Flow Center WP1 Meeting 1st November 2013

PhD on Merging Wakes

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PhD study status / On-going activities / Future work & discussions

DTU Wind Energy
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1. PhD status

Completed tasks (year 1 & 2)

- MW characteristics, NM80 (Tjæreborg): CFD LES ACL, CW lidar (EWEA 2012)
  - Organized part of flow structure (deficit, turbulence level)
  - Validation of CFD model
- SW meandering, NTK 500 (Risø): DWM against pulsed lidar based measured (EWEA 2013)
  - DWM validation
  - Uncertainties on advection velocity using 1D momentum formulation
- Engineering models for SW advection, expansion (in submission WE)
  - Empirical formulation of advection velocity using vortex cylinder, spherical vortex structures, CFD, lidar.
  - Engineering model for single wake expansion using DWM framework and previous advection velocity.
- New wake bench test case for wake model validation (WE?)
  - Wind speed bin averaging of full campaign / Atm. stability impact/ Yaw misalignment estimation from meandering
  - Wake interaction

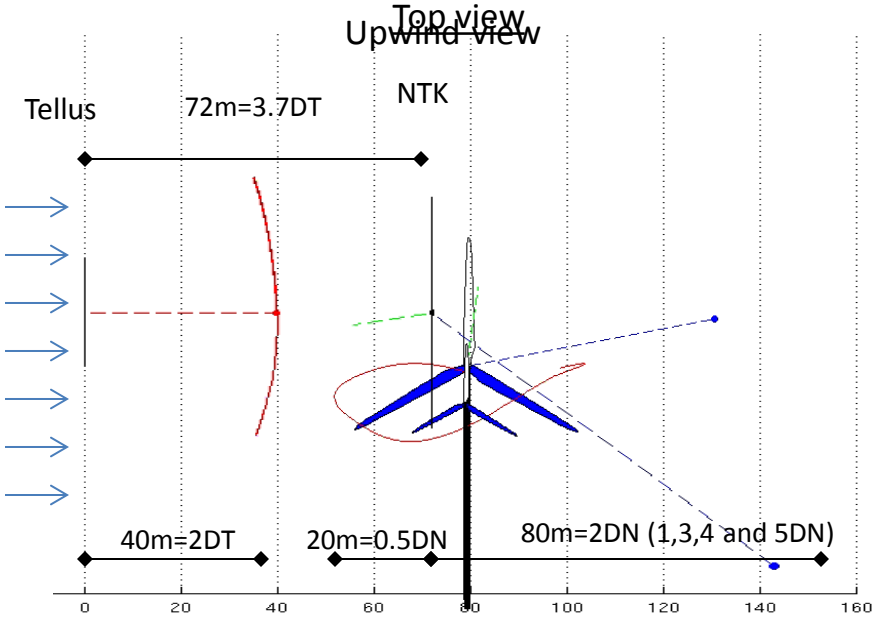
On-going and future activities (year 3)

- Merged wake experiment: post processing
- Numerical simulation on merged wake
- External stay NREL January 2014 – April 2014
- Future work & discussions

