Modeling Hurricane Evacuation Warnings: Effects of Message Content and Timing on Risk Perception and Response

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Acknowledgement: This research was supported by the National Science Foundation under Grant CMS 1760766 and the US Army Corps of Engineers under contract W912HZ2020055. None of the conclusions expressed here necessarily reflects views other than those of the authors.

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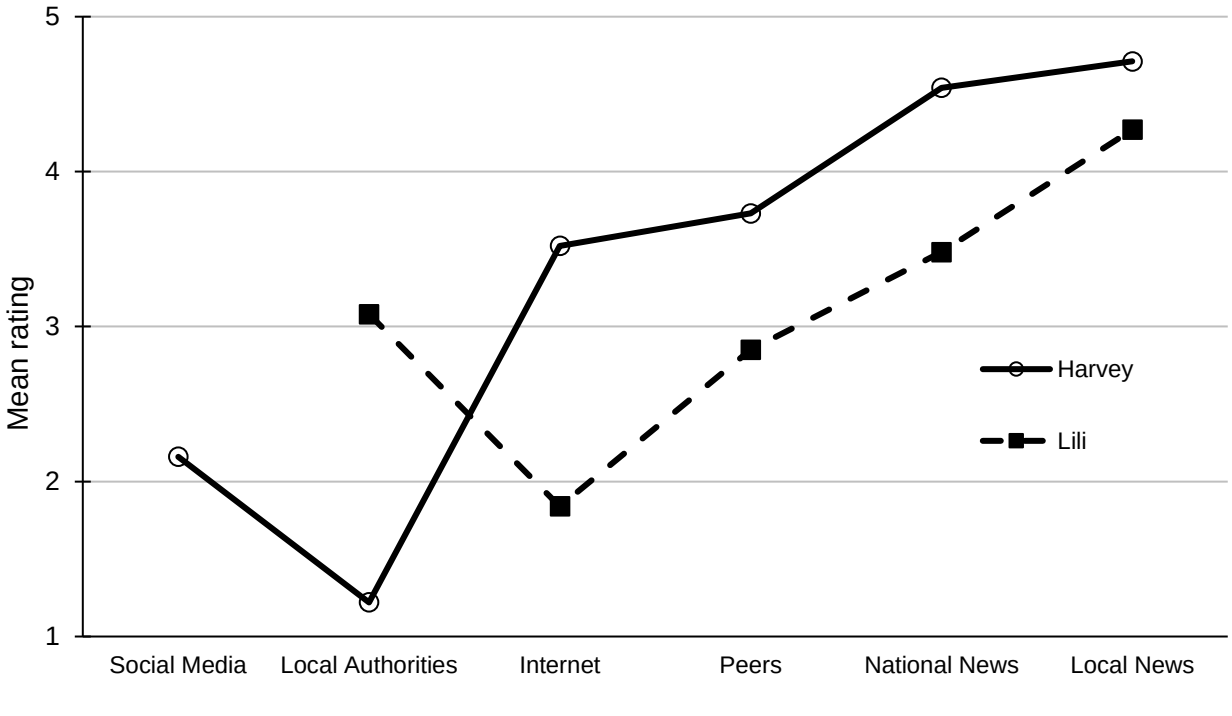
Warning Process

It is well understood (see Lindell et al, 2019a) that evacuation decisions and evacuation logistics (departure time, evacuation mode, route, destination, and accommodations) are affected by:

- Warning sources,
- Warning channels, and
- Warning message content/format

Lindell, M.K., Murray-Tuite, P., Wolshon, B. & Baker, E.J. (2019a). *Large-Scale Evacuation: The Analysis, Modeling, and Management of Emergency Relocation from Hazardous Areas.* New York: Routledge.

Frequency of Consulting Hurricane Information Channels



1 = 0/day; 2 = 1-2/day; 3 = 3-4/day; 4 = 5-6/day; 5 = 7+/day

Lindell et al. (2005); Lindell et al. (2020)

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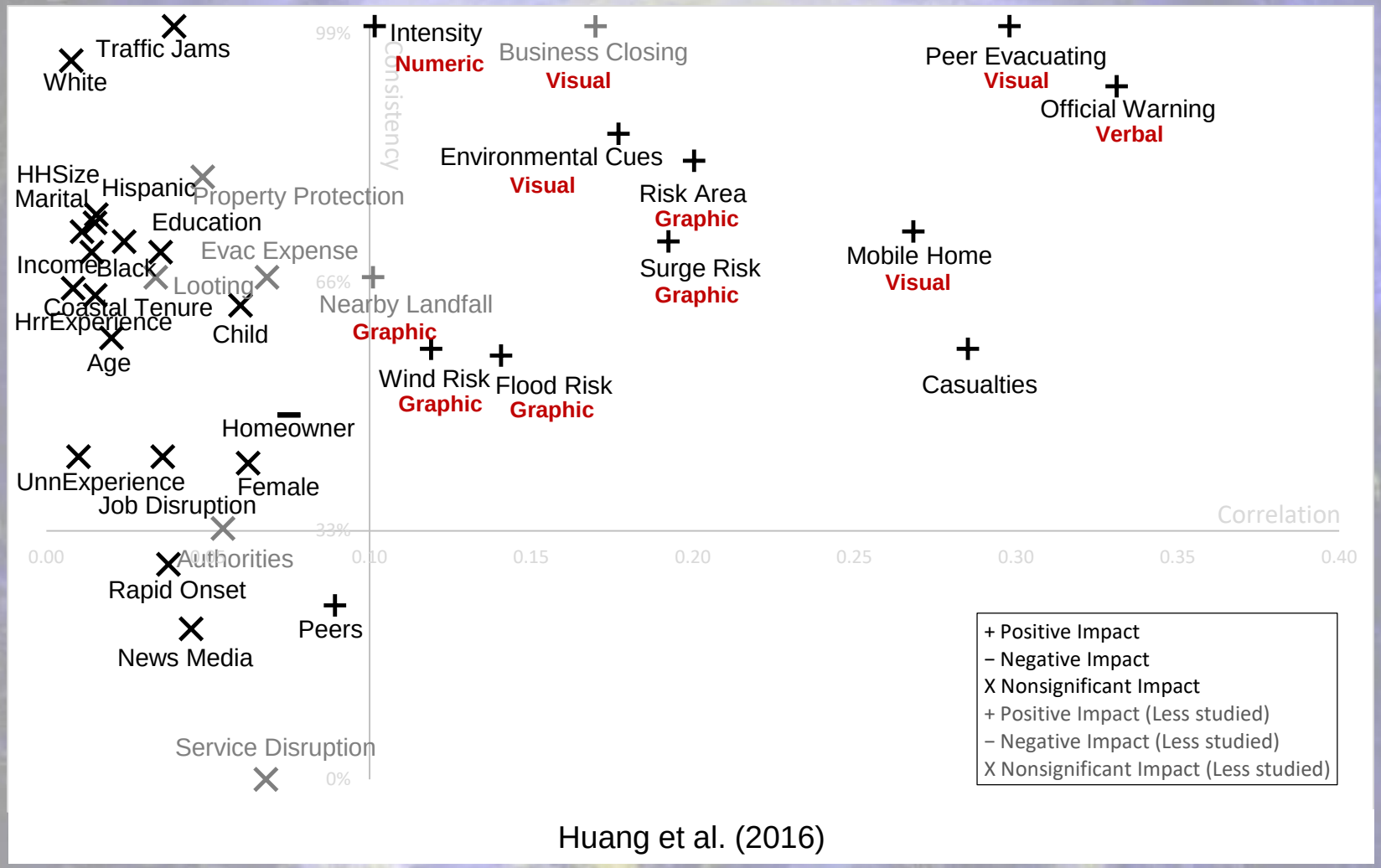
Predictors of Evacuation



