Chapter 13
Climate Change and Evapotranspiration

Abstract Climate change has been acknowledged as one of the greatest challenges for humanity. Although, there may be differences in opinions as to the cause of change, it is generally accepted that climate change is happening. There is sufficient data showing sea level rise and temperature rise and associated ecological changes. Climate change impacts on rainfall and evapotranspiration have not been conclusively determined. Decrease in rainfall and increase in temperature will result in increase in evapotranspiration. Global circulation models' (GCMs) applications have shown spatially varying diverse trends for evapotranspiration. It is essential to put forth the effort to know the impact of climate change on evapotranspiration and use the information for developing adaptations in water use and water management.

Keywords Climate change • Evapotranspiration • Global circulation models • South Florida • Great River Basin Jamaica

13.1 Introduction

Climate change, especially global warming, is expected to impact ecosystems negatively. Expected outcomes are rising sea levels and rising temperature in most regions. Impact on precipitation, evapotranspiration, and runoff is widely believed to vary by region. The worst-case scenario for water supply is decreasing rainfall and increasing evapotranspiration. Evapotranspiration increases with increasing temperature, increasing radiation, decreasing humidity, and increasing wind speed. Decreasing rainfall contributes to increasing evapotranspiration through increase in clear skies, increase in temperature, and lower humidity. Regional evaluation of climate change impact is necessary to evaluate impacts on evapotranspiration, precipitation, and runoff.

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13.2 Climate Change and Evapotranspiration

The United Nations Intergovernmental Panel 2007 report on climate change clearly shows warming trends. Forms of mitigation of the change and adaptation to the change have started developing in many places. Considerations are being given to climate change in infrastructural plans. Evapotranspiration is a main component of the global water and energy cycle. A change in climate and weather parameters will result in a significant change in evapotranspiration. Global warming can directly affect evapotranspiration through increase in radiation, rise in temperature, and increase in water vapor deficit. The results of a global climate model (GCM) simulations for three Alpine river basins for summer temperature increase of 3–4°C was found to increase potential evapotranspiration by 20 (Calanca et al. 2006). The predicted increase in solar radiation was 5, and 10–20% precipitation decrease was anticipated. Based on 317 weather station data analysis in China, it was found that evaporation has increased since 1980 with global warming (Cong et al. 2008). A report by the Union of Concerned Scientists and the Ecological Society of America predicts based on climate models that the Gulf Coast of the United States temperature will increase between 3 and 7°F for summer highs and 5 to 10°F for winters (Twilley et al. 2001). Higher temperature will increase evapotranspiration. A concern on the impact of water vapor contribution from evapotranspiration on global warming and the need to grow water efficient crops is presented by Azam and Farooq (2005). A study on the effect of global warming on evapotranspiration of alfalfa production in California applied a global circulation model and weather simulation model. The results indicated a prediction of daily mean maximum temperature increase of 4.3°C and statewide mean daily evapotranspiration increase of 0.59 mm (Zhang et al. 1996).

Based on 15-model mean changes, the Intergovernmental Panel on Climate Change reported an estimated 15% increase in annual evaporation for south Florida for the period 2080–2099 compared to 1980–1999 (Bates et al. 2008). Application of the Canadian Regional Climate Model to evaluate hydrologic impacts of climate change produced results of as high as a 20 cm (8 in.) increase in reference evapotranspiration with mostly 7–13 cm (3–5 in.) general increase over the whole state of Florida (Fig. 13.1, Obeysekera et al. 2011). Reference evapotranspiration was computed based on the Penman–Monteith equation.

The effects of global warming on south Florida evapotranspiration will be of a similar trend, increasing. Evaporation and evapotranspiration have been shown to have a direct relationship with solar radiation and air temperature (Abtew 1996). Increase in CO_2, solar radiation, and temperature will result in an increase in crop and vegetation productivity and water use. The increase in evapotranspiration should be of sufficient concern to warrant studies to estimate the increases and incorporate in water management strategies.

