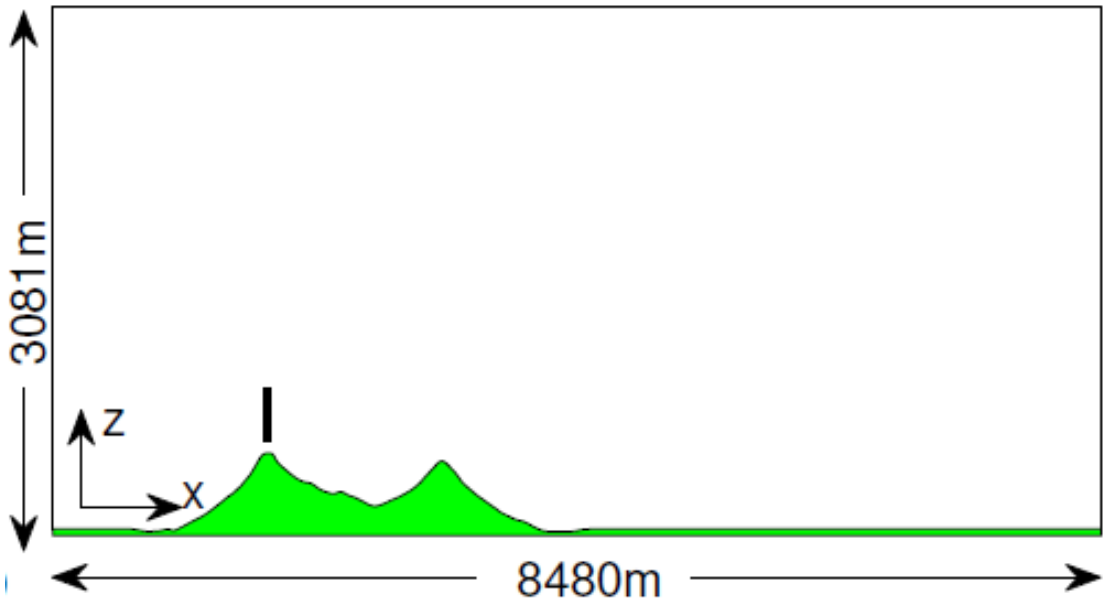
How does complex terrain change the power curve of a wind turbine?

Niels Troldborg, Søren J. Andersen, Emily L. Hodgson, Alexander M. Forsting

Approach

- Large Eddy Simulations (LES) of wind turbine in complex terrain
- Terrain: Perdigao
- Turbine: DTU 10MW (R=89.17 m)
- Rotor modelling: Actuator disc coupled with Flex5



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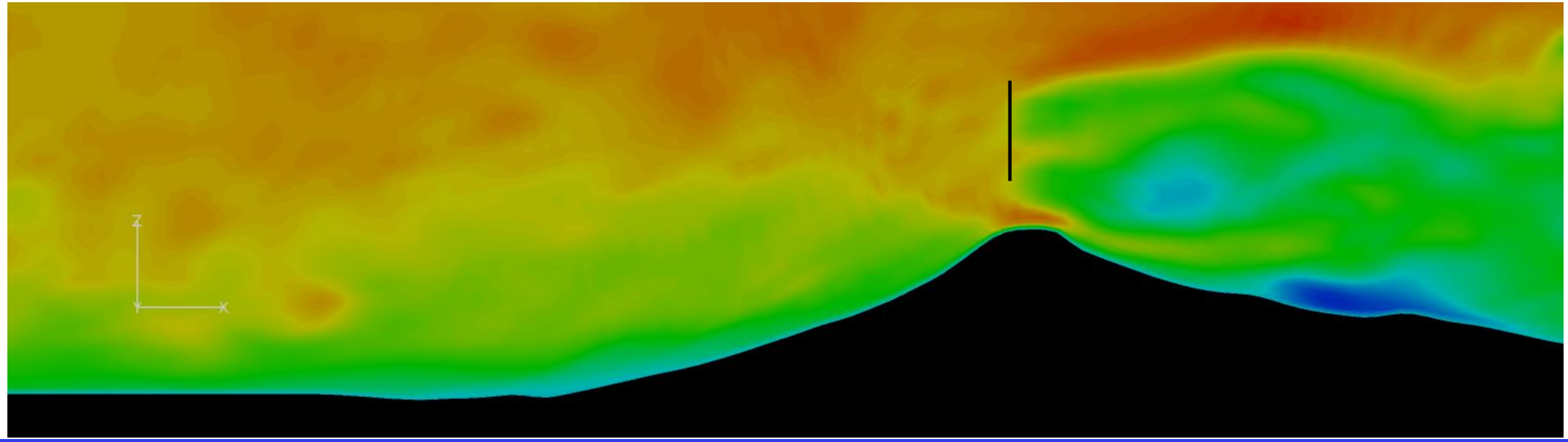

