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Dealiasing strategy for higher-order methods in turbulent flow simulations

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Abstract. Higher-order schemes have been proved to be very efficient in solving turbulent flows. A Compact fourth-order finite volume method was shown to be 10X faster than the second-order scheme. Recently, the author proposed a new discretization called Finite Surface Method (FSM). A sixth-order approximation of FSM was found to be 2.7X faster than the fourth-order FVM. However, FSM needs to dealiase the convection term by means of low-pass filter. The low-pass filter used in the original work was sub-optimal. Therefore the 2.7X factor can be improved. In this work, we investigate several choices of the dealiasing strategy with the combination of different low-pass filters, namely i.) double six-order compact filter, ii.) double fourth-order compact filter, iii.) the mixed-order 6-4 compact filter and iv.) direct sixth-order compact filter. First, we introduce the aliasing error in the convection term and analyse its consequent and the intermingle role with the local truncation error in the Fourier space. After that we present a model spectrum which is used to evaluate the selected filters. We rule that the mixed-order is not as good as the other two filters, when they are at their best. Nonetheless, the mixed-order works satisfactory in every situation. Finally, we perform a careful grid independent study of a turbulent channel flow at Reynolds number = 5,600 from 32^3 grid to 128^3 grid. The results from the turbulent simulations agree well with the analysis. The fourth-order filter work very well at underresolved regime while the convergence ceases after 80^3 grid. The sixth-order works very well on fine grid, but it cannot eliminate the aliasing error at the underresolved resolution. Overall, for a 1%-level error, the fourth-order filter improves the performance of the FSM to 73X faster than the second-order scheme.

Keywords: finite surface method, direct numerical simulation, turbulent flows, high order method, Navier-Stokes Equations