2. Merged wake experiment: status

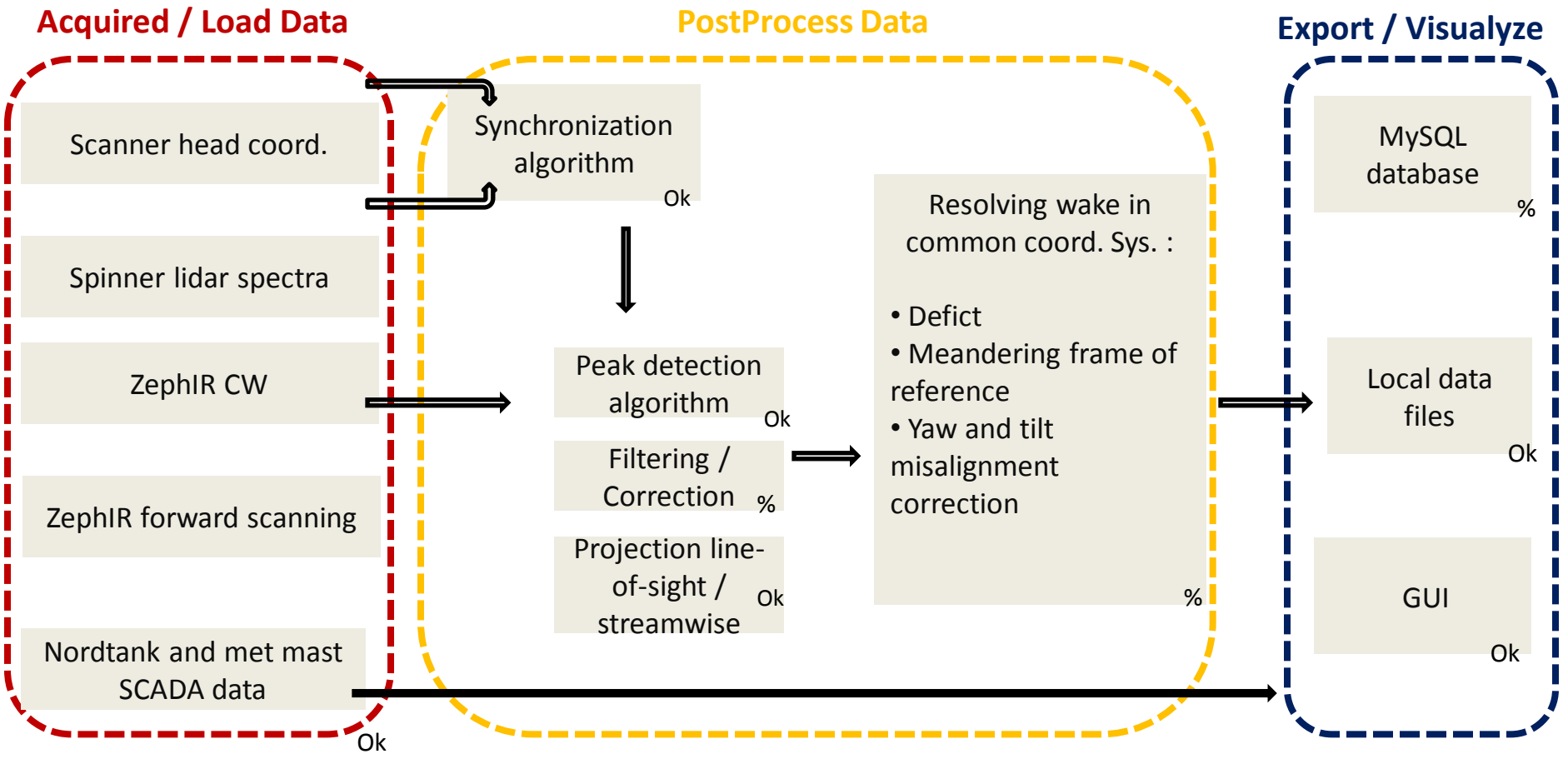
- **3 lidars**: 2 wake scanning NTK/TELLUS, 1 forward scanning NTK
- Measurement phase **completed** end of May 2013. Duration: approx. 4 months
- **26.3 days** of measurements with all lidars operating.
- **68.1 days** of spinner lidar measurements.
- Data gaps due to technical failures on the ZephIR lidar, DTU spinner lidar, NTK sensors.
- **3TB** of data to post process and analyze. Efficient post processing / visualization tool.
- **30 hours of merged wake** situation with **all** lidars functioning
  - 24 hours from northerly inflow. 6 hours of southerly inflow low wind 4-6 m/s.

Inflow 197deg +- 15deg (6 hours of measurements)

