PO.140

Train²Wind

or How Large is an Infinite Wind Farm?

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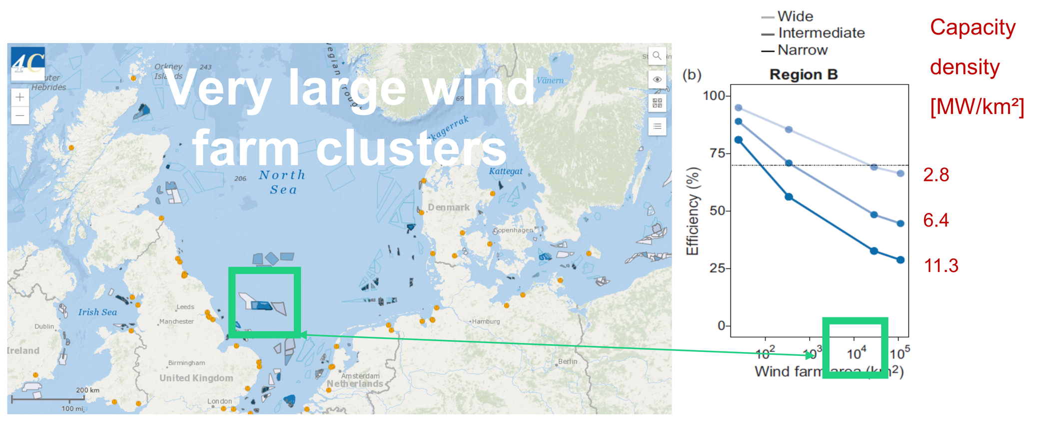
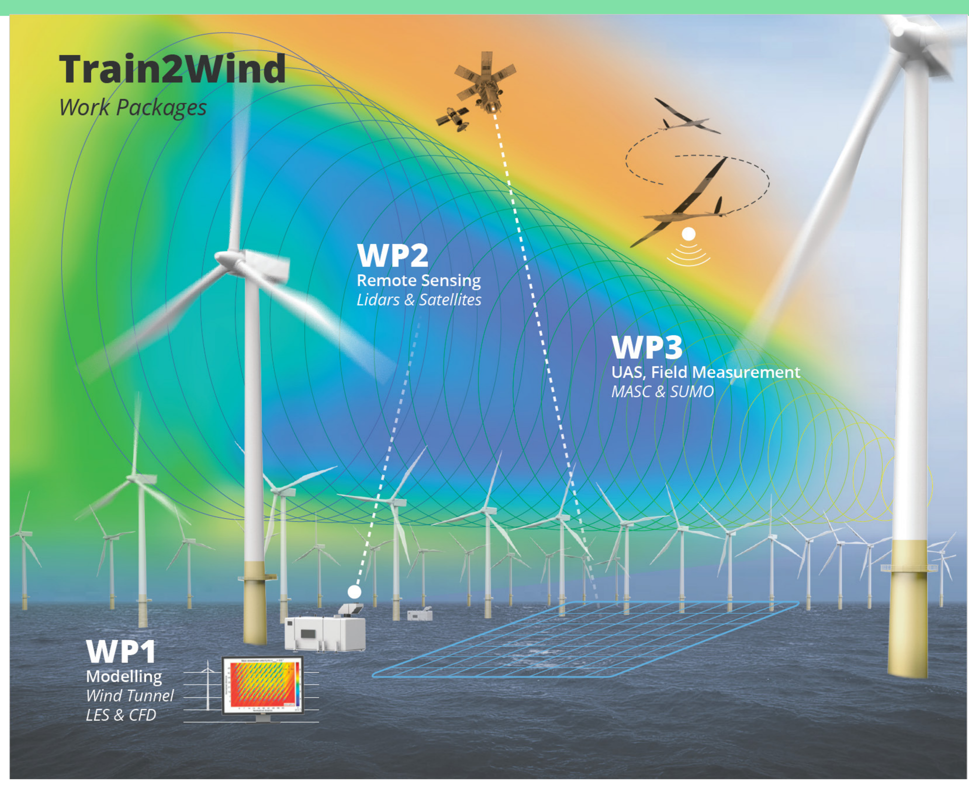
TRAIN²WIND is a PhD TRAINing school analysing enTRAINment in offshore WIND farms.

