Lessons Learned Between Hurricanes: From Hugo to Charley, Frances, Ivan, and Jeanne - Summary of the March 8, 2005 Workshop of the Disasters Roundtable

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LESSONS LEARNED BETWEEN HURRICANES:

From Hugo to Charley, Frances, Ivan, and Jeanne

SUMMARY OF THE MARCH 8, 2005 WORKSHOP
OF THE DISASTERS ROUNDTABLE

By Patricia Jones Kershaw and Byron Mason

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FOREWORD

The Disasters Roundtable (DR) seeks to facilitate and enhance communication and the exchange of ideas among scientists, practitioners, and policymakers concerned with urgent and important issues related to natural, technological, and other disasters. Roundtable workshops are held three times a year in Washington, D.C. Each workshop is an open forum focused on a specific topic or issue selected by the DR Steering Committee. For upcoming meetings, please visit http://www.nationalacademies.org/disasters.

The Disasters Roundtable Steering Committee is composed of five appointed members and sponsoring ex-officio members. The appointed members at the time of the workshop were William H. Hooke, chair, American Meteorological Society; Ross B. Corotis, University of Colorado, Boulder; Ellis M. Stanley, Sr., Emergency Preparedness Department of the City of Los Angeles; Richard T. Sylves, University of Delaware; and Susan K. Tubbesing, Earthquake Engineering Research Institute, Oakland. The ex-officio members were Lloyd Cluff, Pacific Gas & Electric; Dennis Wenger, National Science Foundation; Timothy A. Cohn, US Geological Survey; Stephen Ambrose, National Aeronautics and Space Administration; Elizabeth Lemersal, Federal Emergency Management Agency; James Russell, Institute for Business and Home Safety; and Helen Wood, National Oceanic and Atmospheric Administration; and Frank Best, PB Alltech, Inc. The DR staff includes William A. Anderson, director; Patricia Jones Kershaw, senior program associate; and Byron Mason, senior program assistant.

This document presents the rapporteur's summary of the forum discussions and does not necessarily reflect the views of the roundtable members or other participants. For more information on the Roundtable visit our website: http://dels.nas.edu/dr or contact us at the address below.

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This summary has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published summary as sound as possible and to ensure that the summary meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this summary: Thomas L. Anderson, Multidisciplinary Center for Earthquake Engineering Research, and Richard Stuart Olson, Florida International University.

Responsibility for the final content of this summary rests entirely with the author and the institution

INTRODUCTION

Hurricanes Charley, Frances, Ivan and Jeanne exacted a heavy toll upon Florida and other locales in the 2004 hurricane season, resulting in dozens of deaths and billions of dollars in property damage and business losses. Damages wrought by these four hurricanes in a short span of 44 days highlighted the hazards that hurricanes pose for at-risk communities, including damaging winds, storm surges, floods and tornadoes. The unprecedented series of 2004 hurricanes are part of a long and storied history of memorable hurricane events. Hurricane Hugo pounded the southeastern United States in September 1989, and at the time was the second most costly hurricane disaster in U.S. history. In between Hugo and the 2004 hurricane season the United States weathered such destructive events as Hurricanes Andrew (1992), Fran (1996), and Floyd (1999), which resulted in widespread deaths and many billions of dollars in property damage in the communities they impacted. The span between Hugo and the 2004 hurricane season, which also included impacts from other disaster agents such as the 2001 terrorist attacks, have provided opportunities for emergency managers, academics, government agencies and the general public to learn lessons for coping with hurricanes and other disasters.

On March 8, 2005 the Disasters Roundtable of the National Academies convened a workshop, “Lessons Learned between Hurricanes: From Hugo to Charley, Frances, Ivan, and Jeanne,” to explore the extent that strategies for countering the challenges presented by hurricanes have changed since Hurricane Hugo in 1989. Workshop participants examined the effectiveness of technological advances and efforts to apply knowledge gained from past hurricane events to the response efforts of the 2004 hurricane season. Speakers from academia, industry, and government presented and led discussions on lessons learned in the interim and highlighted the pressing concerns that remain to be addressed.

The workshop summarized herein occurred prior to the hurricane season of 2005 that has produced Hurricanes Katrina and Rita, in August and September respectively, along the Gulf coast of the United States. Some of the statements made by speakers may seem prescient. As of this summary’s writing, the damages from these two hurricanes continue to be assessed. Moreover, the response to Katrina and Rita is ongoing and under review and recovery efforts are in their initial stages. Issues raised by Hurricanes Katrina and Rita will likely be discussed at future workshops of the Disasters Roundtable.

This summary has been prepared by Disasters Roundtable staff to provide an overview of the workshop. It should not be construed as a statement of the Disasters Roundtable or as a consensus study of the National Academies.

FROM HUGO TO JEANNE

Residents of the U.S. Atlantic and Gulf coasts annually brace themselves for the oncoming June 1 to November 31 hurricane season. Some seasons produce more hurricanes than others; hurricanes that make landfall and result in extensive structural damage, as well as human and economic losses, are among the most remembered. Damages wrought by Hurricane

Hugo, in September of 1989, and subsequent hurricane seasons have generated new research and calls for changes in policy and implementation to better protect regions at risk. International Hurricane Research Center director Stephen Leatherman provided a fifteen year overview of Atlantic hurricanes, identifying what he termed "important hurricanes" since Hurricane Hugo, as shown in Table 1 with estimated total losses in dollar values at the time of the events.

Table 1. Important Atlantic Hurricanes Since 1989

Name	*Date*	*Strength at Landfall*	*Damage*
Hugo	**1989**	**4**	**7 billion**
Bob	**1991**	**2**	**1.5 billion**
Andrew	**1992**	**5**	**30 billion**
Opal	**1995**	**3**	**3 billion**
Fran	**1996**	**3**	**3.2 billion**
Mitch	**1998**	**1**	**40 billion**
		(landfall and losses in Central America)	
Floyd	**1999**	**4**	**5 billion**
Irene	**1999**	**1**	**800 million**
Allison	**2001**	**Tropical Storm**	**5 billion**
Michelle	**2001**	**4 (landfall and losses in Cuba)**	**6.5 billion**
Isabel	**2003**	**2**	**4 billion**
Charley	**2004**	**4**	**14 billion**
Frances	**2004**	**2**	**8.8 billion**
Ivan	**2004**	**3**	**13 billion**
Jeanne	**2004**	**2**	**6.5 billion**

Source: Leatherman, 2005.

