SECURE
REGIONAL-SCALE EARTHQUAKE GROUND MOTION PREDICTIONS THROUGH PYHSICS-BASED AND EMPIRICAL APPROACHES: A CASE STUDY CENTRAL ITALY

Regionalized Ground Motion Model for Hazard Applications in Italy

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in collaboration with: S. Sgobba, G. Brunelli, D. Bindi, F. Pacor, L. Luzi

ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA

PIANETA DINAMICO
WORKING EARTH

Dataset: ITACAext 2.0

https://itaca.mi.ingv.it/ItacaNet_40/#/products/itacaext_flatfile

Glossary   Contact us   ITA   ENG

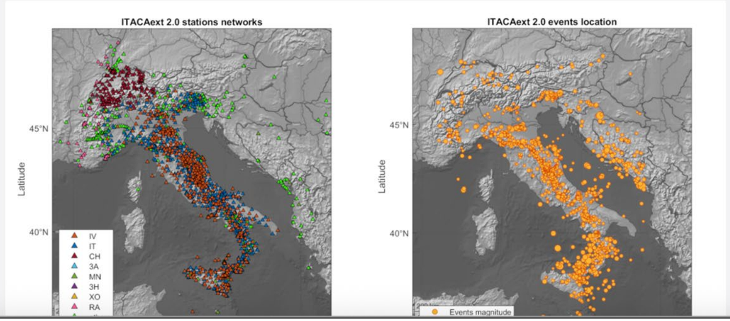
ITACAext flatfiles: parametric tables of metadata and strong motion intensity measures

The **ITACAext** flat-files consist in parametric tables containing metadata and intensity measures of manually processed waveforms, relevant for the analysis of the ground-motion in Italy.

The flat-files are mainly constituted by the data included in ITACA. Moreover, they are integrated with velocimetric records of small magnitude in the less sampled areas in Italy (e.g., Liguria, Piedmont, and western Sicily), taking care to exclude recordings affected by instrument saturation. If the earthquakes are recorded at the Italian boundaries, the records of the networks of the neighbouring countries, such as France, Switzerland, Slovenia, Albania, and Montenegro, are also added to improve the spatial and azimuthal sampling of the events.
All the waveforms of the **ITACAext** dataset were manually processed according to the standard ITACA scheme, described in Paolucci et al. (2011) and Puglia et al. (2018). The flat-files are formatted consistently with the *Engineering Strong Motion flat-file database* (Lanzano et al. 2019).

ITACAext can be considered as the primary source of information to study the local differences of ground-motion in Italy and develop the new-generation regionalized ground-motion models for events in active crustal regions, volcanic and subduction zones.

ITACAext version 2.0 (April 2024)



Data Mine

ITACAext 2.0: A High-Quality Parametric Table of Strong-to-Weak Motion Recordings for Seismological and Engineering Research in Italy

Giovanni Lanzano*[1], Lorenzo Vitrano[1], Dino Bindi[2], Chiara Felicetta[1], Sara Sgobba[1], Lucia Luzi[1], and Francesca Pacor[1]

Abstract

In the most recent release of the ITalian ACcelerometric Archive (ITACA) portal (v. 4.0; Felicetta *et al.*, 2023), a parametric table (intensity measures and associated metadata) of seismic records of interest for the characterization of seismic motion in Italy was made public. This flatfile is called ITACAext and includes accelerometer and velocimeter recordings of $M_w \geq 3.0$ earthquakes and seismic networks in Italy and neighboring countries. The dataset contains parameters of recordings manually processed by experts from 1972 to 2022, with a total of 52,706 observations from 2,338 events and 2,294 stations. This dataset provides the most up-to-date overview of strong motion recordings available for Italy, including the strongest earthquake recordings of all Italian seismic sequences over the last 50 yr (1976 Friuli, 1980 Irpinia, 1997 Umbria–Marche, 2009 L'Aquila, 2012 Emilia, and 2016–2017 central Italy). It also includes a significant number of near-source records of earthquakes in volcanic and subduction areas. The flatfile contains not only the peak amplitudes (peak ground acceleration, peak ground velocity, and peak ground displacement), energy parameters (cumulative absolute velocity, Arias and Housner intensity), and ordinates of the acceleration response spectrum (damping 5%, period interval 0.01–10 s), but also the ordinates of the Fourier spectrum (f = 0.04–50 Hz), calculated for the entire signal as well as for the S phase. ITACAext also includes several metadata, all conveniently referenced, including those most relevant to the calibration and testing of ground-motion models (GMMs), such as various magnitude estimates, different distance metrics, focal mechanisms and site characterization parameters such as $V_{S,30}$. To support the analysis of ground motion of tectonic origin at the national scale, a selection of shallow active crustal recordings was performed. In addition, an analysis of the quality of the dataset was carried out via residual analysis in two stages. These checks also consisted of comparing the seismic responses of collocated sensors and support the inclusion of velocimetric recordings in ground-motion analyses. In the end, we flagged 42,877 records from 2,045 events that can be confidently used to calibrate and test active shallow crustal GMMs at the Italian scale.

Cite this article as Lanzano, G., L. Vitrano, D. Bindi, C. Felicetta, S. Sgobba, L. Luzi, and F. Pacor (2025). ITACAext 2.0: A High-Quality Parametric Table of Strong-to-Weak Motion Recordings for Seismological and Engineering Research in Italy, *Seismol. Res. Lett.* **XX**, 1–22, doi: 10.1785/0220240309.

Supplemental Material

Introduction

Strong motion data recordings are essential for many different purposes in seismological and engineering applications. In particular, empirical parameters derived from observations are used to calibrate ground-motion prediction models, commonly referred to as GMMs, which are used for many applications, including the production of probabilistic (Probabilistic Seismic Hazard Assessment, PSHA) or deterministic (scenario analysis

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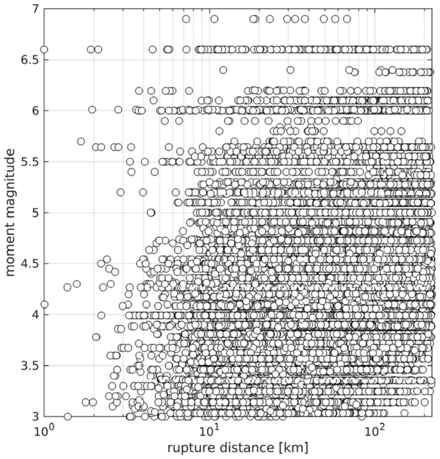
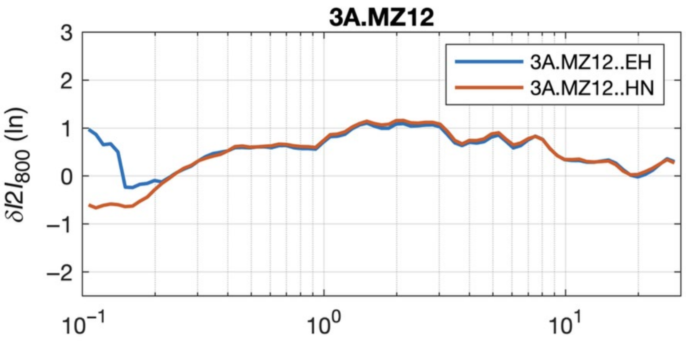
Lanzano et al. (2025) SRL

Dataset: Selection for SACR

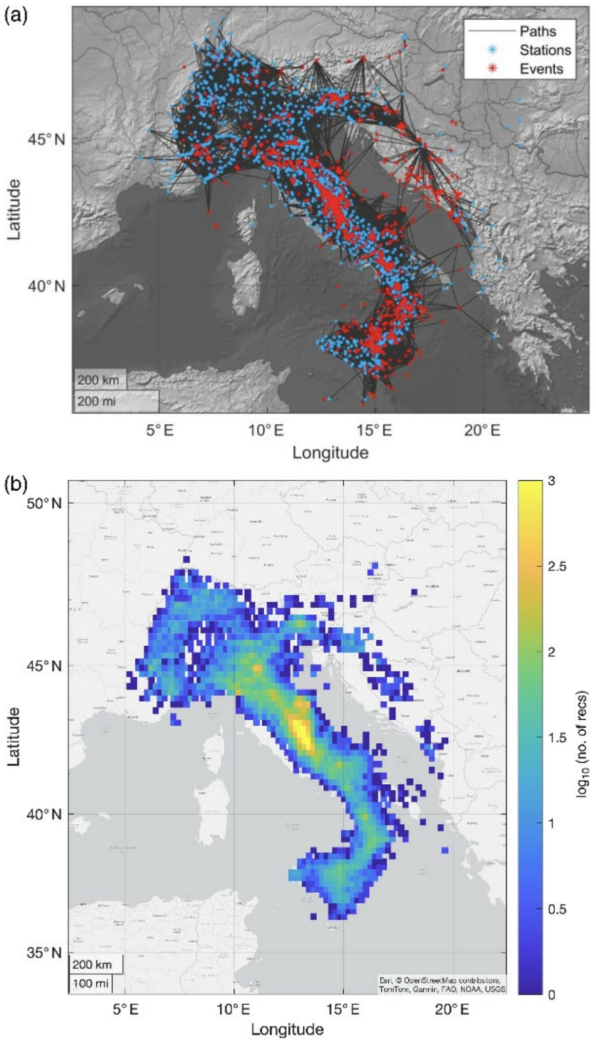
- profondità focale fino a 35km
- distanza epicentrale fino a 220km
- solo sensori fino a -3m di profondità
- esclusi eventi vulcanici e di subduzione
- escluse registrazioni problematiche (Mascandola et al. 2021)
- analisi delle stazioni colocate per evitare il sovracampionamento