Rationale: Very large wind farms influence the boundary layer – where is the momentum coming from?



Volker, P, Hahmann, AN, Badger, J & Ejsing Jørgensen, H 2017, 'Prospects for generating electricity by large onshore and offshore wind farms: Letter', *Environmental Research Letters*, vol. 12, no. 3, 034022. https://doi.org/10.1088/1748-9326/aa5d86

We aim at 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.



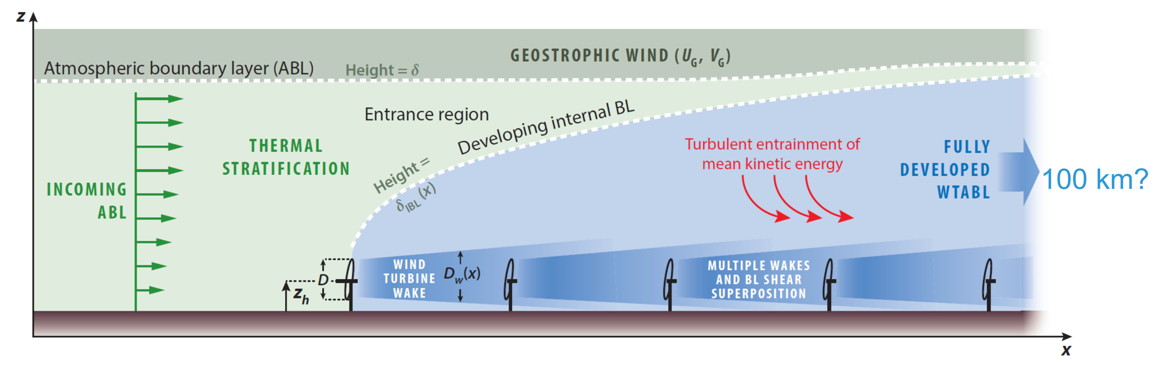


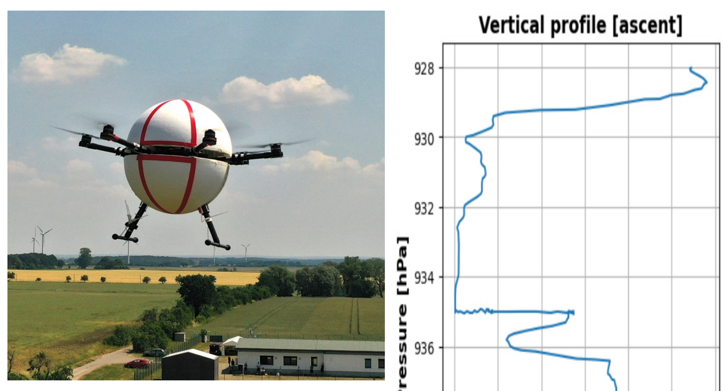
Figure 1
Various fluid mechanical flow phenomena in wind farms, including wakes, their superposition, and interactions with the atmospheric boundary layer (ABL), development of internal boundary layers, and, if a wind farm is large enough, the attainment of a fully developed wind turbine array boundary layer (WTABL) regime.

Source: Stevens and Meneveau: Flow Structure and Turbulence in Wind Farms. AnnRevFluidDyn, 2017

Additionally, one fellow at Copenhagen University investigates how such a geographically distributed and diverse community of researchers actually collaborates.

