

# The Right Call: How Emergency Managers Make Storm Response Decisions Under Conditions of Uncertainty

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## Research Article

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# **The Right Call: How Emergency Managers Make Storm Response Decisions Under Conditions of Uncertainty**

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# 1. Abstract

In the days leading to a hurricane, tropical storm, or nor'easter's landfall, emergency managers (EMs) make critical response decisions to protect lives and property while minimizing avoidable consequences. Often these choices are made under stressful conditions with decision making constrained by insufficient time, incomplete information, cognitive constraints, and organizational limits. Shifting storm characteristics, expanding coastal populations, growing dependence on vulnerable critical infrastructure, and rising recovery costs are increasing the risks hurricanes and tropical storms pose for coastal communities while making it more difficult for EMs to access decision-making data. Uncertainty is a given in EMs' storm response decision process, often requiring the local EM to lean on instinct and experience when empirical data is lacking. But making choices under such conditions can encourage cognitive shortcuts, ad hoc judgments, and biased decision making that lead to suboptimal choices. To develop better decision support tools, researchers need a deeper understanding of the choices EMs make when responding to storms under such conditions. We present findings from ten (10) interviews with emergency management practitioners in the State of Rhode Island, U.S.A., designed to learn more about subjects' storm-related decision-making. Our results identify pre-landfall response choices EMs make at the local level and explore the data gaps they encounter when making such decisions. We apply Simon's theory of bounded rationality to examine EMs' storm-related decision in high-stakes, time-constrained, uncertain environments, validating prior studies showing that EMs often rely on bounded rationality to offset a lack of information and time when making such decisions. Lastly, we explore how simulation-based decision support tools can help EMs overcome these barriers to improve storm outcomes.

## 2. Highlights

- Local EMs often operate in an environment of uncertainty when making emergency response decisions about major ocean storms, forcing them to make pre landfall decisions or recommendations about emergency protective actions with incomplete information.
- EMs frequently need forecast data and consequence predictions beyond what's included in NHC advisories, such as predictions for riverine and urban street flooding. And many of the actions EMs take, such as evacuation and sheltering, require more lead time than forecasts currently provide.
- Bounded rationality is critical in emergency decision making because decision makers do not have enough time to evaluate every option during a disaster. EMs often make storm response decisions with limited information and time pressure, merging empirical data with their own experiences and instincts to identify a solution that best fits the situation in front of them.

- Local EMs need tools that not only supply predictive data but help them maintain situational awareness and form a common operating picture with lateral and vertical partners such as neighboring jurisdictions, state and federal agencies, and local officials.

### 3. Introduction

In the days leading to a major ocean storm’s landfall (hurricane, tropical storm, nor’easter), emergency managers (EMs) make critical response decisions designed to reduce losses and minimize avoidable consequences (Adams et al. 2026). Ocean storms pose a major threat to U.S. coastal communities. Since 1980, hurricanes have caused more damage and resulted in more deaths than any other type of weather-related disaster in the U.S. (NOAA 2025). Climate change, together with expanding coastal populations, growing dependence on vulnerable critical infrastructure, and rising recovery costs, increase coastal communities’ risk exposure while introducing new variables that EMs must factor into their response decisions (Lipiec 2024; Little, Loggins, and Wallace 2015). Climate change is contributing to rapid intensification (RI), increased forward speed of advance, and other storm trends that complicate storm consequence prediction and reduce the time available to act (Parker et al. 2009; Glarum 2020). These factors add considerable uncertainty for EMs making local storm response decisions, often constrained by a combination of limited time, incomplete information, cognitive overload, and organizational capacity (Glarum 2020; Zhang and Schilling 2006). Making choices under such stressful conditions can encourage cognitive shortcuts, ad hoc judgments, and biased decision making that lead even the most seasoned EMs to make suboptimal choices (Glarum 2020; Wernstedt et al. 2019).

To reduce uncertainty, researchers are developing new, simulation-based tools that can help EMs make better-informed decisions about storm response. But EMs have been slow to adopt such technologies as the tools must first demonstrate reliability and usefulness at guiding decisions about disaster preparedness, response, and/or mitigation (Maricle 2011; McNie, Parris, and Sarewitz 2016). Incorporating new tools into existing emergency response workflows requires a thorough understanding of the choices EMs make when responding to hurricanes and tropical storms under conditions of uncertainty (League et al. 2010; Cantor 2021). Researchers need to understand how these tools will fit into existing EM workflows, and we need a framework to describe storm outcomes EMs can alter, a concept we call “avoidable consequences” (Adams et al. 2026). There are limited field studies examining EMs’ naturalistic decision-making for major weather events and the inter-team process used to coordinate decisions across multiple groups (Wernstedt et al. 2019; Waring, Moran, and Page 2020). Most existing studies focus on specific aspects of decision making such as evacuation decisions (Iman

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*The author acknowledges use of Google Gemini AI to locate pertinent literature and help outline key themes related to 1.) decision theory; and 2.) storm trends. However, no AI-generated content has been used in this paper and all references obtained through AI queries have been thoroughly vetted and reviewed by the author before inclusion.*

et al. 2023), tornado warnings (League et al. 2010), and forecast interpretation (Wernstedt et al. 2019).

We present findings from ten (10) semi-structured interviews with EMs in the State of Rhode Island, U.S.A., to learn more about the decisions they make when preparing for a major ocean storm. Our interviews build on a 2023 survey of EMs in the Southern New England region of the United States (Adams et al. 2026) and a series of Homeland Security workshops and exercises (Adams et al. 2025). Our interviews were designed to answer two research questions: RQ1.) *How do local EMs make pre-landfall storm response decisions under conditions of uncertainty with limited time and insufficient data?* and RQ2.) *How can a decision support tool like the Coastal Hazards, Analysis, Modeling, and Prediction system (CHAMP) help local EMs reduce uncertainty and facilitate more effective decision making?*

