

**Report to the  
National Oceanic and Atmospheric Administration  
Science Advisory Board  
in Response to**

**The findings of the Tsunami Science and Technology Advisory Panel's report to the  
Committee on Commerce, Science, and Transportation of the Senate and the Committee on  
Science, Space, and Technology of the House of Representatives  
as Requested in Weather Research and Forecasting Innovation Act of 2017**

**April 2023**

## EXECUTIVE SUMMARY

This report is prepared in response to findings presented to the National Oceanic and Atmospheric Administration (NOAA) Science Advisory Board by the Tsunami Science and Technology Advisory Panel (TSTAP). TSTAP is established as part of the Weather Research and Forecasting Innovation Act of 2017, which provides:

*§3206a. Tsunami Science and Technology Advisory Panel*

*(a) Designation. The Administrator shall designate an existing working group within the Science Advisory Board of the Administration to serve as the Tsunami Science and Technology Advisory Panel to provide advice to the Administrator on matters regarding tsunami science, technology, and regional preparedness.*

...

*(c) Responsibilities. Not less frequently than once every 4 years, the Panel shall— (1) review the activities of the Administration, and other Federal activities as appropriate, relating to tsunami research, detection, forecasting, warning, mitigation, resiliency, and preparation; and (2) submit to the Administrator and such others as the Administrator considers appropriate— (A) the findings of the working group with respect to the most recent review conducted under paragraph (1); and (B) such recommendations for legislative or administrative action as the working group considers appropriate to improve Federal tsunami research, detection, forecasting, warning, mitigation, resiliency, and preparation.*

*(d) Reports to Congress. Not less frequently than once every 4 years, the Administrator shall submit to the Committee on Commerce, Science, and Transportation of the Senate, and the Committee on Science, Space, and Technology of the House of Representatives a report on the findings and recommendations received by the Administrator under subsection (c)(2).*

*Tsunami Warning, Education, and Research Act of 2017, part of the Weather Research and Forecasting Innovation Act of 2017 (Public Law 115-25 § 501, et seq., at § 508(a)(2); codified at 33 U.S.C. § 3206a)*

NOAA has received, reviewed and prepared responses to the report from TSTAP of December 8, 2021. This report is intended to support NOAA's response to the NOAA Science Advisory Board.

NOAA welcomes the input from the TSTAP and in general concurs with the characterization of the NOAA Tsunami Program and views the findings as both relevant and actionable. NOAA agrees with the panel in that the biggest risk related to national tsunami services is the independent operations of NOAA's two operational Tsunami Warning Centers (TWC). This leads to both lack of service consistency between TWCs and, most crucially, lack of service back-up, as directed in law. NOAA is pursuing an initiative to fully integrate TWC operations, and it is expected this will directly address many of the TSTAP findings.

## NOAA Responses to Specific Findings and Recommendations

### I. Improve Unification and Capabilities of the Tsunami Forecast System

1.1. It is recommended that the NOAA Administrator align and consolidate TWCs and overhaul the forecast system to unify detecting earthquake parameters and produce the same products (e.g., forecast wave heights).

NOAA Response: NOAA generally concurs with this recommendation. Independent operations of NOAA's two TWCs are a recognized source of inconsistency and risk; however, physical consolidation of NOAA's TWCs is precluded by the relevant statute, which states:

*(d) Tsunami warning centers*

*(1) In general*

*The Administrator shall support or maintain centers to support the tsunami warning system required by subsection (c). The Centers shall include—*

*(A) the National Tsunami Warning Center, located in Alaska, which is primarily responsible for Alaska and the continental United States;*

*(B) the Pacific Tsunami Warning Center, located in Hawaii, which is primarily responsible for Hawaii, the Caribbean, and other areas of the Pacific not covered by the National Center; and*

*(C) any additional forecast and warning centers determined by the National Weather Service to be necessary.*

*Tsunami Warning, Education, and Research Act of 2017, part of the Weather Research and Forecasting Innovation Act of 2017 (Public Law 115-25 § 501, et seq., at § 504 (d); codified at 33 U.S.C. § 3203(d)(1))*

While not pursuing physical TWC consolidation, NOAA is committed to addressing TWC alignment both technically and organizationally. This will include:

1. Migration of legacy TWC product and message generation systems to the Advanced Weather Information Processing Systems (AWIPS). Expected implementation: Q2 FY25.
2. Development of a TWC Common Analytic System (CAS) to provide common tsunami assessment and forecast guidance to TWCs. Expected implementation: TBD
3. Evaluation of organizational framework. NOAA's TWCs are currently administered within the regional structure of the NOAA National Weather Service (NWS). NWS leadership is reconsidering this framework so as to better support consistent TWC operations and management. Expected implementation: Q4 FY24

This effort is consistent with the current law, which states the TWCs “shall maintain a fail-safe warning capability and perform back-up duties for each other.”

