CATALOGUING EARTHQUAKE ENVIRONMENTAL EFFECTS: A TOOL FOR THE COMPARISON OF RECENT, HISTORICAL AND PALEO EARTHQUAKES

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Abstract (cataloguing earthquake environmental effects: a tool for the comparison of recent, historical and paleoearthquakes):
A global catalogue of earthquake environmental effects is under construction in the frame of the activities within the 0811 INQUA project. Data collection and implementation is based on volunteer contribution by participants to the project. Based on the applications of the ESI 2007 intensity scale, the catalogue will allow an objective comparison among earthquakes over a geological time-window: in fact, the list of earthquakes will comprehend recent, historical and also paleoearthquakes.
Environmental effects induced by five strong earthquakes occurred in the last four centuries in Southern Apennines (Italy) and recorded in historical sources have been reviewed and catalogued in a standard way in order to illustrate the added value provided by this approach for seismic hazard assessment and the relevant role played by the historical sources for the characterization of earthquake environmental effects in Italy.

Key words*: Earthquake Environmental Effects, ESI 2007 intensity scale, historical seismic catalogues, paleoseismicity, Italy*

INTRODUCTION

Earthquake Environmental Effects (EEEs) are any phenomena generated by a seismic event in the natural environment (Michetti et al., 2007). They can be categorized in two main types:

· Primary effects: the surface expression of the seismogenic tectonic source, including surface faulting, surface uplift and subsidence and any other surface evidence of coseismic tectonic deformation;

· Secondary effects: phenomena generally induced by the ground shaking. They are conveniently classified into eight main categories: slope movements, ground settlements, ground cracks, hydrological anomalies, anomalous waves (including tsunamis), other effects (tree shaking, dust clouds, jumping stones).

The use of EEEs for intensity assessment has been recently promoted by the ESI 2007 (Environmental Seismic Intensity) scale since it will unquestionably provide an added value to traditional intensity evaluations being applicable also in not inhabited areas and not afflicted by saturation of all diagnostic effects even for the greatest earthquakes. In addition, some environmental morphogenetic effects (either primary and secondary) can be stored in the palaeoseismological record, allowing to expand the time window for seismic hazard assessment up to tens of thousands of years (e.g. Guerrieri et al., 2007; Porfido et al., 2007).

The aim of this note is i) to point out the added value provided by cataloguing EEEs in a standardized way in order to allow an objective comparison of historical earthquakes, with recent and paleo events in terms of intensity assessment; ii) to illustrate some examples of Italian historical earthquakes whit particular focus on the retrieval of environmental effects from the original descriptions.

THE EEE CATALOGUE

In the frame of the INQUA (International Union for Quaternary Research) activities, a network of geologists, seismologists and engineers experts in the characterization of environmental effects from modern, historical and paleoseismic earthquakes is working on designing and compiling a new catalogue of Earthquake Environmental Effects (EEE Catalogue) of seismic events worldwide.

The main objective of the EEE Catalogue will be to bridge a gap between recent, historical and also paleoearthquakes (e.g. data deriving from paleoseismic investigations).

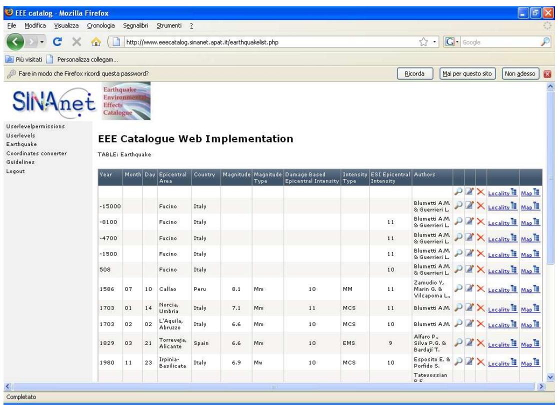

Fig. 1.The web interface for the remote implementation of the EEE Catalogue
http://www.eeecatalog.sinanet.apat.it/login.php

The general structure is based on two available "pioneer inventories" (the EEE database http://www.apat.gov.it/INQUA/ and the catalogue of earthquake ground effects in Spain (Silva et al., 2008) and comprehends three different levels of detail: earthquake, locality and site. A spatial component of the EEE catalogue has been developed using the Google Maps platform. in order to depict the spatial distribution of the recorded effects.

