2nd Announcement of a Workshop on
Understanding Risk and Resilience in Complex Coastal Systems
October 26*, 27 & 28, 2015, Broward County Florida

SURA's Coastal and Environmental Research Committee is promoting a new initiative focused on facilitating the integration of natural and social sciences in order to better assess the vulnerability and resilience of coastal systems subject to changing threats from rising seas, increased storm frequency and intensity, evolving societal pressures and demographics, land loss, altered river discharge and water quality degradation. The overall ***goal*** is ***to integrate social and natural sciences to assist planning and risk assessment of coastal communities threatened by both long-term and event-driven (e.g., by severe storms) inundation, land loss, water quality degradation and resulting risks to human health and safety as well as declines in industries such as tourism, fisheries, agriculture and shipping.***

"Resilience **is the capacity of a system, be it an individual, a forest, a city or an economy to deal with change and continue to develop" (Stockholm Resilience Centre, 2015).** Resilience involves the ability to adapt to constantly changing environmental, economic, and social stressors. It does *not* imply constancy, stasis or resistance to change. It is the capacity **to continually change and adapt yet remain viable**. Humans and nature are interdependent. According to the Stockholm Resilience Centre: "**Resilience thinking embraces learning, diversity and above all the belief that humans and nature are strongly coupled to the point that they should be conceived as one social-ecological system".** With that in mind, community resilience and ecosystem resilience must be considered together, not as separate problems. Furthermore, since the built infrastructure and related services are integral components of communities, infrastructure resilience must be considered in relation to both communities and ecosystems.

As a first step and to identify the priorities, science requirements, cyber support needs and long term goals, SURA brought together a diverse community of natural and social scientists from academia, government and NGOs in a workshop held in Washington, D.C. on October 29 & 30, 2014. The immediate goals of the workshop were ***to identify the most critical issues in assessing future risks, vulnerabilities and resilience of complex coastal systems that involve interdependent social, legal, biogeophysical and biogeochemical factors.*** Stimulating a deeper appreciation of ***interdependence*** and exploring new ways of modeling the mutual connections among the diverse factors was considered crucial and strongly emphasized. The final workshop report was distributed in February 2015 and is available on request.

It was felt by participants at the 2014 workshop that progress would be faster if we identify one or two geographically specific cases and explore ways that we might collaborate to anticipate future system responses to plausible *future* scenarios of changes in natural and social conditions at the selected location. The scenario should be driven by climate change predictions and projections of future demographics. In this exercise, we should attempt to devise problem-focused strategies and innovative solutions that require an integrative approach. At the invitation of the Environmental Planning & Community Resilience Division, Broward County, Florida, we plan to hold the second workshop in Broward County during a time of "king tides" (October 26, 27 & 28, 2015) beginning with visits to sites subject to frequent inundation. The plan is to create a step-by-step process to help workshop attendees visualize the issues and then define courses of action. We will ensure that collaborative teams are multidisciplinary and have appropriate sets of cyber tools to develop courses of action. During the scenario, participants will apply research, communication and advocacy skills to improve Broward County's approach to coastal resilience. The attached draft scenario, ***A Hypothetical Scenario: Broward County Florida in the Storms of 2035,*** is intended to ground discussions and stimulate identification of the information, cyber infrastructure and model developments needed to respond to both long and short-term coastal emergencies. The scenario contains some pessimistic and some overly optimistic parts. We should seek strategies to prevent or reduce the negative possibilities while making the more optimistic possibilities future realities.

