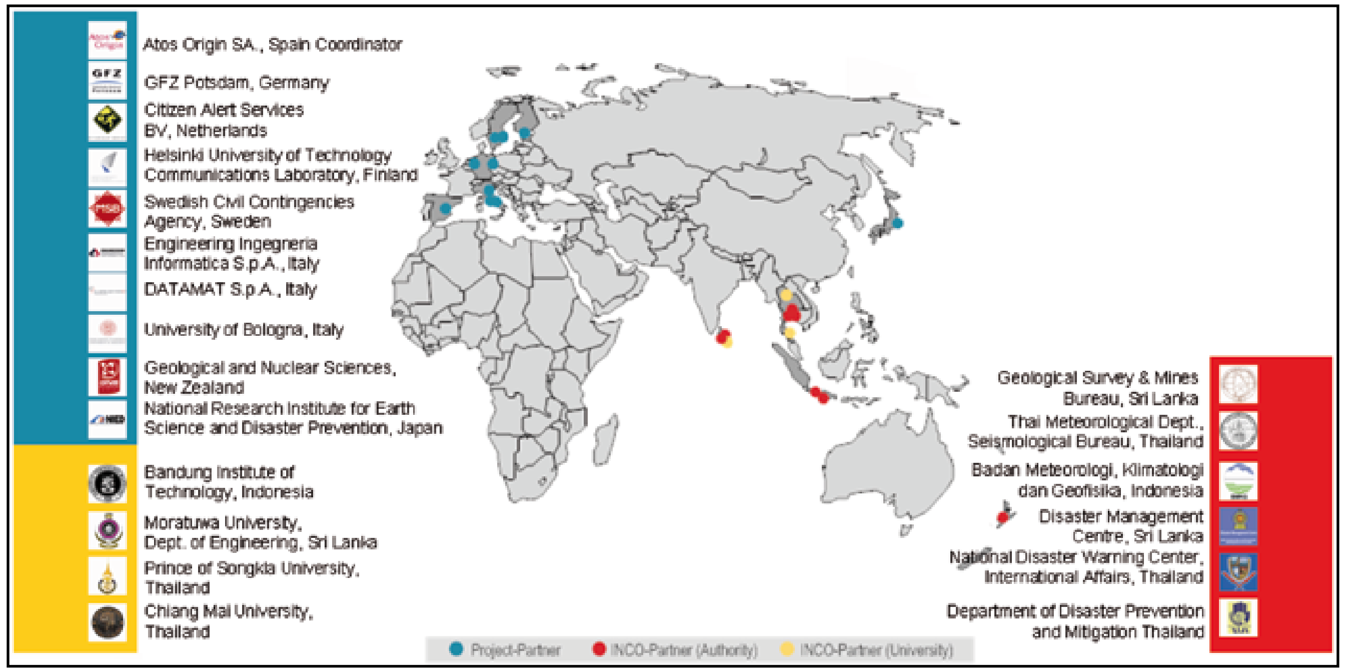

Fig. 1: DEWS Consortium Partners

Another important objective is the modular design of DEWS and its component based architecture. DEWS is using standardised interfaces for accessing different kinds of resources, i.e. sensors, simulation systems, or data bases. New sensors and other resources therefore can be added to the system easily.

On the organizational level warning centre has to organize upstream and downstream information flows (Fig. 2). Upstream information includes observations about physical phenomena measured by sensor systems, e.g. seismic systems, or GPS stations. This information is collected by the warning centre and used for the detection of potential threats. The downstream information consists of warnings and situation reports delivered by the warning centre to the end users of the system.

The DEWS project focuses on tsunami early warning in the Indian Ocean region. The system will be demonstrated in a two prototypical implementations comprising a National Warning Centre and a Wide Area Centre. The National Centres prototype will is dedicated to the dissemination of warning mes-sages via multiple dissemination channels (Fig. 3). The Wide Area Centre will demonstrate the systems capabilities for communication between national warning centres in the Indian Ocean region.

For the future the system is designed to be applied to other geological phenomena e.g. landslides, floods and volcanic eruptions. Geographically the Mediterranean is a highly interesting area for future application.

3 General Architecture
DEWS has been designed as a modular system following the principles of services oriented architecture. The operator is working with the CCUI, the Command and Control user interface (Fig. 4). After starting the message sending process the Information Logistic is generating tailored warning messages for each user that might be interested in receiving this message. The user profiles are stored in a separate database and contain several parameters for each user like language, interested areas and other settings. The generated messages are sent to the Information Dissemination Component that provides adapters for several dissemination channels. It converts the messages into channel specific formats and disseminates the messages. Other components like the sensor platform, the simulation and the map servers are connected via standardized OGC services (Open Geospatial Consortium).

A simplified architectural blueprint provides an overview about DEWS. The upstream components and other resources are integrated via OGC Services and include:

- The Sensor Network with the seismic system, buoys, tide gauges and various other sensors
- The Situation Picture Component for the management of maps, geo-data and geo-processing services
- The Simulation System providing pre-processed forecasts of tsunami wave propagation

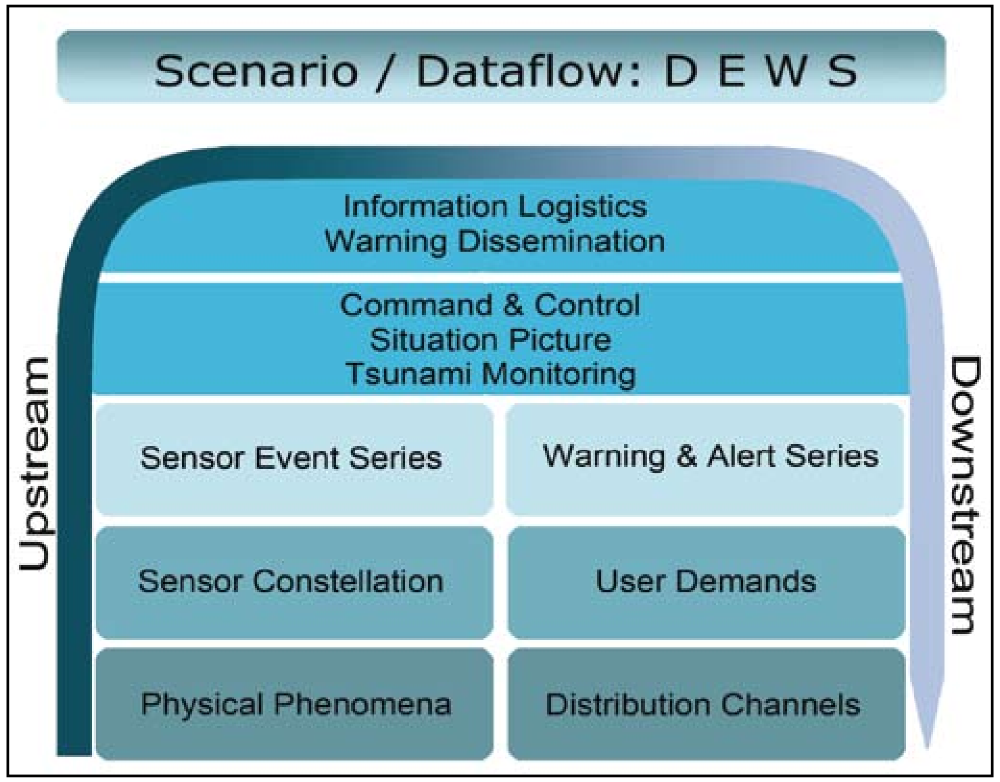

Fig. 2: *Combining upstream and downstream information flow*

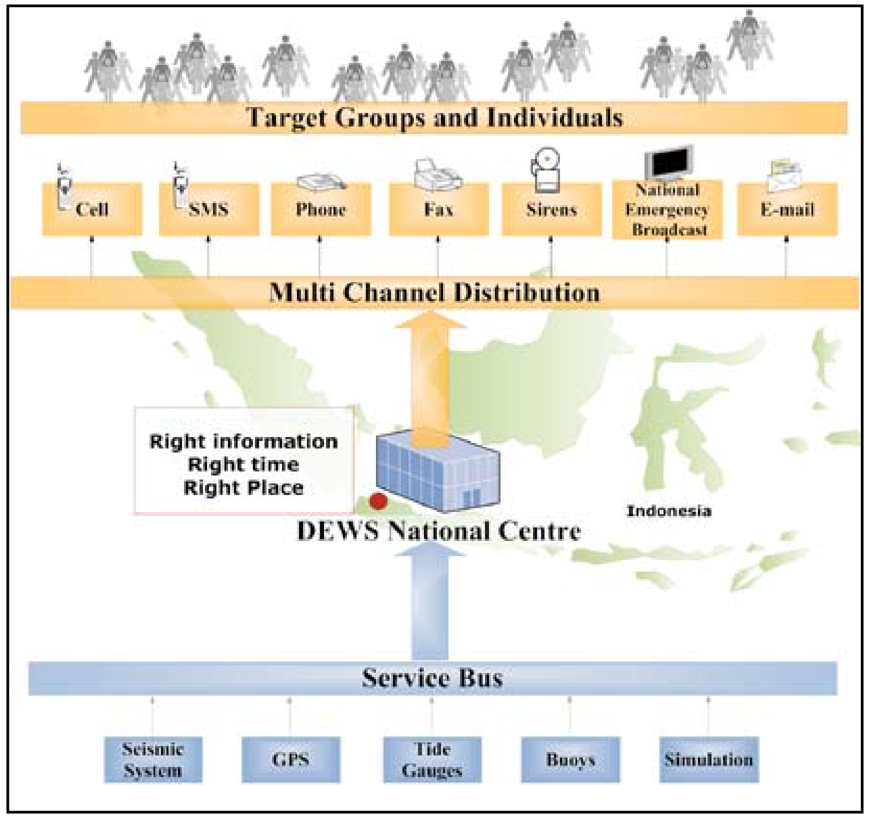

Fig. 3: *DEWS National Centre*

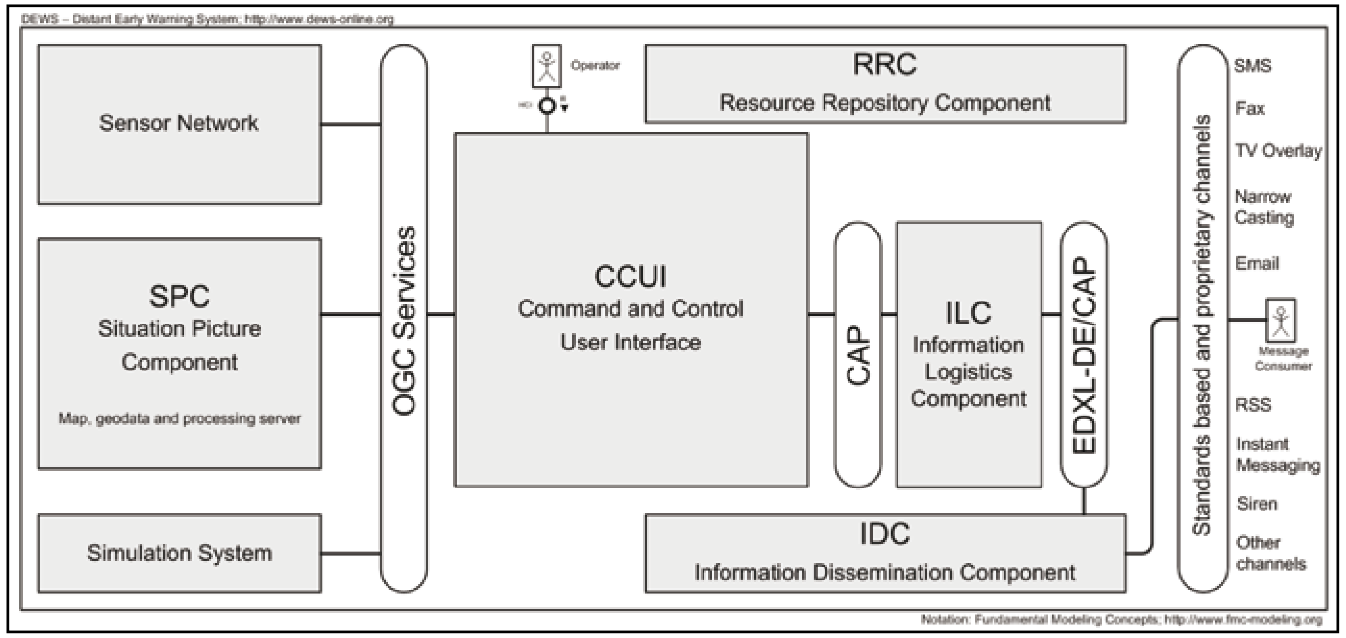

Fig. 4: *Simplified architecture with major components*

The CCUI component offers the Command and Control User Interface used by the operator on duty to manage a tsunami threat including the dissemination of warning messages the warning messages are sent via SOAP services and the Common Alerting Protocol shortly CAP to the ILC the heart of the information logistics.

The Information Logistics Component is responsible for the generation of customized user tailored warning messages respecting different user requirements. The warning messages compiled for the end user are sent via CAP and EDXL-DE with user addressing information to the Information Dissemination Component which finally sends the addressed warning messages to registered dissemination channel providers in a proprietary or other standard based format. The dissemination channel providers then disseminate the messages to the end user or rather the message consumer which might be another system.

3.1 Standards
For the communication and the information exchange between components DEWS applies the Sensor

Web Enablement and OGC Web Service Standards specified by the Open Geospatial Consortium (OGC) and the CAP and EDXL-DE standards specified by the Organization for the Advancement of Structured Information Standards (OASIS):

- SWE (OGC: Sensor Web Enablement): Standardised interfaces for the integration of sensors and sensor system including interface specification and encoding. They include
    - SAS (Sensor Alert Service)
    - SOS (Sensor Observation Service)
    - WNS (Web Notification Service)
- OWS (OGC Web Service): Standardised interfaces to specific services for geospatial data and processing services including
    - WMS (Web Mapping Service)
    - WPS (Web Processing Service)
    - WFS (Web Feature Service)
- EM (OASIS: Emergency Management) Technical Committee has specified standards for the encoding of warning messages and message envelopes
    - CAP (Common Alerting Protocol)
    - EDXL-DE (Emergency Data Exchange Language - Distribution Element)

Furthermore, components with specific tasks are attached as SOAP compliant services.

3.2 Command and Control

The main focus of DEWS is the improvement of information logistic processes. For the intelligent dissemination of tailored warning messages to specific end user groups the so-called Command and Control User Interface (CCUI) is a key component in the development of the project. Within the CCUI, perspectives integrate all functionality necessary for the operator on duty to realise complex workflows and tasks. Each perspective has a map based default user interface. Additional interfaces for specific tasks are available.

Four main perspectives of the CCUI support the operator in his duty to manage a tsunami threat (Fig. 5):

- The Monitoring Perspective to track running events
- The Forecasting Perspective to analyze simulations
- The Message Composition Perspective to prepare and send warning messages
- The Dissemination Perspective to observe all disseminations initiated for the specific user groups

The Administration Perspective is an additional interface is used for the administration of dissemination configuration data necessary for the configuration and adoption of user interfaces for user profiles, information logistics settings, and dissemination channel configurations.

3.3 Information Logistics

The sensor system, the simulation and map servers are responsible for delivering upstream data. The Information Logistics Component is dedicated to the aggregation of user tailored warning messages according to user requirements.

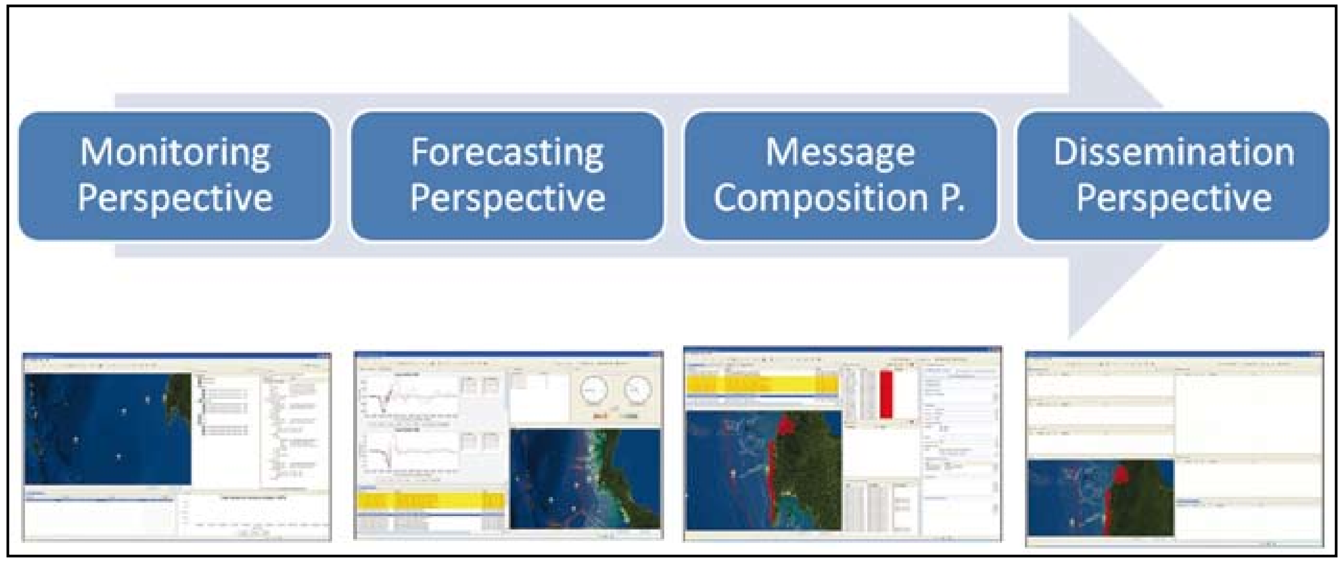

***Fig. 5:** User Interface perspectives supporting the operator*

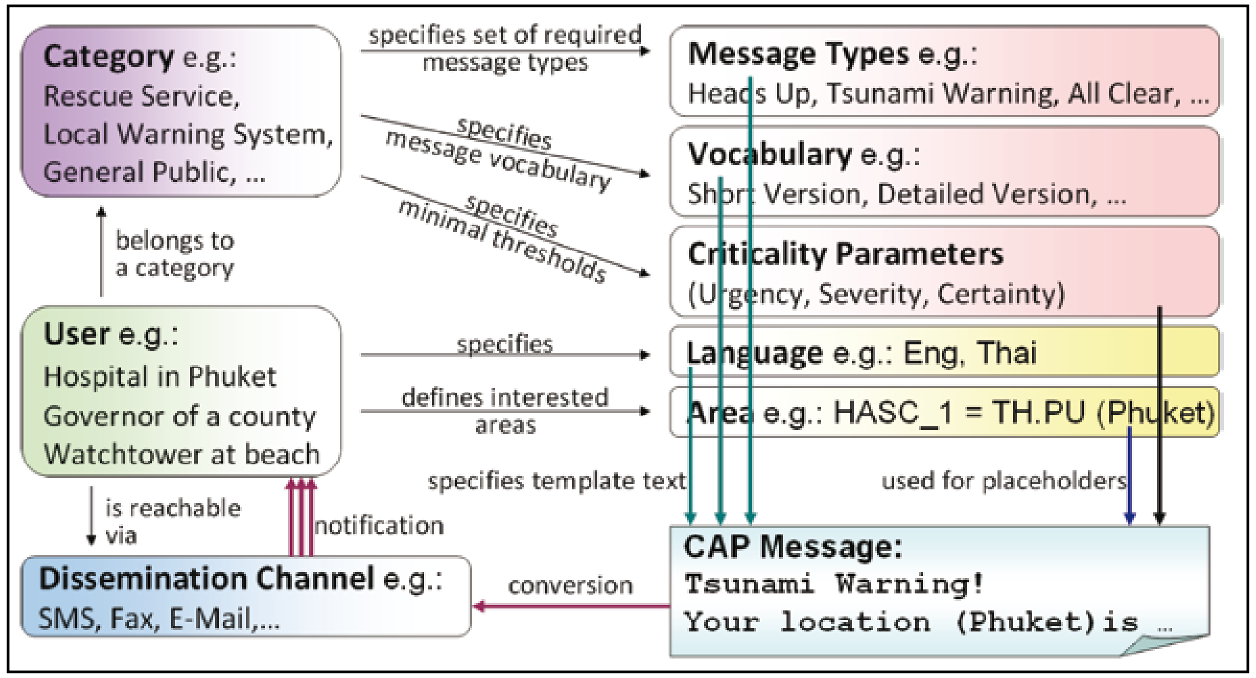

***Fig. 6:** Information Logistics*

The data model for information logistics (Fig. 6) is structured according the following principles. First of all each user (like a district hospital, a tourist or a governor) is assigned to a certain category. This category defines:

- The message types it is interested in. For example, a tourist should not get minor earthquake information or test messages to avoid unnecessary reactions of even panic.
- The vocabulary of the message. While local rescue service will get more detailed message civi-lians only need basic information and clear instructions.
- The minimal thresholds of the three criticality parameters urgency, severity and certainty. Threshold must be exceeded before a message is sent to the respective user.

The user itself defines:

- The language of the warning message he wants to receive and
- The areas of interest.

Only if the affected areas intersect with the defined location the user will be informed. DEWS is using the hierarchical HASC geocode that enables to register countrywide (level 0), for states (level 1), dis-tricts (level 2) or even smaller administrative areas (level 3). With this mapping of user profiles to areas the user is not informed on messages related to areas far away from his position or his area of interest. This reduces the number of disseminated warning messages and avoids false alarms and panic.

The message text itself is stored as template in a database. DEWS applies the Common Alerting Protocol (CAP) that contains title, description and instruction. For each user the template is selected by the combination of message type, language and vocabulary. Templates can contain placeholders that are filled with event specific information. Supported placeholders are, e.g. affected area, minimum time of arrival, estimated wave high, severity, certainty and urgency.

The generated messages are converted into dissemination channel specific format and sent to the user.

3.4 Dissemination Channels

Different dissemination channels are set up and connected to the DEWS system infrastructure with the respective channel gateways or servers (Fig. 7). Based on the situation dependent information the CCUI compiles messages compliant to the CAP standard, the Common Alerting Protocol, and sends them to the DEWS service infrastructure for dissemination. The DEWS system infrastructure itself con-sists of two major components, the Information Logistics Component (ILC), and the Information Disse-mination Component (IDC). The ILC processes the messages from the CCUI and generates persona-lized messages for each of the affected message consumer. Finally the ILC sends the personalized messages in CAP format to the IDC, which relays the message in a channel dependent format to the respective recipient via the registered channel gateways and server.

4 Conclusion

The general approach of the DEWS project has been validated. The Principal Demonstrator (December 2008) was a successful proof of the concept. In the following preparation phase of the National Demonstrator the results stimulated the refinement of the DEWS architecture documented in the "Design Architecture and Technical Specifications" considerably. The evaluation of results of the National Demonstrator will help to update and improve the quality of specifications continuously. The cooperation with the INCO partner countries has been established and will be further intensified for the preparation of the final Regional Demonstrator.

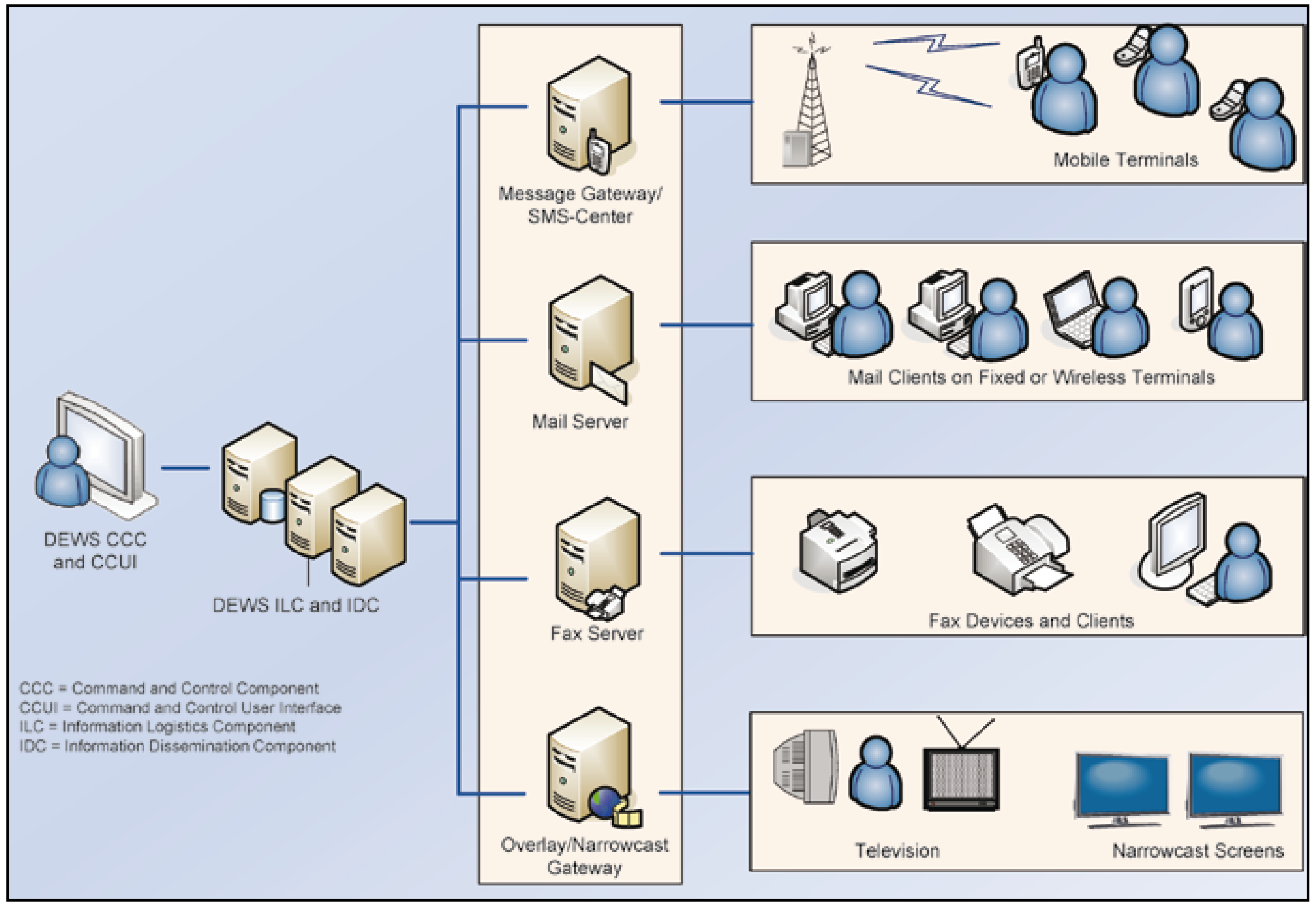

Fig. 7: *Dissemination channels*

User Interface, Workflows and Message Generation of the DEWS National Demonstrator

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The DEWS National Demonstrator is a live presentation of the first prototype of the DEWS national centre. This live demonstration includes the full roundtrip from receiving incoming, simulated sensor events, triggering the simulation and dissemination of tailored warning messages. The whole system is deployed in conference premises and comprises all developed system components.
For the demonstration of the DEWS National Prototype a prepared hazard threat is played to introduce the DEWS Command and Control User Interface with its perspectives as well as the functionality provided by various services running in the background of the system.

1 Constellation of the Demonstration Scenario
Four locations A, B, C and D have been selected as earthquake origin and have been prepared with different magnitude. Dependent on the location and magnitude of the earthquake a minor tsunami threat or major tsunami threat is triggered. For the demonstration the location C and a magnitude of 9 Richterscale has been selected for the earthquake. In this vein the demonstration is showing a major tsunami threat.

Additionally sensor stations have been virtually deployed in the Andaman Sea in front of the Thai coastline. The sensor stations comprise three buoys (named TS01, TS02, TS03) and three tide gauges (named SEBL, ENGG, TEDA). Two tide gauges are existing sensors deployed to the east of Thailand the other sensor stations do not exist physically but are placed virtually at appropriate locations for detection and validation of occurring tsunami threats.

2 Dissemination Channels
For the demonstration of the National Prototype different dissemination channels are set up and con-

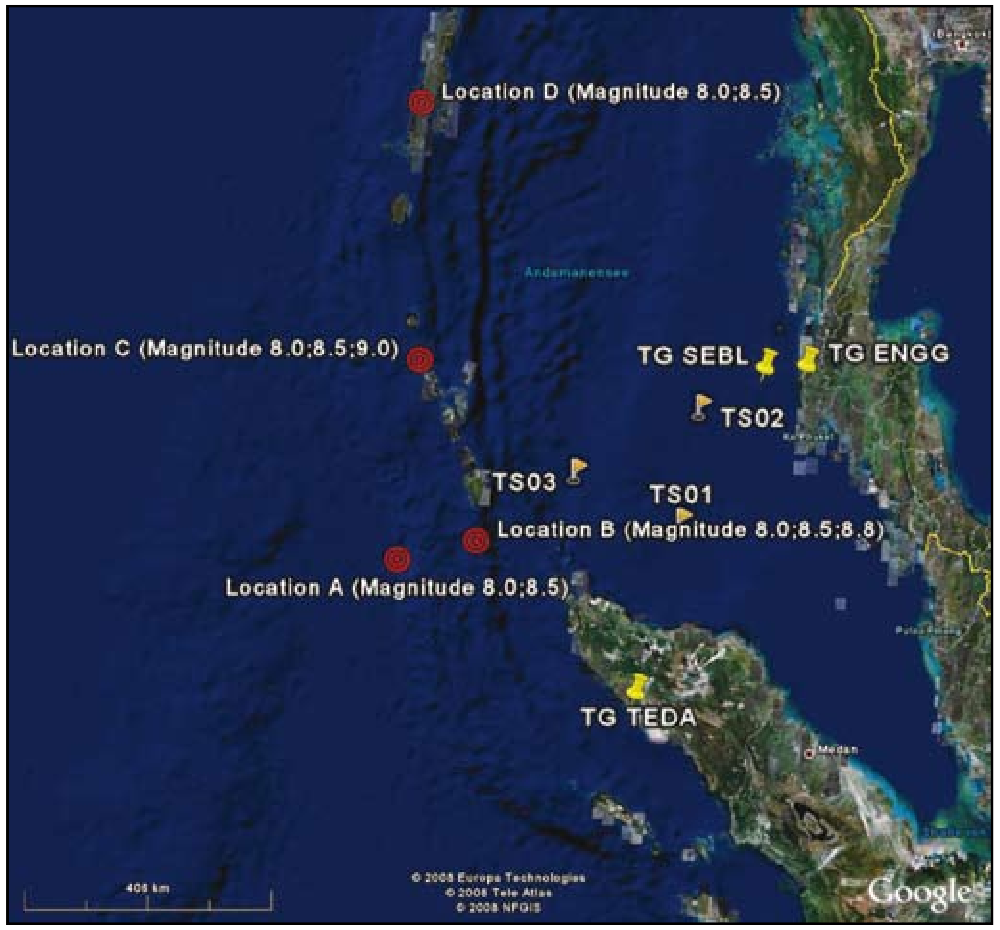


Fig. 1: *Scenario locations in Andaman Sea*

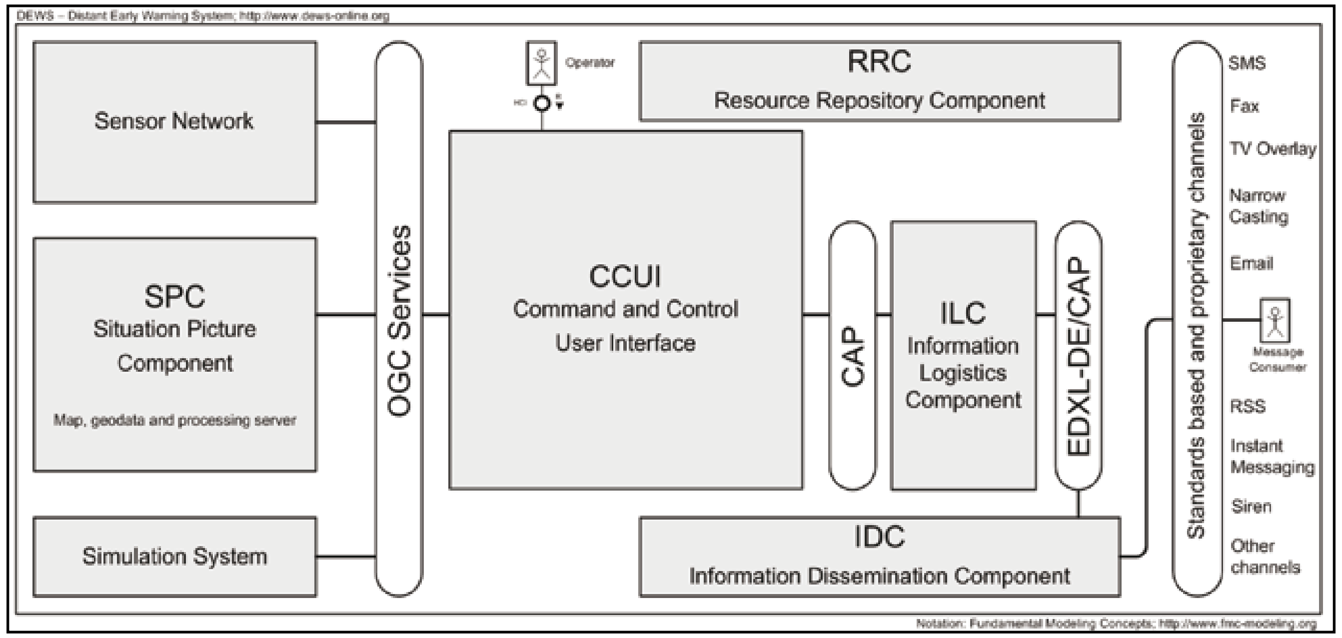


***Fig. 2:** Component architecture of DEWS National Demonstrator*

nected to the DEWS system infrastructure with the respective channel gateways or servers. The DEWS system infrastructure is connected to the DEWS Command and Control User Interface, shortly CCUI.

Based on the ongoing situation and its event parameters the CCUI compiles messages compliant to the CAP standard, the Common Alerting Protocol, and sends them to the DEWS service infrastructure for dissemination. The DEWS system infrastructure itself consists of two major components, the Information Logistics Component, shortly ILC, and the Information Dissemination Component, shortly IDC. The ILC processes the messages from the CCUI and generates personalized messages for each of the affected message consumers. Finally the ILC sends the personalized messages in CAP format to the IDC, which relays the message in a channel dependent format to the respective recipient via the registered channel gateways and servers.
The demonstration exemplarily utilizes six channels:

- SMS Notification:
  SMS text messages are sent with the language the message consumer has registered for. The message is a short message as the abbreviation SMS indicates and contains no media.
- TV Overlay and Narrow Casting:
  Beside a customized text message both, TV Overlay and Narrow Casting, contain media, for example an image of the predicted distribution of the tsunami threat.
- Fax notification:
  The fax message contains a detailed text message and media and has less channel restrictions than SMS, TV Overlay and Narrow Casting according to the length of the text message
- Email and RSS notification:
  Email and RSS channels also do have less channel restrictions and the warning messages contain text and media in a defined detail.

Future versions of DEWS contain supplementary channels, e.g. sirens and instant messaging.

3 Command and Control Workflow
The scenario playing a virtual tsunami threat is managed by an operator on duty (OOD) with the Command and Control User Interface (CCUI) of DEWS.
Within the CCUI, different perspectives show all functionality associated with a comprehensive task to support the OOD. Each perspective has a default layout with a map and additional views appropriate for the respective task.
Four main perspectives of the CCUI support the operator in her duty to manage a tsunami threat:

- The Monitoring Perspective to track running events
- The Forecasting Perspective to analyze simulations
- The Message Composition Perspective to prepare and send warning messages, and
- The Dissemination Perspective to observe all disseminations initiated for the specific user groups

Following the Command and Control User Interface is introduced while running the prepared virtual tsunami threat scenario.

4 Monitoring Perspective
As the name indicates, the Monitoring Perspective provides a survey of a specific area and contributes an overall situation picture to the operator with geospatial information, displayed in a central map, and additional details, contained in multiple views surrounding the map.

The specific area is displayed in a map containing bathymetry of the ocean floor and topography of the coastal area as well as the respective sensors, here buoys and tide gauges, delivering sensor information to the warning centre. In case of hazards further information are depicted in the map. In case of an earthquake its location and magnitude is depicted. Later on, the map contains the tsunami wave propagation and affected areas.

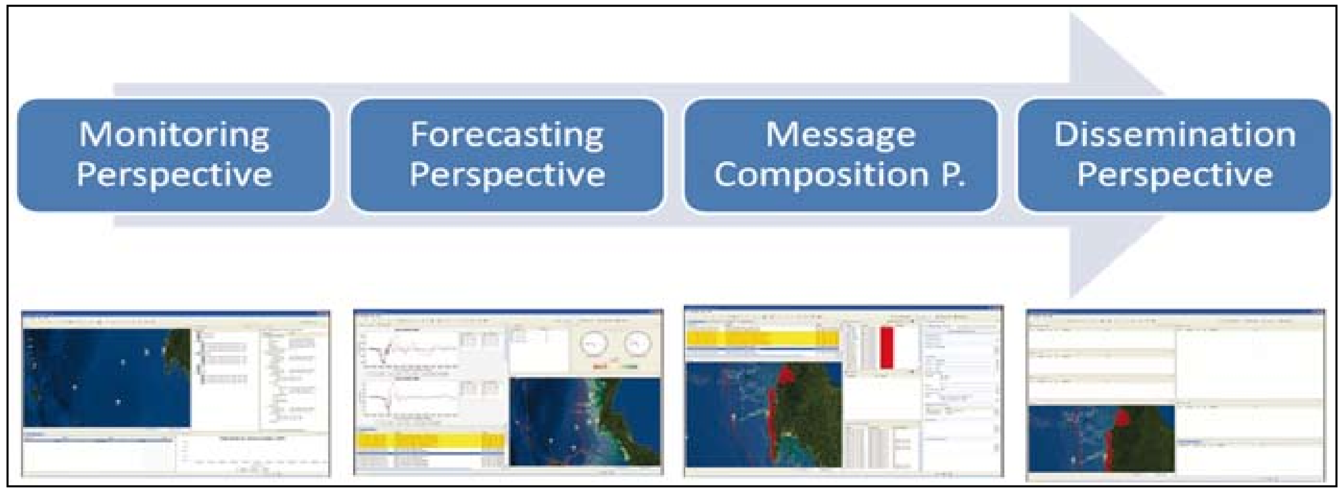


***Fig. 3:** UI perspectives guide operator's tasks*

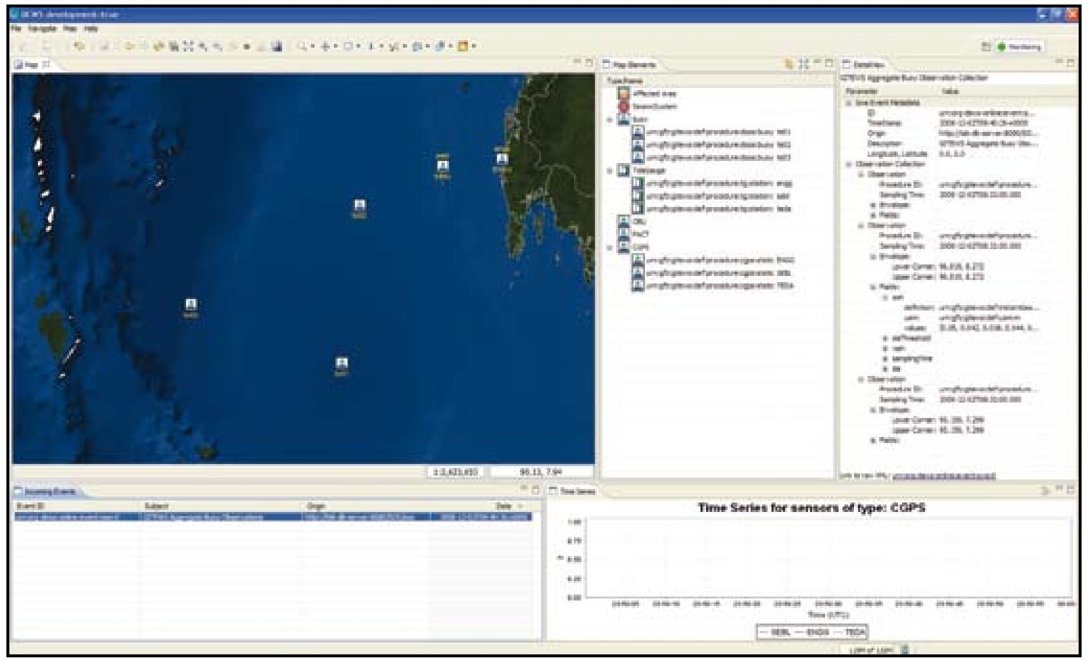


***Fig. 4:** Monitoring Perspective with sensor locations*

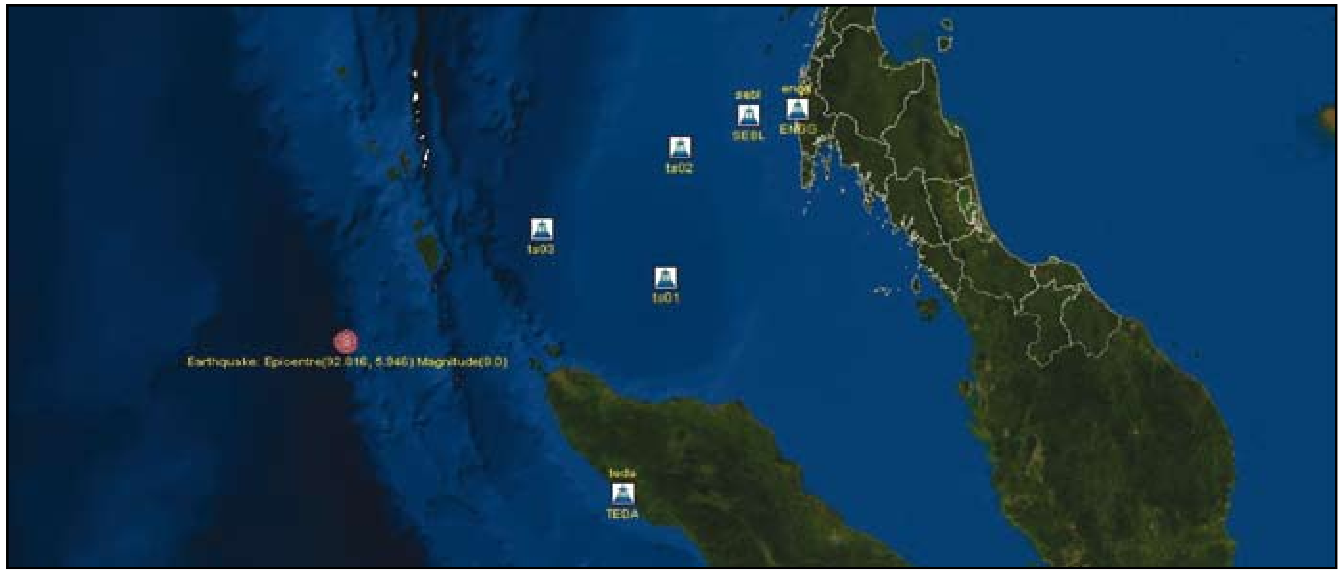


***Fig. 5:** Sensor and earthquake locations in Andaman Sea*

To aid further investigation in details of information according to the specific area, it is possible to zoom and pan the map.
Rightward, a view lists elements contained in the map. Typical elements that appear in this list are

- Sensors, for example buoys and tide gauges displayed with their respective identifiers
- Seismic alerts, that have occurred and have been depicted in the map, and
- Affected areas, generated while message composition

This view supports the operator while working with the map – for example trimming the map to the selected map elements.

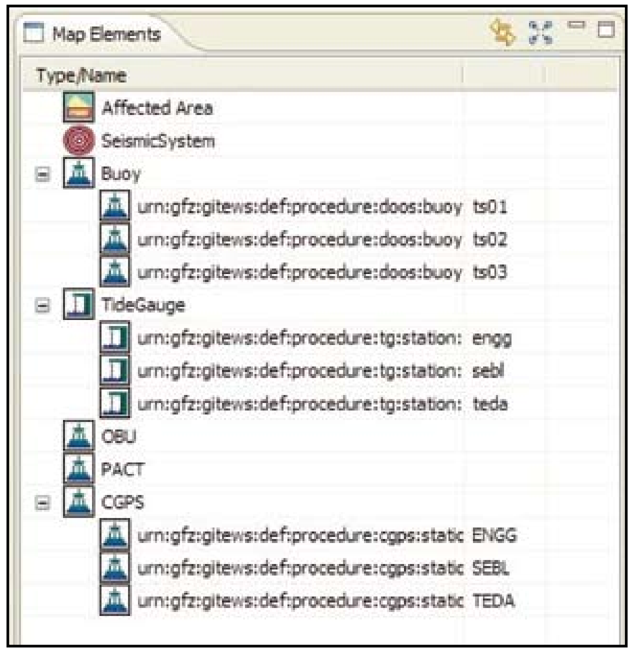


Fig. 6: *Tree showing DEWS related map content*

Below, a list of incoming events tracks ongoing incidences reported by the system with its sensors, sensor networks, other warning centres and everything else that is able to report a status. An event could be an earthquake, detected by a seismometer, an anomaly detected by a pressure sensor at the ocean floor or simply a message from a sensor reporting low battery status.

Furthermore this view not only constitutes the inbox for received events but also serves as kind of a history. The events are organized by date; the latest events are always automatically displayed on top.
In addition all measured data are displayed in form of time series for the different sensors. Graphs allow the operator to track the incoming data successively. The information is the same as in the view of the incoming events but depicted graphically. The Time Series in this example depicts the sea surface height measured by each buoy of the sensor network.
According to the selected event further details are displayed in another view for a close understanding of the respective event data. The appearance of this view strongly depends on the event type selected. For example the information displayed could be all sensed earthquake information regarding to a seismic alert selected within the event list.

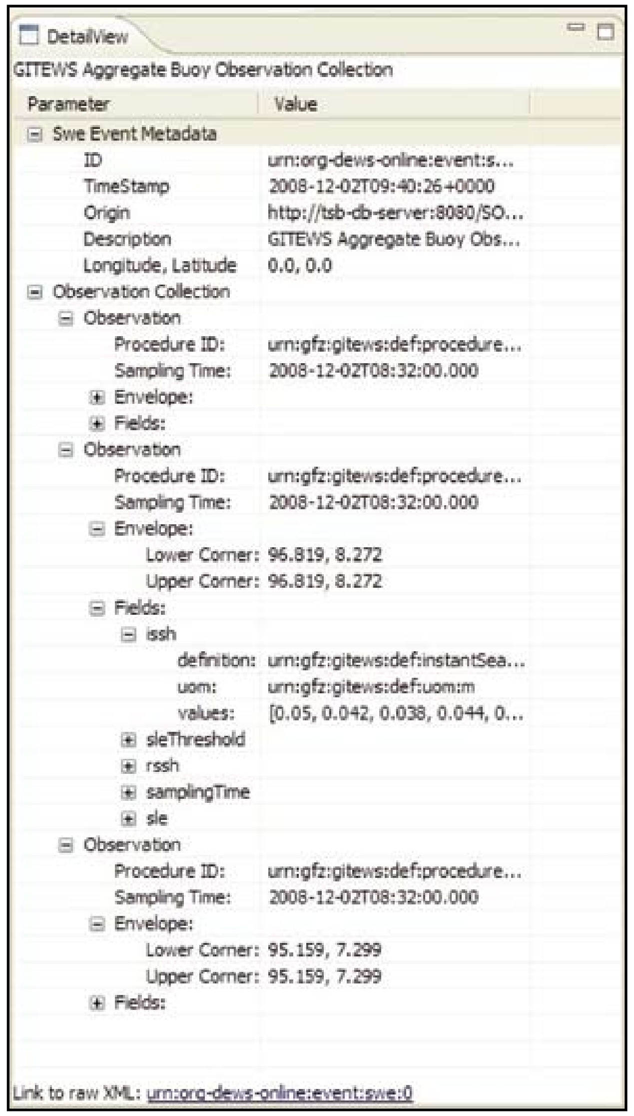


Fig. 8: *Details of sensor event with SWE payload*

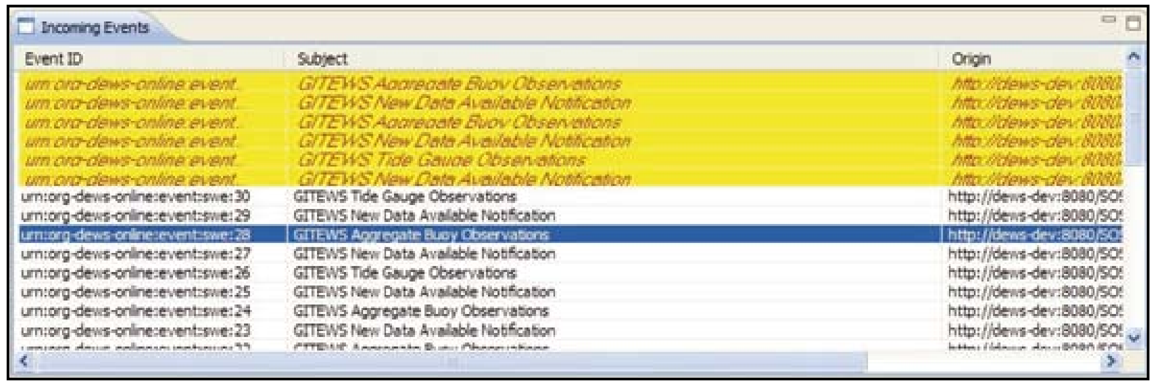


Fig. 7: *Incoming sensor events*

Moreover the event list provides an action in the context menu to start a computation for the evaluation of probable forecasts based on one ore more selected events. The measurements contained in the selected events serve the input for this computation.

5 Forecasting Perspective

The Forecasting Perspective supports the operator in analyzing the different probable forecasts provided by the simulation system. The perspective is divided into

- A view with predicted sensor time series compared to real measurements
- The same event list known from the Monitoring Perspective
- A ranking list with probable predictions
- A view with absolute and relative time measurements, and again
- The map showing the result of the selected forecast

The view with the predicted time series contains one diagram for each sensor. The diagrams for the sensors are ordered one below the other. Which sensors are displayed, depends on the available sensors within the considered geographic area.
Each diagram for the respective sensor includes differently coloured graphs for each predicted measurement calculated by the simulation system and a graph in black representing the real measurement of the sensor. In this vein the operator is enabled to compare and approve the forecasts given by the simulation system with the real measurement.
The X-axis denotes the UTC time and the Y-axis the Sea Surface Height, abridged as SSH. On top of each diagram the name and type of each sensor is displayed. The predicted time series for each sensor are also listed in the two small boxes to the right of a chart. Simulation Visibility is used to select all or only single time lines which should be displayed in the chart. Simulation Weighting is important for the ranking of the probable predictions. The operator selects the best fitting simulation whereas the rest is disregarded.

The time series are updated with each incoming refinement of a simulation calculation. That means the operator continuously receives events according to

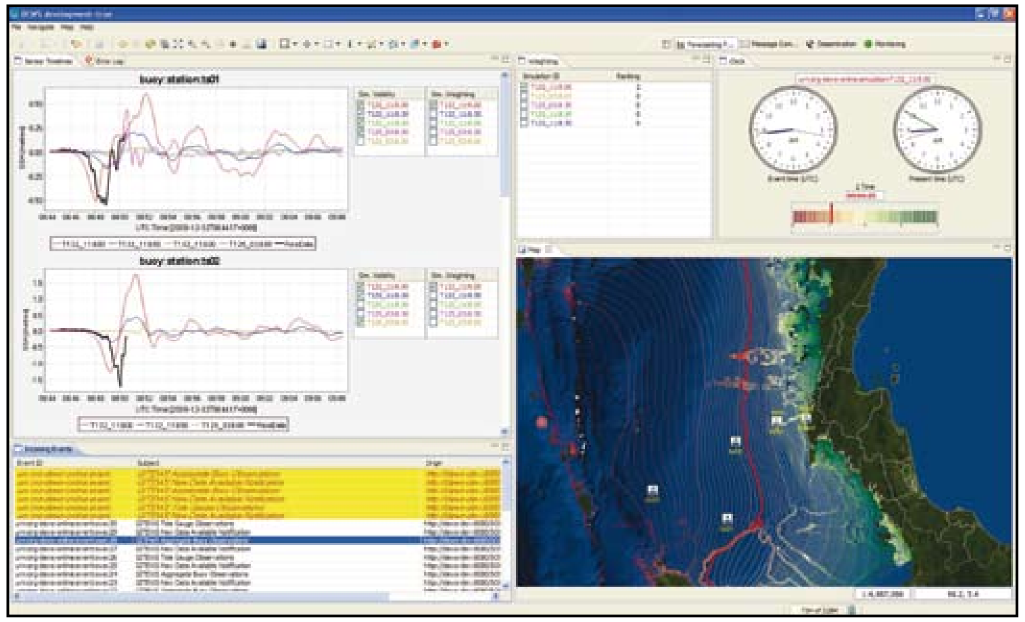


Fig. 9: *Forecasting Perspective showing simulation based forecasts*

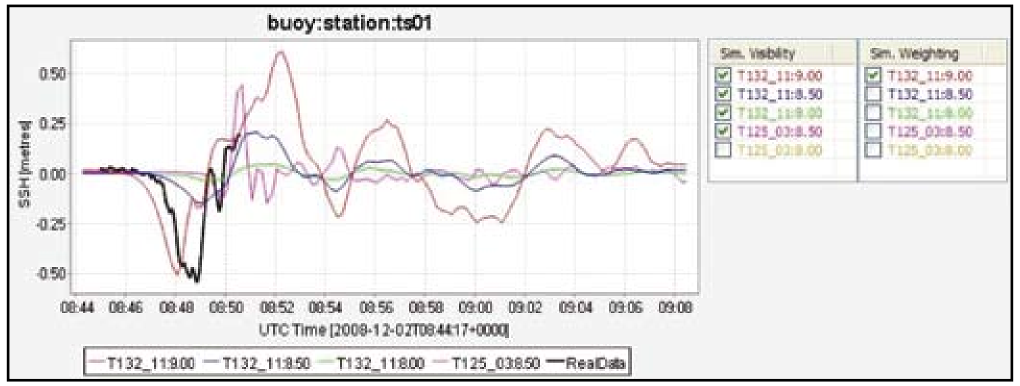


Fig. 10: *Forecasts compared to real data for a buoy sensor*

an incident that already has a simulation calculation. But the incoming events are inputs to refine the selection of forecasts and to display the most likely forecast only. Then the operator starts the simulation calculation again with additional inputs or rather fresh events followed by an iterative analysis and comparison.
In the ranking list the forecasts are simply ordered by the count of their selection done within the Simulation Weighting of each sensor graph. By this selection process the simulation with the highest probability leads to an optimal forecast result and can be used for the dissemination of warning messages.

When selecting a simulation in the ranking list, updated information is displayed in the map and in the time measurements.

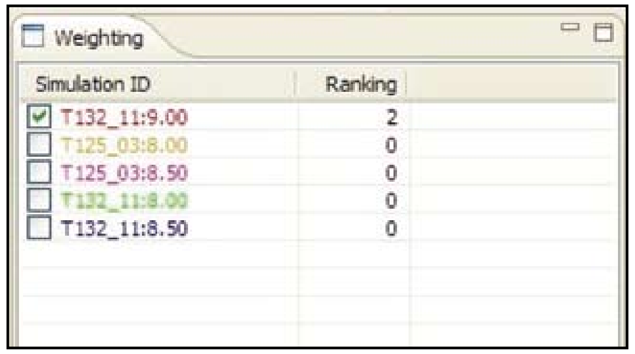


Fig. 11: Simulation ranking

The time measurements provide the following information:

- The left clock shows the UTC time of the occurrence of the initial earthquake.
- The right clock displays the present time in UTC.
- In between the relative time difference between the event time and the present time is shown as a delta value.
- Furthermore a bar with lines in the isochrones colour scheme represents the time axis of the calculated simulation. The current position of the proceeding time in the hazard threat is highlighted with a fat red line.

The forecast selected in the ranking list is displayed in the map with coloured isochrones. The outlined isochrones represent the tsunami wave propagation in time between the earthquake location and the impact at the coast. The distance between two isochrones normally accounts for two minutes. In this demonstration the distance has been shortened to only twelve seconds between adjoined isochrones.

To start the dissemination process based on a forecast the ranking list provides a context menu with the action "Start Tsunami Warning Wizard". By opening the Tsunami Warning Wizard a separate view for the wizard is shown in the Message Composition Perspective.

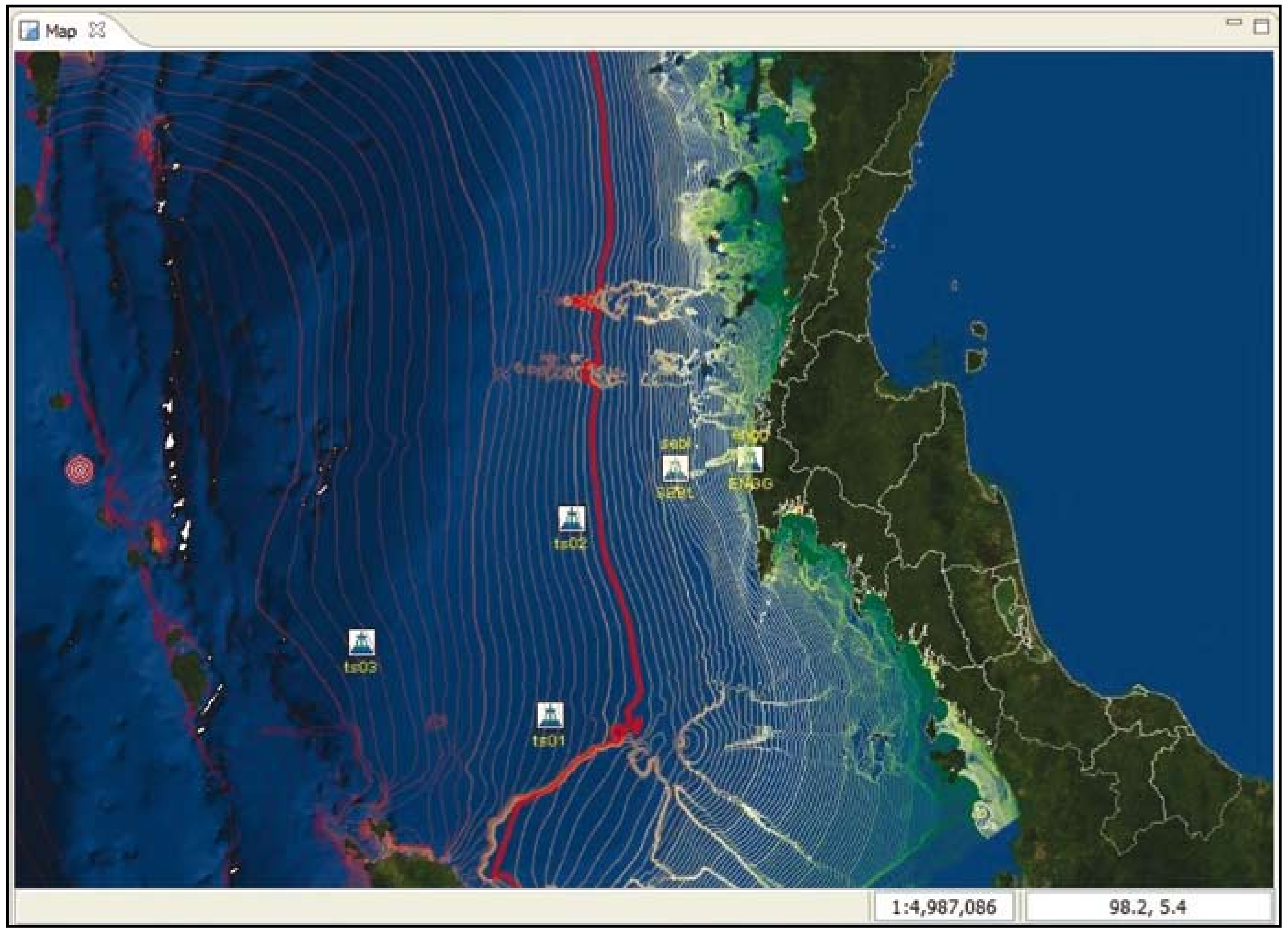


Fig. 12: Simulation based isochrones showing incoming tsunami

6 Tsunami Warning Wizard

The Tsunami Warning Dissemination Wizard represents an automatic support system to identify affected areas on the basis of the best fitting simulation. The simulation result contains predictions for hundreds of coastal points and it is nearly impossible for the operator to check every point and to analyze the situation for each area. The Tsunami Warning Wizard calculates the Estimated Time of Arrival of the wave and the maximum Sea Surface Height for each of the administrative areas.

These values are used to categorize the message according to the severity and urgency attributes of the standardised Common Alerting Protocol, briefly named CAP. The operator configures additional CAP relevant attributes and adds a screenshot of the current map. By pressing the finish button warning messages are sent to each single administrative area considering the area-specific predicted parameters like Estimated Time of Arrival and Sea Surface Height.

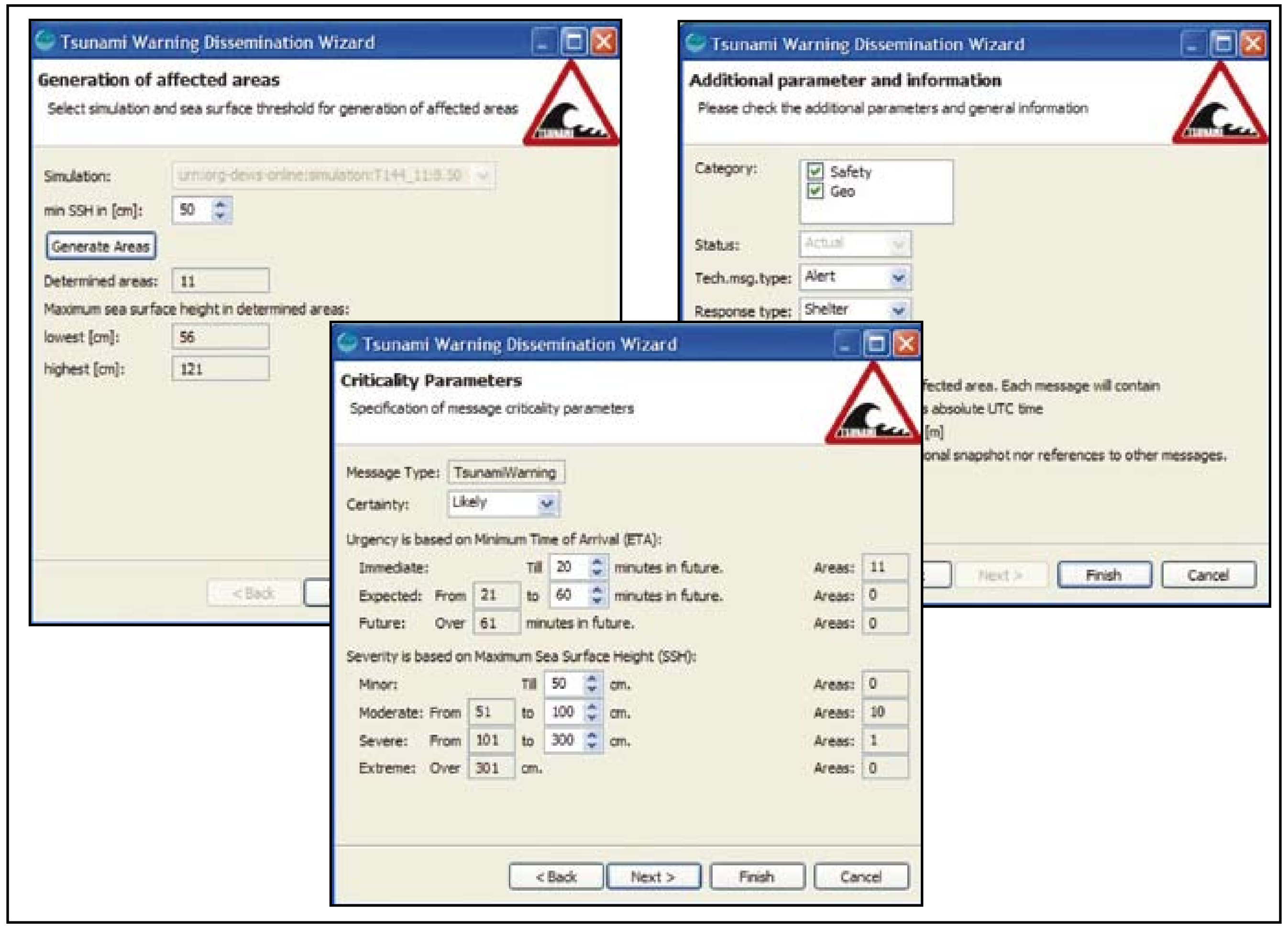


Fig. 13: The Tsunami Warning Dissemination Wizard

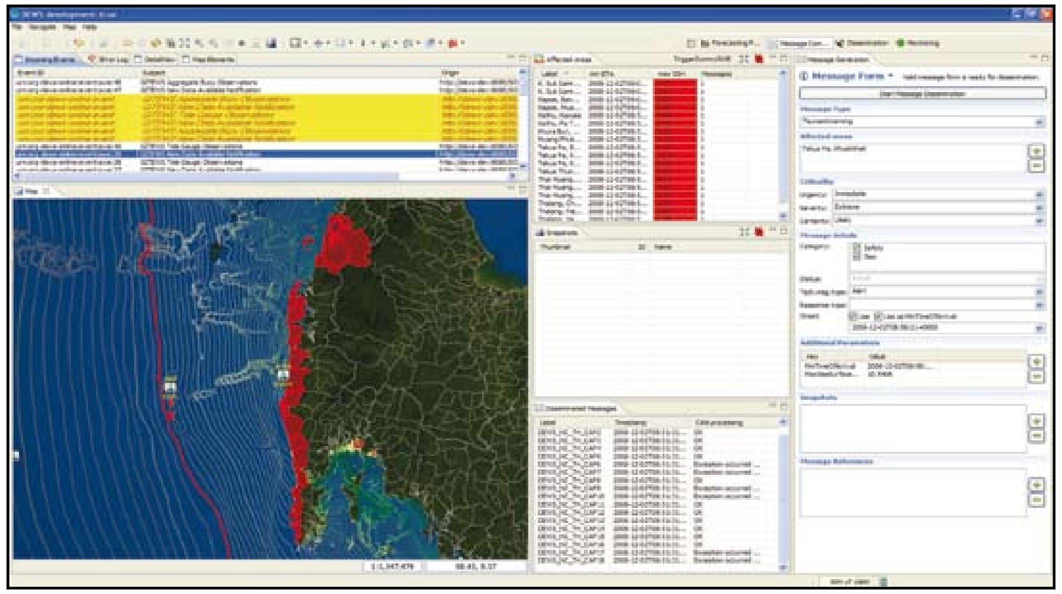


Fig. 14: Message Composition Perspective with Message Generation Form

7 Message Composition Perspective

The Message Composition Perspective is opened automatically in the background when starting the Tsunami Warning Wizard in the ranking list with a selected forecast.

