# Under The Weather:
## Environmental Extremes and Health Care Delivery

American Meteorological Society
Policy Program

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**Under the Weather: Environmental Extremes and Health Care Delivery**

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This event in the AMS Policy Study Series is dedicated to

**Thomas "Tim" Butcher Jr.**
**1955–2008**

Prior to and during Hurricane Katrina (2005), Tim was the Emergency Preparedness director for the Medical Center of Louisiana in New Orleans. He and his team were responsible for saving many lives during the aftermath of Katrina while stranded for five days at University Hospital without power, food, sanitation, or medicine. His home was flooded as well, necessitating his move to Butte La Rose and obtaining a position with the Education Department at University Medical Center (UMC) in Lafayette.

Following Hurricane Katrina, he gave lectures nationally and was a published author of several articles about his experiences and the urgency for hospitals to be more prepared for human-caused and natural disasters. He was a valuable partner to the AMS Policy Program on this Policy Study Series. Tim gave important information and guidance for elevating the nation's awareness for hospital and public health vulnerabilities to severe weather.

In 2007, he was recognized by his coworkers at UMC for his professionalism, mentoring, and caring spirit, and was honored by the National Emergency Nursing Association for his service to the profession. The state of Louisiana and the nation lost a real fighter, and champion for hospital preparedness on January 29, 2008 when Tim passed away from throat cancer.

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## Executive Summary

Severe weather is a necessary product of the natural environment. Storms, though sometimes powerful and deadly, are nature's temperature and moisture balancing mechanisms. We know this with great certainty. We also know that the United States experiences as much or more severe weather than any other country on Earth. And, we are also increasingly informed that a changing climate may intensify the storms that already frequent our coasts and rip through our rural and urban areas on a seasonal or annual timeframe.

Despite this accumulated awareness, the United States' critical infrastructure, most specifically hospital infrastructure, remains unprotected against the expected movements of our natural environment. In April 2007, the American Meteorological Society (AMS) hosted a forum titled "Under the Weather: Environmental Extremes and Health Care Delivery" to spotlight severe weather vulnerabilities to hospitals and to healthcare continuity.

For one and one-half days in the Ronald Reagan Building in Washington, D.C., more than 50 leading federal and local-level decision-makers, who represented a diverse range of disciplines (e.g., public health, meteorology, hospital administration, engineering, and state emergency management), met to discuss what is needed to improve structural preparedness for hospital buildings, the people who staff them, and the people who need them.

Together, we discovered three overarching policy problems that are barriers to preparedness for hospitals and the continuity of healthcare delivery. There is a general lack of awareness of environmental vulnerabilities on the part of local decision makers. Another is the absence of coordination and communication across federal agencies. And, finally, a paucity of financial resources or incentives that could encourage needed structural mitigation or adaptation for current and projected weather risks.

We focused on creating communication and coordination channels because they were so central to tackling the other problems. Namely, new channels could produce products and tools that inform hospital decision-makers about environmental risks to their facilities. Additionally, new channels could open financial opportunities (e.g., grants or subsidies) that make it possible to implement engineering and meteorological solutions. The only trouble is that these channels are presently absent across federal agencies and between federal and private organizations.

As we addressed possible solutions to each, we also realized one common thread—that the science, engineering, and emergency management solutions needed to protect these critical infrastructures and to promote continuity of operations already exist. Several agencies and private companies already have major pieces of the puzzle in place. These pieces, however, tend to be locked within organizations, either in storage (literally) or used for a purpose that is more narrow than its potential (e.g., GIS-applications that could convey location-specific weather forecasts).

The forum, and this report, each addressed the potential policy and financial game changers that are needed to unlock, dust off, or expand existing products and services for hospital and healthcare preparedness against known and probable weather risks. The "Under the Weather" forum was the first in a series of such discussions. With our federal, private, and non-governmental partners we held subsequent forums on this topic. These discussions delve into the available federal programs and services, and private/public partnerships opportunities. We come from diverse fields and are unified for a single purpose, which is to tap the available potential in this nation to protect the only infrastructure that provides for our health, and is a major piece of the engine that keeps the nation moving.

*Wendy Marie Thomas*
Policy Analyst/Meteorologist
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# 1.0 Introduction

## *The Concern*

The United States has an extensive network of health care facilities comprising more than 16,500 private and public hospitals and clinics nationwide. These facilities are critical to health care and the economy[1]. However, their infrastructure (most notably the roof, exterior walls, windows, and generators) remains vulnerable to extreme weather events, such as hurricanes, tornadoes, heavy precipitation events, and extreme temperatures. This vulnerability jeopardizes staff and patients during severe weather and compromises health care delivery.

This is a concern because the United States experiences as much or more severe weather than any other country on Earth. In a typical year, the nation experiences 10,000 severe thunderstorms; 5,000 floods; 1,000 tornadoes; and 10 hurricanes. Extreme temperatures (both hot and cold) also have a major effect—nearly 12,000 people, primarily the aged and economically disadvantaged, are hospitalized each year as a result of extreme temperature conditions. These weather events create surges of demand for health care while simultaneously threatening the continuity of that care. Going forward, climate variability and change may alter the tracks and intensity of storms in the immediate and near term. These realities should compel policy makers to contemplate retrofitting existing hospitals or to otherwise ensure that new hospital construction can "weather" storms and remain operational, especially during periods of greatest need.

Three past events—Hurricane Katrina, Tropical Storm Allison, and the Chicago (Illinois) heat wave—highlight the fragility and vulnerability of America's health care infrastructure to severe weather. Hurricane Katrina, which captured global attention, displayed with stunning clarity the gross vulnerability of New Orleans to hurricanes, despite repeated concerns raised for more than a decade. It also triggered tremendous "ripple" effects that disrupted and overwhelmed health care delivery facilities in and around New Orleans and the Gulf Coast. In many ways, Katrina epitomized a failure of policy to integrate available meteorological knowledge and engineering solutions to protect critical national infrastructure, most especially hospitals, from known risks.

Tropical Storm Allison, which resulted in $2 billion worth of damage to the Texas Medical Center in Austin, Texas, and the Chicago heat wave, which overwhelmed the capacity of both emergency rooms and morgues, reveal other policy failures to plan for weather emergencies and to connect and protect people and resources. Clearly, a game change is needed in the way the nation goes about protecting critical infrastructure, particularly hospitals, against severe weather. The current approach poses unacceptable risks to society.

[1] The United States healthcare sector contributes approximately 16% to U.S. GDP. Source: Organization for Economic Cooperation and Development (OECD), Health Data (2008).

## *A Step toward a Solution*

Addressing these challenges requires a multidisciplinary approach, drawing from all relevant areas of expertise, both inside and outside of government. In pursuit of that goal, on 16–17 April 2007, in Washington, D.C., the American Meteorological Society (AMS) hosted the forum "Under the Weather: Environmental Extremes and Health Care Delivery." More than 50 key decision makers in the fields of public health, medicine, meteorology, hospital administration, civil engineering, and emergency management met to confront the enormous, looming risk facing America's health care infrastructure.

Forum participants made considerable progress in sharing information among disciplines and levels of health care provision and made a key breakthrough discovery: The information, processes, and resources that one element of the disaster risk reduction system needs to increase hospital resilience very often already exist, whether at a different organizational level, in a different geographical location, or even in a different area of the health care or disaster risk reduction systems altogether. The difficulty lies in sharing and coordinating the information, not in creating it through new research or product development. Furthermore, participants identified game changers such as new incentive programs or changes to the grant review process that, if implemented, could potentially drastically improve the current and future protection of the United States'health care system.

## *Two Realities*

A realistic appraisal of the health care infrastructure and its vulnerability to weather events shows certain facts of life. Weather extremes are and will remain major features of the atmosphere. Furthermore, forecasts of these extremes will always be on a time frame too short to provide any real protection to the health care delivery enterprise. Climate change and variability will make future efforts to build resilience more difficult. Population shifts within the United States and demographic changes as the nation ages will place additional stresses on health care infrastructure.

Conversely (and this is the second reality), some factors are highly addressable. While the weather itself and its direct effect on the health care system are effectively nonnegotiable, some elements of the system's vulnerability can readily be improved. First, a little more margin could be built into the system. Currently, the hospital network in many cities lacks surplus capacity that could be employed in a regional-scale emergency. Recall how overflow from Katrina triggered subsequent cascading overflows in adjoining health care systems, which themselves had little spare capacity. In addition, many hospitals and clinics are not hardened to withstand catastrophic weather events, and end up failing and contributing to the problem at the time when they are most needed. These are areas where both material resources and information exchange can be profitably applied, yielding significant improvement in the system's overall resilience. Improved intersector communications would yield tremendous opportunities to upgrade the health care system's resistance to extreme weather events.

## *The Challenges Ahead*

The challenges ahead are not trivial. However, participants shared the processes and experiences of different private and public actors, particularly the internal workings at decision-making agencies, such as the National Oceanic and Atmospheric Administration (NOAA) and the Department of Health and Human Services (DHHS). Through this conversation they found that they could improve interagency partnerships, particularly at the federal level, and contribute to a more weather-resistant national health care infrastructure.

