Wind Tunnel Study of a "Floating" Wind Turbine's Wake in an Atmospheric Boundary Layer with Imposed Characteristic Surge Motion

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Main Questions

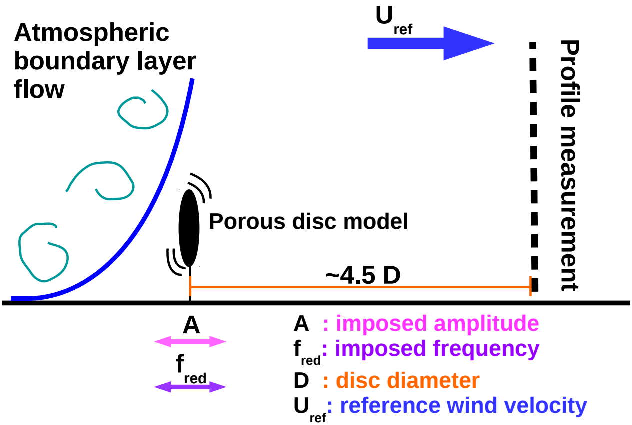
- **How does imposed surge motion affect the wake?**

→ Can the signature of the motion be found in the wake?

→ Can we expect faster or slower wake recovery?

Boundary Layer & Scaling

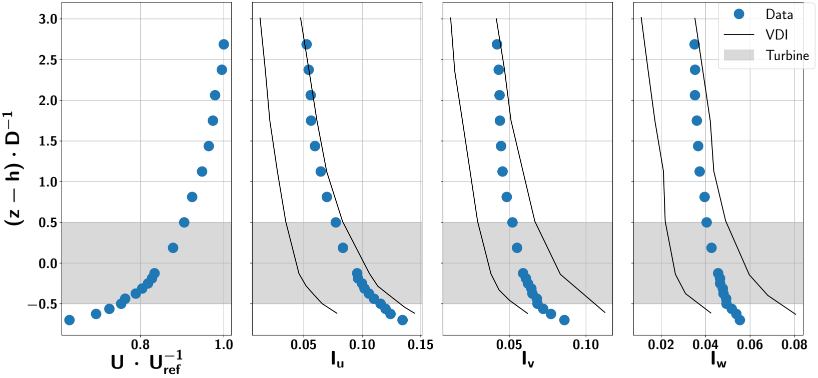
Experimental Set-up



$$f_{red} = \frac{f \cdot D}{U_{ref}}$$

- Geometric scaling: 1 : 500
- Velocity scaling: 1 : 2.5
- Characteristic A: $A = 0.125\,D$
- Characteristic f_{red}: $f_{red} = 0.1$

Modelled Boundary Layer



- Profiles indicate that the flow is representative of a maritime boundary layer according to VDI (2000).

Modelled Boundary Layer

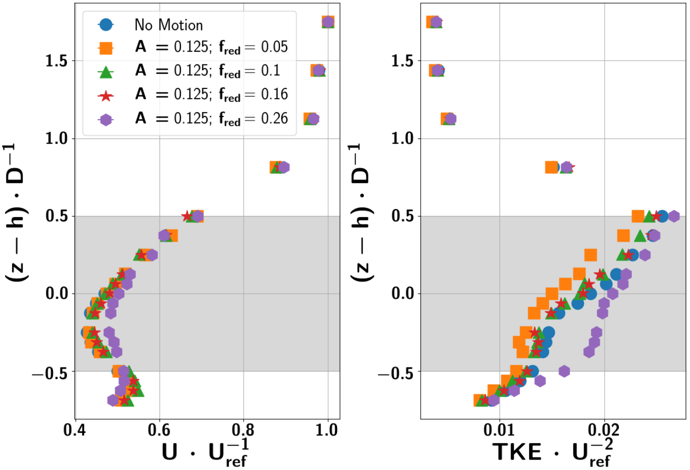
Table: Adaptation from VDI Guideline 3783. z_0 is the roughness length, α the exponent coefficient and L_u^x the integral length scale. Added values for the modelled boundary layer.