1.2. It is recommended that the NOAA Administrator undertake a comprehensive, enterprise-wide technology upgrade for the warning system/program.

NOAA Response: NOAA concurs with this recommendation. The transition of legacy TWC product and message generation software to AWIPS and the development and fielding of the TWC common analytic system will address this recommendation.

1.3. It is recommended that the NOAA Administrator strengthen the collaborative relationship and expand the memorandum of understanding (MOU) with the USGS (U.S. Geological Survey) for identifying earthquake parameters and source mechanisms.

NOAA Response: NOAA generally concurs with this recommendation. The NOAA Tsunami Program has a long and fruitful relationship with the USGS Earthquake Hazards Program concerning rapid identification of key earthquake parameters that are indicative of potential tsunami generation, and relies heavily on USGS seismic monitoring systems. As technology advances accelerate, even tighter collaboration with the USGS is deemed necessary. As such, NOAA has engaged USGS regarding the potential to align both requirements and systems. This will include information sharing site visits, workflow exercises, and scientific exchanges as NOAA begins to develop a CAS to support TWC operations. It is not currently known what, if any, additional leveraging opportunities will be realized through this engagement but, at a minimum, expectations are that operations within both agencies will benefit. NOAA is confident this collaborative effort can be adequately supported through the existing NOAA/USGS MOU.

1.4. It is recommended that the NOAA Administrator ensure sufficient backup capabilities for tsunami forecasting and alerting.

NOAA Response: NOAA is fully committed to complying with this recommendation. Reliable service back-up is a key underpinning of NWS operations. It is expected that by pursuing the TWC alignment activities described in the response to recommendation 1.1, full service back-up between TWCs will be achieved.

## **2. Improve Tsunami Detection and Observation Systems**

2.1. It is recommended that the NOAA Administrator increase development and improve dissemination of observation networks like tide gauges, web-cameras, and real-time observer programs.

NOAA Response: NOAA partially concurs with this recommendation. A primary operational component of NOAA’s Tsunami Forecast and Warning System is real-time, deep-ocean pressure data. These measurements provide the only means of directly detecting and measuring tsunamis prior to impacting coastlines. This data is currently delivered through the Deep-ocean Assessment and Reporting of Tsunamis (DART®) network. The equipment in the DART

network will be modernized and enhanced through funds from the Infrastructure Investment and Jobs Act of 2021, also referred to as the Bipartisan Infrastructure Law, for improved tsunami warnings, forecast of intensity and arrival times and prediction for community inundation. The report authors correctly note the expense of maintaining this network; however, the alternative observational capabilities identified (e.g., tide gauges, web-cameras, and real-time observer programs) cannot adequately substitute for the deep-ocean data provided by the DART network. These additional coastal observations are, nonetheless, important to verification of tsunami impact forecasts and are being pursued as resources permit. The CAS being developed in conjunction with the TWC Unification (TWCU) effort will be crucial to ensure all-source data can be incorporated into the Tsunami Forecast and Warning Process.

2.2. It is recommended that the NOAA Administrator expand detection capabilities to all seismic and non-seismic sources.

NOAA Response: NOAA concurs with this recommendation. While all tsunamis are difficult to detect, seismically-generated tsunamis are normally preceded by large, detectable earthquakes. The correlation between earthquake parameters and tsunami size and impact are imperfect, but this relationship is valuable in ensuring alerts can be issued in a timely manner. Non-seismically generated tsunamis pose even greater challenges. In most cases there are no reliable indicators that a non-seismic tsunami has occurred other than observed changes in coastal water-level itself, which is normally received too late to support issuing advanced alerts. To address this gap in observations, NOAA is considering observational networks that are agnostic to the source. This would include new technologies such as Ionospheric tomography and GPS occultation. These technologies are being pursued as research and development (R&D) resources permit. In addition, initiatives such as the Science, Monitoring, and Real-time Transmission (SMART), which involves placing scientific instrument on deep-ocean fiber-optic cables, could prove valuable in greatly expanding the number of deep-ocean pressure readings available to TWCs, particularly in areas not associated with known seismic sources. The SMART initiative will likely depend on support from the industry deep ocean cable owners (e.g., Amazon, Google, Facebook) – and could involve regulatory/permitting processes. This is not seen as something the NOAA Tsunami Program can have significant, direct influence over. Regardless of specific data sources, the CAS being developed in conjunction with the TWCU effort will be crucial to ensure this data can be incorporated into the operations.

