Detailed validation of dynamic loading simulation of offshore wind turbines operating in wake

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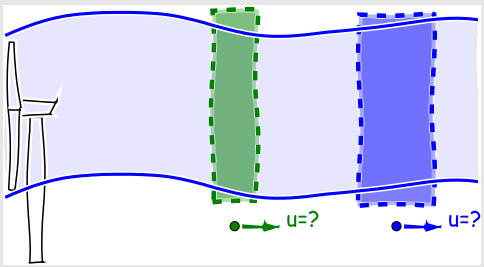
RAVE Offshore Wind R&D Conference
Bremerhaven, 13th of October, 2015

Talk overview

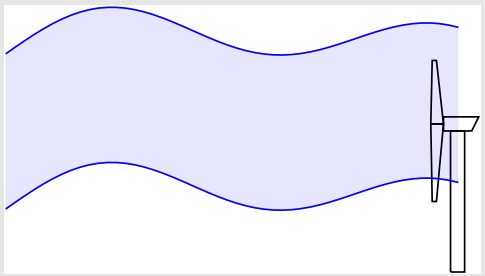
Wake meandering models

Large scale dynamics



Detailed inflow in wake

From long-range measurements



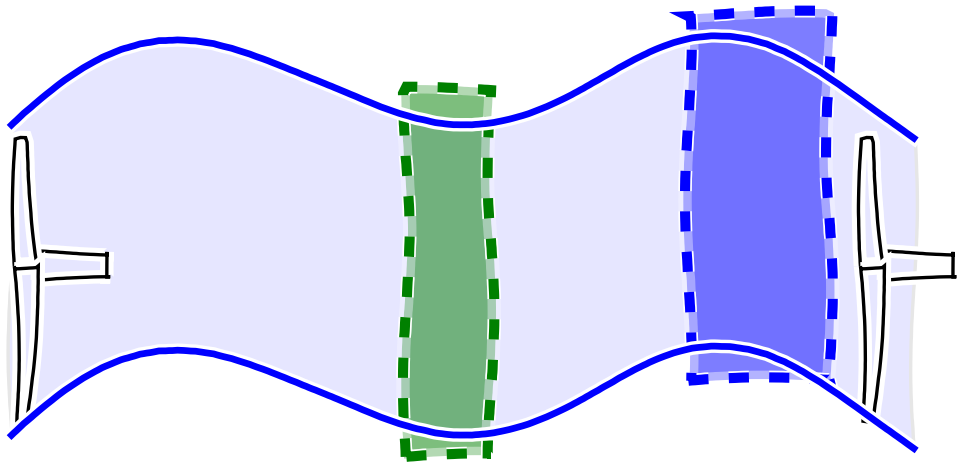
Fatigue loading in wake

Preliminary results application of detailed inflow for simulation with Flex5

What do we mean by detailed validation?

Objective

Provide detailed inflow in wake capturing large-scale dynamic effects



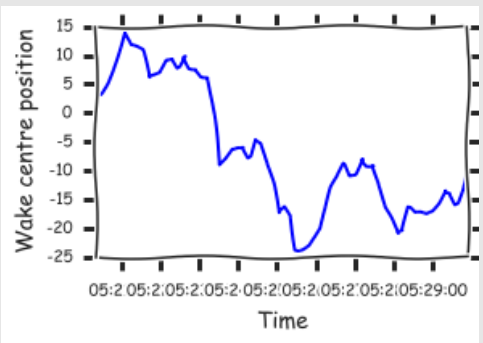
By which means?

