

ACCOUNTING FOR HUMAN BEHAVIOR IN MODELS OF COUPLED NATURAL & HUMAN SYSTEMS

JONATHAN GILLIGAN

VANDERBILT UNIVERSITY

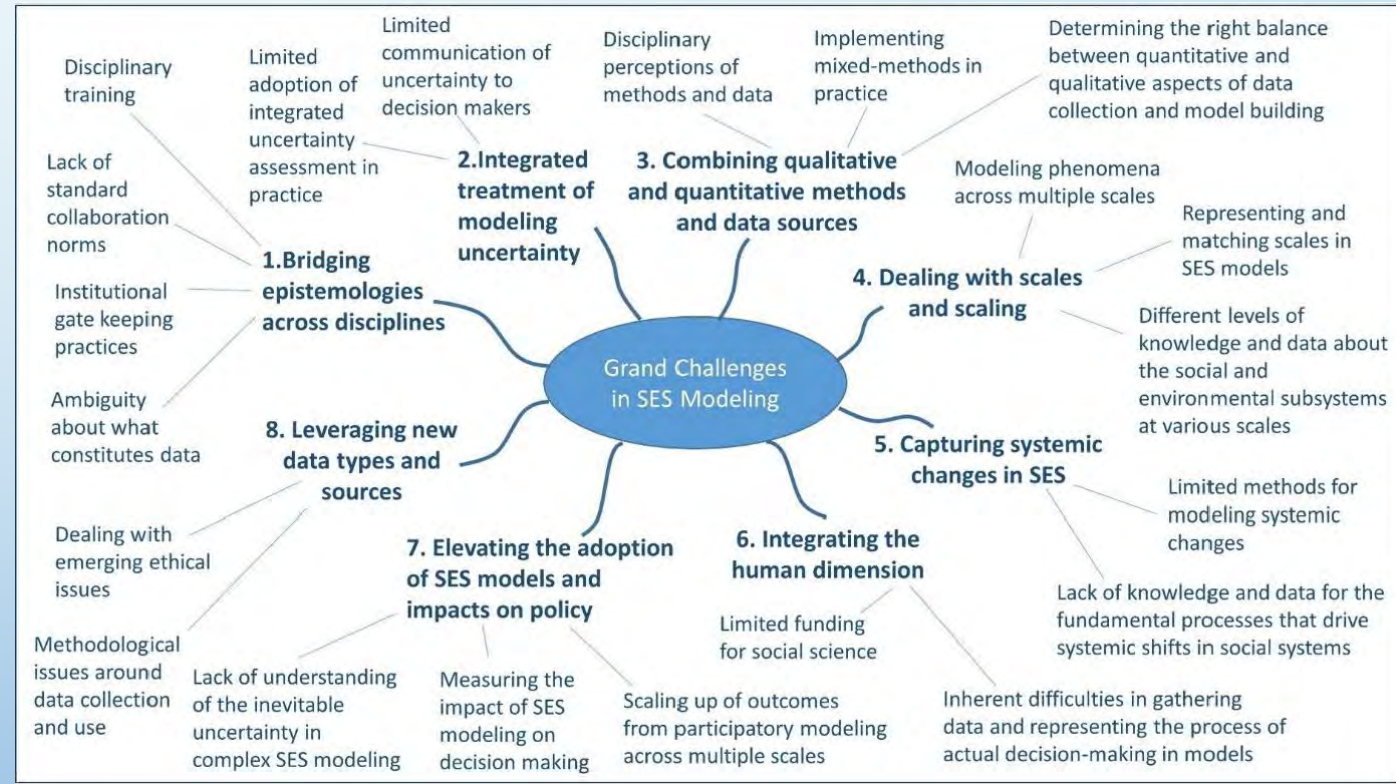
CoPE WORKSHOP ON COASTAL OBSERVATION AND MODELING SYSTEMS
SEPT. 8 2020

Funding from U.S. National Science Foundation
(CNH-1716909, Coastal SEES-1600319, WCS-1204685)
and Office of Naval Research (ONR N00014-11-1-0683)



