International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622
National Conference on Advances in Engineering and Technology
(AET- 29th March 2014)

RESEARCH ARTICLE OPEN ACCESS

Hydrological Impacts of Climate Change

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ABSTRACT
The increasing rate of the global surface temperature will have a significant impact on local hydrological regimes and water resources, which leads to the assessment of the climate change impacts. Main parameters that are closely related to the climate change are temperature and precipitation. Therefore, there is a growing need for an integrated analysis that can quantify the impacts of climate change on various aspects of water resources such as precipitation, hydrologic regimes, floods, drought, etc. There have been many studies of climate-change effects on hydrology and water resources which usually include: (a) use of climate models (GCMs), (b) use of downscaling techniques to model the hydrologic variables (e.g., precipitation) at a smaller scale based on large scale GCM outputs and (c) use of hydrological models for assessment of global climate change impacts. This paper reviews the existing methods for assessing the hydrological impact of climate change and discusses the challenges for future studies in this field.
***Key words*:** Climate change, Downscaling, GCM, hydrological models.

I. INTRODUCTION

Climate change can cause significant impacts on water resources by resulting changes in the hydrological cycle. Study of climate change include: (a) use of general circulation models (GCMs) for simulating time series of climate variables globally, accounting for effects of greenhouse gases in the atmosphere, (b) use of downscaling techniques to model the hydrologic variables (e.g., precipitation) at a smaller scale based on large scale GCM outputs, (c) use of hydrological models for assessment of global climate change impacts [1].

General Circulation Models (GCMs) are an important tool for assessing the impact of climate change on a range of human and natural systems. GCMs perform well at continental and large regional scales, but their ability to simulate climate at finer spatial scales is still limited [2]. Simulations at these finer scales are of considerable interest to hydrologists for assessing the possible impact of climate change on water supply and related aspects. This has led to the development of a range of downscaling methods, which uses the coarse scale GCM atmospheric simulations as the basis to produce finer scale variables. Different climate models have been used worldwide for climate impact assessment studies. The International Panel on Climate Change (IPCC) 4th assessment report identified 23 GCMs for assessment of plausible climate change impact on a range of human and natural systems [3].

General Circulation Models or global climate models (GCMs) are among the best available tools to represent the main features of the global distribution of basic climate parameters. But these models are unable to produce the details of regional climate conditions at different temporal and spatial scales. Anthropogenic global climate change would lead to changes in large-scale atmospheric features. However, the effect of large-scale feature changes on local surface climate cannot be resolved in the current generation of GCMs, which introduces the need for downscaling [4]. Hence, there is a great need to develop tools for downscaling GCM predictions of climate change to regional and local or station scales. Downscaling techniques have been designed to bridge the gap between the information that the climate modeling community can currently provide and that required by the impacts research community [5].

Currently general circulation models (GCMs) are considered to be the best tools for investigating the physical and dynamic processes of the earth surface-atmosphere system and they provide plausible patterns of global climate change. However, it is not yet possible to make reliable predictions of regional hydrologic changes directly from climate models due to the coarse resolution of GCMs and the simplification of hydrologic cycle in climate models [6].

Hydrological modeling is a mathematical representation of natural processes that influence primarily the energy and water balances of a watershed. The main purpose of using hydrological modeling is to provide information for managing water resources in a sustained manner. Some of the hydrologic models used are: SWAT (Soil and Water Assessment Tool), MIKE-SHE, Variable infiltration Capacity (VIC) model [7].

II. DOWNSCALING TECHNIQUES

Downscaling techniques have been designed to bridge the gap between the information that the climate modeling community can currently provide and that required by the impacts research community. There are two broad categories of downscaling procedures: (a) dynamical downscaling techniques, which involves the extraction of regional scale information from large-scale GCM data based on the modeling of regional climate dynamical processes, and (b) statistical downscaling techniques that rely on the empirical relationships between predictors i.e. large-scale atmospheric variables and predictands i.e. surface environment variables [8]. There are many advantages and disadvantages of dynamical downscaling and statistical downscaling techniques for climate change impacts, which indicate that neither technique is better than the other [9]. Based on the assessment of the climate change impacts on the hydrologic regimes of a number of selected basins, it was found that these two techniques could reproduce some general features of the basin climatology, but both displayed systematic biases with respect to observations as well. Further, it was found that the assessment results were dependent on the specific climatology of the basin under consideration. Hence, it is necessary to test different, but physically plausible, downscaling methods to find the most suitable approach for a particular region of interest. A schematic diagram has been shown for illustrating the downscaling approach as shown in Fig 1. Several statistical downscaling techniques have been developed to establish relationships between variables and the large-scale GCMs outputs. Among these techniques, the statistical downscaling method based on the Statistical Downscaling Model (SDSM) and the stochastic weather generators LARS-WG are widely used.