The remote implementation of the catalogue will be based on a volunteer collaboration of the participants (Fig. 1). Data will be published in the catalogue after a validation of their compliance in order to ensure scientific and technical standards.

One of the added values of the EEE catalogue will be the information on EEEs induced by paleoearthquakes (mainly coseismic surface displacements) thanks to the strong development of paleoseismological investigations. This information, although very far to be complete, can be used as a diagnostic tool for intensity assessment based on a tens of thousands years long time window. For example, in the Fucino area (Central Apennines, Italy) it is possible to compare in terms of surface displacements, the effects induced by at least 4 paleoearthquakes in the last 15,000 years with those induced the 1915 event.

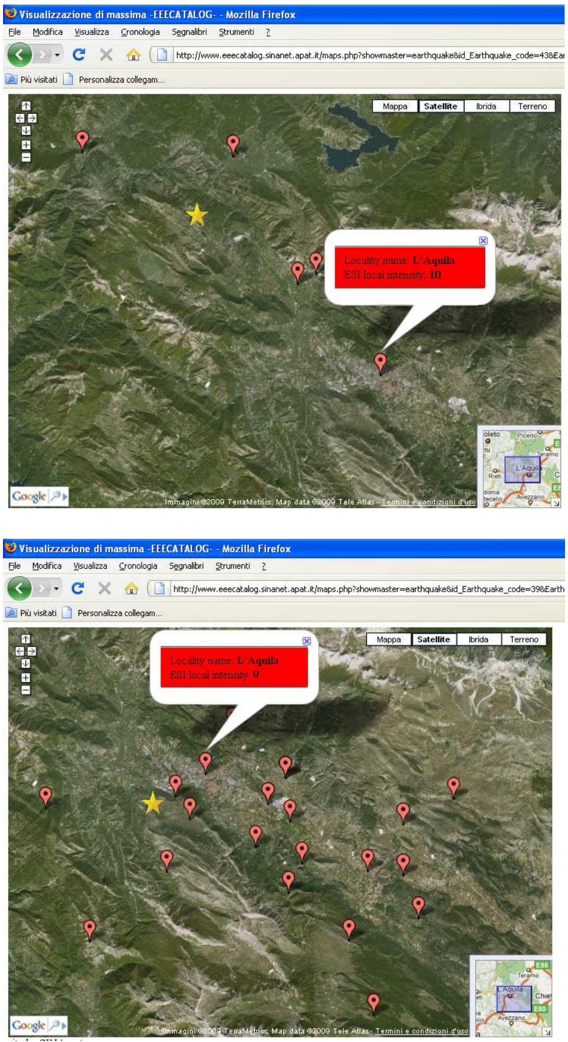

Fig. 2 .Distribution of localities with EEEs triggered by the 1703 (up) and 2009 (down) earthquakes in the L'Aquila region (Central Apennines, Italy). The EEE characteristics and spatial distribution have provides ESI intensity degrees equal to X (1703 event) and IX (2009 event).

The catalogue will allow also an objective comparison between historical and recent earthquakes occurred in the same area. For example (Fig. 2), surface effects induced by the 2009 April 6th event at L'Aquila and surroundings compared with those induced by an historical but well documented event occurred in the same area on 1703 February 2nd, clearly evidences that the more recent event was at least one degree less intense than the previous one. This was pointed out by the extent of surface faulting as well as the total area of secondary effects. Of course, the most complete collection of EEEs regards recent earthquakes. In fact, these events take advantage from "ad hoc" field surveys frequently integrated with data from remote sensing for a more systematic and extensive dataset. In this direction goes the contribution of the EEE Catalogue to the GEO (Group on Earth Observations, www.earthobservations.org) initiative, with particular regard to the SBA "Disasters" (Task DI-09-01: Systematic Monitoring for Geohazards Risk Assessment).

