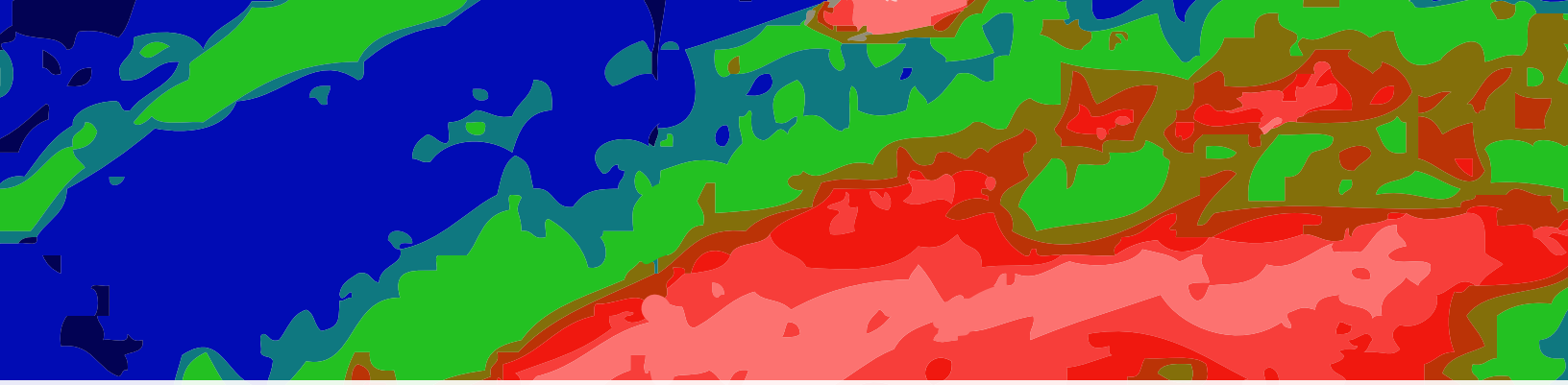


Thirteenth Annual John H. Chafee Memorial Lecture
on Science and the Environment

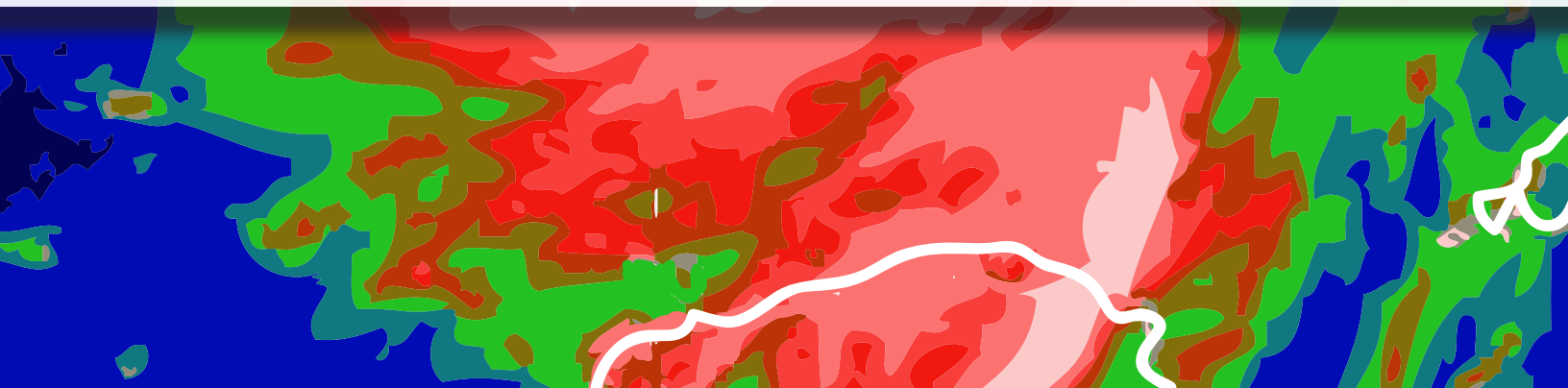
January 16, 2013

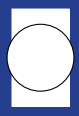
PHOENIX RISING?

RESILIENCE IN A CLIMATE-CHANGE WORLD

Dr. Jane Lubchenco
Under Secretary of Commerce for Oceans and Atmosphere
and Administrator, National Oceanic and Atmospheric Administration

National Council for Science and the Environment
Improving the scientific basis for environmental decisionmaking





National Council for Science and the Environment

Improving the scientific basis for environmental decisionmaking

About NCSE

The National Council for Science and the Environment (NCSE) has been working since 1990 to improve the scientific basis for environmental decision-making. We envision a society where environmental decisions are based on an accurate understanding of the underlying science, its meaning and limitations, and the potential consequences of action or inaction.

NCSE specializes in bringing together the communities creating and using environmental knowledge, including research, education, environmental and business organizations, as well as governmental bodies at all levels.

NCSE operates programs in five strategic areas: Strengthening Education and Careers; Communicating Science to the Public; the National Conference on Science, Policy and the Environment; Providing Science Solutions; and Advancing Science Policy at the National Level.

For more information about NCSE's programs, please visit our website at www.NCSEonline.org.

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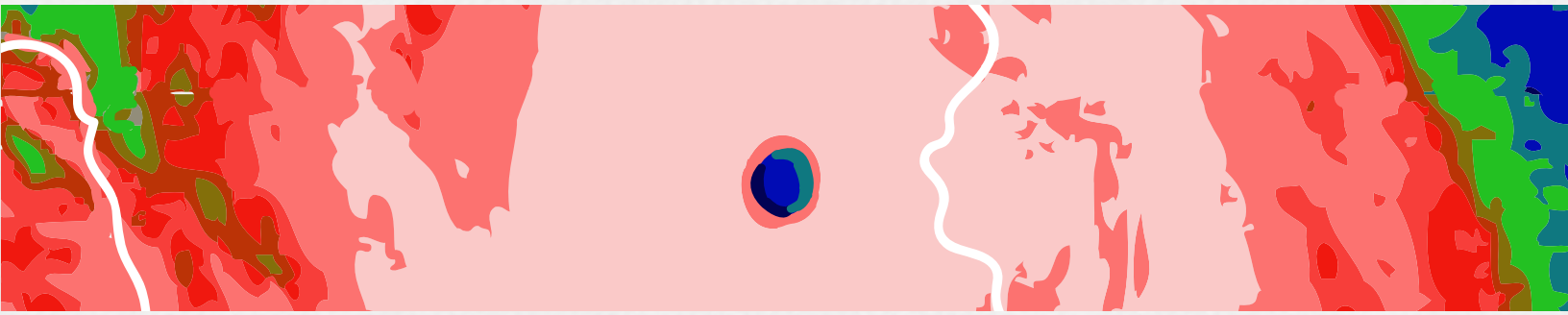

PHOENIX RISING?

RESILIENCE IN A CLIMATE-CHANGE WORLD

Dr. Jane Lubchenco

Under Secretary of Commerce for Oceans and Atmosphere
and Administrator, National Oceanic and Atmospheric Administration

Sponsored by the
National Council for Science and the Environment (NCSE)

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This volume is the thirteenth in a series of books documenting the annual John H. Chafee Memorial Lecture on Science and the Environment. The lecture was delivered at the 13th National Conference on Science, Policy and the Environment: Disasters and Environment: Science, Preparedness and Resilience (Peter Saundry, Conference Chair) on January 3, 2013, in Washington, D.C.

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Manufactured in the United States of America

This book is dedicated to the memory of Senator John H. Chafee who, in his 23 years representing Rhode Island in the U.S. Senate, was a leader in promoting a bipartisan, science-based approach to environmental issues.

Biography of Senator John H. Chafee

Senator John H. Chafee (R-RI) was born in Providence, Rhode Island, in 1922. He earned degrees from Yale University and Harvard Law School. Upon the United States' entry into World War II, Chafee left Yale to enlist in the Marine Corps, and then served in the original invasion forces at Guadalcanal. In 1951 he was recalled to active duty and commanded a rifle company in Korea.

