Enhancing Wind Farm Efficiency by Multi Rotor Wind Turbine Systems with Lifting Devices

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Multirotor Seminar 2025

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Background: Wake losses

TU Delft

WIND CATCHING

Erneuerbare Energien Hamburg

EnBW

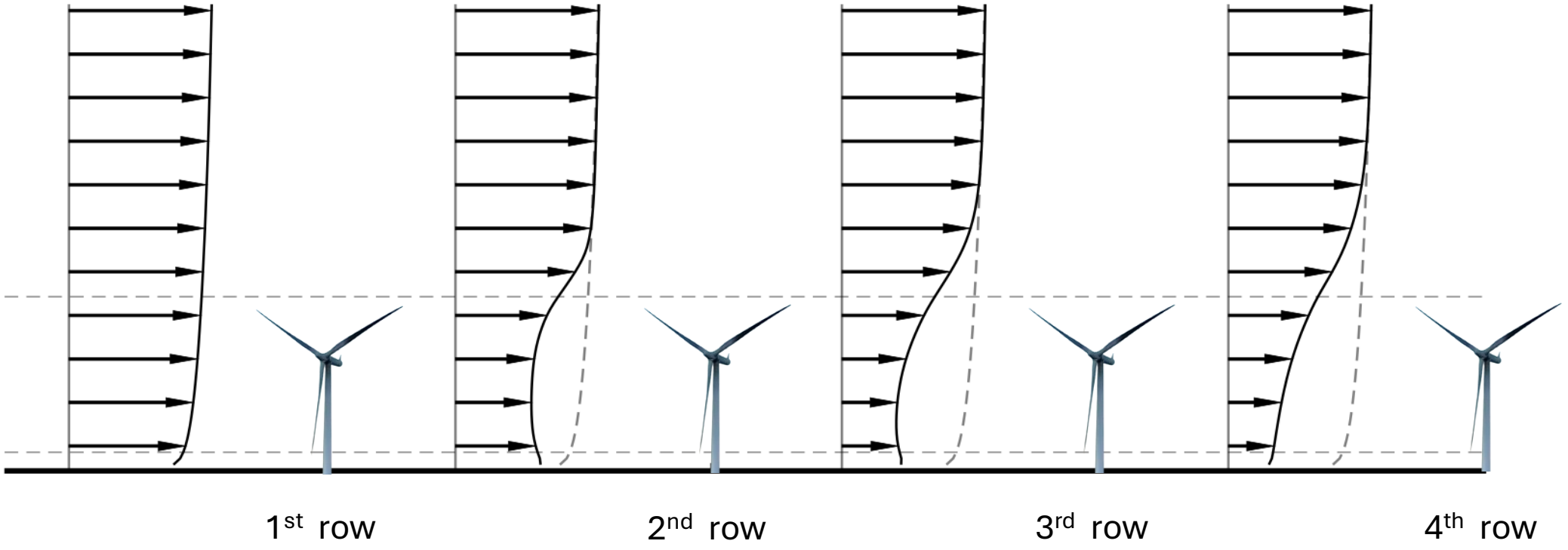
HAW HAMBURG | CC4E

University of Strathclyde Glasgow

RENEWABLE DYNAMICS

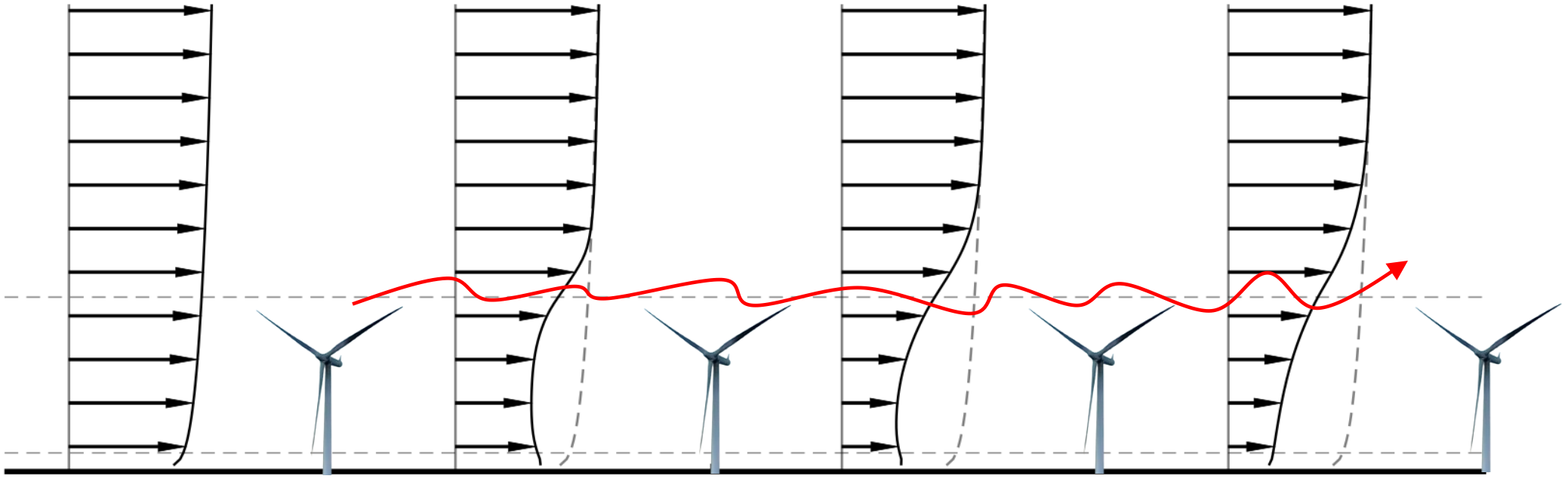
Wake Losses

- In wind farm, downstream turbines suffer from wakes
- Financial consequences



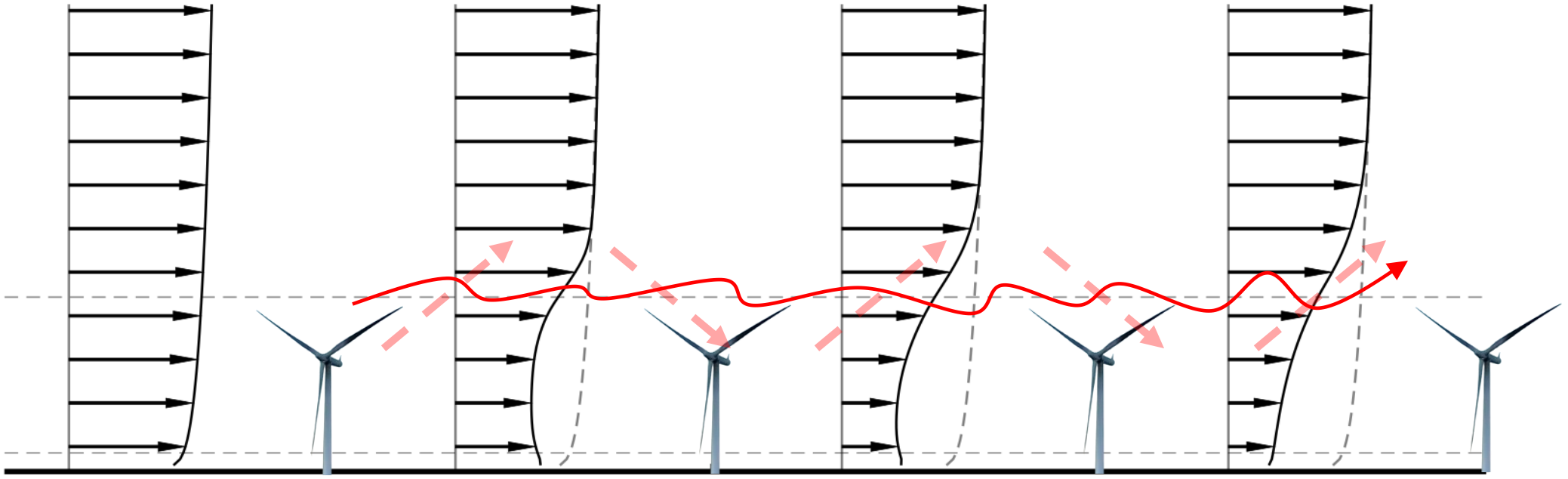
Wakes recover slowly

- Typical wind turbines (HAWTs) rely on **fluctuations** for wake recovery



Very slowly

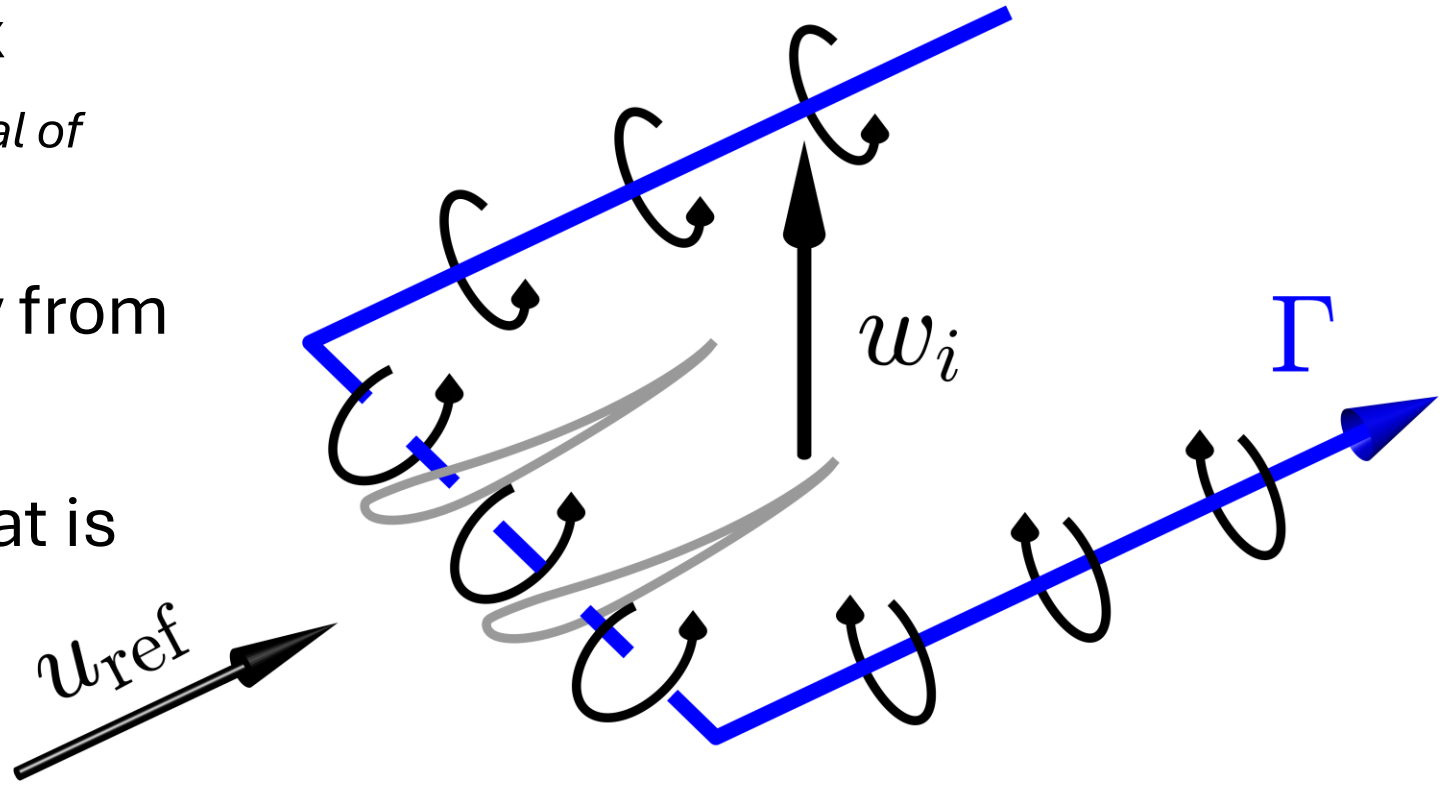
- Typical wind turbines (HAWTs) rely on **fluctuations** for wake recovery
- This process is rather slow as no significant **mean** vertical flows involve



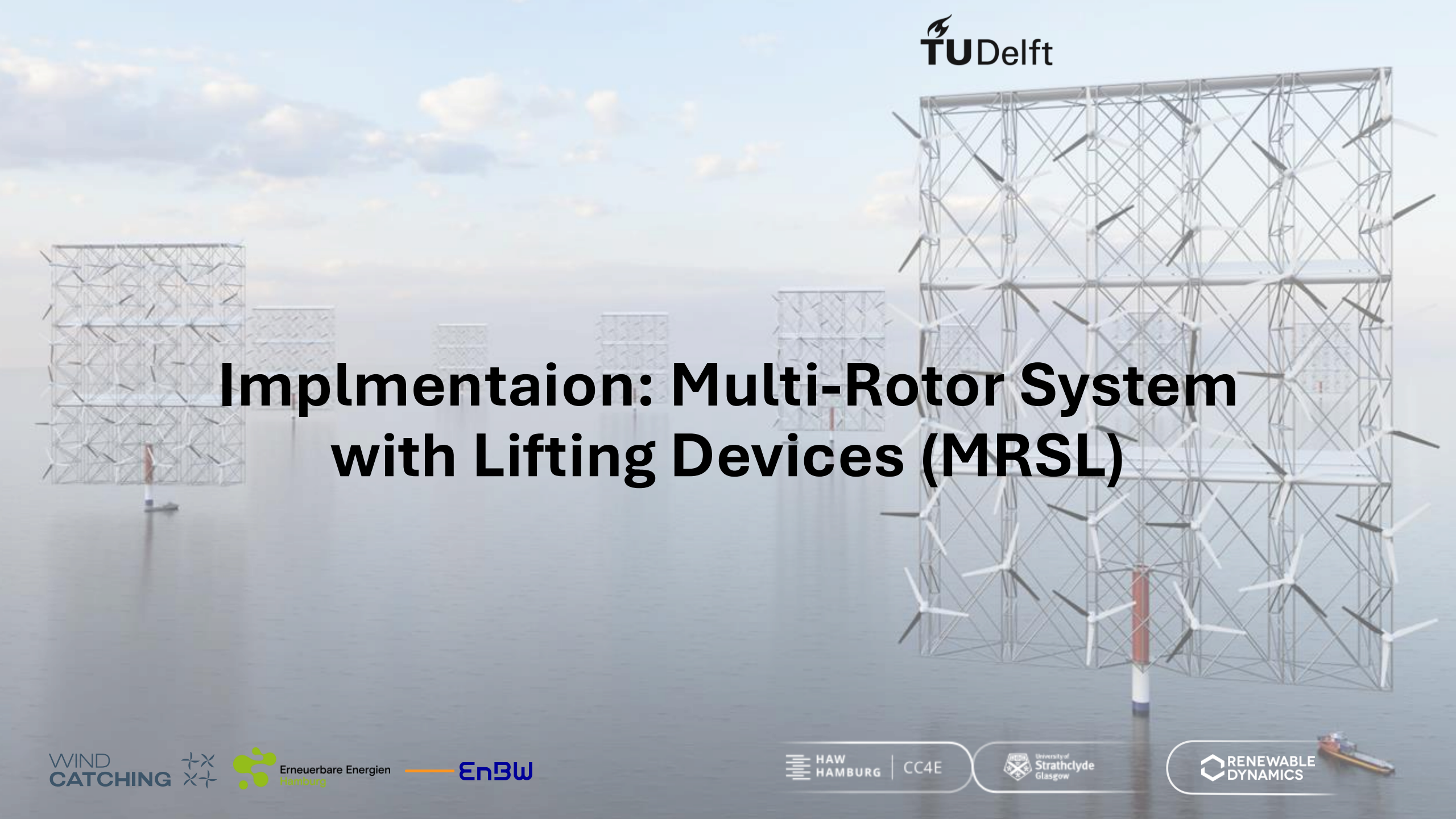
Background: Proposed solution to overcome wake losses

Large airfoils/wings

- Using large wings as vortex generator (C. Ferreira et al. *Journal of Physics: Conference Series*, 2024)
- Entrainment of flow energy from ambient flow faster
- Introduced vertical flow that is typically missing

