Climate Extremes, Uncertainty and Impacts

Climate Change Challenge: The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, AR4) has resulted in a wider acceptance of global climate change caused by anthropogenic drivers of emission scenarios. However, earth system modelers struggle to develop precise predictions of extreme events (e.g., heat waves, cold spells, extreme rainfall events, droughts, hurricanes and tropical storms) or extreme stresses (e.g., tropical climate in temperate regions or shifting rainfall patterns) at regional to decadal scales. In addition, the most significant knowledge gap relevant for policymakers and stakeholders remains the inability to produce credible estimates of local to regional scale climate extremes and change impacts. Uncertainties in process studies, climate models, and associated spatio-temporal downscaling strategies, may be assessed and reduced by statistical evaluations. A similar treatment for extreme hydrological and meteorological events may require novel statistical approaches and improved downscaling. Climate change projections are based on future scenarios, for which quantitative assessments, let alone reduction, of uncertainties may be difficult. Regional impacts need to account for additional uncertainties in the estimates of anticipatory risks and damages, whether on the environment, infrastructures, economy or society. The cascading uncertainties from scenarios, to models, to downscaling, and finally to impacts, make costly decisions difficult to justify. This problem grows acute if credible attributions need to be made to causal drivers or policy impacts.

Climate Extremes Science: Our goal is to develop quantifiable insights on the impacts of global climate change on weather or hydrological extreme stresses and extreme events at regional to decadal scales. Precise and local predictions, for example the likelihood of an extreme event on a given day of any given year a decade late, may never be achievable owing to the chaotic nature of the climate system as well as the limits to precision of measurements and our inability to model all aspects of the process physics. However, probability density functions of the weather and hydrology, for example, likelihoods of intensity-duration-frequency (IDF) of extreme events or of mean change leading to extreme stress, may be an achievable target. The tools of choice range from the two traditional pillars of science: theory (e.g., advances in physical understanding and high-resolution process models of atmospheric or oceanic climate, weather or hydrology) to experimentation (e.g., development of remote and in-situ sensor systems as well as related cyberinfrastructures to monitor the earth and environmental systems). However, perhaps the most significant breakthroughs are expected from the relatively new pillars: computational sciences and informatics. Our research interests in the computational sciences for climate extremes science include the computational data sciences (e.g., high-performance analytics based on extreme value theory and nonlinear data sciences to develop predictive insights based on a combination of observations and climate model simulations) and computational modeling (e.g., regional scale climate models, models of hydrology, improvements in high-resolution processes within general circulation models, as well as feedback to model development based on comparisons of simulations with observations), while the informatics aspects include data management and discovery (e.g., the development of methodologies for geographic data integration and management, knowledge discovery from sensor data and geospatial-temporal uncertainty quantification).

Climate Impacts Science: The study of climate extremes, which include extreme hydro-meteorological events and stresses, is inextricably linked to the study of impacts, including risks and damage assessments as well as adaptation and mitigation strategies. Thus, an abnormally hot summer or high occurrence of hurricanes in unpopulated or unused regions of the world, which do not otherwise affect resources or infrastructures, may not even be termed extremes. On the other hand, extreme events like the after-effects of hurricane Katrina become extremes owing to complex interactions among multiple effects: a large hurricane hitting an urban area, an already vulnerable levee breaking down because of the flood waters, as well as an impacted society and response systems which are neither robust nor resilient to shocks. In general, climate change mitigation (e.g., emission policies and regulations to possible weather modification and geo-engineering strategies, as well as the benefits and side-effects of energy policies) and adaptation (e.g., hazards and disaster preparedness, early warning and humanitarian assistance or the management of natural water, nutritional and other resources, as well as possible migration and changes in regional population growth or demographics), need to be based on actionable predictive insights which consider the interaction of climate extremes science with the critical infrastructures and key resources, as well as population and society. While the science of impacts can get quite challenging and relatively difficult to quantify, our work will focus on two aspects based on recent advances in geospatial modeling, data fusion and GIS: The development of computational data science and geographical visualization tools for poly makers. We will develop a comprehensive treatment for uncertainty in the context of climate change related extreme events and impacts at local to regional scales. New capabilities will be developed to assess and reduce uncertainties, which will not only improve climate process models, but also produce credible information for better decisions and integrated assessments.