



EXECUTIVE SUMMARY OF THE REPORT TO THE PRESIDENT

Extreme Weather Risk in a Changing Climate: Enhancing prediction and protecting communities

Executive Office of the President
President's Council of Advisors on
Science and Technology

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EXECUTIVE OFFICE OF THE PRESIDENT
PRESIDENT'S COUNCIL OF ADVISORS ON SCIENCE AND TECHNOLOGY
WASHINGTON, D.C. 20502

President Joseph R. Biden, Jr.
The White House
Washington, D.C.

Dear Mr. President,

Your administration has made unprecedented advances in addressing climate change. PCAST believes advances in climate science and computation can add to this record by creating an effective and accessible suite of tools that provide individuals, communities, and the federal government with the information they need to prepare for the risks of extreme weather in a changing climate.

The most immediate danger that Americans face from climate change is the worsening of extreme weather, including hurricanes, floods, droughts, heatwaves, and wildfires. Extreme weather disasters have caused over \$1 trillion in damages over the last seven years, and in 2022 alone, displaced an estimated 3.4 million Americans from their homes. Recent scientific studies have found that the likelihood of certain weather patterns, such as extreme hurricane rainfall over the state of Texas, have multiplied due to climate change. This type of change makes historical models and long-term records unreliable guides to future probabilities. Reliable information is critical for American families choosing where to live, municipal leaders developing flood-control plans, or insurers selling wildfire coverage. And yet, when it comes to assessing the future risks from extreme weather, America is flying blind.

The good news is that climate modeling and computation are advancing rapidly. Capabilities exist within federal agencies to make significantly better predictions of the likelihoods of extreme weather – for example the chance that a category five hurricane will hit Miami in any one year, or the chance of another rainfall event like the one that caused catastrophic flooding in Kentucky in July 2022. By sharing resources and information, the federal government also can spur an ecosystem of academic research and private investment that improves and expands access to climate and weather risk information. This in turn can inform smart government policy and support the American people with information they can use to protect themselves.

The households at greatest risk from floods, fires, and heatwaves are often low-income families, and discriminatory historical practices such as redlining have contributed to minority populations living in risk-prone areas. A national effort to improve the quantification of extreme weather risk also would help to ensure that federal funds, including those designated under the Infrastructure Investment and Jobs Act (IIJA), are targeted to areas where their benefit will be highest.

This report recommends steps to dramatically improve our quantification of extreme weather risk, and to share this information with households, businesses, and government agencies. It also recommends the development of a national adaptation plan that would provide guidance that local communities need to tackle changing risks from extreme weather events. Taken together, PCAST believes that these actions can help protect the lives, livelihoods, and property of Americans for generations.

Sincerely,
The President's Council of Advisors on Science and Technology

Executive Summary

Extreme weather has devastating impacts on the American people, our communities, and our economy. All of us have seen the damage wrought by catastrophic wildfires in western states, by floods, and tropical cyclones on the Gulf Coast, and by recent severe tornados in southern and eastern states. Extreme weather also reduces property values, raises the costs of insurance, and poses national and global economic risks from supply chain disruptions and forced migrations. Today, climate change is changing the patterns and risks of extreme weather, including the frequency and severity of many hazards.

The challenge of hurricanes and other severe storms, floods, and wildfires is gaining significant attention and the annual cost of climate and weather disasters has been rising. The National Oceanic and Atmospheric Administration (NOAA) has catalogued over \$1 trillion of damages during the last seven years (2016-2022).¹ Industry reports caution that by mid-century, insurance premiums in certain markets could rise substantially, straining U.S. households.² Last year, the Office of Management and Budget (OMB) cited a potential federal revenue loss of \$2 trillion per year from climate change at the end of the century, along with additional expenditures of \$25 to \$128 billion on selected insurance and disaster relief programs.³ In addition, there are deeper costs from loss of life, negative health impacts, and the destruction of communities.⁴ The Census Bureau recently estimated that in 2022 alone, 3.4 million Americans were displaced from their homes by extreme weather disasters.⁵ Moreover, lower-income households are often those at greatest risk from floods, storms, and wildfires. These households have fewer resources to take actions that will offset a rising risk of extreme weather.

