

Tsunami Modeling and Mapping: Guidelines and Best Practices

Part I: Tsunami Inundation Modeling¹

National Tsunami Hazard Mitigation Program
Mapping and Modeling Subcommittee

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A key outcome specified in the National Tsunami Hazard Mitigation Program (NTHMP) 2009-2013 Strategic Plan was the development of “tsunami inundation maps that support informed decision making in tsunami- threatened communities.” To achieve this goal, the NTHMP Coordinating Committee charged the Mapping and Modeling Subcommittee (MMS) in 2009 with establishment of inundation map guidelines. The Coordinating Committee further specified that, to ensure that tsunami inundation maps support informed decision making in tsunami-threatened communities, all NTHMP-funded models and new map products should meet these guidelines by 2012. The current NTHMP Strategic Plan further enforces the motion that all models and maps funded by NOAA/NWS grants should meet NTHMP guidelines except where they conflict with state/territory-mandated laws or policies.

Purpose

The purpose of this guidelines and best practices document is to establish minimum requirements that should be met to develop accurate, consistent, and cost-effective tsunami hazard and risk assessments across state and territorial coastal boundaries. Included here are guidelines for model inputs, outputs, and direction to ensure that a numerical code is properly applied. In addition to this document, the MMS has developed *Tsunami Inundation Maps and Checklist for Evaluating Tsunami Modeling and Mapping Reports and/or Metadata*, a supplement containing content recommendations for metadata, project reports, or other forms of documentation related to model and map development (<http://nws.weather.gov/nthmp/publications.html>).

Moving forward, the MMS continues to review the activities previously specified every five years or as needed.

Intended Audience

These guidelines and best practices are intended for tsunami modelers and DEM developers with the intent of providing the best attainable products to support informed decisions. These guidelines apply to federally funded NTHMP partners and may be adopted for use by other entities.

¹ Formerly titled *Guidelines and Best Practices for Tsunami Inundation Modeling for Evacuation Planning*

² The draft of this document was developed by the National Tsunami Hazard Mitigation Program Mapping and Modeling Subcommittee (MMS) April 29, 2009. It was revised by a working group of the MMS in May 2009 and reviewed and finalized by the MMS January 26, 2010. It was reformatted as part of the “Tsunami Modeling and Mapping: Guidelines and Best Practices” series in September 2016. No significant changes to the content were made.

Expected Results

The outcome of adherence to the guidelines and best practices set forth for tsunami inundation modeling will result in more uniform and understandable products. These guidelines and best practices may also serve communities or regions where formal tsunami mitigation efforts are in the development stage.

Tsunami Inundation Modeling Guidelines

In these guidelines, “tsunami inundation modeling” refers to the numerical computer code(s) used to simulate tsunami generation at any number of sources, propagation across a body of water, and inundation of normally dry land. These guidelines also address the input and parameters necessary to successfully model the tsunami inundation for chosen simulations or scenarios. Model inputs include, but are not limited to, the bathymetric and topographic digital elevation models (DEMs) and the tsunami source information that define credible local and distant tsunami scenarios for the susceptible coastline. The intent of these modeling guidelines is to support the development of tsunami inundation mapping products that further support clear, consistent evacuation products. For NTHMP efforts:

- Modeling code(s) will meet benchmark standards adopted by the NTHMP MMS. A summary of the tsunami inundation benchmark problems is provided at <http://nws.weather.gov/nthmp/documents/TsunamilnundationBenchmarkProblemsSummary.pdf>. A list of the models that have met accuracy criterion and are in use for NTHMP efforts is provided at <http://nws.weather.gov/nthmp/documents/BenchmarkedTsunamiModels.pdf>.
- All inundation model codes used for NTHMP funded work shall be accessible to interested users.
- Numerical models should be used appropriately with respect to domain of applicability (as identified by benchmarks).
- All modeling efforts and methodology should be described and justified (i.e., in a peer-reviewed technical report or journal).
- This includes input data (e.g., DEM, tsunami sources) and modeling parameters.
- Inputs to model runs from which inundation maps are developed should be archived and made available to ensure reproducibility.
- Model outputs should be compared against tsunami event measurements and other local information where available.
- A suite of relevant and credible tsunami sources, as determined by NTHMP members, should be considered for modeling of inundation. Lessons-learned from the recent tsunamigenic earthquakes need to be evaluated and sources updated where appropriate.
- At a minimum, model output should include the maximum predicted inundation in order to support mapping needs.

