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Components and Systems
ICT for the Environment

Outcome Paper

Tsunami Early Warning & Alert Workshop

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1. Introduction

Early in the morning on December 26th 2004, a violent earthquake occurred off the Western coast of Sumatra causing a mega-tsunami, which travelled across the Indian Ocean causing wide spread devastation and loss of life. In response, the international community mobilized itself to provide overwhelming support and humanitarian aid. Upon witnessing such large scale destruction, many questions were raised by citizens, decision makers and scientific experts alike: why were there so many casualties? Why where people not warned? Will such an event repeat itself? How can people at risk better protect themselves against such disasters?

As the scientific community tried to explain and rationalise the science behind the phenomenon, it became apparent that in addition to sound science, disaster risk reduction strategies require solid institutional frameworks, clear assignment of responsibilities, monitoring, early warning and alert systems, and capacity building mechanisms engaging citizens at all levels.

As a follow up to the South East Asian disaster, the European Commission made an effort to investigate how science could further the knowledge and understanding of geophysical processes and impacts of tsunamis. The Directorate General for Research held two workshops to this effect during the period February to May of 2005. The outcome of these workshops highlighted the need and the urgency to advance research on this topic, which has in fact received little attention. In particular they emphasised the need to develop advanced tsunami early warning and alert capacities not only in the Indian Ocean, but also in Europe, especially in the Mediterranean and the Atlantic coast, given that important tsunami events have occurred there in the past, and are likely to occur again in the future.

On May 12th 2005 a third workshop, organised by the Directorate General for Information Society and Media, was held to address the more technological aspects of developing and testing tsunami early warning and alert capacities, through the use and integration of advanced technologies for real-time monitoring and sensor networking, and all media alert telecommunications.

2. The contribution of European research

With the aim of furthering scientific discovery, the European Commission has been funding research on natural disasters and industrial hazards since the late 1980's, via its Framework Programmes for research and technological development. Until now, most of the disaster related research has focussed on the understanding of underlying processes and hazard assessment. Only recently have more holistic and applied approaches been encouraged which have sought to extend the notion of hazard assessment to include vulnerability assessment, and more importantly the entire risk and emergency management cycle, not only in individual risks (ie: landslides, forest fires, floods, etc) but also in a multirisk and systemic risk perspective. Information on past and ongoing EU disaster research is available at www.eu-medin.org, the web portal for European disaster science.

Although at the EU level much research has been done in the area of earthquake risk and seismic engineering, tsunami research has received little attention, possibly due to the rarity of such events. In particular, the GITEC projects lead to the development of European and regional tsunami catalogues, and the zoning of tsunamigenic sources.

The outcome of the DG Research workshops provides a thorough overview of the future tsunami research needs. Findings suggest that Europe has suffered numerous tsunami events, several of which were quite catastrophic in terms of size and impact, but the historical records are incomplete; many known occurrences of tsunamis are still not linked to reliable sources, and many sources are indeed located close to densely populated areas. Future scientific research is required to improve our understanding of past tsunamis, their sources and their triggering mechanisms, to develop tsunami vulnerability indicators and risk assessment techniques, to improve real-time monitoring and numerical tsunami modelling, integrating tsunami generation, propagation and inundation, and subsequent potential direct and indirect impacts.

Advances in Information and Communication Technologies (ICT) have also contributed to bridging the gap between scientists, industry and disaster managers, by providing operational and cost effective solutions (tools and services) for disaster prevention, hazard monitoring, mapping, emergency management, etc. It is clear that ICT has a fundamental role to play in the development of tsunami early warning and alert capacities, at multiple levels: from local to international, each of which will require scale-specific early warning strategies and technologies suited to the scale of the problem.

3. Objective of the Workshop

Building upon the DG RTD workshops, DG INFSO held its workshop with the aim of defining a possible strategy for the integration of advanced ICT for the development and validation of a tsunami early warning and alert capacity relevant to both Europe and the Indian Ocean. It gathered over 60 experts from various disciplines, including geophysics, ocean monitoring, geo-information, telecommunication, from academia, industry and public authorities. This workshop took into account the recommendations made at the Nice workshop in February where the west Mediterranean regions (arc méditerranéen) met, and where representatives from France, Italy, Spain, Portugal and Algeria expressed the specific concerns. The overall outcome of the workshop was subsequently presented at the EURO-THAILAND conference, which had the aim to promote cooperation between INFSO and S.E. Asian countries, in particular in the field of disaster reduction and early warning.

