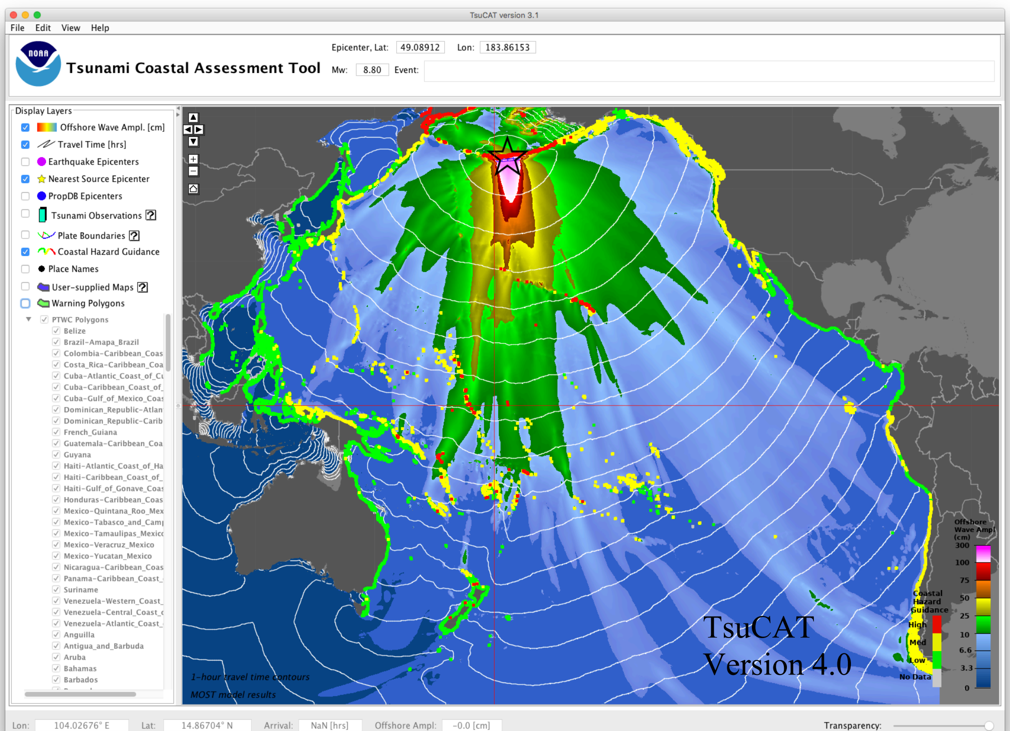
TsuCAT

Tsunami **C**oastal **A**ssessment **T**ool

User's Manual

Version 4.1



NOAA Center for Tsunami Research (NCTR)
International Tsunami Information Center (ITIC)

September 2019

Developed by the NOAA Center for Tsunami Research (http://nctr.pmel.noaa.gov)
in collaboration with the International Tsunami Information Center (http://itic.ioc-unesco.org)

TsuCAT information is available from http://itic.ioc-unesco.org/index.php?option=com_content&view=category&layout=blog&id=2239&Itemid=2763

Application specific questions and bug reports should be directed to:
http://nctr.pmel.noaa.gov/TsuCAT

Scenario based hazard assessment available through TsuCAT is primarily intended to support pre-event tsunami response planning and exercise development. During an event, TsuCAT may assist in early situational awareness (approximate scenario) prior to the availability of event-specific forecasts from national agencies or international tsunami service providers.

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Table of Contents

List of Figures

ABSTRACT

The Tsunami Coastal Assessment Tool (TsuCAT) is a simple and quick, yet powerful tool for exploring the impact from many different tsunamis. It was developed by the NOAA Center for Tsunami Research (NCTR) to support the International Tsunami Information Center's (ITIC) effort to provide countries with tsunami decision support tools.

TsuCAT provides access to a Pacific database of tsunami modeling results from NOAA's pre-computed catalog of sources (Propagation Database) to assist a country in its tsunami hazard assessment, tsunami exercise and response planning, and warning decision-making. Simulations for historical tsunami sources from NOAA's National Centers for Environmental Information (NCEI) and the U.S. Geological Survey earthquake archive are also included.

During an event, national tsunami warning centers must be able to assess their threat, and decide when to issue warnings based on their own alert level criteria. For earliest decision-making, especially for local tsunamis, a pre-computed, look-up database containing plausible warning scenarios and thresholds is often used. TsuCAT may assist in early situational awareness (approximate scenario) prior to the availability of event-specific forecasts from national agencies or international tsunami service providers

TsuCAT is platform independent and 'stand-alone' in that it runs on the Microsoft Windows, Apple Macintosh, and Linux computing platforms, and does not require Internet connectivity. All libraries, databases, and documentation are installed in their entirety on the host machine. The only requirement is a Java v1.8 or higher free installation

Offshore maximum tsunami wave amplitude and arrival time are easily queried on the map. The generated map also provides Coastal Hazard Guidance, which is represented as the deep-ocean wave amplitude extrapolated to the coastline accounting for shoaling using the Green's Law approximation. A Coastal Hazard 'Warning' Polygon map layer is included, which is equivalent to the Pacific Tsunami Warning Center's Coastal Tsunami Amplitude Forecast Polygon map, and also customizable. An exercise tool is available to generate the PTWC test messages and enhanced graphical products for use during tsunami exercises. The user is cautioned that when using real events from the event database that the test messages and enhanced graphical products produced will be based only on the closest source in the TsuCAT catalog and, hence, may not exactly match the PTWC-issued forecast. The feature is meant only to assist in tsunami exercises.

1. Introduction and Background

In 2014, the U.S. Pacific Tsunami Warning Center (PTWC) ceased provision of watches and warnings for countries throughout the Pacific Ocean. Enhanced products that include wave amplitude were developed and are now provided to offer forecast guidance. The 2014 change now requires countries to be responsible for assessing their own threat, and deciding when to issue warnings based on their own alert level criteria. In an effort to assist countries in their decision making, the International Tsunami Information Center (ITIC) and NOAA Center for Tsunami Research (NCTR) developed the Tsunami Coastal Assessment Tool (TsuCAT) that was distributed to delegates to the Twenty-seventh Session of the Intergovernmental Coordination Group for the Pacific Tsunami Warning and Mitigation System (ICG/PTWS-XXVII, March 28-31, 2017)

TsuCAT provides access to a global database of tsunami modeling results from NOAA's pre-computed catalog of sources (Propagation Database, GICA *et al.*, 2008), and from NOAA's RIFT model, to assist a country in its tsunami hazard assessment, tsunami exercise and response planning, warning decision-making, and education and outreach. Simulations for historical tsunami sources from NOAA's National Centers for Environmental Information (NCEI) and the U.S. Geological Survey earthquake archive are also included. The tool is a 'standalone' application not requiring the Internet, and can be used for outreach in remote locations, as well as during events when telecommunications are down.

TsuCAT assists countries in response planning and preparedness by providing a tool that enables planners to determine where the worst case tsunami sources are located, how big the earthquake's magnitude must be to directly threaten their coastlines, how much time they will have before the first tsunami wave hits, and how big the tsunami wave is expected to be. This information can then be used to develop tsunami emergency response and evacuation plans, and to conduct tsunami exercises that will prepare response agencies and communities to be ready for the real event. TsuCAT will create the PTWC text and enhanced graphical products that can be used for tsunami exercising.

TsuCAT can also assist national tsunami warning centers with early situational awareness (approximate scenario) prior to the availability of event-specific forecasts from national agencies or international tsunami service providers. As TsuCAT is a pre-computed database of plausible tsunami scenarios with customizable coastal hazard warning polygons, it could be useful as a look-up tool to provide a conservative assessment prior to PTWC tsunami forecasts (typically 30 minutes after the earthquake due to the time required to reliably characterize the earthquake source).

This manual introduces the user to TsuCAT and describes the workflow and parameters necessary to access all functionality offered through the application.

2. Application Overview

TsuCAT is a platform-independent application that was developed for hardware running Windows, Macintosh, and Linux operating systems and depends only on a Java installation (version 1.8 or higher). A graphical user interface gives access to NOAA's Database of pre-computed tsunami arrival times and maximum amplitudes. In this software release, the Database is populated with results of modeling with the MOST model for magnitudes greater than Mw > 8.0 and with the RIFT model (used by PTWC) for magnitudes less than Mw < 8.0.

The Database contains results from more than 2000 model runs of the tsunami propagation Method of Splitting Tsunamis (MOST) code and PTWC's Real-time Inundation Forecast of Tsunamis (RIFT) code. PTWC uses both models to calculate tsunami forecasts for countries in its international areas of responsibility (Pacific and Caribbean). Information on RIFT can be found in the *Users Guide for the Pacific Tsunami Warning Center Enhanced Products for the Pacific Tsunami Warning System* (IOC Technical Series No 105, Revised edition. UNESCO/IOC 2014 (English; Spanish), and information on MOST can be found in *Implementation and testing of the Method of Splitting Tsunami (MOST) model* (NOAA Technical Memorandum ERL PMEL-112, 11 pp).

The MOST model runs form the basis of the Short-term Inundation Forecasting of Tsunami (SIFT) and are comprised of an initial thrust deformation on a standard 100km-by-50km fault plane, and use seismic parameters appropriate to the hypocenter selected, with a slip value of 1 meter. This 1-meter slip value gives them the name "unit sources", and produces a moment magnitude (Mw) of 7.5 for each of the fault planes. These pre-run models have been combined to represent earthquakes of larger magnitudes, and the wave amplitude for various combinations can be shown to the user to allow assessment of wave amplitude at any given location in the ocean basin. While the standard 100km-by-50km fault plane works well for forecasting larger magnitudes using SIFT, magnitudes below 8.0 have been run using the RIFT model with fault lengths decreasing appropriately with magnitude. This allows accurate results over a range from Mw 6.5 up to the theoretical maximum of 9.6.

Various ways exist to extrapolate offshore wave amplitude values to the coastline to account for shoaling, and the "Coastal Hazard Guidance" algorithm allows a very rapid assessment of hazardous areas along a regional coastline given only earthquake magnitude and epicenter location.

TsuCAT allows the user to view the effect of an earthquake at any location along a coastline using the Propagation Database by calculating the maximum wave amplitude for various combinations of unit sources using the relationships between rupture length and magnitude as outlined in *Wells and Coppersmith* (1994). Over 5,400 combinations are pre-calculated for magnitudes from Mw=6.5 to 9.6 in increments of 0.3, for all three major ocean basins: Pacific, Atlantic (including the Caribbean), and Indian. As of

version 4.0, the scenarios cover the South China Sea and marginal seas of the Western Pacific.

The full installation of TsuCAT includes *all* the combination files, and, therefore allows TsuCAT to run "stand-alone", without an Internet connection. Archives of coastline and historic earthquakes are also provided, allowing the user to search nearby tsunamis and magnitudes to make an accurate assessment of the hazard due to a tsunami for a given stretch of coast. If the user has an Internet connection, new earthquake information is automatically queried from the USGS earthquake archives each time TsuCAT is run. This means that newly occurring events are available in near real-time. Rendering the pre-run offshore wave amplitudes using the closest scenario to the desired epicenter takes only moments, so a rapid assessment for guidance is possible.

2.1 Workflow

TsuCAT was designed for a user to easily and quickly get a baseline feel for the possible impact of a tsunami along their Pacific coastline of interest. An earthquake source from which to generate the tsunami is first selected either from a list of historical events or by choosing one or a combination of NOAA propagation database unit sources. Once selected, the workflow consists mainly of visualization choices, examples of which are shown in Figure 1.

