Setting up an earthquake forecast experiment in Italy

Danijel Schorlemmer[1,*], Annemarie Christophersen[2], Andrea Rovida[3], Francesco Mele[4], Massimiliano Stucchi[3], Warner Marzocchi[4]

[1] *Southern California Earthquake Center, University of Southern California, Los Angeles, USA*

[2] *GNS Science, Avalon, Lower Hutt, New Zealand*

[3] *Istituto Nazionale di Geofisica e Vulcanologia, sezione di Milano-Pavia, Italy*

[4] *Istituto Nazionale di Geofisica e Vulcanologia, sezione di Roma, Italy*

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ABSTRACT

We describe the setting up of the first earthquake forecasting experiment for Italy within the Collaboratory for the Study of Earthquake Predictability (CSEP). CSEP conducts rigorous and truly prospective forecast experiments for different tectonic environments in several forecast testing centers around the globe; forecasts are issued for a future period and also tested only against future observations to avoid any possible bias. As such, experiments need to be completely defined. This includes exact definitions of the testing area, of learning data for the forecast models, and of observation data against which forecasts will be tested to evaluate their performance. Here we present the rules, as taken from the Regional Earthquake Likelihood Models experiment and extended or changed for the Italian experiment. We also present characterizations of learning and observational catalogs that describe the completeness of these catalogs and illuminate inhomogeneities of magnitudes between these catalogs. A particular focus lies on the stability of earthquake recordings of the observational network. These catalog investigations provide guidance for CSEP modelers for developing earthquakes forecasts for submission to the forecast experiment in Italy.

Introduction

The Collaboratory for the Study of Earthquake Predictability (CSEP) is an international working group that aims to promote earthquake predictability research through rigorous earthquake forecast and prediction experiments in many different regions. These experiments are fully specified and carried out in controlled environments, called the testing centers [Schorlemmer and Gerstenberger 2007]. Part of the specification of an experiment is the characterization of the region and the available data for this region that can be used as learning or observation data for the experiment. The rules for testing earthquake forecasts were formulated during the Regional Earthquake Likelihood Model (RELM) project [Field 2007, Schorlemmer et al. 2007, Schorlemmer and Gerstenberger 2007] for the initial experiment in California. These rules include the area for which earthquake forecasts are generated and will be tested against future seismicity. Furthermore, they include which earthquake catalog is used in testing as well as provided as learning data to time-varying models for their forecasts generation. This particular definition also includes a collection area from which earthquakes are used and deployed to the models. Such a deployment involves rules of cutting the catalog at certain magnitudes and declustering [see Schorlemmer and Gerstenberger 2007 for details]. Besides areas and catalog treatment, the testing method is completing the set of rules for a particular testing region [see Schorlemmer and Gerstenberger 2007 for details], called the RELM-tests.

We describe the efforts for setting up an Italian testing region and motivate the rules of testing. Italy is one of the most seismically active region in Europe and is well instrumented by the network of the Istituto Nazionale di Geofisica e Vulcanologia (INGV), Italy, to ensure high data quality. The desire of immediately extending the testing region to all of Europe or at least to the Mediterranean region are hampered by inhomogeneous catalog data. Homogenizing the catalog of the European Mediterranean Seismological Center (EMSC) is certainly worth the effort, however, it will be a major undertaking.

Definition of the experiment

The first step in starting earthquake forecast testing in any region is reaching a consensus among researchers providing models, catalog makers, and researchers operating the testing facility about the rules and boundary conditions of the experiment. For the first Italian experiment, two meetings were held to bring together these stakeholders in November 2007 and October 2008. Details on the meetings like agenda, minutes, participants, and presentations are available on http://www.cseptesting.org/regions/italy. The group of researchers involved in the meetings decided to use all applicable rules that were defined for the RELM experiment in California [Schorlemmer et al. 2007, Schorlemmer and Gerstenberger 2007]:

• The type of earthquake forecast, here rate-based forecasts. Such forecasts provide earthquake rates for each predefined latitude / longitude / magnitude bin. These rates are given for predefined periods, here 1 day, 3 months, 5 years, and 10 years.

• The evaluation metrics (N-, L-, and R-Test). The N- and L-Test provide information about the consistency of the forecast with the observation, and the R-Test compares two forecasts in their performance. Since the start of the RELM experiment, further tests have been developed or implemented and will also be used for the experiment in Italy: the S- and M-Test [Zechar et al. 2010], the Area Skill Score [Zechar and Jordan 2008], the Receiver Operator Characteristics (ROC) [Mason 2003], and the Molchan Error Diagram [Molchan 1990, Molchan and Kagan 1992].

• The constraints on the testing region, the area for which the experiment will be conducted. In California, the resolution of the testing area is $0.1° \times 0.1°$ spatially and 0.1 magnitude unit for the magnitude bins. The lower limits are included while the upper limits are excluded. The magnitude bins are centered around the 0.1 magnitude units. For long-term testing (5-year and 10-year forecasts), the magnitude bins are [4.95, 5.05), [5.05, 5.15), …, [8.95, ∞). For short-term testing (1-day and 3-month models), the magnitude bins are [3.95, 4.05), [4.05, 4.15), …, [8.95, ∞). The borders of the $0.1° \times 0.1°$ cells are aligned to the full degrees; the centers of the cells are shifted from the full degrees by 0.05°, 0.15°, etc. Because a global grid with the same resolution would be aligned this way, such an alignment offers the possibility that any global forecast model could be applied to this testing region as it already covers exactly the same testing region.

To complete the set of rules that are needed for an experiment, we have to define:

• The earthquake catalog (testing catalog) against which the forecasts will be tested.

• The earthquake catalog(s) (learning catalog) that can be used as input data for generating earthquake forecasts.

