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Multi-lidar observations of Vestas multi-rotor turbine wake



Vestas multi-rotor wind turbine

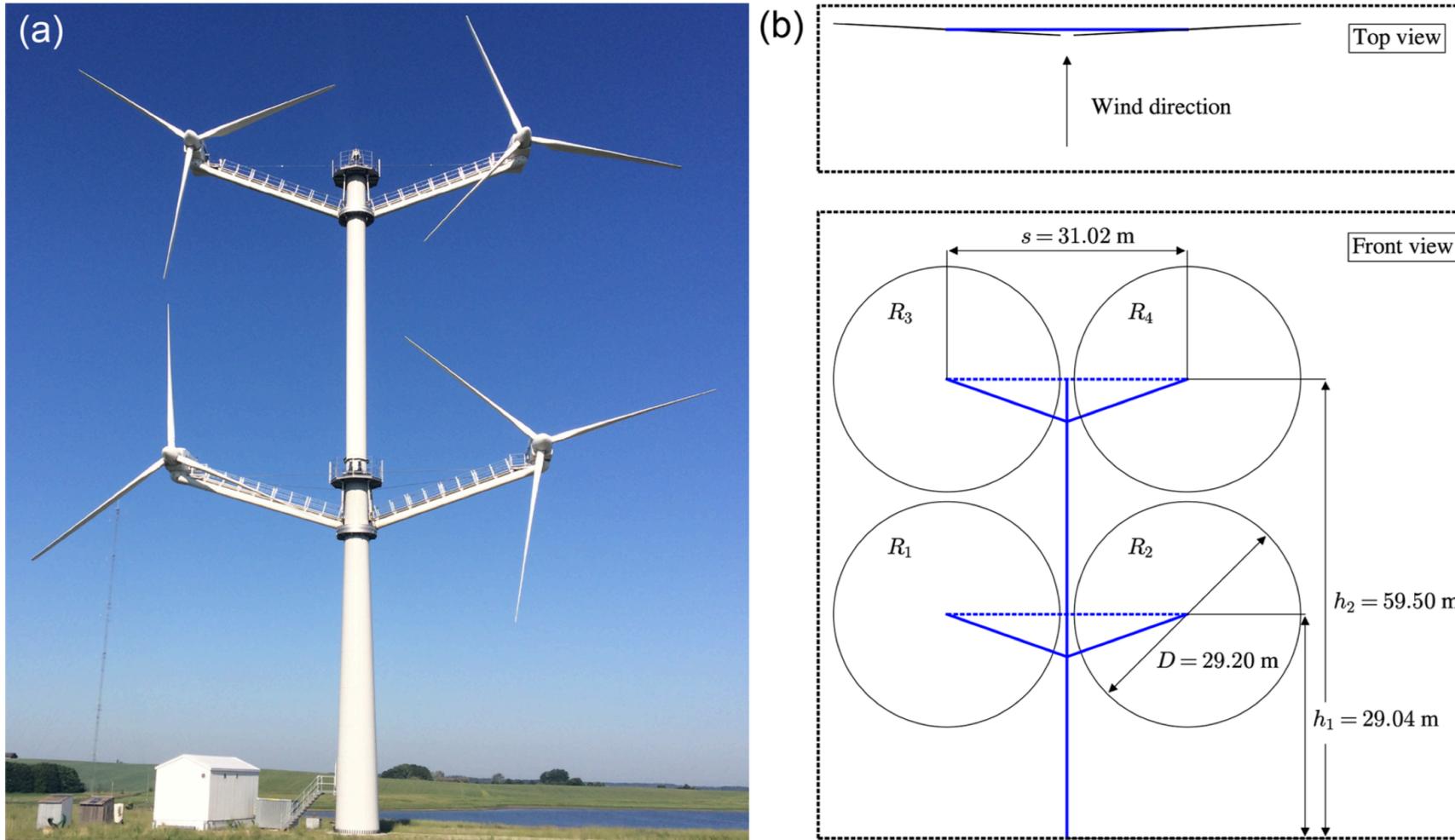
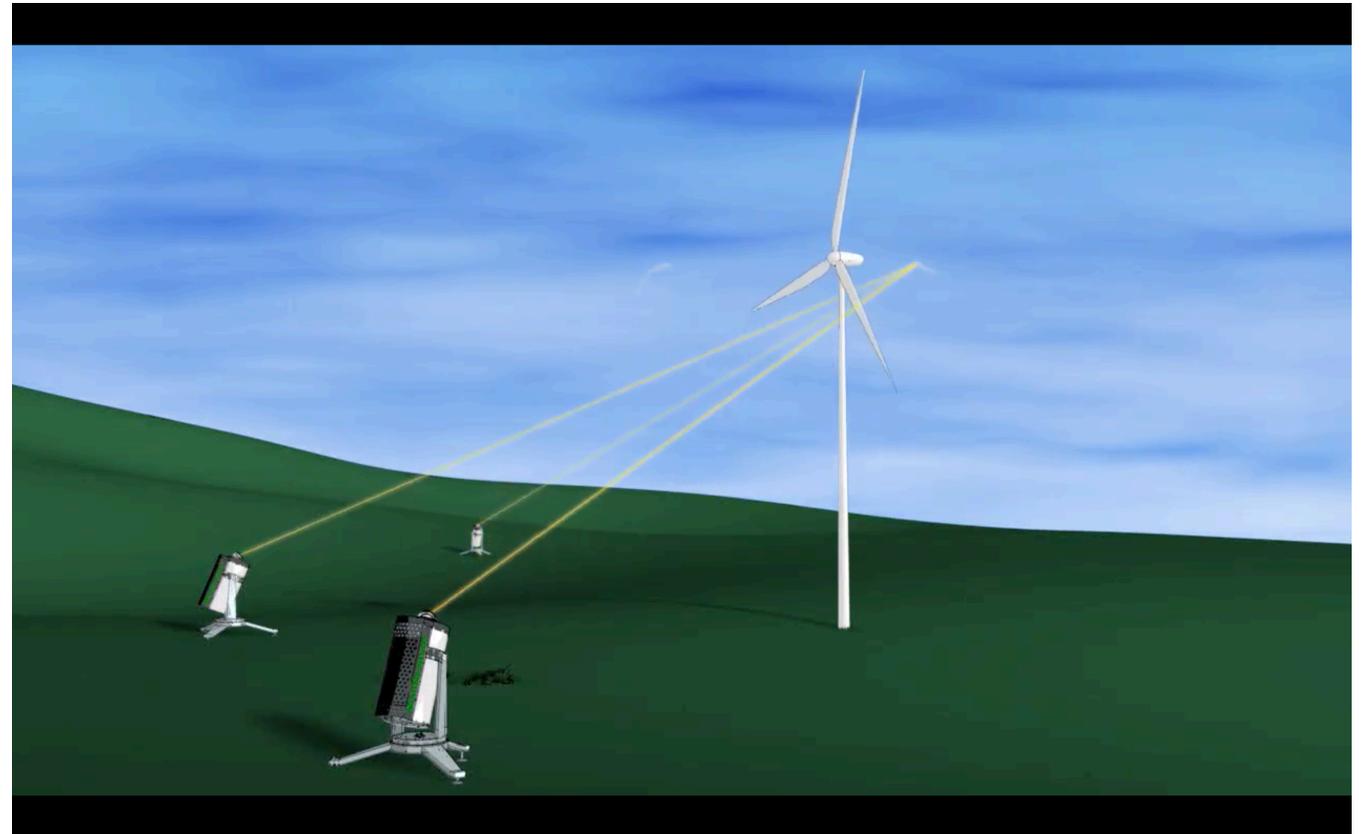


Figure 1. (a) The 4R-V29 wind turbine located at the Risø Campus. (b) Sketch of the 4R-V29 wind turbine, including dimensions and rotor definitions, shown using a top and front view.

