Earthquake scenarios for active seismic gaps: a hybrid deterministic and stochastic approach for tsunami hazard assessment

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Abstract

Plausible worst-case earthquake scenarios definition plays a relevant role in tsunami hazard assessment focused in emergency preparedness, evacuation planning and optimal location of critical infrastructure for coastal communities located in active seismic gaps. During the last decades, the occurrence of major and moderate tsunamigenic earthquakes along worldwide subduction zones has given clues about critical parameters involved in near-field tsunami inundation processes, i.e. slip spatial distribution, shelf resonance of edge waves and local geomorphology effects. To evaluate the behavior of these geological and hydrodynamic variables over the coastal inundation, we focused in the northern (~17° to 24°S) and central (~30° to 37°S) segments of the chilean continental margin that constitutes an active subduction zones, with a high seismogenic potential to release a $M_w > 9$ earthquakes in a near future and therefore a relevant tsunami threat for all near-field cities in the region. Regarding this fact, we propose a hybrid deterministic and stochastic multi-scenario approach to assess the current state of tsunami hazard of the coastal zone. The deterministic worst-case scenarios are estimated using regional distribution of gravity anomalies, a worldwide model of subduction zones geometry and published interseismic coupling anomalies. Initially, we can find the spatial distribution of major seismic asperities of the studied gaps, used to construct a preliminary group of slip-deficit sources for evaluate the range of magnitudes of expected earthquake scenarios. Subsequently following a stochastic scheme, we implement a Karhunen-Loève expansion (LeVeque *et al.*, 2016; Melgar *et al.*, 2016) to generate a finite number of stochastic scenarios (~500 to 1000) (Figure 1) over the maximum extension of the active seismic gaps (González *et al.*, 2019). All the scenarios are simulated through a non-hydrostatic tsunami model, Neowave 2D, using a classical nesting scheme for all studied cities obtaining high resolution data of inundation depth, runup, coastal currents and sea level elevation. The stochastic kinematic tsunamigenic scenarios give a more realistic slip patterns, similar to maximum slip amount of major past earthquakes occurred in the active seismic gaps.

Perspectives of collaboration

- Methodological improvements of proposed approach.
- Implementation in other active seismic gaps (e.g. Cascadia and Japan).
- Reconstruction of major earthquakes scenarios (e.g. 1868 and 1877 earthquakes in southern Peru and northern Chile, 1730 earthquake in central Chile and 1700 earthquake in Cascadia), constraining using historical and geological data.

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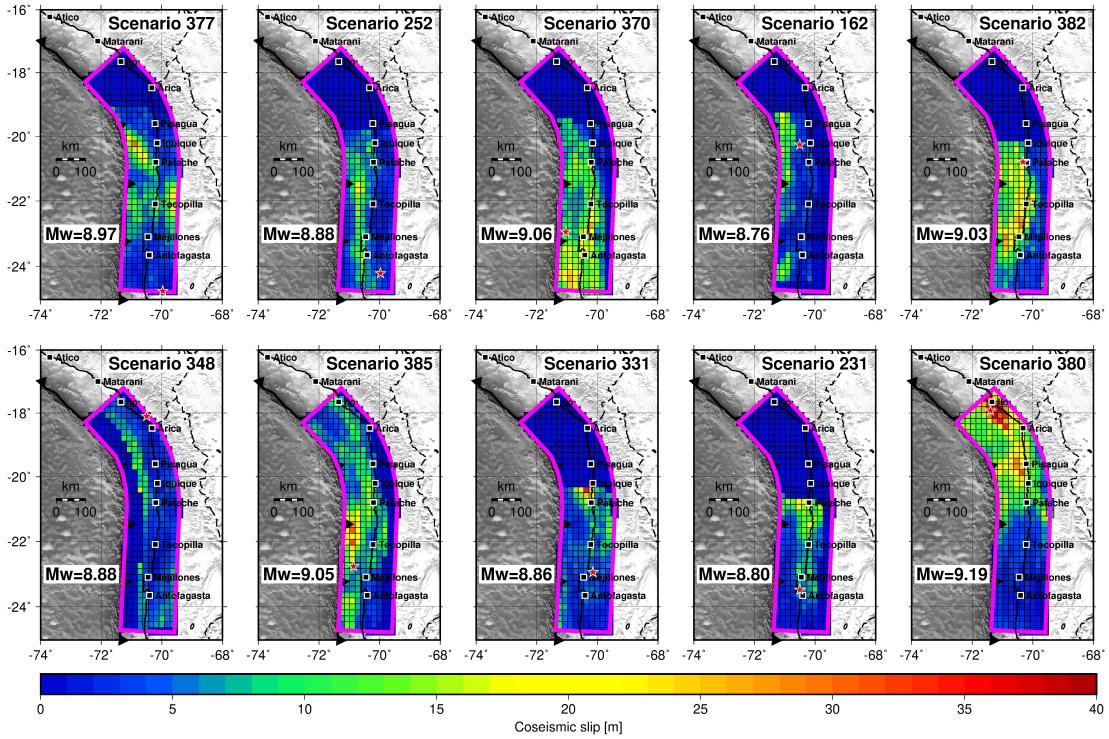

Figure 1. Example of K-L expansion stochastic earthquakes scenarios for southern Peru and northern Chile seismic gap.

References

González, J., González, G., Aránguiz, R., Melgar, D., Zamora, N., Shrivastava, M. N., Das, R., Catalán, P.A., & Cienfuegos, R. (2019). A hybrid deterministic and stochastic approach for tsunami hazard assessment in Iquique, Chile. *Natural Hazards*, 1–41. https://doi.org/submitted

LeVeque, R. J., Waagan, K., González, F. I., Rim, D., & Lin, G. (2016). Generating Random Earthquake Events for Probabilistic Tsunami Hazard Assessment. *Pure and Applied Geophysics*, *173*(12), 3671–3692. https://doi.org/10.1007/s00024-016-1357-1

Melgar, D., LeVeque, R. J., Dreger, D. S., & Allen, R. M. (2016). Kinematic rupture scenarios and synthetic displacement data: An example application to the Cascadia subduction zone. *Journal of Geophysical Research: Solid Earth*, *121*(9), 6658–6674. https://doi.org/10.1002/2016JB013314