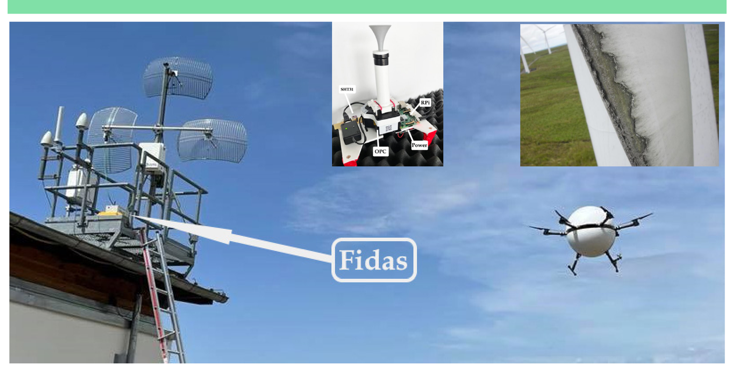
First results from the Fellows

Matteo Bramati, EKUT



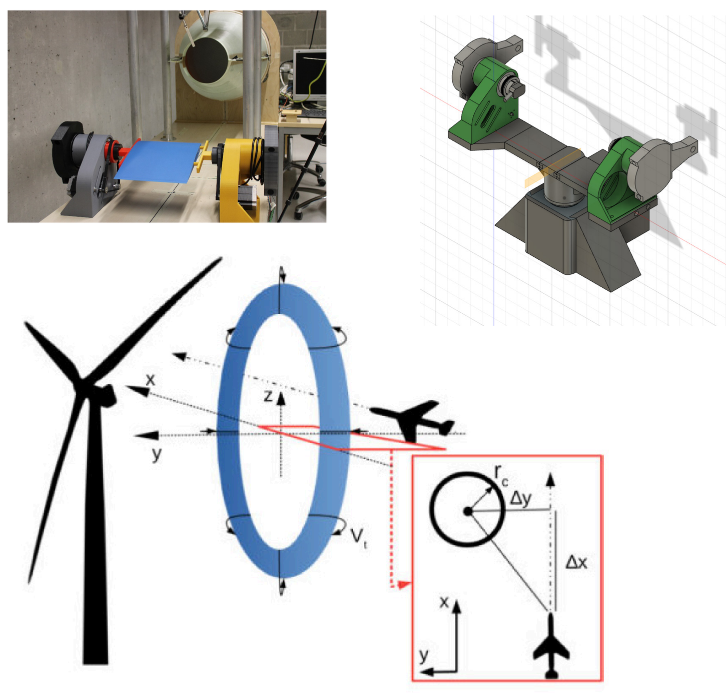
Wind vector measurements within a wind farm using multicopter flight and attitude data, 10-seconds resolution, no wind-tunnel calibration required. Styrofoam domes protect the electronics and make for isotropic air flow. Endurance 25-30 minutes.

Vasileios Savvakis, EKUT



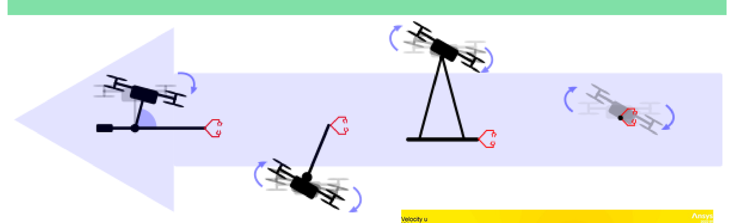
Measuring aerosol particles (e.g. sea spray) within a wind farm using multicopter-born Optical Particle Counter. The OPC arrangement includes a dryer to remove humidity from the particles. It compares well to a high-end fixed mounted Optical Aerosol Spectrometer, for PM1, PM2.5 and PM10 particle sizes. Can be used to determine leading edge erosion.

Mosaab Sajidi, EKUT

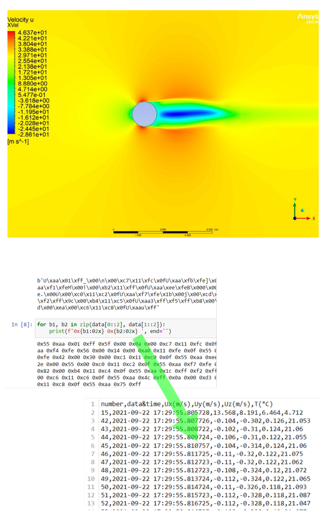


Identifying fine turbulent structures in offshore wind farms with UAS-borne five-hole probe calibrated for various airspeed using a calibration robot.