• The extent of the testing area and the collection area, the area from which the input data will be provided to the forecast models and which is larger than the testing area to include earthquakes that may influence future seismicity in the testing area.

Testing catalog and testing region

Earthquake data covering the territory of Italy are provided by either global catalogs, e.g. from the National Earthquake Information Center (NEIC) [Sipkin et al. 2000] or the Global Centroid Moment Tensor catalog (Global CMT) [Dziewonski et al. 1981, Ekström et al. 2005], by the European-Mediterranean Seismological Centre (EMSC) [Godey et al. 2006], or by local networks or catalog compilers, e. g. the Italian seismic bulletin (Bollettino Sismico Italiano, BSI) [BSI Working Group 2002, Amato et al. 2006] or the Regional Centroid Moment Tensor (RCMT) catalog [Pondrelli et al. 2006], both recorded by the INGV. To use the best-quality earthquake locations and the most complete recordings for testing, the group has chosen to use the BSI as testing catalog. This catalog, the official catalog for the Italian territory, will also be maintained for the expected duration of the experiment (10 years). The BSI is available at http://bollettinosismico.rm.ingv.it/, and since July 2007 at http://ISIDe.rm.ingv.it/ [ISIDe Working Group 2007]. This catalog is compiled from recordings of the National Seismic Network, operated by the INGV since 1999, and fully exploited for the publication of the BSI since April 16, 2005. Therefore, we define the extent of the testing area based on the performance of this network. Many constraints have to be taken into account when defining the polygons of the testing and collection areas:

• The testing area should extend the territory of Italy by roughly 100 km to include earthquakes that are relevant for the hazard in Italy, i.e. can cause stronger shaking in Italy.

• The collection area should extend the testing area by roughly 50 km to include earthquakes outside the testing area that are relevant for models to generate their forecasts.

• The earthquake catalog needs to be complete at $M = 3.7$ down to a depth of 30 km in both areas. The lowest magnitude bin for testing starts at 3.95; however, the testing procedures are taking into account the uncertainties of magnitudes and are modifying magnitudes in simulations. Therefore, the lowest magnitude considered needs to be lower than the lowest magnitude used in testing.

We investigated the detection capabilities of the INGV network in detail [Schorlemmer et al. 2010] using the probabilistic magnitude of completeness method developed by Schorlemmer and Woessner [2008]. This method computes recording completeness based on detection probabilities per station which are derived purely from empirical data. In a first step, the earthquake catalog containing phase picks is analyzed and for each station a detection-probability distribution is computed. These distributions describe the probabilities, P_D, of a station of detecting events at given distance-magnitude pairs and are used, in a second step, to compute detection probabilities, P_E, of detecting earthquakes at given locations and magnitudes. Thus, for each location, this method provides the detection probabilities as a function of magnitude. The completeness magnitude, M_P, at a particular probability level is derived for each location from these functions. These probability levels are typically set to $P = 0.99$, $P = 0.999$, or $P = 0.99999$. We have chosen $P = 0.999$ for this study as was done by Schorlemmer et al. [2010]. For more details about the

