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UR3.13 - MAXIMUM OBSERVABLE SHAKING (MOS) maps of Italy

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Introduction

The main goal of UR 3.13 is to establish a work flow for a multi-layer map that includes the seismicity of Italy in terms of Maximum Observable Shaking (MOS), and the near-field/far-field boundaries (NF/FF) with respect to the major seismogenic faults mapped within the DISS database. Here we will discuss only the procedure to derive the MOS-map of Italy.

BrooadBand waveforms

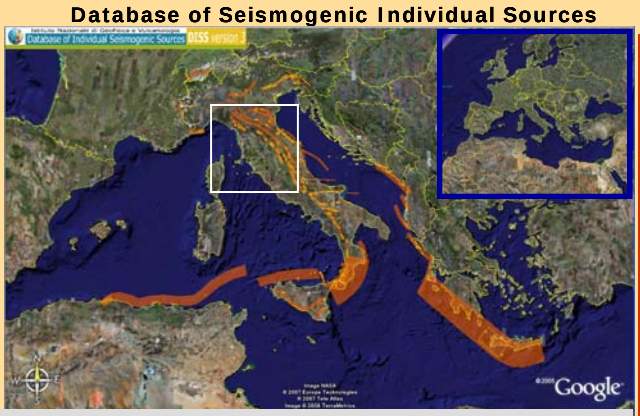
Fore each Maximum Credible Earthquake (MCE) and its Typical Fault (TF) associated to a SZ, amplitude spectra for deterministic Low Frequency and stochastic High Frequency synthetic seismograms are reconciled at intermediate frequency, where their domain of validity overlaps.

Towards Maximum Observable Shaking maps

BroadBand ground motion scenario computed for a single fault (TF) and MCE floats along the SZ allowing to derive a map that plots the Maximum of the Observable Shaking according to that scenario.

So far the procedure was entirely tested on the Macro Region MR4 (central-northern Apennine), while more detailed analysis is done on the MCE and TF of the Colfiorito composite source earthquake. Here we discuss some aspects of the procedure.

Database of Seismogenic Individual Sources

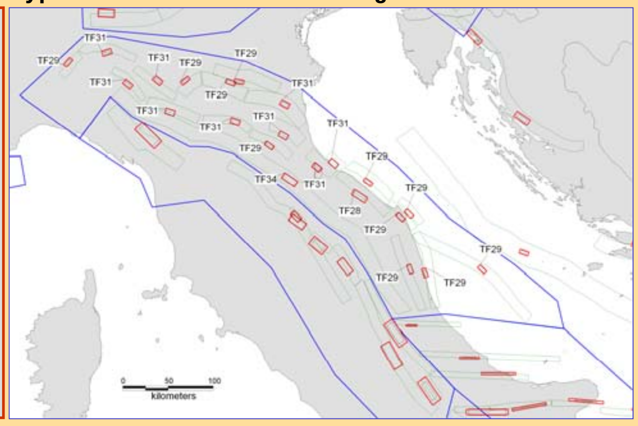


The Database of Individual Seismogenic Sources (DISS) is a repository of geologic, tectonic, and active-fault data for the Italian territory (DISS Working Group, 2007; Basili et al., 2008).

Typical Faults for the macro region MR3

Typical Faults for the MR3 (Central Northern Apennines East), with prevalent reverse faulting. The **TFs** are the black rectangles whereas the red rectangles show the TFs after grouping.

The parent SZ (composite sources from DISS) are shown in green.



THE PROCEDURE of MOS computation

1. **Maximum Credible Earthquake** (MCE): it is defined for each of Seismic Zones (SZ) and associated to a Typical Fault (TF). Each SZ is subdivided with a number of TF
2. **Credible rupture parameters**. The MCE is modeled as a rectangular fault plane. 30 realization of stochastic slip distribution (Mai and Beroza 2002) are used to assess the rupture model
3. **LF wavefield:** computation of the at the site and for a given MCE and TF
4. **HF wavefield:** computation of the at the site and for a given MCE and TF
5. **Hybrid broadband at the site**: derived fom merging the LF and HF spectra in the frequency domain and inverse Fourier transformed to the time domain
6. **Ground shaking computation** (**PGA** from Response Spectral Acceleration, 5% damping; or **SI** (Housner Intensity) from Pseudo Velocity Response Spectrum, 5% damping) at the site
7. **Ground shaking map**: repeat **Step 3 to 6 for each point** of a given GRID surrounding the TF
8. **MOS map**: as the TF floats along the SZ we allow the shake map to "float" as well and pick the maximum shaking at each point of the grid surrounding the SZ

Adopted criteria for grouping the Typical Faults for Italy

Faulting types based on rake (deg)

If Rake > 315 or Rake < 45 then TF = Left lateral;

If Rake >= 45 and Rake <= 135 then TF = Reverse;

If Rake > 135 and Rake < 225 then TF = Right lateral;

If Rake >= 225 and Rake <= 315 then TF = Normal.

