Independent Evaluation of the National Oceanic and Atmospheric Administration's National Weather Service Tornado Forecasting and Warning Services

Jennifer L. Bewley, Ayeisha A. Brinson, R. Abraham Holland, Anusuya Sivaram, Roxana Leal, John E. Sabatini, Kelsey R. Stanley, Katherine CS Ross

July 2025 | IDA Product 3002824

Approved for public release: distribution is unlimited.

Systems and Analyses Center
730 East Glebe Road
Alexandria, VA 22305-3086

The Institute for Defense Analyses is a nonprofit corporation that operates three federally funded research and development centers. Its mission is to answer the most challenging U.S. security and science policy questions with objective analysis, leveraging extraordinary scientific, technical and analytic expertise.

The Systems and Analyses Center conducted this work under contract HQ0034-19-D-0001, EC-7-5341, "Independent Evaluation of National Oceanic and Atmospheric Administration's National Weather Service Tornado Forecasting, Prediction, and Warning Performance," for the Office of Inspector General, U.S. Department of Commerce. The views, opinions, and findings should not be construed as representing the official position of the U.S. government or the Department of Defense.

© 2025, Institute for Defense Analyses
730 East Glebe Road, Alexandria, Virginia 22305-3086 | (703) 845-2000

This material may be reproduced by or for the U.S. government pursuant to the copyright license under the clause at DFARS 252.227-7013 (Feb. 2014).

Jennifer L. Bewley, Project Leader
jbewley@ida.org, (703) 845-2390

Julie E. Hunter, Director, Cost Analyses and Research Division
jhunter@ida.org, (703) 575-4686

James F. Heagy, Thomas D. Olszewski, and W. Patrick Luan were the technical reviewers for this product. A special thank you to Anton Seimon of Center for Environmental Policy for an external review.

Report Highlights

What We Evaluated

Our objective was to assess National Weather Service (NWS) tornado forecasting and warning performance and identify potential opportunities for enhanced effectiveness.

Why This Matters

The goal of the Weather Research and Forecasting Innovation Act of 2017 ("Weather Act") was to improve the National Oceanic and Atmospheric Administration's (NOAA) weather forecasts and predictions of high-impact weather events, including tornadoes. Section 103 of the Weather Act mandated the creation of a Tornado Warning Improvement and Extension Program (TWIEP). This evaluation measured NOAA's progress toward meeting the TWIEP's goal to "reduce the loss of life and economic losses from tornadoes through the development and extension of accurate, effective, and timely forecasts, predictions, and warnings, including the prediction of tornadoes one hour in advance."[1]

What We Found

Since fiscal year (FY) 2011, the NWS has achieved its Government Performance and Results Act (GPRA) performance goal for false alarm ratio in 9 of the last 12 years. However, the NWS has consistently fallen short of meeting performance goals for probability of detection and warning lead times for this same time period. In addition to the NWS's limited effectiveness in forecasting and warning performance, NOAA lacks official outcome metrics to assess progress toward the TWIEP goal of reducing the loss of life and economic losses from tornadoes, leaving this goal unmet without further improvements. Specifically, we found that:

- Improvements are needed in NOAA's plan for achieving the TWIEP goal defined in the Weather Act.
- NOAA does not adequately assess the effectiveness of efforts to improve tornado forecast operations.

[1] Weather Research and Forecasting Innovation Act of 2017, 115th Congress, Public Law 115-25 at 4 (April 18, 2017), accessed September 30, 2024, https://www.congress.gov/115/statute/STATUTE-131/STATUTE-131-Pg91.pdf.

- NOAA does not assess the effectiveness of its tornado forecast research enterprise.
- NOAA does not assess the effectiveness of NWS risk communication efforts for tornado watches and warnings.

- The public-facing GPRA lead-time metric definition is inaccurate, affecting the interpretation and assessment of NWS performance.

What We Recommend

To address shortfalls, we recommend NOAA consider the following six recommendations: 1) develop an implementation plan on how to achieve the TWIEP Plan's activities; 2) develop loss of life and economic loss performance metrics to support performance development; 3) revise existing policies to evaluate the operational performance impacts associated with research investments; 4) conduct an assessment of how impact-based decision support services (IDSS) risk communication efforts for tornado watches and warnings affect the public's actions to reduce loss of life and property; 5) conduct an assessment of existing processes for ensuring the consistent communication of key performance metrics and address identified gaps; 6) conduct an assessment of potential lead-time metrics and determine which approach, or combination of approaches, is best suited for facilitating representative performance assessment and external oversight. NOAA concurred with five of our recommendations, partially concurred with one, and is working to implement them.

Contents

Background

The National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS) mission is to provide "weather, water and climate data, forecasts, warnings, and impact-based decision support services (IDSS) for the protection of life and property and enhancement of the national economy."[1] The Department of Commerce's (DOC) Office of Inspector General (OIG) has oversight responsibility for NOAA's NWS. DOC OIG contracted with the Institute for Defense Analyses (IDA) to assess NWS tornado forecasting and warning performance and identify potential opportunities for enhanced effectiveness.

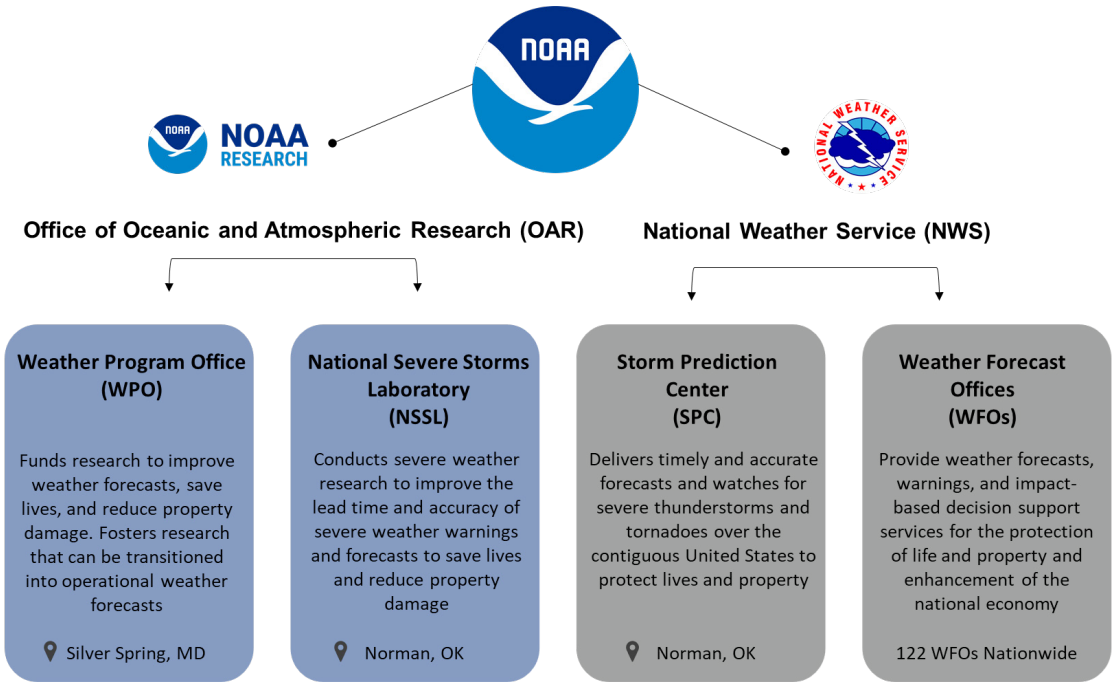
Between fiscal years (FY) 2008 and 2022, the NWS reported approximately 1,400 tornadoes on average each year. The NWS assigns tornadoes a rating based on the Enhanced Fujita (EF) scale: a six-level (0–5) numerical classification of estimated wind speeds based on surveyed damage.[2] The majority of tornadoes in each year were rated EF0 or EF1 (1,170 tornadoes on average per year) and were responsible for light to moderate damage. Severe to devastating tornadoes are rare events. On average, the NWS reported 44 tornadoes rated EF3 or greater per year during the same period.

Several NOAA line offices, including the Office of Oceanic and Atmospheric Research (OAR) and the NWS, play a role in reducing loss of life and economic losses from tornadoes (Figure 1). Within OAR, labs and programs like the National Severe Storms Laboratory (NSSL) and the Weather Program Office (WPO) conduct or fund research to improve lead time and accuracy of severe weather forecasts and warnings. Additionally, the Office of Research, Transition, and Application, which is within OAR, works to integrate research into applications within the NWS and the larger weather enterprise. Finally, the NWS, through its Storm Prediction Center (SPC) and 122 weather forecast offices (WFOs), issues tornado forecasts, watches, and warnings.

---

1 National Weather Service, "NWS Mission," accessed September 30, 2024, https://www.weather.gov/about/, 1.

2 American Meteorological Society, "Glossary of Meteorology: Enhanced Fujita Scale," accessed July 25, 2024, https://glossary.ametsoc.org/wiki/Enhanced_Fujita_Scale, 1.



Source: IDA analysis using NOAA WPO, NOAA NSSL, NOAA's NWS SPC, and NOAA NWS webpages.