This report is the “outcome document” of the tsunami early warning and alert workshop; whose more specific aim was to identify the existing Information and Communication Technology (ICT) gaps which could be filled via a series of dedicated research projects under Call 6 of the Information Society Technologies (IST) priority of the EU’s 6th Framework Programme for Research and Technological Development (FP6).

4. EU Policy Context

Shortly following the Indian Ocean tsunami of 26 Dec. 2004, the European Commission set up a Tsunami Inter-service Taskforce, which gathered all the relevant services active in the field of disaster reduction. In a short time the EC mobilised 103 million Euro in support of humanitarian aid, 350 million Euro were donated for reconstruction activities, and a series of flanking measures were activated.

On the 31 January, during the General Affairs and External Relations Council (GAERC), the presidency presented the **EU Council Tsunami Action Plan**, which was adopted. The action plan addresses three main issues, that is, measures taken to: address the needs of the tsunami-affected regions; improve the EU’s response capacity, its coherence and efficiency; and enhance prevention, early warning and preparation for future disasters. In response to the Action Plan the EC prepared a Communication entitled “Reinforcing EU Disaster and Crisis Response in third countries” adopted on 20 April and subsequently presented at GAERC of 23 May. The Communication includes two annexes. The first is an updated report on the measures taken by the Commission to address the needs of the areas affected by the Indian Ocean Tsunami. The second annex illustrates the range of Community instruments and programmes which contribute to early warning and disaster preparedness across the world. The most relevant parts are “5. REINFORCING PREVENTIVE MEASURES, EARLY WARNING AND DISASTER PREPAREDNESS” and Annex II, “4. RESEARCH AND DEVELOPMENT AND SCIENTIFIC CO-OPERATION”.

In response to the Action Plan and the Communication that followed, DG INFSO was determined to promote measures to support the development and validation of a tsunami early warning and alert capacity relevant to Europe and the Indian Ocean. This research action will provide a clear indication of Europe's commitment to respond to this important issue through applied research. It will constitute the European contribution, from a systems perspective, to a global early warning system envisaged to be set up under the coordination of the UNESCO Intergovernmental Oceanographic Commission (IOC), the UN-International Strategy for Disaster Reduction (ISDR) and the Global Earth Observation Systems of Systems (GEOSS) 10-year implementation Plan. In addition, the research should build upon the principles established by the INSPIRE and GMES initiatives.

In parallel, a German research-lead consortium signed an agreement with the Indonesian government for the deployment of tsunami monitoring infrastructure, which will be used for the development of a sub-national tsunami early warning capacity. This presents a unique opportunity to develop advanced research applications using this infrastructure as a test bed. The premise is that technologies developed in this context will be easily adaptable and transferable to other parts of the world which could benefit from such systems. Naturally they will need to be adapted to local situations depending on the geophysical, environmental, social, cultural and institutional characteristics.

5. International Context

There are several international bodies and initiatives that contribute to disaster reduction at the Global scale, but this report will make reference to three of these as they are directly related to tsunami early warning.

United Nations International Strategy for Disaster Reduction (ISDR) and associated initiatives: The ISDR is the focal point in the UN System to promote links and synergies between, and the coordination of, disaster reduction activities in the socio-economic, humanitarian and development fields, as well as to support policy integration. The ISDR aims at building disaster resilient communities by promoting increased awareness of the importance of disaster reduction as an integral component of sustainable development, with the goal of reducing human, social, economic and environmental losses due to natural hazards and related technological and environmental disasters. It serves as an international information clearinghouse on disaster reduction, developing awareness campaigns and producing articles, journals, and other publications and promotional materials related to disaster reduction (see: http://www.unisdr.org/).