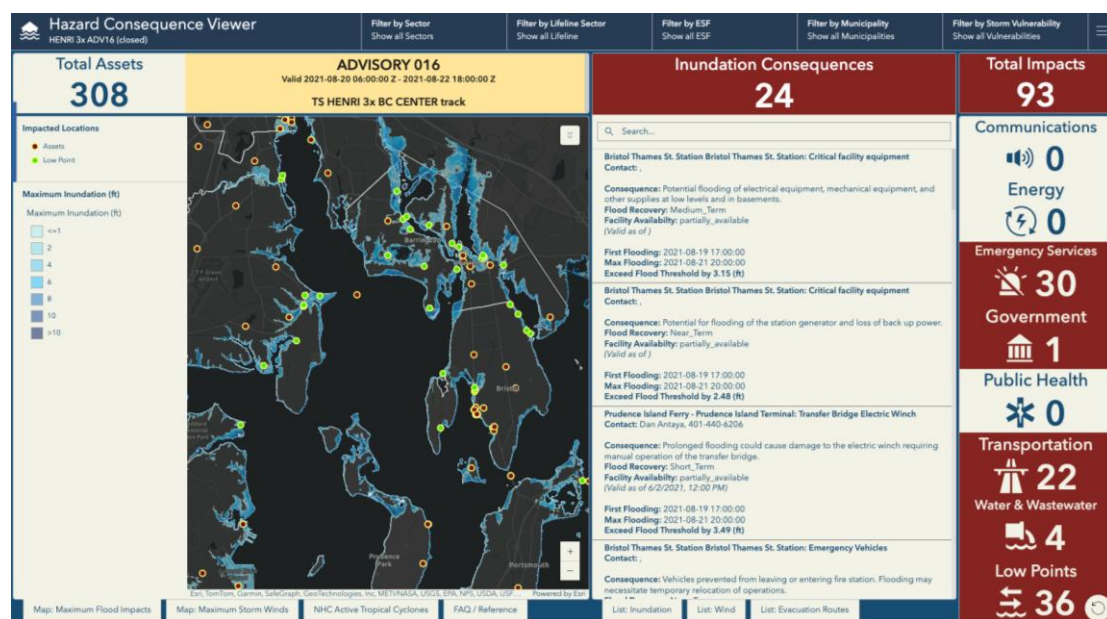


**Fig. 1** Screenshot of the CHAMP dashboard in ArcGIS Online (Figure: authors)

Our study references the Coastal Hazards Analysis, Modeling, and Prediction (CHAMP) decision support tool, developed at the University of Rhode Island in partnership with a large stakeholder group to help EMs make better-informed response decisions using deterministic analysis of risk. (More information on CHAMP can be found at Becker et al. (2021) and Adams et al. (2024)). Unlike tools that depend on aggregate risk assessments and census tract level data, CHAMP combines locally sourced, georeferenced information about specific critical infrastructure (CI) vulnerabilities with high-resolution storm model outputs to produce localized, actionable data about storm impacts and consequences (Stempel et al. 2018; Adams et al. 2024). Data for CHAMP's critical infrastructure database is collected primarily through a Participatory Action Research (PAR) process based on the concerns of local experts. This ensures consequence predictions are directly relevant to EMs when making critical decisions about storm preparedness and response (Adams et al. 2024). The resulting analysis is delivered in an interactive, web-based dashboard and customized reports that EMs can use to identify critical

infrastructure that will be impacted by a specific storm scenario/forecast (see Figure 7) (Adams et al. 2024).

The present study is part of mixed methods implementation research to facilitate the uptake of tools like CHAMP into real world practice. Most often encountered in healthcare and information technology environments, implementation research examines how interventions function in real-world settings without controlling for other causal effects (Aarons et al. 2012; Bhattacharyya, Reeves, and Zwarenstein 2009). Research based tools and technologies often face difficulty transitioning to practical application because their relevance and usefulness must be demonstrated to end users who often are already overloaded with information (McNie, Parris, and Sarewitz 2016; Little, Manzanares, and Wallace 2015). To be accepted into regular practice, new technologies must deliver data that is reliable, timely, and fits into existing storm workflows because, at the height of a disaster, integrating new data streams and processes can overwhelm emergency personnel already struggling to process the information they have (Glarum 2020). Implementation research helps social scientists better understand how decision support tools are used by EMs in the field, facilitating uptake of new innovations into practice by emphasizing the use of knowledge over the mere production of that knowledge (Peters et al. 2013; Bhattacharyya, Reeves, and Zwarenstein 2009). Our research focuses on decisions local EMs make during the response phase of emergency management, prior to landfall, because this is when EMs are most likely to make critical decisions under the pressure of limited time and resources, risk uncertainty, and concerns for the consequences of making a wrong choice (Glarum 2020; Little, Loggins, and Wallace 2015; Waring, Moran, and Page 2020). However, findings are generally applicable to other emergency management phases (preparedness, recovery, and mitigation). We also focus on decisions at the local level given the principal that all disasters are local, meaning the human impact of disaster starts and ends locally.

Our paper begins with a Background on EMs' storm-related decision needs and sources of uncertainty. We then review our Methodology, present Findings from our interviews, and have a Discussion of the implications for other researchers developing decision support tools. A Conclusion summarizes our key findings.

## 4. Background

Reducing negative outcomes of natural disasters is a fundamental goal of the emergency management process. Given sufficient warning about storm impacts and consequences, EMs can reduce the likelihood that storm hazards will harm people, places, and things, or at least minimize the consequences of unpreventable impacts through emergency protective measures. We refer to outcomes EMs can alter through such interventions as *avoidable consequences*: storm outcomes decision makers can: 1.) Reasonably anticipate based on available data; and 2.) Take timely action to reduce or eliminate harm (Adams et al. 2026).

Unfortunately, EMs often have difficulty accessing localized, actionable information about impacts and consequences in time to make a difference (Cutter, Boruff, and Shirley 2003;

Becker et al. 2021). Existing methods and tools are not optimized to address the shifting risk environment associated with climate change, and most cannot deliver detailed, local-scale data that helps EMs safeguard their populations (Stempel et al. 2018). Most tools are designed to predict overall damage and anticipate response and recovery needs rather than deliver information that supports data-driven decisions about local emergency protective measures (Godschalk 2003; Helderop and Grubestic 2019; Becker et al. 2021). And many actions EMs take in preparation for a major ocean storm require days of preparation, such as activating shelters and conducting large-scale evacuation. Yet, despite tremendous advances in forecasting science, there is still significant uncertainty in a storm's track several days out from landfall.

*Emergency decision making (EDM)* is a process of gathering information then choosing a course of action from among the available options (Glarum 2020; Zhang, Wang, and Wang 2018). Simon's (2000) theory of *bounded rationality* helps explain EMs' critical decision making in high-stakes, time-constrained, uncertain environments (Iman et al. 2023). Uncertainty is a given in most EMs' decision process when responding to major ocean storms in coastal communities; Often this results from a lack of useful information but having too much information can be as problematic as not having enough (Waring, Moran, and Page 2020; Wernstedt et al. 2019). Both conditions lead to uncertainty and confusion, and performance deteriorates with cognitive overload as does capacity to manage other activities (Waring, Moran, and Page 2020).

Classical decision theory assumes that decision makers know all the options available to them, understand the potential consequences of each option, and have ample time to weigh all considerations before selecting a course of action (Lunenburg 2010). Of course, such ideal

