engineering laboratory

Disaster Resilience of Buildings, Infrastructure, and Communities

Workshop on Observational and Analytical Climate Modeling for Engineering Applications

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NIST
National Institute of Standards and Technology
U.S. Department of Commerce

Outline

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- Concept of Disaster Resilience
- NIST Research
- Needs for the Engineering Community

Concept of Disaster Resilience

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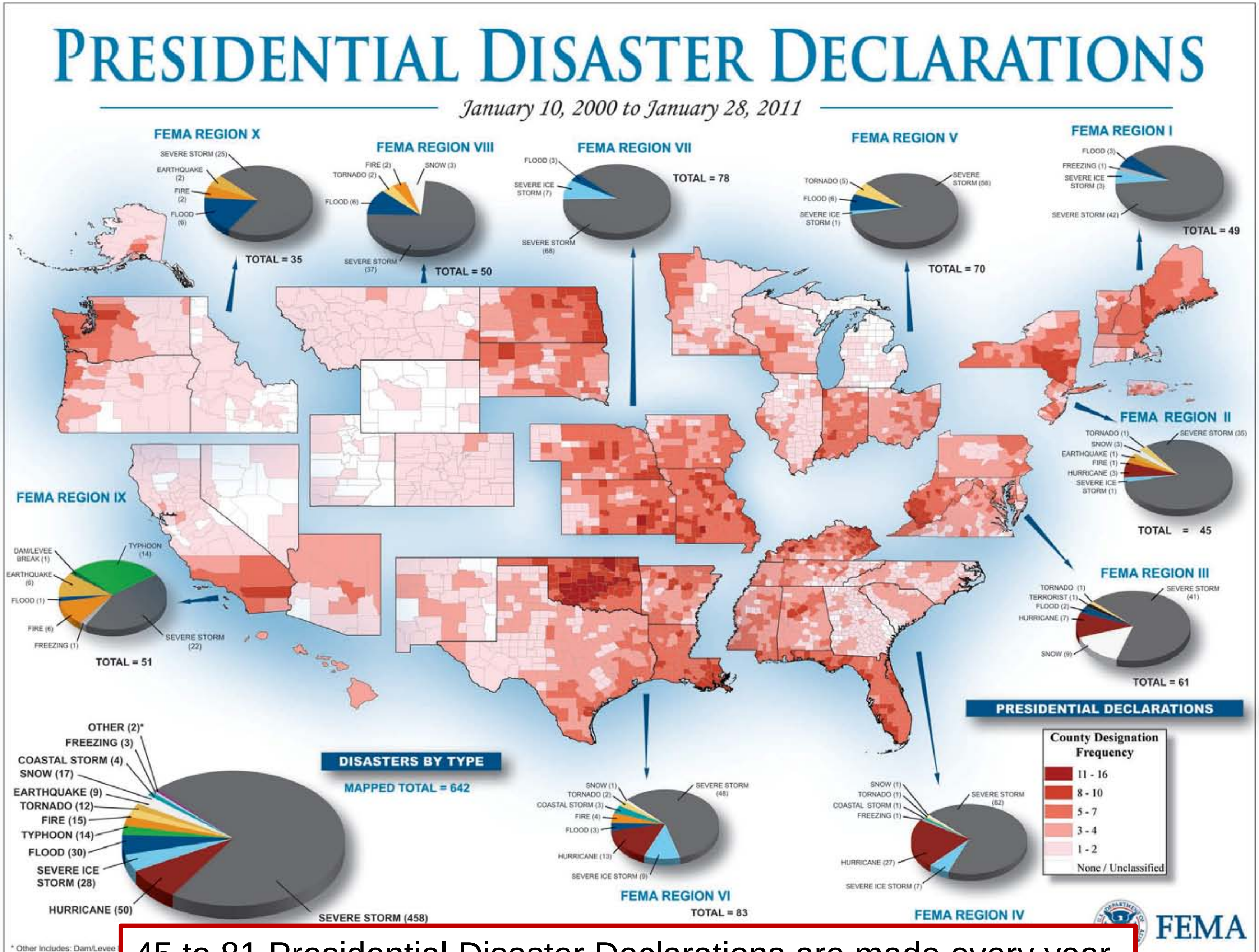
Background

