A BIAS-CORRECTION METHOD OF PRECIPITATION DATA GENERATED BY REGIONAL CLIMATE MODEL

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ABSTRACT

In several climate change impact studies, outputs (especially precipitation) of global and regional climate model are important inputs for hydrological and hydraulic models. Therefore, the quality of precipitation data needs to be assessed. The study conducted to compare downscaled PRECIS precipitation with observed rainfall and to apply a bias correction to this variable. The bias correction has practiced by fitting downscaled data to observed data in terms of frequency and intensity. In comparison with observed data, frequency of downscaled precipitation is significantly greater while intensity is considerable lower than the observations. The bias correction is calculated using data of a decade and validated using another decade before applying for predicted data. Results show that the method performs well; not only precipitation frequency is improved but also precipitation intensity is fitted to the observations. This results encourages the application of the method to multi-decadal precipitation projections.

1. INTRODUCTION

The low resolutions outcome of global climate models were downscaled to regional climate models, which in turns provided inputs for hydrological model, an efficient tool to assess impacts of climate change on water resources. Different downscaling methodology were developed, namely statistics, dynamics and combined approach (Sennikovs and Bethers, 2009; Fowler and Kilsby, 2007). The dynamics and combined approach are rather popular as they took the regional climate cycle into calculation processes (Mejia et al., 2012). Results from regional climate model did, however, not fit in comparison with observed data in general, especially when the regional climate models were developed for a large area, ranging from different landscape components. One of efficient measures was the bias-correction method application in order to correct simulated data. Therefore, this study was conducted to provide inputs to hydrological models to evaluate dynamics of water resources (including salinity and floods) in the future.

2. REGIONAL CLIMATE MODEL AND DOWNSCALED DATA

The simulated precipitation for the future was downscaled from global climate model by the Southeast Asia START Regional Center (http://www.start.or.th). The downscaled model (e.g. PRECIS, http://startcc.iwlearn.org/data) has resolution of 0.2 degree (approximately 20 kilometers) for covering the Mekong basin with around 2,225 cells (Chu Thai Hoanh et al. 2010). The PRECIS model has been used to downscale dynamically from the GCM of ECHAM4 under SRES A2 and B2 scenarios up to 2100.

3. METHOD

Although precipitation data has been generated by dynamical downscaling method through PRECIS model in order to consider local characteristics, the outputs had significant errors compared with the observations. If simulated data is used for any sector, it should be compared with observed data to ensure it fitting with observed data. As a result, there were significant differences between simulated and observed rainfall in terms of frequency and intensity. Therefore, a bias correction needs to be applied to adjust simulated data to be close with observed data. To apply the bias correction method, a hypothesis was that errors of rainfall data were really similar among periods of simulated data. For this study the decades of 1980s and 1990s were used to calibrate and validate the method respectively before applying for decades of future periods up to 2050.

The bias correction method applied in this study was implemented through a 3-step process (Figure 1) as (i) collecting simulated data from cells which are closest to rain gauge stations; (ii) calibrating and validating for the past periods; and (iii) applying the validated method for the future periods.

