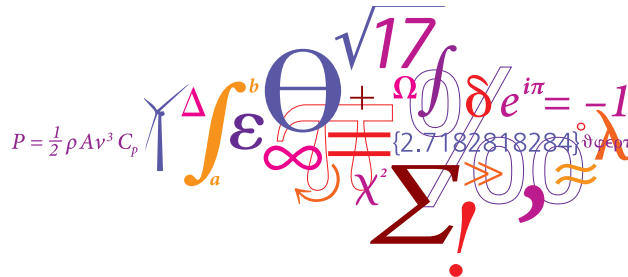


The induction zone in complex terrain

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Motivation

Can we assume the induction zone to be universal?

- Compare flat and complex terrain flow upstream
- Identify governing parameters



CFD - RANS simulations

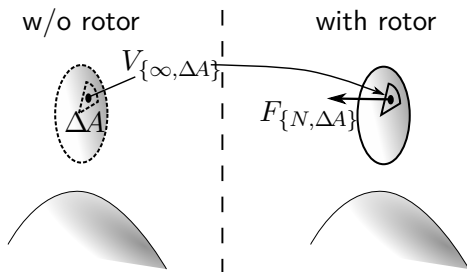
Different inflow profiles:

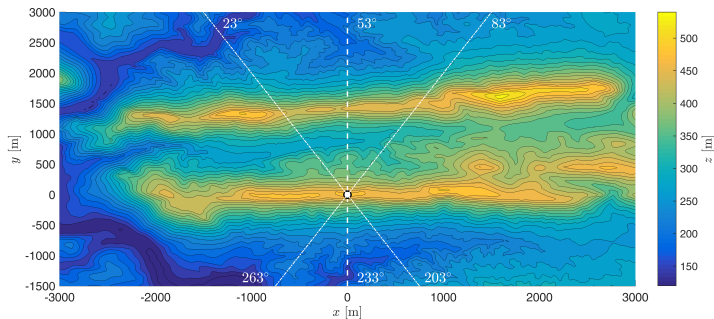
- Uniform
- Sheared
- Complex

Conserve C_T across simulations

Extract velocities from turbine-less flow and compute forces on actuator disc

$$F_{\{N, \Delta A\}} = \frac{1}{2} \rho_{\infty} V_{\{\infty, \Delta A\}}^2 C_T \Delta A$$





Height contours of the parallel ridges at Perdigão (Portugal)

Simulated wind directions

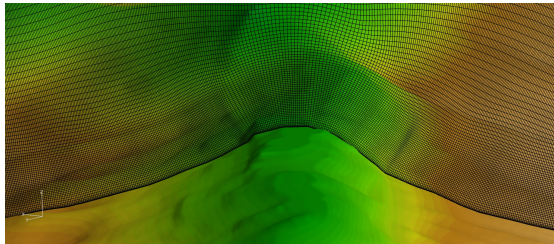
- Main wind directions orthogonal to ridge 53° , 233°
- 60° sectors about main directions divided in 15° steps

Grids

- Close to rotor same spacing $R/16$
- Box domains for uniform and sheared flow
- Automatic O-mesh generation for Perdigão

Simulations

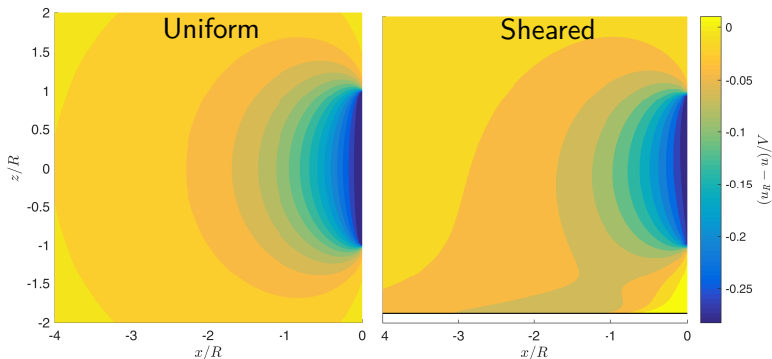
- 2 x uniform
- 2 x sheared
- 40 x complex