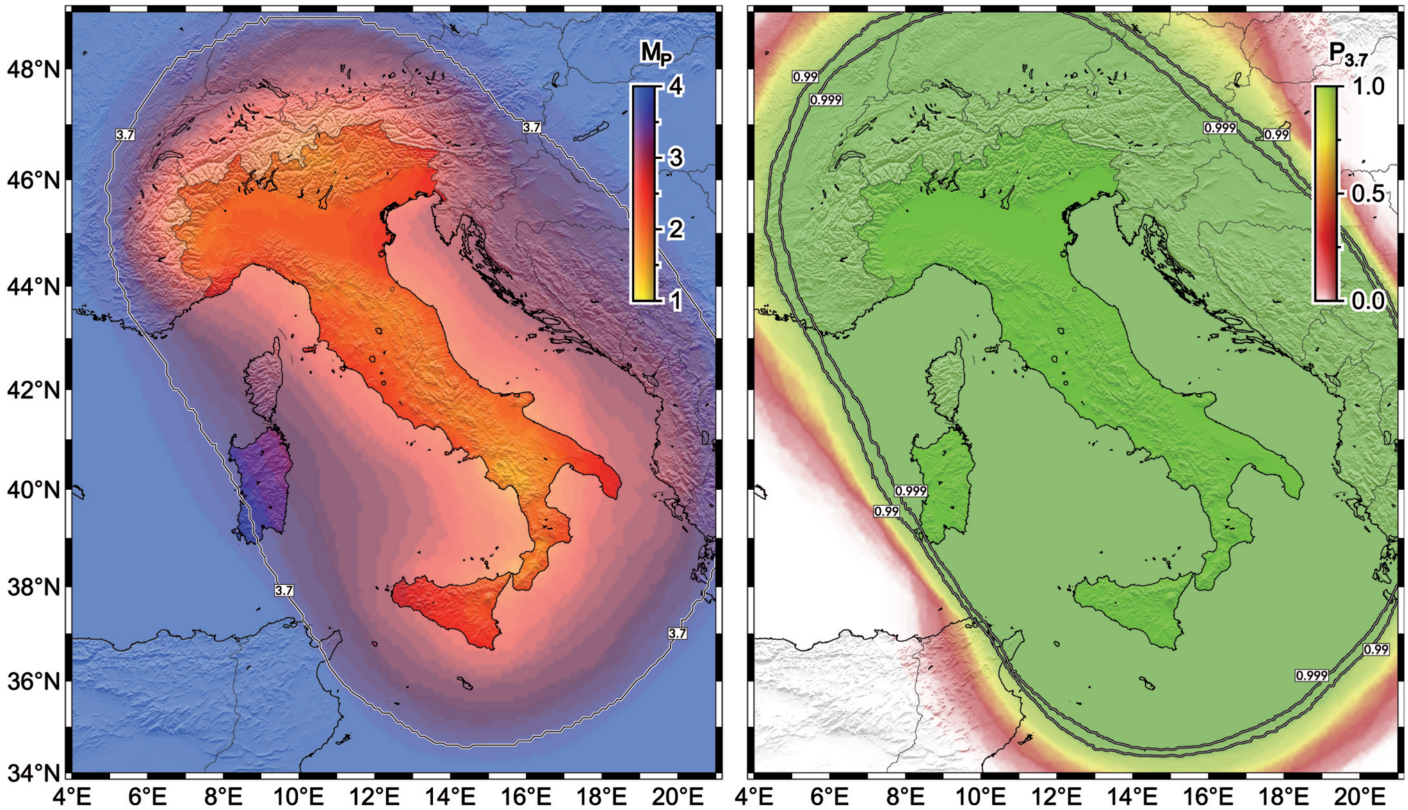

Figure 1. (Left) Probabilistic magnitude of completeness, M_P, at the $P_E = 0.999$ level and at a depth level of 30 km for the INGV network at June 1, 2007. The white-framed line indicates the $M_P = 3.7$ contour. (Right) Probability of detection for magnitude $M = 3.7$ events. The probabilities are computed for a depth level 30 km given the station configuration of June 1, 2007. The two black-framed lines represent the contour levels for detection probabilities of $P_{3.7} = 0.99$ and $P_{3.7} = 0.999$ ($P_{3.7} \equiv P_{E|M=3.7}$). Note that the contour of $M_P = 3.7$ at the $P_E = 0.999$ level does not fully match the contour of $P_E = 0.999$ for $M_P = 3.7$. The discrepancy between the two lines originate from the way the contours are computed. The M_P-values are estimated as discrete values in 0.1 steps unlike the P_E-values. The contour of the latter is computed by interpolating the P_E-values.

method, please refer to the publication by Schorlemmer and Woessner [2008].

Figure 1 shows the completeness magnitude for the depth level of 30 km of the INGV network for June 1, 2007. The mainland and the island of Sicily are very well covered by stations and the completeness is below the target level of $M_P = 3.7$, as used in the RELM tests. The islands of Sardinia, Lampedusa, and Pantelleria do not exhibit the necessary completeness level to be included for testing earthquake forecasts.

As can be seen in Figure 1, the BSI is not entirely complete at $M = 3.7$ for a probability level of $P = 0.999$ when investigating the area of 100–150km extending Italy. The completeness levels are higher in the French provinces Alpes-Côte d'Azur and Rhône-Alpes northwest of Italy as well as in the Austrian province Kärnten and Slovenia northeast of Italy. This demanded a slight lowering of the probability level of detection of magnitude $M = 3.7$ events. We defined minimum probability levels of $P = 0.999$ for the testing area and of $P = 0.99$ for the collection area for a depth level of 30 km. Figure 1 shows the probability of detection of magnitude $M = 3.7$ events with highlighted contours for the two defined probability levels.

As can been seen from Figure 1, the completeness levels for magnitude $M = 3.7$ meet the requirements at the desired probability levels. The distance of the contour lines from the Italian border is becoming sufficiently big in the aforementioned provinces of France as well as in Slovenia and Austria. As it appears from the figure, the minimum distance of the $P = 0.99$ contour line from the Italian border is about 130 km in the French province Alpes-Côte d'Azur. Therefore, attempting to balance the tradeoff between coverage and detection probability, we chose to design the polygons of the collection area and the testing area with a minimum distance of 130 km and 80 km from the Italian border, respectively (see Figure 2 for details of the areas. The polygons and area definition can be downloaded from http://www.cseptesting.org/regions/italy). The drawback of this definition is the fact that we cannot include the islands of Sardinia, Pantelleria, and Lampedusa. The first is not covered sufficiently well with seismic stations while the others are too far away from the denser part of the network. Fortunately, Sardinia is a seismically inactive area and not of great interest for earthquake prediction research. From these polygons, we define the testing area and the collection area as sets of 0.1° × 0.1° degree cells. A cell belongs to one of the areas if the center of the cell lies within the respective polygon. Thus, the two areas are strictly speaking not defined by the polygons but by the set of cells. Figure 2 shows the cells of both defined areas used the same way as described by