First experiment: M. P. van der Laan et al. 2019



Multi-rotor wind turbine

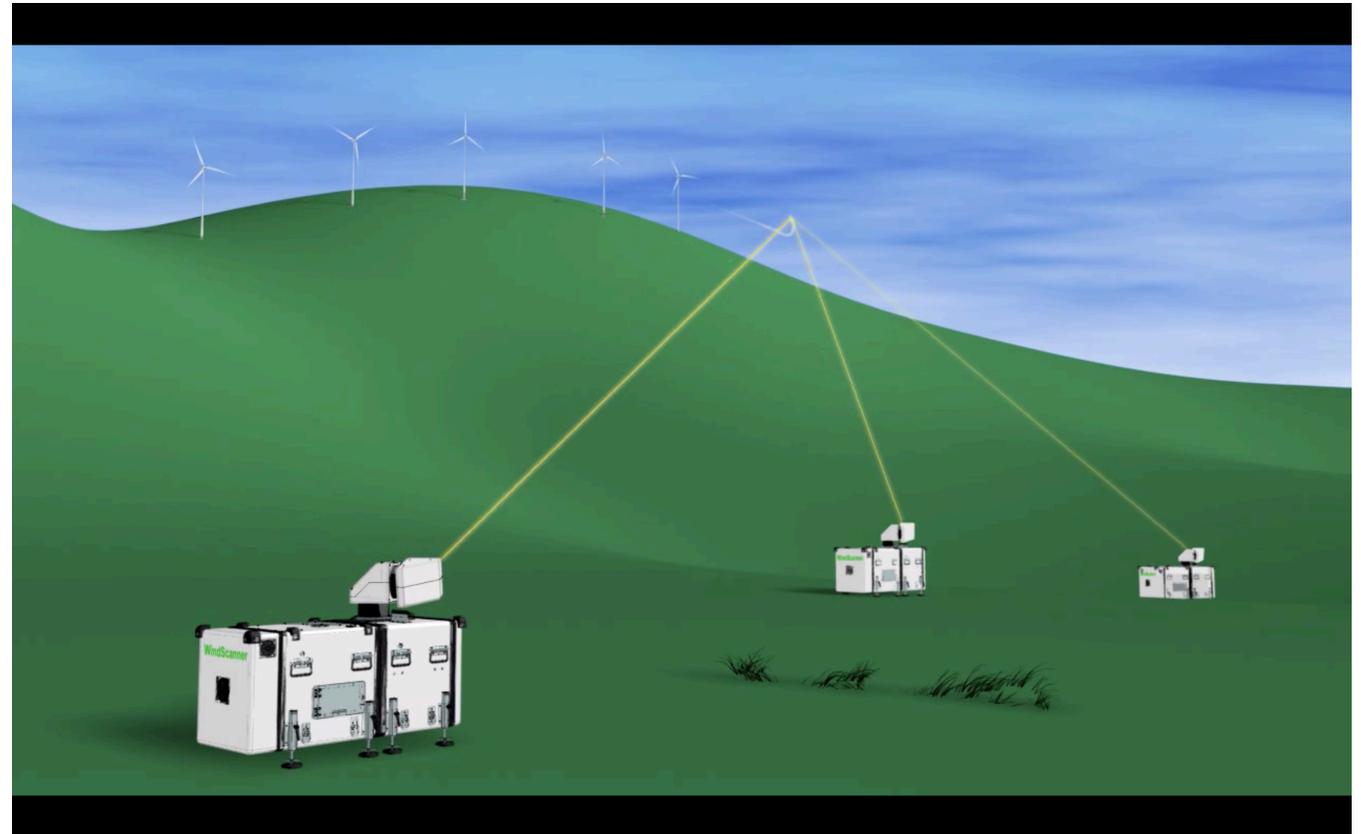


Short-range WindScanner system

Second experiment



Multi-rotor wind turbine



[Long-range WindScanner system](#) (N. Vasiljevic et al. 2016)

Focus of second experiment

- Wake geometry, deficit, and propagation
- Especially wake decay and wind field recovery speed
- We are looking at a far wake scenario (beyond $2.75 D \geq 165$ m)
- Create high quality database of the multi-rotor wake measurements

- First multi-rotor wake experiment done using short-range WindScanners:
<https://www.wind-energ-sci.net/4/251/2019/>

