LinCCCS - Linking Convergent Complex Coastal Systems

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Introduction

Coastal-human systems are extraordinarily complex and span time scales (sub-second to geologic), spatial scales (molecular to global), and multiple systems (including physical, biological, social, economic, cultural and regulatory processes). Tools to reconcile these disparate scales and systems into integrative models are necessary to provide complete understanding of coastal process feedbacks, hazards, and risks. Through collaboration with diverse stakeholders to identify key issues and research questions, CoPe can prepare coastal communities for imminent climate change through adaptation planning and strategies.

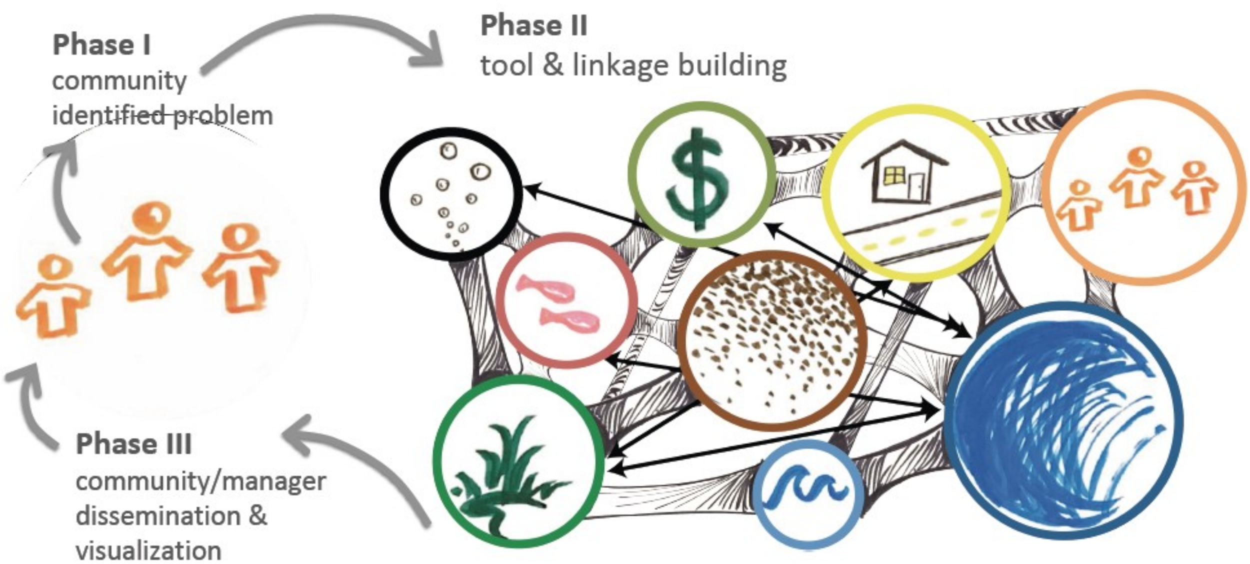
Statement of the challenge. Coastal system model elements operate on very different time and space scales and degrees of complexity. Currently, information is lost in attempts to couple models, so the complexity of the full system cannot be thoroughly represented. **This opportunity will build tools and methods to link/couple models across various spatiotemporal scales and systems in order to address community identified coastal problems.** This approach will create a more complete understanding of system feedbacks and allow communities and policy makers to make informed decisions about their futures.

Examples of the challenge: (1) Boundary components within the system are modelled twice, e.g., soil moisture is represented within meteorological land surface models and in hydrologic models, how can we resolve this dual representation and learn from any differences? (2) Scales differ between systems: meteorological models function on scales of 1-10 km, which is insufficient to resolve terrestrial features such as rain that falls onshore vs. offshore. Similarly, ocean hydrodynamic models typically function on scales of 1-10 km while in order to properly represent the surfzone or to incorporate morphodynamic models, scales of <1-100 m are required. (3) Different systems are sensitive to different information: hydrologic models typically do not track water temperature, but this is a critical input variable for proper representation of estuarine dynamics and the distribution of estuarine organisms.