By the conclusion of the forum, participants reached a new understanding: the nation has the potential to protect its health care infrastructure against severe weather events by connecting currently existing products, services, and information systems and by coordinating these services in a coherent and effective way. The next step in the process is to take the linkages that are today tenuous or theoretical and make them real and cohesive. This report summarizes the suggestions of the forum participants. The hope is to turn this vision into a practical reality: a safer, more secure, and more resilient national health care infrastructure that can function effectively even in the face of natural disasters.

# 2.0 Case Studies

Our review of the presentations made at the forum will begin with case studies. The case studies were explorations of patient management during a weather crisis—that is, critical weather events that damaged health care infrastructure—and innovative developments at the intersection of meteorology and health that reduced patient surges. Each study was presented by an expert in the field or by a senior figure who is affiliated with the institution upon which is being reported.

## *2.1 Hurricane Katrina and the "Imported Surge" Effect*

This case study was presented by **Dr. Bryan McNally**, a meteorologist and practicing emergency room physician at Emory University Hospital in Atlanta, Georgia.

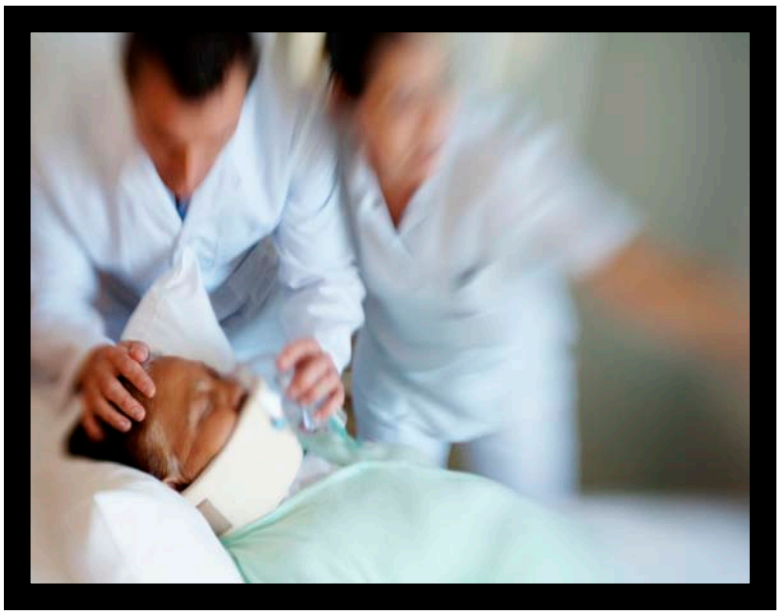

FIG. 1. Depiction of the rushed chaos that occurs during a regular surge. Multiply this level of attention by hundreds to imagine the effect that an imported surge has on staff, patients, and the health care delivery system. (Image courtesy of iStockphoto.)

Patients do not arrive at hospitals in steady streams, so many per hour. Instead, there are surges and lulls in the number of admissions over time. Hospitals analyze these surges and make predictions about peak staffing levels that will be required to handle the course of ordinary variation, but this planning can only go so far in mitigating the effect from surges of extraordinary size. Such large-scale surges are often "imported surges"—the result of a disastrous event in some other locality that begins sending patients in excess of its own capacity to neighboring health care centers. Imported surges can negatively affect patient care. They can intensify and complicate the triage process, by which patients are "sorted" according to the level and urgency of care needed.

Wards that are filled with acutely ill patients compromise the "sorting" approach. Imported surges introduce other challenges, such as meeting staffing demands, absorbing exorbitant costs with questionable repayment potential, and rapidly dwindling medical supply stocks. Dr. McNally presented uniquely relevant information from his own hospital at Emory University, which received 300 overflow patients evacuated by air from Tulane University Hospital in New Orleans, Louisiana, two at a time, during Hurricane Katrina.

Hospital staff knew that the imported surge would strain their capacity but only the actual experience showed how stretched resources and staff would become in such a scenario. Among the issues that staff had to deal with on an ad hoc basis were the following:

- providing care for acutely ill cancer patients in midcourse on chemotherapy regimens, without any medical records;
- filling prescriptions for patients with no documentation of their conditions or existing prescriptions; and
- creating charts and patient records from scratch, with only patient accounts serving as guides.

Medical and public health issues were only one facet of the surge's effect on Emory and on Atlanta as a whole. Hospital and city administrators also faced financial, legal, and social services challenges from the imported surge. Many transported patients lacked any health insurance coverage, and hospitals had to verify coverage for those patients who did have it; uninsured patient coverage represented a large potential financial loss for the facility and for the city. Legal issues quickly arose, and Emory, along with many other jurisdictions, was caught up in months of bureaucratic wrangling over who would recoup which costs. Aftercare treatment posed new challenges, as many patients had neither a local residence nor the ability to return to Louisiana; Atlanta devoted considerable social services resources to securing temporary shelter for these patients. All told, the nonmedical effects of the imported surge, while not as directly critical to human health, were of major import and imposed enormous burdens on the administrative and financial infrastructures of Emory and other receiving facilities.

## *Specific Recommendations*

Dr. McNally made several key recommendations, not only for mitigating imported surge, but also addressing broader forum issues.

**Enhance the use of volunteer health practitioners (VHPs).** VHPs are physicians, nurses, first responders, public health workers, and others who deploy into the disaster zone when a Katrina-type weather event occurs. Providing care within the disaster zone, rather than exporting patients to adjoining regions, mitigates the import surge effect and permits patients to recover in familiar surroundings. During Katrina, a wide array of institutional and physical roadblocks limited the use of VHPs. Since then, the Uniform Emergency Volunteer Health Practitioners Act (UEVHPA) has been drafted, which calls

for uniform statutory provisions concerning VHPs in all 50 states to facilitate the seamless deployment of VHPs during health emergencies. Some state legislatures have moved forward on implementing the protocols, but national leadership is needed to move this act forward and to foster the use of VHPs to blunt imported surges.

**Promote electronic patient record transfer.** Records transferred via electronic means can provide seamless continuity in care, particularly for patients with complex histories and treatment plans and those with limited ability to articulate their own health concerns to a new set of clinicians. Electronic record transfer is strongly preferable to moving paper records with evacuated patients, because paper documents can be easily destroyed during the event, are a burden to attain during crisis situations, and can be lost or compromised during transport.

**Prepartner hospitals outside of probable impact zones.** Before a crisis develops, hospitals and similar facilities should enter into partnerships with similar facilities in other areas of their region but outside the probable impact zone of a similar event. For example, a hospital in a coastal area vulnerable to hurricanes or flooding would partner with a facility located far inland or at elevation, so that the same weather event is unlikely to jeopardize both facilities simultaneously. These facility pairs should then coordinate their communications and emergency management plans so as to harmonize their efforts in the event of a major disaster.

## *2.2 Tropical Storm Allison and the Texas Medical Center Flood*

This case study was presented by **Dr. Baxter Vieux**, a professor of civil engineering and environmental science at the University of Oklahoma.

Major medical facilities—keystones of the national health infrastructure—can become primary victims of major weather events. Few cases better typify the vulnerabilities of health care facilities to catastrophic weather events than the 2001 impact of Tropical Storm Allison. Allison inflicted $3.5 billion in property damage—$2 billion of which occurred at a single place, the Texas Medical Center (TMC) in Austin, Texas. TMC was the world's largest medical complex, with 23 institutions; 13 hospitals; and 100,000 physicians, nurses, and support staff working on any given day. A small city in itself, TMC was a major node in the regional and national health care infrastructure.

FIG. 2. Flood waters from Tropical Storm Allison in 2001 broke through first-stage barriers and into the first floor at TMC, rendering the then-largest medical facility in the world inoperable. (Caption and image courtesy of Dr. Baxter Vieux.)

That node was effectively knocked out when Allison swept through with near-hurricane-force winds and massive precipitation. Though Allison was a large storm, the type is hardly unknown in Texas. Subsequently, building engineers prepared storm response procedures with flood mitigation foremost among them. TMC was no exception; there were procedures for handling floods and storms, and medical staff did its best to implement them. However, its response was not sufficient to preserve a high level of functioning as a medical center. Not only was patient care compromised, but the facility itself suffered enormous damage, impairing TMC's function as a regional health care infrastructure over the long term and requiring costly repairs.

Poststorm reviews at TMC revealed some poor planning decisions that contributed to the failure during Allison. One critical weakness was that the entire power-generating infrastructure for TMC, which was responsible for keeping the facility online even in the absence of grid power, was located at ground level. When the flood penetrated TMC grounds, the electrical system was among the first systems to fail. The flood control plan called for the medical staff to deploy portable flood barriers to block water. However, outdated data collection and communication procedures delayed the effective use of this tool. Plans relied on near-perfect performance times from the TMC staff, and the measures failed when actual performances were merely adequate. One key insight from the poststorm review: The previous emergency plan was response dependent and

applied to events of limited severity. This approach was easily overwhelmed by an event of somewhat greater magnitude than planners had anticipated.

