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Train²Wind, or How Large is an Infinite Wind Farm?

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Abstract

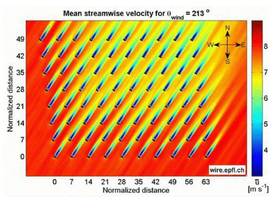
TRAIN²WIND is a PhD TRAINing school analysing enTRAINment in offshore WIND farms with computer models and experiments. By its very nature, a wind turbine extracts energy from the wind, which is replenished from the wind field on the sides and above due to the ambient turbulence. However, offshore the turbulence is lower, and wind farms are typically larger than onshore, therefore the wind can only be replenished from above in a process called entrainment. *TRAIN²WIND* will investigate the entrainment process using advanced high-resolution computer modelling and wind tunnel models together with measurements of the wind field above, in and downstream of large wind farms, using lidars, radars, satellites and Unmanned Aerial Systems.

Some of the largest operators of offshore wind farms will provide access to the data and the wind farms in order to investigate whether there is a limit to offshore wind power installation density coming from the refreshment of momentum in very large wind farms or clusters. For them, and for the government agencies currently preparing the Marine Spatial Plan for the European waters, updated knowledge of entrainment and the associated potential limits to wind power extraction offshore is paramount to avoid mis-allocation of tens of billions of euros when planning offshore wind farms too dense or too close.

Besides the natural science package, one humanities PhD student at the University of Copenhagen will investigate the collaboration between the researchers from a social science and collaboration tools perspective.

Tools

Computer models



Two PhD students at DTU and EPFL will work on the development of the WTABL, with Large Eddy Simulations (LES, here from EPFL), i.e. very high fidelity computer codes. Additionally, one student at DTU will use the meso-scale weather model WRF (right image in Farm Wakes).

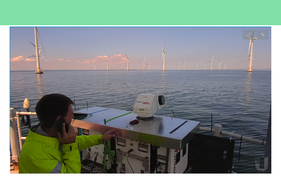
Wind Tunnels

One PhD student and two short-term fellows at EPFL will also investigate wake flows using the wind tunnel at EPFL in Lausanne.

UAS

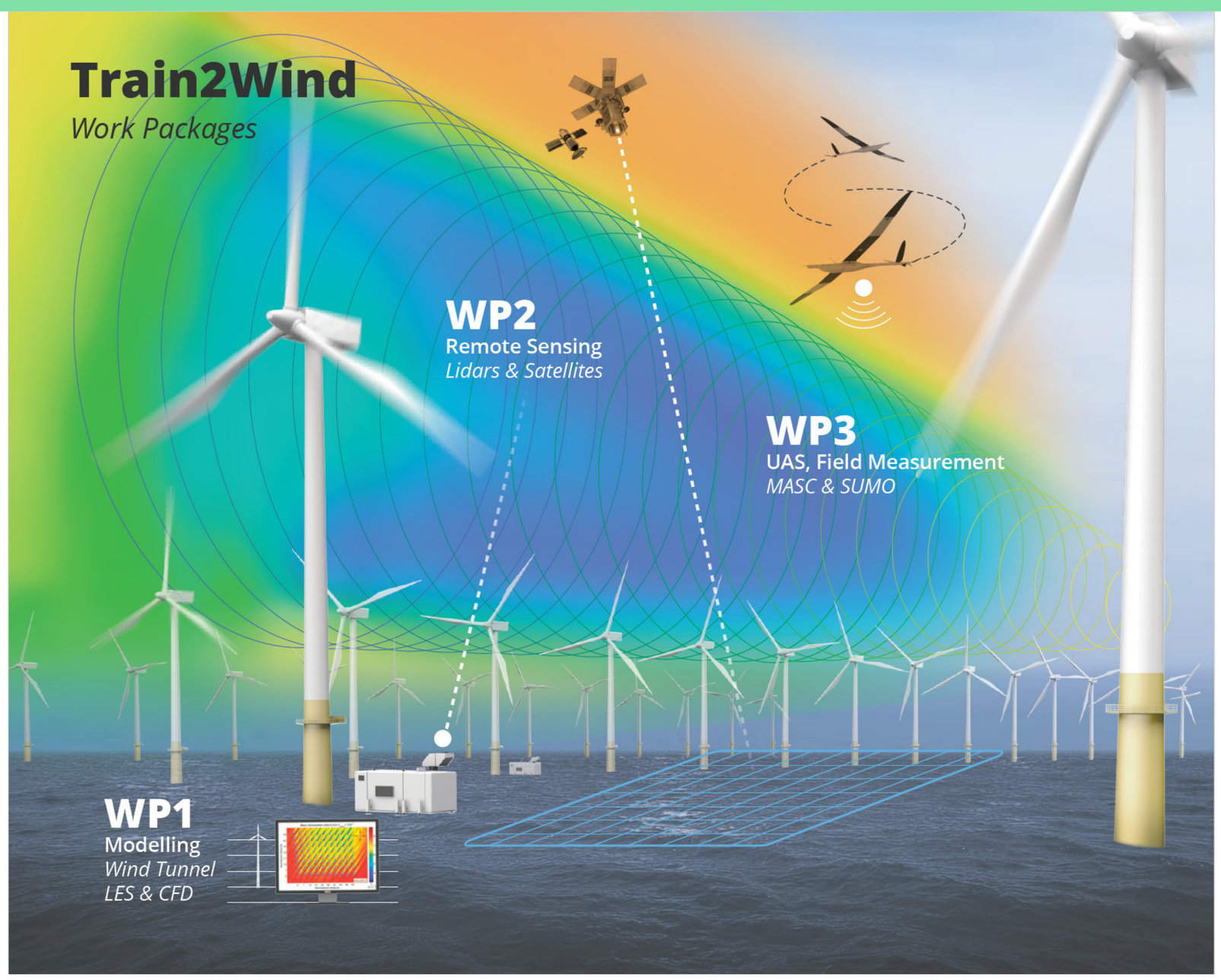
We will further develop and deploy short and long range Unmanned Aerial Systems (MASC, SUMO and AMOR shown here), in two PhD theses in Tübingen and one in Bergen, and with the help of three short-term fellows.

