PRESTo: a new stand-alone software tool for earthquake early warning

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Abstract

PRESTo is the acronym of ***PRobabilistic and Evolutionary early warning SysTem***, a new software platform at the base of the Earthquake Early Warning System (EEWS) under development and testing in southern Italy (Zollo et al., 2009; Iannaccone et al. 2009).

PRESTo is an integrated software tool that continuously processes the live streams of 3-component acceleration from the seismic stations. As an energetic event is detected at a minimum of two stations, the system promptly performs the first P-picking location. Peak ground displacement measurements (PD) in a narrow time windows after the observed P- and predicted S-signals are used to estimate the earthquake magnitude and predict a peak ground motion parameter at distant target sites.

The evolutionary, real-time earthquake location technique is based on an equal differential time (EDT) formulation and a probabilistic approach for describing the hypocenter estimation. The algorithm, at each time step, relies on the information from both triggered arrivals and not-yet-triggered stations. With just one recorded arrival, the hypocentral location is constrained by the Voronoi cell around the first triggering station, constructed using the travel times to the not-yet-triggered stations. With two or more triggered arrivals, the location is constrained by the intersection of the volume defined by the Voronoi cells for the remaining, not-yet-triggered stations and the EDT surfaces between all pairs of triggered arrivals. As time passes and more triggers become available, the evolutionary location converges to a standard EDT location (Satriano et al., 2008).

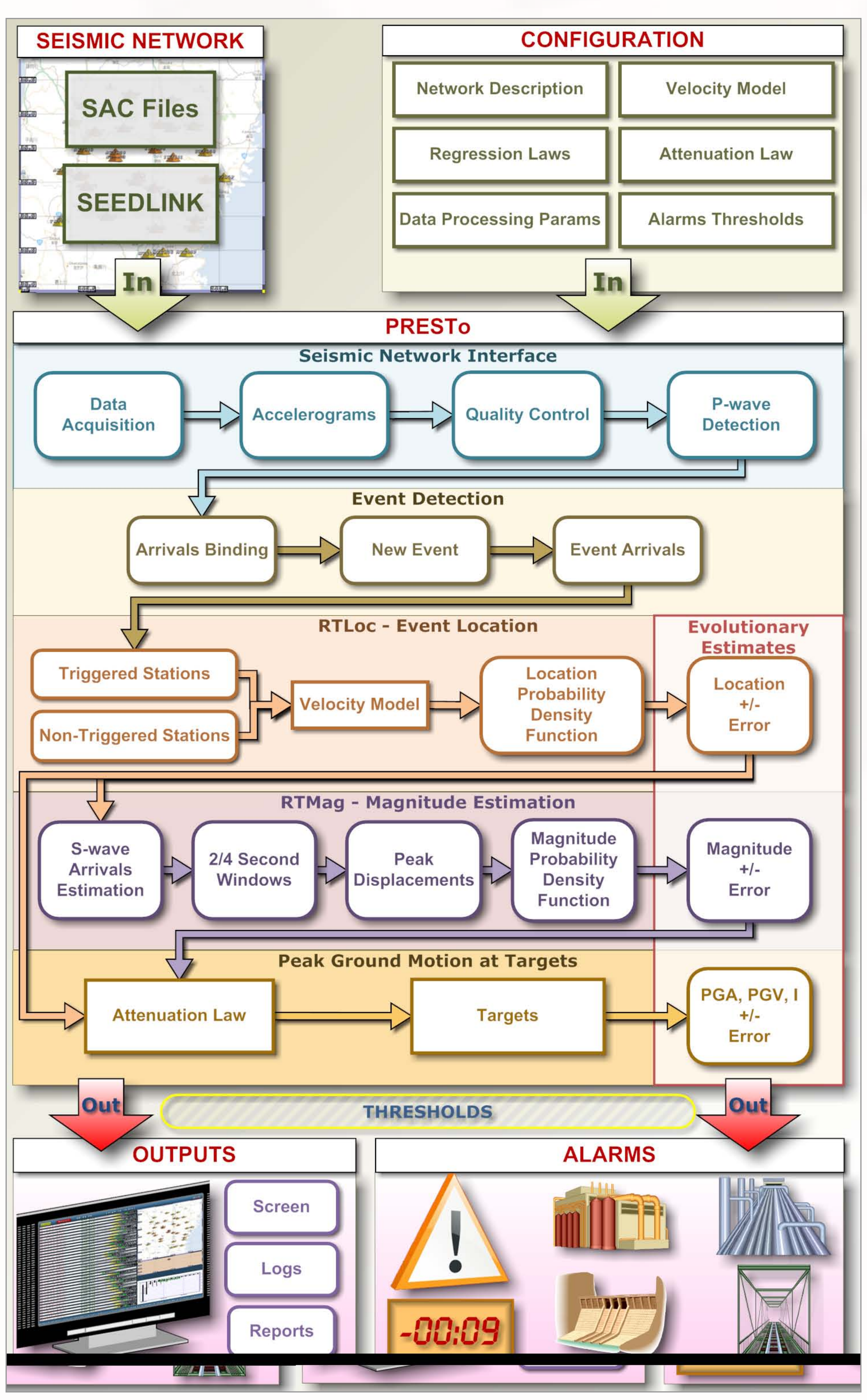
The real time and evolutionary algorithm for magnitude estimation is based on a magnitude predictive model and a Bayesian formulation. It is aimed at evaluating the conditional probability density function (PDF) of magnitude as a function of ground motion quantities measured on the early part of the acquired signals.

