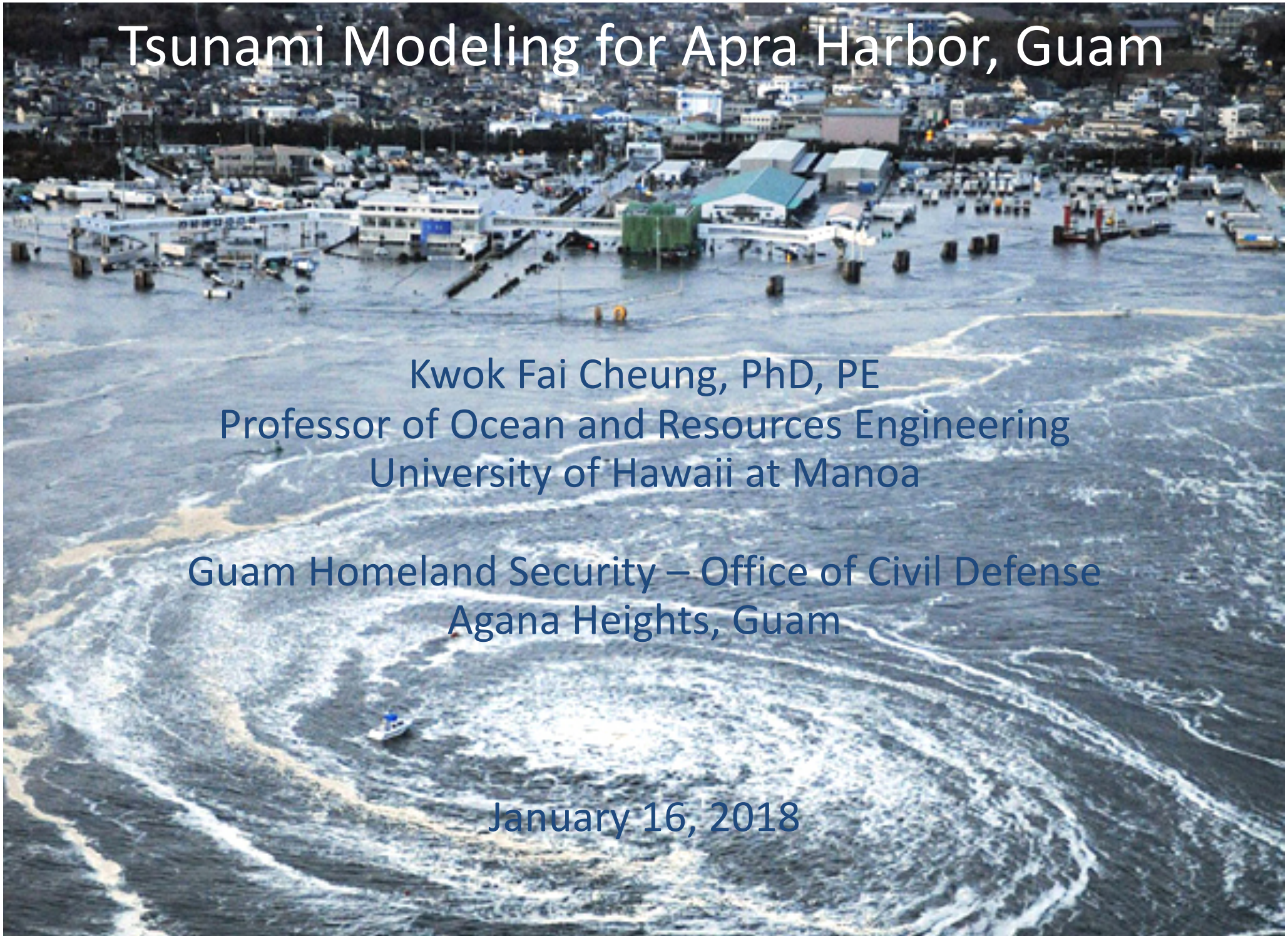
Tsunami Modeling for Apra Harbor, Guam



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January 16, 2018

Outline of Presentation

National Tsunami Hazard Mitigation Program (NTHMP): Tsunami Model Benchmarking 2015

Maritime Hazard Mapping in Hawaii and American Samoa in collaboration with US Coast Guard District 14

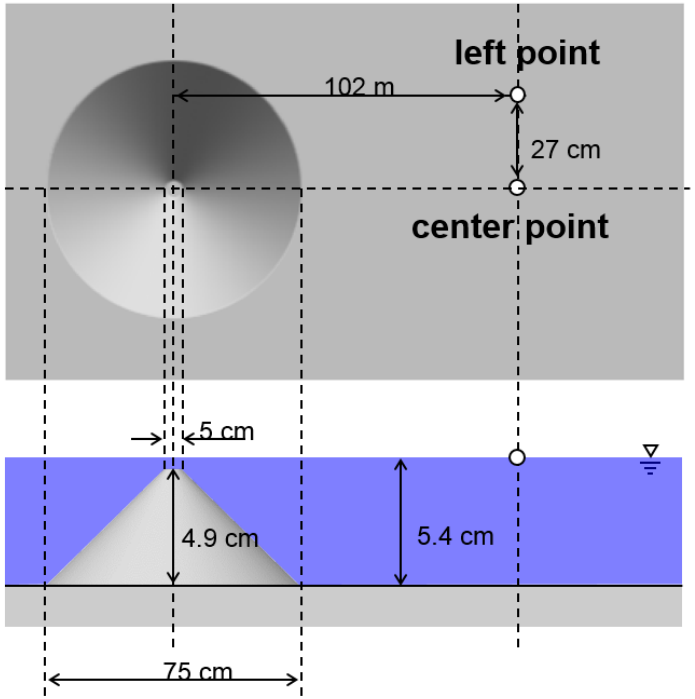
Modeling Strategy for Guam

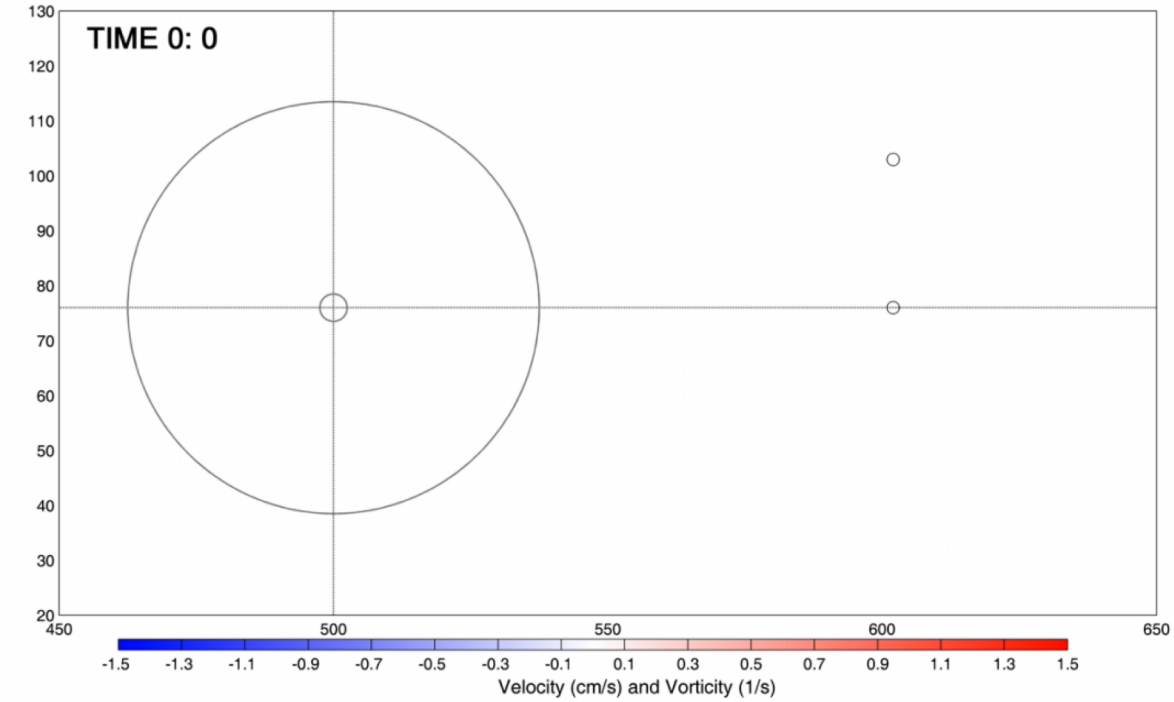
Validation of Model Setup: The 2011 Tohoku Tsunami at Apra Harbor