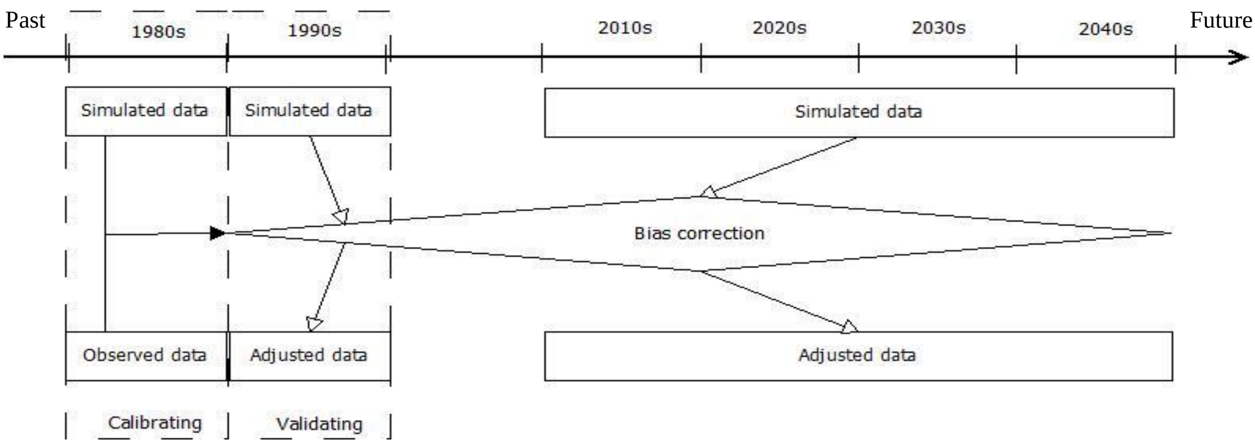

Figure 1. Process of the bias correction

3.1 Data collection

3.1.1 Simulated data

Outputs cell of the PRECIS model that is closest to a rain gauge station would be used as simulated data of that station. The outputs from the regional climate model, simulated data, only have 360 days per year while observed data has real-time days (meaning 365 or 366 days per year); consequently, they needs to be equal in terms of day number. For that reason, there are two ways to do that. The first way is to cut all the 31st to have 360 days per year of observed rainfall; however, it may eliminate considerably rainfall if occurring in those days leading to changes in monthly and annual rainfall. The other way is to add 0 values for 5 days of 31st January, May, July, October and December and another day of 29th February for year of 366 days. The second way is to ensure equality of length of data between simulation and observation and to distribute evenly among months.

3.1.2 Observed data

Figure 5 presents information of rain gauge station network. There are 27 rain gauge stations in the Mekong Delta, including 5 stations in Cambodia and 22 stations in Vietnam. Because available rainfall data in stations was in different periods so the period from 1985 to 1994 was used instead of the period from 1980 to 1989. Besides there were lacks of rainfall data in 12 stations while the bias correction needs continuous data in a period. Thus the lack data series should be filled fully before applying the method. To do this a hypothesis is that impacts of a rain gauge station are over its neighbors. Annual rainfall in average of neighbors of station missed data has been compared to select a suitable station to fill data.

3.2 Bias correction

The bias correction was implemented through 2-step processing of rainfall frequency and intensity. Due to simulated data of regional climate model it should be preprocessed. Based on observed data analysis, days with rainfall below 0.1 mm were identified as no-rain days. Besides simulated data was rounded to precision of 0.1. This preprocessing has been used by Ines and Hansen (2006) as well.

3.2.1 Frequency adjustment

This step was to adjust rainfall frequency of simulation being more fitable with observation. One of main characteristics of rainfall in the Mekong Delta was seasonal fluctuation so differences apmong months are considerable. Therefore the method of correction was practiced based on a month-period. Rainfall frequency was characterized by an indicator that is ratio between numbers of rain and no-rain days. This indicator was calculated for simulated and observed rainfall. The ratio f was used to identify differences between simulated and observed indicators $\boldsymbol{f} = \frac{\boldsymbol{ds_w}/\boldsymbol{ds_d}}{\boldsymbol{do_w}/\boldsymbol{do_d}}$ (Eq 1).

$$\boldsymbol{f} = \frac{\boldsymbol{ds_w}/\boldsymbol{ds_d}}{\boldsymbol{do_w}/\boldsymbol{do_d}} \quad \text{(Eq 1)}$$

ds_w/ds_d is ratio between numbers of rain and no-rain days in simulation;

do_w/do_d is ratio between numbers of rain and no-rain days in observation.

The f ratio was used to adjust simulated rainfall. Frequency of adjusted rainfall was defined based on the f ratio and simulated frequency. As a result, simulated frequency of all rain gauge station was significantly greater than observation while the opposite was true in rainfall intensity. Therefore the simulated frequency was reduced. For that reason, there were several ways to extrude rain days. For instance, a method using threshold of simulated and observed series was used. By comparison this method would figure out the threshold that was a standard to reduce rainfall frequency. Nonetheless, this method would reduce low (or high) rainfall intensity leading to changes seasonal characteristics. To solve this problem, another way was carried out. Firstly, simulated was sorted ascendingly; then the f ratio was used to extrude randomly by f-interval steps. This method ensures extruding rainfall days equally in terms of intensity. After adjusting frequency simulated data is going to adjust its intensity.