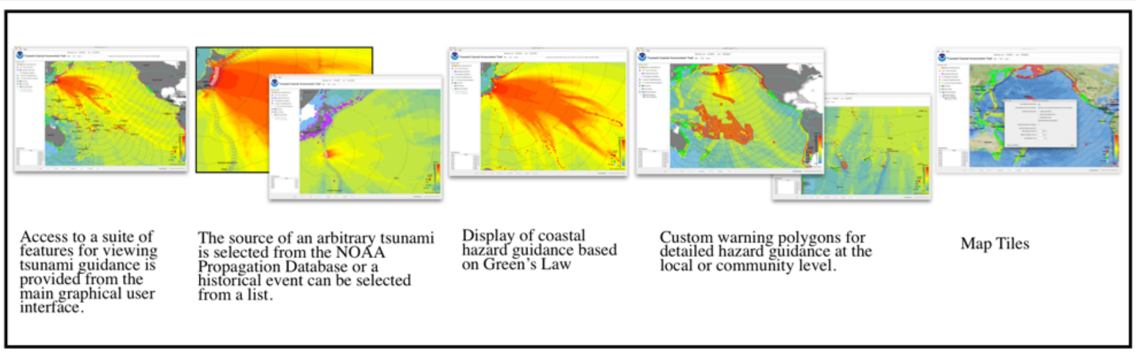


Figure 1: The TsuCAT workflow. Once an earthquake source is selected, the user has options to visualize the impact on large and small scales.

3. The NOAA Propagation Data Base

A pre-computed tsunami propagation database, that consists of deep-water wave elevations and flow velocities pre-computed for a continuous series of 50 x 100 [km] unit sources along all known subduction zones within each ocean basin, provides the sources used to construct the offshore wave amplitude database. Gica *et al.*, (2008) provide details of database generation using the MOST model, including design and seismic considerations. This database is augmented with offshore wave amplitudes from the RIFT model for moment magnitudes less than Mw 8.0, where 50 x 100 [km] faults planes are too large. The RIFT results are created using the same epicenter locations as the MOST results, but appropriately smaller length, width, and slip parameters. The tsunami source approximates a shallow thrust fault earthquake. The database unit sources can be linearly combined to produce synthetic boundary and initial conditions of water elevation and flow velocities to initiate tsunami forecast computations.

4. Graphical User Interface and Features

4.1 Overview

When TsuCAT is first opened (double-click the application icon), the main graphical user interface window comes up with the offshore wave amplitude [cm] and wave arrival time [hours] for the Great Japan Tsunami of 11 March 2011 shown by default (Figure 2).

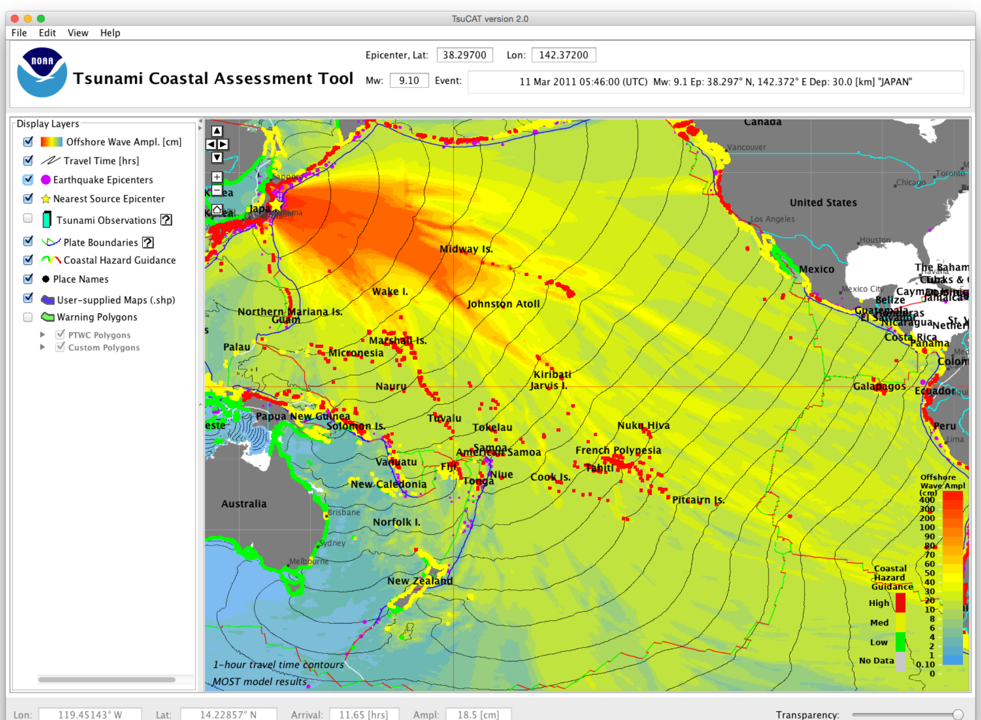
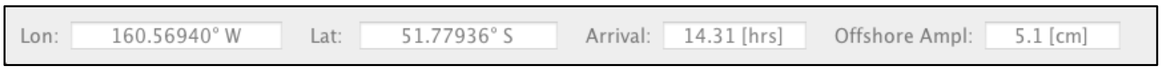
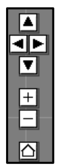


Figure 2: The Tsunami Coastal Assessment Tool main interface.

Event information is displayed in the top center panel, labeled "Event" (i.e., 11 Mar 2011 05:46:00 (UTC) Mw: 9.0 Ep: 38.297° N, 142.372° E "JAPAN"). Colors on the map, from blue-to-yellow-to red, give a quick view of the tsunami maximum amplitude throughout the Pacific Basin. Gradations of color are shown in a vertical color bar plotted in the lower right-hand side of the plot frame. One-hour contours of wave arrival are shown in black. Both offshore wave amplitude and expected arrival of the first wave can be queried for any point by simply moving the mouse over the point of interest and reading the value off the status bar at the bottom of the application. An example of the status bar display is:



The user can also pan and zoom the map in more familiar ways, either by click and drag (pan) or by double-clicking (zoom), or by using these buttons in the upper left of the map window:



4.2 Propagation database unit sources

A yellow star plotted on the map marks the epicenter of the earthquake that generated the event of interest. Blue rectangles outline the Propagation Database 'unit sources.' Once selected, the unit sources are filled white, and are shown as the NOAA Propagation Database codes with their respective weights, as used in the Short-term Inundation Forecast of Tsunami (SIFT) forecast application as well and in the Community Model Interface for Tsunami (ComMIT, TITOV *et al.* 2011) inundation model tool (Figure 3).

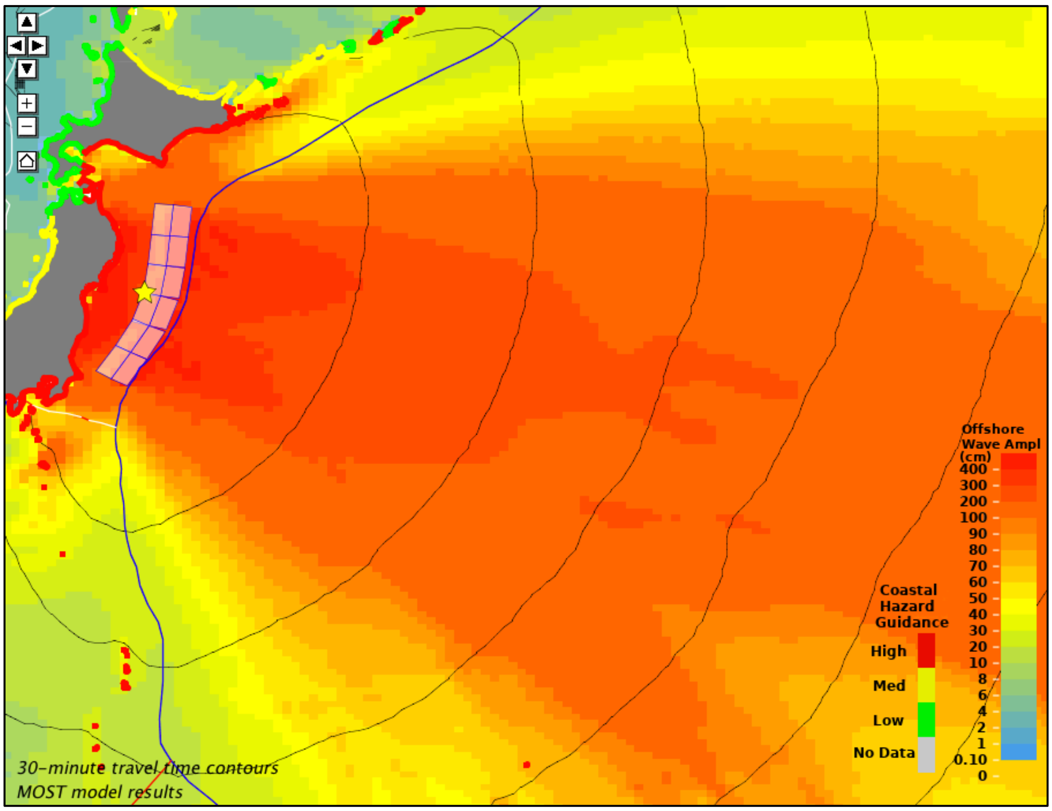


Figure 3: The Propagation Database unit sources selected for the Great Japan tsunami of 2011.

In the case of the Japan 2011 event, empirical relationships between earthquake magnitude, rupture length, rupture width and area, and surface displacement, known as the Wells and Coppersmith relation (WELLS AND COPPERSMITH 1994) chose twelve unit sources in a 2-by-6 configuration for a total fault area of 120,000 km^2 (200 km width and 600 km rupture length). The text representation for this source includes a weight and a reference code for each unit source:

14.784*ki24a+14.784*ki24z+14.784*ki25a+14.784*ki25z+14.784*ki26a+
14.784*ki26z+14.784*ki27a+14.784*ki27z+14.784*ki28a+14.784*ki28z+
14.784*ki29a+14.784*ki29z

These unit sources and their weights can be viewed by selecting the "View->Fault Information" menu item in TsuCAT (Figure 4). The above text representation can be copied-and-pasted by right-clicking on the table. A complete description of the Propagation Database can be found in GICA et al (2008), and online at http://nctr.pmel.noaa.gov/propagation-database.html. This text description can be used as a source in the ComMIT inundation tool.

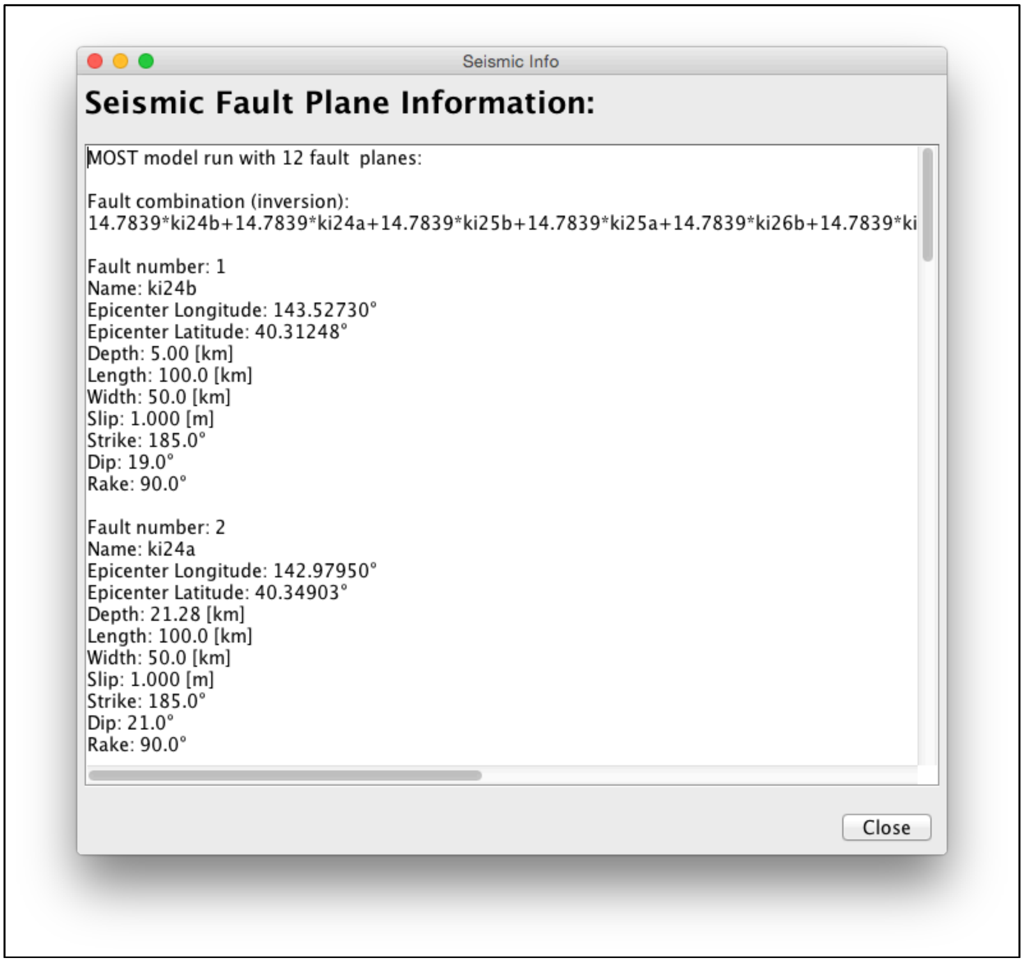


Figure 4: Unit Source table with weights showing the sources used from the Propagation Database for the given event, as well as seismic parameters for the model run.