¹ Smith, A. B. (2023, January 10). *2022 U.S. billion-dollar weather and climate disasters in historical context*. NOAA National Centers for Environmental Information. <https://www.climate.gov/news-features/blogs/2022-us-billion-dollar-weather-and-climate-disasters-historical-context>. The average disaster costs for 2017-21 are \$148 billion per year; the data include only large (> \$1bn) disasters.

² One specific example cited by McKinsey is that (inflation-adjusted) annual flood losses in Florida could rise by 50% by 2050, with corresponding premium increases if the costs are passed to policy-holders. Grimaldi, A., Javanmardian, K., Pinner, D., Samandari, H., & Strovink, K. (2020, November 18). *Climate change and P&C insurance: The threat and opportunity*. McKinsey & Company. <https://www.mckinsey.com/industries/financial-services/our-insights/climate-change-and-p-and-c-insurance-the-threat-and-opportunity>

³ The revenue number is from an OMB blog post “Quantifying Risks to the Federal Budget from Climate Change” (April 4, 2022) that summarizes a set of OMB reports, including “Climate Risk Exposure: An Assessment of the Federal Government’s Financial Risks to Climate Change” which contains the specific estimates on program costs. Estimates of climate damages 75+ years out have a wide range of associated uncertainty, and OMB’s analysis of costs looks only at a small number of federal programs. Executive Office of the President (2022, April 4). Quantifying Risks to the Federal Budget from Climate Change. The White House. <https://www.whitehouse.gov/omb/briefing-room/2022/04/04/quantifying-risks-to-the-federal-budget-from-climate-change/>; U.S. Office of Management and Budget (2022, April). *Climate Risk Exposure: An Assessment of the Federal Government’s Financial Risks to Climate Change*. https://www.whitehouse.gov/wp-content/uploads/2022/04/OMB_Climate_Risk_Exposure_2022.pdf

⁴ Chapter 9 of the 2023 *Economic Report of the President* discusses evidence on a wide range of costs from climate change and extreme weather. <https://www.whitehouse.gov/wp-content/uploads/2023/03/ERP-2023.pdf>

⁵ U.S. Census Bureau. (2023, January 15). *Week 53 Household Pulse Survey: January 4 - January 16*. <https://census.gov>. <https://www.census.gov/data/tables/2023/demo/hhp/hhp53.html>

This PCAST report investigates how recent scientific and technical advances could be used to provide more accurate and actionable information to guide decision-making and policy at all levels. PCAST recommends federal actions to better quantify and disseminate current and future risks of extreme weather, including risks of human and financial losses caused by flood, fire, storms, and drought. PCAST also recommends actions to bolster the emerging private ecosystem providing climate risk information. Finally, PCAST recommends the development of a national adaptation plan to assist communities in preparing for and adapting to changing risks from extreme weather events.

This report builds on the October 2021 White House report, *A Roadmap to Build a Climate-Resilient Economy*, outlining a multi-agency plan to implement Executive Order 14030 on climate-related financial risk.⁶ That plan addresses both the rising *physical risks* from extreme weather, and *transition risks* in moving toward a low-carbon economy. PCAST's recommendations focus on how climate science and computing can provide significantly better information about the physical risks from extreme weather to empower households, communities, and companies and enable smart policy.

Recommendations

Recommendation 1: A National Effort to Quantify Extreme Weather Risk.

To prepare for dangerous weather, one needs to know how damaging it is likely to be and how frequently it will occur. A levee designed for a 100-year storm producing 15 inches of rain is not adequate if the 100-year storm now packs 25 inches. PCAST recommends a focused federal effort to provide estimates of the risk that a weather event of a given severity will occur in any location and year between now and midcentury. These include extremes of temperature, rainfall, and wind speed.

