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ZHEJIANG UNIVERSITY 1897

Tsinghua University 清華大學

Farming the ENvironment into the Grid

Big data in Offshore WIND

风伯-WIND

Rafael Palacios
Sylvain Laizet
Yorgos Deskos

Supergen ORE hub meeting
Glasgow, 6 Nov 2019

NSFC

Newton Fund

UKRI Natural Environment Research Council

UKRI Engineering and Physical Sciences Research Council

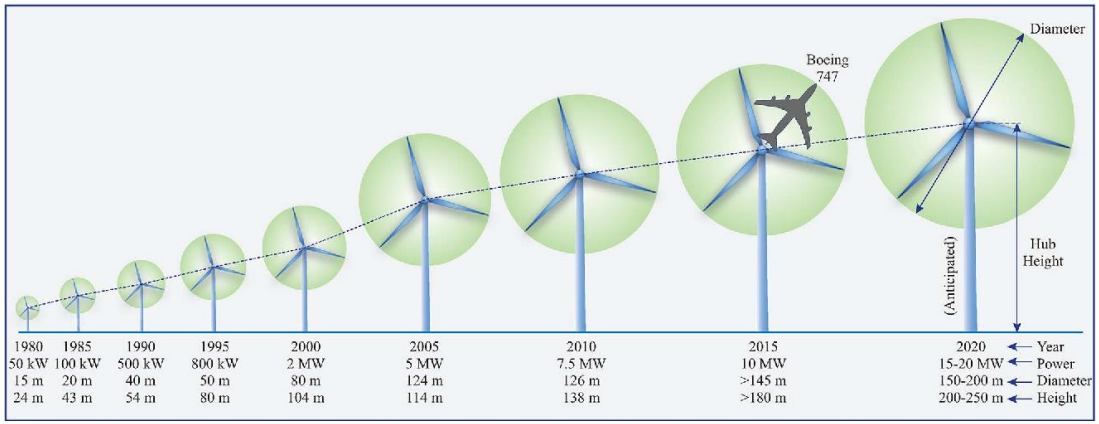
Project objectives

1. Farm modelling

- Very large scale simulation of offshore wind farms
- Simultaneous blade loads and power generation at farm level
- Optimization of wind farm layouts

2. Data analytics

- Data-driven strategies for operation and control
- Combine large-scale physics-based simulations and big-data analytics
- Sensing network to enhance grid resilience



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Co-Is in FENGBO-WIND

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DNV·GL

FTI CONSULTING

国家电网 STATE GRID

ENVISION

ENERGY RESEARCH INSTITUTE

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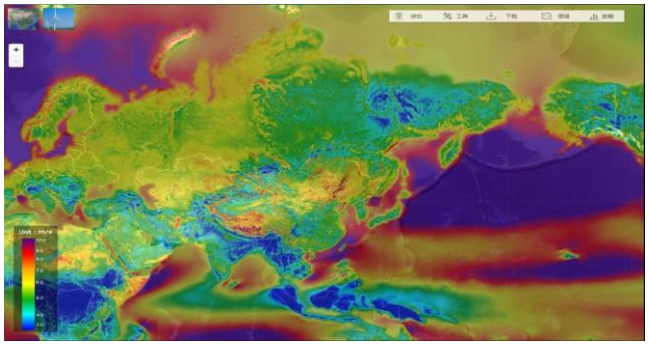
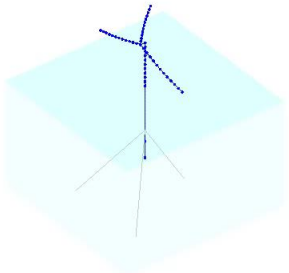
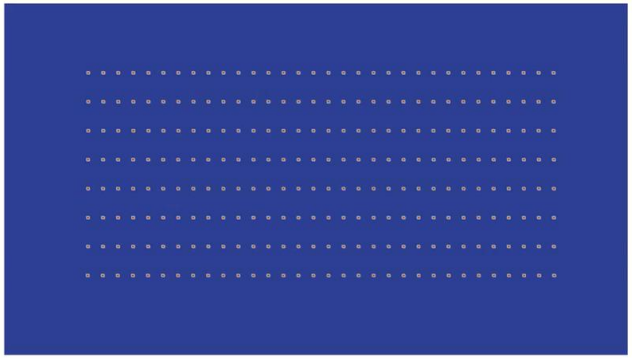
Strategy