Specific Recommendations, Methods

Recommendation Summary*: Advance new knowledge on the links between component systems of the coastal zone, and how to preserve mechanistic information when linking models.*
Convergence approach: Integrate theoretical and analytical knowledge on model coupling from mathematical and computer science disciplines. Cultivate innovative ‘connective tissue’ between systems, including up/downscaling, homogenization, stochastic parameterization, models of uncertainty, prediction and validation, and visualization. For example, dimension reduction/projection methods to help solve the "curse of dimensionality". Statistical methods such as stochastic parameterisation, Bayesian prediction to help deal with uncertainty in model links between systems. GIS/visualization techniques help communities and scientists to visualize links between systems and refine the approach.
Coasts-specific approach: Integrate knowledge and methods specific to environmental modeling disciplines. Within each system, highly developed understanding of dominant processes, sensitivities, critical scales and mechanistic causes of change already exist. Use this understanding to ensure that

'information' rather than just 'data' is passed between linked models, creating efficient model links that transmit everything that the coupled model needs and nothing that it doesn't need.
Data-driven: Environmental data is critical to evaluating models and understanding of linked systems. Individual models, model links and the coupled model system will be evaluated against key metrics/indicator values that describe the physical and societal processes. We benefit from coupled models as environmental data from one system is used to evaluate upstream/downstream system models. This highlights another LinCCCS objective, which is to work towards a common data & metadata format.



Phased Approach:
To ensure research addresses community questions and generates locally applicable results, we recommend a three phase approach to funding and project design.
Phase 1 – community identified coastal challenges
Phase 2 – research identifying candidate model sets, identifying and resolving spatiotemporal discontinuities, and designing & implementing the linking tools between models
Phase 3 - community/manager outreach, dissemination, and feedback through model data visualization and data products.

Vignette: An Estuarine System: understanding stratification, water quality and habitat in an estuary with a sand sill at the opening.
Using this framework, different projects can focus on specific, community identified problems that require multidisciplinary topics integrated across time and space. For example, to develop a simple hydrograph of estuarine inputs, global climate must be downscaled to capture critical coastal zone features (mountains, coastline) to provide climate and rainfall data to hydrology models operating at kilometer scale and to hydraulic and built environment features at meter scales. Coastal erosion models combine this information on flow and sediment delivery to the coast, with basin, regional and near-shore scale wave models (100+km; 10+km, 1 km), and individual waves across beach (cm-m). Individual waves interact with sediment through multiphase flow (air-water) at the molecular level. Coastal erosion

and sediment resuspension influence the distribution of suitable habitat and population/behavioral dynamics of organisms (e.g., represented by dynamic ecological niche models) on short and long time scales. The commercial and recreational fishing industries respond rapidly to the distribution and abundance of resource organisms, while regulatory mechanisms are slower to respond. These cross-scale, cross-system linkages illustrate how local economies and populations depend on the information transfer between component systems and represent a critical knowledge gap in the coastal sciences.

Deliverables

The deliverables for LinCCCS will include several key components. First, LinCCCS will provide a range of open-source tools with common platforms/wrappers for coupling complex coastal models. These tools will be made available to both academics and practitioners via GitHub, the world's largest open source community. Second, LinCCCS will engage scientists and stakeholders in the cooperative production of knowledge using a participatory approach, the goals of which are twofold: 1) to develop a common understanding among researchers and relevant stakeholders regarding the key computational, analytic and data benefits/limitations for connecting complex coastal models. This will include processes and educational efforts for deepening the collective understanding of systems drivers, dynamics, and relevant outcome measures, as well as any relevant societal and institutional capacities and constraints; 2) to cooperatively develop a conceptual approach to guide the development of the open-source tools, engaging scientists, allied stakeholders and community leaders throughout the process to ensure usability, as well as meeting scientific needs in the field and in the laboratory. We anticipate that this participatory development process will increase the use of these tools, which in time, will also encourage the broader scientific community to contribute to and improve upon this foundational work.

Impacts:

- Better understanding of linkages in coastal models: how mechanisms, magnitudes and rates of change in individual systems combine to drive the trajectory of the coupled coastal system
- Intercomparison of models and data by using common data formats as well as common platforms/wrappers for tool development
- Improved predictions and forecasting capabilities across a range of scientific domains (physical, biological, ecological, agricultural, social, political, economic, and the built environment)
- Reduced risk exposure for coastal communities and a more nuanced perspective of vulnerability for local stakeholders
- Applications of tools to diverse coastlines with different hazards, social concerns, economic structures, built environments
- Enhanced data visualization and dissemination of regional vulnerability and risk knowledge to communities and their decision makers
- Improved adaptation planning for coastal futures