- **Registrazioni: 42.887**
- **Eventi: 2.052**
- **Stazioni: 2.072**

Maggiori dettagli in Lanzano et al. (2025)



Metodo di analisi per la regionalizzazione

INGV SECURE REGIONAL-SCALE EARTHQUAKE GROUND MOTION PREDICTIONS THROUGH PHYSICS-BASED AND EMPIRICAL APPROACHES: A CASE STUDY CENTRAL ITALY

1. Reference GMM: ITA18 (Lanzano et al. 2019)

$$ln(Y)_{pred} = a + F_M(M_W, SoF) + F_D(M_W, R) + F_S(V_{S30}) + \varepsilon$$

2. Residual computation

$$Res = ln(Y)_{obs} - ln(Y)_{pred}$$

$$= \delta B_e|event + \ \delta S2S_s|site + \ \delta W_{es}$$

3. Spatial analysis of residual components

δB_e : between-event → Effetti di sorgente

δW_{es} : event- and site-corrected residual → Anisotropia della propagazione

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Data-driven zonations for modelling the regional source and propagation effects into a Ground Motion Models in Italy

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Brunelli et al. (2023) SDEE

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Spatial variability of non-ergodic GMM residuals related to source and path effects in Italy

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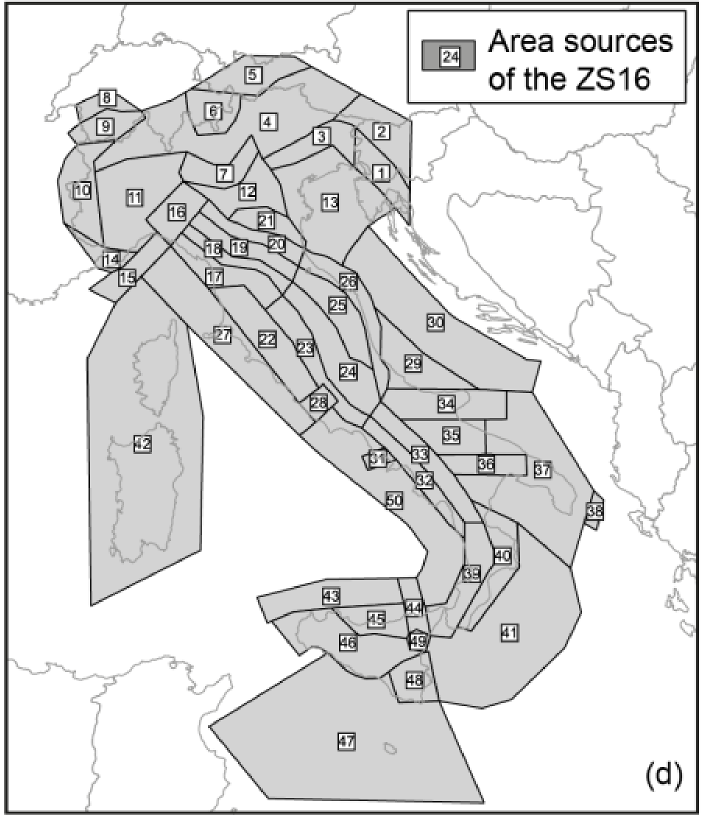
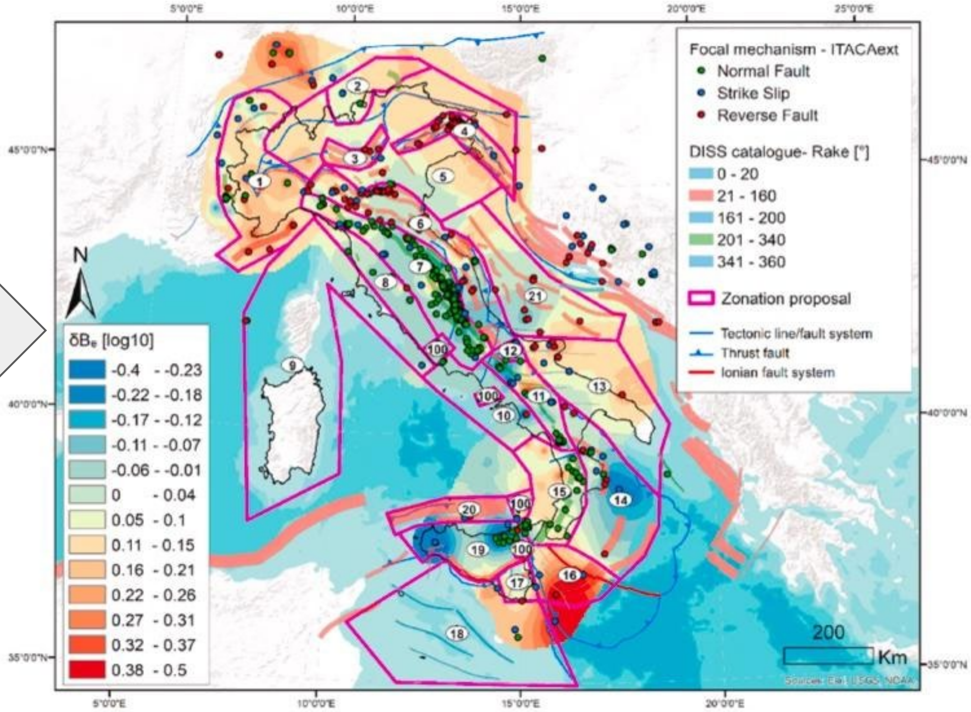
Brunelli et al. (2023) BGO

Zonazione sorgente



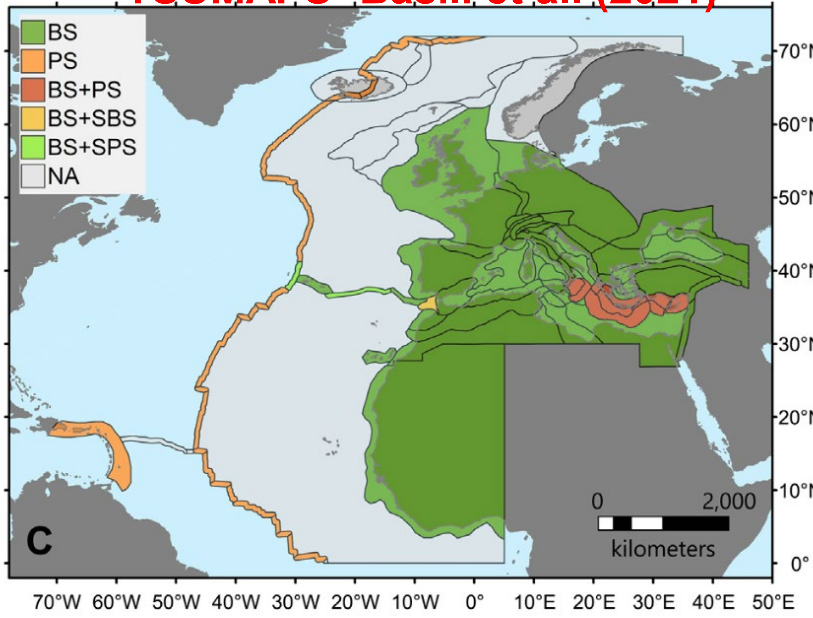
ZS16 - Visini et al. (2022)

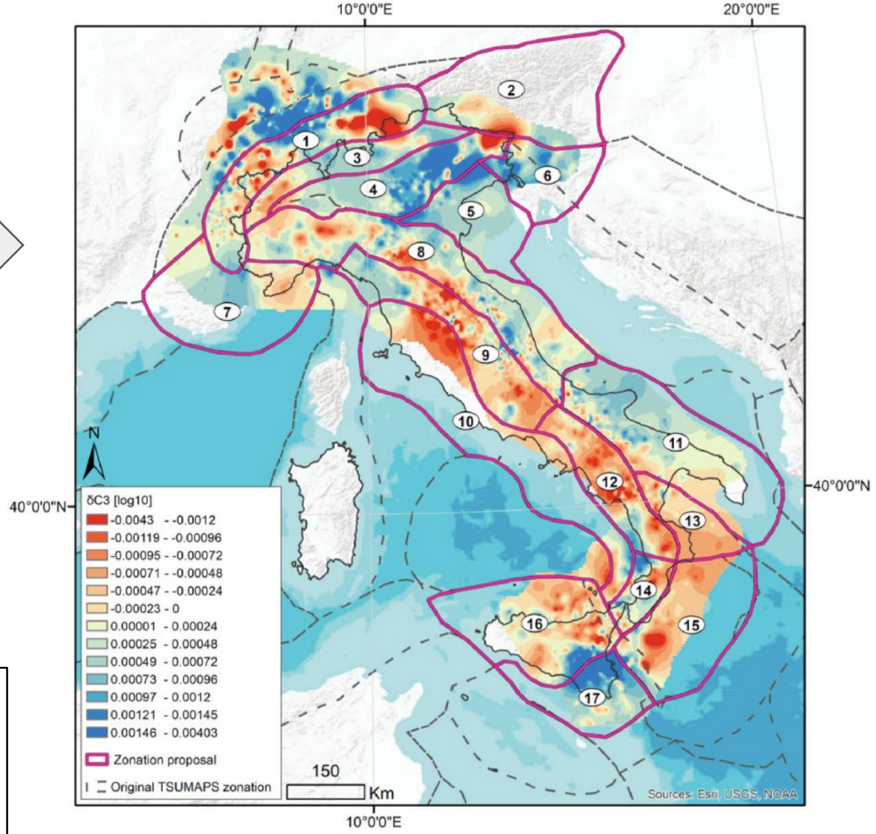


Brunelli et al. (2023)