Huang et al. (2016)

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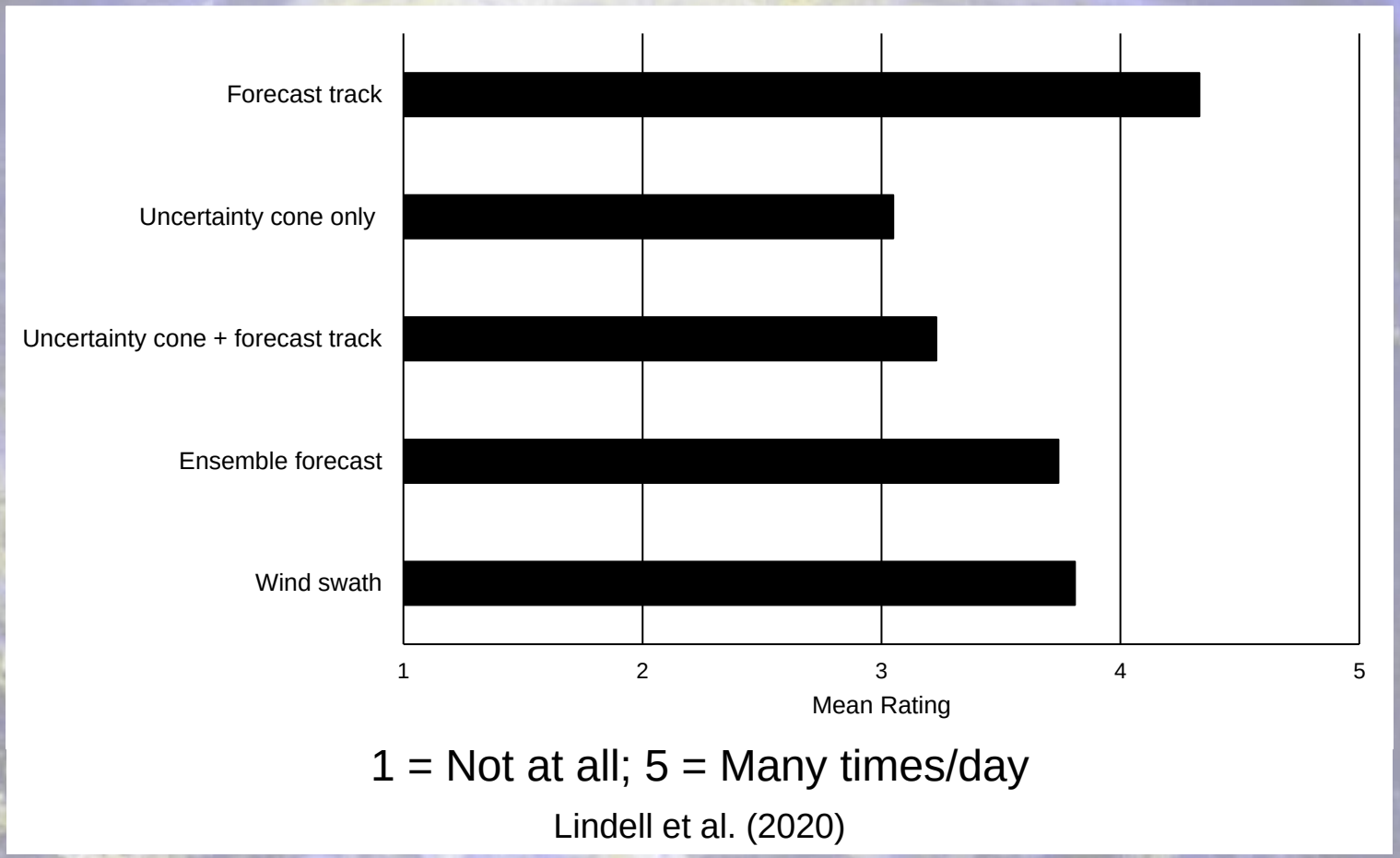
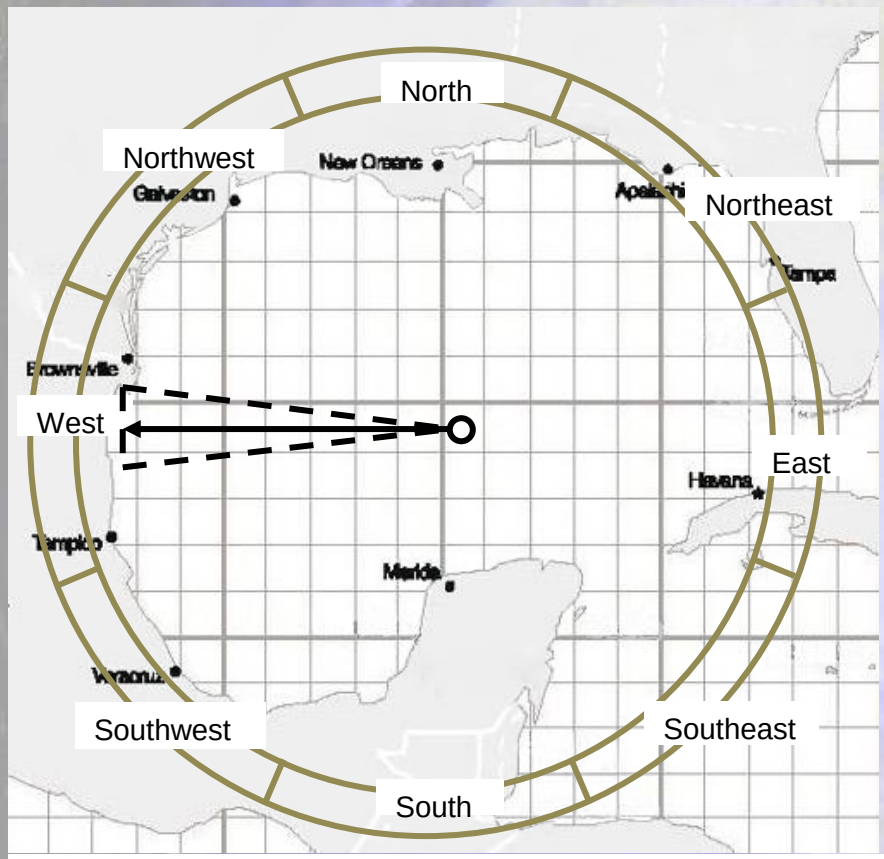
Respondents' Views of Hurricane Harvey Graphics

