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A CONTRIBUTION TO SEISMIC PREVENTION IN CATALONIA (SPAIN)

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ABSTRACT

Emergency plans include various levels of activation or intervention to provide the adequate amount of resources needed depending on the severity of the event. Activation levels can be defined considering not only the ground shaking but also many other factors related to the physical, human and societal vulnerability, as the number of uninhabitable dwelling buildings, the number of homeless and the direct economical losses. All these parameters can be estimated for a regional damage scenario developed previously for an earthquake occurring at any point of the territory with any magnitude.

The existing European seismic information systems are limited in the quantity of useful information provided. The system being implemented in Catalonia (Spain) will increase the information provided with the fast diffusion to Civil Defence agencies of an informative note with a possible damages estimation just a few minutes after the earthquake occurs.

A real time system based on a VSAT seismic network has been developed. This system is now operational generating a SMS message informing about the location and magnitude of the earthquake event within a few minutes of its occurrence. Now this real time system is being updated to perform the estimation of damages based on vulnerability assessment methodologies and using GIS techniques after the earthquake is detected, and then, to send an automatic transmission of an informative note with all the information to the Civil Defence crisis managers within minutes of the earthquake detection..

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Introduction

A methodology for the evaluation of earthquake vulnerability and risk of dwelling buildings at a regional scale is being integrated to an automatic calculation process to generate damage scenarios. These scenarios can be used for the estimation of the possible earthquake effects, and the emergency management preparation and activation. The main objective for simulating damage scenarios is to have, in case of earthquake, a quick evaluation of the possible intensities felt in each municipality of the region, the possible number of people that could have felt the earthquake with several intensities and the affected area for each intensity. If the earthquake has an intensity high enough to produce damages, the method gives an estimation of building damages, human casualties and economic losses.

This damage scenarios simulation becomes an useful, simple and quick tool for civil protection officials in the preparation and activation of the seismic emergency plans. A Geographical Information System (GIS) is used to visualize the results together with different information layers. This tool for generating automatic damage scenarios, in conjunction with a new VSAT based real time seismological network, will allow to distribute this useful seismic information immediately after occurring an earthquake.

Damage scenario mapping

A methodology has been proposed to generate damage scenarios that give an estimation of the possible effects of a given earthquake for the preparation of emergencies. The method can also be used to give a first damage estimation, immediately after the occurrence of an earthquake. Another application of the methodology is the zonation of the territory in order to establish the activation criteria for different levels of the earthquake emergency plan according to the severity of the estimated consequences of the events. The methodology consists of three steps:

1) Estimation of epicentral intensity.
Once the epicenter depth and magnitude of the earthquake has been determined by the Real Time Alert System, it is possible to estimate the epicentral intensity from a correlation between magnitudes and intensities felt by the population.
2) Intensity attributed to each municipality.
It is necessary to adopt a relationship for the attenuation of intensity with distance. The relationship used for Catalonia has been fitted to the intensity data available in its database of felt earthquakes.
3) Estimation of building damage, assessment of the human casualties and evaluation of economic losses.

In the case of intensities greater than 5 (EMS98) these calculations are carried out following the methodology developed by Susagna et al. (2005) and Roca et al. (2005). The number of uninhabitable buildings, the total of homeless, and the total of affected people are also obtained. Data on building occupancy (inhabitants / building) for each municipality and

average surface of houses are used. The economic losses produced by building damage are estimated and expressed in terms of the Gross National Product (GNP). The surface that could be covered by debris is also estimated. This procedure is being integrated to the real-time VSAT transmissions based seismic network of the ICC to provide the Civil Protection authority with fast and complete information to activate adequate levels of the Seismic Activation Plan.

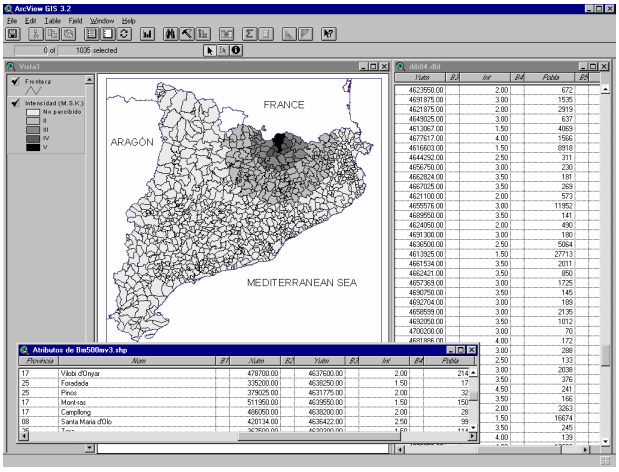

Figure 1. Example of a scenario map with the list of municipalities for an earthquake of M=4.0 in the Pyrenees.

