APPLICATION OF THE “PRESTO” EARTHQUAKE EARLY WARNING (EEW) AND ALERT MANAGEMENT SYSTEM IN NORTH-EASTERN ITALY, SLOVENIA AND AUSTRIA: EXPERIENCE WITH THE CE3R NETWORK

M. Piccozi\textsuperscript{1}, L. Elia\textsuperscript{1}, D. Pesaresi\textsuperscript{2}, A. Gosar\textsuperscript{3}, W. Lenhardt\textsuperscript{4}, M. Mucciarelli\textsuperscript{2}, M. Živčič\textsuperscript{3}, A. Zollo\textsuperscript{1}

\textsuperscript{1} AMRA-Università di Napoli, Napoli, Italy
\textsuperscript{2} Istituto Nazionale di Oceanografia e di Geofisica Sperimentale, Trieste, Italy
\textsuperscript{3} ARSO, Ljubljana, Slovenia
\textsuperscript{4} ZAMG, Vienna, Austria

Introduction. Aiming at the seismic risk mitigation in the eastern sector of the Alps, since 2002 OGS (Istituto Nazionale di Oceanografia e di Geofisica Sperimentale) in Udine (Italy), the Agencija Republike Slovenije za Okolje (ARSO) in Ljubljana (Slovenia) and the Zentralanstalt für Meteorologie und Geodynamik (ZAMG) in Vienna (Austria) are collecting, analyzing, archiving and exchanging seismic data in real time. The data exchange has proved to be effective and very useful in case of seismic events at the borders between Italy, Austria and Slovenia, where the poor coverage of individual national seismic networks precluded a precise earthquake location, while the usage of common data from the integrated networks improves significantly the overall capability of real time event detection and rapid characterization in this area.

Recently, in order to extend the seismic monitoring in north-eastern Italy, Slovenia and southern Austria towards earthquake early warning applications, OGS, ARSO and ZAMG teamed with the RISSC-Lab group (http://www.rissclab.unina.it/) of the Department of Physics at the University of Naples Federico II in Italy. As shown by Allen et al. (2009) and Hoshiba (2013), when accompanied by appropriate training and preparedness of the population, Earthquake Early Warning Systems (EEWS) are effective and viable tools for the real-time seismic risk mitigation in metropolitan areas. The collaboration focuses on massive testing on OGS, ARSO and ZAMG data of the EEW platform PRESTo (Probabilistic and Evolutionary early warning SysTem) developed by RISSC-Lab (http://www.prestoews.org/). PRESTo is a stand-alone software system that processes live accelerometric streams from the stations of a seismic network to promptly provide probabilistic and evolutionary estimates of location and magnitude of detected earthquakes while they are occurring, as well as shaking prediction at the regional scale (Satriano et al., 2010). In order to analyse its performance in different seismic hazard context and seismic networks of varying extension, PRESTo is currently operating in several seismological centres (e.g., the ISNet network in southern Apennines; KIGAM in South-Korea; Kandilli in Istanbul; NIEP in Romania).

Since the beginning of 2014, PRESTo is also running on OGS, ARSO and ZAMG data, by collecting and analysing in real-time the data streams from 20 stations (Fig. 1).

In the following, we first briefly summarize the characteristics of EEWS and PRESTo. Then, we present the CE3RN project and we describe the set-up of PRESTo in the transnational area including North-East Italy, Slovenia and Austria. Therefore, we present the results of a test carried out by playing-back the waveforms of the strong motion data of the Mw 6.5, 1976 Friuli Earthquake. Finally, we report on the performance of the EEW system during this preliminary testing phase.

Earthquake early warning systems and PRESTo. Typically EEWS follow two basic approaches: “regional” (or network based), and “on-site” warning. Regional EEWS are based on the use of a seismic network located near to one or more expected epicentral areas, whose aim is to detect and locate an earthquake, and to determine its magnitude from the analysis of the first few seconds of the arriving P-waves at more stations (Satriano et al., 2010). On the other hand, on-site EEWS are based on seismic sensors directly at the target site and exploit only the information carried by the faster early P-waves to infer the larger shaking related to the incoming S and surface waves.
The key parameter for any EEWS is the “lead-time”, which is the time available for protecting measures at distant targets once an earthquake has been promptly detected and characterized, and an alarm is issued. The lead-time for regional EEWS is defined as the travel-time difference between the P-waves recorded in the source area and the arrival of first S-waves at the target site, after accounting for the necessary computation and data transmission times. In on-site EEWS the lead-time is equal to the difference in P- and S-wave arrival times at the target itself.

