Summary of Hurricane Maria NCST Investigation Progress

NCST Advisory Committee Meeting

September 7, 2023

Joseph Main
Team Lead

Maria Dillard
Associate Team Lead

NIST | NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
U.S. DEPARTMENT OF COMMERCE

Presentation Outline

1. Program Overview
2. Data Collection Status
3. Contracting Updates
4. Analysis Updates
5. Staffing & Stakeholder Outreach
6. Timeline & Next Steps

Program Overview

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Hurricane Maria Program

Event Impacts


Landslides, road damage


Failure of power & communications

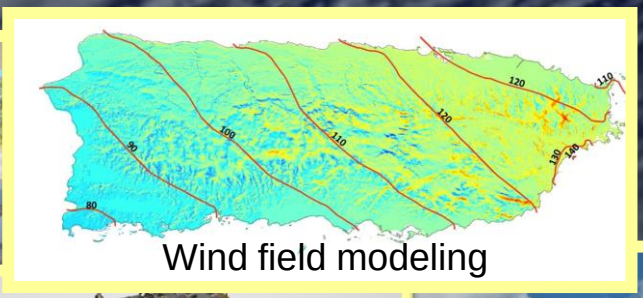

Heavy rain, flooding


Building envelope damage

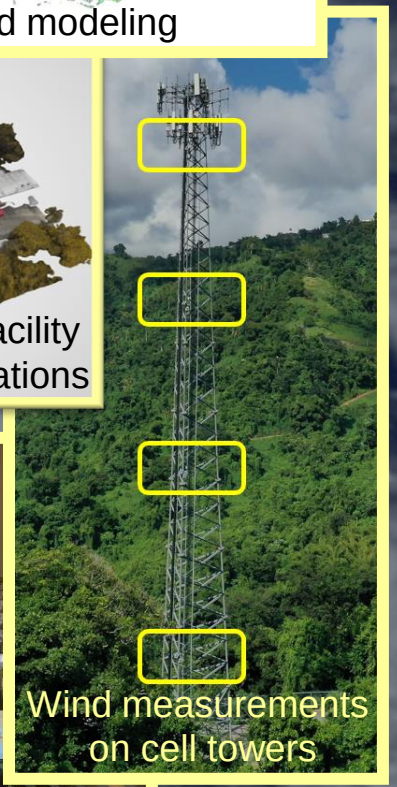

Rainwater intrusion in buildings

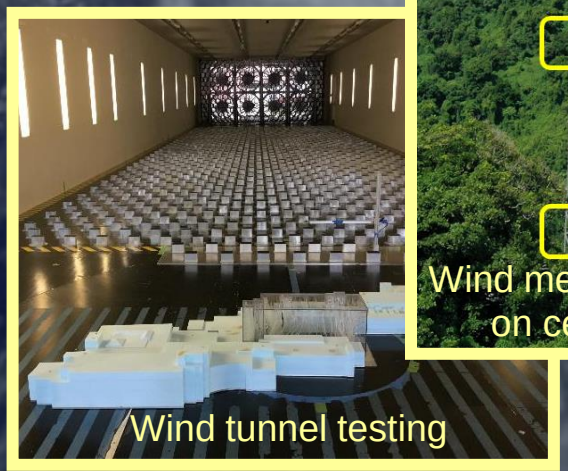
Recommendations


Surveys & interviews


Wind field modeling


Facility evaluations


Wind measurements on cell towers


Wind tunnel testing

Investigation

Hurricane Maria Program

2 Program Components

NCST Investigation	NWIRP* Research Study

7 Technical Projects

Hazard Characterization	Performance of Critical Buildings	Public Response to Emergency Communications	Morbidity & Mortality	Impacts to and Recovery of Infrastructure Systems	Recovery of Business and Supply Chain	Recovery of Social Functions

5 Major Contracts

Applied Research Associates	University of Florida	Stantec Consulting	George Washington University	Horsley Witten Group

Multiple Collaborating and Coordinating Agencies

FEMA	NOAA	HHS	USGS	NCDMHP	PRDOH	PRDOE	PRDTOP	PRASA	PRFAA	Many others…

1 Coordinated Program

*National Windstorm Impact Reduction Program

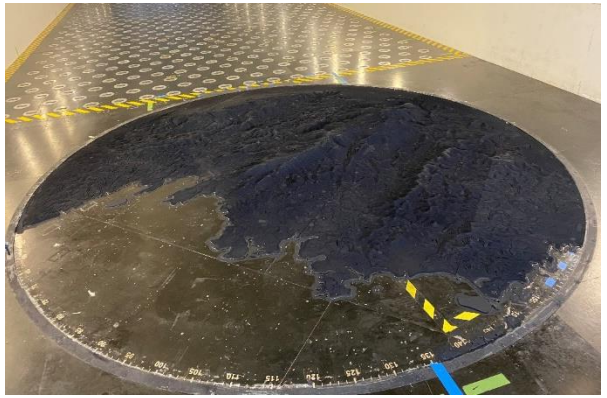
NCST Investigation Goals and Projects

***Goals** are to characterize:*

1. *the wind environment and technical conditions associated with deaths and injuries;*
2. *the performance of representative critical buildings, and designated safe areas in those buildings, including their dependence on lifelines; and*
3. *the performance of emergency communications systems and the public's response to such communications.*

Projects:

Hazard Characterization	Performance of Critical Buildings	Public Response to Emergency Communications	Morbidity & Mortality



NWIRP Research Study Goals and Projects

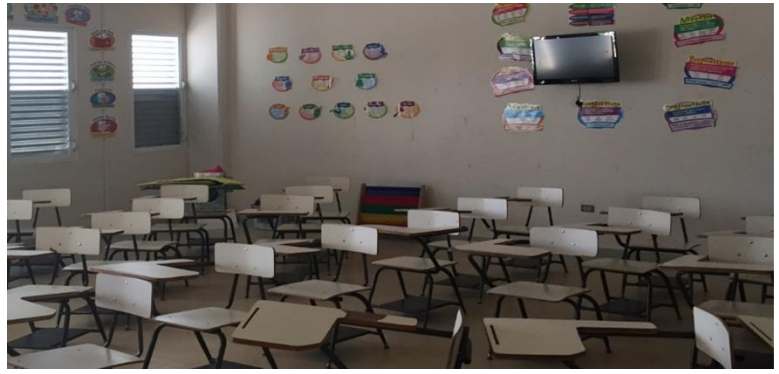
***Goals** are to characterize the impacts to and recovery of:*

1. *small and medium-sized manufacturers, businesses in retail and service industries, and supply chains;*
2. *education and healthcare services; and*
3. *infrastructure systems, with a focus on infrastructure that supports critical buildings (i.e., hospitals and schools) and emergency communications.*

Projects:

Recovery of Business & Supply Chains

Recovery of Social Functions



Impacts to & Recovery of Infrastructure Systems

Data Collection Status

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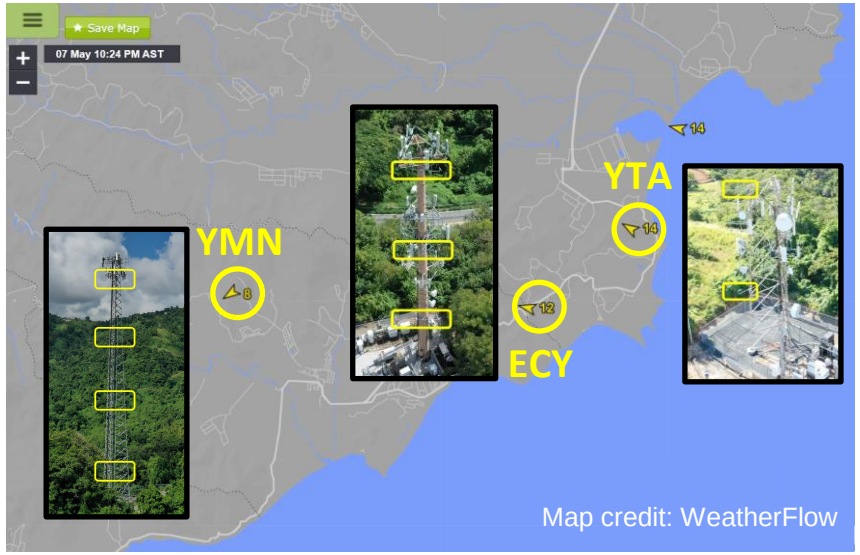
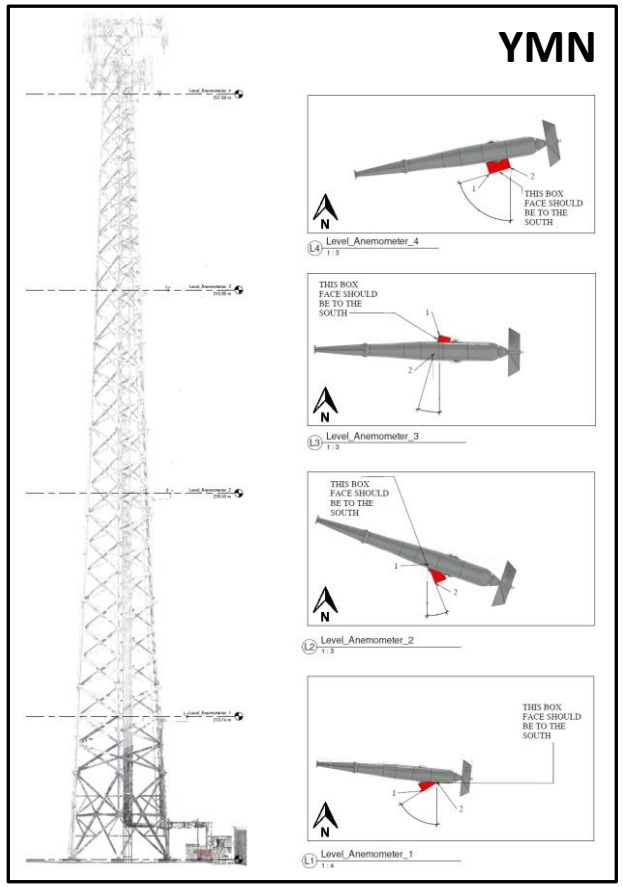
Data Collection Update: *Wind Measurements on Towers*

Completed measurements of anemometer orientation & elevation at all 3 cell towers:

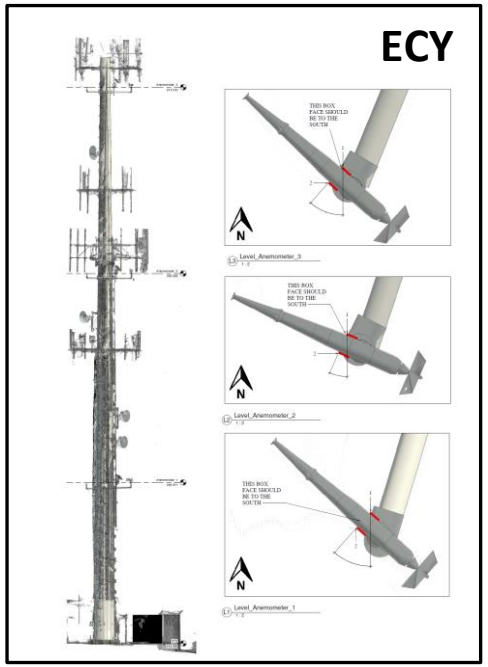
- laser scanning performed by a licensed surveyor on July 19, 2023
- provides significantly reduced uncertainty for measured wind direction data

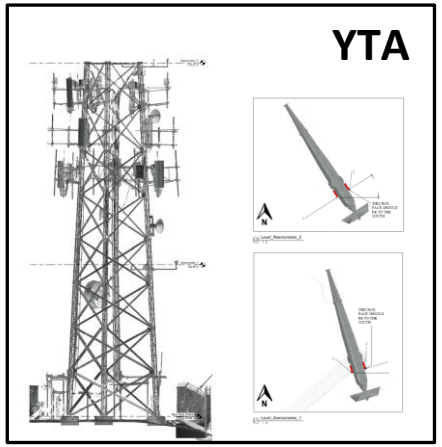


Cell Tower Identifiers:
YMN: Yabucoa Manoabo Norte
ECY: El Cocal Yabucoa
YTA: Yabucoa Tanque de Agua



The zero position for wind direction was determined by measuring the orientation of each junction box (shown in red)





Data Collection Update: *Evaluation of Critical Buildings*

- Completed site visits and interviews for hospitals and shelters
- Tasks completed since previous NCSTAC meeting on June 14, 2023:
  - Site visits to 3 shelter facilities
  - Interviews with 3 shelter operations managers and 1 school director

Data Collection Status:

Facility Evaluations: 5 hospitals, 5 shelters

Phase 1: Document collection and review ✓

Phase 2: Site visits and interviews ✓

Completed July 2023

Stantec Consulting

Wind Tunnel Testing of Two Hospitals ✓

University of Florida

NCST Data Collection Status: *Completed*

Hazard Characterization

- Wind Tunnel Testing of Topographic Models — *University of Florida*
- Meteorological Data for Wind Field Model — *Applied Research Associates*
- Field Measurements of Winds on Cell Towers (2 years) — *University of Florida / WeatherFlow*
- Data on rainfall, storm surge, flooding and landslides

Public Response to Emergency Communications

- Information Provider Interviews — *Horsley Witten*
- Household Surveys — *Horsley Witten*
- Public Messages for Qualitative Content Analysis
- Household Interviews — *Horsley Witten*

Performance of Critical Buildings

Facility Evaluations: 5 hospitals, 5 shelters

- Phase 1: Document collection and review
- Phase 2: Site visits and interviews

Stantec Consulting

- Wind Tunnel Testing of Two Hospitals — *University of Florida*

Morbidity & Mortality

- Verbal Autopsy and Social Environmental Survey — *GW-UPR*
- Integrated Database of Deaths in Puerto Rico — *GW-UPR*
- Medical Records and Hospital Functions Review — *GW-UPR*
- Spatial and Temporal Data for Analysis of Deaths — *GW-UPR*