Criteria of activation of the plan of seismic emergencies in Catalonia (*SISMICAT*)

The emergency plans include various levels of intervention (ALERT, EMERGENCY 1 and EMERGENCY 2), that activate the necessary resources depending on the effects of the earthquake.

The Alert level is activated when wide preventive and control measures are required. The activation in this alert phase implies warning acting groups, providing information to the organisms and services involved and to the population if requested, and the follow-up of the tasks to be done. Actions from Security and Intervention groups are only considered in a preventive way.

The Emergency 1 level involves the activation of the organizational structure of emergency management with the general or partial mobilization of the tools and means assigned to the plan. The SISMICAT plan is activated in emergency 1 when a seismic event with important, but local and limited effects on the territory takes place. This situation will be evaluated from the information available at the moment of the emergency considering the following criteria: the degree of effects on the population and the kind of actions required (e.g. information, evacuation, etc.), the geographical extension of the crisis (e.g. number of affected municipalities) and the tools needed.

The Emergency 2 level is activated when the seismic event affects an important extension of the territory on the basis of the same criteria established for the Emergency 1 level.

Present situation

These activation levels are defined in the current plan SISMICAT (DGEiSC 2002) taking into account the ground shaking and the population density. Three types of zones are distinguished, according to their population density: Zone A, Zone B and Zone C, constituted by municipalities with population density (inhabitants per km^2) greater than 100, between 10 and 100 and less than 10, respectively (Fig. 2).

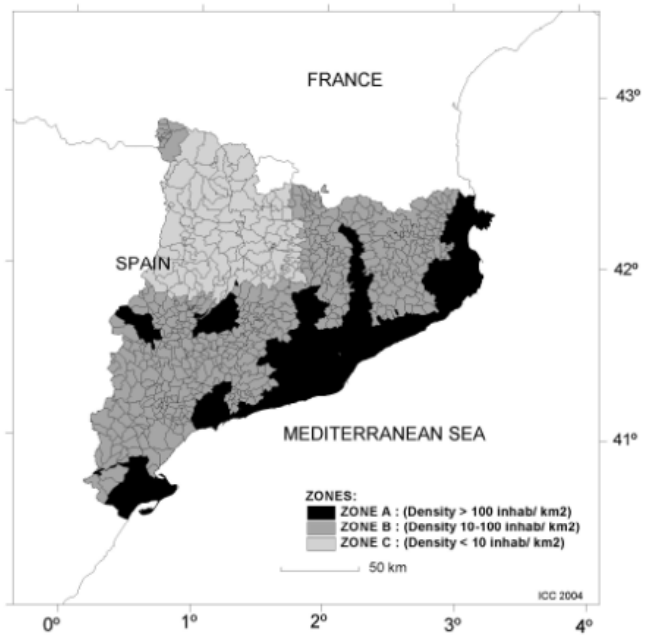

Figure 2. Map of zones according to their population density.

A synthesis of the criteria adopted in the SISMICAT Plan for triggering the above defined activation levels, for each zone of the territory, from felt intensity and complementary data is shown in Fig. 3 and in Table 1. The Pre-Alert level corresponds, as it is indicated by its name, to a non-activation of Civil Protection Services.

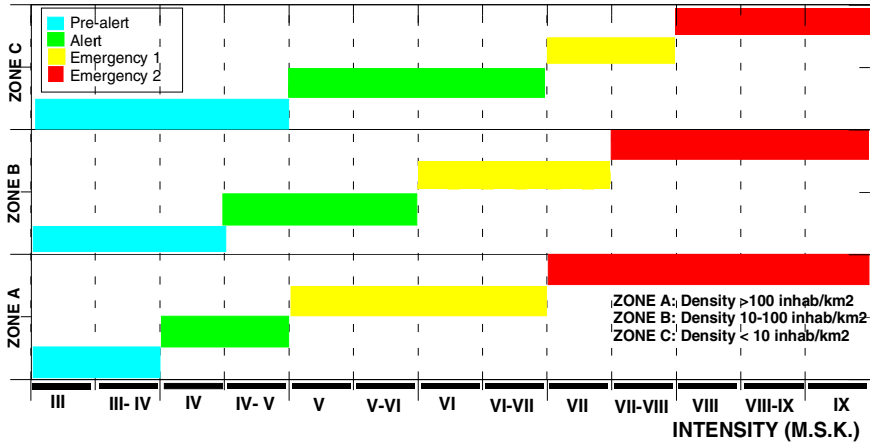

Figure 3. Different level of activation of the emergency plan, depending on the intensity of the seismic action and the population density (zones A, B and C).

