The Hurricane Decision Simulator
A Tool for Marine Forces in New Orleans to Practice Hurricane Preparedness

Eva Regnier, Associate Professor, Graduate School of Business and Public Policy, Naval Postgraduate School
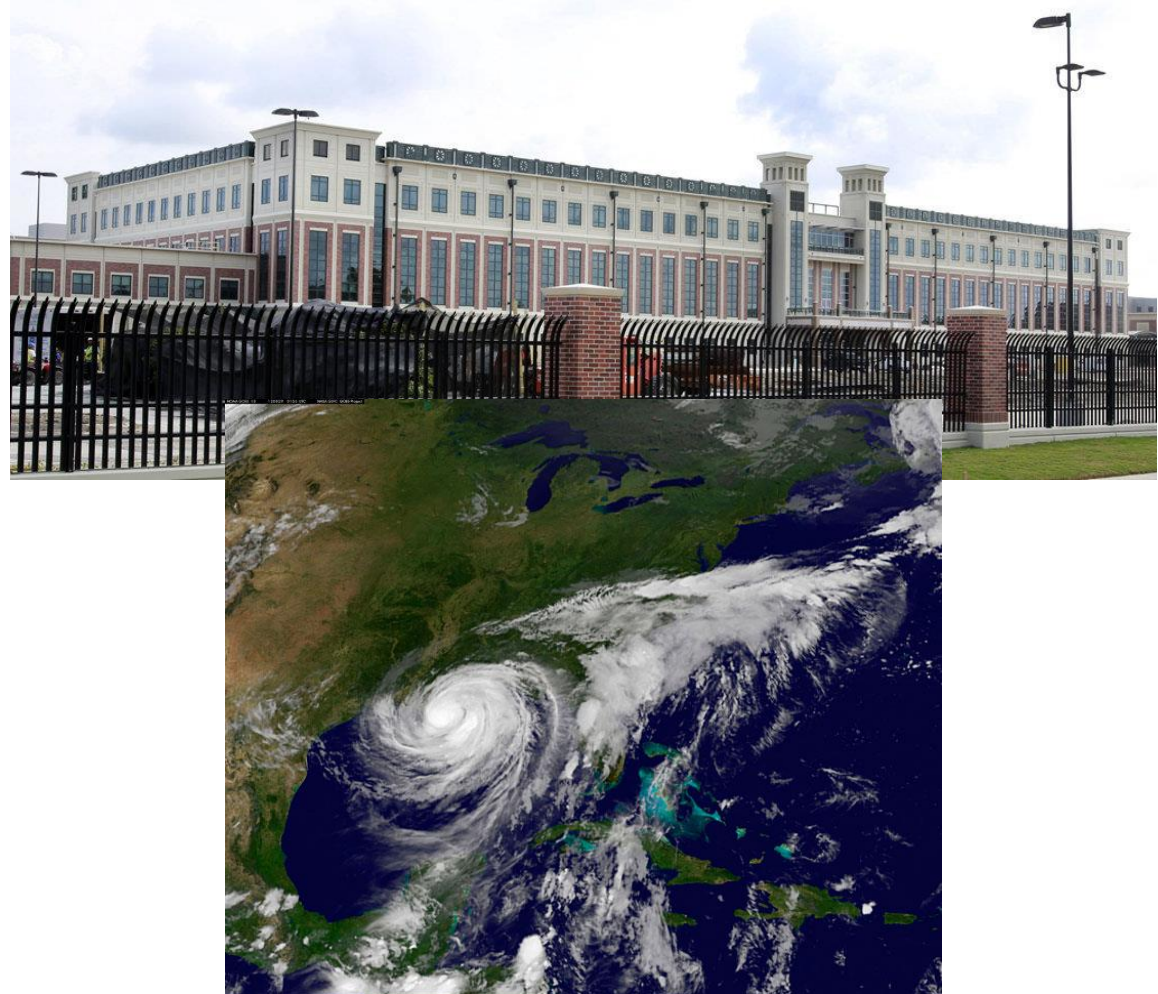
Cameron MacKenzie, Assistant Professor, Industrial and Manufacturing Systems Engineering, Iowa State University

MORS National Security Risk Analysis Community of Practice

September 20, 2018

U.S. Marine Forces Reserve (MFR)


Major General
Burke Whitman

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MFR Decision Support Matrix

Hours before arrival of 39-mph winds

1. 96 hours: Send advance emergency relocation staff (ERS) to alternate headquarters
2. 96 hours: Send liaison officers to local municipal emergency operations centers
3. 72 hours: Send rest of ERS to alternate headquarters
4. 72 hours: Activate remain behind element to stay if evacuation ordered
5. 60 hours: Evacuate or shelter in place
6. 48 hours: Transfer command and control to alternate headquarters

Isaac 72 hours before landfall
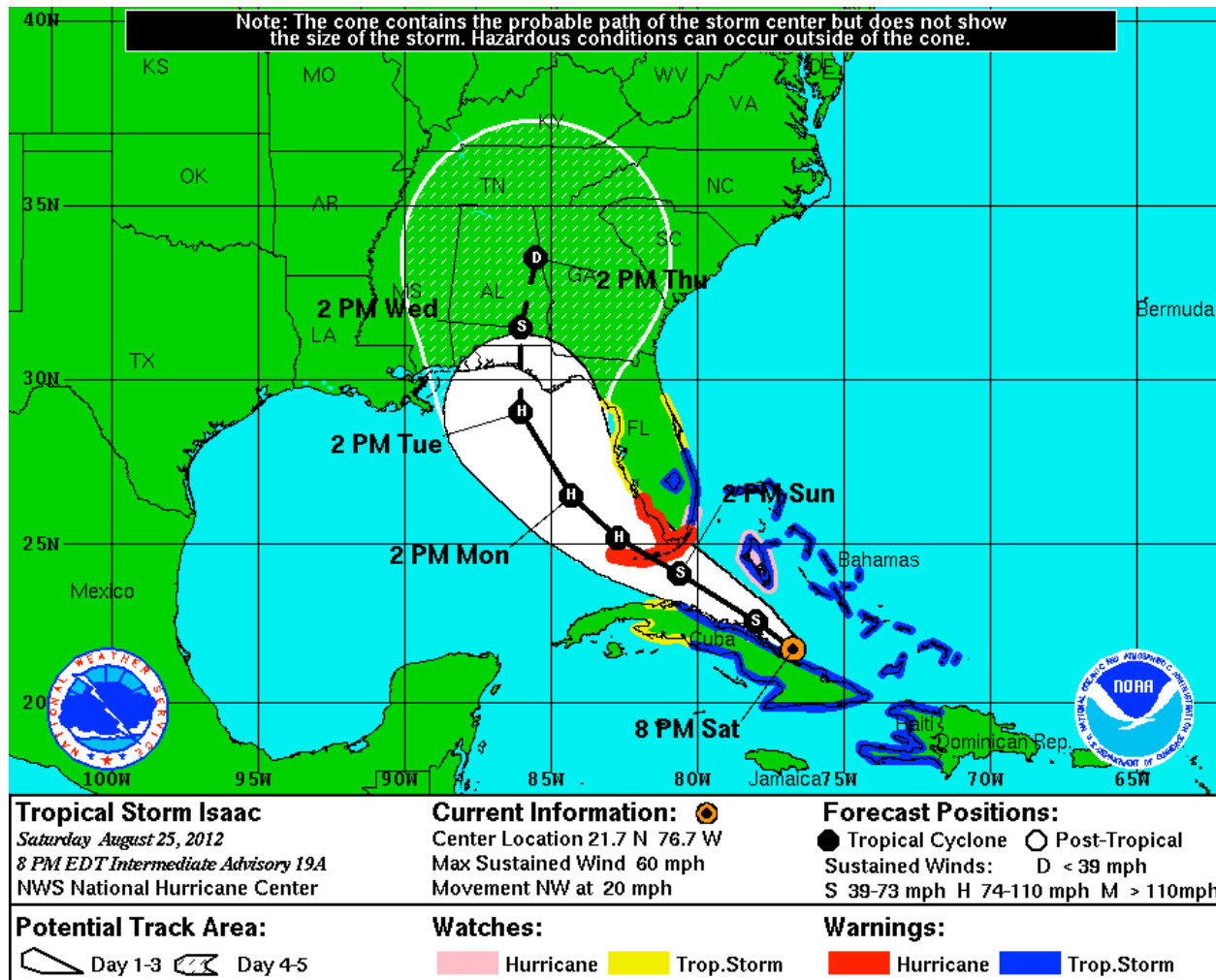
Every storm is different

