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ScienceDirect

Procedia Engineering 154 (2016) 631 – 638

Procedia Engineering

www.elsevier.com/locate/procedia

12th International Conference on Hydroinformatics, HIC 2016

Analysis of capabilities of bias-corrected precipitation simulation from ensemble of downscaled GCMs in reconstruction of historical wet and dry spell characteristics

Xin Li[a,*], Gerard Pijcke[a], Vladan Babovic[a]

[a]*Department of Civil and Environmental Engineering, National University of Singapore, Block E1A,#07-03,No.1 Engineering Drive 2, Singapore, 117576*

Abstract

Precipitation outputs from downscaled GCMs are often used as input data for hydrological models to study the impact of climate change on hydrological cycles and water resources. However, precipitation outputs from downscaled GCMs may bear systematic errors, such as incorrect estimates of seasonal cycles and precipitation extremes and hence cannot be directly used as input to hydrological models. In this context, bias correction methods are often applied to post-process precipitation outputs from downscaled GCMs to adjust the statistics or distributions of the model output to those of historical observations. Though bias corrected precipitation outputs from downscaled GCMs show great improvements over the raw precipitation outputs in terms of reconstruction of seasonal cycles, extreme precipitation, etc., they might misrepresent the wet and dry spell characteristics of precipitation, which play an important role in climate impact studies on surface water quality, agriculture, domestic water use, etc. Therefore, this study presents a detailed analysis of the wet and dry spell characteristics of bias corrected precipitation outputs in Singapore region from a set of dynamically downscaled GCMs, and compare them with those of the historical observations during the baseline period between 1980 and 2009. The cumulative distribution functions of wet and dry spell characteristics (duration and magnitude), and the contributions of wet or dry spells of certain durations or magnitudes to total duration or total accumulated depth for bias corrected downscaled GCM precipitation simulation and historical observations are analysed and compared. The results show that the bias corrected precipitation simulations from the downscaled GCMs tend to overestimate the duration of wet and dry spells, as well as the magnitude of wet spells, in the upper tail of the distributions. Besides, frequencies and contributions of extreme wet

* Corresponding author. Tel.: +6581151743;
E-mail address: xinli@u.nus.edu

Peer-review under responsibility of the organizing committee of HIC 2016
doi:10.1016/j.proeng.2016.07.562

and dry spells are also overestimated. The results have implications for evaluation of climate change impacts on water resources management.

Peer-review under responsibility of the organizing committee of HIC 2016

Keywords: General Circular Model, dynamical downscaling, Regional Climate Model, bias correction, wet and dry spell

Introduction

Assessment of climate change impact on water resources availability relies on high-quality climate projection of hydro-meteorological variables, especially precipitation. The day-to-day variability of precipitation can be characterized by wet and dry spells, which are defined as episodes of consecutive rainy or non-rainy days [1]. Analysis of the capability of precipitation simulation from General Circulation Models (GCMs) or Regional Climate Models (RCMs) in reconstruction of the climatology and statistical characteristics of wet and dry spells during the baseline period is of great significance, before investigating the changes of wet and dry spell characteristics in the near future based on GCM/RCM projection [2-4] .

Wet and dry spells can serve as indicators of flood and drought conditions, and are of great concern for practitioners in the fields of hydrology, ecology, agriculture and water resource management [5]. Aside from the direct impact on water quantity through hydrological cycle, wet and dry spells of precipitation can also affect the water quality in rivers and lakes. For instance, a persistent long dry spell followed by an intensive rainfall event may lead to sudden inflow of contaminants from different pollutant sources in the catchment area into rivers and lakes, posing potential threats to aquatic ecosystems, drinking water safety, etc.

The spatial resolution of GCMs is often too coarse to simulate local climate, hence different downscaling methodologies (including dynamical downscaling and statistical downscaling) have been applied to downscale GCM outputs for regional climate change impact study and adaption planning. Dynamical Downscaling uses GCMs output to drive a higher resolution RCM, which enables a better representation of land surface, coasts, topography and atmospheric dynamics, thus is capable of providing information required for regional climate studies. However, when applied to catchment or at-site study, the downscaled GCM outputs may mismatch the climatology or statistical characteristics of the historical observations due to the bias in both the driving GCMs and RCMs. Therefore, bias-correction approach is often implemented to match the statistics of the downscaled GCM or RCM output to that of the historical observations [6-8]. Though this may improve the performance of downscaled GCMs in reconstruction of the seasonal cycles and cumulative probability functions (CDFs) of historical rainfall, it will not guarantee that climatology and statistical characteristics of wet and dry spells in the historical observation are also reproduced.

Extensive studies have been done in the fields of validation the downscaled GCM or RCM rainfall simulation in reconstruction of the climatology of precipitation field or representing the characteristics of extreme rainfall events during the baseline period [9-12]. However, a detailed literature review demonstrates that to date, studies in the regard of validation of the (bias-corrected) downscaled GCM precipitation simulation in reconstruction of historical wet and dry spell characteristics are still limited, especially in the tropical region. Precipitation in tropical region is often dominated by convective thunderstorms, which is hard to parameterize in GCMs and RCMs, unless the resolution is comparable to the scales of thunderstorm cells (smaller than 10 km.) [13] .

Therefore, the aim of this article is to validate the capability of bias-corrected dynamically downscaled precipitation simulation from an ensemble of GCMs using a high-resolution RCM in reconstruction of the characteristics of wet and dry spells (CDF of wet and dry spell duration, CDF of wet spell magnitude) of the historical observation during the baseline period. In addition, statistical characteristics such as frequency and contribution of extreme wet and dry spells are also compared.

The article is organized as follows. The data set are described in Section 2, followed by introduction of methodology in Section 3. Results and discussion are provided in Section 4. Lastly, Section 5 summarizes the main conclusion of this study.