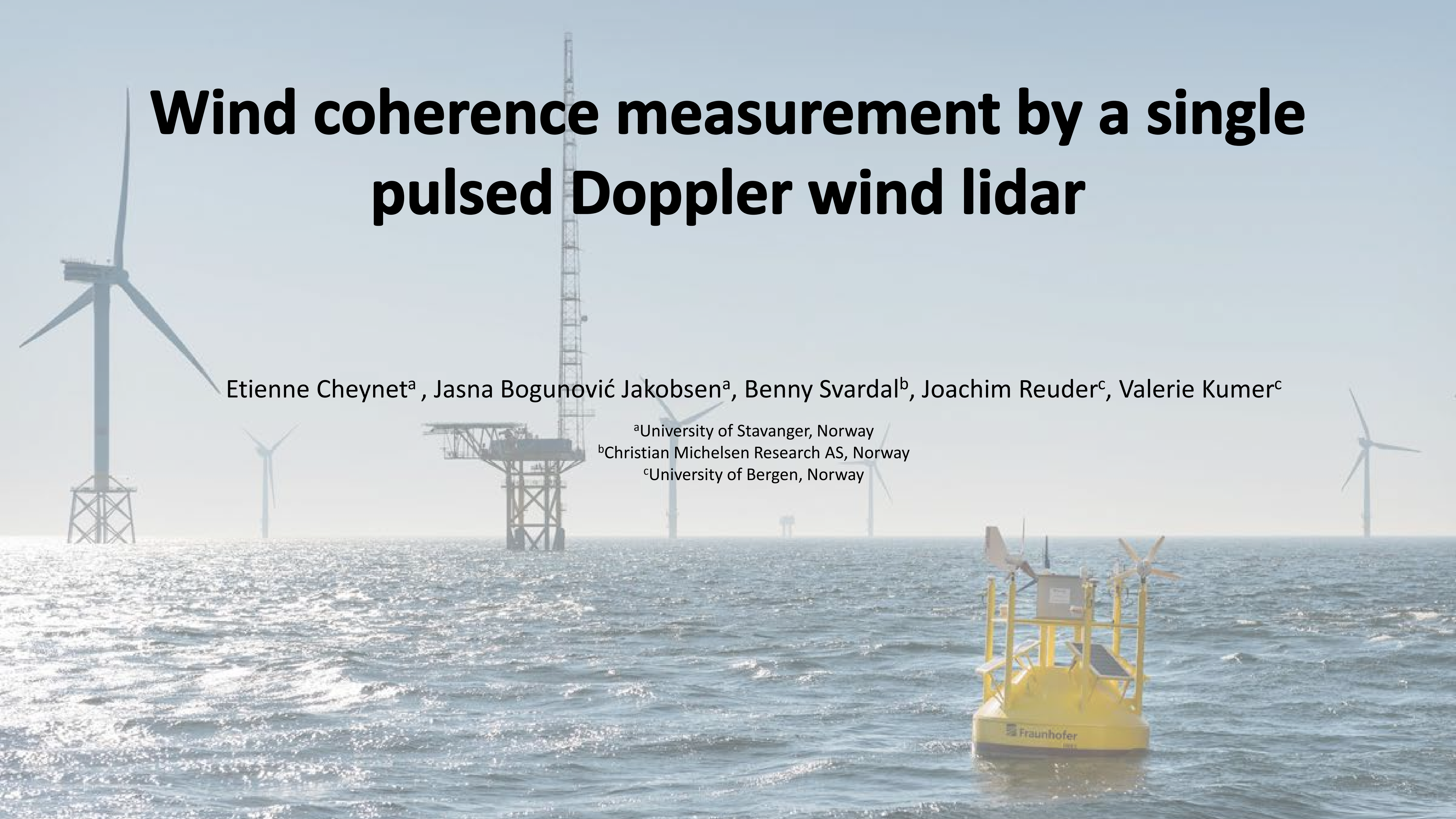
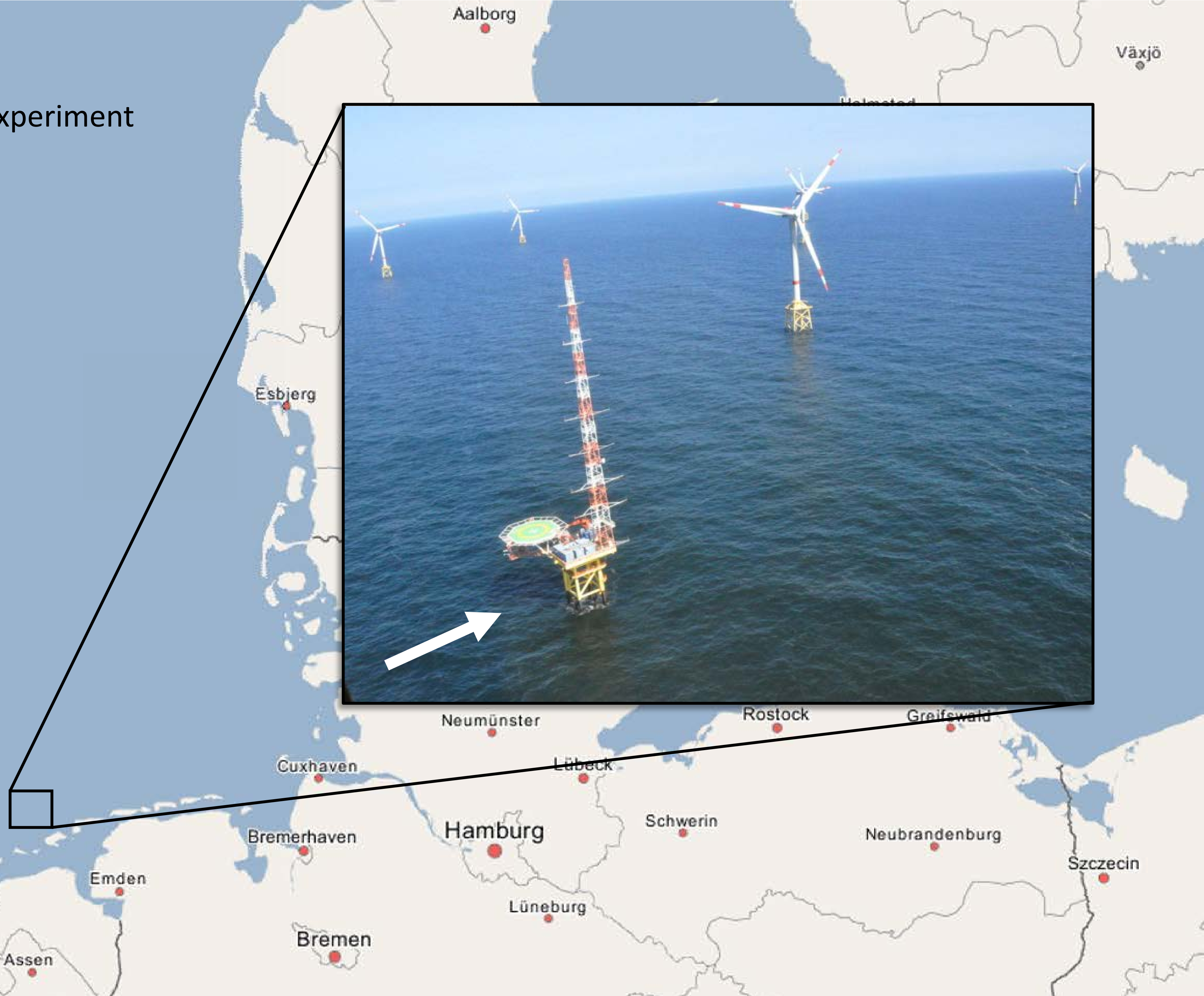
Wind coherence measurement by a single pulsed Doppler wind lidar

Etienne Cheynet[a] , Jasna Bogunović Jakobsen[a], Benny Svardal[b], Joachim Reuder[c], Valerie Kumer[c]

[a]University of Stavanger, Norway
[b]Christian Michelsen Research AS, Norway
[c]University of Bergen, Norway