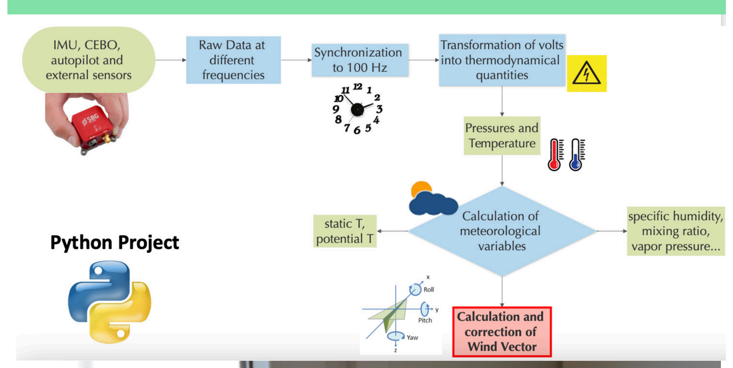
Mauro Ghirardelli, UiB



Sonic Anemometer on a MUlti-Rotor drone for Atmospheric turbulence Investigation: mounting an ultrasonic anemometer (CSAT3B) on a quadcopter (Foxtech D130) for fine scale turbulence investigation. Conducting a CFD analysis, using the commercial software ANSYS Fluent, to better understand the rotors downwash, and the most suitable place to put the sensor. Also handling the sensor integration.

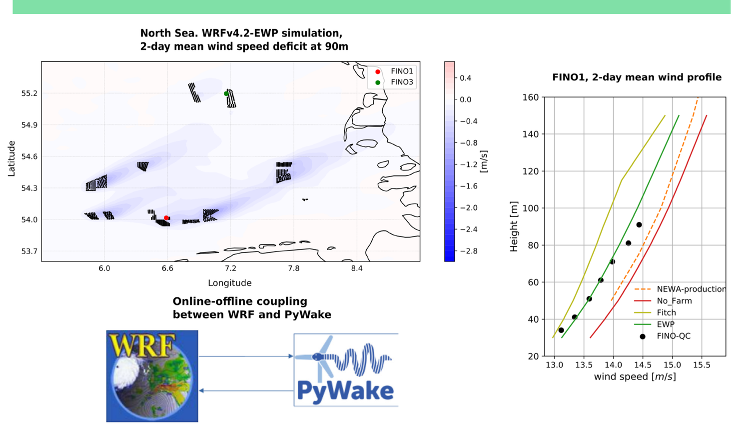


Gabriela Miranda, EKUT



Analysis of airborne in situ data using PASTA. The flight planning software will also be used to fly in virtual LES wind fields, to find the best path for the aircraft before valuable time in the field is wasted.

Oscar Garcia, DTU



Mesoscale modeling of offshore wind farms: The first results compare and evaluate wind farms parametrisations in the Weather Research and Forecasting mesoscale model for the North Sea. Improvements have been added to the Explicit Wake Parametrisation (EWP) to account for layout awareness. Current work focuses on coupling WRF with PyWake to use the CFD-RANS and Engineering models.

Grischa Fraumann, UCPH

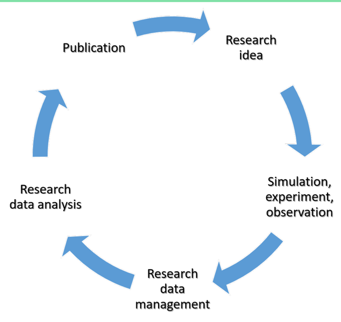
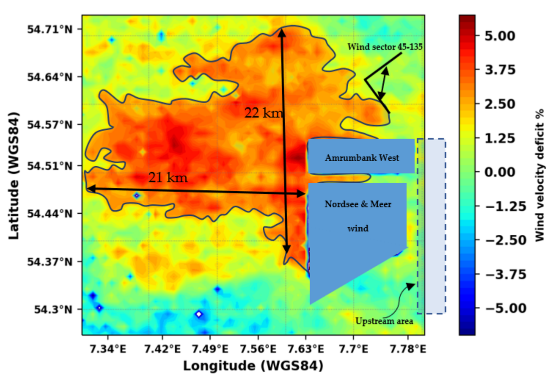