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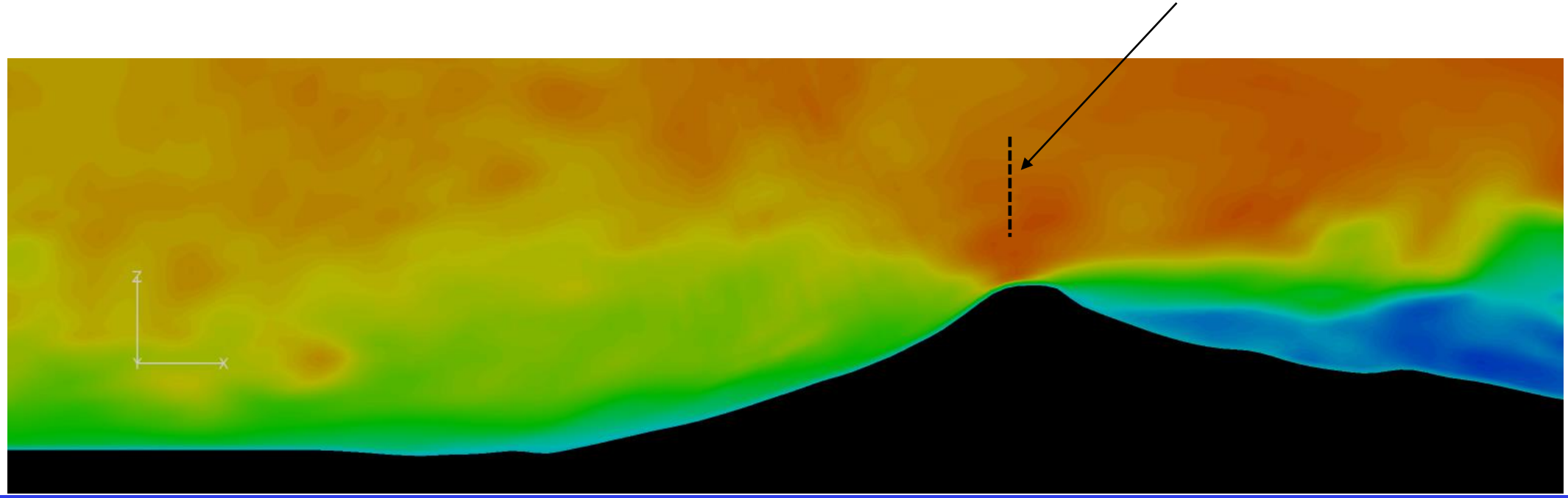
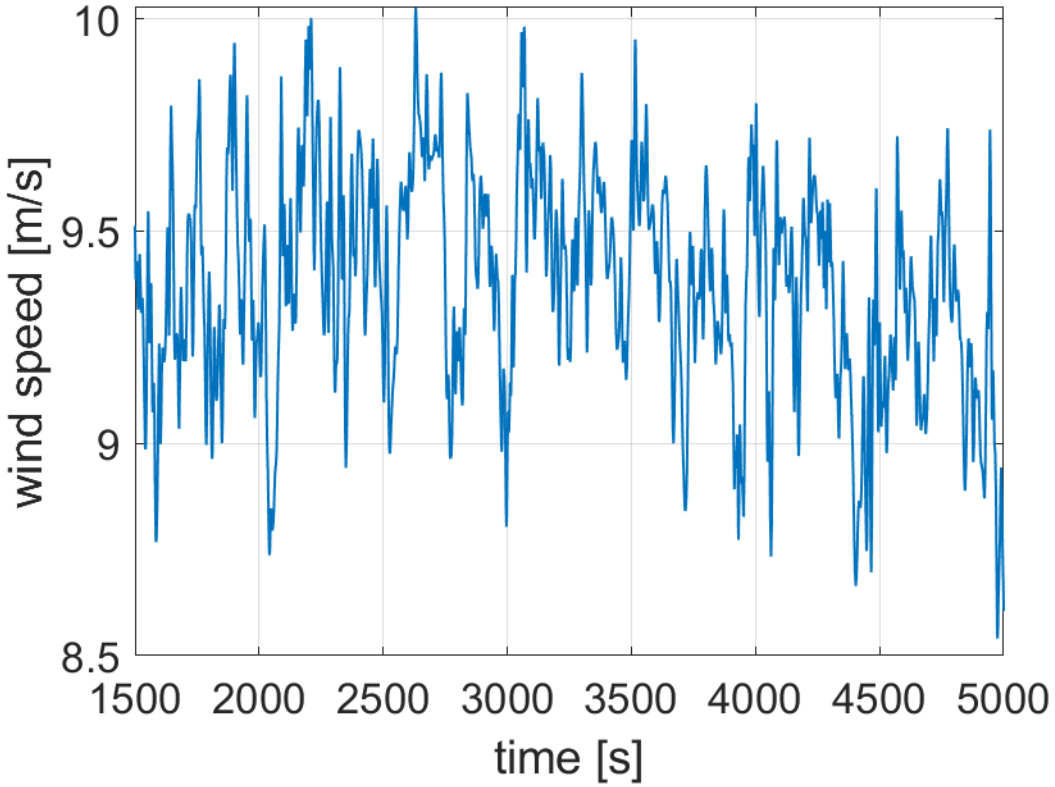
- Exact free-stream flow extracted from simulation without rotor (ghost turbine)