Chafee began his political career by serving for six years in the Rhode Island House of Representatives, during which time he was elected Minority Leader. He was then elected Governor by a 398-vote margin in 1962. He was re-elected in 1964 and 1966—both times by the largest margins in the state's history. In January 1969 he was appointed Secretary of the Navy and served in that post for three-and-a-half years. He was elected to the United States Senate in 1976.

As Chairman of the Environment and Public Works Committee, the Senator was a leading voice in crafting the Clean Air Act of 1990. He led successful efforts to enact oil spill prevention and response legislation and a bill to strengthen the Safe Drinking Water Act. Senator Chafee was a long-time advocate for wetlands conservation and open space preservation and was the recipient of every major environmental award. As senior member of the Finance Committee, Senator Chafee worked successfully to expand health care coverage for women and children and to improve community services for people with disabilities. In 1990, Senator Chafee spearheaded the Republican Health Care Task Force. He went on to lead the bipartisan effort to craft a comprehensive health care reform proposal in 1994.

Senator Chafee also was a leader in efforts to reduce the federal budget deficit and cochaired the centrist coalition that produced a bipartisan balanced budget plan in 1996. He was an active proponent of free trade and was a strong supporter of the North American Free Trade Agreement (NAFTA). He served as Chairman of the Republican Conference for six years. The Senator received awards and endorsements from such organizations as the National Federation of Independent Business, the American Nurses Association, the League of Conservation Voters, the Sierra Club, Handgun Control Inc., Planned Parenthood, Citizens Against Government Waste, and the National PTA.

Senator John H. Chafee died in 1999. He is sorely missed.

Biography of Dr. Jane Lubchenco

Dr. Jane Lubchenco has been the undersecretary of commerce for oceans and atmosphere and administrator of NOAA since 2009. Nominated by President Obama in December 2008 as part of his "Science Team," she is a marine ecologist and environmental scientist by training, with expertise in oceans, climate change, and interactions between the environment and human well-being. She received her B.A. in biology from Colorado College, her M.S. in zoology from the University of Washington, and her Ph.D. in ecology from Harvard University. Her academic career as a professor began at Harvard University (1975-1977) and continued at Oregon State University (1977-2009) until her appointment as NOAA administrator.

Under her leadership, NOAA has focused on restoring fisheries to sustainability and profitability, restoring oceans and coasts to a healthy state, ensuring continuity of the nation's weather and other environmental satellites, developing a Weather-Ready Nation, promoting climate science and delivering quality climate products, strengthening science and ensuring scientific integrity at NOAA, and delivering the highest quality science, services and stewardship possible. Healthy oceans and coasts and a nation prepared for severe weather, disasters and climate change are keys to economic recovery and prosperity.

Lubchenco has served as president for the American Association for Advancement of Science (AAAS), the International Council for Science, and the Ecological Society of America, and was a board member for 10 years on the National Science Board. She also served on the National Academy of Sciences' study on "Policy Implications of Global Warming" under the administration of George H.W. Bush. She served on several commissions, including the Pew Oceans Commission, the Joint Oceans Commission Initiative, the Aspen Institute Arctic Commission, and the Council of Advisors for Google Ocean.

Before coming to NOAA, Dr. Lubchenco co-founded three organizations (The Leopold Leadership Program, the Communication Partnership for Science and the Sea [COMPASS], and Climate Central) that aim to communicate scientific knowledge to the public, policy makers, media and industry; she also co-founded a research consortium, PISCO, which studies the near-shore ocean along the coasts of Oregon and California.

Open Letter from the Executive Director of NCSE

Thank You, NOAA
January 24, 2013

On the afternoon of Friday October 19, 2012, scientists at the National Oceanic and Atmospheric Administration (NOAA) began to pay attention to a seemingly obscure thunderstorm in the middle of the Atlantic Ocean. From this inauspicious beginning, NOAA scientists began tracking and reporting on Superstorm Sandy.

By continually monitoring the conditions of the storm and an extensive area of atmosphere and ocean; and, using sophisticated models developed over many decades to predict future conditions, NOAA scientists did something truly remarkable on October 26, while Sandy was over the Bahamas. The scientists predicted that the storm would gather strength, move northeast and then, abruptly, veer west and slam into New Jersey with major impact on the twenty-two million people living in the metropolitan area of New York.

Demonstrating faith in its science and scientists, NOAA immediately alerted the Federal Emergency Management Agency and state and local governments in the impacted area. Over the next four days, supplied with regular updates from NOAA's scientists and help from NOAA staff deployed to operation centers, communities prepared for the storm which arrived just as predicted.

Tragically, more than a hundred lives were lost. Yet, many more lives were saved. How many? Thousands? Tens of thousands? Even more? It is not possible to know the death toll avoided but for NOAA's early and accurate warnings. Given the population and vulnerabilities of the impacted area, I suspect that Sandy would quite likely have been the worst natural disaster in the history of the Nation, had the critical four days of preparation not occurred.

Today, many of us go about our daily lives, perhaps still cleaning up after the storm, but alive and with our loved ones, blissfully unaware that the fate that we were spared, thanks to NOAA scientists.

We rightly recognize the firefighters, paramedics, police and other "first responders" who come to our aid at such times. They are indeed heroes within our communities. For Sandy, the scientists of NOAA were our first responders, our scientific heroes.

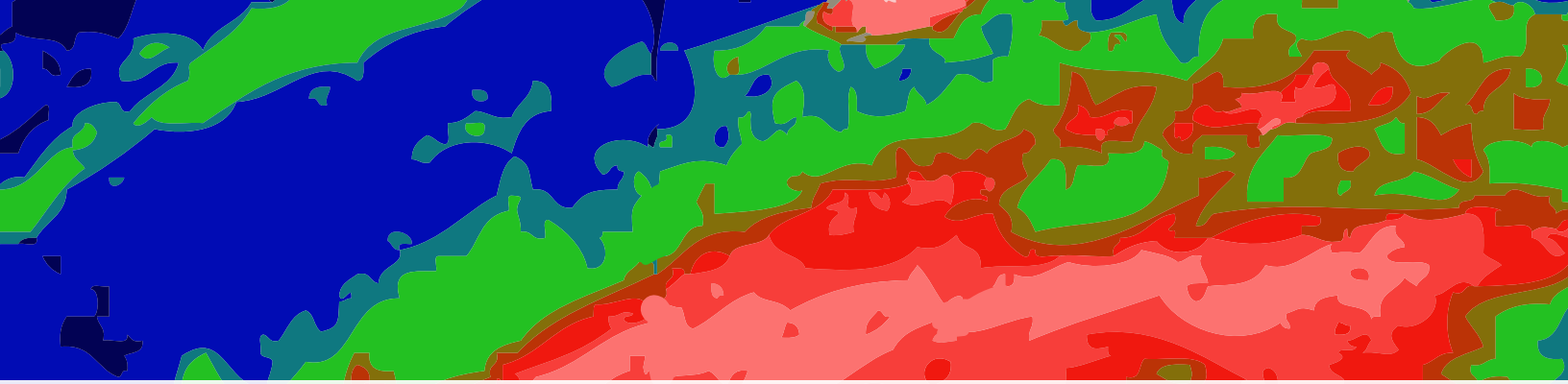
Superstorm Sandy is, of course, just a very visible demonstration of what NOAA does for every hurricane, for every storm, and for every sudden freeze that might send our child's school bus sliding off the road.

As a scientist, I could talk at length about the phenomenal science that is done every day by the NOAA scientists (often with the help of others at federal acronyms like NASA, NSF, DOE, CDC, EPA, USDA, USFS, USGS and so on.)

But today, I would like to say just two words as an American citizen and, if I may, on behalf of the American people, to the scientists of NOAA. . .

Thank You.