Table 1. Criteria of activation of the different levels on the basis of population density, macroseismic intensity and other additional criteria from information on effects. (**comarca* is an administrative division comprising a number of municipalities).

Activation levels	**Intensity**			**Other criteria**
	Zone height density populate (A)	**Zone medium populate (B)**	**Zone low populate (C)**	
ALERT	IV to IV-V	IV-V to V-VI	V to VI-VII	Some people with minor injuries 1-10 homeless
EMERGENCY 1	V to VI-VII	VI to VII	VII to VII-VIII	1-10 dead people 10-100 homeless Panic Failure of basic services (local level) Possibility of dominoes effect
EMERGENCY 2	≥VII	≥VII-VIII	≥VIII	>10 dead people >100 homeless Failure of basic services (at the scale of *comarca**) Domino Effect ,with activation of other special plans.

A tool for the definition of the level of activation

These activation levels can be defined considering not only the estimation of ground shaking but also other factors related to physical, human and societal vulnerability, such as the expected number of uninhabitable dwelling buildings, the total of homeless or the direct economical losses. All these parameters can be estimated for a regional damage scenario developed previously (RSE 2003) for an earthquake occurring at any point of the territory with any magnitude.

The methodology proposed is based on a graphical representation that concentrates all the regional damages estimated for an earthquake on its epicentre. Then, each point of the territory can be characterized by the severity of damages caused by an earthquake with epicentre in this given point, for each possible magnitude. The same methodology explained in the preceding sections has been applied to compute damages. As an example of the method, the number of uninhabitable dwelling buildings that would be observed after an earthquake of M5.5 is shown in Fig. 4.

If the value of one parameter of damage is fixed, it is possible to construct new maps with the magnitude of the earthquake needed at any point of the grid to produce this damage. A seismic zonation proposed for an emergency plan activation is shown in Fig. 5 and in Table 2

(Reinoso et al. 2003). In this table the ranges of magnitude are defined for each zone and for each level of activation, indicating the grades of damages expected (Fig. 5).

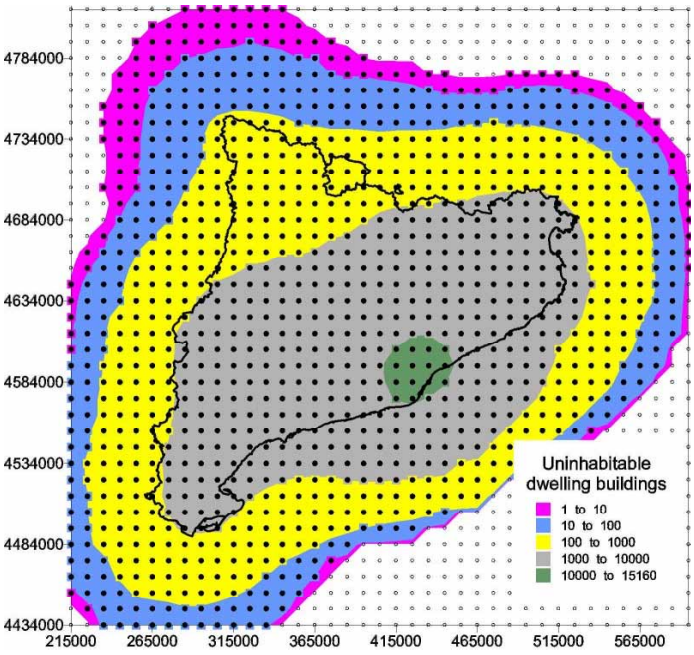

Figure 4. Number of uninhabitable dwelling buildings after an earthquake of M5.5, occurring at each point of the grid.