The extent of the damage caused by Hurricane Hugo in 1989 classified it as the largest hurricane disaster in terms of dollar losses at the time, and highlighted the importance of accurate elevation mapping and evacuation. Hugo, a category 4 hurricane (see Box A for an explanation of categories), ripped through cities such as Charleston, South Carolina and caused destruction on barrier islands as a result of a 20 foot storm surge. During Hugo, a McClellanville, South Carolina public school was used as an emergency shelter. At the height of the hurricane, the shelter flooded to a depth of about 6 feet with approximately 600 evacuees inside. Fortunately, there were no fatalities as a result of the flooding. The school was used as a shelter because it had an assumed elevation that turned out to be incorrect. A 1994 National Research Council (NRC) report noted that "building drawings [of the school] provided by the school board listed the elevation of the ground floor of the building as approximately 20 ft, whereas the actual elevation was closer to 10 ft. No ground survey was conducted as part of the hurricane evacuation studies to verify the actual ground elevation of the building. However, the greater planning failure was that no local officials questioned the 20-ft elevation during the review of the study, despite the fact that the area was shown as flood prone on flood insurance and surge maps generated by the study" (NRC, 1994).

Box A. The Saffir-Simpson Hurricane Scale

The Saffir-Simpson Hurricane Scale is a 1-5 rating based on the hurricane's present intensity. This is used to give an estimate of the potential property damage and flooding expected along the coast from a hurricane landfall. Wind speed is the determining factor in the scale, as storm surge values are highly dependent on the slope of the continental shelf in the landfall region. Note that all winds are using the U.S. 1-minute average.

Category One Hurricanes:

Hurricanes produce winds 74-95 mph (64-82 kt or 119-153 km/hr) and storm surges are 4-5 feet above the normal range. Anticipated damage to building structures is slight, but the potential for damage to unanchored mobile homes, shrubbery, and trees is present. A category one hurricane may produce some coastal road flooding and minor pier damage.

Category Two Hurricanes:

Hurricanes produce winds 96-110 mph (83-95 kt or 154-177 km/hr) and storm surges are frequently 6-8 feet above the normal range. Building structures may experience some roofing material, door, and window damage. Considerable damage to mobile homes, signs, shrubbery and trees is likely. Flooding of coastal and low-lying escape routes is expected 2-4 hours prior to the arrival of the hurricane’s center.

Category Three Hurricanes:

Hurricanes produce winds 111-130 mph (96-113 kt or 178-209 km/hr) and storm surges are commonly 9-12 ft above the normal range. Affected areas will experience some structural damage to small residences and utility buildings. Mobile homes and “poorly constructed” signs will be destroyed, and shrubbery and trees will be blown down. Flooding of coastal and low-lying escape routes is expected 3-5 hours prior to the arrival of the hurricane’s center. Evacuation of low-lying residences near the shoreline may be necessary.

Category Four Hurricane:

Hurricanes produce winds 131-155 mph (114-135 kt or 210-249 km/hr) and storm surges are commonly 13-18 ft above the normal range. Mobile homes will be completely destroyed and shrubs, trees, and signs in the area will be uprooted. Major damage to lower floors of structures near the shore, as well as extensive damage to doors and windows is expected. Flooding of coastal and low-lying escape routes is expected 3-5 hours prior to the arrival of the hurricane’s center. Areas that are lower than 10 ft above sea level may be flooded, requiring massive evacuation as far inland as 6 miles (10 km).

Category Five Hurricane:

Hurricanes produce winds greater than 155 mph (135 kt or 249 km/hr) and storm surges are generally greater than 18 ft above the normal range. Anticipated complete roof failure on many residences and industrial buildings. Mobile homes will be completely destroyed and shrubs, trees, and signs in the area will be uprooted. Some buildings will experience complete failures with small utility buildings uprooted or leveled. Hurricane winds will cause severe and extensive window and door damages. Flooding of coastal and low-lying escape routes is expected 3-5 hours prior to the arrival of the hurricane’s center. Lower floors of all structures located less than 15 ft above sea level and within 500 yards of the shoreline will experience major damages. Massive evacuation of residential areas on low ground within 5-10 miles (8-16 km) of the shoreline may be necessary.

Source: NOAA, 2005 http://www.nhc.noaa.gov/aboutsshs.shtml.

Originally classified as a category four hurricane, Andrew resulted in unprecedented economic devastation along its path through the northwestern Bahamas, the southern Florida peninsula, and south-central Louisiana in August of 1992. The damage resulting from Hurricane Andrew is estimated to be 26.5 billion U.S. dollars, making Andrew the most expensive natural disaster in the United States at the time (NWS, 2005). Andrew's winds devastated the U.S. Air Force Base in Homestead, Florida, rendering 97 percent of its facilities inoperable (DOD, 1996). Poorly enforced building codes and lack of shutters on windows were cited as primary reasons for such significant damages, according to Leatherman. Lessons were learned from Andrew and now approximately 65 percent of south Floridians have shutters or hurricane impact glass. In response to Andrew, the "We Will Rebuild Foundation" was created to rebuild community places such as churches and civic centers. The foundation also granted the initial endowment for the International Hurricane Research Center at Florida International University.

Andrew was a turning point for disaster response efforts of industry and local, state, and federal governments. Leatherman characterized the Federal Emergency Management Agency's (FEMA) response to this event as slow due to a critical shortage of food, water, and ice in the hardest hit areas.

Smaller Category Hurricanes

The perception of the threat posed by Hurricane Irene in 1999 mirrored that of Hurricane Mitch just one year earlier, as people once again dismissed the potential damage of a category one hurricane. Irene produced 15-20 inches of rainfall in southeastern North Carolina, submerging many vehicles and eventually impacting the auto insurance industry's policies for totaled automobiles. Damaged vehicles were previously allowed to be resold without notifying new owners of flood damage. The damage of Hurricane Irene prompted the insurance companies to require impaired vehicles to be issued a new vehicle identification number (VIN) matching the salvage number to improve their tracking in future sales.

In the same 1999 season, Hurricane Floyd made landfall in North Carolina as a category two hurricane. The significance of this event is the major inland flooding and the excess evacuation that occurred. Floyd produced more than 15 inches of rain in eastern North Carolina; approximately 80 percent of the hurricane fatalities were attributed to inland flooding. FEMA's flood maps predated the extensive urbanization that the floodplain areas of eastern North Carolina experienced prior to the 1999 hurricane season. Urbanization in floodplain areas causes rivers and streams to increase peak discharges and can result in flash flooding. Many of the structures built in the floodplain of eastern North Carolina were not built to withstand floods, i.e., they were not properly elevated, and fifty-seven people drowned during this hurricane.

