IPID4all Doctorate Research Exchange with Carl von Ossietzky University of Oldenburg

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Home supervisor: *Prof. Dr. Stefan Heinz*
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Exchange topic: *Stochastic Turbulence Modelling for CFD for wall-bounded flows*

Introduction

Designing means for efficient collection of wind energy requires the use of computational fluid dynamics (CFD). At the same time, current CFD methods are either too expansive to run or do not provide the desired level of accuracy. The reason for this trade-off is our insufficient understanding of physics of turbulence, in particular wall-bounded flows. We either have to compensate this lack of knowledge with an increased detail of simulations or have to be satisfied with not so perfect models.

The most promising way to understand the physics of turbulence (and thus to advance CFD methods) is to use stochastic turbulence models. However, so far there is no physics-based stochastic model for wall-bounded flows.

Our goal at the University of Wyoming is to develop a physically founded stochastic turbulence model for wall-bounded flows. Such model can be constructed only based on the analysis of real turbulence data from experiments and numerical simulations (DNS/LES).

Currently we developed a method to extract stochastic turbulence model parameters from turbulence data. However, application of our method requires analysis of rather specific turbulence data, which is not available right now for wall-bounded flows. This is why we are collaborating with the Oldenburg University to run simulations and experiments to obtain the required data. This partnership is crucial for developing physically founded stochastic turbulence models, which are a basis for developing better CFD methods to solve wind energy problems.

Research Undertaken

During my visit, the research was conducted in three main directions. First, I have been finessing and improving the analysis technique we are using to calculate the parameters of a stochastic turbulence model. Second, I was helping Ghazaleh Ahmadi to set up Large Eddy Simulation for channel flow so we could apply that analysis method to it. Third, I began developing a stochastic turbulence model for general flows. Below I elaborate on these three points.

First, I have continued to analyse the channel DNS data provided by the John Hopkins Turbulence database, which was our only source of data before the visit. Recall, that in the process of our research we are calculating the parameters of a stochastic turbulence model. These parameters a

grouped in two tensor fields in the flow. Before my visit we had a reasonable way to calculate symmetric parts of those two tensors. Although the results looked highly reasonable, we lacked full theoretical justification for the developed method. Moreover, it was unclear how to calculate the antisymmetric part of one of the tensors.

During my visit I was able to solve both these problems and get a theoretically founded technique to calculate all the parameters of a turbulence model. I applied this technique to the DNS data we had. As the next natural step, I used thus obtained stochastic model to set up and conduct Monte-Carlo simulation of the channel studied. This was the first thorough check of both the stochastic model and our method to extract its parameters from data. The simulation results showed agreement with the data with an expected level of accuracy.

Simultaneously with the above, the second direction of my research and the area of extensive contacts with Ghazaleh Ahmadi from the Oldenburg group was setting up Large Eddy Simulation (LES) for the channel flow. For our stochastic analysis method, we need to collect Lagrangian statistics of the flow --- statistical quantities that follow Lagrangian fluid particles, as opposed to Eulerian statistics where we gather data at fixed points in the flow. Once I have arrived to Oldenburg, it became clear that the current Lagrangian particle tracking that Ghazaleh was using was not accurate enough for our goals. We spent a couple of weeks figuring out the root of the problem. Switching to a better Lagrangian particle tracking and testing it took also around two weeks. However, it also turned out that the LES also suffered from greater problems reproducing the mean flow. Luckily, with the great expertise of people from the Oldenburg group as well with the help of my supervisor Prof. Stefan Heinz (who was also there), this problem was overcome in the course of several weeks. Finally, by the time I was leaving, we started to get a steady flow of quality data from Large Eddy Simulation.

During last three weeks of my stay, based on the data from a single channel flow, I have started to develop a stochastic turbulence model applicable to a wide range of lows. However, I am continuing this ongoing effort back in Wyoming.

Last, but not least, during my visit I participated in an international workshop “100 Years of Fokker-Planck Equation” giving a talk “Stochastic Velocity Dynamics of Turbulent Wall Flows”. This was crucial in establishing contacts with people interested in my area of research.

Personal Experience

I want to note a highly productive environment I have found in Oldenburg in general and within the ForWind (TWiSt group) in particular. Nothing distracted me from my work, this is unmatched by anything I have experienced so far. My doctor was pleasantly surprised by 5 kilograms I was able to gain during this summer.

Conclusions

My research exchange was necessary for finishing my PhD thesis and making connections with experts in my area. In addition, it was crucial for PhD progress of Ghazaleh Ahmadi. I am sure that the results I obtained during my visit will contribute to our understanding on near-wall stochastic dynamics of turbulence.

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Outlook

The results obtained during the visit will be at the core of my doctoral dissertation. We are also planning to prepare a publication during the 2017-18 academic year. My visit deepened the partnership between our group in Wyoming and the group in Oldenburg. Although my primary focus right now lies in the stochastic turbulence modelling, I would say there are even greater collaboration opportunities when it will come to applying conventional CFD methods developed from the stochastic model. I will be graduating from the University of Wyoming this year and I hope I would be able to continue cooperation with both the University of Oldenburg and the University of Wyoming.

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