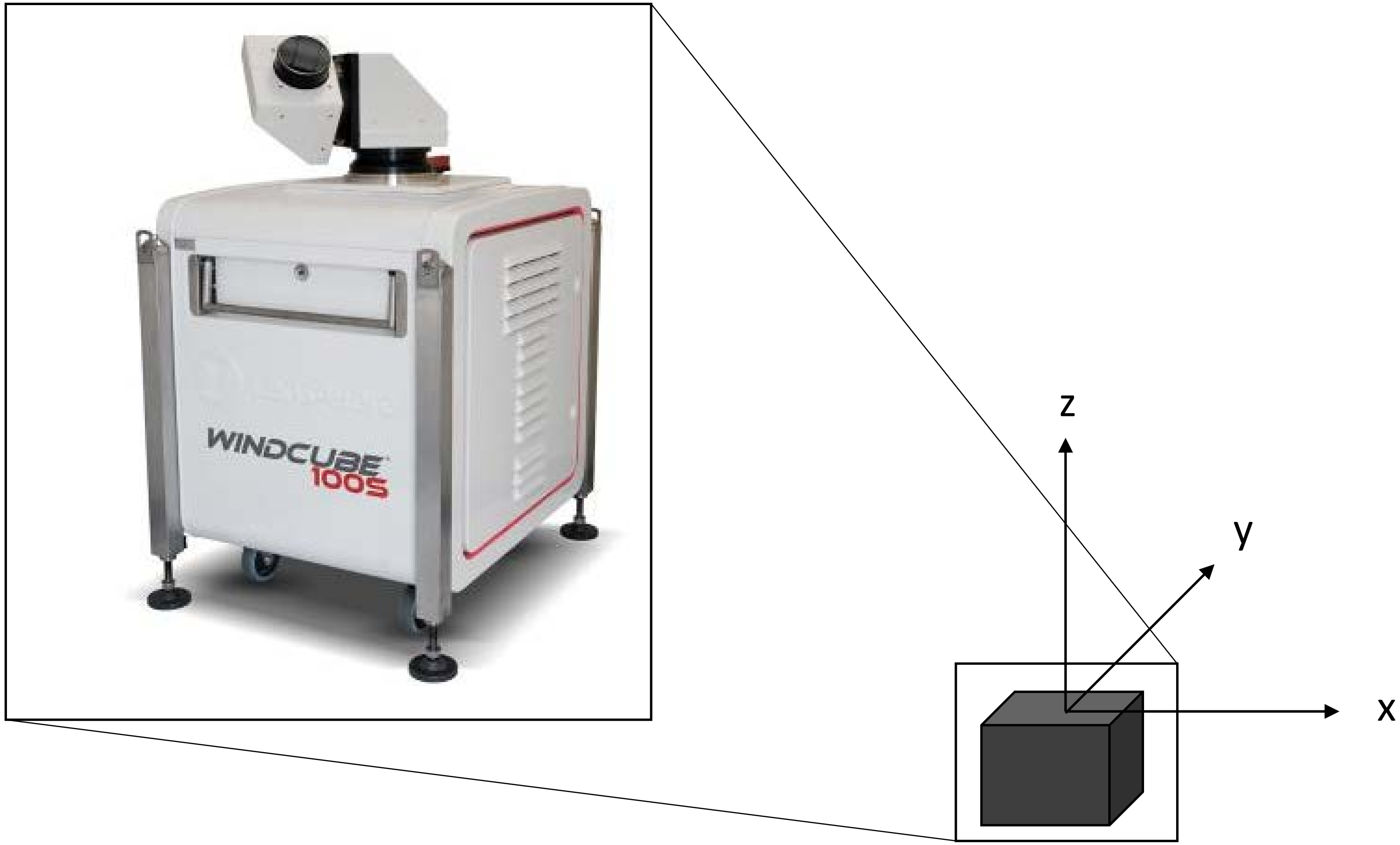


OBLEX-F1. Offshore boundary layer experiment at *FINO1*.



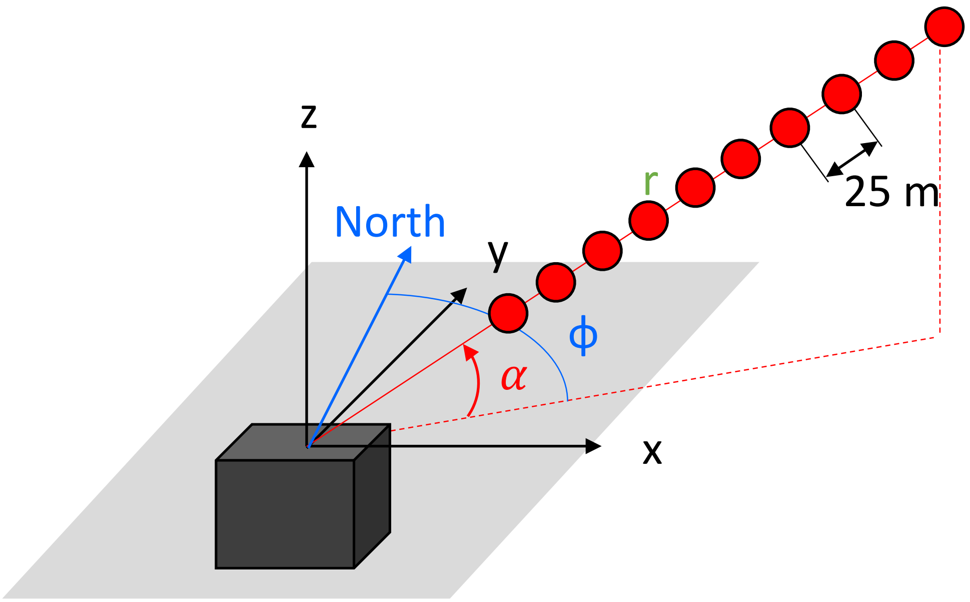
OBLEX-F1. Offshore boundary layer experiment at *FINO1*.