The Message Composition Perspective supports the operator in its task to prepare, to send and to observe the initiated warning dissemination.

The map still depicts the specific geographic region with the information provided by the other perspectives. Additionally affected areas are displayed in the map. According to the selected forecast they are automatically calculated or manually selected by the operator.

Automatically calculated areas are symbolized with different colour schemes for the estimated wave height. Red coloured areas are at high risk. Less endangered areas are depicted in orange, yellow or blue: the colour scheme has been taken from US Homeland Security standards.

The map is editable by the operator with different tools. One of the tools enables the operator to select multiple geographical regions or areas. Thus the operator selects the areas for dissemination.

Selected areas are stored in a list so that the operator is able to manage the affected areas and reuse them later on – for example when composing refined

__Fig. 15:__ Areas generated by the Tsunami Warning Dissemination Wizard

__Fig. 16:__ Less critical situation based on a different simulated earthquake

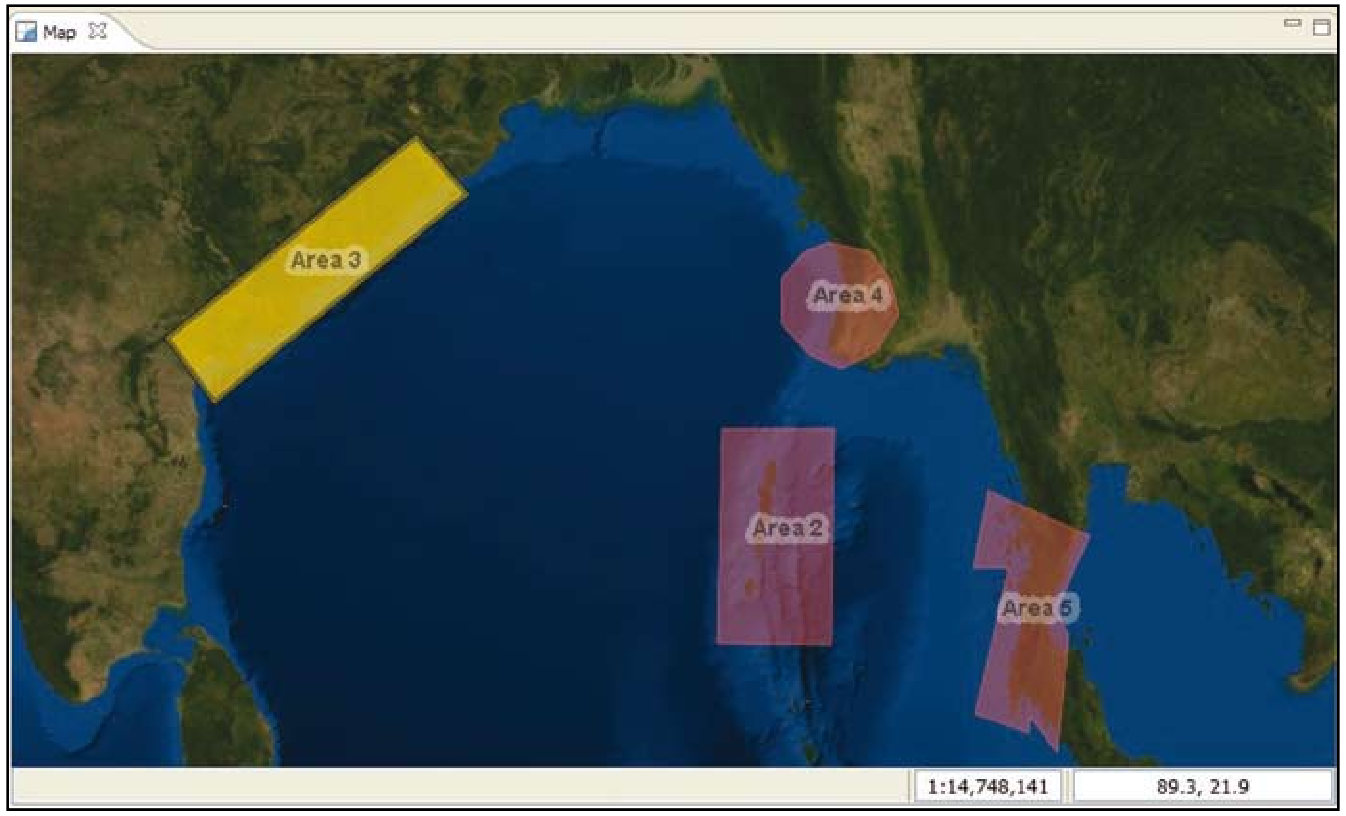
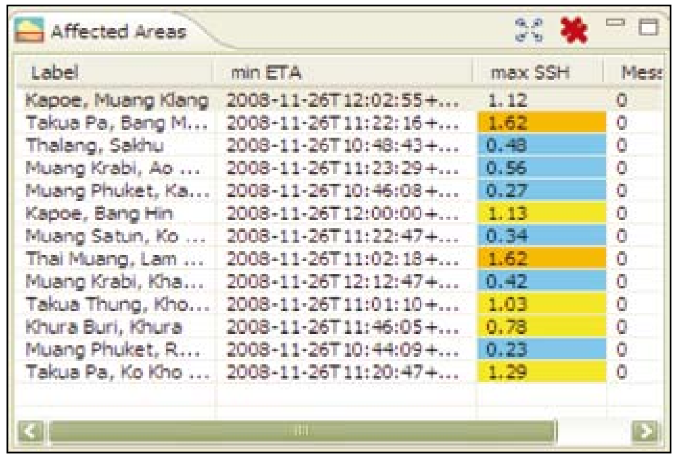


__Fig. 17:__ Manual drawing of affected areas

warning messages. The listed areas serve as input for the message composition of the intended warning dissemination and are attached with drag and drop to a warning message.

To attach an evident situation picture to a warning message, a snapshot of the currently displayed map might be taken. When the operator clicks the respective button, snapshots of the map are taken and stored in a list. The operator selects snapshots from that list and attaches them with drag and drop to the respective warning message.

For the composition of warning messages this perspective contains a form considering elements of the CAP standard. The operator has to select a specific message type first to edit the details of the message. Each message type defines its own range of values for the message details. The operator selects the appropriate value for each message element according to the ongoing situation. Both the affected regions and the resources can be assigned to the message by drag and drop. All values except the resources are mandatory. Resources are optional and serve as input for TV Overlay, Narrow Casting and E-Mail warning messages. The composed message will be sent when each value has been configured appropriate and the operator has triggered the button for dissemination.



Affected Areas

Label	min ETA	max SSH	Mes:
Kapoe, Muang Klang	2008-11-26T12:02:55+...	1.12	0
Takua Pa, Bang M...	2008-11-26T11:22:16+...	1.62	0
Thalang, Sakhu	2008-11-26T10:48:43+...	0.48	0
Muang Krabi, Ao ...	2008-11-26T11:23:29+...	0.56	0
Muang Phuket, Ka...	2008-11-26T10:46:08+...	0.27	0
Kapoe, Bang Hin	2008-11-26T12:00:00+...	1.13	0
Muang Satun, Ko ...	2008-11-26T11:22:47+...	0.34	0
Thai Muang, Lam ...	2008-11-26T11:02:18+...	1.62	0
Muang Krabi, Kha...	2008-11-26T12:12:47+...	0.42	0
Takua Thung, Kho...	2008-11-26T11:01:10+...	1.03	0
Khura Buri, Khura	2008-11-26T11:46:05+...	0.78	0
Muang Phuket, R...	2008-11-26T10:44:09+...	0.23	0
Takua Pa, Ko Kho ...	2008-11-26T11:20:47+...	1.29	0

__Fig. 18:__ List of affected areas with ETA and SSH

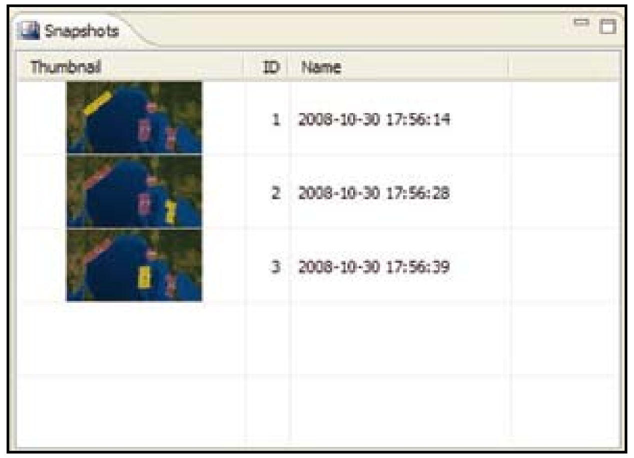


__Fig. 19:__ Snapshots of map can be attached to warning messages

Fig. 20: *Message Generation Form for manual message generation*

Composed and sent messages are listed in the Disseminated Messages View with additional processing information. Each message might be re-used as boilerplate for a refined message in future and presets the form values of the Message Composition View.

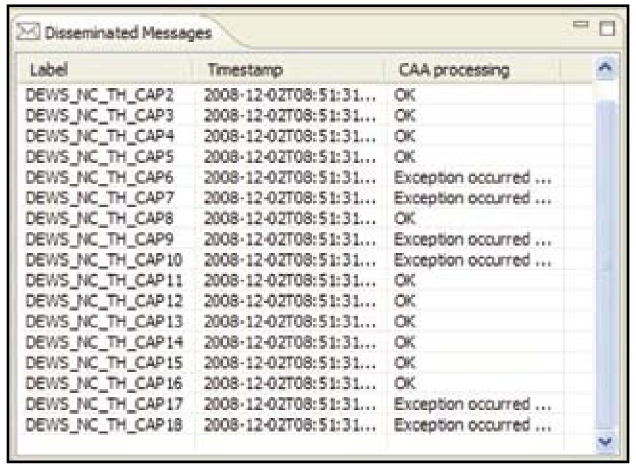


Fig. 21: *List of sent messages*

8 Warning Message Dissemination

SMS text messages are sent with the language and detail of information the message consumer has registered for. SMS messages don't contain media like map images.

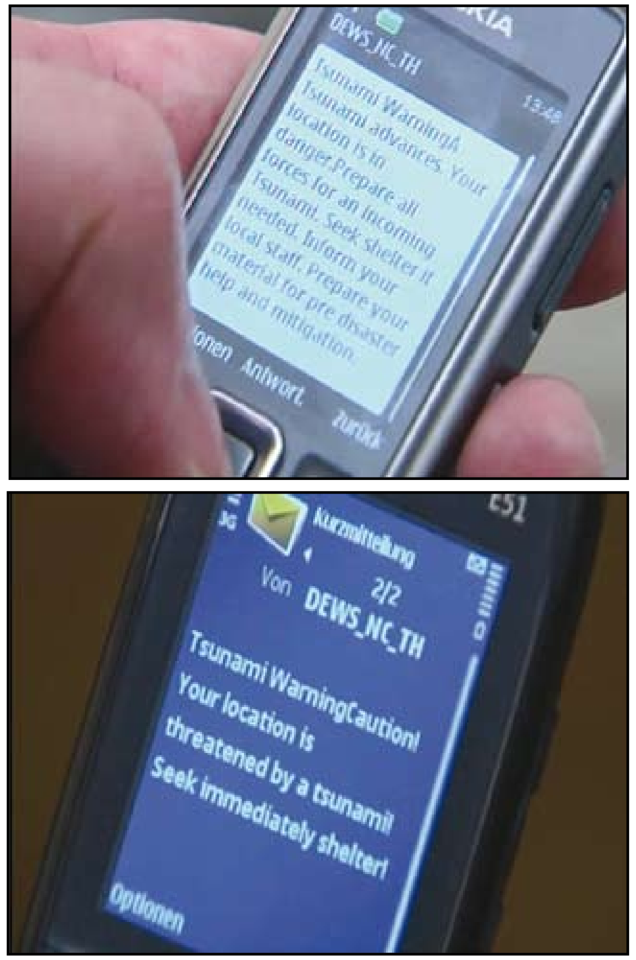


Fig. 22: *Received SMS on mobile phone*

TV Overlay and Narrow Casting contain text and media for example an image of a map.

Fig. 23: *Overlay (left) and Narrowcasting (right) with tsunami warning message*

The fax message contains detailed text information and media and has less channel restrictions than SMS, TV Overlay and Narrow Casting.

Fig. 24: *Incoming Fax tsunami warning message*

Email also has less channel restrictions and the warning messages contain text and media in a defined detail.

Fig. 25: *Received email with Tsunami Warning message and attached screenshot*

Exemplary the Tsunami Warning message is depicted in the language Bahasa Indonesia with dynamic information like the affected area, the estimated time of arrival, the estimated wave height and an image. In contrast an All Clear message contains other information than a Tsunami Warning message.
Since DEWS operates in a multilingual environment

Fig. 26: *Received email with All Clear message and attached screenshot*

the different languages have to be supported with the respective character sets, for example the language Phasa Thai and Tamil.

Fig. 27: *Using Unicode supports local languages like Thai and Tamil*

9 Dissemination Perspective

The Dissemination Perspective provides a comprehensive overview of the status of disseminated messages sent through the different dissemination channels. This overview is based on status reports received and aggregated from the respective telecommunication providers.

At least nine dissemination channels are proposed for DEWS. However, the initial design considers five channels:

- Electronic mail – E-Mail dissemination channel
- Short message service – SMS dissemination channel
- Facsimile – Fax dissemination channel
- Television – TV Overlay dissemination channel
- Narrow Casting dissemination channel
- RSS Feed channel

Moreover, the Dissemination Perspective has the respective channel views containing status information of the ongoing dissemination.
One view aggregates information of all channels related message exchange between the DEWS dissemination infrastructure and the respective dissemination channel provider.
The remaining five views for E-Mail, SMS, Fax, TV Overlay and Narrow Casting show all status information according to the respective channel dissemination.

10 Administration Perspective

The configurations and settings needed for the information logistics are administered with the Administration Perspective of the CCUI. The configuration comprises:

- message types and message templates,
- message consumer profiles and user groups as well as
- dissemination channels and dissemination provider profiles.

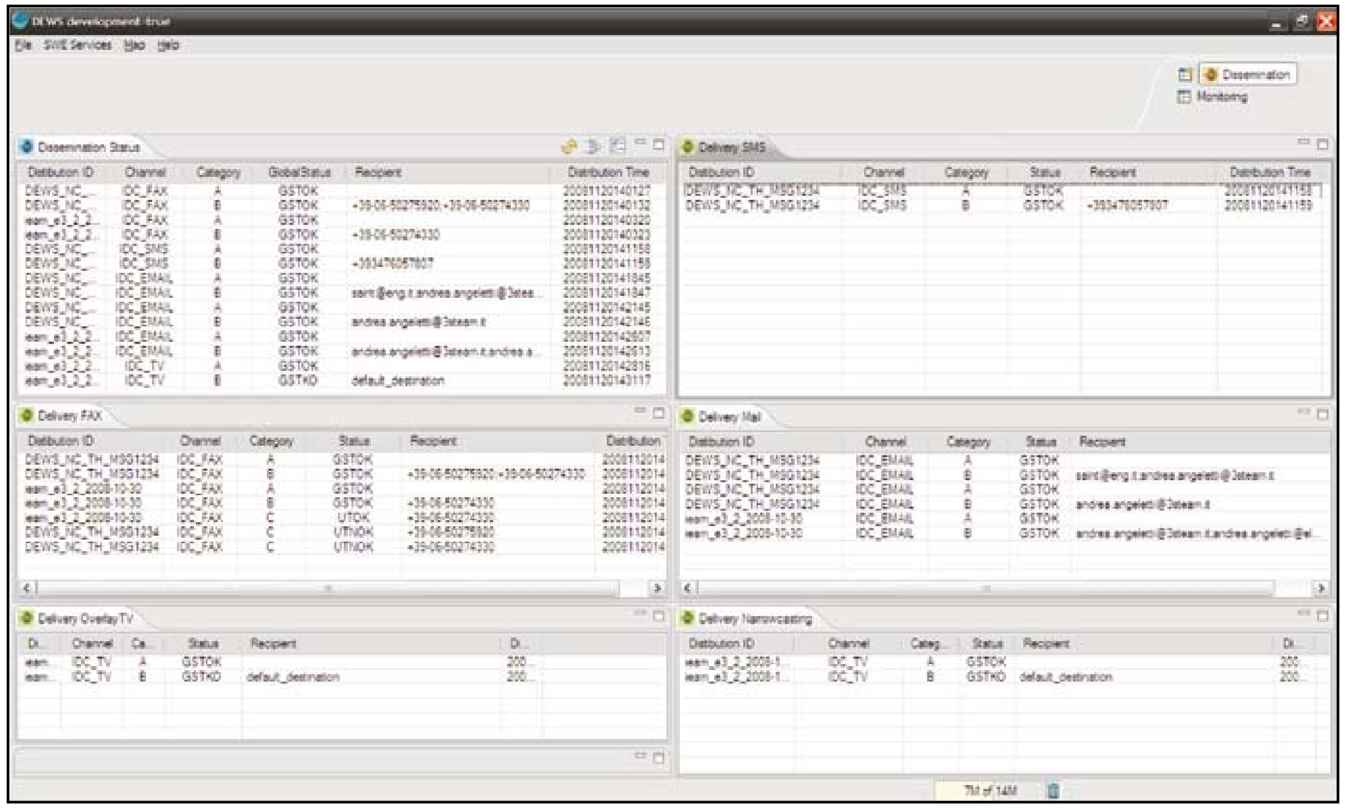


Fig. 28: *Dissemination Perspective with dissemination feedback*

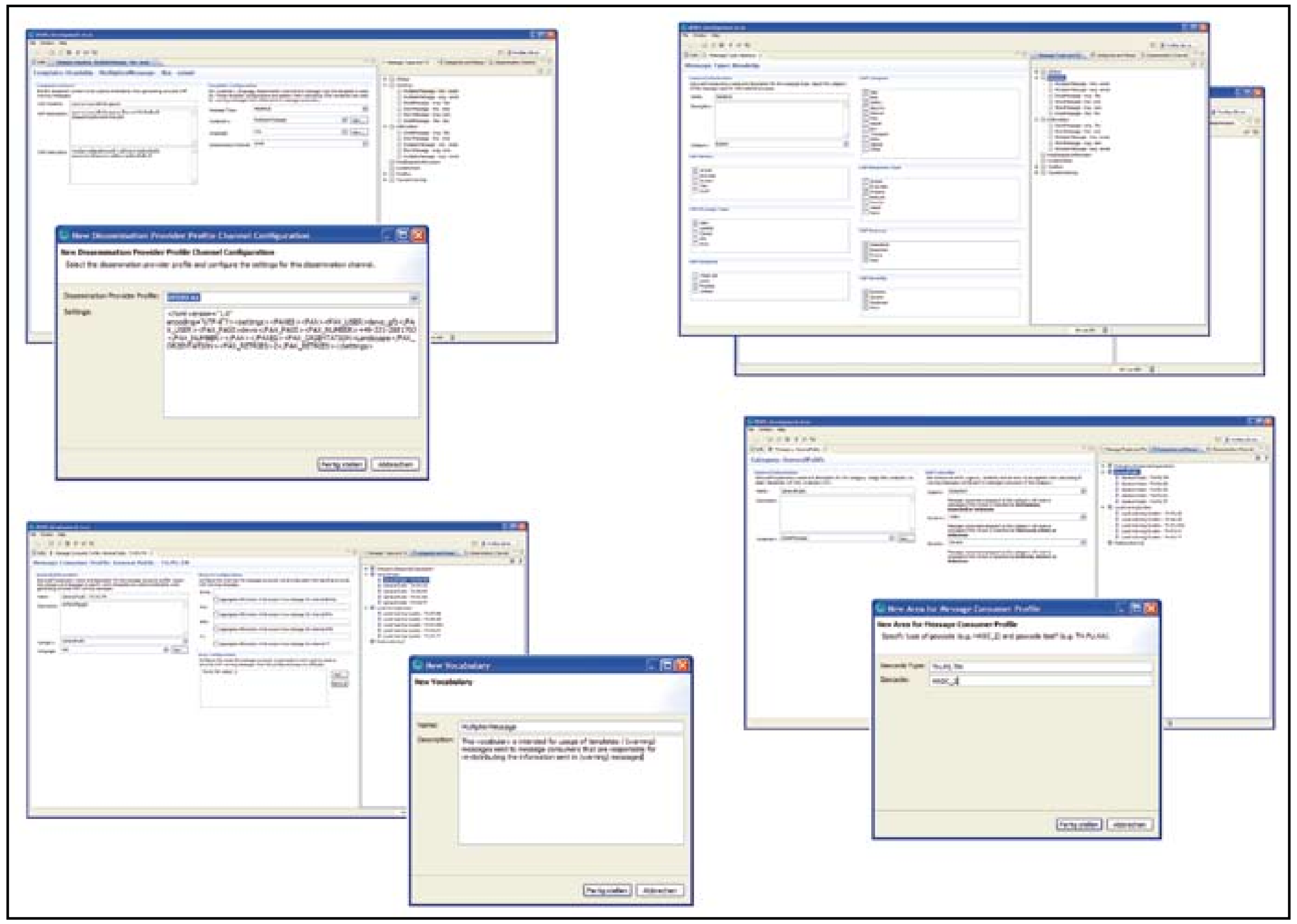


Fig. 29: *Administration Perspective for maintaining information logistics configurations*

The German-Indonesian Tsunami Early Warning System for the Indian Ocean

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The Sumatra earthquake of December 26, 2004 was the second largest ever detected rupture in the Earth's crust. Already after about 12 minutes the seismic waves were automatically recorded and analysed at the GFZ in Potsdam (Germany) and at other seismological centres worldwide. Only a few minutes after the detection of the earthquake the first tsunami waves reached the coastlines of Northern Sumatra.

Shortly after the Tsunami Disaster where almost a quarter of a million humans lost their lives, Germany offered technical support for the installation and implementation of a Tsunami Early Warning System in the Indian Ocean. Since March 14, 2005 Indonesia and Germany have been officially working together to implement a Tsunami Early Warning System in Indonesia. This implementation was largely completed 2009. A joint cooperation on the optimization, operation and maintenance of the system is further planned up to March 2010.

On November 11, 2008, the Indonesian president, Susilo Bambang Yudhoyono, officially launched the Indonesian Tsunami Early Warning System (InaTEWS) at the Indonesian Agency for Meteorology, Climate and Geophysics (BMKG) in Jakarta. The System will not only serve for early warning purposes in Indonesia but is also planned to serve as a so-called Regional Tsunami Watch Provider (RTWP) Center for the entire Indian Ocean in tight cooperation with warning centres in other Indian Ocean rim countries.

The Components

In more than 90% a tsunami is caused by a submarine earthquake. A fast and correct seismological recording and evaluation is therefore essential for the warning system. But based on seismological measurements it is mostly impossible to decide whether a tsunami has been generated or not. Therefore the system also includes quick determination of post-seismic crustal deformations using a dedicated GPS-array along the coast lines and the detection of a tsunami wave directly on the ocean.

Thus the system includes a seismological network consisting of broadband seismometers as well as GPS stations, a network of GPS buoys additionally equipped with ocean bottom pressure sensors and a tide gauge network. The GPS functionality is an important scientific and technical improvement compared to other buoy systems used for example in the Pacific.

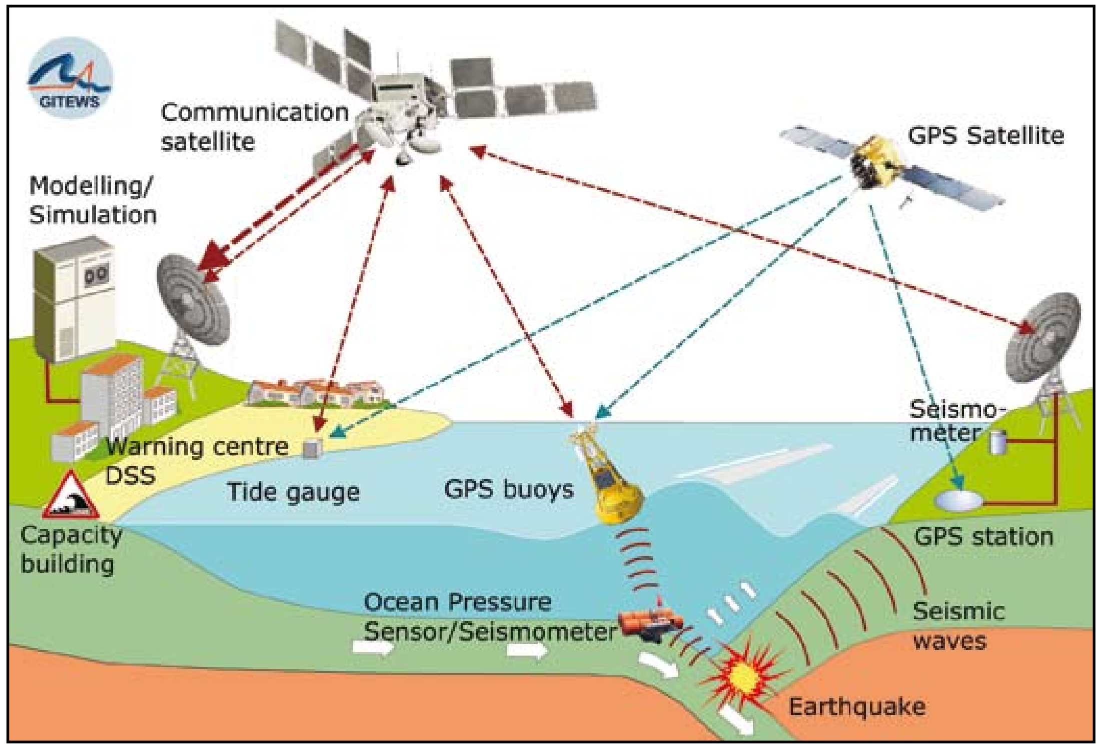

Fig. 1: *GITEWS components*

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The respective sensors are connected by satellite communication to the Earthquake Information and Tsunami Warning Centre (EITWC) operated by the Indonesian Agency for Meteorology, Climate and Geophysics (BMKG) in Jakarta. In this Warning Centre the on-line data-streams are processed, and, on the basis of the sensor data, tsunami simulations can be provided rapidly and used in a Decision Support System for the generation of a fast and detailed picture of the actual situation.

Tsunami simulations are of particular importance for the whole warning process. Based on a few measured data an overall picture has to be calculated. A couple of seconds after the earthquake information the modelling results will give an estimation on the wave height, the time of arrival and the inundation areas. Since warning times in Indonesia are extremely short, thousands of different scenarios are precalculated and collected in databases.

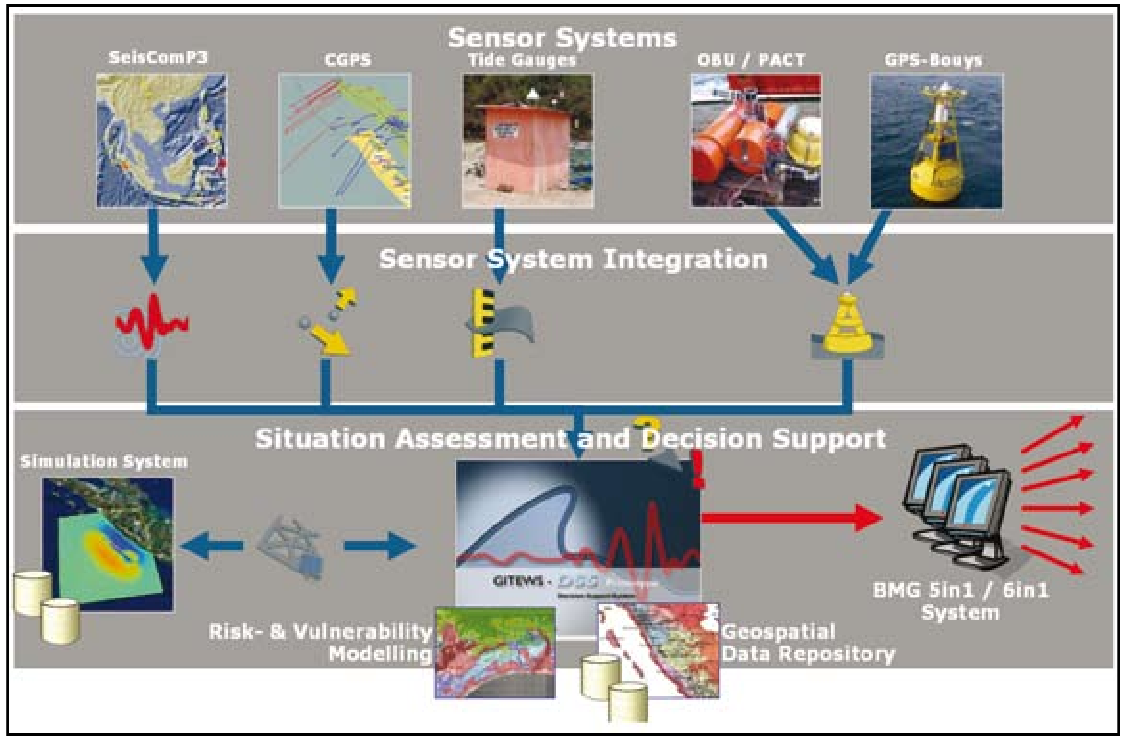

***Fig. 2:** The GITEWS Early Warning and Mitigation System (EWMS)*

Using risk and vulnerability maps of the affected coastal regions detailed warning dossiers are produced and disseminated to the respective authorities, agencies and population. The system is designed in an open and modular structure based on the most recent developments and standards of information technology. Therefore, the system can easily integrate additional sensor components or can be expanded for other purposes using large parts of the infrastructure in a sustainable manner.

An integral part of the project is capacity building which concentrates on academic and engineering training and education for the operation of such a system. The fastest warning is useless as long as the gap to the so called "last mile" is not closed. The population in the threatened area needs to be informed in time, but they also need to be trained how to react properly. The people need to be instructed about evacuation plans and how to behave in a case of emergency. All these activities are accompanied by various activities like organisational consulting.

The GITEWS Early Warning and Mitigation System (EWMS)
As part of the German contribution to InaTEWS, a modular Early Warning and Mitigation System (EWMS) has been installed at the Warning Centre in Jakarta. It consists of the following major elements:

- An Earthquake Monitoring System (SeisComP3);
- A continuous GPS System (CGPS) detects post-seismic deformations shortly after an Earthquake based on precise GPS measurements;
- A Deep Ocean Observation System (DOOS) for direct tsunami detection collects and processes sensor information transmitted from Ocean Bottom Units (OBUs) and buoys;
- A Tide Gauge System (TGS) collects and processes sea level data from a network of tide gauges;
- A central sensor integration platform (Tsunami Service Bus, TSB) collects information from the sensor systems and provides them to a Decision Support System (DSS);
- A Simulation System (SIM) performs a tsunami scenario selection based on multi-sensor inputs, resulting in a list of best matching tsunami scenarios for a given set of observations;
- The Decision Support System (DSS) receives sensor observations via the TSB, requests a scenario selection from the SIM for the current set of sensor observations and communicates with the dissemination systems for message distribution and delivery.

To support the warning process and to address the different situations which individual parts of the coastline may face, the coastline is divided into so-called warning segments. The respective situational information is aggregated and warning messages can be individually addressed by using one of the pre-defined warning levels.

Sensor and Information Fusion
In addition to the collection of real-time sensor observations, the DSS can access a huge collection of a priori information and scenario data for the interpretation of the online input, to assess the tsunami threat and to forecast the consequences. Using this approach, the information gap immanent to the first minutes of a potential tsunami is narrowed as much as possible.

Tsunami Category	Warning Level	Wave Height (WH) Range [m]	Color
<none>	<none>	0,0 ≤ WH < 0,1	Grey
Minor Tsunami	Advisory	0,1 ≤ WH < 0,5	Yellow
Tsunami	Warning	0,5 ≤ WH < 3,0	Orange
Major Tsunami	Major Warning	3,0 ≤ WH	Red

***Tab. 1:** Tsunami Warning Levels*

The most important sources of a priori information are

- A large number of precalculated tsunami scenarios contained in the Tsunami Scenario Repository (TSR), which is used by the SIM to perform the multi-sensor scenario selection process.
- A geospatial data infrastructure which allows standard-based access to large databases of geospatial baseline data, such as administrative boundaries, topographic or bathymetric data;
- Risk and vulnerability assessment information which describe for a particular location the tsunami risk and the vulnerability of the respective location

International Cooperation
The German-Indonesian activities are fully integrated into the overall UN plans and strategies for the establishment of global and regional Early Warning Systems. These activities are coordinated by the Intergovernmental Oceanographic Commission (IOC) of UNESCO with four so-called Intergovernmental Coordination Groups (Indian Ocean, North East Atlantic and Mediterranean, Caribbean, Pacific Ocean). Furthermore, the activities are brought to the attention of the global coordination activity GEOSS (Global Earth Observing System of Systems).

Concrete co-operation work in numerous fields for the establishment of the Early Warning System in Indonesia are underway with a number of other countries, i.e. Japan, China, France and USA. In the Indian Ocean Region the German Project co-operates with Sri Lanka, the Maldives, Yemen, Madagascar, Tanzania and Kenya to build up equipment mainly for seismological monitoring and processing. Close ties have been established to Australia, South Africa and India for the real-time exchange mainly of seismological, but also of sea level data.

Natural hazards such as the tsunami catastrophe 2004 cannot be prevented by a tsunami early warning system, but through GITEWS the number of victims in the event of a tsunami wave can be kept at a minimum.

GITEWS is a project of the German Government to aid the reconstruction of the tsunami-prone region of the Indian Ocean. It is accomplished by a consortium of nine institutions.

Further information: http://www.gitews.org

Development of Indonesia Tsunami Early Warning System (InaTEWS) toward Regional Tsunami Watch Provider (RTWP)

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Indonesian Tsunami Early Warning System (InaTEWS) is set up to produce Tsunami Warning in 5 minutes after the earthquake. This scenario is based on the experience of local tsunami where the first tsunami attacks the coast within 20-40 minutes after the earthquake. To reach the goal, it requires 160 Broadband seismic stations, 500 accelerograph stations, 60 tide gauges, 20 DART buoys, and several continues GPS stations for monitoring purposes. The whole InaTEWS system consists of 4 subsystems namely; 1. Monitoring, 2. Processing, 3. Dissemination, and 4.Preparedness. The monitoring system has 3 types of network; 1. Earthquake monitoring, 2. Sea Monitoring, and 3. Earth Deformation.

The earthquake monitoring system is used to forecast whether the earthquake is potentially tsunami or not, and if potentially tsunami, the warning is issued and then tsunami wave is monitored using sea monitoring network. Tectonic deformation and the impact of the earthquake-tsunami can be seen by using Global Positioning Satellite (GPS) and satellite image by comparing the data before and after the earthquake.

The goal to develop InaTEWS is to be able to produce the first tsunami warning in 5 minutes after the earthquake. There is a possibility to have observation of tsunami within 5 minutes after the earthquake. If no observation is available, the first tsunami warning message is estimated from earthquake parameters and tsunami modeling scenario which contains highly uncertainty. To reduce uncertainty is always trade off with time. The effort to reduce uncertainty needs to develop the network of observation as dense as possible. The effort to reduce time consuming before dissemination needs to develop an integrated system called DSS (Decision Support System) for tsunami and mitigation system.

DSS is basically integrated parameters and aggregated of all monitoring earthquake and tsunami system to support operators on duty to prepare timely the tsunami messages and earthquake information. The tsunami message is updated based on the available observation in a way that DSS links and match between the observation and simulation to produce robust information for distance recipients.

Currently, 148 Broadband seismograph stations, 85 accelerographs, 57 tide gauges, 19 DART – OBU-buoy and 19 GPS stations have been installed in well distributed at tsunami and earthquake prone area in Indonesia. All seismic stations are transmitted to BMKG as National Tsunami Warning Center in real time and provided to the countries in Indian Ocean and ASEAN member states to access the data in real time based on IOTWS and TTF of ASEAN (Technical Task Force) recommendation. All Tide gauge stations are transmitted in real time to BAKOSURTANAL who runs the network in daily basis. Some of the stations are already available in near real time to BMKG and all will be available in near real time in BMKG Jakarta for tsunami warning purposes. DART buoy data is also available in near real time in BMKG and will be available in real time in BMKG based on tsunami mode status.

Using the current capabilities, BMKG is able to issue tsunami warning within 5 minutes after the earthquake based on the earthquake parameters criteria or service level 1. The next effort is to complete the system by early 2010, where tsunami warning contains estimation of tsunami arival and tsunami height as well as inundation.

Interoperability and Dissemination system of Indonesian Tsunami Early Warning System (InaTEWS)

Fauzi

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The tsunami warning messages from warning center need to be responded by the local government in timely and correctly manner to save people life from the threat of tsunami wave. Indonesia Tsunami Early Warning System (InaTEWS) has developed the system to provide tsunami warning messages, not only for national needs, but also for member states of Indian Ocean Tsunami Warning and mitigation System (IOTWS). To serve member states in Indian Ocean rim, IOTWS/ICG working group develops an interoperable system to exchange information among National Tsunami Warning Center (NTWC).

Not all NTWC in Indian Ocean serves other. NTWCs that should be able to serve other NTWC are known as RTWP (Regional Tsunami Watch Provider). Indonesia is one of candidates of RTWP; others are Australia, India, Malaysia, Iran and Thailand. It is up to member states to choose, from which RTWP/s to receive warning messages. This paper describes the preparation of dissemination system toward the RTWP to serve member states of IOTWS.

IOTWS/ICG, Working Group 5 Task Team identified that NTWC should issue 3 levels of services for tsunamigenic earthquake. Service level 1 contains tsunamigenic potential, predicted by using earthquake parameters. Service level 2 contains tsunamigenic potential predicted by using tsunami simulation to estimate time of tsunami arrival and the height. Service level 3 contains additional information on the inundation of tsunami to the land side.

IOTWS defines that there is no single center of tsunami warning but consists of many centers to serve NTWCs with all service levels. Six countries; Indonesia, India, Australia, Malaysia, Thailand and Iran commit to develop their center to be able to provide all service levels namely RTWP (Regional Tsunami Watch Provider). Currently, India, Australia and Indonesia have the capability to serve service level 1 and still develop the system for service level 2 and 3.

The recipients in the member states are NTWCs who receives the messages should be able to decode all of these information through several modes of communication.

Since all RTWPs are new players as NTWC, it requires time to set up the system performances. With some restriction, data have been exchanged for a better configuration of monitoring purposes. The preliminary earthquake bulletin, in term of service level 1, has been exchanged by India, Indonesia and Australia. The content and the format of all types of services need to be discussed and agreed in the next working group meeting. PTWC and JMA as Interim Advisory Service will keep shadowing operation and products until NTWC as RTWP system is completed.

NTWC of Indonesia in the group of InaTEWS develops the dissemination system for public through interface institutions. In case of national needs, the interface institutions are local governments (District Disaster Management Agency), National Disaster Management Agency, Police Headquarter, military head quarter, and Department of Home Affair. For international needs, interface institution is the NTWC of the country. NTWC of Indonesia has no direct communication to the public however; there are direct communication link to 11 TV stations and 2 Radio stations under government regulation.

The Tsunami Early Warning System in the Euro-Mediterranean Region

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The Euro-Mediterranean region is affected by tsunamis that can be even catastrophic. This is confirmed by tsunami catalogues, that though complete only in the last few centuries as regards large events, yet show that the coasts that are the most exposed to tsunami attacks are the Hyberian peninsula, Italy, Greece and Turkey. And this is further confirmed by the seismotectonic setting of the region showing that favourable conditions for tsunami generation may be easily met here, i) since many seismic active areas happen to be located near the coast or offshore, ii) since a number of important active volcanoes are located close to the coast or form volcanic islands, iii) since submarine margins are unstable in many places giving rise to dangerous submarine mass movements. According to statistics, about 10% of the tsunamis occur in the Mediterranean area.

After the catastrophic Indian Ocean tsunami of 26 December 2004, awareness of tsunami menace has grown worldwide and has involves also the EuroMediterranean countries that have recognised a) that their coastal communities were unprotected from tsunamis and b) that there was hence a urgent need for the establishment of a Tsunami Warning System. This recognition led to the creation of an Intergovernmental Coordination Group for the implementation of the North-East Atlantic and the Mediterranean Tsunami Warning System (ICG/NEAMTWS) within the Intergovernmental Oceanographic Commission (IOC-UNESCO). The group was established in June 2005, together with the analogous groups in the Indian Ocean and the Caribbean Sea, and after its first general session held in Rome in October 2005 met regularly every year to develop, update and monitor the TWS implementation plan and the corresponding activities.

There is general consensus among the member states of the ICG that the NEAMTWS will be a system of systems, that will consist of a number of regional centers, called Regional Tsunami Watch Centers (RTWC), and of the national centers, called National Tsunami Warning Centers (NTWC). Further the NEAMTWS will be based on the end-to-end concept, which means that it will cover all the components going from the detection of the event to the dissemination of the appropriate messages to the final receivers (for example the population living at the coast).

In this architecture the NTWCs have the full and exclusive responsibility to launch the alert, namely the "warning" to the population within the national boundaries. As regards the tsunami, one can distinguish between "local" events that affect only a single country, and larger events that are capable to adversely affect more than one country and may also travel across the basin. Local events have to be managed by the NTWCs, that in this respect will be fully operational end-to-end systems. Larger events will be managed by the RTWCs. These will detect the tsunami and deliver the proper message, called "watch", to the connected NTWCs, that will take the final decision on if and how to warn the population. According to this scheme, the RTWC are not end-to-end systems, since their responsibility in the information flow chain stops at the point where the NTWCs responsibility starts.

At present, the ICG/NEAMTWS has approved the list of tasks and activities that the RTWCs and the NTWCs have to cover, but no final decision has been made yet on the number and location of the RTWCs. According to the actual state of the ongoing discussions, probably there will five RTWCs (in Portugal, France, Italy, Greece and Turkey), that will cover adjacent and partly overlapping geographical areas of the EuroMediterranean basins: namely Portugal will cover the NE Atlantic, France the western Mediterranean, Italy the central Mediterranean, Greece the eastern Mediterranean, Turkey the eastern Mediterranean, the Marmara sea and the Black sea.

Apart from the Atlantic sea, tsunami sources in the region are located very close to the coast, which means that the tsunami lead time is very short, and the requirement for the TWS is that event detection has to be completed in a few minutes and correspondingly alert messages have to be issued quite quickly. This is a big challenge. At present, earthquake monitoring and detection in the region has a great level of efficiency due to the satisfactory configuration of the broadband seismic networks that provide real-time data and allow very fast earthquake location. For example, GFZ has shown that good earthquake location and magnitude determination for earthquakes larger than 5.5 are feasible within a few (3-4) minutes in the Euro-Mediterranean region, though accuracy may be improved if some gaps in the northern African countries are filled. However, earthquake data are only proxy data for tsunamis. Detecting a large offshore earthquake gives a strong clue for tsunami generation and permits to lunch a first type of bulletin. Only direct measurements of the ocean can provide evidence of the tsunami. Sea level observation through coastal and offshore system could provide such a tool. Unfortunately, the present-day status of the sea-level monitoring system in the NEAM region does not allow a fast determination of tsunami occurrences on the entire basin, since only a few station exist with the appropriate sampling rate and with real time data transmission capabilities. Therefore, today, one of the main obstacles for the full establishment of a TWS in the Euro-Mediterranean region is the inadequacy of the sea-level monitoring network. Being this network inefficient, the TWS has to rely only on the seismic branch of the observational system and on a tsunami forecast that will be based on numerical models triggered by seismic data.

The consequence might be that forecast could be imprecise. This is a relevant point deserving more attention. One could observe that 1) dislocation theory suggests that knowing the focal parameters of an offshore earthquake is enough to determine the coseismic displacement of the crust, and hence of the sea floor, if a proper Earth model is used; that 2) this in turn is enough to determine the initial waveform of the generated tsunami; and that 3) numerical tsunami models can be used to study the propagation of the tsunami up to the target coasts if bathymetry data are satisfactorily known. Basing on this, one could therefore conclude that seismic data are the only ones really known to trigger the alert system. Unfortunately tsunami catalogues show that the there is yet an ascertain correlation between the magnitude of an earthquake and the intensity of the generated tsunami, but they also show that the associated variability is quite large and that there are numerous examples of large earthquakes producing small tsunamis and of relatively small earthquakes producing strongly damaging tsunamis.

The NEAM region is today the only one in the world with no TWS in place, and not even an interim system is functioning. This situation is clear and is known to the member states. According to the present implementation plan of the ICG/NEAMTWS, it is foreseen that in the next few years, the system, based on the double level architecture of RTWC and of NTWC, will become operational. But the way is still long.

The French Western Mediterranean and North-Eastern Atlantic Tsunami Warning Center

François Schindelé

Commissariat à l'Energie Atomique - CEA/DAM/DIF

After the Indian Ocean tsunami disaster in December 2004, the Intergovernmental Oceanographic Commission (IOC) of the Unesco was mandated to implement the Indian Ocean tsunami warning system. The IOC Member states recognized the need to a global tsunami warning system. Consequently, the Intergovernmental coordination group for the North-Eastern Atlantic, Mediterranean and connected sea tsunami warning and mitigation system (ICG/NEAMTWS) was established in June 2005.

The ICG has met five times since 2005 in different countries (Italy, France, Germany, Portugal and Greece). The main objective of the ICG was to establish a Tsunami Warning System as soon as possible.

This note presents the state of the ongoing efforts towards the implementation of the French tsunami warning center and the upgrade of the seismological and sea-level networks.

The French Western Mediterranean and North-East Atlantic Tsunami Warning Centre will be operated by the Commissariat à l'Energie Atomique (CEA). Based in Bruyères-le-châtel close to Paris, it is established so that France will have a capability to detect, monitor, verify and warn the civil defence authorities of the existence of tsunami in the region and possible threats to Western Mediterranean coast and French coastal locations.

The major objective of the French TWC is to provide French emergency managers and all the Western Mediterranean region's Member states with warning in case of potential tsunami impact in that region, within 15 minutes of an earthquake occurrence.

The French Western Mediterranean TWC is a key component in the establishment of the fully functional Tsunami Warning System in the Euro-Mediterranean region. This three-year project, funded by the French Government, the Minisrty of Interior and the Ministry of Sustainable Developpment, is due to be completed early 2012.

This includes :

- establishment of the French Tsunami warning center with 24/7 tsunami monitoring, operation and analysis for France and the Western Mediterranean region

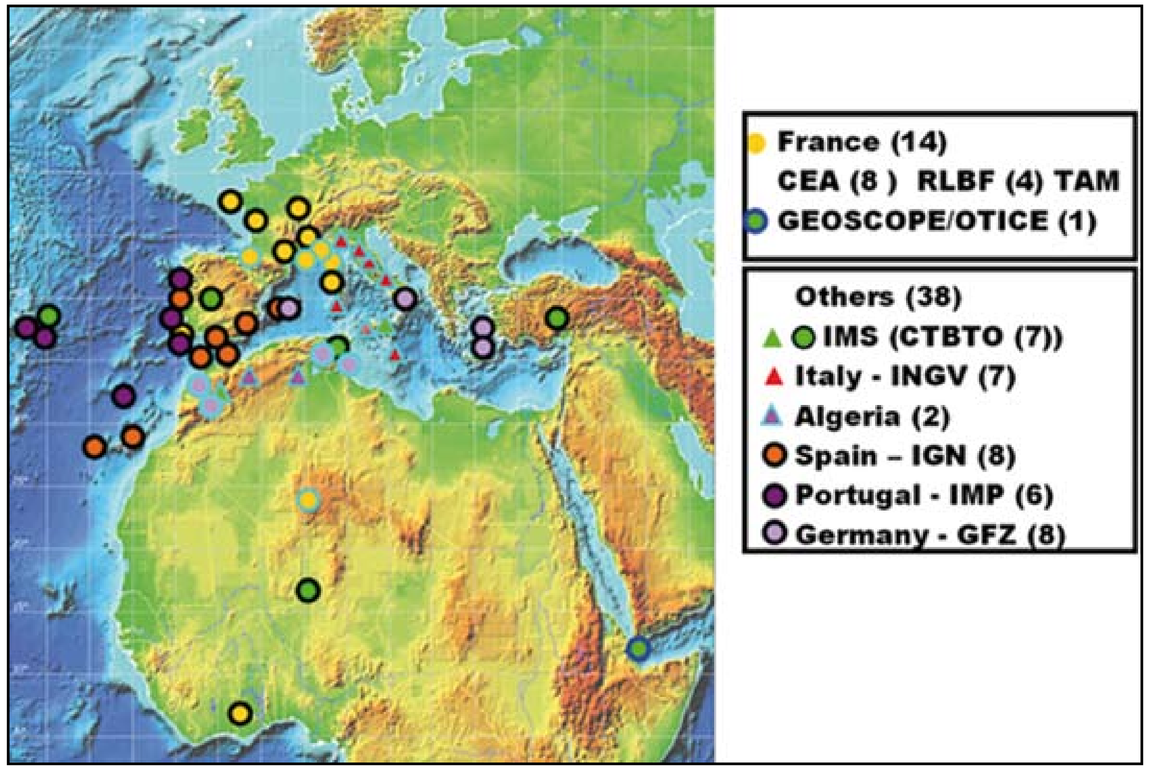

Fig. 1: *NEAM Western Mediterranean and North-East Atlantic seismic monitoring for tsunami warning*

- the upgrade of the seismic monitoring and the extension and upgrade of the sea-level monitoring

- assistance to the Intergovernmental Oceanographic Commission in developing the North-Eastern Atlantic and Mediterranean Tsunami warning and mitigation system (NEAMTWS)

The centre will start the international warning operation in 2012.

CEA will use real-time data from over 10 seismic stations located in France (6 CEA with VSAT satellite transmission, and 4 CNRS that will be upgrated, maintained and equipped with VSAT transmission), and 4 implemented in other territories (2 CEA and 2 IPGP) (Figure 1). The data of these stations will be transmitted to several other countries by robust high speed leased lines, and about 40 additional seismic stations will be received in France, most stations implemented and maintained by IGN (Spain) IMP (Portugal), INGV (Italy) and GFZ (Germany). The data of most stations are transmitted by VSAT from the station to the seismological data center.

The seismic data will then be analysed by specifically designed automatic systems, included the Seiscomp platform, that will form part of CEA's established 24/7 operations centre. Expert will use the results of the automated processes, historical tsunami and tsunami scenario data, to make in 15 minutes an analysis of the potential for the detected earthquakes to cause a tsunami, and will disseminate the relevant information of the expected hazard. Depending on the location and magnitude of the earthquake, a specific message defined by the ICG/NEAMTWS will be sent to all regional watch centers, national warning centers and focal points nominated by the ICG Member states, in accordance with the decision matrix adopted by the ICG (UNESCO/IOC 2007). In case of a large earthquake able to induce a tsunami, the tsunami arrival time will be calculated and included in the messages.

As the closest real-time sea-level station records the tsunami waves, the detection and height measurement of the signal received and processed in CEA will provide the confirmation and level of warning. If necessary, additional messages will then be disseminated.

The enhancement of the current sea-level network is one of the second pillars of the warning system. The Service Hydrographique et Océanographique de la Marine (SHOM) has already upgraded 7 stations to record and transmit the data in real time. SHOM will upgrade the other 20 stations of the French tide gages network (Figure 2). Three new sea-level stations will be implemented in Corsica, and two on French Riviera Coast. SHOM will monitor and maintained the complete network of 32 stations.

In addition, sea level stations should be implemented in priority close to known seismic zones such as the North Coasts of Algeria, Morocco and Tunisia.

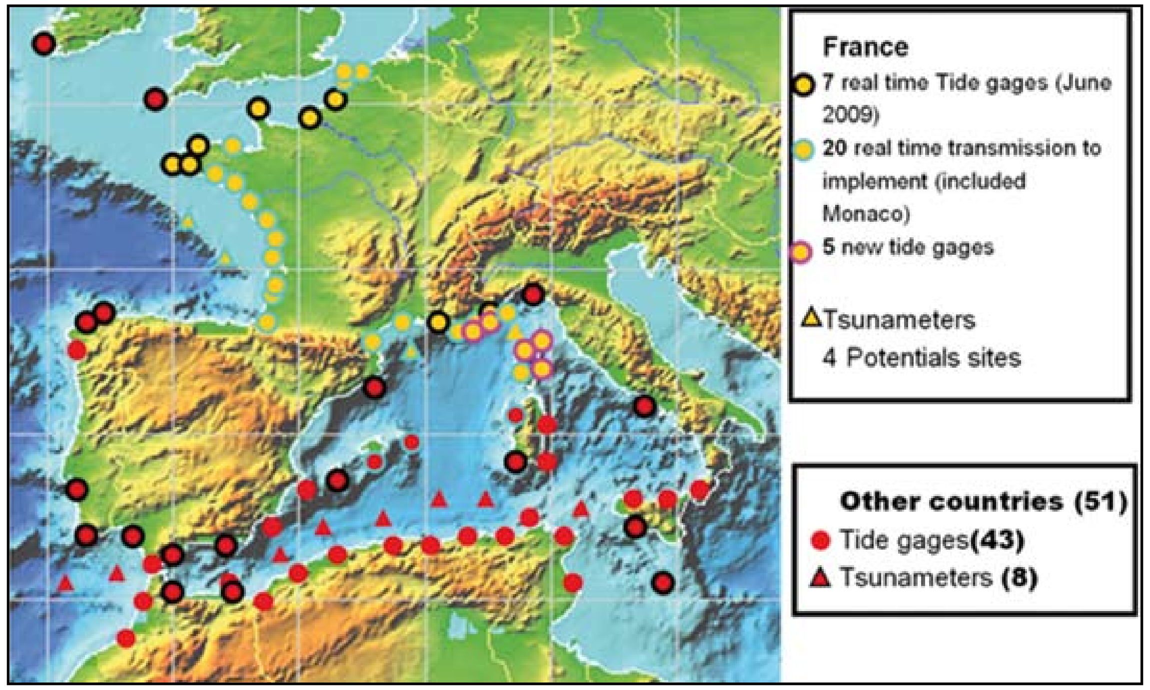

Fig. 2: *NEAM: Western Mediterranean and North-East Atlantic sea level network*

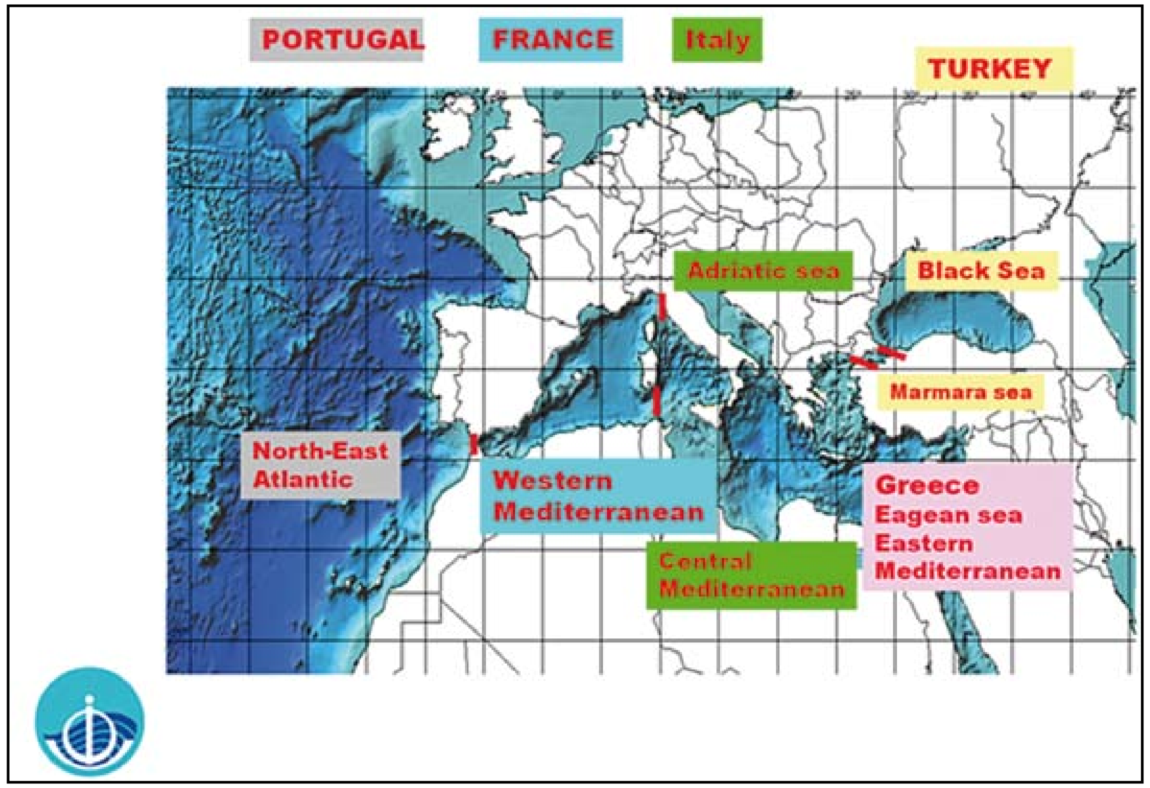

Fig. 3: *Regional Watch Centres Network*

Reference:

Unesco/IOC Intergovernmental Coordination Group for the Tsunami Early Warning and Mitigation System in the North Eastern Atlantic, the Mediterranean and Connected Seas (ICG/NEAMTWS) Fourth Session, Lisbon, Portugal, 21–23 November 2007

http://www.ioc-tsunami.org/index.php?option=com_content&task=view&id=255&Itemid=928

Ethical and legal aspects in the early warning process

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Day-to-day experience with the different stages of the early warning process from basic research over development, technical design, marketing, testing and application exhibits problems and shortcomings which cannot be attributed to the underlying science or technology. Although the hitherto available early warning systems for natural disaster reduction have made significant progress in the recent years in several fields of technical development and societal implementation, it must be concluded from practical experience with „real world conflicts" encountered that for long-term oriented and sustainable concepts of early warning the development and installation of firm overall ethical standards and rules on a global scale, as well as their application and monitoring are becoming indispensable. As a consequence, an extensive means of ethical training for institutions and individuals involved in the divergent fields of the process itself must be seen as an important factor on the way. This constitutes an evolving necessity of bringing the discourse on an appropriate level, by far exceeding the limits of the existing guidelines and common principles in use, which are right away available but necessarily had to be based on „best practice" approaches as a general rule – a substantial step ahead in comparison with the over-all setup of early warning at the time of the Potsdam Conference.

It is felt that the introduction of the term responsibility (Imperative of Responsibility) in the sense of the philosopher Hans Jonas (Jonas 1984) in this discourse clearly adds a strong future orientation and offers a chance to establish a set of consistent base-lines for progress, spanning over the different sectors, from science to legislation, from technology to politics, and from the media to the public sector, to name some more prominent relationships. Having been applied in pure science and technology first, it is shown that the reflection on the imperative of responsibility in this sense offers a useful means of disclosing practical solutions for some of the most critical is-sues of early warning, like definitions of general terms. For instance: What do we have to call a hazard? What is a disaster? What is the quality of a warning? Who de-fines the standards and who is in charge of monitoring them? How much commerce can be seen as acceptable in the respective sectors involved? And, as the most important: what about the truth and communicating it?

These questions lead to different aspects in the given framework which are mostly neglected or simply not identified, namely the legal-political criteria which govern all or at least most of the technical points. Policy making – and this can hardly be over-emphasized – means nothing without an ethical background and its expression in laws: Lawmaking is all. It starts with constitutional law and the very basic question, to what extent the single state is responsible for appropriate institution-building and capacity-building in our given context. Does the welfare of the nation also mean a duty to protect the citizens against disasters? The theme continues with non-constitutional law as international public law. There are consequences, if the disaster is crossing boundaries and it is in many cases not clear, who is in command and what kinds of responsibilities arise in one state for the neighbouring state. Especially in cases where inter-state matters are involved, a solid framework is required in order to let solidarity come into effect. And: to what extent should internal administrative laws like health laws, police and public order laws etc. provide a legal basis for disaster warn-ing and management? Up to now all this has merely been seen as a field for natural sciences and technology, guided by common principles and some kind of spontaneous pragmatism. Ongoing processes and flaws or failures of the recent past taught us that this is not enough. It might be advisable to discuss the legal principles before politics set the pace.