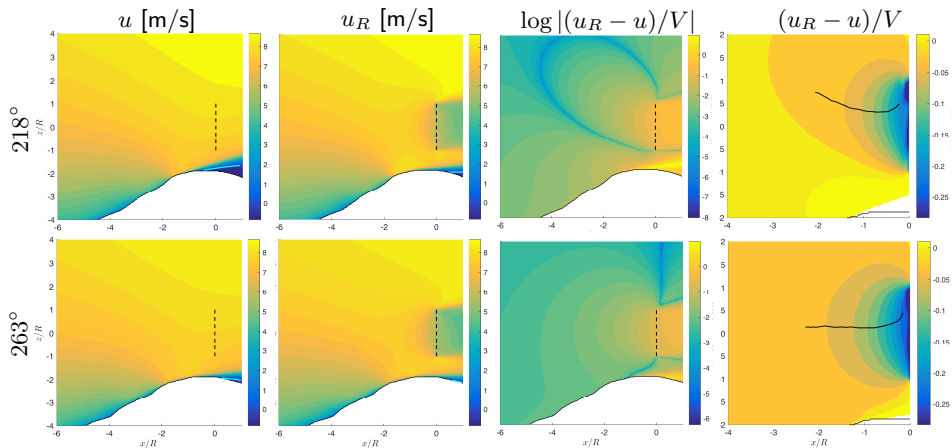
Uniform and Sheared

Isolate induction zone effect

$$\Delta \hat{u} = (u_R - u)/V$$

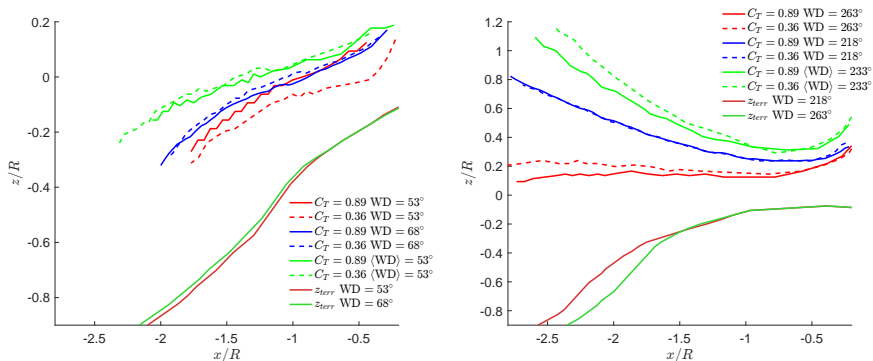


$$C_T = 0.89$$



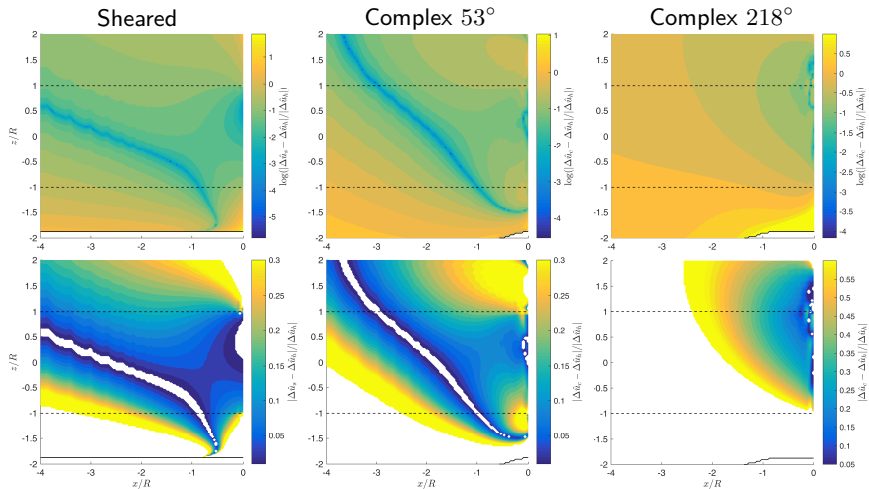
$$C_T = 0.89$$

Does the induction zone follow the terrain?

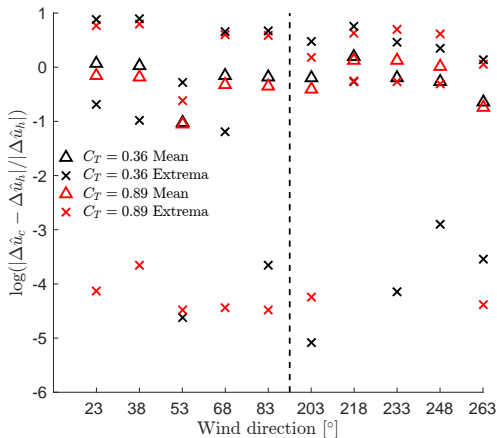


Evolution of maximum deficit in stream-wise velocity component, for $C_T = 0.36, 0.89$ and each sector - left = 53° and right = 233° . The extremes and their corresponding terrain transects are given additionally to the mean for each sector.

$$|\Delta \hat{u}_{\{s,c\}} - \Delta \hat{u}_h| / |\Delta \hat{u}_h|$$



Dependency of the normalised absolute difference on wind direction



For each complex terrain simulation the mean and extrema of an area bounded by $-2 < x/R < -0.25$ and $-0.85 < z < 0.85$ are shown for differing values of C_T .


Takeaways

- Sheared induction zone \approx Uniform + Boundary layer
- Complex terrain depends on wind direction/ wake trajectory

Future work

Parametric hill study

- Identify parameters important for simple model
- Stability & Hill shape

An aerial photograph of a large white wind turbine with three blades, set against a clear blue sky. The turbine is situated in a rural landscape with green fields and a road. The blades have red and white safety markings at their tips.

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A close-up photograph of a person wearing a red hard hat, safety glasses, and a headset, working on a structure. The person is holding a tool or part of the machinery. The background shows a blue sky and parts of a metal structure.

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