Figure 1. Research and Operational Components of NOAA's Tornado Enterprise

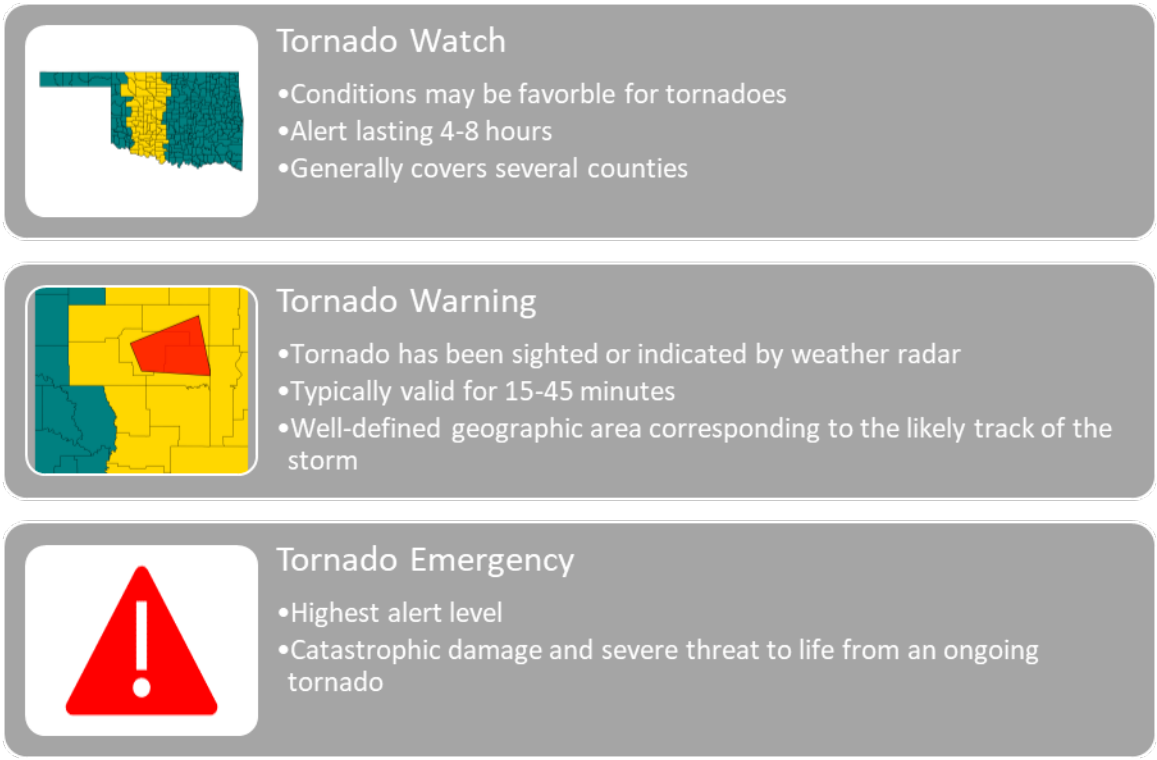
The NWS issues three categories of tornado alerts to the public: Tornado Watch, Tornado Warning, and Tornado Emergency.[3] Figure 2 describes the main characteristics of each type of tornado alert. The SPC issues tornado watches for counties, while tornado warnings and emergencies are issued by the local WFO responsible for the specific area under threat. These tornado watches, warnings, and emergencies provide the public advance notice of tornadoes to protect lives and property.[4] In addition to issuing tornado alerts, the NWS also provides IDSS to core partners,[5] such as local emergency managers, media, and public safety officers. IDSS are forecast advice and interpretive services provided by forecasters who communicate directly with core partners to ensure they have the most up-to-date and accurate weather information to make decisions.

---

3 National Weather Service, "Understand Tornado Alerts: Tornado Terminology," accessed July 18, 2024, https://www.weather.gov/safety/tornado-ww, 1.

4 National Weather Service, "WFO Severe Weather Products Specification," Instruction 10-511 (Silver Spring, MD, 2023), https://www.nws.noaa.gov/directives/sym/pd01005011curr.pdf, 13–25.

5 The NWS defines core partners as governmental and non-governmental users who make decisions that may be affected by weather, water, or climate-related events.



Sources: IDA analysis from multiple sources including National Weather Service Instruction (NWSI) 10-511 *WFO Severe Weather Products Specification* and the NWS "Understand Tornado Alerts: Tornado Terminology" webpage.

Figure 2. Tornado Alerts

Prior to October 1, 2007, WFOs issued county-based tornado warnings. In FY 2008, to increase the geographic precision of these alerts, the NWS introduced storm-based warnings, which outline a warning area within the area under threat that corresponds to the likely track of the storm. This change in warning philosophy included changes to the evaluation methodology of tornado warning performance. In particular, the NWS began assessing the accuracy of its warnings—a process called warning verification—for each tornado event deconstructed into 1-minute segments.

The NWS assesses tornado warning performance across all WFOs using three performance metrics: probability of detection (POD), lead time, and false alarm ratio (FAR). NOAA reports these metrics yearly under the requirements of the Government Performance and Results Act (GPRA) and publishes them on the DOC Citizen's View dashboard[6] as well as in the agency's annual budget. Box 1 defines the current official GPRA metrics for tornado warning performance.

[6] Department of Commerce, "National Oceanic and Atmospheric Administration (NOAA) Citizen's View Dashboard," accessed February 13, 2025, https://performance.commerce.gov/stories/s/NOAA-Performance-Dashboard/2trz-rf9e.

Box 1. GPRA Metrics Definitions Since October 1, 2007

Probability of Detection (POD)

A warned tornado segment is one that occurs within the bounds of a warning area during the valid time of the alert. The Percentage of the Event Warned (PEW) is the proportion of warned segments for a given tornado event. The official POD metric is the mean PEW for all tornadoes occurring nationwide in a given year. The current GPRA goal is greater than or equal to 72%.

Lead Time

Lead time is computed for every 1-minute segment of the tornado track. The lead time of each warned segment is the difference between the warning's time of issuance and the timing of the segment. Each unwarned tornado segment is assigned a zero. The lead time reported for each tornado is the average over all its tornado segments. The official lead-time metric is the yearly national average of this measure. The current GPRA goal is greater than or equal to 13 minutes.

False Alarm Ratio (FAR)

A warning followed by a tornado is considered verified. The FAR is the proportion of unverified warnings, or false alarms, over all warnings issued in a year. The current GPRA goal is less than or equal to 71%.

Sources: NWS *Performance Verification Guide* and GPRA goal data received via a request for information (RFI) on February 29, 2024.

The goal of the Weather Research and Forecasting Innovation Act of 2017 ("Weather Act") was to improve NOAA's weather forecasts and predictions of high-impact weather events through focused investments in weather research.[7] One such event, tornadoes, were addressed in Section 103 of the Weather Act, which mandated the creation of a Tornado Warning Improvement and Extension Program (TWIEP). The program's goal was "to reduce the loss of life and economic losses from tornadoes through the development and extension of accurate, effective, and timely tornado forecasts, predictions, and warnings, including the prediction of tornadoes beyond one hour in advance."[8] To maximize the effectiveness of forecast improvements for tornadoes and other high-impact weather events, Section 406(a) of the Weather Act required that risk communication to the public

[7] *Weather Research and Forecasting Innovation Act of 2017*, Public Law 115-25, 1.

[8] *Id.*, 4.

shall be the NOAA system for issuing watches and warnings.[9] Risk communication alerts the public to hazardous weather and enables them to take actions to prevent the loss of life and property.

[9] *Id.*, 19.

Objective, Findings, and Recommendations

Objective

The objective of this independent evaluation was to assess NWS tornado forecasting and warning performance and identify potential opportunities for enhanced effectiveness. This evaluation used a combination of methods (i.e., quantitative, literature reviews, qualitative, semi-structured interviews, site visits) to assess tornado warning performance since the passage of the Weather Act in 2017 (see Appendix A for additional details on our scope and methodology).

Findings and Recommendations

Since FY 2011, the National Weather Service (NWS) has achieved its GPRA performance goal for false alarm ratio (FAR) in 9 out of the last 12 years. However, it has consistently fallen short of meeting performance goals for probability of detection (POD) and warning lead times during the same period (refer to Appendix B). This performance varied substantially across different Weather Forecast Offices (WFOs), with the lead-time metric failing to account for discrepancies in warnings based on the severity of tornado events (see Other Matters). Despite these performance metrics indicating limited effectiveness in forecasting and warning performance, the NWS has not demonstrated that its tornado forecasting and warning efforts are achieving another key measure of effectiveness-advancing the goal for tornado warning improvement outlined in the Weather Act. Specifically, NOAA lacks official outcome metrics to assess progress toward the TWIEP objective of reducing the loss of life and economic losses from tornadoes, leaving this goal unmet without further improvements. Our evaluation describes three findings and six recommendations that identify potential opportunities for enhanced effectiveness.

1. Finding I: Improvements are needed in NOAA's plan for achieving the TWIEP goal defined in the Weather Act.

Section 103 of the Weather Act required NOAA to develop a program plan that detailed research, development, and technology transfer activities with corresponding resource requirements and timelines needed to achieve the program goal.[10] To fulfil this requirement, NOAA submitted a TWIEP Plan to Congress in 2019 that identified short-

[10] *Id.*, 4.

term (5-year) and long-term (10-year) activities.[11] We found this plan lacked three necessary elements: establishing realistic resource requirements, analyzing execution risks, and creating metrics to assess progress.[12]

Establishing realistic resource requirements. Although Section 103 required the program plan to include information on required resources, the TWIEP Plan did not and instead stated that resource requirements would be included in NOAA's future budget requests and in the annual budget plan.[13] However, prior to 2021, NOAA did not identify personnel or financial resources to accomplish the activities described in the TWIEP Plan. In 2021, Congress appropriated 500,000 dollars per year to OAR via the Verification of the Origins of Rotation in Tornadoes Experiment (VORTEX) USA program.[14] OAR transferred these funds to the WPO, which covered the personnel costs associated with administering tornado research grants unrelated to the TWIEP Plan. There was no dedicated funding left to pursue the activities described in the TWIEP Plan including personnel to monitor the progress of activities.

Analyzing execution risks. The Government Accountability Office (GAO) best practices recommend that agencies identify, analyze, and respond to risks related to achieving their objectives.[15] The TWIEP Plan describes several research activities intended to improve NWS tornado forecast and warning performance when successfully transitioned to NWS operations. While the TWIEP Plan indicated that NOAA would provide more detailed implementation plans that account for risk and uncertainty, none exist. There is also no evidence of an ongoing coordinated effort to address the activities outlined in the TWIEP Plan, including the plan's short-term (5-year) activities for FY 2019–2023. We found 6 of the 10 short-term activities described in the plan remain incomplete.[16]

When asked for an explanation as to why deviations from GAO best practices related to resourcing and risk management exist, the agency responded that developing and

---

[11] National Oceanic and Atmospheric Administration, "Report to Congress: Tornado Warning Improvement and Extension Program Plan" (Washington D.C., 2019), https://repository.library.noaa.gov/view/noaa/22035/noaa_22035_DS1.pdf.

[12] GAO issues comprehensive guidance for effective internal control and project management. We focused on elements which are directly responsible for the agency's failure to meet the Weather Act goal. See, US Government Accountability Office, "Schedule Assessment Guide: Best Practices for Project Schedules," Best Practices GAO-16-89G (Washington D.C., 2015), https://www.gao.gov/products/gao-16-89g, 62.

[13] NOAA, "Report to Congress: Tornado Warning Improvement and Extension Program Plan," 13.

[14] U.S. Congress, "Joint Explanatory Statement, Division B—Commerce, Justice, Science and related Agencies Appropriations Act 2021" (Washington D.C., 2020), https://docs.house.gov/billsthisweek/20201221/BILLS-116RCP68-JES-DIVISION-B.pdf.

[15] U.S. Government Accountability Office, "Standards for Internal Control in the Federal Government" GAO-14-704G (Washington D.C., 2014), https://www.gao.gov/products/gao-14-704g, 43.