GRAND CHALLENGES IN MAKING COUPLED SOCIO-ENVIRONMENTAL SYSTEMS MODELS USEFUL TO DECISIONMAKERS

1. Bridging disciplinary epistemologies
2. Integrated treatment of uncertainty
3. **Combining quantitative & qualitative data & methods**
4. Scales & scaling
5. Capturing systemic change
6. **Integrating the human dimension**
7. Bringing coupled models into the policy process
8. Leveraging new data types & sources



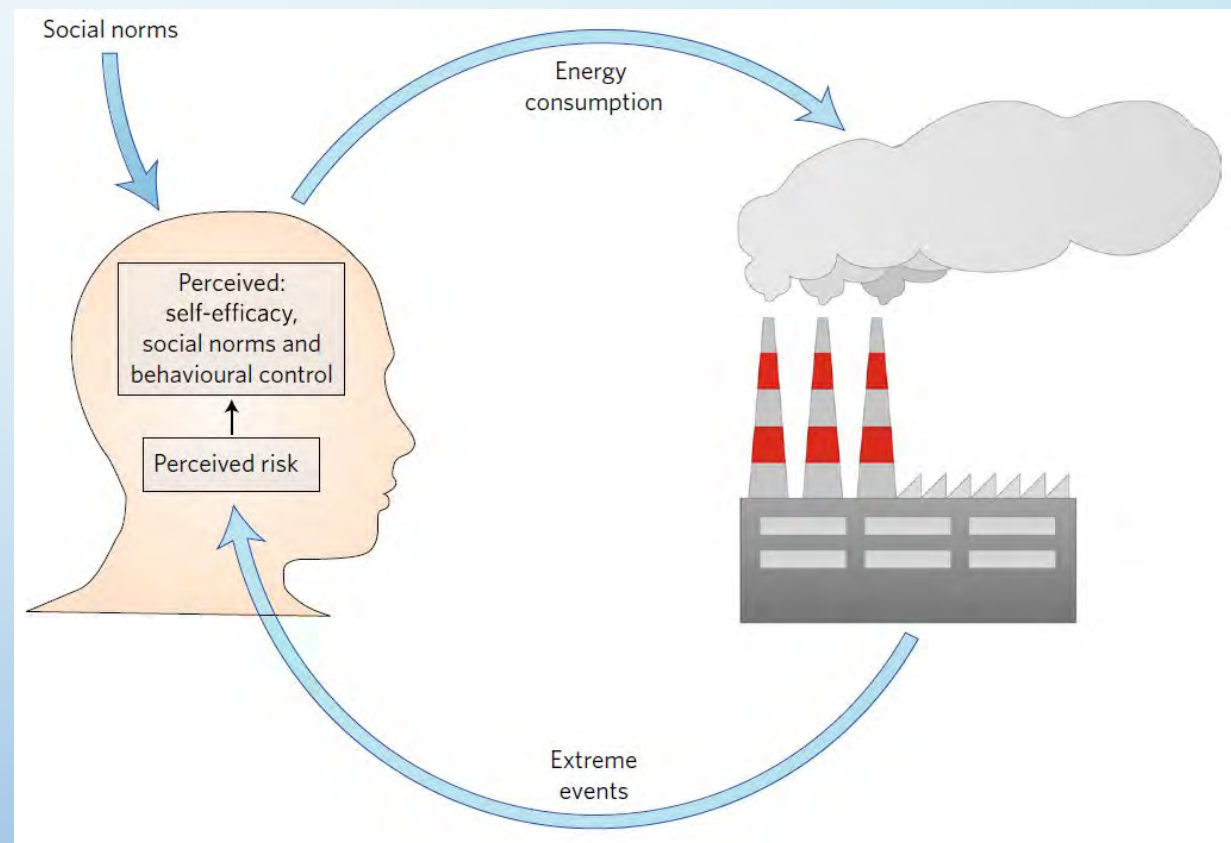
S. Elsworth et al., *Socio-Environmental Systems Modeling* 2, 16226 (2020)

[doi:10.18174/sesmo.2020a16226](https://doi.org/10.18174/sesmo.2020a16226)