2.3. It is recommended that the NOAA Administrator work with NSF (National Science Foundation) and international partners to share and expand the use of GNSS (Global Navigation Satellite System) to determine fault rupture extent and movement.

NOAA Response: NOAA concurs with this recommendation. The NOAA Tsunami Program is actively working with the USGS and the National Aeronautics and Space Administration to operationalize a GNSS-based earthquake and tsunami characterization capability at NOAA's TWCs. This capability is expected to be tested in operations in Calendar Year (CY) 2023, and will be incorporated into the CAS being developed in conjunction with the TWCU effort.

2.4. It is recommended that the NOAA Administrator further consider the use of airborne and satellite observing platforms.

NOAA Response: NOAA concurs with this recommendation. NOAA is actively pursuing airborne and remote-sensing observation platforms for the purpose of tsunami detection and measurement as R&D resources permit. This data will be made available to TWC Duty Scientists through the CAS being developed in conjunction with the TWCU effort.

### **3. Provide More Extensive, Consistent, and Accurate Tsunami Messages and Products**

3.1. It is recommended that the NOAA Administrator improve the integration of TWC warning functions with USGS, state, and local warning needs and functions.

NOAA Response: NOAA concurs with this recommendation. Ongoing dialogue with the USGS regarding capabilities such as ShakeAlert has led to enhanced interagency coordination. There remains an open question of how to integrate Earthquake Early Warning into NOAA tsunami forecasts and warnings, while ensuring messaging consistency. This is an area of ongoing discussion between NOAA, USGS, and state partners.

3.2. It is recommended that the NOAA Administrator improve tsunami message composition and dissemination methods including updating the tsunami.gov website, creating a single domestic bulletin, and early messaging before a tsunami forecast is developed.

NOAA Response: NOAA concurs with this recommendation. The integration of legacy TWC software into AWIPS as part of the TWCU effort is expected to greatly improve the quality of tsunami product generation and messaging. NOAA is actively pursuing a complete tsunami.gov re-design starting in fiscal year (FY) 2023. TWC office procedures are also being reviewed to determine if and how core partners can be provided with additional, early real-time information as TWC duty scientists conduct live tsunami analysis. Regarding the production of a single domestic bulletin, NOAA is evaluating the best way to convey the entirety of the tsunami threat in actionable, consistent terms. Consolidating domestic bulletins is one option being considered.

3.3. It is recommended that the NOAA Administrator make available foundational forecast data from propagation models and inundation model results to constituents.

NOAA Response: NOAA is open to this suggestion. TWC standard operational procedures have to date been careful not to issue speculative information in the typically high-uncertainty, high pressure environment that follows tsunami generation in order to limit confusion. This information is dynamic and can change significantly during an event. With sufficient conditioning, NOAA is open to sharing pre-decisional foundational data and analysis with core partners. NOAA will address this in CY23 through the Warning Coordination Subcommittee (WCS) of the National Tsunami Hazard Mitigation Program (NTHMP).

#### **4. Develop Enhancements to Tsunami Warning Center Forecasts and Alert Systems**

- 4.1. It is recommended that the NOAA Administrator expand granularity in tsunami alert regions where complicated waterways and large bays exist (e.g., Puget Sound, San Francisco Bay)

NOAA Response: NOAA partially agrees with this recommendation. Where sufficient data exists (both temporally and spatially) to support detailed forecasts in complex waterways, NOAA is looking at ways to update the alerting zones to better reflect the state of the science. This will be considered through the NTHMP WCS in CY23. That said, most tsunami sources are not sufficiently constrained, particularly in the near-field, to support high-resolution, non-linear inundation forecasts in complex waterways. In these cases, NOAA thinks it is better to more broadly describe the threat rather than give detailed forecasts unsupported by synoptic scale solutions. Still, a full evaluation of the TWC alerting zones will occur during the transition of legacy software systems to AWIPS as part of the TWCU effort.

- 4.2. It is recommended that the NOAA Administrator update special procedure areas, threat database thresholds, breakpoints, and forecast point locations.

NOAA Response: NOAA partially agrees with this recommendation. As stated in the response to Recommendation 4.1, NOAA must ensure the tsunami source is sufficiently constrained to support high-resolution forecasts. Issuing such forecasts without a properly constrained open-ocean wave field can lead to either excessive over or under warning. In general, NOAA agrees that replacing “procedural” areas with dynamic forecasts and alerts based on real-time data is important as long as this is done carefully and in full consultation with core partners. This will be addressed by the NTHMP WCS in CY23. Changes in product or message generation will be enabled through the transition to AWIPS as part of the TWCU effort.