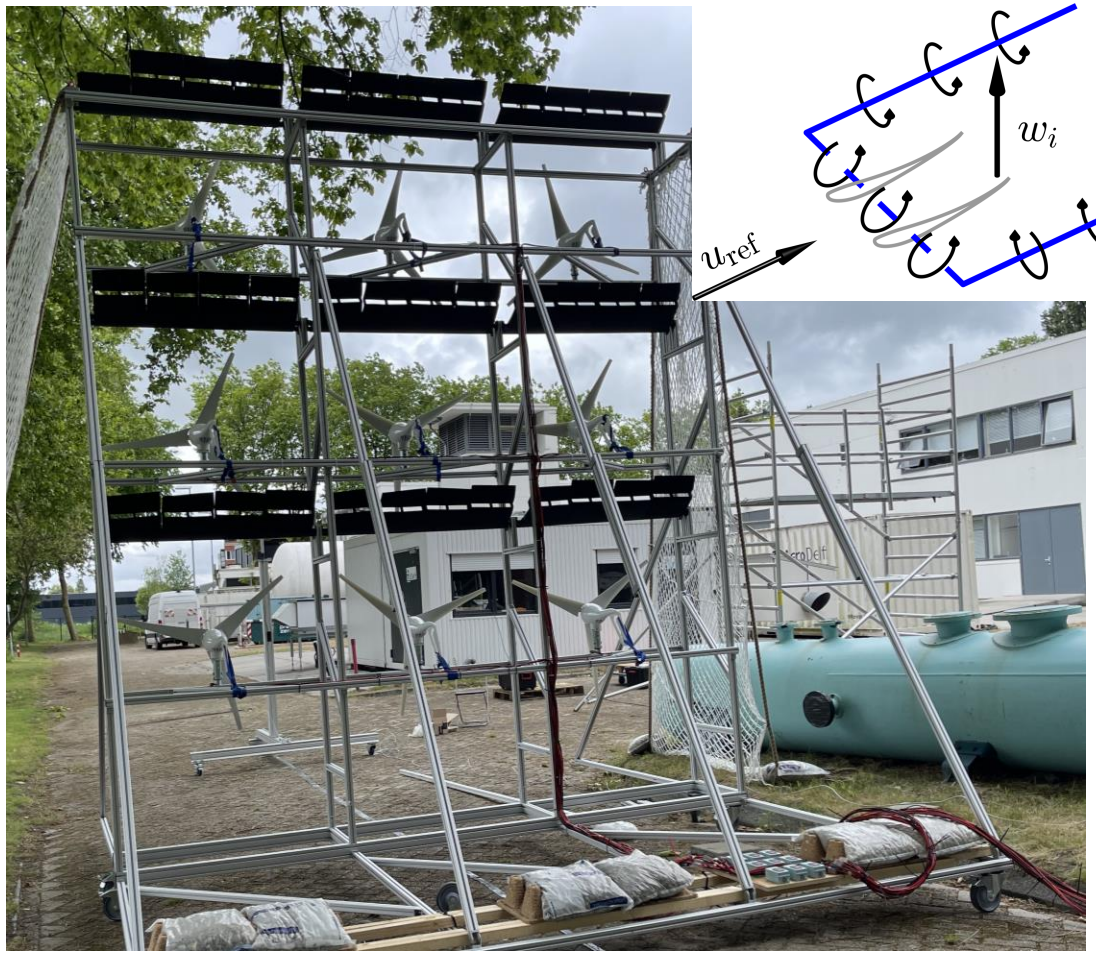


Implmentaion: Multi-Rotor System with Lifting Devices (MRSL)



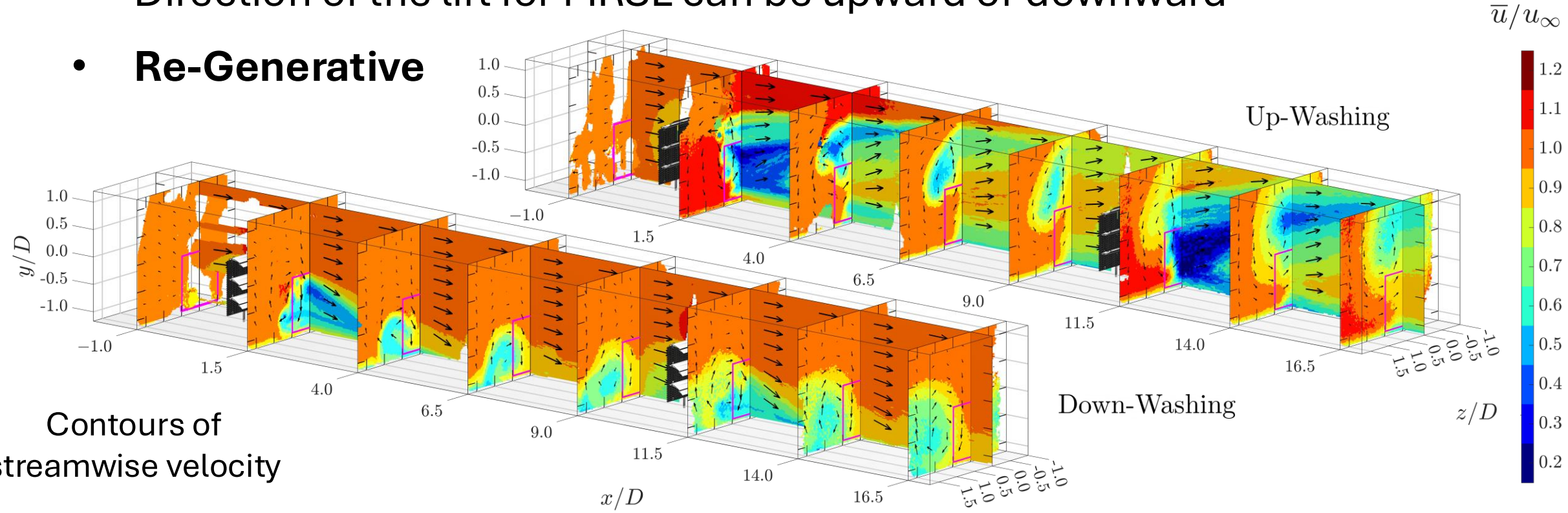
Multi-Rotor System with Lifting devices (MRSL)

- The wings produce strong lift and release strong tip vortices



Enhance wake recovery by altering the process

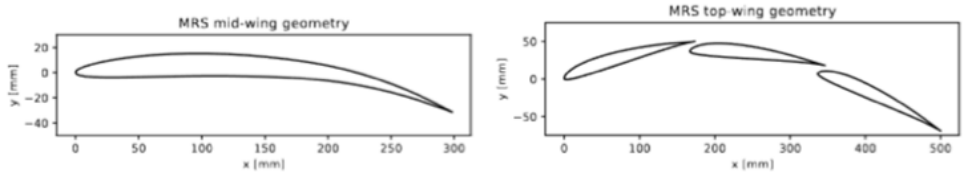
- Instead of relying the **fluctuations**, wake recovery of MRSL is mainly based on **advection** process induced by tip vortices
- Direction of the lift for MRSL can be upward or downward
- **Re-Generative**

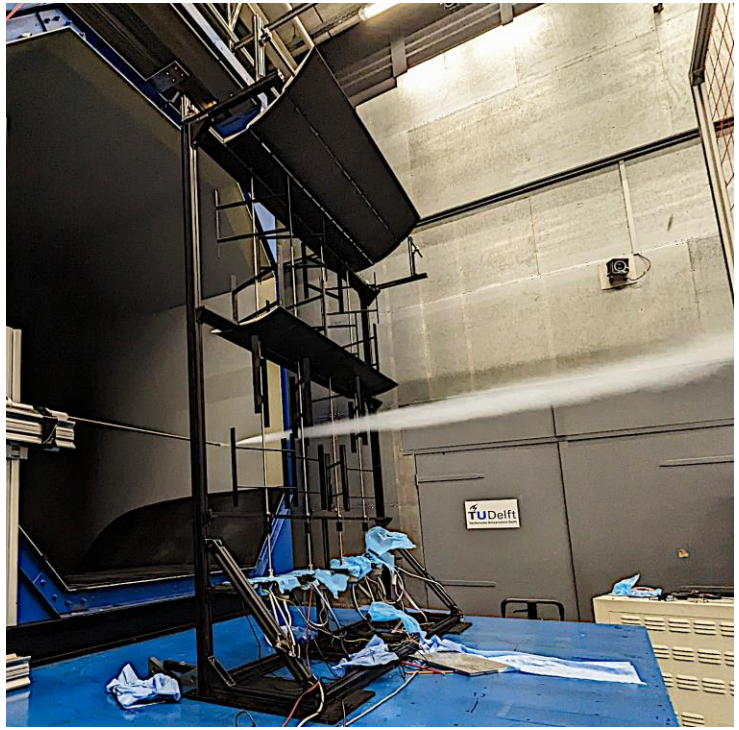


Contours of streamwise velocity

Evaluating the effectiveness: What we have done

Initial proof-of-concept: Experimental & numerical

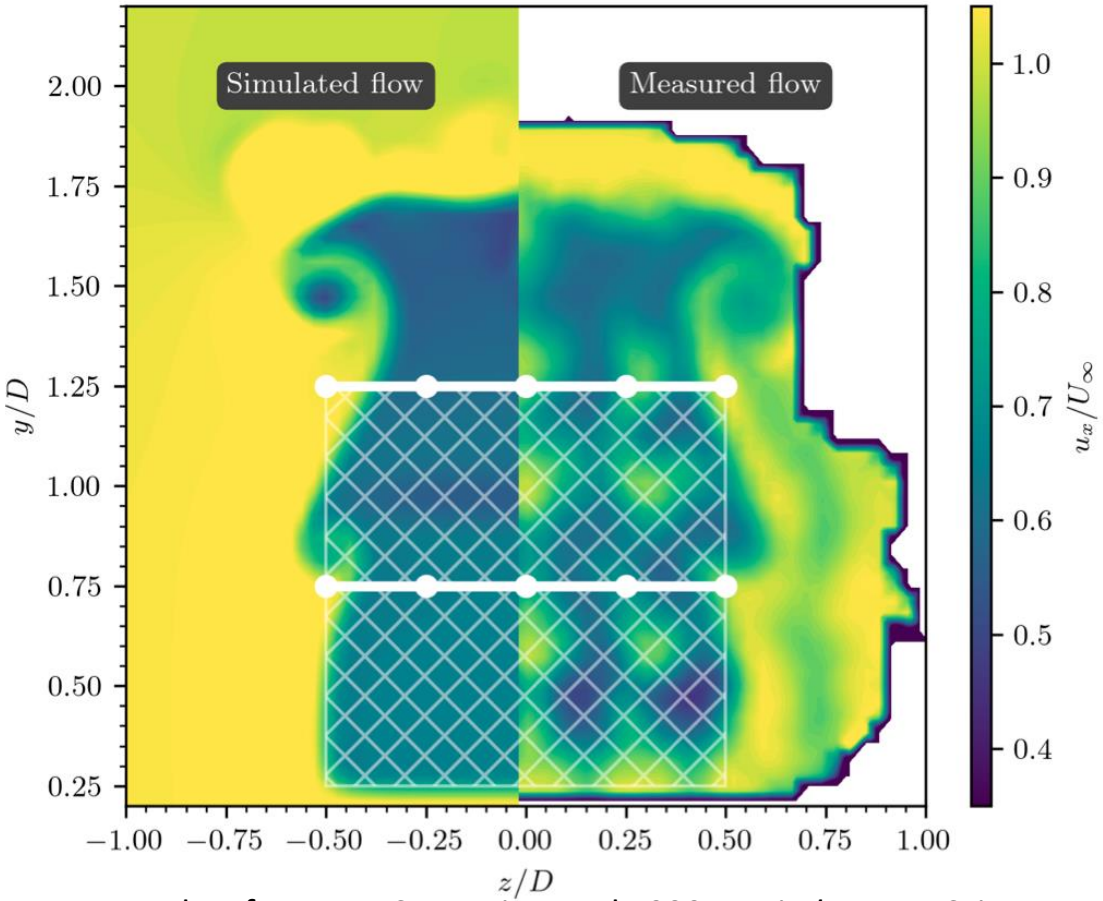




Taken from: T. J. Broertjes et al., 2024, *Journal of Physics: Conference Series*

Steady RANS Actuator techniques

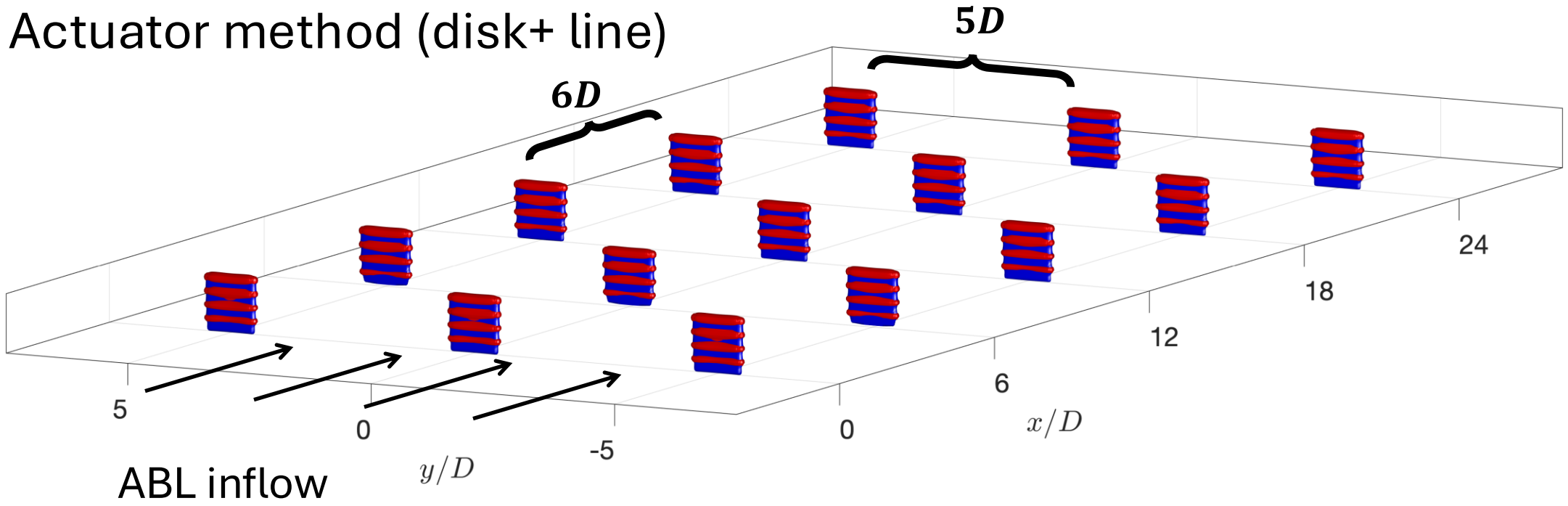
Planner PIV low turbulence inflow



Taken from: F.A.C. Martins et al., 2025, *Wind Energy Science*

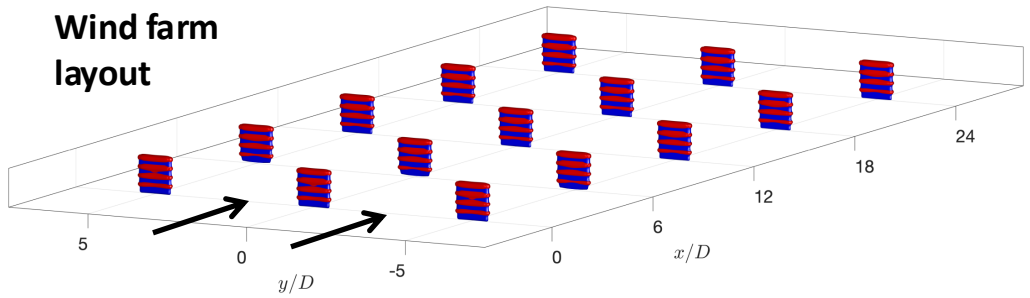
Regenerative wind farm - steady RANS

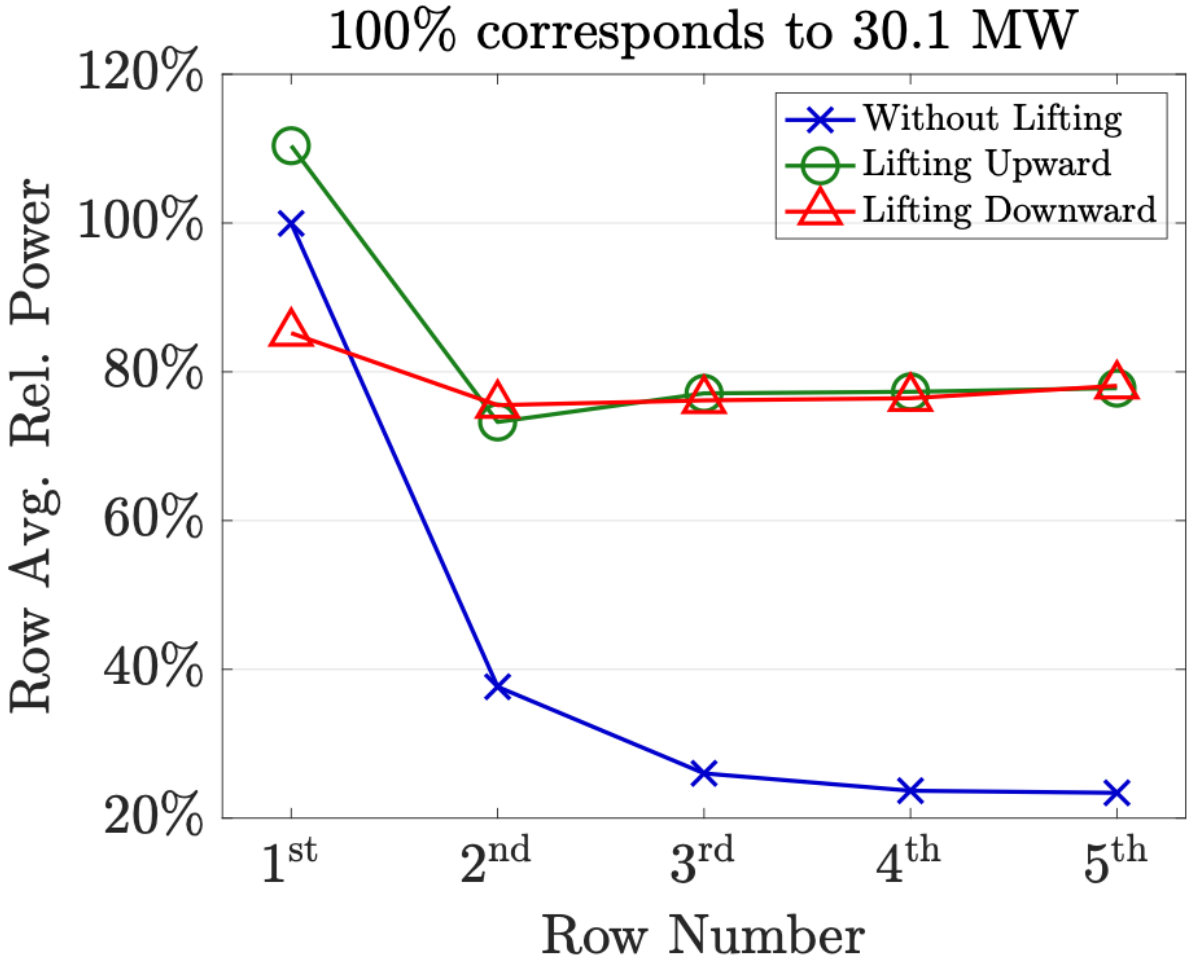
- MRSLs are put together to form the regenerative wind farm
- 5 rows and 3 columns
- Actuator method (disk+ line)



