Modeling Tsunami Inundation for Hazard Assessment of Tarawa, the Republic of Kiribati

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Study Phases

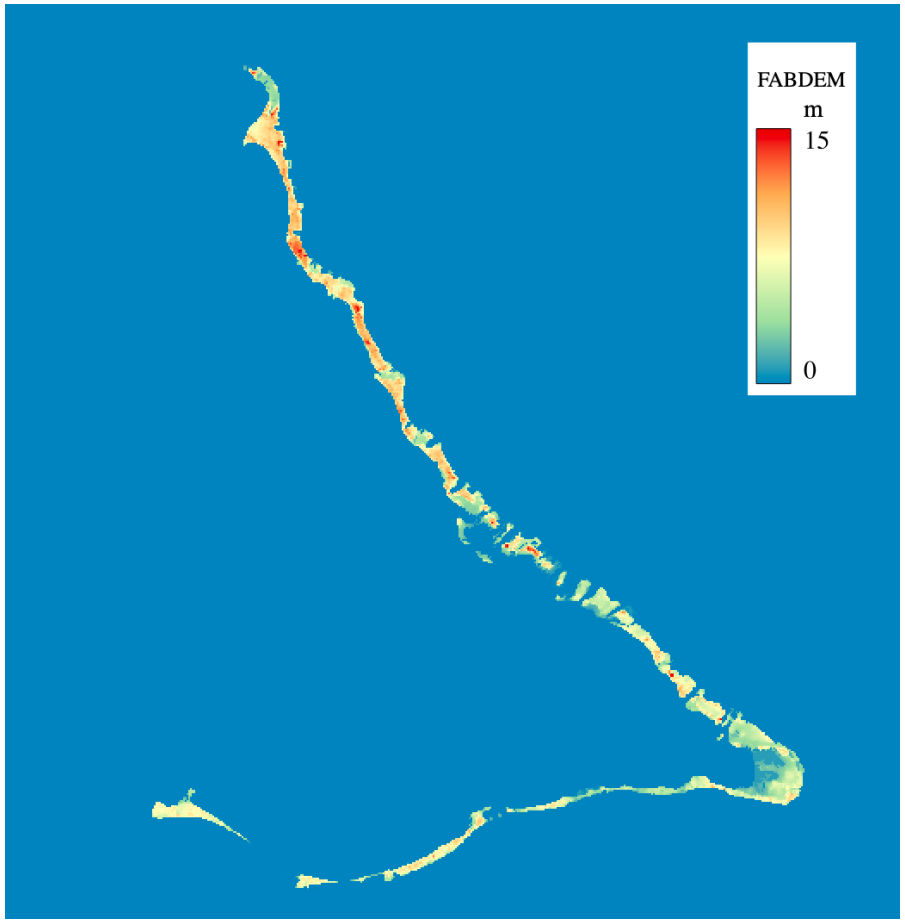
1. DEM Merging/Grid Generation
2. Model Validation/Source Definition
3. Modeling Results and Products

Bathymetry and topography data

Datasets used for the composite Tarawa DEM:

Number	Bathy/topo	Location	Name (Nickname)	Source	Type	Resolution
1)	Bathy	Reefs, shallow water area around the island	Allen Coral Atlas	Allen Coral Atlas	Satellite	10 m
2)	Bathy	Reefs	Reefs Shapefile	Allen Coral Atlas	Satellite	n/a
3)	Bathy and topo	Tarawa Lagoon and the surrounding area	SOPAC	Krüger, 2008	Multi-beam	100 m
4)	Topo	Tarawa land	FABDEM V1-2	Neal and Hawker, 2023	Satellite	1 arc sec
5)	Topo	Tarawa coastline	OpenStreetMap	OpenStreetMap	Satellite	n/a
6)	Bathy and topo	Deep ocean area around Tarawa	GEBCO 2026	GEBCO 2026 (GEBCO, 2026)	Single beam, multi-beam, satellite	15 arcsec

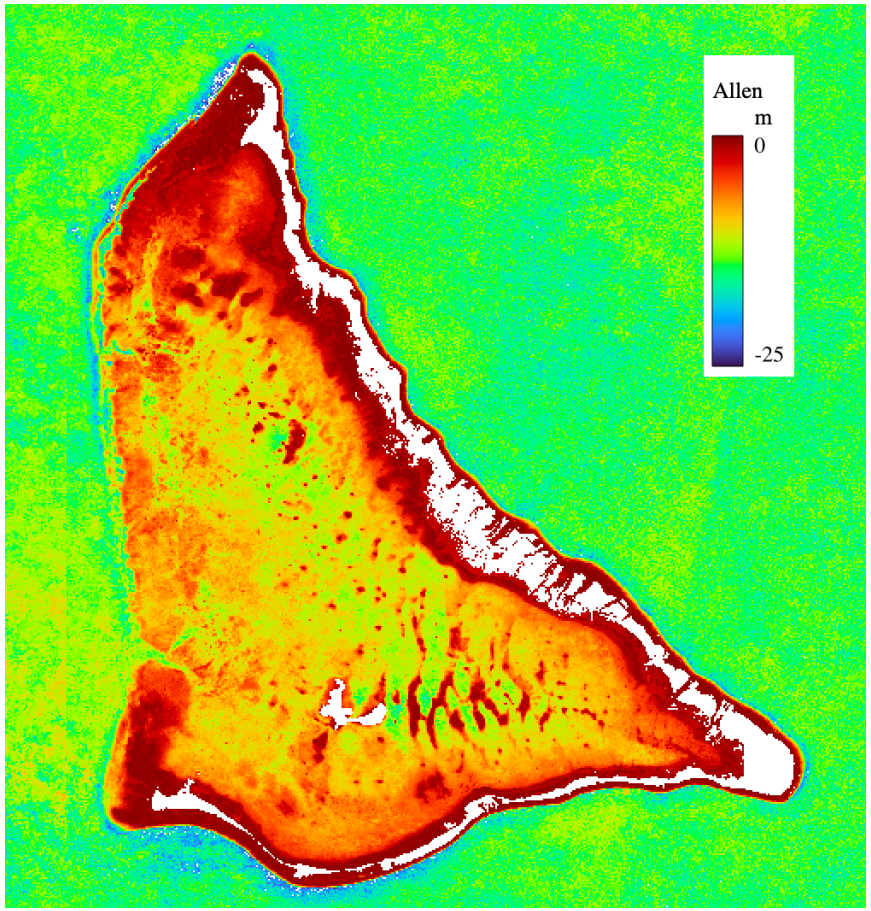
Topography Data

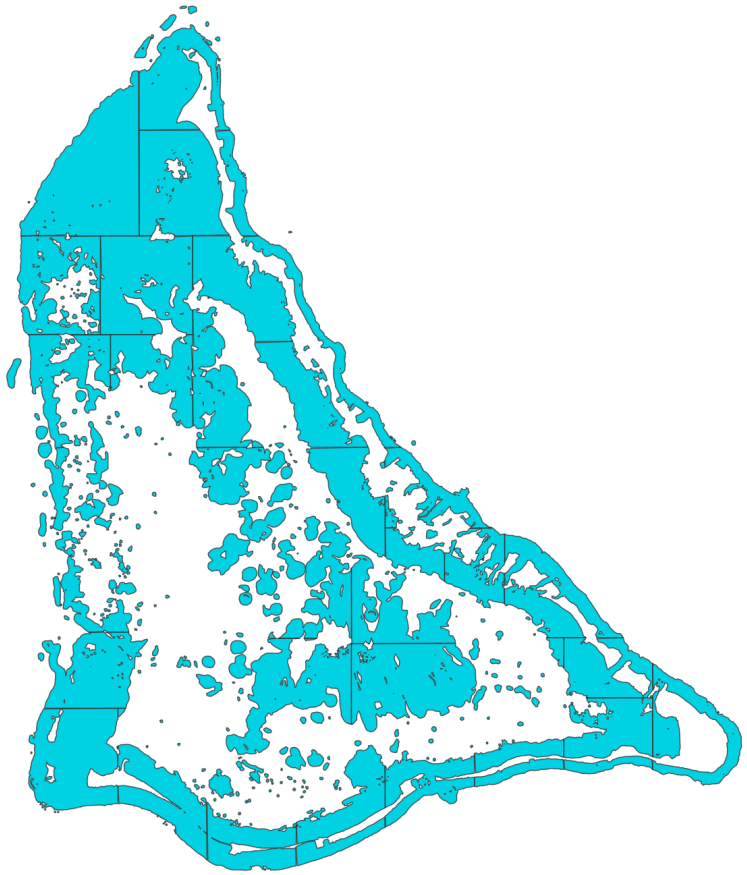


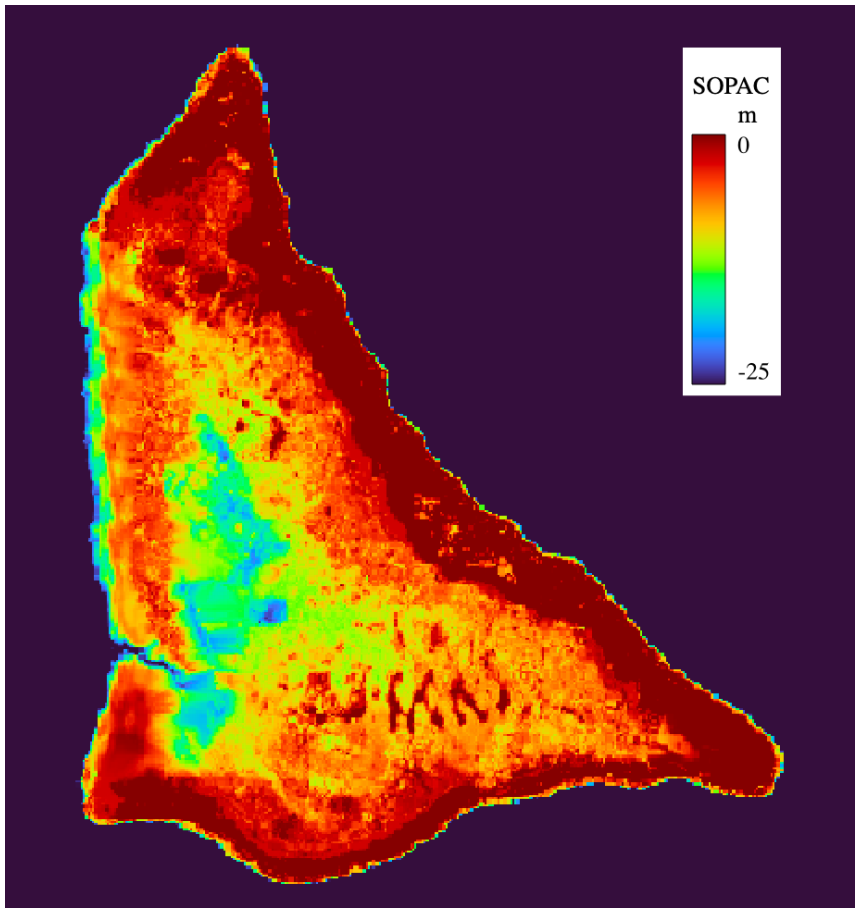
FABDEM V1-2 (Forest and Buildings removed Copernicus DEM). Grid resolution: ~30 m (1 arc-second).

Open Street Map Coastline

Bathymetry Data

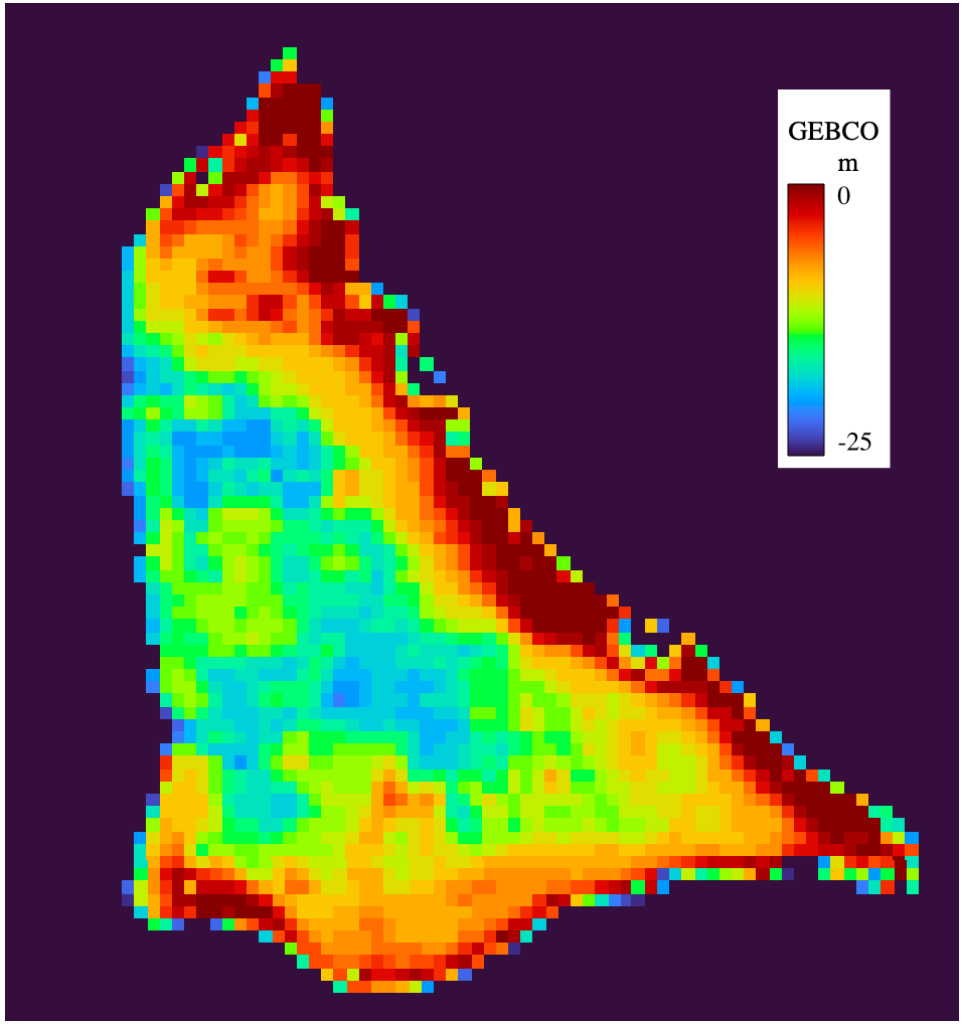




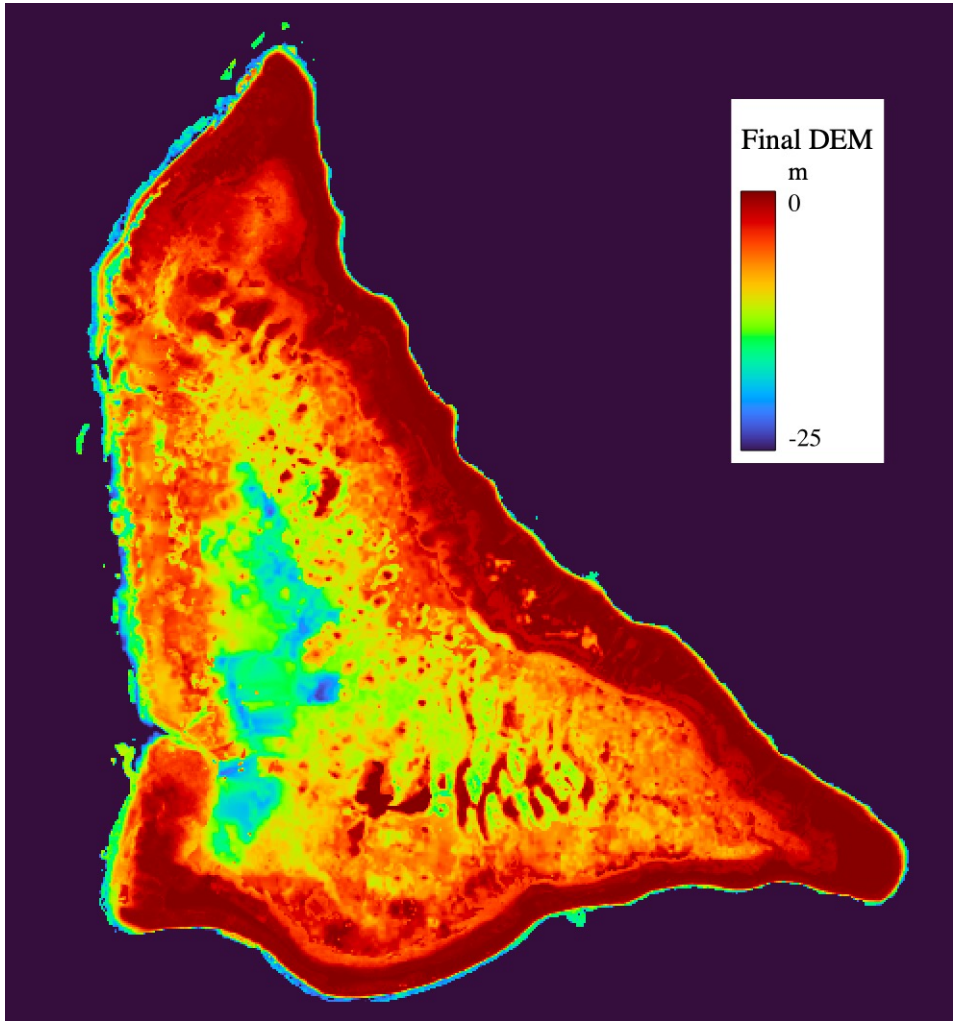


Allen Coral Atlas, 2020. Imagery, maps and monitoring of the world's tropical coral reefs. Grid resolution: 10 m.

SOPAC Multi-beam data, 2008.
Grid resolution: 100 m.



GEBCO,2026. Grid resolution: 15 arcsec.



Final composite DEM. Grid resolution: 20 m.

Study Phases

1. DEM Merging/Grid Generation
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Tsunami Model and Grid Development

- The HySEA model – approved by the US Tsunami Hazard Mitigation Program – was selected for high-resolution island modeling.
- This tsunami model code has been designed to numerically solve the non-linear shallow water equations and utilizes GPU graphics cards for parallelization, making it suitable for very large, very high-resolution grids.
- The nested grids are implemented in the HySea model keeping the accuracy-speed balance. Three levels of larger grids contain these highest-resolution grid, in increasing size and resolution.

