XVIII World Water Congress
International Water Resources Association (IWRA)

Developing a vine copula model to simulate and predict long serial lake water levels

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Objectives

The objective of this study was to capture the dependence between the lake water level and hydro-meteorological variables, and explore the possibility of using a vine copula model for predicting the long-term water level. To achieve this objective, a multidimensional variable vine copula model was constructed and the monthly and daily water levels were predicted from different combinations of the hydro-meteorological factors. The accuracy of the predictions from the constructed vine copula model was tested by comparing the simulation results with those from a BP neural network model and a support vector regression (SVR) model. A vine copula model for lake management was established to predict the lake water level for small data sets. The accuracy of the model was tested and improved by error analysis, such that the obtained lake water level values were further refined.

Methods

We constructed a vine copula model to simulate and predict lake water level that incorporated rolling decisions and real-time correction of prediction results.

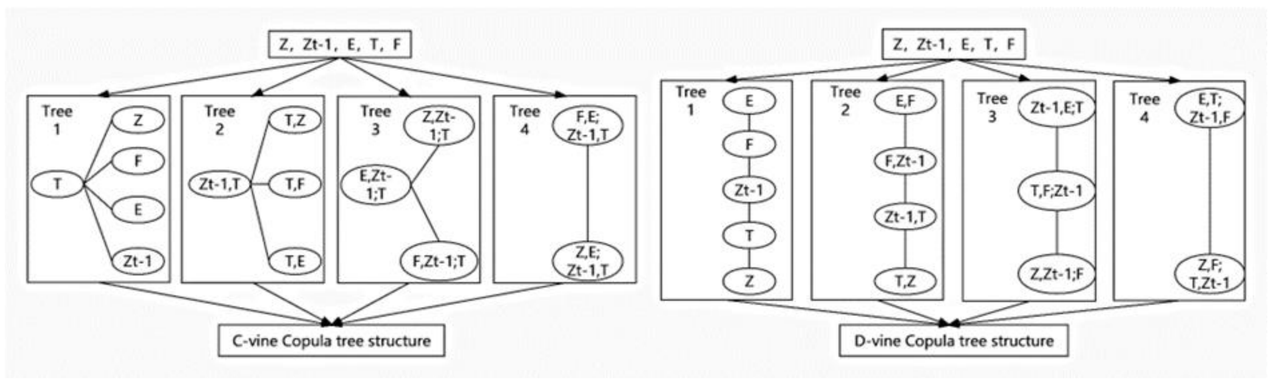

Figure 1. Five-dimensional variable structure of the vine copula

Results

The vine copula models of the three-, four-, five-, and six-dimensional variables with the best de-pendencies were used to predict the water level of Erhai Lake from 1954–2016. The results showed that the predicted time series and the observed time series almost overlapped. These values indicate that the models gave accurate predictions of the in-ter-annual characteristics of the water level, and closely reflected the water level trends in Erhai Lake. However, the prediction results for some of the peaks were not ideal and deviated somewhat from the observed time series. It may be that, when predicting high and low water levels with a vine copula model, the marginal distribution of the variables cannot represent the variable extreme values accurately, which then affects the ability of the vine copula model to simulate the joint distribution structure of different variables.

