An Agent-Based Model for Exploring the Hurricane Evacuation Dynamics

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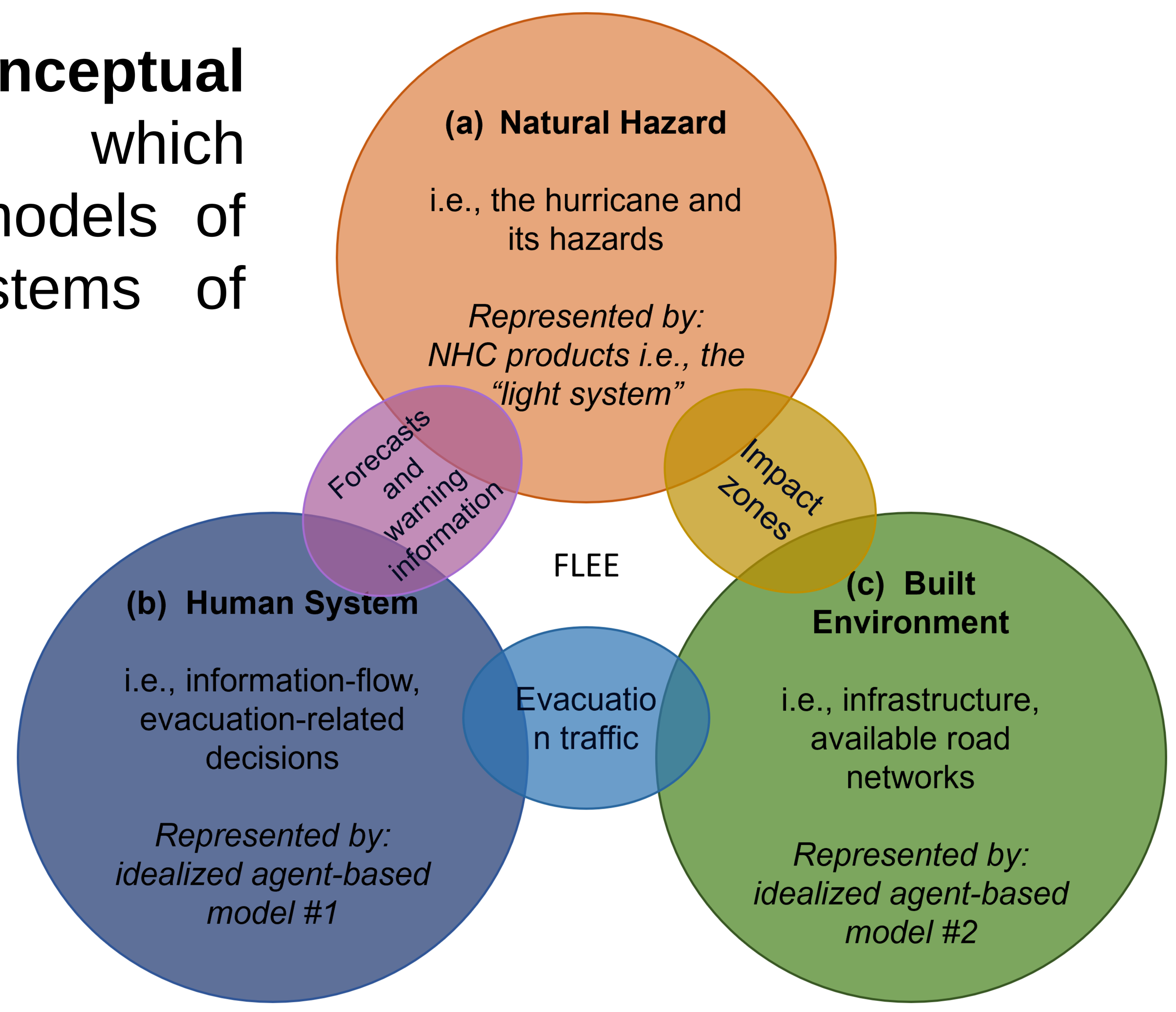
Hurricane evacuations are complex and dynamic

- Surveys, interviews, and other empirical methods are often used to study evacuations
- Computational models built on this knowledge can be compared with empirical data from real cases, and then used to simulate new evacuation scenarios
- **Our goal:** Develop an idealized agent-based modeling framework to study and improve the hurricane-forecast-warning-evacuation system

