A user-friendly gui software for site-specific and multisite seismic hazard assessment

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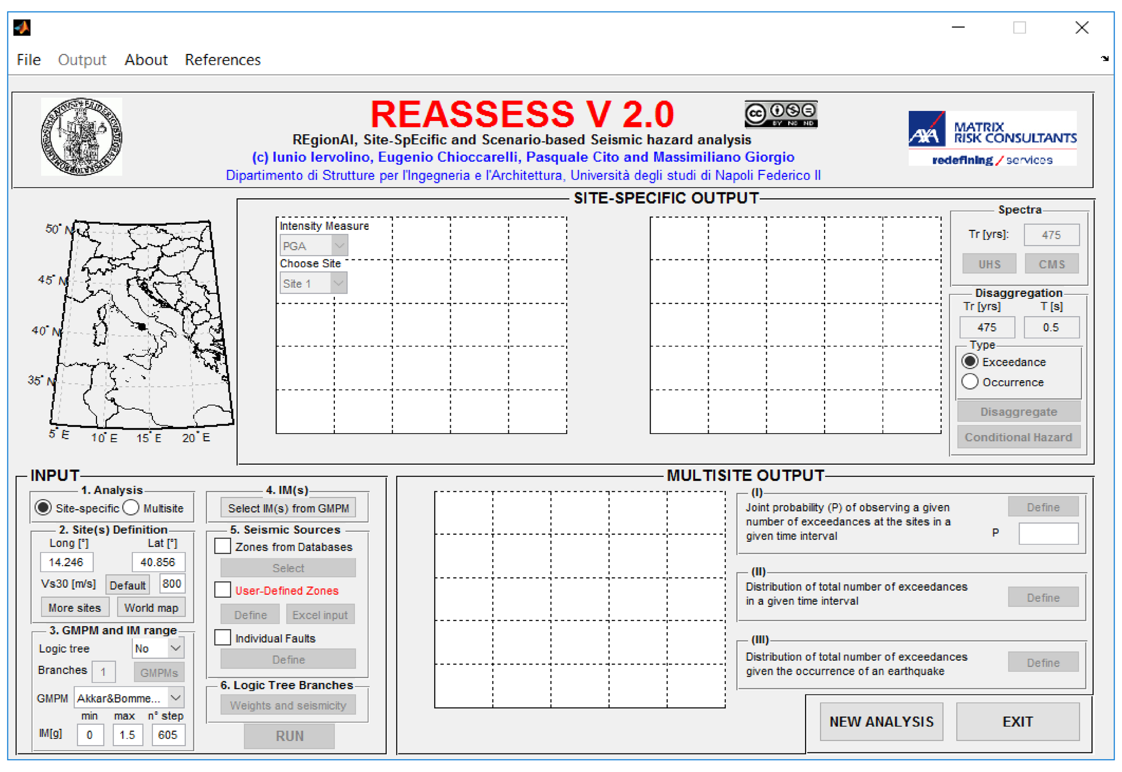


INTRODUCTION

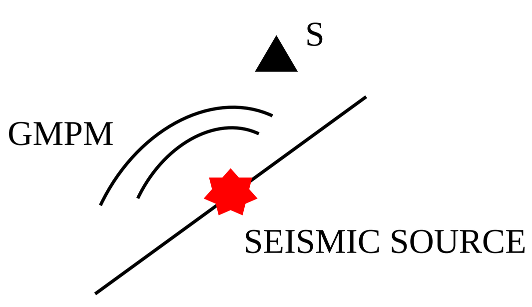
Probabilistic seismic hazard analysis (PSHA) is a consolidated procedure that provides the mean annual frequency of exceeding various levels of seismic intensity measure (*IM*) at a site of interest. Such a procedure usually profits of the homogeneous Poisson process (HPP), used to model the stochastic process of earthquake occurrence. Consequently, the process of occurrence of earthquakes causing the *IM* exceedance at the site is also a (filtered) HPP.

