UNESCO IOC – NOAA International Tsunami Information Center (ITIC)
NOAA Pacific Environmental Laboratory,
NOAA Center for Tsunami Research (PMEL/NCTR)
Pacific Tsunami Warning Center (PTWC)

Tsunami Coastal Assessment Tool

TsuCAT

Dr. Laura Kong and Christa von Hillebrandt-Andrade,
UNESCO/IOC – NOAA International Tsunami Information Center (ITIC)
Christopher Moore, NOAA Center for Tsunami Research (NCTR)
Dr. Charles McCreery, PTWC

TsuCAT v4.4, Aug 2024

GLOBAL TSUNAMI WARNING AND MITIGATION SYSTEMS

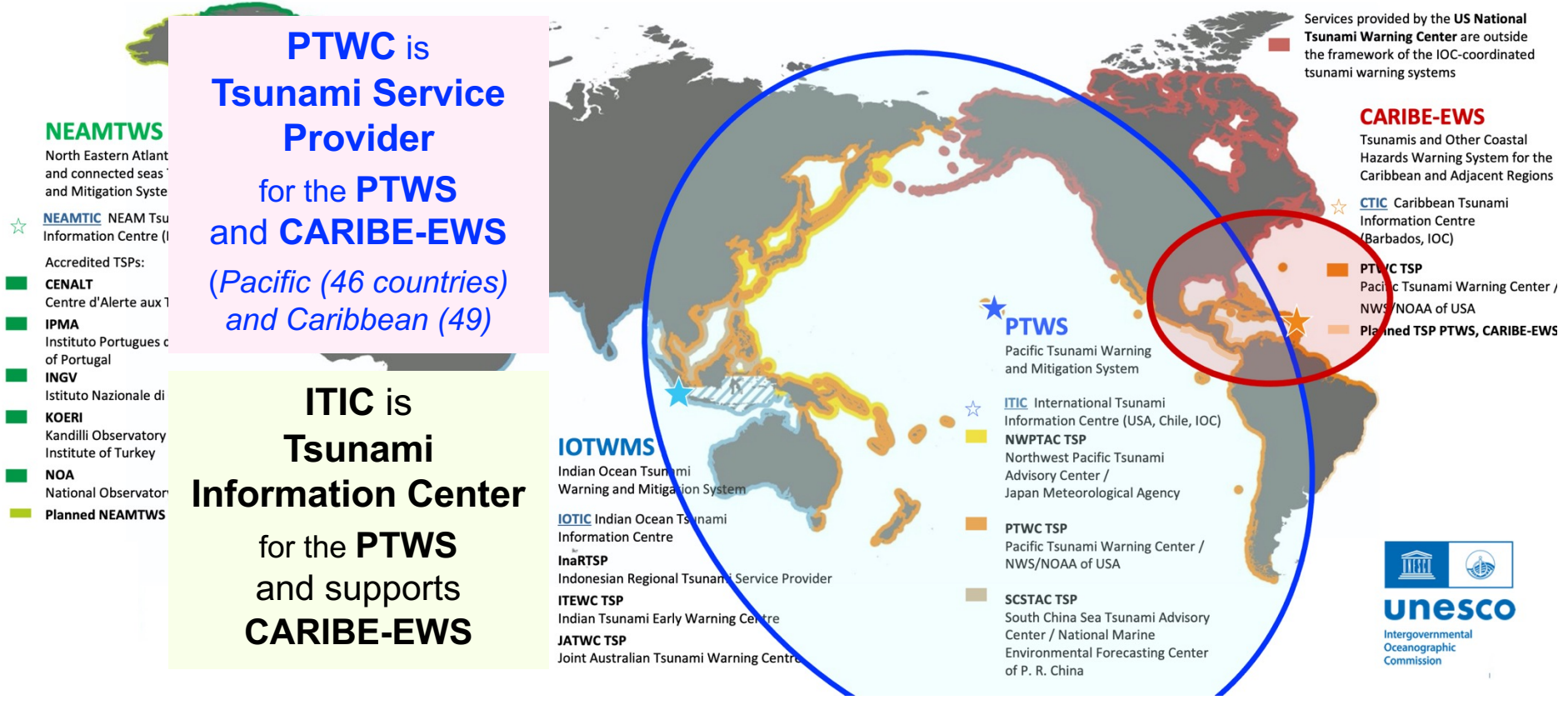
Intergovernmental Oceanographic Commission of UNESCO

2021 www.ioc-tsunami.org

2023

PTWC is
Tsunami Service Provider
for the **PTWS**
and **CARIBE-EWS**
(Pacific (46 countries) and Caribbean (49)

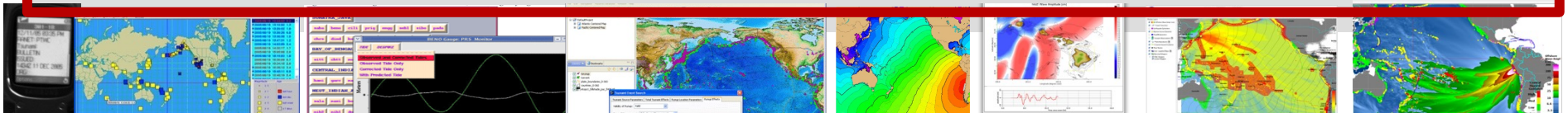
ITIC is
Tsunami Information Center
for the **PTWS**
and supports
CARIBE-EWS



Tsunami Warning Decision Support Tools

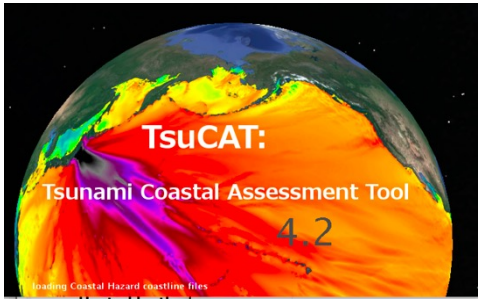
ITIC-distributed, supported with NOAA PTWC, PMEL

- **Tsunami Bull Board** (ITIC, 1995) ~464 science/tsu/govt
- **Real time EQ Display** (v3.13.227 (CISN, USGS / NTHMP, 2005), 350+
- **Real-time Sea Level monitoring**
  - Tide Tool v10.71 – TWC operations monitoring (PTWC, 2005)
  - IOC Sea Level Monitoring web site (IOC, 2008)
- **Tsunami Travel Time Software** v4.0.1 (ITIC, NCEI, 2007) – TTSDK4.0.1
- **Tsunami Historical Database** Online (WDS-NCEI), Offline (TsuDig, NCEI, ITIC, 2009)
- **Tsunami Hazard Assessment Tools – PMEL, ITIC**
  - ComMIT/MOST inundation modeling (2015 TEMPP; put under OTGA for Tsunami Ready)
  - Tsunami Coastal Assessment Tool (TsuCAT) v4.4 Aug 2024 – PTWC messages for multiple countries and situational exercise injects, near-real time event ingest



TsuCAT: Tsunami Coastal Assessment Tool

- **Why / What:** Request by Pacific Islands for warning DSS
  Gives country capacity to assess tsunami hazard.
  Support better understanding, use of PTWC Forecast Products



