Disaster and Failure Studies at NIST

Source: NOAA

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NIST

Long History of Disaster Studies at NIST

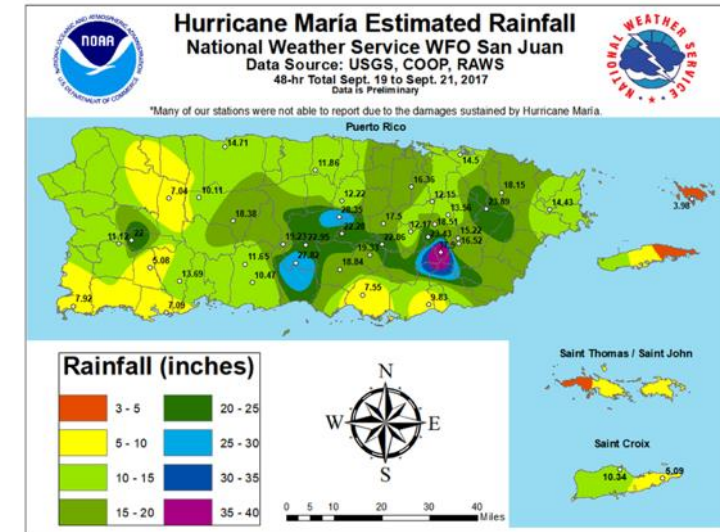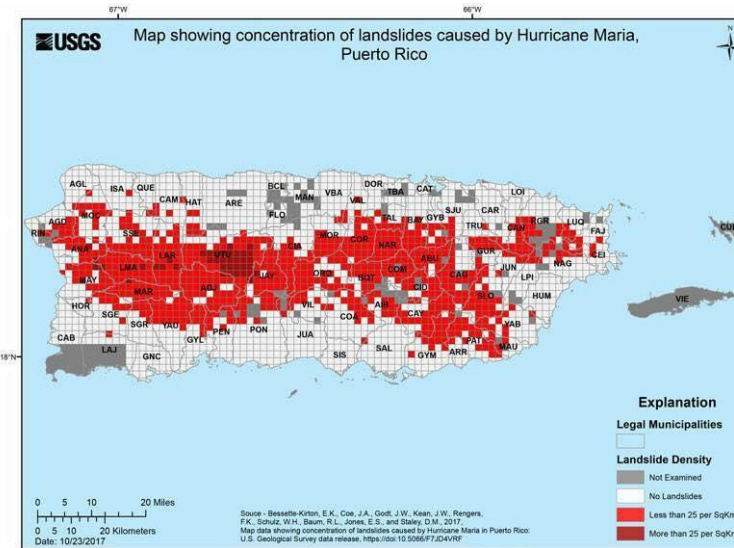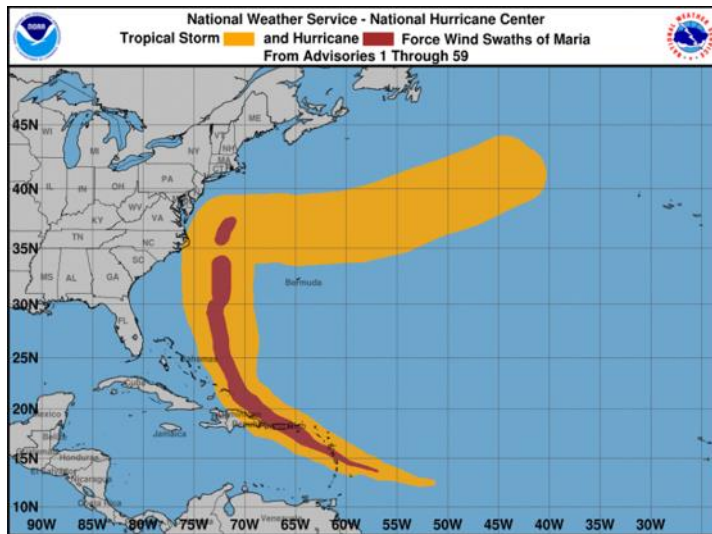| Earthquakes	Hurricanes	Construction & Building	Tornadoes	Fires
San Fernando, CA (1971)	Camille, MS/LA (1969)	Skyline Plaza Apartments, Bailey's Crossroads, VA (1973)	Jarrell, TX (1997)	DuPont Plaza Hotel, San Juan, PR (1986)
Mexico City, Mexico (1985)	Alicia, Galveston, TX (1983)	Willow Island Cooling Tower, WV (1978)	Spencer, SD (1998)	First Interstate Bank Building, Los Angeles, CA (1988)
Loma Prieta, CA (1989)	Hugo, SC (1989)	Kansas City Hyatt Regency, Kansas City, MO (1981)	Oklahoma City, OK (1999)	Loma Prieta Earthquake, CA (1989)
Northridge, CA (1994)	Andrew, FL (1992)	Riley Road Interchange, East Chicago, IN (1982)	Joplin, MO (2011)	Hillhaven Nursing Home (1989)
Kobe, Japan (1995)	Fran, NC (1996)	Harbor Cay Condominium, Cocoa Beach, FL (1981)	Moore OK (2013)	Pulaski Building, Washington, DC (1990)