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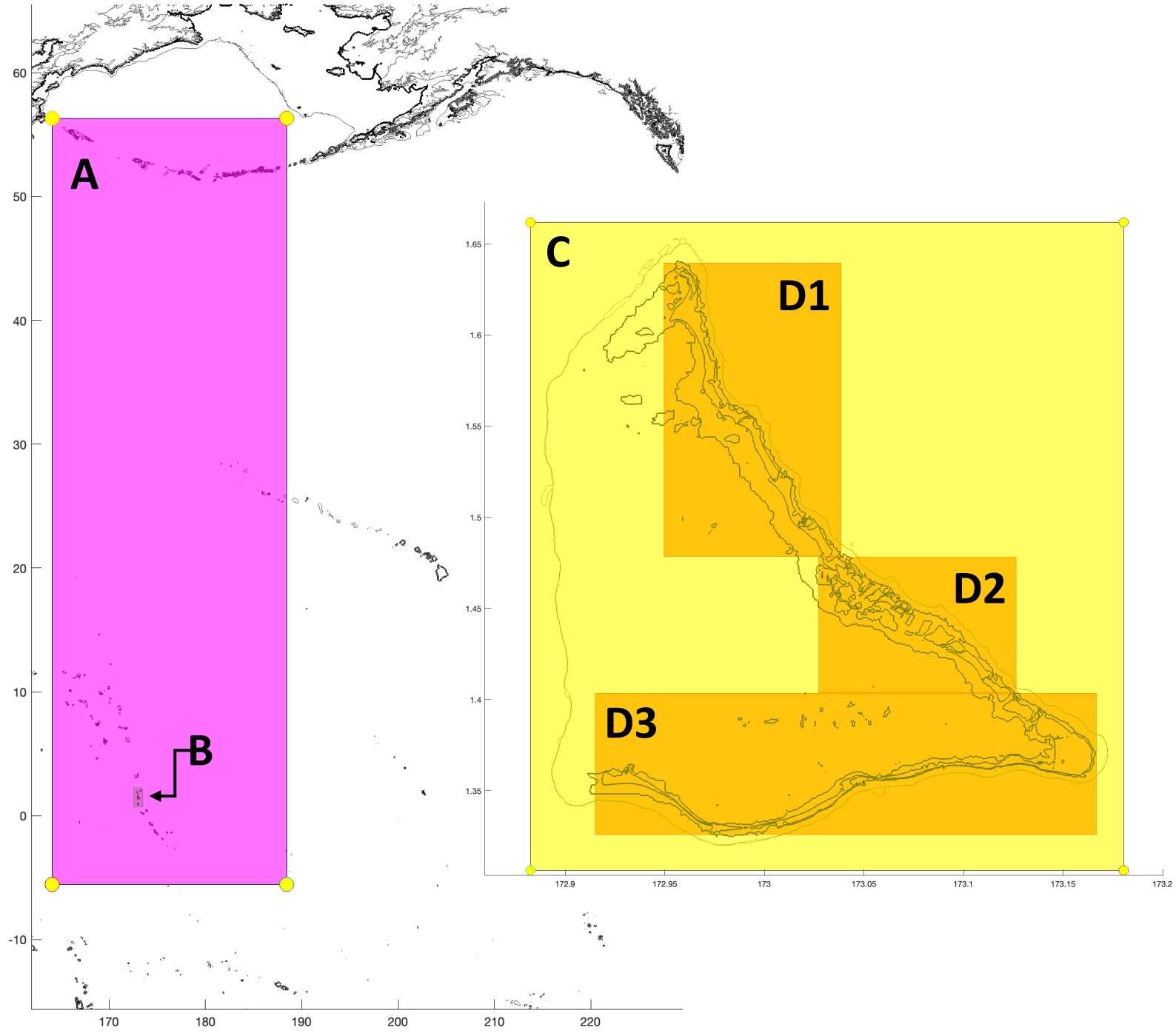
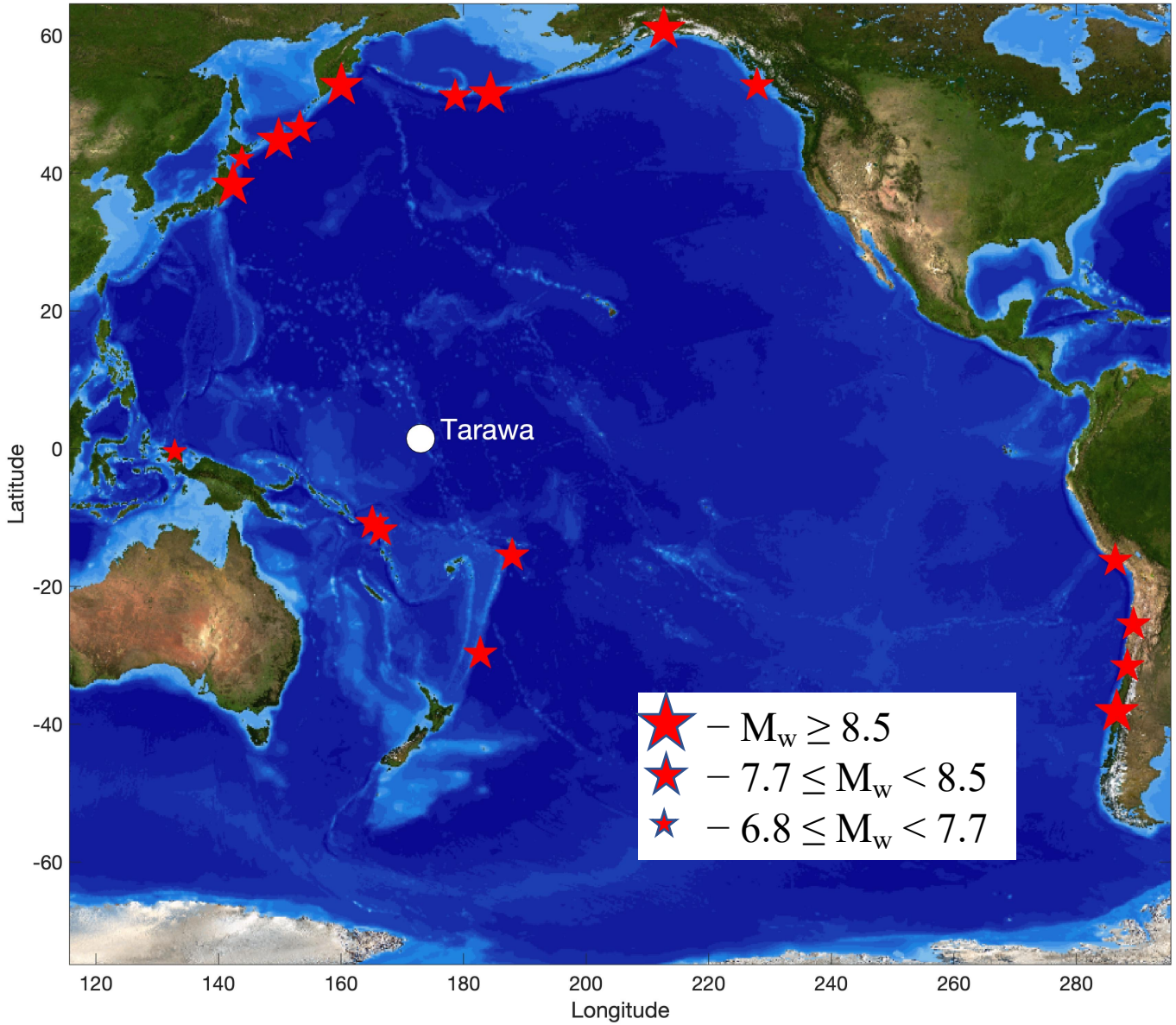


Historic Earthquake-Generated Tsunamis That Have Affected Tarawa

NOAA National Centers for Environmental Information Global Historical Tsunami Database (NCEI, 2026)

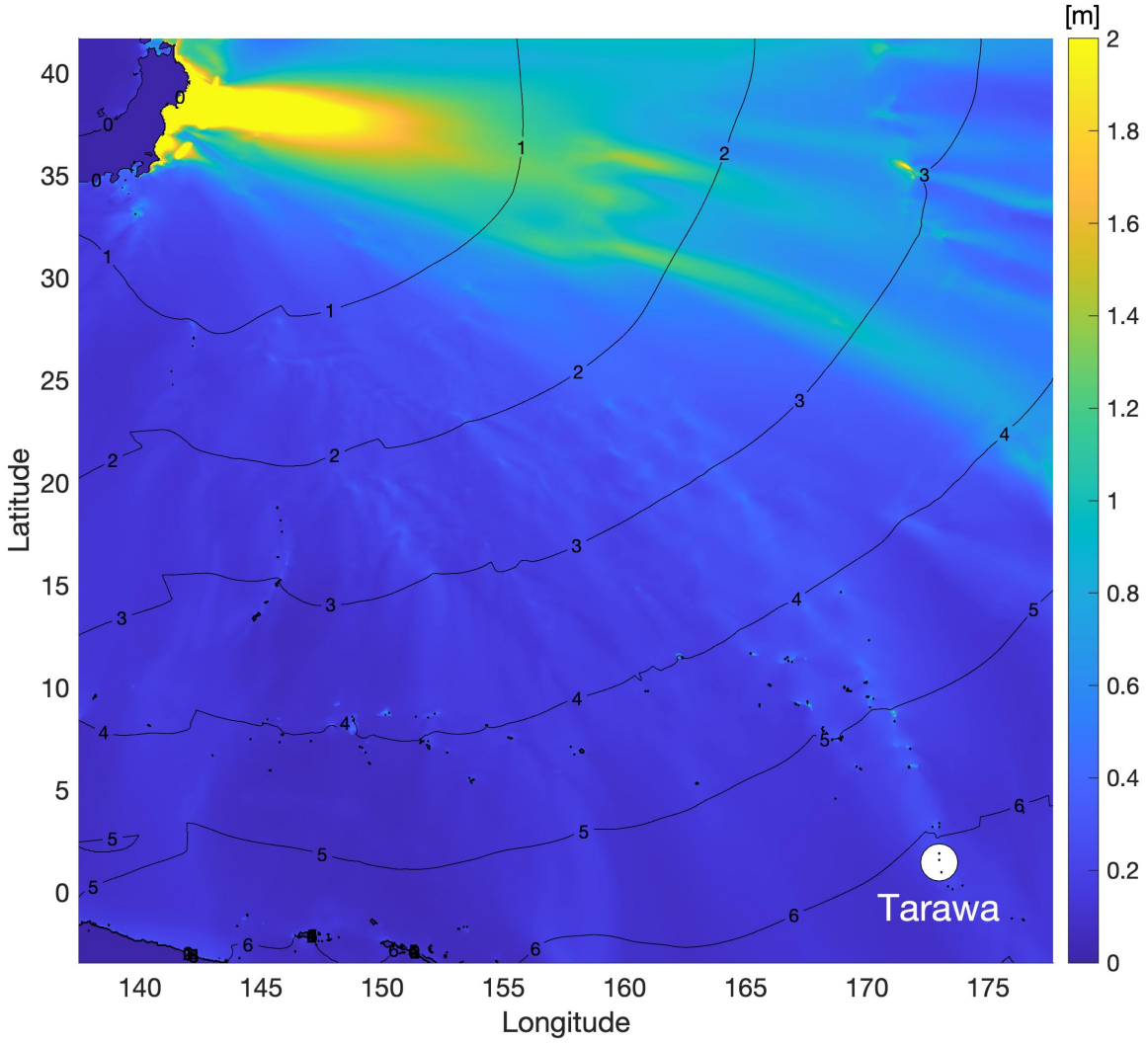


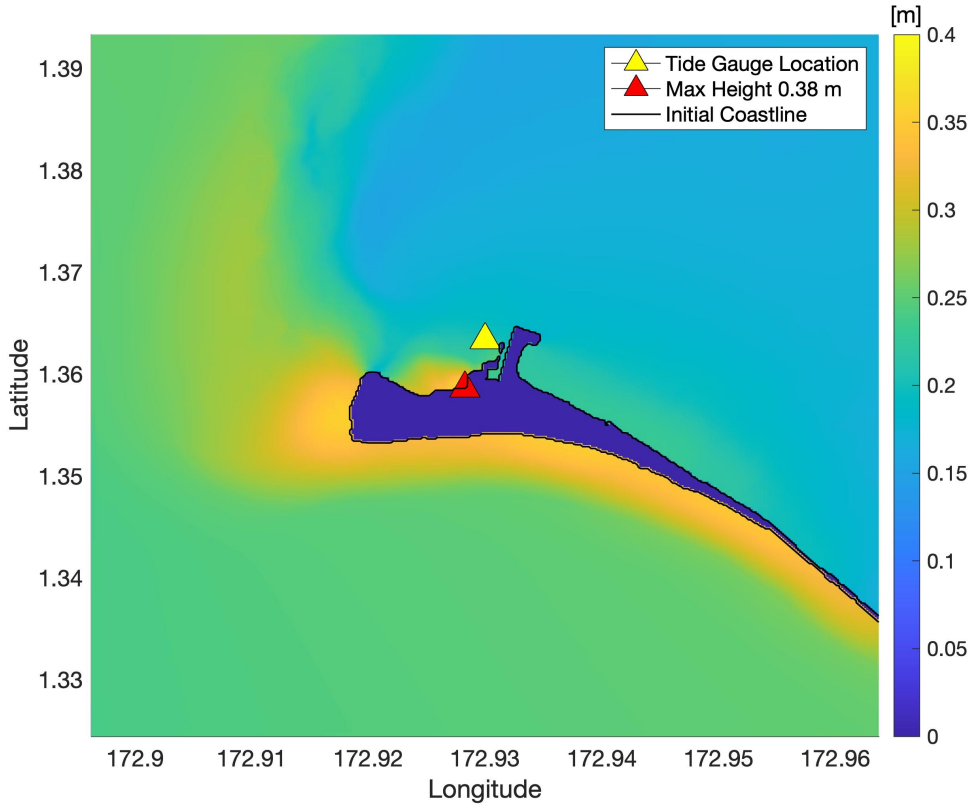
- Eighteen earthquake generated tsunami events affected Tarawa.
- Tsunami originated from the SZ: Japan-Kuril (5), South America (4), Alaska-Aleutian (3), South Solomon and New Hebrides (2), Kermadec-Tonga (2), Cascadia (1) and New Guinea (1)
- The two largest recorded tsunami runups in Betio, Tarawa – 27 cm and 12 cm – were from the 11 March 2011 Mw 9.1 Tohoku, Japan, and the 6 February Mw 7.9 Solomon Islands events, respectively.

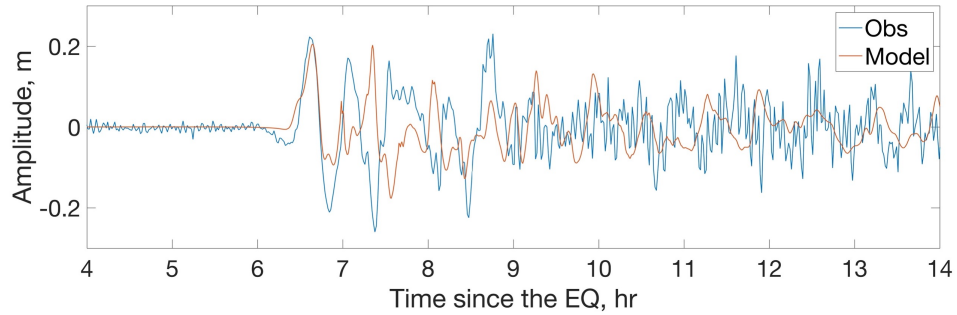
Historic Earthquake-Generated Tsunamis That Have Affected Tarawa (NCEI, 2026)

Date	Date	Source Country	Source Longitude	Source Latitude	M_w	Affected Area	Runup
1	3/4/2021	S of Raoul Island, Kermadec Islands, New Zealand	-177.267	-29.740	8.1	Christmas Island, Line Islands	2 cm
2	9/16/2015	Central Chile, Chile	-71.674	-31.573	8.3	Christmas Island, Line Islands	9 cm
3	2/6/2013	Santa Cruz Islands, Solomon Islands	165.114	-10.766	7.9	Christmas Island, Line Islands Betio, Tarawa	4 cm 12 cm
4	10/28/2012	British Columbia, Canada	-132.101	52.788	7.7	Christmas Island, Line Islands	3 cm
5	3/11/2011	Japan, Honshu Island	142.372	38.297	9.1	Christmas Island, Line Islands Betio, Tarawa Kanton Island, Phoenix Islands	53 cm 27 cm 16 cm
6	9/29/2009	Samoa Islands, Samoa	-172.095	-15.489	8.1	Christmas Island, Line Islands	17 cm
7	1/3/2009	Indonesia, near North Coast	132.885	-0.414	7.6	Betio, Tarawa	2 cm
8	11/15/2006	S. Kuril Islands, Russia	153.266	46.592	8.3	Betio, Tarawa Kanton Island, Phoenix Islands	4 cm 2 cm
9	11/17/2003	Rat Islands, Aleutian Islands, AK, USA	178.650	51.146	7.8	Christmas Island, Line Islands	4 cm
10	6/23/2001	S. Peru, Peru	-73.641	-16.265	8.4	Christmas Island, Line Islands	3 cm
11	12/31/1966	Santa Cruz Islands, Solomon Islands	166.445	-11.893	7.8	Christmas Island, Line Islands	
12	12/28/1966	Northern Chile, Chile	-70.700	-25.5	7.8	Christmas Island, Line Islands	3 cm
13	3/28/1964	Prince William Sound, AK, USA	-147.339	60.908	9.2	Christmas Island, Line Islands Kanton Island, Phoenix Islands	5 cm 3 cm
14	1/13/1963	S. Kuril Islands, Russia	149.798	44.772	8.5	Christmas Island, Line Islands	10 cm
15	5/22/1960	Southern Chile, Chile	-73.407	-38.143	9.5	Christmas Island, Line Islands Kanton Island, Phoenix Islands	23 cm 10 cm
16	3/9/1957	Andreanof Islands, AK, USA	-175.626	51.499	8.6	Christmas Island, Line Islands Kanton Island, Phoenix Islands	17 cm 12 cm
17	11/4/1952	Kamchatka, Russia	160.057	52.755	9.0	Kanton Island, Phoenix Islands	10 cm
18	7/13/1952	Of East Coast of Vanuatu, Vanuatu	143.850	42.150	6.8	Kanton Island, Phoenix Islands	2 cm

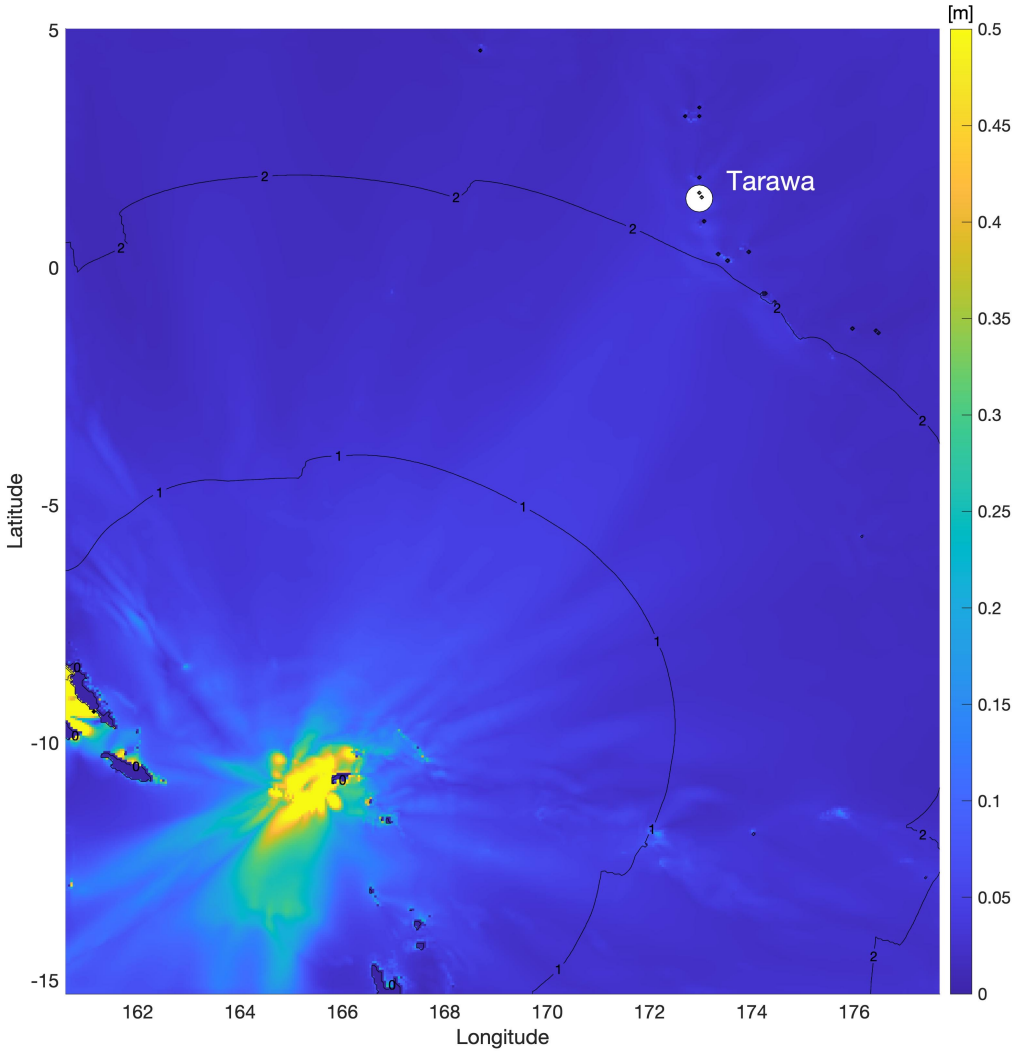
Model Validation. Comparison of modeled and observed maximum wave heights and sea level dynamics in South Tarawa from the **11 March 2011 Tohoku, Japan** event.

