GITEC PROJECT: AN INTERNATIONAL BENCHMARK TO IMPROVE GENERALIZED SPECTRAL INVERSION TECHNIQUES

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Abstract. Generalized inversion techniques (GIT) have become popular techniques for determining ground motion parameters (source, attenuation, and site). Indeed, it has been shown that GIT can potentially provide reliable site response estimates, even at sites where few recordings are available, as well as valuable information about source features (magnitudes, corner frequencies, stress drops…) and regional attenuation characteristics. Following the recent advances using GIT, that involve both the "non-parametric" (linear) and "parametric" (non-linear) inversion schemes, some questions become interesting: depending on the final interest of performing a GIT, what could be the optimal dataset configuration? What is the impact of the different assumptions and implementations considered on the reliability of the results? In view to address these questions, the GITEC (Generalized Inversion TEchniques Comparisons) project will be launched considering different generalized spectral inversion methods and dataset configurations. This project is open to all volunteer teams. Real datasets from Japan, central Italy and France will be provided for the inversions. In addition, few synthetic datasets will be also provided to ensure the control on the inversions. The work should lead to better understand how to use the GIT schemes in different applications. At end of this project, a website repository will include the used datasets and the results obtained by the different approaches, and can hence be used for the latter comparisons. A next step could be the development of an open GIT code which combines the approaches that can be envisaged in the GITEC project.

Key Words: Seismic Hazard, Generalized inversion, Benchmark, GITEC Project.

1. INTRODUCTION

Seismic waves initiate from faults and ruptures in the Earth crust and propagate from its source, through different paths, to reach the surface affecting building structures and other installations above or below Earth surface. The observed strong ground motions on the surface are deeply affected by several factors such as the rupture nature (source effects), the way the waves propagate to reach a specific site (path effects) and the amplification of motion amplitudes that occurs while propagating through certain geological structures to reach the surface (site effects). After several destructive earthquakes through the years (Mexico 1985, Kobe 1995, Tōhoku 2011), accurate evaluation of strong ground motion factors have become a necessity and a crucial step for quantitative predictions of future strong earthquakes for special structures such as high rise buildings and nuclear installations.

In the aim to evaluate ground motion key factors, generalized inversion techniques (GIT), which use Fourier spectra of recorded data, serve a beneficial tool. This technique was first introduced by [1] and is based on the assumption of separation of the Fourier spectrum of a recorded seismic signal into source, path and site factors. Generalized inversions are techniques that became widely used to determine the frequency-dependent attenuation characteristics [2,3] in addition to the source spectra and the main source parameters. GIT also offers the advantage to determine site responses as an alternative method to the commonly used Standard Spectral Ratios method or SSR [4] and the Horizontal-to-Vertical Spectral ratio or HVSR [5,6,2]. There are generally two main ways to perform generalized inversions: first we have the non-parametric approach [7] which describes a linear model with some constraints and then comes the highly non-linear parametric approach which requires a priori functional forms for the different terms [8–10]. As mentioned, this GIT approach has become widely spread and many researchers through the years have developed different schemes with different assumptions and constraints. Hence, a great interest in comparing the different GIT approaches and methods was developed and there was a look to create an international benchmark to test the different approaches and to try drawing out the best ways and aspects of using such inversion techniques.

For these objectives, the GITEC project (Generalized Inversion TEchniques Comparisons) was established and planned to start in May 2018. This project will be based on the idea of performing several inversions with a single GIT scheme but on different datasets as well as inverting the same dataset following different models and scheme conditions. The final objective of such a project will be to highlight the pros and cons of each GIT approach and to define the best ways to perform it. The GITEC project will be launched by sharing datasets and discussions and then will end up in at least two workshops for presenting the results and drawing out the logical conclusions. This project will have a future perspective of developing a new GIT scheme concentrating all the recent efforts and benefits from wide experiences.

2. Project definition:

The main scope of the GITEC is to compare and improve the knowledges on the performance of different generalized spectral inversion methods and hypotheses used for estimating ground motion parameters (i.e. source, attenuation and site) considering different dataset configurations. An expected outcome of the work is to improve the understanding and the use of (GIT) in different applications.

GITs methods have become more and more popular techniques for determining ground motion parameters (source, attenuation, site), especially in low-to-moderate seismicity regions. The generalized inversion scheme initiates from the principle of separation of the amplitude spectrum of the ground motion as follows:

$$FAS_{ij}(f)=E_j(f).P_{ij}(f).S_i(f) \quad (1)$$

where FAS_{ij} is the Fourier amplitude spectrum at a given site for a given event, $E_j(f)$ is the source function for a given event j, $P_{ij}(f)$ is the path term upon an event j at a given site i, and $S_i(f)$is the site response term for site i.