[16] This statement is based on a review of the status of the short-term activities as of August 2024.

executing detailed plans and relevant control activities to ensure the implementation of the TWIEP Plan would require a full-time position which is currently not funded.

Creating metrics to assess progress. Monitoring outcome metrics is important for evaluating performance and assessing progress toward program goals. The Government Performance and Results Modernization Act of 2010 suggests agencies establish a balanced set of performance metrics including outcome metrics.[17] NOAA can measure its progress toward the program goal of extending the prediction of tornadoes beyond 1 hour in advance by monitoring the GPRA lead-time metric. However, NOAA has no official outcome metrics for assessing progress toward the program goal of reducing loss of life and economic losses from tornadoes.[18] NWS staff cited the limited control over the impact of tornado events (e.g., loss of life, economic losses) and the annual variability of extreme events that cause the most damage and injuries as justification for not including outcomes in its performance measurement. However, for other agencies pursuing goals that can be influenced by factors beyond their control, employing a mix of metrics (i.e., metrics related to outcomes for which an agency has limited control as well as metrics related to intermediate outputs where the agency has greater control over performance) is a common practice.[19]

Recommendations

We recommend the NOAA Deputy Under Secretary for Operations direct the Assistant Administrators for the NWS and OAR to:

1. Develop a detailed implementation plan on how to achieve the TWIEP Plan's activities using time-bound goals with clear resource expectations, relevant control activities, and performance measures.
2. Develop loss of life and economic loss performance metrics to support performance assessment.

---

[17] GPRA Modernization Act of 2010, 111th Congress, Public Law 111–352 at 5 (January 4, 2011), accessed February 20, 2024, https://www.congress.gov/111/plaws/publ352/PLAW-111publ352.pdf.

[18] While the NWS performs post-event surveys to verify tornado reports, NWS staff stated that existing economic loss and loss of life data are appropriate for research and informational purposes only due to concerns over data completeness and quality. Staff also reported that the ability for a WFO to obtain official or estimated data varied significantly from one jurisdiction to another, and there was no centralized or official government mechanism for these data to be recorded and/or received.

[19] U.S. Government Accountability Office, "Managing for Results: Measuring Program Results That Are Under Limited Federal Control" GGD-99-16 (Washington D.C., 1998), https://www.gao.gov/products/ggd-99-16, 3.

2. Finding II: NOAA does not adequately assess the effectiveness of efforts to improve tornado forecast operations.

Improving NWS tornado forecast and warning performance relies on the successful completion and transition of the activities described in the TWIEP Plan from research to NWS operations. To maximize the benefit of improved tornado forecasts and warnings, the NWS uses risk communication to the public to inform decisions to prevent the loss of life and property. Multiple statutes and executive branch actions have affirmed the need for systematic program evaluation and evidence-based policymaking in federal agencies.[20] We highlight two distinct challenges related to these needs. Finding IIa addresses the impact of NOAA's tornado forecast research investments on its own operations, while Finding IIb focuses on NWS risk communication efforts. Deficiencies in these areas have two consequences: (1) NOAA management lacks the capability to assess the effect of research and development investments on tornado forecast quality, and (2) intended improvements in NWS risk communication efforts may not lead to better decision-making among the public to prevent the loss of life and property.

Finding IIa: NOAA does not assess the effectiveness of its tornado forecast research enterprise.

The GAO defines program effectiveness as the extent to which a program is achieving its intended goals.[21] NOAA research and development organizations within OAR that support tornado-related research, such as WPO and NSSL, describe their mission in terms of improving NWS operational performance. NOAA's ability to assess the performance impacts of research once it has transitioned to NWS operations is essential for evaluating the impact of the agency's research investments on tornado forecast quality.

NOAA's policy on research and development transitions does not include guidance on post-deployment performance evaluation. This means that NOAA neither evaluated nor measured the performance impacts for research that transitioned to NWS operations. Other NWS policies related to performance verification, system modification, and termination of products also do not reference research and development transitions or discuss the

---

[20] U.S. Government Accountability Office, "Program Evaluation: Key Terms and Concepts" GAO-21-404SP (Washington D.C., 2021), https://www.gao.gov/assets/gao-21-404sp.pdf, 3.

[21] GAO, "Program Evaluation: Key Terms and Concepts," 5.

evaluation of specific research and development investments.[22] When asked about this apparent evaluation gap, agency officials noted that the expertise to support a post-implementation evaluation task does not exist at NOAA.

NOAA's OAR is the primary organization for sponsoring NWS operations-relevant research.[23] OAR-sponsored research can impact NWS operations in at least two ways:

- The research to operations (R2O) process. The R2O process is the transition of research and development projects into operational use with the goal of improving operational capabilities, such as tornado forecasts. OAR identified 10 tornado-related research projects that have transitioned to operations since 2020. However, the NWS did not evaluate or measure the impact of these projects on operational performance.
- The research to applications (R2A) process. The R2A process is more general than the R2O process. It is the transition of research and development projects into operational applications, such as a system, process, product, service, or tool. OAR could not identify research projects that may have transitioned to applications and as a result, the associated impact on NWS operational performance is unknown. When asked why this is the case, the OAR team stated they do not systematically track R2A transitions.

In addition, NOAA's Research and Development Database (NRDD) is the official resource for monitoring NOAA's research portfolio. Despite policy requiring NOAA-wide participation since 2016 and efforts to improve data quality, current NRDD documentation says that NRDD data are limited by incomplete data entry and participation across

---

[22] This statement references four specific policies: National Oceanic and Atmospheric Administration, "Policy on Research and Development Transitions," Administrative Order NAO 216-105B (Silver Spring, MD, 2016), https://www.noaa.gov/organization/administration/nao-216-105b-policy-on-research-and-development-transitions; National Weather Service, "Products and Services Change Management," Instruction 10-102 (Silver Spring, MD, 2018), https://www.nws.noaa.gov/directives/sym/pd01001002curr.pdf; National Weather Service, "Verification," Instruction 10-1601 (Silver Spring, MD, 2022), https://www.weather.gov/media/directives/010_pdfs/pd01016001curr.pdf; National Weather Service, "Termination of NWS Information Services," Instruction 1-1002 (Silver Spring, MD, 2022), https://www.nws.noaa.gov/directives/sym/pd00110002curr.pdf.

[23] An example of operations in NOAA includes "weather and climate forecast models run on a routine basis to provide forecast guidance or seasonal outlooks." Examples of applications include "information products, assessments and tools used in decision-making and resource management." R2O and R2A processes and terms are defined in NOAA, "Policy on Research and Development Transitions," 1; National Oceanic and Atmospheric Administration (NOAA) Office of the Chief Scientist, "NAO 216-105B Procedural Handbook: Policy on Research and Development Transitions" (National Oceanic and Atmospheric Administration (NOAA) Office of the Chief Scientist, 2017), https://www.noaa.gov/sites/default/files/legacy/document/2020/Mar/Handbook_NAO216-105B_03-21-17.pdf, 3.

NOAA.[24] NRDD's challenges extend to tornado-related research; one of OAR's 10 projects that transitioned to operations does not appear in the NRDD database.[25] NOAA cannot assess the effectiveness of its research investments on tornado forecast quality if it does not measure performance impacts.

Recommendation

We recommend the NOAA Deputy Under Secretary for Operations direct the Assistant Administrators for the NWS and OAR to:

3. Revise existing policies (e.g., Policy on Research and Development Transitions, Products and Services Change Management, Verification, and Termination of NWS Information Services) to evaluate the operational performance impacts associated with research investments that have transitioned to operations.

Finding IIb: NOAA does not assess the effectiveness of NWS risk communication efforts for tornado watches and warnings.

In 2013, the NWS implemented a new policy, IDSS, to help improve societal outcomes following weather events. The NWS uses IDSS to provide timely and relevant weather information and assistance to support core partners, such as emergency managers, public safety officers, and media, as they make decisions to protect life and property when under a tornado alert. In 2017, Section 406(a) of the Weather Act codified IDSS as the system for providing risk communication to the public.[26] The NWS IDSS Policy Directive identified core partners,[27] and not the public, as the main customers for IDSS activities.[28] Targeting core partners as intermediaries to fulfill Section 406(a) for tornadoes requires core partners to have the capability to inform the public. There are no assessments of how core partners' activities affect societal outcomes, nor are there measurements of the public's response to tornado warnings. Agency officials noted that a formal, quantitative

---

[24] NOAA Research and Development Enterprise Committee, "NOAA Research & Development Database: About NRDD," National Oceanic and Atmospheric Administration (NOAA), accessed October 30, 2024, https://researchprojects.noaa.gov/Welcome/Information/About.aspx, 1–2.

[25] This statement is based on a review of the NRDD database as of May 28, 2024.

[26] *Weather Research and Forecasting Innovation Act of 2017*, Public Law 115-25, 19.

[27] Using a sample of WFO core partner lists provided by the NWS, we identified the majority of WFO core partners as emergency managers and government partners (local, state, and other federal agencies).

[28] National Weather Service, "Operations and Services: Impact-Based Decision Support Services," Policy Directive 10-24 (Silver Spring, MD, 2024), https://www.nws.noaa.gov/directives/sym/pd01024curr.pdf, 2.

metric on the direct impact of NWS communications was not within staffing and resourcing capabilities.[29]

During our fieldwork, we found that the NWS does not have data on the public's response to NWS messaging and communication, but it does conduct post-storm analysis with core partners for individual events.[30] These post-event activities are used to identify challenges and opportunities associated with communication and messaging of weather information for the individual event. NWS officials planned to conduct a survey for core partners intended to measure the effectiveness of IDSS communications. However, we analyzed the proposed survey questions and concluded they are not structured to evaluate the public's response to tornado warnings. Without data on the public's response, the NWS cannot measure the effectiveness of its IDSS risk communications strategy for the prevention of loss of life and property.

Recommendation

We recommend the NOAA Deputy Under Secretary for Operations direct the Assistant Administrators for the NWS and OAR to:

4. Conduct an assessment of how IDSS risk communication efforts for tornado watches and warnings affect the public's actions to reduce loss of life or property, and revise the IDSS Policy Directive as appropriate.

3. Finding III: The public-facing GPRA lead-time metric definition is inaccurate, affecting the interpretation and assessment of NWS performance.

The GPRA tornado warning lead-time metric is one of three metrics the NWS uses to assess tornado warning performance across WFOs. NOAA reports this and other metrics yearly, per the requirements of GPRA, and publishes them on the DOC Citizen's View dashboard and in the agency's annual budget. GAO standards recommend agencies share accurate information with members of the federal government and the public.[31] We found that public-facing information on the GPRA tornado warning lead-time metric fell short of this standard because the method used to calculate the metric does not match the definition used to describe the metric. This discrepancy affects the public's interpretation of NWS tornado warning performance and systematically overstates NWS warning performance.

