Palau – Tsunami Hazards

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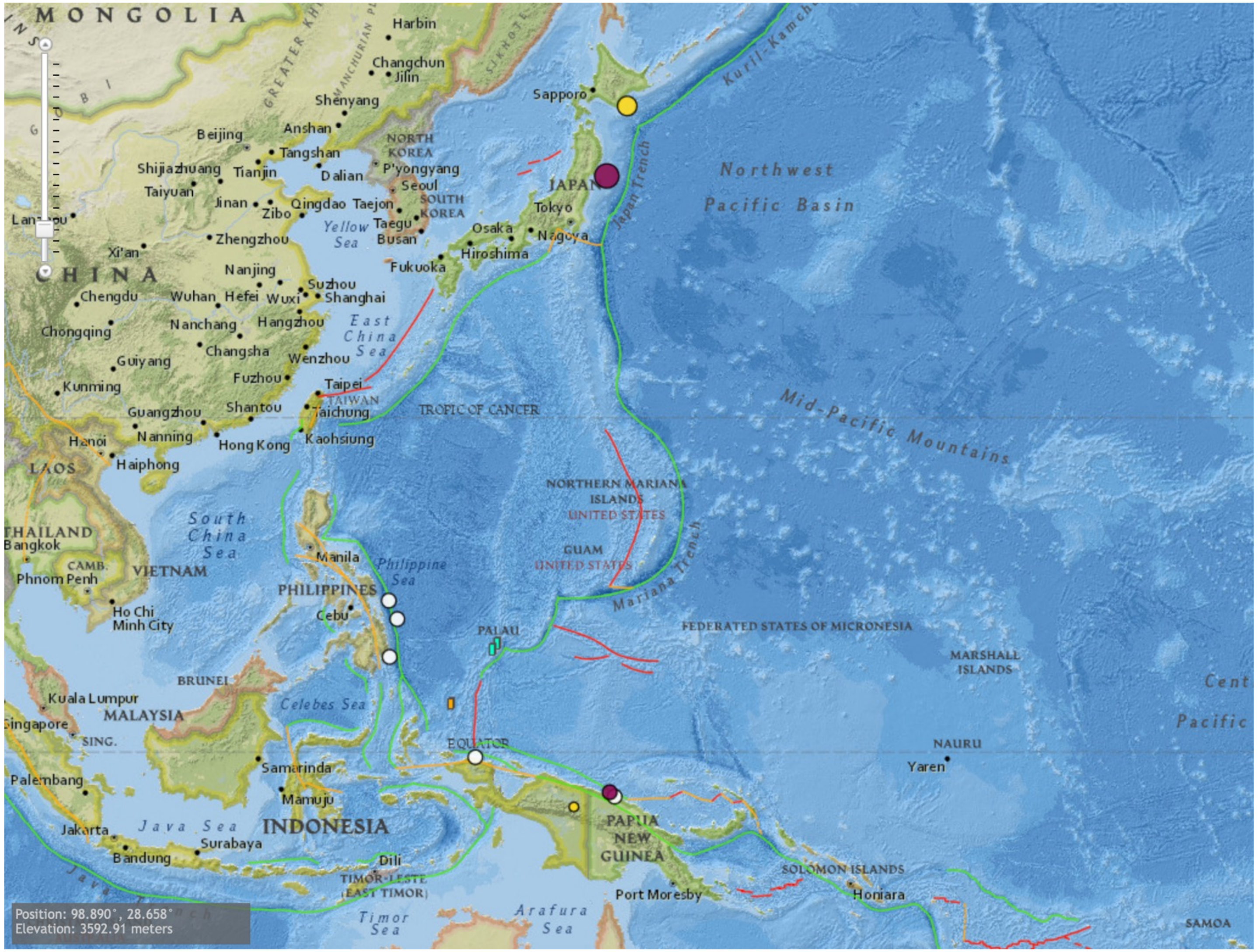
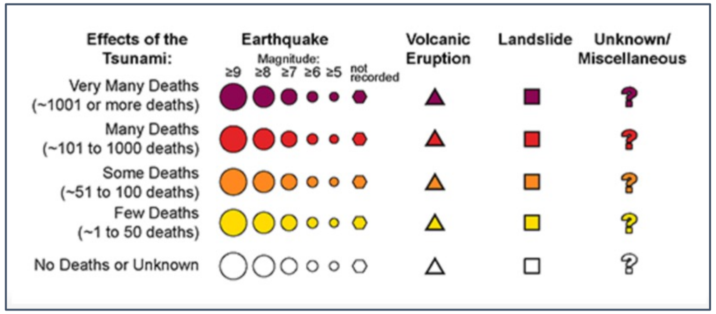
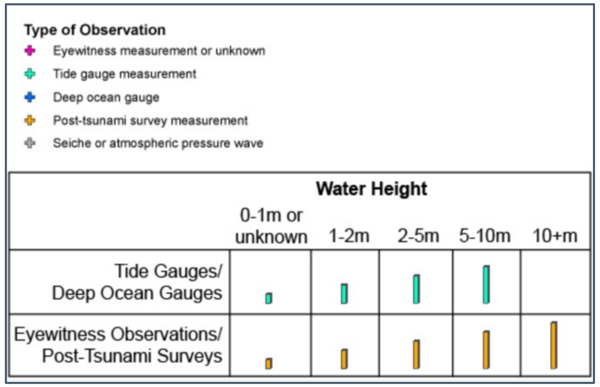
Tsunamis observed in Palau







Tsunamis observed in Palau

SOURCE LOCATIONS

Year	Mo	Dy	Hr	Mn	Earthquake Magnitude	Country	Location Name	Latitude	Longitude	Maximum Water Height (m)	Number of Runups
1952	3	4	1	22	8.1	JAPAN	SE. HOKKAIDO ISLAND	42.15	143.85	6.54	219
1952	3	19	10	57	7.8	PHILIPPINES	E. OF MINDANO, PHILIPPINES	9.5	127.25	0.33	5
1970	1	10	12	7	7.6	PHILIPPINES	PHILIPPINE TRENCH	6.8	126.7	0.06	1
1998	7	17	8	49	7	PAPUA NEW GUINEA	PAPUA NEW GUINEA	-2.943	142.582	15.03	93
2002	9	8	18	44	7.6	PAPUA NEW GUINEA	BISMARCK SEA	-3.26	142.94	5.5	88
2009	1	3	19	43	7.6	INDONESIA	NEAR NORTH COAST	-0.414	132.885	0.39	24
2011	3	11	5	46	9.1	JAPAN	HONSHU ISLAND	38.297	142.373	39.26	6421
2012	8	31	12	47	7.6	PHILIPPINES	PHILIPPINE ISLANDS	10.811	126.638	0.15	18
2023	12	2	14	37	7.6	PHILIPPINES	E. MINDANAO ISLAND	8.527	126.449	0.32	52

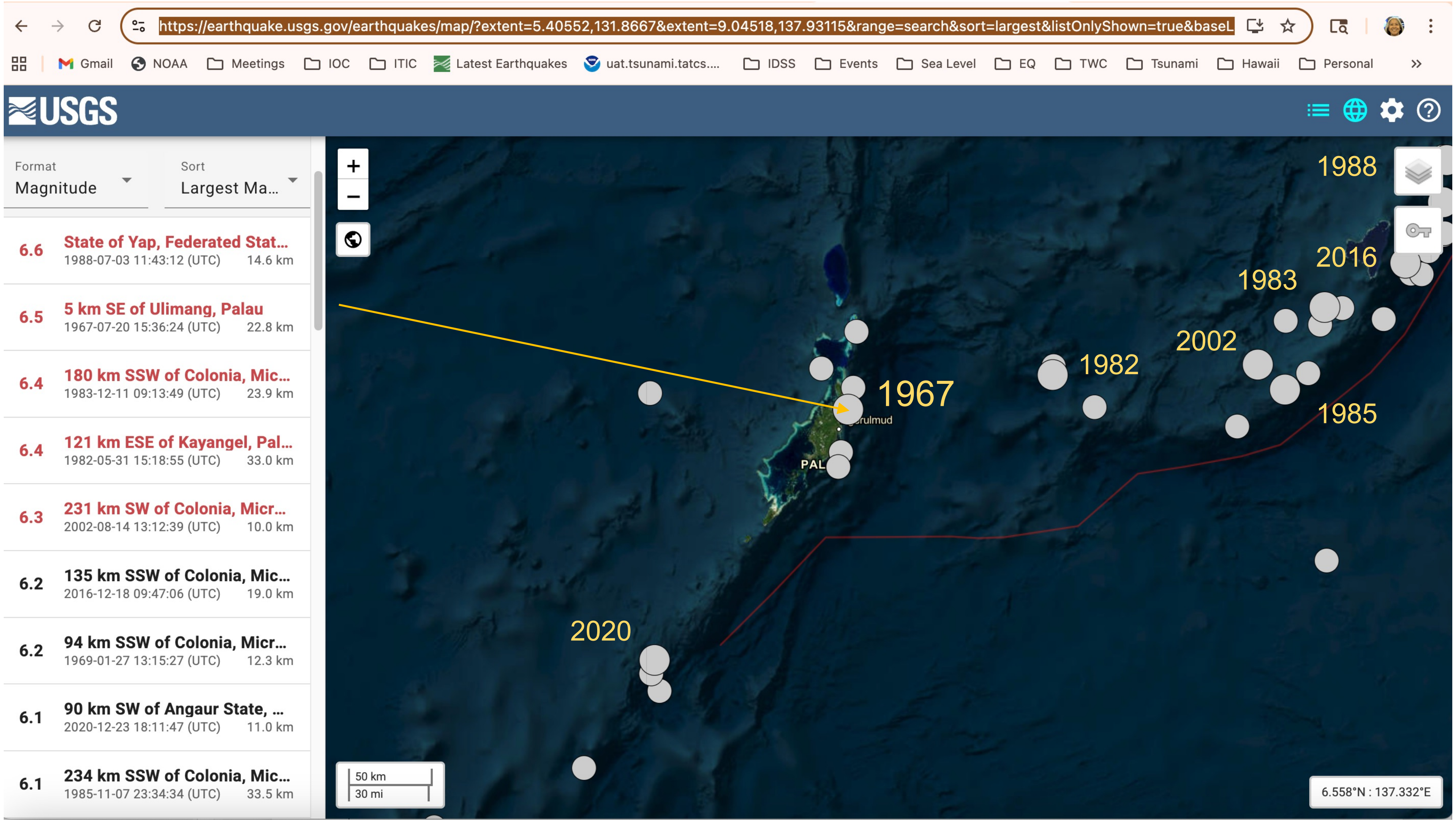
WAVE OBSERVATIONS

Year	Country	Location Name	Latitude	Longitude	Distance From Source (km)	Initial Wave Arrival Dy	Initial Wave Arrival Hr	Initial Wave Arrival Min	Travel Hours	Travel Minutes	Max Wave Arrival Day	Max Wave Arrival Hr	Max Wave Arrival Min	Max Water Height (m)	Period
1952	PALAU	ANGAUR ISLAND	6.9	134.13	4021									0.2	15
1952	PALAU	ANGAUR ISLAND	6.9	134.13	811	19	12	3	1	6				0.33	
1970	PALAU	MALAKAL ISLAND, CAROLINE ISLANDS	7.333	134.463	860									0.06	
1998	PALAU	MALAKAL ISLAND, CAROLINE ISLANDS	7.333	134.463	1451									0.02	
2002	PALAU	MALAKAL ISLAND, CAROLINE ISLANDS	7.333	134.463	1503										
2009	PALAU	MALAKAL ISLAND, CAROLINE ISLANDS	7.333	134.463	874	3	21	11	1	27				0.04	14
2011	PALAU	MALAKAL ISLAND, CAROLINE ISLANDS	7.333	134.463	3521	11	10	30	4	43	11	12	0	0.16	42
2012	PALAU	MALAKAL ISLAND, CAROLINE ISLANDS	7.333	134.463	942	31	14	10	1	22				0.02	13
2023	PALAU	MALAKAL ISLAND, CAROLINE ISLANDS	7.333	134.463	893						2	16	8	0.01	18

USGS Earthquakes near Palau

https://earthquake.usgs.gov/earthquakes/map/?extent=5.40552,131.8667&extent=9.04518,137.93115&range=search&sort=largest&listOnlyShown=true&baseLayer=satellite&timeZone=utc&search=%7B%22name%22:%22Search%20Results%22,%22params%22:%7B%22starttime%22:%221960