Post-Allison, the TMC administration conducted an extensive review and overhaul of the facility's disaster management plans. Consulting with engineers, meteorologists, and hydrologists, TMC developed a new flood management system with much better predictive capability, monitoring real-time radar data for flood risk to the institution, and maintaining a much higher level of awareness.

### *Specific Recommendations*

In light of its experience with Tropical Storm Allison, TMC contracted Dr. Vieux to build an in situ environmental monitoring station. He made four key recommendations to other health care facilities.

**Create structural engineer and environmental scientist teams before an event.** Using these teams, identify the key environmental vulnerabilities for the facility. Combining the information sets of building engineers and hydrologists highlights areas of significant vulnerability.

**Integrate elements into a service.** Incorporate real-time environmental tools and data into an in-house warning coordination and emergency readiness service. This service should also be updated regularly to incorporate new environmental and engineering knowledge, as well as advances in technical hardware and programs.

**Response plans should include evacuation options as well as stay-in-place options.** Each emergency is different and will require a different set of actions. Make emergency plans flexible so as to account for probable events and outcomes. Evacuation plans should include transportation and exit strategies, as well as partnerships with neighboring hospitals. Stay-in-place plans should include developing pharmaceutical and medical storage plans. Though the building may be secure, supplies will likely dwindle and new shipments may be slow to arrive. To remain operational until the waters recede, stored supplies are critical.

**Retrofit/build infrastructure to limit exposure.** Implement structural retrofitting to mitigate identified environmental vulnerabilities and infrastructure weaknesses. For example, after Allison, a detention basin was constructed around TMC to prevent flooding at the entrance ways.

## *2.3 The 1995 Chicago Heat Wave*

This case study was presented by **Dr. Eric Klinenberg**, professor of sociology at New York University.

In Chicago during the summer of 1995, record-high temperatures over the course of two and one-half days contributed to 739 deaths above the norm for the period. City morgues filled beyond capacity so freezer trucks were brought in to store the dead, and massive surges filled the emergency rooms of Chicago's hospitals. Yet, the meteorological details of the Chicago heat wave are not sufficient to explain the higher-than-normal variance in death toll.

FIG. 3. Heat wave effect in New York City, New York, 2008. (Image courtesy of The Associated Press.)

What happened? Poor policy development, inadequate coordination between departments and agencies, and ineffective public communications combined to create a catastrophic situation. Chicago in 1995 was in many ways a dress rehearsal for Hurricane Katrina: its weak preevent policies, unclear chains of command during the response, political blame games, political inertia, and ineffective communication with or guidance to the most vulnerable public all combined to produce a terrible death toll.

Heat waves, from a public health perspective, are among the most preventable weather-related disasters. According to the Centers for Disease Control and Prevention (CDC), simple countermeasures—such as drinking more water (for healthy individuals, some exceptions to this rule apply for patients with renal disorders), staying in the coolest and best-ventilated portions of a house, and avoiding the sun—are ordinarily sufficient to avoid death or debilitating heat stroke. These fundamentally simple public health measures were not communicated to Chicago's vulnerable populations in 1995, however.

The cause, according to Klinenberg, emanated from a policy vacuum that did not coordinate public health, emergency management, and meteorology. To make matters worse, several members of Chicago's government were absent during the heat wave, so no one was on hand to begin to connect the local preparedness and response assets, nor

was there a coordinated public service message that could have informed the public, particularly the most vulnerable: the aged and economically disadvantaged.

The key lesson from the Chicago heat wave of 1995 is that the integration of information and application of good practices will not be integrated across disciplinary and jurisdictional boundaries without policy-level attention. Policies are needed and should be enforced well before an event to channel cross-sector communication and to encourage the fullest utility of scientific knowledge for the public's benefit.

### *Specific Recommendations*

**Connect service with information.** Disaster relief planning must include connecting service and information sectors to provide for the health and well-being of residents. Relevant and appropriate technology, such as geographical information system (GIS) mapping, should be used to identify vulnerable populations, that is, the aged, poor, and those living in isolation or outside of social networks. Communication channels need to be created to effectively reach these individuals to provide lifesaving information during a public health crisis.

**Require that a coherent, consistent message be relayed by all emergency responders.** In New York City, which has a very low heat-related death record, first responders (such as the police officer, paramedics, and firefighters) work with health and weather professionals to develop a consistent and helpful message, and then they go out into communities to deliver that message.

**Prepare for worst-case scenarios.** Chicago was, in fact, lucky that the heat wave of 1995 was of relatively moderate effect and duration. Cities and response agencies need to prepare for much more serious events; for example, the heat wave in Europe in 2003 that lasted not for two and one-half days but for three weeks and resulted in as many as 35,000 excess deaths, according to some estimates.

## *2.4 "Healthcasting": A Partnership between Meteorology and Public Health*

This case study was presented by **Ms. Clare Bryden**, a meteorologist and manager of health research with the Met Office.

The Met Office, the United Kingdom's national weather service, has investigated meteorological tools and forecast products that could mitigate the effects of patient surges (see case study 1) by informing hospitals and health care facilities of impending weather changes that will likely affect health care demand. These changes could be caused at a trivial level, from increased precipitation that might lead to a slight increase in the rate of slips and falls to enormously significant causes, such as large-scale ice storms. The Met Office coined the term "healthcasts" for this new type of forecast that combines weather and its potential public health effects.

In theory, one principal benefit from healthcasting is that it can help health care facilities plan their staffing and resource needs. However, in practice, the necessarily inexact and statistical/probabilistic nature of this type of guidance proved uncomfortable for hospital administrations to implement. For example, if the healthcast projected a patient surge that did not actually happen, then hospitals could be overstaffed. Hospital administrators communicated that they were unwilling to take such risks, so the Met Office decided to redirect its energy and focus on providing information useful in preventive care directly to the patients.

FIG. 4. A man receiving automated healthcasting information, via telephone, that is targeted to his particular health demographic. The healthcasting information is vended by private sector companies through the phone service. The initial weather information is provided by the Met Office, in partnership with NHS. (Image courtesy of the Met Office.)

Meteorological researchers targeted a common health–weather-linked disorder called chronic obstructive pulmonary disease (COPD), a progressive respiratory disease that can be aggravated by air pollution and dust.

COPD is a severe disease that poses a significant public health problem in the United Kingdom, affecting as many as 3 million people in a population of 60 million, and is expected to get worse in the next decade. COPD

healthcasting directly informs those with the disease of risk conditions via a computerized telephone alert system. The system delivers information on risks to the right person (the affected patient) in the right place (where the weather event is changing conditions) at the right time (before the event occurs).

Development of the healthcasting model was made possible by first forging a cross-sector partnership between the Met Office and the National Health Service (NHS). This was a significant challenge, as NHS is a large, bureaucratic organization—in fact, it is the third largest employer in the world. Meteorologists at the comparatively much smaller Met Office took time to understand the NHS structure and to find the right office and people with whom to talk. From that starting point, the collaboration soon involved a range of organizations with relevant competencies and the project was underway.

The NHS–Met Office partnership forged a COPD advisory group consisting of a panel of experts from various public interest organizations. Despite these connections and first steps, it was still a struggle to get the Department of Health (DOH), the parent to NHS, involved in healthcasting. This impediment posed a challenge to rolling out the service nationally, but departmental support was eventually won after the pilot studies received positive results.

The Met Office's COPD initiative resulted in benefits for both patients and practitioners. In the first year, there was a measurable increase in patient education about the health–weather connection. Self-care increased, and 65% of patients commented that the service helped to improve their quality of life. The cost savings was also significant. Extrapolated data suggest that the whole of England could save about £60 million [roughly equivalent to $120 million (U.S. dollars)] per year. In 2006, NHS and DOH honored the Met Office with an Innovative Service Award in recognition of the healthcasting initiative. The existing COPD healthcasting program continues to operate and evolve to provide better services to the public.

### *Specific Recommendations*

Ms. Bryden recommends that those seeking to form partnerships between government agencies and the private (and nongovernmental) sector take the following steps:

**Anticipate differences.** Expect bureaucratic and cultural differences between health and weather communities, as they carry different missions, utilize different procedures, and carry different budgets. These differences are navigable only when the partnership's mission is clear and focused. Avoid attempts to address several health–weather-linked effects at once. Instead, focus on a specific issue that can produce measurable results and benefits.

**Publish health/weather relevant articles in public health/medical literature and attend conferences of leading health/medical societies or associations.** This approach informs and makes the other community aware of the potential utility of weather tools for its field, and it develops mutual credibility for partnership efforts going forward.

**Work in teams.** Work in small, easily manageable, and dedicated cross-sector teams when designing a cross-sector policy agenda. Large teams will only replicate the blocks of their parent organizations. Keep it to 1–2 persons from an organization on a small team, so that the team will be able to foster its own more productive dynamic and be a channel for future progress.

