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Natural Hazards Science--A Matter of Public Safety

P. Leahy

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Spatial Integration Laboratory for Urban Systems

A Collaboration between the Wharton GIS Lab
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Nature has given us several tragic reminders in the past few years of the importance of increasing our resiliency to natural hazards.   More than 27 major disasters were declared in the United States between March 2004 and 2005 from earthquakes, landslides, fires, floods, and hurricanes. Every year, natural hazards that occur in the United States result in hundreds of lives lost and in billions of dollars of destroyed public and private properties and disrupted commerce.

Natural Hazards and the Federal Role

Within the Federal government, the National Oceanic and Atmospheric Administration (NOAA) is responsible for forecasting, tracking, predicting the landfall of, and issuing warnings for hurricanes and tropical storms in the United States and its territories to the public, the media, and other government agencies and authorities. Science to forecast hurricane impacts is a collaborative effort among the U.S. Geological Survey (USGS), NOAA, the National Aeronautics and Space Administration, the U.S. Army Corps of Engineers, and others.

The USGS has the lead Federal responsibility under the Disaster Relief Act (P.L. 93-288, popularly known as the Stafford Act) to provide notification for earthquakes, volcanoes, and landslides, to enhance public safety, and to reduce losses through effective forecasts and warnings based on the best possible scientific information. It is our goal to provide scientific research and analysis that help the public, the emergency management community, and policy makers make informed decisions on how to react to each hazard and how to safeguard society. We produce coastal-change vulnerability products to provide pre-hurricane forecasts of impacts to infrastructure, essential for evacuation and post-storm recovery efforts. In the case of wildfires, USGS with Federal partners monitor seasonal fire danger conditions and provide firefighters with maps of current fire locations, perimeters, and potential spread.

USGS and Natural Hazards

One of the objectives of the USGS is to improve our capability to predict coastal change that results from severe tropical and extra-tropical storms. Such a capability may facilitate locating buildings and infrastructure away from coastal change hazards. New technology in the form of airborne laser surveys and imagery enable us to more accurately portray coastal change. Hurricanes Katrina, Wilma and Rita, and the ones we have yet to face, highlight the increasing need for scientific knowledge.

With USGS science and technology, we are striving to prevent natural hazards from becoming disasters. We must improve our understanding of natural processes, alleviate risks, and develop tools and technology for assessment, and for predictive and prescriptive strategies. Our science can help save lives, minimize property damage, and reduce risks that may result from natural hazards. USGS research on natural hazards is no longer just a scientific endeavor – it is a matter of public safety.

Before a hurricane makes landfall, the USGS ensures that equipment along the Gulf and Atlantic coasts is ready to monitor coastal change. A USGS network of streamgages also reports real-time stream flow to officials issuing flood warnings. USGS geospatial databases and maps assist pre-storm evacuation planning and post-storm rescue and recovery. Before and after major storms, scientists survey habitats and document erosion on coasts and barrier islands by using airborne and satellite imagery. The USGS deploys amphibious aircraft to conduct environmental assessments and to aid emergency response. Immediately after Hurricane Katrina, the USGS used satellite and aerial imagery to create maps linking 911 calls to locations where people needed to be rescued. USGS scientists also assisted Federal and State agencies by conducting water quality and sediment testing to indicate the safety of water for human contact. Scientists also conducted ground surveys to help land managers with habitat and wildlife impact assessments, and to secure scientific equipment in remote field sites. The USGS provides scientific research and analyses that help the public, policy makers, and the emergency management communities make informed decisions on how to prepare for and react to hurricane hazards and reduce losses from future hurricanes.

One of the most damaging aspects of hurricanes is the storm surge. Storm surge, a dome of ocean water, can exceed 20 feet in height and extend along shore for 100’s of miles. As Katrina demonstrated, hurricanes can affect the Nation’s energy supply; more than one fourth of U.S. crude oil production is from the Gulf of Mexico. Often, hurricanes leave an area more vulnerable to subsequent storms.