4.3 Earthquake events, magnitudes, and epicenters

The epicenter for an earthquake (latitude and longitude of location) can be moved by editing the "Epicenter, Lat: Lon:" values, or by right-clicking the yellow epicenter star and dragging it (or "Command-click" on the Mac). It turns green when dragged, and when dropped will find the epicenter for the closest unit source combination in the Propagation Database (Figure 5).

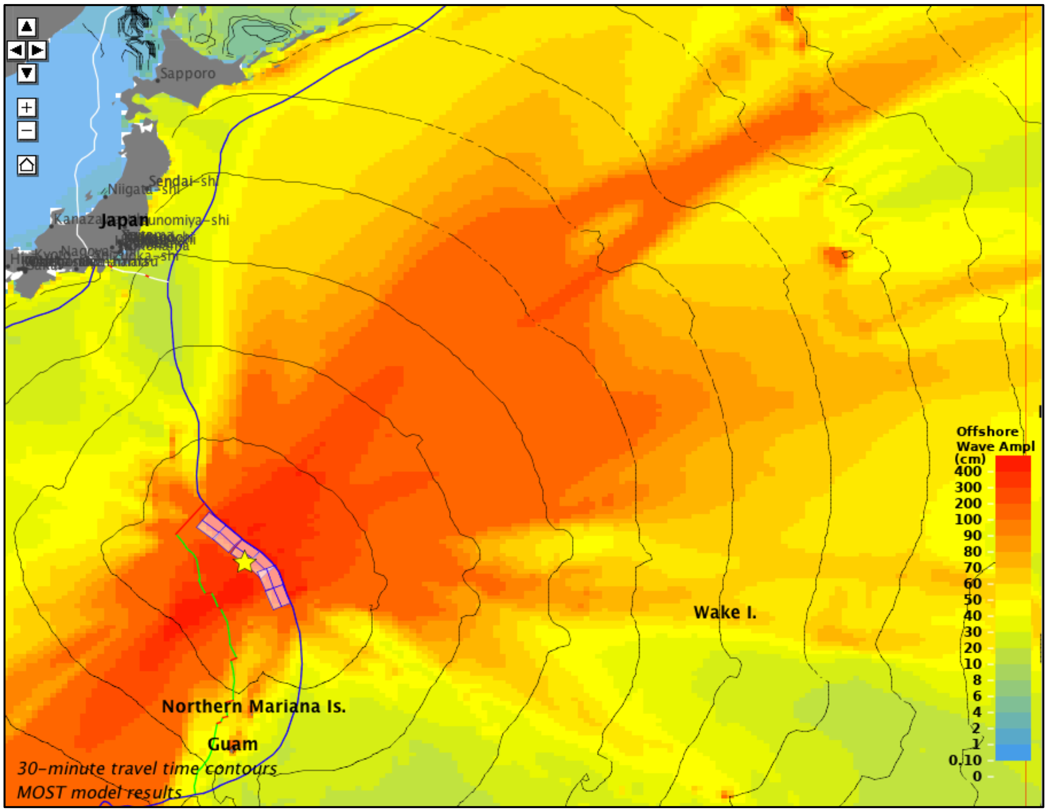


Figure 5: An arbitrary Mw=9.0 along the Kamchatkai-Yap (ki) subduction zone.

The moment magnitude, Mw, can be edited in the upper panel text box labeled 'Mw' at the top of the application window. Changes in Mw show how the impact to a coast might change when smaller or larger tsunamis are generated. The larger the earthquake magnitude, the greater the number of propagation database unit sources. An Mw=8.6 in the same location along the Kamchatkai-Yap subduction zone selects only 6 unit sources, instead of the 12 selected for the Mw 9.0 tsunami. Results from the smaller Mw show correspondingly smaller maximum wave amplitude (Figure 6):

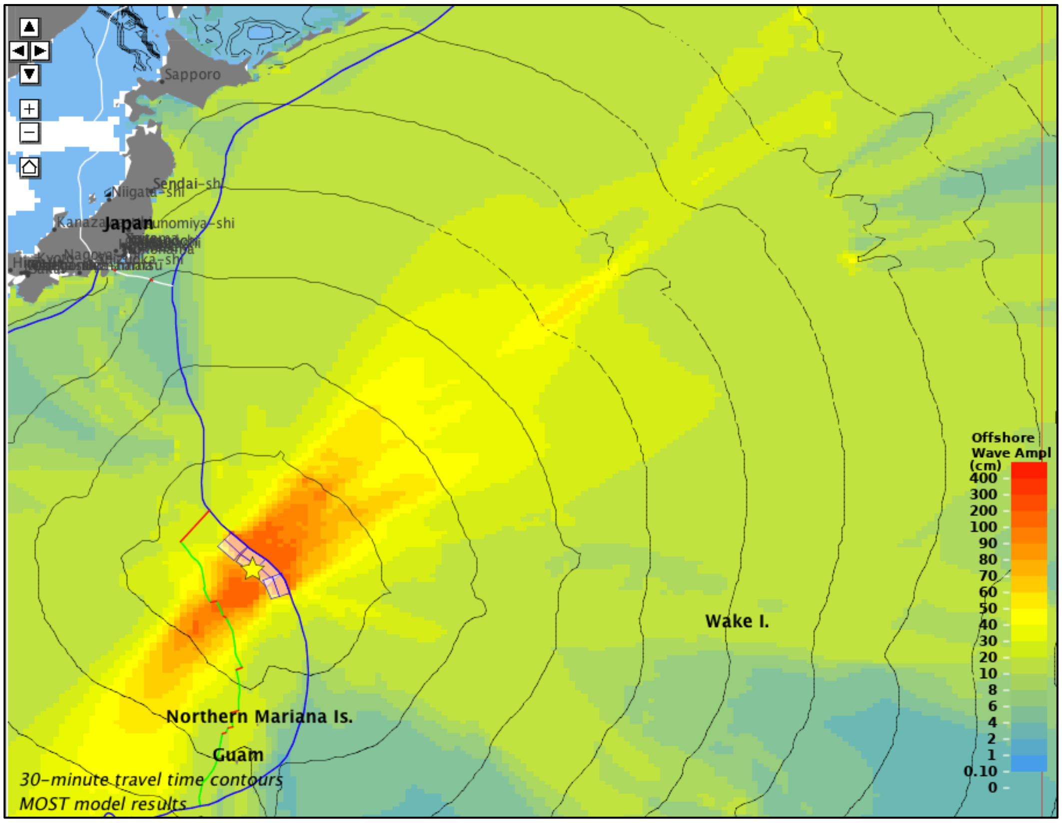
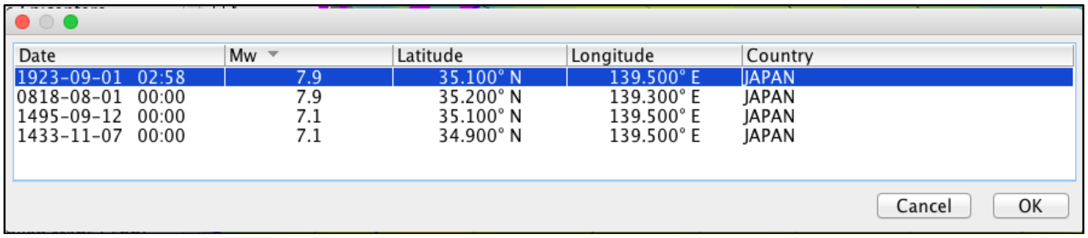


Figure 6: Arbitrary Mw=8.6 along the Kamchatkai-Yap subduction zone.

Users can also turn on the "Earthquake Epicenters" layer by selecting it in the panel to the left of the map. All historic tsunamis contained in the NOAA Center for Environmental Information (NCEI/NGDC) Tsunami Database will be shown (https://www.ngdc.noaa.gov/hazard/tsu_db.shtml) (NGDC, 2000 BC- present). This list includes all events up through December 2016. Events after January 2017 may be obtained from the USGS earthquake archive (https://earthquake.usgs.gov/earthquakes/search/) and are refreshed each time TsuCAT is launched, if an internet connection is found. The most recent vetting of a USGS event is used each time the application is loaded.

Represented as purple dots on the map (Figure 7) the size of the dot is scaled with the size of the event. The user can select the closest epicenter to an historic event by right-clicking on the event of interest and choosing from a list of nearby events:



Date	Mw	Latitude	Longitude	Country
1923-09-01 02:58	7.9	35.100° N	139.500° E	JAPAN
0818-08-01 00:00	7.9	35.200° N	139.300° E	JAPAN
1495-09-12 00:00	7.1	35.100° N	139.500° E	JAPAN
1433-11-07 00:00	7.1	34.900° N	139.500° E	JAPAN

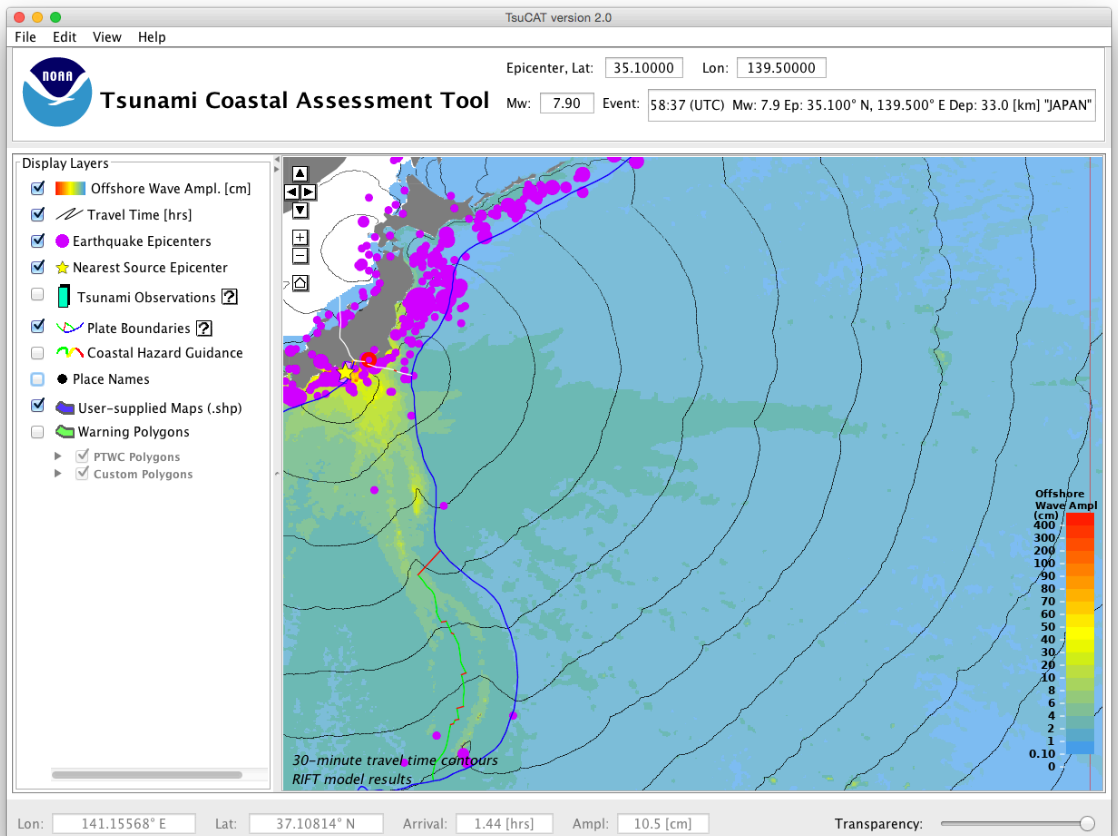


Figure 7: Historical tsunamigenic earthquakes (purple dots) from the Global Historical Tsunami Database

The selected event is then shown (Figure 8) with a red ring around the selected event, and the selected event information is shown in the upper panel, including Epicenter, Mw, Date/time, Depth and nearest country:

Epicenter, Lat: 35.10000 Lon: 139.50000

Mw: 7.90 Event: 01 Sep 1923 02:58:37 (UTC) Mw: 7.9 Ep: 35.100° N, 139.500° E Dep: 33.0 [km] "JAPAN"

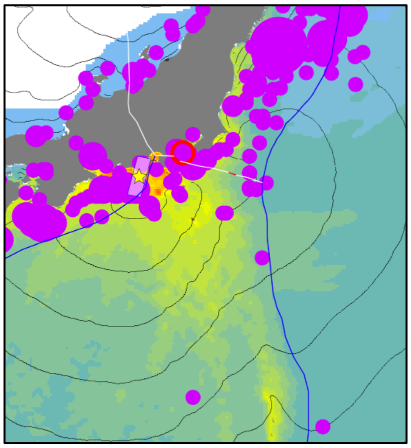


Figure 8: selected earthquake event

All earthquake epicenters can be viewed by choosing the menu item "File->Select Event" (Figure 9). This table can be sorted by Date, Mw, Latitude, Longitude, or Country and the selected event can be viewed in TsuCAT. TsuCAT will show the offshore wave amplitude and Coastal Hazard Guidance for the scenario in its database with the closest epicenter location and Mw of the event, scaling file to the Mw of the selected event.