- Natural and technological disasters cause an estimated $57B in average annual costs (and growing), with catastrophes like Hurricane Katrina and future “Kobe” earthquakes causing mega-losses exceeding $100B.
- Existing extreme load-related prescriptive requirements of building codes, standards, and practices stifle design and construction innovation and increase construction costs by an estimated $50B-$100B per year.

The risk in large disaster-prone regions of the Nation is substantially greater now than ever before due to the combined effects of development and population growth.

“…a primary focus on response and recovery is an impractical and inefficient strategy for dealing with [natural disasters]. Instead, communities must break the cycle of destruction and recovery by enhancing their disaster resilience.”

National Science & Technology Council, *Grand Challenges for Disaster Reduction – A Report of the Subcommittee on Disaster Reduction*, June 2005.



45 to 81 Presidential Disaster Declarations are made every year

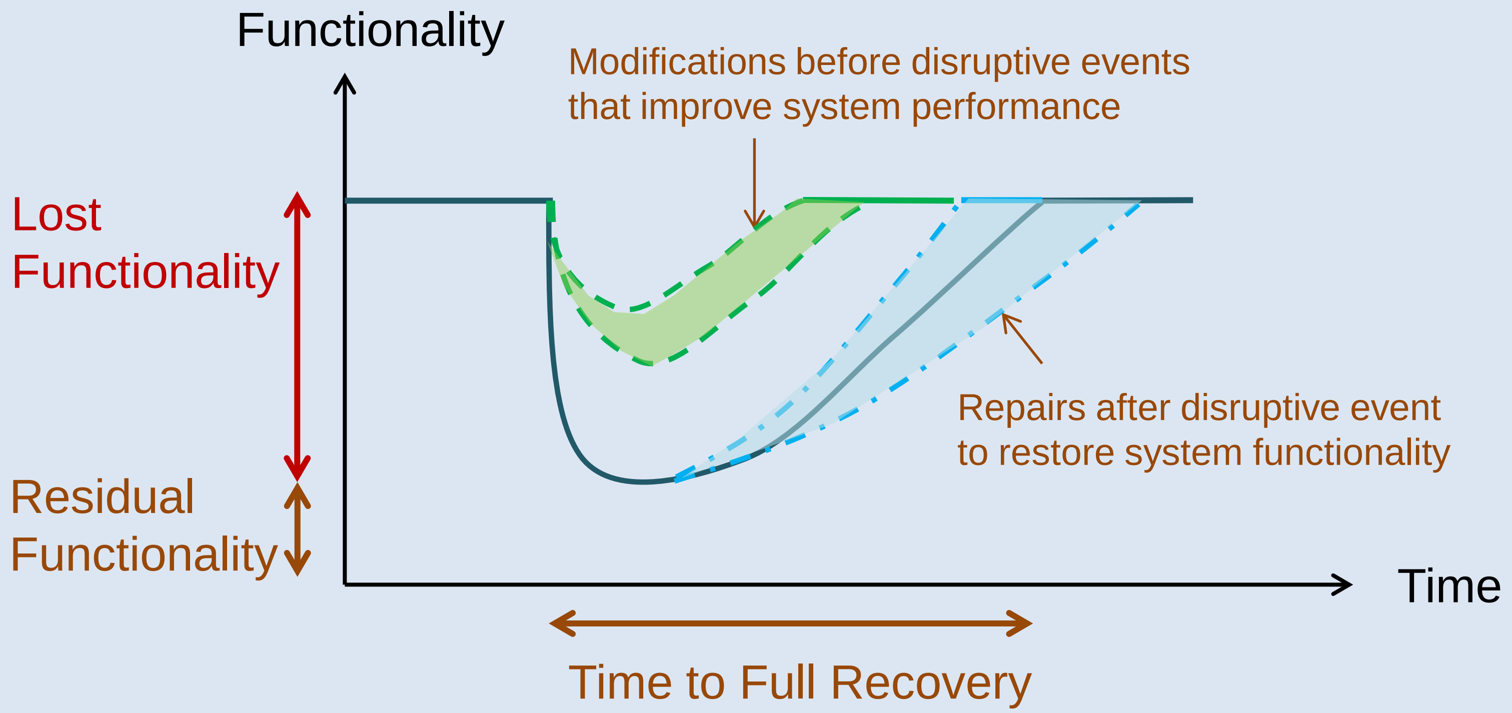
Performance of the Built Environment

- The built environment fails repeatedly during hazard events
- Performance of the built environment is dependent the codes and standards in place at the time of construction, enforcement, maintenance, and operation
- The built environment is highly interconnected; current codes and standards are generally independent and do not account for this interconnectedness

Resilience Concepts

Resilience is the capability of a system to

- maintain acceptable levels of functionality during and after disruptive events
- to recover full functionality within a specified period of time



Adapted from McDaniels, 2008 and Bruneau, 2003

Defining the Built Environment

- Buildings (engineered and non-engineered)
  - All systems necessary for intended function
  - Architectural, structural, life safety, mechanical, electrical, plumbing, security, communication and IT systems
- Infrastructure or lifelines
  - Transportation - roads, bridges, tunnels, ports, rail
  - Utility plants and distribution systems - electric power, water and wastewater, fuels, communication

Community Resilience

- Identify multiple hazard and performance levels
  - *What* are the hazards that are likely to affect a community?
  - *What* is the desired performance *of the community* given different hazards levels?
- Consider the function of buildings and infrastructure systems within the context of response and recovery.
