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NEAREST

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D.19b Requirements and design of the tsunami triggering system

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WP5 - Data integration/ Integrated tsunami detection network

D.19b Requirements and design of the tsunami triggering system

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This report has been compiled by Luis Matias with the contributions from the main partners involved in the establishment of National Tsunami Warning Centres in Portugal and Morocco: the Meteorological Institute at Lisbon (IM) and the National Geophysical Institute of Morocco of the Centre National pour la Recherche Scientifique (CNRST). This report profited also from major contributions by Maria Ana Baptista, Joaquim Luis and Alessandro Annunziato (Joint Research Centre).

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1. Introduction

The key operational components of a Tsunami Warning Centre (TWC) are to provide real-time monitoring, alert of seismic and tsunami activities, timely decision making, and dissemination of tsunami warnings, advisories and information (Figure 1). The chain begins with data collection and ends with saving lives. In this report we will concentrate on the specifications for the tsunami triggering system, the module outlined in figure 1.

Once the tsunami's existence and its severity have been forecasted from seismic information only, there must be a system to assess the potential impact of the tsunami. This tsunami prediction subsystem, the Tsunami Triggering System, should quickly generate the necessary forecasts to expedite the determination of the possible impact of a tsunami. This is necessary for the issuance of credible warnings that cover only areas actually affected, if possible, with few "false alarms" that lead to unnecessary and costly evacuations.

The Tsunami Triggering System must also integrate new data provided from sea level observations and thus update its first severity evaluation. The final product of such a system are messages to be issued to the emergency managers, the agencies that are responsible for taking actions at the extreme end of the Tsunami Warning System, the public.

In this report we present the development of the Tsunami Triggering System as it has been developed at IM, the Meteorological Institute of Portugal, as a preparation for the installation of the future Portuguese Tsunami Warning Centre. This System has been developed thanks to the collaboration of Alessandro Annunziato and the Joint Research Centre in Ispra (Italy).