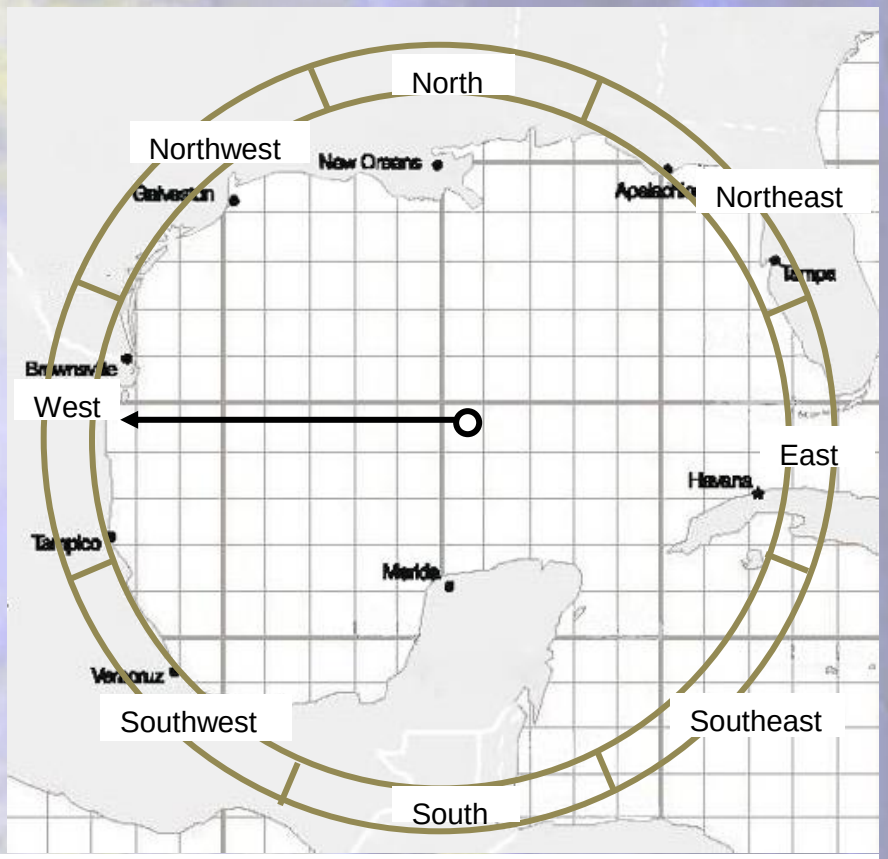


1 = Not at all; 5 = Many times/day

Lindell et al. (2020)

Cone vs. Track Display





Wu et al. (2014)

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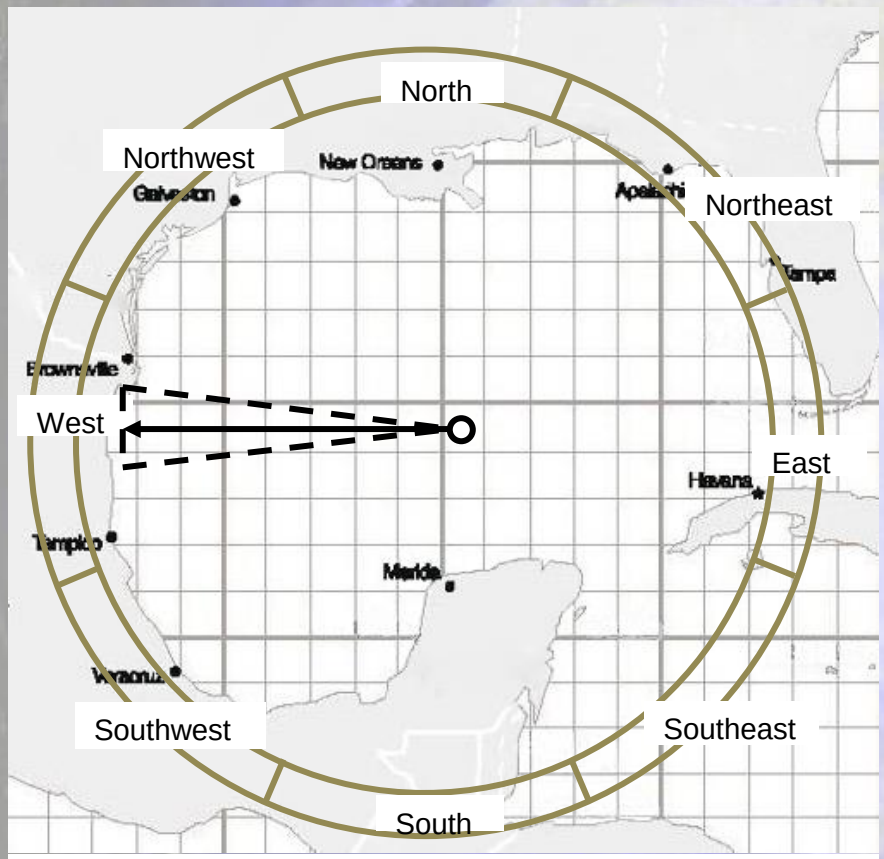
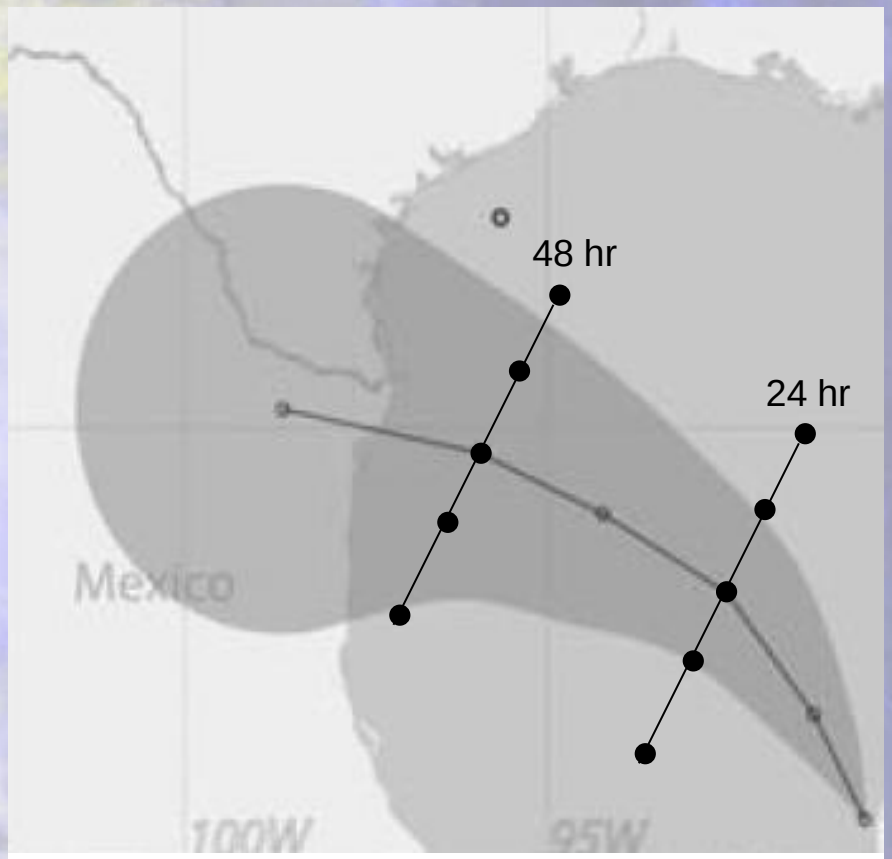
Cone vs. Track Display



Wu et al. (2014)



Ruginski et al. (2016)

