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2001

WEATHERPROOFING THE U.S.:
ARE WE PREPARED FOR
SEVERE STORMS?

HEARING

BEFORE THE

SUBCOMMITTEE ON ENVIRONMENT, TECHNOLOGY,
AND STANDARDS
COMMITTEE ON SCIENCE
HOUSE OF REPRESENTATIVES

ONE HUNDRED SEVENTH CONGRESS

FIRST SESSION

OCTOBER 11, 2001

Serial No. 107–31

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Written Statement

Statement by Representative Dennis Moore, Member, Committee on Science, U.S. House of Representatives

Prepared Statement by Representative Nick Smith, Member, Subcommittee on Environment, Technology, and Standards, U.S. House of Representatives

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Submitted Statement by Dr. Stephen P. Leatherman, Director, International Hurricane Center, Florida International University
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The U.S. Weather Research Program: National Need, Vision, & Interagency Plan for FY 00–06, V.3.3, 9/25/00
WEATHERPROOFING THE U.S.: ARE WE PREPARED FOR SEVERE STORMS?

THURSDAY, OCTOBER 11, 2001

House of Representatives,

Subcommittee on Environment, Technology, and Standards,

Committee on Science,

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Washington, DC.

The Subcommittee met, pursuant to call, at 10:05 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Vernon J. Ehlers [Chairman of the Subcommittee] presiding.

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HEARING CHARTER

SUBCOMMITTEE ON ENVIRONMENT, TECHNOLOGY, AND STANDARDS

COMMITTEE ON SCIENCE

U.S. HOUSE OF REPRESENTATIVES

Weatherproofing the U.S.:

Are We Prepared for Severe Storms?

THURSDAY, OCTOBER 11, 2001

10:00 A.M.–12:00 P.M.

2318 RAYBURN HOUSE OFFICE BUILDING

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I. Purpose

On Thursday, October 11, 2001, the House Subcommittee on Environment, Technology, and Standards will hold a hearing to receive testimony regarding research efforts into the prediction of severe storms, with emphasis on hurricanes, flooding, and wind-related damage. The hearing will address the needs of emergency management officials to ensure the public is adequately warned about storms and their effects. Specifically, the witnesses will address the research required to improve severe weather prediction.

In addition, the hearing will examine three related legislative issues:

1) H.R. 2486, the Tropical Cyclone Inland Forecasting Improvement and Warning System Development Act, introduced by Rep. Etheridge;

2) Draft legislation by Rep. Moore on research related to severe wind damage and its amelioration;

3) Reauthorization of the U.S. Weather Research Program.

The Subcommittee will hear testimony from:

1) Dr. Chris Landsea, Hurricane Research Division, Atlantic Oceanographic and Meteorological Laboratory, National Oceanic and Atmospheric Administration (NOAA).

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2) Dr. Len Pietrafesa, Director of External Affairs, College of Mathematical Sciences, N.C. State University.

3) Dr. Steven L. McCabe, Professor and Department Chair, Department of Civil and Environmental Engineering, University of Kansas.

4) John L. Hayes, Director, Office of Science and Technology, National Weather Service; Co-chair, U.S. Weather Research Program.

5) Doug Hill, Meteorologist, WJLA—Channel 7 News, Washington, DC.

6) Robert Shea, Acting Administrator for Federal Insurance and Mitigation, Federal Emergency Management Agency (FEMA).

Background:

According to the American Meteorological Society (AMS), the U.S. has more severe weather and flooding than any other nation. Each year, severe weather claims about 1,500 lives and causes roughly $16 billion in damages. Also, according to AMS, approximately $2 trillion, or roughly 25 percent of the U.S. Gross Domestic Product, is influenced by weather and climate. This figure includes industries such as agriculture, energy, and air travel.

We have experienced intense and widespread drought and flooding in the past few years. This year, Tropical Storm Allison dumped more than 35 inches of rain in Texas resulting in several billion dollars in flood damage and more than 50 deaths. As urban and coastal population growth continues so does our vulnerability to severe weather. Just as important as the prediction of severe weather is our ability to effectively communicate the proper information to the public. The September 24, 2001 recent tornado in the Washington, D.C. area demonstrated that while we were able to predict the supercell storm, many were not aware of the warnings and potential destruction. Improved prediction, preparation, and response to severe storms are matters life and death, as well as economics, to communities large and small.

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Are More Hurricanes Coming?

Recent research indicates that the North Atlantic is likely to experience a significant increase in the frequency and possibly the ferocity of hurricanes during the next ten to 40 years. The years 1995 to 2000 experienced the highest level of North Atlantic hurricane activity since reliable records began in 1944. Compared with the previous 24 years (1971–1994), the past six years have seen an 100 percent increase in overall activity and a 250 percent increase in the most dangerous hurricanes (categories 3–4–5). There has been a fivefold increase in hurricanes affecting the Caribbean.

Researchers believe the reason for the likely increase stems from a warming of the North Atlantic sea-surface. This warming is part of a natural multi-decadal cycle in the North Atlantic similar to the El Niño/La Niña events of the Pacific Ocean. The increase in ocean temperature will provide extra energy that can lead smaller storms to develop into hurricanes.

In addition to the warming of the ocean surface, researchers have detected a decrease in vertical wind shear, which generally works to counteract the formation of tropical storms. The net effect of these two factors, coupled with others such as global climate change, have led researchers to believe there will be favorable conditions for hurricanes during the next ten to 40 years. See attached chart on next page.

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Potential for Increased Damage:

The period from 1971–1994 had generally low levels of hurricane activity. However, during that time, coastal populations in hurricane zones have swelled to roughly 45 million people. More than 85 percent of these new residents have never experienced a direct hurricane hit. In the 95 coastal counties from Texas through North Carolina, the number of counties with populations of more than 250,000 increased sixfold from 1950–1990. With the population increase have come hotels, businesses and significant economic development, which have raised the average damage cost of each storm dramatically. In 1992, Hurricane Andrew caused more than $25 billion in damages in Florida—an amount exceeding the property insurance premiums paid in that area from 1970–1992. Projections show that if the same hurricanes that made landfall in the 1940's were to occur in the next decade, the insured losses would be more than $60 billion.

While the loss of life associated with these storms has declined, the increase in coastal population has nearly outstripped the ability to evacuate people quickly and safely. Emergency managers estimate evacuation costs at about $1 million per mile of coast, making precise prediction of exactly where hurricanes are going to make landfall more important than ever.

But it is not just the coastal communities that are affected. When Hurricane Floyd hit North Carolina in 1999, 51 deaths and nearly $3 billion in damage occurred. However, of those deaths, 34 were due to drowning far inland. Most of these drowning deaths occur because of a lack of warning and understanding about the destructive nature of floods.

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U.S. Weather Research Program (USWRP):

The USWRP is a federal interagency program that supports government and university research to improve weather forecasts and the use of those forecasts, particularly associated with hurricanes, floods, and heavy snowfall. The program was authorized in the National Oceanic and Atmospheric Administration Act of 1992. USWRP is co-chaired by NOAA's Oceanic and Atmospheric Research office and the National Weather Service. Other agencies participating in the program include the National Science Foundation, the National Aeronautics and Space Administration (NASA), and the U.S. Navy. These four agencies have pooled together approximately $4–5 million per year since 1997 in joint or coordinated grants programs and agency laboratory awards. A breakout of the budget for FY 00 is attached.

For FY 01, NOAA's office of Oceanic and Atmospheric Research (OAR) spent about $40 million on Weather and Air Quality Research in addition to the $2.5 million for USWRP. The FY 02 President's request for USWRP was $4.7 million and about $44 million for other Weather and Air Quality Research. However, NOAA's overall spending on operations for short-term warning and forecasts, or what we think of as daily weather forecasts and functions, is about $1.4 billion. This includes most of the budget for the National Weather Service along with some activities of NOAA's Oceanic and Atmospheric Research, and the National Environmental Satellite, Data, and Information Service. The FY 02 President's request for these activities is $1.474 billion.

Legislative issues:

On July 12, 2001, Rep. Etheridge (et al) introduced H.R. 2486. The legislation authorizes the National Weather Service to spend $7 million over five years to improve the capability, through research and modeling, to forecast inland flooding associated with tropical storms. The National Weather Service is working on a new computer modeling system called Advanced Hydrologic Prediction Services (AHPS), but because of funding issues it has only been implemented in a few areas of the country. In addition, the legislation calls on the National Weather Service to develop an inland flood warning index and system and educate the public on its use. The current index system has categories for minor, moderate, major and flood of record. However, some feel this does not provide enough information to alert people to the actual dangers and believe a new system or scale should be developed.

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Rep. Moore intends to reintroduce a modified version of H.R. 5499, the Windstorm Hazard Reduction Research and Technology Transfer Act from last Congress. The original bill would require the Director of the Office of Science and Technology Policy to establish an Interagency Group to develop and implement a Federal windstorm hazard reduction research, development, and technology transfer program. The aim is to achieve major measurable reductions in losses to life and property from windstorms. The bill would have also established a National Advisory Committee to review the program's progress, advise on any improvements, and report to Congress on actions taken to reduce the impacts of windstorm hazards.

The US Weather Research Program was authorized as part of the National Oceanic and Atmospheric Administration Act of 1992. The Secretary of Commerce was required to submit an implementation plan, which would outline the goals and priorities for federal weather research, the specific activities needed to accomplish the goals, and set forth the role of each federal agency and department to be involved. The program was authorized for a 10-year period starting from the time the plan was submitted, which was January 1994. However, because of a lack of funding, only a minimal amount of the original plan was actually implemented. The plan was updated in September 2000 and the executive summary is attached. The hearing will examine if there is a need to update the authorization language now that agency roles have been outlined and funding levels proposed.

Issues to be considered:

Emergency managers are the linchpin in the effort to prepare communities, safely and effectively evacuate people if necessary, and mitigate damages after the storms have hit. What new tools and information can research provide to help increase the effectiveness of emergency managers?

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FEMA, NOAA, NASA, USGS and other agencies are all involved in flood mapping and modeling. How can their roles and expertise be better coordinated?

The National Weather Service currently has a flood warning index—minor, moderate, major, and flood of record. How would the National Weather Service create a new flood index and warning system as called for in H.R. 2486?

While we continue to improve technology and capabilities to predict severe storms, the public is not always aware of or understands the warnings. How can we improve public communication and education about severe storms?

The U.S. Weather Research Program was unable to implement much of its original plan because of funding constraints. Will agencies be more willing to participate given the increasing influence of weather on the economy and the likelihood of more hurricanes in the near future? Should FEMA be one of the main agencies in the program? How can Congress strengthen this interagency effort?

H.R. 2486: The Tropical Cyclone Inland Forecasting Improvement and Warning System Development Act

The legislation authorizes $1.15 million per year for five years for the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS) to:

Improve the capability through research and modeling to forecast inland flooding associated with tropical cyclones;

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Develop, test, and deploy a simple and distinct inland flood warning index or system for use by the public and emergency management officials that clearly defines inland flood risks and dangers;

Train emergency management officials, National Weather Service personnel, meteorologists, and others as appropriate regarding improved forecasting techniques for inland flooding, risk management techniques, and use of the inland flood warning index or system;

Conduct outreach and education efforts to local meteorologists and the public regarding the dangers and risks associated with tropical cyclone induced inland flooding and the use and understanding of the inland flood warning index or system.

The bill directs the NWS to grant $250,000 per year for five years to supplement ongoing research and modeling efforts to improve the ability to forecast coastal and estuary-inland flooding associated with tropical cyclones. H.R. 2486 authorizes the NWS to make such grants and enter into such contracts as deemed necessary with appropriate research universities and/or institutions to carry out the activities associated with this act.

Finally, the bill requires the NWS to report to the House Science Committee and the Senate Commerce, Science and Transportation Committee 90 days after passage of this act, and annually thereafter until authorization expires, on the progress for improving the forecasting for tropical cyclone induced inland flooding, developing/enhancing an inland flood warning index and system and the success and acceptance of such a system by the public and emergency management professionals.

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Wind Storm Hazard Reduction Research and Technology Transfer Act

The draft legislation calls on the Office of Science and Technology Policy and the Federal Emergency Management Agency to create a multi-agency National Windstorm Hazard Reduction Program. The Program will:

Deliver to Congress a 10 year implementation plan with measurable goals that has been coordinated with appropriate representatives of state and local government and the private sector and of an annual update of progress towards these goals;

Provide a list of 11 priority areas where wind hazard reduction research and development can make the most cost-effective and affordable improvements;

Link all aspects of the plan to the goal of a major, measurable reduction in losses of life and property to wind storms within 10 years of the date of enactment;

Establish a wind hazard reduction technology transfer program;

Establish a National Advisory Committee for Windstorm Hazard Reduction.

The legislation authorizes $50 million for FY 2001, $100 million for FY 2002, and $150 million for FY 2003 to carry out such activities.

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Weatherproofing the U.S.: Are We Prepared for Severe Storms?

Chairman **EHLERS.** I now call the Subcommittee on Environment, Technology, and Standards to order and welcome the Vice Chairman and other members who are here. Let me also mention that a special service is being held at the Pentagon this morning. It is exactly one month since the terrorist activity in New York and at the Pentagon. And so the President is leading a memorial service over there. All Members of Congress were invited.

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Out of consideration for all of you who were already en route here or were here, we decided to proceed with the hearing regardless. But the attendance of members may be quite light at this as a result. I would also ask that we all rise and have a moment of silence in memory of those who perished.

[Moment of silence]

Please be seated. It is a pleasure to welcome all of you here and I especially want to thank the Panel of experts that we have assembled. Once again, our staff has done a stellar job of researching the best available people in this country, and we have them here before us.

Today's hearing will explore research on severe storms, with the emphasis on hurricanes, flooding, and wind-related damage. We will also examine the needs of emergency management officials and investigate how to ensure the public is properly warned about these storms and potential threats. In addition, we will hear comments on proposed legislation regarding flooding, preventing damage caused by wind storms, and better coordination among Federal agencies doing weather research.

Each year severe weather claims about 1,500 lives and causes roughly $16 billion in damages in the United States. Our ability to predict, prepare, and respond to these events are matters of life and death to people and communities large and small.

Dr. Landsea, who will be testifying today, suggests that we may be in store for many more hurricanes than we have experienced over the past two decades. And considering that many more people live on the coasts than ever before, we must do all we can to prepare for this possibility.

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While my home State of Michigan does not have much to fear from hurricanes, we do have our fair share of tornadoes. We do not exactly live in Tornado Alley, but we can certainly at least call it Tornado Cul-de-

Sac. I can tell you, from personal experience, that these events are quite unsettling.

In fact, my very first year of living in Michigan, we spent two hours in the basement with two young children and a 2-month-old baby waiting for a tornado to pass over. And it struck us in a personal way in that we were in the process of selecting a new house to purchase. Our first choice suffered tornado damage and they immediately took it off the market. Our second choice had lost shingles and so we though we could live with that. But everyone in Michigan experiences that at some time or another. But I am sure that Mr. Hill can discuss this—he has experienced firsthand during his time as a meteorologist in Michigan, what Michigan weather is like.

Two recent events demonstrate the importance of having this hearing. This year, Tropical Storm Allison caused the deaths of more than 35 people and did several billion dollars in damage, making it the most costly tropical storm ever. More than 35 inches of rain fell in some parts of Texas, and massive flooding was widespread throughout the southern and eastern sections of the United States. Our inability to adequately predict heavy precipitation affected our flood-modeling capabilities and left most areas ill prepared or without adequate warning about the disaster.

More recently, on September 24, deadly thunderstorms tore through the D.C. Metro Area spawning five tornadoes. One of them touched down in College Park, Maryland, killing two students and injuring about 50 people. Many have complained that there was not adequate warning about the threat the tornado posed.

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I might mention also that—and that afternoon, we looked out the window to the west and saw a tornado that nearly touched down over Arlington. And I was struck by the fact, not only that a tornado was there, but that our Capitol had a totally inadequate warning system and no warning was sent out. No instructions were available to people about what to do should one touch down here. We are dealing with that separately in another committee that I am on.

Our purpose here is to look at the research aspects of the issue. And we must invest in research to increase our ability to predict and model severe weather events. However, having the best models running on the fastest supercomputers will not help to save lives if accurate, understandable, and timely information does not get to the public. We must also pursue ways to educate people about the threats that storms may pose.

I might also add something else that is very important—is having accurate data to put into the computers. And that becomes a particular challenge in the coastal oceanic areas because of the lack of data about the oceans.

The best way to learn and improve is to examine your mistakes. I hope that the National Weather Service will work with the media and with the local communities to evaluate what happened during these two events and future events to determine what worked and what did not. Our goal should be to improve communication, education, and outreach so we can reduce the casualties and damage of potentially deadly storms.

Mark Twain once said, "Everybody talks about the weather, but nobody does anything about it." Well, I want to thank the distinguished Panel for being here today, and for being the people who are trying to do something about it. I would love to have you prove Mark Twain wrong.

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I would now like to recognize the Subcommittee's Ranking Member, Mr. Barcia, for his opening statement.

[The prepared statement of Mr. Ehlers follows:]

PREPARED STATEMENT OF CHAIRMAN VERNON J. EHLERS

Good morning!

Today's hearing will explore research on severe storms, with emphasis on hurricanes, flooding, and wind-related damage. We will also examine the needs of emergency management officials, and investigate how to ensure the public is properly warned about these storms and potential threats. In addition, we will hear comments on proposed legislation regarding flooding, preventing damage caused by windstorms, and better coordination among federal agencies doing weather research.

Each year severe weather claims about 1500 lives and causes roughly $16 billion in damages in the United States. Our ability to predict, prepare, and respond to these events are matters of life and death to people and communities large and small.

Dr. Landsea, who will be testifying today, suggests that we may be in store for many more hurricanes than we have experienced over the past two decades. And considering that many more people live on the coasts than ever before, we must do all we can to prepare for this possibility.

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While my home state of Michigan does not have much to fear from hurricanes, we do have our fair share of tornadoes. We do not live in Tornado Alley, but we might call it Tornado Cul-de-Sac. And I can tell you, from personal experience that, these events are quite unsettling. I am sure this is something that Mr. Hill experienced firsthand during his time as a meteorologist in Michigan.

Two recent events demonstrate the importance of having this hearing. This year Tropical Storm Allison caused the deaths of more than 35 people and did several billion dollars in damage, making it the most costly tropical storm ever. More than 35 inches of rain fell in some parts of Texas, and massive flooding was widespread throughout the southern and eastern sections of the U.S. Our inability to adequately predict heavy precipitation affected our flood-modeling capabilities and left most areas ill prepared or without adequate warning about the disaster.

On September 24, deadly thunderstorms tore through the D.C. Metro Area spawning five tornadoes. One of them touched down in College Park, Maryland, killing two students and injuring about 50 people. Many people have complained that there was not adequate warning about the threat the tornado posed.

We must invest in research to increase our ability to predict and model severe weather events. However, having the best models running on the fastest supercomputers will not help to save lives if accurate, understandable, and timely information does not get to the public. We must also pursue ways to educate people about the threats that storms may pose.

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The best way to learn and improve is to examine your mistakes. I hope that the National Weather Service will work with the media and with local communities to evaluate what happened during these two events and future events to determine what worked and did not. Our goal should be to improve communication, education, and outreach so we can reduce the casualties and damage of potentially deadly storms.

Mark Twain once said, "Everybody talks about the weather, but nobody does anything about it." Well, I want to thank the distinguished panel for being here today, and for being the people who are trying to do something about it.

Mr. **BARCIA.** Thank you, Mr. Chairman. I want to offer a good morning to all of the Panel guests and the audience. I would like to welcome, especially, our distinguished Panel to this morning's hearing. And I want to commend Chairman Ehlers for holding this very important hearing.

As the recent tornado here in the Washington, D.C. area proved, good forecasting capabilities alone are not sufficient to ensure the public's safety. We need to ensure that the public is adequately warned and gets reliable information to protect themselves from severe weather.

Two of our Committee colleagues, Representative Etheridge and Representative Moore, have taken the lead in this area. Congressman Etheridge recently introduced H.R. 2486, The Tropical Cyclone Inland Forecasting Improvement and Warning System Development Act. And Congressman Moore has developed draft legislation on increased research related to severe wind damage.

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The witnesses at today's hearing will address both of these initiatives. I want to thank our witnesses for appearing before the Subcommittee. I also want to join Chairman Ehlers in welcoming Doug Hill. As Chairman Ehlers mentioned, he was a weatherman in the Detroit area in the early '80's, and I want to thank him for taking the time from his busy schedule to talk about the real need for accurate and timely weather information and how to improve the system.

Chairman Ehlers, I would like now to yield the balance of my time to Mr. Etheridge and Mr. Moore so that they can make some brief comments as well.

[The prepared statement of Mr. Barcia follows:]

PREPARED STATEMENT OF THE HONORABLE JIM BARCIA

Good morning, I would like to welcome our distinguished panel to this morning's hearing.

I want to commend Chairman Ehlers for holding this important hearing. As the recent tornado here in the Washington, DC area proved, good forecasting capabilities alone are not sufficient to ensure the public's safety. We need to ensure that the public is adequately warned and gets reliable information to protect themselves from severe weather.

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Chairman Ehlers, I would now like to yield the balance of my time to Mr. Etheridge and Mr. Moore, so they can make some brief comments as well.

Chairman **EHLERS.** Without objection.

Mr. **ETHERIDGE.** Thank you, Mr. Barcia, for yielding to me. And I want to thank you and Chairman Ehlers for holding this important hearing on storm preparedness. You have already talked about the specifics. I especially want to thank you for extending to me the courtesy of participating today even though I am not a member of this Subcommittee.

And as we speak this morning, there are currently tropical systems north of the Equator in the western hemisphere that could turn into tropical cyclones and hit land even now. And the people of North Carolina are all too familiar with the death and devastation that comes from the heavy rains of hurricanes and tropical storms that have so many times hit our state.

In 1999, Hurricane Floyd killed 48 of our citizens and caused nearly $3 billion worth of property damage, primarily through flooding in inland communities. Earlier this year, Tropical Storm Allison cut a path across the Nation killing more than 50 people, many of them killed by flooding. And we have just heard about the hurricane—tornadoes that hit Washington. These storms demonstrate all too clearly that the greatest threat posed by these storms are the torrential rains that often do the most damage hundreds of miles inland.

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I am concerned that people do not understand the nature of this threat because they see hurricanes and tropical storms as affecting only coastal communities. This is why, along with 20 of my colleagues, I have sponsored H.R. 2486, to improve the forecasting of inland flooding associated with tropical storms and to develop an inland flooding warning system to better alert residents of dangerous flooding conditions. I am pleased that this bill has won the support of so many of my science colleagues and that Chairman Boehlert and Ranking Member Hall have also joined as cosponsors and many of my colleagues.

Congress must pass this lifesaving bill soon and I trust we will do it this session. I want to express my appreciation to the Committee and the Subcommittee staff for the work they have given to me on this important issue. I have been in contact with our colleagues in both body—in the other body, and I hope that we will soon see a bill at the White House that can be signed before the hurricane season starts again next year in June of 2002.

Mr. Chairman, with your permission, I will also ask unanimous consent to be allowed to sit on this hearing and hopefully, at some point, introduce my friend, Dr. Pietrafesa from North Carolina.

[The prepared statement of Mr. Etheridge follows:]

PREPARED STATEMENT OF CONGRESSMAN BOB ETHERIDGE

Thank you Mr. Barcia for yielding to me. I want to thank you and Chairman Ehlers for holding this important hearing In storm preparedness.

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I especially want to thank you for extending me the courtesy of participating even though I am not a member of this subcommittee.

As we speak, there are currently tropical systems north of the equator in the Western Hemisphere that could turn into tropical cyclones and hit land.

The people of North Carolina are all too familiar with the death and devastation that can come from the heavy rains that hurricanes and tropical storms often bring to our state.

In 1999, Hurricane Floyd killed forty-eight of our citizens and caused nearly $3 billion worth of property damage, primarily through flooding in inland communities. Earlier this year, Tropical Storm Allison cut a path across the nation, killing more than 50 people, many of them also killed by flooding.

These storms demonstrate all too clearly that the *greatest* threat posed by these storms are the torrential rains that often do the most damage hundreds of miles inland.

I am concerned that people do not understand the nature of this threat because they see hurricanes and tropical storms as affecting only coastal communities.

That is why I, along with 20 of my colleagues have sponsored H.R. 2486 to improve the forecasting of inland flooding associated with tropical storms and to develop an inland flood warning system to better alert residents of dangerous flooding conditions.

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I am pleased that my bill has won the support of so many Science Committee members including Chairman Boehlert and ranking member Hall.

Congress must pass this life-saving bill soon, and I know this subcommittee hearing is an important first step in that direction. I want to express my appreciation to the Committee and Subcommittee staff for working with me on this important issue.

I have been in contact with our colleagues in the other body, and I hope we can send a bill to the White House by the end of the year before the next hurricane season starts on June 1, 2002.

Mr. Chairman, with your permission, I would ask unanimous consent to be allowed to sit in on this hearing.

I look forward to introducing my friend and constituent, Dr. Leonard Pietrafesa, and discussing my legislation with the witnesses. Thank you again Mr. Chairman.

Chairman **EHLERS.** Without objection, so ordered. If there is no objection, all additional opening statements submitted by the Committee members will be added to the record.

Mr. **MOORE.** I do have—Mr. Chairman——

Chairman **EHLERS.** Pardon?

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Mr. **MOORE.** May I make a brief opening?

Chairman **EHLERS.** Very brief. Yes.

Mr. **MOORE.** Very brief. I want to thank you, Chairman Ehlers, and, Ranking Member Barcia, for having this hearing and for your leadership on this important issue. I also want to thank you and your staff for the briefing yesterday on the Washington Metro Area tornadoes. Being from Kansas, I know the need to have an alert system and emergency weather notification system for capital office buildings.

It was just two years ago this month that Representative Walter Jones and I started the Wind Hazard Reduction Caucus. This caucus now has 36 members. And rather than being the subject of political jokes about politicians and big wind, the caucus has successfully brought together a coalition of people who might not normally work together to find solutions to the damage caused by wind storms.

Last Congress we introduced H.R. 5499, The Wind Storm Hazard Reduction Research and Technology

Transfer Act. Since its introduction, staff has been meeting with Federal agencies, engineers, associations, and emergency managers to create the best possible bill for introduction in this session of Congress.

I look forward to hearing the ideas of the witnesses here today. I am especially proud to have with us a professor from my district, Dr. Steven McCabe, Chair of the Department of Civil and Environmental Engineering at the University of Kansas here to testify.

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Again, Chairman Ehlers, thank you so much for holding this hearing. And to the Ranking Member Barcia for holding this hearing and exploring the needs to deal with the problem before us. Thank you, Mr. Chairman.

Chairman **EHLERS.** Thank you. And let me just say that—to the audience and the panelists, it is clear this hearing is not just about the announced topic, but also about two bills that these two gentleman have sponsored, as well as the general question of reauthorization of the agencies involved in this.

If there is no objection, all additional opening statements submitted by the Subcommittee members will be added to the record. Without objection, so ordered.

[The prepared statement of Congressman Nick Smith follows:]

PREPARED STATEMENT OF CONGRESSMAN NICK SMITH

I would like to thank the Chairman and the Ranking member for holding this hearing on the status of research efforts into the prediction of severe storms.

Every year, severe weather claims about 1,500 lives and causes $16 billion in damages. As a farmer, I know all too well the impact that severe weather can have on crops and live stock. According to the American Meteorological Society, roughly 25 percent of the U.S. economy is influenced by weather.

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In June of 1999, the Subcommittee on Research, which I Chair, held a joint hearing with this subcommittee on "Tornadoes: Understanding, Modeling, and Forecasting Supercell Storms" which highlighted the advances that are enabling more rapid and accurate prediction of severe weather today. Thanks to tools such as satellites, Doppler radar and computational modeling and advances in our understanding of the atmosphere, the U.S. is poised to achieve extraordinary advances in the science of weather prediction.

Supporting weather forecasters are a number of research programs that provide critical information on severe weather. Research at the National Science Foundation, NASA, NOAA and the Department of Defense are now coordinated through the U.S. Weather Research Program to work closely with federal, state, and local authorities to facilitate the transfer of improved forecast technologies to the private sector to continuously increase the accuracy and timeliness of weather prediction.

Similar research and coordination challenges can be found in technologies to predict earthquakes. According to the National Earthquake Hazards Reduction Program (NEHRP), no state is immune from earthquake hazards, and at least 44 are at risk of moderate or major seismic activity. Unlike hurricanes, you can't predict earthquakes. We need to understand the physics of earthquakes if we are ever going to predict them. That is why I drafted the "Earthquake Hazards Reduction Authorization Act of 1999" to authorize appropriations for the Federal Emergency Management Agency (FEMA), the National Science Foundation (NSF), the National Institute of Standards and Technology (KIST), and the U.S. Geological Survey (USGS) for the National Earthquake Hazards Reduction Program (NEHRP). This program is a model for interagency cooperation, including local and regional partners, toward improving the science and technology of hazard prediction and loss reduction.

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Whether in the form of earthquakes, tornadoes, floods, or blizzards, severe storms can have a huge impact on our lives. More warning and better preparations has the potential to substantially reduce property damage and can literally make the difference between life and death. I strongly support our research efforts and look forward to the testimony of the distinguished panel.

Chairman **EHLERS.** At this time, I would like to formally introduce our witnesses. First, we have Dr. Chris Landsea, a very appropriate name for someone studying hurricanes, and he is a Researcher in the Hurricane Research Division at the Atlantic Oceanographic and Meteorological Laboratory within the National Oceanic and Atmospheric Administration.

The next person will be introduced for the second time in the history of this Committee by Congressman Etheridge. Since you spent 15 minutes on the introduction last time, could we perhaps have a shorter one this time?

Mr. **ETHERIDGE.** Maybe no more than five, Mr. Chairman. Thank you.

Chairman **EHLERS.** All right. Thank you.

Mr. **ETHERIDGE.** Thank you for extending me this courtesy. And I want to thank you and Ranking Member Barcia also for allowing me to be with you to introduce my friend and constituent, Dr. Pietrafesa. He is currently Professor at the Department of Marine, Earth, and Atmospheric Sciences at North Carolina State University and serves there as the Director of External Affairs at the College of Physical and Mathematical Sciences. He has earned his Ph.D. degree in Geophysics and Geophysical Fluid Dynamics from the University of Washington in 1973, at which time he joined the faculty of North Carolina State University.