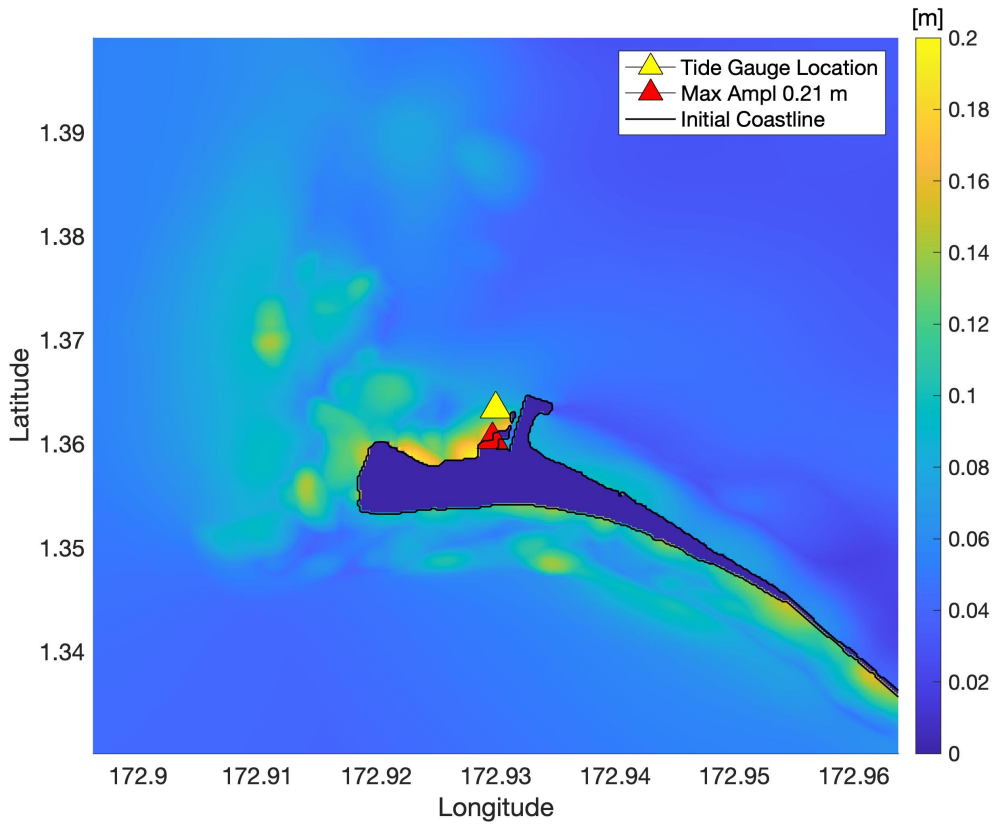


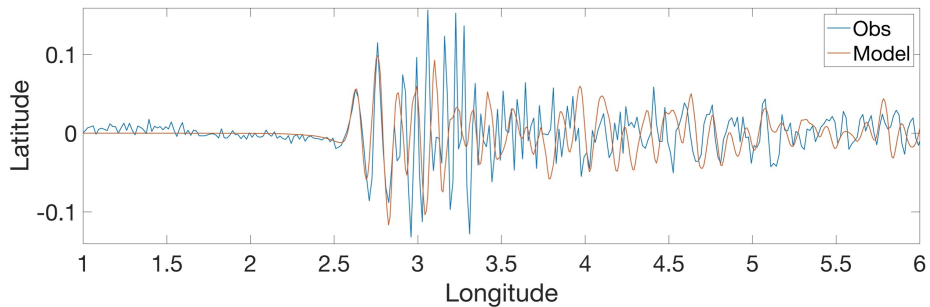




Model Validation. Comparison of modeled and observed maximum wave heights and sea level dynamics in South Tarawa from the **6 February 2013 Solomon Islands** event.

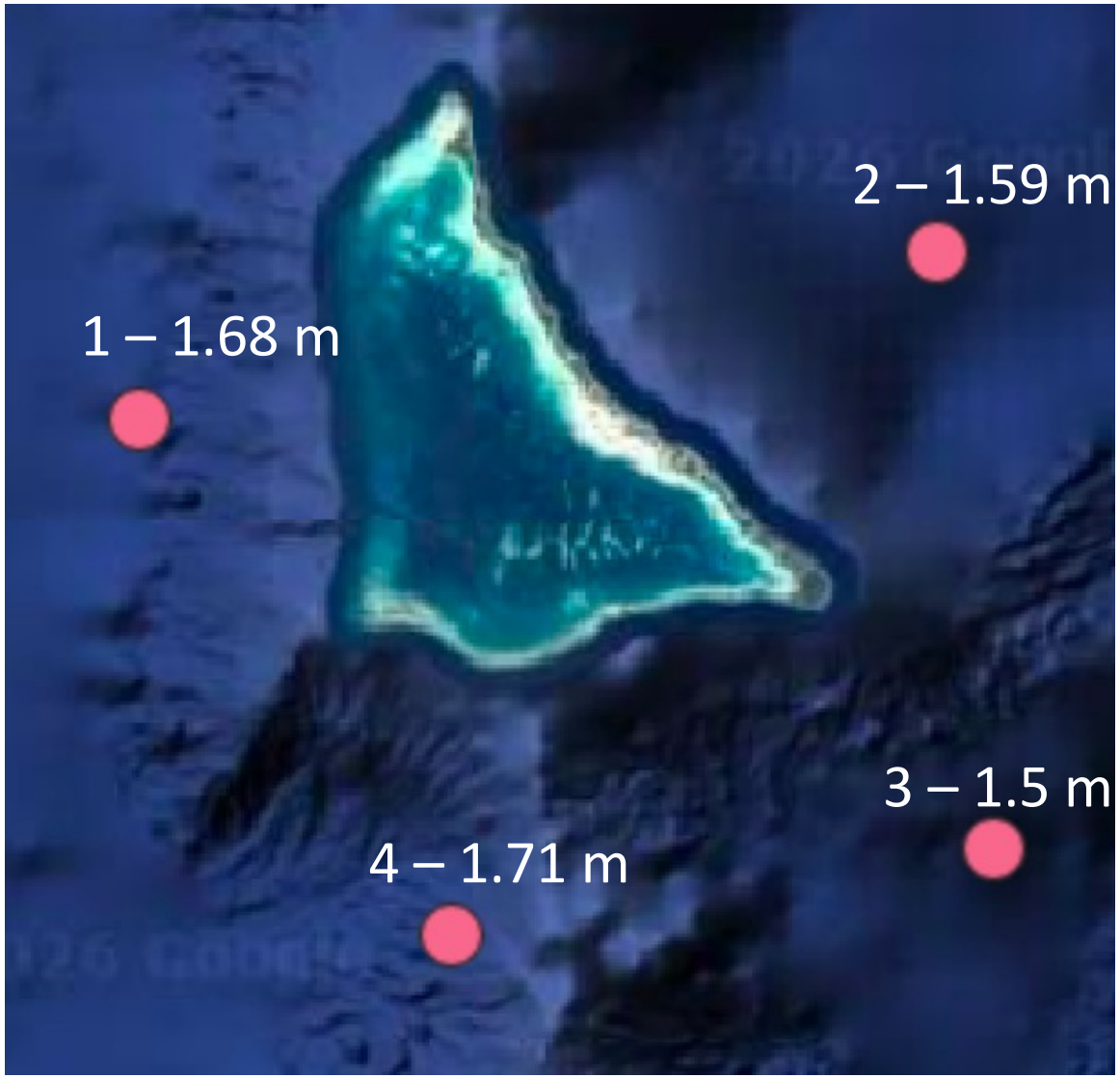






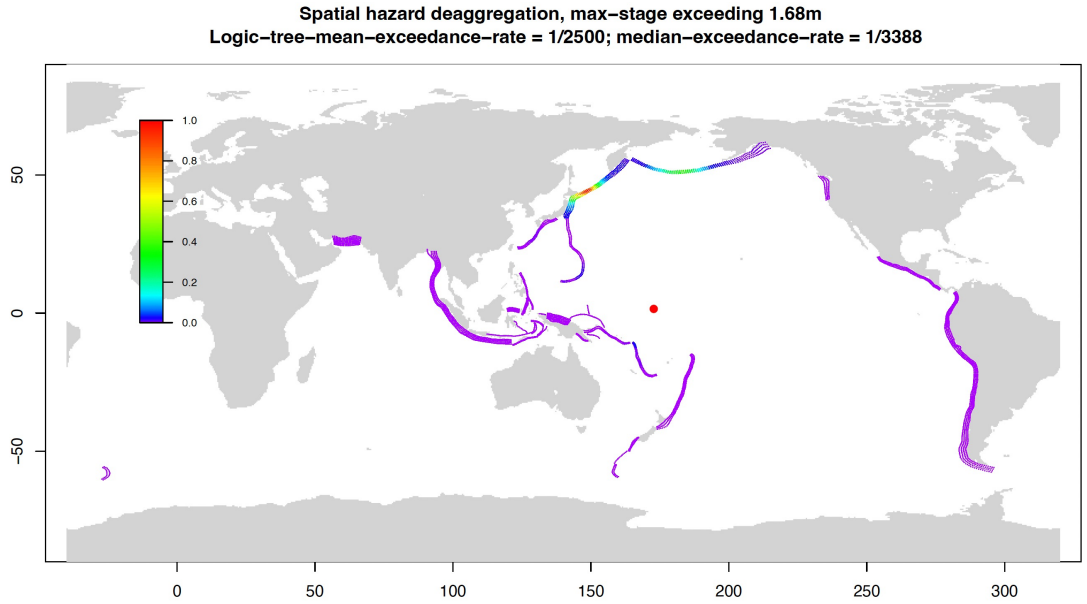
Selection of Tsunami Source Scenarios

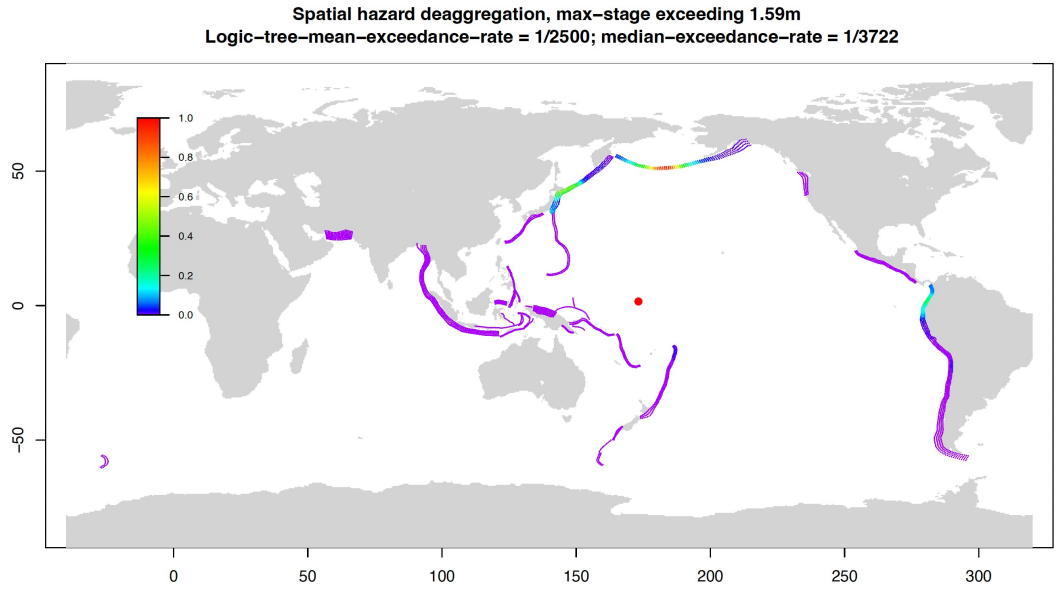
We used a scenario-based assessment technique that combines the Probabilistic Tsunami Hazard Assessment (PTHA18) with the credible worst-case scenario.

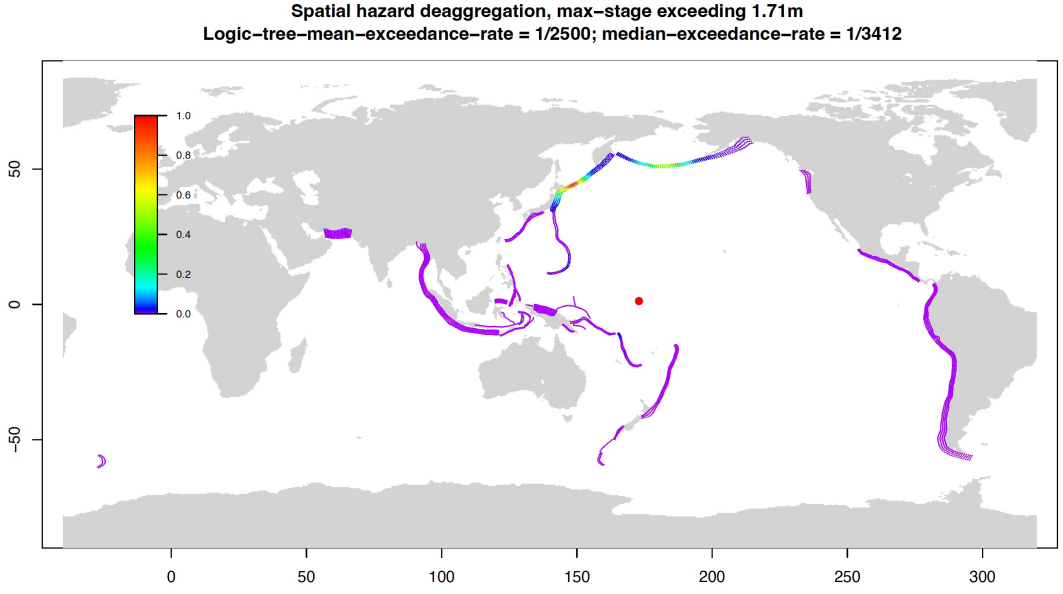


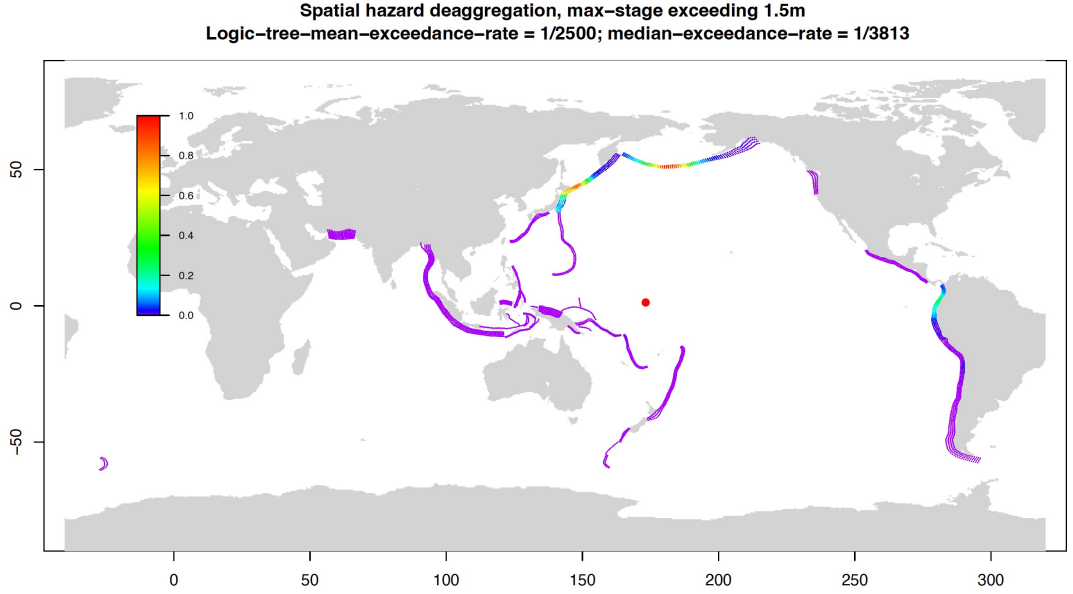
Tarawa and the four nearest PTHA18 hazard points, showing maximum tsunami heights (m) for a 2,500-year return period.

Spatial hazard deaggregation plots for the four hazard points around Tarawa, corresponding to a 2,500-year mean recurrence interval.









Source Selection

We applied **two criteria** to select the most potentially hazardous sources for Tarawa from the PTHA18 database for the Alaska-Aleutian, Japan-Kuril, South America and Vanuatu subduction zones (SZs). **First**, sources with the maximum expert-estimated moment magnitude (Mw) for each SZ were selected (UNESCI/IOC, 2020, 2024). **Second**, following ASCE (2022) guidelines, a source was chosen for full-scale modeling if:

- The maximum wave amplitude at each of the four hazard points nearest the island exceeded 80% of the maximum offshore tsunami stage for the 2,500-year return period, and

- The mean amplitude at all four points was equal to or greater than the mean maximum offshore tsunami stage for the 2,500-year return period.

American Society of Civil Engineers, 2022. Minimum Design Loads and Associated Criteria for Buildings and Other Structures (ASCE/SEI 7-22). Reston, VA: ASCE.
UNESCO/IOC, 2020. Expert meeting on tsunami sources, hazards, risk and uncertainties associated with the Tonga-Kermadec Subduction Zone, Wellington, New Zealand, 29 October–3 November 2018. IOC Working Report 289.
UNESCO-IOC, 2025. Expert Meeting on Tsunami Sources, Hazards, Risk and Uncertainties Associated with Vanuatu, San Cristobal and New Britain Subduction Zones, Port Vila, Vanuatu, 14–17 May 2024. IOC-WR-315.

