Assessing Exposure to Tropical Cyclones for Epidemiological Research

Existing Approaches and Future Needs

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Workshop motivation

Package: `hurricaneexposure`: Explore and Map County-Level Hurricane Exposure in the United States. On CRAN.

NIEHS K99/R00: Investigating Health Effects of Climate-Related Disasters in the United States

NSF Coastlines and People EAGER: Establishing Interface Standards for Physical Exposure and Human Impacts Data Collection and Publication in Rapid Response to Coastal Hazards

Workshop format

- Live (microphones on) participants
- Other participants—please write your questions and comments in the Q&A

Survey for epidemiology workshop on assessing exposure to tropical cyclones

This survey will be used to inform and drive our discussion for the workshop on "Assessing Exposure to Tropical Cyclones for Epidemiological Research: Existing Resources and Future Needs" at the 32nd Annual Conference of the International Society for Environmental Epidemiology.

Tell us about your approaches and challenges in assessing exposure to tropical cyclones:

https://forms.gle/bCRnDnMTKKyufj9M8

If you would like a copy of the slides, visit:

https://github.com/geanders/GuestLectures/blob/master/isee_2020_workshop/workshop_august_26_2020.pdf

Survey overview

Survey overview

Respondents: Twelve

Papers: 1 published, 3 submitted/under review, 2 in preparation

Tropical cyclones and risk of preterm birth: A retrospective analysis of 20 million births across 378 US counties

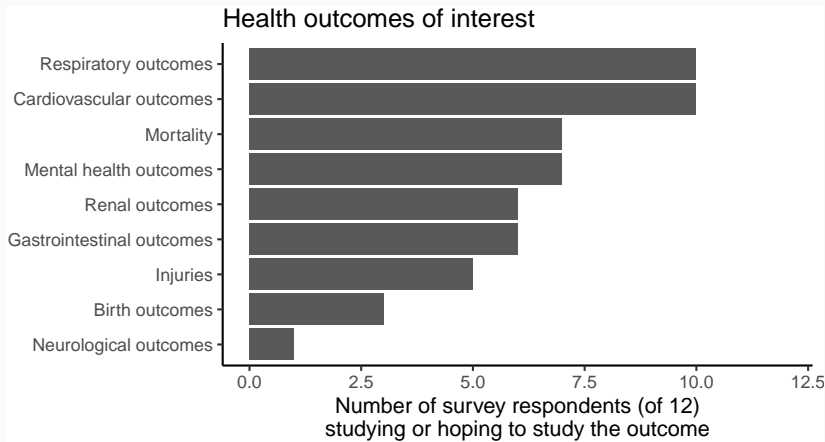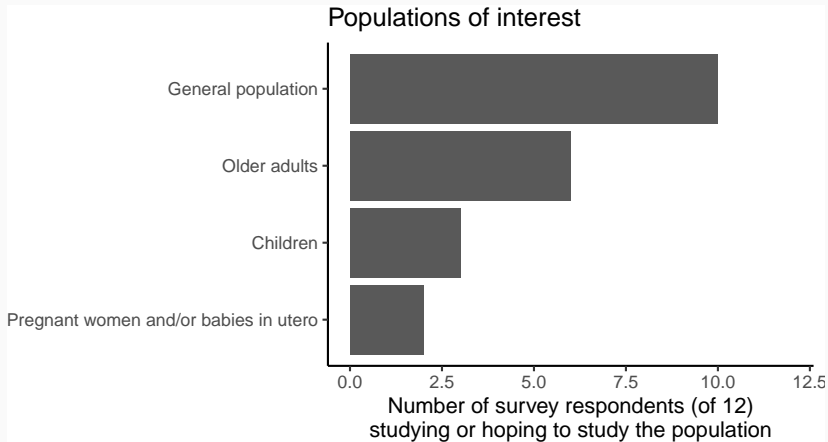Shengzhi Sun [1], Kate R Weinberger [2], Meilin Yan [3], G Brooke Anderson [4], Gregory A Wellenius [5]

