# Rotor–Rotor Interaction in Multi-Rotor Arrays

## Insights from Aerodynamic Simulations and Open Questions

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Sponsored by:

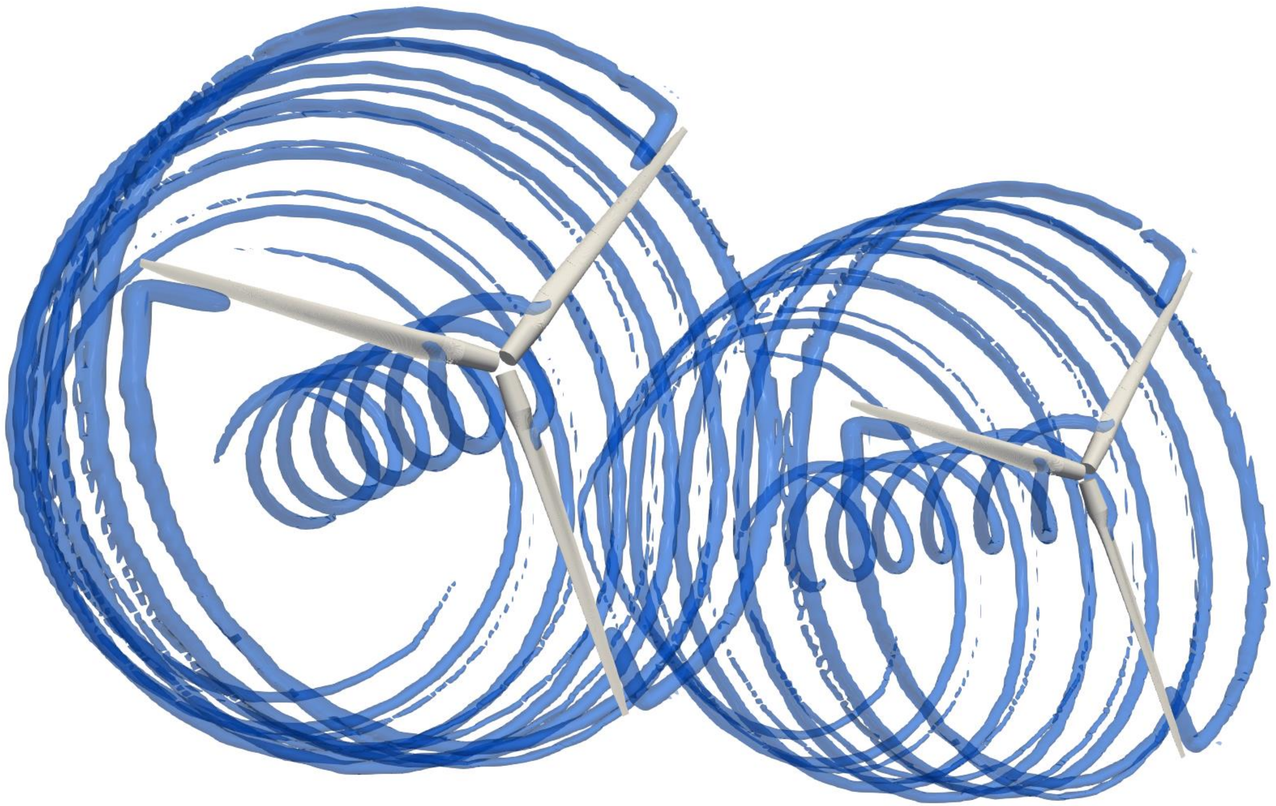
# Outline

- Load Fluctuations
- Power and Thrust
- Wake recovery
- Simulation Methods

# Loads Fluctuate

Because tip vortices.

Image credit: NASA Langley Research Center

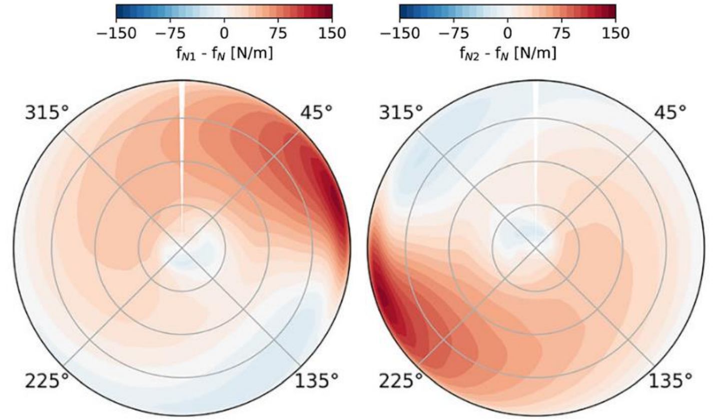


# Loads Fluctuate

Slightly.