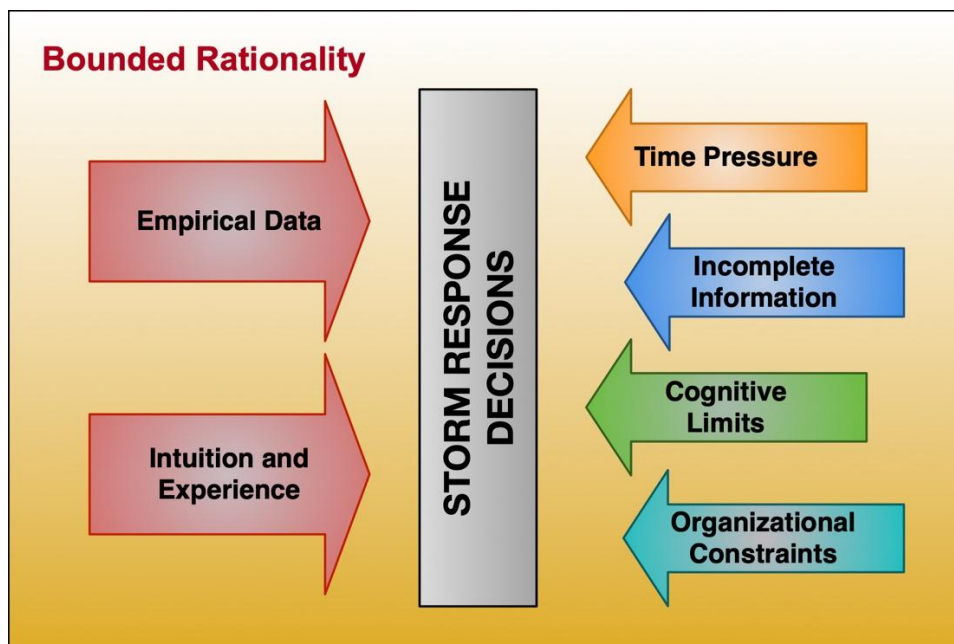


**Fig. 2** EMs supplement empirical data with experience and intuition to make decisions under pressure from time constraints, incomplete information, and cognitive limits (Figure: authors)

conditions rarely exist in the real world and certainly don't apply to EMs making decisions about storm response. With limited knowledge of risks and uncertainty in their choices, compounded by a short window of time to act, decision makers can't possibly evaluate all potential alternatives before making choices (Iman et al. 2023). Instead they must determine a course of action by matching environmental cues with past experience to identify a workable solution based on the knowledge they have (Waring, Moran, and Page 2020; Wernstedt et al. 2019). Bounded rationality assumes that decision makers want to make an optimal choice but are constrained ("bounded") by time and cost pressures, incomplete information, cognitive demands, organizational limitations, and/or other factors (Simon 2000; Iman et al. 2023). So instead of the optimal choice, the EM settles for a solution that is good enough to accomplish the intended goal, an approach referred to as "satisficing" (Simon 2000; Iman et al. 2023). As such, EMs' storm response decisions are typically the product of a tension between EMs' available data, experience, and intuition versus constraints of time, information, cognitive capacity, and organizational function (see Figure 9). Simulation-based decision support can reduce such uncertainty and thus improve EMs' decision-making process (NIST 2003; Little, Loggins, and Wallace 2015; Stempel et al. 2018). Simulation and modeling can also enhance risk assessment and reduce the potential for avoidable consequences (Adams et al. 2024). This approach helps local stakeholders and decision-makers understand hazards facing their communities and identify cascading consequences that may result from their impacts (Haraguchi and Kim 2016; Helderop and Grubestic 2019). But the volume of information produced by such tools can potentially overwhelm decision makers if delivered unfiltered, so the tools must focus on delivering information most relevant to the decisions EMs need to make with the data. EMs need tools that help them make sense of the information in front of them, and are more likely to adopt new technologies if they see them as effective in reducing community vulnerability (Peters et al. 2013).

A challenge with deterministic decision support tools like CHAMP is the potential to create additional uncertainty in storm modeling based on inherent limitations of such systems. CHAMP's consequence predictions are only as good as the information provided to it, both in terms of the reliability of consequence threshold data and the accuracy of the NHC storm track. CHAMP's output is deterministic, meaning it assumes the storm will follow the forecast track exactly, when in reality this is rarely the case. For this reason, it's important to view CHAMP as an additional tool and source of information in the EM's arsenal, not a panacea that renders all previous tools irrelevant. For a tool such as CHAMP to be effective, end users must understand what is—and isn't—in the data CHAMP delivers, and they must view the information received from CHAMP in the context of what they're seeing from other tools and data sources. Depending solely on CHAMP modeling can increase negative consequences rather than reducing them, making it imperative that CHAMP's end-users be sufficiently trained to interpret the data presented to them.

## 5. Methods

To better understand the decisions local EMs make when responding to major ocean storms, we interviewed ten (10) EM practitioners (University of Rhode Island Institutional Review Board Approval 2011717-4) with questions about:

- Background information and demographics
- Specific decisions they typically make during storm response, the process followed, and factors considered when choosing a course of action
- Factors that contribute to uncertainty when making decisions about local storm response
- Data and tools that would reduce decision uncertainty and potentially improve outcomes in future storms

### 5.1 Study site

We based our study in Rhode Island because this is the primary coverage area for the CHAMP system and confining the study to a single state avoids potential state-to-state differences in emergency management structures. Rhode Island's east-west coastline orientation makes the "Ocean State" uniquely susceptible to the effects of tropical cyclones traveling up the United States' eastern seaboard, and the state is prone to hurricane impacts, including areas not on the immediate coast (Thomalla et al. 2006). The capital city of Providence saw significant flooding during the Great New England Hurricane of 1938 and Hurricane Carol in 1954 (USACE 2022), and Rhode Island's southern coast experienced significant damage during Hurricane Sandy in 2012 (FEMA 2013). The Southern New England region generally has short warning times for hurricanes and tropical storms because storms making landfall in the region often accelerate as they move up the East Coast and interact with northern air masses. Additionally, rising ocean temperatures resulting from climate change are sustaining warm ocean waters longer into Fall, increasing the potential for late-season storms and contributing to a northward shift in the point where storms reach their peak intensity (Kossin et al. 2020).

### 5.2 Participant selection and demographics

Our sample population consisted of emergency management practitioners with experience and specialized knowledge of emergency management processes at the local level, including local storm response. Candidates were initially selected from the participants in our 2023 survey (Adams et al. 2026) and/or prior involvement in the CHAMP project and its steering committee. All interview subjects have substantial experience as EMs working in Rhode Island, have jurisdictions within 50 miles of the coast, and have experience responding to hurricanes, tropical storms, and/or nor'easters. See Table 3 for additional interviewee demographics. We conducted a sufficient number of interviews to address our research questions; The literature suggests starting with a minimum of ten interviews, then ending the study when no new themes emerge from several consecutive interviews (Hagaman and Wutich 2017).

### 5.3 Interview protocol

Our interviews expanded on questions asked in our 2023 survey (Adams et al. 2026) plus additional questions about decision making and uncertainty. Interviews lasted approximately 45 minutes and were conducted virtually using Zoom videoconferencing. Interviews were recorded with the interviewee's permission and transcribed using Otter.ai software. The interview protocol, IRB documentation, and curated transcripts are available on DesignSafe-CI (Adams and Becker 2026). The interview protocol is also included in Appendix A.

