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Non-linear filtering of Doppler lidar measurements for fast turbulence estimation

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Wind energy and airport safety are in need of accurate wind and turbulence estimations. Doppler lidar is well proven and common technology to provide fast remote wind measurements. Because of its random nature, turbulence is difficult to measure. In addition, the instrumental noise is also random. The difficulty is to sort out the random noise and to keep in the random turbulence. Usual approaches (threshold of CNR, Kalman filters) are limited by the fast variations of the wind and the non-linearity of turbulence.
Our approach is based on non-linear filtering techniques. These techniques are called "sequential Monte Carlo" methods. The principle is to represent at each time step the probability law of the wind by a Monte Carlo sample. The sample evolves from one time step to the next according to a Lagrangian model. Then the observation is used for the selection of the best wind values in the sample. In the end, the sample is a compromise between the information of the Lagrangian model and the observations. The resulting wind estimate is comparable to the lidar measurements and fits with turbulence known characteristics (Kolmogorov spectrum with a -5/3 slope). As a consequence, turbulence estimations (like turbulence intensity) are more accurate from such wind estimates.
The presentation will be in 3 parts. First, a particular didactic effort will be made to describe step by step the non-linear filtering method. The algorithm will be illustrated on toy examples and linked to the real problem. Next, some results from application cases will be commented. Wind estimates and their spectrum are tested with a validation experience. The improvement on turbulence intensity estimation will be shown. Eventually, the sensitivity analysis of the method will be shortly discussed. Sensitivity scores (Sobol indices) have been calculated and help to spot important parameters.