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

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The Floateole Project

Figure: FLOATGEN, the prototype floating offshore wind turbine, used as a reference in this project. Source: https://sem-rev.ec-nantes.fr/medias/photo/sem-rev-bj-132-bd_1539862739781-jpg?ID_FICHE=196422 Accessed: 2020-09-21

- Duration of the project: 2017-2021
- Funding: Pays de la Loire, Centrale Nantes
- PhD thesis partly funded by ADEME
- Work includes wind tunnel experiments (PhD) and field measurements (LIDAR, Post-Doc)
- Comparison of measurements, when both data sets are available
- Industrial partners: D-ICE Engineering, IDEOL

Main Questions

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

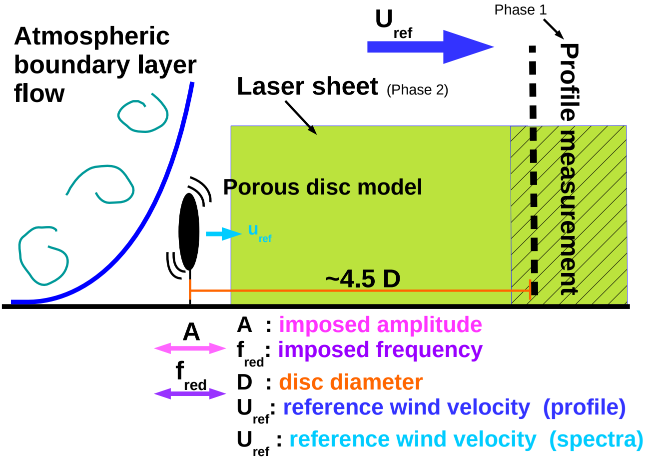
→ Can the signature of the motion be found in the wake?

→ Can we expect faster or slower wake recovery?

→ What does the spatial evolution of the wake indicate?

Boundary Layer & Scaling

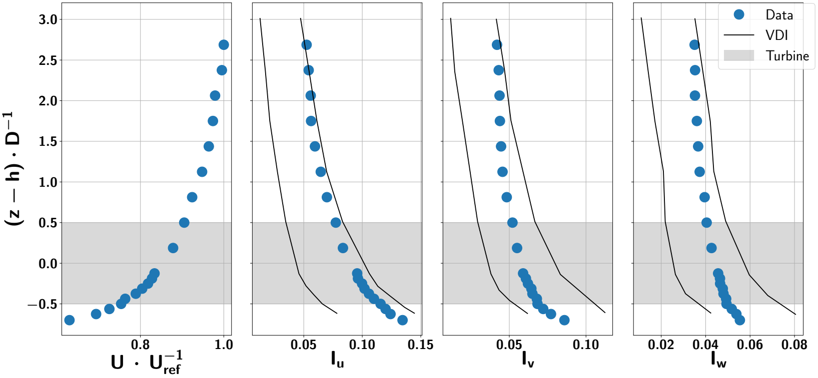
Experimental Set-up



- Geometric scaling: 1 : 500
- Velocity scaling: 1 : 2.5
- Frequency scaling: 200
- Characteristic A: $A = 0.125\ D$
- Characteristic f_{red}: $f_{red} = 0.1$

$\rightarrow$ **Motion derived from numerical simulation**

Modelled Boundary Layer



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

Modelled Boundary Layer

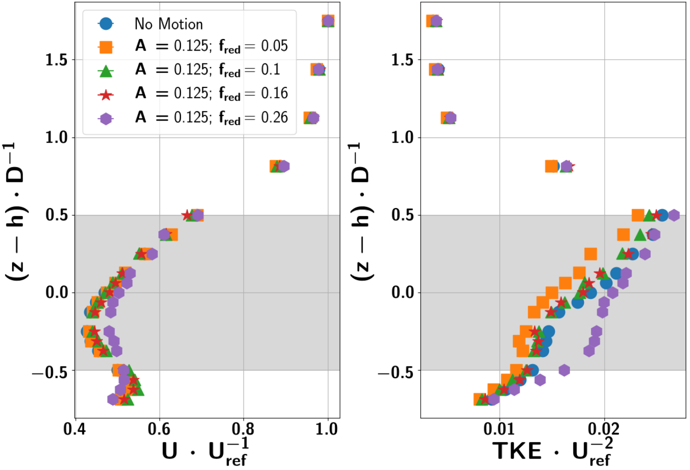
Table: Adaptation from VDI Guideline 3783. z_0 is the roughness length, α the exponent coefficient and L_u^x the integral length scale. Added values for the modelled boundary layer.

