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Influence of limiting the projection region on coarse Large Eddy Simulation-Actuator Line Model simulations

Autores: Martín Draper, Bruno López, Andrés Guggeri, Filippo Campagnolo, Gabriel Usera

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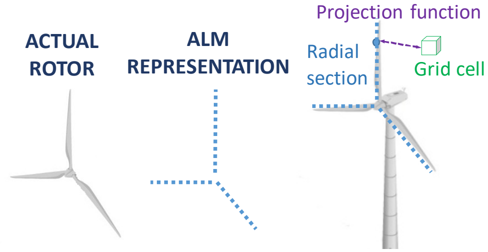
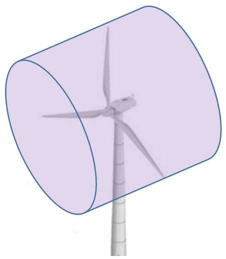
INTRODUCTION

The aerodynamic loads and hence the obtained power production computed with the Actuator Line Model (ALM) depend on the smearing parameter of the projection function, and larger power production is usually obtained when the smearing parameter is increased for the same numerical setup [1].



The main cause for the overprediction of aerodynamic loads near the tip are related to a missing induction generated by the formation of a viscous vortex core, originated from the 3D smearing of the forces [2].



"Allowed" projection region

If the aerodynamic forces are projected onto the numerical domain outside the rotor disk, a reduced force field is applied to the fluid particles that may pass through the rotor. As a consequence, the velocity at the lines representing the blades is larger and the wind turbine will capture more power. This is particularly worst when using coarse spatial resolutions.

In this work the aerodynamic forces are distributed using a 3D Gaussian function, limiting the projection region to a cylinder confined within the rotor disk.

The aim of the present paper is to evaluate the influence of the smearing correction and of the projection region on loads as well as power production of coarse LES-ALM simulations.

METHODOLOGY

Coarse LES-ALM simulations, performed with the open source finite volume **code caffa3d** [4-6], have been performed using numerical models of both **a multi-MW reference wind turbine** and of a **wind tunnel experimental campaign** [5] comprising 3 model WTs..

In both cases different setups have been tested: **applying Prandtl tip loss correction factor (fP), applying the smearing correction proposed in [7] (SC), limiting the projection region to a cylinder confined within the rotor disk (Cyl).**

RESULTS

Multi-MW reference wind turbine case (stand-alone)

Figure 1 depicts the normal and tangential mean loads along the span of one blade when applying or not the projection region restriction and the smearing correction (SC) or Prandtl tip loss correction (fP) while setting the smearing factor at a value of E1 or E2 and fixing the numerical setup.

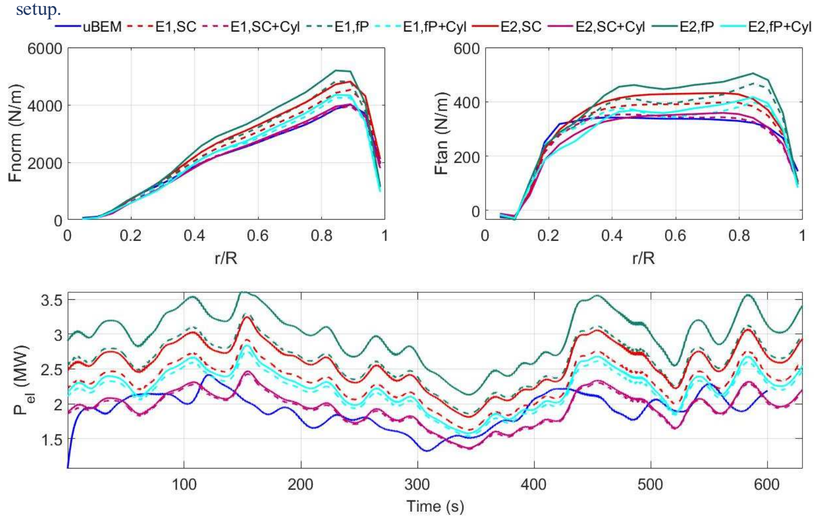


Figure 1. Mean normal and tangential loads along the blades (top, left and right respectively) and electric power time history (bottom). Smearing factor: E1 and E2.