3.2.2 Intensity adjustment

The outputs of frequency adjustment were used as inputs of intensity adjustment. The adjusted period figured out differences between simulation and observation. Then the differences have been considered for the validated period and future periods. The validated step was practiced to assess stability of the method after applying for the future.

Series of simulated and observed rainfall were sorted ascendingly (or decendingly). The differences were identified as spaces of contributed function between simulation and observation ($\boldsymbol{E(x_i) = M(x_i) - S(x_i)}$ (Eq **2**).

$$\boldsymbol{E(x_i) = M(x_i) - S(x_i)} \quad \text{(Eq 2)}$$

$E(x_i)$ is differences; $M(x_i)$ is observed series; và $S(x_i)$ is simulated series.

In the validated period simulated rainfall was sorted ascendingly and the contributed function in combination with the differences figured out adjusted rainfall intensity by $\mathrm{A(x_i) = S(x_i) + E(x_i)}$ (Eq 3. The adjusted rainfall in comparison with observation would show stability of the method.

$$\mathrm{A(x_i) = S(x_i) + E(x_i)} \quad \text{(Eq 3)}$$

$\mathrm{A(x_i)}$ is adjusted rainfall; $\mathrm{E(x_i)}$ is differences; và $\mathrm{S(x_i)}$ is simulated series.

Simulated rainfall data may contain extreme values of spikes. They can change seasonal rainfall significantly. To adjust the extreme values and spikes, the option that was considered by Hoanh et al. (2010) was applied.

4. RESULTS

4.1 Rainfall frequency

There were differences among rain gauge stations in terms of rainfall intensity. High rainfall intensity contributed along the coastal areas while low rainfall intensity appeared in the upstream section of the Vietnamese Mekong Delta (VMD). In this study three levels of rainfall intensity, including low level (Tân Châu), moderate level (Tân Hiệp) and high level (Ca Mau) were chosen to represent (Figure 5). Figure 2 shows results of simulated, observed and adjusted rainfall frequency in those stations and it represents that after adjusted rainfall frequency is more fitable with observation, determining the method efficiency. Besides, seasonal fluctuation has been maintained.

