**International Society for Environmental Epidemiology Virtual Conference 2020**

**EMS 3: Assessing Exposure to Tropical Cyclones for Epidemiological Research: Existing Resources and Future Needs**

**August 26, 2020**

***Brooke Anderson***

Good afternoon, thank you all for joining us today, we're doing a workshop about how we assess exposure to tropical cyclones. I am thrilled to welcome a whole group of people who will serve as a round table of discussants today. The people who are joining us right now are Balaji Ramesh, Amruta Nori-Sarma, Andreas Neophytou, Darren Sun, Gregory Wellenius, Kate Burrows, Kate Weinberger and Marianthi-Anna Kioumourtzoglou. Thank you all for joining, what we’ll do is start with a few slides and then we’ll break apart and have discussions at different parts throughout.

All right, I wanted to start a little bit about the motivation today. I've been doing work on tropical cyclones for a little while through an NIEHS K99 ROL. And as part of that, I developed a package called hurricane exposure that helps in exploring and mapping county-level hurricane exposure in the United States. Based on this research, I think a really interesting question is how we assess exposure when we’re looking at tropical cyclones. So currently along with Andreas Neophytou, who is on this discussion, and several other coauthors, we have a grant through the National Science Foundation that’s helping us explore a little bit more how people who study the human impacts of tropical cyclones look at and need data on the exposure end.

So this workshop is motivated by that, and we have a number of live participants, but I know we also have a lot of participants hopefully who have hopefully joined the regular call. I ask you to participate as well, if you please would write your questions or comments in the Q&A and then those will come over and two of our discussants Mariathi and Andreas will be helping and voicing your comments and questions as we go through. When you do that please include your name too, so we can say who said it.

Our discussion today is going to be driven by a survey. This is a survey that I invited a number of people to take, if you haven't taken it already you're welcome to go and take it. We would love to get your input on it as well. I put the link in here and there's also a copy of this link that's been put in the chat session if you like to click on that. In these slides, I'm going to go through some of the responses that we had initially from the different participants on that, as a way to start our discussion, so if you’d like a copy of the slides you can get those from GitHub if you’d like them for yourself.

So I’m going to start taking about 10 minutes to do an overview of the survey and then I'm going to introduce some of the general themes that came up, and as we go through those themes I'll take a break. I have some specific questions and comments I want to talk about and spur for the discussion, and at that point I’ll stop sharing my screen and we'll move into a discussion point and then we'll move back and forth. This survey was incredible to read. There were a lot of topics that were fascinating and some of them we won't get the chance to get to today, so I’ve put in more slides than we’ll probably need but we’ll see as the discussion goes, how deeply we’ll get in.

So, I wanted to start with an overview of the survey, as of last night when I was pulling everything together we had 12 participants. I think we already have two more and so I'll rerun this analysis later in the week to add in for anybody who has added. But one of the questions I asked was if people have published yet and there is one published paper, I put the link in here it’s really interesting, I may be biased because I’m one of the co-authors on that, as well as a number of the other participants today, but I do think it's really interesting. So I invite you to look at that but, but I think another piece that was really interesting here was how much of this research is ongoing.

So there are three papers that are submitted or are under review, at least 2 in preparation and other people on this call or who answered the survey are at earlier stages in their projects. I think that this is exciting because for ISEE it's been lovely and wonderful to be able to watch the different seminars and oral presentations, to be able to go back and visit them later through the recordings, but what I have missed are those times in between when we have coffee and lunch and we talk about the things that we’re working on right now and what we’re thinking about now and so I really am excited that a lot of these responses are coming from that place of: what are the questions on my mind right now, and hopefully the discussion today in this workshop can serve as that space that we are otherwise missing.

So, just an overview of the kinds of things that people are studying, I ask what the health outcome of interest was, and this had a large range: the respiratory outcomes, cardiovascular mortality, mental health outcomes, renal outcomes, gastrointestinal injury, birth outcomes, and neurological. So a large range of things, and we of course know that there is a possibility for tropical cyclones to impact a lot of different health outcomes.

In terms of the population of interest, most of the people who responded are looking at the general population, but a few are targeted into specific populations including older adults, children, or women who are pregnant and babies in utero. I also asked about where in the world people were studying this. So tropical cyclones can form in seven different bases around the world, and I’ve shown those here. I asked people which basin they were studying. We had one person who has done a study that has looked worldwide, and we have some representation from every basin, but our discussants today are primarily looking at the Atlantic Basin, as well as a few people looking at stuff in the Northwest Pacific basin.

In terms of the area studied, this ranges from single cities, very detailed studies of single cities, up through states or large portions of states and in large regions like the southeastern United States, or in the eastern half of the United States through to the level of countries. So there are some studies of China and then also that one study that looked globally. And then the last thing I wanted to give as an overview, is a question of: are you using primary data, where you going out and collecting it yourself in terms of the exposure data or is it something where you are relying on secondary data that was collected through some other mechanism?  For example through different weather monitoring organizations. And by and large, the respondents for this survey are almost exclusively using secondary data, so I think that's really interesting and driving this question of how we measure exposure.

So next let me talk a little bit about the physical hazards that people think might be at play, because I think this is a key point in assessing exposure to tropical cyclones. Tropical cyclones can bring a number of different hazards. This is some communication from Hurricane Florence which is a storm that several of the participants had studied. In this case it's laying out all these hazards that we can get at, and I think they’ve done a really nice job here at communicating the level of threat, because different storms can bring different levels of those threats.

