Istituto Nazionale di OCEANOGRAFIA e di GEOFISICA SPERIMENTALE
Centro di Ricerche Sismologiche

Complex Source Modelling in Italy: Hints from some Case Studies

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GLOBAL EARTHQUAKE MODEL
working together to assess risk

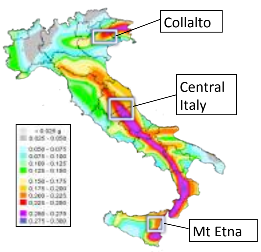
Premise

Earthquake source models based on faults are increasingly being incorporated in seismic hazard assessment. We present 3 probabilistic seismic hazard assessment (PSHA) case studies in Italy that include fault models: the volcanic region of Mt Etna, the Collalto natural gas storage site, and Central Italy following the Amatrice earthquake.

Each of the studies aims to incorporate realistic geological complexities, which is facilitated by using the flexible seismic hazard modeling software, the OpenQuake-engine. For example, all of the studies use complex (i.e. non-rectangular) fault sources to model fault surfaces. We also incorporate the topographic surface in the hazard calculation at Mt Etna, and model aftershock hazard in Central Italy on the fault surface responsible for the Amatrice mainshock.

Sensitivity studies show how changing fault geometry can have large influences on hazard particularly for sites near the rupture surface, and how this depends on the choice of the GMPE. The results of this work are most relevant when working at the local and site-specific scales.

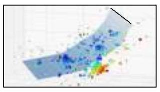
Location of case studies:



National Seismic Hazard Map of Italy
10% PoE 50 years (V_s30=800m/s)

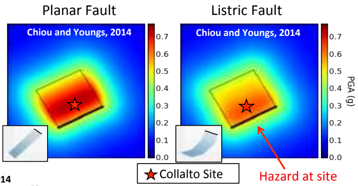
Collalto: listric blind thrust

- Collalto Stoccaggio is a natural gas storage facility, located within the thrust and fold system of South-Eastern Alps. The listric geometry of the faults is depicted thanks to the HQ seismometric network installed for monitoring the potential seismicity induced by the storage (Priolo et al., 2015 and http://rete-collalto.crs.inogs.it/en)



- The area has been affected by a M>6r earthquake in the XVII century, the fault source is unknown; the seismic potential/creeping behavior of Montello thrust debated
- No correlation between the storage activities and seismicity has been observed since 2012 (Romano et al., 2016); thus we assumed the hazard at the site is dominated by natural seismicity
- We performed sensitivity studies to reckon the influences of blind fault geometries on hazard for sites near the rupture, and their dependence on the GMPEs

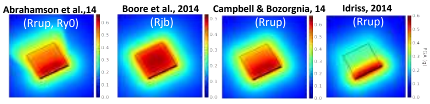
Sensitivity to fault geometry



Comparison of hazard from fault below Collalto site modeled as a planar (left) and listric surface (right). Maps refer to: 2% PoE in 50 years, M_{char}=7.0, and V_s30=800m/s

Hazard at site decreases by 20% using listric geometry

Sensitivity to GMPE distance metric



Comparison of hazard using different NGA-West2 GMPEs (Bozorgnia et al., 2014).
All use the same fault source geometry and magnitude frequency distribution

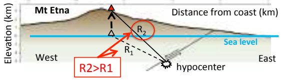
Bozorgnia Y., Abrahamson N. A., Al Atik L., Ancheta T. D., Atkinson G. M., Baker J. W., Baltay A., Boore D. M., Campbell K. W., Chiou B. S.-J., Darragh R., Day S., Donahue J., Graves R. W., Gregor N., Hanks T., Idriss I. M., Kamai R., Kishida T., Kottke A., Mahin S. A., Rezaeian S., Rowshandel B., Seyhan E., Shahi S., Shantz T., Silva W., Spudich P., Stewart J. P., Watson-Lamprey J., Wooddell K., and Youngs R. (2014) NGA-West2 research project, Earthquake Spectra 30 ,973 – 987.

Priolo, E.,Romanelli, M.,Plasencia Linares, M. P.,Garbin, M.,Peruzza, L.,Romano, M. A.,Marotta, P.,Bernardi, P.,Moratto, L.,Zuliani, D., and Fabris, P. (2015). Seismic monitoring of an underground natural gas storage facility: The Collalto Seismic Network, Seismol. Res. Lett. 86, no. 1, 109–123, doi: 10.1785/0220140087

Romano M. A., E. Priolo, M. Garbin, M. Romanelli, M. Plasencia, and L. Peruzza (2016) High-sensitivity seismic monitoring of the Collalto gas storage (Northern Italy) shows no induced seismicity. ESC2016-272, 2016 35th General Assembly of the European Seismological Commission. CCL3.0 http://meetingorganizer.copernicus.org/ESC2016/ESC2016-272.pdf

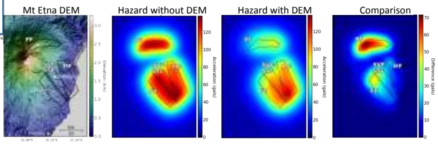
Mt Etna: Volcanic features

- Mt Etna region (Sicily) is modelled by small surficial "tectonic" faults that breathe with the volcanic activity (Azzaro et al., 2017; Peruzza et al., 2017): they are characterized by high quality datasets and intersect a rough topographic surface; local site response cannot be treated by simple rules (e.g. Vs30). Thus, we customized the seismic hazard software, e.g. the OpenQuake-engine, to account for some peculiarities in volcanic contexts, such as GMPE, magnitude scaling relations, to use of a digital elevation model (DEM) for the sites of the hazard calculation and for modeling non-Poissonian processes.
- Results show that the small magnitudes of surficial volcano-tectonic events have a strong impact on 5-10 year shaking forecasts, thus driving retrofitting and impendent strategies for risk reduction.