Regenerative wind farm - steady RANS

- After 2^{nd} row -> more than **100% power gain!**
- After 3^{rd} row -> more than **200% power gain!**





Taken from: Y. Li et al., 2025, *Wind Energy Science*

Regenerative wind farm - steady RANS

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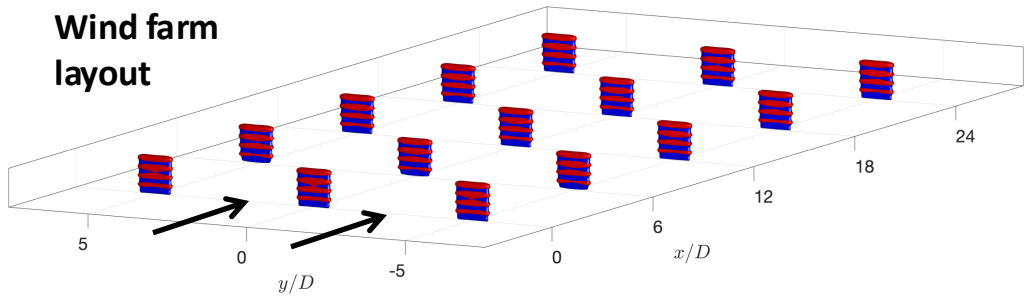
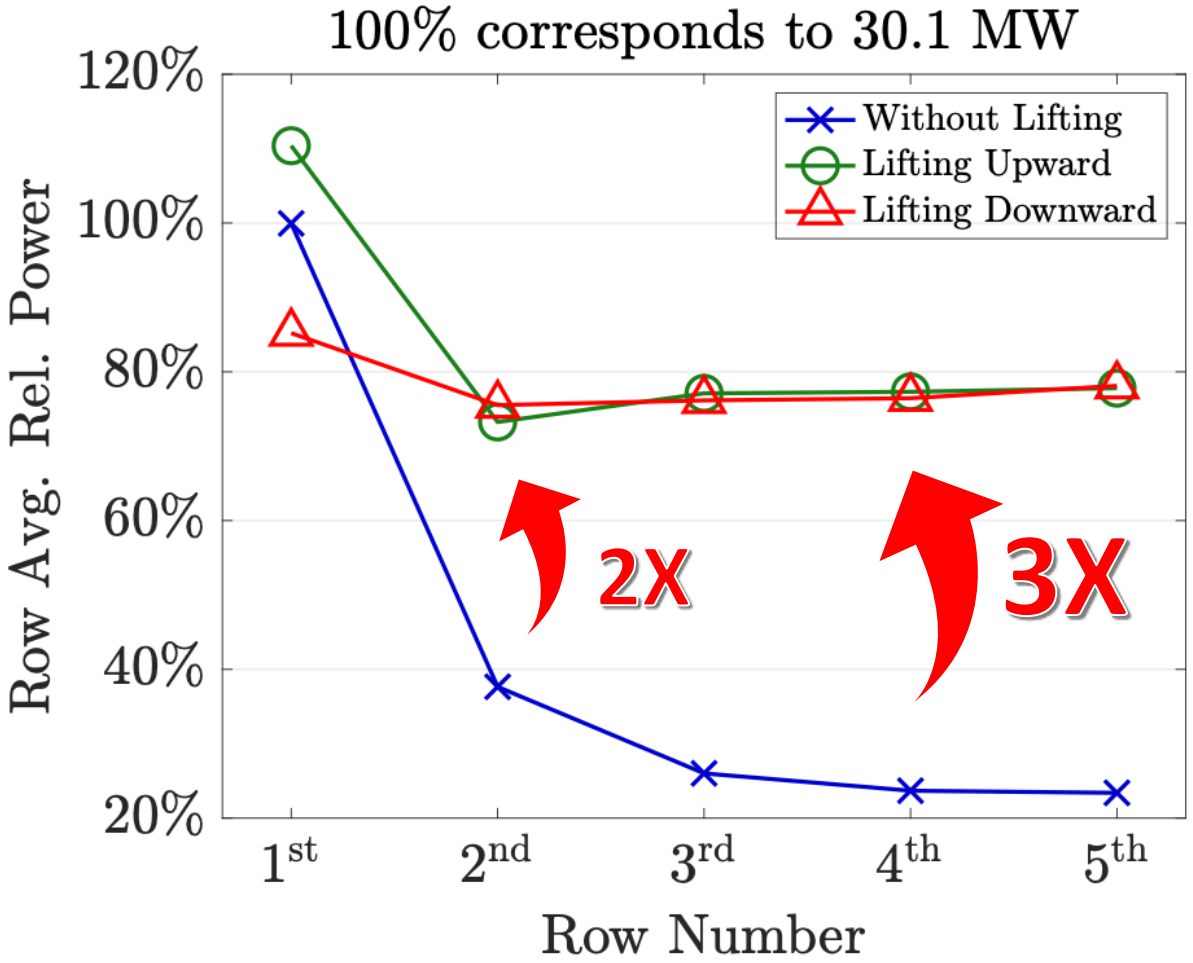
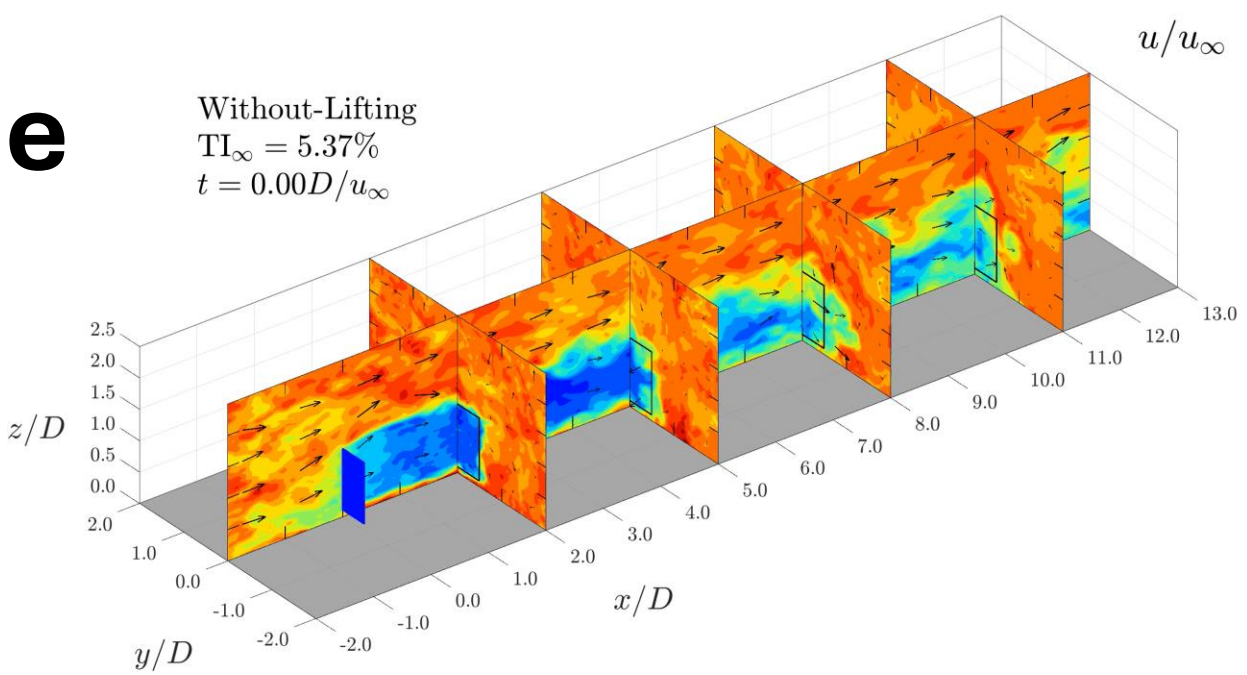


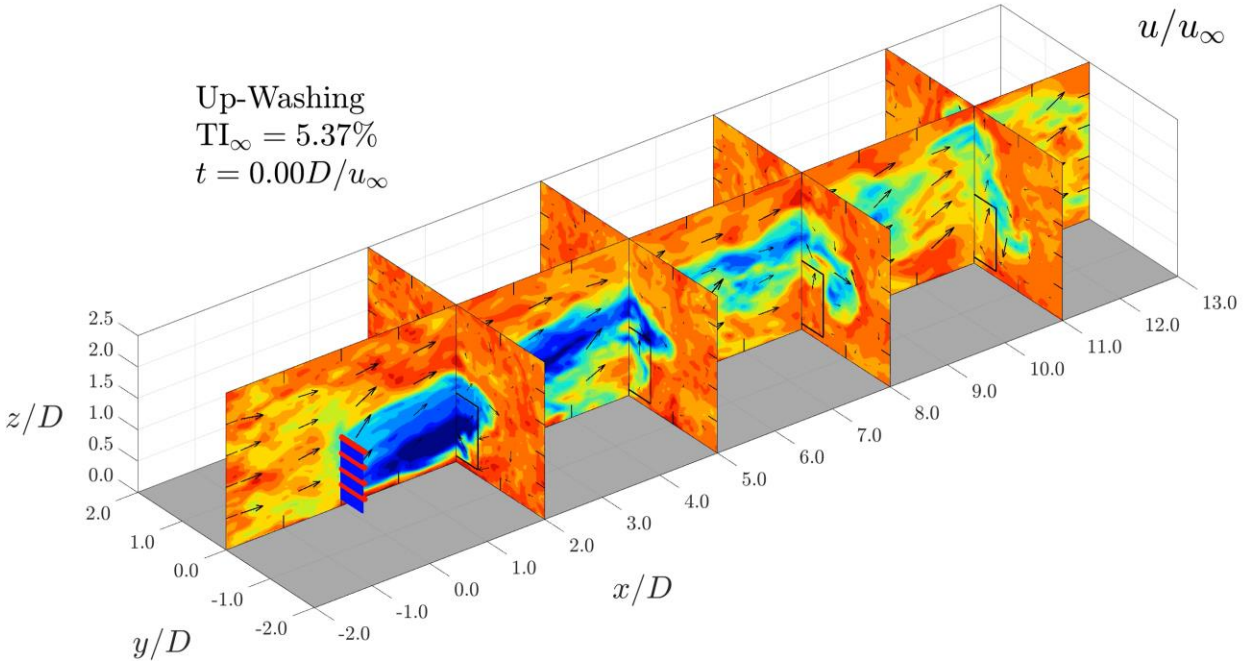


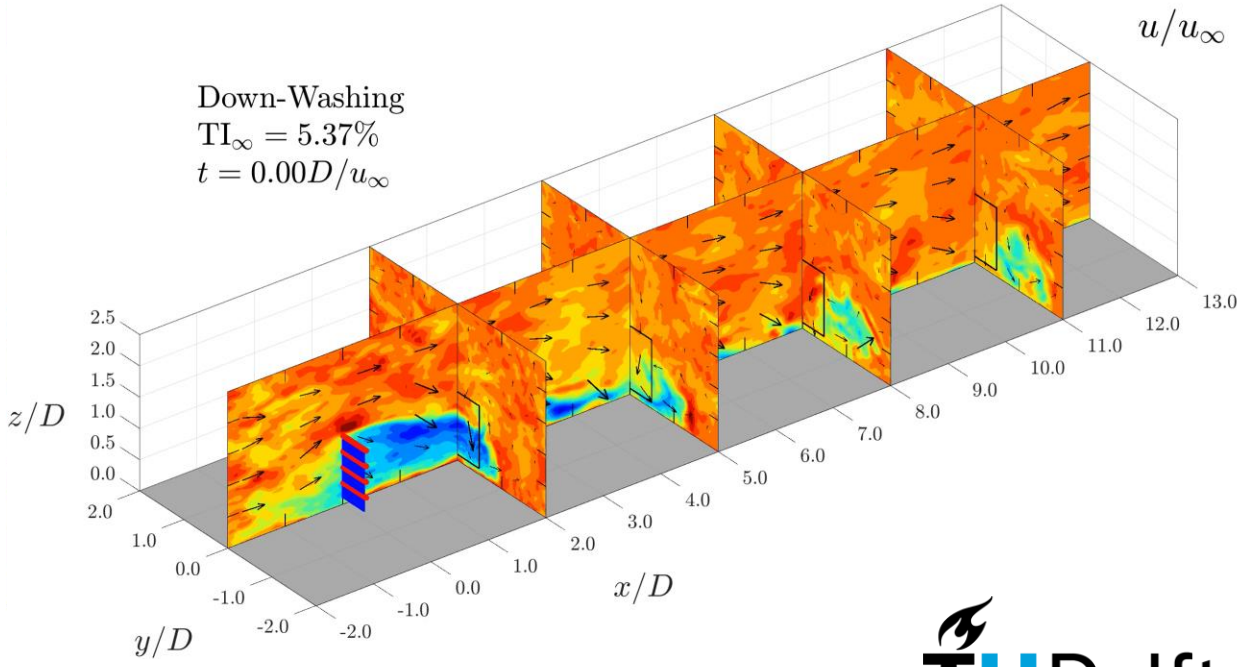
Taken from: Y. Li et al., 2025, *Wind Energy Science*

LES study - turbulence

Wind energy harvesting parts: AD
Lifting-Devices: AL
Inlet: Synthetic turbulence







Taken from: Y. Li et al., 2025, *Journal of Physics: Conference Series*

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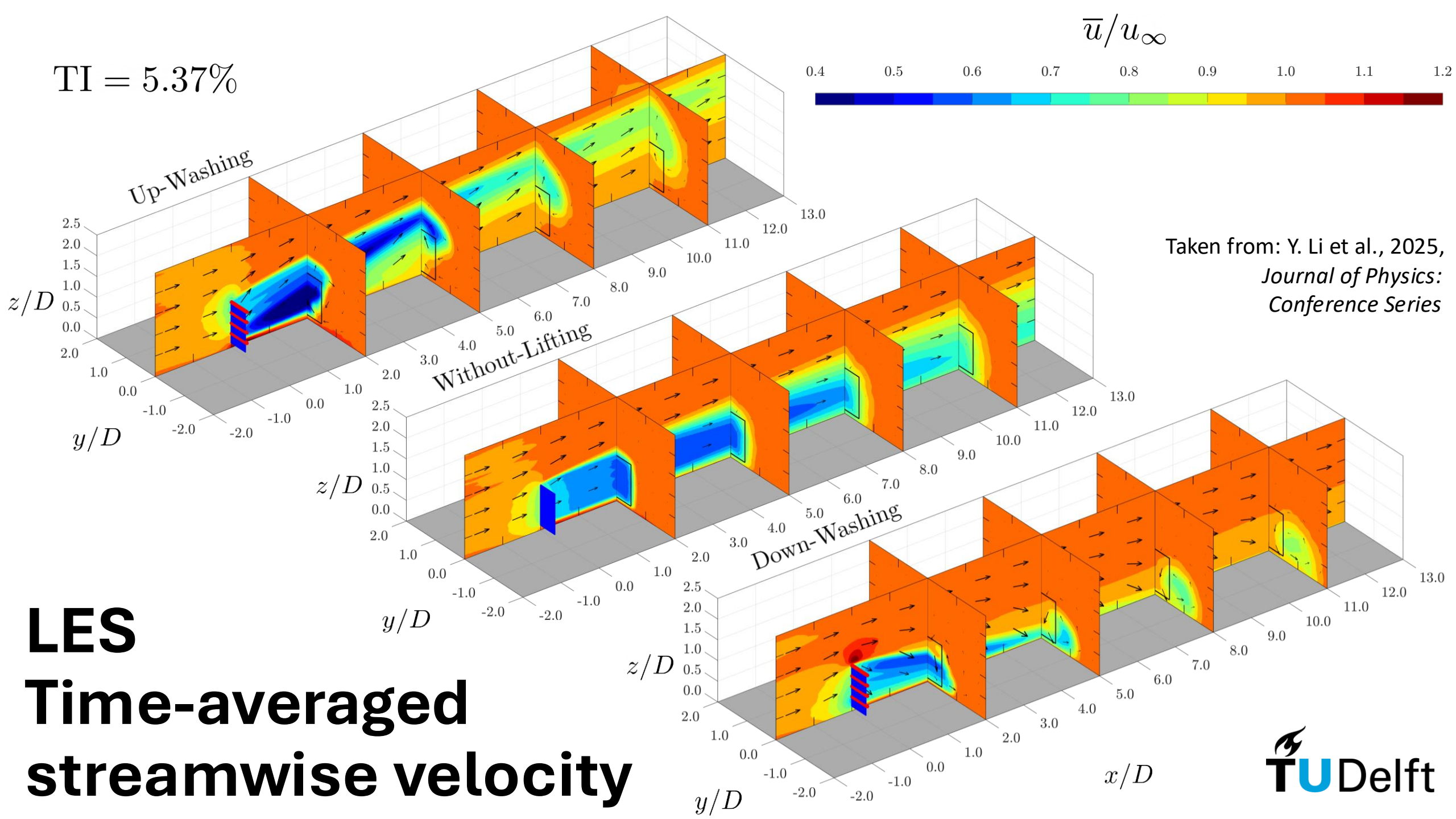