So I asked the survey respondents -  I gave him a number of physical hazard hazards and asked them to rate each in terms of: how likely they think they are in the causal pathways for the health outcomes that they care about. So they have a chance here to build this out as a grid, where they had six different hazards that they could consider, and then I asked them for each to rate the likelihood, where one is that it was pretty unlikely that it's playing a big role, and 5 is up where it's very likely.

So I'm showing this right now and we’ve got the number of respondents in each, but in some of the later slides I'm really going to focus on looking at the hazards where people rated it as very likely, this 4 and 5, but being something in the causal pathway. So if we look at that, here are the number of respondents out of 12 total at the time I did this, who rated each of these physical hazards as being fairly likely to be in on the causal pathway for the health impacts they care about. So some of the hazards that are coming out are heavy rain storm surge and storm winds, but there are some concerns as well for inland flooding, tornadoes, and landslides, for the types of studies that the people who responded are looking at.  I also asked if there were any I missed there, and I thought this was a really interesting comment, that one of the researchers was wondering: if changes in atmospheric pressure might play a role as well and that is one where I think people have wondered that question before, so one more hazard to play in.

All right, so now I've introduced what people are working on, with an overview of this large level concern of having all of these hazards. So I want to get into some specific questions and points, and then pause and ask people to join in the discussion. The first one is this question of whether we assess exposure using a continuous or a binary exposure assessment tool. So I asked everybody this and you can see the darkest blue, these are studies where the researchers are using a binary classification. So they either assess a person or a community as exposed or unexposed. For the medium color blue, these are the people who use a continuous metric, and then for the lightest color these are people who have used a mix of the two in their research.

So I think this is a really interesting point, because of course for all of his study we're doing it in an observational way, and some questions come in about are we really identifying something that might be a cause. So I'm going to go back a couple of times to Sir Austin Bradford Hill and his ideas about causality, not that you can prove anything with it, but the kinds of clues you might want to look for along the way. One of those is looking at this idea of a dose-response, or for environmental epidemiology an exposure response, where we see a more severe exposure being associated with something that has a higher level of risk or higher rate across the community. And of course for all of those hazards that we just looked at, we can create a threshold and divide them into exposed or unexposed, but they are things that inherently have different levels of intensity. So it is a case where the underlying piece tends to be something that is continuous. One of the survey questions I asked is what are the biggest challenges or limitations that you faced in conducting or planning a tropical cyclone epidemiology study, and one of the responses that came out was this: that it is hard to define the appropriate spatial scale and assessing tropical cyclone exposure and further in examining the exposure-outcome association. So this is something that one researcher specifically noted as a key challenge.

I'm going to stop right here for us to have a discussion and some of the points that I would like the discussants to talk about is: if you are doing these studies and you're looking at a binary classification of exposure - so exposed or unexposed. Some of the questions I think are interesting are how are you picking a threshold to define exposed vs. unexposed, and why are you using that binary, rather than continuous. I know we all recognize that sometimes there are a lot of good reasons why you might want to start with doing an exposed - unexposed dichotomy. And then for anybody who is doing continuous measurements it would be really interesting to hear about how you're doing that and also if there are concerns about non-linearity in that exposure response, and if that's something that's creating difficulties as you do this.

All right so let's see if we can start with Robbie Parks. Would you get us started by talking a little bit about how you decided whether you would use continuous or a binary metric in assessing exposure, some of the challenges that came in with that, and the decision process.

***Robbie Parks***

Thanks very much Brooke. Yep, as people may have seen in my talk on Monday, I used a binary exposure. For the national study, all the studies which were exposed to at least one tropical cyclone event - I entered them into my U.S. study, and one of the reasons that we thought that was interesting is because, well first of all,  you would get a good amount of exposures, and second of all I think that has sort of interesting policy implications for whether or not it's easy to release disaster relief planning funds and things like that. So I think this disaster management response was playing a factor in our decision there. I think we were also interested in how different categories, or catchments of wind speed may be important and so one of the things we looked at was isolating hurricane-force winds and above from other tropical cyclone winds to examine whether the relationship or the association was being driven by hurricanes mainly, alone, or otherwise and I think we found it it wasn't just hurricanes. So that was of interest to us, but it was largely driven two factors I would say, I’d say to try and find an appropriate number of exposures and also to try and understand from maybe a policy perspective, that’s what I understand, what would be relevant to policy makers, and oh that counts as a tropical cyclone event, exposure event.

***Brooke Anderson***

Yeah, so you’re really making this wonderful point of the idea that even when you do a binary exposure metric, you might pick a few thresholds to already start getting a picture, if it looks like certain thresholds do lead to a stronger association. Are there others who do that? I know that we saw with Arbor Quist on Monday that she had used a few different thresholds in terms of percent of a community that was flooded. Are there others that are doing studies that have taken that approach as well, of doing a binary exposure assessment, but then investigating where that threshold might best go?