Magnitude (Mw)

If Mw <= 5.9 then TF Mw = 5.9;

If Mw > 5.9 and Mw <= 6.3 then TF Mw = 6.3;

If Mw > 6.3 and Mw <= 6.7 then TF Mw = 6.7;

If Mw > 6.7 and Mw <= 7.1 then TF Mw = 7.1.

Depth of the fault top (km)

If Depth <= 4.0 then TF Depth = 1.0;

If Depth > 4.0 and Depth <= 10.0 then TF Depth = 5.0;

If Depth > 10.0 then TF Depth = 10.0.

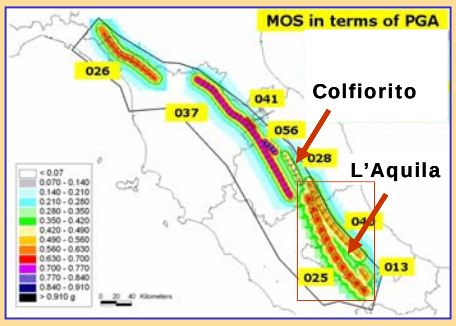
Dip angle of the fault plane (deg)

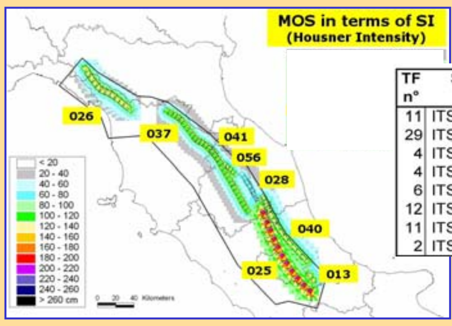
If Dip <= 30 then TF Dip = 25;

If Dip > 30 and Dip <= 60 then TF Dip = 45;

If Dip > 60 and Dip <= 90 then TF Dip = 75.

HF MOS map for the Macro Area MR4



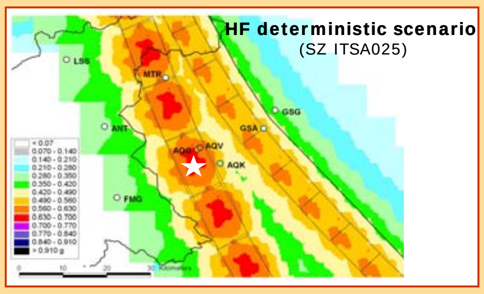


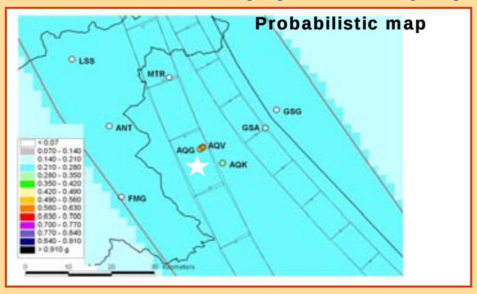
TF n°	SZ ID	MCE Mw	Top (km)
11	ITSA026	6,3	1,0
29	ITSA037	6,1	0,6
4	ITSA041	5,5	1,0
4	ITSA056	6,0	2,5
6	ITSA028	6,0	3,4
12	ITSA040	6,4	1,0
11	ITSA025	6,7	1,0
2	ITSA013	6,4	1,0

The **Macro Region MR4** includes the central-northern Apennines extensional structures and some of the most relevant recent earthquakes in Italy, (i.e., **1915 Avezzano and 1997 Colfiorito, 2009 L'Aquila)**. Top panels plot the MOS maps in terms of PGA (left) and SI (right) computed for an area of about 20 km surrounding each of the typical faults included in MR4. Yellow labels refer to the SZ names (ID) listed in the left table. The red rectangle highlights the area surrounding the **2009 L'Aquila earthquake** .