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DEWS – the Training and Education Strategy

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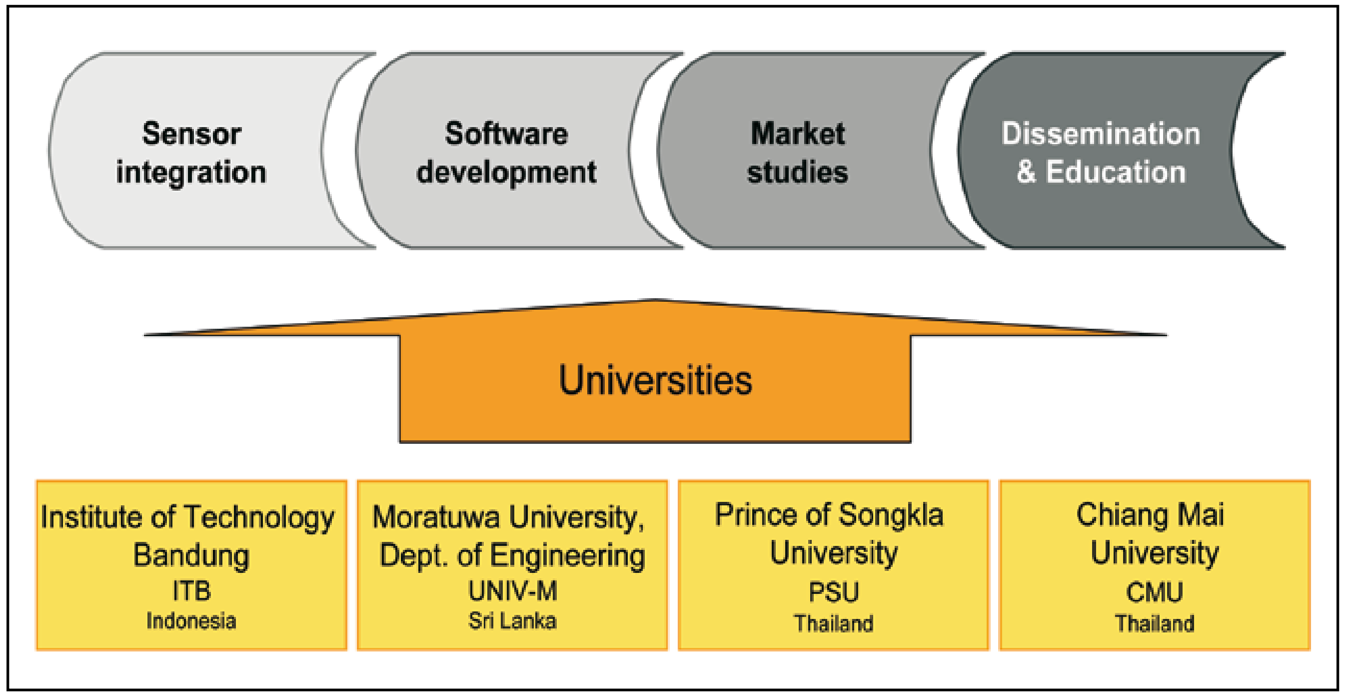
Early Warning for tsunami events is seen as a highly cross cutting task, starting with the understanding of geological processes far out in the oceans and ending in the middle of administrative, medical and financial activities in the heart of the inflicted societies. It is self-evident that at this stage of technical and governance progress, the introduction of a new profession – the early warning engineer – is imminent. The DEWS undertaking with its intersectoral and interdisciplinary partnership is offering a vast field of opportunities towards the curricular generation of knowledgable and responsible professionals, covering the complete warning chain.

The DEWS venture constitutes an enormous bundle of chances for the researchers to enhance the technical systems for early warning as well as their perception about the underlying process in a large number of knowledge areas. In order to attain a long term perspective it is found useful to start with a concept of implementation together with a number of famous universities and research institutions in the Indian Ocean region and in Europe. This group of institutions later should include partners in New Zealand and Japan, among others.



From GITEWS to InaTEWS - An Architectural Blue Print

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1 Introduction
After the Sumatra earth quake in December 2004 the Federal Republic of Germany supports with the GI-TEWS [1] project the Indonesian government to esta-blish the nucleus of a national tsunami early warning system for the Indian Ocean. In the context of GI-TEWS dedicated sensors like buoys with underwater pressure sensors, tide gauge sensors, GPS sensors and seis-mometers are developed and deployed. On the basis of the data provided by the GITEWS sen-sors a simulation system predicts the creation and propaga-tion of a tsunami wave and enables the staff of the warning centre in Jakarta to issue precise war-ning messages for the affected costal areas. Howe-ver, Indonesia has coast lines not only with the Indian Ocean but with the Pacific Ocean too and there are data from non-GITEWS sensors which must be in-cluded to improve the warning process. Therefore, the concepts developed during the GITEWS project have to be extended to incorporate additional sensor data as well as the whole Indonesian coast line into the scope of the warning system to reach the ultima-te goal: The development of an Indone-sian Tsunami Early Warning System (InaTEWS).

The purpose of this paper is to develop an architec-tural blue print for In-aTEWS. It is divided as follows. As an introduction, section 2 gives a short description of the architecture realized in the GITEWS project. Section 3 deals with the distributed data sources and responsibilities in Indonesia and discusses patterns to consolidate data for InaTEWS whereas section 4 de-velops the architectural blue print for the realiza-tion of InaTEWS.

2 The GITEWS Architecture
Figure 1 gives an overview over the logical GITEWS architecture deployed at warning center at BMG in November 2008, which consists of three inde-pen-dent layers:

- A sensor layer where physical or virtual sensors provide relevant measu-rement-, event- and analysis-data,
- A sensor system infrastructure layer to collect sensor data and provide them via standardized services

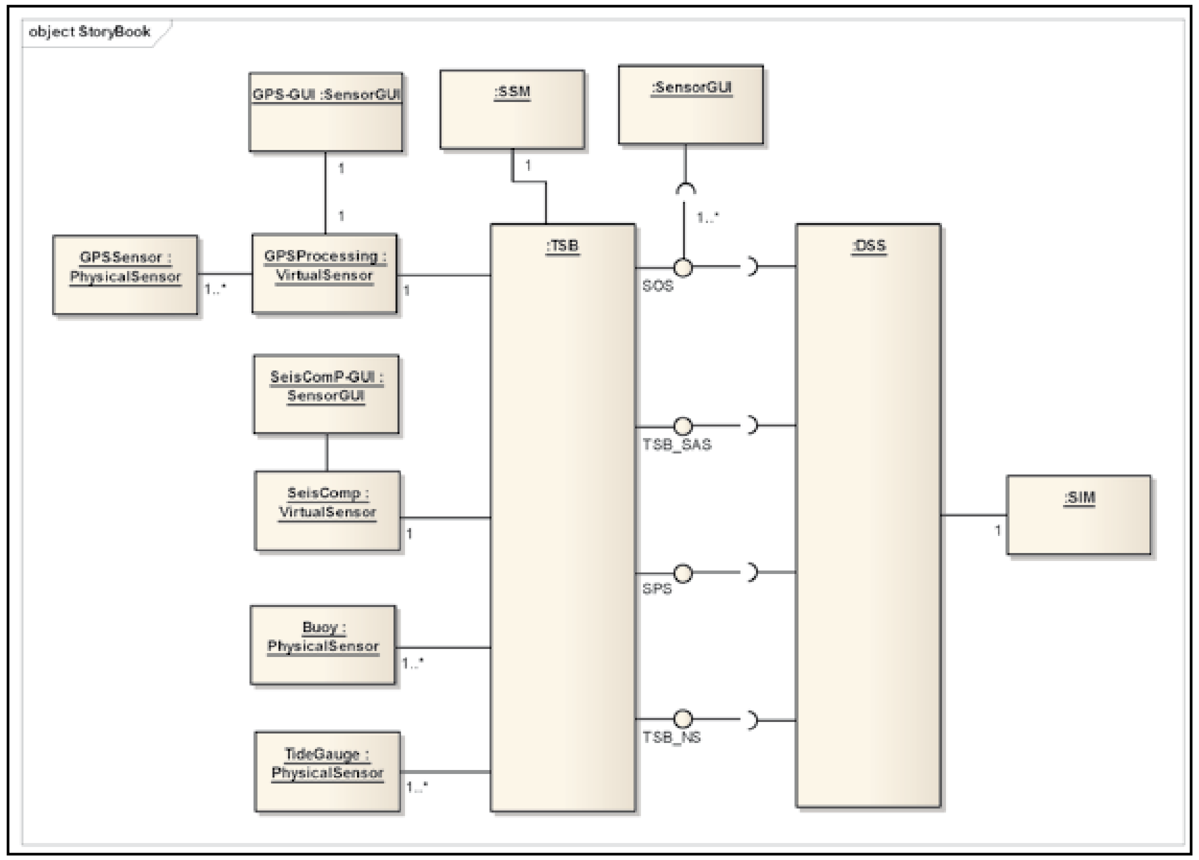

Fig. 1: *GITEWS logical architecture*

- And a decision support layer which contains of a dedicated decision sup-port system with an attached simulation system.

2.1 Sensor Layer
The sensor layer is responsible for collecting tsunami-relevant measurement-, event-, and analysis-data. Sensors in this layer could either be physical sensors like buoys (with OBU- and PACT-sensors, respectively), GPS-VSAT-stations and tide gauges, respectively or virtual sensors which aggre-gate and process data from associated physical sensors. GITEWS has two virtual sensors attached, the SeisComP system which processes data from an international seismic network and the GPS processing system. The later collects raw data from all GPS sensors available in the context of GITEWS, t. m. buoys, GPS-VSAT-stations and tide gauges, processes them and cal-culates displacement vectors for further use in other layers. Both, SeisComP and the GPS processing system have their own graphical user interfaces to handle and visualize their data. Virtual sensors push their data directly onto the tsunami service bus whereas data of physical sensors are periodically collected by the sensor system infrastructure.

2.2 Sensor System Infrastructure Layer
The sensor system infrastructure layer was developed to integrate all sensor data and provide them in a uniform manner for further use. Its core consists of the so called Tsunami Service Bus (TSB), realized on the basis of the J2EE[1] -compliant industrial strength open source application server JBoss [2]. The TSB provides both, a messaging backbone and messaging interfaces on the basis of Java Messaging Service (JMS). Via JMS-topics incoming data are routed to pluggable processing elements, so called dispatchers. Dispatchers allow a pre-processing of fed-in sensor data before the data are provided to potential consumers. They are realized as Message-Driven Beans (standardized server-side components), that allow them to process messages asynchronously. Virtual sensors push their observations actively onto the TSB using the messaging interface. On the contrary, physical sen-sors store their observation and housekeeping data in form of binary files in special upload areas also called data sources. Parametrizable retriever components access the binary files from the data sources and feed then onto the TSB to be processed by dedicated dispatcher components.

The TSB provides sensor data and enables interaction with sensors via the following four services:

- A Sensor Web Enablement (SWE[2])-compliant Sensor Observation Ser-vice (SOS) [4] to retrieve sensor observations and sensor capabilitiies.

- A Sensor Alert Service (TSB_SAS), which is functional equivalent to a SWE SAS [5] but uses Java Messaging Service (JMS) instead of XMPP in order to deliver sensor alerts.

- A SWE-compliant Sensor Planning Service (SPS) [6] to activate or deac-tivate special sensor features or to asynchronously start processing and sensor observations.

- A Notification Service (TSB_NS), which is functional equivalent to a SWE Web Notification Service (WNS) but similar to the TSB_SAS is based on JMS to provide notifications about sensor state changes and success of asynchronously executed processes [7].

To monitor physical sensors there are special graphical user interfaces to display raw and housekeeping data for GPS stations, tide gauges and buoys. A component called Sensor System Management is responsible for managing individual sensors, physical as well as virtual ones, and provides the following functionality:

- Maintenance of a sensor repository
- Visualization of sensor data and sensor housekeeping data
- Change of sensor state (if implemented by a sensor)
- Addition and removal of sensors
- Annotation of sensors with quality attributes
- Adjusting sensor parameters like thresholds, etc.
- Generation and sending of notifications about sensor states
- Delegation of task submissions to virtual sensors (processes, simulation, etc.)

2.3 Decision Support Layer
The Decision Support System (DSS) offers multi-criteria decision support on the basis of data provided by the sensor system infrastructure in conjunction with a simulation system (SIM). Both, DSS and SIM are tightly coupled to guaranty an appropriate performance accessing simulation results like inun-dation maps etc.

1 Java Enterprise Edition is a well known industrial standard for the realization of enterprise scale applications. As an example, in Germany eGovernment applications are required to be realized in conformance to the JEE industrial standard [12].

2 SWE is an initiative of the Open Geospatial Consortium, Inc.® (OGC) [3]. It's an acronym for Sensor Web Enablement and defines standard interfaces to access sensor data via Web Services.

3 Integration of Sensor Data
There are three independent organizations in Indonesia, maintaining sensors and collecting data relevant for tsunami warnings:

- The Meteorological and Geophysical Agency of Indonesia (BMG) [8] in Jakarta, which is responsible for collection and analyze of seismologic da-ta.

- The National Coordinating Agency for Surveys and Mapping (BAKO-SURTANAL) [9] in Cibinong, which is responsible for all tidal data.

- The Agency for the Assessment & Application of Technology (BPPT) [10] in Jakarta, which is responsible for all deep ocean sensor data

The GITEWS as well as the InaTEWS warning centre will be hosted at BMG. Besides the GITEWS sensors all three organizations have own sensors dep-loyed. In addition, they have access to international sensor networks whose data have to be feed into the warning process too.

3.1 Solutions for sensor data integration
Integration and consolidation of data from (distributed) data sources is just a standard task in computer science. There are a few well known solution patterns, however taking into account the performance and security require-ments of in the context of early warning systems only the following two should be taken into account:

- Data level integration

  Integration on data level requires the publication of data storage models, e. g. file formats or database schemas. Data of new sensors to be taken into account have to be fitted into existing data storage models or the data storage models have to be modified. If the participating parties require their own and independent data storage a mutual replication of data bases is necessary. As a consequence, a so-called stovepipe architecture with tightly coupled data stores is created. Due to that tight coupling the evolution of one systems data storage model directly affects all other sys-tems. Because only data are exchanged, implemented functionality at one organization, e.g. to analyze data, cannot be reused in other organizations. From a computer science point of view data level integration is a solution pattern that can be always used as last resort if no other solution pattern is applicable. Because of the induced tight coupling it should be prevented whenever possible.

- Functional integration

  Precondition for functional integration is that systems are realized com-pliant to the service-oriented architecture pattern: Functionality is realized in form of dedicated components communicating via a service infrastruc-ture. These components provide their functionality in form of services via standardized and published interfaces which could be used to access data maintained in - and functionality provided by dedicated components. Functional integration replaces the tight coupling at data level by a de-pendency on loosely coupled services. If the interfaces of the service pro-viding components remain unchanged, components can be maintained and evolved independently on each other and service functionality as a whole can be reused. To ensure that services are of the required quality service provider and consumer must negotiate so-called Service Level Agreements (SLA) and a Service Level Management (SLM) process has to be installed for both, service provider and service consumer.

Because of the advantages described above, in GITEWS the functional inte-gration pattern was adopted. The four services provided by the GITEWS system are realized in conformance to the Sensor Web Enablement (SWE), a standard specified by the Open Geospatial Consortium (OGC) [3]. Be-cause SWE-services define operations like “describeSensor” to access me-ta-information, data of new sensors could be provided dynamically without any change of service interfaces allowing the realization of dynamically con-figurable early warning systems.

4 An Blue Print for InaTEWS (an Indonesian Tsunami Early Warning System)
Early warning systems are long living and evolving: New sensor- systems and types will be developed and deployed, sensors will be replaced or re-deployed on other locations and the functionality of analyzing software will be improved. To ensure a continuous operability of an early warning system its architecture must be evolution-enabled. From a computer science point of view an evolution-enabled architecture must fulfill the following criteria:

- Encapsulation of data and functionality on data in standardized services: Access to the proprietary sensor data is only possible via these services.

- Loose coupling of system constituents which easily can be achieved by implementing standardized interfaces. Interfaces that can be used in early warning systems are comprehensively described in the specifications for the Sensor Web Enablement (SWE) of the Open Geospatial Consortium (OGC). SWE comprises description for both functional and modeling as-pects of sensors.

- Location transparency of services that means that services can be pro-vided everywhere.

- Separation of concerns that means breaking a system into distinct fea-tures that overlap in func-tionality as little as possible. For example, com-ponents that support decision making shouldn't have to deal with access-ing sensors on hard-ware level.

A service-oriented architecture as e. g. realized in GITEWS adopts these cri-teria best. Taking into ac-count the advantages of functional integration on the basis of SWE-conformant services described in the previous section and service oriented architectures in general, InaTEWS should be composed as a fede-ration of GITEWS-like architectures.

Figure 2 shows that vision of InaTEWS as a federa-tion of three GITEWS-like systems located at BAKO-SURTANAL, BMG and BPPT. For the sake of clarity the connections between provided and required in-terfaces are omitted, but it is assumed that interfaces with the same name are connected, t. m. that the decision support system (DSS) at BMG accesses e. g. SWE-services at all three locations.

Deep ocean sensor data are collected by the BPPT infrastructure which also processes GPS data of buoys. Raw data and processed GPS data are pro-vided to other participants in form of services like SOS, TSB_SAS, SPS and TSB_NS. Similarly, tide raw data are processed and provided by the BAKO-SURTANAL infrastructure. The main warn centre of InaTEWS with the deci-sion support system and simulation developed in GITWS is located at BMG where the processing of seismic and GPS data is done.

4.1 Benefits

Making that vision a reality would have the following advantages:

- The architecture was already implemented and tested in the project GI-TEWS. Experiences from operations and operations procedures could ea-sily be reused at BAKOSURTANAL and BPPT, respectively.

- The sensor system infrastructure layer is realized on top of well known and widely used open sour-ce software implementing industrial standards. It can be deployed at minor costs as a core for own development at BA-KOSURTANAL and BPPT as well.

- New sensors could be added easily to the inf-rastructure. GITEWS imple-mented a solution to feed sensor raw data from a (remote) file system into the sensor system infrastructure, accessing sensor raw data stored in a relational database could be realized in a similar way. A sensor type spe-cific dispatcher enables to plug in sensor type specific processing functio-nality at minimal costs without changing the architecture. Client compo-nents don't need to be adjusted if new sensor- types or individuals are added to the system, because they access the sensors via standardized services.

- Institutions like BAKOSURTANAL or BPPT could establish autonomous early warning- or moni-toring systems (like SeisComP) based on their own sensor pool.

- With implementing the Sensor Web Enablement fully compatible to the OGC Specification it is possible to establish the „detection" and integra-tion of sensors via the internet. Thus realizing a system of systems that combines early warning system functionality at different levels of detail (SeisComP, GITEWS and any sensor system) is feasible.

- Any institution could add both its own com-ponents to refine raw data and monitoring, analy-zing and decision support as well as components from third parties if they are developed in confor-mance to the GITEWS archi-tecture.

- Any institution in the federation has the owner-ship of their data and de-cides which data are provided by a service and when.

- One of the outstanding features of service-orien-ted architectures is the possibility to compose of new services from existing ones, which can be done programmatically, or if the corresponding runtime environment[3] is available, via declarati-on (workflow or process design). As described in section appendix A, that feature, which is also called orchestration, allows e. g. the definition of news warning processes which could be adap-ted easily to new requirements.

4.2 Preconditions for the realization of that blue print

In order to make that vision of InaTEWS a reality, the following preconditions must hold:

- Appropriate hardware must be available at BA-KOSURTANAL and BPPT to host the sensor system infrastructure.

- The feed of sensor raw data into the correspon-ding infrastructures must be adapted to the ac-tual data formats as well as to way raw data a pro-vided by sensors (file system or data base).

- GITEWS implemented a Sensor System Ma-nagement (SSM in Figure 2) to add, remove and manage GITEWS sensors. This component must be adapted to foreign sensors and divided responsibilities.

- To ensure that each institution gets the data it requires for its own opera-tions service level ag-reements have to be defined between all three or-ganizations to guaranty data access and qua-lity.

- Access policies for the services at the three lo-cations must be defined and enforced to ensure that only authorized participants could access the services.

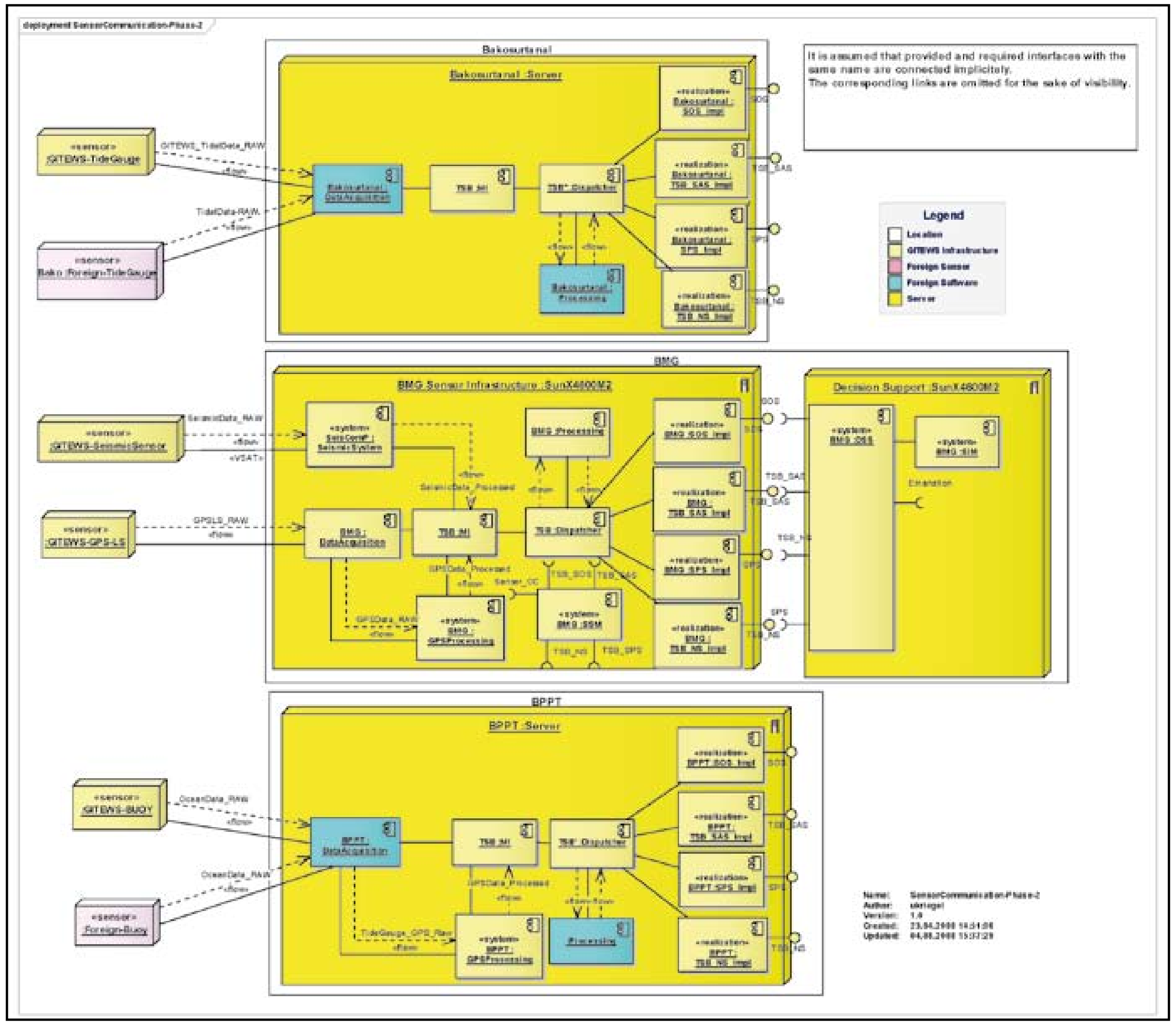

Fig. 2: *An blue print for InaTEWS*

5 References

[1] For further information see

http://www.gitews.de

[2] The open source application server JBoss, see http://www.jboss.org

[3] Open Geospatial Consortium, Inc.® (OGC), see http://www.opengeospatial.org

[4] SOS - the Sensor Observation Service, see

[5] SAS - the Sensor Alert Service, see

[6] SPS - the Sensor Planning Service, see

[7] WNS - the Web Notification Service, see

[8] The Meteorological and Geophysical Agency of Indonesia (BMG), see http://www.bmg.go.id

[9] The National Coordinating Agency for Surveys and Mapping (BAKOSURTANAL), see http://www.bako-surtanal.go.id

[10] The Agency for the Assessment & Application of Technology (BPPT), see http://www.bppt.go.id

[11] Java Enterprise Edition, see

http://java.sun.com/javaee

3 The Business Process Execution Language (BPEL) [13] is a standard for the orchestration of services for which commercial as well as open source products exist.

[12] KBSt - Federal Government Co-ordination and Advisory Agen-cy, see

http://www.kbst.bund.de

[13] Business Process Execution Language, see

http://www.oasis-open.org/committees/wsbpel

[14] Business Process Model Notation, see

http://www.bpmn.org/

Appendix

A Information Workflow with SWE Services

The following examples explain how SWE services could be combined in order to include arbitrary sys-tems in an early warning process.

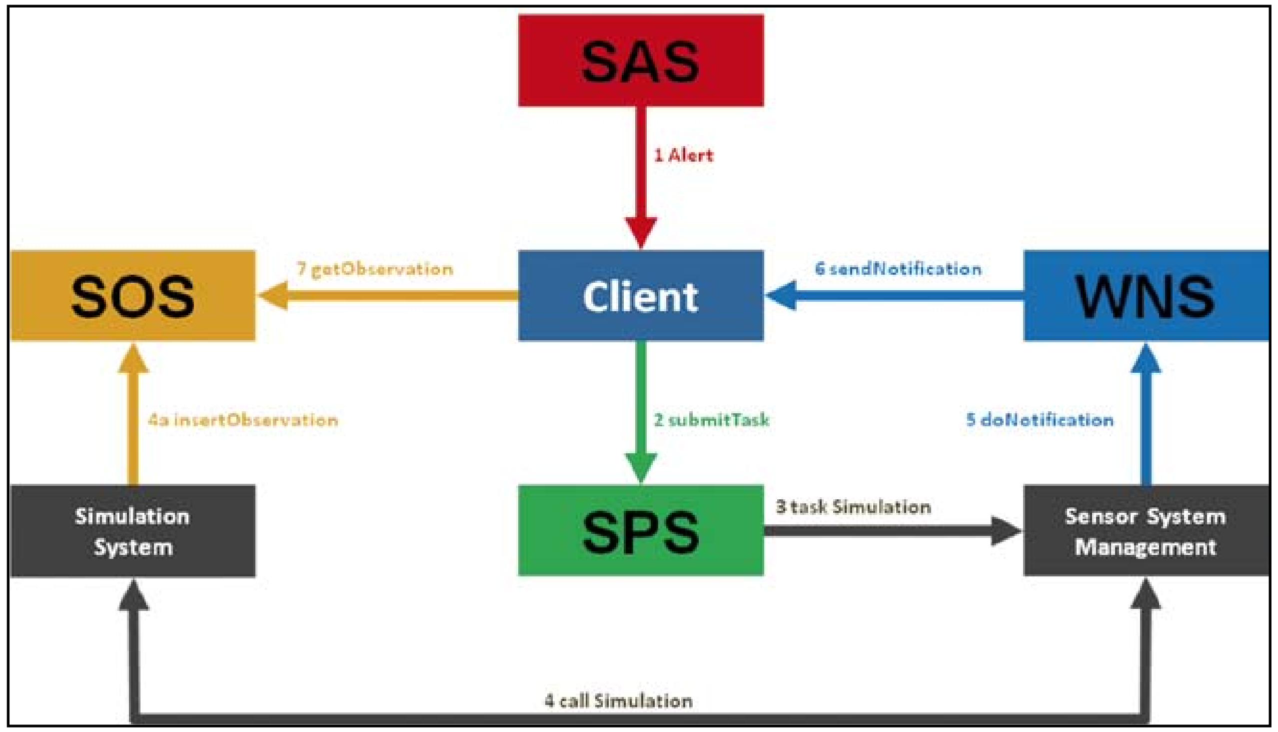

Fig. 3: *Workflow using atomic SWE services for accessing complex prop-rietary components (simulation)*

This is an example for a workflow using the avail-able SWE services TSB_SAS (SAS), SPS, TSB_NS (WNS) and SOS to task and access pro-prietary sys-tems such as simulation- or analyzing components. A workflow like this can be edited and designed using freely available design tools. An access of proprietary components or systems such as the "Simulation Sys-tem" is handled by the standardized interfaces of the services. These pro-prietary components can easily be exchanged without the necessity for ad-justing the client's software. The only adaption to be done is implementing the server side access to the services (e.g. "feeding" the SOS), in the above diagram the methods "callSimulation" and "insertObservation". Thus a client is able to switch between any (avail-able) systems for simulation.

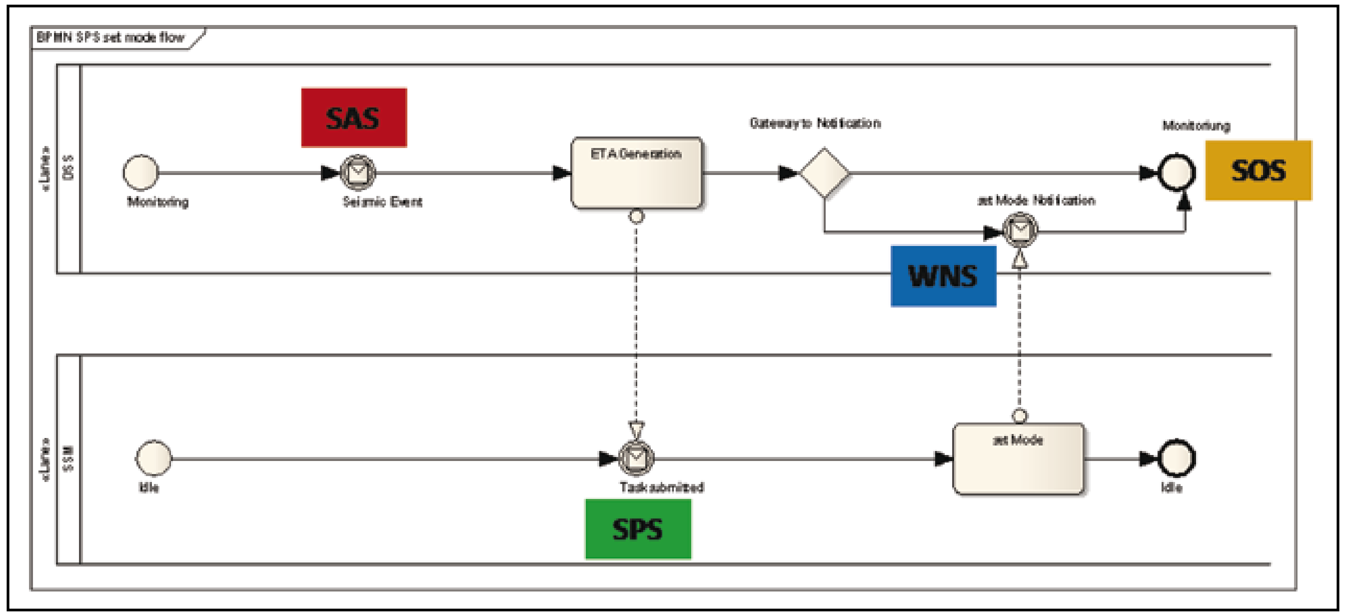

Fig. 4: *Workflow showing the SWE services and components involved in setting a higher sampling rate (Tsunami Mode)*

Figure 4 shows a workflow using the Business Proc-ess Model Notation [14]. Here two autonomous part-ners are involved (visualized as lanes), a Decision Support System (DSS) and a Sensor System Man-agement (SSM) that asyn-chronously communicate via sending messages. In this example the SPS is used to set (task) sensors (buoys) to a higher sam-pling modus in order to react on the generation of Es-timated Times of Arrival (ETA). The notification about success of this operation is done by the WNS.

From ORCHESTRA to SANY - An Open Sensor Service Architecture for Early Warning Systems

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1 Introduction

The paper describes an architectural approach for the integration of sensors into open geospatial service platforms that are compliant with international standards. The conceptual foundation for the Sensor Service Architecture (SensorSA) (Usländer (ed.), 2009), recently published by the SANY project (Schimak et al, 2008), has been the OGC Sensor Web Enablement Architecture (SWE) (Simonis (ed.), 2008) and the Reference Model for the ORCHESTRA Architecture (RM-OA) (Usländer (ed.), 2007).

The paper provides an overview of the generic SensorSA service types that are used for the design of decision support and early warning systems. Particular focus is put upon the task of sensor related discovery, event handling and the integration of models and multi-step fusion algorithms. The OGC SWE approach allows the modeller to see a sensor as a procedure that provides observation results as an "estimate of the value of some property of the feature of interest" from any source of information (Cox (ed.), 2007). As a consequence, SensorSA models the output of fusion and modelling services, cadastres, sensor data archives, event and alert histories, and service status information as "sensors". Their observations may then be accessed through the interfaces of the OGC Sensor Observation Service (SOS) in a uniform manner. Using the SOS in combination with additional OGC services, the paper describes a generic information retrieval model for the provision of observations. The model has been successfully tested within SANY (Kunz et al, 2009) and has been re-used for the development of an earthquake early warning system (Hilbring et al, 2009).

2 From ORCHESTRA to SANY

In autumn 2004 the European Integrated Project ORCHESTRA started with the ambition to define and implement an "open architecture and spatial data infrastructure for risk management" and refine it according to the needs of application pilot in multiple risk domains such as earthquake, forest fires and maritime risks. In addition to the user requirements from these application domains a systematic approach to define system requirements and architectural principles for such a generic architecture has been carried out (Usländer and Denzer, 2009). An example is the principle of "design for change": The architecture shall be designed to evolve, i.e. it shall be possible to develop and deploy the system in an evolutionary way. The result of this approach was the edition of the RM-OA in multiple steps that culminated in the acceptance of the RM-OA as OGC best-practices document (OGC 07-097).

The RM-OA provides a platform-neutral specification of a geospatial service-oriented architecture that responds to the requirements of environmental risk management applications. It comprises generic architecture services and information models based on and extending existing OGC specifications.

This was the starting point for the definition of the Sensor Service Architecture (SensorSA) by the European Integrated Project SANY (Sensor Anywhere). The SensorSA extends the RM-OA with respect to scope and architectural style. It focuses on the access, the management, the processing of information and event notifications provided by sensors and sensor networks. Furthermore, it supports multiple architectural styles: classical remote invocation, event-driven processing and resource-orientation.

The SensorSA foresees mechanisms to generate events and distribute them as notifications to interested consumers. This enables spontaneous distribution of information about changing configurations in underlying sensor networks, e.g. the dynamic addition or removal of sensor devices, which is a prerequisite for the support of the "plug-and-measure" type of operation. Furthermore, the SensorSA foresees the combination of so-called RESTful Web services (following the resource-oriented architectural style) with OGC services (following the remote invocation architectural style). This enables the design of user-oriented Sensor Web applications based upon the concepts of resources and their representation in multiple forms such as reports, map layers (e.g. to be visualised in OGC Web Map Service clients, Google Earth or Google Maps) and diagrams.

3 Sensor Related Discovery

One central service for an open service architecture is the catalogue service, which provides means for the discovery of resources used in a service network. One well known catalogue specification is the OGC CSW specification which provides means for publishing and searching of meta-information. Since meta-information is purpose dependent, several OGC Catalogue Implementation Specifications supporting different meta-information schemas exists (Nebert et al, 2007, Voges et al, 2007, Martell, 2009). ORCHESTRA has defined its own catalogue specification the "Catalogue Service (CS)" re-using the OGC principles (Hilbring, 2009). The specification itself is independent from the definition of a meta-information schema. Further on additional operations supporting semantics were included. To support highly specialized meta-information requirements ORCHESTRA defined a flexible meta-information schema.

The ORCHESTRA meta-information schema consists out of re-usable sections, which are combined to build specific resource types. The section "table of contents" and "core elements" are mandatory for each resource types while other sections can be defined freely. The default schema supports the resource types "service" and "data". For these two resource types the optional sections "Service Description" and "DataDescription" have been defined.

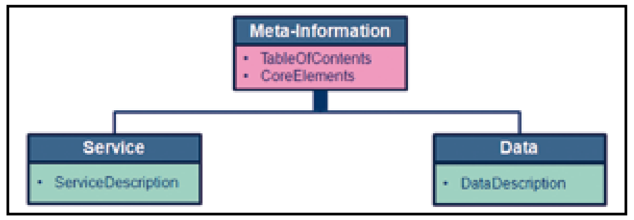

Fig. 1: *ORCHESTRA Meta-information Resource Types*

With this meta-information schema typical queries like „Give me all services supporting a standard interface x" can be answered easily.

However the SANY requirements for meta-information were more specific: SANY meta-information shall be able to address the discovery of resource related to sensor web environments. Examples for typical SANY queries are: "Give me all temperature observation for the time range x in region y" or "Give me all entries observed by a specific sensor". For the support of these complex requirements SANY extended the ORCHESTRA meta-information schema with new elements which were based on the OGC Observation & Measurement Model (Cox, 2007). The following new resource types have been defined:

- The "FeatureOfInterest" resource type can be described via the "FeatureOfInterest" section. Often, feature of interest is the area monitored by the sensor.
- The "ObservedProperty" resource type can be described via the "ObservedProperty" section and describes the phenomenon which is observed by the sensor.
- The "Procedure" resource type describes the sensor itself or algorithms describing the process of the observation collection. For this resource type two new sections were defined. The "Procedure" section describes the main attributes of the sensor or algorithm, while details can be included into the SensorML section which re-uses the OGC SensorML schema (Botts, 2007).

To support the newly defined meta-information resource types SANY defined new queryables for the search for resources in the catalogue. It is now possible to directly search for specific resource types with the queryables "FeatureOfInterest", "ObservedProperty" or "Procedure".

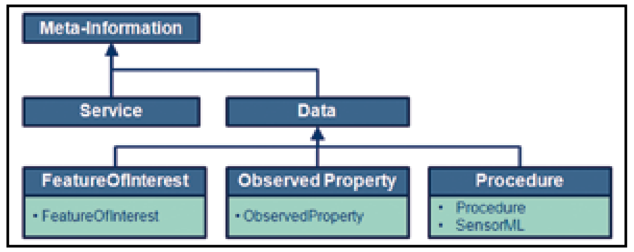

Fig. 2: *Additional SANY Resource Types*

Even with the newly extended meta-information schema one typical issue remains: phenomena defined in Sensor Observation Services (SOS) usually use different kinds of URNs, such that a phenomenon from one SOS means semantically the same as a phenomenon from another SOS but they are named differently (e.g. "relative humidity" and "rh") and therefore not easily found in the catalogue (Nah, 2004). To overcome this issue semantics need to be applied. During the creation of meta-information the meta-information can be semantically annotated using ontologies. This ensures that semantically identical phenomena are connected to the same ontology concept. During discovery the semantic functionality of the Catalogue Service can be applied which provides access to the ontology prior to the search. In a first step the user browses the ontology to identify the concept he is interested in. In a second step the selected ontology concept is used for the catalogue search. All resources related to the concept will be retrieved because of the semantic annotation (see figure 3).

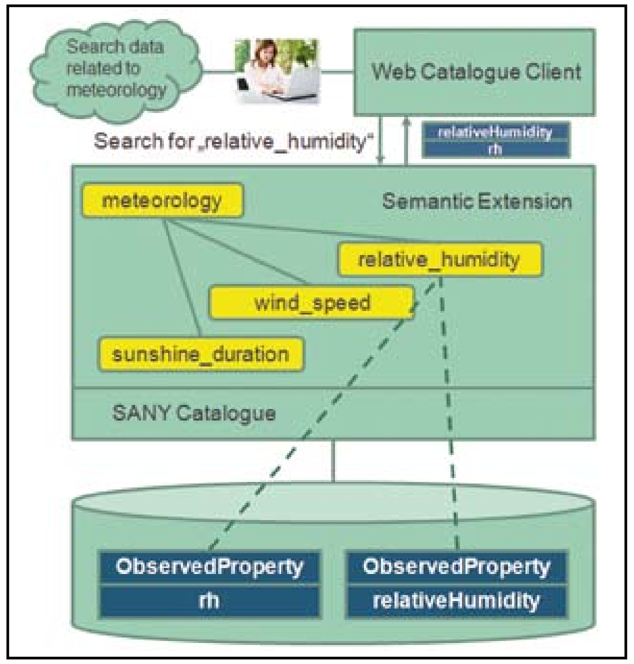

Fig. 3: *Semantic Support for Discovery*

4 Event Handling

A central aspect for a sensor service architecture is the event-based interaction model, because the model represents the basic form of interaction for cases in which timely delivery of observed events is important but needs to be flexible. Flexibility and adaptability are among the key characteristics of the event-based interaction model, because event generators don't call any specific type of event receivers. Indeed, they don't even need to know them.

The event-driven model consists at least of two components, (1) a component (e.g. a sensor) sensing the event and emitting the notification, and (2) a consumer receiving this notification. In more complex scenarios, the consumer can act as a "sensor" itself, emitting new notifications in turn of received ones.

SANY analyzed the OASIS Web Service Notification (WSN) standard for the applicability of event-driven workflows in sensor service architectures (Graham, 2006). The architectural structure applying the WSN was successfully tested (see figure 4).

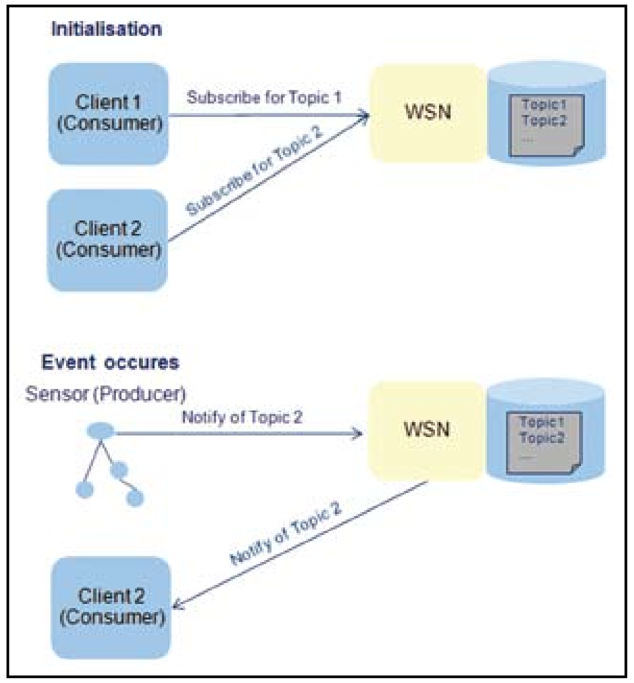

Fig. 4: *Event-based Interaction Model*

In the initialization phase a consumer subscribes its interest for a specific topic to the WSN. In case of an event the producer notifies the WSN of the event occurrence. The WSN filters the event and notifies only interested consumers.

5 Generic Information Retrieval Model

Observations provided by a Sensor Observation Service reflect the available data types and values. Often further processing is needed to retrieve the information which is of interest for the user.

This section describes a generic model for the acquisition of information based on sensor observations. The model consists of several steps:

1. Information retrieval via SOS

2. Configuration via SPS or WPS

3. Access to results via SOS or WFS

Figure 5 shows the architectural structure of the model. The details of the steps will be described in the following.

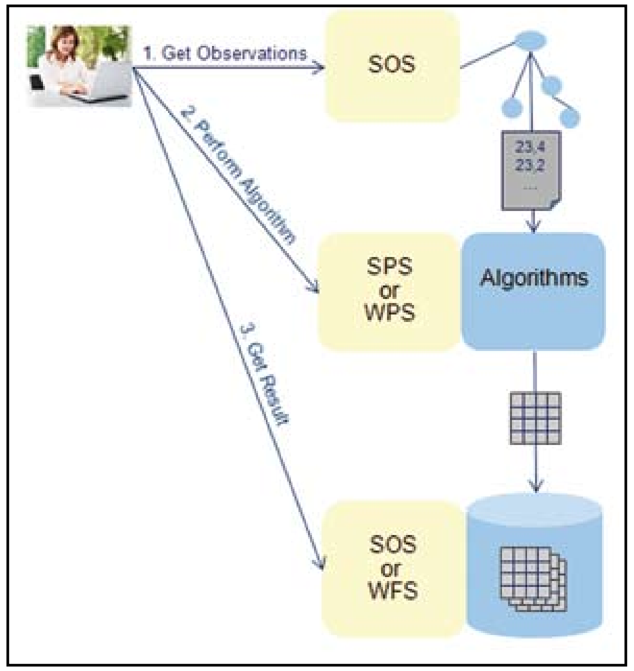

Fig. 5: *Information Retrieval Model*

Step 1: The original observations can be accessed via the Sensor Observation Service with the "GetObservation" operation. Information about the sensor sensing the values can be retrieved via the "DescribeSensor" operation. The returned SensorML document describes the sensor specification.

Step 2: The observations directly accessible via the SOS represent usually raw data which needs further processing until the information of interest for the user has been derived. The generic model foresees two alternatives for the data configuration:

- The Sensor Planning Service (SPS) provides the possibility to submit collection requests directly to sensors (Simonis, 2007). This functionality can be used to configure the access to specific SOS data and their post-processing with available algorithms, described as tasks in the SPS.
- The Web Processing Service (WPS) is not part of the Sensor Web Enablement domain of OGC (Schut, 2007). It provides geospatial processes. This functionality can be used to process and combine geospatial data accessed from an SOS with further data not related to the sensor domain.

Both, tasks from the SPS and processes from the WPS can be described in the catalogue as Procedure resource types.

Step 3: The results received by the processes and tasks provided by the SPS and WPS fulfill the original information retrieval task of the user. They need to be published in a standardized way. As in step 2 two alternatives exists:

- The Sensor Observation Service (SOS) can be used to provide access to the results received by the SPS. Just like raw data it is possible to describe an observation model, which represents the processed data. Now, the "DescribeSensor" operation describes the process method instead of the sensor specification.
- If there is no need to remain in the sensor domain it is possible to make the results accessible via the Web Feature Service (WFS) (Panagiotis, 2005). Here it is not possible to publish information about the calculation process. However the WFS specification is a well known OGC specification and is more likely to be supported outside the sensor domain.

The generic information retrieval model has been tested successfully in the SANY Fusion Testbed and for the creation of an early warning systems. Both will be described in the following sections.

6 SANY Fusion Testbed

The goal of the SANY Fusion Testbed is to analyse fusion techniques, which enable the prediction of environmental parameters where sensing measurements are not available, and to provide this functionality within the sensor domain.

The practical use case of the SANY Fusion Testbed was the creation of a detailed temperature map of IITBs properties based on few spatially distributed temperature observations.

The Fusion Testbed applies the generic information retrieval together with the principles of sensor related discovery. The resulting architecture is shown in figure 6.

In step 1. the user searches the catalogue for Sensor Observation Services providing the observed property temperature in the region of the IITB property. Several Sensor Observation Services are found. They provide the temperature data as time series data for specific sensor locations. In step 2 selected Sensor Observation Services are used to access temperature data from single sensor points. In step 3 the catalogue can again be used to discovery appropriate algorithms which can be used for the fusion of the temperature data delivered by the Sensor Observation Services. The fusion algorithms are provided as tasks via the SPS. With the user selected fusion algorithms triggered by the SPS a temperature map is created.

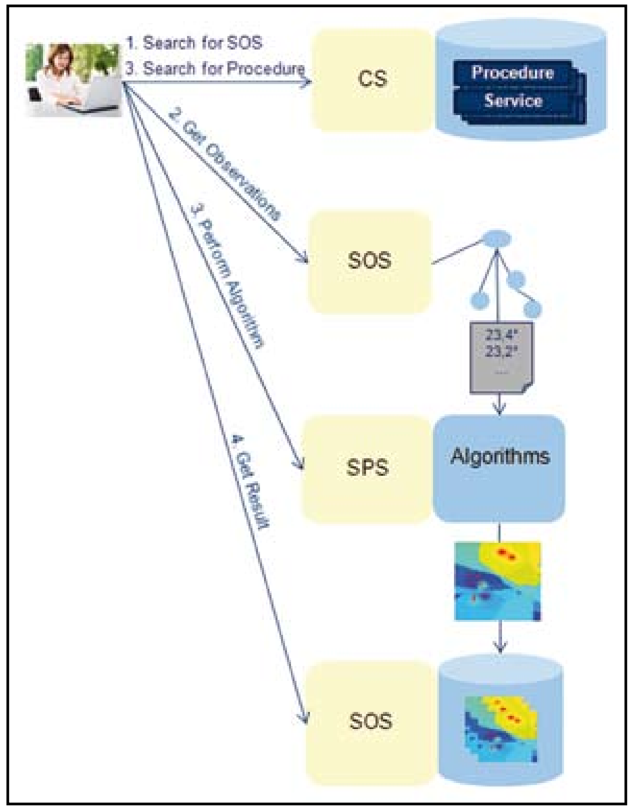

Fig. 6: *Architecture of SANY Fusion Testbed*

In step 4 the Sensor Observation Service is used to provide access to the created temperature map. For this task SANY defined a specific observation type based on the Observation and Measurement Model. The new observation type describes a coverage, the temperature map, unlike the conventional time series observation types. To support this specific observation type SANY implemented its own Sensor Observation Service.

Figure 7 shows the resulting temperature map on the IITB property.

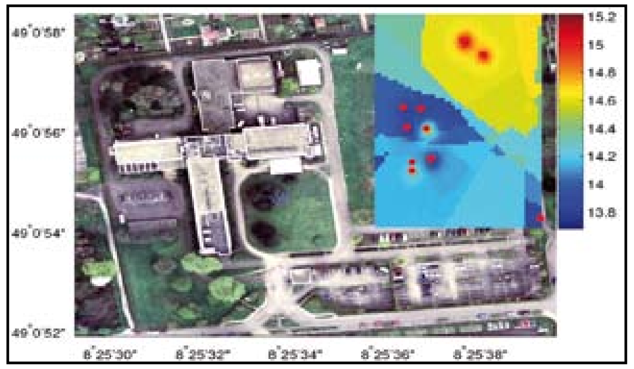

Fig. 7: *Temperature Map on IITB Property*

7 Earthquake Early Warning System

The potential applicability of the generic information retrieval model for early warning was tested in EWS Transport, a project analyzing the task of earthquake early warning for railway systems. The project is funded by Geotechnologien a geoscientific research and development programme, supported by the German Federal Ministry for Education and Research (BMBF) and the German Research Foundation (DFG).

The project goals are the rapid production of an alert map during an ongoing earthquake, which serves as the basis for a hazard calculation useful for alerting the train traffic and the provision of a shake map immediately after the strong-motion phase of an earthquake, which can be used for a damage estimation of the railway infrastructure.

EWS Transports architecture shall be designed as open service architecture and therefore re-uses ORCHESTRA and SANY principles. EWS Transport has implemented an demonstrator applying the generic information retrieval model for the following use cases:

- The use case “Earthquake Early Warning” defines the early warning use case starting with the detection of an earthquake based on its P-Wave, goes on to the hazard estimation for the train traffic up to the notification of the concerned railway operating company.

- The use case “Structural Health Monitoring” starts with the production of the shake map based on the measure S-Wave values and goes on to the damage estimation for railway infrastructure elements like railway tracks and bridges.

EWS Transport tested the applicability of the generic information retrieval model together with the event-based interaction model.

Figure 8 shows the resulting architecture for use case “Earthquake Early Warning”

EWS Transport implements a modified version of the earthquake early warning method PreSEIS (Böse et al., 2008) for the earthquake detection and analysis. PreSEIS triggers an “AlertMap” event to the WSN once an earthquake has been detected. The WSN notifies the EWS Client. The EWS Client accesses the earthquake observations via the Sensor Observation Service. EWS Transport has defined a new observation type for the SOS according to the Observation und Measurement Model of the OGC. The observation type describes an earthquake with the following parameters: location of hypocenter, magnitude and an acceleration field containing peak ground acceleration values in the area, which is monitored by PreSEIS. Since the peak ground acceleration value represent a coverage the newly implemented SANY Sensor

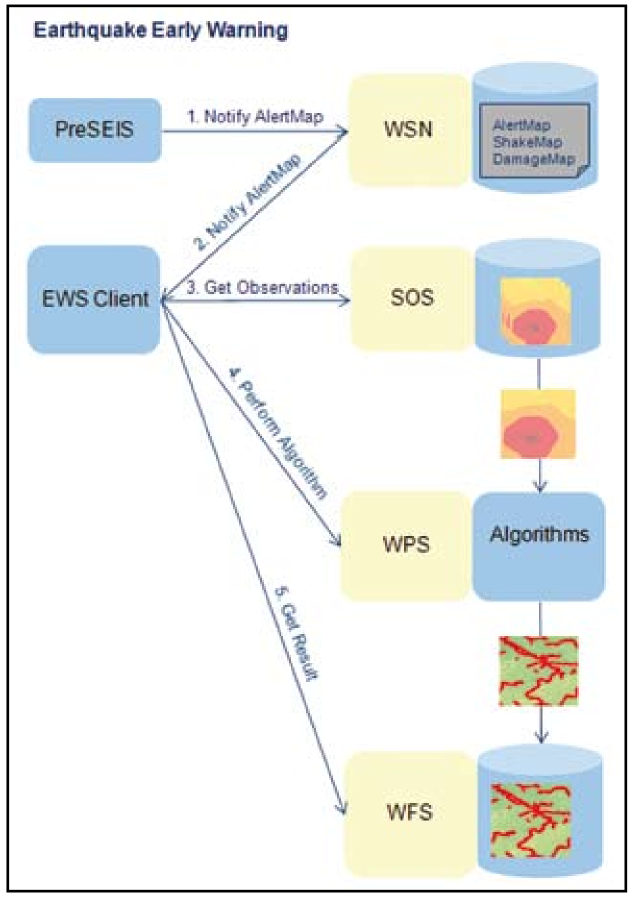

Fig. 8: *Use Case “Earthquake Early Warning”*

Observation Service could be adapted and re-used. In use case “Earthquake Early Warning” the peak ground acceleration values are estimated values of the ground acceleration in the upcoming earthquake and define the alert map (see figure 9).

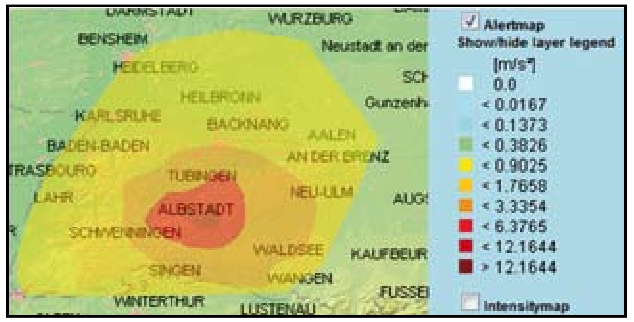

Fig. 9: *Alert Map (Estimated Ground Acceleration)*

The earthquake information needs to be combined with railway infrastructure for the hazard estimation. The railway infrastructure data is not collected by sensor observations. Therefore the WPS was chosen for the realization of step 2 of the information retrieval model. The hazard algorithm is provided by the WPS. It combines the peak ground acceleration coverage with the railway tracks and critical thresholds of the ground acceleration and speed limits on railway tracks to identify tracks at risk. The resulting information can be sent to the railway operating company to influence the train traffic. The resulting spatial data is included into a Web Feature Service. This ensures that the result can not only be accessed from inside the system. Additionally it can easily be accessed and visualized by components “speaking” WFS.

Fig. 10: *Railway Tracks in Danger.*

Further on the generic information retrieval and the event based interaction model has been applied for the use case “Structural Health Monitoring” as shown in figure 11.

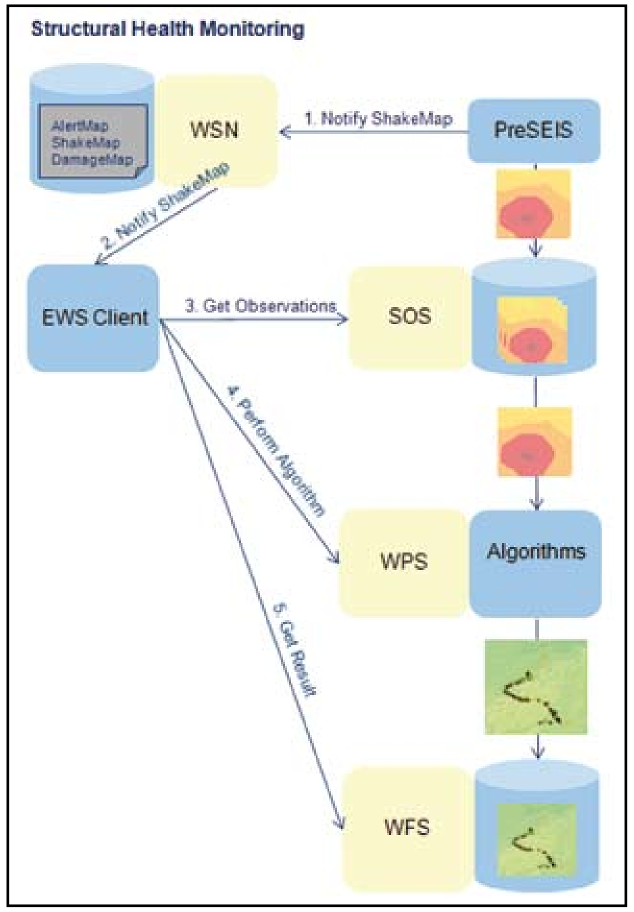

Fig. 11: *Use Case “Structural Health Monitoring”*

PreSEIS triggers a “ShakeMap” event once the strong-motion phase of the earthquake has finished. As in use case “Earthquake Early Warning” the EWS Client notified by the WSN accesses the earthquake observation data via the Sensor Observation Service. The difference is that the values provided in the peak ground acceleration coverage are measured values from the S-Wave defining the shake map (see figure 12).

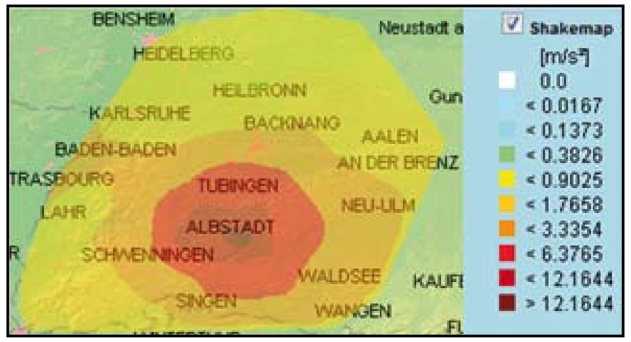

Fig. 12: *Shake Map (Measured Ground Acceleration)*

The earthquake information needs again to be combined with railway infrastructure information. This time the goal is to estimate potential damages to the railway infrastructure, since after the occurrence of an earthquake the railway operating company is in need for information about the condition of its railway tracks and bridges to initiate further inspections, where necessary. The WPS provides damage algorithms for the estimated damages of potential track and bridge damages. The resulting spatial data is included in the Web Feature Service and then available for access and visualization (see figure 13).

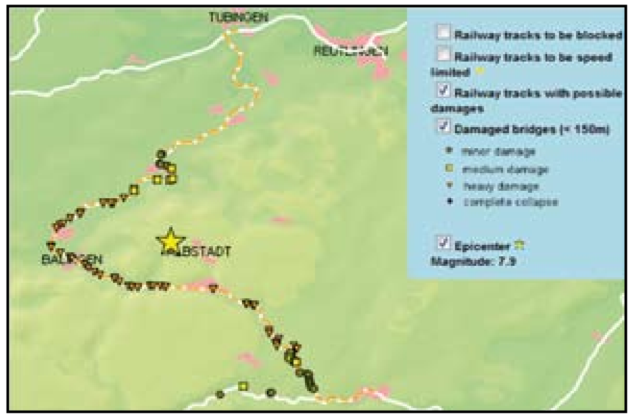

Fig. 13: *Potential Damage To Railway Tracks and Bridges*

The information created by use case „Structural Health Monitoring“ can serve as a basis for further actions. Therefore the EWS Client sends another event, the “DamageMap” event to the WSN, once all estimated damage calculations have been finished. Interested components from outside the system can register for such events to be informed in case of earthquake events. One example is the so called “Lagetisch” a multi display working station for emergency planning, which is able to receive the events and can access information provided by WFS. The “Lagetisch” could be used by the railway operating company to visualize the earthquake effects and plan further steps.

The EWS Transport demonstrator applying the use cases “Earthquake Early Warning” and “Structural Health Monitoring” has been implemented successfully. It is online under the following address: http://

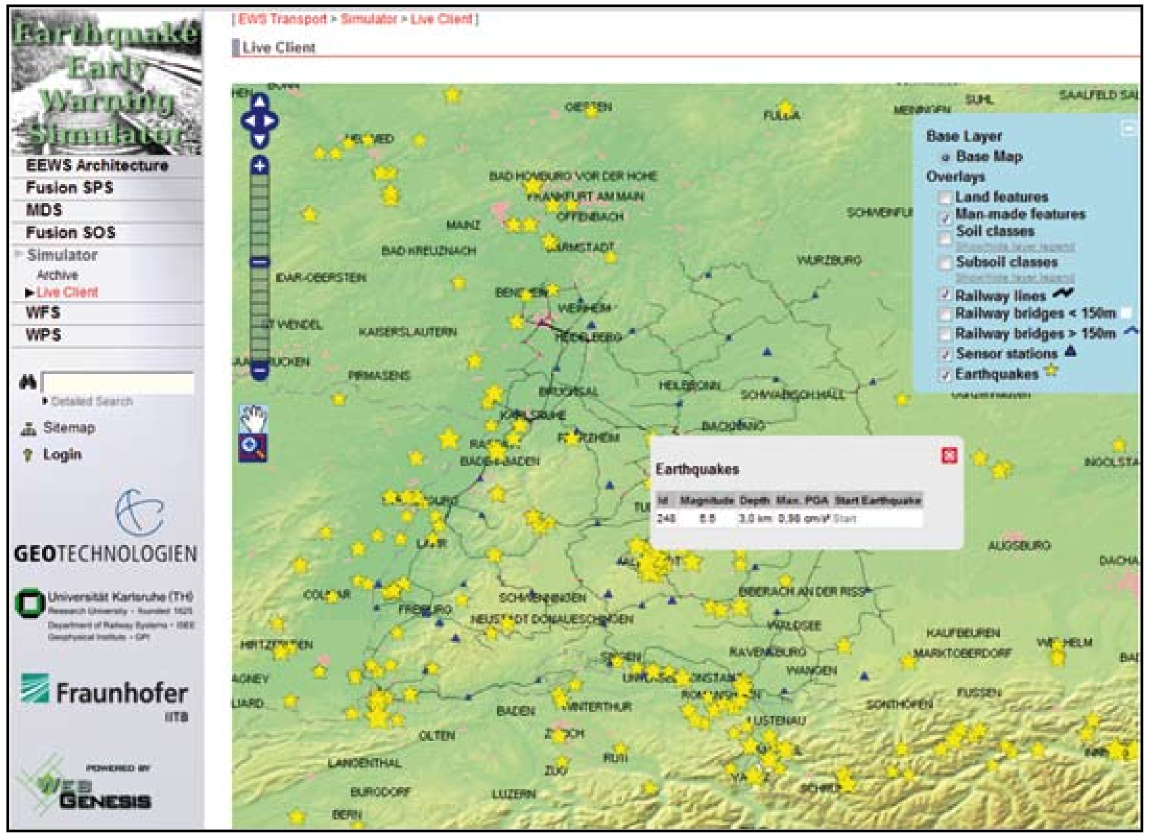

Fig. 14: *EWS Transport Demonstrator Simulating Effects of Earthquakes in Baden-Württemberg to the Railway System.*

ews-transport.iitb.fraunhofer.de/servlet/is/394/.Users can choose from 305 simulated earthquakes in the test area of Baden-Württemberg (see figure 14).

8 Conclusions

This paper showed how SANY has extended principles developed by the ORCHESTRA project and how these extension can be applied to early warning systems.

The methods for defining a service oriented architecture has been directly re-used and extended with means from the OGC Sensor Web Enablement domain, especially the usage of sensor related services like the SOS or SPS. Also the resource discovery process has been extended to address sensor related meta-information. Further on a generic information retrieval model was defined, which specifies a recommended workflow to create post-processed data from original SOS observation values. Event driven aspects are also principles which have been analyzed by SANY. They are of importance for the sensor domain, since changes often arise on the sensor side. Using an event driven interaction model workflows can be initiated by events.

All these aspects can be important for the specification and implementation of early warning systems. Therefore the specifications and developments of SANY support the creation of early warning systems as has been successfully shown in the Earthquake Early Warning System for Transport Lines.

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Intelligent SMS as an effective public warning system: the inspiring results of a Dutch pilot project

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Abstract
The classic Dutch disaster-warning system (the 'siren') is not as effective as it should be. The alarm is not heard by 37% of the population, not all the people that hear the siren do take it seriously. A public-warning system was developed based on so-called 'intelligent SMS'. This system was tested in 2004 among 700 inhabitants of the city of Vlaardingen (region Rotterdam-Rijnmond). The University of Delft conducted an intensive evaluation. The evaluation shows that use of SMS is technically feasible. It diminishes the part of the population that is not reached is by approx. 50%. The public is now not only warned that 'something is going on' but is informed by SMS of the nature of the threat and on what to do. The public perceives intelligent SMS as the most effective warning system. Based on the pilot, the disaster-management authority of the region Rotterdam-Rijnmond, with some 1.2 million inhabitants, decided to structurally implement the system in the whole region in 2005.