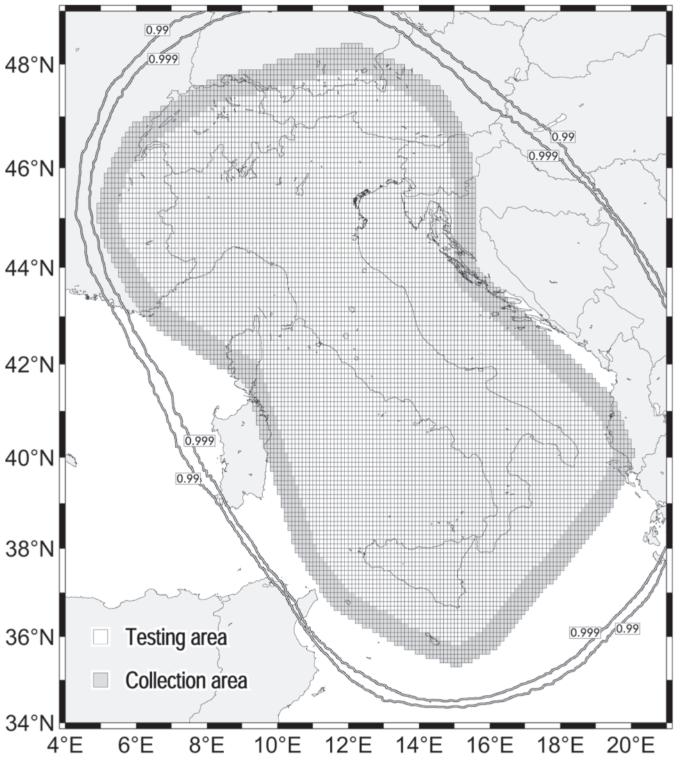

Figure 2. Definition of the collection area and testing area. Cells of testing area and collection area for the Italian testing region. The white boxes indicate cells of the testing area. The gray boxes indicate the cells of the collection area which includes the cells of the testing area as well. The white lines show contours of detection probabilities for events of magnitude $M \geq 3.7$ at the $P_E = 0.99$ and $P_E = 0.999$ level on June 1, 2007.

Schorlemmer and Gerstenberger [2007] for California.

Networks change the station configuration from time to time, which translates to changes in the completeness level. In addition to that, stations do not report continuously for various reasons; e.g. station failure and telemetry failure. Therefore, the set of available stations that report data to the operational center changes almost on a daily basis. To investigate the impact of these changes to the completeness level in the testing and collection areas, we analyzed detection probabilities for magnitude $M = 3.7$ over time. We compute the detection probabilities for detecting events of magnitude $M = 3.7$ for each day since the network started operation (April 16, 2005) until January 1, 2008. Hereby, we considered all stations for which waveform files were available as in operation; at the INGV network, the directory of waveform files reports on data availability per station/channel and hour. Figure 3 shows the detection-probability contours of $P_E = 0.999$ for the testing area and $P_E = 0.99$ for the collection area, as previously defined. As can be seen, most of the 991 contour lines are well outside the testing and collection areas, however, a few can be seen inside. We analyzed these particular days and discovered inconsistencies of the set of triggering stations with the waveform storage. Waveform files for these periods were likely lost for stations that do report triggering for the given period. In a few cases loss of waveform data is obvious as no waveform files were stored

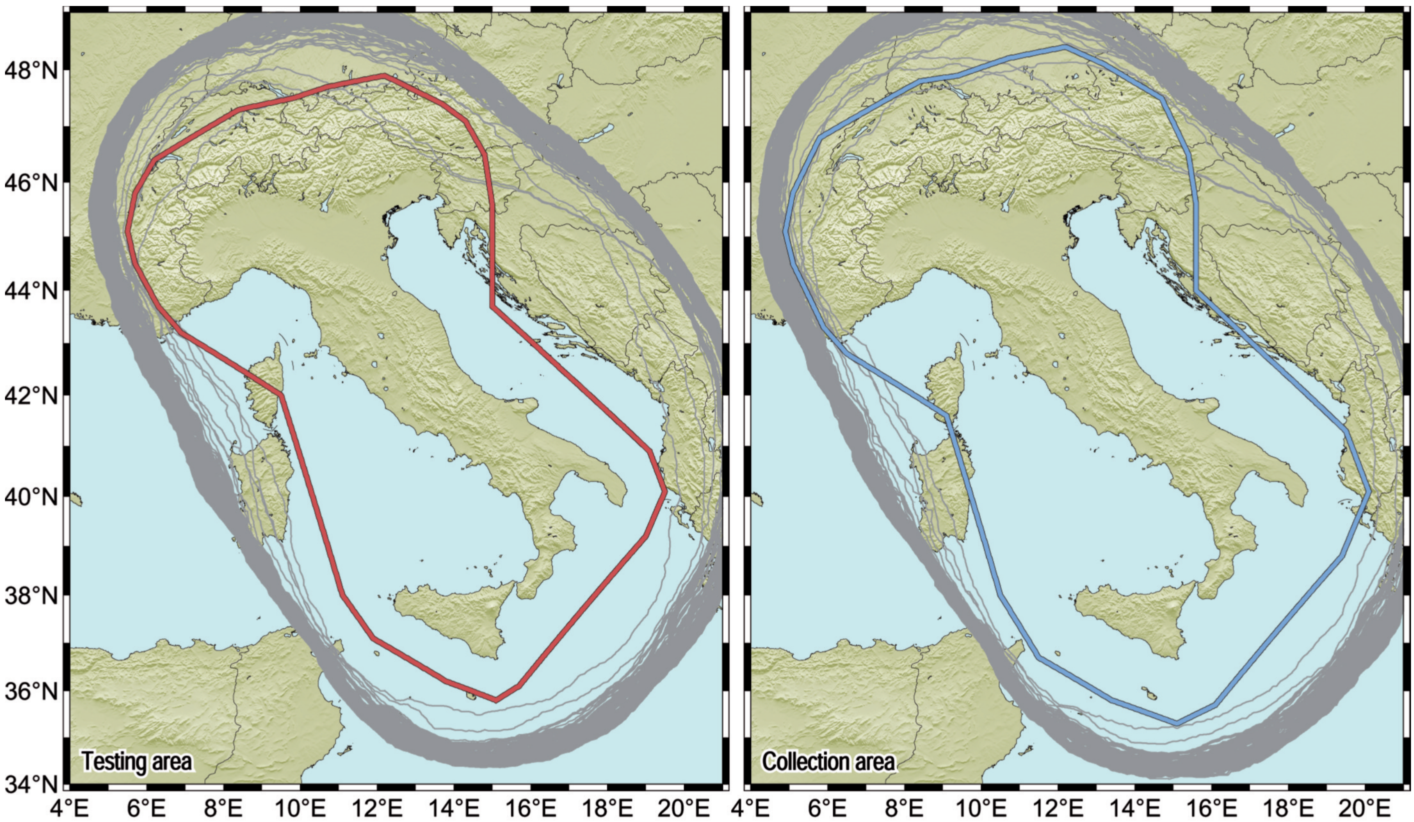

Figure 3. INGV network detection capabilities over time. For each region the corresponding detection probabilities for each day in the period April 16, 2005 to January 1, 2008 are shown as 991 contour lines. (Left) Testing area is shown in red and contour lines show the $P_E = 0.999$ detection probability. (Right) Collection area is shown in blue and contour lines show the $P_E = 0.99$ detection probability.