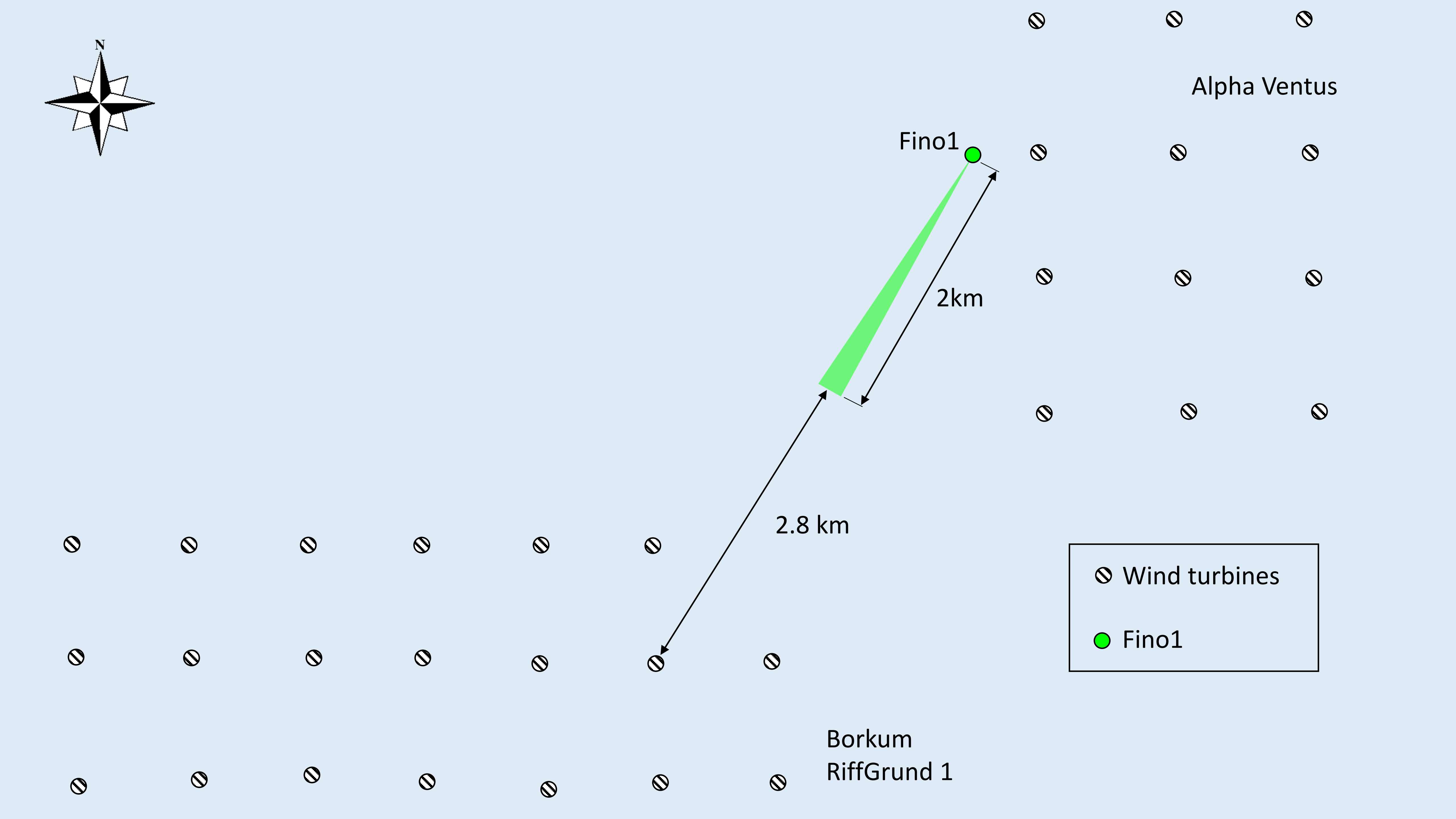
Instrumentation: Windcube 100S

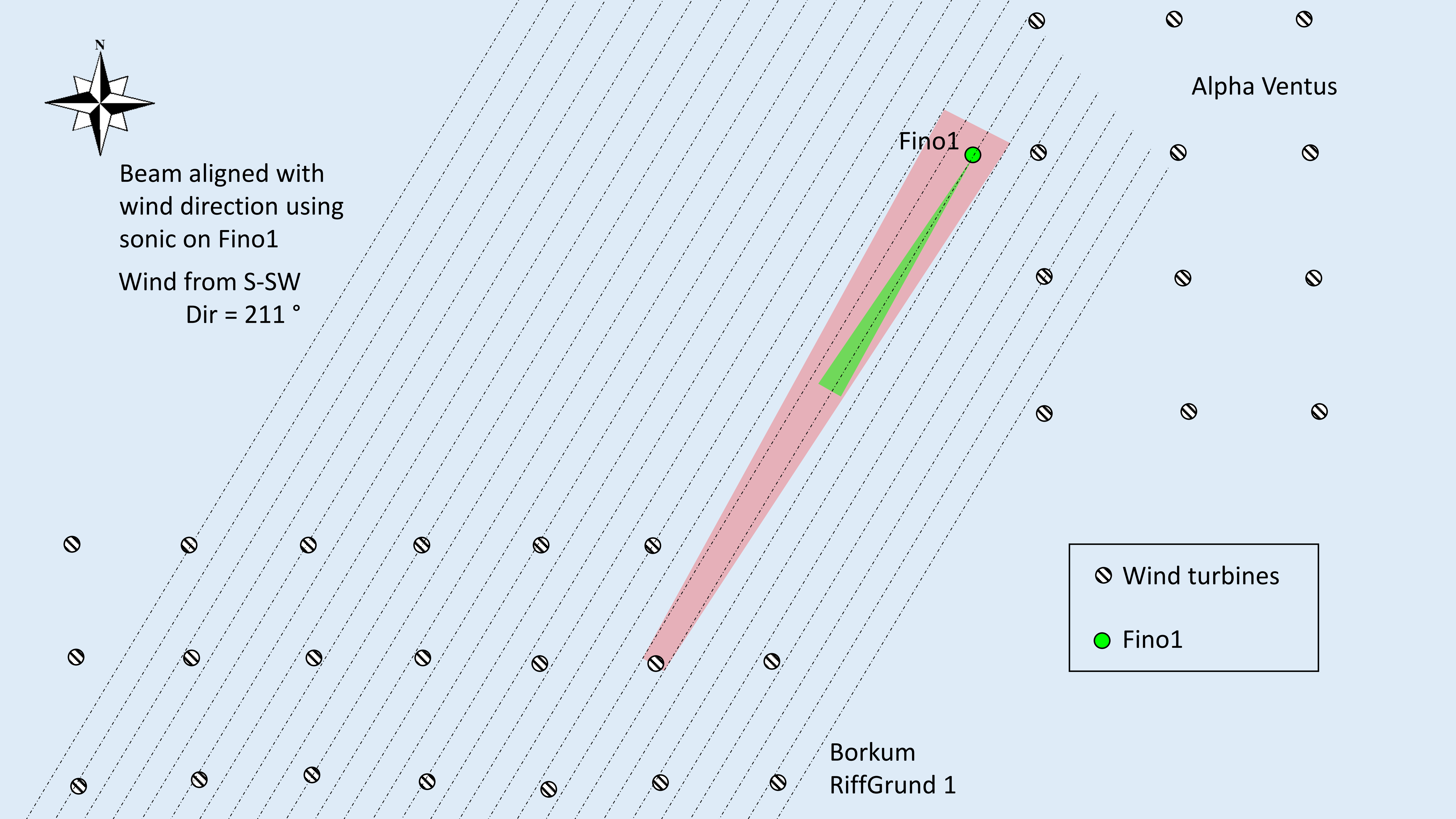


Instrumentation: Windcube 100S

- Simultaneous radial measurements
- Radial velocity measured in a volume
- Range used: from 50 m to 2 km

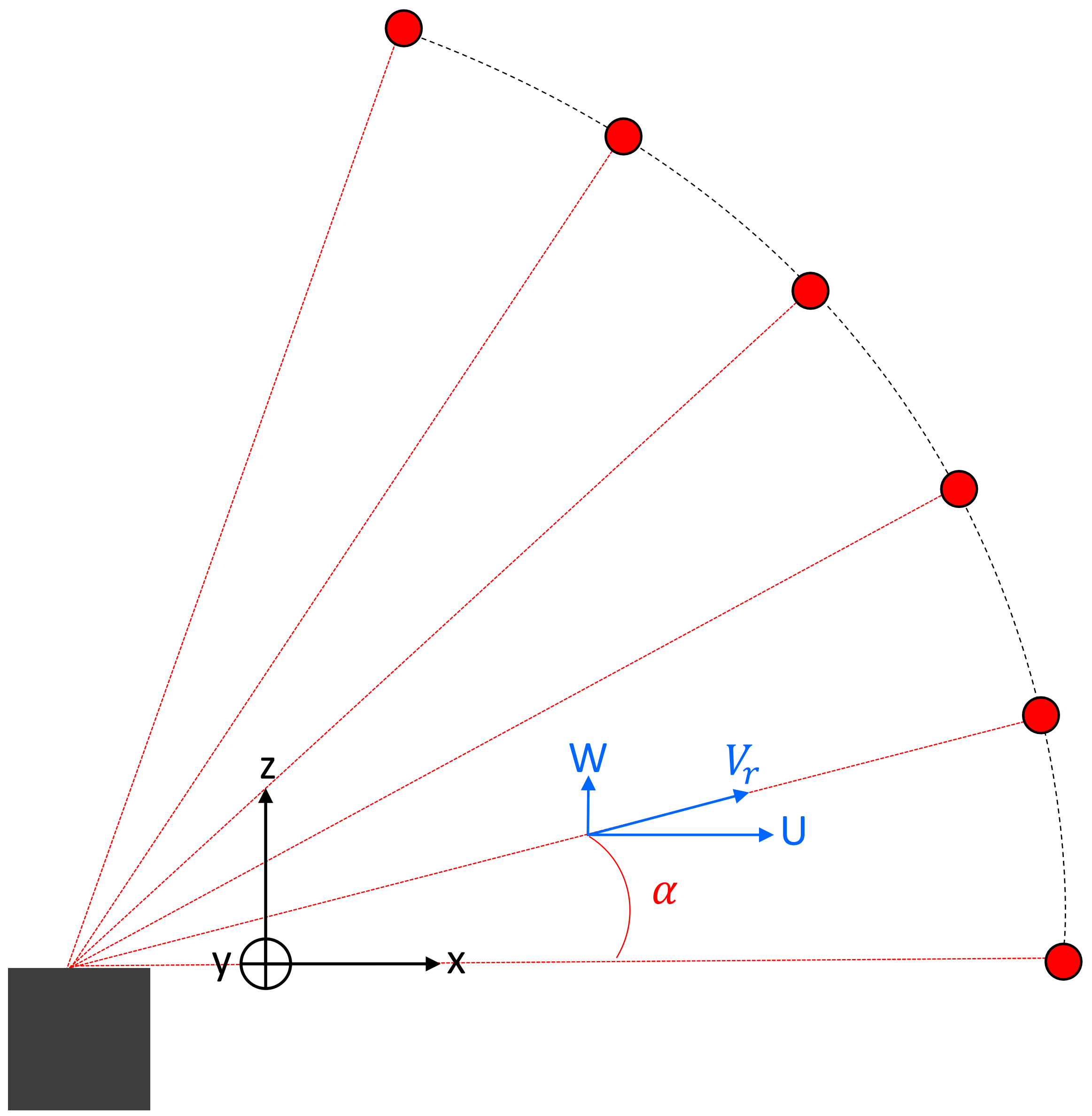



N
Alpha Ventus
Fino1
2km
2.8 km
Wind turbines
Fino1
Borkum
RiffGrund 1


N
Beam aligned with
wind direction using
sonic on Fino1
Wind from S-SW
Dir = 211 °
Fino1
Alpha Ventus
Wind turbines
Fino1
Borkum
RiffGrund 1

