Variations in offshore wind turbine wake profiles with different inflow conditions for non-wake-affected upstream wind

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EMS & ECAC 2014
8th October 2014

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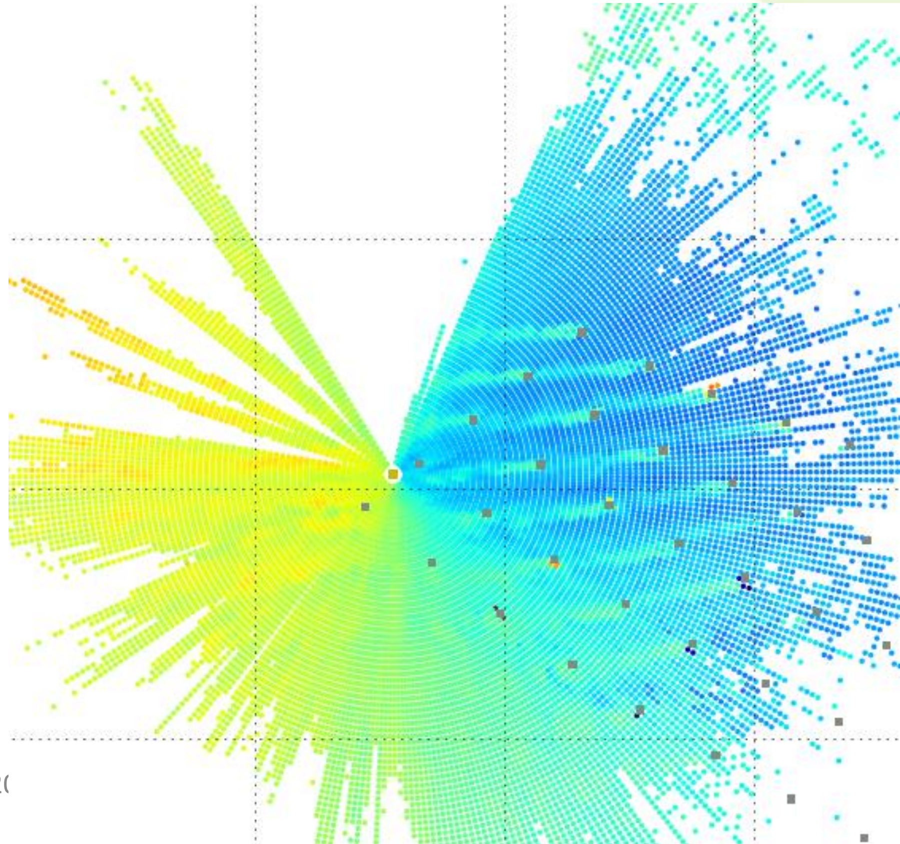
Presentation overview

- Introduction
- Case Study
  - Instrumentation setup
  - Lidar beam geometries
  - Method/Procedure
- Results
- Conclusion



Introduction – Wakes (1)

- Turbulence & momentum deficit
- Characterised by environment/atmospheric conditions & turbine design

- Physics & fluid mechanics
- Effects on local climates
- Structural engineering
- Energy - energy efficiency/maximisation
- Economic/financial

Introduction – Wakes (2)

- Wake behaviour and their response to different environmental/atmospheric conditions
- Interaction with ABL
- Improve wake modelling, wind farm designs, turbine/blade designs

- Lots of wake modelling & small scale studies
  - Model validations, comparisons
- Quite a few full scale wake studies

Case study (1)

- Part of a three phase project
  - **Experimental**
  - Modelling
  - Comparison/validation

- Based on one of the projects from TCT's Offshore Wind Accelerator (OWA) programme
  - Research development and demonstration
  - Study of wake effects

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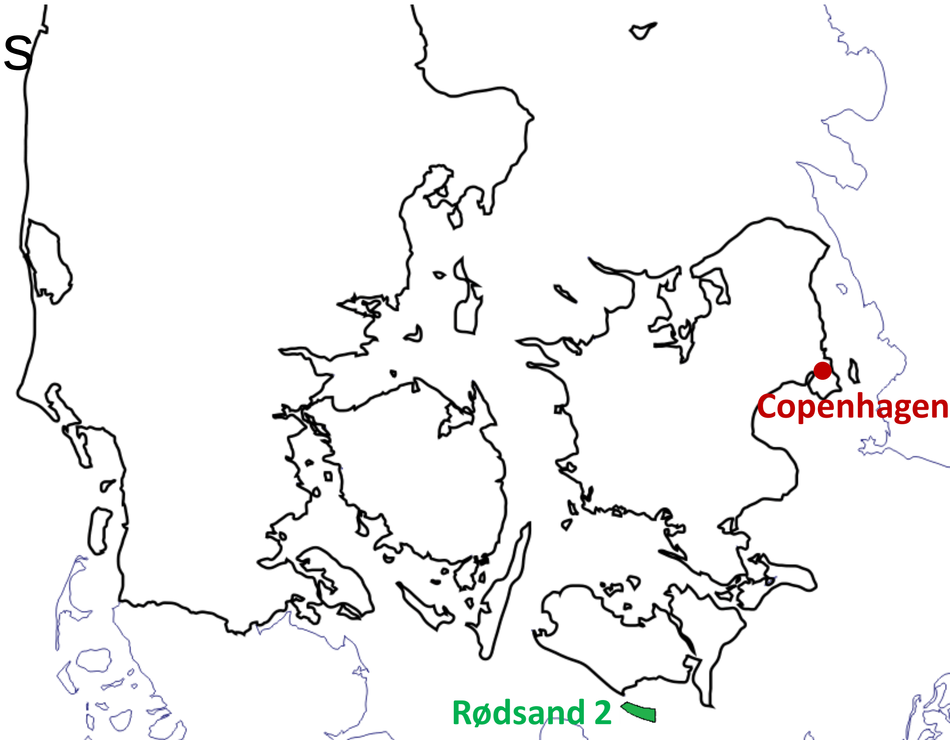
Case study (2)
TCT's OWA