Table 1: Interviewee demographics

| Subject | Current Jurisdiction | Current Role | Years EM Experience | Stated EM Expertise       |
|---------|----------------------|--------------|---------------------|---------------------------|
| S1      | Higher Ed            | Preparedness | 1-3                 | Local, Higher Ed          |
| S2      | Local                | Executive    | 10+                 | Local, State              |
| S3      | Local                | Executive    | 3-5                 | Local                     |
| S4      | Other                | Executive    | 10+                 | Local, State, Higher Ed   |
| S5      | State                | Preparedness | 10+                 | Local, State, Healthcare  |
| S6      | Federal              | Operations   | 10+                 | Federal                   |
| S7      | Local                | Executive    | 3-5                 | Local                     |
| S8      | Higher ed            | Executive    | 10+                 | Local, Federal, Higher Ed |
| S9      | Local                | Executive    | 10+                 | Local, Federal            |
| S10     | Local                | Executive    | 10+                 | Local, Federal            |

### 5.4 Coding and transcription

We coded the interview transcripts using Atlas.ti with a deductive-inductive coding process (Thomas 2006). We developed an initial set of codes based on the interview topics and the research questions we wanted to answer with this study. These codes were applied to the interview transcripts, then refined and expanded as new themes emerged from interview responses. We documented all codes and coding decisions using notes in the Atlas.ti project file (Reyes, Bogumil, and Welch 2024).

### 5.5 Data validation

After the EM interviews were transcribed, coded, and analyzed, we emailed the draft Results section to four of our interview subjects and asked them to review our summations and interpretations for accuracy, completeness, and clarity. The four were selected based on their representing different roles and jurisdiction levels in the EM profession.

## 6. Results

We asked emergency management practitioners in Rhode Island to tell us how they make local storm response decisions and what data and tools would help them reduce uncertainty in their

decision-making process. The following section presents our summary of what we learned, accompanied by the interviewees' own statements, organized by theme.

## 6.1 Key decision points

EMs in our subject group identified their key pre-landfall decision points as:

- **Internal Operating Posture:** EMs must decide about opening their own Emergency Operations Center (EOC) and activating pre-determined policies and plans. Often this decision is made several days before landfall, with key personnel directed to arrive before storm conditions begin.
- **Evacuation:** EMs must determine the need for storm evacuation, either city/town-wide or, more often, only for specific low-lying areas. These actions are typically a recommendation but can in rare instances be an order/mandate. Large-scale evacuations take time and considerable resources to carry out; all evacuation activity must be complete before the onset of tropical storm force winds, meaning EMs often need to make evacuation decisions 1-2 days in advance.
- **Road and bridge closures:** EMs may need to recommend road and bridge closures based on expectations of transportation routes that will become unsafe once storm conditions arrive. Often this is linked to evacuation decisions where locations won't necessarily be flooded but will be cut off from emergency services by flood waters and/or high winds that prevent emergency vehicles from getting through.
- **Sheltering:** EMs make decisions/recommendations to open local and/or regional shelters that will house citizens who have to evacuate. Shelters may also be stood up in anticipation of accommodating those whose homes may be uninhabitable after the storm. Shelters may consist of overnight housing or merely comfort stations and warming/cooling centers. Like evacuations, shelters take time and resources to prepare and the process often must begin 1-2 days before landfall.
- **Flood controls and related protective actions:** EMs participate in decisions about protective measures that include closing flood barriers, opening dams to lower rivers, sandbagging and/or boarding vulnerable critical infrastructure. Some of these activities, such as sandbagging, can be done at the last minute but other actions, such as opening/closing flood gates and dams, require more advance preparation.
- **Public alert and warning:** Throughout a storm event, EMs are responsible for issuing messages to the local community using a variety of methods to reach diverse populations. This requires extensive coordination with lateral and vertical partners to ensure information and instructions are clear, relevant, and consistent. Often messaging decisions begin several days in advance of the storm and will information about the other decisions described above.

## 6.2 EMs depend on a variety of tools and data sources

EMs want to base their decisions on good data and try to gather as much information as possible before a storm. S2 explains, “[W]e have an unquenchable thirst for information, like every

Emergency Operation Center has. *We try to plug in with as many good people and ... as many resources as we possibly can.*” Yet EMs accept that they operate largely under conditions of uncertainty and will rarely get all the data they want. *“As an EM, I tend to obsess about data but not be paralyzed by it. I think that’s a trap for some emergency managers as they wait to have all the information and then they’re ... paralyzed by analysis”* (S9). Waring, Moran, and Page (2020) caution that decision makers may focus attention on information gathering at the expense of making decisions and acting on them, but Wernstedt et al. (2019: 102) find that most EMs are naturally averse to acts of omission and inclined to choose action over inaction. S9 explains, *“You could sit around waiting for all the pieces of information, and it’s two days after the storm by the time you get it ... So, at some point you need to make an educated guess.”* This is an example of bounded rationality in practice, whereby EMs lean on their experience in the absence of concrete data.

When preparing for a major storm, EMs rely heavily on forecast data from the National Weather Service (NWS) and National Hurricane Center (NHC). *“[The] National Hurricane Center is very good at what they do, and they know that the end users of their products, emergency management officials, require advance notice and advance notification ... [so] they’re running their models every X number of hours”* (S3). EMs say they benefit from close relationships with staff in their regional NWS office and often consult with them directly prior to major storms. S2 tells us, *“I call them very, very often, and I know most of those forecasters on a first name basis.”* S3 has a similar relationship with the Norton, Massachusetts NWS staff, *“I’m on a first name basis with all the meteorologists at Norton. Which is ... just a factor of we’ve had a lot of bad weather in the last two years.”* EMs in jurisdictions susceptible to riverine flooding also seek forecast data for their rivers and streams. *“We go into the Northeast River Forecast Office [for] the hydrographs they provide for the Woonasquatucket River ... We live in a state [where] villages are still where people gather around. [They] live in areas where mills once were, and in those mills are these rivers that run through it, which pose unique hazards”* (S2).

Of course, EMs need to know how a given forecast is going to impact their community. S2 says, *“A major storm, a major hurricane that brings heavy rains, we’ve got to make a decision as to whether or not we evacuate some of our low-lying areas, and we don’t have a whole lot of time in doing so.”* EMs traditionally lean on experience with past storms when making these decisions under time constraints. S4 tells us, *“...[W]e know what areas will be impacted just based on repetitive storms, whether it be a winter storm or a hurricane. We know there’s just certain areas that are going to flood or have issues every time. So, we definitely use that historical data to guide our responses.”* EMs recognize that even without climate change, changes in coastal development and infrastructure dependence reduce the usefulness of past storms for benchmarking. S3 observes, *“A lot of things have changed in the last 30 years. So, if [Hurricane] Bob were to happen today, I suspect that a storm of exactly the same magnitude, with exactly the same track, would have vastly higher impacts just based on the development that has happened in the last 30 years.”*

Some EMs are already using simulation and modeling to help them predict storm impacts and make the most effective response decisions. S10 explains, *“As the storm comes in, and we’re making that decision to evacuate, and what population should evacuate, understanding what damage might be happening to that piece of infrastructure or that roadway, is extremely valuable to know.”* Here simulation and modeling are useful; the most common tool mentioned in our interviews was HURREVAC (short for Hurricane Evacuation), developed by the Federal Emergency Management Agency (FEMA) to guide real-time decisions about coastal evacuation (National Hurricane Center). *“HURREVAC is definitely something [we use] ... especially at the local level, up to the state level ... a great resource [that] helps to make predictions”* (S4). Some local EMs also utilize the Rhode Island version of CHAMP, known as RI-CHAMP, to predict specific impacts and consequences although the tool isn’t yet available to all Rhode Island cities and towns. S3 describes their experience using CHAMP, *“So that delta of what impacts would produce which results and effects on our critical infrastructure facilities ... RI-CHAMP goes a long way ... to addressing that.”*