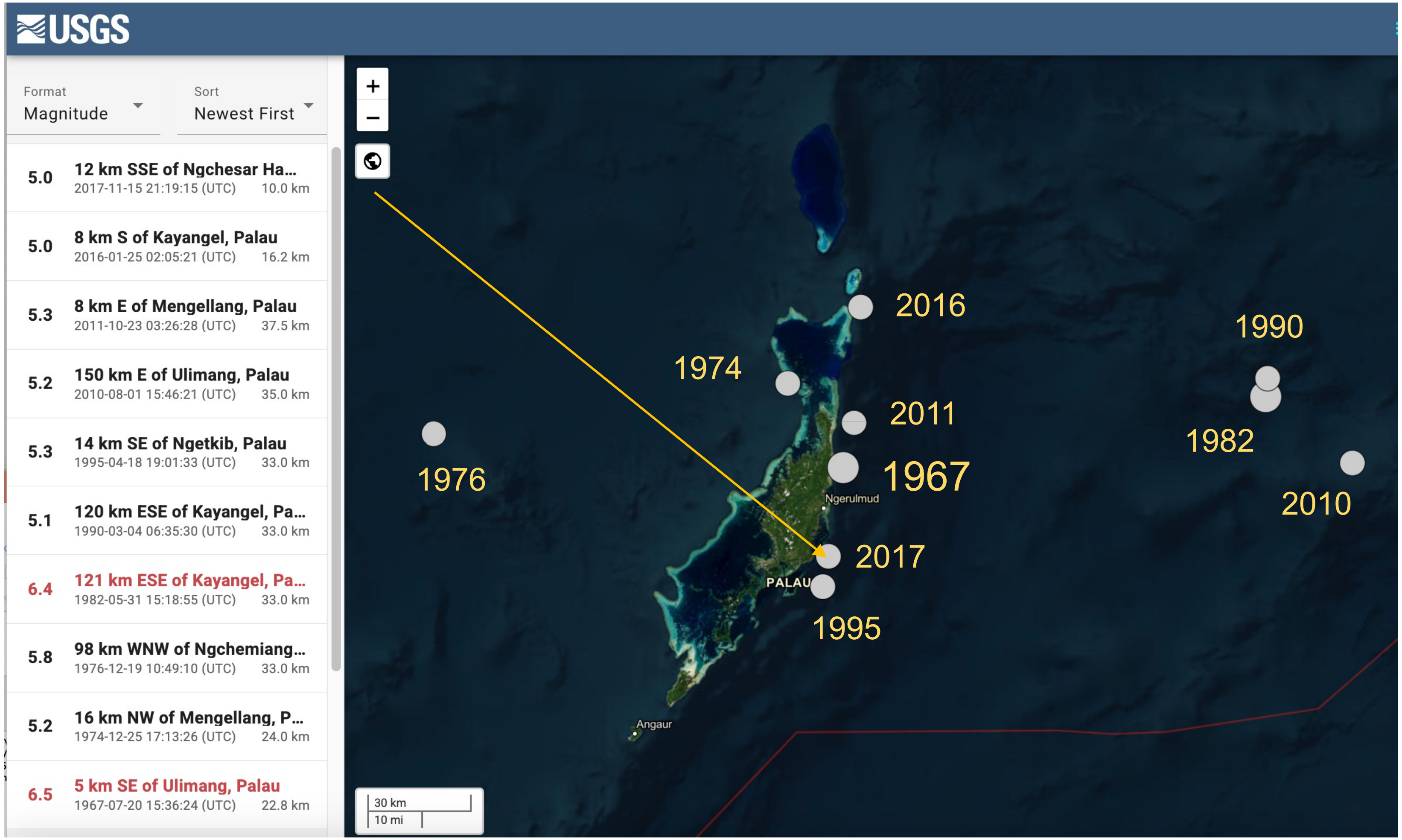
Largest



USGS Earthquakes near Palau

https://earthquake.usgs.gov/earthquakes/map/?extent=6.61629,133.38003&extent=8.65241,136.50839&range=search&listOnlyShown=true&baseLayer=satellite&timeZone=utc&search=%7B%22name%22:%22Search%20Results%22,%22params%22:%7B%22starttime%22:%221960-01-14%2000:

Most Recent

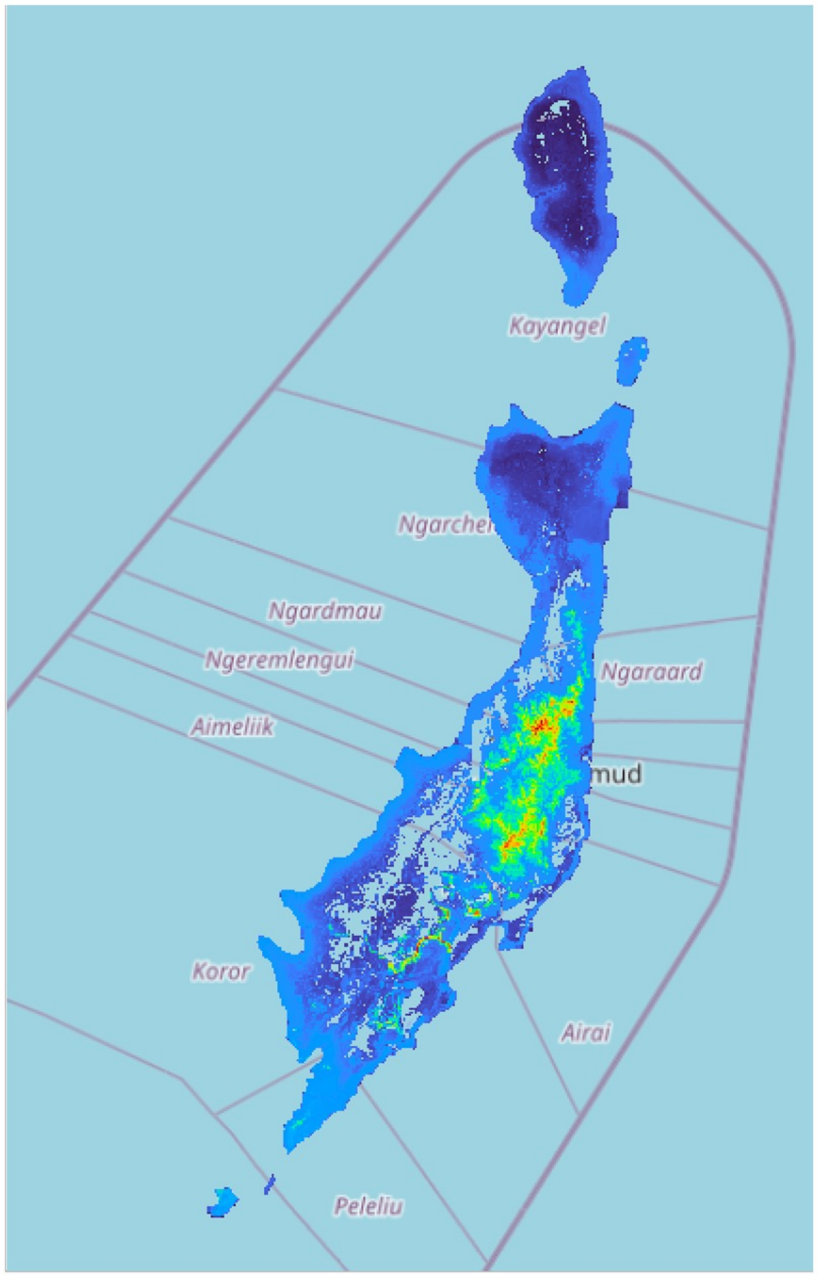


Maximum inundation and run-up

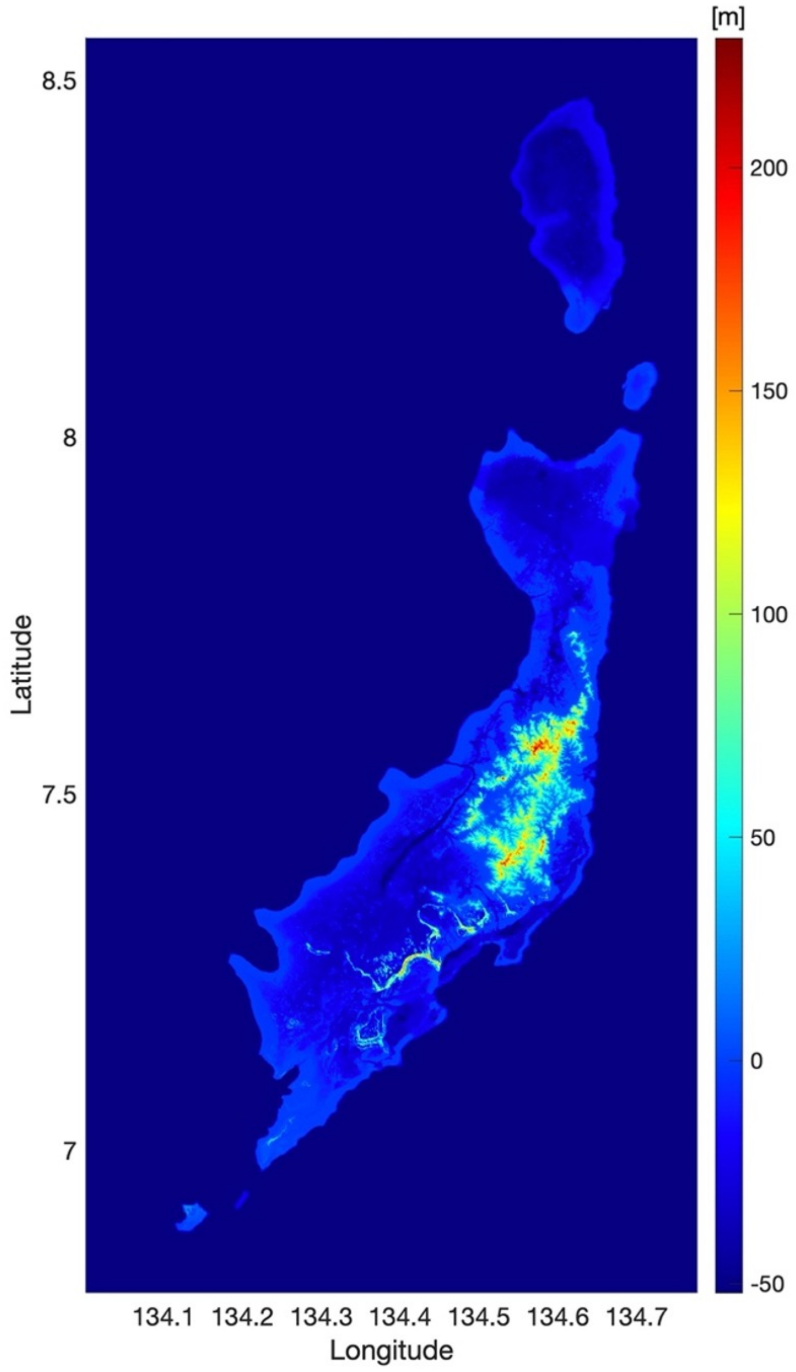
The States of Palau

PALARIS LiDAR DEM (*a*) and final DEM (*b*)