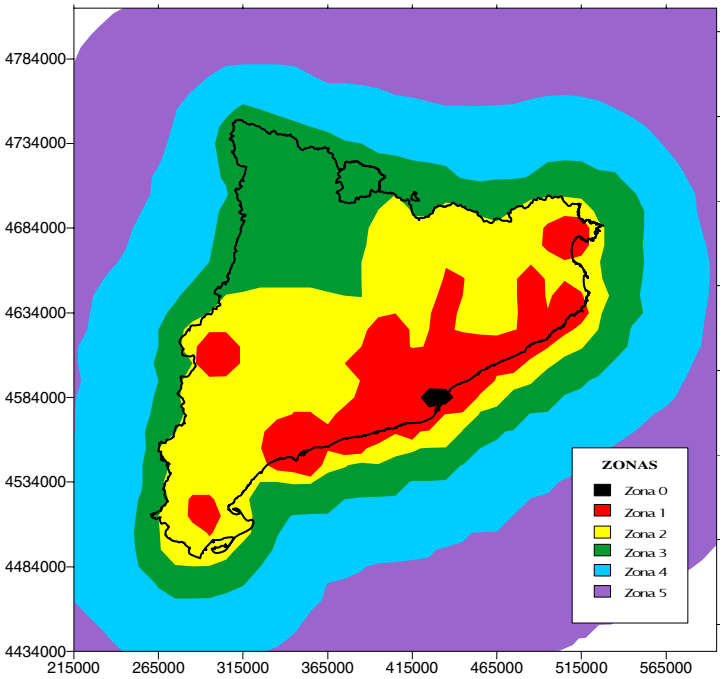

Figure 5. Seismic zonation proposed for activation of the emergency plan.

Table 2. Ranges of values of magnitude for each zone and for each level of activation.

Seismic criteria for emergency plan activation			
ZONES	**Alert** More than 25 000 inhabitants feel an earthquake with intensity ≥ IV	**Emergency 1** Uninhabitable dwelling buildings: < 500 Homeless: < 2.000 Losses: < 180 M€	**Emergency 2** Uninhabitable dwelling buildings: > 500 Homeless: > 2.000 Losses: > 180 M€
0	Magnitude 3.8 to 4.3	Magnitude 4.3 to 4.6	Magnitude > 4.6
1	Magnitude 3.8 to 4.3	Magnitude 4.3 to 4.8	Magnitude > 4.8
2	Magnitude 4.0 to 4.6	Magnitude 4.6 to 5.1	Magnitude > 5.1
3	Magnitude 4.3 to 4.8	Magnitude 4.8 to 5.4	Magnitude > 5.4
4	Magnitude 4.6 to 5.1	Magnitude 5.1 to 5.9	Magnitude > 5.9
5	Magnitude 5.1 to 5.6	Magnitude 5.6 to 6.1	Magnitude > 6.1

With the aid of the zonation established on this basis, the preliminary level of intervention can be quickly selected immediately after an event is detected by the seismological network. This procedure will be integrated with the real-time VSAT transmissions based regional seismological network of the ICC to provide the Civil Protection authority with fast information to trigger the adequate levels of activation of the Seismic Emergency Plan.

VSAT Seismic Network of Catalonia

In 1996 a new concept of seismic network was designed and planned in order to fulfill two main objectives: i) to provide fast information for Civil Defense services, and society in general, and, ii) to obtain systematically high quality data for the scientific community.

To meet these objectives, it is planned to create robust, high performance field infrastructures and install up to 20 stations equipped with three component broadband sensors and a high dynamic range. The stations are based on VSAT platforms sending continuous almost real time seismic data via satellite to the Hub at the processing center of the Institut Cartogràfic de Catalunya (ICC). Data are continuously stored and processed with an automatic location system. After validation by seismologists information is disseminated via Internet. A detailed description of the network can be found in Goula et al. (2001).

At the present time, 8 field stations are operative, with STS-2 and Guralp CMG-3T sensors together with the reception and processing center (See Fig. 6). Seven more stations (# 9 to 15 in Fig. 6) have been financed and their sites are selected. They will be constructed and installed during 2006. Five other stations are under the process of site selection and another one

(# 20 in Fig. 6) constituted by an OBS Broad Band (from Guralp Systems) has been successfully installed on the sea bottom near an oil platform. Data will be sent via satellite VSAT to join the other data in the Reception Center of Data in ICC (Barcelona).