Health outcomes of interest

Populations of interest

Survey overview

Survey overview

Georgraphic study areas
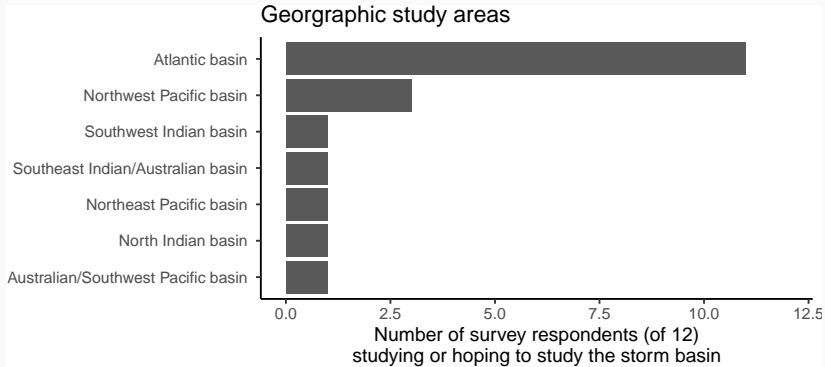
Number of survey respondents (of 12)
studying or hoping to study the storm basin
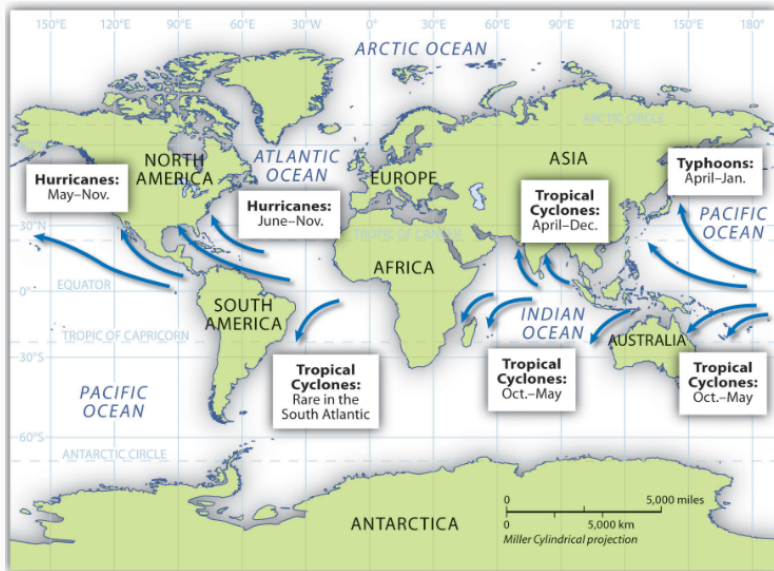
Survey overview

Areas studied:

- New York City
- over 100 counties in Texas
- North Carolina
- Florida
- Southeastern US
- Eastern half of US
- All counties in contiguous US
- China
- Coastal jurisdictions globally

Primary versus secondary exposure data

I am collecting at least some of the exposure data myself

I am relying entirely on secondary data to measure exposure to physical hazards of the storm (for example, data shared by national weather agencies)
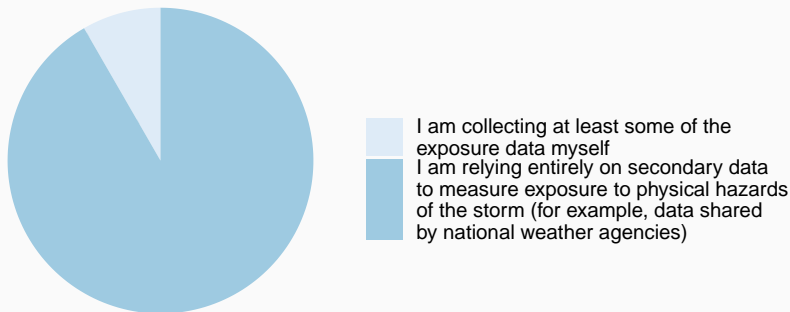
Physical hazards

