Emerging Water Resources Modeling Technologies to Understand Climate Change Impacts on Various Sectors and to Develop Adaptation Strategies

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The current episode of climate change induced by anthropogenic factors is predicted to intensify the hydrologic cycle, which in turn will affect the water resources and the allied sectors. General Circulation Models (GCM's) have shown that this intensification of hydrologic cycle is expected to decrease the number of rainy days, which has been corroborated with historical rainfall data which shows a significant increasing trend of extreme events over central India. The impact caused due to climate change on water availability, water demand, occurrence of flood and drought are assessed using hydrologic models and crop growth models for planning mitigation and adaptation strategies.

The hydrologic models that are presently used to assess the impact of climate change are deterministic and distributed in their spatial representation. The models have come a long-way from a simple conceptual framework and a lumped spatial representation in vogue few decades ago. Each of the hydrologic models use process based or empirical methods to represent various aspects of hydrology such as evapotranspiration, infiltration, surface runoff, snowmelt, channel flow, and ground water flow. Among these, the method adopted by the models to simulate surface runoff often drives the input data and computational effort required by these models. Many models currently in vogue are based on SCS Curve Number method for quantifying direct runoff (rainfall excess) and infiltration. The curve number is an empirical parameter assigned based on the landuse/landcover and the drainage condition of the soil and hence the input data requirements are minimal. On the other hand, there are models that adopt completely physics based approach such a Green-Ampt infiltration method for infiltration. However, the input parameter requirements of physics based models are quite intense. Then there is also the question of the spatial scale at which the empirical or the physical equation and their parameters are valid. This poses a great challenge while choosing or using these models for assessing the climate change impact on water resources.

Further, the water resources of today are heavily engineered and managed, where the rivers are completely dammed and water diverted for various uses such as irrigation, hydro-power, domestic and industrial water supply. In addition, urbanization and land management for agriculture has considerably changed the drainage pattern in addition to the soil characteristics thus affecting ground water recharge. Although the physical representation/understanding of the processes within the hydrologic models have considerably improved, most of the models could effectively represent / simulate only the virgin/natural hydrologic conditions. However, they fall short while representing the managed environment to assess the impact for developing mitigation and adaptation strategies. The aspects of managements to name a few could be: management of land (how the land is put to use such as urban, irrigated agriculture or rainfed agriculture etc.,), management of structures (e.g. purpose of the reservoir and how the reservoir is operated), management of demand (e.g. changes in cropping cycle and irrigation practices). These management aspects could include a wide spectrum of local practices and those that are dictated by law and policy.

In order to address these gaps, there is an emerging trend towards integration/coupling of multiple models such as hydrologic models, river/hydraulic models, reservoir models, with planning level/optimization models that adopt systems approaches. These models in turn depend on the downscaled climate data from GCM's to the scale at which the hydrological processes and management are represented. Hence, there is a challenge in terms of the integration of the scales at which the physical processes are currently understood/represented within these models, the scales at which the input data are available (or the lack of it) and the scales at which the impacts are assessed to develop adaptation strategies. Such impact models run with future climate scenarios show that frequent droughts and floods coupled with increasing population will pose a serious threat to our food and water security.

As stated earlier, there are several sources of uncertainties even with the water resources models themselves, when combined with the uncertainties that arise due to climate models, thus raising questions about the level of uncertainty in their overall predictive capabilities and their usefulness to develop adaptation strategies. For assessing uncertainty in models, techniques such as Monte-Carlo methods that require performing 1000's of model runs are usually adopted. However, due to the serial nature of the computational code adopted by almost all the hydrologic models, till date process level parallelization has not happened. However, system level parallelization are currently being attempted, in order to reduce the computational time while simulating large river basins.

The hydrologic models also produce an enormous amount of spatio-temporal model outputs of various components of the hydrology. However, the visualization capabilities of many of the models are quite limited. Further, there exist a large scope for adopting data mining techniques along with the water resources models that may lead to extraction of hitherto unknown information.

The focus of this talk would be on the current state of the knowledge on the water resources models, the lacuna/knowledge gap that exist in using these models, sources of uncertainties, the interdisciplinary nature of the challenges and emerging approaches to develop adaptation strategies and improve their physical representation within these impact models.