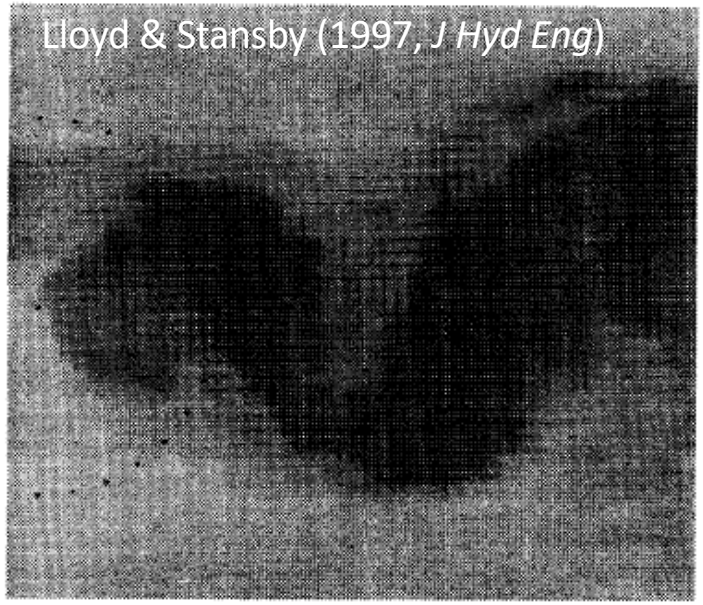
Sample Data Products for Apra Harbor

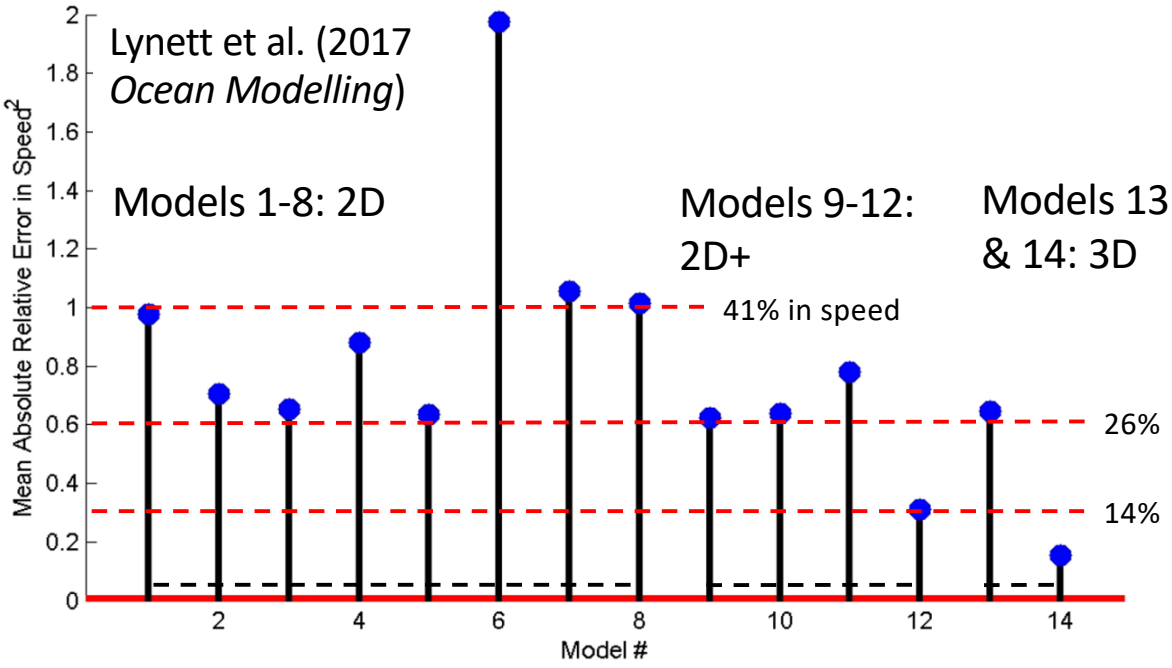
Input from the Maritime Community

2015 NTHMP Benchmark Results









Maritime Hazard Mapping Hawaii

USCG District-14 Responses to Tsunamis

- Integrated plan for Hawaii and American Samoa
- Warning (forecast water-level rise > 1 m): Evacuation of ships and shore personnel
- Advisory (inundation not imminent, but expect strong currents): Severe Weather Plan

Data Products (with community input)

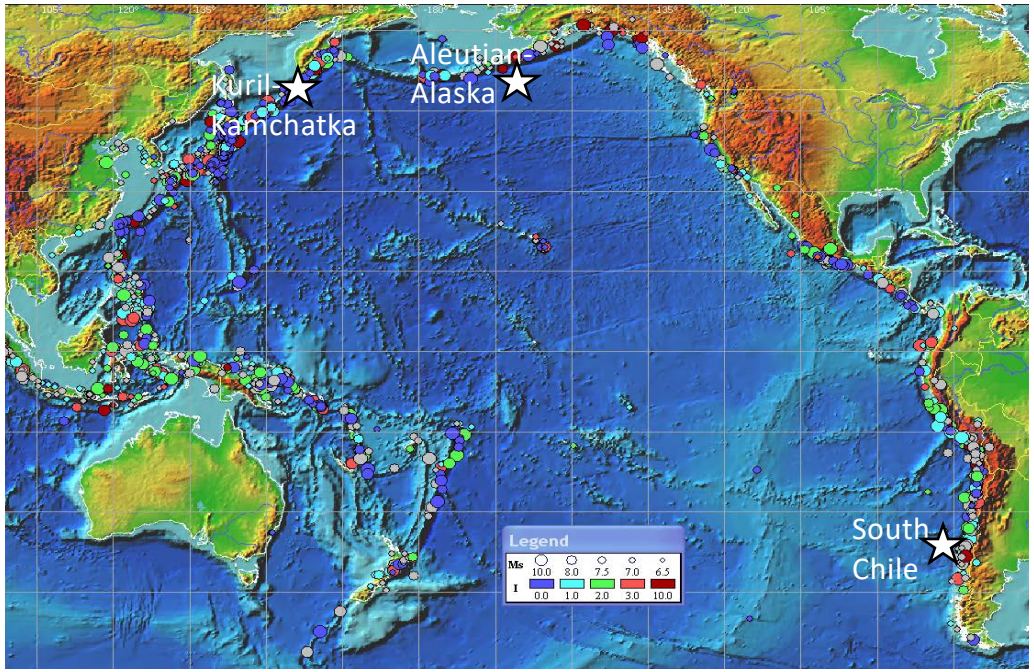
- Offshore currents from Mw 9.3 and 9.6 Aleutian tsunami scenarios for evaluation of safe zones, defined outside the 100-m depth contour
- In-harbor hazard maps of current, surge & drawdown for advisory-level tsunamis

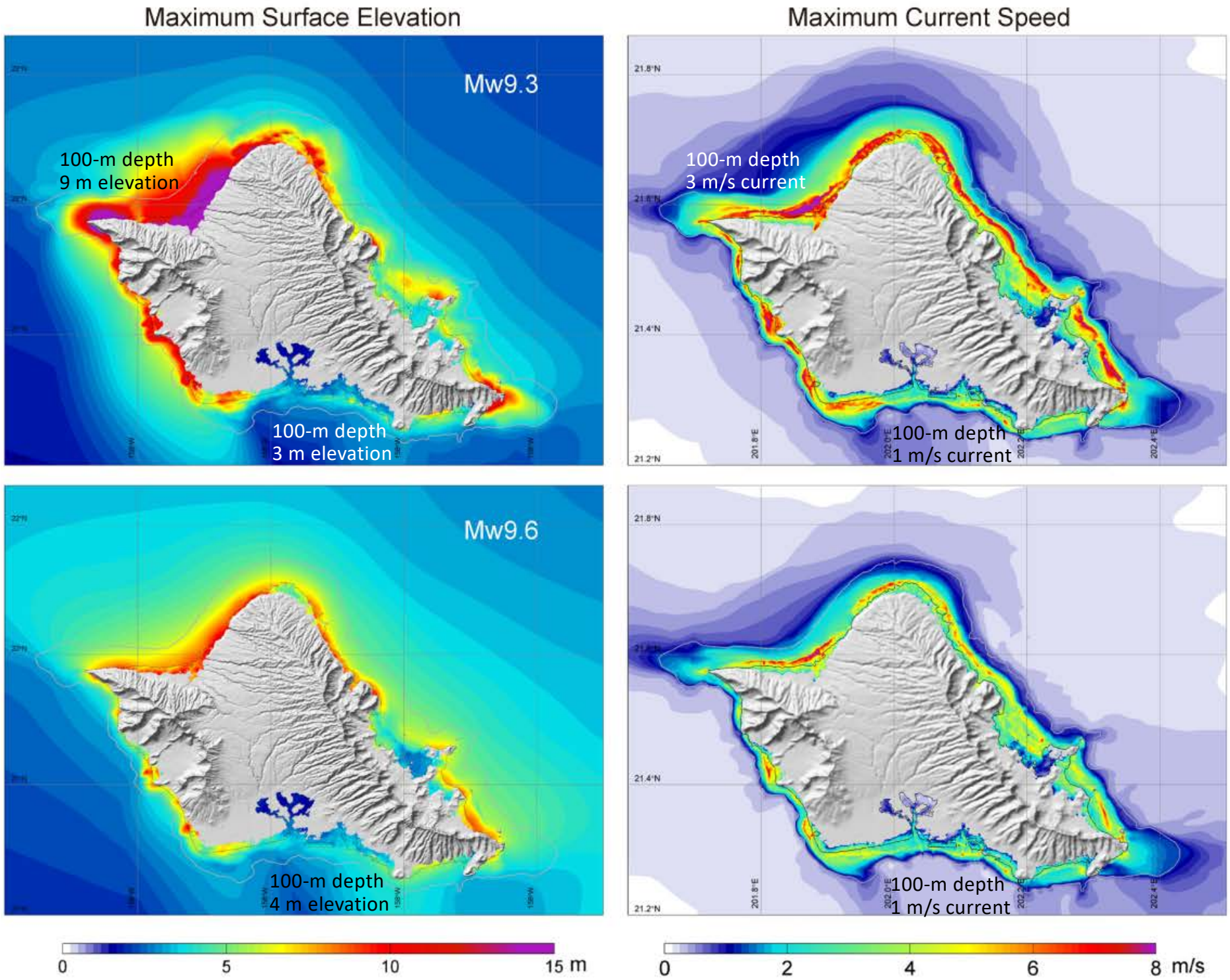
Database of scenarios

- Three major subduction zones
- Earthquake at 0.1 Mw increments up to ~1 m nearshore wave amplitude
- Modeling at the present MSL

