Theme: How do complex systems respond to both short and long-term drivers?

Emma Cutler[1], Dana Hunt[2], Paul Kirshen[3], Geoff Trussell[4], Meredith Welch-Devine[5]
Dartmouth College[1], Duke University[2], UMass-Boston[3], Northeastern University[4], University of Georgia[5]

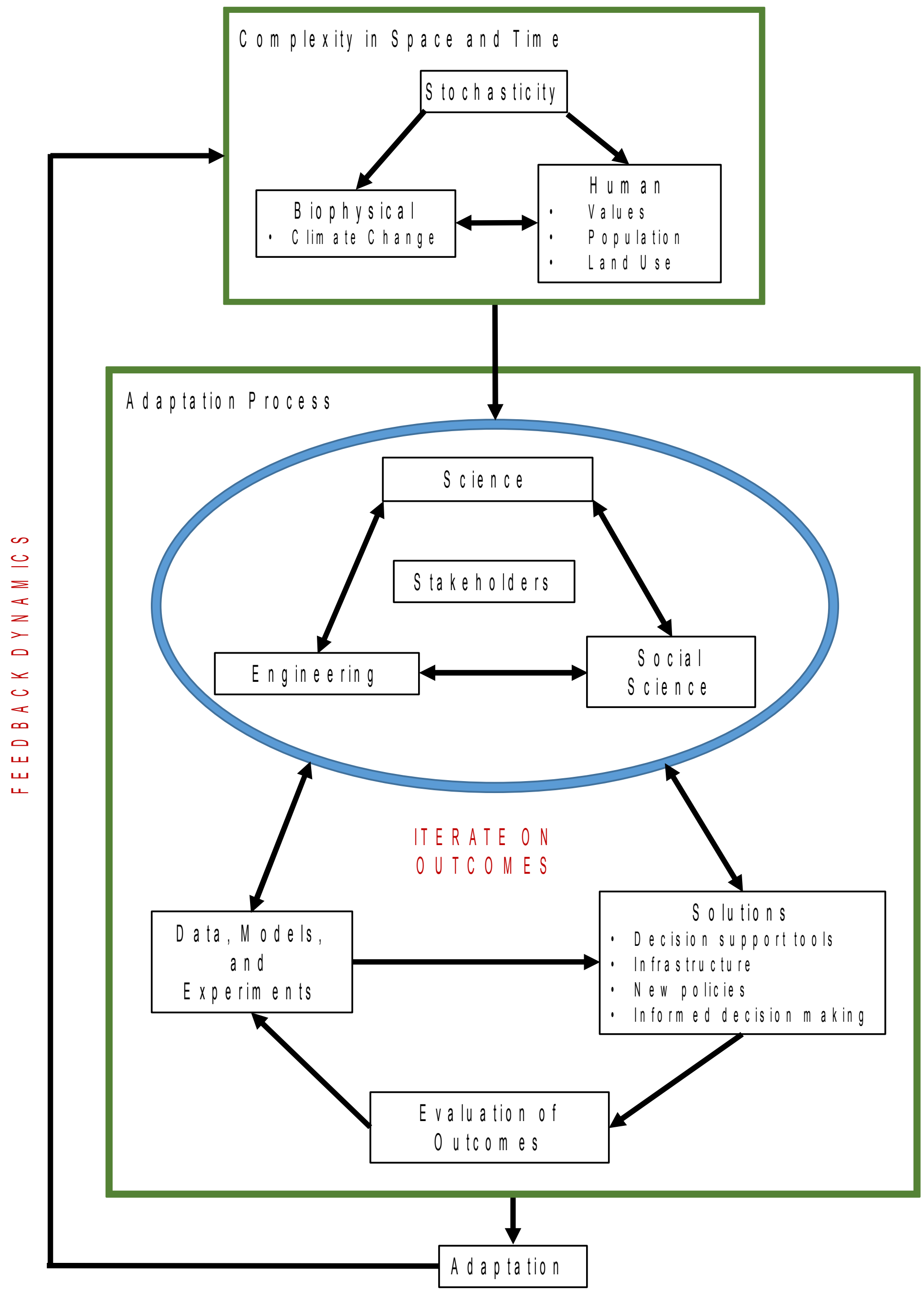
Coastal communities are subject to multiple drivers emanating from the biophysical (e.g., climate change) and human (e.g., land use, population growth and decline, values) domains that create complex challenges for coastlines and people. Stochastic processes and feedbacks further exacerbate this complexity on multiple scales of space and time. Effectively meeting the challenges posed by this daunting complexity requires trans-disciplinary collaboration between scientists, engineers, social scientists and stake-holders that leverage observation, experiments and modeling to produce innovative solutions to enhance adaptation in coastal communities. The outcomes of solutions (e.g., decision support tools, infrastructure, and behavioral and policy changes) that promote adaptation must be iteratively evaluated in space and time in response to unintended consequences and stochasticity. Such iteration will yield dynamic updating of knowledge and predictive models that better inform adaptive strategies. Our approach to these challenges is summarized in Figure 1.