Physical hazards

HAZARDS SUMMARY
HURRICANE FLORENCE
September 11, 2018 – 8AM

HAZARD	DETAILS	IMPACTS	THREAT
Storm Surge	S of Cape Fear: 4-6' Cape Fear-Cape Lookout: 6-12' (Neuse & Pamlico Rivers) Cape Lookout-Ocracoke Inlet: 5-8' N of Ocracoke Inlet: 3-5'	Very dangerous inundation amounts are expected along the NC coast Thu-Sat.	**Extreme**
Inland Flooding	Portions of Eastern NC: 15-20+" Central/Eastern: 6-15" (Up to 30" along track)	Sig. threat to life and property; impassable roads; road wash-outs. Heavy rain will begin Thu and could continue through the weekend. Longer-term river flooding likely, and mountain landslides possible.	**Extreme**
Damaging Winds	Hurricane-Force winds are likely near the coast Tropical Storm-Force winds likely across much of state	Significant downed trees and widespread/prolonged power outages across the state; significant structure damage possible as Florence could make landfall as a Category 4 hurricane.	**Extreme**
Tornadoes	A few tornadoes are possible Thu and Fri, especially across eastern NC. Tornadoes in tropical systems are typically short-lived and weak.		**Moderate**
Marine & Coastal	Life-threatening surf and rip currents will continue for much of the week.		**Extreme**

Threat Levels:	None	Low	Moderate	High	Extreme

12

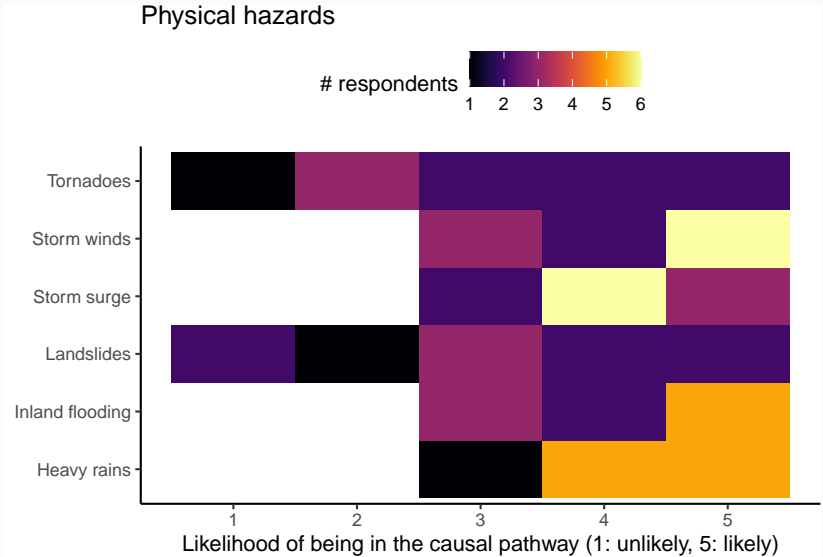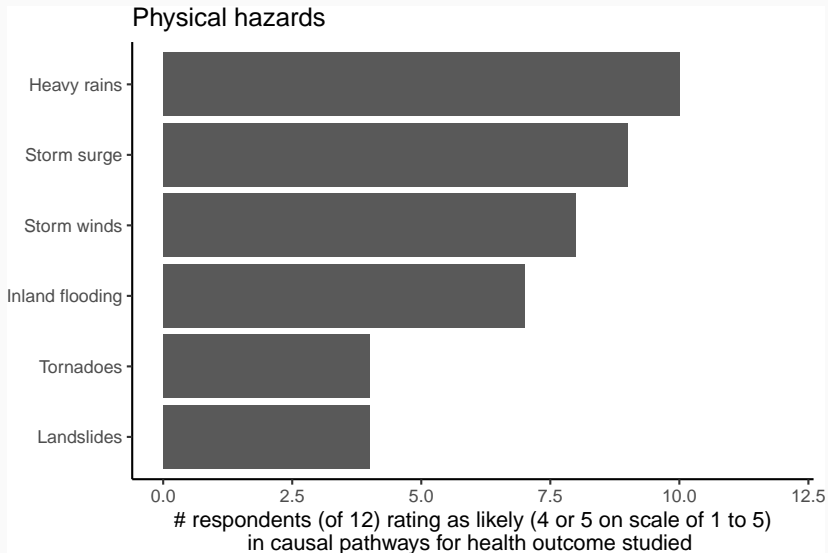**Survey question:**

"Rate each physical hazard terms of how likely you think they are to be in the causal pathway linking tropical cyclones exposure to a change in the risk of the health outcome you are studying."

