Wind & Marine Energy Systems CDT

Improved physical understanding of gust-wing interaction using the Impulse Method

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Motivation and Background

Unsteady fluid loads cause **structural fatigue** and **power fluctuations**, both of which **increase the levelized cost of energy**

Vortex gusts are caused by both **freestream turbulence** and **fluid-structure interaction** (Fig. 1)

Effective gust mitigation requires fast-acting control, which itself relies on **fast, accurate models**[1]

Thoroughly **understanding the underlying physics** helps us make **lower-order, higher-fidelity models**

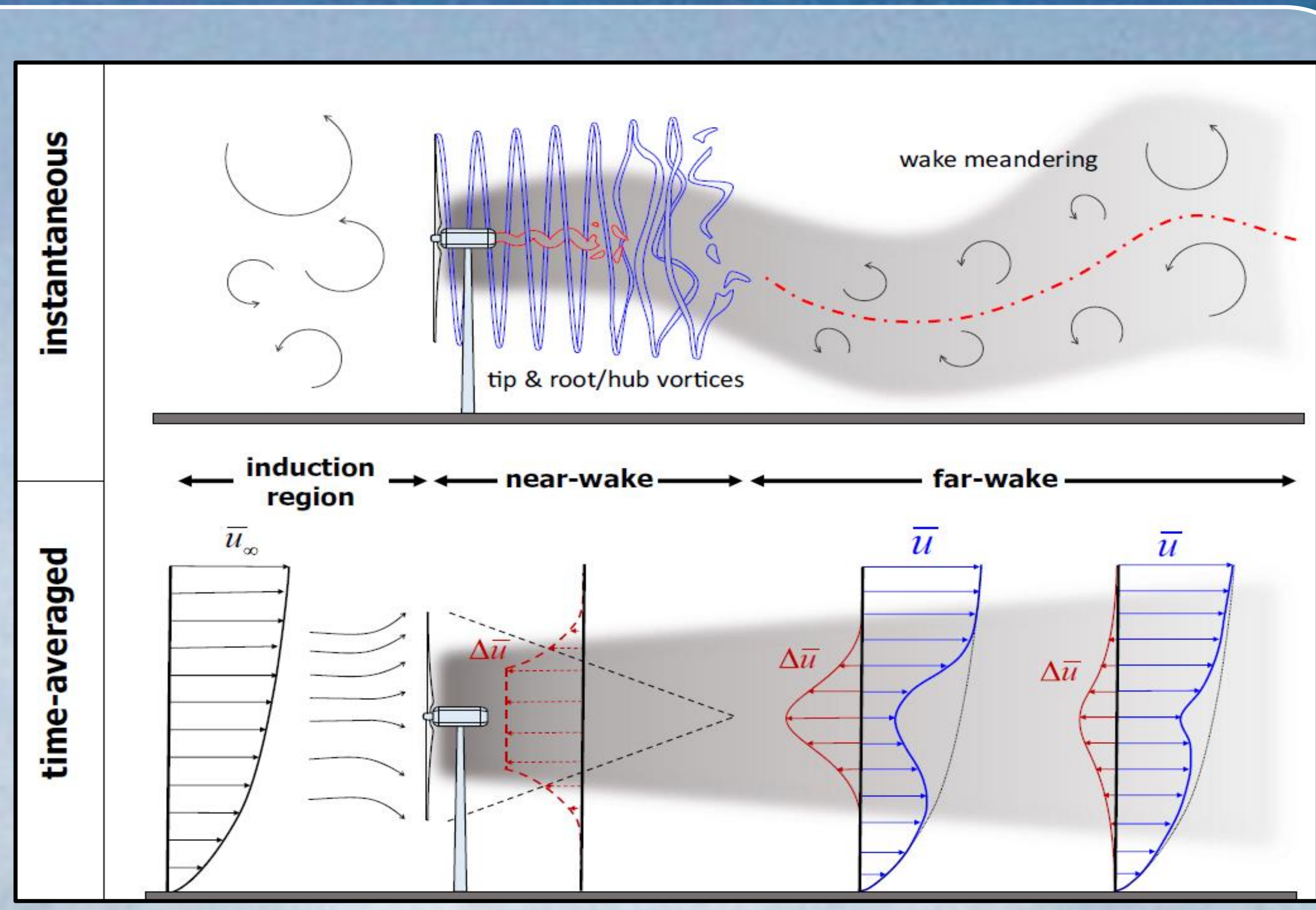

Fig. 1: Relationship between vortex gusts and shear in the incoming atmospheric boundary layer and a wind turbine wake[2]

Methodology

The **Impulse Method** calculates the **fluid forces** on an **immersed body** using the **vorticity** in the surrounding fluid[3]

It is **well-suited** for newer, **non-invasive, experimental, flow visualisation** techniques but, is still **largely unadopted**

Exploring gust-wing interaction with this **alternative, vorticity-based approach** may yield **new insights into the underlying physics**

We can use these insights to **improve existing models**, as researchers at **VOILAb** have **previously demonstrated** (Fig. 2)