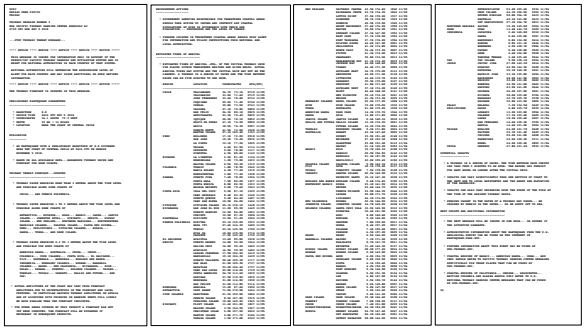
- **Who:** Country agencies with Tsunami Hazard Assessment, Warning and Emergency Response responsibilities
- **Tool use:**
  - Planning tool - assess threat before – 'energy beams'
  - Decision system support tool – Customize country sub-regions (polygons), Quick, early assessment through DB lookup
  - Exercise tool – develop scenarios to use (from v4.0, 2019)

- **Features:**
  - Database: ~5400 earthquake scenarios from along active subduction zones, Pacific, Caribbean, Indian Ocean (M6.5-9.5)
  - Scenarios from Expert Meetings (Caribbean, Pacific)
  - Results from NOAA models (MOST/SIFT (M8+), RIFT (M6.5-7.9)
    - Offshore max amplitude / coastal wave amplitude (Green's Law)
    - PTWC or User custom forecast polygons
  - Exercise Messages and Injects

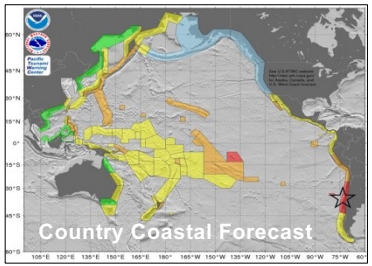
PTWC Text and Graphical Tsunami Products

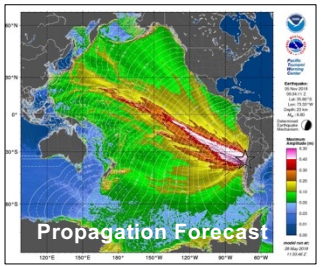
- Issued when there is a potential tsunami threat (~M7.1+)
- Help Countries determine tsunami alert levels for their coasts

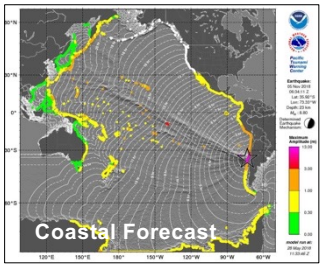
Public Text Product (tsunami.gov)

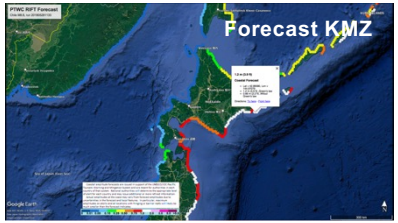


Graphical Products (only sent by email to Country TWC)









Forecast Statistics

WS – RUN ID 20180528113346

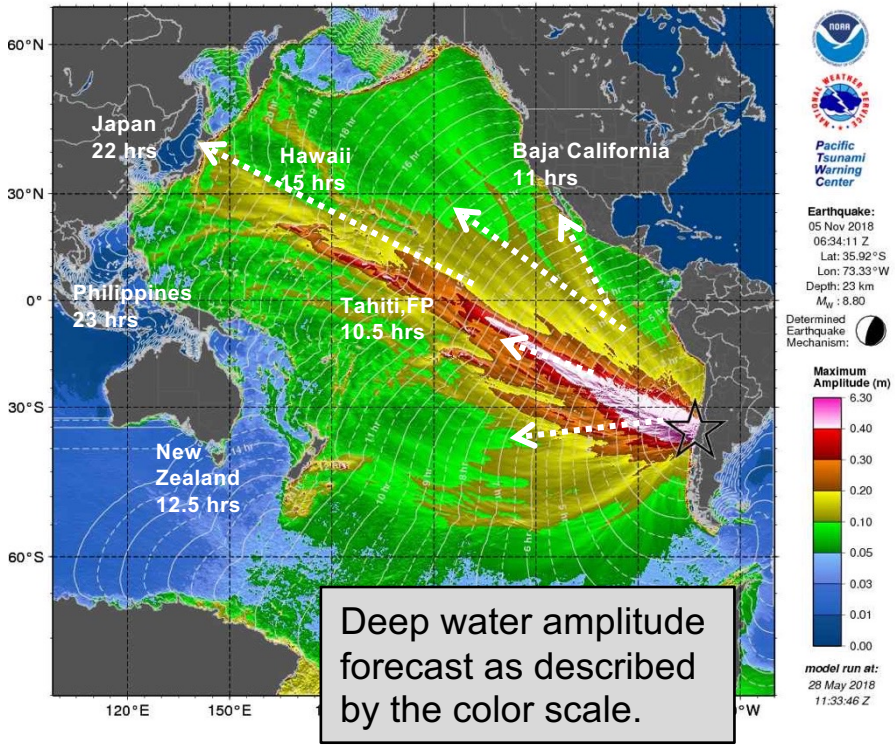
ates: 35.9S 73.3W Depth: 023km Magnitude: 8.8

the UNESCO/IOC Pacific Tsunami Warning and Mitigation System and is t system. National authorities will determine the appropriate nal or more refined information.

Actual amplitudes at the coast may vary from forecast amplitudes due to uncertainties in the forecast and local features. In particular, maximum tsunami amplitudes on atolls will likely be much smaller than the forecast indicates.