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He is the author or co-author of 151 peer-reviewed publications in the area of estuarine and coastal ocean and atmospheric weather and climical fluid, physical dynamics. That is a mouthful. I have the pleasure of working with him in a number of ways, finding ways to predict hurricanes, and, in particular, Mr. Chairman, and regarding inland flooding, which he has done an awful lot of work in. And I know this Subcommittee will find his testimony very informative this morning. Thank you.

Chairman **EHLERS.** Thank you for the introduction and thank you for appearing a second time. I am pleased to hear of your Ph.D. in Geophysics. My son just received his Ph.D. in that field and now is a post-doc at Cal Tech. So you may interact with him at some point.

The next guest is going to be introduced by Congressman Moore.

Mr. **MOORE.** And I can be even more brief. Dr. Steven McCabe, as I indicated in my opening remarks, Mr. Chairman, is the Professor and Chair, Department of Civil, Environmental, and Architectural Engineering at the University of Kansas. He brings his expertise here today and will talk about what we might to do to mitigate and reduce some of the damage and the loss that we suffer as a result of the wind hazards that we all face. And I am really proud to have Dr. McCabe here today. Thank you, Mr. Chairman.

Chairman **EHLERS.** Thank you, Congressman Moore. Next, we have Dr. John Hayes, who is the Director of the Office of Science and Technology at the National Weather Service. And he is a Co-Chair of the U.S. Weather Research Program.

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And following him is someone we both mentioned before. You can tell Mr. Barcia and I are both from Michigan, where Mr. Hill used to give us the world's best weather, although also very changeable weather. He is currently Chief Meteorologist at ABC Channel 7 News here in Washington, DC.

Mr. Robert Shea is the Acting Administrator for Federal Insurance and Mitigation at the Federal Emergency Management Agency, better known affectionately as FEMA. The—I can't—in seeing these witnesses here, particularly those from the Weather Service and from—a TV meteorologist—can't help thinking of the former Congressman who wanted to do away with the National Weather Service on the basis that we didn't need it. He got all his weather from the TV station. He did not get re-elected.

As our witnesses know, spoken testimony is limited to five minutes each, after which the members of the Committee will have five minutes each to ask questions. And just a reminder for those of you who are new, we have a timing clock here. And during the first four minutes of your testimony, it is green. And during the final minute, it is yellow. And when it turns red, five minutes has elapsed and all sorts of bad things can happen. You know, the trap doors open and ceilings fall, etcetera. So we ask you to do your best to summarize your testimony in five minutes. Your written testimony, of course, will go on the record. But please try to restrain your comments to five minutes, particularly since we have a large Panel this morning. We will begin with Dr. Landsea. And please remember to turn on your microphones when you testify.

STATEMENT OF DR. CHRISTOPHER W. LANDSEA, HURRICANE RESEARCH DIVISION, ATLANTIC OCEANOGRAPHIC AND METEOROLOGICAL LABORATORY, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA)

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Dr. **LANDSEA.** Thank you, Chairman Ehlers, for inviting me here today for the Subcommittee. Again my name is Chris Landsea, and I am representing the Hurricane Research Division in NOAA. We are in the research arm studying hurricanes. And I want to talk to you today about some of the implications of the recent research we have been involved with, looking at cycles of hurricane activity. And I have a few Power Point presentations to go with it. To put it in perspective, this is a Category five hurricane that you are looking at, Hurricane Mitch, from 1998, that killed over 10,000 people in Honduras and Nicaragua three years ago.

As horrible as the events of September 11 were, in perspective, hurricanes can be as damaging or worse. The United States' worst disaster on record for the number of fatalities was the Galveston hurricane in 1900, where 8,000 people perished. Similarly, the amount of damage that could occur—Hurricane Andrew caused $26 billion of damage. But if the 1926 great Miami hurricane hit today, estimates are that that could cause $80 billion of damage.

A little bit about the physics. What causes hurricanes to become active and very violent? We look for a combination of environmental factors—warm water in the tropical Atlantic and the Caribbean Sea, lower pressure than normal, indicating less sinking and drying of the atmosphere, and less vertical shear tearing apart the hurricanes. When you have these in a combination, you get active hurricane conditions, whether it is day-to-day, week-to-week, or year-to-year.

But what I want to talk to you about is long-term changes in hurricanes—how have they varied over the last several decades, and what might we expect in coming years? This graph shows how the total number of storms, the tropical storms and hurricanes, have changed since World War II, when we started flying into hurricanes. And you can see there are lots of year-to-year changes, but the long-term average stays right about that black line, right about ten per year.

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In contrast to that, the number of strong hurricanes—these are the Category 3s, 4s, and 5s on the Saffir-Simpson Scale—these are the ones we are most concerned about because they cause over 80 percent of the damage in the United States, even though they only account for 20 percent of the ones that hit us.

You can see a quite different perspective here. On this graph, we see more of a cyclic activity, such that the 1940's, '50's, and '60's were quite busy. We averaged about three of these strong hurricanes per year. And then from the 1970's, '80's, and early '90's, it was very quiet. We were fortunate in the United States, and our friends in the Caribbean, that it was such an inactive period.

Unfortunately, what we have noticed the last few years, starting in 1995: it has gotten busy again. We have averaged about three to four strong hurricanes a year. And the question is, what is this due to and what are the implications for coming years?

What we have identified as the forcing mechanism is the Atlantic Ocean. The Atlantic likes pulsing on periods of 25 to 40 years where it is warm, like what shows here, and 25 to 40 years where it is cool. It is a natural cycle of the Atlantic Ocean variability. And that, together with the atmospheric changes above, lead to these variations in hurricane activity.

As an example, the left-hand side shows about 50 years where the Atlantic was warmer than usual, and the right-hand side, where it is cooler than usual, you see we get over a doubling of the major hurricane activity striking from the Florida Peninsula up through New England. With these changes in the Atlantic hurricane activity, what we see is five times as much damage. And we average currently about $5 billion a year from hurricanes. About half of that would be insured.

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Well, the implications are that if it was just a natural cycle and everything else remained the same, not that big a deal. Well, I mean hurricanes have been around for a millennium. Unfortunately, what we see in the red graph is the Florida population, and this is mirrored all the way from Texas to Florida to the middle Atlantic states to New England—populations are going up dramatically. And, at the same time that the populations were going way up, we saw a big decrease in the strong hurricanes that made landfall.

Now, that we are back into this period, and we should expect strong hurricane activity for the next 20, 30, maybe 40 years, the implications are fairly—kind of scary to me because we are looking at increased strikes where people are located now. And it is starting to show up in North Carolina with Floyd and Dennis and other hurricanes, and in the Caribbean with Mitch and Lenny and the other storms that are causing dramatic impacts there.

So I want to just let the Committee know about this recent research and the implications for the next 20 to 30 years. Thank you very much.

[The prepared statement of Dr. Landsea follows:]

PREPARED STATEMENT OF DR. CHRISTOPHER W. LANDSEA

Good morning, Mr. Chairman and members of the Committee. Thank you for inviting me to discuss potential implications of the recent increase in Atlantic hurricanes and the evidence that this is the beginning of a multidecadal pattern that could have major implications for coastal communities in coming years. Understanding the historical patterns and the present conditions that have led to this increase in Atlantic hurricanes is crucial for developing a management strategy.

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I am Chris Landsea, Research Meteorologist with the Hurricane Research Division of the Atlantic Oceanographic and Meteorological Laboratory in Miami, Florida. The Atlantic Oceanographic and Meteorological Laboratory is one of twelve laboratories administrated by the Office of Oceanic and Atmospheric Research of the National Oceanic and Atmospheric Administration (NOAA). The Hurricane Research Division conducts basic and applied research which directly benefits hurricane track and intensity forecasting which is a direct contribution to NOAA's mission of environmental prediction.

Progress in predicting and understanding weather has been one of the greatest success stories in science. Hurricanes pose a major threat to our Nation's coastal communities which points to a critical need for enhanced predictive capabilities. The impacts of hurricane winds, storm surge and inland flooding remain major threats to the Nation's coastal communities. Inland flooding after hurricane landfall is becoming more devastating as Americans continue the trend of building new homes and businesses in low-lying flood plains. Accurate and early forecasts of hurricanes give emergency managers and people time to prepare for the possibility of disastrous affects that are coming, including possible evacuations. Understanding the location and severity of hurricane landfall is the key to planning long before the event. Well-orchestrated responses in the years, months, days, hours and even minutes before hurricane landfall can limit the loss of human lives and property damage.

NOAA's Office of Oceanic and Atmospheric Research strives to improve the reliability, accuracy, timeliness, and specificity of predictions of hazardous weather, such as hurricanes, to help society cope with these phenomena. Research results from the Hurricane Research Division, in conjunction with the National Weather Service modernization efforts, have helped to improve our hurricane prediction capabilities. Over the last 30 years, the improvement in forecast error has averaged about 1% per year, largely due to an increased understanding of hurricane dynamics, improvements in computing and technology and more data in the region around the hurricane. However, more accurate predictions with greater lead times are becoming increasingly more important with the onslaught of increasing coastal population and infrastructure coupled with the increased likelihood of severe hurricanes over the next couple of decades.

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The following information details the current Atlantic hurricane situation and attempts to relate the increased hurricane activity to an increased potential for storm-related damage caused by hurricanes and their associated flood and wind-related conditions.

The years 1995–2000 experienced the highest level of North Atlantic hurricane activity ever measured. Compared with the previous 24 years (1971–94), there were twice as many hurricanes in the Atlantic, including two and a half times more major hurricanes. Major hurricanes are those reaching Category 3 strength with winds exceeding 110 mph and most of the deadliest and costliest Atlantic tropical cyclones are major hurricanes. In this same period, more than five times as many hurricanes impacted the Caribbean Islands. Today, major hurricanes account for just over 20% of the landfalling United States tropical storms and hurricanes but cause more than 80% of the damage. Overall, the United States has experienced about five times greater average damages from tropical storms and hurricanes during the warm (high activity) than during the cold (low activity) phases of the Atlantic multidecadal mode.

Based upon changes in oceanic and atmospheric conditions, we think this increased activity is due to a natural cycle called the Atlantic Multidecadal Mode, a north Atlantic and Carribean sea surface temperature shift between warm and cool phases that each last 20 to 40 years. The data suggest that we are in a warm Atlantic phase; thus, an active Atlantic hurricane era may be underway, similar to that last seen from the late 1920s to the late 1960s. Further, our results suggest that the record amount of hurricane activity could possibly be caused by a combination of the multidecadal ocean temperature changes plus a small contribution from the long-term warming trend. Known cycles of natural variability are high. However, inadequacies in the data record make long-term warming a difficult issue to resolve because model variability studies are inconclusive.

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The North Atlantic hurricane season officially lasts from June 1 to November 30. The tropical storms that can turn into hurricanes and threaten the east and Gulf coasts of the United States form in the Gulf of Mexico, Caribbean Sea, and Atlantic, many developing from easterly waves moving off the west coast of Africa. Hurricanes are fueled by warm water as they travel across the ocean. An abundance of warm water provides more energy allowing the storm to increase in strength. However, we have found that the warm water alone was not enough. The winds between the upper and lower troposphere (the first seven miles of our atmosphere starting from the ground or ocean and going upwards) also play a major role. Strong vertical shear (i.e., a large difference in the speed and direction of the wind between the lower and upper troposphere) in the wind inhibits the formation or intensification of tropical cyclones whereas, weak wind shear encourages them.

Evidence from our research, recently published in Science, suggests that many of the hurricane seasons in the next two or three decades may be much more active than they were in the 1970's through the early 1990's. The present high level of hurricane activity is likely to persist for an additional 10–40 years. Warmer sea surface temperatures. . .are expected to contribute to conditions that foster more hurricanes over this period. Thus, we should prepare for a busy period of hurricane activity.

Consistent with experience since the active phase began in 1995, there would be a continuation of significantly increased numbers of hurricanes (and major hurricanes) affecting the Caribbean Sea, and basin-wide numbers of major hurricanes. The Gulf of Mexico, however, is expected to see only minor differences. Tragic impacts of the heightened activity have already been felt, especially in the Caribbean. In addition, an increase in major hurricane landfalls affecting the U.S. East Coast is anticipated.

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An active hurricane season does not necessarily mean more storms making landfall. In 1992, Hurricane Andrew became the costliest disaster in U.S. history and was the only hurricane to make landfall that year. While anticipating generally high activity during the hurricane seasons for the next few decades, we do not expect every year to be hyperactive. Nonetheless, rapidly increased population and development means that hurricane damage will be far more than previously experienced by coastal residents. Years with a low level of activity can produce disasters because even weak storms can cause devastating flooding.

Although increased activity during a particular year does not automatically mean increased storm-related damages, years with high activity have a greater overall potential for disaster than years with low activity. Increased occurrence combined with dramatic coastal population increases during the recent lull, add up to a potential for massive economic loss. In addition, there remains a potential for catastrophic loss of life in an incomplete evacuation ahead of a rapidly intensifying system. Government officials, emergency managers, and residents of the Atlantic hurricane basin should be aware of the apparent cyclical changes and evaluate preparedness and mitigation efforts in order to respond appropriately in a regime where the hurricane threat is much greater than it was in the 1970s through early 1990s.

The primary goal of the U.S. Weather Research Program (USWRP) is to increase the accuracy and lead time of hurricane forecast predictions. The USWRP is a well-organized, multi-agency collaborative program. NOAA cooperates with NASA, NSF, the Navy, and the university community to conduct weather research that will improve forecasts of the location and intensity of hurricanes in advance of their arrival. NOAA's Hurricane Research Division provides many observational contributions to the Hurricane Program within the USWRP. As the likelihood of hurricane frequency and severity along the Atlantic coastline increases, the need for accurate prediction capabilities will continue to grow if we are to provide timely warnings for our coastal residents.

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I would like to express my appreciation again to you Mr. Chairman and members of the Committee for this opportunity to explain the multidecadal increase in hurricanes of the Atlantic basin and the far-reaching implications this increase has for our country. I look forward to future milestones and improvements in hurricane research and to the many contributions NOAA can continue to make in this important area. Through NOAA's leadership, our understanding of hurricanes and subsequent improvements in operational hurricane predictions have improved. We have come a long way but still have much to accomplish before all U.S. citizens will reap the benefits of our weatherproofing efforts. Thank you again for the invitation today. I hope this summary has been useful. My testimony for the record will include an attachment of the full text, including figures, from my recent *Science* magazine article providing more specific technical data which served as the basis for my remarks today. I would be happy to address any questions you may have.

APPENDIX I.

The Recent Increase in Atlantic Hurricane Activity: Causes and Implications

Stanley B. Goldenberg(see footnote 1), Christopher W. Landsea1B, Alberto M. Mestas-Nuñez(see footnote 2) and William M. Gray(see footnote 3)

Please Note: This revised manuscript is in the format of the final submission to *Science.* Numerous editorial and several minor content changes where made prior to publication.

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The manuscript appears in the July 20th, 2001 issue of *Science.* Vol. 293, pp. 474–479.

Supplemental material is found on the web at: Posted at *Science* Online at: www.sciencemag.org/cgi/content/full/293/5529/474/DC1

The years 1995–2000 experienced the highest level of North Atlantic hurricane activity in the reliable record. Compared with the generally low activity of the previous 24 years (1971–94), the last six years have seen a doubling of overall activity for the whole basin, a 2.5-fold increase in major hurricanes (= 50 m s–1B) and a five-fold increase in hurricanes affecting the Caribbean. The greater activity results from simultaneous increases in North Atlantic sea-surface temperatures and decreases in vertical wind shear. Because these changes exhibit a multidecadal time scale, the present high level of hurricane activity is likely to persist for an additional 10–40 years. The shift in climate calls for a reevaluation of preparedness and mitigation strategies.

During 1970–87, the Atlantic basin experienced generally low levels of overall tropical cyclone activity. The relative lull was manifested in major hurricane *(1)* activity (Fig. 1), major hurricane landfalls on the U. S. East Coast, and overall hurricane activity in the Caribbean. A brief resurgence of activity in 1988 and 1989 made it appear that the Atlantic basin was returning to higher levels of activity similar to the late 1920s through the 1960s *(2)*. This notion was later discarded when the activity returned to lower levels from 1991–94 *(3)*, due in part to the long-lasting (1990–95) El Niño event *(4)*. This event ended in early 1995 and was followed later that year by one of the most active Atlantic hurricane seasons on record *(5)*. Activity has been well-above average each year since 1995, except for 1997. Here we address the question of whether or not the increase in activity reflects a long-term climate shift, as suggested by previous studies *(6–9)*, and provide evidence that confirms this suggestion based upon changes in oceanic and atmospheric conditions.

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The North Atlantic basin (including the North Atlantic Ocean, Caribbean Sea and Gulf of Mexico) exhibits substantial interannual and interdecadal variability of tropical cyclone activity. This variability is especially pronounced in major hurricane activity. Interdecadal major hurricane fluctuations occur in both landfall locations *(10)* and overall activity *(11–13)*. Most of the deadliest and costliest Atlantic tropical cyclones *(10)* are major hurricanes. Major hurricanes account for just over 20% of the landfalling United States tropical storms and hurricanes but cause more than 80% of the damage *(14)*.

Most Atlantic tropical cyclones form from atmospheric easterly (African) waves that propagate westward from Africa across the tropical North Atlantic and Caribbean Sea primarily between 10 and 20N [termed the "main development region" (MDR) *(15, 16)* (see Fig. 2A)]. The Atlantic tropical cyclones not spawned by African waves usually form poleward of 25N. African waves account for 60% of the Atlantic basin tropical storms and non-major hurricanes but 85% of major hurricanes *(17)*. Almost all major hurricanes formed from African waves begin development (i.e., attain tropical depression status) in the MDR *(15)* and thus are more sensitive to climatic fluctuations in the tropics.

Although the number of easterly waves in the tropical Atlantic is fairly constant from year to year, the fraction that develops into tropical cyclones varies substantially *(18, 19)*. The key to understanding the fluctuations on interannual and interdecadal scales is the MDR. The climatic forcing that affects that region can be separated into local and remote factors. In combination, these factors influence the number of waves that develop into tropical cyclones during each hurricane season. Local factors occur in the actual region and have a direct thermodynamic or dynamic connection to development. Remote factors occur away from the

MDR, but are associated (via teleconnections) with conditions in that region. All factors vary on disparate temporal and spatial scales, and there is considerable interdependence between some of them. The extremely active 1995 season, for example, resulted from the juxtaposition of virtually all of the factors known to favor development *(5).* Among the local tropical Atlantic factors are the lower stratospheric Quasi-Biennial Oscillation *(20, 21)*, sea-level pressure *(5, 20, 22)*, lower tropospheric moisture *(5)*, sea-surface temperature (SST) *(23–25)*, and vertical shear of the horizontal environmental wind *(15, 26).* The two local factors addressed here are SST and vertical shear.

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In general, when looking for long-term variability, it is necessary to look at the oceans because their large thermal and mechanical inertia provide long-term memory and predictability *(27).* The oceans are the primary energy source for tropical cyclones. Localized SSTs play a direct role in providing moist enthalpy to power incipient tropical cyclones *(5, 25).* Warmer SSTs decrease atmospheric stability which increases the penetration depth of a vortex thus making developing tropical cyclones more resistant to vertical wind shear *(28).* Local SST > 26.5C is usually considered to be a necessary condition for tropical cyclone development *(26)*, and higher SST can increase overall activity *(23–25).* Multidecadal variations in major hurricane activity have been attributed to changes in the SST structure in the Atlantic *(2, 12, 13)* as tropical North Atlantic SSTs correlate positively with major hurricane activity. Although North Atlantic SSTs directly impact tropical cyclone activity as a local thermodynamic effect, it appears unlikely that this is their only physical link to hurricane activity. For influencing activity on interannual time scales, this local effect plays either a negligible role (for major hurricanes) or at best a secondary role (for all hurricanes) *(24).*

The dominant local factor for tropical cyclone activity is the magnitude of the vertical shear of the horizontal wind between the upper and lower troposphere, vertical wind shear. Strong Vertical wind shear inhibits the formation and intensification of tropical cyclones (e.g., *15, 26)*, primarily by preventing the axisymmetric organization of deep convection. Local vertical wind shear > 8 m s–1B is generally unfavorable for development *(29).* The climatological mean vertical wind shear, Vertical wind shear, for August-September-October (ASO), the peak three months of the Atlantic hurricane season during which virtually all major hurricanes form, is westerly with a magnitude, vertical wind shear, greater than 8 m s–1B over much of the basin *(15, 16).* Climatologically high values for vertical wind shear are one of the main reasons why conditions in the Atlantic basin are not especially conducive to tropical cyclone development. The tropical North Atlantic SST appears to act in concert with the overlying tropospheric circulation such that warmer SSTs correspond to reduced vertical wind shear in the MDR *(12, 24).*

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A key remote factor is SST variability in the central and eastern equatorial Pacific Ocean associated with El Niño/Southern Oscillation (ENSO). Positive Pacific SST anomalies associated with warm-phase ENSO (El Niño) have been linked to increased vertical wind shear over the MDR, and conversely for cool-phase ENSO (La Niña) *(15, 20, 30).* Another remote factor that has been linked to interannual and multidecadal variability in Atlantic basin tropical cyclone activity is rainfall variability over the western Sahel *(2, 31)*, with positive rainfall anomalies associated with reduced vertical wind shear over the MDR *(15).*

The most obvious indicator of a possible long-term shift is the changes in the tropical cyclone activity itself. The total number of tropical storms and non-major hurricanes in the North Atlantic basin has remained fairly constant from decade to decade *(13).* The numbers of major hurricanes and of Caribbean hurricanes, however, exhibit strong multidecadal variability. The late 1920s to the 1960s were very active, while both the 1900s through mid-1920s and the 1970s through the early 1990s were quiescent *(2, 12, 13).*

The events of each year reflect a combination of temporal scales. Interannual fluctuations in activity occur in both high and low activity periods (Fig. 1). Inhibiting influences during relatively inactive multidecadal periods, however, set a limit on the possible level of activity. During 1944–70 (the portion of the previous active multidecadal period shown in Fig. 1), the average number of major hurricanes per year was 2.7 *(32–34).* Six of the years produced four or more major hurricanes. In contrast, the average for the quieter period of approximate equal duration, 1971–94, was only 1.5, with no years having >3 major hurricanes. The quieter period's threshold of three major hurricanes was then exceeded in 1995 for the first time since 1964. The average number of major hurricanes for 1995–2000 is 3.8 *(34).* Three of those years had four or more. The Net Tropical Cyclone activity (NTC) for the North Atlantic, another measure of activity *(8),* shows a similar combination of interannual and multidecadal fluctuations *(35).* The only year since 1995 with below-average activity was 1997, when the Atlantic hurricane activity was suppressed by the strongest El Niño event of this century *(36).* Even with 1997 included, the mean number of major hurricanes and mean NTC for 1995–2000 are the highest of any consecutive six years in the 1944–2000 record. While this recent period spans only six years, it clearly belongs to a different low-frequency climate regime than the previous 24 years (1971–94).

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Studies of global SSTs using empirical orthogonal function (EOF) analysis (e.g., *37)* have shown that the primary source of interannual SST variability is the ENSO region. To analyze the relationship of Atlantic tropical cyclone activity with Atlantic SST anomalies in a way that is independent of ENSO, it is helpful to first remove the teleconnected effects of ENSO on the Atlantic Ocean *(38).* The first rotated non-ENSO SST mode *(39)* represents interannual to multidecadal variability (Fig. 2). Because the mode's temporal variability is dominated by multidecadal-scale fluctuations (Fig. 2B) with the largest amplitudes in the Atlantic, we refer to it as the "Atlantic multidecadal mode". The positive phase of the mode's spatial pattern (Fig. 2A) has warm SSTs in the tropical North Atlantic from 0 to 30N (which includes the MDR) and in the far North Atlantic from 40 to 70N. This mode is not local to the MDR; it is instead a large-scale feature that, because it is also present in the MDR, affects Atlantic tropical cyclone activity. The primary region for SST anomalies that would affect tropical cyclones directly would be in and just north of the MDR, i.e., 10–25N *(24, 40).*

These multidecadal-scale fluctuations in SSTs closely follow the long-term fluctuations in Atlantic tropical cyclone activity *(13).* The time series for the Atlantic multidecadal mode (Fig. 2B), major hurricanes (Fig. 1) and NTC *(35)* all show similar multidecadal-scale shifts. Ignoring interannual fluctuations, major hurricane activity is high from 1944 through at least 1964 (Fig. 1), NTC is high through 1969 *(35)* and the Atlantic multidecadal mode is predominately warm until 1970 (Fig. 2B). Then, major hurricane activity and NTC are mostly below average and the Atlantic multidecadal mode colder from the early 1970s through the early 1990s. All three quantities have increased dramatically since 1995. Note also that the two busiest periods in the 1970s and 1980s, 1979–81 and 1988–90 *(35),* coincide with two short warming periods, 1979–81 and 1987–90 (see Fig. 2B), indicating the possibility of significant relationships on shorter (decadal) time scales. The correlations between the 5-year running mean of the Atlantic multidecadal mode with the major hurricane and NTC running means are 0.72 and 0.81, respectively *(41).*

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It has been hypothesized that multidecadal changes in oceanic temperatures, major hurricane activity and Sahel rainfall are related to fluctuations in the intensity of the thermohaline circulation in the North Atlantic *(12, 42).* A faster thermohaline circulation is suggested to be associated with warmer SSTs in the North Atlantic and colder SSTs in the South Atlantic. These conditions would enhance Sahel rainfall and decrease vertical wind shear in the MDR. In other words, the decadal-scale SST fluctuations affecting Atlantic hurricane (particularly major hurricane) activity would likely produce the connection via changes in the upper- and lower-level zonal atmospheric circulations over the MDR *(40).* It is also possible, but less likely, that the changes in atmospheric circulation are forcing the SST changes. It is doubtful, however, that long-term increased tropical cyclone activity could cause warmer North Atlantic SSTs since hurricanes result in a cooling of SSTs through vertical mixing and upwelling (e.g., *43).*

Figure 3 shows the fluctuations in vertical wind shear averaged for ASO for the south-central portion of the MDR where the strongest correlations between vertical wind shear and major hurricanes occur *(15, 16).* Although there is substantial interannual variability in vertical wind shear, primarily associated with ENSO, this is being modulated by the obvious multidecadal-scale fluctuations. These fluctuations show a switch from conducive (high percentages of low vertical wind shear) to suppressed (low percentages of low vertical wind shear) conditions in 1970, almost coincident with the shift in major hurricanes (Fig. 1), NTC *(35)* and SSTs (Fig. 2B). In Fig. 3, however, the switch back to conducive conditions appears to start in 1988 *(44),* seven years earlier than the switch for the other parameters. Even though 1991 through 1994 exhibit a short-term return to less conducive values, 1988 through 1990 had the most favorable values since 1969. Figure 2 shows some evidence of North Atlantic SST warming for a few years around 1988 followed by several cooler years in the early 90's before the major warming in 1995. The warming around 1988 is much more evident in the Atlantic multidecadal mode values for ASO and in the actual ASO SSTs for the MDR (not shown). Nonetheless, the dominant shift to warmer values clearly takes place in 1995, which is when occurrences of >3 major hurricanes and hyperactive years [NTC = 150%; *(35)*] resumed.

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For almost every measure of tropical cyclone activity, the differences between the warm and cold phases of the mode are statistically significant *(34, 44).* The single exception is the number of U.S. Gulf Coast landfalling major hurricanes. This is because the Gulf of Mexico activity does not have a significant relationship with vertical wind shear fluctuations in the MDR *(11, 12, 15)* or to the multidecadal North Atlantic SST fluctuations (Fig. 2A). The greatest differences (ratios) are for major hurricanes, hurricane days, U.S. East Coast major hurricane landfalls, and especially Caribbean hurricanes and U.S. damage. The Caribbean Sea has shown dramatic changes in hurricane activity—averaging 1.5 occurrences per year during the warm periods compared to only 0.5 per year during the cold period *(34)*. The current warm period has produced an average of 2.5 occurrences per year with an unprecedented (since 1944) six hurricanes in the region during 1996. These multidecadal changes are illustrated in Fig. 4, which clearly shows the enhancement of overall Caribbean hurricane activity during warmer periods. Not only is the entire Caribbean region much less active during the colder period (Fig. 4A), but the only hurricanes that developed during that period in the Caribbean Sea east of 73W formed during the two intermittent short warming periods (1979–81 and 1987–90) discussed earlier. Large multidecadal fluctuations of major hurricane landfalls are especially evident for the U.S. East Coast from the Florida peninsula to New England and are illustrated in Fig. 5. No major hurricanes made landfall from 1966–83. This relatively quiet period was similar to, but more extreme than, the low activity period during the first two decades of the 20th Century. In contrast, during 1947–65, 14 major hurricanes struck the East Coast *(13)*. Overall, the United States has experienced about five times as much in median damages from tropical storms and hurricanes during the warm (high activity) than during the cold (low activity) phases of the Atlantic multidecadal mode *(44)*.

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The Atlantic tropical cyclone record, which (except for U.S. landfall data) is not considered reliable before 1944 *(33)*, shows less than one complete cycle of the multidecadal signal. The record for the SST signal represented by the Atlantic multidecadal mode (Fig. 2B), however, which has demonstrated a robust relationship with the observed activity, shows about two complete cycles—with some proxy records extending back several additional cycles *(42)*. In addition, U.S. landfall data are able to show almost two periods of the signal *(13, 44)*. Because of the multidecadal scale of the Atlantic SST variability portrayed here, the shift since 1995 to an environment generally conducive to hurricane formation—warmer North Atlantic SSTs and reduced vertical wind shear—is not likely to change back soon (45). This means that during the next 10–40 years or so, most of the Atlantic hurricane seasons are likely to have above average activity, with many hyperactive, some around average, and only a few below average. Furthermore, consistent with experience since the active phase began in 1995, there would be a continuation of significantly increased numbers of hurricanes (and major hurricanes) affecting the Caribbean Sea, and basin-wide numbers of major hurricanes. The Gulf of Mexico, however, is expected to see only minor differences. Tragic impacts of the heightened activity have already been felt, especially in the Caribbean [e.g., Hurricanes Georges and Mitch *(46)*]. In addition, an increase in major hurricane landfalls affecting the U.S. East Coast is anticipated, but has not yet materialized *(47)*.

