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Exploring the feasibility of an early warning system in a moderate seismicity context: case study of Pyrenees

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Introduction

The massif of Pyrenees, who results from compressive movement between Iberic and Eurasian tectonic plates and who marks out the natural border between France and Spain, presents a moderate seismicity responsible of many destructive earthquakes over history, which **maximum magnitude could probably reach 6.0-6.5**. Thus Pyrenees constitute one of the Spanish and French areas where the seismic hazard is the most important, what have led to the progressive development of seismological forecasting networks around the massif.

In this context, the SISPyr Interreg project has as principal objective to allow the pooling of Pyrenean seismological data and to improve the massif coverage by the networks favouring the progressive transition to real-time data transfer technologies. In order to make profit of advantages offer by real-time seismology, the **SISPyr project also aims at to assess the feasibility of a Pyrenean earthquake early warning system (EEW)** that could emit early warnings few seconds before destructive seismic waves in case of major regional earthquake.

Mag.	Nb. of stations 1	2	3	4
5.0	✗	✗	✗	✗
5.5	!	✗	✗	✗
6.0	✓	!	✗	✗
6.5	✓	✓	✓	✓

↑ **Figure 2.** Interest of a Pyrenean EEW confronting past seismicity to theoretical blind zones extension. Configurations for which 80% of historical epicenter lead to blind zones smaller than isoseist I=VI are indicated by "√", while "!" symbols indicate the 50% situation.

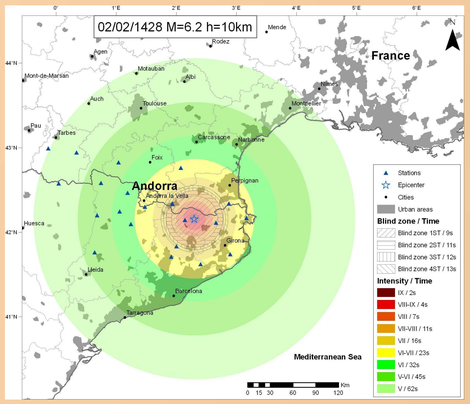

Figure 3. Intensity attenuation versus extension of the blind zone for a scenario earthquake corresponding to the 1428 damaging event. →

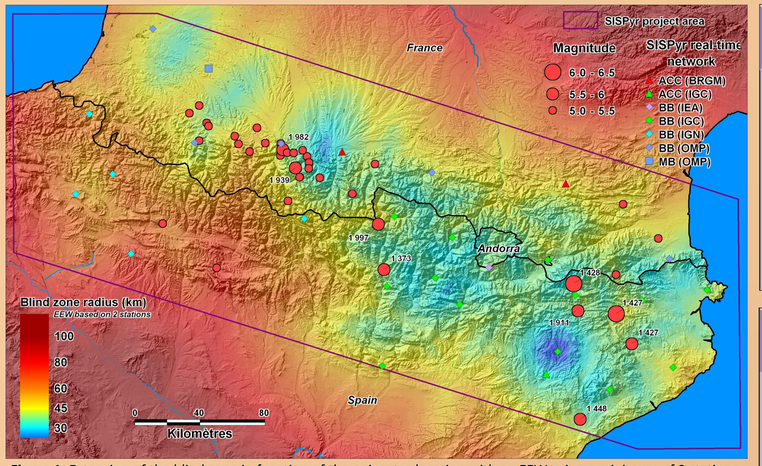

Figure 1. Extension of the blind zone in function of the epicentre location with an EEW using a minimum of 2 stations. Are also represented the SISPyr seismic real-time network as well as the historical Pyrenean seismicity.

Network analysis

Current real-time SISPyr network:

- 24 broad-band stations - 3 strong-motion stations - 1 mid-band station

In a first time, the SISPyr seismic network had been examined in order to assess its adaptability to early warning purposes. In particular, **redundancy** issues, **network coverage**, **data processing** and **time latency** of the existing real-time system have been analyzed. The main conclusion of the previous analysis is that the existing network and system could be the base of an EEW implementation for Pyrenees.