RHI Scan

Fixed azimuth angle
Multiple elevation angles



RHI Scan

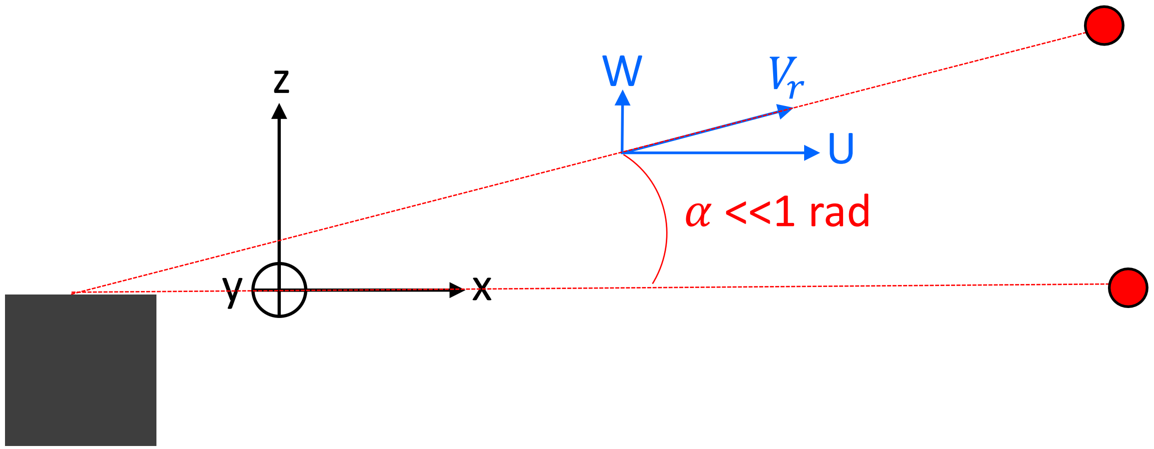
Fixed azimuth angle
Multiple elevation angles

Approximation for small elevation angles:

$$V_r = U\cos(\alpha) + W\sin(\alpha) \approx U$$

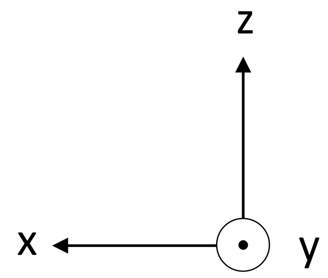
$\bar{V}_r \approx \bar{U}$
(err <1 % with α = 4°)

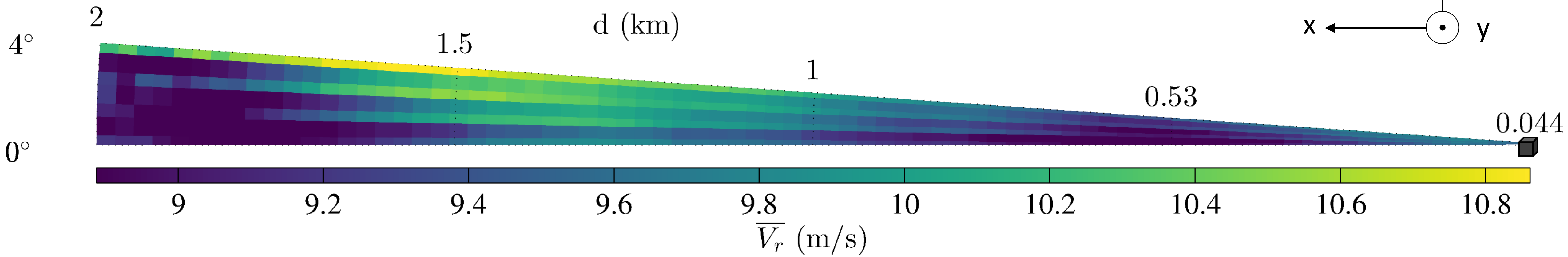
$I_{v_r} \approx I_u$
(err ≈ 4 % with $I_w = 0.6 I_u$ and α = 4°)