The threat of Hurricane Floyd also prompted excessive and unnecessary evacuation of unaffected communities in preparation for its landfall. Residents along the eastern U.S. coastline between North Carolina and Florida perceived Floyd as a threat and many unnecessarily evacuated. Hurricane Floyd made landfall in North Carolina, but large numbers of Florida and South Carolina residents had also evacuated, resulting in massive 12-15 hour traffic backups on Interstate 95 leaving people without food, water, or lavatory facilities for hours.

In 2003 the U.S. east coast would again experience the impact of a small hurricane. Hurricane Isabel, a category two hurricane, resulted in a loss of power from North Carolina to Maryland. Isabel also caused a higher than expected storm surge in the Chesapeake Bay and flooding in Baltimore, Maryland and Alexandria, Virginia. Leatherman noted that as a result of these impacts on the Chesapeake Bay, NOAA is assessing the new generation high resolution predictive surge models.

Rapid Changes in Hurricane Intensity

The hurricane season of 1995 demonstrated the rapidity with which hurricanes are able to increase in intensity; suggesting a need for advanced forecasting. In October of 1995, Hurricane Opal increased in magnitude from a category two to a category five hurricane in about 18 hours. The rapid intensification was difficult to predict given the state of forecasting skill at the time. Opal weakened to a category three hurricane before it came ashore but it still caused significant damage.
Due to modeling difficulties, the storm surge was inaccurately predicted to climax at 8 feet. The actual storm surge surpassed predictions, peaking at 16 feet.

Hurricane Mitch, a category five hurricane of the 1998 season, further demonstrated the potential flux in a hurricane's intensity. Initially, people in the United States and Central America followed the hurricane closely to determine where it would make landfall. Mitch was quickly downgraded to a category one and many people lost interest. When the hurricane made landfall, it moved in slowly over Honduras producing 39 inches of rain in a 24 hour period resulting in landslides and caused more than 10,000 deaths in Honduras and Nicaragua. The category scale was misleading in this case, as people did not understand that significant damage could result from a category one hurricane. This brought into question our reliance on the Saffir/Simpson scale.

The 2004 Hurricane Season

The unprecedented hurricane season of 2004 produced four major hurricanes – Charley, Frances, Ivan, and Jeanne – each made landfall in Florida within a 44-day period. On August 13, Hurricane Charley came ashore along Florida's southwest coastline as a category four hurricane. It hit land further south than originally predicted and caught many people unprepared. Next, Hurricane Frances made landfall on September 4-5 on the central east coast of Florida as a category two hurricane, after 2.5 million people had evacuated. On September 16, Hurricane Ivan came ashore at 2:00 a.m. along Gulf Shores, Alabama as a category three hurricane with a 15 foot storm surge. Ivan caused extensive infrastructure destruction, damaging highways, bridges, and power lines. Approximately 25 deaths have been attributed to Hurricane Ivan. After weathering 3 hurricanes in such a short period, Floridians experienced what Leatherman describes as "hurricane fatigue." Florida residents had put up and taken down their hurricane shutters several times by the time Hurricane Jeanne struck in late September and had tired of the process. Hurricane Jeanne hovered over the Caribbean for several days, causing torrential rainfall flooding that resulted in approximately 3000 deaths, primarily in Haiti. The hurricane hit Florida's central east coast as a category three hurricane on September 26 (Lawrence and Cobb, 2004). By the time of Jeanne, the human resources of Florida Power and Light were overextended; and other states needed their personnel and equipment to deal with their own disaster related problems as the hurricanes made their way up the east coast.

In light of the damages caused by the unprecedented 2004 hurricane season, and damages from previous years, Leatherman highlighted the importance of a national act to address the hazards presented by hurricane force winds. On October 25, 2004, the National Earthquake Hazards Reduction Program (NEHRP) Reauthorization Act of 2004 (HR. 2608) was signed authorizing the establishment of a new National Windstorm Impact Reduction Program to be modeled after NEHRP.

SCIENTIFIC FORECASTING AND RISK COMMUNICATION

An important component in saving lives in the face of disaster is ensuring that the public has the latest, most accurate information and that citizens know how to use this information to safeguard their lives and property. The National Hurricane Center (NHC) at the National Weather Service (NWS) is charged with scientific forecasting. It operates within the United States, but has outreach efforts in other countries such as the Dominican Republic to assist them in their responses to hurricanes.

One of the major challenges for the NHC during the 2004 season was dealing with rapid intensity changes in hurricanes, according to Louis Uccellini of the National Weather Service. As aforementioned, at present rapid intensity change is difficult to predict. Hurricane Charley increased from a category two to a category four hurricane in five hours. Hurricanes may also reduce in intensity just as quickly. In 1995 Hurricane Opal increased from a category two to a category four hurricane in 18 hours and subsequently decreased in intensity to a category two in less than 12 hours. Uccellini noted that rapid intensity change is challenging from a scientific and a societal impact point of view. Increased awareness of the possibility of rapid intensity changes has caused the NWS to urge people to evacuate if the hurricane is a category one or two near land. Residents often choose not to evacuate when faced with an approaching low category hurricane. However, if the hurricane's category is upgraded as the hurricane nears landfall, residents do not have sufficient time to safely evacuate.

NWS has experienced success in hurricane forecasting, and progress continues to be made in this area. For example, forecasters are now capable of issuing reasonably accurate 5 day forecasts. However, as forecasting accuracy improves, the public's expectations of specific forecasts continue to increase.

Developments in Evacuation since Hurricane Hugo

Data and technical documents prepared by FEMA and the U. S. Army Corps of Engineers (USACE) assist local and state governments in their preparation of evacuation plans. USACE and FEMA also sponsor post hurricane assessments after major evacuations. As a result of the collection of evacuation data and information from past hurricanes, the evacuation process is now better informed and more sophisticated than it was prior to Hurricane Hugo. LIDAR (Light Detection and Ranging) is now an effective tool for learning the precise elevation of the area that will be hit by a hurricane, accurately predicting the likelihood of flooding.

Earl J. Baker, Florida State University associate professor of geography, described the decision-making tools that are provided to help emergency management officials use NHC's forecast and hurricane evacuation study products more effectively. Computer programs such as Hurrevac and HurrTrack are two decision tools now available. Hurrevac is provided to state and local governments by FEMA, while HurrTrack is a commercial program. Programs were available in 1989 during Hugo but they were much less capable. Web-based products are now available, including those provided by NHC.