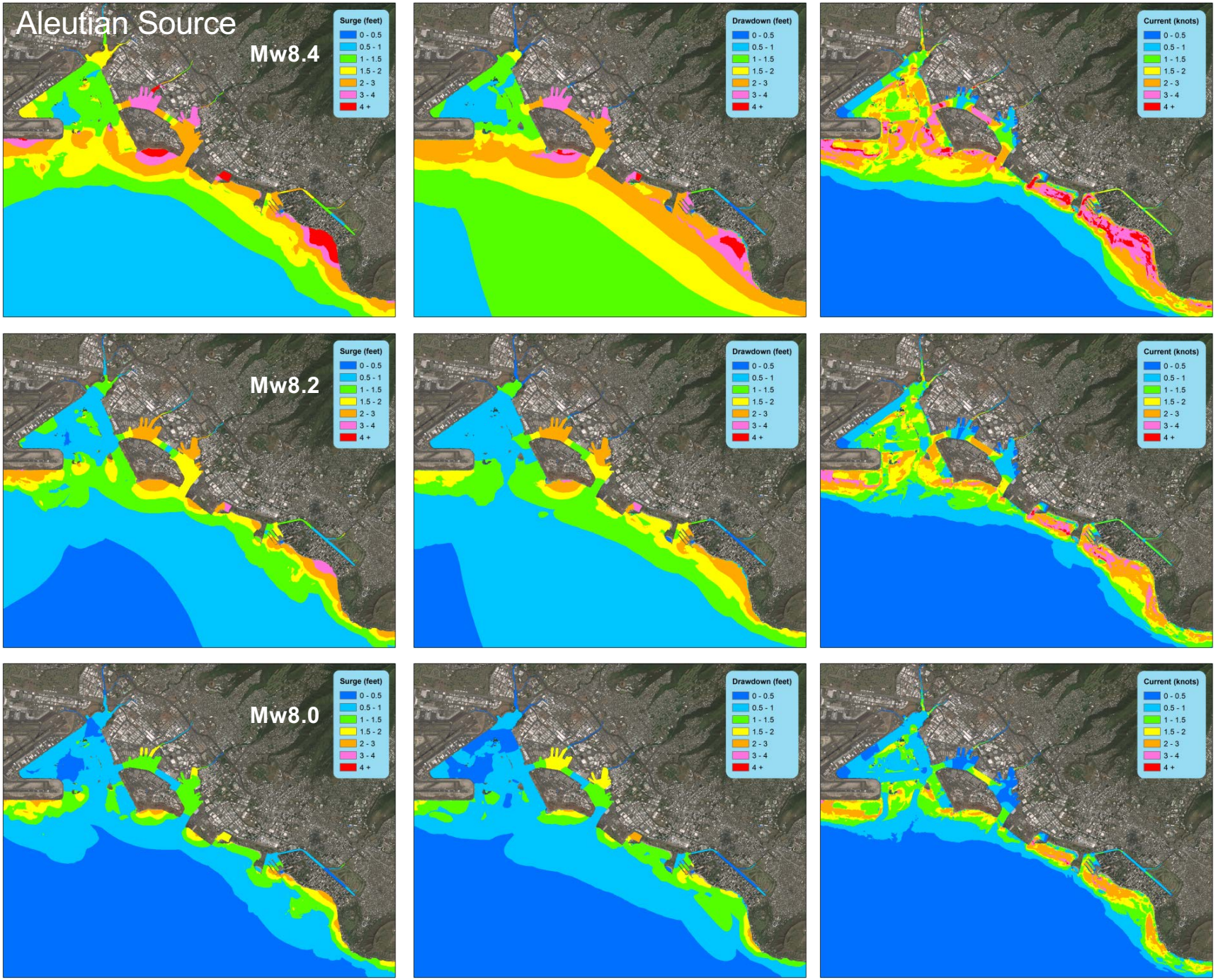
Operation modes:

- Earthquake location and magnitude
- Earthquake location and forecast near-shore wave amplitude




Maximum Surface Elevation
Maximum Current Speed
Mw9.3
100-m depth
9 m elevation
100-m depth
3 m elevation
100-m depth
3 m/s current
100-m depth
1 m/s current
Mw9.6
100-m depth
4 m elevation
100-m depth
1 m/s current
0
5
10
15 m
0
2
4
6
8 m/s

Maximum Surface Elevation | Maximum Drawdown | Maximum Current Speed



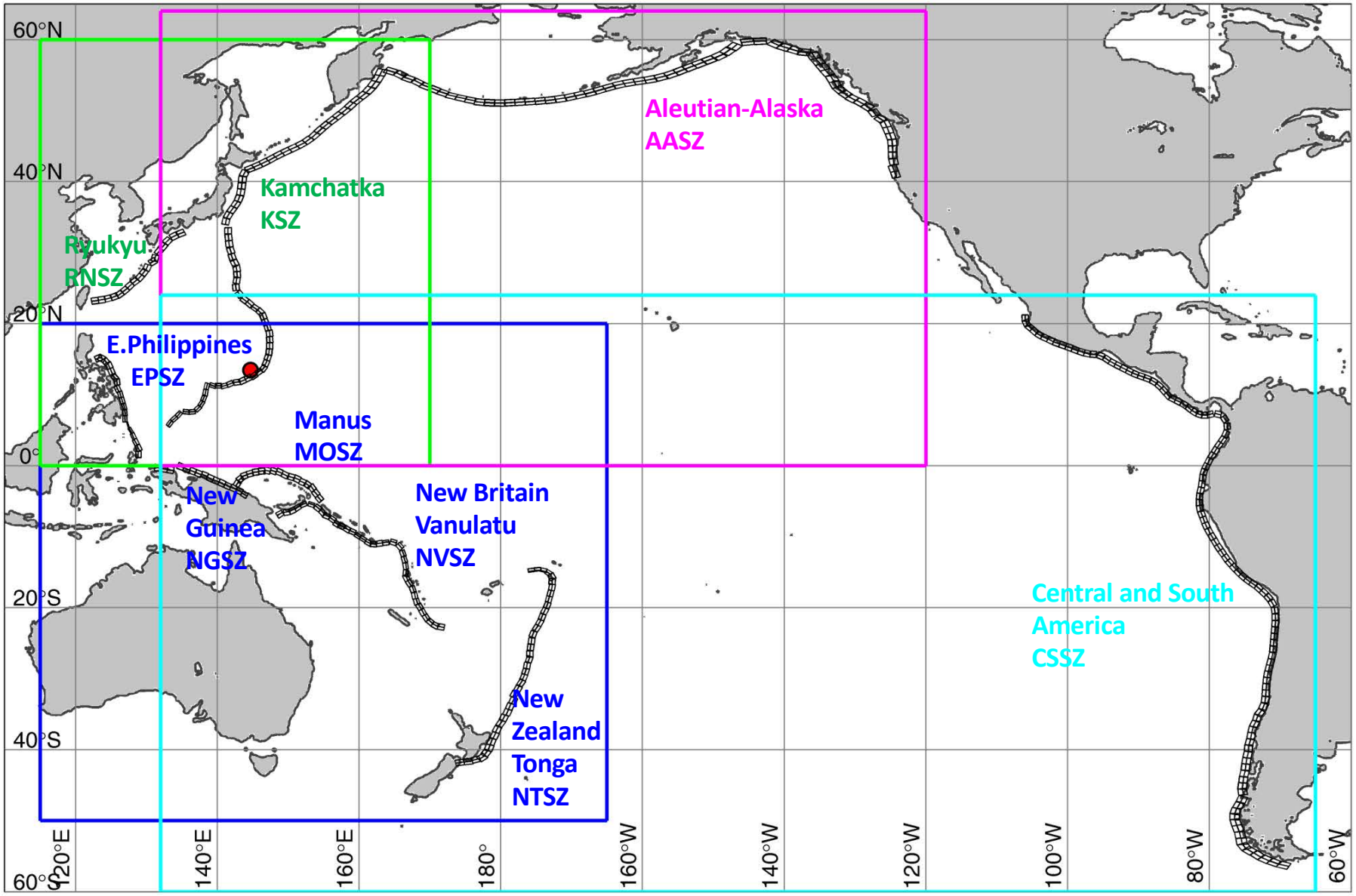
USCG Summary Tables

Aleutian Earthquake Magnitude	Honolulu Harbor: Water Surface Rise/Fall			Water Current	
	Surge (feet)	Drawdown (feet)	Cycle Time Range (minutes)	Speed (knots)	Cycle Time Range (minutes)
7.6	0.6	0.7	9 – 20	0.6	9 – 20
7.7	0.8	0.9	9 – 20	0.7	9 – 20
7.8	1.0	1.2	10 – 20	0.9	9 – 20
7.9	1.3	1.5	10 – 20	1.2	9 – 20
8.0	1.8	2.0	10 – 20	1.6	9 – 20
8.1	2.2	2.4	10 – 20	2.1	10 – 20
8.2	3.0	3.3	10 – 20	2.7	10 – 20
8.3	3.6	4.3	10 – 21	3.5	10 – 21
8.4	4.7	4.7	11 – 21	4.8	11 – 21

