Tsunami Modeling and Mapping: Guidelines and Best Practices

Part I: Tsunami Inundation Modeling[1]

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) Strategic Plan is 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) with the following actions:

- Establish (minimum) inundation map guidelines by 2009.
- Establish a prioritized list of communities for which to develop inundation maps by 2009.
- Develop guidelines to establish areas of inundation for non-mapped and low-hazard areas by 2010.
- Develop a process to assess applicability of previously produced maps by 2012.
- Determine the potential inundation zones for non-mapped coastal regions using the established guidelines by 2012.

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.

Purpose

The purpose of this guidelines and best practices document is to establish minimum requirements that should be met to meet the previously stated Strategic Plan goal. Guidance on the numerical modeling of tsunami inundation for the purpose of producing inundation and evacuation products is expected to provide consistent products 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).

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 state and Federal planners and emergency managers in making informed decisions. Though these guidelines apply to federally funded NTHMP

[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.

partners, it is also recommended that they be adopted for use by other entities with an interest or intent in producing tsunami inundation and evacuation maps.

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) should meet benchmark standards adopted by the NTHMP (Synolakis et al. 2007). A summary of the tsunami inundation benchmark problems is provided at http://nws.weather.gov/nthmp/documents/TsunamiInundationBenchmarkProblemsSummary.pdf. A list of the models that have met these standards and are in use for NTHMP efforts is provided at http://nws.weather.gov/nthmp/documents/BenchmarkedTsunamiModels.pdf.
- 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 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.
- All relevant and credible tsunami sources should be considered for modeling of inundation.
- 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, as available DEMs allow.
- Inundation modeling should use the best available data and the latest, most feasible modeling techniques. Alternative approaches should be justified 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 be the initial 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), as DEM cell sizes coarser than this tend to degrade inundation modeling results.
- 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: http://www.ngdc.noaa.gov/dem/squareCellGrid/map).

Model Parameters

- Model runtime should be sufficient to capture the maximum inundation of the tsunami simulation.
- 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.

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*