***Gregory Wellenius***

Yeah Darren did that in the paper you mentioned at the beginning, that was exactly the approach Darren took. I’ll let him comment on that and how you chose the different threshold Darren. But you know, I did want to add, I love the binary exposure because it is so easy to communicate as Robbie indicates, it’s like okay you know we have a storm that has characteristics, then this research must apply to that kind of storm, you know even in the abstract it’s much easier to communicate that than non-linear response, so the communication angle is very very important there. The part I always struggle with, and I'd be interested to know if anybody has some more ideas about this is you know, those counties that aren’t exposed, like in Robbie’s research where you’re looking at many, many counties, and there's a certain number that meet the criteria for being exposed, but then there's a bunch of counties that are not quite unexposed, they’re just exposed less. They don’t quite meet the threshold, but they’re not zero,  and what do you do with those counties?

***Brooke Anderson***

I love this points that you were raising about the idea that when you do split up at a threshold you've got some that are just misses on either side of that threshold, and that's really hard to tell if you got that right and then the implications through to your analysis.

***Amruta Nori-Sarma***

I just wanted to build on what Greg was just mentioning, that it’s also a little bit difficult because when you do that categorization, I know Greg was saying you don’t necessarily want those margin counties or at the margin counties to be included in the reference group, but oftentimes it seems to me like those might be the most comparable counties to the ones that you are including in the exposure group. So that’s something I’ve been trying to conceptualize as well. Once you get those thresholds that you decided on to create these binary exposure variables, how do you decide how far outside of a hurricane, or tropical cyclone’s path you need to be in order to get that referent county as well.

***Kate Weinberger***

Yeah, if I could add on to that. Full disclosure, I’ve been working on a project with Greg among other people, looking at counties that are exposed and unexposed to storms and it’s exactly the issue we wrestle with. Counties that are close by that didn’t quite meet that threshold seem like the right referent group, but then it’s really more a comparison of exposed to less exposed, than exposed to unexposed. Darren, you were doing a study where you were looking at different thresholds, right? For defining a binary exposure?

***Darren Sun***

Ah yes. We looked at several exposure metrics, you know, the sustained wind speed and also distance from the storm track, as well as cumulative wind force. We examined three exposure metrics. Yeah, where do you define the right threshold to categorize the continuous variable to define where it was. But one of the things we think about is look at some reference, for example for the wind speed, there are wind scales, right? So we pick one of these scales. When we think we have a hazard we pick these thresholds. We think when the wind reached a gale force, it’s like a 17.2 meters per second. We vary this point - not as strong and then very strong like 21 meters. We vary that reference and look at whether our results are reversed or not.

***Brooke Anderson***

I think this is a very interesting point, and I know that in the work I’ve done we’re looking at those as well. And I think this is a really interesting question, we’ll get into this later in the workshop, but so many of the pathways we think might be in play are indirect. So it’s not just that we think a certain level of a physical hazard as having a direct impact on your body, it’s how it plays through other elements like property damages, and power outages, and a number of other things that we’ll talk about, so we’re playing that game of seeing the physical exposure data but then trying to look at scales, like the Beaufort scale, or the Saffir-Simpson if we’re looking at the central wind speeds, to try and get an idea of description of how that plays through to what you see on the ground in terms of other pathways that could be triggered at that point.

So I think that we’ve mostly heard from people who were doing a binary exposure. For those of you doing that, I don't hear any argument that we don't think these are continuous underneath and there might be an interesting relationship there. Would you like to study this as something continuous, or are you just still trying to figure out the right ways to do this, or are there some other reasons why you really think it is good to stay with doing a binary exposure classification, which of course Greg talked a little a bit about these being easier to communicate. I saw Balaji, I think you had your hand raised?

***Balalji Ramesh***

Yeah. So there was an interesting point. We were trying to look at exposures as binary, but the resolution I had was pretty fine resolution. The maps I used were 100 meter resolution. So I was able to use. The problem when running the model was it’s hard to explain. It’s hard to explain the amount of land flooded. It doesn’t make sense. The other problem I faced was having a continuous variable and then dividing it into quantiles. I saw that even when I divided a continuous variable into quantiles it was kind of oscillating between different ratios.

***Brooke Anderson***

Yeah, we have a comment from the audience along those lines as well saying: this seems like a typical pain whenever you’re applying an extreme categorization. It almost seems like a categorical approach where you have more than one category might be necessary. And that might be something that would apply more to rainfall or flooding levels perhaps. So, right in line with what you were just saying.

One more comment from the audience right, now just to put in your mind but let's come back and revisit it later. The question was: are secondary data sources sufficient for exposure assessment in epidemiologic studies of this topic. I think this is an interesting question to start thinking about now, butt for us to revisit later because I think this comes into play with the idea of whether we're trying to measure is a physical hazards where there are extensive monitoring networks in models and things like that where we have a wealth of data we might need to figure out how to use it, but it's all there, versus some of the pathways we’re going through like power outages or water quality or some of the other pieces where it might make more sense to to be able to collect  primary data. So keep that in mind as the discussants and I remind all of the people in the full session to please send any comments you have through the chat. I think we’ll continue on to the next point. I will just share my screen again.

So the second thing I wanted to talk about, this is a pretty global issue, not just something that this going on with exposure assessment but as we talked about it let's talk about how this plays in specifically for the exposure assessment piece, and that's the idea of studying single storms through in-depth case studies vs. studying lots of storms over a long period of time. I think it's critical that we’re doing some of both of these, but I think it's also really important to think how we integrate the results across these different types of studies.

