

# Hurricanes and Health

The association between cardiorespiratory Medicare hospitalizations and tropical cyclones

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# Acknowledgements

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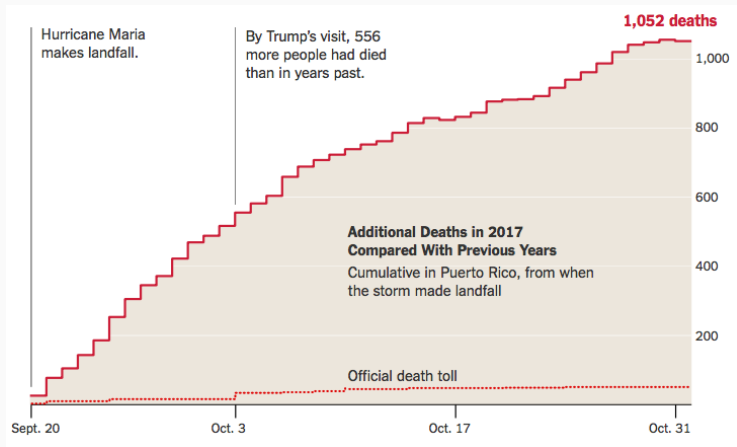
- Steven Quiring

# Motivation

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# Impacts in excess of official death tolls

Evidence from Hurricane Maria in Puerto Rico of extensive mortality impacts.

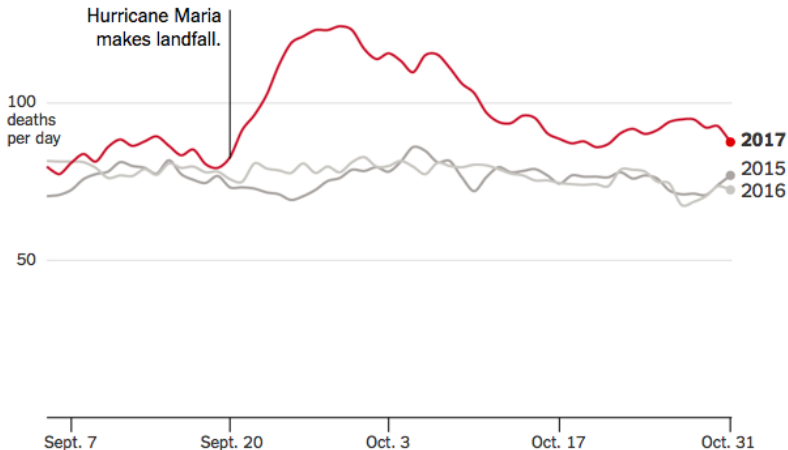


Source: The New York Times

# Impacts in excess of official death tolls

Evidence from Hurricane Maria in Puerto Rico.

**Average Daily Deaths in September and October**

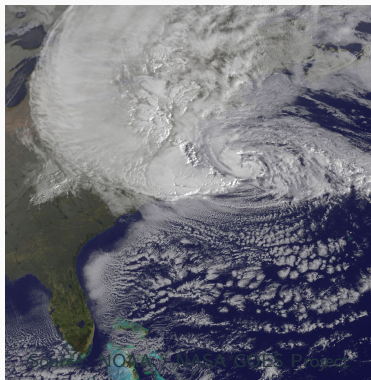


Source: The New York Times

# Health risks associated with Hurricane Sandy (2012)

## Health risks in storm-affected areas

- Change in patterns of emergency department visits (Kim et al. 2016)
- Increased outpatient cases of food and waterborne disease among elderly (Bloom et al. 2016)
- Increased rate of myocardial infarctions (Swerdel et al. 2014)
- Increased hospitalizations for dehydration (Lee et al. 2016)
- Difficulty obtaining medical care, medications, and medical equipment (Davidow et al. 2016)



# Study goals

- Investigate how cardiorespiratory Medicare hospitalization risks change during severe tropical cyclone exposures
- Quantify the association between tropical cyclone exposure and cardiorespiratory Medicare hospitalization risks within a large set of exposures and counties
- Explore the temporal pattern in risks in the days surrounding the storm
- Investigate how estimated associations change with changing definitions of tropical cyclone exposure