- 1.1. U.S. climate-modeling centers supported by the National Oceanic and Atmospheric Administration (NOAA), National Science Foundation (NSF), Department of Energy (DOE), and National Aeronautics and Space Administration (NASA) should enhance their high-resolution modeling capabilities and state-of-the-art statistical methods **to quantify annual extreme weather risks from the present until mid-century** at a resolution of 10 km or finer. *This will require both agency prioritization and collaboration.*

The work of multiple agencies together with an effective leadership framework is critical because, as explained in Box 2 of the report, this activity does not fit within a single existing administrative unit within the federal government.

- 1.2. The White House should **designate a lead agency to maintain an extreme weather data portal** where observations and modeling products are regularly updated and widely accessible, using an analysis-ready format that enables downstream users and hazard models on smaller scales to assess the local risks of wildfire, flood, drought,

⁶ The White House. (2021, October 14). *A Roadmap to Build a Climate-Resilient Economy*. <https://www.whitehouse.gov/wp-content/uploads/2021/10/Climate-Finance-Report.pdf>

and other weather-related hazards. The portal should also provide guidance and recommendations related to the reliability of modeling products.

Here, we are not focused on predicting weather over the coming days and weeks, a problem adeptly handled by the National Weather Service, but on predicting the climate, that is the probability of weather events over years and decades. In particular, the recommendation directly addresses the lack of high-quality estimates of extreme weather probabilities for most locations and types of events. Current risk assessments are based on older models or historical weather records. Older climate models typically have a resolution of 25 to 100 km or coarser, limiting their predictive accuracy, while today's computational resources and downscaling techniques have the potential to provide resolutions of 10 km or finer. Historical weather records are generally too short to estimate the chance of once-in-a-lifetime events and are unreliable when there are changes in the climate. Recent advances in observations, modeling, and computation make it possible to create more accurate and operational assessment of evolving risks, provided that existing federal computational and human resources are deployed at the needed scale, and that information is made readily accessible for downstream uses. The aspiration is that just as Americans today have access to high-quality operational weather forecasts, the time has come to invest in an operational climate science that provides improved tools for risk assessment and management.

Recommendation 2: An Improved Ecosystem for Climate Risk Assessment.

To prepare for changing patterns of extreme weather, the nation will require information beyond the probabilities of extreme temperature, rainfall, and wind speed. One must be able to predict the severity of resulting weather hazards, (e.g., flood, fires and droughts) and the human and economic losses they will cause. PCAST recommends steps that will enable the development of high-quality private and public sector tools to better measure and evaluate extreme weather-related risks across the country.

- 2.1 Designate an interagency group to **inventory and release federal data that are useful to develop and test weather-hazard models**, which predict flood, fire and drought from extreme weather, and **hazard-loss models**, which predict human and financial losses from hazards or directly from extreme weather such as significant heat, cold, hail, or wind. This effort should include any relevant and available fine-scale elevation data and other physical information, as well as data on Federal disaster and insurance claims needed to validate risk models, with appropriate safeguards to protect privacy and security. The interagency group will require expertise about procedures and rules governing the release of federal data.
- 2.2 The National Oceanic and Atmospheric Administration (NOAA) and the Federal Emergency Management Agency (FEMA), and other federal agencies as the President deems necessary, should develop **guidelines for measuring the accuracy of weather-hazard and hazard-loss models** with skill scores and promote the use of skill-scoring among federal agencies that rely on assessments of climate and weather hazards including flood, drought, storm, and wildfire, and the human and economic damages they cause.

- 2.3 Fund research, potentially through multiple agencies, **on risk-assessment modeling systems** that use extreme weather probabilities, weather-hazard models, and hazard-loss models to quantify the likelihood and economic costs of extreme weather events. This effort should aim to foster improved quantification of weather-hazard risks in the public and private sector, through improved access to models and data, and a robust ecosystem of model evaluation and testing.