- Long range lidar measurements
- Wake tracking techniques
- Wind field reconstruction techniques

Key parameters of meandering for simulation

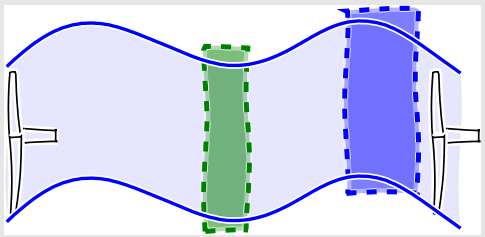
Wake meandering

Time series of transversal wake movement from wake tracking



Wake deficit

Wind speed estimated in the meandering frame of reference



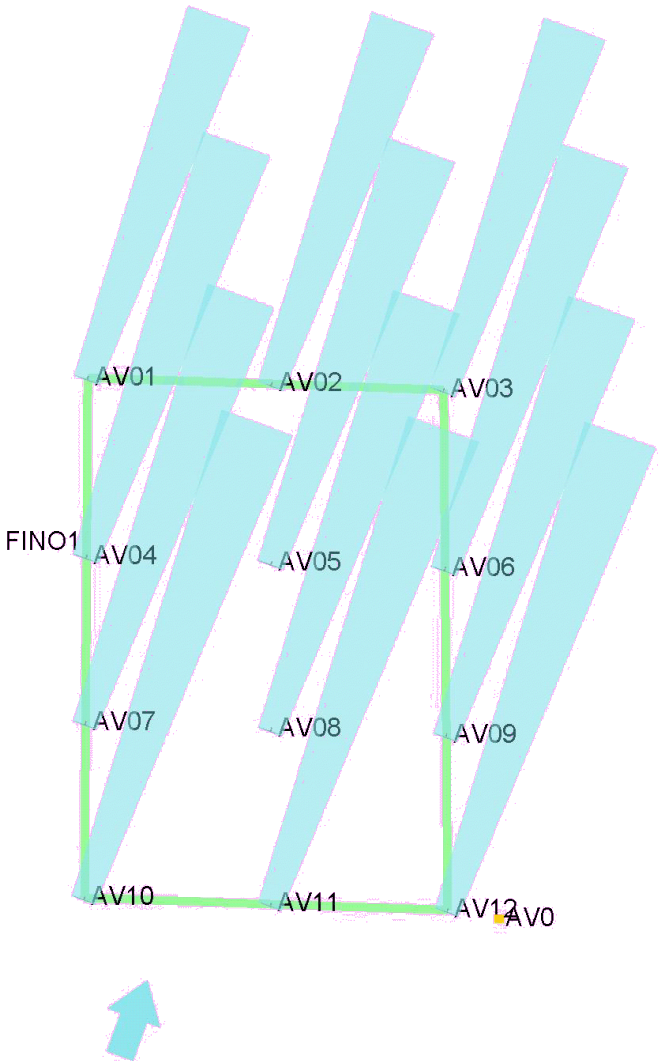
Wake turbulence

Turbulence in the meandering frame of reference not measured by the scanning pulsed lidar

Long range lidar campaign at alpha ventus
Experimental setup

Data sources

- Meteorological mast FINO1
- Leosphere Windcube 200s at FINO1 platform
- SCADA and load data at AV04



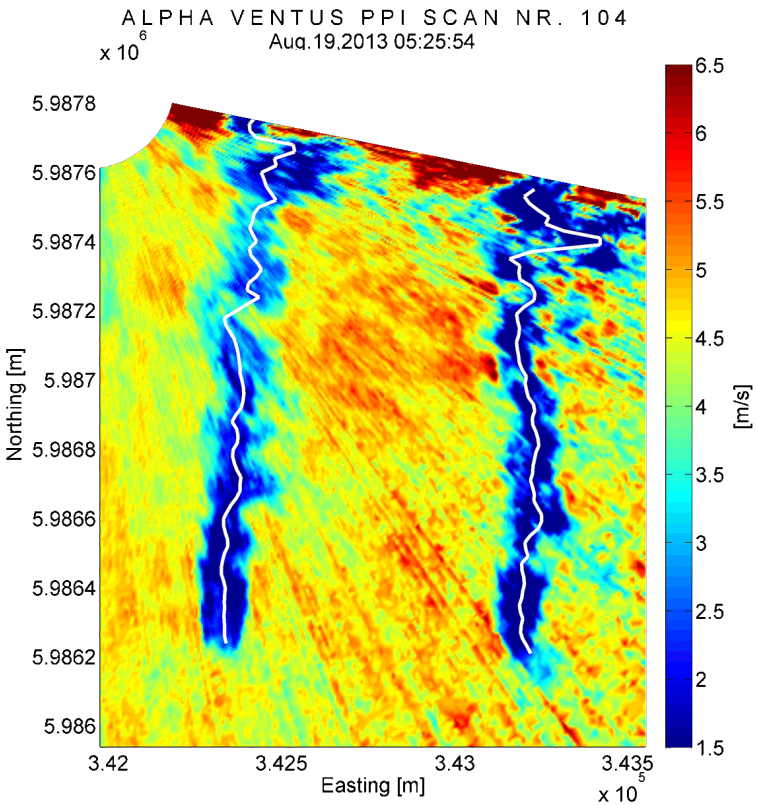
Long range lidar campaign at alpha ventus
Six-hour test case