So one of the questions I asked everybody that participated was whether they were doing mainly studies of single storms (in depth case studies), mainly studies that are looking across a lot of years for multiple storms, or a mix of the two. And we were pretty well divided into people who were focusing on one of those are the other, or  people who were doing a mixture of the two, with the majority focusing on multi-storm studies.  For the single storm studies, storms that have been studied included Hurricane Irene, Sandy, Harvey, Florence, and two studies on Matthew and then for the time period study, these tended to range for the most part from the late 90s into the early 2000s, 2010s, and up to 2018.

So there was a quote that I heard on NPR yesterday that I thought was very informative for this whole topic of tropical cyclone epidemiology. Of course I think all of us are probably attuned to the fact that Laura is on it’s way and is expected to hit the United States this evening, until the early morning hours tomorrow, and this is something that was said by Linda Hidalgo, who is one of the people responsible for encouraging people to evacuate. She said, talking about Laura, “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.” And of course that's very good advice as people are preparing, but it's also something that we're always challenged with in this field, because we are characterizing what happened in past storms, and our hope is not just that we do a good job of saying what happened to something that happened already, we really want to get some idea what might happen next, and how we can prepare and prevent adverse impacts from future storms that come. So there's this interplay of storms being very complex and storms being very different and each storm being his own thing but at the same time do we just throw up our hands and say there is no way that we can get information that we can use help figure out what the risk for the next storm is or do we try to figure out how we can take that complexity and still try to learn something. One of the comments from the survey, in terms of the major challenges, is that one of the respondents said I have not yet investigated single storms, they’re mostly doing multi storm, but I think looking at single storms could disentangle specific effects or phenomenon, and then of course these case studies can get really depth on exploring these pathways.

And then on the other side of things, I'll go back to Bradford Hill. One of the other points that he makes, is that we want to look for consistency across lots of studies, and across lots of exposures,  because it might be more likely that we might expect something in the next big storm that comes, if it is a relationship we have consistently seen in different locations, and in different circumstances and in different times for these storms. And so by doing multi-storm studies, we can help to get some evidence of that consistency. Now for both single storm studies, and multi-storm studies, we have this challenge of assessing exposure in a way that’s very geared and appropriate for the storms in our study, but we also have to think a little bit I think about how our exposure assessment process might make our study comparable when you’re looking at other studies. So you can say with confidence we really did see a different association and we don't I think it's how we measure exposure rather than not being able to compare those results and not knowing if it's a difference in statistical modeling or in study design or an exposure assessment between the different studies that you look at.

Another one of the survey questions that I asked was what challenges have you had in getting exposure data that is relevant for tropical cyclones, and this is from the global study and one of the things that they specifically brought up is it's challenging to get exposure data that’s consistent across multiple countries, so again this interplay of trying to get things that are consistent in a multi-storm study, and in a single storm study trying to assess exposure both in a way that is appropriate for that storm, but also in a way that translates when you’re trying to compare results from other storms.

This is another one, again pointing to that idea, that challenge that we have in exposure assessment given that these storms are so different. So this person said I wonder whether the extent to which a specific physical hazard that I'm looking at, is a good proxy not just for one storm, but across all of the storms that you might have particularly in the context of a case where you think a lot of the pathways for impacts are going through the built environment or other indirect pathways.

So we'll take a break here again and see what other participants had to say about this particular question and some of the prompts that I have for this was if you were doing a single storm study, what characteristics of your exposure assessment do you think might be hard to translate to another storm? Was there something in terms of the length of flooding, or something like that, that might not be consistent across other storms. And then for multi-storm studies, which challenges have you had in feeling like you could meaningfully assess exposure across lots of different storms where the storms might look very very different when you’re looking across them. I think maybe let's start with Balaji for this because I think you did a really interesting study that you presented on Monday where you talked about this question of how you figure it out for your specific storm the flooding period to include in your assessments and not just a threshold of how much flooding but how long to look after the event to identify that flooding.

***Balaji Ramesh***

Our study involved understanding flooding periods. So when we were doing that we started using remote sensing. Like day to day satellite images, which can be used to identify how long the flood waters were there. We used data from USGS stream gages, which is real time data and NWS has a threshold for each gage. So the gage measures height above a fixed gage throughout flooding. Based upon that, I divided all the stream gages in my location and typically came up with a graph like the flooding started on this day and so many gages got flooded and then it stopped at this point. So typically the two ways of looking at the data was the satellite images and the stream gages. The problem with the satellite images was during that period, and during that month we expect a lot of cloud cover, so sometimes satellite images aren’t very good to see that.

***Brooke Anderson***

That sounds like a process that can translate to a lot of different storms as well if there was a specific threshold for both how long you look and then the level that you look at once you’ve got that full period, is that correct?

***Balaji Ramesh***

Yes

***Brooke Anderson***

Amruta, I believe that you are planning on doing a study on the other end of things, it's going to look at a lot of storms, so how are you thinking about trying to make sure that the exposure assessment is consistent across storms but also that it is appropriate across a range of very different looking storms.

***Amruta Nori-Sarma***

Yeah, so that’s a really great question, and one that I’ve begun contextualizing. I'm interested in looking at multiple hazards, so I’m interested in storms and in multiple different ways of assessing storm exposure, but some of those hazards may be occurring with or without the presence of a hurricane, so for example inland flooding, which may happen as a result of large amounts of rainfall, but may not necessarily characterize a hurricane exposure. So, one of the things I’ve been thinking about is following along with some of the excellent work that Darren has been doing. I'm also in the same research group as Darren, Greg is as well. So using that as a template to look at multiple thresholds, maybe some combination of a flooding plus a wind threshold over a specific period of time, and using that as an estimate for a binary indicator of storm or no storm. And then, combining that with flooding separately and some other metrics of storms separately as well.