The Special Report on Emissions Scenarios (SRES) are grouped into four scenario families (A1, A2, B1, and B2) that explore alternative development pathways, covering a wide range of demographic, economic, and technological

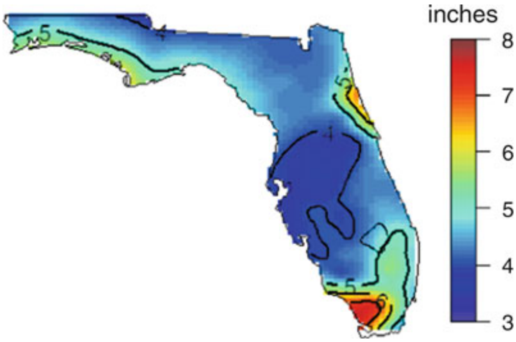

Fig. 13.1 Change in reference evapotranspiration in Florida by 2050 (Obeysekera et al. 2011; provided by South Florida Water Management District); 1 in. = 2.54 cm

driving forces and resulting GHG emissions (IPCC 2007). Based on these scenarios, various analyses for the watershed scale simulation of potential impacts of climate change on the water budget components have been done in different parts of the world. Although the reliability of the various downscaling techniques from large-scale GCM products to the watershed scale is different, it has been an acceptable practice to potentially understand the river basin impacts.

Hydrological impact studies rely on GCM outputs for watershed scale assessment of potential hydrologic alterations emanating from climate change-related variations in precipitation and air temperature. This will necessitate the downscaling of the large-scale GCP outputs to watershed scale. The downscaled outputs are then used as inputs to hydrological models for predicting the changes in stream flow, groundwater availability, evapotranspiration, and other water budget components.

Based on application of three global circulation models (Canadian Center for Climate Modeling and Analysis (CCCMA), Canada, Geophysical Fluid Dynamics Laboratory (GFDL), USA and Max-Planck-Institute for Meteorology (MPI-M), Germany), for three scenarios (A1B, A2, and B1) (IPCC 2007). Air temperature and rainfall were downscaled to the Great River region of Jamaica in an effort to assess the impacts of climate change on watershed scale hydrology. Using the Soil Water Assessment Tool (SWAT) (Arnold et al. 1998) along with stream flow, groundwater, and others, potential ET was predicted for the Great River basin, Jamaica (Melesse et al. 2011). Based on the modeling result, an overall average of 15 mm month^{-1} increase in potential evapotranspiration is projected for the period of 2080–2100. Figure 13.2 shows the average watershed scale-predicated air temperature increase from the base period, 1980–2000. The results project an overall average of 2.36°C increase in air temperature (Fig. 13.2). Figure 13.3 depicts monthly mean potential increase of potential ET for each scenario averaged from outputs of the three models.

There are studies that report plant transpiration increasing with temperature but a significant increase in CO_2 reduces the increase in plant transpiration attributed to an increase in temperature (California Department of Water Resources 2006; Hatfield et al. 2008). Accordingly, open water and soil evaporation does not decrease with an increase in CO_2 while increasing with increase in temperature. A USDA study on effects of climate change on agriculture evaluated the impact of CO_2 on crop

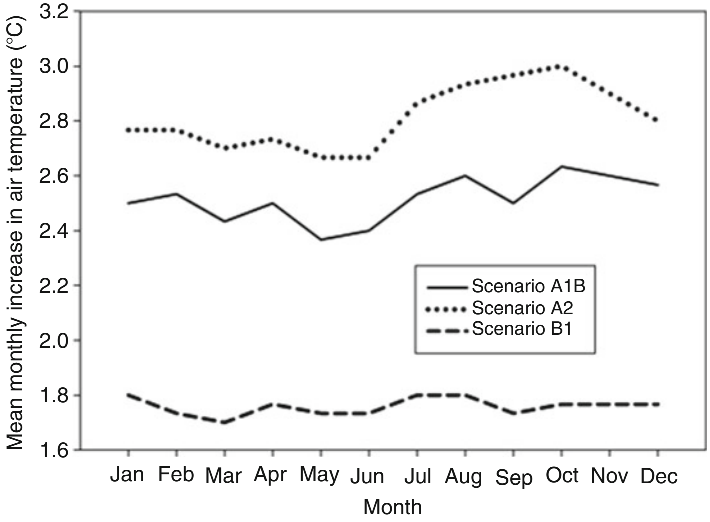

Fig. 13.2 Expected air temperature increase in the Great River region of Jamaica (2080–2100)