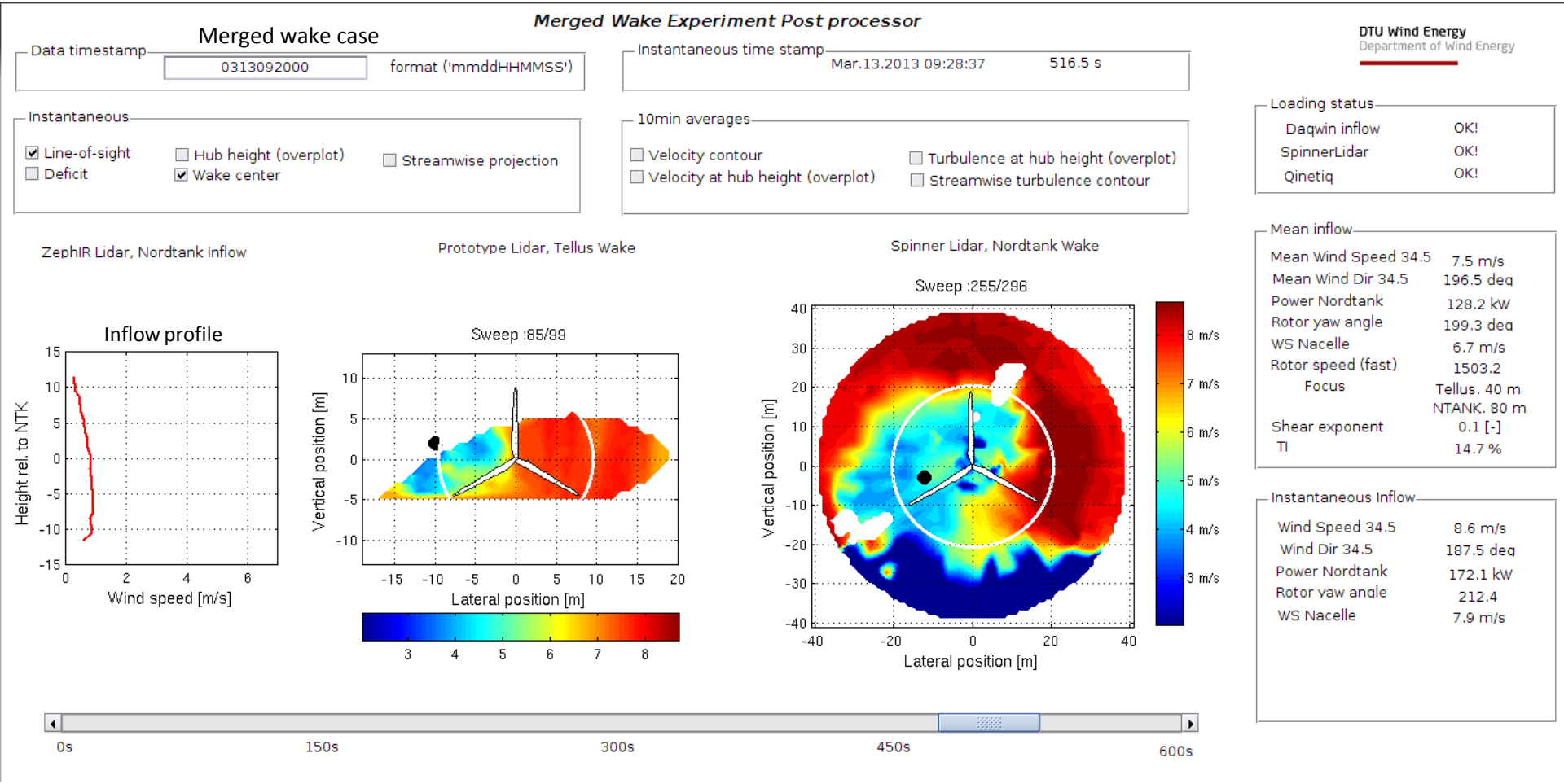


2. Post processing program

- Gather / organize / synchronize all data source in one program
- Post process / filter / correct raw measurements (ground and blade reflection, low aerosols)
- Resolve wake in Cartesian coordinate system
- Ease the investigation and analysis of the measurements
- Save post process data into database / binary files on server



2. Post processing program



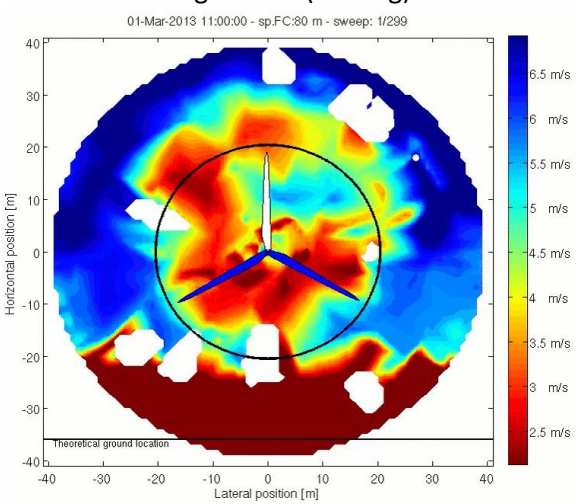
Uncertainties:

- Poor instrumentation of the Tellus (rotor azimuth and yaw position, power produced …)
- Calibration of yaw sensor of NTK ? Strain gauges used in thrust calculation ?
- ……

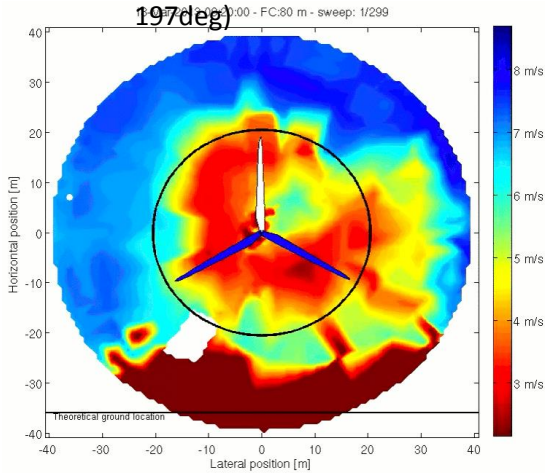
2. Comparison SW / MW

- First investigation: comparison of SW and MW under same inflow conditions
  - Same focus distance (2D), Uinf:7.0 m/s, TI_u: 13%

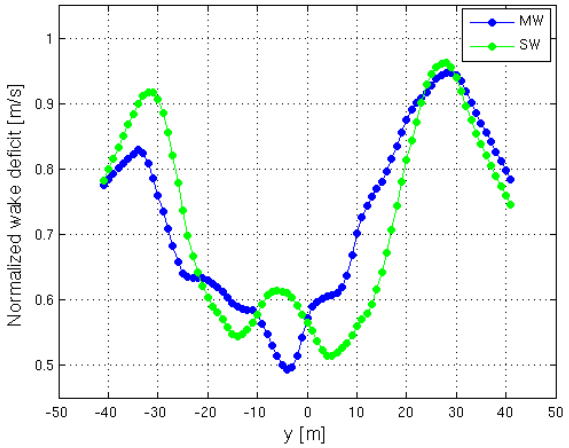
Single wake (313deg)



Merged wake (196.5deg / 197deg)

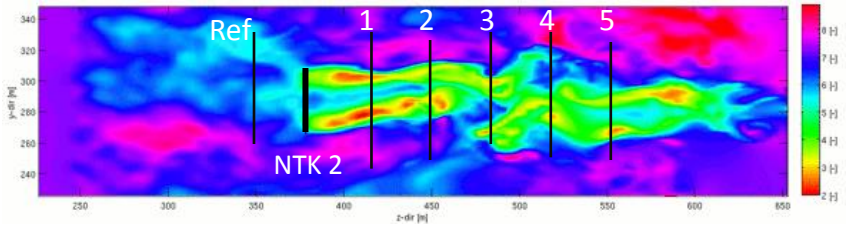


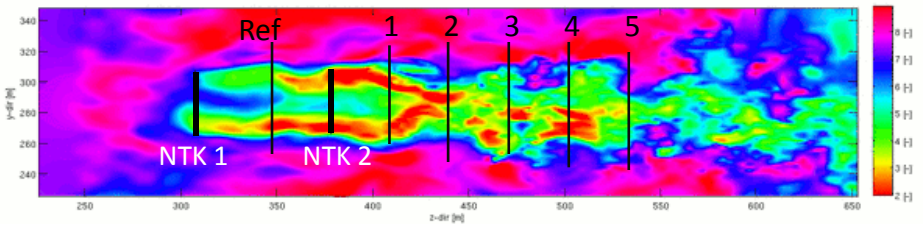
- analysis on superimposed 10 min average wake deficit
- stream wise component of the Reynolds stress tensor. Resolution 2s