In terms of looking across multiple different events, that’s also been an interesting experience, because it turns out there isn’t a huge number of storms in the time range that I’m interested in looking at over a 20 year period, 2000 - 2018 that have impacted heavily populated centers. So, one of the things that I’ve been thinking about also is applying these exposure estimates, and what is the appropriate area, so again going back to some of the questions we were just considering earlier in the talk. How do we define places that are exposed, versus places that are unexposed? And how do we make sure that they are very comparable as well?

***Brooke Anderson***

One of the things you brought up, and one of the things that Balaji brought up is this idea of persistence, and one thing that can come up in single storm studies or in multiple storm studies to consider is sometimes you do get these storms on the heels of each other. So right now we have Marco, and we have Laura coming in next, and you really are running into that period of the after flow of one, for some of these things like flooding, into the one of the next. Have any of you thought of that in the context of exposure assessment? Or kind of how to address that?

***Kate Weinberger***

I can jump in. I’ve been part of one study where we’re looking at a specific health outcome following multiple storms and so I wrestle with a lot of the same issues. I’ve heard this gripe already. Because we’re looking across multiple storms, there are some locations that are unfortunately hit twice in a small span of time and quite honestly the way that we’ve thought about it in the initial analysis that we’re doing, is that we’re actually limiting ourselves to placels that were only exposed to one storm within a year, or sort of defining a washout period is essentially what how we’ve been thinking about it. But obviously, you’re going to be missing potentially really important health impacts of communities that are exposed repeatedly within a short span of time, so I’d be curious to know if anybody else is looking at the impact of sequential exposures.

***Brooke Anderson***

Do you think Kate that when you do that you’re having any kind of selection issues with selecting places that aren’t in heavy hit areas, like losing large areas of Florida for example if you’re doing a large scale study?

***Kate Weinberger***

Yeah, absolutely. I think I saw Greg trying to flag us down. Greg, did you want to say something?

***Greg Wellenius***

Yeah, thanks. So I guess as I think through these questions it just strikes me that so much of the answer depends on what you’re trying to achieve with the research, and I know we’re early on in the research, so we’re trying to understand like, what is the effect of you know storms, like how bad is it? We’re all sort of in that same boat, but then if what we’re trying to do is predict for a storm that looks like this, what are likely the health impacts of it, how worried should I be, then one set of exposure models and analytic decisions are probably appropriate. On the other hand if you’re trying to figure out how to build resilience to those same storms, that’s probably a very different line of research, where you want to know like oh okay what were the impacts of this on infrastructure, how did that have an effect, what are the key things we could do to build resilience. So just to encourage the idea that there isn’t one right answer or a set of right answers, different answers are going to depend on thinking about if from a causal inference point of view, of what are we trying to define here?

***Brooke Anderson***

Absolutely. That’s a really good point. We have a really interesting question from the audience that I wanted to bring in here really quick too. How can funding agencies support looking across multiple storms, when review sessions are interested in specific exposures or a single event?

***Maranthi- Anna***

I have many thoughts. This very nicely builds up to what Greg was saying, because I really think it depends on what the question is. And to the extent that, when you write the proposal, the research team writes the proposal, they make it very clear about what the research question is and why they’re interested, what is the importance of the research question. On average reviewers tend to be reasonable people, and they would understand what the point is. I think the tricky part with some of these super new and exciting fields and exposures is that we want to do everything at the same time and it’s all a bit chaotic so we’re trying to put many things together and then that well defined research question is a bit lost. And that is why the reviewers push back and want to see something more specific. I don’t think they necessarily want to see just one event, but as long as there is a well defined question, and if it is an interesting and important question, then the reviewers will be okay with that on average.

***Brooke Anderson***

I absolutely agree with that. I think there is also this very interesting mix here, where there is some funding resources that are kind of in the regular grant cycle, but there are also these rapid responses, where this is a disaster, and in some of those cases, a single storm study might not be just for us to understand better the next event, but might even be timely enough for us to take some actions to mitigate what’s going on, in an existing event. So I guess maybe there is a role for that as well in these studies. All right, let’s continue on, yes Marianthi go ahead.

***Marianthi-Anna***

It might be worth looking at how wildfire epidemiology looks at this similar issue of sequential simultaneously occurring events.

***Brooke Anderson***

Yeah, very interesting question.

***Marianthi-Anna***

May I say one more thing here…

***Brooke Anderson***

Please do!

***Marianthi-Anna***

I think it depends also on the outcome and the timing window of importance for the specific outcome. So maybe for some of those longer term outcomes that we’re thinking about longer term exposures, having this back to back issue might not be as much of an issue, because it is the accumulation of exposure, versus super acute events maybe, but then yes we do need to know their exposure within the past week.