Zonazione propagazione

TSUMAPS- Basili et al. (2021)



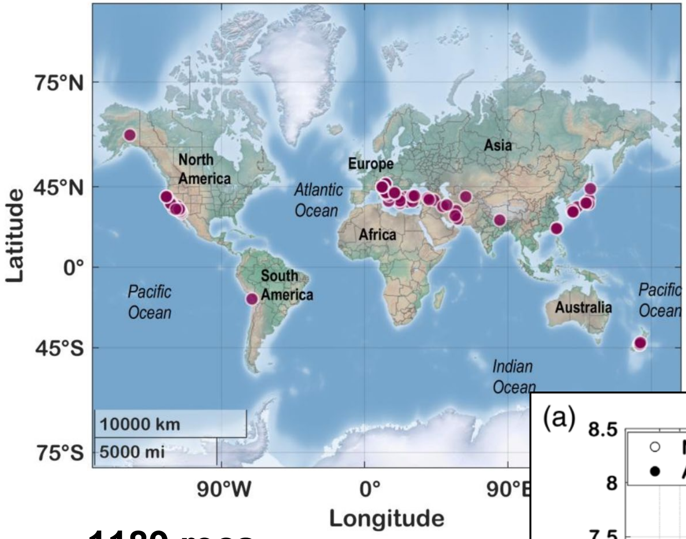


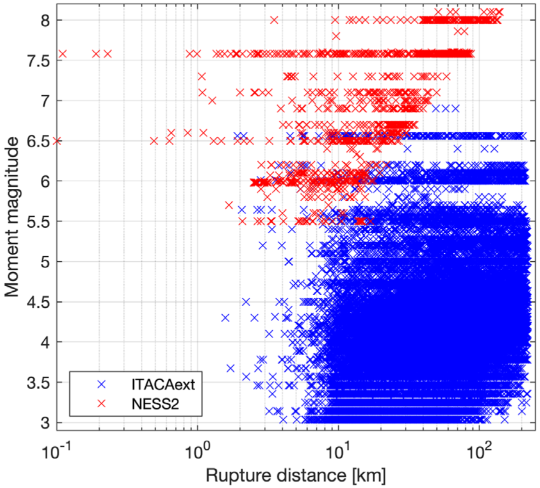
Brunelli et al. (2023)

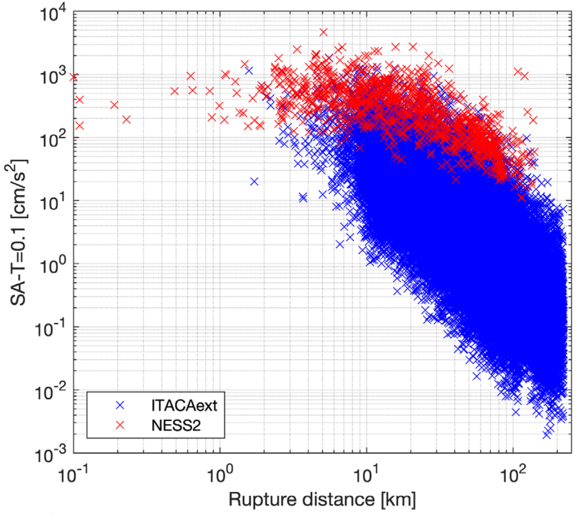
$$\delta c_3 = \frac{\delta W_{es}}{\sqrt{R_{rup}^2 + h^2}}$$

