SEISMIC HAZARD AND STRONG GROUND MOTION: AN OPERATIONAL NEO-DETERMINISTIC APPROACH FROM NATIONAL TO LOCAL SCALE

Giuliano F. Panza
Department of Mathematics and Geosciences, University of Trieste. Italy
The Abdus Salam International Centre for Theoretical Physics, SAND Group. Trieste. Italy
Institute of Geophysics, China Earthquake Administration, Beijing. China

Antonella Peresan
Department of Mathematics and Geosciences, University of Trieste. Italy
The Abdus Salam International Centre for Theoretical Physics, SAND Group. Trieste. Italy

Cristina La Mura
Department of Mathematics and Geosciences, University of Trieste. Italy

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Contents

Summary

Recent advances in the physical knowledge of seismic waves generation and propagation processes, along with the improving computational tools, make it feasible the realistic modeling of the ground shaking caused by an earthquake, taking into due consideration the complexities of the source and of the propagation path. A neo-deterministic scenario based approach to seismic hazard assessment (NDSHA) has been developed that naturally supplies realistic time series of ground shaking, including reliable estimates of ground displacement readily applicable to seismic isolation techniques. The NDSHA procedure permits incorporating, as they become available, new geophysical and geological data, as well as the information from the different pattern recognition techniques developed for the space-time identification of strong earthquakes. All this leads to the natural definition of a set of scenarios of expected ground shaking at the bedrock. At the local scale, further investigations can be performed taking into account the local soil conditions, in order to compute the seismic

input (realistic synthetic seismograms) for engineering analysis of relevant structures, such as historical and strategic buildings.

The NDSHA approach has been already applied in several regions worldwide, including a number of local scale studies accounting for two-dimensional and three-dimensional lateral heterogeneities in inelastic media. A pilot application of the approach, including the detailed evaluation of the expected ground motion accounting for site effects and seismic engineering analysis, has been carried out at a site located in the Friuli Venezia Giulia Region (NE Italy). Further some applications worldwide of a new, highly efficient analytical methodology, developed for modeling the propagation of the seismic wavefield in three-dimensional inelastic media, are presented. This procedure, based on computer codes developed from a detailed knowledge of the seismic source process and the propagation of seismic waves in heterogeneous media, allows not only the detailed study of instrumental and macroseismic data but also the realistic estimate of the seismic hazard, in those areas for which scarce (or no) historical or instrumental information is available, and the relevant parametric analyses: different source and structural models can be taken into account to create a wide range of possible groundshaking scenarios from which to extract essential information, including uncertainty ranges, for decision making.

1. Introduction

The typical seismic hazard problem lies in the determination of the ground motion characteristics associated with future earthquakes, both at regional and local scale. Seismic hazard assessment can be performed in various ways, e.g. with a description of the groundshaking severity due to an earthquake of a given distance and magnitude ("groundshaking scenario"), or with probabilistic maps of relevant parameters describing the ground motion. The first scientific and technical methods developed for seismic hazard assessment were deterministic and based on the observation that damage distribution is often correlated with the spatial distribution and the physical properties of the underlying soil. The 1970s saw the beginning of the development of probabilistic seismic hazard maps on a national, regional and urban (microzoning) scale. In the 1990s these instruments for the mitigation of seismic hazard came to prevail over deterministic cartography.

The classical PSHA (Cornell, 1968), determines the probability of exceeding, over a specified period of time, various levels of ground motion. The main elements of a PSHA are: 1) the seismic sources (i.e. the seismogenic zones), within which the seismogenic process is frequently assumed to be rather uniform; 2) the characteristics of the earthquakes recurrence within the seismogenic zones, which is assumed to be Poissonian; 3) the attenuation relations, which provide estimates of ground motion parameters at different distances from the sources. The hazard at a site is given in terms of probability of exceeding different levels of ground motion during a specified period of time. This is achieved through the calculation of the probability of earthquakes with some damaging potential and the calculation of the conditional probability of exceeding of a given ground motion level, for each of these contributing earthquakes (summed over all potentially contributing sources). Thus, PSHA aims at the statistical characterization of ground motion at a site, although, at most of the sites the available data are not sufficient to verify the assumptions nor to adequately constrain the parameters of the statistical model.

Most of the seismic zonations adopted by the current regulations, either on a national or a regional scale, have been defined according to the conventional PSHA approach (Bommer and Abrahamson, 2006, and references therein), and hence they are basically affected by the limitations of such methodology (Panza et al., 2011; Wang, 2011). Specifically, probabilistic seismic hazard maps are: a) strongly dependent on the available observations, unavoidably incomplete due to the long time scales involved in geological processes leading to the occurrence of a strong earthquake; b) do not adequately consider the source and site effects, since they resort to linear convolution techniques, e.g. GMPE (e.g. Boore and Atkinson, 2008), which cannot be applied when dealing with complex geological structures, because the ground motion generated by an earthquake can be formally described as the tensor product of the earthquake source tensor with the Green's function of the medium (Aki and Richards, 2002); c) time-independence, being based on the assumption of random occurrence of earthquakes (Bilham, 2009). Moreover, the conventional PSHA approach describes the hazard in terms of a single parameter, PGA, which is routinely mapped as the values with 10% probability of being exceeded in 50 years. Actually, it is nowadays recognized by the engineering community that seismic PGA alone is not sufficient for the adequate design, particularly for special buildings and infrastructures, since ground shaking amplitude, frequency content and duration can play a decisive role. The design of seismically isolated structures, which is based on displacements (Martelli and Panza, 2010), requires a reliable characterization of the seismic input, since it is necessary to accurately define the maximum displacement at the period relevant for the isolated structure and the energy content at the long periods (above 1 s), which should be expected at the specific site.

In view of the mentioned limits of PSHA estimates, it appears preferable to resort to a scenario-based approach to seismic hazard assessment that may turn out to be necessary/useful to complement and validate the results that will be eventually produced by large scale projects like GEM (http:// www.globalquakemodel.org /). The NDSHA (Peresan et al., 2011 and references therein), permits us to integrate the available information provided by the most updated seismological, geological, geophysical and geotechnical databases for the site(s) of interest, as well as advanced physical modeling techniques, to provide reliable and robust basis for the development of a deterministic design basis for cultural heritage and civil infrastructures in general (Field et al., 2000; Panza et al., 2001a, 2001b) Neo-deterministic means scenario-based methods for seismic hazard analysis, where attenuation relations and other assumptions about local site responses similarly questionable on mathematical and physical ground, all implying some form of linear convolution, are not allowed in.

Instead realistic synthetic time series are used to construct earthquake scenarios. The NDSHA procedure provides strong ground motion parameters based on the physical modeling of seismic waves propagation at different scales - regional, national and metropolitan – accounting for a wide set of possible seismic sources and for the available information about the mechanical properties of the propagation media. The scenario-based methodology relies on observable data being complemented by physical modeling techniques, which can be submitted to a formalized validation process. The importance to consider different earthquake scenarios to reliably asses the hazard has been recently evidenced by the large earthquakes that stroke Japan, near east coast of Honshu, in 2011. Specifically, the largest event of March 11, 2011 ($M > 9$,where M is the magnitude on Richter Sclae) caused no damage to the Onagawa nuclear power plant, whereas its aftershock of April 7 ($M > 7$) damaged it. When assessing the hazard, such kind of behavior, which can be easily explained by the difference in focal mechanisms between the main shock and the large aftershock, can be dealt with adequately only considering different deterministic scenarios.