  - *What* is the required function of the building or infrastructure system?
  - *When* is the building or infrastructure system required to be restored to functionality to support response and recovery?

Common Terminology/Definitions

- Hazard levels
  - Routine (serviceability)
  - Expected (used in design and to evaluate resilience)
  - Extreme (used in emergency response planning)
- Performance levels
  - Account for function of building or infrastructure system within the context of the community
  - Consider time to return to functionality

Performance Goals/Categories

- Develop performance goals for buildings and infrastructure systems
  - System-wide, interdependent approach
  - Guidelines for rural and urban communities
- Develop performance categories for buildings and infrastructure systems
  - Performance level tied to role of building or infrastructure system in response and/or recovery following a hazard event
  - Generalized for new and existing systems

What is Needed to Achieve Resilient Communities?

Status Quo

- Prescriptive codes and standards for life safety
- Poor buildings and infrastructure resilience performance during hazard events
- Emergency response planning but little community resilience planning
- Reliance upon federal disaster funding for recovery

Moving Forward

- Risk consistent, performance based codes and standards for resilience
- Comprehensive approach to design guidance for built environment
- Proactive planning by communities to achieve resilience
- Reduced emergency response and recovery costs

Identify Gaps in Standards, Codes, and Current Practice

- Hazards and associated load criteria
- Hazards without load criteria (e.g., fire)
- Performance criteria for construction materials and types
- Interdependencies among buildings and infrastructure systems
- Examples from best practices (e.g., for business continuity)

NIST Research in Support of Disaster Resilience

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Research Thrusts

- Develop validated tools that predict structural performance to failure under extreme loading conditions.
- Develop community-scale loss estimation tools to predict consequences of disasters, leading in turn to increased resilience.
- Develop validated tools to assess and evaluate the capabilities of existing structures to withstand extreme loads.
- Develop performance-based guidelines for cost-effective design of new buildings and, where warranted, rehabilitation of existing buildings.
- Derive lessons learned from disasters and failures involving structures.

