An Earthworm based prototype of an EEWS for SW Iberia: first results

X. Goula, N. Romeu, J.A. Jara, Y. Colom, T. Susagna, J.M. Dávila, E. Buforn and A. Roca

Geocat
Gestió de Projectes S.A.

IGC
Institut Geològic de Catalunya

Generalitat de Catalunya

1. Introduction and objectives
2. Alert-es system prototype
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The main objective of Alert-Es project is to study the feasibility of an **Earthquake Early Warning System** (EEWS) in front of potentially destructive earthquakes occurring in the area of Cape San Vicente - Gulf of Cadiz.

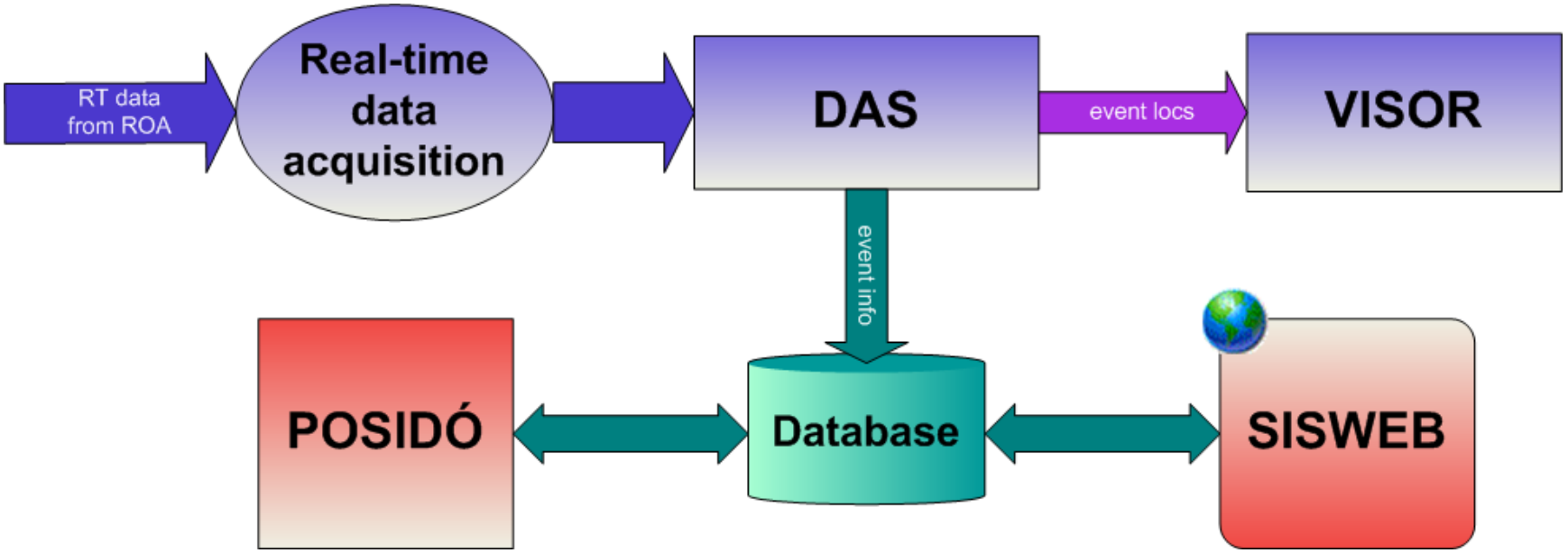
In this study, we show the main functionalities and the first results obtained from a prototype based on ***Earthworm*** developed in **Institut Geològic de Catalunya** (IGC)

In order to develop a feasible Early Warning System, some **requirements** were taken into account:

- Efficient reception of waveforms of seismic stations on the study area
- Optimization of the procedures of picking, event declaration and location to minimize the Warning Time while an acceptable location is being calculated
- Quick computation of the proxies needed to estimate the magnitude

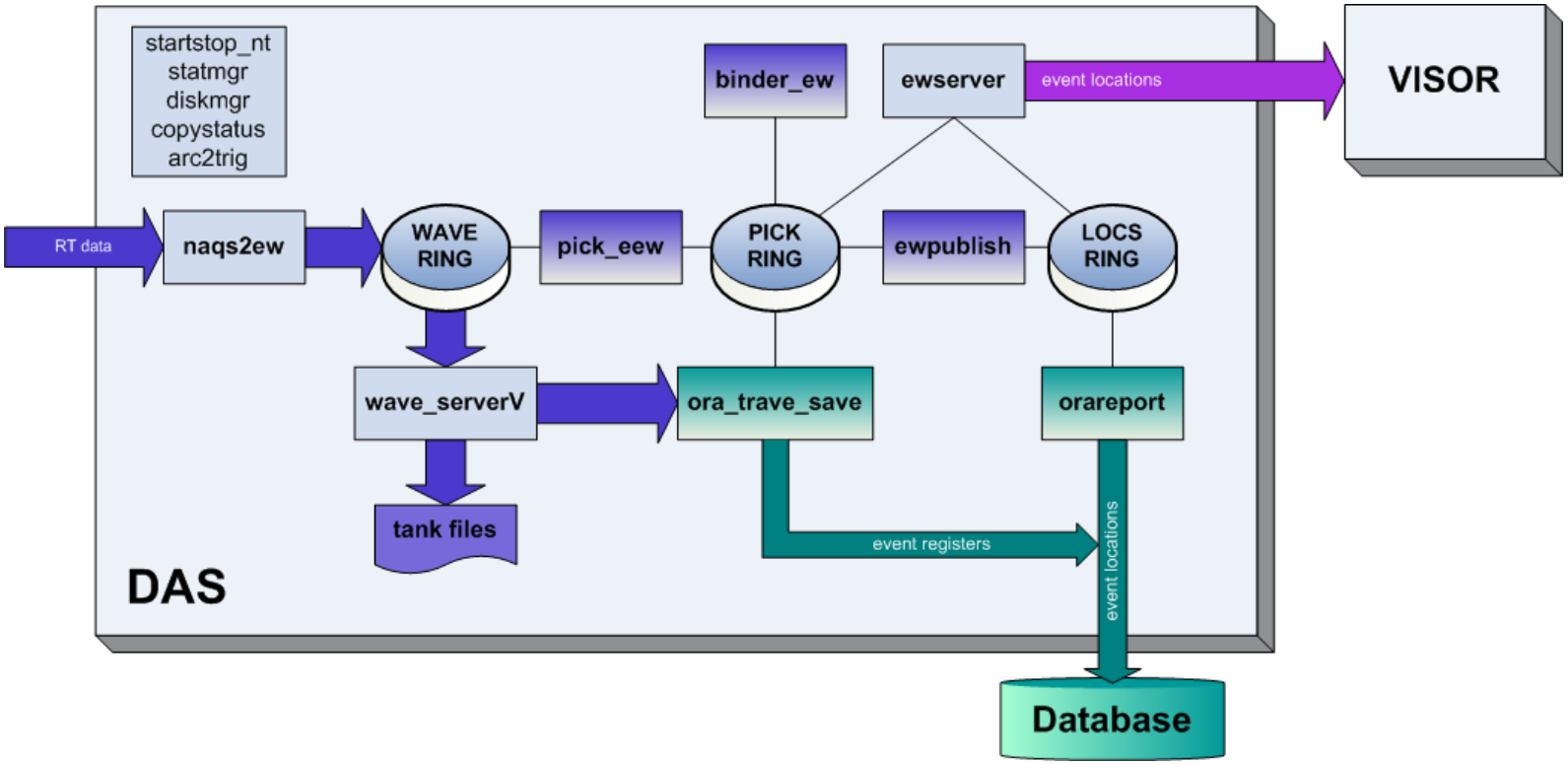
Besides those terms, other **functionalities** were pursuit:

- Monitoring of the evolution of the detection of an event (parameters and Lead Times for selected targets)
- Storage of the information related to the events with the purpose of process them off-line



The complete **Alert-Es system prototype** is composed of several blocks, most of them developed from the system currently in operation in IGC:

- **Real-time system** has the functionalities to acquire data from a Seedlink server, automatic data processing (DAS: picking, event declaration, location, magnitude estimation) and alert monitoring (VISOR)
- **Database:** stores waveforms, arrival times readings, locations and magnitudes from the detected events in an Oracle database
- **Interactive system** handles the information kept in the DB to post-process (POSIDÓ) or browse and query (SISWEB)



Real-time processing system (or **DAS**) is performed by Earthworm tools (USGS) It is a modification of the system held in IGC in order to fit the requirements demanded by Alert-Es project

Modules can be classified depending on their functionality:

- processing modules: **pick_eew**, **binder_ew** and **ewpublish**
- database storage modules: **ora_trace_save** and **orareport**
- auxiliary modules for archiving, status report, data source …

PICK_EEW

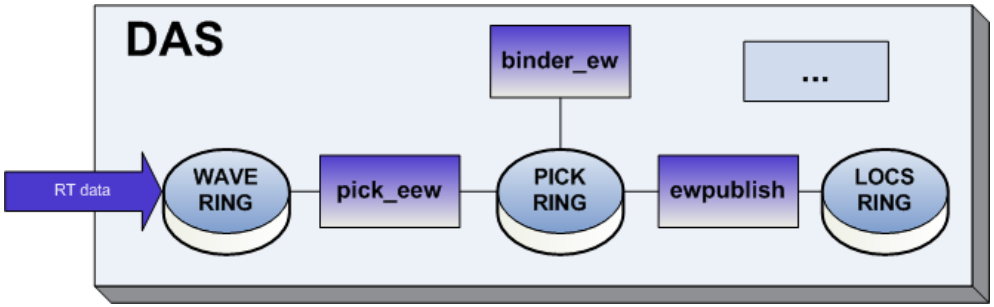
- Picks automatic arrival times of the P waves to seismic stations
- Calculates the Pd and τc parameters, necessary for the estimation of the magnitude of an earthquake in window τ0 whose length depens on the epicentral distance of the channel being processed (new feature)

BINDER_EW

- Automatically declares events from the association of certain arrival time readings of the P waves
- Supplies a rough and quick hypocentral location of the event
- Updates the location for every new arrival-time received

EWPUBLISH (new module)

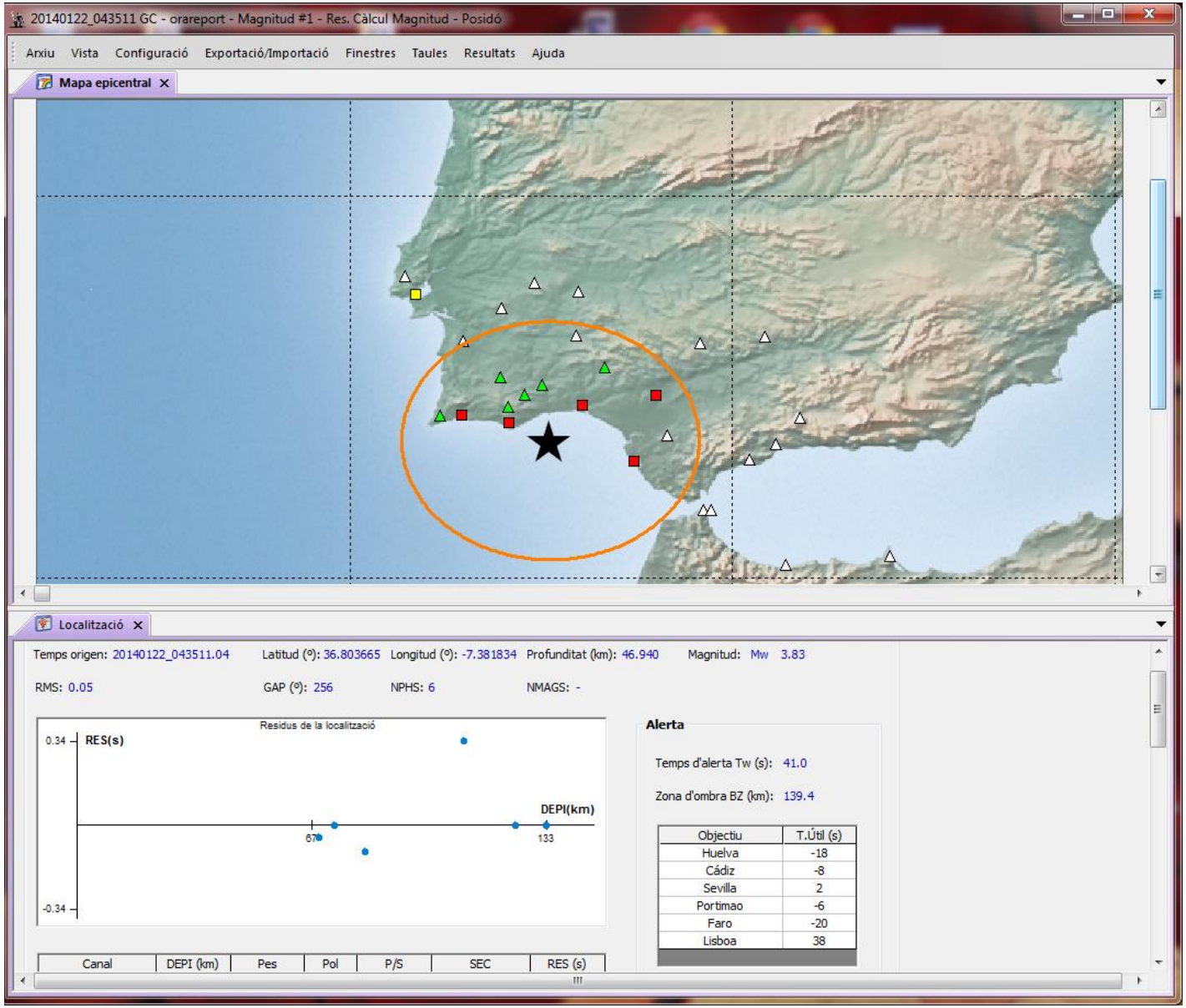
- Estimates the earthquake's magnitude from a weighted average of the magnitudes related to all Pd & τc stored parameters for each location received
- Publishes the complete and updated location and magnitude