Taken from: Y. Li et al., 2025, *Journal of Physics: Conference Series*

LES
Time-averaged streamwise velocity

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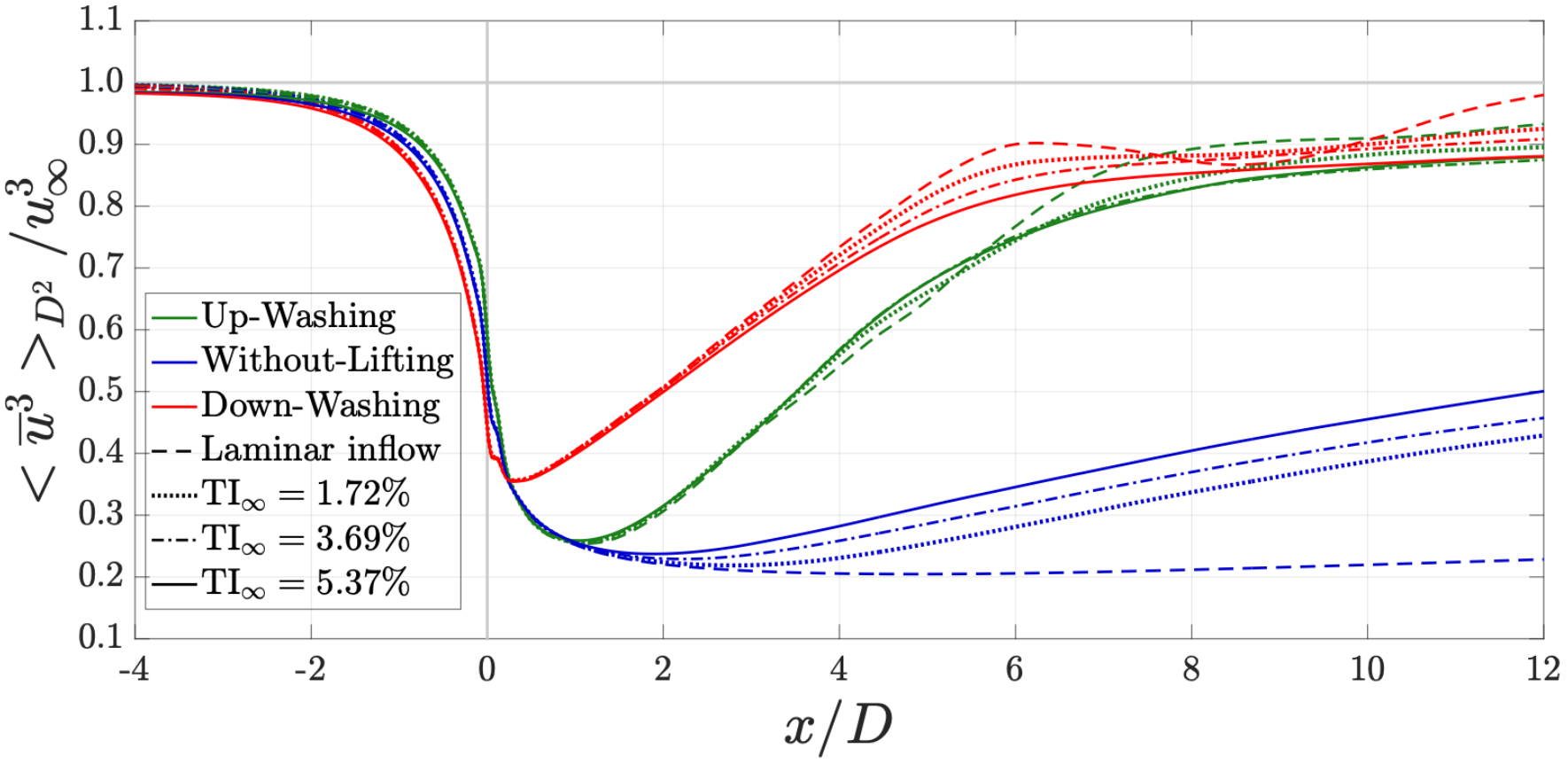
Effects of inflow turbulence with LES

- Comparing the available power within the projection areas of MRSLs



Effects of inflow turbulence with LES

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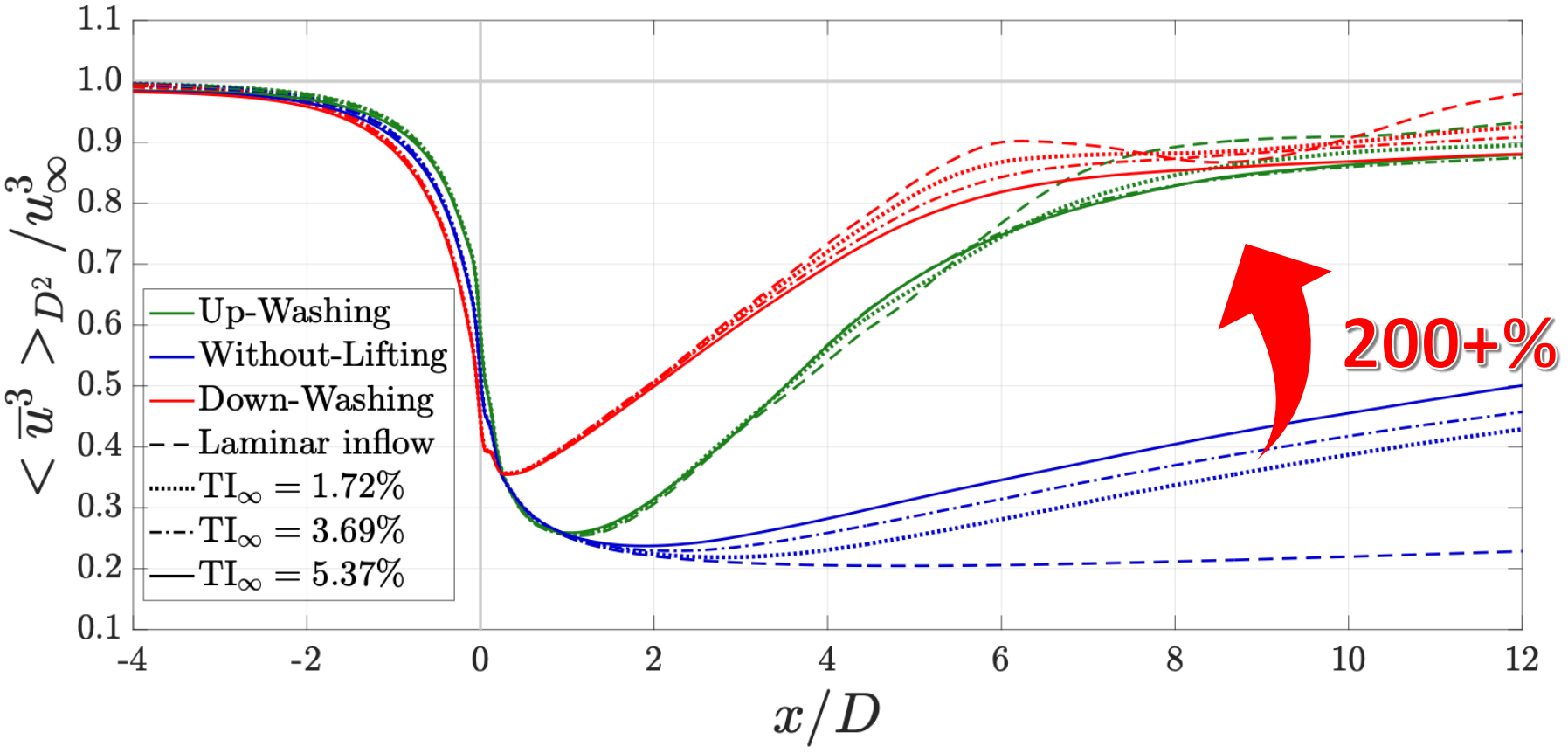
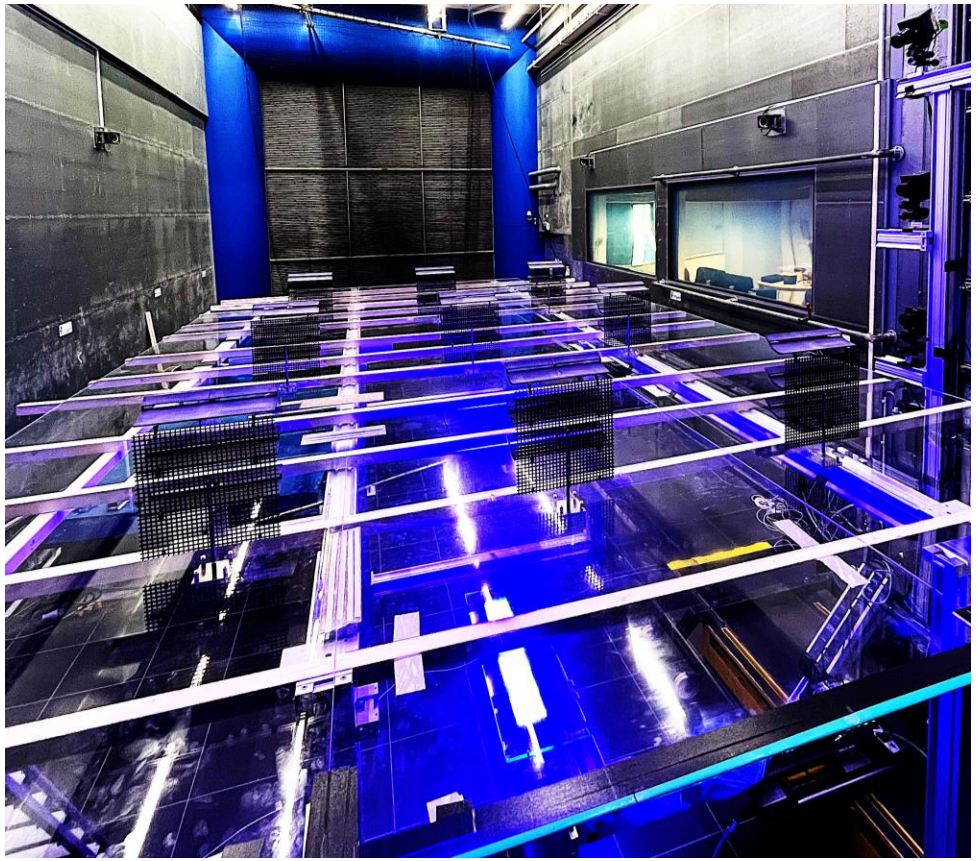


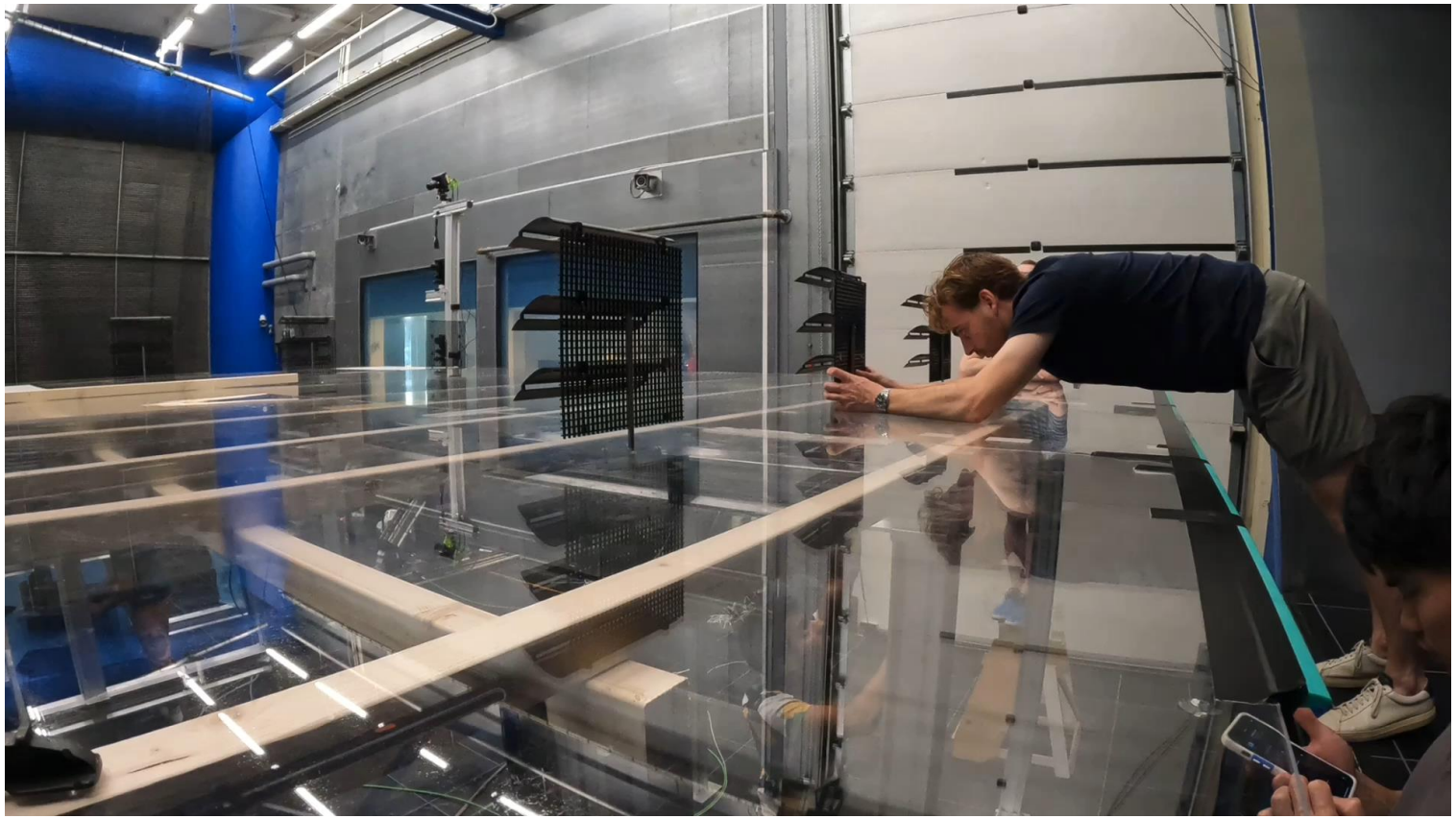
Scaled wind farm in Wind Tunnel

- Regenerative wind farm with 3 by 3 MRSL
- Lagrangian particle tracking with helium-filled soap bubble
- Again found MRSL dramatically promotes wake recovery