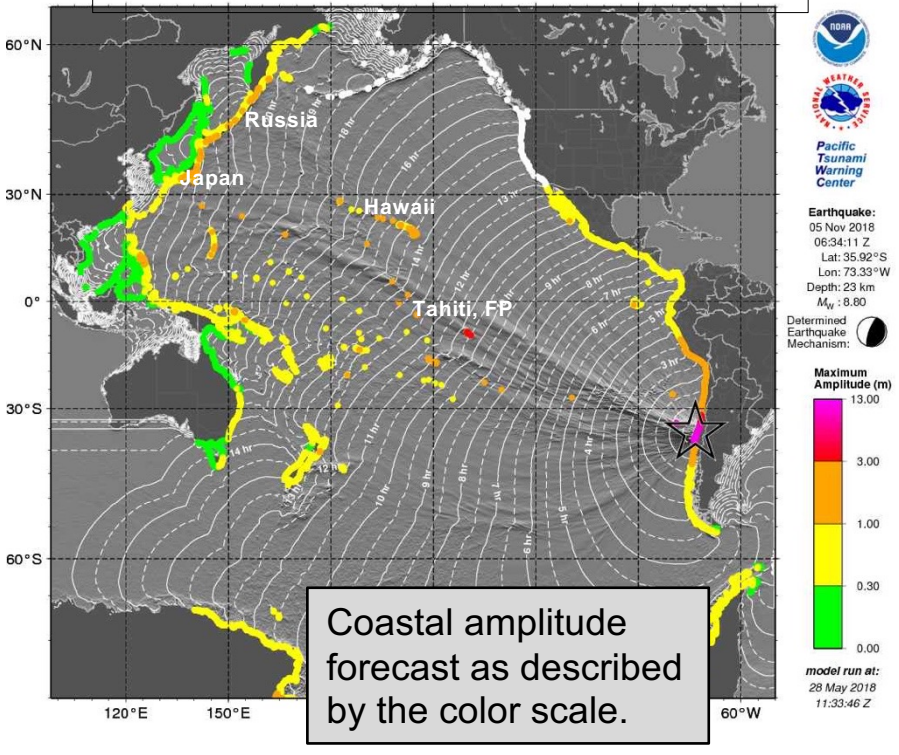
	Coastal Forecast (meters)				Offshore Forecast (meters)				Total
Region_Name	Maximum	Mean	Median	STD	Maximum	Mean	Median	STD	Points
South_Central_Chile	13.	5.70	2.70	4.50	6.3	2.30	2.00	1.40	158
Juan_Fernandez_Archipelago	11.	9.00	8.80	1.10	4.5	3.10	3.30	1.20	5
North_Central_Chile	5.5	2.20	1.90	1.00	2.8	0.86	0.62	0.53	121
Marquesas_Islands	4.2	2.70	2.40	0.74	1.3	0.59	0.55	0.25	24
Palmyra_Island	2.7	2.70	2.70	0.00	0.41	0.41	0.41	0.00	1
San_Felix_Islands	2.1	2.00	2.00	0.05	0.74	0.52	0.50	0.12	5
Southern_Peru	2.0	1.50	1.40	0.15	1.0	0.51	0.48	0.11	86
Society_Islands	1.9	1.30	1.20	0.27	0.50	0.27	0.26	0.07	35
Hawaii	1.8	1.10	1.00	0.32	0.84	0.32	0.29	0.14	147
Line_Islands_Kiribati	1.8	1.20	1.20	0.43	0.34	0.20	0.17	0.10	3
Izu_and_Ogasawara_Islands_Japan	1.7	1.40	1.40	0.30	0.38	0.29	0.29	0.09	2
Pacific_Coast_of_the_Philippines	1.6	0.66	0.66	0.27	1.5	0.28	0.24	0.19	350
East_Coast_of_Japanese_Main_Islands	1.6	0.94	0.93	0.22	1.6	0.53	0.46	0.28	404
Central_Peru	1.6	1.00	0.96	0.23	0.90	0.56	0.54	0.11	110
Northern_Chile	1.5	1.10	1.10	0.14	1.2	0.36	0.32	0.16	118

Propagation and Coastal Forecasts



Deep water amplitude forecast as described by the color scale.

Coastal Hazard Guidance (CHG)



Coastal amplitude forecast as described by the color scale.

Coastal Hazard Guidance – Green's Law

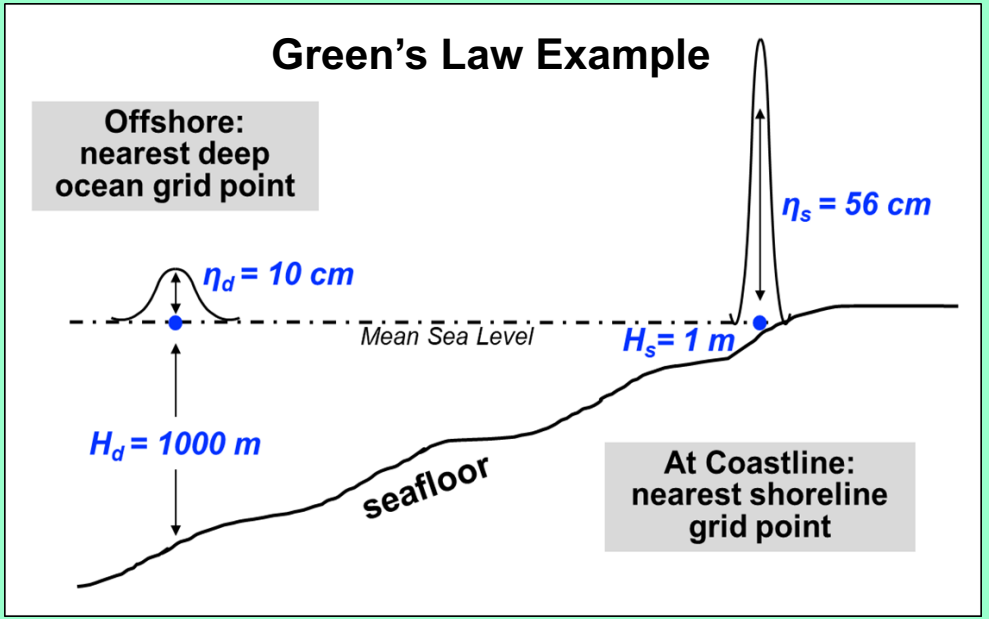
- **PTWC RIFT Model uses Green's Law to quickly estimate coastal ampl**
  - Modeling on fine-scale coastal grids takes too long, even on supercomputers
  - PTWC does not have access to fine-scale bathymetry for all coasts

Green's Law:

$$\eta_s \cong \eta_d \left(\frac{H_d}{H_s} \right)^{1/4}$$

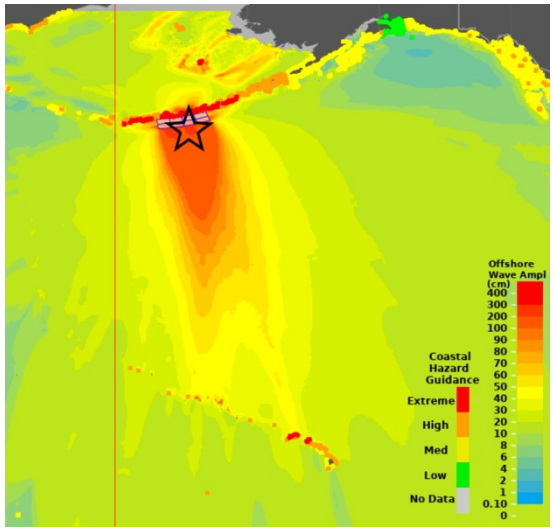
η_s *wave amplitude at shoreline point*
η_d *wave amplitude at nearest deep ocean grid point*
H_d *water depth at nearest deep ocean grid point*
H_s *water depth at shoreline point*

Offshore Tsunami Amplitude (10 cm)	Shoreline Amplitude from Green's Law (1 m water depth)	
Water Depth	**Amplitude**	**Amplification**
1000 m	**56 cm**	**5.6**
500 m	47 cm	4.7
100 m	32 cm	3.2
50 m	27 cm	2.7



