

Written Testimony of Dr. Scott Glenn
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**Before the Subcommittee on Environment
Committee on Science, Space, and Technology
U.S. House of Representatives**

**Hearing on “What’s the Forecast: A Look at the Future of Weather Research”
Tuesday, June 14, 2022**

Congresswoman Sherrill, Ranking Member Bice, members of the Subcommittee, I sincerely thank you for the opportunity to speak to you today about the future of weather research and forecasting for our nation.

My name is Scott Glenn. I have been a professor at Rutgers, The State University of New Jersey, for over 30 years, and I was one of the co-leads for the NOAA Science Advisory Board Report on the *Priorities for Weather Research*, often referred to as the PWR Report (NOAA SAB 2021; 2022). The views that I am sharing today are my own, and not those of Rutgers or NOAA.

The PWR Report was co-led by an industry meteorologist and an academic oceanographer, underscoring both the value of cross-sector partnerships within the Weather Enterprise, and the critical need to accelerate the positive gains we have already made with an Earth System Science approach. The PWR report was produced by over 150 subject matter experts from across the Weather Enterprise. Through a consensus approach, government, industry and academic experts from multiple disciplines came together to provide policymakers the information necessary to prioritize federal investments in weather research and forecasting over the next decade.

PWR is an urgent call to action. That urgency is driven by the increasing frequency of extreme weather events that cause hundreds of deaths and hundreds of billions of dollars of damage annually (PWR Report Figure 3 reproduced below). It is driven by the need to develop a vibrant economy that leverages weather information into competitive advantages rather than blames the weather for economic losses. And it is driven by the need to support equity and environmental justice across our nation.

Billion-Dollar Weather and Climate Disasters in the U.S.

From 1980 to October 2021 (CPI-Adjusted)

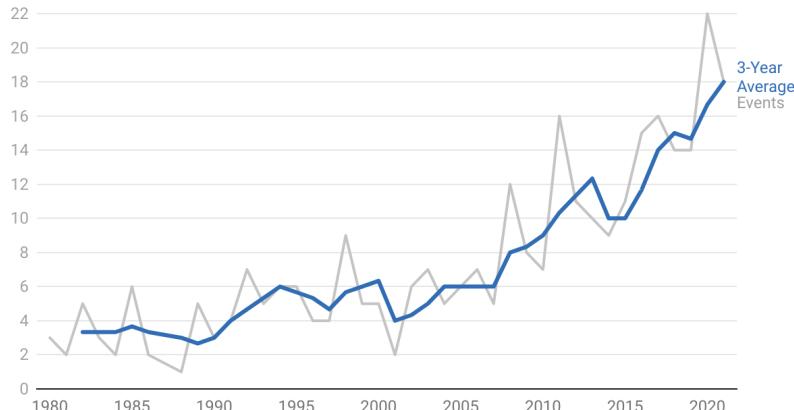
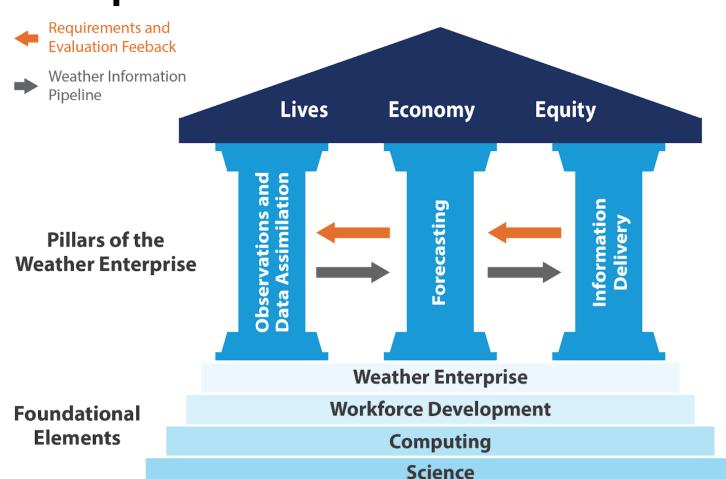


Chart: PWR • Source: NOAA NCEI U.S. Billion-Dollar Weather and Climate Disasters (2021) • Created with Datawrapper

PWR Report Figure 3: Annual (gray) and 3-year running average (blue) number of U.S. Billion Dollar Weather and Climate Disaster Events 1980-2021

The PWR report responds by documenting priority investments across the three pillars of the Weather Enterprise: (1) observations and data assimilation, (2) forecasting, and (3) information delivery (PWR Report Figure 5 reproduced below). These pillars are built on the strong foundational elements of the weather enterprise, workforce development, high performance computing, and the world's best science. Taken together, the pillars and their foundational elements support our shared goal to be a more Weather Ready Nation, which can save lives and protect critical infrastructure, promote a vibrant weather-informed economy, and achieve environmental justice.