Wind farm inflow conditions

- 19th August 2013 0:18h – 5:50h
- Southerly wind
- $u_o = 3.5\,\mathrm{m/s}$ to $6.5\,\mathrm{m/s}$
- $\phi_{wind} = 165\,^\circ$ to $185\,^\circ$

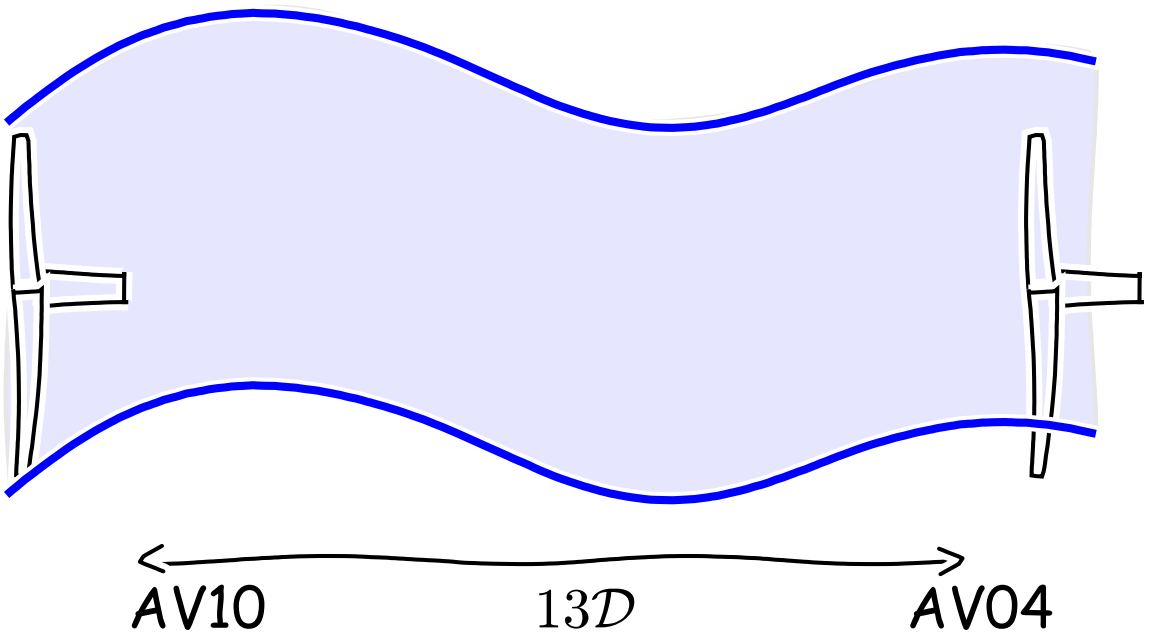
Lidar scanning

- Plan Peripheral Indicator (PPI)
- $3.4\,^\circ$ elevation angle from FINO1
- Scan time of 154 s