Keywords
Public warning system; SMS; Rotterdam-Rijnmond; Vlaardingen; Citizen Alert Services; Research; Pilot; Evaluation; effect; Risk Centre TU Delft

Introduction
During many incidents in The Netherlands in recent years it became more and more apparent that the existing public warning system is not as effective as it should be. The system comprises of computer-steered sirens placed on strategic places all over the country. During more than one incident it became clear that a large part of the public did not hear the sirens. But it also turned out that people who did hear the siren did not take it seriously or acted in exactly the opposite way of what was intended. Research showed that on average 37% of the population did not hear the siren (de Hond, 2003) and that 61% did not know what to do when the siren was sounded (Sillem et al, 2004). By nature the siren could also not be heard by the 125.000 complete or partially deaf people in The Netherlands, the Dutch Ministry of the Interior therefore promised Parliament that a special warning system for this group would be implemented by 2003, but failed to live up to this promise.

Seeing this, a Dutch disaster-specialist and the largest provider of mobile messaging services in The Netherlands teamed up and combined their expertise. They formed a new company, Citizen Alert Services, with one main goal: to develop a better public warning system, based on a clever use of SMS. Penetration of mobile phones is as high as 84% in The Netherlands, coverage is good in the whole of the country and the use of SMS is well known and widely accepted. In major tele-voting events it had been demonstrated that safe, time-critical SMS is possible in high-volumes without congestion problems, when it is designed and executed well.

The System
A system was developed, based on so-called 'intelligent SMS'. In this system, a sophisticated database is combined with a very stable, high-speed, high-capacity SMS Platform. This is placed as a spoke-in-the-wheel between all the providers of mobile communication in The Netherlands. The system is a so-called dedicated mGovernment-system, for safety and reliability purposes strictly separated from the normal commercial SMS-traffic.

The Netherlands have a widely known and commonly accepted postal-code system. This divides the whole country in very small cells, of on average 1.500 inhabitants. Almost every Dutchman knows his or her own postal code. It is this coding system that is the 'default-setting' in the SMS-warning system. People that would like to be warned by SMS in case of danger register in the system the postal codes of their home, their work or school, the school of their children. This is done in a very easy way by SMS or on the Internet. In the database the combination of postal codes and relevant mobile telephone number is stored (even when people switch provider). All kinds of coding can be used however. For instance, special codes can be used for specific professionals, like schoolteachers, shop-owners, doctors in specific areas: they can receive warnings and instructions that differ from the warnings for the general public at the same time.

The local authority has an interface, in which all the geographic and professional selections can be made by a mouse click. The most common warning messages are prepared in advance and can also be selected with a click of the mouse when needed. The preparation of the messages is done to prevent mistakes or the sending of unclear messages in the hectic first moments of an incident.

The system can send different types of SMS-messages. For urgent alerts the so-called flash-message (or 'type-0') messages are used. These high-priority messages can hardly be missed because they, other than normal SMS-messages, pop-up directly on the main screen of the receiving mobile phone. They can also not be faked by the normal mobile telephone user, so the chance of false alarms is minimized.

The way of operating of the system is shown in the figure 1:

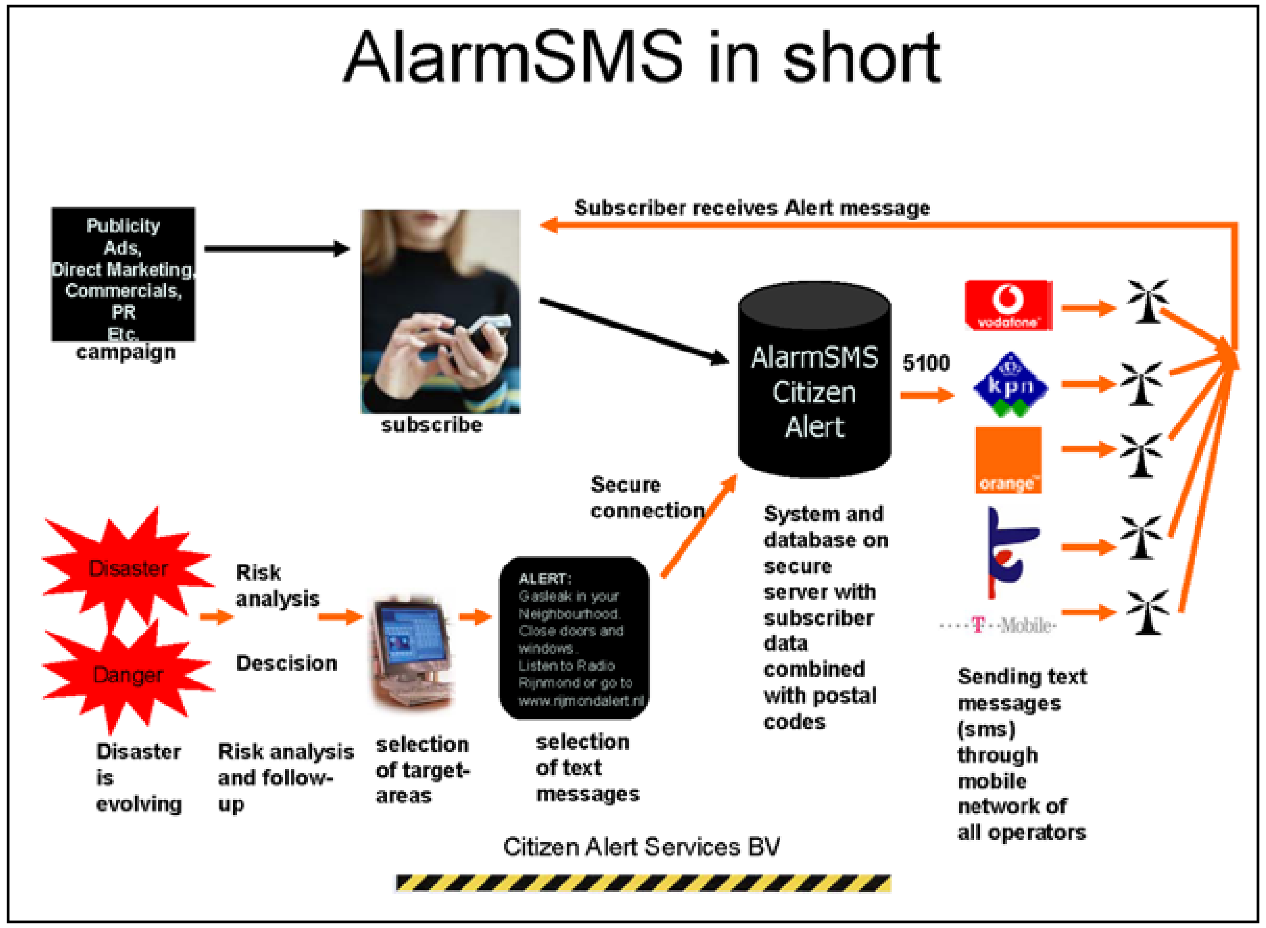

Fig. 1: *The way of operating of the system*

siren-test (the siren is sounded in the whole of the Netherlands once a month to test the system and to keep people aware) and on two occasions unannounced at different times during the week. In the test-messages people were asked to respond by SMS, to see whether they indeed had received and read the message, they were also asked whether they had heard the siren at the same time.

The Pilot
After the development of the system and thorough internal testing the system was tested in 'real life'. The municipality of Vlaardingen, a city of some 65.000 inhabitants in the Rotterdam-Rijnmond region was very eager to test the system: the city is surrounded by heavy industry and harbours and had experience with recent incidents in which the siren warning had not had the expected effect. So the city of Vlaardingen and the regional authority for disaster management (the "Regionale Hulpverleningsdienst Rotterdam-Rijnmond") commissioned and financed a wide-scale test.

The test was run form February till June 2004. More than 700 people from Vlaardingen participated. Within this test-group were segments of inhabitants from all of the neighbourhoods in the city, segments of deaf inhabitants, different groups of professionals et cetera. In the test-period the participants received an SMS-warning around the time of the monthly

The Evaluation
'Self-evaluation is deemed to lead to success' is a well known quote from Wesley Skogan. Therefore Citizen Alert Services asked the Risk Centre of Delft University of Technology to conduct a thorough, independent evaluation. This evaluation consisted of desk-research, two surveys (ex-ante and ex-post), response-analysis, interviews and (3) panel discussions with different segments of participants. The evaluation resulted in the TU-Delft-publication "Evaluation of the Pilot SMS-Alarm Vlaardingen" (Sillem et al. 2004).

The Results
Response-analysis showed that on average 79% of the warned group responded to the SMS-warning. The system checks by itself whether an SMS-message is actually delivered, this showed that 100% of the messages were delivered as intended. But being delivered doesn't mean that the message is also read: therefore only the responses are counted as

effective delivery: to respond, people have to have read the message first of course. But the response of 79% is the minimal score for 'having read the message': the survey shows that not all participants have responded to all the messages they have read, and they also did not always respond immediately. The response time is given in the chart in the next page. Overall 58% of the target group responds within 10 minutes, which means they must have read the message earlier than that. As said, the survey (ex-post) shows that not all participants have responded immediately after having read the message.

heard the siren have more often read the SMS. This can be due to a higher sensitivity due to participating in the pilot, but it is not impossible that this is a structural effect.

The evaluation shows that among the participants in the pilot, the group that is not reached by the public alarm is diminished by approx. two-thirds. The siren alone does not reach 33% of the participants (slightly less than the Dutch average), with the combination of SMS and siren this group is reduced to 11%. This amount should be corrected for mobile telephone-

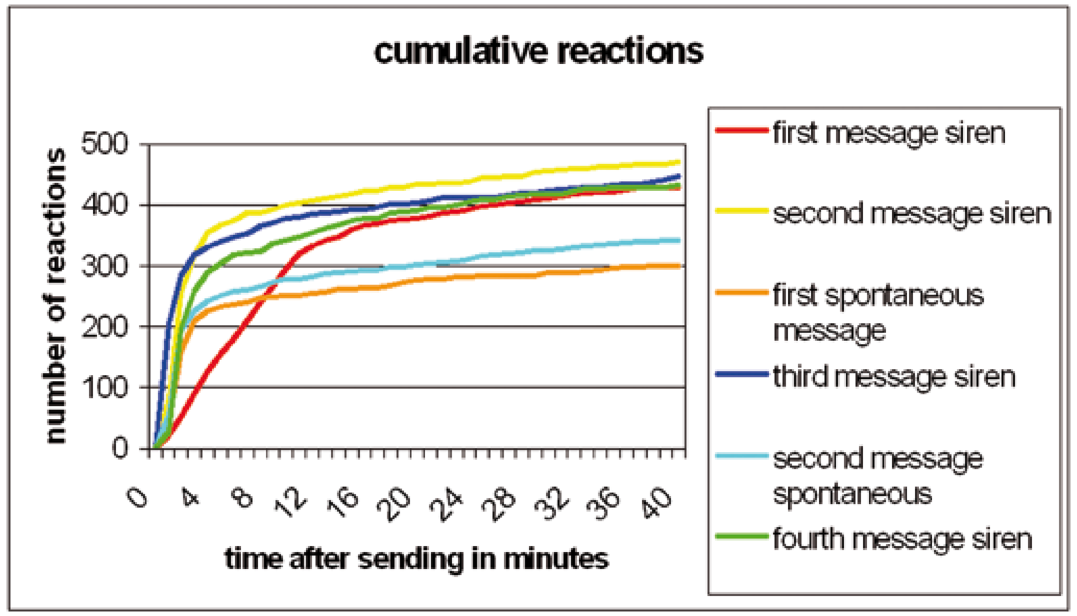

***Fig. 2:** Cumulative Reactions*

Combined coverage by SMS and Siren
The SMS-warning system is – in Holland - meant to be used in combination with the Siren system. In this way, a multimedia warning system is created. There is some evidence that there is a relation between 'reading the SMS' and 'hearing the siren' and vice-versa. People who have read the SMS have more often heard the siren as well and people who have

penetration, time of effective reading et cetera when generalized to the population as a whole. But then still an improvement of approximately 50% remains. Of the same importance is the fact that 79% of the population is now not only notified that 'something is wrong', but they are now informed on the character of the threat and they are given instructions for action at the same time.

		AlarmSMS	
		YES (79%) (Did respond, so must have read)	NO (21%) (Did not respond, so maybe did not read)
Siren	YES (67%) (Did hear siren)	57%	10%
	NO (33%) (Did NOT hear siren)	22%	11%

***Table 1:** coverage by SMS and siren*

Public acceptance
95% of the participants in the pilot consider SMS to be a good or very good addition to the siren warning. 84% has the idea that they will be better warned by the combination of the two systems than by the siren alone. When asked which form of warning they would like to see, the Alarm SMS turned out to be the most popular warning system, which is mentioned by 91% of the research group, followed by to 82% for the siren and 63% radio.

Performance
Apart form a few start-up problems in the first few weeks of the pilot the system performed as planned. The pilot-experience also gave ideas for some further improvements, especially in the field of user friendliness.

Professional acceptance
Both local authority of the municipality of Vlaardingen and the Regional Disaster management-authority were very pleased with the performance of the system and the results of the evaluation. Based on the evaluation, the Board of the Regional Disaster management-authority decided to implement the system in the whole region with urgency. This was done in May, 2005. Some other municipalities and regions are still considering implementation.

Variations
Due to the success of the pilot, variations on the system have been developed for specific other purposes in the public-safety-sector. For some institutions that have a high-risk-profile for terrorist attacks, a smaller-scale warning system was developed with which users of that institution can be warned in a few seconds to evacuate or to stay away. The same can be developed for business parks or dangerous industry. The system is by now capable of spreading so-called regional weather-alarms, with which the population is warned for specific, dangerous forms of weather, like gale force winds.

Conclusion
Due to the wide-spread proliferation of mobile phones, mobile messaging seems to be an interesting way to warn the public for upcoming dangers. Most people have their mobile phones with them, wherever they go. That they switch off their phones during some of the time is not a big problem: to get a warning message across, 100% coverage is not absolutely necessary. Because in case of real danger, people will share information with others in their vicinity. Of course in that case it helps that people know what the threat is and what behaviour is advisable.

The Vlaardingen pilot showed that public warning by 'intelligent SMS' can reduce the amount of people that is not reached by the existing warning systems and that it can provide the public with information on the nature of the threat and the necessary action.

The system is seen as effective by the public and by the responsible authorities, structural implementation is welcomed. The system can also be used for more specific warnings in specific target groups, more specific risks or more defined areas.

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Tsunami hazard studies in South East Asia

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The 2004 Indian Ocean Tsunami has led to an increased awareness of tsunamis on a global level and in particular in South East Asia. Emphasis has been on awareness as well as on establishing warning systems, and to a less degree on tsunami hazard and risk mapping. Notwithstanding, there is a need for quantifying the hazard and risk as an instrument for decision makers on national and regional scales. This study is an extension of a previous tsunami hazard and risk study for the western coast of Thailand (Løvholt et al., 2006); focussing on the Philippines and eastern Indonesia. The hazard analysis presented here is based on parts of a range of projects, most notably the Global Disaster Report conducted for the International Strategy for Disaster Reduction (http://www.preventionweb.net/english/hyogo/gar/), as well as the risk assessment for natural hazards and conflicts in South East Asia (Nadim et al., 2009).

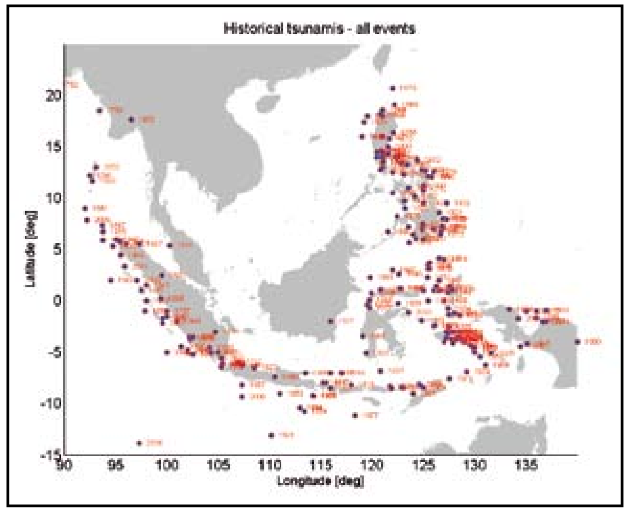

Fig. 1: *Historical tsunami events in South East Asia.*

Historical tsunamis as well as seismicity and the associated tsunami potentials are used as the basis to select scenarios for the hazard analysis. An overview of the historical events is shown in Figure 1. These historical tsunami data are compiled using the online catalogues of University of Novosibirsk and NGDC/NOAA, supplemented by seismic information by Engdahl (2002), Engdahl et al. (2007), and Villasenor and Engdahl (2007). In addition, the regional seismicity is investigated, and is displayed in Figure 1.

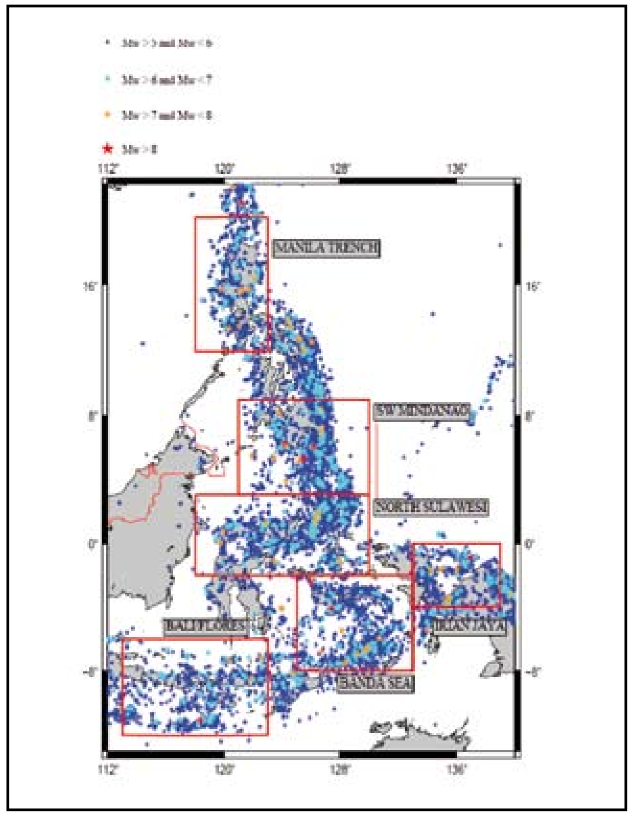

Fig. 2: *Seismicity in eastern Indonesia and the Philippines. The red boxes indicate the study regions.*

A number of tsunami scenario simulations are conducted. Initial wave heights for the tsunami scenarios are computed using a standard analytical dislocation model (Okada, 1985), combined with a smoothing of the sea surface discontinuities above the fault line (Pedersen, 2001). The wave propagation is modelled using the dispersive wave model GloBouss (Løvholt et al., 2009; Pedersen and Løvholt, 2008). Because of the large geographical extent of the study area, quantifying the tsunami hazard assessment has been scenario based, focusing on overall trends rather than details. Most of the scenarios are designed to closely resemble so called 'credible worst case scenarios', i.e. with magnitude equal to or slightly higher than the largest recorded earthquake within a given study region. An example of a tsunami scenario is shown in Figure 3. For a regional assessment of the shoreline run-up heights of each scenario, amplification factors computed for plane waves are utilised (Nadim et al., 2009). Moreover, possibilities in coupling the propagation model to a run-up model (see e.g. Løvholt et al., 2009) for local run-up evaluations have been attempted.

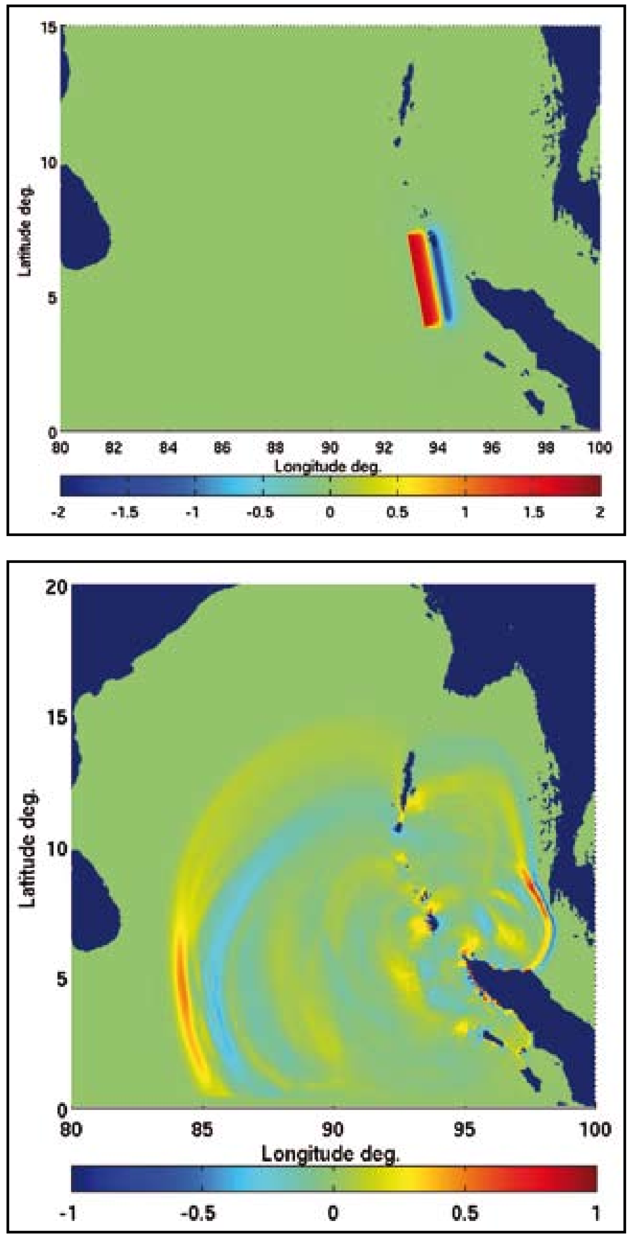

Fig. 3: *Example of tsunami scenario simulations used in the hazard analysis. Upper panel, initial surface elevation for a Mw8.5 scenario. Lower panel, snapshot of the simulated wave after 1 hour 30 minutes.*

The study regions include (i) Bali/Flores Sea region, (ii) The Banda Sea, (iii) Northern Sulawesi, (iv) Irian Jaya, (v) South western Mindanao, and (vi) The Manila Trench and western Luzon Island (Figure 2). Results are presented for a selection of the above mentioned study regions. One example of a merged hazard map for a part of South East Asia is shown in Figure 4. The figure shows both run-up estimated for tsunami scenarios, as well as population densities. By overlying the run-up with the population density maps, the population exposure may be calculated. The exposure is an important first step towards estimating the regional tsunami mortality risk.

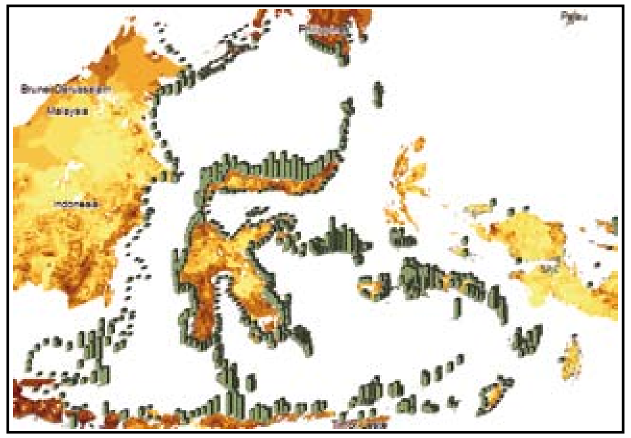

Fig. 4: *Example of a merged map of maximum tsunami run-up from several scenario calculations. The run-up is computed using amplification factors. The bar height indicate the run-up heights, whereas the land color indicate the population density.*

Acknowledgements

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High-rate GPS data analysis during the Bengkulu (South Sumatra) earthquake and tsunami 2007

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Abstract
We analyze SuGAR (Sumatran GPS Array) data during the earthquake by using kinematic technique of BERNESE 5.0 software. On September 12, 2007 two earthquakes hit the southern part of Sumatra near the capital of Bengkulu Province, Sumatra, Indonesia. The first earthquake Mw 8.4 at 11:10:26 UTC is located approximately 130 km Southwest from Bengkulu city while the second (Mw 7.9) occurred approximately 250 km from the first one on 23:49:04 UTC. The rupture initiated at the southeastern edge of a patch of the subduction interface and propated to the north.

The maximum horizontal coseismic displacement estimated from daily solution was 1.2m southwestward and more than 0.6 m displacement toward southwest at Mukomuko. While in Bengkulu city the horizontal displacement was detected more than 0.7 cm. We also detect 0.36 m and 0.04 m horizontal displacements associated with the Mw7.9 and Mw7.1 earthquake, respectively.

1. Introduction
Catastrophic events such as big earthquakes result when the earth's crust fails in response to accumulated deformation. The accumulation of deformation results from ongoing processes of aseismic deformation of subcrustal rock associated with relative plate motions. Modern techniques of space geodesy, such as Global Positioning System now provide data of a quality, temporal and spatial not allowed by more traditional geodetic method. GPS can provide continuous information on three dimensional ground deformations that is important during earthquake occurrence and also hazard assessment.

The most common approach in GPS data processing is static solution. This method is used to estimate 24-hour average positions for each receiver. However, earthquake rupture process can rapidly switch deformation behaviour so the obvious disadvantage of using this method is that dynamics of rapidly evolving deformation event will not be discerned. In order to portrait detail deformation during the 2007 Bengkulu

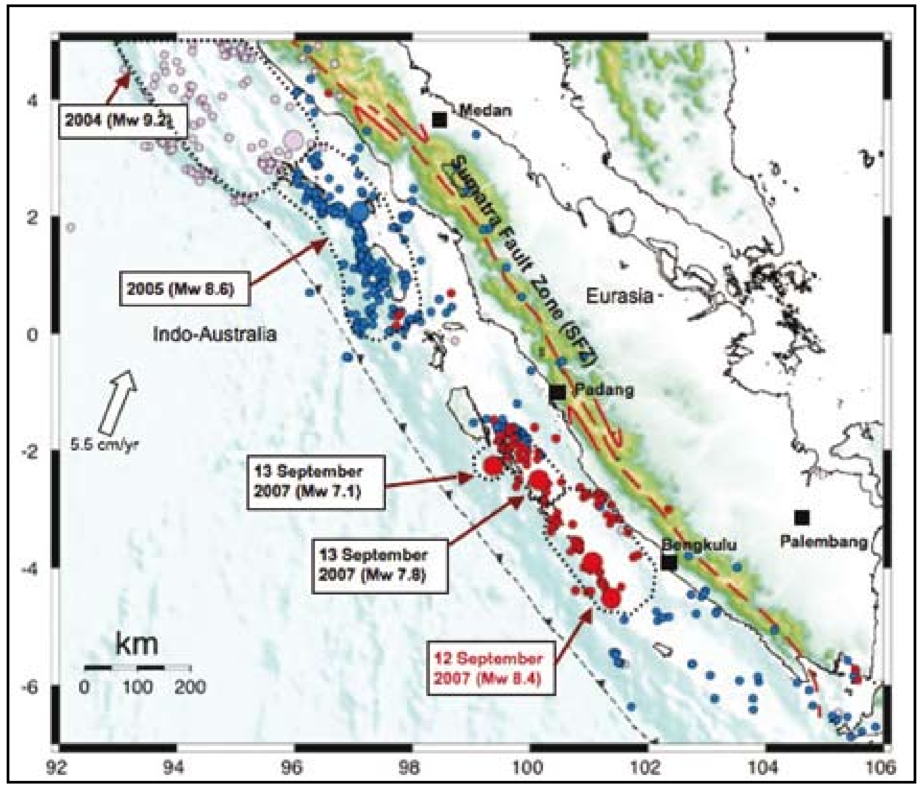

Fig. 1: Tectonic setting and seismic history.

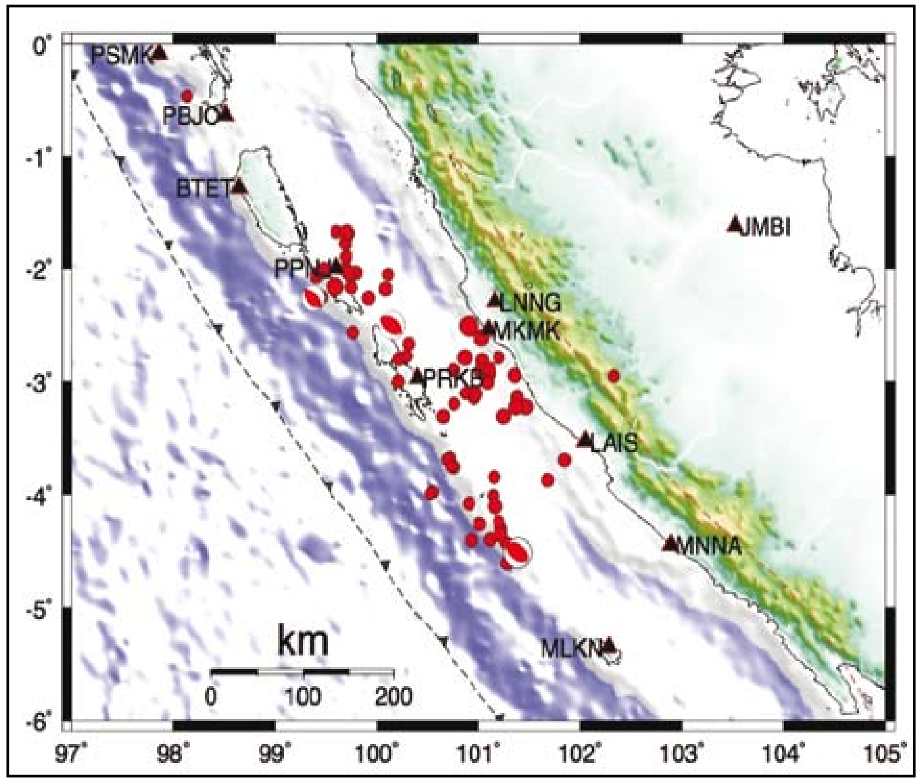

Fig. 2: *Distribution of SuGAr CGPS stations shown by black triangles. Red dots represent distribution of aftershock.*

earthquake sequence we analyze static GPS data in Sumatra by using kinematic analysis method

The 2007 M 8.4 Bengkulu earthquake is very important in term that it contributes to our understanding of the occurrence of great subduction earthquake and to its implication to tsunami potential. The earthquake occurred on September 12, 2007 at 11:10:26 UTC and followed 12 hours later by another earthquake of Mw 7.9, 185 km SSE of Padang (Figure 1). The earthquake sequence continued during the next two days, including a Mw 7.1 earthquake on September 13. This sequence occurred very close to the slip area of the 1833 great earthquake. Slip inversion analysis of tide record indicates that the maximum slip of this even was 10 m with rupture of 350km long and 200km large (Stefano et al., 2008). This rupture area is significantly smaller than that of the 1833 event. It appears that the area experiencing small slip has possibility of re-rupture in a future earthquake.

2. Tectonic setting and seismic history

The Indonesian ocean lies along a highly oblique convergent margin between the Australian plate, which moves with a rate of 40 to 50 mm/year, and the Eurasian plate, which is relatively fixed (figure 1). The regional tectonics has since been shown to comprise a large variety of phenomena associated with plate convergence i.e. seismogenic subduction, forearc deformation, shifting of plate boundaries and microplate tectonics.

Tectonically, western Indonesia consists of the Sunda Shelf, which includes the islands of Sumatra, Java, Bali, Borneo and the southwestern part of Sulawesi. The main structure of Sumatra trends northeast and comprises from southwest to northeast, the Java trench, the forearc ridge, the forearc basin, the Bukit Barisan mountain chain and a Neogene foreland basin that covers most of northeast Sumatra (Hamilton, 1979).

Along the west coast of Sumatra the oblique convergence is partitioned into subduction at trench, which is nearly perpendicular to the arc and arc-parallel motion of forearc along the Sumatran Fault Zone (SFZ) (McCaffrey, 1991). The SFZ has been thought to accommodate most of the right-lateral component of the relative motion between the Australia and Eurasia plates.

SFZ extends parallel to the trench and the volcanic chain, through the western portion of Sumatra, for more than 1600 km along the entire length of the island from the Sunda Strait to the Andaman Sea in the north. McCaffrey (1991) further demonstrated from earthquake slip vector deflections and plate convergence vectors that the forearc sliver plate located between the trench and the SFZ is not rigid but instead undergoes arc-parallel stretching, requiring a northwestward increase in slip rate along SFZ.

Earthquake hypocentral distributions indicate that the subducting plate dips less than 150 beneath the outer ridge and steepens to 500 below the volcanic arc (Newcomb and McCann, 1987). In the 20th century, numerous magnitude greater than (Mw) 7 earthquakes have occurred in the subduction zone and SFZ.

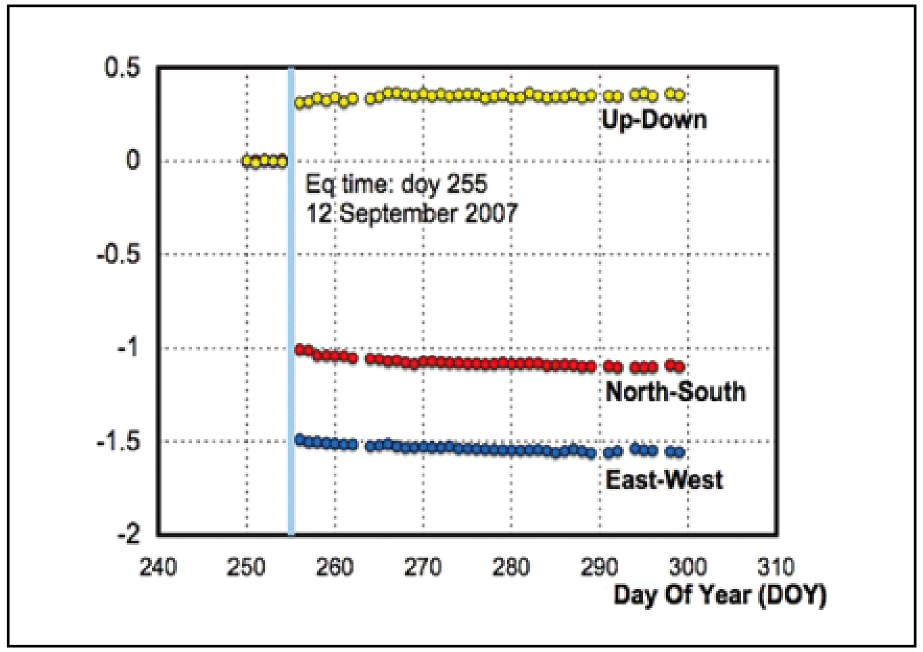

Fig. 3: *Time series of displacement at PRKB.*

The two most important earthquakes are those that occurred in 1833 and 1861. Newcomb and McCann (1987) conclude that the source of the 1833 earthquake was a 550km long segment of the subduction interface extending from Batu Island to Enggano Island and the rupture extended from the trench to a point below the outer-arc island. They suggest that slip of about 4-8 m occurred on the interface. Zachariasen et al. (1999) found in emerged fossil microatolls of sea level changes associated with the 1833 event. The pattern and magnitude of uplift are consistent with about 13 m of slip on the subduction interface and suggest a magnitude (Mw) of 8.8-9.2 for the earthquake.

The result of campaign-style GPS measurements (Prawirodirdjo et al., 2000) shows that the area of 1833 rupture moved in the direction relative to the plate motion, which indicates that the subduction interface is fully locked.

3. GPS data

Major earthquake cause static stress changes within the lithosphere that large enough to excite observable, deformation of earth's surface. Space geodetic techniques by using Global Positioning System (GPS) for measuring surface displacements have advanced to the point where both the spatial and temporal characteristics of this point deformation can be described in detail.

GPS provides three-dimensional relative positions with the precision of a few millimeters to approximately a few centimeters over baseline separations of hundreds of meter to thousands of kilometers. The three-dimensional nature of GPS measurements allows one to determine horizontal as well as vertical at the same time and place (Segall and Davis, 1997).

Crustal deformation associated with earthquake occurrence is often divided into four phases: preseismic, postseismic and interseismic. This fourfold structure has been assembled from geodetic observations in many places: a complete cycle has never been observed at any one location.

GPS measurements are complementary seismological data because they document the full earthquake cycle, including interseismic and transient postseismic processes, as well as coseismic deformation (Segall and Davis, 1997). Detection of slow interseismic strain accumulation is probably the best technique we have for identifying the location of future earthquakes in some areas, because elastic rebound requires elastic strain accumulation prior to earthquakes. Postseismic deformation studies exemplify how geodetic data can uniquely allow determination of aseismic fault behavior, which is essential to understanding the process of strain accumulation and release in a seismogenic region, constraining transient stress transfer and may provide insight into physical processes.

GPS measurements of surface displacement can thus be inverted to determine the geometry of earthquake rupture. Once the fault geometry is known, it is possible to determine the distribution of slip on the fault surface. Geodetic estimates of slip distribution complement seismic data in elucidating the earthquake rupture process. The radiated seismic wave field is dependent on the slip amplitude, rupture velocity, and source time function, whereas the quasistatic displacements depend only on the final slip amplitude. Therefore, a combination of seismic and geodetic data provides stronger constraints on the spatial distribution of slip and the temporal evolution of rupture than do seismic data alone.

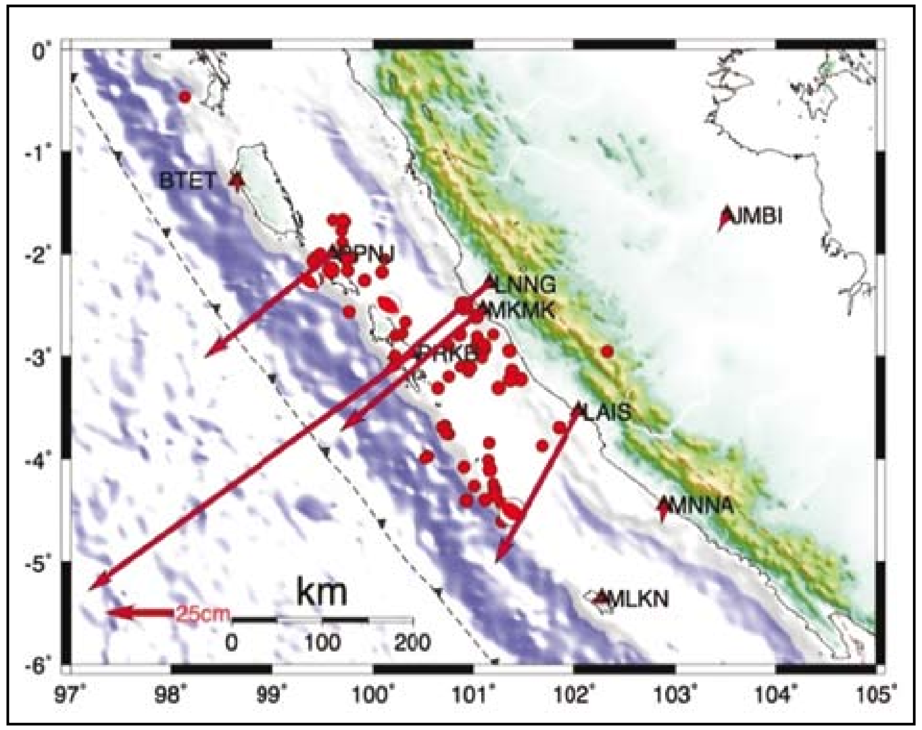

Fig. 4: *Horizontal coseismic displacement of the 2007 Sumatra earthquake.*

The first geodetic measurements of coseismic deformation were made on the island of Sumatra during the course of triangulation survey (Prawirodirdjo et al., 2000). These data which indicate right lateral motion in NW-SE direction were later referenced by Ried as evidence for his famous elastic rebound theory of elastic cycle survey (Prawirodirdjo et al., 2000). The GPS network in Sumatra was initiated in 1989 (Bock et al., 2003) under 5 year GPS project in Sumatra, GPS Geodynamics Project in Sumatra (GPS-GPS).

To estimate coseismic and postseismic displacement we process 10 CGPS (figure 2) data of the Sumatran GPS Array (SuGAr) installed by the Caltech Tectonic Observatory www.tectonics.caltech.edu/Sumatra/data.html from a week before until three months after the earthquake.

The GPS data were processed using Bernese 5.0 software (Beutler et al., 2007), with baseline processing using precise orbit and pole determinations from the CODE. The data were processed with cycle slips removed, tropospheric corrections, ambiguity resolution and network solutions. We used 18 global IGS GPS stations to implement the ITRF-2005 reference frame in the GPS analysis.

4. Coseismic and postseismic placement

Time series at continuous GPS site PRKB is shown in Figure 3. Coseismic offsets of the CGPS sites are estimated by determining the best-fitting straight line to 7 days preseismic and 3 days postseismic portion of the time series.

A static analysis of the September 12 data from the station with the largest horizontal displacement, PRKB (200 km NNW from the epicenter), shows that the station moved approximately 1.71 m during the main shock and 0.21 m (table 1) during the aftershock about 100 days. While at LAIS, 150 km NNE from the epicenter, the horizontal displacement is 0.72 m during the main shock and 0.11 m (figure 4) during 100 days of aftershock indicating a large rupture concentrated NNW from the epicenter.

Station	Easthing (m)	Northing (m)
BITI	0.001	-0.008
BTET	0.002	-0.025
JMBI	-0.030	-0.049
LAIS	-0.352	-0.630
LNNG	-0.467	-0.392
MKMK	-0.600	-0.501
MLKN	-0.014	-0.004
MNNA	-0.007	-0.052
PPNJ	-0.540	-0.429
PRKB	-1.396	-0.997

A static analysis of the September 12 data from the station with the largest horizontal displacement, PRKB (200 km NNW from the epicenter), shows that the station moved approximately 1.71 m during the main shock and 0.21 m (table 1) during the aftershock about 100 days. While at LAIS, 150 km NNE from the epicenter, the horizontal displacement is 0.72 m during the main shock and 0.11 m (figure 4) during 100 days of aftershock indicating a large rupture concentrated NNW from the epicenter.

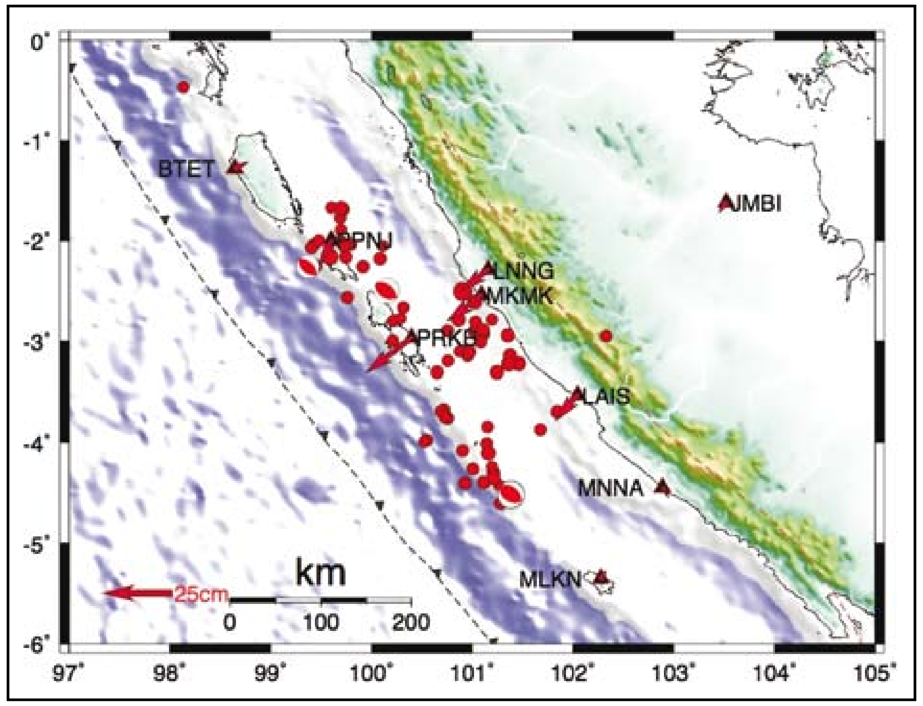

Fig. 5: *Horizontal postseismic displacement of the 2007 Sumatra earthquake.*

Continuous GPS solutions at PRKB, one week from the earthquake shows 3.7 cm deformation the west and 4.9 to south, while from day 7 to day 14 (one week) indicate an additional 0.6 cm deformation the west and 1.5 to south, indicating a slowing postseismic deformation with time.

Conclusion

The maximum coseismic displacement from GPS result was 1.7 m south-westward at South-Pagai Island. More than 0.6 m displacement toward southwest at Mukomuko, while at Jambi i.e. 500 km from the epicentre, significant displacement of more than 6 cm is still detected.

The 2007 earthquake did not rupture the whole source zone of the 1833 event and poses a serious threat for a future big earthquake that will possibly occur in the unruptured area.

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Early Warning Experiences in Padang, Sumatra: The Bengkulu Earthquake of 12 September 2007

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1 Background

On September 12 and 13, 2007, a series of large earthquakes originating from the Sunda Trench off the West coast of Sumatra struck Padang, the capital of West Sumatra Province. The first earthquake, at 18:10:23 (WIB, Western Indonesian Time), was recorded at a magnitude of M 7.9 at BMKG Jakarta, the National Agency for Meteorology, Climatology and Geophysics. aftershocks as shown in figure 1. It appears that seismic activity is migrating from SE to NE towards Padang, a distance of about 400km.

The map of West Sumatra shows the location of the main earthquake of 12 September 2007, origin time 18:10 WIB (11:10 GMT) off the coast of Bengkulu. Large aftershocks are also plotted. All times referred are in West Indonesian time (GMT +7 hours) and magnitudes correspond to Richter Magnitude.

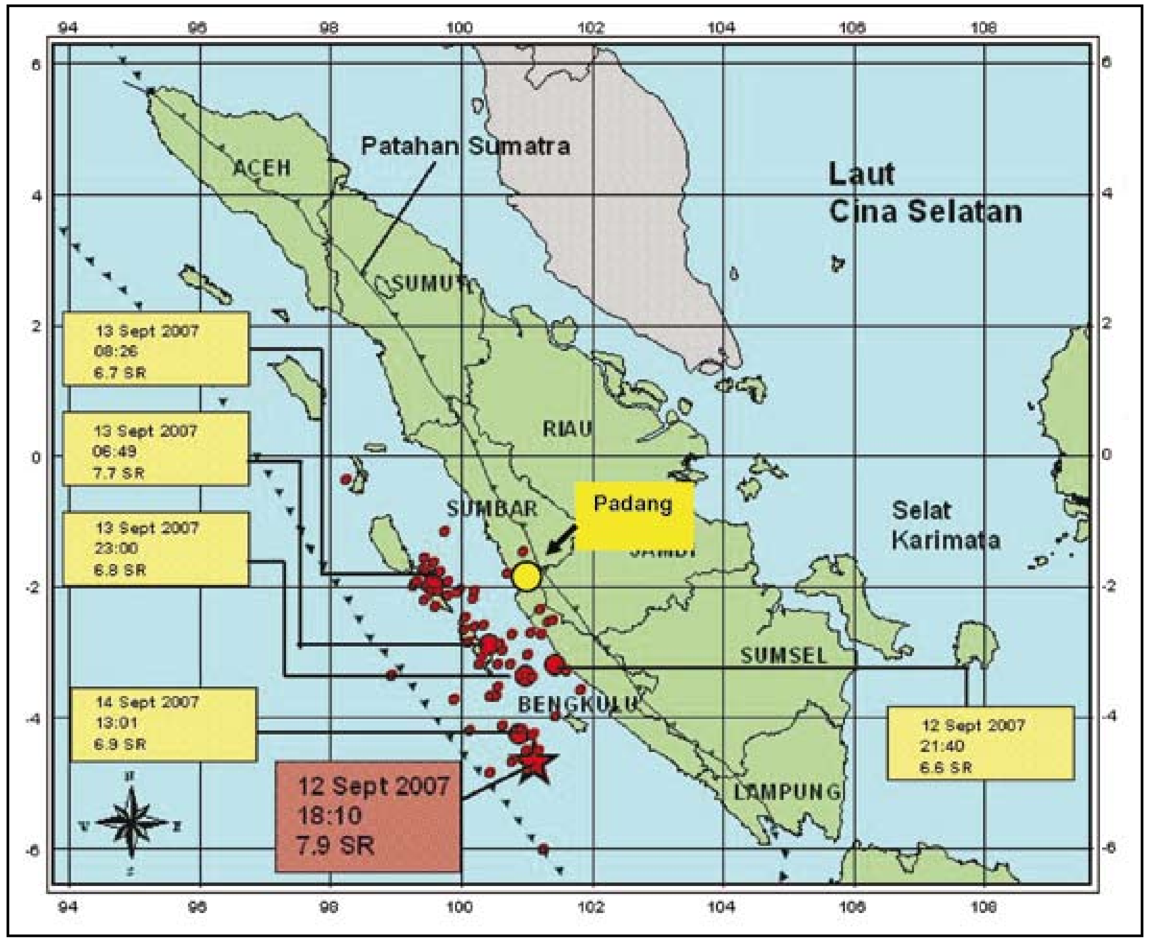

Fig. 1: *Map of West Sumatra, as released by BMKG, with epicentre location of the magnitude 7.9 earthquake and main aftershocks.*

The earthquake hypocenter was located offshore at 4.44 degrees South, 101.37 degrees East, at a depth of 34km. The slant distance to Bengkulu was about 130km, to Padang about 390km. This main event is the objective of this paper. However, this earthquake was followed by a series of medium to large

Arrowheads indicate the beginning of subduction of the Indo-Australian Plate beneath the Eurasian Plate while the toothed line marks the Sumatra fault, a tectonic surface expression associated with the subduction process.

The sequence of aftershocks from 12 to 16 September 2007 following large earthquakes is displayed in figure 2. Earthquakes located in the very same area have been accumulated in intervals of 5 hours. As can be seen, the number of aftershocks is gradually declining.

This triggers the alarm in the Operations Room at BMKG to get the full attention of the operators: 'heads up'! At this time contact is made with Bengkulu BMKG station to get a quick situation report. Bengkulu was significantly closer to the hypocenter than Padang. Felt intensities (on the Modified Mercalli In-

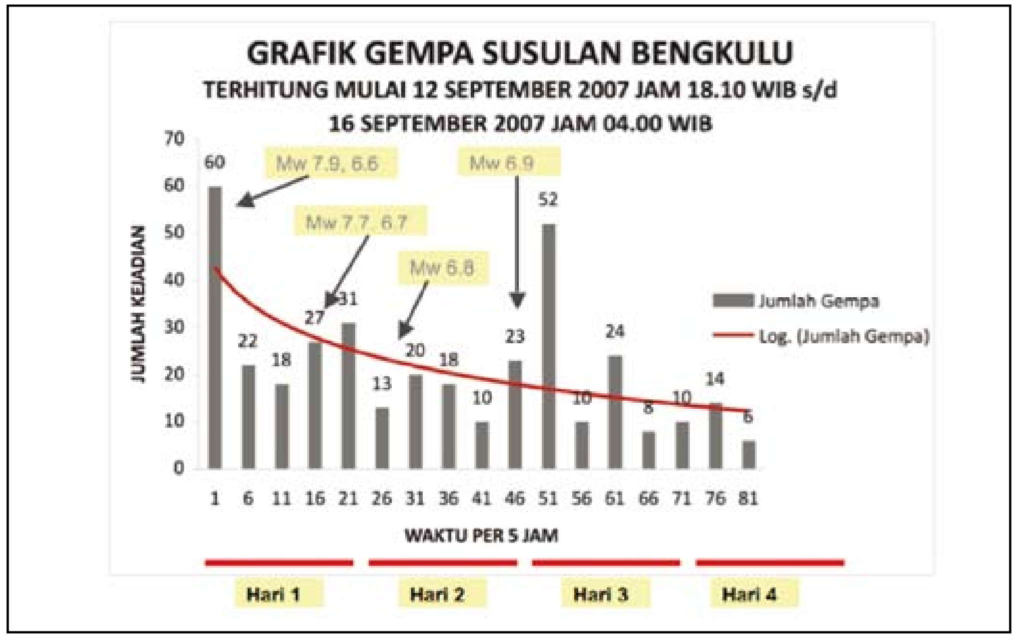

Fig. 2: *Seismic activity following the main earthquake and large aftershocks (source BMKG).*

The time line shown in figure 3 puts subsequent observations and actions taken at the BMKG Warning Centre into perspective. Shown here are BMKG's activities after the main event at 18:10:23 WIB (West Indonesian Time) finishing with the 'All Clear' after a little more than two hours. In two minutes seismic stations are indicating that the seismic P wave arrival has been detected and that data is being processed.

tensity Scale, MMI) are reported. After 4:07 minutes the earthquake location tool SeisComP 3, developed by GFZ Potsdam, delivers hypocenter location and magnitude. The seismic analysis tool developed by CEA (China Earthquake Networks Centre) follows seconds later. BMKG issues SMS messages containing the tsunami warning potensi tsunami being sent after 4:41 minutes and received by decision makers

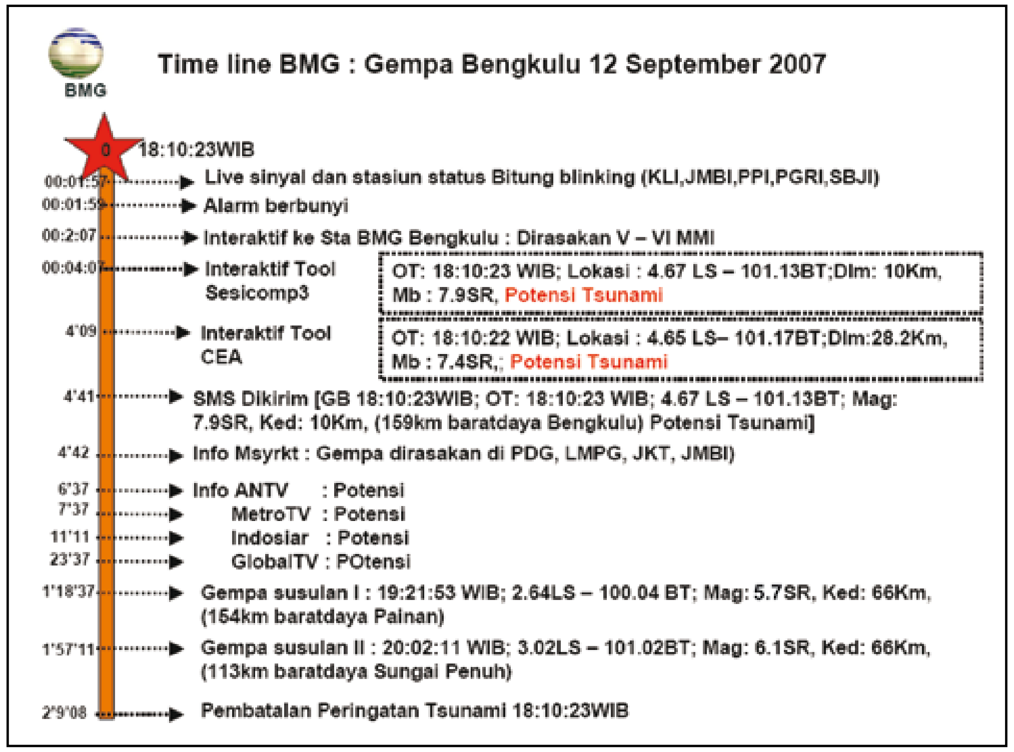

Fig. 3: *BMKG time line of the 12 September 2009 magnitude 7.9 earthquake.*

in Padang, so shortly after the ground shaking. At the same time information from people who have felt the event at Padang, Lampung, Jambi (all locations are in Sumatra) and Jakarta (!) is received. 4:37 minutes after the initial shock TV and radio stations are provided with information which the pass on to the general public. Aftershocks are recorded and widely felt. After 2 hours and 9 minutes the 'all clear' message is issued and the Tsunami Warning cancelled.

As stated by several sources[1], the mayor of Padang announced guidance for evacuation to Padang citizens around 15 minutes after the earthquake via FM radio in response to the tsunami warning.

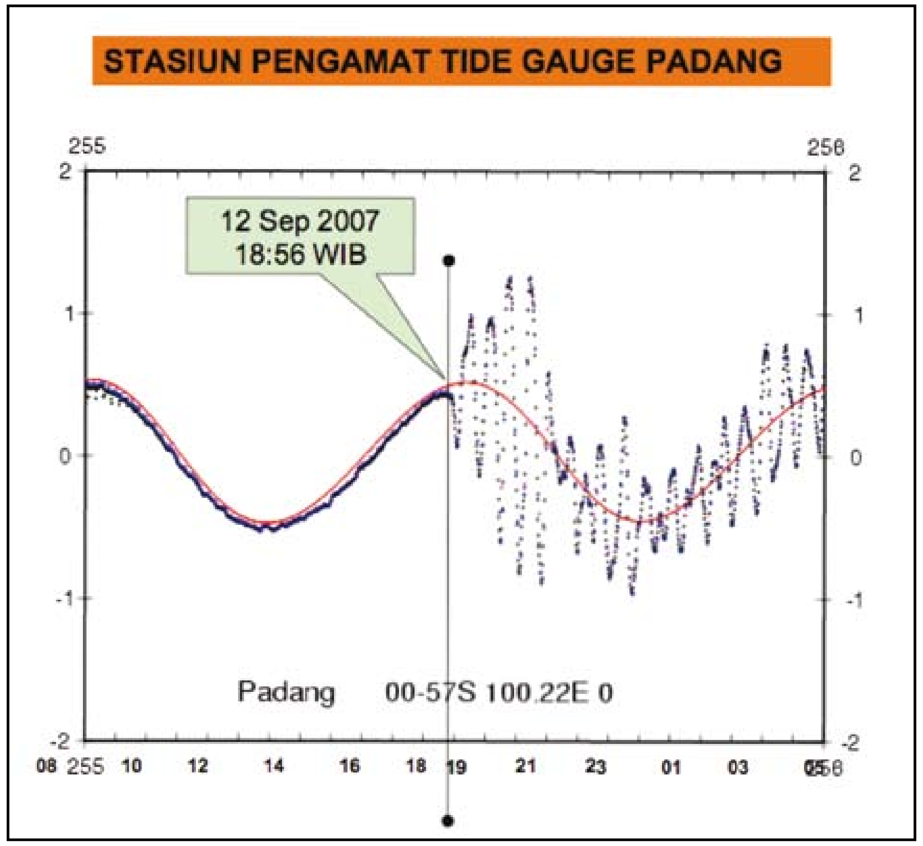

Fig. 4: The tide gauge in Padang is recording a small tsunami at 18:56 WIB. The ordinate is scaled to 10cm intervals. Source BMKG.

As can be seen in figure 4, about 46 minutes after the magnitude 7.9 earthquake the tide gauge monitoring station located at Padang is recording a small tsunami with an amplitude of about 19cm peak-to-peak.

Around one and a half months later, from 29 October to 2 November 2007, GTZ IS-GITEWS conducted an explorative survey in Padang in order to shed some light on the experiences with the first earthquake and the subsequent tsunami warning information potensi tsunami. The survey used a standardized questionnaire to conduct interviews with 200 randomly selected citizens of Padang City who live in the "red zone" (elevation zone: 0-5 m in accordance to the 'First Generation Elevation Zone and Evacuation Map of Padang City', (figure 5) and/or were within that area at the time of the first earthquake.

As stated by several sources, key informant interviews were conducted with representatives of different government and non-government institutions in Padang, the information varied largely. In conclusion, it seems that the mayor actually did call for evacuation. The precise wording of the evacuation message, however, could not be clarified. The mayor of Padang announced guidance for evacuation to Padang citizens around 15 minutes after the earthquake via FM radio in response to the tsunami warning.

The survey does not claim to provide representative results for all Padang City but is considered explorative. It aims to approach the question of tsunami preparedness by providing answers to the following key aspects:

Respondents' actions after the earthquake had ended

- What percentage of respondents evacuated?
- How long after the first earthquake did those who evacuated actually start to do so?
- What did those respondents do who did not evacuate?

Information about potential tsunami

- What percentage of respondents received the information about a potential tsunami? What were their source and channel of information? How long after the earthquake did they receive the information and how did they perceive its content?

2 Main Findings

The two crucial issues for tsunami early warning are timely dissemination of comprehensible information about a potential threat (i.e. warning and guidance) and appropriate reaction by communities at risk. The survey recorded both: it documented a sequence of actions after the earthquake for each respondent and recorded source and channel of information on tsunami potential as well as timing of reception and perceived content.

Section A summarizes the respondents' actions performed after the earthquake had ended in two groups of those who performed some kind of evacuation action and those who did not, irrespective of what triggered these actions (i.e. ground shaking or tsunami warning). Section B examines the information respondents received regarding a potential tsunami threat and relates it to the respondents' actions.

A. Respondent actions after the earthquake had ended

How many respondents evacuated? As figure 6 shows the majority of respondents did NOT evacuate at any time after the first earthquake. To an open question about what the interviewees did after the first earthquake had ended only 29 respondents answered that they evacuated while 9 respondents said they went away from the beach and 4 respondents stated to have gone to higher ground. The question recorded sequence of multiple (max. 5) actions for each respondent after the earthquake as well as the respective timing in minutes after the earthquake occurrance In total 22 % of all respondents reacted with some kind of evacuation action to the potential tsunami threat. The majority of 78 % (158 respondents) neither started evacuation nor went away from the beach or to higher ground.

Fig. 5: First generation of elevation zone and evacuation map of Padang as provided by the Padang Working Group.

[1] Key informant interviews conducted with representatives of different government and non-government institutions in Padang. The information obtained from above sources varied largely. In conclusion, it seems that the mayor actually did call for evacuation. The precise wording of the evacuation message, however, could not be clarified.

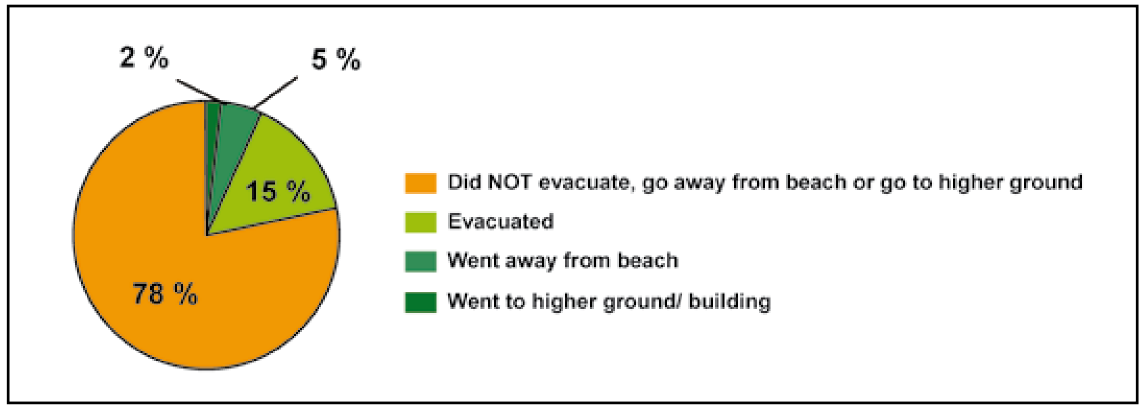

***Fig. 6:** What was the reaction of those receiving the Tsunami warning message?*

How long after the first earthquake did those who evacuated actually start to do so?

The major tsunami threat to Indonesian coastlines is that of a local tsunami. Arrival times of the first wave can be as short as 20 minutes after the earthquake–as experienced in Aceh (2004) . Therefore the time that remains to start evacuation is extremely limited–only a few minutes. A closer look at the group of those who stated to have evacuated (15 %, 29 respondents) provides an idea on the time after the earthquake that it took them to start moving to a safer place (see figure 7).

20 minutes after the first ground shaking at 18:10 WIB, 14 of the 29 respondents who evacuated had left for an evacuation area. After 30 minutes 4 more respondents had begun evacuation, accumulating to 62 % of all 29 respondents.

Some of the respondents who evacuated had initially already gone away from the beach or were on alert/ ready for evacuation; some contacted friends and relatives while others turned on TV and checked their belongings. Overall these cases provide an interesting insight into respondent behaviour after the first earthquake. Figure 8 presents six examples.

These six cases only describe the behaviour of a small fraction of respondents who reacted with evacuation to a potential tsunami threat–with considerably varying reaction time. The majority of respondents were far from reacting with evacuation to the potential arrival of a tsunami wave at the coastline of Padang City.

What did those respondents do who did NOT perform any kind of evacuation action?