According to Baker, the most important lesson learned concerning hurricane evacuations is that people respond to instructions about what to do, rather than watches and warnings. To a large degree, evacuation orders and recommendations from the emergency management community did not reach the public during Hurricane Hugo. Detailing the evacuations in response to Hugo, Baker noted that the public was traditionally advised to evacuate if they resided in areas threatened by predicted storm surges or lived in manufactured housing. However, damages caused by hurricanes can extend far beyond coastal and floodplain regions. To help convey this to the public, the inland wind model was developed to estimate the maximum inland penetration of hurricane force winds by determining the speed at which the storm will likely decay as it moves over land. To further stress the potential danger of hurricanes to inland communities, emergency managers have replaced “marine advisories” with tropical cyclone forecast advisories, inland hurricane watches, and hurricane inland wind warnings.

The public has been surveyed many times about their responses to hurricanes since Hurricane Hugo. In addition to post-hurricane surveys, more general surveys have been conducted in between hurricanes to assess the public’s perception of its risk, as well as to determine the actions that people would likely take in the event of a major hurricane. Most of the survey data available has been generated since Hurricane Hugo. The diminished reliance on public shelters is one result of the Hugo experience. Prior to 1989, as much as 25 percent of the public who evacuated went to public shelters. Since then, only 5 to 10 percent of evacuees utilize public shelters; which is a significant decrease in the demand for and use of public shelters.

Baker also noted that the surveys highlighted the significant ‘shadow evacuation’ that occurred during Hurricane Floyd. Shadow evacuation occurs when residents of areas that are unlikely to be directly impacted evacuate without being instructed to leave by authorities. The shadow evacuation phenomenon gained salience following the unnecessarily large number of people that evacuated their communities in response to the approach of Hurricane Floyd. Often, people evacuate because they do not understand whether or not they are at risk. In addition to evacuating unnecessarily, some residents evacuate farther than they need to by driving through areas that are not targeted for evacuation. This activity may contribute to road congestion. As a result of Floyd, this phenomenon is now well documented, according to Baker. Communities and states now provide public education programs that discourage people from evacuating unnecessarily or traveling farther than needed.

Transportation analysis now plays an important role in the evacuation process, as stated by Baker. Highway networks and road capacities are monitored in real-time and calculations are used to determine how long it would take a community or region's residents to evacuate given their origin, the distance to the designated destination, and how quickly residents are expected to evacuate. Real-time monitoring has made this analysis more useful than it was prior to Hugo. HEADS UP (Hurricane Evacuation Analysis and Decision Support Utility Program) is an example of an analysis program used in Florida. HEADS UP is the next generation of the ETIS program (Emergency Transportation Information System). ETIS was established in FEMA regional headquarters to coordinate traffic flow information across state borders. In response to Hurricane Floyd, Georgia received a large number of evacuees from Florida and South Carolina. In the past, due to a lack of interstate coordination, states that received incoming evacuees often did so without advanced warning.

Although technological advances, public surveys, and research on past hurricane disasters are now used to inform evacuation planning and implementation, many of the issues that predate Hurricane Hugo remain. There are misconceptions about vulnerability, as evidenced by shadow evacuations, as well as a false sense of security evidenced by residents who choose to ignore evacuation orders. Baker also noted that despite all of the software that is now available to emergency officials, forecast uncertainty is still inadequately incorporated into the evaluation of the potential threat of a hurricane as it relates to which communities should be evacuated and when.

Performance of Buildings

Since Hurricane Hugo, significant progress has been made in monitoring the built environment during hurricanes. This progress includes real-time data collection and analysis to better understand the wind component of the hurricane and analyze the implications for structures and building materials, according to Institute for Business and Home Safety vice president for engineering Timothy Reinhold. A major effort has been funded by the State of Florida to equip houses with deployment systems to monitor the pressures and wind speeds experienced during hurricanes (see Figure 1). Currently there are 32 homes spread around the highest probable strike areas in Florida that are pre-wired and ready to be set up with monitoring equipment. The equipment is connected to the wiring about 2.5 hours before a hurricane. During the hurricane, data is collected from the monitoring system and later used in damage assessments, wind speed analysis, and building material analysis.

The set-up of deployment systems also includes erecting meteorology towers designed for use in small areas capable of withstanding 200 mile per hour winds. Information gleaned from monitoring instruments aids in characterizing the gust structure of hurricane events that will in turn help in developing wind gust resistant materials.

Figure 1.

Post-hurricane analysis products, such as H-Wind, help researchers place wind and damage assessments in perspective in terms of sustained winds. Reinhold noted that engineers need to know the typical wind speed in built communities in order to adequately assess the impact of enforced building codes on the overall performance of building structures during a hurricane. For example, the hurricanes of the 2004 hurricane season were primarily considered "design events," or events that the buildings were designed to withstand (performance based design). One exception was Hurricane Charley, which was slightly greater than a design event. Building codes have proven crucial to structural safety during hurricanes.

Reinhold noted that a dramatic example of the importance of updated building codes is demonstrated by changes in the manufactured housing industry. Prior to 1976, few building codes prescribed regulations for manufactured housing. From 1976 to 1994, one standard was applied nationally, regardless of the location of the home. After the damage of Hurricane Andrew in 1992, a three-tiered building code system for manufactured housing was established. Three wind zones were created based on American Society for Civil Engineers (ASCE) Standard No. 7-88[1]. This change made a remarkable difference in the performance of manufactured homes during wind events such as hurricanes. Figure 2 demonstrates the success of the three-tiered building code system, displaying two manufactured homes after a recent hurricane; one

1 Minimum Design Loads for Buildings and Other Structures ASCE 7-88.

built according to 1976-1994 standards and another built post-1994. The home in the foreground, built prior to 1994, has been completely destroyed, while the home built under the three-tiered system sustained relatively little damage. Manufactured houses are not impenetrable, but they are significantly strengthened by the updated codes.

Reinhold also suggested that it is critical that evacuation shelters, particularly special needs shelters, be built to meet the latest codes. Windborne debris such as tiles, shingles, gravel, and unsecured items can be highly dangerous and penetrate even the most well built shutter. Code changes in high wind areas are necessary to ensure that debris do not become projectiles.

Figure 2.

Sustained damages of manufactured housing, pre- and post-1994 guidelines after a 2004 hurricane.