Date	Mw	Latitude	Longitude	Country
2013-02-06 01:12	7.9	10.766° S	165.114° E	SOLOMON ISLANDS
2013-01-05 08:58	7.5	55.393° N	134.652° W	USA
2012-12-07 08:18	7.2	37.890° N	143.949° E	JAPAN
2012-11-07 16:35	7.3	13.988° N	91.895° W	GUATEMALA
2012-10-28 03:04	7.7	52.788° N	132.101° W	CANADA
2012-09-05 14:42	7.6	10.085° N	85.315° W	COSTA RICA
2012-08-31 12:47	7.6	10.811° N	126.638° E	PHILIPPINES
2012-08-27 04:37	7.3	12.139° N	88.590° W	EL SALVADOR
2012-04-14 22:05	6.3	18.972° S	168.741° E	VANUATU
2012-04-11 10:43	8.2	0.802° N	92.463° E	INDONESIA
2012-04-11 08:38	8.6	2.327° N	93.063° E	INDONESIA
2012-03-20 18:02	7.4	16.493° N	98.231° W	MEXICO
2012-03-14 09:08	6.9	40.887° N	144.944° E	JAPAN
2012-02-02 13:34	7.0	17.827° S	167.133° E	VANUATU
2011-10-21 17:57	7.4	28.993° S	176.238° W	NEW ZEALAND
2011-09-02 10:55	6.8	52.171° N	171.708° W	USA
2011-08-20 18:19	7.0	18.311° S	168.218° E	VANUATU
2011-08-20 16:55	7.1	18.365° S	168.143° E	VANUATU
2011-07-10 00:57	7.0	38.034° N	143.264° E	JAPAN
2011-07-06 19:03	7.6	29.539° S	176.340° W	NEW ZEALAND
2011-06-24 03:09	7.3	52.050° N	171.836° W	USA
2011-04-07 14:32	7.1	38.276° N	141.588° E	JAPAN
2011-03-11 05:46	9.0	38.297° N	142.372° E	JAPAN
2011-03-09 02:45	7.5	38.435° N	142.842° E	JAPAN
2011-02-21 23:51	6.1	43.583° S	172.680° E	NEW ZEALAND

Cancel OK

Figure 9: Listing from the full earthquake database.

4.4 Coastal Hazard Guidance

The Coastal Hazard Guidance (CHG) shown by TsuCAT represents the offshore wave amplitude that has been extrapolated to the coastline using a simple-depth based relationship to account for shoaling of waves. The relationship or approximation is given by:

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

where H_d is the water depth at the deep offshore grid point, H_s is the water depth at the coastal shoreline point and η_s is the wave amplitude at the shoreline approximated by the deep-ocean wave amplitude η_d. The ratio of ocean depths, H, provides the scaling factor.

The MOST model was run with a bathymetric grid resolution of 4 arc-min, while RIFT model runs were run with resolution that increases with smaller magnitude. This allows resolving the smaller wavelengths generated by these smaller faults. Since the models use varying resolutions, the depth chosen for the deep water point deepens with lower-resolution runs and is known as the cutoff depth. For each point along the coastline, then, the closest model grid point that is deeper than the cutoff depth is selected and scaled by the ratio.

The Coastal Hazard Guidance (CHG) layer is viewed by selecting it in the left-hand "layers" panel. This layer shows the Global Self-consistent Hierarchical High-resolution Shoreline (GSHHS) coastline color-coded by the nearest offshore model point and scaled to account for shoaling by the Green's Law. Detailed information about the combined shoreline, rivers, and geo-political boundaries GSHHS dataset is available at: https://www.ngdc.noaa.gov/mgg/shorelines/gshhs. The resulting scaled shoreline value is then colored in accordance with the color map. The CHG color map shows gray for values that are less than 1 cm (essentially "no data"), green for values between 1-30 cm, yellow for values between 30-100 cm, and red for values above 100 cm. The values for the CHG bins can be changed in the TsuCAT Preferences as discussed in 4.7 Other Features**.** The CHG takes a few seconds to calculate, so when the user changes the magnitude or epicenter, TsuCAT calculates CHG in the background and renders the colored shoreline values when calculations are complete. Coastal Hazard Polygons are colored according to CHG, so they, too, take a few seconds to render if the user changes the source selected.

The Coastal Hazard Guidance values tend to be larger than the adjacent offshore maximum amplitude due to the scaling for shoaling, which is evident in **Error! Reference source not found.**. Green's Law was designed for estimation of channel flow, so it provides the best coastal estimate where there are gently sloping bathymetries.

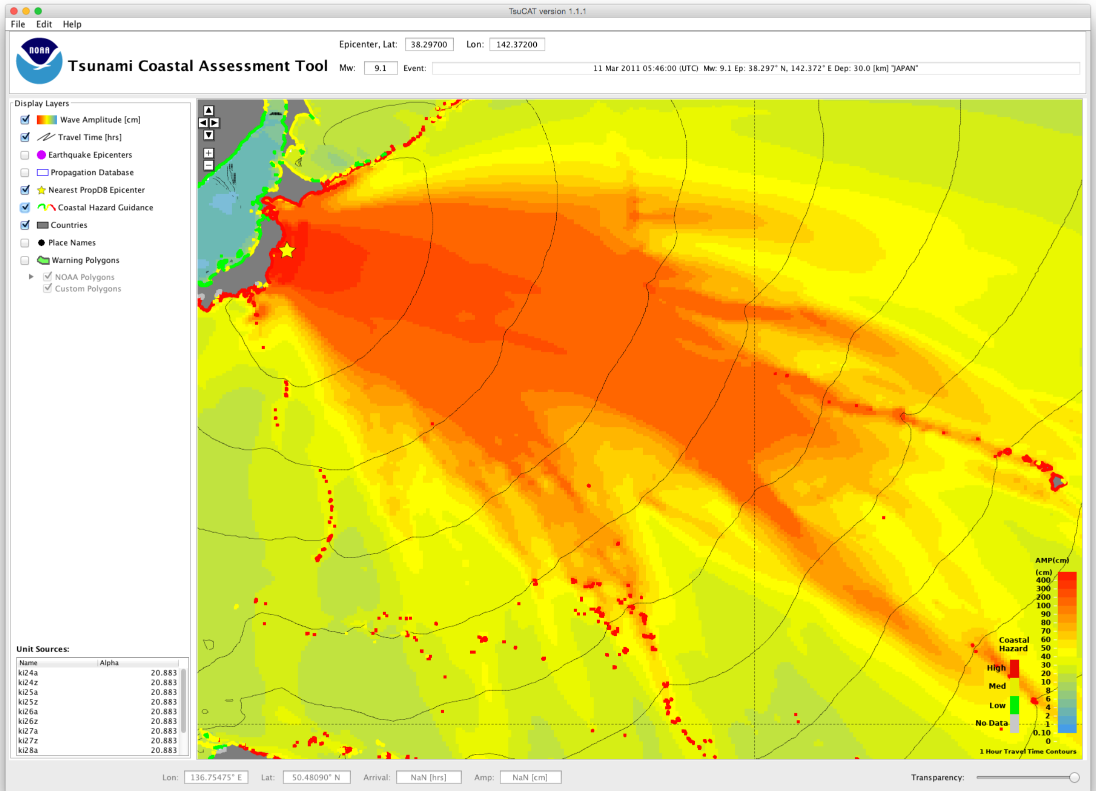


Figure 10: Coastal Hazard Guidance (CHG) based on Green's Law scaling.

Green's Law makes the following assumptions:

1. The coastline is linear and exposed to the open ocean.
2. Tsunami waves near the coast behave as one-dimensional plane waves.
3. There are no significant wave reflections and no dissipation by turbulence.
4. The bathymetry varies slowly compared to the wavelength of the tsunami waves. Thus, for steep bathymetry, Green's Law can overestimate the wave amplitude.
5. Cliff boundary conditions are used. In other words, the coast is assumed to be a vertical wall.

Specifically, the Green's Law approximation breaks down in areas of complex bathymetries. Therefore, where coastlines consist of bays, inlets, or are hidden by offshore islands, or where the sea bottom rises steeply to the shore, Green's Law coastal wave forecasts will likely be in error.

Actual amplitudes at the coast may vary from the forecast amplitudes due to uncertainties in the forecast and local features. In particular, maximum tsunami amplitudes on atolls and at locations with fringing or barrier reefs will likely be much smaller than the Coastal Hazard Guidance indicates. The offshore wave amplitude map should not be used to estimate coastal tsunami amplitude or impacts. Deep-ocean amplitudes are usually much smaller than coastal amplitudes.

4.5 Coastal Hazard Polygons

The Coastal Hazard Polygons layer shows the NOAA Pacific Tsunami Warning Center (PTWC) Coastal Tsunami Amplitude Forecast Polygons as colored by the TsuCAT Coastal Hazard Guidance (CHG), with the following simple algorithm: the 99th percentile maximum of all coastal points within a polygon is used to color the entire polygon, e.g. if the maximum CHG within a polygon is 67.2 cm, the entire polygon is colored yellow. This aggregation tends to be a "broad brush" algorithm, as can be seen in Figure 11: areas like the west coast of the United States and Canada that show mostly green and yellow coastal values have polygons that are shaded red because of the few red coastal points.

