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TSUNAMI SIMULATION AND HAZARD ASSESSMENT FOR MEGATHRUST EARTHQUAKES ALONG THE COASTS OF THE SOLOMON ISLANDS

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ABSTRACT

The Solomon Island has experienced earthquakes that were highly tsunamic genic in nature. Recent large earthquakes occurred near the plate convergence zone between the Australian and the Pacific Plates. Still, seismic gaps exist in areas along the subduction zone. Therefore, this study looks into scenario earthquakes along with these seismic gaps in the western and eastern parts of the Solomon Islands. TUNAMI numerical simulation code was adopted to investigate tsunami hazards in the study area. We assumed the two scenario rectangular fault models with different amounts of slips (i.e., 2 m, 5 m, and 10 m) and calculated seafloor deformation and tsunami propagation. We used GEBCO Data for bathymetry, SRTM data for topography in inundation modeling. We assumed output points to get tsunami waveforms for different islands and to get maximum wave heights and their arrival time on the target locations. Here, we discuss the results for the assumed fault model with 10m slip for two scenario earthquakes. For the western Solomon study areas, the maximum wave height is 4.8 m on Rennell Island and is 3.6 m at the coastline of Guadalcanal Island. For the eastern Solomon study areas, the maximum wave heights of 4.9 m and 1.98 m are observed at Nama and Avita on Santa Cruz Islands, with arrival times of 20 and 10 minutes, respectively. The tsunami inundation modeling shows run-up distance of more than 100 m for Managakiki coastlines and 84m for the coastline of Nama settlement in Santa Cruz Islands. The study demonstrated an overview of possible seismic events that will help tsunami disaster management and planning for the Solomon Islands. Accurate data and finer bathymetric data are crucial in improving simulations within other seismic-prone areas within the Solomon Islands.

Keywords: Tsunami propagation, Tsunami simulation, Tsunami Inundation, Tsunami Height, GEBCO.

1. INTRODUCTION

The Solomon Islands archipelago is located along the ring of fire and has been prone to earthquake, volcano, and tsunami hazards. Records of earthquakes, tsunami, and volcanic events have shown the damages and casualties in the Solomon Islands in the past. The Solomon Island's chain of islands is located close to the active subduction zone and a trench system as described by Peterson et al. (1999). The 2007 western Solomon Islands earthquake with an Mw 8.1 generated a tsunami and caused damages and casualties to villages and provincial centers close to its epicenter (e.g., Wei et al., 2015). Following the western Solomon event, 2010 and 2013 events occurred in the western and eastern part of the Solomon Islands. Still, seismic gaps exist in areas along the Solomon subduction zone (e.g., Chen et al., 2011). Thus, this study develops a tsunami propagation model and estimates tsunami arrival times and maximum wave height to assess tsunami hazards along the coast of the Solomon Islands and

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develop a tsunami inundation model for scenario earthquakes that can be useful for rapid assessment and disaster planning.

2. DATA

The General Bathymetric Chart of the Oceans (GEBCO) is downloaded for use in this study. The GEBCO data is available through the website (https://www.gebco.net/data_and_products/gridded_bathymetrry_data/gebco_2020/), and we download the 15-arc-second grid for use in this study. The 15-arc-second grid, resampled to 1 min-arc grid, forms the basis of data that are used in tsunami modeling along the subduction zones (Figure 1, Table 1). The Shuttle Radar Topography Mission (SRTM) is one arc minute data available from the USGS site. We used the SRTM data for populated islands near the subduction zones and used it to simulate inundation. The SRTM data is merged with GEBCO data to get finer grid data to simulate inundation for a selected region within the study area (Figure 2).

