DTU

# Rotor/ABL Aerodynamics, TASK-1


**Niels N. Sørensen**

Wind Energy Division · Risø DTU


RISØ-DTU, 25-01-2010


Risø DTU

National Laboratory for Sustainable Energy

# Introduction

- Overview and progress
- Planning for next period
- Some technical results

Several researcher have contributed to the technical part of my slides today
Contributions from:

- Wen Zhong Shen
- Frederik Zahle
- Pierre-Elouan Rethorè

# Objective

## Task-1: Rotor/ABL Aerodynamics

Investigate the effect of Atmospheric Boundary Layer characteristics on rotor aerodynamics

- Laminar turbulent transition
- Wind Shear and yaw
- Unsteady inflow, inflow turbulence
- Dynamic stall


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Partners participating in the study

- Risø-DTU, DTU MEK, LM-Glasfiber, Mek-DTU, Siemens, Vestas

## Task-1: Rotor/ABL Aerodynamics

Navier-Stokes simulations, using resolved geometry

- **EllipSys3D**, LM-Glasfiber, Mek-DTU, Risø-DTU
- **CFX**, Siemens Wind Power
- **Fluent**, Vestas

## Task-1: Rotor/ABL Aerodynamics

Navier-Stokes simulations, using resolved geometry

- **EllipSys3D**, LM-Glasfiber, Mek-DTU, Risø-DTU
- **CFX**, Siemens Wind Power
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Additionally, the computations will couple to Actuator-line and -disc computations from Task-2 and Task-3.

## Experiments

A series of experiments are available


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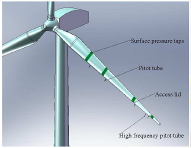



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- Topfarm



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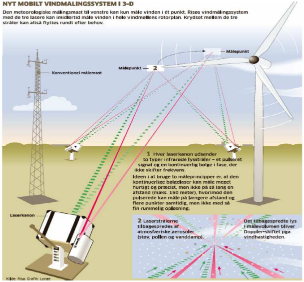



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- MEXICO
- DAN-Aero
- Topfarm
- LIDAR/Wind-Scanner
- Siemens Full Scale
- Tunnel data, e.g. LM-Glasfiber

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The following milestones were defined within the present package

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- M1: Parametric study of two modern turbines in atmospheric shear. **Month 12** Delayed



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- M6: Simulation of various unsteady inflow conditions for the NM80. **Month 36**


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# Ph.D. and Post Doc.

Ph.D. and P.D. in Rotor Aerodynamics


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# Ph.D. and Post Doc.

## AED-PhD

### AED-PhD details

- Shared financing between Siemens, Risø-DTU, and DSF
- Connected to TASK-1, Rotor/ABL Aerodynamics
- We will try and start this Ph.D. one year early, in 2012
- The detailed work description will be in second half year 2011


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# Ph.D. and Post Doc.

## RISØ-PhD2

### RISØ-PhD2 details

- Shared financing between Risø-DTU and DSF
- Connected to TASK-2 and TASK-3, Turbine Wakes and Farms
- We will try and start this Ph.D. one year early, in 2011
- The detailed work description must be made in spring 2011

# Ph.D. and Post Doc.

## AED-RISØ-PD

### AED-RISØ-PD

- Purely financed by DSF
- Planned to be connected to TASK-4 and TASK-5
- No real planning yet, will first start 2014


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# Task-1: Ph.D's and Post Doc's

## Planned Ph.D. activities connected to Rotor Aerodynamics

| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|
| AED-PhD | | | 12 | 12 | 12 | 12 |
| RISØ-PhD2 | | 12 | 12 | 12 | 12 | |
| AED-PD | | | | | 12 | 12 |

## Connection to Task's

| | TASK-0 | TASK-1 | TASK-2 | TASK-3 | TASK-4 | TASK-5 |
|---|---|---|---|---|---|---|
| AED-PhD | | 36 | | | | |
| RISØ-PhD2 | | | 12 | 24 | | |
| AED-PD | | | | | 12 | 12 |

- TASK-1: Rotor/ABL Aerodynamics (NNS)
- TASK-2: Wind Turbine Wakes and Clusters (JNS)
- TASK-3: Wind Farms (JNS)
- Task-4: Siting in Forested and Complex Terrain (JM)
- Task-5: Atmospheric Boundary Layers (JM)

# Planning of work

## First Year, Original plan

Focus on milestone M1
Parametric study of two modern turbines in atmospheric shear

Partners (Risø-DTU, LM-Glasfiber, Mek-DTU, Siemens, Vestas)

The computations will be performed using RANS/DES type solvers, and fully resolved rotor geometry.