Lidars



Two PhD students at DTU and Bergen University will deploy fixed and floating lidars for the campaign.

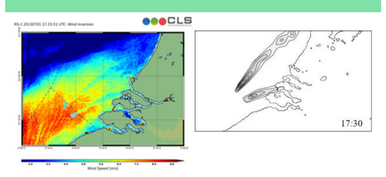
Main Objective



A main event will be a measurement campaign at a full-scale offshore wind farm, with a high-intensity measuring period where we deploy UAS, Lidars, and collect information from satellites to establish the transition between the undisturbed air and the atmospheric boundary layer in the presence of the wind farm.

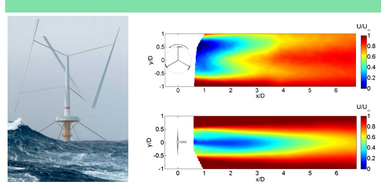
Secondary Objectives

Farm Wakes



The influence of one farm's wake on surrounding wind farms is a topic to be investigated by one PhD student at DTU using satellites (left image) and several others using their tools (here DTU's WRF).

Vertical Axis



Vertical axis turbines have significantly different wake structures, which probably also influence the farm-farm interaction. Based on a lidar study of SeaTwirl's floating prototype (left), we will investigate this in LES (image by EPFL).

Sea Spray

Aerosols have an influence of the development of the ABL. The turbulent mixing by wind turbines changes that effect, but it is unclear how. One PhD student at Tübingen will use lidar data and UAS.

Image source: Jeremy Bishop, Wikipedia.

Wind Farm Control

Wind Farm Control (see e.g. poster 054) can potentially mitigate entrainment loss in too dense wind farm clusters. One short-term fellow at DTU will investigate this option.

Image source: PhD Defense Jonas Kazda, 2019

Conclusions

A new Marie Curie action will start in Spring 2020, educate 20 fellows in offshore meteorology and metrology, and find the length scale and effects where the Atmospheric Boundary Layer (ABL) becomes a Wind Turbine Array Boundary Layer (WTABL).

Recruiting partners

DTU · University of Copenhagen · EPFL École Polytechnique Fédérale de Lausanne · Eberhard Karls Universität Tübingen · Universitas Bergensis

Other partners

Vattenfall · equinor · innogy · SEATWIRL · Johns Hopkins Whiting School of Engineering

Recruitment

The project starts on Feb. 1, 2020, therefore recruiting of PhD students and short-term fellows will start in spring 2020 at DTU, KU, Bergen University, Tübingen University and EPFL. Watch the relevant university jobs pages, or talk to the authors!

MEET US AT C1-B51 (DTU Wind Energy)!

Wind Europe Offshore 2019 26-28 November Copenhagen

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