Extreme Storms

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Figure 1: Aerial photo of the nearshore water-land interface near Atlantic City, NJ showing the range of coastal environments affected by extreme storms, including the nearshore ocean, beaches, dunes, marshes, sounds, infrastructure, and communities.

The Challenge and The Recommendation

Extreme storms have significant impacts on the nearshore water-land system (where ocean and estuarine waves and surge interact with land processes, Fig. 1) that pose high risk to society (NRC 1999, 2014a). Although disciplinary advances have led to improved understanding and modeling of storm processes, a **major challenge** is to understand and predict the one-way interactions and two-way feedbacks that determine the response to major storms. Storm processes may appear disparate, but can be highly coupled, such as the effects of rainfall and ocean-wave infiltration on groundwater levels and salinity, the effects of groundwater, rain, wind, vegetation, and infrastructure on Aeolian sediment transport, dune erosion, overwash sediment deposition, and beach recovery, and the effects of the resulting morphological and ecological change on oceanographic, geomechanic, and hydrogeologic processes. We **recommend** using a transdisciplinary approach to investigate:

- One-way interactions (blue arrows in Fig. 2) and two-way feedbacks (red lines) among oceanography (tides, surge, waves), geomorphology (sediment transport, morphological evolution), ecology and biology (vegetation, fisheries, bacteria), meteorology (wind, rain), hydrogeology (groundwater and solute transport), geo-engineering technology (soil behavior, soil-structure interaction), the built environment (engineering, infrastructure), and socio-economics (societies and people).
- Alongshore variability within this "nearshore-system" on scales of 10 m to 10 km.

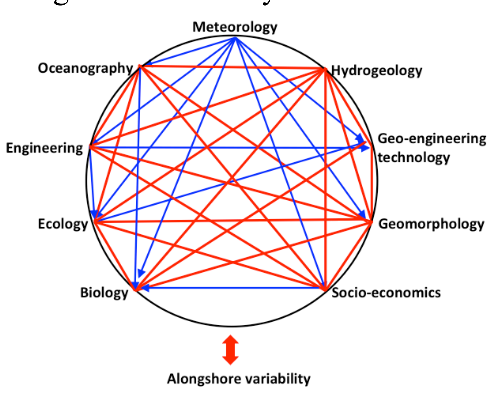

Figure 2: Schematic of one-way interactions (blue arrows) and two-way coupling (red lines) between processes in the nearshore system, arranged by discipline.

Observations during storms are necessary to understand the fundamental, coupled mechanisms that affect the nearshore water-land interface and drive change during extreme events, to determine sources of error in numerical models, to develop data-derived model parameterizations, to quantify model accuracy, and ultimately to provide insights that will lead to improved coastal resilience to major storms. To address system-wide questions, we recommend:

- Coordinating with agencies, NGOs, industry, and communities to ensure long-term science goals focus on storm-related societal needs in different regions, and to leverage infrastructure and observations from a wide range of stakeholders (Meadow et al. 2015).
- Providing logistical support to enable colocation of scientists during regional storm studies, including daily face-to-face interactions between scientists in multiple disciplines that will facilitate co-development of tools and integration of understanding.
- Developing a transdisciplinary, storm-chasing organization, with event identification, team selection, and travel structure based on the NSF-sponsored Geotechnical Extreme Events Reconnaissance (GEER) Association, but with emphasis on rapid pre-event deployment to obtain observations during major storms along US coasts.
- Sponsoring a series of transdisciplinary workshops focused on different coastal areas (e.g., barrier islands, estuaries, urban environments, tropics, arctic, bluffs and lagoons, deltas) (NRC 2014b), and
- Offering internship, citizen-science, and graduate-student-exchange programs to help nurture development of a convergent science field.