3 – CFD simulation of merged wake

- Goal: to model as accurately as possible the experiment
    1. LES-ACL with 2 NTK500 in full wake

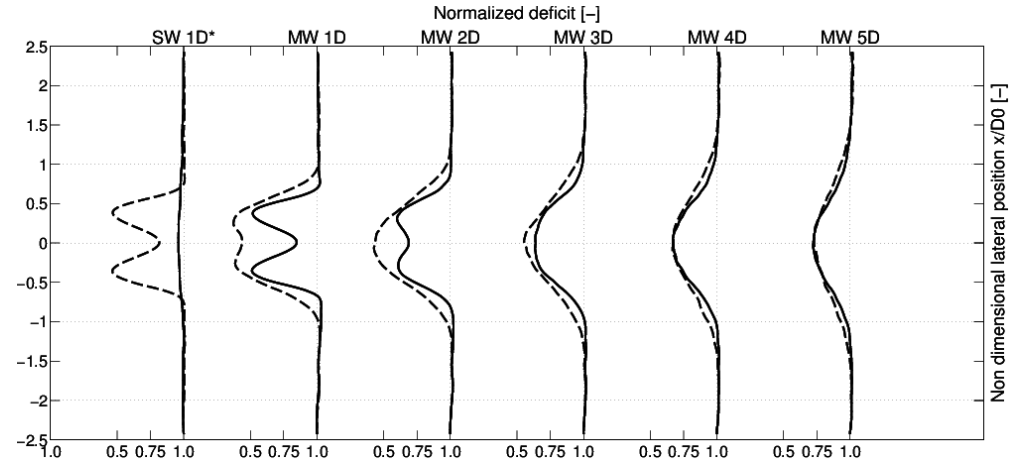


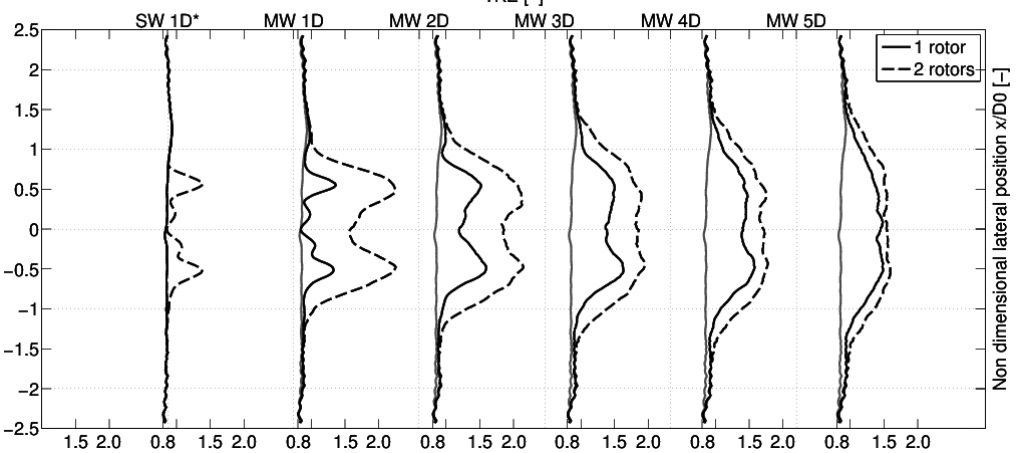


Methodology
- EllipSys3D LES ACL (airfoil data)
- No nacelle
- Stiff turbine
- No yaw
- Rotor tilted 5deg
- Constant rpm (stall regulated)
- Mann turbulence TI_u = 12%
- Sheared inflow, U_inf = 7.5 m/s

Comparison SW / MW
- 2 cases: 1 NTK / 2NTK
- Same turbulent box
- Same mesh
- Same extraction plane location

Results
- Average 10 min normalized deficit and TKE at hub height





3 – CFD simulation of merged wake

2- LES-ACD with disk force generated from Tellus and Nordtank airfoil data
- currently being simulated
- same sheared and turbulent inflow

3- LES-ACL with Tellus and NTK, stiff rotor, no yawing
- generalization of current ACL code to handle different types of rotor
- Prescribed loading from HAWC2 or airfoil tabulated data

4- Coupled LES-ACL / HAWC2
- HAWC2 rotor controller
- Evt. Full aeroelastic simulation ?
- Evt model of the terrain ?