***Fig. 7:** Timeline showing the minutes after EQ respondents (n=29) needed to start evacuating.*

Case	Min	Action 1	Min	Action 2	Min	Action 3	Min	Action 4	Min	Action 5
I	5	On alert	15	On alert and ready to evacuate	30	Went away from beach/ coast	45	Evacuated		
II	5	Went away from beach	15	On alert and ready to evacuate	20	Evacuated				
III	10	Contact friends/ relatives	30	Check/ secure belongings	35	Went away from beach	40	Evacuated		
IV	10	Went away from beach	15	Evacuated						
V	10	Went away from beach	20	Evacuated						
VI	20	Turned on TV	35	Check/ secure belongings	45	Went away from beach	60	On alert	80	Evacuated

***Fig. 8:** Selected cases illustrating action time lines (in minutes) after the earthquake had ended*

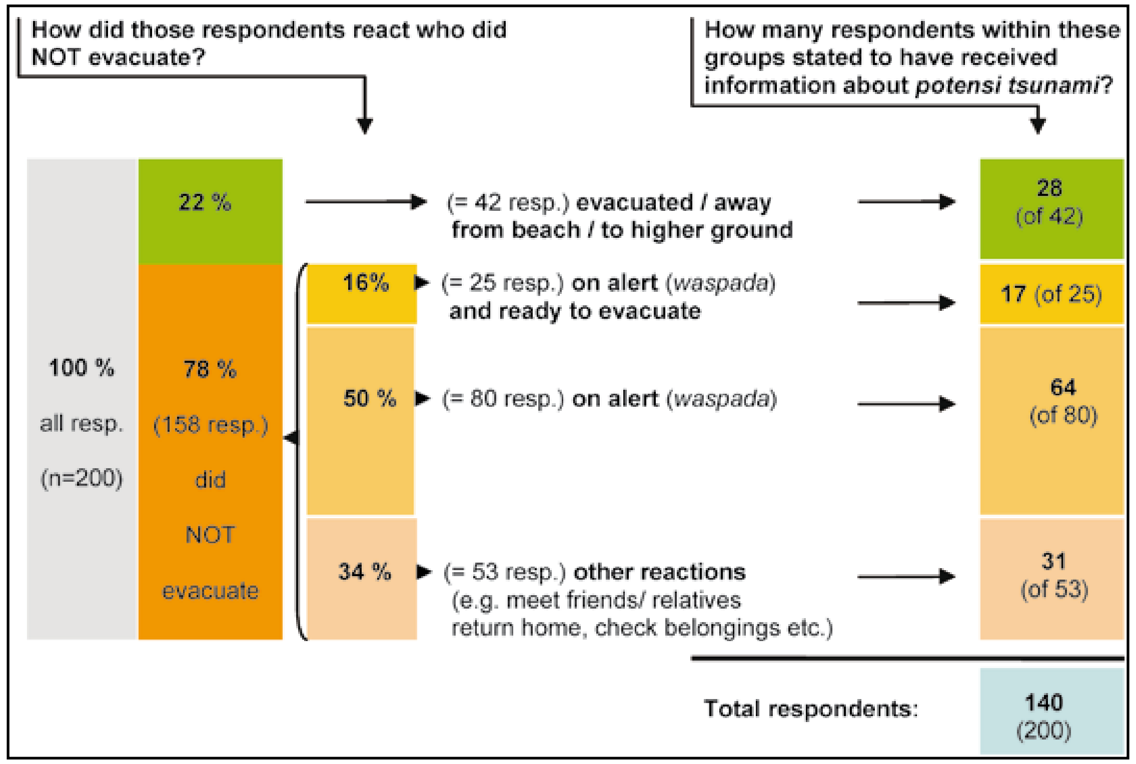

***Fig. 9:** Actions of those respondents who did NOT evacuate, go away from beach/ to higher ground and reception of information on potential tsunami in the respective sub groups.*

The following looks at the group of respondents who did NOT evacuate nor went away from the beach/ to higher ground at any time after the first earthquake (78 %, see figure 9). The major reaction of respondents in this group was to "stay on alert" (waspada). This answer was given by half of those who did not perform any evacuation action. Another 16 % within this group stated to have been "on alert and ready for evacuation" which they, however, never put into action. Finally, the remaining 34 % represent respondents who showed other reactions, e.g. returning home to check belongings; meet friends, relatives and neighbours.

B. Information about Tsunami potential

In total, 70 % of all respondents reported to have received the information potensi tsunami. The right column of figure 9 shows that in each of the respective sub groups more than half of the respondents received the information about a potential tsunami. This is the case for those who evacuated/ went away from beach/ to higher ground, those who stayed on alert/ stayed on alert and were ready for evacuation as well as those respondents who performed other reactions.

Comparing the reception of tsunami information across the different sub groups, there seems to be no significant link between the reception of information and respondent reactions. The majority of respondents (in each sub-group as well as in total) received information about a potential tsunami. However, this information did not trigger a consistent reaction among the people interviewed during this survey.

Reception of the information potensi tsunami – what was its source, channel, timing, and perceived content?

Figure 10 presents the results on information source and channel, displays the time it took to receive the information and shows how the message content was perceived by the respondents. The warning came relatively quick. Radio, informal networks and TV were the main channels for warning reception and over half of respondents stated BMKG and friends and relatives as their source of information. The results regarding the perceived content of the information reveal that 85 % of respondents stated to have received information saying that there is a potential tsunami threat (potensi tsunami). Within this group 21 % of respondents additionally "heard" that they should stay on alert.

3 Conclusions

Only 22 % of the people interviewed in this survey reacted to the earthquake and information about a potential tsunami threat with evacuation/ moving away from the beach or to higher ground. Of those who moved, the majority did not evacuate in a timely manner–considering the limited time for reaction with regards to a local tsunami threat. This indicates that the assumption that people would start evacuation on their own initiative directly after strong ground shaking proves not to be true.

Overall, the information about a potential tsunami quickly reached the respondents in the "red zone" of Padang City and was mainly received via radio, by

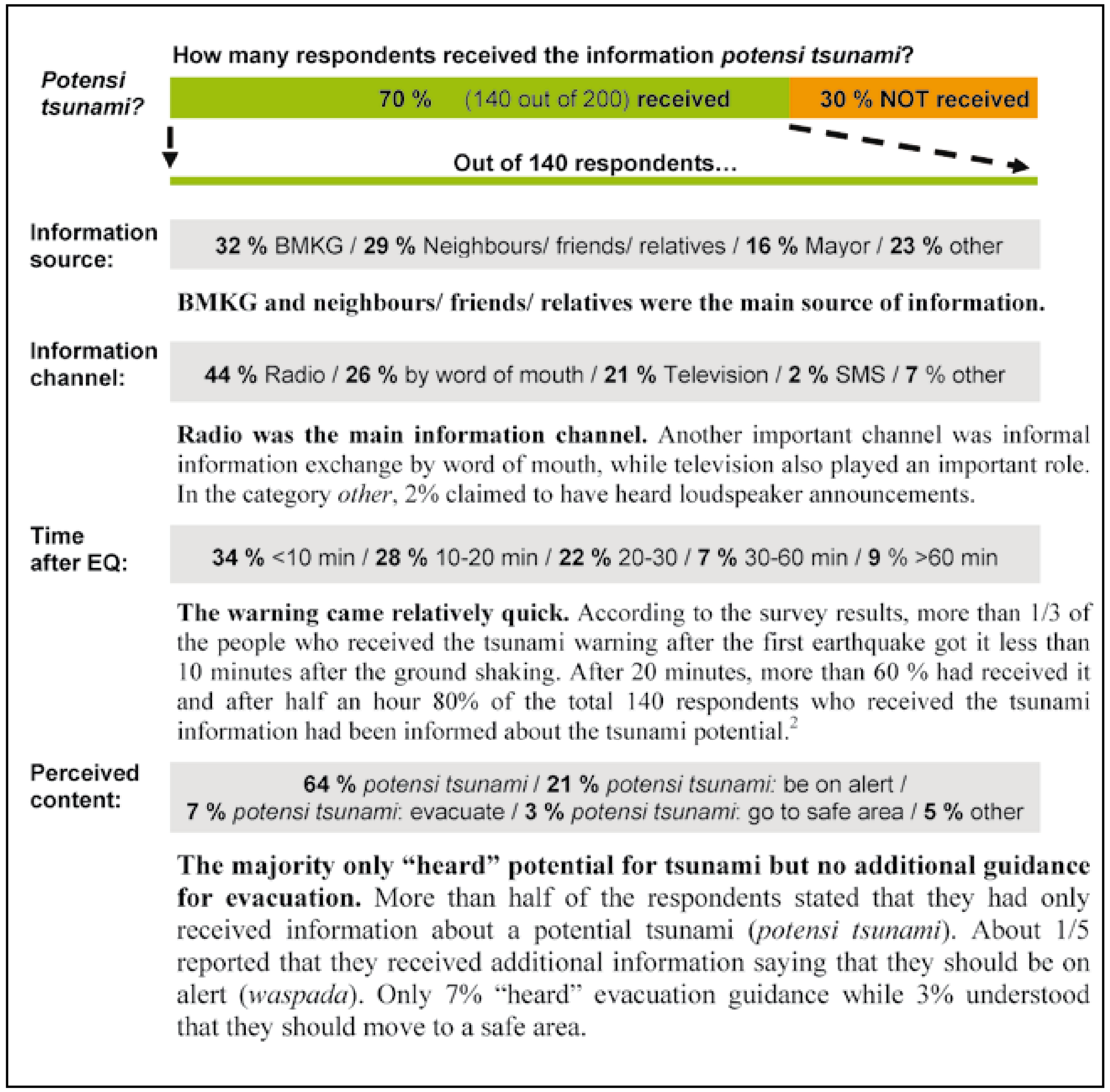

Fig. 10: *Reception of information about potential tsunami – source, channel, timing, perceived content.*

word of mouth within informal networks and television. The content of the information, however, varied significantly.

Although the information about a potential tsunami threat (potensi tsunami) reached 70 % of respondents, most of them only "stayed on alert" as they did not perceive the received message as a call to take further action for evacuation. This confirms that warning without clear guidance does not trigger a consistent reaction.

There are various reasons why respondents did not react in an appropriate way to ground shaking and information about a potential tsunami threat:

1. Many people only received the BMKG warning message via public TV / Radio / SMS or by word of mouth from friends, relatives and neighbours. BMKG warning messages do not provide any guidance nor suggestions or recommendations from official sources on how people should interpret the message and react.

2. The current BMKG warning scheme does not give any information about potentially affected coastal areas and the expected magnitude of the impact. This results in a high level of uncertainty for the people at risk who have to decide whether to evacuate or not.

[2] Any data related to time has to be handled with care since it appears difficult for anyone to recall exact timing more than a month after the event.

3. The BMKG warning was not perceived as information about an imminent threat which requires immediate reaction. The wording potensi tsunami used by BMKG is correct from a factual or scientific point of view (as a tsunami occurrence is still not confirmed) but is apparently perceived by most people as information that still needs to be confirmed before taking further action.

Only a minority of the respondents received information from local authorities. As only few people "heard" evacuation guidance and understood they should move to a safe area, the questions arise whether (1) warning and guidance messages issued by local authorities are comprehensible and clear, and, whether (2) people at risk in Padang are familiar with those messages and know how to react once a warning and guidance message has been issued.

Tsunami Modeling Achievements at Alfred Wegener Institute

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Introduction

The tsunami modeling group of Alfred Wegener Institute (AWI) is part of the GITEWS project (German Indonesian Tsunami Early Warning System) and is responsible for creating a database of precalculated tsunami scenarios of various magnitudes and epicenter locations covering the Sunda Trench. In case of a tsunamigenic earthquake, sensor data (comprising seismometers, GPS instruments, tide gauges, buoys and ocean bottom pressure sensors) will be evaluated. The most probable scenario will be selected and used to forecast arrival times and estimated wave height along the coast. For modeling the wave propagation and inundation we use the unstructured finite element code TsunAWI [3] based on nonlinear shallow water theory.

Tsunami Modelling

Tsunami simulation consists of three basic steps: creating a source, wave propagation and inundation. A source can be computed either by applying Okada's analytical formula or any other suitable initial condition. In our simulations, we employ a method developed by A. Babeyko (GFZ), utilizing a number of micro patches. As input parameters one needs information about the moment magnitude of the earthquake and the epicenter; and for Okada's method additionally the amount of slip, depth of the hypocenter and fault values such as strike, rake and dip angle (see fig. 1).

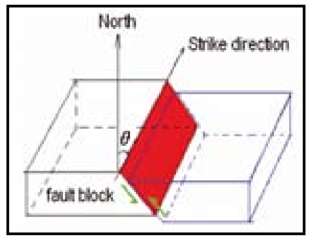

Fig. 1: *Fault plane.*

Wave propagation is calculated by solving the nonlinear shallow water equations:

$$\frac{\partial h}{\partial t}+\nabla\cdot\left(\vec{v}\,(h+H)\right)=0$$

$$\frac{\partial \vec{v}}{\partial t}+(\vec{v}\cdot\nabla)\vec{v}+f\times\vec{v}+g\nabla h+\frac{C_d\,\vec{v}|\vec{v}|}{\rho(h+H)}-\nabla\cdot\left(A_h\nabla\vec{v}\right)=0$$

h denotes the sea surface elevation and *v* the velocity. *H* is the reference depth, *f* is the Coriolis force, *g* is the gravitational acceleration, C_d is the bottom friction parameter and A_h is the viscosity parameter. The finite element discretization of continuity and momentum equation is based on Hanert et al. and uses piecewise conforming linear basis functions for elevation and nonconforming linear basis functions for velocity. Time discretization is performed by the leapfrog scheme.

As a last step, inundation processes will be included. Therefore, a moving boundary technique is utilized which uses linear extrapolation through the coastline into the dry region.

As a result, one obtains arrival times of the tsunami wave, sea surface heights as well as inundation maps.

A crucial issue in tsunami simulation which applies the finite element method is generating a mesh: The finite element method allows a flexible discretization of the computational domain. A coarse resolution of the mesh in the deep ocean and a higher resolution up to 100m in coastal areas can be obtained. The mesh is refined using the CFLcriterion and additional constraints on the bathymetry gradient:

$$\Delta x\le\min\left\{c_t\sqrt{gh},\,c_\nabla\frac{h}{\nabla h}\right\}$$

Different meshes representing the whole Indian Ocean or parts of it are available. The meshes comprise bathymetry and topography data from:

- GEBCO (1 arcmin resolution)
- Sonne Cruise SO186 (400m res.)
- Scott Cruise (20m res.)
- sea maps
- SRTM data (30m res.)
- highly accurate HRSC data (50m res.) in Padang city

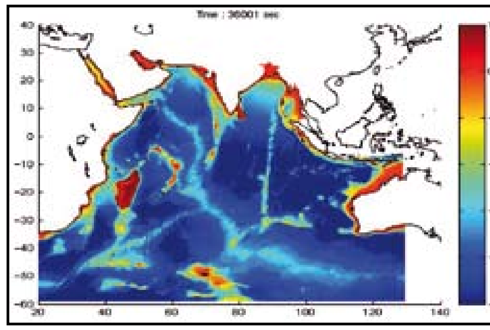

Fig. 2: *Bathymetry of the mesh covering the Indian Ocean.*

Unstructured meshes have several advantages: They allow for an accurate representation of complex domains, especially the approximation of the coastline will be very exact in contrast to structured meshes.

TsunAWI has been validated by benchmark experiments as well as by comparing model results to tide gauge data, satellite altimetry and field measurements of flow depth of the tsunami generated by the SumatraAndaman earthquake on 26 December 2004.

Critical Point

A critical point in tsunami simulation is the data quality. Simulation results depend strongly on topography and bathymetry data. We conducted experiments using different topography data for the city of Padang (Indonesia). Scenario 1 uses SRTM topography data, Scenario 2 uses SRTM as well as highly accurate HRSC data for Padang city. Figures 3 and 4 depict the topography of both scenarios.

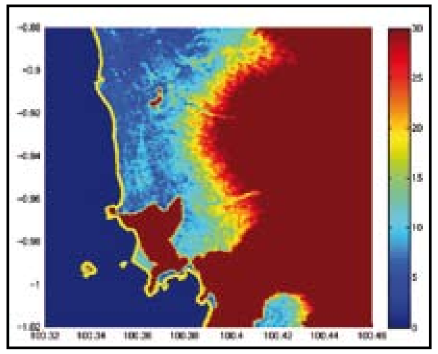

Fig. 3: *Topography of Padang region using SRTM data.*

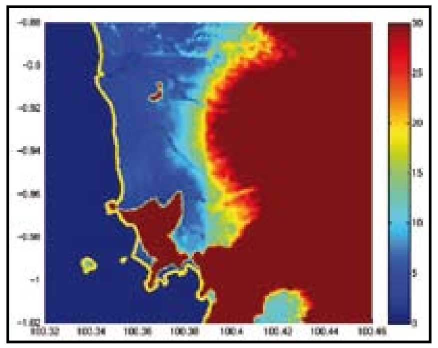

Fig. 4: *Topography of Padang region using SRTM data and HRSC data.*

Figures 5 and 6 show the inundation of Padang city. Using only SRTM data, there is almost no inundation (fig. 5). Using SRTM and HRSC data, the inundated area is much larger (fig. 6).

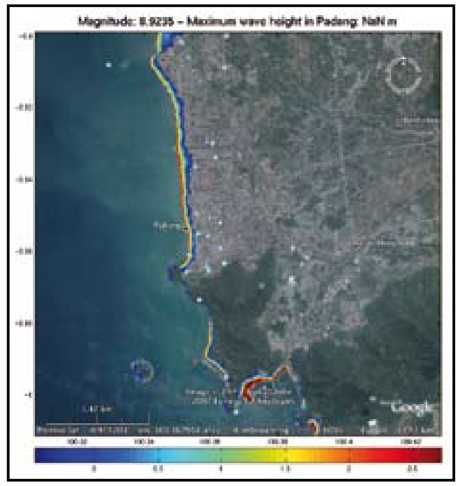

Fig. 5: *Inundation of Padang city using SRTM topography data (Scenario 1).*

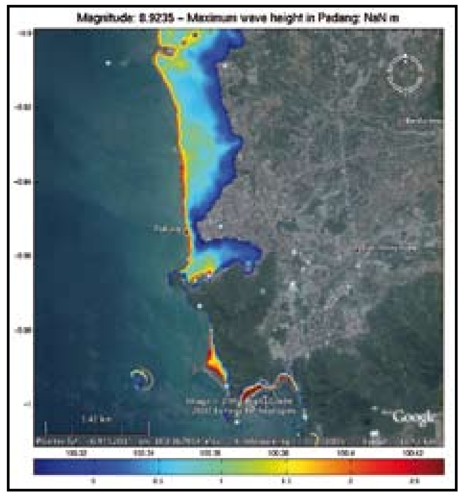

Fig. 6: *Inundation of Padang city using SRTM and HRSC topography data (Scenario 2).*

Example for uncertainty in Tsunami Early Warning

Scenarios having the same epicenter but different rupture zones can lead to extremely different results in inundation: Figure 7 shows the inundation of Padang region generated by two sources which have the same epicenter and magnitude but different rupture zones.

The tsunami modeling group of AWI developed a new approach [1] using multiple indicators such as epicenter location, magnitude of the earthquake, depth, GPS dislocation vectors, gauge arrival times and wave height at gauges simultaneously.

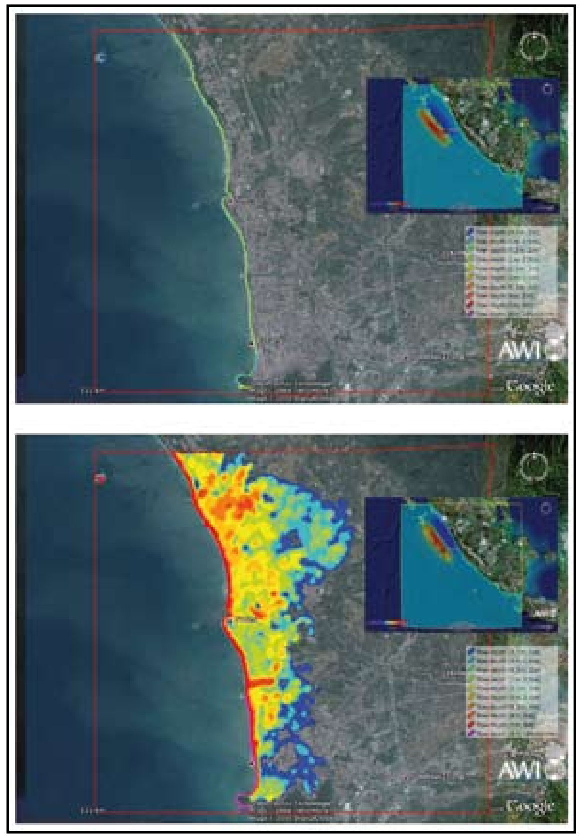

Fig. 7: Initial conditions and inundation of two scenarios having the same epicenter but different rupture zones.

Multisensor Approach
Tsunami scenarios computed by TsunAWI are stored in the Tsunami Scenario Repository. In order to give a reliable prediction in case of a tsunami in very short time, the most probable scenario will be selected and serves as a forecast. Traditional approaches rely on seismic data such as epicenter, depth and magnitude. If a certain threshold is reached, a warning will be issued. This method works well in the far field, but leads to wrong predictions and false warnings in case of near field tsunami forecasts, especially in Indonesia where there are extremely short forecast times.

Conclusion
The tsunami simulation software TsunAWI gives accurate estimates of arrival times as well as inundation results. The multisensor approach allows a fast and reliable nearfield tsunami early warning.

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National Earthquake Monitoring for Tsunami Early Warning

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After the great Sumatra Earthquake on December 26, 2004, all suffered countries from Tsunami have paid more attention to upgrade their own national seismic monitoring system in order to serve more efficiency for tsunami early warning. Consequently Thai Meteorological Department set up new seismic monitoring network which can be divided into 2 phases during 2004-2009. The first phase is now ready in operation with 15 stations for weak motion and strong motion monitoring. In addition 6 individual accelerograph stations were installed in the western and central part to monitor strong ground motion nearby active fault and to study site amplification. Broadband sensors Trillium 40 and Trillium 120 were installed in first phase, when earthquake occurred, data will continuously send using internet communication via IP star (satellite link) to Thai Meteorological Department:TMD in Bangkok. At present it takes few minutes to analyze automatically to determine location, magnitude, occurring time of earthquakes outside country especially epicenter at Andaman sea, Sumatra and neighboring countries by using 2 popular software called Earlybird and Seiscomp3. This system is able to exchange data internationally via naq server, liss server and seedlink server. More than 30 stations from different countries in the Indian Ocean and from global networks (Malaysia, Indonesia, Philippines, Australia, Taiwan, Japan, Africa, IRIS, USGS, Geofon) are retrieved continuously in near real time through internet. The automatic result of position and several analyzed magnitudes (Ml, Mwp, Mb, Ms, Mw) are quite reliable and convenient to help decision of tsunami warning and canceling message.

Second phase of earthquake monitoring upgrading is in the process of installing which will be completed in 2009. The system will integrate all stations in first phase, then totally the whole national seismic network of Thailand will consist of 40 seismic stations, 26 accelerograph stations, 4 GPS stations and 9 tide gauge stations (4 in Andaman sea, 5 in Gulf of Thailand). Similar to the first phase, most of stations will send data via IP Star, satellite internet link and 5 fixed IP of VSAT link. After major earthquake or local earthquake occurred, several messages and announcement will instantly disseminate to agencies concerned, mass media (TV, radio stations), people at risk area via SMS, fax, siren towers and Seismological Bureau web site.

New national seismic monitoring network of Thailand will raise capability of earthquake mitigation and tsunami warning in the region.

Moreover, during 2008-2009, earthquake and tsunami database together with information of buildings in risk area will be compiled in GIS and will apply to assess the damage causing by scenario earthquake. HAZUS software from FEMA will be utilized as a first step to support short term and long term plan for better management of natural disaster in Thailand.

The Uniqueness of Adjacent Beaches for Tsunami Mitigation Efforts - A Case Study from Phuket, Thailand

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Abstract
It is clear that DEWS will provide advanced information of impending tsunami arrival at beaches and coastal areas around the Indian Ocean. It is proposed in this paper that simulation of the possible effects of such tsunami from a variety of locations, directions, and magnitudes be carried out. This can be used in conjunction with the tsunami warning from the DEWS system, to predict the likely specific consequences for beaches, initially in Phuket, but later for other locations in Thailand and for other countries likely to be affected.

Introduction
In the aftermath of the 26 December 2004 Indian Ocean Tsunami, it was observed, that the waves had different impact at three different beaches in Phuket, Thailand, the "Pearl of the Andaman" [1]

The best known and most popular is Patong Beach, where many tourists and local people died or were injured. It is a wide curved beach, with a shallow sea, suitable for safe swimming, because it is only gently shelving. The smaller Kamala beach, north of Patong, is similar in this respect. Both suffered severely from the tsunami. However, Surin Beach shelves steeply in a series of steps, from a shelving beach, reached from a small car park and restaurant, itself about a meter above the sand. Relatively little damage was done here [1].

These details show that each beach is unique and must be considered separately, even at relatively short geographical distances, like in Phuket. This uniqueness has direct implications for run-up modelling and simulation, for tsunami mitigation efforts and consequently for insurance purposes; especially for Phuket, and for Phang Nga and Kao Lak further north, where many hotels and resorts are located close to the beaches and the land behind is quite flat.

Similar situations can be found in countries around the Indian Ocean, particularly in Indonesia, Sri Lanka, and Southern India.

Phuket Island
Phuket is an island of about 50 km by 20 km in the Andaman Sea west of Krabi in Thailand. Figure 1 shows the aerial view of the island, with the principle beaches discussed in this paper identified and highlighted. In addition, the approximate arrival direction of the tsunami wave is also shown so that the different effects on the beaches discussed later may be appreciated.

Current Work
Current work, reported here, concerns evaluation of some specific beaches in Phuket in respect of the size, shape, orientation and shelving, gradients and features of surface and local seabed. Of particular interest are the horns of these beaches and of the very different consequences for each of the selected beaches in respect of the December 2004 tsunami.

The principle beaches concerned are Surin Beach, Kamala Beach, and Patong Beach. It is clear that, although adjacent, being separated by low steep hills, these were all affected in very different ways, especially in respect of the seriousness of the consequences for people and property. Nai Yang Beach, close to the airport was also considered, along with Rawai Beach on the Eastern side of the island, which received the reflected wave from Krabi.

It is intended that the lessons learned from this work be applied to other locations in Thailand, Indonesia, Sri Lanka and India, and in due course elsewhere in the world.

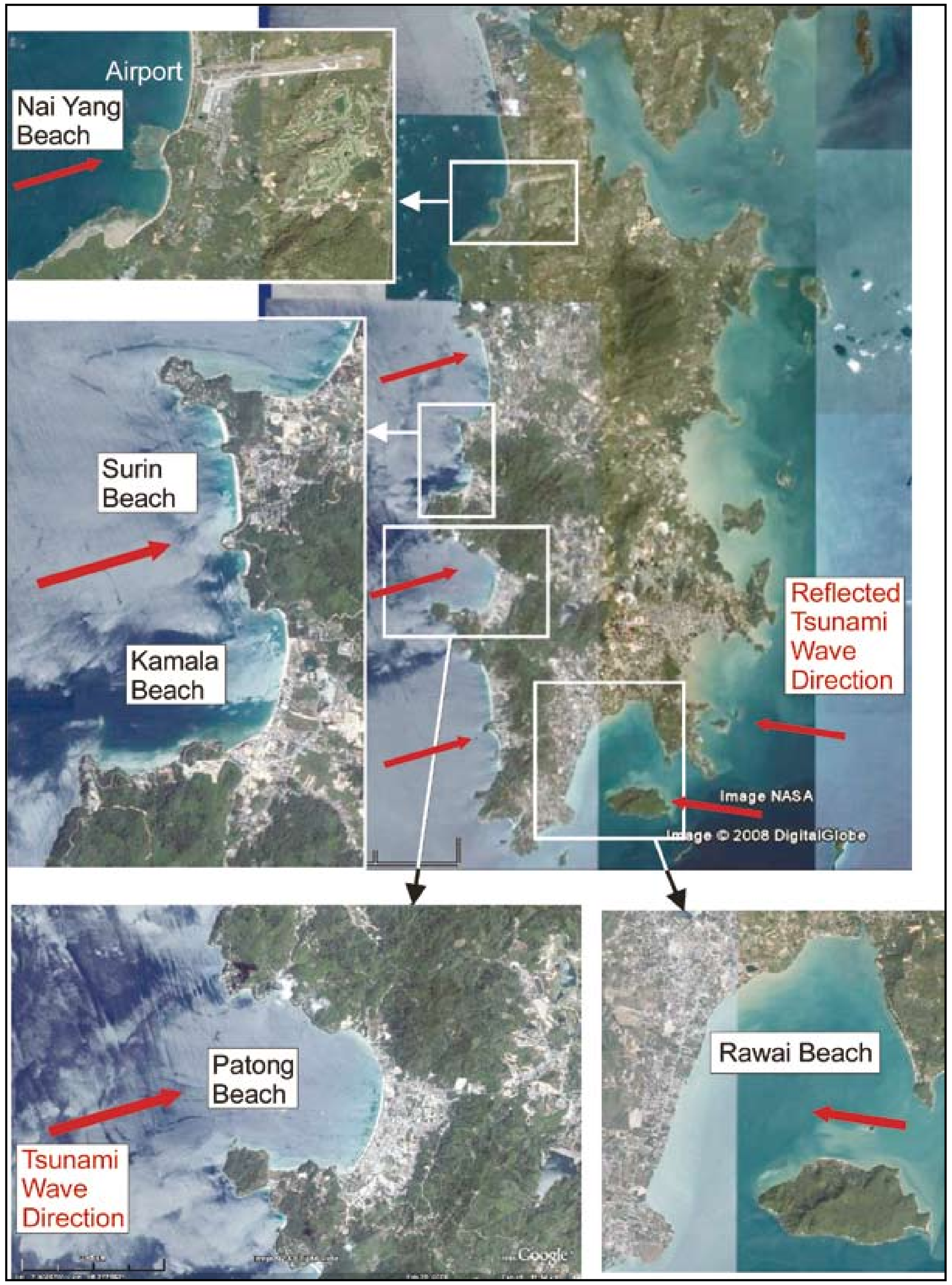

__Fig. 1:__ Phuket Map with Location and Orientation of Key Beaches. The direction of the incoming 2004 Indian Ocean Tsunami waves is indicated. Base Map and Cut-outs Courtesy of GoogleEarth 2009.

Surin Beach

This beach has interesting features in that it has significant shelving in steps of alternating shallow and steeper angles of fall, from the restaurant/car park area above the shore to the surf area, as shown in Figures 2 and 3. This has several consequences. First, the beach is relatively safe for swimming during the peak tourist season (December to March). Outside this period, it is unsafe to swim because of the undertow, especially during the tidal period where the waters edge coincides with the steeper slope. When this occurs, the swimmer will arrive onshore and try to land on a fluidized bed of seawater and sand particles. R. Zobel has experiences with this in person and is aware of the difficulties of a successful landing.

***Fig. 2:** Surin Beach from Nok Restaurant.*

***Fig. 3:** Surin Beach, showing shelving sand and the Southern arm.*

However, the positive side of this is that from the sea surface to the car park/restaurant level is several metres, resulting in relatively little damage to property, personnel, and facilities. In particular, it was observed that some open structure beach bamboo huts, used for lunch and evening meals were still undamaged and still in place four weeks after the tsunami. It is interesting to observe that the Southern arm of the beach protected the shore due to the angle of attack of the tsunami as shown in Figure 3. The rocky shore here would have had overtopping, but significant reduction in force and flow gave significant protection as seen in Figure 3.

Figure 4 illustrates the combined aerial view of Surin and Kamala beaches.

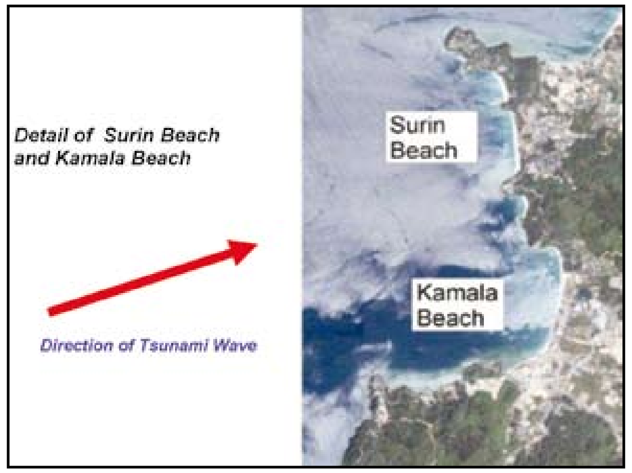

***Fig. 4:** Aerial View of Surin and Kamala Beaches.*

Kamala Beach

Kamala Beach was probably the most severely damaged beach and village on Phuket. This is due to its orientation at right angles to the arriving tsunami wave (see Figure 4). This was further exacerbated by the very flat seabed, the flat local beach, and the littoral behind the beach area, through the village, to the main road and to the area on the inland of the main road, as shown in Figures 5 and 6.

***Fig. 5:** Kamala Beach from the Beachside Accommodation.*

The tsunami flattened the local school, leaving only the concrete base. The school has now been rebuilt as a strong multi-storey building, which can provide a safe refuge and haven for the school pupils and other people fleeing from a tsunami after a DEWS warning (Figure 7).

***Fig. 6:** Northern End of Kamala Beach.*

***Fig. 7:** Rebuilt School at Kamala.*

This is vital, since the area is so flat and the new school is probably the only reachable safe haven in the area. It is also noticeable that only a few other buildings in the village are two or more storey, the remainder have been restored as single storey buildings, providing little or no protection as in 2004.

The canal entering the beach from the village also alters the flow of water to the sea (Figure 8). It is not yet clear whether this had any significant effect during the tsunami. However, there is significant grey

***Fig. 8:** Canal Entering Kamala Beach.*

sediment underneath the yellow sand to the South of the beach. This is only possible because of the flatness of the entire beach and village area. It is desirable to consider what additional measures, particularly in respect of planning and building regulations might be considered for the future [2, 3, 4]. The parts of the village at both sides of the main road joining the beaches to the South and North of Kamala Beach are also flat and were flooded by the tsunami. However, roads to the South and North of Kamala provide steep hills which can give easy escape access, if given sufficient warning from DEWS.

Patong Beach

This is the main and most popular tourist beach on the island of Phuket. It has a fine sandy shore, slightly curved, with a length of about 1.5 km, as illustrated in Figure 9 and 10. The beach area has only a modest slope, which leaves it open to tsunami attack. However, fortunately, the area behind the beach road has small roads (soi) at right angles to the beach, with significant upward slope at leading to the main town areas. Thus, tsunami warnings signs indicating escape routes can be quite effective. Both ends of the beach have steep roads leading uphill to adjacent beaches [5].

***Fig. 9:** Southern Aspect of Patong Beach.*

There was a further danger, however. The tsunami arrived from a West-Southwest direction protected by the Southern horn of the beach. This gave rise to a reflection from the shore towards the Southern end of the beach and then back out to sea (Figure 11). There is also a rocky seabed feature, clearly visible in the video taken from the Southern heights of Patong Beach at the time of the tsunami. It is our view that these are what gave rise to the very dangerous large vortex clearly shown in the video from about 10 minutes after the arrival of the tsunami.

Thus, the three adjacent beaches Surin, Kamala, and Patong exhibited very different hazards and characteristics. These are due to the different size, shape, and orientation of the beaches to the tsunami arrival direction, in addition to their shelving characteristics and their shape, especially of the beach horns. Ra

Fig. 10: *Northern View of Patong Beach.*

Fig. 11: *Arial View of Patong Beach*

Rawai Beach

Rawai Beach is on the South Eastern part of Phuket. It faces the mainland shore of Krabi (Figure 12). It is very popular with both tourists and local Thai residents due to many excellent fish and seafood restaurants along the shore. As such, it received the reflected wave from the shore of Krabi, which was consequently of lower amplitude than that received on the Western side of the island. Nevertheless, it is desirable to consider the consequences.

Fig. 12: *Aerial View of Rawai Beach.*

Fig. 13: *Rawai Beach with Protective Offshore Island.*

Fig. 14: *Rawai Beach from Beach Restaurant.*

Figure 13 shows a typical beach scene, exhibiting a large offshore island, which also gave protection to this beach area. Long- tailed boats provide both fishing and a variety of services for tourists. It also shows that the beach has significant shelving. Figure 14 also indicates that the restaurant and shopping facilities stand at least 1 metre above the sand at the top of the beach.

Further to the North, there are several major Thai restaurants near to the Zoo of some considerable quality and reputation. These suffered substantial damage, particularly to the tables and chairs. These have now been replaced and normal service restored. However, at the time it was evident that much beach sand was brought into the restaurant and out onto the road, at the same time reducing the width of the beach.

Nai Yang Beach

This beach is on the West of the island and South of the Airport (Figure 15). It is relatively undeveloped and popular only to those who are willing to travel to visit it from the south of Phuket. It is a beach of two halves. The Southern half is a lovely tourist beach with a good number of excellent small Thai fish and seafood restaurants.

Fig. 15: *Aerial View of Nai Yang Beach*

Fig. 16: *Nai Yang Beach Southern End Showing Extensive Horn.*

The Southern end of the beach exhibits a significant horn, from which mussels and cockles are collected by local people at low tide (Figure 16). This horn protected the beach from the tsunami arriving from the Southwest but overtopping will have occurred.

Figure 17 shows the Northern end beach, exhibiting significant shelving and a step of around 1m to the area inland. These aspects fortunately protected the airport behind, and allowed author Zobel to land safely three days after the tsunami attack.

Fig. 17: *Nai Yang Beach Northern End by the Airport*

Local Observations

Observations from local Thai people have provided useful information. Recently, sand samples have been taken from these beaches to ascertain their characteristics of density, roughness, and particle size and distribution for modelling purposes [6, 7, 8]. Observations of slope and shelving of beaches and of the horns of ends of the beaches have been made to ascertain their current and future susceptibility to approaching tsunami [9, 10, 11, 12, 13].

Modelling and Simulation

Bousinesq and RANS approaches and their relevance to the proposed studies are being considered, using a large number of parallel PCs for simulation studies. Such facilities may be made available in undergraduate teaching laboratories in Hat Yai and Phuket overnight, after improvement in local connectivity. The public availability of cfd software for these purposes is an encouraging development, as are further developments of variable mesh size representations for run-up simulations.

Of particular interest are cfd model considerations for various aspects of pickup, carriage, and deposit of sand at high Reynolds numbers, and the effects of such sand transport on consequences for beach damage and inundation [13].

Equations for Sand Transportation

The basis of equations and approximations will be initially obtained from existing papers and sources [9, 10, 14]. In respect of this, use of existing estuarine approaches of silt carriage and deposit are being evaluated. Further, existing reported work on modelling and simulation of sand storms in deserts and on industrial fluidized bed systems also needs to be considered [8].

Verification and Validation

We propose the use of existing simulation results at high Reynolds numbers for initial validation, and are also considering the use of local flume and wave basin facilities for experimental model validation, although it is recognised that scaling may not be appropriate at such high Reynolds numbers.

However, recent work by Moore [17] suggests that hydrological inferences may be drawn from studying sediments from the 2004 tsunami along the Sumatra Coast of Indonesia. This could lead to study of similar deposits from the relatively undisturbed beaches in the North of Phuket, in Phang Nga and Kao Lak on the mainland to the North of Phuket and also perhaps in Similan islands offshore to the West of Phang Nga, and the Sea Gypsy Peoples' Island where tribal memory of previous tsunami exists, and other historical data may also be useful.

Further, Takahashi [18] suggests using a hydraulic approach to modelling of sediment transport due to tsunamis to obtain better modelling and simulation of tsunami run-up in shallow waters. This would help to predict consequences for specific beaches with consequent better planning to minimise death, injury, property damage and financial loss for future events.

Conclusions

Consideration of the use of these models and simulations in respect to DEWS warnings and immediate predictions of likely effects on specific beaches on the West Coast of Thailand are the principle aims of this work. It is clear that the beaches considered each have geographical features with significant consequences for the survival, and damage to property due to tsunami. It is also clear that the direction of arrival of the tsunami as well as its amplitude is vitally important to the resulting consequences for local inhabitants, visitors, and property [15, 16].

By modelling and simulating the probable consequences for each beach, of tsunami of varying amplitude arriving from different directions, it would be possible to more accurately provide advice for specific beaches after receipt of tsunami warnings from the DEWS system. This would make the real-time DEWS system more effective at a local level. Further, such studies might also suggest methods for improving effective defences at a local level [3].

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The Chorist Warning System (CHOR-WARN) Communication to Citizen, in case of an emergency

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The Project and its Aims:

Disasters, either from natural or industrial origins, have long harassed us. Though prevention is the key to limiting the effects of these events on population and property, the efficiency of the reaction to disasters can often be improved if the affected population can be warned before a disaster occurs: This is the 'early warning', which is the central concept to which the technologies proposed by CHORIST apply.

CHORIST is a research project active between 2006 and 2009, involving 16 partners from 8 European countries. It studied various technical solutions in the domain of early warning. The technical proposals are aimed at both saving lives and easing the work of the authorities in case of major natural or industrial disasters.

The Chorist system consist of 3 integrated modules: Situational Awareness, Warning the Population and Rapidly Deployable PMR Systems - Tools developed in CHORIST aim at providing more information to authorities and to the population.

These three modules were developed, integrated and tested in the frame of the project:

Module 1: Situation Awareness

Situation Awareness - provides an overall real-time picture of events with an assessment of the consequences on the population and on property. This information helps authorities to make decisions.

Module 1 collects information from existing national or international agencies which monitor and forecast natural hazards (e.g. extreme weather, volcanoes, earthquakes), and from chemical and nuclear industrial areas. Information from dedicated sensor networks (like those monitoring river levels) can also be added, as well as alerts received from the population by emergency service call centres. This information is processed, and by means of simulators and database information, the current and forecasted impact on population and property is assessed.

The results are provided to the authorities by means of a Common Operational Picture (COP) enhanced with an alert level.

The added-value consists of providing clear, concise and consolidated information from a variety of sources to authorities dealing with these incidents and their consequences.

Module 2: Warning the Population

Warning the population - allows authorities to warn the population quickly and through several media routes simultaneously.

A single tool, through a simple interface allows authorities to create and define warning message content, broadcast areas and time durations. A simple click on a button and the warning message can be received by potentially millions of citizens within minutes.

The warning messages give information on the incident and on the action which people should take (for example, to go inside, close windows etc.). The initial messages can also redirect people to other sources (TV, radio, web sites) from which to obtain further information and advice.

Within the scope of the project, tests with sirens, digital radio, digital TV and GSM (cell broadcast technology) were conducted, but many other channels could be used such as satellites, over-road gantry signs and web sites could be utilised.

CHORIST RESEARCH PROJECT- abstract

SIXTH FRAMEWORK PROGRAMME

Information Society and Media

Project manager Patrice Simon - EADS   www.chorist.eu   Author Wim van Setten - SPMM

The added-value for authorities is to provide the mechanisms for timely, appropriate and efficient warning of the population. Decisions on message content whether or not transmit and to whom, will still require the application of professional judgement however. Overall, though, the population can be better warned and informed and lives can be expected to be saved as a result.

Module 3: Rapidly Deployable PMR Systems
Rapidly deployable PMR systems - allows both field rescue and support teams in control rooms to get more information on the situation.

Two complementary technologies are proposed for field rescue teams to exchange information with their control rooms. Both allow the rapid transfer of all the information needed for the emergency services to work more efficiently and effectively.

The TETRA TEDS standard enhances the huge existing TETRA infrastructure and terminals used by millions of public safety end users, similar to what was the 2.5G revolution in the public mobile phone networks.

Rapidly deployable broadband MESH systems incorporate the latest developments in ad-hoc networks. Terminals automatically connect together in a peer-to-peer structure, thus allowing the radio network to expand its coverage area as it grows in terminal numbers.

Cooperation with End Users
The most valuable activity with end-users consisted of setting-up a User Advisory Board (UAB): a committed group of Civil Protection (CP) professionals from various countries and fields of activities helped the CHORIST consortium to design their tools by providing them with feedback and advice. Considerable research has been carried out to understand long-term user requirements and demand for information. Feedback on the concepts of the project has been positive. Field tests conducted in Catalonia (Spain) indicated that, though the prototypes provided limited functionality, the concepts themselves were acceptable to professional users as adding value to their work.

Context: Disasters and Early Warning
Despite her nickname of ‘Mother’ Nature, it has long been understood that sometimes, in some places, she can show a less maternal face: earthquakes, volcanoes, tsunamis, drought, tornados, winter storms, forest fires, floods… are events which many of us may have to face. The Industrial era has added other threats such as chemical or nuclear leakage or dam failures. Such incidents occur daily around the globe and all too often the consequences can be severe in terms of loss of life and damage to or destruction of property.

Early Warning Systems to warn the population in the event of one of these natural and industrial disasters have evolved over the years: The basic functionalities of such systems consist of (1) detecting the event and (2) quickly warning the people. Some dedicated systems have been developed and deployed for volcanoes, earthquake and tsunamis; the detection element is not perfect, and further studies still have to be performed, but they have proven to be effective in many situations. Industrial risks, resulting from human activities are more easily detected, and where systems exist, the early warning of the population has proved to be efficient. However, there are still many examples where an incident can be detected, but there are no means to warn the people at risk.

Early Warning, is to contact the population as soon as possible in case of a major incident which may impact them: to be efficient however, this works best if people are well prepared and trained to react to the warning messages they receive. Awareness of potential threats and of the actions to be carried out in case one of them occurs are key requirements to make Early Warning systems effective. Moreover, the infrastructures have to be built to reduce the impacts of the incident (such as shelters for hurricanes, evacuation routes for volcanoes…). Thus, the foundation for Early Warning is effective preparation.

However, early warning systems monitor one threat and they alert the population in a small area. There are dedicated systems for tsunamis with earthquake sensors, and usually sirens installed along the sea shore. Around chemical plants, warning systems are installed which are able to warn people a few kilometres around the plant.

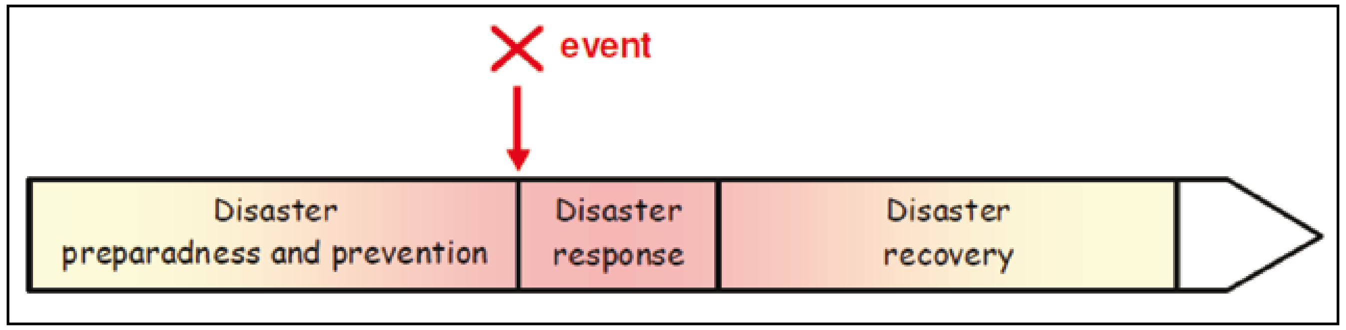

***Fig. 1:** The three-phase disaster time model*

Given these intrinsic problems, the enhancement of the quality of the information provided by the sensors and the efficiency of the sirens network will still not solve all the problems:

A disaster may be bigger than planned for in the contingency procedures, and the threat may expand far beyond the area where dedicated warning systems are installed. For instance, the Chernobyl explosion released radioactive material over most of Europe. Thus, **multi-country** aspects have to be solved.

Multiple hazards may occur at the same time in the same area, and their combination may not be detected, or even if they are, their combined impact may not be evaluated correctly: for instance, in the case of a high-speed wind blowing over a chemical plant where toxic gas is diffused into the atmosphere. Thus, **multi-hazards** aspects have to be addressed.

An opportunity to expand the area where warning messages are received is by the use of mass-media telecommunication or information systems (TV, mobile phone…). Another enhancement plans to use several of these means in parallel to reach more people, wherever they are and whatever they are doing. Thus, **multi-channel** aspects are seen as a key enhancement.

Being warned in time usually means being able to reduce the impacts of the incident on population and property, but these impacts will not be eradicated completely: the quick reaction of the authorities to evacuate, to provide first-aid, to secure areas and to organise long-term operations are key points in damage limitation. This starts by authorities being informed about the initial effects of the incident, and more generally on the situation. **Rapidly deployable networks** for first responders are one of the technical solutions to reduce the impacts of disasters on population and property.

Overview of the Chorist solutions
The logic which underlies the technical solutions set up to address the problem of providing information to authorities and to the population is the watch-decide-act chain: observe and assess what is happening – decide what to do - act.

The system architecture consists of the 3 modules already introduced:

Module 1 observes the environment and provides a picture of the situation to the authorities, along with an assessment on the risks.

Module 2 allows authorities to warn the population through several media in parallel.

Module 3 is a rapidly deployable telecommunication system for field rescue teams which helps them to receive and provide information to and from the authorities.

Existing monitoring agencies (weather, earthquakes, volcanoes…), sensor networks (e.g. along rivers) and emergency call centres provide real-time information as well as forecast about the situation on the environment.

***Fig. 2:** Call Centre*

The Chorist system consists of three integrated modules:
Module 1 (Situation Awareness) analyses this incoming information, performs some filtering on it, and then provides a compact picture of the situation to the authorities. This picture comes with forecasts, either provided along with the input data, or calculated by Module 1 itself: this information is augmented with an assessment in terms of risks on the population, so that the decision making is easier.

Module 2 (Warning the population) allows authorities to warn the population (resident or not) through Digital Audio Broadcasting (DAB), Digital Video Broadcasting (DVB), GSM (cell broadcast technology) and sirens. Messages can be tuned based on templates; and the locations for message transmission and receipt is adjustable. Citizens are warned immediately and then directed to other sources of information.

Module 3 (rapidly deployable PMR systems) provides field units with video and data services. These tools will allow both field units and control room dispatchers to be better informed. Two technologies are proposed:

- an ad-hoc mesh network based on LTE/WiMAX technologies
- TETRA TEDS base station and terminal

MODULE 1: Situation Awareness
The JAVA-based situation awareness tool first classifies the input information following semantic and threshold-based rules and provides results in a tabular presentation. In the event that an incident is detected and making use of this stored raw data, a neighbour-

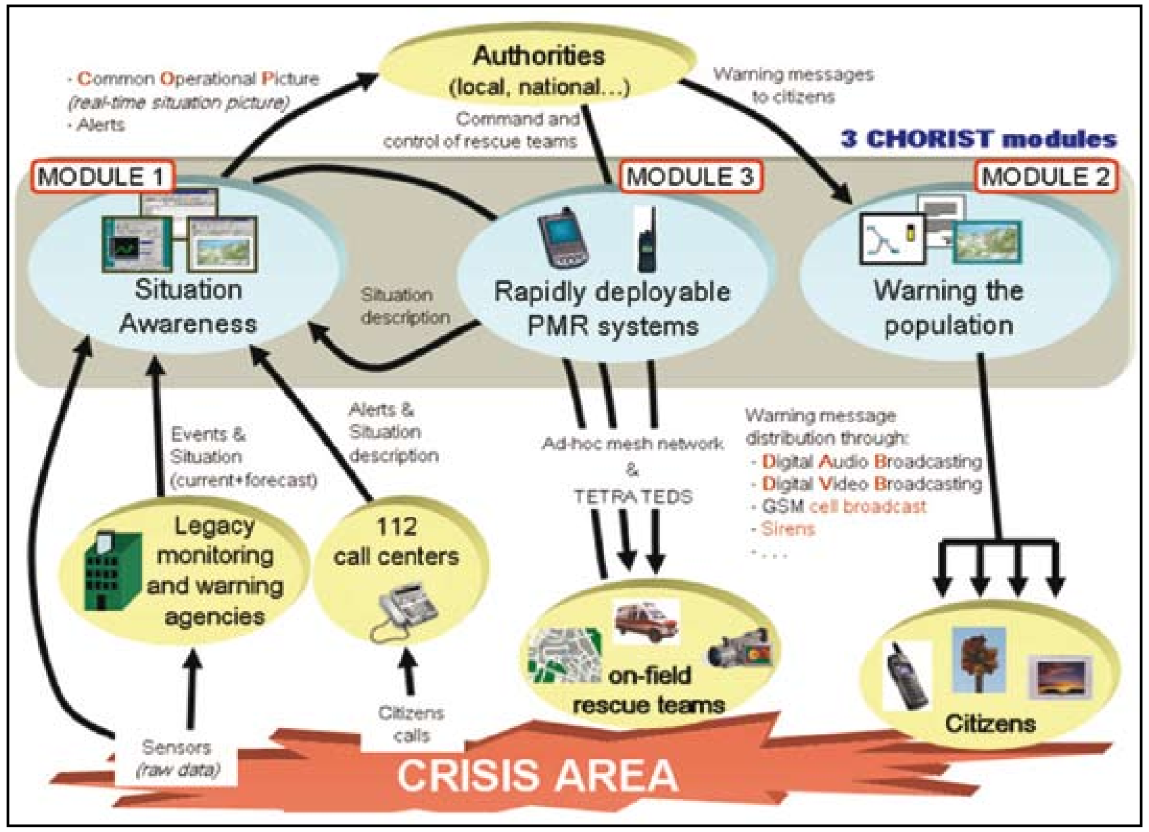

Fig. 3: *The Chorist system*

hood analysis is carried out and displayed on a GIS map to show the extent of the incident; forecasts are also presented. Detected incidents are then sent in CAP messages to decision makers for further analysis and appropriate action.

In parallel, a powerful scripts-based tool was created to train authorities to use Module 1: This tool simulates the data provided by river-level sensor networks, by weather monitoring and forecasting agencies, and by emergency call centres.

Innovation Module 1:
The CHORIST Situation Awareness provides the following advantages compared to other existing decision support systems:

- Useable at different levels (Local / Regional / National), depending on the scale of the incident and according to different roles (e.g. Civil Protection Organisations, police, fire brigades…);
- A generic and versatile platform which can integrate external prediction models (on floods, weather, volcanoes etc.) defined by specialised agencies / experts;
- Correlation of diverse information coming from emergency call centres and from different existing environment-monitoring agencies, with no intent to replace them in their own domain of expertise;
- Improved environmental risk awareness, through the deployment of innovative technology;
- Greater inter-operability among Authorities and improved integration of existing legacy systems for an effective exchange of alert information;
- Better contingency planning, resulting in more rapid and effective incident response management;
- Increased international data standardisation, derived from the ability to identify environmentally vulnerable locations, associated people, and events, and record them uniformly;
- Improved response capability, derived from a system that allows the use of information and the implementation of preventative and contingency plans across boundaries.

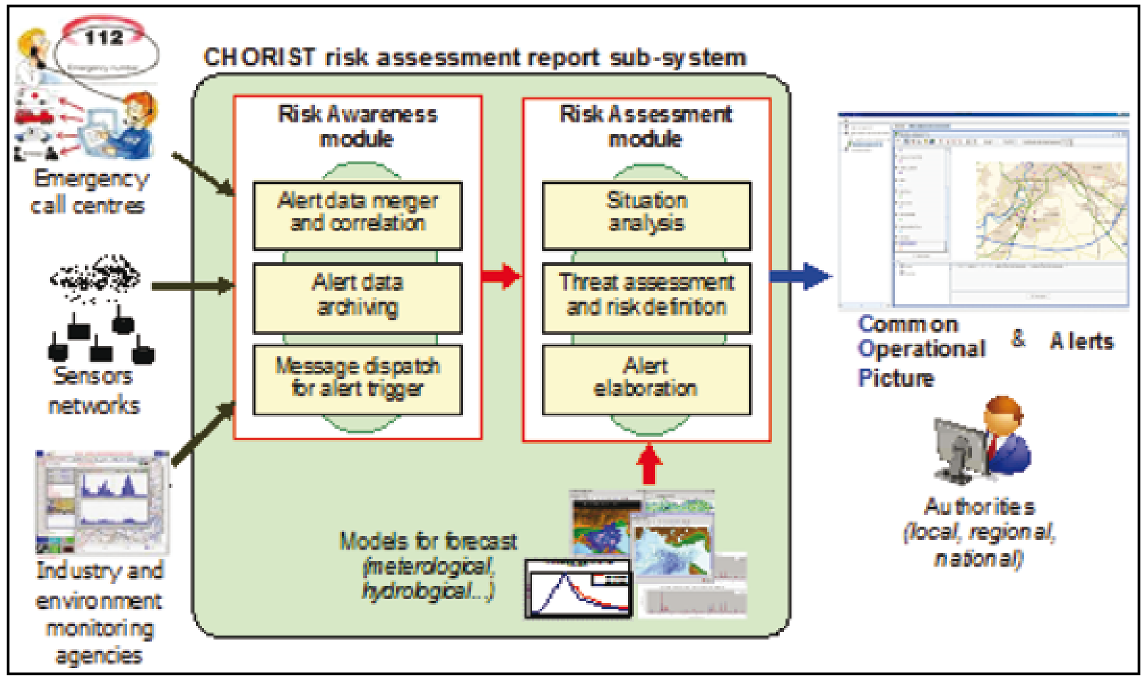

Fig 4: *Module1 - Situation Awareness*

MODULE 2: Warning the population
Message Creator and Dispatcher (MCD)
The Message Channel Dispatcher is a common tool useable by 3 different levels of authorities in chain:

- the first one qualifies the information received about the situation;
- the second one decides what message to send, in which area and through which channels;
- the third one actually creates the messages depending on the specificities of each channel, and triggers their transmission to the population.

The MCD consists of a web server which can be accessed simultaneously by people in different locations through the Internet or an Intranet via a light Firefox web client.

The content of the message has the following structure:

- Alarm level (‚alarm', ‚warning', or ‚information')
- Location (polygon on a map)
- Information (e.g. ‚Fire in …')
- Action (e.g. ‚Go…', ‚Gather at…')
- More info (e.g.'Turn to Radio News for more info')
- Sender (e.g. ‚This message is sent by...')
- Timestamp (e.g. ‚Time is 12:26)

The generic structure has been defined through templates which can however be overridden by the operator. Automatic translation has been achieved although the results so far are not convincing.

The area over which to broadcast the message is a

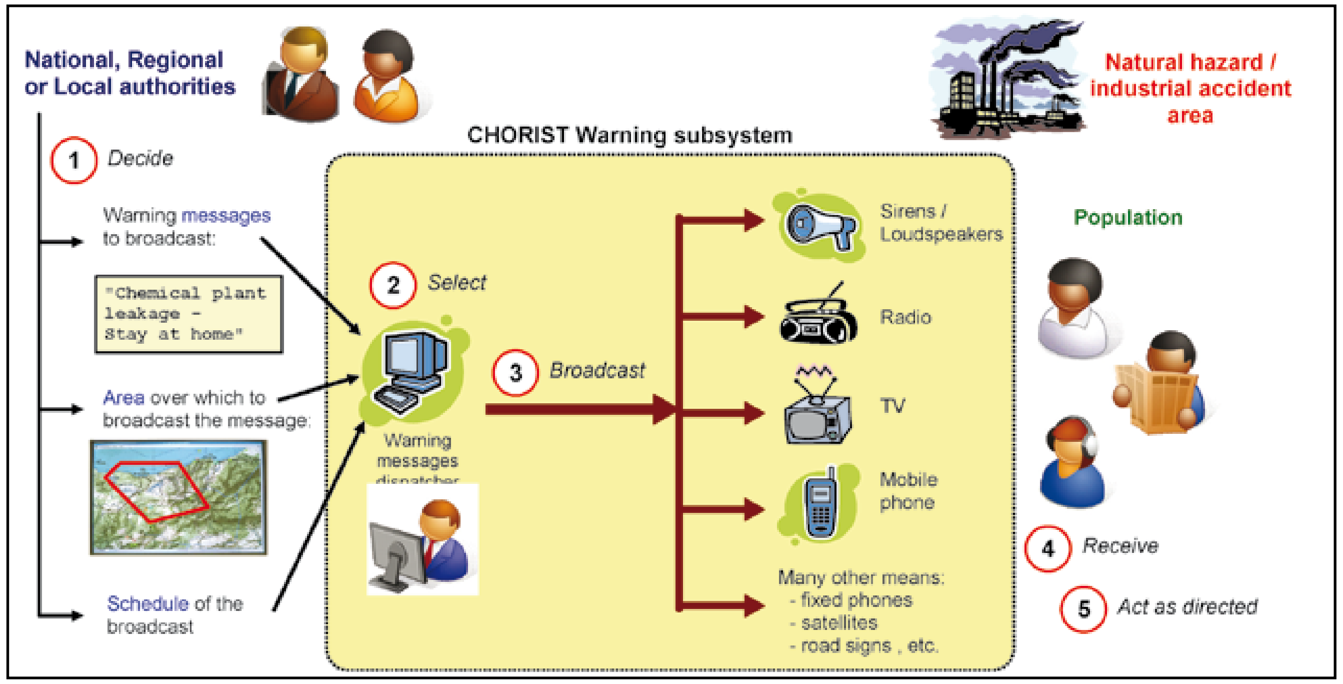

Fig 5: *Module 2 - Warning the population*

polygon simply mouse-drawn on the map. This map is retrieved from any free GIS Internet tool, as well as any other GIS local to the premises where the tool is installed.

The operator can define when and for how long the warning messages have to be broadcast.

Once the operator has defined all the elements of the warning message, the MCD then sends a CAP message through secure TCP/IP links to each Channel (GSM, radio, TV…) which then interprets and forwards the warning messages according to its internal protocols. The relevant CAP protocol for each channel has been clearly defined in documents with codes rather than free text, so that it is understood by machines.

The Web server-based Message Creation and Dispatcher tool allows authorities to create warning messages from predefined templates (potentially in several languages), to define the geographic zone where each message can be broadcast, to select appropriate channels DAB, DVB, GSM (cell broadcast) and/or sirens and then to plan suitable time-scheduling for the sending of the messages.

The CAP-encapsulated warning messages are then transmitted through secured links to various selected gateways giving access to the selected broadcasting networks.

Gateways adapt the warning messages to the protocols in use in the broadcasting network (probably not operated by Civil Protection authorities), and the messages are then conveyed to the appropriate broadcasting elements (TV and radio transmitters, GSM base stations and sirens).

End-user devices (TV set, radio receiver, or GSM mobile phone), as well as sirens are then triggered, providing visual and audible messages to people.

The implementation has been limited to specific methods, though many others could be added: The choice depends on technological constraints (security, reliability…), but most of all on the operators' willingness to provide access to their networks.

WHAT IS…Cell Broadcast ?

Cell Broadcast (CB) messaging is a mobile technology feature of the ETSI GSM standard designed for simultaneous delivery of messages to multiple users in a specified area.

Innovation Module 2:
The CHORIST warning system includes the following advantages when compared to other existing emergency warning systems:

- The CHORIST warning system can be used at multiple levels (Local / Regional / National), depending on the scale of the incident:

  - In case of a major incident, governments and Crisis Response Centres are capable of distributing the warning messages, possibly over large areas and involving several countries.

  - In a more localised incident, the emergency services can select, edit and distribute the warning messages to citizens in their own area of jurisdiction.

- Multiple areas can be selected; for each area, various warning messages can be defined; each message being associated to a broadcast date/time.

- Warning message templates are provided, but can be overridden if required.

- Messages can be written in several languages; citizens will only see the message in the language they prefer.

- The geographic message delivery area can be drawn on a map with just a few mouse clicks.

- Parallel broadcast of messages through multiple networks assists in maximising the number of people reached and to assist in system fallback in the event that one system is not operating properly.

- Standard protocols assist in merging existing and emerging channels.

MODULE 3: Rapidly deployable PMR systems
The ad-hoc mesh network is an experimental inter-vehicular IP network which provides 1-5 Mbit/s to end-users. Inter-node range went up to 1 km (unamplified) during tests, but it could be extended even further. Radio and routing protocols respectively based on LTE / WiMAX, and on emerging dynamic MESH network architectures were set up. The long-term goal is to get this wireless backbone automatically setup and maintained between vehicles with little human involvement.

