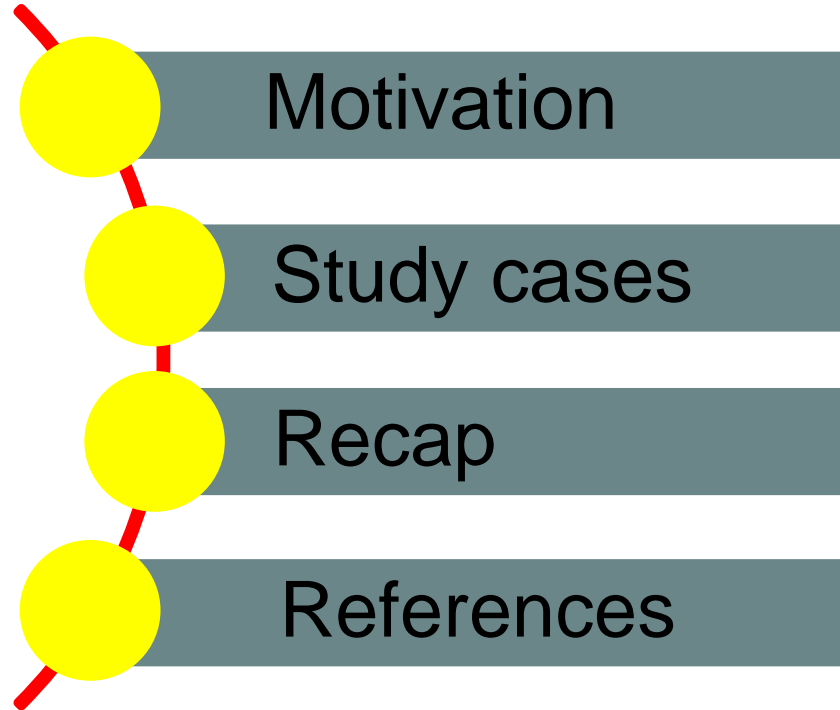


# Simulations and experiments go hand in hand

Wei Yu  
Andrea Sciacchitano  
Carlos Ferreira

Delft University of Technology  
January 25<sup>th</sup> 2023

# Outline



# Why do we need simulations?

## Experiments

- ☐ Costly both in equipment and manpower
- ☐ Actual models
- ☐ Fixed set-up
- ☐ Can only measure limited variables constrained by given meter
- ☐ Can only measure whatever is present

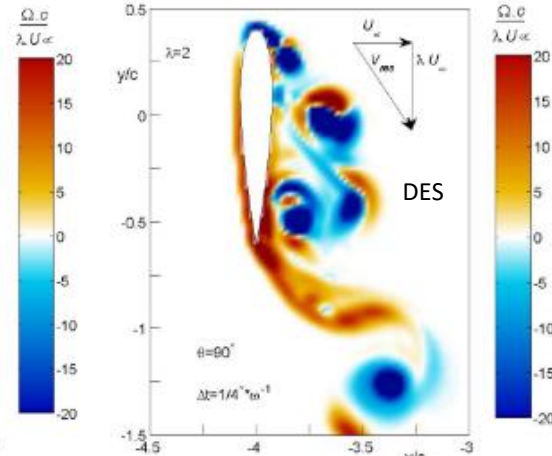
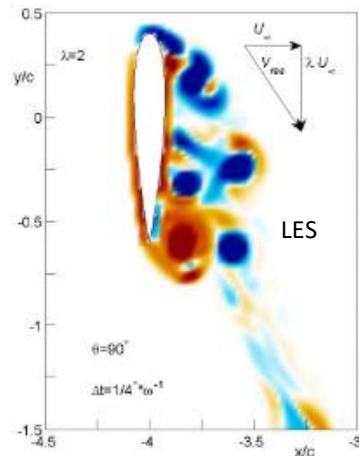
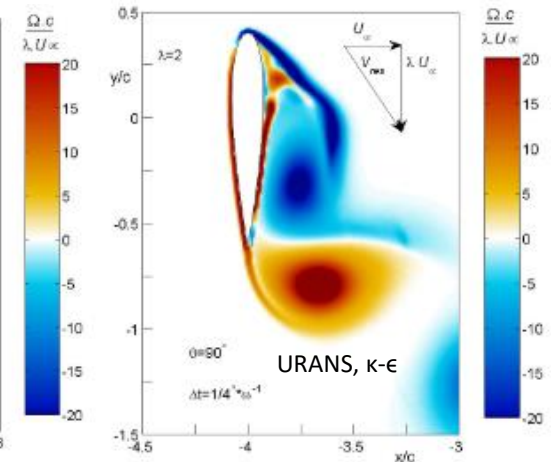
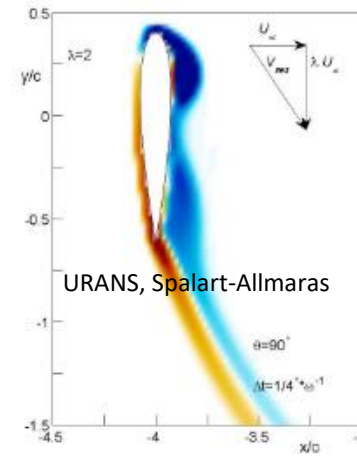
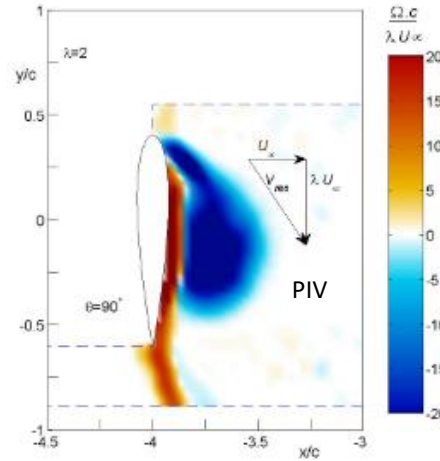
## Simulations