Lessons learnt from recent destructive earthquakes, including the L'Aquila (2009), Haiti (2010), Chile (2010) and Japan (2011) earthquakes, provide new opportunities to revise and improve the seismic hazard assessment. There is the need, however, of a formal procedure for the official collection and proper evaluation of seismic hazard assessment results (Peresan et al., 2010; Stein et al., 2011), so that society may benefit from the scientific studies and may not be misled by the incorrect hazard assessment results. In fact, recent studies (Kossobokov and Nekrasova, 2010) showed that the worldwide maps resulting from the Global Seismic Hazard Assessment Program, GSHAP (Giardini et al., 1999), are grossly misleading and fail both in describing past seismicity, as well as in predicting expected ground shaking.

The comparison between the expected PGA values, provided by GSHAP in 1999, and the actual maximum PGA experienced during the period 2000-2009, performed in terms of related intensities, shows major inconsistencies, particularly severe as earthquakes of greater and greater size are considered. This observation is proved by fatal evidence in all the deadliest earthquakes occurred since the year 2000 (Table 1), including the recent Japan earthquake occurred on March, 11, 2011. For this earthquake, accelerations observed in land exceeded 1 g at several sites, reaching values as high as 2.93 g, while the maximum expected PGA over the entire Japan was not exceeding 0.6 g in GSHAP maps.

The evidenced limits of PSHA estimates, which are due not only to scarcity of data, but also to the not valid physical model and mathematical formulation employed (Wang, 2011; Paskaleva et al., 2007), become unacceptable when considering the number of casualties and injured people (Wyss et al., 2012). The evolving situation makes it compulsory for any national or international regulation to be open to accommodate the most important new results, as they are produced and validated by the scientific community.

An example is provided by the Ordinance of the Prime Minister (OPCM) n. 3274/2003, plus its amendments and additions, which have enforced the current Seismic Code in Italy: in the Ordinance it is explicitly stated that the rules of the code must be revised as new scientific achievements are consolidated. Destruction and casualties caused by the L'Aquila earthquake (April 6, 2009; M6.3), despite it took place in a well known seismic territory of the Italian peninsula, are just a sad reminder that significant methodological improvements are badly needed toward a reliable assessment of ground shaking and engineering implementation.

Region	**Date**	M	**Fatalities**	**Intensity difference** ΔI_0
Sumatra-Andaman "Indian Ocean Disaster"	26.12.2004	9.0	227898	4.0
Port-au-Prince (Haiti)	12.01.2010	7.3	222570	2.2
Wenchuan (Sichuan, China)	12.05.2008	8.1	87587	3.2
Kashmir (North India and Pakistan border region)	08.10.2005	7.7	~86000	2.3
Bam (Iran)	26.12.2003	6.6	~31000	0.2
Bhuj (Gujarat, India)	26.01.2001	8.0	20085	2.9
Off the Pacific coast of Tōhoku (Japan)	11.03.2011	9.0	15811 (4035 missing)*	3.2
Yogyakarta (Java, Indonesia)	26.05.2006	6.3	5749	0.3
Southern Qinghai (China)	13.04.2010	7.0	2698	2.1
Boumerdes (Algeria)	21.05.2003	6.8	2266	2.1
Nias (Sumatra, Indonesia)	28.03.2005	8.6	1313	3.3
Padang (Southern Sumatra, Indonesia)	30.09.2009	7.5	1117	1.8

Table 1. List of the deadliest earthquakes occurred during the period 2000-2011, and the corresponding intensity differences, $\Delta I_0 = I_0(M) - I_0(mPGA)$, among the observed values and predicted by GSHAP. $I_0(M)$ and $I_0(mPGA)$ are computed from the observed magnitude M and the maximum GSHAP PGA around the observed epicenter, respectively, using existing relationships (modified after Kossobokov and Nekrasova, 2010).

2. The Neo-Deterministic Approach

NDSHA is an innovative, but already well consolidated, procedure that supplies realistic time histories from which it is natural to retrieve peak values for ground displacement, velocity and design acceleration in correspondence of earthquake scenarios (e.g. Parvez et al., 2010; Paskaleva et al., 2010).

The procedure is particularly suitable for the optimum definition of the characteristics of the modern anti-seismic devices, when the accelerometric data available are not representative of the possible scenario earthquakes – as it is often the case – and when non-linear dynamic analysis is necessary. By sensitivity analysis, knowledge gaps related to lack of data can be easily addressed, due to the limited amount of scenarios to be investigated.

NDSHA addresses some issues largely neglected in traditional hazard analysis, namely how crustal properties affect attenuation: ground motion parameters are not derived from overly simplified attenuation relations, but rather from synthetic time histories. Starting from the available information on the Earth's structure (mechanical properties), seismic sources, and the level of seismicity of the investigated area, it is possible to estimate PGA, PGV, and PGD or any other parameter relevant to seismic engineering, which can be extracted from the computed theoretical signals.

Synthetic seismograms can be efficiently constructed with the modal summation technique (e.g. Panza et al., 2001; La Mura et al. 2011) to model ground motion at sites of interest, using knowledge of the physical process of earthquake generation and wave propagation in realistic media and this makes it possible to easily perform detailed parametric analyses that permit to account for the uncertainty in input information.

Where the numerical modeling is successfully compared with records, the synthetic seismograms permit the microzoning, based upon a set of possible scenario earthquakes. Where no recordings are available the synthetic signals can be used to estimate the ground motion without having to wait for a strong earthquake to occur (pre-disaster microzonation). In both cases the use of modeling is necessary since the so-called local site effects can be strongly dependent upon the properties of the seismic source and can be properly defined only by means of envelopes.

In fact, several techniques that have been proposed to empirically estimate the site effects using observations (records) convolved with theoretically computed signals corresponding to simplified models, supply reliable information about the site response to non-interfering seismic phases, but they are not adequate in most of the real cases, when the seismic sequel is formed by several interfering waves.

One of the most difficult tasks in earthquake scenario modeling is the treatment of uncertainties, since each of the key parameters has its own uncertainty and intrinsic variability, which often are not quantified explicitly. A possible way to handle this problem is to vary systematically (within the range of related uncertainties) the modeling parameters associated with seismic sources and structural models, i.e. to perform a parametric study to assess the effects of the parameters describing the mechanical properties of the propagation medium and of the earthquake focal mechanism (i.e. strike, dip, rake, depth etc.).

The parametric studies allow us to generate advanced ground-shaking scenarios for the proper evaluation of the site-specific seismic hazard, with the necessary and complementary check based on both probabilistic and empirical procedures. Once the gross features of the seismic hazard are defined, and the parametric analyses are performed, a more detailed modeling of the ground motion can be carried out for sites of specific interest. Such a detailed analysis duly takes into account the earthquake source characteristics, the mechanical properties of the path and of the local geology, nevertheless it can be easily performed using widely available computational tools, like modern laptops or, for very complex situations, to worldwide grid-and-cloud advanced e-infrastructures (e.g. Prace, EGI, EU-IndiaGRID2, EUMEDGRID-Support and Chain).

2.1. Ground Motion Scenarios at Bedrock

In the NDSHA approach the definition of the space distribution of seismicity accounts essentially for the largest events reported in the earthquake catalogue at different sites. The flexibility of NDSHA permits to incorporate the additional information about the possible location of strong earthquakes provided by the morphostructural analysis, thus filling in gaps in known seismicity. Specifically, the areas prone to strong earthquakes are identified based on the morphostructural nodes, which represent specific structures formed around the intersections of lineaments. Lineaments are identified by the Morphostructural Zonation Method (Alekseevskaya et al., 1977) that, independently from any information about earthquakes, delineates a hierarchical block structure of the study region, using tectonic and geological data, with special care to topography. The boundary zones between blocks are called lineaments and the nodes are formed at the intersections or junctions of two or more lineaments. Among the defined nodes, those prone to strong earthquakes are then identified by pattern recognition on the basis of the parameters characterizing indirectly the amount of neo-tectonic movements and fragmentation of the crust at the nodes (e.g. elevation and its variations in mountain belts and watershed areas; orientation and density of linear topographic features; type and density of drainage pattern). For this purpose, the nodes are defined as circles of radius $R = 25\,\mathrm{km}$ surrounding each point of intersection of lineaments. The morphostructural zonation of Italy and surrounding regions, as well as the identification of the sites where strong events can nucleate, has been performed by Gorshkov et al. (2002), (2004) considering two magnitude thresholds: $M \geq 6.0$ and $M \geq 6.5$.