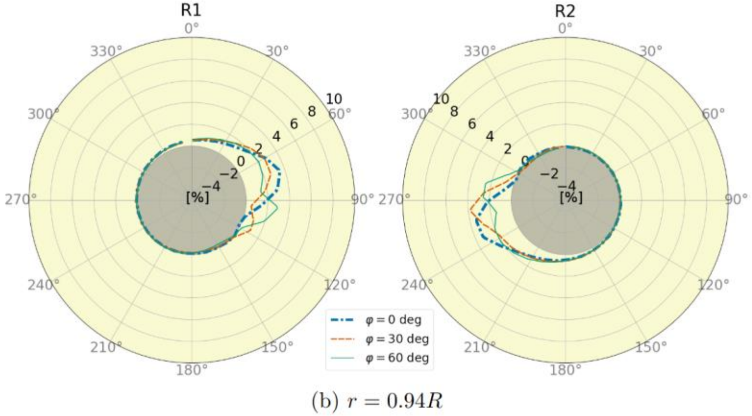
Load amplitudes:

- Root bending moments: 2-3%
- Section near tip: up to ~8%
- Tangential > normal
- Azimuth offset:
  - roughly same amplitude
  - „tip to tip“ not critical
- Aero only studies




Normal force variation

Mendoza et al. (2023), Wind Energy



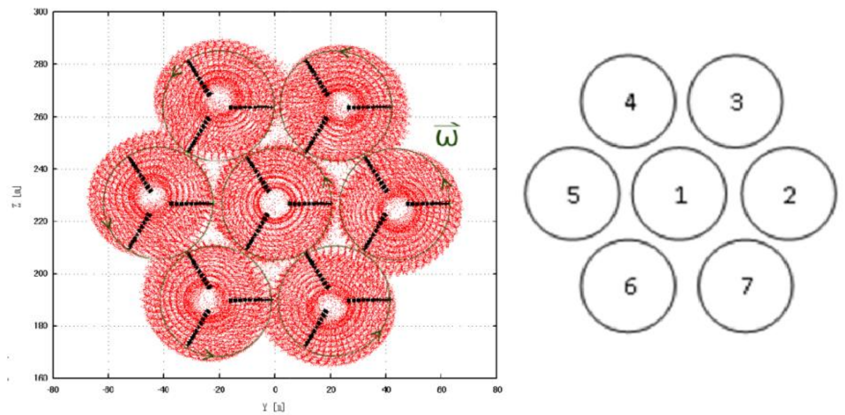

Section load fluctiations at 94% blade span
(Raquel Martín-San-Román et al 2024)