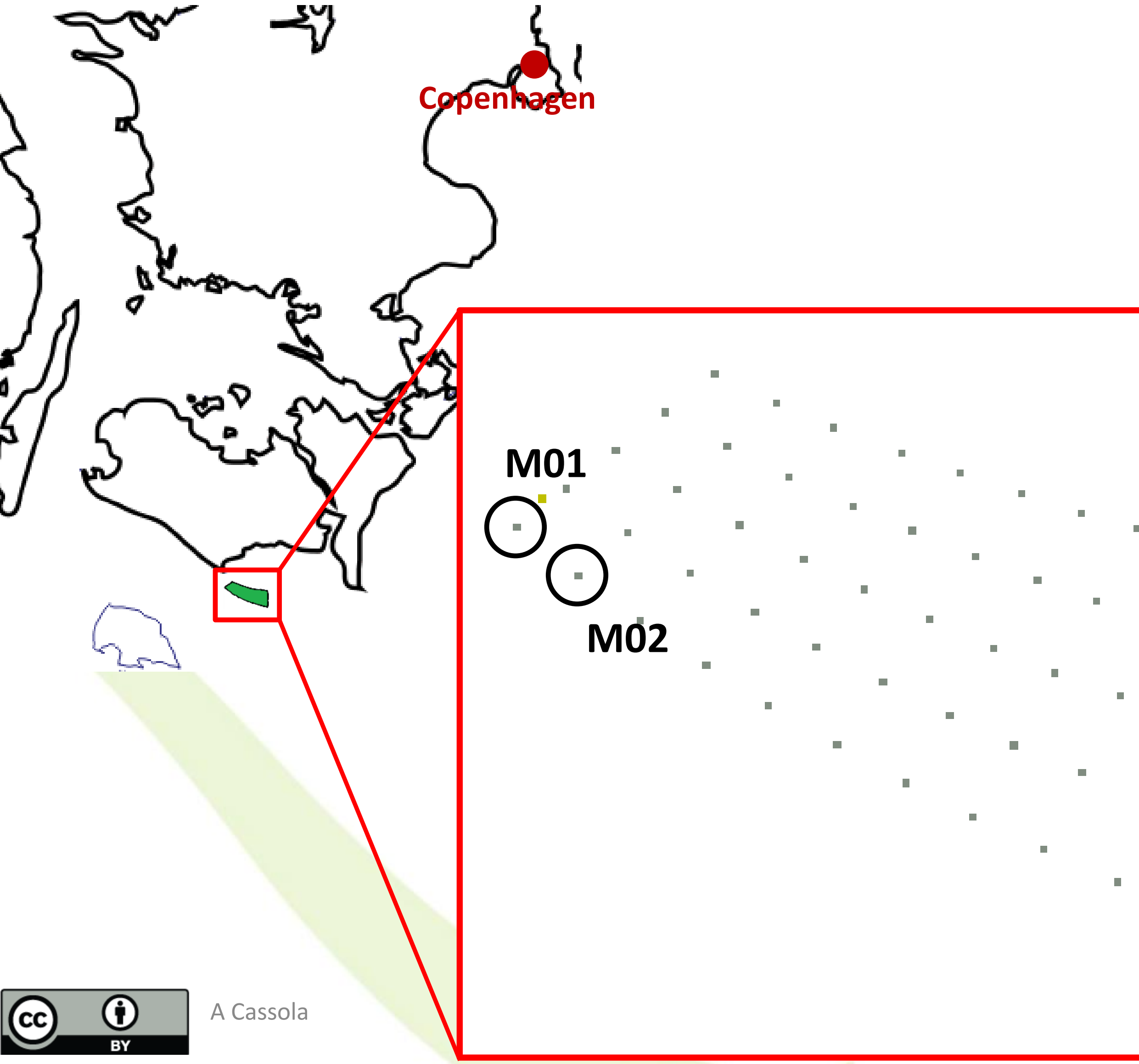
Case study (3)
Setup of instruments

- Part of the OWA study involved using remote sensing lidars on two wind turbines on Rødsand 2 offshore farm
  - Lidars measuring upstream and downstream wind of two neighbouring turbines



Case study (4)

Setup of instruments

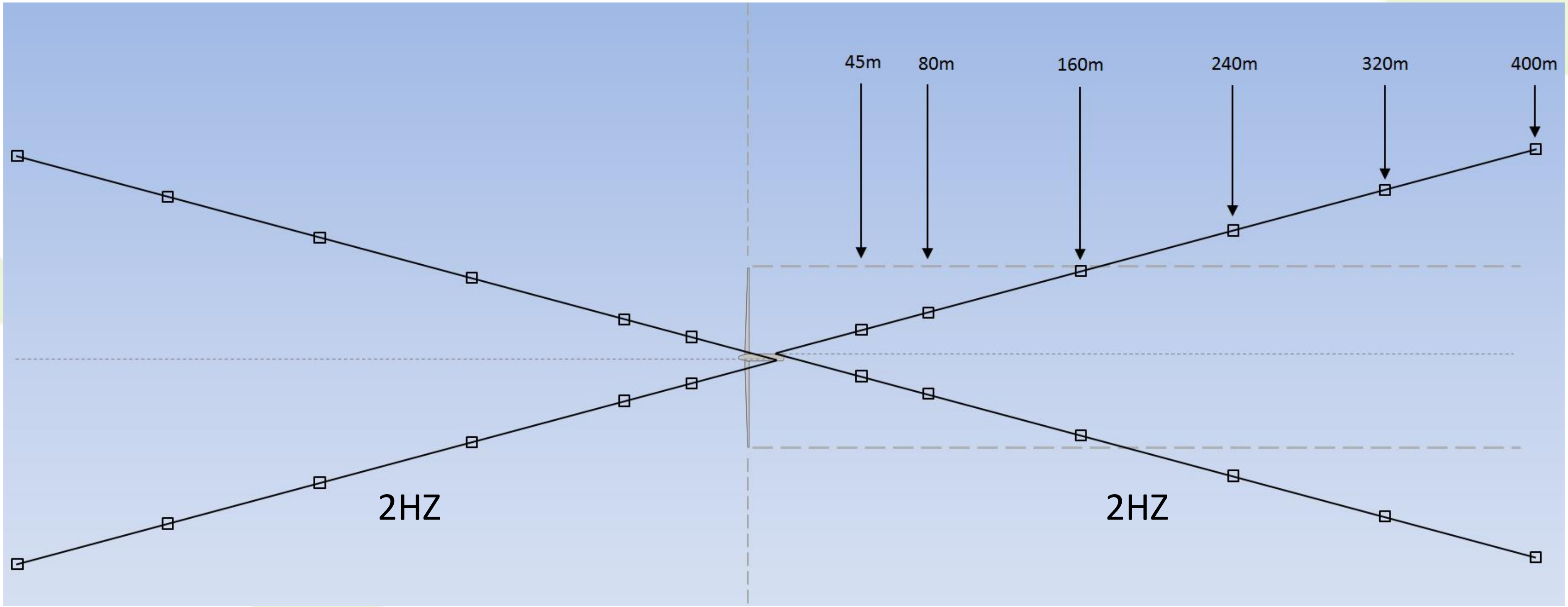


Case study (5)

- Opportunity to look at wind speed profiles through the two wind turbines
  - upstream
  - downstream
- Particular attention to oncoming wind conditions
  - wind speed
  - turbulence intensity
- Free stream wind case
- No external data except turbine yaw angles
- Lidar data @ 2Hz – short period with aft lidars @ 4Hz

Case study (6)

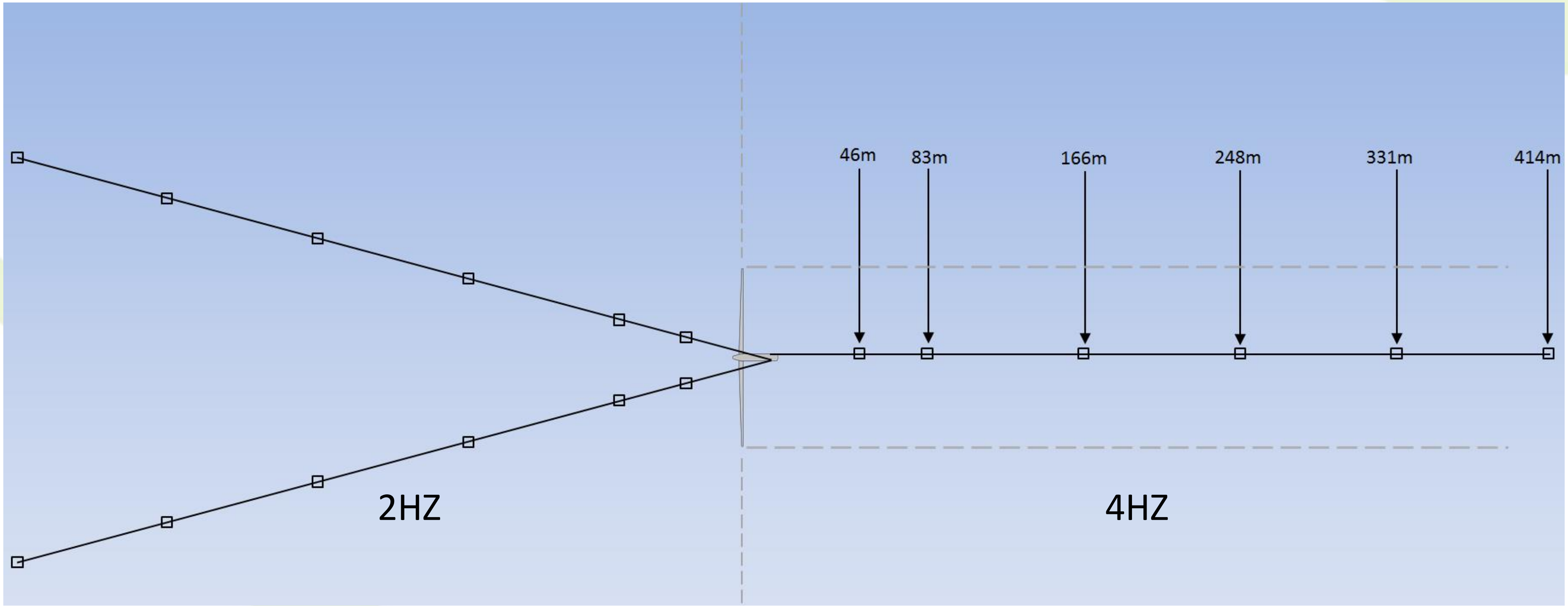
- Beam geometries
  - Two-beam aft lidar