Building Hurricane Resilient Communities

Reinhold indicated that the key to building hurricane resilient communities are good, up-to-date codes coupled with uniform code enforcement and building material inspections. Moreover, home builders and owners must be educated to fully understand and appreciate the risks posed by hurricanes. According to Reinhold, there has been a major effort in Florida to educate builders and homeowners about the 2001 Florida Building Code that was enacted March 1, 2002 in response to Hurricane Andrew.

Reinhold also observed that hurricane wind gusts are not uniform within a region, yet all residents receive the same general hurricane information and reports of wind gusts within their region. Because hurricanes are ranked according to category, all residents of an area may believe that they will experience the brunt force of the hurricane's winds equally. Products, like the Automated Surface Observing System (ASOS) wind sensor, that help to differentiate wind gusts can provide more accurate predictions of what the wind load is likely to be on a particular structure.

FEMA Response

According to FEMA director Michael Brown, the 2004 hurricane season and the agency's response were unprecedented. No state had been hit by four major hurricanes in a single hurricane season since the 1800's. FEMA deployed over 5000 personnel as part of the response and recovery efforts in Florida, and FEMA personnel also worked in Georgia, Louisiana, Mississippi, Alabama, North Carolina, and South Carolina. Post hurricane response and recovery efforts were also established in Ohio, Indiana, and Pennsylvania to address flooding due to low pressure systems remaining from the hurricanes that produced heavy rains in areas that were previously saturated by normal seasonal rainfall. FEMA distributed more than 11 million gallons of water, 163 million pounds of ice, 14 million meals ready to eat, 1000 generators, and 140,000 rolls of plastic roofing. Additionally, the National Disaster Medical System was deployed in Florida to treat patients that were unable to get to a hospital, as well as patients in hospitals that were damaged or without power due to the hurricanes.

Brown noted that during the 2004 hurricane season, FEMA relied on lessons learned from previous hurricane responses. He indicated that in previous hurricane seasons FEMA was criticized for not being able to efficiently distribute ice to damaged areas. As a result, greater effort was undertaken to ensure that adequate amounts of ice were sent to Florida. Also, FEMA provided plastic roofing as a quick and temporary fix to cover roofs that suffered hurricane damage. The large number of homes that were damaged during the 2004 hurricane season made building supplies and contractors difficult to secure in a timely manner and thus temporary plastic roofs were left on homes for many months. This roofing material was not designed to last longer than a few months, but FEMA was criticized for not continuing to distribute it and for not providing more durable material, according to Brown. He stated that FEMA's job is to provide people with the essential items needed to get by until they are self-sufficient or able to connect with non-profit organizations like churches, the Red Cross, or the Salvation Army.

Response time is crucial for success in reducing the impacts of disasters, according to Brown. In contrast with its response to Hurricane Andrew in 1992, FEMA pre-positioned manpower and equipment in Orlando, Florida and throughout the southeast United States in advance of the 4 major hurricanes in 2004 to facilitate quicker response. Unfortunately, when Orlando was hit by one of the hurricanes FEMA personnel and equipment had to be evacuated out of state, according to Brown. FEMA personnel were redeployed once the immediate danger subsided. Brown characterized the pre-positioning effort as an example of preparation excess. He noted that this was the greatest lesson learned during the 2004 season. As a result of this experience FEMA is conducting an internal review to create operational constructs for various contingencies to ensure that there are policies and procedures for a situation like the Orlando evacuation, according to Brown.

Brown noted that FEMA was able to provide financial aid quickly during the 2004 hurricane season. After Hurricane Charley's landfall on Friday, August 13, FEMA dispersed disaster assistance on the following Monday. This was the quickest that FEMA had ever processed monetary disaster relief, according to Brown. FEMA was able to increase the efficiency of its financial response due to technological advances and contracts with other organizations, such as the Internal Revenue Service (IRS), to share call centers and handle claims over the Internet.

Brown observed that FEMA's challenge has been, and continues to be, to remain a multi-focused agency. In addition to preparations for and responses to natural disasters, FEMA's charge includes man-made disaster preparedness, response, and recovery. In many cases, such as distributing resources, the response is the same. A significant difference between man-made and natural disasters is that a natural disaster can not only be prepared for, but mitigated. Brown indicated that FEMA has a pre-disaster mitigation grant program to encourage mitigation practices. Another large challenge for FEMA is catastrophic disaster planning. Brown noted that the United States is not prepared for a large-scale disaster that could potentially result in more than 10,000 deaths. A catastrophic planning pilot project was performed in New Orleans, Louisiana because of its susceptibility to hurricanes and tropical storms. The lessons learned from this project will be applicable nationwide, according to Brown.

Insurance

According to Laurie Johnson, vice president of technical marketing and catastrophe response at Risk Management Solutions, a catastrophe modeling firm, hurricanes significantly impact the insurance industry. The United States accounts for 80 percent of the insurance market; and four of the top ten insurance losses in the world have been a result of damages caused by hurricanes. Moreover, eight of the top ten U.S. insurance catastrophes were caused by hurricanes. As of the Disasters Roundtable's March 8, 2005 workshop, Hurricane Andrew was the most expensive insurance disaster on record.

Hurricane Andrew was a turning point for the insurance industry's response to natural disasters. The insurance industry responded to Andrew by developing catastrophe modeling which considers the responses of built environments to the threats presented by hazards in order to better understand risk and loss potential. Historical data is used to simulate thousands of events to create probabilistic wind speeds and vulnerability data that aid in estimating loss. Using robust financial modeling capabilities, the insurance industry is able to analyze loss from a risk perspective, average annual loss, and loss during different timeframes (100 year, 200 year, etc.).

In addition to catastrophe models, re-insurance programs, and building code changes have also been instrumental in aiding financial recovery. According to Johnson, the 2001 Florida Building Code is the most stringent building code in the world. The state also responded by creating its own re-insurance program, the Florida Hurricane Catastrophe Fund (know as the CAT fund), which is the largest re-insurance program in the world. Every insurer in Florida deposits a premium into the CAT fund, the fund in turn provides re-insurance when losses exceed certain thresholds. The state also established the Florida Residential Property and

Casualty Joint Underwriting Association (FRPCJUA) and the Florida Windstorm Underwriting Association (FWUA) to be the market of last resort for individuals that are deemed too high of an insurance risk, or for other reasons, could not obtain insurance. In 2002, the Florida Legislature passed a law that combined the FRPCJUA and the FWUA resulting in the creation of Citizens Property Insurance Corporation (Citizens). Citizens provides insurance to homeowners in high-risk areas and to others who cannot find coverage in the open, private insurance market (http://www.citizensfla.com/gen_info.asp).