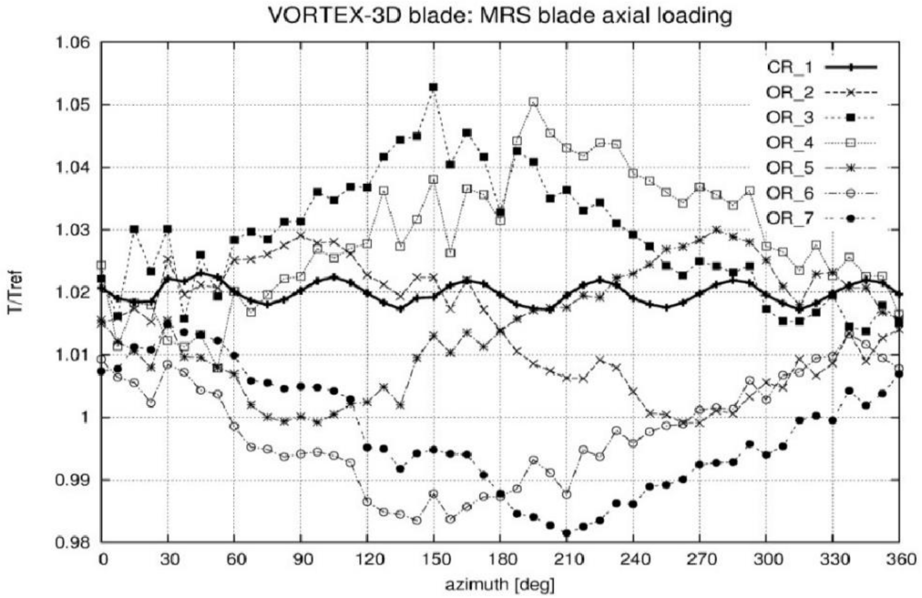
# Loads Fluctuate

At 1P or nP.

Frequencies:

- Center:
  - One peak per neighbor (6P)
- Outer:
  - Neighborhood vs freeflow dominates (1P)
- Intermediate Frequencies for Azimuth offset?

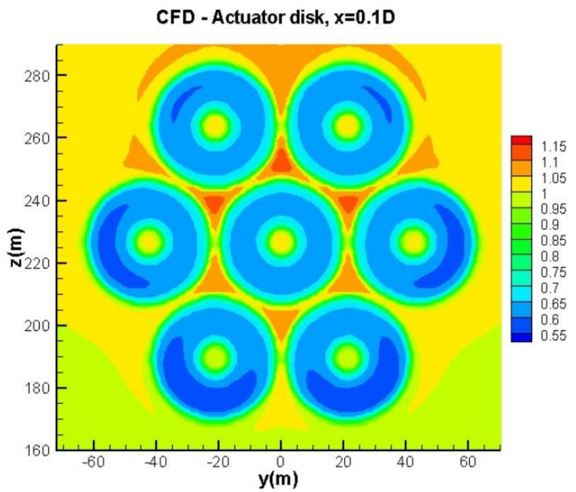


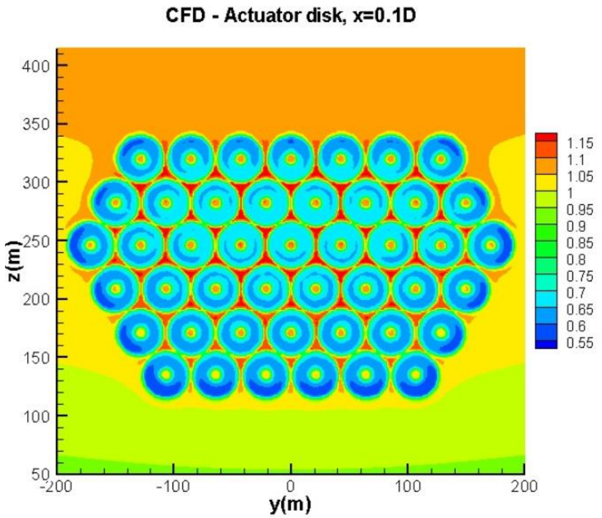

Chasapogiannis et al. (2014), J. Phys.: Conf. Ser.

# Power and Thrust increase

- Blockage adds power and thrust
- Increasing with
  - larger arrays
  - tighter spacing
- Ideal rotor sizing?




+3% Power




+8% Power

Chasapogiannis et al. (2014), J. Phys.: Conf. Ser.

INNWIND.EU Deliverable 1.33 (2017)