We are encouraging and inviting a diversity of participants from academia, federal, state and local government agencies, environmental and social justice advocacy groups, the private sector and other stakeholders. As was the case in 2014, we want to bring together communities and disciplines that have not traditionally worked together and facilitate the sharing of diverse perspectives. On October 26, the workshop participants will tour sites in Broward County that are prone to flooding. Facilitated workshop activities are planned for October 27, culminating in a poster session. The resilience workshop will conclude with a government panel discussion on October 28. A detailed agenda will be available soon. If you, or any of your colleagues are interested in participating please send us a brief memo outlining your interests and background. If you are interested, please contact Don Wright (wright@sura.org) or Reid Nichols (rnichols@sura.org). More background for the workshop, including a template for the optional poster presentation and an on-line registration form can be accessed at http://scholarworks.uno.edu/resilience/**.**

* October 26 will be devoted to an optional daylong field trip to visit vulnerable sites subject to frequent inundation.

A Hypothetical Scenario: Broward County Florida in the Storms of 2035

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Abstract —At SURA's October 2014 workshop, entitled "***Understanding and Modeling Risk and Resilience in Complex Coastal Systems,"*** it was decided that a future workshop to assess the benefits of collaboration among social and physical scientists should be guided by a conceptual scenario applied to a specific coastal community. The following scenario weaves complex engineering, environmental, and community resilience elements into a story, which is coherent, systematic, comprehensive, and plausible. This scenario has been developed to create integrated word pictures of how the future might evolve in coastal Broward County, Florida. These images provide context for planning, a proving ground for ideas, or the stimulus for new research and development. The scenario-driven exercises may serve as a tool for improved decision making against a background of possible future environments.

Contents

1. Introduction

1.1. The purpose of this series of workshops is to identify ways that the understanding, predictive modeling and management of risk and resilience of coastal communities can be improved and facilitated by an interdisciplinary, multi-institutional collaborative approach. The collaborative framework envisioned should incorporate physical, social, organizational, economic, environmental, and engineering variables supported by observations and is intended to engage scientists and decision makers from universities, federal, state and local agencies, industry, NGOs and social justice advocacy groups. *The intent of the following fictional/hypothetical scenario is to ground discussions and stimulate identification of the information, cyber infrastructure and model developments needed to respond to both long and short-term coastal emergencies. The scenario contains some pessimistic and some overly optimistic parts. We should seek strategies to prevent or reduce the negative possibilities while making the more optimistic possibilities future realities.*

2. Background: Long Range Planning, Budget Constraints, and Infrastructure

The Greater Fort Lauderdale/Broward County Convention Center is a waterfront facility that has been built along the Intracoastal Waterway (Credit http://ftlauderdalecc.com/).

2.1 In the years leading up to 2035, Broward County's infrastructure was maintained and enhanced to the extent that budget constraints allowed. As was the case throughout Florida, the county government relied on intermittent funding from Federal and State sources and most of the private sector offered little assistance. An exception was the hotel and insurance industries, which acknowledged the serious threats from rising seas and increased storminess. Congress provided just enough funds for absolutely critical repairs, and left other infrastructure work to non-federal sources and the tax revenue obtained from the Inland Waterways Trust Fund, itself now stretched to cover federal infrastructure expenses other than waterways. Despite these limitations of resources, Broward County endeavored to maintain a forward looking and holistic approach to planning.

2.2 The most populous cities in 2015 remain so in 2035, however cities in Eastern Broward can expect more growth than their Western counterparts. Fortunately, enlightened county administrators heeded the predictions of increasingly sophisticated numerical models. Those models predicted increased groundwater elevations and decreased storm-water storage and discharge capacity as a result of accelerated sea level rise and increased erosion and storm surge damage as a result of increased frequency and intensity of tropical storms making Southeast Florida the most threatened coastal urban center in the world. In anticipation of potential future disasters, Broward County and its municipalities had already, by 2015, begun developing adaptation strategies and "triaging" allocations of limited resources to protect the most vulnerable -and critical public infrastructure. Included in infrastructure development by 2025 were improvements in storm water drainage systems including installations of tide back-flow flaps on outfalls, new pumps and an increase in land dedicated to surface water storage. In accordance with conventional wisdom, prioritizations of resource allocations were guided by traditional cost-benefit analyses. Those analyses suggested that, in 2015 assets worth nearly $420B were in jeopardy in Miami and $5B in Broward County, assuming 2 feet of sea level rise by 2030. These cost estimates do not include storm damage events, impacts from loss of services or other indirect impacts to the economy.

