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

My name is Brad Colman. I am currently the Director of Weather Strategy for Bayer / Climate LLC, President-Elect of the American Meteorological Society, and one of the co-leads for the NOAA Science Advisory Board's Report on the Priorities for Weather Research, or the PWR Report. The views that I am sharing here are my own, and not those of Bayer or NOAA.

I applaud the sub-committee for recognizing the importance of Federal investments in weather research, forecasting, and dissemination as a means to mitigate the impact of weather and climate extremes on our society. This is a topic that is increasingly critical to the citizens and businesses of the United States and beyond. We are faced with the sobering statistics of increasing weather and climate impacts and disasters suffering losses in the billions of dollars multiple times each year and losing hundreds of American lives with increasing frequency.

My testimony is based upon a nearly four-decades long career with NOAA (ranging from being a forecaster in Juneau, Alaska, to a NOAA/NWS Lab Director, in Washington, DC) that has been followed by nearly a decade of working in private industry (at Microsoft and Bayer). Over my career, I have had the great fortune of working in positions within NOAA that have included helping to implement a modernization of the weather service and introduce research positions as a critical component of field offices across the country. I have seen first-hand in my lifetime the increase in value of weather information and forecasts, which has been nothing short of remarkable. As such, I am particularly proud of what the weather enterprise (a close and critical collaboration between public, private, and academic sectors) has delivered.

Indeed, the weather enterprise has an exceptional and proven track record. The dramatic results derive from years of investment from the Federal government, along with tremendous contributions and advances from the academic and private sectors. NOAA has served as a solid foundation guided by its mandated mission to protect life and property and better the U.S. economy.

When I started college, a weather forecast was skillful for only a few days and often more likely the source for a joke or a complaint, than considered in a decision to evacuate or take cover.

Today, 5-day forecasts are as good or better than a 3-day forecast was at the turn of this century, and skillful weather forecasts extend well into the second week. For just a moment, consider the value this kind of improvement has brought to Americans and American businesses. People can now better plan their activities for the week, industry can make critical business decisions that dramatically increase their profit margins, and emergency managers can make earlier and better decisions about when and who to evacuate in their efforts to better protect Americans and their property.

These gains were not achieved through singular investments, or major breakthroughs, rather they were developed through continuous investment across many fronts, and hard work and collaboration across the weather enterprise over these past decades. Let me call out a few past examples (and these are only a few, there are many others) that we are all likely familiar with to underscore this linkage between significant Federal investments and proven benefits to our country.

A great example is the investment that was made to install and maintain the NOAA/FAA/DOD WSR-88D national radar network. As a result, minutes have been trimmed off the lead time of warnings for severe thunderstorms and tornadoes. The radar data are assimilated into weather prediction models and contribute to improvements in weather forecast skill. Each of us is now able to enjoy phone apps from the weather industry that provide short-term forecasts that were unimaginable just a few years ago. For example, they provide each of us with minute-by-minute updates on when rain or snow is going to stop or start – essentially down to our neighborhood or exact location. The benefits to the public, agriculture, transportation, and other industries have been immense.

Another example, to which I briefly alluded to previously, took place between 1989 and 2000, when the nation invested approximately $4.5 billion to implement the Modernization and Associated Restructuring (MAR) of the NWS. As part of that project, new observational and computational systems were planned and deployed, including the 88D network. Critically, NWS field offices around the country were redefined around new models for observing, forecasting, and service delivery that allowed them to capitalize on the investments in these new systems. I had the good fortune of being part of that restructuring and was one of the first Science Operation Officers introduced into forecast offices around the country. I and my colleagues helped introduce and demonstrate ways in which new technological advances could be implemented within NOAA's production systems and allow for delivering longer range, yet more targeted, forecasts. The entire NWS workforce was restructured around these concepts, with targeted investments in training and recruitment that gave the forecasters the skills and knowledge necessary to implement what was then a modernized NWS.

As forecast skills increased, their potential value increased, yet it was soon recognized that the optimal value of the weather information to the stakeholders was not being achieved. In other words, there was a growing gap between the information being produced by the forecasting process and the value gained by the end users. As this was becoming more apparent, efforts to address this gap occurred both on the public side and within private industry. NOAA/NWS turned their field office focus to communication and support through their Impact Based Decision Support Services program, which provided the interpretation, expressions of confidence, and details necessary to ensure that not only were the NWS's forecasts increasingly accurate, but they were also consumable and actionable, and resulted in the right actions being taken. Equally, private industry made great strides in adding customized value to the NOAA foundation and increasingly developing additional internal capacity to better serve the U.S. and global economies.

As remarkable as these advances have been at saving countless lives, enabling the protection of infrastructure, and mitigating business losses due to weather impacts, we have likely fallen short of where we could have been, and more work still needs to be done. In fact, there is some evidence that the progress in some areas we have all enjoyed and benefited from is slowing (e.g., the skill of medium-range numerical model forecasts). Fortunately, the weather community feels strongly that if done correctly, the weather enterprise can build upon this overall remarkable success story and extend its proven track record through and beyond the next decade. These new benefits would be delivered at a critical time as our Nation is increasingly challenged by weather extremes and climate change impacts.

