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 **Adithya Vemuri**

The public defense will take place on **Thursday 17th October 2024 at 4:00 pm** in room **D.2.01** (Building D, VUB Main Campus)

To join the digital defense, please click here
Meeting ID: 380 811 871 691
Passcode: CQDvXH

MULTISCALE MODELING OF THE ATMOSPHERIC BOUNDARY LAYER FOR REALISTIC WIND TURBINE LOADING

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Abstract of the PhD research

The rise of the wind energy industry has significantly contributed to countering climate change. Recent advancements in wind turbine technology, particularly in performance improvements, reliability, predictive maintenance, and cost efficiency, have accelerated the energy transition. However, accurately downscaling atmospheric conditions for realistic wind turbine loading remains a challenge for the industry.

This doctoral dissertation focuses on the downscaling of atmospheric conditions, with a specific emphasis on extreme weather events (EWEs), to predict wind turbine loading in the Belgian North Sea. Recent advancements in numerical weather prediction (NWP) techniques have made it possible to downscale weather conditions for operational use using models such as the Weather Research and Forecasting (WRF) model.

Initially, a sensitivity study is conducted for multiple EWEs over the Belgian North Sea, evaluated against SCADA data from a Belgian offshore wind farm. It underscores the advantages of scale-aware physics parameterizations in the WRF model. It is further extended to investigate the added benefit of air-sea interactions through the Coupled Ocean-Atmosphere-Wave-Sediment Transport (COAWST) model, highlighting marginal improvements in capturing wind behavior in specific cases.

Subsequently, a new scale-aware planetary boundary layer (PBL) parameterization, VKI-3DTKE, is developed in-house and implemented in the WRF model. This new implementation is tested in both idealized convective and neutral boundary layer simulations, as well as in the eXperimental Planetary Boundary Layer Instrumentation Assessment campaign and in extreme weather events. This dissertation discusses the advantages and limitations of this scheme and proposes potential avenues for further research.

Finally, two new loosely coupled model frameworks are developed to downscale weather conditions for realistic wind turbine loading. These frameworks involve coupling the COAWST and WRF models with the OpenFAST aeroelastic solver. An offshore wind turbine is scaled and implemented in the OpenFAST model to represent its physical counterpart. This dissertation also highlights the proposed model frameworks' ease of use, capabilities, and limitations.