Data Collection Update: *Wave 2 Survey of School and Hospital Recovery*

Created by Adrien Coquet from the Noun Project

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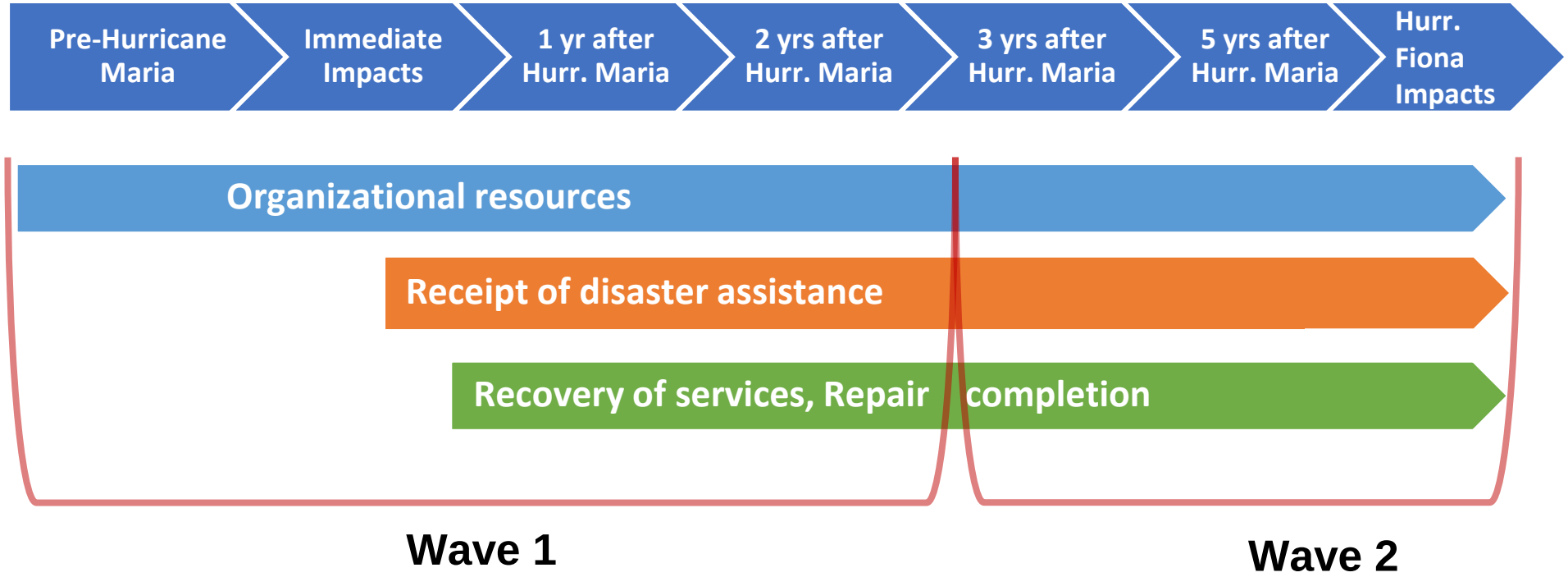
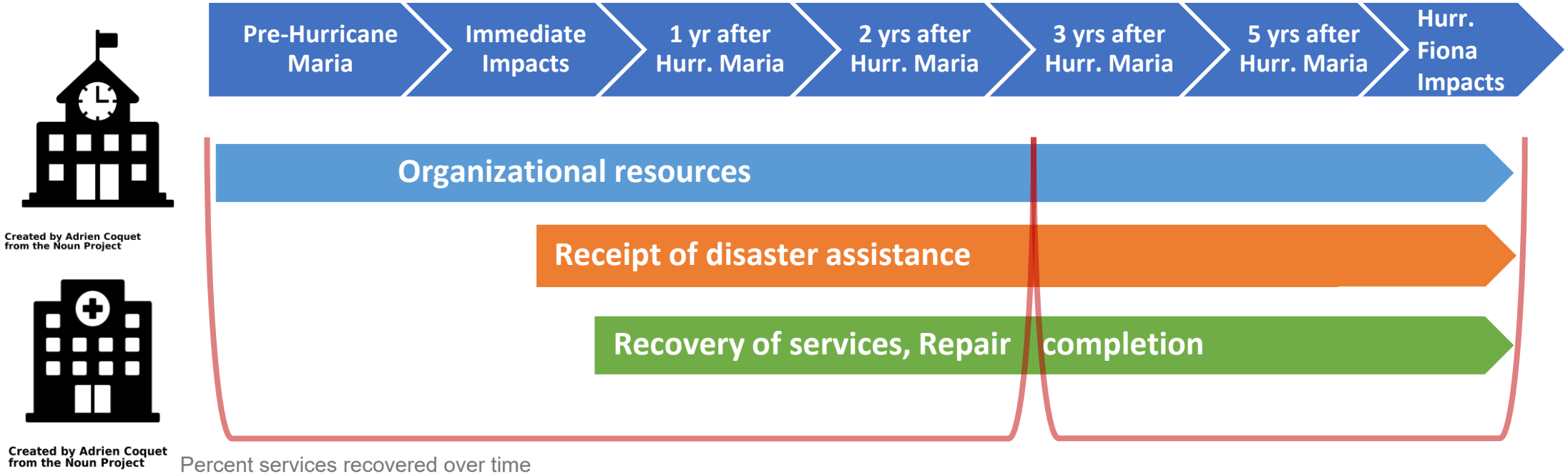


Wave 1 is focused on assessing initial impacts of Hurricane Maria and tracking recovery progress for schools and hospital services

Wave 2 is focused on tracking recovery progress and capturing initial impacts of Hurricane Fiona on schools and hospital services

Data Collection Update: *Wave 2 Survey of School and Hospital Recovery*



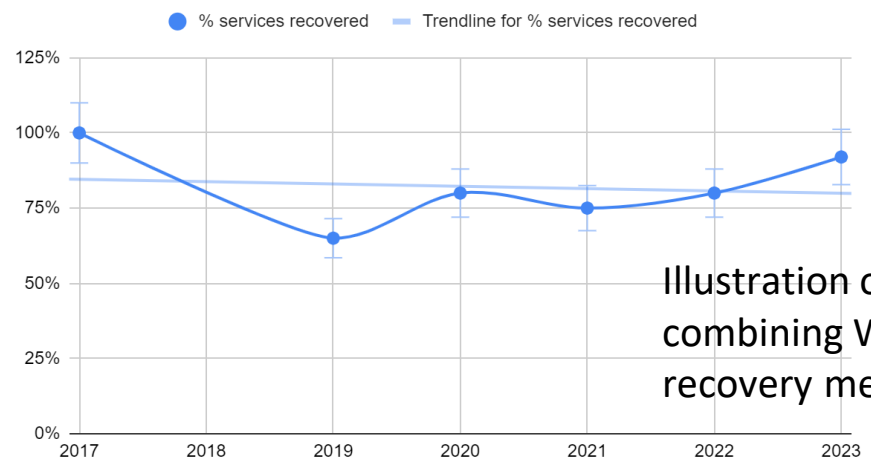


Illustration of analysis combining Waves 1 and 2 recovery metrics

Wave 2 Data Collection In Progress

School Surveys: 45 completed; 56 in progress

Target sample is Wave 1 respondents (~300 schools)

Hospital Surveys: Surveying began late August

Target sample is Wave 1 respondents (~16 hospitals)

Contracting Updates

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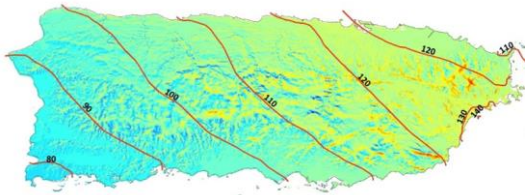
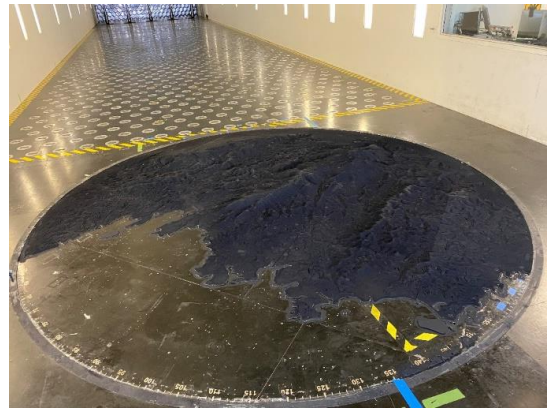
Supporting Contracts

Contract
Wind Field Modeling
Wind Tunnel Testing and Field Measurement of Winds
Engineering Services to Evaluate Critical Building Performance
Social Science Data Collection
Morbidity and Mortality Assessment



