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# A test case of meandering wake simulation with the Extended-Disk Particle model at alpha ventus

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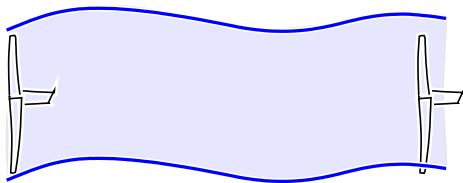


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# Why do we care about large-scale wake dynamic models?

The wake deficit sweeping in front of the turbine affects its performance



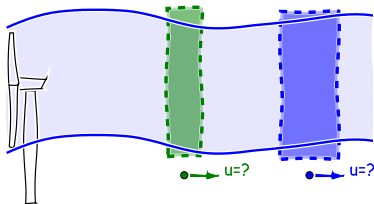
## Areas of application

- Fatigue loads
- Wind farm control

# How does the EDPM approaches the meandering problem?

## Summary

Discrete volumes (extended disks) advect downstream independently and make up the meandering flow



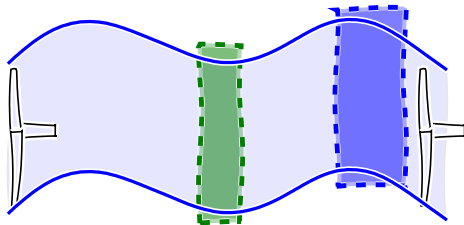
## Main characteristics

- Passive advection of the disks
- The disks *contain/transport* a mean wake deficit
- and also wake turbulence

# We aim a detailed validation of meandering models

## Objective

Perform direct validation of the main assumptions of meandering models



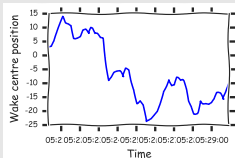
## By which means?

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

# Key parameters of meandering simulation

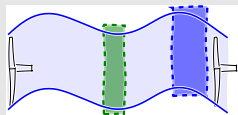
## Wake meandering

Time series of transversal wake movement from wake tracking



## Wake deficit

Wind speed estimated in the meandering frame of reference



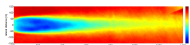
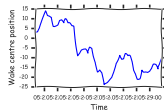
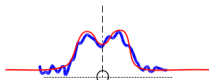
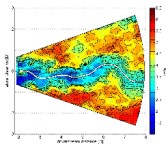
## Wake turbulence

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

# Summary of lidar data processing

## Capturing large scale wake movements

1. Lidar wake measurements
2. Wake tracking by fitting axi-symmetrical template
3. Time series of wake position at a downstream station
4. Stacking aligned wake profiles  $\rightarrow$  Wake in meandering frame of reference

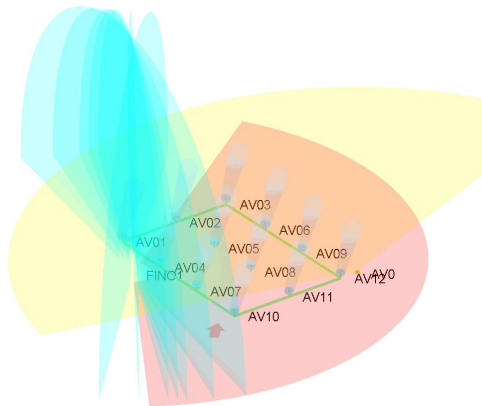


# Long range lidar campaign at alpha ventus

## 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

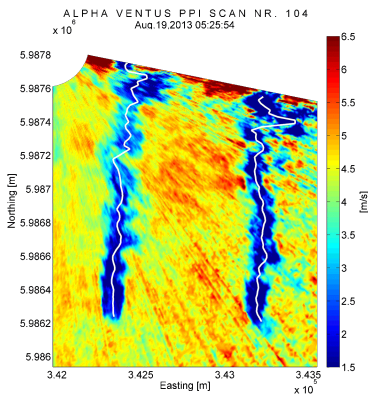
## Six-hour test case

### Wind farm inflow conditions

- 19th August 2013 0:18h – 5:50h
- Southerly wind
- $u_o = 3.5$  m/s to 6.5 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