- This one was done using long-range WindScanners

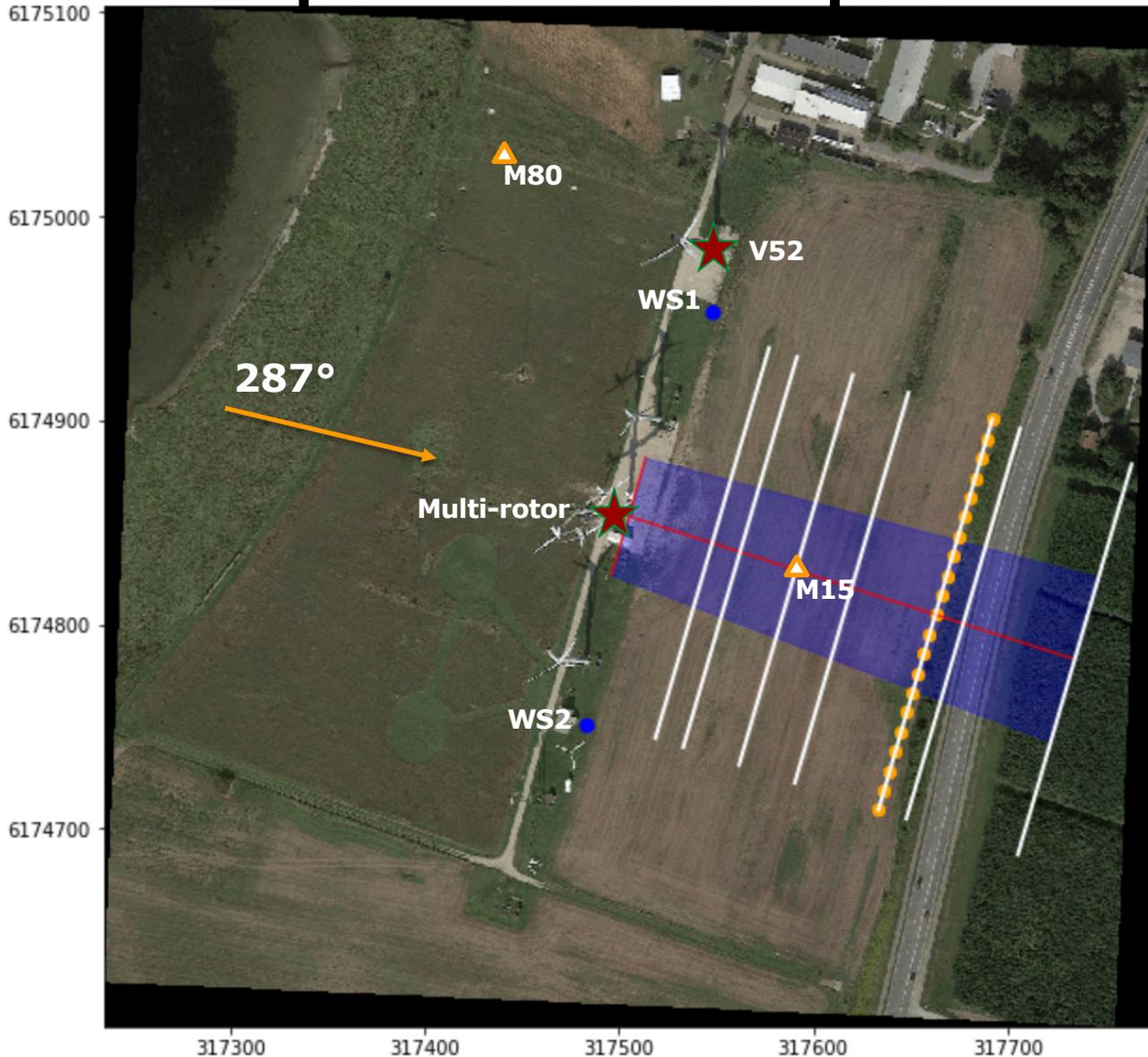
Experiment description

Location: Risø campus, Denmark

Measurements started: 2018/08/13

Measurements stopped: 2018/11/13

Total: **92 campaign days**



WS – long-range WindScanners