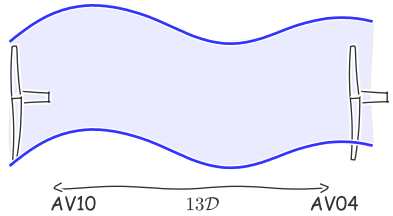


Six-hour test case
Single wake on AV04

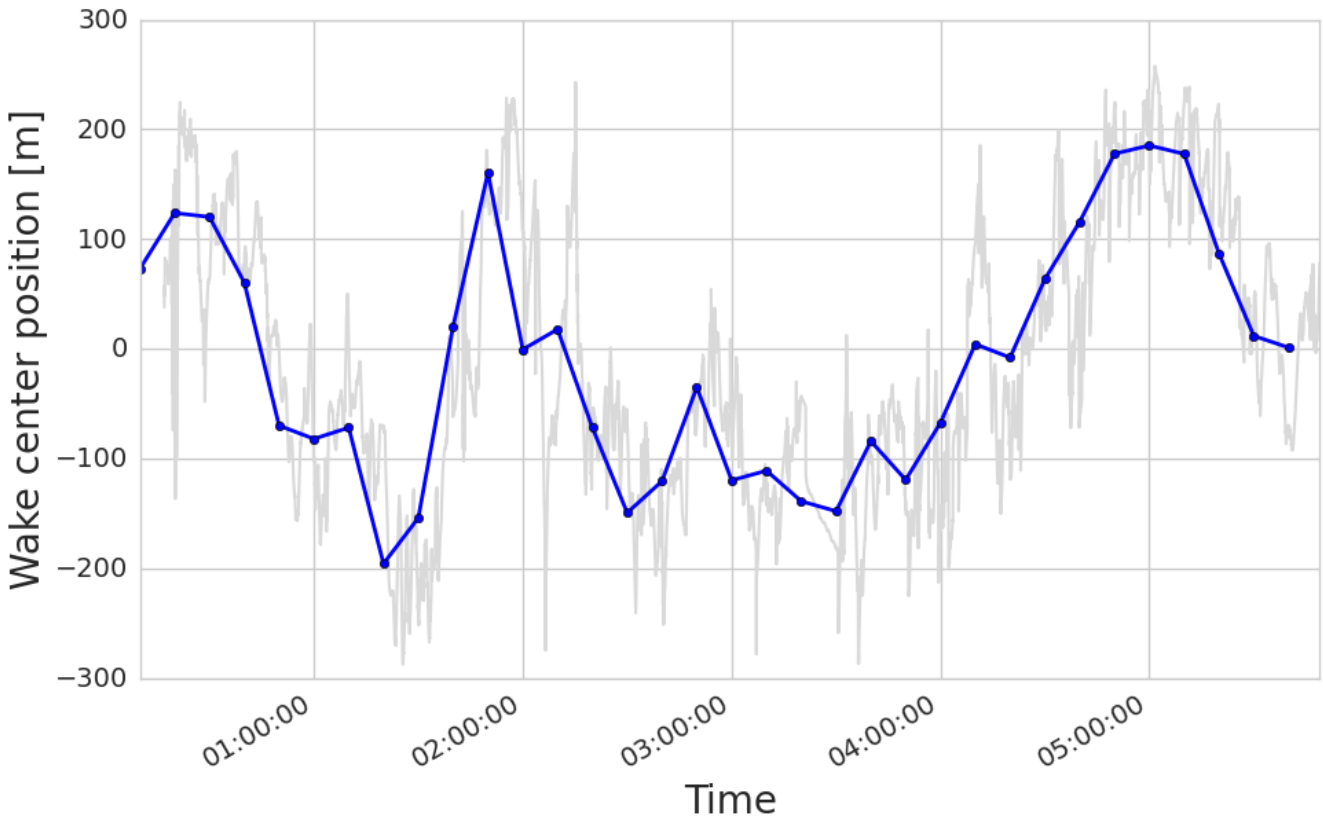
- Turbine AV04 experiences meandering single wake from AV10
- Downstream distance approx. $13\mathcal{D}$ ($\mathcal{D}$: rotor diameter)
- FINO1 platform remains *unaffected*