**Understand the user and identify user requirements.** One key element in the success of the COPD trial was that it provided obvious and appreciated value to the public. By grasping the COPD sufferers' need for predictive and geographically relevant information, the Met Office was able to provide immediate productive results. That public credibility facilitated greater organizational buy-in from other governmental entities when the program needed resources to expand. Data-based programs can be improved by directly communicating with users to find out how data output could be changed to be of greater value to them.

**Allow for and encourage growth.** Foster the continuous evolution of the program, especially as levels of both health and weather understanding improve. This type of collaborative work is relatively new, and best practices may change on a routine basis as new ground is broken. Focus on providing value to users of the program even as those users' needs change over time. Work constantly with educators and social scientists to improve public awareness of the program, so that the user constituency is aware of and supportive of the benefits the program provides.

# 3.0 Panel Discussions

In addition to case studies, the forum included panel discussions moderated and staffed by top experts in fields relating to weather and health.

## *3.1 "Overcoming Barriers": Health Care Delivery Perspectives*

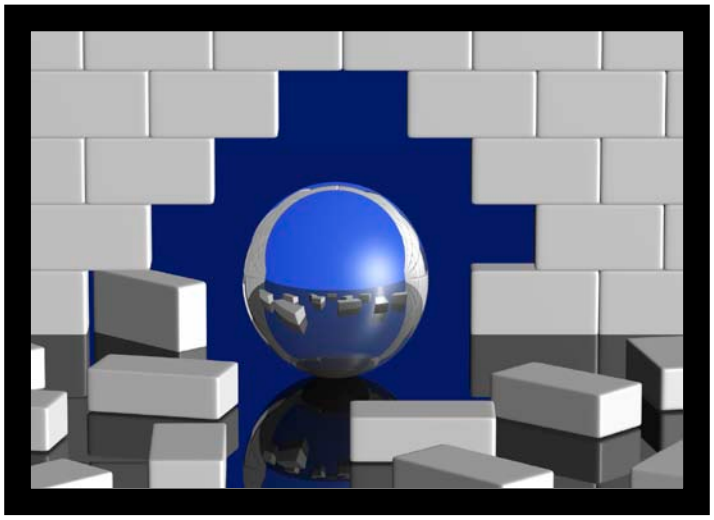

FIG. 5. (Image courtesy of iStockphoto.)

The Health Care Delivery Perspectives panel was moderated by **Dr. Howard Frumkin**, director of the National Center for Environmental Health at the CDC. The discussants were **Dr. Mark Keim**, medical officer at the Coordinating Office for Terrorism Preparedness and Response at the CDC; **Dr. Jim James**, director of the Center for Public Health Preparedness and Disaster Response at the American Medical Association (AMA) and also the editor in chief of the AMA's new journal, *Disaster Medicine and Public Health Preparedness*; **Dr. Linda Degutis**, associate professor of surgery, research director of emergency medicine, director for the Center for Public Health Preparedness at Yale University, and president of the American Public Health Association (APHA); **Dr. Ed Johnson**, director of the Strategic Planning and Policy Office in NOAA's National Weather Service (NWS); and **Mr. Jason Samenow**, climate science analyst at the U.S. Environmental Protection Agency (EPA).

The core objective for this panel was to foster a high-level discussion between the meteorological and health care sectors, with the aim of identifying the needs, issues, and differences between the sectors. To further this objective, the panel was tasked with the following questions:

**Q1** What are the biggest problems with respect to coordination and communication across internal/external boundaries between the health sector and the weather sector?

**Q2** What environmental information does the health sector utilize for preparedness? What environmental information is issued and to whom?

**Q3** What resources (e.g., infrastructure support, changes, and cross-sector education) and information do the public and private health sectors need to better prepare for natural hazards, and how should these resources be used?

Panelists also presented specific recommendations for addressing the problems being analyzed.

## *Q1: Problems of Coordination and Communication*

Panelists identified several key problems interfering with coordination between different agencies.

### Terminology

There is often significant confusion about the meaning of terms, particularly when professionals in one sector are describing the actions or organization of the other sector. For example, to medical professionals, the "medical sector" refers to the system(s) of hospitals, and pharmaceutical and medical supply chains, while the "public health sector" pertains to disease prevention through epidemiological surveillance and advocacy for healthy behaviors (e.g., "Hand Sanitization before Eating" campaigns/education). Yet for weather professionals, these two terms are often used interchangeably, causing ambiguity and confusion. Similarly, nonmeteorologists regularly use the terms "weather" and "climate" interchangeably, although weather is the day-to-day variation in atmospheric conditions, and climate is characterized by the aggregate pattern of weather events over large geographical and temporal scales.

> **Recommendation:** Professionals working across sector boundaries should be aware of differences in language usage "across the aisle," and they should educate themselves on the nuances within each field. Communicators with cross-sector audiences should invest time and care in ensuring that attention is paid to definitional rigor in their papers and documents and that language is used clearly and correctly.

### Different Perspectives on "Vulnerable" Populations

In both the health care and meteorological sectors, the preservation of human life is an implicit or explicit key objective for most organizations and governmental entities. However, the sectors have varying perspectives on the exact constituency for their primary efforts. Often termed the "vulnerable group" in the context of particular studies or initiatives, the different sectors have different expectations and assumptions. Health care professionals, for example, generally define this group as those most susceptible to some pathogen. They break the general population into clusters categorized by age, race, gender, or other common factors and determine which clusters show the greatest risk of disease susceptibility and development. The weather community conversely tends to class vulnerable groups in terms of geographic proximity to discrete weather events or

climactic patterns. These varying assumptions lead to some mismatch in scope for interagency cooperation.

> **Recommendation:** Despite this potential for mismatch, both communities are sophisticated in their understanding of vulnerable populations and can readily adapt to more common standards, either through a case-by-case ad hoc approach or a more formalized policy discussion. In fact, professionals in these communities already do on occasion adapt the approach to vulnerable groups of the other sector, when that approach is more appropriate. For example, meteorologists commonly recommend extra care be taken by the aged and the economically disadvantaged during heat wave events, as the medical community's cluster analysis has shown that those are the groups most susceptible to heat. This tacit recognition of commonly recognized realities can be broadened by continued professional practice to create greater common ground between the communities.

### Disparity in Sector Size

The health care sector is enormously larger in both physical and financial scale. By common measures, the weather sector is two orders of magnitude smaller than the health care sector. This disproportion leads to obvious differences in bureaucratic cultures and administrative complexities that must be understood in developing a strategy for establishing links between the two sectors, particularly on joint projects.

> **Recommendation:** Understand the bureaucratic and functional differences and use them to the advantage of the cross-sector partnership.

### Cross-Sector Research Gaps

Public health research has increased our knowledge of environmental health connections. Yet, the extent of climate- or weather-scale attributions to healthcare continuity requires more precision and accuracy that further research can provide.

> **Recommendation:** Research on the integral connections between health and environment is needed. Research funding should be made available for collaborative studies at the university level. Research at the academic level also will pay dividends by immersing future leaders and scholars in the practice of cross sector–disciplinary partnerships, which increase the utility of their present and future work.

### Right Resources, Empty Rolodexes

An agency or regulatory body may have top-notch resources and in-house competencies to create informational and educational material. However, those skill sets are not always matched with a deep institutional network of contacts required to get those resources to the people and places that need them most. As one example, NOAA, EPA, CDC, and the Federal Emergency Management Agency (FEMA) co-published the *Excessive Heat Events Guidebook*, which shares best practices and practical resources for responding to heat events. The federal government printed 4,000 copies of the guidebook; however, 3,000

copies of the guidebook remain crated in a warehouse simply because the agency with the knowledge does not know who else could use it, nor does it have access or the capability to reach them.

> **Recommendation:** Greater interagency cooperation and information sharing is needed to create channels where information on available products can be announced and disseminated. Agencies should also partner with professional societies and associations to create an additional distribution stream that reaches private- and public-sector users at the state and local levels.

## *Q2: Environmental Information and its Use*

Panelists held a wide-ranging discussion on suggestions for improving meteorological content. Panelists developed a widely held view that the focus of information initiatives should be on providing the most useful information for health care decision support. The panel also developed a list of significant issues and problems with the current environmental information programming.

### Forecast Data

Much of the basic data of meteorological reporting (e.g., reporting of atmospheric conditions such as temperature, relative humidity, and pressure variables) are generally uninformative and unhelpful to health decision makers in terms of preparedness for weather extremes. The pressure may be dropping and the temperature rising, but what does this mean in terms of the changing intensity of a storm? Health care decision makers in general should not have to decipher these data. Forecasts intended for decision-making use by health care professionals need to clearly associate potential health ramifications with predicted weather events.

> **Recommendation:** Forecasters and health care decision makers should jointly determine the kinds of information most helpful to the health care sector. These dialogues should lead to ongoing feedback about the utility and effect of weather forecasting on health care infrastructure. One possible tool is GIS, where simultaneous overlays of both weather and health-relevant information could be possible.