***Brooke Anderson***

Absolutely, and in terms of the exposure itself, the winds might come in and pass very quickly in one day, while for flooding, that might be something that builds up over a long period, both the potential impacts from it but also the exposure itself

***Greg Wellenius***

Yeah, there is an interesting parallel here between how we view these events and their properties and the growing body of mixtures epidemiology where you know, typically we say in mixtures people think of chemicals, it could be air pollution mixtures, Joe Brawn has done a very nice job of it. There was an EHP commentary back in 2017, where he distinguished between what do we really mean by mixtures, is it the additive effect, or superadditive, or sort of an effect modification, is it a cumulative effect, or is it that these are just confounders and we’re trying to isolate the independent effects? So, I encourage people to, going back to how we frame the question, what do we mean by these cumulative effects, or when multiple hazards happen at the same time is it that we’re trying to find the independent effects of those hazards, or are we trying to figure out the cumulative effects of those hazards, or something else.

***Brooke Anderson***

Greg, that is a perfect segway into the next little section. Looking at the time this might be our last one to work through today, but there is plenty more information about the survey results in the slides, and again there is a copy of the slides in a link in the chat if you would like to have a copy of the chat for yourself. Now, this next peace is that exact idea, we have these mutliple hazards, and how do we think about assessing those? So, one of the survey questions about the biggest challenge, one of the responses was just that: accounting for multiple hazards. So we went through some of those different hazards before, and I showed which hazards were popping up, but I also thought it was interesting to see if researchers think if many are in play for each of their outcomes. So it could be that gastrointestinal is just linked to flooding, and maybe that injuries are mostly linked to wind, and in that case we don’t have maybe as many of those problems, but if you really think that a lot of these hazards play into what you’re looking at, then this does become more and more of a concern. So I looked to see how many of those six hazards each researcher linked as being likely in the pathway for the outcome they were looking at, and there were a few where it was just a couple, but for most of the respondents in this survey, they are in that case where they think that a lot of these hazards play a role in the health outcome they’re looking at. I also ask what they are putting into their exposure assessment. So, the first questions were just about what they thought played a role, and this one was about what are you actually using in your study to assess that?  And some of the main ones here were storm winds, rainfall, and then there also were some that were looking at different proxies, so for example the distance from the storm track, meant to be a proxy for exposure to physical hazards, and then disaster declarations as a potential proxy. So, I also looked at how many exposures people were including, or proxy measurements, and it turns out that they are looking at a lot of different exposures as they go in. I think this is really interesting because we know that a lot of these exposures can have different patterns. This is an example for Hurricane Ivan, and this is just one threshold choice for each of these classifications, you could choose some other, but I think it already gives a really interesting picture of how the places that experience tornadoes were different from the places that experience flood or the main storm winds, or even the rain exposures. We see as well this interesting pattern that for some of these, this comes into play with whether we’re looking more and seeing more of the exposures in coastal areas versus more inland ones. A lot of the storm winds are mostly at the coast because these storms tend to disintegrate as they move inland and lose their energy, whereas rain can go well inland. We have this piece where there is this distinction between coastal and inland counties that comes across with the differences in exposures that they experience from the storm.

So I ask which concerns people had based on the fact that they are assessing exposure to multiple hazards, and many of these hazards might play a role somewhere down the track, and these are some of the things that came up: that if they were using a proxy, they were worried that that might cause exposure misclassification. In some cases they were using one to measure the exposure, and they really were focused on that specific exposure, but there were some concerns that there might be confounding from other hazards that tend to be correlated with that.

Some of the other ones there were concern, either from using multiple hazards and introducing multi-colinearity when they fit their models, or that they were using a single hazard to try to assess exposure to the storm as a whole, and then that might be misclassifying the exposure because that might not be well capturing some of the other hazards that might be important. So, we’ll stop here again and see if we have more questions.

***Kate Burrows***

I’d like to jump in on this. I think this question of multiple hazards is really interesting and one challenge that I’ve been sort of thinking about, which I think came up with these slides a bit, is the degree to which whatever combination of multiple hazards you choose, is actually the right way to estimate the indirect or causal pathways that are leading to the health outcome of interest. So again it comes back to thinking about what health outcomes you’re interested in, and maybe we need to back up a bit and think more about those causal pathways in order to better identify which combinations of hazards would accurately assess what it is that we’re trying to assess. If you’re concerned with power outages, which combination of hazards would get you closest to understanding power outages.

I’m currently working on a project that’s looking at a single hazard as a sort of jumping off point to look at individual level and community level stratification, but I think in the future I think it would be really interesting to, maybe this is where a single case study comes in then, to try to understand that causal pathway better and see if I could better estimate exposure using some type of multiple hazards approach.

***Mariathi-Anna***

I have a comment to build on what Kate was saying, and then we have something from the audience as well. So, I absolutely agree, I think it’s very important to say what we are interested in, because that would define how we - there are so many mixture methods that could or could not work, but they all depend first and foremost on what we want to study. We may want to look at independent effects, because maybe we want to better inform how we structure buildings for example. Or, we might be going back to the comment about categorization. We could include many different scales, exposures, hazards to create a categorical variable of storms, and that might be our exposure in space and time, so I think starting with a very well defined research question again, would also help choose the appropriate methods to group those multiple hazards and also whether you dichotomize or use continuous, etc. A very interesting comment, that I know you Brooke are interested in, is whether psycho-social stress plays a part in the multiple hazards.

***Brooke Anderson***

Yes, absolutely. I think that will be the next topic we’ll get into, but I wanted to raise one more point before we move in there. We’ve been talking a lot, mostly I think about more inferential modeling and assessment, where we’re really trying to understand the relationship that happens. But of course, for many of the disasters there is an interest in maybe prediction as well, when we know a storm is coming, can we anticipate what might be some of the major impacts from it? So that point of view there are certain hazards that can be better modeled, by atmospheric scientists, as a storm is approaching. So we might have a better idea of what winds are going to come than what rains, and even better for those than for something like floods or landslides. So, I wonder if anybody had any thoughts on whether there is a usefulness, in terms of this predictive piece of modeling, especially bringing into account the skill we have in anticipating certain hazards compared to others as the storm approaches.