# Wakes recover faster

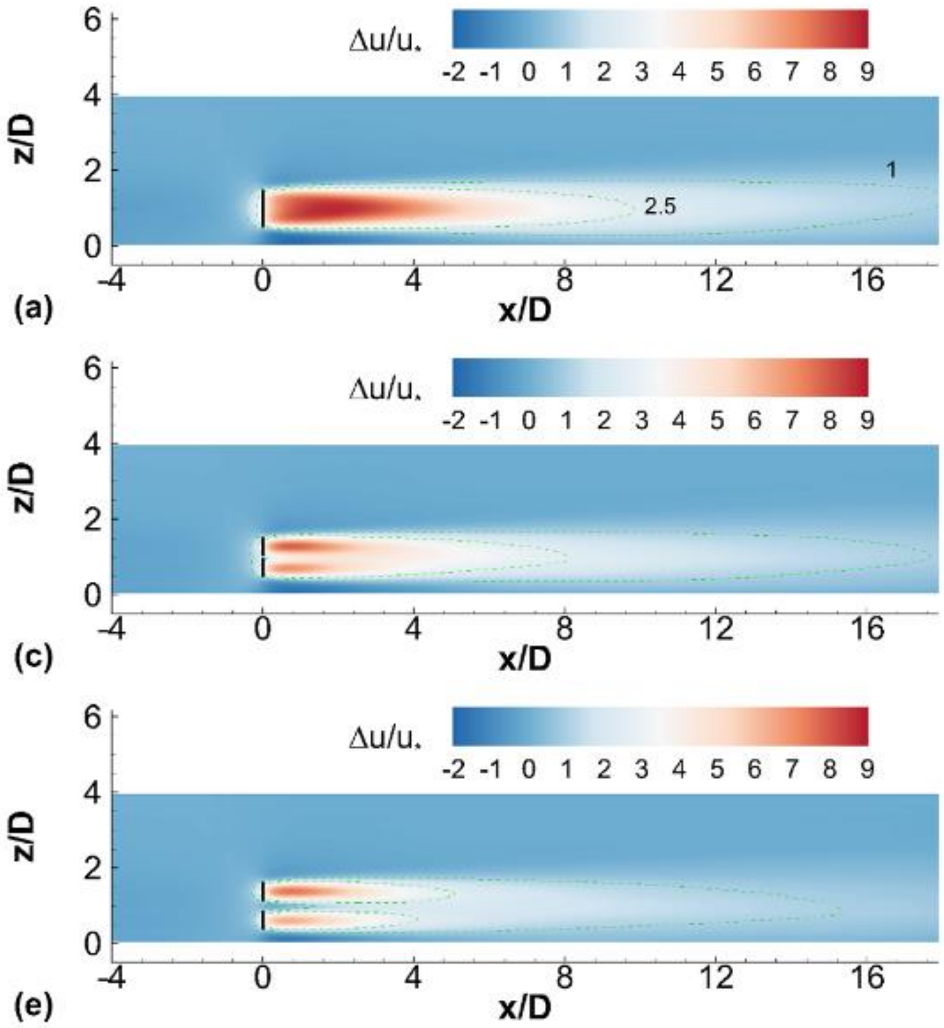
Up to a point

- Wake length ~ Rotor Diameter
- Small rotors – small wakes?
    - Wakes merge
- Only first rows in farm benefit
- Lower turbulence

Single rotor

MRS
10% dist.

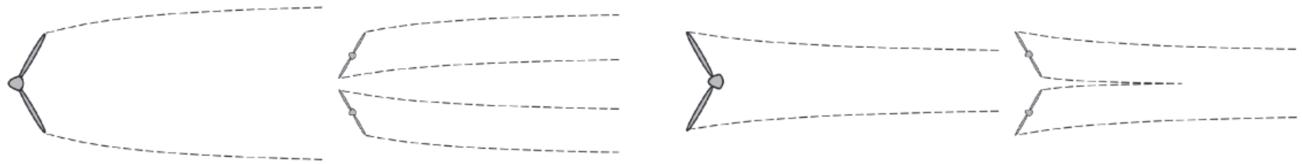
MRS
50% dist.




Ghaisas et al. (2020), Wind Energy Sci.