### Accuracy, Consistency, Probability

Forecasting is a both a science and an art. Therefore, it has a subjective element that can lead to different reported values for a forecast, for example, 20% versus 25% (or 1 in 5 versus 1 in 4) chance of an event occurring. In the meteorology community, these disagreements are understood; however, they could confuse the public. One panelist stated "[the public] doesn't understand uncertainty. They just understand that there was supposed to be 12 hurricanes but there were eight."

> **Recommendation:** Meteorology is inherently probabilistic, and it is our community's responsibility to help others utilize this information for their benefit. As stated above, one way of doing this is to convert percentages to the

least common fractional value (e.g., 20% is a 1-in-5 chance). Additionally, public and private sector groups should work together to communicate seasonal- and climate-scale projection information that is accurate, yet avoids precise numerical values that can reduce public (or decision maker) confidence in future projections (e.g., hurricane forecasts).

### Confusing Climate and Weather

Dr. James, paraphrasing baseball legend Yogi Berra, said "I don't know what the future is going to bring, but I know it is coming." The media focus on climate change, without descriptions of its geographic range and scale (global and 10-100 years) has led to a great deal of confusion in the public mind concerning weather-related issues, which are local and diurnal in scope. One major result of this confusion is the association of future climate change and today's daily or seasonal forecast. While climate is the mean state of the atmosphere with ranges of variability, weather is really characteristic of this mean state. As climate moves to a new mean, weather will subsequently change. These alterations can take from years to decades to become a new norm. Hence, we will not see the projected climate change today, but rather in decades or a century from now in the form of changed daily and seasonal weather patterns.

> **Recommendation:** The forecasting community should be extremely prudent in associating particular events to climate change, unless the peer-reviewed data are compelling or strong enough to make such a case. Further, when talking about climate change, we should make a point to call it "a projected climate change scenario," which more accurately reflects the probable occurrence of an event or scenario at some point in the future.

### Focusing Data Usage and Distribution

The NWS has moved away from a county-based to a storm-based warning system. The improvement leads to targeted alerts that reach the affected area based on meteorological science. While this new approach has many advantages and benefits, the health community voiced interest in overlaying this information with health-relevant content, for example, traffic access for emergency medical services (EMS), severe weather threats to a hospital, or weather exposure to vulnerable populations.

GIS can help. GIS-based mapping has already made major contributions to public health analysis, enabling the visualization of many data to express a complex message with simplicity. Decision makers in other fields, such as health, could benefit by having critical information in a fast and easy-to-understand format.

The state of Alabama's Health Disaster Preparedness Department uses a software system called the Alabama Incident Management System (AIMS). AIMS has GIS capabilities and serves as an online tracker for hospital status, bed capacity, and information on hospital bypass status. This system was in place and was used during Hurricane Katrina. Emergency managers in Alabama had detailed information at the ready and provided tremendous information and decision support to the federal assets.

**Recommendation:** Further development of GIS-based forecasts could be a next-generation product that revolutionizes the application of weather content for the protection of health care continuity and infrastructure. Private and public weather services should investigate how they could play a role in delivering forecasts using this format.

## *Q3: Resources and Information*

Panelists identified a number of areas in which resources and information could be better shared cooperatively between the health care and weather sectors.

### Publishing in Cross-Sector Journals

Both formal and informal communication networks between professionals in the health and meteorological sectors are relatively underdeveloped, and there is not extensive cross-pollination in the research communities. Yet, this type of cross-sector communication is critical for developing innovative solutions to address the effect of weather on health care infrastructure. Communicating through journals opens concerns to wider audiences and is a low-cost method of cultivating future change. As detailed elsewhere in this report, the Met Office attributes some of its success in its "healthcasting" initiative to its early efforts in cross-sector publishing.

**Recommendation:** Professionals in both sectors need to reach across the aisle and publish in health and meteorological journals (e.g., *Disaster Medicine and Public Health Preparedness* or the AMS' Weather, Climate, and Society journal). Publication themes (e.g., health care and weather) could serve as an opportunity to initiate cross-sector authorship in society and peer-reviewed journals. Editors should solicit cross-sector authorship, and authors should also seek out editors in the "other camp" when they have an idea that is of value to the other sector.

### Emergency Management

All states are currently linked through the Emergency Management Assistance Compact (EMAC), which is a congressionally ratified organization that provides form and structure to interstate mutual aid, enabling organizations and levels of government to cooperate in times of crisis without first having to jump through bureaucratic hoops. However, many impediments add friction to the EMAC system. For example, although each state is mandated to have a computerized system that keeps hourly inventory of human and physical resources (e.g., patient beds and medical supplies), there is at present little connectivity between state systems and crisis responders dealing with regional or multiregional crises like Hurricane Katrina. Crisis responders do not yet have access to a "system of systems" that would present all the available resources in a unified way.

**Recommendation:** Organizational and structural obstacles to cooperation can and should be smoothed and mitigated. Entities can form additional compacts and agreements to implement technology-based solutions in mutually interoperable ways, for example, by using similar coding languages for computer

analysis. Privacy and market information concerns that limit cooperation from private hospitals can be overcome with strong controls on information security and privacy protection.

### Public Service Announcements (PSAs) and Co-messaging

One of the key competencies that the meteorology sector brings to the partnership with the health care sector is a strong commitment to providing public information as a key mission element. By partnering, policy makers in the weather and health care sectors can develop PSAs (for example, modeling the famous "Only You Can Prevent Forest Fires" campaigns launched in past decades by the Department of the Interior), which can be used as a tool for shifting society to a preparedness mindset.

> **Recommendation:** To maximize the credibility of messaging that relates to both health and weather, key institutions from both sectors should endorse/produce PSAs jointly. Organizations such as the DHHS, CDC, NOAA, National Aeronautics and Space Administration (NASA), or EPA and even private sector entities, including insurance companies, AccuWeather, and The Weather Channel, can jointly produce and distribute these model public communications campaigns. As reported above, the Met Office campaign offers valuable insight on this type of partnership.

## *3.2 "Building Bridges": Policy Perspectives*

This panel was moderated by **Dr. John Gaynor**, director of Weather and Air Quality within NOAA's Office of Oceanic and Atmospheric Research (OAR). The discussants were **Ms. Rona Birnbaum**, chief, Climate Science and Impacts Branch, U.S. EPA; **Dr. Larry Robinson**, deputy commissioner, Philadelphia Department of Public Health; **Mr. Mitch Stripling**, preparedness education and media coordinator, Florida Department of Health; and **Mr. John Droneburg**, director, Maryland Emergency Management Agency (MEMA).

FIG. 6. (Image courtesy of iStockphoto.)

The discussants represent a range of emergency management functions at the national, state, and local levels. All are members of organizations or part of teams where cross-sector information on health and weather are frequently exchanged; they represent key decision makers in jurisdictions all over the United States who work together during weather-related health crisis.

The core objective for this panel was for discussants to pull information from their professional experiences to identify the impediments, challenges, and successes in establishing policy agendas that require cross-sector information, cooperation, and communication. To further this objective, the panel was tasked with the following questions:

**Q1** What are the institutional barriers to linking the environmental and health sectors and how can they be overcome?

**Q2** What are the policy options available today to decision makers?

**Q3** How can the environmental and health sectors advance the policy process to improve the resilience of U.S. health care infrastructure against severe weather events?

Panelists also presented specific recommendations for addressing the problems being analyzed.

## *Q1: Institutional Barriers to Linking Environmental and Health Sectors*

### Creating Channels for Knowledge Exchange

An ideal policy framework should enable communication and coordination between agencies. The federal system presently lacks cross-agency communication for three principal reasons: 1) the federal funding process is intensely competitive and therefore sometimes engenders a lack of cooperation rather than the spirit of innovation and partnership; 2) agency coordination must be centralized and strengthened within the administration; and 3) stringent bureaucratic impediments (e.g., gaining agency clearance to talk with peers or colleagues in another agency) severely limit the opportunity to connect agencies.

> **Recommendation:** New funding mechanisms should be explored to create a paradigm shift of cooperation and partnership. Financial incentives to agencies that initiate or participate in cross-agency programs that address a large-scale, multiparticipant issue (such as protecting the nation's health care infrastructure from severe weather) could be effective game-changing instruments.

### Mixing Local Politics and Preparedness

State and local emergency management professionals face numerous challenges to getting the organizational ranks within local and state government to understand the gravity of extreme weather vulnerabilities. Moreover, elected officials implement projects that could start and finish within relatively short time scales because of election cycles. Severe weather events, however, often recur on interannual to decadal time scales. Addressing the disconnect between the political and hazard time scales requires a long-term systemic approach.

> **Recommendation:** Overcome political inertia by offering incentives such as conducting a national preparedness competition aimed at local officials. State and local jurisdictions should be rewarded, through federal subsidies or tax rebates, for implementing mitigation or adaptation strategies. Similarly, hospitals, which tend to be privately owned, should also receive tax benefits for taking significant steps to protect their infrastructure against severe storms.