Specifically, the USGS science priorities for addressing hurricane impacts are to develop an ability to make near real-time maps for emergency planning and response and increase our ability to record hurricane impact and recovery of natural systems. We use airborne and other remote sensing techniques with hurricane response models to improve coastal mapping and to predict where barrier islands and evacuation routes will likely be severed or washed over in an approaching hurricane. Also, we are expanding the network of near real-time streamgages for flood forecasting and developing an ecological alert system based on a hurricane's potential to spread wildlife diseases and invasive species, and destroy critical habitat.

Hurricanes

Hurricanes bring destructive winds, storm surge, torrential rain, flooding, and tornadoes. A single storm can wreak havoc on coastal and inland communities and on natural areas over thousands of square miles. In 2005, Hurricanes Katrina, Rita, and Wilma demonstrated the devastation that hurricanes can inflict and the importance of hurricane hazards research and preparedness. More than half of the U.S. population lives within 50 miles of a coast, and this number are increasing. Many of these areas, especially the Atlantic and Gulf coasts, will be in the direct path of future hurricanes. Hawaii is also vulnerable to hurricanes.

As seaside populations and development escalate, so does property damage from hurricanes. Recent Atlantic hurricane seasons have been the costliest on record, with losses of $42 billion in 2004[1] and in the hundreds of billions in 2005. Research suggests that Americans should brace for more of the same, because the Atlantic basin is in an active period that might persist for decades.

Hurricanes and coastal storms can devastate great swaths of the coast and inland structures. They not only destroy structures but cause extreme coastal erosion, overwash, barrier island loss, flooding, wetland loss, and sometimes landslides as they move inland.

Barrier islands and coastal wetlands are the first line of defense for many Atlantic and Gulf coast communities, and many are rapidly eroding. Wetlands reduce storm surge and buffer hurricane impacts. However, since the 1930s, Louisiana has lost about 1,900 square miles of coastal land from subsidence, inundation, and erosion during hurricanes. Hurricane Katrina eliminated more than 100 square miles of wetlands protecting New Orleans. In 2004, Hurricane Ivan eroded Alabama’s coast an average of 40 feet.

Hurricane Katrina caused significant damage in New Orleans with much of the city being inundated by flood waters. The challenge of rebuilding New Orleans is complex, requiring multiple skills and capabilities, as well as diverse opinions and perspectives from federal and state government agencies, the local government and the citizens New Orleans.

[1] Figure taken from NOAA website: www.nhc.noaa.gov/archive/2004/tws/MIATWSAT_nov.shtml.

USGS Response to Hurricanes Katrina and Wilma

Hurricane Katrina made landfall as a category 4 storm in Plaquemines Parish, LA on August 29, 2005. Immediately, the USGS began collecting satellite imagery to assess the impact on wetlands, coasts, and changes in the elevation, collecting water samples to determine the water quality in areas where there had been significant salt-water intrusion, marking and flagging high-water marks to document flooding and storm surge, and repairing and replacing damaged streamgages to restore flood warning capabilities.

Aerial video, still photography, and laser altimetry surveys of post-storm beach conditions were collected August 31 and September 1, 2005 for comparison with pre-storm data. The comparisons show the nature, magnitude, and spatial variability of coastal changes such as beach erosion, overwash deposition, and island breaching. These data are being used to further refine predictive models of coastal impacts from severe storms. The data are available to local, state, and federal agencies for purposes of disaster recovery and erosion mitigation via the internet.

Hurricane Wilma made landfall in the U.S. as a category 3 storm at approximately 6:30 AM EDT on October 24, 2005 at Cape Romano, FL, approximately 20 miles south of Naples, FL. The long, thin barrier islands that comprise the Gulf of Mexico coast of west Florida have been particularly vulnerable to inundation during hurricanes because of their low elevation. In a cooperative research program between the U.S. Geological Survey, NASA, and the U.S. Army Corps of Engineers, these islands have been surveyed using airborne laser mapping (lidar) providing detailed elevation maps of the island's 'first line of defense', essentially the Gulf-front dune (or in the absence of dunes, the crest of the beach berm or seawall).

Pre-landfall vulnerability estimates were made available by the USGS online for west Florida's barrier islands falling within the October 21 cone of uncertainty for Wilma's predicted path. These predictions extended south from Anclote Key to Ft. Myers Beach, but did not include the Marco Island-Cape Romano area where Wilma made landfall. Nonetheless, these maps highlighted the extreme vulnerability of the west-Florida coastline to a direct hit from the waves and surge accompanying a storm of Wilma's magnitude. The beaches north of Cape Romano were very lucky to have Wilma's powerful right-front quadrant pass to their south, sparing them from a major wave and surge event.