The Florida Commission on Hurricane Loss Projection Methodology was also established following Hurricane Andrew in 1992. The commission evaluates computer models and other recently developed or improved actuarial methodologies for projecting hurricane losses. Reliable projections of hurricane losses are necessary to assure that rates for residential property insurance are neither excessive nor inadequate. Johnson stated that this commission is aggressive in setting standards and challenging the science behind the models.

Johnson noted that the 2004 hurricane season demonstrated the need for catastrophe modelers to model for "clustering" and not just event specific losses. Clustering occurs when hurricanes follow one another in an unbroken sequence over a region over a relatively short time period. Florida's response to clustering was to pass a law requiring seasonal deductibles on all residential properties instead of per event deductibles. The implications of this change for the insurance industry in Florida are not yet known.

Johnson indicated that the insurance industry had not accounted for issues such as demand surge and poor construction practices prior to 2004. When claims were filed after the four hurricanes, demand for construction services and materials grew resulting in inflated prices. Claims were also inflated as a result. According to Johnson, catastrophe modeling and insurance industry practices are going to make a giant leap forward as a result of lessons learned from the 2004 hurricane season.

Reliable data is essential for advancements in catastrophe modeling, according to Johnson. The multitude and quality of insurance claim data available from the 2004 season has helped to improve models.

Disaster Recovery

Betty Hearn Morrow, Florida International University professor emeritus, observed that disaster recovery is a lengthy process that often produces unexpected changes in the social structure of an affected community. Morrow originally studied the devastation that Hurricane Andrew caused in one working class community of homeowners in south Miami-Dade County, Florida in 1993, one year after Andrew pummeled south Florida. Her team returned 10 years later and discovered that the area had yet to fully recover. Of those who had remained in the community, many were still living in damaged homes, and reported lasting effects on their families. The researchers documented sharp changes in the social and economic demographics of the entire impacted area of south Miami-Dade County. In particular, they noted an increase in the number of Hispanics spurred by white-flight that accelerated after Hurricane Andrew. This shift was already occurring prior to Andrew, but increased dramatically as many whites used the money received from their insurance claims to relocate. Morrow also noted that the county experienced an influx of low-income housing as newly formed community development corporations took advantage of federal funding opportunities. The availability of low-income housing led to an influx of poorer residents.

Morrow suggested that there is an ethnic component to disaster recovery. Basing their findings on a sample of 58,000 household property records examined over a 10-year period, most regained their pre-Andrew value within two years. However, Morrow's group found ethnicity to be a salient factor. South Miami-Dade County neighborhoods with higher concentrations of blacks and non-Cuban Hispanics recovered at much slower rates, and as a result property values were negatively impacted for longer periods of time.

Morrow noted that some communities of south Miami-Dade County, Florida were also experiencing instability and increased transience due to rapid turnover in home ownership. Many badly damaged homes had been repeatedly sold, often without repairs, based on housing market speculation. There was an important relationship between the extent of the damage to a house and the number of times it was likely to be resold. Homes that suffered as much as 80 percent damage had been sold and resold as many as six times. She also observed that many of the minority-owned homes in this area had been insured by marginal insurance companies that offered poor coverage or went bankrupt. Socio-economic demographics complicated matters as many residents were taken advantage of due to lower levels of education and limited fluency in English. The nature of the community also changed due to the increased number of residents that rented rather than owned their homes. Morrow's experience suggests that disaster recovery is uneven. For those with limited resources, economic or human, recovery can be a long, frustrating process, and some never fully recover.

FUTURE CHALLENGES

Climate Change

The possibility that climate changes may have contributed to increased Atlantic hurricane activity gained attention during the 2004 hurricane season. Thomas Knutson, National Oceanic and Atmospheric Administration (NOAA) research meteorologist, explained that there is immense uncertainty regarding the effect of climate change on the frequency of hurricanes, however both hurricane intensity and precipitation are likely to increase.

In comparison to recent hurricane seasons between 2000 and 2003, the 2004 season was not unusual in terms of the total number of named storms or the number of hurricanes, but it was unusual in terms of the number of major hurricanes that made landfall in the United States, according to Knutson. Increased landfalls have heightened public awareness of these hurricanes. Part of the uncertainty in hurricane frequency is the multi-decadal variability of major hurricane activity. A large number of major hurricanes occurred during the 1950s and 1960s, but the following two decades were relatively quiet. The mid-1990s saw a return of more frequent major hurricane activity

In terms of future changes to hurricane frequency and intensity related to anthropogenic climate change, according to Knutson there is no clear evidence of any long-term trends in the available records for the twentieth century. The maximum intensities of hurricanes, however, are likely to increase due to continued warming of tropical sea surface temperatures. Simulations performed by NOAA indicate that hurricane intensities may increase by about one-half category over the next century if a strong build-up of greenhouse gases continues. Hurricane precipitation is also likely to increase as the warmer atmosphere retains more water vapor, which becomes available to fuel storms.

Demographic Change

Havídan Rodríguez, director of the Disaster Research Center at the University of Delaware, remarked that recent changes in the demographic makeup of the U.S. population present new challenges for disaster management. The unprecedented growth of the U.S. Hispanic population coupled with the overall aging of the American public have created populations with special needs. Increasingly diverse communities with disparate cultural values, economic backgrounds, and languages can impact emergency managers' ability to effectively communicate hazard and risk information. Rodríguez relayed the experience of Oklahoma emergency managers now presented with the challenge of effectively communicating emergency information to an increasing Hispanic population with specific language needs.

The rapid aging of the U.S. population (e.g., the number of people 65 and older in the United States is increasing at a rapid rate) also presents challenges in terms of emergency evacuations and shelters. According to Rodríguez, women over the age of 70 are among the fastest growing groups in the United States. Elderly individuals with chronic illnesses, such as diabetes and heart disease, require special care and medications during times of emergency, noted Rodríguez. These needs of the elderly, and the infirm, must also be considered in evacuation planning.

Poverty is also an important factor that increases a community's vulnerability to disasters. Rodríguez noted that poorer communities often have less access to emergency information and are less likely to be prepared for a disaster.

