Sixth HRLM Symposium, 26-28 September 2016, Strasbourg University, France

Session:

Recent results with grey-area improved DDES for a wide range of flows

M. Fuchs[1], C. Mockett[2], J. Sesterhenn[1] & F. Thiele[1]

[1]Institute of Fluid Mechanics and Engineering Acoustics, Technische Universität Berlin, Germany
[2]CFD Software E+F GmbH, Berlin, Germany

Introduction

To achieve a fast transition from smooth RANS flow inside the boundary layer to turbulence resolving LES in separated flow regions is one of the major challenges of hybrid turbulence model approaches. For Detached-Eddy Simulation (DES), this so called "grey area" problem can lead to a strong degradation of predictive accuracy for applications featuring shallow separation zones or jets. In Mockett et al. [1], we proposed two extensions to Delayed DES (DDES) aiming at accelerating the transition from RANS to LES in early shear layers after separation.

The first improvement concerns a modification to the LES-mode of DES, which is reformulated to be equivalent to the σ-model of Nicoud et al. [2] rather than the standard Smagorinsky model. The σ-model distinguishes between 2-component flow states and fully 3D turbulence, returning zero eddy viscosity for the former. Another improvement concerns an alternative definition of the LES grid filter width Δ, where a new vorticity-adaptive length scale $\tilde{\Delta}_{\omega}$ is used. The length scale neglects the influence of the grid spacing aligned with the vorticity vector for the evaluation of Δ, which proves beneficial on strongly anisotropic grids in 2D flow regions like the early shear layer.

Expected results

The contribution presents a selection of different external aerodynamics test cases conducted since the first publication of the method at the previous HRLM Symposium. These include a compressible static round jet at M=0.9 and incompressible flow over a delta wing featuring vortex breakdown. For both test cases, the improved σ-DDES along with the $\tilde{\Delta}_{\omega}$ definition proves very effective in freeing shear layer instabilities after separation and thus strongly accelerates RANS to LES transition (see Fig. 1).

In addition, the performance of the improved DDES variant has been evaluated for wall-modelled LES (WMLES) in channel flow. Although not intended to enhance solution accuracy for such flows, the σ-DDES model shows a clear improvement relative to standard DDES over a wide range of Reynolds numbers. Results are very comparable to Improved DDES (IDDES), which was specifically designed for WMLES of attached flows.

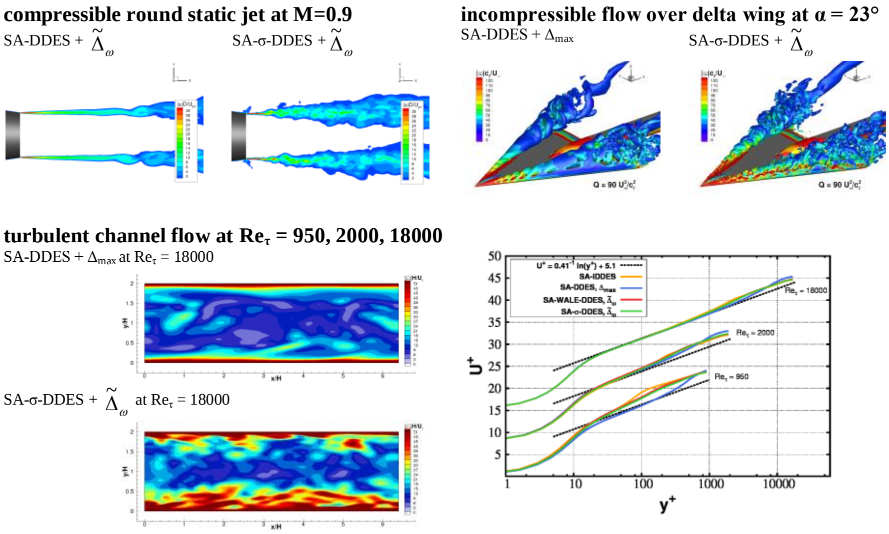

Fig. 1: Comparison of performance of improved σ-DDES relative to standard DDES for various complex test cases.

Acknowledgements

This work has been financed by the EU FP7 project “Go4Hybrid” (ACP3-GA-2013-60536-Go4Hybrid).

References

[1] C. Mockett, M. Fuchs, A. Garbaruk, M. Shur, P. Spalart, M. Strelets, F. Thiele and A. Travin. Two non-zonal approaches to accelerate RANS to LES transition of free shear layers in DES. In: *Progress in Hybrid RANS-LES Modelling, Notes on Numerical Fluid Mechanics and Multidisciplinary Design 130*, pp 187-201.

[2] F. Nicoud, H. Toda, O. Cabrit, S. Bose and J. Lee. Using singular values to build a sub-grid scale model for large-eddy simulations. *Physics of Fluids*, 23(8):5106, 2011