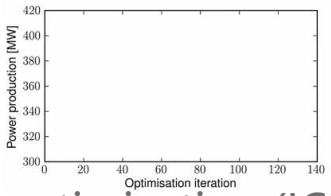


Global Wind Power (Tsi)

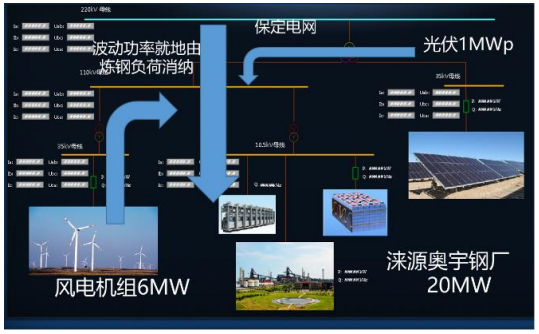


HAWT aeroelastic control (ICL/UW)





Array optimization (ICL)



Smart grid design (Tsi)

National Supercomputer Centre, Wuxi, China

ICL/ZJU Joint Applied Science Data Lab (ZJU)

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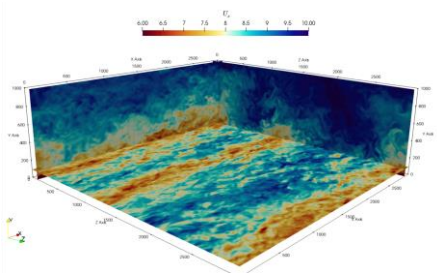
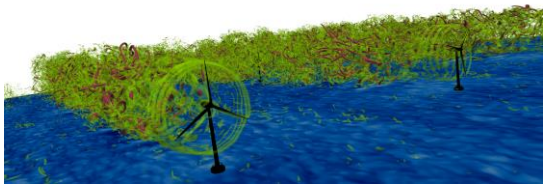
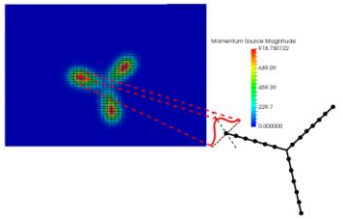
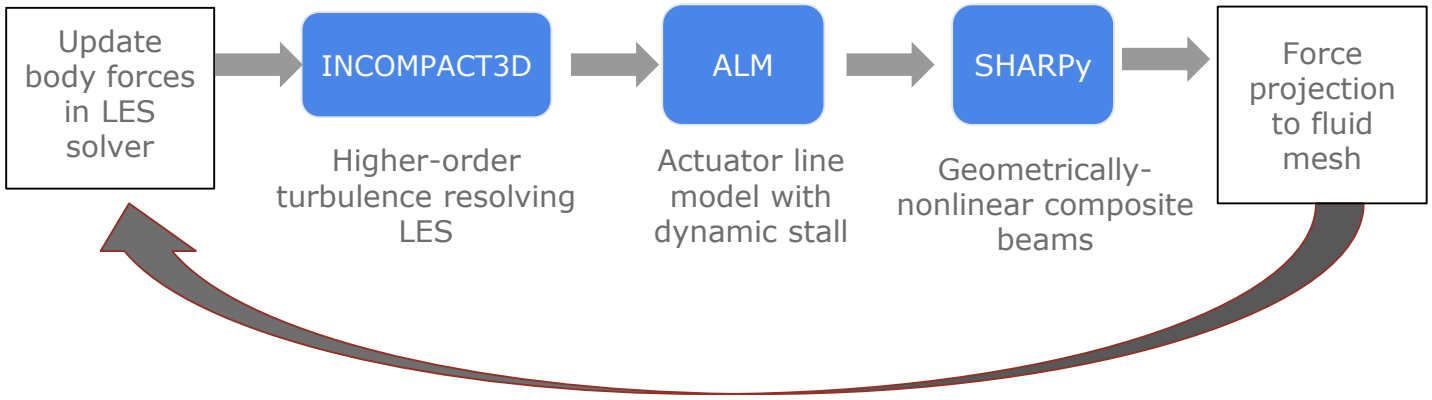
Aeroservoelastic simulation of farms with large turbines

