Chapter 12

Climate Change Impact on the Water Resources of the Limpopo Basin:

Simulations of a Coupled GCM and Hybrid Atmospheric-Terrestrial Water Balance (HATWAB) Model

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ABSTRACT

This chapter aims to evaluate the impacts of climate change on both hydrologic regimes and water resources of the Limpopo River Basin in southern Africa. Water resources availability in the basin, in terms of, seasonal and annual runoff (R), soil moisture (S) and actual evapotranspiration (Ea) is simulated and evaluated using the hydrological model, HATWAB. These water balances were computed from precipitation (P), potential evapotranspiration (Ep) and other variables that govern the soil-water-vegetation-atmospheric processes at 9.2km latitude/ longitude gird cells covering the basin. The 1961-90 simulated mean annual runoff reveals mixed patterns of high and low runoff across the region. Although relatively small changes in runoff simulations are prevalent among the three climate change scenarios, generally the OSU simulated relatively high runoff compared to the UKTR and HADCM2 GCMs.

INTRODUCTION

The UN expert panel on climate change has concluded that high rates of CO_2 emission into the atmosphere will induce global warming. The effects will be felt worldwide, but the regional and local implications are uncertain. Major effects are expected to be increases in temperature and extreme weather events, along with sea-level rise. Appendix presents some of terminology as used in the climate research community.

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The worst consequences of global climate change are expected in the developing countries which have little resources to mitigate the effects of extreme climatic events such as storms, floods and droughts.

Alternation in the availability of freshwater resources, including changes in stream flows and soil moisture is one of the most important regional consequences of global climatic changes. Since the current generation of climate models are well suited to the evaluation of detailed water resource problems, a variety of other impact assessment techniques and tools must be developed and tested. The hydrologic effect of climatic change is a subject of much interest in recent environmental research. Almost exclusively, conceptual type hydrological models have been used to study the impact of climate change on basin hydrology (Miller and Russell 1992; Schaake and Chunzhen 1989; Middelkoop et al. 2001).

In studying the impact of climate change on water resources at a catchment or regional scales, various hydrological models at varied temporal scale have been commonly applied, such as the monthly time step regional hydrological models (e.g., Guo et al. 2005), hourly and daily time step models (e.g., Middelkoop et al. 2001) and daily time step model, (e.g. Hulme et al. 1996).

In this study, we undertake hydrological and water resources assessment at relatively low resolution to map local level water availability and hydrological impacts as a result of climate change. Therefore, for this study, HATWAB (Alemaw, 2012), which is a modified version of its predecessor, hydrologic model known as a distributed GIS-based hydrological model (DGHM) for southern Africa, is applied (Alemaw and Chaoka 2003, Alemaw, 1999). It is employed in order to partition regional rainfall and climatic forcing of potential evapotranspiration into surface runoff, evapotranspiration, soil moisture, and other components of the hydrologic cycle. The adopted hydrological model, HATWAB, uses monthly accounting of water balances to model surface water balances and monthly soil moisture. For the latter, we employed a soil moisture accounting technique suggested in Vorosmarty et al. (1989), Alemaw and Chaoka (2003).

The basis of various climate change scenarios adopted by many researchers was founded on the global warming guidelines recommended by the International Panel on Climate Change (IPCC) (IPCC 1995a,b, 1996, 1998, 2000, 2001a,b, 2007). Scenarios of changes of up to 4°C in temperature and changes from 0 to ±20% in mean monthly rainfall have been considered for studying possible climate change impacts on hydrology and water resources (Guo et al. 2005; Panagoulia 1991; Nemec and Schaake 1982). On the other hand, several other researchers such as Hulme and Jones (1989), Hulme et al. (1996), IPCC (1995b) identify scenarios based on physical and statistical reasoning, from past instrumental data, from spatial analogues, and from climate models. These approaches and their limitations are described in Hulme and Jones (1989) and Carter et al. (1993). Among these, the most widely accepted approach involves the use of results from GCM climate change experiments (Arnell 2003; Hulme and Jones 1989), and this approach is adopted in this study.

The IPCC Emissions Scenarios have been subjected to series of revisions: the First Assessment Report (FAR) (IPCC 1990), the Second Assessment Report (SAR) (IPCC 1996), the Third Assessment Report (TAR) (IPCC 2001a), and the Fourth Assessment Repror (AR4) (IPCC 2007). Even though, the IPCC SRES (Special Report on Emissions Scenarios) (IPCC 2000) emission scenarios and subsequent IPCC Assessment Report revisions supercede the IS92a simulations, the latter was adopted in this study as it contained relatively high resolution regional climate data simulations at 0.5 degree grids. For this, we conducted GCM experiments using an integrated model called MAGICC (Hulme et al. 1995) and scenario generator (SCENGEN) (Wigley et al. 2000). The climate model employed by MAGICC which is an acronym for Model for the Assessment of Greenhouse-gas Induced Climate Change, is a standard

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