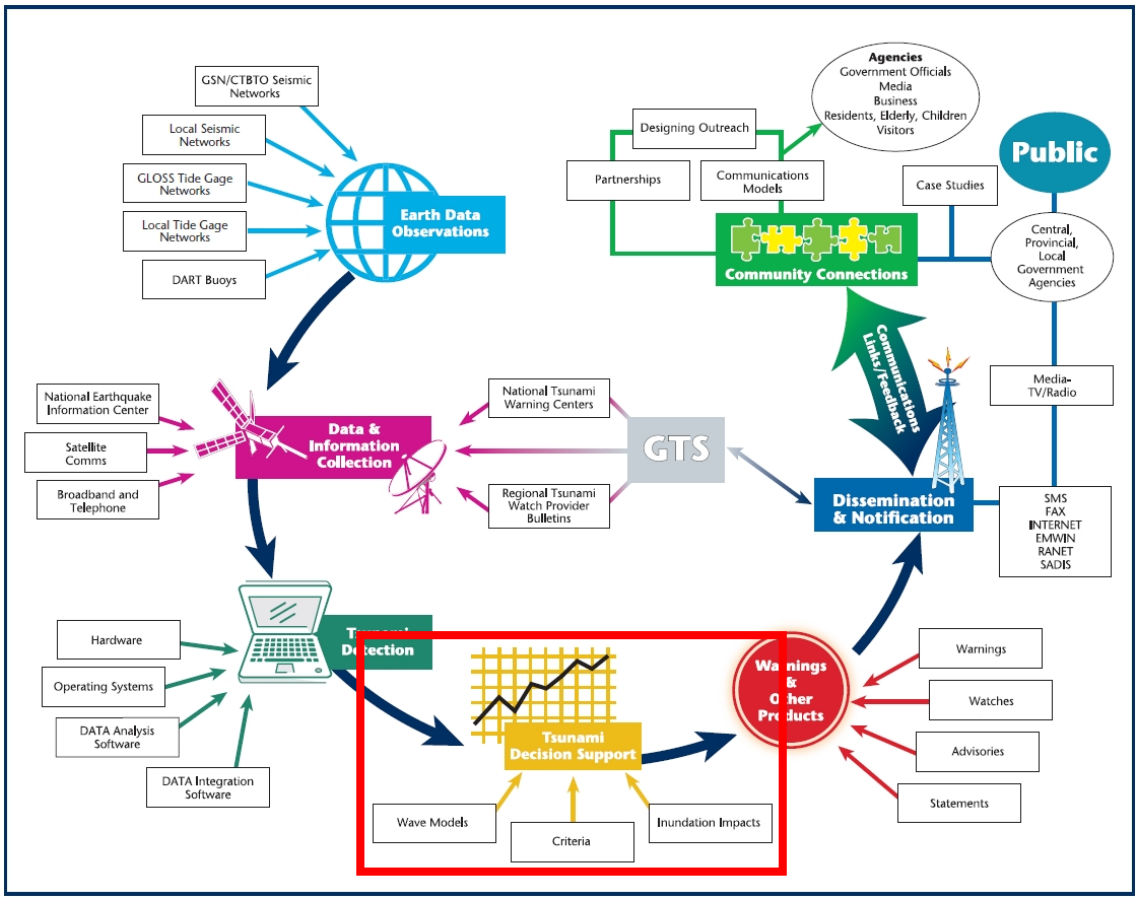

Figure 1. Key Components of a Tsunami Warning Centre End-to-End Chain (from US-IOTWS)

2. Basic requirements for the tsunami triggering system

Once an earthquake has been detected and its magnitude and location analyzed, Tsunami Warning Centres use criteria and, where available, models to determine if an initial tsunami warning should be issued. Tsunami warning centres require additional capabilities to refine the forecast beyond the initial warning (in US-IOTWS, 2007). The Tsunami Triggering System is the module that provides decision support programs that are used in operational decision-making (ibid.):

- Criteria for issuing warnings based upon science and historical events.
- Situational awareness software that helps watch-standers detect events in real time.
- Computer models of tsunami wave height based upon science, historical events, and earth observations.
- Assessment of impacts of events based upon inundation models, preparedness, land use and mitigation programs, etc.

- Training for operational watch standers.
- Research and development to improve centre operations and products.

The most important requirements for a Tsunami Decision Support Tool, after the need for a rapid detection of tsunami-generating earthquakes, are (in US-IOTWS, 2007):

- Situational awareness software is crucial to watch-stander efforts to respond as quickly as possible to seismic events.
- Computer applications programs are used to analyze sea level data to generate forecasts of tsunami wave height and inundation for specific coastal areas.
- Training programs and applied research help centres improve their performance.

The first message to be issued by the Tsunami Warning Centre is based exclusively on seismic information (Location, Moment Magnitude and Depth). Taking into consideration the pass tsunami experience in each region, a Tsunami Decision Matrix is defined beforehand and applied to each event. The Tsunami Decision Matrixes for the North-East Atlantic were define by the Working Group I of the ICG/NEAMTWS and approved at the Lisbon meeting in Lisbon (figure 2).

Seismic criteria for ATLANTIC Advisories

Depth	Location	(Mw)	Tsunami Potential	Bulletin Type
< 100 km	Under or very near the sea (< 30 km)	5.5 to 7.0	Small potential for a destructive local tsunami	Information Bulletin
		7.0 to 7.5	Potential for a regional tsunami < 1000 km	Regional Tsunami Watch
		7.5 to 7.9	Potential for a destructive regional tsunami < 1000 km	Regional Tsunami Warning Ocean-wide Tsunami Watch
		> 7.9	Potential for a destructive ocean-wide tsunami > 1000 km	Ocean-wide Tsunami Warning
	Inland (> 30 km)	5.5	No tsunami potential	Information Bulletin
≥ 100 km	All Locations	≥ 5.5	No tsunami potential	Information Bulletin

Figure 2. Tsunami Decision Matrix approved by the ICG/NEAMTWS for the North-East Atlantic.

The NEAMTWS Operational Users Guide (under construction) provides all the details regarding the messages content to be provided in each case. It has been recommended that only two levels of severity should be considered to evaluate the urgency, severity and certainty of tsunami related messages (see table below).

	Level I (high)	**Level II (low)**
Urgency	Tsunami to arrive in less than 1 hours	Tsunami to arrive in more than 1 hour
Severity	Tsunami wave height greater than 0.5m and/or tsunami run-up greater than 1m	Tsunami wave height less than 0.5m and/or tsunami run-up less than 1m
Certainty	Tsunami confirmed by sea-level measurements	Tsunami not yet confirmed by sea-level measurements, information based on seismic parameters only

The tsunami messages to be provided by the TWS to emergency managers must include information on the severity of the expected tsunami wave and also an estimate of the tsunami travel time (ETA) to a number of pre-defined coastal locations, the tsunami forecast points.

Given the large uncertainties on the seismic source that generated a tsunami (at least during the first few minutes after its onset) and the large computer time required to model the propagation and inundation of a tsunami, it is recommended that the severity of the tsunami impact is evaluated by a set of pre-computed tsunami scenarios, or a combination of them. On the other hand, the ETA can be computed much faster and can be provided in real-time by the TWC. It must be however recognized that the speed of computation is provided at the cost of a reduced precision, since a number of details, particularly the interaction close to the coastline, are ignored. Emergency authorities must be informed that ETA can differ from true values by several minutes.