☐ = range gate location

Case study (7)

- Beam geometries
  - Single-beam aft lidar

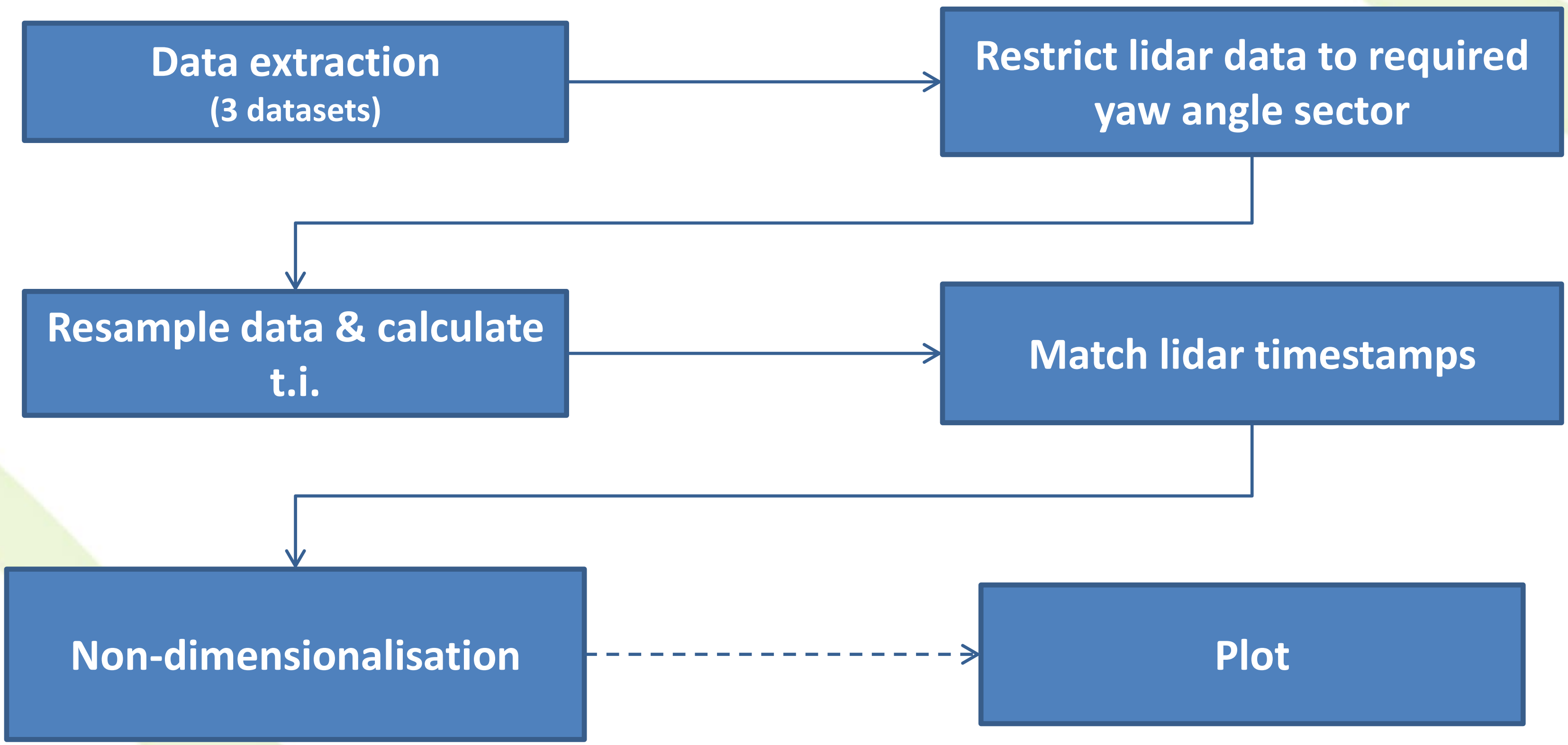


□ = range gate location

Case study (8)

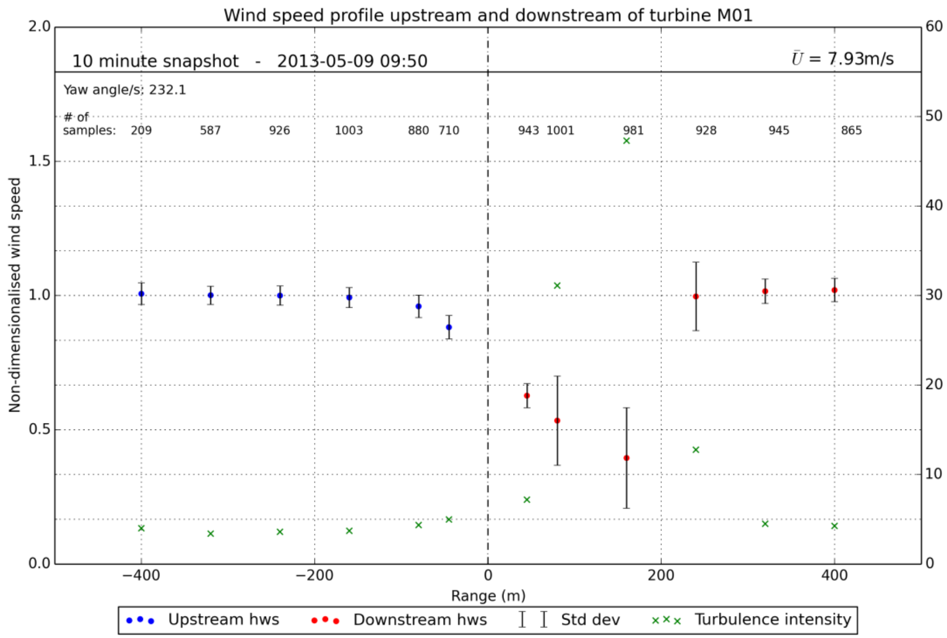
Method

- Data manipulation process



Results (1)