Kocaeli, Turkey (1999)	Mitch and Georges, LAC (1998)	L'Ambiance Plaza, Hartford, CT (1987)		Happyland Social Club, Bronx, NY (1990)
Maule, Chile (2010)	Katrina and Rita (2005)	Ashland Oil Tank Collapse, Floreffe, PA (1988)		Oakland Hills, CA (1991)
Christchurch, NZ (2011)	*Matthew, NC (2016)	U.S. Embassy, Moscow, USSR (1987)		Watts St, New York City (1994)
	Harvey, TX (2017)	Murrah Federal Building, Oklahoma City, OK (1995)		Northridge Earthquake, CA (1994)
	*Maria, PR (2017)	World Trade Center Disaster, New York, NY (2001)		Kobe, Japan (1995)
		Dallas Cowboys Indoor Practice Facility, May 2009		Vandalia St, New York City (1998)
				Cherry Road, Washington, DC (1999)
				Keokuk, IA (1999)
				Houston, TX (2000)
				Phoenix, AZ (2001)
				Cook County Administration Building Fire (2003)
				The Station Nightclub, RI (2003)
				Charleston, SC, Sofa Super Store Fire (2007)
				Witch Creek & Guejito, CA, WUI Fire (2007)
				Amarillo, TX, WUI Fire (2011)
				San Francisco, CA (2012)
				*Gatlinburg, TN WUI (2016)
				Fuse-47, MD (2017)
				*Camp Fire (2018)