Gustav
August 2008

Humberto
September 2007

Ivan
August 2004

Katrina
August 2005

5
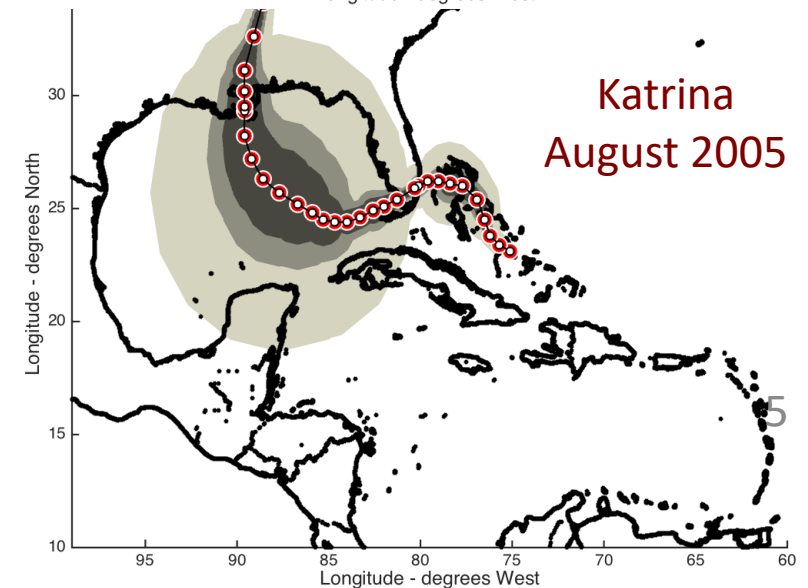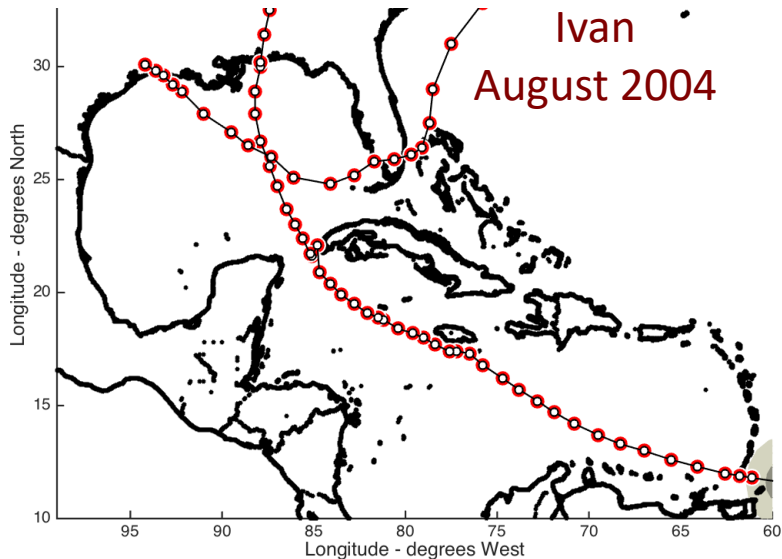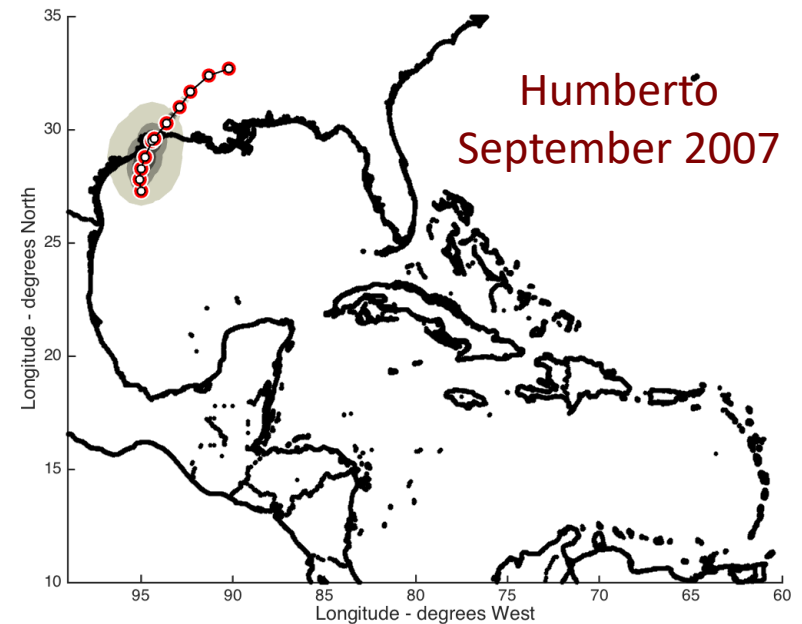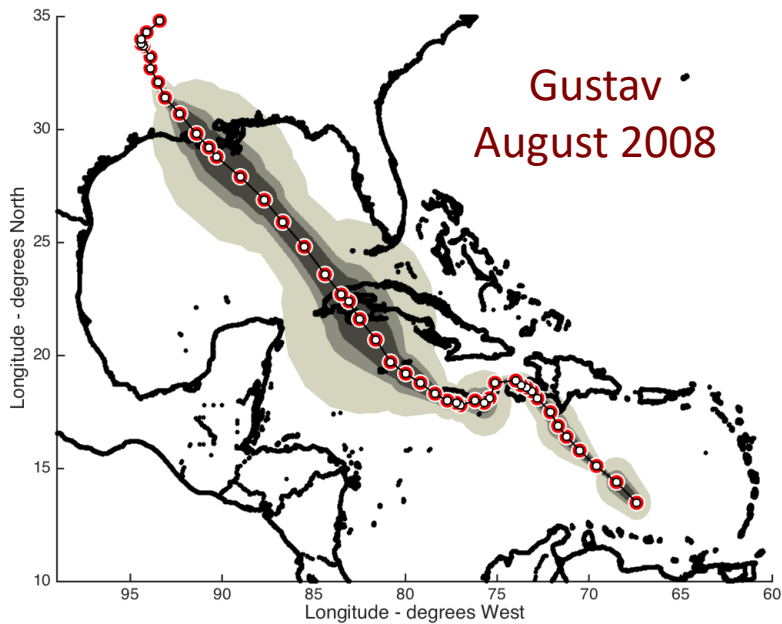
Challenges in hurricane preparation

Progress: Errors and forecast products ≠ last season's

Updates: current forecast ≠ next forecast

Error: forecast ≠ outcome

Forecast variables ≠ impact variables

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Hurricane Decision Simulator (HDS)

- Training tool to make hurricane preparation decisions

- Key characteristics

  - Simulated storms (storm and forecasts)

  - User decisions

  - Actions of other entities

  - Consequences of storm plus decisions

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Storm model

- Synthetic storms
    - Realism – storms should <u>feel</u> believable
    - Features should <u>span</u> realistic ranges
    - Unusual events <u>should</u> occur in synthetic storms
- Storm forecasts in 6-hour increments
    - Most likely path (forecast track)
    - Probability forecasts for next 120 hours
- Realistic forecasts: forecast errors consistent with recent National Hurricane Center forecasts