Users on foot are under the coverage of cells local to the vehicle's surroundings: Though WiFi is proposed, standard mobile WiMAX in 1-to-N mode would be better.

Remote connection to fixed control centres could be made through WiMAX line-of-sight links, or through satellites.

The TETRA TEDS base station is an evolution of the narrowband TETRA base station. This ETSI standard allows an achievable transmission rate of 100 kbit/s with spectrum occupancy of 25 MHz and over cells as large as TETRA narrowband cells.

Both solutions plan the wide usage of video (live and off-line), still image (high quality) and data transmission (maps, schematics, ECG, documents, emails…) to field rescue teams, making it the equivalent 3G revolution for professionals that GPRS and UMTS were for the Public some years ago.

Innovation module 3:

- IP radio network allowing a huge set of video and data access applications for public safety field teams.

- Vehicular to pedestrian broadband cells.

- A self-forming inter-vehicular IPv6 mobile broadband wireless core network:

  - Two-tier, rapidly deployable and auto-configurable core network, where dynamically - allocated cluster-heads (CHs) allocate the radio resources (MAC/PHY) to the first tier

  - Flexible routing decisions based on traffic identification.

  - Negotiated Quality of Service (QoS), naturally managed by using the Class of Service label fields.

  - Compatibility with security approaches (L3) as IP packets remain untouched inside the core network (e.g. with Virtual Private Networks -VPNs)

  - IPv6 unicast and multicast support.

- VoIP-distributed Group Call application taking advantage of the IP multicast features. Connection with legacy PMR network is done through a patch by Dispatch Operators.

- A vehicular-to-infrastructure WiMAX off-the-shelf long-range backhaul.

Any additional information we like to refer to the Chorist website: www.chorist.eu

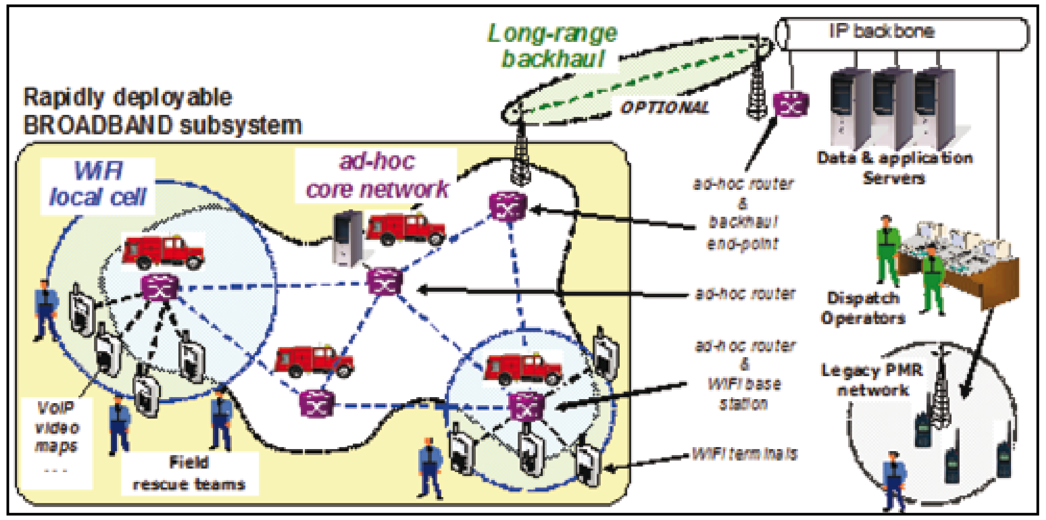

Fig. 3: Module 3 - Rapidly deployable PMR systems

Professional Mobile Radio: Providing a Dependable Message Delivery Infrastructure for Early Warning Systems

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Abstract
This paper highlights the benefits of utilizing a dedicated Professional Mobile Radio (PMR) network infrastructure for disseminating early warning messages to first responders. The discussion focuses on the strength of this approach in comparison to the use of public mobile networks for dissemination to both the general public and first responders. The TETRA standard PMR network features and services are used to illustrate the key advantages of PMR networks. Furthermore, the Finnish national TETRA network is briefly described to provide more practical insight of PMR for early warning dissemination.

Introduction
The main objective of any early warning system is to rapidly disseminate warning messages to specific users groups in response to an imminent hazard event. The dissemination has to be executed in a manner that ensures that the message delivery is timely and reliable enough to reach all intended recipients; and that the message content is accurate, understandable, and usable [GLANTZ (2003), WMO (2007)]. To meet these requirements, it is customary that all available broadcast (television, radio) and telecommunication infrastructure available in a particular area are employed as these represent tried and tested channels that are familiar to message recipients.

In the following discussion we shall classify the message recipients into two coarse groups:

- General Public: This refers to the general population situated in the area under risk and hence expected to evacuate to safe areas in response after receiving the warning message.
- First Responders: This group represents the organizations (government agencies, local authorities, emergency response organizations, transport operators, etc.) expected to react first to the alerts or warning messages. They will then immediately provide resources and leadership in the evacuation of the general public; amplify the warning message; and minimize potential damage to critical infrastructures and the environment.

Limitations of Warning Dissemination to First Responders via PLMN
The Public Land Mobile Networks (PLMNs) are considered one of the most important telecommunications infrastructures for delivery of messages from early warning systems. This is due to the fact that the mobile sector has seen unprecedented levels of adoption of affordable and innovative mobile services in most countries, thus increasing service penetration to hitherto unconnected citizens. To that end, PLMN meet the needs of early warning systems for a message delivery infrastructure with sufficiently wide coverage and large user base.

In recent times, the privatization and deregulation measures widely adopted within the telecommunications sector (particularly the mobile sector); have resulted in fast-paced innovations; increased competition; higher efficiency; affordable services, and significant revenues for all companies involved in value chain. As a result privately-owned mobile network operators and service providers are being relied upon to support emergency services (such as, hazard early warning), not just for the general public but also for first responders (see Figure 1).

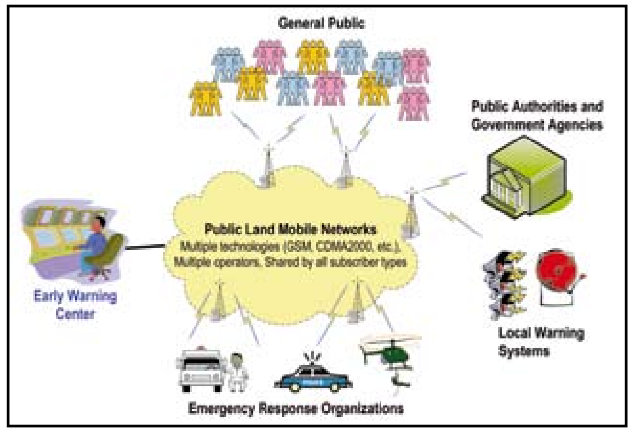


***Fig. 1:** Early warning message dissemination via PLMNs*

However, conventional PLMNs were not originally engineered to support broadcast-type mass text or multimedia messaging services. Therefore, attempts to disseminate early warning messages over the network may result in excessive delays due to network congestion or even message non-delivery. Example measurements previously carried out in a live network on performance of the Short Message Service (SMS) indicated an overall delivery failure ratio of 5% and delays in excess of 5 minutes for a tenth of the messages sent [MENG (2007)]. This performance could degrade significant due to a sudden surge in call or message sending attempts by subscribers when a hazard event appears imminent. Moreover, possible network security breaches may compromise message dissemination resulting in denial-of-service, erroneous or hoax message delivery.

The rapid response to early warning alerts and messages is a multi-agency operation that relies on the communications interoperability between concerned agencies. This interoperability can be effectively supported by public networks not only due to aforementioned congestion problems and security gaps, but also due to the great difficulty in dynamically prioritizing network resources to guarantee access to specific user types and integrating an agency's command and control (dispatch) functionality into the network.

The aforementioned shortcomings not only reduce capability to rapidly disseminate warning messages to right recipients, but also hamper the efforts of the first responders in coordinating and facilitating the evacuation effort.

Warning Dissemination to First Responders via PMR Networks
In view of PLMN limitations, there is an increasing preference by governments to build and/or operate dedicated Professional Mobile Radio (PMR) networks [KETTERLING (2004)], that are designed to guarantee robust security and high service availability at all times for first responders (see Figure 2). The European Telecommunications Standardization Institute (ETSI) has specified an open and harmonized digital PMR standard (ETS 300-392 to 300-396) known as TErrestial Trunked RAdio (TETRA), which is now arguably the most widely deployed PMR technology standard and is considered a replacement for the legacy fragmented analog PMR systems still used by a significant number of first responder organizations. Alternative digital PMR standards have been adopted in various regions, most notably the APCO-25 standard.

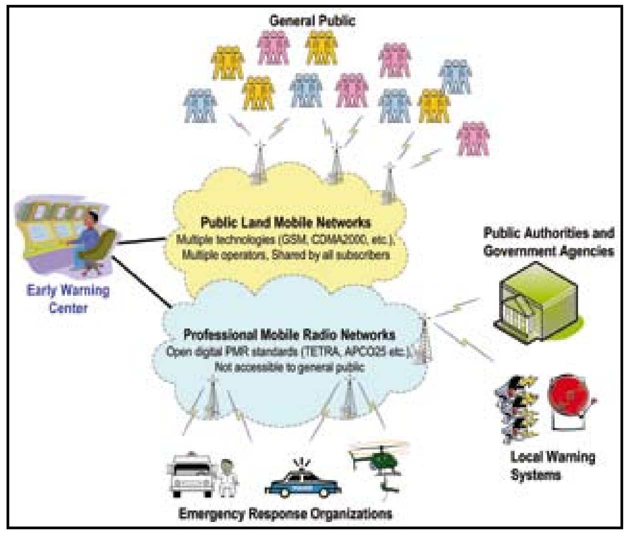


***Fig. 2:** Early warning message dissemination via PMR networks*

The objective of the TETRA standard was necessary to harmonize a fragmented PMR market and the user community (mainly public safety and security organizations) requirements have had a strong influence in the development of the standard (http://www.tetra-association.com/). Therefore, TETRA PMR networks are ideally positioned to support of initial alerts, early warning and post-warning communications for first responders. In other words, the current quest for effective early warning systems further highlights the need for adoption of PMR networks (such as, TETRA) that are dedicated for use by first responders.

This paper seeks to underline this point by providing an overview of TETRA systems highlighting beneficial features which make it useful for early warning purposes. The arguments are illustratively supported by a relevant early warning case study from an existing TETRA network implementation.

Overview of TETRA PMR
TETRA PMR networks share many common architectural features with conventional PLMN. However, there are several supplementary features in TETRA that make it a more suitable option for first responder organizations particularly in terms of network architecture; performance; security; resilience and redundancy; user terminals; services and applications.

Network Architecture
A TETRA network is divided into multiple cell coverage areas, which enable the limited radio frequency resources to be efficiently reused in non-adjacent cells. TETRA users are connected to the TETRA network via a base station (BS) that maintains radio coverage within that cell (see Figure 11). A typical city or region would be covered by hundreds of BSs that are connected to Mobile Switching Center (MSC) that provides switching functions; coordinates location updating and manages user mobility. Interconnection of multiple MSCs enables implementation of TETRA networks with regional or nationwide coverage. All the MSCs, BSs and the network management system (NMS) in a TETRA network are collectively referred to as, the Switching and Management Infrastructure (SwMI). The connectivity between different TETRA networks is provided over an Inter-System Interface (ISI). This interface defines common protocols to support all the important roaming and security services between interconnected cross-organizational or cross-border networks.

Furthermore, APIs (Application Programming Interfaces) can be provided to enable the smooth integrati-

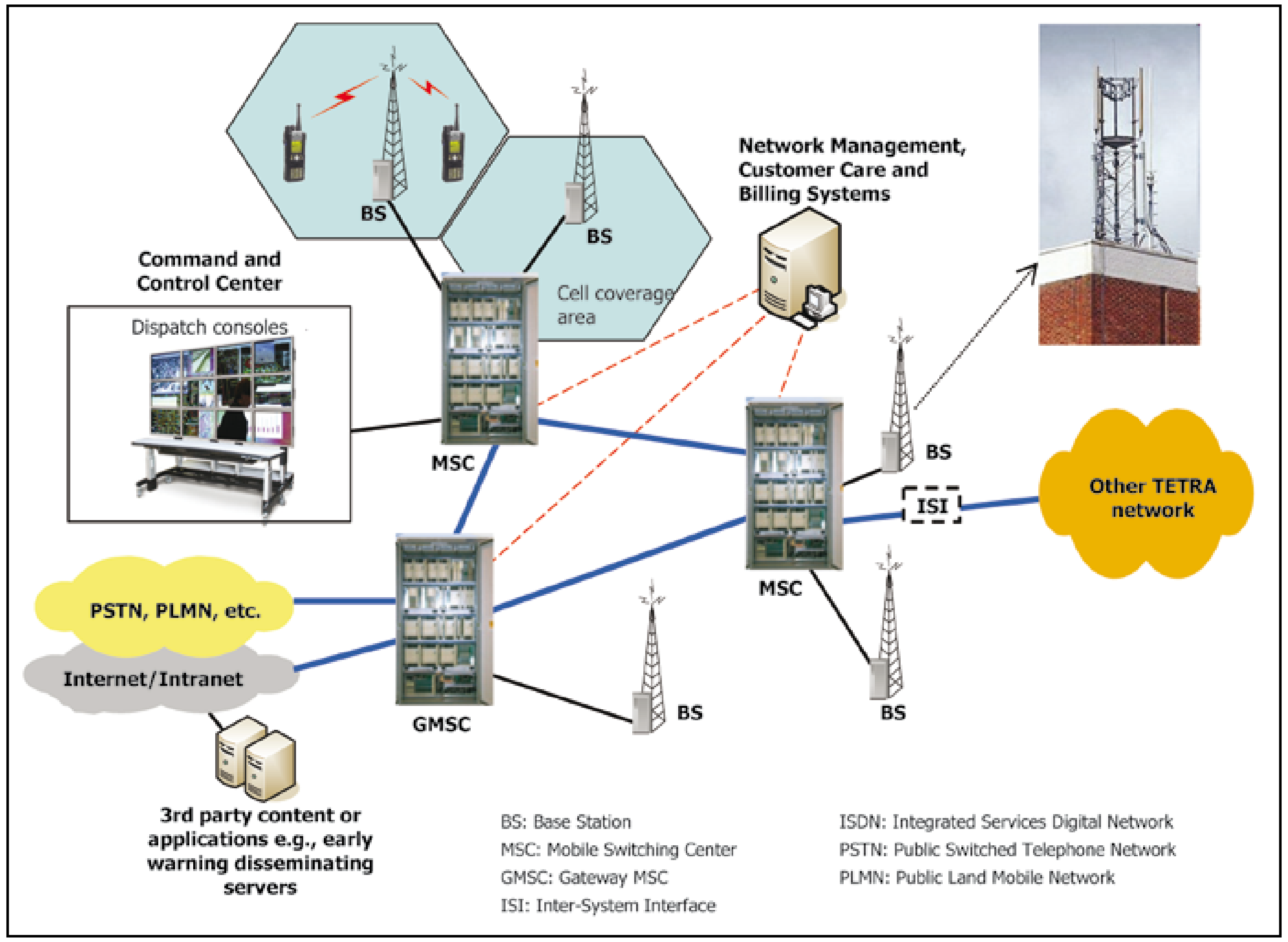


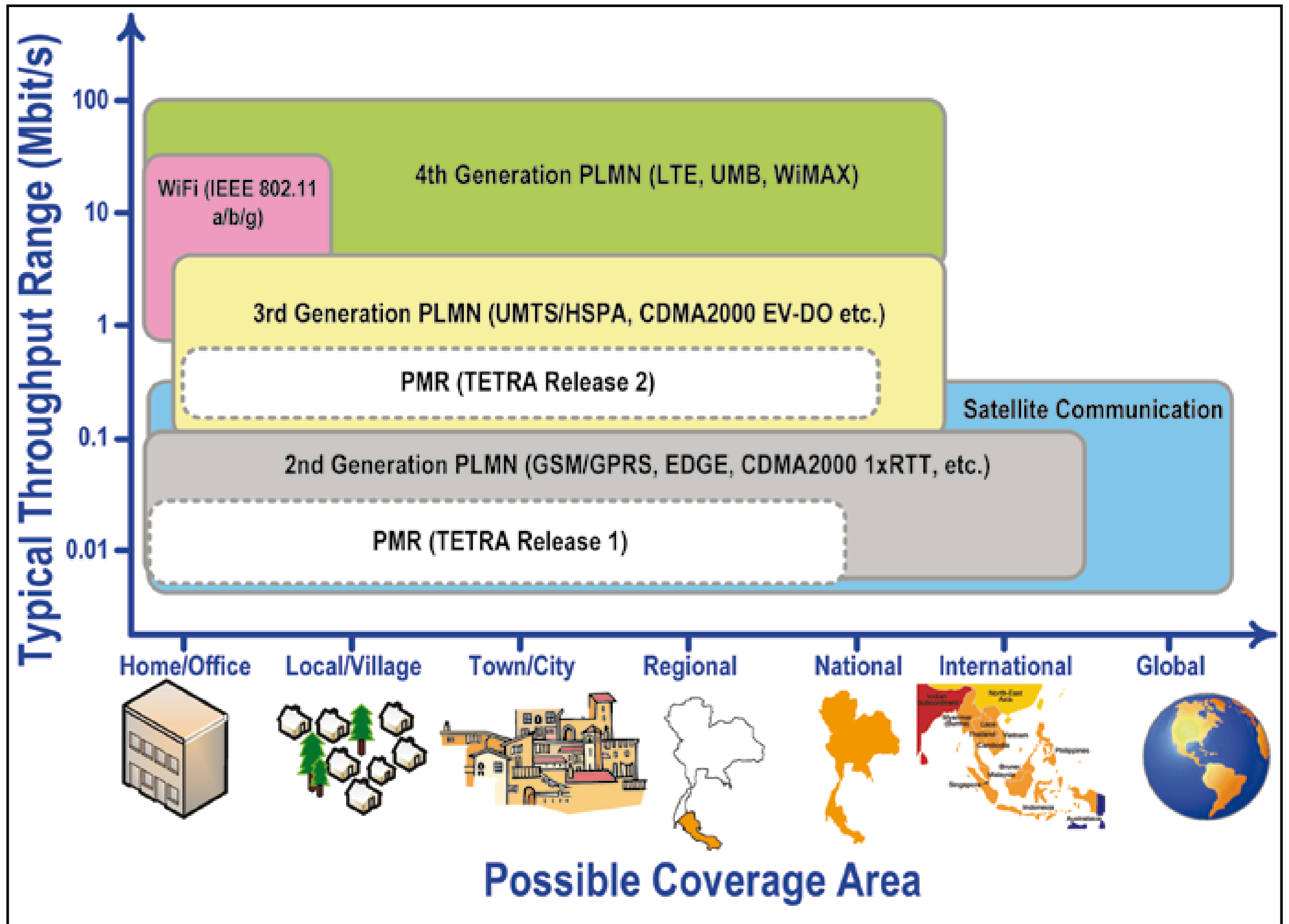
Fig. 3: *TETRA network architecture*

on of network applications developed by third parties, such as, early warning messaging services. Uniquely for PMR systems are the presence of a command and control center with dispatchers whose primary function is to control and coordinate communication of users or members of a user group belonging to a particular agency or authority. Dispatchers are able to fulfill those roles by having a broad view of the situation picture in an unfolding event. For instance, a police force dispatcher upon receiving a warning message from an early warning center would then send voice or data dispatches to police within area under risk and create temporary communication groups dynamically for efficient co-operation in the mass evacuation process. This dispatch functionality is very difficult to integrate in conventional PLMNs.

User Terminals
The user terminals or mobile stations for TETRA systems (see Figure 4) are typically rugged handheld terminals that visually resemble conventional mobile handsets, but differ in various essential functionalities provided. For instance, most TETRA terminals are shipped with integrated GPS functionality, which enables the dispatcher to maintain knowledge of the location of field units. TETRA vehicle-mounted terminals (for squad cars, ambulances, fire engines, traffic motorcycles, trains, etc.) with higher output power are also available for high mobility users. The TETRA standards define an open Peripheral Equipment Interface (PEI) that enables TETRA terminals to be interfaced to peripheral devices, such as, laptops installed in field unit vehicles (see Figure 4).

Fig. 4: *Handheld and vehicle-mounted TETRA mobile stations*

TETRA terminals are also available as Remote Terminal Units (RTUs) for remote telemetry, automation and control applications. For instance, a TETRA RTU can be used to perform automatic control and diagnostics functions on remote sirens from an early warning center via a TETRA network.



Notes: CDMA = Code-Division Multiple Access, EV-DO = Evolution-Data Only, GPRS = General Packet Radio Service, GSM = Global System for Mobile communication, IEEE = Institute of Electrical and Electronics Engineering, LTE = Long Term Evolution, PMR = Professional Mobile Radio, TETRA = Terrestrial Trunk Radio, UMB = Ultra-Mobile Broadband, UMTS = Universal Mobile Telecommunications System, WCDMA = Wideband CDMA, WiMAX = Worldwide Interoperability for Microwave Access, 1xRTT = 1 times Radio Transmission Technology. .

Fig. 5: *TETRA performance in comparison to public terrestrial wireless and satellite networks*

Performance
TETRA was defined from its onset (TETRA Release 1) to handle both voice and low-speed data traffic. The capacity and coverage performance of these networks is roughly equivalent 2G mobile networks. An order of magnitude improvement in data transfer rates is achieved for TETRA Enhanced Data Service (TEDS) as part of TETRA Release 2. This raises the performance to a level equivalent to early 3G mobile networks (see Figure 5). Whilst TETRA compares favorably with current PLMNs in terms of capacity and coverage, it offers additional advantages in terms of:

- Higher bandwidth utilization efficiency (32 channels per 200 KHz carried bandwidth);
- Faster call setup times (0.3-1s), essential in situations that require fast responsive actions;
- Modulation schemes that are relatively simple to implement;
- Higher tolerance to multipath impairments (delay spread) caused by signal reflections, diffractions and scattering in the mobile radio environment.

Security
The TETRA standards define a range stringent security measures, these include:

- Authentication of user terminal (UT) by the TETRA network (SwMI), and vice versa. Authentication basis for mechanisms to disable lost or rogue UTs and/or subscriptions. Moreover, authentication measures applied to dispatchers, network administrators and external applications (e.g., early warning sending applications).
- Secure air interface encryption (AIE) communication between the UT and the network. AIE keys may be derived dynamically for every authentication procedure and sent to UTs using Over the Air Re-keying (OTAR). Or static keys may be preloaded in the UT or Subscriber Identity Module (SIM).
- End-to-end encryption (E2EE) for more robust security (see Figure 6), for instance, over backhaul leased lines or shared TETRA networks.

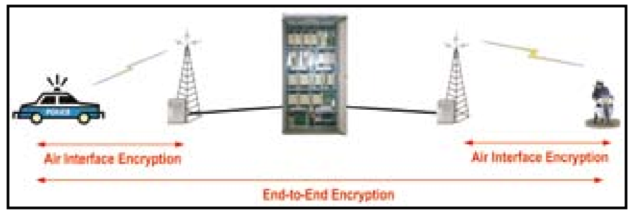


***Fig. 6:** Implementation regions for air interface and end-to-end encryption schemes*

The TETRA standard defines three security classes depending on the usage of authentication; encryption and OTAR key management (see Table 1). A UT may support one, two or all security classes. Mission-critical public safety and security (PSS) TETRA networks would normally employ the most robust (Class 3) security level to support services, such as, early warning.

Security Class	Authentication	Encryption	OTAR
Class 1	Optional	E2EE (optional); AIE (none)	None
Class 2	Optional	E2EE (optional); AIE using static key encryption (mandatory)	Optional
Class 3	Mandatory	E2EE (optional); AIE using dynamic key encryption (mandatory)	Mandatory

***Tab. 1:** TETRA security classes*

Resilience and Redundancy
TETRA networks have inherent resilience that enables continued connectivity for high priority communications even after failure or damage to parts of the network infrastructure (SwMI). The resilience mechanisms include base station (BS) fall back, whereby, the BS continues to operate as a local "repeater" when the backhaul link to the Mobile Switching Center (MSC) is lost or the MSC is in a failed state (see Figure 7). Direct Mode Operation (DMO) enables TETRA user terminals to communicate directly (with limited features) or via vehicle-mounted repeaters, independent of the network infrastructure. The use of DMO could be considered as a fallback scheme that ensures continued local communications even after failure to the BSs.

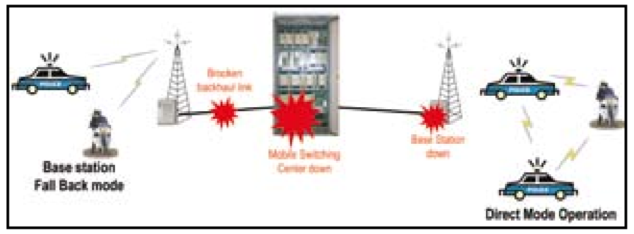


***Fig. 7:** TETRA network resilience methods*

In addition to resilience measures, the availability of TETRA network infrastructure components is improved (preferably up to 99.999%) by significant in-built redundancy and instant failover switching.

Services and Applications
TETRA networks support a range of calling features and services crucial for professional users (see Figure 13). These include:

- Individual calls;
- Broadcast and group calls (broadcast talk groups, scanning of talk groups, dynamic regrouping, talk group area definition, etc.);
- Supplementary services (priority call, late entry, area selection, call report, call authorization by dispatcher, etc.).
- Messaging by Status Messaging (encoded as 16-bit numbers) or Short Data Service (SDS) an SMS equivalent;
- Circuit mode data and IP data services for Internet/Intranet access, file transfer (e.g. images, maps, etc.), email, database lookups, Automatic Vehicle Location (AVL), telemetry and so forth. Even faster data rates to support rich multimedia services (e.g. streaming video) will be possible with the implementation of TEDS.

The aforementioned services empower the dispatcher with a very wide array voice and data mechanisms for disseminating warnings to the right individuals or units in the right locations.

Case Study
VIRVE (VIRanomaisVErkko) is a TETRA network that covers the whole of Finland (330,000 km2) using extensive TETRA infrastructure made of around 1300 BSs and 15 MSCs (see Figure 8). VIRVE is operated by the state-owned State Security Networks Ltd. (Suomen Erillisverkot Oy). The network is currently accommodates around 40,000 users belonging to several public safety, security and health agencies (see Figure 8). All those organizations sharing the VIRVE network are afforded the same privacy and resources as similar to dedicated networks, via strong guarantees on data protection and provision of high-speed data services.

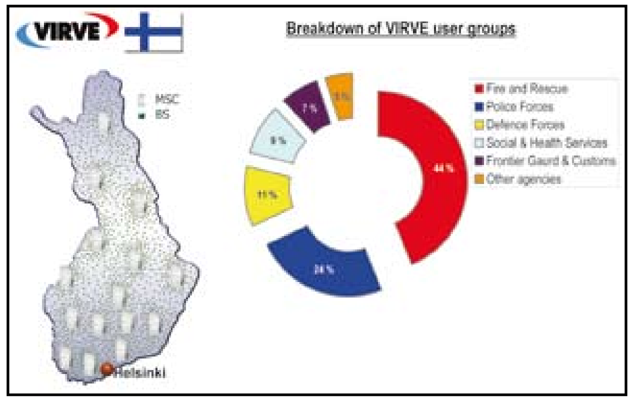


***Fig. 8:** VIRVE TETRA infrastructure and the breakdown of VIRVE user groups*

As a shared network, VIRVE enables a more flexible and coordinated response among relevant authorities and agencies when dealing with small scale emergency incidents or high-impact hazard events. Inter-agency cooperation is further boosted by the use of shared Emergency Response Centers (ERCs), which house dispatchers for different agencies on the same premises. Finland is divided into 15 emergency administrative areas, and each one of them is served by a single ERC.

Example use of VIRVE network for hazard early warning is by the Radiation and Nuclear Safety Authority (STUK) of Finland [VESTERBACKA (2007)]. STUK is responsible for monitoring, prevention and limitation of the harmful effects of radiations (due to nuclear fallouts, dirty bombs, etc.). Radiation dose rate measurement data is gathered every 10 minutes from around 200 monitoring stations spread across Finland (see Figure 9).

***Fig. 9:** Radiation dose rate monitoring station*

The collected data is encoded as XML messages (see Figure 10) and then relayed by TETRA telemetry modules (Sepura SRM3500 Mobile Radios) at the station to STUK, local authorities and ERCs via the VIRVE network. The principle message transfer method used is TETRA IP packet data, while SDS messaging is used as backup.


```xml
<?xml version="1.0" encoding="UTF-8"?>
<radiologicalMessage>
  <doseRate>
    <idMsg>5118</idMsg>
    <stationId>4567</stationId>
    <endTime>2004-10-29 08:03:07</endTime>
    <doseRateAvg>0.123</doseRateAvg>
    <doseRateAvgUnc>0.009</doseRateAvgUnc>
    <rain>0</rain>
    <temperatureDetAvg>5.11</temperatureDetAvg>
    <unit>mikroSv/h</unit>
  </doseRate>
</radiologicalMessage>
```


***Fig. 10:** Example fragment of XML message for radiation dose rate measurement*

Conclusions
This paper has presented arguments for the use of PMR networks for early warning message dissemination. The benefits in terms of network security, robustness, prioritized messaging and integrated dispatcher functionality make PMR networks an ideal platform for effective dissemination of warning message to first responders. The features of TETRA network services, structure and user terminals add value and flexibility in how the messages could be delivered to targeted first responder consumers. Furthermore, the case study of the Finnish VIRVE network illustrates the many possibilities of utilizing a PMR network as an upstream/downstream, multi-hazard and multi-agency message dissemination platform.

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Early Warning Systems as Critical Information Infrastructure: Analysis of Potential Threats and Related Concepts

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Abstract
This paper discusses early warning systems (EWS) from a perspective of EWS being critical information infrastructure (CII). To that end, an analysis of the potential threats in the context of EWS is presented using detailed concept map analysis and description of some real life examples. The analysis underlines the need for critical information infrastructure protection (CIIP) strategies to be applied to EWS to ensure that they retain capability for reliable early warning even when compromised by various threat actions. Furthermore, initial proposals for the CIIP approach are presented.

Introduction
The increased frequency of occurrence of natural and man-made hazards has underscored the need for early warning systems capable of rapidly and reliably disseminating suitably targeted warning messages in response to an imminent hazard event [GLANTZ (2003), WMO (2007)]. The message dissemination process is typically initiated and executed out by a combination of human operators, Information Technology (IT) systems and existing communication resources that constitute an end-to-end early warning system. The constituent components of an early warning system would be designed to interact in a predictable, harmonised and effective matter, to enable messages to be rapidly composed and disseminated in time to save lives and property at risk.

To that end, early warning systems could be considered to be critical information infrastructure (CII). A CII has been defined to be IT and communications systems that are critical infrastructures for themselves or for the operation of other critical infrastructure [EC (2005)]. The actual designation of what constitutes critical infrastructure varies from country to country [ABELE-WIGERT (2006)], but it generally includes both the people and public or private assets that would be saved if early warning systems function as specified.

As with other CII, early warning systems continuously operate under a specter threats (human/non-human, deliberate/non-deliberate, etc.) that could potentially disrupt their normal operation or cause them to function in a way that deviates from their original purpose. For instance, ill-intentioned individuals could compromise the system into sending hoax warnings causing unnecessary panic and long-term loss of confidence in the legitimate early warning service. Or then, significant outage or faults in parts of the early warning system or interconnected message dissemination infrastructure could result in failure to disseminate messages during crucial moments of imminent hazard events.

Therefore, the concept of critical information infrastructure protection (CIIP) that has recently gaining significant attention [DUNN (2003)] is also highly relevant for early warning systems. CIIP constitutes the programs and activities of various stakeholders (operators, users, authorities, etc.) which aim to keep the performance of CII (such as, an early warning system) above a defined minimum level of service in case of failures, attacks or accidents [EC (2005)]. Moreover, CIIP aims to minimize recovery time and any potential damage to a CII.

The implementation of an effective CIIP strategy requires a comprehensive analysis of potential threats and related concepts of security, vulnerability and attack for a CII. This paper analyzes the potential threats to an early warning system. This analysis includes the classification of threat consequences, the nature of the threats and the accentuation of threats due to system (intra)interdependency. The objective is to contribute to the discourse on early warning systems within the CIIP framework and hopefully bring attention to hitherto unanalyzed aspects of early warning systems.

Overview of Threats and Related Concepts
Critical Information Infrastructure Protection (CIIP) is built around the closely interrelated concepts of threats, security, attacks and vulnerability. A clear understanding of the relationship between these concepts in the CII context is crucial for CIIP strategy-making for Early Warning Systems (EWS). Various standards development organizations have produced definitions that help to explain interrelationship between the concepts. The International Telecommunications Union Telecommunication Standardisation Sector (ITU-T) Recommendation X.800 provides the following definitions [ITU-T (1991)]:

- Security: A term used in the sense of minimizing the vulnerabilities of assets and resources.
- Threat: A potential violation of security.
- Attack: An intentional threat that has been realized.
- Vulnerability: Any weakness that could be exploited to violate a system or the information it contains.

To further analyze the aforementioned concepts, we use concept maps that provide a labeled graphical node-arc representation of relationships among a collection of concepts. The relationship between various information security concepts would be rather large and cumbersome to depict with sufficient clarity on a single integrated map. Therefore, we devise a high-level concept map representing only the major concepts (the nominal “view from 50,000 feet”) shown in Figure 1. Further explanation of these initial observations is provided in the subsequent subsections with the aid of detailed low-level concept maps.

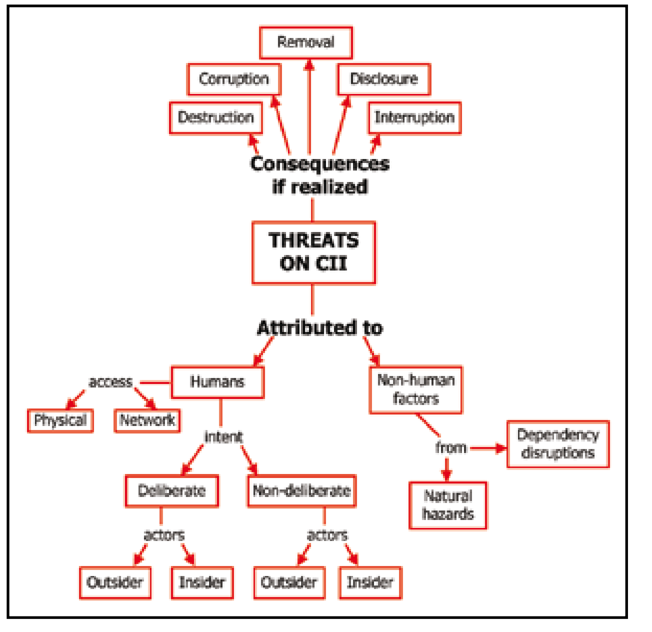

Fig. 1: High-level concept map depicting various aspects of threats on CII

Consequences of Realized Threats
A realised threat would result in at least one of the following outcomes:

- Destruction of information, system assets or resources;
- Corruption or modification of information;
- Theft, removal or loss of information, system assets or resources;
- Undesired or unauthorized disclosure of information;
- The interruption of service delivery.

The action leading to each threat consequence may vary as illustrated in Figure 4. Destruction, removal or interruption could potentially lead to partial or complete EWS failure to function and provide intended early warning services. Furthermore, corruption, disclosure or removal of system or user information may not directly lead to noticeable EWS failure, but compromises the integrity of the information delivered over the system and may even provide a gap for more severe attacks on the system.

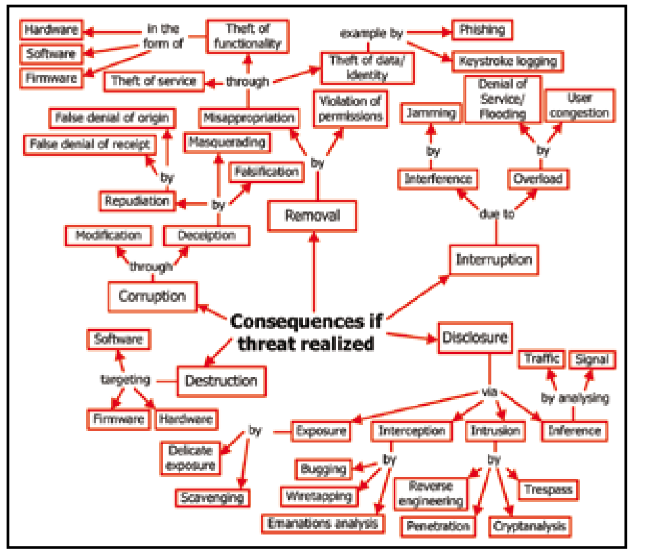

Fig. 2: Low-level concept mapping of the consequences of realized threats

Non-human threat factors are those that cannot be directly attributed to human threat actions. This includes the factors illustrated in Figure 3 outlined briefly below.

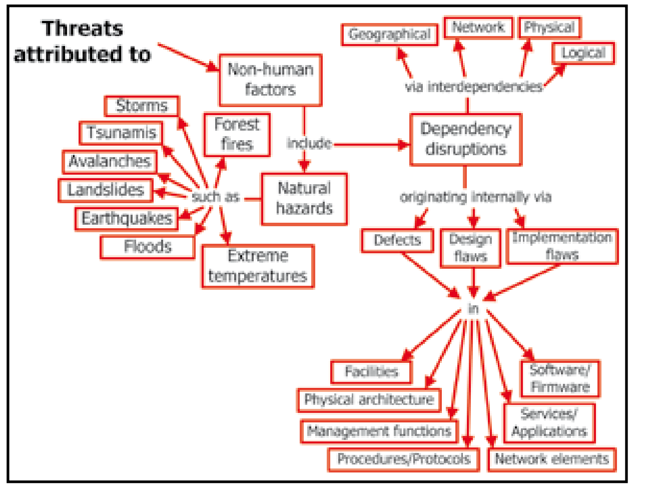

Fig. 3: Low level concept mapping of non-human threat factors

I. Natural hazards
Natural hazards are known to cause direct physical destruction to critical infrastructure, resulting in widespread disruptions or common-cause failures. The EWS elements such as above-ground transmission lines, poles, towers and tele-housing facilities, could be damaged by winter storms, forest fires, earthquakes and so forth. Furthermore, heavy downpours and flooding could disrupt access holes and damage underground telecommunication cable plant. Any signi-

ficant damage to the EWS of related infrastructure in the aftermath of a natural hazard would reduce the early warning capacity in the case of follow-up natural hazard event.

II. Dependency Disruptions
Internal failures usually result from defects or flaws in hardware, software, procedures, management functions and so forth. Failures may also originate externally due to complex interdependencies between the EWS and other infrastructure. These interdependencies may be classified as follows [RINALDI (2001)]:

- Physical interdependency: due to need for resources provided by another infrastructure. For instance, the operation of CII facilities (e.g., switches, servers, transmitters etc.) requires a constant supply of clean electrical power from power networks.

- Geographical interdependency: due to collocation or close proximity with other infrastructure. For instance, telecommunication cables could be suspended from pylons of a power network or buried alongside a railway track.

- Cyber or networked interdependency: whereby the commodity exchanges between dependent infrastructures is information. An example is when a backbone network aggregates traffic from other information infrastructures

- Logical interdependency: accounts for other complex relationships that are not easily associated with in any of the aforementioned interdependency categories.

It is very likely that the effects of failures or their ensuing disruptions in one infrastructure may cross infrastructure boundaries depending on existing interdependencies. This crossover is manifested in the triggering of new failures or aggravation (escalation) of existing failures in interdependent infrastructure. For instance, faults in the power network (e.g., blackouts, power surges, sags etc.) may lead to EWS service outage and even damage equipment.

Nature of the Threats –Human Factors
Threats attributed to human factors are carried out by threat actors with either a deliberate or non-deliberate (accidental) intent (see Figure 4). Threat actors may be positioned within a designated security perimeter (insiders) or intentionally outside the parameter (outsiders). For EWS insiders include Operator on Duty (OOD) or system administrators with privileged multilevel access to EWS functionality and assets. The type and degree of access privileges (e.g., access time, allowed operations etc.) accorded to emplo-

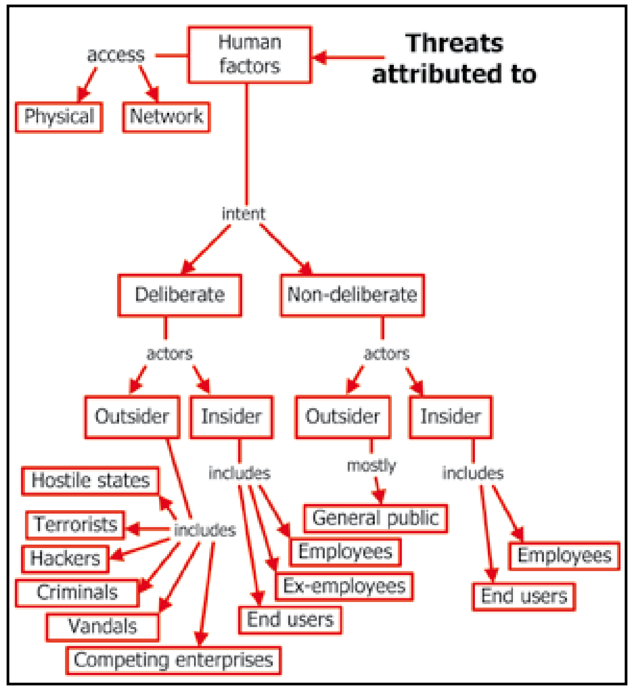

Fig. 4: *Low level concept mapping of human threat factors*

yees also varies depending on their job description (e.g., systems administration, housekeeping etc.) within the organization.

Both outside and inside threat actors may have physical and/or networked access to a EWS. For instance, physical access may enable deliberate threat actors to disrupt or damage system assets (e.g., server racks, routers etc.) in way that would weaken overall system functionality. Network-based access enables delivery and execution of threat actions (e.g., malicious software, denial-of-service attacks etc.) that target information flows, stored data, bandwidth resources or software resident in the system, with the end results being just as debilitating to the system as a physical attack.

The type of access to the system also determines the method by which the EWS could be threatened (non-)deliberately by the human threat actors. For instance, members of general public may exhaust network resources in response to hazard event in a bid to stay in touch with family members or friends during the critical period. This in turn would seriously compromise the capability of those networks to deliver warning messages to individuals under risk.

Selected Study Examples
This section presents a few selected real life examples that depict realization of previously described threats on existing tsunami EWS.

I. June 2006, Tsunami Siren Stirs Anger in Aceh (Source: BBC)[1]

[1] http://news.bbc.co.uk/2/hi/asia-pacific/6730545.stm

Residents in Aceh were angered by a false tsunami alarm that sent thousands of people in the capital and a nearby area rushing from their homes to higher ground. The tsunami warning siren was too high up, so they stoned it causing damage to the siren tower.

II. November 2006, Australian Government Slams Hoax Tsunami Email (Source: The Age)[2]

The Australian government launched an investigation on a hoax email warning of an impending tsunami bound for Japan. The hoax email was in a form similar to official earthquake and tsunami warnings. A government spokesman stated that the only organization with authority to disseminate tsunami warnings was the Bureau of Meteorology.

III. June 2007, Hoax Text Message Spreads Tsunami Terror in Indonesia (Source: AFP)[3]

Residents in Aceh were angered by a false tsunami alarm that sent thousands of people in the capital and a nearby area rushing from their homes to higher ground. The tsunami warning siren was too high up, so they stoned it causing damage to the siren tower.

IV. June 2005, Tsunami Scare Exposes Glitches in Warning System (Source: Seattle-Post Intelligencer)[4]

An offshore earthquake was initially estimated as magnitude 7.4 and considered capable of generating a dangerous tsunami. In fact, the tsunami was almost imperceptibly small, not worthy of a warning. Yet the evacuations up and down the West Coast continued because the tsunami warning remained in effect. Automated emergency radio tsunami alert was sent, but to a dead Qwest phone line. Malfunctioning equipment prevented the signal from ever reaching the emergency radio transmitter at Neah Bay. A spokesperson stated that "we hadn't had a tsunami warning on the California coast for many years."

CIIP for Early Warning Systems
The examples of the previous section further highlighted the implementation of CIIP strategies for EWS. However, CIIP implementation for systems such as EWS is challenging due to the following factors:

- Highly complex architectures and interconnectedness (see Figure 5)

- Geographically dispersed layout

- Highly interactive with their human operators, users and other systems

- No single entity has complete control of the whole system

Utilization of Security Frameworks
The increased ubiquity, diverse features and functionality of CII such as EWS has been accompanied by the increase in complexity of implementing ne-

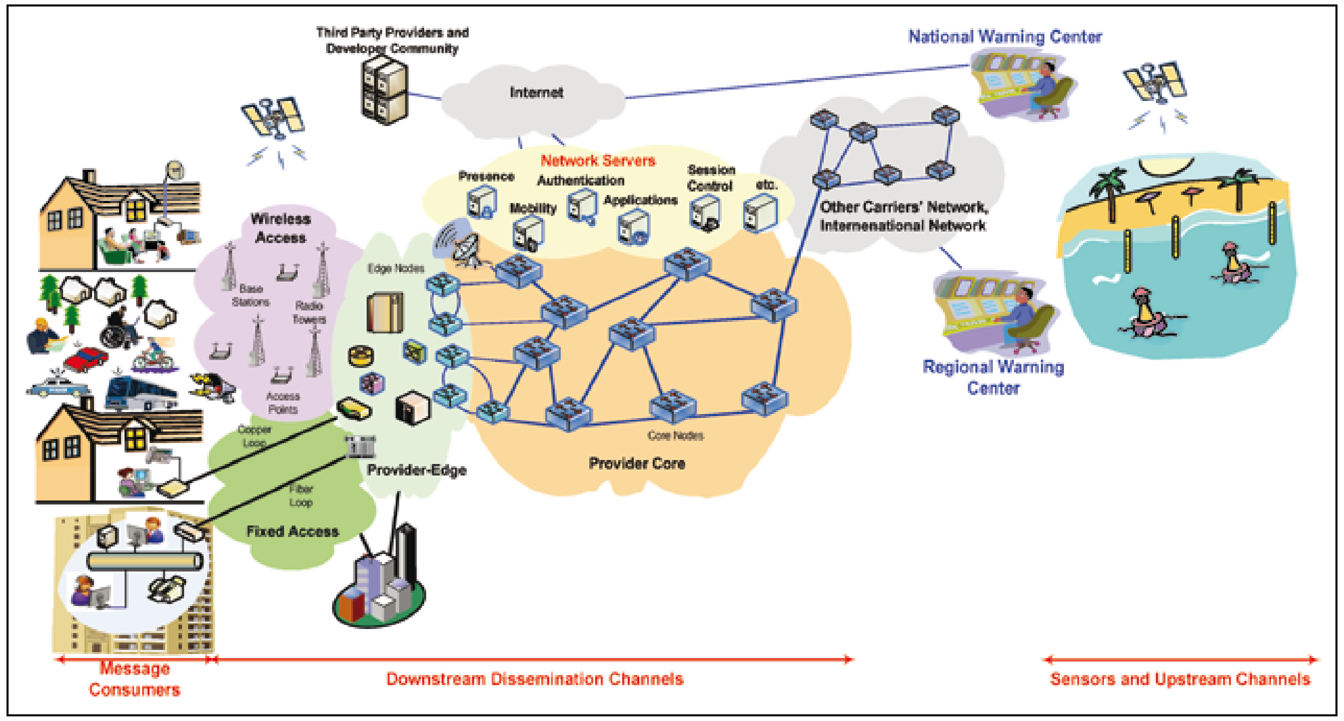

Fig. 5: *End-to-end (upstream and downstream) architecture of an early warning system*

[2] http://www.theage.com.au/news/National/Australian-govt-slams-hoax-tsunami-email/2006/11/04/1162340091108.html
[3] http://findarticles.com/p/articles/mi_kmafp/is_200706/ai_n19191174/
[4] http://www.seattlepi.com/local/228690_tsunami16.html

cessary security measures. This has created a need for security frameworks that provide a streamlined way for assessing and analyzing CII security taking into account: threats and attacks, vulnerabilities, and security (detection, correction and prevention) measures. The insight provided by this assessment is paramount for implementation of successful CIIP strategy.

To that end, a range of security assessment methodologies have been proposed, such as the ITU-T X.805 security framework [ITU-T (2003)] depicted in Figure 6.

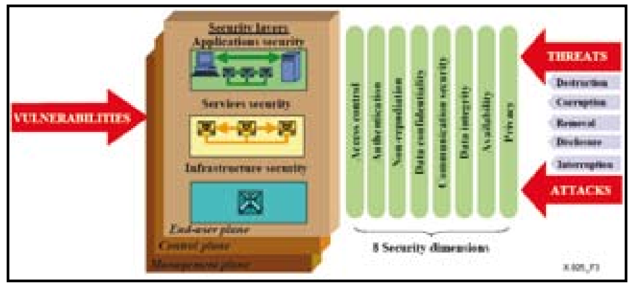

Fig. 6: *ITU-T X.805 security framework*

The ITU-T X.805 security architecture provides a comprehensive top-down, end-to-end perspective on system security. It is therefore applicable to assessing security of system's infrastructure, services and applications. Moreover, flexibility in the definition of the security architecture enables it to be applied to diverse system types independent of underlying technology, as is the case for complex heterogenous EWS. The security architecture addresses various questions on system protection based on three architectural components:

- Security dimensions: are measures that address a particular aspect of system security.
- Security layers: are hierarchies of system equipment, resources and other assets upon which the security dimensions are applied. Each Security Layer has unique vulnerabilities, threats, and mitigations.
- Security planes: are categories of system-related activities protected by security dimensions.

Implementing CIIP for EWS
The implementation of CIIP for EWS (and other CII) requires a range of input information ranging from assessment results (e.g. using X.805 framework), comprehensive system description documents, organizational guidelines, standards and so on. This input is necessary for the carrying out a range of actions that underlie CIIP implementation strategy (see Figure 7 for detailed description). This expected output of these actions includes report cards and findings on identified security gaps and recommendations on improvements to the security posture of the system.

The CIIP actions would typically be carried out throughout the lifetime of the EWS, encompassing the definition and planning phase; implementation phase and maintenance phase. Furthermore, in view

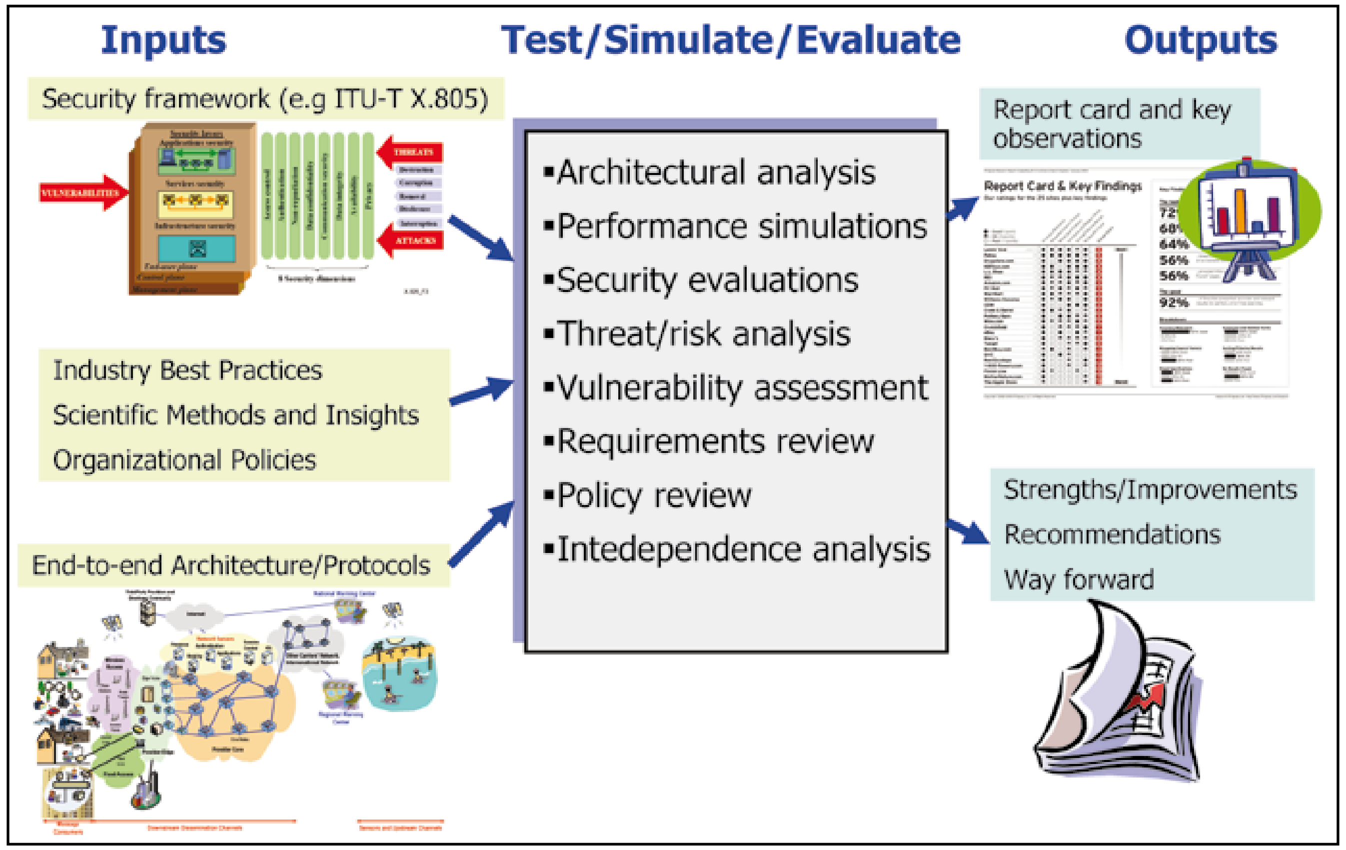

Fig. 7: *Inputs, actions and expected outputs for CIIP implementation for a EWS*

of the strong interdependencies between the EWS and other infrastructure or organizations, it is necessary that the CIIP program also includes actors from outside the EWS organization. This could for instance be operator of mobile networks, IT security experts and so on.

Conclusions
In this paper we analyzed the EWS from a CII perspective. The range of potential threats that could lead to a malfunctioning or incapacitated EWS clearly highlights the need to implementing comprehensive CIIP strategies for EWS. We presented some possible approaches in the CIIP implementation for EWS and highlight some of the challenges involved. As the discussion of EWS in the CII(P) context is yet to be conducted (to the best of our knowledge) within the practitioner, scientific and research communities, the increasing importance of EWS as a CII for saving lives and property underlines the need for CIIP to ensure that the EWS functions as expected before and after hazard events.

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Geological Records of Tsunami in the Southern Coast of Sri Lanka

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Studies based on 2004 Boxing Day Indian Ocean tsunami deposits of Sri Lanka, could contribute to interpret tsunami deposits elsewhere in the world geological record in much better way. Tsunamis leave behind layers of sediments that can be used to understand the waves which deposited them. By examining texture and the structure of the Tsunami deposits, we may be able to evaluate the wave height and flow velocity of the wave. Tsunami sediments may also contain markers which illustrate different sources (deep sea, terrestrial, estuarine, etc.) of sediments. Such records are important evidences to understand regions which may be at risk from a Tsunami.

In the present work, we have studied Tsunami sediment thickness, run-up, heights, inundation distance, and topographic profiles for 8 transects along the Tsunami affected south western coastal zones. Samples were collected (by open pit sampling) for laboratory analysis for grain size distribution, sedimentary structures, microfossils, mineralogy, and chemistry. Box cores were taken at several sites to study the stratigraphic details of the sediments. Sedimentary characteristics of the Tsunami deposits and underlying materials were logged and photographed. Erosion and flow-direction indicators were also documented. Residents were interviewed to obtain local conditions before and after the recent Tsunami.

Results show, that the 2004 Tsunami waves were capable of eroding the coastal region, up to 100 m inland. For example at Patanangla (South East of Sri Lanka) effect of erosion extends up to 75m inland and at a nearby location (Mahaseelawewa) it extends up to 100m. At Patanangala thickness of Tsunami sediments at 75m distance inland is 20 cm. The thickness decreases gradually inland. One cm thickness was found at 750 m distance, inland. Tsunami deposits show recognizable layering due to different Tsunami waves, incoming and out going waves and seiches. There were many laminations which could contribute to sedimentations occurred due to seiches between second and third waves. Parameters of 3 layering indicates three main Tsunami waves affected the Mahaseelawa area and the second wave has been identified as the biggest wave due to occurrence of thick coarse and poorly sorted sediments. Even the numerical modeling using the ComMit model also supports the same. Textural and structural data of sediments indicate that the third wave came after a considerable time lag. In between the second and third waves, there were many laminations which may have occurred because of seiches common during Tsunamis. In addition, results show that the mangrove forests have considerably decreased the wave energy (e.g. Yakghagala area in Western coat of Sri Lanka).

In the Sri Lankan history there is a record of major sea inundation in the coastal areas around the city of Colombo during the period of King Kelanithissa (approximately 2100 -2300 yrs B.P; resulted setting afloat his daughter, Princess Vihara Mahadevi into the sea to appease the gods). Extensive investigations of sediment cores collected from Lunawa, Dikwella, Karagan Lagoon (Hambanthota), Kirinda (altogether over 20 cores) do not show presence of paleotsunami sediments belongs to the period of 2100 -2300 yrs B.P. Thus, the particular event could be a local storm surge rather than a Tsunami.

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Standardisation of tsunami warning message generation in Indonesia: Approach and implementation

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1 Introduction

In recent years numerous tsunami events in the Indian Ocean, and in particular along the Sunda Arc, have shown how vulnerable human society and the environment is to this sudden-onset type of disaster. The December 2004 tsunami demonstrated the need for an effective tsunami early warning system for the Indian Ocean. Within the Framework of UNESCO-IOC and its Intergovernmental Coordinating Group (ICG), various efforts on national and bilateral basis are coordinated and combined to ensure a fast and reliable tsunami warning for the whole Indian Ocean and its 27 rim countries. The work presented here is embedded in the German-Indonesian Tsunami Early Warning System (GITEWS) project. GITEWS is funded by the German Federal Ministry of Education and Research (BMBF) to develop a Tsunami Early Warning System for the Indian Ocean in close cooperation with Indonesia. The system integrates terrestrial observation networks of seismology and geodesy with marine measuring sensors, satellite technologies and pre-calculated simulation scenarios.

What makes tsunami detection for Indonesia unique and challenging is on the one hand the extremely short time window between tsunami generation and the arrival time at the nearest Indonesian coastline, and on the other hand the lack of sensor technologies that detect and measure tsunamis as such.

The GITEWS sensor systems integrate the respective sensor information and process them to aggregated sensor observations in real-time. The processed information from all these sensor systems is transmitted to the GITEWS Decision Support System (DSS) for further processing, analysis and decision support.

Unlike classical decision support problems, the process of putting together sensor and other information, generating situation awareness and assessing and proposing decision options is an iterative process, as sensor information comes in in pieces, initially with considerable uncertainties, in arbitrary order, and major information gaps and uncertainties will still be present when deadlines for warning decisions are reached. GITEWS therefore adds additional components in order to achieve the best situation awareness possible by compiling a huge repository of a-priori knowledge:

- A tsunami simulation system generates a large number of precalculated tsunami scenarios; in case of a potential tsunami, sensor observations can be compared and matched with these scenarios in order to find the most likely tsunami scenarios.
- A risk and vulnerability analysis component determines probable consequences and impacts on coastal communities exposed to tsunamis, including the determination of potentially endangered coastal regions and the vulnerability assessment of society and the environment.

All this information is assessed and combined into a common operational picture (situation awareness) as the basis for decision proposals to the decision maker not only to make an informed decision regarding whether to warn or not, but also when to decide. Once the decision to warn has been made, the DSS also supports the warning product generation and dissemination process.

2 German Indonesian tsunami early warning system

The paper describes the concept of Situation Awareness and Decision Support, how the different sensor systems and additional components interact and complement each other, new developments in the area of automated processing, scenario-based situation assessment, and DSS graphical user interface (GUI), and the experiences gained so far. The DSS is able to generate situation awareness and individual decision proposals on a very detailed level, considering so called warning segments as homogeneous parts of the coastline to which warnings can be addressed.

The requirements regarding product generation and dissemination include:

- The generation of warning segment specific messages, focussing on the situation in the respective warning segment, and

- The generation of so-called aggregated messages that combine information for many, if not all, warning segments.

In addition,

- as different dissemination channels need to be adressed, the messages mentioned above need be formated according to the needs of the specific dissemination channels, usually resulting in versions like “long”, “short”, “text-only”.

Furthermore,

- in order to adress national and international target groups, multi-lingual versions of the above mentioned messages need to be provided.

The recipients of these messages need to be able to decode all this information, and the chosen format of the DSS products must allow for regionalized and target group specific dissemination.

The paper describes how the GITEWS DSS makes use of the Common Alerting Protocol (CAP) standard in order to adress the above mentioned requirements.

Among the dissemination systems registered with the GITEWS DSS in Jakarta is the 2WCom FM-RDS-based message dissemination system which implements the DSS CAP dissemination interface.

The paper presents the CAP-based warning product dissemination process between the DSS and the 2wcom FM-RDS system, refers to other standard based message dissemination options and gives an outlook on future extensions of the DSS dissemination interface.

3 The early warning and mitigation system
GITEWS´ novel “system of systems” concept is based on a modular and extensible architecture of different systems deployed in the BMKG Warning Center in Jakarta as part of the GITEWS Early Warning and Mitigation System (EWMS) / InaTEWS Earthquake Information and Tsunami Warning System (EITWS).

Fig. 1 shows the EWMS concept which consists of following elements:

- A sophisticated Earthquake Monitoring System (SeisComP3 by GFZ Potsdam) collects real-time data from seismic sensors in the region and worldwide and is able to detect and locate earthquakes very quickly.

- A continuous GPS System (CGPS) describes the seafloor deformation/rupture in (near) real-time based on very precise GPS measurements at smart land stations (stations equipped with GPS and other sen-sor technology).

- A Deep Ocean Observation System (DOOS) collects and processes sensor information transmitted from Ocean Bottom Units (OBUs, located on the seafloor underneath buoys) and Buoys equipped with tsunami-detecting instruments.

- A Tide Gauge System (TGS) collects and processes measurements of a network of tide gauges in order to detect sea level anomalies.

- An interface to future Earth Observation systems is provided.

- A central Tsunami Service Bus (TSB) collects information from the sensor systems and provides them to the DSS.

- A Simulation System (SIM) is able to perform a multi-sensor tsunami scenario selection, resulting in a list of best matching tsunami scenarios for a given set of observations.

- The Decision Support System (DSS) receives sensor observations via the TSB, requests a scenario selection from the SIM for the current set of sensor observations and communicates with the dissemination systems for message distribution and delivery.

4 The decision support system
As part of the Early Warning and Mitigation System (EWMS) the DSS provides processing, assessment, visualization, decision support, analysis, warning and management functions for the purpose of supporting disaster management related activities regarding tsunami threats for the region of Indonesia. This section will describe the resulting system requirements and solution approaches.

4.1 Status of Decision Support in Tsunami Early Warning
Tsunami Early Warning Systems exist in a number of countries e.g. the Pacific Tsunami Warning System PTWS by the PTWC (Pacific Tsunami Warning Centre near Honolulu/Hawaii) serving also the West Coast/Alaska Tsunami Warning Center (WC/ATWC) as well as the research centre in New Zealand of the National Institute of Water & Atmospheric Research (NIWA) or by the Japan Meteorological Agency (JMA).

These all differ from the system required for Indonesia, which will have to handle near-field tsunamis and enable the operators to assess the situation using a heavily aggregated situation picture with a high accuracy and cer-tainty. The system used for WC/ATWC for instance can be assumed to be used for early warning for tsunamis traveling as long as several hours before they hit the coast. Therefore information aggregation can almost be done manually or at least there is a lot more time to consider the effects and consequences of a wave before taking the decision whether to warn or not. A decision maker/ operator in the German-Indonesian GITEWS system needs to be able to send a warning or information message within a very short time span (5 minutes) after a potentially tsunamigenic event. Thus the whole system logic of when and whom to warn necessarily is different from the requirements with respect to decision support in the new tsunami early warning system.

4.2 Operational Prerequisites
In principle, the spatial situation awareness analysis and early warning process does not require shoreline segmentation, except when limited computational resources require aggregation and priorization or when mapping products to recipients or administrational structures.