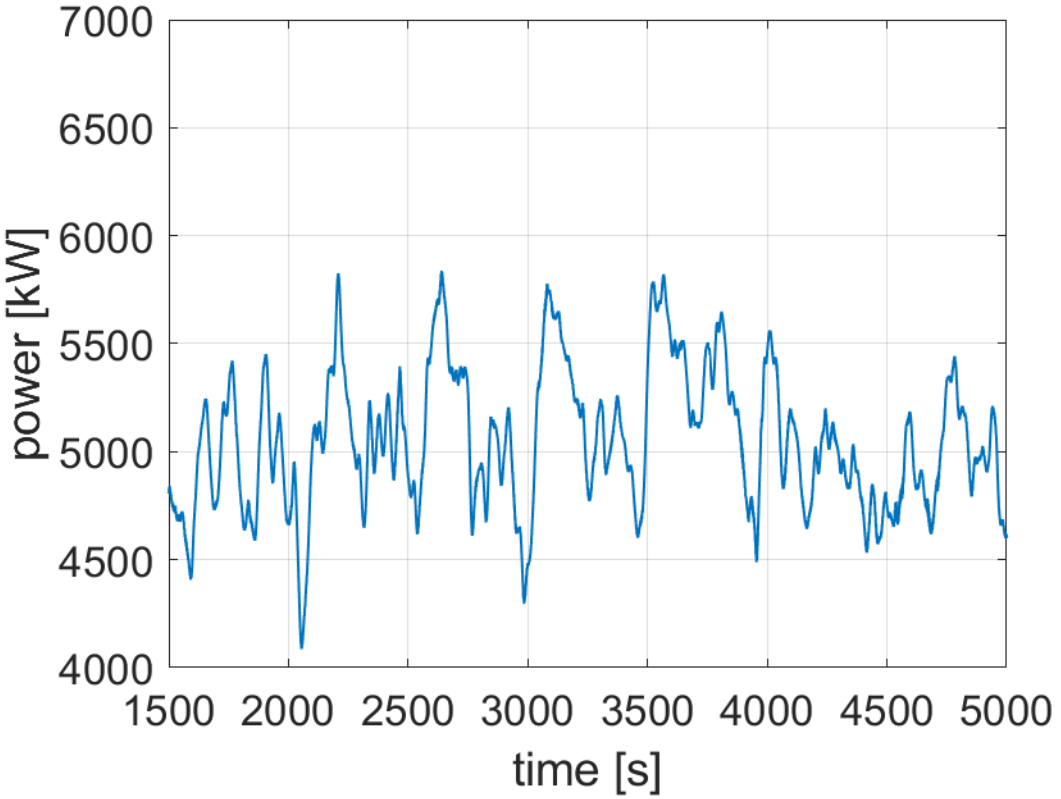


Results

Free-stream velocity at hub height (LES)



