



REPORT TO CONGRESS

The National Oceanic and Atmospheric Administration's Report on Tsunami Warning & Education Act

*Developed pursuant to the Weather Research
and Forecasting Innovation Act, 2017 (P.L. 115-25)*

Louis W, Uccellini, Director
National Weather Service
National Oceanic and Atmospheric Administration

Tim Gallaudet, Ph.D.,
Rear Admiral, U.S. Navy (Ret.)
Assistant Secretary of Commerce for Oceans and Atmosphere / Deputy NOAA Administrator,
Acting Under Secretary of Commerce for Oceans and Atmosphere / NOAA Administrator

THE WEATHER RESEARCH AND FORECASTING INNOVATION ACT, 2017 (P.L. 115-25) INCLUDED THE FOLLOWING LANGUAGE

(1) IN GENERAL.—Not later than 1 year after the date of the enactment of this Act, the Administrator of the National Oceanic and Atmospheric Administration shall submit to Congress a report on the implementation of the Tsunami Warning and Education Act enacted as title VIII of the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006 (Public Law 109–479; 33 U.S.C. 3201 et seq.), as amended by this Act.

(2) ELEMENTS. —The report required by paragraph (1) shall include the following:

(A) A detailed description of the progress made in implementing sections 804(d)(6), 805(b), and 806(b)(4) of the Tsunami Warning and Education Act the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006 (Public Law 109–479; 33 U.S.C. 3201 et seq.).

(B) A description of the ways that tsunami warnings and warning products issued by the Tsunami Forecasting and Warning Program established under section 804 of the Tsunami Warning and Education Act (33 U.S.C. 3203), as amended by this Act, may be standardized and streamlined with warnings and warning products for hurricanes, coastal storms, and other coastal flooding events.

THIS REPORT RESPONDS TO THE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION OF THE SENATE AND THE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY OF THE HOUSE OF REPRESENTATIVES REQUEST.

TABLE OF CONTENTS

		Page
I.	Executive Summary	5
II.	Introduction	6
III.	Progress on Selected Legislation Sections	6
	A. Section 804(d)(6) -- Supercomputing Resources	6
	B. Section 805(b) -- National Tsunami Hazard Mitigation Program Coordinating Committee	6
	C. Section 806(b)(4): Tsunami Research Program	7
IV.	Standardizing and Streamlining Tsunami Warning Products with other National Weather Service Products	10
V.	Conclusion	11

I. EXECUTIVE SUMMARY

The Department of Commerce’s National Oceanic and Atmospheric Administration (NOAA) prepared this document in response to the direction provided by the Weather Research and Forecasting Innovation Act (WRFIA) of 2017 (Public Law 115-25), which requested a report on the following items:

(1) IN GENERAL.—Not later than 1 year after the date of the enactment of this Act, the Administrator of the National Oceanic and Atmospheric Administration shall submit to Congress a report on the implementation of the Tsunami Warning and Education Act enacted as title VIII of the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006 (Public Law 109–479; 33 U.S.C. 3201 et seq.), as amended by this Act.

(2) ELEMENTS.—The report required by paragraph (1) shall include the following:

(A) A detailed description of the progress made in implementing sections 804(d)(6), 805(b), and 806(b)(4) of the Tsunami Warning and Education Act the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006 (Public Law 109–479; 33 U.S.C. 3201 et seq.).

(B) A description of the ways that tsunami warnings and warning products issued by the Tsunami Forecasting and Warning Program established under section 804 of the Tsunami Warning and Education Act (33 U.S.C. 3203), as amended by this Act, may be standardized and streamlined with warnings and warning products for hurricanes, coastal storms, and other coastal flooding events.

This report responds to this Congressional direction. NOAA continues to operate a comprehensive, end-to-end tsunami forecast, warning and mitigation capability and implement the actions required by law. NOAA has been effective in obtaining the necessary supercomputing resources to run the tsunami prediction models, as directed by the Tsunami Warning and Education Act (TWEA) enacted as title VIII of the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006 (Public Law 109-479; 33 U.S.C. 3201 et seq.). NOAA also continues its ongoing efforts to engage federal, state, tribal, and local partners through administering the National Tsunami Hazard Mitigation Program, as directed by TWEA. NOAA has been investing in applied research and, through Federal Fiscal Year 2018, is continuing its research and development activities, including improvement of near-field and distant tsunami detection and forecasting capabilities. NOAA is developing the 4th Generation of NOAA’s Deep-ocean Assessment and Reporting of Tsunamis (DART) detection system, and has incrementally improved the speed and accuracy of NOAA’s primary tsunami forecast system: Stand-by Inundation Forecast of Tsunamis (SIFT). NOAA is also pursuing a joint initiative with the National Aeronautics and Space Administration (NASA) to consider real-time Global Positioning System (GPS) offsets to augment traditional seismic analysis. All of these initiatives target increasing the speed and accuracy of near-field tsunami detection, measurement, and forecasting.