2.3 Prior to 2030, waterfront and oceanfront real estate property was most valuable and was precluded from ownership by lower and middle class income households. As these low-lying vulnerable areas were more frequently flooded by storms, eventually on a daily basis by tides and gradually over time completely inundated by sea level rise, wealthy populations migrated to higher ground. Higher ground was located along the coastal ridge (an ancient sand dune running north to south) and within the central corridor of the county. As value of these higher elevation properties escalated, low income families were forced to move into higher density areas or to low-lying, flood-prone areas in the western part of the county adjacent to the Everglades. The population of these areas nearly doubled between 2015 and 2035 as more low-income retirees, service-related hotel employees and Port Everglades workers including many non-English-speaking immigrants, located there.

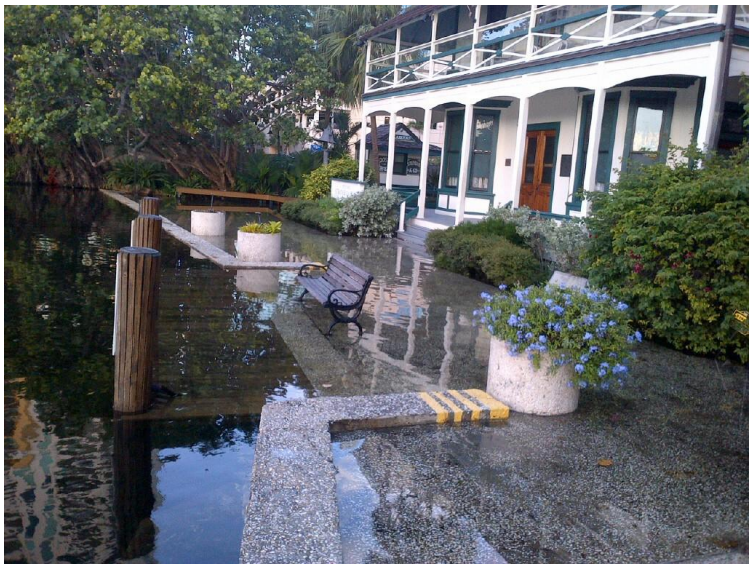
Port Everglades, Florida is one of the top three cruise ports in the world, is among the most active containerized cargo ports in the United States, and is an important seaport for petroleum products such as gasoline and jet fuel. (Credit http://www.porteverglades.net/).

2.4 Affluent neighborhoods became increasingly inward-focused and isolated from their less fortunate neighbors. Low lying communities needed improved drinking water facilities, wastewater management plants, and storm sewers. Tragically, lack of funds prevented all of the required infrastructure improvements from being extended to outlying areas or to poor communities. Poor people suffered from unreliable water systems that often promoted disease. Groundwater pumping and septic tanks dramatically increased in the outer suburbs as communities refused to extend their infrastructure to new housing developments. Water became an issue that often surfaced in local political and statewide contests. Road maintenance had been significantly neglected and by 2025 many low-lying communities became cut off by flooded roads during “King Tides” and increasingly recurrent storm surges. This created a growing impediment for effective and timely hurricane evacuation.

3. The Rising Threat

3.1 Over the period from 2015 to 2035, the average high tide had increased steadily, but between 2030 and 2035 the rate of sea level rise increased at an average rate of 1.27″/year more or less as predicted by numerical models. In the year 2035, the mean sea level in Southeast Florida was already more than a foot higher than it had been only a

quarter of a century earlier. The rise in sea level was related in p art to the global rise in average ocean surface elevation, in part to a slowing of the Gulf Stream and in part to increased occurrences of strong onshore winds. When the highly predictable "King Tides" of October were superimposed on the higher sea level, flooding of neighborhoods prevailed and the effects were greatly magnified when tropical-storm force onshore winds coincided with the high water events. On an almost annual basis after 2025 street flooding of low-lying neighborhoods paralyzed traffic, sewers were flooded, drinking water was contaminated and water-borne pathogens were spread throughout low-income neighborhoods.