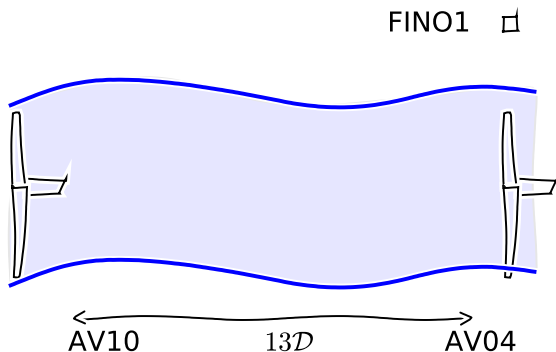




## Six-hour test case

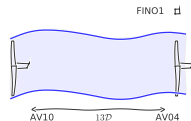
### Single wake on AV04

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

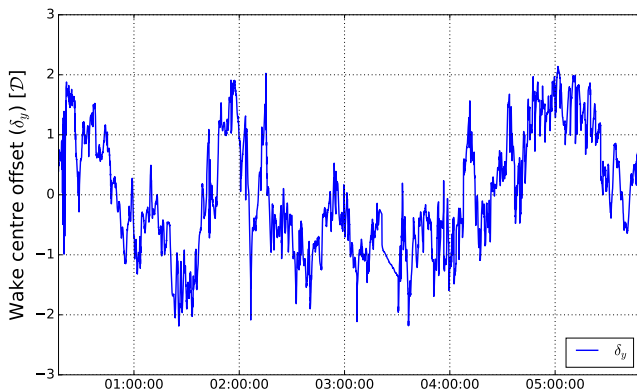


# Six-hour test case

## Wake position time series $2D$ in front of AV04

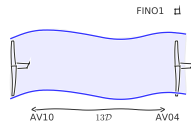


- Wake tracking with fit of Gaussian template function
- Over-sampling via reconstruction with a passive advection method

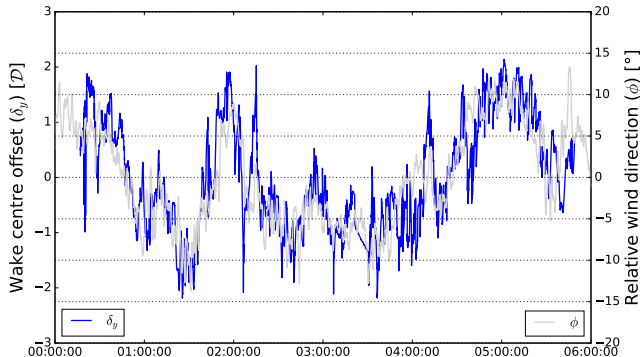


# Six-hour test case

## Wake position time series $2D$ in front of AV04

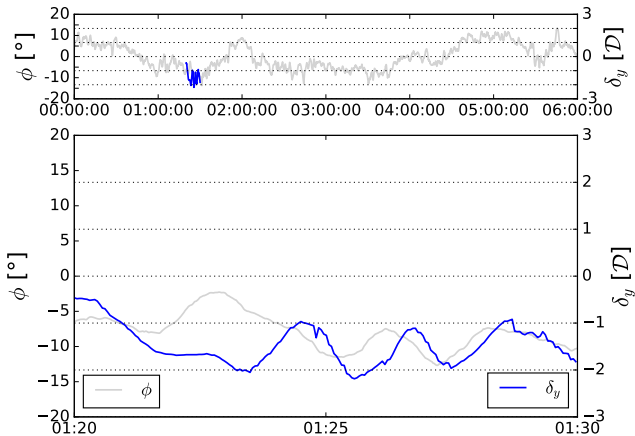
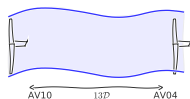