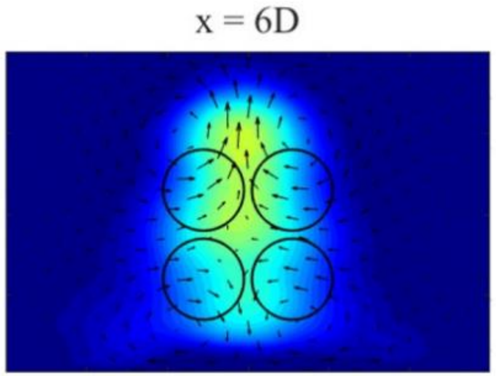
# Wake steering

## New possibilities

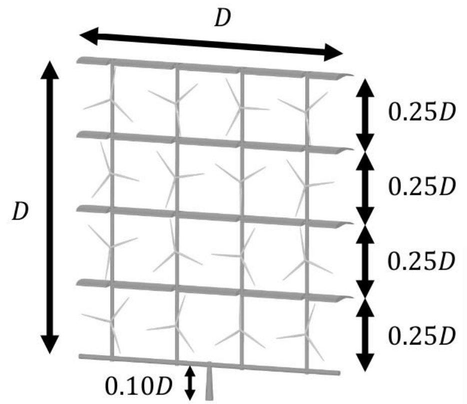


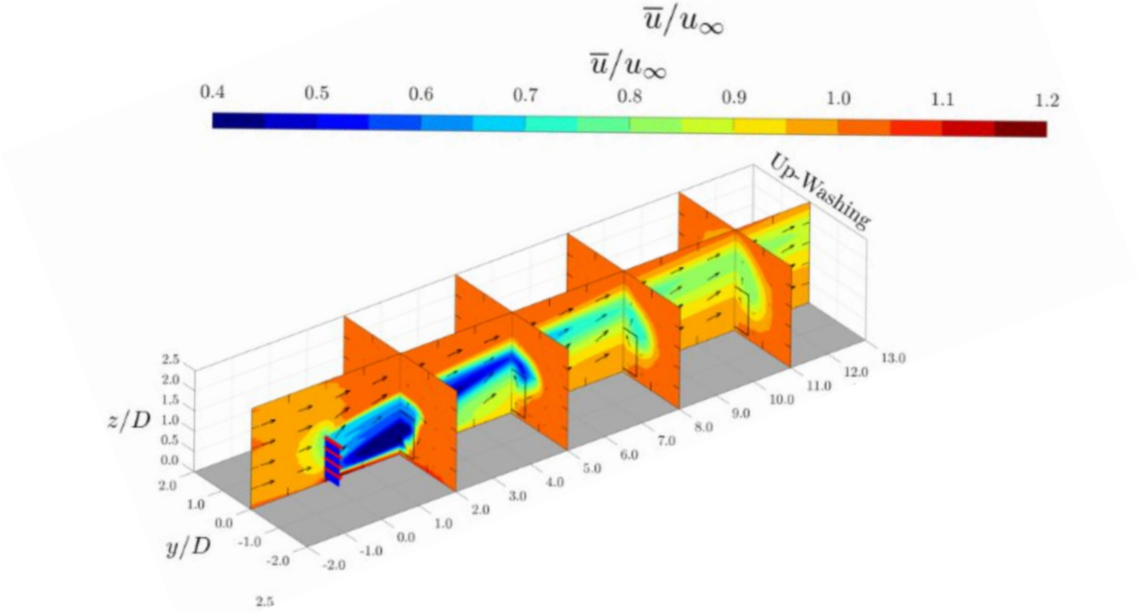
(A) Wake expansion by coning (left) and multirotor yaw (right)

(B) Wake channelling by coning (left) and multirotor yaw (right)




Speakman et al. (2021), Wind Energy




Li et al. (2025), J. Phys.: Conf. Ser.



