Societal and Infrastructural Responses to Increases in Extreme Precipitation (SIRIEP)

Research problem As increasing greenhouse gases (GHGs) in Earth's atmosphere drive a warming climate, it is projected with high confidence that the frequency and severity of extreme precipitation events (heavy rains) will increase. This is based on both an understanding of basic physical principles and analysis of simulations of future climate from global climate models (GCMs). As the globe warms in response to increasing atmospheric greenhouse gas concentrations, the amount of water vapor over the warming ocean surfaces will increase substantially, because the saturation vapor pressure of water increases by about 7% per °C. With global temperatures projected to increase in the range of 1.5-4.5°C for a doubling of GHGs, increases of water vapor content near the ocean surface are expected to be 10-30%. Since extreme rainfall events over land require oceanic sources of moisture, this increase will directly impact the magnitude of such events. GCM simulations, for various scenarios of increasing GHGs, produce large future increases in extreme rainfall over land, even in regions where overall precipitation decreases.

The expected increase in extreme rainfall has stark implications for the design of infrastructure and buildings, for the management of landscapes that must be resilient to peak flows, and for planning how emergency responders act in rainstorm events. The current design of infrastructure uses extreme rainfall values derived only from historical rainfall records. As a result, it does not incorporate highly probable future increases in the frequency and intensity of extreme rains and does not provide the protection expected by society. In fact, current rainfall design values do not even fully incorporate the increases in extreme rainfall that have already occurred in many areas. Expanded risks of rainfall induced flooding are especially problematic for growing urban areas, with their increasingly complex storm-water management infrastructures and transportation networks. *SIRIEP, an integrated program of fundamental and applied research, will make NC State the national leader in addressing one of the most vexing issues arising from climate change.*

A resilient response to extreme precipitation demands that designers and stakeholders act upon reliable, useable, and trusted information about the evolving risks of extreme rainfall. At present, this information does not exist, but the urgent need is increasingly being recognized, as discussed at a May 2016 White House conference on building design codes. This is not a hypothetical need. The co-PI (Kunkel) recently (Aug. 25, 2016) received an inquiry from a major U.S. city which is abbreviated below (**bold emphases ours**):

"…*What we're wanting to figure out is how to bridge the gap between climate information and design standards/design decisions for water infrastructure, particularly stormwater and wastewater infrastructure. …* ***there is a growing need/desire to move beyond just considering to actually informing capital decisions****. We have one very large project …. where there is increasing clamor for guidance on* ***how to size a facility given climate change. This need is shared by many other jurisdictions****...So I'm wondering if…you would be willing to …lend your leading thinking on how to incorporate changing precipitation patterns into stormwater design. …* ***we're not looking for perfection but rather for a practical, credible and transparent way that we can reflect the climate signal in infrastructure design/planning****."*

SIRIEP will meet such needs, founded on the best weather/climate/statistical science and couched in appropriate estimates of uncertainty. There is, as yet, no consensus within the climate-science community about how best to do this. Thus, multiple approaches will be taken, drawing on new observing technologies, advanced statistical methods, and cutting edge numerical modeling. Beyondclimate science, this problem poses challenges for engineering and design, for planning, and for exchanging knowledge with practitioners who design infrastructure and coordinate emergency response. Its solution must be interdisciplinary, involving meteorology and climate change, the assessment and communication of risk, the development and use of new standards for engineering infrastructure, the development of innovative design practices, and the development and use of new technologies through which designers, stakeholders and the public can visualize changing environmental threats and the benefits of resilient responses. *SIRIEP will create, at NC State and RTI, an* *interdisciplinary community of practice to address these challenges.*

The proposed central outcome of our project is a prototype information and decision support system/tool that will provide an unprecedented level of novel, actionable information for (1) long-term planning and design of new development, (2) assessment of current risks within the present climate of extreme rainfall, and (3) *post hoc* analysis of flooding events. The purpose of the system is to provide an accurate assessment of areas and magnitude of risk (both present and future), based on the latest knowledge of climate/hydrologic/statistical science and land use, visualization of flooding from historical and projected future extreme storms, and interactive testing of various mitigation and design options along with cost/benefit assessments, all transmitted based on modern communication principles to maximize understanding, acceptance, and application. This system will be developed in partnership with our two stakeholder project participants, to ensure that the system is effective and meets real needs. We have commitments to participate from the City of Raleigh and from North Carolina Emergency Management (see attached letters). Additional stakeholders will likely be engaged over the course of the project as it evolves, and the development of our prototype elicits wider interest.

The prototype system will be designed so as to make information accessible, understandable, and usable, and to enable collaboration with users. It will be developed applying current principles of communication throughout. Language and graphics will be developed that can readily be understood and applied by trained practitioners in relevant disciplines as well as non-technical decision makers and the general public. With these goals in mind, there will be a strong reliance on visualization to convey information. Because user needs are place-specific, visualization of flooding from historical and future storms will be be provided down to the scale of individual housing units - this is possible by drawing upon the recently (2015) updated 1-meter resolution digital elevation model available in the most of North Carolina. Users will engage with the system by being able to explore options of flood mitigation in the existing built landscape and in planned future developments, and they will be able to study the impacts of historical storms, as they occurred and as they are projected to be enhanced by climate change. Because users may wish to consult the system “on the fly” or in the field, the key products will be built into mobile apps. So as to make the information provided fully credible, estimates of uncertainty will be provided throughout. The system will also provide guidance for cost-benefit analyses of flood mitigation options.

The focus of the development during the project will be on a spatial extent of a rapidly growing metropolitan area, specifically on the Research Triangle and selected other locations statewide, to ensure that we will have a working prototype by the end that is in use by our stakeholder participants. This prototype and its successful uses during the project will provide the foundation for proposals to federal and other funding agencies.

Why NC State? NC State, in collaboration with RTI, is optimally positioned to become a global leader in addressing the problem of extreme precipitation under climate change: we have a unique assemblage of expertise in weather and climate science, statistics, hydrology and hydrological engineering, landscape architecture, architecture, geospatial analytics, economics, and communications. Further, this problem closely aligns with NC State’s strategic research initiatives in Energy & Environment and Safety & Security. Finally, our region, the Southeast US, is increasingly vulnerable, over the coming decades, to flooding from extreme rains, as exemplified by recent devastating floods in South Carolina, in greater Houston, and in Louisiana.