Peter Saundry
Executive Director
National Council for Science and the Environment



John H. Chafee Memorial Lecture
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RESILIENCE IN A CLIMATE-CHANGE WORLD

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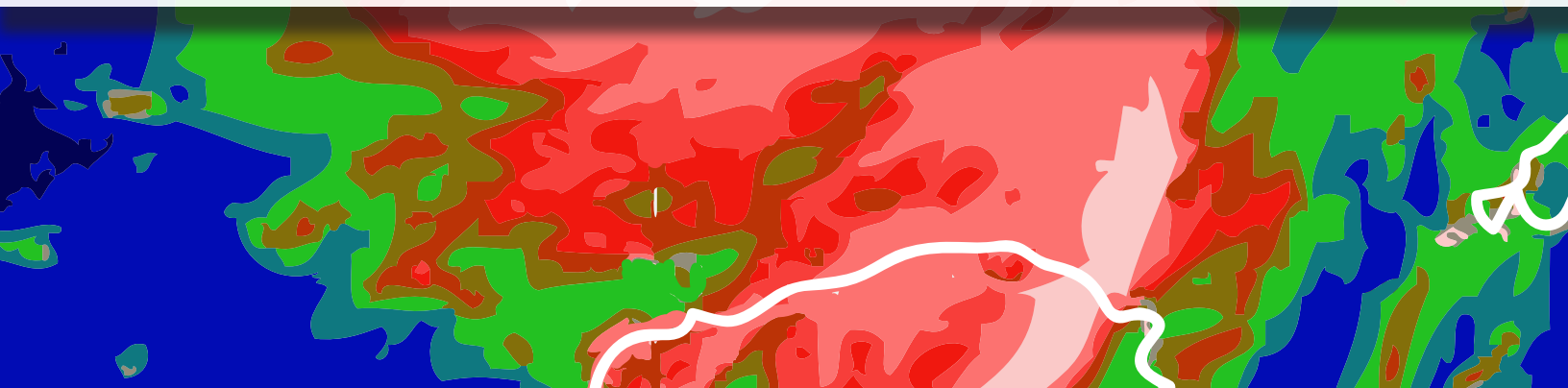

INTRODUCTION AND SENATOR CHAFEE

First, let me congratulate NCSE on 13 amazing years of annual conferences. The vision that created NCSE was bold. It has led to significant advances in environmental science and policy. I want to thank the staff and all of you for making NCSE such a vibrant organization and helping to make this conference on "Disasters and the Environment: Science, Preparedness, and Resilience" be so successful.

It is my great pleasure to honor Senator Chafee with this lecture. He was an ardent champion of the environment and of people in his roles as captain, governor, secretary, and senator. From Rhode Island, the "Ocean State," he championed coastal interests.

I had the privilege of interacting with Senator Chafee when he chaired the Senate Environment and Public Works Committee. I was impressed by his openness, his desire to understand options and move ahead with solutions, and his willingness to focus on what his constituents and the Nation needed, not on partisan posturing and bickering. I was later struck by the truth of President Bill Clinton's remarks about the Senator:

"John Chafee proved that politics can be an honorable profession. He embodied the decent center which has carried America from triumph to triumph over 200 years."

In my remarks today, I will share personal reflections on 'Disasters and the Environment,' and, in honor of Senator Chafee, they will focus primarily on coastal areas, although I believe the conclusions are universally applicable.

My main points will be: Climate change and degraded coastal habitats are combining to put people at great risk, especially during extreme weather events. Making coastal areas more resilient to disasters will require new approaches that integrate three elements: smarter built infrastructure; conservation and restoration of natural habitat or green infrastructure; and enhanced social safety networks or

social infrastructure. These three elements cannot function in isolation. The gray, the green and the social infrastructure need to be integrated and strengthened.

The knowledge required to achieve resilience is emerging. However, it needs to be strengthened, shared and used. We know a great deal about risk, but we are not incorporating that knowledge into policy and management. We know a great deal about vulnerability, but we are not incorporating that knowledge into our recovery from current disasters. We know a great deal about future environmental change, but we are not using that knowledge to improve preparedness at the rate we could or should.

THE FIREBIRD, THE PHOENIX

When I was a little girl, my grandmother used to tell my five sisters and me wonderful stories about the life and culture of Moscow, Kiev, and what is now Uzbekistan – places where she or her Ukrainian husband had lived. A gifted storyteller, her tales ranged from Russian and Ukrainian fairytales to life in Russia in the 1900s prior to the 1917 revolution. She made those stories come alive. To keep alive our heritage, my grandmother and mother introduced us to Russian and Ukrainian music, ballet, and special foods. One of my all-time favorite ballets was Igor Stravinsky's Firebird (Figure 1), a Russian fairytale of death and rebirth, of immortality and magic. It was not until later that I came to appreciate the similarities between the Russian firebird and the ancient Greek symbol of rebirth, the phoenix, a bird that is reborn from ashes. These two birds, the firebird and the phoenix, symbolize death and rebirth and provide an apt metaphor for

Figure 1. Hand-painted firebird in the Russian tradition as depicted on a lacquered brooch.

current concerns about recovery from disasters, such as Hurricane Sandy, and about communities becoming more resilient to future disasters, especially in light of climate change.

A disaster can be transformed into a phoenix if it changes the way people conceptualize and deal with a problem. Out of the ashes of the tragedy can emerge a more robust community that is better prepared and more resilient to future disasters. I say that it is possible for a disaster to become a phoenix, knowing full well that most disasters are simply real tragedies that do little to make individuals or communities or nations more resilient to future tragedies. Two tragedies come to mind as examples of disasters that triggered actions to enhance resilience to future disasters.

PAST DISASTERS RESULTING IN TRANSFORMATION

One example involves the responses to the major earthquakes in southern California in the late 1920s and early 1930s (Figure 2). Appalled by the death and destruction caused by those earthquakes, coastal communities, engineers, scientists, and political leaders seized the moment to envision a different future -- one where buildings were constructed with earthquakes in mind and one in which a significant earthquake would not result in loss of life. Fresh from the horrors of their tragedy, they began reformulating local, then state, then national building codes. Our current building standards reflect that legacy. Today, even severe earthquakes in the United States are far less damaging and less tragic than they would have been otherwise. Most of us take those building codes for granted; they are simply standard building practice. In this example, a local tragedy was transformed into a significant national benefit.

Figure 2. Photograph of a wood-frame building in Long Beach, California destroyed by the March 11, 1933 earthquake. Photo credit: Seismicity of the United States, 1568-1989 (Revised), by Carl W. Stover and Jerry L. Coffman, U.S. Geological Survey Professional Paper 1527, United States Government Printing Office, Washington: 1993.

Another example of a disaster that triggered action leading to greater resilience was the Indian Ocean tsunami in 2004. Concerned about the vulnerability of U.S. coastlines to tsunamis, the

federal government and scientists at the National Oceanic Atmospheric Administration (NOAA) took the initiative to design and implement a warning system consisting of buoys, models, and community preparedness plans. The buoys would provide the observations to detect tsunamis. The models would incorporate those observations and provide the ability to alert communities who might be affected. Communities would need to be prepared and know how to spread the word and what to do should a tsunami be headed its way. Thanks to Congressional leadership and support, the warning buoy system, research to develop and refine models and training for vulnerable communities was funded. The observing network went from six buoys before the Indian Ocean tsunami to 39 buoys today (Figure 3). Research has progressed significantly due to sustained investments, and numerous communities are now 'Tsunami-Ready'. (However, current budget cuts and uncertainties put much of this progress at risk, as funds for maintenance of buoys, continued advancement of models, better tailoring of models to local shorelines, and community preparedness are increasingly uncertain.)