Recently Zollo et al. (2010) demonstrated that the two approaches can be profitably integrated within an integrated system that allows the early estimation of the Potential Damage Zone (PDZ) associated to an event. Clearly, the integration of regional and on-site approaches results particularly useful whenever target sites are threatened by more than one seismic source areas, and these latter are placed at variable distances from the target sites. An exhaustive review of the concepts, methods, and physical basis of EEWS has been presented by Satriano et al. (2010).

PRESTo continually processes real-time streams of three-component acceleration data detecting P-waves arrival, and following the idea proposed by Zollo et al. (2010) implements both regional and on-site approaches. Alarm messages containing the evolutionary estimates of source and ground motion at target parameters, with associated uncertainties, are sent via internet and can thus reach also distant vulnerable infrastructures before the destructive waves, enabling the initiation of automatic safety procedures.

Since 2009 PRESTo is under real-time experimentation in Southern Italy on the data streams of the Irpinia Seismic Network (ISNet). Real-time testing is also underway in South Korea on the KIGAM network (Korean Institute of Geoscience and Mineral Resources), in Romania on RoNet - Romanian Seismic Network (National Institute of Research and Development for Earth Physics), and in the Marmara region (Turkey) on the KOERI network (Kandilli...
Observatory and Earthquake Research Institute). Moreover, a feasibility study of a nation-wide Early Warning System in Italy using the National Accelerometric Network (RAN) and PRESto is in progress.

The CE\textsuperscript{3}RN project. The region of the Central and Eastern Europe is an area characterised by a relatively high seismicity. The active seismogenic structures and the related potentially destructive events are located in the proximity of the political boundaries between several countries existing in the area. An example is the seismic region between the NE Italy (Friuli-Venezia Giulia, Trentino-Alto Adige and Veneto), Austria (Tyrol, Carinthia) and Slovenia. When a destructive earthquake occurs in this area, all the three countries are involved. In 2001 OGS (Istituto Nazionale di Oceanografia e di Geofisica Sperimentale) in Italy, the Agencija Republike Slovenije za Okolje (ARSO) in Slovenia, the Zentralanstalt für Meteorologie und Geodynamik (ZAMG) in Austria and the Università di Trieste (UniTS), signed an agreement for the real-time seismological data exchange in the South-eastern Alps region. Soon after the Interreg IIIa ItaliAustria “Trans-National Seismological Networks in the South-Eastern Alps” and “FASTLINK” projects started. The main goal of these projects was the creation of a transfrontier network for the common seismic monitoring of the region for scientific and civil defence purposes. During these years the high quality data recorded by the transfrontier network has been used by the involved institutions for their scientific research, for institutional activities and for civil defence services. Several common international projects have been realized with success (Pesaresi et al., 2014). The instrumentation has been continuously upgraded, the installations quality improved as well as the data transmission efficiency.

In 2014 OGS, ARSO, ZAMG and UniTS signed a Memorandum of Understanding naming the cooperative network “Central and Eastern European Earthquake Research Network – CE\textsuperscript{3}RN” (Bragato et al., 2014).

Starting from 2001, CE\textsuperscript{3}RN represents an excellent example of international high quality research infrastructure and the starting point for the enlargement of the transfrontier network to all countries and their seismological institutions of the Central and Eastern Europe region. Furthermore, one of the main goals of CE\textsuperscript{3}RN is to intensify the cooperation between these institutions through common research activities and preparation of common international projects. At the moment (2014) discussions are undergoing to include in the CE\textsuperscript{3}RN partnership also Croatia.

Since the beginning of 2014, PRESto is under experimentation in the transnational area including NE Italy, Slovenia and Austria. For this purpose, a dedicated SeisComP server at OGS CRS data centre in Udine collects data of 20 accelerometric stations (Fig. 1) and sends them to the RISSCLab in Napoli, where a dedicated PRESto system performs the real-time analyses. After an initial period during which we tested different set-ups of the system parameters, since end of March 2014 we are experimenting: the velocity model used for routine earthquake analysis and bulletin production at OGS (OGS, 1995-2013); a minimum number of five stations required to trigger within twelve seconds for the event declaration; the coefficients of the empirical correlation laws between the peak displacement (Pd) measured on short time windows of P-waves and the earthquake magnitude (M) estimated by Lancieri and Zollo (2008); and the Akkar and Bommer (2007) ground motion prediction equation.

