UNESCO/IOC – NOAA ITIC Training Program (ITP)
END-TO-END TSUNAMI EARLY WARNING SYSTEMS
AND THE PACIFIC TSUNAMI WARNING CENTER (PTWC) ENHANCED PRODUCTS
Training Workshop on Strengthening Tsunami Warning and Emergency Response and
the development of Standard Operating Procedures

PTWC Enhanced Products Guidance for National Warnings and Evaluation: Land and Marine Threats and Public Safety

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Country NTWC tsunami event - Key SOPs:

- **Alert Criteria Table.** **Gives alert thresholds and Emergency Response actions**
  (TSP-SCS Guidance 2018; PTWC Enhanced Products User's Guide App VI, VIII)
- **Message templates and Checklists** **Facilitates quick standard responses. Checklists remind Duty Staff**
- **Communication Flow Chart.** **Shows primary agencies / stakeholders of warning chain (TSP => Natl / Local Warning / Emergency Authorities => Public)**
- **Timeline-driven SOPs. Describe by Time, Who, What, How, and To whom.**

=> Exercises practice / improve TWC / TER SOPs

Alert Criteria Table

- **Thresholds are used to assign Alert Levels (Warning, Advisory, Watch, Information)**
- **Alert Levels correspond to country's**
  - Forecast Maximum Coastal Wave Amplitude and/or Earthquake Magnitude, along with
  - Estimated time to first impact and certainty or confirmation of forecast
- **Emergency Response Actions correspond to Alert Level**

Simple Criteria Table

Countries can further customize by assigning different thresholds for different source regions. 2 cases:

- **NO TSP QUANTITATIVE FORECAST**
  TSP Information Statement or Threat Message issued within 10 minutes after M6.5+ earthquake.

- **TSP QUANTITATIVE FORECAST**
  TSP Threat Message issued 10 minutes to 1 hour after a large earthquake with tsunamigenic potential
  - **Warning / Watch Alerts (1.0 m threshold)**
  - **Warning / Advisory / Watch Alerts (0.3 / 1.0 m thresholds)**

PTWC, NWPTAC, SCSTAC
Alert Criteria Table: OT + 8-10 min – Case 1

1. CRITERIA TABLE - NO QUANTITATIVE TSP FORECAST PRODUCT

Criteria Table for NTWC tsunami alerts and emergency response actions based upon the initial TSP product, typically issued within 10 minutes of any large South China Sea region earthquake, prior to the computation of a quantitative tsunami forecast. Key criteria for each situation are indicated in bold red letters.

TSP Product Type	Earthquake Parameters	Potential Tsunami Type	Are Possible Hazardous Tsunami Waves Indicated for Your Country or Area	Threatened Coast	Time left to Initial Wave Arrival (ETA)	NTWC Alert Level for Threatened Coast	Emergency Response Action
PTWC Information **NWPTA** **SCSTAC Information**	Magnitude of 6.5-7.0, or on land, or ≥ 100 km depth	None or Very Minor	No	None	Not applicable	INFORMATION	No action required
PTWC Threat **NWPTA** **SCSTAC Threat**	**Magnitude of 7.1-7.5**, undersea or very near the sea, and < 100 km depth	Local Tsunami	**Yes**	< 300 km from earthquake	< 1 hour typical	WARNING	Evacuate threatened coast
			No	≥ 300 km from earthquake	> 1 hour typical	INFORMATION	Monitor subsequent messages
	Magnitude of 7.6 and greater, undersea or very near the sea, and < 100 km depth	Regional Tsunami	**Yes**	< 1000 km from earthquake	**< 3 hours**	WARNING	Evacuate threatened coast
			Yes	≥ 1000 km from earthquake	**3 to 6 hours**	WATCH	Prepare to evacuate
			No	≥ 1000 km from earthquake	**> 6 hours**	INFORMATION	Monitor subsequent messages

NOTES for 1., 2A, 2B:

- In a local tsunami situation, in order to provide the fastest alert, earthquake magnitude criteria should be used. Issuance of a Warning, Watch, or Information is dependent on the size of the earthquake and its closeness to coastlines. Smaller magnitude earthquakes that are closer to the coast may warrant issuance of a Warning.
- Local tsunami criteria based solely on magnitude should be determined after examining a country historical earthquake tsunami hazard. In some places, the local tsunami magnitude threshold may need to be lower than M7.1. The M7.1 threshold is used by PTWC for its Caribbean Tsunami Watch Service and was used by the PTWC for its Indian Ocean Tsunami Watch Service.
- The 3-hour time criteria is based on the amount of time required for a country to safely complete a coastal evacuation. The 3-hr threshold used by PTWC is considered a conservative, but reasonable time criteria. Historically, the value is from a requirement from Hawaii State Emergency Management Agency as the time required to safely evacuate all coasts of the State of Hawaii. Each country should consider their situation.
- The 6-hour time criteria is based on the amount of time required for a country to activate its emergency response personnel to be able to carry out an orderly evacuation. The 6-hr threshold used by PTWC is considered a conservative, but reasonable time criteria. Historically, the value is from a requirement from Hawaii State Emergency Management Agency as the time required, given the location of likely tsunami sources that will impact Hawaii. Each country should consider their situation.

PTWC, NWPTAC, SCSTAC
Alert Criteria Table: OT + 8-50 min – Case 2A

CASE 2A, 2B: TSP FORECAST AVAILABLE
Earthquake: Magnitude 7.1 or greater, undersea or very near the sea, and < 100 km depth

2.A. CRITERIA TABLE – QUANTITATIVE TSP FORECAST PRODUCT:
Warning / Watch Alerts (1.0 m threshold)

Criteria Table for NTWC tsunami alerts and emergency response actions based upon TSP messages that includes a quantitative tsunami forecast typically issued between 8 minutes to one hour after a large South China Sea region earthquake with a tsunami-genic potential. Key criteria for each situation are indicated in bold red letters. This uses the same criteria (> 1 m) used by PTWC until September 30, 2014 to designate Warning/Watch alert levels.

Threat Level Criteria Table (1m Warning threshold)

TSP Product Type	TSP Forecast of Maximum Coastal Amplitude	Country's Threat Level	Estimated Time of Wave Arrival (ETA)	Emergency Response Action
PTWC Threat NWPTA SCSTAC Threat	H >= 1 m	WARNING	< 3 hours	Evacuate tsunami evacuation zones
PTWC Threat NWPTA SCSTAC Threat	H >= 1 m	WATCH	3 to 6 hours	Prepare to evacuate
PTWC Threat NWPTA SCSTAC Threat	H >= 1 m	INFORMATION	> 6 hours	Monitor event, alert EM stakeholders
PTWC Threat or Information NWPTA SCSTAC Threat or Information	H < 1 m	INFORMATION		No Action
PTWC Threat	H >= 1 m at distant coastline	Determine from distant tsunami threat: PTWC message nbr 1	> 3 hours	Monitor event, alert EM stakeholders

PTWC, NWPTAC, SCSTAC
Alert Criteria Table: OT + 8-50 min – Case 2A

Threat Level Criteria Table (0.3m Advisory, 1m Warning threshold)

TSP Product Type	TSP Forecast Coastal Amplitude	Country's Threat Level	Estimated Time of Wave Arrival (ETA)	Emergency Response Action
PTWC Threat NWPTA SCS Threat	H >= 1 m	WARNING	< 3 hours	Evacuate tsunami evacuation zones
PTWC Threat NWPTA SCS Threat	0.3 m <= H < 1 m	ADVISORY	< 3 hours	Clear Beaches, low lying coastal areas, harbors, waterways
PTWC Threat NWPTA SCSTAC Threat	H >= 0.3 m	WATCH	3 to 6 hours	Prepare to evacuate
PTWC Threat NWPTA SCSTAC Threat	H >= 0.3 m	INFORMATION	> 6 hours	No Action
PTWC Information NWPTA SCSTAC Information	H < 0.3 m	INFORMATION		No Action
PTWC Threat	H >= 1 m at distant coastline	Determine from distant tsunami threat: PTWC message nbr 1	> 3 hrs	Monitor event, alert EM stakeholders