Physical hazards

Physical hazards

respondents

1 2 3 4 5 6

Likelihood of being in the causal pathway (1: unlikely, 5: likely)

Physical hazards

Physical hazards

respondents (of 12) rating as likely (4 or 5 on scale of 1 to 5)
in causal pathways for health outcome studied
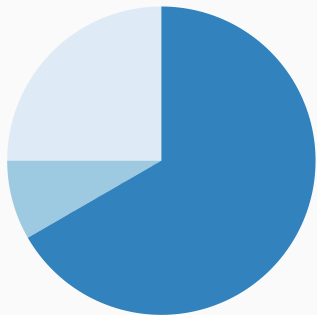
Physical hazards

Are there any other physical hazards from the storm that you think are plausibly in the causal pathway for your study?

*"This is pretty speculative, but I've wondered whether **changes in atmospheric pressure** play a role"*

Continuous versus binary exposure assessment

Continuous versus binary exposure assessment

I typically use a process that uses an even mix of exposure classification and exposure measurement

I typically use continuous exposure measurement (estimate, for each person or individual, a quantitative value capturing the intensity or severity of the exposure).

I typically use exposure classification (classify locations or people as "exposed" or "unexposed").

Continuous versus binary exposure assessment

"If a dose-response is seen, it is more likely that the association is causal."

–Sir Austin Bradford Hill
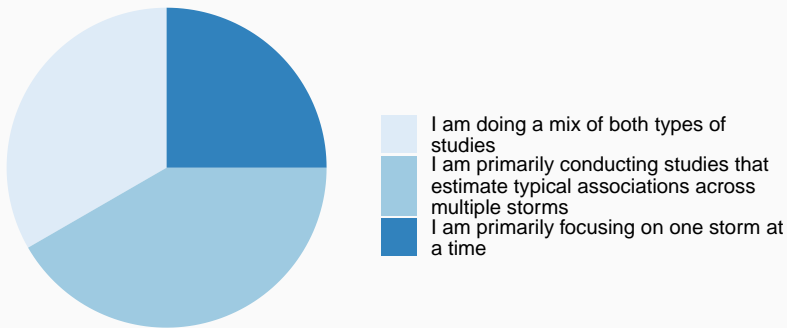
Continuous versus binary exposure assessment

Survey question: What are the biggest challenges or limitations you have faced in conducting or planning a tropical cyclone epidemiology study?

*"It is hard to define the appropriate spatial scale in assessing tropical cyclone exposure and further in **examining the exposure-outcome association.**"*

Single-storm versus multi-storm studies

Single−storm or multi−storm studies

I am doing a mix of both types of studies

I am primarily conducting studies that estimate typical associations across multiple storms

I am primarily focusing on one storm at a time

Challenges for single-storm versus multi-storm studies

Single storms studied:

- Hurricane Irene
- Hurricane Sandy
- Hurricane Harvey
- Hurricane Florence
- Hurricane Matthew (2 studies)

Time periods studied:

- 1988–2005
- 1999–2010
- 1999–2015
- 1999–2016
- 1999 and later
- 2000–2012
- 2000–2018

> ""This is not Harvey, this is not Imelda, this is not Allison. This is Laura. Every storm is different, and **we urge folks not to use any prior storm as a template** for what could or will happen. What we need to do is prepare for the worst."
>
> –Lina Hidalgo, Harris County Judge

Challenges for single-storm versus multi-storm studies

Survey comment:

> *"I have not yet investigated single storms, but I think looking at single storms **could help disentangle specific effects/phenomena**"*

*"Next on my list of features to be specially considered, I would place the **consistency** of the observed association. Has it been repeatedly observed by different persons, in different places, circumstances and times?"*

–Sir Austin Bradford Hill

Challenges for single-storm versus multi-storm studies

Survey question: What challenges have you had in getting exposure data relevant for tropical cyclones for epidemiological research?