Aleutian Earthquake Magnitude	Hilo Harbor: Water Surface Rise/Fall			Water Current	
	Surge (feet)	Drawdown (feet)	Cycle Time Range (minutes)	Speed (knots)	Cycle Time Range (minutes)
7.5	2.3	2.0	8 - 13	2.7	13
7.6	2.6	2.6	8 - 13	3.5	13
7.7	3.6	3.9	8 - 13	4.5	13
7.8	4.6	4.3	8 - 13	5.2	13 - 20
7.9	6.2	5.2	8 - 13	6.0	13 - 20
8.0	8.2	6.6	8 - 13	7.4	13 - 20
8.1	9.2	8.2	8 - 13	9.3	13 - 20

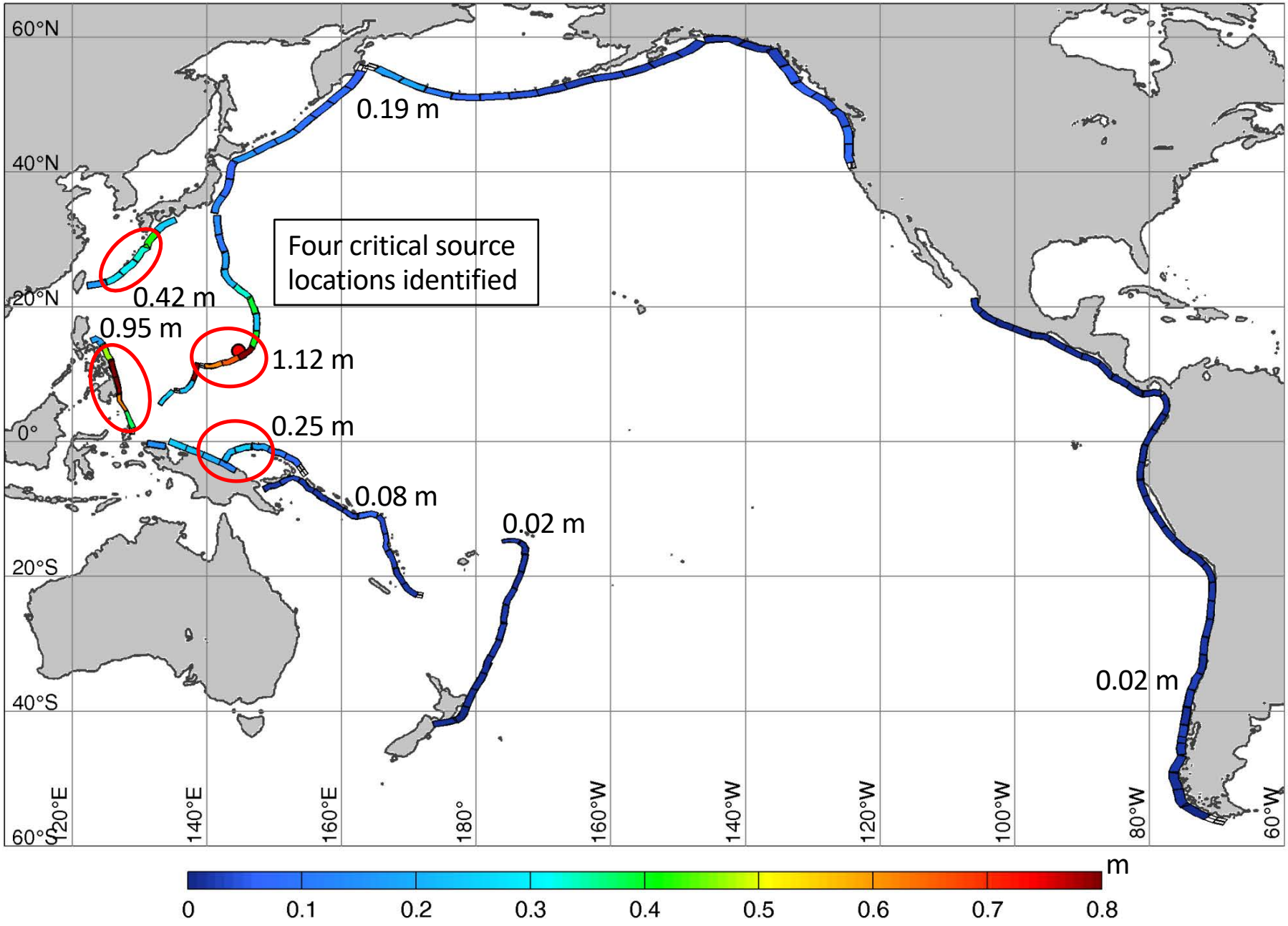
Computational Domains for Sensitivity Test

Identify Critical Source Regions for Guam



Maximum Sea-surface Elevation offshore of Apra Harbor, Guam

From Mw 8.5 earthquakes at Pacific Subduction Zones



Critical Tsunami Sources for Guam

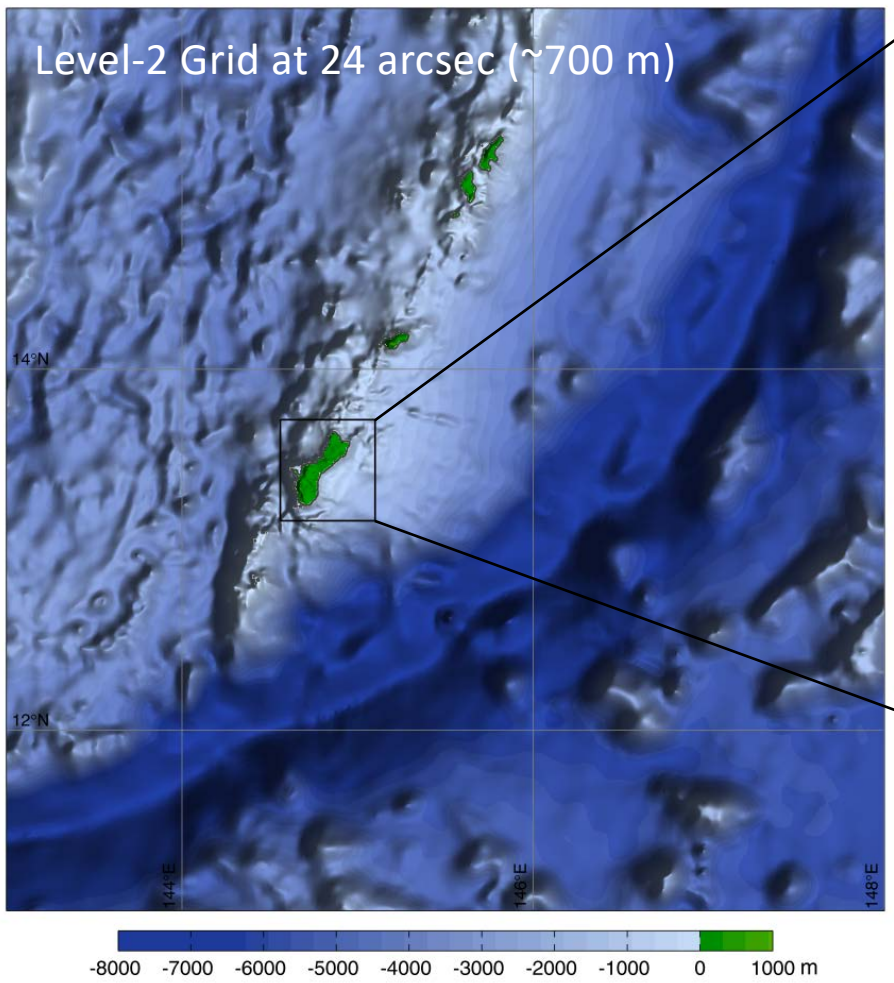
Source characteristics from Global Earthquake Model (Berryman et al., 2015)

