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Session:

Application of a stochastic backscatter model for grey-area mitigation in detached eddy simulations

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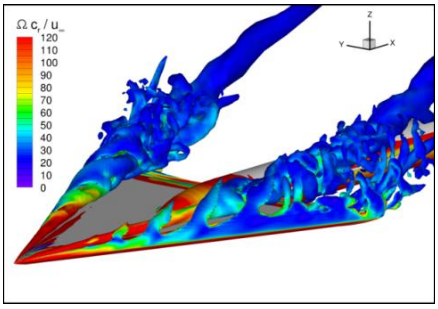
Abstract

A recent focus of research for Detached Eddy Simulations (DES) has been the mitigation of so-called grey areas. In these areas the simulation has switched from RANS to LES, but little or no resolved turbulence has developed yet. This may lead to unphysically stable free shear layers, just after the flow has separated. Besides zonal approaches, such as adding synthetic turbulence at the RANS–LES interfaces, there is also a need for alternative, non-zonal approaches in-line with the essentially non-zonal character of DES, in which the user does not need to specify the RANS and LES zones in advance. Several non-zonal approaches have been proposed in the literature for free shear layers, generally along two lines: either reducing the level of the subgrid stresses in the initial free shear layers or triggering instabilities by some form of stochastic forcing.

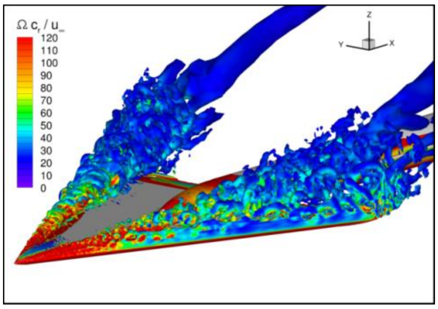
Recently, a new stochastic backscatter model has been proposed for DES that strongly accelerates the development of resolved turbulence in free shear layers [1], and as a result significantly reduces the grey areas, compared to a previously proposed stochastic eddy-viscosity model [2]. The new stochastic model adds stochastic forcing to the momentum equations, following the ideas of Leith [3] and Schumann [4], as the curl of a stochastic vector potential, leading to a rate of backscatter from the subgrid to the resolved scales that is consistent with theory, without functioning as a noise source. Furthermore, temporal and spatial correlations of the stochastic forcing are introduced by Langevin-type stochastic differential equations, thus enhancing the effectiveness of the backscatter model.

Basic test cases, in particular the plane free shear layer and the round jet, demonstrated the effectiveness of the backscatter model in mitigating the grey area. Further applications will be shown, such as a delta wing at high angle of attack (see Fig. 1) and a three-element aerofoil. In these applications, the stochastic backscatter model has been added to the X-LES method, which is a k–ω based DES-type method, in combination with

a high-pass filtered SGS model that reduces the subgrid stresses in initial free shear layers.



a) SST-DDES



b) HPF DX-LES with stochastic backscatter model

Fig. 1 NASA delta wing at high angle of attack: iso-contours of Q-criterion coloured with vorticity magnitude

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