*"**Exposure data across multiple countries**"*

Challenges for single-storm versus multi-storm studies

Survey question: What are the biggest challenges or limitations you have faced in conducting or planning a tropical cyclone epidemiology study?

*"I also wonder whether **the extent to which a specific physical hazard is a good proxy across storms** is modified by aspects of the built environment or the population exposed in a specific location."*

Assessing exposure to multiple hazards

Survey question: What are the biggest challenges or limitations you have faced in conducting or planning a tropical cyclone epidemiology study?

*"**Accounting for multiple hazards**"*

Assessing exposure to multiple hazards

Number of hazards rated as likely in causal pathways by individual researchers

Assessing exposure to multiple hazards

Hazards/proxies incorporated into exposure assessment

Assessing exposure to multiple hazards
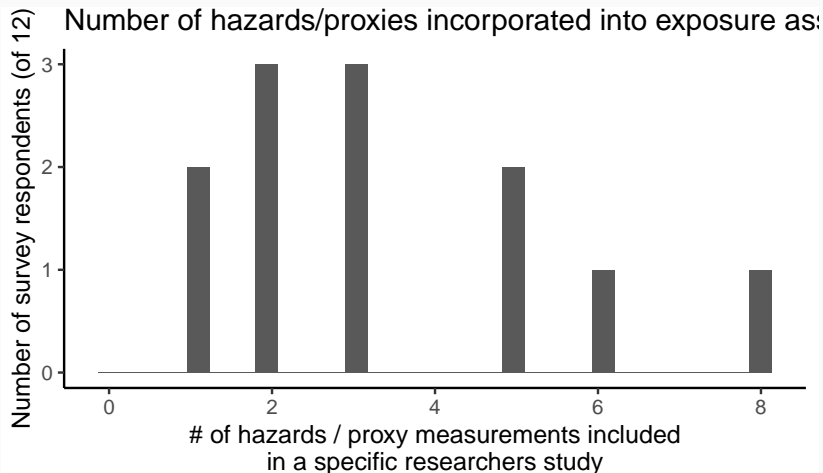
Number of hazards/proxies incorporated into exposure ass

County-level patterns of physical hazard exposures, Hurricane Ivan
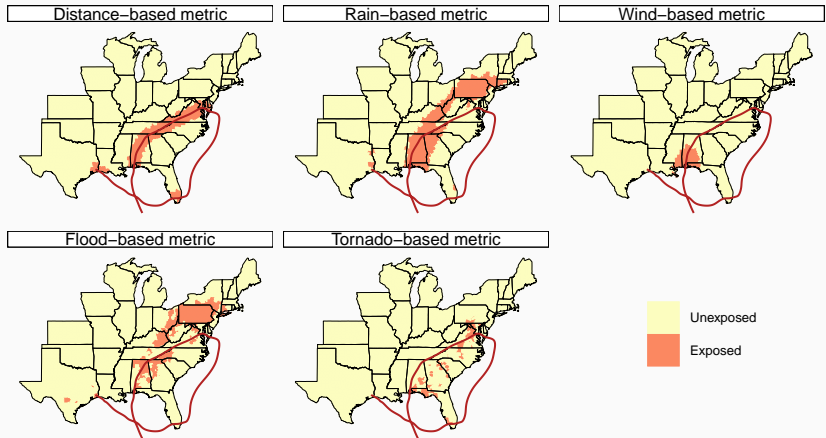
Assessing exposure to multiple hazards