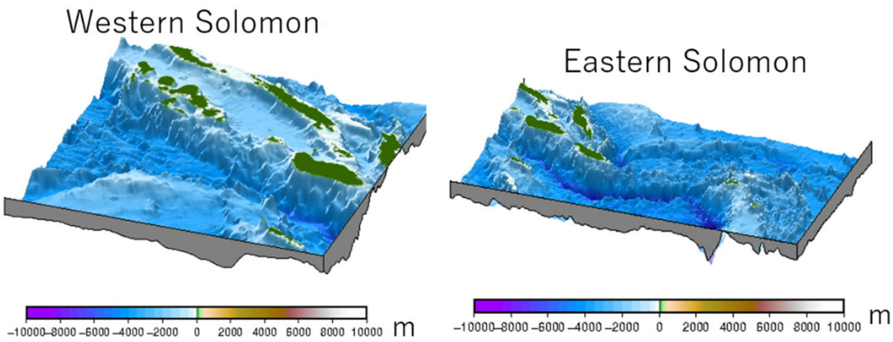


Figure 1 GEBCO Data for bathymetry of Western Solomon (left) and Eastern Solomon (right).

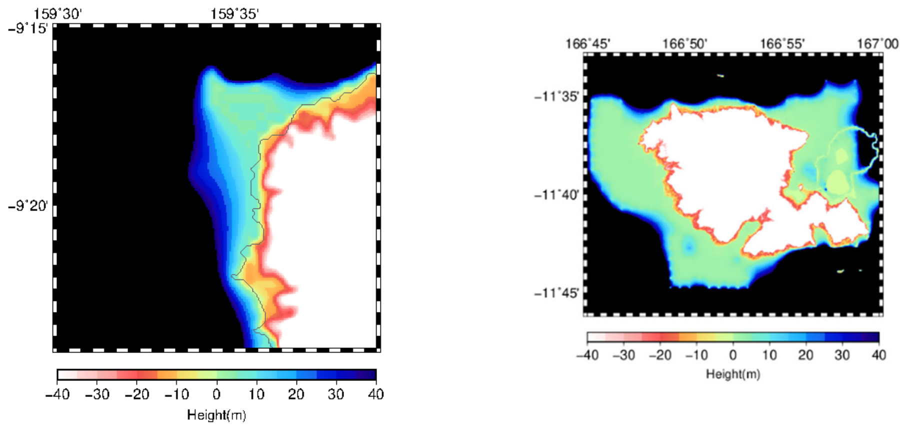


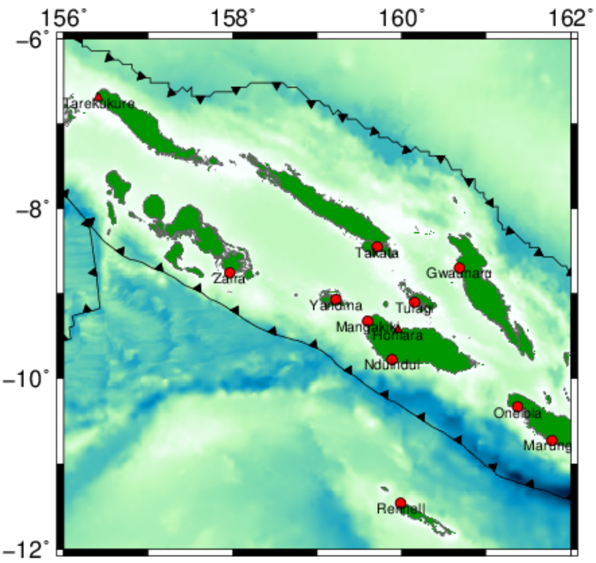
Figure 2 Merged SRTM Data with GEBCO data for Guadalcanal (Western Solomon) (left) and Vanikoro island (Eastern Solomon) (right).

To simulate wave propagation and to investigate tsunami heights and arrival times for the study areas, the computation parameters for the broader regions are given in Table 1. Output points for tsunami wave calculation to estimate tsunami height and arrival times are shown in Figure 3.