In addition, NOAA is collaborating with other federal agencies and leveraging advances in social science to better communicate threat information. Part of this social science work includes improving and clarifying tsunami messages in ways to better communicate the potential impacts of the threat (e.g., by placing the location and tsunami threat up front in the message instead of at the end).

Improving tsunami warnings and communication remain a NOAA priority to meet its environmental prediction mission in the protection of life and property.

II. Introduction

This Report is prepared in response to the direction provided by the Weather Research and Forecasting Innovation Act (WRFIA) of 2017 (Public Law 115-25), which requires a report on actions directed by the Tsunami Warning and Education Act (TWEA) enacted as title VIII of the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006 (Public Law 109-479; 33 U.S.C. 3201 et seq.). The original TWEA authorization required NOAA to address supercomputing for tsunami warnings, the National Tsunami Hazard Mitigation Program, tsunami modeling and detection research and development, and other issues. This Report provides a summary of NOAA's progress on the items identified by the WRFIA. The Report is organized by the specific requests made in the WRFIA.

III. Section I: Progress on Selected Legislation Sections

A. Section 804(d)(6) -- Supercomputing Resources

AVAILABLE RESOURCES. —*The Administrator, through the National Weather Service, shall ensure that resources are available to fulfill the obligations of this Act. This includes ensuring supercomputing resources are available to run, as rapidly as possible, such computer models as are needed for purposes of the tsunami warning system operated under subsection (c).*

Response: NOAA's current generation of tsunami forecast models are optimized to run locally at NOAA's Tsunami Warning Centers (TWCs). The propagation components rely on pre-computed source models and parameters. The flooding and inundation component of the forecast modelling system does rely on more sophisticated calculations that need to be performed in real-time. This has been addressed through code parallelization and implementation of high-capacity graphics processing unit (GPU) workstations. As such, NOAA's TWCs currently have sufficient local computational resources to run the operational models and centralized supercomputing assets are not currently required. NOAA is in the early stages of developing a more sophisticated near-real-time dynamic source characterization capability that may require leveraging NOAA's National Centers for Environmental Prediction High Performance Computing assets depending on how the system is developed and optimized.

B. Section 805(b) -- National Tsunami Hazard Mitigation Program Coordinating Committee

COORDINATING COMMITTEE.—*In conducting the program under this section, the Administrator shall establish a coordinating committee comprising representatives of Federal,*

State, local, and tribal government officials. The Administrator may establish subcommittees to address region-specific issues.

Response: The NOAA Administrator, through the National Weather Service (NWS), has established a Coordinating Committee of the National Tsunami Hazard Mitigation Program (NTHMP) composed of an emergency management and science representative for each NTHMP partner state (AK, WA, OR, CA, HI), territory (Guam, American Samoa, Puerto Rico, CNMI, USVI) or region (Gulf Coast, East Coast), as well as two partners each from the Federal Emergency Management Agency (FEMA), NOAA, and the U.S. Geological Survey (USGS). The representatives to the NTHMP and a description of how they participate in governing the program are defined in the NTHMP Rules of Procedure.¹ The Coordinating Committee is chaired by a Senior Leader of NWS. NWS headquarters provides administrative staff to support the NTHMP Coordinating Committee.

The Coordinating Committee meets regularly, both in person and by conference call. More information about the NTHMP Coordinating Committee, along with a record of actions (meeting minutes), may be found at <http://nws.weather.gov/nthmp/nthmpcc.html>.

The NTHMP also has three active subcommittees:

- Mapping and Modeling
- Mitigation and Education
- Warning Coordination

These subcommittees meet both in person and by conference call on a regular basis throughout the year. More information about activities of these subcommittees may be found at <http://nws.weather.gov/nthmp/subcommittees.html>.