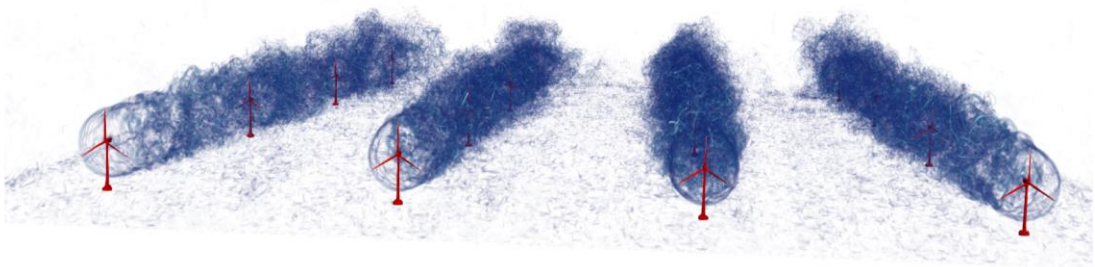
Imperial College Wind Farm Simulator*:











16 5MW HAWTs, neutral ABL, 8 m/s wind, turb 6%
Calculated power: 16.7 MW (average over 10 min)

1 billion DoFs on 8192 cores
(<1 day for aero only simulations)

*Deskos Y., Laizet S., Palacios R., "WInc3D: A novel framework for turbulence-resolving simulations of wind farm wake interactions", Wind Energy, to appear

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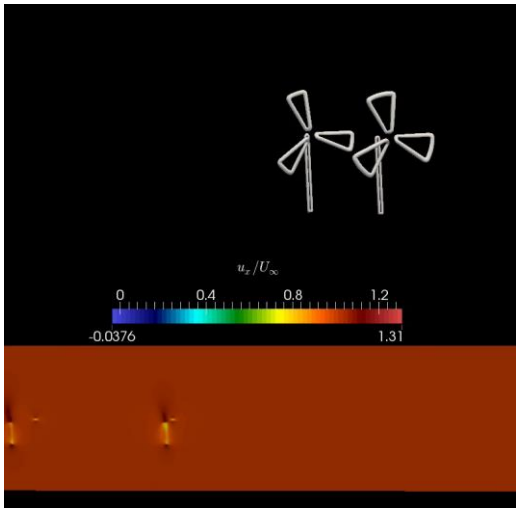
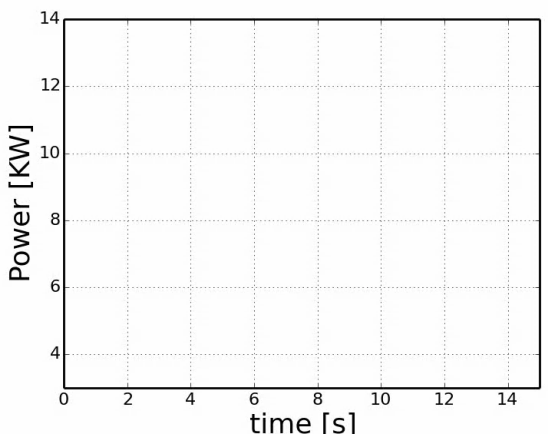
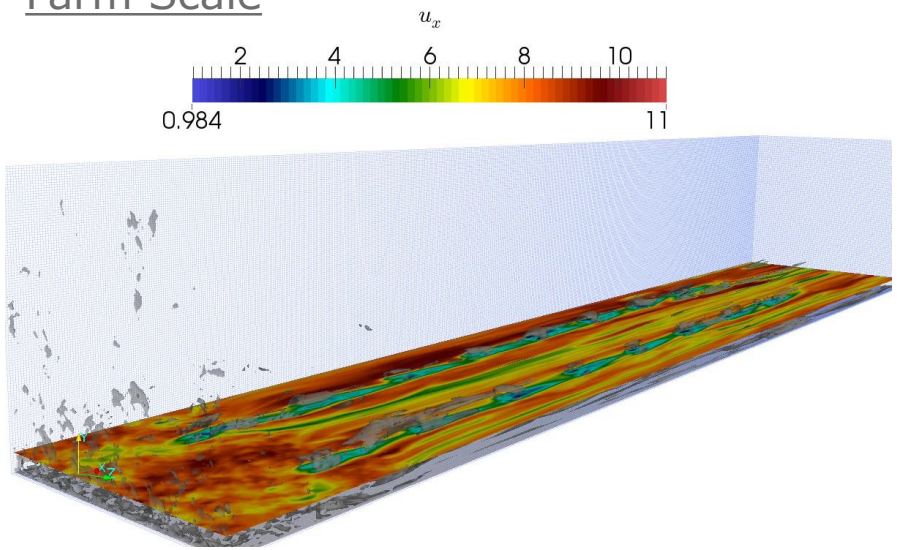
High-fidelity simulation of wind farm aerodynamics

