Evaluation of tsunamigenic hazard through numerical modeling from seismic and non-seismic sources in the Crotone offshore (Calabria, Southern Italy)

Evaluation of tsunamigenic hazard through numerical modeling from seismic and non-seismic sources in the Crotone offshore (Calabria, Southern Italy)

F. Zaniboni[1,3], C. Angeli[1], A. Argnani[2], Antoncecchi I.[5], Di Bucci D.[4], G. Gallotti[1], L. Lipparini[3], I. Molinari[3], M. Rovere[2], G. Sgattoni[3], M. Zanetti[1], A. Armigliato[1]

1. Dipartimento di Fisica e Astronomia "A. Righi", Università di Bologna, Bologna, Italy
2. ISMAR – CNR, Bologna, Italy
3. INGV - Sezione di Bologna, Bologna, Italy
4. Dipartimento della Protezione Civile, Roma, Italy
5. Italian Ministry of Environment and Energy Security dell'Ambiente e della Sicurezza Energetica, Roma, Italy

Tsunamis in the Mediterranean Sea can be considered among the major sources of hazard, both for the extension of the area that can be involved by the water impact and for the closeness of potential sources to the coast, which reduces dramatically the alert and evacuation time. Moreover, landslides, as other non-seismic tsunami sources, are often characterized by a lack of precursors (such as seismic shaking), a reason for which the ensuing waves are sometimes called "surprise tsunamis".

Numerical simulations can first quantify the coastal stretch extension and the size of the tsunami impact on coastal buildings and infrastructures. The University of Bologna Tsunami Research Team has developed in the years a set of numerical codes simulating the different phases of the phenomenon, both for seismic and for non-seismic sources: for the former, the hypothesized seismogenic fault provides the instantaneous impulse for the wave propagation; for the latter, the landslide stability is studied, also taking into account the possible seismic trigger, whereas the simulation of the slide dynamics supplies the time-dependent forcing for tsunami propagation. In both cases, then, wave propagation in the marine water body and coastal flooding are mimicked by solving the hydrodynamic equations through numerical techniques. This numerical approach has been applied to many cases (see the recent publications by Gasperini et al., 2022; Gallotti et al., 2021; Zaniboni et al., 2021, and further references therein).

The H&RA Lacinia project, funded by the Italian Ministry of Environment and Energy Security, aimed at developing a methodology to study natural hazards potentially triggered by offshore production activities. In this framework, the area offshore Crotone (Ionian Calabria coast, Southern Italy) has been chosen as a test site.

Here, two types of potential tsunami sources have been identified: on one side, five possible earthquake scenarios have been defined, based on the seismogenic structures known in the area, the historical and instrumental seismic data, and the general geodynamic model defined within the project. On the other side, geomorphological considerations and geophysical data analysis contributed to the individuation of three underwater landslide scenarios, located respectively in the study area's northern, central and southern part.

The tsunami simulation codes provide outputs that can be used to assess the impact of the flooding on coastal structures, allowing to estimate casualties and damages related to the tsunami scenarios. This latter task has been accomplished by the engineering component of the H&RA Lacinia project (ReLUIS, the Italian Network of the University Laboratories of Seismic Engineering).

The scenarios deriving from the seismogenic faults with an inferred magnitude ranging from 6.0 to 6.9 Mw and located offshore Crotone provide the tsunami initial condition in terms of coseismic vertical displacement of the seafloor and the coast. In addition, the related seismic shaking may also contribute to landslide destabilization: such a trigger is parametrized in the model with the maximum peak ground acceleration affecting the landslide area. Landslide scenarios are placed in relatively deep water (from 400 to 1000 m sea depth), with volumes of less than 0.5 km^3: for two of them, a slump behavior is prescribed (low run-out and deformation); for the remaining one a debris-flow-like motion has been defined (long run-out and high deformability).

The application of the numerical routines described above produces tsunami propagation in the computational domain and an assessment of the wave impact on the coast. In this case study, it is found that no catastrophic waves are hitting the coast: in one of the landslide scenarios, the maximum water height can reach more than 3 m, localized over a short coastal stretch, while only two out of five earthquake scenarios are able to produce local maxima between 1.5 and 2 m. Coastal flooding is generally limited to the first inland cells, since the maximum waves hit the steepest coastline, whereas the flat coast (north of Crotone harbor) is affected by lower water elevations. Two features in the area may deserve further analysis: the first is the Crotone harbor, where the two sub-basins can give rise to resonance phenomena that can considerably enhance the effects of the incoming wave, causing possible damage to boats and facilities; the other is the mouth of water streams, especially the Neto river, about 10 km north of Crotone, and the Esaro river, just at the northern end of the Crotone harbor, in correspondence of which underwater morphology may cause tsunami energy focusing, and the presence of the water streams themselves fosters the tsunami inland penetration.

References

Gallotti G., Zaniboni F., Pagnoni G., Romagnoli C., Gamberi F., Marani M., Tinti S.; 2021. *Tsunamis from prospected mass failure on the Marsili submarine volcano flanks and hints for tsunami hazard evaluation*. Bulletin of Volcanology (2021) 83: 2. https://doi.org/10.1007/s00445-020-01425-0.

Gasperini L. Zaniboni F., Armigliato A., Tinti S., Pagnoni G., Özeren M.S.,·Ligi M., Natali F., Polonia A. (2022). Tsunami potential source in the eastern Sea of Marmara (NW Turkey), along the North Anatolian Fault system. Landslides, 19 (10), 2295-2310. DOI 10.1007/s10346-022-01929-0.

Zaniboni F., Pagnoni G., Paparo M.A., Gauchery T., Rovere M., Argnani A., Armigliato A. and Tinti S. (2021), Tsunamis From Submarine Collapses Along the Eastern Slope of the Gela Basin Strait of Sicily). Front. Earth Sci. 8:602171. DOI: 10.3389/feart.2020.602171.

Reference author contact: filippo.zaniboni@unibo.it