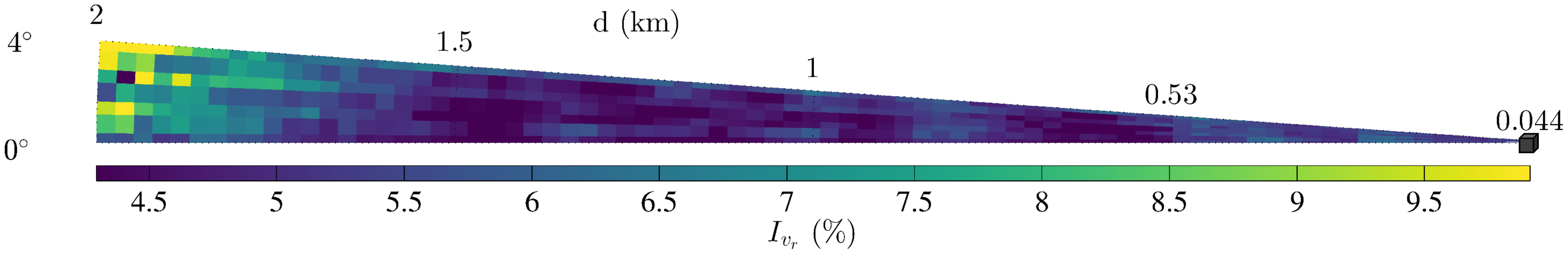


RHI Scan with small elevation angles

- fs = 0.19 Hz
- Averaged over 84 «snapshots»
- CNR > -23 dB

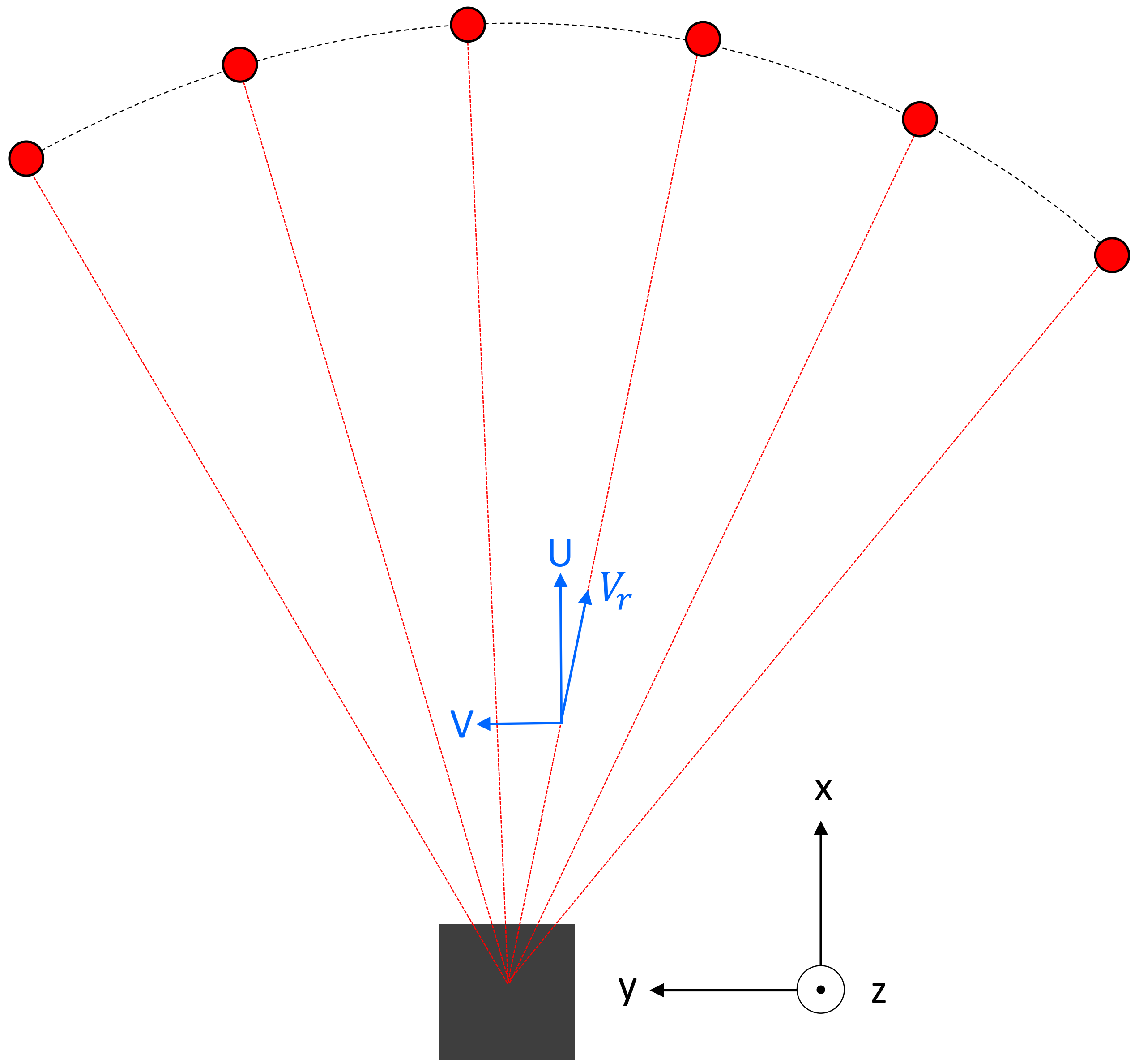






PPI Scan

Fixed elevation angle
Multiple azimuths



PPI Scan

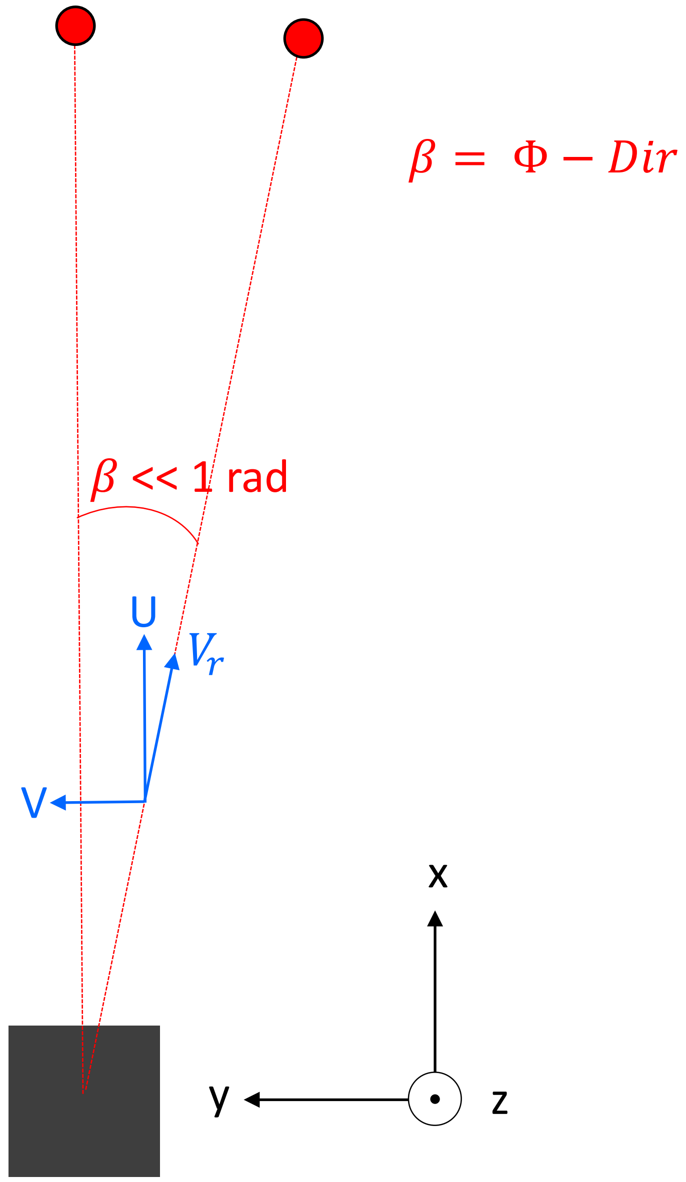
Fixed elevation angle
Multiple azimuths

Approximation for small elevation angles:

$$V_r = U\cos(\beta) - V\sin(\beta) \approx U$$

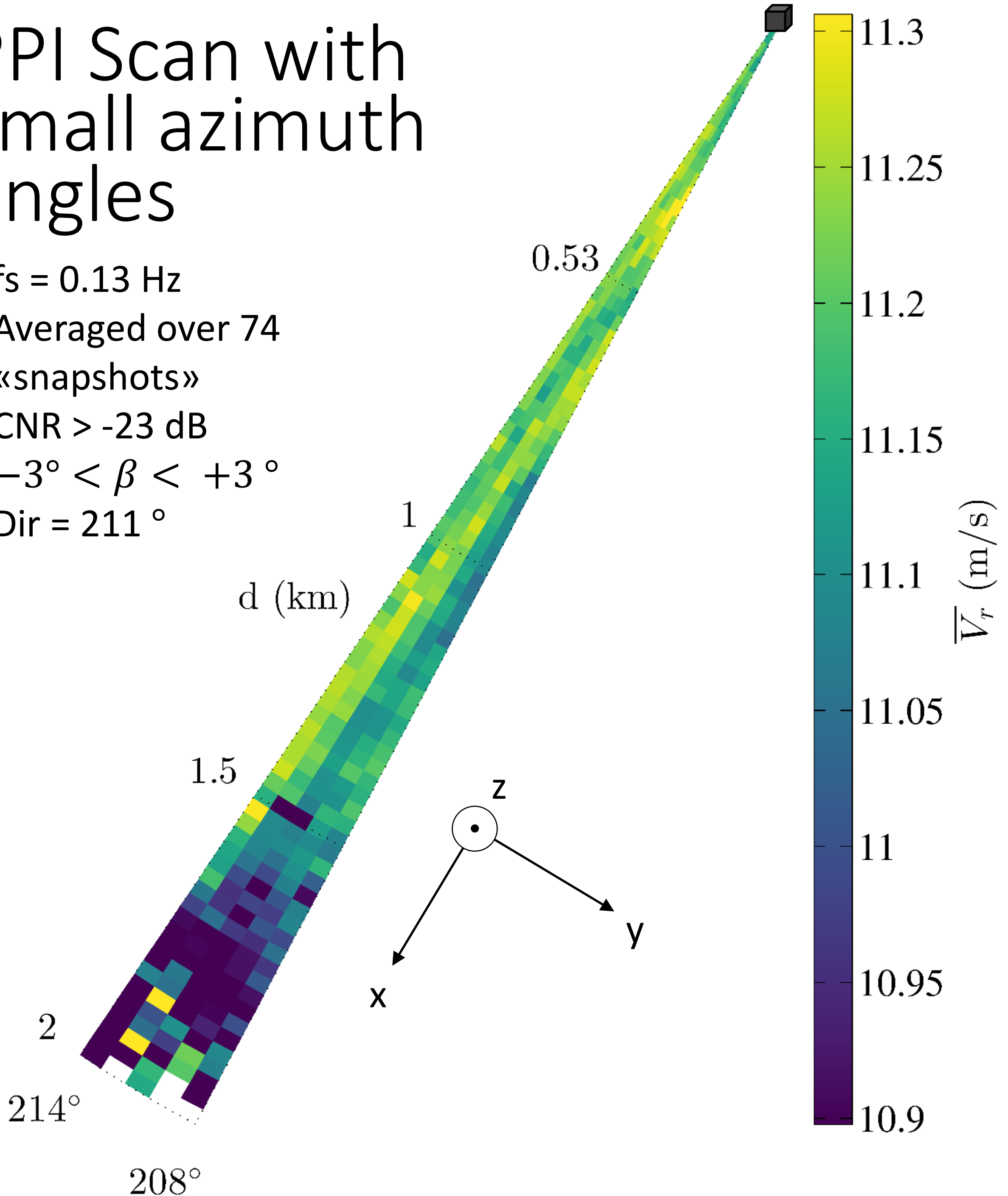
$\bar{V_r} \approx \bar{U}$
(err <1 % with β = 3°)