The identified seismogenic nodes are used, along with the seismogenic zones (Meletti and Valensise, 2004), to characterize the earthquake sources used in the seismic ground motion modeling, as described by (Peresan et al., 2009). The earthquake epicenters reported in the catalogue are grouped into 0.2°x0.2° cells, assigning to each cell the maximum magnitude recorded within it. A smoothing procedure is then applied, to account for spatial uncertainty and for source dimensions. Only the sources located within the seismogenic zones, as well as the sources located within the earthquake prone nodes, are considered; moreover, if the smoothed magnitude M of a source inside a node is lower than the magnitude threshold, M_0, identified for that node, in the computation of the synthetic seismograms M_0 is used.

In the first applications of NDSHA (Costa et al., 1993; Panza et al., 1996, 2000, 2001) a double-couple point source is placed at the centre of each cell, with a focal mechanism consistent with the properties of the corresponding seismogenic zone or node and a depth, which is a function of magnitude (10 km for $M < 7$, 15 km for $M \geq 7$). To define the physical properties of the source-site paths, the territory is divided into an appropriate number of polygons, each characterized by a structural model composed of flat, parallel inelastic layers that represent the average mechanical properties of the lithosphere at regional scale. Synthetic seismograms are then computed by the modal summation technique for sites placed at the nodes of a grid with step 0.2°x0.2° that covers the national territory, considering the average structural model associated to the regional polygon that includes the site. The seismograms are computed for an upper frequency content of 1 Hz, that is consistent with the level of detail of the regional structural models, and the point sources are scaled for their dimensions using the spectral scaling laws proposed by Gusev (1983), as reported in Aki (1987).

From the set of complete synthetic seismograms, different maps of seismic hazard that describe the maximum ground shaking at the *bedrock can be produced*. The acceleration parameter in NDSHA is usually given by the DGA. This quantity is obtained by computing the response spectrum of each synthetic signal for periods, consistent with the detail of knowledge about earthquake sources and propagation media, of 1 s and longer (the periods considered in the generation of the synthetic seismograms). The spectrum is extended at frequency higher than 1Hz using the shape of the Italian design response spectrum for soil A), which defines the normalized elastic acceleration response spectrum of the ground motion, for 5% critical damping (for details see Panza et al., 1996). In the PSHA the hazard maps are only defined in terms of PGA, which is the horizontal peak ground acceleration. DGA is comparable to the PGA, since an infinitely rigid structure (i.e. a structure having a natural period of 0 s) moves exactly like the ground (i.e. the maximum acceleration of the structure is the same as that of the ground, which is the PGA). This is why PGA has been used over the years to provide a convenient anchor point for the design spectra specified by various regulatory agencies. Moreover, DGA is practically equivalent to EPA, which is defined as the average of the maximum ordinates of elastic acceleration response spectra within the period range from 0.1 to 0.5 seconds, divided by a standard factor of 2.5, for the 5% damping (Panza et al., 2003). Among the parameters representative of earthquake ground motion (maximum displacement, velocity, acceleration), we focus our attention on the maximum displacement estimates, which turn out to be relevant for seismic isolation design (Figure 1).

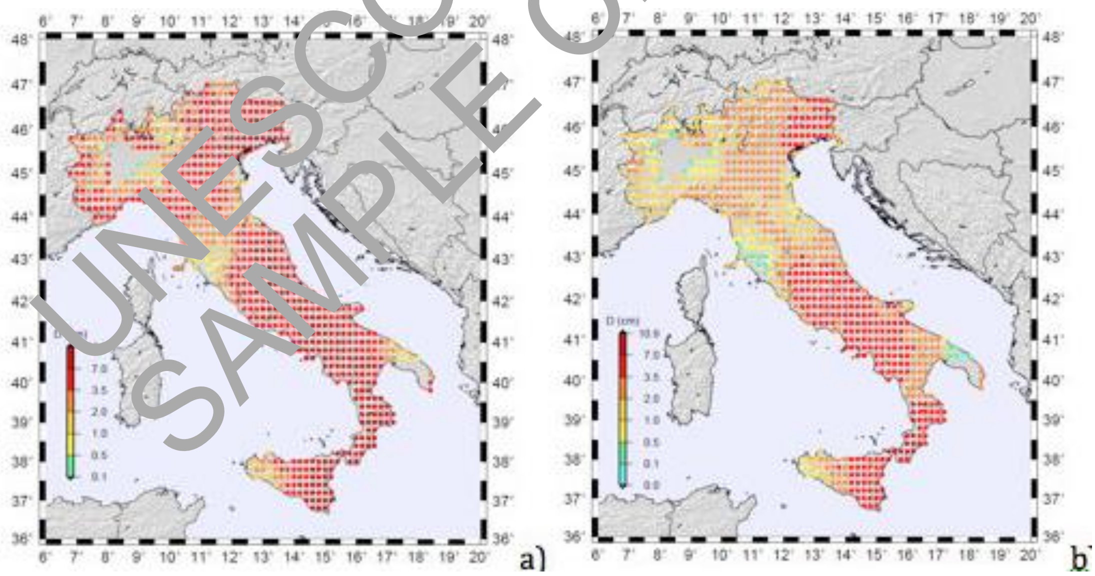

Figure 1. Map of Peak Ground Displacement *D* for the Italian territory. At each node of the grid, the maximum value of a) horizontal displacement and b) vertical displacement, is extracted from the computed synthetic seismograms.

The effect of a change in the properties of the medium traveled by the seismic waves generated at the sources has been tested by replacing the models described in Costa et al. (1993) with a set of cellular structures (1°x1°), obtained through an optimized non-linear inversion of surface wave dispersion curves (Boyadzhiev et al., 2008; Brandmayr et al., 2010). The properties of the uppermost layer are quite different for the two considered structural models; nevertheless, the variation in the computed ground motion, both positive and negative, gives rise to macroseismic intensity variations (Panza et al., 1997) not exceeding one degree in the MCS scale.

NDSHA has been recently extended to frequencies as high as 10 Hz, to account for the source process in some detail (rupture process at the source and the consequent directivity effect). The preliminary results provided by this ongoing research (i.e. the regression relations between the strong motion parameters and the macroseismic intensities), confirm the results obtained with a 1 Hz cut-off frequency in the point-source approximation.

Considering specific faults included within alerted nodes, with this second variant of NDSHA it is possible to perform parametric studies, which permit to single out the relevance of source-related effects, like directivity. In Fig. 2 we provide an example of scenario corresponding to the fault ITIS038 from the database DISS3 (Basili et al., 2008), which falls within the node I26 (Gorshkov et al., 2002).