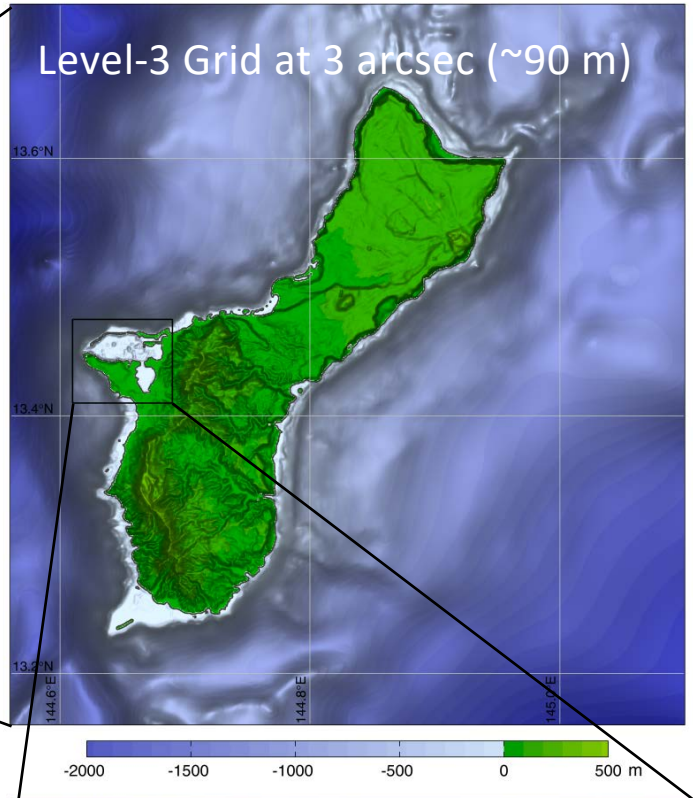
Tsunami Source	Convergence Rate (mm/yr)	Preferred Coupling Coef	Preferred Max Magnitude
Marianas*	49	0.2	8.3
Nankai*	44	0.9	8.7
Ryukyu	58	0.2	8.5
New Guinea*	22	0.7	8.8
Manus	9	0.5	8.5
Philippine*	29	0.3	8.5

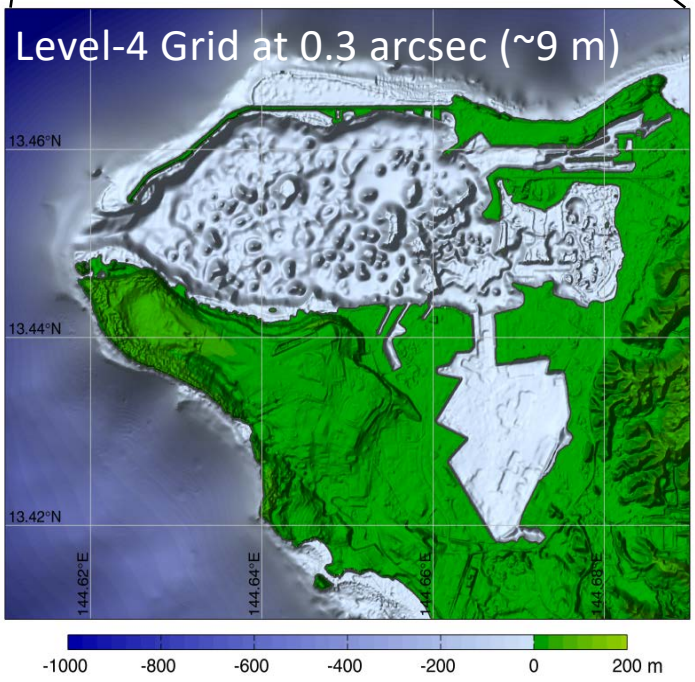
*Selected for modeling

Nested Grids

Level-1 grids at 2-arcmin (~3600 m) from tsunami sources to Guam.







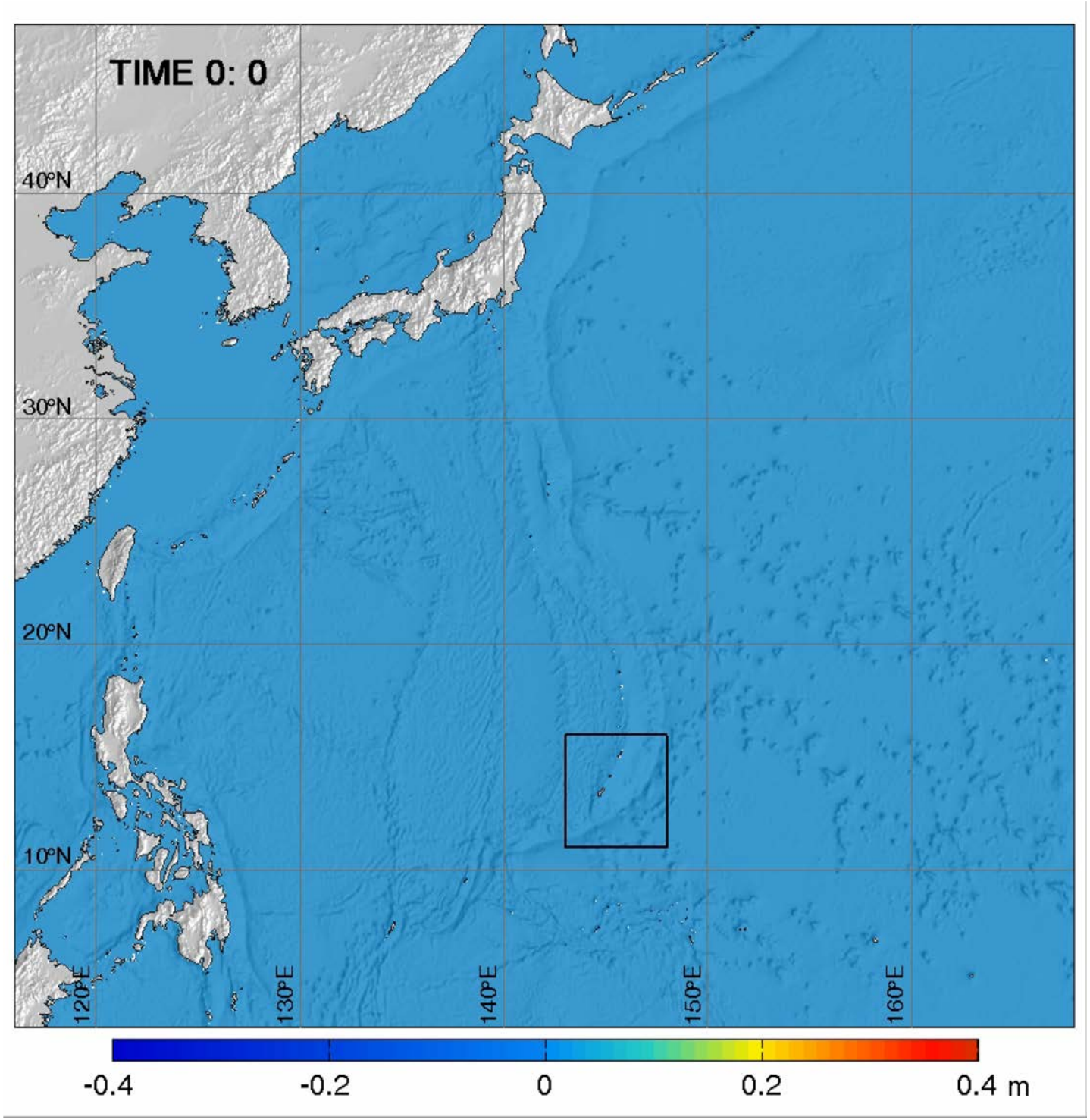
DEM Sources:

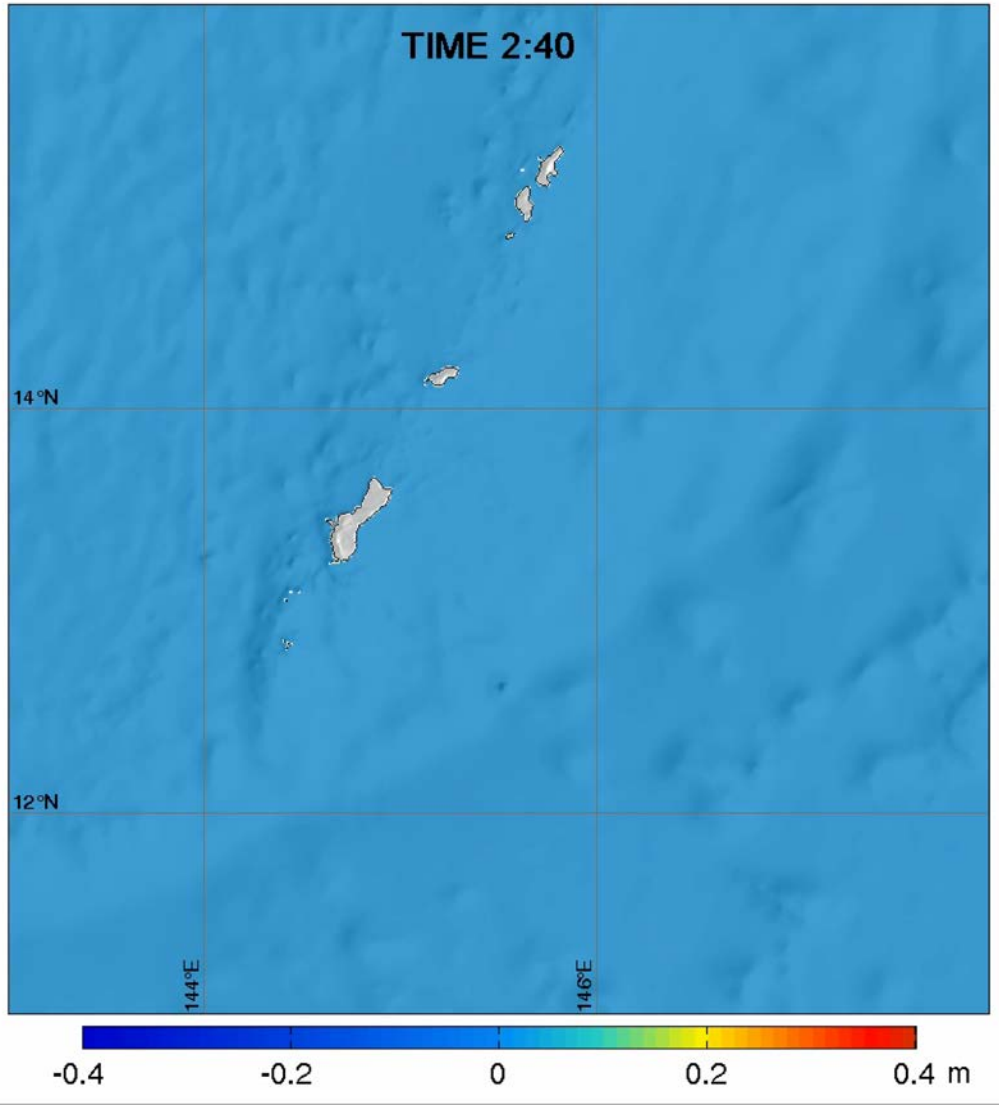
- 30 arcsec (~900 m) GEBCO;
- 2001 USACE SHOALS LiDAR at 4 m resolution;
- 2003 UH SOEST multibeam at 5 m resolution;
- 2007 UH SOEST multibeam at 60 m resolution;
- 2007 USACE LiDAR topography at 0.5 m resolution;
- 2007 USACE LiDAR bathymetry at 4 m resolution
- 2008 US Navy & NOAA multibeam at 1 m resolution at Apra Harbor
- Digitization of nautical charts for shallow reefs at Apra Harbor