Electrical power



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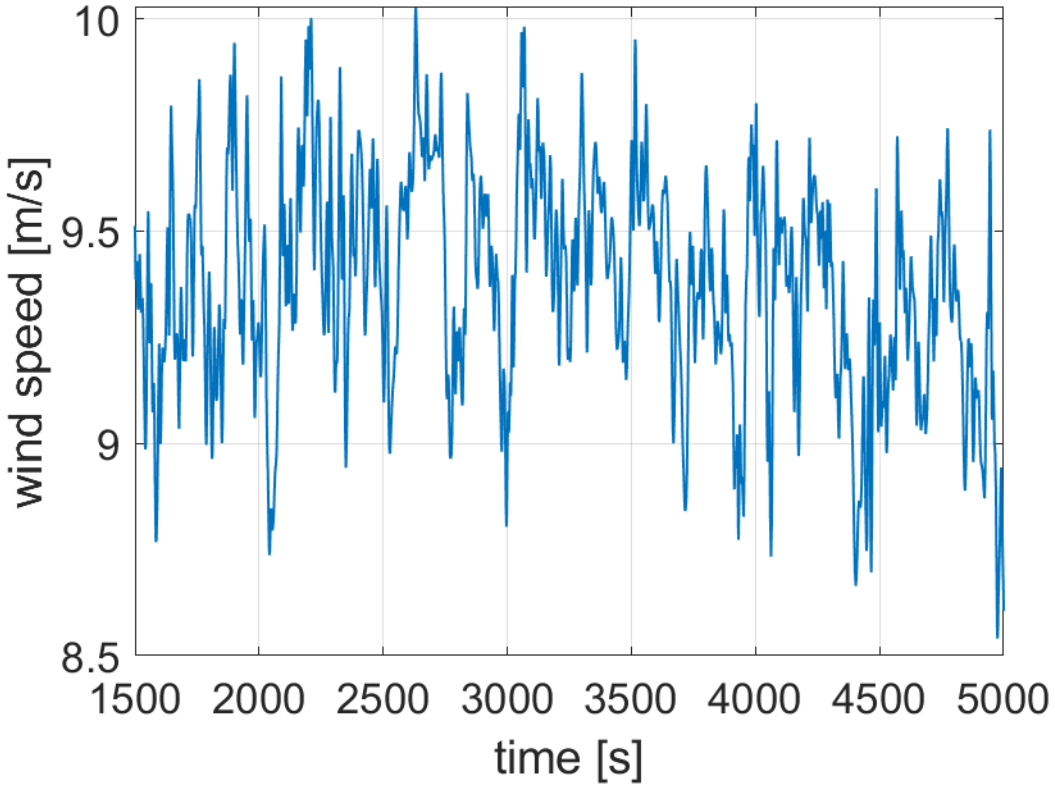

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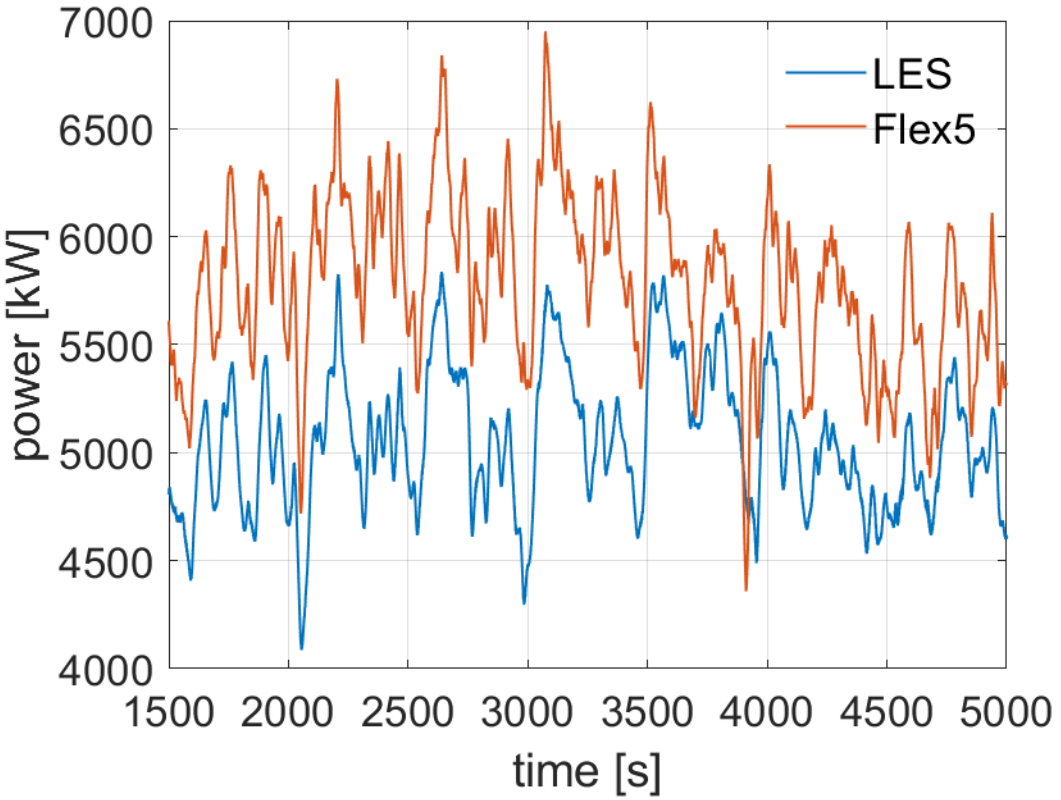