The historic Stranahan House in Fort Lauderdale is sited along the New River which originates in the Everglades and flows east (Credit Environmental Protection and Growth Management Department, Broward County).

3.2 Also, after a comparative lull of a decade, tropical storms and hurricanes resumed their assault on Southeast Florida beginning in 2017. Over the period 2020 to 2035, Florida was impacted by 75 named storms. Of these, 11 were hurricanes of Category 3 or greater. The toll enacted by these storms on Broward County, particularly on the poorer neighborhoods was cumulative and devastating. In early July 2028, Category 5 "*Hurricane Etienne* made landfall just south of Homestead Florida. Fortunately, forecasts by the National Hurricane Center (NHC) had begun over a week before the storm's arrival. The forecasts were accurate and were heeded and all vulnerable residents had been safely evacuated prior to landfall. But the aftermath was catastrophic: over half of the county's homes were destroyed by storm surge flooding and wind damage, the capacity of storm water control systems was exceeded, the entrance to Port Everglades was filled with sand and rubble, and the lower floors and lobbies of high-end hotels were flooded. Thankfully, because of greatly improved computer forecasts, and the wisdom of emergency managers, there was no loss of life. But the worst was still to come.

4. Emergency Management 2035: Preparing for Hurricane Yvonne

4.1 In the years following *Hurricane Etienne* there were numerous named storms that crossed the Atlantic toward Florida or formed over the warm waters of the Caribbean or Gulf of Mexico. Fortunately for Southeast Florida, the few storms that made direct landfall there between 2028 and 2035 were either tropical storms or Category 1 Hurricanes. In contrast to the trend that had prevailed prior to 2010, the strongest storms tended to turn northward well to the east of Florida and track up the coast ultimately

striking the coasts of the Mid Atlantic states including New York Bight and, on occasion, New England. Others intensified over the hot waters of the Gulf of Mexico impacting West Florida, Alabama, Mississippi, Louisiana and Texas. The seven years of low storm activity in Southeast Florida allowed Miami-Dade and Broward Counties to make much-needed repairs to infrastructure and allowed many homes and businesses to be rebuilt. However, many of those repairs were still underway by late summer 2035 when Southeast Florida was hit by a rapid succession of two tropical storms and Category 2 *Hurricane Ursula.* With no further disruptions, recovery from those events would have required several months to a year.

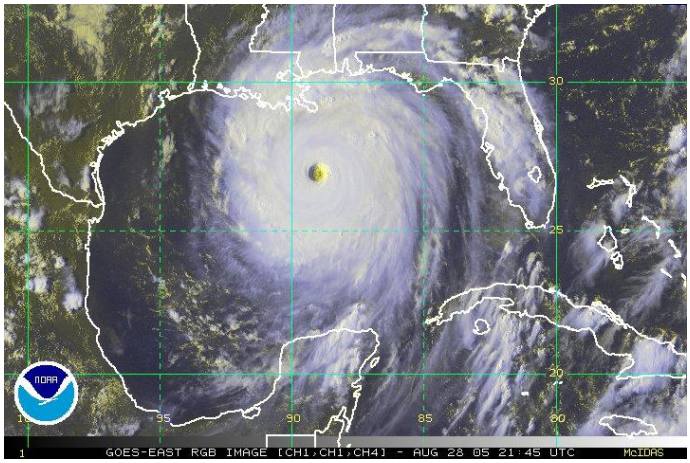
4.2 Throughout most of the Northern Hemisphere, the summer of 2035 lingered well beyond the beginning of autumn. Early in the second week of October, hot Saharan winds carried an "easterly wave" off the west coast of Africa and out over the warm waters of the tropical Atlantic Ocean. Within a day, an incipient low pressure system had developed and was moving steadily westward. Shortly after passing over the Cape Verde Islands on its westerly track, the system was labeled a "tropical disturbance" by the National Hurricane Center. Two days later, the NHC issued maritime warnings for "*Tropical Storm Yvonne*". As the system progressed along its westward course, it continued to develop: it was classified a Category 1 Hurricane on October 20 and Cat 2 on October 22. A Hurricane watch was issued by NHC for the Lesser Antilles on October 23 but hours later, in accordance with forecasts, the system took an abrupt turn to the north, then back to the northwest. By October 25 it was clear that *Hurricane Yvonne*, now a Category 3 storm with a growing diameter, had a high probability of making landfall somewhere along the coast of Southeast Florida. The NHC issued the appropriate warnings immediately. In the thirty years since Hurricane Katrina devastated the city of New Orleans, the uncertainties inherent in numerical predictions had been reduced substantially, and forecasts were now widely trusted by public officials as well as the general public. There was little dithering as all in the storm's path prepared for the worst.

