Center for Wind Turbine Aerodynamics and Atmospheric Turbulence

Wakes and Wind Farms
Tasks 2 and 3

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Steering group meeting
DTU, 3rd of February, 2011

Objectives

Task 2: Wind Turbine Wakes and Clusters

Analyse and simulate turbulent wakes and turbine to turbine interaction subject to

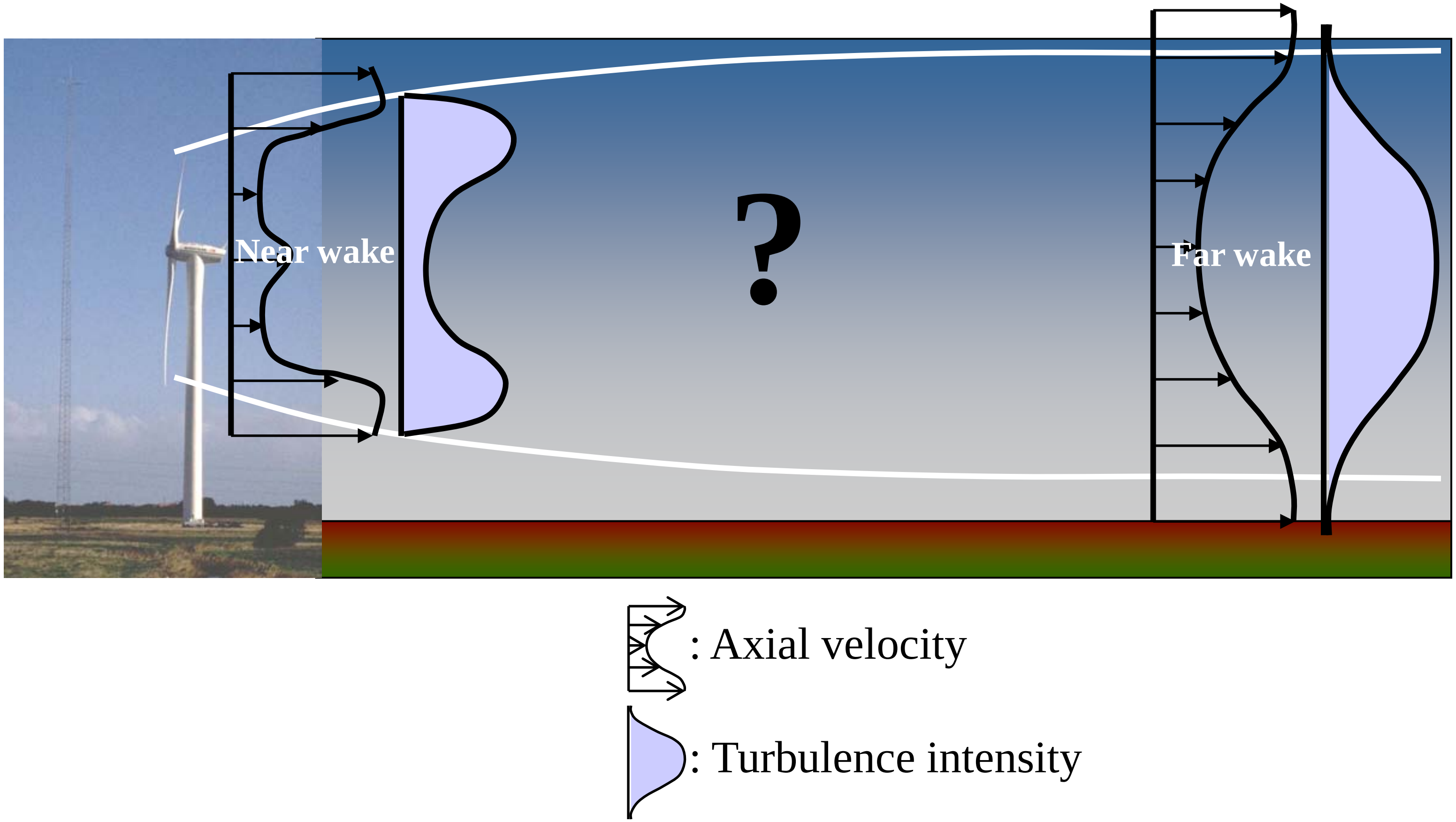
- Wind shear
- Turbulent inflow
- Different wind directions
- Wind veer