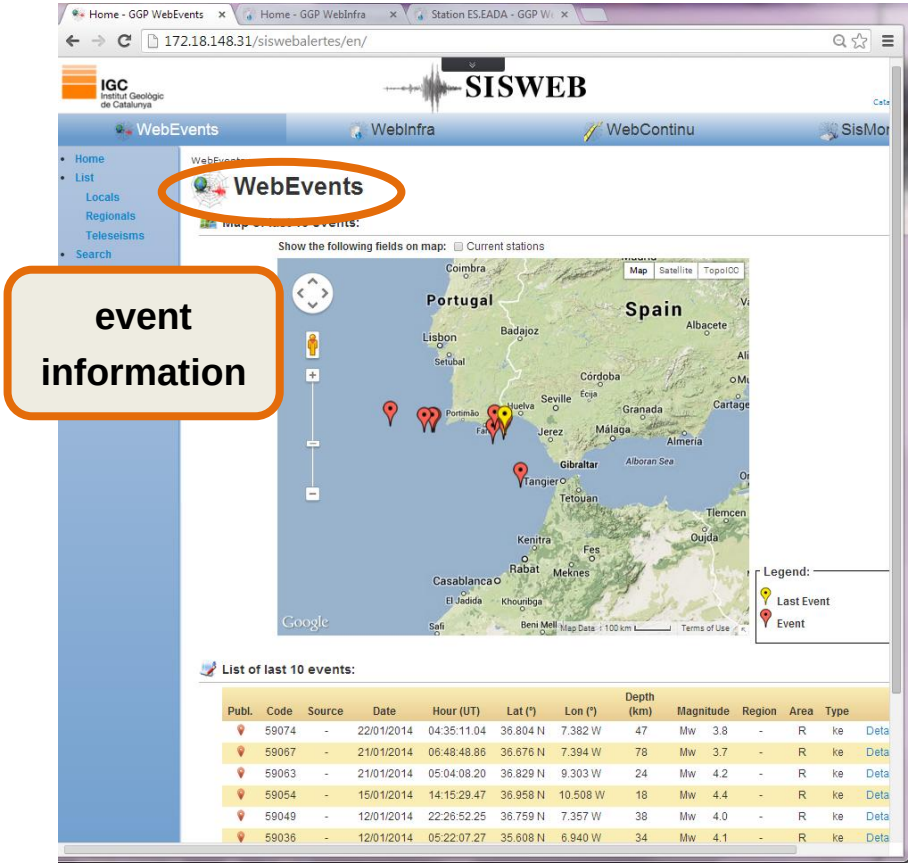
VISOR is the last stage of the Real-time system and monitors the last event detected by **DAS**:

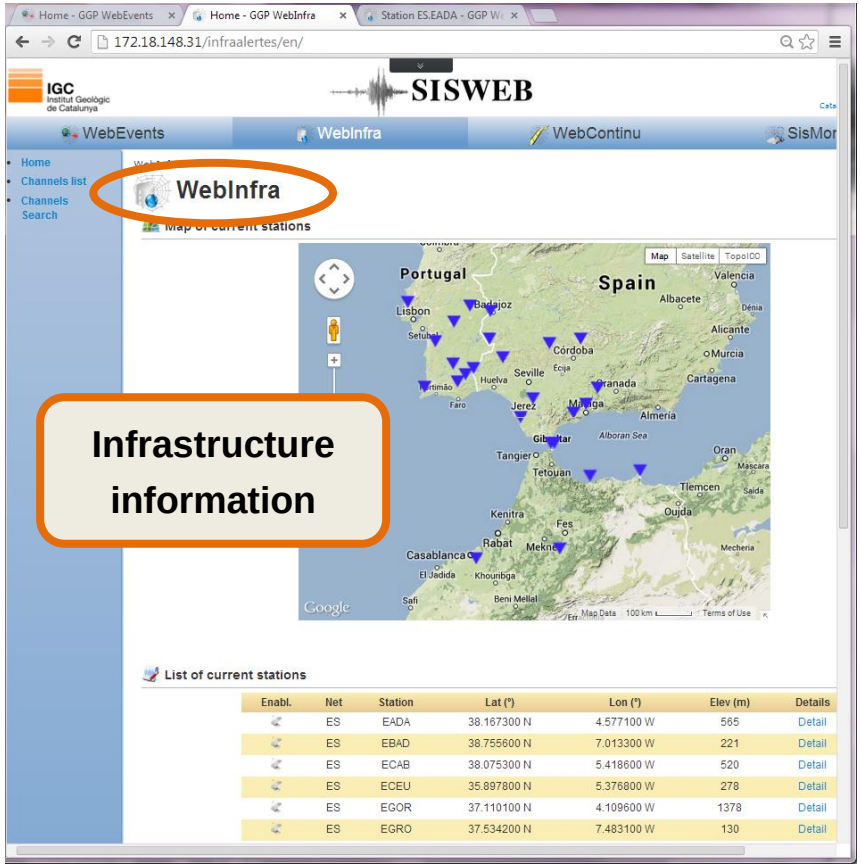
- Represents detailed earthquake parameters (location, arrival times, magnitude)
- Shows the Warning Time and computes the Lead Times at the targets
- Displays a map that combines geographical data of epicenter and stations with the progress of the S wave