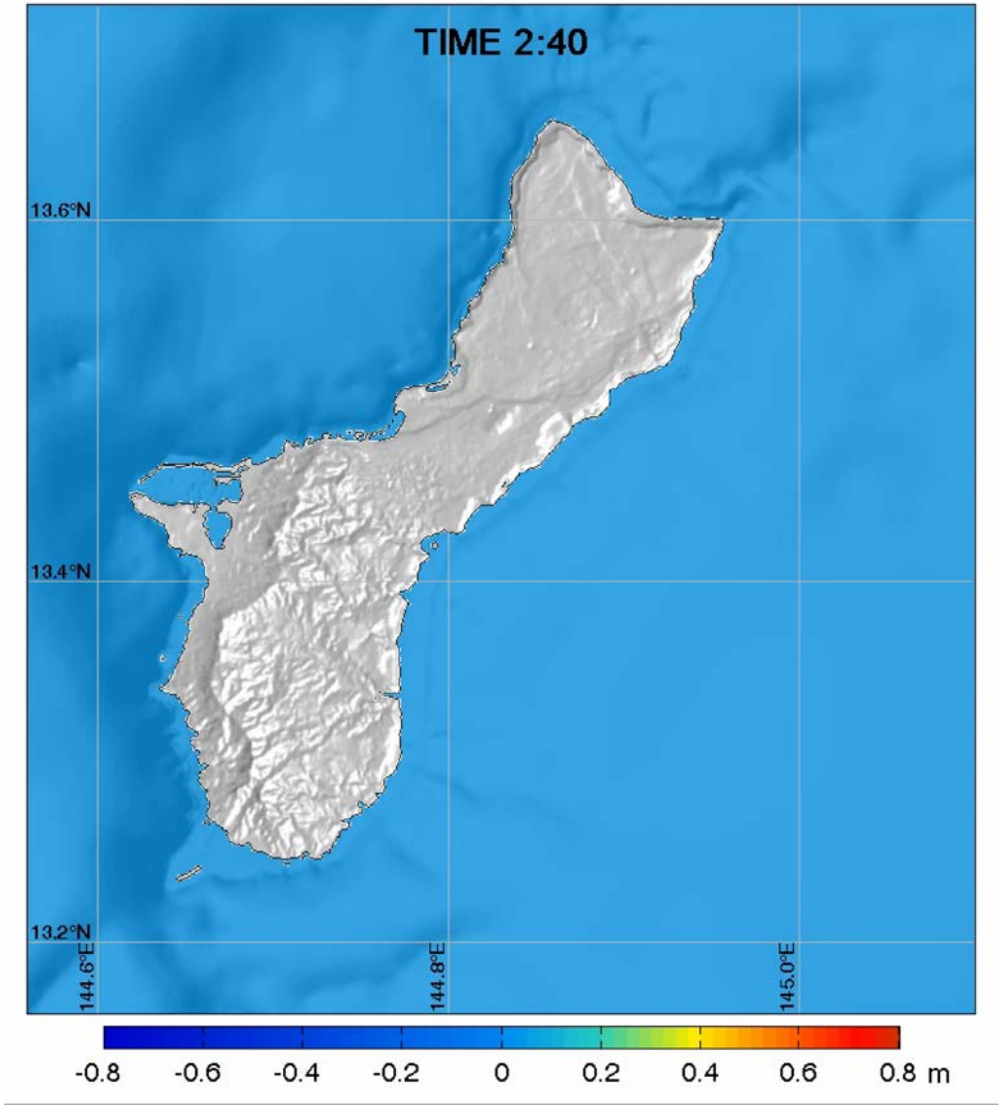
Model Validation

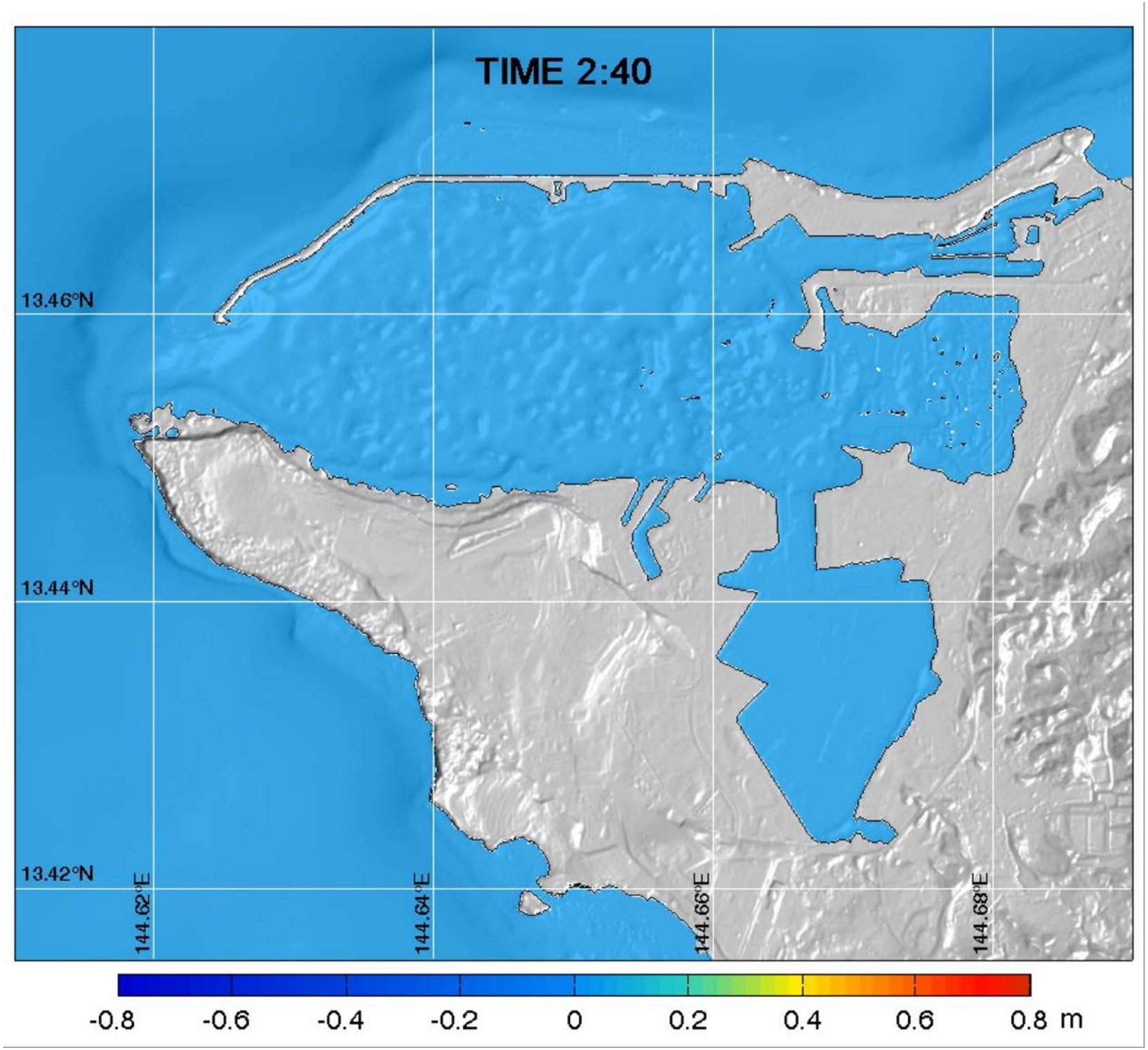
2011 Tohoku Tsunami

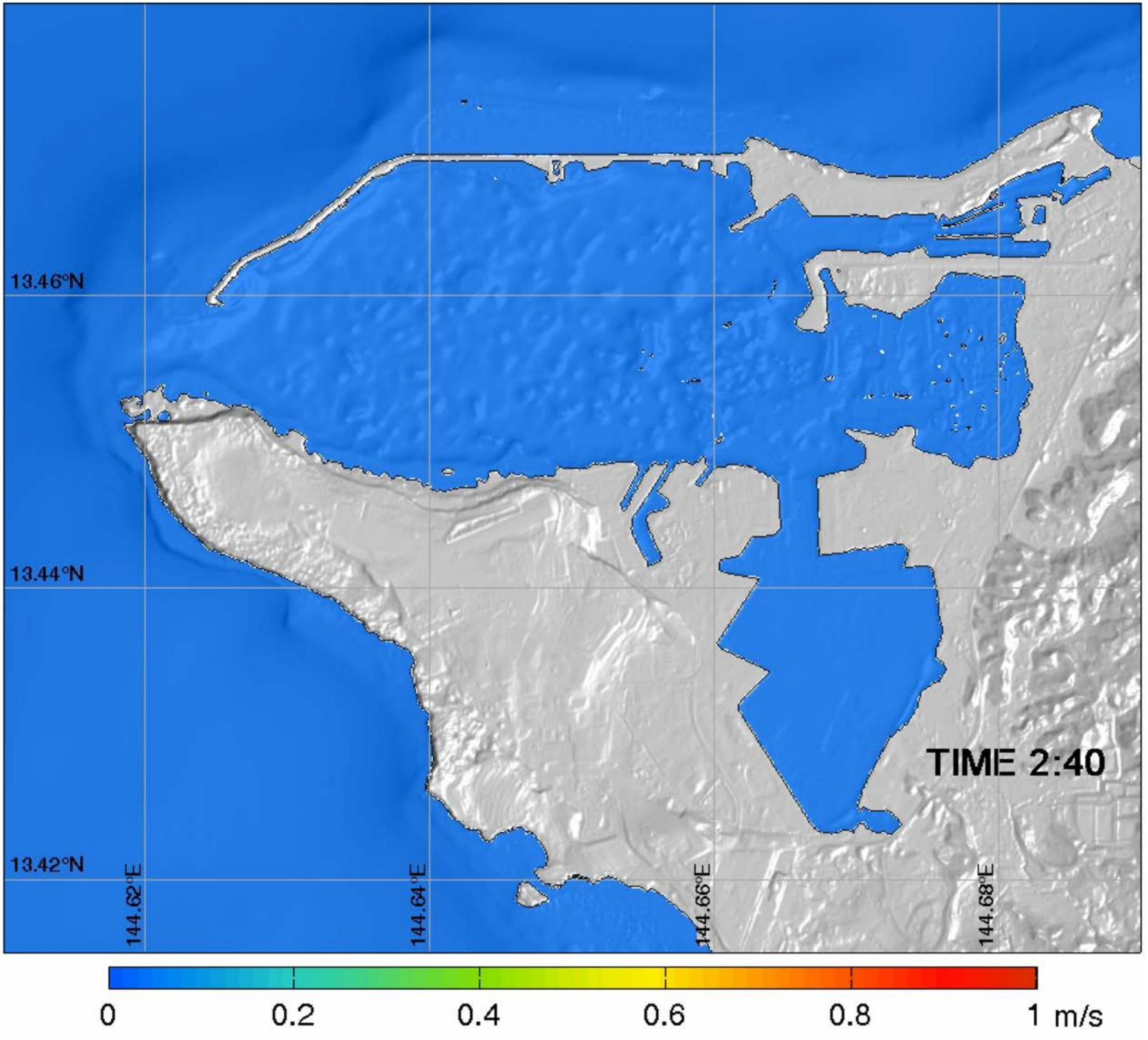
- Self-consistent fault-slip model for the earthquake and tsunami (Yamazaki, Cheung, and Lay, JGR Solid Earth, 2018)
- Prior validation with coastal waveform and runup along Japan coast, current measurements in Hawaii, and DART records across the Pacific