In both the earthquake building code and tsunami warning examples, transformational systemic changes required leadership, scientific information, changes in infrastructure, public education,

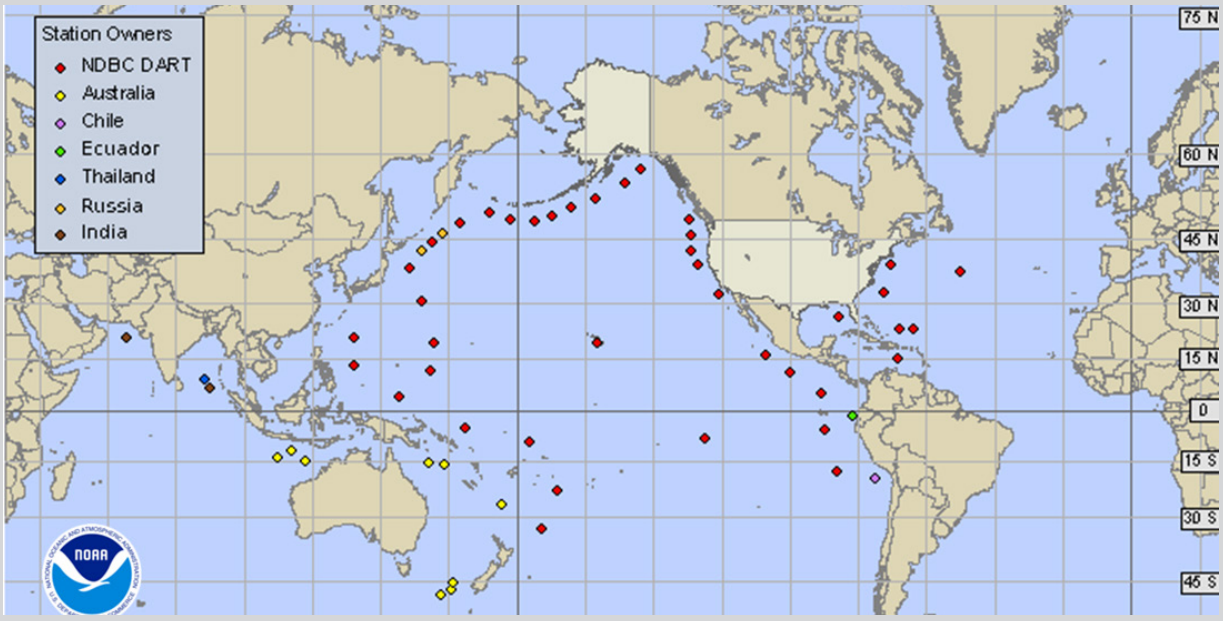

Figure 3. Locations of NOAA's National Data Buoy Center Deep-ocean Assessment and Reporting of Tsunami (DART®) stations via Google maps on March 11, 2013 (http://http://www.ndbc.noaa.gov/dart.shtml). NOAA completed the original six-buoy operational array in 2001 and expanded to a full network of 39 stations in March, 2008. (Source: NOAA/NDBC)

targeted funding and social networks. These changes also required state legislatures or Congress to take action.

TODAY'S DISASTERS: THE NEW NORMAL

Today, we are witnessing a flurry of extreme events, a new normal of weather-related disasters. According to Munich Re, a global leader in the reinsurance industry, the number of weather-related disasters in North America jumped nearly five-fold in the last 31 years. Among the many statistics NOAA tracks is the number of weather-related disasters that cause at least $1 billion in damages. Until recently, the average number of such disasters in a year was three to four. The pattern has changed dramatically in the last few years. In 2011 and 2012 combined, the US had 25 disasters each totaling over a billion dollars. The year 2011 set the all-time record with 14 such disasters (Figure 4). Moreover, those 2011 disasters occurred in nearly every single category of severe weather or weather-related disasters one might imagine: floods, droughts, hurricanes, wildfires, blizzards and tornadoes.

Figure 4. Top U.S. billion-dollar weather and climate-related disasters in 2011. NOAA's National Climatic Data Center (NCDC) is the Nation's Scorekeeper for addressing severe weather/climate events in their historical perspective. As part of its responsibility of monitoring and assessing the climate, NCDC tracks and evaluates weather and climate events in the U.S. and globally that have great economic and societal impacts. Billion-dollar disasters each cost more than one billion dollars in losses. Preliminary information for 2012 estimates 11 such events, including seven severe weather/tornado events, two tropical storm/hurricane events, and the year-long drought and associated wildfires (http://http://www.ncdc.noaa.gov/billions/events)

These billion-dollar disasters have become the new normal and are ubiquitous in the U.S. No matter where you live, billion-dollar disasters are occurring (Figure 5). Droughts and heat-waves are concentrated in the center of the country. Hurricanes, tropical storms, and winter storms impact the east, and those winter storms lead to crop freezes in the southeast. Flooding and wildfires are concentrated in the west. In short, every place in the United States has seen at least one kind of major disaster since 1980.

In a world where greenhouse gases continue to rise, where there are more people with more material possessions, and where people are concentrated along the coastal margins, we need to start thinking differently about being better prepared for these disasters. Hurricane Sandy brought to light the importance of timely warnings and preparedness but also many lessons about how to be better prepared and more resilient.

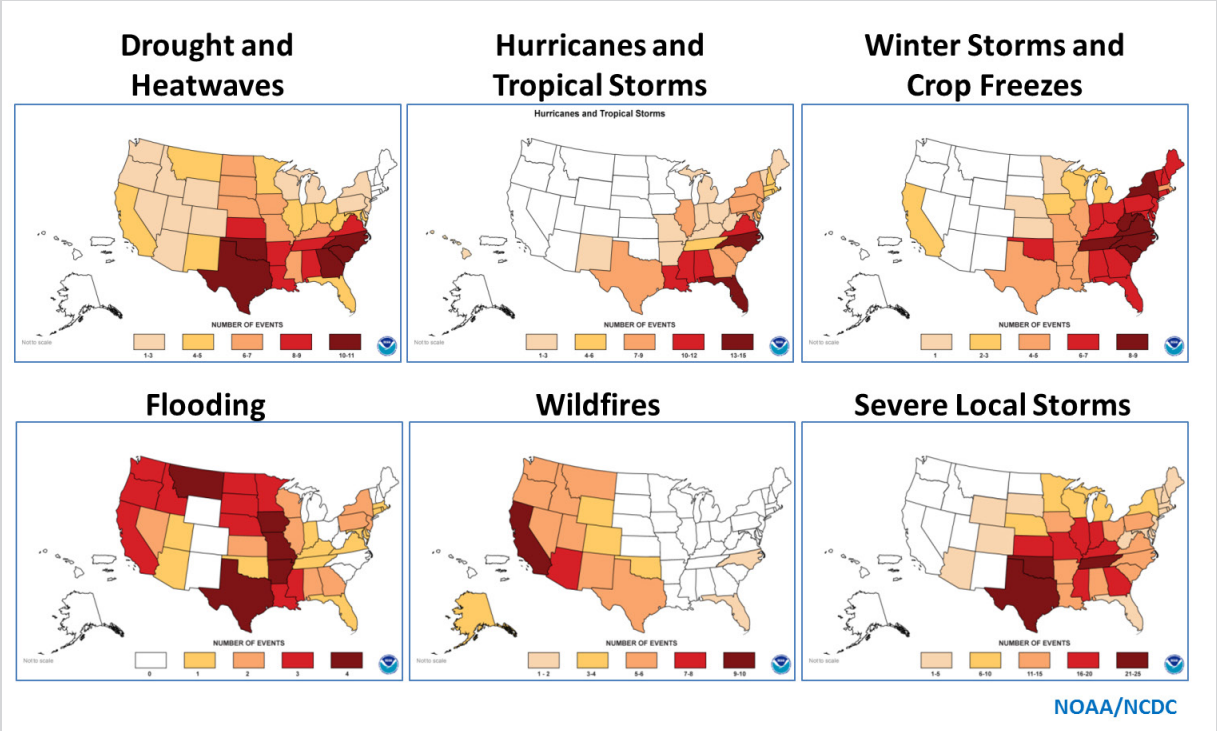

Figure 5. U.S. billion-dollar weather and climate-related disasters: 1980-2011. Though geographical distribution for each type of event varies, every part of the country has been affected by some type of billion-dollar disaster. The U.S. is one of the most vulnerable countries in the world with regard to weather and climate-related disasters. This graphic is based on NOAA's National Climate Data Center data on billion-dollar weather and climate-related disasters. (Source: NOAA National Climate Data Center)

Sandy was a disaster (Figure 6), but it could have been much worse. Thanks to the many people who worked under very challenging conditions, Sandy was not as destructive as it might have been had communities and emergency managers not had accurate and advance knowledge of what was coming their way. NOAA's Hurricane Sandy forecasts and warnings were timely and accurate -- even despite the highly unusual trajectory -- and this advance warning gave communities and emergency responders time to prepare. One clear message was that your taxpayer dollars are supporting tangible information that makes a difference in real world disaster response.

