Correction of daily ECMWF air temperature data based on copula concept

Research Problem

Systematic underestimation or overestimation of a global weather forecast system compared to local measurements from weather stations leads to bias. Various bias correction methods have been proposed in the literature. Most are able to correct for bias in the mean, but do not consider other moments of a probability distribution. In addition, they use the same distributions families to estimate both marginal and multivariate distributions. To avoid these restrictions we propose to use copula-based bias correction methods for which, a conditional distribution describes the dependence structure between weather forecast data and measurements at weather stations.

Objective

This study presents three copula-based bias correction methods for daily air temperature data derived from the European Centre for Medium-Range Weather Forecasts (ECMWF). The aim is to predict conditional copula quantiles at different unvisited locations, assuming spatial stationarity of the underlying random field. The three methods are: bivariate copula quantile mapping (P_{BCQM}), spatial copula quantile mapping (P_{SCQM}), and quantile search (P_{QS}). These are compared with marginal quantile mapping (P_{MQM}) and expectation predictor (P_{EP}) that are commonly applied for bias correction.

Method

Marginal quantile mapping: In the marginal quantile mapping (P_{MQM}), the marginal distribution function of forecasted values is corrected to agree with the observed marginal distribution function (figure 1).

Expectation predictor: In the expectation predictor (P_{EP}), the conditional expectation is used as the optimal predictor, minimizing the Bayes risk (figure 2).

Bivariate copula quantile mapping: The bivariate copula quantile mapping (P_{BCQM}) borrows the idea from the classical quantile mapping method and relies on two bivariate copulas incorporating the dependence of the location's coordinates and variables of interest (figure 3).

Spatial copula quantile mapping: The spatial copula quantile mapping (P_{SCQM}), also borrows the idea from the classical quantile mapping method, but relies on two spatial bivariate copulas incorporating the dependence of the variables of interest and their nearest neighbor in space (figure 4).

Quantile search: The quantile search (P_{QS}) allows combining different criteria in the estimating different conditional quantiles at different unvisited locations. Conditional quantiles can be estimated using a search algorithm by means of maximizing a fitness function (figure 5).

Study Area

The study area is an agricultural area containing five weather stations in the Qazvin Plain in Iran. We considered data on observed and forecasted temperature (figure 6). For all weather stations, Daily air temperature is determined for the period 1– 31 March 2014. We used the operational forecast weather data provided by the European Centre for Medium-Range Weather Forecasts (ECMWF). All ECMWF data can be retrieved for a 0.125° lat/lon grid points. A sample subset of 3 × 8 grid points is selected.

Result

The observations from weather stations are used for cross-validation to quantify the performance of the presented procedures. The time series of the bias-corrected variable at each weather station was predicted by the cross-validation (figure 7). The five copula-based bias correction methods were applied to all stations for 31 days. They resulted in mean absolute errors of air temperature equal to 1.3 ˚C, 1.5 ˚C, 1.6 ˚C for P_{QS}, P_{SCQM}, P_{BCQM} and 1.3 ˚C, 1.4 ˚C for P_{EP} and P_{MQM} respectively. The spatial variabilities obtained by PQS were much higher than by P_{MQM} and P_{EP} (figure 8). The methods are compared to reproduce the moments of the marginal distribution. The newly developed procedures further preserved the dependence structure between the coordinates and the air temperature (figure 9).