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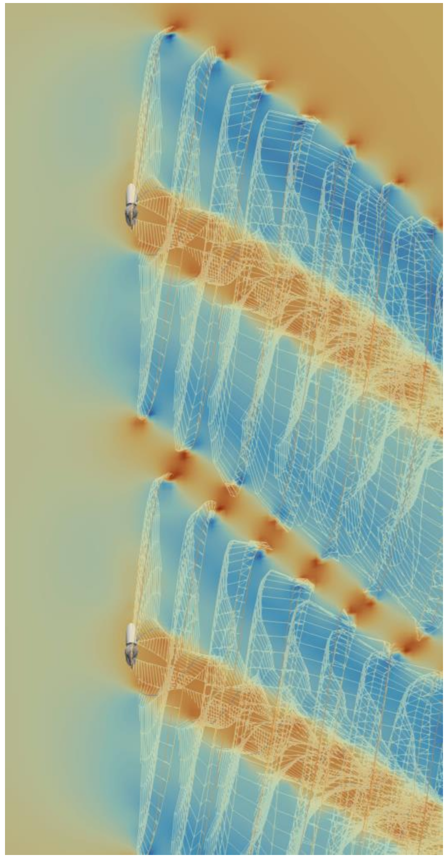
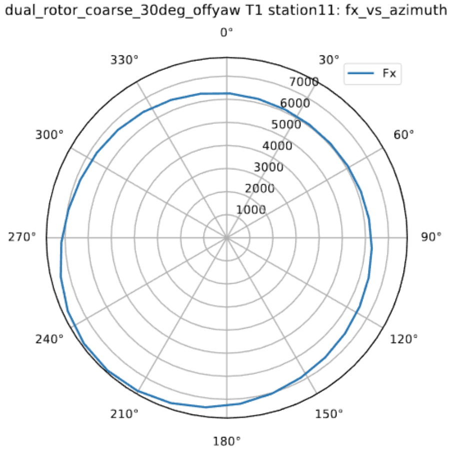
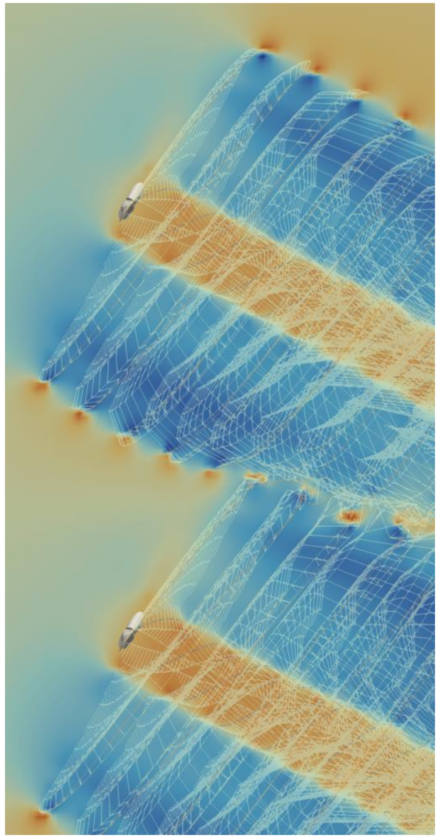
# Related work at CC4E

## Influence of wind veer

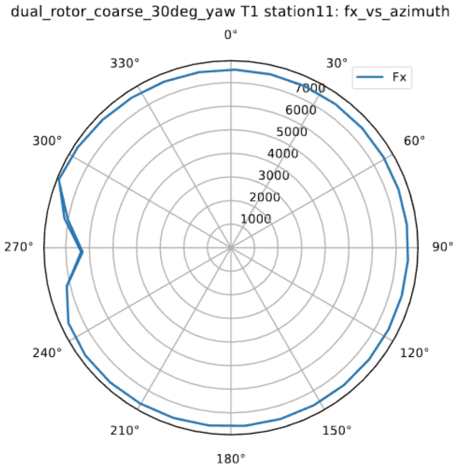


- Reduced efficiency
- Load oscillations (like single rotors)