- ☐ Faster and cheaper
- ☐ Virtual models, can predict for future products
- ☐ Iterating is easier
- ☐ All information of the entire field is available
- ☐ Can decompose/decouple effects from different sources

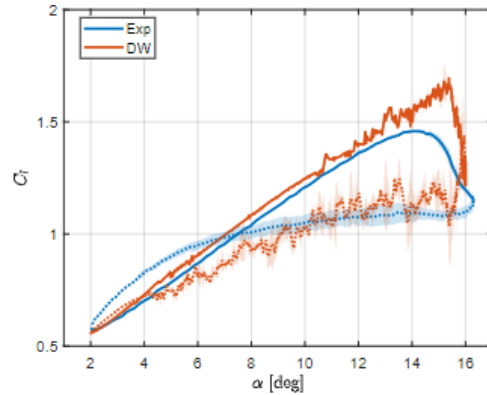
# PIV vs CFD

Phase-averaged  
vorticity field of  
an airfoil at  
 $\text{AOA}=90^\circ$ <sup>[1]</sup>

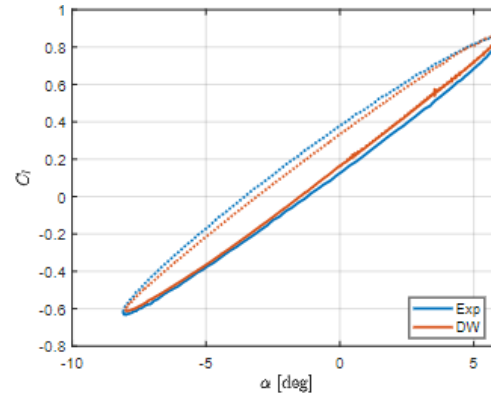
Select the right model



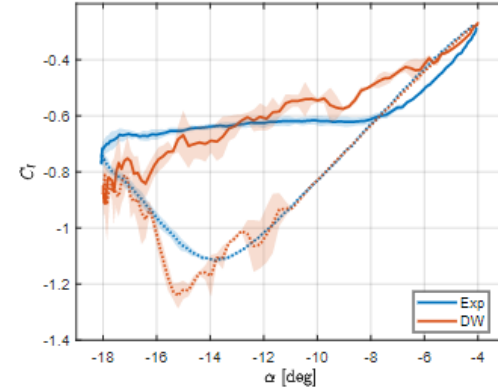
# Exp vs vortex model



(a)  $\alpha_0 = 9^\circ$

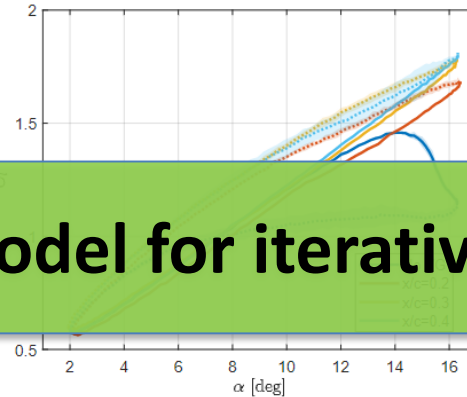


(b)  $\alpha_0 = -1^\circ$

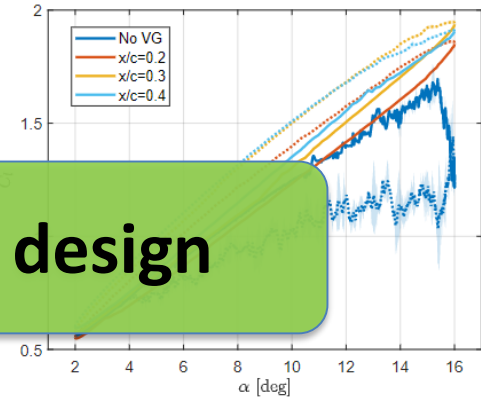


(c)  $\alpha_0 = -11^\circ$

Double wake model validation of a clean airfoil (above) and with VGs(below) under dynamic stall