Study Phases

1. DEM Merging/Grid Generation
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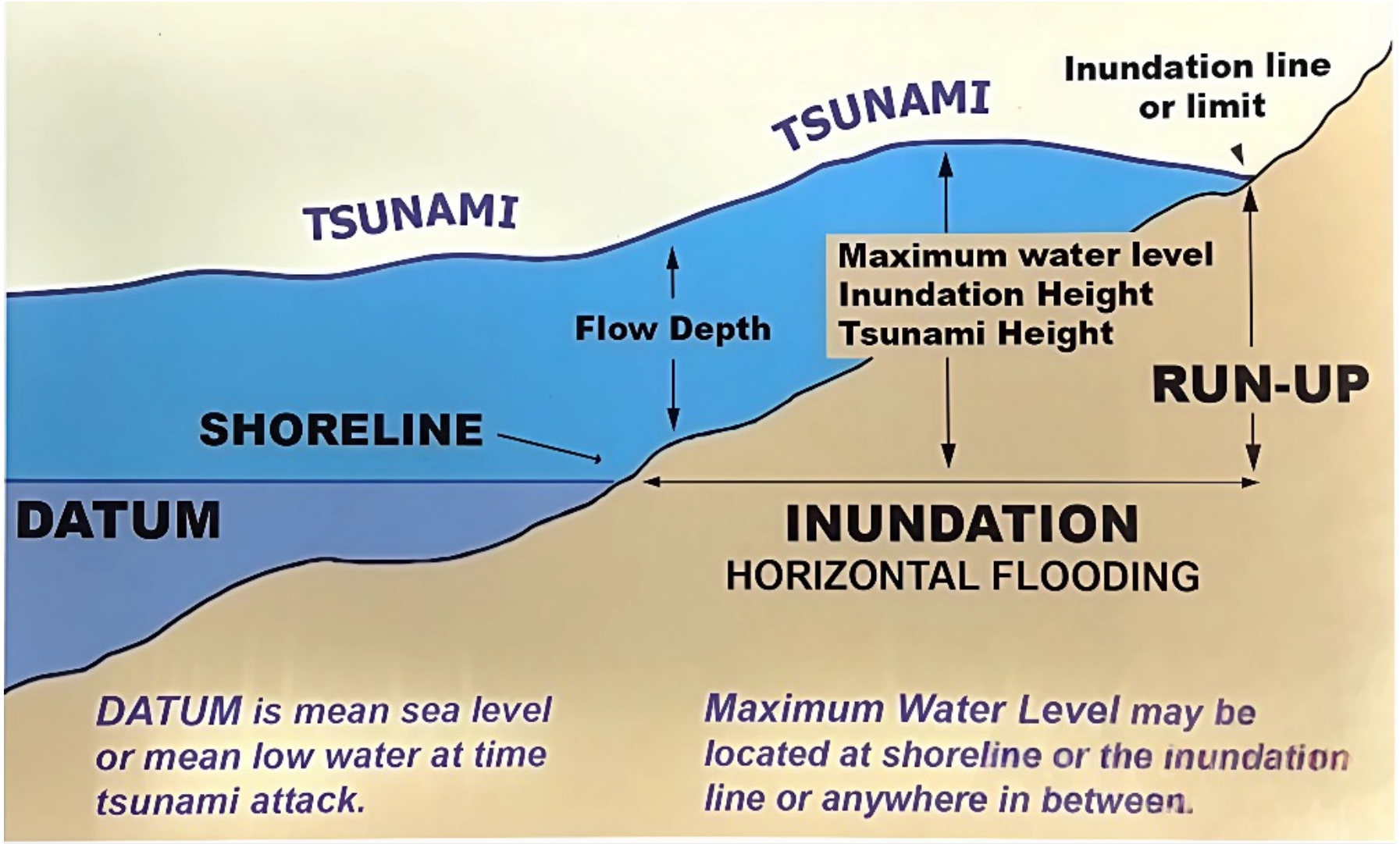
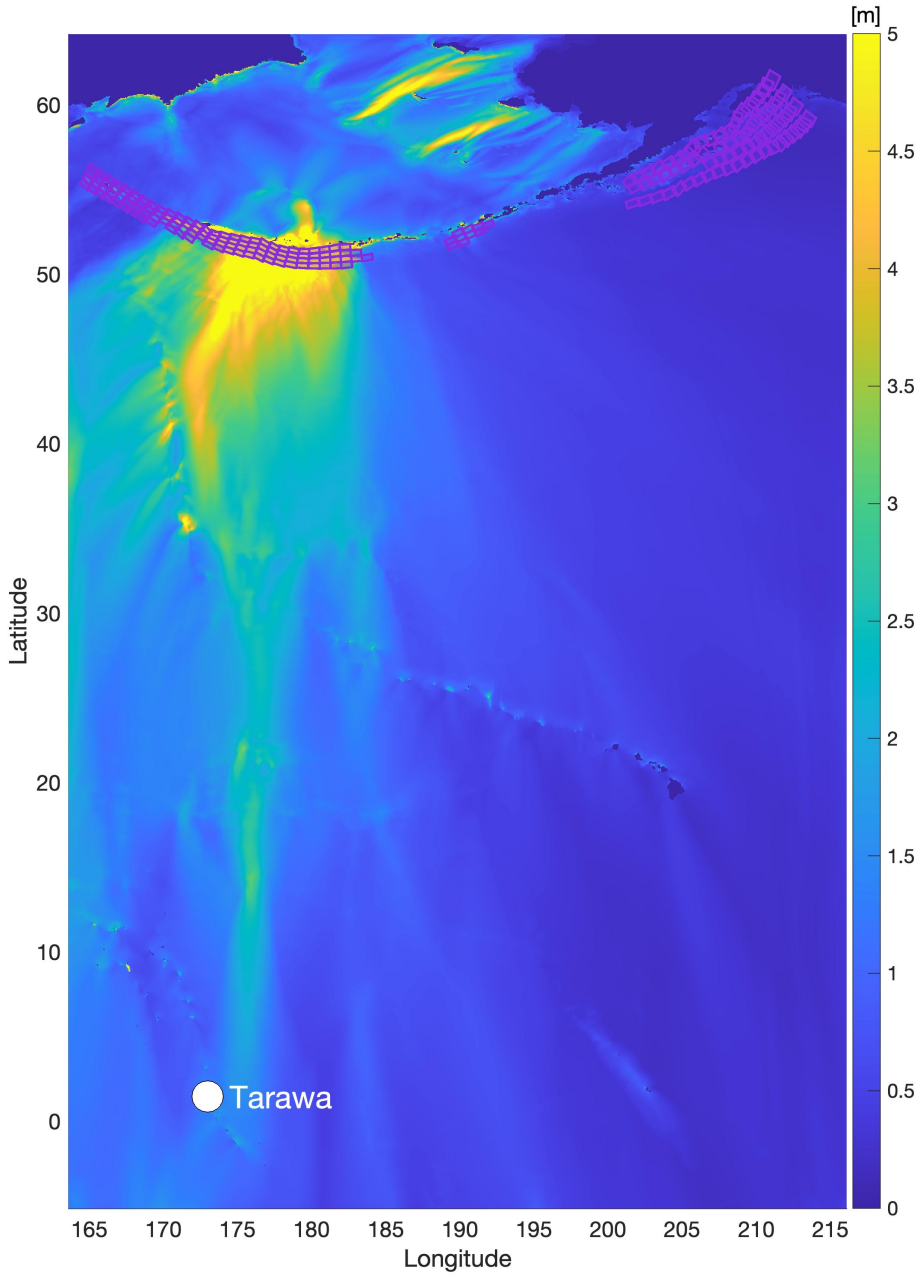
3. Modeling Results and Products

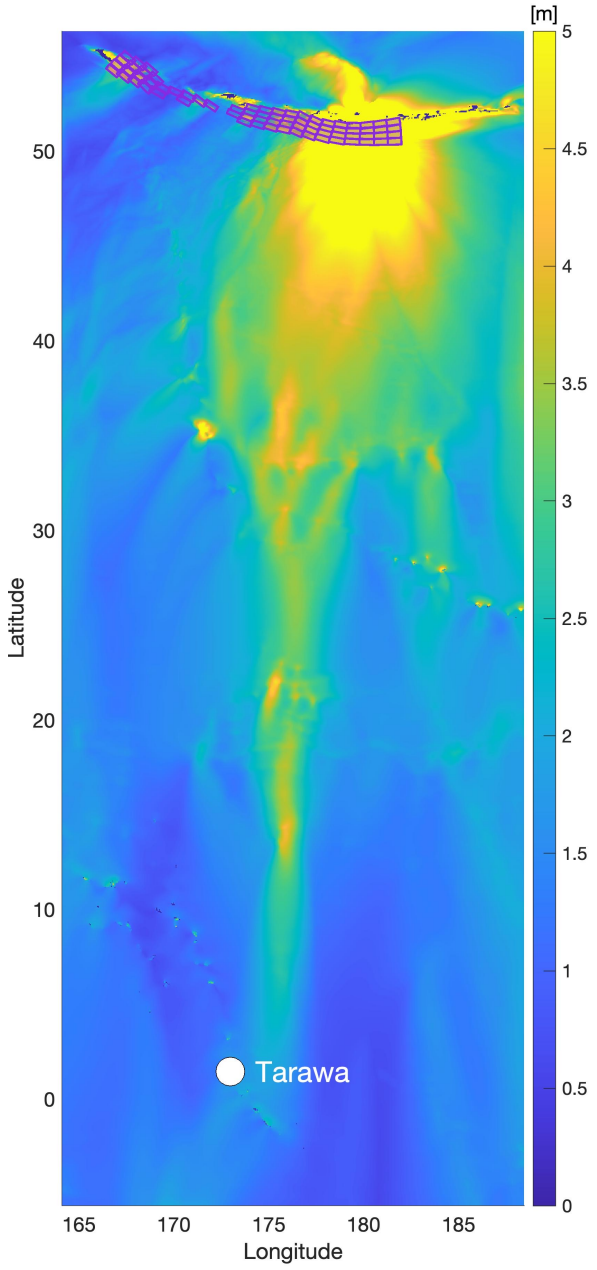
Tsunami Inundation Terms

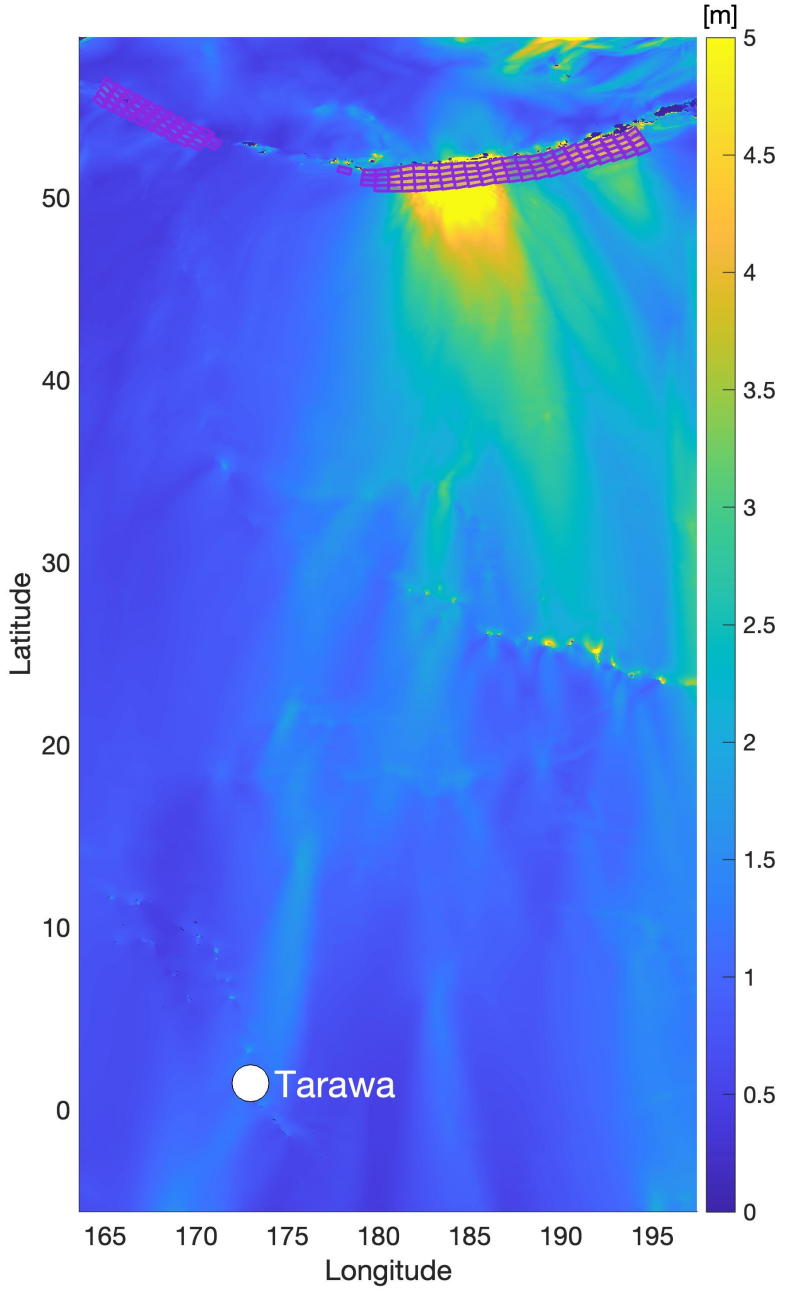
(Intergovernmental Oceanographic Commission, 2019)



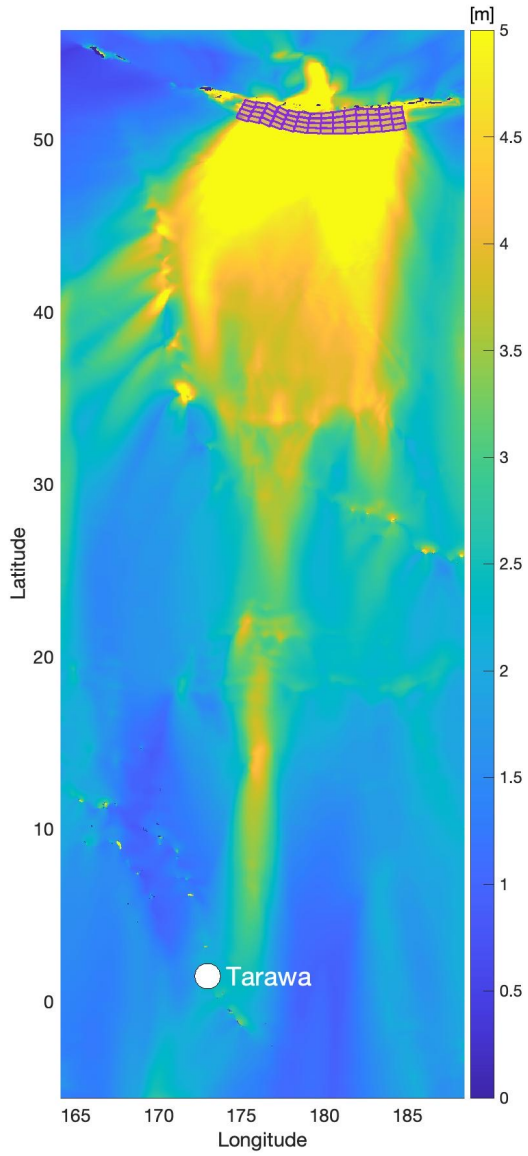
Source locations and maximum deep-ocean wave heights from the Alaska-Aleutian sources.