Lab Scale

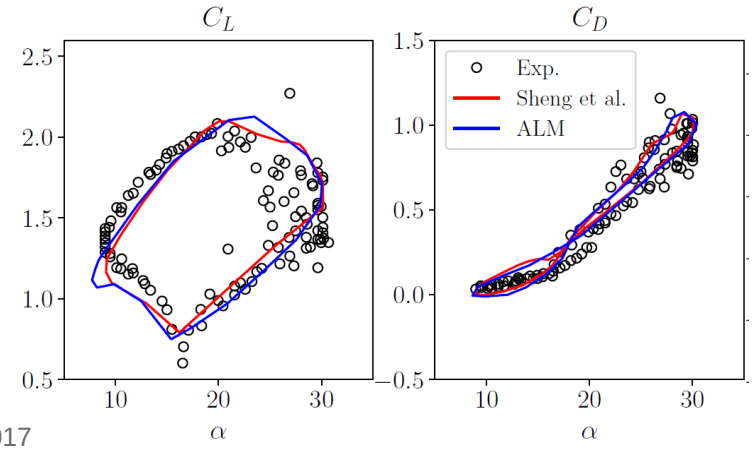




Farm Scale



Blade scale:

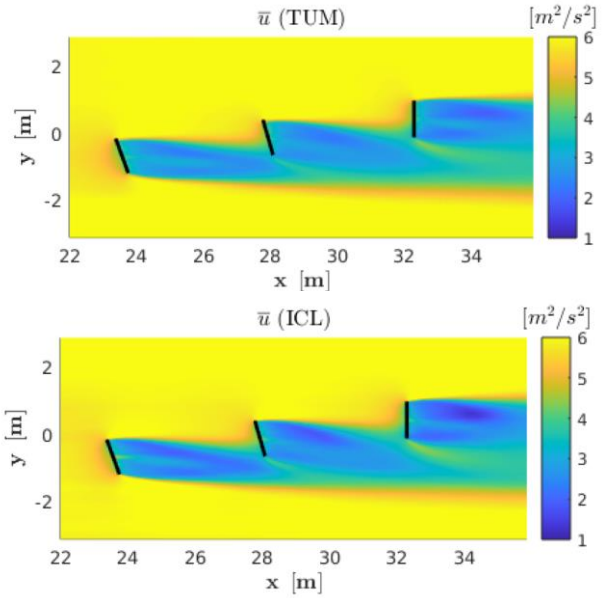


Left: Two laboratory-scale turbines operating in-line (From Deskos et al. 2017

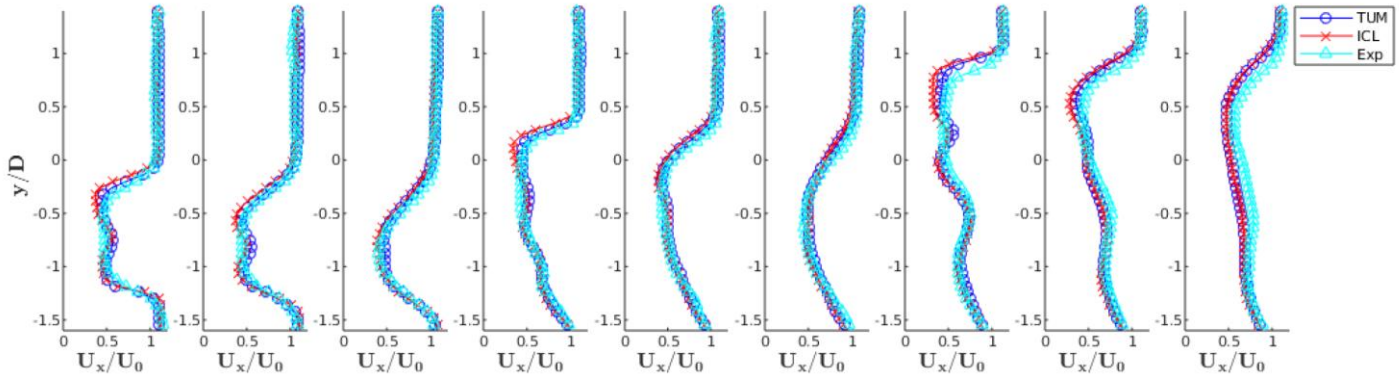