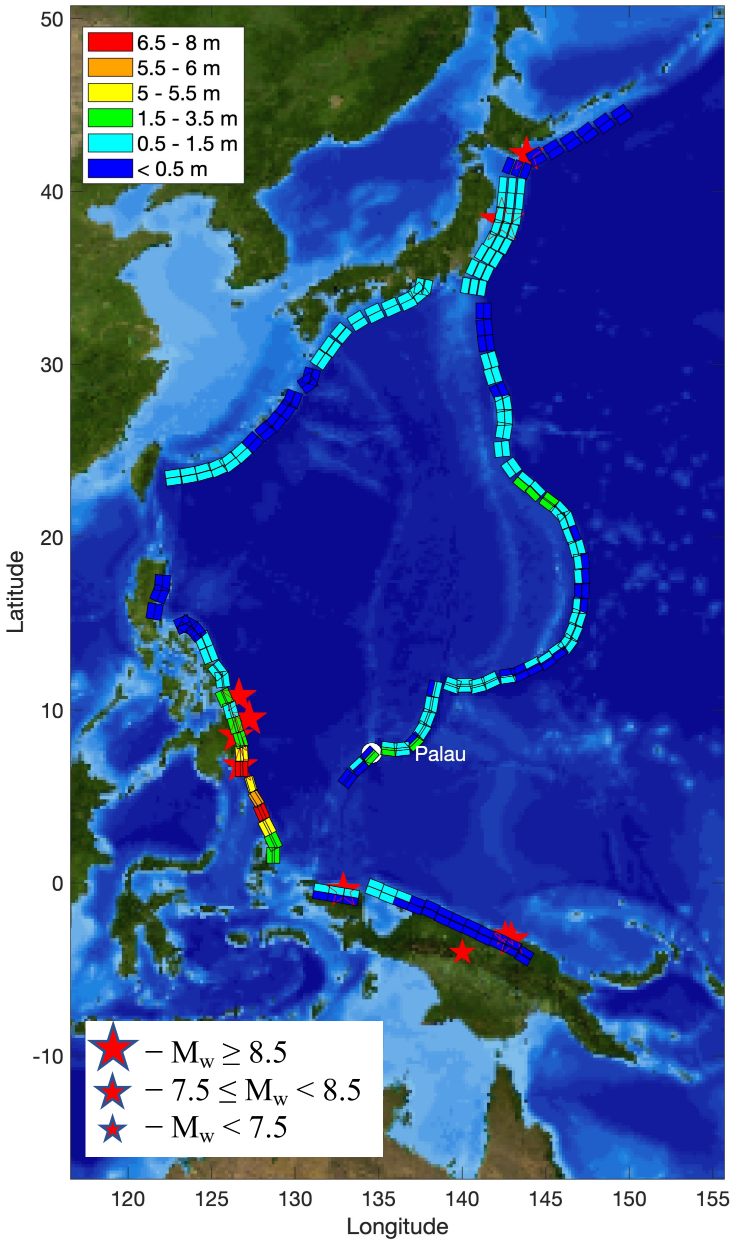
a



b



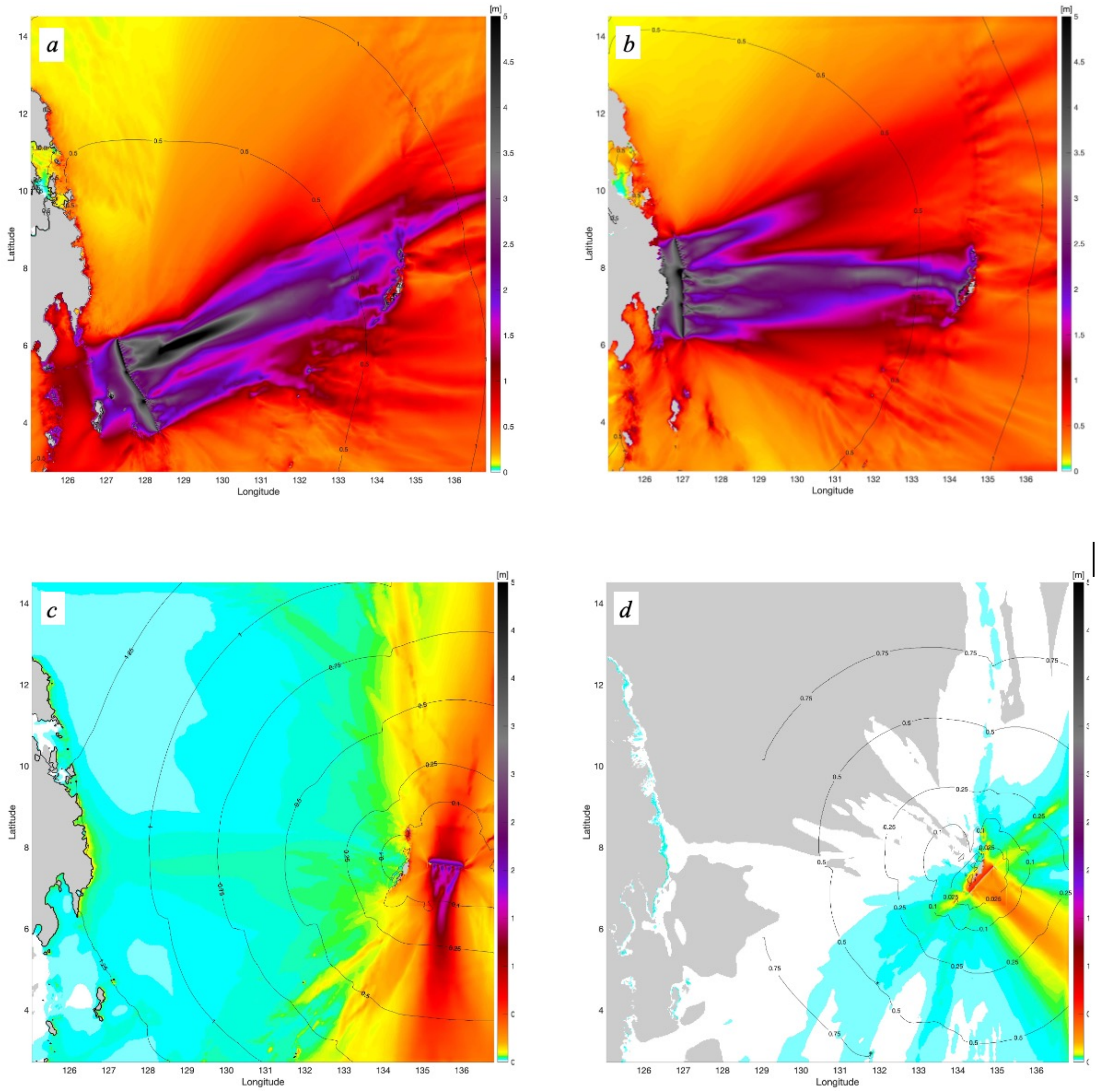
Sensitivity Study



Stars mark the origin of historic tsunami that ever affected Palau

- Synthetically generated tsunami source scenarios from around the Pacific Basin were modeled with computationally optimized grids 3.239, 12.957, 51.828 and 207.313 arc-seconds
- Source parameters were selected based on maximum possible earthquake magnitude of the subduction zone (SZ) with the return period 2500 years (**Philippine Trench – Mw 8.5, New Guinea – Mw 8.2, Palau – Mw 7.4, Yap – Mw 7.8, Mariana – Mw 8.4, Izu-Bonin – Mw 8.6, Japan – Mw 9.1, Kuril-Kamchatka – Mw 9.0, Ryukyu – Mw 8.5, Nankai – Mw 9.0**)
- HySea – an NTHMP-benchmarked inundation model was used for modeling
- The study helps to determine potential earthquake-generated tsunami sources of greatest concern to Palau
- Maximum wave amplitudes were received from the sources originated from the **Philippine Trench**
- Source parameters, distance to the source and direction of the most energy released determine the potential tsunami hazard

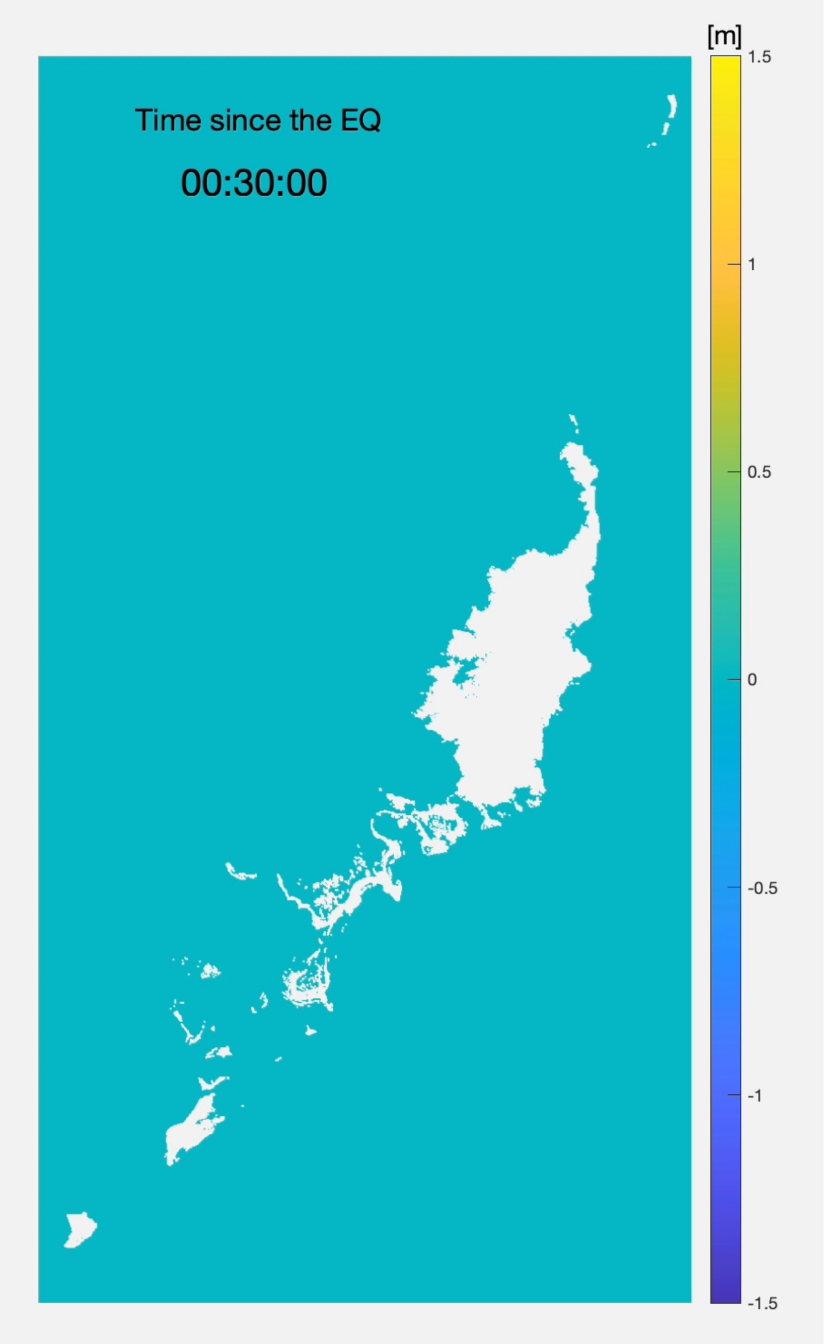
Subsequent to the sensitivity study, we selected four earthquake scenarios to be modeled at the highest resolution of 10 m: **two the most hazardous to Palau sources along the Philippine Trench and two closest to Palau sources with the significant impact (one source from Palau and one from Yap Trenches).**



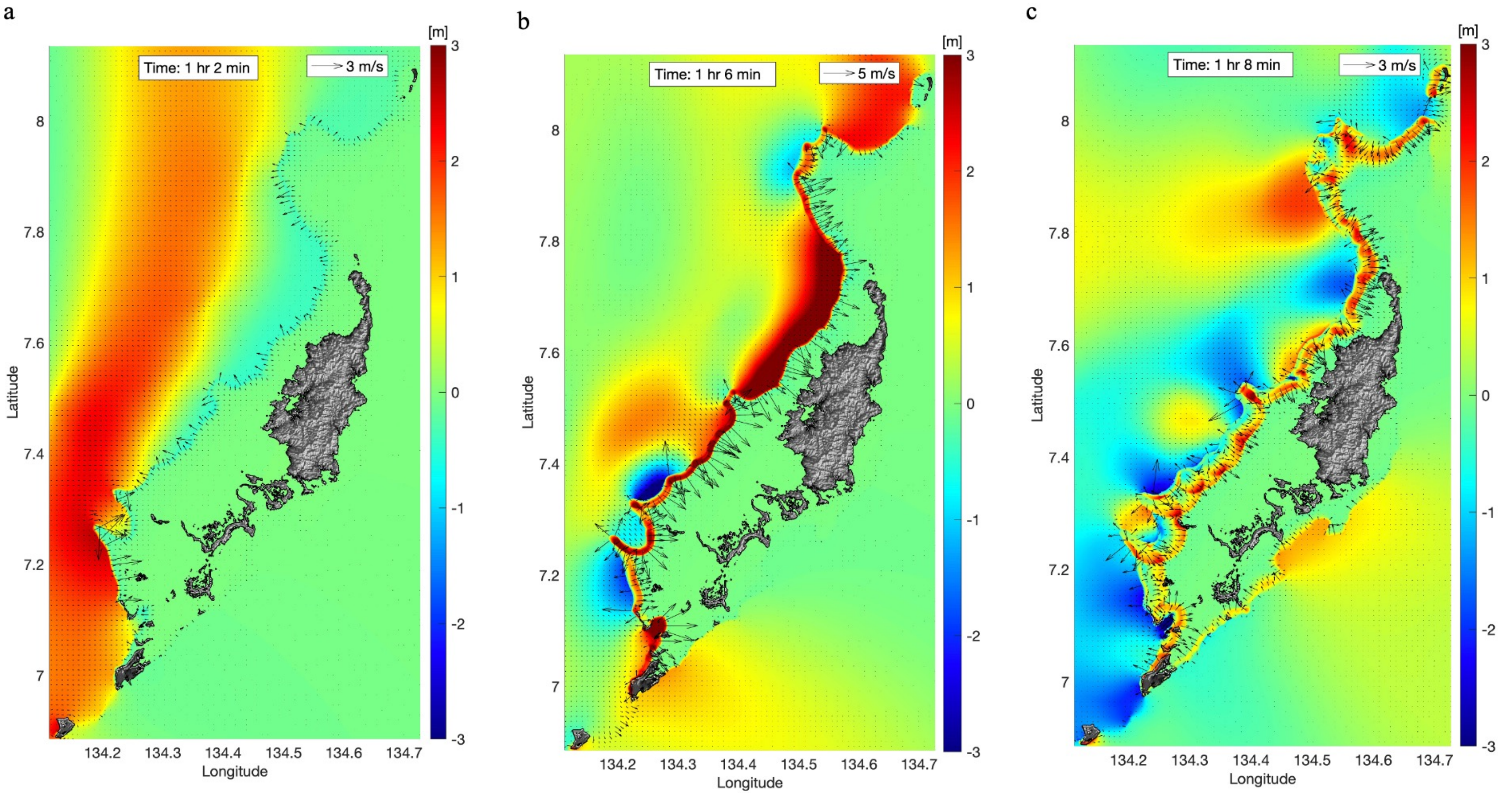
Source location, arrival times, and maximum wave amplitudes in deep ocean for the most hazardous sources Phillipine1 (*a*), Philippine2 (*b*) and the closest to Palau significant impact sources Yap (*c*) and Palau (*d*).