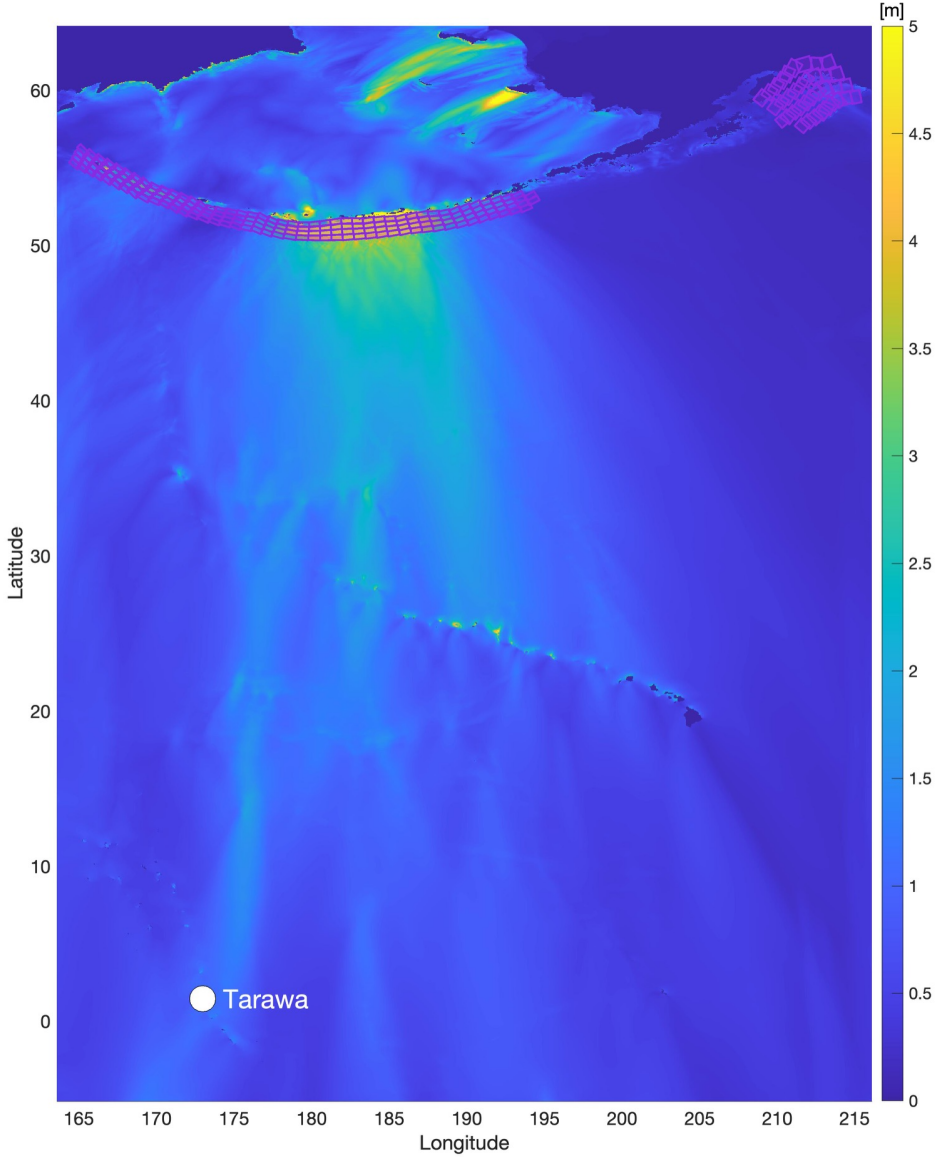




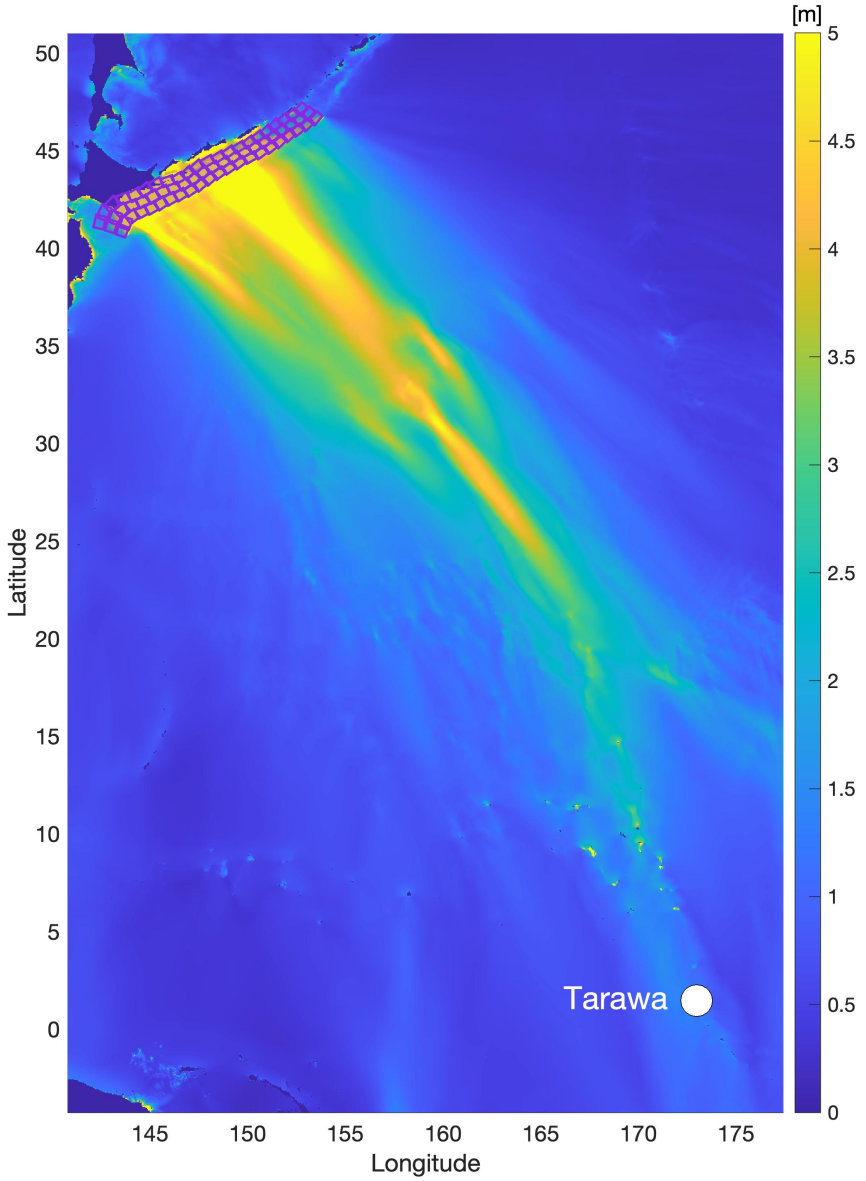


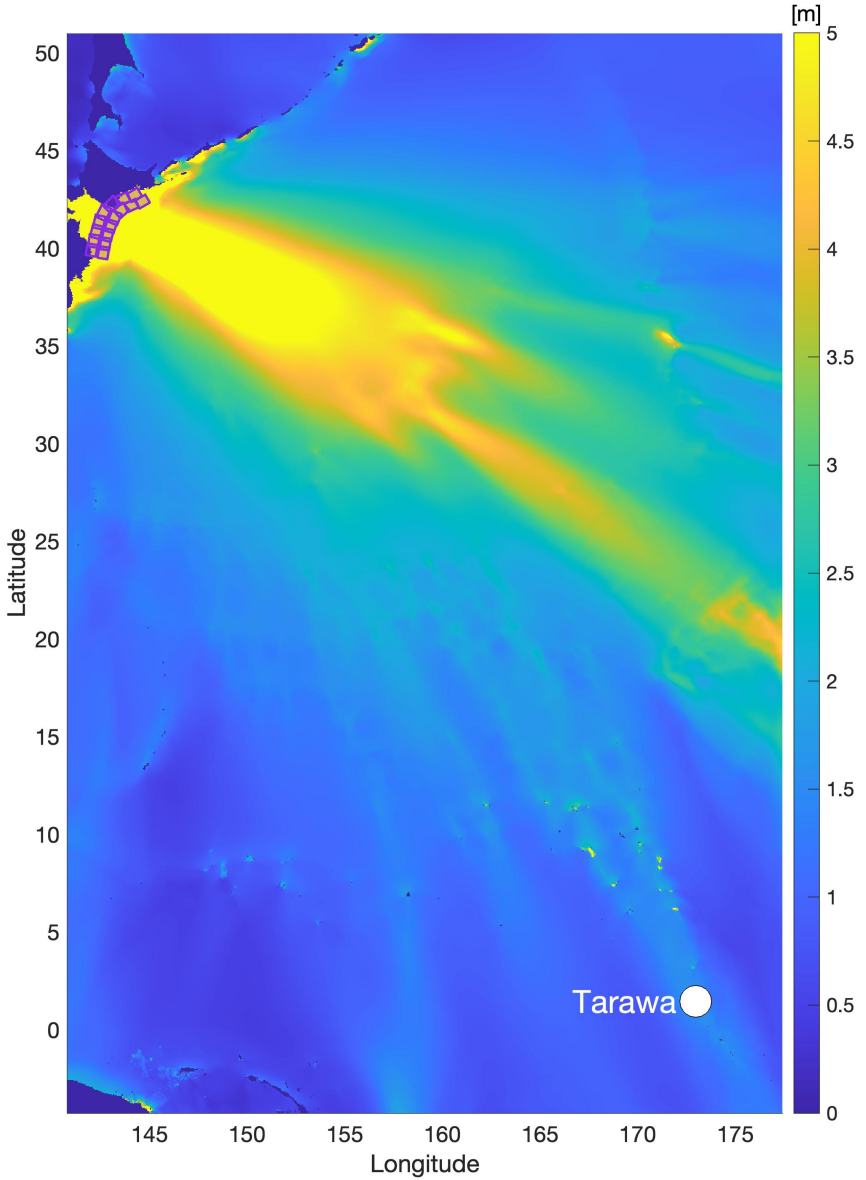
Source locations and maximum deep-ocean wave heights from the Alaska-Aleutian sources.



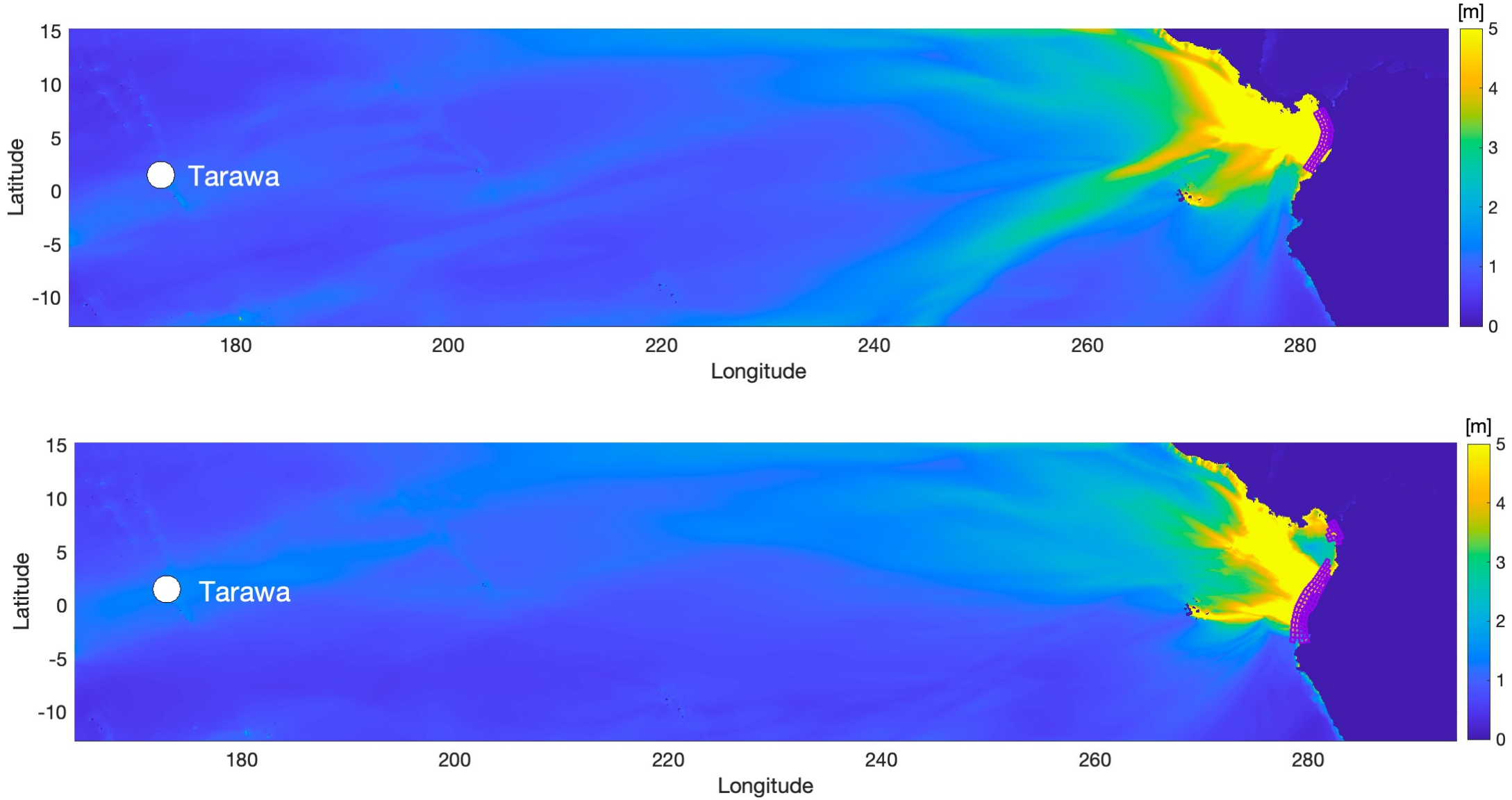


Source locations and maximum deep-ocean wave heights from the Japan sources.

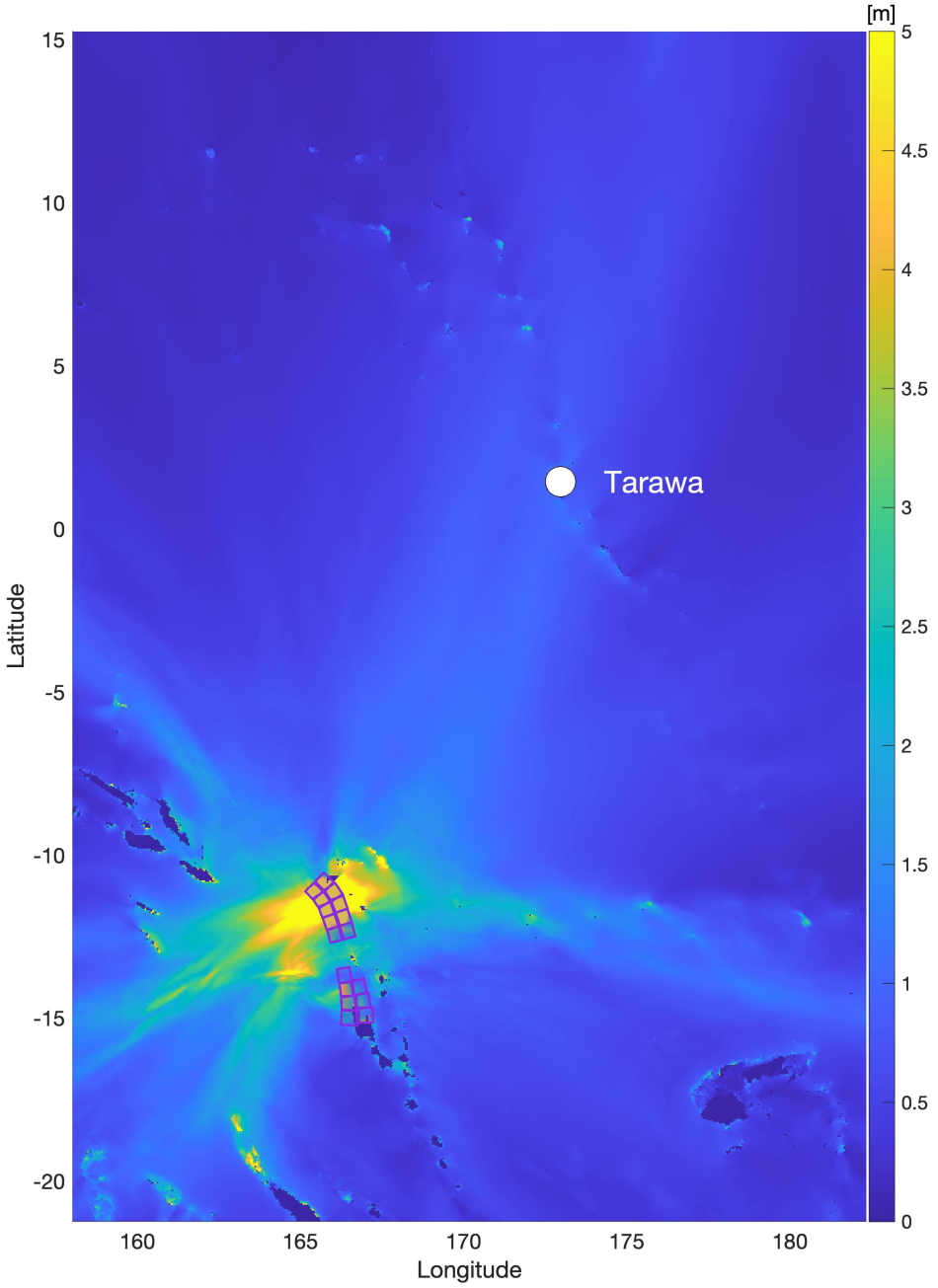




Source locations and maximum deep-ocean wave heights from the South American sources.

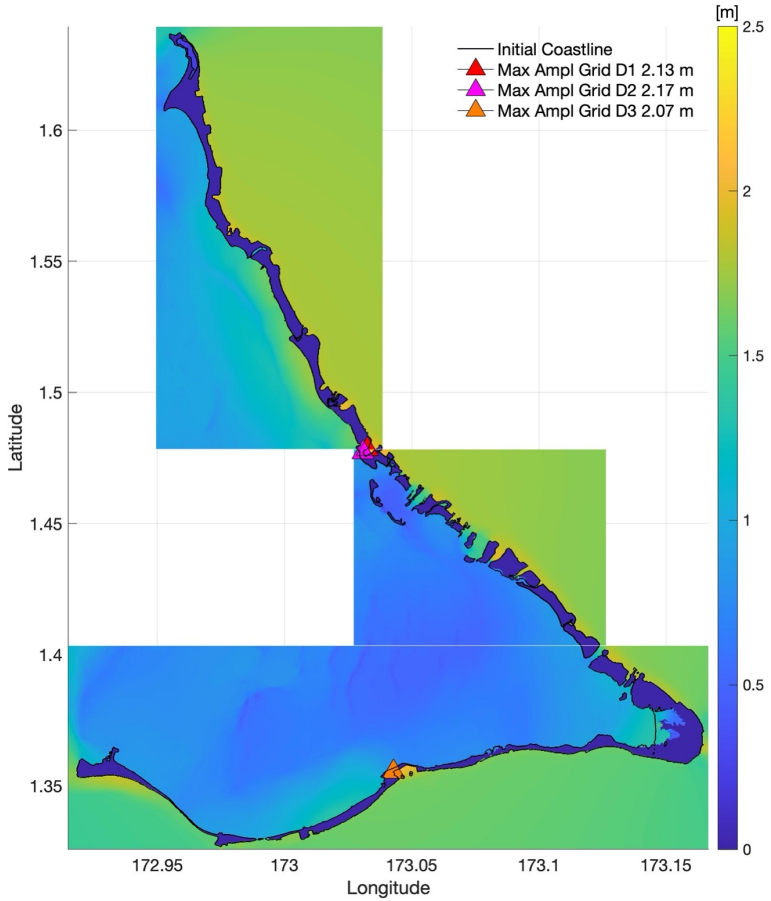


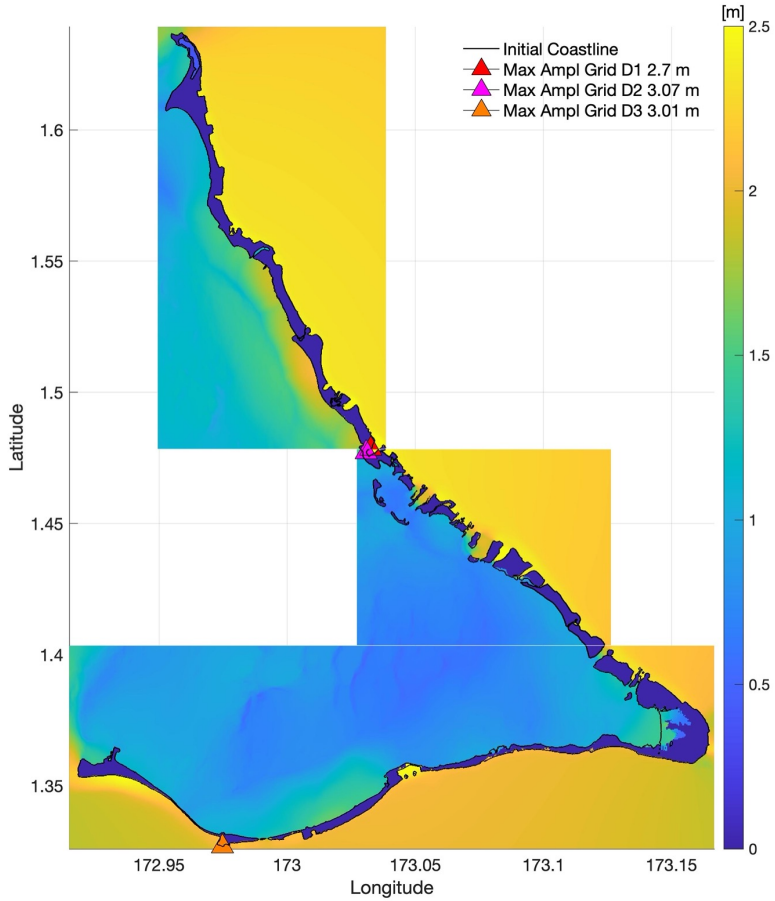
Source locations and maximum deep-ocean wave heights from the North Vanuatu sources.