## Methods and Results

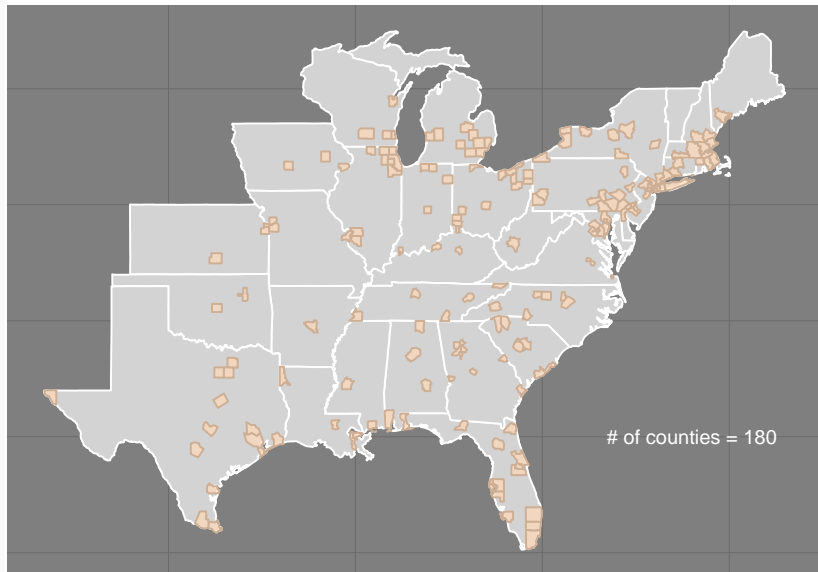
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# All study storms and counties

Counties considered in our study

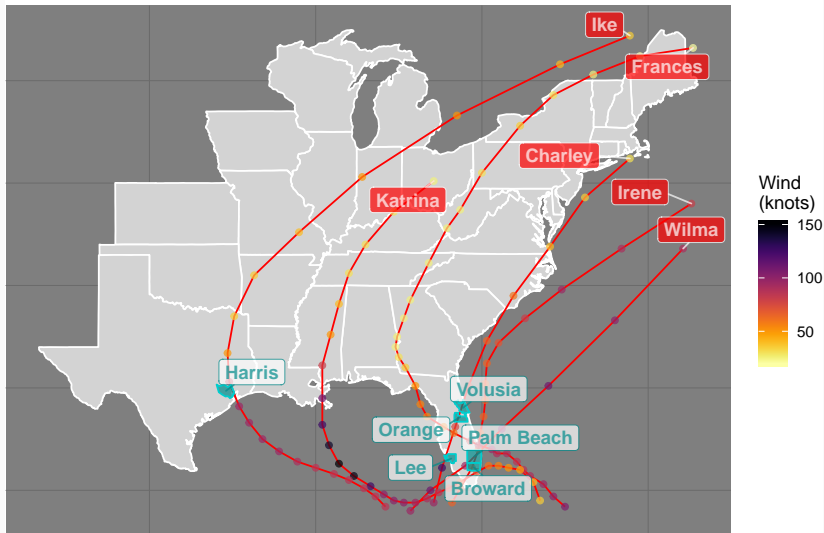
Data from the Medicare Cohort Air Pollution Study (MCAPS)



# Top 10 wind-based exposures in our study

Storms and counties for top 10 wind-based exposures

Color of points corresponds to storm's maximum 1-minute sustained surface winds



# Potential for seasonal confounding

It is important to control for potential seasonal confounding because:

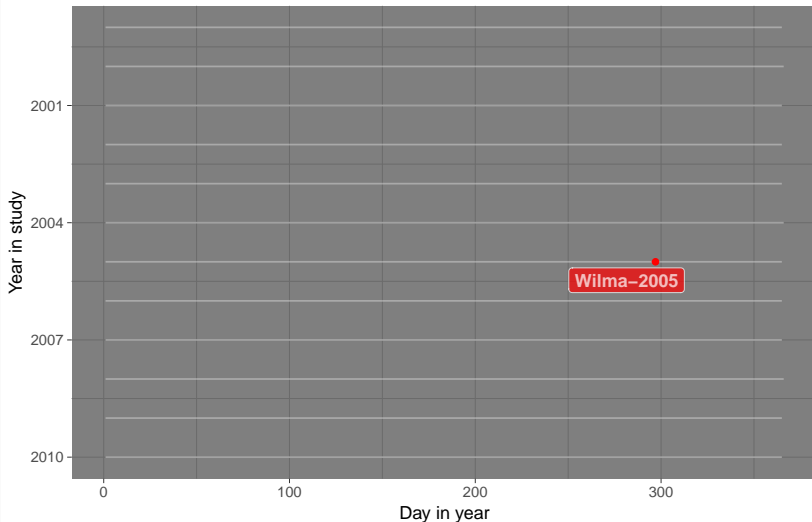
- There are strong seasonal patterns in many **health outcomes**
- There are strong seasonal patterns in **tropical cyclone exposures**

Given this potential for seasonal confounding, we used **a matched analysis** to ensure that the seasonal distribution was similar for exposed and unexposed days, matching across years within a community.