Some have asked whether the increase in activity since 1995 is due to anthropogenic global warming. The historical multidecadal-scale variability in Atlantic hurricane activity is much greater than what would be "expected" currently from a gradual global temperature increase attributed to global warming *(5)*. There have been various studies investigating the potential effect of long-term global warming on the number and strength of Atlantic-basin hurricanes. The results are inconclusive *(48)*. Some studies document an increase in activity while others suggest a decrease *(49)*. Tropical North Atlantic SST has exhibited a warming trend of 0.3C over the last 100 years *(38);* whereas Atlantic hurricane activity has not exhibited trend-like variability, but rather distinct multidecadal cycles as documented here and elsewhere *(12, 13, 17)*. The extreme activity in 1995 has been attributed in part to the record-warm temperatures in the North Atlantic *(25)*. The possibility exists that the unprecedented activity since 1995 is the result of a combination of the multidecadal-scale changes in Atlantic SSTs (and vertical shear) along with the additional increase in SSTs resulting from the long-term warming trend. It is, however, equally possible that the current active period

(1995–2000) only appears more active than the previous active period (1926–70) due to the better observational network now in place. During the previous active period, only 1966–70 had continual satellite coverage *(33, 50)*. Further study is essential to separate any actual increase from an apparent one due to more complete observations.

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Although increased activity during a particular year does not automatically mean increased storm-related damages *(51)*, years with high activity have a greater overall potential for disaster than years with low activity. Increased occurrence combined with dramatic coastal population increases during the recent lull, add up to a potential for massive economic loss *(13)*. In addition, there remains a potential for catastrophic loss of life in an incomplete evacuation ahead of a rapidly intensifying system. Government officials, emergency managers, and residents of the Atlantic hurricane basin should be aware of the apparent shift in climate and evaluate preparedness and mitigation efforts in order to respond appropriately in a regime where the hurricane threat is much greater than it was in the 1970s through early 1990s.

References and Notes

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33. Although these data are available since 1851, only the data for the years since 1944, when routine aircraft reconnaissance of Atlantic tropical cyclones began, are considered very reliable. The greatest reliability starts around the mid-1960s when operationally satellite detection of Atlantic tropical cyclones began *(50).* Before satellite coverage, a portion of the lifetimes of many systems had probably been missed.

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56. We thank H. Willoughby, F. Marks, J. Gamache, A. Barnston, L. Shapiro, P. Reasor, R. Rogers, R. Burpee and M. Finke for comments on the manuscript and helpful discussions, S. Feuer and J. Harris for assistance in processing the wind data, D. Enfield for assistance with SST data and helpful suggestions, N. Dorst and S. Murillo for other technical support, S. Taylor, R. Simon, and B. Goldenberg for editing assistance, and D. Lewis for additional helpful support. In addition, we wish to thank M. DeMaria and an anonymous reviewer for their insightful comments and N. Ward for suggestions that helped initiate this study. Partial funding for this research comes from the NOAA Office of Global Programs (Pan-American Climate Studies).

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Chairman **EHLERS.** Thank you. And next, Dr. Pietrafesa. Turn your microphone on, please.

STATEMENT OF DR. LEONARD J. PIETRAFESA, DIRECTOR OF EXTERNAL AFFAIRS, COLLEGE OF MATHEMATICAL SCIENCES, NORTH CAROLINA STATE UNIVERSITY

Dr. **PIETRAFESA.** Thank you, Chairman Ehlers, for inviting me and, Congressman Etheridge, for introducing me. I very much appreciate the opportunity to appear before you to address the question, are we ready for severe storms, particularly tropical cyclones and hurricanes? The short answer is, no. However, I have more to say.

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What we need is an interdisciplinary approach through research and management, coupling the physical sciences and engineering technology to the social and behavioral sciences to economic principles and then to policy makers, planners, and managers to get the information out. This is really at the heart of the proposed legislation of Congressman Etheridge.

The roots of the problem lie in interactions between the environmental physical system in which we live, which are not well understood and changing, and those interactions with the human system, with its social and demographic characteristics, where demographic differences play a large role in determining the risks and damage potential to the people who encounter these events. This is especially true in the loss of life and destruction of property due to floods, the Nation's most injurious and frequent natural hazard.

Severe storms cover the full range of phenomenon which have enormous wind and flood damage potential. And I did a master's degree at the University of Chicago in the Department of Atmospheric and Ocean Sciences, Geophysical Sciences, actually, so I understand mid-western weather events as well.

This is where the Federal Government can play a very important role in providing the enabling capital to fund the observations in fundamental science issues related to establishing a more complete understanding and predictive capability for severe storms of different types.

As you heard just now from Dr. Landsea, our capability and capacity to predict how many tropical cyclones will occur, as well as assessing the damage of those tropical cyclones, has been improving. However, we have found that in North Carolina, we have some variations to the theme that Dr. Landsea has put forth.

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For example, we find that for land-falling tropical cyclones in North Carolina, there are actually four periods that are important. We have a 2 to 5-year period, a 10-year period, a 30-year period, and the 50-year period that Dr. Landsea just alluded to. So depending on the phases of those various periods, if they are in phase, then you have very robust years. If they are out of phase, then you have decreased numbers. So North Carolina has had the potential for zero to five tropical cyclones in any given year. Again, Dr. Landsea has pointed out that 83 percent of the effects or damage that has been caused by tropical cyclones has been in major categories of three, four, and five. In North Carolina, those categories have been responsible for 54 percent of the damage over the history—recorded history.

However, one category alone is responsible for 42 percent. And that is tropical cyclone Category 2—hurricane Category 2. Why? We have had more of them and because they are wetter and more moist. So wetness becomes an important factor here. And wind has been very damaging, but water has been at least, if not more, damaging in North Carolina.

What this suggests is that because of the hidden nature of estuarian, coastal, and inland flooding, a new risk scale is needed to parallel the Saffir-Simpson Scale, which focuses on wind speed. And this, again, is at the heart of the legislation proposed by Congressman Etheridge.

The bottom line here is that there is an enormous amount of research that must be conducted in these areas and the United States would be well served to invest in the undertaking. The U.S. Weather Research Program is a program that has gained added support in the recent past. It has 3.7 million, I have noticed, in the Senate side, and 3 million on the House side. My opinion, as a university scientist is that an order of magnitude additional funding is required to undergird the U.S. Weather Research Program, and that would ensure that the United States would become weatherproofed.

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So where are we presently in our ability to predict coastal, estuary, and inland flooding? North Carolina State University has developed a state-of-the-art, or a state-of-the-science, coastal storm surge and estuary flooding predictive tool. The model can be ported and implemented along any part of the U.S. coastline, including the Great Lakes.

Further, the model, as I said, is coastal and estuarine in nature and it must be, or should be, coupled to an inland flooding capability. And that capability is being advanced by the National Weather Service through its Advanced Hydrologic Prediction and Forecasting System, the AHPS, effort.

AHPS, as well as the NC State modeling efforts, both rely on NOAA's Doppler weather radar and the National Weather Service rain gauge network to input precipitation data, and the NOAA satellite information, as well. So coupling the inland and the estuary and coastal flooding modeling, as could be accomplished by coupling the NC State activity to the AHPS activity, would create the end-to-end physical system. But we also need the social and economic aspects involved, as well. And this would—this is, once again, at the heart of the Etheridge initiative.

For example, Hurricane Floyd, a weakening Category 2 at landfall, would have been a Category 5 risk hurricane, given the potential for record rainfall and record flooding, an enormous impact to lives and properties. And that is where the demographic aspects have to be included as well.

So I thank you for the opportunity to appear before you and I thank Congressman Etheridge for introducing this visionary bill.

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[The prepared statement of Dr. Pietrafesa follows:]

PREPARED STATEMENT OF DR. LEONARD J. PIETRAFESA

Introduction

My name is Dr. Leonard J. Pietrafesa, Director of the Office of External Affairs in the College of Physical and Mathematical Sciences at North Carolina State University in Raleigh, NC. and Professor in the

Department of Marine, Earth and Atmospheric Sciences at North Carolina State University. I was Head of that department for 11 years. I hold a Ph.D. from the University of Washington in Geophysical Fluid Dynamics, actually the fluid physics of oceanic, atmospheric and hydrologic physical processes. I have been author or co-author of 151 peer reviewed publications in the areas of estuarine and coastal ocean and atmospheric weather and climate fluid physics dynamics. I have served as national Chair of the Board on Oceans and Atmosphere of the National Association of State Universities and Land Grant Colleges (NASULGC) and as national Chair of the Council on Ocean Affairs, the precursor to the Consortium for Oceanographic Research and Education (CORE), was Chair of the Board on Education of CORE, of which I am a "Fellow", am on the Board on Higher Education of the University Corporation for Atmospheric Research (UCAR) and the American Meteorological Society (AMS) and I also served on the Natural Hazards Mitigation Committee of the American Geophysical Union (AGU) and on the Science Advisory Committee of the US Weather Research Program (USWRP) and co-chaired the USWRP 3rd Prospectus Development Team Workshop on Coastal Atmospheric and Oceanic Processes. I am also a member of the NOAA Science Advisory Board and am on the US Geological Survey/NASULGC Partnership Committee.

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I very much appreciate the opportunity to appear before you and am here to testify in the hearing entitled "Weatherproofing the U.S.: Are we ready for Severe Storms?", being held by the Environment, Technology and Standards Subcommittee of the U.S. House of Representatives Committee on Science. In short, the answer to the question is "No". Albeit, my comments will address the question, per se, and also focus specifically on the ability of the United States to mitigate against and deal with coastal, estuary and inland flooding both nationally as well as locally and on how to create and provide a scientifically based physical-social-economic risk analysis or potential for damage as they relate to the passage of tropical cyclones. While my comments are directed towards tropical cyclone impacts, many conclusions and suggestions are generic in nature and apply to strategies for dealing and coping with and mitigating against other severe storms.

Background

Environmentally speaking, we live on a planet under pressure in a nation at risk. In 1975, geographer Gilbert F. White and sociologist J. Eugene Haas published a report (*Assessment of Research on Natural Hazards*, MIT Press, Cambridge, MA), documenting the Nation's ability to cope with and respond to natural hazards/disasters. Their findings were basically that the ability was in dire straits. They recommended an interdisciplinary approach to research and management, coupling the physical sciences and engineering technology to the social and behavioral sciences to economic principles and then to policy makers, planners and managers. Rather than dealing with natural hazards in general and severe storms in particular, by reacting to the emergency after the fact and then rebuilding in place, as was the practice of the time, they proposed that the Nation support and employ preemptive tactics such as better planning, land use controls, and mitigation measures to reduce the impacts. As Dennis Mileti points out in his 1999 book *Disasters by Design* (John Henry Press, Washington, DC) "unfortunately the Nation then and now believed that coping with hazards means that we can employ technology alone to make us safe". But as they say in Gerschwin's *Porgy and Bess*, "It ain't necessarily so". Excessive losses from natural hazards resulted then and still result today from our shortsighted and narrow conceptions of the human relationship to the natural environment.

Rather, what is needed is the declaration of a firm national policy of "sustainable hazard mitigation". Twenty five years after the pioneering work of White and Haas, the pieces have not yet been fitted together, but this hearing is a clear sign that Congress is considering doing so. I applaud this Subcommittee for its proactive stance.

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The sources of the problems in achieving sustainable hazard mitigation are several-fold. We as a society have not yet melded our knowledge base of the physical systems to wise management of natural resources to local economic and social resiliency, thereby viewing hazard mitigation as an integral part of the much larger context of a community's ability to function. Accepting the fact that hazards will occur and are a part of the many issues that a community must deal with and then adopting sustainable hazards mitigation policies and procedures will ensure that the community's fabric will endure. The roots of the problem lie in the interactions between the environmental physical system in which we live, but which is not yet well understood and changing climatically, with the human system, with its social and demographic characteristics and demands, also ever changing, and components of the constructed environment. Sociologists claim that most people are unaware of the risk choices that they will face, plan only for the immediate future and overestimate their ability to cope with disasters. Moreover, demographic differences play a large role in determining the risks and damage potential that people encounter as well as in their ability to cope.

The country must foster local sustainability to natural hazards. For some natural hazard phenomena, the U. S. has succeeded in reducing the loss of life and property but one area where this has not occurred is in the loss of life and destruction of property due to floods, the nation's most injurious and frequent natural hazard. For example, allowing building at the base of flood plains puts people and property directly in harms way and the realities and consequences of doing so must be fully understood by all. The removing of maritime forests and or bulldozing of sand dunes on beaches are examples of the destruction of ecosystems that have provided protection from high energy wind and storm surge events and are thus unwise management of natural resources. Further examples of poor management are the drainage of swamplands in Florida for development and the bulldozing of hillsides for home construction in California. All of these activities have disrupted natural drainage patterns and magnified flood hazards. Albeit, the principles that White and Haas defined over a quarter century ago apply today and must be put in place with an explicitly defined end to end process, with protocols.

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The Issues

The fundamental issues in planning for, dealing and coping with and mitigating against severe storms require an end to end process. This process connects routine but necessary observations to modeling and model development for predictions and forecasts to development of information and technological tools that managers, planners and decision makers need. We do not yet have that end to end process in place. And, unfortunately, we who appear before you, including the University community and the government and state agencies are the impediments to the creation of the simple wiring diagram. An electrical engineer might say that our present system is contaminated with impedance mismatches. But the system can be fixed. I will make some recommendations therein.

Several specific issues that I will address relate to inland, estuary and coastal flooding related to the occurrence of severe storms. Not surprisingly, these issues are also both physical-environmental and social-economic in nature. Additionally, I was asked to evaluate the present architecture and infrastructure that presently exists within and between government federal and state, agencies and academia, and asked to address its adequacy and comprehensiveness. The goal is a robust program that is necessary, sufficient and comprehensive without duplication of effort, which is inefficient and wasteful of valuable resources, both material and intellectual. The science involved must be of the highest quality and it should create results that can be packaged for seamless and transparent transitioning into tools that can be easily used by managers, planners, private industry and the public.

I should state up front that the University community understands that it has a responsibility to serve the citizenry of the Nation, and believe that we must play an integral role in building a resistance to the effects of natural hazards, particularly weather related. Simply stated, we must work to equip our residents and public policy officials with the best information and tools which can be developed to mitigate against natural hazards I offer one example of such an effort.

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With present funding from the National Oceanic and Atmospheric Administration (NOAA), Dr. Lian Xie (a colleague at NCSU) and myself have teamed to develop a state of the science coastal storm surge and estuary flooding predictive tool. Essentially, we are implementing a hydrodynamic model of the coupled coastal ocean and the entire Albemarle-Pamlico Sound (all in North Carolina) estuary complex. The model includes all of the physics, i.e., the phenomena that contribute to flooding. The model presently has a spatial resolution of 300 meters (3 football fields) in the horizontal. We have developed a wetting and drying scheme, i.e., an inundation algorithm that allows water to run up the topography and across highways, and so on. This capability will be fully implemented when the Digital Elevation Data which the State and FEMA have funded, become available to us. The model can be ported and implemented along any part of the U.S. coastlines including the Great Lakes.

However this is only one component of the complete end to end process needed which would lead to the development of a Risk or Potential Damage Index that will allow communities to better plan for future atmospheric, oceanic and hydrologic coastal and estuary events. Such an index should include an assessment of vulnerability and the capacity of the communities to implement measures to protect property and lives and must thus engage physical and mathematical and social scientists with economists, and thus bring together natural and human processes. We are at the beginning of the process. It is of note that there is research in kind ongoing around the Nation but it is fragmented and unconnected presently. Moreover observations and data are lacking or are unavailable in real or near-real time.

There is a serious lack of observations over, in and along our coastal oceans of the east and west coasts, the Atlantic and the Pacific, the Gulf of Mexico and in the Great Lakes. Both atmospheric and water direct observations are needed to build the Nation's enabling capacity to predict and understand severe storms. Fundamental observations such as can be provided by Meteorological Buoys, CMAN, and coastal and estuary waters level stations are simply not available to the degree needed. Likewise, good topographic data at the vertical resolution of a foot or better and more hydrologic data either do not exist or are not available or are not available in real time. Models developed and used by both NOAA and the University community are all seriously compromised by a lack of real time or near real time atmospheric, ocean and hydrologic data as well as by topographic data. Unless this situation is fixed, the Nation will never be "ready for severe storms".

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Scientific and Technological Advancement

Severe storms cover the full range of phenomena that can have their origins on land, over the ocean or in the atmosphere of itself. However, I will limit my comments to Tropical Cyclones (TCs), phenomena derived from ocean/atmospheric interactions but which use the atmosphere as both the causal function and partially as the delivery system. Wind, atmospheric pressure differential and precipitation are atmospheric components of the delivery system. Other components of the complete delivery system are tides and mechanically driven waves, currents and water levels on both the coastal ocean and estuary sides of the coastal zone. It should be noted that in addition to TCs, there are many other types of severe storms prevalent on U.S. coastlines, including the Great Lakes, as well as in the interior of the country which have enormous wind and flood damage potential. For example, during fall, winter and spring, mid-latitude or extra-tropical cyclones (ETCs) frequently occur across the Nation. Alike TCs, ETCs are characterized by strong winds, heavy precipitation and associated flooding. While this hearing is focused on TCs, ETCs as well as other storms should not be overlooked because they also wreak havoc and destruction via strong winds, heavy precipitation and floods.

Recent examples of high energy, even catastrophic events related to busted forecasts include but are certainly not limited to the following experiences. The first example is Hurricane Mitch (1999) which turned south against all model predictions, struck Central America and killed 10,000 people. Why were the models wrong? A lack of observations both on land in Central America and in the Gulf of Mexico. Models need data for boundary conditions and for re-initialization and for assimilation into the model. Then there was the NC experience with Hurricane Floyd in September, 1999. The flooding which ensued was not anticipated. Again a lack of observations, a lack of data availability, incomplete model architecture and a lack of appreciation for what the environmental conditions which remained in the wake of TC Dennis only a week and a half earlier all contributed to the bust. There was also the Great Raleigh Snowstorm of January 2000, when 20–24 inches of unpredicted snow fell. This was an atmospheric "bomb", an ETC. Then there is the counter example of the Greatest Potential Blizzard of the first weekend of March, 2001 in Washington, DC. It didn't happen. The "bomb" failed. Again, the latter two forecasts lacked observations and data over the coastal oceans of the eastern U.S. seaboard. Moreover a more complete and comprehensive understanding of the science of these types of events must be established.

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This is where the federal government can play a very important role in providing the enabling capital which will fund the observational networks and modeling facilities and the Nation's scientific engine needed by federal agencies and the university community to address these issues. For example, support for the USWRP would help facilitate and broker the sciences of quantitative precipitation forecasting, the influence of topography, vegetation and ground cover and soil moisture on storms, the optimal mix of observations and other fundamental science issues related to establishing a better observational network. All of these issues will lead to a more complete understanding and predictive capability for severe storms of different types. Moreover the social and economic factors related to these storms and their impacts must be researched contemporaneously with the physical and mathematical studies if a sustainable hazard mitigation capability is to be created for the Nation. Here the USWRP can play an integrative role.

From the environmental perspective, concerns related to our present capacity and capability to predict how many, how large, when and where atmospheric tropical cyclone storms will occur are of great interest and importance. Moreover the science of assessing the damage due to tropical cyclones has also advance significantly. Significant progress has been made over the past decade in both areas. For example, you will hear today that University and government agency scientists have improved and are improving the state of the physical and mathematical science of predicting the number of TCs likely to occur in the North Atlantic, well in advance of hurricane season (June-November). Recently, Dr. Christopher Landsea (of the NOAA National Hurricane Center), and his colleagues there as well as from Colorado State University (Dr. William Gray) have revealed that we have entered a 50 year period of increased major hurricane activity in the North Atlantic Ocean. Likewise Dr. Landsea and Dr. Roger Pielke Jr. (of the University of Colorado) have found that 83% of all damage due to land-falling tropical cyclones on a national basis are due to "major" or Categories 3, 4 and 5 hurricanes. While these findings provide very important, the numbers may vary at the state to regional levels and planners and managers must know and understand those differences if they are to plan properly. For example, North Carolina (NC) is a state which does not follow these national patterns.

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In recent studies conducted a North Carolina State University and funded by NOAA via its Line Office, the National Ocean Service, Dr. Lian Xie and myself have made three recent findings. One, for the State of North Carolina (NC) there are significant differences in the variability of the frequency of occurrence of tropical cyclones that make landfall as well as in the category of tropical cyclones that have historically caused most of the damage. For NC, above an annual trend of about 0.8 TC/year (just under 1), there are four periods of variability involved in the frequency of occurrence of TCs which strike the state. The 1st period occurs over a 2 to 5 year window and is coupled to the phase of the El Niño Southern Oscillation, with the warm phase unfavorable and cold and neutral phases favorable for TCs making landfall in NC and contributing up to 2 TCs/year as well as the Biennial atmospheric Oscillation. The 2nd period occurs over 10 year cycles and is tied to the Atlantic Ocean sea surface temperature dipole pattern. If the surface waters on the north side of the equator are warmer than they are on the south side of the equator, then more tropical cyclones will strike NC, and vice versa contributing up to about 1 TC/year. A 3rd period of oscillation is about 30 years and is correlated with the North Atlantic (Atmospheric Pressure) Oscillation (the NAO). If the NAO is large then more TCs strike NC and vice versa contributing up to about j's of a TC/year. Finally, there is the 50 year period which for NC, is tied to both the tropical Pacific Ocean SST and Western Sahel of

Africa. Warm and wet, respectively mean more TCs which strike NC and vice versa contributing up to b TC/year. So NC has the potential for zero TCs up to 5 TCs per year. Has this ever occurred? Yes, 5 TCs struck the State in 1893 with 1996 a close 2nd with 4 events.

In our studies Dr. Xie and I have also found that the major hurricanes (Categories 3, 4, 5) have accounted for 54% of the damage in NC unlike the 83% national figure that Drs. Pielke and Landsea found. For NC, we find that the category TC that has been responsible for most of the damage (42% of the total) in NC has been Category 2. Why is this so? Because there have been more Cat 2s striking NC and because the Cat 2s have been wetter than the higher category events. In fact, a poor correlation exists between TC intensity and maximum rainfall for TCs that strike NC. Additionally, TCs that strike NC also tend to cross the Gulf Stream which can act as a source of heat and moisture for TCs. Dr. Xie and I have found that 82% of the TCs that have struck NC have been affected during their encounters with the Gulf Stream. Wind has been very damaging but water has been much more damaging. Do these findings for NC hold elsewhere? Perhaps and perhaps not. What this suggests is that because of the hidden nature of estuary and inland flooding, a "new" risk scale is needed to parallel the Saffir-Simpson scale which itself focuses on sustained wind speed. Here, any new methodologies developed must conform to an end to end sustainable hazard mitigation strategy should be generic and portable with regional to state shifts in emphasis. Some of the legislation I have heard being discussed by this Subcommittee has exactly that flavor.

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What are the scientific reasons for the above findings? Those are research questions that are still being be addressed by ourselves, but more broadly by national University community and with NOAA scientific staff working in collaboration. So, are there sufficient research dollars to find answers to the above and other questions dealing with TCs, such as what track and intensity will a specific event take and how wet will it be? The short answer is "not presently". There is a need to fund research for the generic scientific issues and there is need to fund local to state to regional scale studies of storm events, if a truly predictive capability is to be achieved. The scientific community has recognizes the need for research funding in these areas. They have predicated this need, not only on the basis of scientific challenge, but also on the basis that the Nation needs this information to better anticipate, plan for, cope with and recover from severe storms in a way that creates "sustainable hazard mitigation".

While skill at predicting the number of TCs likely to form, probable tracks and even intensity is improving, the advances have been slow in coming. This can be attributed to a lack of necessary and sufficient federal support for scientific research to address these and associated issues. Moreover, the risks or damage potential associated with these storms has only been addressed marginally. The bottom line here is that there is yet an enormous amount of research that must be conducted in these areas and the U.S. would be well served to invest in this undertaking within the University community in partnership with the National Atmospheric and Oceanic Administration and the Federal Emergency Management Agency. Scientific challenges related to the track and intensity of tropical cyclones, (TCs) particularly those which eventually make landfall or have close encounters with land, are amongst the original three of the major foci of the US Weather Research Program. The USWRP identified Hurricanes at Landfall along with the Quantification of Precipitation and the Optimal Mix of Observations as its top three foci during a brilliantly conceived and organized series of Prospectus Development Team Workshops which involved the best and brightest across the U.S. These three research challenges are what we are here to talk about today. I do note that the USWRP account had $1.5M in base funding last year and the Senate/House marks for this year are $3.7/3.0M as of last week, so there is a glimmer of hope in this signal of growing support. Even the social-economic dimensions of storm impacts are now included in the USWRP portfolio. However, the resources required to properly mount a monitoring, modeling, and end to end strategy are not there and significant cross-cutting research activities are seriously lacking. Hopefully, this hearing will be the onset of significant support for the undertaking needed.

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The New Paradigm

Over the spatial scales of event impacts, challenges related to wind and precipitation induced inland, coastal and estuary flooding are several. They relate to having: better local topography data; an improved end to end modeling forecast capability for coastal and estuary and inland flooding areas; a better capability in probabilistic flood maps; and a more inclusive and easily communicated flood warning impacts index which defines risk and damage potential. This is a job for the optimal mix of University experts in the physical and mathematical scientists working together with their counterparts in the social sciences and economics, coupled to federal agency scientists and staff, all working to create the technology needed by the same and other federal as well as state agencies. No federal agency nor grouping thereof can accomplish what needs to be accomplished and the University community cannot accomplish this either. There must be a partnership. Moreover, state agencies have a very important role to play as well on the delivery and distribution end of the process. Consider an example of the potential that presently exists for the new paradigm described above.

The experience that N.C. had with Hurricane Floyd introduced a new level of understanding of how a system can be coupled via the atmosphere, the coastal ocean and the land via its hydrologic systems to produce what could be called "the perfect (coastal, estuary and inland) flood". For six prior years, NC State University scientists and NWS staff routinely predicted the time and height of coastal and sound-side flooding in and around the Pamlico- Albemarle Estuary on the N.C. coast. A state of the art NCSU model called Coastal and Estuary Modeling and Environmental Prediction (CEMEP) which couples the coastal ocean to the estuary system had been used very successfully from August, 1993 when Hurricane Emily caused 11 feet of flooding in the estuary until September, 1999. The model used monthly mean river discharge as a lateral model input. However, the inadequate performance of the model to properly predict levels of flooding following the passage of Hurricane Floyd have been resulted in an assessment of the model architecture. A more advanced approach has been developed. The approach includes the requirement that better topography be provided for the model It also requires that more reliable river discharge into the heads of the estuaries be provided, that lateral water inundation and retreat be calculated directly in the model and that precipitation estimates be accurate and be provided in real time. Here again, data and observations are needed and they are needed in real time. Further, this modeling activity is coastal and estuary based and must be coupled to inland flood modeling that the NWS is conducting in its Advanced Hydrologic Prediction (and forecasting) Service (AHPS) effort.

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AHPS is a program of the NWS which builds upon NOAA's Doppler weather radar data, NOAA's satellite information and automated weather data network to feed into hydrologic models. The activity is ongoing and the goal is to produce a suite of hydrologic forecasts from hours to days to months into the future; particularly as related to inland flooding events and drought conditions. This will have tremendous payoff to the Nation in better advanced hydrologic information. As the program is implemented nationally. It should also be noted here that Dr. B Vieux of the University of Oklahoma also has established an active inland hydrologic flow capability which could be compared to the AHPS model. Coupling the inland to the estuary and coastal flooding modeling such as could be accomplished via coupling the NWS AHPS model to the NCSU CEMEPS model would create the end to end physical system. But this is not the complete end to end coupling needed to cover the anatomy of a flood warning system.

What has been missing from the above is a social-economic framework that is capable of measuring the social and economic importance of this kind of information. What is required is University based research that will develop and demonstrate a social-economic model that will provide such measures. It relies on the fact that land and property markets are capable of signaling the economic significance of location specific factors that influence the values that people derive from living in coastal and estuary areas. These factors can be either or both positive and negative. They can be expected to include loss of life and or risk of damage to properties from coastal and estuary hazards as well as the costs of any anticipated mitigation activities to reduce personal risks. But here, even the existing measures of "risk" from the physical sciences perspective need revisiting.

Recent experience with large amounts of rainfall accompanying Hurricanes Mitch in Central America (1998), Floyd in North Carolina (1999) and Irene in Florida (1999) and Tropical Storm Allison in Texas (2001) have all highlighted the dangers of coastal, estuary and inland flooding to life and property. As mentioned previously, what is suggested is that there is a need for a new "risk" hurricane scale which parallels the brilliantly conceived and simple to understand Saffir-Simpson wind intensity scale. This new risk scale must be temporally and spatially dependent and useful to emergency management officials, the public and the media. Coupling this new scale with the existing Saffir-Simpson scale and a social/economic based damage potential scale would portray all the inherent risks of a particular TC making landfall at a particular location. For example, given the conditions which remained in the wake of Hurricane Dennis, Hurricane Floyd a weakening Category 2 at landfall would have been at least a Category 4 or more likely a Cat 5 risk hurricane given the potential for record rainfall and record flooding and enormous impact to lives and property. A more complete and detailed index would be of great value in informing the public of the complete suite of dangers associated with a particular storm would help save lives and property and also allow for a better planning and mitigation to be established within local communities.

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This entire effort is cross cutting, whether nationally, regionally or locally, and includes the National Weather Service of NOAA, the US Geological Survey (USGS), the University community, the Federal Emergency Management Agency (FEMA) and then state and other agencies.

The U.S. Agencies Principally Involved in Predicting Coastal and Inland Flooding and Associated Risks/

Damages

The National Oceanic and Atmospheric Administration (NOAA), the US Geological Survey (USGS) and the Federal Emergency Management Agency (FEMA) are the three lead federal government organizations charged with providing the appropriate and necessary data and information needed to mitigate against, plan for, cope with and recover from coastal, estuary and inland flooding events.

NOAA and USGS are environmental mission agencies founded on the generation and applications of scientific and technological environmental data and information and knowledge to provide information and services used to support the process of environmental decision-making in service to the citizenry of the United States. Both organizations claim this responsible to be central to their respective missions and charges. FEMA is responsible for mitigation planning and recovery strategies. So the interactions between and collaborations across these three federal agencies is essential for sound environmental decision-making which is dependent on the collection, integration, synthesis and timely dissemination of these data and this information and knowledge from scientists to policymakers, managers, the public and private industry. The role of the University/Academic community is also an integral part of this end to end process; weighted especially in the middle of the process where knowledge is created.

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NOAA is the lead environmental agency responsible for providing the public and policy makers the best data, information and advice on oceanic, atmospheric and hydrologic processes and impacts. The collection of atmospheric and oceanic data including both remote and in-situ, and the facilitation and transfer of scientific knowledge and technological tools underlie NOAA's mission to monitor and forecast atmospheric, oceanic, hydrologic and climatic events.