The mean power computed using E1 and E2 using setup (SC+Cyl) deviates from the BEM results by 0.3% and 1.7% respectively. These values increase to 20.7% and 34.3% when using setup (SC) (without limiting the projection region).

Applying the limitation in the projection region (Cyl) lowers the wind speed at the disk as larger forces are applied in front of the rotor disk. In this way, two mechanisms are playing together: on one hand the forces are projected onto the numerical domain affecting the expected flow region and on the other hand as the forces are spread over a smaller region its value in each cell is larger. As a result, the aerodynamic loads are lower and the wind turbine operates at a lower angular velocity and produces less power as shown above.

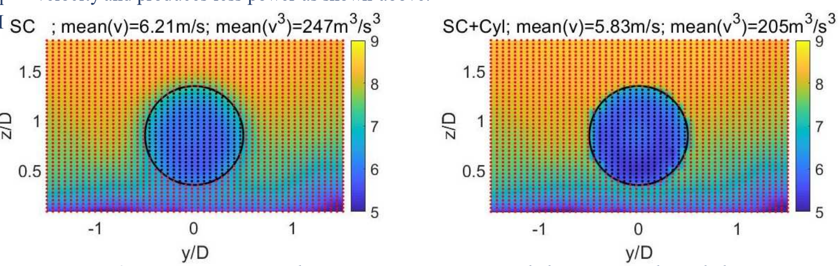


Figure 2. Mean streamwise velocity component at a vertical plane passing through the rotor plane. Black and red dots: points with interpolated data from the CFD grid outisde and inside the rotor disk, respectively. The title of each subplot includes the mean streamwise velocity component and the mean value of the kinetic energy flux per unit mass. Smearing factor: E1.

To assess the influence of the spatial resolution, LES-ALM simulations with the smearing correction (SC) and with/without the projection region limitation (Cyl) are performed taking into account another spatial resolution. The same numerical setup, but with a new precursor simulation, is used. A better agreement with BEM is obtained when using the limitation in the projection region (Cyl). The difference in mean power computed is +11.2% and -0.5% for setups SC and SC+Cyl respectively.

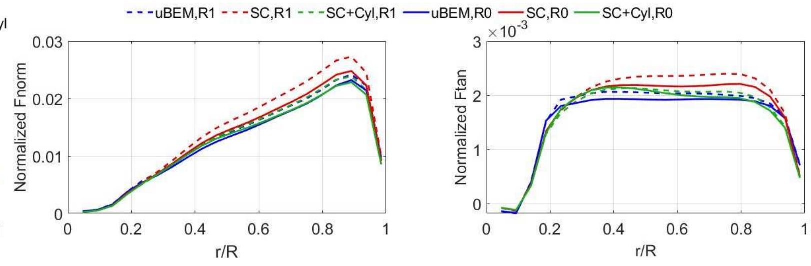


Figure 3. Mean normalized loads along the blades (left: normal force, right: tangential force)..

Wind tunnel case (3 G1 separated 4D and 0.5D in the streamwise and spanwise direction respectively)

When looking at power production, similar conclusions can be drawn from this case. Regarding the wake, the simulated results are in quite good agreement with the experimental data and there is no big difference between the setups tested for the locations considered. These results are consistent with the ones obtained in the previous case (not shown here), but as the wind turbine models are separated 4D in the streamwise direction, it is not possible to analyze the influence of the numerical setups further downstream in the wake where differences in the maximum velocity deficit are observed in the previous case.