Right: Section of the real-scale Horns Rev I offshore wind farm (From Deskos et al. 2018b)

Validation and verification exercises

- Code-to-code/code-to-experiment campaign with TU Munich



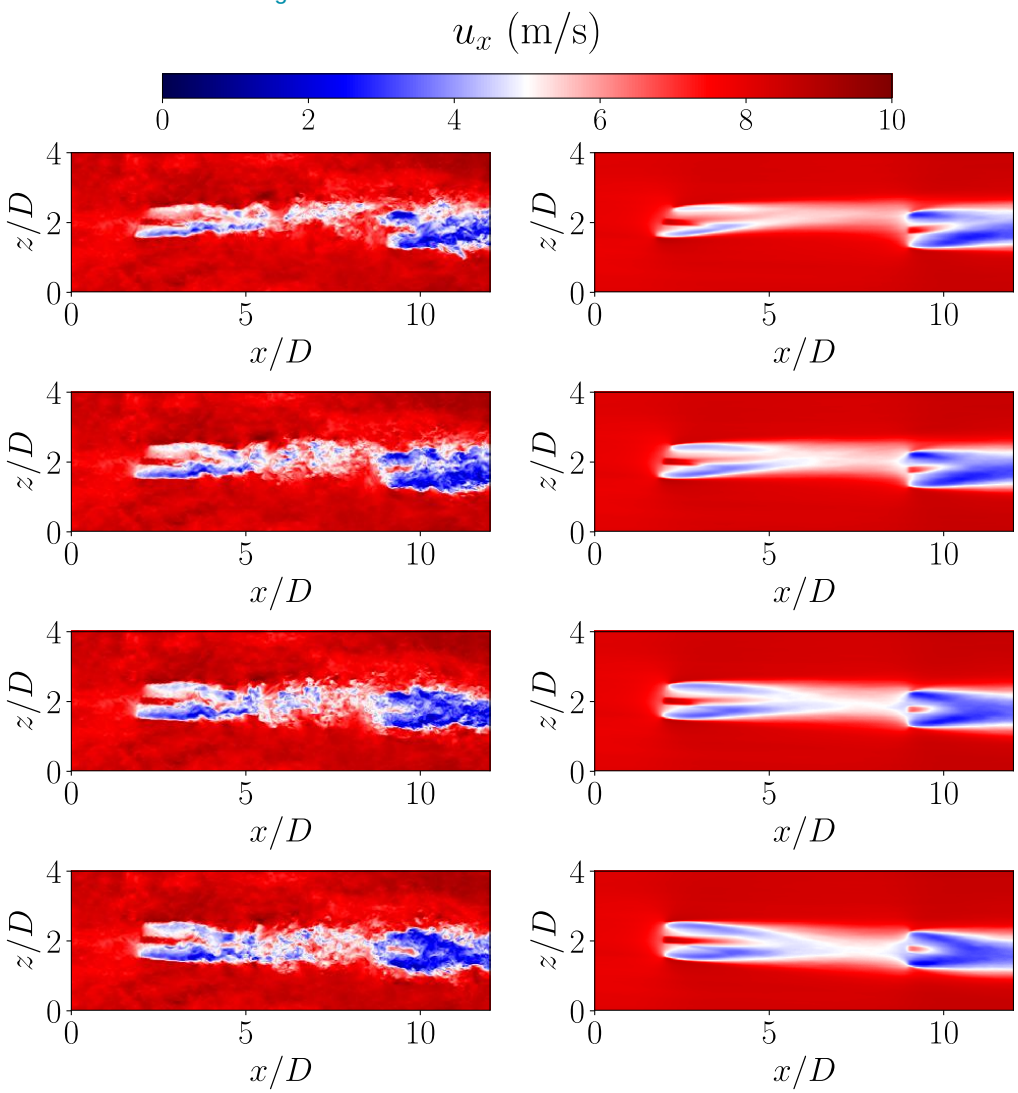
- Wake profiles (turbulent inflow)