CATALOGUING EARTHQUAKE ENVIRONMENTAL EFFECTS IN ITALY: ANALYSES OF SOME STRONG EARTHQUAKES

A catalogue of earthquake environmental effects in Italy is an essential tool for i) research studies, since it is helpful for the identification of active/capable faults; ii) Civil Protection purposes, especially for the emergency management; iii) territorial planning, since it allow to contour the most vulnerable areas in terms of geological effects (e.g. landslides).

Thanks to the extraordinary wealth of information retrievable from historical documents (chronicles, letters, newspapers, scientific reports) and iconographic (pictures, draws, photographs, etc.), the historical record of Italian earthquakes spans in more than two millennia long time-window. Thus, even for the compilation of an inventory of seismically-induced effects for the Italian region, the use of historical sources is crucial.

The compilation of the Italian catalogue is still in progress in the frame of the aforementioned INQUA 0811 project: in the following we have reported some synthetic information about EEEs triggered by 5 strong historical events (MCS / ESI > X and inferred magnitude 6.6<M<6.9)) in a relatively homogeneous setting within the Southern Apennines. These earthquakes occurred in the last four centuries.(Fig.3) (epicentres in Fig. 3).

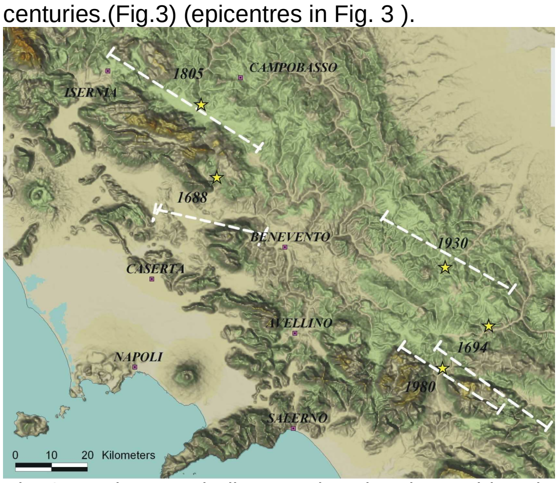

Fig. 3 – Epicenters (yellow stars) and end-to-end length of rutprue zones (white lines) regarding five strong historical earthquakes in Southern Apennines (see text)

Date	Epicentral area	Victims	MCS intensity	Surface faulting
1688.06.05 (*)	Sannio	10,000	> X	**SRL: 32 km Max D = 90 cm**
1694.09.08	Irpinia-Basilicata	6,000	> X	**SRL: 38 km**
1805.07.26 (*)	Molise	6,000	> X	**SRL: 40 km Max D = 150 cm**
1930.07.23 (*)	Irpinia	1,404	X	**SRL:38 km; Max D: 40 cm**
1980.11.23 (*)	Irpinia-Basilicata	3,000	X	**SRL: 40 km Max D = 100 cm**

Tab. 1 – Surface faulting extent resulting from the revision of historical sources and, only for starred (*), events with field observations

The analyses were conducted in details on the 5 June 1688 earthquake in the Sannio area, the 5 September 1694 and the 23 November 1980 events in the Campania-Basilicata regions, the 26 July 1805 earthquakes in the Molise region and the 23 July 1930 events in the Irpinia area (Tab.1).
Historical sources have provided enough information to estimate the extent of surface faulting, expressed in terms of rupture length (SRL), maximum displacements (Max D) and the area of secondary effects (Oddone 1932; Serva, 1985a, b; Esposito et al., 1987; Esposito et al.,1998; Porfido et al., 2002; Blumetti et al., 2002).
Rupture length values, ranging from 30 to 40 km, are comparable and also consistent with damage based MCS intensities and have been sufficient to estimate the epicentral intensity according to the ESI 2007 scale (Serva et al.,2007).
Regarding secondary effects, the wealth of information for each event can be roughly measured by the number of localities with EEEs and by the total number of EEEs (Fig. 4). Of course, the age of the earthquake strongly influences these numbers that, although cannot be used as an independent measure of the earthquake size, highlight anyway the most important effects on natural environment. This scenario, integrated with effects on damages, depict the most reliable image of the earthquake effects.

