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Probabilistic power ramp forecasts using multivariate Gaussian regression

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Efficient wind farm operation requires reliable probabilistic forecasts of power ramps. These are sudden fluctuations in power production which, if unanticipated, can lead to significant imbalances in the electrical grid. The power produced by a turbine strongly depends on the wind speed at hub-height, making it is useful to base these forecasts on calibrated wind speed scenarios generated by statistically postprocessing numerical weather predictions (NWPs). Since the probability of a ramp event depends jointly on the wind speed distributions forecasted at multiple future times, postprocessing methods must not only calibrate the marginal forecasts for each lead time, but also estimate temporal dependencies among their errors.

We use new multivariate Gaussian regression (MGR) models to postprocess all next-day hourly 100m wind speeds near offshore wind farms in one step. The postprocessed forecast is a multivariate Gaussian distribution with mean vector μ — containing the 24 forecasted hourly mean wind speeds — and Σ — the 24×24 covariance matrix containing uncertainties of the individual forecasts as well as their temporal error correlations. Joint distributions are estimated conditionally by flexibly linking the components of μ and parameters specifying Σ to predictors derived from an ECMWF ensemble using generalized additive models for each distributional parameter.

The joint distribution — predicted uniquely for each ECMWF initialization — can simulate postprocessed wind speed ensembles with any number of members. Subsequently, the forecasted ensembles are transformed into power space using an idealized turbine power curve and probabilities computed for different ramp events. Ramp forecasts from MGR outperform those obtained using reference methods which postprocess wind speed forecasts in two-steps: (i) first calibrating the marginal distributions with nonhomogeneous Gaussian regression before (ii) constructing temporal error dependencies using either the order statistics of the NWP ensemble (ensemble copula coupling, ECC) or those of raw observations (Schaake Shuffle).