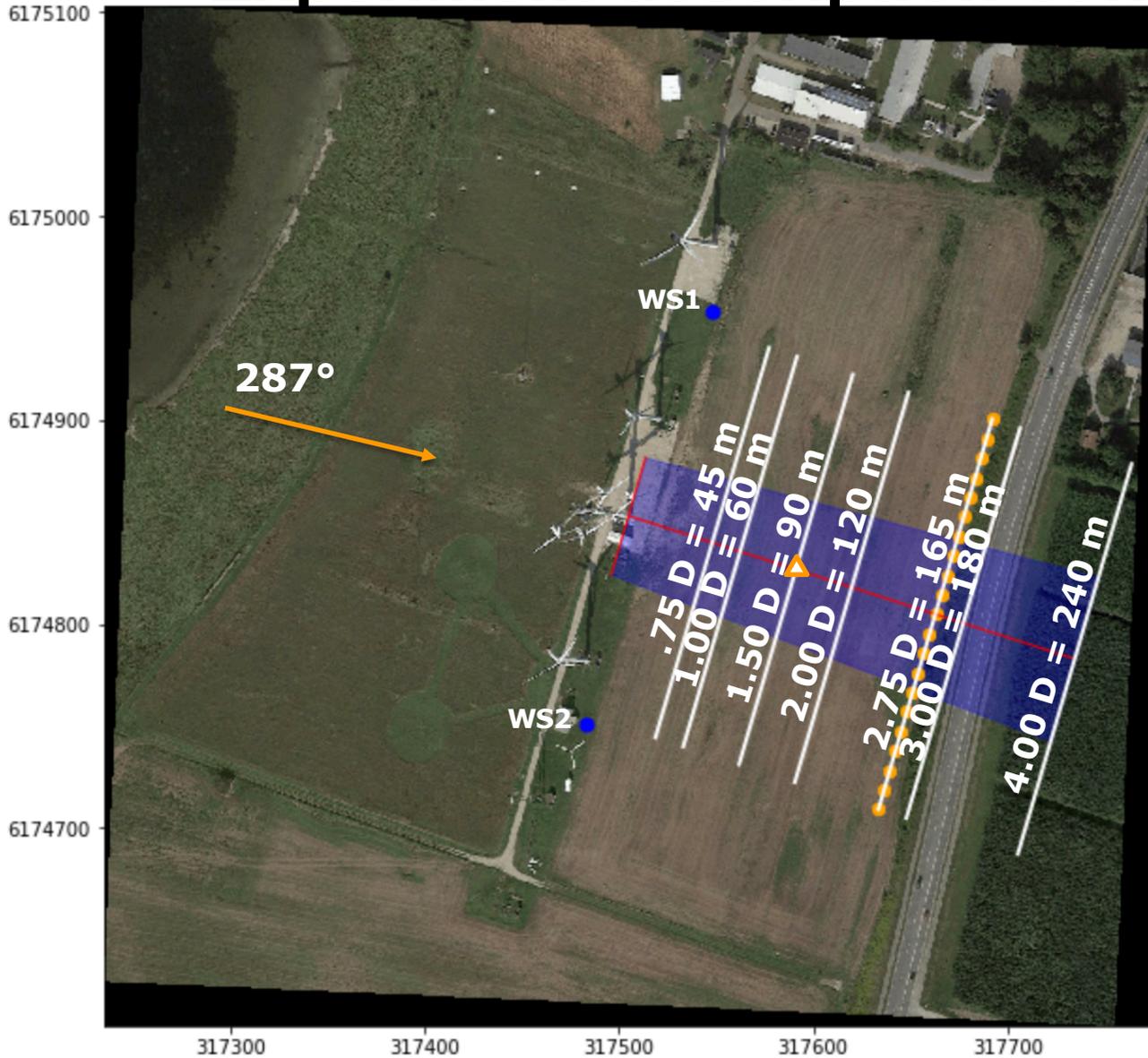
M15 – 15m mast

M80 – 80m mast

V52 – V52 wind turbine

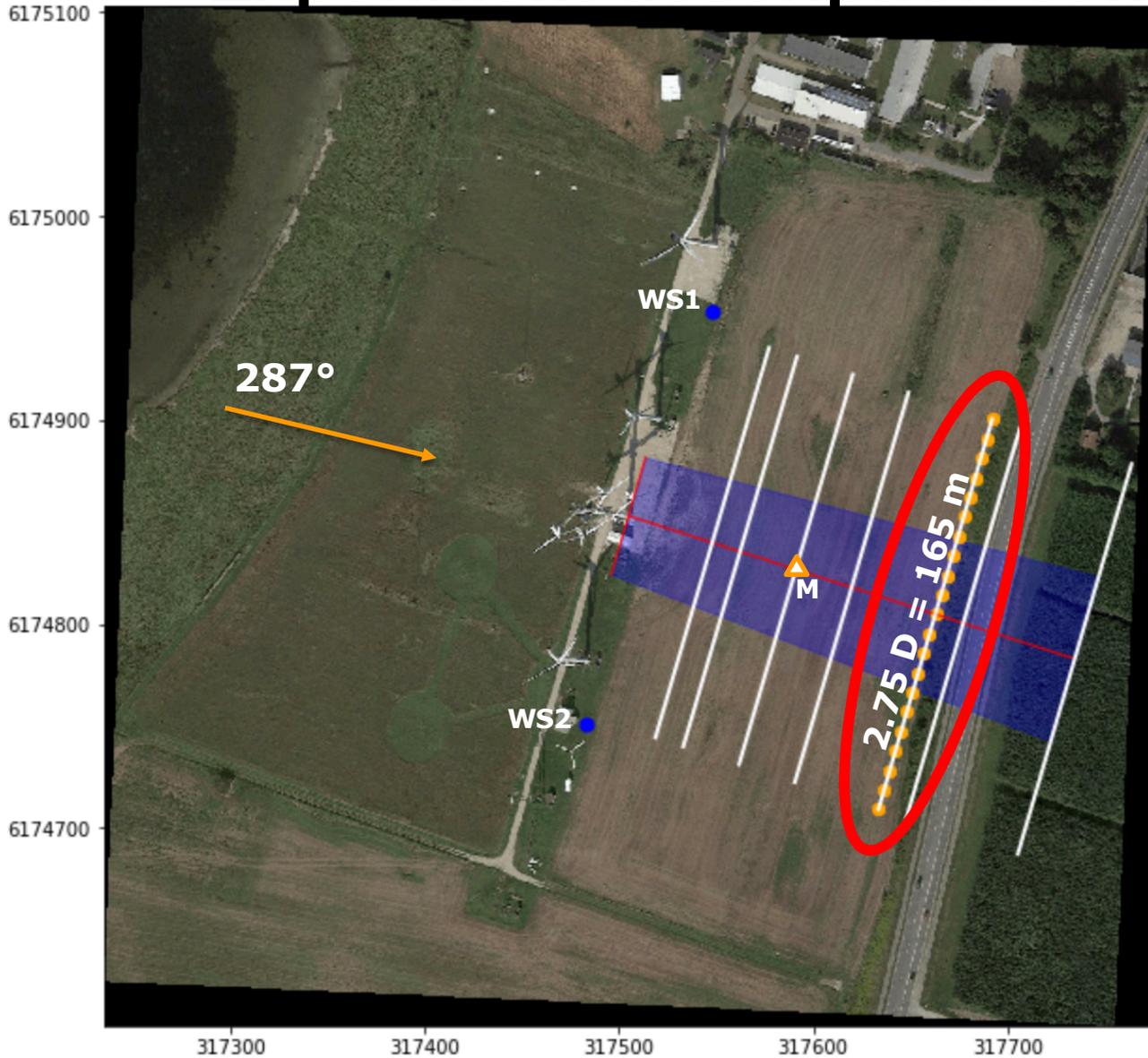
Multi-rotor – multi-rotor wind turbine

Experiment description continued...

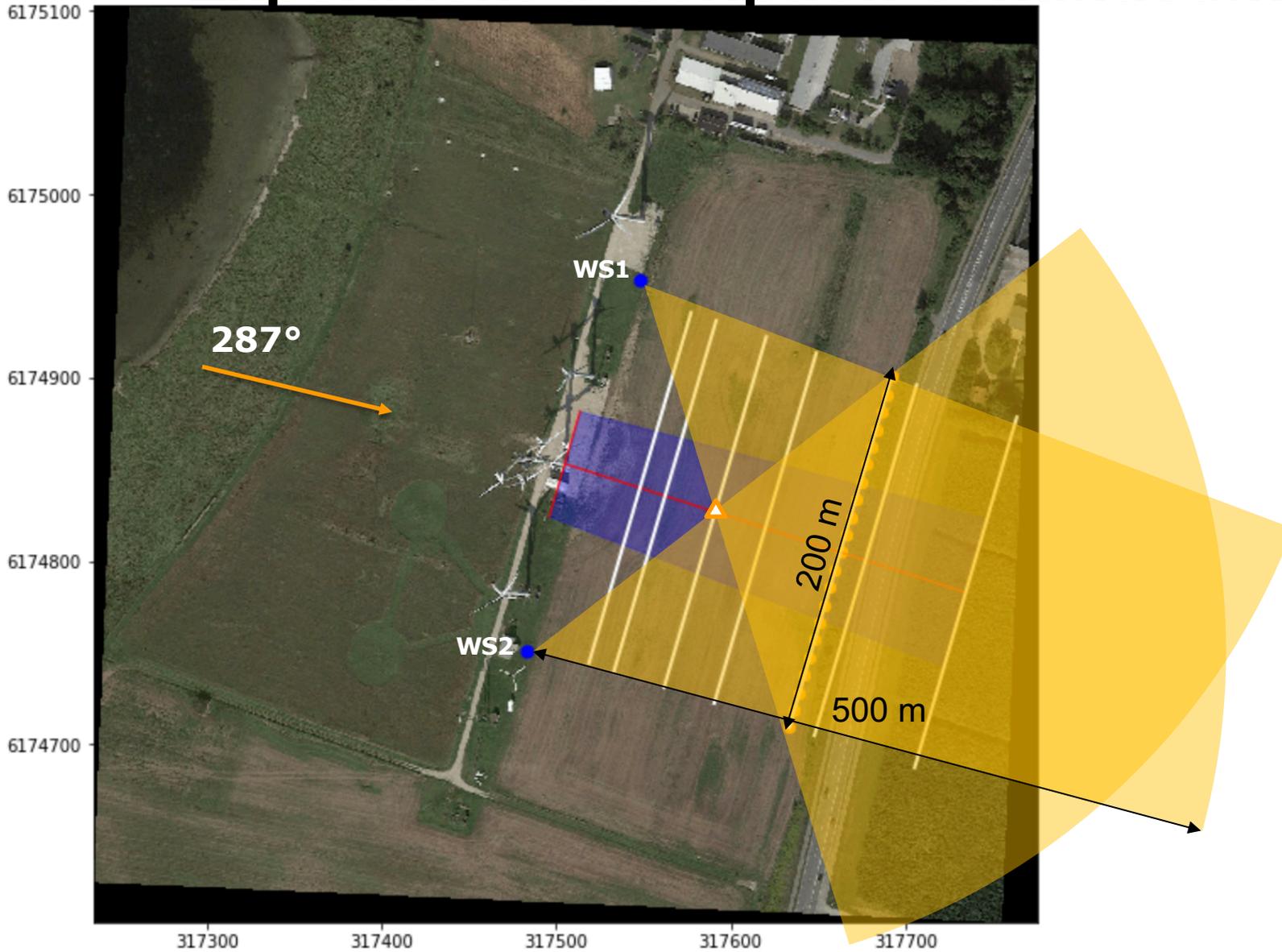


Experiment description continued...