Storm hits per county per decade based on rain (left) and wind (right) exposure metrics.
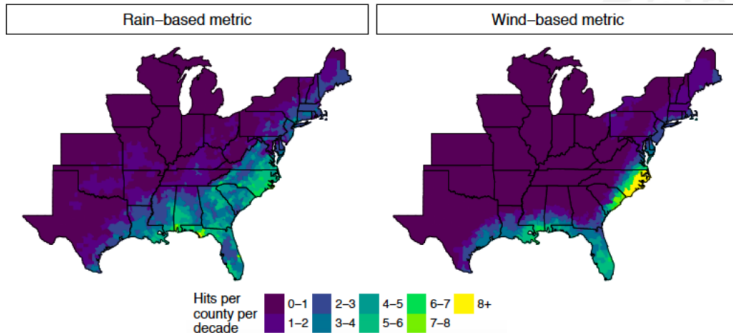
Criteria for exposure classifications: **Rain:** $\geq$ 75 mm of rain total for two days before to one day after storm. **Wind:** Modeled wind of $\geq$ 15 m/s.

Assessing exposure to multiple hazards

Pathways for indirect effects

Pathways for indirect effects

Survey question: If you think that any exposure-related factor—physical hazard or ensuing problems with the built environment, psychological stress, evacuation, etc.—dominates as a key factor for the outcome you are studying, please list that factor here and explained why you think it may have a very important role.

> *"One of my current studies examines whether children with asthma experience more frequent exacerbations of their symptoms i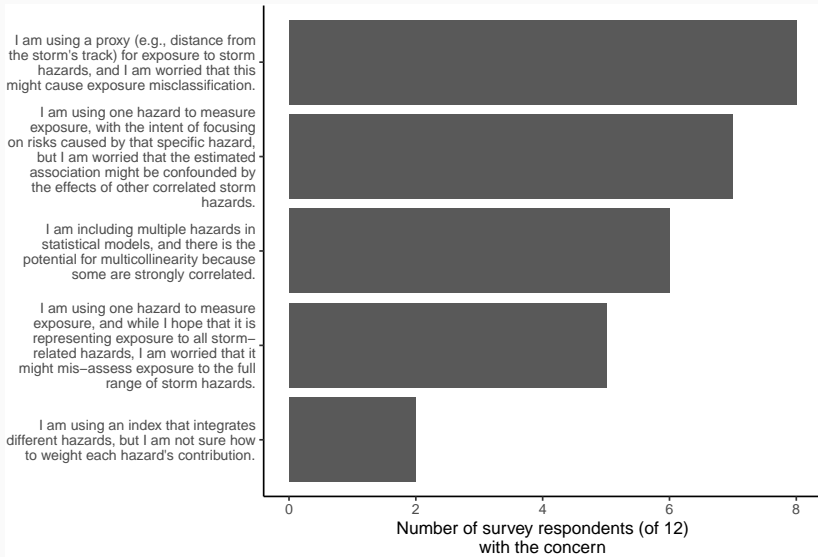n the months following tropical cyclones. I hypothesize that **exposure to bioaerosols (e.g., mold)** in the aftermath of the storm would be a key driver of an increase in symptom exacerbation frequency, but that there may be other factors at play as well especially immediately after a storm (e.g., psychological stress, interrupted access to routine care/medication)."*

> *"**Power outages**, they likely lead to increased hospitalization for people dependent on electric powered medical devices."*

Pathwasys for indirect effects

Survey question: Do you collect and incorporate data on any of factors beyond the physical hazards of the storm (like wind and flooding) for your study or studies? Examples could include property damage reports, data on evacuations, measurements related to mold growth, surveys about psychological stress, or data on power outages.

"**Drinking water quality** samples"

"I've been working on trying to obtain data on **power outages** from the ESRI utilities reporting"

"No but I think **this is a really important direction** for future work related to my study."

Pathways for indirect effects

Survey question: What are the biggest challenges or limitations you have faced in conducting or planning a tropical cyclone epidemiology study?

*"The question I've been doing some soul-searching about is whether **using information on physical hazards is a reasonably good proxy for exposure to the downstream hazards** that I think drive my health outcome of interest. I also wonder whether the extent to which a specific physical hazard is a good proxy across storms is modified by aspects of the built environment or the population exposed in a specific location."*

*"In planning a study on mental health, I think major challenges include defining and accessing health data and **developing models to explore causal pathways**, particularly as outcomes may occur much later than exposures."*

Pathways for indirect effects

Survey question:

"Listed below are several ways that the physical hazards of a tropical cyclone can impact the built environment and so increase risk of adverse health outcomes. Please rank how likely you think each is as a factor in causal pathways for the health exposure(s) you are studying or planning to study."

