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Minute-scale power forecasts of offshore wind farms based on long-range lidar scans and turbine operational data

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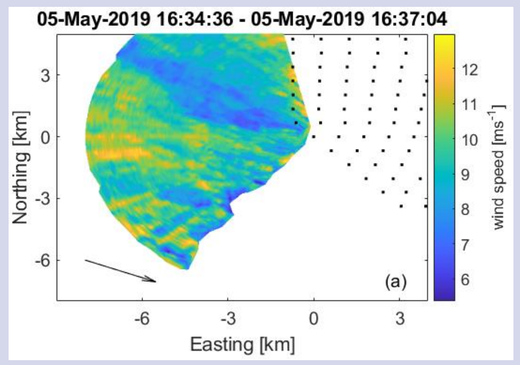
Introduction & Motivation

- Increasing contribution of (offshore) wind energy to electricity production
- High volatility of feed-in
- Minute-scale power forecasts support system integration and electricity trading
- Statistical methods are not able to predict ramp events, i.e. strong and sudden changes of wind speed or direction

→ Remote sensing-based forecasts that rely on upstream wind measurements

Lidar-based forecasting methodology

- Wind field reconstruction of horizontal long-range lidar-scans
- Wind vectors propagated in space and time using Lagrangian advection
- Selection of vectors reaching a target turbine within a pre-defined time interval



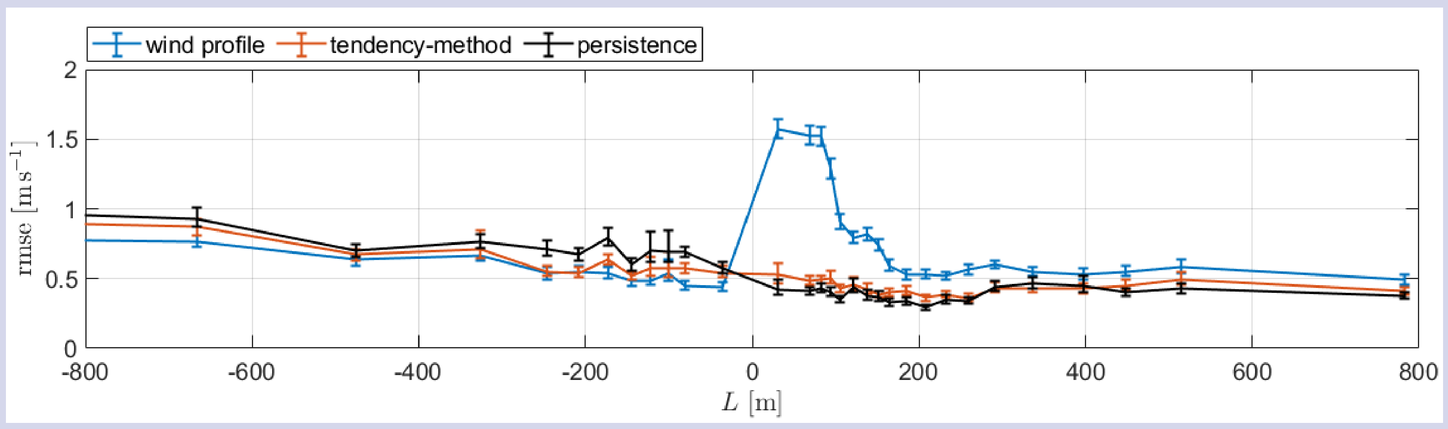
Forecast skill and uncertainty dependent on atmospheric condition

- Comparison of wind speed extrapolation from measurement to hub height i) using the logarithmic wind speed profile (blue) or ii) by applying a wind speed tendency to recent hub height wind speed (red). Forecast skill is evaluated against the benchmark persistence (black).

→ Large uncertainty introduced by the logarithmic profile

→ Forecast skill is generally higher during stable atmospheric conditions

→ The lidar-based forecast outperforms persistence during unstable conditions



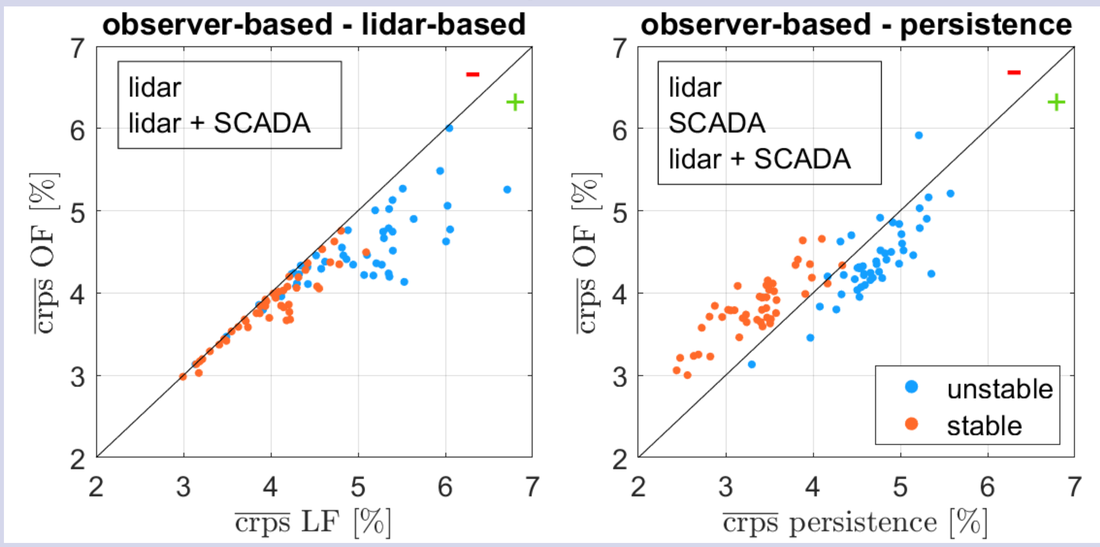
Combination with turbine operational data to forecast wake-impacted wind turbines

- Advection of high-frequency turbine operational data (= SCADA-based forecast) in addition to lidar data (= observer-based forecast)

→ Forecast availability can be significantly increased when combining the lidar- and SCADA-based forecast

→ Turbines with long wind vector travelling distances benefit most from the SCADA-based forecast

→ Persistence can be outperformed for most turbines during unstable atmospheric conditions



Publications

Theuer, F., van Dooren, M. F., von Bremen, L., and Kühn, M.: Minute-scale power forecast of offshore wind turbines using long-range single Doppler lidar measurements, Wind Energy Science, 5, 1449-1468, doi: 10.5194/wes-5-1449-2020, 2020.

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Theuer, F., Rott, A., Schneemann, J., von Bremen, L., and Kühn, M.: Observer-based power forecast of individual and aggregated offshore wind turbines, Wind Energy Science, 7, 2099-2116, doi: 10.5194/wes-7-2099-2022, 2022.

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