Applied Research Associates



University of Florida

Stantec Consulting

Horsley Witten Group

Source: Bernardo Hernández Prado

GW/UPR

Contracting Updates: *Summary*

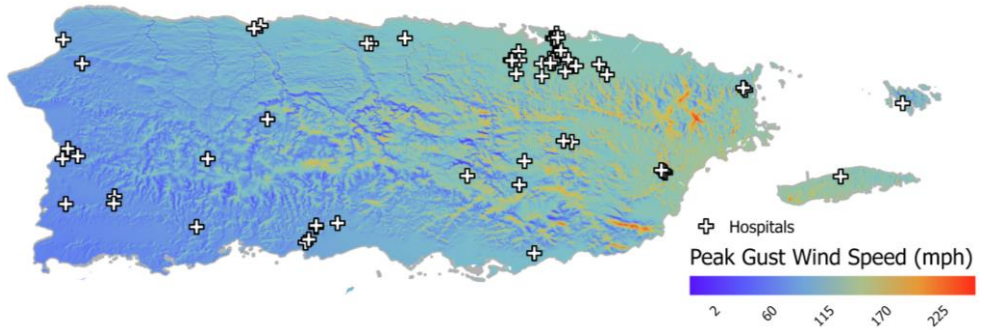
Status	Contract	Contractor(s)	Project(s) Supported
New Contract (award imminent)	Wind Field Modeling	Applied Research Associates	• Hazard Characterization • Critical Buildings
New Contract (awarded 8/31/2023)	Field Measurement of Winds	WeatherFlow, Inc.	• Hazard Characterization
Modification (awarded 9/6/2023)	Social Science Data Collection	Horsley Witten Group, Inc. • Eastern Research Group • Issues and Answers • Albizu University (San Juan)	• Emergency Communications • Recovery of Business • Recovery of Social Functions • Infrastructure Systems

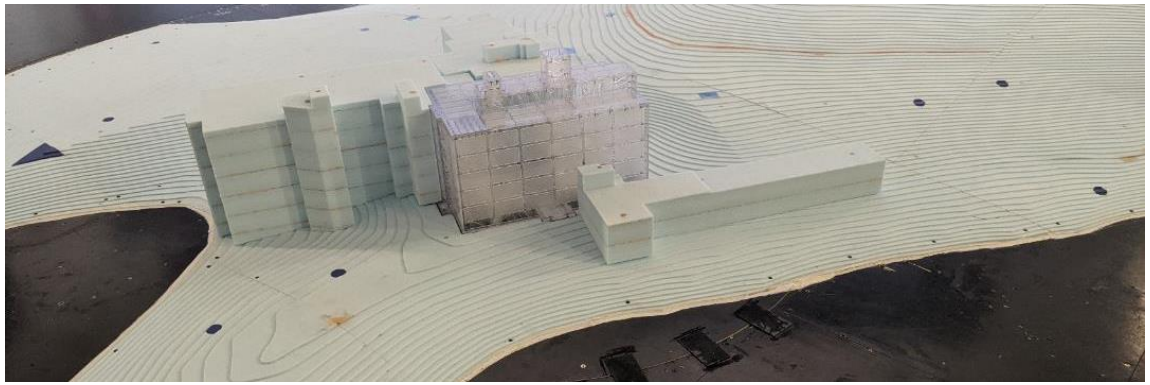
New Contracts

Applied Research Associates: Additional tasks (building on previous contract) to support:

- development of final HM wind-field model, including documentation of total uncertainty in wind speeds,
- analysis of wind loads on two hospital buildings tested in the UF wind tunnel, and
- development of wind-field model for Hurricane Fiona.

WeatherFlow: Continuation of data collection and system maintenance for a 3rd year of wind measurements at the three cell tower sites





Credit for aerial imagery: Google, Maxar Technologies, CNES / Airbus, Landsat / Copernicus

Contract Modification: *Social Science Data Collection*

Horsley Witten Group, Inc., along with subcontractors Eastern Research Group, Issues & Answers, and Albizu University in Puerto Rico

- Function: Support the Hurricane Maria Program social science survey and interview data collection needs
- Awarded: December 2019
- Latest Modification: September 2023

- Added support from contract team during report review period

- Added new geospatial work to link hazard exposure data to survey data

- Extended period of performance

Analysis Updates

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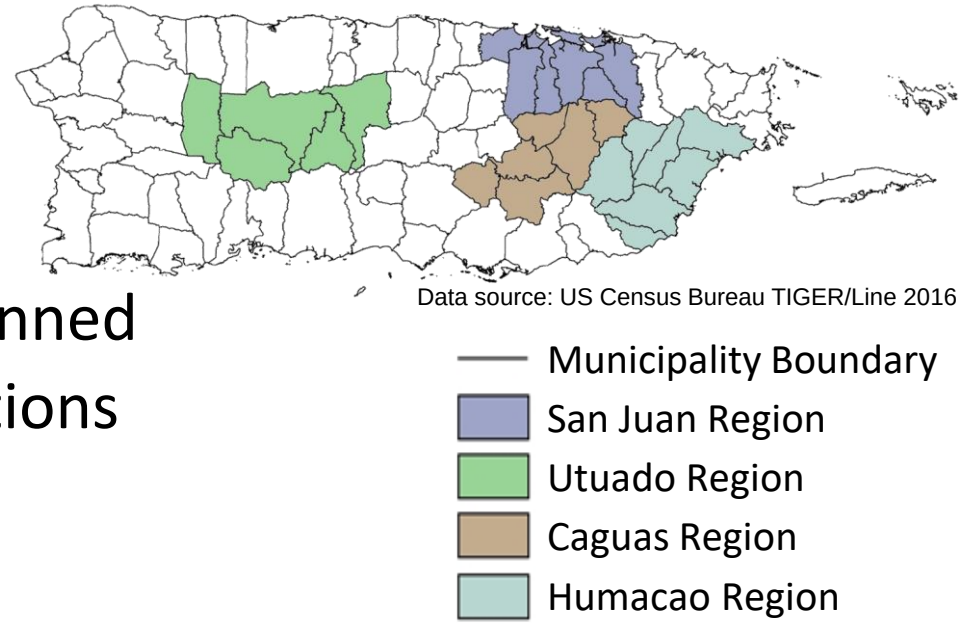
Geospatial Analysis Planning & Coordination

GIS leads are working with Project Leaders to document and coordinate geospatial analysis plans across projects, including:

- Geospatial data being generated
- Variables of interest for analysis
- Required spatial and temporal resolution
- Questions of interest and geospatial analyses planned
- Map products required for reports and presentations



Outcomes of this process

- Identification and prioritization of opportunities for cross-project analyses
- Plan and timeline for geospatial analyses and map development

Representation of Hazard Exposure

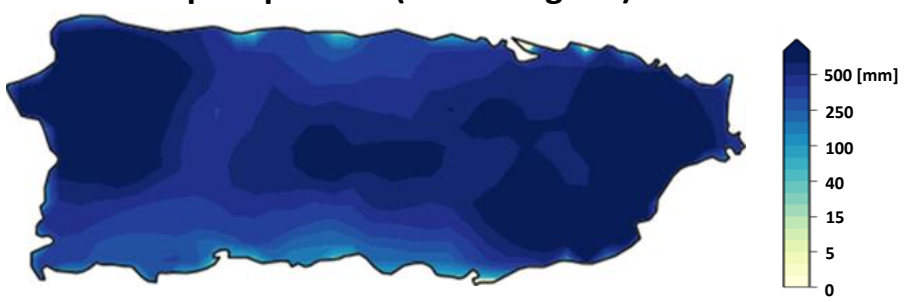
Key priority identified from cross-project geospatial coordination:

Selection of suitable datasets to represent hazard exposure for each project

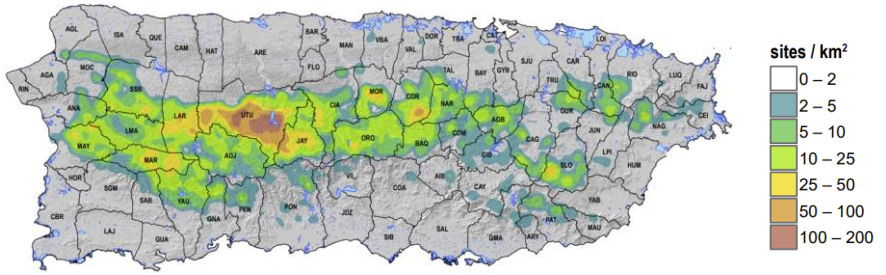
Suitable representation of hazard exposure depends on factors such as:

- spatial resolution of analysis (e.g., municipality, census tract, or GPS coordinates),
- temporal resolution of analysis (e.g., storm total rainfall or variation of rainfall rate over time), and
- questions being addressed by the analysis (e.g., building performance, evacuation decisions).