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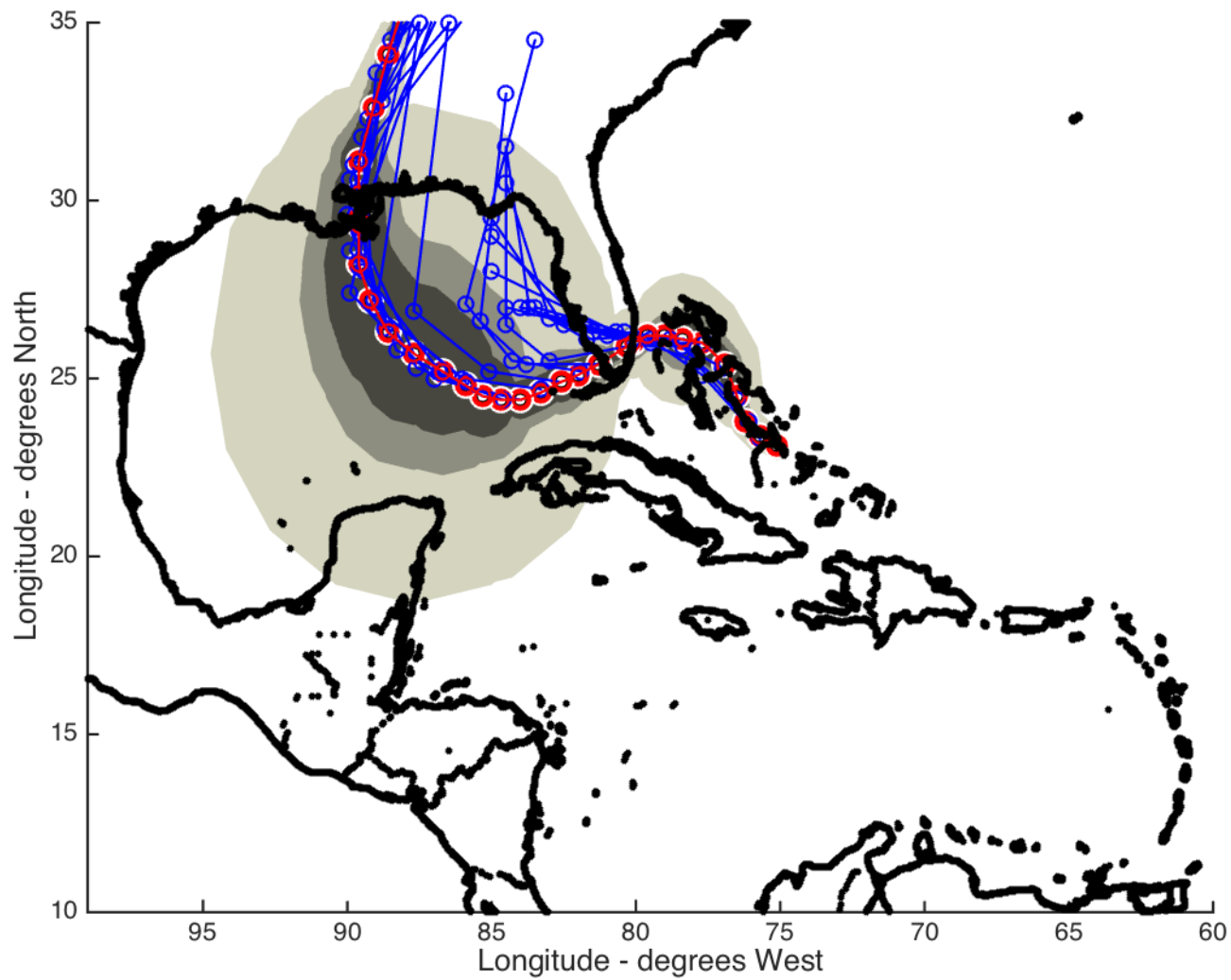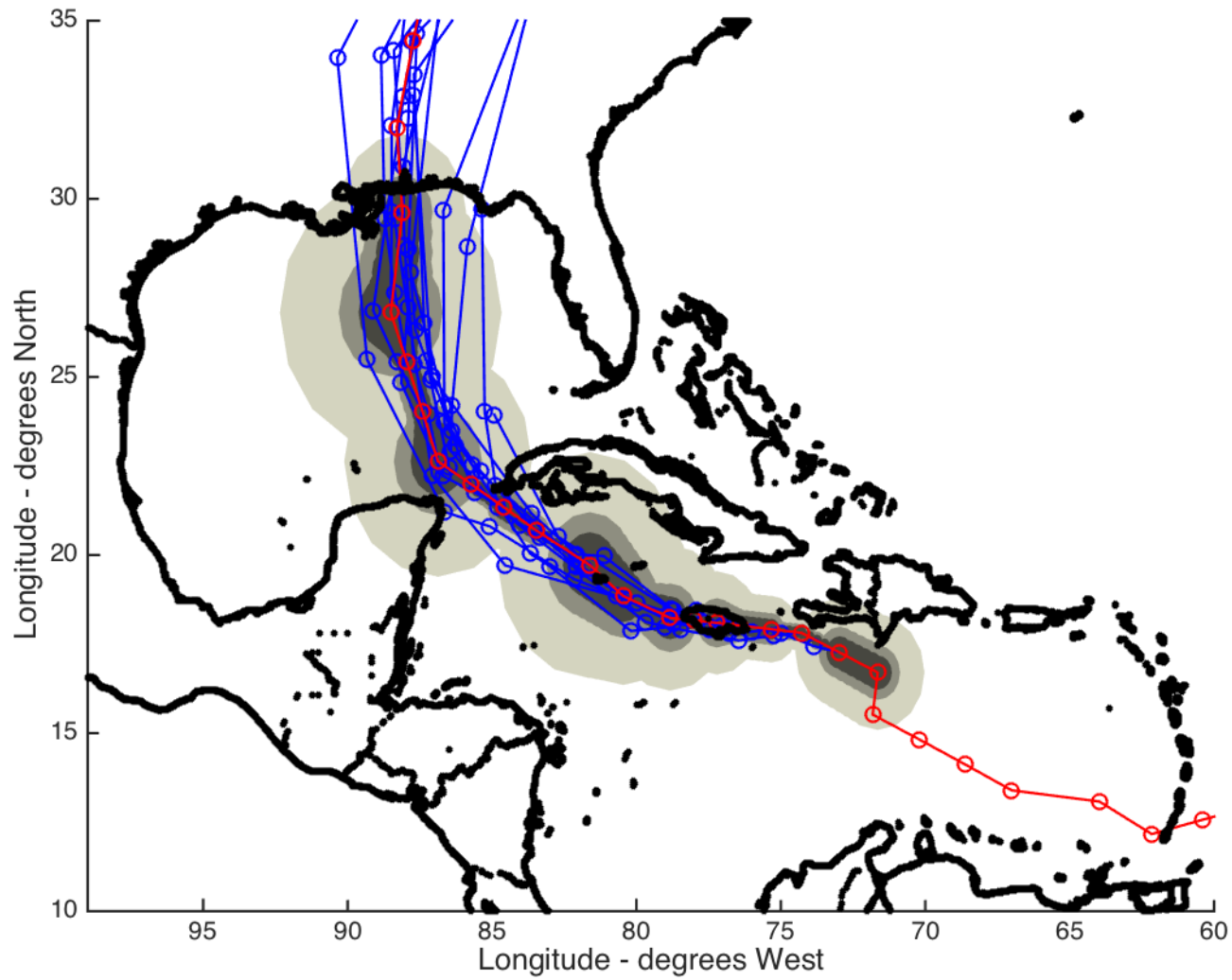
Use by the Marines

- Individual training by crisis action team and emergency relocation team (almost 200 people) since Fall 2015
- Used in developing annual (team) specialized hurricane exercises

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Experience more simulated storms