Principal Pillars and Foundational Elements

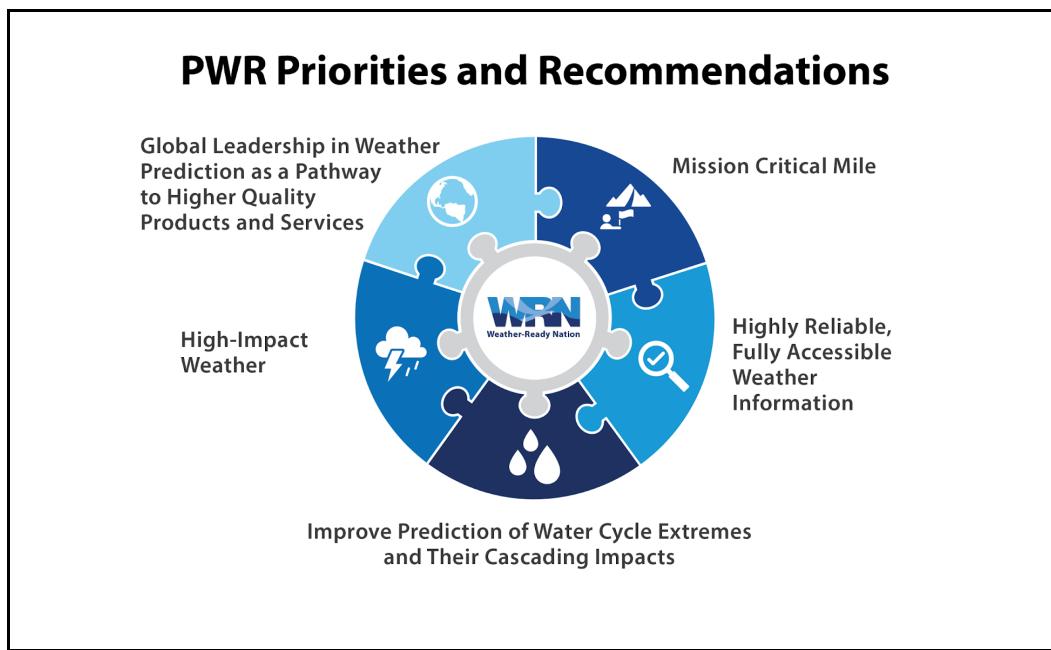


PWR Report Figure 5: Priorities for Weather Research Strategic Framework

The results of the PWR study are 11 Priority Areas for investment spread across the three pillars and the four foundational elements. Within these Priority Areas, PWR developed 33 Recommendations, and 102 specific Critical Actions to achieve their goals. Acting on these recommendations would be transformational for NOAA, our Weather Enterprise, and the people we serve.

Realizing that implementation of a comprehensive suite of priority recommendations will take time, PWR provides a roadmap highlighting 10 immediate first steps in the categories of research and development, infrastructure, actions and impacts, and the continued development of the prioritization process. These first steps were identified by their ability to promote significant advances, close significant gaps, or enable other recommendations when properly sequenced.

In addition, PWR produced five Narrative Themes to illustrate broad scientific and societal benefits that could be delivered by a focused and well-supported Weather Enterprise. One of these themes is High-Impact Weather. An example under this theme, one in which I have studied throughout my professional career, is hurricanes.



PWR Report Figure 6: Narrative Themes supporting a Weather-Ready Nation

Hurricanes are among the most destructive weather events on Earth. Since 1970, the world's top six economic losses from weather, climate and water extremes were hurricanes in the U.S. (WMO, 2021, Table 1, Page 18, \$490 Billion in damage for 6 events). Since 1980, hurricanes have caused over \$1 Trillion in damage in the U.S., more (52 percent) than all other weather and climate billion dollar disasters combined (NOAA, 2022a). In my home state of New Jersey, over 80 percent of the billion dollar disaster damage was caused by hurricanes (NOAA, 2022b).

I have been a storm researcher for over 40 years. Working with faculty colleagues at Rutgers, our government and industry partners, and our students (some of whom have gone on to work at NOAA), we have pioneered new ruggedized, autonomous technologies for ocean observing in extreme conditions. We have developed a fundamentally new understanding of how the atmosphere and ocean can rapidly co-evolve as hurricanes approach my home state of New Jersey (e.g., Glenn et al., 2016). And we have helped transition both observing systems and model improvements into operational systems for NOAA, the Coast Guard, and the Navy.

Having lived through the intense winds and flooding caused by Hurricanes Floyd, Irene, Sandy, Isaias and Ida, I personally know the value of a good forecast from our trusted National Hurricane Center. Through disaster supplemental appropriations provided by Congress that support hurricane observations and research, our science community has also learned what we can do to help make those forecasts even better. Fundamental to those advances is continuing NOAA's transition to an Earth System Modeling approach, supported by observations of both the atmosphere and the ocean below, and implemented across NOAA line offices and through cross-sector partnerships. All of these investment categories and approaches are outlined in the PWR Report.

For nearly 15 years, hurricane forecasting in the U.S. has benefited from federal investments in the Hurricane Forecast Improvement Program (HFIP), which is designed to rapidly transition high readiness level research into operations that improve hurricane forecasts and warnings. Many of the documented hurricane forecast improvements can be directly attributed to Congressional investments in HFIP activities. However, the success of HFIP, and the broader Weather Enterprise, is currently being limited, not by vision, but by support. The following are three ways HFIP has been limited:

1. HFIP is supported at approximately half the level required to fully implement its strategic plan. Investments are currently weighted toward the early part of the Weather Enterprise, such as observations and modeling. This comes at the expense of other areas, particularly improvements to information delivery. This partial level of support is not uncommon for valuable NOAA programs.