Main GIT approaches are based on either, linear non-parametric inversion schemes, or non-linear parametric inversion schemes. Within these two approaches different computational hypotheses have been made by different researchers in these recent years.

Through scientific discussions and exchanges and performing GIT computations of different methods on common datasets (real and synthetic) within the framework of a "methodological benchmark", several goals would be addressed:

- First of all, due to the presence of different implementations of the inversion schemes (i.e. parametric and non-parametric) it is important to investigate for the pros and cons of each approach depending on the dataset characteristics considered (dataset geometry, configuration, etc…).
- Exploration of dependence of the results which may be greatly affected by reference conditions or strategies followed to solve trade-offs.
- The use of synthetic data will provide a useful evaluation of the predictive power of each inversion scheme.

Several groups will be working on the same dataset but following different methods and strategies, hence an additional objective can be addressed which is the estimation of the uncertainties on the predicted parameters between and within final models, in particular for source, attenuation, and site terms. GITEC project targets were not finalized and are open for discussions, so they can be refined by the participating groups adding specific targets.

GITEC project will pass through several phases (***FIG. 1***). In a first phase comes the invitation of researchers to participate and the following exchanges to receive suggestions and comments. The second phase holds the initialization of the project work by exchanging the datasets and other information for this project. Computations then are launched in a third phase of this project. After computations are finished, it is planned to have a first workshop to exchange discussions about the results and to decide about whether the final goals or objectives are reached or not.

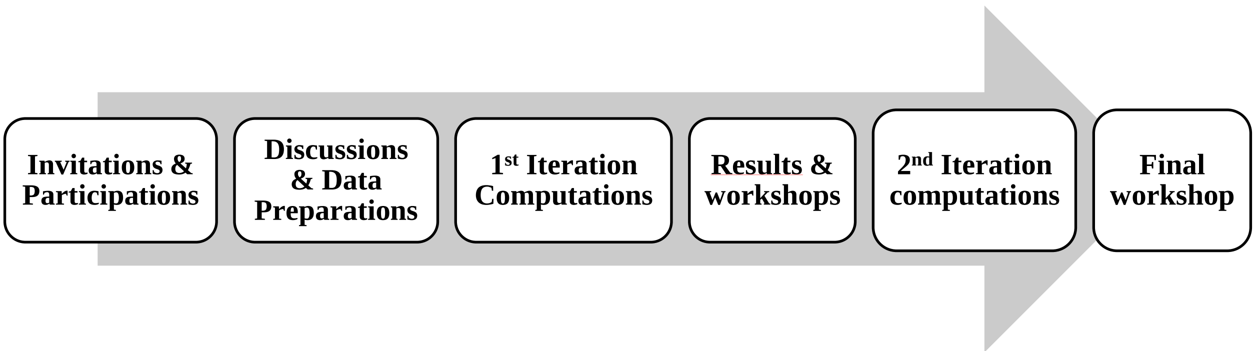

FIG. 1 : Illustrative diagram showing main GITEC project phases.

3. Project definition:

As the main aspect of GITEC project is to compare the methodologies of different generalized inversion schemes in terms of the assumed hypotheses and results and also in terms of the functionality of the GIT scheme with respect to the different dataset types considered, it is necessary to provide several datasets. Taking into account that datasets may exhibit different configurations and densities and to study its impact on GIT results, we propose to perform the inversions on the following:

- One dense national dataset national dataset (such as the data from the KiK-net/K-net networks).

- A very dense local dataset (example of the central Italy data).
- A regional sparse dataset (example of the RAP dataset in the Alps region).
- Synthetic datasets that would play a control role in the inversion results.

It is important for the start of the project to provide several datasets that would have variable characteristics and from different regions. The best possible way to start is to have datasets that have been used in previous investigations. First, as a dense national network data, the Japanese dataset (FIG 2) used in [11] is proposed, which consists 2105 sites in total (between K-NET, KiK-net and JMA Shindokei network sites) and covers events between 1996 and 2011 (976 events) which were also divided into different event types according to their source nature. This dataset contains the magnitude range of events $M_{JMA}>4.5$ (where M_{JMA} is a magnitude widely used in Japan and is almost the same as the moment magnitude); source depth D<60 km; hypocentral distance $R_{ij}<200$ km. Crustal earthquakes form this dataset will be selected.