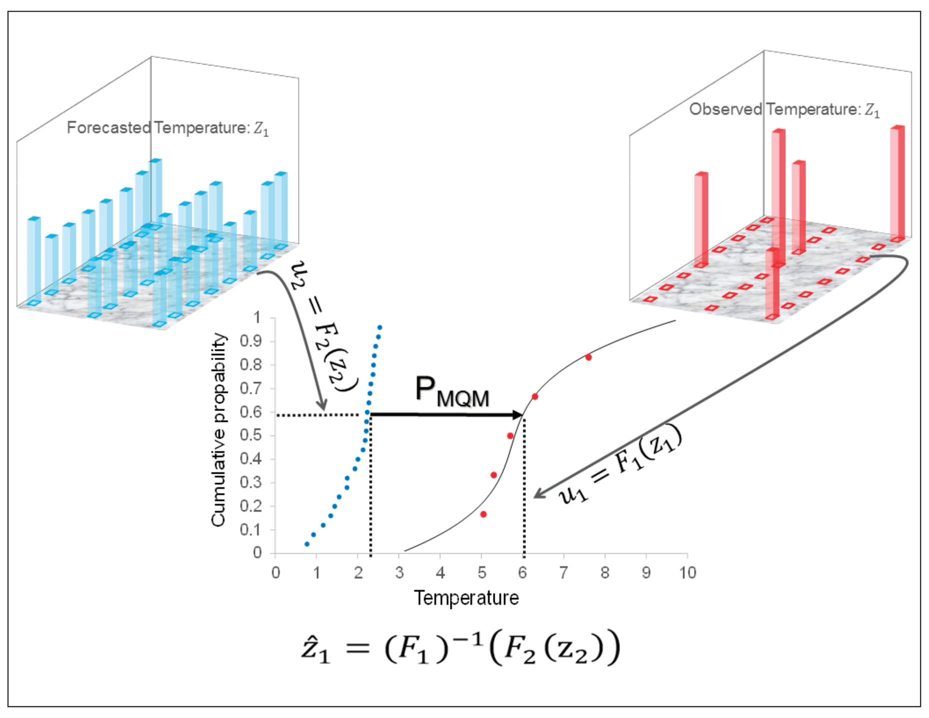

Figure 1: Marginal quantile mapping procedure

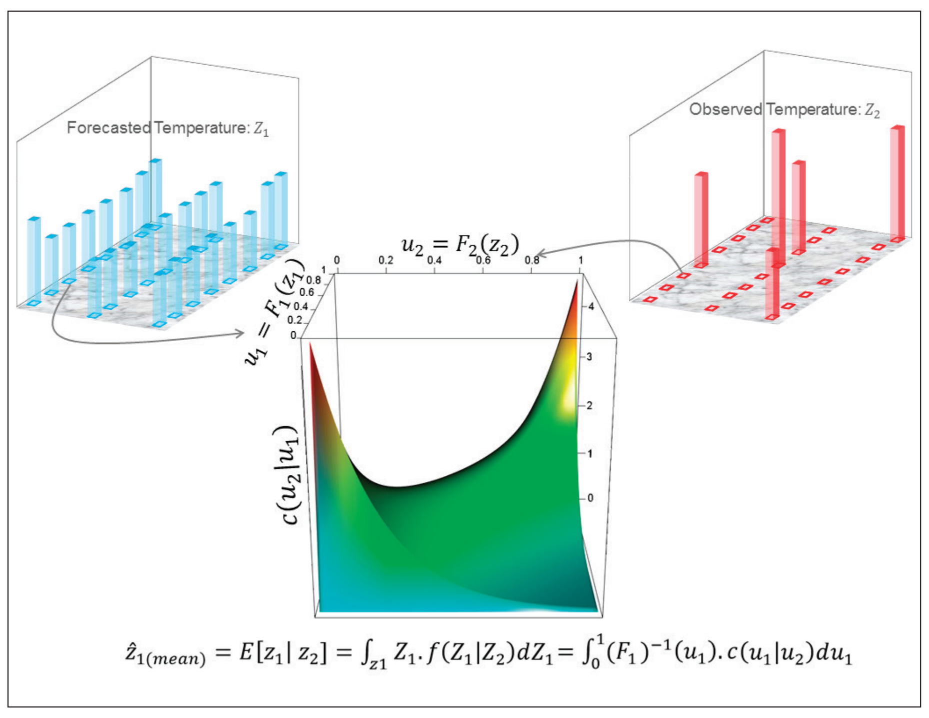

Figure 2: Expectation predictor procedure

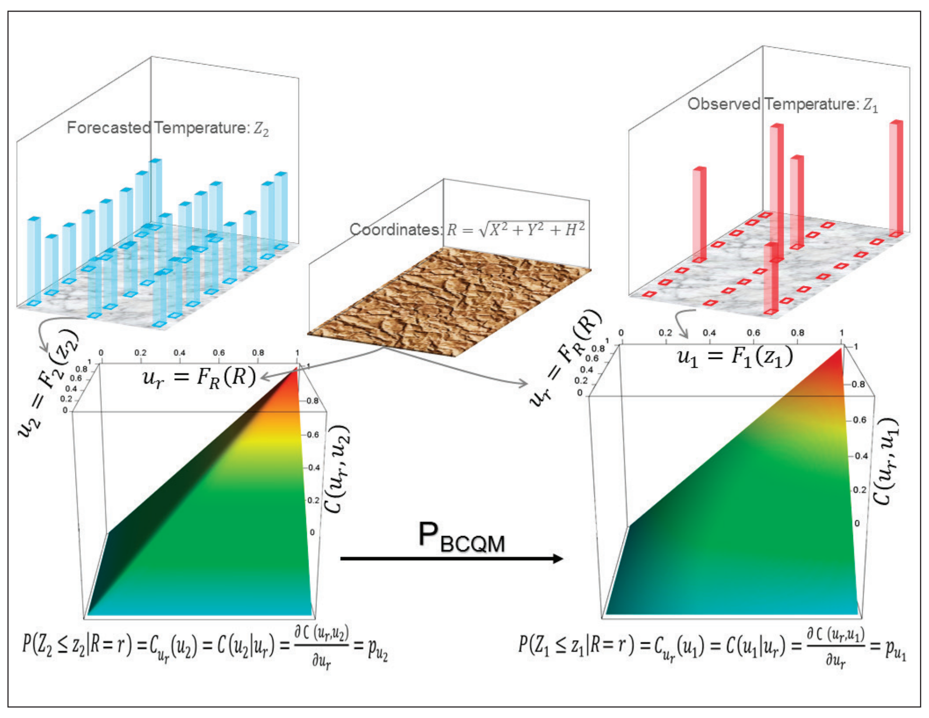

Figure 3: Bivariate copula quantile mapping procedure