Table lists the 8 SZ belonging to MR4. TF (n) is the number of TF subdivision for each SZ; ID is the identification code for each SZ; Mw is the magnitude moment for each MCE; Top is the depth to the top of TF.

Deterministic HF MOS scenario and Probabilistic map (R.P. 500 yrs)

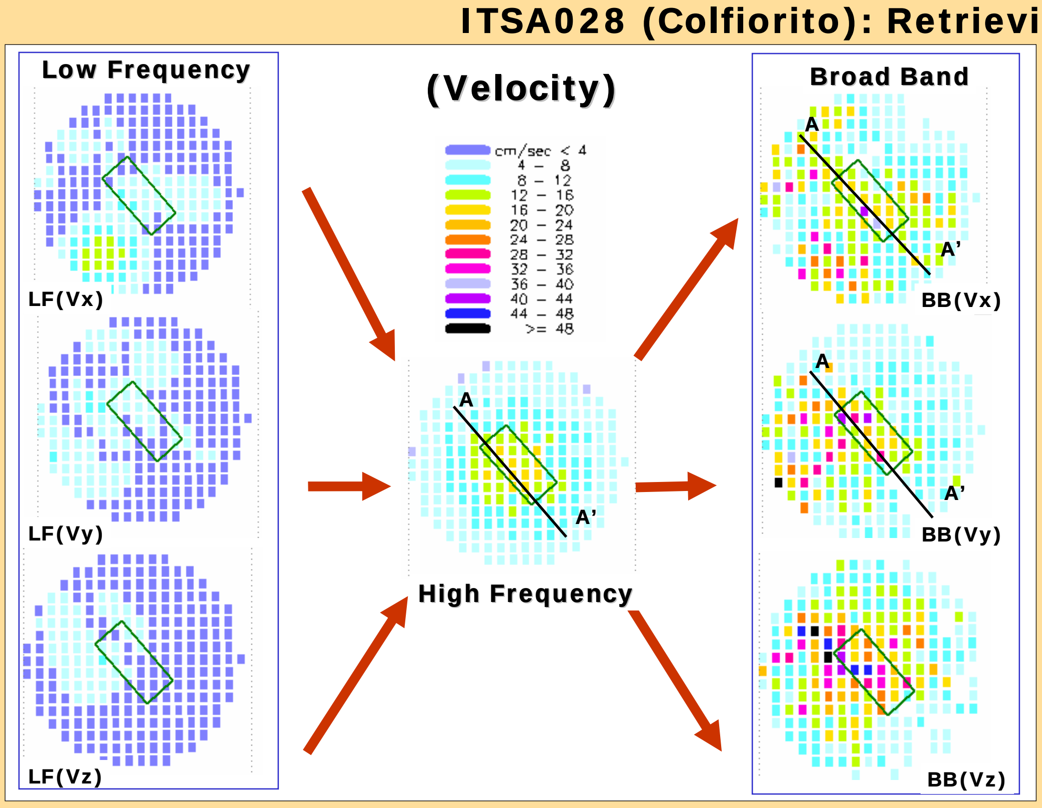




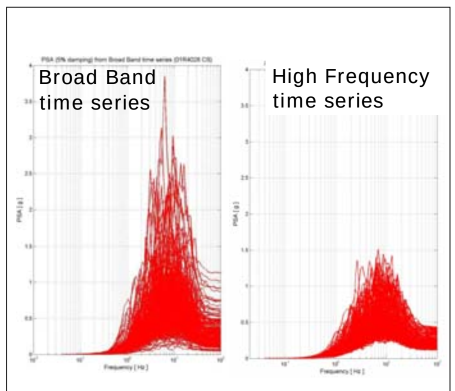
The **2009 (Mw 6.3) L'Aquila earthquake** (white star) occurred within SZ ITSA025. Left panel shows a zoom-in of HF MOS map surrounding the earthquake.

The High Frequency scenario predicts (0.56-0.63 g) higher levels of PGA than those measured during the quake (0.49-0.6 g). However the PGA map (*Pericolosità sismica di riferimento per il territorio nazionale, Ordinanza PCM del 20 marzo 2003*) with return period of 500 years (http://zonesismiche.mi.ingv.it/mappa_ps_apr04/abruzzo.html [interpolated]) predicts acceleration peak of about 0.2 g, well below those measured during the quake (right panel).