Coastal Hazard Guidance - improvement

Wave shoaling: Green's Law, plus Modified Amplification Factor

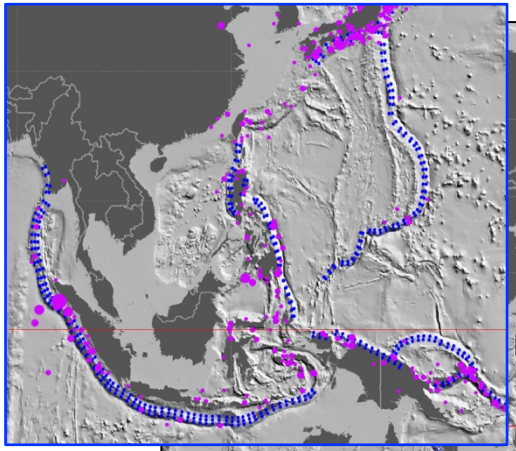


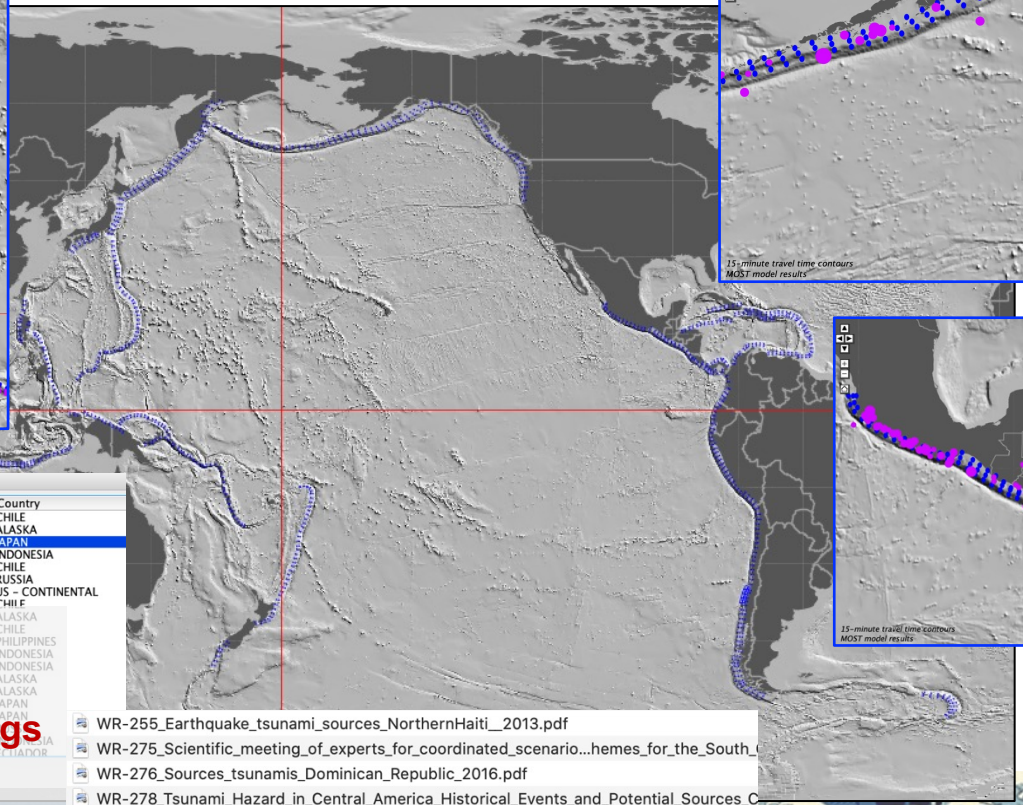
- Modifications to plane-wave ampl: $a \propto h^{-1/4}$
- Model runs on 4 arcmin grids: deeper reference depth (to account for poorly resolved shelf waves)
- Steep slopes (atoll, > 1:10): $a = 1.25$ (approximately profile #1, Løvholt 2012)
  e.g., much reduced AF1.25 compared to 50-meter AF 2.69

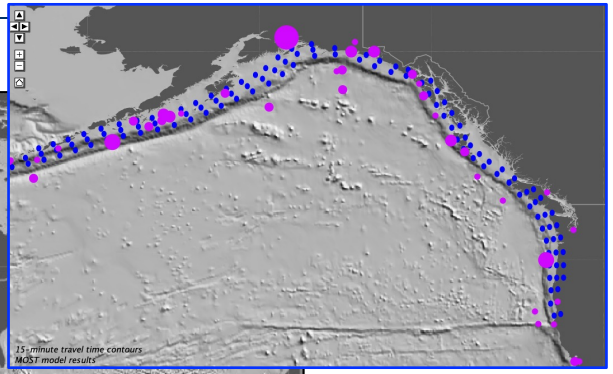
TsuCAT - Background

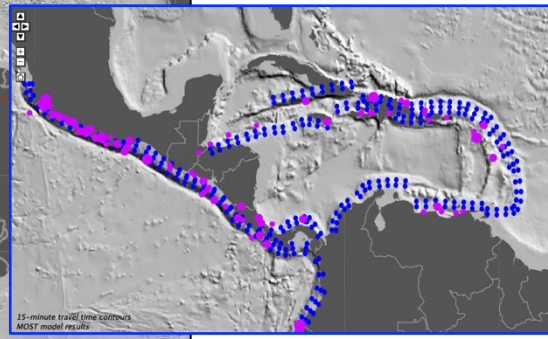
- **Requirements**:
  - Offline (no internet required) - portable
    Online (internet, adds geographic map tiles (OpenStreet, ESRI)
  - Platform: Windows, Linux, Macintosh; Java v1.8
  - Storage: 28 GB; No installation - run from flash drive
  - Bathymetric grid resolution: MOST (compute 4 arc-min),
    RIFT (compute 4 arc-min decr to 30 arc-sec)
- **Layers**
  - Offshore Wave Amplitude, Coastal Hazard Guidance, Travel Time
  - PTWC coastal polygons, or user-customized
  - Results export – model, regional report
  - Reference information: Historical Seismicity(USGS, NOAA NCEI Significant), Tsunami Obs (NOAA NCEI), USGS Plates, Place names
  - User-supplied maps (polygon shape files), Quick guide tutorial
  - PTWC Enhanced Products Exercise messages

Scenarios - NOAA Propagation DB, Historical Tsunamis









Tsunamigenic Earthquakes, 1700-present

Date	Mw	Latitude	Longitude	Country
1960-05-22 19:11	9.5	38.143° S	73.407° W	CHILE
1964-03-28 03:36	9.2	61.017° N	147.648° W	ALASKA
2011-03-11 05:46	9.1	38.297° N	142.372° E	JAPAN
2004-12-26 00:58	9.1	3.316° N	95.854° E	INDONESIA
1730-07-08 08:45	9.1	32.500° S	71.500° W	CHILE
1952-11-04 16:58	9.0	52.755° N	160.057° E	RUSSIA
1700-01-27 05:00	9.0	45.000° N	125.000° W	US - CONTINENTAL
2010-02-27 06:34	8.8	36.122° S	72.898° W	CHILE
1965-02-04 05:01	8.7	51.290° N	178.550° E	ALASKA
1922-11-11 04:32	8.7	28.553° S	70.755° W	CHILE
1897-09-21 05:12	[illegible]	[illegible]	122.000° E	PHILIPPINES
2012-04-11 08:38	8.6	2.327° N	93.063° E	INDONESIA
2005-03-28 16:09	8.6	2.085° N	97.108° E	INDONESIA
1957-03-09 14:22	[illegible]	[illegible]	[illegible]	ALASKA
1946-04-01 12:29	[illegible]	[illegible]	[illegible]	ALASKA
0887-08-26 00:00	8.6	33.000° N	135.300° E	JAPAN
0869-07-13 00:00	[illegible]	[illegible]	143.800° E	JAPAN
1963-10-13 05:17	[illegible]	[illegible]	[illegible]	[illegible]
1938-02-01 19:04	[illegible]	[illegible]	[illegible]	[illegible]
1906-01-31 15:36	8.5	0.988° N	79.347° W	ECUADOR