2. ALERT-ES SYSTEM PROTOTYPE: real-time monitoring system (VISOR)



SISWEB is a web application to browse or query specific seismic activity such as earthquakes by time, depth, magnitude and location (**webevents**) or instrument data from the seismic stations of the network (**webinfra**)





POSIDÓ is an interactive data processing package for extracting and locating, among others features, and organizing digital seismograph data from **DAS** databases and files of different formats

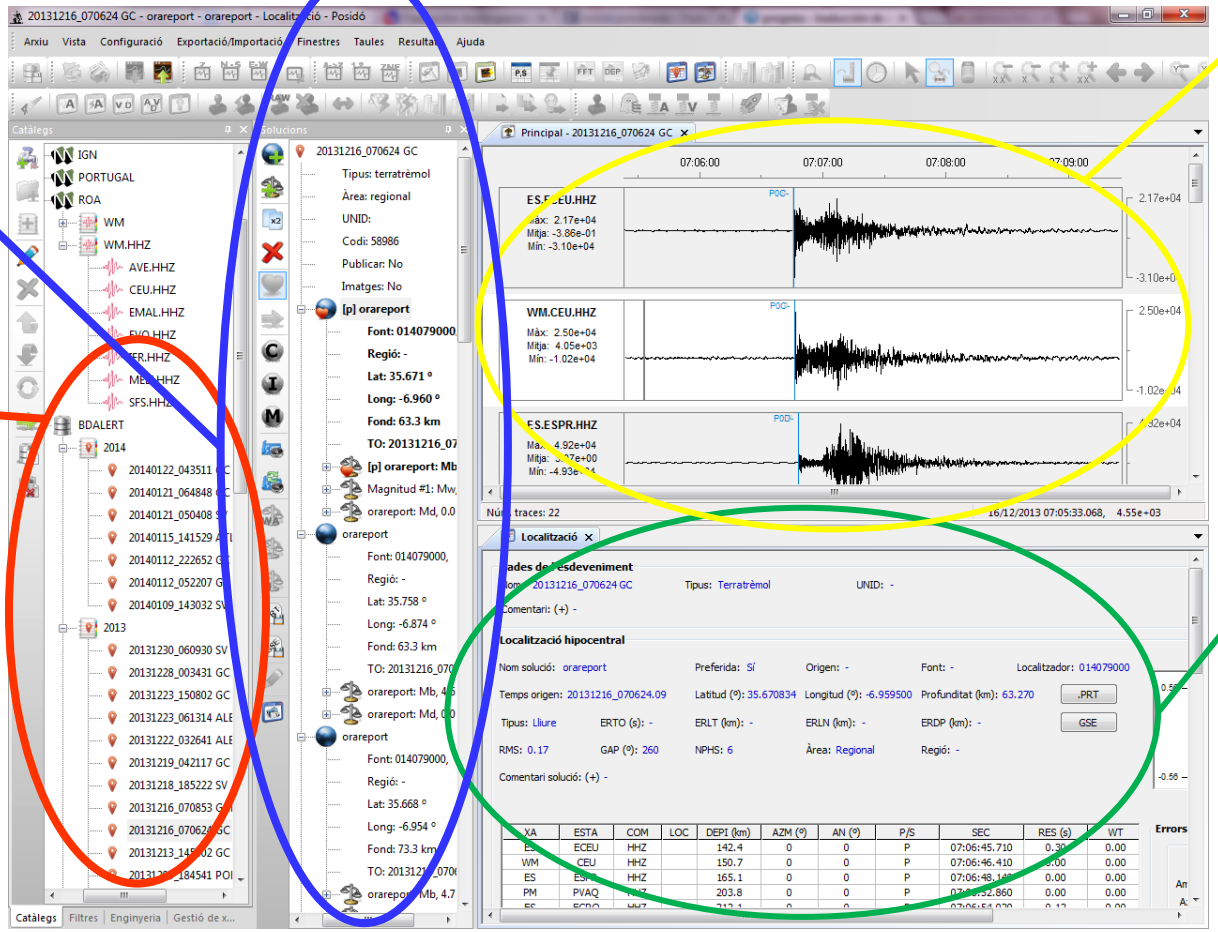
This software application lets view and filter the registers of the events and compare the different locations of the RT system

Different locations for an event

Access to the database and servers

Waveforms

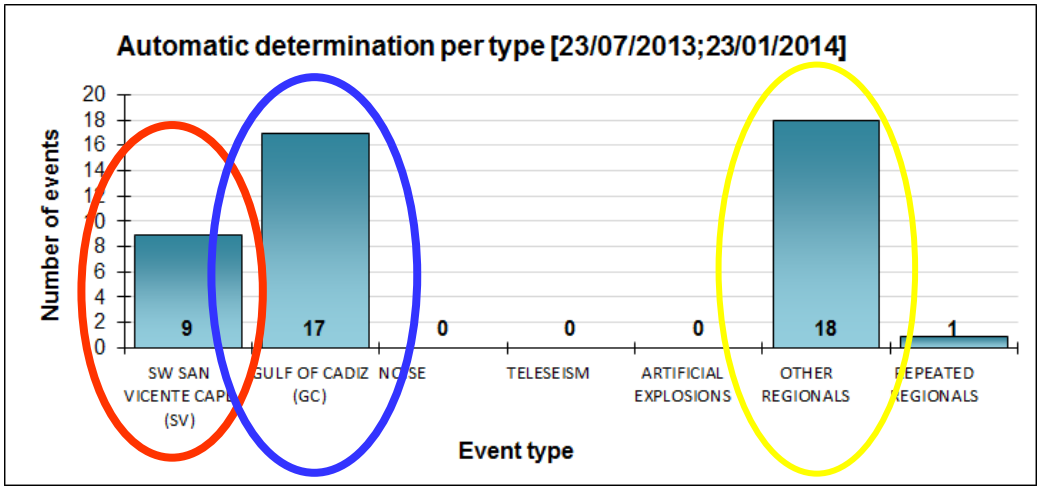
Detailed parameters



- Main parameters of **configuration**:
  - Grid: Latitude [35,37]º, Longitude [-11,-6]º
  - Event will be declared after the reception of **6 phases**
  - IGN velocity model for crust
  - BB stations from IM, IGN and WM networks in three different states: configured, testing, disabled
  - Pd magnitude estimation