Anomalia del termine di propagazione anelastico

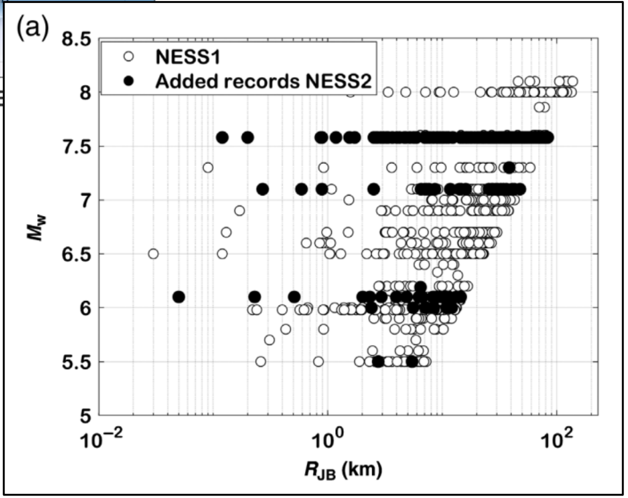
NESS 2.0

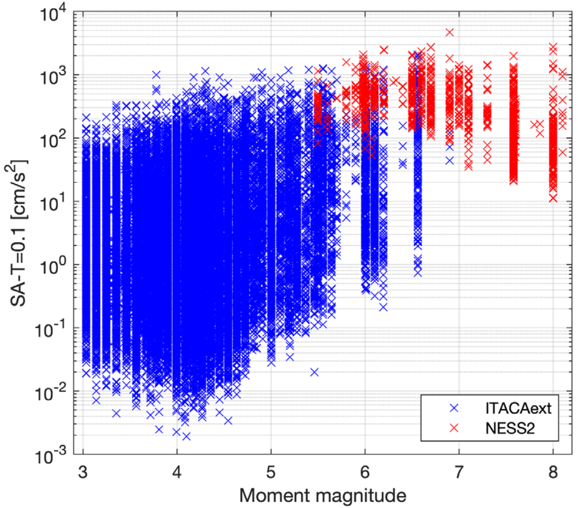






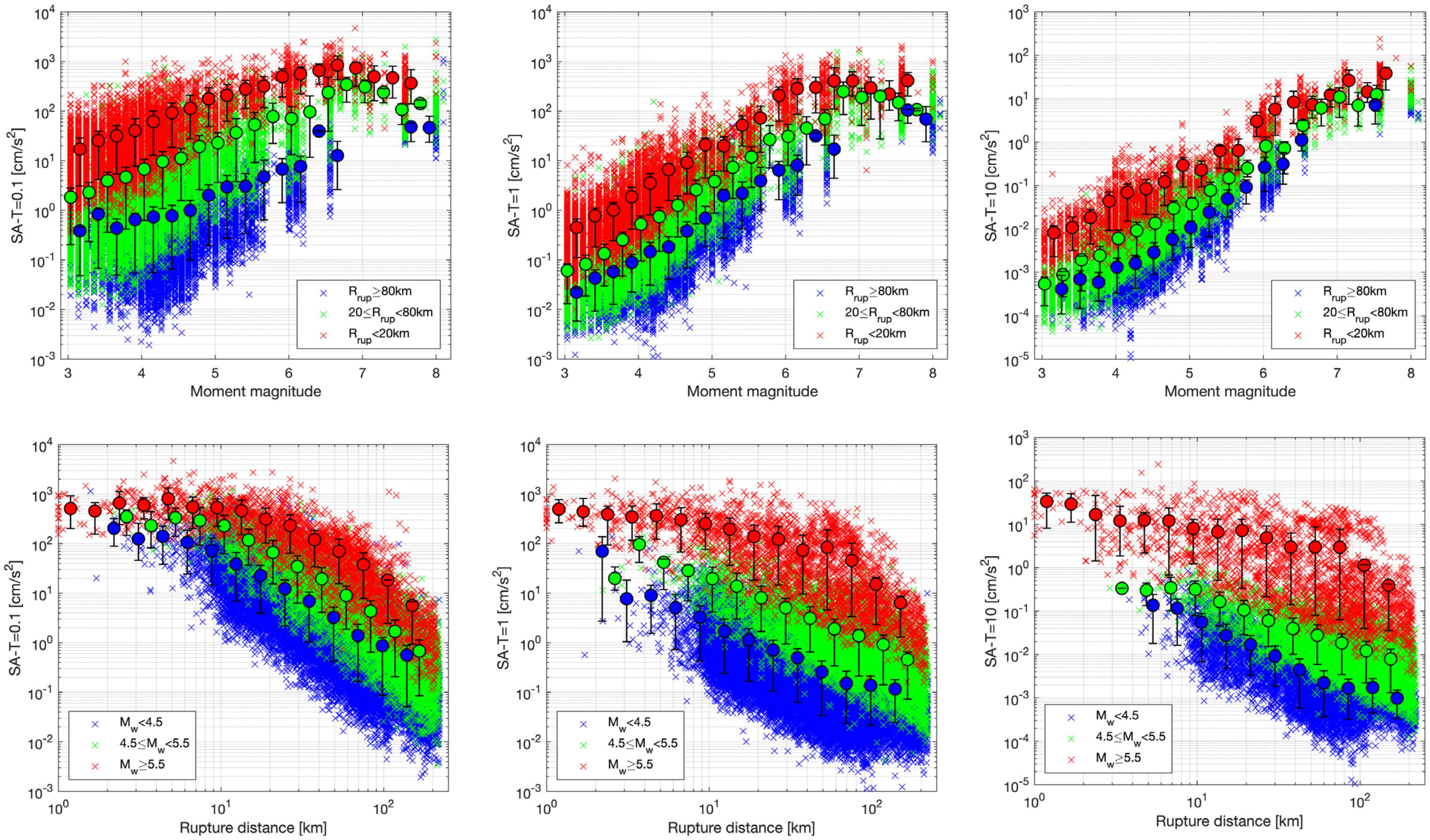
1189 recs
81 eqs





Sgobba et al. 2021 BSSA

Data merging



Modellazione dei termini fissi

Forma funzionale ITA18

$$log_{10}Y = a + F_M(M, SOF) + F_D(M, R) + F_S(V_{S,30})$$

$$F_M(M, SOF) = b_1(M-M_h)*(M<M_h) + b_2(M-M_h)*(M>M_h) + f_j*SOF_j$$

where j=1 for NF, j=2 for SS, j=3 for TF

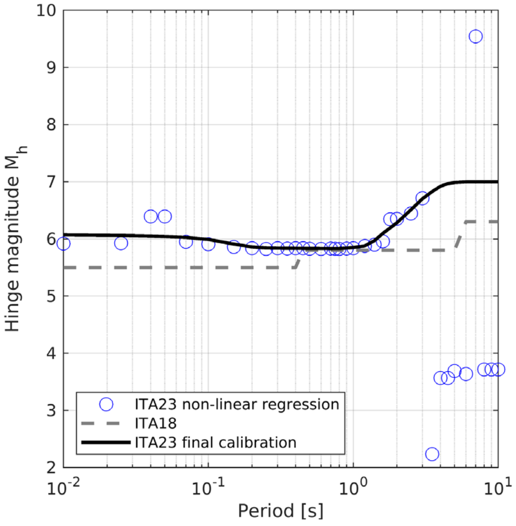
$$F_D(M, R) = c_1*log_{10}(radq(R^2 + h^2)) + c_2*(M-M_r)*log_{10}(radq(R^2 + h^2)) + c_3*(radq(R^2 + h^2)-R_r)$$

$$F_S(V_{S,30}) = k*log_{10}(V_0/800)$$

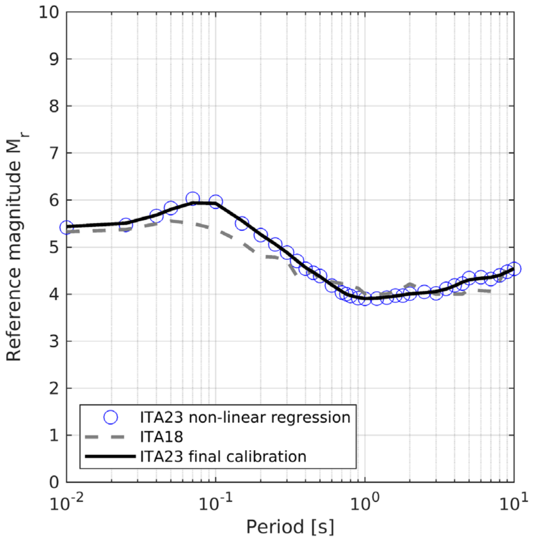
where $V_0=V_{S,30}$ *for* $V_{S,30}<1500m/s$ *or* $V_0=1500$ *for* $V_{S,30}>1500m/s$