Tsunami Inundation Modelling Study (NOAA PMEL, 2024)

- Maximum of Maximums forecast amplitude
- Uses all plausible tsunami scenarios
- Dominated by M8.5 off-Philippines (Philippines Trench) ‘local’ scenario, with 1.5 hrs tsunami travel time

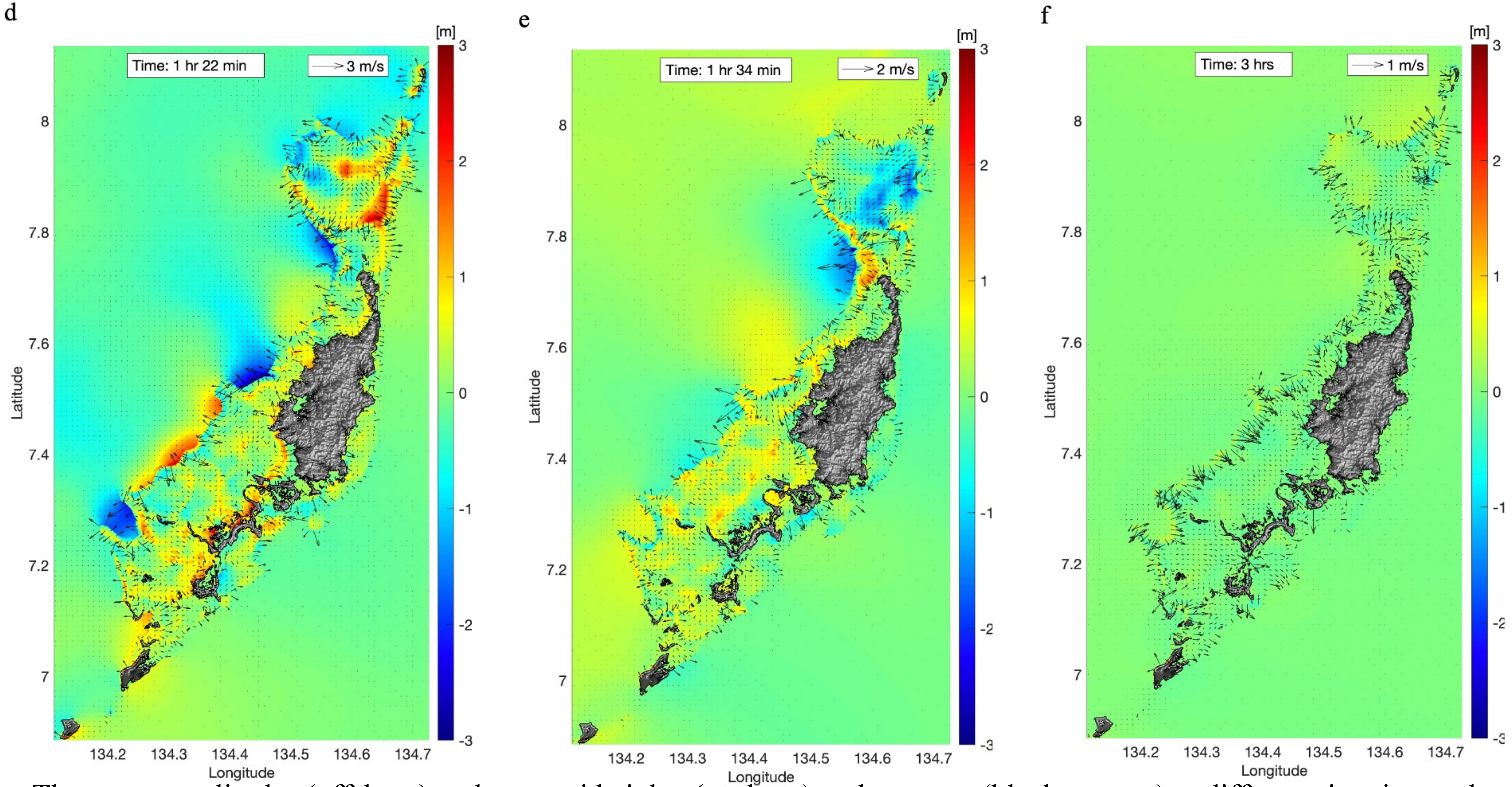


Wave Propagation – Philippines source



The wave amplitudes (offshore) and tsunami heights (onshore) and currents (black vectors) at different time intervals after earthquake from the Philippine2 source, the most dangerous for Koror.

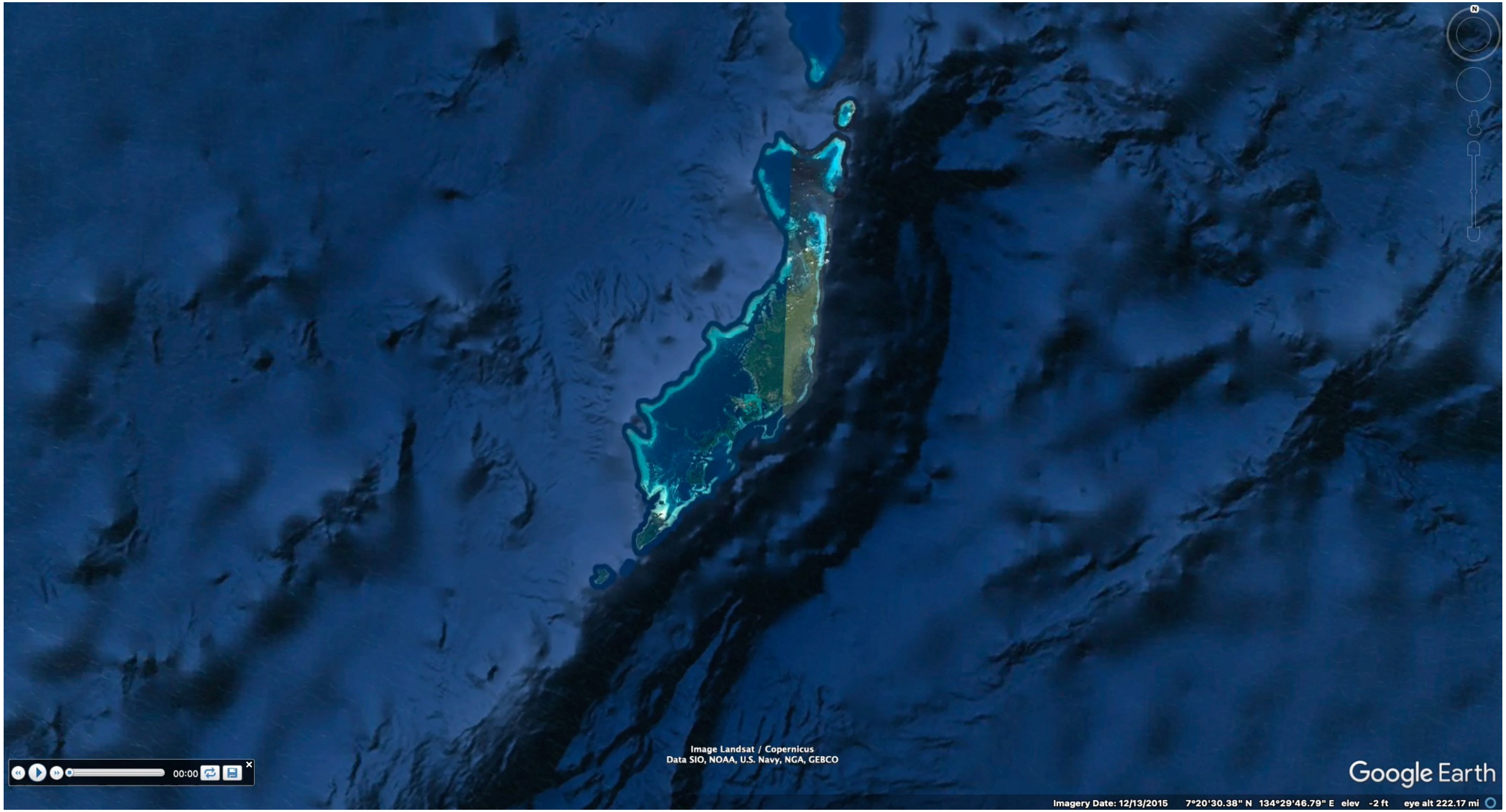
Wave Propagation – Philippines source



The wave amplitudes (offshore) and tsunami heights (onshore) and currents (black vectors) at different time intervals after earthquake from the Philippine2 source, the most dangerous for Koror.

Tsunami Inundation Modelling Study (NOAA PMEL 2024)

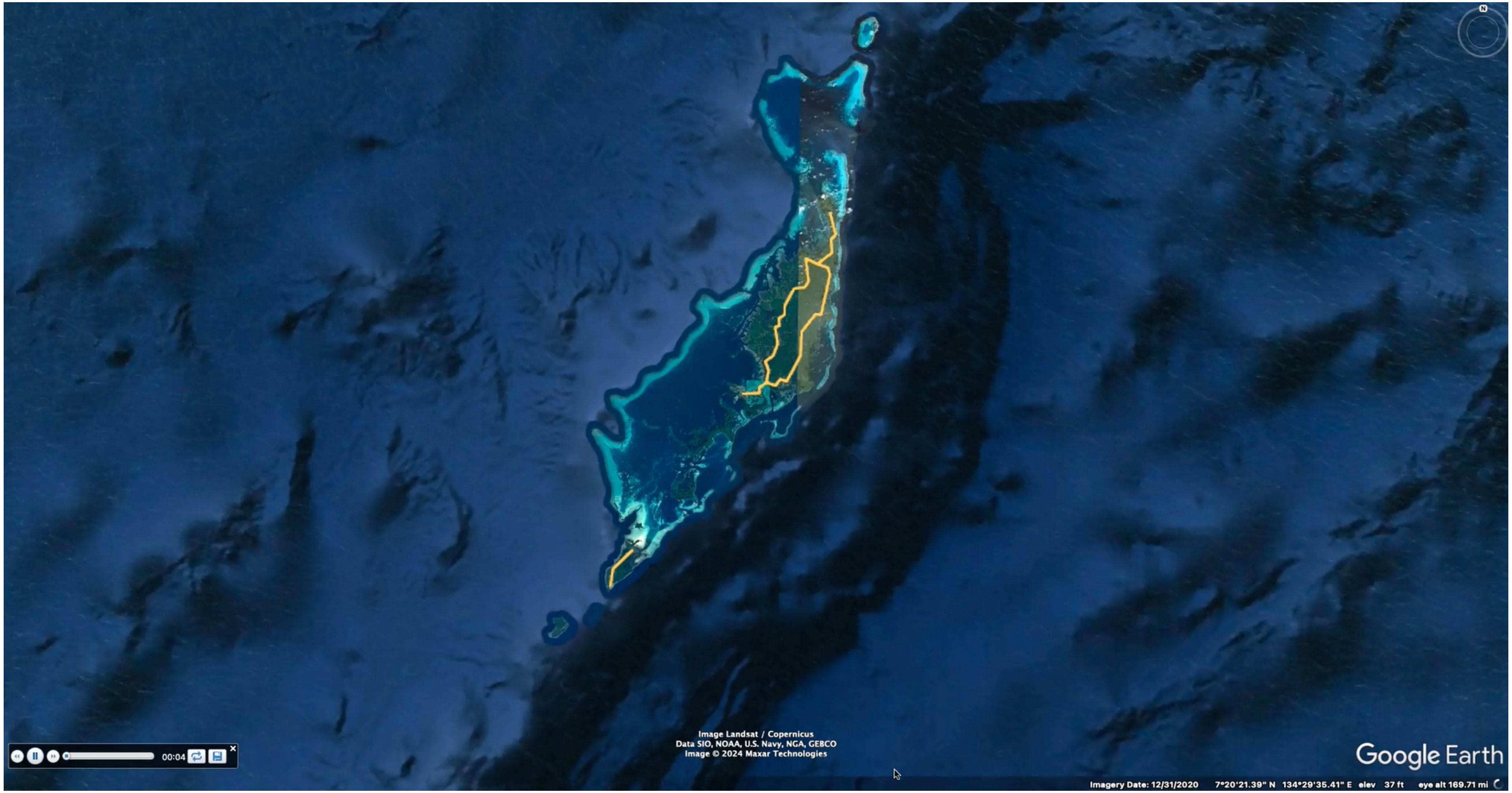
Google Map flyover with Inundation Layer overlay (light blue shade)



Tsunami Inundation Modelling Study (NOAA PMEL 2024)

Google Map flyover with Inundation Layer overlay (light blue shade)