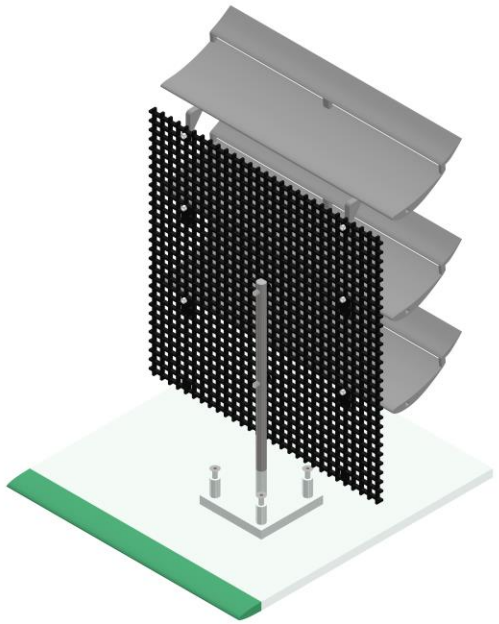
M. Fijen

B. Dsouza

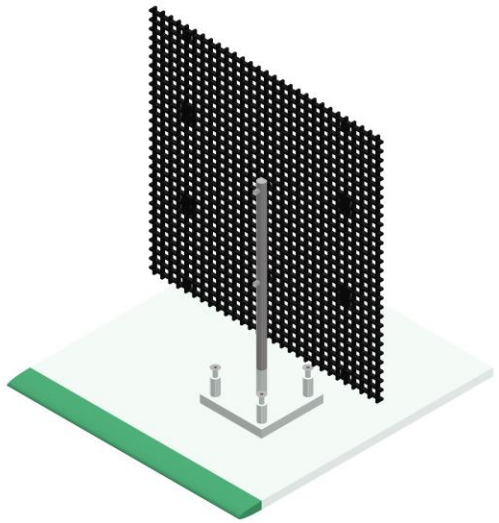




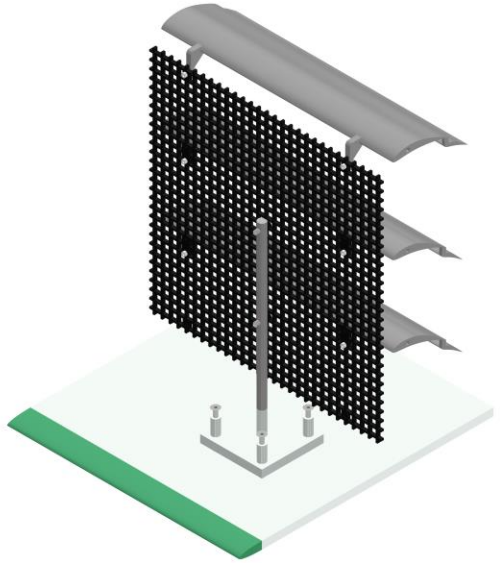
Aerodynamic scale mode of MRSL



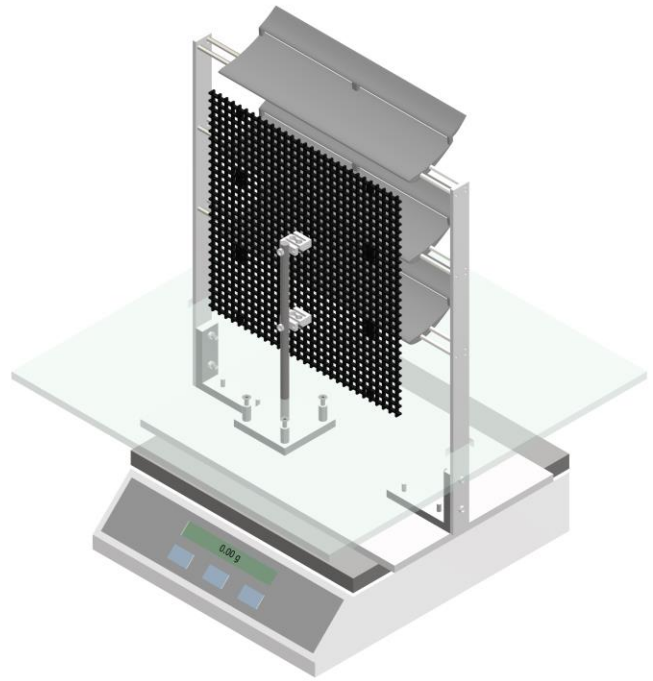
Up-Washing



Without-Lifting

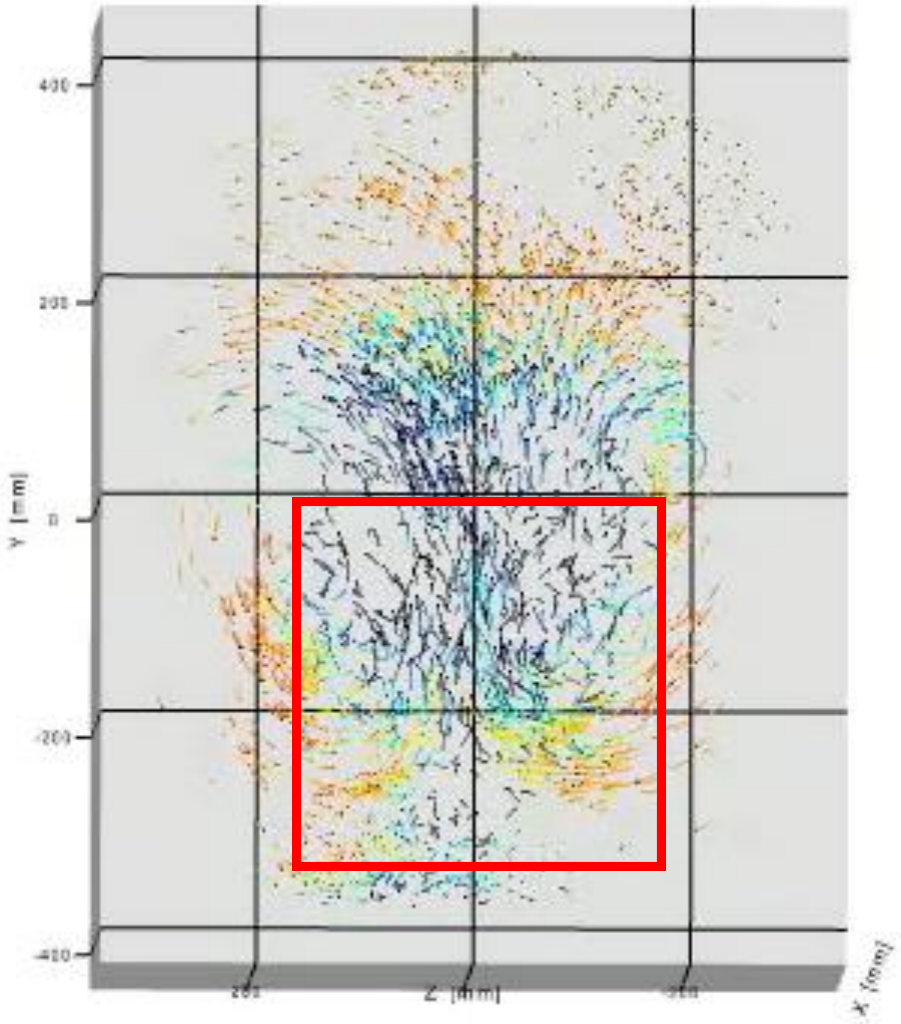


Down-Washing

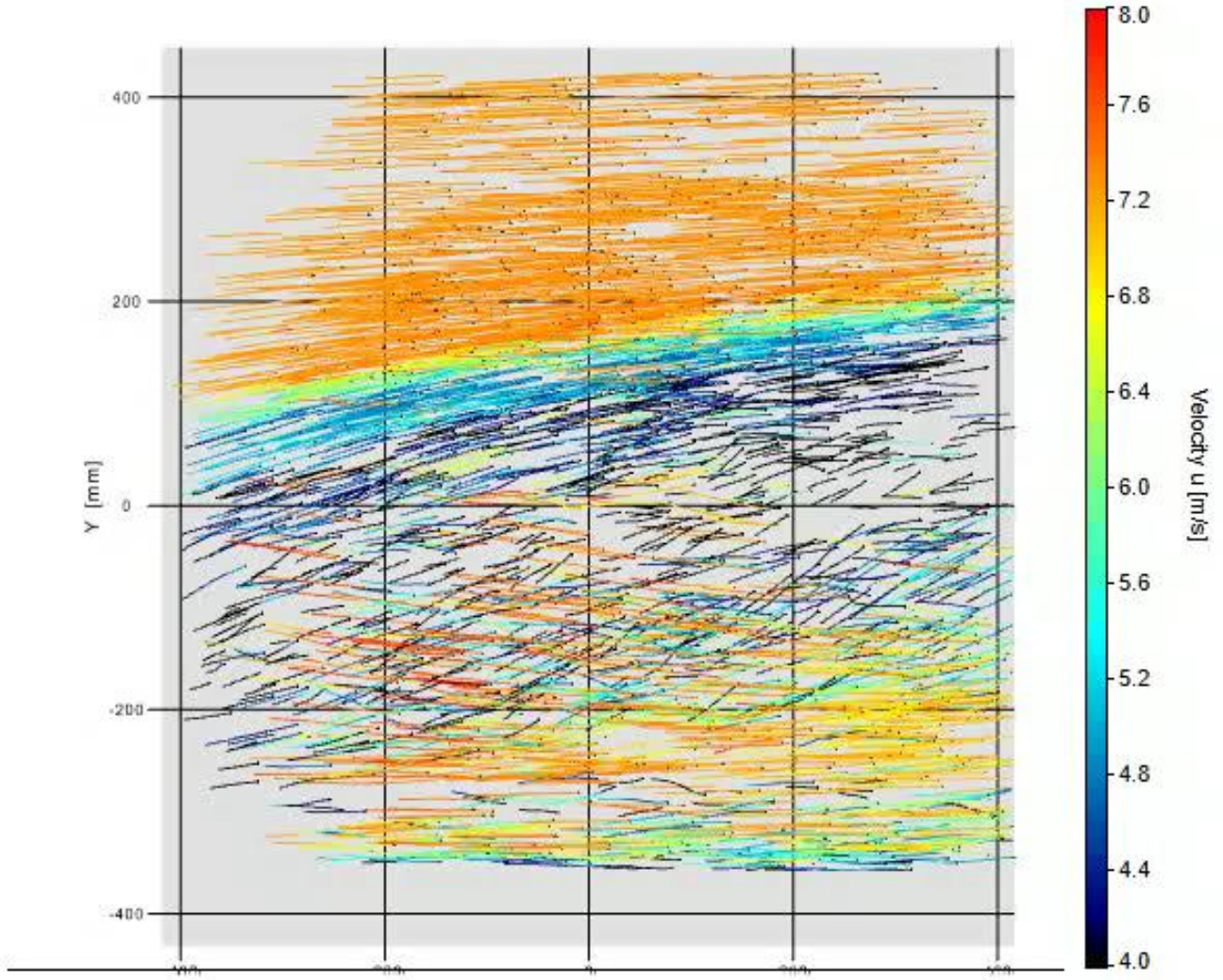


Measuring
Thrust + Lift

Flow fields captured

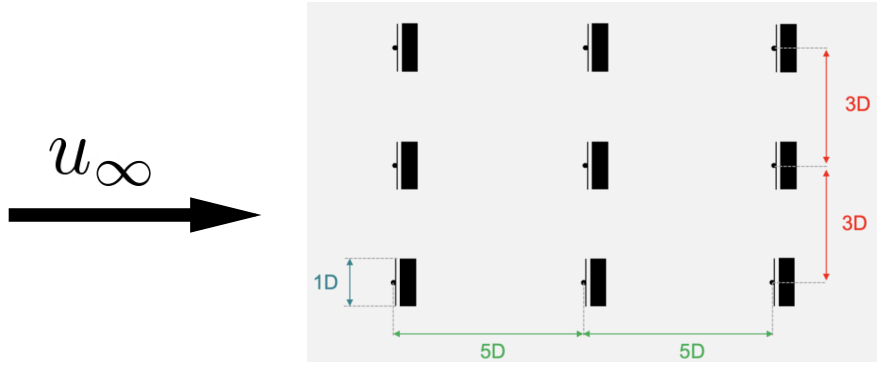


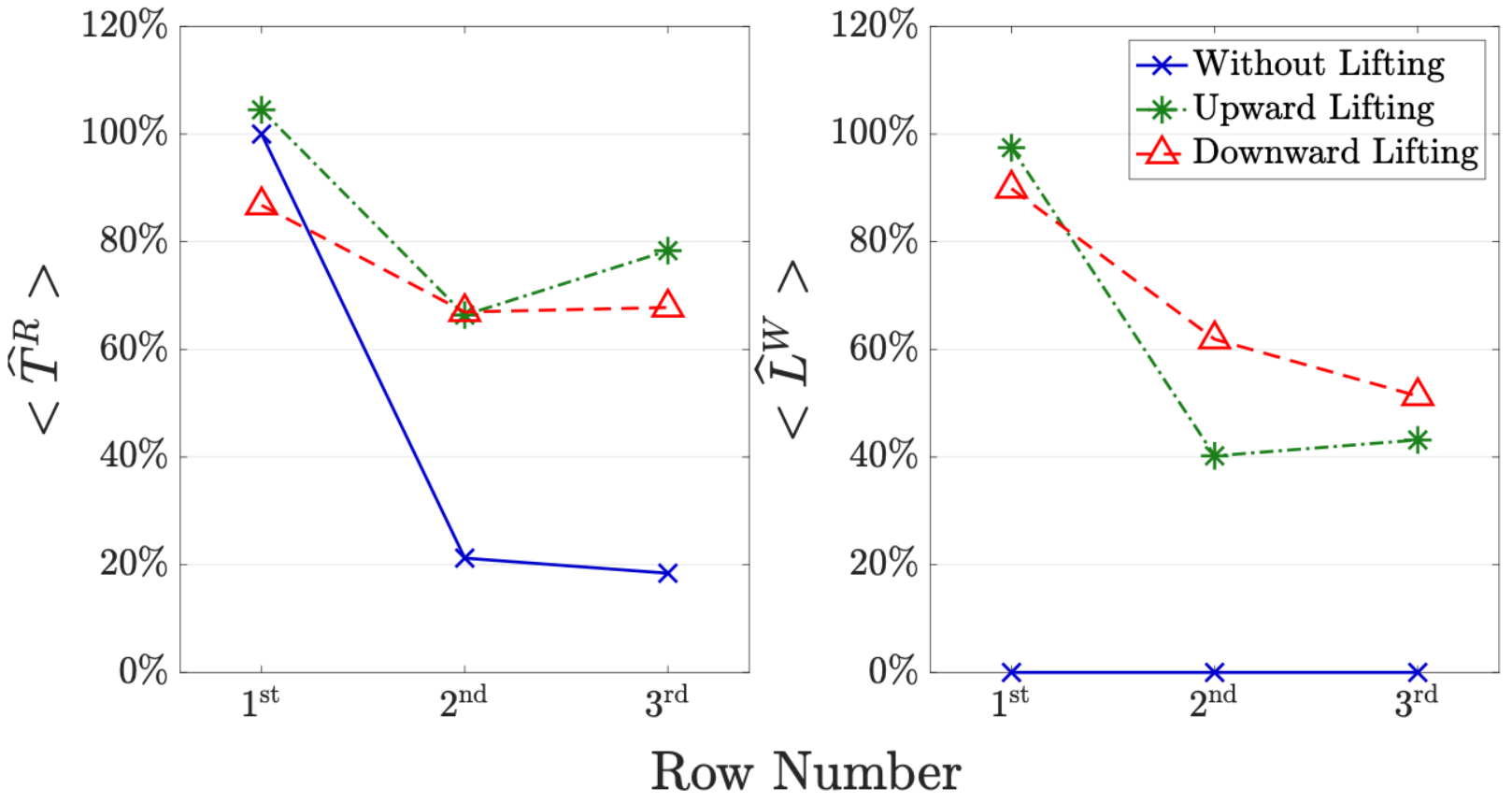
Rear-view



Side-view

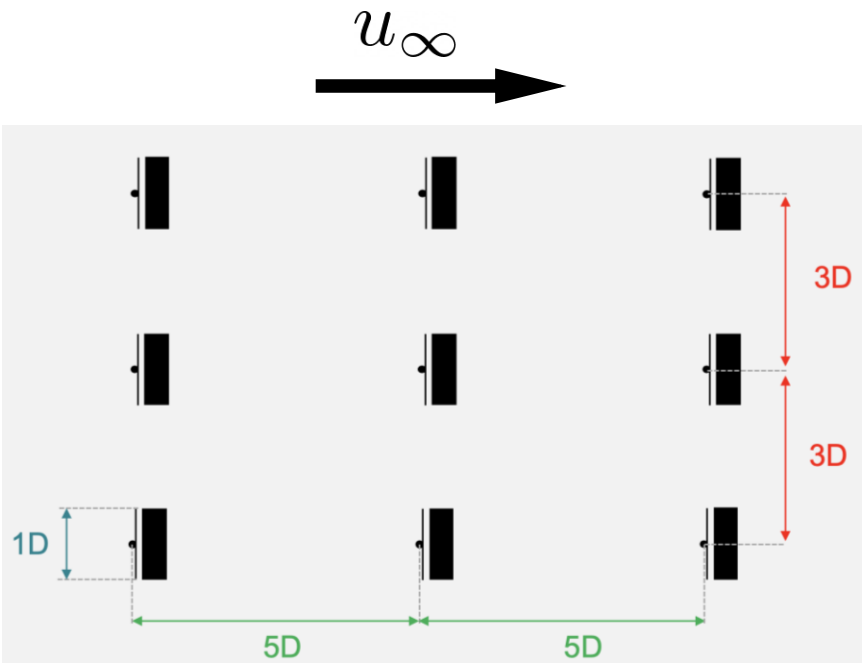
Thrust and lift measured

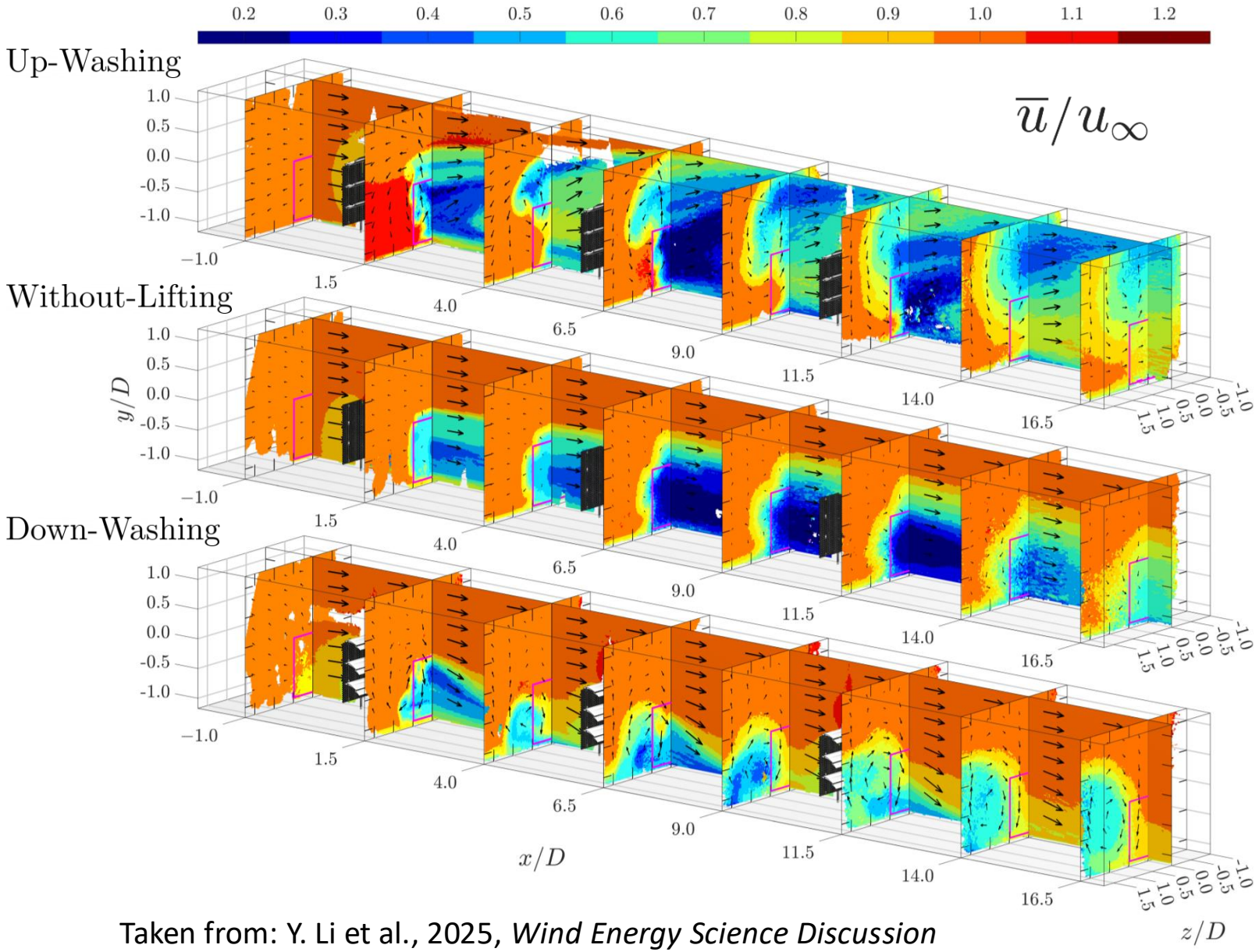




Taken from:
Y. Li et al., 2025,