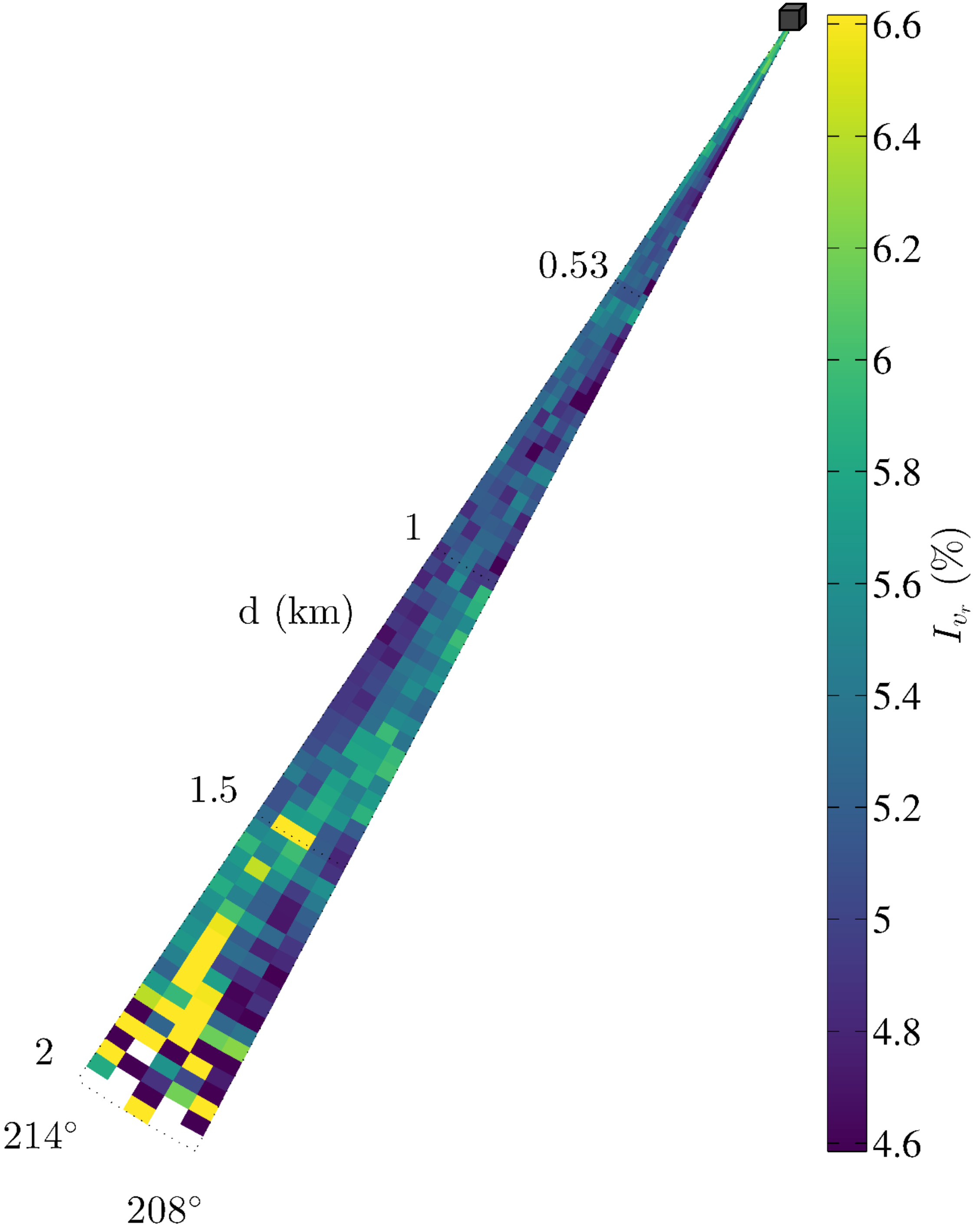
$I_{v_r} \approx I_u$
(err ≈ 5 % with I_v = $0.9 I_u$ *and* β= 3°)



PPI Scan with small azimuth angles

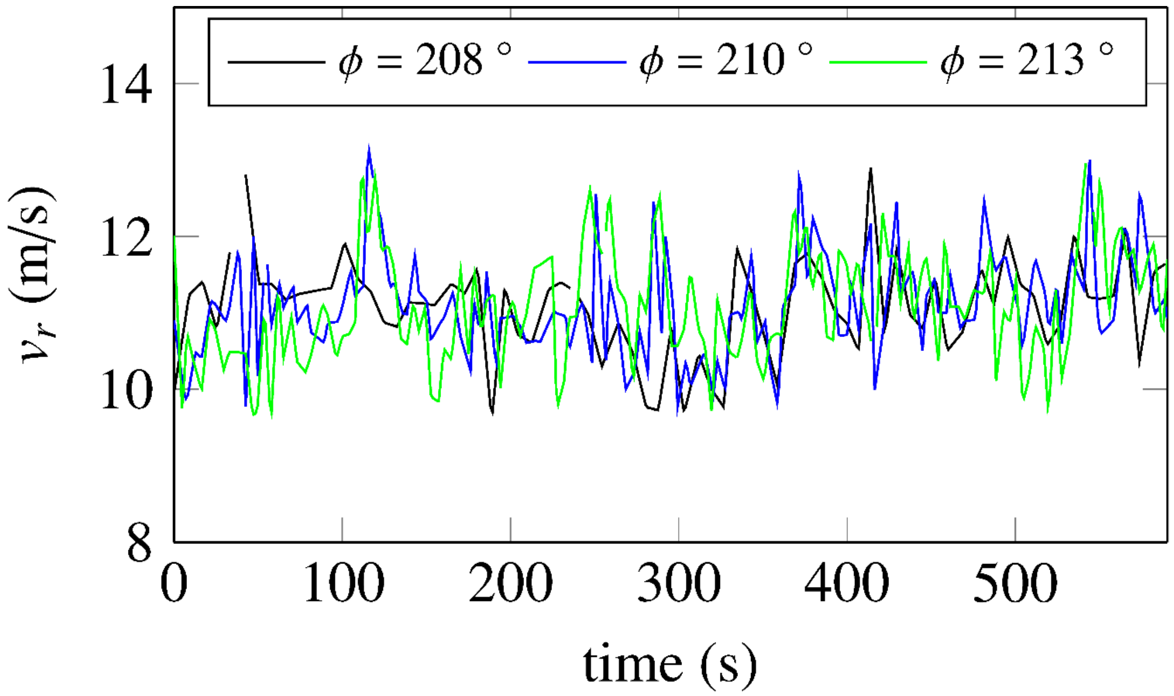
- fs = 0.13 Hz
- Averaged over 74 «snapshots»
- CNR > -23 dB
- $-3° < \beta < +3°$
- Dir = 211 °