Research Scope

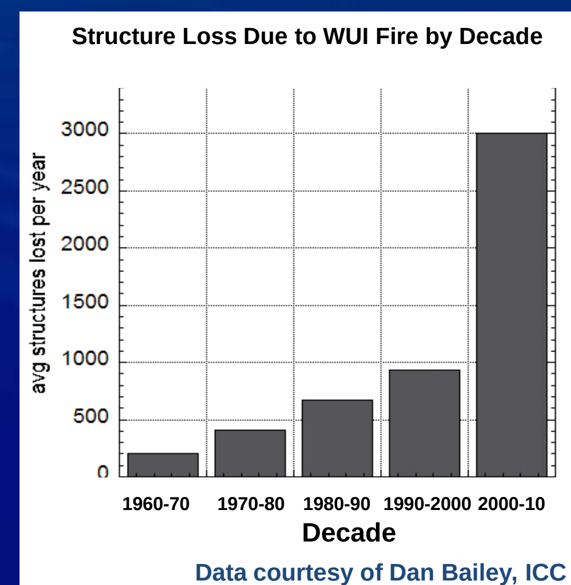
- Hazard Specific Research
  - Earthquake Engineering
  - Structural Fire Resistance
  - Extreme Wind Engineering
  - Fire Risk Reduction in Buildings
  - Fire Risk Reduction in Communities
- Cross-Cutting Research
  - Measures of Building Resilience and Structural Robustness
  - Multi-Hazard Failure Analysis
  - Disaster and Failure Studies

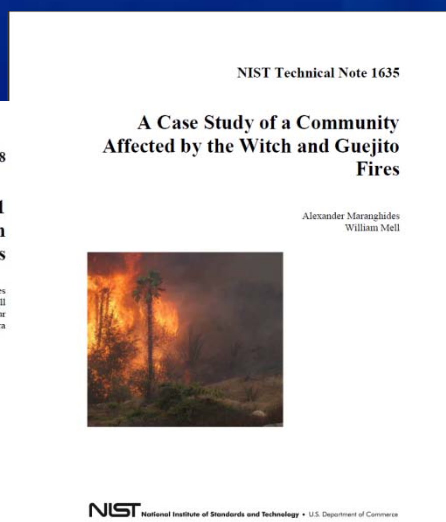
WUI Fire Research at NIST

Develop mitigation tools to reduce the risk of fire spread in the WUI

WUI fires: A growing national problem

- 39% of US homes in WUI (60% of new houses)
- 50,000 high risk communities in wildland urban interface
- Climate change causing extreme weather (droughts)
- Burden of WUI fires on U.S. economy in 2009 = $14B (2009)
- 2007 So. California fires displaced 500,000 people, and cost $1.8 B.




NIST Technical Note 1635

A Case Study of a Community Affected by the Witch and Guejito Fires

Alexander Maranghides
William Mell

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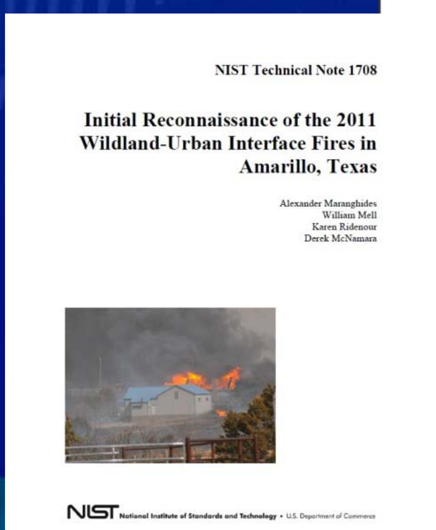
NIST Technical Note 1708

Initial Reconnaissance of the 2011 Wildland-Urban Interface Fires in Amarillo, Texas