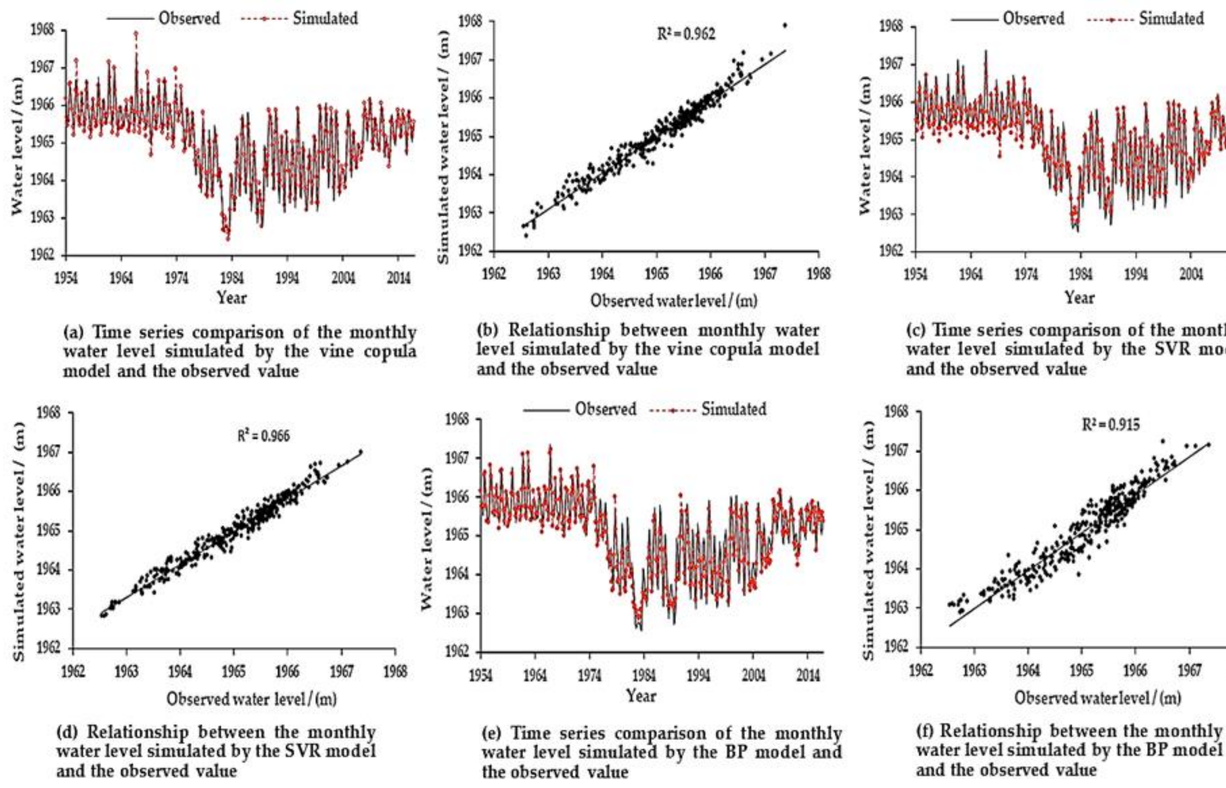

Figure 2. Comparison of the simulated monthly water levels from the different models and the observed values

Conclusions

The vine copula model is better at dealing with the nonlinear relationships between the predicted water level and climatic factors than other model types, and can also indicate the trends in water level and the inter-annual variations in the water level. However, there were deviations in some peaks, possibly because the marginal distribution of the variables poorly represented the extreme values of the variables when the vine copula was predicting low- or high-water levels. These promising results show that it is worth evaluating the advantages and disadvantages of the vine copula simulation method in future studies.

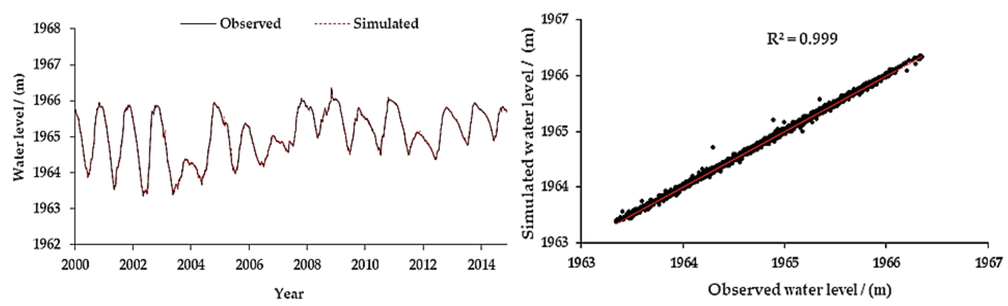

Figure 3. Simulated and observed value of the daily water level from vine copula mode

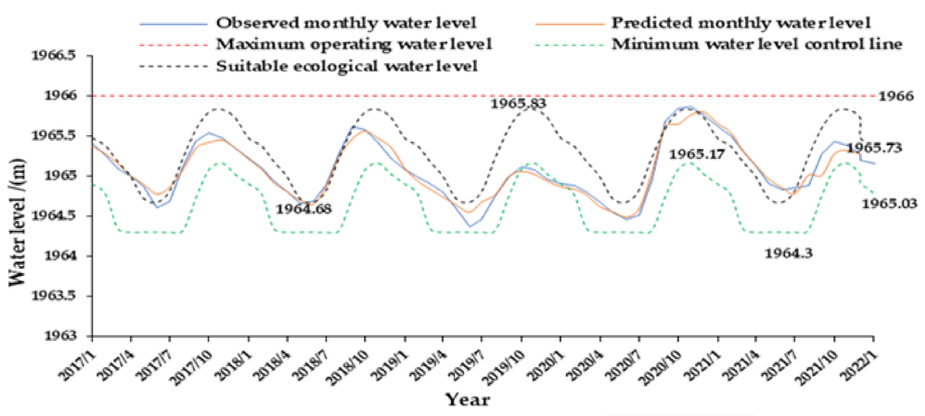

Figure 4. Water level changes in Erhai Lake from 2017 to 2021