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Good morning Chairman Begich, Ranking Member Snowe, and Members of the Subcommittee. My name is Mary Glackin and I am the Deputy Under Secretary for Operations at the National Oceanic and Atmospheric Administration (NOAA). Thank you for the opportunity to testify today about the need for, and NOAA's role in, supporting innovation to improve weather and climate services.

NOAA, since its beginnings, has relied on mission-focused research and innovation as a means of improving services to the Nation. NOAA has the sole responsibility of issuing severe weather warnings to communities across the country. NOAA-led weather innovations such as the national Doppler RADAR network and weather modeling improvements continue to provide our Nation with increases in advanced warnings that protect lives and property from tornadoes and other severe weather events. This year we have seen an unprecedented number of natural disasters, from the heart wrenching tornado outbreaks in Alabama and neighboring states in April, Joplin, Missouri in May, to record flooding in the upper Plains and the Northeast. In the face of these challenges, NOAA has been able to provide advanced and accurate forecasts because of its continued investment in the long-term research and development that drive innovation. There is much more to be done if we are to achieve new life saving advancements in the future, and NOAA is committed to working with its academic, private sector and other partners in the broader climate and weather enterprise to continue this record of success.

NOAA scientists have been at the forefront of weather and climate science, forecasting and public preparedness for decades—our science helps save lives and livelihoods. NOAA has a leading role in understanding changes in weather and climate extremes, such as trends in severe local storms and extremes in precipitation—too little or too much, too often or too infrequent. Extreme weather and associated societal impacts have increased in recent years, and with our changing climate, the Nation can expect more frequent extreme weather events in the future. To combat this increased vulnerability, communities across the country must become more resilient to extreme events, with smarter land use planning, more widespread use of emergency action plans, and numerous other actions.

Our Nation's environmental predictive capabilities are supported by four foundational pillars: observations, computer modeling (including High Performance Computing), scientific research, and our people, who provide forecasts, warnings, and decision support

services to key decision makers. By strengthening the pillars – through improved satellite and in-situ observations, computational capacity, and coupled atmosphere, ocean, land models, and necessary research – we can revolutionize the forecast process across the entire spectrum, from relatively small-scale, short range applications to long range weather and climate predictions.

Yet, the success of NOAA's mission should not only be measured by the accuracy of its information, but by the effectiveness of its application. As such, NOAA is pursuing a number of innovative approaches to not only to provide significantly more lead time for forecasts, but to also ensure that people hear these warnings and take informed and appropriate actions to protect their own safety. This mixture of technological and social science advancements is a new approach to building a "Weather-Ready Nation" and one that we expect to provide huge returns – measured in avoided economic losses and lives saved.

A Historic Year in the Making

Despite NOAA's quality forecasts and outlooks, severe weather events in 2011 have demonstrated the need for continued investment in scientific innovation to improve environmental intelligence. 2011 has already established itself in the record books as a historic year for weather-related disasters, and it is not over. We have already seen ten $1-billion-plus disasters. Total damages from weather- and water-related events since January for the United States are well over $45 billion and climbing. 2011 is now the fourth deadliest tornado year for the United States since 1875, and the deadliest since 1936, with 548 people killed as of November 6. April 2011 ranks as the most active tornado month on record with 875 tornadoes, breaking the previous record of 542 set in 2003. More tornadoes occurred on April 27 of this year than any other day in the past 61 years. On May 22, a large portion of Joplin, Missouri was devastated by an EF-5 (winds greater than 200 mph) tornado, resulting in over 150 fatalities and over 1,000 persons injured. The Joplin tornado was the deadliest this year and is ranked 7th among the deadliest tornadoes in U.S. history.

Fueled by record-setting precipitation totals, historic flooding has hit the Midwest and Ohio Valley, from the smallest streams to the largest rivers. The Ohio Valley region had its wettest April on record, and the record goes back to 1895 for some states. Record breaking heavy rains across Montana and the Dakotas, combined with runoff from record winter snowpack, caused tremendous flooding across those states, with Minot, North Dakota, being among the hardest hit.