# Selecting matched unexposed days

## 1. Identify the day-of-year of the storm

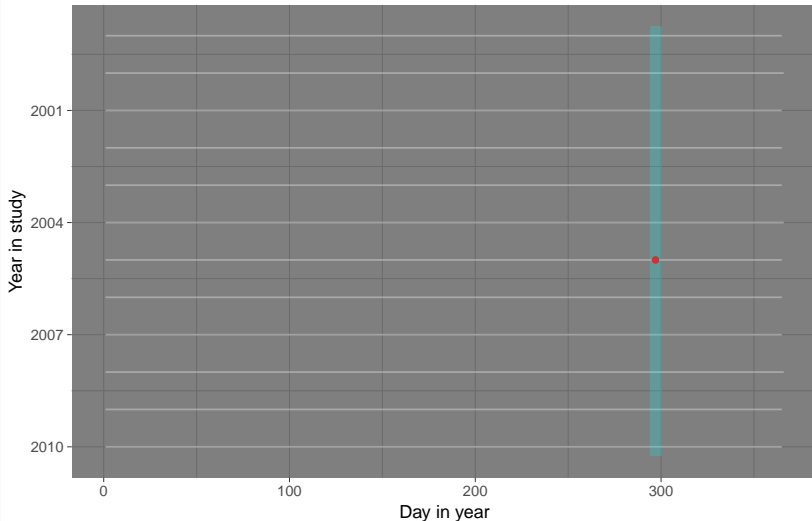
Example for Hurricane Wilma in Palm Beach County, FL



# Selecting matched unexposed days

2. Create a seven-day window centered on the storm's day-of-year

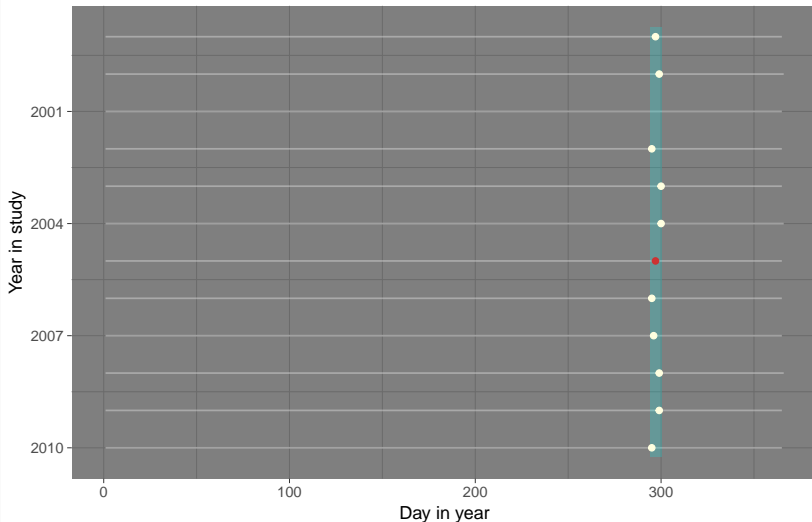
Example for Hurricane Wilma in Palm Beach County, FL