The ISDR combines the strengths of many key players through the Inter-Agency Task Force on Disaster Reduction (IATF/DR) and the Inter-Agency Secretariat of the ISDR**.** The IATF/DR is the principal body for the development of disaster reduction policy. It is headed by the UN Under-Secretary General for Humanitarian Affairs and consists of 25 UN, international, regional and civil society organizations. It meets twice a year. Working Groups reporting to the IATF/DR bring together specialists and organisations to discuss issues of common and global relevance to disaster reduction such as climate variability, early warning, vulnerability and risk analysis, wildland fires and drought

The ISDR, was leading player in the definition of Yokohama Strategy and Plan of Action for a Safer World (outcome of the World Conference on Natural Disaster Reduction held in Yokohama, Japan, in 1994), which provided guidelines for natural disaster prevention, preparedness and mitigation. The more recent Wold Conference on Disaster Reduction (WCDR), held in Kobe, Japan in January 2005, lead to the endorsement of the Hyogo Declaration, and the **Hyogo Framework for Action** (HFA) 2005-2015: Building the Resilience of Nations and Communities to Disasters, which is blueprint for the next 10-year plan for disaster risk reduction. They represent a strong commitment of the international community to address disaster reduction and to engage in a determined, results-oriented plan of action for the next decade.

Although not specifically focussed on tsunami risk alone, the HFA aims to:

- ensure that disaster risk reduction is a national priority with a strong institutional basis for implementation;
- identify, assess and monitor disaster risks and enhance early warning;
- use knowledge, innovation and education to build a culture of safety and resilience at all levels;
- reduce the underlying risk factors; and
- strengthen disaster preparedness for effective response.

All of which are highly relevant to enable tsunami risk reduction strategies.

The **Platform for the Promotion of Early Warning** (PPEW) was initiated by the ISDR, and started operations in 2004. The aim of the PPEW is to help the development of early warning and preparedness systems by (i) advocating for better early warning systems, especially in development assistance policy and programs, (ii) collecting and disseminating information on best practices, and (iii) stimulating cooperation among early warning actors and the development of new ways to improve early warning systems.

UNESCO Intergovernmental Oceanographic Commission (IOC): Since 1968 an International Coordination Group for the Tsunami Warning System in the Pacific (ICG/ITSU) has existed under the auspices of the IOC. ICG/ITSU is an international cooperative effort involving many Member States of the Pacific Region, and meets every two years to review progress and coordinate activities resulting in improvements of the service. In addition, the IOC also maintains the International Tsunami Information Centre (ITIC), established in 1965 in Hawaii, in collaboration with NOAA's Richard H. Hagemeyer Pacific Tsunami Warning Centre (PTWC). Following the Indian Ocean tsunami of this year, the IOC has been mandated to take on a further intercontinental coordination effort towards the establishment of a series of regional tsunami early warning capacities.

GEO/GEOSS: The Ad hoc Group on Earth Observations (GEO) was established in 2003 and currently comprises over 60 nations, the European Commission and over 40 participating international organisations. Its main objective is to take stock of the societal value of integrating space-borne, airborne, and in situ observations, to help understand and address global, environmental and economic concerns. It aims to develop a comprehensive, coordinated, and sustained Global Earth Observation System of Systems (GEOSS); which will focus on nine societal benefit areas, including "Reduction of loss of life and property from disasters" and "Protection and monitoring of our ocean resources". A tsunami ad-hoc group is currently being established under GEOSS (see: http://earthobservations.org/).

6. Basic Principles of tsunami early warning and alert

According to the Platform for the Promotion of Early Warning (PPEW), *a complete and effective early warning system is more than just a prediction. It comprises a chain of four elements, spanning the knowledge of the risks faced through to preparedness to act on early warning. Failure in any one part can mean failure of the whole system.*

The Four Elements of Effective Early Warning Systems

Prior knowledge of the risks faced by communities	***Technical monitoring and warning service for these risks***	***Dissemination of understandable warnings to those at risk***	***Knowledge and preparedness to act***
Risks arise from both the hazards and the vulnerabilities that are present – what are the patterns and trends in these factors?	*Is there a sound scientific basis for predicting the risks faced? Are the right things being monitored? Can accurate warnings be generated in timely fashion?*	*Do the warnings get to those at risk? Do people understand them? Do they contain useful information that enables proper responses?*	*Do communities understand their risks? Do they respect the warning service? Do they know how to react?*