Table 1 Computational settings for wave propagation

Region	Data Source	Grid dimension (nx /ny)	Spatial grid size (Δx /Δy) (m)	Temporal grid size (sec)
Western Solomon	GEBCO 1-arc minute	360 /360	1832 / 1843	3

Eastern Solomon	GEBCO 1-arc minute	480 / 480	1821 / 1843	3



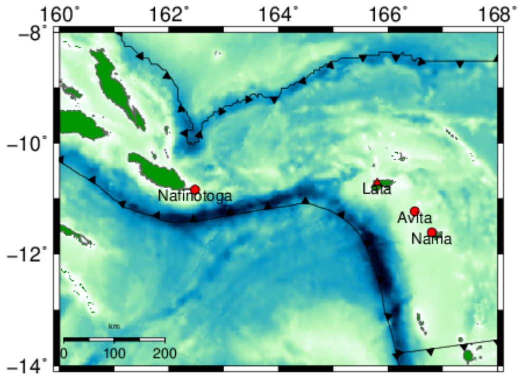


Figure 3 Output points used for tsunami wave height and arrival time calculations for western (left) and eastern (right) Solomon study area

For tsunami inundation modelling, we use a nesting grid system. Tables 2 and 3 give four regions and resolutions for the nesting grid system for the western and eastern Solomon Islands.

Table 2 Nesting grid parameters for western region tsunami simulation

Region	Longitude	Latitude	Grid size (arcsec)	Number of Grid nx * ny	Data Source
1	156/162	-12/-6	60	480x360	GEBCO_2020
2	159/161	-10/-8.8	20	300x210	GEBCO_2020
3	159.2/160.30	-9.214/-9.075	6.6667	225 x 252	GEBCO_2020
4	159.45/159.75	-9.46/-9.23	2.2222	405 x 540	GEBCO_2014/2020+SRTM

Table 3 Nesting grid parameters for eastern region tsunami simulation

Region	Longitude	Latitude	Grid size (arcsec)	Number of Grid nx * ny	Data Source
1	160/168	-14/-8	60	480x360	GEBCO_2020
2	165/167.8	-12.5/-10.5	20	510x360	GEBCO_2020
3	166.085/167.433	-12.214/-11.075	6.6667	728 x 615	GEBCO_2020
4	166.75/167	-11.8333/-11.5	2.2222	405 x 540	GEBCO_2014/2020+SRTM

3. METHODOLOGY

Tsunami wave propagation can be explained by the shallow water theory. Here, we introduce equations used in tsunami numerical simulation (Koshimura, 2021). The continuity equation and the momentum equation derived from the Euler's equation set (Koshimura, 2021) are adopted to describe the water motion. This study adopts the Tohoku University's Numerical Analysis Model to investigate Near-field tsunamis (TUNAMI) code. More specifically, we use the modified version of TUNAMI code by Prof.

Koshimura (Fuji, 2021), to calculate tsunami propagation and simulation along the coastlines of the study area. We use the inundation simulation model (Yanagisawa, 2021), which adopts the spherical coordinate system for both study areas.

4. RESULTS AND DISCUSSION

We simulate tsunami wave propagation for two different regions using the GEBCO bathymetry data. We use different fault slips (2, 5, 10 m) for two earthquake scenarios. Figure 4 shows snapshots of tsunami wave propagation for case I-3 (10 m slip) in western Solomon and for case II-3 (10 m slip) in eastern Solomon, respectively, at the elapsed time of zero minutes (initial time), 15 minutes, and 30 minutes.

Figures 5 and 6 show the calculated tsunami waveforms for the study regions for the case of 10 m slip in the western Solomon and for the case of 10 m slip in the eastern Solomon, respectively.

For the western Solomon study region, there are 11 output points (the results of four points are shown here), and for the eastern Solomon study region, there are four outpoints. From the calculated waveforms, the tsunami arrival times and the maximum tsunami height can be determined. Travel time and the maximum tsunami height are important in this simulation study. We investigate three models (2, 5, 10 m) for western and eastern study regions to examine tsunami wave heights and the travel time for coastlines close to the hypocenter.

