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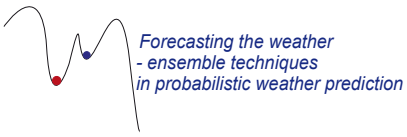


# Ensemble and probabilistic forecasting of $(u, v)$ wind for the energy application

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Over the last decade, developments in the use of various renewable energy sources have been tremendous. Europe has been a pioneering region in opting for the large-scale deployment of wind energy, now being followed by solar and wave energy. Other countries like the United States, China, India and Brazil are catching up by giving increasing importance to renewable energies in their electricity generation mix. The common and maybe most important characteristics of these renewable energy sources is that their power generation depends upon atmospheric and marine conditions, with a stochastic behaviour embedding variability and potentially limited predictability. This forces substantial changes to the energy management and trading activities, which are to increasingly rely on high-quality meteorological forecasts for various lead times ranging from a few minutes to a few months, while evolving from a deterministic to a stochastic approach to decision-making.

Early developments mainly concentrated on single-valued prediction every single wind farm, by post-processing deterministic forecasts of wind speed and direction (or alternatively wind in its $(u, v)$ component form). Today ensemble and probabilistic forecasts are becoming increasingly popular among the actors of the power system and electricity markets. The energy application is particularly interesting since covering a variety of decision-making problems requiring different types of input forecasts. A few of them will be reviewed: it will be explained how some basic decision-making problems only require appropriately defined single-valued predictions that can be extracted from probabilistic forecasts, while some more advanced ones call for space-time (and possibly multivariate) trajectories, hence fully utilising the information given by ensemble forecasts. Anecdotal examples of irrational decision-making will also be given.

The quality of wind power forecasts heavily depends upon that of the meteorological ones used as input. Ensemble forecasts of $(u, v)$ wind should be calibrated before to input wind power prediction methodologies. But since their nature as space-time trajectories is crucial for a number of decision-making problems, focus is given to a multivariate calibration method which does not alter their nature. This method consists of translating and dilating ensemble forecasts based on models for the generating processes of the ensembles and the wind stochastic process. The parameters of these models are adaptively and recursively estimated, hence allowing for seasonal variations in the calibration while accommodating changes in the operational setup of the ensemble forecasting system considered. These model parameters are also seen as different for each model grid point. The overall methodology is applied and evaluated for the case of ECMWF ensemble forecasts of $(u, v)$ wind over a period of 3 years (Dec. 2006 - Dec. 2009) and over Europe. The substantial improvements in the (bivariate) reliability of the ensemble forecasts, as well as for various deterministic and probabilistic scores, will be shown. Improvements in terms of CRPS and bivariate RMSE of the ensemble mean are substantial for lead times up to 3 days (10-25%) then fading out for lead times further than 5 days. The temporal and spatial patterns of the translation and dilation factors will finally be discussed.