A so-called Warning Segment is a well-defined segment of the shoreline defined according to administrational boundaries and is used as smallest warnable unit for which tsunami threat information is aggregated and to which warning products may be addressed.

A coastline segmentation workflow has been developed by BMKG and DLR; the current definition of warning segments for the coastline of Indonesia along the Indian Ocean covers 125 warning segments for Sumatra, Java and Bali and will be extended to cover all coastlines of Indonesia and the Indian Ocean.

Warning segments can be set to specific states which are called warning levels in connection with the dissemination of warning products (e.g. warning messages). The warning levels depend on the expected or confirmed tsunami threat. Which warning level is assigned during the decision proposal generation process depends entirely on the height of wave at the coastline.

Tsunami Category	Warning Level	Wave Height (WH) Range [m]	Color
<none>	<none>	0.0 ≤ WH < 0.1	Grey
Minor Tsunami	Advisory	0.1 ≤ WH < 0.5	Yellow
Tsunami	Warning	0.5 ≤ WH < 3.0	Orange
Major Tsunami	Major Warning	3.0 ≤ WH	Red

***Tab. 1:** Tsunami Warning Levels*

Wave heights of larger than 10 cm are considered to require a warning level of ‘Advisory’ (yellow). Warning segments which reach wave heights from 0.5 m up to 3 m are assigned a ’Warning’ level (orange level). Warn-ing segments with a wave height of 3 m or more are assigned the level ‘Major Warning’ (red) (see Table 1).

4.3 Core DSS Tasks
The decision process shall help the chief officer on duty (COOD) to become aware of a current situation, assess incoming information, exploit synergies of information fusion and analysis, assess impact and consequences and make informed decisions.

Unlike many other problems covered in the area of decision support, the situation evolves over a certain period of time, and the decision process itself must be time and space sensitive due to nature of the underlying physical phenomenon which may threaten widely dislocated places over a time period of several hours.

The core decision support loop consists of two major components:

- Situational Awareness

- Decide and Act

Situation awareness in turn comprises the steps perception (gather information), comprehension (fuse and judge information) and projection (effect estimation / projection).

In the perception step the DSS receives sensor input, including results from the simulation system. Following the sensor input will be processed and analyzed. In the comprehension step there is further analyzing of sensor input across sensor types. The projection step comprises the projection of the current situation into the future. An assessment of consequences takes place. These three steps result in an improvement of situation awareness. While situation awareness focuses on understanding the situation that evolves and its consequences, this knowledge needs to be transformed into decisions and actions.

This is the focus of the second part of the core decision support loop:

- decide refers to the derivation of decision proposals from a given situation that the EWMS has become aware of.

- act refers to the implementation of the decisions that the COOD has made. Examples for such decisions are product dissemination or sensor (de-) activation.

The workflow is repeated each time new information is received by the DSS or a deadline has been reached. The workflow is terminated by the COOD if no tsunami threat exists anymore.

4.4 Additional Sources of Information

In addition to the collection of real time sensor observations, the DSS can access a huge collection of a-priori information and scenario data that helps interpreting the online input, assessing the tsunami threat and forecasting the consequences.

Using this approach, the information gap immanent to the first minutes of a potential tsunami is narrowed as much as possible.

The most important sources of information are

- A geospatial data infrastructure which allows the standard-based access to large databases of geospatial baseline data, such as administrational boundaries, topographic and bathymetric data etc.

- Risk modeling and vulnerability assessment information which describe how high the tsunami risk at a particular location is and how vulnerable the people and infrastructure are. Information is also contained about the expected capability of people to respond to the event.

- The large number of tsunami scenarios contained in the Tsunami Scenario Repository (TSR) which is used by the SIM to perform the online multi-sensor-scenario selection process.

4.5 Graphical User Interface (GUI)

The user interface and process workflows of the DSS have been designed for decision making under uncertainty and time pressure (Endsley, 2003). Based on the large body of research literature on this topic and the results of an eye-tracking based study regarding a first DSS GUI version (Breuer, H. et al., 2009), it is now available in an improved and optimized version. The GUI (see Fig. 6) consists of four displays (called perspectives) shown simultaneously to the decision maker (COOD) through which the operator can go in sequence or iteratively to gain support for the decision whether to send a warning or not. The DSS GUI was implemented as a set of plugins and extensions to the the uDIG Open Source GIS client.

The Situation Perspective (Fig. 6, upper left) illustrates the overall situation including higher-level spatial and temporal views of all facts of interest (e.g. observations, simulation forecasts, sensor system states). For this purpose, a map view acts as spatiotemporal information display visualizing geospatial sensor data such as the event location, travel-time isochrones, estimated times of arrival (ETAs), thematic maps (e.g. borders, geologic realities), and sensor status information. A timeline view maps the incident data onto a temporal scale. All incoming sensor observations and simulation results that are relevant for the selected incident are displayed in detail in the Observation Perspective (Fig. 6, upper right). In addition, the user is provided with functionality to further explore single observations e.g. to view parameters, time series, plots, etc.

The Decision Perspective (Fig. 6, lower left) contains all information that is necessary for the COOD decision making process, including decision proposals and functionality for the configuration of warning products. This includes highly-aggregated classification bars for the individual sensor systems and the SIM to support the COOD in assessing the situation. A color code is used to represent the conclusions which may be drawn on the basis of the corresponding observations. Centered, a segment map and a list display the warning product proposals for each warning segment based on the simulation results. A similar color code is used here to graduate the warning levels.

Additionally, indexes for risk-relevant information are shown for each of the affected warning segments: e.g. number of exposed people, number of critical facilities, number of high loss facilities, response index and an overall risk factor.

The COOD may override the warning product proposals generated by the DSS. If the selected warning products should be sent, the button “Ready for Dissemination” needs to be pressed. The actual execution/ confirmation of actions is performed on a separate perspective where a product preview and a summary of the actions that are about to be trig-gered is shown (Fig. 6, lower right).

The COOD is required to confirm his choice (“Disseminate” button) in order to prevent unintended warning message dissemination; alternatively, the dissemination process can be cancelled (“Cancel” button).

4.6 Warning Product Generation and Dissemination

Regarding the generation of warning and other products generated by the DSS, a template-based approach is applied. For all products and each of the formats and languages a product shall be provided, templates are pre-pared that contain fixed elements (e.g. text) and keywords. At the time of product generation, the keywords are replaced with up-to-date information of the tsunami threat (e.g. magnitude, depth and location of the earthquake, warning levels for warning segments).

The generation of products is a two-stage process:

- In stage 1 the required basic products are generated (e.g. text warning messages);
- In stage 2 these basic products are embedded into an additional message formatted according to the CAP standard (OASIS, 2005).

Once the required products (warning messages) have been generated, they are transmitted to the dissemination systems which are connected to the DSS. Currently two dissemination systems are connected to the DSS: the BMKG dissemination system / 5-in-1 system and the 2wCOM FM-RDS (Frequency Modulated – Radio Data System) based dissemination system. The DSS sends the appropriate selection of products to the individual dissemination systems and initiates thereby the dissemination process which itself is outside the scope of the DSS.

5 Standards and Interoperability

Extended effort is put into compliance to interoperability standards defined by the Open Geospatial Consortium (OGC) for geospatial and sensor data. In particular the OGC initiative “Sensor Web Enablement” (SWE) (Botts et al., 2006) that aims at defining standards to enable the discovery, exchange, and processing of sensor observations, as well as the tasking of sensor systems as applied in the context of GITEWS.

Within the context of GITEWS SWE will be used as a basis for integrating the various external sensor systems with the EWMS and to offer sensor observation data to DSS components for further processing. This espe-cially makes sense when additional sensors become available in the future, e.g. new tide gauge or buoy systems or even remote sensing or airborne sensor systems. By adhering to these standards GITEWS will remain open and extensible in the future. For accessing geospatial information by the DSS GUI the established OGC standards Web Mapping Service (WMS) and Web Feature Service (WFS) are also used.

5.1 OGC Sensor Web Enablement (SWE)

For realizing the DSS Sensor Data Center (SDC) presented here the SWE architecture specified by the OGC is an important foundation. Thus this section will shortly introduce the basics of the OGC SWE framework and will provide an introduction into those SWE components which were used for building the sensor data center.

The activities of the OGC, an international consortium consisting of more than 350 members, focus on the development of open standards that form the basis geospatial data infrastructures. Within these activities the SWE initiative deals with the integration of sensors and sensor data. In order to fully integrate sensors and their data into a geospatial data infrastructure the SWE framework provides a broad range of functionalities. This includes the discovery of sensors and sensor data, the description of sensor metadata, access to sensor data (real time and historic), tasking of sensors and alerting mechanisms based on sensor measurements. For fulfilling this set of requirements a framework of standards has been developed. It comprises two aspects: the information model dealing with data formats and the service model describing service interfaces. The information model consists of the following standards:

- Sensor Model Language (SensorML) (Botts & Robin, 2007): Metadata format for sensors and sensor systems

- Observations and Measurements (O&M) (Cox, 2007): Data format for observations and measurements performed by sensors

- Transducer Markup Language (TML) (Havens, 2007): Data format, optimized for data streaming, that allows encoding sensor data and metadata

The SWE service model provides standardized interfaces for accessing sensor data, alerting and controlling sensors:

- Sensor Observation Service (SOS) (Na & Priest, 2007): Pull based access to sensor data and metadata

- Sensor Alert Service (SAS): Alerting based on sensor data and user defined criteria (for example if a measurement value exceeds a certain threshold)

- Sensor Planning Service (SPS) (Simonis, 2007): Controlling sensors and their parameter

- Web Notification Service (WNS): Asynchronous communication between web services (e.g. a SAS or SPS) and/or clients.

For the DSS sensor data center two of the above mentioned standards are of special importance: the O&M and SOS standards. Thus these two specifications will be introduced in more detail in the next two paragraphs.

The O&M specification defines a standardized format for observation and measurement results. It is based on the OGC Geography Markup Language (GML) as it specifies a GML application schema. The basic concept within O&M is the observation which is defined as an event that occurs at a certain point in time and which generates a value for an observed phenomenon. Besides time and value of measurements, O&M allows encoding further measurement properties like information about processes used for obtaining measurements or the location and quality of observations. Another important concept of O&M is the binding of measurements to features of interest (FOI). These FOIs are used for describing the objects or the measurement locations (= features) at which the measurement was performed.

Whereas O&M describes the data format for sensor data, the SOS specification standardizes an interface for accessing data gathered by sensors and sensor metadata. Thus the SOS relies on O&M as a response format for returning measurement data (for sensor metadata SensorML is mostly used). The SOS specification is divided into three profiles: core profile, transactional profile and enhanced profile. Whereas the operations of the core profile comprise the mandatory functionality the operations of the other profiles are optional. The core profile provides the essential functionality of a SOS: access to a description of the service and the available data (GetCapabilities), access to measurement data (GetObservation) and retrieval of sensor metadata (DescribeSensor). For inserting data into a SOS instance the transactional profile provides the necessary operations: registering sensors (RegisterSensor) and inserting sensor data (InsertObservation). Finally, the enhanced profile offers additional optional functionalities like retrieving FOIs or information about time dependent data availability.

5.2 DSS Sensor Data Center (SDC)
The Sensor Data Center (SDC) is the core component of the DSS for ingestion of and provision of access to sensor data. The SDC is part of the DSS Data Management Center (DMC) which is responsible for managing all data relevant to the DSS operations (e.g. Crisis and Risk Products, Geospatial Data) and includes software components for ingestion and archive tasks. All incoming sensor observation data passes an ingestion process during which the data is validated, transformed into the DSS-internal O&M data model and forwarded to the SDC. It provides mechanisms to store and access observation data as well as metadata about the used sensor systems. By implementing the open sensor web standards and models such as the SOS, O&M and SensorML specifications, it seamlessly integrates into the existing spatial data infrastructure (SDI).

The software components Feeder and SOS used in the SDC are further developments and adaptations of 52° North open-source SWE implementations.

5.2.1 Ingestion of observation data and sensor metadata into the SDC
In-situ observation data measured by the different sensor systems is sent to the SDC. After an ingestion component has verified and transformed the data it is forwarded to the Feeder component. This component acts as a Java Servlet and receives data transmitted through HTTP-POST. After validating the incoming data, the feeder determines the observation type. Depending on that type data is parsed and stored in a designated PostgreSQL database. All corresponding data, i.e. feature of interest (FOI), is being created and associated with the observation automatically. For each result element of such an observation a unique id will be generated that is returned to the plugin together with the corresponding pickup point for later service access to this specific observation.

The ingestion of SensorML data works analogously, but stores incoming SensorML files directly in a certain directory in the file system and not in a database. In both cases the SOS is being notified that new data is available by the Feeder components to update its service metadata.

5.2.2 Providing Observation Data and Sensor Metadata
Provision of observation data and sensor metadata is realized by a SOS. The service supports the implementation specification 1.0 (OGC 06-009r6) as defined by the OGC. Observation data is encoded using the O&M standard 1.0 (OGC 07-022r1). The SOS provides the operations defined in the core profile such as DescribeSensor and GetObservation. Furthermore it offers the GetFeatureOfInterest and GetObservationById operation as defined by the enhanced profile. The implementation is based on the data access object (DAO) pattern (SUN) and supports an implementation for a PostgreSQL database. Since the SOS runs as a Java Servlet, too, it is capable of receiving HTTP-GET and -POST requests. Incoming requests are analyzed and translated into SQL queries. After execution of these queries the response is encoded using the Geography Markup Language (GML) for feature requests or O&M for observation requests. SensorML docu-ments are returned directly as stored in the file system and associated with the requested procedure. The SOS interface offers the possibility to query observation data by id or allows applying certain filters such as temporal or spatial constraints. Due to performance issues there is one SOS instance for each observation type.

5.2.3 Access to Observation Data
One of the main advantages of the OGC standards applied here is to have a unified access layer for the retrieval of spatial data which can be reused by server-side components as well as the GUI. Access to spatial data is realized in GITEWS by using uDig GIS (Geographical Information System). A plugin based on the 52° North OWS (OGC Web Service) Access Framework (OX-Framework) for uDig allows retrieving observation data from a SOS. It provides mechanisms for creating SOS requests and parsing the O&M responses of the service. The encapsulated data is transformed into the uDIG data model and as such are accessible for further actions.

Beside in-situ data of the sensor systems the SDC is also able to store and provide simulation results. These contain a huge collection of a-priori information with best matching tsunami scenarios for a defined set of input parameters.

5.3 Common Alerting Protocol (CAP)
The warning messages generated by the DSS are provided in the Common Alerting Protocol (CAP) format, an open standard for disaster management message exchange (Incident, 2008; OASIS, 2005). CAP defines a standard for alerts and notifications in the public warning domain independent of the hazard type and the technology used for transmitting warning messages. The CAP XML structure allows the inclusion of event data, text, images and geospatial references. The Federal Emergency Management Agency FEMA of the US Dept. of Homeland Security has, among others, explained their commitment to use a profile of the CAP protocol in their Integrated Public Alert and Warning System (IPAWS, FEMA, 2008).

The DSS Dissemination Component offers services for creating, updating and disseminating Warning Products. For those dissemination systems connected to the DSS which are able to parse CAP the message (which includes related geospatial references) is encoded and transmitted in CAP XML.

5.4 Message Generation and Dissemination
On request of the decision maker, a set of predefined messages is generated in different languages and formats, filled with the most recent information regarding the current tsunami threat. While the product dissemination is pending the information is continuously updated. For security reasons, the decision maker must confirm the dissemination of the requested DSS products.

The DSS applies a template based approach in order to meet these requirements.

For the generation and dissemination of DSS products the DSS uses two dedicated software components:

- the DSS product generation (PG)
- the DSS product dissemination (PD)

The individual messages are created at first according to a job list based on the warning configuration in the decision perspective. As already described above, a number of templates is used to generate individual language and message types (long message, short message, messages with a map etc.).

In a second step these “payload” messages can be wrapped into the CAP XML container file. This adds a number of metadata to the messages including information about the sender, date, message type (actual/test), severity, urgency, incident number amongst others (see Fig. 7).

These individual message files are then distributed through predefined distribution channels, which can use FTP or HTTP POST protocols. Using templates and the described mechanism to wrap payload files into an XML container allows for a very flexible way to shape messages. The definition of distributors in an easily configurable initialization file contributes a flexible interface to existing dissemination systems.

Experience shows that a small file size of resulting CAP messages is desirable, while at the same time the recipients shall be provided with supporting information such as geographic or multimedia information. Examples are geographic descriptions of the area affected by the hazard or targeted by the warning message, or multimedia files such as maps or audio information. The 2wcom FM-RDS based system is capable of sending an audio message via the audio broadcast channel in addition to the text warning message.

It is planned to complement the current CAP messages, while keeping the small file size, with external URIs for several types of supplementary documents (audio, geodata, maps, etc.).

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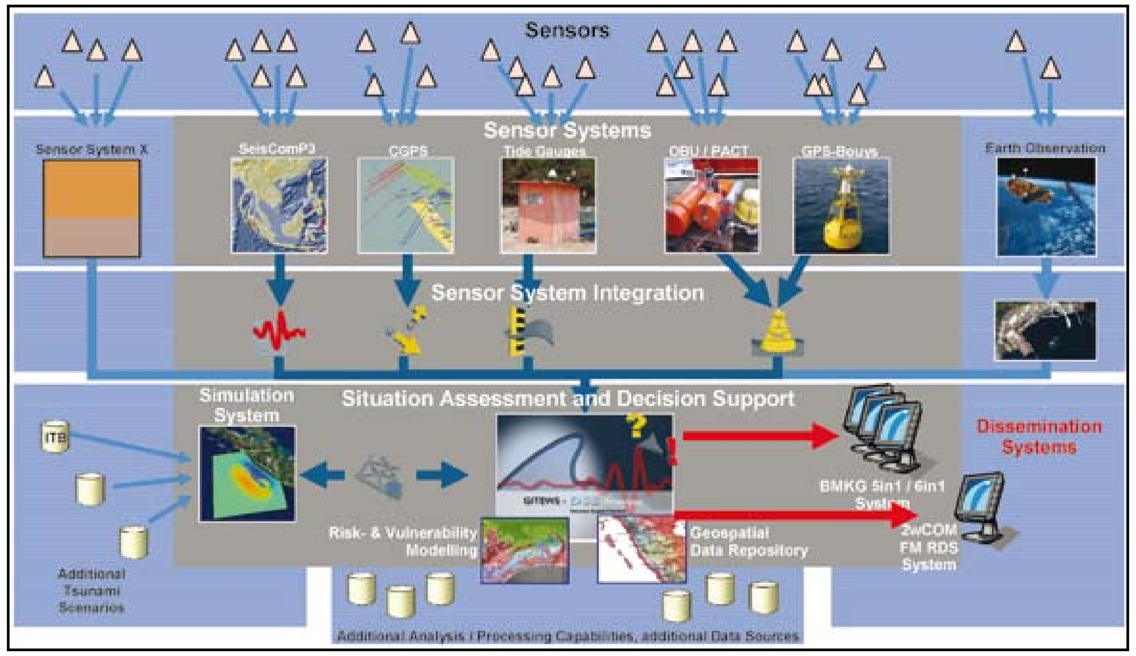

***Fig. 1:** The Early Warning and Mitigation System Concept (Top line shows the incoming systems, bottom line their comparison/matching/fusion with data from risk and vulnerability modeling and the geospatial data repository before dissemination of a warning through the BMG 5in1/6in1 dissemination system. The intermediate layer is where observations are transmitted through the OGC SWE services to and from the DSS. The open architecture supports future extensions (blue areas).*

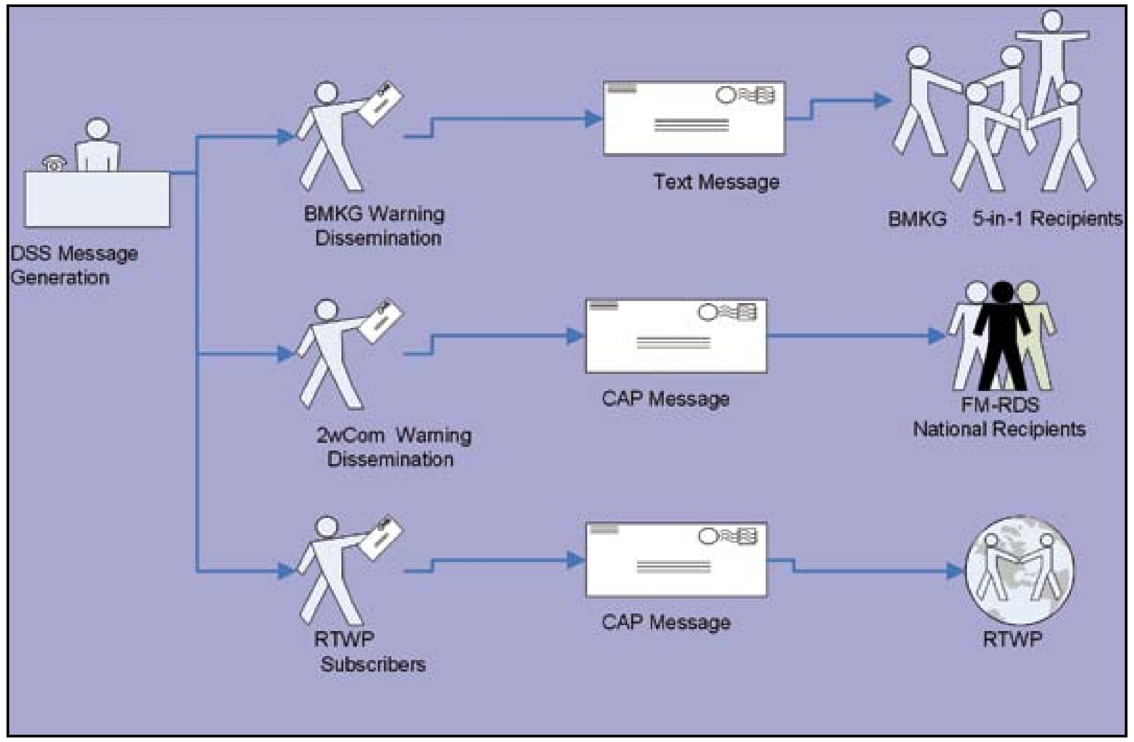

***Fig. 2:** Delivery of Messages generated by the InaTEWS DSS: As primary dissemination channel, text messages are delivered to the BMKG Dissemination System (existing '5-in-1' dissemination). An additional channel is currently tested which uses FM-RDS based dissemination of regionalized messages via the 2wcom system using CAP-based messages. Messages generated in the RTWP (regional tsunami watch provider) context will be delivered by the DSS as CAP-message.*

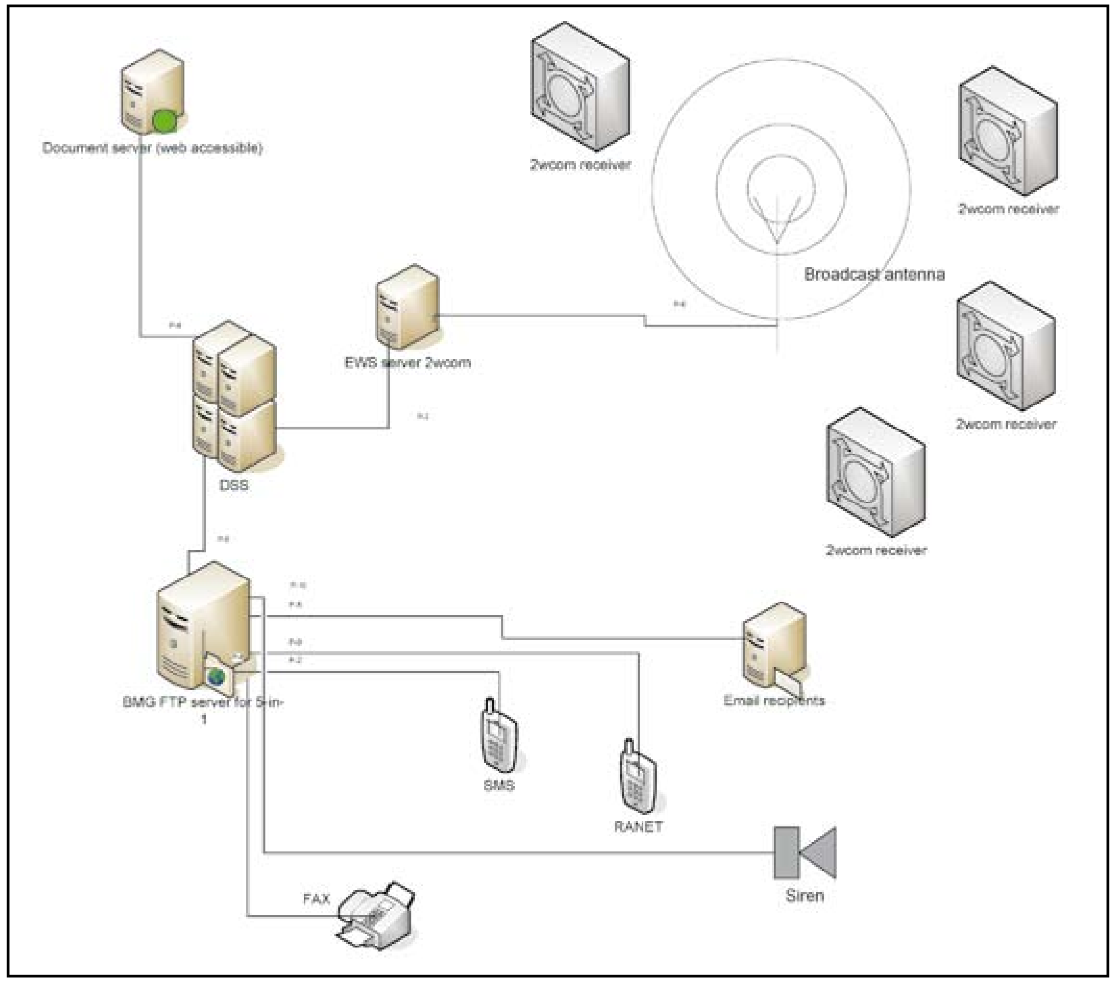

Fig. 3: *Overview of the dissemination paths of the products generated by the InaTEWS DSS, including the DSS Documentation Server, the FTP server of the BMKG dissemination system and the 2wcom HTTP server which manages the FM-RDS based dissemination to the respective receivers through a radio broadcast antenna and specialized receivers.*

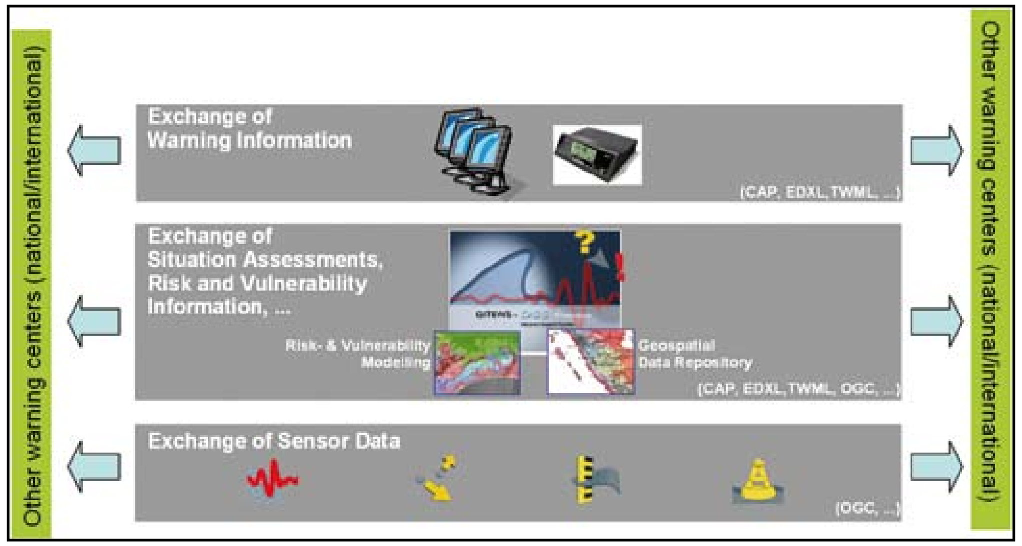

Fig. 4: *Three levels of information exchange between national and international centers, also correlated with the IOTWS RTWP service level specification. The basic level refers to the exchange of sensor data (the "input" level for RTWPs), and the upper level refers to the exchange of warning/watch information (the "output" level for RTWPs). Level 2, corresponding to IOTWS RTWP service level 3, refers to the exchange of situation assessment, risk and vulnerability data.*

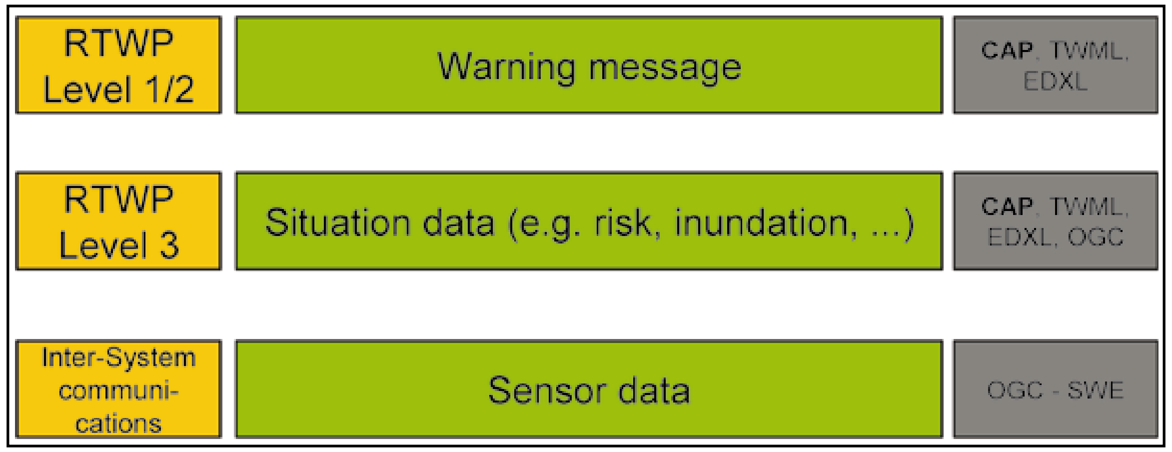

Fig. 5: *The three levels of information exchange between national and international centers can benefit from standardized communication (e.g. CAP, TWML, EDXL, OGC).*

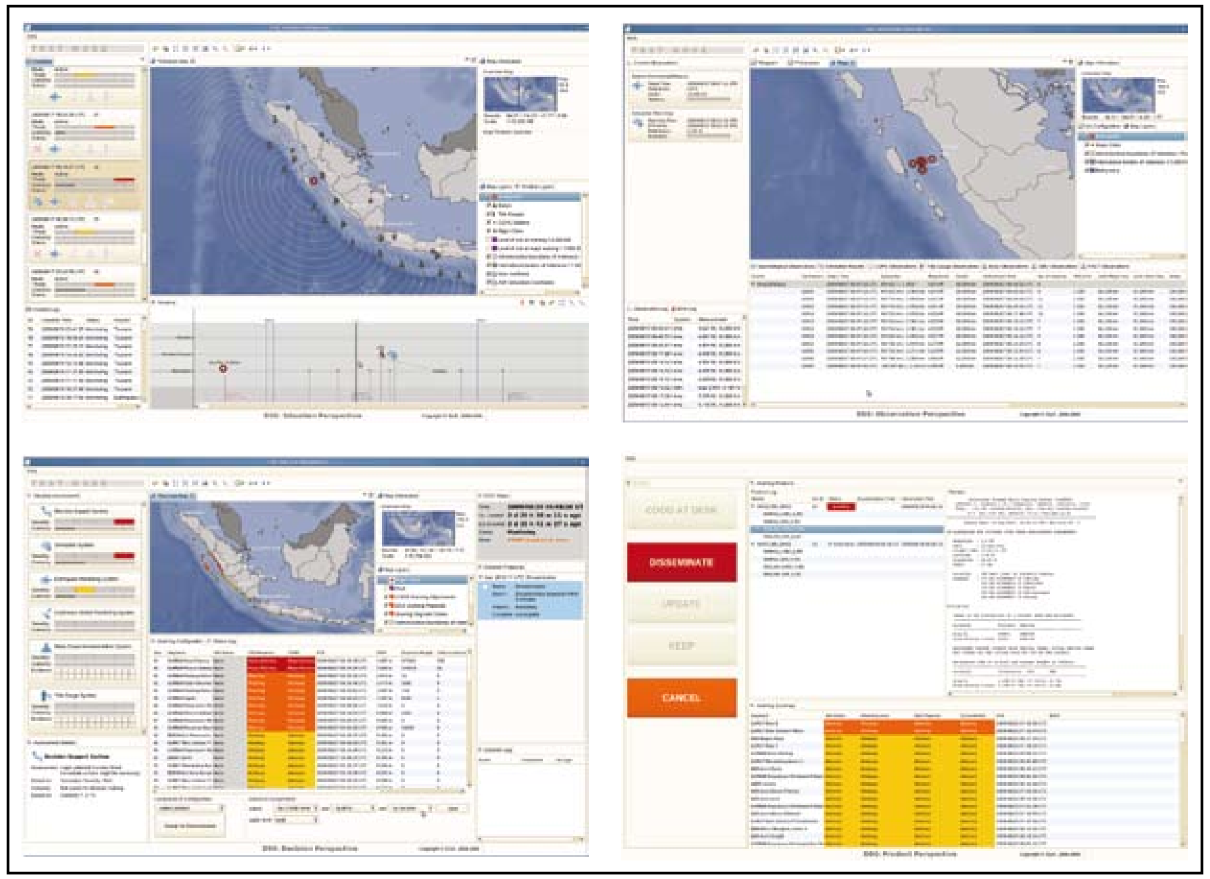

Fig. 6: *DSS Graphical User Interface (GUI) Perspectives. Four separate screens which can be used sequentially and/or iteratively by the operator to assess an event from situation overview to dissemination of the warning message contain all the relevant observations and the assessment of the DSS in support of an ease of use in a fast decision process (From upper to left to lower right these are: situation perspective, observation perspective, decision perspective and product dissemination perspective).*

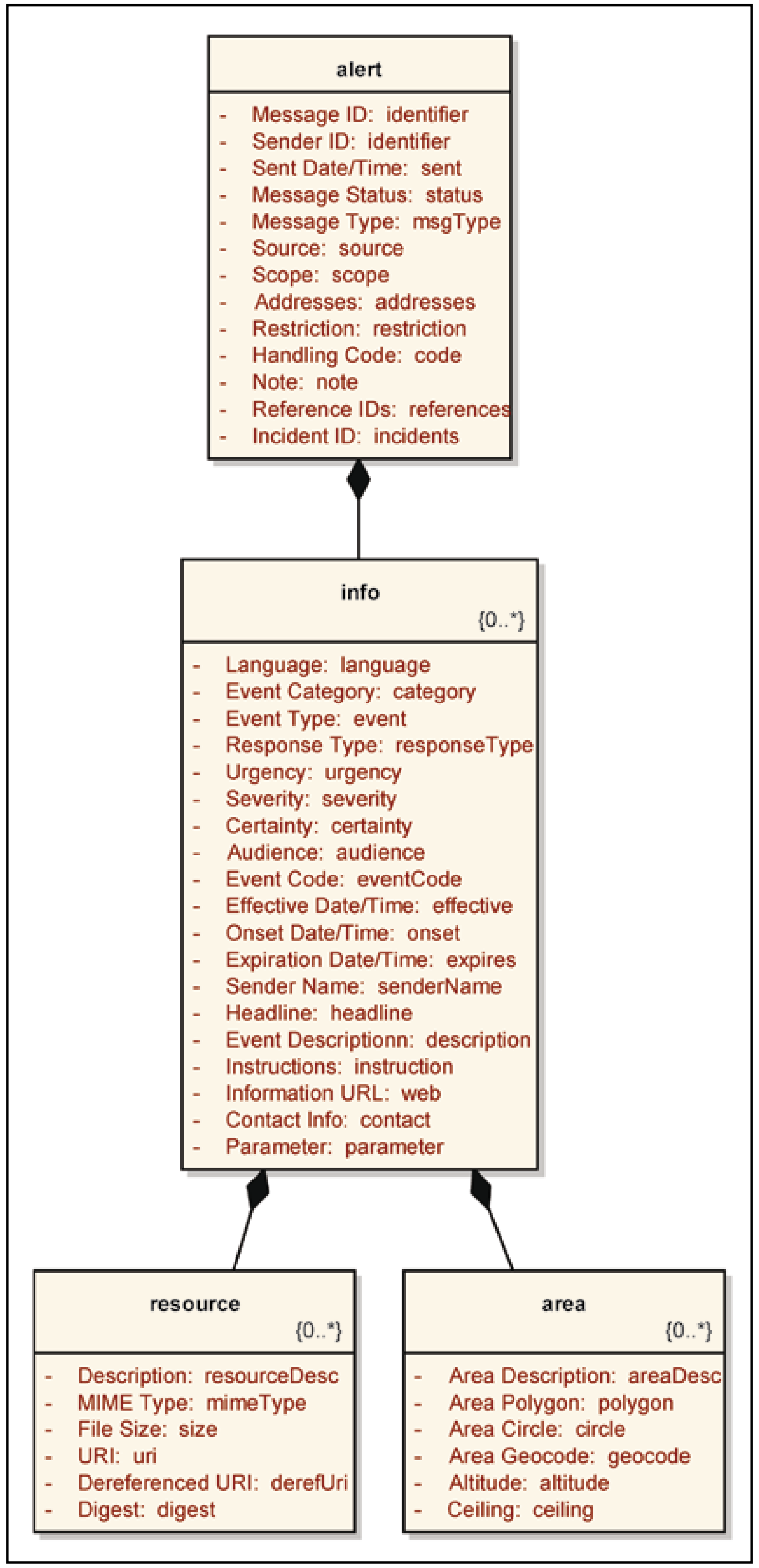

Fig. 7: *CAP message structure. External Resource URI: can be external map, audio file; area polygon could be definition of warning segment.*

MSB´s areas of work/expertise and how this could be connected to and used by the partners within the DEWS Project

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The Swedish Civil Contingencies Agency (MSB) was established on the 1st of January 2009. It replaced the Swedish Rescue Services Agency, the Swedish Emergency Management Agency and the Swedish National Board of Psychological Defence. As a new, consolidated authority, the MSB has a mandate and responsibility that covers all of the other previous agencies. Given this change, Peter Månsson presented an overview of MSB, but focussed on the course of actions it may take in the event of a tsunami.

The MSB is tasked to deal with national as well as international disasters and emergencies and its mandate spans the entire spectrum of threats and risks, from everyday accidents (i.e. traffic accidents, fires or even elders safety at home), up to chemical emergencies, power cuts and other technical failures all the way up to even more serious emergencies, such as bomb threats and other antagonistic attacks, epidemics, natural disasters and even war.

This all encompassing responsibility applies to measures taken before, during, and after the occurrence of emergencies, crises and disasters. Before crises, i.e. under normal conditions, the MSB works with preparation – training, education and exercises. It works with developing legislation and follows up on how different municipalities live up to regulations. The MSB also conducts research and develop technical tools and operational methods to deal with accidents and emergencies. After accidents, disasters or emergencies, the MSB will analyse the management (strategic and operational) of the situation in order to learn and develop through these experiences.

During emergencies, the MSB:s mandate varies depending on if it's a national or an international emergency. Nationally, the MSB has an important role coordinating across and between actors from various sector boundaries, but it has no operative role. The principles of proximity and responsibility applies, which means it is the local actors (i.e. municipalities) that carries the responsibility of dealing with disasters, whilst the MSB provide them with support (e.g. expert advice and materiel) in order for them to retain this responsibility. The MSB also briefs the Government on the consequences and management of ongoing major disasters. During this presentation I will focus on the international operations.

The term international operations can be misleading, however, because the word operation often makes one think about acute missions to save lives (i.e. response), whereas in fact our international operations are much wider than that. It is easier to use the term aid and to differentiate between humanitarian aid/relief and development aid operations.

The aims of humanitarian aid are often short-term and provide acute relief for people in distress following an armed conflict or a disaster. Development aid is a more long-term form of work that intends to develop a country's own capacities for managing crises.

Fig. 1: *Disaster management cycle*

The disaster management cycle

Disaster management comprises a number of phases which can be illustrated by a cycle. The cycle is a way of explaining what happen before, during and after a disaster. It is important to stress that the phases do not have clearly defined limits – phases overlap and vary in length due to the type of incident.

The response phase is characterised by rapid response operations to save lives and property. For example, this phase includes search & rescue, and evacuation of survivors, setting up temporary accommodation, and delivering necessities, provisions and water, to people in need.

The recovery/reconstruction phase, starts when the acute problems have been taken care of and the affected community can start functioning again. During this phase the reconstruction of infrastructure commences, as does the reestablishment of public services and planning for future needs.

The prevention phase is one part of the strengthening of a society's capacity to manage major emergencies. This is done by reducing or completely removing risks that can worsen the situation during a disaster. Community and building planning, the establishments of health and medical services and support for authorities are just some examples of measures that are taken during this phase.

The preparation phase can start early and aims to prepare a population for a possible major emergency. This is primarily achieved through training and exercises for medical personnel, emergency and rescue services, and other vital public services.

Given this brief overview on the emergency cycle – what does the MSB actually do in the field?

MSB´s areas of work
The different types of operations that the MSB currently has the capacity for can be summarised with a few headings. But each of these headings embraces a lot of different types of operations.

Support to other organisations in a disaster or conflict area can also be called indirect support. This means that the MSB for example provides specialists (electricians, telecom-technicians or water purification – experts) to UN or European Union operations (we have a big database with different kinds of specialists for these types of operations). The MSB might also build a base camp with temporary accommodation and workplaces for humanitarian aid-workers.

The MSB can also directly support victims and casualties. Health and medical care, sanitation, and water supply are elements of that type of support.

Another form of direct support is to ensure that there is accommodation for those made homeless and that they get the necessities and provisions they need. We can do this by providing tent camps and tent sites, early reconstruction/recovery work and transportation and distribution.

The mobilising and carrying out of SAR operations belong on the list of the most urgent operations carried out after a disaster.

Mine Action covers not only surveying and clearing of contaminated areas, but also education for the victimized people on how to avoid the dangers of mines.

The MSB also conducts capacity-building projects in the field of disaster management; and provides support for the recovery work needed for infrastructures that have been damaged by conflicts and natural disasters. The MSB works actively towards developing the capacities of poor countries so that they can better prevent and manage major disasters.

The Swedish Response Team (SRT) is a specifically trained operational team that can, at short notice, in the event of disasters overseas be dispatched to provide support for people usually resident in Sweden who have been affected by a disaster.

Fig. 2: MSB´s areas of work

In order to be on top of things, the MSB has a Duty officer, i.e. a man or a woman that always is prepared to pick up the phone and answer to calls from inside or outside the country. When he´s not on the phone he should be surveilling the news and information sights like, GDACS, Virtual Osocc and so forth to get a forewarning about big accidents or emergencies that may lead to requests of assistance by the MSB. Apart from international websites, MSB has developed an own tool to receive swift information, called Connect and Protect, which I will present to you soon.

***Fig. 3:** An inside of Connect and Protect*

But first, let us take a look on how international rescue services, like the MSB, may act during humanitarian relief operations? For the sake of this conference we take a fictive tsunami as an example.

The process of an aid operation
When a tsunami occurs, it is swiftly registered by the GDACS (The Global Disaster Alert and Coordination System) which provides near real-time alerts about natural disasters around the world. As a subscriber to the GDACS, MSB:s Duty Officer will instantly receive an alert notification that combines information on the event, the population in the affected area and the vulnerability of that population. MSB may in this instance start to prepare for incoming requests of assistance (e.g. identify existing resources that answers to presumable needs in the affected area) but will never act without such a request. A request of assistance may come from the UN, the EU or the stricken country directly. As a standard operation procedure, the UN and the EU rapidly (within hours) send assessment teams to the area in order to provide first-hand information on the disaster situation and priority needs of the victims. The team is composed of disaster management professionals who are nominated and funded by member governments (MSB often deploys personnel for such missions). Based on their information, the UN or the EU may send a specified request to member countries and ask them to assist in the relief operation.

Usually the assessment team enacts an OSOCC – On-Sight Operations Coordination Centre - with the purpose of assisting the local authorities of the affected country with the management of the disaster, in particular the coordination of international assistance (e.g. search and rescue teams). Together with local emergency management Authorities, the OSOCC will assess the need for and use of further international resources, register international relief teams and provides them with basic information about the situation, operations of national authorities and logistics arrangements. During an operation the MSB maintains close and regular contact with personnel in the field. A project manager is responsible for the communication with the field and works from the office in Sweden to facilitate the operation. The MSB also stand in close contact with other organisations active in the area that can facilitate the operation in various ways.

What MSB would do in the operation depends of course on the type of aid that is being requested. If it was an earthquake, fast response teams would definitely be sent out. Time is of the essence when searching for survivors after natural disasters. The MSB can send an urban search & rescue team (USAR) within ten hours of a request for assistance. The team con-

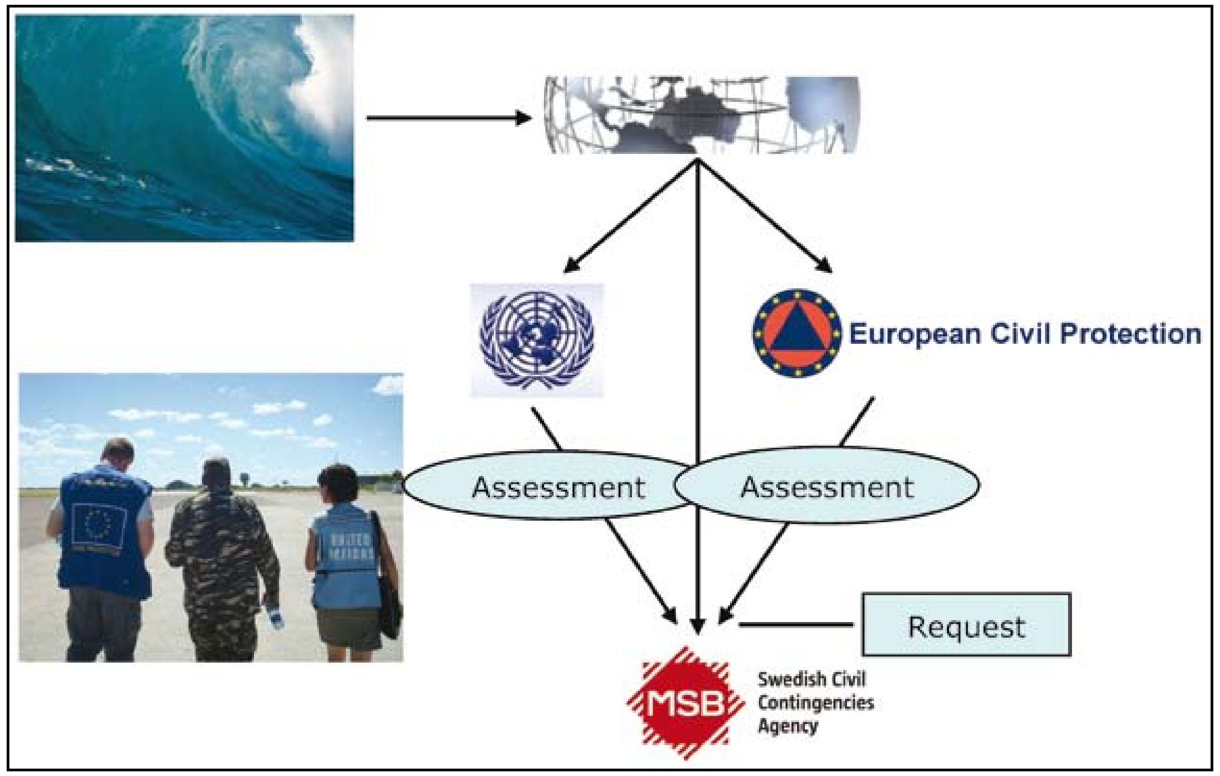

Fig. 4: *The process of an aid operation*

sists of up to 78 members and 12 dogs (incl. search cameras, listening equipment and medical resources). The team is self-sufficient for 10 days so as not to further burden the affected country.

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Fig. 5: *USAR-team in practice*

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The Swedish Response Team (SRT)
After the tsunami in 2004, the government in Sweden decided to establish a Crisis Management Centre within the Government Offices as well as a permanent consular stand-by team that can assist the Swedish embassy in the stricken country (to assist with passports and other travel documents). On top of this, 30 national agencies and 21 regional authorities were obliged to establish Duty officers so that they would be reachable 24 hours a day, every day of the year. A decision was also taken to build up a resource to provide support for Swedish residents in distress overseas due to emergency situations. The Swedish Response Team (SRT) consists of 171 members divided among three base units, which means that in theory at least, Sweden can send an SRT unit to three different emergencies simultaneously. The SRT contains priests, doctors, police officers, psychologists, and many other professions. Some of them are tasked to assess the needs for further deployment of resources by the MSB and others to assist with evacuation, crisis support and medical care for those affected.

In a situation where thousands of people have lost their homes or have been forced to flee, the opportunity to get some temporary accommodation can provide a greater chance of recovery. The MSB has experience from a number of missions of preparing and

Fig. 6: *The Swedish Response Team (SRT)*

setting up refugee camps and taking responsibility for transportation and the distribution of necessities. One goal in this kind of support is that the local population receives the training it needs to erect tents and even to meet the need for water, sanitation and electricity. This can also include education/training in first aid, nutrition and the spread of diseases.

Accommodation, provisions & necessities
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Health, sanitation, and medical care
A functioning medical service is vital if the MSB:s overseas operations are to function properly. Therefore there are always nurses or doctors on every large mission. For missions that require a more thorough level of medical care for operational personnel, the MSB can despatch a Medical Emergency Response Team. But this kind of medical support is provided for the humanitarian aid workers only and not for the victims of disasters. The MSB does however have the capacity to despatch medical personnel to carry out their own tasks.

Fig. 7: *Accommodation, provisions & necessities*

Fig. 8: *MERT – Medical Emergency Response Team*

Support to other organisations

The MSB has been involved in several missions where the main task has been to enact so called "base camps", which are temporary camps for personnel, for example, from the UN to live and work in. A base camp has all the necessary functions for a tolerable existence in a troubled area (sleeping spaces, working spaces, areas for toilets and sanitation, kitchens and dining areas and spaces for recreation can all be included). Around 150-200 humanitarian aid workers could be self-sufficient with regard to power, food and water. Thus the humanitarian aid workers will not be a further burden to the affected country.

The MSB can contribute towards capacity development with regard to the reconstruction of public buildings such as schools, hospitals, airport, roads, bridges, water systems and waste disposal. Capacity building contains of course more than infrastructural projects. For instance the MSB currently trains and supports the development of rescue services in Pakistan and Tadjikistan (urban search and rescue-projects).

Development of strategic and operational IT-tools

Some of the tasks of the MSB are to develop technical systems and tools for work on societal protection and emergency preparedness (both preventive – such as public warning systems - and operative systems in order to enhance cooperation between different actors once an accident has occurred). To

Fig. 9: *A base camp in Pakistan*

Fig. 10: *Secondment of experts*

Fig. 11: *Enacting temporary bridges*

Fig. 12: *Education and exercises with rescue services*

get a forewarning about big accidents or emergencies MSB uses the Connect and Protect, which has been developed in cooperation with the ESRI-group (a world leading research company and provider of Geographical Information Systems). It aggregates thousands of data sources online (e.g. on earthquakes, civil disturbances, terrorist incidents, weather, local traffic, crime statistics) and contains various real-time information sources (traffic cameras, notifications from alarm centres that immediately are disclosed on a map and news-feeds.

WIS is a national, Internet-based information system created to facilitate information sharing between players in the Swedish emergency management system before, during and after emergencies. With WIS,

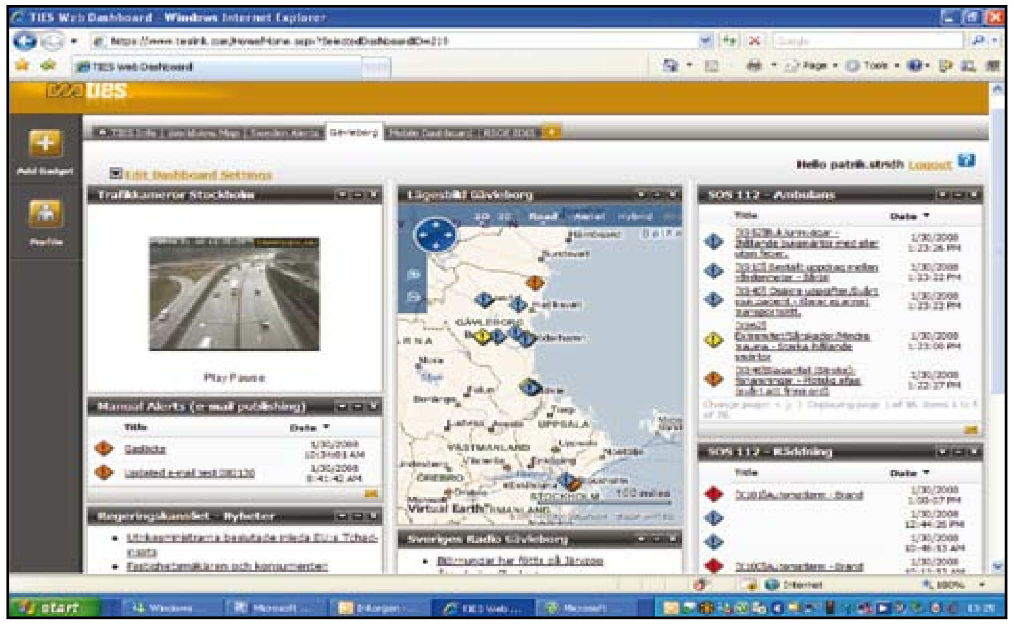

Fig. 13: *Picture from the inside of Connect and Protect*

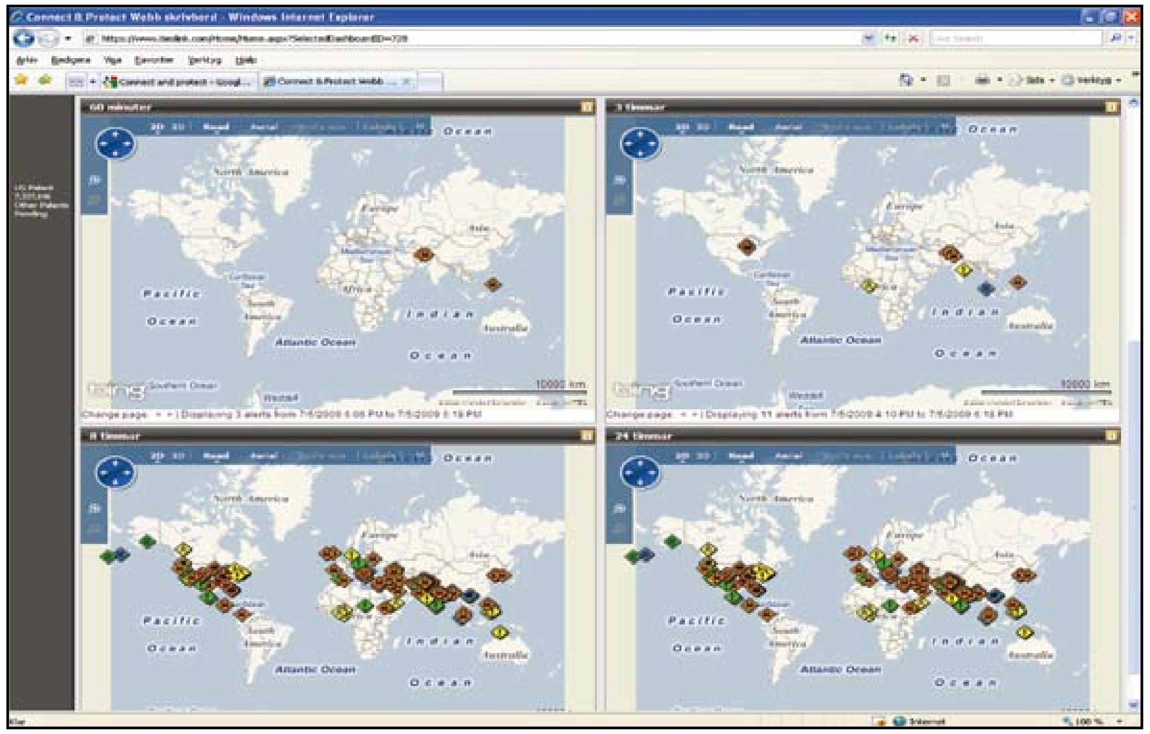

Fig. 14: Picture from the inside of Connect and Protect

various actors (on local, regional and national levels) can share management information with one another in journal form. When widely deployed, it creates the prerequisites for quickly obtaining comprehensive situational assessments during emergencies. In this way, WIS supports joint communication and situation awareness, that is the decision-making process, which enhances the possibilities of making wise decisions during an emergency.

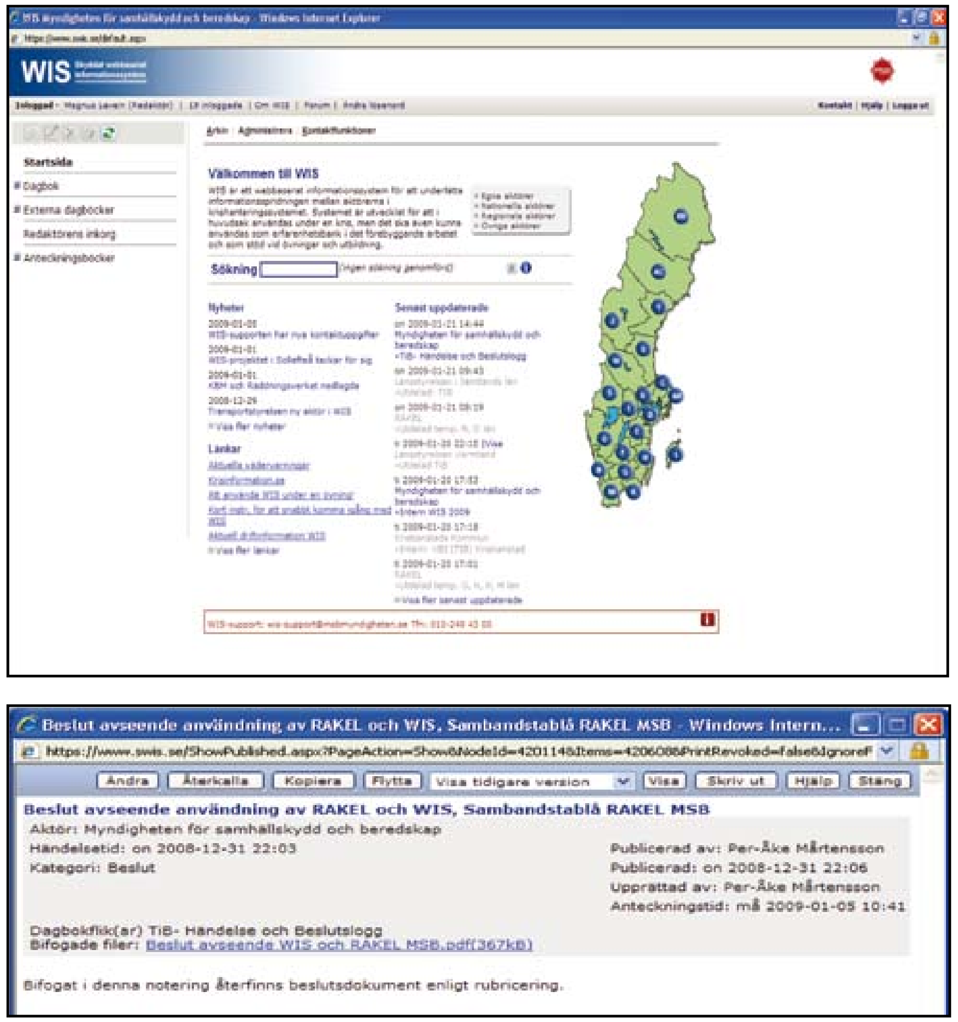

Fig. 15: Pictures from the inside of WIS, where you have the logbook and a journal sheet open, which ones uses to publish information about ones activities or decisions

The MSB also to provides a national website for emergency information, directed at the general public and the media. The purpose of the website is to describe how emergency management works in Sweden, and to explain the roles and responsibilities of various authorities in the event of an emergency. During an emergency, the site provides an overall view of events, FAQ:s and contact information to authorities who are stakeholders in the event. After the emergency, it summarises events and describes experiences gained.

these issues. During one of the presentations yesterday it was mentioned that "if one is building a system to deal with natural disasters, one should also have knowledge of how one deals with such disasters". During the course of the project the MSB is naturally willing to help by trying to answer any questions you – our partners – may have in this regard.

These days we have heard about and also witnessed the progress and substantial results that has emanated from the work put down. We seem to be pacing

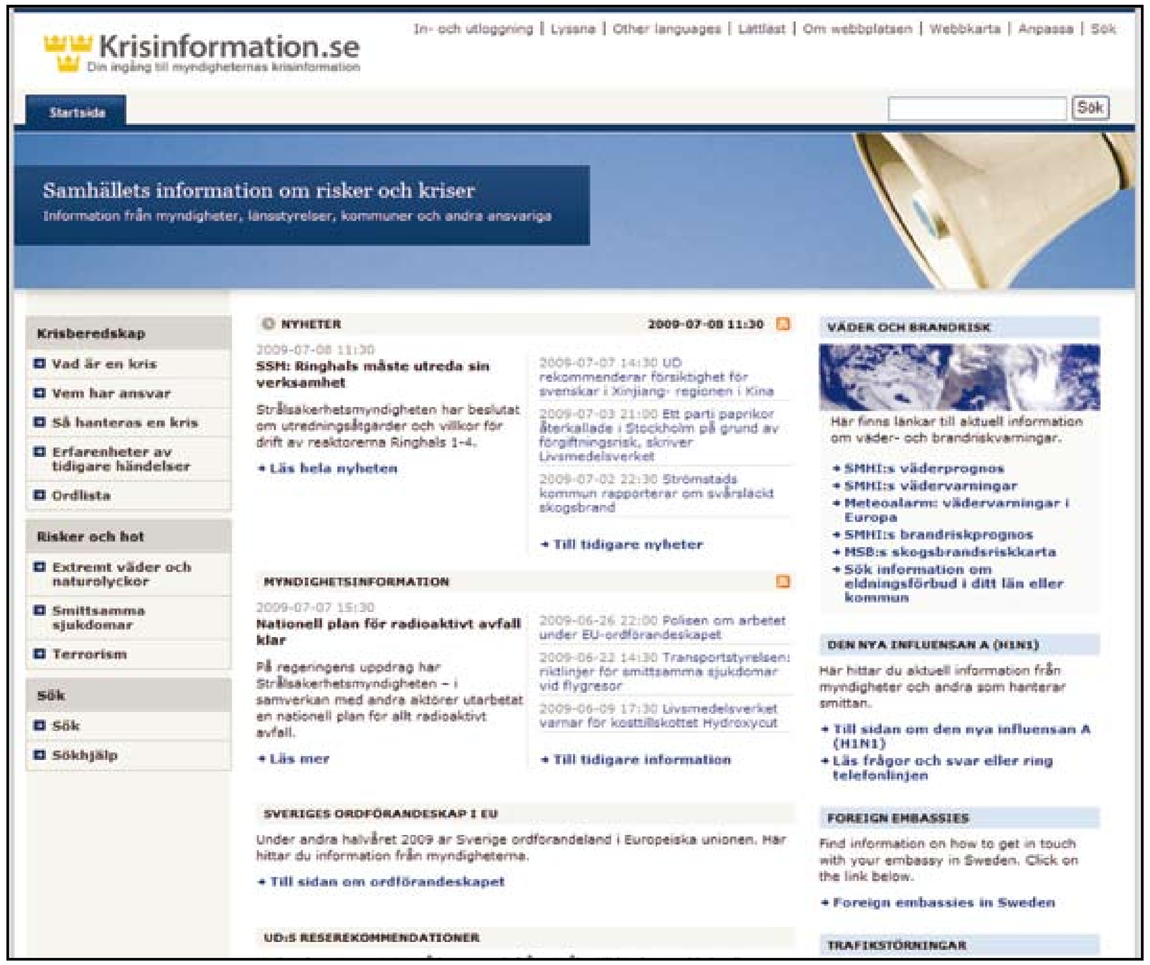

Fig. 16: Pictures from the national website for emergency information

Continuous contributions to the DEWS-project

During the DEWS-project MSB:s main obligations have been focused on the establishment of an end-user panel in order to gather information on the existing warning system structures as well as the operational needs of the DEWS-system. In order for the downstream part of the project to function in an optimal way it is nevertheless necessary to analyze the information chain between actors on the national, regional and local levels of society. Not only regarding how tsunami alarms are to be dispatched but also on information exchange on operational decisions and activities which different actors in the emergency system undertake in order to deal with the consequences of a tsunami. As shown, MSB has developed IT-tools for strategic information exchange and can also share experiences with the INCO-partners on well on the track of reaching the aims of the project. Nevertheless, an alarm system in itself – no matter how perfect it is – does not save lives. Lives are saved because we act upon information that can be delivered by alarm systems. And it is how we act in those situations that will determine how many lives are spared.