PREPAREDNESS CAN MINIMIZE DISASTER

Let me digress for a moment to give you a glimpse of what was behind NOAA's ability to make such timely and accurate warnings because the insights are relevant to my larger point about becoming more

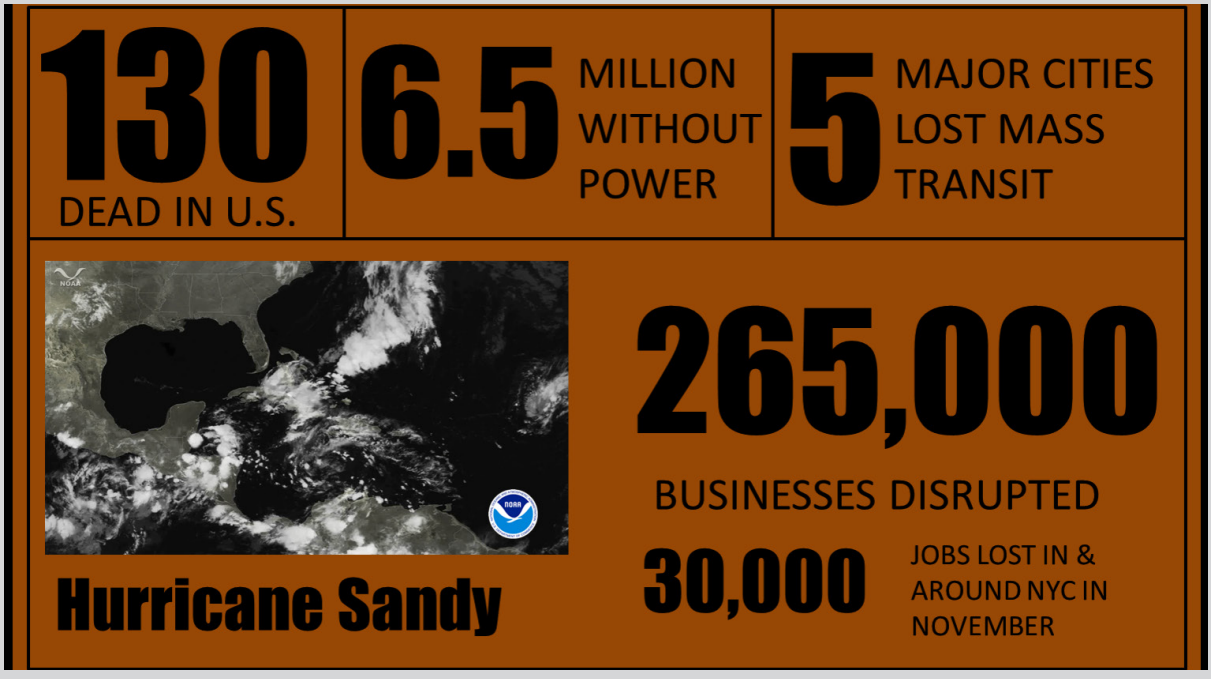

Figure 6. Selected Hurricane Sandy statistics. According to the NOAA National Hurricane Center's Tropical Cyclone Center Report on Hurricane Sandy, 159 deaths occurred as a result of Sandy (72 deaths directly attributed to Sandy; 59 indirectly, the vast majority resulting from extended power outages during cold weather) (http://http://www.nhc.noaa.gov/data/tcr/AL182012_Sandy.pdf). Approximately 8.5 million customers lost power. (Note: Number of deaths and power loss figures are as of the February 12, 2013 report and are updated from the time that this speech was delivered on January 16, 2013.) The five major cities that shut down mass transit during Sandy were Boston, New York City, Philadelphia, Baltimore, and Washington, DC (NOAA National Weather Service Operations Center report). Jobs statistics come from New York State Labor Department statistics as reported by the New York Times City Room on December 20, 2012.

resilient to disasters. These warning were especially impressive because Hurricane Sandy behaved in a very unusual manner. After heading north-northeast up the Atlantic Ocean coast, Hurricane Sandy – as predicted by NOAA -- made an uncommon and abrupt turn to the northwest before smacking into New York and New Jersey (Figure 7). NOAA forecasted this trajectory five days in advance of landfall, giving residents and emergency managers ample warning. Many hurricane experts doubted the westward turn back towards the U.S., but Sandy did indeed follow the path forecasted by NOAA.

To compare the forecast track of Hurricane Sandy with the actual path the storm took, go to the NOAA Environmental Visualization Laboratory[1] under the "All Animations" page.

1 http://www.nnvl.noaa.gov/

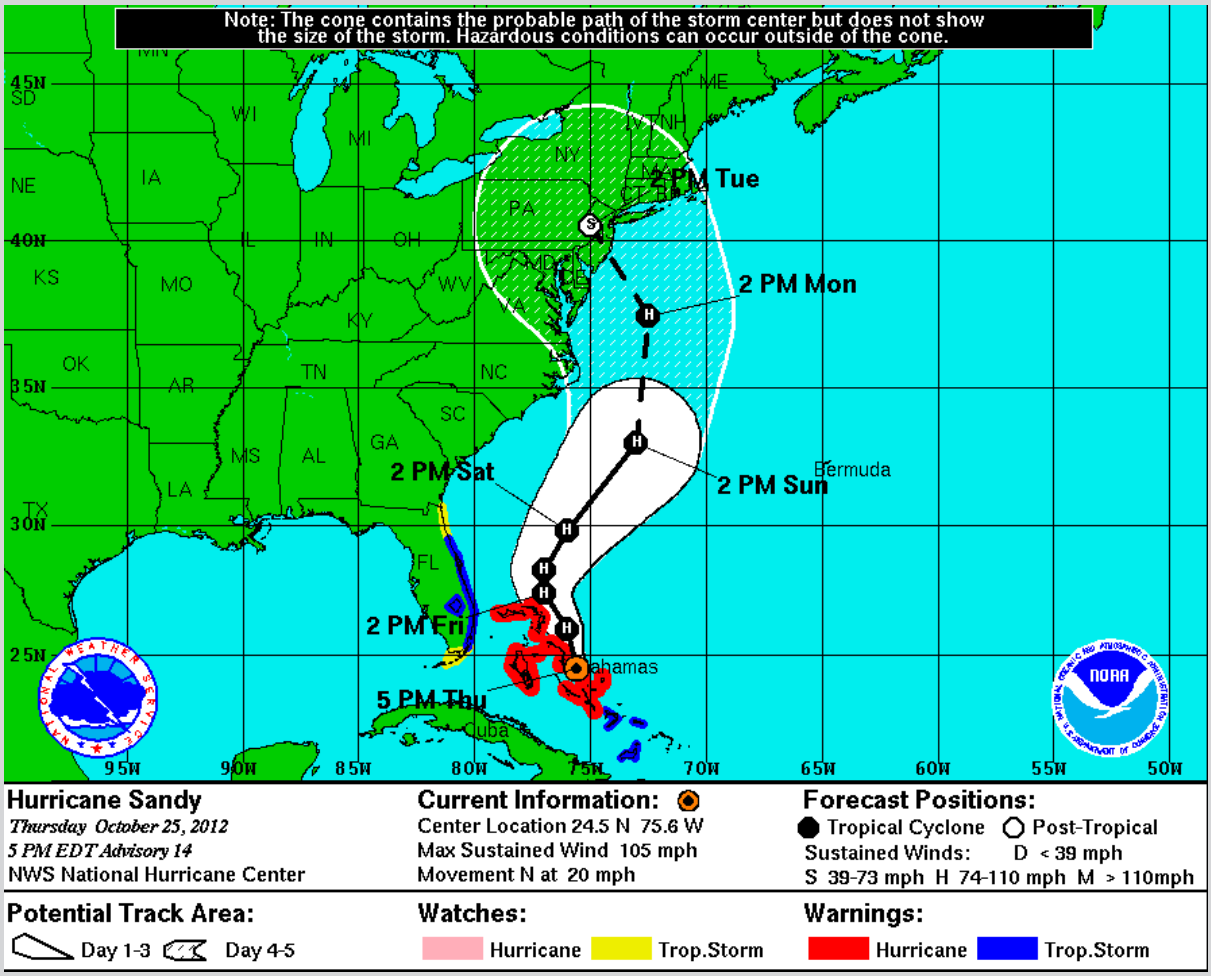

Figure 7. The official track forecast from the National Weather Service for Hurricane Sandy on Thursday, October 25 at 5 PM EDT, which correctly predicted the left-hand turn on Monday evening.