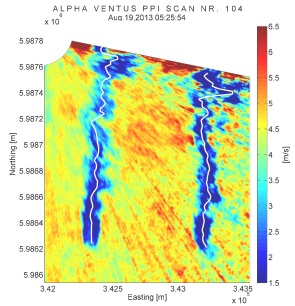
Six-hour test case
Wake position time series $2\mathcal{D}$ in front of AV04



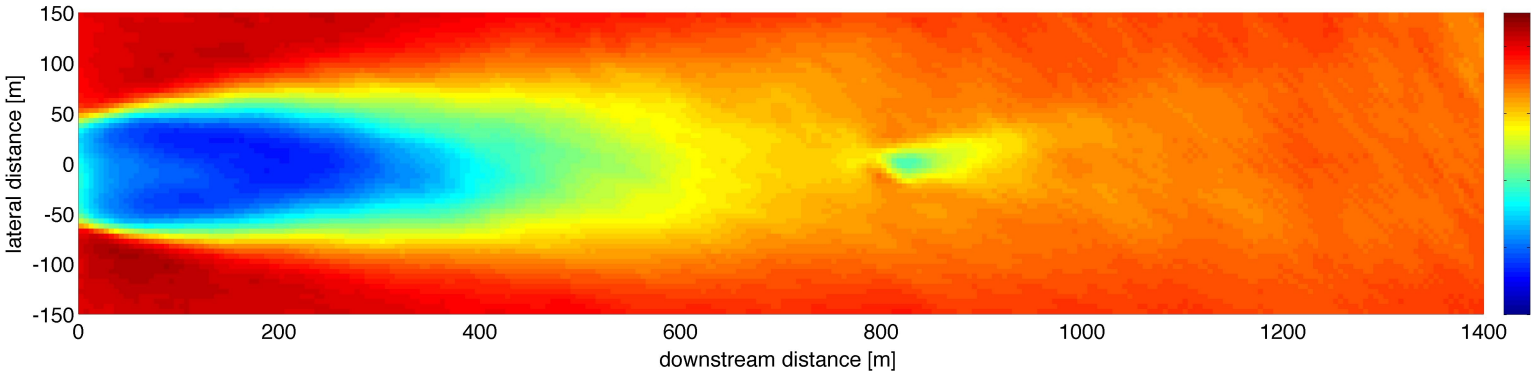
- Wake tracking with Gaussian fit and gradient methods
- Over-sampling via reconstruction with a passive advection method



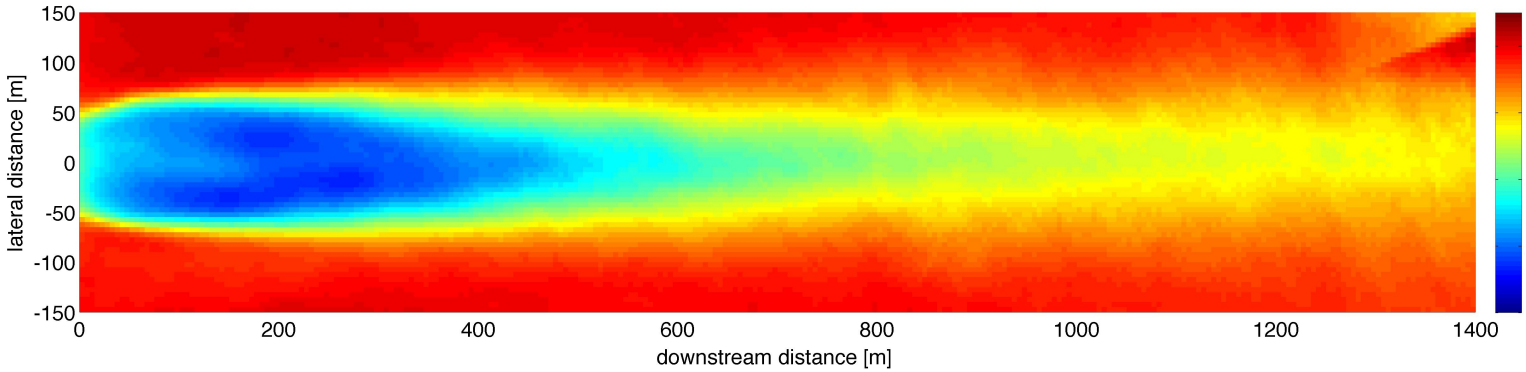
Six-hour test case
Wake of AV10 estimated from lidar measurements