Roughness class	Target values	**Modelled**
Type of terrain	ice, snow, water surface	**water surface**
z_0 [m]	10^{-5} to 5×10^{-3}	**5.5×10^{-6}**
α	0.08 to 0.12	**0.11**
L_u^x [m]	200 to 250	**200**

- **Profiles and values show: flow is representative of a maritime boundary layer ✓**

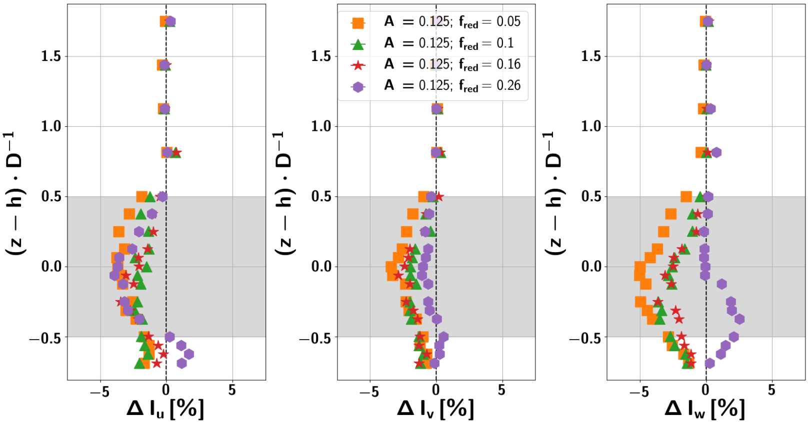
Profile Measurements & Spectra

Profiles - Velocity & TKE



- $f_{red} < 0.26$: U unchanged, decreases in TKE
- $f_{red} = 0.26$: increases in U , local increases in TKE

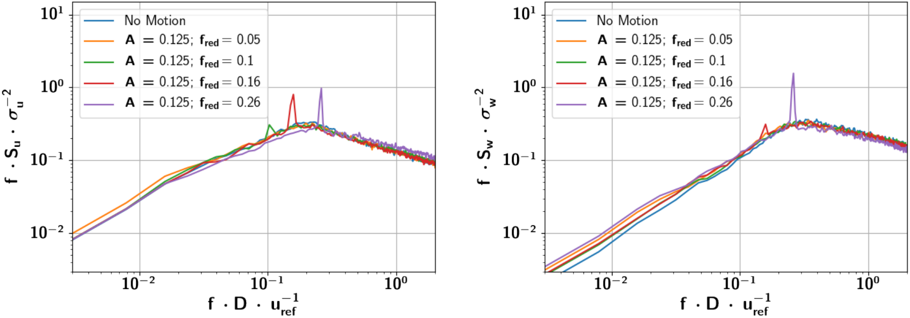
Profiles - Turbulence Intensity



$$\Delta I = I_{f_{red}} - I_{No\ Motion}$$

- $f_{red} < 0.26$: reduction in I
- $f_{red} = 0.26$: local increases in I_w

Spectra - Hub Height



- Peaks in spectrum at imposed motion frequencies
- Minimal shift in energy to higher frequencies in *u*
- Minimal shift in energy to lower frequencies in *w*

Conclusions & Outlook

How does induced motion affect the wake?

→ Can the signature of the motion be found in the wake?

- **Yes!** (if the motion frequency is sufficiently high, i.e. at the very edge of the operating envelope.)

→ Can we expect faster or slower wake recovery?

- **Profiles:** *U* unchanged, decreases in *TKE* and *I* (except for $f_{red} = 0.26$)
- **Spectra:** shift in energy to higher frequencies in *u*, inverse for *w*
- **→ Signs that imposed surge motion may lead to faster wake recovery at** 4.5 *D* **downstream**

Outlook

- To gain a more global understanding of the longitudinal development of the wake:
  - $\rightarrow$ Spatial characteristics of the wake to give 'context' to the profile measurements
  - $\rightarrow$ *TKE* budget and production analysis to assess wake recovery
  - $\rightarrow$ Measure wake up to 8 D to 10 D downstream
  - $\rightarrow$ Measurements using stereo PIV for spatial resolution
- More complex experiments: repeat analysis with several degrees of freedom as well as regular and irregular motion

VDI (2000). Umweltmeteorologie - Physikalische Modellierung von Strömungs- und Ausbreitungsvorgängen in der atmosphärischen Grenzschicht - Windkanalanwendungen. Technical report, VDI Verein Deutscher Ingenieure e.V., VDI-Platz 1, 40468 Düsseldorf, Germany.