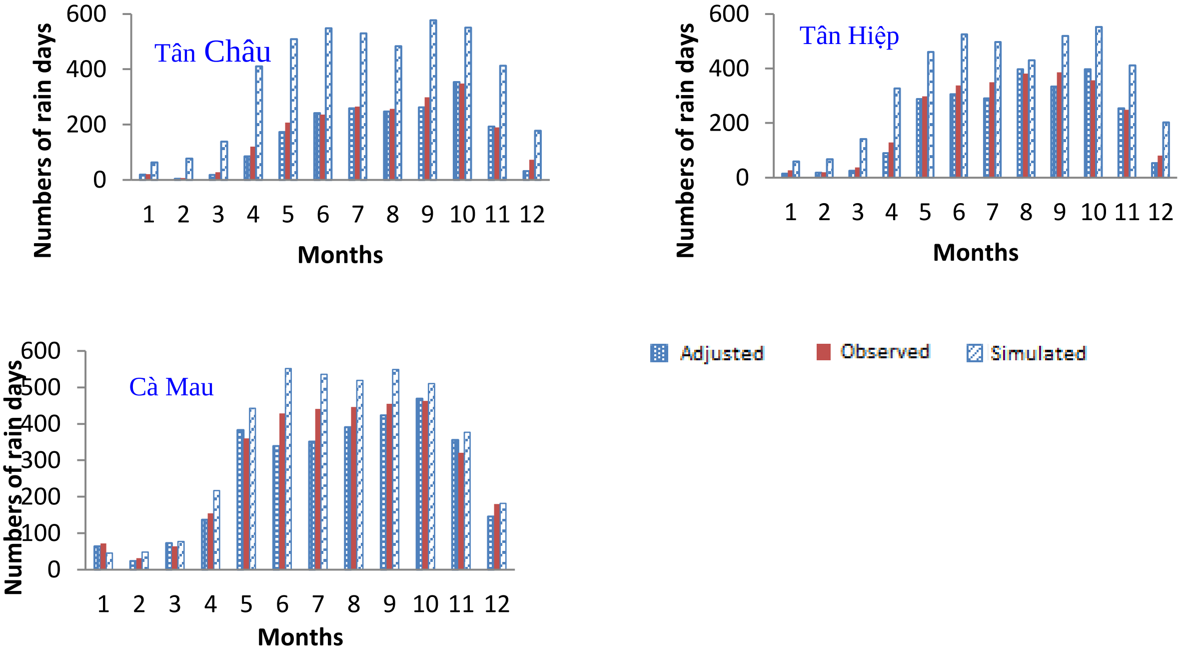

Figure 2. Comparison among simulated, observed and adjusted rainfall frequency

4.2 Rainfall intensity

The average rainfall observed at Ca Mau is around 2400 mm annually. However, rainfall simulated is fluctuating from 700 to 1300 mm, being considerably lower than the observations (Figure 3). Figure 4 shows daily observed, simulated and adjusted rainfall at Ca Mau station from 1985 to 2004 and 2010 to 2049. Pattern of daily simulated rainfall is that there are too many rain days, with figure of intensity of below 16 mm (as low level defined by the Southern Hydro-Meteorological Station[1]). In fact, numbers of moderate and heavy rain day are one-third of total rain days. After applying the bias correction method, pattern of daily rainfall is significant improved. The results show that rainfall intensity after adjusted has been improved and trends have been remained.