---

[29] We were unable to further assess the effectiveness of core partners' activities for the public because a more comprehensive analysis of NWS core partners and their activities was beyond the scope of this evaluation.

[30] Examples include: local/regional After Action-Reports, WFO Integrated Warning Team Meetings, or national/regional Service Assessments.

[31] GAO, "Standards for Internal Control in the Federal Government," 66; GAO, "Standards for Internal Control in the Federal Government," 69.

Since FY 2008, the NWS has calculated the GPRA lead-time metric based on a definition found in internal guidance, but publicly portrayed those results as coming from a different lead-time metric calculation method used prior to that year. These two calculation methods have different definitions and interpretations (see Table 1). As an example, the public-facing DOC Citizen's View dashboard defines the calculation method for tornado warning lead time as "the difference between the time the warning was issued and the time the tornado occurred […] in minutes." However, the dashboard presents performance data calculated using a different method based on a different definition of lead time.[32] This discrepancy also exists in every congressional budget submission, performance report, and performance plan since FY 2008.

An internal NWS guidance document defines the actual calculation method. The NWS divides a tornado event into 1-minute segments and then averages lead time across all segments.[33] The metric defined in internal guidance is equivalent to the *average lead time of a tornado segment (average lead time)*, while the metric definition used in public documents is consistent with the *initial lead time of a tornado event (initial lead time).* The origin of the divergence between these calculation methods began during the FY 2008 transition from the county-based warning era to the storm-based warning era. We did not find any documentation on NWS' rationale for adopting a different lead time calculation methodology.[34]

Table 1. GPRA Tornado Warning Lead-Time Metric

	Prior to FY 2008	After FY 2008
Description	Initial lead time of a tornado event	Average lead time of a tornado segment
Definition	The difference between the time the warning was issued and the time the tornado occurred […] in minutes	The NWS divides a tornado event into 1-minute segments and then averages lead time across all segments
Warning era	County-based warning era	Storm-based warning era
Lead time for a tornado warning issued *after* the tornado is on the ground	0 minutes	Greater than 0 minutes

Sources: IDA analysis using NWS *Performance Verification Guide* and DOC Citizen's View dashboard.

[32] Department of Commerce, "Severe Weather Warnings for Tornadoes: Storm Based Lead Time," National Oceanic and Atmospheric Administration (NOAA), accessed May 20, 2024, https://performance.commerce.gov/KPI-NOAA/NOAA-Severe-weather-warnings-for-tornadoes-Storm-b/ysdv-8h2r, 1.

[33] National Weather Service, *Verification Procedure Reference Guide* (2020), 9. The *Verification Procedure Reference Guide* is not available publicly.

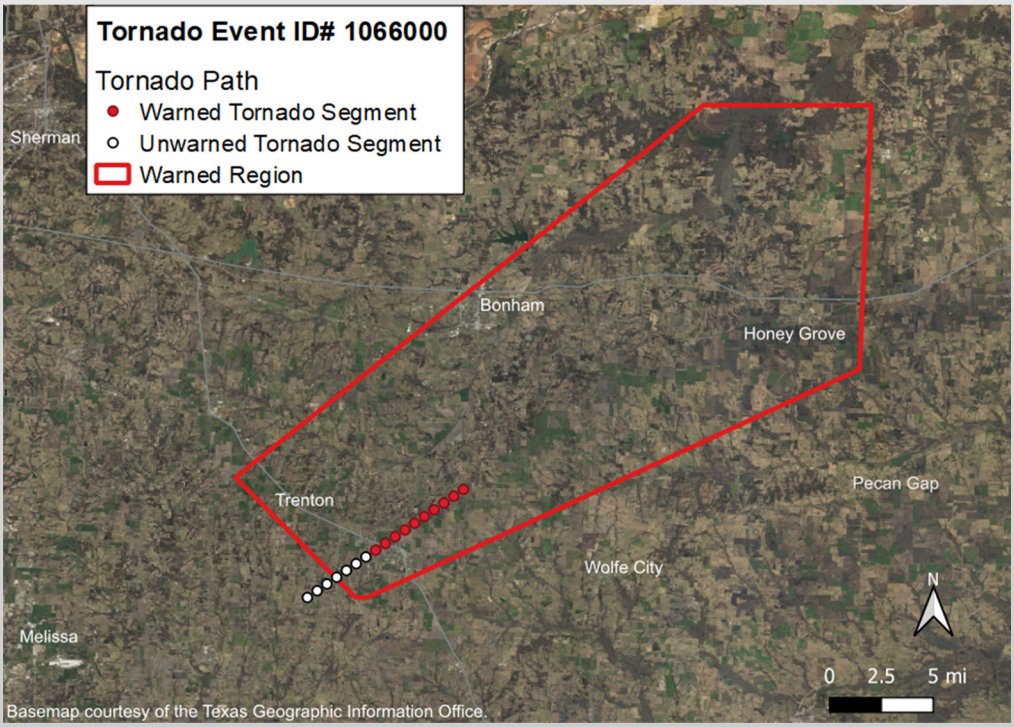
[34] While NOAA reports the average lead time of a tornado segment as the official GPRA lead-time metric, NWS personnel stated that their internal management tracking system tracks both average lead time and initial lead time.

This difference in definitions affects the interpretation of NWS tornado warning performance. Using the *average lead time* calculation method from internal guidance, only completely (or nearly completely) unwarned tornadoes can have 0-minute lead times. This means that a tornado warning issued after a tornado is on the ground will have an *initial lead time* equal to zero and an *average lead time* greater than zero. Box 2 (below) uses a case study to illustrate these differences in interpretation between these two metrics.

In terms of NWS tornado warning performance, the *average lead time* metric (the official GPRA lead-time metric since FY 2008) showed a 12 percent (0.85 minutes) improvement in NWS performance compared to the *initial lead time* calculation method because of the difference in definitions (Figure 4). Public-facing information on the GPRA lead-time metric displays the *initial lead time* definition while reporting metrics are computed using the *average lead time*. In other words, NOAA continued to use the lead-time metric definition from before the transition to the storm-based warning era at the beginning of FY 2008 on public-facing websites and reports, systematically overstating NWS warning performance.

Box 2. A Case Study of Initial and Official Lead-Time Metric Differences

On December 13, 2022, the NWS reported an EF2 tornado in the Dallas/Fort Worth WFO region (Figure 3). This event was part of an outbreak of 16 tornadoes in the northern half of the WFO's area of responsibility. The outbreak resulted in nine injuries.

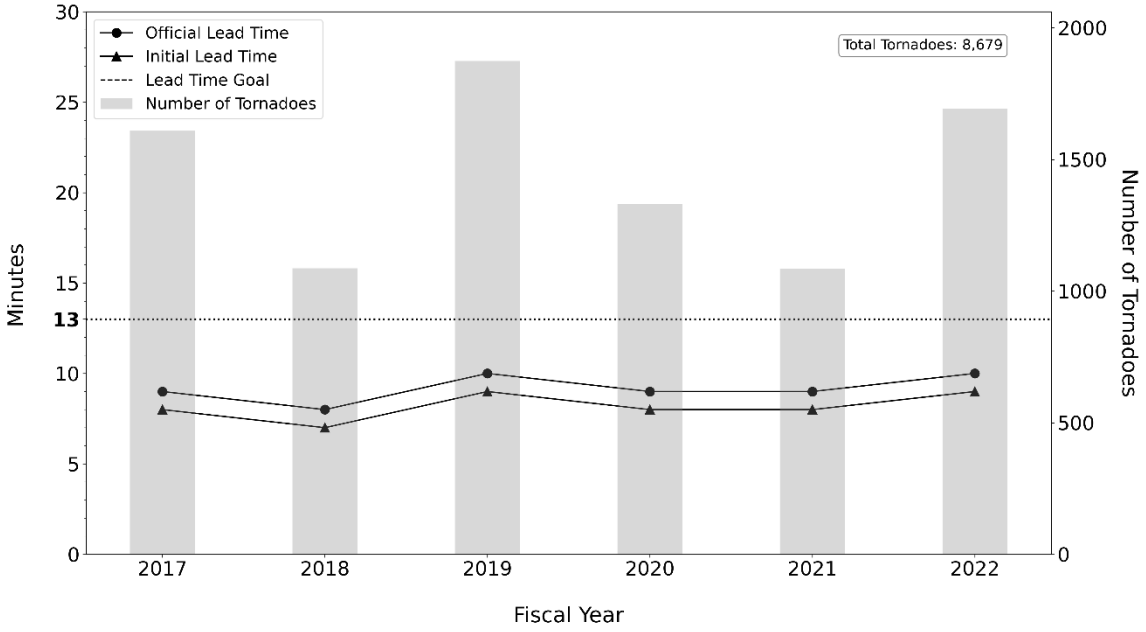


Source: NWS Performance Management Database - https://verification.nws.noaa.gov/services/public/index.aspx.

Notes: White markers represent an unwarned event segment. Red markers represent warned event segments. The red shape represents the warned area for this event.

Figure 3. NWS Performance Database Entry for Tornado Event ID# 1066000

The tornado in Figure 3 was on the ground for 16 minutes. A warning was issued 7 minutes **after** the tornado touched down. The *initial lead time* for this event is 0 minutes. The *average lead time* (the official GPRA lead-time metric since FY 2008) for this event is 2.65 minutes.



Source: IDA analysis using tornado event and WFO warnings data received via RFI on November 3, 2023.

Figure 4. Comparison of Official and Initial Lead-Time Metrics Since 2017

Recommendations

We recommend the NOAA Deputy Under Secretary for Operations direct the Assistant Administrator for OAR to:

5. Conduct an assessment of existing processes for ensuring the consistent communication of key performance metrics and address identified gaps, such as the inaccurate public-facing GPRA tornado lead-time metric definition.
6. Conduct an assessment of potential lead-time metrics and determine which approach, or combination of approaches, is best suited for facilitating representative performance assessment and external oversight.