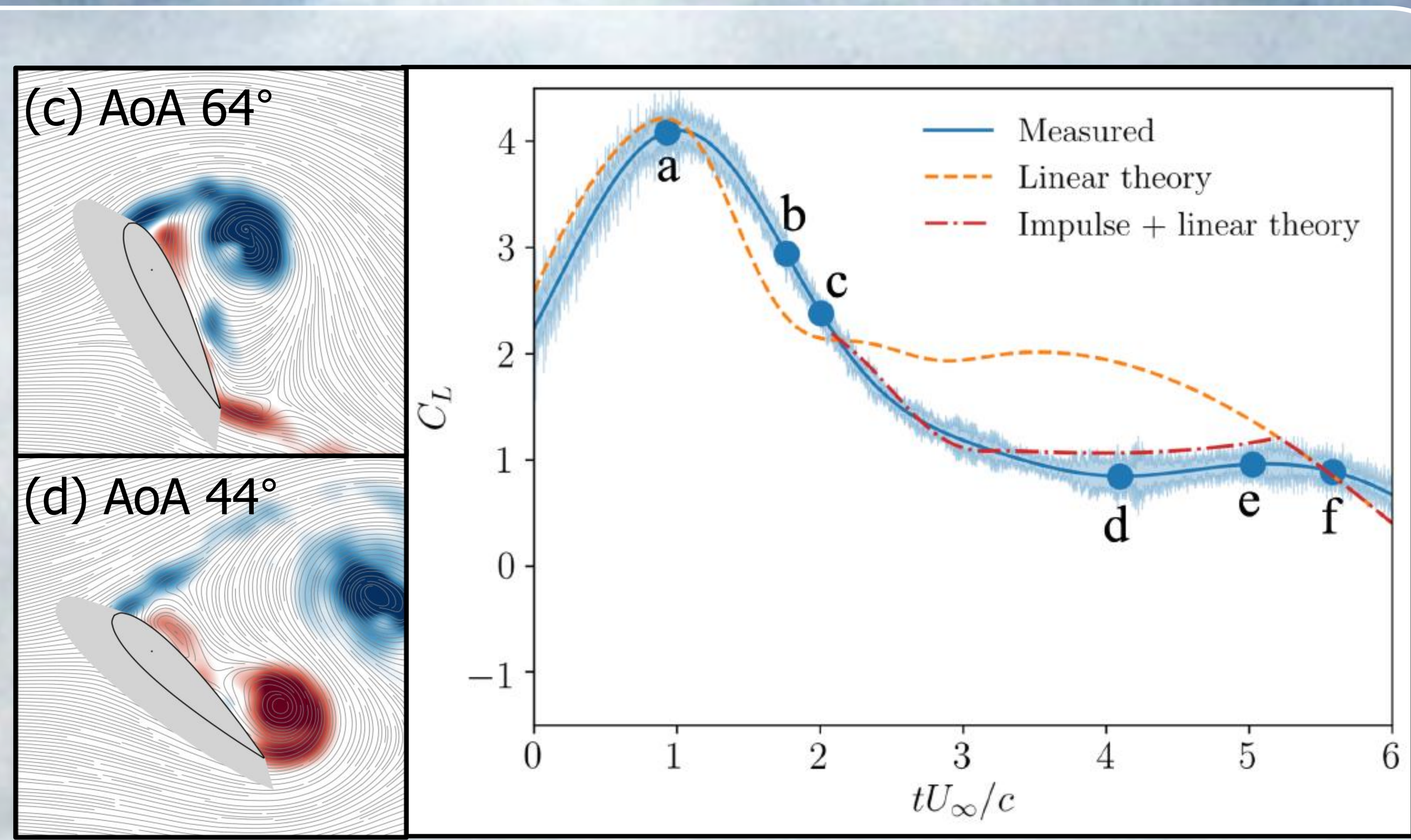

Fig 2: Improved prediction of lift on pitching and plunging foils by combining the Impulse Method with an existing model[4]

Research questions

1. How can the Impulse Method describe the force production mechanisms of a 2D foil at incidence, including parameters governing vorticity production rate?
2. How is the 2D description in (1) affected by 3D effects?
3. How can the Impulse Method describe the force production mechanisms of a 3D wing during a vortex gust?
4. Can we build a model based on (3) capable of predicting the low-order effects of a vortex gust on a 3D wing?
5. [Time permitting] How are these models extended to rotating blades?

Key deliverables

An **analytical examination** of the **equivalence** of the **Impulse Method** and the theories underlying existing low order models

A **low-order code** that predicts the **fluid forces on an immersed body** due to vortex gusts and **improves upon or replaces existing models**

Experimental apparatus capable of **generating a series of discrete vortices** that travel downstream in the flow and **impact upon and/or pass a foil**

Particle image velocimetry data showing the **evolution of the vorticity in the fluid field** surrounding the foil over time

References

[1] G. A. M. van Kuik et al., "Long-term research challenges in wind energy – a research agenda by the European Academy of Wind Energy," Wind Energy Sci., vol. 1, no. 1, pp. 1–39, 2016, doi: 10.5194/wes-1-1-2016.
[2] F. Porté-Agel, M. Bastankhah, and S. Shamsoddin, "Wind-Turbine and Wind-Farm Flows: A Review," Boundary-Layer Meteorol., vol. 174, no. 1, pp. 1–59, Jan. 2020, doi: 10.1007/s10546-019-00473-0.
[3] G. A. M. van Kuik et al., "Long-term research challenges in wind energy – a research agenda by the European Academy of Wind Energy," Wind Energy Sci., vol. 1, no. 1, pp. 1–39, 2016, doi: 10.5194/wes-1-1-2016.
[4] S. Otomo, K. Mulleners, K. Ramesh, and I. M. Viola, "On the lift and vortices of an asymmetrically pitching foil," Bull. Am. Phys. Soc., 2019.

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