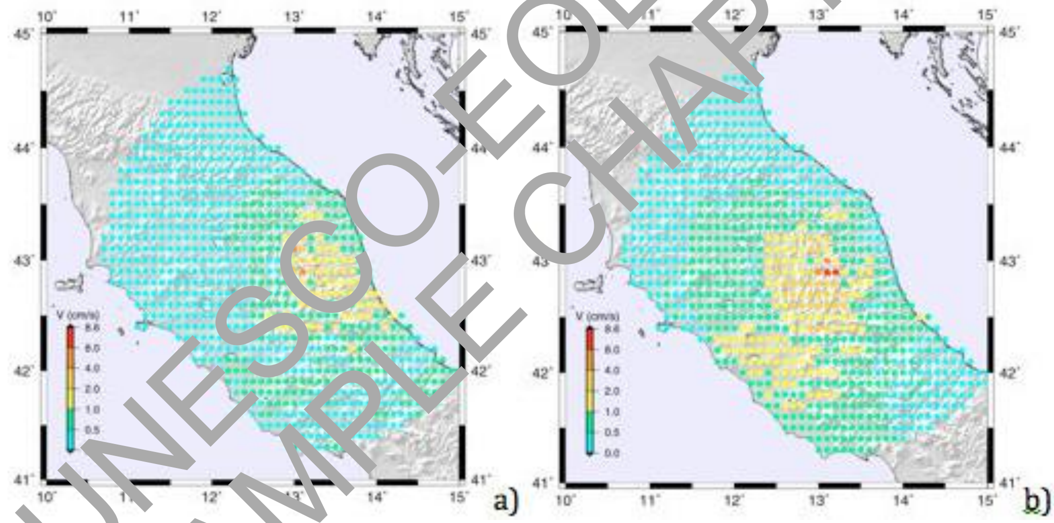

Figure 2. Ground shaking scenarios at bedrock (PGV) a) for source directivity south-east; a) for source directivity north-west. The fault ITIS038 from the database DISS3 (Basili et al., 2008) is considered. Cellular structural models of the lithosphere are considered to model waves propagation.

The rupture process at the source and the consequent directivity effect (i.e. radiation at a site depends on its azimuth with respect to rupture propagation direction) is modeled by means of the algorithm developed by Gusev and Pavlov (2006) and Gusev (2011), that simulates the radiation from a fault of finite dimensions, named PULSYN (PULse-based wide band SYNthesis).

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Gusev A.A., Radulian M., Rizescu M., Panza G.F. (2002). Source scaling of intermediate-depth Vrancea eartquakes, *Geophysical Journal International* 151, 879-889. [In this paper source scaling properties are studied for the intermediate-depth seismic nest in the Vrancea region, Romania.]

Gusev A.A., Pavlov V. (2006). Wideband simulation of earthquake ground motion by a spectrum-matching, multiple-pulse technique. First European Conference on Earthquake Engineering and Seismology, Geneva, Switzerland, 3-8 September 2006. Abstract Book 408. 2006. [In this paper to simulate earthquake ground motion, a multiple-point stochastic earthquake fault model and a suite of Green functions computed with discrete wavenumber method are combined. The simulation package can generate example motions, as a test, realistic analogues of recorded motions in the epicentral zone of the 1994 Northridge, California earthquake were synthesized and related uncertainties were estimated.]

Gusev A.A. (2011). Broadband Kinematic Stochastic Simulation of an Earthquake Source: a Refined Procedure for Application in Seismic Hazard Studies, Pure and Applied Geophysics 168 (1), 155-200. [The approach in this paper to model to specify earthquake source is well adapted to the study of deterministic seismic hazard: it may be used for simulation of individual scenario events, or suites of such events, as well as for analysis of uncertainty for expected ground motion parameters from a particular class of events.]

Healy J. H., Kossobokov V.G., Dewey J.W. (1992). A test to evaluate the earthquake prediction algorithm, M8, *U.S. Geol. Surv. Open-File Report* 92-401, 23 p. with 6 Appendices. [The document provides essential information and reference about the real-time testing procedure of the intermediate-term middle-age earthquake prediction algorithm M8. This prediction experiment, ongoing since more than twenty years now, already permitted to assess the significance of the issued predictions.]

Indirli M., Nunziata C., Romanelli F., Vaccari F., Panza, G.F. (2009). Design and placing of an innovative 3D-Isolation system under the Herculaneum Roman ship. In: Protection of Historical Buildings PROHITECH, vol. 1, Ed: F.M. Mazzolani, CRC Press, Taylor and Francis Group, London, 681-687. [An innovative 3D-Isolation system has been designed and installed to protect the Herculaneum Roman ship. In the design process, the expected ground motion has been estimated also taking into account the Design Ground Acceleration obtained with the neo-deterministic approach, based on the computation of synthetic seismograms.]

Indirli M., Puglisi C., Screpanti A., Romanelli F. (2010). Multi-hazard maps for the Valparaiso area (Chile). CRC Press, Taylor and Francis Group, London: pp.999-1004, 9780415606851 : In: Proceedings of the final COST Action C26 Conference. [In the framework of the MAR VASTO Project the impact of main hazards have been evaluated in the Valparaìso urban area.]

Indirli M., Razafindrakoto H., Romanelli F., Puglisi C., Lanzoni L., Milani E., Munari M. and S. Apablaza S. (2010). Hazard Evaluation in Valparaíso: the MAR VASTO Project, *Pure and Applied Geophysics*, DOI: 10.1007/s00024-010-0164-3. [In this paper realistic modeling of ground motion in the Valparaìso urban area is carried out and a successful comparison with records did permit the generation of ground-shaking maps for the area.]

Kantorovich L.V., Keilis-Borok V.I. (1991). "Earthquake prediction and decision-making: social, economic and civil protection aspects" (Proc. International Conference on Earthquake Prediction: State-of-the-Art, pp. 586-593, Scientific-Technical Contributions, CSEM-EMSC, Strasbourg, France, 1991). Based on "Economics of earthquake prediction" (Proc. UNESCO Conference on Seismic Risk, Paris, 1977). [The paper discusses the possible use of formally defined earthquake predictions in decision making processes. It provides a hierarchical list of mitigation actions that, having different costs, can be reasonably implemented over different space-time scales and can be increased or decreased depending on the specific state of alert].

Keilis-Borok V.I., Rotwain I.M. (1990). Diagnosis of time of increased probability of strong earthquakes in different regions of the world: algorithm CN, *Physics of Earth Planet Interior* 61, 57-72. [The paper provides a definition of the algorithm CN, where pattern recognition procedures for infrequent events are used to identify patterns of clustering of small- and intermediate-scale seismicity before large earthquakes. Identification procedures derived from analysis of large California and Nevada earthquakes are successfully tested in several regions of the world].

Keilis-BorokV.I., Primakov I. (1997). “Earthquake Prediction and Earthquake Preparedness: The Possibilities to Reduce the Damage from Earthquakes”. Fourth Workshop on Non-Linear Dynamics and Earthquake Prediction, 6 - 24 October 1997, Trieste: ICTP, H4.SMR/1011-11, 30 pp. [The document provides a hierarchical list of the wide set of possible mitigation actions that can be taken in response to an earthquake prediction].

Kossobokov V.G., Romashkova L.L., Panza G.F., Peresan A. (2002). Stabilizing intermediate-term medium-range earthquake predictions, *Journal of Seismology and Earthquake Engineering* 8, 11-19. [A new stabilized scheme for M8 algorithm application is proposed, where the precursory seismicity patterns are analyzed within a dense set of circles covering the study area].

Kossobokov V. (2005). Regional Earthquake Likelihood Models: A realm on shaky grounds? Eos Trans. AGU, 86(52), Fall Meet. Suppl., Abstract S41D-08. [The abstract provides a brief critical re-appraisal of Regional Earthquake Likelihood Models, RELM, pointing to the low significance of their results.]