Select from:

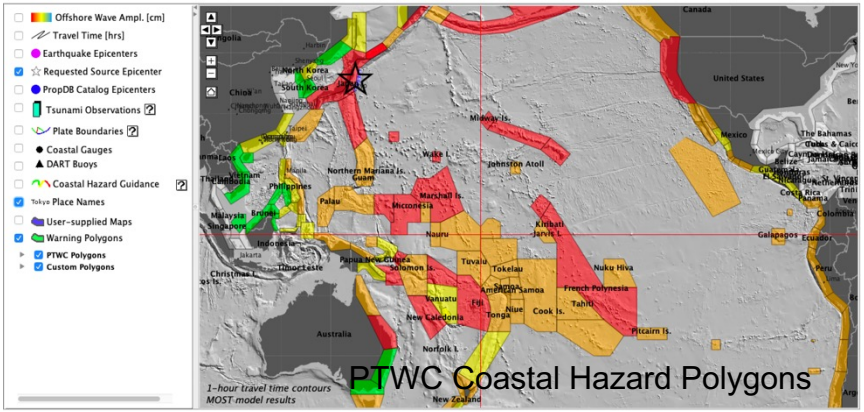
- **Tsunamigenic Eqs,**
- **UNESCO Expert mtgs**
- **User-chosen**

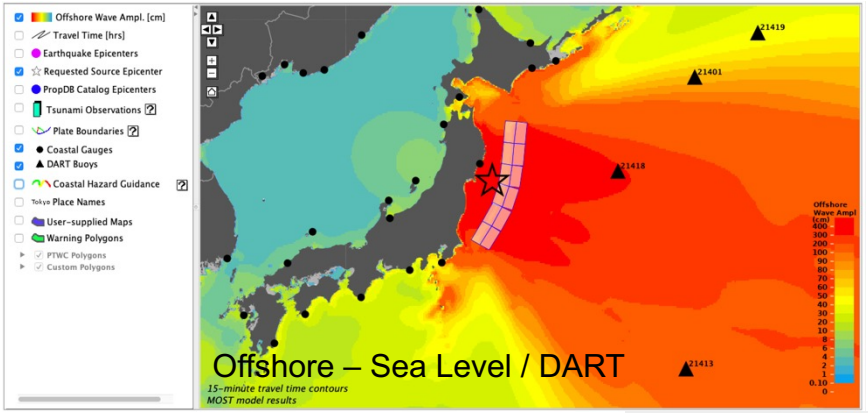
WR-255_Earthquake_tsunami_sources_NorthernHaiti__2013.pdf
WR-275_Scientific_meeting_of_experts_for_coordinated_scenario...hemes_for_the_South_
WR-276_Sources_tsunamis_Dominican_Republic_2016.pdf
WR-278_Tsunami_Hazard_in_Central_America_Historical_Events_and_Potential_Sources_C
WR-289_Experts_Meeting_on_Tsunami_Sources_Tonga-Kermadec.pdf
WR-291_Expers_Meeting_on_Sources_of_Tsunamis_in_the_Lesser_Antilles_2020.pdf

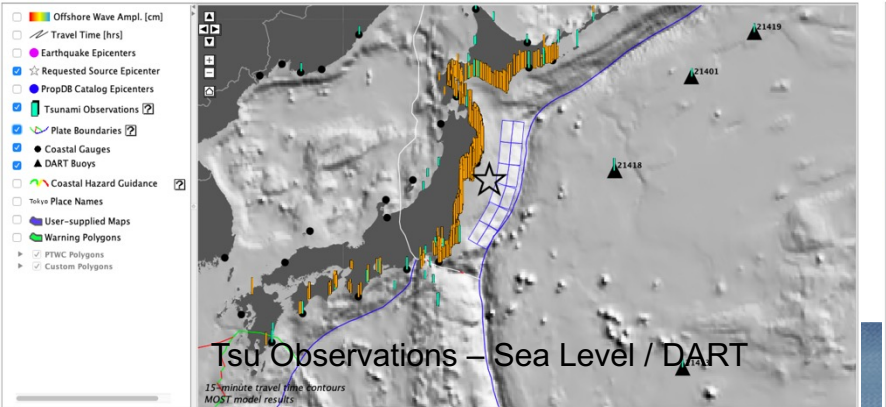
2011 Great East Japan, M9.1 – Data / Result Layers

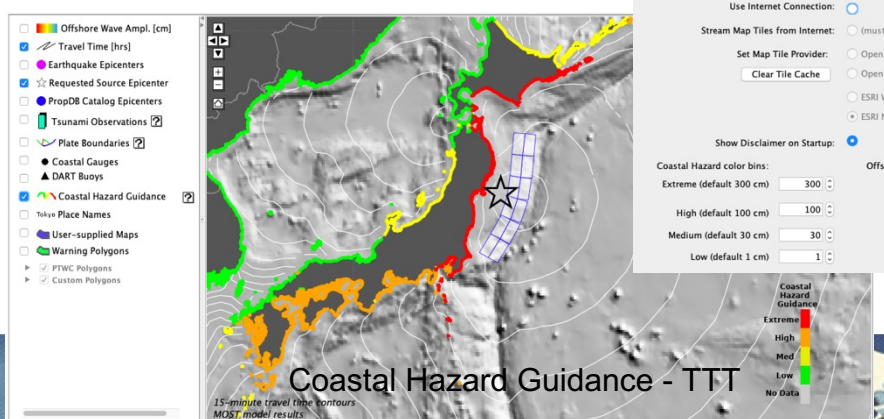
Requested Epicenter, Lat: 38.29700 Lon: 142.37200 Closest in Catalog, Lat: 38.18725 Lon: 142.73354 (34 [km] away)

Mw: 9.10 Event: 11 Mar 2011 05:46:24 (UTC) Mw: 9.1 Ep: 38.297° N, 142.372° E Dep: 30.0 [km] "JAPAN"