but the network operated normally and detected many events. In such a case, we decided to compute detection probabilities using the same stations as were operating the day before. We consider our detection-probability estimates as conservative. Only in 8 out of 991 days, the testing and collection areas are not entirely covered with the desired detection probabilities for the target events of magnitude $M = 3.7$. It is likely that during these days the detection probabilities were higher but some waveform files were lost.

These results indicate that the INGV network is very stable and does provide the necessary detection probabilities with high reliability.

Learning catalogs

The development and calibration of earthquake forecast models require homogenous earthquake catalogs that are consistent with the testing catalog. The testing catalog is only available in its current form since April 16, 2005. The catalog has 30 earthquakes of $M \geq 3.95$ within the collection area up to April 1, 2009, three months before the start of testing the long-term models and before the L'Aquila sequence with the $M_L = 5.9$ mainshock on April 6, 2009 that delayed the processing of the testing catalog. As most earthquake models require more data for the calibration, we present alternative earthquake catalogs and provide recommendations how to use them in model development.

Earthquake catalogs and their content undergo many changes in time due to changes in the seismic network, data processing techniques, changes in triggering conditions (e.g. number of stations triggered to start location procedure) or attenuation relations, but also availability of historical records. All these man-made changes can easily give the impression of seismicity changes [Habermann 1987]. In particular, the aspects influencing the data availability for historical catalogs are discussed by Stucchi et al. [2004]. For the development of earthquake models for the Italian testing center it is important to have the largest possible set of homogeneous data and to understand how the data relate to the testing catalog. We investigate two catalogs in detail: The Catalogo Parametrico dei Terremoti Italiani (parametric catalog of Italian earthquakes, CPTI08) [Rovida and the CPTI Working Group 2008] and the Catalogo della Sismicità Italiana (catalog of Italian seismicity, CSI 1.1) [Chiarabba et al. 2005, Castello et al. 2006].

The CPTI08 is a pre-release version of the CPTI catalog family, which was prepared for the CSEP project and covers the period 1901–2006. The catalog is available in its original form including a description at http://www.cseptesting.org/regions/italy. The predecessor of the CPTI08 is the CPTI04 [CPTI Working Group 2004], covering the period 217BC to 2002 (http://emidius.mi.ingv.it/CPTI04/).