In fact, there are cases in which the probability of exceedances of IM thresholds at more than one site has to be evaluated (e.g., risk assessment of spatially distributed systems). The key issue, in these cases, is to account for the existence of stochastic dependence among the site-specific processes, each counting the exceedances of IM at single site. Such a dependency implies that, in the same hypothesis of HPP of earthquakes occurrence on the source, the process counting the total number of exceedance at the sites is, in general, not a Poisson process.

A stand-alone software for the probabilistic assessment of seismic hazard was developed. The name of the software is REgionAl, Site-SpEcific and Scenario-based Seismic hazard analysis (REASSESS). Coded in Matlab®, the software is able to provide results of both multisite (regional) and site-specific PSHA through two modules integrated in a user-friendly graphic interface. The two analyses shares the same input which are described below.

The REASSESS Beta version is now freely available for testing and research purposes at http://wpage.unina.it/iuniervo/.

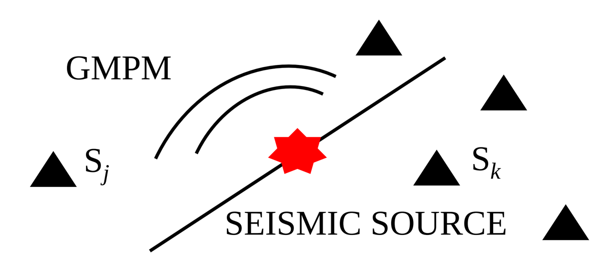
1. ANALYSIS AND SITE(S) DEFINITION



In the case of site-specific analysis, the software performs probabilistic seismic hazard analysis in its classical formulation for one site or at multiple sites separately.

Site-specific — **Site-specific or multisite PSHA?** — Multisite

In the case of multisite analysis (e.g. Giorgio and Iervolino, 2016), the software provides the joint probability of exceedance of a vector of ground motion *IMs* thresholds at multiple sites. The equation is written in the illustrative case of two sites.



$$P\left[\left(IM_k > im_k^*\right)\cap\left(IM_j > im_j^*\right)\right] = \int_M\int_X\int_Y P\left[\left(IM_k > im_k^*\right)\cap\left(IM_j > im_j^*\right) \mid m,x,y,\theta\right]\cdot f_{M,X,Y}(m,x,y)\cdot dm\cdot dx\cdot dy$$

Mean annual rate of seismic events exceeding an *IM* threshold, *im**, at a site

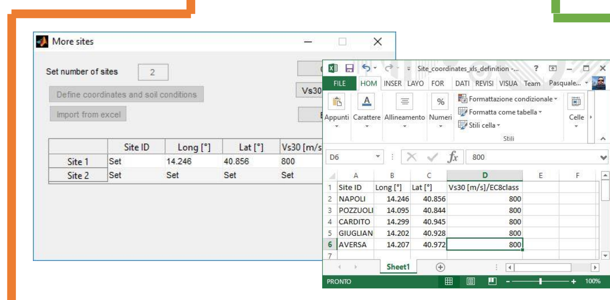
Probability of *im** exceedance given event magnitude, *m*, event location, {*x*,*y*} and additional parameters, θ, (ground motion prediction model, GMPM)

$$\lambda_{IM>im^*} = \nu\cdot\int_M\int_X\int_Y P\left[IM > im^* \mid m,x,y,\theta\right]\cdot f_{M,X,Y}(m,x,y)\cdot dm\cdot dx\cdot dy$$

Mean annual rate of earthquake occurrence on the source

Joint probability density function of *M* and {*X*, *Y*}

Definition of coordinates and soil classes: the coordinates and soil classes of the sites can be defined through the GUI or Excel sheets.