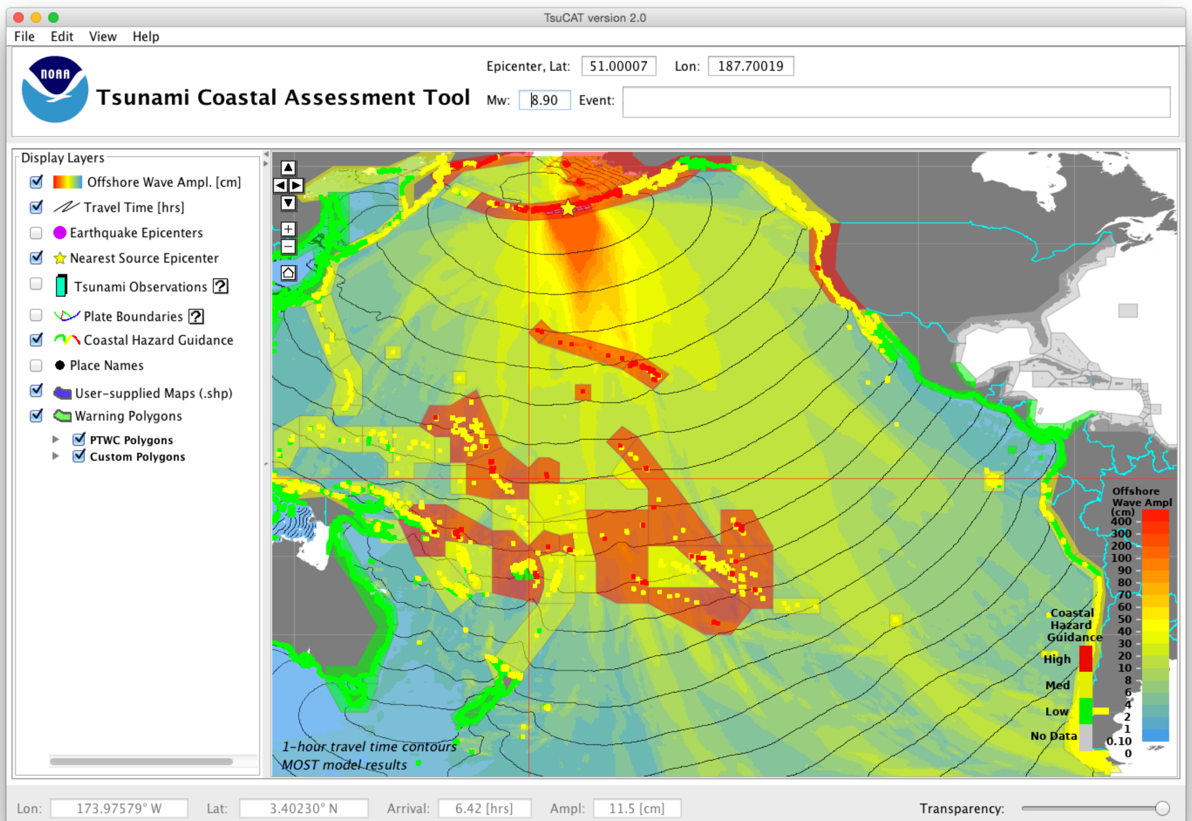


Figure 11: Coastal Hazard (Warning) Polygons for a hypothetical Mw=8.9 in the Aleutian islands.

4.6 Custom Coastal Hazard Polygons

TsuCAT gives the user the option to create their own coastal hazard polygons using the menu item "Edit->Add Custom Warning Polygons". To best use this option, the user should zoom to the region of interest before starting. It is also a good idea to keep the Coastal Hazard Guidance map layer selected. As an example, we will create a custom polygon around the Republic of Vanuatu by zooming into the region and selecting the menu "Edit->Add Custom Warning Polygon" (Figure 12).

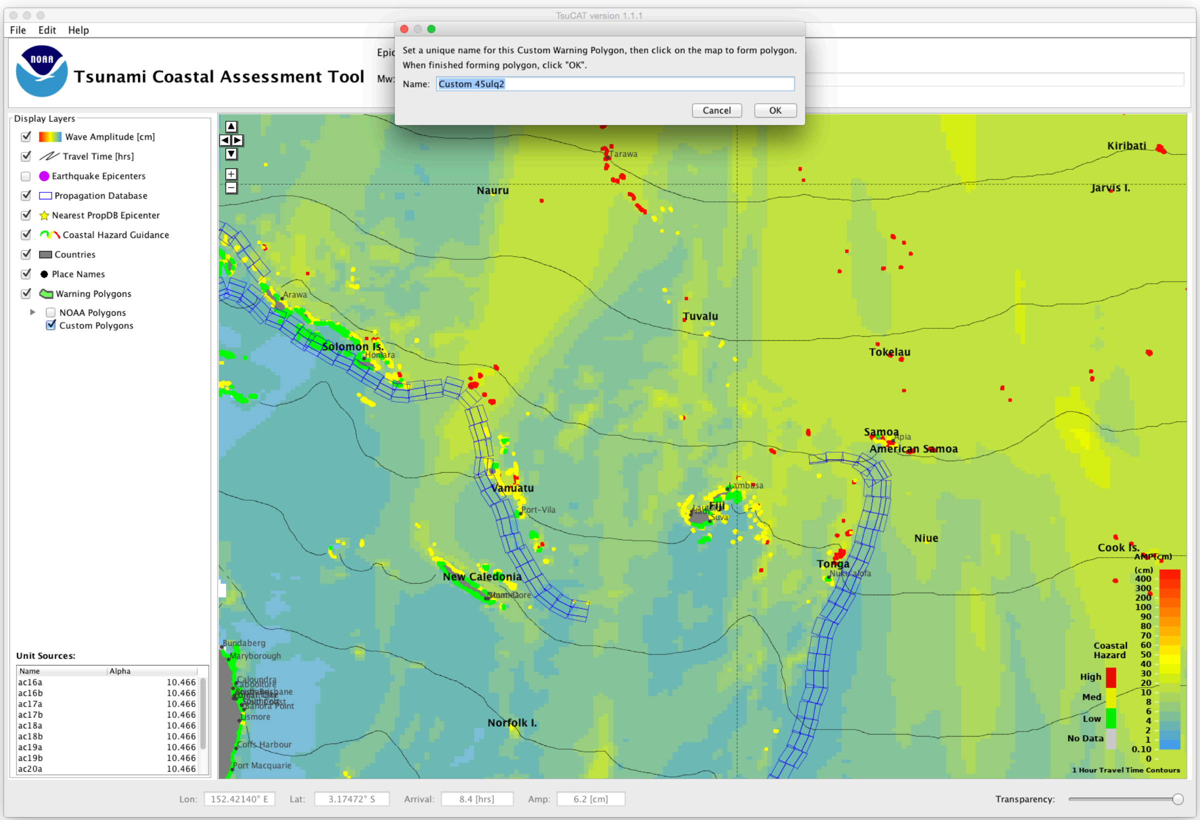


Figure 12. Zoomed into a region of interest around Vanuatu in preparation to create a Custom Coastal Hazard Polygon

The Custom Coastal Hazard Polygon dialog appears, with a default unique name. The first step is to name this polygon with an appropriate name. We'll choose "Vanuatu: Tafea" by typing it into the Name box. Then we will click points surrounding the islands; when we're done, we'll click "OK" and the polygon will be rendered and added to the "Tree" of Coastal Hazard Polygons on the map layers panel on the left (Figure 12). The new Polygon will be rendered according to the Coastal Hazard within it, and updated automatically. To delete the polygon, either right-click on its name in the layer list on the left, or right-click directly on the polygon and select "Delete Polygon" (Figure 14). A warning dialog will appear to confirm the deletion.

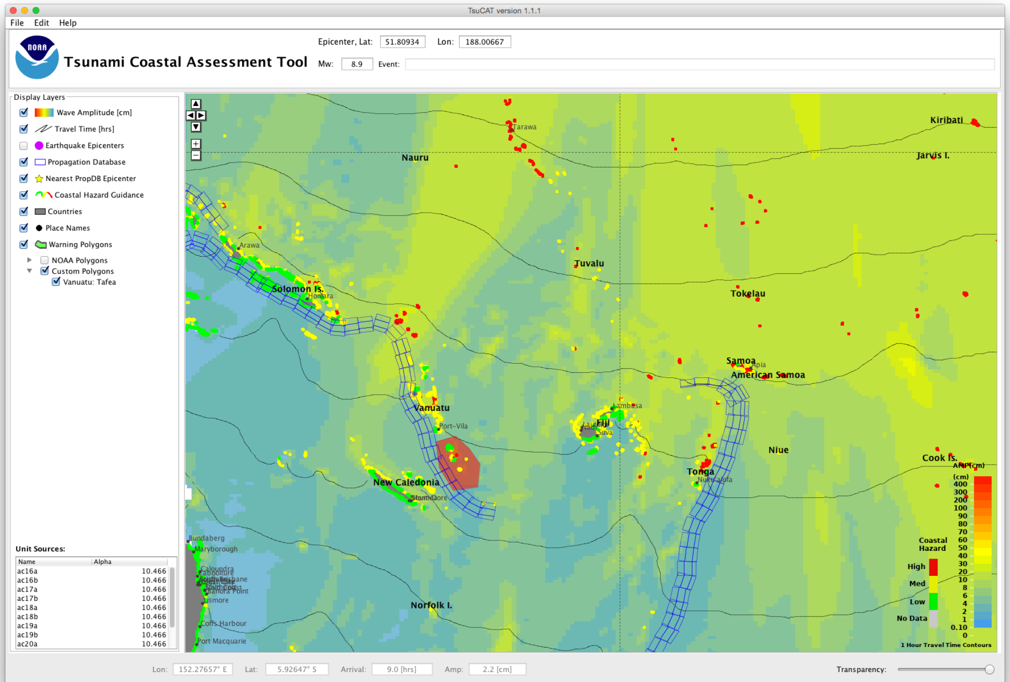


Figure 13. A newly-created Custom Coastal Hazard Polygon named "Vanuatu: Tafea".

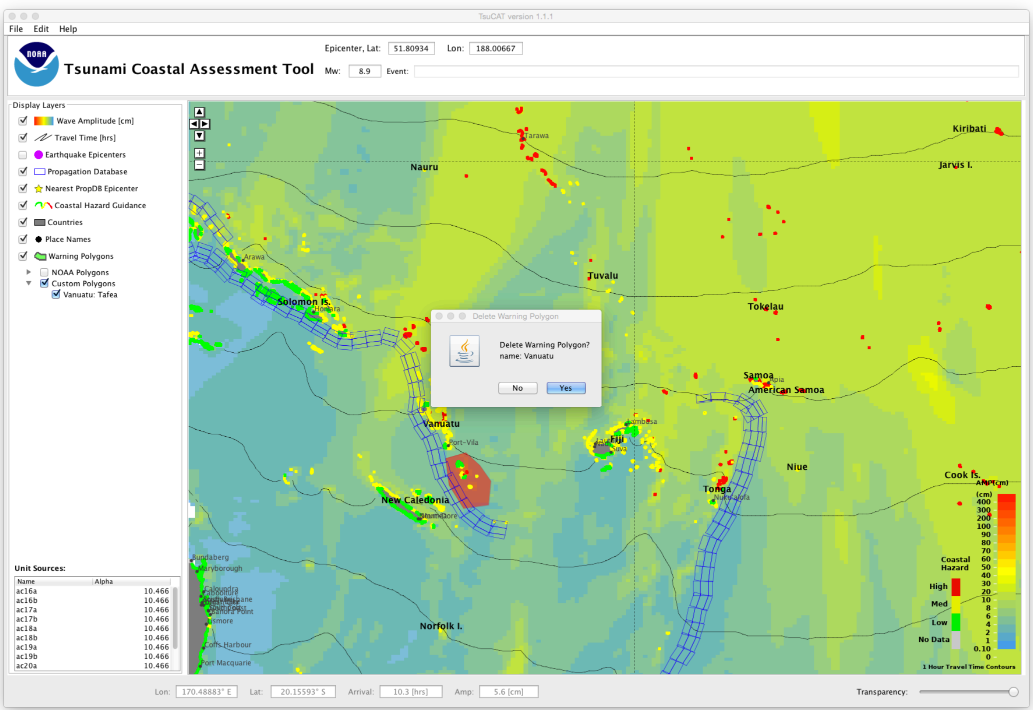


Figure 14: Deleting a Custom Coastal Hazard Polygon.

The custom polygons are saved in Google Earth format (KML) in the application folder in a file named "Custom_Warning_Polygons.kml". Users can further edit the file by locating it (select menu item "Help->View Application Folder" then open the folder "etc"). Double-clicking the Custom_Warning_Polygons.kml file will launch the free Google Earth application.

4.7 Other Features

Exporting Images

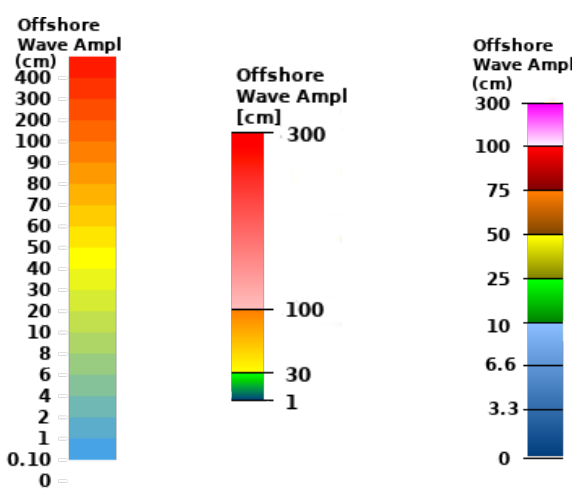
The user may export the TsuCAT map as a "PNG" image file by choosing the menu "File->Export Map Image".