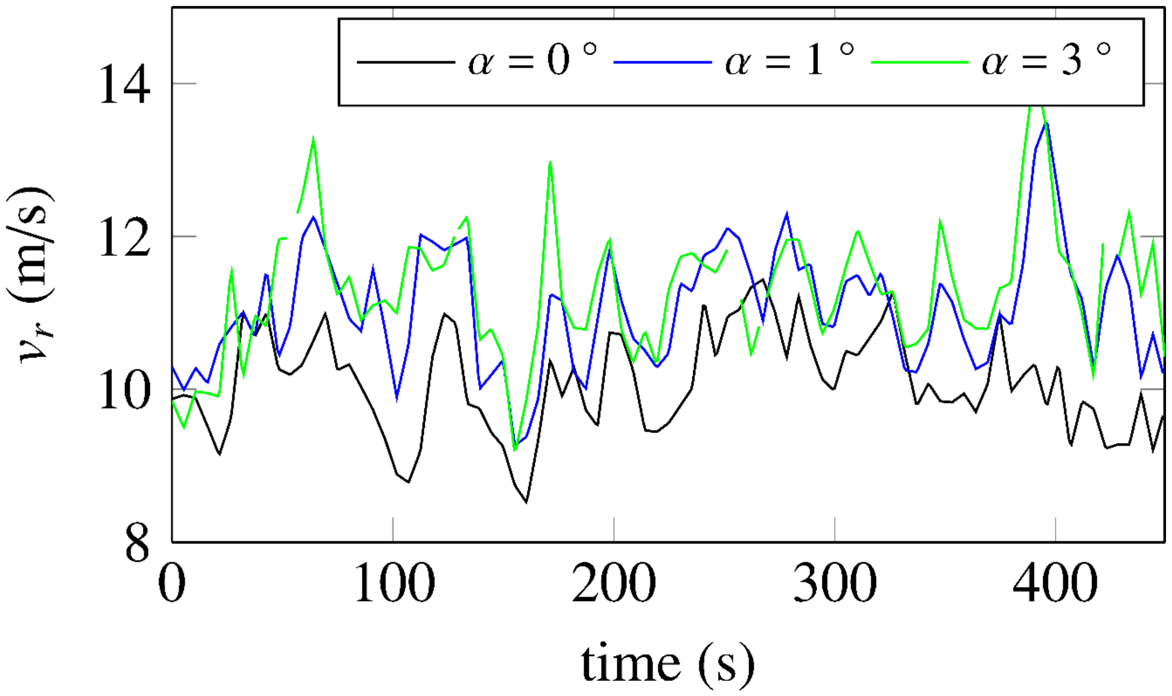


Wind stationarity

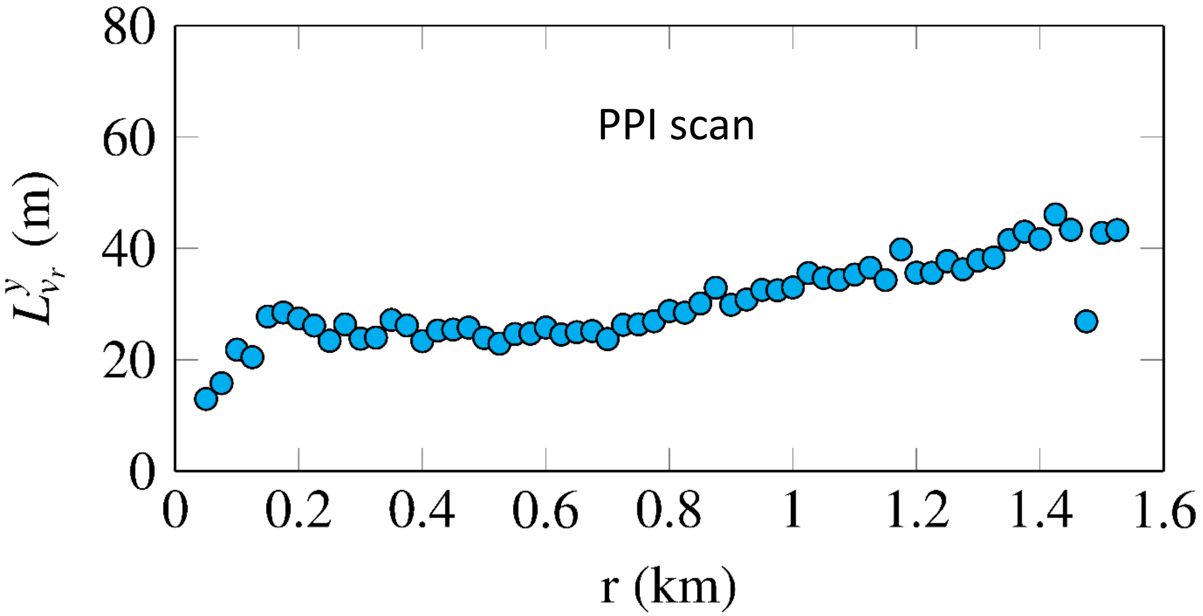
PPI (r = 1.5 km)

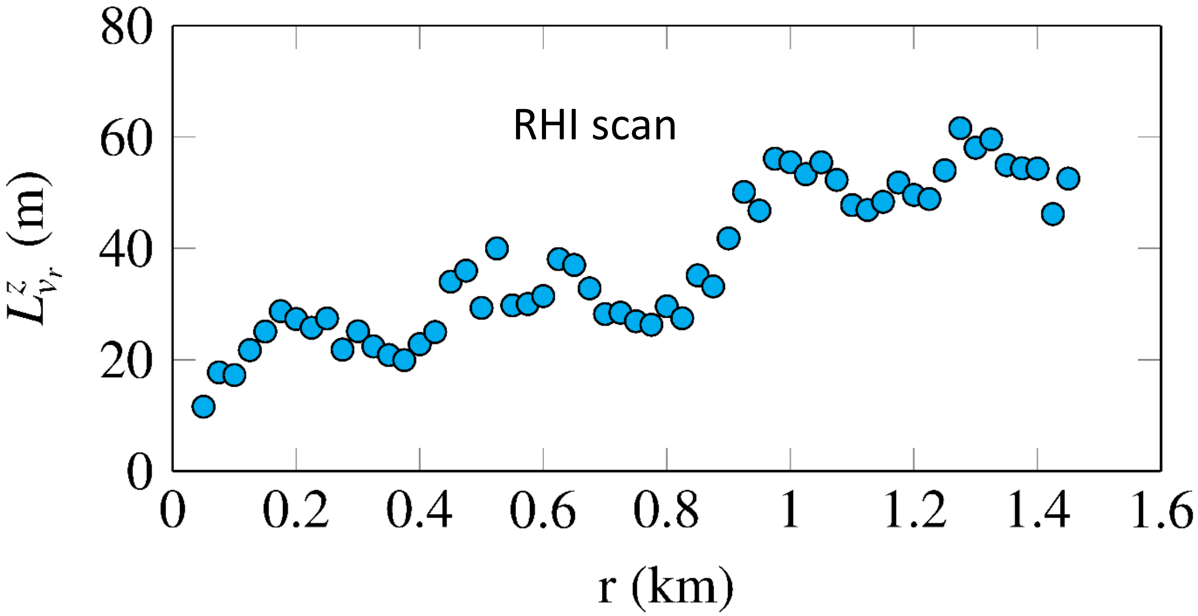


RHI (r = 1.5 km)



Cross-wind turbulence length scales





IEC reference root-coherence model

Frequency

$$\gamma_{v_r} = \exp\left\{-12\sqrt{\left(\frac{f \cdot d}{\bar{U}}\right)^2 + \left(0.12\frac{d}{L_c}\right)^2}\right\}$$