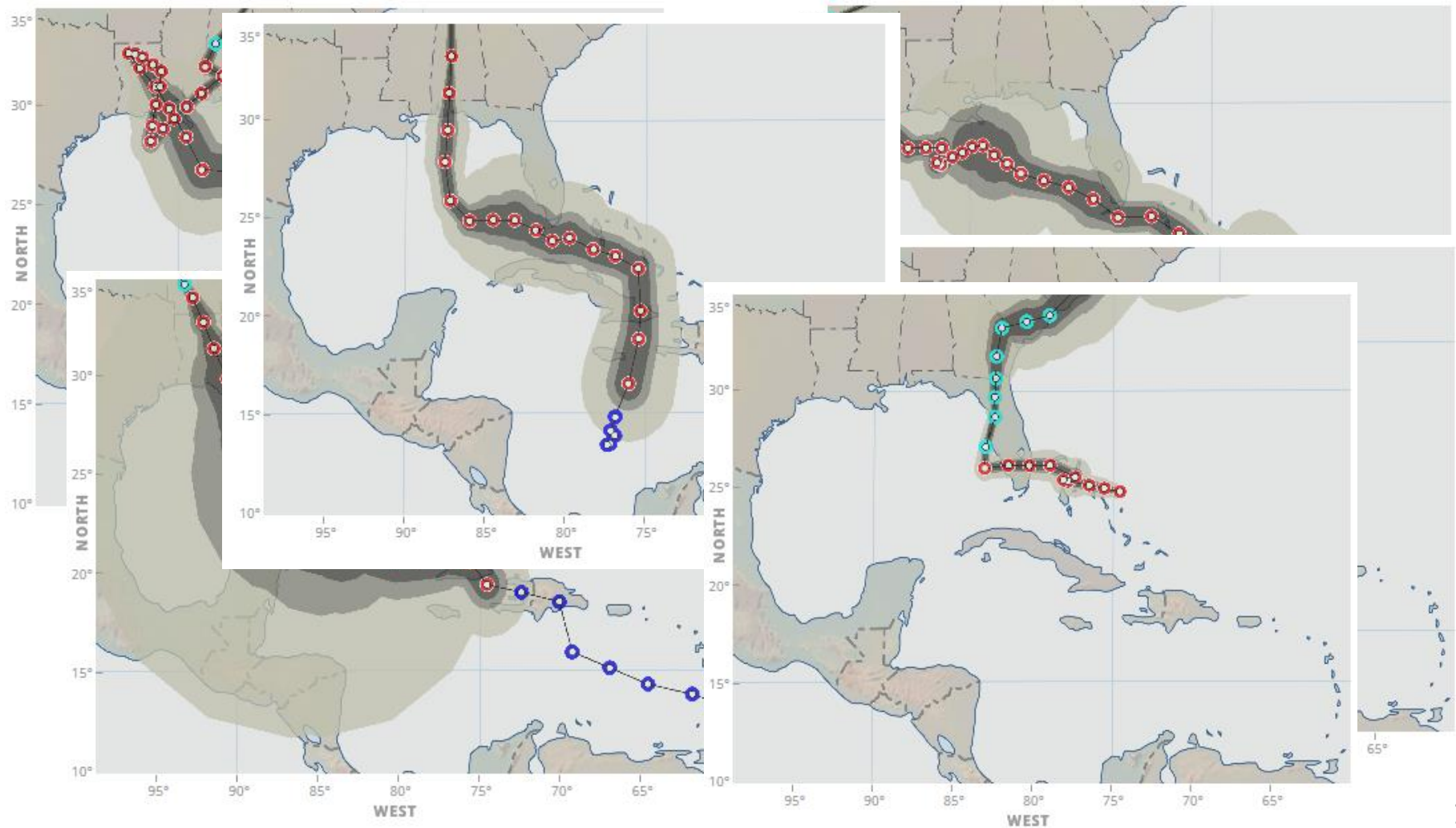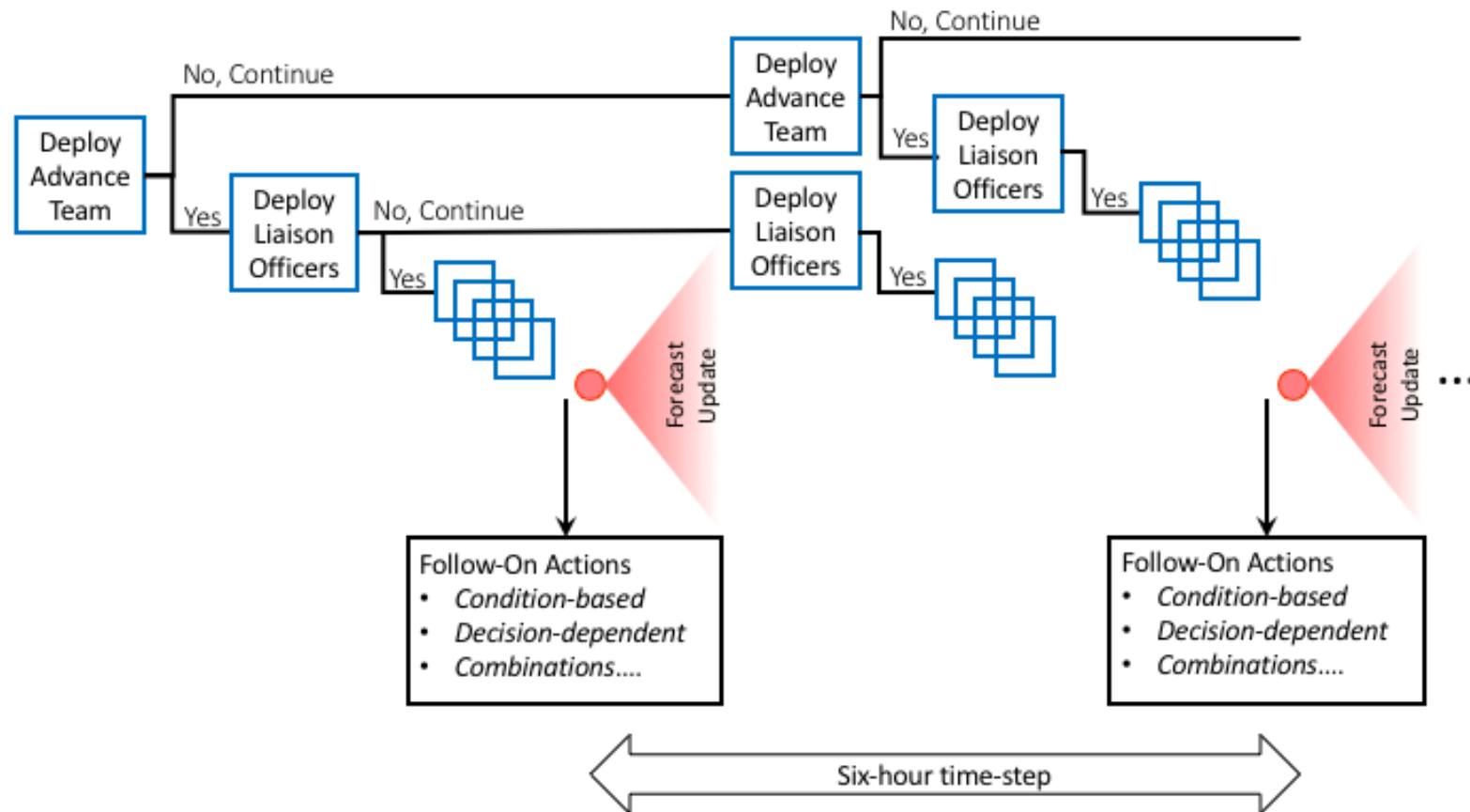**IOWA STATE UNIVERSITY**

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Focus on decision making with uncertainty

Understand forecast products

Tropical Storm Force Wind Speed Probabilities
For the 120 hours (5 days) from 8 PM EDT Sat Aug 25 to 8 PM EDT Thu Aug 30

Probability of tropical storm force surface winds (1-minute average >= 39 mph) from all tropical cyclones
◇ indicates TROPICAL STORM ISAAC center location at 8 PM EDT Sat Aug 25 2012 (Forecast/Advisory #20)

5% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

PROBABILITIES (of Winds Exceeding Threshold) ?

| 39 mph | 58 mph | 74 mph | Cone | 28 Jul 2000 |

Key
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
5%

156 HOURS AGO   28 Jul 2000   ☰ Actions   i Details

120-hour probability of 39 mph winds affecting NOLA: **58**%

Expected Landfall	Storm Center	Radius of Max Winds	Max Sus. Winds
73 hrs (at 29.5°Nx90.1°W)	**22.4°N x 77.0°W**	**49** mi	**62** mph