We use the empirical relationship between low-pass filtered, initial P- and S-peak displacement amplitudes and moment magnitude (e.g. Zollo et al, 2006). While the P-wave onset is identified by an automatic picking procedure, the S-onset is estimated from a theoretical prediction based on the hypocentral distance given by the earthquake location. At each time step, progressively refined estimates of magnitude are obtained from P- and S-peak displacement data. Following a Bayesian approach, the magnitude PDF computed at the previous step is used as *a priori* information (Lancieri and Zollo, 2008).

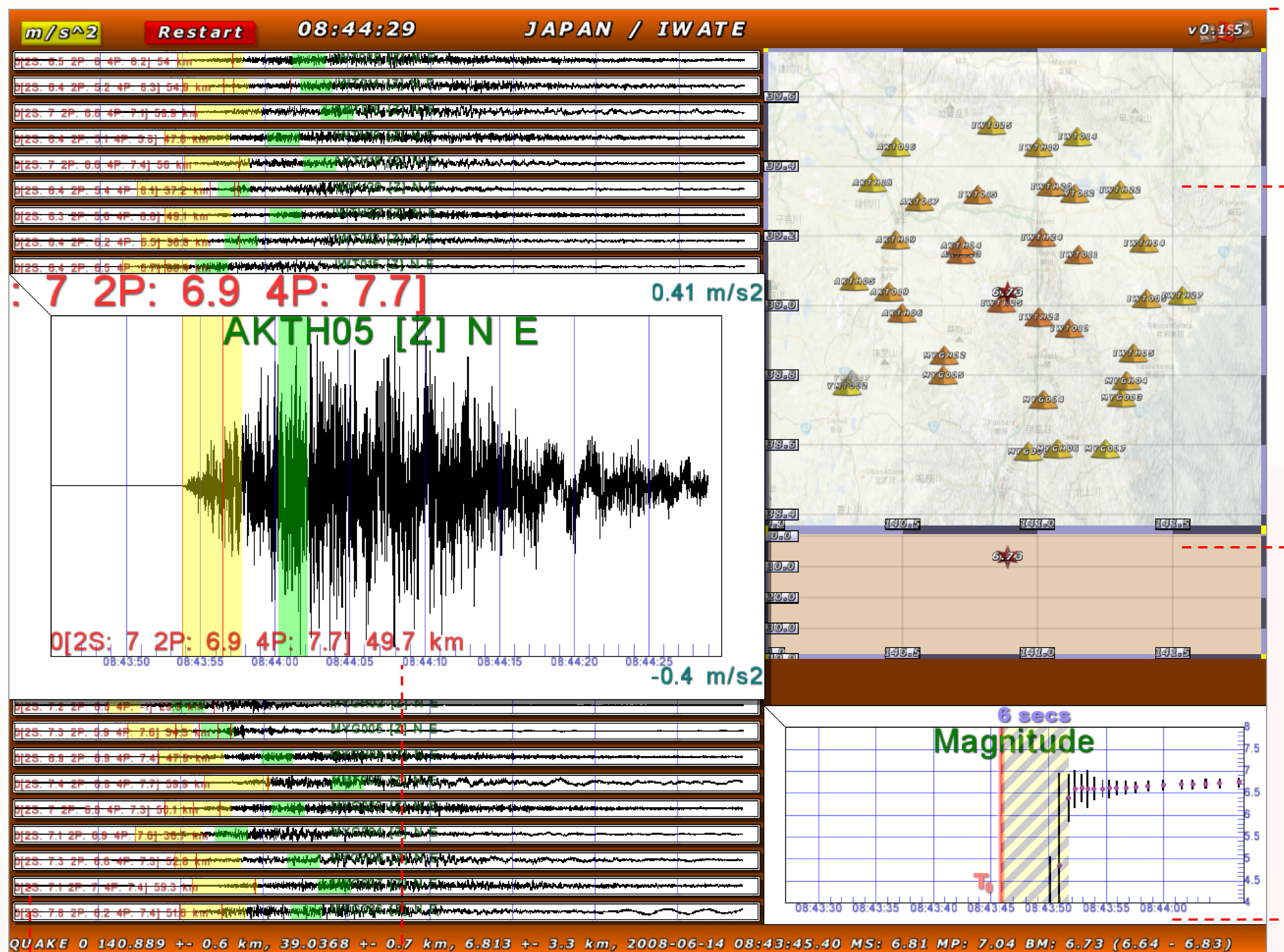
An empirical attenuation model at regional scale is used to predict the peak accelerations at target structures. For the Iwate region the attenuation relation of Kanno et al (2006) was used.