Coherence scale parameter

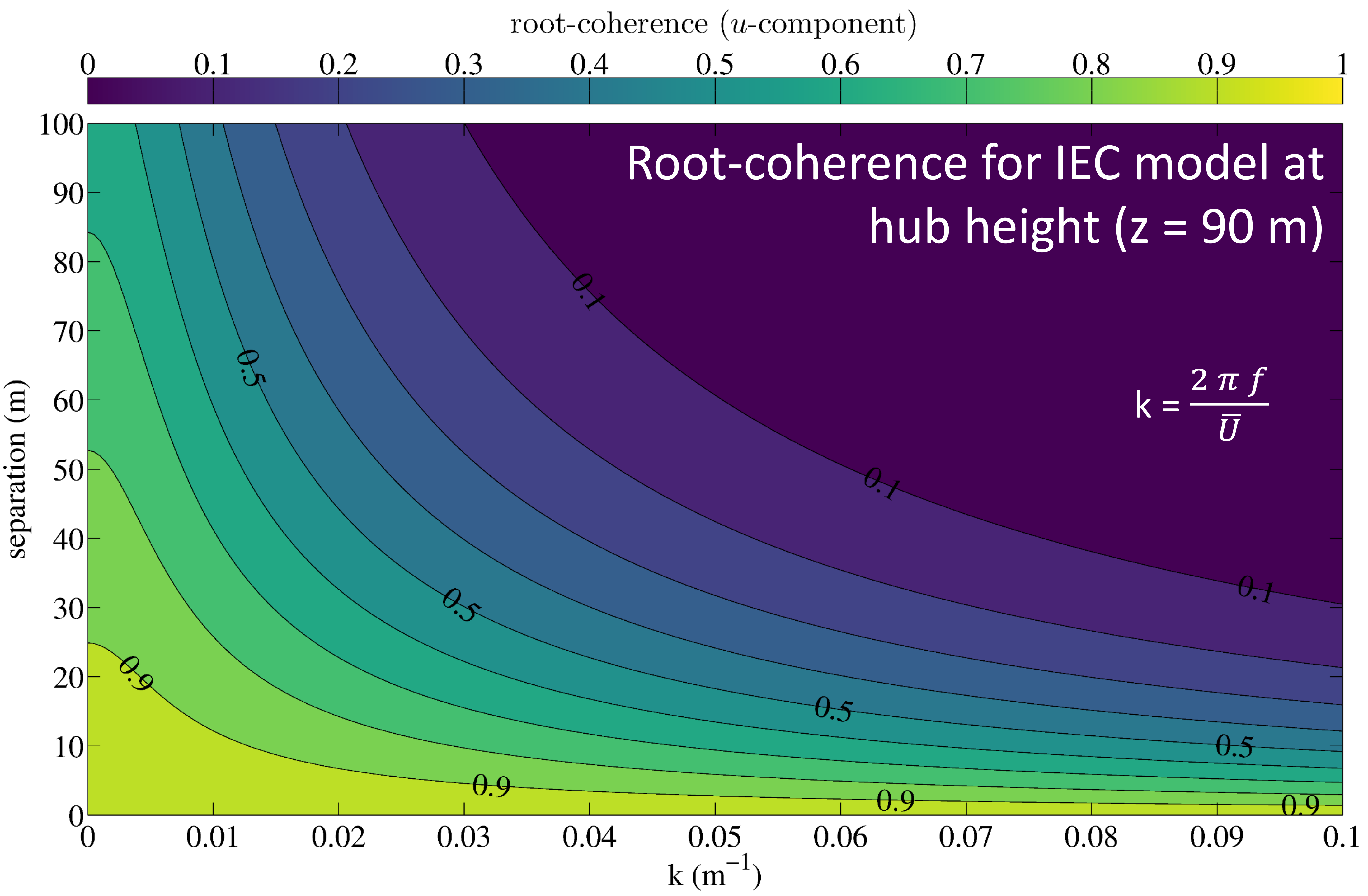
Lateral or vertical separation

Mean wind velocity

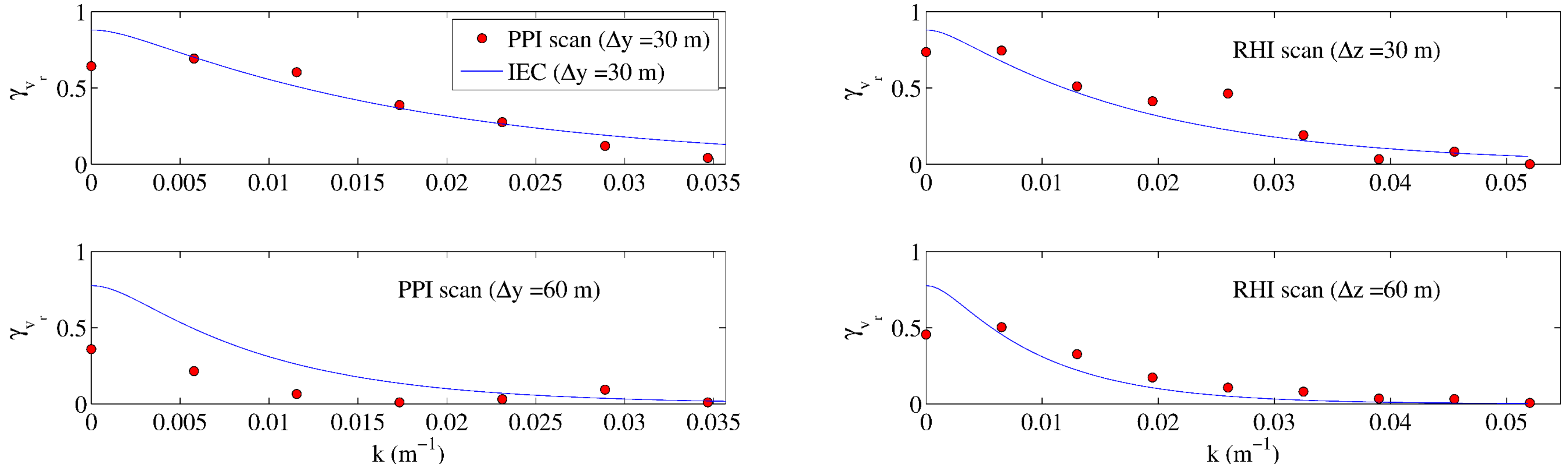
$Lc = 8.1\ \Lambda_1$

$$\Lambda_1 = \begin{cases} 0.7\,z\ (z < 60\text{ m}) \\ 42\text{ m}\ (z \geq 60\text{ m}) \end{cases}$$

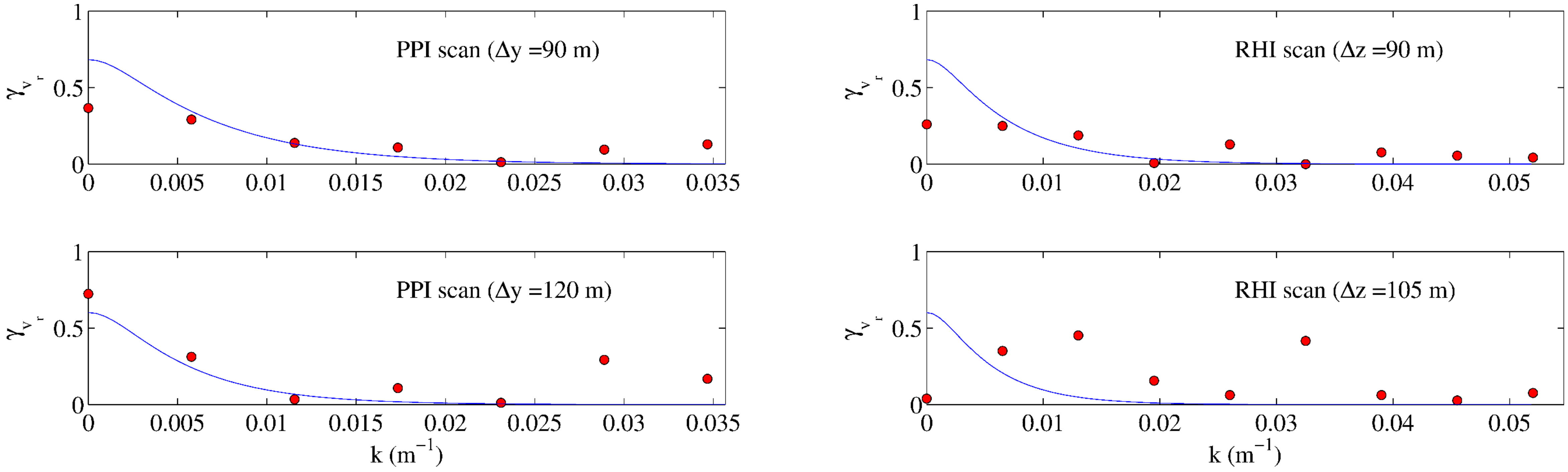
Here z = 90 m


root-coherence (u-component)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Root-coherence for IEC model at hub height (z = 90 m)
$k = \frac{2\pi f}{\bar{U}}$
separation (m)
k (m^{-1})
0.1
0.5
0.9

Lateral and vertical root-coherence



Lateral and vertical root-coherence



Conclusions

Summary:

- A single pulsed Doppler wind lidar is used to record wind time histories (PPI & RHI scan)
- This requires a particular configuration (small angles relative to mean wind direction)
- The measured coherence showed a rather good agreement with the IEC model

Challenges and prospects:

- The alignment of the lidar beam with the mean wind direction is done manually.
- Multiple samples should be used for coherence estimation.

Questions ?