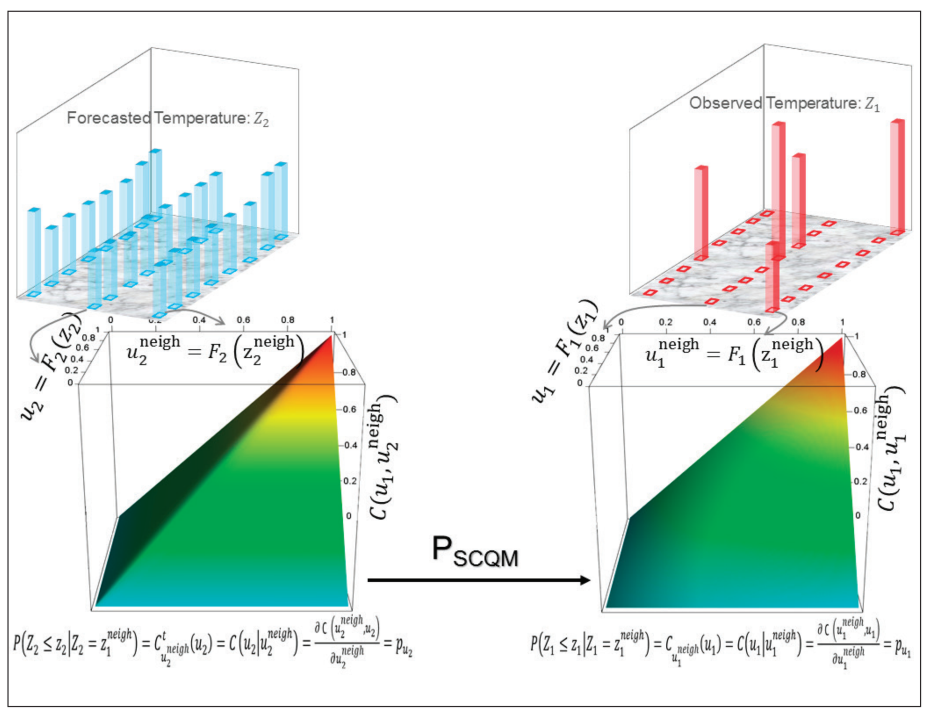

Figure 4: Spatial copula quantile mapping procedure

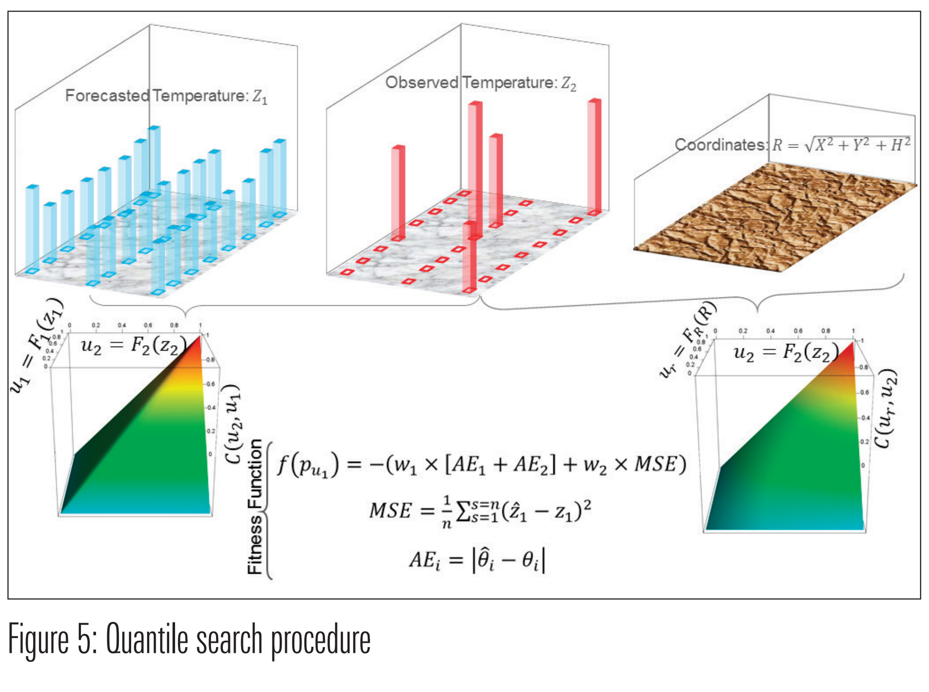

Figure 5: Quantile search procedure

Conclusion

The three new methods utilized the flexibility of selecting different distribution families and allowed for temporal variability of dependencies. This presentation shows that P_{SCQM} and P_{QS} are powerful methods to predict conditional quantiles at unvisited locations. They improve the higher order moments of marginal distributions, and take the spatial variabilities of the bias-corrected variable into account.