**EEWS performance for the 1976 Friuli earthquake.** One of the first tests that we carried out was devoted to verify what could have been the performance of PRESto in the case of the 1976, Mw 6.5, Friuli earthquake in north-eastern Italy. To this aim, we ran a playback of this earthquake using the historical recordings downloaded by ITACA 2.0 (Luzi et al., 2008; Pacor et al., 2011). The playback was run considering the network geometry of 1976, and pretending that at that time the hardware and the management software necessary for the real-time data streaming to the OGS’s seismological centre of Udine were already existing.

Fig. 2 shows a snapshot of the first event detection and characterization provided by PRESto at the instant when three stations have triggered and the first alert is issued. However, only for
two stations, which were closer to the epicentre, the 2 seconds P-wave window necessary to estimate the magnitude is available. Hence, the first magnitude estimate is at this very initial stage of the analysis constrained only by two stations and has a value of $M_L 6.8$, already very close to the final value of $M_w 6.5$ from authoritative catalogue. Given the stations density available at that time, we estimated a blind-zone (i.e. the region where no lead-time is available and no safety actions can be undertaken) of 36 km. Despite in a such condition the municipalities affected by the most severe damage level could not have been alerted, the comparison with the macroseismic field estimated by Giorgetti (1976) shows that some of the municipalities in the area of intensity VII and most of those in the area of intensity VI could have been potentially received an alert (Fig. 2). For instance, the city of Pordenone (falling in the area of intensity VII and located at about 65 km from the epicentre) could have had a lead-time of about 9 seconds.

Considering the network geometry existing nowadays, we estimated that for an event having the same epicentre of the 1976 one, the blind zone could decrease to about 22 km. In the case of Pordenone, the lead-time might increase to about 13 seconds, which could assist users to take protective measures reducing the risk of injuries and minimizing the damage.

**Performance of the real-time EEWS.** Since the end of May 2014, that is to say when a sTab. configuration of the EEWS was found, PRESTo detected in real-time 12 earthquakes (Tab. 1), of which 10 correctly characterized (i.e. early warning magnitude falling within the +/-0.5 interval around the true magnitude), while 2 were false events. Concerning these latter, they occurred in a sector of the network with lower stations density. In these cases, we observed that the most isolated stations among those that have first triggered did not pass the binding criteria and were excluded by following analysis when the event was declared on other stations. This led the event to be mislocated and the magnitude overestimated.

On the contrary, the EEW system showed a good performance whenever the earthquakes occurred in areas with high stations density, which corresponds to higher seismic areas. For example, Fig. 3 shows the first event correctly detected and characterized by PRESTo (i.e. a ML 3.8 occurred on May 29, 2014 in Slovenia). In this case, both location and magnitude early warning estimations are in very good agreement with those from the authoritative bulletin. It is worth noting, these information are released by the EEW system after only 10 s after the first P-wave arrival detected at the station coded DRE (Fig. 3).
Conclusions. This work presents the preliminary results of a feasibility study carried out with the EEW platform PRESTo in the high seismic hazard region including north-eastern Italy, Slovenia and Austria, where the 1976 Friuli earthquake occurred.

Results from the offline analysis with PRESTo of recordings from the 1976 Friuli Earthquake indicate that, despite the network geometry at that time was rather poor, also at that time the EEWS could have been potentially very useful. Indeed, we estimated that the blind-zone could...
have been in the order of 36 km, and that those municipalities located within the intensity VI and VII areas could have potentially benefit of an alert. Interestingly, we also found that, in the case of an event having similar epicentre to the 1976 Friuli earthquake, the performance of the EEWS would considerably improve considering the actual CE³R Network configuration. For instance, the city of Pordenone, which is about 65 km distant from the 1976 epicentre, had about 9 seconds of lead-time in the 1976, while could potentially benefit of about 13 s today, thanks to the higher stations density of the CE³RN.

During the period May–September 2014, PRESTo detected in real-time 12 earthquakes in the magnitude range 1.7 to 3.5, of which 10 were correctly detected, while 2 resulted false events. Despite the testing period being still too short to come up with definitive conclusions, it seems that the EEWS given by the integration of PRESTo and CE³RN is efficient with respect to earthquakes that occur nearby the area with higher stations density.

This testing period of the system was carried out primarily with the goal of highlighting the existence of weak points (both in the hardware, and in the network management and analysis software), as for instance we have identified the problem of using simple time based binding criteria with the network at variable stations density. Indeed, besides the specific characteristics of an EEW algorithm, the performance of an EEW system strongly depends also on technological issues, like for instance the efficiency of the data telemetry and the seismic noise level at the stations. Therefore, especially these latter two aspects will be studied in the next tests of the EEWS. Of course, the realization of the EEWS in the area monitored by CE³RN will be accompanied by an extensive activity of communication and training, specifically tailored for the different stakeholders.

References