Overall goals:

- Understanding of wake aerodynamics
- Development of turbulent wake model

Wake Aerodynamics

Wake development:



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Wake Aerodynamics

Issues to be addressed:

- **Dynamics of the vortex system**
- **Strength of the vortices and dependency of blade load**
- **The roll-up take phenomenon**
- **Conditions for vortex instability**
- **Relationship between vortex dynamics and meandering**
- **Interplay between ambient and local turbulence**
- **Dynamics of the wake interaction between more turbines**
- **Optimization of wind turbines in large parks**
- **Mutual influence between wind farms**

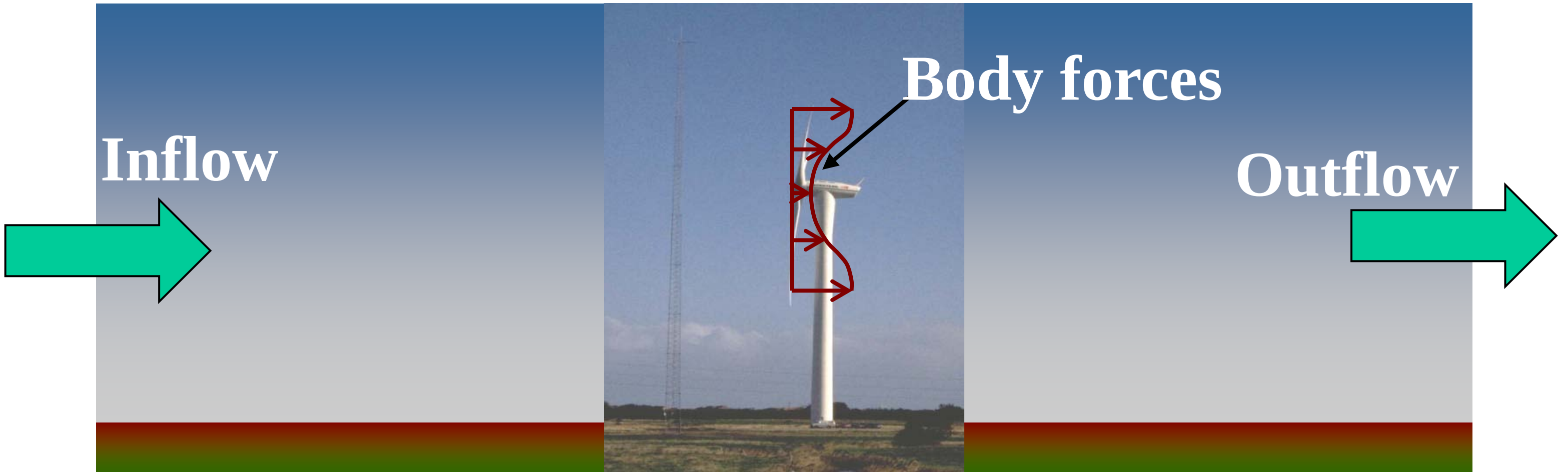
Milestones Task 2

- **M7:** Parabolized stand-alone N-S park model. **Month 14.**
- **M8:** Validation of N-S model for wake behind a single wind turbine. **Month 24.**
- **M9**: Refined far wake model. **Month 24.**
- **M10**: Parametric study of wake interaction. **Month 36.**
- **M11:** Parametric study of wake stability. **Month 36.**
- **M12:** Refined Dynamic Wake model. **Month 48.**