***Robbie Parks***

Yeah, I would say absolutely because I think one of the points of the research that I’m looking at and I’m sure everyone is looking at is to try and minimize the impacts of disaster relief. You need a lead up time for preparation resources to minimize disaster risk and some of that would be anticipation of the particular event, not just reaction to it afterwards. So absolutely, yes.

***Amruta Nori-Sarma***

Sorry, I just wanted to jump in as well and say that I think one of the things we discussed earlier which is maybe worth revisiting as well is that within this concept of the predictive capability, I think focusing in on very specific storm events and using our understanding of previous events to inform how we anticipate future events to play out, for my own work I’ve really been thinking about this idea across multiple events, but one of the things that I really lose in that framework is the highly resolved spatial estimation of the exposure, and going back into the single event, which may then allow us to develop really strong spatial elements. Growing up in Southeastern North Carolina, I think I’ve experienced ten or eleven hurricanes as a child, and I know that there is a very stark spatial differential even within small amounts of space and time in the exposure effects - in the flooding levels, in the storm surge, in the wind levels, and I think that may have some implications for highly localized vulnerability in the communities. But I think that’s something that is also really important to take into consideration.

***Brooke Anderson***

All right I think I want to move on right now, and we’re down to about five more minutes, so there’s one comment that I want to raise and a really interesting question I want to get to. We do still have the question that we might not get to about all of these indirect pathways, so I think we have this channel for a little bit longer if a few more people want to stick around, we can talk a little bit about that then. But the question I wanted to make sure we get to is about funding, so one of the comments that came up in terms of what’s the biggest challenge that you face, in terms of doing this research is so far funding. And we have a question from someone in the audience that says that they are interested in what the research community thinks is needed from a programmatic standpoint to facilitate disaster research. What needs to happen to grow this research field? So I think that these are some really good questions to end on. I’d love to hear if anybody has comments on that point. Greg, did you maybe want to start on this?

***Greg Wellenius***

Yeah sure. Funding is always tricky. There’s never quite enough around. Many years ago, one of my senior mentors at Harvard said that grants get funded the same way mosquitoes get through your bug screen on your windows, you just get enough trying to get through and eventually one lands. So we’re not going to single handedly fix the funding problem in the U.S. But I think it does go back to some of the issues we’ve raised before and having a really specific question, a clearly laid out question. So, we can’t do everything in a grant. I think that reviewers, to Marianthi’s point, are fairly amenable to being convinced that if this is a really important question and you have a solid design to answer that really important question, that increases the chances of funding. No magic formula obviously, of course more money would be better but I think part of it is embracing the need for more people working in this area, in the same way that we’ve seen that being successful in other areas of environmental health.

***Brooke Anderson***

So, I’ll come back with this, and also this is for everyone, we can start with Greg, but for everyone. You are answering that from the position of the fundee, but if you were the funder, or the program officer at the NIH or EPA, or NSF, what do you see as some of the areas where we could make a lot of mileage if there are efforts to fund things. I know we’ve mentioned mixtures research before, and I think it is really inspiring how some of the NIEHS efforts to really support growth in that area have just led to some wonderful methods that we’re using now. So if you are sitting in the chair of the person who gets to give out the dollars, what kinds of things do you think would be worthwhile to look at and I’ll open this up to everyone as well.

***Greg Wellenius***

Yeah, I’ll throw out a slightly provocative comment. I think that almost everything we do around climate change falls under the umbrella of preparation and resilience building, so I don’t think that we actually need new mechanisms to fund things. NIEHS and sometimes EPA or even NSF have provided money for resilience, and I think that framing these comments, I can’t promise it will work, but framing these as issues of resilience is a great starting point.

***Kate Burrows***

I think there is also an interesting opportunity to build interdisciplinary collaborations because the field of disaster research is definitely still in its early stages from an epidemiologic perspective, but there is a lot of research in fields like sociology, and I’m very interested in population dynamics and evacuations after storms for example. Demographers have been working on this for a long time. So I think if there were better pathways through which we could better collaborate with other fields that do have some of this expertise, maybe we could build out more effective research programs.

***Brooke Anderson***

All right, great. So I think let’s just wrap up now by talking a little bit about these indirect pathways. I’m not going to bring up the slides again, but we can just talk about this. We have a question in the chat: is psycho-social stress part of the multiple hazards. In the slides and in the survey I’ve got some of those issues people were pointing out as pieces they think exist in the pathway through the built environment or other. Psychosocial stress I think was certainly a large part of that. Some of the others were power outages and issues with water quality. So if we could go through and if some of the people who are doing research could talk about what some of these pieces in the indirect pathway that are really critical for research are. We’ll wrap up that way for today. So if we can go through everybody and if you could just say two or three things that are really on your mind with what we’re doing. We’ll start with Kate Weinberger.