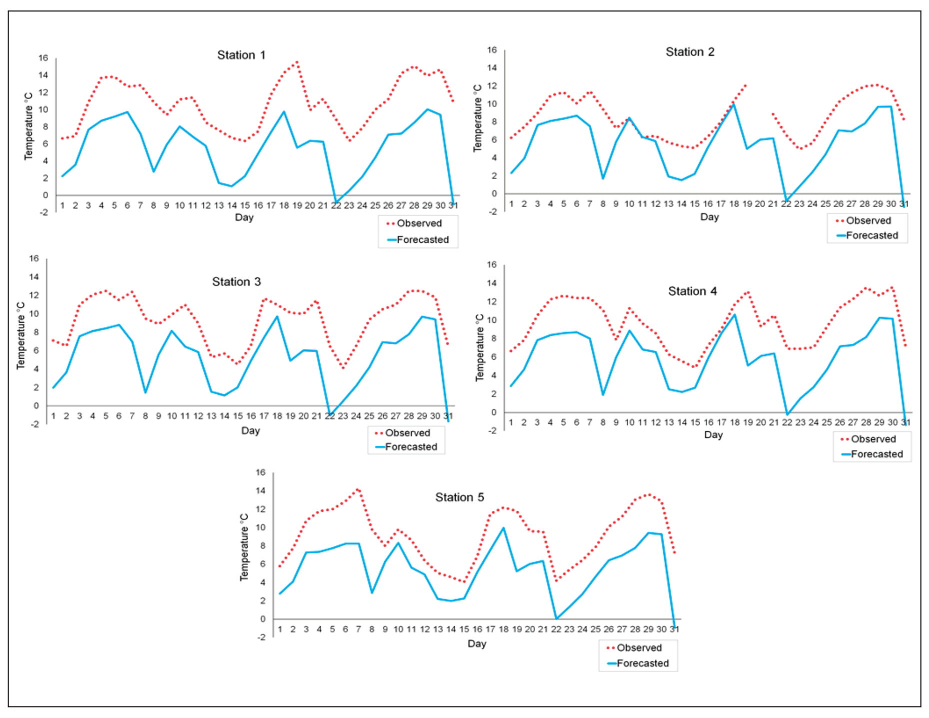

Figure 6: Time series of the observed and the forecast values

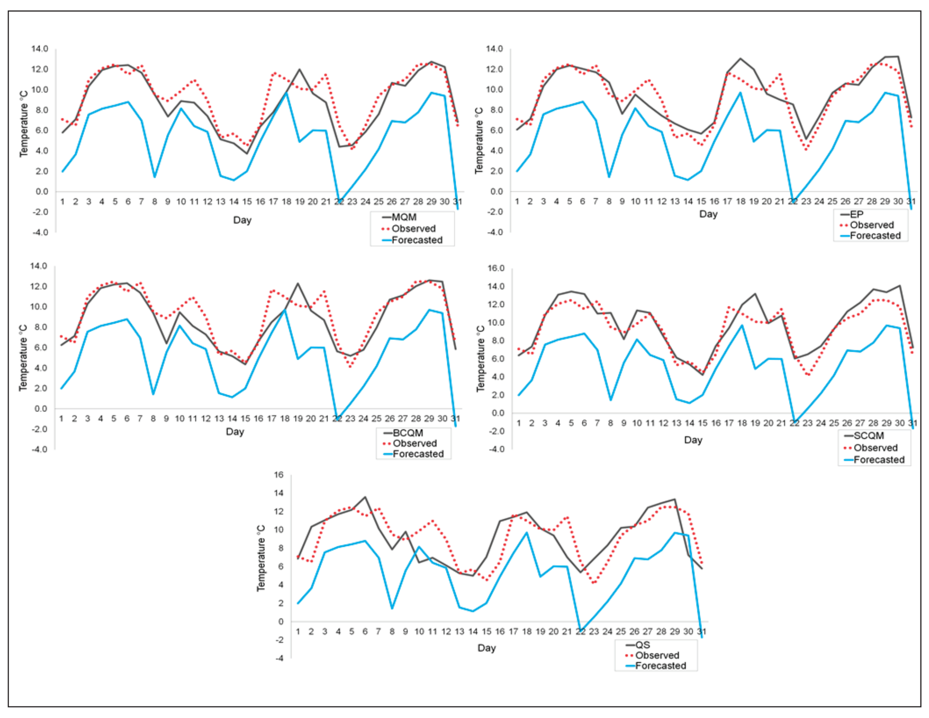

Figure 7: Time series of the observed, the forecast values and the bias corrected values at the third station