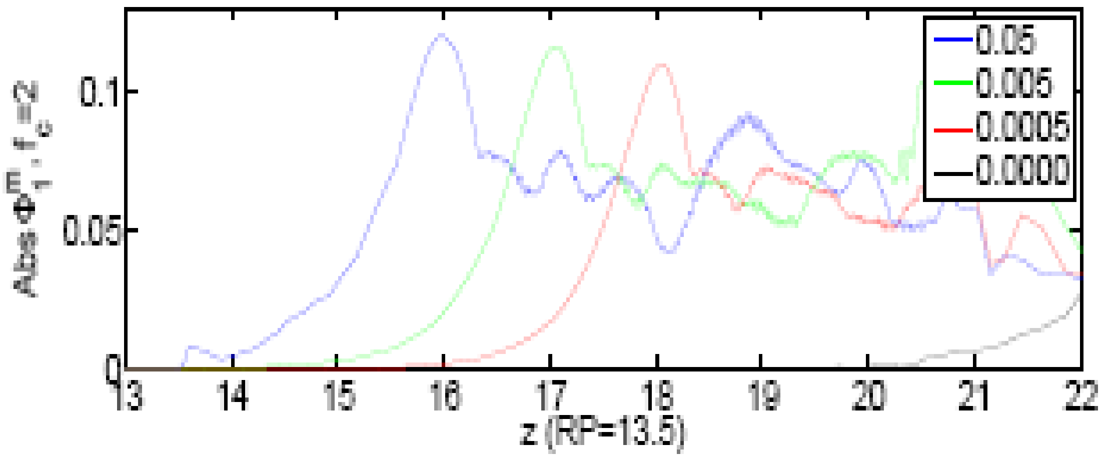
The actuator line technique

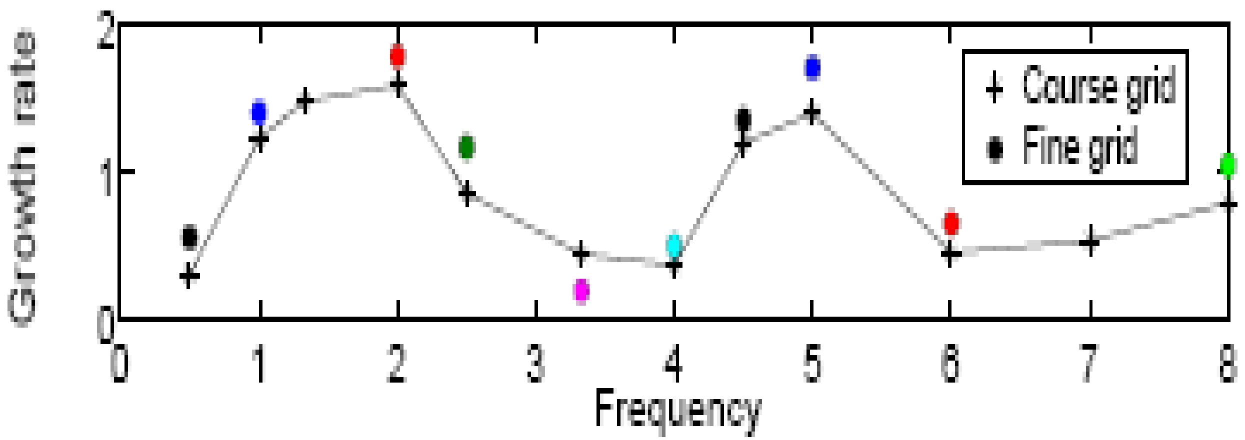
Basic idea:

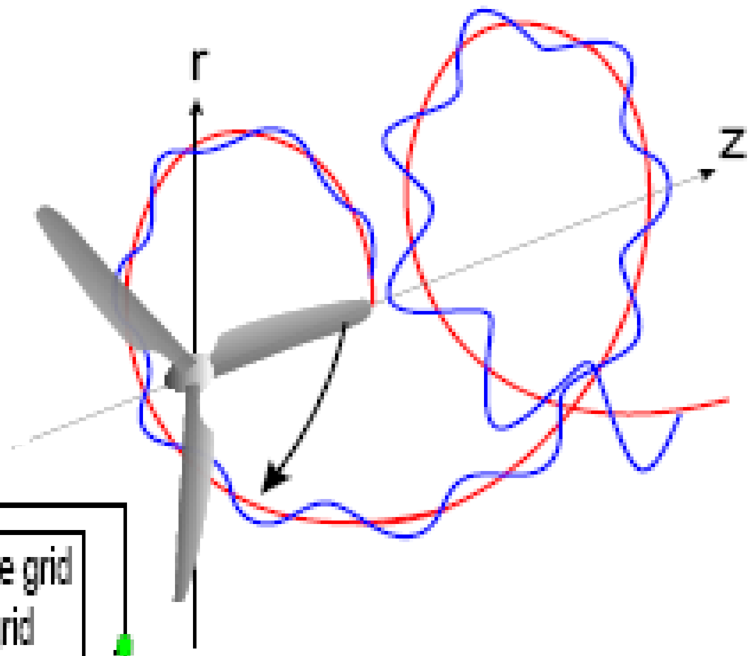
- Replace rotor blades by body forces
- Determine body forces from aerofoil data
- Simulate flow domain using DNS or LES



Stability analysis of vortex structures







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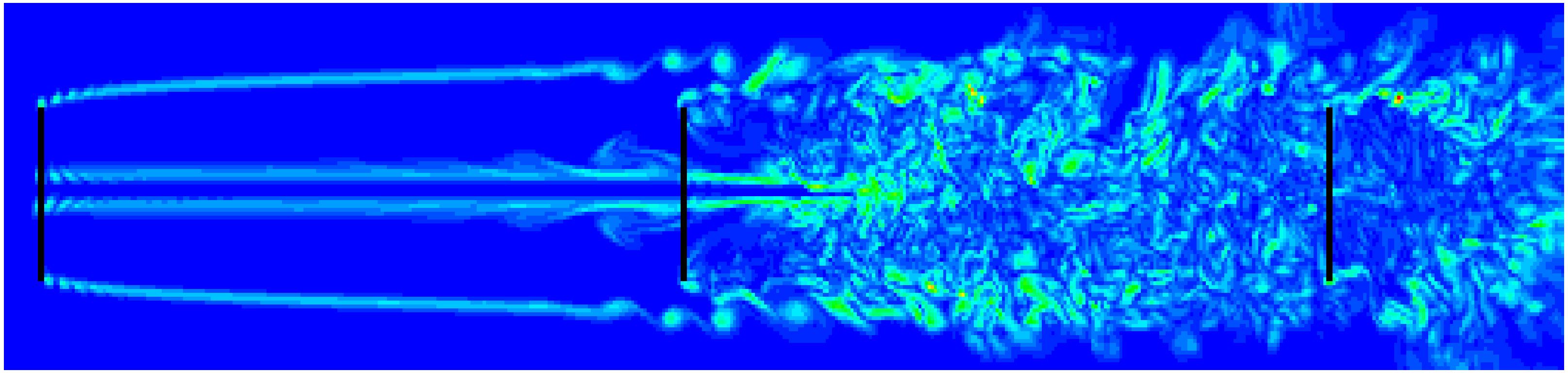
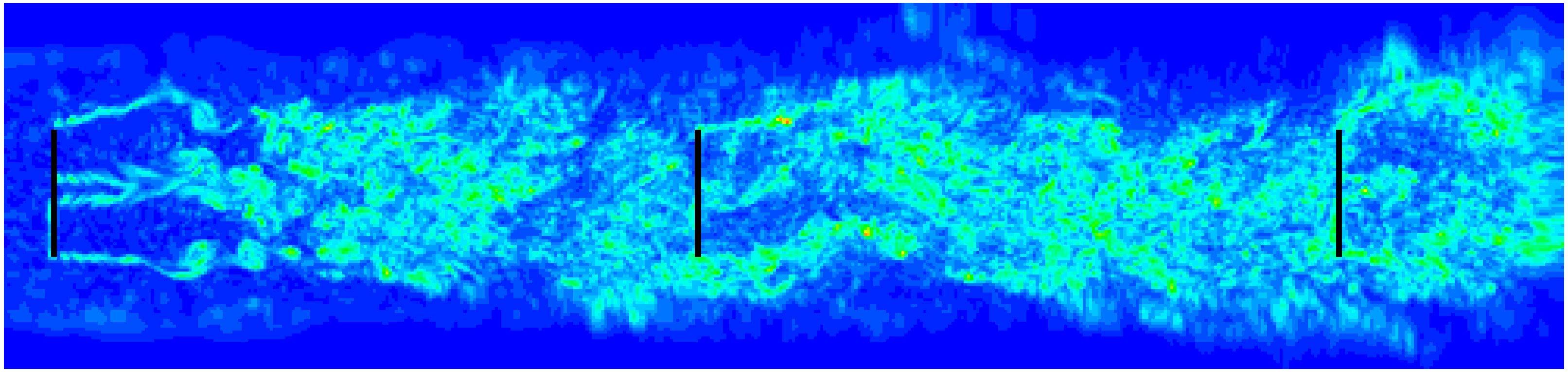
Vortex structures in the wake of a row of rotors