The completeness of the CPTI04 was assessed with the

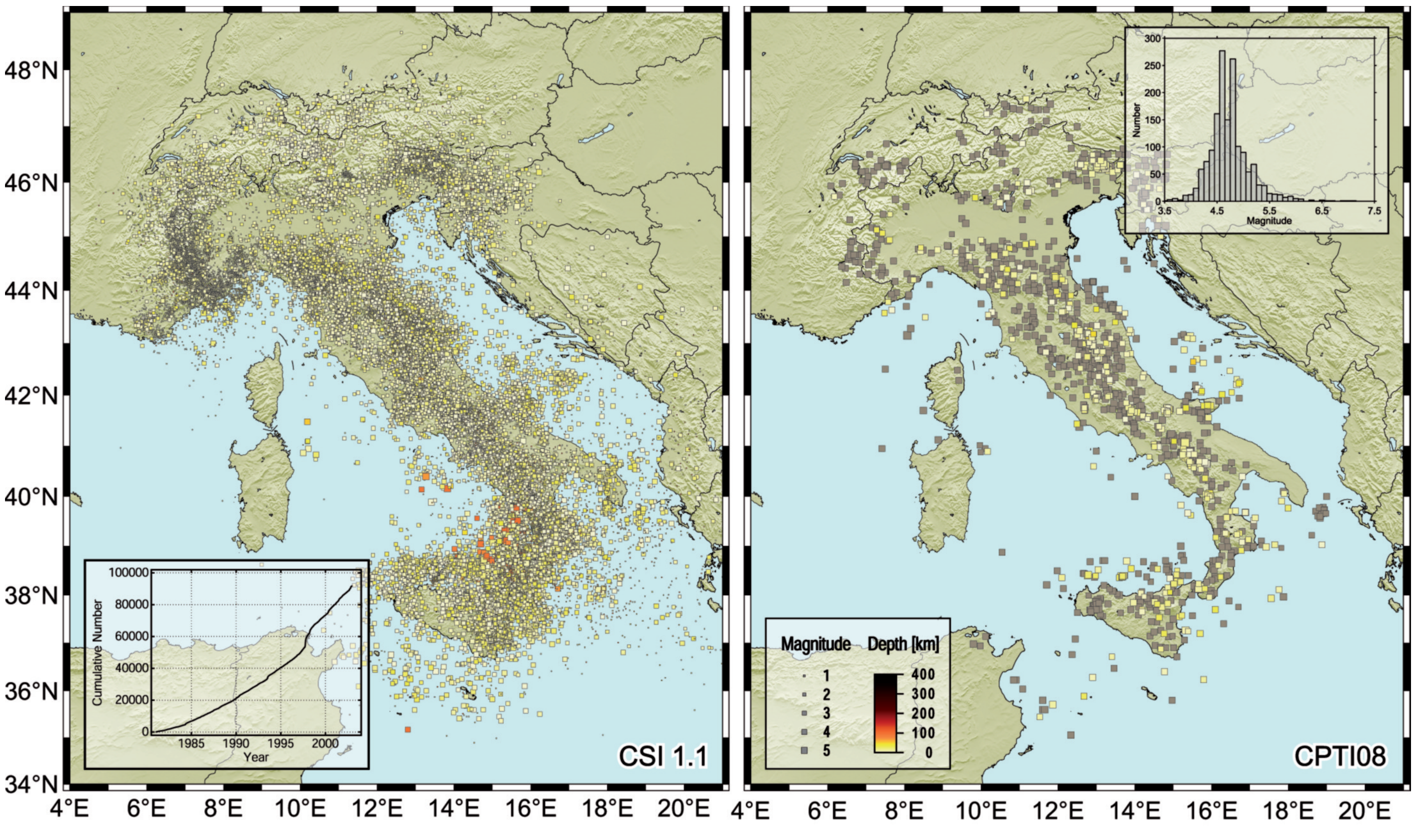

Figure 4. (Left) Map of earthquakes in the CSI 1.1. The inset shows the cumulative number of events over time in the CSI 1.1. (Right) Map of earthquakes in the CPTI08 catalog. Events without depth information are plotted in brown. The inset shows the histograms of 1579 macroseismic moment magnitudes from the CPTI08 with $M_w \geq 3.5$.

historical approach proposed by Stucchi et al. [2004], in combination with the statistical approach proposed by Albarello et al. [2001] in the probabilistic seismic hazard assessment of Italy [CPTI Working Group 2004]. According to the historical approach, which is more effective for moderate to large events in the centuries before 1800, the CPTI04 catalog is complete for $M_w \geq 4.7$ since at least 1871 while according to the statistical approach, it is complete for $M_w \geq 4.7$ since at least 1920 (1910 in northern Italy). The completeness of lower M_w values was not assessed.

The CPTI08 represents an evolution of the CPTI04 with respect to both content and structure. The time window has been expanded to 2006 and the supporting dataset includes new macroseismic data published up to 2007 and instrumental data improved with the use of instrumental bulletins and instrumental parametric catalogs. The CPTI08 provides for the first time in Italy, both macroseismic and instrumental magnitude determinations, when available, together with uncertainty estimates. Macroseismic locations and magnitudes are computed by means of the Boxer code [Gasperini et al. 1999] or adopted from other catalogs; instrumental magnitudes are either native moment magnitudes or calculated by a linear regression relationship from surface wave, body wave, or local magnitudes. To make life easier to users, a default set of parameters is also provided, made up by a location, either macroseismic or instrumental, selected on the basis of its reliability, and a M_w value, either native moment magnitude or computed as the mean of the available M_w, derived by other types of magnitude and weighted according to the relevant uncertainty. According to MPS Working Group [2004], the linear regression equation to calculate moment magnitudes from local magnitudes is

$$M_w = 0.812\, M_L + 1.145. \tag{1}$$

The CPTI08 contains 1591 earthquakes of which 25 have no location information, as they are aftershocks and their intensity distributions were not deemed reliable. Figure 4 shows the spatial distribution of all 1574 earthquake with location information, including 21 earthquakes in the depth range 30–50 km. The magnitudes in the CPTI08 are given with accuracy to the second decimal place. However, the macroseismic magnitudes favor 4.6 and 4.8 as shown in the right inset of Figure 4. We note that the binning of the magnitudes might affect model calibration.

To select earthquakes for model development and calibration, we excluded events deeper than 30 km and cut the catalog in collection and testing area respectively. We replaced missing depth information for about one third of the earthquakes by 0, assuming that the events were shallow. The smallest depth in the original catalog is 0.1 km so that the replaced values are unique and traceable. For around one third of earthquakes, some time information, mostly seconds, is missing. We find 1528 and 1518 earthquakes in the collection and testing area respectively and make those reduced catalogs available on the web at http://www.cseptesting.org/regions/italy.

We analyzed the magnitude of completeness of the data in the collection area using the Maximum Curvature method and the Entire Magnitude Range method [Woessner and Wiemer 2005]. The completeness magnitude improves with time as the availability of macroseismic data and the seismic network increases. In the first few years of the catalog the completeness is $M_w = 4.7$ which agrees well with findings for the CPTI04. Due to uneven distribution of magnitudes (see Figure 4), we conservatively assumed the completeness magnitude to be $M_w = 4.8$. Deriving magnitude regressions has a number of problems [e.g. Castello et al. 2006] and reversing a regression is theoretical not correct. However, inverting such an equation does not introduce significant biases. Any such bias is usually not easy to estimate because it depends on many factors, like the correlation coefficient, the slope of the regression line, etc. In this experiment, we assume that the bias introduced inverting Equation 1 is negligible when applied to setting the model parameters, resulting in

$$M_L = 1.231\,(M_w - 1.145). \tag{2}$$

Comparing the magnitude scales in Figure 6, we conclude that for practical purpose the conversion seem to work well. Using Equation 2, $M_w = 4.8$ corresponds to $M_L = 4.5$. The CPTI08 has 683 earthquakes above completeness within the collection area, which are not enough to perform a meaningful spatial analysis of completeness.

The target magnitude for testing time-varying models is $M_L = 4.0$ and this corresponds to $M_w = 4.393$. The target magnitude for long-term models is $M_L = 5.0$ which corresponds to $M_w = 5.205$. Assuming a frequency-magnitude distribution with a *b*-value of 1.0, the cumulative number of earthquakes of magnitude 4 and larger increases by a factor of 2.47 for a magnitude difference of 0.393 and a factor of 1.603 for a magnitude difference of 0.205. As a consequence, models that use the CPTI08 M_w to forecast earthquakes of magnitude 4 and larger would overpredict the number of earthquakes reported in M_L.