Wind Energy Science Discussion

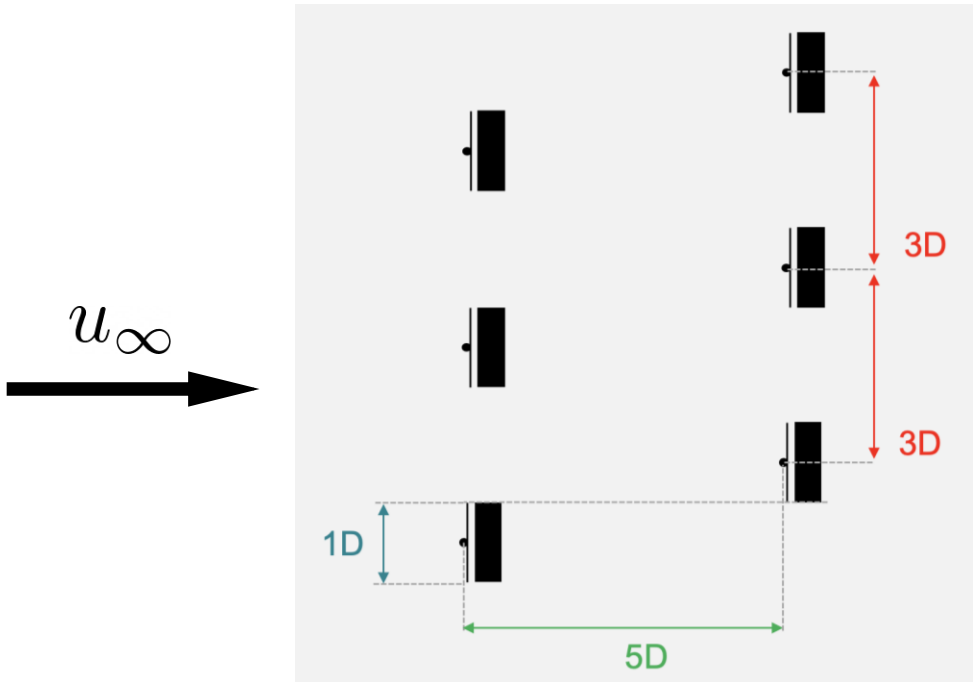
Streamwise Velocity - PIV

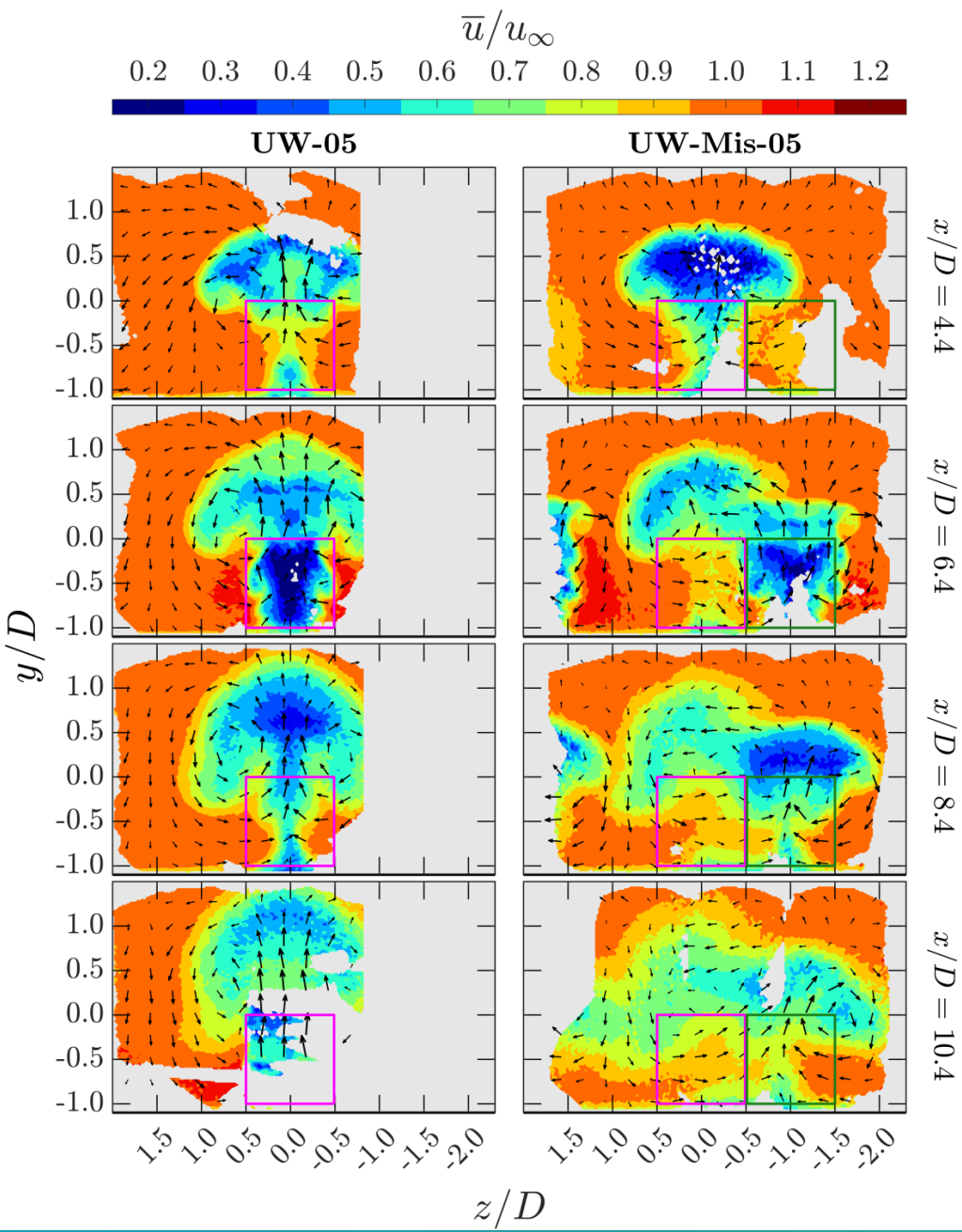




Taken from: Y. Li et al., 2025, *Wind Energy Science Discussion*

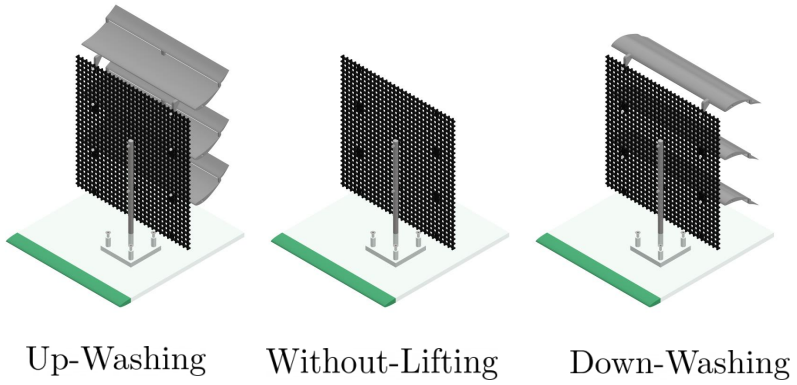
Mis-aligned case
Up-Washing

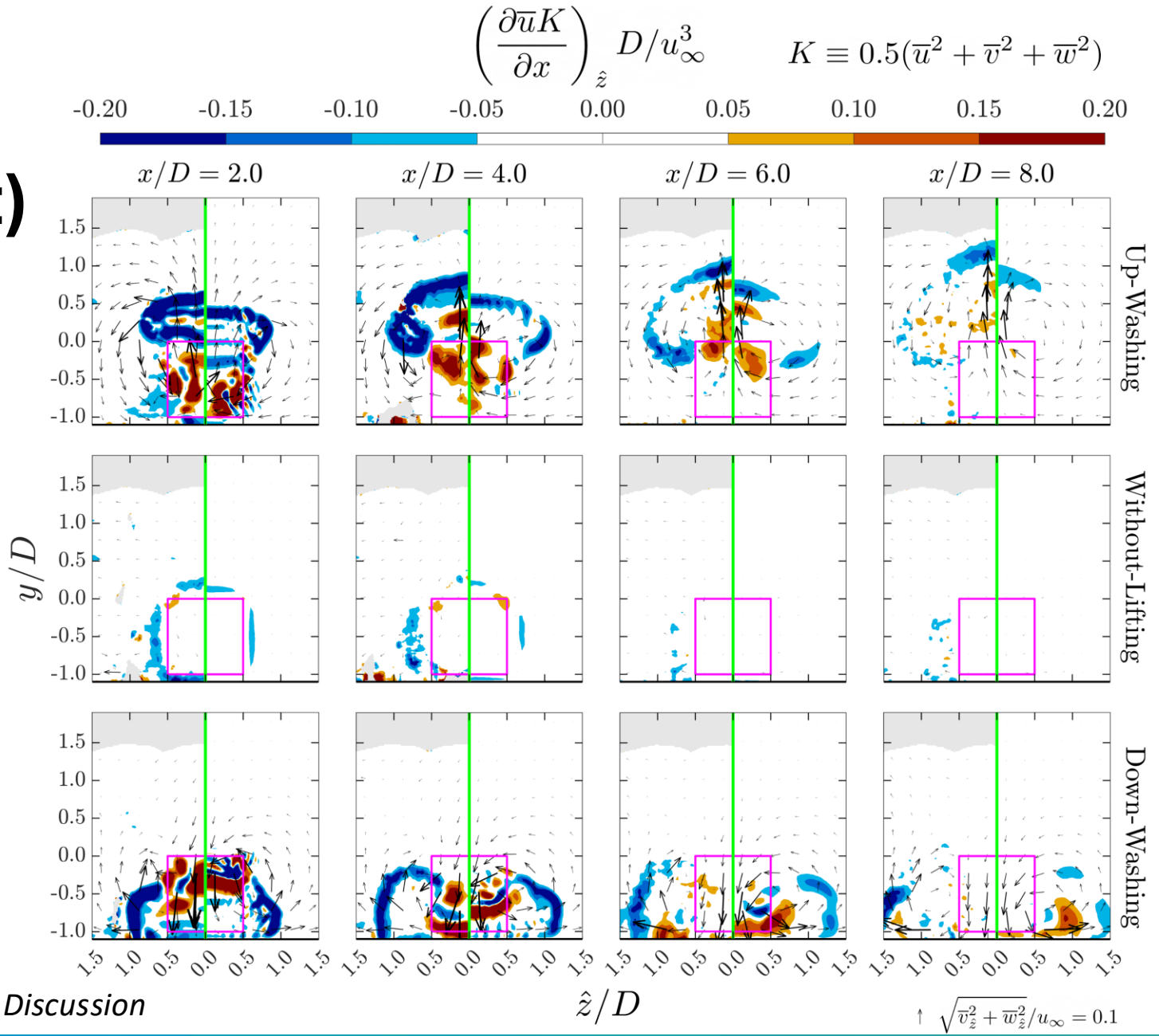




Taken from: Y. Li et al., 2025, *Wind Energy Science Discussion*

Cross validation:
PIV (left) vs LES (right)





Taken from: Y. Li et al., 2025, *Wind Energy Science Discussion*


TU Delft
Following works
WIND CATCHING
Erneuerbare Energien Hamburg
EnBW
HAW HAMBURG
CC4E
University of Strathclyde Glasgow
RENEWABLE DYNAMICS