Translating Science into Useful Information: Science Impact

Despite making significant advances in understanding the processes of natural hazards, the scientific community has been less successful in bridging the gap between science and policy. Science information is not always used as effectively as it could be. Decisions are sometimes made without the benefit of the best available scientific information. In some cases, institutions have not been established to react effectively to scientific information. To some extent, this was the case in December 2004 with the Indian Ocean tsunami. In other situations, scientific information is presented in forms that are not especially useful or easy to use by decision makers who are not scientists.

The scientific community has a proactive responsibility to ensure that scientific information informs public policy decisions as effectively as possible. This means taking steps to translate that information into forms that are meaningful to decision makers. It also means working with professionals in other disciplines to develop methods and tools for using scientific information more effectively sometimes in combination with other information important to decision makers such as socioeconomic information.

With regard to natural hazards, the scientific community needs to focus on the fundamental issues relating to understanding hazards processes and the spatial and temporal likelihood of hazard events occurring. In this endeavor, we need to keep our focus on the key societal goals of reducing our Nation's risk from natural hazards and of increasing our resiliency in responding to hazard events. Increasing our scientific knowledge and information relating to natural hazards is important to our ability to achieve these goals. However, this by itself will not result in reduced risk and in increased resiliency. The science is a necessary condition to achieving these goals, but it is by no means sufficient.

In discussing natural hazards, three terms are commonly used to describe natural events and their relationship with society: (1) hazards; (2) vulnerability; and (3) risk. *Hazards* relates to the physical processes and to understanding the spatial and temporal likelihood of an event occurring. This is the area that physical science addresses. To achieve our societal goals of reducing risk and increasing resiliency, we need to improve our physical understanding of hazard processes and the likelihood of an event occurring.

However, the societal impact of a hazard depends in large part on the population and property exposure to the hazard and on society's ability to respond. Certainly, a natural hazard in a deserted part of the world will have less significance than that same hazard in a population center. *Vulnerability* addresses the population and property exposure to the hazard, the sensitivity of these assets to a hazard and society's resilience in responding and adapting to an extreme event if it occurs. Even if the likelihood of a hazard is similar throughout a region, local variations in land-use, demography, economies and cultural settings can create different levels of community vulnerability.

Risk relates to the likelihood of life or property loss to a natural hazard. It combines information on the likelihood of the hazard with information on societal vulnerability. As a society, we need to understand risk to make informed decisions on land use as well as on where, when, and at what level mitigation efforts should be implemented.

The usefulness and value of our knowledge about natural hazards depends in part on our ability to combine the physical understanding of the hazard with knowledge and information about our societal vulnerability to the hazard and the resulting risk. Understanding only one part of this process will not allow us as a society to make the most informed and effective decisions. It should be emphasized that these decisions are based on both information and on values. Information on the hazard as well as on vulnerability and risk inform decision makers, but are used in combination with societal values to develop public decisions.

We need to remember that societal decisions can affect vulnerability and risk, but for the most part, have little impact on the hazard itself. For instance, we can take steps to reduce risk and increase resiliency to earthquakes if we understand earthquake processes and their likelihood, as well as population and property vulnerability. However, there is little that we can do to reduce the hazard of the earthquake itself.

To bridge the gap between science and policy for natural hazards, the scientific community needs to improve linkages between the physical processes associated with hazards and society's vulnerability and risk. This means in some cases extending research efforts to combine and integrate physical and socioeconomic investigations. It also means developing tools and methods for more effectively using physical science information in combination with information on vulnerability and risk.

The need for these efforts is compounded by the fact that vulnerability and risk are not static. As society changes, so does our vulnerability and risk. Population is growing and is expected to continue growing in areas with significant natural hazards. For instance, the Gulf Coast and coastal Florida are expected to sustain significant increases in population over the next 25 to 50 years which means that exposure to hurricane hazards will grow even if the physical hazard does not change. Areas along the west coast with significant hazard for earthquakes and landslides are also experiencing rapid population growth. Our vulnerability and risk from natural hazards will increase if we as a society do not act proactively to address these issues, even if the physical hazard itself does not change.