The software accounts for the stochastic dependence among the site-specific processes counting the number of exceedances at single sites, which is related to the spatial correlation of *IMs* at the sites.

$$\log IM_{j,i} = E\left(\log IM \mid m_i, \{x,y\}_i, \theta\right) + \eta_i + \varepsilon_{j,i}$$

Logarithm of *IM* at site *j*, due to earthquake *i*; Median value of log of *IM*; Interevent residual; Intraevent residual

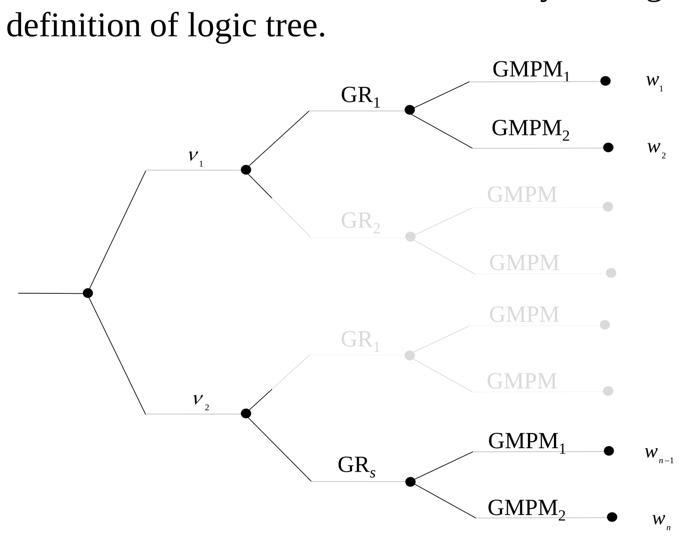
The logs of *IMs* at the sites form a Gaussian random field with covariance matrix:

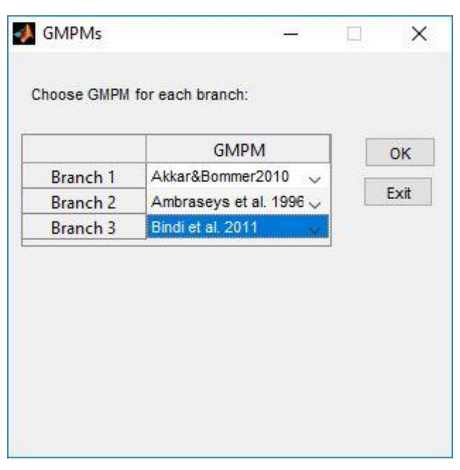
$$\Sigma = \sigma_{inter}^2 \cdot \begin{bmatrix} 1 & 1 & \cdots & 1 \\ 1 & 1 & \cdots & 1 \\ \vdots & \vdots & \ddots & \vdots \\ 1 & 1 & \cdots & 1 \end{bmatrix} + \sigma_{intra}^2 \cdot \begin{bmatrix} 1 & \rho_{1,2} & \cdots & \rho_{1,s} \\ \rho_{2,1} & 1 & \cdots & \rho_{2,s} \\ \vdots & \vdots & \ddots & \vdots \\ \rho_{s,1} & \rho_{s,2} & \cdots & 1 \end{bmatrix}$$

correlation coefficient between intraevent residuals at sites *1* and *s*.

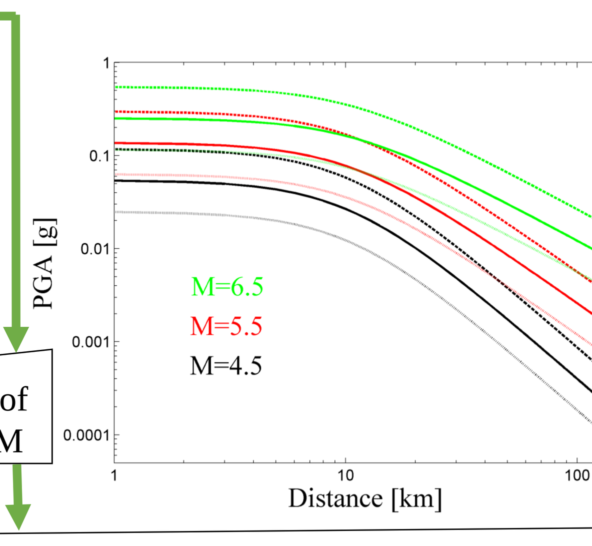
2. GMPM AND IM RANGE

The site-specific module of REASSESS enables the user to account for model uncertainty through the definition of logic tree.