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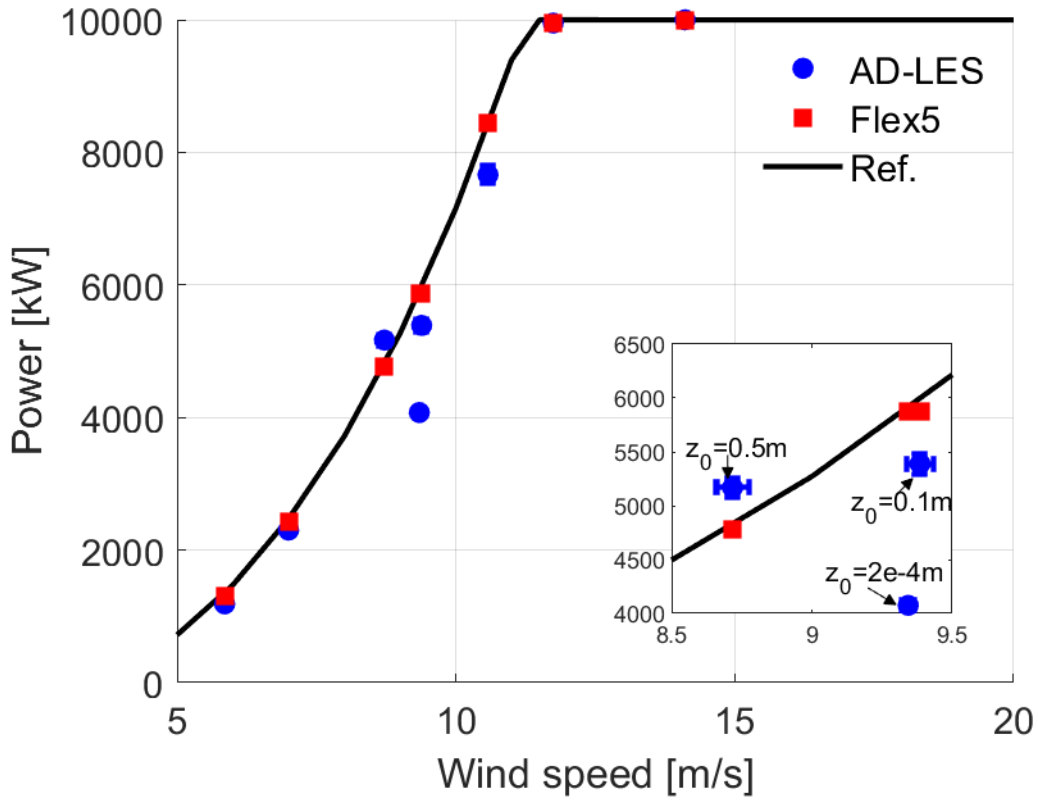
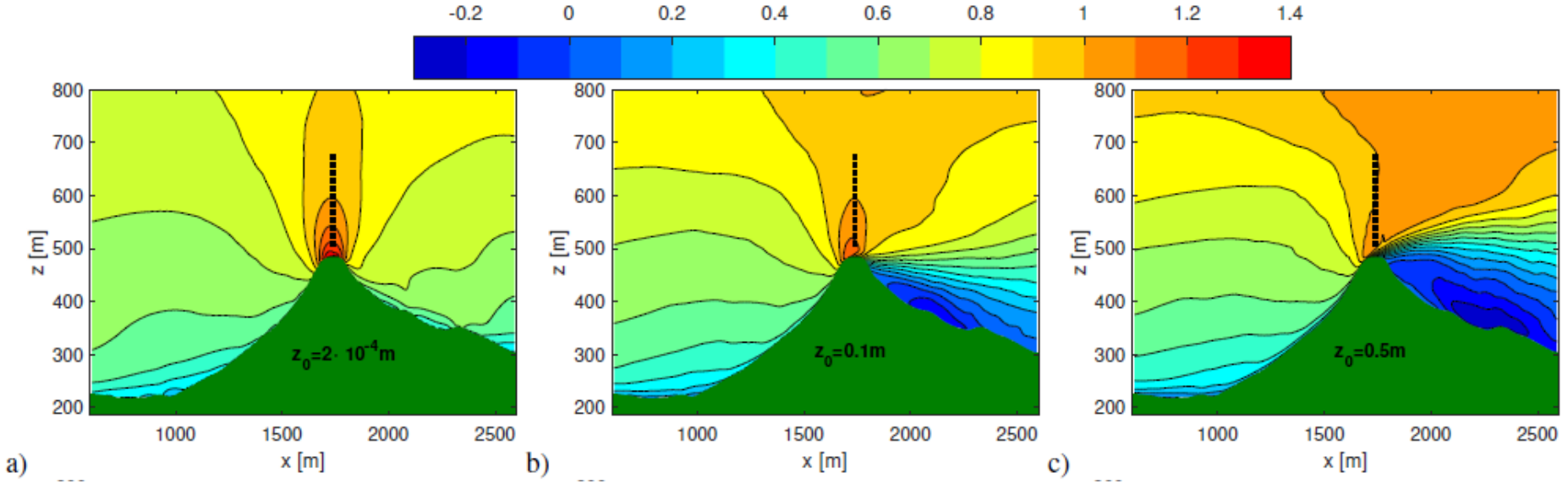