2.B. CRITERIA TABLE – QUANTITATIVE TSP FORECAST PRODUCT:
Warning / Advisory Watch Alerts (0.3 / 1.0 m thresholds)

Criteria Table for NTWC tsunami alerts and emergency response actions based upon TSP messages that includes a quantitative tsunami forecast typically issued between 8 minutes to one hour after a large South China Sea region earthquake with a tsunami-genic potential. Key criteria for each situation are indicated in bold red letters. This adds another NTWC alert level; the Advisory corresponds to a lower level of Warning, and calls for evacuating the beaches and harbors only.

Laboratory studies complementing empirical structural damage and casualty data collected from recent tsunamis show that tsunami inundation or flow depths of less than one meter, and as small as tens of centimeters, can be dangerous and destructive (e.g., Arikawa et al., 2006; Suppasri et al., 2013)[1,2]. The data suggest that a lower level of warning for a marine threat may be desirable. The response to this lower level of warning would be for people to avoid beaches and low-lying coastal areas, and for vessels in harbors and waterways to take precaution against unusually strong water currents. This lower level of warning is used in the United States, and is termed an Advisory. In an Advisory status, a full scale land

ENHANCED PRODUCTS GUIDANCE: FORECAST => WARNING => EVACUATION

- **Amplitude ≥ 3 m WARNING**
  => Major Land Threat:
  Evacuate Tsunami Coastal Evacuation Zones
- **1 m ≤ Amplitude < 3 m WARNING**
  => Land Threat:
  Evacuate Tsunami Coastal Evacuation Zones
- **0.3 m ≤ Amplitude < 1 m ADVISORY**
  => Marine Threat:
  Clear beaches, harbors, low lying coastal areas
- **Amplitude < 0.3 m** *=> No Threat, No Evacuation*
- **Value not computed** *=> Monitor Event*

ADVISORY - Marine Threat – CLEAR BEACH

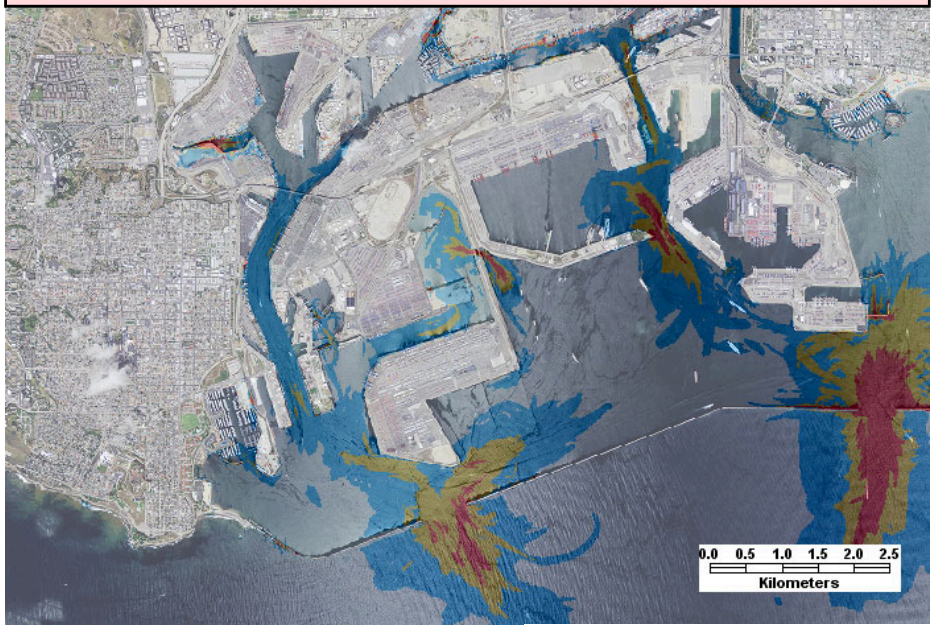
Eddies generated by the interactions of tsunami waves as they hit the coast of Sri Lanka, 26 December 2004. Photo courtesy of Digital Globe.