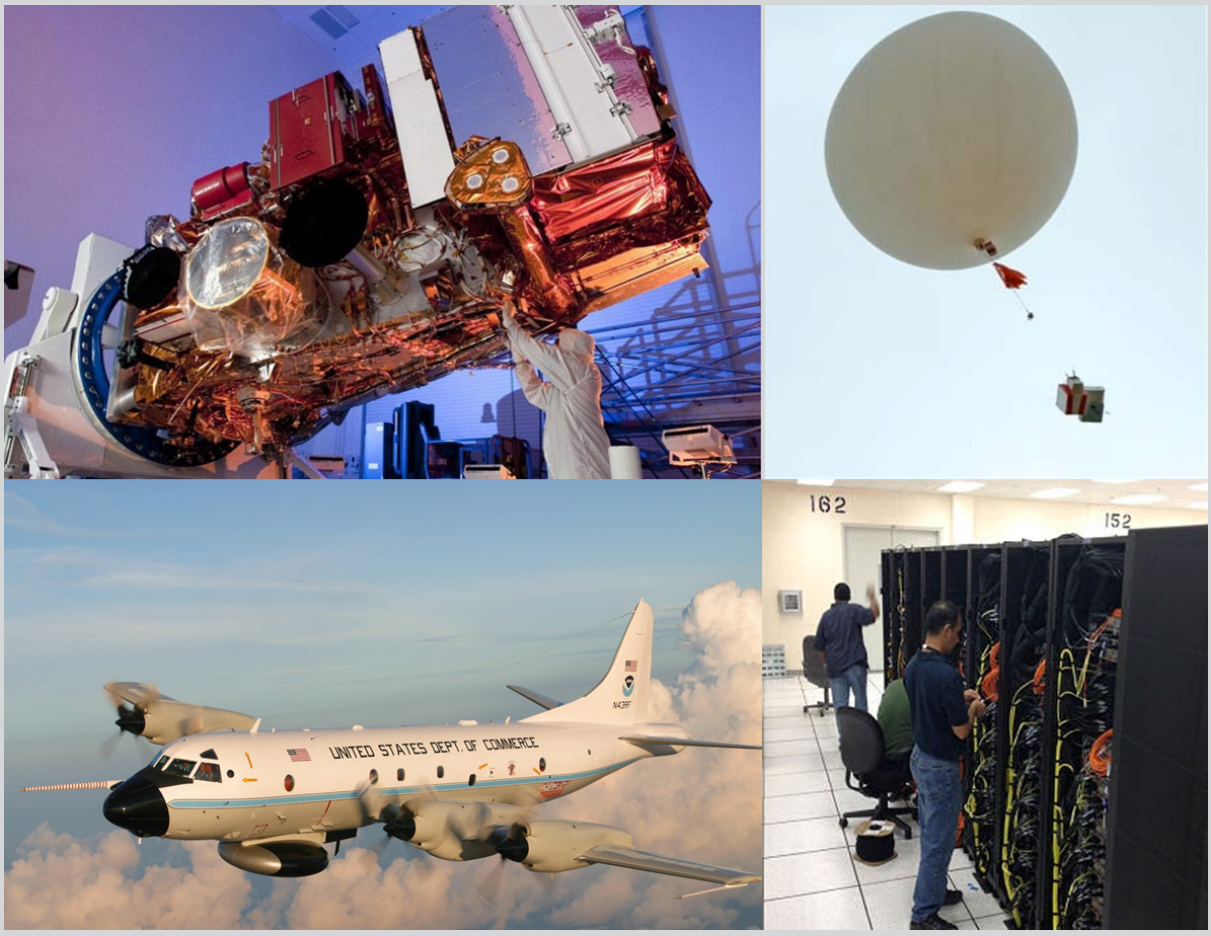

Figure 8. NOAA investments that proved critical for accurately forecasting Sandy's track include the polar-orbiting Suomi-NPP satellite launched in 2011 (upper left, instrumentation aboard Suomi-NPP), Hurricane Hunter WP-3D aircraft (lower left), weather balloons (upper right) and high performance computing (lower right). (Photo credits: NOAA)

The accuracy of the Sandy forecast was the result of a number of investments in science and service and their integration during a crisis (Figure 8). Past and current investments in multiple arenas paid off: investments in (1) research to better understand the behavior of storms, (2) weather satellites that provide core data for long- and short-term forecasting, (3) 'Hurricane Hunter' planes to fly through storms and obtain critical data that are only available from inside the storm, (4) radiosondes to obtain real-time information about weather conditions across the land, and (5) high performance computers to assimilate and analyze mountains of data and run models multiple times at lightning speed. Complementing these technical and scientific approaches is the deep experience of talented forecasters who have developed a feel for storms. Once an early warning is issued, NOAA relies on good relationships with emergency managers, media, and partners at federal, state, and local levels to

do their jobs to keep people informed and NOAA uses social media to help disseminate forecasts and information.

The response to Hurricane Sandy illustrates the chains of information and the coordination required to minimize the impacts of disasters that do occur. I have emphasized NOAA's role, but others provide complementary contributions: research by academics, modeling by international teams, advanced planning by emergency managers and communities, communications by media, and of partnerships in preparing for disasters.

Ever anxious to learn from each event and prepare better for the next one, NOAA is conducting a retrospective analysis of Hurricane Sandy. That information will be shared widely and used to guide planning and response. What is clear even now is that accurate advanced warning five days out was essential to preventing even greater disaster. This advanced warning undoubtedly saved lives and protected property.

HURRICANE SANDY AND CLIMATE CHANGE

Many people are asking about the connection between Sandy and climate change. This is a very active area of research. There is no doubt that sea level rise contributed significantly to the damaging effect of storm surge produced by Sandy. Climate change is causing sea levels to rise; continued sea level rise is expected. Greater flooding in the future is likely. We can say definitively that storms like Sandy are occurring in a climate-changed world.

I find it useful to talk about the relationship between Sandy and climate change through an analogy with a baseball player taking steroids. Any player taking steroids is going to have a much greater chance of hitting more home runs and more powerful home runs. Although one cannot attribute any particular home run to steroids, one can say the pattern of more homers is quite likely due to his use of steroids. I believe we are witnessing weather on steroids --- storms on steroids. More extreme weather-related events; more heat waves, more droughts, more intense precipitation events, more

floods. The expectation of more of these events should cause us to think differently about becoming more resilient to events such as Sandy.

The analysis of global temperature by decade is a useful indicator of climate trends (Figure 9). The upward trend is obvious. NOAA just released data showing that 2012 was the warmest year on record in the contiguous U.S.[2] and the tenth warmest year globally[3]. The long-term record is clear: both the US and the world are getting warmer. But climate change is about more than simply warmer temperatures.