Here, we explore an example concrete research topic that could be addressed by this framework and explicitly incorporate critical issues surrounding the temporal scale of both drivers and responses. We use flooding and sea level rise as an example of a critical environmental change with impacts on the built, natural and human environments. Coastal ecosystem flooding is event-driven, resulting from large storm events or king tides; however, these episodic events are layered onto a background of long term sea level rise. In Figure 2, we explore this example of episodic and long-term changes for potential impacts and responses across the natural, built and human dimensions.

The threats faced by human — natural — built systems in coastal areas are complex. By focusing our approach on the complexities of individual systems and their feedbacks we can achieve a synthetic understanding of the influences of the various component systems as well as the integrated system. Our approach also provides a road map for interdisciplinary research and how the evaluation of the results of this research feeds back to enhance future research. The results will be valuable to both the interdisciplinary research community and the community of stakeholders involved in problem formulation and solution.

Historically there has been a lack of consistent and effective management of coastal systems in regard to both high and low frequency events. These deficiencies and their adverse consequences are partly due to inattention to system complexity. Our systems approach should produce more robust and just solutions to current and emerging threats to coastal communities.

Figure 1. Conceptual diagram illustrating drivers of complexity in space and time and an observational, experimental and analytical framework that iteratively achieves adaptive solutions to threats faced by coastal systems.


Complexity in Space and Time
Stochasticity
Biophysical
• Climate Change
Human
• Values
• Population
• Land Use
Adaptation Process
Science
Stakeholders
Engineering
Social Science
ITERATE ON OUTCOMES
Data, Models, and Experiments
Solutions
• Decision support tools
• Infrastructure
• New policies
• Informed decision making
Evaluation of Outcomes
Adaptation
FEEDBACK DYNAMICS

	Event: storm or tidal flooding		Long-term: sea-level rise	
	Impacts	**Responses**	**Impacts**	**Responses**
Short-term	• Pollution • Human and Environmental Health • Economic impacts	• Fishery closures • Reduce nutrient loads • Insurance claims	• Policy planning difficulties • Uncertainty	(Mal)adaptation Mitigation
	Impacts	**Responses**	**Impacts**	**Responses**
Long-term	• Infrastructure damage • Population shifts • Ecosystem changes • Shoreline changes • Social disruption	• Change building codes • Long range planning • Restoration or policy changes • Loss of community identity	• Decreased property values • Loss of habitats/species • Economic impacts • Loss of cultural resources	• Retreat • Localized extinctions • Poverty • Loss of community identity

Figure 2. Example topic: Coastal flooding as both event-driven (storm or king-tides) and a long-term driver (sea level rise). A subset of potential impacts is organized by whether they occur on short or longer term time scales and are paired with responses.