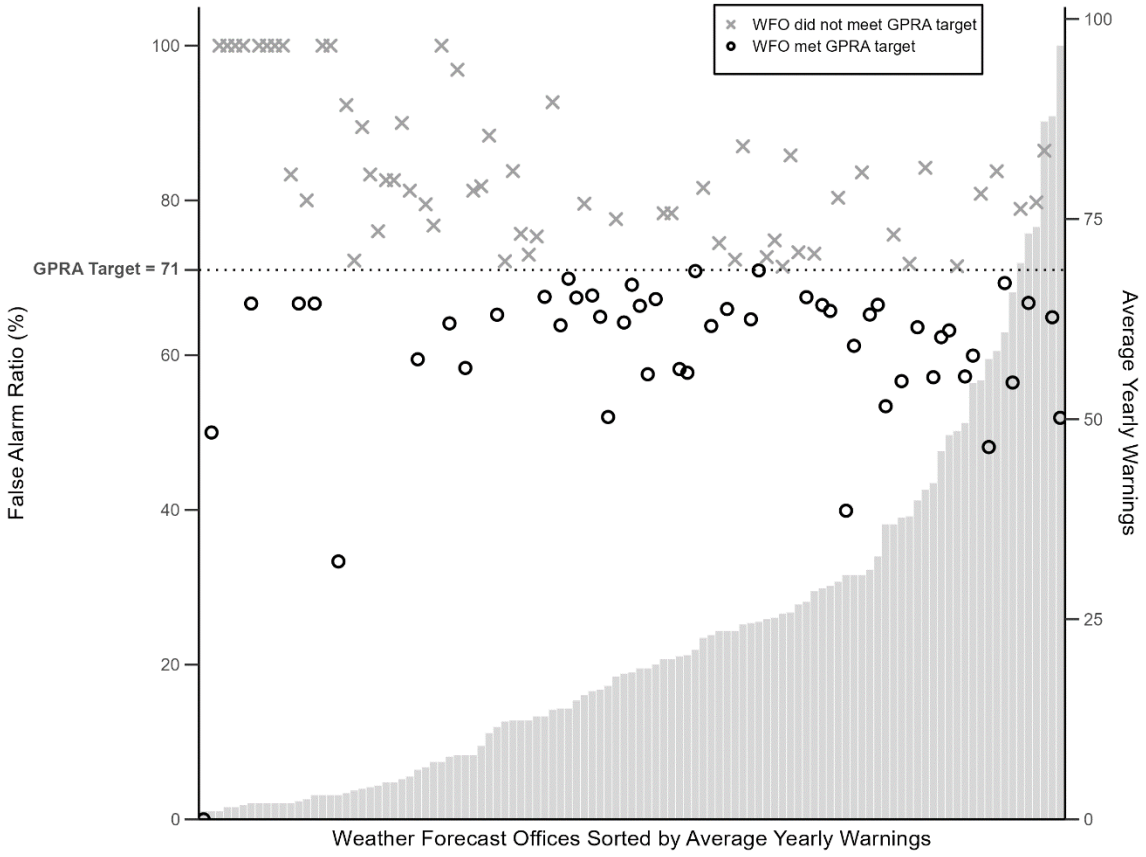
Other Matters

WFOs have significant variation in tornado warning performance.

In its 2023–2033 strategic plan, the NWS identified a goal to "Ensure the National Weather Service remains indispensable and a global leader in equitable weather, water, and climate services to build a Weather-Ready and Climate-Ready Nation."[35] Between 2017

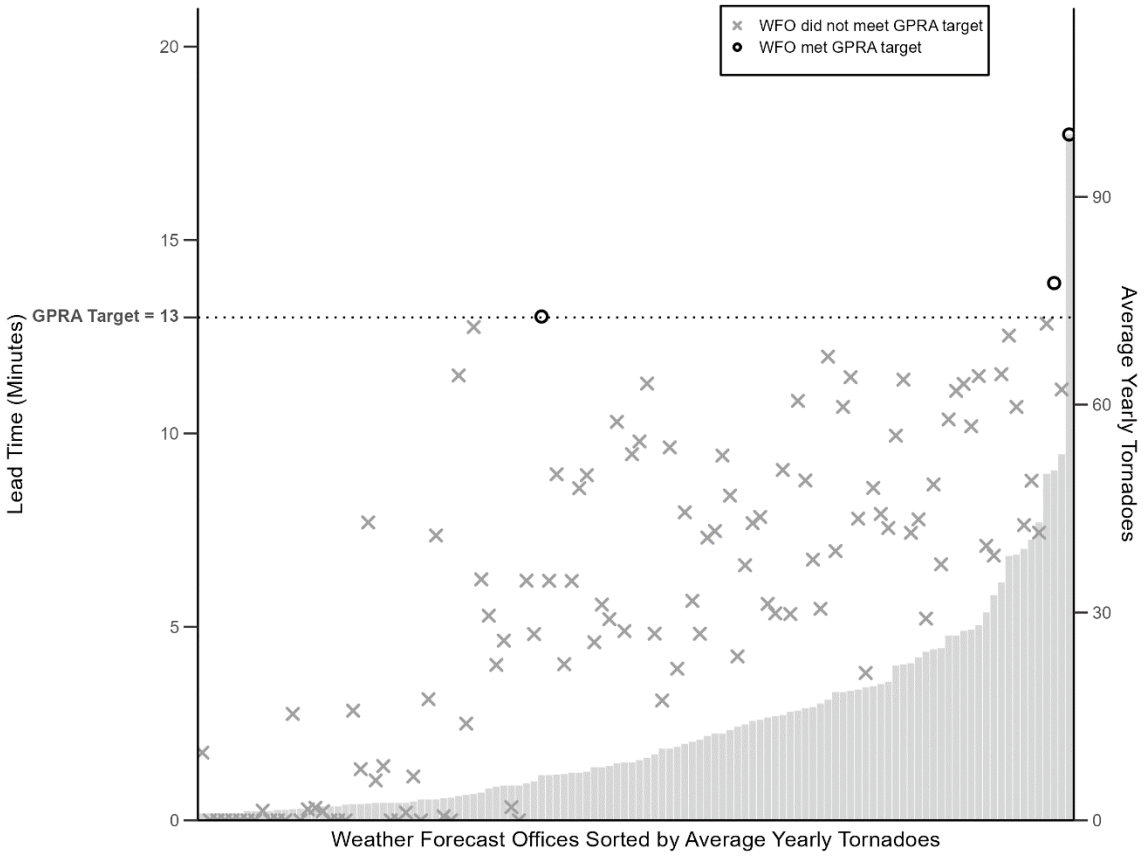
[35] National Weather Service, "2023-2033 Strategic Plan" (Silver Spring, MD, 2023), https://www.weather.gov/media/wrn/NWS-2023-Strategic-Plan.pdf, 6.

and 2022, average yearly WFO performance on the three GPRA metrics related to tornadoes (POD, FAR, lead time) varied, even between locations with similar rates of tornadoes. Figure 5 to Figure 7 illustrate the differences in average yearly performance between WFOs on each GPRA metric. We have not identified the source of this variation; forecaster experience, training, and staffing may play a role, as might other factors. These differences illustrate that Americans are not receiving the same level of tornado warning performance across the United States.



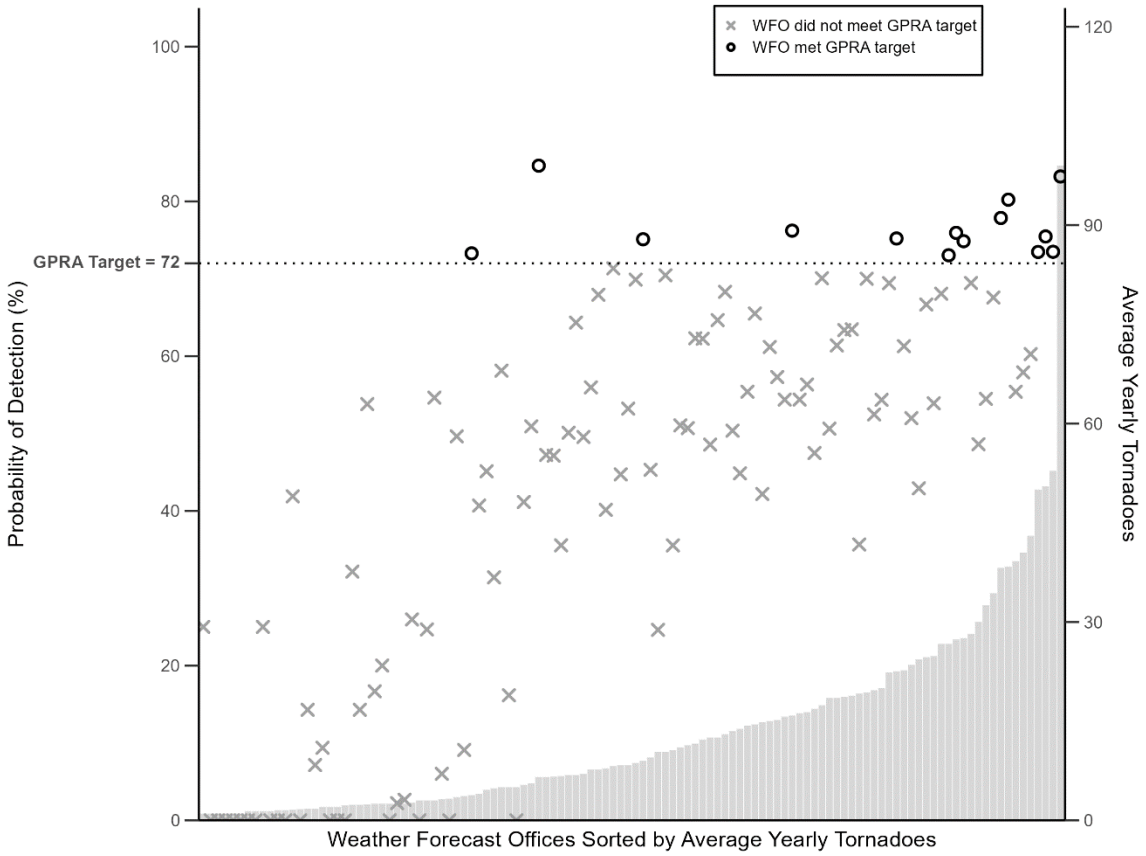
Source: IDA analysis using tornado event and WFO warnings data received via RFI on November 3, 2023.

Figure 5. Average Yearly False Alarm Ratio (FAR) by WFO, 2017–2022, Average Number of Warnings Issued Per Year by WFO Plotted in Shaded Bars



Source: IDA analysis using tornado event and WFO warnings data received via RFI on November 3, 2023.

Figure 6. Average Yearly Lead Time by WFO, 2017–2022, Average Number of Tornadoes Per Year by WFO Plotted in Shaded Bars



Source: IDA analysis using tornado event and WFO warnings data received via RFI on November 3, 2023.