Development of wake behind three rotors in a row at W_0 = 10 m/s; Turbine spacing 6 rotor radii. A) Constant inflow; B) Turbulent inflow.

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PhD-project: Søren Juhl Andersen
Simulation and prediction of wakes and wake interaction in wind farms

Year 1:

Literature review on wake models.

Courses

Further development of an existing CFD code to conduct a thorough parametric study of the flow field in the wake of a single wind turbine. The parametric study aims at investigating the following:

- The influence of shear in the inflow(i.e. a gradient in the atmospheric boundary layer)
- Vortex collapsing
- Transition between near- and far-wake
- Relation between induced turbulence and thrust
- How to correctly add ambient and induced turbulence

Year 2:

Develop guidelines based on the parametric study of a single wind turbine

Continued parametric study on the flow field within wind turbine farms investigating the following influences:

- The spacing between individual wind turbines.
- Stable or unstable atmospheric boundary layer, including vertical mixing.
- Wake meandering

Year 3:

Analysis and interpretation of parametric studies leading to a procedure to optimize wind farms.

Objectives

Task 3: Wind Farms

Analyse and simulate wind farms and farm to farm interaction subject to

- Wind shear/stratification
- Turbulent inflow
- Different wind directions
- Wind veer

Overall goals:

- Understanding of flows in wind farms
- Development of optimization tools for farm siting