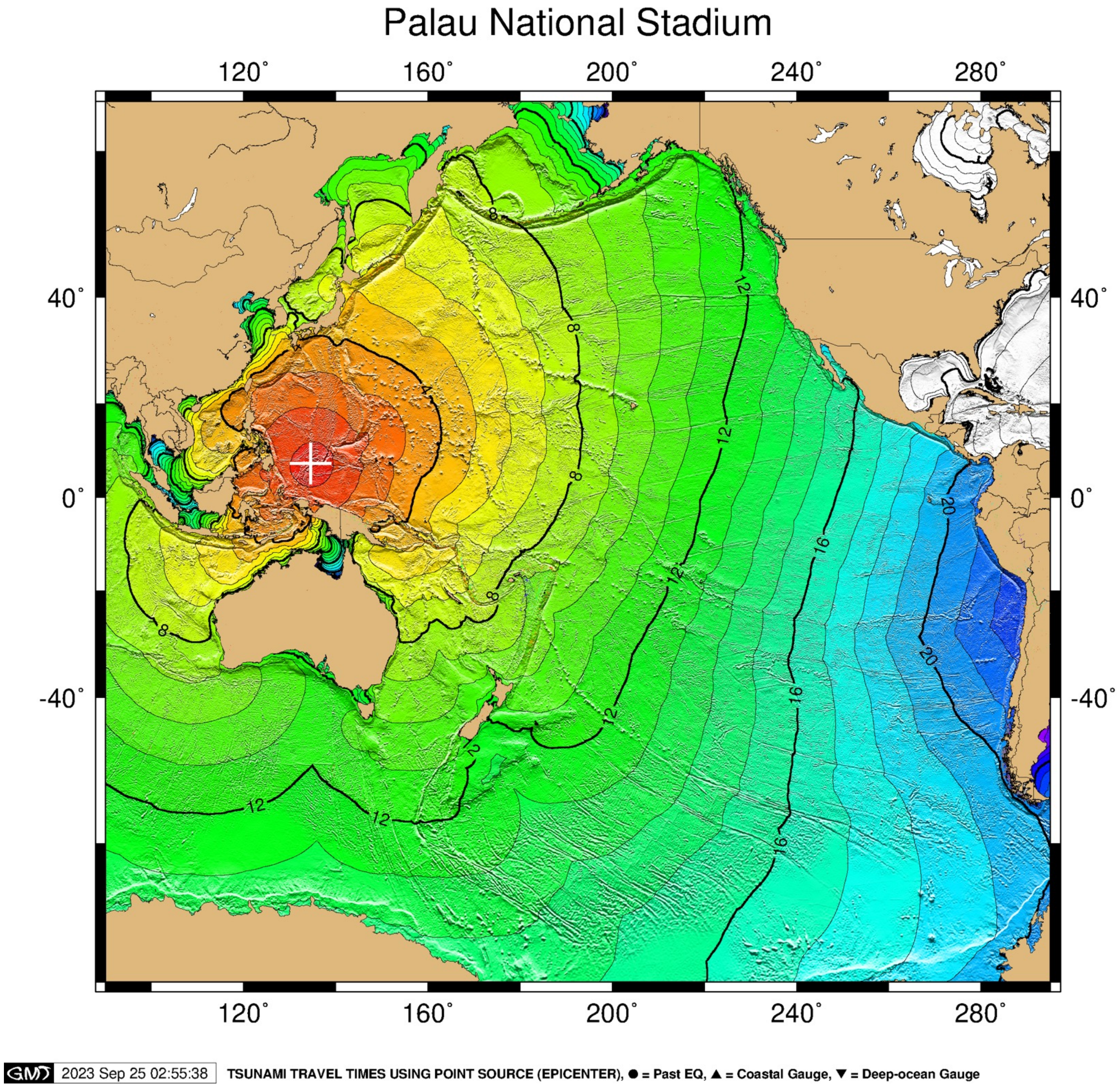
Elevation Contour (10 m red (evacuation map), 5 m yellow



How long do you have?

Tsunami Travel Time

(TTT, 2-arc min (~4 km) grid)

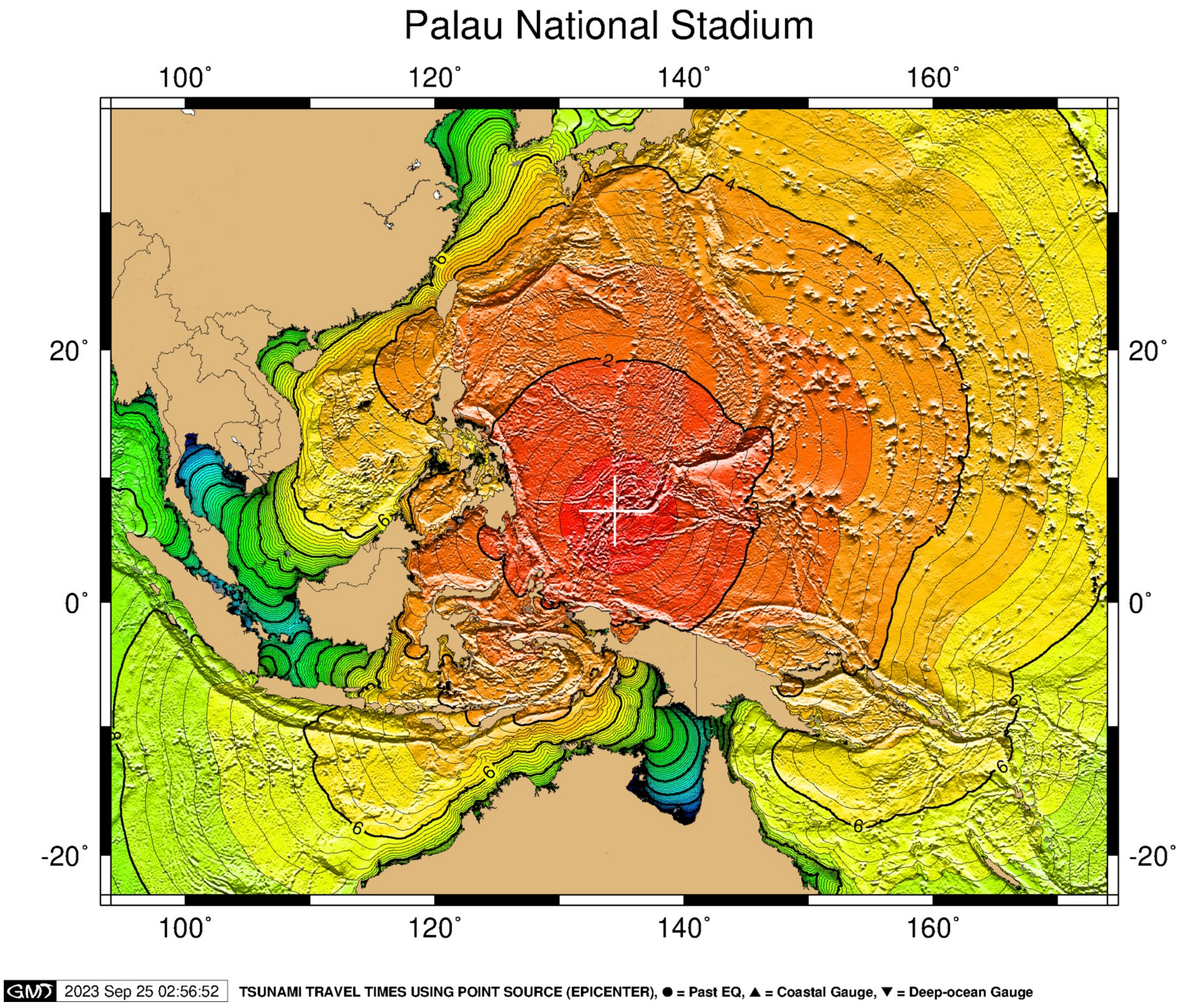


Presented to
Palau National Emergency Committee
27 September 2023

How long do you have?

Tsunami Travel Time

(TTT, 2-arc min (~4 km) grid)



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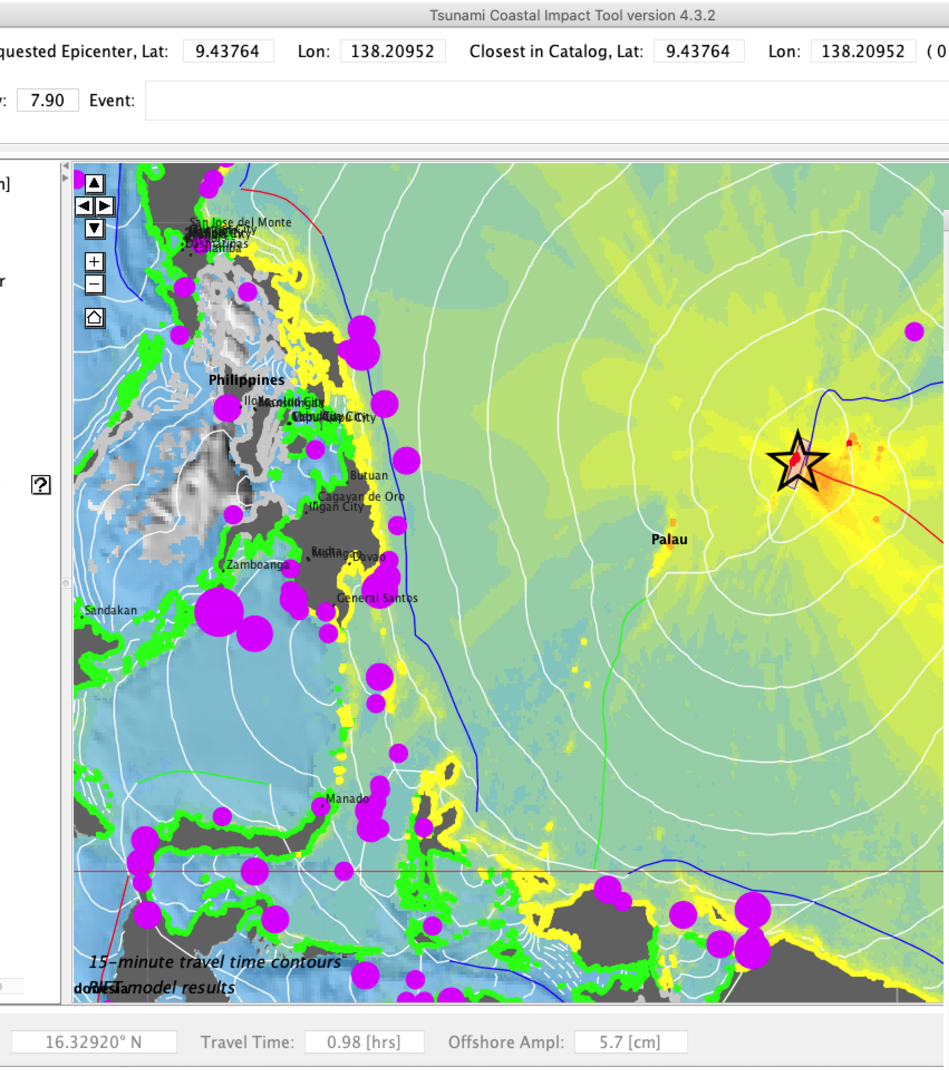
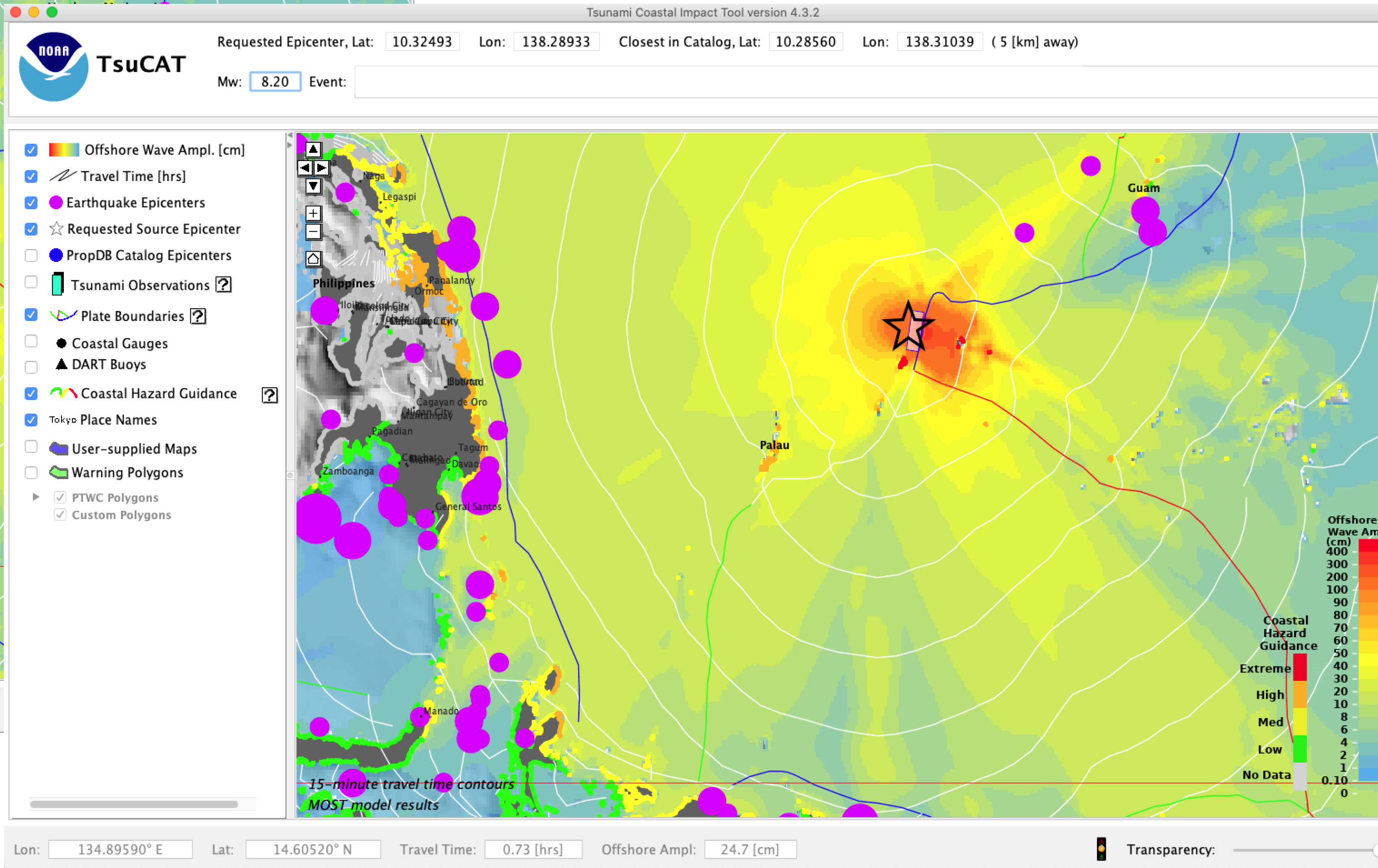
Tsunami Scenarios – what could happen