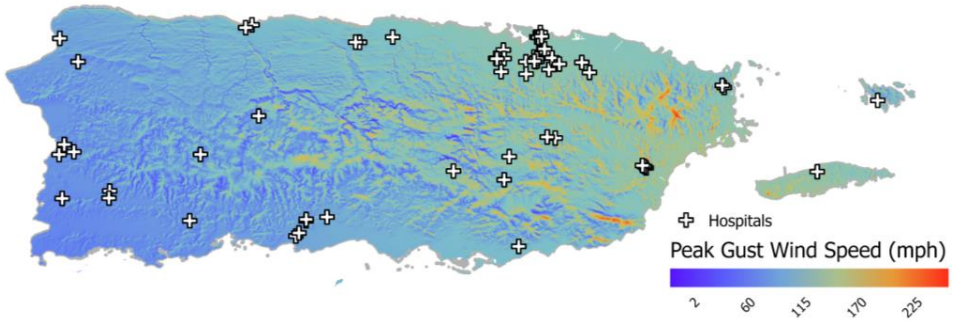
Total precipitation (NCEP Stage IV)



Landslide density (USGS)



Wind field model: peak gust speed with topographic effects (NIST)



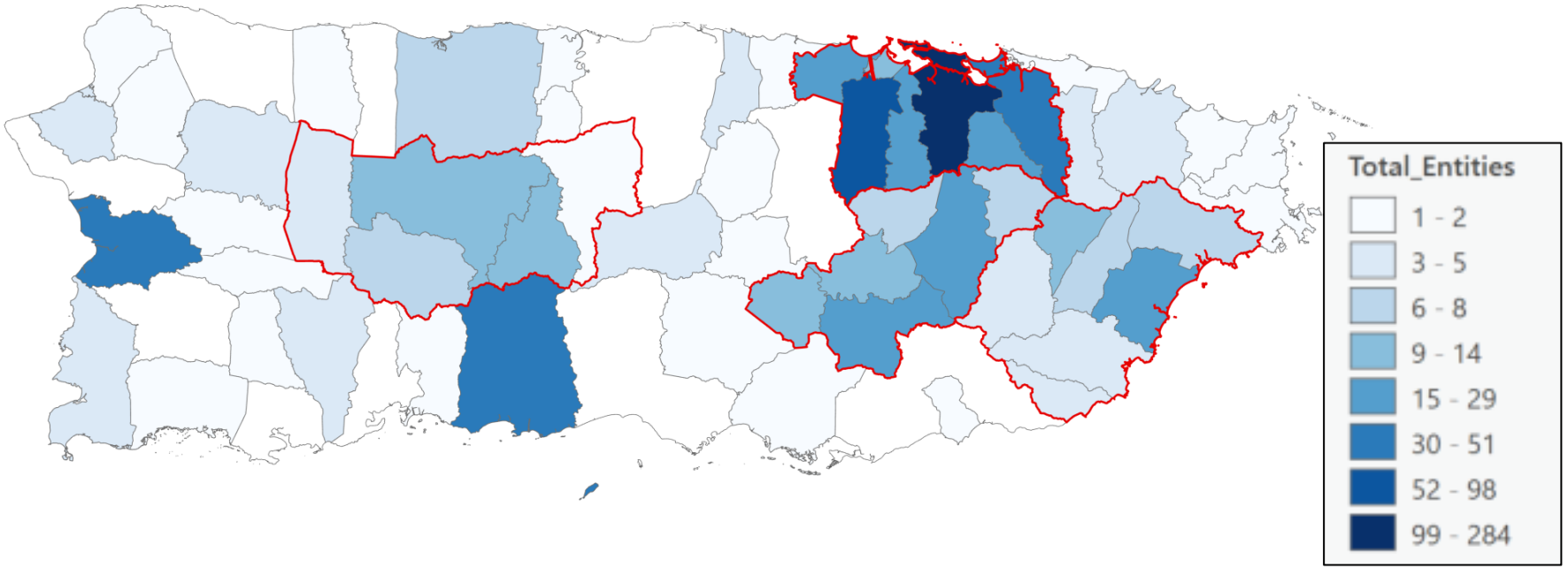
Hazard Exposure and Building Performance

Key priority identified from cross-project geospatial coordination:

Need to link the best available hazard data to the precise locations of schools, hospitals, and businesses in the sample.

The Horsley Witten contract modification will allow this link to be made, to inform a broader understanding of building impacts and performance across Puerto Rico while maintaining NIST's plan to analyze deidentified data.

Distribution and concentration of schools, hospitals, and businesses that responded to a survey for the Recovery of Social Functions Project or the Recovery of Business and Supply Chain Project shown at right; NIST Study Regions shown in red. (Data Source: NIST)



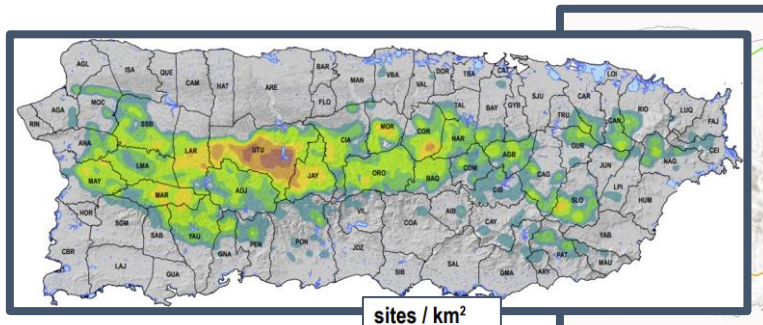
Further Analysis of Integrated Mortality Database

Key priority identified from cross-project geospatial coordination:

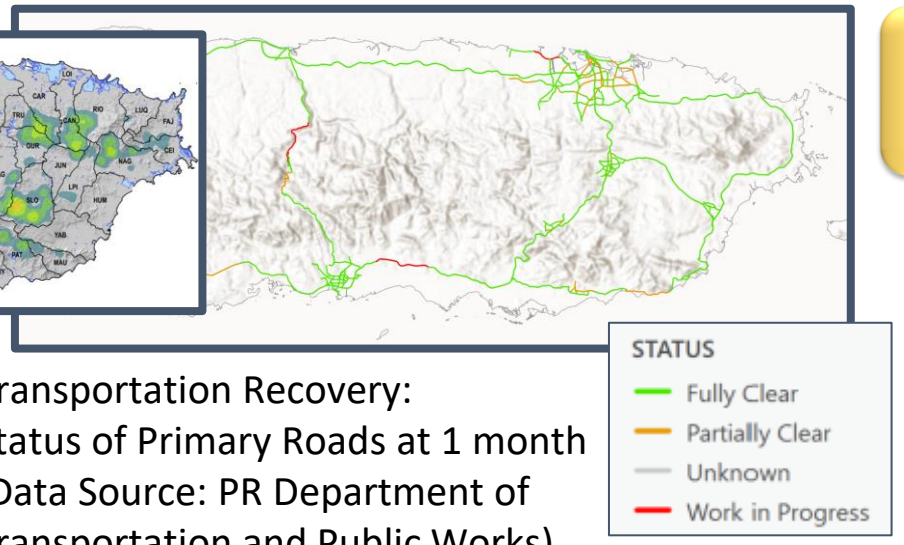
Further analysis of integrated mortality database to identify patterns between where deaths occurred and additional information obtained by other projects