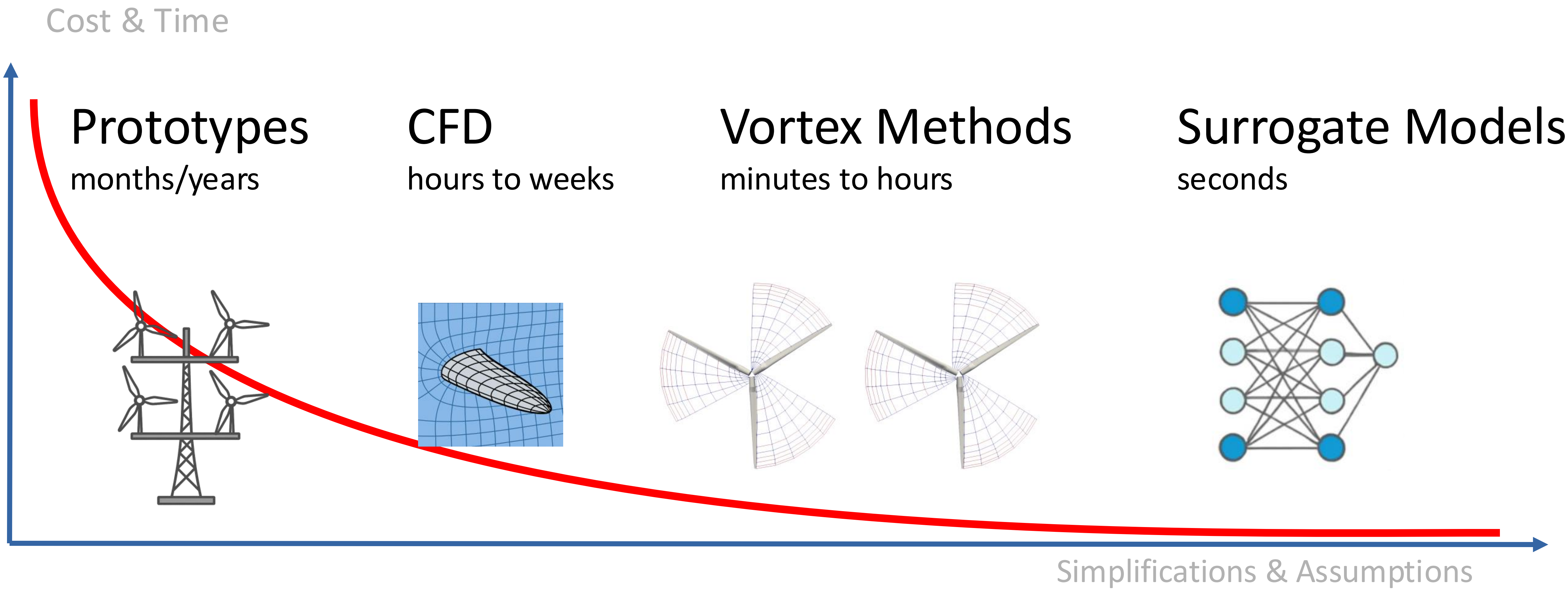



- better efficiency
- Larger spacing?