# Selecting matched unexposed days

3. Randomly pick ten unexposed days from other years within window

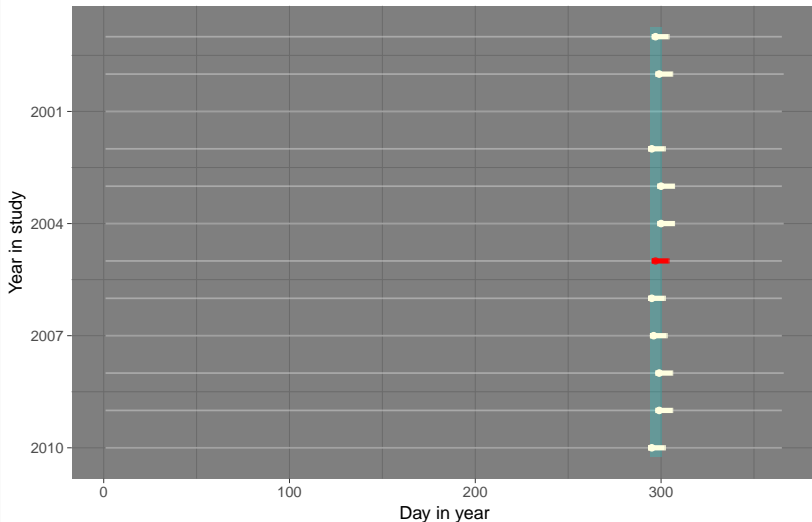
Example for Hurricane Wilma in Palm Beach County, FL



# Selecting matched unexposed days

4. Determine the number of hospitalizations for a period around each day

Example for Hurricane Wilma in Palm Beach County, FL



# Estimating tropical cyclone-hospitalization associations

We then used this matched data to fit a generalized linear model of hospitalization rates in association with tropical cyclone exposure:

$$\log[E(Y_T)] = \log(n_T) + \alpha + \beta x_T + \delta Z_T$$

where:

- $Y_T$  is the total count of hospital admissions in the 10-day period  $T$
- $n_T$  is an offset for the number of unhospitalized Medicare beneficiaries in the county in period  $T$
- $\alpha$  is the model intercept
- $x_T$  is an indicator variable for storm exposure, with associated coefficient  $\beta$
- $Z_T$  is the year of period  $T$ , fit as a linear term and with associated coefficient  $\delta$



# Respiratory hospitalizations

Respiratory hospitalization risks during the top 10 wind-based storm exposures compared to matched unexposed days

Tropical cyclone	County	Wind <sup>a</sup>	Percent increase <sup>b</sup>
Wilma (2005)	Palm Beach County, FL	52	38 (-3, 95)
Charley (2004)	Lee County, FL	45	25 (-10, 73)
Charley (2004)	Orange County, FL	41	44 (4, 99)
Ike (2008)	Harris County, TX	39	44 (25, 65)
Charley (2004)	Volusia County, FL	37	8 (-15, 38)
Wilma (2005)	Broward County, FL	37	66 (36, 104)
Katrina (2005)	Broward County, FL	34	36 (19, 57)
Frances (2004)	Palm Beach County, FL	33	35 (15, 59)
Irene (1999)	Broward County, FL	33	10 (-14, 41)
Irene (1999)	Palm Beach County, FL	33	40 (-3, 100)

<sup>a</sup> Modeled maximum sustained surface wind (m/s) at county center

<sup>b</sup> Percent increase in hospitalizations compared to matched unexposed days

# Cardiovascular hospitalizations

Cardiovascular hospitalization risks during the top 10 wind-based storm exposures compared to matched unexposed days

Tropical cyclone	County	Wind <sup>a</sup>	Percent increase <sup>b</sup>
Wilma (2005)	Palm Beach County, FL	52	-1 (-16, 17)
Charley (2004)	Lee County, FL	45	7 (-6, 21)
Charley (2004)	Orange County, FL	41	20 (2, 41)
Ike (2008)	Harris County, TX	39	-7 (-22, 10)
Charley (2004)	Volusia County, FL	37	23 (-5, 60)
Wilma (2005)	Broward County, FL	37	0 (-15, 18)
Katrina (2005)	Broward County, FL	34	15 (9, 21)
Frances (2004)	Palm Beach County, FL	33	8 (-8, 26)
Irene (1999)	Broward County, FL	33	-11 (-27, 9)
Irene (1999)	Palm Beach County, FL	33	-14 (-30, 7)

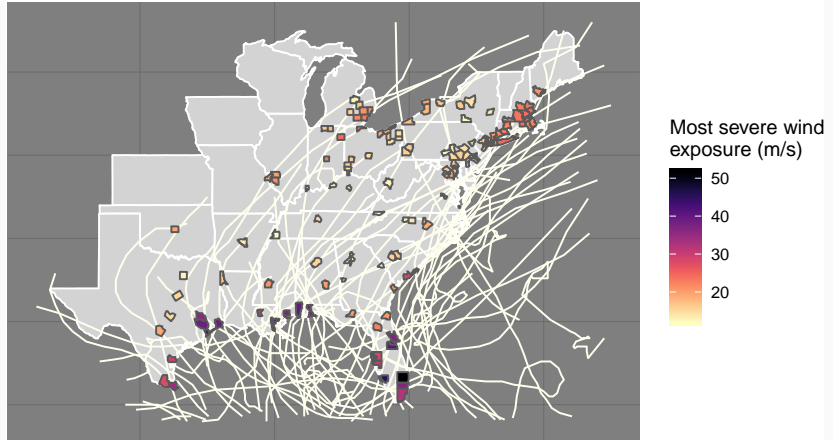
<sup>a</sup> Modeled maximum sustained surface wind (m/s) at county center