### Federal Program Evaluation/Metrics Requirements

Federal programs are mandated by statute to undergo continual review and evaluation. The purpose of this exercise is to quantify the benefits to society produced by federal spending programs. There is a challenge to identifying the success of preparedness and mitigation programs against potential environmental extremes that have long time frames (e.g., sea level rise over decades). There is genuine concern in the environmental policy community that an inability to identify clearly early program success could affect nearer-term (re)funding.

> **Recommendation:** The federal government should revisit its metrics and requirements to more realistically scale them to weather and climate effects. For example, metric reports on mitigation projects should have a step function built

in for measuring the short- and medium-term benefits (e.g., reduced insurance premiums, improved land usage patterns, increased property values, and concomitant tax receipts), in addition to longer-term metrics for climate-scale concerns, such as sea level rise.

### Forecast Uncertainty

Discussants agreed with the health care delivery panel that conflicts in forecasts (between various private sector and independent forecasts) and language used in forecasts that is sometimes misleadingly precise (e.g., "17 hurricanes in the Atlantic" versus "a potentially severe hurricane season") contribute to a lack of public confidence in the forecasts, in general. This credibility drain, in turn, negatively affects the efforts of local leaders and the public.

> **Recommendation:** Public and private weather sectors should pay more attention to the downside of excessively precise forecasts. Accuracy is key, and a seasonal forecast for a "severe hurricane season" means more and does more for preparedness building than saying to expect "17 storms" (What if these 17 storms are mild or stay out at sea, for example? Either event could change public perception for the next season.)

### Difficulties in Creating Effective Public Messaging

There are a number of challenges to creating effective messaging via PSAs and Emergency Alert System (EAS) broadcasts, particularly when integrating meteorological and health care sector concerns. At the local level, demographic heterogeneity, cultural differences, language barriers, immigrant populations, physically/mentally disadvantaged populations, and the growing "digital divide" all pose serious challenges to reaching appropriate user communities with preparedness information and warnings. Public messaging must encompass these complex dynamics and yet deliver a message that is universal, generally to a geographic area rather than to a discrete community. State and local emergency management authorities often do not have access to the resources and research needed for effectively addressing these hurdles.

> **Recommendation:** Policy makers should recognize that all hazards are local. Preparedness directives should empower local officials to work with communication specialists and sociologists to effectively reach the local populations, particularly the most vulnerable and least served, by traditional public messaging efforts.

## *Q2: Available Policy Options*

### Developing the All-Hazards Platform

Procedures for funding upgrades and mitigation measures are often highly constricted and categorized; for example, one New Orleans hospital spent years seeking FEMA funding for flood mitigation in the event of a levee failure due to flood, only to be denied each time. Post 9/11, the facility switched strategies and sought and received funding for mitigation efforts to prevent flood damage caused by a terrorism-related levee failure.

The real risk to the facility came from both weather and human action, but myopic categorizations of hazards restricted the hospital decision makers' ability to effectively prepare for all valid hazards.

> **Recommendation:** Develop an "all hazards" platform that includes hospital infrastructure preparedness along with bioterrorism and pandemic flu, among others. This direction would empower the nation's emergency management assets by readying them for the full range of responsibilities to protect and save lives and property.

### Creating Seamless Connections between Federal and Local Assets

Emergency management systems from the federal, state, and local levels operate nonuniformly, with each jurisdiction maintaining its own practices and complex lines of hierarchy. These contrasts become more vivid during crises. For example, when federal response teams arrive to a disaster zone, the federal assets often completely replace local emergency assets in the decision-making process. However, it is generally the local assets who have an awareness of the local terrain and conditions, well-developed social networks, and a civil force of volunteers already in place.

> **Recommendation:** Long before any event, cooperation and communication at the interfaces of the levels of government should be planned and exercised. Emergency response services in Florida, for example, developed a list of state agencies and the support roles they are expected to provide in an emergency situation and promulgated the list to emergency response departments, so that local teams knew to whom to report. In addition, the state created "strike teams" to arrive at the scene of an emergency quickly, often preceding the federal response, to ensure that local, on-the-ground knowledge and skill sets were available to the federal teams when they arrived.

### Building a Mitigation/Adaptation Portfolio

Decision makers need practical options to deal with the real weather crises they face in their particular circumstances, whether those tools are based on a mitigation strategy (e.g., tools to reduce the severity of an effect) or an adaptation strategy (e.g., tools to build the capacity for reducing the impact of long-term change). To choose the best tool, decision makers need real choices.

> **Recommendation:** National emergency management policies should encourage the development of a "portfolio" of both mitigation and adaptation measures, so that decision makers have an array of options to choose the best strategy that could address the most pressing vulnerabilities.

## *Q3: Advancing the Process, Improving the System*

### Vertical/Horizontal Policy Integration

One advantage of the U.S. system of widely distributed authority is that with so many different bureaucracies in place, considerable experimentation takes place, leading to

developments and breakthroughs in best practices that could save numerous lives and considerable material resources.

Ironically, the disadvantage of that same model is that great discoveries and insights do not always propagate to other parts of the system. Bureaucratic inertia, the not-invented-here syndrome, whatever the cause, stifles effective policy innovations at one level of government that could successfully work elsewhere, regularly leaving them to languish at their point of invention. Propagating outstanding and innovative policy ideas needs to be a critical priority.

> **Recommendation:** Information must feed from the local to the national level, just as general policies should move from the top down. Agencies need to be encouraged to communicate up, down, and sideways within their bureaucracies or networks and to share best practices and policies. Agencies should be encouraged to find and commit to joint policy statements, to harmonize their policies when that is possible, and to improve their interoperability for specific national missions—such as protecting hospitals.

### Weather and Climate Distinction

Both the health care and meteorological sectors, particularly where they intersect in the field of emergency management, must do a better job of preparing U.S. health care infrastructure to respond to threats both in a short time horizon and over the long term. Whether it is today's hurricanes or the sea level rises in 100 years, weather threats to the health care infrastructure are both an acute and chronic condition, requiring a state of constant preparedness.

> **Recommendation:** The health, weather, and engineering sectors should engage in continued conversation and joint research into both short- and long-term weather threats to the health care system.

### Enhance Private Sector Involvement

The private sector has a strong incentive to assist in improving the resilience of the health care system to weather events. Business relies on both public and private health care infrastructure to maintain the health of its own workers and management. Further, particularly at the local level, business owners are keenly aware of risk management as an operational requirement of doing business. As such they make natural allies for public sector risk management efforts and are receptive to being informed about the particular risks facing the local community. Emergency management can harness this affinity to seek greater private sector involvement in preparedness and response.

> **Recommendation:** Local and state chambers of commerce are an ideal location for the public and private sectors to convene and to discuss the levels of support they could provide one another.

# 4.0 Summary and Policy Recommendations

## *Summary*

The continuity and resilience of the national health care infrastructure and delivery services are at risk in the face of severe weather. This is a great concern because the United States is one of the most weather vulnerable nations in the world, and climate change and variability are likely to lead to more frequent, intense storms, in both traditional and historically unusual locations. Moreover, the nation's health care infrastructure (i.e., hospitals, clinics, and similar facilities) are located, like much of the national population, in geographic areas of known or projected severe weather risk. Some 50 decision makers participated in "Under the Weather: Environmental Extremes and Health Care Delivery" —a forum that was convened to dialogue about the problems from all angles, the concerns from all points of view, and the solutions from an all-hands approach.

Participants found that the adaptation and structural mitigation (i.e., retrofitting) strategies that are needed to protect the U.S. health care infrastructure from severe weather threats exist in pieces and parcels within federal agencies and the private sector. They surfaced the need to connect these services and products to protect the nation's health care system and also the economy. Hospitals are irreplaceable sanctuaries for emergency and general medical care and also a lifeline to local and national economies. To that point, consider that hospitals also provide an essential backbone to national public health functions, serve as major employers for urban/rural communities, contribute a significant share to the 16% U.S. gross domestic product (GDP), operate as a hub for major supply chains of other products and services (e.g., pharmaceuticals, linens, sanitary removal, and food and water), and contribute more broadly to community disaster recovery.

Damage to or outright collapse of one hospital could have devastating health, medical, and economic effects to a local area. Yet that is only a partial picture. Individual hospitals (16,500 from coast to coast) collectively make up the national network of health care infrastructure, and this becomes most evident during disasters. Experiences from Hurricane Katrina, most notably, show that interruptions to a critical node (e.g., hospitals in a large city, or the lone hospital in a rural area) tend to reverberate throughout the entire network in the form of patient surges, social services burdens, mental stress (for practitioners and patients), and systemic economic losses.

The United States has available resources and ingenuity to do better at protecting this critical infrastructure.

### *Focus Areas*

Participants identified three major areas where attention is needed to bolster health care infrastructure resilience and to promote the continuity of health care during disasters:

1) **Environmental and Adaptation/Mitigation Awareness:** Health care and hospital decision makers lack environmental awareness or disbelieve warning projections. Both situations restrain the adoption of adaptation or mitigation strategies.