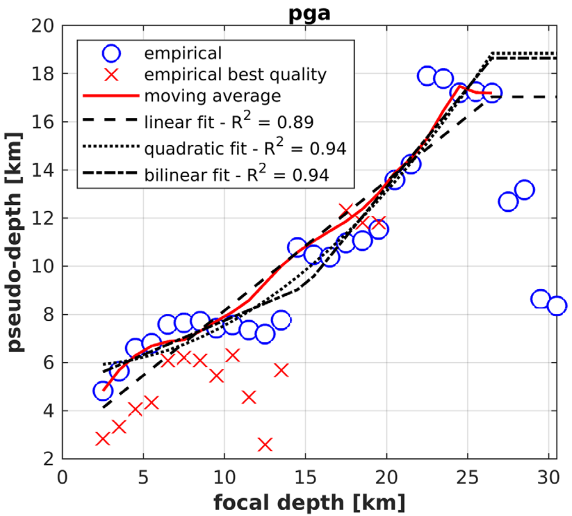
Stima degli effetti fissi 1/2

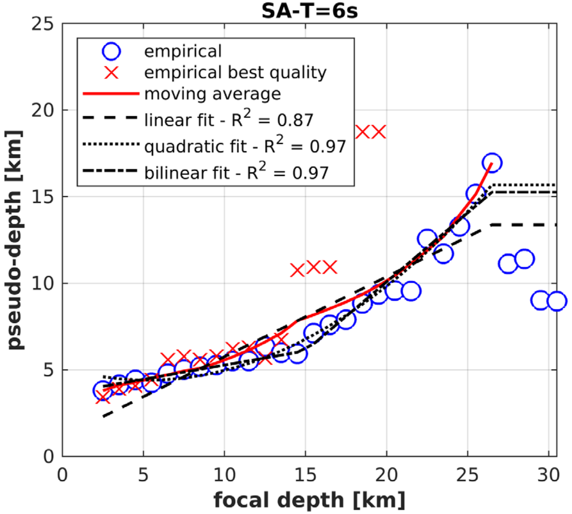
hinge magnitude - Mh



reference magnitude - Mr

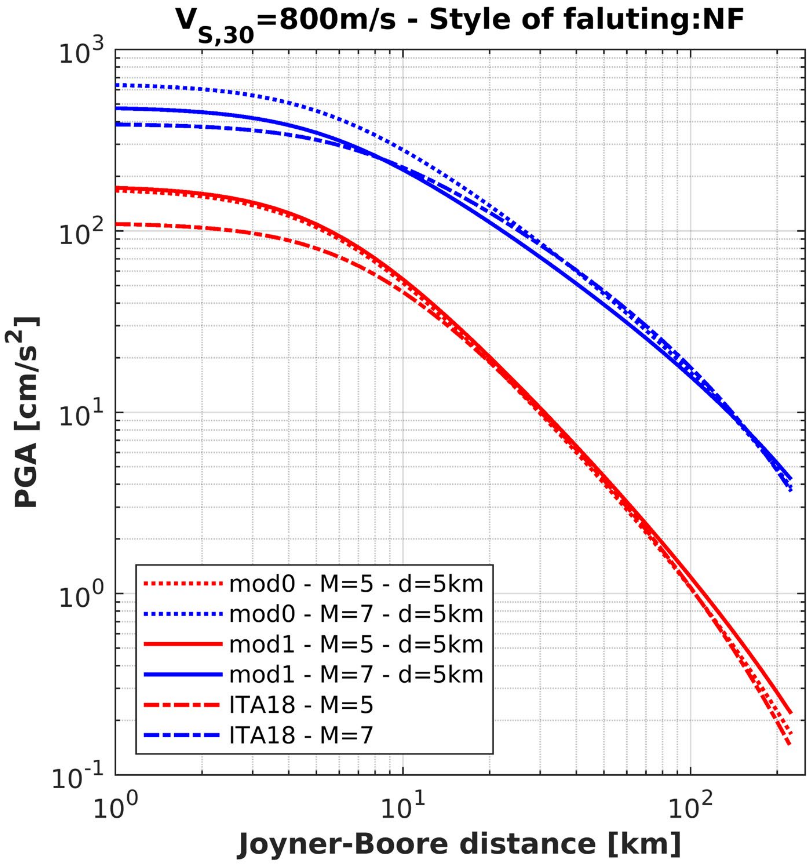


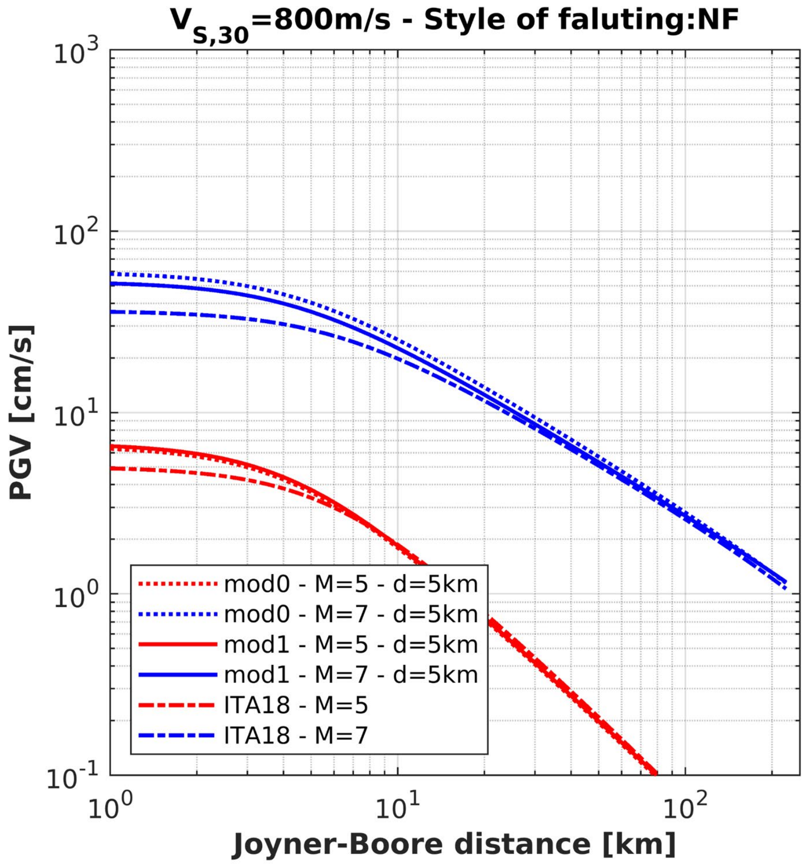




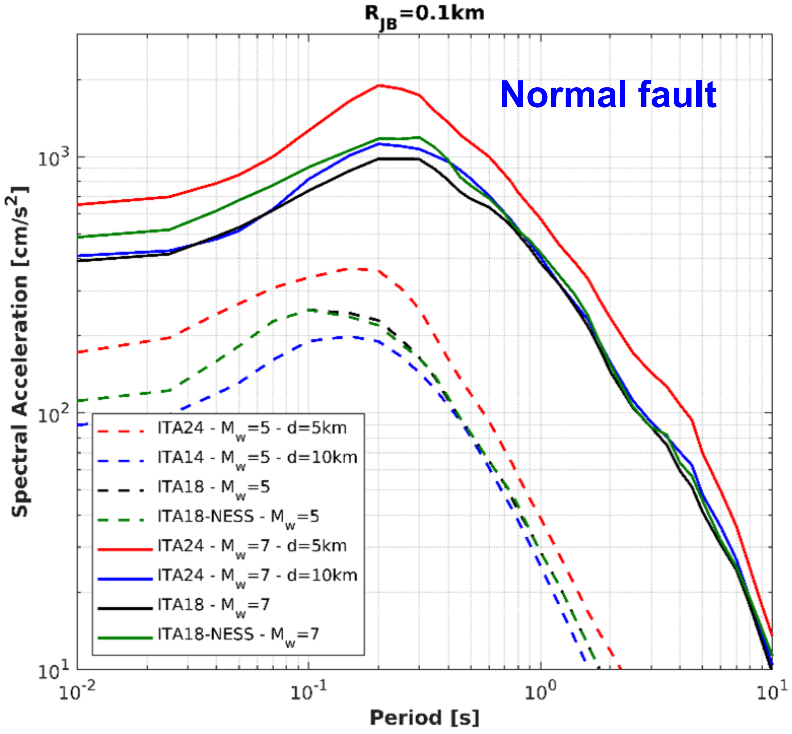
pseudo-h [km] = a_h + b_h*focal_depth

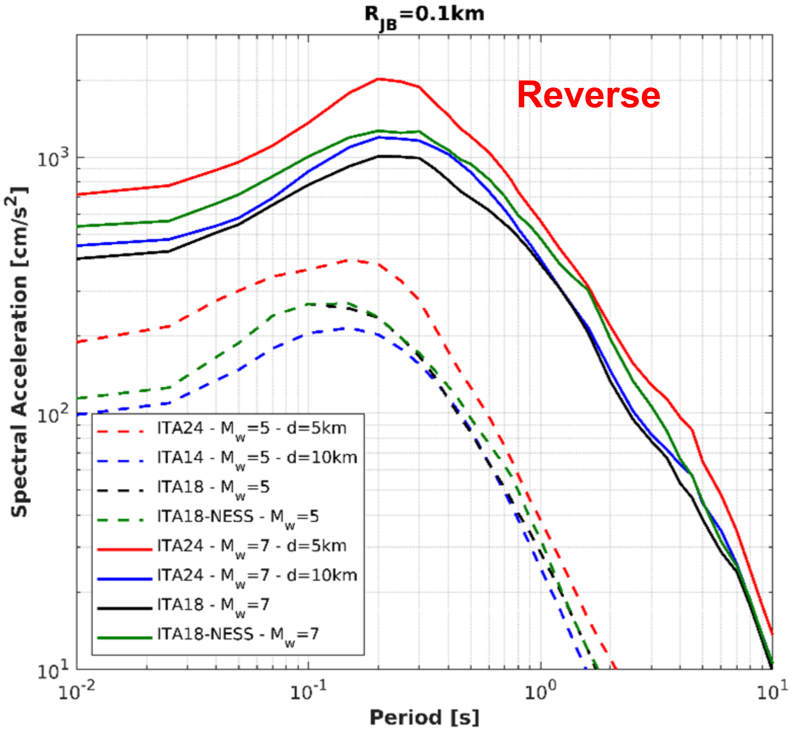
Stima degli effetti fissi 2/2





Spettri predetti ergodici





Modellazione dei termini random

- **Modello 0 - parzialmente non-ergodico**

$$log_{10}Y = a + F_M(M, SOF) + F_D(M, R) + F_S(V_{S,30}) + \boldsymbol{\delta B_e|eventi + \delta S2S_s|stazioni + \delta W_{0,es}}$$

$$\boldsymbol{\sigma^2 = \tau^2 + \varphi_{S2S}^2 + \varphi_0^2}$$

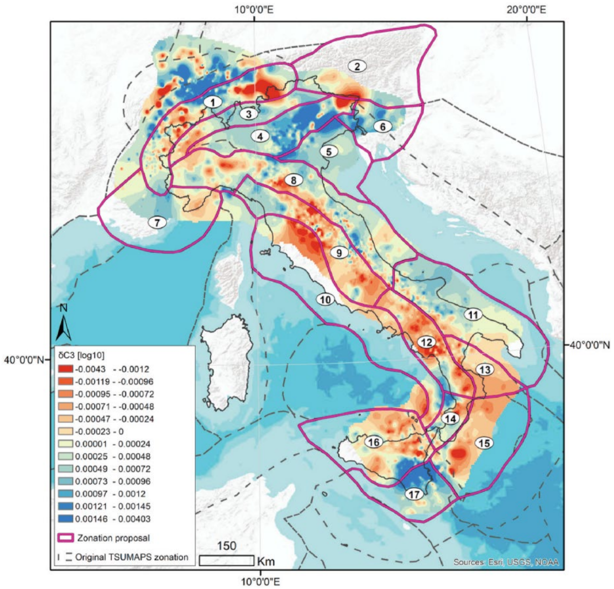
- **Modello 1 - completamente non-ergodico**

$$log_{10}Y = a + F_M(M, SOF) + F_D(M, R) + F_S(V_{S,30}) + \boldsymbol{\delta B_e|eventi + \delta S2S_s|stazioni + \delta L2L_z|source\_zones + \delta c_3(radq(R^2 + h^2)\text{-}R_r)|path + \delta W_{0,es}}$$

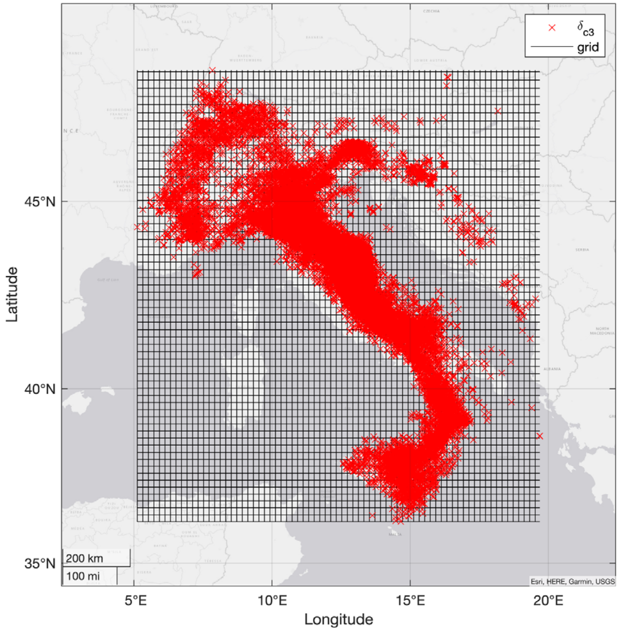
$$\boldsymbol{\sigma^2 = \tau^2 + \varphi_{S2S}^2 + \tau_{L2L}^2 + \varphi_0^2}$$