Relevant information from other projects includes:

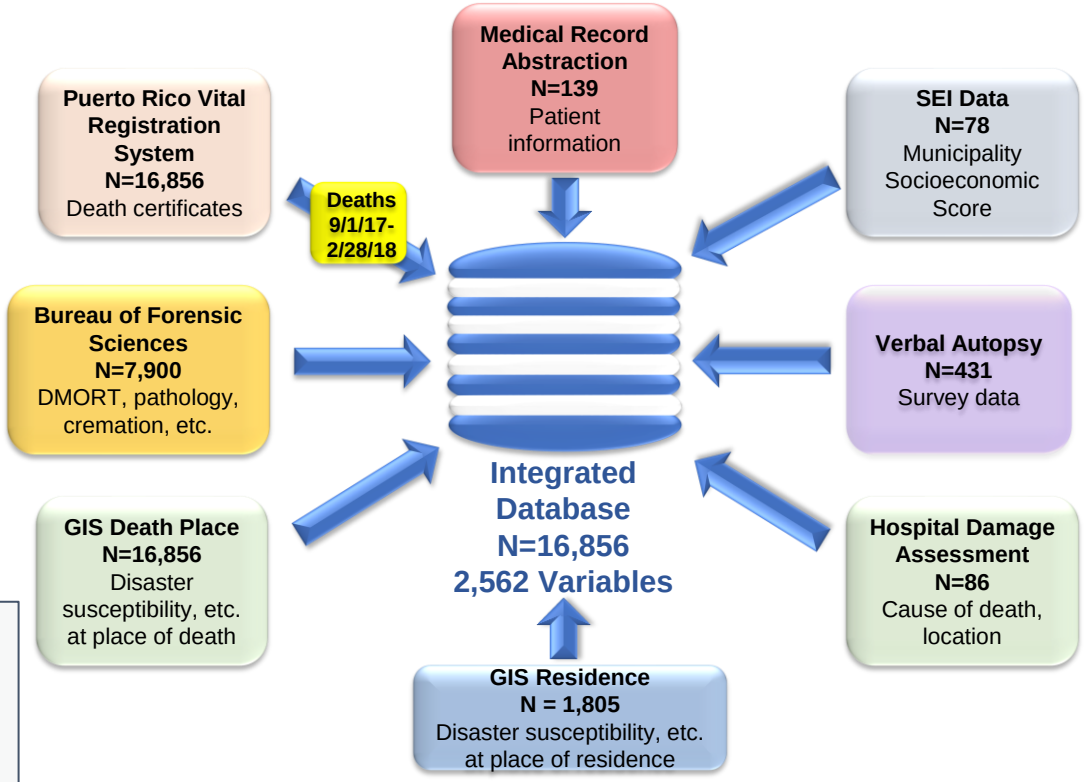
- hazard exposure
- impacts to transportation networks
- household decisions related to evacuation



Hazard Exposure:
Landslide density
(Map Source: USGS)



Transportation Recovery:
Status of Primary Roads at 1 month
(Data Source: PR Department of Transportation and Public Works)



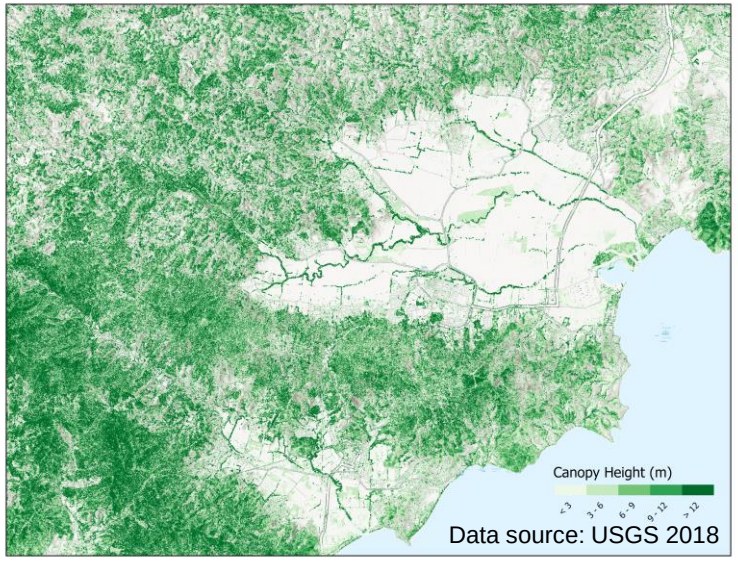
Tree Canopy Analysis from Lidar Data

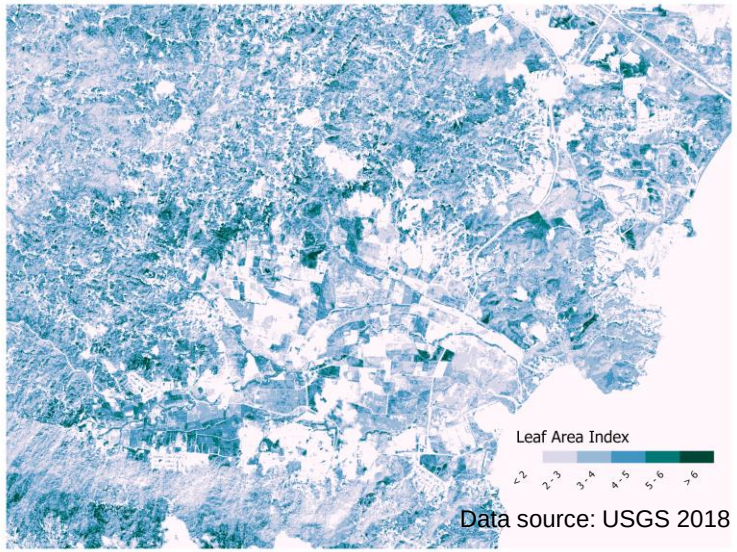
Key priority identified from cross-project geospatial coordination:

Quantitative characterization of tree canopy from available Lidar data sets at different points in time

A data processing model has been developed for evaluation of ***Canopy Height*** and ***Leaf Area Index*** from Lidar data:

- Provides input data for modeling tree canopy in Computational Fluid Dynamics simulations of wind flow over complex terrain
- Allows for consistent modeling of tree canopy from different points in time, before and after Hurricane Maria





Statistical Analysis Support

Uncertainty

Goal: to determine the degree of confidence in the output of an analysis or model

Weighting

Goal: to improve the accuracy of survey estimates

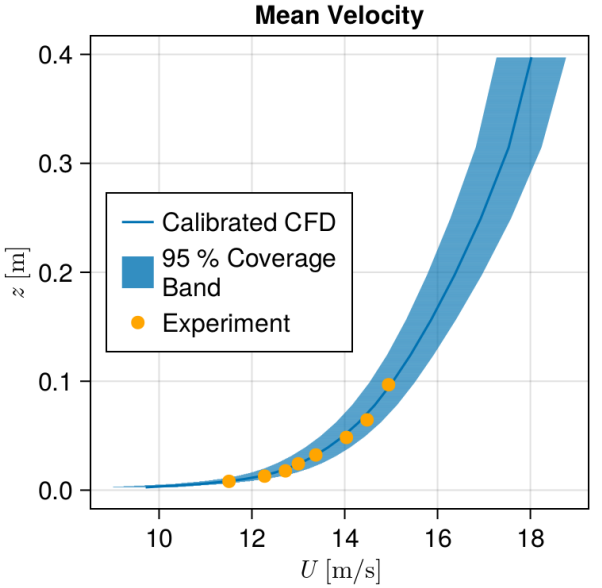
Imputation

Goal: to fill in missing data and therefore, to retain as many cases as possible during analysis