The mission of the USGS is that it is the agency that serves the Nation by providing scientific information to: describe and understand the Earth; to minimize loss of life and property form natural disasters; to manage water, biological, energy and mineral resources; and to enhance and protect our quality of life. In the context of inland, coastal and estuary flooding, the USGS is responsible for providing data, information and knowledge about the geologic structure including information on soils, and processes which impact these regions. Within this mission lies the responsibility to oversee and maintain the nation's hydrologic stream-gage network, to collect and archive the data and to disseminate the data in real time. Progress is being made in the latter arena.

In the overall scheme of providing data and information about the hazards associated with coastal and estuary flooding to the public, decision and policy makers and private industry, FEMA is the federal agency designated to be the principal delivery system. Through the agency's traditional role as the mitigation planning and after-the-event recovery organization, FEMA has developed a natural hazard impacts and loss portfolio that is quite extensive. Its natural hazards loss estimation methodology is extensive and has great utility.

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These multiple agency responsibilities and challenges illustrate the importance of their role in collecting and providing the complete suite of data and observations necessary to conduct the science and research necessary for technology development and transfer in issues related to severe storms. NOAA's and the University community's needs for hydrologic data and geologic information must be provided by the USGS. Thus NOAA and the University community must form a partnership with USGS in this endeavor. Such a partnership will help facilitate the best research by providing access to the best data and information from the federal agencies charges to collect the data and the best science via leveraging the University community's considerable intellectual and physical resources. This strategy will ensure that the Nation will have the best environmental information, reliable environmental assessment and most advanced predictions and forecasts. Further the USGS, an agency with physical science and engineering studies and programs as integral components, occupies a unique niche in the suite of federal agencies that have inland-coastal and estuarine flooding as part of their responsibilities.

FEMA's mission is to provide leadership and support to reduce the loss of life and property and protect our nation's institutions from all types of hazards through a comprehensive, risk-based, all-hazards emergency management program of mitigation, preparedness, response and recovery. Clearly this umbrella mission relies heavily on other agencies, such as NOAA and the USGS, and particularly on the University community, to provide the environmental research and knowledge-base to meet its mission.

The science of understanding, mitigating against and coping with inland, estuary and coastal flooding must be credible, reliable and respected. This means it must be based on science that has of itself, been subjected to the scrutiny of peer review. Further, the science should be conducted and completed in timeframes and operational scales that are useful to managers, decision-makers, and society, and directly linked to policy decision-making. NOAA, the USGS and FEMA should assist its state and local government partners to build capacity to address scientific and technical questions related to coastal, estuary and inland governance. Moreover, understanding complex environmental systems requires the integration of the social and economic sciences within the biological and physical sciences. Successful integration occurs in problem formulation at the beginning rather than at the end of the research to development to technology transfer pipeline. This integration should occur with the clear involvement of the University community where the cross cutting expertise between the physical, life and social sciences and economics exists.

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Steps Which Need to Be Taken to Improve the Nation's Capacity to Deal With Severe Storms

First, there is a need for better monitoring of the oceans, atmosphere and land; where effective monitoring addresses the full continuum from bringing data into laboratories and archives to putting information and knowledge out into the hands of diverse internal and external clients. Recent examples of the outcomes of insufficient in-situ observations, as presented above, suggests that additional data would have allowed for model re-initialization and improved boundary conditions, resulting in more accurate forecasts.

More precise flood modeling capability requires that the USGS have a special focus on producing the best state of the art topographic maps nationally. While the present vertical resolution of 2–3 feet is laudable, a resolution of 1 foot or better is needed to keep apace with existing numerical modeling capabilities.

Numerical modeling wetting or inundation and drying or retreat schemes are now sufficiently advanced that they can be coupled to GIS technology to produce very highly detailed flooding and inundation maps under all possible severe storm scenarios. Also, more stream gage data are necessary and the data must be placed on-line in real time.

Second, there is the creation and dissemination of new knowledge, continually expanding our understanding of how the oceans, estuaries and atmosphere function and interact with land and watersheds, and impact human activities. This new knowledge is best created through a process of teamwork, both internal and external to NOAA, USGS and FEMA. This team effort, best effected through partnerships with the University community, will equip the Nation with the world's best science and technology and maximizes the return on the investment while minimizing transition time and cost. This process ensures that the Nation's weather, water, climate, environmental research and observing and forecasting capabilities are the best that they can be.

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Third, there is the application of scientific data, information, and knowledge to real-world problems, particularly in the context of saving lives, the protection of private and public property, and environmental stewardship. Application of physical science and technology to social-economic factors will make the choices available to decision-makers and policy-setters clear, and describe the consequences and uncertainties of each alternative. Such choices, and their associated questions, must be seen and addressed in advance of crises, rather than in response to them. Herein, Universities have the in house cross-cutting expertise necessary to provide the connectivity between the physical and social sciences and between the scientific knowledge base and the federal agencies charged with providing products and services to the citizenry of the U.S. An end to end wiring diagram detailing the agencies and their respective roles and responsibilities along with their university partners should be constructed. It would document the data flow, institutional responsibilities and make clear how the delivery system of information can best be achieved to provide the necessary services to the Nation. To the degree that the system does not work, the problem nodes will become evident and should be attended to.

In summary, there is need to:

Expand the existing national observational network to create the backbone, capacity building, enabling in-situ observational network which along with satellite data creates the optimal mix of an integrated monitoring network, that is necessary to drive the science and technology needed to meet the Nation's capacity to deal with and mitigate against severe storms

Establish and fund long-term science programs, which include the end to end transfer of new information and technology to decision-makers and managers.

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In summary the specific research areas that require more attention are those processes, events and conditions which pose an immediate or long term risk to the health, safety and welfare of human communities and environmental systems. These include a better understanding of:

Ocean-atmospheric-hydrologic coupling as related to persistent or extreme weather events and climate conditions.

Processes leading to deleterious impacts on ecosystem structure including plants, animals and humans.

Non-linear, non-stationary couplings between physical and biological systems, focussing on the interaction between nature and society.

Finally, because of the hidden nature of estuary and inland flooding, a "new" risk scale is needed to parallel the Saffir-Simpson scale. Here, any new methodologies developed must conform to an end to end sustainable hazard mitigation strategy, should be generic and portable and easily understandable by the public.

I thank you for this opportunity to meet with you and would be happy to provide any additional information and opinions to you and your staff.

Chairman **EHLERS.** Thank you. Dr. McCabe.

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STATEMENT OF DR. STEVEN L. MCCABE, PROFESSOR AND DEPARTMENT CHAIR, DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING, UNIVERSITY OF KANSAS

Dr. **MCCABE.** Good morning, Mr. Chairman, and, members of the Subcommittee. My name is Steven McCabe. I am Professor and Chair of the Department of Civil, Environmental, and Architectural Engineering at the University of Kansas. We recently acquired architectural engineering, so that is why the department name has been mentioned in a couple of different variations.

I am a structural engineer, and my research areas have been response and analysis of structures to lateral loads, including earthquakes, wind, and blast loading. So my remarks will be from an engineering perspective.

I am visiting with you today on behalf of the American Society of Civil Engineers, as well as the West Central Wind Research Consortium, regarding the issue of wind storms and their effects on the citizens and economy of the United States.

Simply stated, property damage, personal injuries, and death from wind storms is a national problem, resulting in an average annual economic loss in the United States on the order of several billion dollars. You have heard a number of statistics. Hurricane Andrew, causing 26 billion in damage and 86 deaths; Floyd, resulting in 7 billion and 56 deaths; the recent tornadoes in the Washington area. From my area of the country in Tornado Alley, on a single day in 1999, more than 70 tornadoes struck from Texas to the northern plains, resulting in 41 deaths and over 2,700 homes being damaged. This is, simply stated, a national problem.

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The Federal Government's response to such events has been to initiate search and rescue operations, help clear the debris, provide financial assistance for rebuilding—essentially a focus on the end of the problem. As far as the front end of the problem, preventing or minimizing the impact of these events, the Federal Government spends between five and ten million dollars annually on wind research.

In light of the injuries, loss of life, and damage that wind storms cause every year, ASCE strongly feels that the Federal Government can and should do more. The ASCE has worked closely with the Congress to help form the Congressional Wind Hazard Reduction Caucus and to assist in writing legislation. The task has been to work toward improving U.S. preparedness and toward mitigating the effects of such major wind events.

We believe the goal is straightforward—to significantly reduce loss of life, injuries, and property damage due to wind storms. The draft legislation represents a community effort. All interested groups have been involved from the beginning. We commend Congressman Moore and his staff, as well as the Science Committee staff, for working with the design, building, materials and research community, to create this consensus, and, more importantly, to write technically sound legislation.

The Tornadoes, Hurricanes, and Related Natural Hazards Act is designed to achieve significant reduction in the loss of life, injuries, and property damage due to major wind events. The legislation will coordinate Federal wind hazard reduction efforts through a multi-agency National Wind Storm Hazard Reduction Program. It will link all aspects of the program to the goal of a major measurable reduction in losses from wind storms within ten years. It will drive wind hazard reduction research and development in 11 specific areas that promise a large performance payoff.

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It will establish a wind hazard technology transfer program. It will establish a National Advisory Committee for Wind Storm Hazard Reduction. Lastly, the legislation will authorize appropriation levels sufficient to bring the wind research program to parity with the federally funded earthquake research program over a 3-year period.

ASCE has identified several areas where additional research could pay important dividends. One example is roof system testing procedures and new devices for wind resistance. No standardized testing procedures or devices exist to test roof-cladding materials for resistance to extreme winds and wind borne debris. Development of these items is a necessary prerequisite for improving roofing performance.

Another area is retrofitting of existing buildings. Although it is much easier to build wind resistance into new construction, the country has an enormous investment in existing buildings. Technologies for cost-effective retrofits to improve wind resistance of these buildings should be an important focus of any new research program.

It is very important to note that research to improve structural performance under wind loading will result in tougher structures, as we engineers would say, that will generally exhibit improved performance under other lateral loads, such as earthquake and blast. Simply put, the improved performance under wind will aid in resisting other, perhaps, unforeseen, lateral loads, as well. The overall goal to lateral load performance is to produce structural elements that work together so that structures can stay together.

The problem is so significant that the University of Kansas recently joined three other universities to form the West Central Wind Research Consortium to pool expertise and resources to attack this problem. We believe that collective efforts, similar to that employed in the various earthquake programs, will lead to significant advances in our understanding of wind and its effects while being a cost-effective investment.

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Currently, there are a number of important independent activities, such as FEMA's Project Impact and HUD's Project Path, that are underway to reduce the disastrous effects of wind storms. These activities will have limited impact on reversing the trend of increasing costs unless action is taken to improve the resistance of the physical infrastructure that is now susceptible to damage by wind.

A unified national plan for wind hazard reduction has a potential of reducing losses significantly in the next decade. I want to thank you for the opportunity to express ASCE's views on behalf of 125,000 civil engineers. We look forward to working with members of the Subcommittee to move this legislation forward. And I will be happy to answer any of your questions. Thank you.

[The prepared statement of Dr. McCabe follows:]

PREPARED STATEMENT OF DR. STEVEN L. MCCABE

The American Society of Civil Engineers (ASCE) has long recognized the need for better research into predicting and mitigating the damage from major wind events. All 50 states are vulnerable to the hazards of windstorms. In 1998, hurricanes, tornadoes and other wind related storms caused at least 186 fatalities and more than $5.5 billion in damages.

On May 3, 1999 more than 70 violent tornadoes struck from north Texas to the Northern Plains. Forty-one people died and more than 2,750 homes were damaged. In 1992, Hurricane Andrew resulted in $26.5 billion in losses and 61 fatalities, in 1989, Hurricane Hugo resulted in $7 billion in losses and 86 fatalities and in 1999, Hurricane Floyd resulted in more than $6 billion in losses and 56 deaths.

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The United States currently sustains several billion dollars per year in property and economic loss due to windstorms. The Federal government's response to such events is to initiate search and rescue operations, help clear the debris and provide financial assistance for rebuilding. I am here today on behalf of the ASCE and the West-Central Wind Research Consortium. We are calling upon the Federal government to provide research funding to help reduce the significant annual toll in casualties and property damage from windstorms.

Founded in 1852, ASCE represents more than 125,000 civil engineers worldwide and is the nation's oldest engineering society. ASCE members represent the profession most responsible for the nation's built environment. Our members work in private-practice, industry, government and academia. ASCE is an American National Standards Institute (ANSI)-approved standards developer and publisher of the Minimum Design Loads for Buildings and other Structures (ASCE–7), which is referenced in the nation's major model building codes. As part of the ASCE–7 document, engineers are provided guidance in estimating the loads resulting from wind effects on structures. Thus, ASCE is at the forefront in the development of new information for engineers regarding wind and is in a unique position to comment on the status quo and our needs for the future.

Near-surface winds are the most variable of all meteorological elements, making the prediction and control of their impacts all the more challenging. In the United States the mean annual wind speed is 8 to 12 mph, but wind speeds of 50 mph occur frequently throughout the country, and nearly every area occasionally experiences winds of 70 mph or greater. In coastal areas of the East and Gulf coasts, tropical storms may bring wind speeds of well over 100 mph.

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With the average annual damage from windstorms at more than $6 billion, the $5–10 million Federal investment in research to mitigate these impacts is woefully inadequate. In contrast, the Federal government invests nearly $100 million per year in reducing earthquake losses through the National Earthquake Hazards Reduction Program, a program which has lead to a significant reduction in the affects of earthquakes. A Federal investment in wind hazard reduction would pay similar or greater dividends in lives saved and decreased property damage.

Unfortunately, reducing vulnerability to wind hazards is not just a question of developing the appropriate technical solution. Wind hazards are created by a variety of random events with large uncertainties in the magnitudes and characteristics of the winds. The relevant government agencies and programs, as well as the construction industry, are fragmented. Finally, implementation requires action by owners and the public, who may not consider hazard reduction a high priority. Solving wind vulnerability problems will require coordinated work in scientific research, technology development, education, technology transfer and public outreach.

In 1993 the National Research Council published a report entitled "Wind and the Built Environment."(see footnote 4) The report included the recommendations of the Panel on the Assessment of Wind Engineering Issues in the United States. The panel recommended the establishment of a national program to reduce wind vulnerability. Such a program would include wind research that draws upon the expertise of both academia and industry and addresses both structural and nonstructural mitigation methods, an outreach program to educate state and local governments on the nature of the wind risks they face, a conscious effort to improve communication with in the wind community and a commitment to international cooperation in wind-engineering.

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A 1999 NRC study concurred in that recommendation and specifically urged Congress to designate "funds for a coordinated national wind-hazard reduction program that encourages partnerships between federal, state and local governments, private industry, the research community, and other interested stakeholders."(see footnote 5)

As far as preventing or minimizing the impact of major wind events, the Federal government has mainly limited itself to improvements in weather prediction and public warnings. In light of the damages and loss of life that windstorms cause every year, ASCE strongly feels that the Federal government can and should do more.

To that end, ASCE has worked with Congressmen Dennis Moore of Kansas, Walter Jones of North Carolina, and others, first to help form the Congressional Wind Hazard Reduction Caucus and then to develop legislation. The Caucus was created in October of 1999 and is chaired by Mr. Moore and Mr. Jones. It has as its goal to increase Congress' awareness of the public safety and economic loss associated with major wind events and to establish and fund programs to mitigate those impacts.

On October 19, 2000, Congressmen Moore and Jones and others introduced H.R. 5499, the Windstorm Hazard Reduction Research and Technology Transfer Act." ASCE supported the development of this legislation by providing technical advice, and by helping to form the Wind Hazard Reduction Coalition. The Coalition includes professional societies, research organizations, industry groups and individual companies with knowledge and experience in dealing with the impact of high winds.

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Beginning this year, the same group that developed H.R. 5499 came together to refine and improve our legislative efforts. The draft legislation being circulated is the result of two years of collaborative effort and is designed to achieve those goals expressed by both the Congressional Wind Hazard Reduction Caucus and the Wind Hazard Reduction Coalition.

Now entitled the "Hurricane, Tornado and Related Natural Hazards Research Act," this legislation is truly a community effort. All interested groups have been involved with this from the beginning. ASCE commends Congressmen Moore, Jones and their staffs, as well as staff from the House Science Committee, for working with the community to create this consensus and, more important, technically and scientifically sound legislation.

Specifically, the legislation creates a coordinated Federal windstorm and related hazards reduction research, development and technology transfer program. The object of the program is to achieve, within 10 years, a measurable reduction in losses that would otherwise occur to life and property from wind and related disasters.

This is accomplished by the following actions:

Coordination of Federal wind hazard reduction efforts through a multi-agency National Windstorm Hazard Reduction Program that is coordinated by the Office of Science and Technology Policy and the Federal Emergency Management Agency.

Linkage of all aspects of the program to the goal of a major, measurable reduction in losses of life and property due to wind storms within 10 years of the date of enactment.

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A list of 11 areas where wind hazard reduction research and development with an emphasis on developing cost-effective and affordable improvements can pay big dividends.

Establishment of a wind hazard reduction technology transfer program.

Establishment of a National Advisory Committee for Windstorm Hazard Reduction.

Authorization of appropriation levels that could bring the program to parity with the Federally funded earthquake research program over a three-year period.

The research program would be overseen by an *Interagency Group* of federal agencies involved in research, weather, natural disaster mitigation, housing and construction, and related standards and would give the group responsibility to develop and implement a coordinated Federal program for wind hazard reduction research, development and technology transfer.

The group is to be co-chaired by the White House Office of Science and Technology Policy and the Federal Emergency Management Agency. The program should, in part, build on current agency and private sector efforts. Major program elements are to include peer-reviewed basic and applied research. Other research will focus on ways to achieve a better understanding of impediments and disincentives to wind hazard reduction. Data collection programs will be established to achieve a better inventory of information on building components and materials and their interactions. Technology transfer components will be implemented to achieve better dissemination of wind hazard reduction technology, techniques and knowledge. The bill supports continuation of current efforts to improve technology for weather prediction and disaster response. The bill also places a priority on research to ensure proper performance of critical structures and lifelines needed during a time of disaster.

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The research and development program may include basic weather research, research on materials and building technologies including retrofits, and mapping techniques. The technology transfer program is to include information collection, classification, presentation and dissemination of research results and other pertinent information to state and local officials, the private sector, and the general public and a delineation of responsibilities among these parties. The Interagency Group is to coordinate with appropriate representatives of state and local governments and the private sector in the development of a 10-year implementation plan. The plan would set out research and implementation priorities and goals, development of improved forecasting techniques, technology transfer plans, and plans for intergovernmental cooperation and coordination.

The bill would also create the National Advisory Committee for Windstorm and Related Natural Hazard

Impact Reduction consisting of 21 members, appointed by the President. The members of the advisory committee will be drawn from state and local governments and the private sector with expertise in areas such as architecture, engineering, construction, finance, insurance, and research. The Committee is to review program progress and to report to the Congress annually on program status and needed improvements.

At a regional level, the West-Central Wind Research Consortium has been formed by researchers from the Colorado State University, South Dakota School of Mines and Technology, the University of Wyoming and the University of Kansas to pool our resources and expertise to address this urgent need. The focus of the Consortium will be to conduct research into wind issues in this part of the country and to help development new knowledge into wind and how it effects structures. The Consortium will work to formulate economically viable strategies to improve the safety and economic health of citizens in the member states. Improving our knowledge of wind not only can reduce damage and injury but also can help development wind as a cost effective renewal energy sources.

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Minimizing the loss of life, property damage and disruption of economic activities from windstorms are primary objectives of wind engineering research. The research, engineering and scientific communities have provided some of the technical underpinnings for reducing the vulnerability of buildings and other structures to wind damage. Significant work remains to be done in this area to ensure that key vulnerabilities are identified and that technically sound, cost-effective and affordable solutions are developed and implemented.

ASCE has identified the following areas where increased research would pay significant dividends in the form of reduced loss of life and property.

Roof System Testing Procedures and Devices for Wind Resistance—No standardized testing procedures and devices exist to test roof-cladding materials for resistance to extreme winds and debris. Development of these items is a necessary prerequisite for improved roofing performance.

New Roofing Systems—Damage to roofing is perhaps the single most common result of high wind. Even small failures can allow wind and rain inside the building leading to significant interior and content damage and possible structural failure. Development of new wind-resistant roofing materials and technologies could significantly reduce wind-induced damage.

In-Residence Shelters for Hurricane Protection—In collaboration with the university research community, FEMA has conducted research and developed plans and guidelines for in-residence shelters for protection from tornadic winds. These designs provide near complete protection for occupants from even large tornadoes, but are too costly and overly conservative for use on hurricane coasts. New research is needed to find more appropriate and cost effective solutions for construction on the hurricane coasts.

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Dual-Use Public Hurricane and Tornado Shelters—Schools are the most commonly used buildings for hurricane evacuation shelters, but they may not be structurally designed to provide a safe haven. Similarly, children shelter in-place while in school during tornado warnings, but these buildings are not designed with adequate protection. Research and development of design guidelines and methodologies on how best to construct schools and other public buildings for dual function as shelters from hurricanes and tornadoes are desperately needed.

Retrofit Technologies for Wind Resistance—Although it is much easier to build wind resistance into new construction, the country has an enormous investment in existing building stock. Technologies for cost-effective retrofits to improve wind resistance of these buildings should be an important focus of any new research program.

Improved Connections and Framing Systems for Light Frame Construction—Much of the structural damage which occurs in severe winds is to light frame one- and two-story construction. There has been relatively little improvement in wood and other light framing technology in the past 20 years. New cost-effective construction techniques could significantly reduce structural damage to low-rise buildings.

Boundary Layer Meteorology for Landfalling Storms—Little is known about the structure of the wind in a hurricane and how it changes as it passes over land. Research is needed to better understand the nature of boundary layer transitions, turbulence, rainfall, and decay rates as storms move inland. The design wind speed and gust factors used in all building codes and standards (including ASCE–7) are based on a set of assumptions that hurricane winds have similar properties to winds from other events, which we know to be untrue. This research can lead to significant improvements in wind-loading related portions of our building codes and standards.

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Rapid Damage Assessment using Remote Sensing for Improved Response and Recovery—The key to optimization of response and recovery operations is timely access to detailed information on the extent and intensity of damage throughout the effected areas. Very high-resolution data can be obtained from commercial satellite-based remote sensing systems, which was previously unavailable except to intelligence and defense communities. Resolutions have improved to the point where data are available on individual buildings and vehicles. Development of computerized analysis tools that automate and map damage assessment estimates will significantly assist response and rescue and recovery operations.

Conclusion

Windstorm-related costs have averaged several billion dollars per year during the last decade with a high in 1992 exceeding $25 billion, primarily as a result of Hurricane Andrew. If a severe hurricane makes landfall in Miami, New Orleans, or New York City, the damage could exceed $50 billion. Hurricanes, tornadoes, and other windstorms cause death and injury, business interruption, and unacceptably high levels of property damage in all 50 States and all U.S. territories. People continue to move to coastal areas adding to the trend toward larger disasters and increasing damage costs will continue unless an effective wind hazard reduction plan is implemented.

Currently, a number of important independent activities (e.g., FEMA's Project Impact and HUD's Project

PATH) are underway to reduce the disastrous effects of windstorms. These activities will have a limited impact on reversing the trend of increasing costs unless action is taken to improve the resistance of the physical infrastructure that is now susceptible to damage by windstorms. A unified national plan of wind hazard reduction has a potential of reducing losses significantly in the next decade.

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An important consideration is that improving structural performance under wind loads will have benefits in resisting other loading regimes as well. While the details of the loading may be different, a structural system that has been toughened to perform better under wind will in general perform better under earthquake or even blast loading. The recent tragic events in New York and Washington have shown the need for structural performance under load—even those that are unforeseen.

As the recent tornadoes in the Washington, DC area demonstrated, windstorms pose a threat in many areas of the country; a threat we should not dismiss with the thought that we can not do anything about the weather. With the proper information gained from research, we still will not be able to change the weather, but we can change the way it affects peoples lives.

Thank you for the opportunity to express ASCE's views. We look forward to working with members of the Subcommittee to move this legislation forward.

Chairman **EHLERS.** Thank you. Dr. Hayes.

STATEMENT OF DR. JOHN L. HAYES, DIRECTOR, OFFICE OF SCIENCE AND TECHNOLOGY, NATIONAL WEATHER SERVICE, CO-CHAIR, U.S. WEATHER RESEARCH PROGRAM

Dr. **HAYES.** Good morning, Mr. Chairman, and, members of the Subcommittee. My name is Jack Hayes and I am the Director of the National Weather Service's Office of Science and Technology within NOAA, the National Oceanic and Atmospheric Administration. I am also the Co-Chair of the Interagency Working Group for the U.S. Weather Research Program.

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I want to thank you for the opportunity to speak with you about the U.S. Weather Research Program. And I would like to begin this morning by outlining for you the research and operational context within which USWRP resides.

Every day weather affects all of us. It influences our daily activities and, unfortunately, can devastate our lives and our livelihoods. Hazardous weather, like tornadoes, hurricanes, and winter storms, each year cause thousands of fatalities, far more injuries, and tens of billions of dollars in damage to property. In fact, between 1965 and 1998, approximately 90 percent of all presidential disaster declarations were weather related.

The implementation of Doppler radar, new satellite, upper air and surface observing, super computers, better weather prediction models, and sophisticated local data processing technologies over the last decade has resulted in significant improvement to operational weather and flood warnings and forecasts. For example, between 1986 and 2000, average warning lead times for tornadoes increased by over 100 percent.

Despite successes such as this one, some recent notable weather events indicate we must do better. For example, in 1999, Hurricane Floyd was close to its predicted track. Forecast uncertainties led to the evacuation of over three million people, including 2.5 million evacuees in Florida alone, one sixth the state's population. The cost associated with over warning amounted to over $100 million. In 2000, the National Weather Service correctly predicted a January snow storm, but with insufficient lead time. The event paralyzed the entire middle Atlantic and New England coasts with far-reaching financial impacts.

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As part of the meteorological science community, USWRP believes we can improve warning and forecast accuracies and lead times by more fully exploiting our advanced technologies and improving the scientific basis for weather prediction.

Mr. Chairman, the stage is set. With the National Weather Service modernization and restructuring complete, other civilian and Department of Defense technologies in place and leveragable, and accelerating capabilities in information technology, the United States is poised to make great advances in weather prediction. The USWRP is a catalyst to make that happen.

The U.S. Weather Research Program is an approximately nine million dollar multi-agency effort to accelerate improvements in forecasting high-impact weather, particularly those associated with hurricanes, floods, and heavy snowfall. It is a collaborative effort of operational and research communities and academia and government. The current participants include NOAA, the National Science Foundation, NASA, and the Department of Defense.

Our overall objectives are to mitigate the impacts of weather-caused disasters, reduce the cost of disruptive weather, increase the economic productivity of the Nation, and serve the needs of national security, all through better weather information.

We have established specific goals to improve hurricane prediction, heavy precipitation and flood forecasts, and two to 10-day weather forecasts. The USWRP can respond promptly to changing federal, societal, and economic priorities by setting research themes, facilitating research gains, and transferring the results of those gains to operations more rapidly than traditional research programs.

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Recent accomplishments of the program include an improved operational hurricane model with a 30-percent improvement in 3-day intensity forecasts, a prototype new Weather Research and Forecasting model that will improve short-range forecast accuracy and will provide a framework for enhanced collaboration between operational and research communities, ongoing field studies over the Pacific Ocean and tropics to improve basic knowledge for improved forecasts across the nation, and meteorological test beds to facilitate the rapid transition from research to operations for better pay back on our investments.

Our future plans include three research projects; a regional project called IHOP to improve forecasting of significant rainfall, both location and amount; a hemispheric observing experiment called THORpex to improve the accuracy of extended-range weather forecasts out to ten days; and, a warm season precipitation research program to improve forecasting of summer storm rain, hail, and flooding.

The challenges for the program include ensuring a research focus that makes a positive impact on the American public and its economy, coordinating diverse research interests toward common scientific goals, developing the good science that provides solutions, and transferring those solutions to operations for immediate benefit to the United States.

In summary, Mr. Chairman, the Nation has made a substantial investment in the infrastructure associated with meteorological support. Today we have observational and computational capabilities second to none. However, we must leverage this investment with better meteorological understanding and science to further improve our weather prediction models and methods.

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The USWRP is an interagency Federal team and it offers a vision and path toward that goal. How far we go down that path will be determined by our resolve as a Nation seeking to protect its citizens from nature's wrath.

[The prepared statement of Dr. Hayes follows:]

PREPARED STATEMENT OF JOHN L. HAYES

Good morning, Mr. Chairman and members of the Committee. My name is Jack Hayes and I am director of the National Weather Service's Office of Science and Technology within the National Oceanic and Atmospheric Administration (NOAA). I want to thank you for this opportunity to speak with you about The U.S. Weather Research Program (USWRP). While we are not commenting on any specific bill today, we would like the opportunity to comment on any future authorization bills related to this program. USWRP is a unique, multi-agency program designed to pool the talents and resources of government, academia and industry scientists to rapidly improve specific weather forecasting capabilities. By focusing these efforts on a few specific problems, the USWRP can achieve results more quickly than the traditional, incremental research programs and will be able to respond promptly to changing federal, social and economic priorities. I would like to begin this morning by outlining for you the research and operational context within which USWRP resides.

Introduction

Our everyday existence depends on weather. It influences our daily activities and can devastate our lives and livelihoods. Natural disasters related to hazardous weather like tornadoes, hurricanes, and winter storms cause thousands of fatalities each year, far more injuries, and tens of billions of dollars in damage to property (see Table 1). Such impacts are worsened by inaccurate and uncertain forecasts. For example:

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The flooding potential of hurricanes is exemplified by Hurricane Mitch, which in 1998 stalled over the Central Americas causing persistent torrential rains leading to landslides and flooding that killed some 10,000 people.

In 1999, although Hurricane Floyd followed its predicted track, forecast uncertainties led to planned and unplanned evacuations of over 3 million people, including 2.5 million evacuees in Florida alone, one-sixth the state's population. The costs associated with over-warning amounted to over $100 million.

In 2000, the National Weather Services (NWS) correctly predicted a January snowstorm but with insufficient lead-time. The event paralyzed the entire Middle Atlantic and New England coasts with far-reaching financial impact.