3. The tsunami triggering system implemented at IM

The Tsunami Triggering System implemented at IM is based on the Tsunami Analysis Tool (TAT) developed by Alessandro Annunziato and the Joint Research Centre in Ispra (Italy). The operation of TAT is supported by a Memorandum of Understanding signed between IM and JRC aiming to the development of the Portuguese Tsunami Warning Centre.

The basics of the TAT developed by JRC are explained in Annunziato and Best (2005), Annunziato 2007a and Annunziato 2007b. They will not be presented here in this report. The status of the current Portuguese Tsunami Triggering System is developed in the paper by Annunziato et al. (2009) that is presented as Annex-I and makes part of this report.

One of the most important components of TAT is the pre-computed set of tsunami scenarios. These have been computed for a series of locations, spaced every half a degree in longitude and latitude, with magnitudes ranging from 6.5 to 9.5. The first generation of scenarios, based on an empirical model for the surface deformation generated by a thrust fault, is thoroughly discussed in the documents Annex-II and Annex-III that are part of the current report.

Following a series of tests on TAT and its components, it was agreed with JRC that the 2nd generation of tsunami scenarios should be based on the template for credible tsunami sources in the Gulf of Cadiz (NEAREST deliverable D39). Furthermore, it was requested that water velocity should also be stored, together with time-lapses of amplitude, so that the scenarios could be used as border conditions for detailed

inundation modelling. A description of the 2nd generation of tsunami scenarios inside TAT is described in Annex-IV that is part of this report.

The 2nd generation computations were already performed at JRC and are currently available at IM as a set of 7 Tb disks. The recommendations done on Annex-IV were adopted for the computation. Presently IM is evaluating the best technical solution to make the 7 Tb database available online to TAT.

Another important component of the Tsunami Triggering System is the list of coastal forecast points where tsunami information is provided to the emergency managers. The proposal of forecast points for Portugal is discussed in the Annexes V and VI of this report. The methodology there outlined could be the base for building a list of forecast points in the other countries surrounding the Gulf of Cadiz, Spain and Morocco.

Since tsunami events or large earthquakes are rare in the Gulf of Cadiz, it is necessary to keep the team on watch trained to the basic operation of TAT. These exercises should be done periodically in an operational regime, at least twice per year. Even if TAT is not yet operational at IM, we developed an application, **syn-tsunami**, that allows the simulation of a tsunamigenic event, from the detection of the earthquake event by the seismic network to the analysis of coastal sea level observations recorded by tide-gauges. This tool has been used for demonstration purposes and to illustrate the work of TAT.

4. Future perspectives and recommendations

The Tsunami Analysis Tool developed by JRC and installed in IM under a common agreement has proved to perform the basic functions of a Tsunami Triggering System as required by a National or Regional Tsunami Warning System. TAT is not yet prepared to go operational but very few developments are required:

- Inclusion of the basic message wording proposed by the NEAMTWS Operational User's Guide (under construction)

- Improvement of the filtering routine applied to the real-time sea level data. The current algorithm generated very large border effects

It is thus recommended that the cooperation with JRC regarding the development of TAT is pursued in order to make these improvements and correct some minor application bugs detected.

5. References

Annunziato, A., C. Best, 2005. The Tsunami Event Analyses And Models, Institute for the Protection and Security of the Citizen, Joint Research Centre, European Commission, 42 pp.

Annunziato, A., 2007a. The Tsunami Assessment Modelling System by the Joint Research Centre, Science of Tsunami Hazards, 26(2), pp 70-92.

A. Annunziato, 2007b. The JRC Tsunami Assessment Modelling System, EUR 23063, nstitute for the Protection and Security of the Citizen, Joint Research Centre, European Commission, 56 pp.

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6. Annexes

I - Annunziato, A., F. Carrilho, L. Matias, M.A. Baptista, R. Omira, 2009. Progresses in the Establishment of the Portuguese Tsunami Warning System, EMSC Newsletter, April 2009, pp.10-12.

II - The first generation of TAT-JRC Tsunami Scenarios: comparison of the JRC Tsunami source and the Okada model

III - The first generation of TAT-JRC Tsunami Scenarios: computing a scale factor between the JRC tsunami source and the Okada model

IV - The 2nd generation of the tsunami scenario computation by TAT/JRC

Annex V - Building the list of Forecast Points for the Portuguese NTWS, Part I

Annex VI - Building the list of Forecast Points for the Portuguese NTWS, Part 2