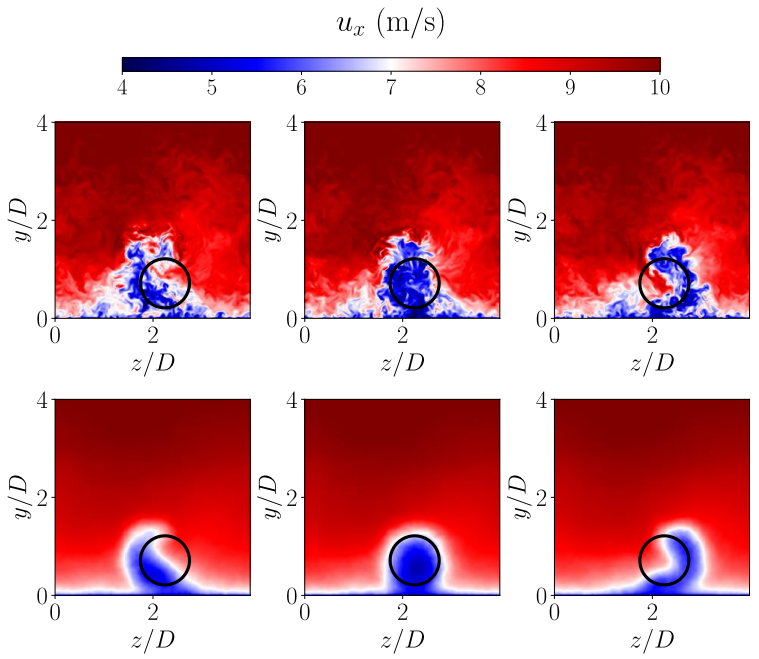
Power maximisation via wake steering

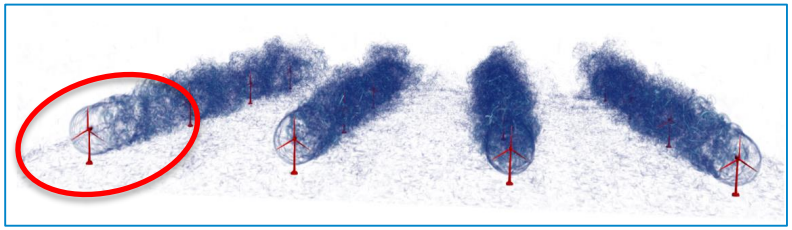
- Multiple configurations to cover a large operational region → FLORIS + SLSP