BACK TO RESULTS

14

Develop simulation tool for other bases
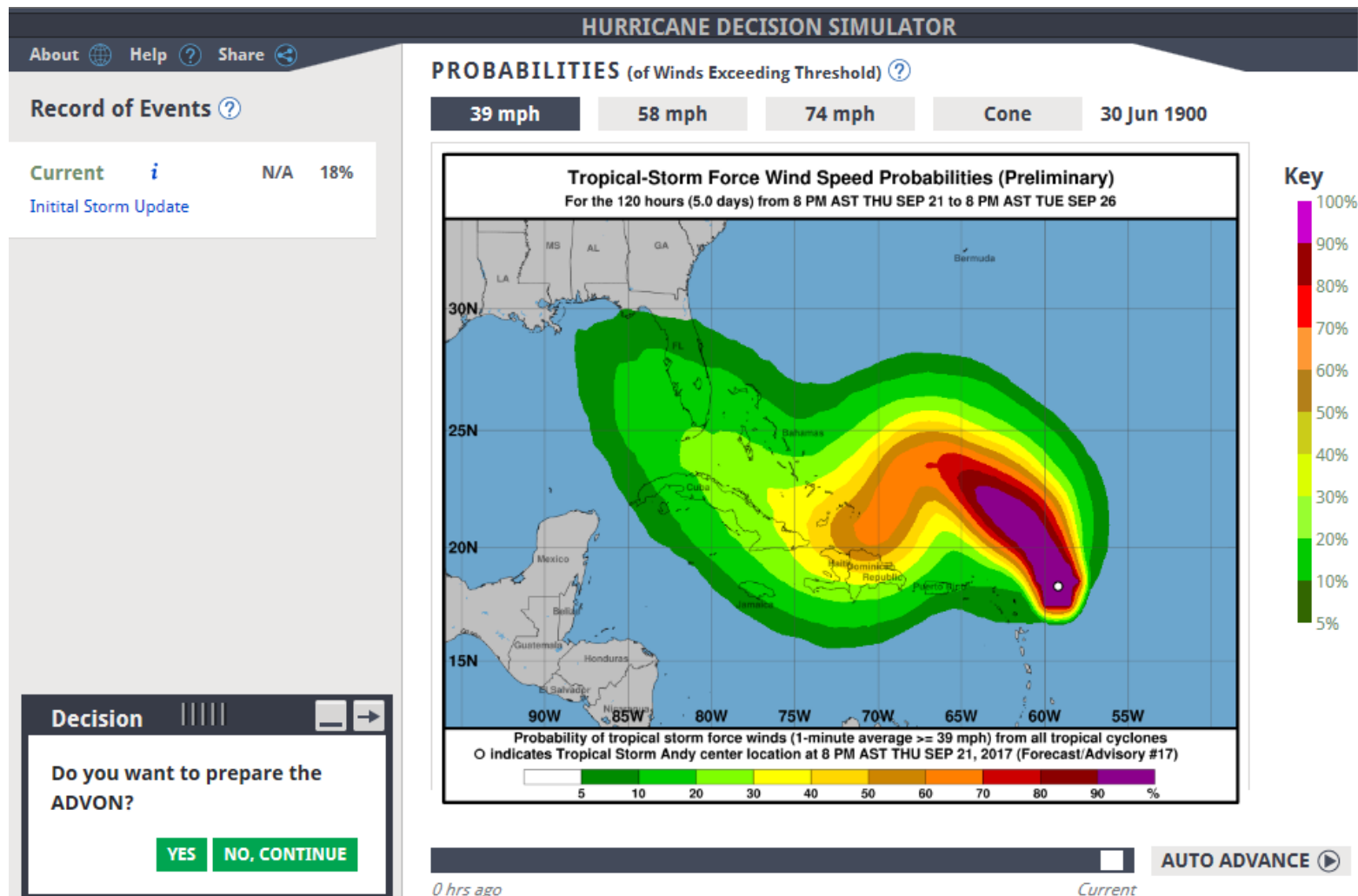
Storm selector

HURRICANE DECISION SIMULATOR: Storm Selector

FILTERS

Sort by: Unsorted ⌄   Showing 13 of 13 storms   Page 1

Closest Approach ⓘ

☐ 0 - 25 mi
☐ 26 - 50 mi
☐ 51 - 100 mi
☐ 100 - 200 mi
☐ > 200 mi

Wind Speeds ⓘ

☐ < 39 mph
☐ 39 - 53 mph
☐ 54 - 73 mph
☑ > 73 mph

Hurricane Probability ⓘ

☐ < 1%
☐ 1 - 25%
☐ 26 - 50%
☐ 51 - 75%
☐ 76 - 99%
☑ > 99%

32 mi	103 mph	100%	Storm ID: 262018	Get URL
33 mi	121 mph	100%	Storm ID: 032017	Get URL
46 mi	102 mph	100%	Storm ID: 322018	Get URL
46 mi	120 mph	100%	Storm ID: 312018	Get URL
79 mi	118 mph	100%	Storm ID: 182019	Get URL
47 mi	121 mph	100%	Storm ID: 312020	Get URL
54 mi	121 mph	100%	Storm ID: 442020	Get URL
87 mi	103 mph	100%	Storm ID: 402020	Get URL

Research question

- Does the Hurricane Decision Simulator help people make better decisions?

- How does the Hurricane Decision Simulator impact or change people's decision making?

17

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Subjects

- Engineering economy class in Spring 2017
- 157 undergraduate students, engineering majors
- Mostly juniors and seniors

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Text description (day 1)

- You are the Commander of U.S. Marine Forces Reserves (MARFORRES) whose headquarters are located in New Orleans, Louisiana. …

- Tropical cyclone

  - Probability of tropical force winds

  - Probability of hurricane winds

  - Expected time to landfall

- Evacuation costs

- Marines timeline

Evacuate, shelter in place, neither?

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Three scenarios

	Probability wind speed > 39 mph	Probability wind speed > 74 mph	Expected hours to landfall
Scenario 1	77	31	58
Scenario 2	84	22	59
Scenario 3	100	52	58

- Costs of evacuation = $300,000 per day for 1-2 weeks
- Marines' timeline recommends evacuating 60 hours before arrival of winds

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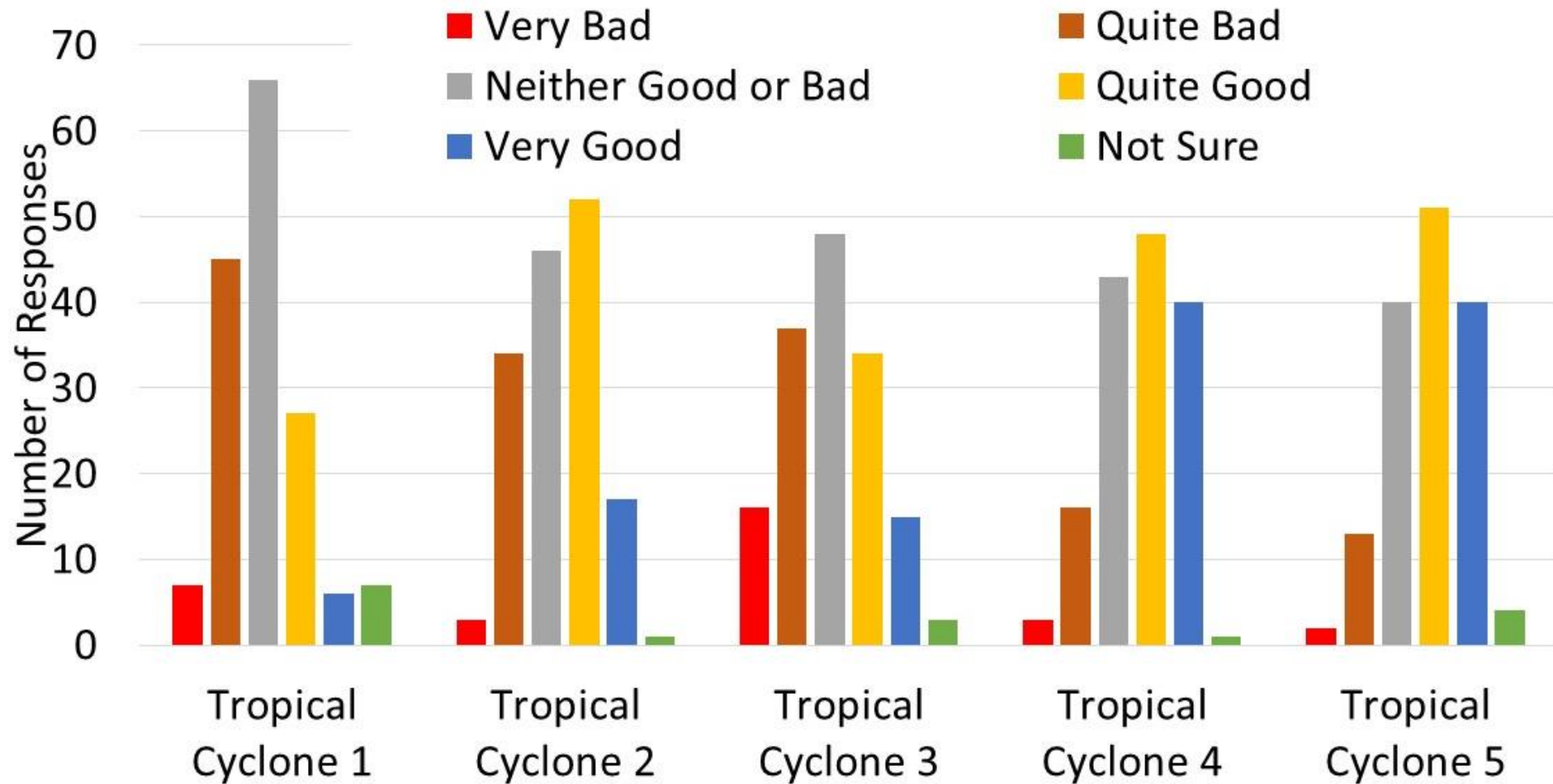Industrial and Manufacturing Systems Engineering