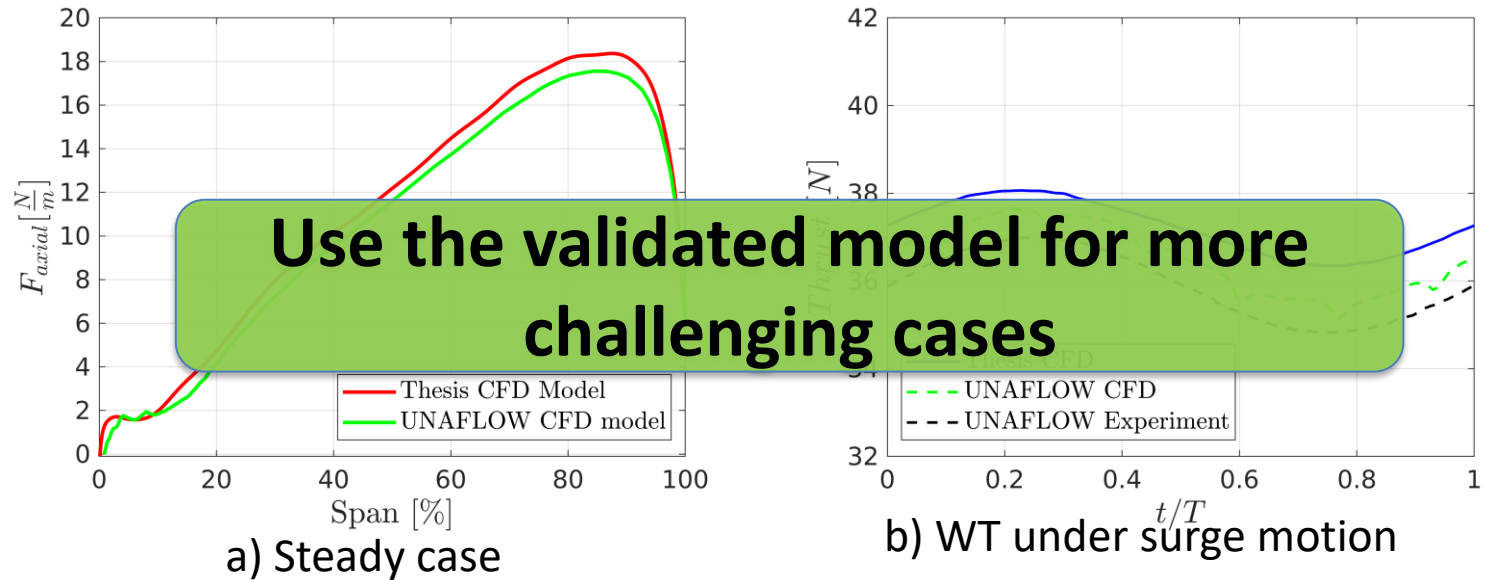
(a) Experiment



(b) DW

**Use the validated model for iterative design**

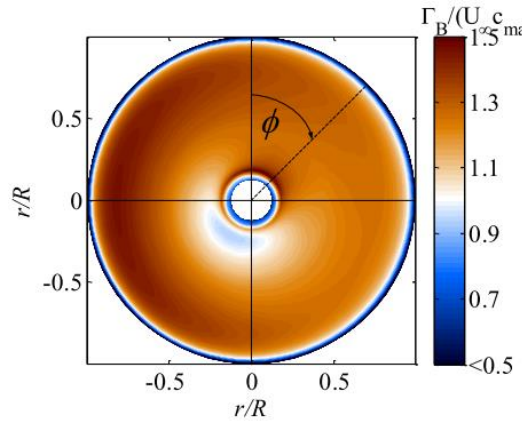
# Exp vs CFD



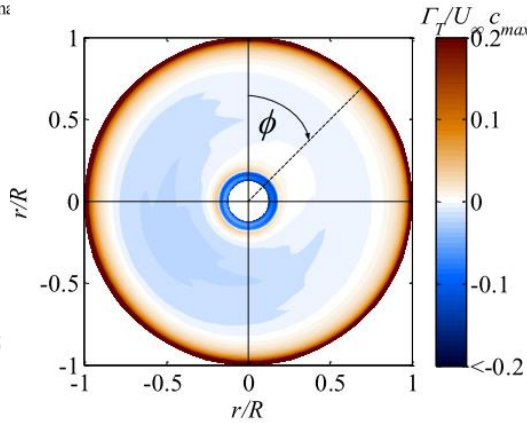
Blade resolved CFD simulation of UNAFLOW<sup>[2]</sup>