Alexander Maranghides
William Mell
Karen Ridenour
Derek McNamara

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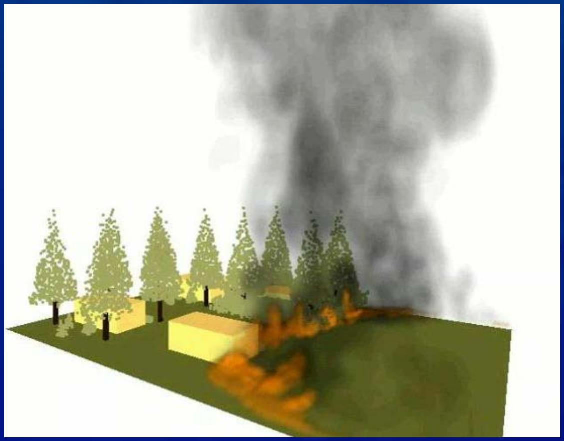
Fire Research at NIST

- Focus on impact-based research.
- Research to support the technical basis for standards, codes, guidelines, models, software decision-tools, standard reference materials, databases, etc.
- Rich technical partnerships with USFA, DHS, NFPA, USFS, BLM, ICC, CalFIRE, Texas Forest Service, and many other organizations.

Standards for structural and WUI firefighting equipment



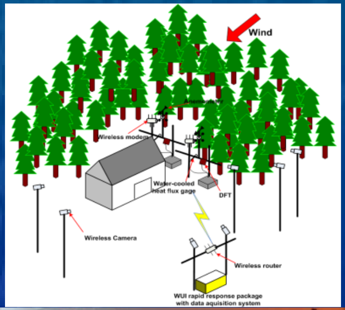
WUI fire modeling for performance based design

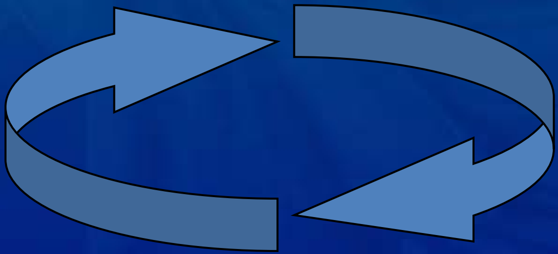
Building code changes to protect against fire brands

Integrated NIST WUI Projects

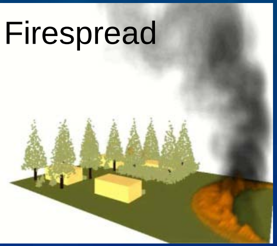
Pre- and Post-Fire Data Collection & Analysis
CAL FIRE, City of San Diego, *Coeur d'Alene Tribe, McNamara Consult.*

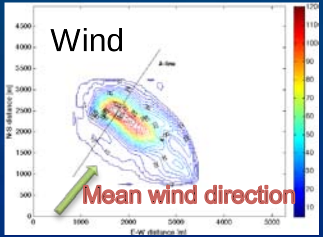
Structure Ignition
USFS, CALFIRE, ASTM, DHS, BRI