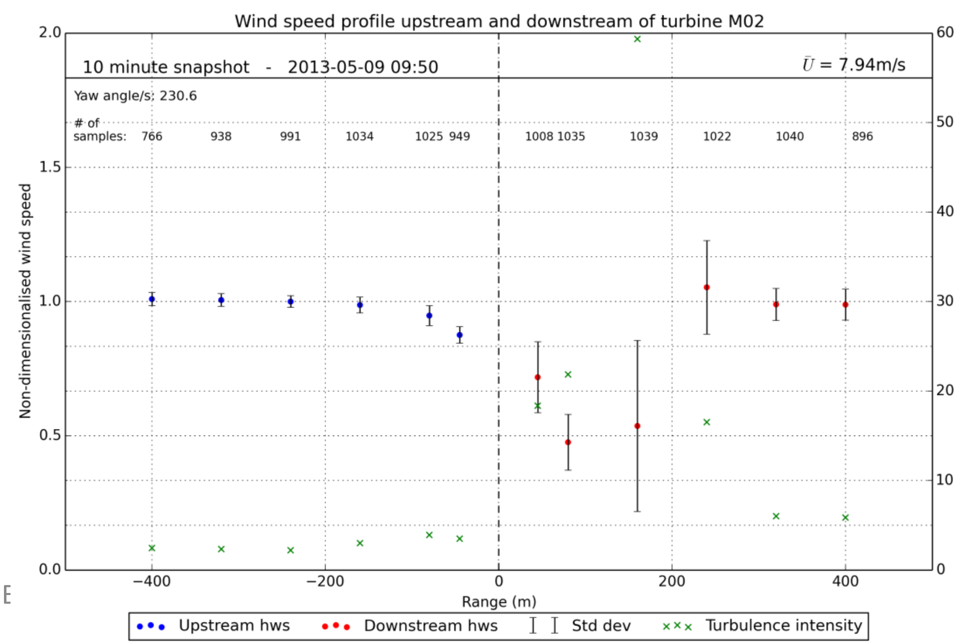
Wind speed profiles – **two beam** aft lidar



M01

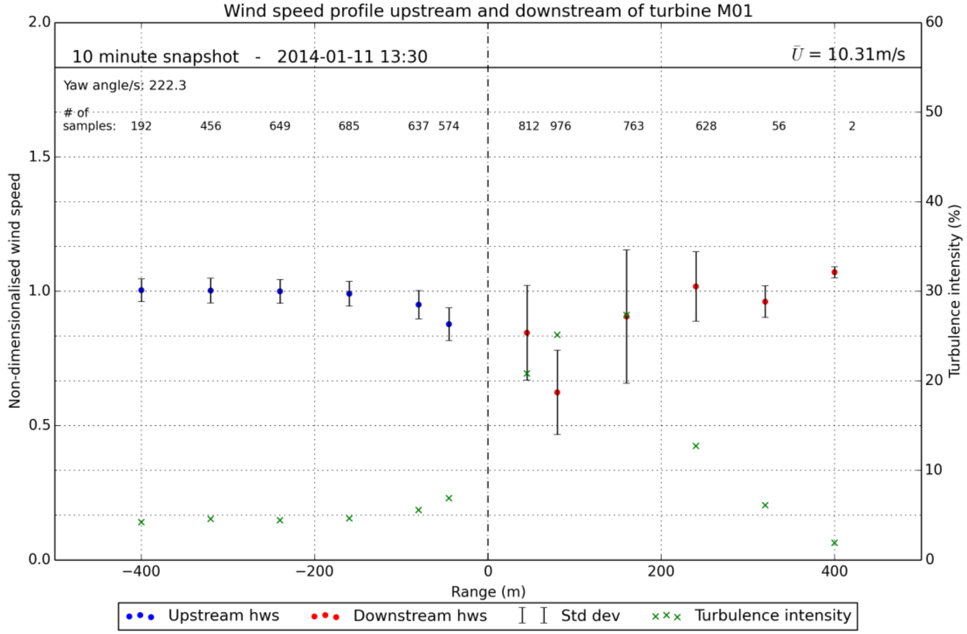
Upstream wind speed ~8 m/s

M02



Results (2)

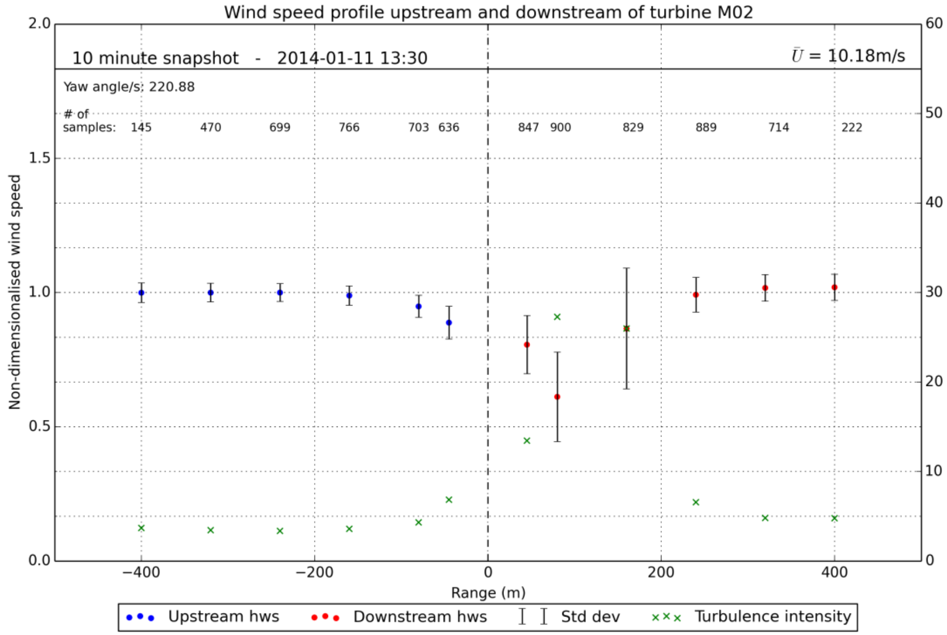
Wind speed profiles – **two beam** aft lidar



M01

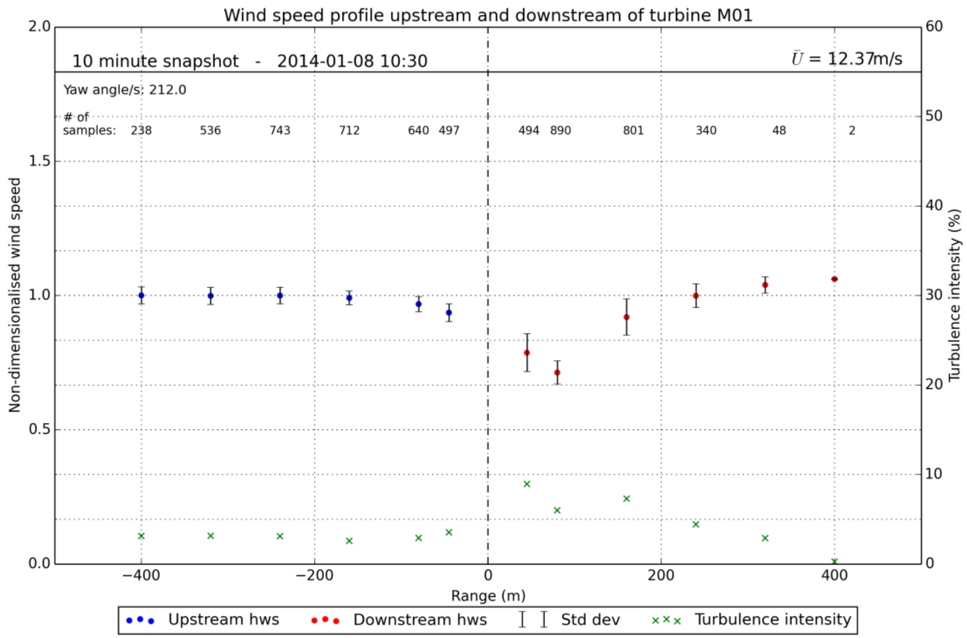
Upstream wind speed ~10 m/s

M02



Results (3)