10000
8000
6000
4000
2000
0
Power [kW]
5
10
15
20
Wind speed [m/s]
AD-LES
Flex5
Ref.
6500
6000
5500
5000
4500
4000
8.5
9
9.5
z_0=0.5m
z_0=0.1m
z_0=2e-4m

Results

- Free-stream velocity varies downstream of turbine position
  - Slower transport of wake away from rotor
  - Increased induction at rotor
  - Lower power
- Site calibration only accounts for upstream variation



Free-stream velocity contours at a) z0=2e-4m, b) z0=0.01m and c) z0=0.5m

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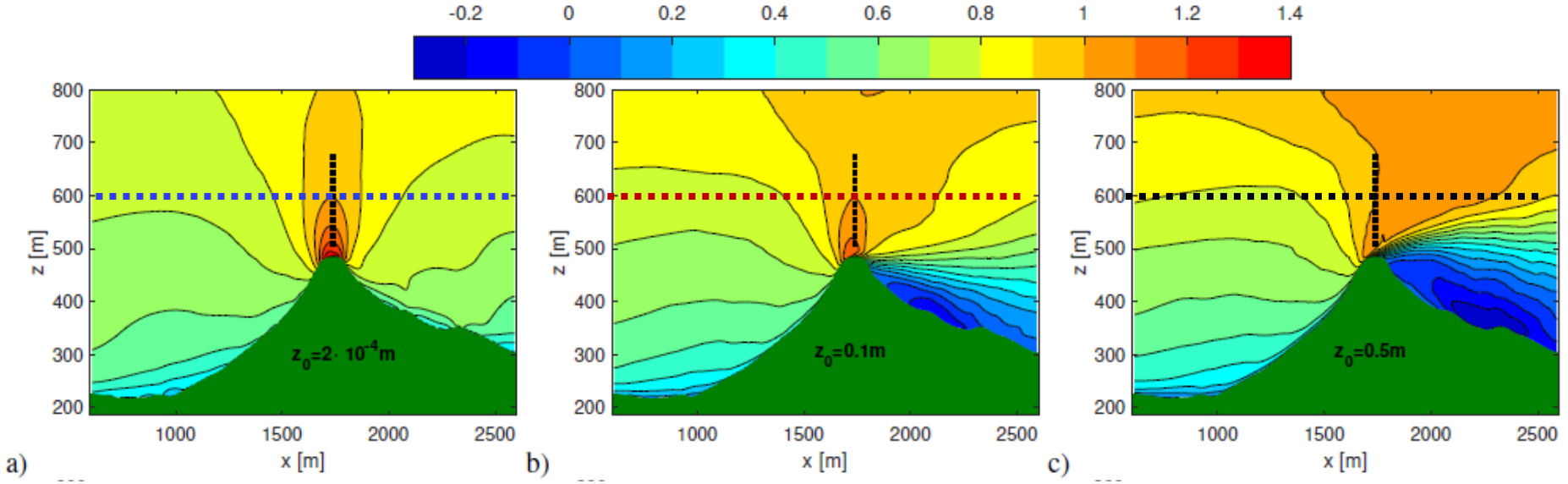

