VRIJE UNIVERSITEIT BRUSSEL

The faculty of Engineering of the Vrije Universiteit Brussel invites you to attend the public defense leading to the degree of

DOCTOR OF ENGINEERING SCIENCES

of **Tsvetelina Ivanova**

The public defense will take place on **Tuesday 25th November 2025 at 4 pm** in room **D.2.01** (Building D, VUB Main Campus)

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HIGH-IMPACT WIND AND PRECIPITATION CONDITIONS FOR OFFSHORE WIND FARMS FROM NUMERICAL WEATHER PREDICTION AND REMOTE SENSING

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Abstract of the PhD research

This dissertation investigates atmospheric conditions relevant to offshore wind energy, with a focus on precipitation variability and high-impact weather events linked to wind turbine blade erosion. Five core objectives guide the research: mapping long-term European precipitation, comparing atmospheric datasets with ground observations, assessing wind farm parameterization effects on modeled precipitation, characterizing high-impact weather events, and improving local weather simulations via data assimilation.

Using atmospheric reanalysis and satellite data over multiple years, an erosion potential index identified high-risk zones. High-resolution numerical weather simulations with the Weather Research and Forecasting (WRF) model revealed seasonal precipitation variability. Comparisons with Belgian stations showed satellite estimates had the highest monthly correlations. WRF captured intense hourly precipitation events, identifying twice as many as ERA5. Wind farm parameterization caused localized precipitation changes of 10 to 18%, with minimal domain-wide impact.

Assimilating upwind LiDAR observations into WRF via nudging improved wind and power simulations during extreme events. At 47 km downwind of the assimilation site, improvements were evident compared to SCADA data. Wind speed RMSE decreased from 10.5% to 5.2%, wind direction errors were reduced by a factor of 2.4, and power RMSE fell from 23% to 10%.

These findings underscore the value of high-resolution modeling and observational data assimilation in supporting the mitigation of weather-induced degradation in offshore wind farms. Future work should expand offshore measurements, refine erosion metrics, and integrate turbine performance data for predictive maintenance and planning.