4.3 At 10 AM on the morning of October 26, 2035, NHC upgraded *Hurricane Yvonne*, which was now centered about 400 miles north of the Dominican Republic, to Category 4. Further intensification was expected prior to landfall and the size of the storm had also increased: hurricane force winds now extended outward 120 miles from the center. The precise point of landfall had become irrelevant. Evacuations were underway in Monroe, Miami-Dade, Broward, and Palm Beach Counties. Southbound lanes on Interstate 95 and Florida's Turnpike were closed to southbound traffic and opened as northbound evacuation corridors. Emergency responders, the National Guard, Coast Guard and Florida State Police were placed on alert. By early afternoon on the 26th, most affluent residents had already departed for higher ground in their private cars but many low-income people remained behind, waiting to be picked up by emergency buses or friends. For many, neither would come.

4.4 As *Yvonne* continued its advance toward the Bahamas and Florida, multi-institutional teams of numerical modelers from NOAA, the Navy, Department of Homeland Security, the Netherlands and U.S., Australian and European Universities

worked together feverishly in a *virtual cyber domain* trying to predict the course and consequences of the storm. These efforts were appropriately under the auspices of NOAA's National Hurricane Center, which had the final authority for issuing forecasts. The ensemble of results from a suite of models converged with little scatter or uncertainty on a path that carried *Yvonne* to the north of Andros Island, across the Gulf Stream, where some intensification was predicted, with landfall expected somewhere between Homestead and Palm Beach on the evening of October 27 or early morning of October 28. The wind-field output from the atmospheric models was immediately used as input to ocean process models that predicted current, wave and storm surge characteristics generated by the storm. Following the wave model predictions, swell forerunners of the wind-generated waves were already arriving on Ft. Lauderdale Beach by late afternoon on the 26th with heights of 8 to 10 feet. Breaker heights were forecast to reach 30 ft over the next 24-36 hours and cause massive beach erosion along with overtopping of breakwaters and roads. Most ominous of all, however, the recently refined storm-surge model, *ADCIRC IV*, was predicting storm surge heights of 30 feet or more above normal tidal elevations to prevail shortly prior to landfall of *Yvonne*, which was upgraded to Category 5 by noon on October 27. And routine astronomical tide tables predicted a high "King Tide" to occur at 11:15 PM on October 27. Catastrophic inundation, overprinted by severe wave and wind damage now appeared imminent for Miami-Dade and Broward Counties.