Modellazione effetto di percorso

1. **Zonation**

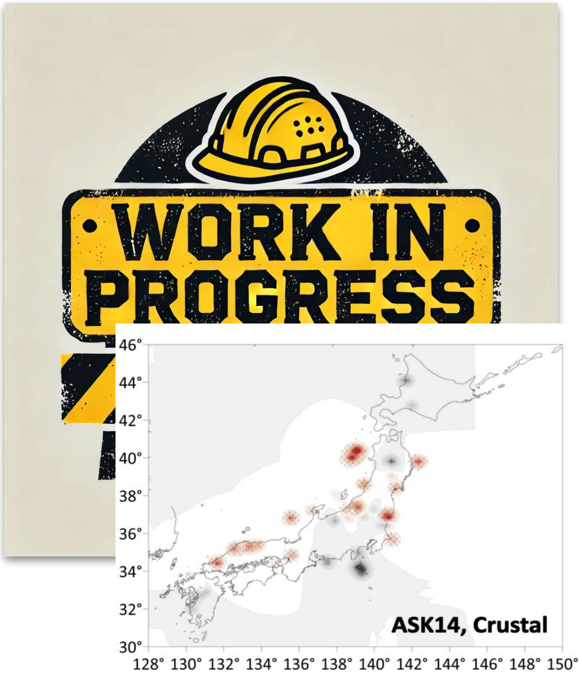


2. **Middle-point**

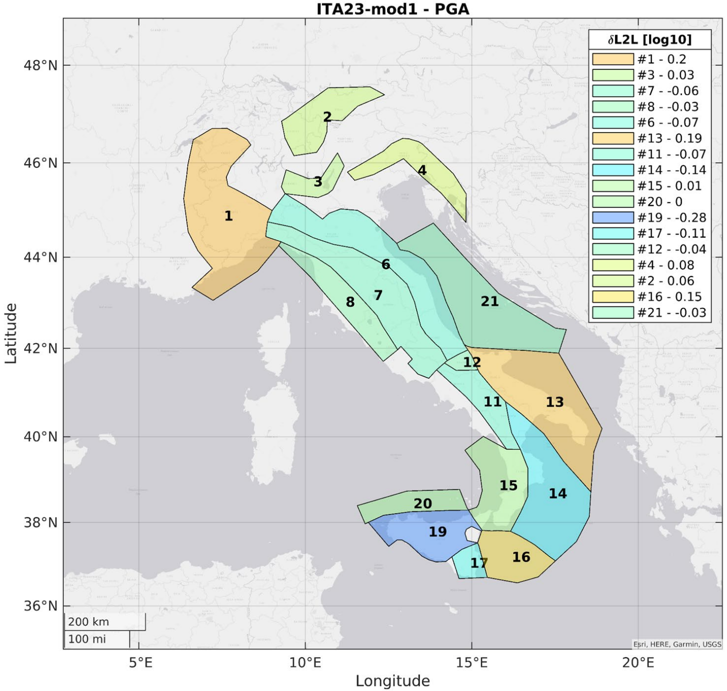


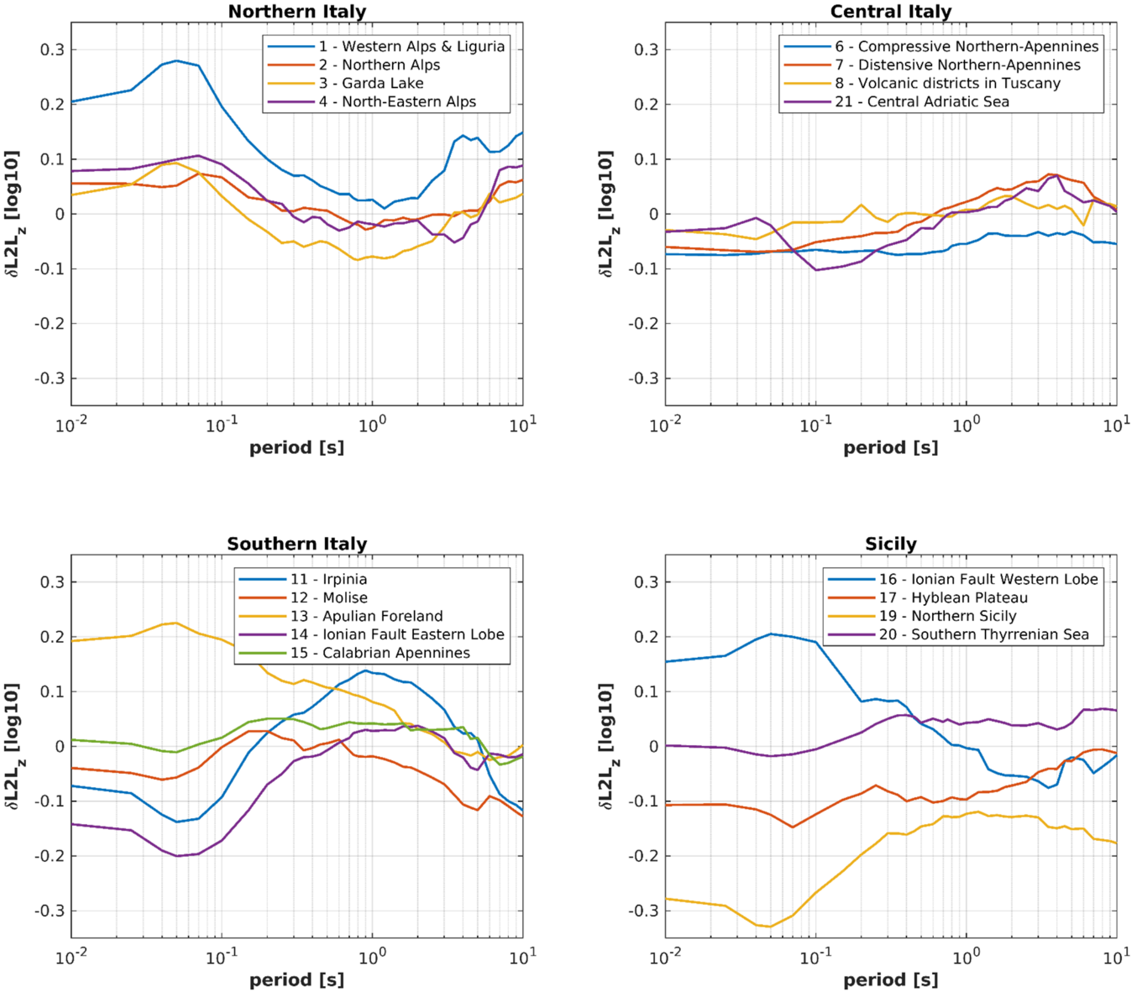
path_grid: 0.2°x0.2

3. **2D Tomography (in progress)**

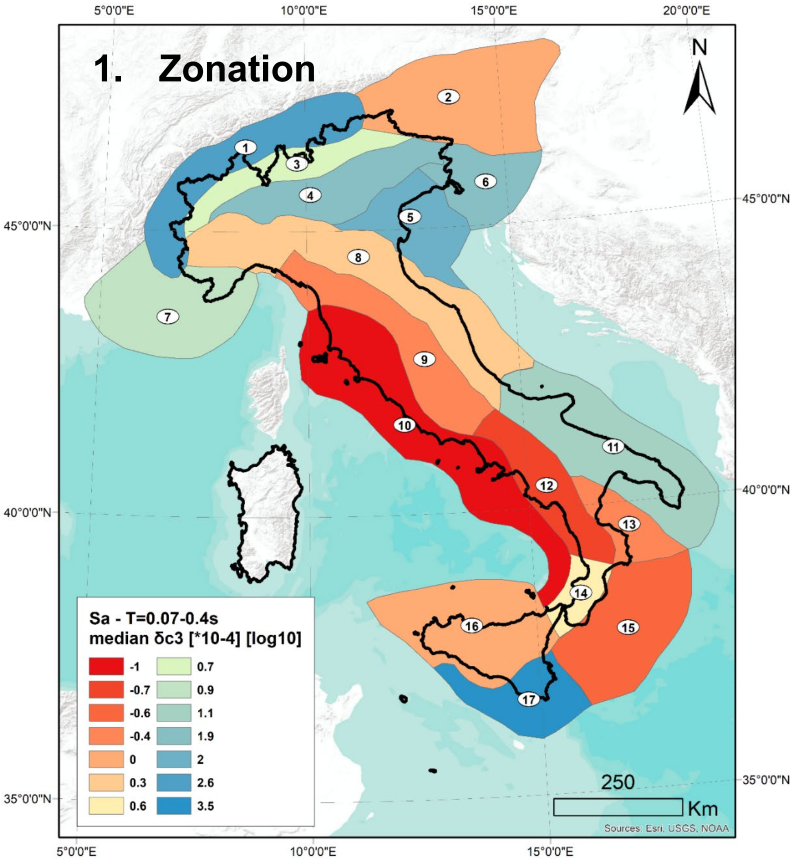


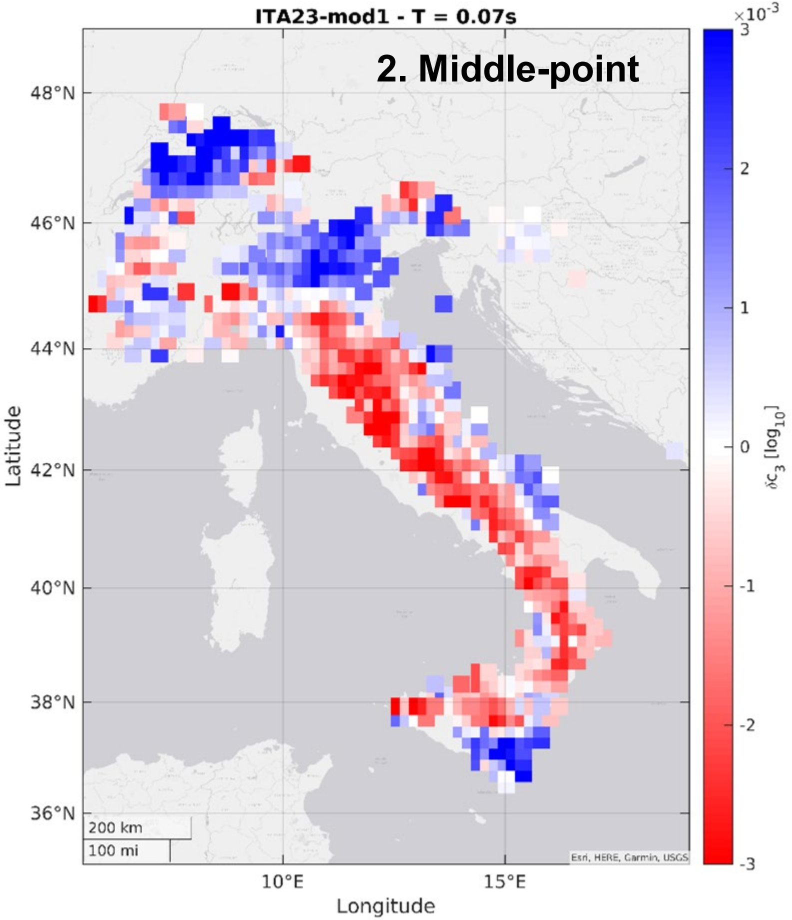
Termini random per area sorgente



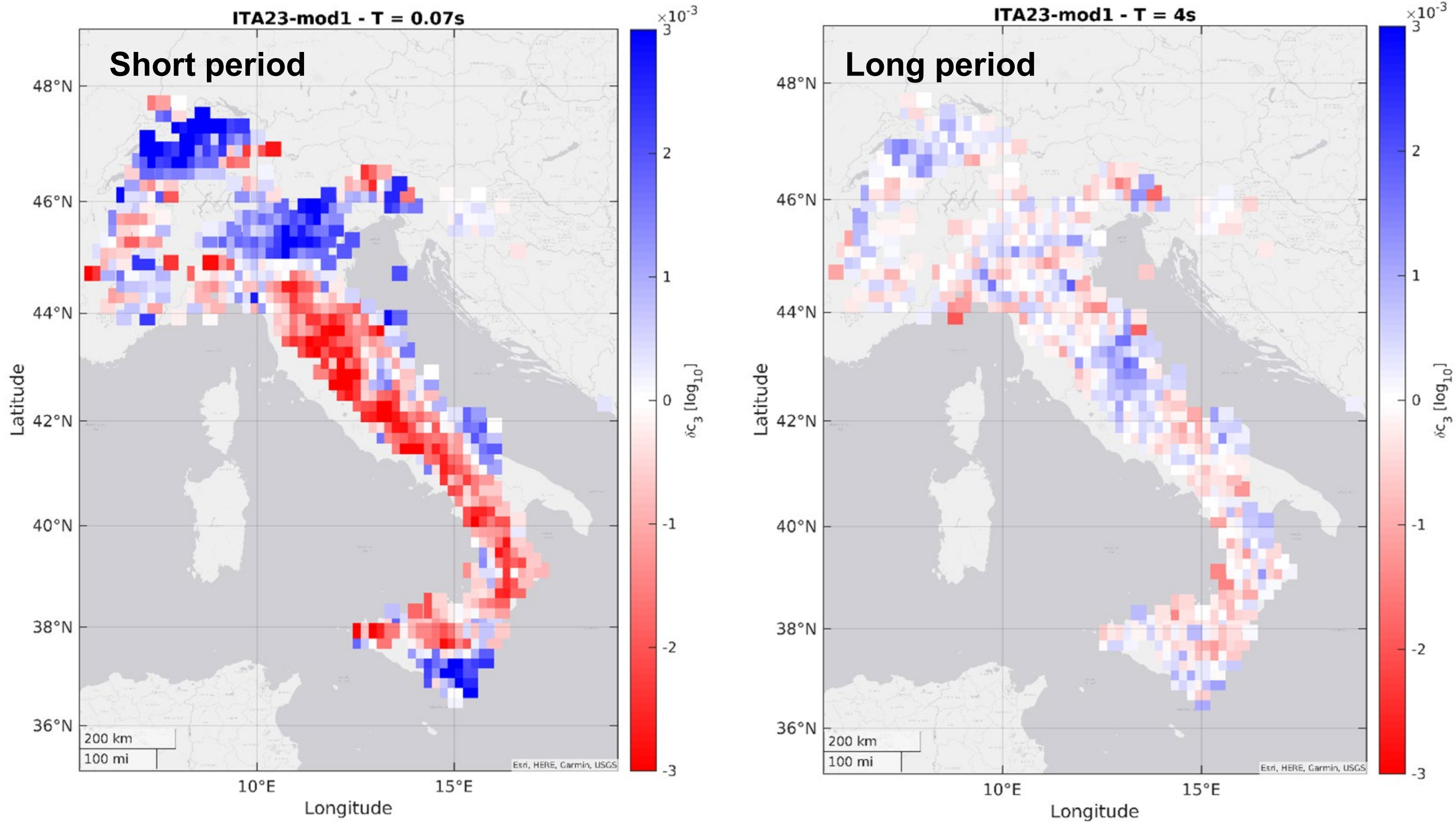


Termini random per effetti di percorso

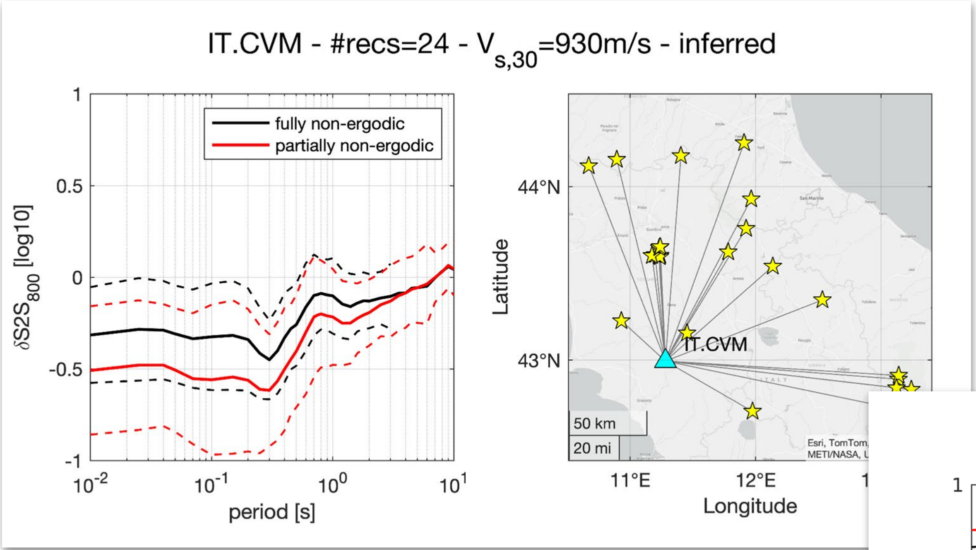


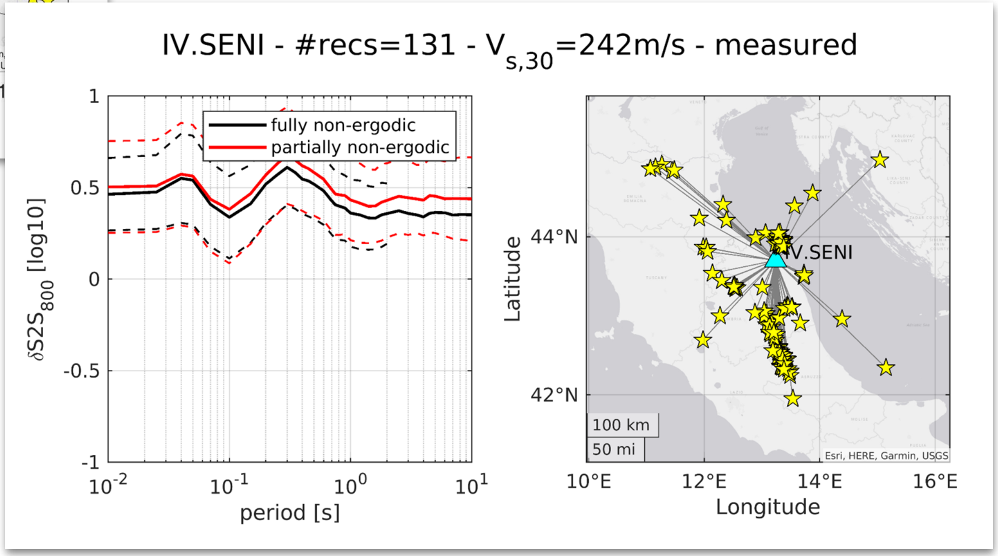


Termini random per effetti di percorso

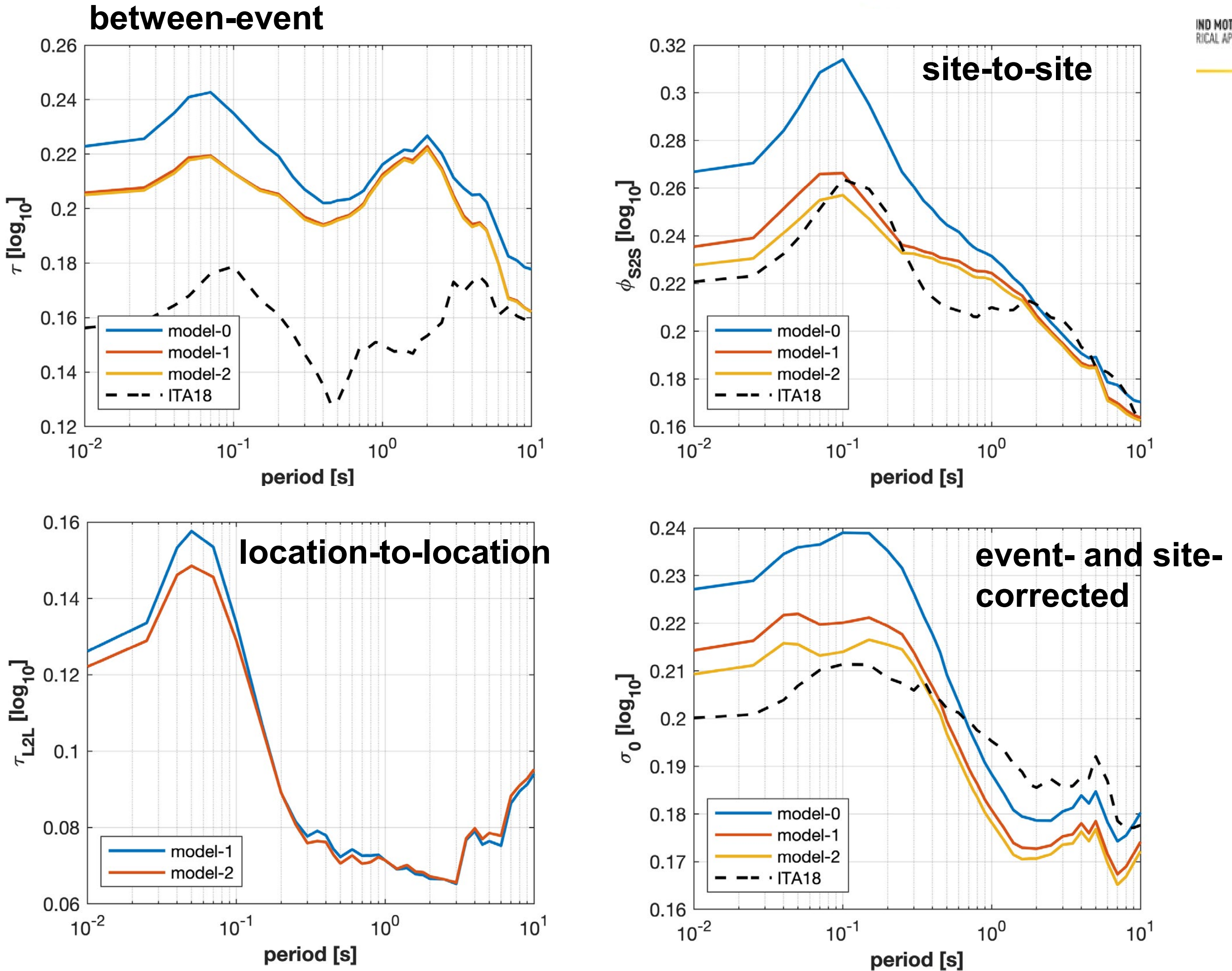