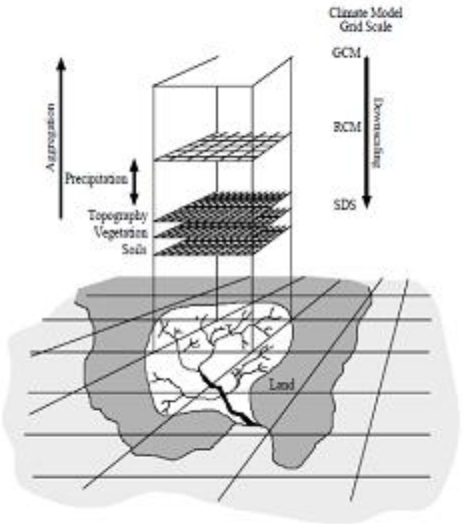

Fig 1: A schematic illustrating the general approach to downscaling [10]

III. CLIMATE CHANGE IMPACTS ON INDIAN WATER RESOURCES

Changes in temperature, precipitation and other climatic variables are likely to influence the amount and distribution of runoff into Indian River systems. The impact of future climatic change is expected to be more severe in developing countries such as India whose economy is largely dependent on the agriculture and is already under stress due to population increase and associated demands for energy, fresh water and food.

The river systems of central, western and southern India are charged by groundwater and their flows are reinforced by the seasonal rainfall. The water potentials of these non- snow and glacier fed rivers are strongly associated with the conditions of monsoons. A poor monsoon rainfall leads to drought conditions and situation is further motivated if monsoon fails for consecutive years and back-to-back drought occurs. Studies carried out on 12 river basins of India using SWAT model indicated that as a result of global warming, the conditions may deteriorate in terms of severity of droughts in some parts of the country and enhanced intensity of floods in other parts [11]. A general overall reduction in the quantity of the available runoff is expected under the GHG scenario.

The water resources of the country are likely to be affected due to climate change. The adaptation strategies have to be considered in the water resources sector in view of these changes. Studies are required to be taken up for developing the modified methodologies for the assessment of water resources, hydrological design practices, flood and drought management, operation policies for the existing as well as proposed water resources projects and assessment of available water for irrigation including the land uses and cropping patterns.

IV. CLIMATE CHANGE IMPACT ON WATER RESOURCES

Some of the issues concerned with the impacts of climate change on water resources are:

1. Determining extent of current climatic/hydro meteorological variability and future projections due to climate change.
2. Reliable downscaling of GCMs (Global Circulation Models) projections to regional and basin level.
3. Improvement required in hydro-meteorological network design for adaptation.
4. Assessment of impact on surface and ground water interaction.
5. Impact of Climate Change on LandUse/LandCover.

V. CHALLENGES FOR FUTURE

Modeling seems to be the only remedy to address complex environmental and water resources problems. Models will continue to find increasing use in the planning and management of water resources. As the demand placed on hydrologic models for environmental decision making has increased, particularly for problems involving prediction of future hydrologic conditions resulting from changes in land use or climate, the use of distributed models in environmental analysis is becoming more common in recent studies.

For evaluating the effect of climate change at smaller scale and finer resolution, an integrated modeling system that links climate model (GCM/RCM) with hydrological model through statistical downscaling is needed [12]. Previous studies have shown that the existing regionalization methods need to be improved, uncertainty induced from transferring the regionalization scheme based on the sub-catchment scale to basin scale, from basin unit to rectangular grid unit of the similar size, and from one geographic/climatic region to the other need to be evaluated and quantified. The importance to quantify this uncertainty for allowing the use of the predictions and for assessing the value of different model approaches and additional data to reduce the degree of uncertainty is to be emphasized.

VI. CONCLUSION

General Circulation Models (GCMs) are among the best available tools to represent reasonably well the main features of the global distribution of basic climate parameters. Outputs from GCMs are usually at resolution that is too coarse Downscaling of GCM projections of climate variables are therefore necessary. Outputs from climate model integrations are used to drive hydrological models and estimate climate change impacts. The main aim of this paper is to highlight the existing methods for assessing the hydrological impact of climate change at different spatial and temporal scales and discusses the future challenges in this field.

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