Logic tree? — YES: Definition of number of branches → Selection of the GMPM for each branch; NO: Selection of the GMPM



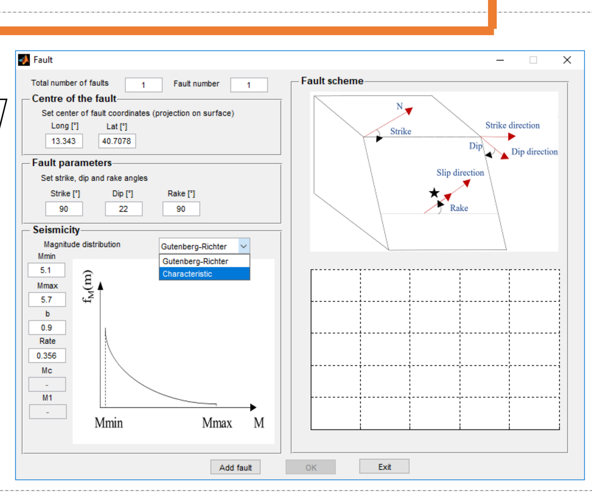
A database of alternative GMPM referring to different geographic areas is embedded. In particular, the following models are included:
- Ambraseys et al. (1996), based on European dataset;
- Akkar and Bommer (2010), derived from data from Southern Europe, North Africa, and active areas of the Middle East;
- Bindi et al. (2011), derived from Italian data;
- Cauzzi et al. (2015), based on worldwide dataset.

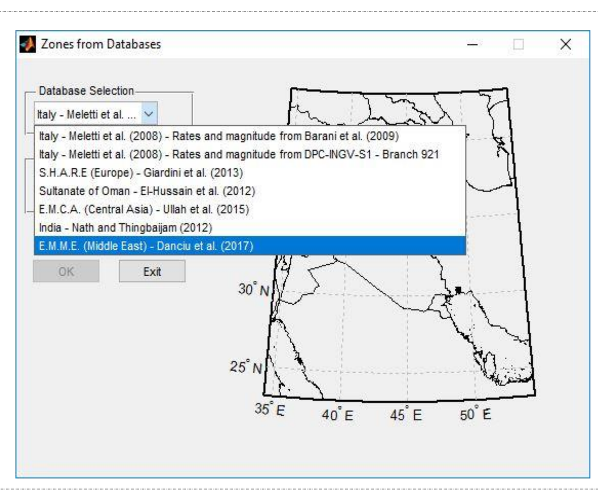
Assigning minimum and maximum IMs and number of steps: according to the minimum and maximum values, the software indicates the minimum number of steps of IM such that the elements of the vector are spaced by a factor at most equal to 0.05g