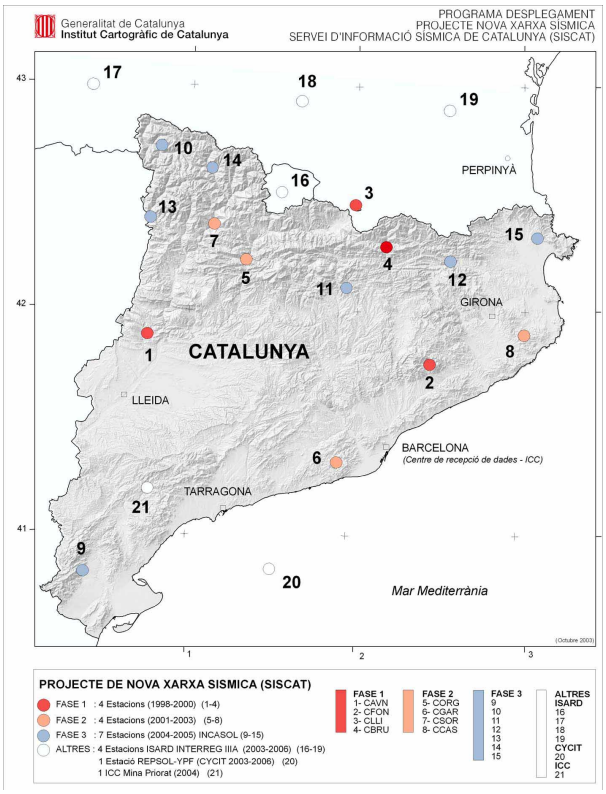

Figure 6. Map of situation of BroadBand stations of the VSAT Network.

A view of Bruguera Station in the Pyrenees (# 4 in Fig. 6) with the seismometer vault, the instrumental house, the solar cells and the VSAT antenna is shown in Fig. 7. All stations are provided with high performance electrical and environmental protections.

Figure 7. View of VSAT- Bruguera Station.

Real time alert system

At the central site, an acquisition computer stores the seismic data into ring buffers with a capacity of 16 days of data using NAQS Server software. NAQS Server software is a primary software element for data acquisition and seismic data handling. At present, seismic data and triggers are automatically processed by a Data Analysis Computer, which performs the automatic event detection, and determinates the hypocenter and the magnitude of the earthquake. A complete documentation of the event location is automatically generated.

When an event occurs and it is located, the alert system sends an SMS message to a distribution list (See fig.8). According with the configuration parameters the distribution list can be different depending of the event characteristics. The alert system reports when one message is delivered and when it is stored at the Message Service Center. The latent period of the alert message is between 2 and 3 minutes since the event detection. The information sent in the alert message is the following:

–Header
–Origin time (UTC)
–Magnitude (ML)
–Hypocenter location (lat, long, depth)
–Location error (RMS)
–Number of stations witch have detected it
–Nearest station which has detected it
–Distance between the epicenter and the nearest station (Km)
-Level of Emergency depending on the magnitude and location.

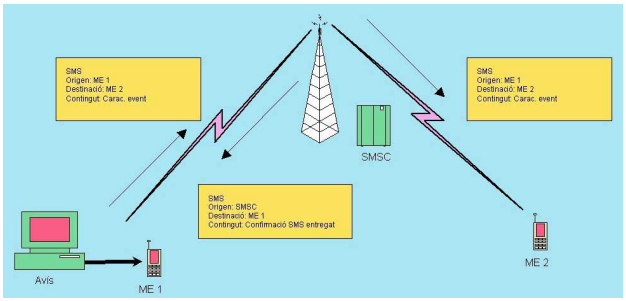

Figure 8. Schematic representation of the real-time alert and SMS.

This automatic process will be substituted by an Earthworms based system (USGS 2005), now under development, in order to generate triggers, detect events, and determinate location and magnitudes of events quickly with great accuracy.

Conclusions

A methodology has been proposed to generate damage scenarios that give an estimation of the possible effects of a given earthquake for the preparation of emergency seismic plans. The application of this methodology has permitted to obtain:

- Regional damage scenarios that can be used for preparing preventive emergency plans in order to reduce the action of earthquakes in a simple and economical way. In particular it has

been used for the Emergency Plan of Catalonia (SISMICAT)

- An estimation of the possible effects of a given earthquake for the preparation of emergencies using a computer application (ESCENARIS V1.00) that has been developed and implemented.

- A zonation of the territory in order to establish the criteria for activation of different levels of an earthquake emergency plan according to the severity of the estimated consequences of the events.

This procedure is now being implemented in connection with the real-time VSAT transmissions based seismic network of the ICC to provide the Civil Protection authority with fast and complete information to activate adequate levels of the Seismic Activation Plan.

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