Fixed frame of reference

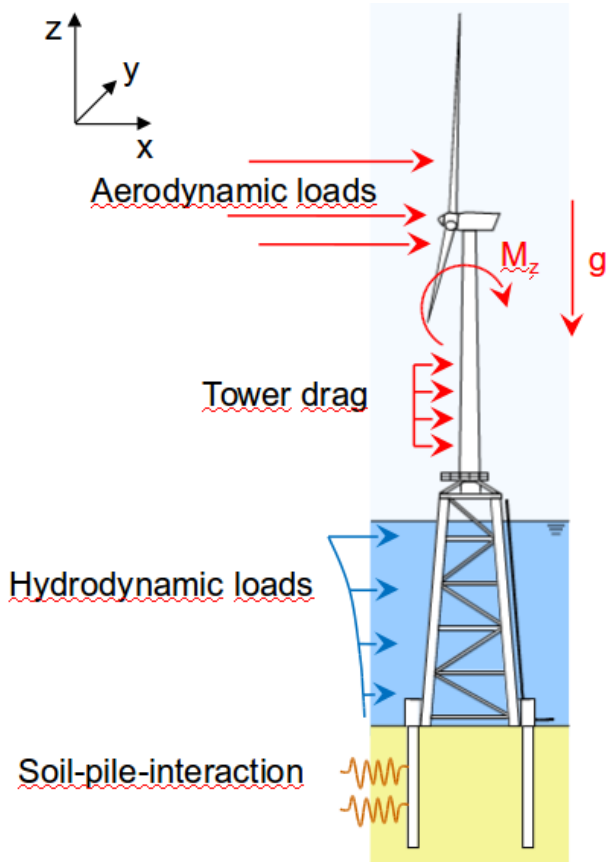


Meandering frame of reference



Six-hour test case
Simulation experiment of AV04

- Flex5 + Poseidon
  - Integrated approach
  - Coupled turbine, substructure and foundation model
  - Validated model of AV04[1]
- Inflow conditions for six hours
  - Free
  - Frandsen effective turbulence
  - Lidar meandering (detailed)
  - DWM dynamic wake meandering
  - EDPM extended disk particle