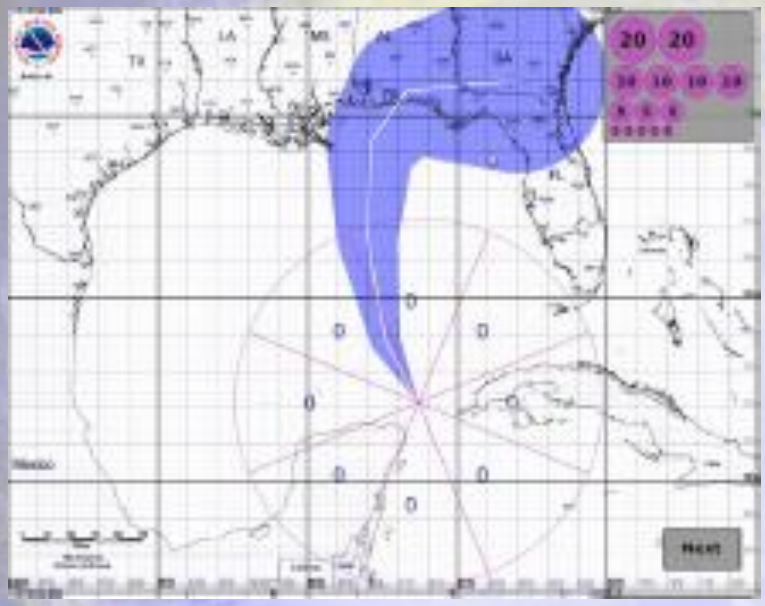
Research Findings on Storm Displays

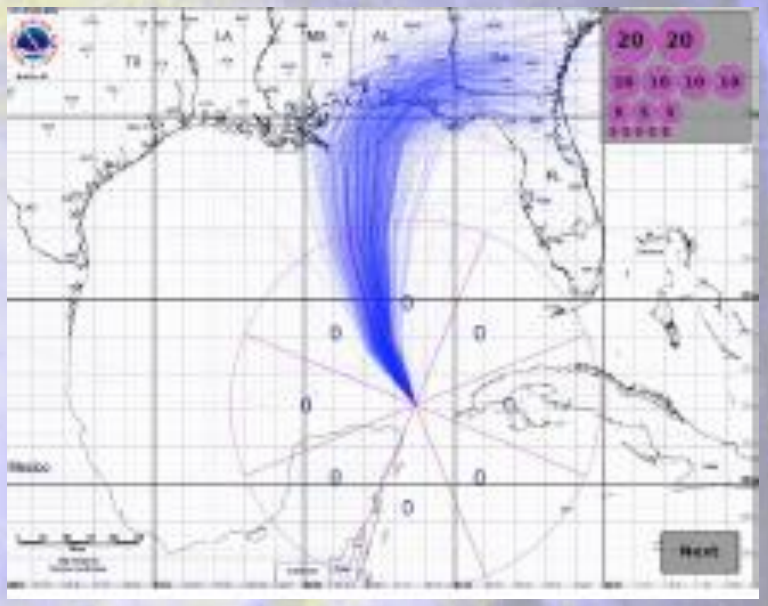
- There does not appear to be an *edge effect* in which people perceive a zero probability of the track moving outside the uncertainty cone (i.e., Broad et al., 2007)
  - > Instead, people appear to rely on a proximity heuristic.
    - Wu et al. (2014) found that perceived strike probability decreases with distance from the projected point of landfall but is not zero anywhere, even in the opposite direction of the track.
    - However, there might be a framing effect in which perceived strike probability is affected by the scale of the map.
  - > Moreover, some people misinterpret the uncertainty cone's increasing cross-section as increasing storm size (Ruginski et al., 2016; Padilla et al., 2017).
    - This suggests that these viewers confuse the uncertainty cone with the hurricane wind swath, which might affect evacuation shadow laterally along the coast but probably not warning compliance in designated evacuation zones.

Research Findings on Storm Displays

- The *increasing storm size illusion* is unsurprising because other research has shown that some people have poor map comprehension.
  - > Many people misinterpret map contours (Arlikatti et al, 2006; Zhang et al., 2004), and
  - > Some even are unable to use the compass and scale correctly (McPherson-Krutsky et al., 2020).
- There is little research on training to improve map comprehension.
  - > An attempt to reduce the *increasing storm size illusion* associated with the uncertainty cone had minimal effect (Boone et al., 2018).

Cone vs. Ensemble Display

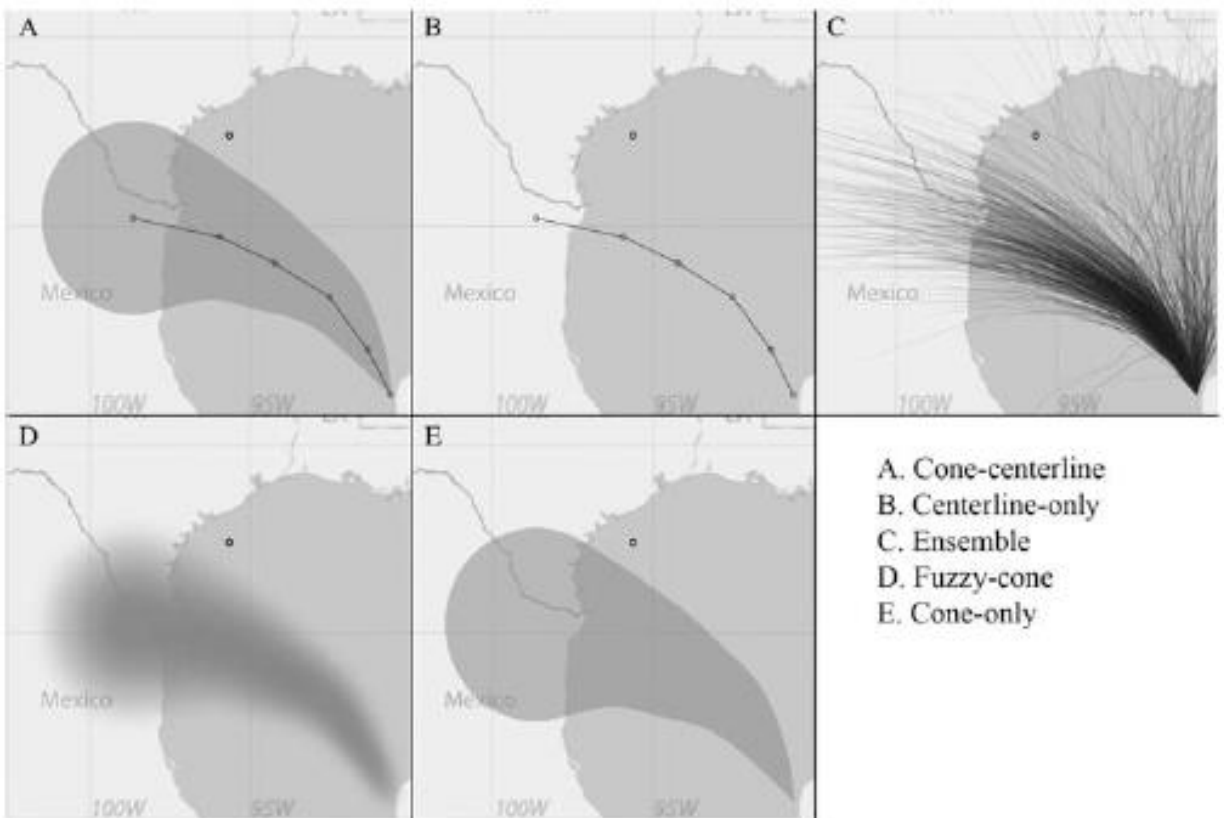




- There is relatively little research on the effectiveness of alternatives to the track and cone such as track ensembles.
  - Cox et al. (2013) found little difference between track/cone and ensemble displays.

Multiple Display Comparison

However, Ruginski et al. (2016) compared multiple visualizations in terms of the distribution of estimated damage to drilling platforms 24 hr and 48 hr in the future.



