Weather and Climate Extremes 12 (2016) 1–14

Contents lists available at ScienceDirect

Weather and Climate Extremes

journal homepage: www.elsevier.com/locate/wace

Skill of precipitation projectionin the Chao Phraya river Basinby multi-model ensemble CMIP3-CMIP5

S. Supharatid *

Climate Change and Disaster Center, Rangsit University, Thailand

ARTICLE INFO

Article history:
Received 7 May 2015
Received in revised form
30 March 2016
Accepted 30 March 2016
Available online 7 April 2016

Keywords:
The 2011 great flood
CMIP3
CMIP5
Climate downscaling
Distribution mapping

ABSTRACT

Weather and climate extremes are of many types and they result in various physical and environmental impacts. The massive flooding and inundation in the Chao Phraya River basin, in Thailand, caused serious damage to various activities for a prolonged period of time. The consequence of 2011 great flood was a total of 815 deaths and has been recorded as the most economic damage (US$45.7 billion). The present study analyses the skill of the two generations of global climate model ensembles, CMIP3 and CMIP5, in projection of precipitation. We firstly examine the flood behavior in 2011 and perform statistical downscaling for 9 GCMs of CMIP3 and CMIP5. The observed precipitation data from 83 stations around the country were interpolated to grid data using various methods. The Inverse Distance Weighted (IDW), after performing cross-validation, is found to give the best statistical performance and is used for GCMs assessment. Both CMIP3 and CMIP5 models underestimate the mean precipitation in the southwestern and eastern regions for historical climatology (1980–1999). The CMIP3 and CMIP5 MME show similar pattern but different magnitudes (CMIP5 gives higher mean precipitation than CMIP3). The majority of CMIP3 and CMIP5 models overestimate the dry spell and the peak precipitation. The precipitation projection was downscaled by the distribution mapping for the near-future (2010–2039), the mid-future (2040–2069) and the far-future (2070–2099). Both model generations perform reasonably well in capturing the amplitude and phasing of past mean annual precipitation. The correlation coefficient from all models lies between 0.6 and 0.9, implying reasonable simulation. The summer monsoon precipitation has an increase trend (from low to high GHG emissions), of 7–32% in October, 6–28% in September, and 8–20% in September for Bhumibol reservoir, Sirikit reservoir, and Nakhon Sawan, respectively. A possibility of increase in hydrological extreme flood in the wet season may be indicated by these findings.

1. Introduction

Weather and climate extremes can result in various physical and environmental impacts. Extremes occur at different spatial and temporal scales, from continental-scale multi-year drought, to large-scale heat-waves and urban floods that last days to several weeks, and to localized short duration events such as flash floods. The physical and environmental impacts of weather and climate events are also complicated by many other factors. For example, the severity of flooding or drought can be very different for a similar storm or precipitation deficit depending on antecedent soil moisture conditions. Compound events, the combination of different extreme events or even a series of events that are not individually extreme (e.g. IPCC 2012, Seneviratne et al. 2012), can have far reaching devastating impacts. For example, coastal inundation can be caused by local precipitation, high wind and wave, high tide, and combinations of some or all these factors; extreme temperatures in heat waves soar under low-moisture conditions, such as observed for the 2003 European heat wave.

Observations reveal changes in the frequency and intensity of many kinds of extremes such as extreme temperatures and precipitation, or severity of ocean winds and waves. There is also evidence indicating that some of these changes can be attributed at least in part to forcing external to the climate system, such as increased greenhouse gases and global warming. The impact of global warming is likely to increase vulnerability from climate disasters, especially increase the frequency and harshness of weather events such as heavy rainfall, shifting in rainy season, increasing in number wet days. Therefore, it would need rather long-term future climate projection to be able to clearly detect the change in future climate pattern (IPCC et al., 2007a).

Southeast Asia is expected to be severely affected by the climate change impacts due to the high dependency of economy on

* Corresponding author.
E-mail address: supratid@yahoo.co.th

http://dx.doi.org/10.1016/j.wace.2016.03.001
2212-0947/

agriculture and water resources in the region (IPCC et al., 2007a). The region's water resource is already affected by the rapid population growth, urbanization and agricultural demand. Recent extreme events in Thailand shows it is under water crisis, in addition the intensity of the extreme events are also expected to increase in the future. Two most important problems attributed by climate change in the region are floods and droughts. Flooding negatively affects the crops, livelihoods and infrastructures throughout the country whereas drought affects the crop production specifically in the central and northeast regions. Similarly, studies show that the impact of climate change are regional and its affects are also concentrated at regional scale although the water management policies target at national scale.

Since the Coupled Model Intercomparison Project (CMIP) was launched in 1995, coupled ocean-atmosphere general circulation models developed in dozens of research centers around the world have been compared and analyzed extensively. The program has improved our scientific understanding of the processes of Earth's climate system and of our simulation capabilities in this field. CMIP also plays an important social role by contributing to the Intergovernmental Panel on Climate Change (IPCC). The CMIP phase three (CMIP3) provided the scientific base for the Fourth Assessment Report (AR4) of IPCC published in 2007. The CMIP5 data are now available for analyses and are expected to provide new insights on our climate for the Fifth Assessment Report (AR5). The data have been available since 2012 and the AR5 was published in 2013 and 2014.