Experiment

- Introduction to the Hurricane Decision Simulator (HDS)
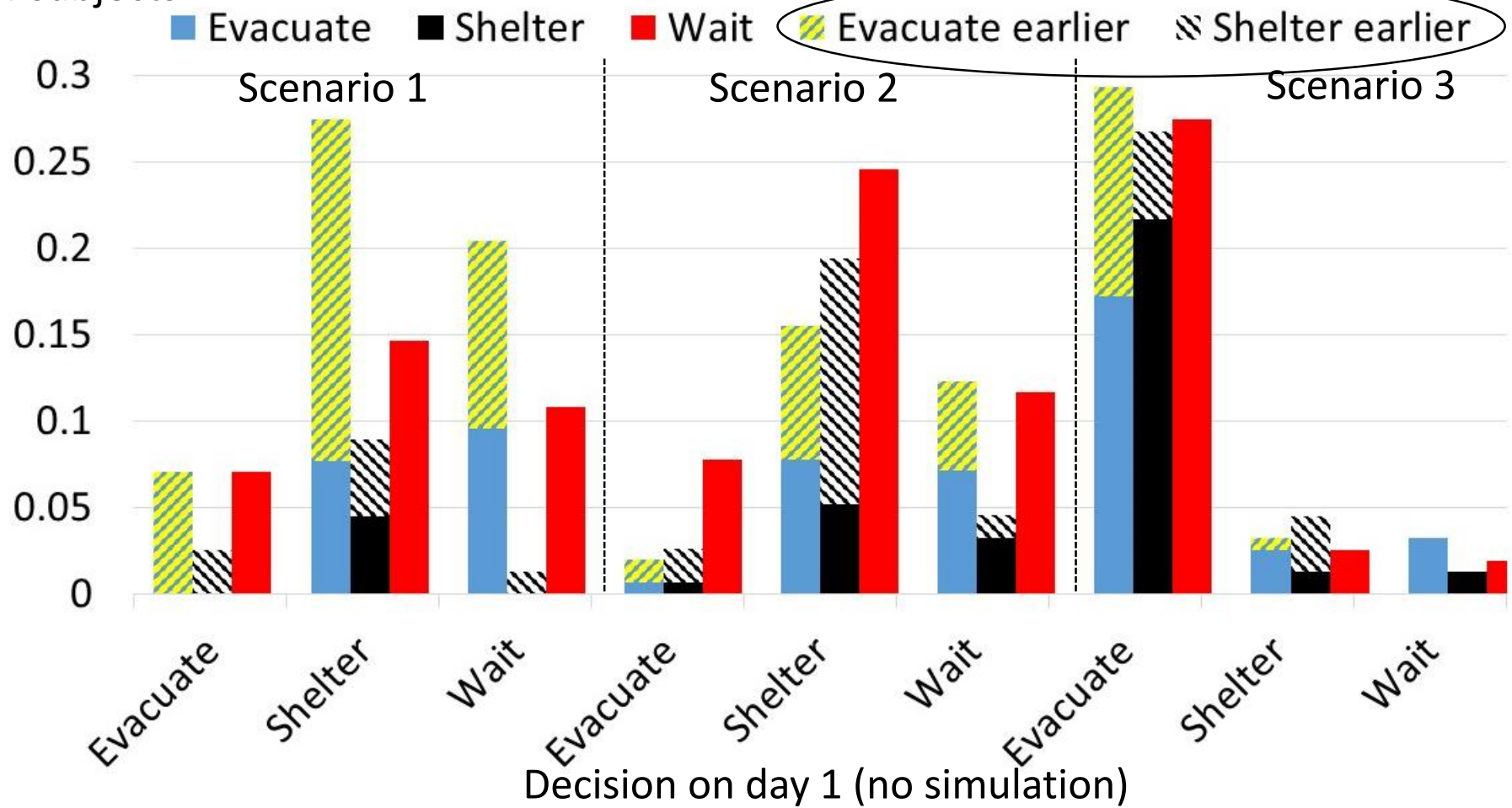- Subjects practiced with HDS (~15 minutes)

Day 2

- Each subject made decisions for the exact same 5 storms in HDS
- Subjects recorded information
  - Details of the storm
  - Riskiness of storm
  - Subjective evaluation of decision-making processes
- Final 3 storms in HDS equivalent to text description on day 1

Subjective evaluation of decision-making process

Comparison of decisions (pre vs post)

Proportion of subjects

Legend: Evacuate, Shelter, Wait, Evacuate earlier, Shelter earlier

Scenario 1, Scenario 2, Scenario 3

Decision on day 1 (no simulation)

23

Excluding subjects who evacuate / shelter earlier

Proportion of subjects

Scenario 1 (85 subjects)
Scenario 2 (106 subjects)
Scenario 3 (124 subjects)

Legend: Evacuate, Shelter, Wait

X-axis categories: Evacuate, Shelter, Wait (repeated for each scenario)

Decision on day 1 (no simulation)