Customizing Coastal Hazard Range Bins

The user may change the Coastal Hazard color bin cutoffs from the default values of 100 cm for "High" hazard, 30 cm for "Medium", and 1 cm for "Low" hazard. These default values are in use at NOAA's Pacific Tsunami Warning Center, and the user can reset to these values by pressing the User Preferences button "Reset to Defaults" (Figure 15).

Offshore Wave Amplitude Color Map

The user may choose between the NCTR color map, the MOST/SIFT color map used and the PTWC Enhanced Products RIFT color map:



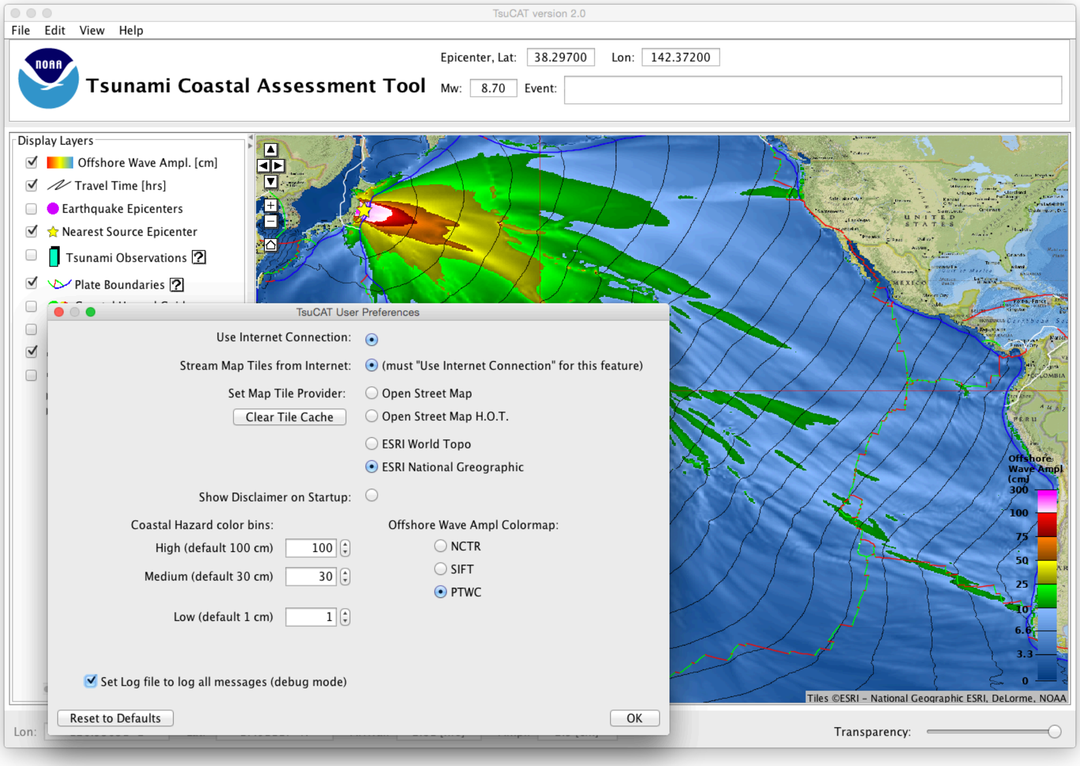


Figure 15. TsuCAT User Preferences window allowing user to customize "Coastal Hazard color bins," select Wave Amplitude color map, and select Internet map streaming using "View->Stream Map Tiles from Internet."

Additional Map Layers, Place Names

The requirement that this tool "stand alone" (work without an internet connection) gives it the added benefit that it can be depended upon during an event, even if the only information a user has is location and magnitude. However, there are two ways in which an internet connection will make this tool even more useful.

The first is that the user may elect to load base-layer map image tiles by opening the User Preferences dialog under "Edit->Preferences" (Figure 15). Background image "tiles" then stream from a server as an online map would in a browser. This has the advantage that place names are shown that might not show in the stand-alone database of places (populations less than 15,000). The stand-alone place name database is used under Creative Commons license from GeoNames.org.

If the user pans and zooms, new background imagery appropriate to that zoom level is loaded, keeping the application more responsive, as the grey continents need not be refreshed each time a user pans or zooms. The Provider for background tiles can be selected for a different look to the basemap by choosing the User Preference "Set Map

Tile Provider." In addition to clear advantages of this feature, there are, however, drawbacks that are described here. The first drawback is that the coastline for the Coastal Hazard Guidance is still the medium-resolution GSHHS dataset. This means that if the user zooms in very closely, e.g. to the island of Tahiti (Figure 16), the coarseness of the coastline dataset is evident, though it is still of sufficient resolution to use as guidance at the community level.

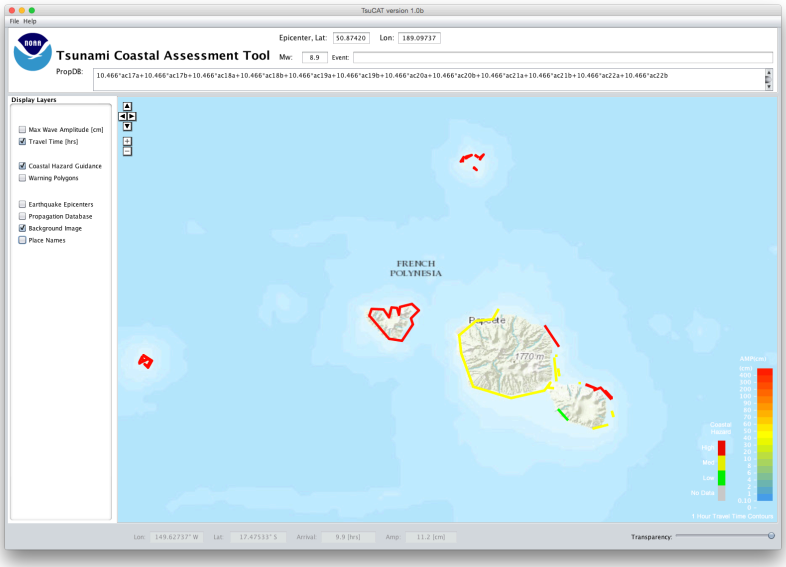


Figure 16. Using background image tiling to view CHG at Tahiti.

A second drawback is that if the user selects background image tiling, *and* the Offshore Wave Amplitude layer, the Offshore Wave Amplitude tends to obscure the background map. The way to mitigate this is to use the Transparency slider at the lower right to make the wave amplitude transparent enough to see the place names.

Figure 17. Using background image tiling with the Offshore Wave Amplitude layer and transparency.

Figure 18. Same as Figure 12, but with packaged gray coastal outlines.

The second feature available in TsuCAT is the ability to turn on and off the Place Names layer. While selected, the 30 most populous city/town names are shown at any given time. The packaged city/town names are those with populations greater than 15,000. Since all of the country names are shown at all times, the map can get 'crowded' with labels when zoomed all the way out. Please note that political borders (shown in blue) also come from the GSHHS data set, and, therefore, do not always accurately reflect current situations.

Regional Reports

The ability to create a report of statistics including minimum/maximum offshore wave amplitude and earliest/latest wave arrival times for a region has been added to TsuCAT. The menu item "File->Export Regional Report" launches a dialog that asks the user to first select a country from the drop-down list. This initializes the region. The user can then zoom and pan to show the best effect of a given tsunami on the region, and the statistics update as the user moves the map (Figure 19). The user can then edit the "Region" name for the title of the report, and click "Generate" to save this as a file in the application folder called "TsuCATReport.png" (Figure 20). Note that each time this feature is used the file is over-written, so copy this file if you wish to save it.

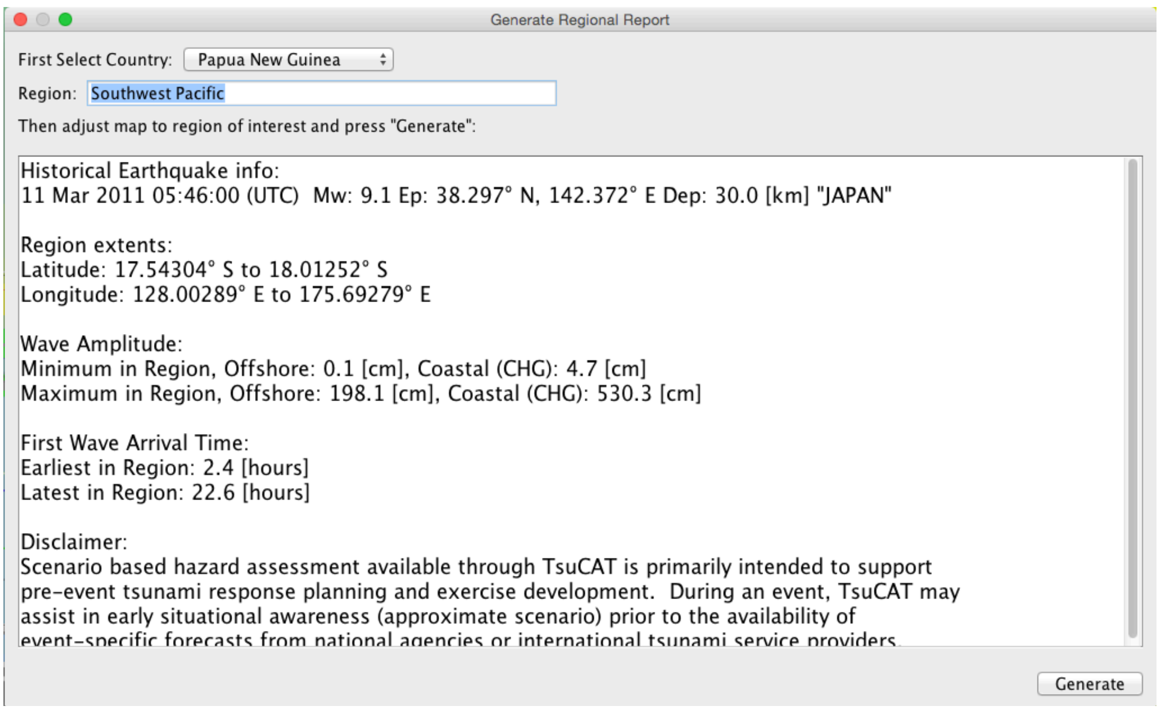
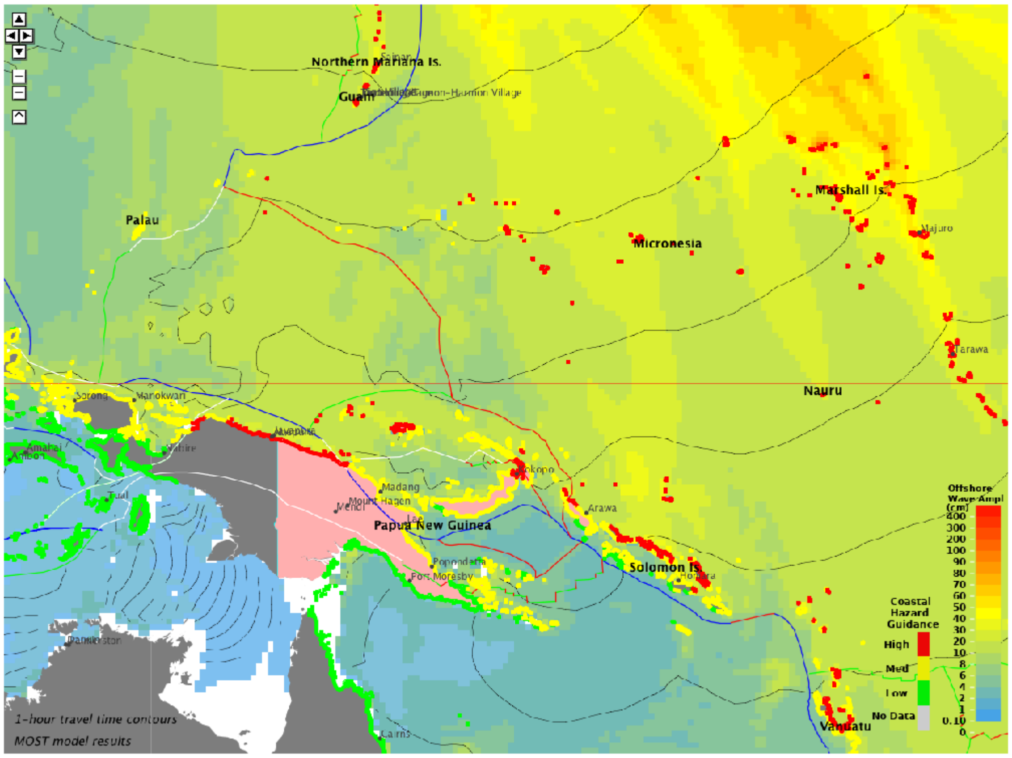


Figure 19: Regional Report creation, showing the dialog with statistic from the given region.