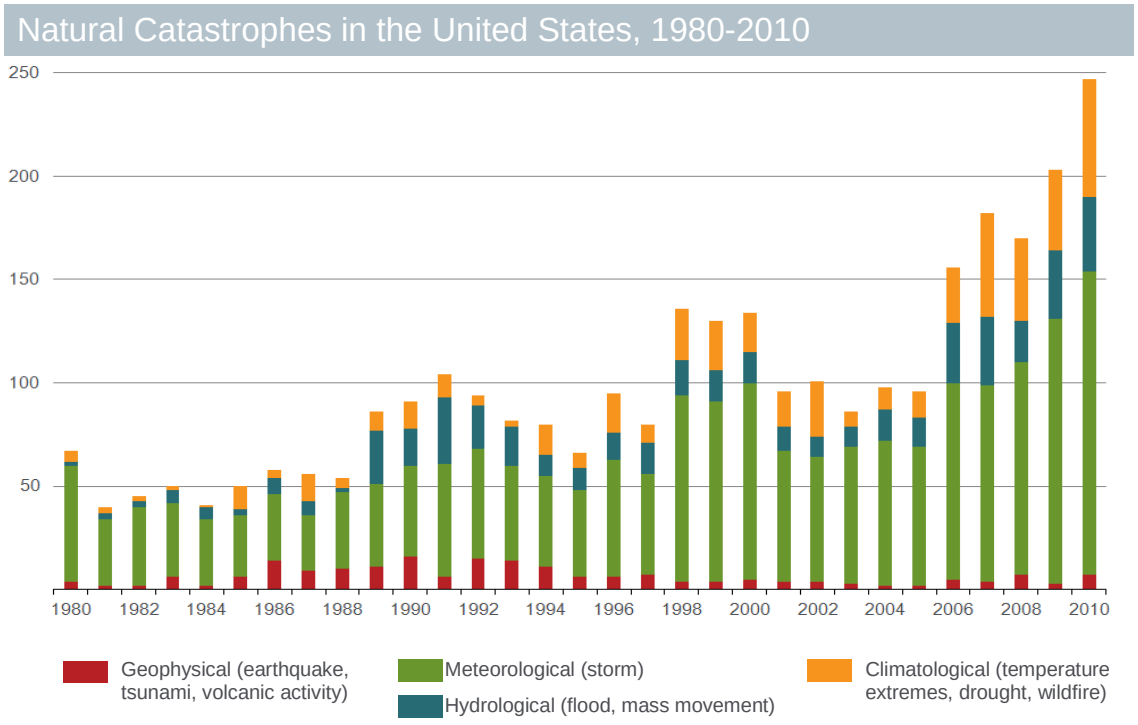
This year the United States has also experienced severe impacts due to decadal-scale changes in our climate. Across the U.S. Southwest extreme drought continues – stretching from New Mexico through Texas and Oklahoma across the Gulf States and Florida. According to the State of Texas, the past twelve months – from October 2010 through September 2011 – have been the driest in state history since 1895. Nearly two-thirds of Texas is currently experiencing drought categorized as "exceptional" – the most severe type. Texas has responded to more than 24,000 fires in approximately the same

period, which have burned more than 3.8 million acres and destroyed over 7,000 businesses and homes. The Texas Agrilife Extension Service has calculated that Texas' agriculture sector alone experienced losses of roughly $5.2 billion through August.

Prime wildfire conditions continue across large portions of the Southern Plains and Southwestern States. More than 8.2 million acres have burned nationwide – nearly 120 percent of the ten-year average by this time of year.

WHAT IT MEANS

Nearly 90 percent of all Presidentially-declared disasters are weather and water-related, and our vulnerability to the impacts is increasing as our population grows. As shown in the chart below, the number of natural catastrophes resulting in property damage and/or bodily injury in the United States is trending upward, with 2011's numbers on track to surpass last year's record as of July.