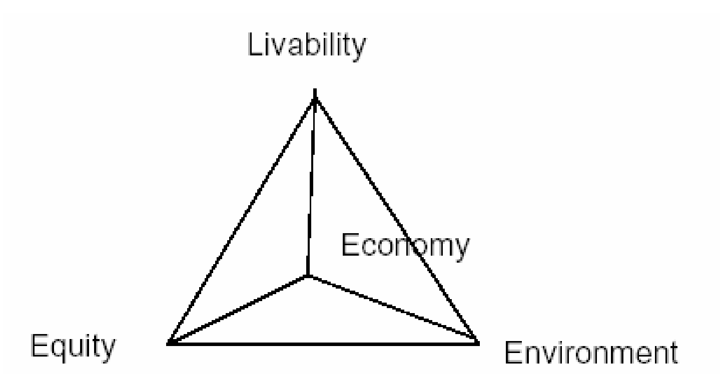
Greater vulnerability also results from increased population density and urbanization, especially in coastal areas. Ongoing population growth in the coastal regions of the United States presents difficulties in evacuating large numbers of people to safer areas during emergencies. Demographic changes in at-risk areas highlight the importance of effectively communicating emergency information to diverse populations. The needs of an aging population also need to be considered. According to Rodríguez, U.S. emergency managers will continue to face challenges presented by demographic changes in the population.

Coastal Development

Disasters result from inadequately planned urban development in inappropriate places, compounded with hazard events, noted David Godschalk, an urban planner at the University of North Carolina, Chapel Hill. Increasing development in states that are the most vulnerable to hurricanes (Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, and Texas) puts more property and people in harms way. The good news, according to Godschalk, is that much of the development that will exist in the next 30 years remains to be built. This provides opportunities for developers to implement mitigation techniques, planners to establish safe and smart growth initiatives, and communities to begin thinking in terms of sustainability and livability.

There are many examples of communities that have taken advantage of post-disaster mitigation funds to incorporate mitigation techniques, such as relocating or elevating homes. Buying out homes and businesses located in the floodplain and converting them to open space makes communities safer and also increases the livability of the community, according to Godschalk. He suggested that new development presents the opportunity to build resiliency into community design. Environmental protection and livability can also be part of this type of new development. Godschalk has developed a sustainability prism incorporating all of the concepts that make a sustainable and livable community, as shown in Box B.

Box B. Sustainability and Livability



Each point of the prism is a value. Equity, environment, and economy are three of the values of sustainability. The fourth point, livability and the connecting axes between the points denote the interactions between those concepts. Livability, environment, economy, and equity all interact.

Sustainability in itself is a two dimensional concept. When the sustainability prism is drawn, there is a flat, two-dimensional concept consisting of equity, economy, and environment. When you add livability it changes it to a three dimensional concept, which is how people think in terms of the environments they look at. They don't look at them as flat planes, rather as three dimensional environments, according to Godschalk.

Livability includes public space, movement systems, building designs, and transit-oriented development to move people to the coast without the use of bridges. The heart of the prism would be the ideal sustainable, livable, resilient community. Godschalk views the prism as a tool for conceptualizing and planning communities. It not only tries to balance the values of economy, environment, and equity, but it blends those characteristics with livability in order to generate consumer and market acceptance (Godschalk, 2005).

Godschalk remarked that "If we are to transform the looming growth of our hazard-prone areas into truly hazard resilient communities, then I don't think we can rely on government regulations alone. I think we have to recognize the role of the markets and what people want, consumer desires in shaping growth." Given the sheer amount of projected development and re-development in hazard-prone states, planners are presented with a significant opportunity to build disaster resilience into development projects, according to Godschalk.

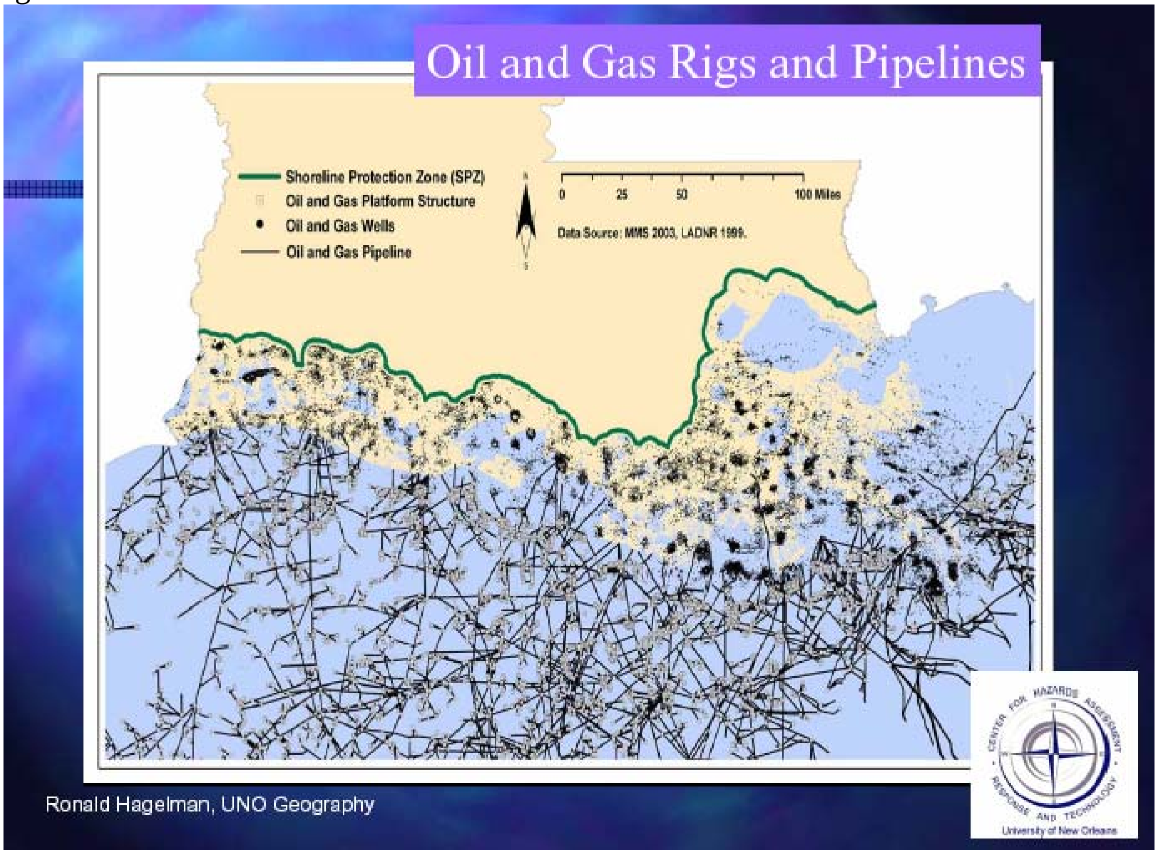
New Orleans: Disaster Waiting to Happen

The unrelenting deterioration of the natural environment in New Orleans, Louisiana is the prime contributor to the city's risk, according to Shirley Laska of the University of New Orleans. The deterioration began with the levying of the Mississippi River by early settlers. After major flooding along the Mississippi River in 1927, the levees were transformed into a continuous, solid, effective levy system along the entirety of the river. In addition to the levying process, pipelines were laid throughout Louisiana's coastal marsh to aid oil exploration traffic and canals were dredged to shuttle oil and gas to other regions of the United States (see Figure 3). These two dynamics have come together to produce a slow onset risk, noted Laska.

