Spatio-Temporal Probabilistic Wind Vector Forecasting over Saudi Arabia

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Saudi Arabia has recently begun promoting renewable energy heavily with the potential to replace fossil fuels for domestic power generation. Optimally integrating wind energy into power systems requires accurate and reliable predictions of wind energy together with a quantification of uncertainties. Based on a dataset of hourly wind speed from 28 stations in Saudi Arabia, we build spatio-temporal models for short-term probabilistic prediction of wind vectors. Traditionally, wind speed and wind direction have been addressed independently, without taking dependencies into account. However, in many situations, e.g. energy management, it is important to use the full information about the bivariate structure of wind. When comparing a coregionalization model for the wind vector to a univariate spatio-temporal model for the transformed wind speed in terms of reliability and sharpness, both models are able to produce calibrated forecasts for wind speed while the univariate model results in smaller prediction intervals. In both cases, the linear predictor is a function of covariates, a smooth function to capture the daily seasonality in wind and a latent Gaussian field to model the spatial and temporal dependencies. To meet the computational requirements, we take a Bayesian framework and obtain fast and accurate forecasts not only at locations where recent data are available but also at stations without observations. Simulated high-resolution data from a computer model are used to validate spatially out-of-sample forecasts. A detailed analysis based on this case study shows how increasing the number of locations can improve the forecast performance.