ADVISORY – Marine Threat - Harbors

2011 Japan tsunami
Crescent City, CA USA

Crescent City, California boat harbor damage after the 2011 Japan tsunami. Strong wave currents entering the enclosed harbor (from top of photo) formed an eddy, which was left in the sediment swirls. The tsunami caused USD $55 million in damage to moorings and vessels in two dozen harbors in California. (Credit: R. Hiser and L. Dengler)

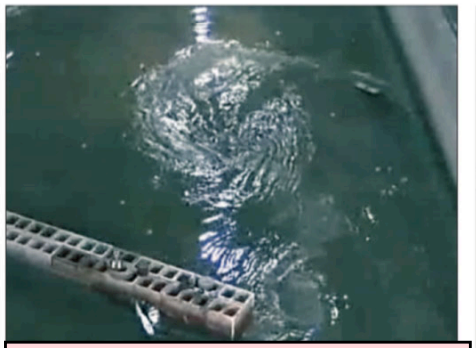
M9.2 Alaska-Aleutian Scenario
Los Angeles / Long Beach, CA USA



Wilson et al, US NTHMP (2016)

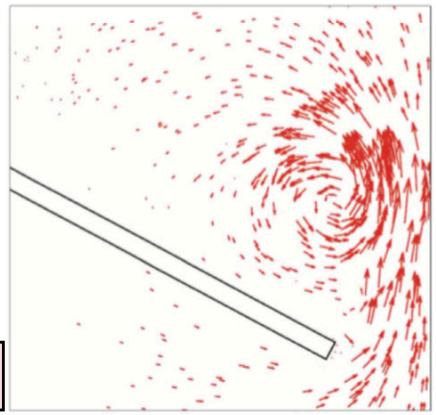
Current Thresholds for Potential Damage

- Minor to moderate damage
- Moderate to major damage
- Major damage/complete destruction



Wave Tank - modeling

Wave Tank formation of an eddy around breakwater long pier. (Credit: Univ. of Southern California).

