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Evaluation of classical and machine-learning based wall-models for wall-modeled LES (WMLES) in view of ship hydrodynamics

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ABSTRACT

Within the on-going EuroHPC Centre of Excellence CEEC (https://ceec-coe.eu/) exascale algorithms for current CFD problems are being developed, implemented and their capabilities have to be demonstrated through light-house cases, like the flow around a Japanese Bulk Carrier (JBC). The flow around such a ship hull is characterized by curved surfaces, potential flow separation by adverse pressure gradients and very high Reynolds numbers in general (Visonneau et al., 2023). Despite growing computing power there is still a strong need for turbulence modeling, here via LES, together with wall-modeling resulting in a wall-modeled LES (WMLES) approach. For WMLES of flows over curved surfaces classical approaches like Werner&Wengle or Spalding's types of models are documented in the literature (Breuer et al., 2007 or Liefvendahl et al., 2021). Beside these classical approaches, machine-learning enriched models become more and more popular nowadays. In particular, reinforcement learning (RL) has been used to learn wall shear stress distribution in WMLES environments, reducing the dependence on the empirical correlations and also have seen to generalize to different Reynolds numbers during inference (Vadrot et al., 2023). To reliably capture the turbulent flow field while making most use of nowadays HPC-architectures, the spectral element method (SEM) offers an excellent compromise between high-order accurate discretization and fast convergence on the one hand and geometric flexibility on the other hand. Thus, the filtered incompressible conservation equations are numerically solved and integrated in time with the high-order spectral element flow solver Neko (Jansson et al., 2024) delivering an excellent parallel scaling on CPUs as well as on GPUs. The code is relying on the so called $P_N - P_N$ splitting scheme to estimate the velocity and pressure field at each time step.

Within this contribution results on combining Neko with classical type and machine-learning enriched wall-models are presented for the canonical case of the flow over periodic hills and the flow around a bulk carrier in model scale.

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