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- Definition of cases to run
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- Shear computations

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# Planning of work

## Actual activities, First Year

- Mexico axial flow cases, investigating differences with measurements


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- Rotors in partial wake and in shear

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## Actual activities, First Year

- Mexico axial flow cases, investigating differences with measurements
- Mexico yaw cases
- NREL Phase-VI dynamic stall computations during standstill
- Rotors in partial wake and in shear
- Finding and extracting data sets from the DAN-AERO exp.


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# Plans for 2011

## Second Year

Focus on the following milestones

- M1: Parametric study of two modern turbines in atmospheric shear
- M2: Evaluation of the importance of cross flow instabilities for modern wind turbine rotors
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- NDA issues
- Access to Mexico data if needed


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Selected Technical Results

## Questions surrounding the tunnel effect

- Can the tunnel explain the thrust/induction issue seen in exp?
- Does the recirculation region affects the wake measurements?
- Does the wind turbine blockage effect affects the wind speed measurements?
- Is the wind turbine affected by the wind tunnel?
- How far downstream can we measure the wake?
- Is there some unsteady effects?


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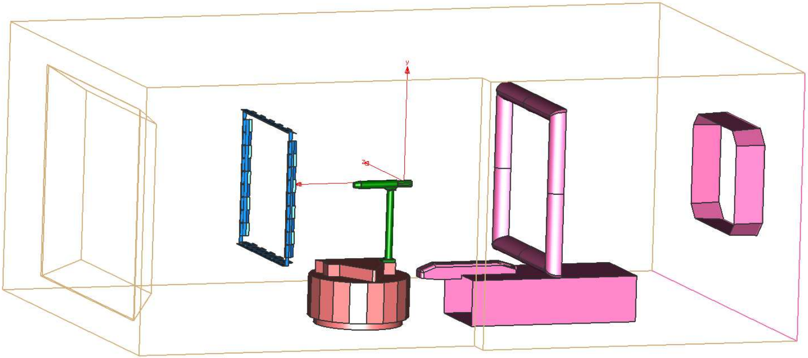
## Perspective view



- The nozzle and collector shapes are not available (confidential).
- We made up some streamlined designs.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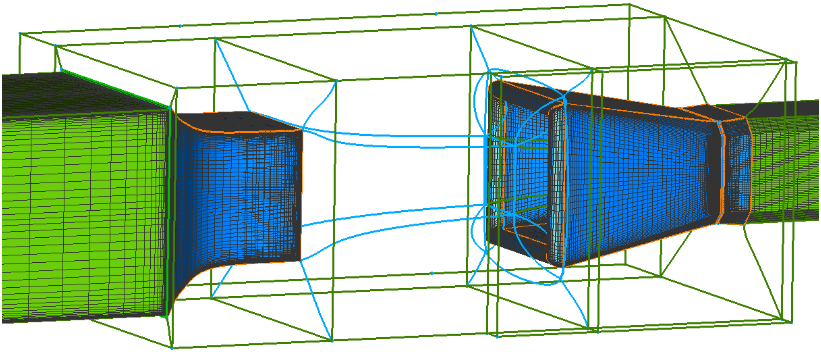
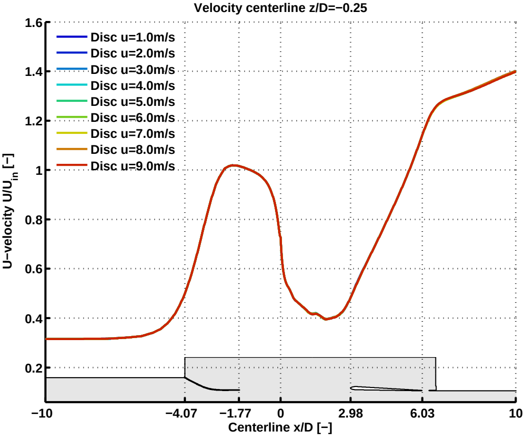
## Perspective view



- We use a slip boundary condition at the surface (zero gradient).
- This reduces dramatically the number of cells necessary, but it is done at the expense of the boundary layer description.

## Different wind speeds & same $C_T = 0.77$




- All the velocities collapse completely.
- $C_T$ is the only parameter.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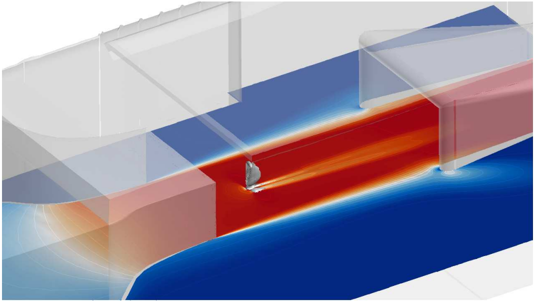
## Resolved geometry in the tunnel