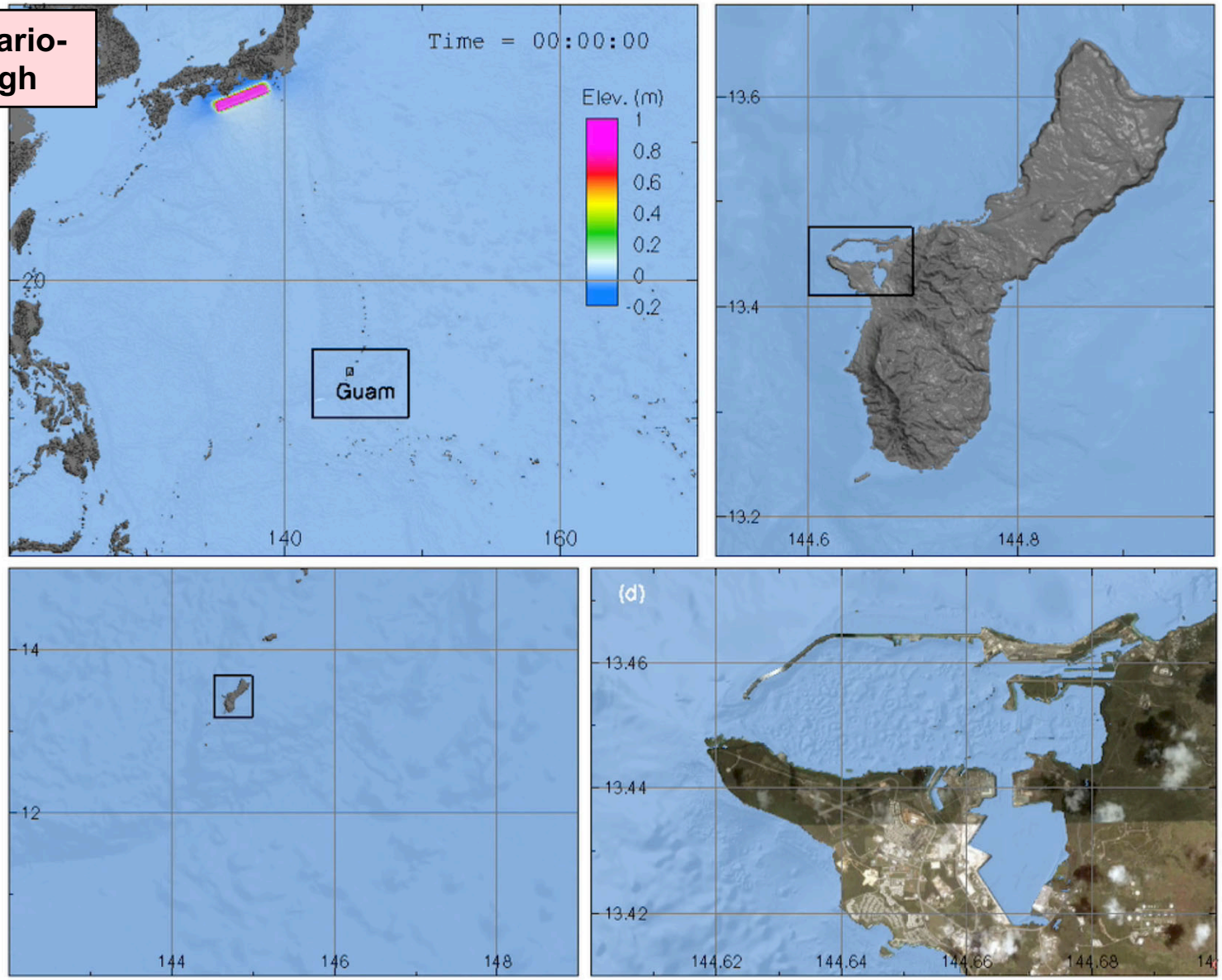


Numerical model of eddy forming around breakwater long pier. The length of each arrow is proportional to the current speed. (Credit: Univ. of Southern California)

Pacific Tsunami Warning System:
A Half-Century of Protecting the Pacific (1965-2015)
NOAA, ITIC, NCEI, 2015