4.5 Thirty years before *Yvonne*, as *Hurricane Katrina* bore down on New Orleans in 2005, numerical models, verified by wave moorings in the Gulf of Mexico, were predicting high storm surges for Coastal Louisiana. Those predictions were readily accessible in real time on the World Wide Web in the form of color-coded animations and numerical data, but they were largely ignored by local, State and Federal leaders as well as by most emergency managers. In 2035, the story was entirely different. Models had proven their reliability over and over in real-world storm events and had undergone rigorous testing, inter comparisons and refinements by way of a long series of testbed programs. Few, if any, responsible leaders in 2035 would have ignored the forecasts rendered by those models. So when Florida's Governor was briefed on the forecasts on the evening of October 26, more than 24 hours before the storm was expected to reach Florida, she contacted the President of the United States and asked that a state of emergency be declared for South Florida. The President was initially reluctant but eventually agreed. Soon after sunup on the 27th, FEMA convoys carrying emergency supplies, food, water and temporary housing were headed for high-ground staging areas



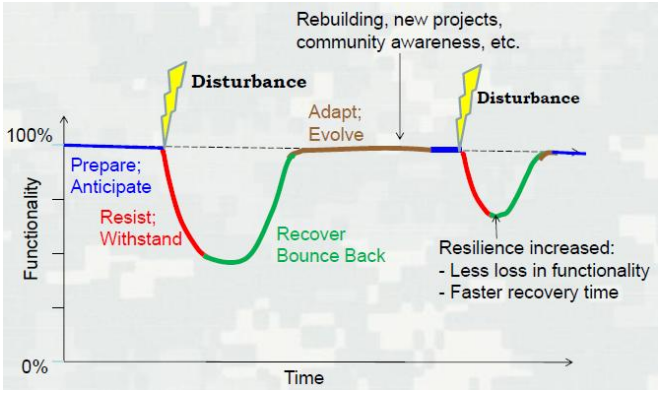
Hurricane Katrina nearing the Gulf Coast on August 28, 2005 (Credit National Oceanic and Atmospheric Administration).

in central Florida. Two naval amphibious ships carrying helicopters, long-haul communications, and engineering equipment for deployment in rescues were underway from Norfolk Naval Base in the hope of being on site as soon as possible after *Yvonne* crossed the southern end of the Florida peninsula into the Gulf of Mexico. Coast Guard vessels were also *en route.*

4.6 Resilience assessments conducted by Broward County were instrumental to disaster preparedness for *Yvonne*. Findings during resilience assessments contributed to the planning of effective humanitarian assistance by interagency partners by helping to identify the most vulnerable communities, environments, and facilities. The development of realistic scenarios for Broward County benefitted from integrated approaches where researchers from the natural and social sciences have worked together with a diversity of stakeholders and managers. Programs initiated during 2015 helped to overcome gaps between knowledge production on the one hand and the demand for knowledge to contribute to the solution of social problems, on the other. For example, efforts since 2015 were focused on the integration of physical and social models to understand parameters on the same spatial and temporal scales. Information from *ADCIRC IV* was used with urban models to support search and rescue, selecting parking areas for emergency vehicles, supply distribution points, favorable sites for temporary food and medical services, sites for sanitation facilities, and debris clearance. Information from *ADCIRC IV* with ecological models and imagery were useful to assess the degree of degradation and likely responses of ecosystems to storms since 2015.

5. Emergency Management 2035: The Aftermath of *Hurricane Yvonne*

5.1 Broward County has become more vulnerable due to usual urban issues and the additional pressure of natural hazards such as an increased occurrence of tropical cyclones. Increasing numbers of people are now living in low-lying lands that were once unoccupied because they are flood prone. Such factors stress facilities, ecosystems, and communities and weaken resilience. The response to the aftermath of Hurricane *Yvonne* exposed the weakness of existing emergency management and response policies on all levels - local, state, and federal.



Coastal Resilience (Credit Dr. Julie Rosati, USACE, August 26, 2014).

5.2 Much progress has been made since 2015, but it is only through review of the underlying problems of the current policies and practices that continued progress will occur. Resilience approaches in Broward County focuses on five dimensions – physical, social, economic, institutional, and natural. Resilience assessments that include

multidisciplinary discussions on global and uncertain threats can help advance the ability of Broward County to bounce back from disasters.