The USGS is taking explicit steps to narrow the gap between science and policy so that science can more effectively be used to reduce risk and increase resiliency. We are developing an integrated multi-hazards initiative that responds to the need for improved information on natural hazards processes and the associated spatial and temporal likelihood. The initiative addresses the need to fill key information gaps in our understanding of natural hazards such as earthquakes, volcanoes, landslides, and floods. The initiative also focuses on the development of methods and tools for more effectively using hazards information in combination with vulnerability and risk information.

As part of the hazards initiative, the USGS in the fall of 2006 will initiate a Multi-Hazards Demonstration Project to show that integrating information and products about multiple hazards can reduce loss of life and property from natural hazards. The Demonstration Project will bring the unique research and systems capabilities of the USGS to bear on the complex issues surrounding natural hazards events, especially interrelated hazards, such as fire, floods, and debris flows, or earthquakes and tsunamis.

The Demonstration Project will be conducted in southern California, which has one of the Nation's highest potentials for extreme, catastrophic losses from a number of natural hazards. Estimates of expected losses from natural hazards in the eight counties of

Southern California exceed $3 billion per year[2] and are expected to increase as the present population of 20 million grows at more than 10 percent per year. The project will focus on those natural hazards posing a significant threat to life and property in Southern California—earthquakes, floods, landslides, tsunamis, and wildfires—and will build on work already underway in the study area.

The project will have three principal components. Modernizing earth observation hazard networks will include adding 18 streamgages and raingages to the streamgaging network and developing a prototype flash-flood and debris-flow warning system for burned areas in Southern California. Targeted research on hazard processes and prediction will focus on assessment of the southern San Andreas Fault, the role of fire suppression and fuels accumulation in chaparral ecosystems and the wildland-urban interface, tsunami and inundation mapping and modeling, and developing models for predicting landslides and debris flows. To improve communication of USGS science to communities at risk, the USGS will work with local planners, emergency managers, and first responders to develop products and tools such as integrated hazard maps, tools to assess coastal vulnerability to extreme storm events, rainfall intensity-duration thresholds, and planning scenarios and decision tools.

The USGS is also developing a Science Impact program (SI) which is a focused research effort to increase the use and value of USGS science information in informing societal

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[2] This is an estimate based on 2000 FEMA366 report numbers for earthquakes alone, updated for inflation and rounded up to include all the other hazards. That report gave expected 8-county loses at $2.4 billion. At 3%/yr inflation, that yields $2.95 billion in 2006 dollars. *HAZUS®99 Estimated Annualized Earthquake Losses for the United States*, Federal Emergency Management Agency Report 366, Washington, D.C., September, 2000, 32 pp.

decisions. SI encompasses developing methods and tools to combine USGS natural science with socioeconomic information to enhance linkages between science and decision making. For natural hazards, this means combining our understanding of the hazard with vulnerability and risk analyses. The methods and tools developed as part of the Science Impact program will be applied to the multi-hazards initiative described above.

USGS efforts to bridge the gap between science, policy, and the public requires expertise in disciplines beyond those that are traditional to the USGS. Combining vulnerability and risk analysis with an understanding of the physical hazard requires an understanding of the decision sciences, economics, and the social sciences, as well as the physical sciences. To promote external innovation and to gain access to these skills, the USGS is developing partnerships with universities such as the University of Pennsylvania. These partnerships are an important component of our Science Impact program and are critical to our ability to combine understanding of natural hazards with information that will help make important decisions to increase resiliency and to reduce risk.

Conclusion

Natural hazards will always be with us. They are unpredictable and can have tragic consequences. We are doing our part to reduce risk and increase society's resiliency to natural hazards. If we can use our science to help save lives and minimize the damage caused by natural hazards, we will have achieved an enormous goal – helping to prevent natural hazards from becoming disasters.

Additional USGS Web Resources

US Geological Survey Homepage

http://www.usgs.gov/

USGS Responds to Hurricanes

http://www.usgs.gov/hazards/hurricanes/kat_rit_wil/

USGS and Natural Hazard Research

http://www.usgs.gov/science/science.php?term=53

USGS Science Impact Program

http://www.usgs.gov/science_impact/