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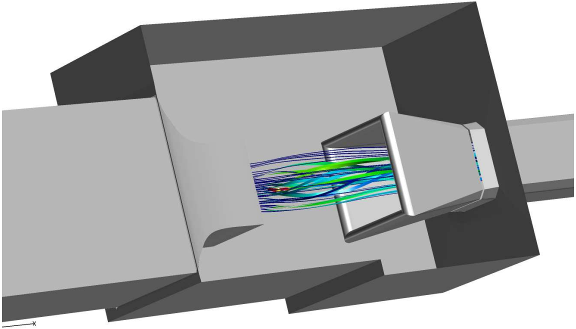
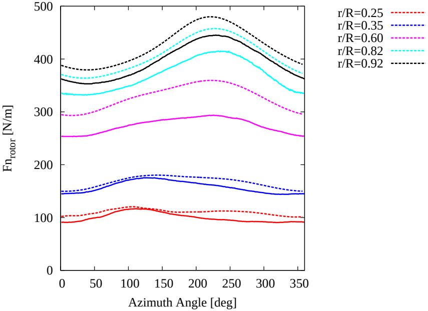
## Present Conclusion

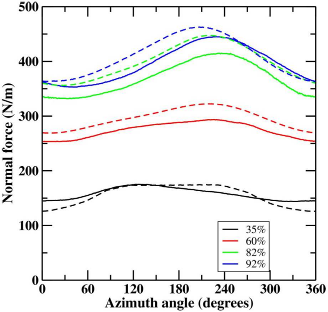
- The collector has a big impact on the wake region $x > 1.3 \times D$
- Thrust/Induction discrepancy not explained by tunnel effects



# Mexico, Yaw Computations

Mexico 30 degrees Yaw, W=15 [m/s], Normal Force. Left resolved geometry, right Actuator Line





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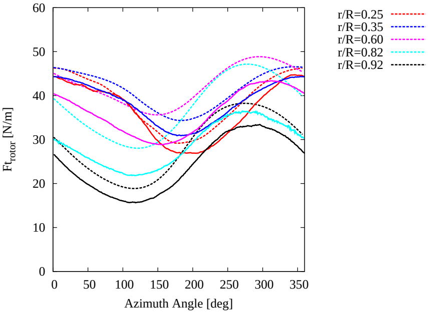
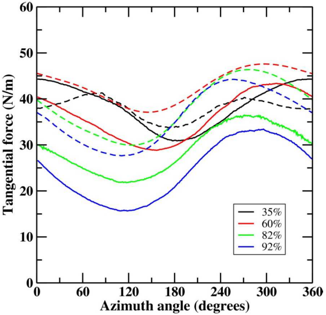
# Mexico, Yaw Computations

Mexico 30 degrees Yaw, W=15 [m/s], Tangential Force. Left resolved geometry, right Actuator Line





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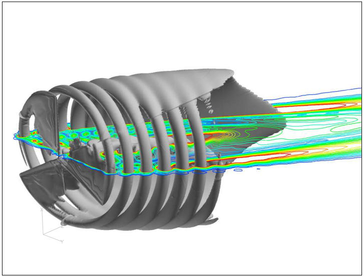
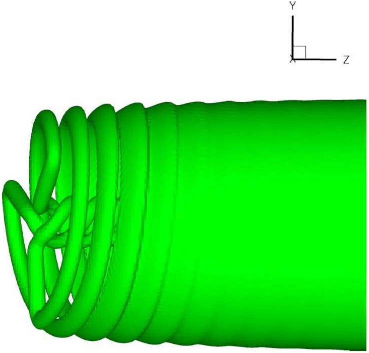
# Mexico, Yaw Computations

Mexico 30 degrees Yaw, W=15 [m/s], Wake Development. Left resolved geometry, right Actuator Line







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## The configuration

The tested configuration is based on the NREL-Phase-VI turbine during standstill

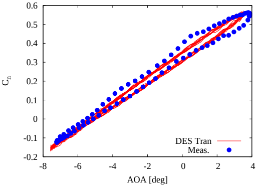
- The blade is parked straight up, zero azimuth position.
- The geometrical AOA is defined as the angle between the local chord and the test section center line
- The mean AOA given below is for the 47% section

| Name | Mean Aoa [deg] | Amplitude [deg] | Pitch time [s] | Reduced freq. |
|---|---|---|---|---|
| 47311 | 7.91 | 5.55 | 0.8496 | 0.099 |
| 47320 | 13.89 | 5.55 | 0.8126 | 0.099 |
| 47040 | 22.92 | 5.04 | 1.1261 | 0.075 |

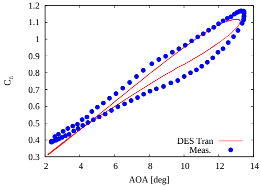
# Technical Results *Nrel Standstill Pitch*