The center of attention:
A plan at $2.75 D$ from the multi-rotor turbine

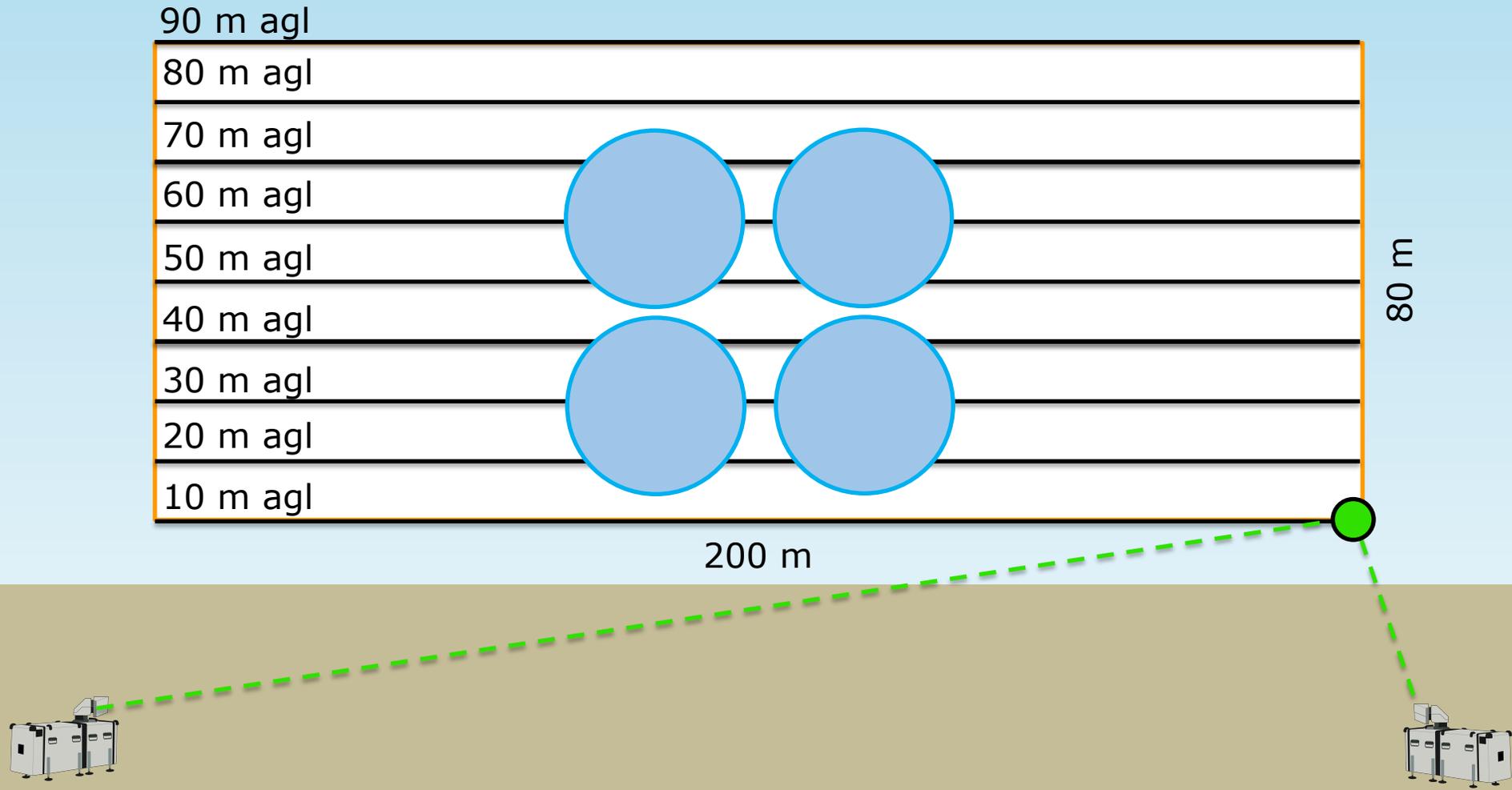


Experiment description continued...