$Exp V_{max,red} = 0.025 \longrightarrow CFD V_{max,red} > 1.0$

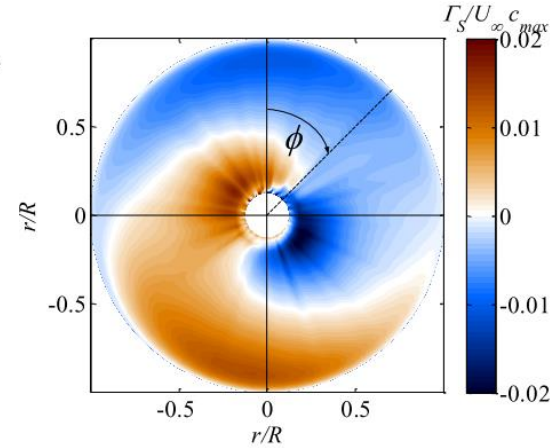
# Decompose the effects



Bound vorticity



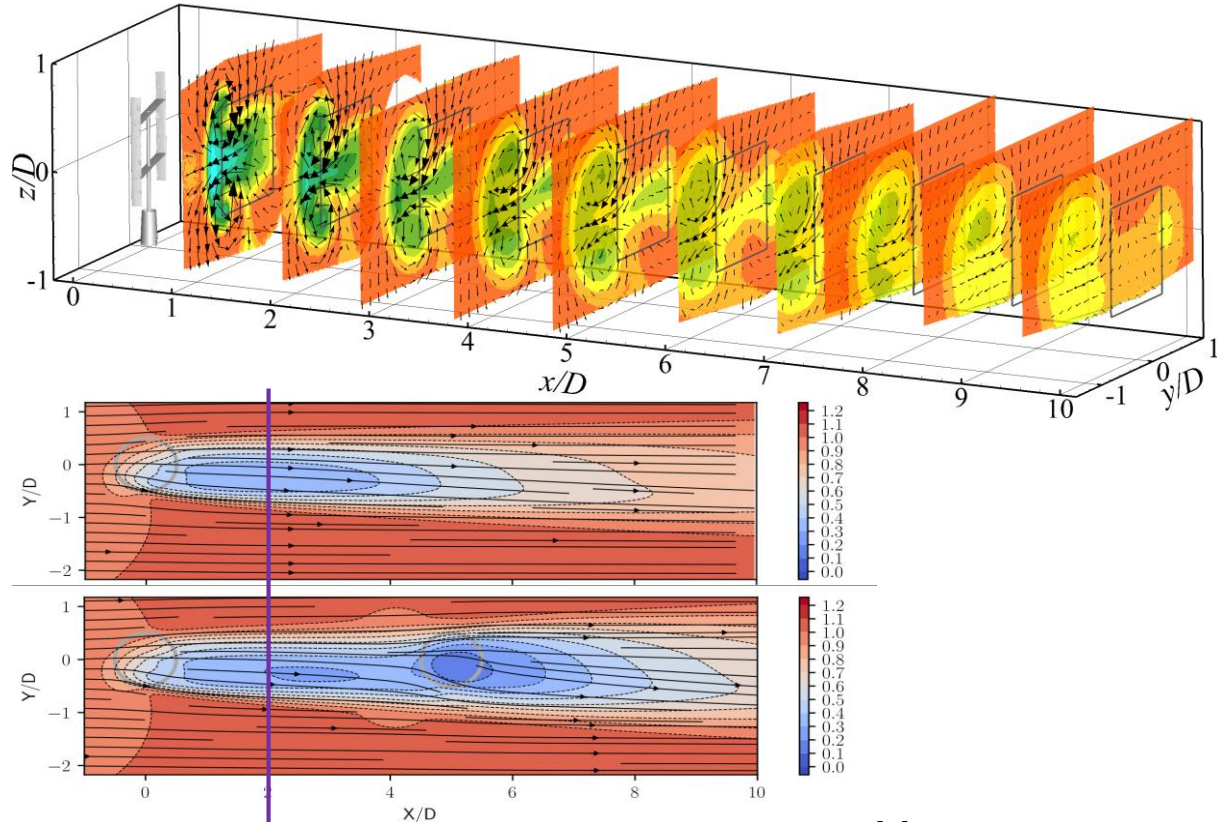
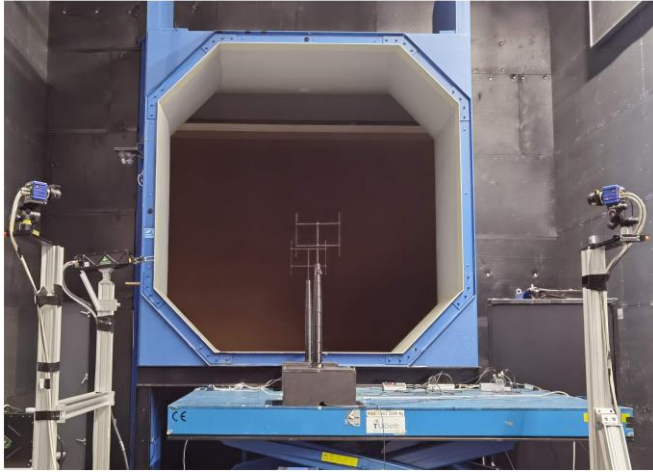