## CASE 47040, Low AOA case

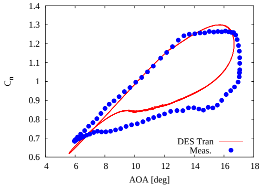
r/R=0.30



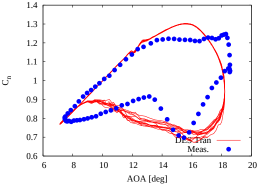

r/R=0.47



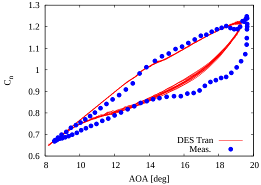

r/R=0.63




r/R=0.80




r/R=0.95



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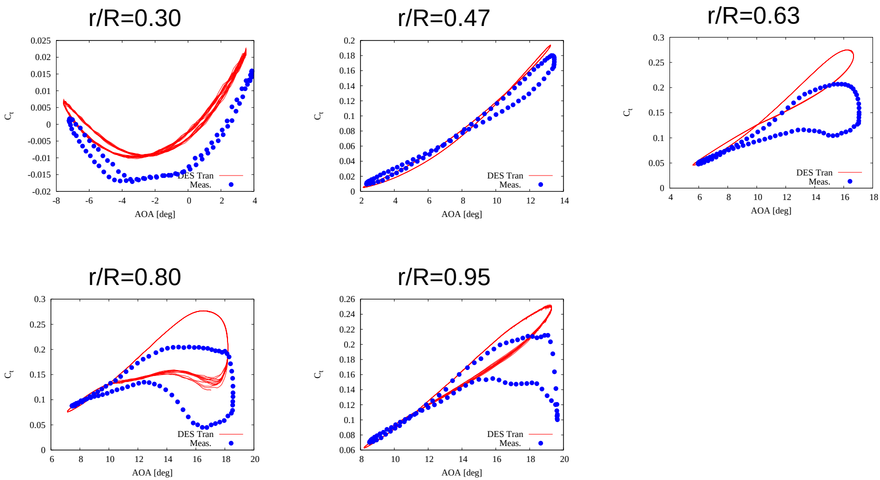
# CASE 47040, Low AOA case



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# Technical Results *Nrel Standstill Pitch*

## CASE 47040, High AOA case

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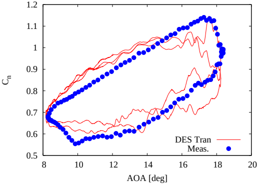


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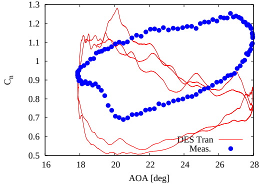


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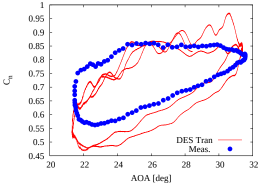


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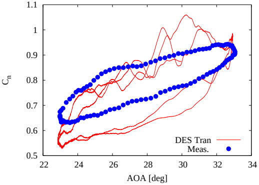


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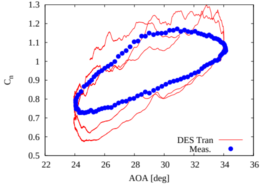



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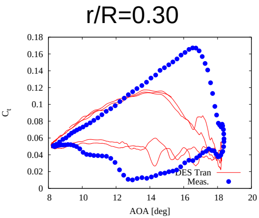


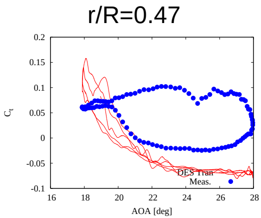


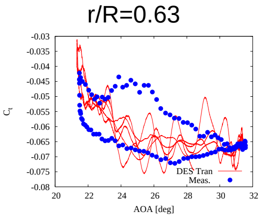


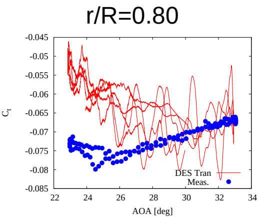


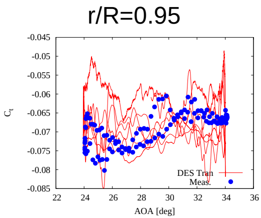



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## Conclusion

- The coupled methodology DDES and transition are numerically stable
- The transition model opens the loops improving agreement with measurements
- We have obtained general good agreement with measured values, even at high AOA
- We believe that we are ready for the rotating cases


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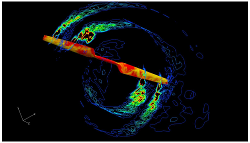


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