- Nearby sources: 1-1.5 hour or less
  - Philippine Trench
  - Southern Marianas
  - New Britain Trench (New Guinea)
- Regional and Distant Source: 2.5-3 to 21 hours
  - Ryukyu Trench (northwest from Taiwan)
  - Aleutian Trench
  - South American Trench

Yap Trench, M7.9 to 8.2, TTT=0.45 hr





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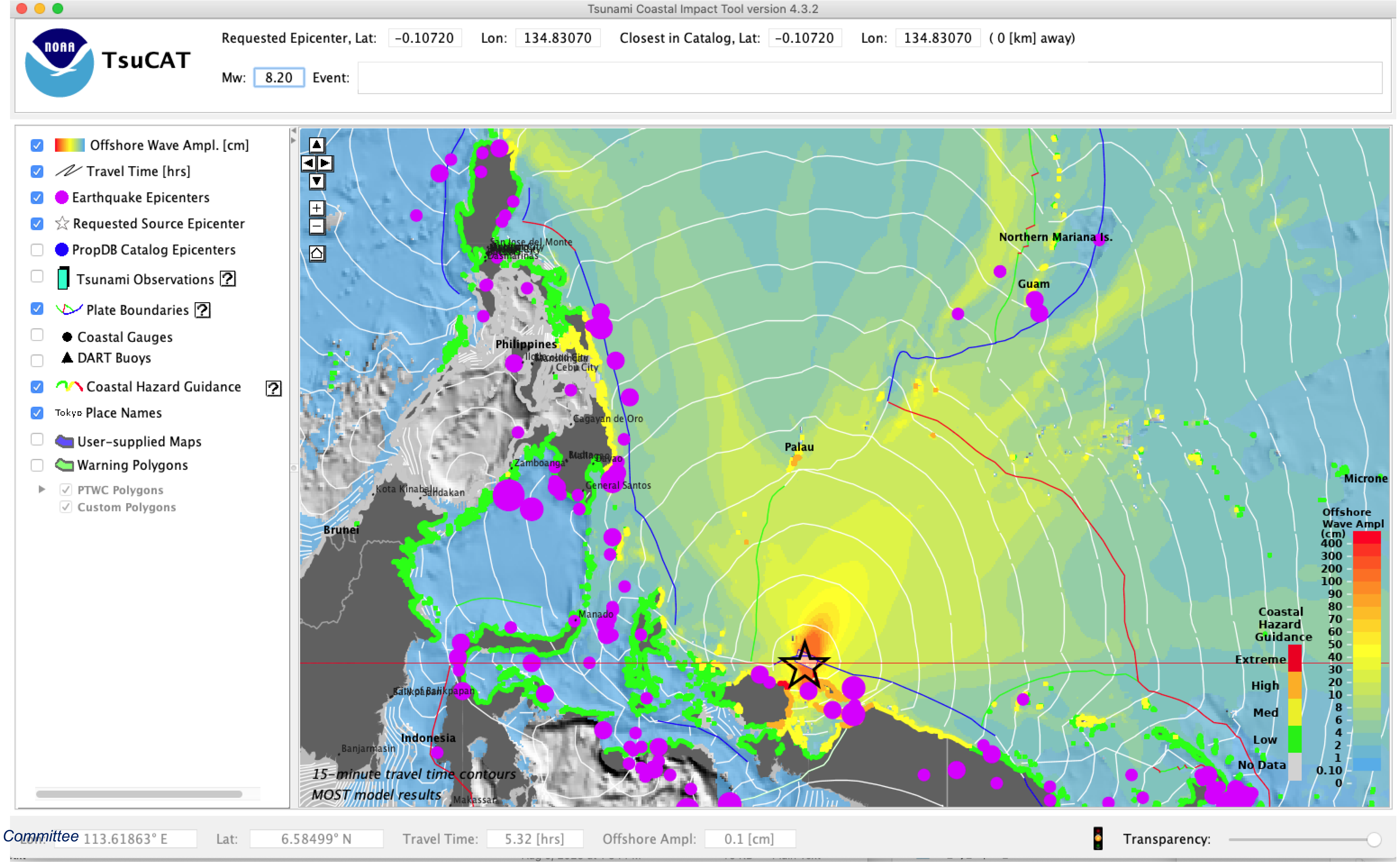
New Britain (New Guinea), M8.2, TTT=1 hr



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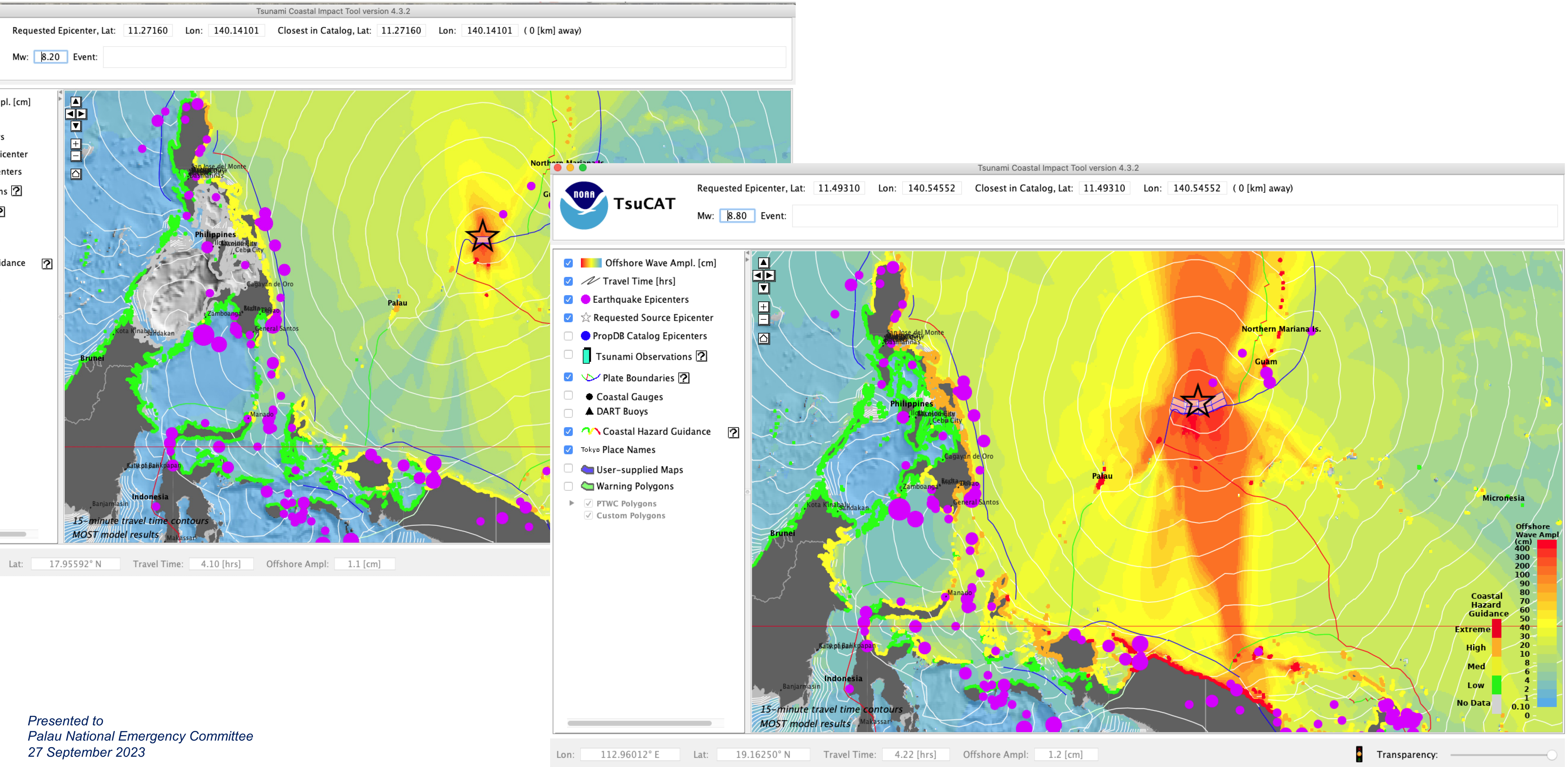
Western Marianas, M8.2 to 8.5, TTT=1 hr



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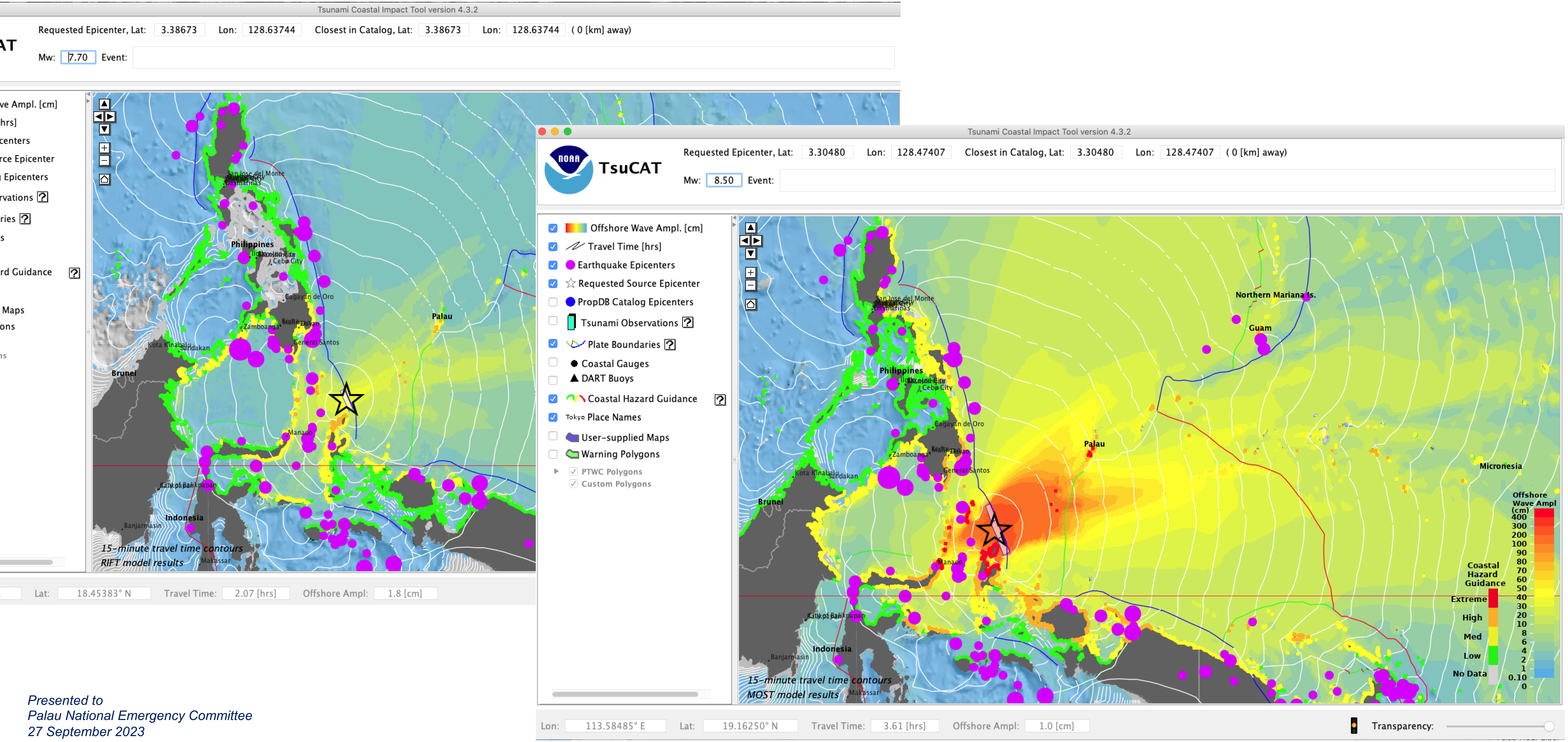
Southern Philippines, M7.7 to 8.5, TTT=1 hr