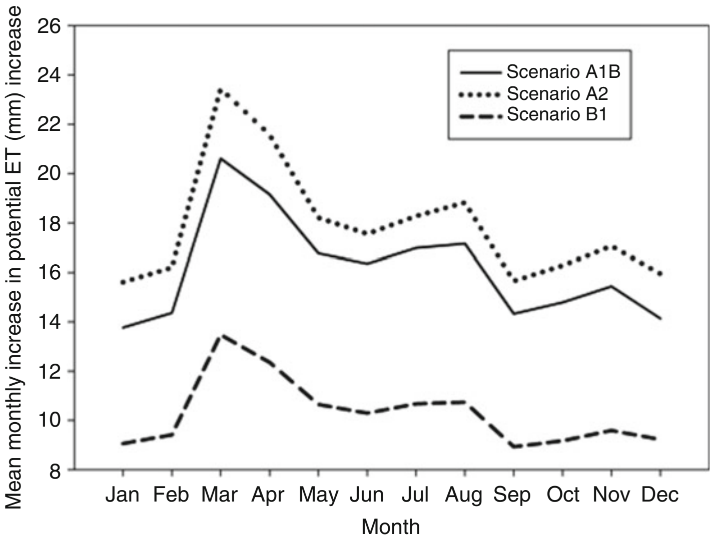

Fig. 13.3 Expected potential evapotranspiration increase in the Great River region of Jamaica (2080–2100)

evapotranspiration in the United States without considering the change in temperature. It concluded that with ample nitrogen and limited water, evapotranspiration will stay the same for both C3 and C4 plants. But, with ample nitrogen and ample water, reduction in evapotranspiration is projected at 550 ppm CO_2 concentrations

(Hatfield et al. 2008). Contrary to these projections, based on modeling impacts of climate change on water resources of Finland, evapotranspiration increases of 6, 13, and 23% are reported for 2020, 2050, and 2010 (Vehviläinen and Huttunen 1997). Sensitivity of evapotranspiration to global warming in a study for the arid region of Rajasthan in India concludes that a marginal increase in ET on such climatic area will have significant impact (Goyal 2004). A study of climate change, evaporation, and evapotranspiration using six global climate models projected the likelihood of increased potential evapotranspiration over India (Chattopadhyay and Hulme 1997). A global study of the Palmer drought index relationship to soil moisture and effects of surface warming concluded that as anthropogenic global warming progresses, risk of droughts will increase due to increased temperature and increased drying (Dai et al. 2004).

According to Jung et al. (2010), more than half of the solar energy absorbed by land surfaces is used for evaporation. They project that climate change will alter evapotranspiration through changes in the hydrologic cycle. Analyzing global meteorological monitoring network data, and remote sensing data and applying modeling, they concluded that evapotranspiration increased by 7 mm year^{-1} between 1982 and 1997. Also, they concluded that the decline in evaporation from 1997 to 2008 was due to limitation of moisture availability.

13.3 Summary

Climate change impacts the rate of evaporation from open water and evapotranspiration from vegetation. It has been demonstrated that increasing solar radiation and increasing temperature increases evaporation and evapotranspiration. During drought periods, a deficit in rainfall results with more clear sky days and low humidity. This condition creates a highly favorable environment for increasing evaporation and evapotranspiration resulting in accelerated water loss from lakes, reservoirs, and the soil. Studies on climate change impact on hydrology of every region need to include changes in evaporation and evapotranspiration. Increase in CO_2 and available energy would increase plant productivity, if moisture is available. Plant reaction to climate change in the rate and amount of water use is a subject for study.

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