Despite having these tools available, EMs encounter challenges maintaining situational awareness about what’s happening in their community. S4 says, *“[G]athering information about what is impacted, what’s closed, there’s always such a time delay, because we don’t always have boots on the ground in all the areas where things happen.”* EMs may tap a variety of data sources to bridge the gap. S4 tells us, *“[T]he most accurate and most timely is crowd sourced information or social media information ... We do a lot of social media screening, whether it be social media sites and stuff like that, local media.”* They may also turn to unorthodox methods. *“We go to certain areas where we know the river is in the roadway, where we put spray paint and cones down on the road, just so that we can get a handle as to whether the river’s coming up, going down, or staying the same”* (S2). S4 says a lack of boots-on-the-ground intel can hamper response and recovery efforts, *“If roads are closed and flooded and washed out and National Grid doesn’t have good information about where those locations are or have the resources to go through and clear streets or roads or debris, whatever it might be, it’s going to delay their power restoration.”* And S9 describes difficulty getting reports back from the field, *“Relying on others’ interpretation of a particular local situation at the street level is sometimes important, and sometimes that’s hard as an emergency manager to rely on information coming back from the field.”*

To synthesize all the information EMs are receiving—both dynamic data about the storm scenario as it unfolds and static data about local infrastructure and floodplain mapping—some EMs employ Geographic Information Systems (GIS) tools. According to S4, *“In recent years, we’ve been working more with GIS. So, taking different layers and displays from those different data sources and compiling them together in a GIS map so that we can really pinpoint and zoom into the areas.”* But other local emergency management agencies have limited resources and lack this capacity. S10 tells us, *“Well, no, I’m not very good at it. So, we have a ... GIS person. He works primarily for [the town’s Planning Department] ... and they’re using him all the time because they need him all the time.”* Such barriers limit the usefulness of GIS at a local level and

underscore the need to deliver tools that local EMs can use with minimal training. *“If you overwhelm that emergency manager or decision maker with too many tools, they won’t use them, right?”* (S5).

### **6.3 EMs weigh many factors when making decisions**

Emergency Managers need to know how an approaching storm is going to affect their communities, including whether their community sits to the left or right side of the anticipated storm track and what the primary hazards will be. In addition to empirical data such as weather forecasts and threat assessments, emergency managers must also consider social, environmental, and technological cues that inform their choices (League et al. 2010; Iman et al. 2023).

According to S2, *“That’s really part of that decision ... not only how close the storm is going to get to us, but also which side of the storm we’re going to be on. Because that is ... what makes us react.”* S4 also pays close attention to the storm track, *“You know, the first couple things that you look at is, is the storm going to track one way or another? Are we going to be on the windy side or the rainy side and the flooding side of the storm?”* The characteristics of a specific storm matter. S2 says EMs want to know if it will be a slow-moving storm with significant precipitation or a fast-moving storm with damaging winds, *“You know, the wind... we just hide from the wind, [but] you’ve got to run from the rain. And that rain is what really makes us decide to open up the emergency shelters.”*

The complexity of storm response decision-making is amplified by the need to think beyond the immediate risk at hand and consider contextual issues such as a population’s mobility for evacuation (Iman et al. 2023). Storm evacuation and sheltering decisions can be highly nuanced from one town to another. Some local emergency managers have authority to make such decisions themselves; in other cases, the EM makes a recommendation, typically to a senior elected official, who has final say. S3 tells us, *“I would make the recommendation to the mayor based on the resources and knowledge that I have, and he would make the ultimate decision.”* In Rhode Island, decisions about sheltering and evacuation are generally made at the local level and state officials serve in a limited role. S4 explains, *“So, our role at the state level, as far as evacuations, is really to provide guidance and recommendations, [and] the decision to actually evacuate is really left to the locals.”*

EMs also need to anticipate how their communities will respond to decisions they make, and public compliance can be a challenge. S3 explains, *“For evacuations, the impact on the public is a major factor. Evacuations are not popular. They can be hazardous. For some individuals, they’re extremely stressful, they’re extremely expensive ... [And] mandatory evacuations have problems with compliance and enforcement.”* Often the need for evacuation is limited to specific vulnerable locations and communities rather than townwide. EMs’ ability to accurately identify such locations is critical. According to S9, *“We have a couple of mobile home parks and a campground, and we’ll go door to door in those places saying, hey, if there’s a hurricane coming this might not be the best place to be and offer them sheltering opportunities.”* EMs must also consider how vulnerable populations will be affected by the

storm and the resources required to support their evacuation if it becomes necessary. *"We're concerned about our vulnerable populations that might not be able to relocate or move, because they're going to need a high level of assistance"* (S4). Rhode Island has a statewide Special Needs Emergency Registry that state and local officials often reference when preparing for major storms and other types of emergencies. *"We work with the Social Services Department ... She knows where all the [people] are that may need some special attention and giving her some resources to check on those folks has been a successful strategy in the past to make sure people are not in in in harm's way that we could have prevented"* (S9).

#### **6.4 Limited time and information constrain EM decision-making**

To minimize avoidable consequences, EMs need specific, localized information they can use to make decisions, and they need sufficient time to implement those decisions. S4 says, *"[We want to know] are there any facilities that we're concerned with that might be impacted, whether it's from wind, water, tornadoes, whatever it might be."* But EMs have difficulty accessing such specific data. S4 says, *"We still don't have the ability to predict exactly what the impacts from a hurricane are going to be down to a street or neighborhood, or even a town-by-town area."* Although it has no particular scientific basis, EMs in Southern New England frequently reference a hurricane passing the Carolinas as the point when they start to have confidence in the storm track; Often this is too late, as S2 explains, *"[B]ecause storms move so very quickly, as soon as they start making that that jog up the coast, unlike other parts of the country, where you can say we're still days away, you may have a storm that's right off the coast of South Carolina. Next thing you know, it's at our back door knocking."* The Hurricane of 1938, for example, closed that gap in a little over 24 hours, earning the storm's nickname 'The Long Island Express.'