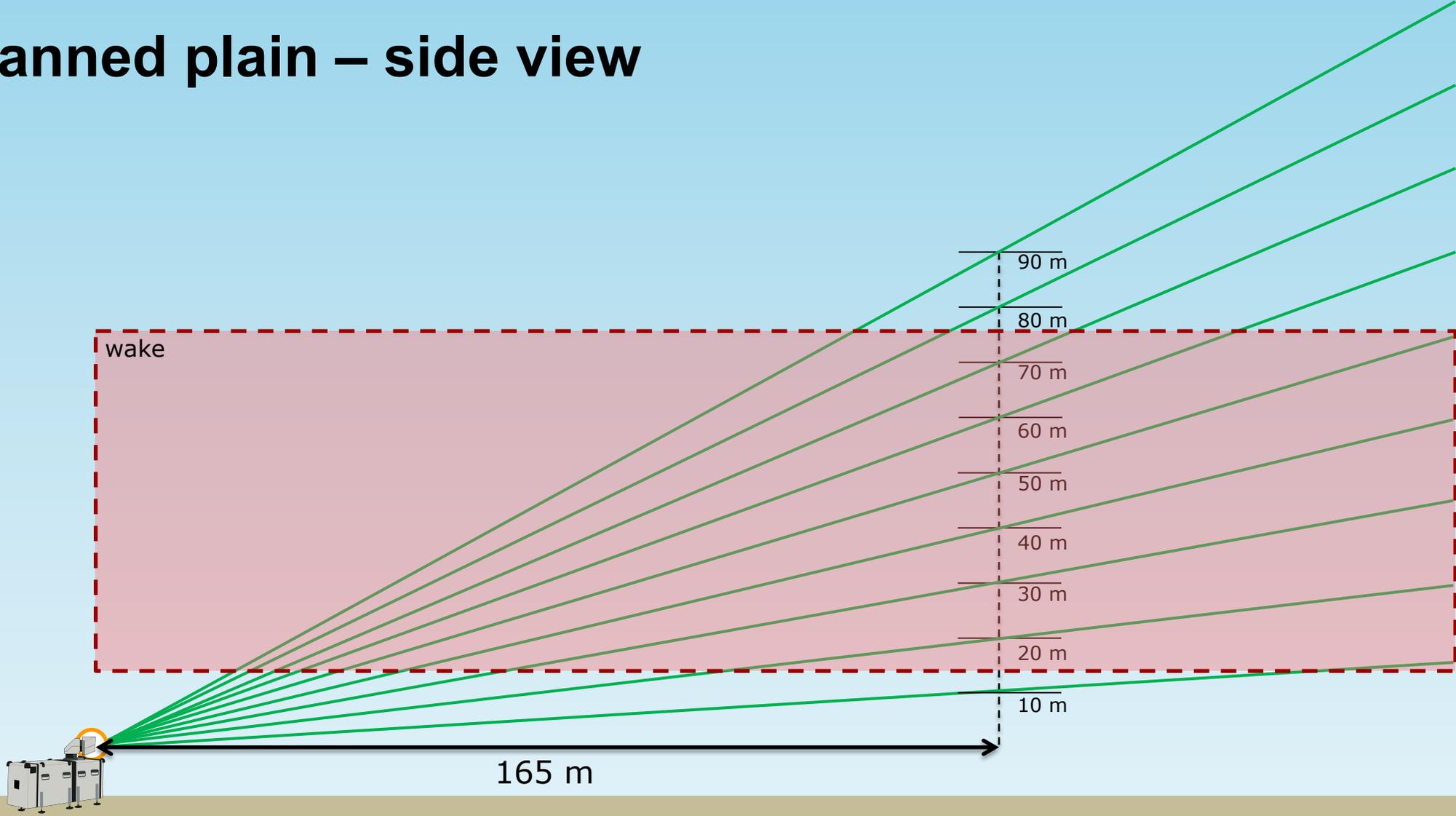


Scanned plain

Should be able to capture wake if wind direction is between **260°** to **310°**



Scanned plain – side view



Turning pulsed lidar into 'CW' alike

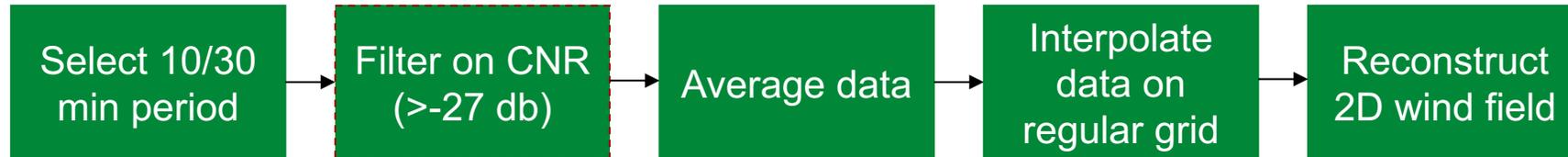


Why did we do that?

- **Beam focused around 200m**
- **This allows 5 times higher measurement frequency (i.e. 5 Hz)**
- 9 transects scanned of 200 m in length
- Each transect completed in 4 s
- Accumulation time 0.2 s
- Transverse resolution = $(200 / 4) * 0.2 = 10 \text{ m} \Rightarrow$ i.e. every 10 m along a transect there is one measurement
- Probe length 35 m (200 ns laser pulse) = longitudinal resolution

- Measurement range from 50 m to 500 m
- Along each LOS we acquire radial velocity every 5 m (91 range gate)
- Total measurement points per one full scan:
 - 2 WindScanners *
 - 9 Transects *
 - 20 LOS per Transect *
 - 91 range gate per LOS
 - = 32 760**
- **During 10 min period 9 transects scanned 13 to 14 times**

Data analysis workflow



Preliminary WindScanner data status

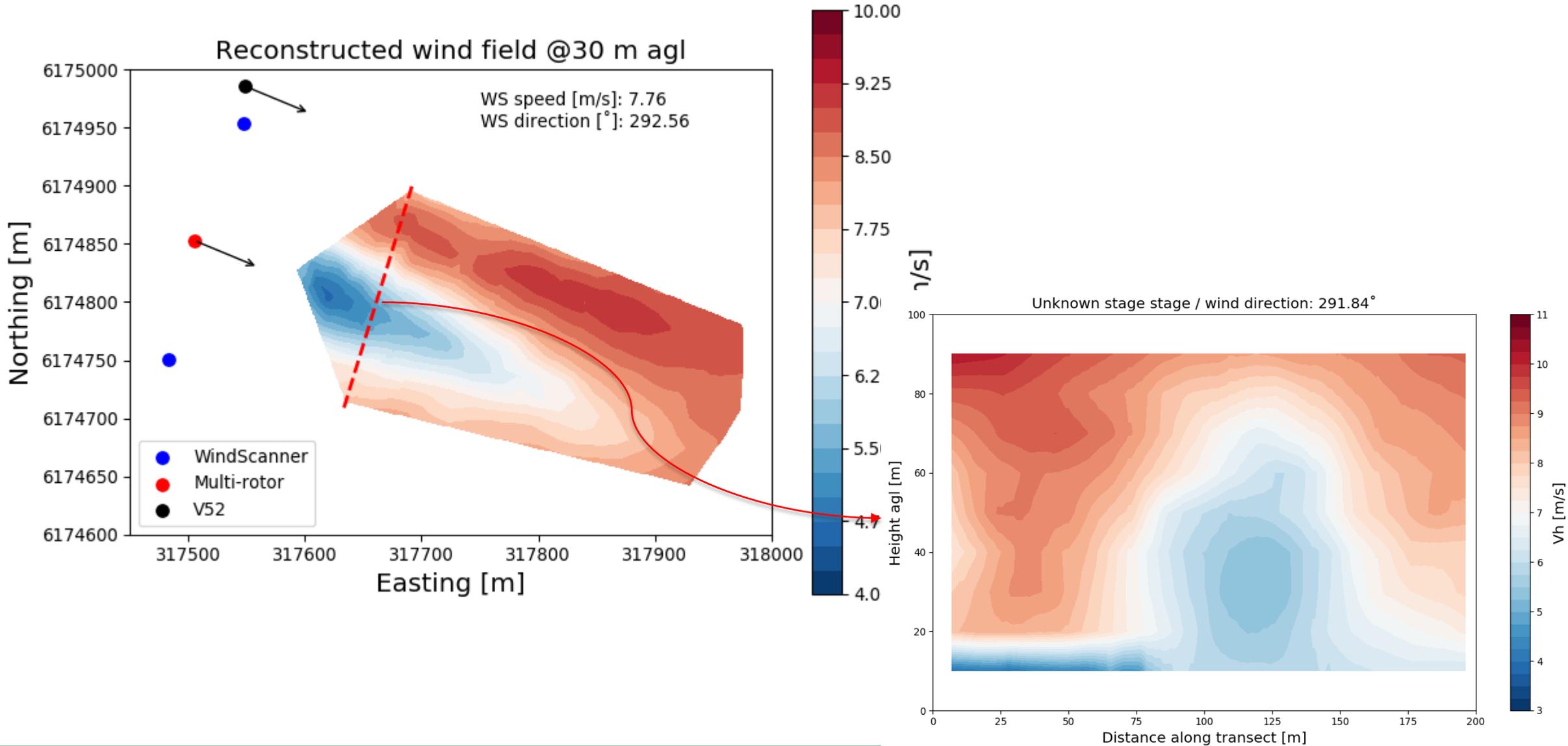
- Processed **42** out of **92** days
- Mean WindScanner data availability ~ 70 %
- **2727** periods processed (all 42 days!)
- One period can last between 10 to 30 minutes