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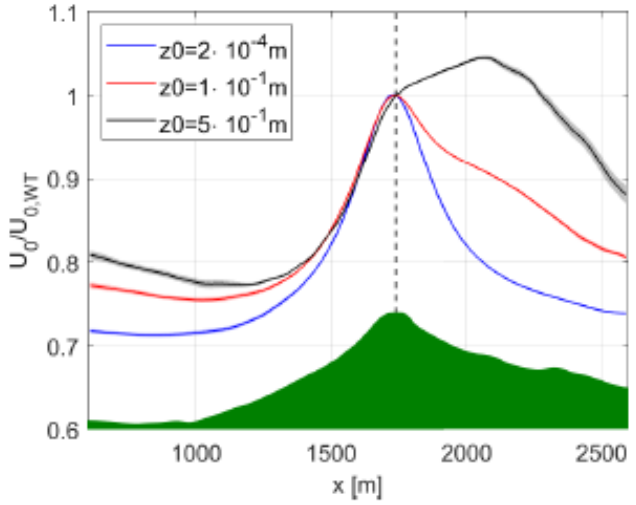
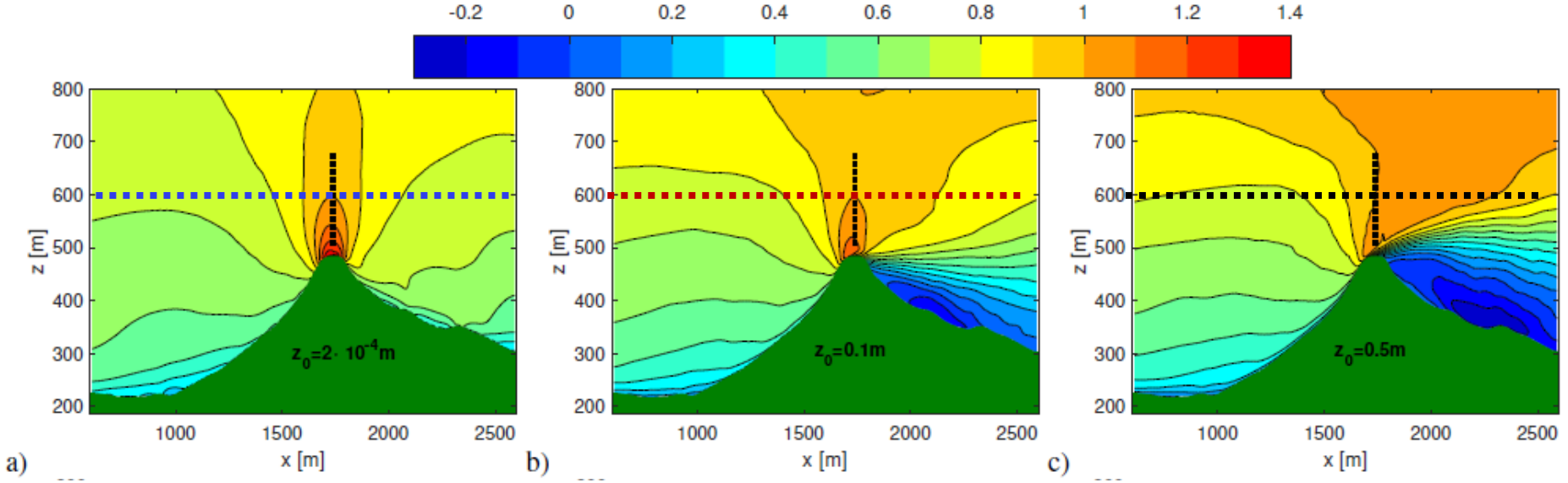
Centreline free-stream velocity