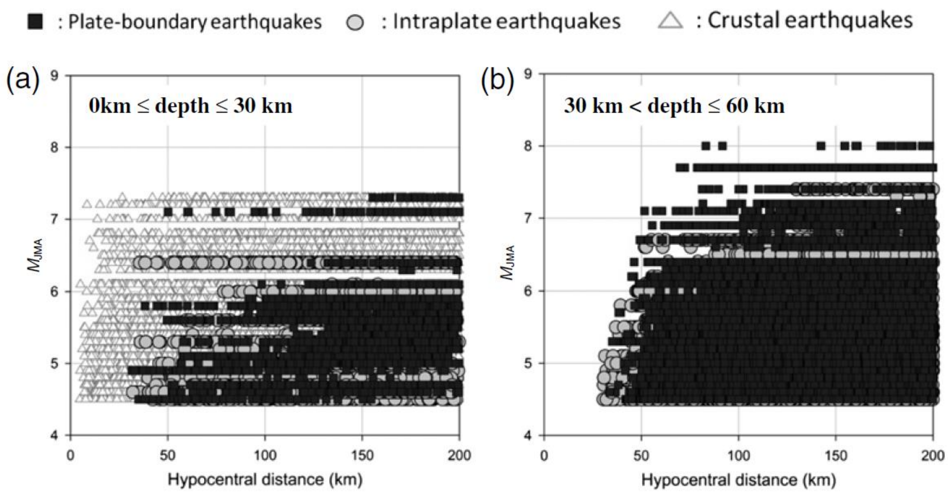

FIG 2: Magnitudes M_{JMA} and hypocentral distances for the dataset used: (a) depths 30 km or less; (b) depths between 30 and 60 km [11].

Secondly, a regional dense dataset proposed in the project will be from the central Italy investigations [12] and [13], as seen in FIG 3, which consists of 231 earthquakes recorded by 148 stations which includes the 2009 L'Aquila sequence (M_w=6.1) and spans the time period between January 2008 to May 2013. In this dataset the local magnitudes vary in the range 2.9-5.9 mainly concentrated within 3.0-3.5, and the hypocentral distances reach up to 120 km. The possibility to extend the data set in the magnitude range from 5 to 6 by including recordings from the recent 2016-17 sequences is under evaluation.

In addition, the French regional sparse datasets used by [8,14] will be also considered. In fact, the final three datasets (FIG 4) after application of selection criteria consist of 72 earthquakes in the Alps area, 23 in the Rhine Grabin area and 66 in the Pyrenees. The hypocentral distances of events come from the French national network agency: RéNaSS, and local magnitudes from RéNaSS and another French national agency: LDG. Note that all the mentioned real datasets might be considered or subsets of them will be extracted for the project.

Since the primary objective of such a project is to provide consistent comparisons of the different approaches, it will be very essential to provide synthetic datasets that serve as a control of the results, having the opportunity to invert the data obtained from the forward problem. So in addition to real datasets, two synthetic datasets will be addressed too. For the first iteration of the project, a very simple synthetic dataset will be chosen to start with to ensure consistent comparisons. For the second iteration of the project (after validations of the first iteration) the use of complex synthetics is planned. No specific dataset was considered for the moment and the choice will come through the project progress.

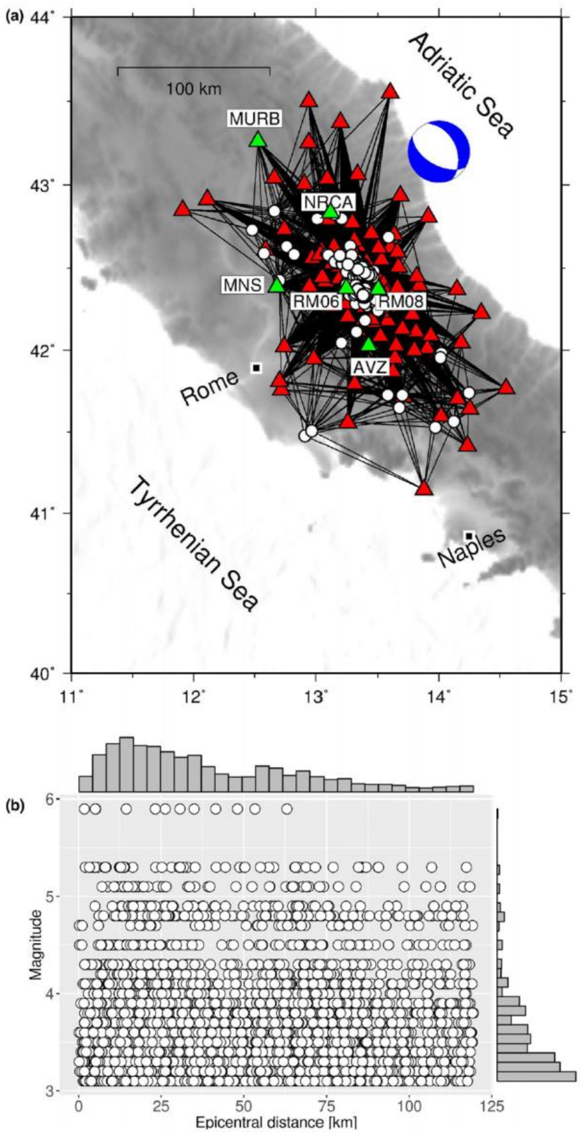

FIG 3: (a) Path coverage, station locations (triangles) and earthquake epicentres (circles) of Abruzzo data set. The focal mechanism of the 2009 L'Aquila [12].