- **380** out of 2727 periods when multi-rotor wake is captured

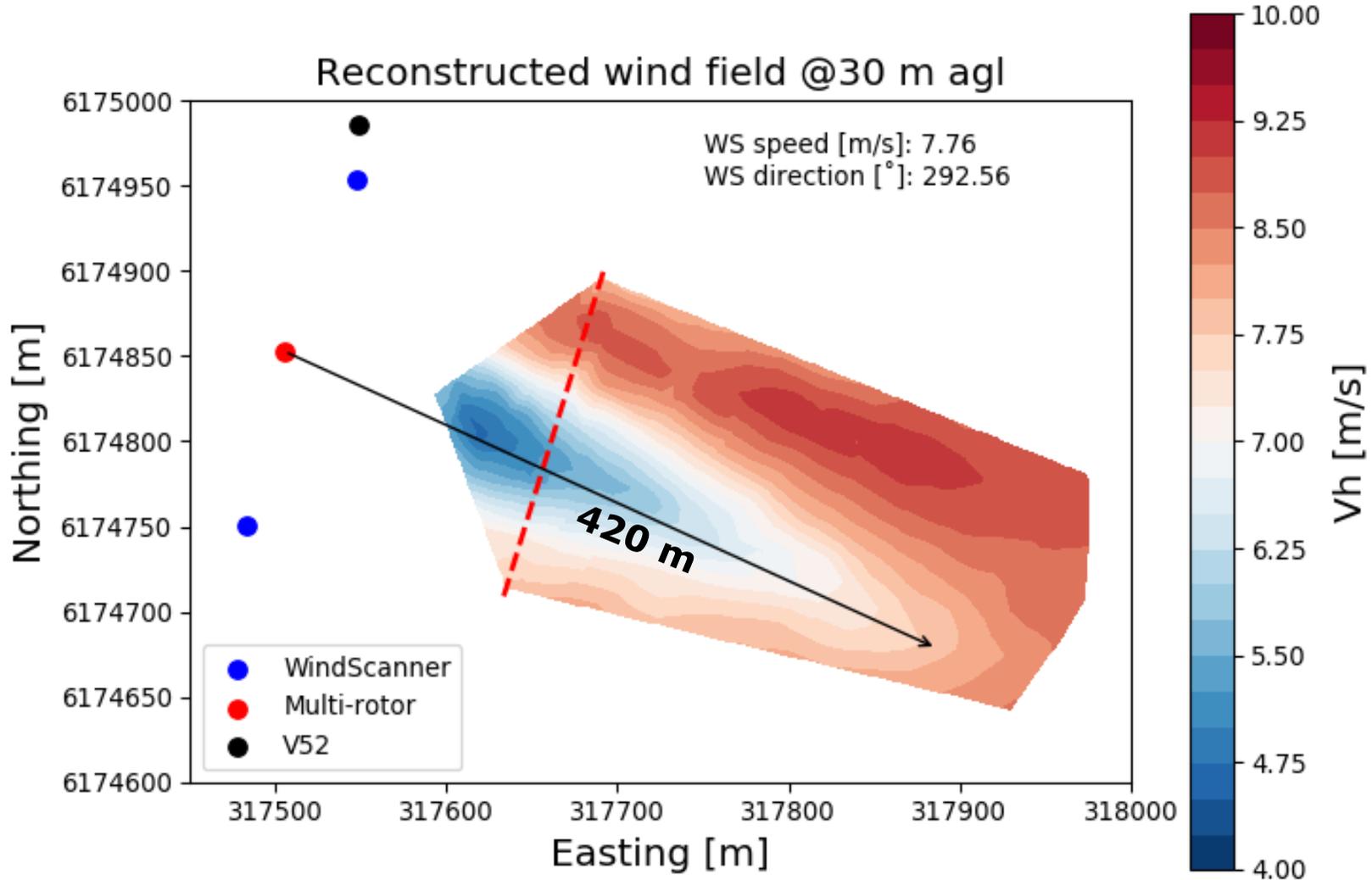
- **268** out of 2727 periods when V52 wake is captured
 - out of this 268 there are periods when we have both V52 and multi-wake captured simultaneously

- Max total of **648** periods when wakes are captured (~140 hours)

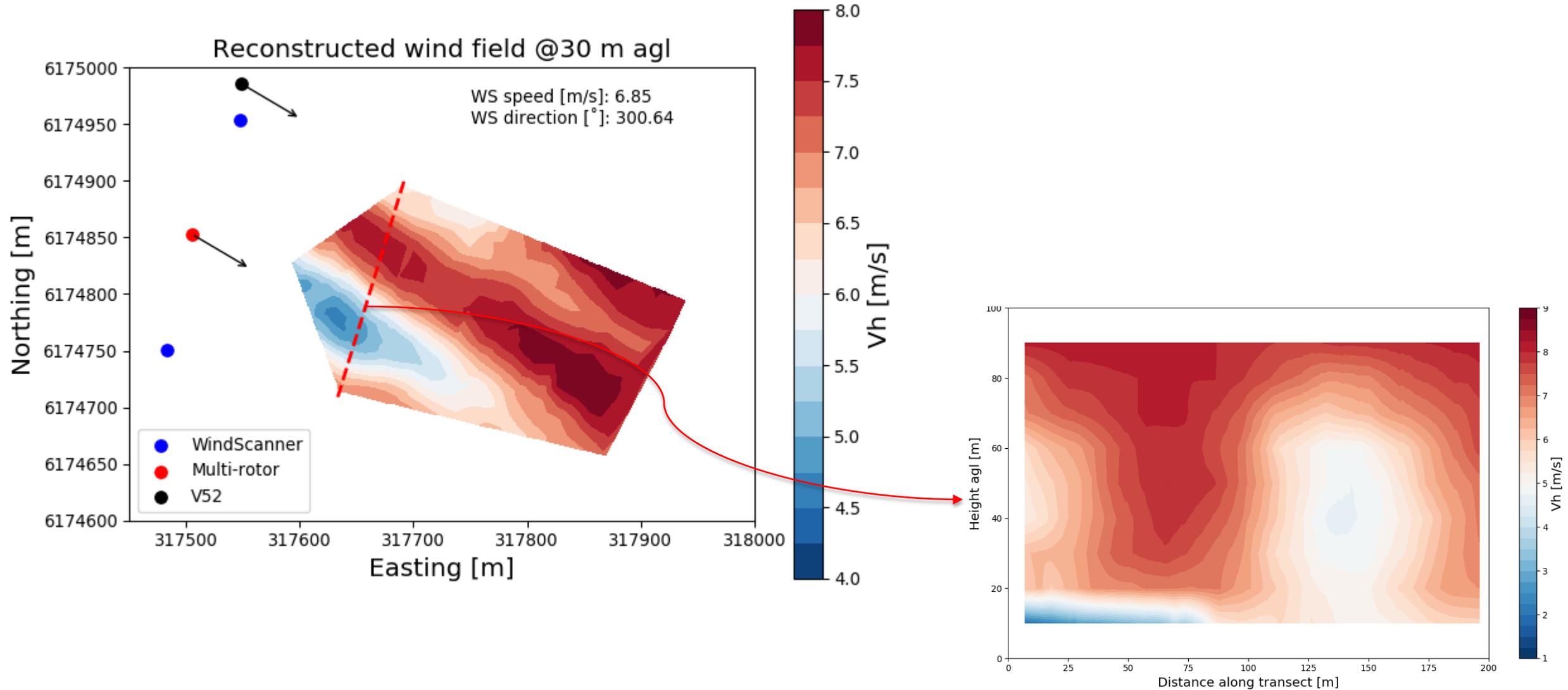
Examples: 23/09/2018 from 12:30 to 12:40 UTC