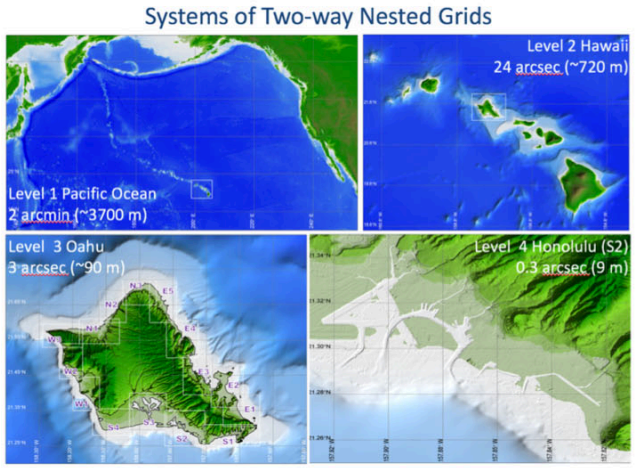
Apra Harbor, Guam – modeling wave ampl

Japan scenario-
Nankai trough

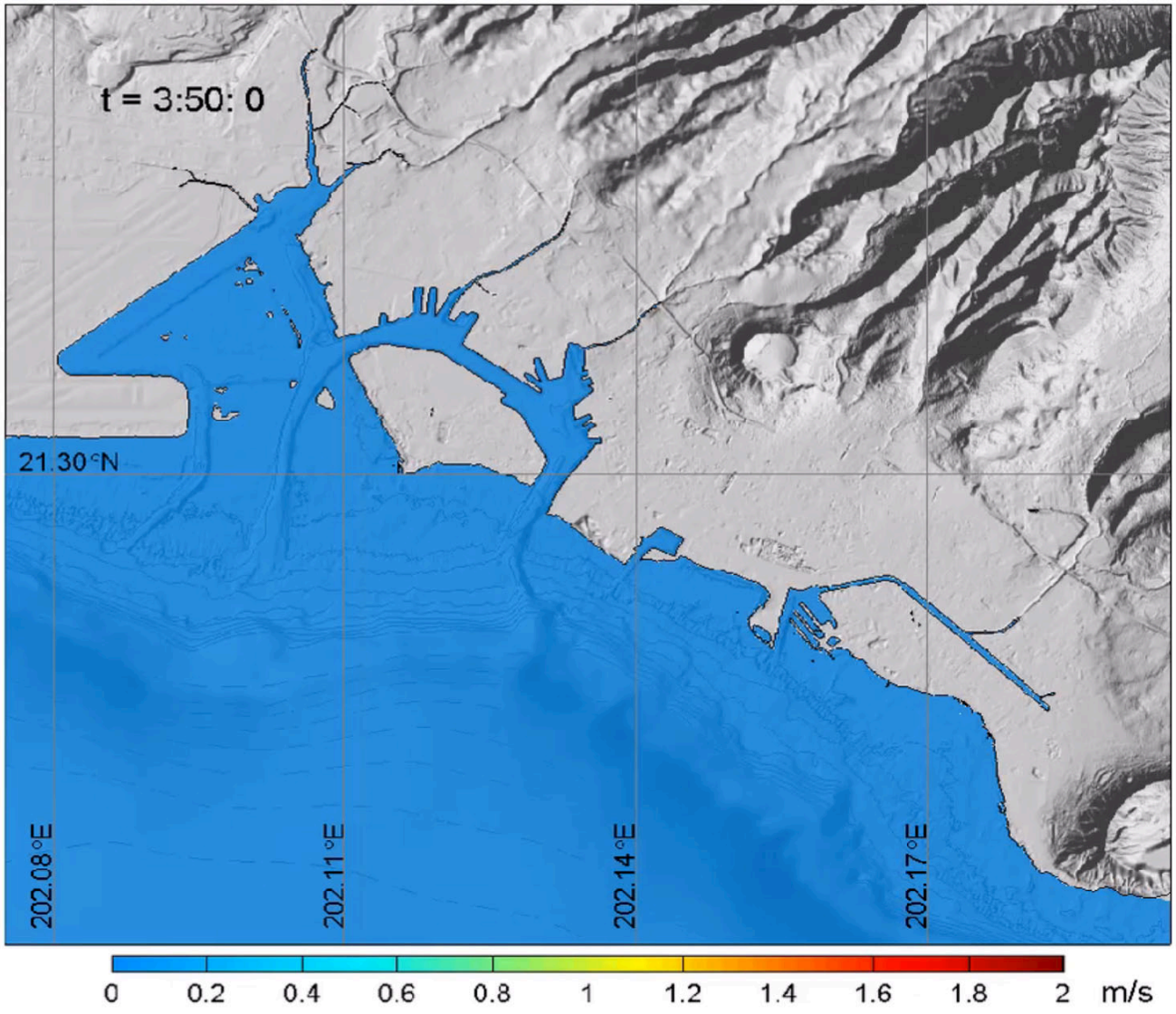


Kwok Fai Cheung, Univ of Hawaii

Honolulu Harbor, Hawaii – modeling currents



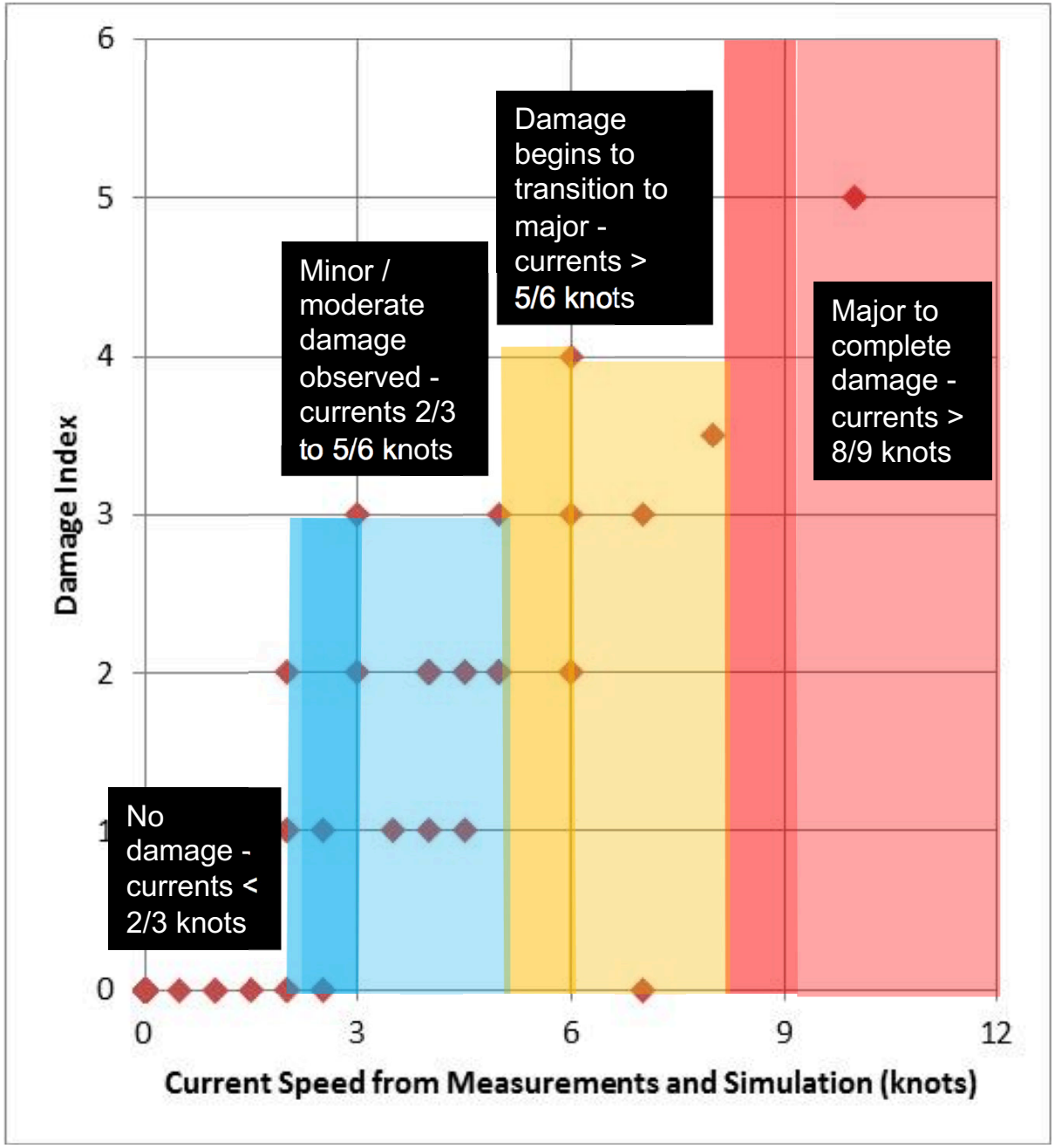
Aleutian scenario M9.3



Kwok Fai Cheung, Univ of Hawaii

Tsunami Current Hazard

Damage Index:	Damage Type:
0	no damage
1	small buoys moved
2	1-2 docks/small boats damaged, large buoys moved
3	Moderate dock/boat damage, mid-sized vessels off moorings
4	Major dock/boat damage, large vessels off moorings
5	Complete destruction