C. Section 806(b)(4): Tsunami Research Program

RESPONSIBILITIES.—The research program supported or maintained under subsection (a) shall—”; and

1. consider other appropriate research to mitigate the impact of tsunami; consider other appropriate and cost effective solutions to mitigate the impact of tsunami, including the improvement of near-field and distant tsunami detection and forecasting capabilities, which may include use of a new generation of the Deep-ocean Assessment and Reporting of Tsunamis array, integration of tsunami sensors into commercial and Federal telecommunications cables, and other real-time tsunami monitoring systems and supercomputer capacity of the Administration to develop a rapid tsunami forecast for all United States coastlines;

Response: NOAA is actively pursuing tsunami research initiatives as part of a larger strategy to ensure that the most recent science and technology advancements are folded into operations. A

¹ <http://nws.weather.gov/nthmp/documents/NTHMPRulesofProcedure.pdf>

recent example specific to the tsunami program includes the Pacific Marine Environmental Laboratory's (PMEL) ongoing development of the 4th Generation of NOAA's Deep-ocean Assessment and Reporting of Tsunamis (DART) detection and measurement system, which is expected to greatly improve NOAA's ability to detect tsunamis near their point of generation. NOAA has also developed and implemented changes to the Stand-by Inundation Forecast of Tsunamis (SIFT) modeling system (e.g., replacing central processing units (CPUs) with GPUs) that will result in improved forecast speed and accuracy. NOAA is also pursuing a joint initiative with the National Aeronautics and Space Administration (NASA) to consider real-time Global Navigation Satellite System (GNSS) offsets to augment traditional seismic analysis. This will allow NOAA's TWCs to more quickly determine tsunami source parameters enabling faster and more accurate forecasts. All of these initiatives target increasing the speed and accuracy of near-field tsunami detection and measurement. NOAA supports the integration of tsunami sensors into commercial and Federal telecommunication cables, and is currently ingesting pressure data from cable systems such as Neptune Canada, but there are significant engineering and cost considerations that would need to be identified by the commercial or Federal cable system owners before NOAA could determine the level of investment required.

2. *coordinate with the National Weather Service on technology to be transferred to operations;*

Response: As refinements to NOAA's modeling and sensing capabilities are tested and validated, they are transferred to NWS for integration into existing operations. This occurs on an ongoing basis through the standard Research-to-Operations practices of the NWS in accordance with NOAA's Policy on Research and Development Transitions (NOAA Administrative Order 216-105B)². Incremental improvements to both the SIFT modeling system and DART observing system have been transitioned into operations in this manner.

3. *conduct social science research to develop and assess community warning, education, and evacuation materials; and*

Response: NOAA recognizes the importance of incorporating social science research findings into tsunami forecasts and warnings. In March 2014, a social science report³ by *C. Gregg et al.*, funded by NOAA/NWS, was delivered to the NWS Headquarters Tsunami Program addressing the language used in tsunami alerts for community warning. Results of the report were provided to the TWCs. Changes to the wording in tsunami watch, advisory, and warning notifications, now clearly indicating threatened areas and potential impacts at the beginning of the bulletin, were incorporated and are now fully operational. Another social science report⁴ on the NWS

² http://www.corporateservices.noaa.gov/ames/administrative_orders/chapter_216/216-105B.html

³ Gregg, C.E., Sorensen, J., Vogt-Sorensen, B. and Johnston, D.M., (2014). *Recommended Revisions to Warning Product Prototypes of the NWS National Tsunami Warning Center*. Johnson City, TN: East Tennessee State University, Department of Geosciences.

⁴ Gregg, C.E., Wood, N., Meinhold, S., Johnston, D.M. and Horan, J.E. (2014). *Proposed and Existing Guidelines for Recognition in the NWS TsunamiReady® Community Program*. Johnson City, TN: East Tennessee State University, Department of Geosciences.

TsunamiReady Program, also developed by *C. Gregg et al.* and delivered in March 2014 to the NWS Headquarters Tsunami Program, was used to support a complete revision of the existing TsunamiReady recognition guidelines. As a result, the previous highly-generalized guidelines all communities used were focused into three specific subsets based on both alignment with the traditional phases of emergency management (mitigation, preparedness, response, and recovery) and actual localized tsunami risk. TsunamiReady recognition can now be achieved as either (1) TsunamiReady Supporter, for non-governmental entities (such as a business, hotel, or private school); (2) TsunamiReady Fundamental, for local governments (county or municipality) with an identified risk of tsunami impact; or (3) TsunamiReady Tier Two, for communities with the highest level of risk and in areas where long-term investment of community planning and resources for tsunami mitigation are required—often associated with a significant near-field tsunami threat. The revised TsunamiReady Guidelines were more relatable to emergency management professionals and were instituted June 2015 for all newly recognized communities and subsequent TsunamiReady renewals for previously-recognized communities. The new TsunamiReady Guidelines are located online at <https://www.weather.gov/tsunamiready/>. Education and evacuation materials are developed by coastal states and territories that are engaged with the NTHMP, not by Federal agencies. NOAA intends to award a Tsunami Activities Grant in FY18 for states to conduct a social science evaluation of state/territory tsunami evacuation materials and to recommend updates and changes based on social science research.