4 – Conclusion / Future work

- Measurement phase completed. Post processing in progress. Merged wake case selected and EllipSyS3D LES-ACL /ACS simulations.

- External stay NREL Boulder January 2014 – April 2014 (3 months)
  - Benchmark EllipSys3D LES ACL / HAWC2, NREL SOWFA code OPENFOAM LES ACL / FAST and DTU merged wake measurements.

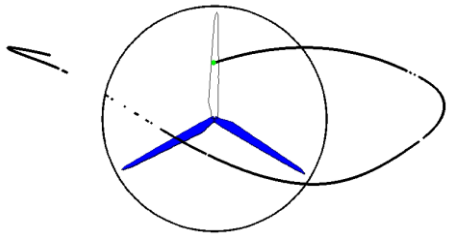
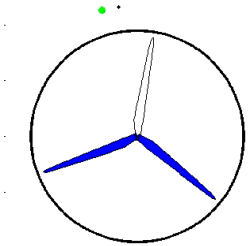
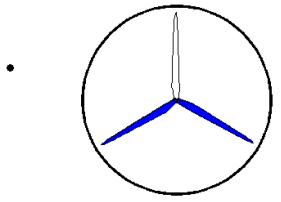
- Condensing experimental work and numerical simulation into simple engineering model for wake interaction
  - simple wake deficit summation rule
  - added wake turbulence
  - …

- Integration of engineering model into the DWM framework in HAWC2 for power and load calculations in wind farms.