#### **5. Improve Consistency in Tsunami Preparedness and Mitigation Products for Communities**

- 5.1. It is recommended that the NOAA Administrator develop a standardized framework for characterizing, selecting, and using consistent tsunami sources between states.

NOAA Response: NOAA is open to this suggestion, though it does not have the sole authority to implement it. NTHMP member states and territories are responsible for developing tsunami emergency response plans to include expected inundation lines and evacuation maps. NOAA will work with the NTHMP Modeling and Mapping Subcommittee (MMS) to evaluate the value of establishing common source parameters to be used by all states and territories, understanding that risk assessments may vary.

- 5.2. It is recommended that the NOAA Administrator improve guidelines for evacuation maps that ensures consistency between states/communities and develop a national online repository.

NOAA Response: NOAA is open to this suggestion, though it does not have the sole authority to implement it. Evacuation maps are established at the state level and providing common guidelines for their construction is potentially valuable. This will be addressed in CY23 within the NTHMP MMS.

- 5.3. It is recommended that the NOAA Administrator prioritize probabilistic tsunami hazard mapping at a national scale, especially for updating ASCE/Building Code “Tsunami Design Zone” maps.

NOAA Response: NOAA is open to this suggestion. To date, specific engineering values related to building codes has been outside the scope of the NOAA Tsunami Program, but NOAA understands the value in a national probabilistic database to support common design and construction concerns. NOAA will raise this issue within the appropriate NTHMP subcommittees, as well through consultation with Department of Homeland Security and National Institute of Standards and Technology, and consider further actions as resources permit.

## **6. Produce Guidance for Improving Long-Term Community Resilience to Tsunami Hazards**

- 6.1. It is recommended that the NOAA Administrator develop guidance and products for tsunami mitigation/recovery consistent with and leveraging climate change adaptation strategies

NOAA Response: NOAA is open to this suggestion, though sees this as falling largely outside of the tsunami program. While climate change certainly contributes to tsunami impacts, it does not directly impact NOAA’s detection, forecast, and alerting capability. NOAA will discuss potential next steps with the Office of Oceanic and Atmospheric Research and National Ocean Service leadership.

- 6.2. It is recommended that the NOAA Administrator conduct evacuation modeling, feasibility studies, and risk analyses for vertical evacuation structures.

NOAA Response: NOAA is open to this suggestion, though primary execution of this action would take place primarily outside of NOAA. Vertical evacuation is an important consideration of a comprehensive tsunami impact mitigation strategy. NOAA will work with NTHMP Partners and other government and industry experts, as resources allow, to explore establishing common standards. NOAA will also encourage states to consider incorporating vertical evacuation studies in their NTHMP grant proposals.

## **7. Improve Tsunami Hydrodynamic Modeling**

- 7.1. It is recommended that the NOAA Administrator improve tsunami modeling capabilities in the following conditions/areas: variable landscapes (i.e., surface roughness), heavy vegetation, built environment, and dynamic river systems.



NOAA Response: NOAA partially concurs with this recommendation. As stated in the responses to recommendations 4.1, and 4.2, NOAA must match high-resolution flooding models to the fidelity of deep ocean propagation models in order to provide acute, actionable alerts. The type of fine-scale modeling suggested here would normally be outside NOAA’s operational alerting scale. That said, this scale of modeling can be useful for emergency management planners. NOAA will look for opportunities to partner with NTHMP member states and territories to advance this scale of modeling capability as resources permit.

7.2. It is recommended that the NOAA Administrator conduct a greater number of high-resolution bathymetric surveys.

NOAA Response: NOAA concurs with this recommendation, and will address as resources permit. NOAA has a well-defined procedure, led by the National Ocean Service and the National Weather Service Office of Water Prediction, for establishing priorities for bathymetric surveys. With increasing emphasis on terrestrial and coastal flooding, this will include areas important for tsunami warning and mitigation. We will ensure the concerns of the TSTAP are emphasized in future year budget and program planning processes.

7.3. It is recommended that the NOAA Administrator develop a data portal for detailed information for advancing research and model development.

NOAA Response: NOAA concurs with this recommendation and will look to provide this sort of portal in FY23 through the Office of Oceanic and Atmospheric Research.

## **8. Develop Tsunami Research Priorities and Leverage Research Opportunities**

8.1. It is recommended that the NOAA Administrator coordinate with Federal, state, and territory agencies that fund research that includes tsunami to leverage and prioritize research opportunities and provide consistent and useful products.

NOAA Response: NOAA concurs with this suggestion. This will be raised as an agenda item with the Interagency Council for Advancing Meteorological Services as a potential Interagency working group.