The CSI 1.1 is available for the period 1981–2002. Magnitudes are local magnitudes, M_L, which were calculated consistently to the testing catalog [Castello et al. 2007]. The catalog can be downladed from INGV (http://csi.rm.ingv.it/). The summary files contains 91,797 earthquakes. However, when we processed it, we found 10 duplicates so that Figure 4a shows a map of the 91,787 earthquakes. The inset of Figure 4a shows the cumulative number of earthquakes. There are 4,152 earthquakes in the first three years of the catalog while there are on average 4,612 events per year in the remaining 19 years of the catalog. There were many network changes during the early 1980s. Therefore we recommend using data from July 1, 1984 for lower completeness magnitudes. Figure 5 shows a map of the completeness magnitude using data from July 1984. The completeness was calculated by maximum curvature on a 0.1 × 0.1 degree grid using earthquakes within a radius of 30 km around each nodes. Nodes that had not at least 30 earthquakes above the completeness are blank. The completeness magnitude varies in space. It is probably safe to assume that it is at least 2.5 onshore from 1984.5.

Italy has various quarry activity that is recorded by the seismic network. Gulia [2010] investigated the CSI for possible quarry blasts. She pointed out four areas where the number of daytime events is much larger then the number of night-time events: the provinces of Savona and Cuneo in north-western Italy, a large portion of the Marche region, a spot of possible blasts in the central-south Apennines (attributed by her to the construction of the Arcichiaro dam in the Campobasso province, but more probably due to a distribution of still active quarries along the border between the provinces of Campobasso, Benevento, and Caserta), the Siracusa onshore belt in eastern Sicily, and a suspicion for the presence of quarries in the Murgia district (Apulia). The number of currently active quarries in Italy is considered to be over 7000 while it is almost impossible to estimate the number of dismissed locations). A recent study on the Italian seismicity of 2008 [Mele et al. 2010] confirmed the presence of quarries in at least fourteen areas (including the ones pointed out by Gulia [2010]). In the selected quarry areas, the BSI of 2008 has more than 746 events in the 12 hours from 7:00 to 19:00 (local legal time), and 102 events between 19:00 and 7:00. The mean M_L of the day-time events is 1.4, with standard deviation 0.3 and a symmetric distribution (the symmetry coefficient is 0.09, but becomes −0.04 after removing the only three events with $M_L > 2.2$). In practice, a magnitude greater than 2.3 can be considered a marker that distinguishes true events from possible blasts. Therefore, earthquake models that use magnitudes smaller than 2.5 for model calibration need to be careful about possible quarry contaminations in the catalog.

For model development and calibration we again cut the catalog in collection and testing area. We removed all events with no magnitude information and deeper than 30 km and found 38,609 and 38,277, respectively in collection and testing area. Again we have made the cut catalogs available online at http://www.cseptesting.org/regions/italy.

The CPTI08 fully covers the period of the CSI 1.1. Moreover, it was compiled taking CSI 1.1 into account and adopted the parameters for some events. Thus the two catalogs are not fully independent. To further stress the difference in magnitude scale in the two catalogs, we searched for common events in both catalogs. We selected earthquakes in the CSEP collection area only and applied

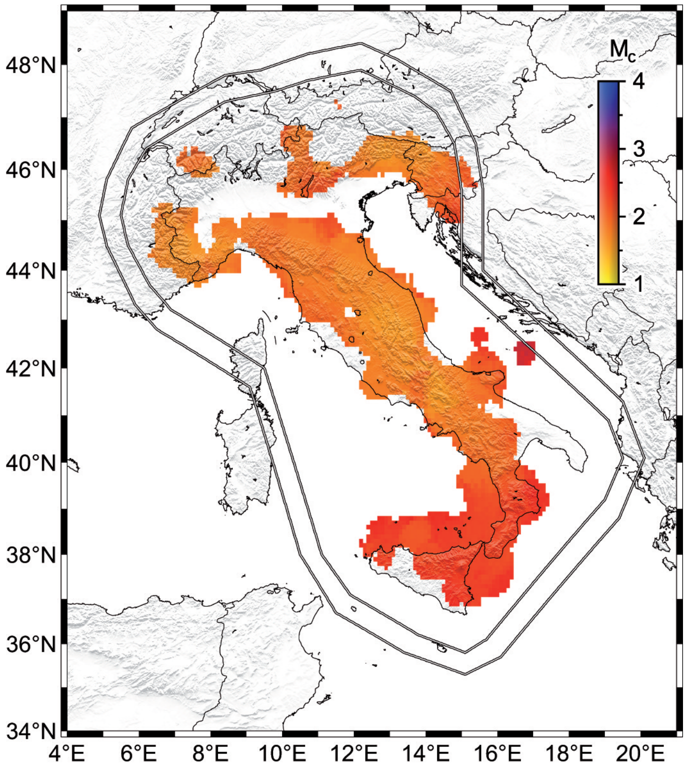

Figure 5. Map of completeness magnitude, M_c, of the CSI 1.1 computed using the Maximum Curvature method with sampling radii of 30 km. Nodes with less than 30 sampled earthquakes above the computed completeness level are left blank. The inner and outer polygons mark the extent of the testing area and collection area, respectively.

different cut-off magnitudes taking into account the difference between M_L and M_w. For $M_L \geq 3.95$, we found 318 earthquakes in the CSI 1.1. For the corresponding moment magnitude $M_w = 4.393$, the CPTI08 has 254 earthquakes in the collection area in the period 1981–2002. Applying a simple search algorithm with a maximum temporal difference of 1 minute between events and 100 km maximal spatial separation, we found 186 identical events in the two catalogs. For a magnitude comparison, we excluded 33 events that had their magnitudes in the CPTI08 catalog calculated solely from the CSI 1.1 local magnitudes by using Equation 1. The remaining 153 magnitude pairs are compared in Figure 6. The black circles show a scatter plot of the CSI 1.1 M_L and CPTI08 M_w. The mean magnitude difference of the identical events is -0.31 ± 0.23. When we apply Equation 2 to transfer M_w in the CPTI08 into M_L, then the average magnitude difference is -0.00 ± 0.24. The transferred data is plotted with red circles. The comparison shows that the magnitudes of the two catalogs agree reasonably well when the different magnitude types are taken into account.