Figure of a typical or simplified research process; adapted from Tenopir, C., Allard, S., Douglass, K., Aydinoglu, A. U., Wu, L., Read, E., Manoff, M., & Frame, M. (2011). Data sharing by scientists: practices and perceptions. *PloS ONE* 6(6). https://doi.org/10.1371/journal.pone.0021101

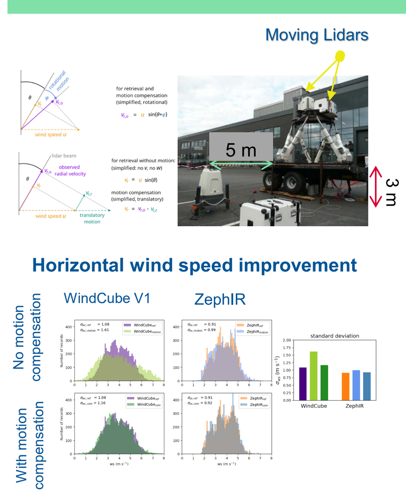
Scientific collaboration: 28 interviews conducted concerning scientific collaboration with PhD Fellows and Supervisors of the following four wind energy Innovative Training Networks (ITNs): FLOAWER, LIKE, STEP4WIND, and Train²Wind.

Abdalmenem Owda, DTU



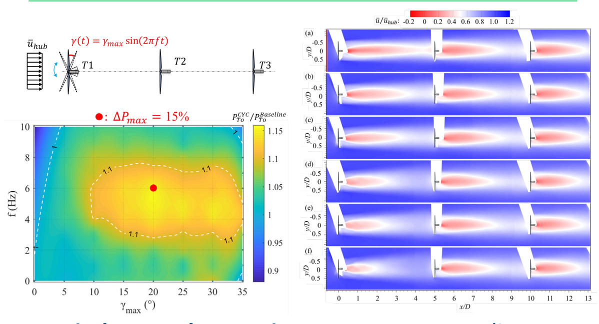
Wind wake analysis using SAR observations: Satellite remote sensing has been extensively used in wide range applications including offshore wind energy applications. Synthetic Aperture Radar (SAR) observations are unique remote sensing data, have high spatial resolution up to 500*500 m pixel resolution and can be used to study wind entrainment up to few kilometers from the coasts. European Space Agency (ESA) offers free-online access to big SAR archive which covers the globe since beginning of 2002. Offshore wind farms (OWFs) are being built in coastal zone; therefore, SAR is the only side-looking sensor which can use to map wind wakes and costal wind speed gradients in those areas. Moreover, SAR can be used in wind resource assessemnt and map the wind conditions before and after commissioing of OWFs. This PhD topic ,"Satellite remote sensing for offshore wind energy applications", is going to improve the wind speed retrieval process using SAR and validate the outcomes with other PhD topics in Train2Wind.

Shokoufeh Malekmohammadi, UiB



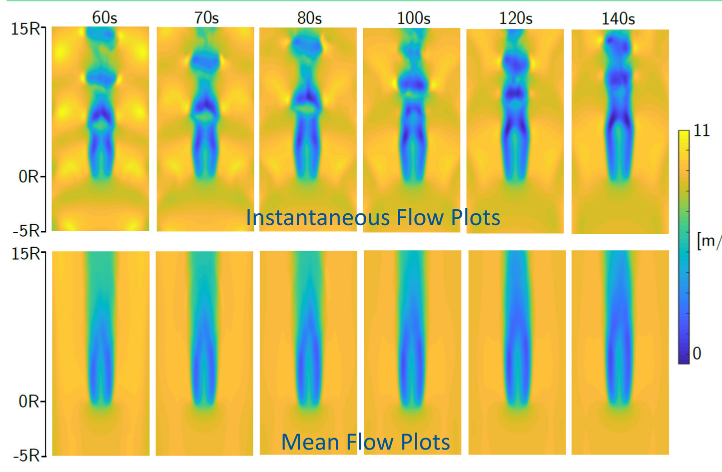
Floating Lidars: We have investigated the error induced by motion on ship-based lidars measurements and have applied motion compensation algorithms to remove these errors.