BEHAVIORAL SCIENCE PERSPECTIVES

- Most models used to inform policy represent human behavior in simplistic economic terms:
 - e.g., Rational utility maximization
- Behavioral science tells us real people behave differently
 - Heuristics & biases
 - The role of emotions
- Interactions among people add complexity to decision processes

Theory of Planned Behavior & GHG emissions



J.M. Gilligan, *Nature Climate Change* **8**, 14 (2018) [doi: 10.1038/s41558-017-0038-0](https://doi.org/10.1038/s41558-017-0038-0)

K.S. Nielsen et al., *One Earth* (in press, 2020)

B. Beckage et al. *Nature Climate Change* **8**, 79 (2018) [doi: 10.1038/s41558-017-0031-7](https://doi.org/10.1038/s41558-017-0031-7)

AGENT-BASED MODELS

- Interacting agents
 - Individual-level decisions & actions
 - Potential for heterogeneous population:
- Collective behavior arises from interactions between individuals

Challenges:

- Model structure
 - How do individuals make decisions?
 - How do individuals interact?
 - Agent-environment interactions?
- Model calibration & testing

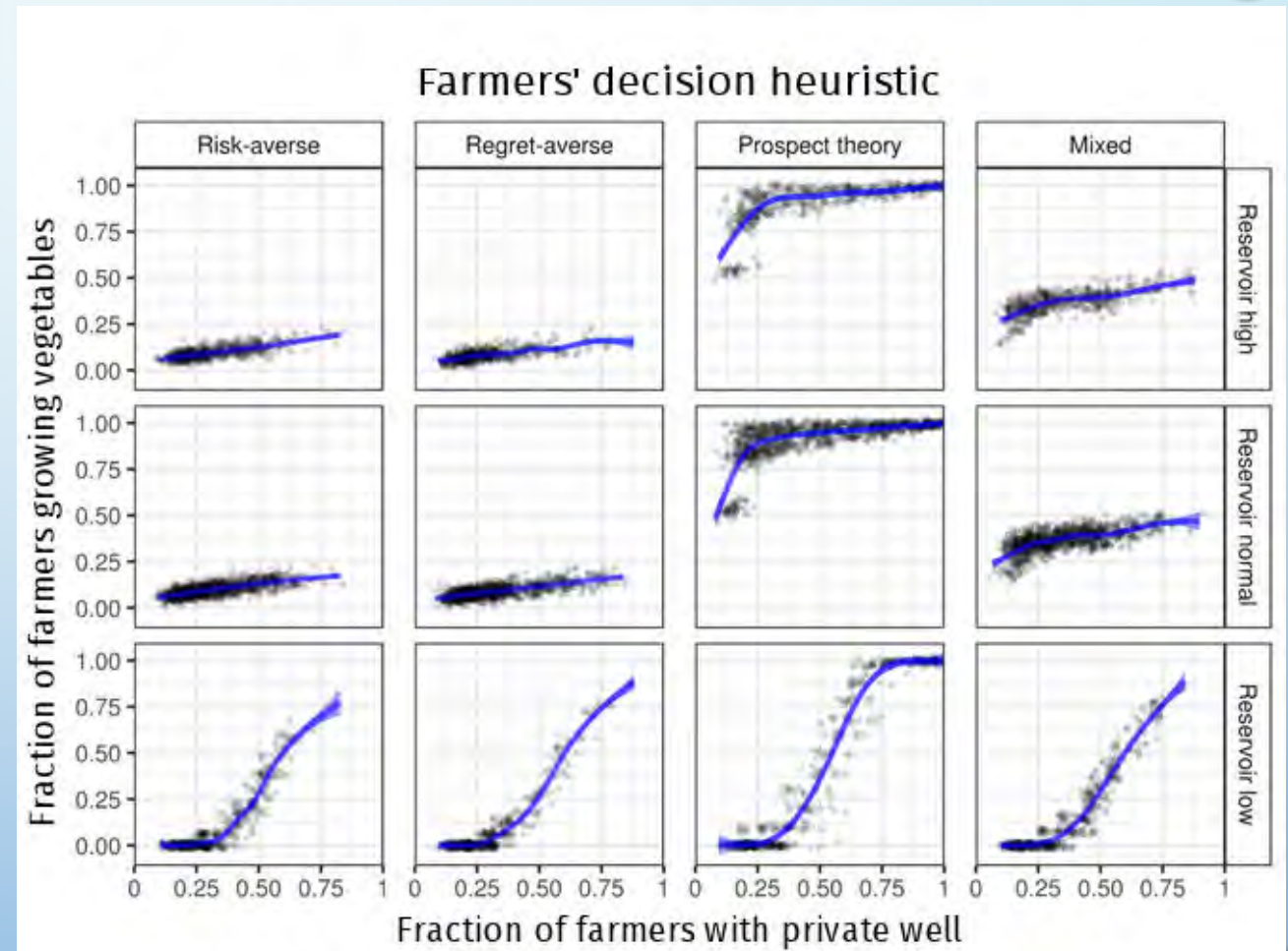
Use of Data:

The model is a narrative

- Qualitative data is valuable for shaping model structure
- Qualitative vs. quantitative evaluations of model performance

EXAMPLE: DROUGHT RISK AND CROP CHOICE

- Agent-based model of crop choice by farmers in Sri Lanka
 - Rice vs. vegetables
 - Variation by reservoir condition & private irrigation wells
- Different results for different psychological decision models
- **Implication:**
We need to understand decision processes

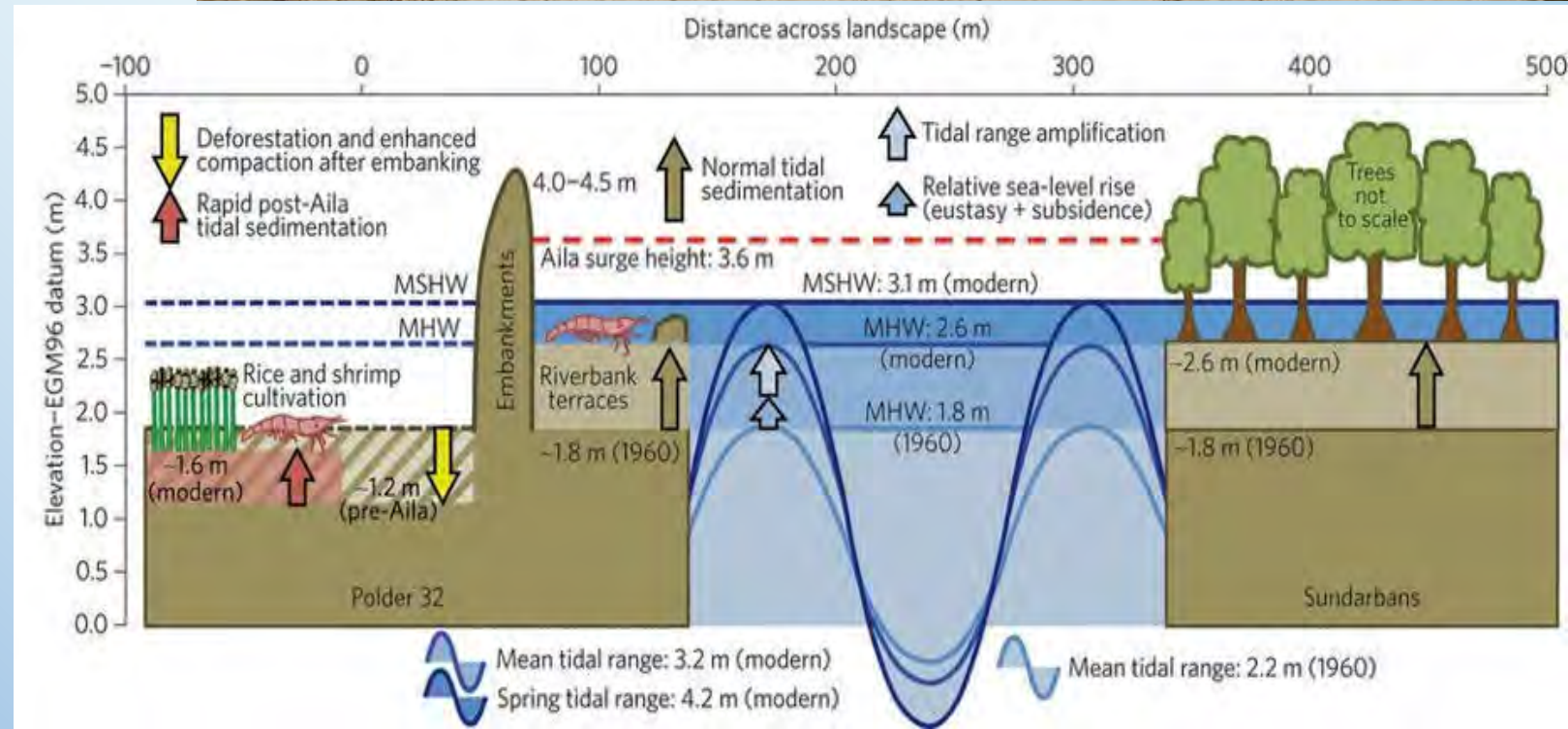


ENVIRONMENTAL CHANGE & MIGRATION IN COASTAL BANGLADESH



Coupled natural-human system dynamics

- Land-use affects hazards:
 - Flood-control embankments block sediment flow
 - Accelerated subsidence
- Hazards:
 - Flooding
 - Drainage/Waterlogging
 - Relative sea-level rise
- Environmental stress affects society:
 - Reduced crop yields
 - Loss of homes & property in floods



L.W. Auerbach et al., *Nature Climate Change* **5**, 152 (2015)

[doi: 10.1038/nclimate2472](https://doi.org/10.1038/nclimate2472)

C. Wilson et al., *Elementa* **5**, 78 (2017) [doi: 10.1525/elementa.263](https://doi.org/10.1525/elementa.263)

ENVIRONMENTAL CHANGE & MIGRATION IN COASTAL BANGLADESH

- Simplistic picture:
 - Drought, floods, sea-level rise happen
 - Mass out-migration of refugees
- Migration is more complex:
 - Active migration patterns for 1000 years
 - Follows economic opportunity & social/cultural connections
 - Environmental stresses (droughts, floods, storms, etc.) interact with existing patterns
- Migration can be both a sign of
 - **System failure** (desperation → leave)
 - **Resilience** (remittances strengthen home community)

“[Migrants] did not react blindly to the furies of nature. What appears to be natural takes work.”
— S.S. Amrith, *Crossing the Bay of Bengal* (2013)