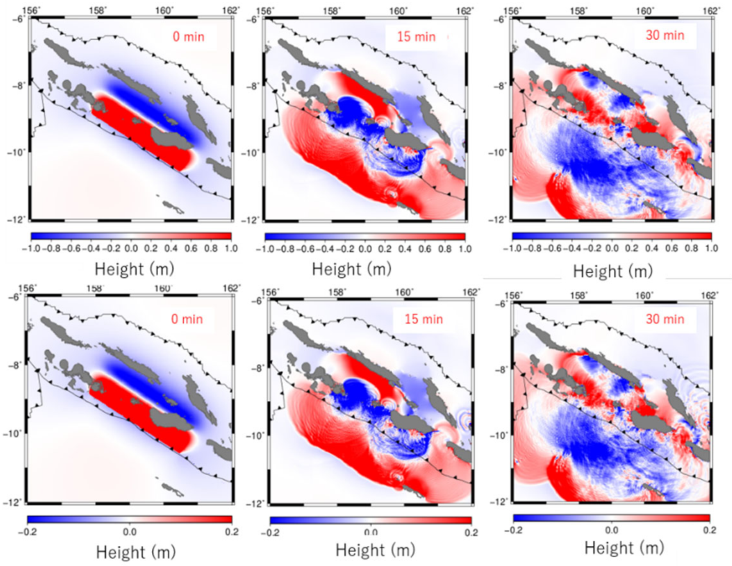


Figure 4 Snapshots of tsunami wave propagation (0, 15, 30 min.) for western (top) and eastern (bottom) Solomon study area

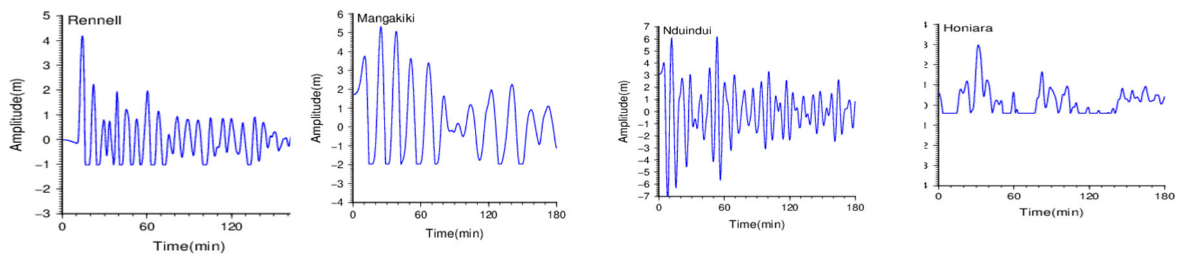


Figure 5 Waveforms at output points (Figure 3 left) for the western Solomon study area.

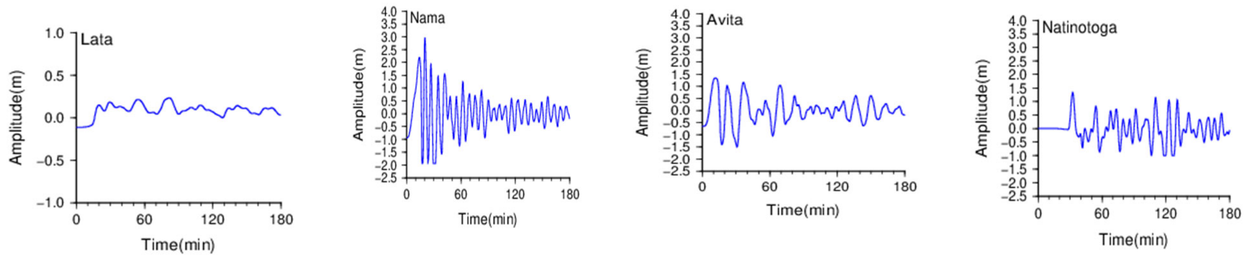


Figure 6 Waveforms at output points (Figure 3 right) for the eastern Solomon study area.