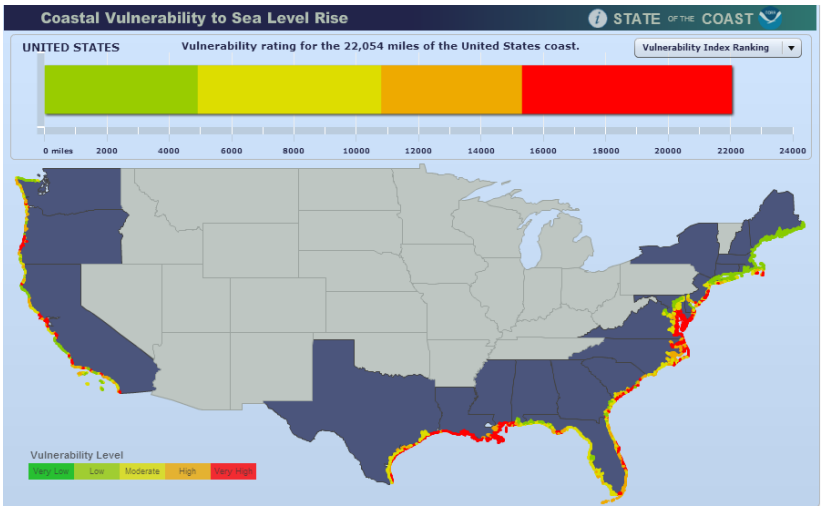
5.3 The focus on improvements is at the local level since local governments and institutions are first respondents and geographically close to the affected community. Local universities are sought to play a leadership role to advance resilience in Broward County by learning from disasters and teaching and advancing the lessons learned.

6. Meeting the Challenges Identified in the Foregoing Scenario: Some Questions

6.1 The relatively gloomy demographic and infrastructural developments portrayed in Section 2 of the scenario just described are not inevitable. What kinds of data, model predictions, management policies and governmental investment strategies might have prevented the rather dire circumstances faced by low income residents of Broward County in the Year 2035? Consider the possible needs for predicting "street by street" flooding probabilities utilizing detailed topographic data and projected sea level rise as well model predictions of future demographics. What are some human health considerations such as the feasibility of immunizations against water-borne diseases? What kind of protective structures such as sea walls or dikes might have helped had the "triaged" allocation of limited resources been more favorable to low income communities? What are some of the ways that the academic community can assist governmental agencies at local, state and federal levels in making long-range plans that serve all residents?

6.2 The 4th paragraph of Section 4 describes a high level of collaboration within a diverse *cyber-enabled* international team of academic and governmental modelers. That facet of this scenario is highly optimistic and promising. Sadly, it would be unlikely in 2015 or within the next few years for reasons discussed at length in the first workshop in October 2014. Most of those reasons are more related to the cultures of universities and government agencies than to science and technology. But it is entirely feasible for such advanced collaboration to happen within the next decade and this would probably save countless lives and alleviate the suffering of millions of people. Some questions to consider: How can integration of knowledge, tools and ways of thinking from several disciplines and across contrasting administrative entities (e.g., agencies, countries, universities) be more effectively facilitated? What are the primary impediments to such collaboration and how can they be overcome? What advances in cyber tools for rapid skill assessment and inter comparison of models are needed before the 2035 modeling scenario described can be realized? What advances (if any) in high performance computing capabilities are still needed to enable the *virtual cyber domain* imagined in Section 4, paragraph 4?

6.3 Another very optimistic- and presently unrealistic- part of the above scenario is the complete trust of science-based model predictions by emergency managers and leaders at all governmental levels. In 2015, scientific projections are widely denied by many politicians and decision makers. The enlightenment envisioned in this scenario must be nurtured by the scientific community at large. This will require careful and well-articulated, non-jargonized communication over a prolonged period combined with clear demonstrations- over and over and over - that the models really work and are not "hocus pocus". This may be the largest challenge of all. So the question is: How do we do that?



Coastal vulnerability to Sea Level Rise (Credit U.S. Geological Survey - Woods Hole Coastal and Marine Science Center).

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