*Ongoing Studies

NCST Investigations

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Hurricane Maria Program at NIST

National Weather Service - National Hurricane Center
Tropical Storm and Hurricane Force Wind Swaths of Maria
From Advisories 1 Through 59

Map showing concentration of landslides caused by Hurricane Maria, Puerto Rico

Hurricane María Estimated Rainfall
National Weather Service WFO San Juan
Data Source: USGS, COOP, RAWS
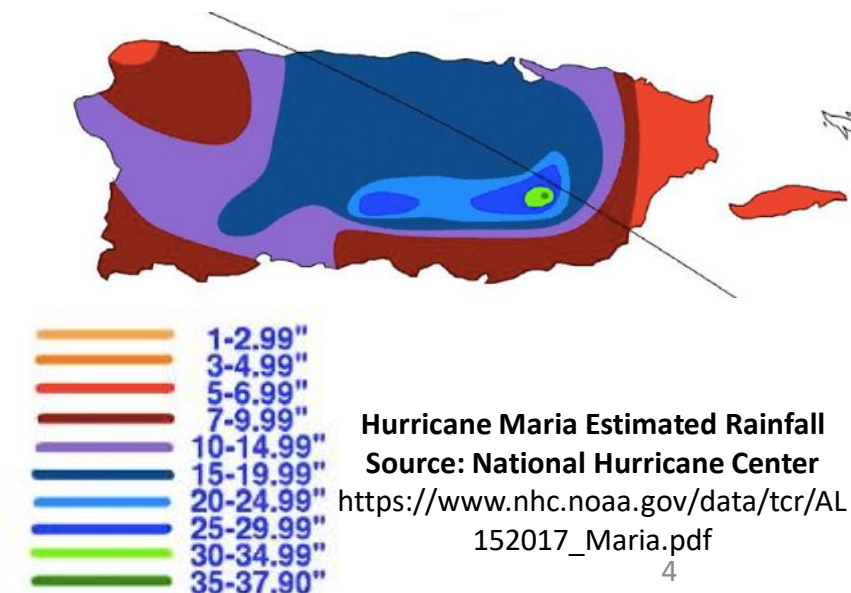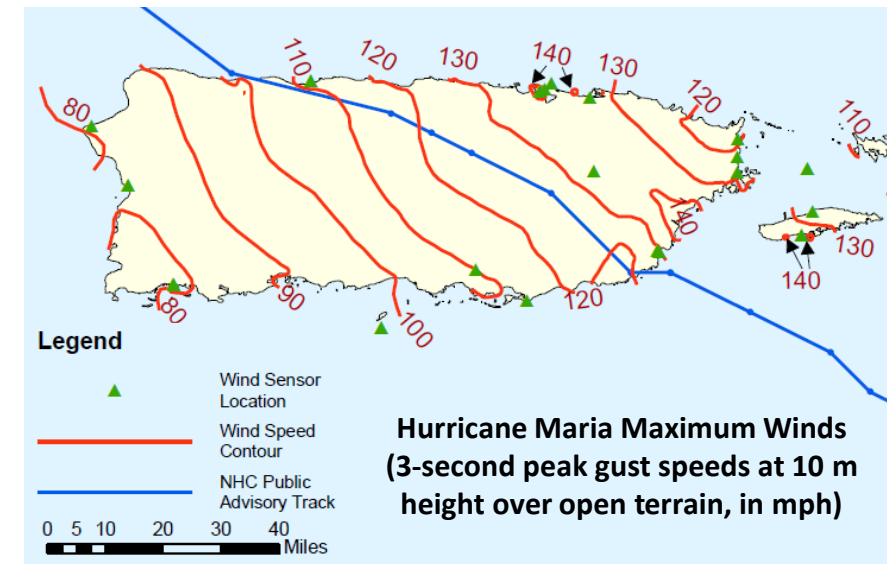48-hr Total Sept. 19 to Sept. 21, 2017

- NIST is studying Hurricane Maria's effects on Puerto Rico's buildings and emergency communications systems and recovery from the hurricane.

- Program is authorized by two federal statutes NCST and NWIRP.

- Goal: **recommend improved codes, standards, and practices to help communities in Puerto Rico and across the U.S. to be more resilient.**

Project 1: Characterization of Hazards

Investigative Goal: Characterize the wind environment and technical conditions associated with deaths and injuries.

Background: Hurricane Maria subjected Puerto Rico to multiple hazards: peak gusts exceeded 140 mph, peak coastal inundation exceeded 6 ft, rainfall totaling up to 40 inches causing inland flooding. The storm damaged instrumentation, resulting in challenges to the metrology of the hazards related to the windstorm.

Investigative Objective: Characterize the wind environment associated with Hurricane Maria's impact on Puerto Rico, using measurements and modeling of the time-dependent hurricane wind-field in conjunction with wind tunnel studies of topographic effects, and to document other hazards associated with the hurricane, including storm surge, rainfall, flooding, and landslides.

Legend

▲ Wind Sensor Location

— Wind Speed Contour

— NHC Public Advisory Track

0 5 10   20   30 40
Miles

Hurricane Maria Maximum Winds (3-second peak gust speeds at 10 m height over open terrain, in mph)

1-2.99"
3-4.99"
5-6.99"
7-9.99"
10-14.99"
15-19.99"
20-24.99"
25-29.99"
30-34.99"
35-37.90"

Hurricane Maria Estimated Rainfall Source: National Hurricane Center https://www.nhc.noaa.gov/data/tcr/AL152017_Maria.pdf

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Project 2: Performance of Critical Buildings

Investigative Goal: Characterize the performance of representative critical buildings, and designated safe areas in those buildings, including their dependence on lifelines.

Background: Preliminary observations of engineered structures showed: limited *structural* damage to reinforced concrete and concrete-block buildings with concrete roofs; some failures of non-concrete roofs (wood or steel frame) on reinforced concrete and concrete-block buildings; and wind-induced damage to and failure of metal building systems, potentially due to corrosion.