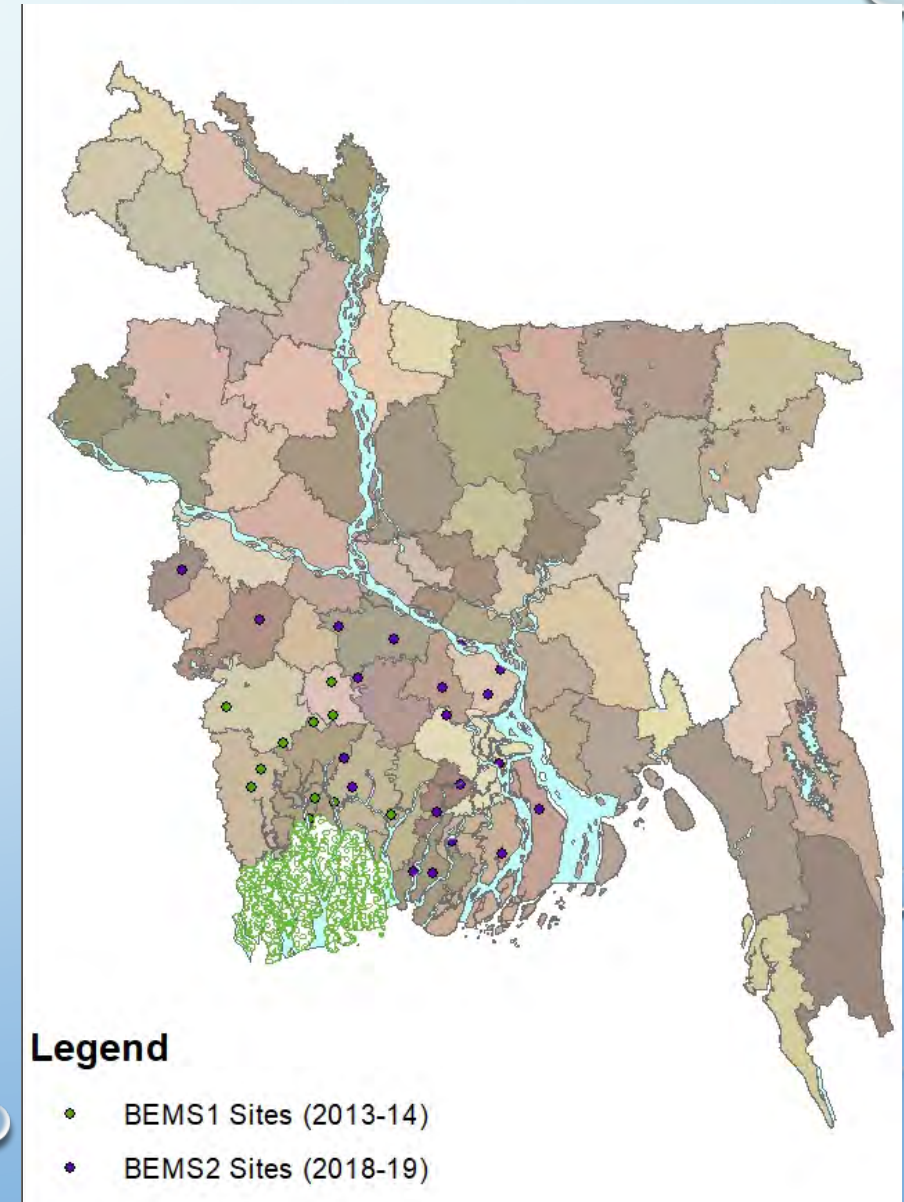
“[We urge] greater attention to climate, whilst avoiding climatic determinism.”
— Lieberman & Buckley (2012)