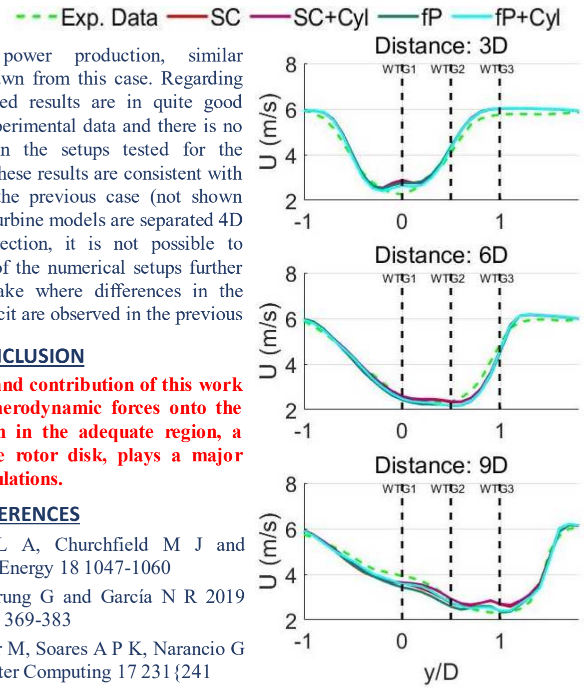


Figure 4. Mean streamwise velocity component at different locations in the wake. Distance measured from the rotor plane of the upstream WT, being D the rotor diameter.

CONCLUSION

The main conclusion and contribution of this work is that applying the aerodynamic forces onto the computational domain in the adequate region, a cylinder confining the rotor disk, plays a major role in LES-ALM simulations.

REFERENCES

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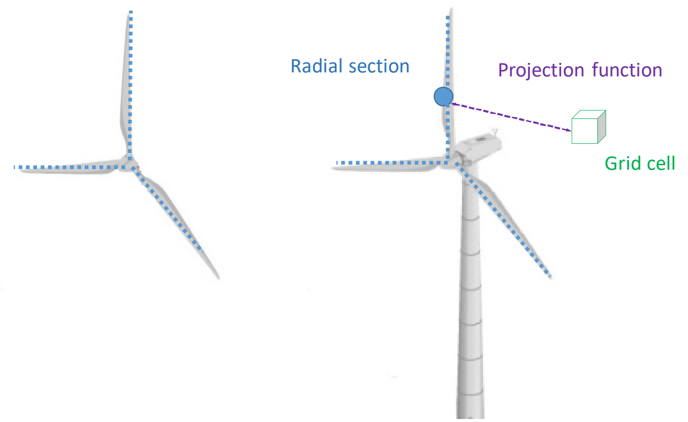
ACTUAL ROTOR **ALM REPRESENTATION**



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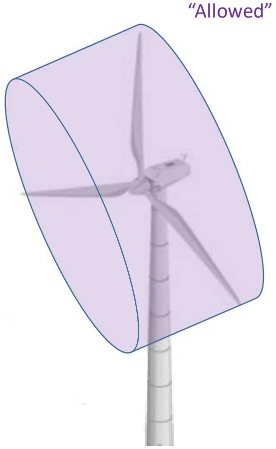

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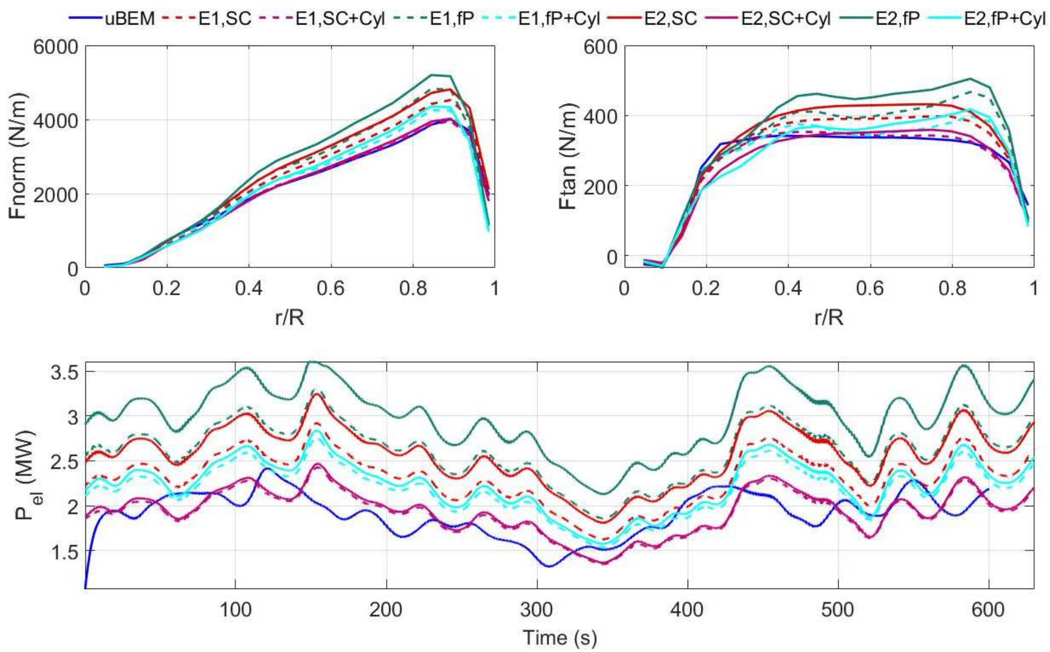