***Kate Weinberger***

Okay, yeah, so the two that are at the top of my mind with the study I’m working on right now, I’m interested in respiratory outcomes, particularly in the long term following storms, not just the acute period. So asthma for example, and so some of the indirect or at least further down the causal chain exposures that I’m interested in are flooding, property damage, and mold growth in homes as sort of an extreme consequence of that. It’s been sort of fun actually to hear from people who are thinking about satellite products for assessing flooding extent. It’s been great to hear how other folks are thinking of exposure to these downstream hazards.

***Brooke Anderson***

Great. Amruta?

***Amruta Nori-Sarma***

Yeah, so I’ve been thinking of multiple hazards in the context of hurricanes, but I’ve also been thinking of multiple hazards in the context of broader climate hazards and how they interpolate with each other, and how we might start to understand the joint and independent effects of different types of relevant climate hazards that may occur close to each other in space and time. So hurricanes tend to happen in the summer season, in an area that may also be experiencing heat waves, and so I’m really interested in the ways that the health effects may be compounded by the occurrence and recurrence of these multiple types of hazards. I’m also interested in some of the multiple ways in which hurricanes cause power outages, which would lead to increased health effects in areas that are experiencing a subsequent heat wave event. So these are some of the things that have really been at the top of my mind. That’s where I really see my research agenda going as well.

***Brooke Anderson***

Great. Robbie, did you have something you wanted to add?

***Robbie Parks***

Broadly, I’ve been focusing on acute reactions to tropical cyclone exposure. I’m also interested in mid to long term impacts, so that would be something where I’d be interested in what variables are relevant, what drivers, and also how they differentiate between parts of society, how different geographies and different SES variables may impact both the acute and chronic health conditions over a long period of time.

***Brooke Anderson***

Great. Kate Burrows?

***Kate Burrows***

So, something that’s been on my mind from a personal perspective, after experiencing Hurricane Irma at my parent’s house on Long Island, was the impact of not only power outages, but also disruptions to other forms of communication. So having issues with cell service for example can really impact connectivity and access to health care services. But for most of my research I’m also really interested in the role of displacement and evacuation, which can impact psycho-social well-being through stressors, but also can have important implications in terms of physical exposure so whether or not the people that we think are in a certain area are actually there or not, I think is a really important question as we start building out this research.

***Brooke Anderson***

Great thanks. Greg, did you have on to add?

***Greg Wellenius***

Yeah, so I think these are all really great points and I’m excited to see such enthusiasm for a diversity of questions. I think what sort of keeps me up at night is the totality of the impacts. It’s not about the gastrointestinal illness, or the asthma, or the mental health effects. These are all incredibly important, but it’s like a total detraction from our broader well-being. Sometimes I wish I was an economist and I could just sum things up in dollars, because that’s so much easier. How do you figure out what is the total human sacrifice or misery that this causes? How do you put a number on that, and if anybody has smart ideas about how to integrate across these very diverse health outcomes I’d love to talk to you.

***Brooke Anderson***

Thank you. Darren?

***Darren Sun***

Yes, I’m in the same group as Kate and Greg and I’m also very interested in multi-hazard effects.

***Brooke Anderson***

Great. Marianthi?

***Marianthi-Anna***

I’m involved in multiple different projects that I’m not leading, so that means I’m interested I guess in examples of what not to do - wanting to do everything. Personally I think my heart is in long term neurological outcomes, which is mostly indirect. I don’t know if it is mostly through psycho-social stress, but I’m sure it will play a large part of it. My biggest concern is how we disentangle that from SES and other specific factors. So this will be fun to try and figure out.

***Brooke Anderson***

Great. Andreas, did you have anything you wanted to add?

***Andreas Neophytou***

Well, as a non-exposure expert, speaking more from the analysis point of view, with the indirect effects I actually think that’s going to be the more interesting part from the causal inference literature, because speaking in terms of interventions whether or not they are hypothetical or actual, we’re not going to be able to reduce the wind speed over a certain cyclone, we’re not going to be able to make the cyclone go away, we’re not going to be able to reduce the rainfall. But we can actually intervene to reduce flooding, or power outages, or preparedness for those things. I think that’s going to be the more interesting part, at least from the causal inference literature. On the other hand, it sort of becomes a mediation question, where you are intervening on the mediator, so it also becomes very difficult to get that estimate of interest. So, I’d be interested to see what’s coming out in the literature, but I did want to point that out - you are essentially talking about a mediation question at some point.

***Brooke Anderson***

Yeah, I think that’s a great point, and definitely some interesting things to think about there in terms of how we think about and learn for next year, but also how we think about and learn for what our climate might look like in 100 years, because there maybe we can change the winds, and can change the rain on average, for some of these events through the issue of climate change. All right, we’ll end with Balalji and then we’ll wrap up.

***Balaji Ramesh***

---bad internet connection---

***Brooke Anderson***

Great. Thank you so much to everyone joining in our discussion and for the wonderful questions from the audience. This has been really interesting for me, and I look forward to all of us continuing this discussion, hopefully in Beijing for ISEE next year, but maybe before that either remotely or in person. Thank you all for joining us.

***Greg Wellenius***

Brooke, before you go, a huge thank you and your team for the hurricaneexposure package, which has I think single handedly been the most important aspect of opening up this field to people, that exposure assessment. So, that’s really been a gift to science and thank you so much for you and your team for publishing that.

***Marianthi-Anna***

Absolutely. So, when we were doing that last night, the survey, I was saying whatever your package has, that’s what I’m using! So definitely thank you!

***Brooke Anderson***

Thank you! And thank you all for participating.