Ruginski et al. (2016)

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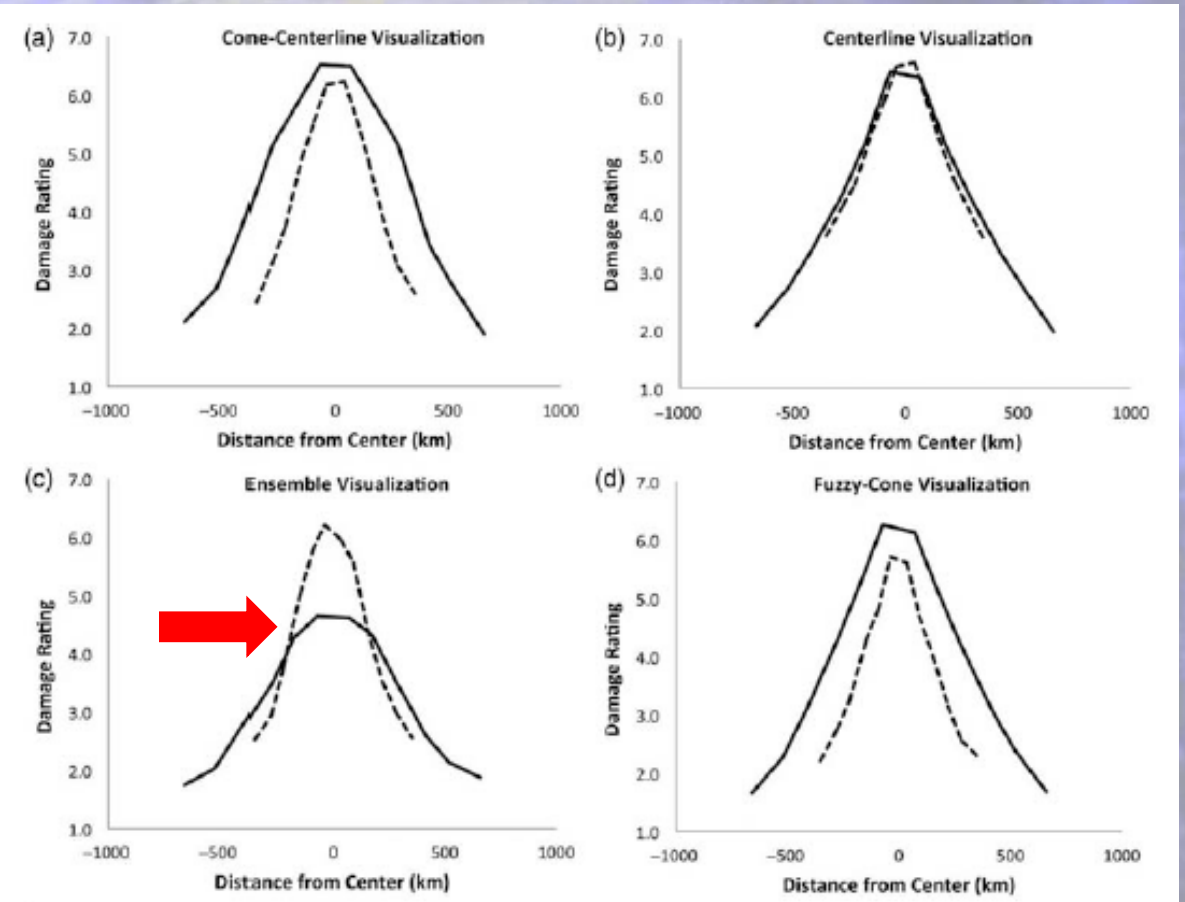
Multiple Display Comparison

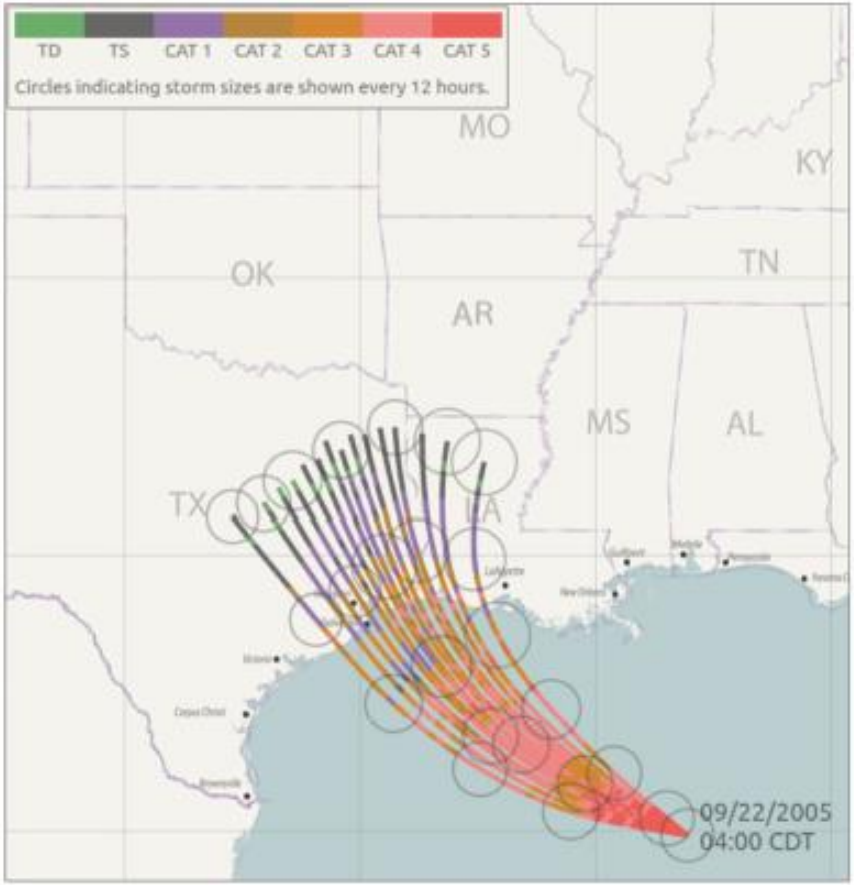
They found that the ensemble visualization was the only one that produced a flatter distribution of damage estimates at 48 hr than at 24 hr



Ruginski et al. (2016)