Kossobokov V. (2008). “Testing earthquake forecast/prediction methods: "Real-time forecasts of tomorrow's earthquakes in California". Geophysical Research Abstracts, Volume 10, Abstracts of the Contributions of the EGU General Assembly 2008, Vienna, Austria, 13-18 April 2008 (CD-ROM), EGU2008-A-07826. [The abstract briefly discusses the results from real-time forecasting of California earthquakes, coming to the conclusion of low significance of the obtained results.]

Kossobokov V. (2009). Testing earthquake forecast/prediction methods: "Real-time forecasts of tomorrow's earthquakes in California". In *Some Problems of Geodynamics*, Moscow, KRASAND, p. 321-337 (*Comput. Seismol.*, 39). (in Russian) [The paper discusses in some detail the results from real-time forecasting of California earthquakes, providing a critical re-appraisal of the obtained results and evidencing the low significance of the issued forecasts.]

Kossobokov V. G., Nekrasova A.K. (2010). Global Seismic Hazard Assessment Program Maps Are Misleading. Eos Trans. AGU, 91(52), Fall Meet. Suppl., Abstract U13A-0020. [The abstract summarizes the results from a systematic analysis, comparing intensities from recent M>6 earthquakes with those predicted according to GSHAP global map. It concludes that the global hazard map underestimated actual ground shaking, particularly for the larges earthquakes]

Kossobokov V.G., Nekrasova A. K. (2011). Global seismic hazard assessment program (GSHAP) maps are misleading. *Problems of Engineering Seismology* 38 (1), 65-76 (in Russian). [The capability of Global Seismic Hazard Assessment Program in anticipating ground shaking from future earthquakes has been evaluated against the earthquakes which occurred since the publication of its results. This systematic analysis shows that the results of GSHAP maps, published in 1999, are in poor agreement the actual occurrence of recent strong earthquakes. Specifically, all of the sixty earthquakes with magnitude larger than 7.5 occurred since 2000, exceeded the ground shaking values predicted by the GSHAP maps.]

La Mura C., Yanovskaya T.B., Romanelli F., Panza G.F. (2011). Three-Dimensional Seismic Wave Propagation by Modal Summation: Method and Validation, *Pure and Applied Geophysics*, 168, 201-216. [This paper contains the development and the validation of a new analytic methodology for computing synthetic seismograms in 3D inelastic media.]

La Mura C., Gholami V., Panza G.F. (2011). Three-dimensional synthetic seismograms computation by Modal Summation: method and applications, 30 GNGTS, 14-17 November, 2011. Trieste, Italy. [This abstract contains the computation of synthetic seismograms in 3D inelastic media with the new analytic methodology and their comparison with available records both at low and high frequencies.]

Lee Y., Turcotte D.L., Holliday J.R., Sachs M.K., Rundle J.B., Chen C., Tiampo K.F. (2011). Results of the Regional Earthquake Likelihood Models (RELM) test of earthquake forecasts in California. PNAS, 108 (40): 16533-16538. doi: 10.1073/pnas.1113481108. [The paper presents results from The Regional Earthquake Likelihood Models (RELM) test of earthquake forecasts in California, a competitive evaluation of forecasts of future earthquake occurrence. In this paper, the authors compare the forecasts to evaluate which forecast is the most "successful" in terms of the locations of future earthquakes].

Levshin A. L. (1985). Effects of lateral inhomogeneities on surface waves amplitudes measurements, Annals of Geophysics 3, 511-518. [This paper is the main reference in the study of the influence of lateral inhomogeneities on surface wave amplitude spectra]

Martelli A. (2010). On the need for a reliable seismic input assessment for optimized design and retrofit of seismically isolated civil and industrial structures, equipment and cultural heritage, *Pure and Applied Geophysics*, DOI 10.1007/s00024 -010-0120-2. [The paper discusses the limit of traditional approaches to seismic hazard assessment from the point of view of engineering design. The paper pays special attention to the design of seismically isolated structures, which requires an accurate definition of the maximum value of displacement and a reliable evaluation of the earthquake energy content at low frequencies, for the site and ground of interest. It is concluded that to overcome the limits of PSHA, this method shall be complemented by the development and application of deterministic approaches].

Martelli A., Forni M. (2010). Seismic isolation and other anti-seismic systems: recent applications in Italy and worldwide, Seismic Isolation And Protection Systems (SIAPS), DOI 10.2140/siaps.2010.1.75, Mathematical Sciences Publishers (MSP), Berkeley, Vol. 1, No. 1, pp. 75-123. [A number of applications of seismic isolation systems are illustrated, pointing to the need for an appropriate definition of the seismic input to be used for seismic design].

Martelli A., Panza G.F. (2010). Note sull'International Advanced Conference on Seismic Risk Mitigation and Sustainable Development svoltasi a Miramare (TS) dal 10 al 14 maggio 2010 – Valutazione della pericolosità sismica – È importante affiancare l'utilizzo dell'approccio deterministico a quello del consueto approccio probabilistico e non ignorare le previsioni a medio termine, *Rivista degli Ingegneri del Veneto*, FOIV 29, 35-39. [The paper evidences the need and practical relevance of integrating the traditional approaches for seismic hazard assessment with the newly available information provided by ground motion modeling and validated earthquake predictions.]

Martelli A., Forni M. (2011). Recent worldwide application of seismic isolation and Energy dissipation and conditions for their correct use, SEWC, Cernobbio (Como), April 2011. [The paper mentions the increasing number of structures that have been protected by anti-seismic systems, including bridges and viaducts, civil and industrial buildings, cultural heritage. It provides a short overview on the dissemination of such applications worldwide, paying particular attention to applications in Italy. Some important conditions for the correct use of the antiseismic systems and devices are mentioned in the conclusions].

Meletti C., Valensise G. (2004). Zonazione sismogenetica ZS9 – App.2 al Rapporto Conclusivo. In: Gruppo di Lavoro MPS, 2004. Redazione della mappa di pericolosità sismica prevista dall'Ordinanza PCM 3274 del 20 marzo 2003, Rapporto Conclusivo per il Dipartimento della Protezione Civile. In Italian. [The report provides the basic reference for the seismogenic zonation ZS9, which is used to define the probabilistic seismic hazard map of the Italian territory, including an overview of the considered input data].

Panza G.F., Vaccari F., Costa G., Suhadolc P., Fah D. (1996). Seismic input modeling for zoning and microzoning, *Earthquake Spectra* 12 (3), 529-566. [Ground shaking scenarios have been computed both at the regional (Italy, Ethiopia, Bulgaria) and at the local scale (Mexico City, Rome, Naples, Benevento), based on the computation of synthetic seismograms.]

Panza G.F., Cazzaro R., Vaccari F. (1997). Correlation between macroseismic intensities and seismic ground motion parameters, *Annali di Geofisica* 40, 1371-1382. [The authors propose correlation relations between the macroseismic intensity felt in Italy and displacement, velocity, acceleration, design ground acceleration obtained from synthetic seismograms modeling the ground motion generated by past seismicity.]

Panza, G. F., Radulian, M. e Trifu, C. (2000) - Editors "Seismic Hazard in the Circum Pannonian Region", PAGEOPH Topical Volume, Birkhauser Verlag, 280. [The special volume collects several contribution concerning the topics related to the seismic hazard assessment with special attention to the region affected by the intermediate depth Vrancea earthquakes.]

Panza G.F., Romanelli F., Vaccari F. (2001). Seismic wave propagation in laterally heterogeneous inelastic media: theory and applications to the seismic zonation, *Advances in Geophysics 43*, 1-95. [This paper contains a detailed presentation of the Modal Summation method and its application for the modeling of seismic wave propagation in laterally heterogeneous structures in connection with the seismic hazard assessment.]