The PWR report (NOAA Science Advisory Board, 2021) lays out a comprehensive plan that has the potential to be transformational over this coming decade if fully executed. The report identifies three pillars (observations, forecasting, and information delivery), along with several foundational elements (science, computing, workforce development, and the weather enterprise), as being critical to achieving the gains in the value in weather information that are believed possible and critical over this coming decade. Similar to how gains over the past decades were achieved, the report highlights that future advances will be best enabled by the continued investments across multiple fronts. For example, gains in observations must be balanced by better data assimilation and improved numerical models. In turn, these investments need to be informed by societal needs and benefits. Finally, research and investment in the development and delivery of weather information are necessary if related efforts are to keep pace with the scientific and forecast advancements and ultimately improve the ability to protect lives and property, expand the communities served with relevant weather information, and promote economic vitality at this critical time of rapidly changing weather trends and extremes.

I now want to draw your attention to, and focus on, a critical part of the PWR report, namely the section on critical first steps. This section is a collection of ten actions or recommendations that stand out as critical to the success of any plan to move the weather enterprise forward. They are a subset of all recommendations and critical actions identified by the PWR Study Team.
One of three factors drove the selection of each: (1) an ability to deliver immediate benefit (low risk/high reward); (2) necessary to close a critical gap or shortfall; or (3) first in a temporal dependency across multiple actions. These steps were further clustered into four areas including: Research and development, Infrastructure, Action and impacts, and NOAA prioritization and investment. These critical first steps are also highlighted in the PWR Report in Brief (NOAA Science Advisory Board, 2022). I will now briefly call your attention to efforts within each of these four areas.

RESEARCH & DEVELOPMENT: This first area identifies three specific recommendations or actions. The first is an immediate focus on the development of an Earth System Modeling (ESM) framework approach to improve forecast accuracy and lead time. I mentioned earlier that there is some slowing of forecast skill improvements across all major global modeling efforts, including the European Center for Medium Range Forecast and NOAA's Global Forecast System (GFS). While there are several candidate explanations for this slowing, one possibility is that we are reaching the limits of an atmosphere-focused framework. Moving to a fully coupled earth system that includes oceans, the cryosphere, and improved land surface models, is needed to help extend skillful forecasts to longer lead times and deliver greater benefit. Furthermore, the ESM framework is critical to many aspects of the decadal plan and should be immediately prioritized.

The second effort in this area identifies the need for increased and immediate investments in social and human behavioral sciences research, in order to address service gaps, especially for historically underserved and socially vulnerable populations. Investments in this area are absolutely necessary to ensure the full value and benefit from the weather information pipeline are achieved, including across the full diversity of decision makers and weather information users. A critical need is in the collection of relevant data that allow us to understand the needs and circumstances of our wide and varied populations across the nation.

A final key research effort that requires immediate prioritization is data assimilation. This is necessary to deliver sustained improvements in forecast skill and to train the next generation of experts in this area to fill an existing critical workforce gap. Investments in new observing systems cannot be prioritized if a commensurate data assimilation capability to leverage the observations within the modeling system does not exist. Without doubt, the effective utilization of existing and future observations depends on rapid and significant advancement in data assimilation capabilities.

INFRASTRUCTURE: Investments in infrastructure are clearly critical to our success and this second area involves three specific recommendations. The first is that NOAA must accelerate and enhance the ability to deliver to all stakeholders the full volume of foundational data that is generated across their many Centers. There is an exponentially increasing amount of data collected from radar, temperature and wind sensors, and satellites, as well as growing output from NOAA's suite of numerical models and access to these data is critical to many stakeholders within the weather industry. In many ways, NOAA/NWS has been a victim of its own success with the accelerating demand exceeding expectations. NOAA/NWS must commit to improved weather data dissemination, increased open science approaches, and expanded applications through weather industry partnerships. These data are the lifeblood of much our private weather industry, and full and highly reliable access to them is essential.

The second effort in this area involves high performance computing (HPC), which is likely the lynchpin of the success of weather research over this next decade. Without significant and sustained HPC resources, many of the core programs and efforts identified within the PWR report will not be possible. As such the report calls for an increase in capacity by two orders of magnitude (over the next ten years) with a 3:1 ratio of research-committed HPC to production-committed HPC. The benefits of accelerated and long-term investments into HPC cannot be overstated, nor can the detrimental impact of continuing with sub-optimal, incremental, and irregular investments.