Investigative Objective: Characterize the performance of critical buildings in Hurricane Maria by (1) documenting failures of structural systems, building envelopes, and rooftop equipment, along with the resulting damage caused by wind-driven rain for a representative sample of hospitals and schools, (2) identifying dependencies in loss of function on lifelines, (3) characterizing wind loads on building envelopes and rooftop equipment through wind tunnel testing for a subset of these hospitals and schools to correlate with observed damage, and (4) evaluating the adequacy of existing selection criteria and design requirements for storm shelters.
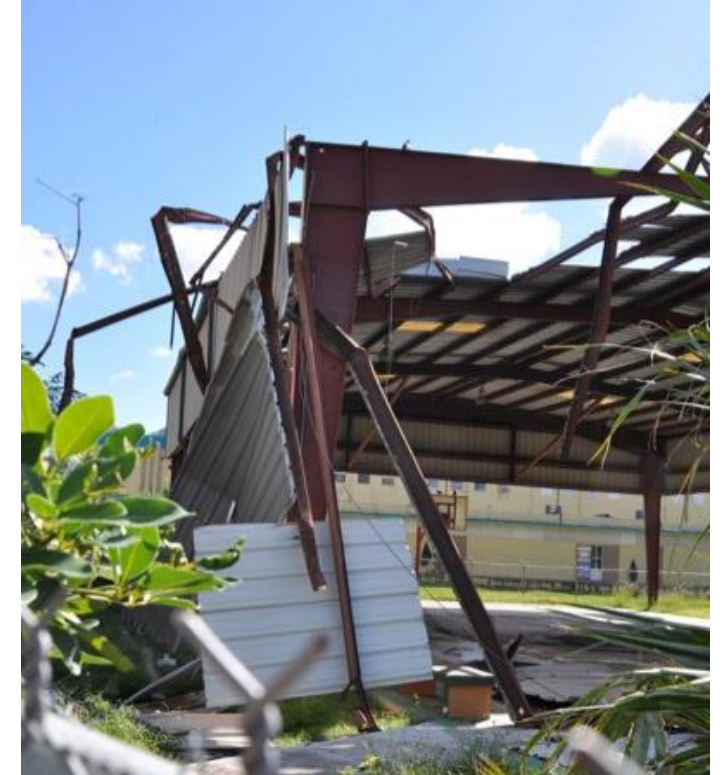
Project 3: Public Response and Emergency Comm's

Investigative Goal: Characterize the performance of emergency communications systems and the public's response to such communications.

Background: Preliminary observations highlighted severe evacuation and emergency response challenges: the threat of a Category 5 hurricane hitting an island that had just been affected by Hurricane Irma two weeks prior; an island's heterogenous terrain that posed different risks (flooding, heavy winds, storm surge, landslides), requiring different protective actions; societal preference for sheltering in place; lack of communication between emergency and building officials, and with the public for extended periods of time; and many people/families requiring rescues, e.g., from flooding in multiple towns on the island.

Investigative Objective: Investigate the role of emergency communications in public response for those under imminent threat from Hurricane Maria. This project will also investigate the use of communications in disaster response (during and immediately after the hurricane event).

Project 4: Characterization of Morbidity and Mortality

Investigative Goal: Characterize the wind environment and technical conditions associated with deaths and injuries.

Background: The official death toll by the Puerto Rico's Dept. of Public Safety was initially **64***, but on June 13, 2018 the Government of Puerto Rico revealed that there were **1,427**** more deaths in the four months after the hurricanes than normal (based on the previous four years), and updated the official count to **2,975***** based on George Washington University's study. It has been challenging to develop guidance/policy to prevent disaster attributed mortality due to the *lack of standards, consistent data collection and reporting.*

Investigative Objective: Complete a quantitative morbidity and mortality assessment of Puerto Rico, to better understand how damaged buildings and supporting infrastructure played a role in the injuries and deaths associated with Hurricane Maria. The study results will provide guidance to improve codes, standards and inform future approaches to accurately attribute and predict life loss due to building failure(s).

Project 5: Recovery of Business and Supply Chains

Study Goal: Characterize the impacts to and recovery of small and medium-sized manufacturers (SMMs), as well as businesses in retail and service industries.

Background: Manufacturing and retail business services are an important part of understanding the impacts of Hurricane Maria, as well as the long term recovery of Puerto Rico and its supply chains. **Manufacturing** activity in the Commonwealth accounts for about **45% of Puerto Rico's Gross Domestic Product (GDP) and over 20% of its employment** (PR BLS 2017). According to FEMA (2015), 40% of small businesses never reopen after a disaster and another 25%, that do reopen, fail within a year. Evidence suggests that businesses located in communities that are facing economic downturn ahead of a natural disaster event typically fare less well in recovery (e.g., Corey and Deitch 2013).