Source: Munich Re NatCat*SERVICE* (statistics and chart)

Over the past thirty-plus years, the United States has seen a total of 107 weather- and climate-related disasters each totaling over $1 billion dollars in damage. Total standardized losses since 1980 exceed $750 billion (inflation-adjusted to 2011 dollars using the Consumer Price Index).

Demographic trends and population growth and an increased reliance on technology have made our society more vulnerable to high impact events at a time when we are seeing an

increasing trend in extreme weather events. As a result, many agricultural, business, and urban planners are looking for ways to increase community resilience now. For example, the City of Chicago is taking steps to prepare for the likelihood of intense storms striking more often, of rainfall events causing more flooding, and of warmer temperatures. Local climate studies, along with recent trends such as an increase in the frequency of heavy rainfall events, have led them to conclude that proactive steps are needed to mitigate the cost and impact of these events. New York City is also engaged in adaptation planning, with particular focus on the risk of flooding from rising sea level. The Navy's Task Force on Climate Change has advised that the Navy should prepare to police the equivalent of an extra sea as the Arctic ice melts. These cities and organizations, among many others, recognize the need to understand changes and trends in weather patterns, and to apply this to planning that may reduce vulnerability to high-impact weather and water events. Their recognition of the need to reduce their vulnerability to weather and water extremes is an important first step. However, there is much more that needs to be done in other sectors of our economy and with the general public to increase our resiliency to the impacts of these events.

NOAA SCIENCE SPURS INNOVATION TO BETTER MEET SOCIETAL NEEDS

NOAA's science spurs innovation within the agency. NOAA science includes discoveries and ever new understanding of the oceans and atmosphere, and the application of this understanding to such issues as the causes and consequences of climate change, the physical dynamics of high-impact weather events, the dynamics of complex ecosystems and biodiversity, and the ability to model and predict the future states of these systems. NOAA is supported in these efforts by key pieces of legislation, such as the Global Change Research Act and America COMPETES Act, the latter of which this Committee reauthorized in 2010.

NOAA conducts and supports innovative research in order to provide the public with information, products, and services that enable stakeholders to make the best decisions possible to advance economic growth while promoting a healthy environment. NOAA is not alone in these endeavors and works in close partnership with the broader weather and climate enterprise that includes other federal agencies, the private sector weather and climate industry, academic institutions and consortia, state and local governments, and other organizations. NOAA supports research at partner institutions such as Cooperative Institutes, its Sea Grant college network, Regional Integrated Science and Assessments program, and other mechanisms.

Often, NOAA-supported advances are conducted in partnership with the private sector, such as through the NOAA Small Business Innovation Research program, and foster additional opportunities for economic growth in the private sector. Many innovative weather and climate technology advances spurred by NOAA investments in its own and partner institutions have been commercialized by the private sector and are now sold by the private sector around the world as the gold standard, such as NOAA's Argo floats, which are state of the art profiling floats that are providing realtime pressure, and ocean temperature and salinity for climate, weather, and other service applications and research

efforts.

Research, Observations and Prediction

Longer lead-time forecasts for droughts, seasonal flooding, heavy rainfall events, heat waves and cold spells provide tremendous economic value for the Nation through overall reductions in loss of life and in physical and economic damage. NOAA provides a spectrum of critical information across a range of time and space scales, which is used by government, business, emergency managers, planners, and the public. The value of that information increases when businesses, farmers, energy producers and utilities, as well as the general public, are prepared and have effective plans of action to mitigate impacts.

Returning to NOAA's four pillars, future investments in innovation will be focused on: observations, computer modeling (including High Performance Computing), foundational scientific research, and our people, who will be better positioned to advise key decision makers during extreme events. For example, on the larger scale, coupled environmental models provide improved simulations of the interaction between the ocean and atmosphere, resulting in more accurate predictions of tropical cyclone behavior. On smaller scales, higher resolution observations and models can provide the type of short-term severe weather predictions that will one day allow us to know up to 60 minutes ahead of time where a tornado will touch down, and to provide warning to the public based on these forecasts.