Forecasting Laboratory for Exploring the Evacuation-system

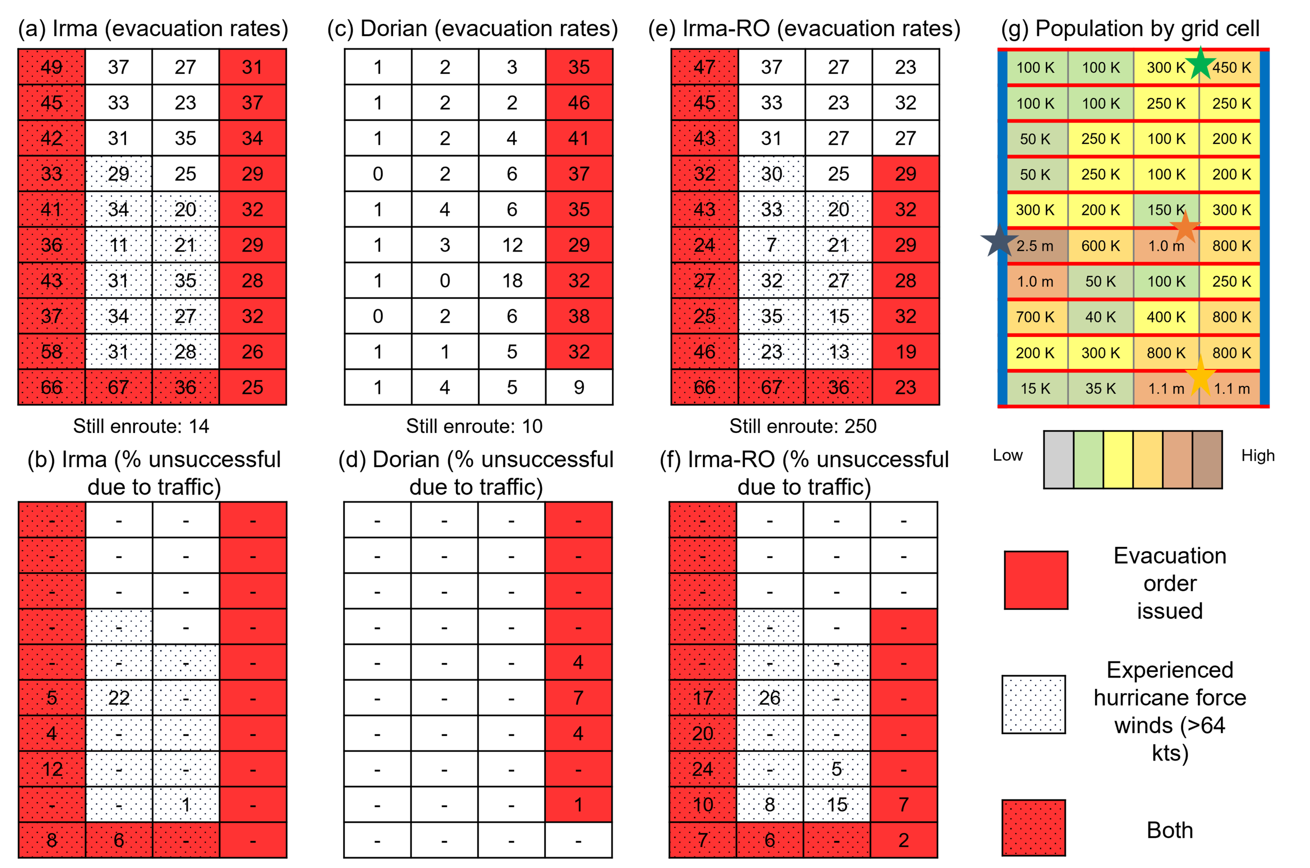
- **Figure 1: A conceptual overview of FLEE** which includes agent-based models of the interconnected systems of hurricane evacuations
- FLEE is described in the *International Journal of Disaster Risk Reduction.*
- Important components to note include:



- **Virtual world** – is a 10 x 4 cellular depiction of Florida. FLEE includes 4.1 million household agents whose spatial distribution is approximated via Census data.
- **Forecast data** – Every 6 hours, NHC products depicting the storm's forecast information are synthesized to create a red-orange-yellow-green "light system" forecast of wind, storm surge, and rain risk for each of FLEE's grid cells
- **Evacuation orders** – EM agents, located within FLEE's coastal grid cells, decide whether to issue evacuation orders based on storm surge risk, clearance times, and the forecast time of arrival of tropical storm force winds
- **Evacuation decisions** – Household agents decide to evacuate based on wind, surge, and rain risk for their location, evacuation order information, and household characteristics (mobile home ownership, age, car ownership, and socioeconomic status)
- **Traffic and the built environment** – Idealized highways simulating key aspects of Florida's road network are overlaid on FLEE's grid. The roads allow evacuating households to move between grid cells

What improves evacuations? Using FLEE to explore evacuation outcomes across scenarios