2) **Coordination and Communication (between agencies, private sector companies, and disciplines):** The resources and processes needed to secure the national health care infrastructure already exist in large part. The greatest present need is for coordination and communication channels among agencies, private sector partners, and disciplines to create a portfolio of concerns and attendant adaptation/mitigation options.

3) **Financial Resources and Incentives:** Hospitals from coast to coast are subject to nearly identical structural vulnerabilities (chief among them are elevator crankcases, window penetration, and generator disruption). On average the cost to mitigate damage to these common points of vulnerability is $3–$5 million per hospital. This upfront mitigation cost is one to two orders less in magnitude than recent hospital damage costs ($60–$600 million, per facility), but the escalating costs of health care reduce the profit margin that is needed to afford even minimal structural protection. Financial resources and incentives could overcome this hurdle.

*Policy Recommendations*

These findings suggest the following policy recommendations:

## Environmental and Adaptation/Mitigation Awareness

***Goal/Vision:*** Working partnerships exist between hospital administrators, engineers, and meteorologists that inform hospital decision makers of their environmental risks and the adaptation and mitigation strategies available from the private and public sectors that could strengthen facility infrastructure. Communication is two-way and informs engineers and meteorologists on how to package information that is most useful to health care decision makers. The following are **recommendations** for achieving this vision:

1) **Working partnerships need a context** and an impetus to become accepted and well practiced. Federal policy should create a cross-agency effort [e.g., between DHHS, Department of Homeland Security (DHS), NOAA, and others] and engage the private sector. Financial incentives could spark participation and also reduce rivalrous behavior between agencies and/or agencies and the private sector.

2) The working partnerships **should explore GIS and other visual tools** that could be effective at translating severe weather forecasts and long-term (i.e., climate) projections into actionable steps for decision makers who need to get important information fast.

3) The **partnerships should lead toward the identification of preevent partner hospitals** that are outside the areas of probable impact. For example, a hospital in a coastal area that is vulnerable to hurricanes or floods would partner with a facility located far inland or at elevation, so that the same weather event is unlikely to jeopardize both facilities simultaneously. These facility pairs should then coordinate their communications and emergency management plans, so that their efforts complement each other in the event of a major disaster.

4) The **partnerships should incorporate real-time environmental tools and data** into an in-house warning coordination and emergency readiness/alert system. The partnerships should meet periodically to update and incorporate new environmental and engineering knowledge, as well as advances in technical hardware and programs.

## Coordination and Communication

***Goal/Vision:*** Good two-way coordination and communication within and between agencies, private sector interests, and disciplines. This paradigm elevates national attention to protect hospitals and generates packaged material (from research to operations) that informs hospital decision makers of their options to reduce risks from known and projected environmental threats. This shift produces mitigation strategies that result in substantial savings (e.g., the Multihazard Mitigation Council's 2005 findings that for every $1 invested in mitigation yields a $4 return in savings). The following are **recommendations** for achieving this vision:

1) **Carry out a federal inventory of programs** at DHHS (including CDC), DHS/FEMA, National Institute of Standards and Technology (NIST), U.S. Geological Survey (USGS), NOAA, and other agencies that could contribute to this vision.

2) **Create multidisciplinary teams** (including the private sector) to match known environmental vulnerabilities to emergency management and engineering solutions.

3) Building on recommendation 2**, provide funding to invest in supporting cross-sector research**.

4) **Include severe weather vulnerabilities on the all-hazards platform**. Also, contingent planning should be made for dual simultaneous events of a bioterrorism attack and a severe weather event.

5) **Anticipate and plan for bureaucratic and cultural differences** between agencies, sectors, and disciplines. Focus on a specific high-priority issue instead of tackling the entire problem at once.

6) **Advocate for cross-pollination** (or publishing and attending meetings) in the partner sectors of health, medicine, emergency management, engineering, and meteorology.

7) To maximize the credibility of messaging that relates to both health and weather, key institutions from both sectors should **jointly endorse/produce PSAs**. Organizations such as DHHS, CDC, NOAA, NASA, USGS, or EPA and even private sector entities, such as health insurance companies, AccuWeather, and The Weather Channel, can jointly produce and distribute these model public communications campaigns.

8) **Increase the understanding and application of meteorological information** by making the statistics more applicable. For example, instead of stating "a 20% chance of occurrence," relay its equivalent reduced fraction form of "a 1-in-5 chance." Such approaches may give a more concrete image or understanding of the science and compel action.

## Financial Resources and Incentives

***Goal/Vision:*** While keeping health care costs down remains a challenge, federal resources and incentives provide meaningful reduction in the financial burden for adaptation/mitigation. These federal contributions are given in recognition of keeping health care costs down and of the invaluable health, medical, and economic benefits hospitals provide to the country. The following are **recommendations** for achieving this vision:

1) **Subsidies, tax incentives, and other cuts should be offered to hospitals** where working partnerships exist and measurable approaches are taken for retrofitting the facilities against probable severe weather effects.

2) **The federal government should revisit its metrics and requirements in adaptation/mitigation grant review cycles** to be more realistically scaled to weather and climate effects. For example, review/metric reports on mitigation projects should have a step function built in for evaluating the short- and medium-term benefits (e.g., reduced insurance premiums, improved land usage patterns, increased property values, and concomitant tax receipts), in addition to longer-term metrics against climate-scale concerns, such as sea level rise, which will happen gradually.

3) **Public/private partnerships could strengthen the utility of insurance as a risk management tool**, particularly for companies that require structural mitigation against probable environmental threats in exchange for lower commercial insurance premiums. Federal subsidies and grants could go toward the payment of the required mitigation costs, thereby reducing the financial burden on hospitals directly. In the long run, this strategy could also reduce health care costs by cutting premium rates and decreasing the need for costly rebuilding efforts.

# 5.0 Conclusions

Securing the U.S. health care infrastructure and delivery services against severe weather impacts requires new thinking, not necessarily new research. New and effective policies are needed to unlock, dust off, and expand existing solutions that presently exist behind bureaucratic lines. Programs and services that could be applied for hospital resilience already exist, but are presently underutilized or used for a more narrow purpose that their potential. Decades of federal and private sector investments made it possible to have engineering, meteorology, and emergency management solutions available to address this current challenge, and the United States has the opportunity to capitalize on this by constructing policies that deliver a return of benefit to the public.

In this process it is important to recognize that no single agency or organization is solely responsible (based on mission) for hospital protection. Furthermore, several agencies and organizations (e.g., DHHS, DHS/FEMA, NOAA, and private weather services) provide expert and technical information that contribute to a holistic approach to hospital preparedness. The first policy action, therefore, should be to build a communication channel for dialogue and information exchange between agencies and organizations in order to make current public/private sector products and services available for health care decision-makers.

It is also important to recognize that thoughtful assimilation of data is part of the solution. Policy should institute a central hub for collecting and stringing together packages of information that inform healthcare decision-makers of their environmental awareness, preparedness opportunities, and financial resources or incentives to make life-saving changes that protect one facility directly, while simultaneously building the resilience of the entire network of hospitals from coast-to-coast.

This recommended paradigm shift in the nation's approach to protecting its hospital infrastructure and health care delivery services is a challenge, but is well within the capabilities of United States governance. In this report we laid out many of the tools and techniques to advance us toward the intended goal. Our journey is just beginning, but we at least know the direction in which we need to travel. Our next step will address the specific agency and private organization activities to provide policy options in packaging information for health care decision-makers.

# APPENDIX A: AGENDA

**UNDER THE WEATHER:**
**Environmental Extremes and Health Care Delivery**
an AMS Policy Study Series Forum

**Ronald Reagan Building and International Trade Center**
1300 Pennsylvania Avenue NW
Washington, DC 20004
16–17 April 2007

**Day I (Monday, 16 April)**
***7:30–8:00*** **BREAKFAST**

***8:00–8:20*** **Introduction and Overview**

***8:20–9:40*** ***Issues, Challenges, and Successes***

1. New Orleans/Hurricane Katrina (***Dr. Bryan McNally, Emory University Hospital***)
2. Texas Medical Center (***Dr. Baxter Vieux, University of Oklahoma***)
3. Chicago Heat Stress (***Dr. Eric Klinenberg, New York University***)
4. Met Office (via video conference) (***Ms. Clare Bryden, meteorologist***)

***9:40–10:10*** **Discussion**

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***10:10–10:40*** **BREAK**
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***10:40–12:00*** ***Perspectives I:*** Health Care Delivery panel

- Introduction and brief statement on their links with the environment or health sector.
- What are the biggest problems with respect to coordination and communication across internal/external boundaries?
- Environment: What environmental information do you issue and to whom?
- Health: What environmental information do you use for preparedness?
- What resources (e.g., infrastructure support, changes, cross-sector education) and information do the public and private health care sectors need to better prepare for natural hazards, and how should these resources be used?