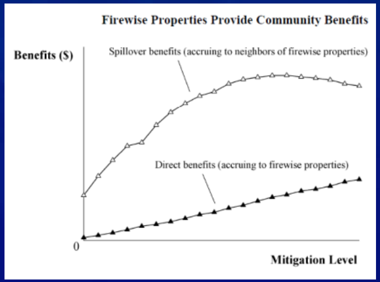


Physical Modeling
NOAA, USFS, JFSP, *U Utah. Tribe, McNamara*





Economic Modeling
USFS, JFSP, DHS



Field Scale Fire Behavior & Wind Measurements
USFS, NOAA, *CU, RIT, SDSU*

Lab Scale Fire Behavior Measurements
UCR, USFS

Recent WUI and Fire Standards Committee Participation

National Fire Protection Association

- Technical Correlating Committee, Protective Clothing and Equipment (Putorti)
- NFPA Research Section (Madrzykowski)
- NFPA-2 Hydrogen Technologies. (Yang)
- NFPA-13D Residential Sprinklers (Madrzykowski)
- NFPA-72 Fire Alarm Systems (Cleary)
- NFPA-76 Telecommunications (Cleary)
- NFPA-101 Life Safety Code (Bukowski, Averill, Peacock)
- NFPA-130 Fixed Guideway Transit and Passenger Rail Systems (Peacock)
- NFPA 211 Chimney, Fireplace, Vent and Solid Fuel Burning Appliances (Peacock)
- NFPA-262 Fire Tests (Gann)
- NFPA-295 Forest and Rural Fire Protection (Maranghides)
- NFPA 1141 Forest and Rural Fire Protection
- (Maranghides)
- NFPA-921 Guide for Fire and Explosion Investigation (Madrzykowski)
- NFPA-1800 Electronic Safety Equipment (Putorti)
- NFPA 2001 Clean Agent Extinguishing Systems (Yang)
- NFPA-5000 Building and Construction Code (Peacock)
- Technical Toxicity Advisory Committee, Chair (Gann)
- Tech. Advisory Committee modeling incipient fires with FDS (McGrattan)
- Tech. Advisory Committee modeling smoke detectors sloped ceilings (McGrattan)

American Society for Testing and Materials

- ASTM Protective Clothing Committee F23
- ASTM Fire Test Committee E-5 (Manzello)
- ASTM Vents E05.14.06 (Manzello)
- ASTM Quant. Ext. Fire Exposures E05.14.08 (Manzello)
- ASTM Decks-Brands Exposure E05.14.09
- ASTM Field Vents E05.14.10 (Manzello)

International Code Council

- ICC Performance Building Code Committee
- ICC Performance Fire Code (Bryner)

California State Fire & Building Code

- Chapter 86A Fire Code
- Chapter 7A Building Code
- Residential Setbacks

National blue Ribbon Panel on WUI

(Maranghides)

National Cohesive Strategy

- Wildland and WUI Data (Maranghides)
- Public Safety, Property Loss, & Social/ Community Vulnerability (Maranghides)

Wind and Storm Surge Research

- Objective: To develop the measurement science methods and tools that will enable performance-based standards for designing structures to resist wind and storm surge in a multi-hazard context.
- Thrusts:
  - Develop realistic wind hazard maps to update current ASCE 7 Standard maps.
  - Develop science-based methodologies for aerodynamic simulation and measurements to eliminate the errors in wind tunnel estimates.
  - Develop methodology for computation of risks posed by the combined hurricane hazards of wind, storm surge, and waves.
  - Develop methodology for risk-consistent design criteria for coastal structures.

National Windstorm Impact Reduction Program (NWIRP)

- Created by the National Windstorm Impact Reduction Act of 2004 (Public Law 108-360)
- Objective: "achievement of major measurable reductions in losses of life and property from windstorms"
- Lead Agency: OSTP
- Interagency Working Group: NIST, NSF, NOAA, and FEMA
- NIST responsibilities (PL 108-360, Section 204(c)(1)):
  - Support R&D to improve building codes and standards and practices for design and construction of buildings, structures, and lifelines

Storm Surge

Current Design Practice for Coastal Infrastructure:

- Considers wind and storm surge hazards independently
- Combined wind/storm surge effects considered for special structures only (*Standard Project Hurricane*), but risk in SPH often not quantified
- Saffir/Simpson (S/S) Hurricane Scale does not account for local bathymetry. Not intended for structural design, frequently misunderstood
- Coupling of physical processes (wind, storm surge, waves) not considered