Also at stake are the competitiveness and sustainability of the U.S. economy, particularly agriculture, airline and other transportation systems, and more efficient energy and water resources management. Improved weather information provides an opportunity for more effective decision-making, with aggregate potential savings totaling billions of dollars annually. The rapid growth and increasing dispersion of the commercial infrastructure in the U.S. makes it more sensitive than ever before to weather-induced losses. Significant loss reductions and economic benefits can be realized from better current weather information and weather predictions. For example, opportunistic use of weather information creates opportunities for financial gain via weather-sensitive futures markets, and efficiencies in aviation can be achieved through reduced fuel consumption and decreased passenger delays. The success of military operations and the effectiveness of military systems can also be improved with more accurate meteorological analyses and forecasts. A good example of the need for accurate weather information in military operations is the number of missions aborted for unforecast cloud cover during Desert Storm and operations following. Even good weather can create problems: a few-degree error in a summer day's forecast high temperature can cause an energy company to exhaust its reserve and lose millions in buying power on the open market.

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The Role of the U.S. Weather Research Program (USWRP)

The USWRP is an interagency program that supports government- and university-based research to improve weather forecasts and the use of those forecasts, particularly those associated with hurricanes, floods, and heavy snowfall. To tap into the talents and capabilities of the scientific community, the USWRP makes research grants to academic research institutions, laboratories, and field programs.

The USWRP focuses mostly on near-term scientific and technological themes that will produce results within five years, and it has the flexibility to respond promptly to changing federal, social and economic priorities. It builds on the existing investments, including the National Weather Service (NWS) *modernization and other weather research programs, to dramatically accelerate improvement in weather forecasts.*

The USWRP accomplishes this acceleration in progress by focusing its attention and resources in areas where it has determined that progress can be made quickly and where the impacts of the improvements will be the greatest. It has established goals that can be attained by leveraging the resources of several agencies and by the collaborative scientific efforts of the operational and research communities in academia and government.

Four U.S. agencies currently support the USWRP:

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The National Oceanic and Atmospheric Administration—NOAA is responsible for preparation of operational weather forecasts through the NWS and the National Environmental Satellite, Data, and Information Service (NESDIS). Through its Office of Oceanic and Atmospheric Research (OAR), it conducts the applied research and technical development leading to forecasting improvements.

The National Science Foundation (NSF)—NSF provides resources to the atmospheric science research community, particularly to university scientists, for basic research on weather systems and weather forecast technology.

The Department of Defense—The Navy and Air Force have interest and capabilities in developing techniques for optimal addition of observations in data-sparse regions and in the development of new numerical weather forecast models.

The National Aeronautics and Space Administration—NASA develops and deploys the satellite borne remote sensing observing systems and conducts research assessing the relative impact on forecast accuracy of various observing systems. It develops data assimilation systems to incorporate the observation from satellites and other systems into forecast models.

The work of the USWRP contributes directly to the missions of the Federal Emergency Management Agency (FEMA) and the Departments of Transportation, Energy, and Agriculture. Each of these agencies is either a provider or user of weather information and each benefits from jointly supporting weather research programs that lead to better meteorological understanding, the development of new systems, and transition into operations. This coordinated effort complements the individual agencies' current activities that focus primarily on long-term forecast improvements.

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Goals of The USWRP

The USWRP has established three primary areas where resources are being and may be directed. These are areas where Prospectus Development Teams (PDTs) described below, see potential for rapid advancement and large societal impact, and where specific, five-year goals are defined. The PDTs are small groups of distinguished scientists and technical experts who define critical research issues and opportunities related to the improvement of atmospheric prediction. These groups recommend future USWRP focus areas and research techniques based on societal need and potential for progress.

Hurricanes

The USWRP has begun to address hurricane predictions offshore and onshore. The program will improve forecasts of landfall location and hurricane strength leading to more timely evacuations. The program will address damage estimates from winds and encroaching seas, when and where rains will create flooding. The program will also focus on societal impacts such as cost/benefit, forecast and warning information content, dissemination, and use of warnings in saving lives and safeguarding property.

The USWRP will develop methods to achieve the following goals:

reduce the landfall track and intensity forecast errors by 20% and extend track forecasts out to 120 hours;

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increase the warning lead time beyond 24 hours without increasing the warning area;

make skillful forecasts for hurricane and gale-force winds out to 48 hours;

extend quantitative precipitation forecasts out to 3 days and improve forecast lead-time and coverage of inland floods.

Heavy Precipitation and Flooding

The USWRP will improve forecasts of winter storms and torrential spring and summer rains by better predicting timing, location, and intensity. Coupling these improved precipitation forecasts with the NWS' Advanced Hydrologic Prediction Service (AHAPS) will lead to better flood forecasts nationwide. In winter, coastal and inland areas will receive more precise warnings of how much rain or snow will fall and where it will fall. Such improvements will reduce flood damage, air-traffic delays, and power outages, and will help prevent road and rail accidents. For summer storms, the program will provide ways to refine 6- to 48-hour flood warnings and give specific flash-flood warnings by drainage basin. It will also improve warnings for tornadoes, lightning, hail, and high winds. These advances will save lives, reduce property damage, mitigate agricultural losses, and minimize disruptions to air and ground traffic.

The USWRP will develop methods to achieve the following goals:

improve same-day forecasts (timing and coverage) by 50 percent;

make two day precipitation forecasts as accurate as current one day forecasts, and three day forecasts as accurate as today's two day forecasts; and

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improve warning lead-time of flash floods by 50 percent (from the current 39 minutes to 60 minutes ahead of a flood).

Two-to-Ten Day Forecasts of Storms

Most U.S. weather systems flow across the continent from west to east. Because the continental U.S. is covered by a wide range of observing systems, forecasters on the East Coast can look upstream to predict the coming weather as it moves across the country. Forecasters on the West Coast have no such luxury. Pacific weather lies in small, constantly shifting wellsprings, or sources, across the vast oceanic expanse. Mostly unobserved, these systems spawn the precursors of heavy weather for the West Coast and continent, particularly in the winter. Through a program known as THORpex (The Hemispheric Observing System Research and Predictability Experiment), USWRP is capable of developing techniques to detect these incipient winter storms. THORpex is an international program involving countries from around the Northern Hemisphere to develop the global observing system and technology for using these observations to improve hemispheric forecasts out to ten days. The goals for THORpex are the same as those described for Heavy Precipitation and Floods. This program addresses the longer-range part of the forecast problem, two to 10 days.

Societal and Economic Impacts

To ensure that scientific advances are useful to the consumers of weather information, USWRP will identify methods of delivering weather information effectively and recommend ways to better tailor weather communications. The program will assess the social and economic impacts of adverse weather from disastrous to routine, study how a particular community uses weather information, and evaluate what is most useful to public and private decision makers. By allocating resources for research in societal and economic impact, USWRP ensures a connection between weather research and improvement of the human condition.

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How Does USWRP Work?

Through USWRP, a number of federal agencies can and do team with universities and other research institutions to identify social, economic, and military needs and requirements for weather information; the research necessary to meet these needs; the pathways to transition the research to operational services; and methods for dissemination of weather information to user communities.

The framework for USWRP was developed by blue-ribbon panels of scientists in consultation with users of weather information. Together, the 200 participants in the early stages of the program represented virtually all aspects of the U.S. weather establishment and weather-affected sectors of the economy. These Prospectus Development Teams (PDTs) continue to collaborate today as new issues emerge. For example, the program is currently considering ways in which to improve air quality forecasting to help reduce the human health impacts of air pollution and, given the recent tragic national events, the PDTs will address improved methods for monitoring and predicting urban airflow for mitigation of toxic threat. The published PDT reports highlight the breadth of the program and the mission to solve the most critical weather issues facing the nation in the 21st Century. PDTs are listed in Table 2, which includes the names and affiliations of the team co-chairs. PDT reports have been reviewed and published in the *Bulletin* of the American Meteorological Society (See References).

A Science Steering Committee (SSC), made up of experts from academia, government, and the private sector, oversees the program and ensures its integrity. The SSC reviews each of the PDT reports and recommends the scientific focus of the Program to the USWRP Interagency Working Group (IWG), the joint agency management team the members of which are listed in Table 3. The IWG is responsible for the overall direction of USWRP and guides it to meet national priorities *based on information in the PDT reports.*

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The program works closely with federal, state, and local authorities and private sector meteorologists to facilitate the transfer of improved forecast technologies to various public- and private-sector applications. Adjustments to future forecast systems include improved conceptual models, revised data-utilization techniques, advanced numerical models, revised observational strategies, redistribution of existing observational systems, improved instrumentation, and additional observing systems. Key to realizing the program goals are test bed forecast development facilities, providing personnel and quasi-operational forecast systems, that will test and evaluate new technologies, techniques, and observations in parallel with operational systems.

As national priorities evolve, the USWRP continually evaluates its foci through dialogue with agencies and experts in universities, the private sector, and government laboratories with an eye toward identifying the intersection of achievable scientific breakthroughs with important societal impacts. The program accomplishes these evaluations by maintaining expert committees, holding workshops, and assembling teams of experts to examine critical issues.

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What has USWRP accomplished already?

For the first years after the program was authorized, the efforts of USWRP were directed toward developing plans and refining the focus of the program. Much of this activity was accomplished through the Prospectus Development Teams and refined by the Scientific Steering Committee and the Interagency Working Group. With the first Joint Announcement in 1997, the work of the Program began.

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Each of the following projects receives direct funding from USWRP:

Forecasting Hurricane Intensity

Many hurricanes fail to develop even when conditions seem favorable. Others intensify far more rapidly than expected. Forecasters have little skill in predicting these events. In part, this is because the deep, warm water that fuels hurricanes is poorly defined by weather reports and sea-surface temperatures. The NOAA Geophysical Fluid Dynamics Laboratory has improved its atmospheric model and coupled it to an ocean model that extrapolates temperatures at and below the ocean surface. Among other elements, this model can depict the cool wake left behind a hurricane path that may affect other storms for many days. This coupled model became operational this year and has shown 25% improvement in predicting the evolution hurricane intensity in situations where ocean temperatures are a key component of storm strength.

The Weather Research and Forecasting Model (WRF)

It is often possible to experience within an hour's drive, the effects of paralyzing snow, dangerous ice, and low-impact rain. Even computer models that predict day-to-day weather skillfully have trouble delineating rain and snow in the most complex and intense winter storms. Scientists at four centers have completed the prototype for a groundbreaking new model to be used for research as well as forecasting. This new model, WRF, will provide data at critical points every square mile, as opposed to every 200 square miles in current models. Such a model may begin to allow prediction of the individual thunderstorms that generate damaging hail and tornadoes. One of the chief benefits of the WRF approach is that research and operational modelers will utilize the same basic software framework so that developments in research can be adapted quickly for operations. This will help bridge the traditional gap in transferring technology from the research laboratory to the forecast center.

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The PACific Land-falling JETs Experiment (PACJET)

Winter storms are taking an increased human and economic toll on the U.S. West Coast. When averaged over many years, the financial impact is comparable to that of earthquakes. A two-phase study, PACJET, is sending "hurricane hunter" P–3 aircraft from NOAA across the Pacific Ocean to sample the air in and near winter storms. The data from these and other research tools are helping scientists understand the physics that drive these storms so that computer modelers can represent them more accurately. Researchers in PACJET are working closely with forecasters along the western coast of the U.S. to use the data collected during the experiment to improve forecasts of severe winter weather and heavy rainfall in the region.

The Convective and Moisture Experiment (CAMEX)

CAMEX is a series of field research investigations funded by NASA to collect data during tropical storms. Hurricane tracking, intensification, and landfall are studied by gathering data sampled by aircraft and surface remote sensing platforms, and performing scientific analysis. The first three CAMEX campaigns have been able to obtain data with high spatial and temporal resolution that are leading to improvement of tropical storm modeling and ultimately hurricane forecasts.

National Test Beds

It has long been recognized by both research and operational meteorologists that there is a critical need for a more direct conduit for new, mature research systems and techniques to be evaluated for transference into operations. These ideas need to be tested in an environment identical to operations (using the data available to operational meteorologists when they make their forecasts) that will not interfere with official operational procedures. Under sponsorship of the USWRP member agencies, initiatives to create three such centers have been launched:

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The Joint Center for Satellite Data Assimilation (JCSDA), where scientists can prepare our national models and assimilation systems to capitalize on the impending flood of satellite data from new space-based sensors in the latter half of the decade.

The Joint Hurricane Test Bed, where new hurricane models, algorithms, and methods for displaying data and model output, are tested for integration into operations.

The Joint Model Test Bed, where the new advances in numerical prediction are tested including the WRF model evaluation prior to its introduction into operations.

History of the U.S. Weather Research Program

The roots of USWRP date back to the 1980s when the modernization of the NWS was being discussed and implemented. It was argued that in addition to bringing the observing and operational forecast systems up-to-date, a closely aligned program named the Storm-scale Operational and Research Meteorology (STORM) program was necessary to ensure that the observational data from the modernization was fully utilized to maximize the impact on weather forecasting. Even though this research program was a small fraction of the modernization budget, to minimize costs, it was never implemented.

In the early 1990s, seeing that the benefits from the modernization were not being fully realized, the research community increased its efforts to establish a focused program to utilize the data from the new observing systems and take advantage of new developments in numerical weather prediction. In order to revitalize critical program components outlined within the original STORM program, it was renamed the U. S. Weather Research Program (USWRP) and management of the program was reorganized. In 1992, USWRP was authorized by an act of Congress for the purpose of:

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increasing the benefits to the nation from the substantial investment in modernizing the public weather warning and forecast system in the United States;

improving local and regional weather forecasts and warnings;

addressing critical weather-related scientific issues; and coordinating governmental, university and private-sector efforts.

Congress further directed NOAA, the designated lead agency, to prepare an implementation plan. This plan was completed and published in early 1994.

The USWRP has worked to address the tasks outlined in the 1992 Authorization Bill and described in the Implementation Plan of 1994. Program milestones include:

Establishment of the USWRP Program Office (1993)

Establishment of the Office of the Lead Scientist (1994)

Convening of the Interagency Working Group (1995)

Convening of the Scientific Steering Committee (1995)

Convening the Prospectus Development Teams (1994–1998)

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Definition of the initial foci of the Program (1996)

Definition of the Program Goals (1998)

Publication of the Implementation Plans for the initial foci (2001)

Joint agency announcements of opportunity to submit proposals for USWRP research (1999, 1997)

Funding for USWRP has grown slowly since it began in 1994. Direct funding available to USWRP by agency since 1997 is as follows:

1997 $5,126,000

1998 $5,603,000

1999 $6,805,000

2000 $8,968,000

In addition to the direct funding, portions of existing base funding within the agencies were reprogrammed to augment the direct funding. At the existing level of funding it will take over 25 years to fully carry out the program that was defined in the Implementation Plan. Over the next five years the program will focus on the following high priority areas: Hurricanes, Heavy Precipitation, and Extended Range (10-day) Forecasting.

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FUTURE PLANS OF THE USWRP

Two upcoming initiatives for USWRP are profiled below. The program will also continue work on the WRF model (described above) and additional ongoing projects.

The International H*O Project (IHOP)*

The USWRP is teaming with a number of agencies and universities to sponsor the largest atmospheric field study ever organized in North America. Its goal is to improve forecasts of heavy rain from showers and thunderstorms through a better understanding of how water vapor behaves. Water vapor is difficult to measure and to depict in a computer model, but it plays a major role in rainfall intensity. This study will assemble a variety of high-precision instruments across the southern Great Plains in order to track water vapor and learn more about its variations. IHOP will lead to more precise forecasts of how much rain might fall from a given system—a critical task in warning for such events as the catastrophic flooding that struck Houston in June 2001 in association with Tropical Storm Allison.

The Hemispheric Observing system Research and Predictability Experiment (THORpex)

Some large-scale storm systems, such as the 1993 East Coast Super Storm, have been accurately predicted up to a week ahead of time. Others, such as the January 2000 snowstorm that surprised Washington, D.C., have not. Forecasters are hampered by the lack of data across large expanses of the globe such as the Pacific Ocean, and the inability of computer models to predict particular rare but devastating weather regimes. A comprehensive study is needed to learn which enhancements, such as improved observations at certain locations, will lead to the most improvement in computer-model forecasts. This study will identify and profile the most challenging prediction regimes. Model experiments with real and "virtual" data will show how observations can be brought into computer models most effectively. The overall goal is to improve the accuracy of weather forecasts issued up to ten days in advance.

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Warm Season Precipitation Forecasting

Planning is underway to create a warm season research program that will address attainable improvements in forecasting summer storm precipitation amounts (including drought-ending systems), flash flooding, hail, high winds, and tornadoes. This program will likely also address the very difficult problem of forecasting summer temperatures with the accuracy few degrees Fahrenheit, an accomplishment that would pay enormous dividends for our country through more efficient production of energy by power companies.

Challenges for The U.S. Weather Research Program

The increasing complexity and dependence of the economy and society on accurate environmental information and weather information in particular, highlights the need for multi-agency approaches to provide the necessary services. The challenge for USWRP is to expand the number of participant agencies to provide the most comprehensive and cost-effective weather information possible for the nation. For example the Department of Transportation including the Federal Aviation Administration and Federal Highway Administration, the Department of Energy, and FEMA have departmental goals that would fit well with USWRP's mission. USWRP is working with representatives from these agencies through the Office of the Federal Coordinator for Meteorology.

The increasing need for more accurate weather information to support economic decisions places federal weather services at the heart of the U.S. economy. The challenge for USWRP is to be able to respond decisively and rapidly to emerging needs so that weather information can be delivered where and when needed.

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Possible global climate changes suggest that there may be less predictability in extreme weather events in the future: for example, hurricanes may be more intense; tornadoes may occur where they have been historically rare. The challenge for USWRP is to stay ahead of these changes and ensure that gains in our research and technology directly contribute to better predictions of extreme weather to minimize harm to the population and the nation's infrastructure.

The USWRP has developed an ambitious plan to improve forecasts of hurricanes and precipitation over periods ranging from hours to ten days. It has established goals that provide a clear metric to assess its progress in reaching these goals within five years. These are ambitious goals, but past successes have proven the USWRP capacity to deliver. The USWRP has created a far reaching vision and a path to meet many of the critical weather information needs of the millennium's first ten years.

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Chairman **EHLERS.** Thank you. Mr. Hill.

STATEMENT OF MR. DOUG HILL, CHIEF METEOROLOGIST, WJLA—CHANNEL 7 NEWS, WASHINGTON, DC

Mr. **HILL.** Good morning, Mr. Chairman, and, committee members, and staff. Thank you for inviting me. My name is Doug Hill. I am the Chief Meteorologist at ABC 7 Television here in Washington. And as the Chairman pointed out, I worked in Detroit from 1980 to 1984.

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And I had an experience very early on—the closest experience I ever had to a tornado—happened in Macomb County when we lived there. It was a nice house and a nice yard. As a matter of fact, backed up to an elementary school. What I did not know at the time was there was a tornado siren, a warning siren, right at that school. And I had a four o'clock in the morning wake-up call, as many Michigan tornadoes occur overnight. And it came to my attention very quickly that some towns and areas are prepared for severe weather, better than others, especially in the Midwest and the central and southern plains. Other areas, like Washington, may not be so well prepared.

Specifically what I am concerned about, and what I am interested in is our role as broadcasters. I can speak specifically for my TV station and for WTOP Radio. I can speak generally for most broadcast organizations.

What I found most disturbing about the tornado outbreak on September 24, was that there was only one station, only one broadcast station in Washington, DC, which happened to be WTOP, that activated the emergency activation alarm system.

Now, here is the problem. We have become so desensitized, I think, as a population, that when we are riding in our cars and we hear the emergency tones, which are digital now, the first impulse is to change stations and hit some music or talk. People really don't pay attention to that. And broadcasters, themselves, don't take it seriously, even though the headline issued by the National Weather Service about the tornado warning is preceded by "request activation emergency system." So everybody is supposed to do it, but hardly anybody does. So we need to find a way, I believe, that it becomes more routine, if not required, that broadcasters issue tornado warnings.

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In our business, at our station, tornado warnings have the highest priority of anything coming to weather. We will run tornado warnings over commercials, which, in most parts of TV, you never interrupt a commercial, because then you would have to do a make-good and give them a free commercial. But what you do is run it over every part of broadcast—over network programming. If the President is speaking, you run it over that. It does not matter. That is the first priority. And, in essence, and to simply state it, that is our first priority as television meteorologists and broadcasters—to convey emergency information about the weather to the public in the most rapid and reliable way possible.

One of the problems I have noticed over the years, and many others in and out of the business have as well, is you unfortunately find yourself sometimes watching a TV station in a city, usually smaller markets rather than large, but it even happens there, where the person responsible for relaying those warnings, for relaying life-saving information and life-saving prevention tips during a weather crisis situation, really aren't qualified to do that. So I am very much interested in bringing it a couple levels up so that the public is better served.

We serve the public. That is our job. That is why radio and TV stations have broadcast licenses—to serve the public interest. And I can think of no higher call in public service, through broadcasting, than to relay these emergency warnings. We do not create them. We relay them from the Weather Service. And the investment in time and technology at our TV station and many others, is to buy the systems, to buy the hardware, to buy the software that allows us to, as quickly as humanly possible, relay those messages. But if those messages are relayed to the public by people that really don't understand what they mean and what the implications of the storm are, I don't think they are doing a great service.

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I will be happy to answer questions in a little bit about September 24 and the University of Maryland. Yesterday, in a conference up the hall, we talked about what happened at the University of Maryland. I spoke especially about the fact that only one broadcast station activated their emergency system. And especially, in these times, that is a scary thought, that most people still continue to ignore them, including the broadcasters.

And also, I want to assure that the role and the call of broadcasters is not to compete with the National Weather Service. And I know in some cities there are a strained relationship, at times, between TV stations and the local forecast office. I can tell you it has been my role for 24 years that the first thing I do when I get in town, as I did in Detroit, and as I did here in Washington, was get to know the staff of the local Weather Service office. That cooperation and the trust that Weather Service people can have in the broadcasters, makes for a very good marriage. Because the Weather Service people are in the same business we are, warning the public. And as many of these gentlemen have testified, more can be done to do that.

And as we go through the future and technology increases, it is going to be a marriage of science and broadcast that is going to continue to save lives. And I am very happy to be part of that and would be very happy to answer any questions you have, again, specifically about my stations or generically about the stations across the country in general. Thank you, Mr. Chairman.

Chairman **EHLERS.** Thank you. And you can tell you are in the media. You left—you ended with 3 seconds to spare.

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Mr. **HILL.** Okay.

Chairman **EHLERS.** I might also mention this is the first time I realized it was voluntary for stations to do it. In Michigan all the stations do it. I assumed it was mandatory. And that clearly is something that has to be corrected. Thank you. Dr. Shea.

STATEMENT OF MR. ROBERT F. SHEA, ACTING ADMINISTRATOR FOR FEDERAL INSURANCE AND MITIGATION, FEDERAL EMERGENCY MANAGEMENT AGENCY (FEMA)

Dr. **SHEA.** Thank you, and good morning, Mr. Chairman, and, members of the Committee, staff. My name is Robert Shea and I am the Acting Administrator of the Federal Insurance and Mitigation Administration, which is part of FEMA, the Federal Emergency Management Agency. And as requested, I am really just going to make a few summary comments this morning about the issues that are before you.

But as we, in FEMA, look at the issue of research into natural hazards, we really believe that we need to keep an eye on transferring knowledge into effective practice. And let me just give you an idea of some of the mechanisms that we have brought about in order to do that.

Really what we are trying to accomplish, I think, is to influence specifically the built environment. As an example, over the past several years, FEMA has been developing a multi-hazard risk assessment and loss estimation tool that is called HAZUS or Hazards U.S.

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In 1997, we brought the first module on line that dealt with earthquake issues. Next year, we will have a module on line that will deal with flooding issues. And we will have a prototype of one dealing with wind issues late, late next year. These are designed, really, to provide a tool, both to Federal and state and local people to determine the kind of risk that you are involved in, and then how to deal with it. In other words, how to strengthen the built environment.

Another mechanism that we use is building performance assessment teams. We typically trigger these in the aftermath of a major event. And the purpose of these teams is to really conduct forensic engineering. In other words, we go out and look at the damage and try and determine what caused it and then what measures we can incorporate in order to eliminate that kind of damage in the future. Our major thrust is really to translate research into tools, guidance, and improved building practices.

I would also like to just commend Congressman Etheridge for his efforts to address this serious issue of inland flooding. I believe the Congressman's approach to inland flooding is correct. In other words, inland forecasting, warning, and also, particularly, education of local officials and the public that will provide a much-needed life-saving bridge to the public at large.

FEMA's third approach to implementation is through the National Flood Insurance Program, particularly flood mapping. Our flood hazard maps provide long-term projection of flooding conditions. But it is important to note that there are many—there are many common elements between FEMA's predictive capability and mapping real-time events, which is really the business of the National Weather Service.

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Let me just outline a few of these differences for you so you can understand. FEMA maps a hypothetical and static event, while the National Weather Service is trying to map a dynamic event, one in progress, in effect. While both FEMA and the National Weather Service use stream-gauging information, FEMA issues a probabilistic model that is calibrated to historical events. The National Weather Service determines real-time information using telemetric data from the gauges themselves—that is the stream gauges.

FEMA and the National Weather Service also use different flood modeling techniques, primarily because, again, we are interested in modeling a static projection of an event. The National Weather Service is properly concerned about timing of a crest, flood threshold exceedance, and return time to normal flow patterns.

Finally, FEMA tends to conduct studies in much greater detail, and, frankly, even in small stream areas, where the National Weather Service will focus more on major water bodies.

Nonetheless, FEMA is making a concerted effort to share data through the Federal Geographic Data Committee, which coordinates the development of national spatial data infrastructure. This is a very long-term effort which will require a long-term investment, but it will result in future data-sharing efforts.

FEMA is also, though, embarking on this goal, as well, through pilot efforts with a cooperating technical partners agreement with state and local governments. And we are looking forward to some success in our initiative with the State of North Carolina. To give you a snapshot, as part of this effort, the state, the National Weather Service, the U.S. Geological Survey, and FEMA are partnering to develop an enhanced real-time flood warning system by using FEMA's more-detailed approach to flood hazard mapping to enhance the forecasting and, frankly, avoid the duplication of data collection.

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FEMA has enjoyed a highly collaborative partnership with the National Weather Service and the U.S. Geological Survey and the Federal Geographic Data Committee, and we look forward to future sharing projects. Thank you, Mr. Chairman.

[The prepared statement of Dr. Shea follows:]

PREPARED STATEMENT OF ROBERT F. SHEA

Thank you for the opportunity to discuss FEMA's mitigation activities for our country to be better prepared to withstand the impacts of extreme weather events. We would appreciate an opportunity to supply written views to the Committee in advance of its consideration of any authorizing legislation on this important subject.

In general, FEMA's approach to mitigation includes:

a multi-hazard focus,

a focus on research that can be transferred into practice,

an emphasis on systematic building performance data collection,

an emphasis on developing quantitative assessment techniques, such as the HAZUS loss estimation model currently under development at FEMA, and

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a strategic planning element to address research and development goals, data collection systems, technology transfer, and outreach.

With respect to research, while there are still knowledge gaps relating to weather phenomena and nature's impact on the built environment, and while our technology for studying these phenomena has improved dramatically, there is also much that we have already learned that has not yet been fully incorporated in our design guidance and construction practices and in tools to assist local governments with land use planning. In addition to pure research, we need to embark on a robust program of technology transfer and outreach to the design, construction, and regulatory communities and we must develop easy to use tools for local governments. We must take existing and future knowledge and use it to improve the way we live in hazard-prone areas and FEMA has been working with other Federal agencies and other organizations to do just this.

Over the past several years, FEMA has been developing a multi-hazard loss estimation and risk assessment tool called Hazards US or HAZUS. Incorporating data on infrastructure, building inventory, geology, damage estimation formulas, and critical operating center locations, HAZUS estimates damages at critical operating centers, probabilistic damages for buildings and infrastructure, and forecasts casualties for a vast array of forecasted and historical events. HAZUS has the flexibility to adjust the location and intensity of the event and to analyze the resulting impact on a study region. The model is also a valuable response tool following an event by providing early estimates of damage and areas where the immediate need is likely to be greatest.

The first model in the series to be developed was for earthquakes, completed in 1997 with a re-release in

1999. The second module under development is the flood loss module, to include both coastal and riverine flooding. Currently, HAZUS includes the Q3 data on 100- and 500-year flood plain boundaries and can be used for gross estimates of evacuation zones. Software development to enable depth and damage estimate has begun and we expect to release the first complete version of the flood module towards the end of 2002. The third module is a hurricane module. Damage estimates are based on storm characteristics, a description of the built environment, and state-of-the-art hurricane building codes in the various hurricane susceptible states. Software development on this module will begin soon and its initial, preview release should also be in at the end of 2002, with the full hurricane model finished by 2005.

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With the release of HAZUS03, a full multi-hazard capability loss estimation model, FEMA and the states will be able to compare annualized losses among the three major hazards that affect the United States. States and localities will be able to analyze the risks to their communities and begin to build rational, comprehensive mitigation plans. HAZUS will be invaluable to states and communities in establishing priorities on where to focus their available energy and resources.

Mecklinburg, North Carolina recently performed a regional risk assessment using elements of the HAZUS Flood Model (which is still under development) to determine their current risks and to look at the effect of future development on those risks. A number of other nations, such as Turkey, have examined HAZUS and are adapting it to their building inventory and geology. In time, HAZUS may be used around the world to estimate annualized losses and save lives.

In order to accelerate the completion of HAZUS and to enhance certain elements of the model, FEMA is coordinating with other Federal agencies, including NASA and NOAA to leverage existing resources and expertise.

Obviously, before tools can be developed and before building design and construction can be improved, you have to have the basic knowledge. To get that knowledge, you often have to conduct studies. In the mid-1980s, FEMA created the Building Performance Assessment Team (BPAT) to marshal the combined resources of Federal, State, and local governments and the private sector to study building performance as part of our national mitigation effort. The objectives of the BPAT are to:

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Inspect buildings and infrastructure,

Conduct forensic engineering analyses to determine causes of structural failure and success, and

Report on lessons learned and recommend actions that State and local governments, the construction industry, and building code organizations can take to reduce future damages and protect lives and property from hazards, both natural and manmade.

Generally, these BPAT studies are conducted following very large or unique disasters. The purpose of the

BPAT is to study specific issues, such as crawlspaces that were collapsing due to flooding, which resulted in flood vent requirements and the floodplain management regulations, rather than simply to document typical disaster damage. Specific types of damage discovered during post-event engineering analysis, such as the unanticipated damage to the welded beam column connections of steel moment frame structures in the Northridge earthquake, are followed up with more extensive studies, in this case, the $12 million FEMA steel moment frame buildings project, completed last year.

