A reduced order model to predict flows around vertical axis turbines

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Abstract. *The simulation and prediction of the temporal evolution of flows around vertical axis turbines is difficult. This difficulty is caused, on the one hand, by the above mentioned blade motion, which leads to unsteady flow features and dynamic effects, but also to the turbulent flow regime in which these devices operate (i.e. high Reynolds numbers). Turbulent flows require modelling to be simulated at an affordable cost.*

In this text, we simulate a vertical axis turbine with an expensive 3D high order numerical method that resolves the geometry and blade movement explicitly [1,2]. Only the small scales in the turbulent flow (LES approach) are modelled in these simulations. Since these computations are expensive, we propose to device a Reduced Order Model (ROM) using snapshots extracted from the accurate high order simulation [3]. We show that combining high order simulations with ROM enables accurate solutions with high fidelity, and outperforms cheaper 2D Navier-Stokes simulations (using a simpler turbulent model: based on a Reynolds Averaged Navier-Stokes approach). Furthermore, we show that even when the number of snapshots is small (e.g. do not cover an entire turbine rotation), the reduced order model is capable of predicting the temporal behaviour at any time or blade azimuthal location.

In figure 1, we compare velocity components: streamwise (Ux) and normal (Uy), on a horizontal line close to the blade (at y=-4) for a fixed simulation time. We observe, in figure 1-left, that the low order uRANS solver provides similar trends that the high order LES simulation, but does not capture all details. Finally, figure 1-right, compares the original high order solution to the ROM prediction at y=-4, for an increasing number of DMD modes. We observe enhances accuracy as the number of modes increases but also good predictions even when only 3 modes are retained (top figure).
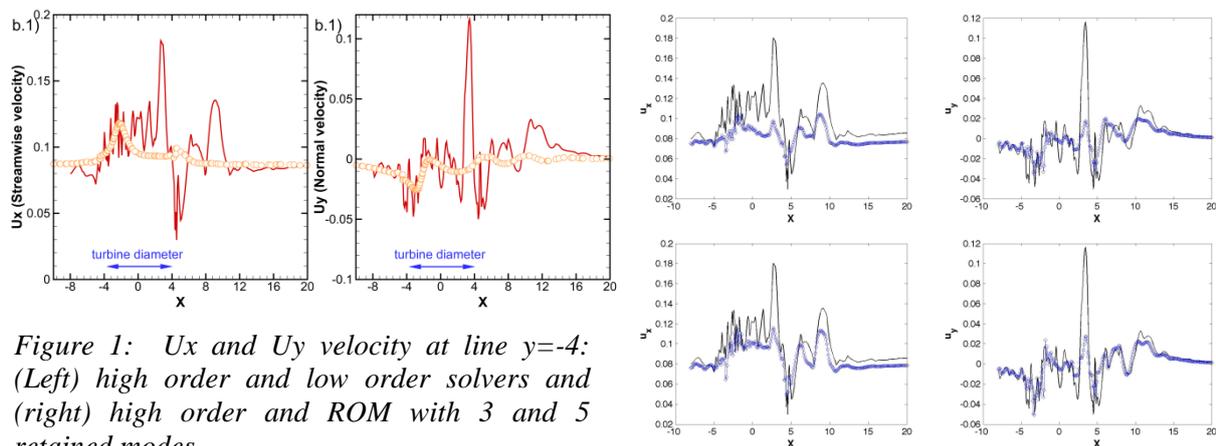

Figure 1: Ux and Uy velocity at line y=-4: (Left) high order and low order solvers and (right) high order and ROM with 3 and 5 retained modes.

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