4. *develop the technical basis for validation of tsunami maps, numerical tsunami models, digital elevation models, and forecasts; and;*"

Tsunami Maps: The technical basis of tsunami map validation, both for inundation maps and evacuation maps, rests with individual coastal states and territories. Through their ongoing participation with the NTHMP, scientists in coastal states and territories validate their maps based on accuracy, completeness, and how well they inform local officials and the public. Map validation activities in states and territories have been funded through the annual NWS Tsunami Activities Grants process.

Numerical Tsunami Models: Operational tsunami forecast models are validated through a benchmarking process accomplished jointly by NOAA's Office of Oceanic and Atmospheric Research (OAR) PMEL and NWS' TWCs (Synolakis et al. 2007. OAR PMEL-135)⁵. Models used to support coastal preparation and mitigation measures are validated by scientists serving with NTHMP partner states and territories. The benchmarking report and validation results⁶ are posted on the NTHMP website⁷.

⁵ Synolakis, C.E., E.N. Bernard, V.V. Titov, U. Kânoğlu, and F.I. González (2007): *Standards, criteria, and procedures for NOAA evaluation of tsunami numerical models*. NOAA Tech. Memo. OAR PMEL-135, NOAA/Pacific Marine Environmental Laboratory, Seattle, WA, 55 pp.

⁶ <http://nws.weather.gov/nthmp/documents/TsunamiModelSummary.pdf>

⁷ <http://nws.weather.gov/nthmp/publications.html>

Digital Elevation Models (DEMs): DEMs are developed by NOAA’s National Centers for Environmental Information (NCEI) and critical to producing the detailed tsunami coastal inundation and flooding maps that the States produce. NOAA also depends on DEMs to deliver the operational forecasts and warnings that come out of NOAA’s TWCs in real-time. The technical basis for validation of DEMs rests with scientists in coastal states and territories for which DEMs were developed. These validation procedures are shared through the NTHMP and its regular scientific exchange meetings. DEMs incorporated in NOAA’s operational modelling system are validated according to NCEI technical standards.

Forecasts: Tsunami forecasts are verified in real-time by each NWS TWC. Results of the forecasts are compared with both deep ocean pressure measurements obtained through the DART network and coastal amplitude and inundation values observed at coastal tide gauges. These results are used to refine input to models to improve forecasts in real-time, and more broadly to improve the modeling system for future events.

5. *ensure that research and findings are available to the public and scientific community.*

Response: As findings from tsunami research are developed, reports and products such as DEMs are published and are made available to the public on NOAA or NTHMP websites.

IV. Section II: Standardizing and Streamlining Tsunami Warning Products with other National Weather Service Products

(B) A description of the ways that tsunami warnings and warning products issued by the Tsunami Forecasting and Warning Program established under section 804 of the Tsunami Warning and Education Act (33 U.S.C. 3203), as amended by this Act, may be standardized and streamlined with warnings and warning products for hurricanes, coastal storms, and other coastal flooding events.

Response: Tsunami Warning products related to classic seismically induced tsunamis, such as wave amplitude and arrival times, are unique and are derived in ways that are not easily integrated with hurricane, coastal storm, and coastal flooding products. However, despite the unique characteristics of the tsunami phenomena, NWS is making efforts to standardize and communicate these outputs using common, simplified language and intuitive visualization interfaces. To ensure consistent messaging, NWS recently conducted a comprehensive, revision of tsunami.gov that combined the output of NOAA’s two TWCs into a single, easily understood depiction of the tsunami threat. In addition, NWS actively explores opportunities to leverage common geospatial information gained through a wide range of topography and bathymetry collection initiatives, to include those collected by the National Geodetic Survey, in an ongoing effort to create and deliver more precise tsunami forecasts. Finally, NOAA is making efforts to integrate non-seismic source tsunami products, such as meteotsunamis, into already established alerting protocols such as coastal flood warnings and Special Weather Statements. This was the case with the May 15, 2018, meteotsunami that formed in the coastal waters south of Long Island New York.

V. Conclusion

NOAA has made significant progress in meeting the direction from the original TWEA authorization and will continue implementation of Title V of WRFIA, the Tsunami Warning, Education and Research Act of 2017 (33 U.S.C. 3201 *et seq.*). NOAA continues to operate a comprehensive, end-to-end tsunami forecast, warning, and mitigation capability and will continue improving our modeling, observation, detection, and communication capabilities for tsunamis to meet our environmental prediction mission for the protection of life and property.