The recently released draft of the United States National Climate Assessment puts these temperature changes into a broader context for different sectors and regions of the United States. This assessment

2 http://www.ncdc.noaa.gov/sotc/national/2012/13
3 http://www.ncdc.noaa.gov/sotc/global/2012/13

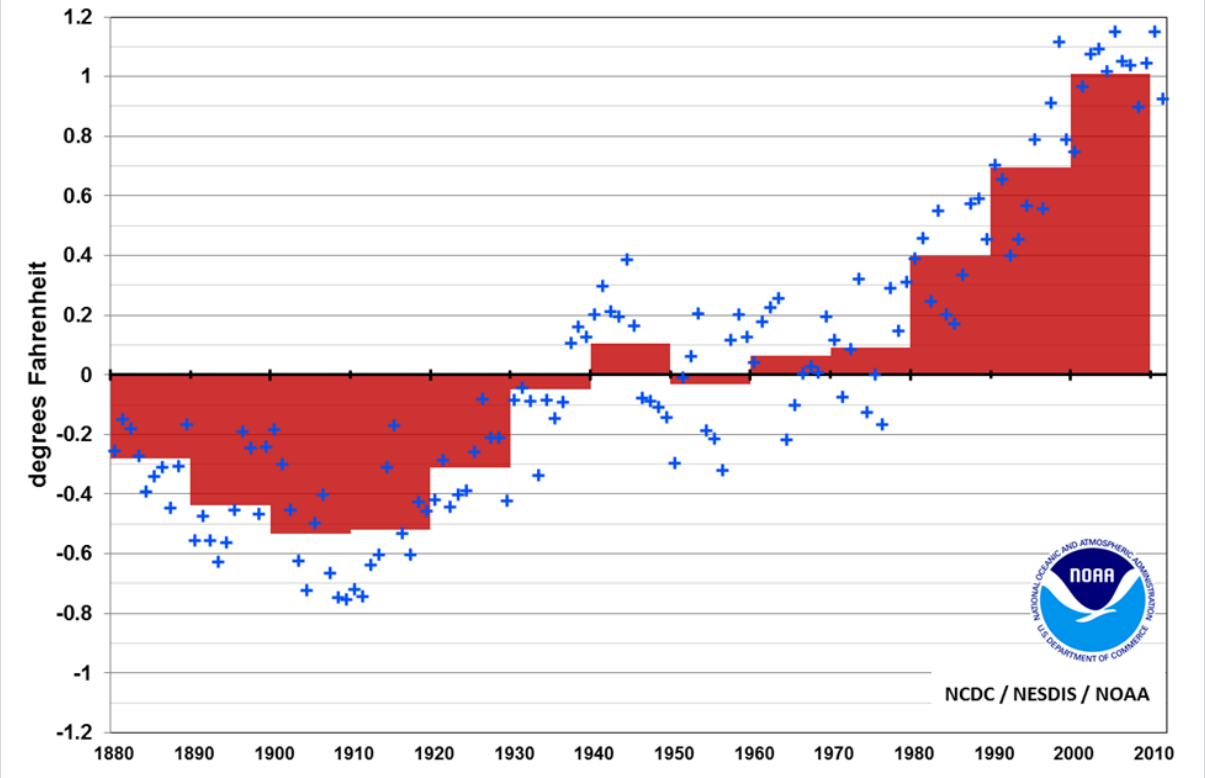

Figure 9. Annual global (land and ocean) temperature anomalies from 1980-2010 relative to the 1901-2000 base period. Since the 1980s, every decade has been warmer than the previous decade. During this 132-year record: 2010 was the warmest year on record globally (tied with 2005); 2011 was the 11th warmest globally (tied with 1997); 2012 was the 10th warmest globally and the warmest ever for the U.S., with July 2012 being the record warmest month for the U.S. (Source: NOAA/NCDC)

is a Congressionally-mandated report produced every four years. This most recent National Climate Assessment is the most ambitious, by a large margin, reflecting more public engagement than any previous version. This assessment is available for public comment and is under review by the National Academy of Sciences, with the final draft scheduled to be released in 2014. A number of technical reports prepared to inform the assessment, for example, one on sea level rise and one on climate trends, also are available.

WHAT WILL HURRICANE SANDY'S LEGACY BE? A DISASTER OR A PHOENIX?

Sandy was a disaster. The need for recovery is urgent. It is time to pose a larger question: What will Sandy's full legacy be? Will leaders respond in traditional fashion by dealing only with the aftermath and ignoring larger lessons and opportunities that could recover in a manner that would reduce future suffering and economic loss? Or will Sandy be a phoenix that triggers new thinking, new solutions, and new opportunities to better prepare for the next Sandy? In short, will Sandy be a catalyst for transformational change? The answer depends on the choices leaders and citizens are prepared to consider and the actions they are willing to make – both as part of recovery and as part of a larger effort to re-think coastal development and planning, especially in light of the need to reduce the rate of and adapt to a changing climate.

As with the response to California earthquakes almost a century ago, an immediate opportunity is to construct buildings differently so they are better able to withstand the fury of storms, for example by driving pilings deeper and anchoring them to bedrock, not just sitting on sand. This is the 'how to build' component. However, it is time to look beyond just improving the built (or 'gray') environment, and to pay attention to the natural habitats that can complement buildings in providing resilience, the 'green' environment.

The 'where to build' is more important than has been generally appreciated. For storm surge in coastal communities, where we put buildings and how we couple the gray infrastructure with the

green infrastructure hold much promise. Healthy coastal habitats can play a key role in increasing resilience to some of the impacts of storms, climate, and other stressors (Figure 10). For example, dunes, marshes, mangroves, wetlands, seagrass beds, and oyster and coral reefs help protect coastal communities from the damaging effects of waves and storm surge. Ironically, just at the time when we need them the most, many of these coastal habitats are being lost to development, pollution or other threats. When Superstorm Sandy surged into New York harbor, the 260 thousand acres of oyster reefs that once protected the city's residents had long been gone. Fortunately, in 2010, efforts began to restore those oyster reefs.

Because coastal habitats provide much more than coastal protection, serious efforts are underway to restore them to health (Figure 11). Cascading benefits such as places for recreation, natural hatcheries and nursery areas for many fisheries, habitat for birds and fish, and carbon storage provide strong motivation to some communities. The San Francisco Bay, one of the most heavily urbanized estuaries in the world, has suffered millions of dollars in damage from coastal flooding and habitat degradation. Aspiring to a vision of a prosperous and healthy coastal community, the South Bay Salt Ponds project is restoring approximately 15,000 acres of coastal estuarine habitat to gain flood protection, water quality, carbon storage, recreation, and ecosystem health benefits. In doing so, this restoration effort also helps protect San Jose, CA, and other large cities on the bay, along with Silicon Valley businesses, from future disasters.

Figure 10. Coastal habitats, such as salt marshes (top), mangroves (middle) and seagrass beds (bottom), are the green infrastructure that provide protection from coastal flooding. (Photo credits: NOAA)