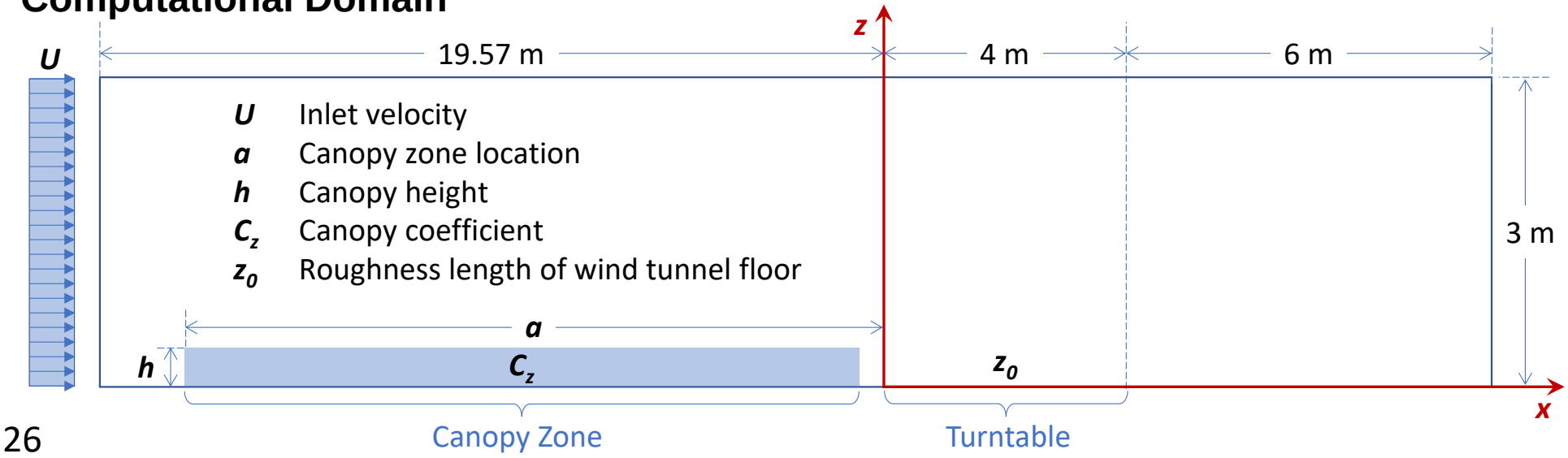
The Statistical Engineering Division is supporting the Hurricane Maria Team through engagement in analysis plans, review of data and results, and expert input.

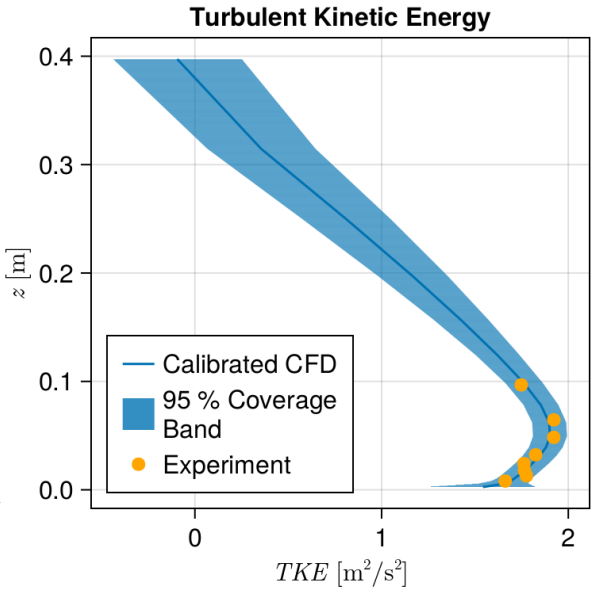
Uncertainty Quantification for CFD Models

- Gaussian Process (GP) emulator developed for Computational Fluid Dynamics (CFD) model with 5 varying inputs (50 CFD runs)
- Emulator used to optimize the 5 inputs to the experimental data
- CFD model calibrated to the experimental data using a second GP
- Sources of uncertainty accounted for:
  - Emulation of the CFD model
  - Estimation of calibration function from finite data
  - Experimental noise (deviations from a smooth function)



Computational Domain

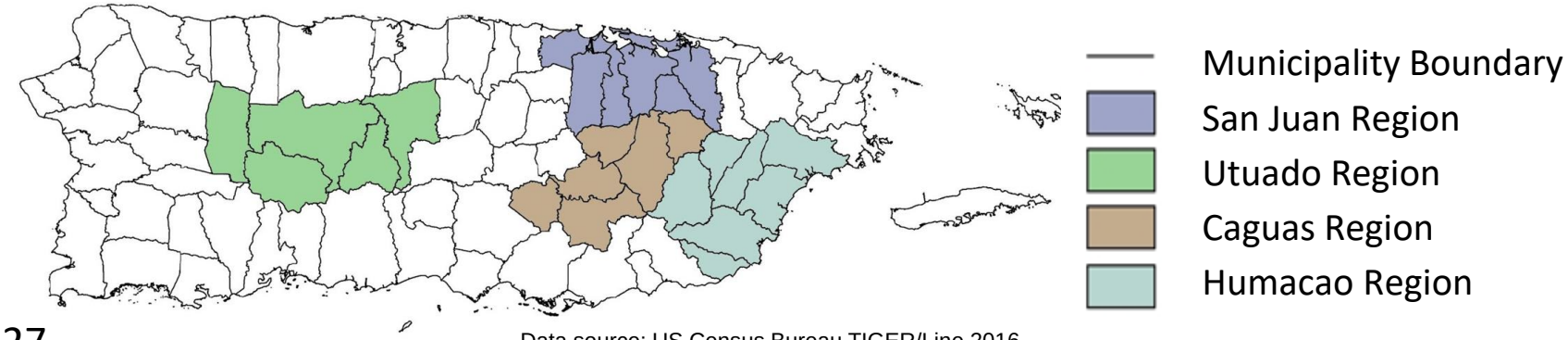




Sample Weighting for Surveys

Weighting procedures being developed for the Emergency Communications Survey of Households

- Households responded across 4 study regions
- Over 1500 households surveyed
- Survey response rate is 26.6%
- Responses provide detailed information on:
  - Receipt of emergency communications
  - Evacuation behavior and decision-making