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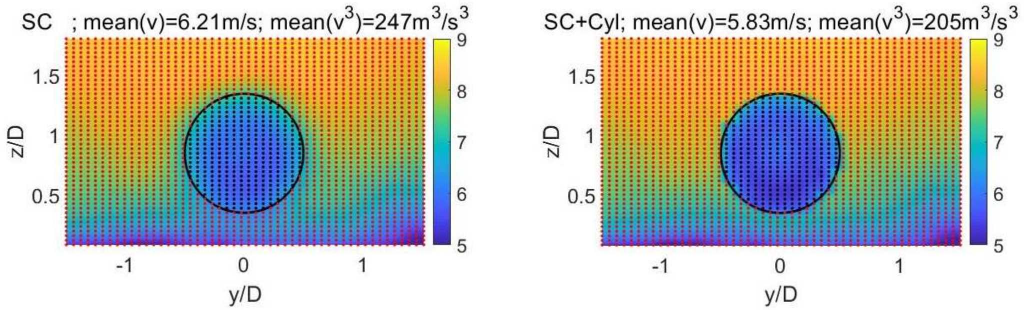

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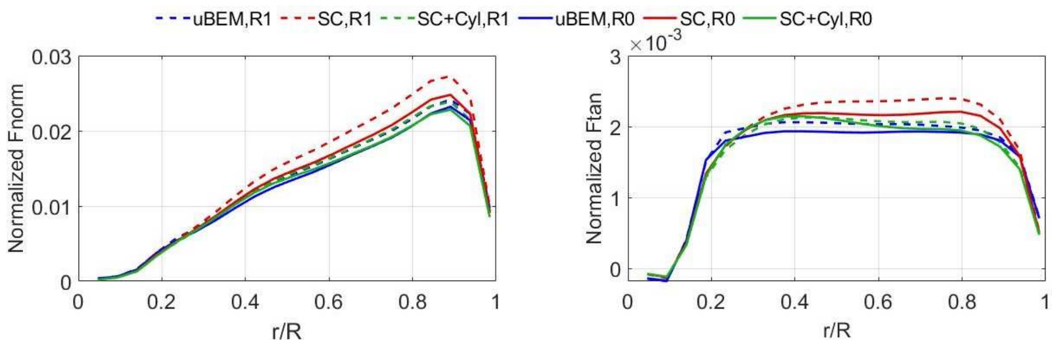