TIME 2:40
14°N
12°N
144°E
146°E
-0.4
-0.2
0
0.2
0.4 m

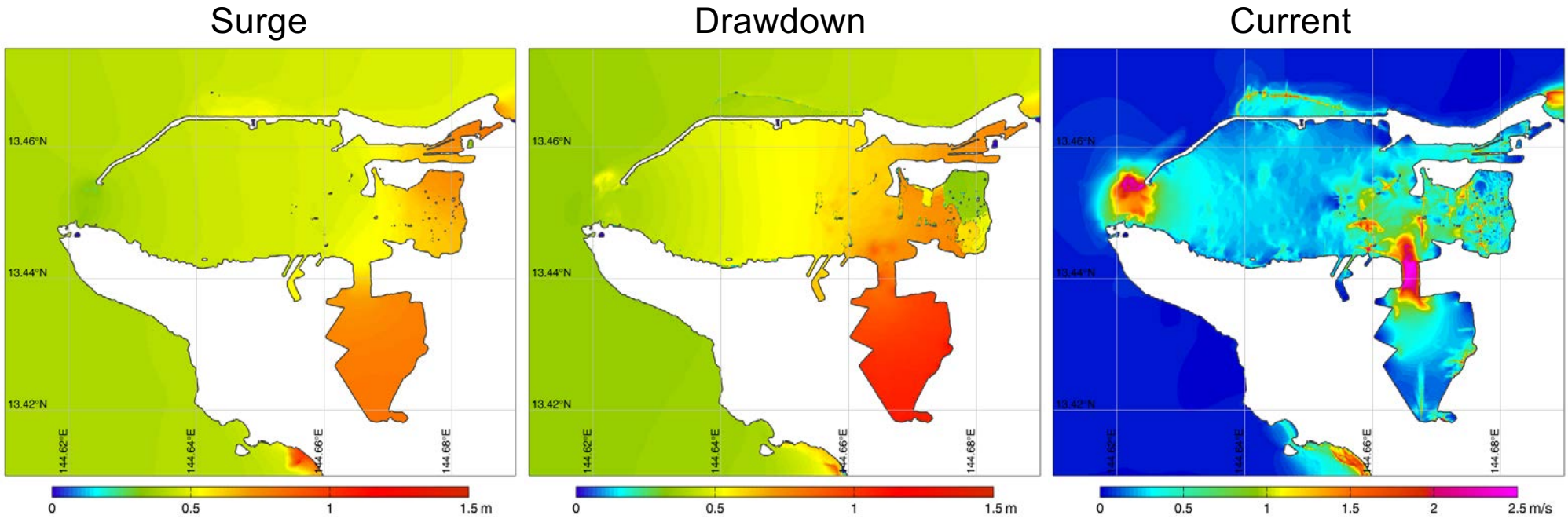

TIME 2:40
13.6°N
13.4°N
13.2°N
144.6°E
144.8°E
145.0°E
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8 m

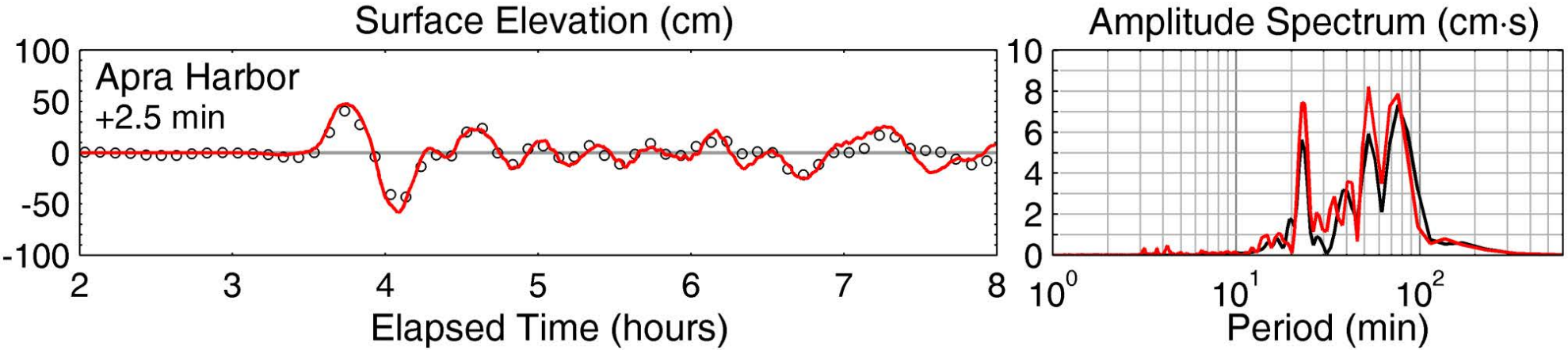

TIME 2:40
13.46°N
13.44°N
13.42°N
144.62°E
144.64°E
144.66°E
144.68°E
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8 m