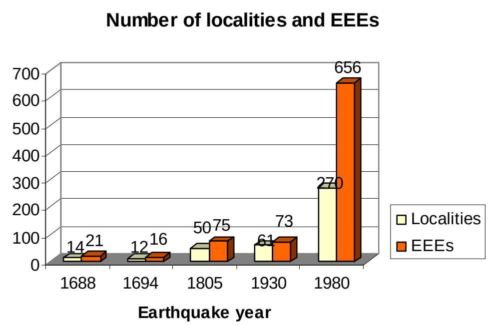

Fig. 4 – Number of localities and EEEs (secondary) for each of the analysed earthquakes (see text)

Among secondary effects, slope movements are typically the most common effect, generally followed by ground cracks and hydrological anomalies. It is also noteworthy that the maximum distance from the fault of the main types of landslides for the five earthquake fall within the envelope curves for magnitude proposed by Keefer (1984).
Most hydrological changes occurred within 30–110 km from the fault rupture segment, the maximum distance of such variations from the fault was 190 km (Porfido et al., 2002; Esposito et al. 2009).
In conclusion , even if the type and the relevance of surface effects strongly depend on local geologic, geomorphic and tectonic setting, their characterization allows for a realistic estimation of source parameters, and for a proper evaluation of the environmental vulnerability in the presence of significant releases of seismic energy.

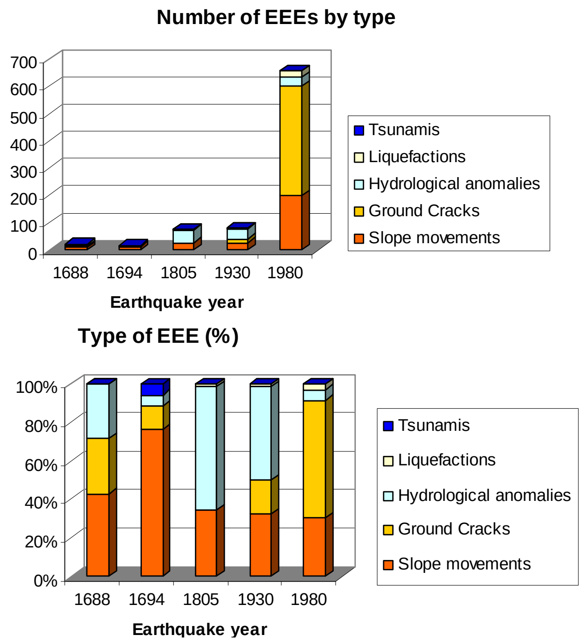

Fig. 5 – Type of EEEs for each earthquake (above) and in % (below)

CONCLUSIONS

The compilation of the Earthquake Environmental Effects catalogue, in progress in the frame of the 0811 INQUA Project, will allow for the first time an objective comparison of recent, historical and paleoearthquakes. Preliminary results of the EEE catalogue implementation are showing that it is possible to compare the earthquake size in terms of ESI intensity, even if data sources are very different.
The analyses of five strong earthquakes in Southern Apennines has clearly shown the importance of historical documents for the collection of EEEs in the Italian area and pointed out the typical scenario of environmental effects induced by a intensity ≥X (i.e. M ~ 7) earthquake.
For these reasons, the added value provided by the EEE catalogue is evident. Therefore it will be very helpful, not only for scientific purposes but also for a correct definition of most vulnerable areas and

consequent measures to be adopted for the mitigation of seismic risk.

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