Panza G.F., Romanelli F., Vaccari F. (2001). Realistic modeling of seismic input in urban areas: a UNESCO-IUGS-IGCP project, *Pure and Applied Geophysics* 158(12), 2389-2406. [This paper represents a contribution to seismic disasters preparedness that requires producing results using the knowledge available now, improving scenarios as new data become available. Ongoing activities, at the times the paper was published, within the UNESCO-IUGS-IGCP project 414 are described.]

Panza G. F., Alvarez L., Aoudia A., Ayadi A., Benhallou H., Benouar D., Chen Yun-Tai, Cioflan C., Ding Zhifeng, El-Sayed A., Garcia J., Garofalo B., Gorshkov A., Gribovszki K., Harbi A., Hatzidimitriou P., Herak M., Kouteva, M., Kuznetzov I., Lokmer I., Maouche S., Marmureanu G., Matova M., Natale M., Nunziata C., Parvez I., Paskaleva I., Pico R., Radulian M., Romanelli, F., Soloviev A., Suhadolc P., Triantafyllidis P., Vaccari F. (2002). Realistic modeling of seismic input for megacities and large urban areas (the UNESCO/IUGS/IGCP project 414), *Episodes* 25 (3),160-184. [Considerations are made on pre-disaster activities (hazard prediction, risk assessment, and hazard mapping) in connection with seismic activity and man-induced vibrations. The definition of realistic seismic input has been obtained from the computation of a wide set of time histories and spectral information, corresponding to possible seismotectonic scenarios for different source and structural models. In the framework of the UNESCO/IUGS/IGCP project 414, ground shaking scenarios have been computed for the following cities: Algiers, Beijing, Bucharest, Cairo, Debrecen, Delhi, Naples, Rome, Russe, Santiago de Cuba, Sofia, Thessaloniki, Zagreb.]

Panza G.F., Romanelli F., Vaccari F., Decanini L., Mollaioli F. (2003). Seismic ground motion modeling and damage earthquake scenarios, a bridge between seismologists and seismic engineers. OECD Workshop on the Relations between Seismological DATA and Seismic Engineering, Istanbul, 16-18 October 2002, NEA/CSNI/R (2003) 18, 241-266. [Advanced seismic hazard indicators, like the earthquake damaging potential, are considered in order to better describe the outcome of simulated ground shaking scenarios, with an approach that can better suit the needs of the seismic engineers in the design of seismo-resistant structures]

Panza G.F., Kouteva, M., (2008). Earth Sciences Contribution to the Sustainable Development of Ground Transportation Systems: Relevant Case Studies in Central Europe. Geodynamics of Central Europe and Transportation. Ed: T. Beer and A. Ismail-Zadeh, Risk Science and Sustainability, pp. 127-148. [The article deals with the general problem of seismic safety of lifelines and transportation systems, paying attention to safety during road design, construction and maintenance and urban safety management schemes.]

Panza G.F., Irikura K., Kouteva M., Peresan A., Wang Z., Saragoni R. (2011). Introduction to the Special Issue on Advanced seismic hazard assessments, *Pure and Applied Geophysics*, 168 (1-2). [Introduction to the special issue on advanced seismic hazard assessment.]

Panza, G.F., Irikura I., Kouteva M., Peresan A., Wang Z., Saragoni R. Eds., (2011) - Topical Volume on “Advanced seismic hazard assessments”. Pure and App. Geophys., Vol. 168. ISBN 978-3- 0348-0039-6 & ISBN: 978-3-0348-0091-4., 752 pp. [The aim of this special issue is to supply multifaceted information on the modern tools for seismic hazard assessment.]

Panza G.F., A. Peresan, A. Magrin, F. Vaccari, R. Sabadini, B. Crippa, A.M. Marotta, R. Splendore, R Barzaghi, A. Borghi, L. Cannizzaro, A. Amodio, S. Zoffoli (2011). "The SISMA prototype system: integrating Geophysical Modeling and Earth Observation for time-dependent seismic hazard assessment". *Natural Hazards*. DOI 10.1007/s11069-011-9981-7. [The paper illustrates an innovative approach to seismic hazard assessment that, based on Earth observation data and geophysical forward modeling, allows for a time-dependent definition of the seismic input. In the proposed system the modeled deformation maps at the national scale complements the space- and time-dependent information provided by real-time monitoring of seismic flow and permits the identification and routine updating of alerted areas. At the local scale, EO data and geophysical modeling permit to indicate whether a specific fault is in a critical state. In this way, a set of neo-deterministic scenarios of ground motion, which refer to the time interval when a strong event is likely to occur within the alerted area, is defined both at national and at local scale.]

Panza G.F., Peresan A., Vaccari F., Romanelli F. e Martelli A. (2011). “Scenario-based time-dependent definition of seismic input: an effective tool for engineering analysis and seismic isolation design” Proceedings del congresso “SEWC2011 - Structural Engineers World Congress (Como, 4-6 April 2011). [The paper discusses the method and advantages of the time-dependent neo-deterministic approach to seismic hazard assessment, where the seismic input is defined by realistic modeling of seismic wave propagation. It presents examples of regional scale scenarios of ground motion at bedrock, including the analysis of source directivity effects. The local scale scenarios, accounting for site effects, are also introduced, considering a selected site in the city of Trieste (North-Eastern Italy)].

Panza, G.F., La Mura, C., Peresan, A., Romanelli, F., & Vaccari, F. (2012). Seismic Hazard Scenarios as Preventive Tools for a Disaster Resilient Society. In R. Dmowska (Ed.), Advances in Geophysics. Elsevier, London, 93–165. [This paper contains the recent advances in seismic wave modeling by mean of the Modal Summation method and presents the use of a scenario-based approach, that permits to integrate the available information provided by the most updated seismological, geological, geophysical, and geotechnical databases for the site of interest to provide reliable and robust background for the development of a deterministic design basis for cultural heritage and civil infrastructures in general. This paper is the newest milestone in Neo-Deterministic Seismic Hazard assessment.]

Parvez I.A., Vaccari F. and Panza G. F. (2003). A deterministic seismic hazard map of India and adjacent areas, *Geophysical Journal International* 155(2), 489-508. [A seismic hazard map of the territory of India and adjacent areas has been prepared using a deterministic approach based on the computation of synthetic seismograms complete with all main phases.]

Parvez I.A., Romanelli F., Panza G. F. (2010) Long period ground motion at bedrock level in Delhi city from Himalayan earthquake scenarios, *Pure and Applied Geophysics* doi: 10.1007/s00024-010-0162-5 [In this paper a sound description of the seismic ground motion due to an earthquake in the range of distances of 250–300 km, is given simulating the ground motion, at bedrock level, in Delhi city, for an earthquake scenario corresponding to a source of Mw = 8.0 located in the central seismic gap of Himalayas, using modeling techniques developed from physics of the seismic source generation and propagation processes].

Paskaleva I., Dimova S., Panza G. F., Vaccari F. (2007). An Earthquake scenario for the microzonation of Sofia and the vulnerability of structures designed by use of the Eurocodes, *Soil Dynamics and Earthquake Engineering*, 27, 1028-1041. [The study of the site effects and the microzonation of a part of the metropolitan Sofia, based on the modeling of seismic ground motion along three cross-sections are performed, for M=7 scenario earthquakes.]

Paskaleva I., Kouteva M., Vaccari F., Panza G.F. (2010). Some Contributions of the Neo-Deterministic Seismic Hazard Assessment Aproach to the Earthquake Risk Assessment for the City of Sofia, *Pure and Applied Geophysics*, doi: 10.1007/s00024-010-0127-8. [This paper describes the outcome of seismic hazard and seismic risk estimates performed for the city of Sofia, Romania]

Peresan A., Kossobokov V.G., Romashkova L.L., Panza G.F. (2005). Intermediate-term middle-range earthquake predictions in Italy: a review, *Earth Science Reviews* 69 (1-2), 97-132. [The paper includes a comprehensive overview of formally defined methods for intermediate-term middle-range earthquake predictions for the Italian territory. Specifically, it provides detailed information about CN and M8 algorithms, ranging from their theoretical basis to the considered input data. The paper provides the basis for the real-time earthquake prediction experiment ongoing for the Italian territory since July 2003.]