Khulna District, Bangladesh 2012



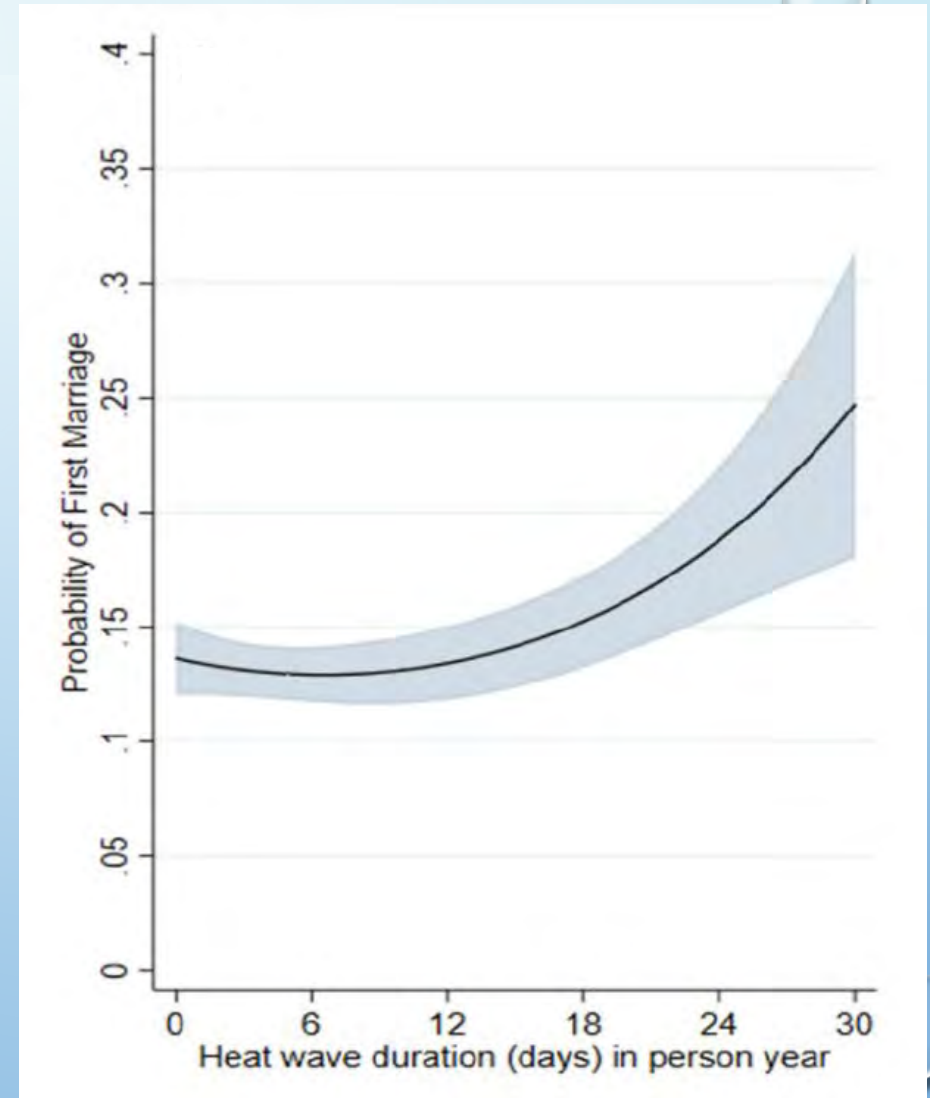
GATHERING DATA ON MIGRATION & ENVIRONMENTAL CHANGE

- Interdisciplinary collaboration (NSF-CNH)
 - Bangladesh Environment and Migration Survey (Katharine Donato & Amanda Carrico)
 - Retrospective capture of lifetime migration history for all members of household
- Phase 1 (2013-2014):
 - 1695 households in 9 communities
 - 1997 variables, 3000 individuals
- Phase 2 (2018-2019):
 - 4000 households in 20 communities



INTEGRATING DATA

- Combine migration data with:
 - Weather
 - Changes in land & water
- Analysis:
 - Sometimes we have a theory-driven hypothesis
 - e.g., “**Extreme weather affects marriage rates**”
 - Conventional regression/survival analysis
 - Other times we don't
 - With thousands of variables, how do we make sense?
 - Machine learning models show promise at identifying salient variables
 - But predictive skill is disappointing so far
 - Qualitative data is valuable for developing theory & hypotheses



INCORPORATING DATA INTO SIMULATION MODELS

- From the literature:

- The political economy is an important linkage between environmental stress and outcomes like migration & marriage
