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Real-Time Automated Forecasting System for Tsunami Hazard and Exposure Reports Using Numerical Simulations and Web-Based Geospatial Visualization

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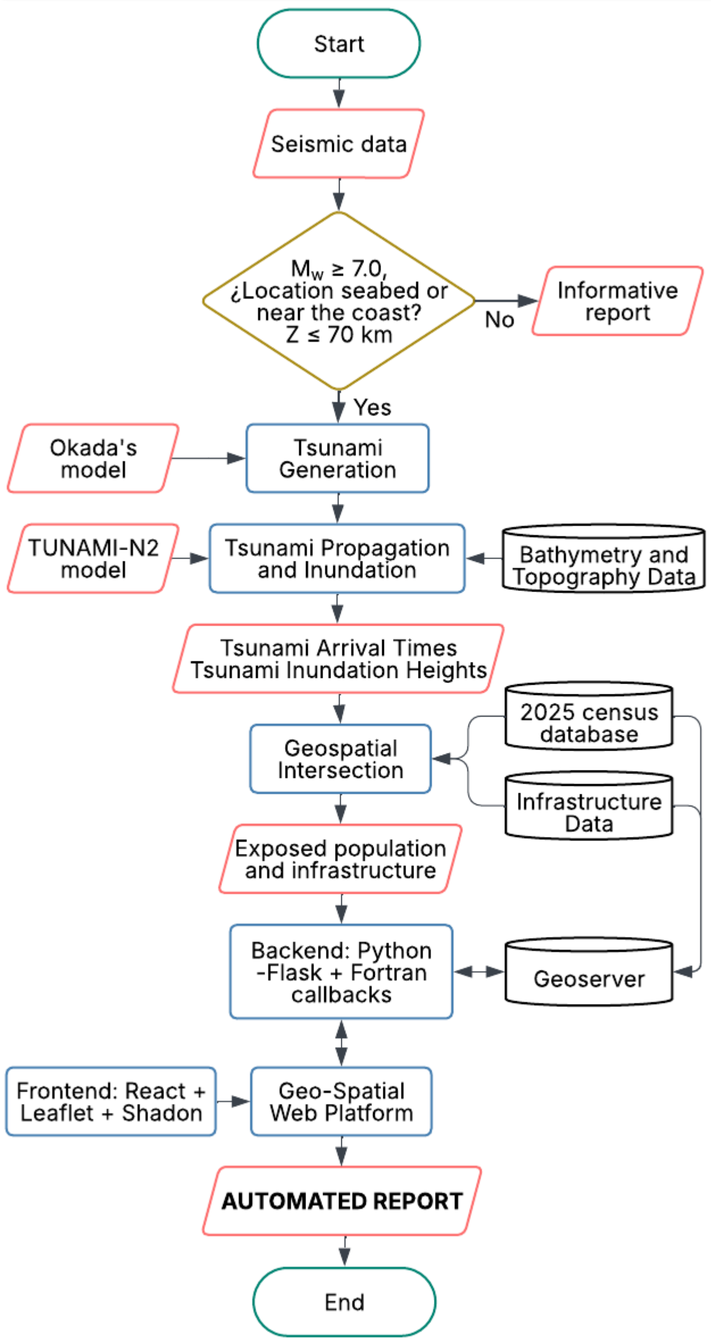
INTRODUCTION & AIM

Recent tsunami disasters worldwide have highlighted the need for rapid hazard assessments in tsunami-prone regions. In Peru, existing technical reporting procedures often require extensive manual analysis [1], slowing down official response actions. Advances in numerical modeling [2], geospatial data [3], and web-based technologies [4] now enable the development of automated systems capable of delivering actionable hazard information in near real time. Building on this motivation, we present a forecasting system that automatically generates standardized technical tsunami reports within minutes by integrating (1) numerical simulations, (2) geospatial exposure analysis, and (3) interactive web visualization.

METHOD



Preliminary Analysis:
Seismic data are automatically extracted from seismic reports by the Geophysical Institute of Peru.
Filter to identify tsunamigenic earthquakes ($M_w \geq 7.0$, shallow and offshore).

(1) Numerical Simulation:
Initial deformation and tsunami propagation/inundation are simulated using the Okada and TUNAMI-N2 models. Key outputs include tsunami arrival times and inundation heights.