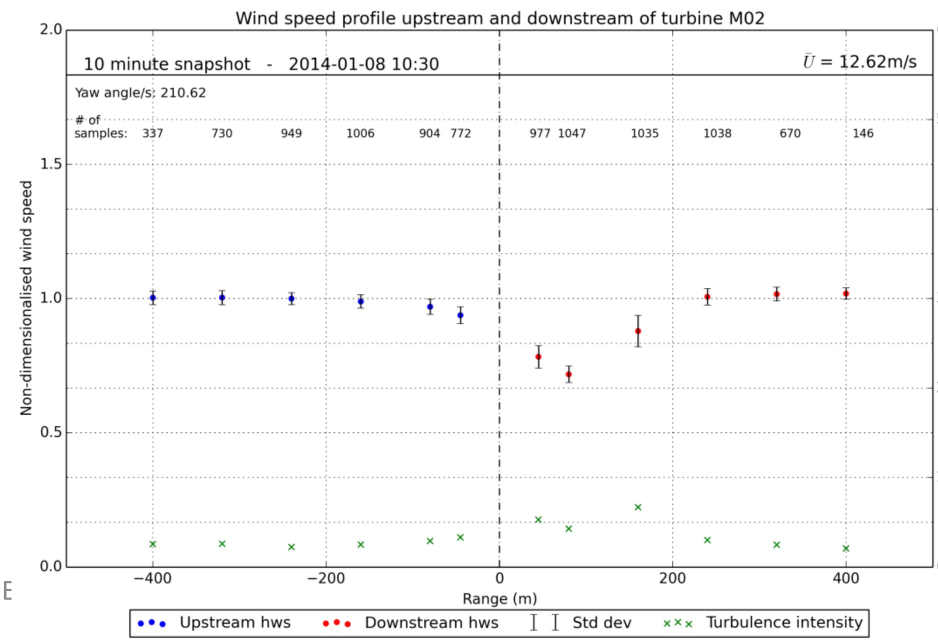
Wind speed profiles – **two beam** aft lidar



M01

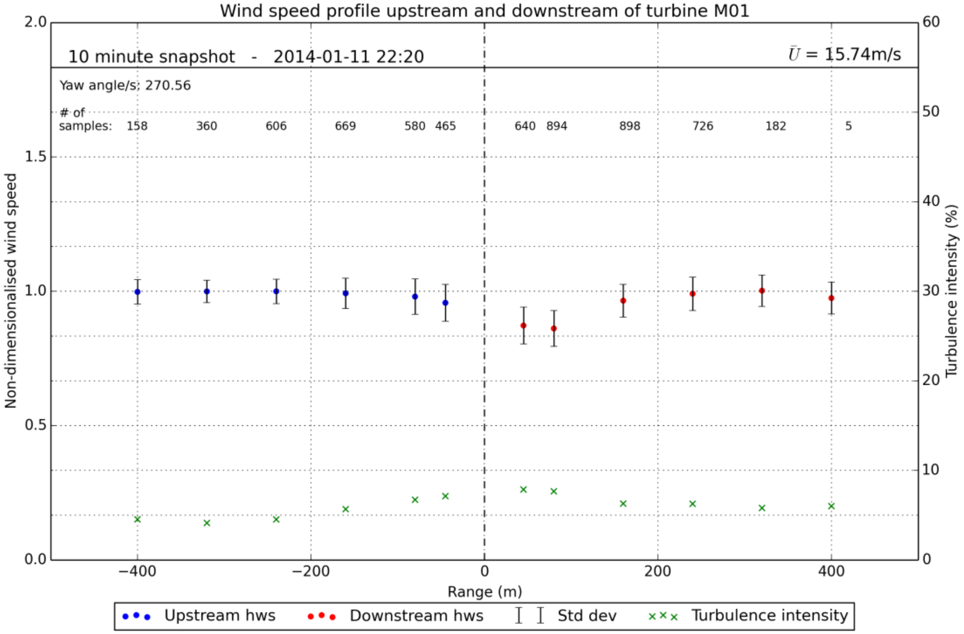
Upstream wind speed ~12-13 m/s

M02



Results (4)

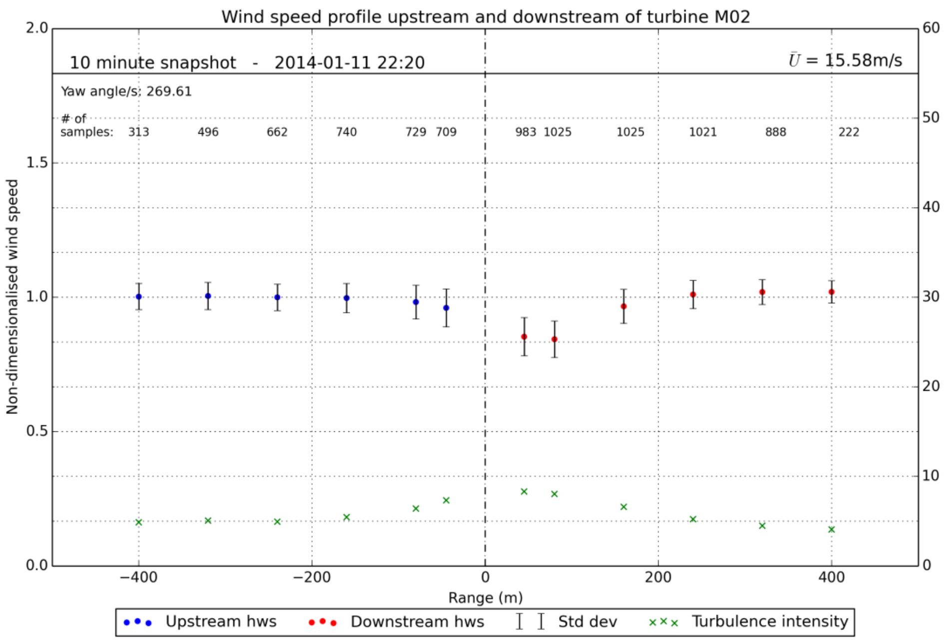
Wind speed profiles – **two beam** aft lidar