Good early warning systems have strong linkages between the four elements. The major players concerned with the different elements meet regularly to ensure they understand all of the other components and what other parties need from them. Risk scenarios are constructed and reviewed. Specific responsibilities *throughout the chain are agreed and implemented. Past events are studied and improvements are made to the early warning system. Manuals and procedures are agreed and published. Communities are consulted and information is disseminated. Operational procedures such as evacuations are practiced and tested. Behind all of these activities lies a solid base of political support, laws and regulations, institutional responsibility, and trained people. Early warning systems are established and supported as a matter of policy. Preparedness to respond is engrained in society* (reference: http://www.unisdr.org/ppew/whats-ew/basics-ew.htm).

Although a fully operational TEWS requires the integration of the four elements stated above, the workshop focussed mainly on two of these: the "technical monitoring and warning service" and the "dissemination of understandable warnings to those at risk". The reason for this is that these two elements are particularly ICT related, and thus under the direct competence of DG INFSO. While the first element "prior knowledge" is more dependent on the basic science, and the last element "knowledge and preparedness to act" relies largely on education, risk perception and risk awareness; thus two elements in which ICT plays a lesser role.

From a purely technological point of view, a TEWS can be regarded as being composed of : i) a system aiming at the early and rapid detection of events that may cause a tsunami; ii) a processing step to analyse the data collected, and to confirm that the event detected is likely to trigger a tsunami; iii) a step generating the relevant information to be released; iv) the transfer of such information to an appropriate authority or to the public, v) maintaining emergency telecommunication through the crisis. This slicing of the whole sequence of tasks in five parts is not sharp: feedback between the different steps should be taken into consideration as well; further considerations could lead to distinguishing more (or less) steps.

Tsunamis: Most tsunamis are generated by earthquakes, but they can also be caused by other natural hazard phenomena like submarine landslides and volcanic eruptions. They are generally caused either by a vertical displacement of the sea floor, by the sudden slumping of large masses of debris, and very rarely, meteorites and asteroids. Tsunami triggers or "sources" may be located "offshore" or "near shore" (close to the coast). In the case of distant sources, the tsunami may take hours to reach the shore. When the source is close to the coast, a tsunami, which may be just as destructive as an offshore-generated wave, may hit in just a few minutes. The location of the "source" and the type of tsunami generated is thus an issue that plays a crucial role in the definition of a TEWS. When the time to wave impact is very short, fully automated (non-supervised) TEWS procedures are required. If several hours are available, the TEWS can adopt a more analytical procedure, given there is sufficient time to elaborate, adapt and disseminate the information to those concerned.

Detection: Detection of causative events is done via the installation of different scientific instruments for monitoring earthquakes, crystal deformation activity and changes in sea-level in the region. In-depth knowledge of the geophysical characteristics of the region is necessary to identify where the instruments ought to be positioned. Such instrumentation, which should consist of a combination of seismometers, altimeters, sea-level gauges and underwater pressure gauges, supplemented by Global Positioning System (GPS) receivers, is usually costly and requires constant maintenance. At present only some such instruments are able to transmit data in real-time, so they should be supplemented by specific communication facilities in order to rapidly transfer data collected “in the field” to one or more data processing centres.

- Coastal tide gauges: although there are numerous tide gauges situated in near-shore environments, often installed for other purposes, current transmission rates (up to daily) and sampling rates (from 1 to 15 minutes) are generally not adequate for tsunami detection, and the network coverage needs to be expanded. Some of the GLOSS stations used on the Global scale use hourly transmission rates and hence are also not ideal for tsunami monitoring. Improvements in this domain would be to densify the networks and to reduce sampling rates, and possibly by enhancing tide gauges with GPS capabilities.

- Deep ocean sensors: these are rarer and very costly sensors which need to be anchored to the sea floor and must be supplemented by an energy source. The most utilised buoys are the DART systems, in Europe M3A and ANIMATE buoy networks are in operation. Improvements in this domain would render the buoys more robust and autonomous (in terms of power supply) to lower maintenance costs, and to improve data transmission and processing capacities by enhancing them with GPS. In the near future, the cabled network ESONET will provide the capability of data transmission of submerged sensors. When in place, seismic, pressure and other sensors around Europe will provide off-shore data with little extra effort.