An example of scientific innovation in observations is NOAA's deployment of Dual Polarization radar technology. Developed in NOAA, "Dual Pol" is the latest weather radar upgrade, providing both horizontal and now vertical components to what NEXRAD Doppler radar is seeing. It will add fourteen new products to the suite of data already available to NOAA weather forecasters and our partners who receive radar data. These new tools will assist forecasters in the warning and forecast process. With Dual-Pol radar, forecasters can better glean information such as the size, shape, and type of precipitation particles. This information will lead to better estimation of total precipitation for water management and flood forecasting; accurate identification of the snow levels in higher terrain; improved ability to identify areas of heavy rainfall, including flash flooding potential; identification of rain-to-snow transitions, to alert travelers and road crews; and more precise severe thunderstorm warnings, especially for those containing hail. The full benefit of Dual-Pol radar, however, will not be fully realized until weather forecasters and research meteorologists develop new ways to utilize the data specific to their geographic areas and gain experience.

One of NOAA's very promising technologies toward improving higher resolution observation that supports weather predictive capabilities is called Multi-Function Phased Array Radar (MPAR) – the potential future generation replacement of weather radars. These new prototype radars, MPAR build off existing military technology, with a unique antenna that collects the same weather information as existing weather radar, but in about one-sixth the time. MPAR could not only expand the current weather surveillance network, but also has the potential to meet air traffic surveillance, homeland security and

defense requirements for identifying and tracking non-cooperative aircraft over the United States. The decision to determine the feasibility of MPAR deployment is still several years out and will require significant research and collaboration with academic and industry partners. Steps for finalization include research, prototype development, testing and evaluation, and, if the technology proves feasible, eventual deployment of new systems.

We anticipate numerous enhanced weather and climate service benefits from MPAR. MPAR's adaptive sensing capability has the potential to support continued improvements to the severe weather warning system for tracking tornadoes, strong wind gusts, hail and locally heavy rains responsible for flash floods and mudslides. In addition, MPAR will provide observations that allow for more precise information about hazardous weather that affect flight safety and airspace capacity, in turn providing economic efficiency to domestic aviation and surface transportation systems. Finally, more detailed atmospheric observations, such as would flow from MPAR, are anticipated to improve air quality real-time advisories and forecasts, climate variability monitoring and forecasting, and wildfire monitoring and prediction.

We know that shifts in weather patterns are often regional in nature, and have variable time spans. For example, El Niño and La Niña, which have become household words, are generally predictable over fairly definable areas and time spans. During the 1997-1998 El Niño and 1998-1999 La Niña, the U.S. agricultural sector experienced damages of $2.4-2.8 billion and $3.6-10.7 billion (in 2010 dollars), respectively. We are coming to understand many of these larger scale phenomena, such as the North Atlantic Oscillation, which is a change in the water temperature in the North Atlantic that is strongly correlated with heavy snowfall events in the Mid-Atlantic and Northeast states. These patterns, observed in-situ by NOAA's Tropical Atmosphere-Ocean (TAO) buoy array in the equatorial Pacific Ocean, strongly influence and can help inform NOAA's seasonal forecasts, including the recently-published 2011-2012 Winter Outlook. NOAA has successfully transitioned numerous research innovations such as the TAO array into operations, turning wise investments into critical operational tools for accurate environmental prediction.

Our tornado warnings have improved significantly over the past two decades primarily because of past research efforts. More research would help us better understand the rapid evolution of severe thunderstorms and why some produce tornadoes and others do not. We face a similar challenge with our understanding of hurricanes. While our track forecasts have improved greatly – our forecast location for 5 days out is now as accurate as the forecast location for 3 days out was 15 years ago – we still do not understand what causes some tropical systems to jump two intensity categories in less than 24 hours, while others do not. NOAA's goal – through an innovative research-to-operations test-bed called the Hurricane Forecast Improvement Project (or HFIP) – is to demonstrate a 20% reduction to the average errors of hurricane track and intensity forecasts by the end of FY 2013 and operationalize that improvement over the next few years. This will improve the accuracy and reliability of hurricane forecasts; extend lead time for hurricane forecasts with increased certainty; and increase confidence in hurricane forecasts. The desired