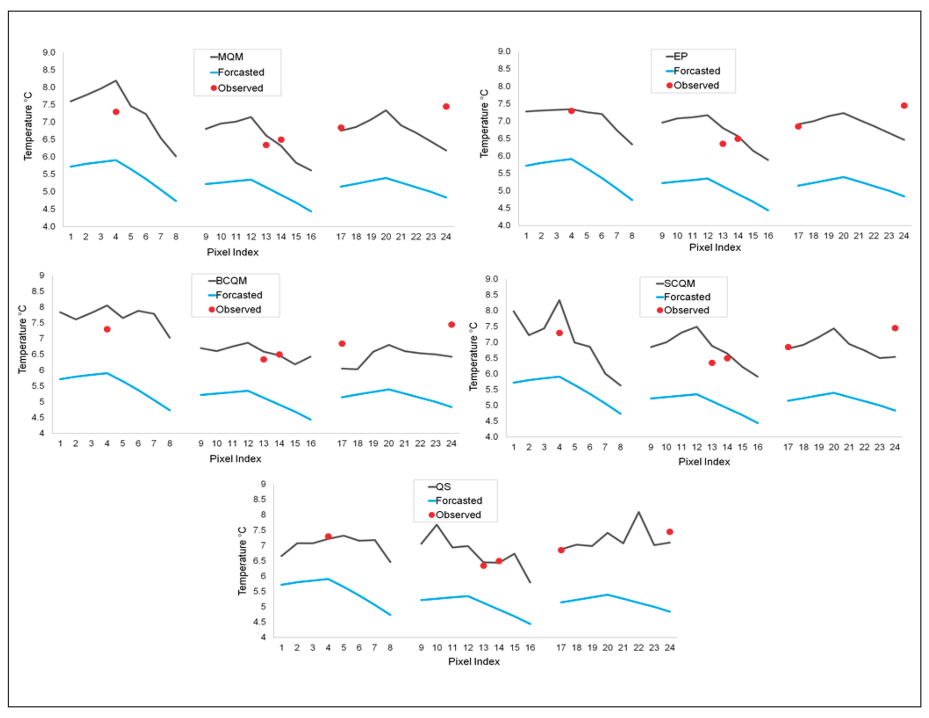

Figure 8: The spatial variability of the observed and the bias-corrected values comparing with the forecast values over the study area at 16 March 2014.

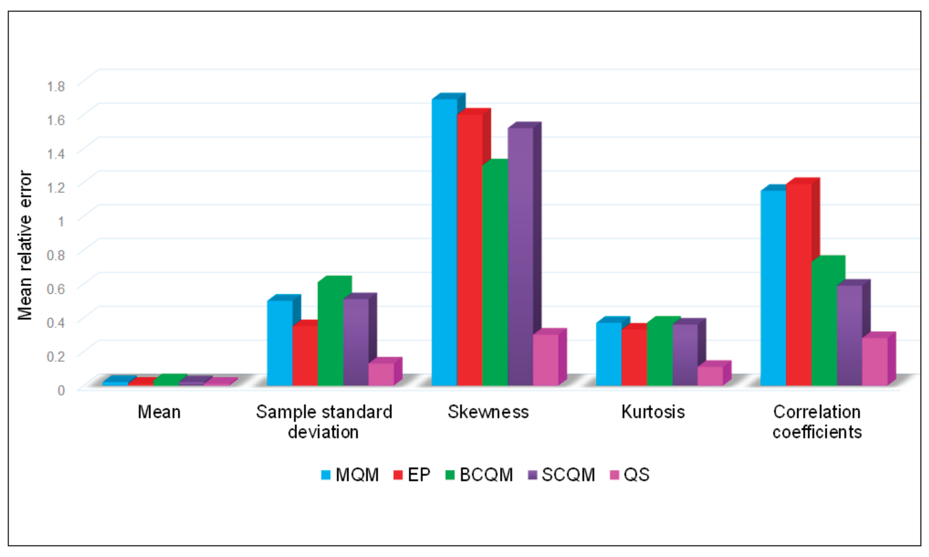

Figure 9: The mean relative error for four moments of the distribution of bias-corrected and observed values, and the mean relative error for the correlation coefficients between coordinates and bias-corrected air temperature.

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