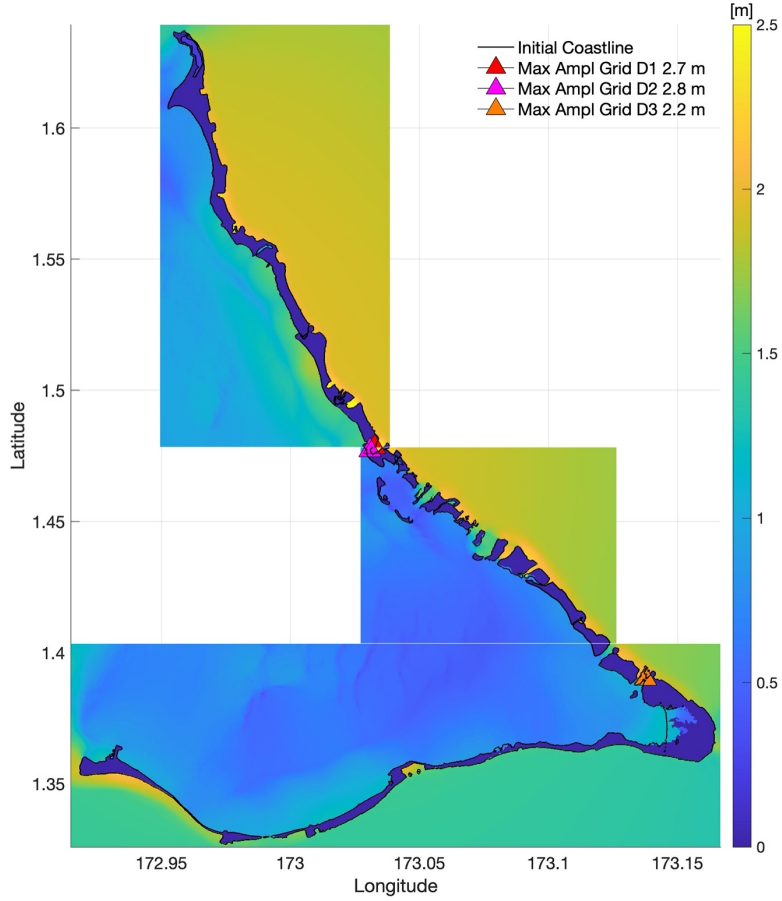


Maximum tsunami heights and inundation from the Alaska-Aleutian sources.

Triangle: overall grid maximum; black curve: initial coastline.

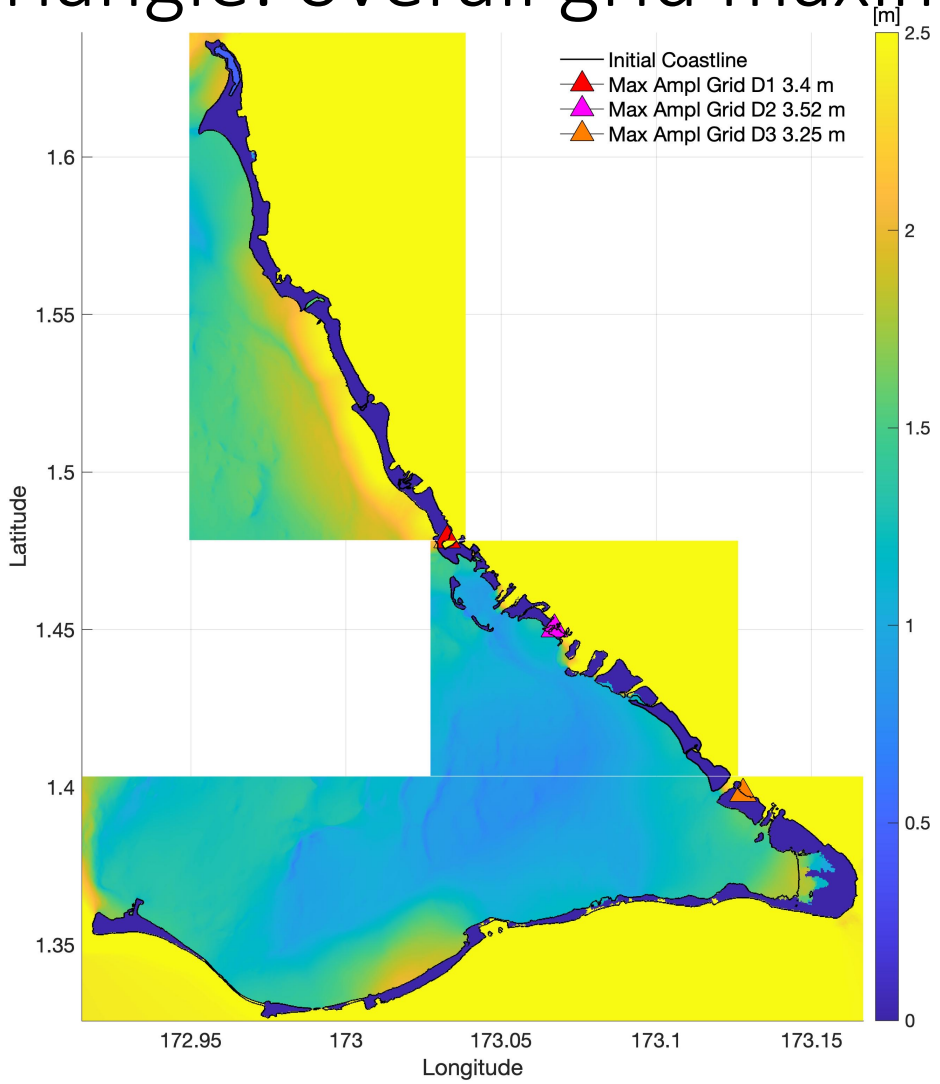


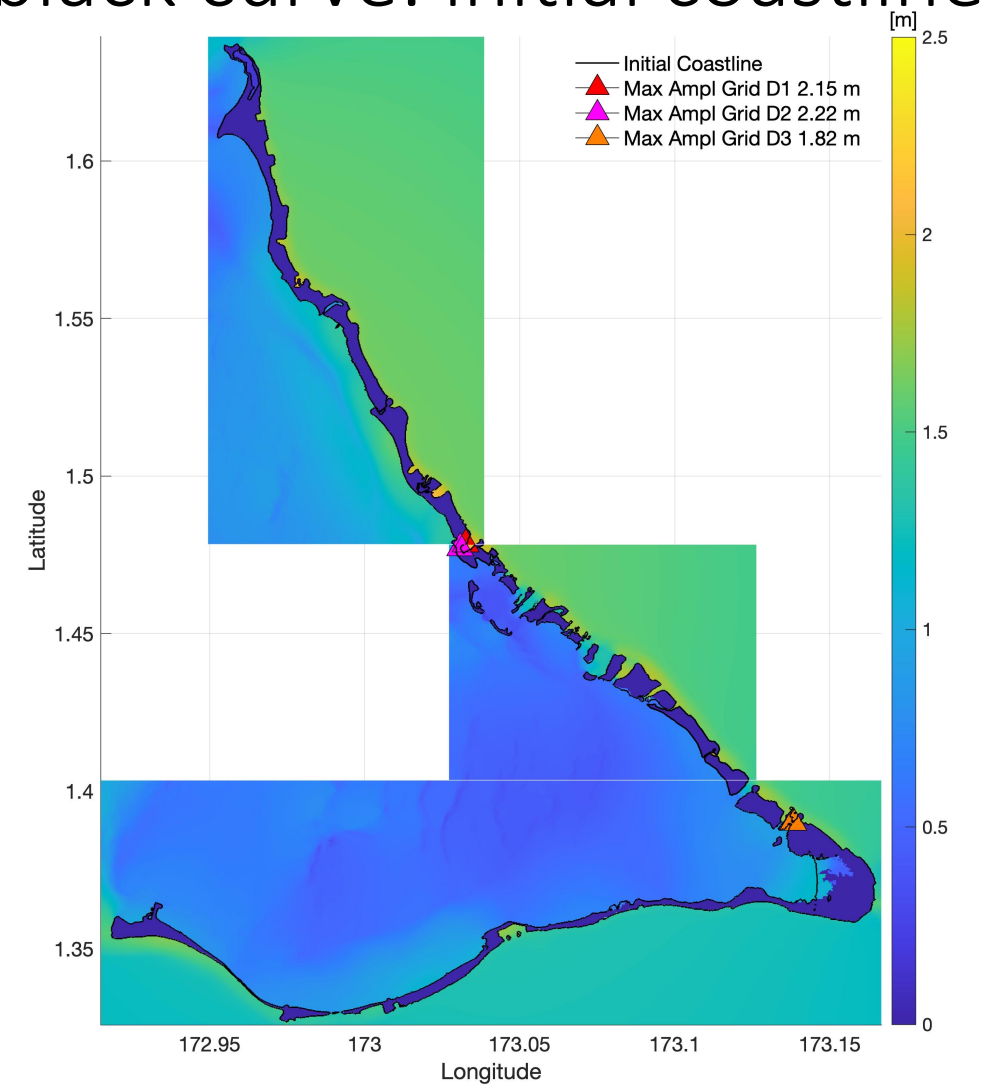




Maximum tsunami heights and inundation from the Alaska-Aleutian sources.

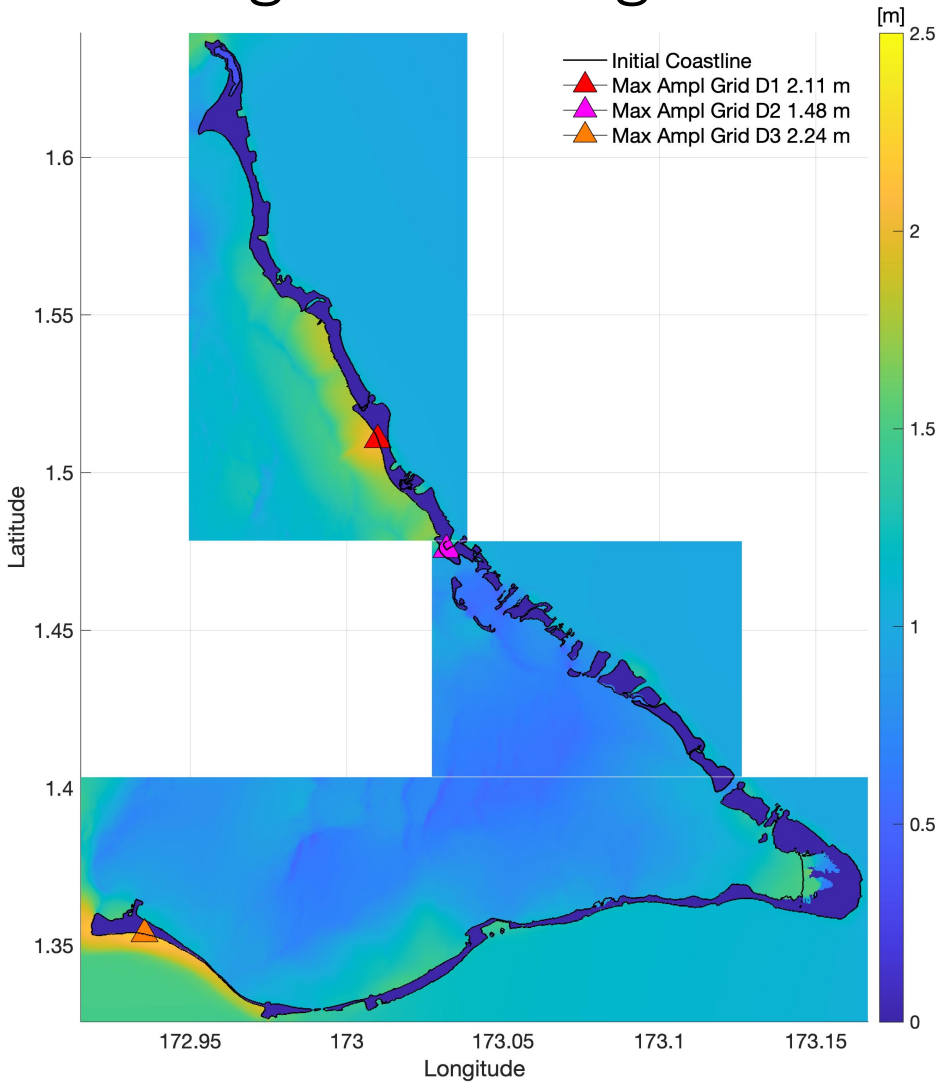
Triangle: overall grid maximum; black curve: initial coastline.

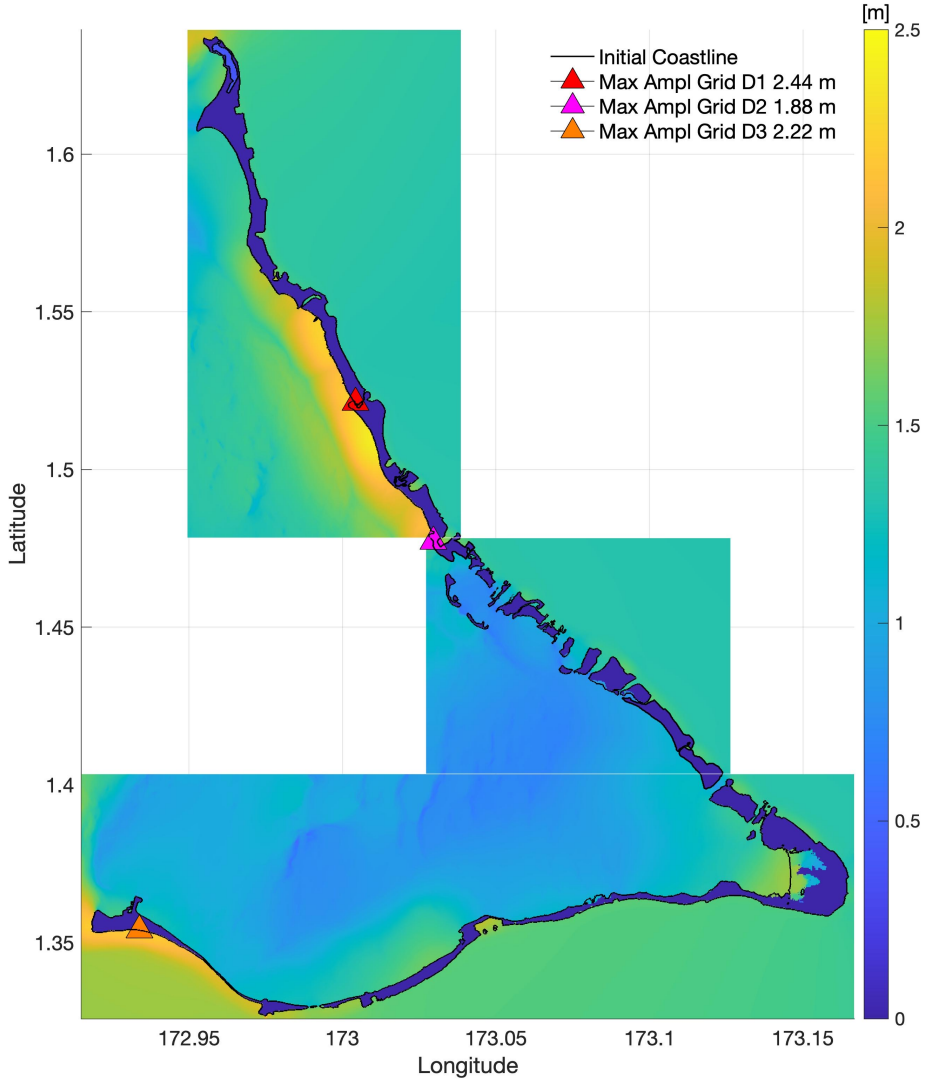




Maximum tsunami heights and inundation from the Japan sources.

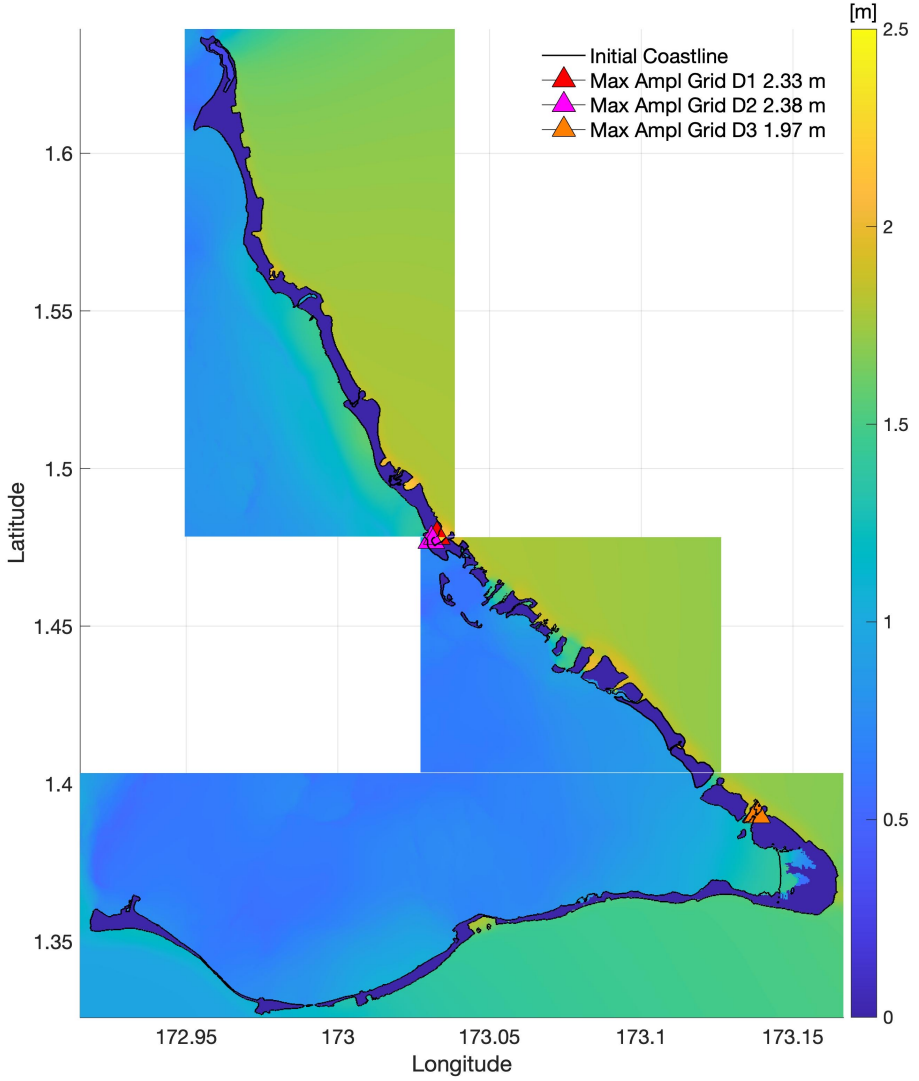
Triangle: overall grid maximum; black curve: initial coastline.