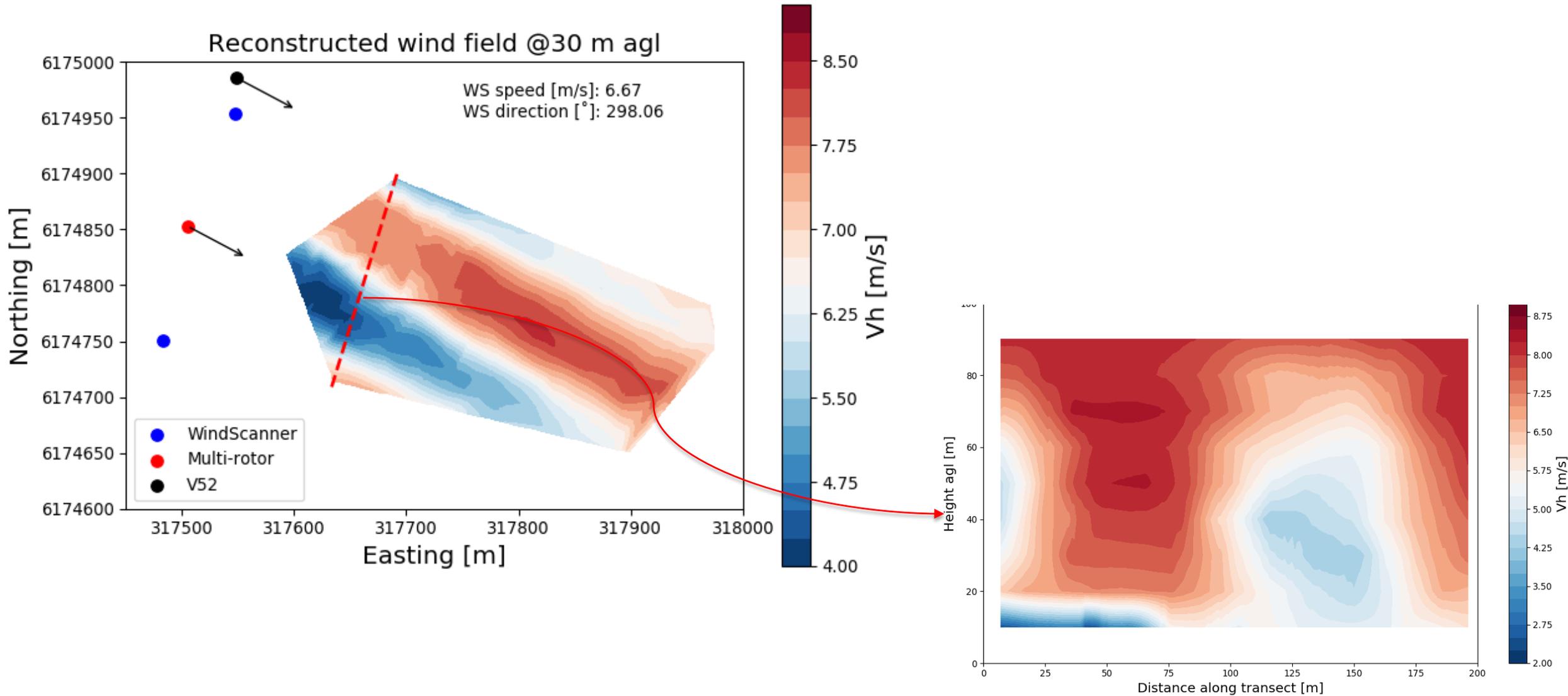
Examples: 23/09/2018 from 12:30 to 12:40 UTC



Examples: 15/08/2018 from 01:20 to 01:30 UTC

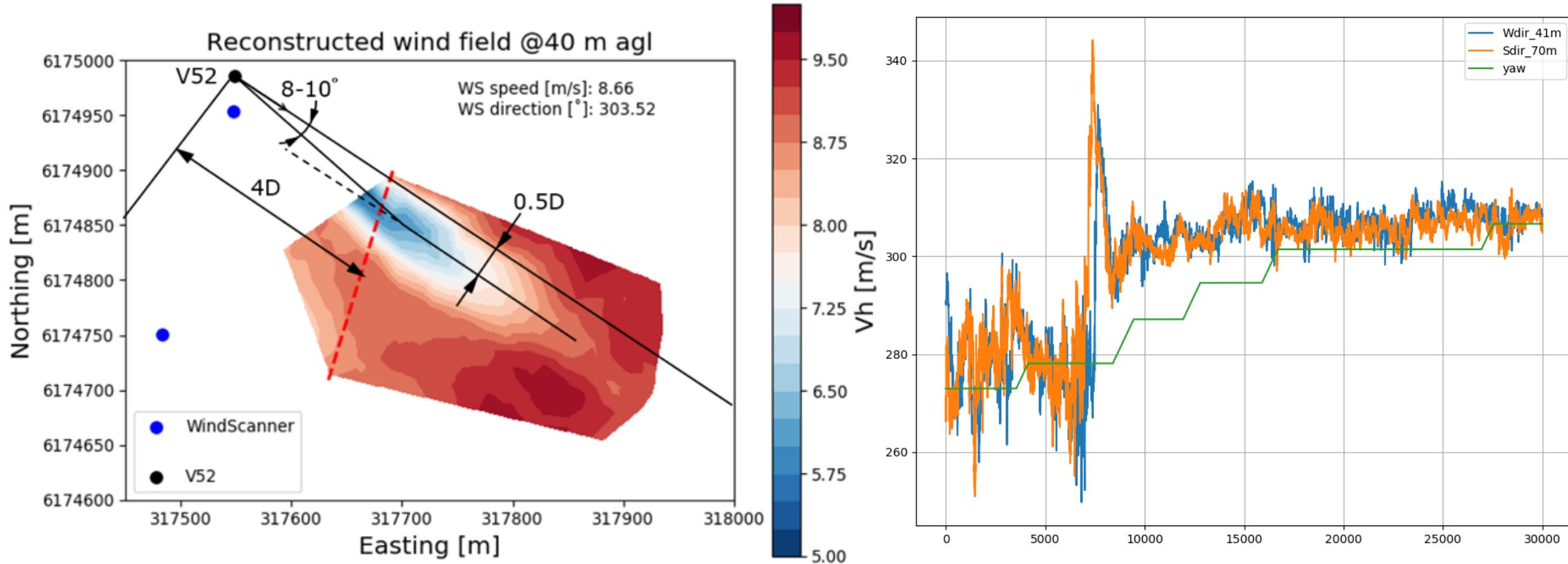


Examples: 14/08/2018 from 11:00 to 11:10 UTC



Examples: 15/09/2018 from 10:50 to 11:00 UTC

Wake deflection of the V52 research turbine



Future work

- Analyze remaining 50 days of campaign
- Finish building data catalogue
- Convert the processed data in NetCDF format
- We are considering a three-part paper:
 - part 1: campaign and data overview
 - part 2: data analysis results and selection of cases for simulation studies
 - part 3: simulation of cases and comparison with measurements

Thank you for your attention

Questions?

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