Since 2014, OGS has been contributing to the development and implementation of the Open-Quake engine (Pagani et al., 2014)

Sensitivity to topography



Comparison of hazard using area sources, all assigned the same magnitude frequency distribution at 2.5 km depth. Maps refer to: 10% PoE in 50 years and V_s30=800m/s

Azzaro et al. (2017) When probabilistic seismic hazard climbs volcanoes: the Mt Etna case, Italy. Part I: model components for sources parametrization, NHESS Discuss., https://doi.org/10.5194/nhess-2017-127

Pagani M., Monelli D., Weatherill G., Danciu L., Crowley H., Silva V., Henshaw P., Butler L., Nastasi M., Panzeri L., Simionato M. and Viganò D. (2014). OpenQuake-engine: An open hazard (and risk) software for the Global Earthquake Model, Seismol. Res. Lett., 85, 692-702; doi:10.1785/0220130087

Peruzza et al. (2017) When probabilistic seismic hazard climbs volcanoes: the Mt Etna case, Italy – Part 2: computational implementation and first results, NHESS Discuss., https://doi.org/10.5194/nhess-2017-121

TAKE HOME message

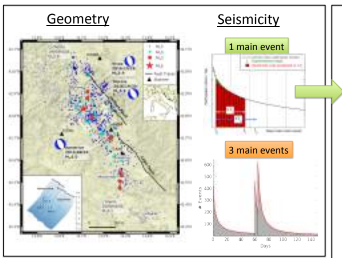
Collalto: if you don't know the fault geometry with precision, avoid using sophisticated fault source models as they can drive the hazard in wrong places

Mt Etna: metrics of volcanic regions is different (e.g. for MSR, magnitude scaling relation; GMPE, ground motion prediction equation); minor-moderate earthquakes (M<4.5) and topography/local site response are key components

Central Italy: aftershock hazard is driven by the occurrences of minor-moderate earthquakes. Simple rules on the decay of aftershock, joined with a precise fault geometry definition and hypocentral parametrization of the main events, are able to reproduce the observations

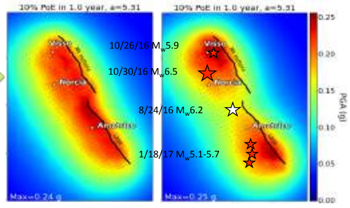
Central Italy: Aftershock PSHA on a normal fault

Source characterization



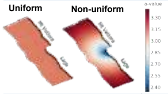
Fault source geometry (inset, left figure) based on past (e.g. Barchi et al., 1999) and recent investigations (e.g. Lavecchia et al., 2016); seismicity rate are taken from the initial aftershocks decay (right figure, upper frame) , applied and renewed after the Visso earthquake (Oct 26, M5.9); after the main Main earthquake (M6.5, Oct 30) the global aftershocks decay curve has been re-evaluated, following the same rules adopted in Peruzza et al., 2016.
The APSHA is given by the combinations of decay curves rates, on the basis of the investigation period selected.
The Maximum magnitude for aftershock hazard is taken as M_{main}-0.5, b-value assigned at 1.0

Aftershock hazard



Hazard maps from Oct 1, 2016 with aftershock seismicity distributed uniformly across fault (left) and increasing away from the rupture (white star, right)

Seismicity partitioning based on simple rules



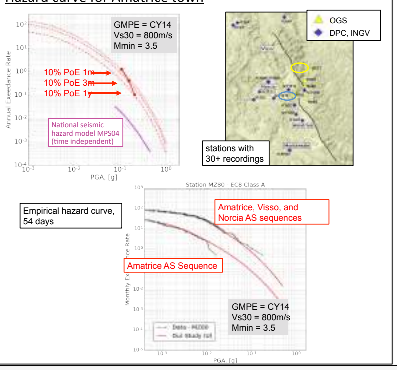
Consider 2 cases:
1. Uniform across fault
2. Non-Uniform (fn of distance from hypocenter)

Not applied for multiple main shocks

(a-value = 5.75, 400 point sources, $\dot{M}_o$ conserved)

Results and comparison with observations

Hazard curve for Amatrice town



- We performed Aftershock PSHA just after the August 24th, 2016 Amatrice earthquake (Peruzza et al., 2016)
- The time-dependent model computes occurrence rates with a decrease following an Omori-Utsu decay curve
- Different partitioning scheme are used, all based on very simple rules
- After the occurrence of the October "main" events, the Omori curve is done by the summation of decay curves
- Aftershock hazard is compared with observations at some accelerometric/velocimetric stations.
- The agreement of modelled and observed hazard is very promising
- Great care has to be applied in extrapolating these results to uncomplete series of observations, or to sites with strong local site effects

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Lavecchia, G., et al. (2016), Ground deformation and source geometry of the 24 August 2016 Amatrice earthquake (Central Italy) investigated through analytical and numerical modeling of DInSAR measurements and structural-geological data, Geophys. Res. Lett., 43, 12,389–12,398, doi:10.1002/2016GL071723.
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