Data source: US Census Bureau TIGER/Line 2016

Sample Weighting for Surveys

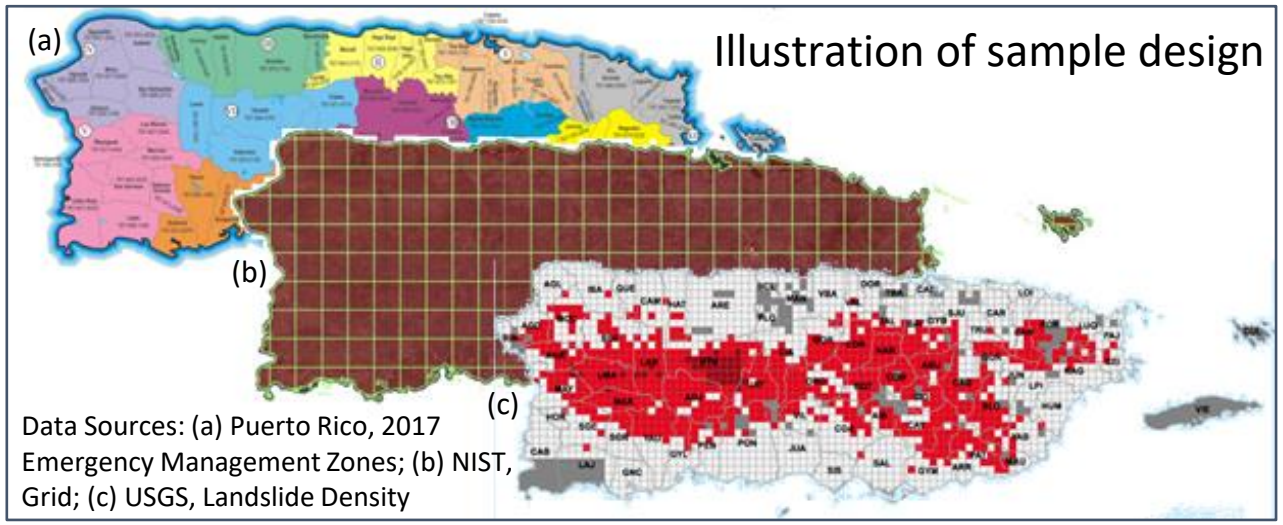
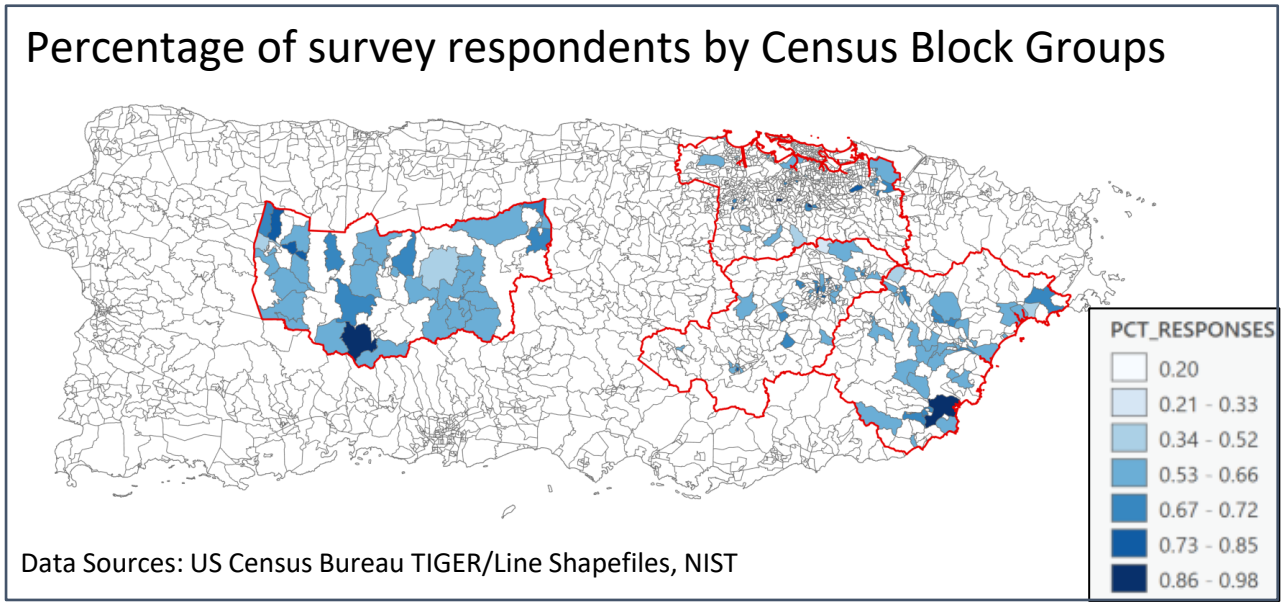


Illustration of sample design

Data Sources: (a) Puerto Rico, 2017 Emergency Management Zones; (b) NIST, Grid; (c) USGS, Landslide Density



- The sample was designed to over-represent areas prone to flooding and landslides and to be representative of socio-economic status across Puerto Rico
- The final survey sample over-represents females and older age groups when compared to the Puerto Rico 2017 population estimates
- To correct for sampling bias, strategies are being considered that weight the sample by key demographics (e.g., adult age; household income; education) and by flood and landslide risk levels

Staffing & Stakeholder Outreach

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Staffing

- **Dr. Thomas Kirsch** reappointed as outside NCST member following retirement from NCDMPH*, now Adjunct Professor of Emergency Medicine in the GWU School of Medicine and Health Sciences.
- **NIST Associates** reappointed under newly awarded Professional Research Experiences Program (PREP), following expiration of previous program on June 30, 2023.
- Additional staffing appointments in process to provide support for data analysis and report writing.


Thomas Kirsch

* National Center for Disaster Medicine and Public Health


Kelly Anderson


Dereka Carroll-Smith

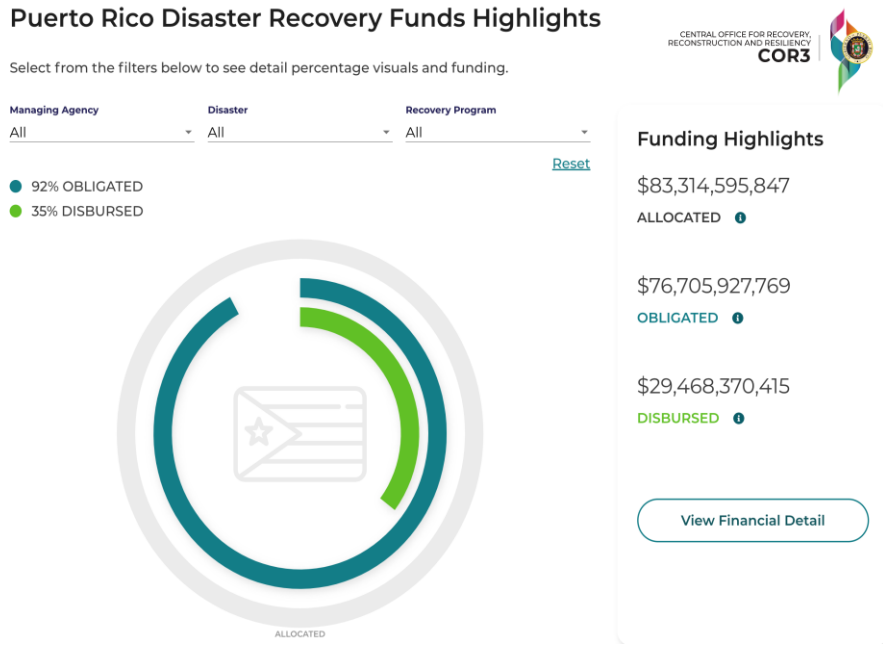

Zeinab Farahmandfar


Yunjae Hwang


Alizabeth Sánchez-López

Stakeholder Outreach

- **September 15, 2023:** Briefing on HM investigation progress for the Seismic Commission of the College of Engineers and Land Surveyors of Puerto Rico (CIAPR)
- Coordinating with Puerto Rico Hospital Association (AHPR) to support increased response rates for ongoing hospital surveys and interviews on recovery of social functions
- **Ongoing:** NIST is engaged in the Fast-Track Action Committee (FTAC) on Data Infrastructure for Puerto Rico, established by the National Science and Technology Council (NSTC). The goal is to "enable data-driven decision-making in the distribution of unprecedented levels of federal funding available in accordance with the President's policies on scientific integrity and evidence-based policymaking…"



Timeline & Next Steps

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Expected Timeline: September 2023 Update

Phase 1
- September 2017: Hurricane Maria occurs
- December 2017: Preliminary reconnaissance
- February 2018: Team established under NCST Act

Phase 2
- May 2018: Initial briefing to NCSTAC on investigation plans
- February 2019 through September 2020: Supporting contracts awarded
- January 2021: Progress report published
- Data collection

Phase 3
- Data analysis
- Development of findings and recommendations

Phase 4
- Draft final report written
- Internal and interagency review
- Draft final report released for public comment

Phase 5
- Final report revised
- Final report and associated data published

September 2023: NCST data collection completed, data analysis well underway

Fall 2024: Data analysis and draft reports complete

Winter 2024/25: Internal review process underway

Next Steps

- Review and acceptance of contract deliverables, including reports and datasets
- Comprehensive analysis of collected data
- Development of draft findings and recommendations
- Completion of draft report volumes by project
- Internal and interagency review

Questions?

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