Figure 7. Average Yearly Probability of Detection (POD) by WFO, 2017–2022, Average Number of Tornadoes Per Year by WFO Plotted in Shaded Bars

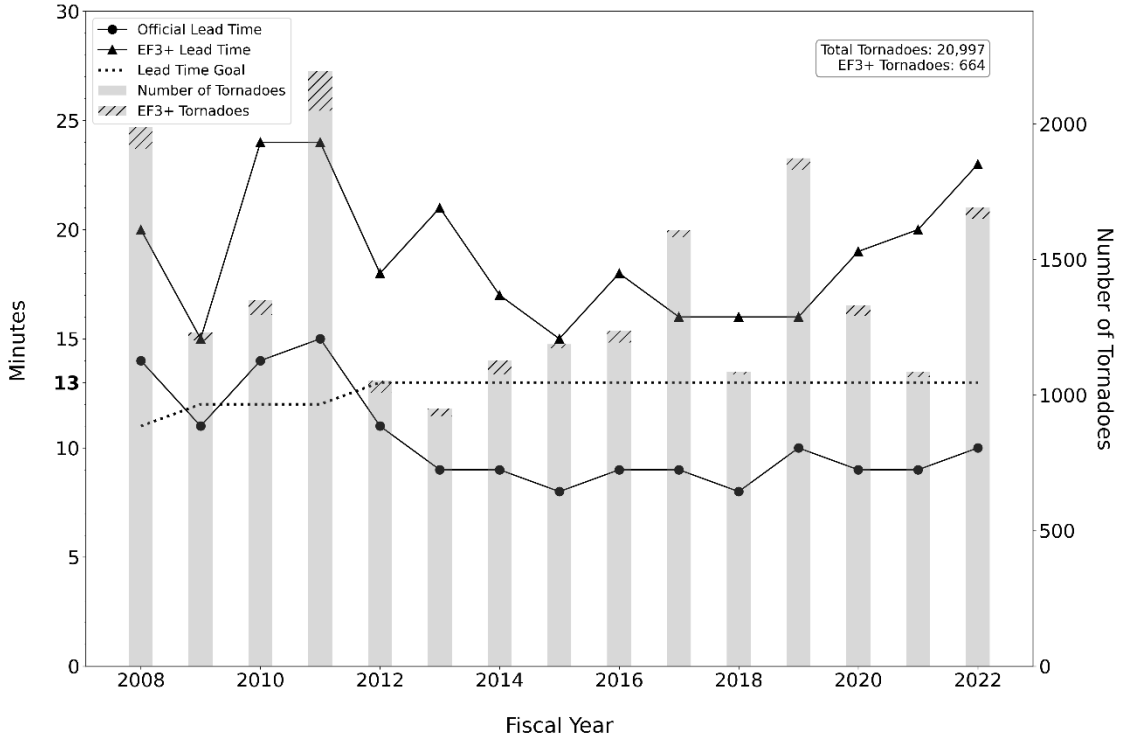
The current GPRA lead-time metric obscures opportunities for improvement in NWS performance.

Quality information is necessary for effective internal control, and to support informed decisions and evaluate performance.[36] The current lead-time metric obscures opportunities for improvement in NWS performance because it combines tornadoes of varying severity, multiple aspects of NWS performance, and factors unrelated to NWS performance into a single metric. This creates challenges for informing decisions and evaluating performance, especially for the most damaging and deadly tornado events (EF3 or greater).

The current lead-time metric combines tornadoes of varying severity. Weaker tornadoes (EF0–EF2), that account for 97 percent of verified tornadoes since 2008, obscure NWS performance for the most damaging and deadly tornadoes (EF3 or greater). As shown

[36] GAO, "Standards for Internal Control in the Federal Government," 66.

in Figure 8, the NWS has met the official lead-time goal for the most damaging and deadly tornado events (EF3 or greater) since 2008, despite not meeting its official lead-time goal since 2011. This performance trend is undetectable when combined with weaker tornadoes (EF0–EF2).



Source: IDA analysis using tornado event and WFO warnings data received via RFI on November 3, 2023.

Figure 8. Official Lead Time for Tornadoes Since 2008

The official lead-time metric combines multiple aspects of NWS performance and factors unrelated to NWS performance. It combines the time between the issuance of the warning and the time the tornado occurred, the POD, and the duration of the tornado event (see Finding III for formal definition and Box 2 for a detailed example). As a result, changes in lead-time performance are obscured by changes in either POD or tornado duration. For tornadoes fully warned (i.e., the tornado warning is issued before the tornado occurred),[37] every minute of additional tornado duration increases average lead time by 30 seconds. This effect, unrelated to NWS performance, is a consequence of the method used to calculate the official metric where each tornado is composed of 1-minute segments. Although the official lead-time metric accurately represents the average lead time for an

[37] Tornadoes with multiple warnings can have their lead-time numbers reset during the event because of how the NWS reports tornado events and warnings. To maintain the simplicity of the example, we exclude tornadoes with multiple warnings.

individual segment of a tornado, its sensitivity to tornado duration and other aspects of performance like POD, obscures opportunities for improvement in NWS performance, especially for tornadoes of varying severity.

Summary of Agency Response

NOAA reviewed a draft version of this report and responded to our findings and recommendations. Of the six recommendations in our report, NOAA concurred with five and partially concurred with one. NOAA also described actions it has taken, or plans to take, to address the findings identified in our report.

In NOAA's partial concurrence with recommendation 2, *develop loss of life and economic loss performance metrics to support performance assessment*, NOAA described challenges related to creating these performance metrics. Consistent with our discussion in Finding 1, we agree creating appropriate metrics can be challenging. We also agree with NOAA's stated intention to develop more relevant metrics and explore an agency-wide strategy for performance evaluation. NOAA's complete response is included in this report as Appendix C.

We are pleased that NOAA concurs with our recommendations. We look forward to receiving NOAA's action plan, which will provide details on its corrective actions.

Appendix A.
Objective, Scope, and Methodology

The objective of this evaluation was to assess NWS tornado forecasting and warning performance and identify potential opportunities for enhanced effectiveness. The DOC OIG contracted with IDA to perform this evaluation. The DOC OIG announced the evaluation on August 1, 2023, and we conducted the evaluation from September 2023 through April 2025. We created an evaluation plan containing five subobjectives that DOC OIG representatives accepted on November 2023. Our fieldwork completed in June 2024, and we discussed the findings with the auditee on July 30, 2024, and February 26, 2025.

To assemble evidence sufficient to provide a reasonable basis for the three findings and six recommendations identified in this report, we employed a combination of quantitative and qualitative strategies. To assess NWS tornado forecasting and warning performance, we calculated and evaluated GPRA performance metrics (i.e., FAR, POD, and lead time) for all tornadoes reported from FY 2008 through 2022 using tornado event and WFO warnings data received from the auditee via a request for information (RFI) in November 2023. We verified the GPRA metrics we calculated against those provided by the auditee and reported in official reports and peer-reviewed literature.

We reviewed NWS Policy Directives, NWS internal training course materials, and peer-reviewed literature on NWS tornado forecast performance and the economic impact of tornadoes, and conducted site visits and interviews. The site visits included two NWS WFOs, NWS's SPC, NOAA's NSSL, NWS's Warning Decision Training Division, and the Cooperative Institute for Severe Weather Research. We interviewed personnel from the Performance and Evaluation Branch of the NWS, NWS Portfolio experts from the Office of Management and Budget, researchers in the fields of economics and severe weather, and core partners (i.e., emergency managers and broadcast media).

To identify potential opportunities for enhanced effectiveness, we reviewed several government documents, including: congressional documents (The Weather Act and Final NOAA Budget Appropriations (2017-present)), reports to Congress (TWIEP Plan, Gaps in NEXRAD Radar Coverage, NWS Hazard Simplification Report), GAO documents, agency strategic plans (NOAA, NWS, NSSL, NWS Service Equity Plan), NOAA Administrative Orders (NAO 216-105, NAO 216-105B: Procedural Handbook on Research and Development Transitions), NOAA Response to Report on Radar Gaps, agency (self) assessments (NWS Service Assessments for major events and Southern Region Severe Weather Operations Team Report), 2021 NSSL Lab Review documents,

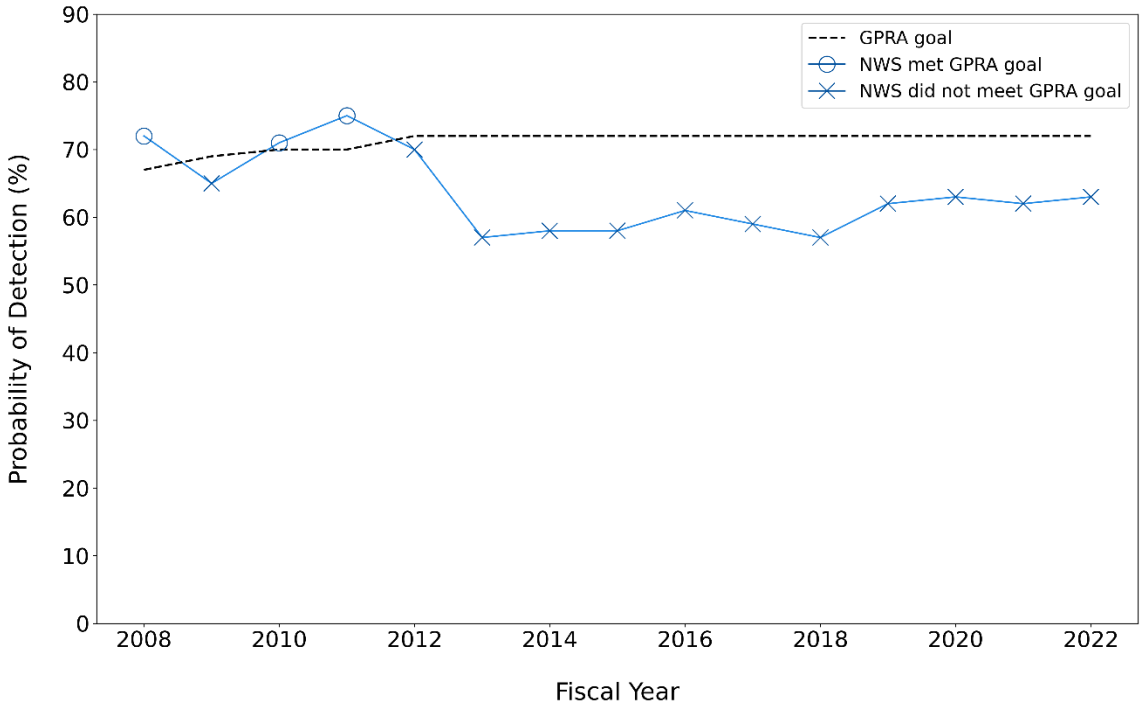
and project and transition plans for WPO-severe weather and NSSL-VORTEX funded projects. We assessed project technical readiness levels using NOAA's NRDD and found outdated information for some projects provided by the auditee. We also reviewed peer-reviewed literature on risk communication, vulnerability, and economic and societal impacts of tornadoes. We conducted a site visit at the NOAA headquarters where we interviewed personnel from the NWS Social, Behavioral and Economic Sciences Program. In addition, we interviewed personnel from the Office of Science and Technology Integration, WPO, and current/former leadership from the National Institute of Standards and Technology's National Windstorm Impact Reduction Program. We also analyzed a breakdown of core partners for a sample of WFOs from the Eastern, Central, Southern, and Western Regions of the NWS.