Future Research on Storm Displays

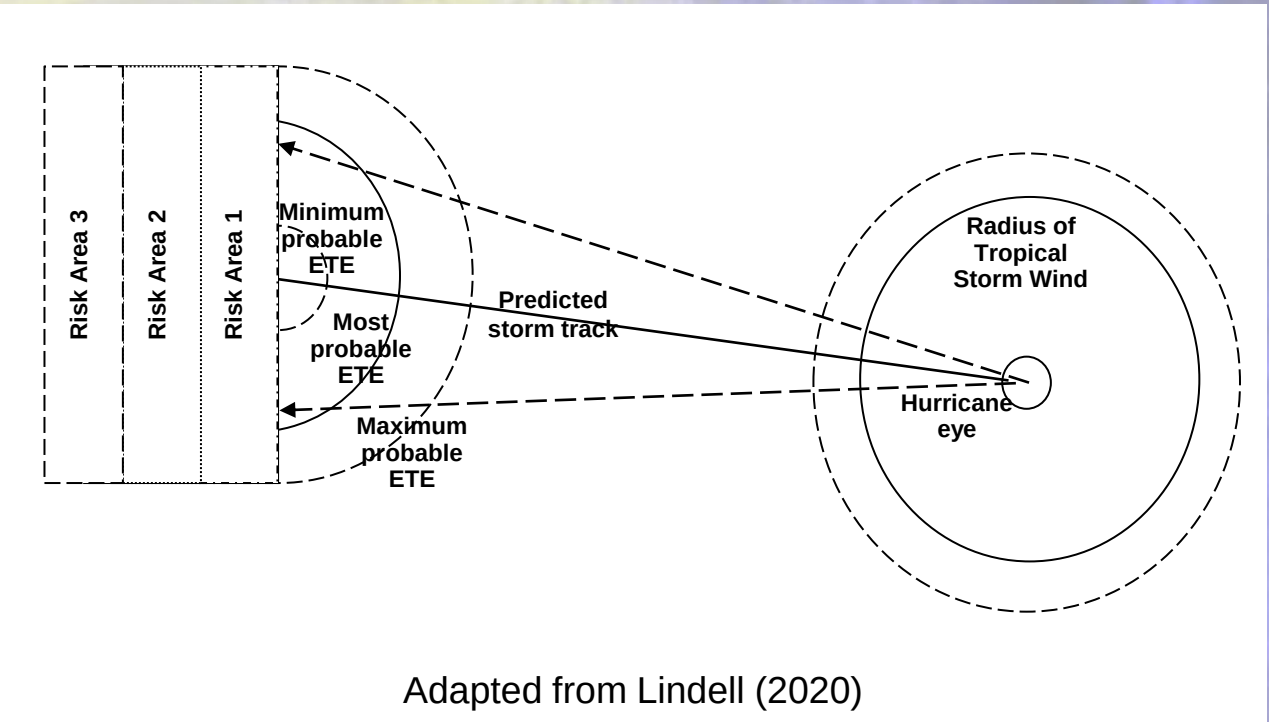
- Future research could compare the track and cone to a multi-parameter storm display that provides information about the track/center location, size, and intensity.
  - > However, this display is likely to be too complex for anyone other than local meteorologists and emergency managers with specialized training.



Liu et al. (2019)

Future Research on Storm Displays

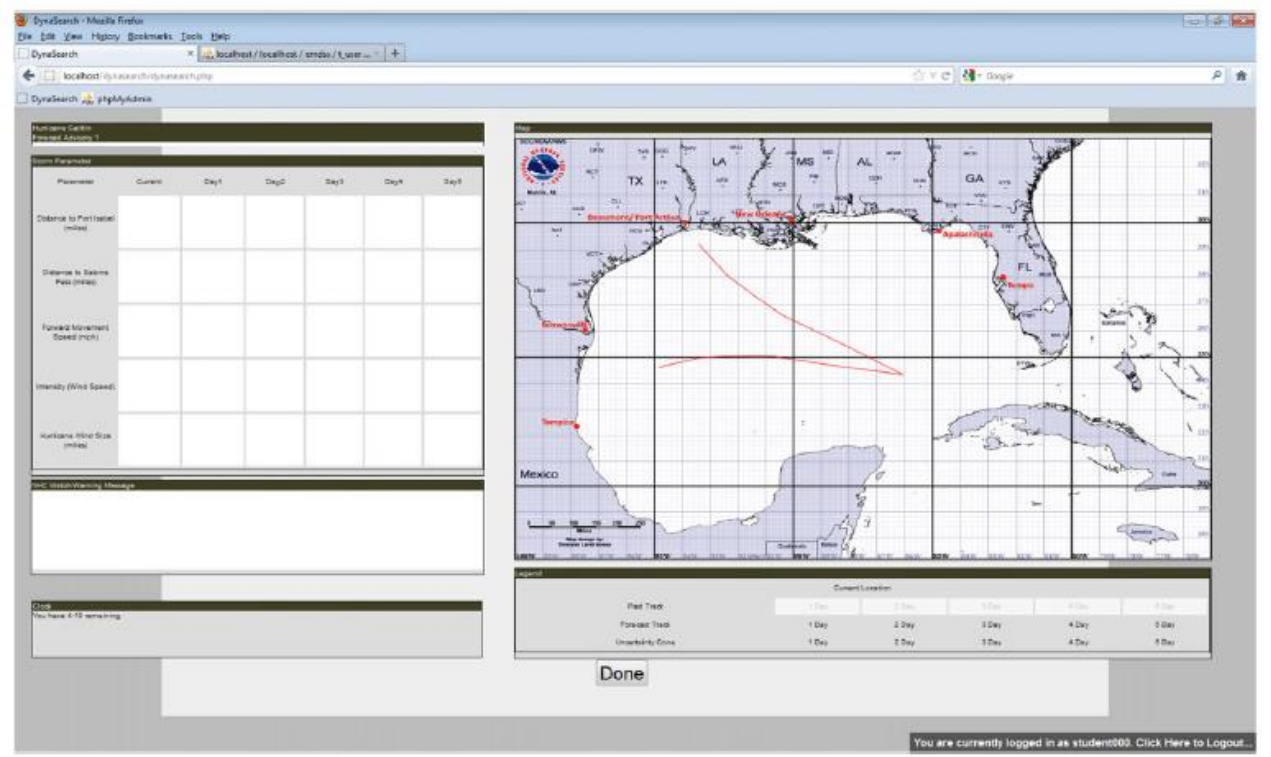
Future research should also compare storm forecast displays to a combination display of storm forecast displays with evacuation decision arcs.



Adapted from Lindell (2020)

Future Research on Storm Displays

These comparisons can be made using DynaSearch, which allows experimenters to provide graphic, numeric, and textual information (Lindell et al. 2019b).



Wu et al. (2015a, 2015b)

Future Research on Storm Displays

- Some researchers have advocated providing interactive maps (e.g., Cao et al., 2017; MacPherson-Krutsky et al., 2020).
  - > However, more research is needed on people's ability to use these displays effectively.
- Future research should also examine the effects of impact-based warnings (e.g., Casteel, 2016).
  - > These could show the types of damage that could be expected at different distances inland from the coast.
- Future research should also examine samples with more representative demographic characteristics than the laboratory studies that are typical of past research on this topic.