Peresan A., Zuccolo E., Vaccari F. and Panza G.F. (2009). Neo-Deterministic Seismic Hazard Scenarios For North-Eastern Italy, *Bollettino Della Società Geologica Italiana* 128 (1), 229-238. [This paper describes the neo-deterministic scenarios of ground motion defined for North-Eastern Italy, based on the information provided by CN and M8S algorithms, as well as by the pattern recognition of earthquake prone areas. An example of local scale scenario, including site effects, is provided for the city of Trieste.]

Peresan A., Zuccolo E., Vaccari F., Gorshkov A., Panza G.F. (2010). Neo-deterministic seismic hazard and pattern recognition techniques: time dependent scenarios for North-Eastern Italy, *Pure and Applied Geophysics*, 168 (3-4). DOI 10.1007/s00024-010-0166-1. [The paper illustrates how different pattern recognition techniques can contribute reducing the space and time uncertainty of impending strong earthquakes. These techniques allow for a formalized, systematic and testable analysis of seismicity changes and of morphostructural features. The paper describes the procedure which allows us to compute the time-dependent ground shaking scenarios at regional and local scale, accounting for the information provided by pattern-recognition].

Peresan A., Kouteva M., Dmowska R., Roubhan B. (2010). Towards validation of SHA: lessons learnt from recent earthquakes. Panel Discussion. Panelists: A. Lerner-Lam, V. Kossobokov, Z. Wang, Z. Wu. In: Advanced Conference on “Seismic risk mitigation and sustainable development”, ICTP. Trieste, Italy. http://cdsagenda5.ictp.trieste.it/askArchive.php?base=agenda&categ=a09145&id=a09145s3t12/Panel_discussion. [Summary report of the Panel Discussion, evidencing the need for formal testing and validation of seismic hazard estimates].

Romanelli F., Panza G.F., Vaccari F. (2004). Realistic Modeling of the Effects of Asynchronous motion at the Base of Bridge Piers, *Journal of Seismology and Earthquake Engineering* 6(2), 19-28. [In this paper a complete synthetic accelerogram dataset is computed by using as input a set of parameters that describes the geological structure and seismotectonic setting of the area near Vienna (Austria) where the Warth bridge is placed. The results show that lateral heterogeneities can produce strong spatial variations in the ground motion even at small incremental distances. In absolute terms, the differential motion amplitude is comparable with the input motion amplitude when displacement, velocity and acceleration domains are considered.]

Romanelli F., Peresan A., Vaccari F., Panza G.F., (2010). Scenario based earthquake hazard assessment. Proceedings: Urban Habitat Constructions under Catastrophic Events, Mazzolani (Ed), © 2010 Taylor & Francis Group, London, p.p. 105-110. [The paper discusses the advantages of the neo-deterministic, NDSHA, approach to seismic hazard assessment, which is based on the possibility to compute synthetic seismograms by the modal summation technique, particularly when dealing with historical and strategic buildings, when it is necessary to consider very long return period. The realistic modeling of the seismic input, taking in account the source and site effects, combined with the evaluation of the seismic response of buildings provides an effective approach to the assessment of seismic risk].

Stein S. (2010) Disaster Deferred: How New Science Is Changing our View of Earthquake Hazards in the Midwest. Columbia University Press. The book revisits the 1811-12 series of large earthquakes in the New Madrid seismic zone. The author clearly explains the techniques seismologists use to study Midwestern quakes and shows how limited scientific knowledge has exaggerated these hazards. Stein shows how new geological ideas and data, including those from the Global Positioning System, provide a much less frightening hazard estimate].

Stein S., Geller R., Liu M. (2011). Bad assumptions or bad luck: why earthquake hazard maps need objective testing, Seismological Research Letters 82, 5. [This opinion paper evidences the need for a systematic and objective validation of developed hazard maps. The motivation for a formal testing of existing seismic hazard maps is provided by the several fatal failures of PSHA maps, particularly in occasion of the Tohoku 2011 and Haiti 2010 earthquakes. Only by understanding whether such failures are due methodological limits it is possible to improve the future hazard assessments.]

Stirling M., Petersen M. (2006). Comparison of the historical record of earthquake hazard with seismic-hazard models for New Zealand and the continental United States, *Bulletin of the Seimological Society of America* 96, 1978–1994. [The paper includes examples evidencing inconsistencies between historical records of seismic hazards and PSHA estimates].

Vaccari F., Romanelli F., Panza, G.F. (2005). Detailed modeling of strong ground motion in Trieste, *Geologia Tecnica and Ambientale* 2, 7–40. [Using the specific knowledge about geology and geotechnical properties described in the cartographic material available for the Trieste area, ground motion scenarios have been computed along three profiles in the city, varying the source position and magnitude. The three-component synthetic seismograms, computed, with a broad band content and in laterally inelastic models in the domains of displacement, velocity and accelerations, have been processed to estimate the site effects and to extract some parameters significant from the engineering point of view.]

Vaccari F., Peresan A., Zuccolo E., Romanelli F., Panza G.F., Marson C., Fiorotto V. (2009). Neo-deterministic seismic hazard scenarios: Application to the engineering analysis of historical buildings. In: Protection of Historical Buildings PROHITECH, vol 2, Ed: F.M. Mazzolani, CRC Press, Taylor and Francis Group, London, 1559-1564. [The paper illustrates the integrated neo-deterministic approach to seismic hazard assessment and its application to the engineering analysis of an historical building located in the city of Trieste (Italy).]

Wang, Z. (2011). Seismic Hazard Assessment: Issues and Alternatives. *Pure and Applied* Geophysics 168, 11-25. [The article analyzes the main shortcomings of traditional PSHA and DSHA approaches to seismic hazard assessment, starting from the basic concepts and focusing on practical application to the New Madrid (USA) zone. It favors using DSHA particularly when available information is not sufficient to reliably estimate earthquake recurrence.].

Wyss M., Nekrasova A., Kossobokov V. (2012). Errors in expected human losses due to incorrect seimic hazard estimates, *Natural Hazards*, DOI 10.1007/s11069-012-0125-5. [The paper shows that the numbers of fatalities in recent disastrous earthquakes were underestimated by the global seismic hazard maps, developed in the framework of GSHAP, by approximately two to three orders of magnitude. This observation suggests that the maps based on the standard PSHA method do not allow a reliable estimate of the risk to which the population is exposed due to large earthquakes.]

Zuccolo E., Vaccari F., Peresan A., Dusi A., Martelli A., Panza, G.F. (2008). Neo-deterministic definition of seismic input for residential seismically isolated buildings, *Engineering Geology*, doi:10.1016/j.enggeo.2008.04.006. [This paper deals with the neo-deterministic definition of the seismic input in the municipality of Nimis (Italy), aimed at the design of residential seismically isolated buildings. The seismic input is defined by the computation of realistic synthetic seismograms considering different levels of detail for the earthquake source.]

Zuccolo E., Vaccari F., Peresan A., Panza G.F. (2010). Neo-deterministic (NDSHA) and probabilistic seismic hazard (PSHA) assessments: a comparison over the Italian territory. *Pure and Applied Geophysics* 168 (1-2). DOI 10.1007/s00024-010-0151-8. [Estimates of seismic hazard obtained using the neo-deterministic approach (NDSHA) and the probabilistic approach (PSHA) are compared for the Italian territory. The differences suggest the adoption of the flexible, robust and physically sound NDSHA approach to overcome the proven shortcomings of PSHA.]