Emergency managers want to start making decisions ideally when the storm is still four to five days away. S8 says, *"Once it gets within probably five days, we start meeting on a regular basis and determine what's going to be the impact."* But there is often a great deal of uncertainty remaining in the forecast that far out. S4 reports, *"At [my agency], 72 to 96 hours out, we're still trying to determine what the impact from the storm will be to Rhode Island in general"* This puts EMs in a time crunch. According to S2, *"I like to say we have 96 hours, but we really don't. We have to usually make it the 72- to 48-hour window."* S8 says, *"You don't know until it's two days out, and by two days out, you need to already be doing everything."* So, while five days would be an ideal lead time, local EMs in Rhode Island typically have a window of only 2-3 days to decide and act. Evacuation and sheltering generally require more lead time than this; These actions must be completed before storm force winds arrive, which can happen as much as twelve hours ahead of the actual storm. *"It takes time to actually ... reverse traffic or to make arrangements to open shelters"* (S5). This forces EMs to gamble on forecasts, acting before there is reasonable confidence storms will even reach Rhode Island. Deploying resources so far in advance, with so much uncertainty, can be hard to justify. According to S6, *"It's very difficult at 96 hours to suddenly put resources towards mitigation, because it can change."*

EMs say they often encounter gaps in forecast data, particularly riverine and flash flooding predictions. The overall quality of current forecast products from NWS and NHC isn't a problem. S3 observes, *"Storms are unpredictable, even with the best forecasting materials, and the forecasting models that they have now are better than they've had in history."* But forecasts often lack the granularity local EMs need to decide on storm response actions. NHC surge models are generalized over a wide area and don't predict what flooding may result once the storm surge flows beyond the high tide line. *"We know a Category One hurricane is going to impact the coast, and here's the impacts. So, we're telling the people in Westerly the same preparedness information that we're telling people in Little Compton where they might see completely different impact from the storm"* (S4). The U.S. Army Corps of Engineers' 'SLOSH' model is similarly limited. S5 says, *"It is not [localized] at all, it's [only] going to tell me 'coastal flooding Rhode Island.'"* This makes it difficult to advise residents, as happened in 2012 with Hurricane Sandy. *"I don't think anybody anticipated that Westerly was going to see such impacts that they did, whereas South Kingstown, Narragansett, they literally saw almost nothing. They had power outages but didn't suffer [the same] impacts"* (S4).

Predicting urban street flooding has become a major challenge for some local EMs. S3 tells us, *"The area in which we have seen unexpected impacts that were beyond our preconceived preparations, has been flash flooding events ... If we had better flash flooding modeling or street flooding modeling, we could be advising homeowners on where they need to be buying flood insurance."* Riverine flooding, which isn't part of NHC hurricane modeling, presents a similar challenge for rural EMs. According to S2, *"This is one of the biggest problems that we have. We can't get reliable information as to what the river is doing ... I can tell you that's the most frustrating part. Our biggest vulnerability is the river that runs through the town, and then all of the sudden, we hear 'poof.' And the river stays at 6.6 feet for the next six, seven hours."*

EMs also struggle with public complacency resulting from previous false alarms and near misses. *"I mean, the problem you got is complacency, right? Like, the last one that came up was just underneath a hurricane, wasn't a lot of damage in town. And then people go, well, nothing happened last time, and that's what we fight"* (S9). This results in part from a lack of recent experience with major hurricanes in Rhode Island. S3 says, *"We have not had a significant landfalling storm in the 30 years since Hurricane Bob. So, the lived experience of most people in this realm are much smaller storms."* This can give local residents a false sense of security. S10 reports, *"A lot of them have said, 'We've been through Hurricane Bob, and survived. I'm not going to leave.'"* Locals may also complain when their EM officials ask them to prepare for a storm. *"[We try] to be as broad as we can without losing the interest of the public and our partners who say, 'Oh, you know, every time there's a storm in the ocean, you give us this checklist that we have to run through'"* (S2). EMs also note that the experience of residents living on the immediate coast can be vastly different from those just one town inland. S2 tells us, *"When you hear 'coastal storm,' we still have a lot of people who sit back and say, well, they don't mean us."* The contrast in levels of engagement between a coastal town and a neighboring

community on their inland side can be stark despite the proximity. S9 says, *“It’s completely different ... yet I can be from [my town] to the harbor in [the next town over] in ten to twelve minutes, right?”*

## 6.5 Data gaps can lead to uncertainty and negative outcomes

EMs typically operate in an environment of uncertainty when making emergency response decisions. S3 tells us, *“There’s always a data gap, because the degree of certainty is always a variable factor.”* EMs are often forced to make or recommend pre landfall decisions without a full understanding of the situation. This is especially problematic when present day storms exceed EMs’ previous experience, leaving them without a reliable reference point for heuristic decision making. S6 says, *“Incomplete information is probably the rule ... It would be a rare day that I was making decisions based on a full suite where I have sat back in my desk and gone, okay, that’s absolutely everything, here’s my decision. That ... never happens.”* We asked interviewees how often storm impacts result in cascading consequences, whereby an initial impact results in additional hazards, consequences, and impacts. S7 responds, *“I’d say probably most of the time”* and S5 says, *“Yes, would be the simple answer.”*

EMs can struggle to anticipate the impacts of even minor weather events because of changing precipitation patterns. According to S3, *“What we’re seeing is tremendous variability in the amount of rainfall, even within a relatively small geographic area ... We are now up to 13 flash flooding events in the last two years ... and those have been extraordinary events, in that they had massive damage outside of flood zones.”* This can lead to negative outcomes that EMs weren’t anticipating and/or weren’t prepared for—outcomes that are potentially avoidable given better (more specific, localized) storm hazard predictions. S2 reports, *“Practically every three weeks there we had to close down that road, and those were high impact, heavy rainfall storms of three and a half to four and a half inches ... If the river is continuing to go up and we have another three hours of storm over here, we’re going to have to make ... a decision as to whether or not we get people out of town.”*

The problem of data gaps was evidenced in 2012 by Hurricane Sandy, which caused extensive damage along a portion of Rhode Island’s southern coastline while leaving other communities untouched (see **Error! Reference source not found.**). *“I think if you look at Sandy, that’s probably a good example where data said one thing and then other things happen, and nobody really expected to get the flooding and that type of erosion that occurred with Sandy”* (S7). And according to S4, *“[If you] look back to Hurricane Sandy and some of the other storms that we saw in that time period ... I don’t think that the impacts that we ended up seeing were what was predicted.”* The result can be impacts that might have been avoidable given more specific predictions delivered further in advance. S4 explains, *“The consequence was that ... their coastline really took a major impact ... The sand was washed up onto shore, businesses and homes were impacted based on the weather and the erosion and the flooding that took place ... There’s a lot of those actions that take a little bit longer that they could have done*

524 *that would have helped to lessen the impact from flooding and beach erosion and the migration*  
525 *of sand.” EMs say the recurring theme is a lack of information about specific, local impacts.*  
526 *“We don’t have the ability right now to have a more granular view of what the impacts will be”*  
527 *(S4).*

## 528 **6.6 Lateral and vertical coordination is essential**

529 Although Rhode Island’s cities and towns have significant autonomy when it comes to storm  
530 response decisions, vertical and lateral coordination is essential. S4 says, “[T]he locals rely on  
531 data and storm information from the state and state recommendations, and coordination with  
532 our other coastal communities ... Coordinating the resources together with all the local  
533 communities is pretty significant, because we want to make sure that one community is not  
534 monopolizing any resource.” There’s also a need to coordinate with NGOs and private partners,  
535 according to S4. “The coordination pieces, especially when we’re talking about sheltering,  
536 because there’s other partners involved in sheltering from Red Cross.”