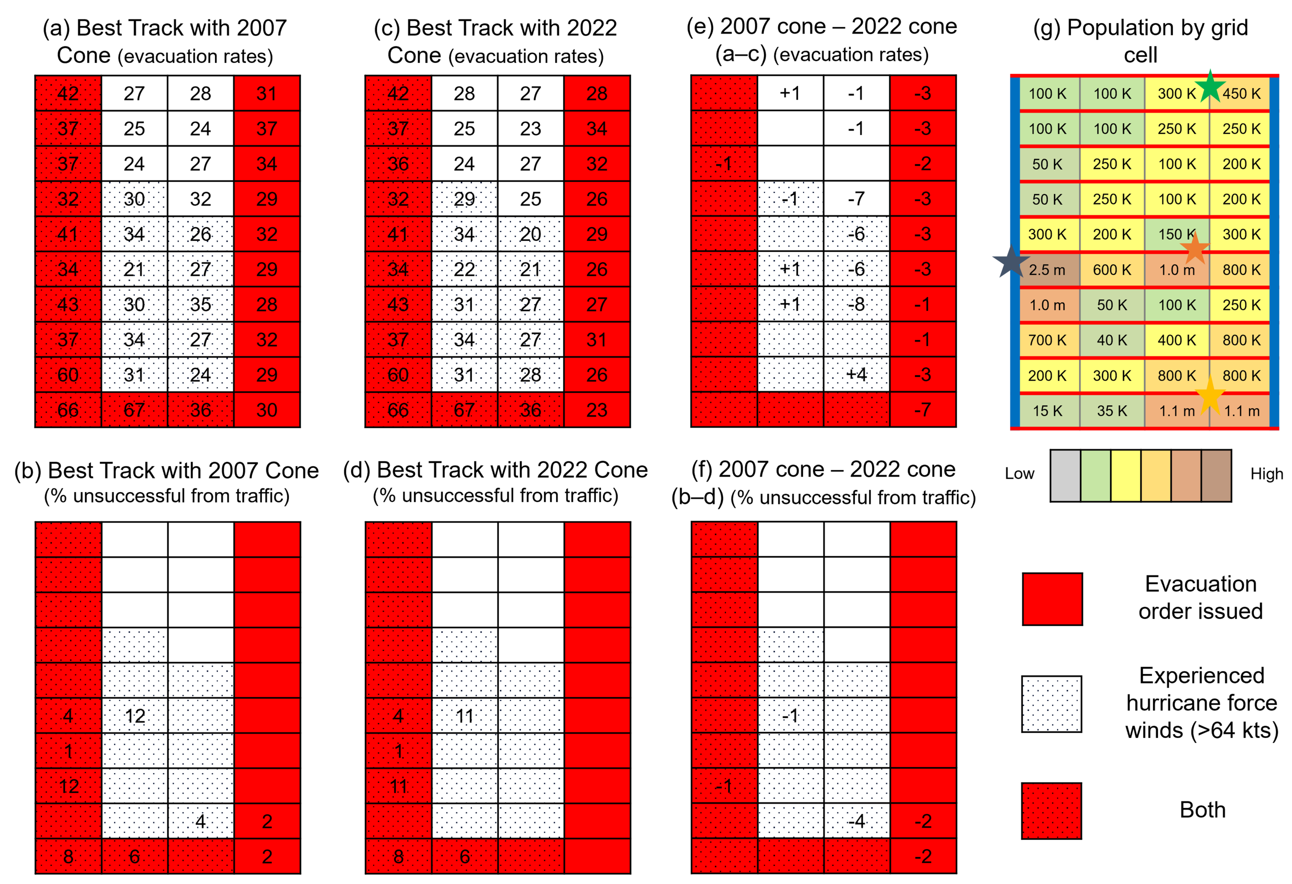
- **Figure 2:** Simulated evacuations for Irma (2017), Dorian (2019), and a hypothetical rapidly-intensifying /onset version of Irma
- **Model verification –** FLEE's evacuations match empirical studies of Irma and Dorian (not shown), a critical step



- In the *Natural Hazards Review*, for these scenarios, we change the number of cars on roads, implement contraflow, shift EO timing, and increase the population to 2030-2040, then quantify impacts on evacuations (not shown)

A new verification approach? Using FLEE to evaluate the impact of forecast errors on evacuations

- In a *BAMS* study, we find evidence that:
  1. Reduced track errors across the 2007–2022 period translate to improvements in evacuation **(Figure 3 – changing cone sizes during Irma)**
  2. Unexpected rapid intensification can reduce evacuation rates, and increase traffic, across most impacted areas



- **Key point –** Coupled natural-human models offer a societally relevant complement to traditional metrics of forecast accuracy

Future research directions (feedback wanted)

- **Next steps –** Improve model resolution, computational speeds, and compare against evacuation data from Hurricane Ian (2022) to better study impact of forecast errors on evacuation outcomes
- **Longer term vision –** Use FLEE to study evacuations in future climate-population scenarios, impacts to marginalized groups, have conversations with stakeholders to improve FLEE, extend framework to tornadoes, wildfires, and different regions