MSB has several projects going on in a number of countries that focuses on enhancing various disaster management capacities. In these projects MSB shares an aim with the other countries to have a joint development – a sharing of experience that leads to a transfer of know-how. Below I have listed some areas that I think could be interesting for the INCO-partners to look into:

- Identify shortcomings in given emergency systems and operative procedures
- Mass scale evacuations - exercises and making assessments and mappings of good assemble areas after evacuation and places for temporary accommodations. Prevention of accidents during mass scale evacuations.
- The reception and coordination of international assistance
- Urban and maritime Search and Rescue
- Provision on temporary shelters and bridges
- Water purification and sewage systems
- Waste management including building rubble

I am not saying that it is a “free smorgasbord”. MSB will not initiate projects unless a country has requested for assistance. And the projects must also be financed by an external part – and liked – or at least not disliked – by the government. But given that INCO-partners find an interest in a joint capacity building project, I would like to invite you to send in a request which hopefully will be a basis for launching such a project.

The more prepared we are the less severe will be the consequences of emergencies and crises. The first step towards a stable and robust society is to analyze the given systems and procedures that are in place today in order to detect vulnerabilities at different phases of an emergency cycle – from preparedness to response and recovery. These analyses must be done by the relevant actor/country themselves, but after having detected areas that needs to be developed, the MSB can be a partner that can contribute to achieving your goals.

Rescue Work and Coordination with the National Authorities in Thailand

Göran Schnell

The Swedish Fire Protection Association, SFPA, SE-11587 Stockholm, Sweden, goran.schnell@svbf.se

Göran Schnell has worked 35 years in the Municipal Civil Protection, served two years in Kosovo and equal time in the NATO headquarters in Brussels. There he worked with international disaster management coordination. Since 2003 Göran is the CEO of the Swedish Fire Protection Association.

Göran Schnell tells us about his personal experiences as the leader of the Swedish Rescue Services Agency in southern Thailand after the tsunami disaster on December 26, 2004. The story contains facts about the tsunami and its impacts, the cooperation between different actors during the occasionally chaotic rescue work, handling of deceased, the repatriation of survivors, heavy processes such as identification work, meetings with families of victims, official ceremonies and visits as well the robust Thai society. Mr. Schnell also underlines how important it was to be sensitive to those affected. Being present and showing compassion is essential in crisis management.

Scientific and Technical Poster Session

Leveraging Femtocells for Dissemination of Early Warning Messages

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Abstract
The timely, reliable and accurate dissemination of early warning messages to targeted recipients under a hazard risk is challenging operation. Of the existing telecommunications infrastructure, Public Land Mobile Networks (PLMN) are considered highly useful for dissemination of text-based warning messages, due to the high penetration of mobile services and ability to reach subscribers wherever there is network coverage. However, conventional macrocellular mobile networks are constrained by capacity and/or coverage, causing delay or non-delivery of warning messages. To that end, femtocellular networks, which provide capacity gains and ubiquitous indoor coverage, have emerged as an attractive solution that could complement macrocellular networks in disseminating warning messages. In this paper, we analyze the limitations of existing mobile networks for early warning dissemination, identify the benefits of leveraging femtocells for the purpose of disseminating early warning messages and highlight some possible implementation challenges.

Introduction
The main objective of any early warning system is to rapidly disseminate warning messages to specific individuals, communities or organizations in response to an imminent or oncoming hazard event (e.g. hurricane, coastal flooding, forest fire, nuclear fallout, etc.). The warning dissemination has to be executed in a manner that ensures that the message delivery is timely; the message content is accurate; understandable, and usable [GLANTZ (2003), WMO (2007)]. Therefore, all available broadcast (television, radio) and telecommunication infrastructure must be used to increase the likelihood of the warning message reaching all persons under risk and organizations expected to respond to a hazard scenario.

In recent times privatization and deregulation measures widely adopted within the telecommunications sector, resulting in, increased competition; higher efficiency; cutting-edge innovations; affordable services for users (thus increasing service penetration to hitherto unconnected citizens), and significant revenues for telecommunication service providers. As a result privately-owned telecommunication service providers are being relied upon to provide services, not just for the general public and the private sector customers, but also for government agencies and authorities. These services include both traditional (commercial) services and emergency services, such as, the early warning services addressed in this paper.

Public Land Mobile Networks (PLMN) are now considered one of the most important telecommunications infrastructures for delivery of messages originating from early warning systems. The high level of penetration of mobile handsets, subscriber mobility and the widespread adoption of mobile messaging services (in particular, the Short Message Service or SMS) make the PLMN attractive for mass dissemination of messages to targeted recipients.

However, conventional (macrocellular) PLMN are engineered to support busy hour traffic loads, rather than simultaneous messaging to a large user base, as required for early warning. As a result, warning messages delivered using mobile messaging services, such as SMS, may be excessively delayed or dropped altogether due to inadvertent network congestion or deliberate denial-of-service attacks [MENG (2007)]. Moreover, cost-constraints applied to network planning may lead to imperfect coverage, particularly in indoor environments. The methods employed to improve indoor coverage include the use of repeaters, distributed antenna systems, microcellular base stations (BSs), and the more recent femtocellular network concept [CHANDRASEKHAR (2008)].

Femtocells are characterized by simple, low cost, low transmission power and plug-and-play femto or home BSs, which are deployed indoors similar to WiFi access points. Another attractive feature of femtocells is the utilization of IP backhaul through a local broadband connection (e.g., digital subscriber lines, passive optical networks, cable modems etc.). This reduces the likelihood of congestion by avoiding possible traffic bottlenecks in macrocellular networks. Moreover, the offloading traffic from macrocellular networks to local broadband connections allows redirection of macrocell BS resources towards delivery of early warning or emergency call services to users in the area under risk but without femtocellular network coverage.

This paper presents the most significant and positive aspects of using femtocells as platform for dissemination of early warning messages. These benefits are emphasized further by pointing out the limitations in existing approaches. The possible implementation challenges for warning message delivery via femtocells are also highlighted.

Conventional Mobile Warning Message Dissemination

System Implementation

The diagram of Figure 1 illustrates the general configuration of the conventional mobile network networks dissemination of early warning messages. In this case, the message generated by the Early Warning Center (EWC) would be delivered to the mobile network via a component that we generally refer here to as the external messaging entity (EME). The EME transforms the warning messaging generated by the EWC (e.g., XML-based CAP message with image attachments) to a message format (e.g., 160 character SMS) suitable for delivery over the mobile network. The EME might be a client messaging application, voicemail server, mail server, third-party messaging gateway or any other entity capable of originating mobile messages.

Multimedia Broadcast Multicast Service, MBMS) and so on. The network's subscriber/equipment registers and location centers provide profile information and functionality that could be exploited for location-based messaging, allowing warning messages to be disseminated to particular geographical areas.

Limitations

1) Message delivery delay or non-delivery

The conventional PLMN was not originally conceived to offer broadcast-type mass text or multimedia messaging services. Therefore, attempts to disseminate messages over the network may result in excessive latency or even message non-delivery. Furthermore, limitations in network coverage may also result in message reaching certain target recipients over when they move back to areas with coverage. In an early warning use case, the any significant delay or failure in message delivery would imply failure of a EWS to meet its basic functional requirements.

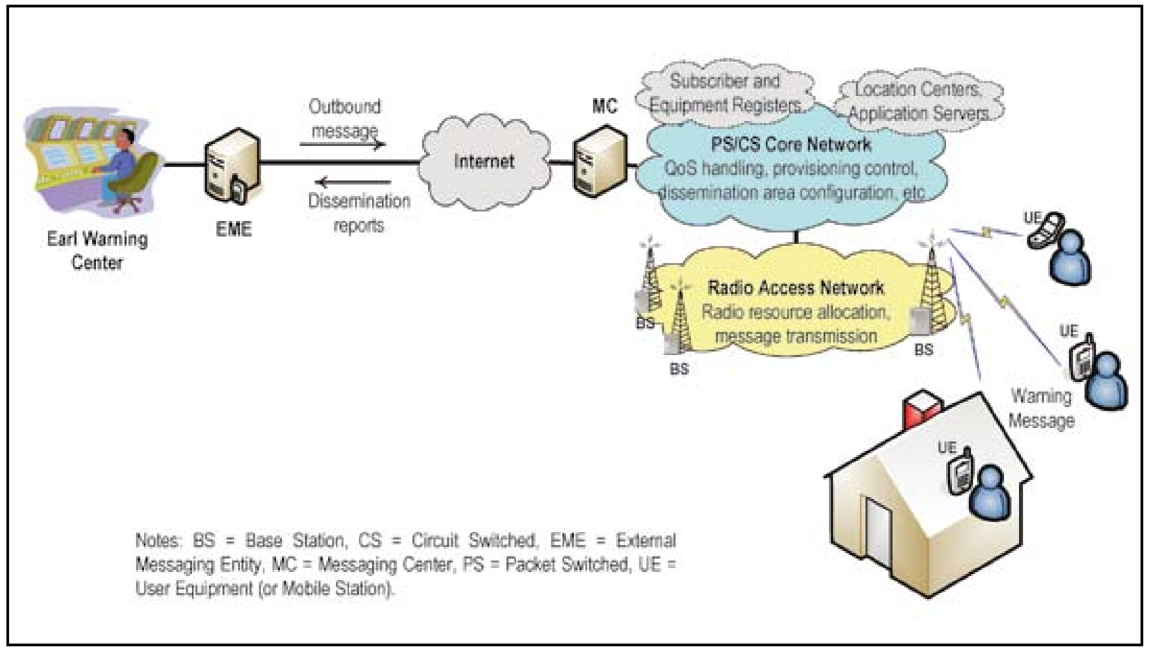

Fig. 1: *Simplified illustration of early warning dissemination via conventional mobile networks*

The EME submits the message to a mobile network's Messaging Center (MC) typically via a secure IP connection and access protocol (SMPP, CIMD2, UCP/EMI) selected by the MC vendor. The MC is a messaging server that authenticates the message originator, initiates and manages message delivery through the mobile network to Mobile Station (MS) or User Equipment (UE). Furthermore, the MC may inform the EME on the status (success, queued, failure due to invalid UE address, etc.). The EWC may request the status reports from the EME to monitor overall progress of warning dissemination process. Depending on the messaging scheme employed, the MC could be a SMS-SC or SMSC (for SMS), MMS-SC or MMSC (for Multimedia Messaging Service, MMS), CBC (for Cell Broadcast Service, CBS), BM-SC (for

Example measurements previously carried out in a live network on performance of SMS indicated an overall delivery failure ratio of 5% and delays in excess of 5 minutes for a tenth of the messages sent [MENG (2007)]. This performance could degraded significantly with the development of "flash-crowds," that cause significant increased in traffic intensity [MENG (2007)], for instance during a festive occasions. A similar phenomenon is observed when a sudden surge in call or message sending attempts congests networks in the immediate aftermath of a hazard event (e.g. severe network congestion observed after the 7/7 London Bombing [GLA (2006)]). This makes it difficult to send post-event instructional messages or further warning messages in case a follow-up to the hazard even it imminent.

2) Geographical targeting

Another significant challenge is the ability of the EWC to send SMS messages to a particular geographical areas deemed to be under risk. This is because the UE is a mobile (non-geographic) network endpoint that could be located anywhere within coverage area of the mobile network. Therefore, target message recipients (mobile subscribers) cannot be georeferenced at the EWC centre based solely on their address value (typically, the MSISDN).

The subscriber location information is available at the discretion of the mobile network operators. The operators are able detect geographical location (and optionally velocity) of UE based on positioning functions (measurement of radio signal and position computations) performed by UE (subscriber-based), network infrastructure (operator-based), or both. This subscriber location information (e.g., latitude/longitude, cell ID) is continuously updated in the network's subscriber registers (HLR/HSS, VLR, EIR, etc.) for purposes of billing, service marketing, service provisioning, fault resolution, service customization, transaction processing and so forth.

Cell Broadcasting

Cell Broadcast Service (CBS) is considered a viable alternative to SMS warning message dissemination [ETSI (2006)], as it uses a common broadcast channel to be broadcast text messages to all subscribers within a defined geographical cell broadcast area, comprising one or more cells. The EWC could specify the area under risk to the mobile operator using the standardized Universal Geographical Area Definition (GAD) [3GPP (2006)]. The operator would then translate the GAD into a radio coverage map to be used for defining the cell broadcast area. Furthermore, the use of a common broadcast channel in CBS means that message non-delivery due network congestion could be avoided and the message sending could be repeated periodically.

However, current the CBS service has several limitations:

- Can send only text-based messages of a limited length (15-93 characters);
- Some user devices are shipped without basic CBS capabilities;
- Some CBS-capable user devices may have to be enabled and configured to listen-in (opt-in) on the broadcast channel(s) reserved for emergencies;
- There are no acknowledgements from UE for successful message delivery;
- The cell size resolution is poor, particularly in rural areas where macrocell diameter could be 10s of km, making CBS impractical for sending warning to smaller areas under risk (see Figure 2);
- Lack of significant commercial interest in CBS has meant slow development of technologies for CBS enhancement and low motivation for some operators to enable the service in their networks.

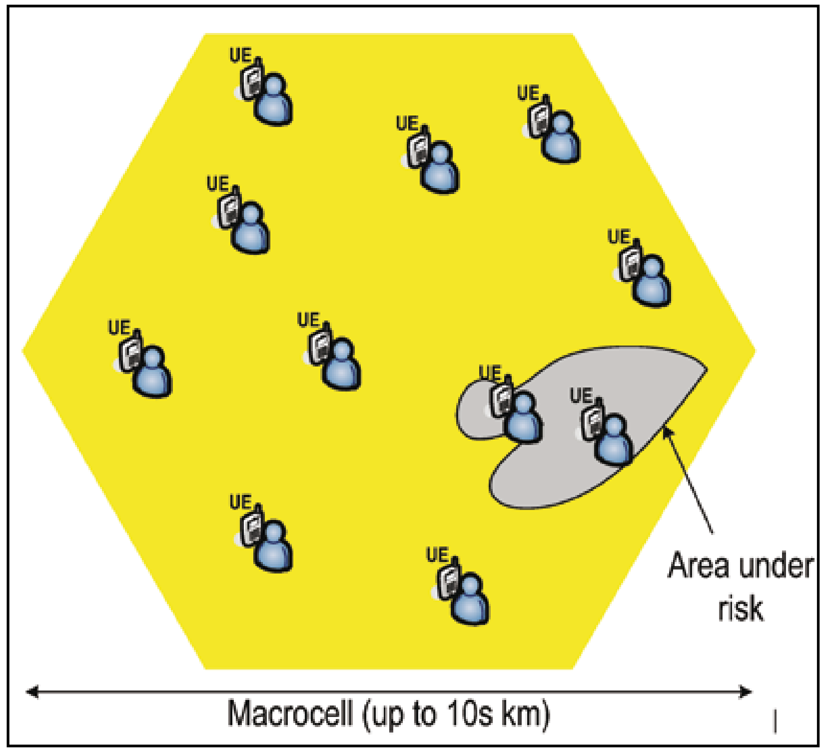

Fig. 2: *Macrocellular coverage exceeding size of area under risk. With CBS even UE outside risk area receive warnings.*

Using Femtocells for Message Dissemination

Femtocell Concept

Recently, indoor solution based on femtocellular networks has been proposed in order to provide ubiquitous coverage for in-building communications

Parameter	Specifications
System Capacity	1Carrier / Omni
Traffic Channel	Up to 4 simultaneous users
Air Interface	WCDMA / HSPA
Frequency (Hz)	2.1GHz
RF Output	Up to 20mW
Input Power	100~240VAC
Network Interface	10/100 Base-T Ethernet
Volume	1.4 Liters
Weight	600g
Operating Temperature	0°C to 45°C
Dimension	185 x 210 x 36 mm (HWD)

Samsung HSPA UbiCell™

Fig. 3: *Example of a commercially available femto BS device*

[CHANDRASEKHAR (2008)]. The primary advantages of femtocellular networks are that they consist of inexpensive femto Base Station (BS) units (see example of Figure 3), installation of the network follows a plug-and-play approach, and the femto BS transmission power levels are several decibels lower relative to handheld terminals.

One unique characteristic of the femto BS approach is that the CPE can be deployed autonomously in a private or business customer premises by a user in much the same way as digital subscriber line (DSL) modems. The femto BS equipment can potentially be owned by user, and configured to closed access. Then it only provides access to a restricted group of users, e.g., family or household members who form the so-called Closed Subscriber Group (CSG). If CSG is not used, femtocell allows open access to all subscribers of the operator. The femto BS is connected to the femtocellular gateway (femto GW) of the operator. In turn, this gateway services up to hundreds of femto BS units, which forwards the data to operator network or Internet.

Benefits of using Femtocells for Warning Message Dissemination

Figure 4 shows the architecture of the EWS with femtocell. We note that it is foreseen that strong interest of large mobile operators towards femto BS concept will drive the mass deployment of femtocells.

From a EWS perspective, the following aspects are especially interesting:

(a). Femtocells provide potential means to omit the congestion in wide area cellular network while broadcasting warning messages. Yet, this property may put some additional requirements on the architecture of femtocellular networks.

(b). Femtocells offer finer cell size granularity typically in terms of 10s of meters (see Figure 5) compared to 10s of km for macrocells (see Figure 2). This enables warning message dissemination to be more precisely targeted even to the small geographical areas covered by femtocells. We also note that CSG can be disabled if there is a need to broadcast warning messages to all terminals within the coverage area of the femto BS.

(c). It is an option to require that privately owned femtocells can be switched on remotely by operator in case of request from public authorities or emergency response organizations.

(d). Femto GW maintains the so-called neighbor list of femto BSs, that is, it knows the identities of the closest neighbors of each femto BS, operated by the same operator.

(e). Operator can potentially reconfigure both open and closed access femto BSs so that, for instance, transmission power is increased in order to maximize the broadcasting coverage. On the other hand, in case of misuse or other fraudulent practices (e.g., sending spam messages or hoax warnings), operator can choose to disable a rogue femto BS.

(f). Femtocellular networks provide at least an order of magnitude improvement in capacity compared to purely macrocellular network implementation [CHANDRASEKHAR (2008)]. This capacity gain enables efficient dissemination of rich multimedia warning messages using MMS instead of SMS or MBMS instead of CBS. The SMS and CBS lightweight messages only offer very brief textual information to the recipient, thus obliging the recipient to check alternative information sources (TV, radio, web bulletins, etc.) for supplementary details on the warning. On the other hand, multimedia warning messages may include maps, pictures, audio or video clips, and so on, with self-sufficient details (see examples of Figure 6).

Concluding Discussions

Conclusions

Femtocellular networks promise to be a competitive technology solution for future mobile broadband networks. This paper described how the benefits and features of femtocells could be leveraged for dissemination of early warning messages by a EWS, creating the possibility of sending rich multimedia messages with more comprehensive details, targeting relatively small geographical areas and relieving congestion from macrocellular networks.

Recent technical studies, laboratory trials, early product development and standardization activities on beyond 3G femtocells, in the form of Long Term Evolution (LTE) Home eNodeB [SIEDEL (2008)] and WiMAX Femto Access Points [YEH (2008)], indicate that equipment manufacturers and operators are already addressing the challenges of evolving the femtocellular networking concept. These advances could offer even more benefits not only for early warning, but for emergency telecommunications in general.

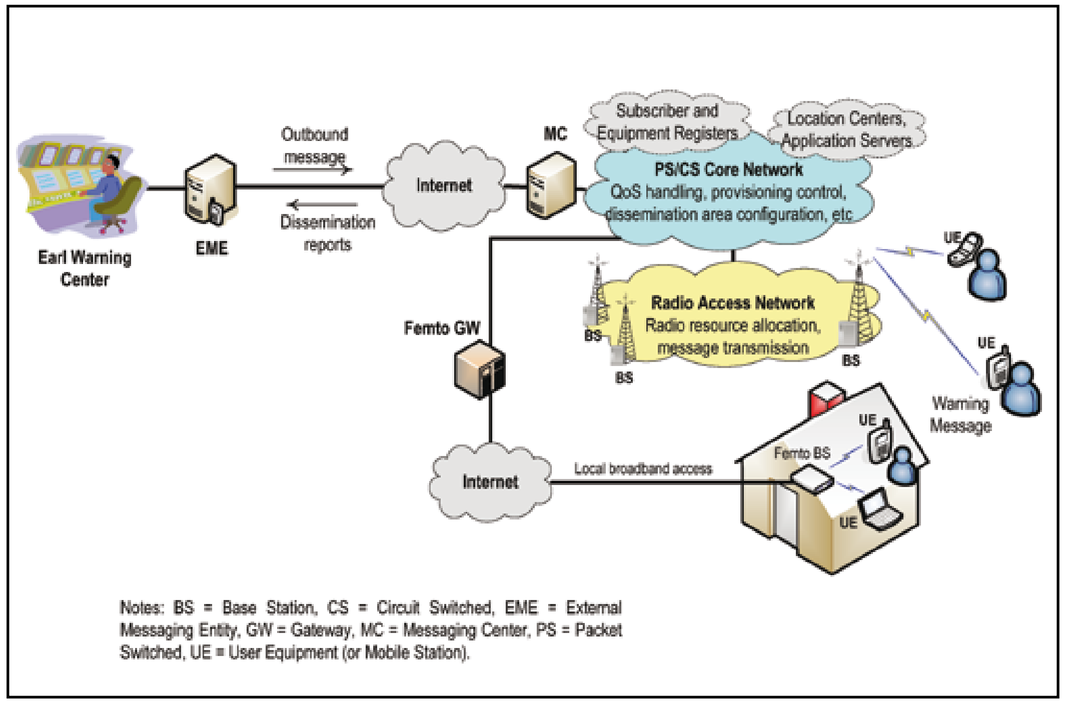

Fig. 4: *Simplified illustration of early warning dissemination via conventional and femtocellular networks*

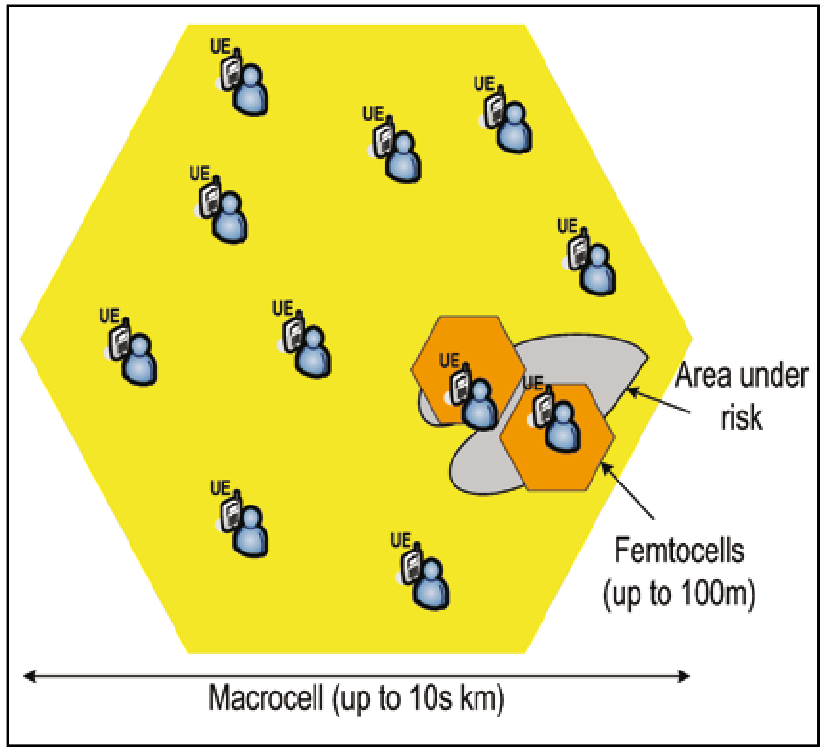

Fig. 5: *Smaller femtocellular coverage areas enabling more precise broadcast of warnings to areas under risk*

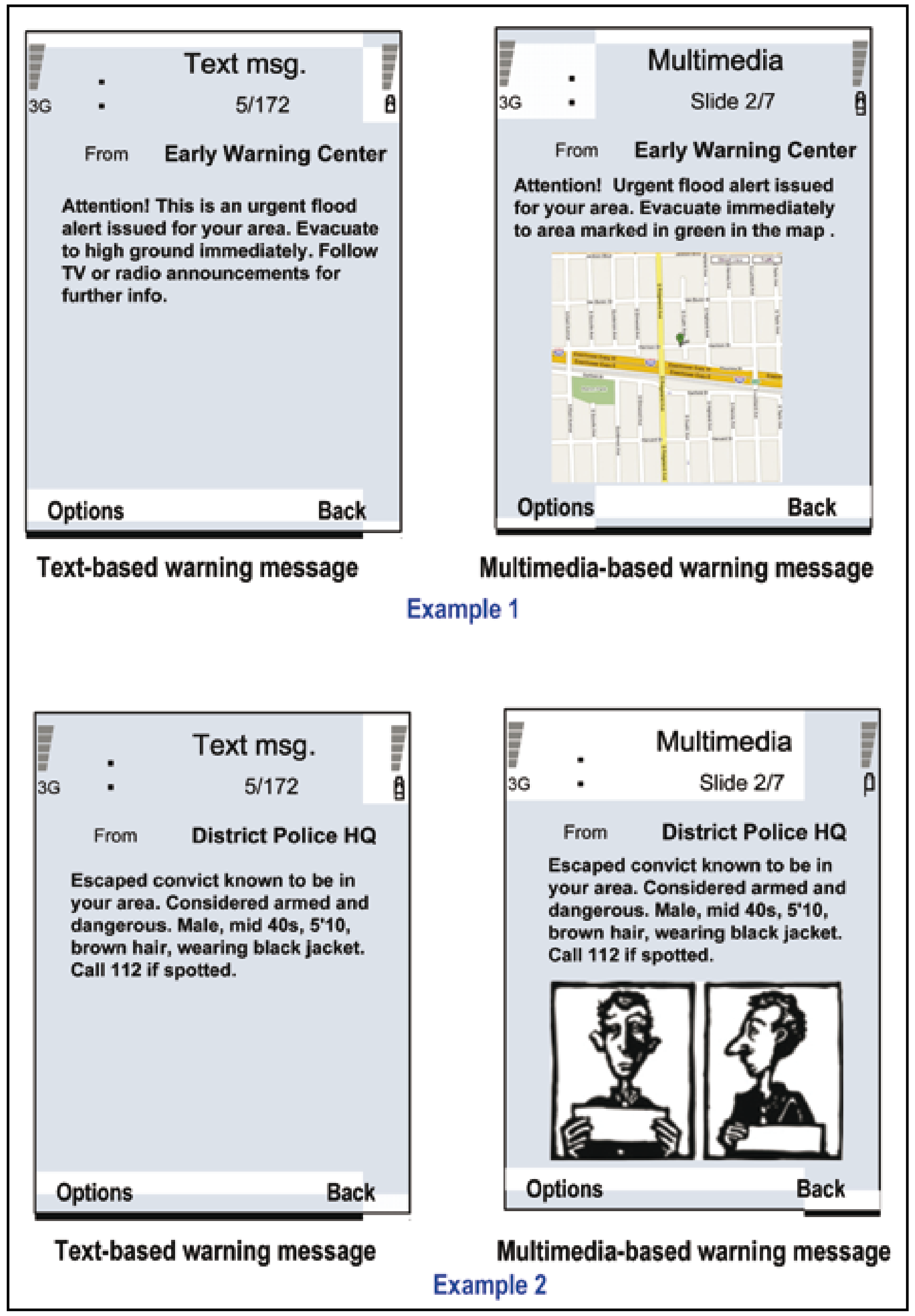

Fig. 6: *Example enhancement in early warning information offered by multimedia messaging*

Future Research Challenges

The development of the femtocell concept has been ongoing for just a few years and first versions of pre-standards femto BS have only recently reached the markets. While the business prospects of femtocells for residential markets have been the main driver for the femtocell development work, emergency telecommunications and other potential services for public authorities have not been considered in great detail at this stage of the development. Therefore, emergency response organizations and public authorities need to be made aware of the progress and potential new opportunities provided by femtocells.

On technical side the implementation of early warning systems through femtocells will be challenging because currently vendor-specific architectures and protocol solutions are applied. Furthermore, the requirement to temporary open-up closed access femtocells for early warning message dissemination purposes, presents many macrocell-to-femtocell interworking research questions (interference mitigation, handover mechanisms, spectrum allocation, dimensioning of IP backhaul capacity to accommodate macrocellular users, etc.) that need to be addressed. Therefore, detailed system simulation studies and market analysis (to evaluate various market penetration scenarios for femtocells) will are required to fully understand the immediate and future potential impacts of femtocell deployments for early warning purposes.

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Tsunami hazard assessment and early warning systems for the North East Atlantic

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NE Atlantic tsunami hazard – summary of the tsunamigenic source potential

Potential tsunamigenic sources in the North East Atlantic (NEA) are assessed for a first screening of regional tsunami hazard. The study is performed within the framework of the EU project TRANSFER (Tsunami Risk And Strategies for the European Region). Both near-field and far-field sources are considered. An overview of past tsunami events in the region is revealed in Figure 1.

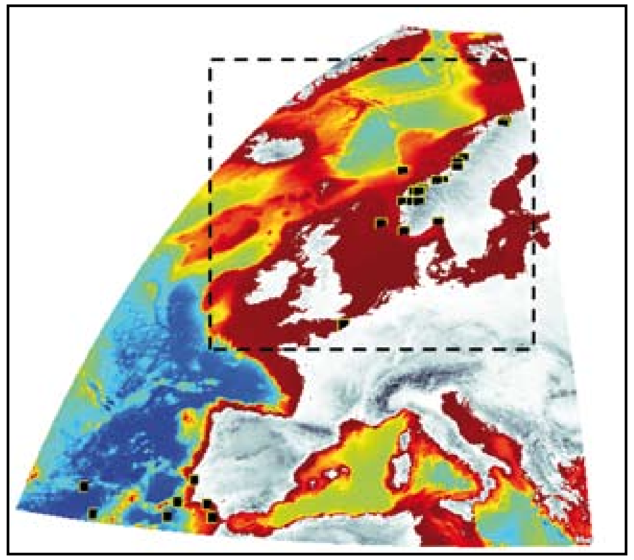

***Fig. 1:** Past tsunami events with relevance for the NEA region. From the EU GITEC-TRANSFER tsunami catalogue.*

Based on modelling and evaluation of the corresponding tsunami scenarios (in parts elaborated below), potential rock slides located in the fjords of Western Norway are considered the only high risk tsunamigenic sources in NEA (the fjords in Greenland are not investigated). Submarine landslides off the Norwegian continental margin, rock slides in Northern Norway, as well as earthquakes off the Portuguese coastline are identified as sources constituting moderate tsunami hazard.

Tsunamigenic earthquakes in the North Sea, the Norwegian Continental Margin, and the Norwegian-Greenland Sea are considered non-critical as the intraplate seismicity is low-to-intermediate, the active spreading zone does not produce tsunamigenic earthquakes, and there are few historical earthquakes above Mw6 (Bungum and Lindholm, 2007). Also the Jan Mayen and Iceland volcanic sources, the landslide sources north of Svalbard as well as the Grand Banks, Canary Islands, Cape Verde, and Caribbean far-field sources are considered non-critical with regard to tsunami hazard in NEA. It should be noted that a proper classification of the tsunamigenic potential of the continental margins surrounding the northern North Atlantic and Arctic Ocean is difficult to assess, as important segments of these margins are not mapped in sufficient detail. This is particularly the case for the margins of the Arctic Ocean, but also for parts of the margins of Iceland, Greenland and Svalbard, and to a lesser degree the Barents Sea margin and some areas off Norway.

Rock slide tsunami studies

There are several historic records of catastrophic rock slide tsunamis in Norwegian fjords and lakes (cf. e.g. the EU GITEC-TRANSFER tsunami catalogue, Figure 1).

Potential Aknes rock slide tsunami

In the inner part of Storfjorden, Western Norway, an unstable rock slope is detected at Aknes, Figure 2. The fracture 800 m.a.s.l. opens with a rate of 7-20 cm/year. To gain information about probable rock slide velocities and flow depths, different numerical rock slide models have been applied and compared. The tsunami simulations are based on the Boussinesq equations (including the effects of both dispersion and non-linearity) for the generation (with input from the rock slide models) and propagation, Figure

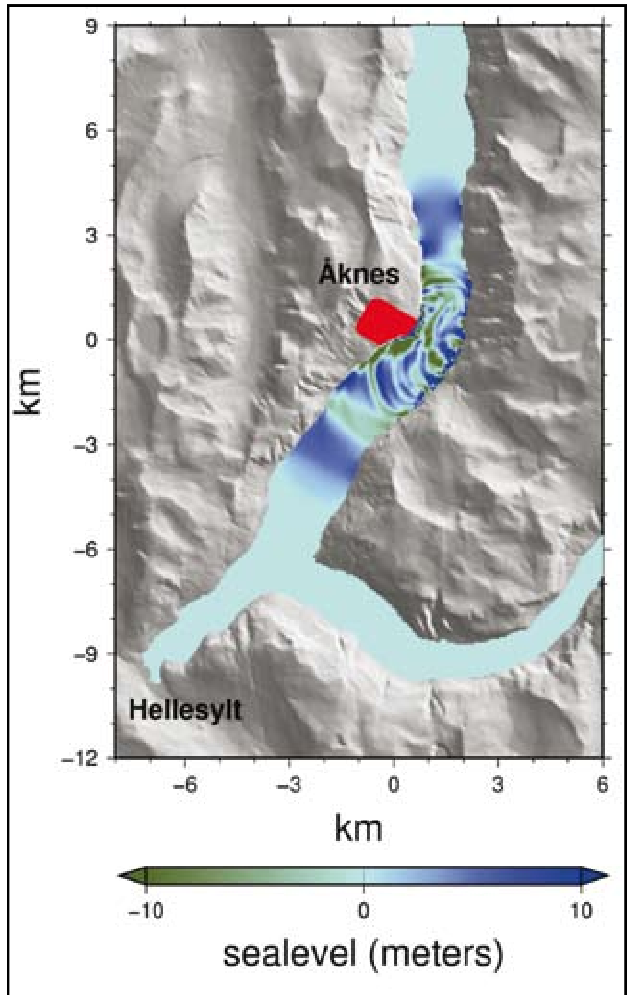

***Fig. 2:** Wave propagation in Storfjorden 90 s after release of a 35 Mm3 rock slide at Aknes (red area).*

2, and finally nested (one way) with the run-up model ComMIT (Løvholt et al., in press; NOAA, 2009).

The ongoing investigation includes simulations of altogether twelve potential scenarios and historical events located at Aknes and elsewhere in the same fjord system. The historical events are included to put the efforts into a proper historical context and applied for model comparison. In addition to numerical simulations, both the two-dimensional laboratory experiments performed at the Hydrodynamics Laboratory, University of Oslo, and the three-dimensional laboratory experiments performed in the 1:500 scale model at the Coast and Harbour Research Laboratory, SINTEF, Trondheim, have provided useful input for the numerical modelling as well as data for verification of the numerical model setup. As a preliminary conclusion, the results indicate that the dispersive long wave model is capable of modelling the generation phase fairly accurate.

Example of a run-up calculation for a 35 Mm3 rock slide tsunami scenario at Hellesylt is shown in Figure 3. The resolutions applied for the nested grids are varying from 5 m to 40 m. The surface elevation in the fjord prior to amplification of the wave is about 5 m while the maximum inundation height is about 20 m. Comparisons with other run-up models are also performed. For further details and results, see NGI (2008a; in prep.).

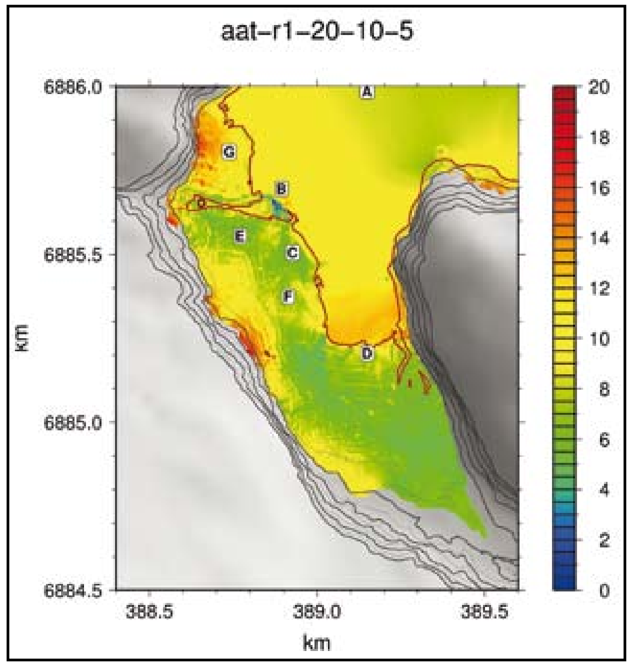

***Fig. 3:** Maximal surface elevation (m) of the 35 Mm3 scenario at Hellesylt. The shoreline at equilibrium is represented by the red line.*

Run-up heights as described above may be disastrous for the inhabitants. Moreover, in the summer time thousands of tourists visit this fjord system. Hence, an early warning system is established based on the fact that large rock slides give many pre-failure signals. The rock slope is monitored by rod extensometers, GPS systems, instrumented boreholes, laser technology, radars, a seismic network of geophones, an automated total station with 30 prisms, a weather station, and web cameras. When motions in the rock slope pass certain threshold values, warnings are disseminated by air horns and cell phones. The mitigation measures further include evacuation plans, routes, and drills. The awareness of the people is ensured by comprehensive information and education, see http://www.aknes-tafjord.no

Three different aproachs have been used to assess the risk associated with the potential Aknes rock slide. Eidsvig et al. (in press) apply a simple and practical method for estimating the risk due to a potential tsunamigenic rock slide, by assessing quantitatively hazard, vulnerability, and elements at risk. The proposed method introduces empirical relations between the risk components and illustrates the uncertainty propagation through the steps in the risk analysis. The risk assessment considered two hazard conditions: One based on historical data, and another based on the expert's beliefs for the slope stability (site dependent).

Eidsvig and Medina-Cetina (2008) followed an approach based on Bayesian Network (Medina-Cetina and Nadim, 2008), which introduces the notion of casual effects. An important feature of the Bayesian

Network approach is the capacity to back-propagate evidence to generate a diagnosis based on current evidence. Diagnosis analysis results for prescribed risks could be a useful tool during operation of an early warning system.

Finally, Lacasse et al. (2008) describe risk assessment by event tree analysis. The event tree analysis approach is especially useful for geo¬tech¬nical problems that involve large uncertainties. The probability of occurrence and the risk were obtained through a consolida¬tion of all the branches of the event tree.

Potential Nordnes rock slide tsunami
In the fjord Lyngen, located in Troms county, Northern Norway, an unstable mountain side is detected at Nordnes. The potential rock slide is located 7 km away from the village Lyngseidet on the opposite side of the fjord, see Figure 4.

Simulations of the generation and propagation of the tsunami for two scenarios are performed using a linear hydrostatic model, as well as a finite element Boussinesq model. The run-up estimations are based on empirical data for the amplification factors from laboratory experiments. The result for the largest scenario (11 Mm3) is shown in Figure 4. The surface elevation outside the rock slide area is above 60 m. The amplitude is reduced over the shallow submarine ridge outside Lyngseidet due to wave breaking. The run-up for the largest scenario is estimated to be in the range of 25-45 m at Lyngseidet. A breaking feature in the Boussinesq model is included by adding a diffusion term to the equations (Glimsdal et al., 2007). For more results and details, see NGI (2008b).

Potential Stampa rock slide tsunami
Near the village Flam located in Sognefjorden, Western Norway, a huge potential rock slide is observed. The total volume may be of order 100 Mm3 and potential rock slides will impact the fjord only 1 km from the village Flam and 4 km from the village Aurlandsvangen. Minor damping due to radial spread in a narrow fjord system will cause large waves also far from the location of the impact.

Simulations of the generation, propagation, and run-up for three potential scenarios (0.2, 5, and 40 Mm3) are performed. The run-up at Flam is calculated to be in the range 3-4 m for the smallest scenario while the largest may give a run-up of 40-80 m, Figure 5. For the generation and propagation we have applied the Boussinesq type GloBouss model (Pedersen and Løvholt, 2008; Løvholt et al., 2008; Løvholt et al., in press). The run-up calculation is performed with the ComMIT model.

Investigations in order to stabilize the largest scenarios by rock slope pore water drainage are underway. For the smallest scenario, there is no such cure,

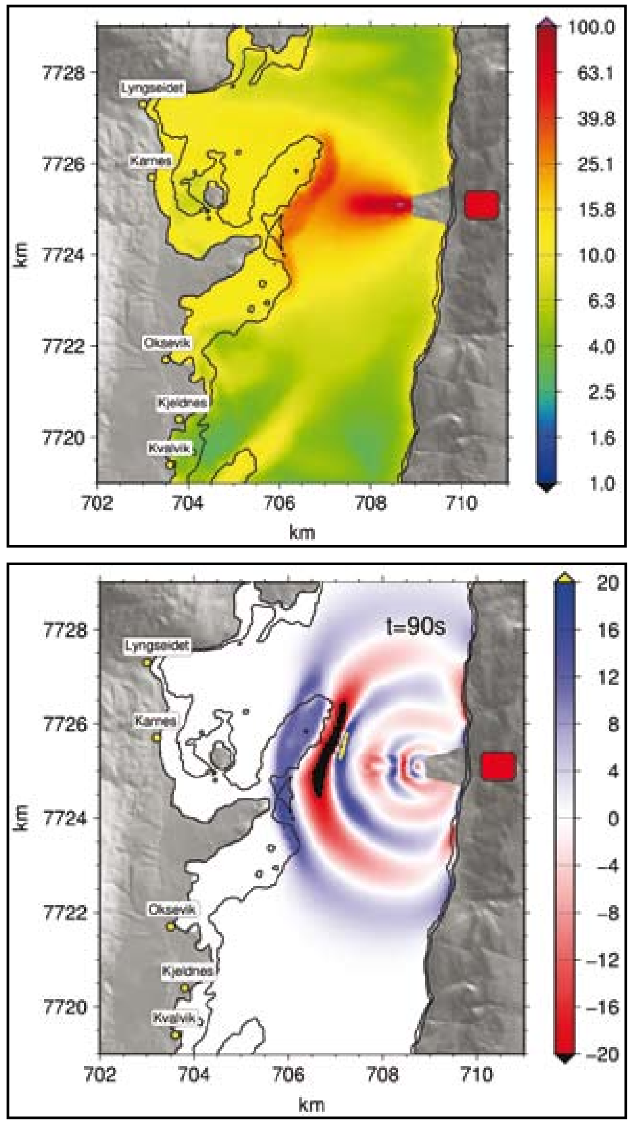

Fig. 4: *Upper panel: Maximum surface elevation (m) between the village Lyngseidet and the rock slide area (red box). Lower panel: Surface elevation (m) 90 s after rock slide release (lower panel). Both panels show results for the largest scenario with a volume of 11 Mm3. The shoreline and the 20 m depth contour line are plotted.*

but potential waves may be handled by appropriate structural design of the buildings and infrastructure close to the shoreline. For more details and results, see NGI (2009).

Submarine landslide tsunami studies
Potential North Sea Fan landslide tsunamis
The North Sea Fan is the location of several landslides that contribute to the Storegga Slide complex. The 8200 BP Storegga Slide itself did not encroach much on the fan, but older landslides with dimensions in the same order of magnitude as the Storegga Slide have occurred there during previous interglacial periods over the last 500 kyrs (Solheim et al. 2005). The rapid deposition on the North Sea Fan potentially builds up quite high pore pressures. Some concern that new landslides may develop in the area therefore led to the initiation of a study of slope stability and the area's tsunamigenic potential. The main findings are that the pore pressures have been dissipating since the ice age and the stability of the slopes is generally good.

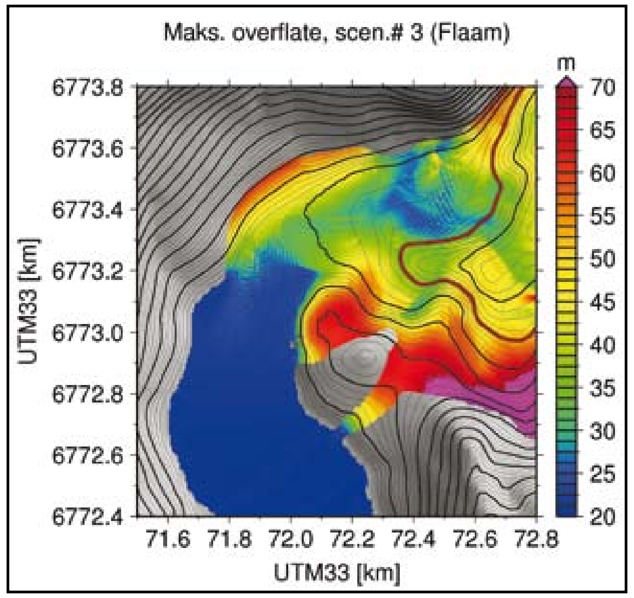

Fig. 5: *The maximum surface elevation (m) during run-up in Flam for the largest scenario. The shoreline is coloured red and the equidistance for the thickest contours is 20 m. Pink colour is elevation above 70 m.*

Preliminary numerical simulations of the tsunamis generated by different submarine landslide scenarios on the North Sea Fan are extended with various landslide and tsunami models. An example of a tsunami generated by a 300 km3 landslide with a maximum velocity of 16 m/s and a run-out distance of 100 km is presented in Figure 6. The tsunami scenarios have much smaller volumes (and maximum velocities) than the Storegga Slide, and therefore give correspondingly smaller waves.

Tsunamis generated by potential North Sea Fan landslides further appear to have only somewhat smaller impact on coastal areas than the scenarios discussed for the Storegga/Ormen Lange area (Løvholt et al., 2005), due to larger generation depths (which yields relatively smaller Froude numbers) and larger distance from the source to the coastline (more radial spread). The effect of dispersion and non-linearity is small. To improve the understanding of the landslide dynamics and the corresponding effect of the generated tsunami, the problem has to be revisited, among others due to a discrepancy in the maximum velocity in the landslide models.

The 8200 BP Storegga Slide and potential for large scale tsunamigenic landslides in the Storegga/Ormen Lange area

Combinations of landslide morphology, dating, tsunami modelling, and paleotsunami data provide solid understanding of the tsunami generated by the 8200 BP Storegga Slide (Bondevik et al., 2005). However,

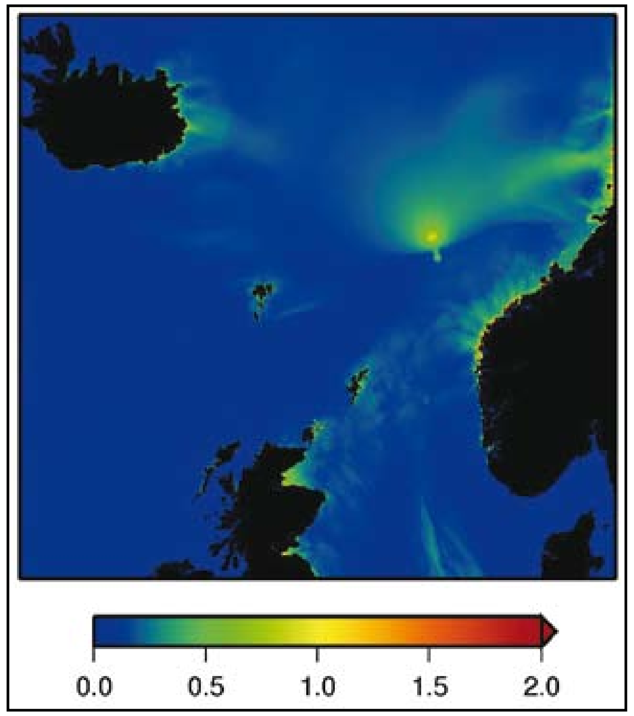

Fig. 6: *Maximum surface elevation (m) for a potential 300 km3 North Sea Fan landslide tsunami with a maximum velocity of 16 m/s and a run-out distance of 100 km.*

a new glacial period causing sedimentation and weak layers followed by isostatic landlift and earthquakes is required to trigger new landslides large enough to produce a damaging tsunami (Bryn et al., 2005).

Due to offshore exploration of the Ormen Lange gas field located in the scar of the Storegga Slide, the seabed in this area is probably the best studied deep sea area globally. Based on the present soil conditions and slope stability analysis, it is found that the potential for large scale landslides in the Storegga / Ormen Lange area is small (Kvalstad et al., 2005; Nadim et al., 2005). Simulating landslides of different volumes and dynamics, Løvholt et al. (2005) found that a landslide with a volume of 5 km3 combined with a maximum velocity of 10 m/s is needed to generate waves with near shore surface elevation of more than 2 m. The probability of such landslides is in the order of 10-8 and thus hardly quantifiable (Nadim et al., 2005).

Tsunamis generated by earthquakes off Portugal and by landslides at La Palma, Canary Islands
Simulations of two synthetic earthquake scenarios of magnitudes 8.5 and 8.7 off the Portuguese coast are conducted. The scenarios have different orientations, and the consequences towards Great Britain, Ireland, and the Nordic Sea are briefly investigated. Simulations are performed using the dispersive GloBouss model and a linear shallow water model on ETOPO1 bathymetry, used with 2' resolution. Only a small effect of dispersion is found by comparing the two models. Far-field directionalities towards (slightly north of) Newfoundland and the West Indies are found for the two sources, respectively. In addition to

the protection provided by the directivity, the northern North Atlantic is in the shadow of the British Isles.

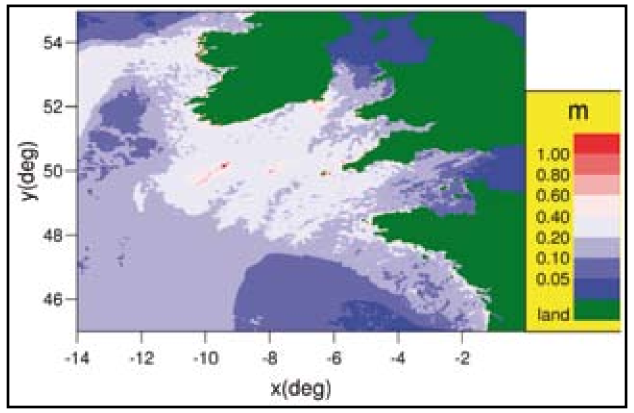

Fig. 7: *Maximum surface elevation (m) for a Mw8.7 earthquake off the Portuguese coast; close-up for France, Ireland, and Great Britain.*

On the Irish coast, incident waves of amplitude somewhat below 0.5 m are found for the Mw8.7 earthquake, Figure 7. More detailed modelling of the near shore wave propagation may be worthwhile. Our experience from the La Palma study (Løvholt et al., 2008) is that a high resolution grid is required for detailed modelling in this region. Beyond the Irish Sea to the northeast, the coastlines of the North Sea and the Norwegian Sea are not threatened by tsunamis generated off Portugal.

Extreme landslides at La Palma, Canary Islands, capable of producing devastating tsunamis are found unlikely (the probability should be lower than the annual rate of 10-5 y-1 for large landslides in this region), and the resulting tsunamis will anyhow not pose any threat to the north of the British Isles (Løvholt et al., 2008).

Acknowledgements
The EU Project TRANSFER (Tsunami Risk And Strategies for the European Region), the International Centre for Geohazards, the Norwegian Geotechnical Institute, and the Research Council of Norway are all thanked for financial support. Dave Long is thanked for helpful discussions on the tsunami hazard. This paper is ICG publication no. 270.

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2004 Boxing Day Tsunami - Sri Lanka`s worst natural disaster

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The "Boxing Day Tsunami 2004" was the worst natural disaster recorded in the Sri Lankan history. Sri Lanka is geographically located in a geologically stable zone of the earth's crust. So disaster of this nature was never expected.

Except the North–Western coastal zone all other coastal zones where badly affected. Nearly 40,000 pepole lost their lives and nearly 300000 peoples were homeless and badly affected.

With a tsunami lead time of over 2 hours from Northern Sumatra to Eastern coast of Sri Lanka and at least 30 minutes from Eastern coast of Sri Lanka`s Western part, why we could not save majority of our people's life? A proper sensor platform together with a well co-ordinated Disaster Early Warning System is essential to solve these problems.

An express train from Colombo to Southern city of Galle was hit by the tsunami wave at 9.35 am at Telwatta in South-western coast of Sri Lanka with 1500 people on board. Only 200 survived.

1

A coastal road leading to the Southern part of Sri Lanka .

2

Southern coast of Sri Lanka. Mathara district. Near Mathara town. Remains of a coastal temple. Dome shaped Buddhist temple was not destroyed.

3

4

Southern coast of Sri Lanka. Mathara District near Dikwella town. Site of a Sunday market. Over hundred persons who came to purchase their weekly food items lost their lives.

5

South eastern coast of Sri Lanka Hambanthota district Ruins of one of the main communication towers.

6

South-Eastern coastal area at Kirinda. Most of the fishing vessels were moved inland with the waves.

Eastern Province In Sri Lanka- Inundation is over 2 km inland

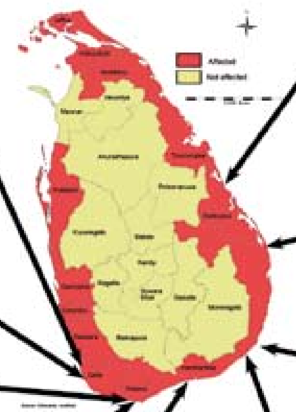
7

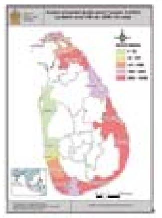
South-Eastern coast of Sri Lanka-Yala National Park located along the coastal zone. Animals moved inland before arrival of the tsunami waves. Most of the visitors to the park lost their lives. Hotels were destroyed.

8

A coastal main road. Access to the effected area was hindered due to damage of the coastal road network.

9





GRASS Development with Eclipse/CDT in the Distant Early Warning System (DEWS) Project

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Introduction

The Distant Early Warning System (DEWS) Project provides a standard-based reference model (RM) for integrated tsunami early warning systems focussing on information logistics and dissemination aspects of the delivery of messages to end user groups.

DEWS provides upstream functions based on a multi sensor platform and on the downstream-side target group-oriented compilation of warning messages and multi channel dissemination.

A necissity to accomplish the task of regionalized warning message generation is the proactive bulk processing of large amounts of geodata and its subsequent management and provision as customised content for dissemination.

Free Open Source Software GIS in DEWS

The project's selection of Free and Open Source Software (FOSS) GIS tools enables the future-proofing which is required for the underlying challenge: As the occurrence of the next major tsunami is unknown, the longevity of the integrated monitoring and warning systems is crucial.The RM itself is implemented by using proven FOSS GIS technologies such as uDig and PostGIS.

Geodata preprocessing with GRASS GIS

The DEWS RM FOSS GIS infrastructure requires the availability of significant amounts of geospatial data. The initial compilation and configuration of the required pool of geospatial data was done at the GeoForschungsZentrum Potsdam (GFZ).

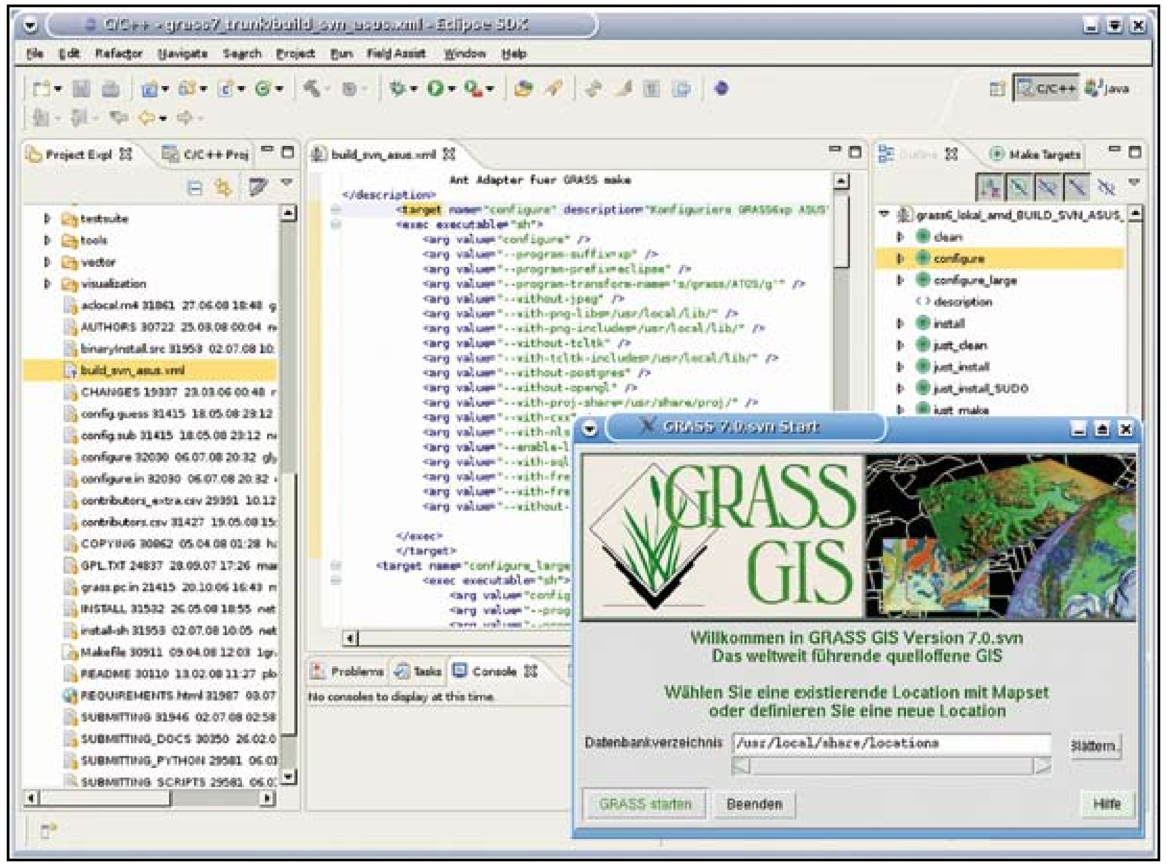

***Fig. 1:** Screenshot of the Eclipse IDE with the GRASS code trunk, the ANT configure-script wrapper and the GRASS splash screen of the application, which has just been built and invoked from within Eclipse.*

This included the determination of potentially affected coastal communities by applying spatial buffers on all islands of the three nations covered by DEWS. For this, GRASS GIS was used by implementing the original data processing workflows.

The decision to use GRASS GIS was caused by its scripting capabilities and the filesystem-based data processing and storage. This enables automated bulk processing of very large datasets which uses less RAM ressources than other software solutions.

DEWS-specific Software Enhancements
While GRASS GIS is a mature software project of over 20 years, some sourcecode-level improvements were required for the specific needs of DEWS, i.e. changes applied to the v.select module. It was not forseeable how many other GRASS modules would have also to be customised for DEWS. This reason led to the provision of an IDE-based platform-independent GRASS-development environment to provide suitable enhanced GRASS versions for bulk geodata processing on various platforms, preferably on different operating systems for all DEWS partners.

GRASS GIS / IDE - Integration
The Development for platform independent customisation of GRASS GIS was started by using the integrated development environment (IDE) Eclipse in conjunction with the C-Development Tool (CDT)-plugin. As Eclipse was already used for uDig development in DEWS, developers were familiar with this IDE. The reuse the same IDE for GRASS GIS development helped to save development ressources.

As a challenge, GRASS' custom build-mechanism had to be wrapped in ant-code to enable support during the software configuration. The final result is a GRASS GIS development environment capable to access, manage and compile the GRASS sourcecode via the IDE. This approach helps to optimize the overall development capacity as a critical resource. The immediate benefits are extended options for collaborative development and code refactoring.

Summary
GRASS GIS was successfully used for the initial setup of the geospatial data repository in DEWS. Since project-related code adaptations became necessary, a general development environment was set up, based on the Eclipse IDE.

The Tsunami Service Bus, an integration platform for heterogeneous sensor systems

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The Sensor Integration Platform was developed to access sensor measurements and events as well as to task and control sensor system components in a uniform manner. Its core consists of the so called Tsunami Service Bus (TSB), built on top of a service and messaging backbone. The TSB realizes functional integration compliant to a service-oriented architecture pattern: Functionality is implemented in form of dedicated components communicating via a service infrastructure. These components provide their functionality in form of services via standardized and published interfaces which can be used to access data maintained in - and functionality provided by dedicated components. Functional integration replaces the tight coupling at data level by a dependency on loosely coupled services. If the interfaces of the service providing components remain unchanged, components can be maintained and evolved independently on each other and service functionality as a whole can be reused. The TSB provides four services that are realized in conformance to the Sensor Web Enablement (SWE*), a standard specified by the Open Geospatial Consortium (OGC):

- A Sensor Observation Service (SOS) to retrieve sensor measurements (e.g. time series).
- A Notification Service (TSB_NS) to provide any notifications (e.g. sensor system state changes).
- A Sensor Alert Service (TSB_SAS) to deliver sensor alerts (e.g. earthquake events).
- A Sensor Planning Service (SPS) to task special sensor features (e.g. filtering).

Beyond services SWE specifies data encoding both to access sensor measurements and to describe the sensor itself in a comprehensive way:

- Observations & Measurements (O&M)
- Sensor Model Language (SensorML)

Because SWE-services define operations like "describeSensor" to access meta-information, data of new sensors could be provided dynamically without any change of service interfaces allowing the realization of dynamically configurable early warning systems.

* SWE is an initiative of the Open Geospatial Consortium, Inc. ® (OGC) [5]. It's an acronym for Sensor Web Enablement and defines standard interfaces to access sensor data via Web Services.

For further information see

http://www.gitews.de

The Meteorological and Geophysical Agency of Indonesia (BMG), see http://www.bmg.go.id

The National Coordinating Agency for Surveys and Mapping (BAKOSURTANAL), see http://www.bakosurtanal.go.id

The Agency for the Assessment & Application of Technology (BPPT), see http://www.bppt.go.id

Open Geospatial Consortium, Inc.® (OGC), see http://www.opengeospatial.org

The open source application server JBoss, see http://www.jboss.org

Java Enterprise Edition, see http://java.sun.com/javaee

KBSt - Federal Government Co-ordination and Advisory Agency, see http://www.kbst.bund.de

Business Process Execution Language, see http://www.oasis-open.org/committees/wsbpel

PACT – a bottom pressure based, compact deep-ocean tsunameter with acoustic surface coupling

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The German-Indonesian Tsunami Early Warning System (GITEWS) is currently established to minimize the risks of disastrous events such as the December 26, 2004 Indian Ocean tsunami. To maximize alerting periods, to avoid false alarms and to accurately predict tsunami wave heights, real-time observations of ocean bottom pressure are required from the deep ocean. To this end, the PACT system (Pressure Acoustic Coupled Tsunameter) was developed. PACT's bottom unit combines a highly-sensitive pressure sensor, a data processing unit for automatic tsunami detection, and an acoustic modem in a single, robust housing. The data are transferred via a bidirectional acoustic link to PACT's surface unit, which is mounted to a surface buoy (not part of the PACT system), allowing also remote activation of the tsunami mode in case a wave is expected from e.g. seismic data. The PACT system has successfully passed extensive laboratory and at-sea tests. The first deployments off Indonesia as part of GITEWS are scheduled for April 2009.

Fig.1: *Tsunami Detector*

Natural Hazard Preparedness

Kriengkrai Khovadhana

National Disaster Warning Center, Thailand

Warning Transmitting of NDWC/Secondary Warning Transmitting

Kriengkrai Khovadhana

National Disaster Warning Center, Thailand