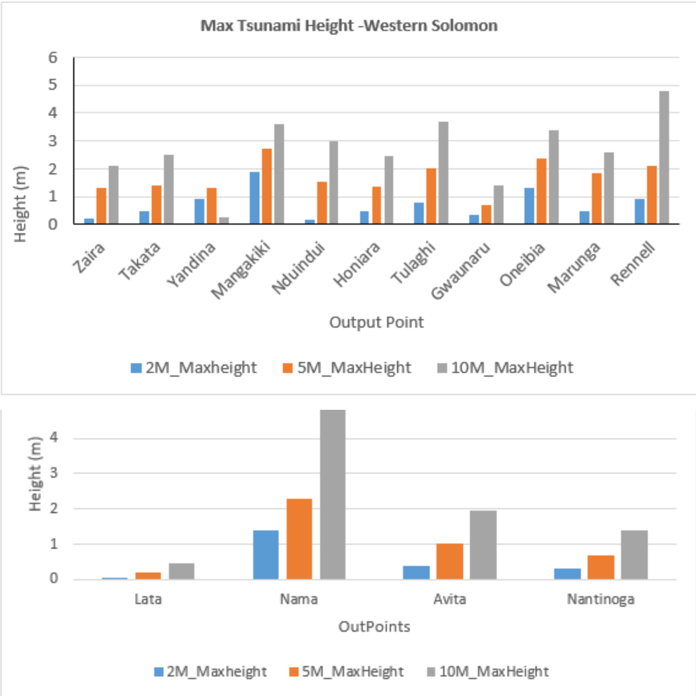


Figure 7 Maximum tsunami heights graphs for both western (top) and eastern (bottom) study area

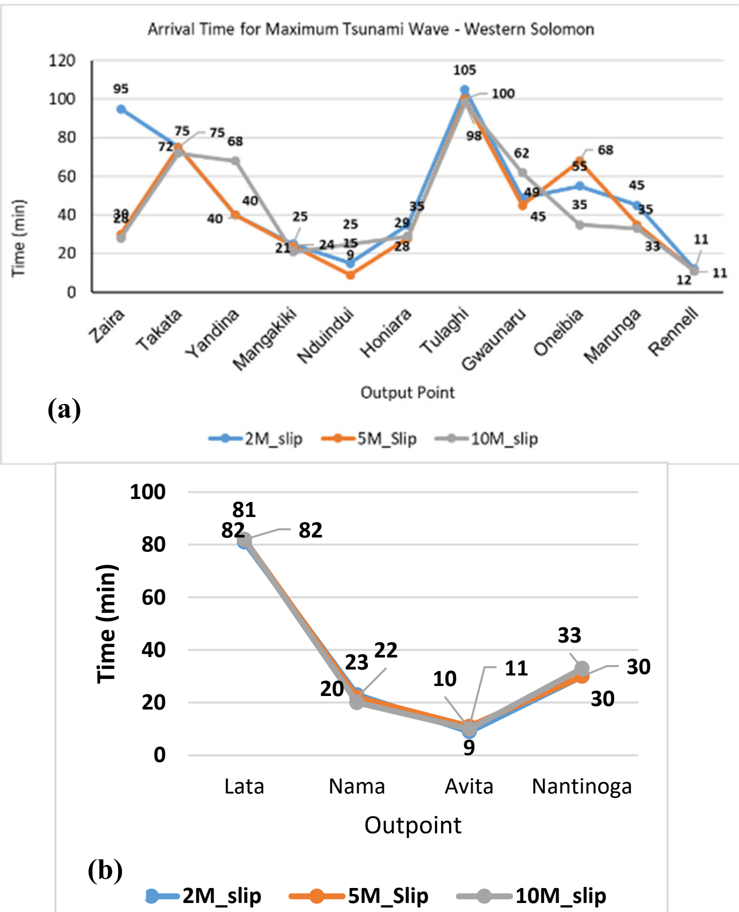


Figure 8 Maximum tsunami arrival time for both western (a) and eastern (b) study areas.

Figure 7 shows the calculated maximum tsunami wave heights for different output points for the western and eastern Solomon study areas. Hereafter, we discuss the results of 10m slip models.

For the western Solomon study areas, the maximum wave height is 4.8 m on Rennell Island and is 3.6 m at the coastline of Guadalcanal Island. The arrival time of the maximum tsunami wave is 11 minutes at Rennell Island (Figure 8a).