Termini random per il sito

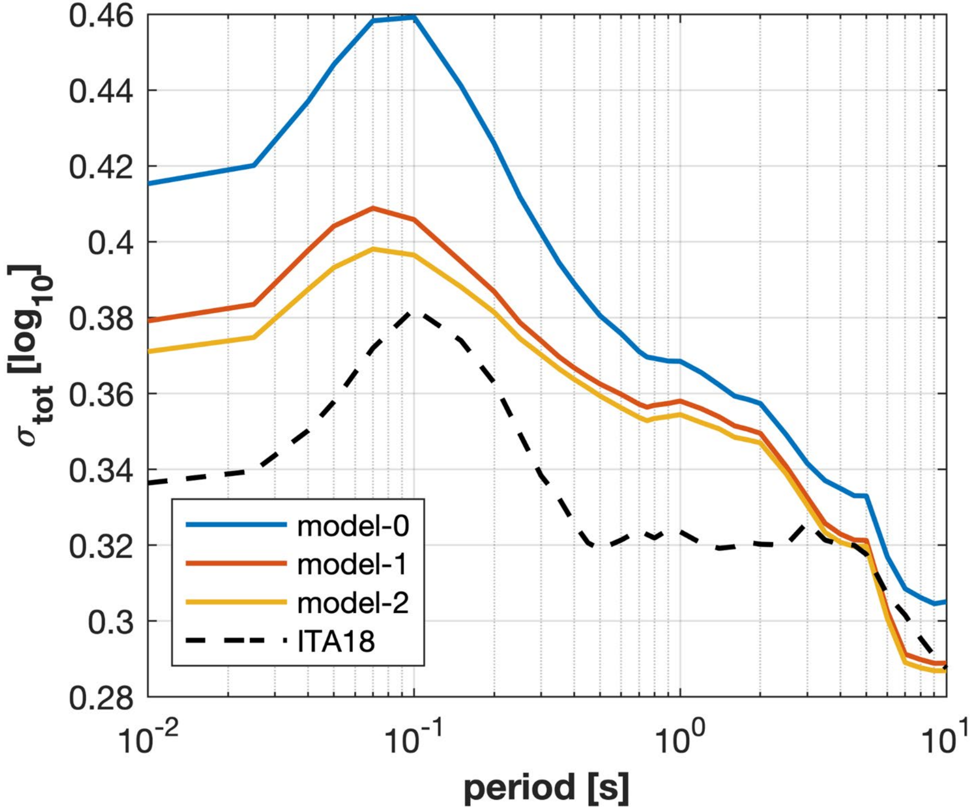




Deviazioni standard

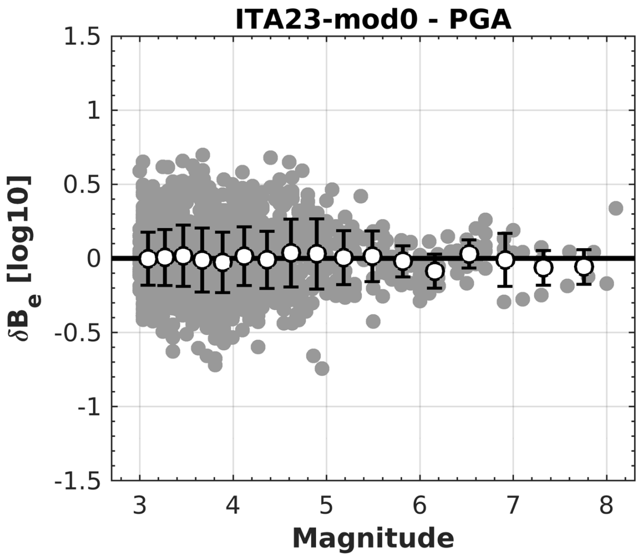


Deviazioni standard

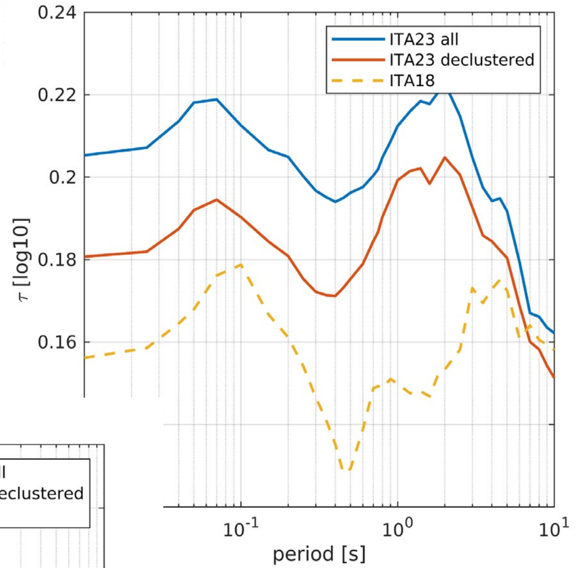


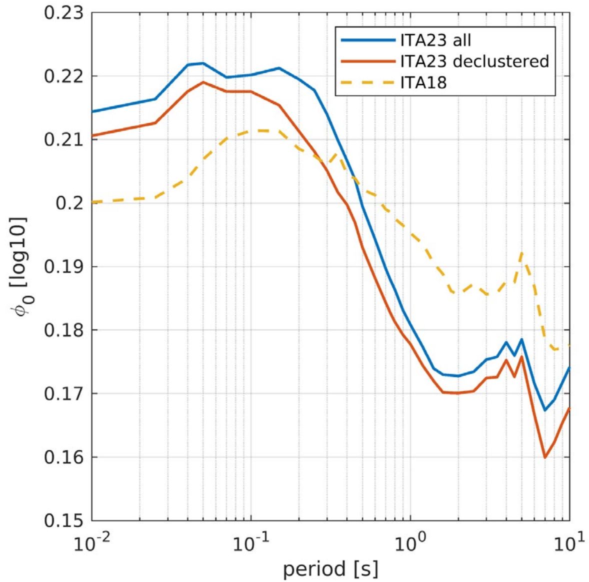
total std

Gestione dell’incertezza (in corso)



Declustering del catalogo di ITACAext 2.0
Gardner & Knopoff





Modello eteroscedastico
$\tau = f(M_w, T)$
$\varphi_{S2S} = f(V_{s30}, T)$

Conclusioni

- Viene proposto un modello regionalizzato (completamente non-ergodico) per l'Italia con un approccio simile a Kotha et al. (2020) che incorpora anche un dataset near-source per migliorare le predizioni per scopi ingegneristici
- Vengono migliorate le predizioni in near-source anche grazie alla modellazione della pseudo-profondità in funzione della profondità
- Sono state esplorati vari approcci per modellare l'anisotropia della propagazione ed alcuni di questi sono ancora in corso. Sembra tuttavia che colgono alcuni caratteristiche principali della propagazione
- Si procederà ad affinare il metodo, specializzando l'incertezza (es. approcci eteroscedastici), opportunamente validando il modello e testandolo per la produzione di scenari empirici

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