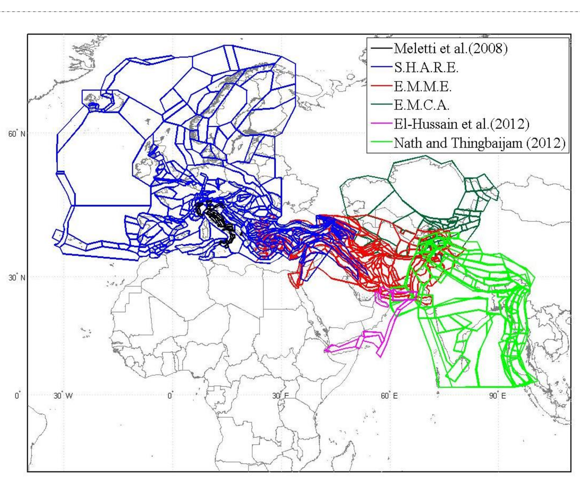
Select IM(s) from GMPM

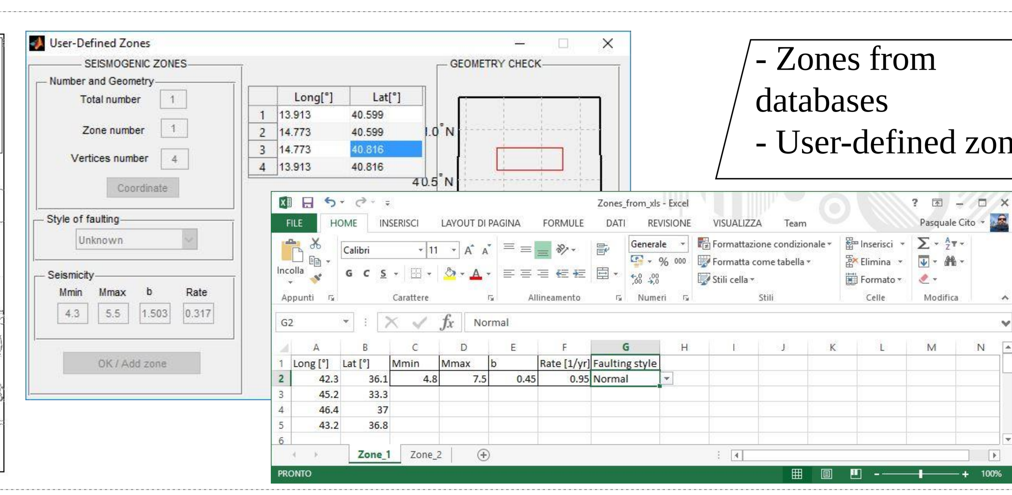
3. SEISMIC SOURCES

- Zones from databases
- User-defined zones
- Individual faults



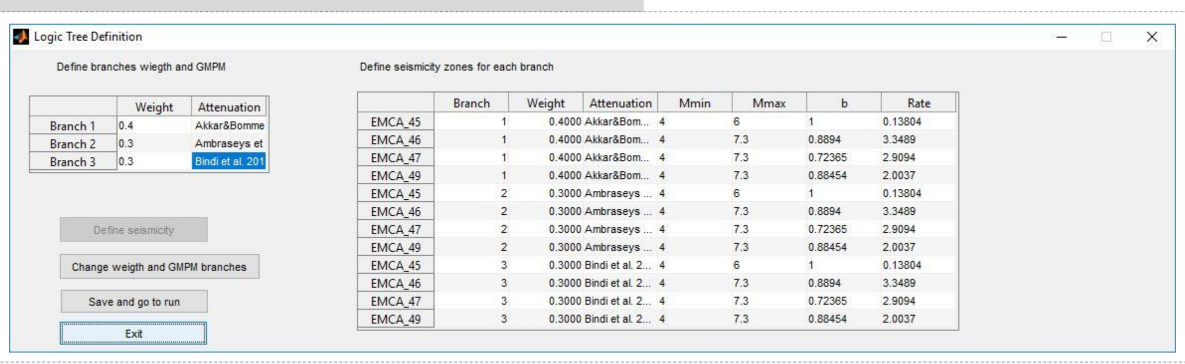






- Zones from databases
- User-defined zones

4. LOGIC TREE BRANCHES



Weights and seismicity definition: the branches of the logic tree can account for different GMPMs, magnitude distributions and annual rates of earthquakes occurrence. The number and geometry of the seismic sources have to be keep constant.