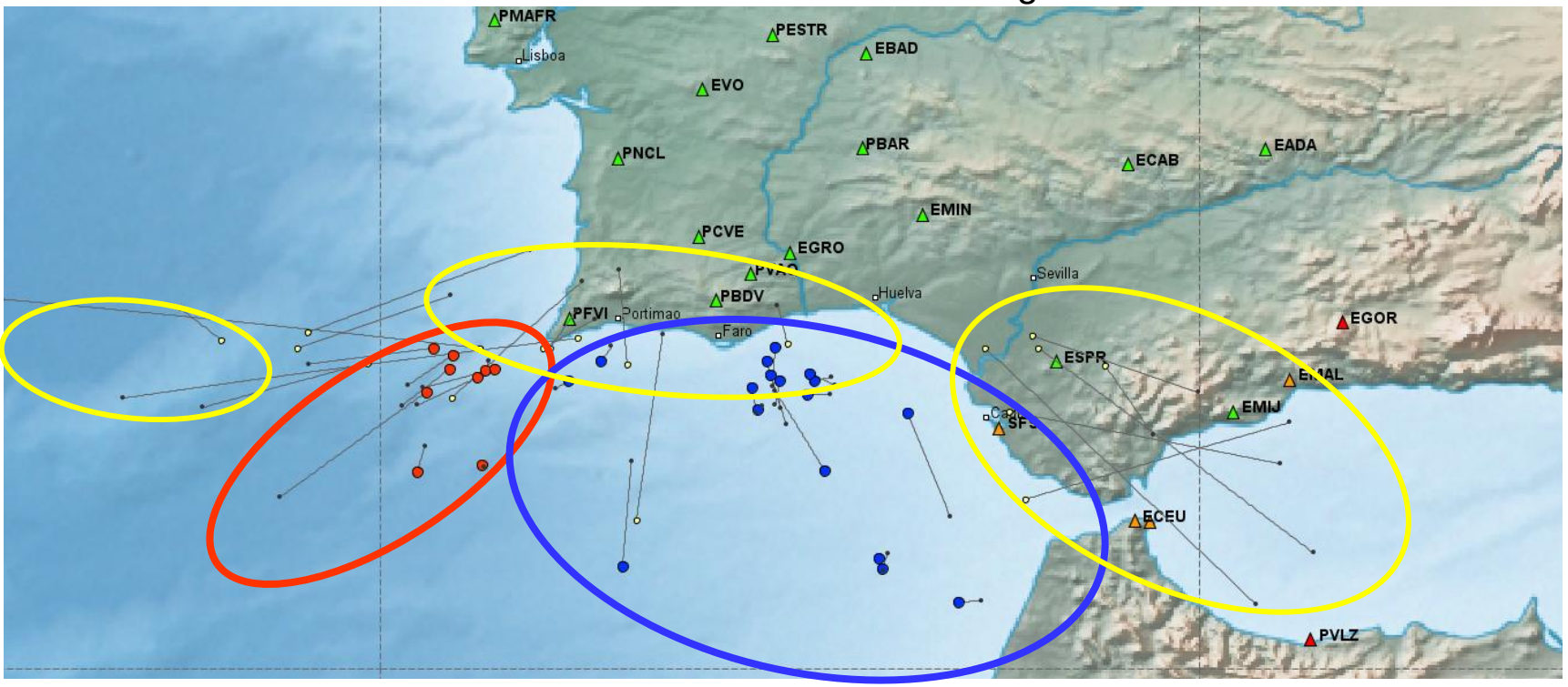
- **Operation** of the RT system
  - Period of **6 months**:

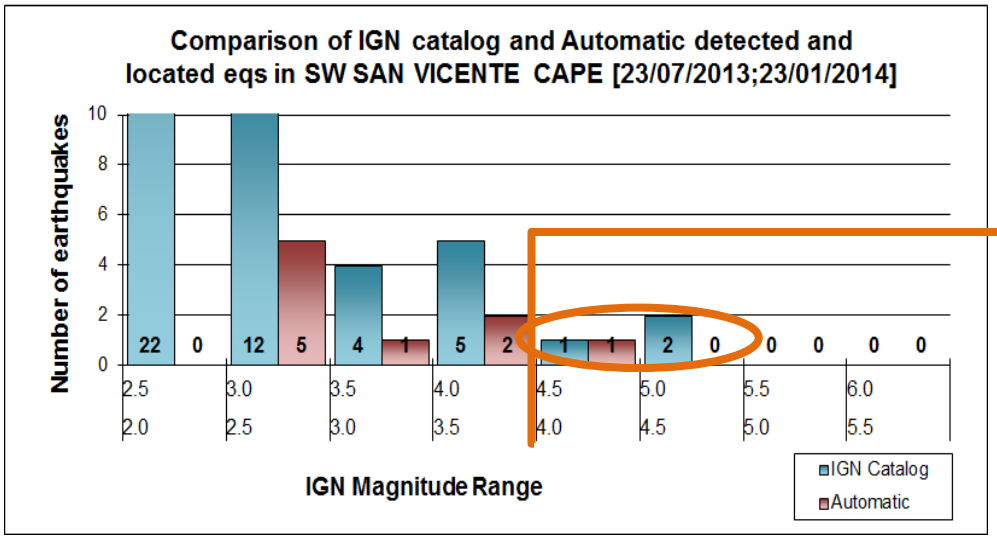
    23/07/2013 - 23/01/2014
  - Foremost issues: no reception of data, inoperative system



- ✓ Only regional earthquakes are detected (no teleseisms, no noises,…)
- ✓ Most of them are useful:

  9 SV and **17** GC
- ✘ **18** other regionals, coming from the surrounding area (mostly Portugal) are detected inside the grid