M01

Upstream wind speed ~15-16 m/s

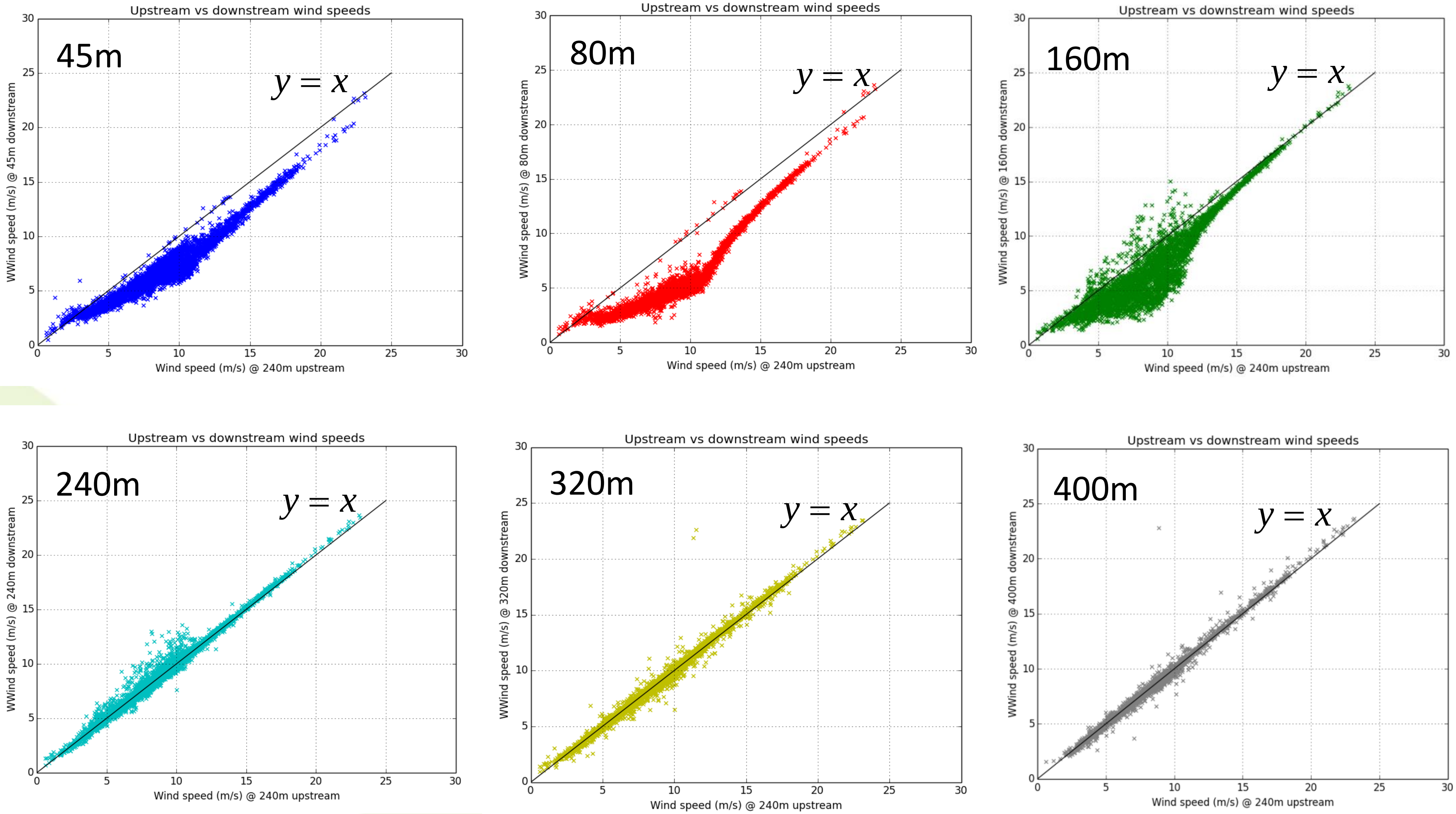
M02



Results (5)

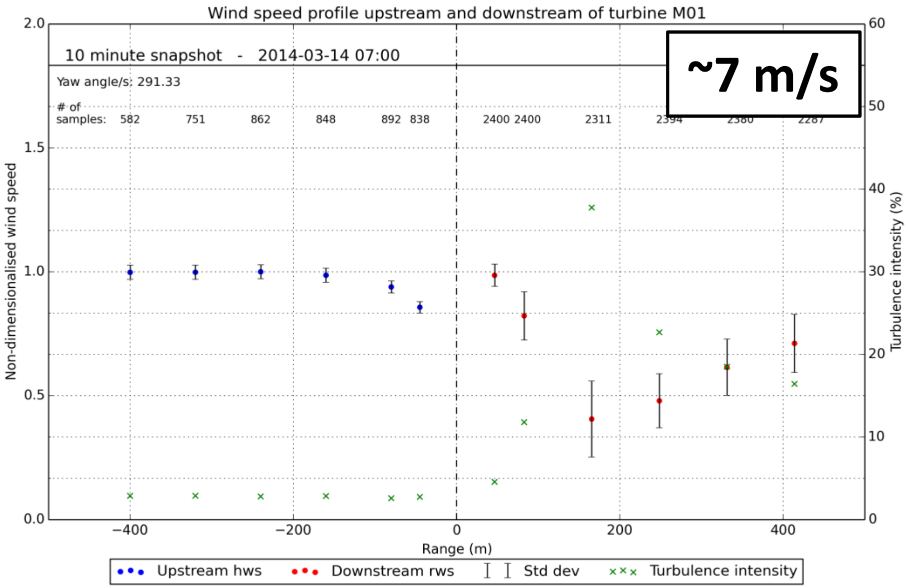
Upstream (@240m) vs downstream wind speeds

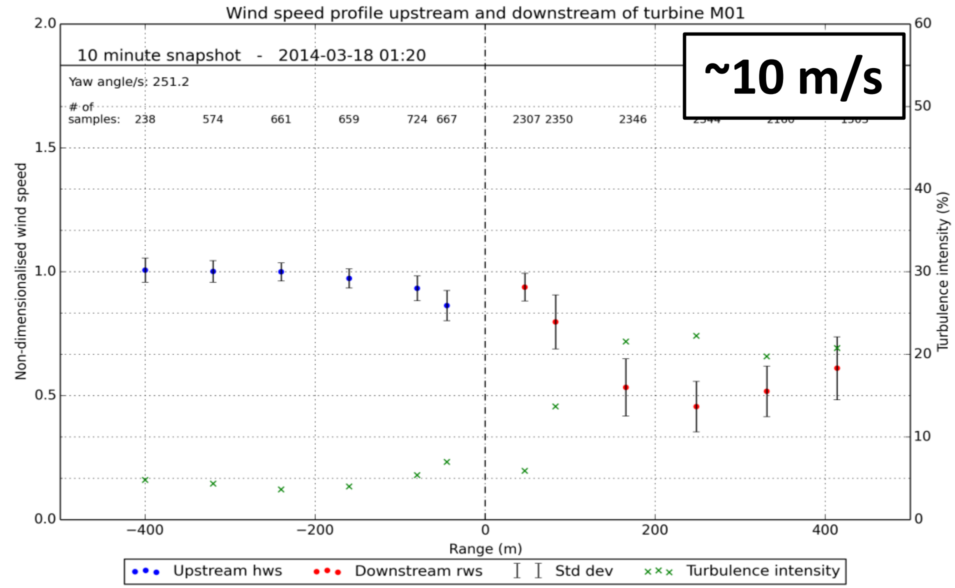
Two beam aft configuration

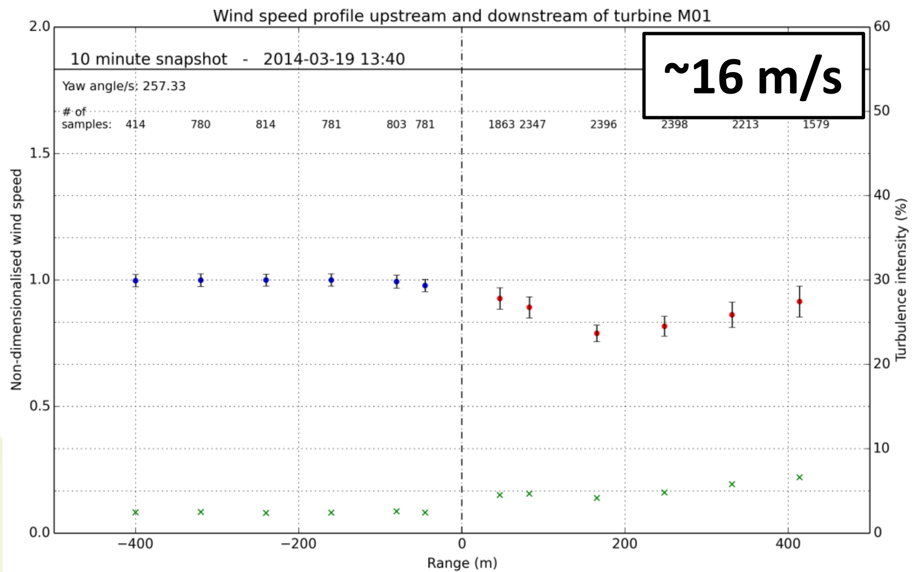


Results (6)