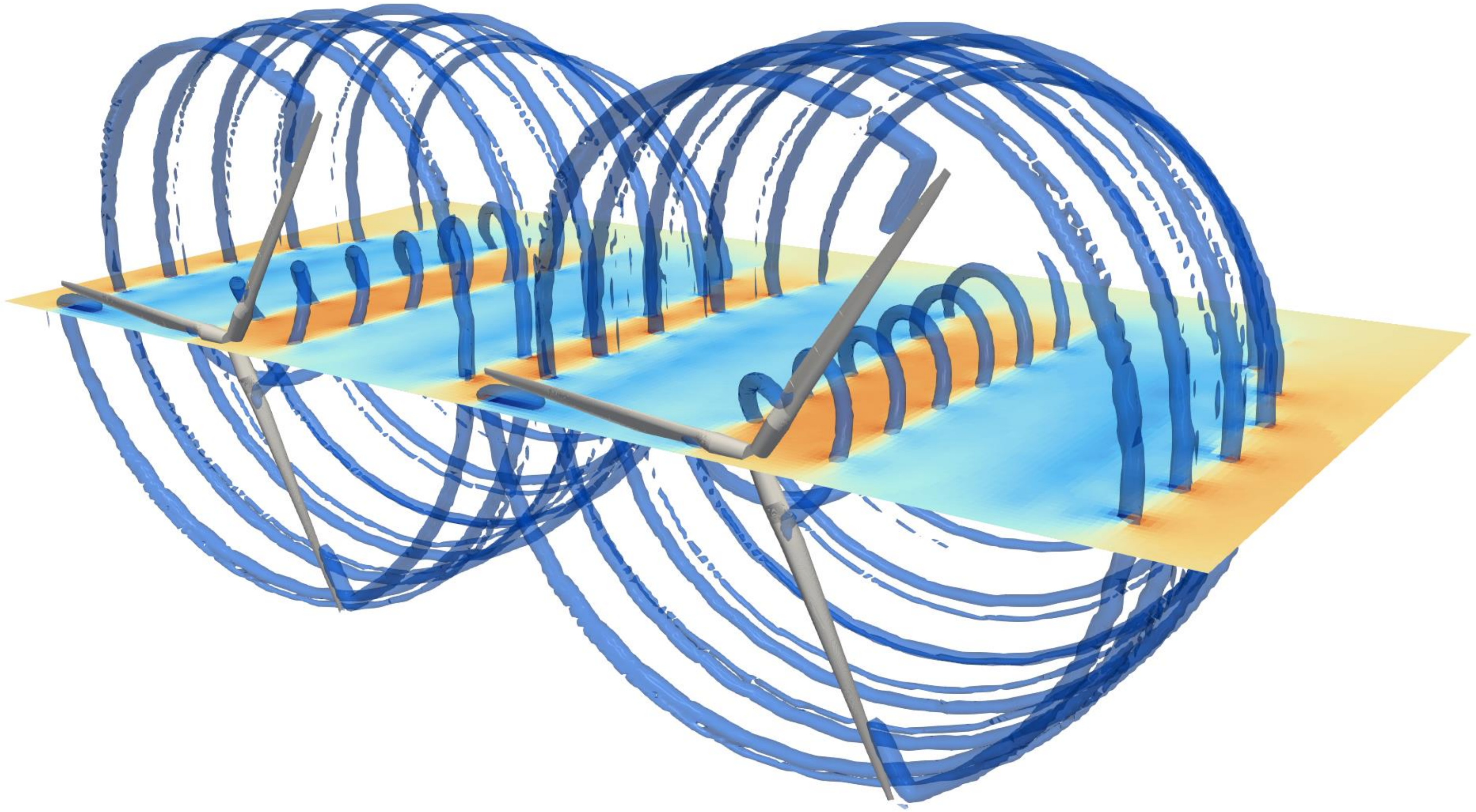
# Simulation Fidelities and Cost

- Efficiency enables optimization



# Recap

- Cyclic Loads?
  - 2-3% root bending
  - More in tip sections
- Thrust and Power increase
  - with tight spacing
  - Larger arrays
- Wakes?
  - A lot of potential



# Interesting Papers

## On rotor-rotor interaction


- Chasapogiannis, P. et al. (2014). Analysis of the aerodynamic performance of the multi-rotor concept. DOI: 10.1088/1742-6596/524/1/012084
- INNWIND.EU (2017). Innovative Turbine Concepts – Multi-Rotor System (Deliverable 1.33). Deliverable Report, INNWIND.EU project. Available at: https://www.innwind.eu/publications/deliverable-reports
- Ghaisas, N.S., Ghate, A.S. & Lele, S.K. (2020). Effect of tip spacing, thrust coefficient and turbine spacing in multi-rotor wind turbines and farms. Wind Energy Science, 5(1), 51–72. DOI: 10.5194/wes-5-51-2020
- Speakman, G.A. et al. (2021). Wake steering of multirotor wind turbines. Wind Energy, 24(11), 1294–1314. DOI: 10.1002/we.2633
- Martín-San-Román, R. et al. (2022). Influence of lateral rotor spacing on the benefits in power generated by multi-rotor configurations. J. Phys.: Conf. Ser., 2362(1), 012024. DOI: 10.1088/1742-6596/2362/1/012024
- Zhang, Y. et al. (2022). CFD simulation of co-planar multi-rotor wind turbine aerodynamic performance based on ALM method. Energies, 15(17), 6422. DOI: 10.3390/en15176422
- Mendoza, V. et al. (2023). Aerodynamic performance of a dual turbine concept characterized by a relatively close distance between rotors. Wind Energy, 26(6), 521–537. DOI: 10.1002/we.2813
- Gong, S. et al. (2023). Experimental study on the effect of the blade tip distance on the power and the wake recovery with small multi-rotor wind turbines. J. Marine Sci. Eng., 11(5), 891. DOI: 10.3390/jmse11050891
- Martín-San-Román, R. et al. (2024). Assessment of the azimuthal loads variation by a bi-rotor configuration. J. Phys.: Conf. Ser., 2767(2), 022015. DOI: 10.1088/1742-6596/2767/2/022015
- Matras, F. & Dinhoff Pedersen, M. (2025). Control strategies for multirotor wind turbines. Wind Energy Science Discussions, 1–27. DOI: 10.5194/wes-2024-185
- Li, Y. et al. (2025). Wake aerodynamic of multi-rotor system with lifting-devices under different ambient turbulence. J. Phys.: Conf. Ser., 3016(1), 012042. DOI: 10.1088/1742-6596/3016/1/012042
- Arabgolarcheh, A., De Vanna, F. & Micallef, D. (2025). Offshore multi-rotor wind turbines: Blade interactions under surging conditions. Energy, 331, 136694. DOI: 10.1016/j.energy.2025.136694