We conducted this evaluation from September 2023 through April 2025 in accordance with Quality Standards for Inspection and Evaluation (December 2020) issued by the Council of the Inspectors General on Integrity and Efficiency. Those standards require that the evidence must sufficiently and appropriately support evaluation findings and provide a reasonable basis for conclusions and recommendations related to the objective. We believe that the evidence obtained provides a reasonable basis for our findings, conclusions, and recommendations based on our review objective. When possible, we compared the information we collected to all other available sources to confirm consistency and to determine reliability. The evidence we obtained and analyzed for this evaluation are believed to be reliable. With the exception of site visits, we performed our fieldwork remotely from IDA offices headquartered in Alexandria, Virginia.

Appendix B.
NWS Tornado Warning Performance Trends

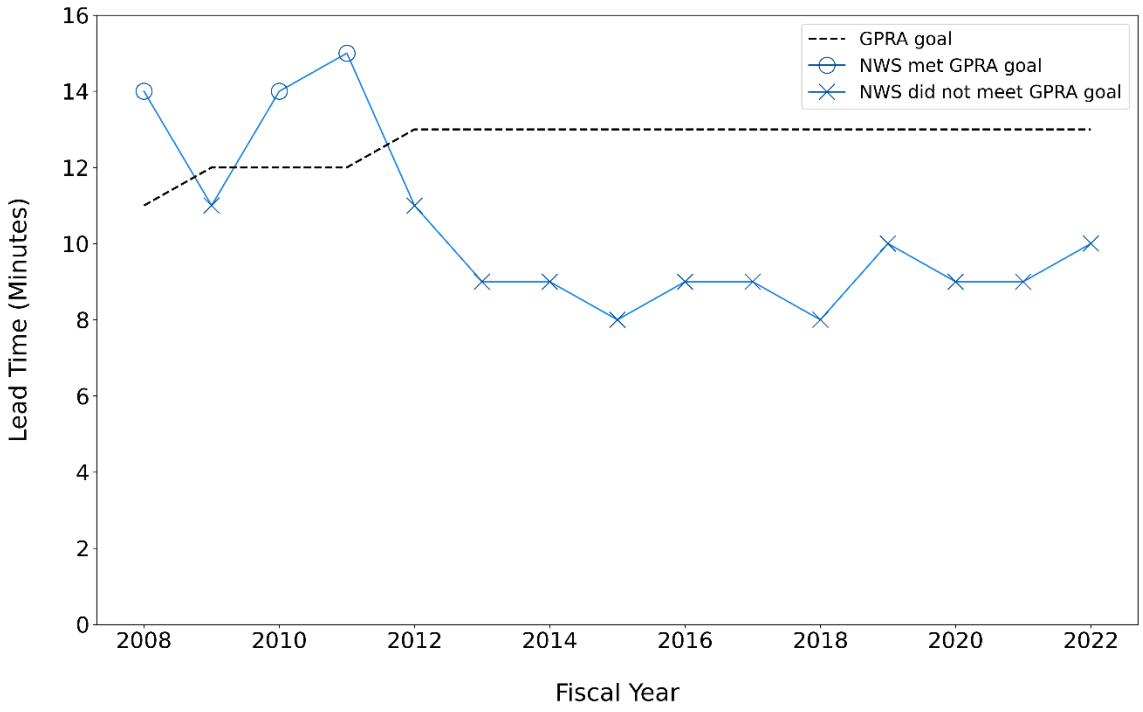
The NWS assesses tornado warning performance across all WFOs using POD, lead time, and FAR. Figure B-1 to Figure B-3 show the trends in these performance metrics since the beginning of FY 2008. The NWS has not met the GPRA goal for POD or lead time since FY 2011, but it has met the GPRA goal for FAR in 9 out of the 12 years over the same period. We found that performance for both POD and lead time declined following FY 2011. While people interviewed for this evaluation acknowledged this decline in performance, we were unable to determine the cause. Academic literature suggests the observed decline in POD and slight improvement in FAR are consistent with forecasters' actions to reduce false alarms following the tornado events occurring in spring 2011, including the Joplin, Missouri, tornado.[1] In other words, the threshold for a forecaster to issue a tornado warning was higher after FY 2011 to prevent issuing warnings when no tornado occurred. Because of this emphasis, fewer warnings were issued, the number of tornadoes that occurred without a warning increased, and the amount of lead time to protect life and property decreased.

[1] Harold E. Brooks and James Correia, "Long-Term Performance Metrics for National Weather Service Tornado Warnings," *Weather and Forecasting* 33, no. 6 (2018): 7, https://doi.org/10.1175/WAF-D-18-0120.1.



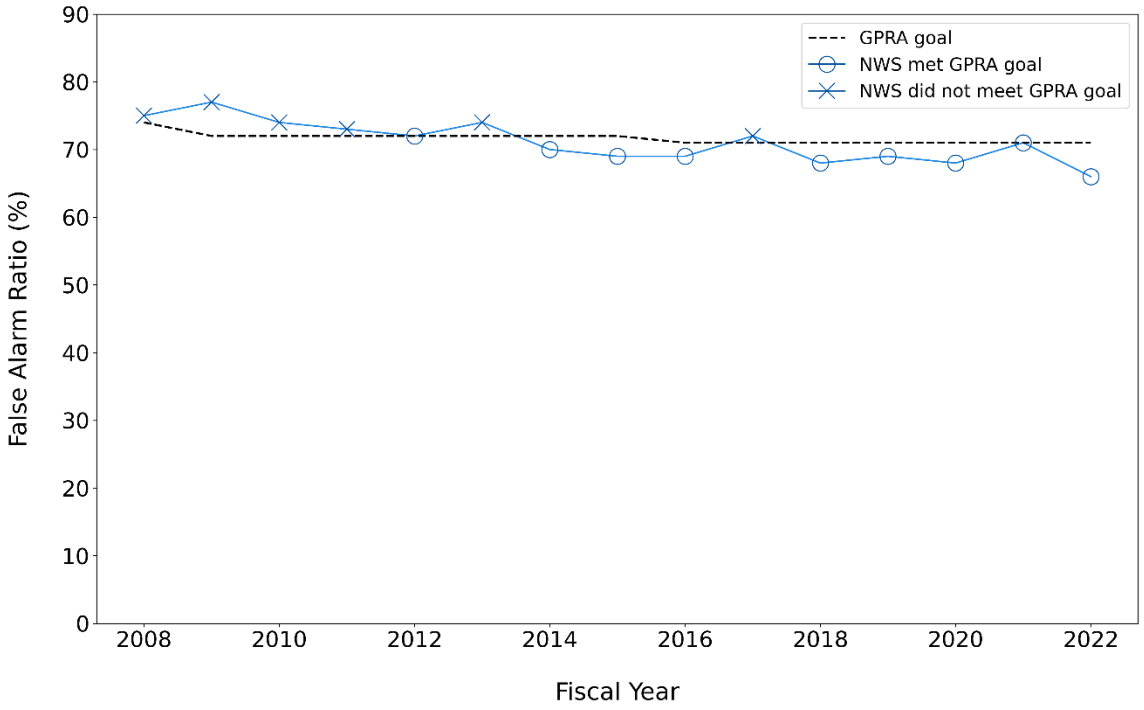
Source: IDA analysis using tornado event and WFO warnings data received via RFI on November 3, 2023.

Figure B-1. POD for Tornadoes Since 2008



Source: IDA analysis using tornado event and WFO warnings data received via RFI on November 3, 2023.

Figure B-2. Lead Time for Tornadoes since 2008



Source: IDA analysis using tornado event and WFO warnings data received via RFI on November 3, 2023.

Figure B-3. FAR for Tornadoes Since 2008

Appendix C.
Agency Response

UNITED STATES DEPARTMENT OF COMMERCE
Deputy Under Secretary for Operations
National Oceanic and Atmospheric Administration
Washington, D.C. 20230

MEMORANDUM FOR: Kevin D. Ryan
Acting Assistant Inspector General for Audit and Evaluation
U.S. Department of Commerce
Office of Inspector General

FROM: VADM Nancy Hann
Deputy Under Secretary for Operations Nancy Hann, VADM/NOAA Date: 2025.05.22 08:54:57 -04'00'

SUBJECT: **Draft Report**: *Independent Evaluation of the National Oceanic and Atmospheric Administration's National Weather Service Tornado Forecasting and Warning Services*

The Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) is pleased to submit the attached response to the draft report on NOAA's Tornado Forecasting and Warning Services.

We appreciate the opportunity to review and respond to your draft report. If you have any questions, please feel free to contact my office or Mia Forgy, Director, Audit and Information Management Office at Mia.Forgy@noaa.gov, or (301) 427-7893.

Attachment

Department of Commerce
National Oceanic and Atmospheric Administration
Draft Report Response to
Department of Commerce Office of Inspector General's
Independent Evaluation of the National Oceanic and Atmospheric Administration's National Weather Service Tornado Forecasting and Warning Services
(2023-461, April 2025)

General Report Comments

The Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) appreciates the opportunity to review the Department of Commerce Office of Inspector General's (DOC OIG) report on Independent Evaluation of the National Oceanic and Atmospheric Administration's National Weather Service Tornado Forecasting and Warning Services.

NOAA Response to Recommendations

The draft report made six recommendation(s) pertaining to NOAA.

Recommendation 1: Develop a detailed implementation plan on how to achieve the TWIEP Plan's activities using time-bound goals with clear resource expectations, relevant control activities, and performance measures.