24
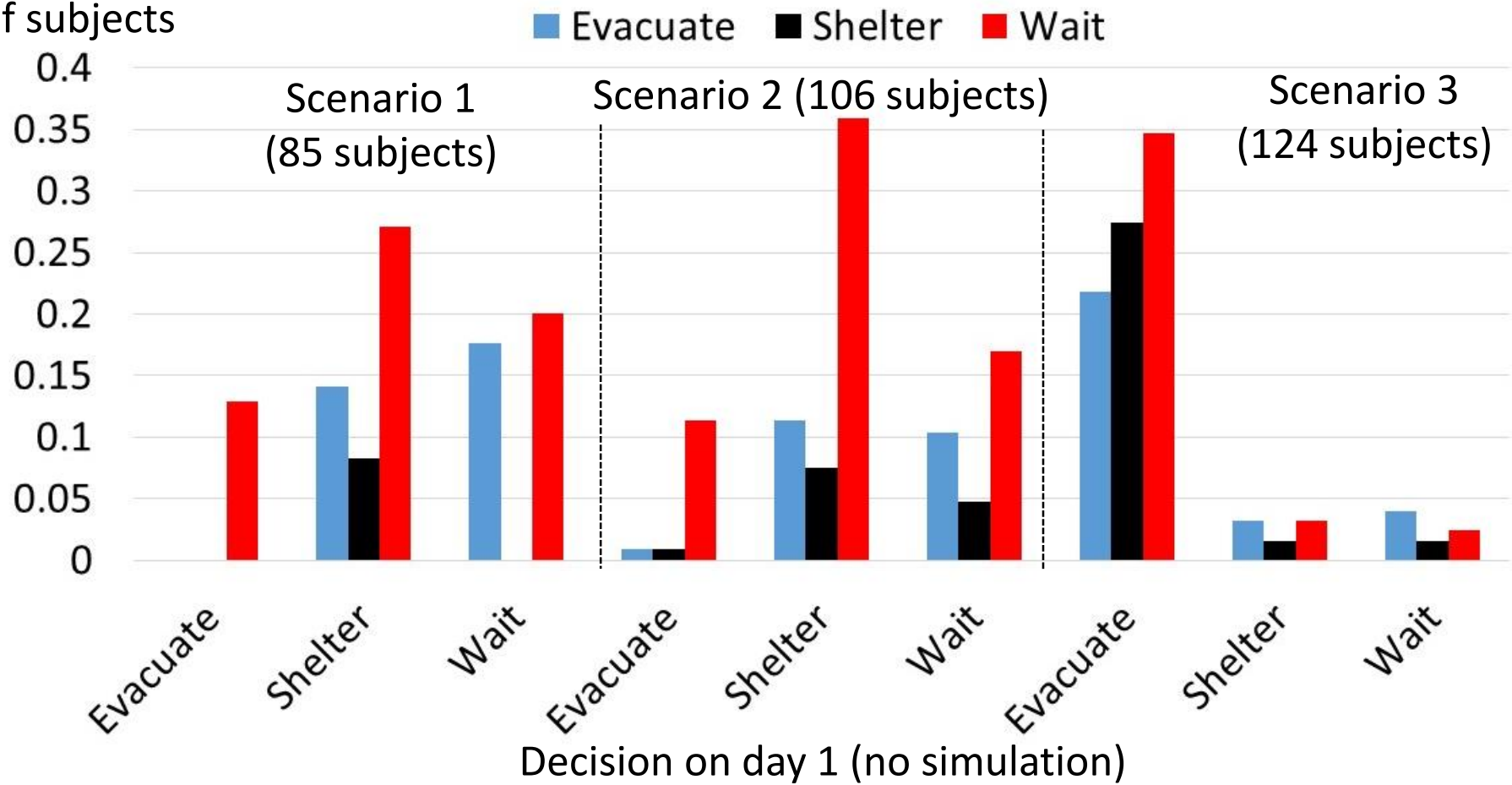
Impact of practicing with the HDS

- People seem more likely to switch their decisions after practicing with HDS

- Choosing decision with HDS seems more than just random chance

- HDS may slightly influence people to wait to evacuate or shelter, especially for difficult decisions

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Conclusions

- HDS provides
  - Experience that impossible to gain through real world
  - Unique tool to help senior leaders practice making decisions in a dynamic an uncertain environment
- People that practice with the HDS feel more comfortable making decisions in that context

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Acknowledgements

- Funding for this research provided by Marine Forces Reserve through Naval Postgraduate School to Ames Lab

- Marine Forces Reserve
  - Col Russel Mantzel
  - Robert McGuiness
  - Jose Garcia

- Charles Sampson, Naval Research Laboratory

- Associate Professor Andy Hernandez, Naval Postgraduate School

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Acknowledgements

- Center for Education Design, Development, and Distribution (CED3), Naval Postgraduate School

- Iowa State student researchers: Sophia Hetherington, Anna Prisacari, Sarat Sivaprasad

- Professor Steve Vardeman, Iowa State University

- Professor Mark Bryden, Iowa State University

camacken@iastate.edu

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BACKUP

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Hypothesis 1

- Subject is more likely to make a different decision when using the Hurricane Decision Simulator

- Null: probability of making same decision on days 1 and 2 equals probability of making different decision

30

Hypothesis 1

Proportion of subjects

Scenario 1 (85 subjects)

Scenario 2 (106 subjects)

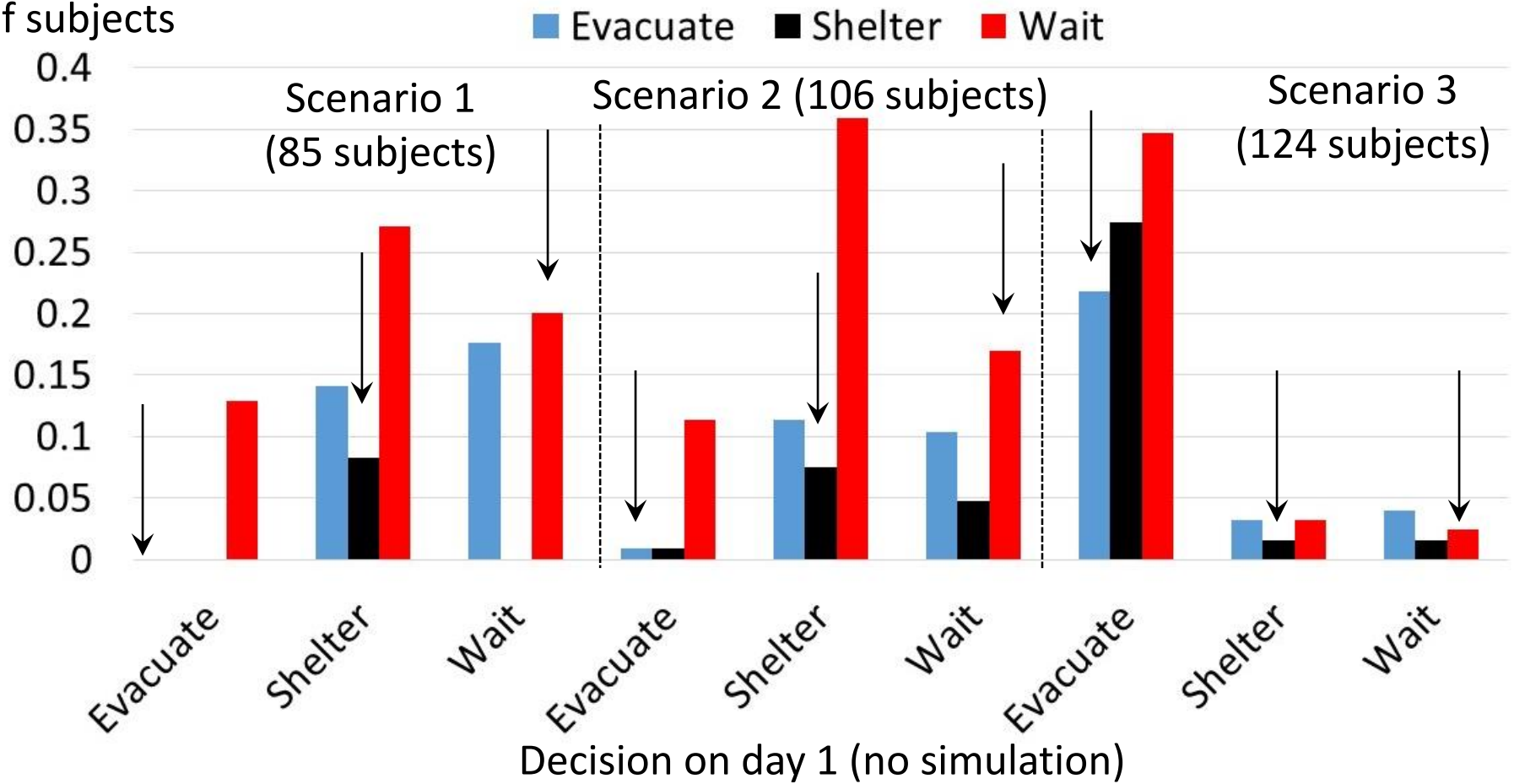Scenario 3 (124 subjects)

Decision on day 1 (no simulation)

Hypothesis 1

- Subject is more likely to make a different decision when using the Hurricane Decision Simulator

- Null: probability of making same decision on days 1 and 2 equals probability of making different decision)

