Advancing the Understanding of Coastal Flood Transition Zones

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IDEA

Recent storm events resulted in immediate and lingering flooding impacts that exemplify a need to better understand the interplay between hydrologic, tidal and storm surge processes to provide a more comprehensive understanding of flood hazards. Coastal flood plain phenomena can be delineated through careful consideration of the dominant contributors to flood hazards, risks, and associated impacts. High frequency events such as winter storms and nor'easters, and higher impact lower frequency events such as hurricane storm surge govern flood hazards in the immediate coastal flood plain region. Upland regions experience rainfall-induced flooding that is generally removed from the coast. In between these two regions there exists a flood transition zone where both rainfall runoff and storm surge (from winter and tropical storms) overlap.

Characteristics of the flood transition zone (including physical, numerical, social, economic, ecological, climatic, etc.) are poorly understood as a system. This research will advance basic science to better understand the physics of the interaction of two distinct flows (hydrologic and coastal surge) and enable a more complete assessment of socioeconomic impacts. A major product will be a coastal systems approach to flood hazards that will integrate hydrologic, coastal, biogeochemical, and anthropogenic systems at the coastal land margin.

DIFFERENTIATED RECOMMENDATION

The first step towards integrating these processes is to learn from the past by analyzing historical data. This requires compiling historical coastal and hydrologic data (e.g., surge height and precipitation) before, during, and after hurricanes or tropical storms, and uploading the data into a data hub that is accessible to the public. The data should be analyzed to rigorously define the transition zones by characterizing the spatial extent of the coastal flood transition zones and by evaluating the temporal duration of coastal and hydrologic processes affected by the transition zones. The second step is to identify data and knowledge gaps by evaluating inadequacy of current understanding. At the conceptual level, it is critical to examine the phenomena that cannot be adequately understood by the current conceptual models of coastal and hydrologic processes and their interactions. At the data level, it is of tantamount importance to examine the data that cannot be adequately explained by current numerical models of coastal and hydrologic processes and their interactions. The third step is to advance understanding of the coastal flood transition zones. This necessitates the development of new conceptual and numerical models to advance the understanding of and to improve prediction capability for the dynamics of the transition zones. Since data is the basis for advanced understanding and predictive understanding, it is indispensable to integrate insight gained with a monitoring network design and citizen science for cost-effective data collection and data repository. The last step is to go beyond natural science to couple with social science by linking coastal flood transition zones with decision variables of socio-economic decision-making, producing workforce of the future generation and offering guidelines for coastal ecosystem sustainability. To support science-informed decision-making for coastal zone urban planning, water resources protection, economic growth, etc, uncertainty of the decision variables should be first quantified and then reduced based on new understanding and/or new data. The coupled natural and social science cannot be achieved by engaging the communities of scientists, engineers, decision-makers, stakeholders, and general public.

REASONING & SUPPORTING EVIDENCE

Recent hurricanes that impacted the U.S. East Coast and the Gulf of Mexico highlight the significance of different components that contribute to flooding, namely flooding originated from water side (storm tide) and inland precipitation-driven flow. For example, hurricanes Matthew (2016), Harvey (2017), Maria (2017), and Florence (2018) caused small/moderate storm surge while they were extreme precipitation events. Present storm surge models do not account for precipitation-driven flow and infiltration, i.e. it is implicitly assumed that ground water level is so high that prevents infiltration. An additional implicit assumption is that precipitation-driven flow is negligible compared to storm tide. If any of these assumptions become invalid, i.e. significant infiltration or considerable storm water runoff is generated, storm surge models become unable to produce reliable estimates of water levels. Therefore, there is a critical need for advancing our understanding of the interactions between hydrologic and hydrodynamic processes in the transition zone where both become significant.

Understanding the interactions between hydrologic and hydrodynamic processes, and their effect on biogeochemical processes in the transition zone improves our capacity to seamlessly predict flooding from shoreline to upland and its impact on environment and coastal communities. Enhancing short- and long-term forecast capabilities is particularly important as climate change drives sea level rise, more intense hurricanes, and heavier rainfall events.

VALUE & IMPACTS

Direct impacts of this project will include development of flood transition zone models constructed from interactions between hydrologic, and tidal and storm surge models. Data collections required to develop these models will be available for other researchers. Development of models will require data aggregation and field collection. Making these curated data available to other disciplines is an added benefit of this work. The models produced by integrating hydrologic and tidal and storm surge models will represent a fundamental advance in our ability to predict storm impacts. The ability to predict storm impacts can lead to a better understanding of where flooding is likely to occur and where floodwaters will ultimately flow. A numerical model describing the transition zone between hydrologic and tidal and storm surge models can be used to develop a detailed understanding of how transitions zones respond to variations in storm frequency and intensity. Sensitivity analysis of model components can increase our understanding of the role each of these systems play in in flooding. Finally, a model can provide for a rigorous definition of flood transition zones.

SUMMARY

It is important to rigorously define coastal flood transition zones because their occurrence has long lasting impacts on the socioeconomic and ecological processes in low lying coastal areas. Predictive models of flood extent and fate can be used to assess risk in low-lying areas and provide a basis for policy decisions in these regions. We anticipate that development of scalable flood transition zone models will be of value to other fields of inquiry and locales. Ecosystem managers require transport models that predict the distribution of contaminants and nutrients following flooding events. Other regions beyond the Gulf of Mexico and US east coast need these coastal systems models. For example, delayed ice formation in the US Arctic is leading to increased coastal flooding, potentially impeding gas and oil development. Synergies from coupling a flood transition zone model to other processes can provide managers with important tools to predict flooding and associated effects.

A major product will be a coastal systems approach to flood hazards that will integrate hydrologic, coastal, biogeochemical, and anthropogenic systems at the coastal land margin.