NOAA Response:
We concur with this recommendation. Achieving the Tornado Warning Improvement and Extension Program (TWIEP) Plan's goals is a priority, and ongoing efforts by the National Weather Service (NWS) Severe Weather Services Program are consistent with the recommendation. Examples include:

- A FY25 milestone associated with developing a Concept of Operations for the Warn-on-Forecast System (WoFS) as it transitions from the Office of Ocean & Atmospheric Research (OAR) to Science & Technology Integration (OSTI) is consistent with short-term goals 2 and 4.
- Collaborative work with OAR, the Global Systems Laboratory, and the Operations Proving Ground to implement probabilistic hazard information (PHI) as a recommender within warning generation software aims to improve warning consistency, accuracy, and lead times, aligning with short-term goal 3.
- Continued work with various groups across NWS aiming at transitioning to modernized dissemination methods (i.e., Valid Time Event Code (VTEC) to Common Alerting Protocol (CAP)), which is consistent with long-term goal #2. Of note, these efforts would also facilitate the implementation of Threats-in-Motion, further improving warning accuracy and lead time.
- Shifting the paradigm in warning operations that would increasingly leverage and foster severe weather expertise, promoting more consistent warning accuracy and lead time nationwide, which is consistent with the Tornado Warning Improvement and Extension Programs Goal (#3) "Triple the current skill and effectiveness of tornado forecasts and warnings."

Further, the National Severe Storms Laboratory (NSSL) and Weather Program Office (WPO)

documented our joint TWIEP-focused accomplishments since 2019 in a report entitled, "Executive Summary of the Mid-Point Review VORTEX-USA (formerly known as the Tornado Warning Improvement and Extension Program Plan (TWIEP))," to be released pending approval. Through coordination and collaboration with the NWS, scientific findings and advanced forecast tools are at various stages of transition to the NWS, and it is imperative that OAR and NWS leadership work together to ensure these advancements are fully realized. While transition plans exist for some of these tools, a detailed implementation plan that scopes the resource requirements, modifications, execution risks, and performance metrics, co-developed by OAR and NWS, pending funding, would further ensure achievement of TWIEP goals. OAR will coordinate with NWS to complete a draft implementation plan by the end of FY25.

Recommendation 2: Develop loss of life and economic loss performance metrics to support performance assessment.

NOAA Response:
We partially concur with this recommendation. Economic losses attributable to tornadoes cannot practically be correlated to tornado warning performance. The majority of economic losses arising from tornadoes (e.g., damaged homes, businesses, and other structures) could not be precluded regardless of warning accuracy or lead time, given the time and geographic scale of tornadoes. Additionally, economic losses show high annual variability and are heavily dependent on the intensities and locations of tornadoes in a given year. As such, an economic loss performance metric would not provide useful information when assessing the value of tornado warnings.

Loss of life due to tornadoes is very complex and variable, tied to a myriad of meteorological, socioeconomic, and infrastructural factors. A significant problem with life/property metrics for tornadoes are that <1.5% of tornadoes result in a death, and of the deadly tornadoes, half result in the death of one person, while a quarter kill 5 or more. Thus, metrics associated with loss of life are associated with very few events. Property loss is difficult to reduce on a warning time scale since almost all of it is associated with building damage. There is little to do to reduce that type of damage on a forecast time scale. However, improved preparedness, safety information, and forecasts have likely been a factor in a decreased loss of life with other phenomena (e.g., lightning). Leveraging past approaches from the National Highway Traffic Safety Administration (NHTSA), we could introduce a metric such as the ratio of tornado-related fatalities to the number of tornadoes in a given year, or tornado-related fatalities to the accumulated tornado path length in a given year. We could also consider the percentage of tornadoes that are significant (EF2+) or violent (EF4+), as tornado intensity plays a large role in expected casualties. Unlike NHTSA, we lack the ability to create or enforce guidelines that could prevent loss of life in tornadoes. For instance, the NWS can provide forecasts and alerts to inform decisions, but it is not within the mission scope to require storm shelters at all homes.

Thus, we recommend exploring and developing more relevant metrics for performance evaluation, such as influence on informed decision-making ("informed decisions" comes from the 2017 Weather Act.). Together, OAR and NWS have the expertise to define such informed decision-making metrics, and the NWS can commit to internally testing a loss of life related tornado warning metric for a period of time to determine its utility. However, we recommend that the NWS consider an agency-wide strategy for performance metrics tied to loss of life, as tornadoes are not unique as a weather-related phenomenon that leads to fatalities.

Recommendation 3: Revise existing policies (e.g., Policy on Research and Development Transitions, Products and Services Change Management, Verification, and Termination of NWS Information Services) to evaluate the operational performance impacts associated with research investments that have transitioned to operations.

NOAA Response:
We concur with this recommendation. We have ways of assessing the value of advancements after implementation, such as after-action reviews, integrated warning team (IWT) meetings with local partners, and service assessments. However, a collaborative and systematic approach to reviewing the R2O process and formalizing evaluation of operational advancements could be further developed between OAR and NWS. To ensure an appropriate action plan is developed, we will confirm the list of "10 tornado-related research projects that have transitioned to operations since 2020" that the OIG references for this audit.

Additionally, the referenced "Policy on Research and Development Transitions" is NOAA Administrative Order (NAO) 216-105B, which we agree does not have evaluation of transitioned projects included in it and falls under the purview of the LOTMC (Line Office Transition Manager Committee). However, NAO 216-115B, focused on Research and Development (R&D), does have a section on evaluation that is currently conducted through lab and program reviews. While those reviews will use transition success as a metric, they don't go to the degree recommended by the OIG of evaluating operational performance of those transitions. This is an effort that the Research and Development Enterprise Committee and LOTMC could look at jointly.

Recommendation 4: Conduct an assessment of how IDSS risk communication efforts for tornado watches and warnings affect the public's actions to reduce loss of life or property, and revise the IDSS Policy Directive as appropriate.

NOAA Response:
We concur with this recommendation, "*IDSS risk communication efforts for tornado watches and warnings*" can be further defined for clarity. The NWS informs decisions during tornado

events through a variety of products and services, as well as year-round outreach and education (e.g., seasonal outreach campaigns, SKYWARN Spotter Training, pre-event briefings, ongoing messaging to public and partners in the watch-to-warning space, embedded operations with partners). These efforts work together to support protective action decisions and thus can't be meaningfully separated when measuring impact. In addition, the NWS operates within a broader network of information, and NWS information may be only one source of many for the public.

With that said, the NWS can commit to an assessment of our collective communication, outreach, and decision support services to better understand areas of improvement , which will support a better understanding of how NWS products and services lead to improved outcomes across all hazards, including tornadoes.

At a more tactical level, the NWS is in the process of implementing a suite of online tools that facilitate decision support between NWS and partners, "NWS Connect." This set of tools will allow NOAA to document and track partner needs and design valuable metrics in alignment with community outreach and education activities. We will also ensure that the IDSS Policy Directive is updated as appropriate.

Recommendation 5: Conduct an assessment of existing processes for ensuring the consistent communication of key performance metrics and address identified gaps, such as the inaccurate public-facing GPRA tornado lead-time metric definition.

NOAA Response:
NOAA concurs with this recommendation. Clear, consistent definitions of our performance measures are critical to maintain public confidence in the life-saving products we provide. We will ensure that the public-facing GPRA Tornado Warning Lead Time definition is consistent with the values we track internally and report to Congress.

Recommendation 6: Conduct an assessment of potential lead-time metrics and determine which approach, or combination of approaches, is best suited for facilitating representative performance assessment and external oversight.

NOAA Response:
NOAA concurs with this recommendation. The two Tornado Warning Lead Time metrics explained in the report are each associated with particular strengths. Initial lead time agrees with the public-facing definition of lead time and exhibits consistency with metrics prior to the adoption of storm-based warnings; however, it masks specific lead times for communities and individuals along the tornado's path. Average lead time is more consistent with the true advanced warning of a tornado at a given location.

NOAA will review the potential options associated with tracking and reporting lead times, to include considering an assessment of the warning system from a decision-theoretic basis, and the interrelationship between all the metrics, as well as research required to ensure meaningful and useful performance metrics. Additionally, we will ensure consistency between internal calculations and public-facing definitions, as noted in response to Recommendation 5.

Illustrations

Figures

Table

Abbreviations

DOC	Department of Commerce
EF	Enhanced Fujita
FAR	False Alarm Ratio
FY	Fiscal Year
GAO	Government Accountability Office
GPRA	Government Performance and Results Act
IDA	Institute for Defense Analyses
IDSS	Impact-Based Decision Support Services
NOAA	National Oceanic and Atmospheric Administration
NRDD	NOAA Research and Development Database
NSSL	National Severe Storms Laboratory
NWS	National Weather Service
NWSI	National Weather Service Instruction
OAR	Oceanic and Atmospheric Research
OIG	Office of the Inspector General
PEW	Percentage of the Event Warned
POD	Probability of Detection
R2A	Research to Applications
R2O	Research to Operations
RFI	Request for Information
SPC	Storm Prediction Center
TWIEP	Tornado Warning Improvement and Extension Program
VORTEX	Verification of the Origins of Rotation in Tornadoes Experiment
WFO	Weather Forecast Office
WPO	Weather Program Office

REPORT DOCUMENTATION PAGE

PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ORGANIZATION

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED	
		START DATE	END DATE
xx-07-2025	Final	Aug 2023	May 2025

4. TITLE AND SUBTITLE

Independent Evaluation of the National Oceanic and Atmospheric Administration's National Weather Service Tornado Forecasting and Warning Services

5a. CONTRACT NUMBER	5b. GRANT NUMBER	5c. PROGRAM ELEMENT NUMBER
HQ0034-19-D-0001		
5d. PROJECT NUMBER	**5e. TASK NUMBER**	**5f. WORK UNIT NUMBER**
EC-7-5341		

6. AUTHOR(S)

Bewley, Jennifer L.; Brinson, Ayeisha A.; Holland, R. Abraham; Sivaram, Anusuya; Leal, Roxana; Sabatini, John E.; Stanley, Kelsey R.; Ross, Katherine CS

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	8. PERFORMING ORGANIZATION REPORT NUMBER
Institute for Defense Analyses / Systems and Analyses Center Research Division 730 East Glebe Road Alexandria, Virginia 22305	IDA Product 3002824

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)	11. SPONSOR/MONITOR'S REPORT NUMBER
National Weather Service Programs, Office of Inspector General Department of Commerce 1401 Constitution Ave., NW, Room 7099 Washington, DC 20230	OIG DOC	

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release: distribution is unlimited.

13. SUPPLEMENTARY NOTES

Project Leader: Jennifer L. Bewley

14. ABSTRACT

This report is the result of an evaluation conducted under CIGIE Blue Book Standards of the National Weather Service (NWS) Tornado forecasting, warning, and prediction performance since 2017.

15. SUBJECT TERMS

National Weather Service; National Oceanic and Atmospheric Administration; Tornado; Weather; Forecasting; Evaluation; Weather Act

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES
a. REPORT	b. ABSTRACT	c. THIS PAGE		
U	U	U	UU	48

19a. NAME OF RESPONSIBLE PERSON	19b. PHONE NUMBER
Tersigni, Frank	(202) 793-2939