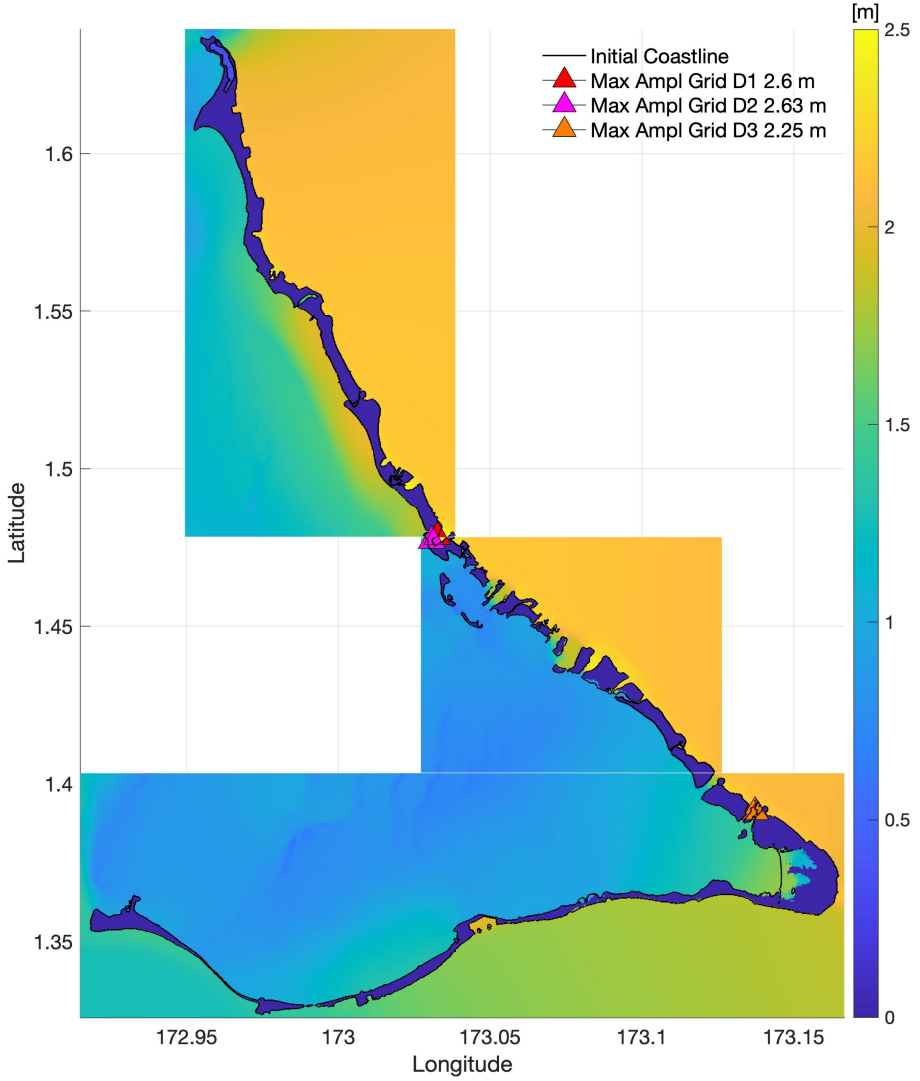




Maximum tsunami heights and inundation from the South American sources.

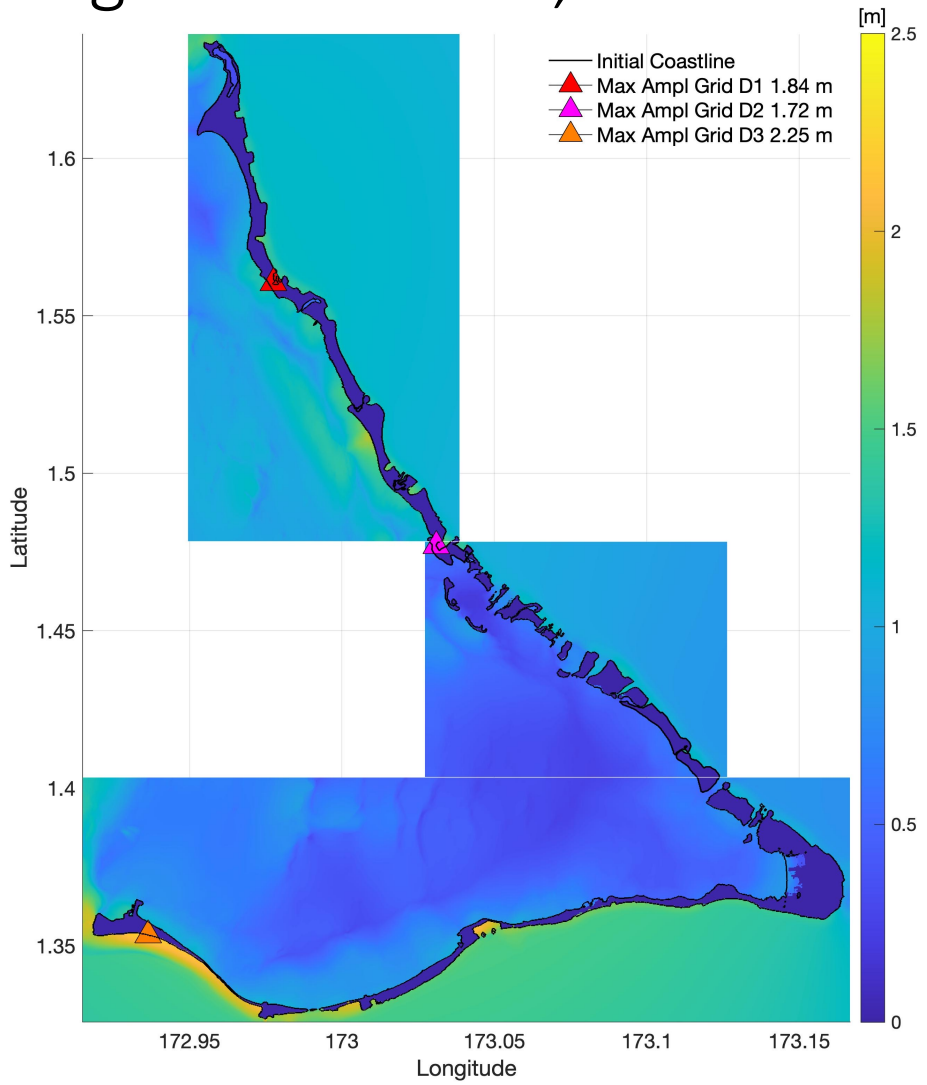
Triangle: overall grid maximum; black curve: initial coastline.





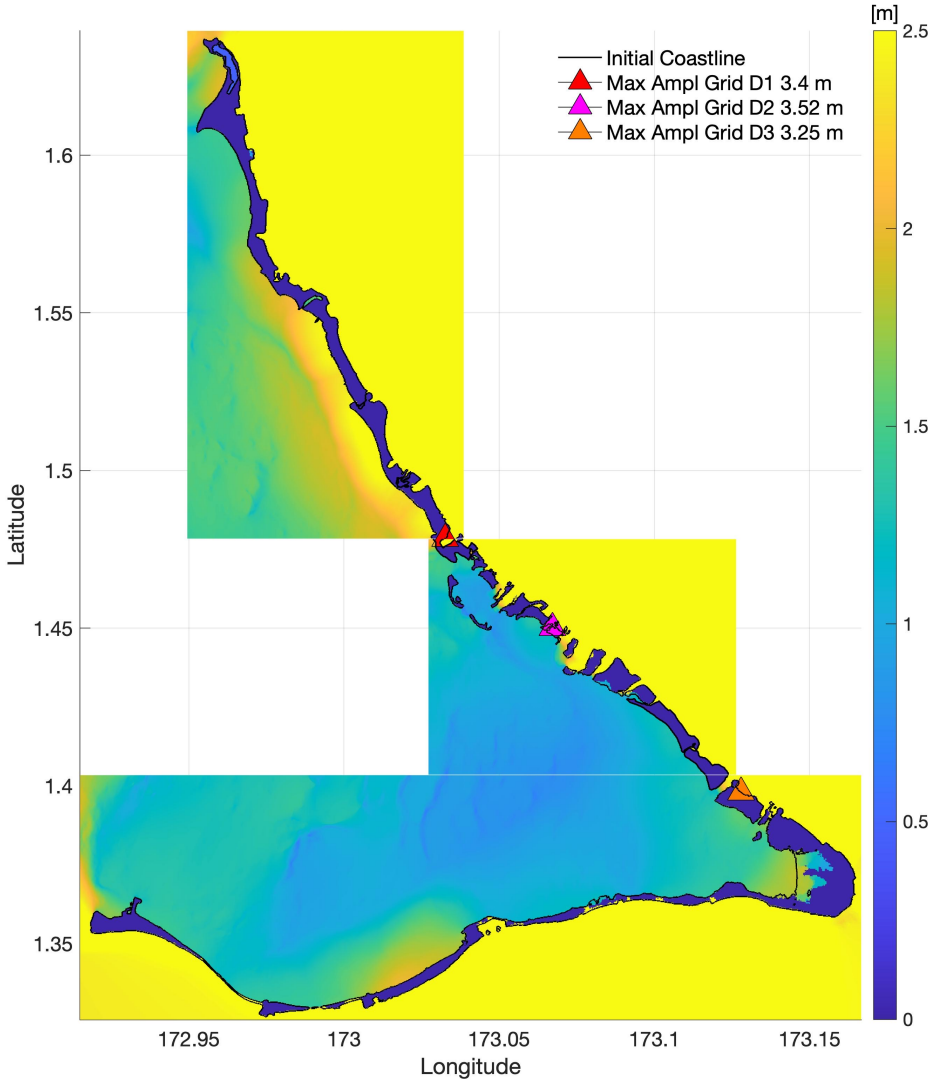
Maximum tsunami heights and inundation from the North Vanuatu source.

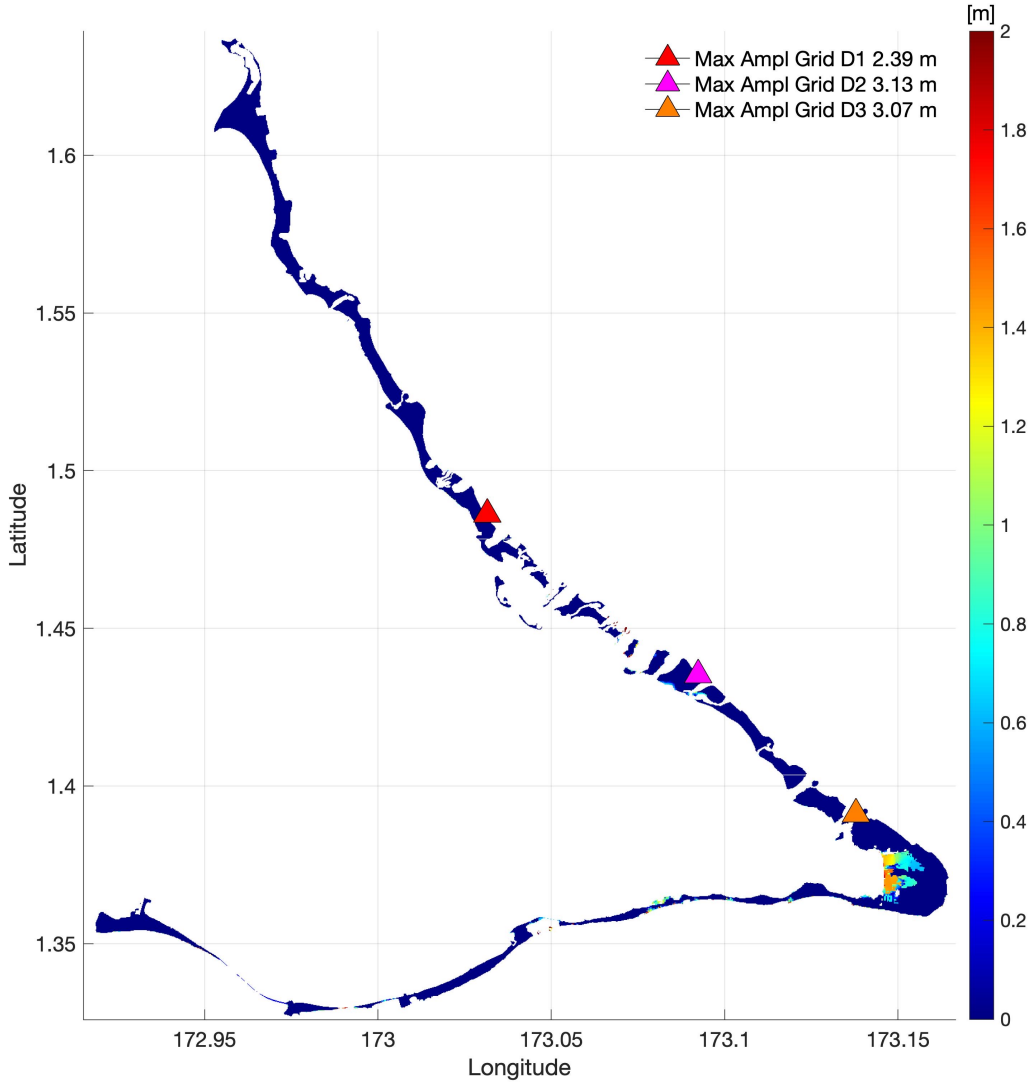
Triangle: overall grid maximum; black curve: initial coastline.



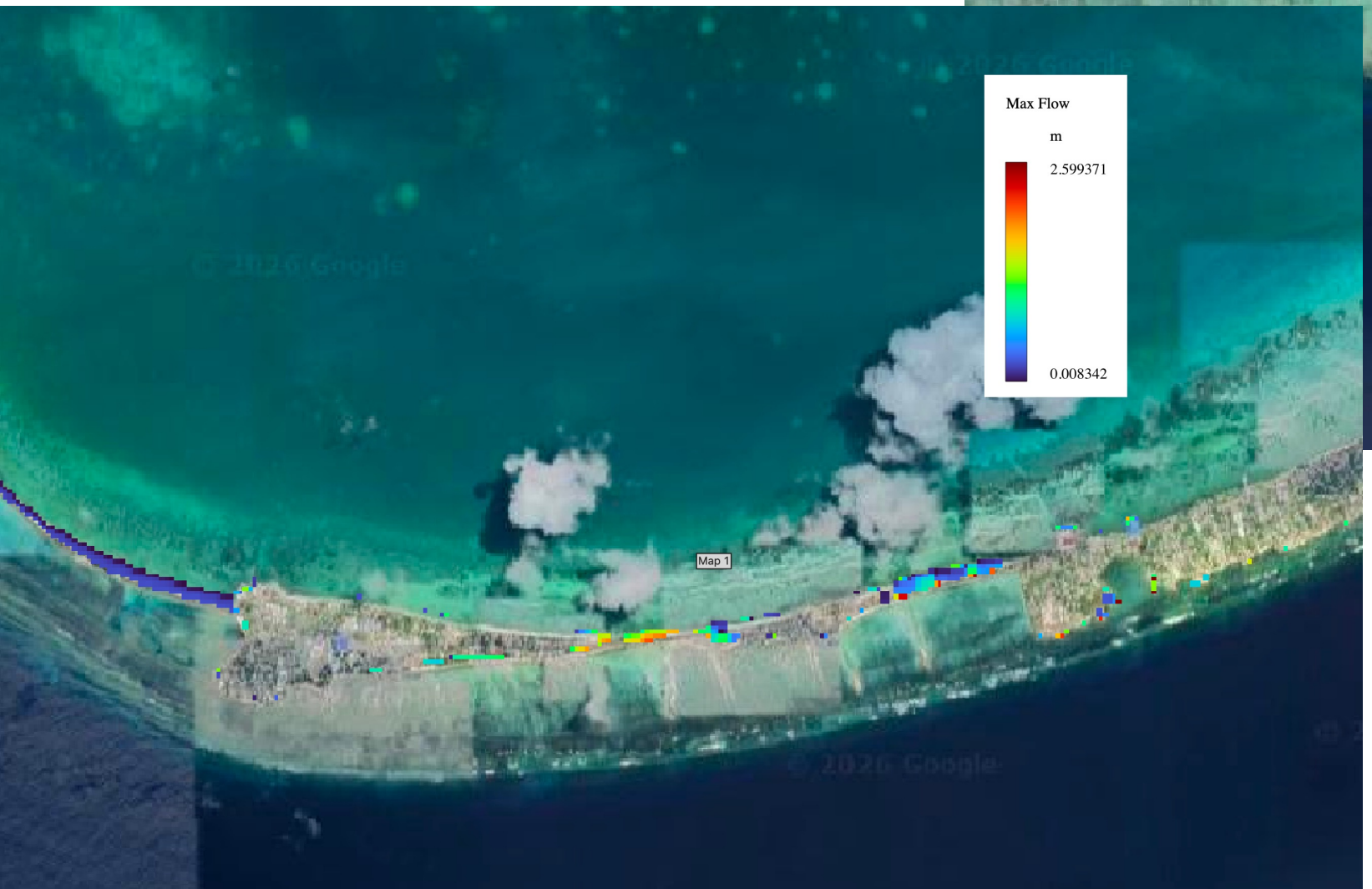
Composite maximum tsunami height and flow depth

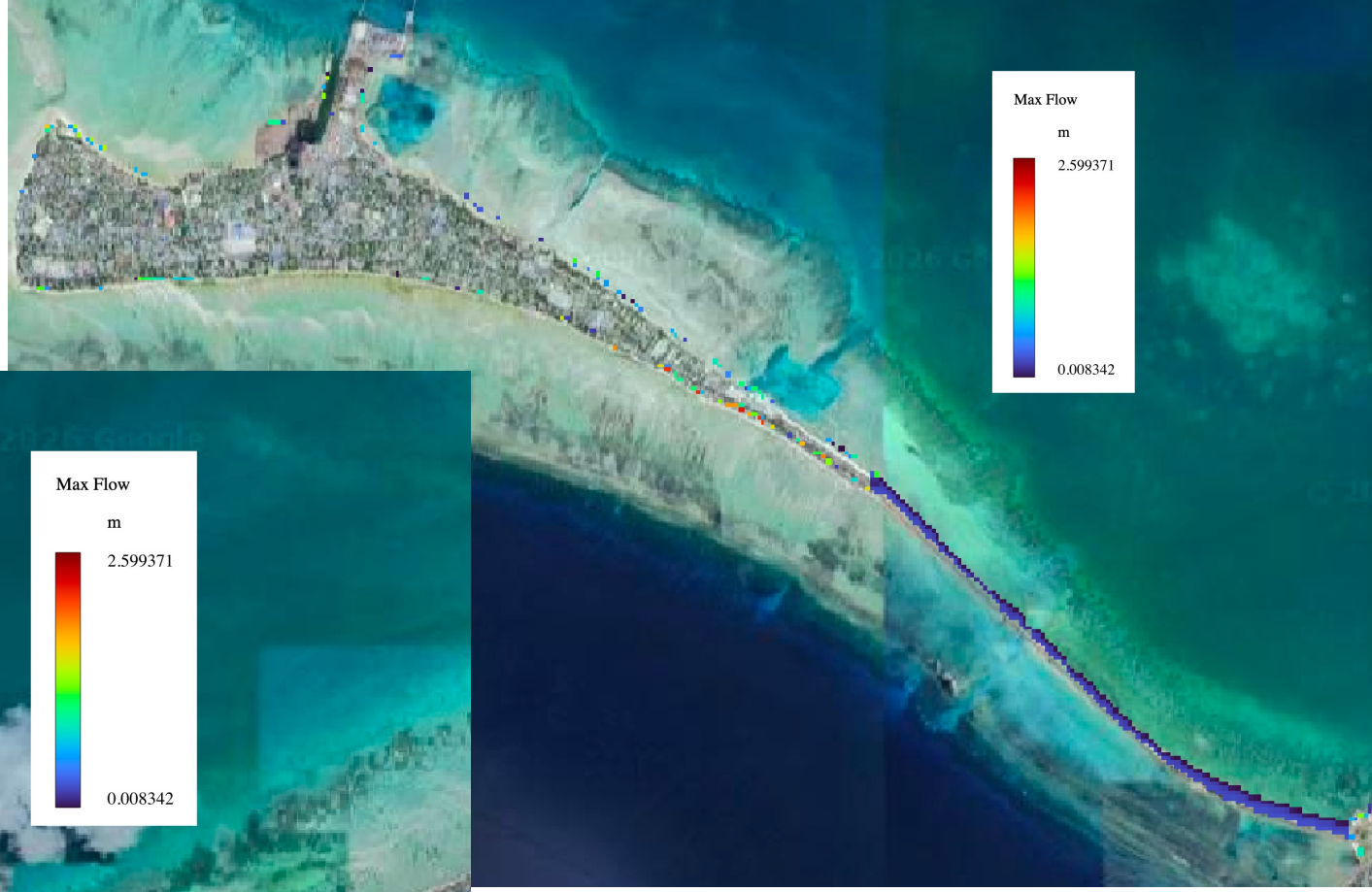
Triangle: overall grid maximum; black curve: initial coastline.