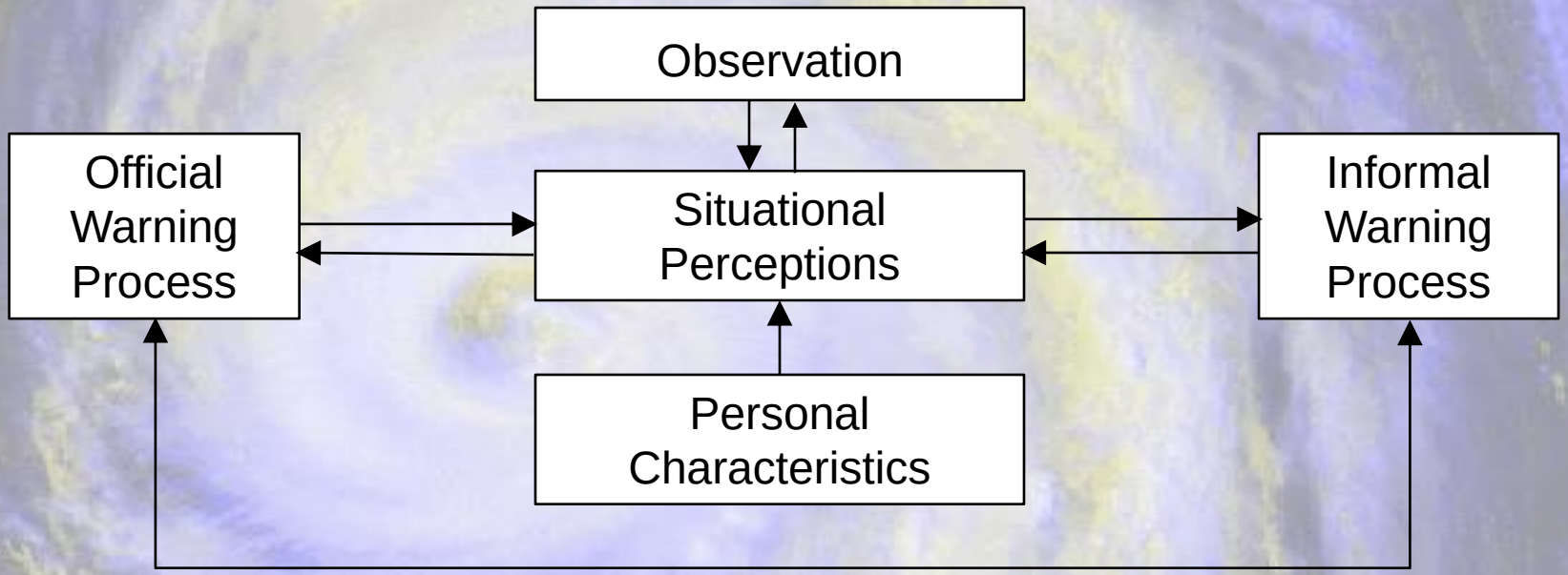
Research Findings on Warning Sources

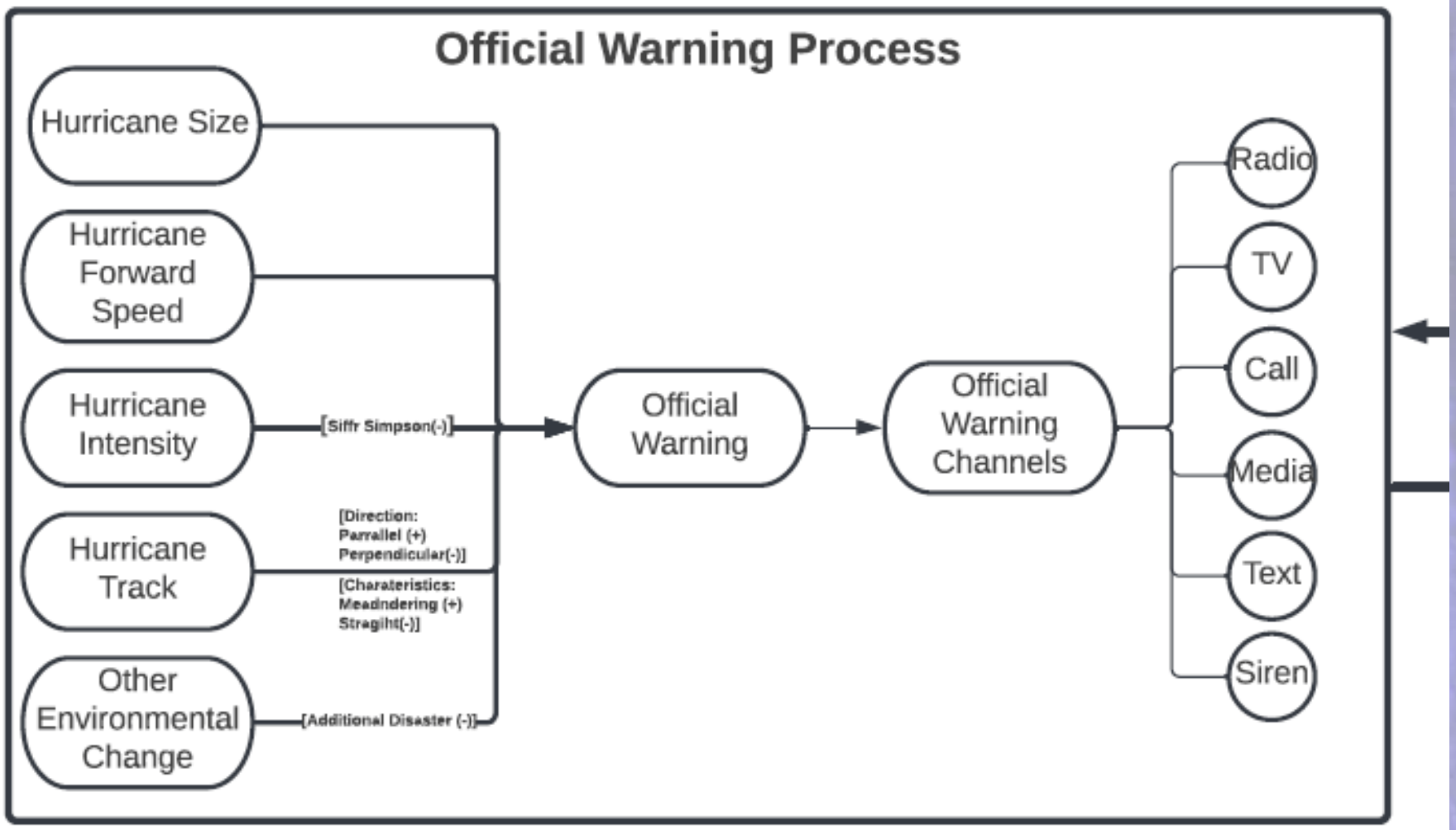
- Most hurricane warning research has focused on the dissemination of warning information from authorities through the news media.
- There is little research on the communication of hurricane information from unofficial warning sources.
  - > Observations of peers evacuating are known to affect hurricane evacuation rates (Baker, 1991; Huang et al., 2016).
  - > However, there has been little research on *warning receipt* from peers other than in rapid onset disasters such as flash floods (Perry et al., 1981; Lindell et al., 2019c).