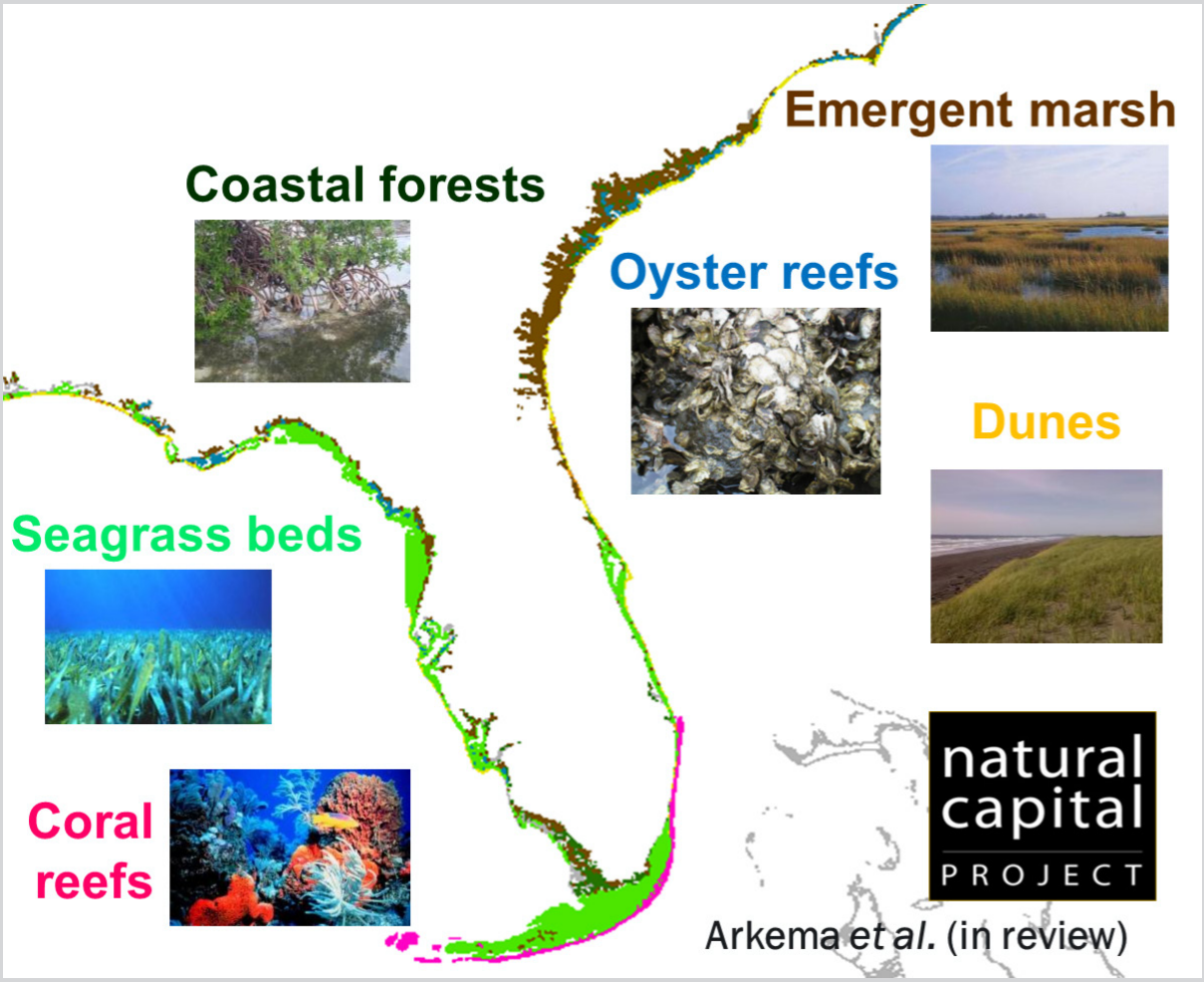

Figure 11. Coastal habitat maps for Florida showing the potential contributions of coral reefs (pink), seagrass beds (green), oyster reefs (blue), emergent marsh (brown), dunes (yellow) and coastal forests (dark green) to flood protection. (Source: K. Arkema of the Natural Capital Project and colleagues, manuscript submitted)

As we think about recovering from and rebuilding in the wake of Superstorm Sandy, the Coastal Zone Management Act, the South San Francisco Bay Salt Ponds project, and other similar projects remind us that resilience must be a priority amidst continued coastal population growth and other increasing risk factors.

In light of increasing risk to coastal communities, two critical questions stand out: How do we actually reduce the risk of threats? How do we minimize the impact of disasters when they occur? Reducing the number and intensity of disasters involves decreasing greenhouse gas emissions and becoming more energy efficient. Minimizing the impacts of disasters when they do occur involves restoring

healthy coastal communities, especially protecting and restoring coastal habitats, which are "nature's shield," as Arkema et al. (manuscript in review) refers to them. Also part of the response is accurate and timely warnings. However, we have learned at NOAA that people need to know how to interpret warnings and they need to take action in a timely manner. Social science is an undervalued tool useful for helping us to understand if people are heeding weather warnings and interpreting the information correctly. Social science also is useful for learning how social networks work. These networks are critical for disseminating early warnings that enable people to take action. The National Weather Service assessments in the aftermath of tornadoes in 2011 suggest that many people did not actually heed the warnings until friends and families urged them to take action. Smart policy and management are essential for creating responsive and responsible building codes that consider where and how to build, as well as how to create or strengthen social safety networks. The knowledge needed to answer many of these questions is emerging. Tremendous resources exist in *America's Climate Choices*[4] produced by the National Academy of Sciences and in other publications. However, the knowledge offered by these syntheses and, even more so, in our implicit experience from previous disasters, has not been integrated into plans, policies, practices, and actions.

This critical step of synthesis and integration is the task of many of the sessions in this conference. There is ample opportunity to build on what we know and, equally important, to help each other use our collective knowledge. For example, the Natural Capital Project, a collaboration of Stanford University, The Nature Conservancy, the World Wildlife Fund, and the University of Minnesota, is in the process of helping drive focus to ecosystem services and tradeoffs in the restoration and management of coastal areas. Natural Capital is a prime example of opportunities to incorporate resilience thinking into planning for and implementing recovery from storms like Sandy.

Smart policy and management means being smarter about where we build and how we build, coupling the built environment with a green environmental infrastructure, evaluating the science we need to help inform that gray–green connection. The third opportunity is to couple the gray and green infrastructure with 'social infrastructure.' How can communities be constructed to maximize strong

4 National Research Council. America's Climate Choices. Washington, DC: The National Academies Press, 2011

social cohesion and sense of communities so neighbors know and assist one another in times of crisis? What does social science tell us about community design? Recent analyses of disasters and what factors contribute to resilience in the face of disaster is pointing strongly to the importance of information networks and neighbors helping neighbors as keys.

NOAA is involved in a large number of activities that help underpin these efforts. There is an urgent need for a much larger dialogue about resilience to disasters in coastal areas and elsewhere. Sandy provides an opportunity to rethink coastal restoration, adaptation to climate change, and increasing resilience to future disasters. Doing so will require blending the triad of gray, green, and social infrastructure in fresh and innovative ways. Achieving this more holistic approach will not be easy, both because it is not the way restoration is usually done, and because there are intense pressures to simply build things back the way they were. Building resilience to coastal disasters requires new approaches. The knowledge to carry out this integration and to achieve this resilience is emerging and needs strengthening. Knowledge alone will not be sufficient to solve the problems at hand. We also must exert the social will and political will to use that information to effect the transformations that I believe are possible.

Sandy can become a firebird. Sandy can become a phoenix. But only if we choose to make that happen.

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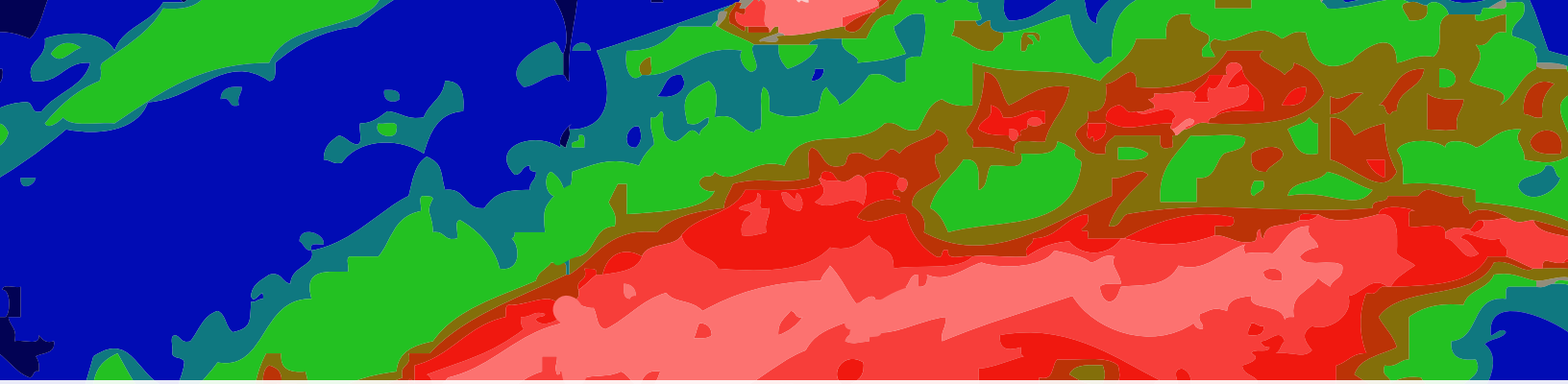

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