Louisiana is located on the Mississippi River deltaic plain, which is subsiding naturally due to sediment dewatering and compaction. In addition, New Orleans tapped its artesian aquifers for groundwater supplies, which led to land surface subsidence in several parts of the city. The drainage of organic soils for development has caused a decomposition of soils and compaction, which increases vulnerability to coastal flooding. Moreover, the weight of buildings, levees, roads and other developments has added to compaction and subsidence (NRC, 2002). The levies that protect the city from the river are also sinking. Laska recounted that a woman from New Orleans told her, "Even when the sun shines, it floods."

It is estimated that 20 square miles of land is being lost in coastal Louisiana annually, according to Laska. Louisiana has lost approximately one-third of its barrier islands since 1880 and it continues to lose more coastal wetlands each year than the rest of the United States. The land loss is largely due to the intrusion of salt water introduced into the marsh by hurricane winds. Salt water kills marsh grasses anchoring the soil and results in soil erosion. (See NRC, 2002 for a further discussion on the potential for disaster in New Orleans.)

Figure 3.



Courtesy of University of New Orleans.

Laska noted that New Orleans has deteriorating coastal defenses and huge evacuation challenges because it is surrounded by water and wetlands. She reported that the Center for Hazards Assessment, Response, and Technology (CHART), which she directs at the University of New Orleans, is working on a project to aid evacuations called "Our Brothers' Keeper." This is a faith-based collaborative with church congregations in the city that also involves the Red Cross. The congregations work to identify individuals that do and do not posses personal transportation and links the groups together. And as part of evacuation planning, they also identify relocation sites, which are other congregations in northern Louisiana and in Mississippi. Another evacuation alternative is to utilize the New Orleans Superdome as a shelter for individuals unable to evacuate during a hurricane. However, a total and efficient evacuation is the best scenario, Laska noted.

Laska also remarked that mitigation is a salient challenge for New Orleans. For example, she suggested that elevating houses is futile in a city that is mostly below sea level. Also, raising the levies may make a difference, but it would be expensive and USACE's budget has been cut, according to Laska. She noted that retrofitting of buildings may be possible but that the city's budget is not adequate to build new buildings. Laska remarked that instead of spending funds on mitigation, New Orleans is holding its breath waiting to see if the worst case scenario happens.

Laska estimated that it will take at least nine months to drain New Orleans after a direct hit from a major hurricane. During that time, relocation sites in other parts of the United States will be necessary to house hurricane evacuees. When the city is drained, the question will be "will it be open for redevelopment as other coastal areas have been?" Laska suggested that it will not, because the disaster will leave environmental conditions that hinder redevelopment. She speculated that the city will reform on the north shore, with an urban area on the port for commerce.

Increasing the public's appreciation and understanding of the risk that hurricanes pose to New Orleans are the real hurdles, according to Laska. After Hurricane Ivan, the debris deposited on the banks of the Mississippi river from the rising waters was quickly cleared away. Laska asserted that this step was taken to prevent public alarm. Had the public been allowed to view the deposits they may have realized how high water can potentially rise and then would more fully understand the risks. The mere mention of the gravity of such an event makes many uncomfortable. According to Laska, Walter Maestri, emergency manager for Jefferson Parish, Louisiana, once mentioned the possible need for 100,000 body bags during a talk about hurricane risk to New Orleans and was then asked not to talk about that because of the image it projected. People do not want to deal with reality in New Orleans, but a dire situation is inevitable, noted Laska.

Science Policy and Hurricanes: Where do we go from here?

In the final workshop discussion, Roger Pielke, Jr. of the University of Colorado suggested that the hazards and disaster research community is "paralyzed by a lack of information." Pointing to a recent 2003 RAND study requested by the Office of Science and Technology Policy (OSTP), Pielke stated that exact figures for government expenditures on hazard loss reduction, hazards' costs, and the links between funds allocated to research and the reduction of hazard losses are unknown. Without this information, reliable and informed decisions cannot be made about the allocation of funds for disaster research and reductions.

Citing the RAND report, Pielke stated that an estimated $1 billion is spent annually on hazard loss reduction research and development. The majority of this funding is allocated for the study of natural phenomena. However, as noted by earlier workshop speakers, hazards themselves do not make disasters. A hazard becomes a disaster when it adversely impacts human lives and property. Thus, the human element of disasters is a salient factor deserving of more research. Yet, according to Pielke, there is little knowledge of the connection between the expenditure of federal funds on research on the one hand, and on the other the development of effective policies related to disaster vulnerability, or risk. Additionally, he believes that U.S. priorities for hazard-related research and development do not adequately address the information needs of decision-makers. According to Pielke, the largest fraction of research and development spending supports work on weather hazards and broadly related research on climatology, atmospheric science, and oceanography.

Pielke noted that scientists and policymakers rely on knowledge about the allocation of funds in order to identify the extent of disaster impacts on human populations, why these impacts occur, and the relationship between research and development and these impacts. Available information suggests an excessive focus on predictions and short-term hazard predictions.

CONCLUDING REMARKS

The ongoing need for enhanced hurricane disaster preparedness and response plans, that include effective and enforced mitigation practices, advanced forecasting technology, and evacuation and sheltering plans, was highlighted by speakers and participants throughout the workshop. Ensuing discussions about the lessons learned from previous hurricane seasons suggested that it is important for at-risk communities to employ a combination of adjustments involving science and technology, regulations, institutional and organizational arrangements that include partnerships and intergovernmental linkages, and processes. The nature of these adjustments, which involve both the public and private sectors, has and will continue to change to reflect past experiences and anticipated future needs.

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