Guiyue Duan, EPFL



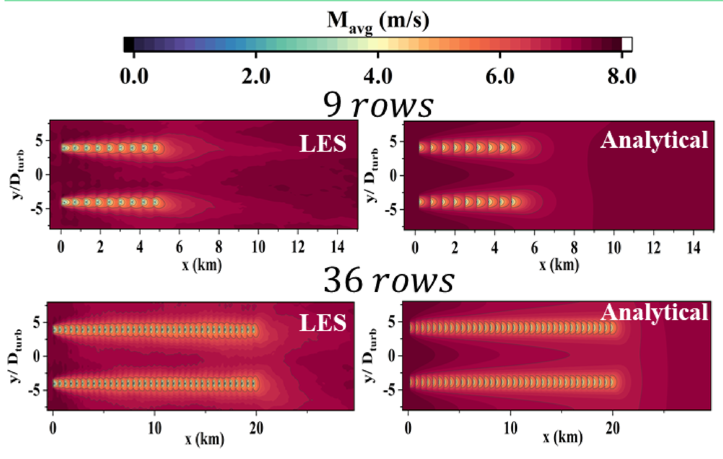
Wind tunnel experiments: a new cyclic yaw control (CYC) strategy has been investigated in a wind farm model in the EPFL atmospheric boundary layer wind tunnel. The results show that by applying CYC the power production can be improved up to 15%, compared to the baseline case. PIV measurements also reveal faster wake recovery for all individual wind turbines.

Emily Hodgson, DTU



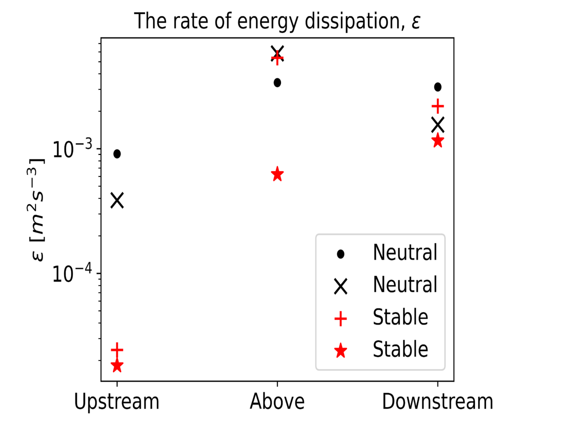
Large Eddy Simulations (LES) of wind turbine wakes and wind farms, to investigate the impact of the turbulent time scales of the atmosphere on the turbine wake recovery and entrainment into wind farms. These results show the impact of changing only the time scale of a sinusoidal inflow on the wake breakdown – a 60s time period induces a much faster wake roll-up and recovery than longer scales. This indicates that the beneficial length scales for entrainment exist, and the PhD will aim to identify these and then introduce them into wind farm scenarios to improve efficiency and power production.

Marwa Souaiby, EPFL



Modelling in LES: working with the WIRE-LES code and available analytical models, aiming towards assessing the wind farm length and layout effect on the ABL and the wind farm wake under different stability conditions. The study comparing wind farms with different lengths and layouts under a conventionally neutral boundary layer (two aligned cases shown above) shows the decreasing velocity magnitude at the exit while approaching the infinite wind farm case the longer the farm considered. Additionally, a noticeable overestimation in the wind farm wake recovery rate is introduced by the implemented analytical model.

Abdul Haseeb, DTU



How do large wind farms break the incoming wind flow? The rate of energy dissipation describes the rate at which energy is being dissipated from large-scale eddies to smaller flow structures due to either ambient turbulence or the turbulence generated by wind turbines. From the measurements obtained via instruments mounted on an aircraft flying above large offshore wind farms in the North Sea, we can clearly observe the contrast between neutral and stable conditions in the upstream of the wind farm, while the energy dissipation values are alike in above and downstream positions of the wind farm.

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