This recommendation addresses the fact that households, communities, companies, and government agencies do not have sufficiently reliable and geographically specific information about how they may be affected by extreme weather. While a burgeoning industry is beginning to provide climate risk information, much of this is of questionable quality, either because it has not been transparently skill-scored to show that it can predict past events, or because it relies on methods that have been shown by the academic literature to have significant bias.⁷ Also, much of this information is too costly for most individuals or small municipalities to afford, although some is available at no cost. To improve the quality of the models, developers need support in overcoming two primary barriers: 1) the data required to improve models is often siloed or inaccessible, and 2) the field lacks sufficiently robust mechanisms to allow consumers of the information, including federal agencies, to assess model skill. Transparent and accessible skill-scoring would promote model improvement and help standardize nascent industry efforts, especially if federal agencies were to prioritize applications for funding that rely on relatively skillful models. Addressing these barriers will help foster a stronger academic and private sector ecosystem of climate risk assessment. This will also leverage prior investments, such as the DOE's HyperFACETS project or the World Climate Research Program's CORDEX project.

Recommendation 3: A National Adaptation Plan to Mitigate Extreme Weather Risk

To prepare for changing risks from extreme weather, the provision of information will not be enough, especially given uneven resources across local communities. The federal government can accelerate preparedness by creating a national plan that guides and supports investment at all levels, and by funding research that illuminates which policy responses are effective and equitable.

- 3.1 The White House should develop and publish a National Adaptation Plan** to prepare for and mitigate increased risks from extreme weather. The Plan should include:
- (a) A systematic approach to mapping near term and longer-term high-danger zones for each extreme weather hazard, updated as estimates of risk are improved.
 - (b) Decision frameworks to assist local communities in making plans to mitigate or adapt to extreme weather risk.
 - (c) Regulatory and legal options to reduce long-term risk exposure, for instance through land-use planning, zoning, and building code adoption.
 - (d) Comprehensive assessment of Federal and State programs in alleviating disaster risks, including the distribution of federal funds for disaster preparation with attention to whether these programs are accessible to low-income communities.

⁷ Condon, Madison (2023). Climate Services: The Business of Physical Risk. *Arizona State Law Journal*. Forthcoming. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4396826#

(e) Guidelines for equitable allocation of disaster relief. These guidelines should anticipate the potential for recurring extreme weather events, so that relief programs work to mitigate future dangers to a community.

3.2 Fund research on the adaptation of households, real-estate and insurance markets, and local governments to changing climate and extreme weather risk.

This effort should aim to illuminate the behavior of households and firms in response to evolving climate and weather risks, and the benefits and costs of alternative policies aimed at mitigating and adapting to these risks. NSF may be best positioned to lead this effort, especially if coordinated with mission-oriented agencies such as NOAA, HUD, EPA, and others.

This final recommendation addresses the current lack of a national adaptation plan to guide federal and local investments to mitigate extreme weather risk and to improve the safety of lower-income and marginalized communities in greatest peril,⁸ particularly Black, Latino, Indigenous and other communities of color. Relevant programs are distributed over a score of federal agencies, and in many cases, responsibility lies with communities and local governments who confront a disjointed array of federal programs and initiatives.⁹ A coherent national plan should address issues of equity as well as economic efficiency and resilience, especially given the disproportionate risks faced by lower-income and marginalized communities. This adaptation plan also must incorporate current data and modeling that quantifies the changing climate, avoiding likely significant inaccuracies from exclusive reliance on the historical record.

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⁸ White House Environmental Justice Advisory Council. (2021, May 21). Final Recommendations: Justice 40 Climate and Economic Justice Screening Tool & Executive Order 12898 Revisions. <https://www.epa.gov/sites/default/files/2021-05/documents/whiteh2.pdf>

⁹ A broad set of federal programs are relevant for disaster recovery. For instance, social-safety net programs (disability, unemployment, Medicare) play an important financial role in areas affected by disasters, although not specifically designed for this purpose (e.g. <https://www.aeaweb.org/articles?id=10.1257/pol.20140296>).