Plan view at hub height



Vertical cross-section upstream th rear turbine





- Wake profiles at 2D, 4D and 6D downstream the front turbine

Power maximisation via wake steering

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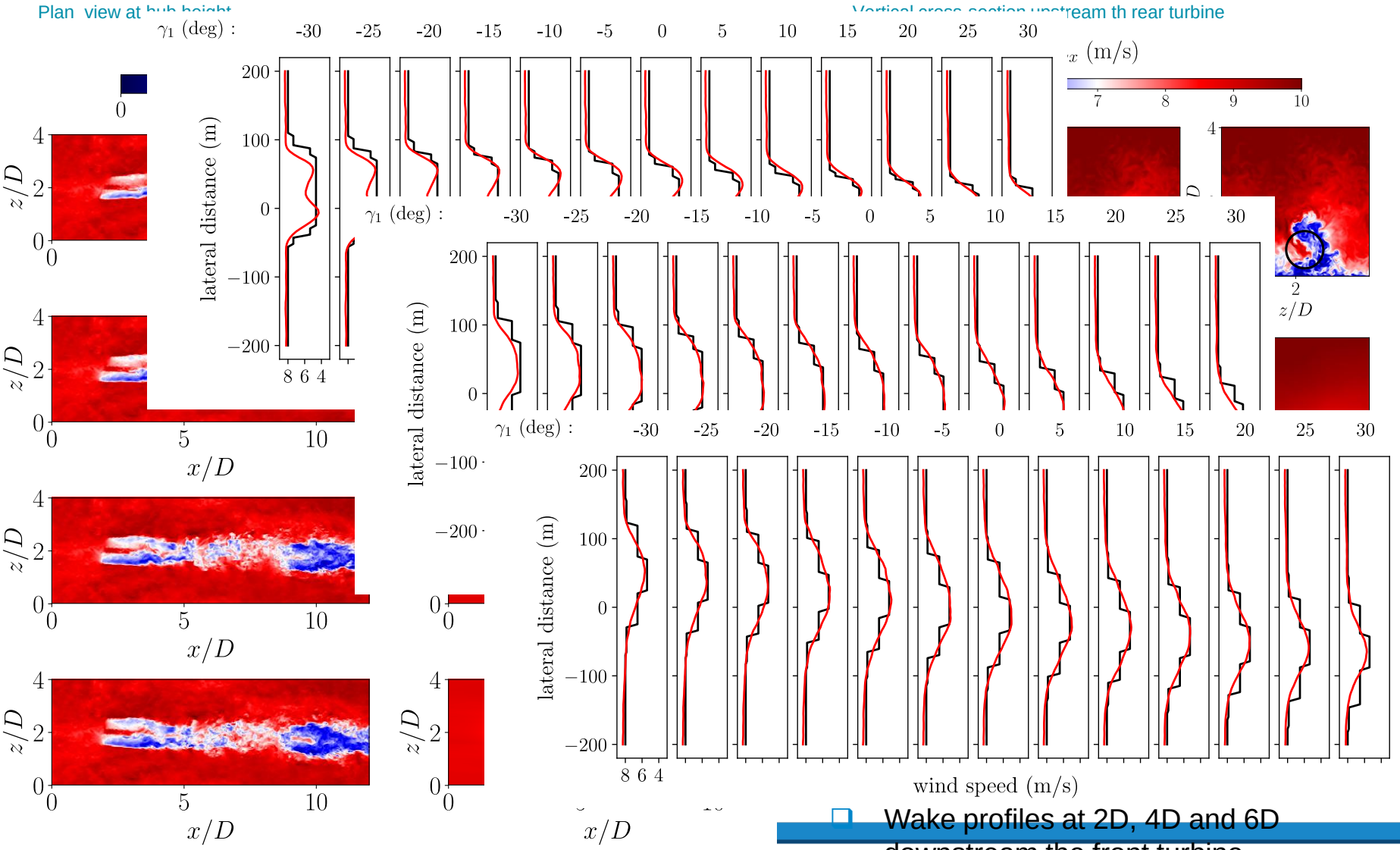
- Multiple configurations to cover a large operational region → FLORIS + SLSP