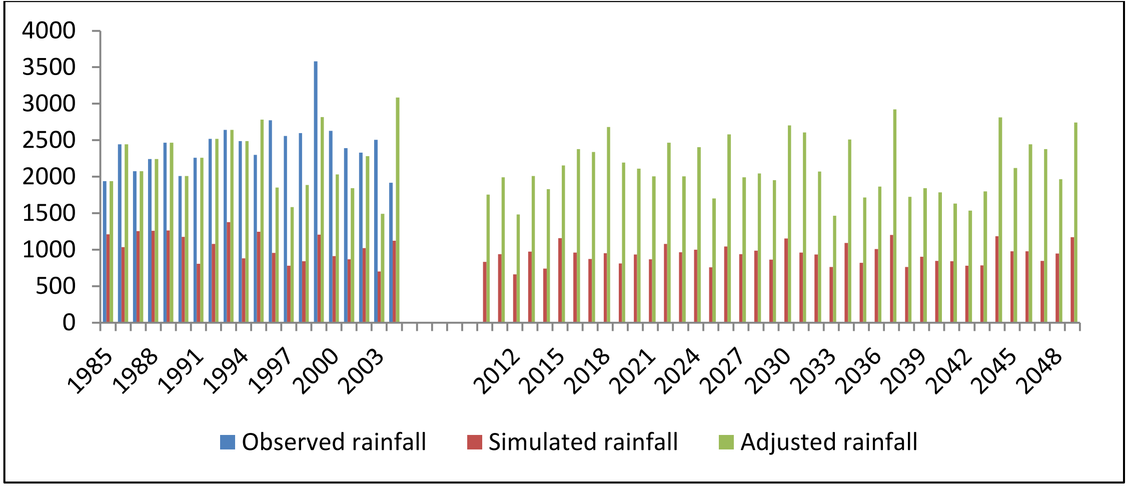

Figure 3. Annual rainfall intensity at Ca Mau station

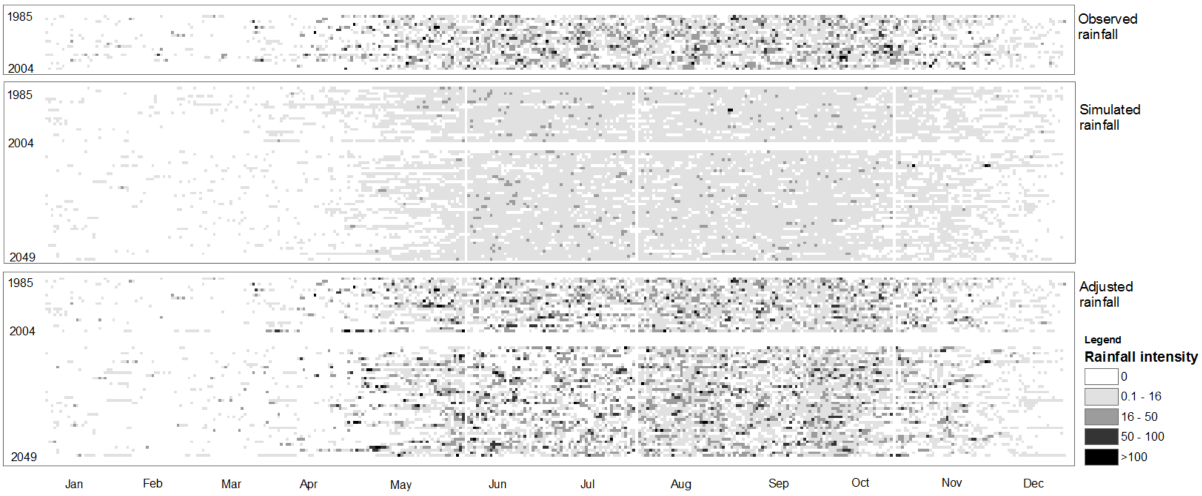

Figure 4. Daily rainfall intensity at Ca Mau station

4.3 Spatial distribution

There are many interpolation techniques in terms of geographical statistics and non-geographical statistics applied to interpolate rainfall distribution. For instance, interpolation techniques are nearest neighbor, Thiessen polygons, splines and local trend surfaces, global polynomial, local polynomial, trend surface analysis, radial basic function, inverse distance weighting (IDW), geographically weighted regression and Kriging method forms (Chen and Liu, 2012). As Chen and Liu (2012) estimated, the IDW method has widely been applied for rainfall interpolation and had insignificant errors (Chen and Liu 2012; Nusret and Đug 2012). Figure 5 presents spatial distribution of average observed rainfall from 1985 to 2004 by using IDW

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[1] Southern Hydro-Meteorological Station , 2011. http://kttv-nb.org.vn

method. The annual rainfall in the VMD is approximately 1700 mm and concentrates in rainy season (from May to Nov). The heaviest rainfall occurs in Ca Mau whereas the opposite is found in Tan Chau and Chau Doc.

5. CONCLUSION

The study was to apply a simple bias correction method to improve projected rainfall and reduce impacts of systematic model errors. This applied method considerably reduced rainfall frequency and improved rainfall intensity (to reflect the observed rainfall patterns) in all rain gauge stations in the VMD. Besides, the method also ensured trends of rainfall projection. The applied interpolation approach has been widely used for rainfall interpolation; however, such the approach needs to be validated in order to do spatial analysis deeply.

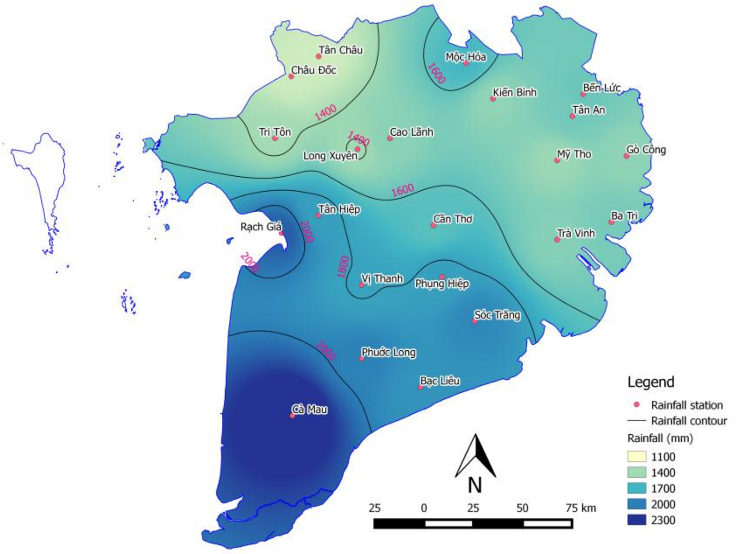

Figure 5. Average rainfall distribution from 1985 to 2004

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