Appendix A: Supplementary materials: Workflow of bias-correction methods

A1 Linear Scaling (LS)

In this study, we decided to use several correction methods and their hybrids to correct the deviation of GCMs. Linear scaling is one of the correcting methods to correct the precipitation and temperature. The corrected value is calculated based on the differences between observed and GCM-simulated data and we use the monthly scaling factor to correct it as the corrected GCM simulations should be perfectly agree with the corresponding monthly mean values of observations according to the definition [17]. We multiply the scaling factor to correct the data:

$$P_{cor}^{LS}(t) = P_{GCM}(t) \times \frac{\mu_m(P_{obs}(t))}{\mu_m(P_{GCM}(t))} \quad (1)$$

$$T_{cor}^{LS}(t) = T_{GCM}(t) + \left[\mu_m(T_{obs}(t)) - \mu_m(T_{GCM}(t))\right] \quad (2)$$

where $P_{obs}(t)$ and $P_{GCM}(t)$ denotes the actual precipitation of observation and GCM respectively, $\mu_m(\cdot)$ is the *m*th month mean value, $P_{cor}(t)$ and $T_{cor}(t)$ is the final GCM output after correction.

A2 Local intensity scaling (LOCI) for precipitation

Its main principle is to find out the threshold of both model and observed precipitation series that the days exceed the threshold of the model matches the frequency of the wet-day in observed series. That is, to find the threshold of the GCM above which the number matches the days of observed precipitation larger than 0mm. Then, a scaling factor is calculated by taking only days exceed the threshold into account to ensure that the monthly mean precipitation of GCM is equal to that of observation. Scaling factor is calculated as follow:

$$s = \frac{\mu(P_{OBS} \mid P_{OBS} \geq OBS, thres) - P_{OBS,thres}}{\mu(P_{GCM} \mid P_{GCM} \geq GCM, thres) - P_{GCM,thres}} \quad (3)$$

where s denotes scaling factor, $P_{OBS,thres}$ and $P_{GCM,thres}$ denotes the precipitation threshold of observation and GCM respectively. μ denotes the mean value, and $\mu(P_{OBS} \mid P_{OBS} \geq OBS, thres)$ is the mean observed precipitation exceeds the threshold in a certain period, and the same thing as that of GCM. Finally, the output precipitation after bias correction is calculated by the following:

$$P_{cor}^{LOCI}(t) = \max\left(0, P_{OBS,thres} + s\left(P_{GCM}(t) - P_{GCM,thres}\right)\right) \quad (4)$$

A3 Empirical cumulation distribution function (ECDF)

This is the extension method of cumulation distribution function (CDF) that is based on the distribution mapping (DM) method. Its hypothesis is to make the distribution of GCM outputs identical to the observed distribution. According to the current researches and empirical statistics, the precipitation variable obeys the Gamma distribution while temperature variable obeys the normal distribution [17]. The expression of CDF are as follows:

$$F(x)=\int_0^x f(t|\alpha,\beta)dt=\frac{1}{\beta^{\alpha}\Gamma(\alpha)}\int_0^x t^{\alpha-1}e^{-\frac{t}{\beta}}dt \qquad x\geq 0;\alpha,\beta>0 \tag{5}$$

$$G(x)=\int_{-\infty}^x g\left(t\mid\mu,\sigma^2\right)dt=\int_{-\infty}^x \frac{1}{\sqrt{2\pi}\sigma}e^{-\frac{(t-\mu)^2}{2\sigma^2}}dt \tag{6}$$

where x denotes the precipitation or temperature variable, $f(t|\alpha,\beta)$ is the probability density function of Gamma distribution with two parameters α and β, and $g\left(t\mid\mu,\sigma^2\right)$ is the probability density function of normal distribution with two parameters μ and σ^2. However, the theoretical CDF is only estimated from wet days without considering the days that has no rainfall. Thus, to overcome this problem, ECDF is used to consider both wet and dry days and consequently applicable to almost all possible climatic parameters [32]. The correction equation is expressed as:

$$P_{cor}^{ECDF}(t)=ecdf_{obs}^{-1}\left[ecdf_{GCM}\left(P(t)\right)\right] \tag{7}$$

$$T_{cor}^{ECDF}(t)=ecdf_{obs}^{-1}\left[ecdf_{GCM}\left(T(t)\right)\right] \tag{8}$$

where *ecdf* is the function that is used to find the cumulative probability corresponding to the certain precipitation or temperature, and $ecdf^{-1}$ is the inverse *ecdf*.

The red and black line in Figure A1 is the cumulative distribution function of GCM output and observed data. The method of correcting the GCM output data based on ECDF method is shown in ①②③ in Figure A1. First, find out the CDF under a certain data of precipitation or temperature; second, keep the CDF value and find the corresponding observed line; third, find out the corresponding observed data based on the CDF value.

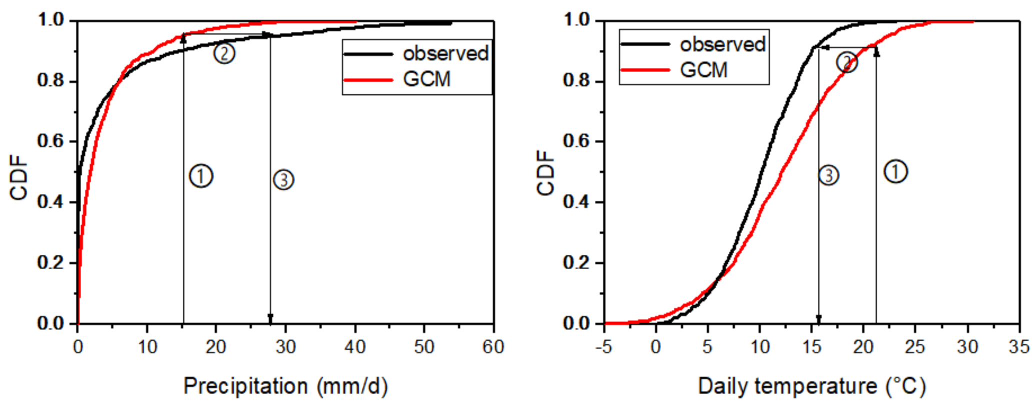

Figure A1 Illustration of ECDF method

A4 Variance Scaling (VARI) for temperature

The variance scaling for correcting temperature variable of GCM is presented by [33, 34], which is called "variance scaling" afterwards. This is also an extension of linear scaling method using mean and only standard deviation is used in the later period of VARI method with the equation below:

$$T_{cor}^{VARI}(t)=\left[T_{LS}(t)-\mu_m\left(T_{LS}(t)\right)\right]\cdot\frac{\sigma_m\left(T_{obs}(t)\right)}{\sigma_m\left[T_{LS}(t)-\mu_m\left(T_{LS}(t)\right)\right]}+\mu_m\left(T_{LS}(t)\right) \quad (9)$$

where $T_{LS}(t)$ is the corrected daily temperature using LS method (see Eq.**Error! Reference source not found.**), σ_m is the mth month standard deviation of temperature. This approach can guarantee that the corrected GCMs has the same mean and standard deviation as observed predictands and higher accuracy may be improved compared with only LS method [17].