Moderator: ***Dr. Howard Frumkin, MPH, CDC***
Panelists:
***Dr. Linda Degutis, Yale University/APHA***
***Dr. Jim James, AMA***
***Dr. Ed Johnson, NWS***
***Dr. Mark Keim, CDC***

*Mr. Jason Samenow, U.S. EPA*

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*12:00–12:20* **BREAK**

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*12:25–13:50* **LUNCH (Polaris Room)**

*13:05–13:10* ***Introduction of Weather and Climate Enterprise Address***
Brigadier General D. L. Johnson, USAF (retired), director of NOAA's NWS
Theme: "Where and how the weather and climate enterprise and the health care delivery sectors are connected, and where they need to be synergistically heading for better preparedness."

*13:10–13:40* **Lunch Address**

*13:40–14:15* **Q & A**

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*14:15–14:50* **BREAK**

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*14:50–17:00* ***Perspectives II:*** Evaluation, Planning, and Policy panel

- Introductions
- What are the institutional barriers in linking the environment and health sectors and how can they be overcome?
- What policy options are available?
- How can the enterprise and health sectors advance the policy process to address this critical societal issue (e.g., Weather and Environment certified regulation)?

Moderator: ***Dr. John Gayor, NOAA***
Panelists:
***Dr. Rona Birnbaum, U.S. EPA***
***Mr. John Droneburg, Maryland Emergency Management Agency***
***Dr. Larry Robinson, Philadelphia Department of Health***
***Mr. Mitch Stripling, Florida Department of Health***

***

*17:15–18:00* **WINE RECEPTION (Rotunda foyer, 8th floor)**

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*18:00–21:00* **DINNER (Rotunda, 8th floor)**

*18:45–18:50* ***Introduction of Health Sector Address***
Dr. Eric Noji, James A. Baker III Distinguished Fellow in Health Policy, The Gingrich Group

Theme: Where and how the weather and climate enterprise and the health care delivery sectors are connected, and where they need to be synergistically heading for better preparedness

*18:45–19:15* **Dinner Address**

*19:15–20:00* **Q & A**

*Day I Adjourns*

**Day II (Tuesday, 17 April)**
Objective: Solution building; create working groups to implement solutions.

*8:00–8:30* **BREAKFAST**

*8:30–8:45* **Overview and Recap**

*8:45–9:45* ***Critical Infrastructure Vulnerabilities: Issues and Engineering Solutions***
***Tim Butcher, University Medical Center***
***Tom Smith, TLSmith Consulting, FEMA***

**9:45–10:10** **Q & A**

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**10:10–10:25** **BREAK**
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**10:25–11:35** ***Breakout Sessions***
Mock scenarios

**11:35–12:15** Reconvene in the Polaris Room to discuss mock scenario outcomes, form Working Groups, and set the agenda for next forum

**12:15–12:30** Wrap up
***Forum Adjourns***

# APPENDIX B: PARTICIPANT LIST

| Last Name | First Name | Affiliation | Role/Office |
|---|---|---|---|
| Abrams | Elliot | AccuWeather | Senior Vice President |
| Anderson | Bill | Division on Earth and Life Studies/National Research Council/National Academy of Sciences | Associate Executive Director |
| Arispe | Irma | Office on Science and Technology Policy | Assistant Director, Life Sciences |
| Baker | J. Alan | American Public Health Association (APHA) | Chief of Staff |
| Birnbaum | Rona | Climate Science and Impacts Branch/U.S. EPA | Chief |
| Blanchard | Heather | Department of Homeland Security | Business Liaison Director |
| Braund | Wendy | Johns Hopkins Bloomberg School of Public Health | Preventive Medicine Resident |
| Bryden | Clare | Met Office | Manager, Health Research |
| Butcher | Tim | Louisiana State University Health Care Services Division/University Medical Center | Registered Nurse; Inservice Instructor |
| Carey | Curtis | NOAA/NWS | Director |
| Carter | Scott | The Carter Strategy Group, LLC | President |
| Cohn | Alan | U.S. EPA | Environmental Scientist |
| Coussens | Christine | Institute of Medicine The National Academies | Senior Program Officer |
| Degutis | Linda | Emergency Medicine and Public Health/Yale University; School of Medicine and American Public Health Association (APHA) | Associate Professor; President |
| Droneburg | John | Maryland Emergency Management Agency (MEMA) | Director |
| Dumont | Robert (Bob) | NOAA/Office of the Federal Coordinator for Meteorology (OFCM) | Assistant Federal Coordinator |
| Espinoza | Sara | National Environmental Education & Training Foundation | Program Manager, Weather and Environment |
| Ferrell | Jannie | NOAA/NWS | Staff Meteorologist |
| Fisher | Genene | AMS | Senior Policy Fellow |
| Fortier | Stephen | George Washington University | Research Associate |

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|---|---|---|---|
| Frumkin | Howard | Agency for Toxic Substances and Disease Registry/National Center for Environmental Health/CDC | Director |
| Gaynor | John | Office of Air and Water Quality/Oceanic and Atmospheric Research/NOAA | Director |
| Gird | Ron | NOAA/NWS | Outreach Program Manager |
| Greene | Ashley | University of Maryland | Student |
| Hallgren | Dick | AMS | Executive Director, Emeritus |
| Haynes | John | NASA | Program Manager |
| Higgins | Paul | AMS | Senior Policy Fellow |
| Hooke | William | AMS | Director and Senior Policy Fellow |
| Jenkusky | Eric | Base-X, Inc. | Representative |
| James | James (Jim) | Center for Public Health Preparedness and Disaster Response/American Medical Association | Director |
| Johnson | Ed | Office of Policy and Planning/NOAA/NWS | Director |
| Johnson | Veronica | NBC (Washington, DC) | Broadcast Meteorologist |
| Johnson, U.S. Air Force (retired) | D. L. | NOAA/NWS | Director |
| Keim | Mark | Coordinating Office for Terrorism Preparedness and Response/CDC | Medical Officer |
| Klinenberg | Eric | New York University | Associate Professor |
| Leggett | Jane A. | Congressional Research Service | Specialist in Environmental and Energy Policy |
| Marshall | Curtis | National Research Council | Program Officer |
| Martin | Josh | Office of Congressman Michael Burgess (TX) | Legislative Director |
| McCaffrey | Mark | American Red Cross National Capital Area | Director of Health and Safety and Disaster Training |
| McCurdy | Leyla | National Environmental Education & Training Foundation | Senior Director, Health and Environment |
| McGeehin | Michael | Division of Environmental Hazards & Health Effects/National Center for Environmental Health/CDC | Director |

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|---|---|---|---|
| McNally | Bryan | Emory University Hospital | Emergency Room Physician |
| McPeak | Holly | Office of Disease Prevention and Health Promotion/DHHS | Nutrition Advisor |
| McPherson | Ron | AMS | Executive Director Emeritus |
| Meekhof | Sarah | Capstone Consulting Group, LLC | President |
| Meekhof | John | Capstone Consulting Group, LLC | Vice President |
| Milzman | David | George Washington Hospital | Emergency room Physician |
| Noji | Eric | The Gingrich Group | James A. Baker III Distinguished Fellow in Health Policy |
| Oshinski | Bryan | Pennsylania State University | Student, rapporteur |
| Ott | Jim | Georgetown University Hospital | Emergency Preparedness Coordinator |
| Prestigiacomo | Charles | Neurological Institute of New Jersey/New Jersey Medical School | Assistant Professor |
| Reasoner | Kim | Office of Congressman Burgess (TX) | Legislative Counsel |
| Robinson | Larry | Philadelphia Department of Public Health | Deputy Health Commissioner |
| Ross | Tim | NOAA/NWS | Deputy |
| Rubin | Claire | Claire B. Rubin & Associates | President |
| Samenow | Jason | U.S. EPA | Climate Science Analyst |
| Shimere | William | U.S. House of Representatives | Professional Staff Member |
| Sliter | Deborah | National Environmental Education & Training Foundation | Vice President for Programs |
| Smith | Tom | TLSmith Consulting Inc. | Architect |
| Socci | Tony | AMS | Senior Policy Fellow |
| Sprague | Jennifer | NOAA/NWS | Policy Analyst |
| Stephens | Pam | National Science Foundation | Senior Associate for Science Coordination |
| Stripling | Mitch | Division of Environmental Health Florida Department of Health | Preparedness Education and Media Coordinator |
| Sundararaman | Ramya | Congressional Research Service | Analyst |
| Thomas | Jeri | Chestnut Hill Hospital | Histology |
| Thomas | Wendy Marie | AMS | Policy Analyst |

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|---|---|---|---|
| Vieux | Baxter | Center for Natural Hazards and Disaster Research; National Weather Center | Presidential Professor and Director |
| Wagoner | Richard | Research Applications Lab/National Center for Atmospheric Research | Assistant Director |
| Westergard | Richard | Shade Tree Meteorology, LLC | President and Certified Consulting Meteorologist |
| Wilkerson | Jan | AMS | Administrative Assistant |

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