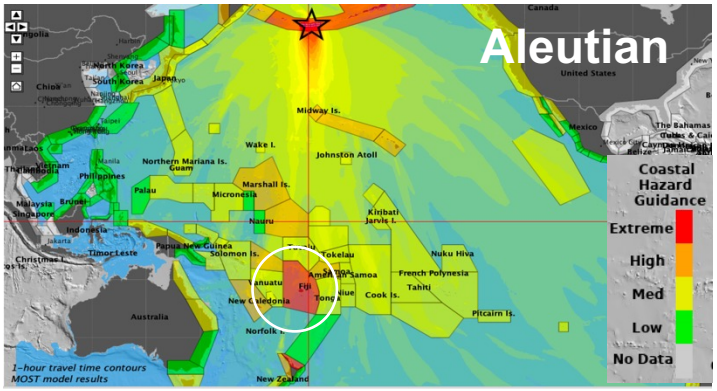


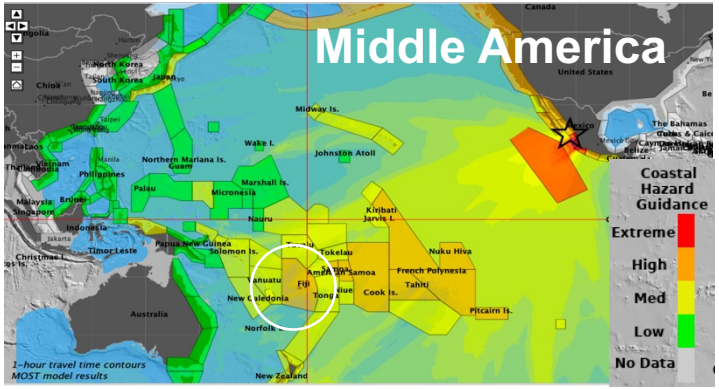
TsuCAT – Tool Applications

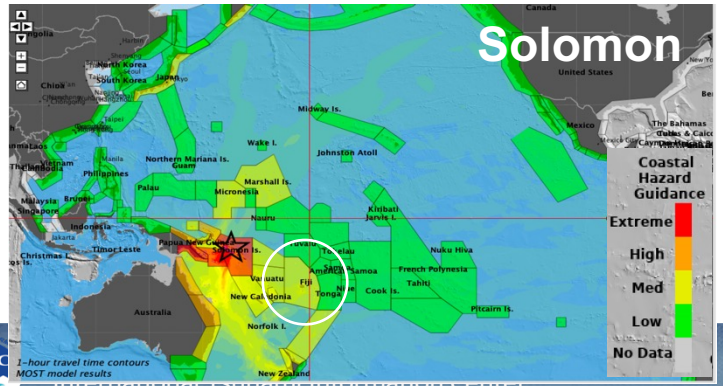
- **Hazard Assessment -** conduct study to determine worst case, or likely impact, to a country's coast from different scenarios
- **Exercise development -** decide which scenario to use for a tsunami exercise, generate PTWC exercise messages
- **Response Planning –** use scenarios to develop tsunami response plans, protocol and procedures (SOPs)
- **Warning decision making –** estimate tsunami impact using the nearest similar scenario during a real event (early assessment prior to receiving PTWC forecast products

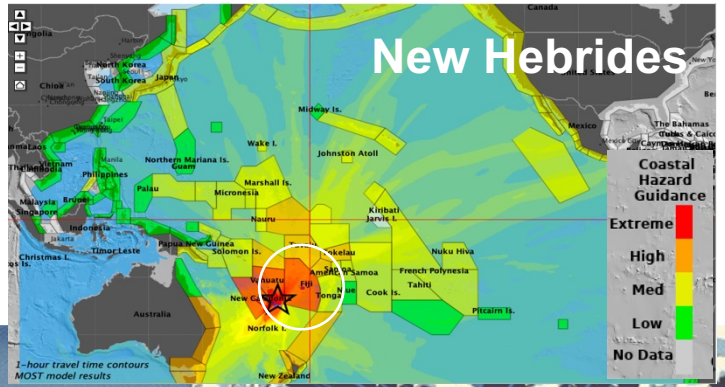
Uses: Threat Assessment

What location is most dangerous to Fiji for a M8.7?