Pathways for indirect effects

Built environment

respondents (of 12) rating as likely (4 or 5 on scale of 1 to 5) in causal pathways for health outcome studied
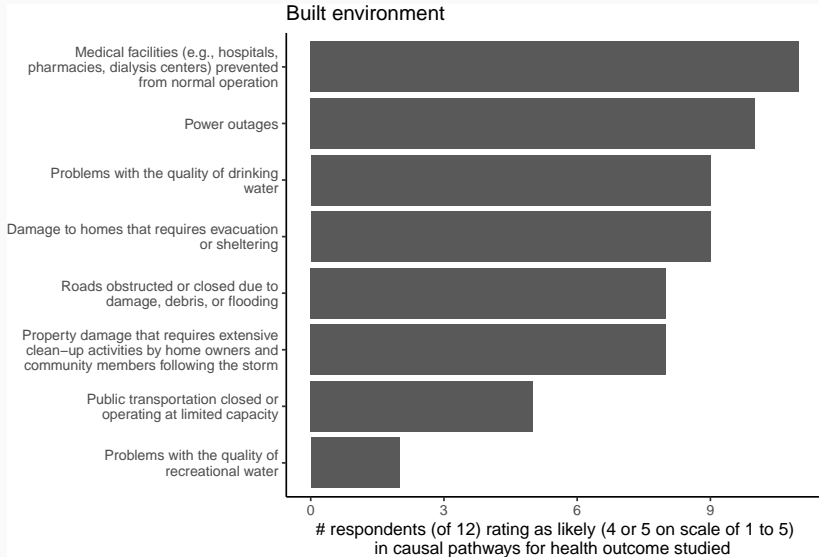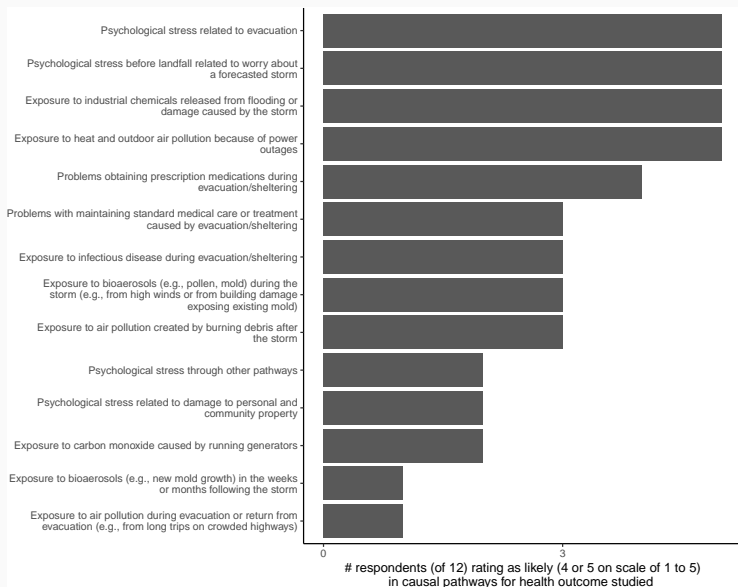
Pathways for indirect effects

Other potential pathways through the built environment:

"**Communication infrastructure outages** (beyond power outages as it might be to do with internet cables cut etc.)"

