

A strategy for predicting seismic scenarios¹

Una strategia per la previsione di scenari sismici

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Riassunto: In questo lavoro illustriamo brevemente una strategia che permette di passare dai campi macrosismici osservati a scenari macrosismici espressi in termini di probabilità che un certo grado di intensità della scala Mercalli-Cancani-Sieberg sarà avvertito in un sito quando un terremoto è accaduto in un raggio di alcune centinaia di chilometri. Caratteristica saliente di tale strategia è la suddivisione dei campi macrosismici in gruppi che mostrano un andamento simile del decadimento. Tale suddivisione costituisce la base per la stima della distribuzione di probabilità dell'intensità in un sito posto ad una qualsiasi distanza dall'epicentro. Il processo di stima usato è di natura bayesiana.

Keywords: attenuation, Bayesian inference, hierarchical clustering.

1. Introduction

The analysis of the seismic attenuation is a crucial and problematic component of the hazard assessment procedure. In the last decade the opinion that the intrinsic uncertainty of the decay process must be expressed in probabilistic terms has been growing stronger and two are essentially the approaches followed. The former assumes functional relationships between the intensity decay and the epicentre-site distance and includes in the models a gaussian error centered in the values of these relationships. The latter considers the intensity decay, ΔI , as a random variable and therefore requires the estimate of its probability distribution. The idea illustrated in this work is that of decomposing a set of macroseismic fields representative of the temporal and spatial distribution of the seismicity of interest in order to select groups of fields homogeneous from the attenuation point of view and use them to estimate the above distribution in a Bayesian framework.

2. Methodology

To group the macroseismic fields we use a hierarchical agglomerative method (Kaufman and Rousseeuw, 1990), since we think that this class of methods allows a more thorough understanding of the clustering process than the methods designed for a fixed numbers of

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groups. As it is typically the case when hierarchical methods are used, a particular partition can be selected looking at the fusion levels in the dendrogram. Because the different decay trend depends on many geological characteristics, some of them not available or not easily measurable, we apply the clustering method to location and dispersion measures computed for each set of distances from the epicentre to the sites where the same intensity is recorded. We use the median and the mean values and the 75-th percentiles in order to capture different aspects of the empirical distribution of the data.

In the work by Rotondi and Zonno (2004) ΔI is considered as a random variable having a binomial distribution with parameter p , in its turn taken as a random variable having a beta distribution. The binomial distribution was chosen to respect as much as possible the ordinal nature of the intensity, whereas the prior beta distribution of p was chosen to account for the difference in ground shaking even among sites at the same epicentral distance. Because of the dependence of the attenuation from the epicentre-site distance, the data are subdivided in distance bins around the epicentre and different distributions are estimated for each bin. According to the above approach, we apply the two-steps estimation process to each of the classes identified by the clustering method and for each class we proceed as follows. We choose a value i_0 of the epicentral intensity I_0 and estimate the hyperparameters of the prior beta distribution by using the macroseismic fields of the class that have epicentral intensity different from i_0 . Afterwards we consider the macroseismic fields of the class that have epicentral intensity i_0 and use them to update the hyperparameters of the beta distribution. In this way, given a value of I_0 , the class and the epicentre-site distance, for the intensity at site, I_s , we obtain a binomial distribution with p equal to its posterior mean. Before a new earthquake and its macroseismic field are recorded, the expected likelihood with respect to the posterior distribution of p expresses the uncertainty about the felt intensity points; this function is called *predictive* distribution. The mode of this distribution is the estimate of the intensity I_s . By smoothing the posterior means of p in each bin, we can express the parameter as a function of the distance varying with continuity, and the binomial distribution in which the parameter is given by this function can be used instead of the predictive distribution to forecast I_s at any distance from the epicentre.

The strategy above outlined has been applied to a set of 55 earthquakes with epicentral intensity ranging from VII to XI, drawn from the Italian felt report database. We identified three classes $\mathcal{C}_A$, $\mathcal{C}_B$ and $\mathcal{C}_C$ of macroseismic fields with decreasing attenuation, and it is reasonable to assume that they are associated to three different epicentral depths. To test the whole strategy we forecasted the scenario really observed in the Colfiorito earthquake that occurred in Umbria-Marche on September 26, 1997. Of course this event is subsequent to those forming the set used to perform the clustering. For both the predictive and the smoothed binomial distributions the forecasting was given in terms of mode, probability of exceeding a given intensity, and value of I_s not exceeded at least with a fixed probability value. The scenarios estimated for each of the three classes $\mathcal{C}_A$, $\mathcal{C}_B$, $\mathcal{C}_C$ were compared through different validation criteria.

References

- Kaufman L. and Rousseeuw P. (1990) *Finding groups in data*, Wiley, New York.
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