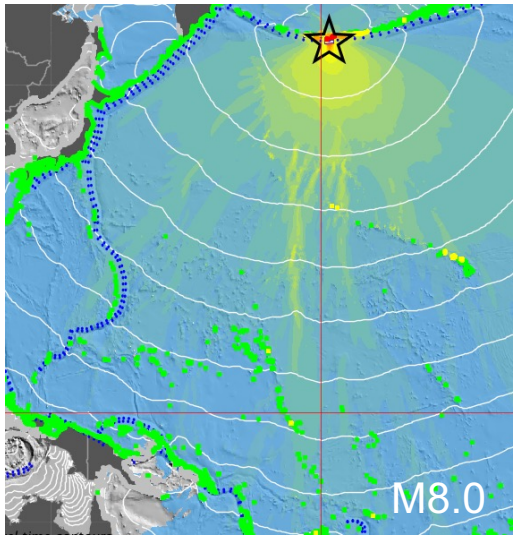


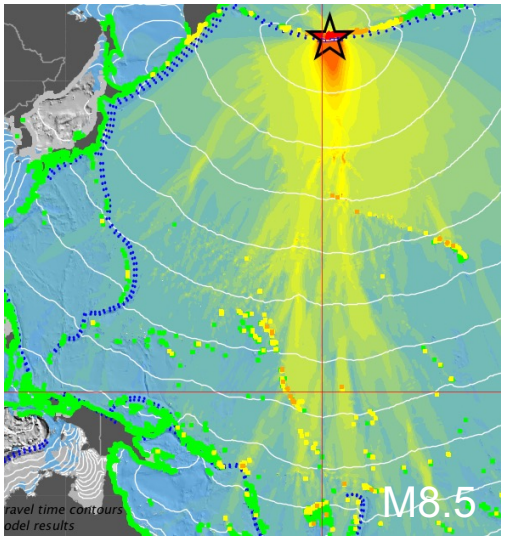


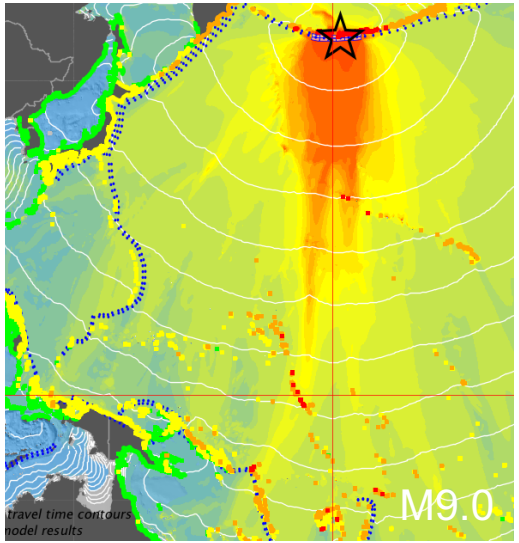


Uses : Threat Assessment

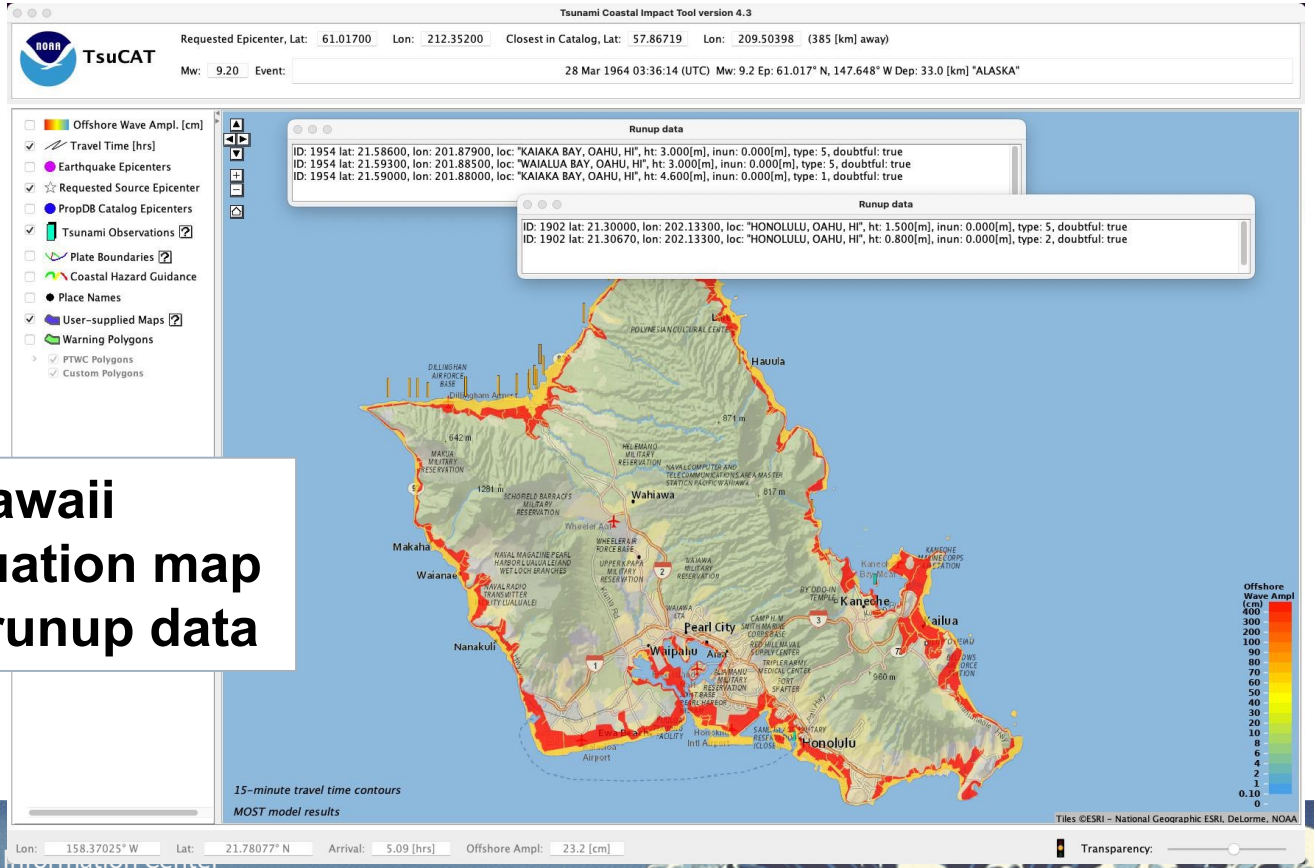
What size earthquake is most dangerous?
Aleutian Trench source: M8.0, 8.5, 9.0







Uses : Overlay of additional data layers



Oahu, Hawaii

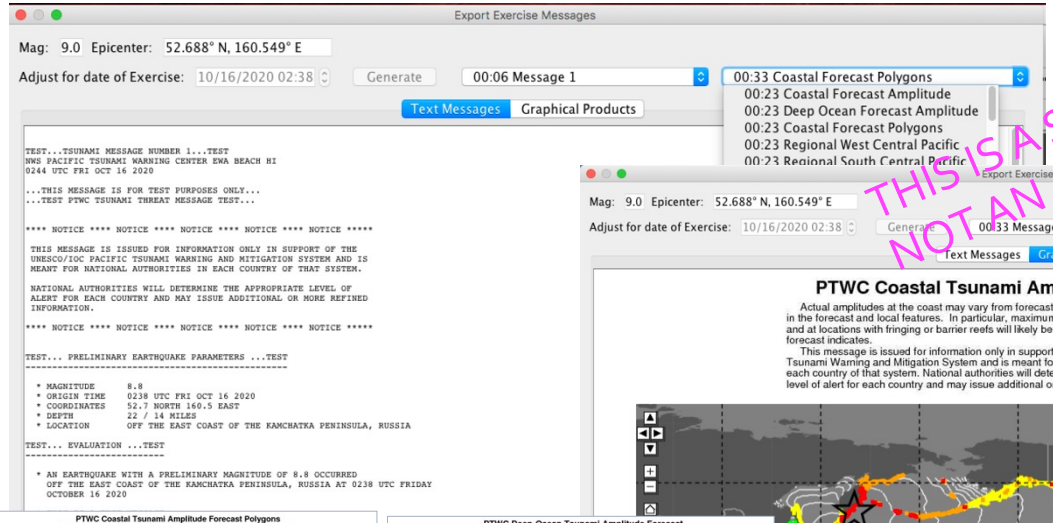
- **Evacuation map**
- **NCEI runup data**

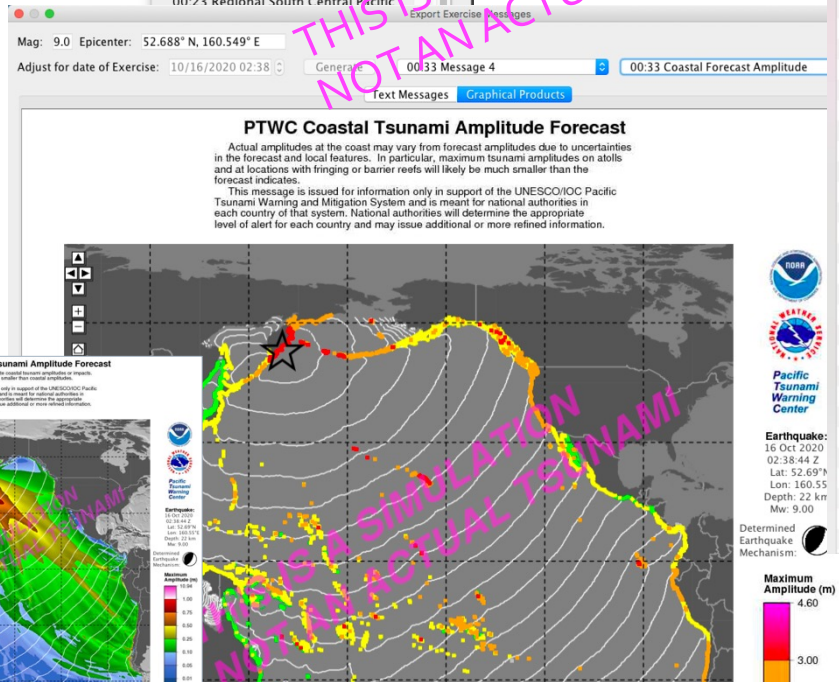
Uses: Generate Exercise messages with Injects