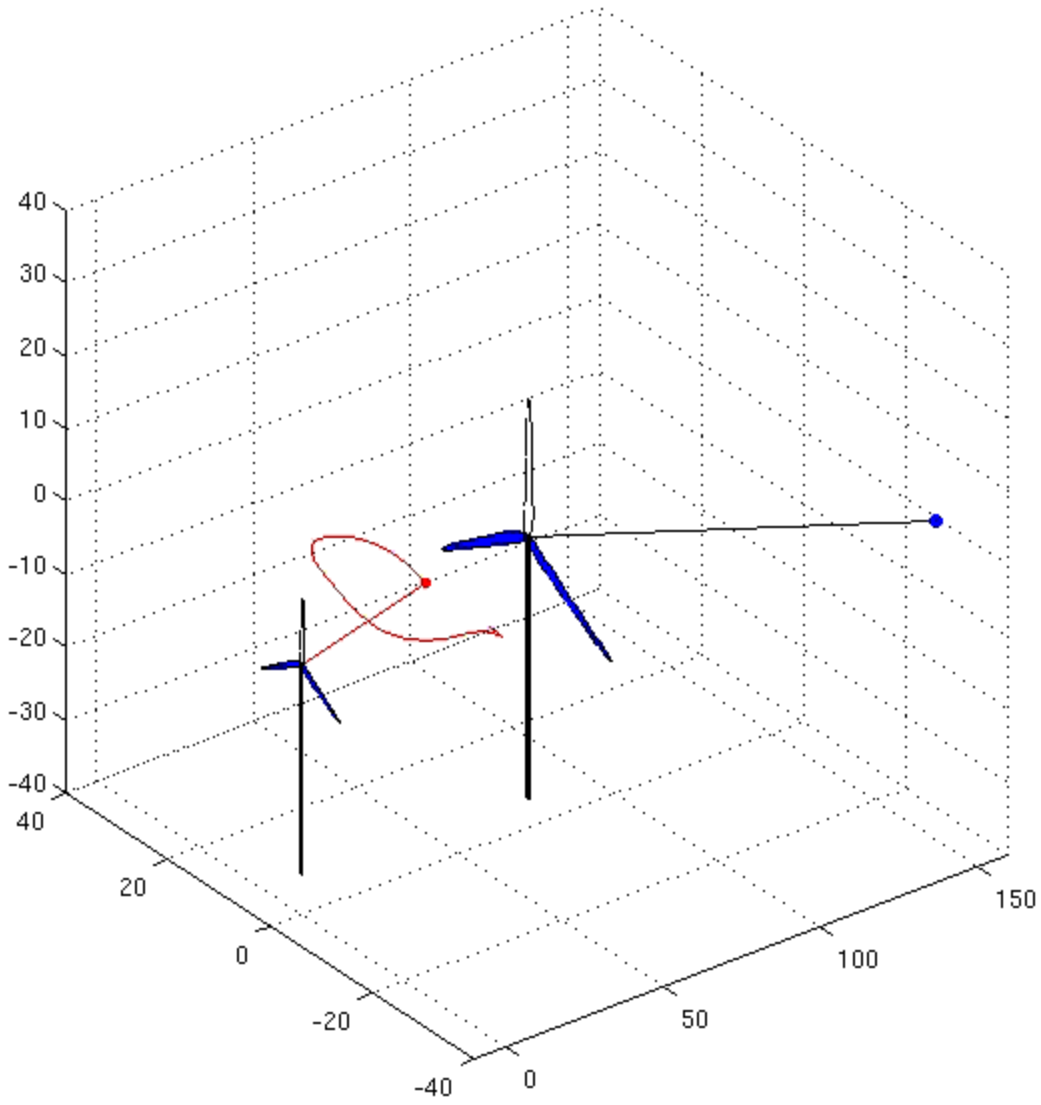
End
Thank you for your attention

2 – Merged experiment set up

Measurement phase completed - January to May 2013

Lidar	Mounting	Meas. Freq.	Focus distance	Sweep time	Meas. length total	Scanning pattern
ZephIR CW Lidar (proto.)	Nacelle of Tellus 95kW – wake scanning	Approx. 300Hz	40m	Approx. 6s	3844 datasets ≈ 27 days	
ZephIR Unit 351 Conical (proto.)	Top of nacelle Nordtank 500kW – forward scanning	Approx 50Hz	90m – 20m in DW	1s		
Spinner lidar DTU Wind Energy (proto.)	Nacelle of Nordtank 500kW – wake scanning	Normal 312Hz High freq 400Hz	40m 80m 120m 160m 200m	2s	Scanner: 152 GB Spectra: 2.4TB	

3D view



Merged Wake Experiment Post processor

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Data timestamp
Edit Text
format ('mmddHHMMSS')

Instantaneous time stamp
- -

Instantaneous
- ☐ Line-of-sight
- ☐ Deficit
- ☐ Hub height (overplot)
- ☐ Wake center
- ☐ Streamwise projection

10min averages
- ☐ Velocity contour
- ☐ Velocity at hub height (overplot)
- ☐ Turbulence at hub height (overplot)
- ☐ Streamwise turbulence contour

Loading status

Daqwin inflow	Loading...
SpinnerLidar	Loading...
Qinetiq	Loading...

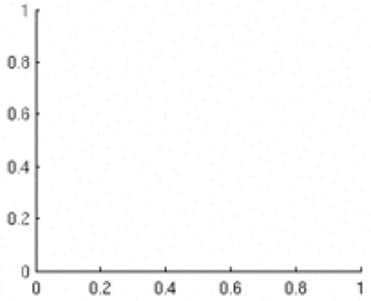
Mean inflow

Mean Wind Speed 34.5	-
Mean Wind Dir 34.5	-
Power Nordtank	-
Rotor yaw angle	-
WS Nacelle	-
Rotor speed (fast)	-
Focus	-
	-
Shear exponent	-
TI	-

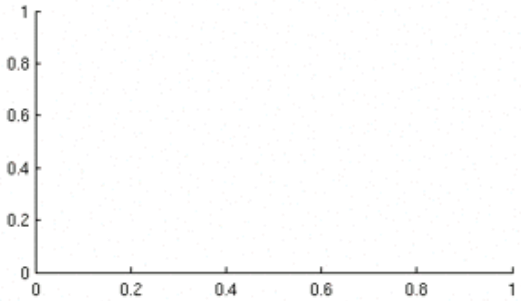
Instantaneous Inflow

Wind Speed 34.5	-
Wind Dir 34.5	-
Power Nordtank	-
Rotor yaw angle	-
WS Nacelle	-

ZephIR Lidar, Nordtank Inflow



Prototype Lidar, Tellus Wake



Spinner Lidar, Nordtank Wake