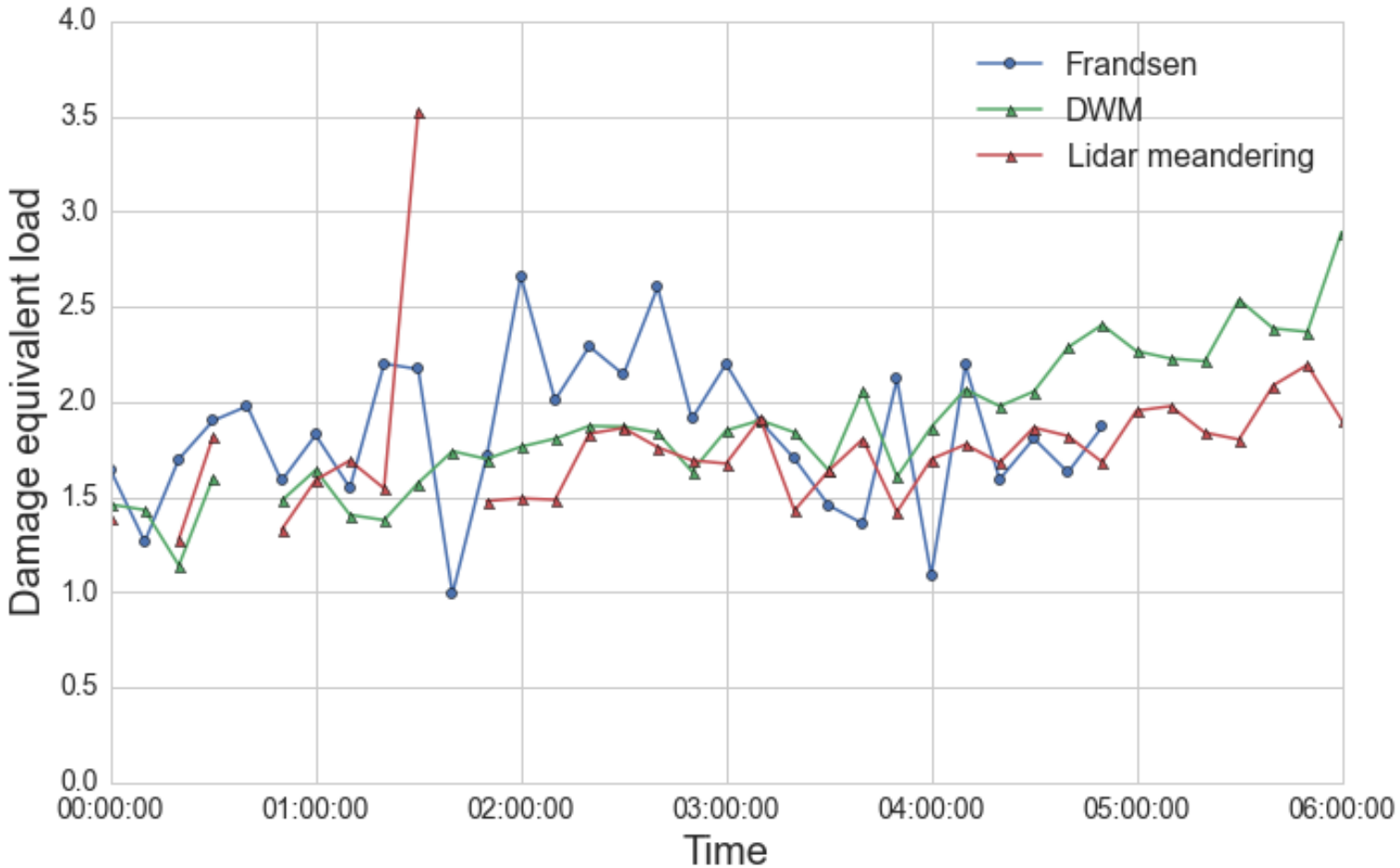


[1] D. Kaufer et al. "Validation of an Integrated Simulation Method with High Resolution Load Measurements of the Offshore Wind Turbine REpower 5M at Alpha Ventus." 23rd International Offshore and Polar Engineering Conf.

Six-hour test case

Preliminary damage equivalent loads – Tower bottom bending moment

Damage equivalent loads normalised with respect to free conditions



Conclusions & Outlook

Conclusions

- Long range lidar measurements provide unique data for validation of wake meandering models.

- Added turbulence and vertical meandering can not be obtained by this setup, therefore assumptions have to be made.

Outlook

- Analysis of fatigue loads from the aero-elastic simulations and comparison against measurements

Acknowledgements

We would like to thank Senvion for the access to the wind turbine data and the permission to perform the simulations of the wind turbine AV04.

This research was carried out in the frame of the RAVE (Research at Alpha Ventus) projects «OWEA Loads»and «GW Wakes», funded by the German Federal Ministry for Economic Affairs and Energy (BMWi) based on a decision of the Parliament of the Federal Republic of Germany (grant numbers 0325577B and 0325397A, respectively).

Federal Ministry for Economic Affairs and Energy