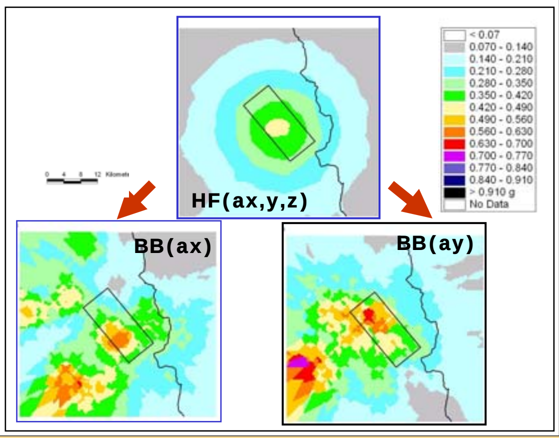
ITSA028 (Colfiorito): Retrieving a BB ground motion map

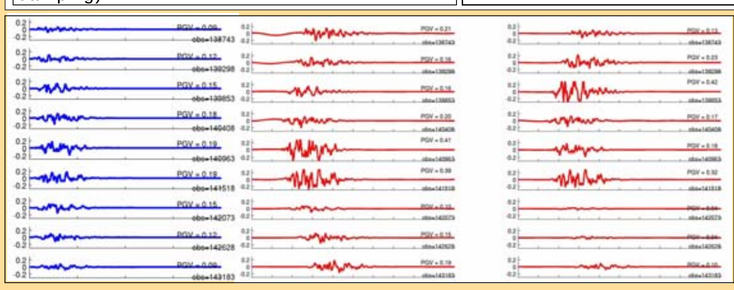


(Acceleration)



Response acceleration spectra (PSA, 5% damping)





AA' profile: High frequency velocity (blue) and BB x and y component velocities (red)

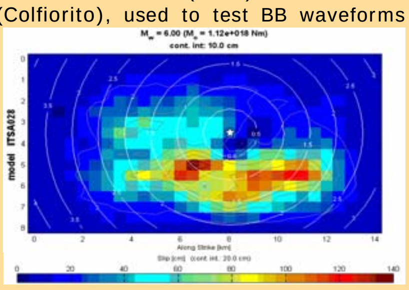
When taking into account the broadband frequency content (from Low to High frequency), ground shaking reveals the complexity of the rupture process. We can observe that the circular fault-centered shaking pattern typical of a simple High Frequency computation is replaced by a more complex distribution where high values of shaking occur both on the fault than in lobe-shaped areas surrounding it (southwestern corner on the map). However, because the process of merging a deterministic LF with a stochastic HF waveforms is not a trivial task several parameters need to be tuned up. For instance we have check carefully the use of magnitude-dependent constant rise time and the BBtool matching frequencies. The BB resulting ground shaking map might have spurious spots that could be avoided applying a smoothing to the plotting routine.

Stochastic rupture model

The input rupture model is defined stochastically according to Mai and Beroza (2003). Here we show rupture simulation for the MCE ITSA028 Seismic Zone (Colfiorito), used to test BB waveforms computation discussed above.

	Rupture parameters									Correlation Function (anisotropic von Karman ACF)		
	M_w	L (km)	W (km)	mech	D_{mean} (cm)	D_{Max} (cm)	M_0 (N m)	τ_r (s)	v_r	a_x (km)	a_y (km)	H
DISS	6.0	14	8	ds	33		1.11e+018					
SlipReal	6.0	14	8	ds	30.36	152.5	1.12e+018	1.5	0.8	3	5	0.6

Table: Length (L); Width (W); faulting mechanism (mech); D_{mean} and D_{Max}= slip; Mo=moment magnitude; r= rise time; v_r=rupture velocity ratio; parameter published in DISS are compared with those derived with the stochastic slip distribution code (SlipReal).



Conclusions & Outlook

- **We have used a "kriging technique" to interpolate the Broad Band MOS map (g) and we can see an underlying simple regular directivity pattern which is overlain by same high/low ground-motion variations**
- **We are ready to calculate the BB MOS maps for Italy, making simple assumptions to group the Typical Faults and reduce computational costs**
- **We need to improve and solve some technical problems in the automatic procedure**

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