outcome is to ultimately reduce the Nation's risk to hurricane impacts by delivering improved forecasts and tools for community planners and other decision-makers. The anticipated societal benefits will reduce deaths, injuries and property damage, and reduce the other costs associated with hurricanes by enabling decision makers to better identify at-risk populations and property, and by raising the confidence levels to initiate mitigation measures further in advance of approaching hurricanes

NOAA is making investments in key research and development areas that address a key information gap today between instruments on Earth's surface and on satellites. One area of NOAA investment that could help bridge that gap is in Unmanned Aerial Systems (UAS). Operated by remote pilots and ranging in wingspan from less than six feet to more than 115 feet, UAS collect data from dangerous or remote areas. UAS have the potential to improve NOAA's ability to monitor and understand the global environment by collecting data from areas that are currently inaccessible. In partnership with NASA NOAA spent six weeks in the fall of 2010 studying hurricane formation and development in the Gulf of Mexico and the western Atlantic Ocean. Researchers sent the Global Hawk, equipped with a suite of instruments, over hurricanes Earl, Karl, and other storms in the region. The UAS flew multiple times over hurricane eyes, soared above one storm (a record for a unmanned aircraft system), and collected high-resolution data on the storms' wind and cloud structures, particles in the air, lightning strikes and other meteorological variables. NOAA is partnering with other federal agencies, academia, and private companies to test a variety of UAS. UAS may also have significant benefits beyond hurricanes, including new observational support for improving: the accuracy of other storm, flood, and drought forecasts, benefiting emergency managers and diverse private industries; our understanding of climate change; assessments of changes in Arctic sea ice and effects on ecosystems and coasts; and fire weather forecasts to increase safety and success in fighting wildfires that threaten people and property.

NOAA also fosters innovation through partnerships. Water management decision makers require a new generation of water information, forecasts, and decision support. NOAA is working with its federal partners USGS, USACE and others to implement Integrated Water Resources Science and Services, creating an integrated, high-resolution common operating picture for water information, supporting timely and critical water management decision in full coordination and collaboration with forecasting and decision support services.

And finally, advances in data assimilation, computer modeling, and atmospheric observations through high-tech polar orbiting satellites and geostationary satellites have led to substantial improvements in NOAA's model forecasts. For example, leading up to the "Snowmageddon" event of February 2010, NOAA was able to detect the storm threat seven-plus days in advance and begin alerting the East Coast up to five days in advance of the storm. This allowed states to implement contingency and continuity of operations plans, airlines to rearrange flights, and the retail industry to pre-stock their shelves. As a result, there was minimal impact to national and local airline and highway transportation. This long lead time was made possible in large part by observations obtained by NOAA's polar-orbiting satellite and numerical weather prediction models.

Polar-orbiting satellites are the backbone of *all model* forecasts for three days and beyond; however, future innovation in our observations and improvements in our forecasting are at risk. The launch of the next generation of NOAA's polar-orbiting satellites, the Joint Polar Satellite System (JPSS), has been further delayed by funding shortfalls in FY2011. As a result, NOAA is faced with a nearly 100 percent chance of a data gap in the U.S. civilian polar orbit, on which both civilian and military users rely, by late 2016 to early 2017 when the current polar satellites reach the end of their life expectancy. JPSS is a critical part of NOAA's future infrastructure needed to continue our path of forecast improvement – and to maintain what we have built over the last 30 years. NOAA thanks the Committee, and the Senate as a whole, for their recognition of this crucial need and their support in the Senate's FY 2012 appropriations bill for NOAA.

Uninterrupted flow of data from NOAA satellites is required to support two Department of Commerce Primary Mission Essential Functions (PMEF),[1] which have been approved by the National Continuity Coordinator, thus making NOAA satellites not just NOAA priorities but also national priorities. NOAA is investing now to ensure that the Nation can continue to rely on these critical observations in the future. These observations and the derived products and services allow the Nation to prepare effectively for and deal with severe weather and other environmental phenomena.