- Community & social networks are important
- Gray & Mueller (2012):
 - If disaster affects **small fraction** of community, **migration drops**
 - If disaster affects **large fraction** of community, **migration rises**

Model development:

- Focus on the local political economy:
- Study how migration can indicate either
 - **System failure** (desperation → leave)
 - **Resilience** (remittances strengthen local community)

THANKS

• Funding:

- NSF CNH-1716909, Coastal SEES-1600319, WCS/EAR-1204685



- ONR N00014-11-1-0683



• Students:

- Kelsea Best
- Laura Benneyworth
- Emily Burchfield
- John Nay
- Chris Tasich

Collaborators:

- Brooke Ackerly
- Kazi Matin Ahmed
- Mujibul "Labib" Anam
- John Ayers
- Hiba Baroud
- Joshua Bazuin
- Janey Camp
- Amanda Carrico
- Dilip Datta
- Bina D'Costa
- Katharine Donato
- James Fraser
- Steven Goodbred
- Thushara Gunda
- Richard Hale
- George Hornberger
- Bishawjit Mallick
- Dhiman Mondal
- Dayan Munasinghe
- Gouranga Nandy
- Irina Overeem
- Paola Passalacqua
- Kimberly Rogers
- Kushal Roy
- Christopher Small
- Michael Steckler
- Kishan Sugathapala
- Lanka Thabrew
- Heather Truelove
- Carol Wilson