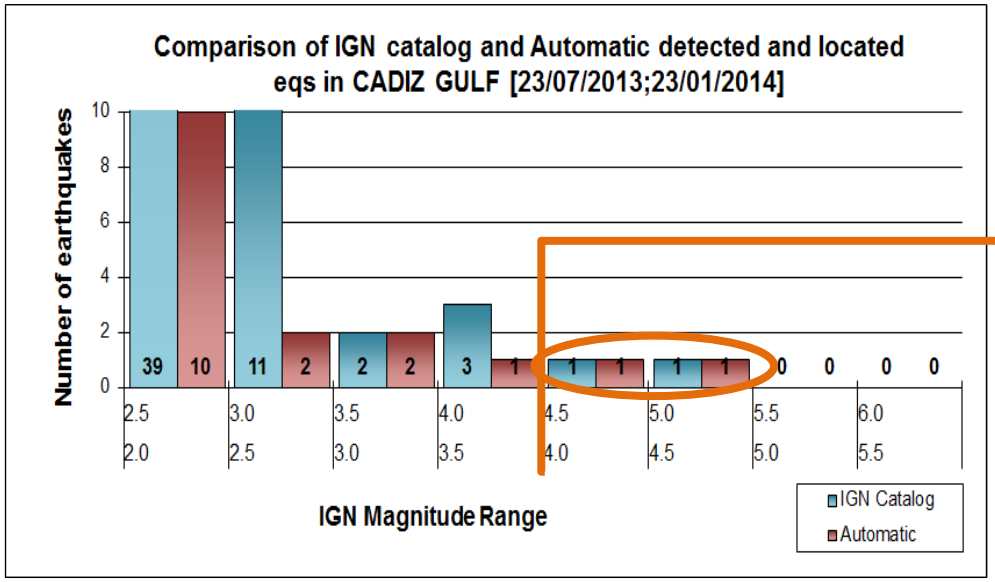


Magnitude ≥ 4.0

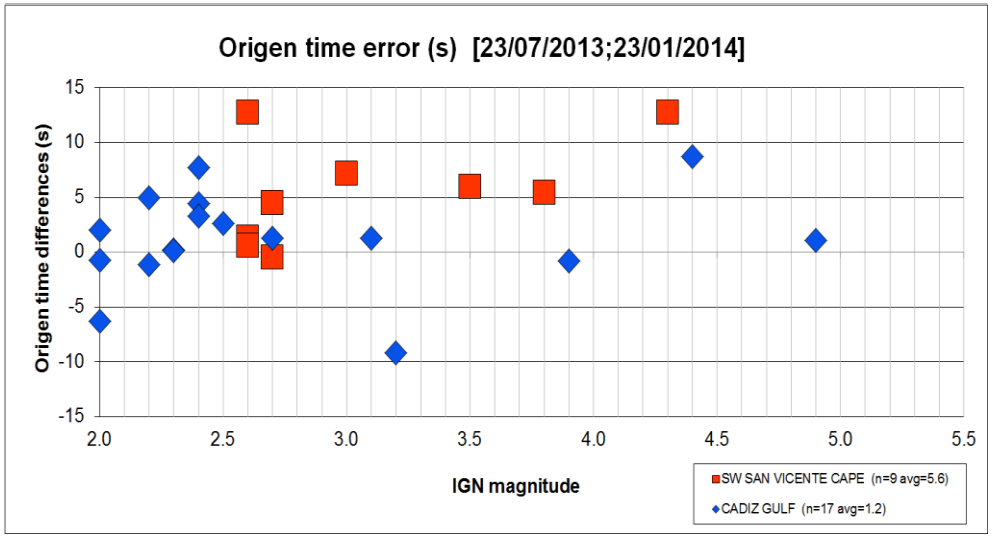
- **SV: 3 earthquakes in IGN catalog**
- × 2 earthquakes lost (Mag's 4.5,4.6) by the Automatic System because of different issues (no data period; inoperative system)

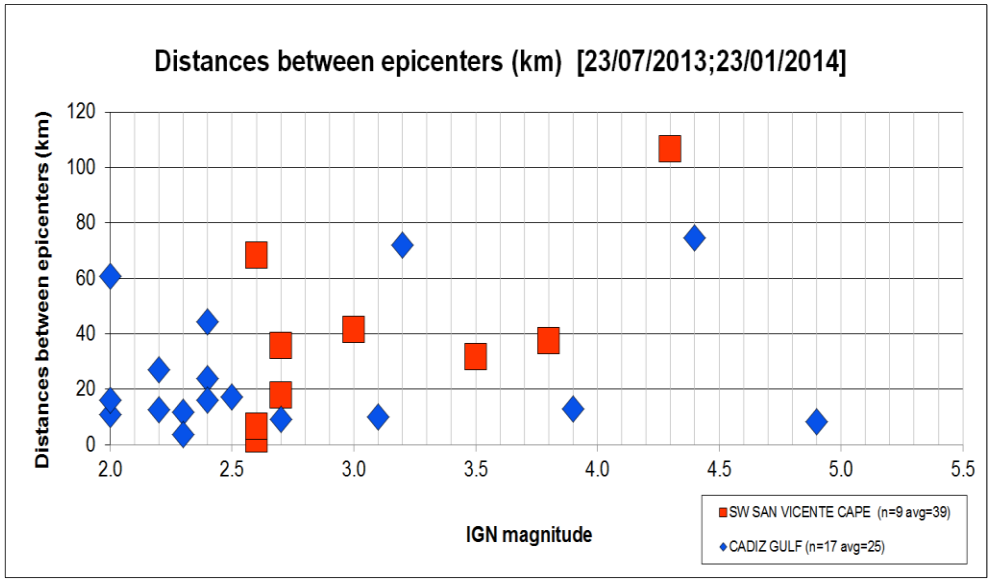
3 eqs automatically detected

(24/07, Mag:4.4; 23/09, Mag:4.3; 16/12, Mag:4.9)