Building and infrastructure performance data collected after most disasters is often ad hoc and anecdotal. While a lot of data are collected after these types of disasters, it is not done in a consistent manner and it is not catalogued or warehoused in an accessible manner so that all interested parties can share in and benefit from the information. This represents a serious, ongoing weakness that is slowing our progress towards finding and implementing solutions and improvements to design and construction standards for better protection.

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A systematic, consistent approach to data collection and analysis would allow us to learn from the unfortunate events that cause so much destruction and to translate the scientific analysis of building performance to improved guidance and regulations to make the country safer.

Clearly, there are still gaps in our knowledge of how natural phenomena affect the earth, changing the topography, climate, geology, and how these events impact the built environment, especially related to high wind and flooding events. Examples of areas in which we should consider improving our knowledge include:

more accurate descriptions of the nation's coastal and near coastal topography and ground cover, essential for accurate determination of wind loads on buildings;

improved analysis techniques for determining design loads on residential construction;

better understanding of near ground wind behavior in built up environments; and

the development of a comprehensive database of the nation's levee systems.

By translating research in these and other areas into application—into tools, guidance, and improved buildings standards—we could make significant progress in our mission to reduce the loss of life and property due to natural disasters.

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Turning now to the subject of inland flooding, FEMA commends Congressman Etheridge for his efforts to raise the awareness of the dangers of inland flooding from tropical storms and hurricanes. As he points out, 48 inland deaths and nearly $3 billion in property damage occurred in inland communities as a result of Hurricane Floyd in 1999 and more than 50 people died from the floods caused by Tropical Storm Allison earlier this year. All too often, once a Hurricane, or other high wind event, begins to move inland the media and the public stop thinking of it as dangerous. This idea persists despite the fact that at times, as with

Hurricane Floyd, there is more rain-related flooding and wind damage inland than damage from coastal wind and surge damage.

Inland flood forecasting, a warning system, and outreach efforts to educate local meteorologists and the public could provide life saving information. These efforts in conjunction with the flood hazard maps provided by FEMA are critical components of preparing for, responding to, and recovering from flooding disasters.

FEMA's flood hazard maps provide long-term projections of flooding conditions and are used to safely site and design new buildings and infrastructure and make long-term flood insurance decisions for real property in the floodplain. Flood forecasting and warning systems by local entities and by the National Weather Service provide real-time information about an imminent event so that state and local officials and citizens can take appropriate emergency actions to reduce flood-related losses of life and property.

While there are many common elements between FEMA's predictive flood hazard mapping and real-time flood forecasting, there are important differences in the products and analytical techniques, including:

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FEMA maps a hypothetical static event, whereas the NWS system must be dynamic, reflecting an actual, real-time event. FEMA's flood hazard maps show flood elevations and floodplain delineations for a specific probability event: the 1% annual chance flood (a flood that has a 1% chance of being equaled or exceeded in any given year; also referred to as the 100-year flood because it has an average recurrence interval of 100 years). The maps also frequently show the 0.2% annual chance (500-year) floodplain. The maps are accompanied by a report that typically includes flood profiles of the 10% (10-year), 2% (50-year), 1%, and 0.2% annual chance events.

While both the NWS and FEMA use data from the USGS national stream gaging network, FEMA determines discharges using probabilistic methods based on long-term gage data and/or models calibrated to historical events; the NWS determines discharges using real-time telemetric data from the stream gages. The NWS also uses real-time remotely sensed data about precipitation and atmospheric conditions in its analyses; FEMA's analyses do not consider atmospheric conditions.

While both agencies make extensive use of flood modeling programs, FEMA can make use of "steady flow" models to predict the maximum peak of discharge and elevation because FEMA is concerned only with the ultimate peak of elevation and inundation. The NWS, however, uses more complex "unsteady flow" models because NWS is concerned not only with the crest of the flood, but also the timing of the peak, as well as the timing of when the flood will exceed the flood threshold and when it will return to its normal flow. While unsteady flow models provide the capability to project the timing of the peak, they are, in general, more costly to develop and run than steady flow models. However, much of the input data are the same between steady and unsteady flow models.

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Because FEMA's flood hazard maps are used to make Federal mandatory flood insurance purchase determinations, there is a demand for greater precision and detail than in flood forecasting, which can and should be more conservative in warning the public. Therefore, FEMA uses closely spaced cross sections (i.e., survey of topography along a line perpendicular to stream flow), typically at least at every thousand feet as well as immediately upstream and downstream of hydraulic structures (e.g., bridges) in analyzing flood hazards and delineating floodplains. The NWS, however, does not need closely spaced cross sections in its modeling.

The NWS typically forecasts flood crests only on major streams and rivers in its flood forecasting. For small streams subject to "flash" flooding for which there is not sufficient lead-time to collect and analyze real-time data, the NWS issues more generalized warnings (without predicted crest elevations) based on precipitation amounts and atmospheric conditions. FEMA, on the other hand, typically studies relatively small tributaries of those major streams. Indeed, FEMA typically maps any stream with a drainage area of at least 1 square mile.

Nonetheless, despite these differences in predictive flood hazard mapping and flood forecasting, there are many similarities and common data elements that should allow for close cooperation between the NWS and FEMA. In particular, both agencies make extensive use of:

stream and rain gage data,

topographic, cross sectional, and watershed characteristic data needed for hydrologic analyses and hydraulic analyses.

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In recent years, FEMA has been very much involved in important data-sharing efforts across all levels of Federal, state, and local government. Specific examples of activity in which FEMA and other Federal agencies, as well as state and local agencies, are cooperating are the National Digital Orthoimagery Program (NDOP) and the National Digital Elevation Program (NDEP).

These cooperative efforts have been facilitated by the Federal Geographic Data Committee (FGDC), which coordinates the development of the National Spatial Data Infrastructure (NSDI). The NSDI encompasses policies, standards, and procedures for organizations to cooperatively produce and share geographic data. The FGDC and both of these cooperative efforts seek to share information about new technologies, influence commercial developments, and provide a mechanism for cooperative data production and sharing over areas of common geographic interest. In short, these programs seek to eliminate duplication of effort among agencies that use photogrammetric and topographic data.

Cooperative flood forecasting efforts that involve data sharing can be modeled on these two programs. Indeed, FEMA is participating in a pilot of such an initiative in the Tar River basin in North Carolina. The State of North Carolina, through a Cooperating Technical Partnership (CTP) with FEMA and numerous other Federal, state, and local agencies, has embarked upon an ambitious program to modernize the flood maps statewide. As part of this effort, the state, NWS, USGS, and FEMA are partnering to develop an enhanced real-time flood warning system that will make use of the Geographic Information System (GIS), high-accuracy topographic information and other data being developed by the state and FEMA for the flood hazard maps. This partnership will eliminate duplication of effort and will have the added benefit of using more accurate data for flood forecasting than are typically available. Additionally, the forecast system will include the development of maps showing the area expected to be inundated and disseminating that information to the public via the Internet. Development of such visualization techniques has long been a goal of the NWS so that the public can better understand and "picture" the potential impacts of a forecasted event. If successful, this system can be implemented statewide and, eventually, be a model for flood forecasting and warning systems nationwide.

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In addition, FEMA encourages communities to implement flood-warning systems through the Community Rating System, a program under the NFIP where communities are rewarded with lower flood insurance premiums for actions taken to further reduce the impact of flooding. In developing and implementing the flood warning systems, these communities often work with the NWS.

While real-time flood forecasting and warning systems are certainly needed, the value of long-term projections and guidance on site planning and designing new buildings and retrofitting existing building should not be overlooked in the fight to reduce the loss of life and property from inland flooding. FEMA enjoys a highly collaborative relationship with the National Weather Service and looks forward to future shared projects.

In closing, I would like to reiterate that only by better understanding natural phenomena can we develop sound practices to protect our nation's property and its citizens from the destruction caused by nature's force.

I would like to thank the Committee for its interest and support in this area. I appreciate the time and would welcome the opportunity to respond to any questions you may have.

Discussion

Chairman **EHLERS.** Thank you very much. It has been an excellent Panel. We appreciate your testimony. We will now turn to questions from the Panel and I will begin by yielding myself five minutes for the first round of questions. First, just a very mundane thing. I want to get the terminology straight. Some have referred to hurricanes, some to cyclones, and I know there is another term, typhoons. What is—who wants to volunteer the—Dr. Landsea.

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Definition of Cyclone

Dr. **LANDSEA.** Yes. Chairman Ehlers, tropical cyclones is the generic term used around the world. Near India, they are called cyclones. In the northwest Pacific, they are called typhoons. And in the Atlantic and east Pacific, they are called hurricanes.

Chairman **EHLERS.** But they are all cyclones.

Dr. **LANDSEA.** They are all the same creature. Yeah.

Chairman **EHLERS.** Yeah. Except that they rotate differently in the southern hemisphere. Correct?

Dr. **LANDSEA.** Certainly.

Building Codes

Chairman **EHLERS.** Yes. Thanks to good old physics. Okay. I am interested in the comments—in a number of the comments made. If I could summarize what I hear you saying, we are doing much, much better on weather prediction. We are doing slightly better on weather warning, but we have a ways to go. But what we are not doing too well at is damage mitigation. And I don't know if that is a fair summary or not. But my question is getting at that last point. What can we do to reduce damage?

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First of all, we want to reduce loss of life. That is most important. And I don't know whether we have to require storm cellars for—or secure spots within our basements throughout the plains areas or what we might we require on that. But in terms of reducing building damage, do we have to revamp our national building codes to take account of the things that you are discovering in your work? And that is open to anyone who would like to answer that.

Dr. **MCCABE.** Mr. Chairman, you raise a—the central question, and that is how do you—how do you protect life and minimize the effects on the built environment. As engineers, we need the scientific information to better determine the loads and the demands that are going to be made on the structure. The building envelope consists of the exterior cladding, the windows, the roofing elements. In a severe wind, not necessarily a tornado, but in a severe wind, very often the failure modes—or the roof will be pulled off.(see footnote 6) And once the roof goes, the walls will fall over and the structure is gone.

In many other cases, there is wind borne debris that will cause tremendous numbers of injuries, from flying glass, things of that nature. So, in part, it is a building code problem. It is a loading—a knowledge of the loading issue. Better knowledge means more informed design decisions are made. In some cases, financial interests may dictate certain decisions being made that may, in the unlikely event of a severe wind, may cause damage and injury.

A lot of engineering decisions are based on probabilities, earthquake design, for example. So we may be looking at introducing that kind of philosophy into this whole problem. But the key, as I mentioned in my statement, is making sure that the systems are tied together—that you don't have a wall being pulled out, that you don't have schools being built with unreinforced masonry, that if there are buildings out there that have got long spans that they are able to take the loads adequately. So it becomes a fairly daunting task, but is one that really needs to be looked at.

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Chairman **EHLERS.** Continuing on that, are building practices part of the problem? Are there—I—maybe this story is a pocketful, but I have heard that Hurricane Andrew—the homes built by Habitat for Humanity withstood the storm much better than those built by other builders because with Habitat, it is volunteers that are pounding the nails in. They know when they have hit the crossbeams. Whereas with the automatic hammers, you are never quite sure. And I didn't really believe that until we had some remodeling done and right alongside one rafter there is a whole bunch of nails coming through. They obviously missed.

Dr. **MCCABE.** Well, I think you can—the only thing it takes is a look at some of the video where you will see one subdivision area on one side that is completely in ruins and you see a corresponding one which didn't do that badly.

Chairman **EHLERS.** But is that due to a code problem or to building practices problems?

Dr. **MCCABE.** It is partly a practice problem. It is partly a—there is a lot of financial pressure on builders to try and make profits to stay in business. A large part is the inspection. How do you assure that what the engineer or the architect has put down on the plans actually gets built in the field? I always tell my students that the best single thing that a building owner can do is hire the meanest, nastiest inspector to go out on the job site to make sure that they are getting their money's worth.

Chairman **EHLERS.** But homeowners are not likely to do that.

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Dr. **MCCABE.** That is right. That is right.

Dr. **SHEA.** Mr. Chairman, I would like—I am sorry.

Chairman **EHLERS.** Yes. Dr. Hayes.

Warning Lead Time

Dr. **HAYES.** Yes. Mr. Chairman, the discussion—your question was on mitigation and the focus is on buildings. There is another aspect to mitigation that I would like to air before the Committee, and that is lives saved. I think with regard to the D.C. tornado, our post analysis showed that we had about ten minutes lead time. Doug Hill mentioned getting the forecast out to the public. The process involved in warning the public about tornadoes involves detection, and that is the scientific aspect. And then there is the broadcast piece, and that is getting the word out. It has to be considered end-to-end.

I think certainly efforts to shorten the amount of time it takes to get that warning to the media and from the media to the public is important. But if you think about the 10-minute lead time, that is really as far as you can go. You have ten minutes to warn the public. And so that argues that we can't forget fundamental science.

I think back to the 1970's, when our National Weather Service lead time on tornadoes was virtually zero, and with an investment, we have gotten it up to ten minutes, but ten minutes can't be where we stop. I think scientifically if we set a national goal for the next decade or two—and it is not—this is not a short-term solution—to invest in the fundamental research so that we better understand the triggering mechanisms for tornadic and other severe weather that is an important aspect of any program to mitigate the effects of severe weather.(see footnote 7)

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Chairman **EHLERS.** Dr. Pietrafesa. Turn your microphone on, please.

Environmental Practices

Dr. **PIETRAFESA.** I would like to offer two other considerations as well. One is I think we need to look at better environmental management practices. That is that eliminating maritime forests or bulldozing sand dunes eliminate natural protection from storm surge and waves and the like. They break the energy up and the like. And so that is, we need to look at what we do to the environment in trying to live in that environment.

The second thing is that we also need to look at what we build where. It is not just how we build it. But building in flood plains, with low-cost housing or even mobile homes and the like, is putting people at risk where they needn't be.

And the third thing gets to Dr. Hayes' comments about a better—establishing a better understanding of the events themselves. The—we need to do more science in understanding the events. And I give you an example. While I alluded to the need to couple coastal ocean, estuarian, and inland flooding modeling, the reason I used Hurricane Floyd as an example—here was a weakening Category 2 storm that created unprecedented flooding in coastal North Carolina.

What actually occurred was that Hurricane Dennis, which was Category 1, when it was in the coastal ocean, sat off the coastal ocean—sat in the coastal ocean off the coast of North Carolina for six days. And in the process of doing that, that storm flooded a large estuarian system. And it added 80 percent more volume of water into that system than was there prior to the onset of that event. That 80 percent additional water actually caused backup of the rivers, the coastal plain estuaries that feed into that coastal lagunal system, and that backed up the rivers.

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So you need to have a coupled modeling capability. You need to understand what kinds of storms can create what kinds of outcomes in different parts of the country because these storms do have different characteristics and different outcomes differentially. And so Dr. Hayes is absolutely correct. We need to do more science into that and extend the science into the social and economic factors, which is what Congressman Etheridge's bill introduces. So I applaud Congressman Etheridge again. Thank you.

Chairman **EHLERS.** Thank you. My time has expired. Next, we recognize Congressman Etheridge.

Inland Flooding Warning Index

Mr. **ETHERIDGE.** Thank you, Mr. Chairman. And I think from the—what we have heard already from our Panel, again, let me thank you and the Ranking Member for pulling this together, because I think it is so important to what we are about. We have seen the damage and there have been—we have already heard today about the number of storms and the potential for the future and I think it ought to put us on notice.

And there was a 1970 report on—the Tropical Prediction Center put out showing that since 1970, freshwater flooding caused about 59 percent of the storm deaths in the United States. You know, it is coming from fresh water, from the storms that come in. And only about one percent of those deaths or loss of lives really came from the surge along the coastline. And I think we have done a pretty good job. I mean, I can admit, we have done a pretty good job of preparing people for the storms as they were coming. They understand the Saffir-Simpson Scale. They have been—we have done a good job of educating on that.

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That gets me to a couple of questions I want to ask in the limited time I have, because I think it does raise the issue of the inland problem. Because, as Dr. Pietrafesa was just talking about, in North Carolina and in other places, one in Houston and others, we were 150 miles inland and lost substantial toll of life. And a whole bunch of these issues came together and that is what raised my awareness of this.

I noticed in the written statements from you, Dr. Pietrafesa, and from you also, Dr. Shea, that you support the idea of a new kind of index or warning system as it relates to inland flooding associated with these tropical cyclones that we have had. I would ask Director Hayes, Dr. Hayes, you, and, Dr. Landsea, what your comments are on that, because I think that is important as we look at the whole integration of these issues.

Dr. **HAYES.** Well, sir, I think I would support that. I think if you are asking from a National Weather Service perspective, we do have a flood scale. Where that has weaknesses, I think we are prepared to work with both, as Dr. Pietrafesa said, physical and social scientists——

Mr. **ETHERIDGE.** Good.

Dr. **HAYES** [continuing]. To improve that, to involve academia, conduct user forums, and modify it and make it a better scale, one that communicates to people the threat that is out there. I think beyond that I would say, we are prepared to help train emergency managers, our own personnel, our Federal partners, meteorologists, representatives from the media, so that they could properly interpret what we are trying to communicate.

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And then I think the next step beyond that, as Dr. Pietrafesa mentioned, is our Advanced Hydrological Prediction Service, coupling that with available data and making sure that gets to the right people so that we can get those warnings out.

Dr. **LANDSEA.** I agree. What Dr. Hayes suggests makes sense. The Weather Service has been issuing forecasts for rainfall. It is just communicating that to the public. And I would say we do have a tremendous need for education still and communication. And our colleagues on—the TV weathermen, play a big role in that.

An example of a shortfall still was 1998 Hurricane George. It was coming off the coast of Cuba. It was forecast by the National Hurricane Center to be a Category 3, a major hurricane to hit in the Keys. They ordered mandatory evacuations and only about half the people left. Fortunately, that hit as a Category 2. But if it had been a 4, and that is the error bounds, one category is the best we can do right now 24 hours out, there would have been hundreds of people dead because they were stubborn and they stayed at home in the Keys. So there is a tremendous need for education still. I would have to disagree on that point. Thank you.

Communicating With the Public

Mr. **ETHERIDGE.** Well, I am going to ask this one of Mr. Hill because I hear so many times when we hear so many inches of rain, I think sometimes people—that is why I think it is so important that we educate with a new scale. If we tell people there is a Category 1, 2, 3, 4, or 5 hurricane, they understand that. If you tell them you are going to have a flash flood, what does that really mean? I think we get in some real trouble.

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And, Mr. Hill, I would ask this question of you of a well-known meteorologist who has traveled—been around the country and has a very large audience. I would appreciate your comments on the viewing public, whom you communicate with, of their ability to effectively judge the information that you give them from the Weather Service or others as it relates to where we are now or where we may need to go with these issues. In other words, if you say there is going to be a flash flood somewhere, what does that really mean to your viewing public? And that is one of the concerns I have. We just say that and they don't really know what we are talking about.

Mr. **HILL.** Absolutely, Mr. Etheridge. You are right about that. And I think what we can do, and do a better job of, is giving viewers a way to visualize what this would mean. A lot of times what we will do is we will, in a flash-flooding situation, be it tropical or non-tropical——

Mr. **ETHERIDGE.** Uh-huh.

Mr. **HILL** [continuing]. Flooding, we will try to give them another storm, from another date a few years earlier, to say this one, if you remember the one out in the Shenandoah Valley, June 1994, then this one will be a little bit worse than that or a little bit more water. We do our best to tell people how many inches of water it takes to float your car right off the surface of the roadway. So these simple little bullet points, I think, are the best we can do, obviously a better job.

But I think if I made one observation comment—that is that television viewers, when it comes to weather, when it comes to big storms, they like variety. They will go from station to station to station, listen to private weather service forecasts, albeit Accu-Weather or The Weather Channel, mix in with National Weather Service forecasts, then start flipping the radio and TV dials, and they hear a lot of times different versions of how much rain, how strong the winds. It is wintertime—how much snow. And I think, in general, the public is fairly confused. They kind of mix and match and make their own forecast.

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And that is one of the situations we have. When the National Weather Service comes out with their official forecast for a storm event, and then other people manipulate it, change it, add their own spin on it. And I think that is sometimes where we are doing a disservice to the general public.

Mr. **ETHERIDGE.** Thank you. And thank you, Mr. Chairman.

Chairman **EHLERS.** The gentleman's time has expired. I am extra pleased to recognize the gentleman from Minnesota, our most faithful attendee at these hearings.

Mr. **GUTKNECHT.** Thank you, Mr. Chairman.

Chairman **EHLERS.** Mr. Gutknecht.

Mr. **GUTKNECHT.** Well, this is certainly an interesting subject. And I want to thank the Chair and the staff for assembling such a distinguished Panel. And we appreciate your coming here today. And I—representing Minnesota, we get the best of all worlds. We are sort of at the north end of the Tornado Alley and we also are—generally speaking, can expect one or two blizzard events in our part of the world.

A couple of comments. I was—we were coming in from Dulles Airport the day of the big storm. And as I understand, there were people literally here in this building on the top floors looking eastward that could see the funnel cloud. And we were listening, I think, to your radio station, and they were doing an excellent job.

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But I—if I recall correctly, there were people calling in. They were taking calls on the air. And I was somewhat surprised how cavalier some of the people seemed to be about this. I don't know what you can do to get people to realize how serious it is. Because I remember, you know, the next morning when I read the paper and I saw the pictures of those two girls at the university there. And I thought, man, what a terrible tragedy. That didn't have to happen. I don't know what we can do to get the public and the broadcasters to work together to do a little better job of telling people. But I suspect, you know, the students at the university may not have been listening to talk radio that afternoon.

Mr. **HILL.** I think that is a very good possibility. Although warnings were issued for that one. What we do, and what I did that same afternoon—and, again, I don't know—I don't know the numbers, but a lot of people listened to that particular news station here in the Washington area. And I felt it very important, as this was unfolding, to give along with a warning and the location of exactly where the tornado was right now—that at our TV station, we have the advantage of having a real-time Doppler radar system of our own, so we can be very precise in where it is—but every time I went on the radio, I felt a need to not only tell where the storm was, where it was headed, but what to do if it comes your way.

Specifically, when this was straddling between Route 1 and I-95, north of the north side of the beltway, knowing that 95 was jammed packed with motorists, the last thing you want them to do is abandon their cars ——

Mr. **GUTKNECHT.** Right.

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Mr. **HILL** [continuing]. Because people would get hit by traffic and die from that. But I did include, as best I could, if you are on 95 and suddenly you feel the car rocking, get off to the side, try to find an underpass. If you hear a roar, keep your window down—if you hear what is the typical tornado sound and you see debris flying, you are better off to get out of your car, go into a ditch, even though you might get soaking wet, crouch, duck, and cover. And those are the kinds of safety points you have to push every time. But unfortunately, in the real world, that is not done.

A lot of times it is just rip and read. The National Weather Service says there is a tornado spotted here and there. It is moving here. And then back to music. And I think then generally broadcasters don't take it as seriously as they should.

Mr. **GUTKNECHT.** I would hope that you, Mr. Hill, and others—you know, this is something I am not sure that Congress is really well-equipped to deal with in terms of statutes. But I would hope that the National Association of Broadcasters would, as part of your next meeting, talk about this and see what we can do to do a better job.

Severe Winter Storms

I do want to get back to another point because, as the one—well, I guess, Dr. Ehlers thinks that he represents a cold weather climate. But we in Minnesota really do represent a cold weather——

Chairman **EHLERS.** If the gentleman would yield, I remind him I was born in Minnesota.

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Mr. **GUTKNECHT.** That is right. So, yeah, in fact, you were born out where they really have blizzards. Dr. Hayes, can you talk a little bit about what we are doing in the United States now in terms of research as it relates to winter storms, and particularly blizzards? Because those of us who experience those—we take them very seriously. We understand—in fact, we have done a pretty good job in Minnesota and throughout the Dakotas. We literally now put gates on the on-ramps and we keep people from getting out on the highways when the weather is coming in. What else are we doing? Are we doing enough and can we do more?

Dr. **HAYES.** Well, we can always do more. I will outline for you areas within the U.S. Weather Research

Program. One of the things that has lagged behind—and we talked about the improvements we have made in forecasting the occurrence of severe storms—but it is skill in heavy precipitation forecasting, that is both in cold climates and in warm climates. It has not kept up with the rest. And one of our foci within the U.S. Weather Research Program is to improve quantitative precipitation forecasts.

I mentioned in my opening remarks the weather research and forecast model. I have great confidence that we are making strides in our understanding of the dynamics of the atmosphere. And it is just a matter of taking that extra step, doing the applied research necessary to convert that understanding, and it is something that we can use to forecast weather. And I think with that commitment and with what we are doing in the program, we will be able to forecast.

And just very briefly, you know, if you recall last winter we had forecast a heavy snow event for D.C. The people in D.C. didn't get the snow forecast by the National Weather Service. But if you remember watching on New Year's Eve how Mayor Guiliani had the snow plows prepared. And it was because we did that. And if you look back to what we did, we actually had the first ideas of those storms five days in advance. I think when I was a kid, if I could know about snow the next day, that was saying a lot. So I think we are making progress in that area. It just needs to be more.

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Mr. **GUTKNECHT.** Thank you.

Chairman **EHLERS.** The gentleman's time has expired. Since we have a few members here, I believe we can have a second round of questions for those interested. So I will yield myself five minutes. I would just observe, Mr. Gutknecht, I remember very fondly the blizzards of my youth. We would just hold up for three days in the house. The kids thought it was great; the parents were going crazy. And after it was all over, I remember 1 year we had to scoop the snow away from the door from the inside because the wind—the snow covered the door of our house. Those are fearsome storms.

CO C**ONCENTRATION AND** H**URRICANES**

I would like to address a few other issues. And one is, Dr. Landsea, a question about hurricane activity. Is the increasing concentration of carbon dioxide in the atmosphere and in the water a factor at all in hurricane intensity?

Dr. **LANDSEA.** The original suggestions about 20 years ago, or 15 years ago, were that increased carbon dioxide would cause warming of the tropical oceans and, therefore, an increase in hurricane intensity, because hurricanes are, in essence, a heat engine. But in recent years, we have realized, because of the warming in the upper atmosphere, that extra energy in the ocean isn't going to really be tremendously realized. So the best estimate right now is hurricanes in a doubling of carbon dioxide may increase about five percent in wind speed.

Now, that still is not zero. But in comparison to a doubling, if it—because of this natural cycle, we are going from one and a half to three strong hurricanes a year, the global warming aspects in hurricanes are very marginal. It is not significant. I am not saying global warming isn't important for other factors, but global warming and hurricanes is not an issue.

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Chairman **EHLERS.** Is it possible that there might be a location shift as a result of that? That you would have hurricanes occurring further north than you otherwise might?

Dr. **LANDSEA.** No. The best that we can understand is that the regions where we get hurricanes are typically where you get large thunderstorm activity in the tropics. And in the subtropics, you get sinking. It is the end of the Hadley cell circulation. Those are going to stay in place. So even though the threshold for hurricane activity, it is about 80 degrees Fahrenheit, that will probably go up in a doubled carbon dioxide world. So the areas where they have warmed is going to stay about the same it looks like.

Flood Plain Restrictions

Chairman **EHLERS.** Thank you. On the issue of flooding, is it time for us to review the flood plain restrictions in this Nation and perhaps increase the boundaries that we normally assign to flood plains? And this, of course, has implications for flood insurance that is available and so forth. Or are the storms and the flooding no worse now than they were let us say 50 years ago? Anyone?

Dr. **SHEA.** Mr. Chairman, I guess what I would say to you is this—that, generally speaking, while there may have been some changes in weather patterns, what we have found in the National Flood Insurance Program is that when mapping is done accurately and building is done appropriate to the hazard, that generally speaking the impacts are very limited. So to the extent that we are successful in those endeavors, that is part of the issue.

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But I think the other thing that has been spoken about this morning that needs to be taken into account is this, which is, generally, what we do have is more people in contact with more hazardous areas in this country. And right now, one of the constituent groups that we work with, the Association of State Flood Plain Managers, is beginning to afford an idea. It is called no-adverse impact. And the notion there is that if you do something in a flood plain, that you then make sure you mitigate whatever the impact of that issue is. So if you cause a rise in flood waters on your neighbor's property, then you need to mitigate that as part of that effort. I think that is a very sensible approach—letting people be responsible, but asking them really to do it to higher standards than we are currently looking at right now.

Chairman **EHLERS.** So in other words, a lot of the increased damage from flooding is caused by increased population, what you saw in Dr.——

Dr. **SHEA.** Well, there is no—again, there is no question about that. But if you build appropriate to the hazard——

Chairman **EHLERS.** Yes.

Dr. **SHEA** [continuing]. That you are in—and it is almost without regard to the type of hazard, there are ways to mitigate the built environment. Probably the major exception to that is in the wind hazard area. And, you know, generally speaking, you either build against a hazard, you insure against it, or you warn against it. And the one hazard area of warning is clearly the most effective mechanism out there right at the moment.

FEMA has fostered some building design practices. We have a safe room initiative that we use particularly out in the west, in Oklahoma and Kansas and areas like that. This is an interior room where we have come up with a design that will protect against 250 mile-an-hour winds. So we know building practices can be successful when they are employed.

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Flood Modeling at FEMA and the National Weather Service

Chairman **EHLERS.** And is there an overlap between the activities of the weather service and FEMA in terms of the mapping and other activities you are doing, and could there be more coordination there?

Dr. **SHEA.** I don't think there is any question. Dr. Hayes and I were talking just before we were sitting down to testify this morning. And we both agree more collaboration is necessary. It is critical. We are doing a lot of collaboration already, but I think there is no question that more would benefit everybody involved.

Chairman **EHLERS.** Do you think you would need statutory authority to do more or is it something that can be done administratively?

Dr. **SHEA.** From my perspective, I don't think statutory, you know, guidance is necessary. I think we are —it is just a—in many respects, I guess the—what I would do is compare this a little bit to what my children teach me about life, which is, you know, 35 or 40 years ago, when I was growing up as a younger person, I wasn't very sensitive about throwing a can out of the car window into the environment.

Chairman **EHLERS.** Yeah.

Dr. **SHEA.** Now, my kids are teasing me about that. And I think that is—that we are sort of in that stage where we are beginning to peer into—and beginning to understand more about living in the environment we live in. And so we need to educate ourselves as a key element of this.

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Chairman **EHLERS.** Dr. Hayes, comment?

Dr. **HAYES.** Yes, sir. I would wholeheartedly agree. And I would just add to that in the budget environment we are in right now, it only makes sense to——

Chairman **EHLERS.** In what?

Dr. **HAYES.** In the budget environment we are in right now, it only—with FEMA as a major service area of the National Weather Service, it only makes sense to collaborate with them on architectures to pass information. It benefits us both. So I don't think we need the statutory guidance.