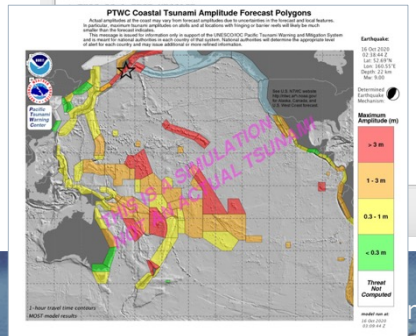
- **PTWC Public Text and Enhanced Products for multiple countries for events in pre-computed Pacific and Caribbean database**
- **Situational Injects for responding to based on selected scenario**
- **Password protected – to minimize 'hoaxes'**
- **Select Menu - "Export Exercise Messages"**
  - Set Event (historical database or by mouse, origin time, magnitude)
  - Choose Generate (PTWC Text Messages, Enhanced Products (graphical, polygon table, kmz file)
  - Output folder, e.g., message/2019-04-02_0000_M9.0_Russia_PTWCproducts
- **Varying issue time and magnitude update**

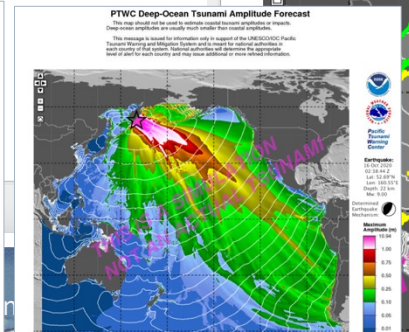
GUI – Export PTWC Exercise Messages

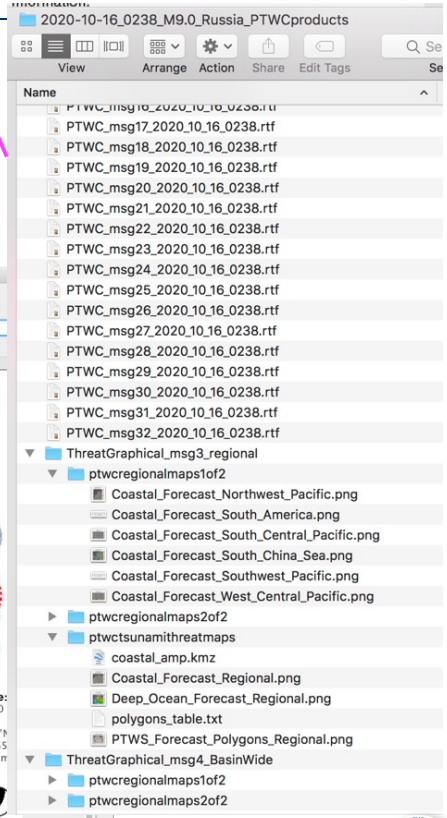
1957 Kamchatka M9.0





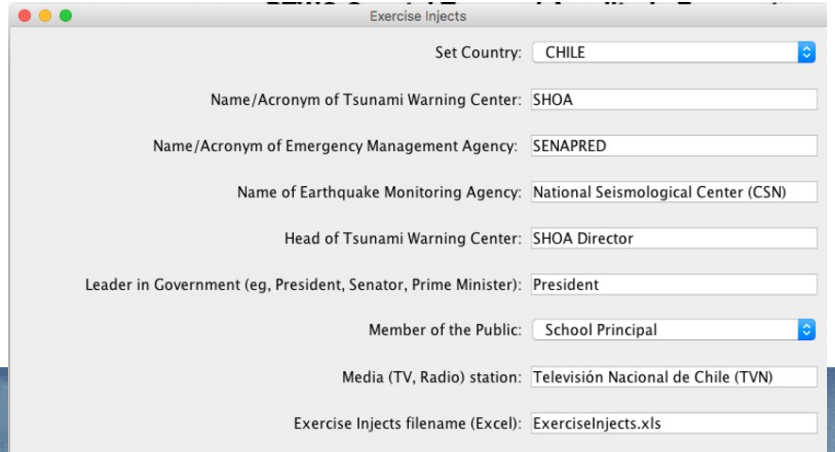






Exercise Situational Injects

- **Injects enable customization**
- **Injects: unexpected scenario, questions, inquiries related to PTWC messages**
- **Excel format** (can further add)



CHILE

Inject No	Event Time	Local Time	Event	To	From
1	0	1000	Earthquake Occurs!	All	Controller
2	2	1002	Earthquake alamrs trigger from P wave amplitudes off-scale at regional seismic network station	SHOA	Controller
3	2	1002	National Seismological Center (CSN) calculates Preliminary Earthquake Parameters:	SHOA	Controller
4	5	1005	CISN Display shows PTWC Earthquake Observatory Message, M8.5	SHOA	Controller
5	6	1006	PTWC Message 1: PTWC Tsunami Threat Message Initial M8.5	SHOA	PTWC
6	7	1007	The shaking woke me up and my house was shaking for more than 60 seconds. Some power lines fell down are down. What has just happened? Where was the earthquake? Is there a tsunami? When will it hit?	SHOA, SENAPRED	Coastal Resident
7	16	1016	Many coastal provinces and local governments hear media reports that PTWC is forecasting waves more than 2.3-meters. A school principal calls SENAPRED: What should she do? Her school is on the beach	SHOA, SENAPRED	Controller
8	17	1017	PTWC Message 2: PTWC Tsunami Threat Message Magnitude Update M8.8	SHOA	PTWC
9	22	1022	Televisión Nacional de Chile (TVN) News broadcasts live video of start of surf contest at North Coast beach It looks like a great day and waves look to be 3 m high. Surf's up. There are surfers heading into the water, and crowds are gathering	SHOA, SENAPRED	Media
10	27	1027	PTWC Message 3: PTWC Tsunami Threat Message Regional M8.8	SHOA	PTWC
11	29	1029	SHOA confirms tsunami at gauge: TALCAHUANO by Tide Tool, measured 13.4 m at 0055 UTC, Wave Period 40 min	SHOA	Controller
12	30	1030	President calls and wants an update immediately as to what going on and what actions are being undertaken. What is expected for our country and when? Do we need to call a Tsunami Warning?	SHOA	President
13	37	1037	PTWC Message 4: PTWC Tsunami Threat Message Pacific M8.8	SHOA	PTWC
14	44	1044	SHOA confirms tsunami at gauge: VALPARAISO by Tide Tool, measured 2.0 m at 0111 UTC, Wave Period 38 min	SHOA	Controller
15	47	1047	SHOA Director calls to request: 1) Earthquake and Tsunami report, 2) Tsunami travel time plot and coastal arrival times, 3) When will waves hit coasts and how big will they be, 4) Will it arrive at high tide or low tide?	SHOA	SHOA Director
			Public phone calls begin to saturate the telephone lines. They		

How to use - simple

- **Run from flash drive (or can copy to hard disk, 28 GB)**
- **Requirement – Java 1.8x installed** https://java.com/en/download/
- **Click on application (Window, Mac, Linux)**
  - On 1st time opening, set password (unique to user)
  - Default is 'No Internet'
  - With Internet, on starting, will
    - Update EQ &Tsunami database files, e.g., ingests latest USGS earthquake hypocenters, and shows threat assessment
    - Use addtl online map databases (more detailed but req bandwidth
  - Enter 'start' password, Set 'personal' password
  - For exercise messages/injects tool, enter password

Thank You

tsunamiwave.org (Tools & Products / TsuCAT)

Email: ITIC: itic.tsunami@noaa.gov, laura.kong@noaa.gov
NCTR: Christopher.Moore@noaa.gov