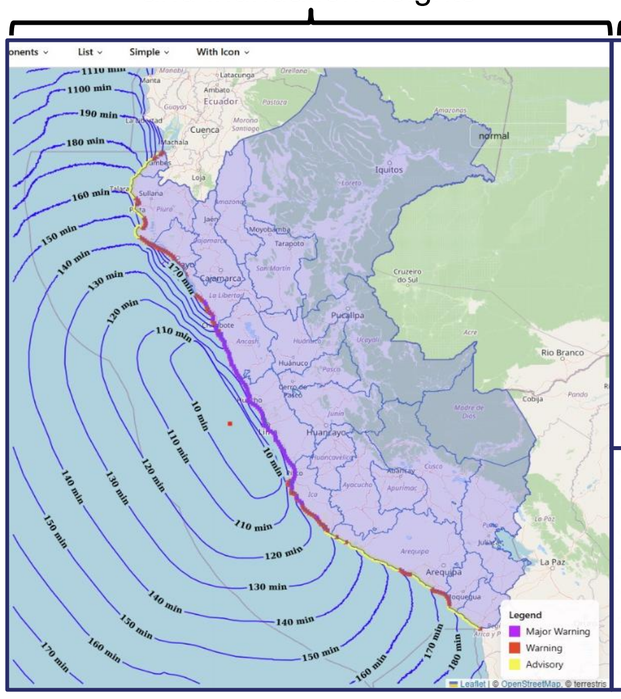
(2) GIS Exposure Analysis:
Tsunami inundation results are intersected with census and infrastructure datasets to estimate exposed population and infrastructure.

(3) Int. Web Visualization:
Hazard and exposure outputs are published on a web platform with interactive maps for rapid decision support.

RESULTS & DISCUSSION

(1) Tsunami arrival times and inundation heights

(2) Summary of exposed population and infrastructure



Element	Attributes	Sub-attribute	Advisory	Warning	Major warning
Population	Age	<15 years old	1,785	3,389	3,143
		15–65 years old	5,078	9,367	8,531
		>65 years old	905	2,167	1,731
	Community education	Students	4,066	3,987	4,173
		Teachers	213	204	240
Buildings	Critical	Educational institutions	30	24	41
		Health facilities	4	5	6
		Public health facilities	0	2	0
		Police station	1	0	0
		Fire stations	0	1	0
	Residential	Housing	2,054	4,167	3,744
		Urban blocks	73	97	121

Population and building exposure by level of the scenario.

Province	Arrival time (min)	Innundation height(m)	Condition
ZARUMILLA	112	1.26	Warning
TUMBES	92	1.62	Warning
CONTRALMIRANTE VILLAR	54	0.86	Advisory
TALARA	46	0.84	Advisory
PAITA	51	2.21	Warning
SECHURA	44	1.87	Warning
LAMBAYEQUE	69	1.62	Warning

(3) Summary of tsunami results for each region

The forecast system was applied for the great 1746 Lima-Callao earthquake (M_w 9.0, one of Peru's largest tsunamigenic events) using the optimized gWave model [5] to obtain simulation results within minutes. The left panel (1) shows tsunami arrival times and inundation heights categorized into three ranges (0.3–1 m, 1–2 m, and >2 m for advisory, warning, and major warning, respectively), allowing rapid identification of the most impacted coastal regions. The upper-right table (2) is dynamic: users can zoom and select regions, provinces, or districts, and the table automatically updates to summarize population and infrastructure exposure for the selected area. Finally, the lower-right table (3) provides arrival times, maximum inundation heights, and the corresponding hazard level for each region, clearly distinguishing areas requiring advisory, warning, or major warning actions. These results demonstrate the system's ability to rapidly convert simulations into actionable decision-support information.

CONCLUSION

The automated tsunami forecasting system for hazard and exposure reports successfully integrates numerical simulations, geospatial exposure analysis, and interactive web visualization to produce technical reports within minutes. Tests with historical events demonstrate that the system can rapidly calculate tsunami arrival times and inundation heights, quantify exposed populations and infrastructure, and deliver action information for disaster response. This approach accelerates decision-making during tsunami emergencies and provides a baseline for future multi-hazard and real-time research.

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