Chairman **EHLERS.** My time has expired. But Dr. Pietrafesa is eager to add to this discussion.

Dr. **PIETRAFESA.** I just wanted to comment that I also believe that the flood mapping capability is on the verge of being greatly improved. And that is because the science of inundation, water inundation and retreat, is improving. That is that the physical and mathematical capabilities have gotten to the point now where within the models themselves we now have conservations of mass and volume and we can put absorption in as boundary conditions and the like.

And so what it really requires is improved understanding of the biota and the soils, the conditions that exist within the areas adjacent to the rivers and the estuaries. It also requires that there be better topography information. To the degree that the topography improves, where you have vertical topography improvements, then you have incredible improvements in your horizontal inundation and retreat capabilities mathematically and physically speaking.

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Chairman **EHLERS.** Uh-huh.

Dr. **PIETRAFESA.** So the—science has been advanced and what we need is better topography and better information about the topography—the land. Thank you.

Chairman **EHLERS.** Thank you. My time has more than expired. Mr. Etheridge.

Forecasting Different Rainfall Events

Mr. **ETHERIDGE.** Thank you, Mr. Chairman. Dr. Hayes, I noticed in your testimony that two of the goals of the USWRP deal with extending and improving participation forecast, and the difference being one goal addressing hurricanes and the other addressing winter storms and torrential spring and summer rain. Could you discuss the difference between forecasting rainfall and flooding from hurricanes versus the same associated with other rain events?

Dr. **HAYES.** Well, I guess one would like to think that precipitation forecasting is precipitation forecasting. But there are some unique dynamics in tropical systems. So targeted research into tropical cyclones is absolutely essential if we want to improve there. I don't know that I could say much more. Does that answer your question, sir?

Inland Flooding Warning Index

Mr. **ETHERIDGE.** That probably covers it. Dr. Pietrafesa, could you elaborate on how you see an inland flooding index similar to the Saffir Simpson? And would it be geared more for the benefit of scientists or meteorologists or should it be a tool for the general public or a combination?

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Dr. **PIETRAFESA.** I believe it should be focused as a tool for the general public. That is that it needs to —it needs to be an index that is easily communicated and conveys the information that the general public and emergency management folks, planners, and policy folks can very well and easily understand. And so I believe it needs to be end to end. It actually has to go from the physical mathematical sciences up through, as I said, the social and economic impacts.

And it needs to be very site specific—that is, location specific, so that it can meld—it will probably have to change as we move up and down our coastlines and even in the areas of the Great Lakes and the like. But I believe it is a model that could actually—or it is an index that could actually be ported nationally to—as we modernize our hydrologic forecast capabilities. And so I think it really needs to be focused on the public and communicating the risks and hazards and the potential damages that can be done through flooding.

Mr. **ETHERIDGE.** Thank you. Thank you, Mr. Chairman. One thing I think people understand is when you are forecasting weather, it is complicated. And when we are dealing with power, it is more so. But differing parts of the country really have different problems. But in the end, it is a national issue that affects us all and what happens even offshore has a significant impact to where we are. And Mr. Chairman, I appreciate you calling this meeting and thank you for the opportunity to participate. And I thank again the panelists for their very enlightening and substantive discussions this morning. And I yield back.

The Media's Role in Warning the Public

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Chairman **EHLERS.** I want to pursue one other thing I didn't have time for before, and that is, Mr. Hill, I deeply respect you based on the comments you have made here about what your duties and responsibilities are, and I wish that were shared by all individuals in the broadcast media. I fear, in some cases, the weather aspect has almost reached the point of entertainment rather than information dispensing. But you play an extremely valuable role, not just in providing the weather forecast, but educating the public about weather. And I am very pleased that on The Weather Channel, I think they are doing a better and better job of educating people, particularly now with their special programs about certain aspects of weather. So I commend you for that.

I want to ask you, I was struck too in this recent tornado at how little people in this area know about tornadoes. For example, I saw a large number of staff members pressed up against the window watching the funnel cloud. And I told them—I said, don't forget, that is the most dangerous place to be if a tornado strikes. So don't stay there. But also I find that people in this area tend to treat tornadoes as sort of a curiosity, as something not to be concerned about. It always hits the other person. But also, they don't know what to do in it.

You know, as I said, they were standing against the window watching, but the two young ladies killed at the University of Maryland were violating one of the first principles of tornadoes, and that is, get out of your car and seek shelter because a car is not a safe place to be in a tornado. They assumed it was.

We have an immense educational task here. And I am interested in your ideas—first of all, how the media can help with that education. And, secondly, how we can get—not just in your case where you do an excellent job of alerting people to emergencies—but are there ways we can do that with all the electronic media, including those that don't have trained personnel? Could they simply be required to read a short script from the Weather Service or something of this sort? I would appreciate any comments you might have.

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Mr. **HILL.** Yes, sir. Routinely when the National Weather Service issues a warning for tornadoes, at the bottom of the warning are cautionary statements. They will tell people exactly what to do. In the reality—in the real world, though, a lot of time the broadcasters, when relaying those warnings, do not follow all the copy and do not read the advisory at the end of the bulletin from the National Weather Service that tells people precisely what to do—to get away from windows, to go to a basement. If there is no basement, get to an interior room without windows. And then all the other things that have been prescribed.

I think a lot of it comes to—first of all, a lot of weather folks from the Weather Service and in the private world visit schools regularly and give these kind of drills. I know many elementary schools and junior high schools in this area do that routinely. But I think your observation about the public in general is absolutely on the money, that it is just kind of an unreal thing. You know, a tornado always happens somewhere else. You will see the video that people will take.

As a matter of fact, one student at the university—we showed the video on TV, where she stood there in the window as a F–3 tornado is approaching. And from what I understand from one our reporters that spoke with her, she was just frozen. She was so—was just frozen by the event—that it was so spectacular and couldn't believe what she was seeing that she was just frozen and prevented from taking any sensible action. And I think that happens in some cases.

But generally, people just don't take it seriously. In many things in life, they don't take it seriously. Using seat belts until something happens to a family member—if only they had worn their seat belt, they would still be here.

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And I think in weather emergencies, it is very similar. It is human nature, when a hurricane warning is issued for the coast, the first thing people will do is rush to Ocean City to experience it firsthand rather than get out of town. And I think that is human nature, but I think we can do a better job to demonstrate how dangerous these storms are and how foolish some of the activities of private citizens can be.

Chairman **EHLERS.** Thank you very much. I appreciate your comments. I don't know if any of you, the rest of you—yes, Dr. Hayes.

Dr. **HAYES.** Well, Congressman Ehlers, every time I see on the news or read in the paper that there is a loss of life related to weather, I say, as much as we have done, we have got to be able to do better. And when I look at this area, I think it strengthens our resolve in the National Weather Service to do better outreach, to work better with the media, and with the private sector to help in that education.

There is one capability I didn't mention earlier that I don't know if you are aware of. It is called the NOAA weather radio. We have got 91 percent of the country covered. Our goal is to get 95 percent coverage. You talk about timely warnings and getting severe weather out to the public. It is educating the public—that they can get that message fairly quickly. Thank you.

Inland Flooding Warning Index

Chairman **EHLERS.** Thank you. And I—one last question. And I have to tell you this was handed to me by my staff members. So I don't—I am not sure if I fully understand it. But the question is, who should do—or which agency should do the warning index we have talked about? And should it be just for flooding or hurricanes or should we have it for other cases as well? I would welcome any comments or——

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Dr. **SHEA.** I guess from a FEMA perspective, Mr. Chairman, we would say the National Weather Service would be the appropriate Federal agency to look at that issue and come to conclusions. We would certainly be happy to collaborate with them on that and we would be anxious to do it. But I think the National Weather Service would be——

Chairman **EHLERS.** Dr. Hayes.

Dr. **HAYES.** Well, as I said in my earlier remarks, we do have a flooding scale and I think that a natural place to start, is to take a look at that, work with FEMA, work with the local communities, find out where it is working. We need to involve academia, social scientists in that. And is that communicating to the public and, where it is not, we need to improve it, and I think we would be happy to take the lead.

Chairman **EHLERS.** Dr. Pietrafesa.

Dr. **PIETRAFESA.** I would second what the two gentlemen said, but also I would like to put in a plug for the role of the university community in this activity. We have the breadth and depth of coverage from the physical sciences through the social and economic sciences as well. And we have a great deal to offer in terms of not only doing the kinds of retrospective studies that need to be done in collecting the data, but also putting the—putting this kind of an index together, along with the Weather Service and emergency management—Federal Emergency Management Agency as well. Thank you.

Conclusion

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Chairman **EHLERS.** Well, thank you all very much. I appreciate your participation. If I had to sum it up without thinking a great deal about it, I would say what we have learned here, first of all, is that the university community or the research community could certainly use more funding to do the research and develop better and more accurate models. The building trades could learn a great deal about better construction and providing not only building integrity, but safety for occupants as well, having a safe place somewhere in the house where people can move.

And the Weather Service should continue with its fine work and improve its accuracy and warning ability. The FEMA and the Weather Service and Mr. Hill and his colleagues all should do a better job of educating the public about it, but also we have to get it into the schools rather directly. I think that is an essential part because what you learn there tends to stay with you. I mean, we just routinely, every spring, replace the batteries in our portable radio. And I probably wouldn't even have a portable radio if we didn't have tornadoes. But that is just standard practice. And when the sirens go, you grab the radio, the flashlight, and you head for the basement. That sort of education. If you can get it done early, it sticks with someone for life.

So I really appreciate the insights that you have brought before us. Thank you very much for your participation. We will continue to work on this issue, particularly the bills that have been introduced, as well as the authorizing bills.

The money, increased money for research—as you probably know, I have been the champion of that in the Congress. I have devoted an inordinate amount of my time and effort to increasing research funding in all areas. The success has certainly not been what I would like, but it is certainly far better than what it would have been had I not been in Congress. So the lesson that the Research Community can take back—get more scientists to run for Congress. It is a little tiring being the only one who really is pursing this issue of funding.

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So thank you very, very much for your participation and your time. We appreciate it. And with that, I declare the meeting adjourned.

Let me incidentally just mention that the record will remain open for additional questions. You may receive questions from us and we would appreciate responses from you. Thank you very much.

[Whereupon, at 11:42 a.m., the Subcommittee was adjourned.]

Appendix 1:

Legislation

107**TH CONGRESS**

1**ST SESSION**

H. R. 2486

To authorize the National Weather Service to conduct research and development, training, and outreach activities relating to tropical cyclone inland forecasting improvement, and for other purposes.

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IN THE HOUSE OF REPRESENTATIVES

JULY 12, 2001

Mr. **ETHERIDGE** (for himself, Mr. **BOEHLERT**, Mr. **HALL** of Texas, Mr. **BRADY** of Texas, Mr. **MCINTYRE**, Mr. **JONES** of North Carolina, Mr. **PRICE** of North Carolina, Mr. **BARRETT** of Wisconsin, Mr. **MARKEY**, Ms. **JACKSON-LEE** of Texas, Ms. **MCKINNEY**, Mrs. **CHRISTENSEN**, Mr. **LANTOS**, Mr. **HOEFFEL**, Mrs. **CLAYTON**, Mr. **CRAMER**, and Mr. **DIAZ-BALART**) introduced the following bill; which was referred to the Committee on Science

A BILL

To authorize the National Weather Service to conduct research and development, training, and outreach activities relating to tropical cyclone inland forecasting improvement, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. SHORT TITLE.

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This Act may be cited as the "Tropical Cyclone Inland Forecasting Improvement and Warning System Development Act of 2001".

SEC. 2. AUTHORIZED ACTIVITIES.

The National Weather Service shall——

(1) improve the capability, through research and modeling, to forecast accurately inland flooding associated with tropical cyclones;

(2) develop, test, and deploy a simple and distinct inland flood warning index or system, for use by the public and emergency management officials, that clearly defines inland flood risks and dangers;

(3) train emergency management officials, National Weather Service personnel, meteorologists, and others as appropriate regarding improved forecasting techniques for inland flooding, risk management techniques, and use of the inland flood warning index or system developed under paragraph (2); and

(4) conduct outreach and education activities for local meteorologists and the public regarding the dangers and risks associated with tropical cyclone-induced inland flooding and the use and understanding of the inland flood warning index or system developed under paragraph (2).

SEC. 3. AUTHORIZATION OF APPROPRIATIONS.

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There are authorized to be appropriated to the National Weather Service for carrying out this Act $1,150,000 for each of the fiscal years 2002 through 2006. Of the amounts authorized under this section, $250,000 for each fiscal year shall be available for a grant to an institution of higher learning equipped to further the development and application of an interactively coupled modeling, environmental, and predictive system to improve the ability to forecast coastal and estuary-inland flooding associated with tropical cyclones.

SEC. 4. REPORT.

Not later than 90 days after the date of the enactment of this Act, and annually thereafter through fiscal year 2006, the National Weather Service shall transmit to the Committee on Science of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate a report on its activities under this Act and the success and acceptance of the inland flood warning index or system developed under section 2(2) by the public and emergency management professionals.

[Discussion Draft]
October 10, 2001

107**TH CONGRESS**
1**ST SESSION**
H. R. **XX**

IN THE HOUSE OF REPRESENTATIVES

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Mr. **MOORE** introduced the following bill; which was referred to the Committee on **XXXXXXXXXXXXXXX**

A BILL
To reduce the impacts of hurricanes, tornadoes, and related natural hazards through a program of research and development and technology transfer, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. SHORT TITLE.

This Act may be cited as the "Hurricane, Tornado, and Related Natural Hazards Research Act".

SEC. 2. FINDINGS.

The Congress finds the following:

(1) Natural disasters cause enormous loss of life. Almost all States and territories are at risk from the effects of 1 or more types of natural disaster. Coastal States and many island States and territories are vulnerable to the hazards of windstorms. All Midwest, Southern, and Mid-Atlantic States are vulnerable to the hazards of tornadoes and thunderstorms and increased building activity is occurring in high-risk areas such as the seashore and "tornado alley".

(2) Hurricanes, which combine high winds and flooding, and related natural disasters cause enormous loss of life, injury, destruction of property, and economic and social disruption, as evidenced by the 56 deaths and $6,000,000,000 in property damage in 1999 from Hurricane Floyd. From 1990 to 1999 hurricanes caused an average of 14 deaths and $4,970,000,000 in property losses annually while tornadoes and other windstorms caused over 58 deaths and $871,000,000 in property losses annually.

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(3) Improved windstorm and related natural hazard reduction measures have the potential over the next 10 years to reduce these losses that will only increase if steps are not taken to help communities reduce their vulnerability. These measures include—

(A) cost-effective and affordable design and construction methods and practices;

(B) effective mitigation programs at the local, State, and national level;

(C) informed land use decisions;

(D) impact prediction methodologies and early warning systems;

(E) application of research results; and

(F) public education and outreach programs.

(4) Engineering research needs to address both improving new structures and retrofitting existing ones.

(5) There is an appropriate role for the Federal Government in the collection, preparation, coordination, and dissemination of windstorm and related natural hazards reduction information in order to protect public health and safety and in increasing public awareness of the dangers of these hazards and of affordable steps homeowners can take to preserve life and property. Improved outreach and implementation mechanisms are needed to translate existing information and research findings into usable, state-of-the-art specifications, criteria, and cost-effective practices for design and construction professionals, State and local officials, manufacturers, and the public.

(6) An effective Federal program in windstorm and related natural hazard reduction will require interagency coordination, input from individuals and institutions outside the Federal Government who are expert in the sciences of natural hazards reduction and in the practical application of mitigation measures, and improved mechanisms for the transfer of new knowledge to State and local officials, to homeowners, and to the design and construction industry. Tax credits are an effective incentive for helping homeowners apply mitigation measures.

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(7) Windstorms and related natural hazards are a worldwide problem, and international cooperation is

desirable for mutual learning and mitigation.

SEC. 3. DEFINITIONS.

In this Act:

(1) The term "Director" means the Director of the Office of Science and Technology Policy.

(2) The term "related natural hazards" means any naturally destructive environmental phenomena related to windstorms such as flooding, wildfires, and hail.

(3) The term "State" means each of the States of the United States, the District of Columbia, the Commonwealth of Puerto Rico, the United States Virgin Islands, Guam, American Samoa, the Commonwealth of the Northern Mariana Islands, and any other territory or possession of the United States.

(4) The term "windstorm" means any storm with a damaging or destructive wind component, such as a hurricane, tropical storm, tornado, or thunderstorm.

SEC. 4. NATIONAL WINDSTORM AND RELATED NATURAL HAZARD IMPACT REDUCTION PROGRAM.

(a) **INTERAGENCY GROUP**.—Not later than 90 days after the date of the enactment of this Act, the Director shall establish an Interagency Group consisting of representatives of appropriate Federal agencies, including the National Science Foundation, the National Oceanic and Atmospheric Administration, the National Institute of Standards and Technology, the Department of Energy, and other agencies with jurisdiction over housing, construction, and natural disaster mitigation and relief, to be responsible for the development and implementation of a coordinated Federal windstorm and related natural hazards reduction research, development, and technology transfer program based on identified public needs. In establishing the Interagency Group, the Director is encouraged, where appropriate, to designate lead agencies and to preserve existing programs and functions of Federal agencies and organizations, and shall ensure regular agency coordination and information sharing.

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(b) **OBJECTIVE**.—The objective of the windstorm and related natural hazard impact reduction program is the achievement, within 10 years after the date of the enactment of this Act, of major measurable reductions in losses that would otherwise have occurred to life and property from windstorms and related natural hazards. The objective is to be achieved through the creation of a program involving cooperation among governments at all levels and the private sector featuring—

(1) pertinent basic research and applied research based on identified public needs, which takes into account locality-specific weather, susceptibility to natural hazards, design and construction practices, and performance of the built environment during windstorms and related natural hazards;

(2) better understanding of costs and benefits associated with natural hazard impact reduction;

(3) systematic collection of physical and performance data for buildings and other structures for use in developing and deploying mitigation measures;

(4) an ongoing program of information dissemination on cost-effective and affordable hazard reduction research results and hazard-resistant building construction techniques to industry, State and local governments, homeowners, and the general public;

(5) improved technology for loss estimation, risk assessment, hazard identification, prediction, warnings, advanced planning, and disaster response;

(6) increased public awareness of the dangers of windstorms and related natural hazards, and the value of taking preventative action to preserve affected property and life; and

(7) priority attention to critical lifelines, including infrastructure and utilities, that are especially needed in

time of disaster.

(c) **RESEARCH AND DEVELOPMENT ELEMENTS**.—The research and development elements of the program may include—

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(1) peer-reviewed research and development on and demonstration of disaster-resistant systems, based on identified public needs, and materials for new construction and retrofit of existing construction, including composite materials; building envelope components, including windows, doors, and roofs; structural design; and design and construction techniques, through physical testing and postdisaster assessments, and through computer simulation when appropriate, taking into consideration life safety and cost-effectiveness, affordability, and regional differences including susceptibility to windstorm and related natural hazards;

(2) development of quantitative assessment techniques to evaluate the direct, indirect, and societal costs and benefits associated with natural hazards, including exploration of mitigation measures that could reduce windstorm vulnerability, and to effectively exploit existing and developing mitigation techniques;

(3) development of mechanisms for collecting and inventorying information on building systems and materials performance in windstorms and related natural hazards, information on identified public mitigation priorities, and other pertinent information from sources such as the construction industry, insurance companies, and building officials;

(4) development of cost-effective and affordable planning, design, construction, rehabilitation, and retrofit methods and procedures, including utilization of mitigation measures, for critical lifelines and facilities such as hospitals, schools, public utilities, and other structures that are especially needed in time of disaster;

(5) research and development on wind characterization and micro-climates and on techniques, methodologies, and new technologies for the mapping in finer detail of windstorms and related natural hazard risks, to be coordinated with the mapping of other natural and manmade hazards;

(6) development of improved loss estimation and risk assessment systems for predicting and evaluating damaging windstorm impacts and for identifying, evaluating, and reliably characterizing windstorm hazards; and

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(7) development of improved approaches for providing emergency services, reconstruction, and redevelopment after a windstorm or related natural hazard event.

(d) **TECHNOLOGY TRANSFER**.—The technology transfer elements of the program shall include—

(1) the collection, classification, presentation, and dissemination in a usable form to Federal, State, and local officials, community leaders, the design and construction industry, contractors, home owners, and the general public, of research results, cost-effective construction techniques, loss estimation and risk assessment methodologies, and other pertinent information regarding windstorm phenomena, the identification of locations and features which are especially susceptible to natural hazard damage, ways to reduce the adverse consequences of natural hazards, and related matters;

(2) in coordination with the private sector, academia, and the States, curriculum development and related measures to facilitate the training of employees of the design and construction industry, the insurance industry, and State and local governments, and other interested persons; and

(3) development of an outreach effort to increase public and community awareness, including information related to windstorm and related natural hazard mitigation.

(e) **IMPLEMENTATION PLAN**.—The Interagency Group established under subsection (a) shall refine, in conjunction with appropriate representatives of State and local units of government and private sector organizations, the objective stated in subsection (b), develop measurements related to the objective, including emphasis on safety, cost-effectiveness, and affordability, and develop a 10-year implementation plan for achieving the objective with a strategic review of goals and objectives every 3 years, working in coordination with the private sector and State and local government for implementation in all appropriate instances. Not later than 210 days after the date of the enactment of this Act, the Interagency Group shall submit to the Congress the implementation plan. The plan shall include—

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(1) a statement of strategic research and development goals and priorities;

(2) plans for the development of improved forecasting techniques for windstorms, early warning systems, and systems for comprehensive response;

(3) plans for the development of a systematic method for collecting an inventory of buildings, building components, and damage to buildings from natural hazards;

(4) a strategy to implement the transfer of technology and information to State, county, local, and regional governmental units and the private sector for appropriate implementation of research and development results;

(5) provisions for outreach and dissemination, on a timely basis, of—

(A) information and technology in a form that is of use to the design professions, the construction industry, and other interested parties; and

(B) other information and knowledge of interest to the public to reduce vulnerability to wind and related natural hazards;

(6) a description of how Federal disaster relief and emergency assistance programs will incorporate research and development results;

(7) establishment, consistent with this Act, of goals, priorities, and target dates for implementation of the program;

(8) assignment of responsibilities with respect to each element of the program that does not already have a Federal lead agency;

(9) a description of plans for cooperation and coordination in all phases of the program with interested governmental entities in all States, particularly those containing areas of high or moderate wind and related natural hazard risk; and

(10) staffing plans for the program and its components.

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(f) **PARTICIPATION**.—The implementation plan shall complement existing Federal research programs and shall avoid duplication of existing programs including earthquake programs whenever possible and assign responsibilities to Federal agencies with existing expertise.

(g) **BUDGET COORDINATION**.—The Director shall each year, after consulting with the Interagency

Group established under section 4(a), provide guidance to the other program agencies concerning the preparation of requests for appropriations for activities related to this Act, and shall prepare, in conjunction with the other program agencies, an annual program budget to be submitted to the Office of Management and Budget. Each program agency shall include with its annual request for appropriations submitted to the Office of Management and Budget a report that—

(1) identifies each element of the proposed program activities of the agency;

(2) specifies how each of these activities contributes to the program; and

(3) states the portion of its request for appropriations allocated to each element of the program.

(h) **MANUFACTURED HOUSING STANDARDS**.—Nothing in this Act supersedes any provision of the National Manufactured Housing Construction and Safety Standards Act of 1974. No design, construction method, practice, technology, material, mitigation methodology, or hazard reduction measure of any kind developed under this Act shall be required for a home certified under section 616 of the National Manufactured Housing Construction and Safety Standards Act of 1974 (42 U.S.C. 5415), pursuant to standards issued under such Act, without being subject to the consensus development process and rulemaking procedures of that Act.

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SEC. 5. NATIONAL ADVISORY COMMITTEE FOR WINDSTORM AND RELATED NATURAL HAZARDS IMPACT REDUCTION.

(a) **ESTABLISHMENT**.—A National Advisory Committee shall be established to review progress made under the program established under section 4, advise on any improvements that should be made to that program, and report to the Congress on actions that have been taken to advance the Nation's capability to reduce the impacts of windstorm and related natural hazards.

(b) **MEMBERSHIP**.—The Advisory Committee shall be composed of no more than 21 members to be appointed by the President (one of whom shall be designated by the President as chair). The members shall include representatives of a broad cross-section of interests such as the research, technology transfer, architectural, engineering, and financial communities; materials and systems suppliers; State, county, and local governments concerned with the reduction of windstorm and related natural hazards; the residential, multifamily, and commercial sectors of the construction industry; and the insurance industry, and other representatives (not including members of Federal agencies) from areas impacted by windstorms and related natural hazards.

(c) **COORDINATION**.—The Advisory Committee shall coordinate with existing advisory committees of the Federal Government and of the National Academies of Science and Engineering.

(d) **ANNUAL REPORT**.—The Advisory Committee shall provide a summary report to Congress each year.

(e) **EXEMPTION**.—Section 14 of the Federal Advisory Committee Act shall not apply to the Advisory Committee established under this section.

SEC. 6. ANNUAL REPORT.

The Interagency Group established under section 4(a) shall, within 180 days after the end of each fiscal year, submit a report to the Congress describing the status of the windstorm and related natural hazards reduction program, describing progress achieved during the preceding fiscal year, by government at all levels and by the private sector, toward achieving the objective stated in section 4(b) and implementing the plan developed under section 4(e), and including any amendments to the implementation plan. Each such report shall include any recommendations for legislative and other action the Interagency Group considers necessary and appropriate.

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SEC. 7. AUTHORIZATION OF APPROPRIATIONS.

There are authorized to be appropriated to carry out activities under this Act $50,000,000 for fiscal year 2003, $100,000,000 for fiscal year 2004, and $150,000,000 for fiscal year 2005.

LEGISLATIVE SUMMARY FOR REPRESENTATIVE MOORE'S
Wind Storm Hazard Reduction Research and Technology Transfer Act

While wind storms and related natural disasters including hurricanes and tornadoes cause dozens of deaths and billions of dollars in property damage each year, the Federal efforts related to these storms is aimed more at aiding victims than at understanding how to minimize loss of life and property and helping homeowners implement that knowledge. The Wind Hazard Reduction Caucus within the Congress and the Wind Hazard Reduction Coalition in the private sector were formed to address this situation. Both groups are dedicated to a major, measurable reduction in loss from windstorms over the next decade.

The Windstorm Hazard Reduction Research and Technology Transfer Act is a first legislative step in achieving these groups' goals. The Act's major features follow:

Coordination of Federal wind hazard reduction efforts through a multi-agency National Windstorm Hazard Reduction Program.

Linkage of all aspects of the program to the goal of a major, measurable reduction in losses of life and property to wind storms within 10 years of the date of enactment.

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A list of 11 areas where wind hazard reduction research and development with an emphasis on developing cost-effective and affordable improvements can pay big dividends.

Establishment of a wind hazard reduction technology transfer program.

Delivery to Congress of a 10-year implementation plan with measurable goals that has been coordinated with appropriate representatives of state and local government and the private sector and of an annual update of progress towards these goals.

Establishment of a National Advisory Committee for Windstorm Hazard Reduction.

Authorization of appropriation levels that could bring the program to parity with the Federally funded earthquake research program over a three-year period.

We expect that a companion bill to provide federal tax credits to help ease the cost to homeowners of retrofits will be introduced in the near future.

Section by section analysis

Section 1. Short Title. The bill is to be cited as the "Windstorm Hazard Reduction Research and Technology Transfer Act.

Section 2. Findings. The Act's findings describe the substantial destruction caused by wind storms, methods of reducing damage, the benefits of a well-funded wind research program, efforts required to transfer hazard reduction knowledge, and the appropriate Federal role in a wind hazard reduction program which includes Federal tax credits to help homeowners afford the cost of mitigation measures.

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Section 3. Definitions. Terms defined for this Act are Director as Director of the Office of Science and Technology Policy, State, United States, and windstorm.

Section 4. National Windstorm Hazard Reduction Program. This section establishes an Interagency Group of agencies involved in research, weather, natural disaster mitigation, housing and construction, and related standards and gives the group responsibility to develop and implement a coordinated Federal program for wind hazard reduction research, development and technology transfer. The program is to have the objective of attaining a major, measurable reduction in wind-related loss of life and property within ten years and is to build on current agency and private sector efforts. Program elements are to include peer-reviewed basic and applied research, better understanding of impediments and disincentives to wind hazard reduction, a better inventorying of information on building components and materials and their interactions, better dissemination of wind hazard reduction technology, techniques and knowledge, improved technology for weather prediction and disaster response, and priority attention to structures and lifelines needed during a time of disaster. The research and development program may include basic weather research, research on materials and building technologies including retrofits, and mapping techniques. The technology transfer program is to include information collection, classification, presentation and dissemination of research results and other pertinent information to state and local officials, the private sector, and the general public and a delineation of responsibilities among these parties. The Interagency Group is to coordinate with appropriate representatives of state and local government and the private sector in the development of a 10-year implementation plan that sets out research and implementation priorities and goals, development of improved forecasting techniques, technology transfer plans, and plans for intergovernmental cooperation and coordination. Designs, construction methods, technologies, materials, and other developments under this Act will apply to manufactured housing only after going through the consensus development and rulemaking procedures of the Manufacturing Housing Construction and Safety Standards Act of 1974 as amended.

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Section 5. National Advisory Committee for Windstorm Hazard Reduction. This section sets up a 21-member, Presidential appointed, advisory committee drawn from state and local government and the private sector with expertise in a areas such as architecture, engineering, construction, finance, insurance, and research. The Committee is to review program progress and to report to the Congress annually on program status and needed improvements.

Section 6. Annual Report. This document is to be submitted by the Interagency Group to the Congress within 90 days after the end of each fiscal year. The Interagency Group also may disseminate research findings through an annual conference.

Section 7. Authorization of Appropriations. The authorized levels for the program are $50,000,000 for FY 2001, $100,000,000 for FY 2002, and $150,000,000 for FY 2003.

Appendix 2:

Witness Biographies and Financial Disclosures

BIOGRAPHY DR. CHRISTOPHER W. LANDSEA

Christopher W. Landsea is a Research Meteorologist at the Hurricane Research Division (HRD) in the Atlantic Oceanographic and Meteorological Laboratory (AOML) of the National Oceanic and Atmospheric Administration (NOAA) located in Miami, Florida, U.S.A. Dr. Landsea received his Master's Degree and Doctorate in Atmospheric Science from Colorado State University (1991, 1994). His graduate work was under Dr. Bill Gray, one of the world's leading experts on hurricanes and tropical meteorology.