Tsunami Forecast Report: Southwest Pacific

Report generated from TsuCAT on 2017-11-07T11:08:37

Historical Earthquake info:
11 Mar 2011 05:46:00 (UTC) Mw: 9.1 Ep: 38.297° N, 142.372° E Dep: 30.0 [km] "JAPAN"

Region extents:
Latitude: 17.54304° S to 18.01252° S
Longitude: 128.00289° E to 175.69279° E

Wave Amplitude:
Minimum in Region, Offshore: 0.1 [cm], Coastal (CHG): 4.7 [cm]
Maximum in Region, Offshore: 198.1 [cm], Coastal (CHG): 530.3 [cm]

First Wave Arrival Time:
Earliest in Region: 2.4 [hours]
Latest in Region: 22.6 [hours]

Disclaimer:
Scenario based hazard assessment available through TsuCAT is primarily intended to support pre-event tsunami response planning and exercise development. During an event, TsuCAT may assist in early situational awareness (approximate scenario) prior to the availability of event-specific forecasts from national agencies or international tsunami service providers.

Figure 20: Example report of the southwest Paciifc showing statistics from the effects of the 2011 Japan tsunami on the region around Papua New Guinea.

User-supplied Maps

The user can overlay a shapefile layer using the menu "File->Add/Remove User-supplied Maps". This feature allows loading an evacuation area map in GIS file (in shapefile format) containing any polygon shapes OR from ComMIT by selecting a Composite Wave File exported from ComMIT. TsuCAT can then render them as a colored, semi-transparent layer. This feature is a convenient way to load Evacuation Maps. The user simply clicks the "Add" button and navigates to their shapefile. The "Name" field is initially set to the filename, but the user can edit this for convenience, and set the color and transparency level. This file is then re-projected (if necessary) to WGS84 and saved in the application "userMapOverlays" folder. Several shapefiles can be used in this way, and TsuCAT will load them automatically each time it is run.

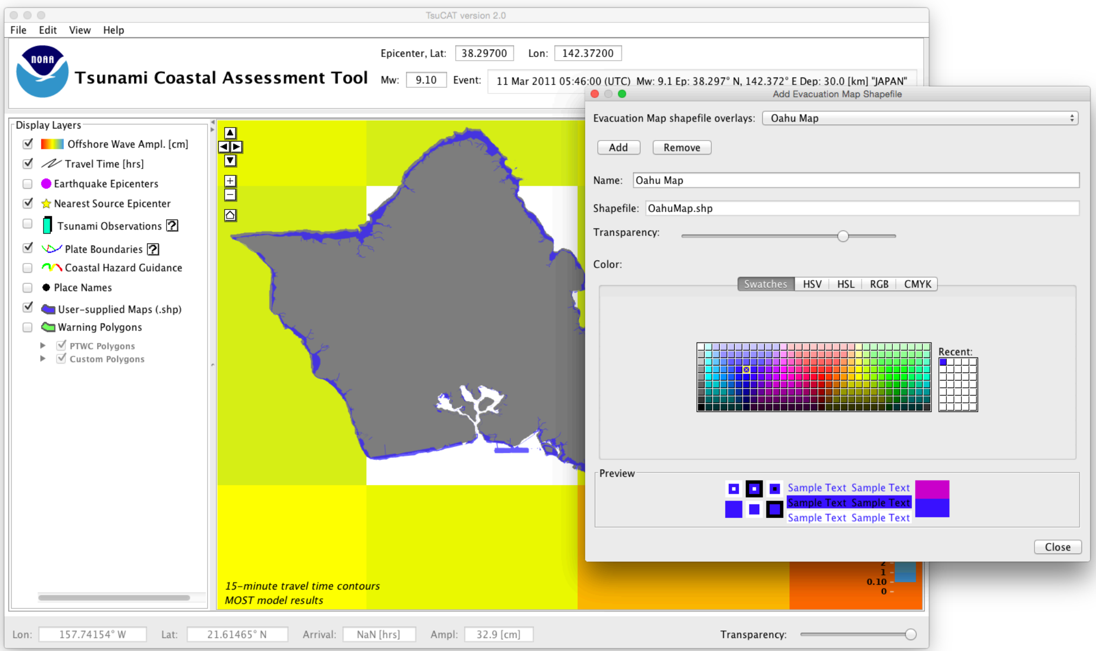


Figure 21: Adding a user-supplied shapefile as a Map Layer.

Generating Exercise Messages

New with version 4.0 is the capability of producing messages that mimic the PTWC text and graphical products to assist in preparing for national and regional tsunami exercises such as the PacWave and CaribeWave. For these exercises, PTWC generates sets of regional or basin-wide products for a simulated event to aid in training for response to an actual event. TsuCAT is similarly able to produce sets of PTWC Tsunami Threat Messages or Information Statements appropriate for the earthquake parameters and for PTWC's procedures and protocols. TsuCAT includes in the messages simulated tsunami wave measurements at coastal and deep ocean sea level gauges.

To use this new feature, the user simply chooses an event (either by selected from the historical database or by moving the epicenter and typing in a magnitude). Then, from the File menu, the user chooses "Generate Exercise Messages". This brings up the dialog window (Figure 22), adjusts the date of the Exercise, and presses the "Generate" button:

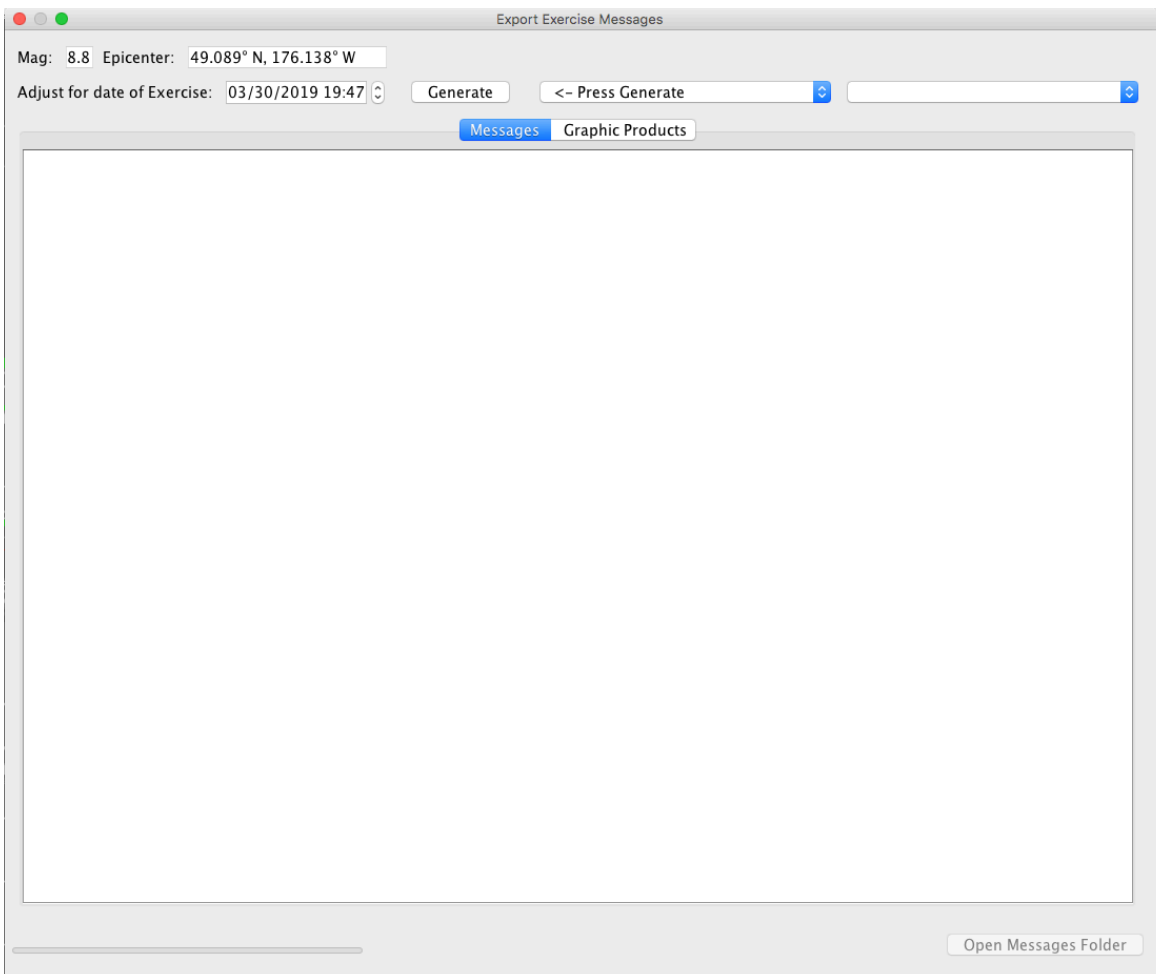


Figure 22: The TsuCAT "Export Exercise Messages" dialog.

The window has a status/progress bar along the bottom, which shows "…analyzing…", and the progress it makes. This feature is a fairly intensive process and typically takes anywhere from 30 seconds to two minutes. When it completes, the text bulletin Messages are shown on the tab titled "Messages" and the Enhanced Graphical Products and shown in the tab titled "Graphical Products":