Lynett et al. (2013)

WARNING - Minor Land Threat – EVACUATE

WARNING - Major Land Threat - EVACUATE

Timeline-driven SOPs

- Planning for seamless, effective response. Manage expectations.
- Specify critical actions / decision points. What decision, and when it must occur
- Add TIME to Communication Flow Chart
- When, What, Who, How, To whom

EVENT	TIME (When)	ACTIVITY (What actions)	AUTHORITY (Who)	MEDIUM (How)	TO (Target audience)
EQ Occurs					
Assess Threat - Tsunami might come					
Evacuate					
Tsunami comes					
Safe to return / Declare “All Clear”					

EXAMPLE: TIMELINE-DRIVEN SOP

TSUNAMI SCENARIO: Distant Tsunami (8 hrs to arrive)
TIMELINE-DRIVEN INFORMATION FLOW AND SOP for REPUBLIC OF MARSHALL ISLANDS
Draft 0.2, April 2014, ITIC

Notes:

- PTWC will issue 1st Message in 5-15 min, 2nd Message in 30-60 min, and as new information received and/or regularly (nominally hourly). PTWC Text,, Graphical, Statistical Forecast Products only to PTWS TWFP (WSO Majuro) by email; PTWC Text Product is public and goes to many and posted on PTWC web site.
- WSO will issue TIS, Watch, Warning based on PTWC Messages and monitoring of earthquake and tsunami as it propagates across the Pacific. Updates as new information received and/or regularly

TIME (HRS AFTER EQ)	TIME (HRS BEFORE WAVE ARRIVAL)	TIME (WHEN)	EVENT	ACTIVITY - ACTION (WHAT IS DONE AND BY WHOM / INFO AVAILABLE)	AUTHORITY (WHO FROM)	MEDIUM (HOW)	TO (TARGET)	IMPACT
0	8	0000	EQ Occurs	WSS on Duty				
0.08	7.8	0005	PTWC EQ Observatory Message	WSS on Duty responds to Alarm / Email	PTWC	CISN (internet) Alarm / PTWC Email	All with CISN, or WSO	Unknown
0.12	7.75	0007	PTWC Message 1	PTWC Message – earthquake info WSO read and interpret message	PTWC	Email, Fax, Phone from WFO Guam, EMWIN?	WSO	
0.5	7.5	0030	PTWC Message 2	PTWC Message – W-phase Forecast. WSO read and interpret message.	PTWC	Email, Fax, Phone from WFO Guam, EMWIN?	WSO	3ft forecast in RMI
0.75	7.25	0045	TIS	WSO recommends to NDMO/NDC to issue TIS to inform that earthquake has occurred, and is monitoring	WSO issues?	Fax, Phone, ?	NDMO	
0-2	8-6	0000-0200	Large earthquake occurred	Read & Interpret PTWC Bulletins. WSO assess hazard (check for historical impact (online NGDC, offline TsuDig), monitor Tide Tool, contact WFO Guam/PTWC as needed). Inform & coordinate with NDMO.	WSO	Fax, Phone, ?	Natl Govt	Possible Tsunami at source. Waiting for confirmation

Final Guidance

- Remember Goal: Early warning to save lives
- Successful warning must be in time, understood, and actionable (e.g., Warning => Evacuate)
- For local threat (< 30-45 min), Education priority.
  People must: 1. Act on Natural Warnings,
  2. Self-Evacuate - do not wait for NTWC warning
- NTWC issue Alert using pre-determined criteria.
  Duty Staff know what to look for in PTWC products
- NTWC can decide Alert Level using only Public Text (e.g., map forecast height to Warning).
  NTWC does NOT need to use all products (these add value, further detail).

Thank You

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