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 ✓**
- **Spectra also correspond to atmospheric boundary layer reference data ✓**

Profile Measurements & Spectra

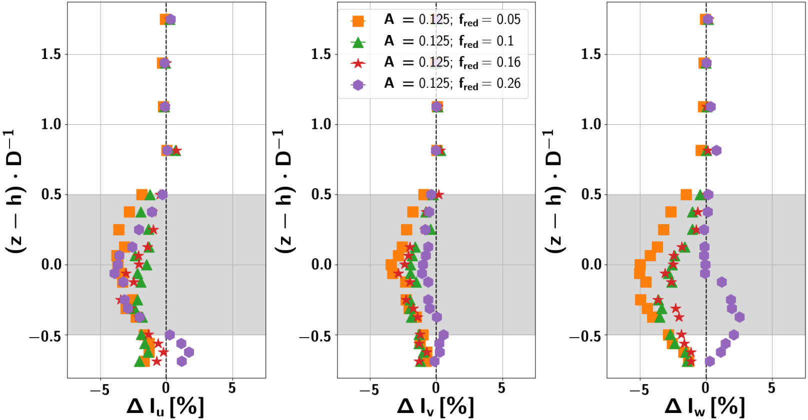
Profiles - Velocity & TKE



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

- Modifications of U and TKE in the wake through imposed motion

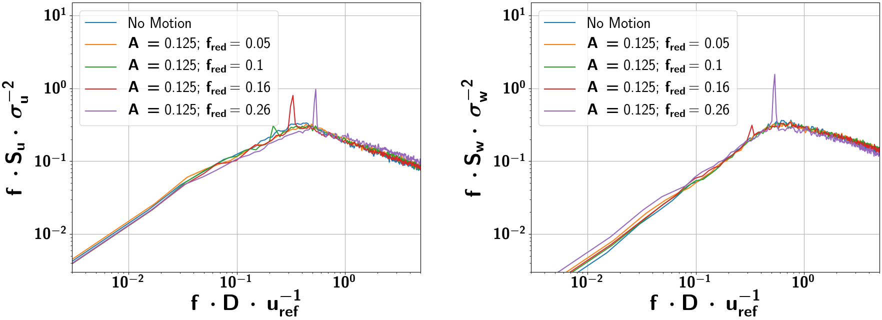
Profiles - Turbulence Intensity



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

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

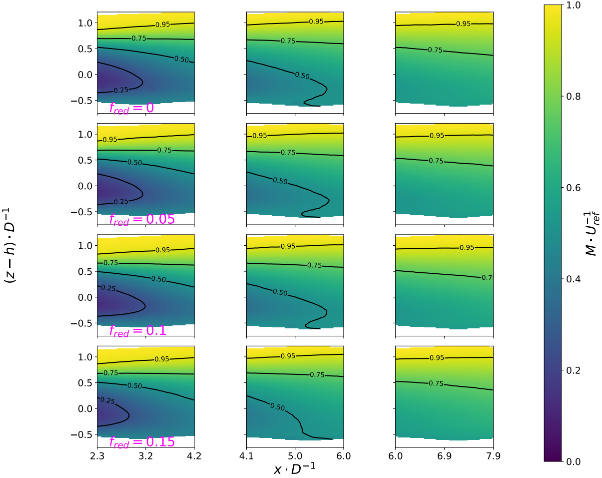
Spectra - Hub Height



- Peaks in spectrum at imposed motion frequencies
- $f_{red} = 0.26$: Minimal shift in energy to higher frequencies in u
- $f_{red} = 0.26$: Minimal shift in energy to lower frequencies in w
- all results up to here can be found in Schliffke et al. (2020)

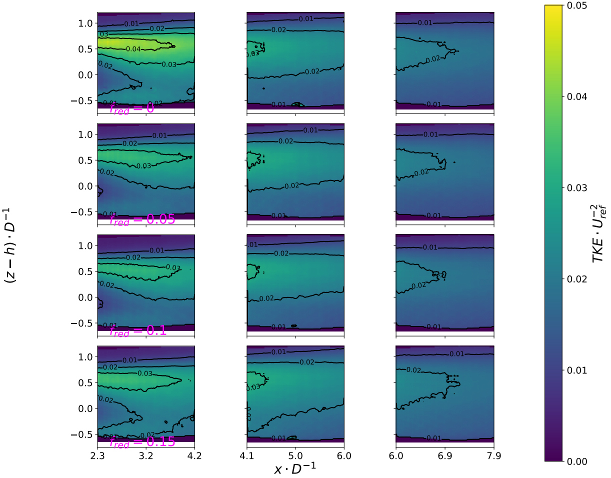
PIV Measurements - Velocity & TKE

PIV - Velocity



- Motion below $f_{red} <= 0.1$ has little effect on the mean flow
- $f_{red} = 0.15$ leads to of faster recovery of the mean flow

PIV - TKE



- Motion below $f_{red} <= 0.1$ has little effect on the TKE
- $f_{red} = 0.15$ leads to increased TKE below $(z-h)/D = 0$ up to $\approx 5\ D$

Conclusions & Outlook

Conclusions

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

- **Yes!** (if the motion frequency is sufficiently high)

→ 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*
- → **imposed surge motion may lead to faster wake recovery** 4.5 *D* **downstream**

→ What does the spatial evolution of the wake indicate?

- **Velocity:** $f_{red} <= 0.1$: little effect on the mean flow; $f_{red} = 0.15$: perceived faster recovery
- **TKE:** $f_{red} <= 0.1$: *TKE* largely unchanged; $f_{red} = 0.15$: local increases in *TKE*
- → **First analysis seems to confirm observations in Schliffke et al. (2020)**

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
- More complex experiments: repeat analysis with several degrees of freedom as well as regular and irregular motion

Schliffke, B., Aubrun, S., and Conan, B. (2020). Wind tunnel study of a “floating” wind turbine’s wake in an atmospheric boundary layer with imposed characteristic surge motion. *Journal of Physics: Conference Series*, 1618:062015.

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.