Getting the Word Out

As the federal government's sole official voice for issuing warnings during life-threatening weather events, and as an established, reliable, and trusted source, NOAA provides the Nation's first line of defense against severe weather. NOAA operates the Nation's geostationary and polar orbiting satellites, a nationwide network of Doppler weather radars and surface observing stations. Scientists develop computational models that combine these observations with equations describing the physics of our atmosphere and ocean, and our forecasters interpret and deliver critical information. Alerts and warnings for severe weather and other near term hazards (tornadoes, hurricanes, severe thunderstorms, winter storms, most floods, chemical spills, volcanic ash, tsunami, space weather, etc.,) are delivered through multiple redundant mechanisms, including: NOAA Weather Radio, which triggers the Emergency Alert System; NWSChat, which focuses on real-time coordination with local core customers in the broadcast media and

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[1] **PMEF DOC-2:** Collect and provide the Nation with critical intelligence data, imagery, and other essential information for predictive environmental and atmospheric modeling systems and space-based distress alert systems by operating NOAA-controlled satellites, communications equipment, and associated systems.

PMEF DOC-3: Provide the Nation with environmental forecasts, warnings, data, and expertise critical to public safety, disaster preparedness, all-hazards response and recovery, the national transportation system, safe navigation, and the protection of the Nation's critical infrastructure and natural resources.

emergency management; the Internet; and, through our private sector partners, commercial television and radio, which communicate critical information to much larger audiences and effectively inform those in harm's way to take appropriate action.

Preparedness

Our prospects for achieving our vision of resilient communities lie in our unique enterprise capabilities. The goal of disaster resilience is to enhance the capacity of a community exposed to hazards to adapt, by resisting or changing, in order to reach and maintain an acceptable level of functioning and structure. The preparedness challenge remains essentially the same across both short-term and long-term weather and water events: public awareness, education, and plans of action to mitigate impacts on the personal, community, and regional scales provide the best protection against potential disasters. NOAA has long-held and strongly established ties to the emergency management community, through state, local, and tribal officials, which help ensure appropriate action is taken to prepare communities for weather and water events. NOAA and its partners, such as the National Sea Grant network, use integrated research, training, and technical assistance to enhance the ability of communities to prepare for, respond to, and rebuild after disasters strike. For example, we are developing a Coastal Resilience Index that provides a tangible way for communities to identify gaps and examine how prepared they are for storms and storm recovery, and provide guidance on how to increase resilience through measures including strengthening infrastructure or adopting stricter building codes.

The historic floods, which spanned from Montana across the Dakotas, into northern and central plains and southern Mississippi Valley earlier this year, are an excellent example of why we need to prepare for catastrophic events. The NOAA spring flood outlook highlighted those particular areas as having the likelihood of major flooding. Our River Forecast Centers and local Weather Forecast Offices worked with Federal, state and local emergency managers and planners to help prepare for and plan to mitigate the impact of the flooding. Based on our forecasts, communities took extensive actions to limit the impact of the flooding, including massive levee reinforcements and eventual evacuations to prevent loss of life. FEMA prepositioned relief assets, and the USGS ensured their river gauges were operational – all of the agencies worked together to help mitigate the potential impact.

Unfortunately, in spite of our best efforts, severe weather events still cause loss of life and significant damage. More of this could be mitigated with more timely, accurate and focused warnings. The impacts and lives lost from the disasters mentioned above would have been far worse without critical data input of observations from satellites and in-situ observations, and the extensive work of NOAA and our federal, non-federal, state and local partners to improve the Nation's preparedness for these events through education and outreach. However, as evidenced by the tragic loss of life in a number of these events, there is a long way to go to truly achieve a Weather-Ready Nation.