Out Door test
Real wind turbines

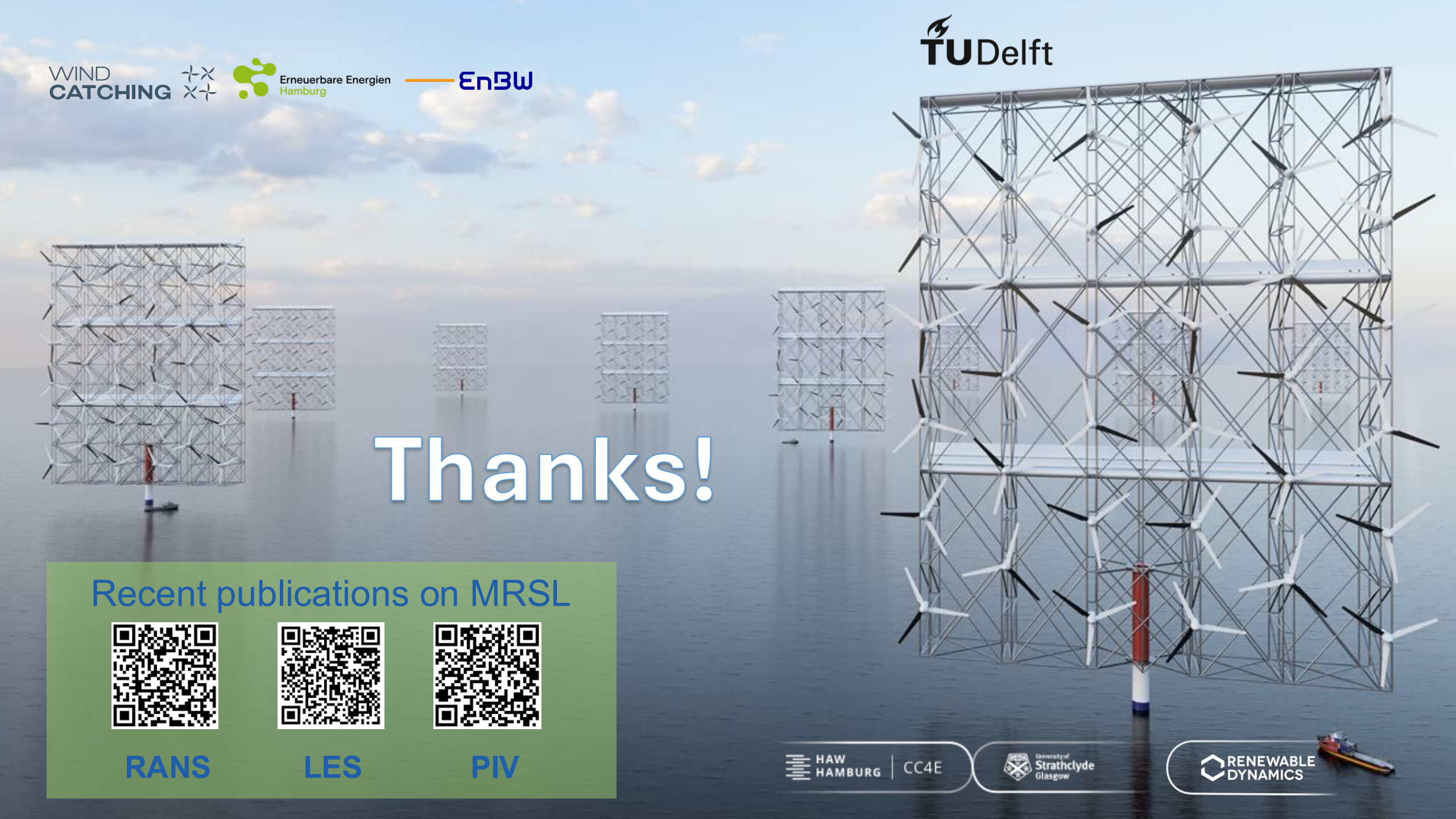
D. Bensason

S. A. S. Madani

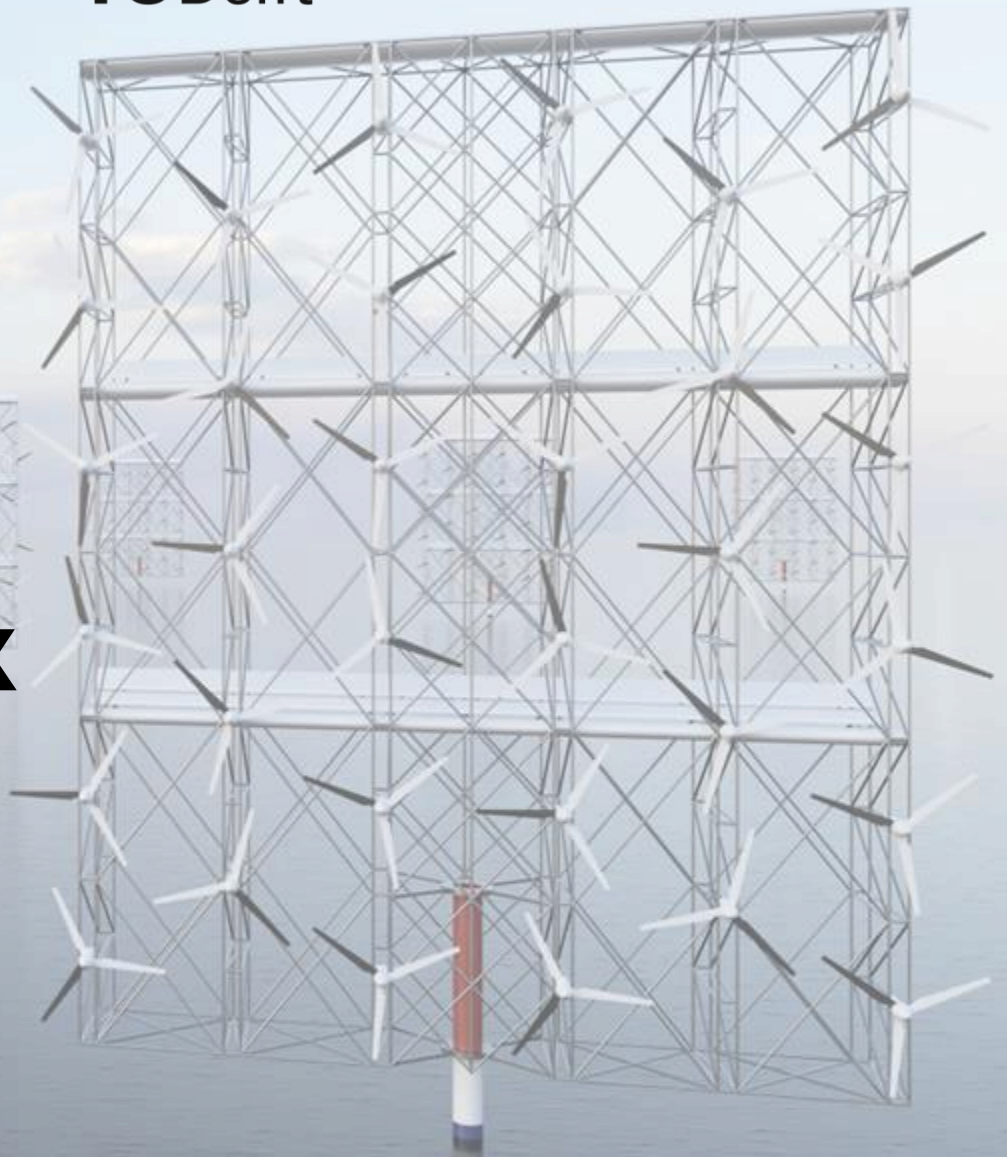
H. Sun

S. Purohit

B. Dsouza


WIND CATCHING
Erneuerbare Energien Hamburg
EnBW
TU Delft
Thanks!
Recent publications on MRSL
RANS
LES
PIV
HAW HAMBURG
CC4E
University of Strathclyde Glasgow
RENEWABLE DYNAMICS

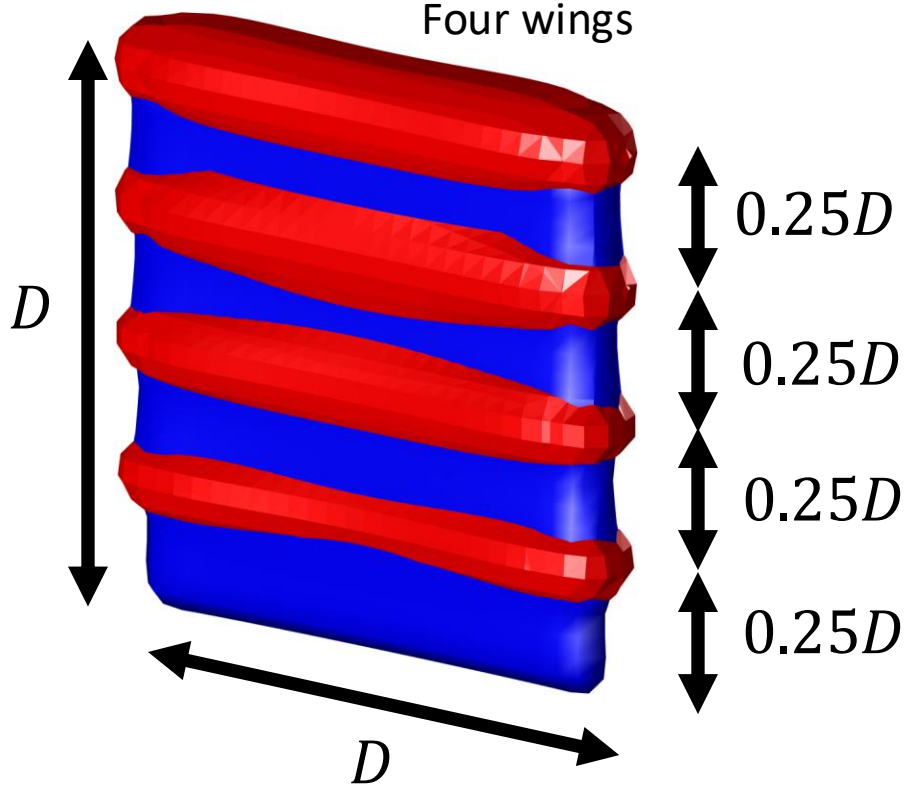
Appendix



Modelling MRS in CFD simulation

Detail specifications:
Side length D: 300 m
Local thrust coefficient: 0.7
Chord length: $D/8$
Airfoil polar: S1223 airfoil
Four wings

- Applying body force fields to model MRS in CFD domain (actuator model)
- The rotor of MRS is represented using a square of actuator “disk” and the wings are represented using actuator lines
- Lifting Upward and Lifting Downward are tested and compared to a reference case (Without Lifting)



Iso-surfaces of body force field. Blue: Thrust force. Red: vertical force

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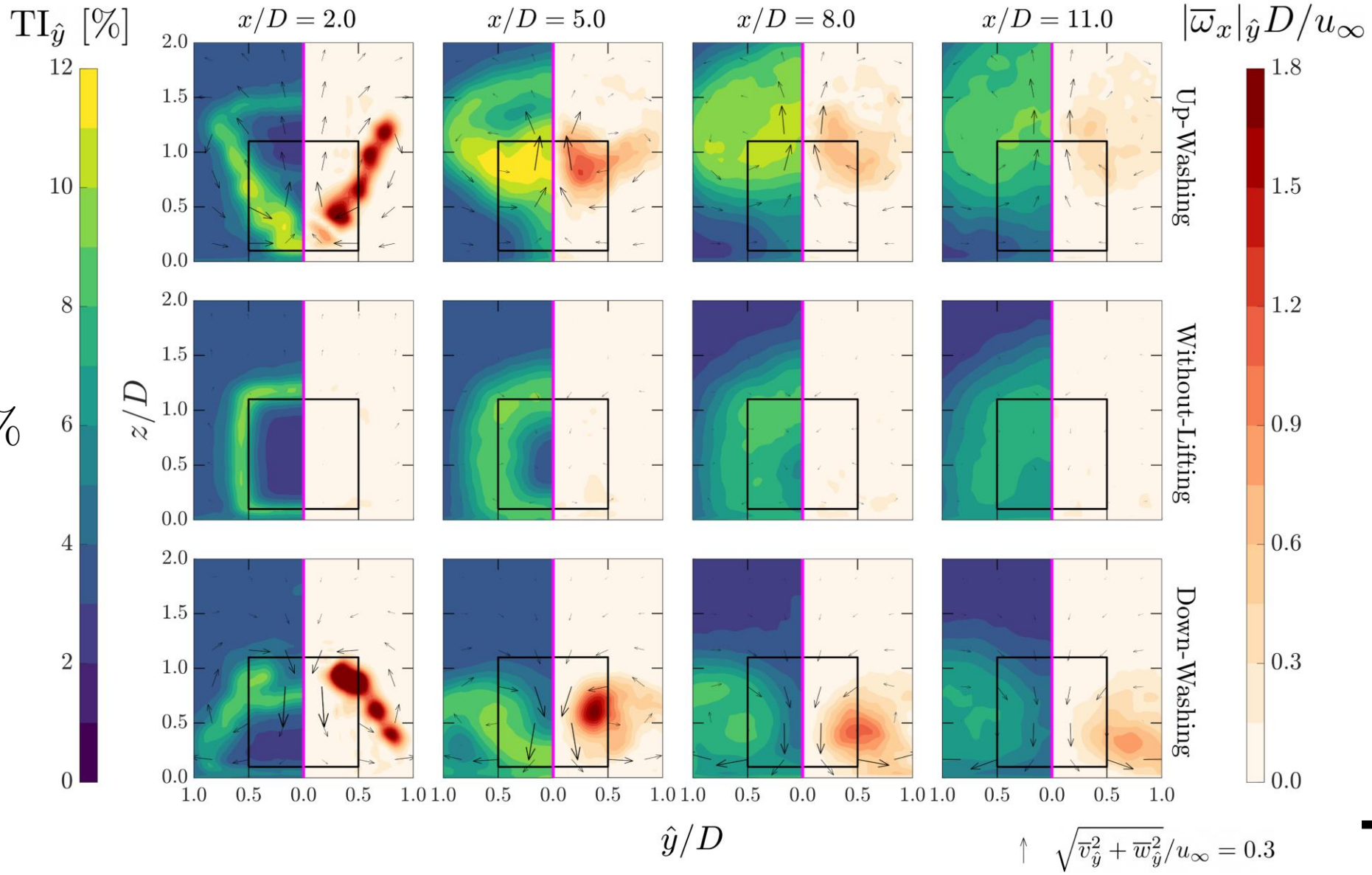
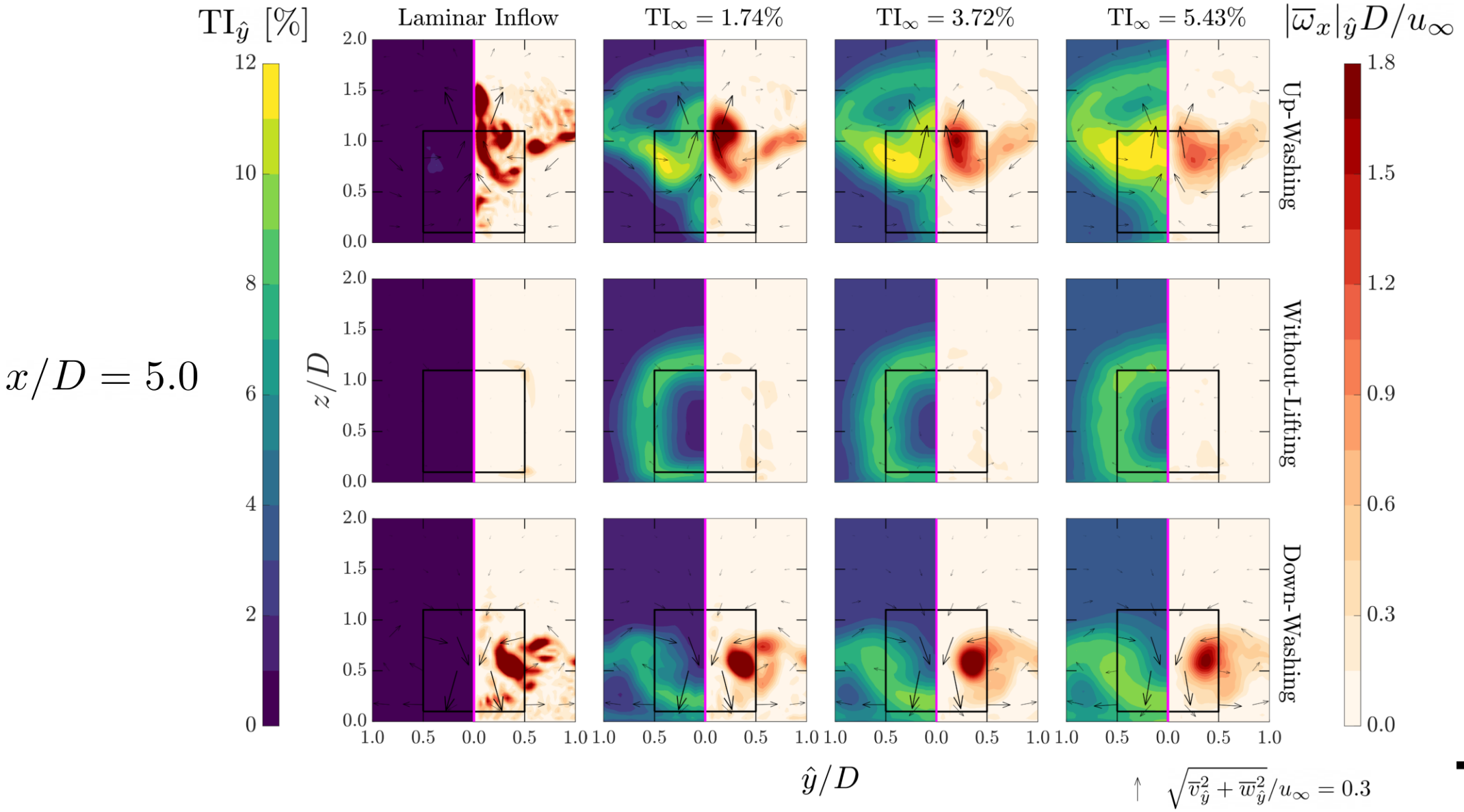
Development of vortical structures