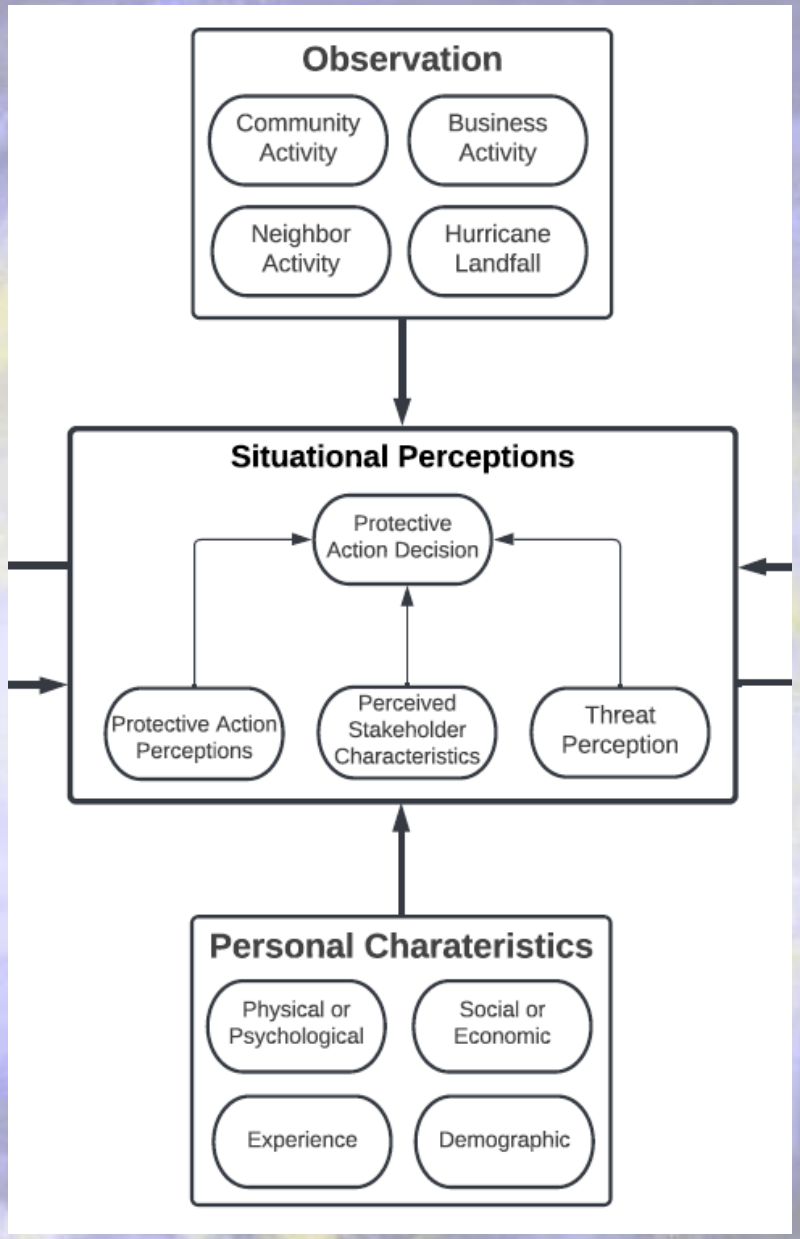
Research Findings on Warning Sources

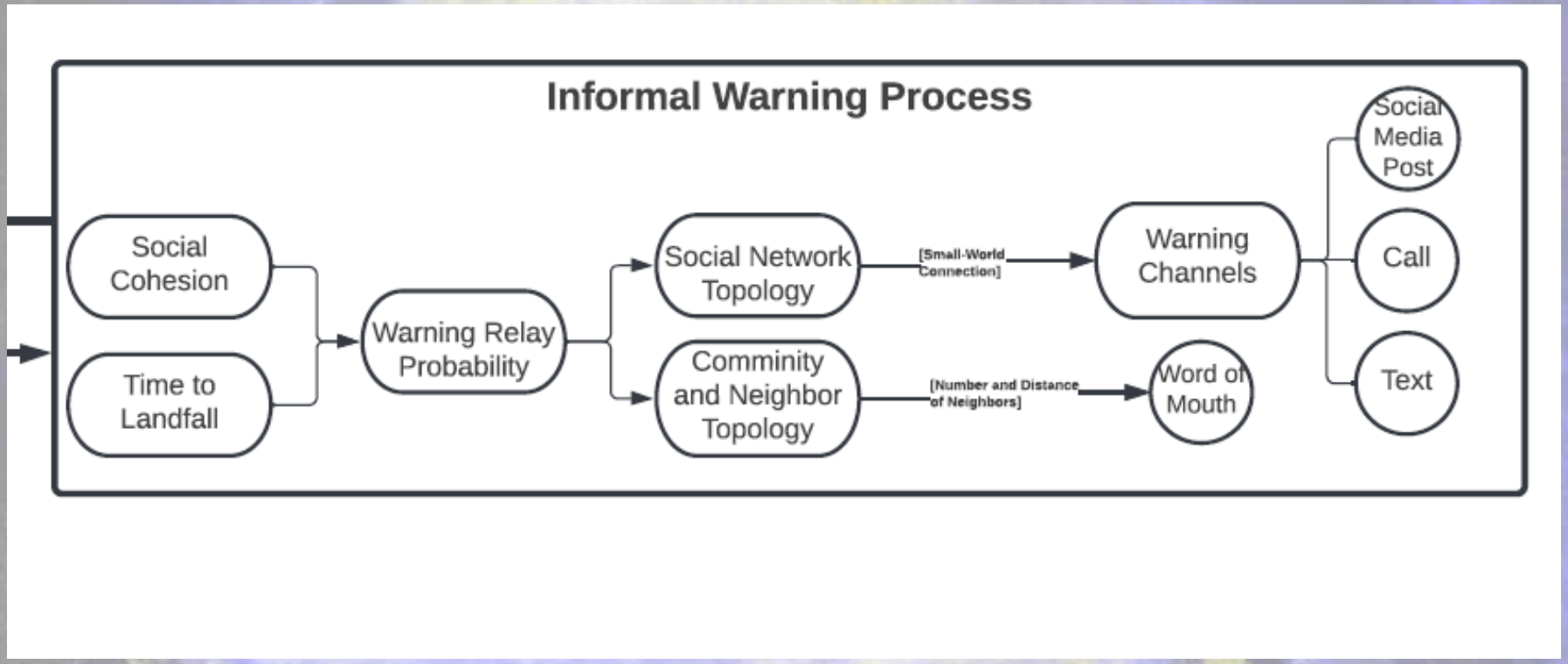
- There is some recent research on the influence of social networks on evacuation (Hasan & Ukkusuri, 2011; Sadri et al., 2017; Urata & Hato, 2021).
  - > However, these studies have not distinguished the effects of *normative influence* (what peers do) from *information influence* (what peers say).
- There has also been limited attention to unofficial sources and peers communicating (mis/dis)information through social media and other channels.
  - > Long et al. (2020) addressed this issue but focused on political orientation rather than the information sources that people's political orientations led them to seek for hurricane information.
- A current project is developing an agent-based model of the hurricane warning process based on the Protective Action Decision Model.

Warning Process




Official Warning Process
Hurricane Size
Hurricane Forward Speed
Hurricane Intensity
[Siffr Simpson(-)]
Hurricane Track
[Direction: Parrallel (+) Perpendicular(-)]
[Charateristics: Meandering (+) Stragiht(-)]
Other Environmental Change
[Additional Disaster (-)]
Official Warning
Official Warning Channels
Radio
TV
Call
Media
Text
Siren


Observation
Community Activity
Business Activity
Neighbor Activity
Hurricane Landfall
Situational Perceptions
Protective Action Decision
Protective Action Perceptions
Perceived Stakeholder Characteristics
Threat Perception
Personal Charateristics
Physical or Psychological
Social or Economic
Experience
Demographic


Informal Warning Process
Social Cohesion
Time to Landfall
Warning Relay Probability
Social Network Topology
Comminity and Neighbor Topology
[Small-World Connection]
[Number and Distance of Neighbors]
Warning Channels
Word of Mouth
Social Media Post
Call
Text

Thank you. Questions?

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Warning Elements

Warning sources

- Types: Authorities, news media, peers
- Perceived characteristics: Expertise, trustworthiness, protection responsibility, and protection capability

Warning channels

- Types: Print, broadcast, Internet, social media, word-of-mouth
- Characteristics: Precision of dissemination, penetration of normal activities, rate of dissemination over time, message specificity, susceptibility to message distortion, receiver requirements, sender requirements, and feedback

Warning Elements

- Warning message contents
  - > Threat: Risk areas/consequences for wind, surge, and inland flooding; arrival time
  - > Protective action recommendations
    - Voluntary vs. mandatory evacuation for different locations (coastal vs. inland) and building types (mobile homes, single story wood frame, multi-story steel-reinforced concrete)
  - > Sources of additional information
    - Emergency management agency websites
  - > Sources of assistance
    - Transportation, accommodations
- Warning message format
  - > Graphic, numeric, verbal/textual