Trailing vorticity



Shed vorticity

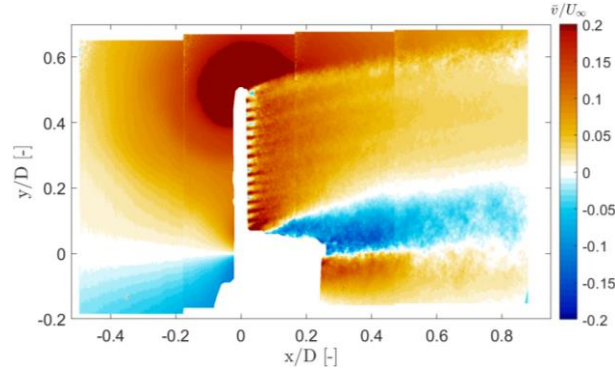
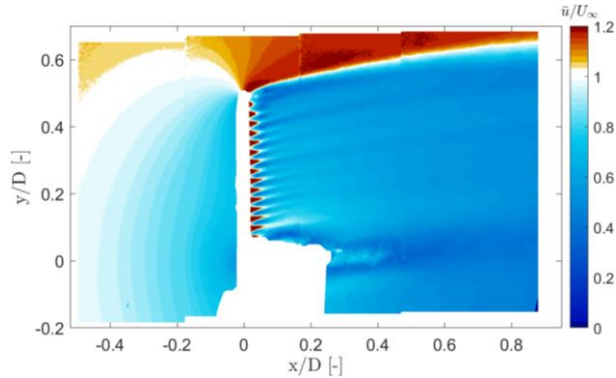
Decomposed azimuthal variation of vorticity field for MEXICO rotor at yawed condition using panel method<sup>[3]</sup>