- Wind direction from ultrasonic anemometer at 40m (FINO1)
- Low-pass filter with an approximate  $2D$  length scale



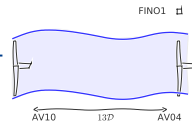
# Six-hour test case

## Wake position time series $2D$ in front of AV04

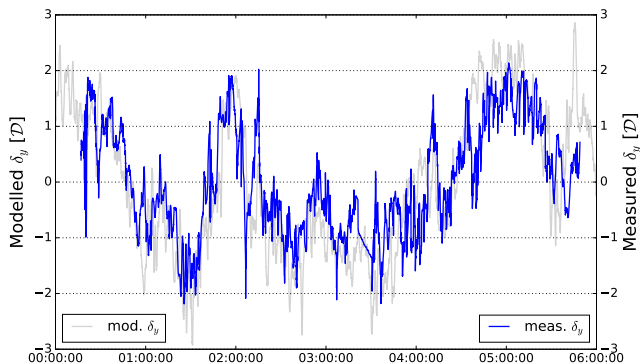
FINO1 

# Six-hour test case

## Modelled wake position time series $2D$ in front of AV04

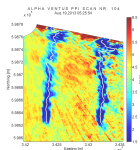


- Straight advection with identical initial conditions as at FINO1
- $RMSE = 0.78D$

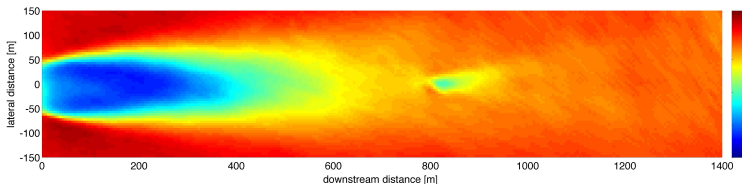


# Six-hour test case

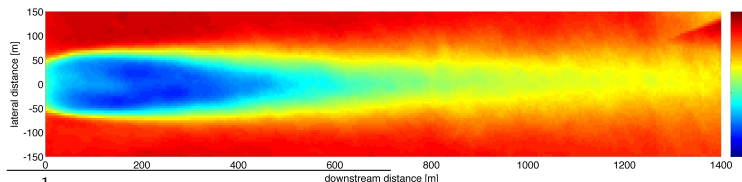
## Wake of AV10 estimated from lidar measurements<sup>1</sup>



### Fixed frame of reference



### Meandering frame of reference

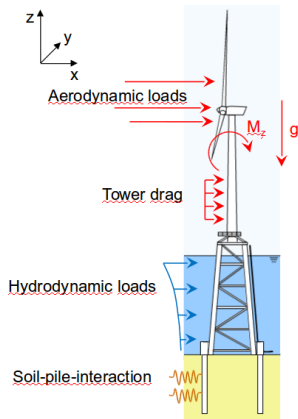


<sup>1</sup>H. Beck et al., "Analysis of wake sweeping effects based on load and long-range lidar measurements." German Wind Energy Conference – DEWEK, Bremen, 2015.

# Six-hour test case

## Planned simulation experiment of AV04

- Flex5 + Poseidon
  - Integrated approach
  - Coupled turbine, substructure and foundation model
  - Validated model of AV04<sup>2</sup>
- Inflow conditions for six hours
  - Free
  - Frandsen effective turbulence
  - Constrained to lidar meas.
  - DWM proxy
  - EDPM extended disk particle



<sup>2</sup>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.

# Final remarks

## Preliminary observations

- Long range lidar measurements provide unique data for direct validation of wake meandering models.
- Preliminary results suggest an acceptable correlation of lateral wake position estimated by simplified EDPM and by lidar wake tracking

## Outlook

- Analysis of fatigue loads from the aero-elastic simulations with meandering models 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.

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