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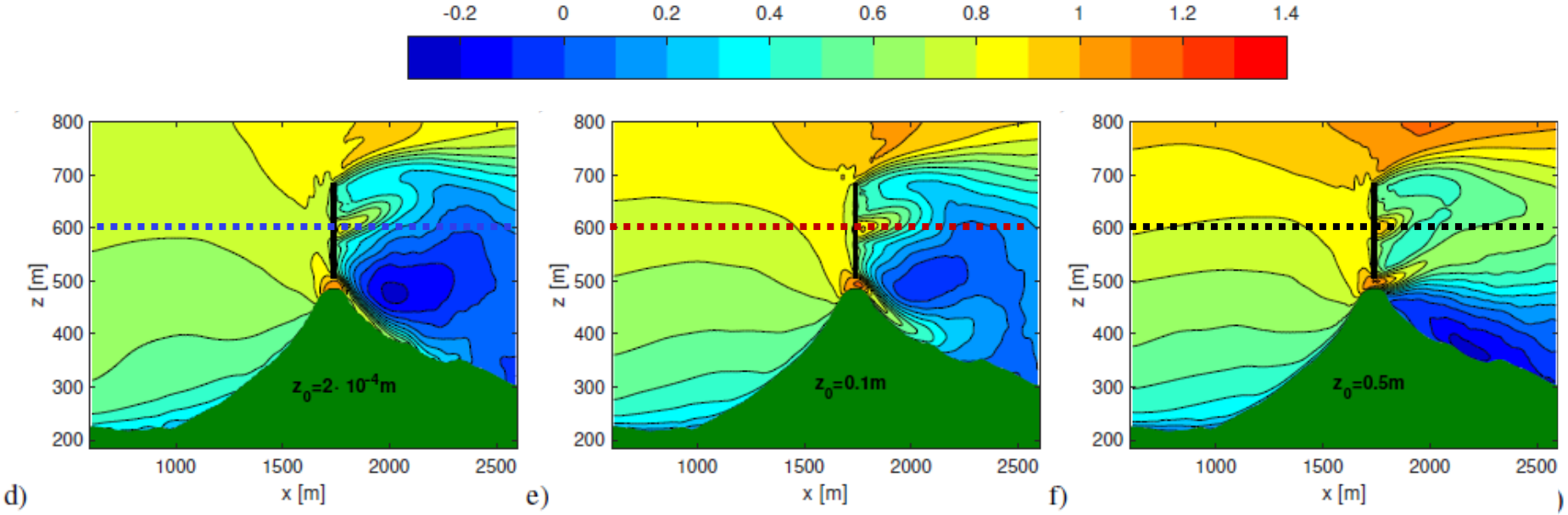
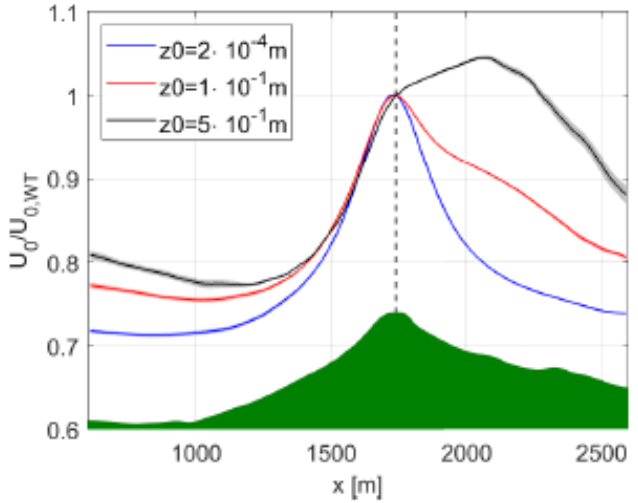
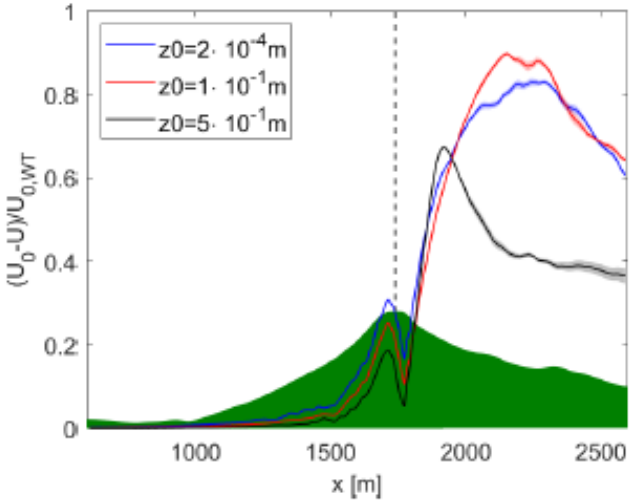


Wake contours at d) z0=2e-4m, e) z0=0.01m and f) z0=0.5m

Centreline free-stream velocity



Centreline induced velocity



Conclusions

- The power curve for a turbine in complex terrain is significantly different from than for the same turbine in flat terrain.
- A standard site calibration is not enough to predict power performance of turbine in complex terrain
- A terrain-specific correction is needed to account for the development of the free-stream flow behind the turbine.

Read more: Troldborg et al. (2022). Brief communication: How does complex terrain change the power curve of a wind turbine? Wind Energy Science. https://doi.org/10.5194/wes-7-1527-2022

Challenges

- Zengler et al. (2024). Is the free wind speed sufficient to determine aerodynamic turbine perfomance in complex terrain? Torque conference
  - So far the answer is no
  - Non-linear interaction of wake and background flow

- Menke et al. (2018). Does the wind turbine wake flow the topography? A multi-lidar study in complex terrrain. Wind Energy Science.
  - The answer is: only sometimes