# Exp and Sim complements each other



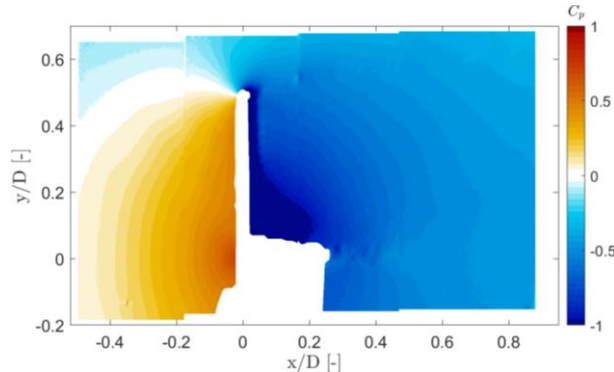


# To infer unknown variables --- traditional methods



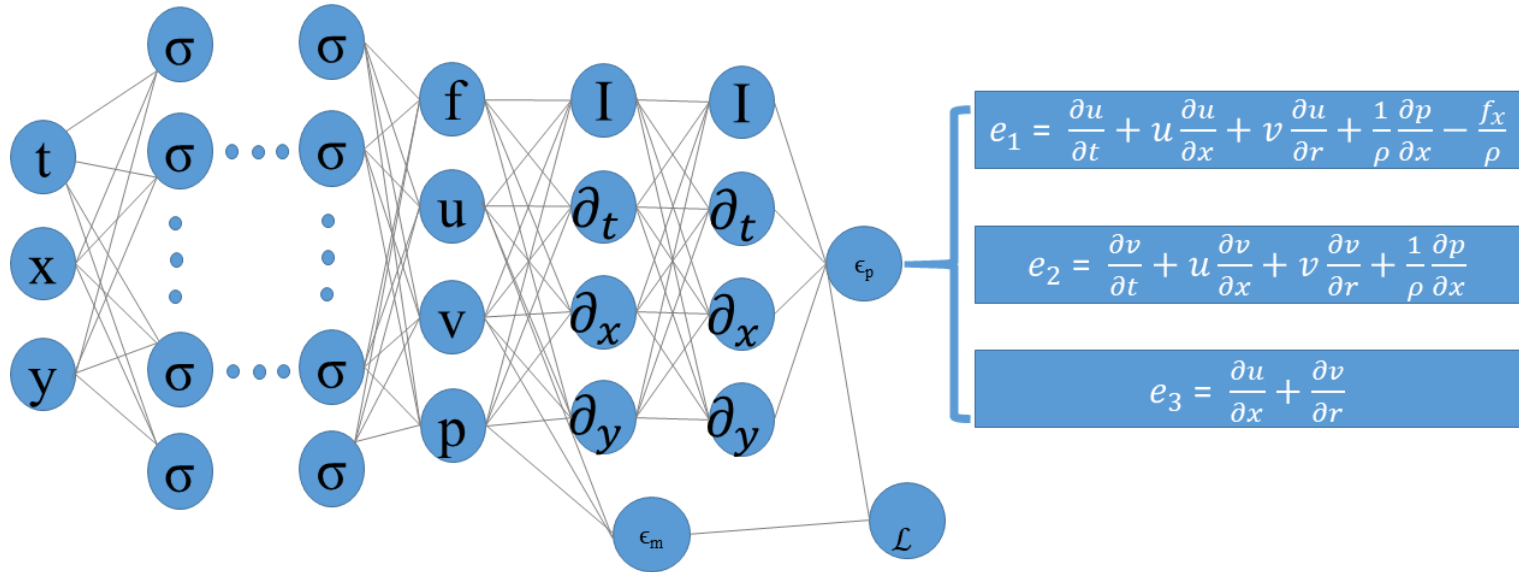
Measured velocity field of an actuator disc