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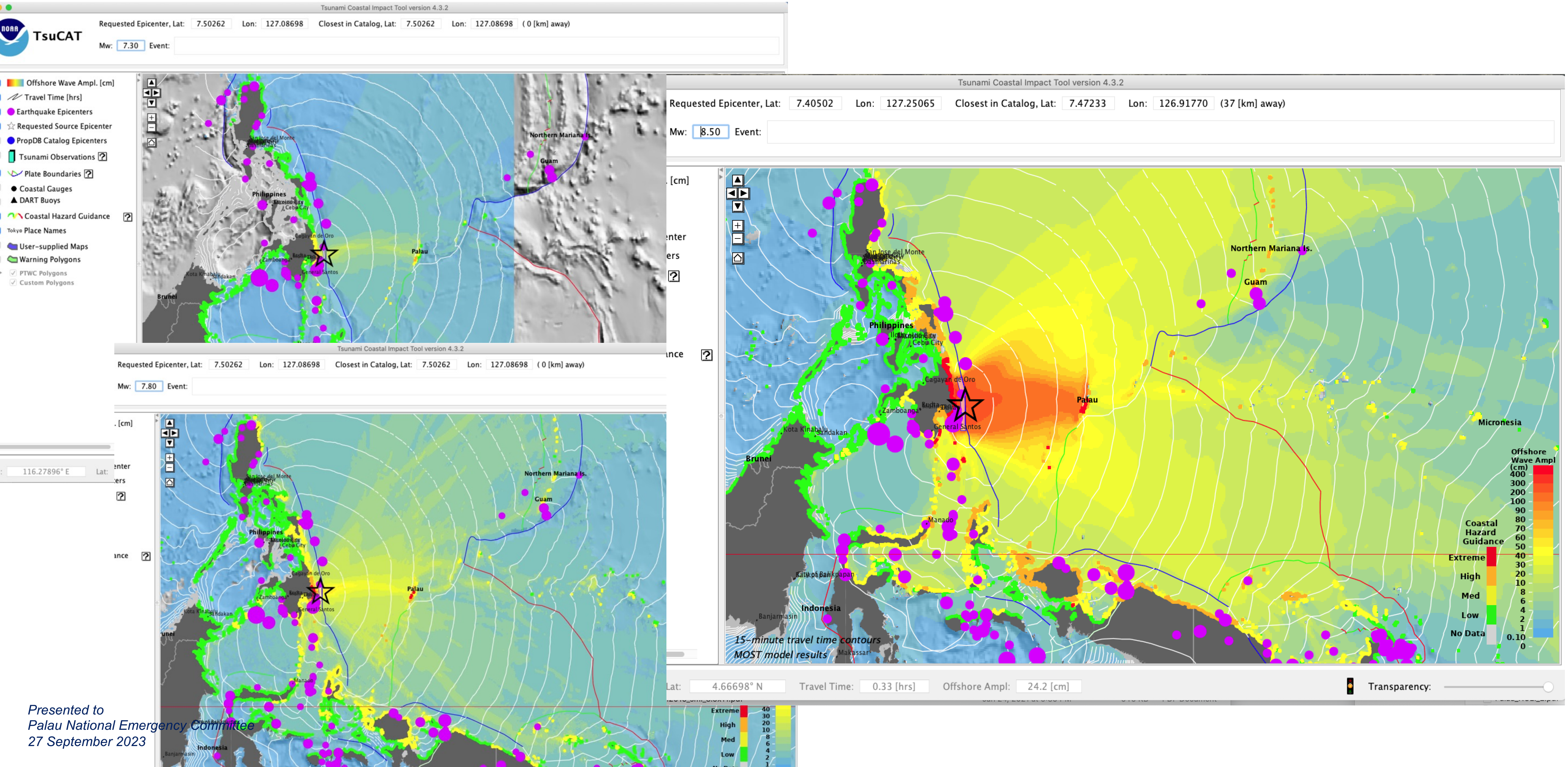
Central Philippines, M7.3/7.5 to 8.5, TTT=1 hr



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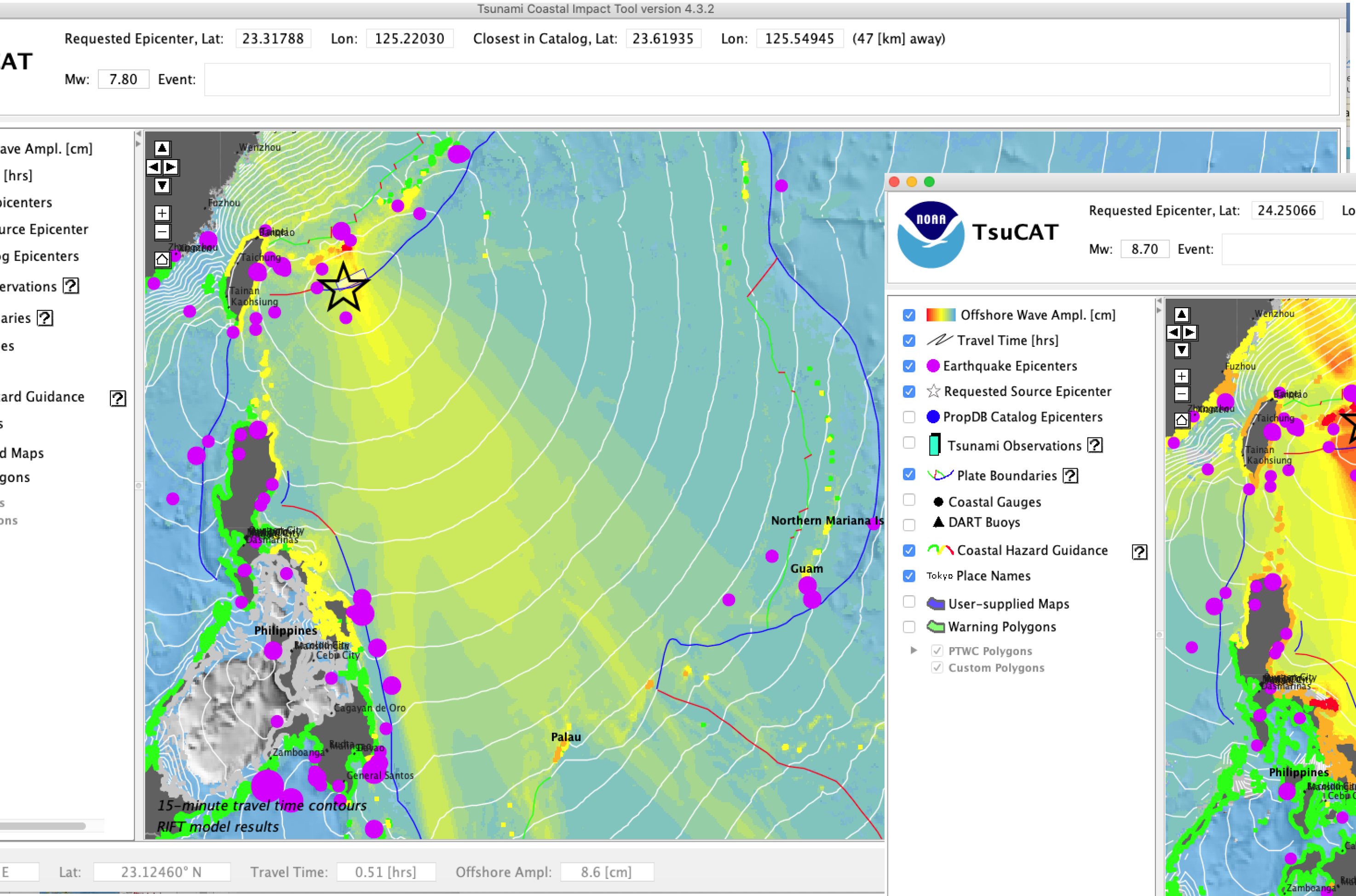
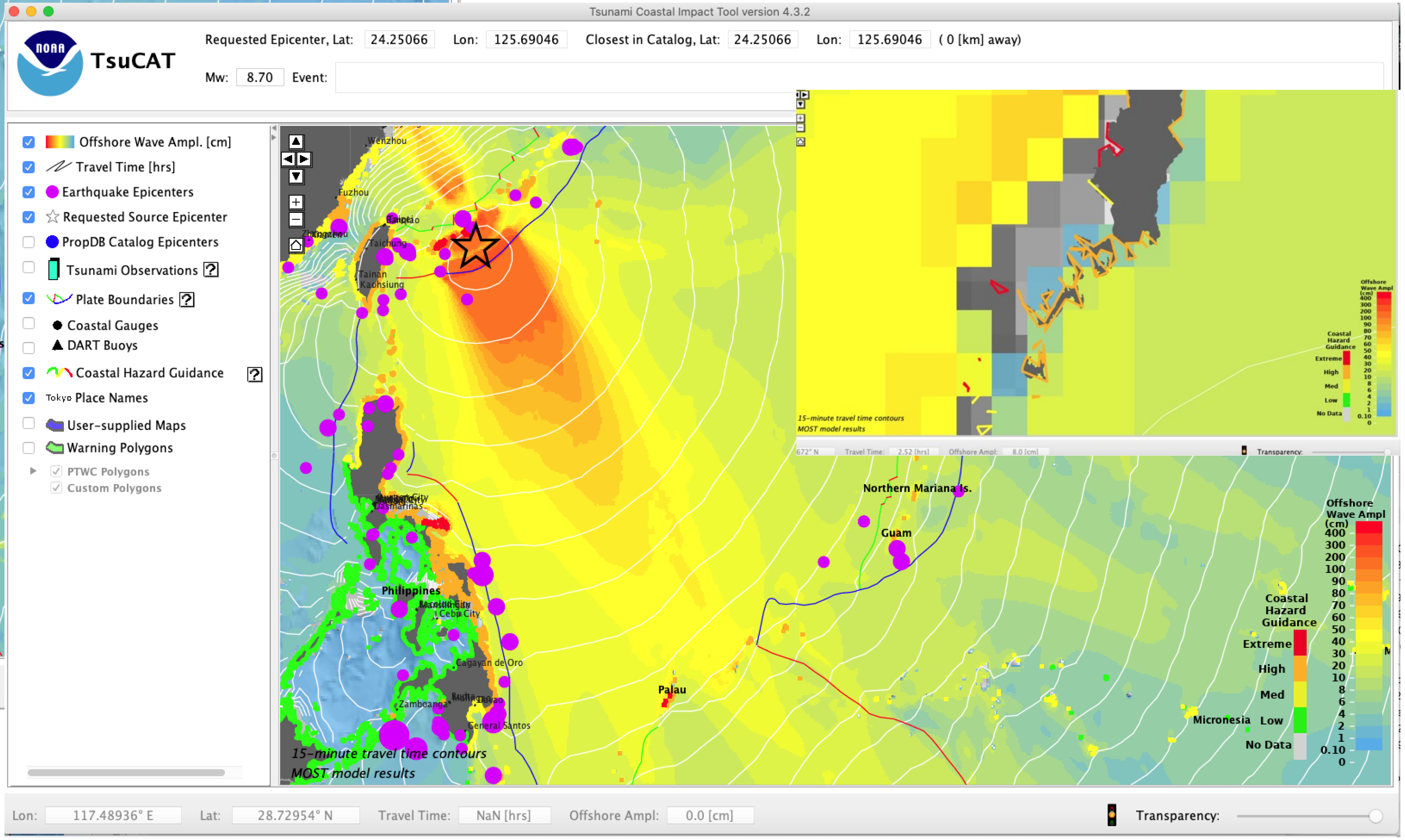
Western Ryukyu, M7.8 to 8.7, TTT=2.5 hours





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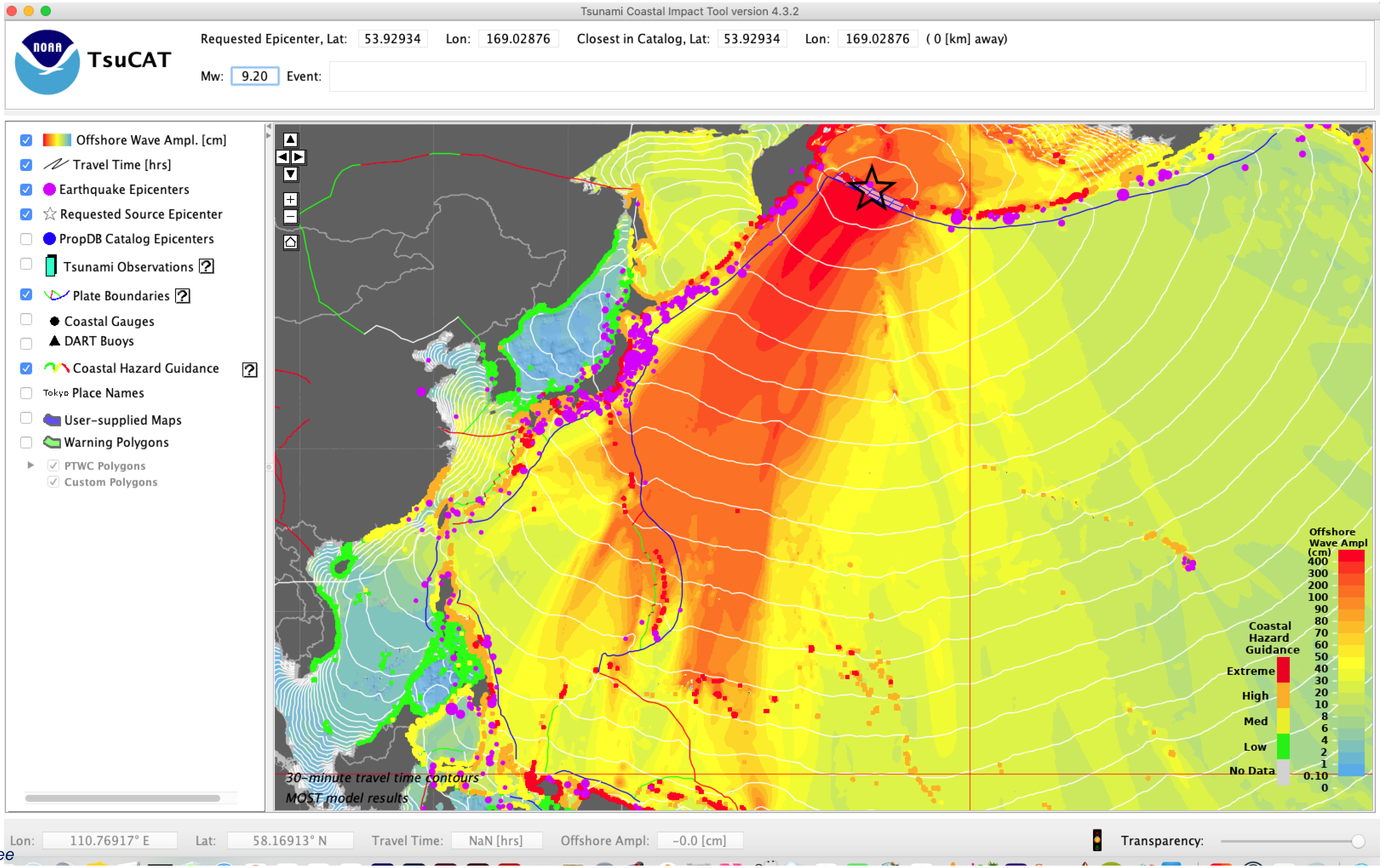
Western Aleutians, M9.2, TTT=14 hours