Tsunami Inundation Modeling Best Practices

General

- The near-shore computational grid should be of a cell size sufficient to resolve significant coastal features and narrow passages, as available DEMs allow.
- Inundation modeling should use the best available data and appropriate modeling techniques and described in a technical report.

- Modeling should include DEMs developed from the highest resolution bathymetric and topographic data available, appropriate computation resolution, current deformation models, and credible source characterizations.
- Collaboration between forecast and inundation modeling groups is encouraged to provide the opportunity to identify and address unusual or significant differences in various model results that could impact inundation and/or forecast products.

Source Characterization

- Tsunami source selection should be based on credible tsunami generating scenarios, considering relevant local and distant sources and generation mechanisms.
- The NOAA Forecast Source Database (<http://nctr.pmel.noaa.gov/propagation-database-access.html>) should serve as the default distant source database for inundation modeling, recognizing that the depiction of potential tsunami sources will evolve and change.
- Source characterization should be as detailed as necessary to capture the relevant characteristics of the tsunami waves. For example, local sources should have more detailed characterization than distant sources.

DEM Development

- For DEM cell size smaller than 3 arc-second, source elevation data should be converted to a common vertical datum before construction of a DEM. Where available, NOAA's VDatum tool (<http://vdatum.noaa.gov/>) should be used to convert between vertical datums. Otherwise, values derived from nearby NOAA tide stations (<http://tidesandcurrents.noaa.gov/>) or other appropriate datums should be used.
- A DEM vertical datum of Mean High Water (MHW) or alternative maximum flooding condition is recommended for inundation modeling conducted in support of evacuation planning (MHW is the vertical datum used by NOAA's National Centers for Environmental Information (NCEI) to develop coastal DEMs for tsunami forecast and warning).
- DEM cell size should not be smaller than the source elevation data spacing of the most significant data sets (e.g., shallow-water hydrographic soundings or coastal LiDAR survey)—unless required to resolve important morphologic features.
- DEM source elevation data should be obtained in an area 5-10% larger than the DEM extents, to create a "data buffer" to avoid DEM edge effects or grid transition problems during gridding.
- Modeling of tsunami inundation should be performed using DEMs with cell sizes less than 3 arc-seconds (~90 meter, i.e. Type 1), as DEM cell sizes coarser than this tend to degrade inundation modeling results.
- Topographic or bathymetric features, rivers, or community related features that are highly significant to modeling results should be communicated to the DEM development group. Once source data for the features are reviewed, options to ensure correct results can be presented to modelers for feedback.
- DEM source elevation data and development methodologies should be thoroughly documented in standards-compliant metadata records and technical reports.

- DEMs and associated documentation should be described and disseminated online to support use by other groups (e.g., NCEI's DEM Web Portal: <https://www.ngdc.noaa.gov/mgg/coastal/coastal.html>).

Model Parameters

- Model runtime should be sufficient to capture the maximum inundation of the tsunami simulation and to estimate a time period when hazardous waves are present.
- To resolve significant features that impact inundation, the computational grid should be fine enough that the feature covers more than 3 cells.
- The computational grid domain should have enough extent to capture important tsunami wave dynamics.
- To capture the contribution of high tidal conditions, inundation models should be run at a minimum of MHW level conditions for a specific region.
- A bottom "Manning's n" friction coefficient which best represents the overall terrain and product use should be used. A common value used in tsunami modeling is $n=0.025$ (e.g. ASCE-7). Some modeling teams have adopted a variable friction factor that approximates the variable landscape terrain.

This document is part of the "Tsunami Modeling and Mapping: Guidelines and Best Practices" series. All the documents in this series are available on the NTHMP website at

<http://nws.weather.gov/nthmp/publications.html>:

- *Part I: Tsunami Inundation Modeling*
- *Part II: Tsunami Inundation Maps*
- *Part III: Tsunami Inundation Determination for Non-Modeled Regions*
- *Part IV: Tsunami Evacuation Maps*
- *Checklist for Tsunami Modeling and Mapping Reports and/or Metadata*