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Multivariate quantile mapping bias correction: An N-dimensional probability density function transform for climate model simulations of multiple variables

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Most bias correction algorithms used in climatology, for example quantile mapping, are applied to univariate time series. They neglect the dependence between different variables. Those that are multivariate often correct only limited measures of joint dependence, such as Pearson or Spearman rank correlation. Here, an image processing technique designed to transfer colour information from one image to another – the N-dimensional probability density function transform – is adapted for use as a multivariate bias correction algorithm (MBCn) for climate model projections/predictions of multiple climate variables. MBCn is a multivariate generalization of quantile mapping that transfers all aspects of an observed continuous multivariate distribution to the corresponding multivariate distribution of variables from a climate model. When applied to climate model projections, changes in quantiles of each variable between the historical and projection period are also preserved. The MBCn algorithm is demonstrated on three case studies. First, the method is applied to an image processing example with characteristics that mimic a climate projection problem. Second, MBCn is used to correct a suite of 3-hourly surface meteorological variables from the Canadian Centre for Climate Modelling and Analysis Regional Climate Model (CanRCM4) across a North American domain. Components of the Canadian Forest Fire Weather Index (FWI) System, a complicated set of multivariate indices that characterizes the risk of wildfire, are then calculated and verified against observed values. Third, MBCn is used to correct biases in the spatial dependence structure of CanRCM4 precipitation fields. Results are compared against a univariate quantile mapping algorithm, which neglects the dependence between variables, and two multivariate bias correction algorithms, each of which corrects a different form of inter-variable correlation structure. MBCn outperforms these alternatives, often by a large margin, particularly for annual maxima of the FWI distribution and spatiotemporal autocorrelation of precipitation fields.