PRESTo can easily be configured and tailored to different networks, by providing the seismic stations details, velocity model, coefficients of the regression laws, and by tuning the parameters controlling the data analyses algorithms and the alarms dissemination. A simple integration with the underlying seismic network is guaranteed by the widely available **SeedLink** communication protocol used for data acquisition.

Block diagram of the PRESTo software package



Application of PRESTo to the June 14, 2008, 08:43 (JT), Mw = 6.9 Iwate earthquake



Screenshot of PRESTo, processing the SAC files of the Iwate earthquake

Map of the seismic network. Triggered stations are colored according to their P-wave arrival time. The red star marks the current estimated epicenter, and reports the current magnitude estimate

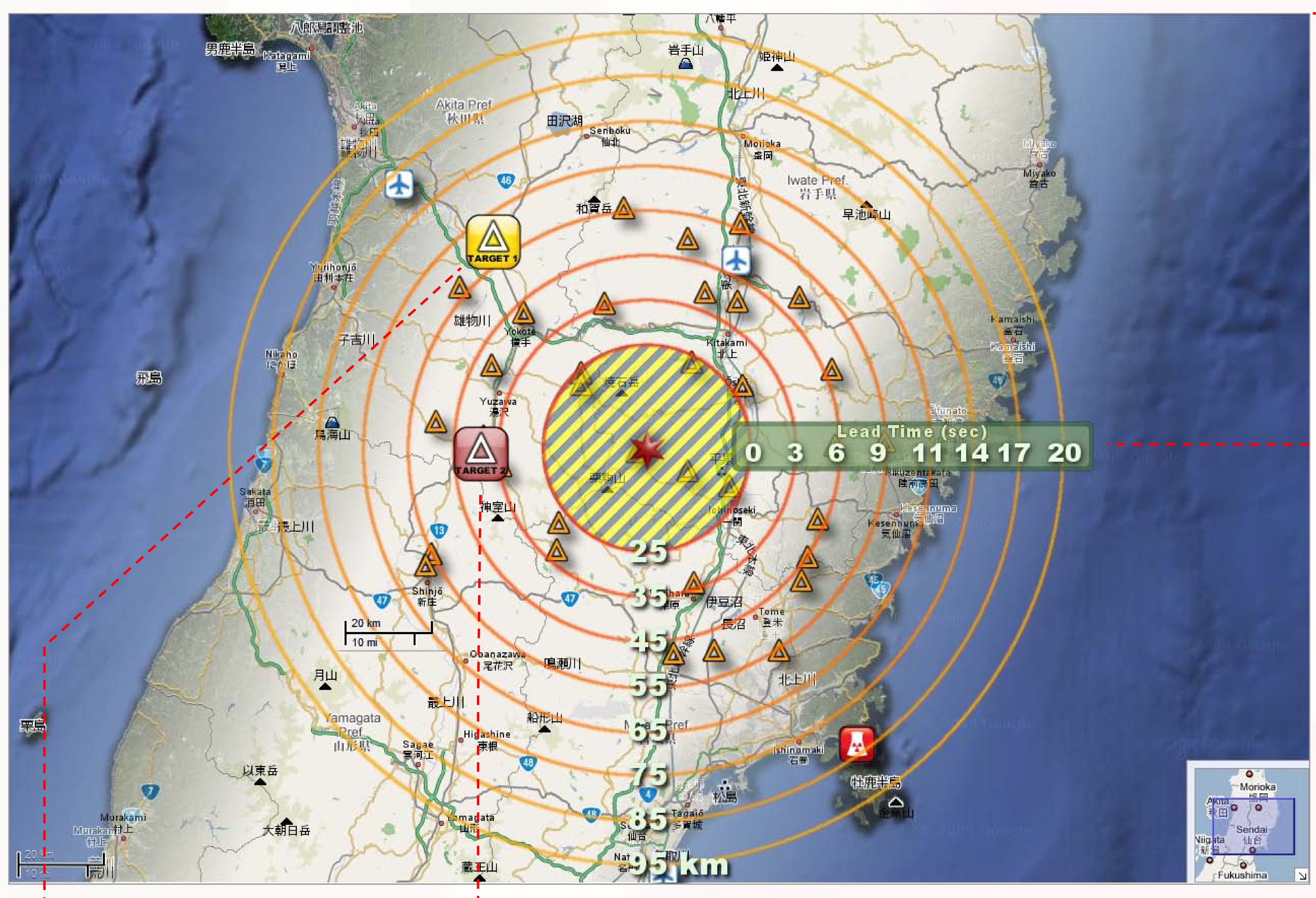
E-W section of the current estimated hypocenter, with earthquake magnitude

Evolution with time of the magnitude estimate and of its uncertainty. The vertical red bar marks the estimated origin time (T_0) of the earthquake. The interval (6 sec) elapsed from the origin time to the first magnitude estimate with a low uncertainty is highlighted by a yellow dashed pattern

Incoming 3-component accelerograms from all the seismic stations

Interactive zoom on a station component, showing the time windows used to compute the earthquake magnitude:
- The yellow window covers 2 or 4 seconds after the automatically computed P-wave arrival.
- The green window covers 2 seconds after the estimated S-wave arrival.

In red are the three estimates of the magnitude obtained using those three different time windows