13.46°N
13.44°N
13.42°N
144.62°E
144.64°E
144.66°E
144.68°E
TIME 2:40
0
0.2
0.4
0.6
0.8
1 m/s


13.46°N
13.44°N
13.42°N
144.62°E
144.64°E
144.66°E
144.68°E
TIME 2:50

Sample Results based on the 2011 Tohoku Tsunami





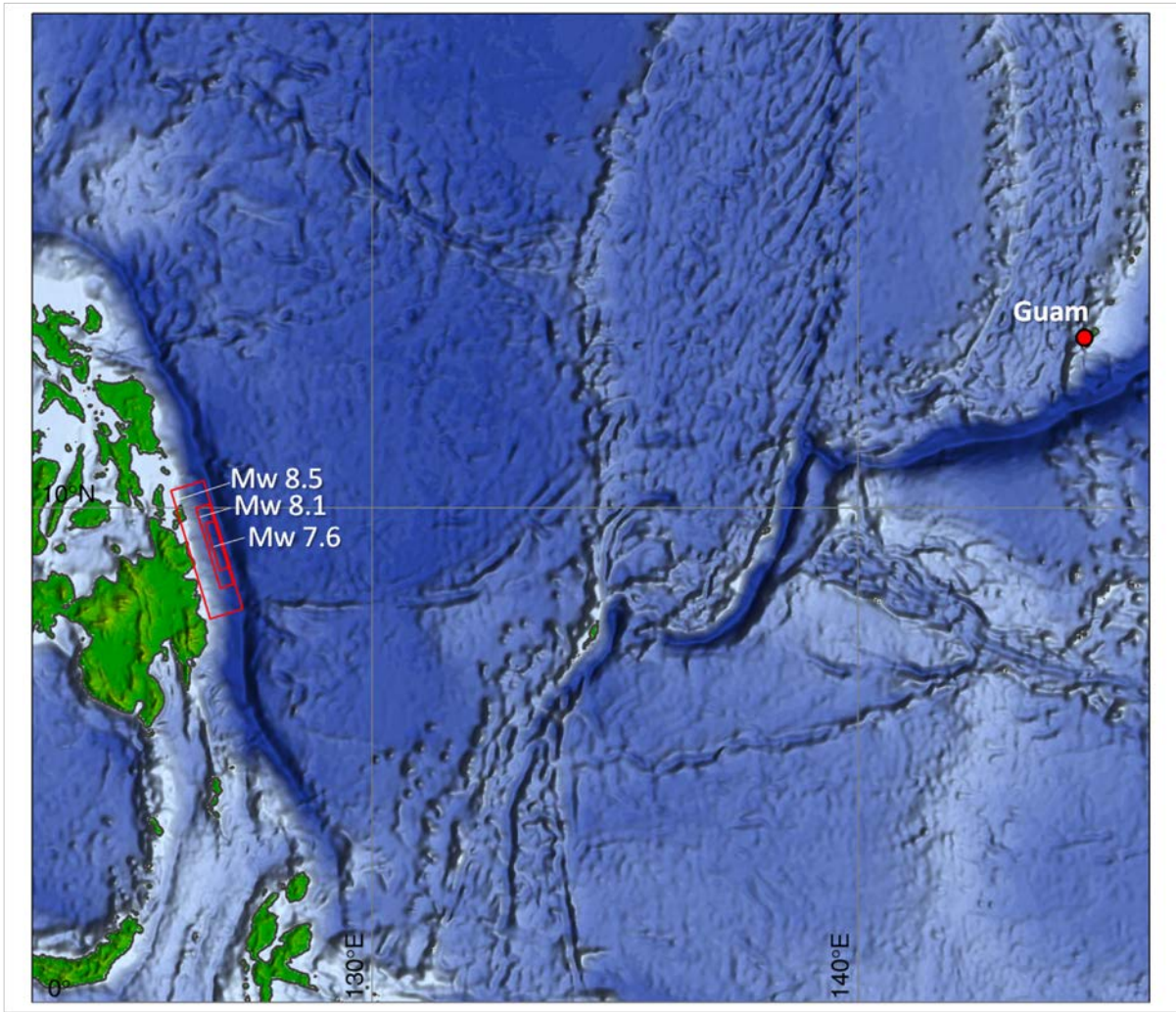
Tsunami Sources along the Philippine Trench (Advisory level)

Tectonic Structures

- USGS/PMEL seismic source parameters and geometry

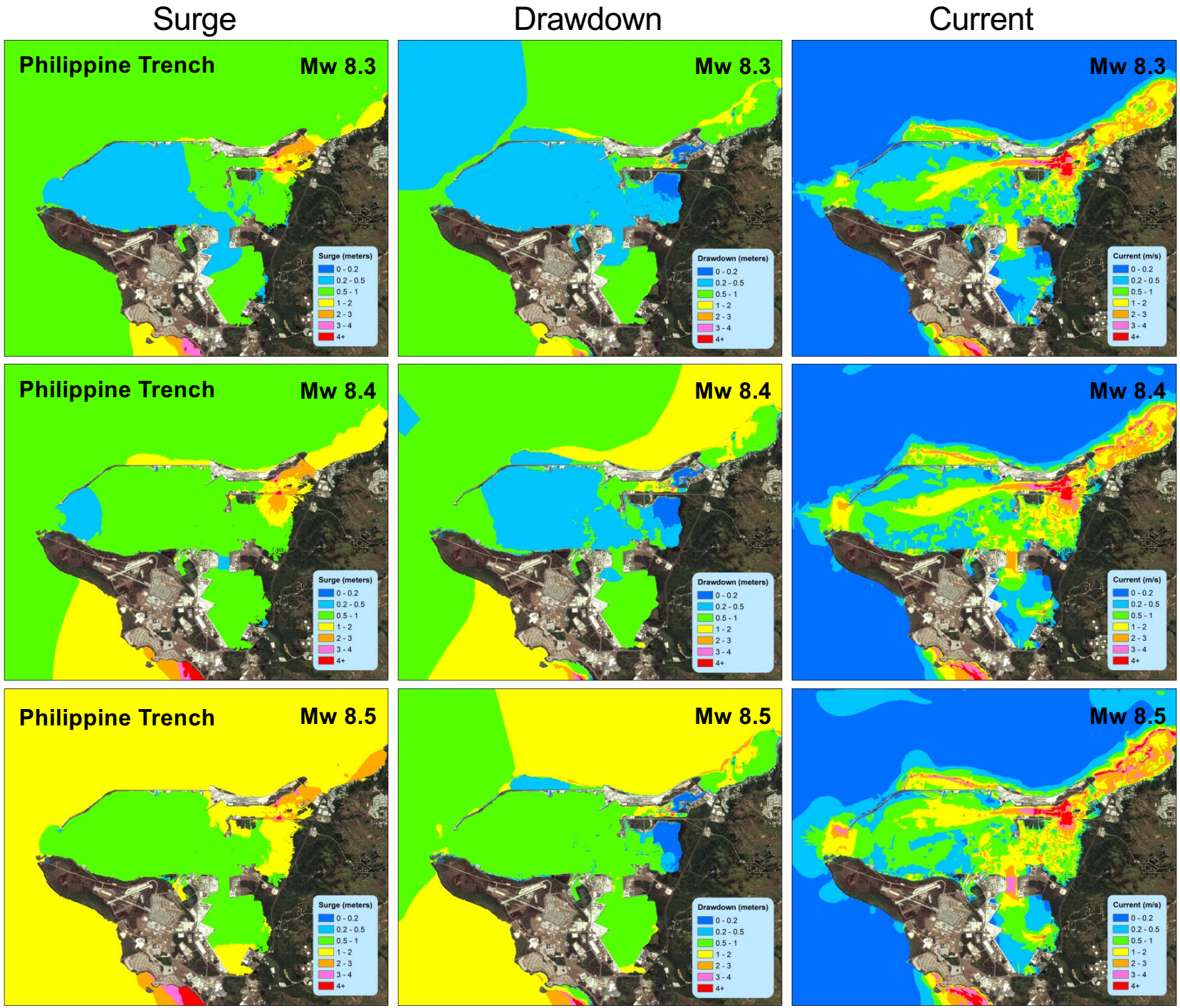
Rupture scenarios

- Ye, Lay, Kanamori & Rivera (2016a, b, JGR Solid Earth)
- Scaling relation from Mw 7.0+ megathrust earthquakes from 1990 to 2016
- Dimensions constrained by local subduction zone
- Slip determined from seismic moment with assumed rigidity of 3×10^{10} N/m^2



Earthquake location

- Most direct path of the tsunami to Guam


Surge
Drawdown
Current
Philippine Trench
Mw 8.3
Mw 8.4
Mw 8.5
Surge (meters)
Drawdown (meters)
Current (m/s)
0 - 0.2
0.2 - 0.5
0.5 - 1
1 - 2
2 - 3
3 - 4
4+

Input from Maritime Community

Need to identify pile-supported docks and piers in Apra Harbor. LiDAR survey showed structures as terrain by water can freely pass through underneath.

New bathymetry survey data?

Potential data products include

- In-harbor hazard maps of surge, drawdown, and currents for advisory-level tsunami scenarios from four critical source locations.
- Maps of offshore surge and current for preferred maximum tsunamis from the critical source locations


Agana Bay
Hagåtña
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