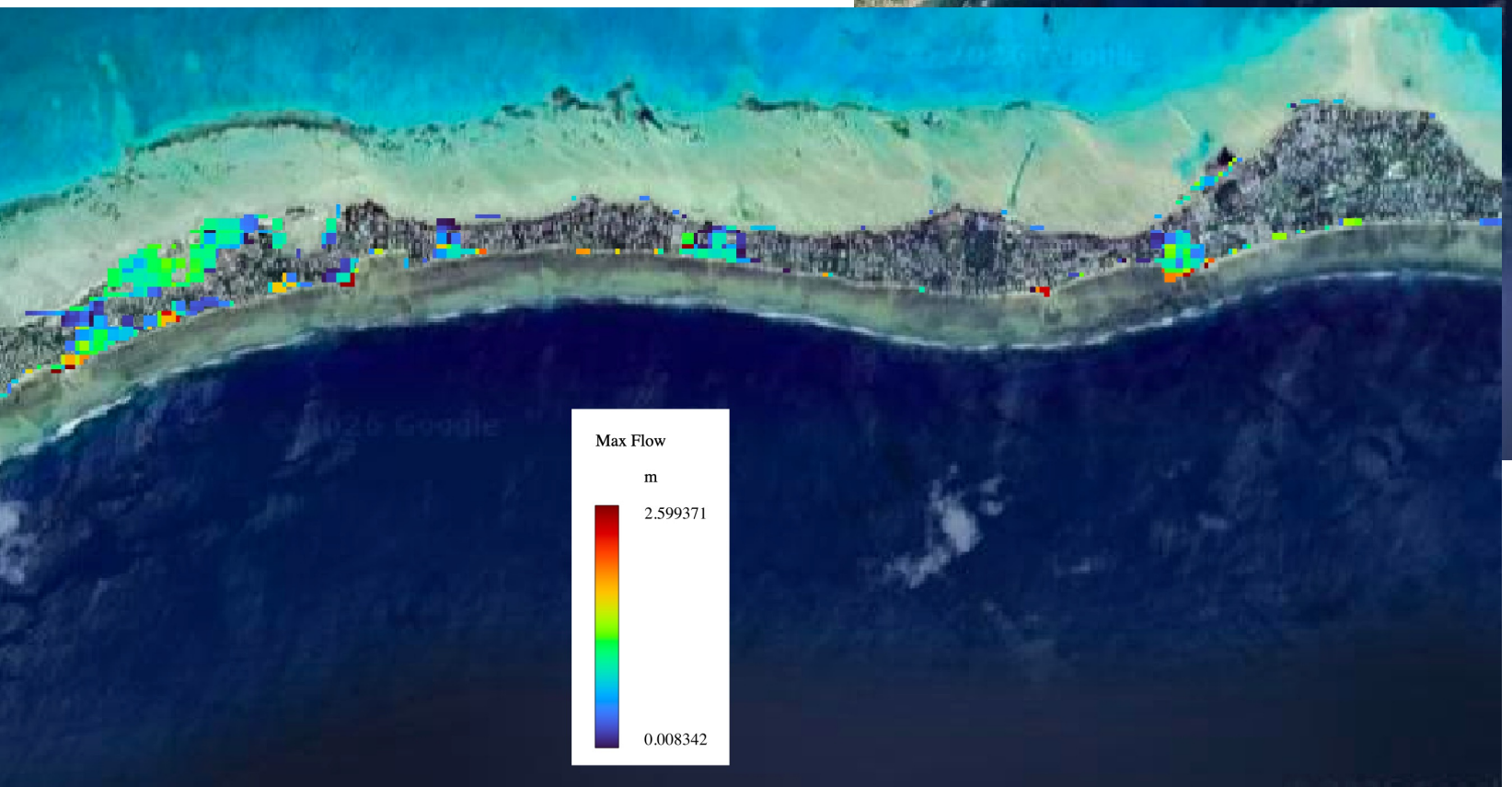


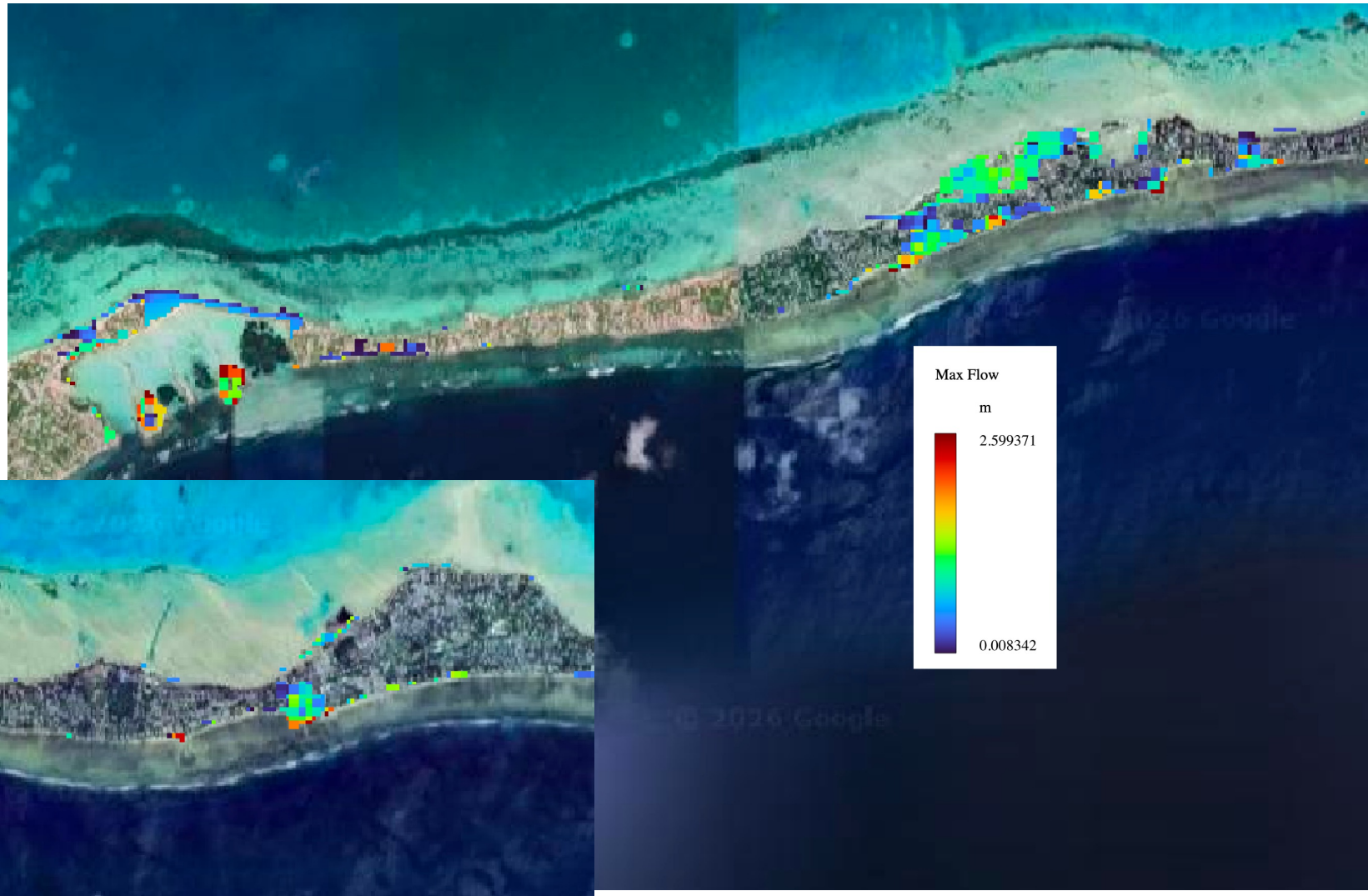
Maximum composite depth flow and inundated area.



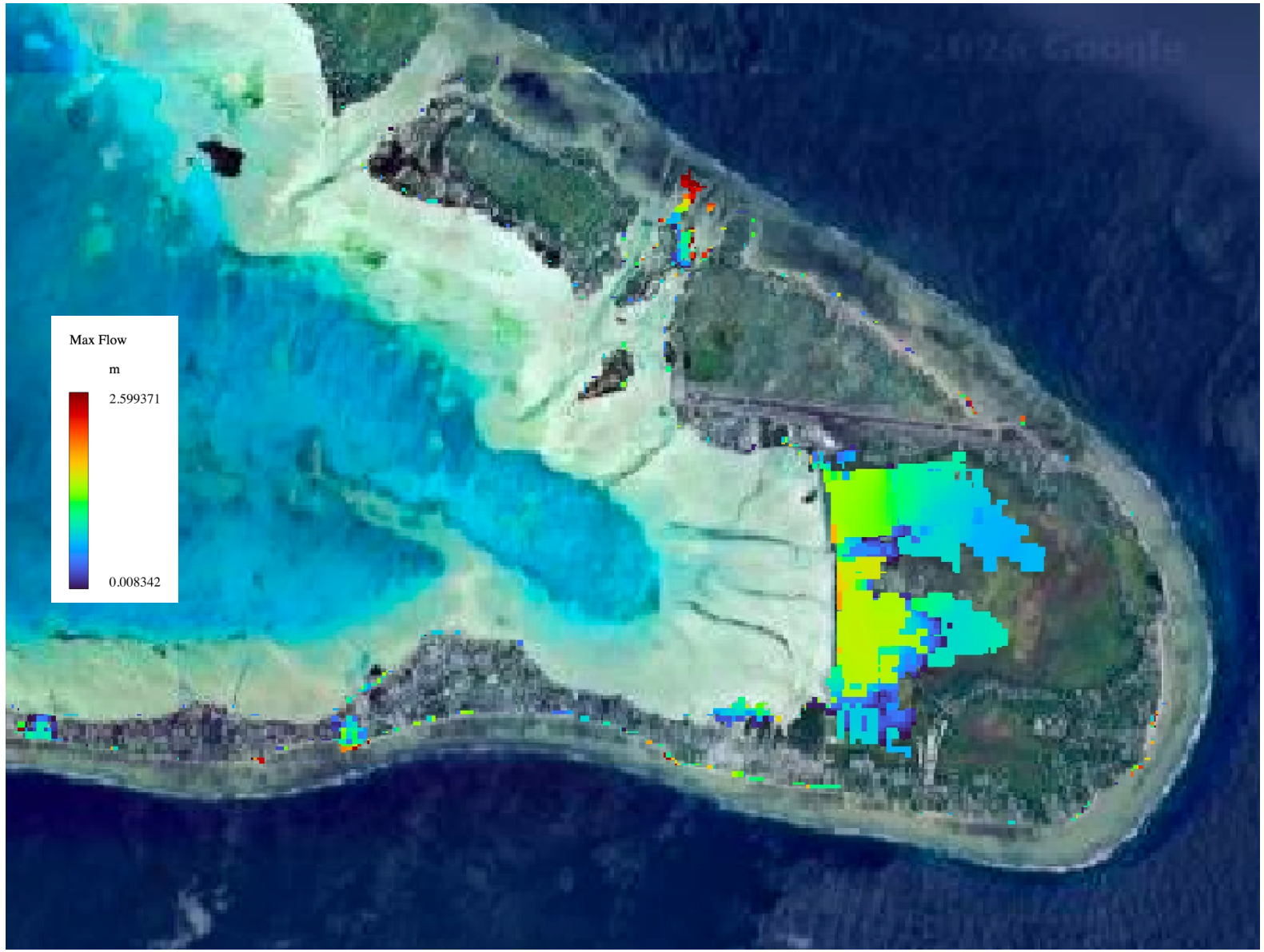


Maximum composite depth flow and inundated area.

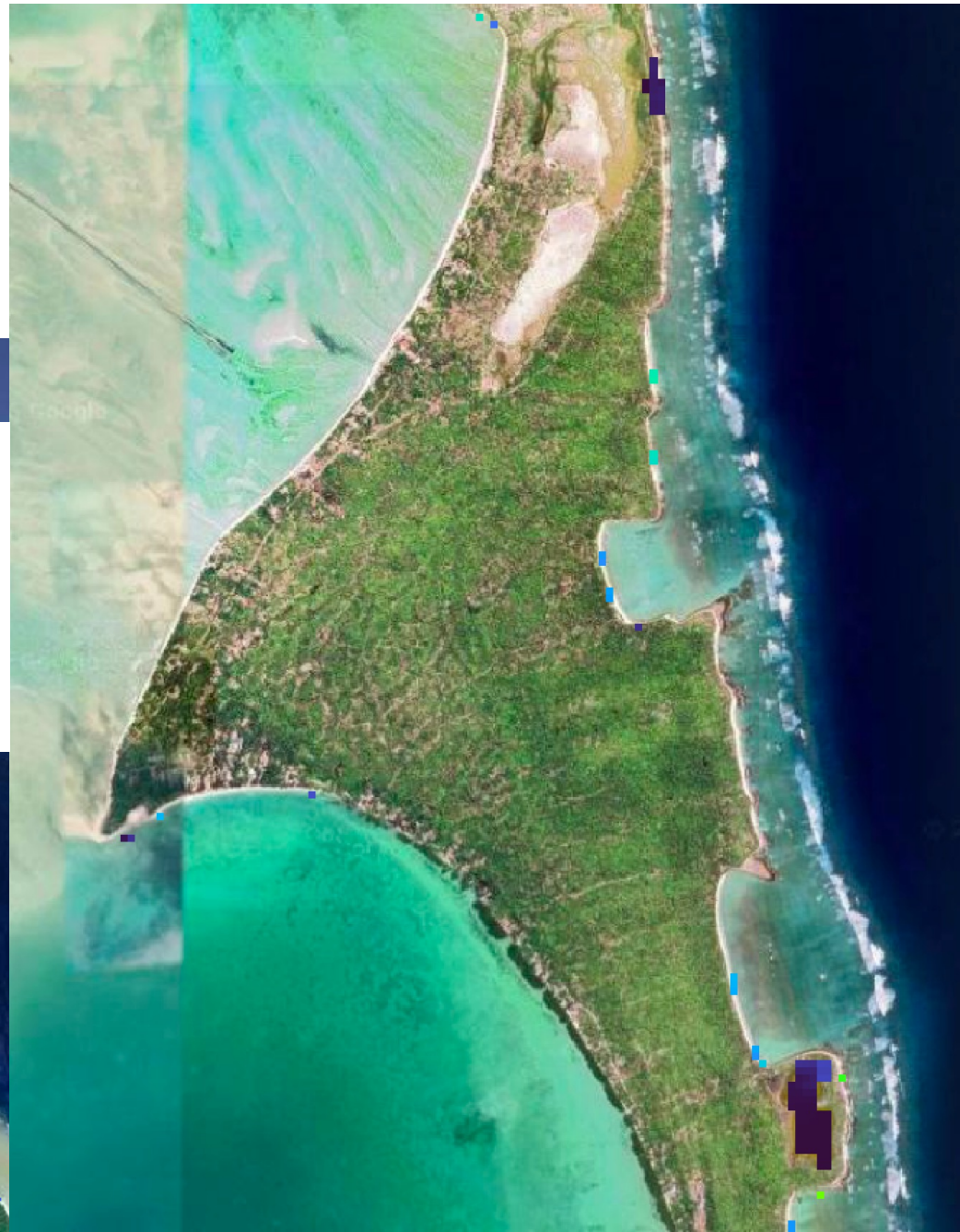




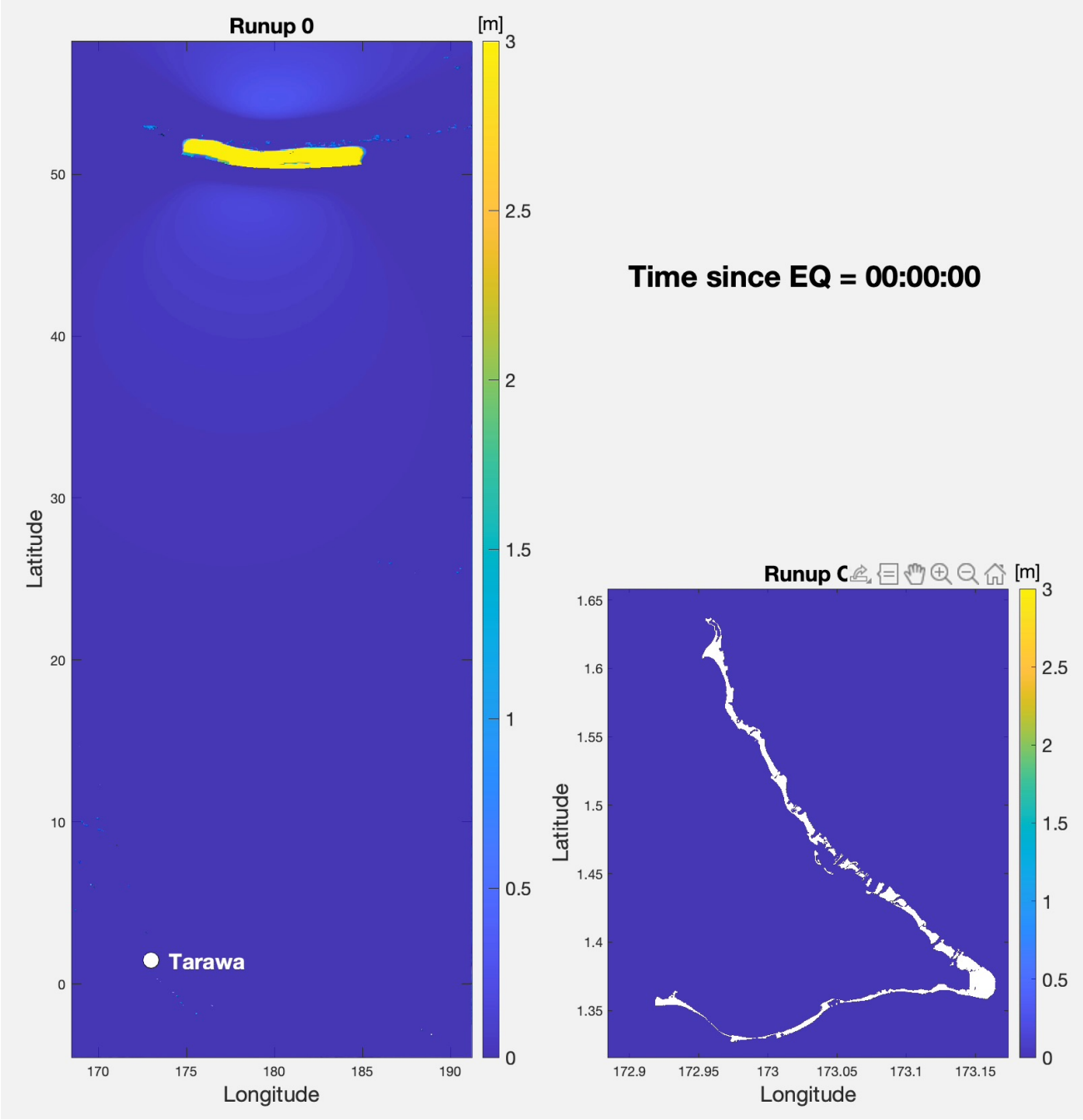
Maximum composite depth flow and inundated area.



Maximum composite depth flow and inundated area.



Tsunami propagation animation from the most hazardous source.



Thank you!