- Satellite data: satellite technology can provide altimetry sea level data, but at present data is limited, and the current spatial and temporal resolutions are insufficient. Improvements in this domain would consist of developing GNSS altimetry and receivers, and in the longer term, via the establishment of a constellation of nano-satellites for altimetry.

Data integration and analysis: Raw data should be processed, analyzed, combined with each other, and checked against data acquired earlier which corresponded to events which have in turn (or have not) caused a tsunami. This step is crucial in that, depending on the outcome of data analysis conducted, it will lead or not to the launching of an alert, what could have quite serious consequences. Thus, this step deserves significant resources in databases, data analysis capabilities and in educated/trained personnel, all automatic procedures requiring scientific/technical supervision, at least to a certain extent. In order to provide reliable alerts, supporting data is needed, including land elevation, landuse, and population data. The integration and visualisation in GIS expert systems, together with advanced analyses techniques is an urgent issue. To appropriately model tsunamis in oceanographic modelling software, deep sea, continental shelf and shallow water bathymetry are essential for the computational modelling of tsunami propagation and inundation. However, even around Europe large areas are insufficiently mapped.

Information Transmission: Once summarised, the information should be transmitted to the proper targets; which must be known and pre-determined recognised authorities. The target(s) may not necessarily be the same in all circumstances, but their identification and empowerment to handle the situation that arises, raises major societal and political issues which must be thoroughly investigated and framed in an institutional setting. Solutions adopted will vary from country to country. Compromises have to be sought between the political requirements and the technical conditions imposed by the emergency situations. Technical problems raised by communications at this stage are also of primary importance.

Information for supporting decision making: Scientific data may not be readily understood by lay-persons in charge of disaster management. They must be summarised and put in a form suitable for transmission to authorities, without distorting and degrading their content. This is an essential step which must not be overlooked, seeing it is the information upon which decisions will effectively be taken (or not).

Information to the public: The information and the manner in which it is to be delivered to the public needs to be carefully defined. This largely depends on the social target groups. For instance, professional groups (first-aid rescuers, planners, insurers, NGOs, *etc*.) have needs that will greatly differ from the information needed by the general population. Major efforts are required to investigate these questions in detail, having in mind that customizing and localizing (language, *etc*.) the information disseminated could save precious seconds/minutes in terms of exposed populations' response. In parallel, the "channels" (ie: media types) used for communicating depend on the target groups as well.

Maintenance of a monitoring system: Large tsunamis are infrequent phenomena. This leads to serious problems regarding the maintenance of (material and immaterial) systems in the long-term: motivation and sustainability are likely to become a serious burden, especially if too few events occur. This can be partially prevented if the TEWS (or part of it) can be used for other more frequent applications such as earthquake monitoring. Earthquakes are much more frequent than tsunamis; they can be equally damaging, and call upon some of the same components as a TEWS, apart from the sea-level monitoring and tsunami propagation modelling. In other words, implementing a TEWS necessarily includes the implementation of the elements applicable also to an earthquake early warning system.

Computational capabilities and data transmission: TEWS require large computer facilities for collecting and exchanging data in quasi real-time, for maintaining and using large databases with rapid data retrieval capabilities, and for conducting intensive model computations. Significant computational resources are required, which can be facilitated by techniques like GRID-computing (or computing on-demand), and access to wide-band backbones (GEANT-type connectivity).). For most of the offshore and remote sensors, high-rate satellite links are necessary, but are largely missing. Low-power high-bandwidth links and equipment for communication via geostationary satellites needs to be developed.

Promoting risk awareness: An essential component of any TEWS is education and training. It applies at all levels, from elementary education to the general population. The aim is to build a risk culture and awareness, whereby citizens will know what to do when an alert is given. In the case of tsunamis generated near the shore, the available response time is minimal, so people should know in advance how to respond. This is a type of local capacity building exercise, which is the responsibility of local authorities, but deserves guidance and support at the highest political levels (which means permanent or recurrent education/training as the terms of political authorities are not commensurable with the repeat-times of tsunami, or even earthquakes); through the education/training of all workers involved in the systems, at any level.