<sup>b</sup> Percent increase in hospitalizations compared to matched unexposed days

# Wind-based exposures in study counties

All tropical cyclone wind exposures

Counties and storms with at least one exposure of 21 m/s or higher



# Estimating tropical cyclone-hospitalization associations

We then used this matched data to fit a generalized linear mixed-effect model of hospitalization rates in association with tropical cyclone exposure:

$$\log[E(Y_t^c)] = \log(n_t^c) + \alpha + \alpha_c + \sum_{l=-2}^7 \beta_l x_{t-l}^c + \delta Z_t + \gamma D_t$$

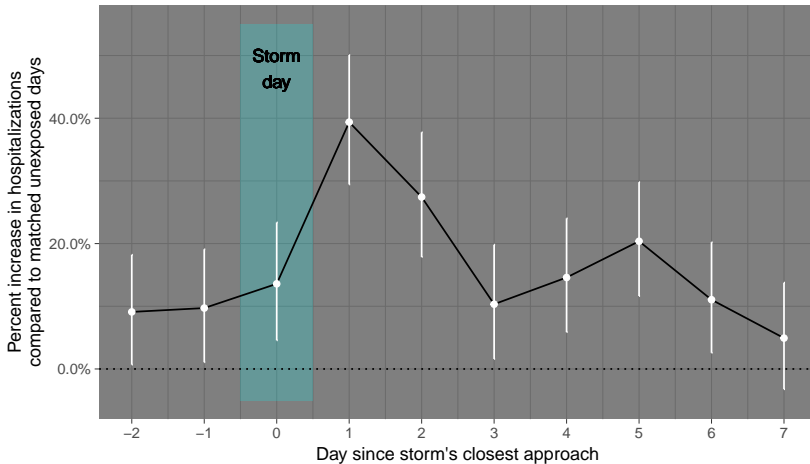
where:

- $Y_t$  is the total count of hospital admissions on day  $t$  in community  $c$
- $n_t^c$  is an offset for the number of unhospitalized Medicare beneficiaries in the county on day  $t$  in community  $c$
- $\alpha$  is the model intercept
- $\alpha_c$  is a random effect for study county
- $x_{t-l}$  is an indicator variable for storm exposure, with associated lag-specific coefficients  $\beta_l$
- $Z_t$  is the year of day  $t$ , fit as a factor and with associated coefficient  $\delta$
- $D_t$  is the day of week of day  $t$ , with associated coefficient  $\gamma$

