ODTLES: A MULTI-SCALE ANSATZ FOR HIGHLY TURBULENT FLOWS

Christoph Glawe [1], Heiko Schmidt[1] & Alan R. Kerstein[2]
[1] *Flow modeling group, Brandenburg University of Technology (BTU), Cottbus-Senftenberg, Germany*
[2] *Consultant, Danville, CA, USA*

Abstract We use ODTLES, a multi-dimensional extension of the One-Dimensional-Turbulence model (ODT). ODT describes turbulent advection on a 1D sub-domain using a stochastic process for turbulent advection. These 1D sub-domains are coupled to obtain a 3D approach. ODTLES is applied to channel flow. Preliminary results for the pdf of the wall shear stress are compared to DNS.

Keywords: numerical simulation, one-dimensional-turbulence model, ODTLES, channel flow

Introduction

Direct numerical simulations (DNS) are limited to mostly fundamental research due to the range of spatial and temporal scales emerging in turbulent flows. In large eddy simulations (LES) a scale separation ansatz for the flow field is performed where large scales are resolved using a full 3D numerical simulation and the turbulent small scales are modeled using a sub-grid model. These models have limited predictive capabilities near walls or buoyant inversion layers without additional model assumptions (see e.g. [1]). Interesting alternatives are stochastic approaches based on the One-Dimensional-Turbulence model (ODT) [5] and multi-dimensional approaches that incorporate ODT like ODTLES (e.g. [3] and [7]). These models resolve molecular effects in small scales and introduce a stochastic process, compatible with conservation laws, to reproduce a 3D turbulent flux. We will introduce the ODTLES model, illuminate its relationship to LES models, and show its application to highly turbulent flows.

ODTLES

In ODTLES three different ODT domains (see Figure 1) are introduced. Each domain contains an array of ODT lines (see Figure 1(b-d)). The domains are coupled to each other to ensure a consistent 3D velocity field (corresponding to the LES domain in Figure 1(a)). ODTLES has proved its ability to describe turbulent flows in several test cases described e.g. in [3], [7] and [2].

Preliminary results and first conclusions

Turbulent channel flow is a fundamental turbulent flow investigated in experiments and direct numerical simulations e.g. [4]). In Figure 2 the probability density function for the wall shear stress τ_W is compared to DNS results by Örlü and Schlatter [6]. These results were obtained with a resolution $N_{LES} = 8$ respectively $N_{LES} = 16$ and $N_{ODT} = 2048$. The ODTLES results show backflow at the wall even with a very low LES resolution $N_{LES} = 8$ (pure ODT results doesn't capture backflow mechanisms). With increasing LES resolution the ODTLES results tend towards the DNS results. We will elaborate on this preliminary results and additionally compare ODTLES against ODT and DNS with respect to other turbulence statistics. The Reynolds number will be increased beyond available DNS results.

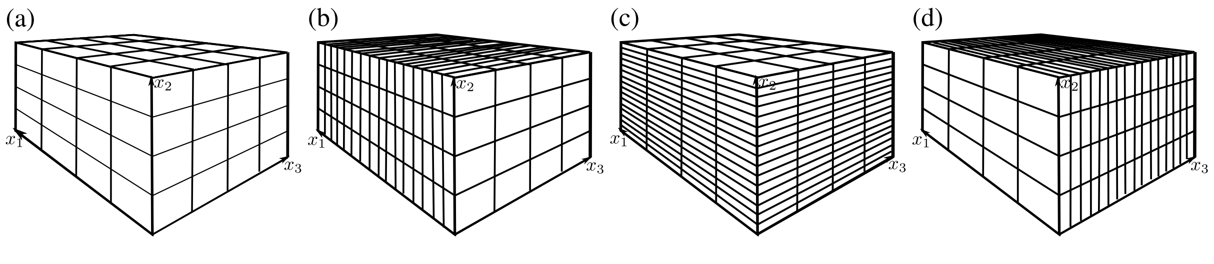

Figure 1: Each ODT domain (b), (c) and (d) is formed by a stack of thin control volumes or wafers containing a set of dynamic variables. The large scale field (a) is enforced to be consistent with these dynamic variables. It is defined by spatially averaging the variables from all ODT domains (b)-(d). Here, each domain is divided into $N_{ODT} = 16$ wafers and a LES resolution $N_{LES} = 4$. This is done for illustration purposes since $N_{ODT} \gg 1$ in practice.

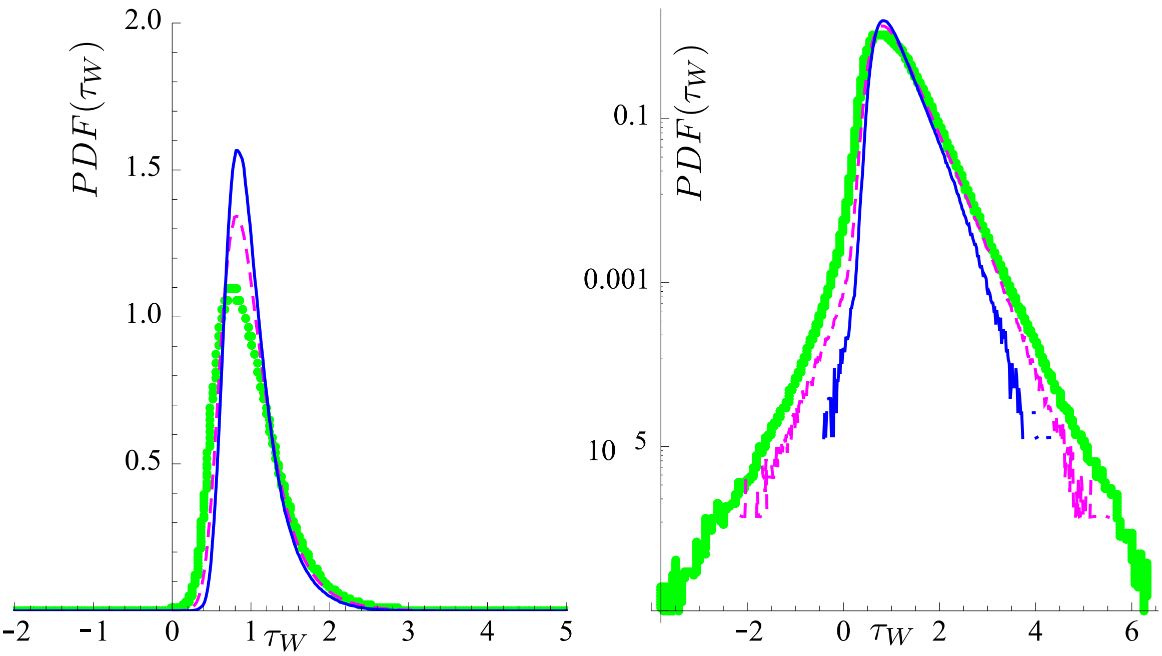

Figure 2: Probability density function of the wall shear stress τ_W: DNS (points, green), ODTLES with $N_{LES} = 8$ (solid line, blue) and ODTLES with $N_{LES} = 16$ (dashed line, magenta). The right plot shows the results using a logarithmic scale.

References

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