Precipitation Downscaling with Expanded Downscaling (EDS) Method in the Ruhr Catchment in Germany

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1. Aim

Downscaling is one of the most important steps to have a practical use of the output of global climate model. Among various downscaling methods are regression methods, which achieve an optimal model based on the least-square criteria. However the least-square criteria significantly reduces the variability of climate variables, which is not desirable, e.g., for the use in impact models. Alternatively, the EDS method preserves the observed variability. This means that EDS also minimizes the square-error, but under the constraining side condition that the **simulated covariance equals the observed**. Accordingly, the EDS model yields more realistic climate variability, especially regarding extreme events. Another advantage of EDS is that the relationship between different stations in the study area is also kept.

2. Methodology

In linear regression, the local variables $\mathbf{y}=(y(j),j=1,n)$ and large scale variables $\mathbf{x}=(x(i),i=1,m)$ are modelled according to

$$\mathbf{y}=\mathbf{L}\mathbf{x}$$

by minimizing the model error using a linear matrix $\mathbf{L}$. If the global and local covariance are denoted by $\mathbf{C_x}$ and $\mathbf{C_y}$, respectively, the simulated local covariance equals $\mathbf{L C_x L'}$. Usually, one has $|\mathbf{L C_x L'}| < |\mathbf{C_y}|$, implying that the simulated variability is too small. If we reformulate the regression principle of error minimization by imposing the side condition that the simulated covariance equal the observed, i.e.

$$\mathbf{L C_x L'} = \mathbf{C_y}$$

then the resulting (unique) solution is called the Expanded Downscaling (EDS) model. Algorithmically, the solution can only be found approximatively, which poses a nonlinear programming problem (NLP) that becomes computationally quite expensive for large local dimensions n.

3. Study area and data

Figure 1 shows the data points and location of local-scale and large scale variables. The large-scale is a rectanglular grid with 2.5×2.5 latitude and longitude resolution (117 dots in upper figure). The local-scale is Ruhr catchment (lower right) in Germany (lower left) with 53 precipitation stations and 5 temperature stations. Daily data from 1961 to 1990 have been applied for calibrating the model and validating model.

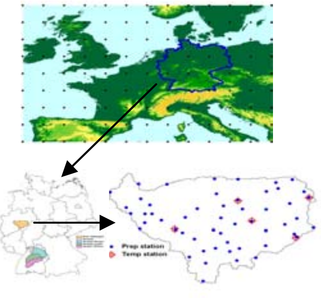

Fig. 1

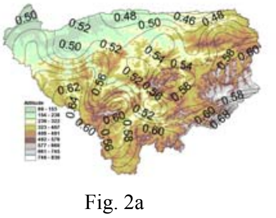

Fig. 2a

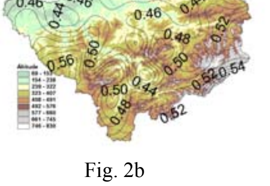

Fig. 2b

4. Validation

Figure 2 displays the validation of downscaling results with correlation coefficients for EDS methods (Fig. 2a) and classic regression method (Fig. 2b). The shaded color represents the altitude. The two methods give the similar correlation distribution with higher altitude having better downscaling results. In contrast, correlation is smaller with EDS than other two methods

5. Regression vs. EDS

Figure 3 show the random selected time span of precipitation process with 7-day running average. (a) for the area average precipitation; (b) for the poorest simulated single station based on correlation validation. The simulation by regression shows a much smaller variability, especially with respect of a single stations, while EDS simulation give the similar variability as observed.

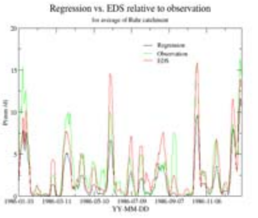

Fig. 3a

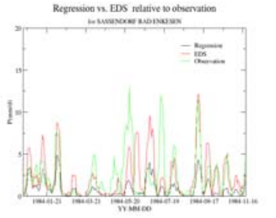

Fig. 3b

6. Precipitation scenario

Figure 4 show the frequency and intensity of precipitation with randomly selected one station (ID number 78867) as example for summer and winter respectively. It can be found that precipitation intensity increases significantly under the future climate change condition.

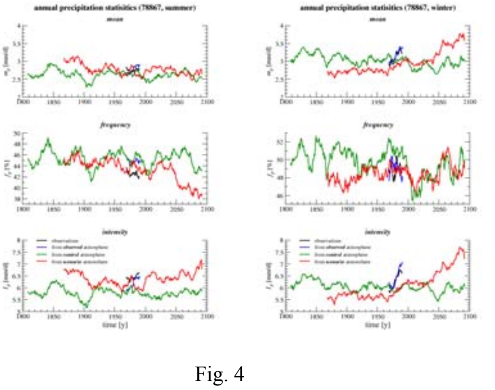

Fig. 4

6. Conclusion

The EDS, by preserving the observed daily covariance, is capable of reproducing observed precipitation clusters quite satisfactorily; similarly, extreme events are simulated with reasonable reliability. The precipitation scenario produced with EDS in Ruhr catchment show a remarkable characteristic that the mean precipitation will increase, but its frequency will slightly decrease and its intencity will significantly increase.