Rapid assessment of magnitude

Different rapid magnitude determination methodologies have been tested (so called τ_c, τ_p^{max} and P_d/P_v methods) in order 1) to check their adaptability to the Pyrenean context and 2) to establish empirical relationships usable in Pyrenees. To that end, a waveform catalog had first been constituted, gathering more than 4.000 records from 195 Pyrenean seismic events. The analysis of these records has allowed us to bringing to light **clear correlations between earthquakes' reference magnitudes and four waveforms indicators calculated from first seconds of the P wave on the vertical component, validating the EEW concept for Pyrenees**.

In particular, in agreement with theoretical analysis performed by Murphy et Nielsen (2009), it appears that **a 2-second analysis is long enough to assess moment magnitudes smaller than 6.5**.

Technical feasibility

EEW utility test

Crossing available information on the SISPyr seismic real-time network with preliminary results on fast magnitude estimate , it is then possible to assess theoretical benefits of a virtual Pyrenean EEW thanks to some hypotheses.

Among these hypotheses, the most important one is the minimum number of stations considered to perform the automatic real-time analysis (including detection/location/magnitude assessment/etc.): we decided to vary this value from one (i.e. "onsite" EEW) to four stations. This work has been performed in order to get first deciding factors on the opportunity of such a system in Pyrenees. In a first time, results can be represented as maps showing extension of the blind zone in function of the epicentre location.

Coupling that kind of approach with a look on historical major Pyrenean earthquakes, it appears that an EEW using a minimum of 2 stations (cf. figure 1) would conduct to a maximum blind zone radius of 41 km for 50% of considered past events and of 47 km for a 80% value. Considering that locations of these historical events are representative of regional seismicity and thanks to the use of the Bakun & Scotti (2006) intensity prediction equation, it is also possible to compare theoretical blind zones' extension with typical radius of the VI intensity curve corresponding to the minimum intensity for which early warning is of some help (cf. figure 2).

Nevertheless, illustrations such as figure 1 also indicate that performances of an EEW based on the SISPyr network would not be homogeneous in whole Pyrenees due to differences on seismic monitoring coverage. As a consequence, such a system would be much more efficient for earthquakes occurring eastward of the Pyrenean massif (cf. early warning scenario shown on figure 3).

End-user opportunity

End user enquiry

Today, the main remaining issue on the evaluation of the feasibility of an EEW in Pyrenees deals with the question of the end-users in order to assess if such a system could answer to an existing need or not.

Indeed, the technical feasibility of the system should be disconnected from its potential use in such a way that the potential EEW be useful. In particular, the question of "How usefully use an early warning for earthquakes associated to high return periods?" is preponderant and strongly linked to the potential end-users' seismic hazard perception. This aspect will rely on a potential end-users survey that will be conducted in 2011 in order to evaluate their wishes in terms of earthquake early warning.

This survey will focus in a first step on a selection of industrial facilities and energy/transportation network managers which are used to react in a very short time in response to warnings thanks to automatic or semi-automatic processes.

Conclusions and perspectives

Thanks to improvements realized through the SISPyr project, it is now possible to test the feasibility of an EEW in order to prevent of major regional earthquake like the 1428 Catalonia event.

Even though regional EEW usually rely on dedicated seismic networks, a look on the **SISPyr real-time network shows that the existing seismic stations may be used for early warning purposes**. However, **operational setting up of this type of innovative tool in Pyrenees technically faces to important barriers due to 1) the moderate seismicity context of Pyrenees** implicating strong attenuation of destruction effects with distance that implies that the EEW should be effective at short epicentral distances, **and to 2) the current limited coverage of the real-time network as well as to the time-latency of the existing system**.

Consequently, a possible approach to bypass these issues would be to consider a "hybrid" system that would initially conduct an "onsite" analysis (from a single station) and then make the warning gradually more substantive by means of a regional approach (using several stations). In addition, network improvements would be necessary in order to make it safer, for example implementing redundant systems.

The coming potential end-users survey should allow establishing if that kind of seismic risk exposure mitigation tool is desirable in Pyrenees.

References

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