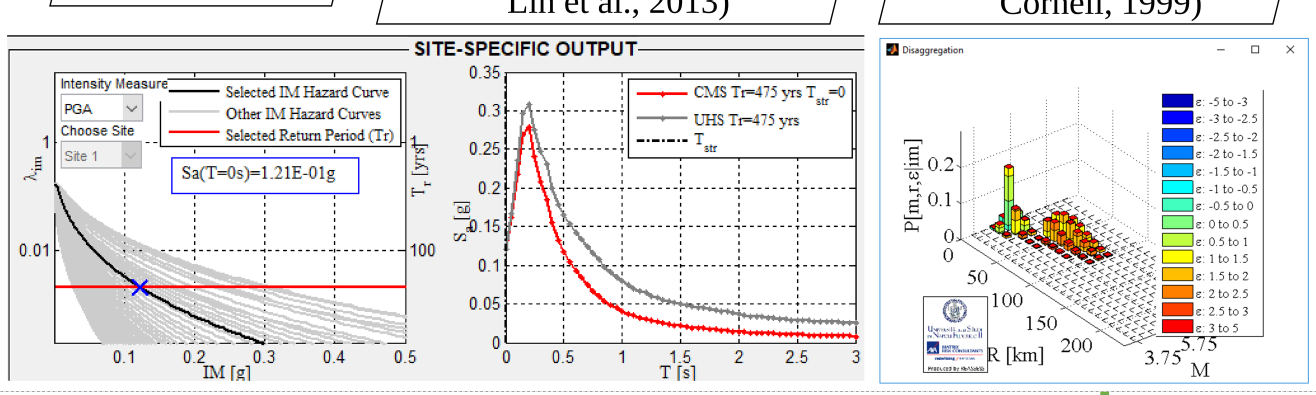
Select IM(s) from GMPM

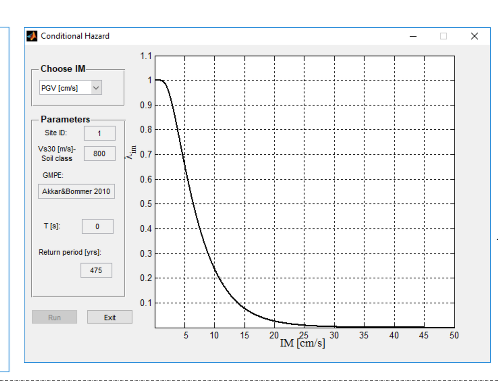
5. OUTPUTS OF THE ANALYSIS

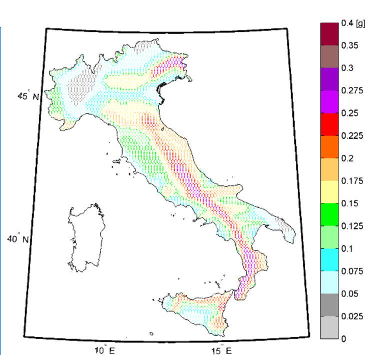
RUN

Site-specific

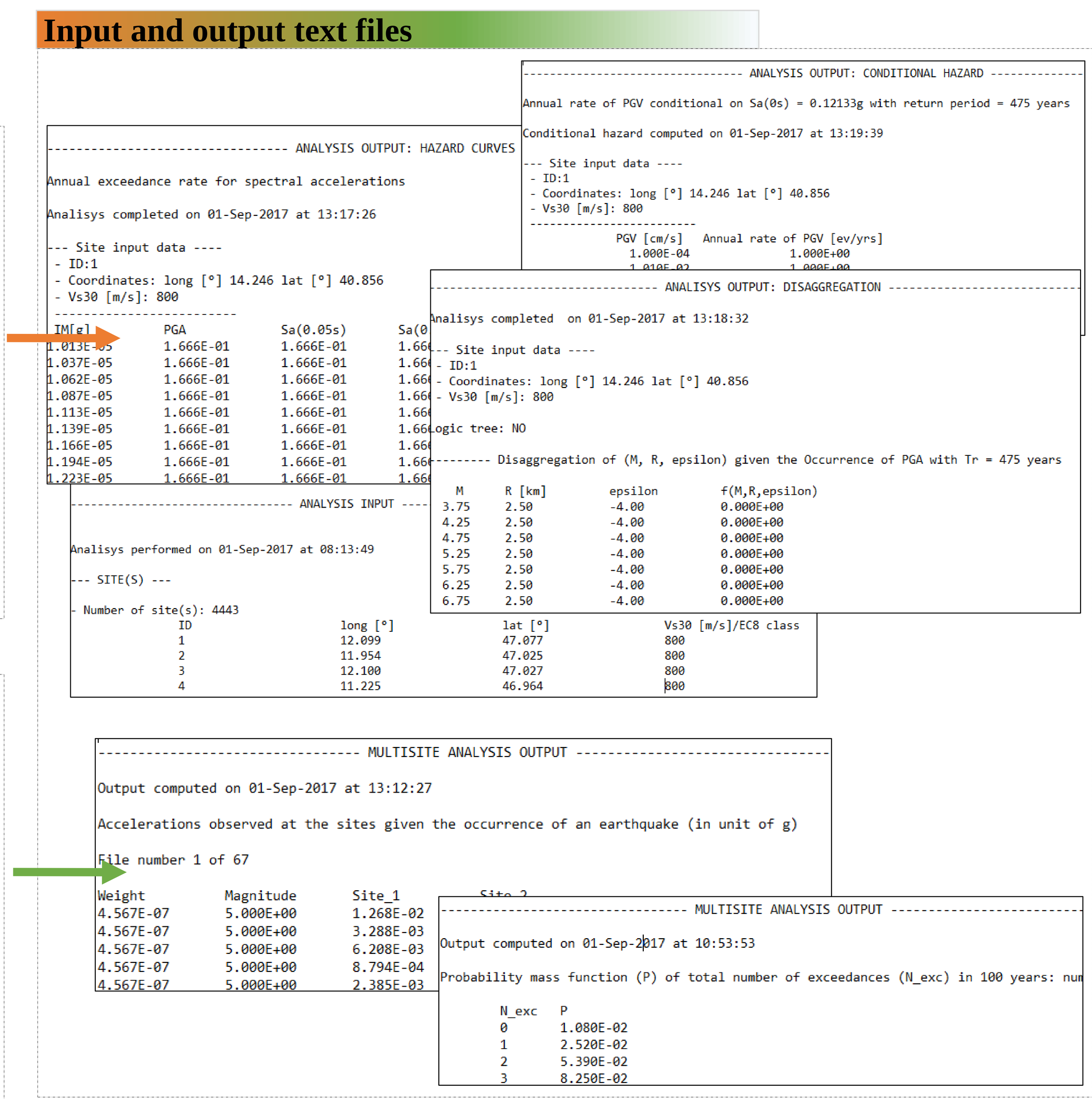
Hazard curves | Uniform hazard spectrum and conditional mean spectrum (e.g. Lin et al., 2013) | Disaggregation of seismic hazard (Bazzurro and Cornell, 1999) | Conditional hazard (Iervolino et al., 2010) | Seismic hazard map