- **GC: 2 earthquakes in IGN catalog**

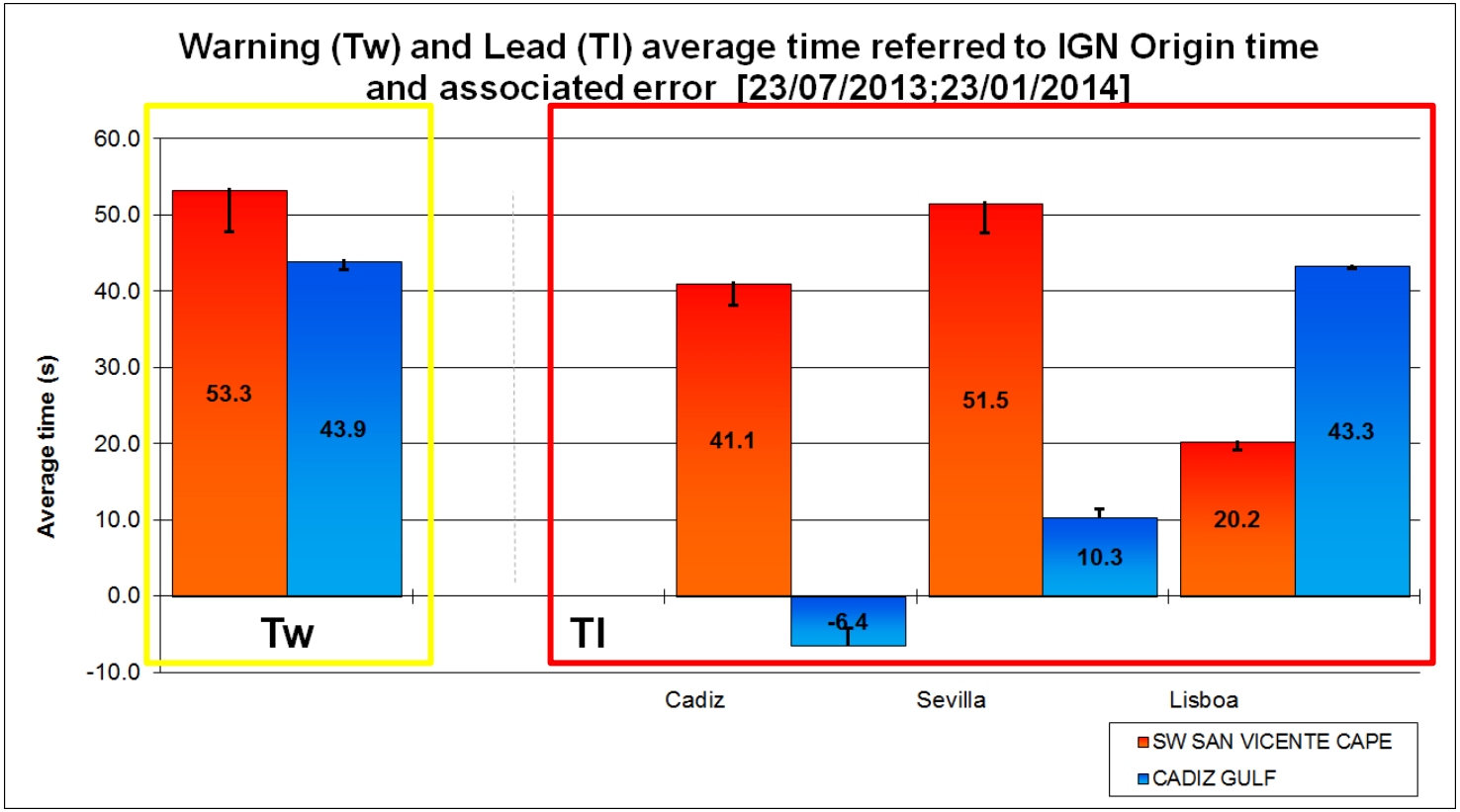




Comparison of average errors between **Simulation** of 6 historical earthquakes and the **RT system**:

Region	Average of Origin time error (s)	
	Real-time system	Simulation of 6 historical earthquakes
SV	**5.6** ✓	6.3
GC	**1.2** ✓	-0.2
Others	8.1 ~	-

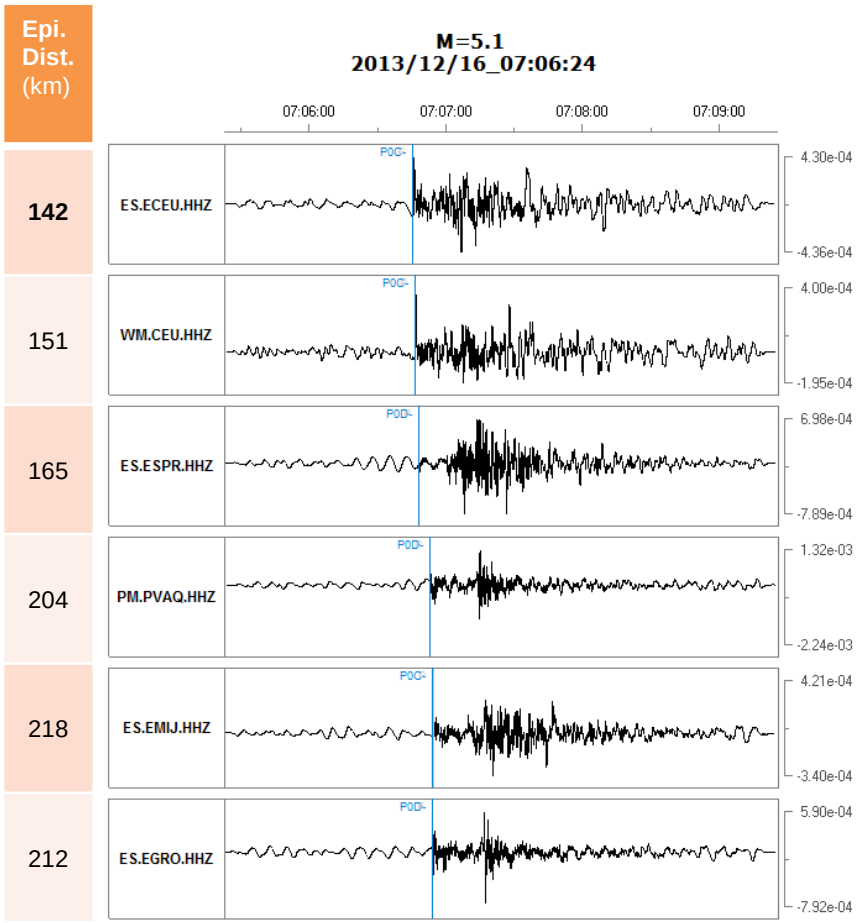
Region	Average of Distance between epicenters (km)	
	Real-time system	Simulation of 6 historical earthquakes
SV	**39** ✓	47
GC	**25** ✓	22
Others	126 ✗	-



Comparison of average errors between **Simulation** of 6 historical earthquakes and the **RT system**:

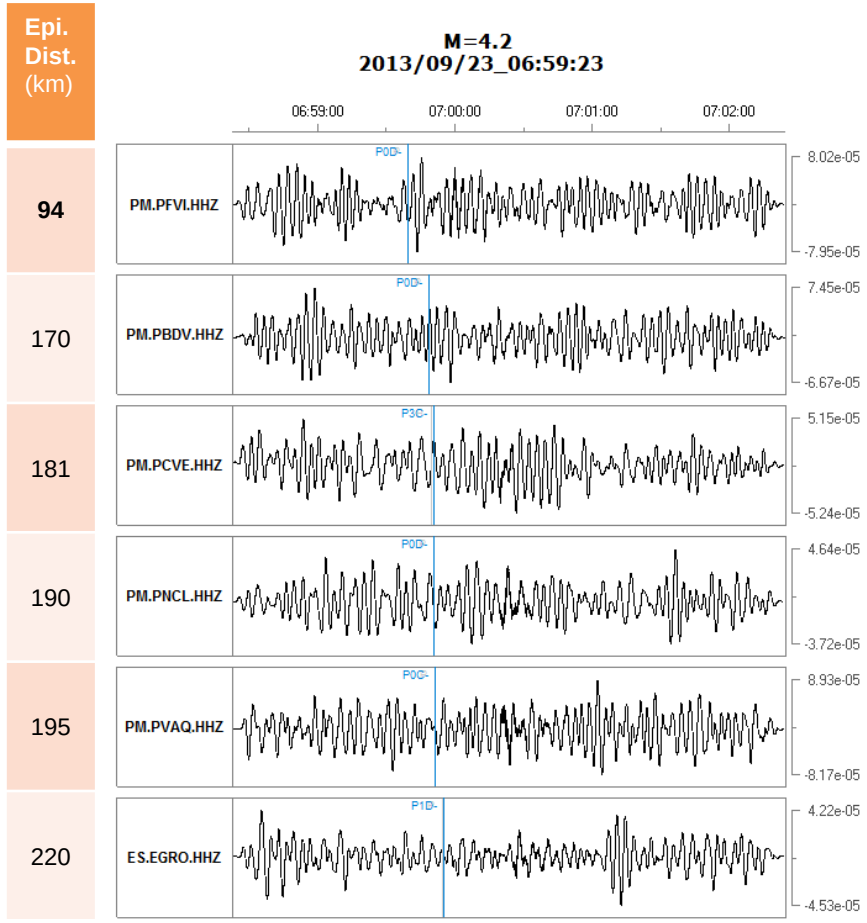
Region	Average of Warning time, Tw (s)	
	Automatic Determination	Simulation of 6 historical earthquakes
SV	53 ✓	54
GC	44 ~	40