Wind speed profiles – **single beam** aft lidar



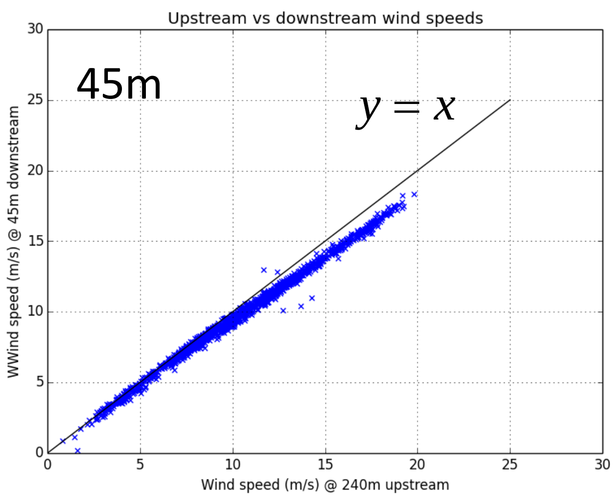


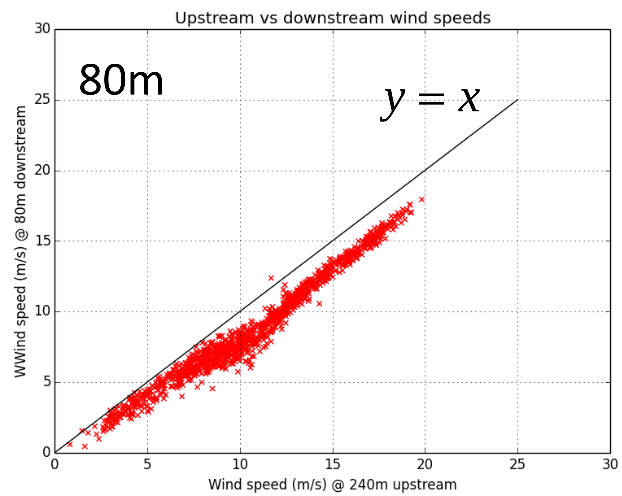


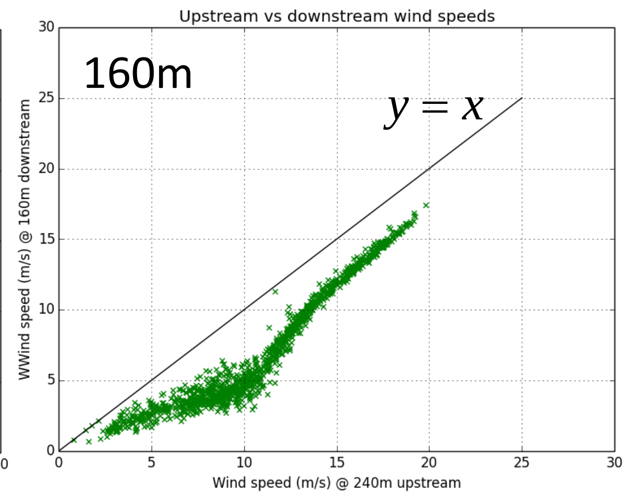
Results (7)