The latest generation of Global Climate Models (GCMs), the framework of the fifth phase of the Coupled Model Intercomparison Project (CMIP5), reflects 5–6 years of effort by multiple climate modeling groups around the world. Compared to CMIP3, CMIP5 models typically have finer resolution processes, incorporation of additional physics, and better-developed or well-integrated earth system components (Taylor et al. 2012). Emerging literature on CMIP5 (Taylor et al. 2011a, b, 2012; Meehl et al. 2009) has reported improvements in simulating certain key processes. Kug et al. (2012) reported that CMIP5 suite of models performs slightly better than CMIP3 models in simulating two types of El-Nino events: Warm Pool El-Nino (a new type) and Cold Tongue El-Nino (the conventional El-Nino). A few studies have been performed on the intercomparison of the performance of CMIP3 and CMIP5 (Brands et al. 2013; Joetzjer et al. 2013). Blázquez and Nuñez (2013) studied internal and inter-model variability in future climate projections with eight models of CMIP3 and CMIP5 over South America. Cattiaux et al. (2013) studied historical biases and future uncertainties in temperature over Europe by CMIP5 and compared with the known results from CMIP3 models. However, other emerging studies have reported no improvements of note in CMIP5 compared to CMIP3 (Knutti et al., 2010).

For the last two decades GCMs have confirmed to be an essential tool for climate change impact assessment studies. Although the simulated scenarios are advisable for the regional to national scale studies, they are less suitable for basin level studies due to their coarse spatial resolution. Several techniques have been developed to overcome this issue but still there is a demand to further develop the existing methods for impact assessment studies. Bias correction has been successfully applied in many parts of world for linking GCMs and hydrological models of impact assessment (Xu et al. 2005; Koutrolis et al., 2013). The use of hydrological models in climate change studies can range from the evaluation of annual and seasonal streamflow forecasting using simple water-balance models (Arnell, 1992) to the evaluation of flood and drought impact processes (Cameron, 2006; Vasiliades et al. 2009; Arheiner and Lindstrom, 2014). Recently, the use of multi-model ensembles for climate change impact studies has become much more routine (Christensen and Lettenmaier, 2007; Maurer, 2007). The advantage of using many GCMs for future climate projection is that the uncertainty in the projection, as represented by model consensus or spread, can be quantified. However, most of the available hydrological impact studies focus either at a relatively large spatial scale or on projections at a low temporal resolution (seasonal/ annual changes etc.). In contrast, the number of studies on regional impacts or extreme events, such as flooding peaks and droughts, is still limited.

Despite of the significant progress on the basin level climate change impacts assessment studies, a comprehensive study comprising of basin scale study attributing to national level flood management is necessary for Thailand. With limited adaptive capacity, the people are expected to be severely threatened by the additional influence of climate change. In order to address this issue, the precipitation projection at the local scale is a key input for flood impact assessments. In this study, we select the Chao Phraya River basin for the case study and employ projections of 9 GCMs of CMIP3 and CMIP5, each under a low and high greenhouse gas (GHG) emission scenario (IPCC et al., 2000). Therefore, we examine the difference in impacts under CMIP3 and CMIP5 at least 4 emission scenarios, B1, A2, RCP4.5, and RCP8.5. All these findings will carry implications related to the degree to which the region will need to adapt to projected changes in precipitation and flood and drought from the future warming.

2. Study area: Chao Phraya river basin and flooding history

Thailand has begun using river basin based water resources development and management systems since 2002 by dividing the country into 25 river basins(Fig. 1), covering an area of approx. 513,000 km^2. Tropical wet climate dominates the country however; the south and east experience a tropical monsoon climate. The wet season starts with the monsoon from May to October contributing 75% of total rainfall and consecutively leaving rest part of the year dry with very low available water. Dry period extends longer in the Northeast part of the country from November to April. In general the seasons can be classified as follows:

Summer season This occurs from February to May during transition between northeast monsoon and southwest monsoon, during which temperatures range from 35.0 to 39.9° Celsius.

Rainy season This occurs from May to October during which the southwest monsoon blankets the country with wind and rains, until reversed by the northeast monsoon in October, when temperatures cool down and rainfall declines, particularly in the north and northeast regions. However in the south of the country, the rain continues through December and sometimes is so heavy that it causes flooding on the eastern side of the region.

Winter season This occurs from October to February when the northeast monsoon begins to cover the country. The transition period during October is marked by climate variability.

Total average annual rainfall is about 1572.2 mm. During summer, the western coast of the south experiences more annual rainfall than the East with highest precipitation rates in September. During winter, the reverse is the case, with heaviest rainfall in November. Thailand is located in the tropical climate zone and thus experiences high temperatures year-round with an average annual temperature of 27 °C, with a maximum daily temperature of 40° C during the summer season. During winter, the central of Thailand primarily was buffeted by winds from the north and northeast. In the south the winds are coming from the northeast and east. During the rainy season most of the winds are coming from the west, southwest and south.

In this study, we are interested in the Chao Phraya river basin group (Fig. 1b), which is the largest basin in the country, covering an area of 159,000 km^2 or about 35% of the total land area of the