Calculate



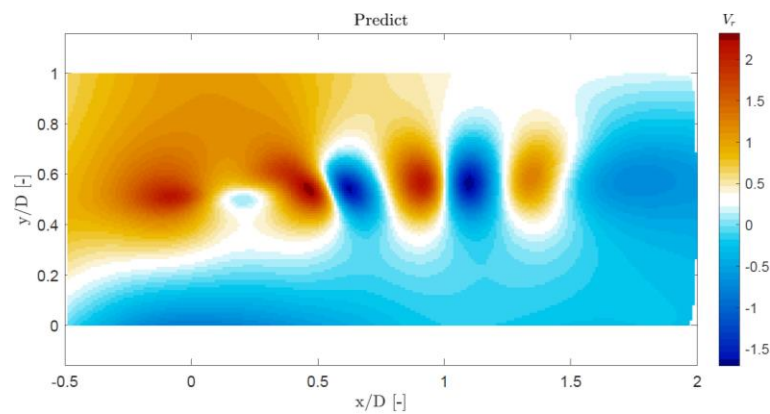
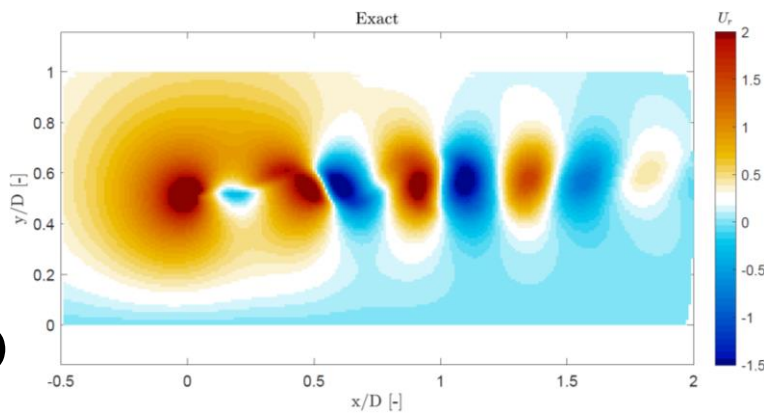
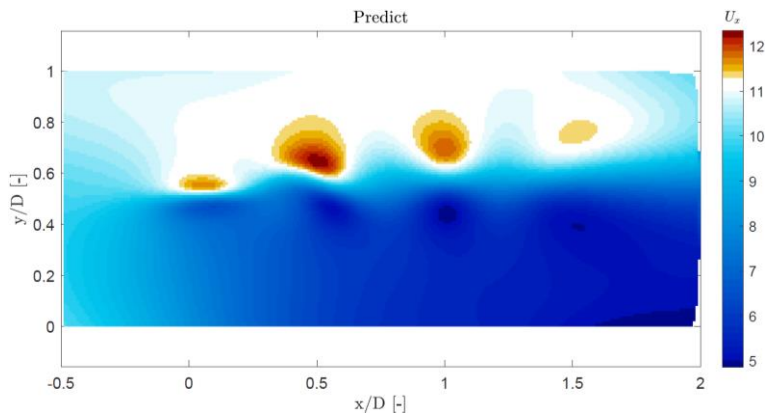
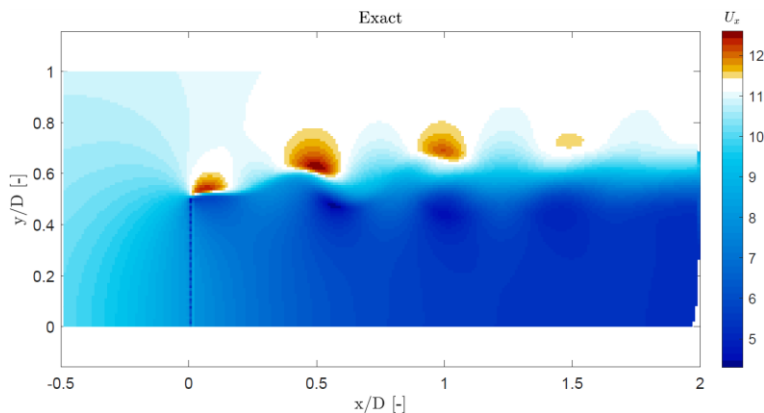
Loads

# To infer unknown variables --- Machine Learning



Representative of a Physics-Informed Neural Network (PINN)

# To infer unknown variables --- Machine Learning



# Recap

Experiments and simulations will never replace each other, they will go hand in hand.

1. After the model is validated and assessed against experimental data, we can:

- Select the right model;
- Do iterative design;
- Extend the test matrix to more interesting and critical cases, which are challenged in experimental set-up;
- Better understand of the physics as models are more flexible to change settings.
- .....

2. Based on experimental data, we use numerical models

- To complement measurements
- To infer unknown fields
- .....

# References

- [1]Ferreira C. PhD thesis, 2009.
- [2]Spyridonos G. Ongoing MSc thesis, 2023.
- [3]Micallef D. PhD thesis, 2012.
- [4]Hunag M. Ongoing PhD thesis,2023

# Questions?