537 Coordination can be hampered by the lack of a common operating picture across  
538 agencies. S4 tells us, “In my experience, both at the state and local level, when I talk about the  
539 coordination between all the entities ... the public, private partners, state government, local  
540 government, you know, we’re pretty good at communicating. We’ll get on a conference call and  
541 kind of talk and stuff like that, but what I think we’ve always been lacking is that visual tool or  
542 system to actually guide those conversations.” The Rhode Island Emergency Management  
543 Agency uses Juvare WebEOC™ to manage information during storm responses, but local  
544 partners have limited access to the system and FEMA has none. According to S4, “FEMA uses  
545 WebEOC, [but] they have their own instance of it ... it’s not connected to and it doesn’t share



**Fig. 3** Damage to Rhode Island’s southern coast caused by Hurricane Sandy, 2012 (Figure: The Providence Journal)

Rhode Island's WebEOC. So, while we might have FEMA embedded in our EOC to share the information, there's no direct linking." Local EMs need better data aggregation tools so they can make decisions jointly instead of operating in silos. "We can talk about things, but until you can pull it up on the screen and visualize it and visualize it all together as one... one common operating picture, working together, I think would make a big difference in helping to share information with all the partners" (S4). This builds public confidence and media trust according to S10, "Having that data that is common to everybody is vital to confidence, not only in me making and justifying a decision, but also in public confidence."

## **6.7 Implementing technology to improve decision making**

Many EMs are interested in using more technology, such as decision support tools like CHAMP, to reduce uncertainty and supplement their traditional reliance on knowledge of past storms. S3 says, "I think there needs to be more of a focus on using scientific measures that we have at our disposal and not just measuring things as 'Oh, well, in this storm in X year XYZ happened,' because the conditions that we're facing are notprecedented. They're not going to be the same as what happened last time." EMs also want to see how new tools can fit into their decision process and storm preparation workflows. S2 says, "I would definitely look at some of the modeling. I would use some of the forecasts that more local systems could help us generate. I would make that part of our decision process so that we can ... change some of the perspectives."

GIS technology can support such collaboration when leveraged with tools like CHAMP. "If you can present easy to read, easy to follow products such as mapping GIS ... that's huge, because now you've got something visual that assists with decision making" (S5). Tools like CHAMP offer the potential to improve collaboration and information across jurisdictions and critical infrastructure sectors. S6 explains, "Being able to definitively say this is the impact to me, but also having the guy next to you who is using my stuff to say, 'Oh, wait, what do you mean? It's going to impact you. Tell me more about that.' And to have that kind of understanding and knowledge that you can drag across all the functional areas, because it is all one interwoven system that you won't find the lynchpin until it fails."

Supporting more effective storm decision making for EMs isn't just a question of more and better data, but how the data is synthesized and interpreted. According to S6, "Having a common operating picture, something you look at to actually do the predictive modeling and then overlay with what is critical within those areas is really the white whale when it comes to emergency management, to be able to get to that. That's the real goal, the dream." EMs need a complete, detailed understanding of the hazards they're facing for a given storm, the likely direct impacts, and the potential secondary effects of those impacts. S4 elaborates, "[T]he cascading consequences of things are not always entirely obvious. So, knowing kind of, hey, this takes out this, which then leads to this, would be pretty important." Ideally EMs would rely more on deterministic data less on instinct and experience. According to S6, "To get to the point where we can absolutely make decisions based on predictive analysis ... There are a lot of variables that

585 *are going to go into this, and a lot of that variability comes from cross walking the information*  
586 *from each of the affected areas...”*

## 587 7. Discussion

588 Bounded rationality is useful for making decisions about routine, relatively predictable weather  
589 events that are consistent with EMs’ experience and knowledge of past storms. But this approach  
590 is less reliable when responding to major storms that exceed historic precedents, especially for  
591 communities that may not have experienced a major hurricane in decades. In the bounded  
592 rationality construct, decisions are informed by the knowledge decision makers may or may not  
593 have of the world and their ability to call up that knowledge when needed, come up with various  
594 courses of action and the potential consequences of each, navigate uncertainty, and prioritize  
595 among competing demands of others (Simon 2000; Iman et al. 2023). Under pressure and  
596 lacking sufficient data, EMs may revert to a decision-making model wherein they determine a  
597 course of action by trying to match environmental cues to past experience and identify a  
598 workable solution (Waring, Moran, and Page 2020). This heuristic approach works so long as the  
599 situation at hand fits EMs’ knowledge of previous storms, but falls short when trends such as  
600 Rapid Intensification and changing coastal development present scenarios beyond EMs’ comfort  
601 zone.

602 When responding to a major ocean storm, EMs in coastal communities need detailed,  
603 actionable information about potential storm impacts so they can recognize avoidable  
604 consequences and act to minimize loss (Stempel et al. 2018). Implementation research is helping  
605 us build decision support tools that reflect EMs’ real-world data needs based on the decisions  
606 they need to make. Understanding the choices EMs make when preparing for a major storm, and  
607 identifying the data most useful to them when making those decisions, ensures our tools are  
608 streamlined and tailored to their specific needs. Cantor (2021) calls this “decision driven data  
609 design” whereby the data system is designed around the questions users need to answer with data  
610 produced by the tools. Our end goal with CHAMP is to help EMs identify and reduce avoidable  
611 consequences of hurricanes, tropical storms, and nor’easters. Our study has key implications for  
612 building and implementing storm hazard consequence prediction tools that help local EMs make  
613 decisions during their response to for a major ocean storm (hurricane, tropical storm, nor’easter):

- 614 • Local EMs’ key pre-landfall storm decisions include evacuation of flood-prone areas,  
615 shelter openings, road and bridge closures, flood controls and protective actions, com-  
616 modities distribution, and their own agency response posture.
- 617 • EMs frequently encounter gaps in forecast data when their needs exceed what’s included  
618 in NHC advisories, such as predictions for riverine and urban street flooding. And many  
619 of the actions EMs take, such as evacuation and sheltering, require more lead time than  
620 forecasts currently provide.

- Local EMs have difficulty accessing specific, actionable information about the likely impacts of a given storm in their community, especially cascading consequences. This increases their reliance on experience with previous storms when making decisions.
- EMs use bounded rationality to make decisions in tight timeframes with limited information, relying on past storm experience to bridge information gaps and identify solutions. They recognize climate change is making historic storms increasingly unreliable as planning benchmarks as is growing societal dependence on critical infrastructure and changing development patterns that make it difficult to anticipate how a given storm will interact with the present-day built environment.
- EMs see value in advanced decision support tools like CHAMP and want to make better use of science when making critical storm response decisions. However, many have limited resources to implement new solutions without considerable outside support. Regardless, all the EMs we interviewed want to see more than predictive data from CHAMP and similar tools; they want solutions that help them build situational awareness and facilitate a common operating picture across agencies and jurisdictions.

## 8. Conclusion

We asked ten (10) emergency management practitioners to tell us about local storm response decision making to better understand how a decision support tool like CHAMP reduces uncertainty and improves decision making. We learned that many of local EMs' existing tools and data sources aren't giving them the information they need in the timeframe they need it. The EMs in our study describe information gaps leading to uncertainty, which can encourage ad hoc decision making and unstudied choices. Without the information they need, EMs work under time pressure to merge what data they do have with their experience and intuition and come up with the best options to reduce losses and minimize avoidable consequences (Iman et al. 2023). The lack of accurate storm consequence predictions is associated with negative outcomes that may be avoidable if decision makers have better data (Adams et al. 2026).