7. Towards an integrated tsunami early warning and alert system

The aim of the proposed DG INFSO supported research activity is to develop, validate and demonstrate a distributed tsunami early warning and alert system for improved disaster prevention and preparedness, applicable to coastal and mainland Europe and the Indian Ocean and capable to provide effective protection from local as well as remote tsunami sources. The system should enable strong collaboration and interoperability across the whole disaster-reduction cycle.

The approach should be based on the integration of advanced ICT systems and services, to meet the specific needs of local, regional and basin-wide tsunami early warning and alert including: data exchange and fusion technologies, computational scenario-building, real-time monitoring, advanced prediction through high performance computing and collaborative networking, interfacing with decision-support systems, and subsequently linked to all-media broadcasting and telecoms satisfactory for tsunami alert, and also applicable to other coastal hazards. Validation environments need to be established for testing prototype integrated systems and services.

A realistic joint programme of activities involving the key European research, operational earth-observation and monitoring centres, emergency services, and public information and broadcast services, is proposed. Cooperation with other international bodies that are active in this domain is required, in particular, including relevant organisations in North America for the monitoring of the eastern Atlantic coast; and in southern European countries for monitoring the Mediterranean basin; and relevant organisations covering the Indian Ocean.

In addition to advancing applied and pre-operation research on this topic, there is a need to promote technology transfer between EU and tsunami-prone countries and regions bordering the Indian Ocean, sharing best practice on the use of advanced ICT for early warning and alert systems, promoting standards and adapting these to local needs and conditions. Essential is the collaboration with countries bordering the Mediterranean sea, with the aim of promoting a harmonised approach to tsunami early warning and alert for the Mediterranean basin.

Some of the specific areas where the integration of advanced ICT have a potential to contribute to tsunami early warning and alert include:

Geo-Information:

1. Data collection (historical and future data requirements/surveys)

2. Data management and legacy (including static data, ie: existing and future tsunamis catalogues, as well as real-time point source and spatio-temporal data)

3. (Exploratory) data analysis

4. Data integration (different data sources, scales, temporal and spatial resolutions)

5. Metadata (protocols and management)

6. Distributed data warehousing

7. Data sharing, access rights and security

8. Mapping (ie: protocols, spatial and temporal evolution)

Tsunami Monitoring (seismic, GPS, deep ocean and sea level):

1. Specific sensor networks (ie: sensor web, integration, harmonisation, common architecture)

2. Integration of data from seismic, GPS, deep ocean and sea level sensors

3. Data capture (i.e: multiparametric, sampling rate, data compression)

4. Enhancing quality and speed (real-time) of data transmission and processing capabilities

5. Sensor maintenance and enhancing sensor robustness

Tsunami Modelling:

1. (Distributed) spatial and non spatial information systems

2. Integration of different types of models (ie: loose coupling vs: tight coupling)

3. Mapping aspects (ie: hazard, vulnerability, risk, inundation; etc.)

4. Computational scenario development and simulation

5. Improved processing time for predictive and real time modelling (forecasting)

Decision Support Systems:

1. Integration of models into decision support systems

2. (Distributed) modelling and decision support systems and interfaces for planning and mitigation

3. Linking early warning to all-hazards/all-media alert capacities

System of systems infrastructure:

1. Linking of baseline and legacy data, with monitoring data and modelling and decision support

2. Business and workflow analysis and modelling

3. Provision of services

4. Developing and testing the architecture in an inter-institutional and international context

8. Conclusion

Early warning and alert are fundamental issues for disaster risk reduction. However, to be successful they must operate within a pre-defined institutional framework, and must be integrated within a holistic risk reduction strategy. Although early warning, per se, is largely dependent on the type of hazard, all-media alert is necessarily multirisk. The research efforts being promoted by DG INFSO aim in particular to further develop the technological aspects of operationalising such early warning and alert capacities for tsunamis. The overall objective is to promote the development of open, generic, reusable and low-cost methods and tools which have a high potential for operationalisation and take-up by disaster management communities, in Europe and worldwide.

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