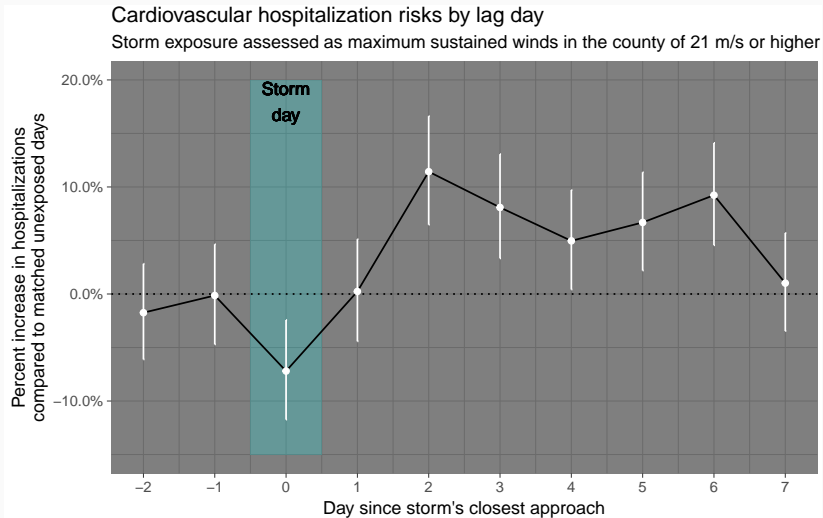
# Hospitalization risks by lag day

## Respiratory hospitalization risks by lag day

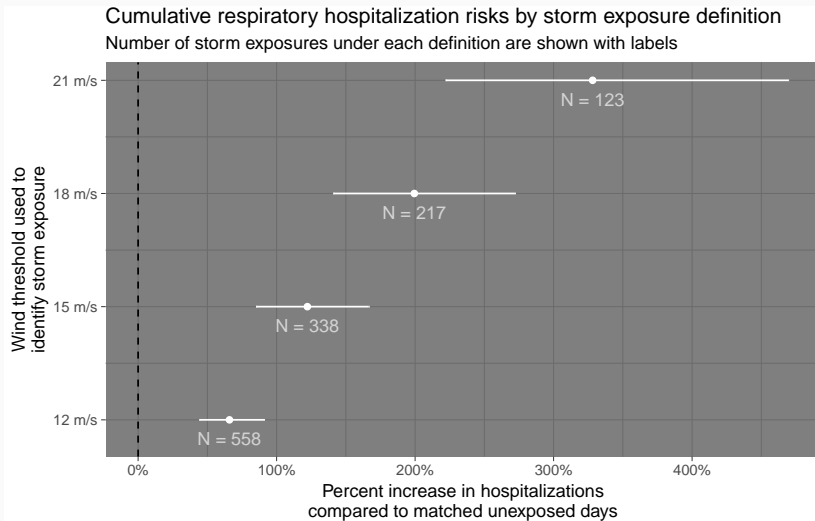
Storm exposure assessed as maximum sustained winds in the county of 21 m/s or higher



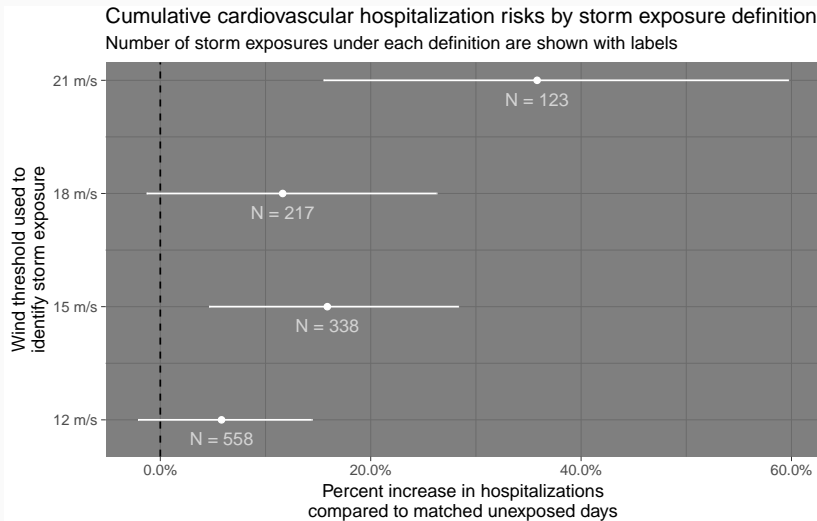
# Hospitalization risks by lag day



# Cumulative risks by storm exposure threshold



# Cumulative risks by storm exposure threshold





## Discussion

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# Tropical cyclones under climate change



National Oceanic and  
Atmospheric Administration  
U.S. Department of Commerce

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## Study: Climate warming to boost major hurricanes in active Atlantic seasons

Research | hurricanes measuring and modeling climate research

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Based on recent research, climate change is likely to increase the number of major hurricanes in active hurricane seasons

# Understanding variation across storms in health effects

Tropical Storm Allison (2001) caused extensive flooding in Houston, TX



*Source: National Oceanic and Atmospheric Administration*

## LETTER

### Quantitative attribution of climate effects on Hurricane Harvey's extreme rainfall in Texas

S-Y Simon Wang<sup>1,2</sup>, Lin Zhao<sup>3</sup>, Jin-Ho Yoon<sup>4,6</sup> , Phil Klotzbach<sup>5</sup> and Robert R Gillies<sup>1,2</sup>

### Increased threat of tropical cyclones and coastal flooding to New York City during the anthropogenic era

Andra J. Reed<sup>a,1</sup>, Michael E. Mann<sup>a,b</sup>, Kerry A. Emanuel<sup>c</sup>, Ning Lin<sup>d</sup>, Benjamin P. Horton<sup>a,f</sup>, Andrew C. Kemp<sup>g</sup>, and Jeffrey P. Donnelly<sup>h</sup>