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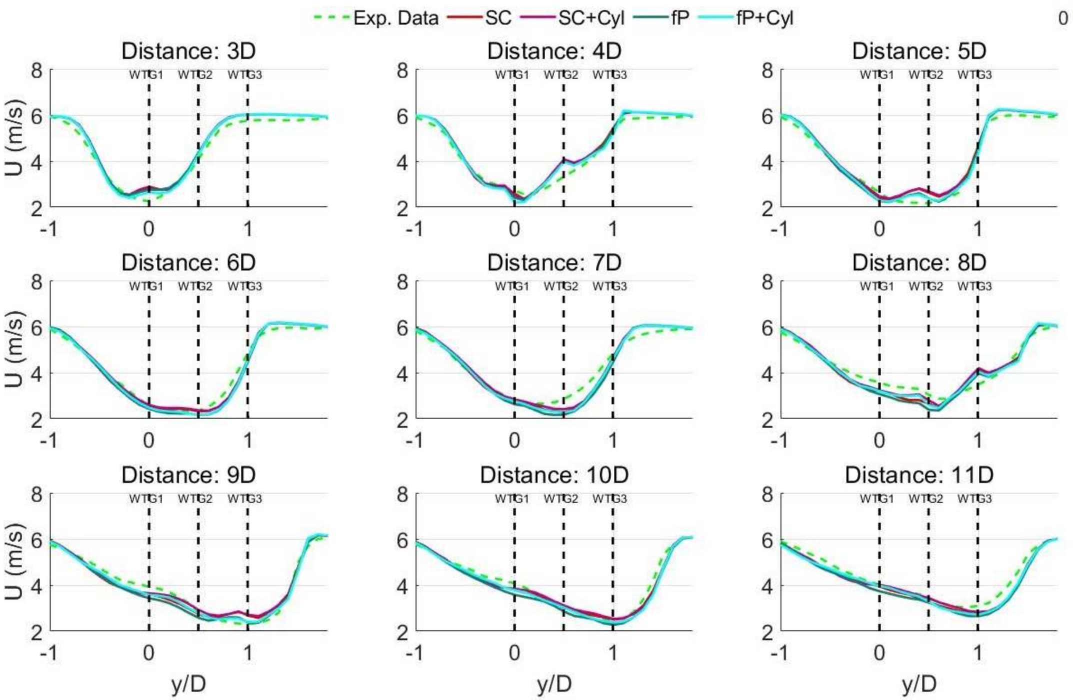

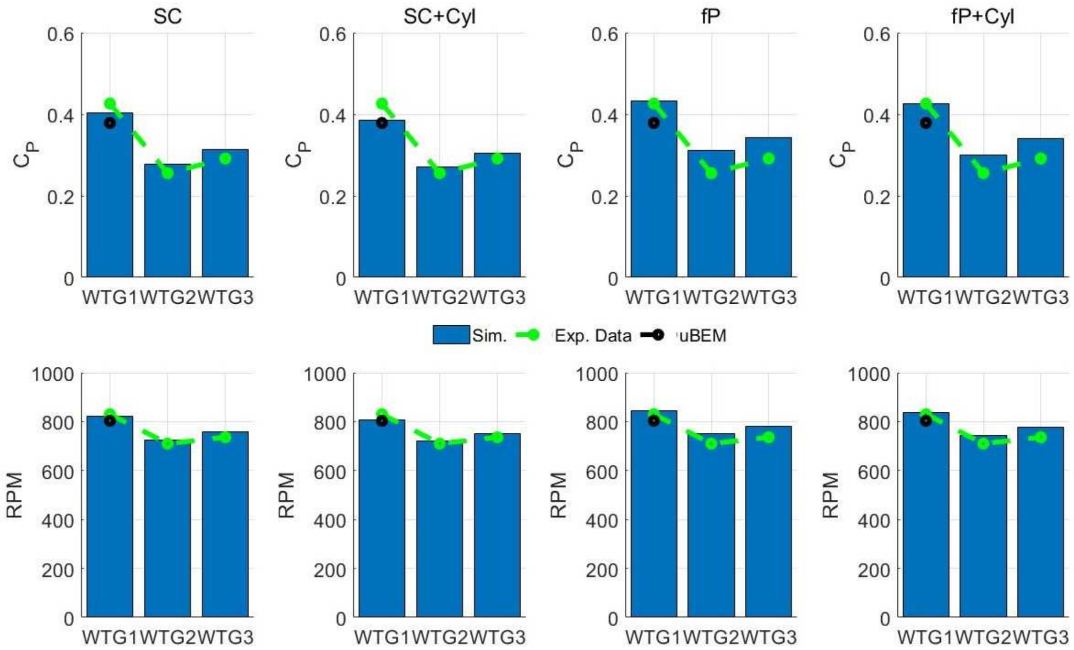

Figure 5. Mean power production (top) and angular velocity (bottom). Case: 3 G1.

CONCLUSION

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