Biographical Sketches

Giuliano Francesco Panza is Full Professor of Seismology at the University of Trieste, Italy. The scientific activity of Giuliano F. Panza is marked by the broad multidisciplinary nature of the problems considered: integrated analysis of structure and dynamics of the lithosphere-asthenosphere system; integrated approach to modeling of the seismic waves in the near-field and far-field; earthquake-prone lineaments and premonitory seismicity patterns. A wide range of sophisticated theoretical methods and models was developed in these studies: the advanced methodology for seismogram synthesis; inversion; pattern recognition. He received, in 2006 the Beno Gutenberg medal by the European Union of Geosciences for outstanding contributions to Seismology, is dedicated and successful leader of several international projects. He has been coordinating, for the CEI University network, Seminars and stages on "Earth and Environmental Physics: Geodynamical Model of Central Europe for Safe Development of Ground Transportation Systems", at the Department of Earth Sciences of the University of Trieste and at The Abdus Salam International Center for Theoretical Physics. With the Seismology Group of Dipartimento di Matematica e Geoscienze dell'Universita' di Trieste and with the SAND group of the Abdus Salam International Centre for Theoretical Physics (ICTP), he supervises, has developed a very powerful, essentially analytical tool for the computation of realistic synthetic seismograms in three-dimensional inelastic media, that is at the base of his methodology for the neodeterministic assessment of seismic hazard, currently applied in several large urban settlements and megacities. Recently, in cooperation with ASI, the Italian space agency, the simultaneous use of the neodeterministic approach for the ground motion estimation, of the monitoring of the space-time variation of hazard, and of the Earth observation data, lead to the construction of time-dependent hazard models based on strong geophysical ground, that have generated particular interest at Civil Defense level.

ACADEMIC EXPERIENCE Laurea in Fisica University of Bologna (Italy) 1967 Post Doc University of Bologna (Italy) 1968-1970 Visiting post Doc University of Uppsala (Sweden) 1969 Assistant Professor University of Bari (Italy) 1970-1980 Post Doc Fellow University of California Los Angeles (USA) 1971/1974 Associate Professor University of Bari (Italy) 1973-1980 Associate Professor University della Calabria Cosenza (Italy) 1975-1977 Visiting Professor Polytechnic of Zurich (Switzerland) 1977 Prof. Geophysical Prospecting University of Trieste (Italy) 1980- 1988 Professor of Seismology University of Trieste (Italy) 1988- Lecturer Diploma Course in Earth System Physics at ICTP, 2006-

HONORS (before 2003) Prize Ettore Cardani, Università di Torino 1968; Fulbright Fellow 1970; Premio Linceo Accademia Nazionale dei Lincei Roma 1990; Beno Gutenberg medal from the European Geophysical Society, for outstanding contributions to Seismology, 2000; Doctor Honoris Causa in Physics from University of Bucharest - Romania, 2002. SERVICES (before 2003) Council member: European Geophysical Society 1982-1986; European Union of Geosciences 1983-1994; Vice President European Union of Geosciences 1991-1994 Chairman UNESCO-IUGS-IGCP project “Realistic modeling of seismic input for Megacities and large urban areas” 1997-2001. Project leader NATO SfP project “Impact of Vrancea earthquakes on the security of Bucharest and other adjacent urban areas” 2000-2004
PUBLICATIONS Author and coauthor of more than 480 scientific papers in refereed journals; Co-Author, Editor and Co-editor of 12 books. h-index (2011) 26.
FIELDS OF EXPERTISE Elastic wave propagation, interior structure of the earth, plate tectonics, earthquake prediction, active tectonics, seismic microzonation of urban settlements and seismic hazard, volcano seismology.
REFERENCE LISTINGS Who's Who in the World; Who's Who in Italy; Who's Who in Science and Engineering; Dictionary of International Biography

Antonella Peresan is a researcher at ICTP-SAND Group and Department of Mathematics and Geosciences, University of Trieste (Italy) since 1997. She earned her academic degrees at University of Trieste, Italy: MSc Physics, 1996; PhD in Geophysics of the Lithosphere and Geodynamics, University of Trieste, 2001.
Guest Editor of the PAGEOPH Topical Volume on “Advanced seismic hazard assessments” and Director of the Advanced Conference on “Seismic risk mitigation and sustainable development”, ICTP, Trieste (May 2010). Organized and participated in several seismological courses and workshops. Further she has been:

- Lecturer of the “Environmental Data Analysis” Course, within the framework of the ICTP pre-PhD Diploma in Earth System Physics, since 2006.
- Lecturer in the framework of various courses in Seismology and Seismic and Volcanic Hazard at the University of Trieste, since 1998.

Other Appointments:

- Research fellow. Department of Earth Sciences, University of Trieste (1997).
- Visiting scientist at the Department of Astronomy and Meteorology - Geophysics University of Barcelona, Spain (2000)
- Visiting scientist at the Institute of Geophysics, Vietnam National Centre for Natural Science and Technology. Hanoi, Vietnam (2002)
- Visiting scientist at the Institut de Ciències de la Terra “Jaume Almera”, Barcelona, Spain (2002 and 2003)
- Member of the IASPEI Commission on "Earthquake Sources - Modeling and Monitoring for Prediction"
- Convener at AGU, ESC and AES; invited lecturer in several international Conferences, Workshops and Schools.

Main fields of Research and Scientific contribution: Seismic hazard and risk; non-linear dynamics and earthquake prediction.

- Development of an integrated procedure for the time dependent neo-deterministic seismic hazard assessment. Application of seismic input for engineering analysis, based on the application of pattern-recognition methodologies and ground shaking modeling
- Analysis, integration and updating of earthquake catalogs for seismic hazard assessment and analysis of seismicity patterns in several regions of the world.
- Analysis of seismicity and its evolution and correlation at various space and time scales, including studies of temporal variations of volcano seismicity. Application and evaluation of intermediate-term earthquake prediction algorithms, using data on past and present seismicity, as well as synthetic catalogs.
- Application and validation of intermediate-term earthquake prediction algorithms.
- Analysis of the possible correlations existing between seismic energy release and secular and seasonal climatic variations

- Numerical simulation of seismicity in the block structure model of lithosphere dynamics.

Cristina La Mura is a Post-Doc researcher in Seismology at the Department of Mathematics and Geosciences, University of Trieste, Italy, since 2009. She earned the Master Degree in Physics at University of Napoli FEDERICO II on 2003 and the Ph.D. in Geophysics of Lithosphere and Geodynamics at University of Trieste, under the supervision of Prof. Giuliano F. Panza. She attended the Master Program in Mechanical Engineering at the Department of Engineering Science and Mechanics at Virginia Polytechnic Institute and SU, VA, US, on 2001/2004 with a good standing grade (3.8/4.0). Her research activity, since 2006, is devoted to the modeling of seismic wavefield in three-dimensional inelastic media. Since 2004 she is member of the Gruppo Nazionale di Fisica Matematica (Italian National Group of Mathematical Physics). She earned several grants issued by Department of Engineering Science and Mechanics, Virginia Polytechnic Institute and SU, VA, US; INOGS - Istituto Nazionale di Oceanografia e Geofisica Sperimentale, Trieste, Italy; CISM – International Centre of Mechanical Science, Udine, Italy; The Abdus Salam International Centre for Theoretical Physics, Trieste, Italy.
REFERENCE LISTINGS Who's Who in the World 2011; Great Minds of 21st Century.