2013/12/16 GC Mag_{IGN}= 4.9

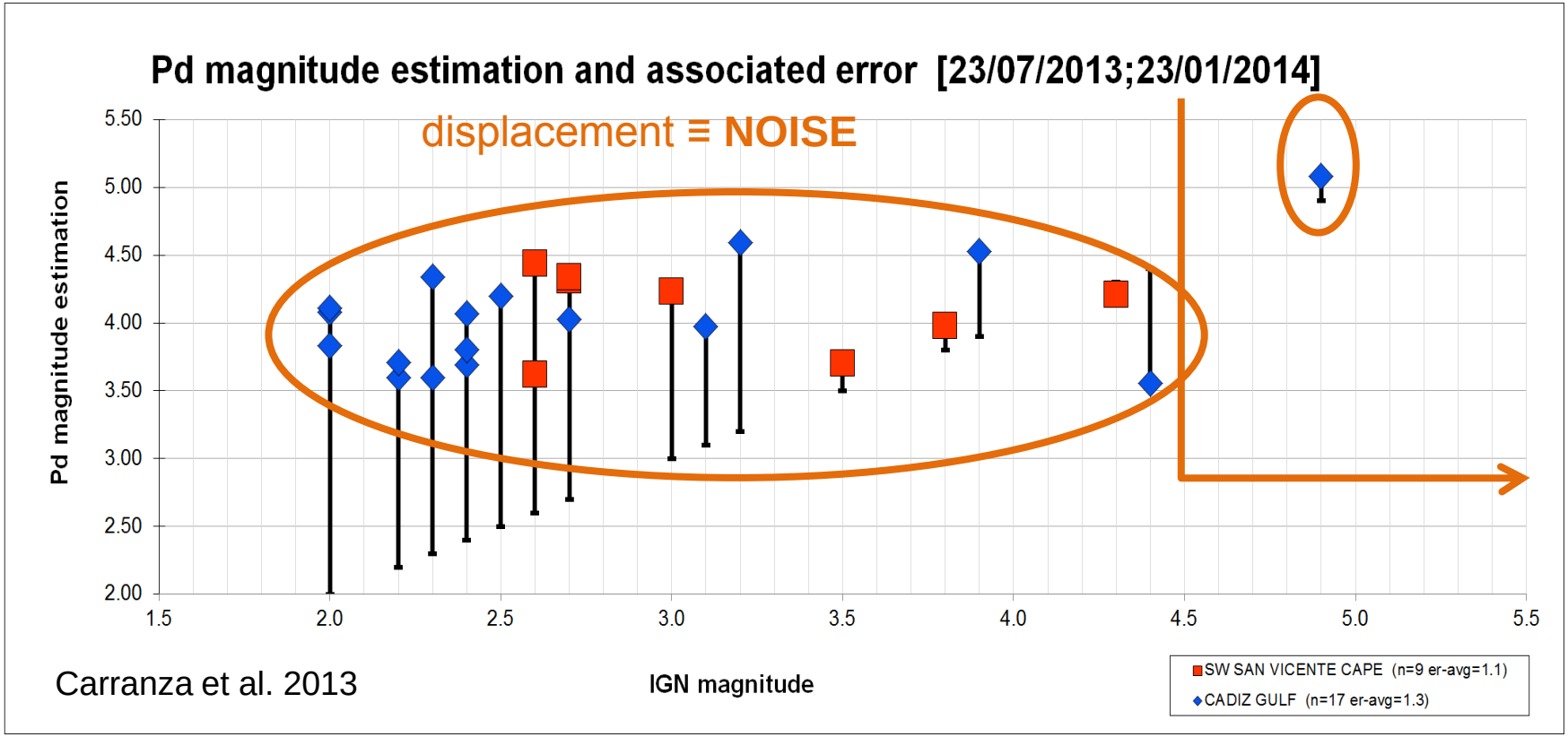


∃ SIGNAL

2013/09/23 SV Mag_{IGN}= 4.3



displacement = NOISE



Carranza et al. 2013

- ✗ Estimated Pd magnitude is always >3.5
  - ⇨ **displacement ≡ NOISE for IGN magnitudes <4.5**
- ✓ Good SNR in the displacement of the only earthquake with IGN magnitude >4.5
  - ⇨ **2013/12/16 07:06:37 GC IGN Mag = 4.9**

- Continuous and real-time waveforms from 25 stations from IM, IGN and WM networks are being received since April 2013 in IGC
- An EEWS prototype has been developed based on Earthworm tools currently in operation in IGC
- The whole Alert-Es system prototype has been completed with:
  - Oracle database,
  - real-time monitoring program
  - interactive processing system and
  - web applications
- The system is fully operational since 23rd July 2013
- First results show:
  - Obtained average parameters values are very similar to the results of the simulations
  - The resulting lead times are useful for all the Southwest Spain and South Portugal, apart from some parts of shoreline which depend on the earthquake epicentre area

It is necessary:

- Establish a strategy to avoid the magnitude estimation for earthquakes of magnitudes <3.5
  - ⇨ SNR threshold for the displacement signal
- Evaluate the behaviour of the stations under test
- Study the consequences of the detection of *other regional earthquakes*
- Analyse the τc magnitude
- Carry on the period of testing to collect more data