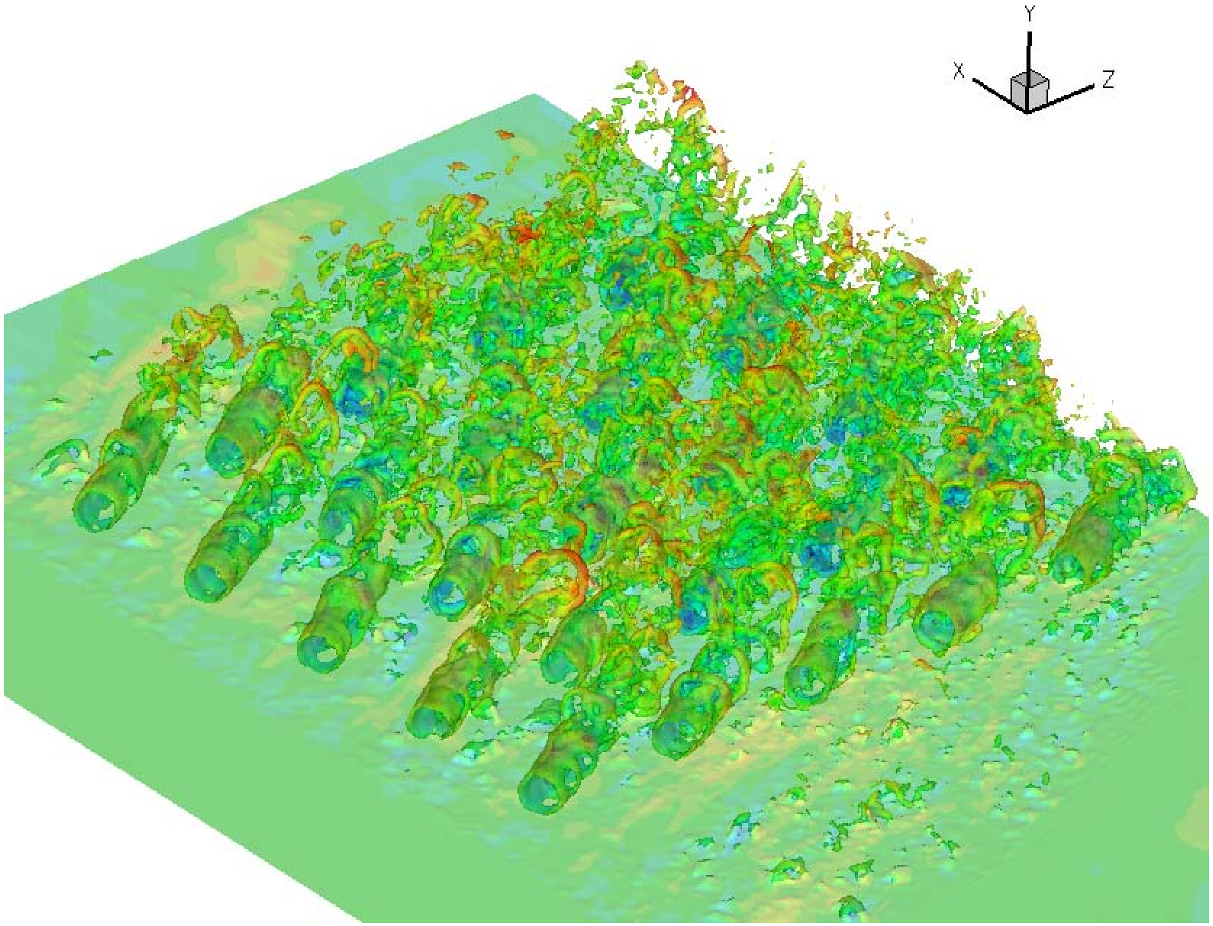
Milestones Task 3

- **M13**: LES simulations of wind farms; Compariosns to experiments. **Month 24.**
- **M14:** Low-dimensional turbulence model for wind farms. **Month 36.**
- **M15:** LES simulations subject to neutrally stable ABL . **Month 36.**
- **M16**: Simulation of influence of stratification on wind farm performance. **Month 48.**
- **M17:** Simulation of mutual influence between two wind farms. **Month 60.**

Wind Turbine Wake Aerodynamics

Horns Rev offshore wind farm:

Modelling of Turbulent and Atmospheric Turbulence



Vorticity shed from 5x5 turbines in a farm computed by actuator disk method

PhD Project: Hamid Sarlak

"Simulation and prediction of wakes in offshore wind farms subject to turbulent and stratified atmospheric boundary layers"

- Literature survey on wake models based on CFD. Further development of an existing CFD code to include modelling of inflow effects on scales relevant for offshore wind farms

- Modelling of turbulent and thermal atmospheric boundary layer with existing CFD code. Development of engineering predictive tool. Comparison to experiments with particular emphasis on densely located wind turbines, such as the Lillgrund wind farm.

- Interaction between wind farms.

- Numerical experiments and parametrical studies. Guidelines/recommendations.

International collaboration

- **Monash University (Australia):**
  Vortex structures in wind turbine wakes and their modification
- **KTH, Univ. of Gotland (Sweden):**
  Nordic consortium for optimization and control of wind parks
- **Johns Hopkins University (USA):**
  PIRE: USA/Europe Partnership for Integrated Research and Education in Wind Energy
- **IRPHE/CNRS (France):**
  HELICE: Helical Vortex Wakes