What can be done? Leveraging experience across NOAA line offices (e.g., OAR for basic and applied Earth System research, NWS and NOS for an Earth System approach to observations and modeling, NESDIS for additional satellite data, ...) can promote efficiencies and accelerate progress. But this will still require that both HFIP, and the leveraged components within NOAA, be fully supported in the sustained and coordinated manner required to accelerate progress.

2. Having high readiness level research available for rapid transition by HFIP requires a significant pool of well-supported basic and applied research available to be elevated in readiness level and accelerated into operations. For example, the basic and applied research required in understanding air-sea interactions and rapid intensity change (both rapid intensification and rapid weakening), in developing new data assimilation

techniques for coupled systems, and in improving coupled Earth System Models (ESM), will deliver benefits to a much broader community than just hurricane forecasting. It will contribute to global leadership in all applications of weather prediction.

What can be done? Leveraging the disaster supplemental support that accelerated development of the Hurricane Analysis and Forecast System (HAFS) within the framework of the Unified Forecast System (UFS), with community involvement to be enabled through the Earth Prediction Innovation Center (EPIC), is an existing collaborative framework waiting to be populated with academic and industry researchers and their students. The open science community that develops in this curated workspace will also require research-level High Performance Computing resources to succeed.

3. Once high readiness level research is transitioned, there has to be an operational home with the capacity to sustain the upgrades. This again includes the need for additional operations-grade High Performance Computing resources to run upgraded Earth System Models and coupled data assimilation schemes. It also needs to include operational support for the additional atmosphere and ocean observations required for assimilation in the coupled forecast models. Currently there are significantly less ocean observations assimilated in the global ocean models than in the atmosphere, mainly due to the challenges in subsurface ocean data acquisition and the timely transfer of data to operational centers.

What can be done? One example is the collaborative approach of supplementing year-round Argo ocean profiling float data with seasonally deployed underwater hurricane gliders in critical locations. The success of this approach has been demonstrated by the NOAA-led U.S. Integrated Ocean Observing System (IOOS), NOAA's Office of Oceanic and Atmospheric Research, and their external partners, leading to a dramatic increase in the available ocean data during the 2018 through 2021 hurricane seasons. The IOOS Regional Associations implementing much of the hurricane glider fleet are NOAA-certified partnerships between government, tribal, academic and industry groups with the regional knowledge and experience to efficiently implement a nationally coordinated response. Currently, any entity operating an underwater glider for any purpose can share its data through the IOOS system, thereby enabling even broader contributions to improved hurricane forecasts. This IOOS capability has been leveraged by the energy companies in the Gulf of Mexico, the offshore wind industry in the Mid Atlantic, and by the Navy for training exercises in U.S. waters, so that each group can accomplish their own mission goals while also seamlessly contributing to improved hurricane forecasts. But unfortunately, the current hurricane season is between disaster supplementals, greatly reducing the anticipated size of the 2022 hurricane glider fleet, and leaving our nation's coasts with reduced coverage during what is expected to be an above-average North Atlantic hurricane season (NOAA News-Release, 2022). This is a prime example of the PWR recommendation to complete the build-out of the observational networks required to support the new Earth System Models.

In conclusion, the PWR Report provides a framework that could transform NOAA and positively impact NOAA's many partners that comprise the Weather Enterprise. The growing challenges of supporting a Weather Ready Nation during a time of increasing extreme weather events lends urgency to the PWR recommendations. Today I have highlighted one example of how the PWR recommendations positively impact an issue that I am most familiar with – improving hurricane forecasts. There certainly are other issues, and you will hear about some of them from other speakers today. I urge this Committee and Congress to act upon the priority recommendations outlined in the PWR Report so that NOAA, and the Weather Enterprise, will be enabled to better serve the needs of our nation.

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Scott Glenn – Short Biography

Scott Glenn began his career in storm research at the Massachusetts Institute of Technology and the Woods Hole Oceanographic Institution Joint Program where he received his Sc.D. in 1983. He worked in hurricane and ocean observations, modeling and forecasting for Shell Development Company until 1986, and transitioned the U.S. Navy's first dynamical ocean forecast model to operational use while working at Harvard University in 1989. Since joining Rutgers in 1990, his research has focused on the development of remote and autonomous technologies for ocean observing in extreme environments, the modeling of coupled ocean-atmosphere systems, and improving the forecasting of hurricanes. He currently is a Board of Governors Professor of Marine and Coastal Sciences at Rutgers, The State University of New Jersey, where he is the Co-Director of the Center for Ocean Observing Leadership. Honors include U.S. Professors of the Year for New Jersey by the Carnegie Foundation, the Office of Naval Research Collaboration Award for supporting the Navy warfighter, the first transatlantic underwater glider displayed at the Smithsonian, the Oceanography Award from the International Society for Underwater Technology in London, and being named a Fellow of the international Marine Technology Society.