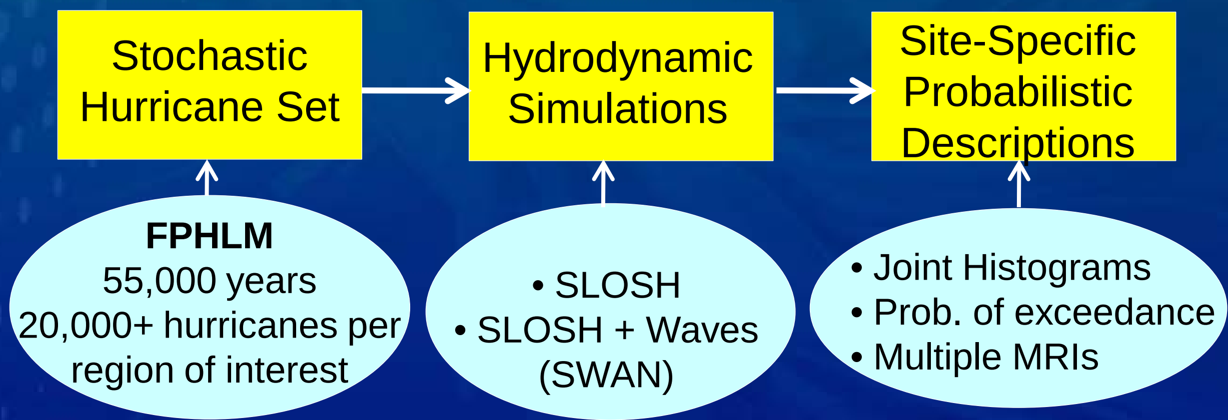
Project Aim:

- Develop methodology for (1) computation of risks posed by multiple, combined hurricane hazards for any specific coastal locations (accounting for variations in local topography and bathymetry), and (2) development of risk-consistent design criteria for coastal structures.

Storm Surge

NIST Methodology:

- Collaborative (NIST, NOAA-NWS, NOAA-OAR, U. of Florida)
- Integrative, interdisciplinary (hurricane science, hydrology, probabilistic)



- Account for *site specificity* and *multiple MRIs*
- Coupling of wind, surge, waves

FPHLM: **F**lorida **P**ublic **H**urricane **L**oss **M**odel (NOAA-OAR)
SLOSH: **S**ea, **L**ake, and **O**verland **S**urges from **H**urricanes (NOAA-NWS)
SWAN: **S**imulating **WA**ves **N**earshore (Delft University)

Emerging Results and Impacts of Recent Windstorm Research

- **Extreme Wind Speeds Estimation:** development of directional wind speeds database and non-directional wind speed maps for any specified non-hurricane location in the US
- **Wind Tunnel Techniques:** Enforceable standards for wind tunnel testing of low-rise buildings, resulting in repeatable tests
- **Computational Fluid Dynamics for Low-rise Buildings:** Efficient engineering office methodology for numerical computation of pressure distributions
- **Risk-consistent Design Criteria for Coastal Infrastructure in Hurricane Prone Regions:** Potential application of NIST methodology to create risk-consistent design criteria considering the combined effects of multiple hurricane hazards (wind, storm surge, and waves), with proper consideration of local topography and bathymetry
- **Total Storm Surge Inundation:** Potential improvement in estimation of total storm surge inundation using SLOSH by incorporation of SWAN wave model

Needs for the Engineering Community

Effects of Climate Change

- Climate change may affect the frequency and intensity of natural hazards in the future
- An increase of greenhouse gases in the atmosphere will likely boost temperatures over most land surfaces; the exact change will vary regionally
- Possible impacts of climate change on natural hazards may include*:
  - Increased frequency of heavy precipitation events resulting in increased frequency of flash floods and large-area floods in many regions, especially at high altitudes
  - Increased frequency and intensity of wildfires, especially in forests and peatland
  - Increased intensity of tropical cyclone activity including hurricanes and typhoons
  - More frequent and intense storm surge due to the combination of rising sea level and more intense storms
- Western wildfire fire season is now 205 days; 78 days longer than in the mid-1980s.**

*Intergovernmental Panel on Climate Change (IPCC 2007)

**National Center for Atmospheric Research

Needs for Engineering Community

- Climate change will influence the hazard (load) for which structures must be designed
- Risk-consistent tools are needed to assess these hazards
  - New tools to assess hazards such as storm surge and tsunami, that are affected by changes in sea level
  - Updated wind hazard maps reflecting improved knowledge of the hazard and probability of occurrence
  - New tools for assessing the hazard due to WUI
  - Updated flood hazard maps (coastal and riverine)
- Decision-support tools are needed that more accurately reflect hazards to support performance objectives for buildings and communities to achieve resilience

Questions?