In summary, we have two catalogs available for the development of models for the Italian CSEP testing region: The CPTI08 covering the period 1901–2006 and the CSI 1.1 covering the period 1981–2002. The catalogs agree reasonably well in the overlapping time period when the differences in magnitude types are accounted for and corrected with the regression equation $M_w = 0.812\, M_L + 1.145$.

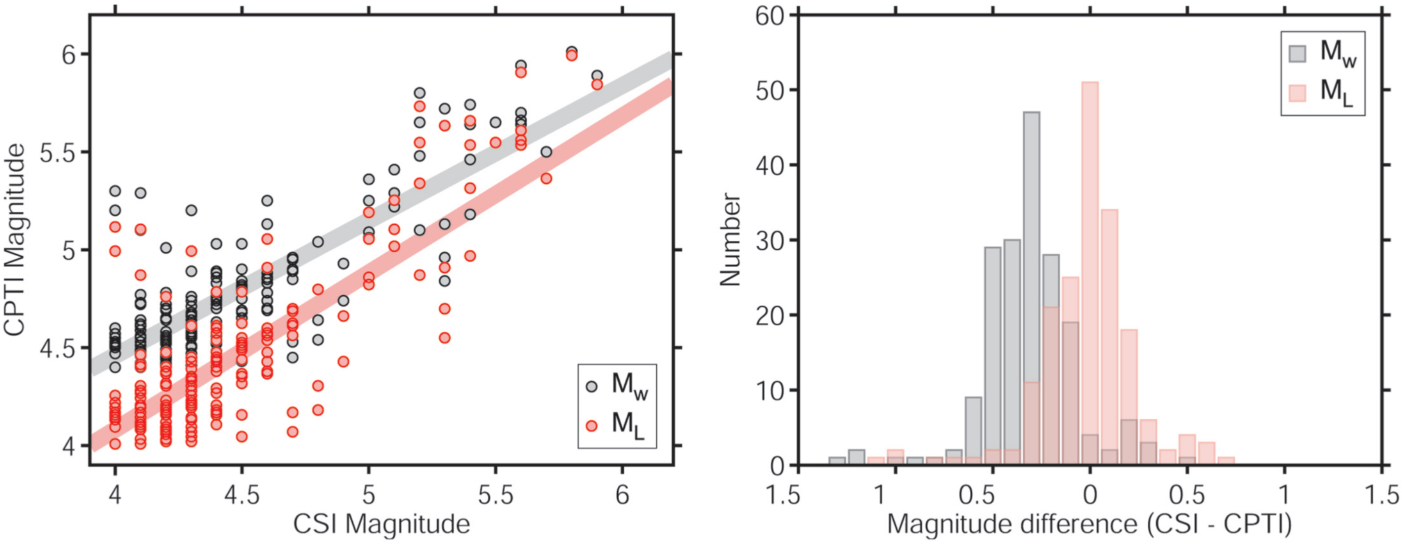

Figure 6. (Left) Comparison of magnitudes for 153 identical events in the CSI 1.1 and CPTI08 for $M_L \geq 4.0$. The black circles show M_w in the CPTI08 compared to M_L in the CSI 1.1. The red circe show M_L calculated from M_w using the linear regression equation (1). (Right) The histograms show how the magnitude difference between CPTI08 and the CSI 1.1 shifts when the magnitude transformation is applied.

Conclusions

The development of testing regions should be pursued with in depths investigation of the used data stream, in this case the earthquake bulletin (BSI) of INGV. Given the network configuration and the network's detection capabilities, we defined the largest possible area extending beyond the borders of Italy to ensure capturing hazard-relevant events on the territory of Italy. However, the islands of Sardinia, Pantelleria, and Lampedusa are not included in the testing area as the network coverage, and subsequently, the detection capabilities do not allow for extending the testing area to cover them. Nevertheless, the mainland of Italy and the island of Sicily, the most seismically active parts of Italy, as well as the most hazardous areas, are well covered by the testing area.

We discussed two earthquake catalogs that are available as learning catalogs for the model development. The CPTI08 is a combination of macroseismic and instrumental data from 1901–2006 and reports M_w which is complete from $M_w = 4.8$ from the beginning of the catalog. The CSI 1.1 covers the period 1981–2002 and reports M_L that has been determined consistently with the magnitudes in the testing catalog. In the overlapping period, the catalogs agree reasonably well, when the magnitude scale difference is accounted for. Thus we have more than 100 years of learning catalog with a consistent completeness corresponding to $M_L = 4.5$. From July 1985 until the end of 2002 we have a completeness of $M_c = 2.5$ on mainland Italy. Work is in progress at INGV to close the gap between 2003 and the beginning of the BSI.

We propose this procedure to become the standard approach for CSEP when defining testing and collection areas in new testing regions.

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*Corresponding author: Danijel Schorlemmer,
Southern California Earthquake Center, University of Southern California, Los Angeles, USA; email: ds@usc.edu