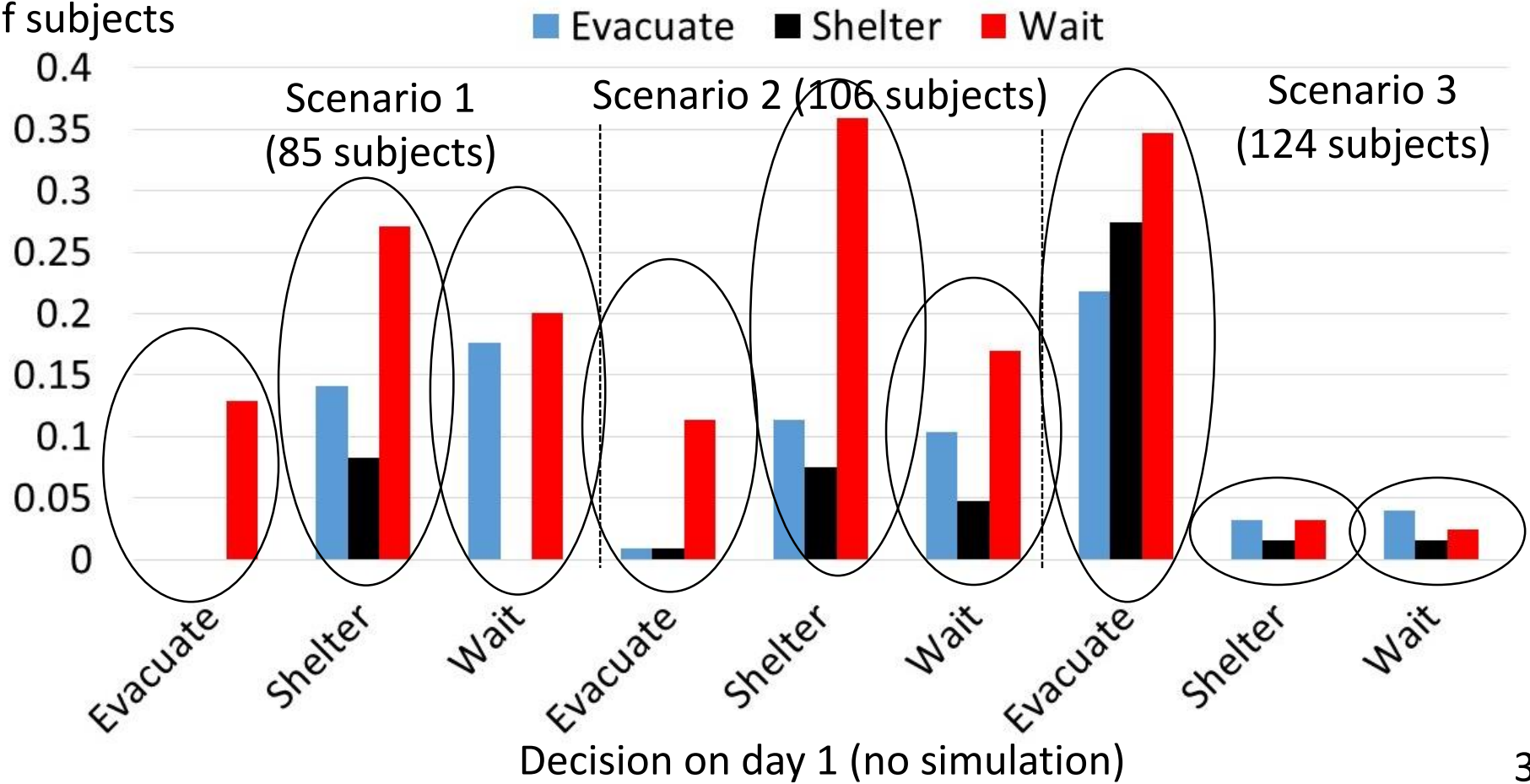|	p-value
Scenario 1	4E-06
Scenario 2	3E-06
Scenario 3	4E-10

→ **Reject null**

Hypothesis 2

- Subject more likely to switch than what random chance would predict

- Null: probability of "Evacuate" equals probability of "Shelter" equals probability of "Wait"

33

Hypothesis 2

Proportion of subjects

Evacuate   Shelter   Wait

Scenario 1 (85 subjects)

Scenario 2 (106 subjects)

Scenario 3 (124 subjects)

Decision on day 1 (no simulation)

34

Hypothesis 2 using Bayesian analysis

- Jeffrey's prior, $\mathbf{p} \sim Dirichlet(0.5)$

- Posterior, $\mathbf{p} \sim Dirichlet(0.5 + \text{number of subjects})$

	Given day 1 decision, probability 3 decisions on day 2 are equally likely		
Day 1 decision	Evacuate	Shelter	Wait
Scenario 1	0	4E-4	0
Scenario 2	2E-5	0	9E-4
Scenario 3	0.01	0.11	0.07

Based on 200,000 simulations of posterior distribution

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Hypothesis 3

- Given that a subject switches between days 1 and 2, more likely that a subject switches to "Wait"

- Null: probability of switching from "Evacuate" to "Shelter" or from "Shelter" to "Evacuate" equals probability of switching to "Wait"

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Hypothesis 3 (data for all subjects)

Proportion of subjects

Scenario 1   Scenario 2   Scenario 3

Legend: Evacuate, Shelter, Wait, Evacuate earlier, Shelter earlier

Decision on day 1 (no simulation)

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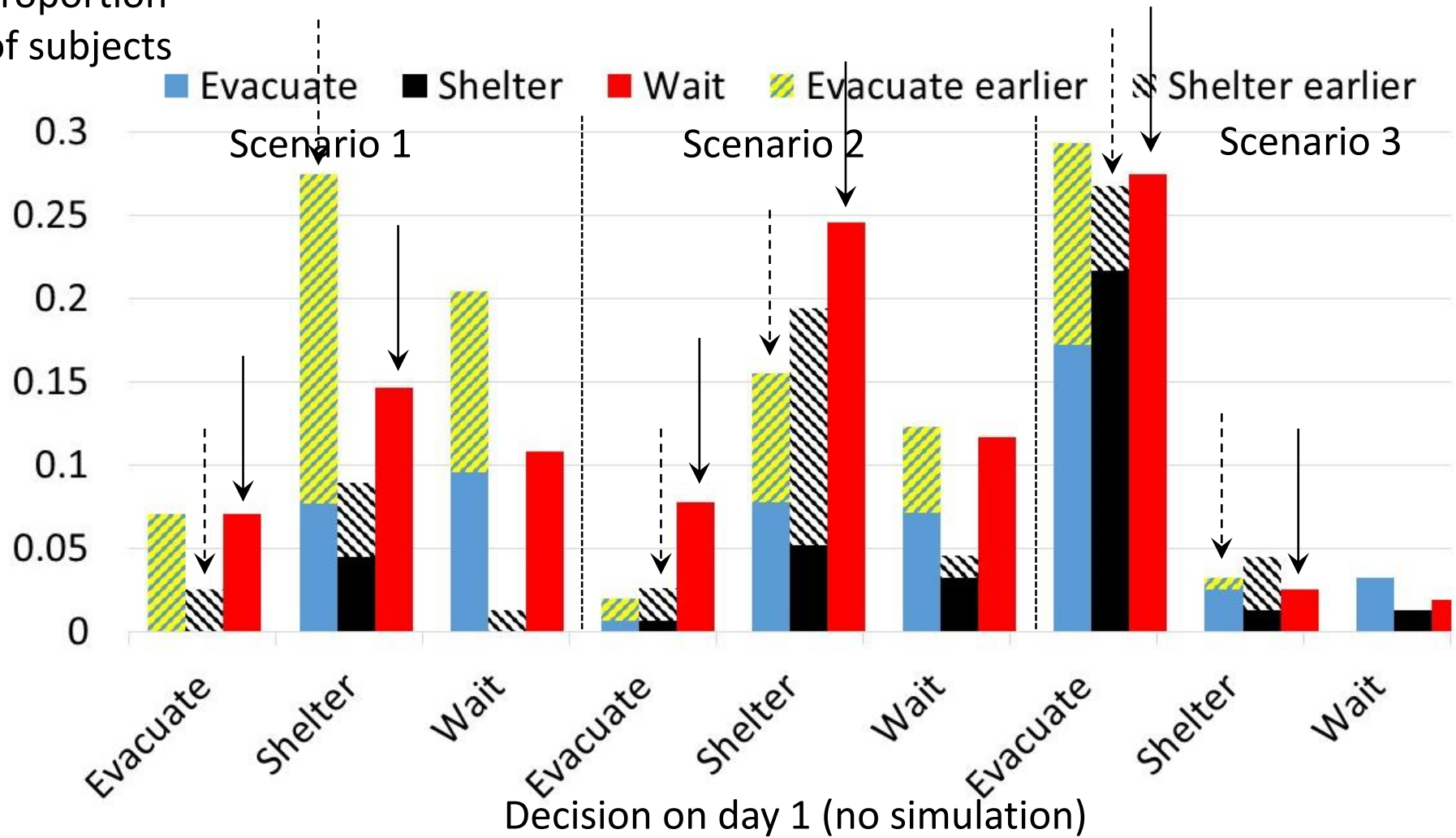
Hypothesis 3 using Bayesian analysis

- Jeffrey's prior, $\mathbf{p} \sim Dirichlet(0.5)$
- Posterior, $\mathbf{p} \sim Dirichlet(0.5 + \text{number of subjects})$

	Given evacuate on day 1, P(shelter > wait) on day 2	Given shelter on day 1, P(evacuate > wait) on day 2
Scenario 1	0.034	0.99
Scenario 2	0.021	0.038
Scenario 3	0.46	0.63

Based on 200,000 simulations of posterior distribution

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