Study Objective: Characterize the recovery of small- and medium-sized businesses, including manufacturing, retail, and service sectors in Puerto Rico to provide greater understanding of business continuity resilience planning and supply chain continuity and how these may differ between industries/affected regions.

Project 6: Recovery of Social Functions

Study Goal: Characterize the impacts to and recovery of education and healthcare services.

Background: NIST investigation will include a project focused on the recovery of education and healthcare services associated with critical buildings (schools and hospitals) in Puerto Rico. Both education and healthcare services are an important part of understanding the impacts of Hurricane Maria, as well as the long term recovery of Puerto Rico. The Department of Education in Puerto Rico is expected to close over 283 schools, and will receive nearly $600 million in emergency federal assistance for school recovery and rebuilding.

Study Objective: Examine the recovery trajectories of sampled schools and hospitals in Puerto Rico to identify the underlying characteristics and conditions associated with recovery of critical social functions from Hurricane Maria.

Project 7: Recovery of Infrastructure Systems

Study Goal: Characterize the impacts to and recovery of infrastructure systems in Puerto Rico, with a focus on infrastructure that supports the functioning of critical buildings (i.e., hospitals and schools) and emergency communications.

Background: Puerto Rico's experience with Hurricane Maria presents an opportunity to better understand the infrastructure support of critical buildings. This support may be direct, e.g., delivering power to a hospital, or indirect, e.g., delivering power for telecommunications equipment that provides for hospital communications. Cascading impacts and the recovery of power, water, and transportation infrastructure are the focus. Also, wireless communications equipment failure is the focus.

Objective: Investigate dependencies of building function on distributed infrastructure, including cascading loss of function and sequencing of recovery activities, and also to investigate causes of the loss of functionality and extended-duration outage of the wireless communication system in Puerto Rico following Hurricane Maria.
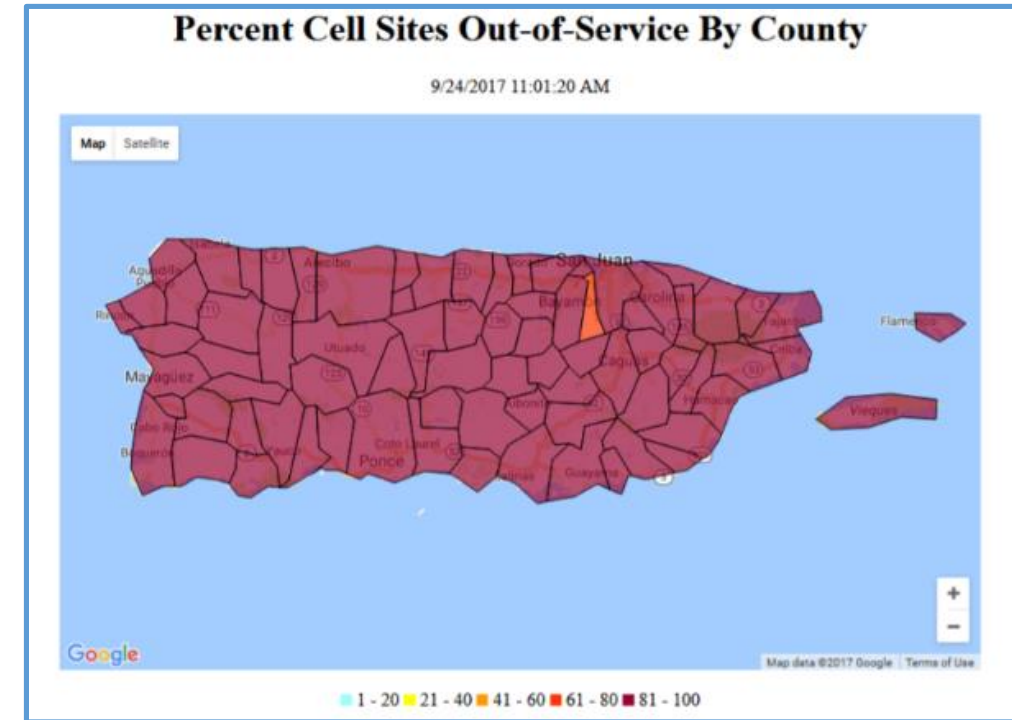
Thank you

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