"**Damage to personal vehicles**, reducing capacity to evacuate or reach a hospital in an emergency situation"

Other indirect pathways

Bar chart showing # respondents (of 12) rating as likely (4 or 5 on scale of 1 to 5) in causal pathways for health outcome studied:

- Psychological stress related to evacuation
- Psychological stress before landfall related to worry about a forecasted storm
- Exposure to industrial chemicals released from flooding or damage caused by the storm
- Exposure to heat and outdoor air pollution because of power outages
- Problems obtaining prescription medications during evacuation/sheltering
- Problems with maintaining standard medical care or treatment caused by evacuation/sheltering
- Exposure to infectious disease during evacuation/sheltering
- Exposure to bioaerosols (e.g., pollen, mold) during the storm (e.g., from high winds or from building damage exposing existing mold)
- Exposure to air pollution created by burning debris after the storm
- Psychological stress through other pathways
- Psychological stress related to damage to personal and community property
- Exposure to carbon monoxide caused by running generators
- Exposure to bioaerosols (e.g., new mold growth) in the weeks or months following the storm
- Exposure to air pollution during evacuation or return from evacuation (e.g., from long trips on crowded highways)

respondents (of 12) rating as likely (4 or 5 on scale of 1 to 5) in causal pathways for health outcome studied

Aggregating data spatially

Survey question:

> *"Listed below are several ways that the physical hazards of a tropical cyclone can impact the built environment and so increase risk of adverse health outcomes. Please rank how likely you think each is as a factor in causal pathways for the health exposure(s) you are studying or planning to study."*

Aggregating data spatially
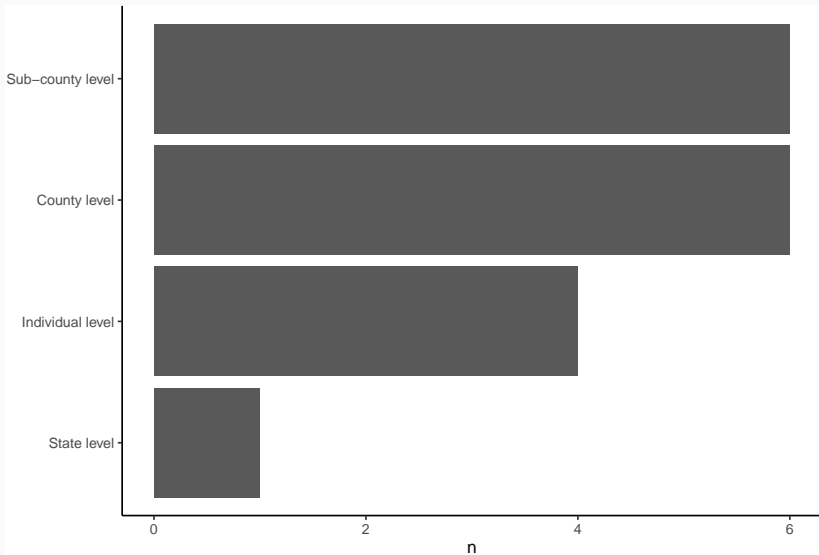
Survey question: What are the biggest challenges or limitations you have faced in conducting or planning a tropical cyclone epidemiology study?

　　*"**Linking spatially** exposure and human health outcomes"*

Survey question: What challenges have you had in getting exposure data relevant for tropical cyclones for epidemiological research?

　　*"Hard to get exposure data at **high spatial resolution**"*

Aggregating data spatially

Survey question: What challenges have you had in getting exposure data relevant for tropical cyclones for epidemiological research?

> *"One challenge that I have had with aggregating data over time is **changing geospatial boundaries** (i.e. the fact that zip codes, ZCTAs, and county boundaries all change regularly in the United States)"*

Assessing exposure during evacuation/moving

Assessing exposure during evacuation/moving

Survey question: What are the biggest challenges or limitations you have faced in conducting or planning a tropical cyclone epidemiology study?

*"Understanding the **population dynamics** in turn affects the ability to **classify the populations that were really affected by the storm / flood** during the event"*

Wrapping up

The constant challenge

Survey question: What are the biggest challenges or limitations you have faced in conducting or planning a tropical cyclone epidemiology study?

"***so far funding!***"

Thank you

- Kate Burrows
- Jacob Hochard
- Tiantian Li
- Rachel Nethery
- Balaji Ramesh
- Robbie Parks
- Arbor Quist
- Darren Sun
- Kate Weinberger
- Meilin Yan
- Marianthi Kioumourtzoglou
- Jaime Madrigano

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