The final effort of the infrastructure section focuses on guiding investments across Earth system observing networks. In some cases, these are existing networks where additional minimal investments could quickly enable more extensive use of the data. In others they are large investments that require committed strategic programs to be successful. I discussed earlier the tremendous value we have gained through the WSR-88D network that was installed primarily in the 1990s, yet that network is, at this point, primarily being sustained through multiple life system extensions, and only slow progress is being made toward a next-generation phased array network. A strong commitment for this next generation system is critical. Finally, the private sector is increasingly capable of partnering with, and or, delivering, new and innovative observing systems that can be both sold for commercial viability and shared with the NOAA/NWS. These opportunities must be actively identified and evaluated to identify the best and optimal path forward.

ACTIONS & IMPACTS: Specific to actions and impacts, one area that the report calls out repeatedly is reanalysis and reforecasting (RA/RF). These efforts are vital to Earth system model evaluation and improvement, to characterize extremes, and to provide training datasets for artificial intelligence applications. Unfortunately, NOAA does not have a good track record of prioritizing and investing in the generation of RA/RF. Ideally, they will become part of the operational production system, which will enable constant assessment.

As our country faces increasing climate and weather threats, an area of research that will likely bring significant benefit is to target the understanding and prediction of high-impact weather (HIW). Sharply focused research program on specific hazards (e.g., severe convection and tornadoes, hurricanes, fire weather, drought, and floods) will be the best and most expedient way to match the urgent need imposed by climate trends, population and infrastructure increases, and disproportionate impacts on vulnerable communities. These challenges are only going to grow further and early focused attention on providing relevant targeted observations, modeling, and forecasts, will best serve the WRN strategy.

The forecasting of water, both too little and too much, is one of the grand challenges of the weather forecasting industry. Water cycle extremes, i.e., drought and flood are leading causes of economic and human disruption, yet the prediction of precipitation extremes has been exceedingly slow to improve, with serious adverse impacts on people and the economy. Numerous opportunities exist that would increase resilience to extremes if precipitation, streamflow, and flooding could be better predicted. Immediate and substantial action to implement these recommendations are poised to yield high-value benefits in hazard mitigation and cost avoidance and economic efficiency and opportunity, and environmental justice.

NOAA PRIORITIZATION & INVESTMENT: NOAA and other partner Federal agencies deserve considerable praise for their long-term track record in the area of weather and climate forecasting. Nonetheless, there is little doubt that more could have been achieved and efforts must be made to strive for the best and optimal weather research trajectory possible; especially in the light of what will hopefully be significantly increased resources.

NOAA must focus on developing improved, increasingly objective, methods to balance investments across the weather information value chain and expand efforts to more precisely target future investments. These plans should include ongoing prioritizations, carefully vetted implementation plans, and detailed gap analyses that are designed to call attention to any potential negative impacts. It is also critical that NOAA immediately develop more systematic methods to prioritize investments, including improved metrics to measure success, set goals, and focus resources. Not only will these methods better inform NOAA leadership, but they will also provide Congress with additional tools to prioritize investments for their greatest impact. Ideally these methods will be structured, will cross line offices, and will promote an integrated approach to budget decisions. They must also incorporate the broader weather enterprise. We have learned from the past that a thriving private industry can provide data, products, and services to federal agencies, which will help accelerate applied research and innovation through partnerships, including the academic sector.

The immediate first-step topics from the PWR report are, indeed, an excellent place for you to either accelerate and/or begin investing in immediately. If resources can be acquired to execute ~~on~~ the PWR plan, the benefits will be transformational as we move into this next decade. Having said that, the work will not be easy and will require the continued growth of the weather enterprise through increased collaboration and investment. The synergy will be high across the Enterprise, with NOAA focusing on its core mission, and private industry playing an increasingly essential role in the process.

I hope I have provided through this testimony some helpful insights that will support as you work to chart a course forward that will build off of our past successes, learn from past challenges, and build toward a better prepared and Weather Ready Nation.

I look forward to your questions. Respectfully, Dr. Brad Colman

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Short Bio – BRAD COLMAN

Bradley R. "Brad" Colman is the Director of Weather Strategy for Bayer/ Climate LLC, and President-Elect of the American Meteorological Society. At Bayer, he coordinates across multiple divisions to set weather priorities and works with scientists, engineers, and vendors, to deliver critical environmental information across Bayer's global agricultural industry.

Prior to joining the private sector, Colman enjoyed a long and diverse career with NOAA where he was both Meteorologist in Charge and Science and Operations Officer at the National Weather Service forecast office in Seattle, Washington; and a Forecaster in Juneau, Alaska. He also served as Acting Director of NOAA's Meteorological Development Laboratory, Silver Spring, Maryland; and worked as a Research Meteorologist at NOAA's Environmental Research Laboratory in Boulder, Colorado.

Brad is a member of the National Academy of Sciences' Board on Atmospheric Sciences and Climate (BASC); an elected Member of the Washington State Academy of Sciences; Co-Chair of the Environmental Information Services Working Group (NOAA-SAB); and a Bayer Science Fellow. Colman earned his Sc.D. in Atmospheric Sciences from the Massachusetts Institute of Technology (1984) and a B.S. in Earth Sciences from Montana State University (1977).