## HURRICANE SANDY BEFORE 1900 AND AFTER 2100

BY GARY M. LACKMANN

# Climate attribution studies

Past, present, and future **intensities** for Hurricane Sandy from an attribution study

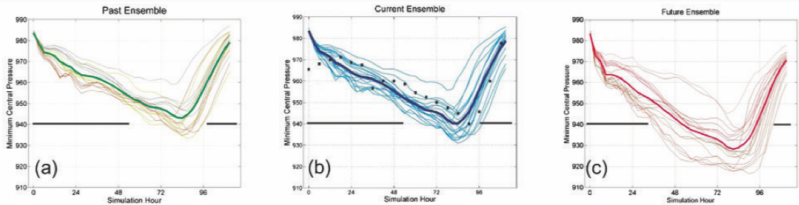


FIG. 7. Time series showing ensemble intensity plots for (a) past, (b) current, and (c) future simulations. Enhanced horizontal line corresponds to landfall intensity of 940 hPa.

Source: Lackmann 2015, BAMS

# Climate attribution studies

Past, present, and future **paths** for Hurricane Sandy from an attribution study

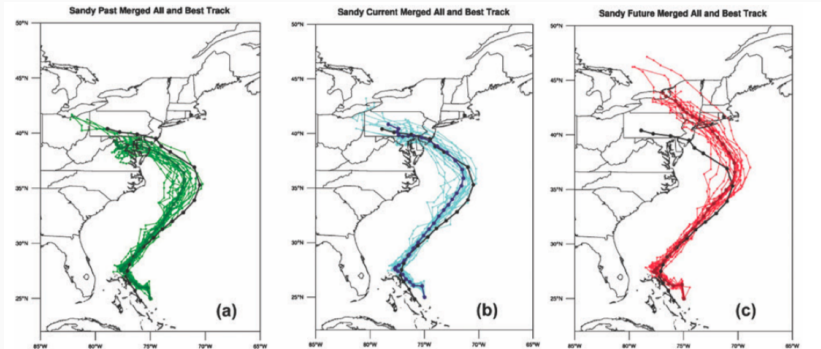
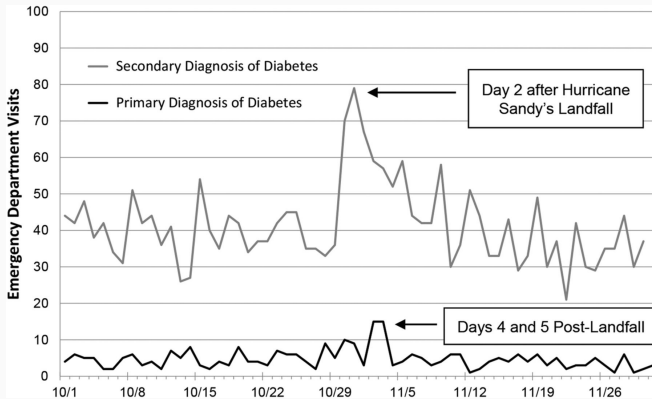


FIG. 5. Track ensembles for (a) past, (b) current, and (c) future paths of Hurricane Sandy, derived from 6-day WRF simulations initialized 0000 UTC 26 Oct. The black line represents the National Hurricane Center best track; lighter colored lines represent ensemble members, and darker colored lines represent ensemble means for past (green), current (blue), and future (red).

Source: Lackmann 2015, BAMS

# Delayed association with morbidity outcomes

Example of another study that found the largest association between tropical cyclone exposure and morbidity outcomes (emergency department visits among patients with diabetes)



Source: Lee et al. 2016, *BMJ Open Diabetes Research and Care*.

## Other related research in our lab

We have a number of related research projects ongoing in our lab:

- Estimating associations between tropical cyclone exposures and human mortality risks (all-cause, cardiovascular, respiratory, accidental)
- Exploring how the associations between tropical cyclone exposure and health outcomes change across definitions of tropical cyclone exposure
- Enabling access to county-level tropical cyclone exposure data for multiple storm hazards (wind, rain, floods, tornadoes)
- Developing methods for epidemiological research on climate-related disasters
- Quantifying health-related risks for other climate-related disasters, especially extreme temperatures and heat waves



# Questions?



*"Remember that hurricane a thousand miles away? That was me!"*