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Dr. Landsea's main research interests and expertise are seasonal forecasting of hurricanes and El Niño, as well as climatic change issues for tropical cyclones around the world. During the hurricane season, Dr. Landsea participates in the HRD Hurricane Field Program by flying in Orion P–3 aircraft into and in a Gulfstream IV jet around Atlantic hurricanes (including Gilbert, Opal, Georges and Floyd) for research and forecasting purposes.

He has published over 30 book chapters and articles in the journals *Bulletin of the American Meteorological Society, Climatic Change, EOS, Geophysical Research Letters, Journal of Climate, Journal of Insurance Regulation, Meteorology and Atmospheric Physics, Monthly Weather Review, Science, Tellus, Weather* and *Weather and Forecasting.* Dr. Landsea is a member of the American Meteorological Society (AMS), the National Weather Association and the American Geophysical Union.

He is currently serving as the Chair of the AMS Committee on Tropical Meteorology and Tropical Cyclones for the years 2000–2002. Dr. Landsea was the recipient of the AMS's Max A. Eaton Prize for the Best Student Paper given at the 19th Conference on Hurricanes and Tropical Meteorology in May 1991 and was co-recipient of the AMS's Banner I. Miller Award given for the best contribution to the science of hurricane and tropical weather forecasting at the May 1993 meeting of the 20th Conference on Hurricanes and Tropical Meteorology. In 2000, Dr. Landsea was a co-recipient of a U.S. Department of Commerce Bronze Medal "for issuing the accurate and first official physically-based Atlantic seasonal hurricane outlooks for the 1998/1999 seasons, based upon new research".

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BIOGRAPHY FOR STEVEN L. MCCABE

Professor and Chairman, Department of Civil, Environmental and Architectural Engineering, University of Kansas

Address: University of Kansas, Department of Civil and Environmental and Architectural Engineering, 2006 Learned Hall, Lawrence, Kansas 66045–2225; Phone: (785) 864–3747; FAX: (785) 864–5631; e-mail: slmccabe@ku.edu

Education:

Ph.D. University of Illinois at Urbana-Champaign, Department of Civil Engineering (Structures, Structural Dynamics, and Earthquake Engineering), 1987

M.S. Colorado State University, Mechanical Engineering, (Engineering Mechanics), 1974

B.S. Colorado State University, Mechanical Engineering, 1972

Registered Professional Engineer in Kansas, Colorado, and Oklahoma

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Professional Experience:

University of Kansas, Department of Civil and Environmental Engineering, Lawrence, Kansas, Professor, April 1998–present; Department Chair, June 1998–present; Associate Professor, April 1991–April 1998; Associate Department Chairman, July 1997–June 1998; Assistant Professor, August 1985–1991. Member of the Structural Engineering faculty involved in teaching, student advising, research and service. Teaching has included all the courses in the structures sequence with primary emphasis in reinforced concrete design, matrix structural analysis and finite element method. Research has included work in response and damage assessment from earthquake, bond and development of reinforcement, design software development and shear behavior of structural systems.

Active in University of Kansas exchange programs with University of Stuttgart and University of Dortmund, Germany. Active in professional and university service activities as well. Specific duties have included computer systems in department and coordination with Regents Center Edwards campus in

Overland Park. Former faculty advisor of Earthquake Engineering Research Institute student chapter, former faculty advisor to student ASCE chapter, served as committee member on School and University computer committees, director of Department graduate computer laboratory and served in University Governance on University Council and SenEx—Senate Executive Committee.

HNTB Corporation, Bridge Department, Kansas City, MO; Senior Bridge Engineer with HNTB Corp. summer 1997; assisting in the design of structural and mechanical systems for a new movable lift span bridge and rehabilitation of 80 year old approach spans. Also consulting on other design projects.

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Norwegian Institute of Technology, Institutt for Konstruksjonsteknikk, Trondheim, Norway; Visiting Professor of Structural Engineering, August 1995–July 1996. Selected for Fulbright Grant to teach and conduct research at NTH. Research concerns testing of new reinforcement technologies, finite element analysis of reinforced concrete systems, fracture mechanics applications to concrete, bond and development of reinforcement.

University of Illinois at Urbana-Champaign, Urbana, Illinois, June 1981–July 1985, Graduate Research Assistant. Examined the interaction of structures and earthquake ground motion to identify key parameters that contribute to strong response and damage.

Black & Veatch Consulting Engineers, Kansas City, Missouri, October 1978–June 1981, Project Stress Engineer. Responsible for finite element analyses of special equipment components and structures, development of seismic analysis procedures also, project engineering responsibilities for pipe support group.

R.W. Beck & Associates Consulting Engineers, Denver, Colorado, May 1977–September 1978, Senior mechanical engineer. Responsible for analysis of power plant piping systems, alternate energy source analysis, and plant start-up duties.

Public Service Company of Colorado, Denver, Colorado, July 1974–May 1977, Resident Mechanical Engineer at Fort St. Vrain Nuclear Power Plant. Responsible for design and start-up of various nuclear power systems and for seismic analysis and qualification of equipment support structures and piping systems.

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Professional Societies:

American Concrete Institute: Elected Fellow 1998; Chairman, Committee 439, Steel Reinforcement 1992–1998; Secretary, ACI–ASCE Committee 447, Finite Element Analysis of Reinforced Concrete Structures 1992–98; Member, Building Code Subcommittee 318–B, Development of Reinforcement; Member, Committee 368, Earthquake Resisting Elements and Systems; Member, Committee 408, Bond and Development of Reinforcement; Member, Committee 446, Fracture Mechanics; Former President of ACI Kansas Chapter.

American Society of Civil Engineers: Member, Committee on Concrete and Masonry Structures; Associate Editor, Journal of Structural Engineering, 1992–1995; Faculty Advisor, University of Kansas ASCE Student Chapter, 1988–1994; Former Member of Engineering Mechanics Division Committee on Inelastic Behavior; Former Associate Member of Engineering Mechanics Division Committee on Computational Mechanics.

American Society of Mechanical Engineers: Member, Seismic Engineering Technical Subcommittee, Pressure Vessels and Piping Division; Member, Structural Design Subgroup, Committee on Nuclear Air and Gas Treatment 1979–1999; Chairman, Applied Risk Committee, Safety Engineering and Risk Analysis Division 1992–1995.

American Society for Testing and Materials: Member, Committee A01.05 on Reinforcing Bars; Chairman, Wire Products Task Group; Chairman, Headed Reinforcing Bars Task Group.

Committee Euro-International du Beton (CEB) [European/International Concrete Society]: Member of Task Group 2/5 Bond Models, Associate Convener and Member, Task Group 2/5 on Tension Design and Size Effect; Member of Task Group 2/2 on Ductility.

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Earthquake Engineering Research Institute; Member, Traditional Education Committee and Publications Co-Chair, 5th U.S. National Conference on Earthquake Engineering, Chicago 1994; faculty advisor EERI student chapter.

Prestressed/Precast Concrete Institute, Member

Seismological Society of America, Member, National and Eastern Branch

American Society of Engineering Education, Member

American Welding Society, Member

Construction Specifications Institute, Member

IEEE Computer Society, Member

Phi Kappa Phi, President of KU Chapter 1988–1992

Awards:

Recipient (with D. Darwin, H.H. Ghaffad and O.C. Choi) American Concrete Institute Structural Research Award for paper "Bond of Epoxy-Coated Reinforcement: Cover, Casting Position, Slump and Consolidation." presented at ACI Spring Convention, 1996.

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Recipient, Fulbright Grant, Center for International Exchange of Scholars, Washington DC for 95–96 academic year to teach and conduct research at NTH

Recipient, University of Kansas School of Engineering Miller Professional Development Award for Engineering Service, 1995

Recipient (with M.J. Schmidt), ASME Pressure Vessel and Piping Division Certificate of Recognition for PVP Tutorial-Shortcourse "UNIX for Engineers" presented at 1994 PVP Conference

Recipient, University of Kansas School of Engineering Miller Professional Development Award for Engineering Research, 1992

Recipient, University of Kansas Silver Anniversary Teaching Award, 1990

Recipient (with W.J. Hall), ASME Pressure Vessel and Piping Division Certificate of Recognition for PVP Honor Paper "Seismic Damage Assessment in Structures: Implications for Life Prediction and Extension" presented at 1989 PVP Conference

Honors:

Elected Fellow of the American Concrete Institute, 1998

Nominated for Gould Award for teaching by students, KU School of Engineering, 1997

Selected as a University of Kansas Teaching Fellow, 1994

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HOPE Award for Outstanding University of Kansas Teaching, Semifinalist, 1988 and 1989

Nominated for National Chi Epsilon Teaching Award (Civil Engineering Honorary Society) by KU Chapter, 1989

Rated as outstanding teacher in Civil Engineering Department, University of Illinois (including full-time faculty) based on student reviews, Fall 1984 for Steel Design I

Chi Epsilon Civil Engineering Honorary, 1988

Sigma Xi Research Honorary, 1984

University of Illinois Fellow, 1981–1982

Phi Kappa Phi Academic Honorary, 1974

Pi Tau Sigma Mechanical Engineering Honorary, 1972

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BIOGRAPHY FOR DR. JOHN L. HAYES

John (Jack) L. Hayes is currently Director of the Office of Science and Technology in the National Weather Service (NWS). In this position, he is responsible for science and technology infusion into the NWS including science and engineering planning, acquisition and refresh of critical technologies, and the scientific development of the Meteorological Development Laboratory.

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Prior to joining the National Weather Service, Dr. Hayes was the General Manager of the Advanced Weather Interactive Processing System (AWIPS) program for Litton-PRC where he led the nationwide deployment of AWIPS between 1998 and 2000. Prior to that, he served 28 years with the United States Air Force in a variety of positions. These included Director of Aerospace Science and Technology, Plans and Programs, for the Air Weather Service at Scott Air Force Base, Illinois; Commander of the Weather Squadron supporting space and missile launches from Vanderberg Air Force Base, California; Director of Weather Operations for Air Force Material Command units nationwide; and in his last assignment Commander of both the Air Force Global Weather Center and Air Force Weather Agency at Offutt Air Force Base, Nebraska.

Dr. Hayes received both his Ph.D. and Master of Science degrees in meteorology from the Naval Post Graduate School in Monterey, California. He is a Fellow in the American Meteorological Society.

A native of Ohio, he is a three year resident of Reston, VA. He and his wife Sharon have three children: Laurel, Jennifer, and Marc.

BIOGRAPHY FOR DOUG HILL

Chief Meteorologist, ABC's Channel 7 News

Doug Hill has earned a reputation as Washington's most accurate weather forecaster. As Chief Meteorologist, he brings over two decades of experience to ABC7, where he anchors weather coverage on ABC 7 News at 5, 6 and 11 pm.

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Hill has been honored with a Washington Emmy Award for broadcast excellence. He has also been awarded the "Seal of Approval" from the American Meteorological Society for his outstanding forecasting skills and meteorological knowledge. He received the AMS credential with less than 3 years broadcast experience, much faster than most in his field. Hill's lifelong fascination with weather culminated with a three-year side by side tutorialship with his co-worker, Mal Sillars, a college professor, while at WDIV TV in Detroit.

Prior to joining Channel 7, Hill served as the primary meteorologist for the local CBS affiliate for 16 years. He also worked at two different Detroit television stations between 1980 and 1984. Hill spent 1979 at WWBT–TV in Richmond, Virginia. Before television, Hill served as a Prince Georges County Officer. After 2 years at Towson State College, Hill entered the United States Air Force where he served as a security specialist assigned to the Presidential Support Unit at Andrews Air Force Base.

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BIOGRAPHY FOR ROBERT F. SHEA

Deputy Administrator for Mitigation, Federal Insurance Administration and Mitigation Directorate; currently Acting Administrator (June, 2001)

Robert F. Shea was appointed by Joe Allbaugh, Director of the Federal Emergency Management Agency, in June of 2001 to be the Deputy Administrator for Mitigation within the Federal Insurance Administration and Mitigation Directorate. By doing this Mr. Allbaugh is signaling the importance of mitigation under the George W. Bush Administration, and the strength of aligning mitigation with Flood Insurance.

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In November of 1993, Mr. Shea was appointed as the Director of the Program Support Division and served in this role until this recent promotion. In this capacity, Mr. Shea provided executive direction to the Hazard Mitigation Planning Program and the Hazard Mitigation Grant Program of the Robert T. Stafford Disaster Relief Act, and the Flood Mitigation Assistance Program of the National Flood Insurance Reform Act.

In assuming the position, Mr. Shea stated that, "Mitigation has now been established as the foundation of emergency management, and is clearly the future of FEMA. We have learned that response to disasters is critical to our nation but the only rational approach to the issue of disasters is to seek the reduction of the impacts on our lives, our structures and our economy through aggressive mitigation of the built environment."

Mr. Shea has spent nearly 25 years in emergency management, serving in various capacities from Chief of the Coordination Office of the former State and Local Programs and Support Directorate to Chief of the Program Development Division of the former Office of Earthquakes and Natural Hazards. Mr. Shea followed in the footsteps of his father, who served in the American Red Cross for 42 years. He and his wife, Mary Hope Katsouros-Shea, live in Alexandria, Va., where they are rearing four daughters: Sofia, Michele, Hope, and Victoria.

Appendix 3:

Additional Material for the Record

SUBMITTED STATEMENT OF DR. STEPHEN P. LEATHERMAN

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Director, International Hurricane Center, Florida International University, Miami, Florida 33199

INTRODUCTION

During the past two decades, damages due to hurricanes have averaged about $5 billion a year. According to insurance industry estimates, hurricanes account for 62% of insured losses nationwide from natural hazards (Figure 1). In terms of economic impact, two back-to-back hits by major hurricanes have the potential for wiping out the insurance industry.

There is a coastward migration of the population, and approximately 50% of U.S. citizens already live in hurricane-prone areas along the East and Gulf Coasts. For instance, the State of Florida is gaining about a thousand residents per day with most of those congregating in vulnerable South Florida. Hurricane Andrew in 1992 resulted in $30 billion in damages, which represents the most costly natural disaster in U.S. history.

Funding for hurricane research has been meager in spite of costs to our national economy. By contrast, earthquake funding has been substantially greater than that for hurricanes (Figure 2) because a National Act for Earthquake Hazard Reduction that was passed several decades ago. In a similar manner, a National Act is needed to coordinate and fully fund hurricane research.

COASTAL VULNERABILITY MAPPING

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Hurricane storm surges can exceed 15–20 feet (e.g., H. Camille in 1969 generated a 22.4 foot storm surge) and extend for miles inland. Storm surge models, such as the National Weather Service SLOSH model, are used to estimate water level heights and the extent of inundation. Accurate topographic information is an essential component of such models, but the best existing topographic data often consist of contour maps produced at 5- to 10-foot intervals. Five feet is the difference between getting your feet wet and drowning. In low-lying areas, such as South Florida, a 5-foot range corresponds to several miles positionally.

The Federal Emergency Management Agency (FEMA) has spent over $1 billion acquiring topographic data for coastal and riverine floodplains of the United States in order to generate 100-year flood maps (Flood Insurance Rate Maps or FIRMs). But these data are much out of date and often inaccurate for coastal areas because of rapid urbanization and changes in beach and dune dimensions over time. FEMA uses the "540 rule" in combination with a height criteria to determine if a sand dune can withstand a 100-year storm and hence whether the landward-flanking houses are safe from flooding (A-zone) or subject to attack by waves, requiring (V or velocity) Zone designation. The insurance rate for a particular property varies greatly, depending upon which zone a house is located. The "540 rule" refers to the volume of sand (540 ft•) per foot of shoreline, but the status of the barrier dunes (e.g., volume and height) along the U.S. East and Gulf Coasts is not presently known because of continued storm impact and long-term erosional trends.

AIRBORNE LASER MAPPING

Recent advances in the technology known as airborne laser altimetry or LIDAR allow us to map shore positions and coastal topography promptly and accurately in order to provide timely updates. This new high-technology system employs microcomputers, laser-ranging technology, and GPS positioning mounted in a small aircraft to provide the necessary topographic information for predicting storm damage and flooding. The laser data are accurate to within 6–8 inches (compared to 5–10 feet with the USGS and FEMA maps). In fact, the crown of a highway can actually be pinpointed from the LIDAR data. In addition, this highly accurate mapping can be done for a fraction of the cost of conventional surveying, which has been used by FEMA to date.

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The International Hurricane Center (IHC) at Florida International University in concert with the Geomatics Program at the University of Florida were the first university in the United States to purchase an airborne laser. We have been operating an Optech ALTM 1210 LIDAR mapping system, mounted in a dedicated Cessna 337 aircraft, to collect topographic data since 1999 (Figure 3). Recently, the IHC team completed the hurricane-storm surge vulnerable eastern area of Broward County, Florida. Over 100 million ground surface elevations were measured by the airborne laser. A portion of this enormous data set (unfiltered 2 meter digital elevation model—DEM) is shown on Figure 4. The laser data must be filtered to remove vegetation in order to obtain a "bare earth" DEM (Figure 5), which clearly shows a coastal ridge that can block storm surges.

The improved laser maps produced by the International Hurricane Center team have resulted in significant reductions in predicted flood areas during hurricane storm surges (Figure 6). Newspaper headlines proclaimed that "Hurricane evacuees cut by 175,000" by the revolutionary new airborne laser mapping conducted by the IHC for Broward County, Florida. There has been an over-evacuation problem in South Florida and elsewhere along the U.S. Southeast coast as amply illustrated by the occurrence of Hurricane Floyd in 1999; over 3 million Americans tried to flee the advancing hurricane in their cars, creating massive traffic backups and snarls and stranding millions on the nation's highways without actually reaching safety. Clearly, not everyone can attempt to evacuate, and this new technology is filling a major void in terms of providing timely and accurate data for scientific assessments and management programs.

The airborne laser altimetry represents a quantum step forward in coastal erosion and flood hazard mapping. This new laser mapping is not "pie in the sky" potential, but rather it is proven technology that should be fully embraced by the Federal Emergency Management Agency (FEMA) in coastal vulnerability mapping.

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CONCLUSIONS

Hurricanes are already taking a huge economic toll, and we are now entering a 20 to 30 year period of increased Atlantic hurricane activity. We have learned some important lessons in the wake of Hurricane Andrew; and, indeed, the International Hurricane Center at Florida International University (FIU) was established to insure that such devastation to a local economy does not happen again. While a great deal has been learned and significant progress made, much more needs to be done. Despite the efforts of FIU and others, Florida and the rest of the nation remain unprepared for hurricanes and other wind hazards.

The members of House Subcommittee on Environment, Technology and Standards need to quickly pass national wind hazard reduction legislation that funds hurricane research, including damage mitigation, and to actively work to seek its enactment.

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SUBMITTED STATEMENT OF THE WIND HAZARD REDUCTION COALITION

The Wind Hazard Reduction Coalition was formed due to the recognized need for better research and action (or mitigation) into predicting and mitigating the damage from major wind events. All 50 states are vulnerable to the hazards of windstorms. In 1998, hurricanes, tornadoes and other wind related storms caused at least 186 fatalities and more than $5.5 billion in damage.

On May 3, 1999 more than 70 violent tornadoes struck from north Texas to the Northern Plains. Forty-one people died and more than 2,750 homes were damaged. In 1992, Hurricane Andrew resulted in $26.5 billion in losses and 61 fatalities, in 1989, Hurricane Hugo resulted in $7 billion in losses and 86 fatalities and in 1999, Hurricane Floyd resulted in more than $6 billion in losses and 56 deaths.

The United States currently sustains billions of dollars per year in property and economic loss due to windstorms. The Federal government's response to such events is to initiate search and rescue operations, help clear the debris and provide financial assistance for rebuilding. The Coalition is calling upon the Federal government to provide research funding to help reduce the significant annual toll in casualties and property damage from windstorms and to mobilize the technical expertise already available.

The Wind Hazard Reduction Coalition currently represents 23 associations and companies which are committed to the creation of a National Wind Hazard Reduction Program (NWHRP) that would focus on significantly reducing loss of life and property damage in the years to come. The Coalition includes professional societies, research organizations, industry groups and individual companies with knowledge and experience in dealing with the impact of high winds.

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Near-surface winds are the most variable of all meteorological elements, making the prediction and control of their impacts all the more challenging. In the United States the mean annual wind speed is 8 to 12 mph, but wind speeds of 50 mph occur frequently throughout the country, and nearly every area occasionally experiences winds of 70 mph or greater. In coastal areas of the East and Gulf coasts, tropical storms may bring wind speeds of well over 100 mph. In the middle of the country, wind speeds in tornadoes can be even higher.

With the average annual damage from windstorms at more than $6 billion, the current $5–10 million Federal investment in research to mitigate these impacts is woefully inadequate. In contrast, the Federal government invests nearly $100 million per year in reducing earthquake losses through the National Earthquake Hazards Reduction Program, a program that has lead to a significant reduction in the effects of earthquakes. A Federal investment in wind hazard reduction would pay similar or greater dividends in saved lives and decreased property damage.

Unfortunately, reducing vulnerability to wind hazards is not just a question of developing the appropriate technical solution. Wind hazards are created by a variety of events with large uncertainties in the magnitudes and characteristics of the winds. The relevant government agencies and programs, as well as the construction industry, are fragmented. Finally, implementation requires action by owners and the public, who may not consider hazard reduction a high priority. Solving wind vulnerability problems will require coordinated work in scientific research, technology development, education, technology transfer and public outreach.

In 1993 the National Research Council published a report entitled "Wind and the Built Environment."(see footnote 8) The report included the recommendations of the Panel on the Assessment of Wind Engineering Issues in the United States. The panel recommended the establishment of a national program to reduce wind vulnerability. Such a program would include wind research that draws upon the expertise of both academia and industry and addresses both structural and nonstructural mitigation methods, an outreach program to educate state and local governments on the nature of the wind risks they face, a conscious effort to improve communication within the wind community and a commitment to international cooperation in wind-engineering.

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A 1999 NRC study concurred with that recommendation and specifically urged Congress to designate "funds for a coordinated national wind-hazard reduction program that encourages partnerships between federal, state and local governments, private industry, the research community, and other interested stakeholders."(see footnote 9)

As far as preventing or minimizing the impact of major wind events, the Federal government has mainly limited itself to improvements in weather prediction and public warnings. In light of the damages and loss of life that windstorms cause every year, the Coalition strongly feels that the Federal government can and should do more.

To that end, the Wind Hazard Reduction Coalition has worked with Congressmen Dennis Moore of Kansas, Walter Jones of North Carolina, and others, first to help form the Congressional Wind Hazard Reduction Caucus and then to develop legislation. The Caucus was created in October of 1999 and is chaired by Mr. Moore and Mr. Jones. It has as its goal to increase Congress' awareness of the public safety and economic loss associated with major wind events and to establish and fund programs to mitigate those impacts.

On October 19, 2000, Congressmen Moore and Jones and others introduced H.R. 5499, the Windstorm Hazard Reduction Research and Technology Transfer Act." The Coalition supported the development of this legislation by providing technical advice.

Beginning this year, the same group that developed H.R. 5499 came together to refine and improve our legislative efforts. The draft legislation being circulated is the result of two years of collaborative effort and is designed to achieve those goals expressed by both the Congressional Wind Hazard Reduction Caucus and the Wind Hazard Reduction Coalition.

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Now entitled the "Hurricane, Tornado and Related Natural Hazards Research Act," this legislation is truly a community effort. All interested groups have been involved with this from the beginning. The Coalition commends Congressmen Moore and Jones and their staffs, as well as staff from the House Science Committee, for working with the community to create this consensus and, more important, technically and scientifically sound legislation.

Specifically, the legislation creates a coordinated Federal windstorm and related hazards reduction research, development and technology transfer program. The object of the program is to achieve, within 10 years, a measurable reduction in losses that would otherwise occur to life and property from wind and related disasters.

This is accomplished by the following actions:

Coordination of Federal wind hazard reduction efforts through a multi-agency National Windstorm Hazard Reduction Program that is coordinated by the Office of Science and Technology Policy and the Federal Emergency Management Agency.

Linkage of all aspects of the program to the goal of a major, measurable reduction in losses of life and property due to wind storms within 10 years of the date of enactment.

Research, development and deployment in 11 with an emphasis on developing cost effective and affordable improvements that can pay big dividends in reducing wind damage.

Establishment of a wind hazard reduction technology transfer program.

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Establishment of a National Advisory Committee for Windstorm Hazard Reduction.

Authorization of appropriation levels that would allow the development of a wind hazard mitigation program that would be as effective in reducing wind related losses as current programs aimed at mitigation in other natural hazard areas such as floods and earthquakes.

The research program would be overseen by an *Interagency Group* of federal agencies involved in research, weather, natural disaster mitigation, housing and construction, and related standards and would give the group responsibility to develop and implement a coordinated Federal program for wind hazard reduction research, development and technology transfer.

The group is to be co-chaired by the White House Office of Science and Technology Policy and the Federal Emergency Management Agency. The program should, in part, build on current agency and private sector efforts. Major program elements are to include peer-reviewed basic and applied research. Other research will focus on ways to achieve a better understanding of impediments and disincentives to wind hazard reduction. Data collection programs will be established to achieve a better inventory of information on building components and materials and their interactions. Technology transfer components will be implemented to achieve better dissemination of wind hazard reduction technology, techniques and knowledge. The bill supports continuation of current efforts to improve technology for weather prediction and disaster response. The bill also places a priority on research to ensure proper performance of critical structures and lifelines needed during a time of disaster.

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The research and development program may include basic weather research, research on materials and building technologies, including retrofits, wind effects on structures, and mapping techniques. The technology transfer program is to include information collection, classification, presentation and dissemination of research results and other pertinent information to state and local officials, the private sector, and the general public, and a delineation of responsibilities among these parties. The Interagency Group is to coordinate with appropriate representatives of state and local governments, universities and the private sector in the development of a 10-year implementation plan. The plan would set out research and implementation priorities and goals, development of improved forecasting techniques, technology transfer plans, and plans for intergovernmental cooperation and coordination.

The bill would also create the National Advisory Committee for Windstorm and Related Natural Hazard Impact Reduction consisting of 21 members, appointed by the President. The members of the advisory committee will be drawn from state and local governments, universities and the private sector with expertise in areas such as architecture, engineering, construction, finance, insurance, and research. The Committee is to review program progress and to report to the Congress annually on program status and needed improvements.

Conclusion

Windstorm-related costs have averaged several billion dollars per year during the last decade with a high in 1992 exceeding $25 billion, primarily as a result of Hurricane Andrew. If a severe hurricane makes landfall in Miami, New Orleans, or New York City, the damage could exceed $50 billion. Hurricanes, tornadoes, and other windstorms cause death and injury, business interruption, and unacceptably high levels of property damage in all 50 States and all U.S. territories. People continue to move to coastal areas adding to the trend toward larger disasters. Damage costs will continue to increase unless an effective wind hazard reduction plan is implemented.

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A unified national plan of wind hazard reduction has the potential of reducing losses significantly in the next decade. Currently, a limited number of independent activities (e.g., FEMA's Project Impact the PATH program) are underway to reduce the disastrous effects of windstorms. Unfortunately, these activities will have a limited impact on reversing the trend of increasing costs unless action is taken to improve the resistance of the physical infrastructure that is now susceptible to damage by windstorms.

As the recent tornadoes in the Washington, DC area demonstrated, windstorms pose a threat in many areas of the country; a threat we should not dismiss with the thought that we cannot do anything about the weather. With the proper information gained from research and the ability to share this knowledge with those who need it, we still will not be able to change the weather, but we can change the way it affects people's lives.

Thank you for the opportunity to express the views of the Wind Hazard Reduction Coalition. We look forward to working with members of the Subcommittee to move this legislation forward.

Submitted on behalf of the Wind Hazard Reduction Coalition

American Association for Wind Engineering
American Portland Cement Alliance
American Society of Civil Engineers
Applied Technology Council
Colorado State University—Wind Engineering and Fluids Laboratory

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Factory Mutual Research
Florida International University—International Hurricane Center
Florida State University—Center for Ocean-Atmospheric Prediction Studies
International Code Council, Inc.
Louisiana State University—LSU Hurricane Center
National Association of Mutual Insurance Companies (NAMIC)

National Fire Protection Association International
New Necessities
Saffir Consulting Engineers
Solutia, Inc.
Steven Winter Associates, Inc.
Texas Tech University—Wind Engineering Research Center

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(Footnote 1 return)
National Oceanic and Atmospheric Administration/Atlantic Oceanographic and Meteorological Laboratory/ Hurricane Research Division, Miami, FL 33149 USA.

(Footnote 2 return)
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(Footnote 3 return)
Colorado State University, Department of Atmospheric Sciences, Fort Collins, CO 80523 USA.

(Footnote 4 return)
National Research Council, Wind and the Built Environment (1993).

(Footnote 5 return)

National Research Council, Review of the Need for a Large-scale Test Facility for Research on the Effects of Extreme Wind on Structures, (1999).

(Footnote 6 return)

Dr. McCabe clarified: ". . .often the failure modes involve damage to the cladding, windows, the walls being breached or the roof will be pulled off."

(Footnote 7 return)

Mitigation of the effects of tornadoes, hurricanes, and other severe storms involves saving lives and property. As Doug Hill mentioned, saving lives involves getting the warning out to the public in a timely and efficient manner. Efforts to shorten the amount of time it takes to get warnings to the media and from the media to the public are important. However, saving lives also critically involves providing enough lead time for people to react. For example, post analysis of the D.C. tornado showed that the NWS provided about a 10-minute lead time. Therefore, even with a very efficient communication system, people would only have had 10 minutes at most to react. To extend warning lead times, we must continue to apply science and technology to the problem. Before the NWS Modernization, the lead times on tornadoes were virtually zero. Through the investment in science and technology associated with the Modernization (Doppler Radars, Advanced Weather Interactive Processing System, etc.) the average lead times are now over 10 minutes. In my opinion, we should not stop. We should set a national goal to continue over the next decade to perform research and development, invest in science and technology, and improve the communication of longer lead-time severe weather warnings to the public to increase their ability to take life and property-saving actions.

(Footnote 8 return)

National Research Council, Wind and the Built Environment (1993).

(Footnote 9 return)

National Research Council, Review of the Need for a Large-scale Test Facility for Research on the Effects of Extreme Wind on Structures, (1999).

CONTENTS SPEAKERS INSERTS

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STATEMENT OF MR. ROBERT F. SHEA, ACTING ADMINISTRATOR FOR FEDERAL INSURANCE AND MITIGATION,
FEDERAL EMERGENCY MANAGEMENT AGENCY (FEMA)

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INSERTS SPEAKERS CONTENTS

NO INSERTS IN THIS HEARING