4. Future perspectives:

During the project it is expected that the participants remain at continuous updates and contact till the first workshop where the first results of the project will be discussed and logical conclusions will be drawn out. The workshops outcomes will be illustrated in future publications.

At the end of the project, it is planned to provide open the access to the used datasets and all participating teams' results through a website (or an electronic supplement of a scientific paper) in order to allow further code validation and comparisons. The opportunity of developing an open GIT code that takes the advantage of the results and combines all the past experiences will probably be addressed in GITEC workshops.

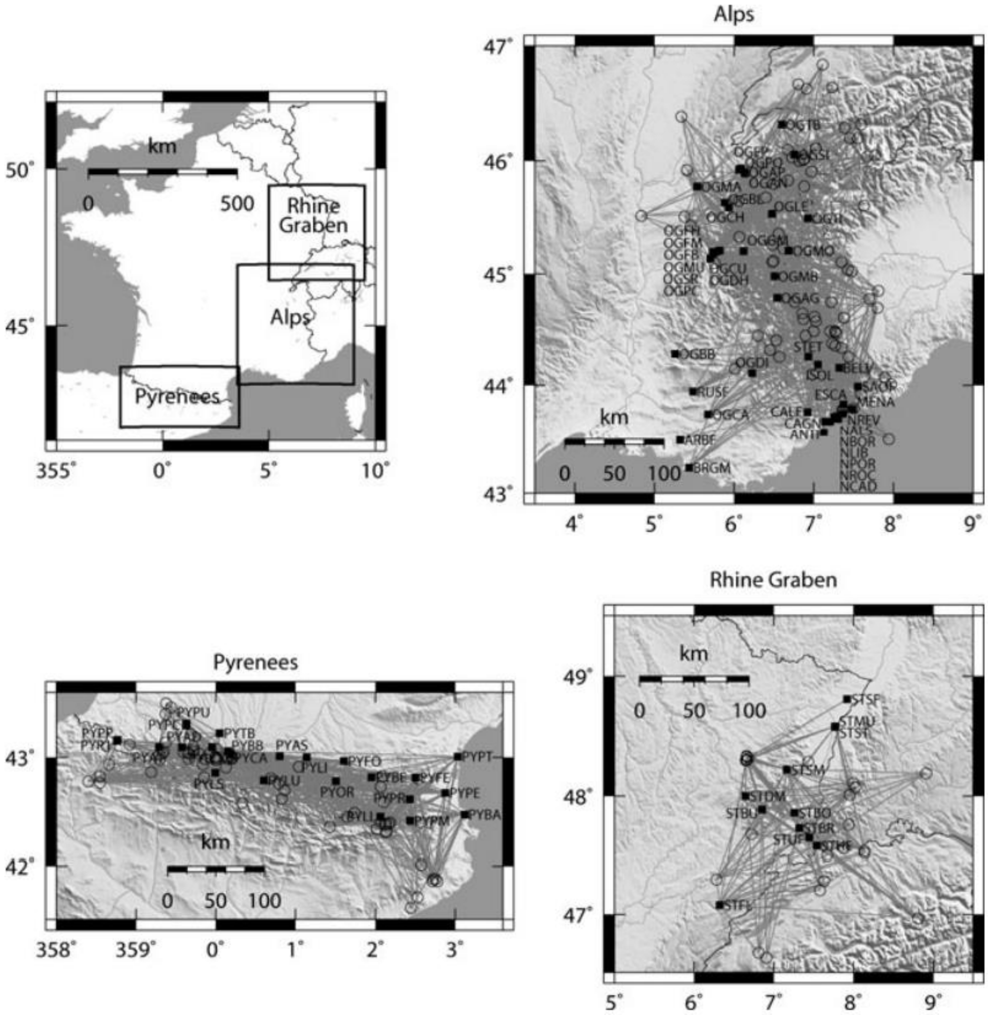

FIG 4: Maps of the earthquakes (circles), stations (squares) and paths (lines) used in this study for the three data sets: Alps, Rhine Graben and Pyrenees [14].

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