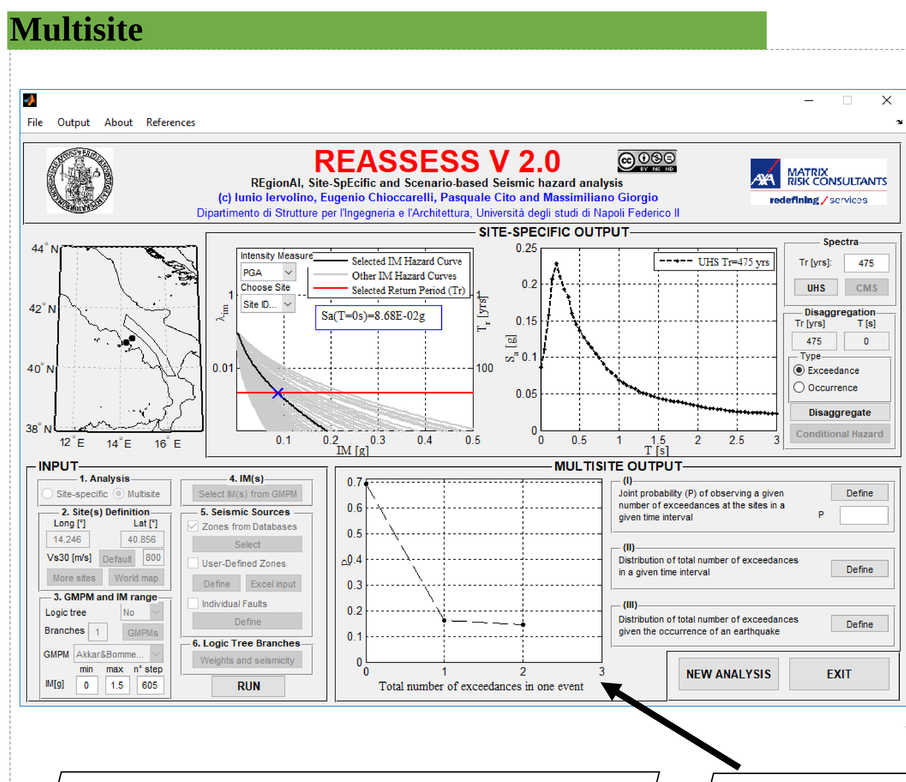




Input and output text files

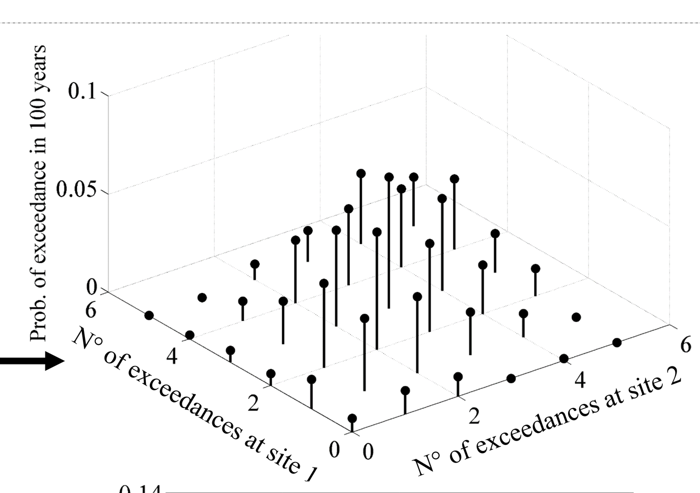


Multisite

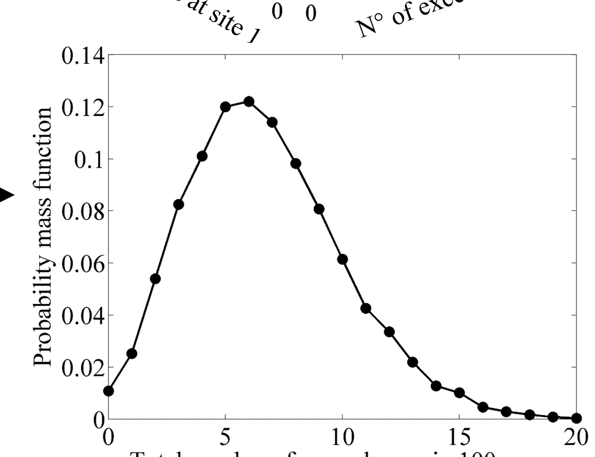


Dataset of IMs at the sites in a given time interval

(I) Joint probability of observing a given number of exceedances at the sites in a given time interval



(II) Distribution of the total number of exceedances at the sites in a given time interval



Dataset of IMs at the sites conditional on the occurrence of an earthquake

(III) Distribution of the total number of exceedances at the sites given the occurrence of an earthquake

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