With the high death toll and impacts we've seen this year, we take little solace in knowing that outcomes could have been worse without the extensive work of NOAA and our federal, non-federal, state and local partners. There is much more that needs to be done to improve the Nation's resilience for these events. Research, education, and outreach are the essential ingredients to improving preparedness and via improved forecast and warning accuracy and lead times. Realizing a Weather-Ready Nation, where society is prepared for and responds to weather dependent events, is vital.

NOAA has started a national dialog with the Nation's top experts in broadcast meteorology, emergency management, and the weather industry to examine what is happening with severe weather and what can be done in the short- and long-term to improve the Nation's severe weather forecasts and warnings, and community preparedness. Included in this effort are social sciences, innovative technologies, and social media to improve our effectiveness in reaching those in harm's way and provoking appropriate response, whether to the urgency of a tornado or tsunami warning, or to the longer-term likelihoods of flooding or drought. For example, most NWS offices have established Facebook pages, providing an additional medium for conducting outreach and education, as well as highlighting information about ongoing or upcoming weather events. Additionally, NOAA uses NWSChat to give private sector partners an invaluable opportunity to interact with NWS experts and to refine and enrich their communications to the public. Moreover, more private companies are carrying weather warnings on wireless networks, providing real-time alerts to your cell phone or e-mail.

Sustaining our commitment to existing services, while continuing to innovate to improve our capacity to meet the Nation's weather and water needs, requires targeted investments to shore up aging infrastructure, improve scientific understanding, and implement enhanced services to reduce risk to the Nation caused by weather and water. NOAA must increase our capacity to collect and assimilate increasing amounts of data to improve model performance, which is achieved through scientific innovation and technological advancements. Future technology improvements include more advanced polar and geostationary satellites, more sophisticated radar coverage, observing systems, and improved computing capabilities. These technology assets are crucial pieces of our national infrastructure.

Additional, innovative projects, such as the Weather and Emergency Manager Decision Support (WxEM) and the HFIP's Socio-Economic Research Recommendations Projects are also integrating social science into NOAA products and information to encourage more resilient behavior that reduces loss of life and property.

Through the Weather and Emergency Manager Decision Support, NOAA is exploring ways to make its information easier to find, easier to understand, and easier to apply in operations by the Emergency Management community. This will result in improved decision making for risk management of life and property. Further, the HFIP Socio-Economic Research project is using social science to help improve tropical cyclone risk communication, including the development of new or reconfigured existing graphics

(e.g., the hurricane forecast cone of uncertainty), and visualization techniques, to better communicate tropical cyclone and storm surge risk and promote appropriate public response.

We know that NOAA forecasts, warnings, and community-based preparedness programs are vital in enhancing the economy and saving lives. It all starts with a commitment on improved forecasting and ends with a Weather-Ready Nation in which businesses, governments, and people are prepared to use those forecasts to mitigate impacts.

SUMMARY

To achieve an increase in community resilience and reduce the Nation's vulnerability to weather and water related extreme events, we must continue to improve predictions. Again, our Nation's environmental predictive capabilities are supported by four foundational pillars: observations, computer models, research, and our people. By strengthening the pillars – through continued innovation in improved satellite and in-situ observations, computing capacity, coupled atmosphere, ocean, land models, and necessary research and science improvement – we can revolutionize the forecast process across the entire spectrum from relatively small-scale, short range applications to long range weather and climate predictions.

The dual goals of preparing for and mitigating natural hazards require the continuous commitment and partnership of many individuals and sectors – from Federal, state, tribal, and local to public, private, and academic. The investments made by Congress and the Administration in NOAA's weather prediction and warning capabilities *directly* save lives in the United States during these weather disasters. NOAA remains committed to leading U.S. efforts to save lives and property through preparedness, detection, modeling, and forecasting efforts necessary for improved decision making. Although nothing can eliminate the physical threat that severe weather and natural hazards pose, NOAA has demonstrated success in better predicting them, reducing their impact, and helping vulnerable communities become more resilient to their devastating effects – and will work to continuously improve its natural hazards products and services to the Nation.