The maximum tsunami wave heights are observed on Nama (4.9 m) coastline and Avita (1.95 m). The arrival time for maximum tsunami heights on the coastline of Avita is within 10 minutes, and for Nama, the arrival time is within 20 minutes (Figure 8b) of earthquake event

4.1 Tsunami inundation

Inundation modeling is performed for Mangakiki in the western Solomon and one of the islands in the Santa Cruz regions in the eastern Solomon. The run-up height and inundation area are important for tsunami hazard assessment and disaster planning. Figure 9 below shows inundation depths and run up distance for Mangakiki and Nama. Figure 9 shows tsunami height for Mangakiki and nearby villages. The maximum tsunami inundation depth for the coastline of the target area shows significant wave heights. More than 100m of inundation distance is measured. The inundation for the coastlines of Nama and nearby villages, as seen in Figure 9, shows significant run-up distance and inundation depths. The run-up distance is between 84 m and 300 m on these coastlines, with inundation depths that vary between 0 to 6 m.

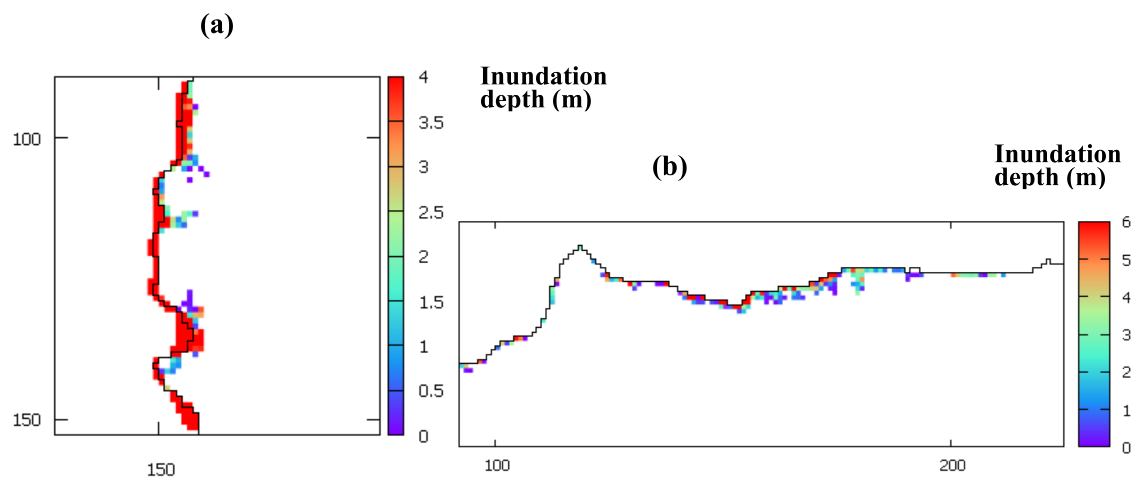


Figure 9 Inundation depths for Mangakiki (a) and coastline of Nama (b).

5. CONCLUSIONS

The study used numerical simulation to investigate tsunami hazards caused by scenario earthquakes occurring along the subduction zone between the Australian Plate and the Pacific Plate in the vicinity of the Solomon Islands Archipelago. We adopted the TUNAMI numerical code to simulate wave propagation caused by scenario earthquakes for the western Solomon and eastern Solomon regions. We then estimated important parameters such as the maximum tsunami heights and the arrival times that will be very useful for disaster planning and future mitigation. For the western Solomon study area, the coastline of Rennell Island and Guadalcanal (Mangakiki) shows a maximum tsunami wave height of 4.8 m and 3.6 m. The inundation depth along the coastlines of Mangakiki was 4 m with a run-up distance of more than 100 m. For the eastern Solomon region, maximum tsunami wave heights of 4.8 m and 1.95 were observed on Nama and Avita coastlines. The run-up distance for parts of the coastline of Nama was 84 m with a maximum inundation depth of 6 m. The arrival times for maximum tsunami wave heights for the study areas (western and eastern Solomon study regions) is within 20 minutes of an earthquake as simulated, which is crucial for tsunami disaster

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