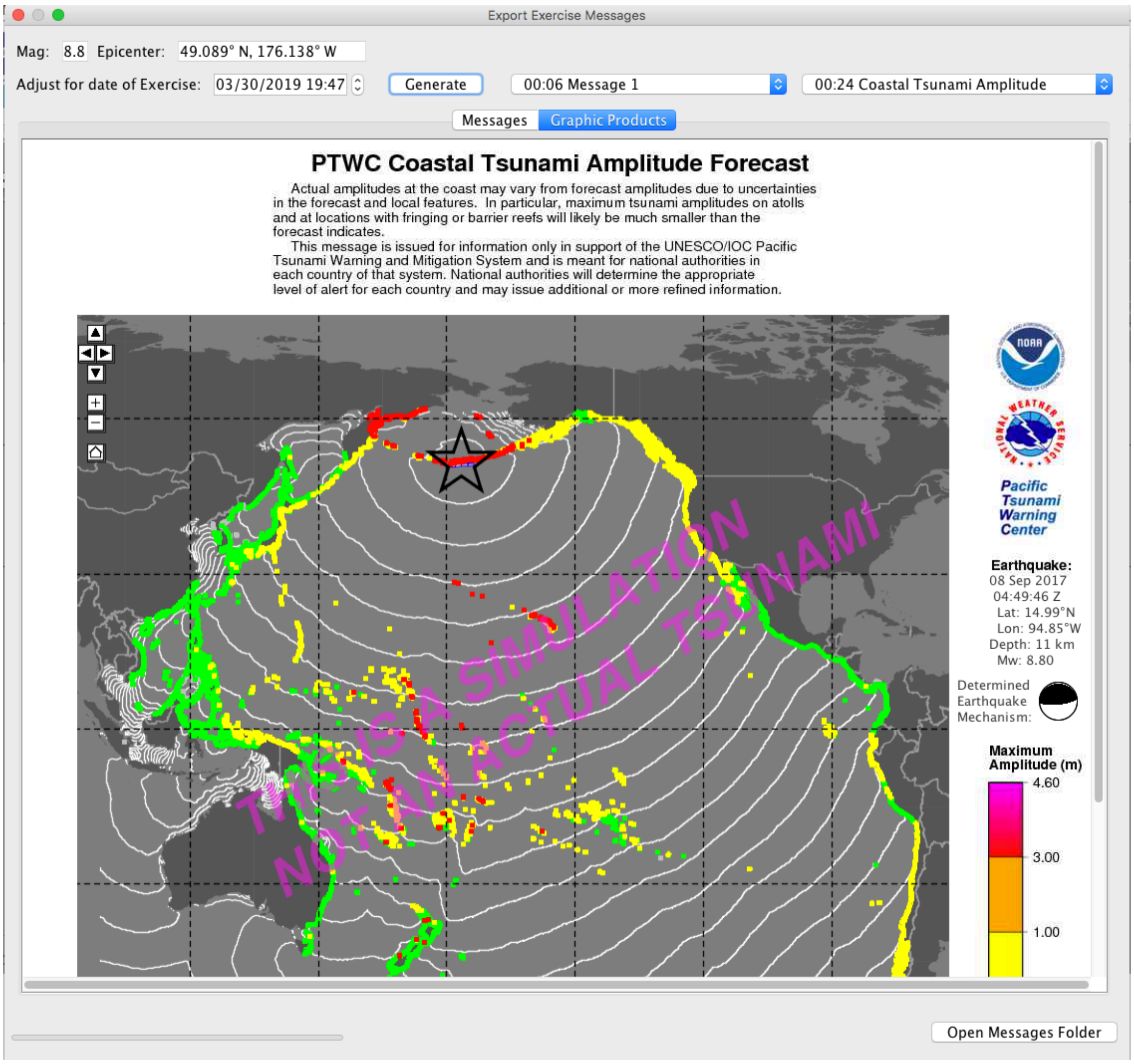


Figure 23: The Export Exercise Messages window, with a Coastal Tsunami Forecast graphic from the Enhanced Products showing.

The user can select the Messages or the Graphical Products to view by clicking on the drop-down list. The lists show the simulated Event Time they were produced for in hours:minutes, and a description (e.g. "00:30 Message 2"). Just as PTWC produces updates for real events every hour, so do TsuCAT … the total event time is calculated as the time it takes for waves to fall below 30 centimeters, and for a typical basin-scale M8.0 event is anywhere from 6 to 18 hours depending on epicenter location.

The user can click on the "Open Messages Folder" button at the button (Figure 23) to view "hard copies" of the products in the format typically dispersed by PTWC for exercises: Messages in Rich Text Format (RTF), and Graphical Products in Portable Network Graphics (PNG) format. A typical Tsunami Threat Message is shown below (Figure 24) for an M8.8 event in the Aleutian Islands. Information about the forecast and countries affected are listed, as well as Estimated Times of Arrival and Potential Impacts. Messages are updated hourly until the event is over.

When using the TsuCAT PTWC Exercise Text Message feature, please be aware that even though a real tsunami event can be selected from the Global Historical Tsunami Database, the source that TsuCAT uses is the *closest source in the TsuCAT catalog* and Text Messages and Graphical Products produced may not exactly match those PTWC produced for the event. In most cases, TsuCAT will produce slightly higher wave amplitudes.

For more information on the PTWC Enhanced Products, refer to IOC Technical Series no. 105 (rev), User's Guide for the PTWC Enhanced Products for the PTWS (Aug 2014, English, Spanish), or visit the PTWC New Enhanced Products website http://itic.ioc-unesco.org/index.php?option=com_content&view=category&layout=blog&id=2143&Itemid=2582
or the Users Guide

For more information on Tsunami Exercises, please visit the ITIC website on Tsunami Exercises, http://itic.ioc-unesco.org/index.php?option=com_content&view=category&layout=blog&id=1439&Itemid=1439

```
TEST...TSUNAMI MESSAGE NUMBER 2...TEST
NWS PACIFIC TSUNAMI WARNING CENTER EWA BEACH HI
2002 UTC SAT MAR 30 2019

...THIS MESSAGE IS FOR TEST PURPOSES ONLY...
...TEST PTWC TSUNAMI THREAT MESSAGE TEST...


**** NOTICE **** NOTICE **** NOTICE **** NOTICE **** NOTICE *****

 THIS MESSAGE IS ISSUED FOR INFORMATION ONLY IN SUPPORT OF THE
 UNESCO/IOC PACIFIC TSUNAMI WARNING AND MITIGATION SYSTEM AND IS
 MEANT FOR NATIONAL AUTHORITIES IN EACH COUNTRY OF THAT SYSTEM.

 NATIONAL AUTHORITIES WILL DETERMINE THE APPROPRIATE LEVEL OF
 ALERT FOR EACH COUNTRY AND MAY ISSUE ADDITIONAL OR MORE REFINED
 INFORMATION.

**** NOTICE **** NOTICE **** NOTICE **** NOTICE **** NOTICE *****

THE TSUNAMI FORECAST IS UPDATED IN THIS MESSAGE.

NOTE EARTHQUAKE MAGNITUDE UPGRADED.


TEST... PRELIMINARY EARTHQUAKE PARAMETERS ...TEST
-------------------------------------------------

  * MAGNITUDE      8.8
  * ORIGIN TIME    1947 UTC SAT MAR 30 2019
  * COORDINATES    49.1 NORTH 176.1 EAST
  * DEPTH          11 / 7 MILES
  * LOCATION       SOUTH OF THE ALEUTIAN ISLANDS

TEST... EVALUATION ...TEST
--------------------------

  * AN EARTHQUAKE WITH A PRELIMINARY MAGNITUDE OF 8.8 OCCURRED
    SOUTH OF THE ALEUTIAN ISLANDS AT 1947 UTC SATURDAY
    MARCH 30 2019

  * THIS IS A TEST MESSAGE.

  * BASED ON ALL AVAILABLE DATA... HAZARDOUS TSUNAMI WAVES ARE
    FORECAST FOR SOME COASTS.


TEST... TSUNAMI THREAT FORECAST...UPDATED ...TEST
-----------------------------------------------

  * TSUNAMI WAVES REACHING MORE THAN 3 METERS ABOVE THE TIDE
    LEVEL ARE POSSIBLE ALONG SOME COASTS OF

      MIDWAY ISLAND AND NORTHWEST HAWAII.


  * TSUNAMI WAVES REACHING 1 to 3 METERS ABOVE THE TIDE
    LEVEL ARE POSSIBLE ALONG SOME COASTS OF

      ALASKA... BIG ISLAND... HAWAII... HOWLAND AND BAKER...
      JOHNSTON ISLAND... KAUAI... KIRIBATI...
      MAUI... MOLOKAI... NIIHAU... OAHU... RUSSIA...
      SAMOA AND SOLOMON ISLANDS.


  * TSUNAMI WAVES REACHING 0.3 TO 1 METERS ABOVE THE TIDE LEVEL
    ARE POSSIBLE FOR SOME COASTS OF

      AMERICAN SAMOA... AUNUU... CALIFORNIA... CANADA...
      CHILE... CHUUK... CNMI... COOK ISLANDS... ECUADOR...
      FRENCH POLYNESIA... GUAM... INDONESIA...
      JAPAN... JARVIS ISLAND... KOSRAE... LANAI...
      MANUA... MARSHALL ISLANDS... MEXICO... MINAMITORISHIMA...
      NAURU... NEW ZEALAND... NIUE...
```

Figure 24: Typical Tsunami Threat Message issued from TsuCAT.

Seismic Expert Regional Sources

Through a collaboration with UNESCO's Intergovernmental Oceanographic Commission (IOC), a series of workshops were held with the goal of identifying regional seismic sources that represent the credible tsunami sources with potential impact for regional coastlines. The workshops were held in Haiti (2013), Xiamen, China (2015), Costa Rica (2016), Dominican Republic (2016), and New Zealand (2017), and defined a series of sources for the Caribbean Sea, Central/South America, Tonga Trench and the South China Sea. Sources from these workshops were published in Workshop Reports (pdf files of these reports can be found in the TsuCAT/eventSources folder). The source parameters published in these reports were named using the report source name, run with MOST/RIFT models, and made available through the "File->Select Expert Regional Source" feature (Figure 25). The maximum offshore wave amplitude, arrival time, and coastal amplitude are then accessible in the same way as any other source in TsuCAT. Fault plane parameters from these sources (or any other) can be used in ComMIT by using the "View->Fault Information for ComMIT" feature.

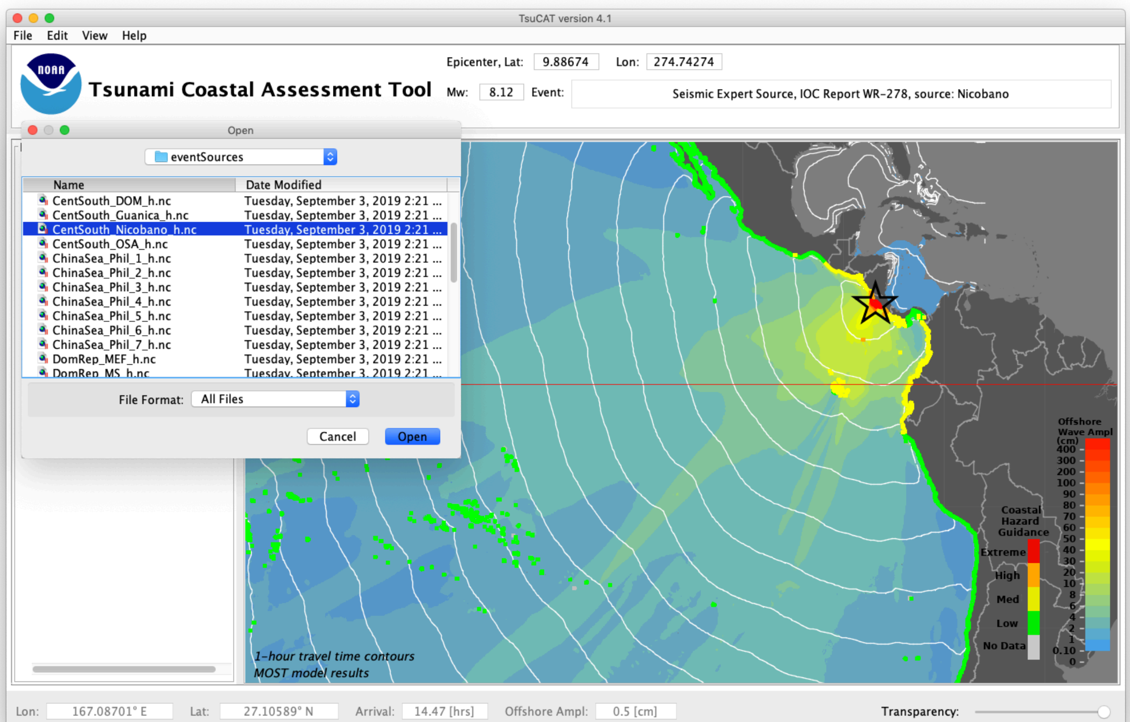


Figure 25: Seismic Expert Source loading in TsuCAT (File->Select Expert Regional Source)

Acknowledgments

The Tsunami Coastal Assessment Tool (TsuCAT) and documentation were developed by Christopher Moore and Marie Eble, respectively, with the NOAA Center for Tsunami Research in the Pacific Marine Environmental Laboratory in Seattle, WA under the sponsorship of the International Tsunami Information Center. Funding for development of TsuCAT was provided by the U.S. National Weather Service. Feedback or questions about TsuCAT, its use, or to report bugs are welcome and should be directed to NOAA/PMEL and/or ITIC;

Christopher.Moore@noaa.gov, Marie.C.Eble@noaa.gov
Laura.Kong@noaa.gov

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National Geophysical Data Center / World Data Service (NGDC/WDS): Global Historical Tsunami Database. National Geophysical Data Center, NOAA. doi:10.7289/V5PN93H7

Titov, V.V., C. Moore, D.J.M. Greenslade, C. Pattiaratchi, R. Badal, C.E. Synolakis, and U. Kânoğlu (2011): A new tool for inundation modeling: Community Modeling Interface for Tsunamis (ComMIT). Pure Appl. Geophys., 168(11), doi: 10.1007/s00024-011-0292-4, 2121–2131.

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Notes