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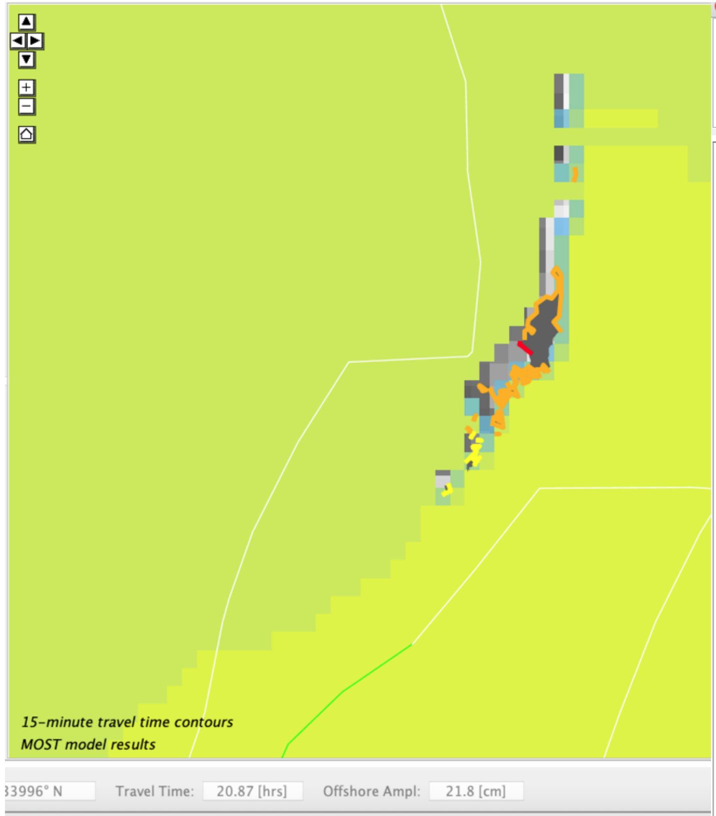
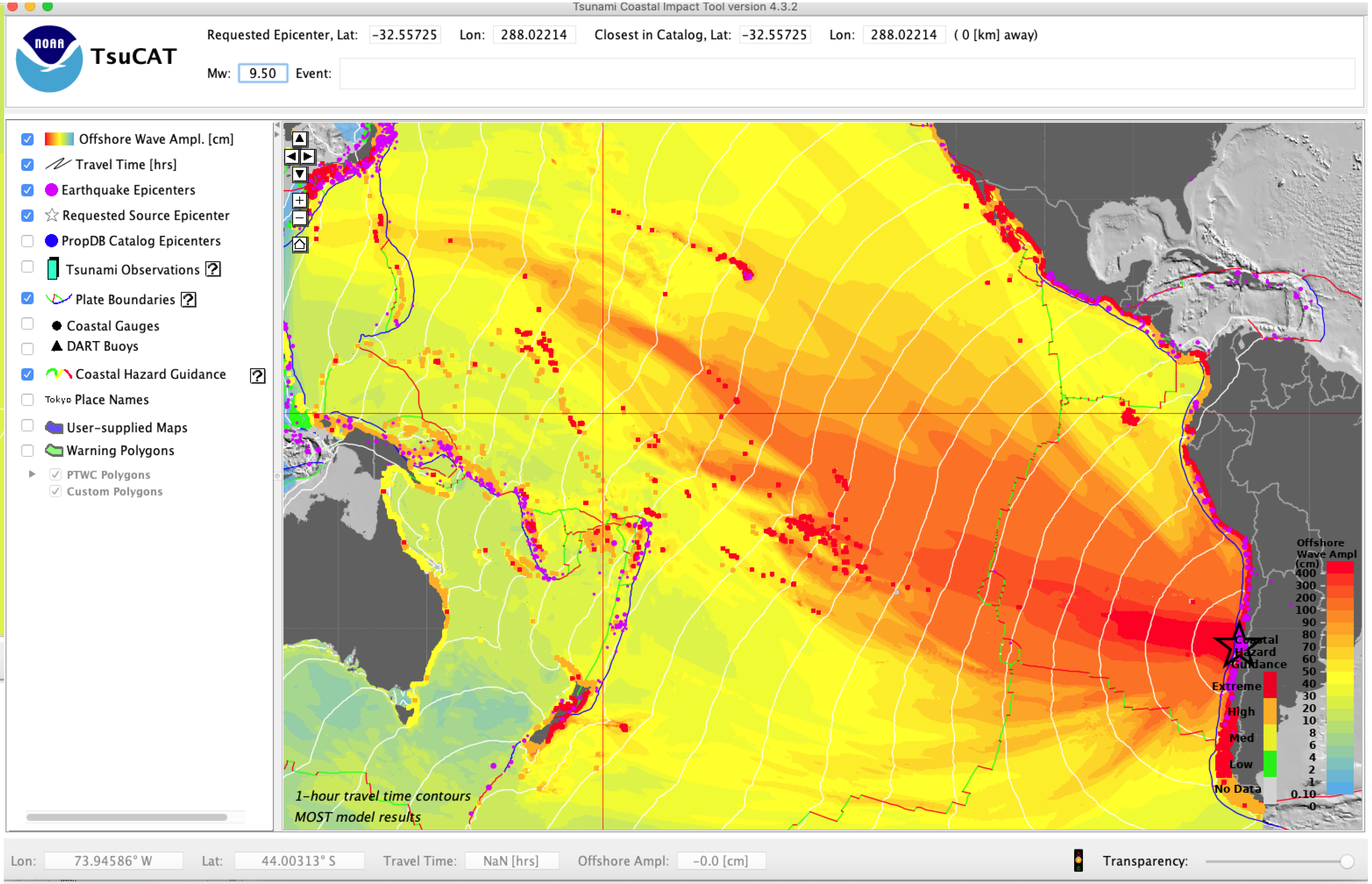
Southern Chile, M9.5, TTT=21 hours





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Storm Surge vs Tsunami Waves

Considerations of impact along coastlines

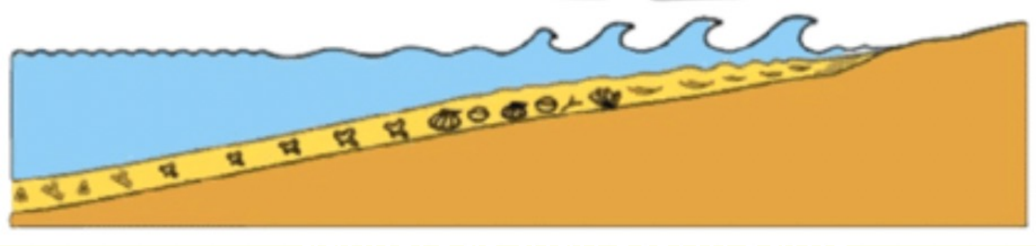
Tsunamis more dangerous than Storm Surge

STORM SURGE VS TSUNAMI IMPACT CHARACTERISTIC

STORM SURGE

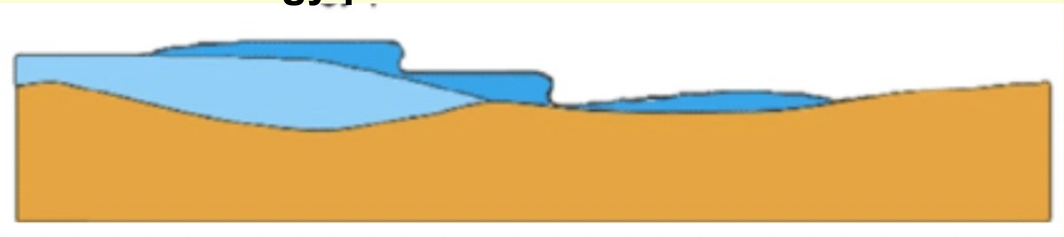
Shoreline characteristics

- smaller amplitude growth
- low erosion
- small wave run-up
- low velocity at shore
- turbulent water surface



Inundation characteristics

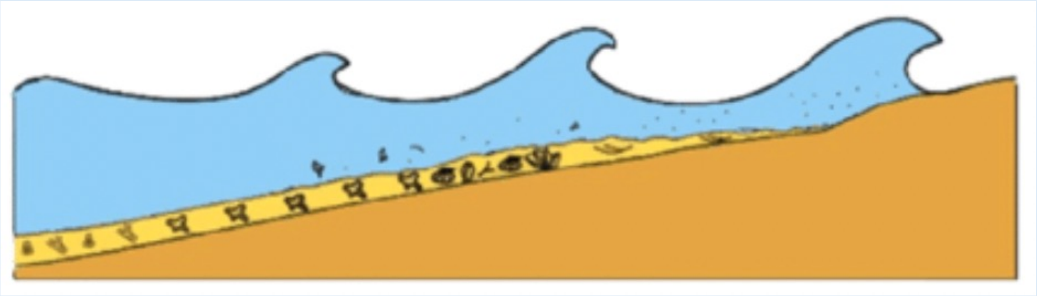
- multi-directional inundation from many waves
- short time interval between inundation
- lower energy pulses



TSUNAMI

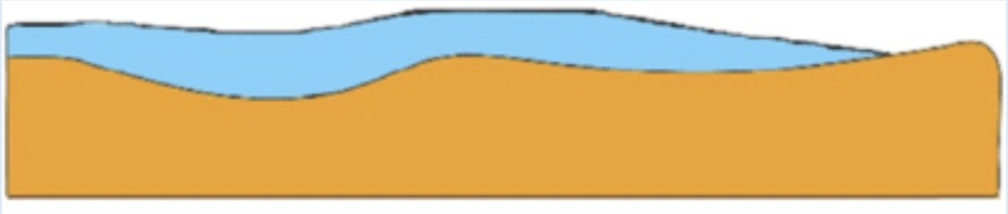
Shoreline characteristics

- large amplitude growth
- high velocity at shore
- large wave run-up
- Rapid amplitude rise
- High erosion



Inundation characteristics

- less frequent number of waves with backflow
- longer period between waves and inundation
- inundate further due to greater energy than storm surge



Schematic comparison of storm surge and tsunami along shore and backshore (from Switzer and Jones 2008)

MODELING OF STORM SURGE VS TSUNAMI

Storm Surge

- Storm surge models output flooding. SLOSH (Sea, Lake, and Overland Surges from Hurricanes) is a commonly used model that inputs weather and climate measurements, geographic features, and structures to show where flooding is expected.

Tsunamis

- Tsunami models output wave direction, flow depths, and currents. HySEA, GEOCLAW, TUNAMI, MOST are a few of the many numerical models used to generate, propagate, and inundate tsunami waves onto normally dry land.

SUMMARY

- Storm surges are NOT waves. They are a dome of water created by winds near a storm center and pressure gradients. Surges move at the same speed as the storm and are slow moving so most damage is caused solely by flooding.
- Tsunamis are much faster than storm surges and carry much more energy so frequently impact a shore with massive kinetic force.
  - Damage is caused by flooding, strong currents, dislodged and variably sized floating debris (incl boats, autos, containers, trees, buildings, household goods…)
  - Flow is bi-directional (180˚ inland then recedes back out to sea).
- Both waves cause flooding and may reach the same shore height, but
  - Tsunami waves flood QUICKLY and can reach 10-20 meters in height in a few minutes to 10s of minutes, and then recede equally as fast. Surge heights are reached more gradually
  - Tsunami waves may travel GREATER INLAND DISTANCES, set up damaging currents, and will destroy whatever lies in the waves path.

Questions

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