Our findings improve our understanding of EMs' response decisions for major ocean storms while validating previous studies of bounded rationality in the emergency management context by League et al. (2010), (Iman et al. 2023), and Glarum (2020). We are using our study to implement CHAMP with state and local EMs and ensure CHAMP delivers data useful to them in an easily accessible format. While our discussion focuses largely on CHAMP, our results are relevant to others developing simulation-based support tools.

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## 10. Appendix A: Interview Protocol

**Subject Name:** \_\_\_\_\_ **Interview Date:** \_\_\_\_\_

### **INTRODUCTORY SCRIPT (Read to subject):**

Thank you for agreeing to participate in this interview. The purpose of the research study is to understand how your emergency management organization predicts/anticipates the impacts of various storm hazards to improve vulnerability assessments and storm preparedness. This includes use of computer-based simulations such as the Coastal Hazards Modeling & Prediction (CHAMP) system. Your participation will provide crucial input regarding how local decision-makers and emergency management practitioners may use tools like CHAMP to improve emergency planning, emergency response, and hazard mitigation in the future. Findings from this study may be used in professional journals, presentations, or other publications. Unless express permission is granted by you to share quoted information, reported results of this study will not identify you, or any individual as a participant in this project. The interview should take about 30 minutes and the interview protocol has been approved by the University of Rhode Island Institutional Review Board. You receive no benefits in exchange for your participation. As we go through the interview, please try to answer questions from your own individual perspective as an emergency management professional. If it makes sense at times to speak from the broader perspective of the organization where you work, please be sure to let me know when that's the case. Also, because this is academic research, it's important that you please provide a full response to each question as if I, the researcher, have little or no knowledge of the subject at hand. Do you have any questions before we begin?

### **SURVEY QUESTIONS AND PROMPTS**

First, I would like to capture some basic information about you and your professional role. Could you please state your name.

What is the name and location of the agency/organization where you primarily work as an emergency manager? Does your jurisdiction include locations within 50 miles of coastline? What type of agency/organization do you work for and what is your jurisdictional level?

- Ex: federal, state, local, tribal, regional, other

What is your title and emergency management role in that agency/organization?

- Examples: executive leadership, planning, operations, administration, etc.

What experience do you have in storm preparedness and response?

- How many years of experience do you have in emergency management
- Prior experience with major ocean storms

Next, we'll talk about some of the decisions you make as part of storm response.

Can you please describe some of the key decisions do you (or your agency) need to make in the 72-96 hours prior to landfall for a major ocean storm (hurricane, tropical storm, nor'easter)?

- 801 • Who makes the decisions and how they make them, what's the chain of decision making
- 802 • What information sources are used/relied upon
- 803 • Are there barriers to effective decision-making

804

805 Where do you get the information you rely on when making pre-landfall decisions?

- 806 • Does it include real-time/storm-specific predictions (e.g. HURREVAC) versus general-  
807 ized/static (e.g. floodplain maps)
- 808 • What are the sources, how timely is the information
- 809 • Do you typically refer to previous storm impacts
- 810 • Does your agency share information with external partners and/or receive information  
811 from other agencies

812

813 Do you currently have an inventory of vulnerable critical infrastructure you automatically  
814 consider when preparing for a major storm's landfall?

815 Do you currently use a real-time decision support tool (e.g. HURREVAC, RI-CHAMP) for pre-  
816 landfall decision making? How has it changed your approach to decision making?

- 817 • What tool(s) are used
- 818 • How do they fit into decision making (and how has incorporating that tool changed deci-  
819 sion making versus previous approaches)
- 820 • If not, what are the barriers that prevent you from doing so?

821

822 Does your agency currently use GIS tools and how?

- 823 • Is GIS data available and used in the EOC during storm preparations?
- 824 • Is GIS data used for longer term planning and hazard mitigation?

825

826 To what extent do you encounter barriers that impact your ability to make effective pre-landfall  
827 decisions? Can you describe some of these barriers?

- 828 • External, internal, cultural/political, administrative...

829

830 How often do you find yourself making pre-landfall decisions made with incomplete  
831 information? In other words, are there data gaps that you must deal with when making pre-  
832 landfall decisions?

- 833 • What specific information is often lacking
- 834 • How would it make a difference if you had it
- 835 • Are there barriers to getting the information you need to make good decisions

836

837 Let's talk a bit more about storm consequences and outcomes.

838 Would you agree with the statement: "Minimizing the negative consequences of major ocean  
839 storms is a natural goal of the emergency management process in terms of both long-term  
840 mitigation and preparedness activities and real-time response and recovery"?

841 How have information gaps resulted in storm impacts and consequences that you either didn't  
 842 anticipate and/or weren't fully prepared to deal with?

- 843 • Can you provide some examples of unanticipated impacts and consequences
- 844 • Have there been cascading effects that resulted from those impacts and consequences
- 845 • Were the consequences truly unanticipated, or were they foreseen but adequate prepara-  
 846 tions were not made?

847 How often do storm impacts result in cascading consequences, where an initial impact results in  
 848 additional hazards, consequences, and/or impacts?

- 849 • How easily can you anticipate these ripple effects?
- 850 • Can you provide examples?

851 To what extent do you believe such consequences would be avoidable if you had access to more  
 852 extensive, detailed, or specific prediction data for storm impacts?

- 853 • Relationship to current information/data gaps
- 854 • How would that additional information be used to prevent unanticipated consequences

855 Can you tell me more about the specific information that would help you make better decisions,  
 856 such as more detailed, localized storm forecasts or more specific impact predictions and  
 857 vulnerability assessments?

858 Lastly, I would like to talk about emergency protective measures, steps you might take as part of  
 859 your storm response to limit damage and loss.

860 When responding to a major storm, what measures can you take to prevent negative  
 861 consequences if you know about them far enough in advance? Can these measures materially  
 862 change storm outcomes for your community?

- 863 • Are there additional actions you can take to mitigate consequences if you know in ad-  
 864 vance that specific impacts are likely to occur?

865

866 Are emergency protective measures typically focused on preventing the hazard itself or  
 867 managing potential consequences? Or both?

868 And to what extent do you decide on emergency protective actions based on storm-specific  
 869 analysis (such as modeling and simulation) versus general experience with past storms or  
 870 professional instincts?

871 In addition to the information you've already provided, is there anything else you would like to  
 872 point out or anything that you think was missing from our conversation?

873

874

## 875 11. Statements and Declarations

### 876 11.1 Funding

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### 881 11.2 Competing interests

882 The authors have no relevant financial or non-financial interests to disclose.

### 883 11.3 Author contributions

884 Both authors contributed to the study conception and design. Material preparation, data  
885 collection and analysis were performed by Samuel Adams. The first draft of the manuscript was  
886 written by Samuel Adams and both authors commented on previous versions of the manuscript.  
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