- Wake profiles at 2D, 4D and 6D downstream the front turbine

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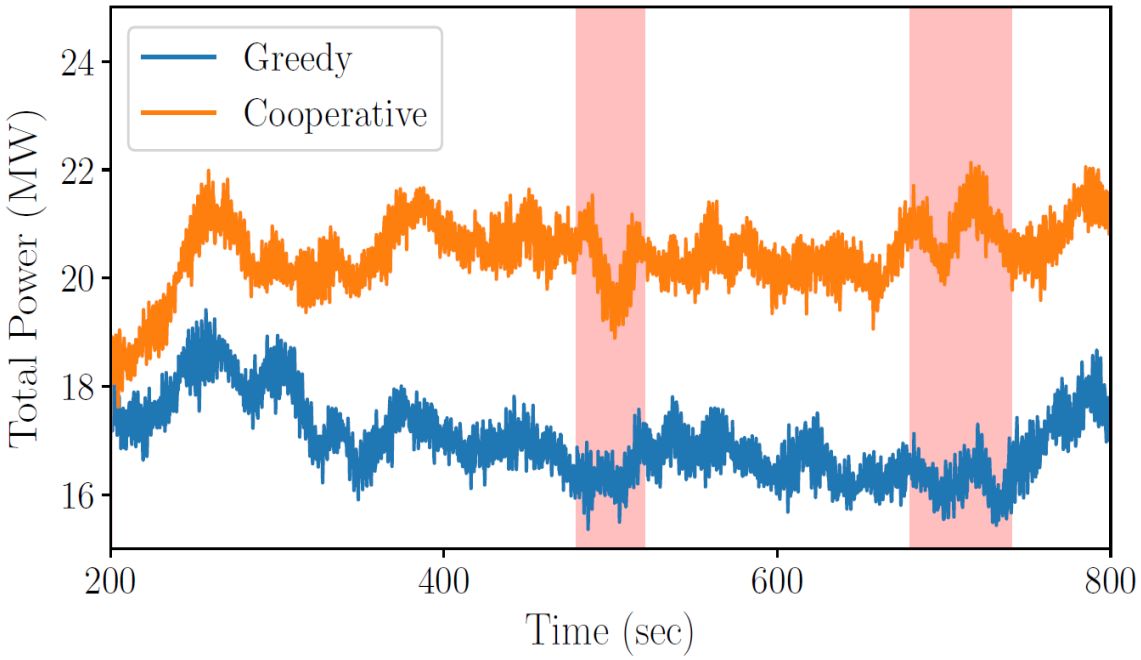
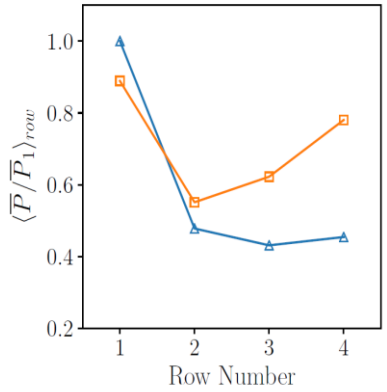
Optimal Yaw Control of Wind Farm Power Generation

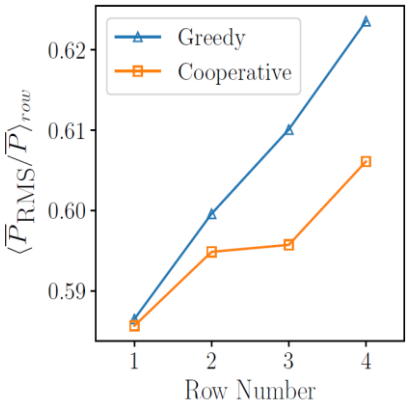
- 4x4 NREL 5MW turbines
- Below-rated, 6% turbulence
- Offline yaw optimization (FLORIS)



Total power output of farm



Mean power per row



r.m.s. power per row

*Deskos Y., Laizet S., Palacios R., "WInc3D: A novel framework for turbulence-resolving simulations of wind farm wake interactions", Wind Energy, to appear

Concluding remarks

- We are building an open-source wind farm simulator that scales to 100k's of CPUs.
  - High-order Large-Eddy Simulation aerodynamics
  - Flexible multibody solver with nonlinear composite beams
  - Turbine + farm control
- High-fidelity modelling can be used to resolve more relevant turbulence flow scales and therefore used effectively to study the structure of turbulence and its impact on wind turbines
- Wake steering (re-direction) is an efficient technique to mitigate the wake effects within wind farms
  - Mean values - power
  - Fluctuating values – fatigue (aeroelastic)
- Data reduction algorithms under development by project partners