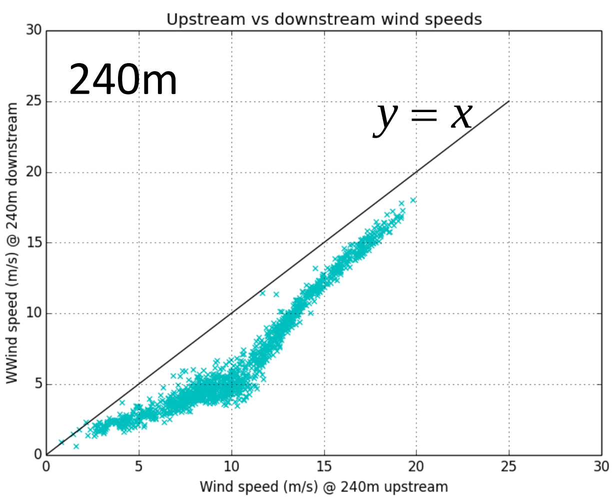
Upstream vs downstream wind speeds

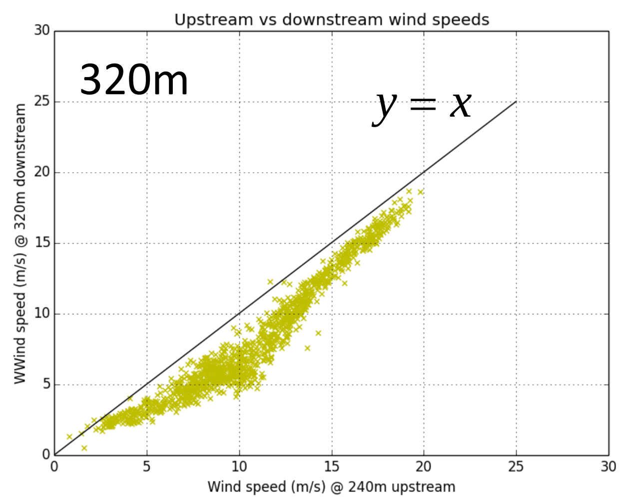
Single beam aft configuration

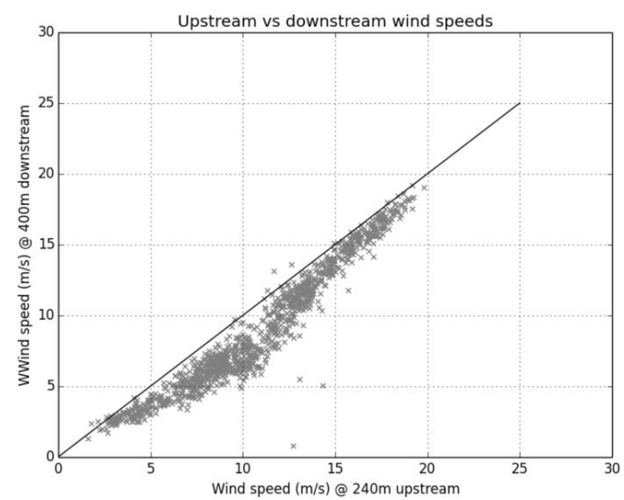






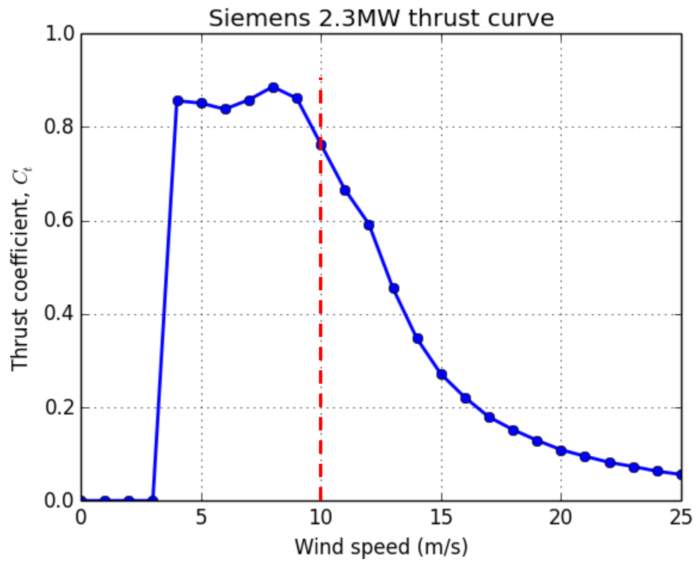


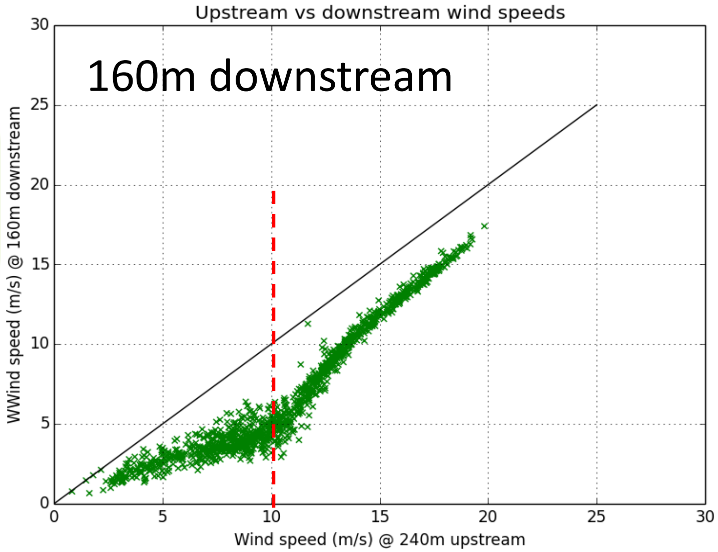


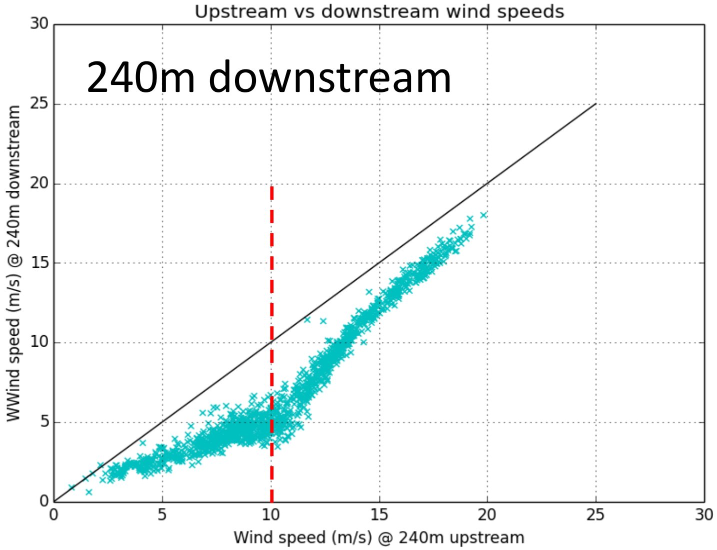


Results (8)

Downstream wind speeds & thrust curve

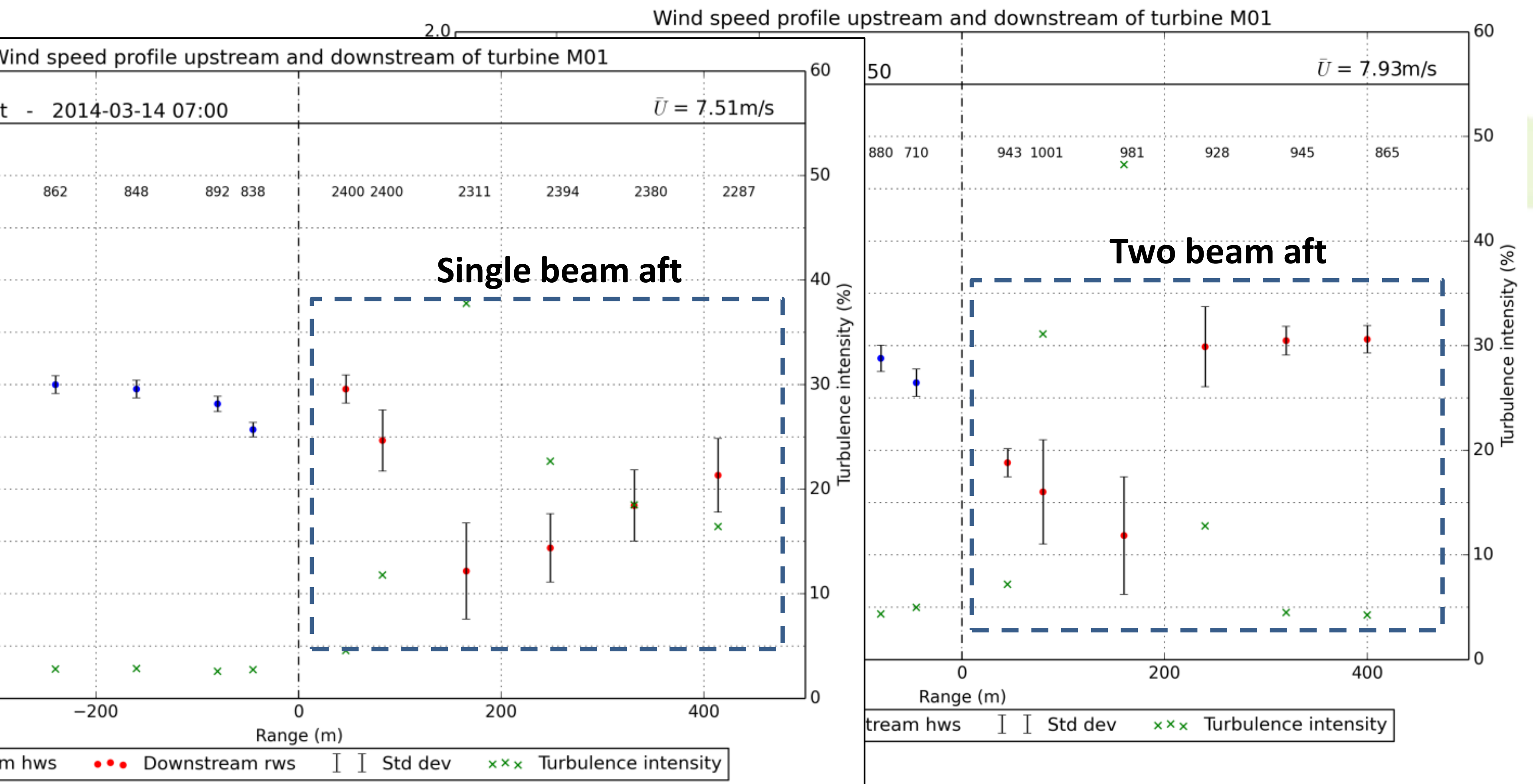






rofiles

Single beam vs Two beam aft profile



Conclusions (1)

- Wind speeds deficits of more than 0.5*(free stream wind speed)
- Markedly different wake profiles for different beam geometries
- Two beam aft measurements & blade tip effects
- Wake along turbine centreline beyond measuring distance

Conclusions (2)

- Lower wake deficit with higher wind speeds
- Also lower standard deviation of wind speed
- Blockage effect of rotor upstream of turbine

- Ongoing work
- Look at T.I. in more detail
- Non-free stream cases
- CFD modelling

THANK YOU!