Evidence of Need for a Transdisciplinary Approach to Extreme Storm Impacts

Recent cross-disciplinary studies have improved our understanding of one-way (in which one process affects another) and two-way, coupled (in which two or more processes affect each other, possibly resulting in positive or negative feedbacks) interactions between nearshore water-land processes during storms. However, important processes and their interconnections, especially during storms, have been neglected owing to challenges caused by a lack of cross-disciplinary knowledge, terminology, methods, and scales, and by single-discipline-focused funding avenues that often constrain project size. Developing a holistic understanding of the critical interactions and feedbacks resulting in storm impacts to the nearshore water-land system, including socio-economic effects and responses requires integrated, simultaneous transdisciplinary studies of oceanography, biology (e.g., vegetation, bacteria, fisheries), hydrogeology (groundwater flow, biogeochemistry, solute transport), geotechnology (sediment characteristics, soil behavior, pore pressure response to waves), morphology (erosion), and natural and built infrastructure, and how these processes interact with each other.

For example, groundwater infiltration and exfiltration affect (and are affected by) vegetation and biota, soil properties, and ocean processes. Thus, changes in hydrogeology can alter geomorphology, biology, and oceanography, and changes in oceanography, biology, or geomorphology can affect the hydrogeology. Storm-induced changes in hydrogeology can increase erodibility of soils, with potential damaging effects on man-made infrastructure and natural defenses (dunes, marshes), while infrastructure may channel flows or reduce overwash, alter groundwater movement and water quality, affect dune and marsh evolution, and impact coastal biology. Economics and social responses to storms determine what structures are built or repaired, and whether communities persist.

The interactions and feedbacks between processes can result in alongshore variability on scales of 10's of meters to kilometers. Recent developments in observational, modeling, and data analytics capabilities make this an ideal time to form interdisciplinary teams to make rapid advances in understanding the response of the nearshore water-land system to storms.

Value and Impact of Transdisciplinary Extreme Storm Research Program

Deep integration of geosciences, math and physical sciences, biology, social sciences, economics, and engineering, along with emerging new data-analysis and computational approaches, is required to advance understanding of the nearshore water-land response to extreme storms. Through the intermingling of understanding, theories, and data analysis methods, the coastal community can be transformed to include broader participation by researchers from traditionally disparate disciplines. Working together will generate a transdisciplinary understanding of the interactions and feedbacks among tides, surge, waves, groundwater, soils, vegetation, fisheries, sediment transport, geomorphology, infrastructure, economics, and social responses that affect the co-evolution of coastal communities.

Coordinating multi-discipline studies with PIs colocated in shared offices and laboratories will ensure broad participation (with task relevant diversity, NRC 2014b). Daily face-to-face meetings to exchange information towards addressing a common goal will enhance convergence by enabling the broader academic team to identify and quantify interactions and feedbacks among processes during storms and to develop a common language and methods.

Despite the importance of coastal sustainability, there are few field observations during large storms (NRC 1999, 2014a). Although several studies have obtained pre- and post-storm topography, concurrent observations of geomorphological, oceanographic, hydrogeological, engineering, and biological processes are rare. Integrating these observations during extreme storms with sociological and economic studies will lead to new theories and understanding of the nearshore water-land system and community response.

Bi-annual workshops will enhance exchange of ideas and techniques, and keep the community focused on the big challenges and guiding questions. Travel support can be used to entrain scientists in disciplines that are not yet represented well within the larger group, and to teach PIs new techniques and methodologies and how to communicate effectively with residents, business leaders, and policy makers. Internships and citizen-science programs will enable members of local communities to participate in storm research. Exchange programs that enable graduate students and postdocs to work with scientists in different disciplines will provide new learning experiences so that they may become successful convergence researchers.

Summary

The proposed convergent, integrative systems approach will enable rapid advances in understanding and predicting impacts of extreme storms on the nearshore water-land interface and on coastal resilience, leading to improved coastal management strategies. The nearshore water-land interface is vital to the national economy, security, commerce, and recreation. As the frequency of intense storms increases, the threat of damage to communities, infrastructure, and ecosystems will increase. Coastal-storm-related economic losses have risen substantially, largely owing to increases in population and development in hazardous coastal areas (NRC 2014a). Thus, it is critical to improve our ability to predict the impacts of, and coastal response to major storms. By enabling convergence of research spanning geosciences, engineering, biology, economics, and sociology, the proposed effort will result in a better understanding of the feedbacks among and between nearshore water-land system processes and coastal communities during extreme storms.

References:

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