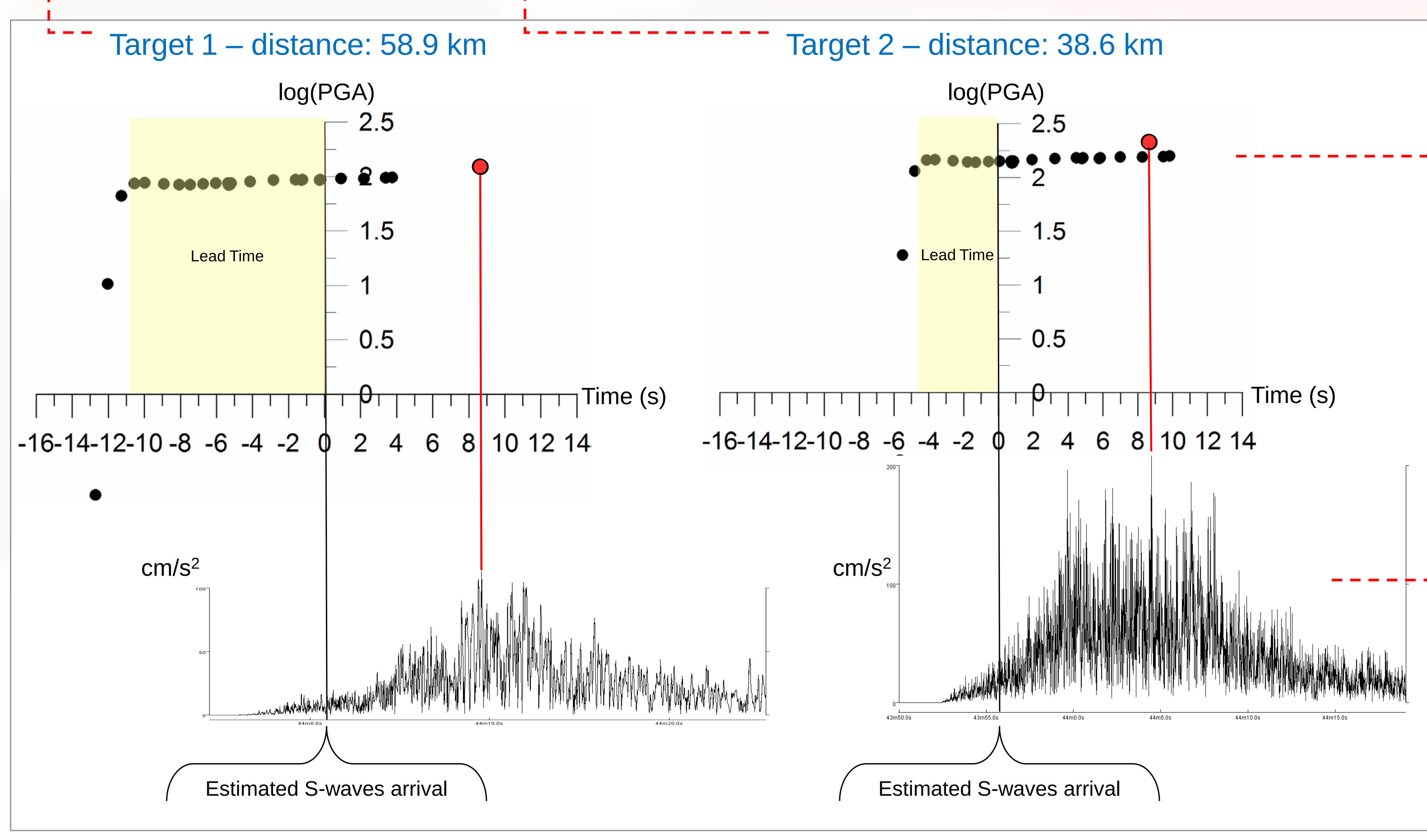


Final estimate of the earthquake location (red star) and lead times

The seismic stations are shown as orange triangles. Two stations are highlighted as possible targets to be alerted by PRESTo.

Seconds available for targets at increasing distances from the epicenter, to carry out their automatic safety procedures (**lead time**)

The zone around the epicenter (yellow dashed pattern) corresponds to the distance traveled by the S-waves before a **stable estimate** of the magnitude is computed by PRESTo. It corresponds to a lead time of zero.



Comparison of estimated and observed PGA at the two targets

Alarms sent from PRESTo to two target sites. Each point is an improved estimate of magnitude and hypocenter performed with the probabilistic and evolutionary procedures implemented in PRESTo. An alarm contains the estimated PGA (represented by the logarithm in the graph) vs. the count-down to the estimated S-waves arrival at the target.

Observed acceleration at the target. The plot shows the module of the acceleration in the horizontal plane (cm/s^2), and the PGA (marked in red). The time axis is the same as that in the alarms plot.

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