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Bivariate Gaussian Models for Wind Vectors in a Distributional Regression Framework

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Accurate probabilistic forecasts of wind speed and wind direction are of great importance for decision making processes and risk management in today's society, e.g., in air traffic management and renewable energy production. Wind is one of the classical circular quantities, and wind speed and wind direction are mutually dependent. Thus, we employ a new probabilistic post-processing method for the zonal and meridional wind components within the framework of distributional regression using a bivariate Gaussian response distribution. In contrast to previous studies we explicitly model all parameters of the distribution simultaneously, namely mean and variance for both wind components but also the correlation structure between them employing flexible regression splines. The performance of the new method is tested for stations located in alpine valleys, mountain foreland, and over flat terrain. Forecasts of the ECMWF ensemble prediction system are used as explanatory variables for all parameters.

To allow the statistical model to correct for a possible mismatch between the predicted and observed wind direction, ensemble forecasts of both wind components are included using two-dimensional smooth spline effects. This encompasses a smooth rotation of the wind direction conditional on the day of year and the ensemble wind direction. The rotation-permitting model specification shows distinct improvements in terms of predictive skill for all sites tested. Various model specifications for the correlation structure have been tested, e.g., employing wind direction and speed as potential valuable covariates by non-linear smooth effects. Although the effects are significant and the estimated correlation parameters seem to be reasonable, the predictive performance improves only slightly over a model without correlation. Based on these findings, a recommendation is provided which statistical model setup should be used for calibrating meridional and zonal wind components in terms of simplicity and predictive performance.