$\mathrm{TI} = 5.37\%$



Vortical structures and inflow turbulence



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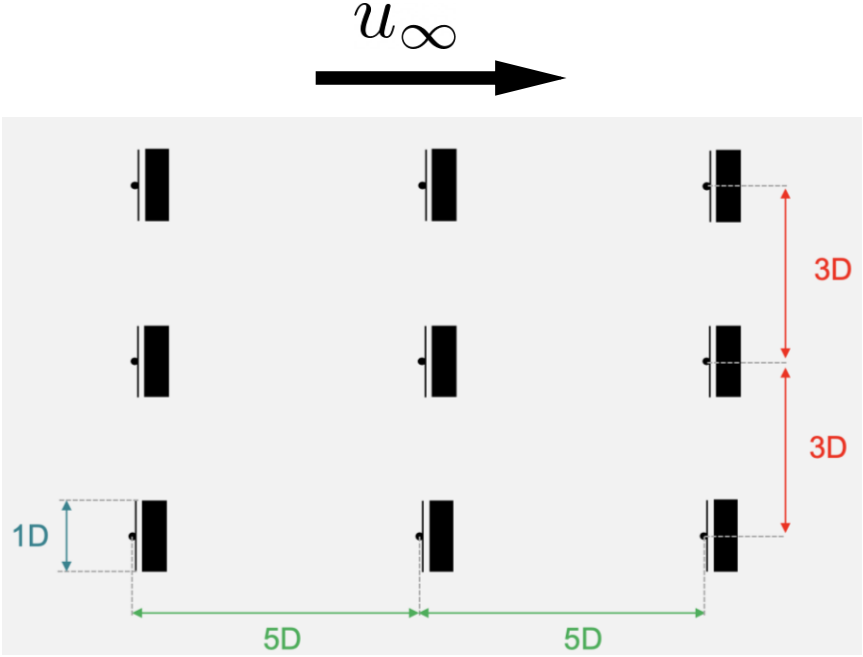
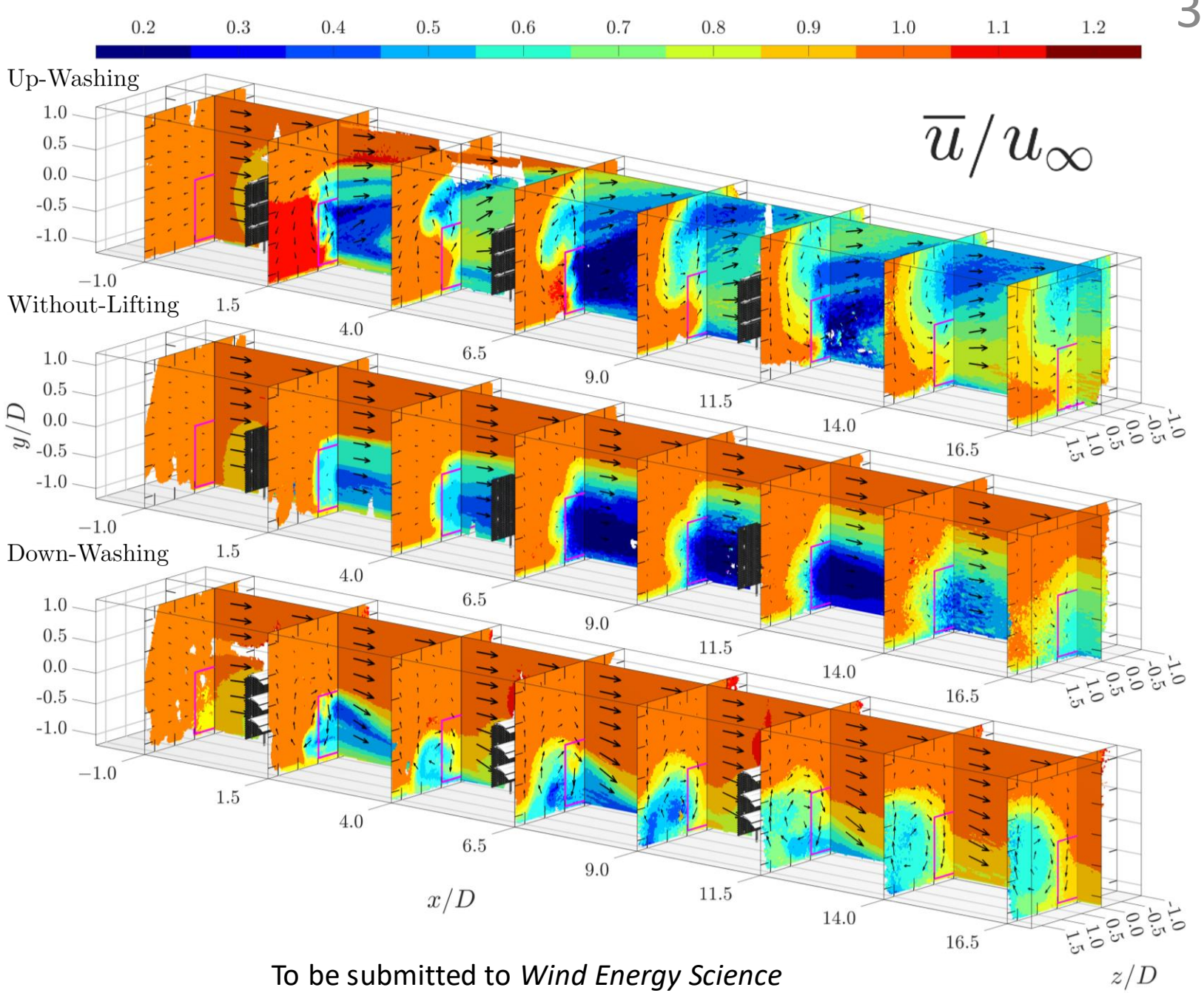
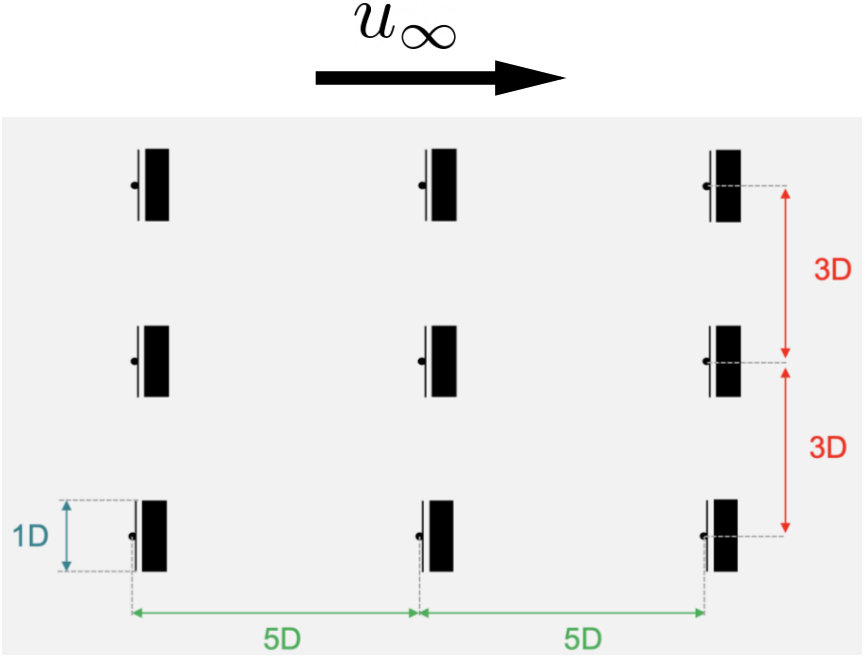
PTV: Streamwise Velocity

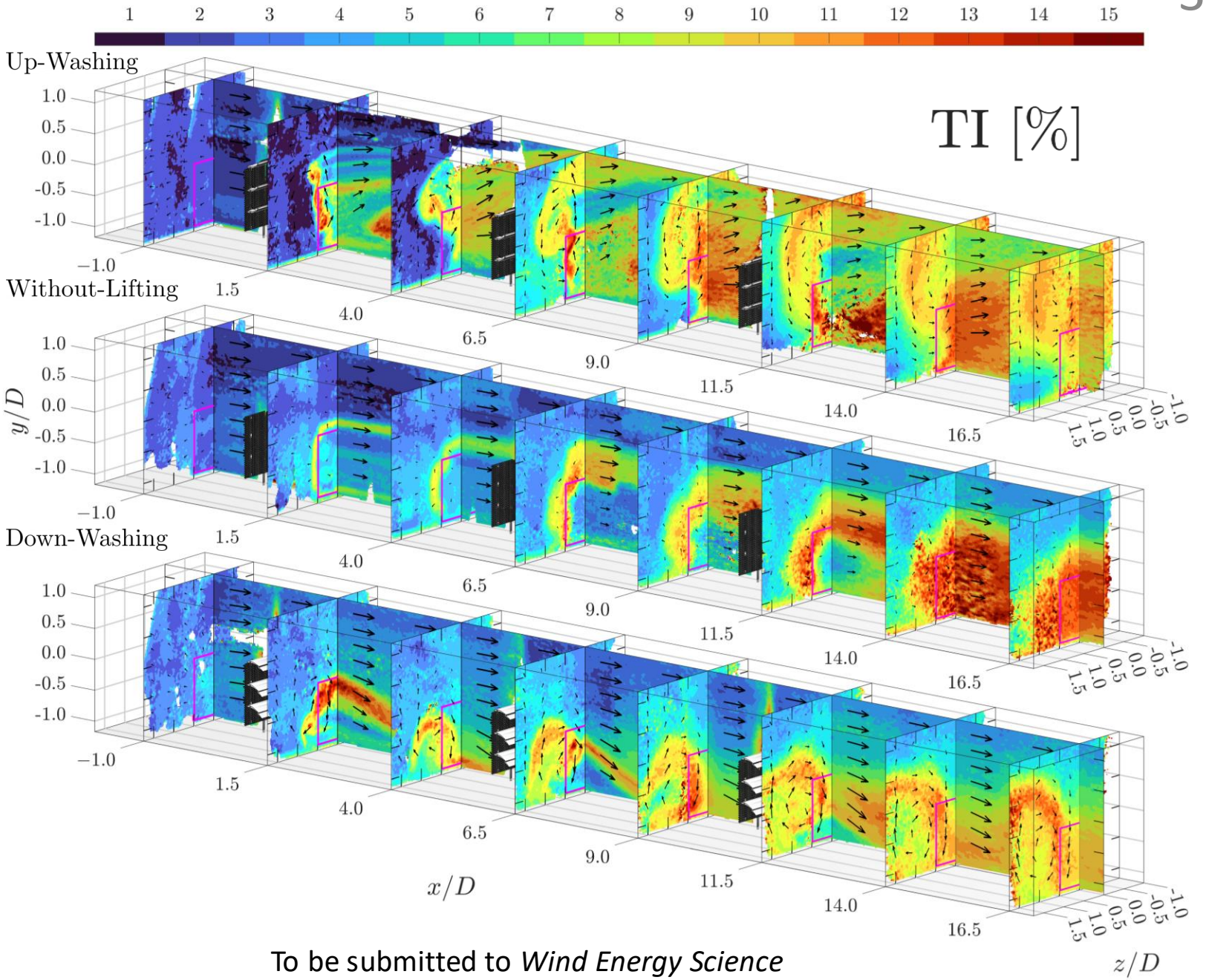




To be submitted to *Wind Energy Science*

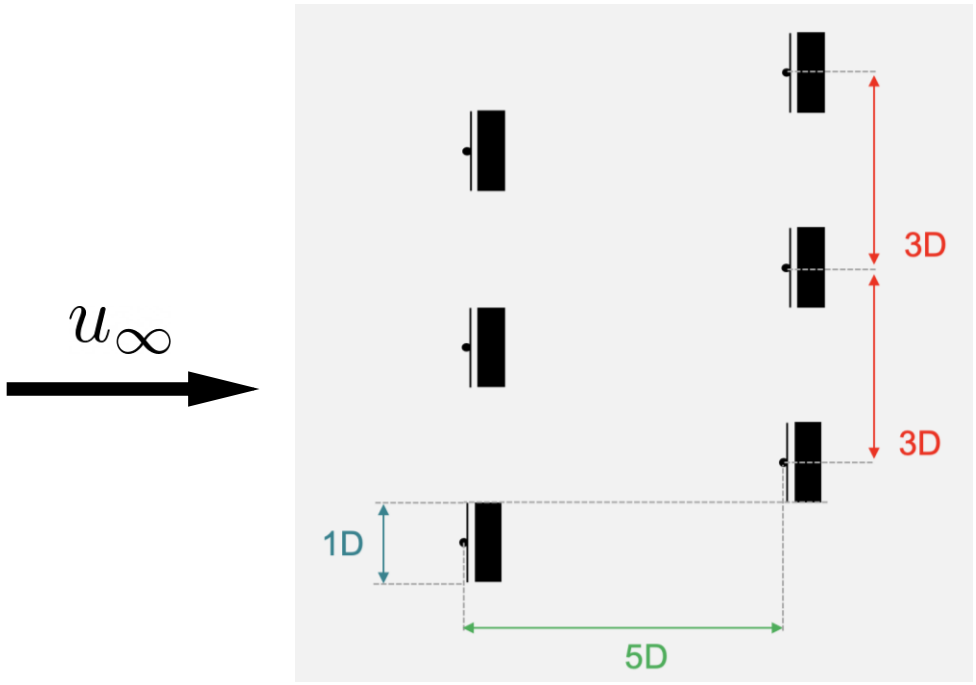
PTV: Turbulence Intensity

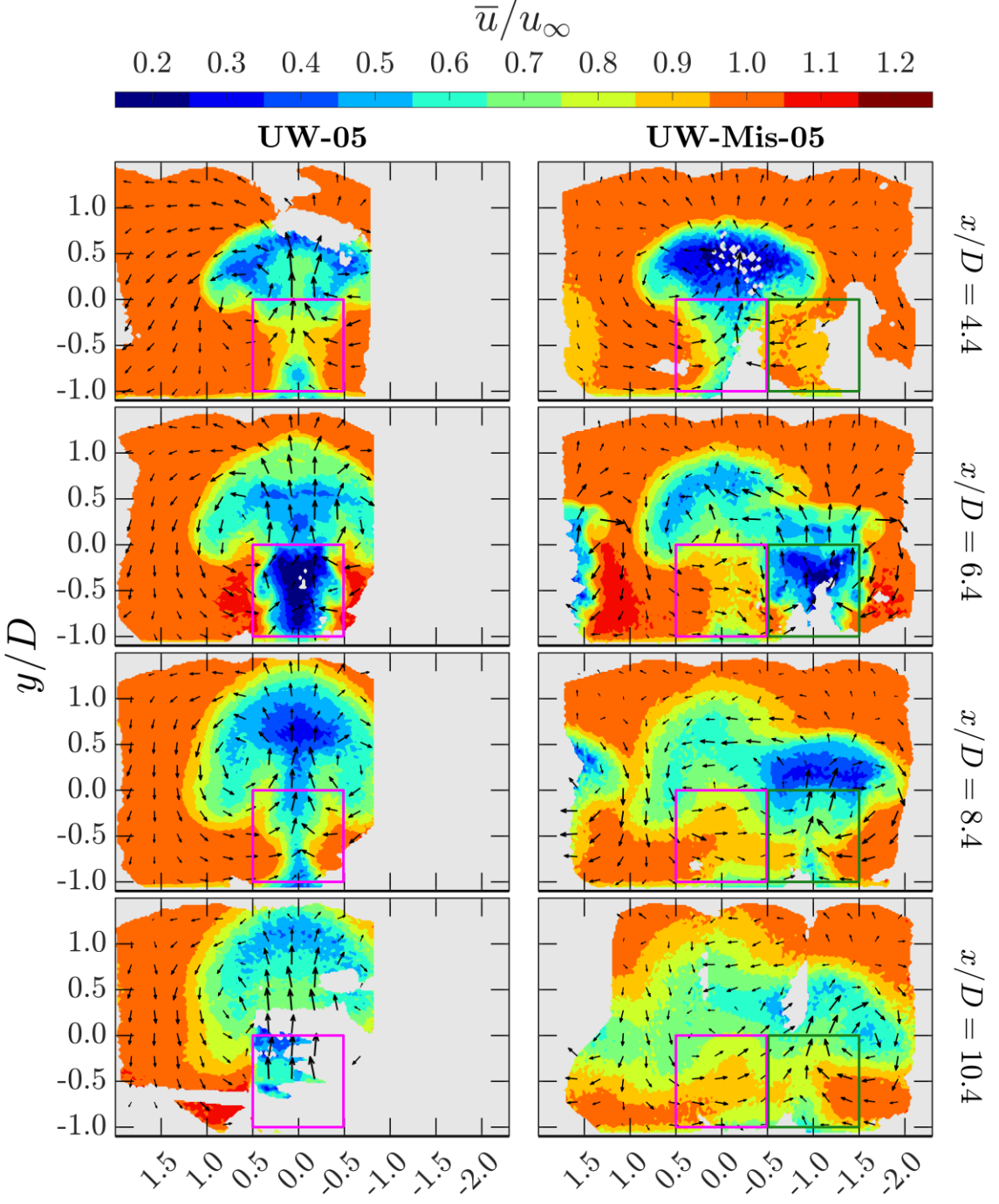




To be submitted to *Wind Energy Science*

PTV: Mis-aligned case Up-Washing





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